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PUBLIC CLEANSING:

COLLECTION, TREATMENT AND UTILISATION OF TOWN REFUSE

THE OFFICIAL TEXTBOOK OF THE
"JAS. JACKSON" STUDY CIRCLE

JAS. JACKSON, Esq., O.B.E., F.Inst.P.C., F.R.S.Inst., A.M.Inst.T.

General Manager, Birmingham Corporation Salvage Department.

PUBLIC CLEANSING:

COLLECTION, TREATMENT AND UTILISATION OF TOWN REFUSE

by

THE "JAS. JACKSON" STUDY CIRCLE
OF
THE BIRMINGHAM CORPORATION SALVAGE DEPARTMENT

1929
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THIS BOOK IS DEDICATED TO

THE RIGHT HON. NEVILLE CHAMBERLAIN, ESQ., P.C., M.P.,

Minister of Health,

in recognition of his great task, successfully accomplished, for the improvement of the health services of this Country, and particularly so with regard to the operations of Public Cleansing.

PREFACE

By

JAS. JACKSON, Esq.,

O.B.E., F.Inst.P.C., F.R.S.Inst., A.M.Inst.T.,

General Manager of the Birmingham Corporation Salvage Department.

It gives me great pleasure to comply with the request of the Class designated under my name to write a "foreword" on the occasion of the publication of the lectures which have been given during the past two sessions.

It has for long been my desire to write a complete work dealing with Cleansing problems, but calls on my time have been so numerous that this hope has not been fulfilled.

The articles have been written in a simple manner in order to appeal mainly to students of Salvage and Public Cleansing work.

I do not suppose that the Lecturers claim that this book should be regarded as a "text-book" in the full sense of the term, but I am satisfied that it will in a large measure supply a long-felt want for those engaged in technical Cleansing.

The Class was primarily formed by me for the education of the members of the staff of the Birmingham Salvage Department, but as its activities became more widely known, a number of officials from other towns who were desirous of sitting for the examinations of the Institute of Public Cleansing, expressed a wish to join the Class, and it has now assumed somewhat large dimensions.

It is the intention of the Class to publish every two years a new volume which will incorporate many new lectures on other subjects, whilst many subjects which have already been dealt with will be treated in a different form.

To students of Public Cleansing, the book should be of real service, whilst it is hoped that the publication will constitute a reliable reference book.

The members joining the Class will continue to receive their weekly home-work, which includes questions and answers on all kinds of Public Cleansing matters, but the reading of the lectures now published will enable such students to give a closer application to the study of the manifold problems and ramifications of Cleansing Work, which probably could not otherwise be obtained.

The "Jas. Jackson" Study Circle has not been formed with the intention of financial gain for its promoters, but with the sole object of educating and assisting those who are engaged or interested in the Cleansing Service.

Jas. Jackson.

161 Corporation Street,
Birmingham,
May 1929.

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LAW

Part I. Duties and Powers of Local Authority.

1. Scope of Law Chapter.

The chapter dealing with law will be mainly confined to Acts and Bye-laws which have a direct bearing upon cleansing and salvage work. Apart from what for want of a better term may be called Cleansing Acts, there are of course many Acts of Parliament, such, for instance, as the Workmen's Compensation Acts, Factory Acts, etc., which are of great importance in the work of Corporation Departments, but as these and other Acts do not refer particularly to cleansing work they do not fall within the purview of this chapter.

2. Public Health Act, 1875.

The law dealing with Cleansing as regards England and Wales is principally contained in the Public Health Act, 1875, as amended and amplified by subsequent Public Health Amendment Acts, Local Acts and Bye-laws.

The Public Health Act, 1875, is the basis of Public Cleansing Law, and has been referred to as the Charter of Public Cleansing. This Act does not extend to Scotland and Ireland, however, nor to London. In passing, it may be mentioned that London is provided for by the Metropolis Management Act, 1855, and the Public Health (London) Act, 1891.

It is essential that students wishing to sit for the examination of the Institute of Public Cleansing should obtain a thorough knowledge of the various sections of the 1875 Act, as, quite apart from this Act being the basis of Public Cleansing Law, the law section of examination papers almost invariably includes questions upon this Act.

3. Urban and Rural Authorities.

The Authorities for the purpose of the Public Health Act, 1875, are described in that Act as Urban and Rural Sanitary Authorities. The effect of the Public Health Act, 1875, taken in conjunction with the Local Government Act, 1894, is that the country is divided into cities, boroughs, and urban districts, on the one hand, and rural districts on the other; the distinction between the two classes of district rests upon the degree of development which has taken place. In the case of cities and boroughs, the Corporation acting by the Council is the Urban Sanitary Authority; in the case of the urban districts and rural districts, the Urban District Councils and the Rural District Councils are respectively the Sanitary Authorities.

4. Public Health Act, 1875, Section 42.

This is probably the most important section of the Act so far as cleansing is concerned, and reads as follows :—

"*Local Authority to provide for cleansing of streets and removal of refuse.*

Every local authority may, and when required by order of the Local Government Board shall, themselves undertake or contract for—

The removal of house refuse from premises.

The cleansing of earth-closets, privies, ashpits and cesspools; either for the whole or any part of their district. Moreover, every urban authority and any rural authority invested by the Local Government Board with the requisite powers may, and when required by order of the said Board shall, themselves undertake or contract for the proper cleansing of streets, and may also themselves undertake or contract for the proper watering of streets for the whole or any part of their district.

All matters collected by the local authority or contractor in pursuance of this section may be sold or otherwise disposed of and any profits thus made by an urban authority shall be carried to the account of the fund or rate applicable by them for the general purposes of this Act; and any profits thus made by a rural authority in respect of any contributory place shall be carried to the account of the fund or rate out of which expenses incurred under this section by that authority in such contributory place are defrayed.

If any person removes or obstructs the local authority or contractor in removing any matters by this section authorised to be removed by the local authority, he shall for each offence be liable to a penalty not exceeding five pounds: Provided that the occupier of a house within the district shall not be liable to such penalty in respect of any such matters which are produced on his own premises, and are intended to be removed for sale or for his own use, and are in the meantime kept so as not to be a nuisance."

It will be observed that no power is given to a Local Authority to charge occupiers for the removal of house refuse, and also that the section does not require a Corporation to remove trade refuse—an important point, which will be referred to in a subsequent chapter.

Particular note should be taken of the wording of the section in regard to cleansing and watering of streets. It will be seen that an Authority can be compelled to cleanse streets, but watering is optional. A further point requiring emphasis is that any Local Authority (whether Urban or Rural) is empowered to set up a cleansing service for house refuse removal, but Rural Authorities are not empowered to undertake street cleansing unless they are granted special powers to do so by the Local Government Board (now the Ministry of Health).

In case any student does not understand the descriptions of the various types of receptacles referred to in the section, the following notes are given :—

Earth-closets.—Receptacles having an arrangement whereby earth is mixed with fæcal matter after each time the receptacle is used.

Privies.—Generally called privy middens. Nothing more than a hole in the ground, sometimes brick-lined. They are used as receptacles for all kinds of filth, fæcal matter, ashes, etc.

Both these types of "conveniences" (a better description would be "inconveniences") are abominations, and the dangers consequent upon their use are too apparent to need mention.

Fortunately, in Birmingham there are comparatively few of either of these insanitary arrangements, and where they are in use they are generally attached to isolated dwellings.

Cesspools.—in Birmingham usually called "dumbwells." They generally serve houses on the outskirts of the City for which no sewer is available. They are underground chambers (which should be water-tight) and generally both sewage and waste sink water are drained into them. The law requires dumbwells to be at least 50 feet away from a dwelling house, water springs or wells.

Ashpits.—These places are too well known to require description. They are a relic of an insanitary past, and Birmingham is spending large sums of money each year upon their conversion into dustbin-sheds.

5. Public Health Act, 1875, Section 43.

"Penalty on neglect of local authority to remove refuse, etc.

If a local authority who have themselves undertaken or contracted for the removal of house refuse from premises, or the cleansing of earth-closets, privies, ashpits and cesspools fail, without reasonable excuse after notice in writing from the occupier of any house within their district requiring them to remove any house refuse or to cleanse any earth-closet, privy, ashpit or cesspool belonging to such house or used by the occupiers thereof, to cause the same to be removed or cleansed, as the case may be, within seven days, the local authority shall be liable to pay the occupier of such house a penalty not exceeding five shillings for every day during which said default continues after the expiration of the said period."

This section does not require any lengthy explanation. It will be seen that occupiers of properties in districts where a refuse collection service is in operation have very definite rights, and that Corporations affected have well-defined responsibilities. Although it might be thought that this section enables an occupier to require a free weekly collection, the Courts have decided that a Local Authority can only be required to carry out a free collection at reasonable intervals, having regard to all the circumstances.

The case of an occupier who took proceedings against the Epsom Corporation for the more frequent cleansing of his dumbwell might be instanced. Dumbwell emptying is a very expensive operation, and as will be seen from an account of the case which is given below, it was held that, although the dumbwell in question had only been emptied at three-monthly intervals, the occupier concerned had received good value for his money, and that if he required more frequent service, he must pay for it :—

Extract from "The Surveyor," 31st March, 1922.

"*Local Authorities and Cesspools.*

It will come as rather a relief to many local authorities who have undertaken the duty of cleansing cesspools under Section 42 of the Public Health Act, 1875, to learn that there is some limit to the demands for unreasonably frequent emptying that may be made upon them by certain occupiers. The provision of Section 43 for a daily penalty to be paid to the occupier if a local authority fail to cleanse after seven days' notice might obviously become oppressive if it were enforced without qualification. For example, in a case which was recently before the Courts it had cost £37 18*s*. 0*d*. in one year for labour alone to meet the demands of the occupier of a house having a rateable value of no more than £100. It appears from the report of this case—Leck *v*. Epsom Rural District Council—which appears in the current issue of *Knight's Local Government Reports*, that on account of the heavy cost of the work the Council decided that the occupier concerned must pay the cost of any cleansings he might require in excess of one every three months. To this the appellant objected, and summoned the Council under Section 43 for refusing to empty his cesspool a second time in one quarter without payment. It was, however, held by the Court that in the circumstances they had a reasonable excuse for not complying with the demand without payment, and the appeal was accordingly dismissed. It cannot be denied that this particular ratepayer was receiving full value for his rates, and the decision that he was not entitled to an unlimited service is not only good law but also sound common sense."

The writer is not aware as to the amount of rates levied by the Epsom Council, but assuming they were 15*s*. in the £, which would probably be on the high side for a Rural Authority, it would mean that this particular occupier would pay £75 per annum in rates. He received nearly £40 in value in labour only, and it can be safely estimated that other items such as use of vehicles, overhead charges, etc., would bring the total cost of emptying his dumbwell to at least £50 per annum, or no less than two-thirds of his total payments, so that he was certainly getting very good value for his money.

6. Public Health Act, 1875, Section 44.

"*Power of Local Authority to make bye-laws imposing duty of cleansing, etc., on occupier.*

Where the local authority do not themselves undertake or contract for :—

The cleansing of footways and pavements adjoining any premises.

The removal of house refuse from any premises.

The cleansing of earth-closets, privies, ashpits and cesspools belonging to any premises, they may make bye-laws imposing the duty of such cleansing or removal, at such intervals as they think fit, on the occupier of any such premises.

An urban authority may also make bye-laws for the prevention of nuisances arising from snow, filth, dust, ashes, and rubbish, and for the prevention of the keeping of animals on any premises so as to be injurious to health."

The first portion of this section covers those smaller authorities who do not undertake refuse removal and cleansing, and who can require occupiers to undertake the duty at prescribed intervals.

It should be noted that Section 44 does not authorise any conditions being laid down by a Corporation as to the method of cleansing to be adopted, but only authorises the interval between cleansings being specified.

The second part of Section 44 empowers an *Urban* (note Urban) Authority to make bye-laws upon the matters referred to.

This is the section which allows bye-laws to be passed such as those in operation in Birmingham regarding the deposit of liquid matter in dustbins. It is also from this section that an Urban Authority can require occupiers to remove snow from pavements to roadway.

7. Public Health Act, 1875, Section 45.

" *Power to provide receptacles for deposits of rubbish.*

> Any urban authority may, if they see fit, provide in proper and convenient situations receptacles for the temporary deposit and collection of dust, ashes and rubbish; they may also provide fit buildings and places for the deposit of any matters collected by them in pursuance of this part of this Act."

It is upon this authority that an Urban Authority may erect a refuse disposal works or provide a tip.

Some Corporations themselves provide dustbins at properties instead of requiring owners or occupiers to do so, as is done in Birmingham, and this section would provide the necessary authority for this method of installing bins. The section would also cover the provision of receptacles for refuse which are fixed by some Corporations in the streets, and usually attached to lamp or tram standards.

8. Public Health Act, 1875, Section 47.

" *Penalty in respect of certain nuisances on premises.*

> Any person who in any urban district :—
>
> (1) Keeps any swine or pigsty in any dwelling house, or so as to be a nuisance to any person; or
>
> (2) Suffers any waste or stagnant water to remain in any cellar or place within any dwelling house for twenty-four hours after written notice to him from the urban authority to remove the same; or
>
> (3) Allows the contents of any water closet, privy or cesspool to overflow or soak therefrom, shall for every such offence be liable to a penalty not exceeding forty shillings, and to a further penalty not exceeding five shillings for every day during which the offence is continued, and the urban authority shall abate or cause to be abated every such nuisance, and may recover in a summary manner the expenses incurred by them in so doing from the occupier of the premises on which the nuisance exists."

The reasons for the provisions contained in par. (3) of this section are rather difficult to follow, as it appears that with regard to overflowing of privies or cesspools an occupier is in the hands of the Corporation concerned. If the latter do not empty his privy or cesspool sufficiently frequently to prevent overflowing, it is difficult to see how the occupier can be held responsible. The section may be framed to cover districts where no cleansing of the conveniences mentioned is undertaken by the Authority, in which case the onus of cleansing could be placed on occupiers.

The section might also be intended to be used in requiring occupiers to keep the conveniences mentioned in sufficiently good repair, *i.e.*, to prevent refuse escaping, presuming emptying is carried out often enough, although this seems doubtful, as it will be noticed that the Authority can only proceed against an occupier and not against an owner.

9. Power of Local Authority to undertake cleansing of certain types of conveniences only.

It will be remembered that Section 42 of the Public Health Act, 1875, refers to the cleansing of several types of conveniences, and the question once arose as to whether in putting a cleansing service in operation an Authority is obliged to undertake the cleansing of each type of convenience mentioned in that section. The Local Authority concerned passed a bye-law requiring cesspools to be emptied every three months by the occupiers of houses, and at the time this bye-law was passed the Local Authority did not undertake cleansing of any nature.

It was subsequently decided by resolution of the Council to cleanse ashpits, privies and earth-closets. The occupiers of houses possessing cesspools then claimed that the Local Authority were obliged to undertake the cleansing of all types of conveniences mentioned in Section 42. The case was taken to law, and it was held that the Authority could by resolution of the Council decide to undertake the cleansing of a portion only of the types of conveniences referred to in Section 42.

It has been ruled in the Courts also that a Local Authority, once having decided to undertake cleansing under Section 42, can, if they so desire, cease to undertake the work.

10. Public Health Act, 1875, Section 36.

" *Power of Local Authority to enforce provision of privy accommodation for houses.*

> If a house within the district of a local authority appears to such authority by the report of their Surveyor or Inspector of Nuisances to be without a sufficient water-closet, earth-closet or privy and an ashpit furnished with proper doors and coverings, the local authority shall, by written notice, require the owner or occupier of the house, within a reasonable time therein specified, to provide a sufficient water-closet, earth-closet, or privy and an ashpit furnished as aforesaid, or either of them, as the case may require.
>
> If such notice is not complied with, the local authority may, at the expiration of the time specified in the notice, do the work thereby required to be done, and may recover in a summary manner from the owner the expenses incurred by them in so doing, or may by order declare the same to be private improvement expenses: Provided that where a water-closet, earth-closet or privy has been and is used in common by the inmates of two or more houses, or if in the opinion of the local authority a water-closet, earth-closet or privy may be so used, they need not require the same to be provided for each house."

Sections 42 to 47 were discussed earlier in this chapter, and the reader may wonder why Section 36 is dealt with subsequently. The reason is that Sections 42 to 47 are placed under the heading of " Scavenging and Cleansing " in the Act, and these sections may therefore perhaps be regarded as more closely concerning a Cleansing or Salvage Department than other sections.

Section 36 comes under the heading of " Privies and Water-closets," but, as will be seen, contains one very important clause affecting Cleansing Departments, viz.—that bearing reference to the provision of ashpits.

Under Section 11 of the Public Health Acts Amendment Act, 1890, the term " ashpit " as used in the 1875 Act, is extended to include movable receptacles such as dustbins. Section 11 of the Public Health Acts Amendment Act reads as follows :—

> " The expression ' ashpit ' in the Public Health Acts and in this Act shall for the purposes of the execution of those Acts and of this Act include any ashtub or other receptacle for the deposit of ashes, fæcal matter or refuse."

It will be seen that under the sections mentioned of the two Acts, a Local Authority can obtain the provision of dustbins by owners or occupiers, and, in some districts, the installation of dustbins is obtained under these sections. In actual practice, however, this method is somewhat cumbersome, possesses certain loopholes, and to put the matter on a sound basis some Authorities have obtained definite powers under local Acts to require the provision of bins. Birmingham possesses full powers under local Acts to obtain the installation of dustbins at any property, and these Acts will be dealt with in a subsequent chapter upon local law.

11. Public Health Act, 1875, Section 39.

" *Public Necessaries.*

> Any urban authority may, if they think fit, provide and maintain, in proper and convenient situations, urinals, water-closets, earth-closets, privies and ashpits and other similar conveniences for public accommodation."

This section requires no explanation and, as will be seen, gives authority for the provision of public conveniences.

12. Public Health Act, 1875, Section 102.

"*Power of entry of local authority.*

The local authority, or any of their officers, shall be admitted into any premises for the purpose of examining as to the existence of any nuisance thereon, or of enforcing the provisions of any Act in force within the district requiring fireplaces and furnaces to consume their own smoke, at any time between the hours of nine in the forenoon and six in the afternoon, or in the case of a nuisance arising in respect of any business, then at any hour when such business is in progress or is usually carried on.

Where under this Act a nuisance has been ascertained to exist or an order of abatement or prohibition has been made, the local authority or any of their officers shall be admitted from time to time into the premises between the hours aforesaid, until the nuisance is abated, or the works ordered to be done are completed, as the case may be.

Where an order of abatement or prohibition has not been complied with, or has been infringed, the local authority, or any of their officers, shall be admitted from time to time at all reasonable hours, or at all hours during which business is in progress or is usually carried on, into the premises where the nuisance exists, in order to abate the same.

If admission to premises for any of the purposes of this section is refused, any justice on complaint thereof on oath by any officer of the local authority (made after reasonable notice in writing of the intention to make the same has been given to the person having custody of the premises) may, by order under his hand, require the person having custody of the premises to admit the local authority, or their officer, into the premises during the hours aforesaid, and if no person having custody of the premises can be found, the justice shall, on oath made before him of that fact, by order under his hand authorise the local authority or any of their officers to enter such premises during the hours aforesaid.

Any order made by a justice for admission of the local authority or any of their officers on premises shall continue in force until the nuisance has been abated, or the work for which the entry was necessary has been done."

13. Public Health Act, 1875, Section 267.

This section deals with the serving of notices and reads as follows :—

"Notices, orders and any other documents required or authorised to be served under this Act may be served by delivering the same to or at the residence of the person to whom they are respectively addressed, or where addressed to the owner or occupier of premises by delivering the same or a true copy thereof to some person on the premises, or if there is no person on the premises who can be so served by fixing the same on some conspicuous part of the premises, they may also be served by post, by a prepaid letter, and if served by post shall be deemed to have been served at the time when the letter containing the same would be delivered in the ordinary course of post, and in proving such service it shall be sufficient to prove that the notice, order or other document was properly addressed and put into the post.

Any notice by this Act required to be given to the owner or occupier of any premises may be addressed by the description of the 'owner' or 'occupier' of the premises (naming them) in respect of which notice is given, without further name or description."

It will be seen that there are several ways of serving notices, and it may be advisable to comment upon some of the methods mentioned :—

(*a*) *Fixing Notices on Buildings.*—This course should be adopted only when it is found impossible to serve a notice either personally or by registered post.

(*b*) "*Prepaid Letter.*"—It will be noted that "Registered Post" is not demanded. Notices served under the Public Health Acts can be served by ordinary post, postage and prepayment being proved by the individual who made up, stamped and posted the postal packet. If notices are served by ordinary post, however, it is desirable for one person only to carry out the making up, stamping and posting of the postal packet, as otherwise difficulty might be experienced in proving posting. Another method of proving prepayment is by means of a certificate of posting, which can be obtained on payment of ½*d*. at a post office, at the time of posting an unregistered letter, postcard, printed paper or newspaper.

Either method satisfies the requirements of the section, but it should be noted that certain local Acts such as the Birmingham Consolidation Act, 1883, require notices sent by post to be registered.

(*c*) *Addressing as "Owner"* (without name).—This method should be adopted only after reasonable efforts have been made to obtain the actual name and address of the owner.

14. Public Health Act, 1875, Section 306.

This section deals with the obstruction of an Authority in execution of the provisions of the Act and reads :—

> "*Penalty on obstructing execution of Act.*
>
> Any person who wilfully obstructs any member of the local authority, or any person duly employed in the execution of this Act, or who destroys, pulls down, injures or defaces any board on which any bye-law notice or other matter is inscribed, shall, if the same was put up by authority of the Local Government Board or of the local authority, be liable for every such offence to a penalty not exceeding five pounds.
>
> Where the occupier of any premises prevents the owner thereof from obeying or carrying into effect any provisions of this Act, any justice to whom application is made in this behalf shall, by order in writing, require such occupier to permit the execution of any works required to be executed, provided that the same appear to such justice to be necessary for the purpose of obeying or carrying into effect the provisions of this Act; and if within twenty-four hours after the making of the order such occupier fails to comply therewith, he shall be liable to a penalty not exceeding five pounds for every day during the continuance of such non-compliance.
>
> If the occupier of any premises, when requested by or on behalf of the local authority to state the name of the owner of the premises occupied by him, refuses or wilfully omits to disclose or wilfully mis-states the same, he shall (unless he shows cause to the satisfaction of the Court for his refusal) be liable to a penalty not exceeding five pounds."

It must not be assumed that this section gives a Local Authority power to enter premises without the permission of the occupier, as is evidenced by the following report of an action which was taken by a Local Authority against an owner for obstruction :—

> "A notice having been served by an urban district upon the owner of premises requiring him to abate a nuisance thereon, certain members of the Council went to the premises, and, without the permission of the owner, some of them entered the premises to make an inspection, the rest remaining outside. The owner thereupon locked the door of the premises, thus preventing the members who were outside from entering, and those who were inside from getting out. Upon information charging the owner with having wilfully obstructed the members in the execution of the Public Health Act, 1875, it was held that the members had no power under Section 102 of the Act to enter premises except by permission of the owner or by an order of a magistrate, and that therefore they were not lawfully there, and the owner was not guilty of obstructing them in the performance of their duty (Consett Urban District Council *v.* Crawford, 1903)."

The proper course for the Authority to have taken was to ask the owner's permission to enter the premises, and if sanction was refused, a magistrate's order should have been applied for, in accordance with Section 102 of the Public Health Act, 1875.

15. Public Health Acts Amendment Act, 1890, Section 26.

This section, part of which appears to be supplemental to Section 44 of the Public Health Act, 1875, deals with the making of bye-laws in connection with refuse removal and reads as follows :—

"*Power to make bye-laws for certain sanitary purposes.*

"(1) An urban authority may make bye-laws in respect of the following matters, namely :—

(*a*) For prescribing the times for the removal or carriage through the streets of any fæcal or offensive or noxious matter or liquid, whether such matter or liquid shall be in course of removal or carriage from within or without or through their district.

(*b*) For providing that the vessel, receptacle, cart or carriage used therefor shall be properly constructed and covered so as to prevent the escape of any such matter or liquid.

(*c*) For compelling the cleansing of any place whereon such matter or liquid shall have been dropped or spilt in such removal or carriage.

(2) Where a local authority themselves undertake or contract for the removal of house refuse they may make bye-laws imposing on the occupier of any premises duties in connection with such removal so as to facilitate the work which the local authority undertake or contract for."

The times for removal of offensive matter as specified in bye-laws made under this section are determinable by the Local Authority.

In a Metropolitan Police Act (now repealed) it was laid down that the hours for removal of noxious matter should be restricted to the hours of from 12 midnight to 6 a.m.

In a series of bye-laws made as recently as August 1925 by a Midland Authority, the hours for removal are from 6 a.m. to 8.30 a.m. from March to October and from 7.30 a.m. to 9.30 a.m. from November to February.

The second paragraph of the section empowers an Authority to pass bye-laws to facilitate the work of refuse collection, such, for example, as requiring occupiers to remove dustbins to the pavement to await the collecting vehicle. In this connection it might be mentioned that there is some limit to which occupiers can be called upon to assist in this direction, in spite of bye-laws which may be brought into operation, as will be evident from the case in which an occupier whose house was situated 40 feet from the kerbstone, and who declined to remove his bin to the kerb. The Authority refused to remove his house refuse until the bin was delivered by the occupier to the kerb, and in the legal action which resulted it was held that the occupier was justified in his refusal.

Part II. Local Acts and Bye-laws.

Introduction.—The powers obtained under the various Acts and Bye-laws which will be dealt with are applicable only to the City of Birmingham. Most cities have their own local Acts and Bye-laws, and each may differ from the other according to local conditions.

Ashplaces.—Before proceeding to deal with the Acts and Bye-laws it is necessary to describe the more frequent types of ashplaces for the temporary storage of refuse, in use in this city before the introduction of dustbins.

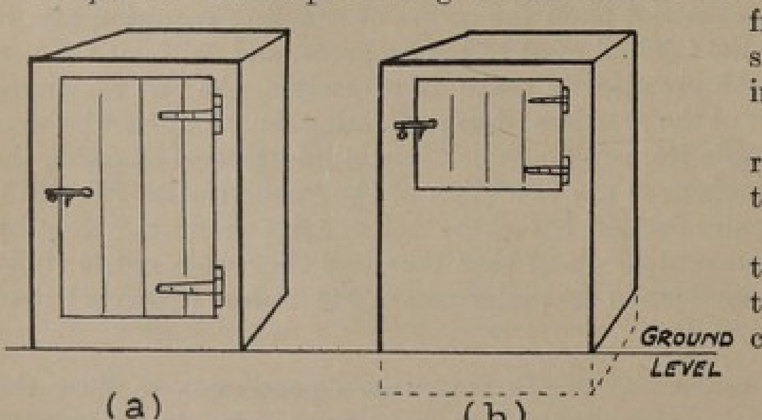

Fig. 1.—Ashplaces (*a*) Suitable (*b*) Unsuitable.

The question of ashplaces as a means of storing refuse pending its removal by the Corporation and their great disadvantages will be dealt with later.

In order that the terms used in the local Acts to be dealt with may be better understood, the types of ashplaces are divided into the following classes :—

(*a*) Suitable construction.
(*b*) Unsuitable construction.

Class (*a*) are ashplaces of such construction as to give a ready means of access and in which there are no obstructions to the removal of refuse (see Fig. 1).

Class (*b*) are ashplaces of such construction that, to remove the contents, the refuse collectors have to climb through the small door and shovel the refuse out.

It is obvious that the collection of refuse from this class of ashplace has numerous objections, which render them of "unsuitable construction."

Birmingham Corporation Act, 1914, Section 28.

"*Regulation Dustbins.*

28. (1) The Corporation may by notice in writing require the owner or occupier of any dwelling house, warehouse or shop to provide portable dustbins of galvanised iron or other impervious material in lieu of ashpits or ashtubs or other receptacles for refuse and such bins shall be of such size and construction as may be approved by the Corporation.

(2) Any owner or occupier who fails within fourteen days after notice given to him to comply with the requirements of the Corporation under this section shall be liable to a penalty not exceeding twenty shillings and to a daily penalty not exceeding five shillings.

(3) Provided that this section shall not apply to any ashpits or ashtubs or other receptacles for refuse in use at the passing of this Act so long as the same are of suitable material size and construction and in proper order and condition and for a period of five years after the passing of this Act this section shall not apply to any ashpits or ashtubs or other receptacles for refuse in use at the passing of this Act which complied with the bye-laws in operation at the time when they were provided and which are in proper order and condition."

Remarks on Section 28.

From Sub-section (1) it will be seen that the Corporation may serve the notices upon either the owner or occupier. The Salvage Committee have by resolution adopted the principle that notices shall be served upon the owners of properties except in special cases such as when a tenancy is for a number of years on lease, when it is left to the discretion of the General Manager to serve such notices upon the occupiers if he thinks fit.

The City Council has approved for use in the city two sizes of dustbins and the detailed specification of construction is given on the back of all notices served under this Act.

It will be observed that Sub-section (3) prevents the Corporation from requiring dustbins to be installed at any property which has an ashplace, ashtub or other receptacle in use, which at the passing of the Act was of suitable size and construction and in proper order and condition.

In order to overcome this difficulty the Corporation obtained further powers by Section 54 of the Birmingham Corporation Act, 1922, as follows :—

Birmingham Corporation Act, 1922, Section 54.

"*Further Provisions as to Dustbins.*

54. (1) Section 28 (Regulation Dustbins) of the Act of 1914 is hereby amended by the insertion of the words 'and to maintain in good order and condition' after the word 'provide.'

(2) Where the Corporation are prepared to pay one-half the expense of providing a portable dustbin, the said Section 28 as amended by this Act shall notwithstanding Sub-section (3) thereof apply to ashpits, ashtubs and other receptacles for refuse in use at the passing of the Act of 1914, although they are of suitable material, size and construction and in proper order and condition.

(3) In cases where a portable dustbin is substituted for an ashpit the Corporation may (if they think fit) contribute to the cost of converting the ashpit into a dustbin shed, a sum not exceeding one half of such cost."

Remarks on Section 54.

Sub-section (1) gives the Corporation power to require owners or occupiers to renew dustbins when worn out.

As already stated, the Corporation could not require dustbins to be provided at any property where the ashplace was of suitable size and construction and in good order and condition, and therefore to obtain dustbins at such properties the Corporation had to agree to pay half the cost of the first dustbin(s) required in lieu of such ashplaces.

Sub-section (3) deals with the ashplace of unsuitable size and construction and empowers the Corporation to make a contribution not exceeding one-half the cost of having such alterations carried out as will convert the ashplace into a dustbin shed.

The alterations required to do this are usually of a very small character.

From Fig. 1 (*b*) it will be seen that if the door and jambs are taken off, the brickwork is cut down for the width of the door from the bottom of the door to the ground, and a 3-inch sill built at the bottom, a suitable bin-shed is obtained. If the floor of the ashplace is below the ground level, it would be necessary to have the floor raised to the same height as the sill.

Birmingham Corporation (Consolidation) Act, 1883, Section 259.

This section deals with the serving of notices and how such notices are to be made out :—

"1. Notices may either be in writing, print (including lithograph), wholly, part or both, and shall be sufficiently authenticated by the signature of the proper officer, in print, writing or stamp.

2. Notices can be served on owner or occupiers addressed " Owner or Occupier " (as the case may be) of the premises (naming them).

3. *Serving of Notices :*

Notices can be served in any of the following methods :—

(*a*) Personally.

(*b*) Registered post addressed to him by name at his last known place of abode or business.

(*c*) By delivering same to some inmate at his last known or usual place of abode or business. In the case of an occupier, to any inmate of the premises of which it is served or given, or if the premises are unoccupied, and after diligent enquiry the place of abode cannot be traced, by fixing the notice or copy on some conspicuous part of the premises.

4. The date of service is the date on which such letters would be delivered in the ordinary course of post.

5. The section of the Act or Bye-law under which the notice is served must be set out at the head or foot or back of the notice."

Birmingham Corporation Act, 1903, Section 79.

This section empowers the Corporation to contribute not exceeding one-half the cost towards the conversion of existing closet accommodation (other than a water-closet) into a water-closet at any dwelling-house in the city.

Bye-laws to Facilitate the Collection of Refuse.

The following Bye-laws were made by the City Council in May 1921, and approved by the Ministry of Health, by virtue of the provisions of the Public Health Acts Amendment Act, 1890—

Section 26.—1. In these Bye-laws the expression " the Council " means the Lord Mayor, Aldermen and Citizens of the City of Birmingham acting by the Council.

2. (*a*) Where under Section 28 of the Birmingham Corporation Act, 1914, a portable dustbin has been required to be provided in connection with any premises the occupier of such premises shall cause all house refuse on the premises, intended for removal by the Council, to be placed in such portable dustbin.

(*b*) Where no portable dustbin has been required to be provided he shall cause all such house refuse on the premises intended for removal by the Council to be placed in the ashpit or other receptacle for refuse provided in connection with the premises.

(*c*) He shall cause such portable dustbin or other receptacle containing the house refuse to be placed in such a position on the premises as for the purpose of removing the contents of such portable dustbin or other receptacle will be most conveniently accessible from the nearest street used as a means of access to the premises for the removal of house refuse, otherwise than through any dwelling-house.

3. The occupier of any premises shall not deposit or cause to be deposited in or within four feet of any receptacle provided for the reception of house refuse intended for removal by the Council any house refuse not intended for removal by the Council.

4. The occupier of any premises shall not deposit or cause to be deposited in any portable dustbin or other receptacle provided for the reception of house refuse any liquid or fæcal matter whatever.

5. Every person who shall offend against any of the foregoing bye-laws shall be liable for every such offence to a penalty of 40*s*. Provided nevertheless that the Justices or Court before whom any complaint may be made or any proceedings may be taken in respect of any such offence may, if they think fit, adjudge the payment as a penalty of any sum less than the full amount of the penalty imposed by this Bye-law.

These Bye-laws deal entirely with the collection of house refuse and were made to facilitate this work. Bye-laws 2 (*a*) and (*b*) apply more particularly to court or back premises where usually the refuse accommodation is common to two or more houses and the occupiers of such properties are not as clean and careful in their habits as could be desired. Prior to the introduction of these Bye-laws, it was found that refuse was frequently thrown in the direction of the dustbins, and most of it fell on the ground.

Great assistance has been afforded by Bye-law 2 (*c*) especially in the case of houses with long gardens, with the street entrance furthest from the house. Dustbins are now kept near the entrance, thus obviating the refuse collectors having to carry the dustbins the length of the garden.

Bye-law 3 clearly defines what refuse is intended for removal by the Corporation, and assists considerably in meeting complaints from occupiers of articles having been wrongly removed by the refuse collectors.

It is not necessary to dwell upon Bye-law 4, as the evil of liquid or fæcal matter in dustbins is apparent. More particularly is the enforcement of such a Bye-law necessary in towns where the refuse is treated at a salvage works.

It has not been found necessary to serve any notices under these Bye-laws; a letter calling the attention of defaulting occupiers has, so far, always been sufficient. If, however, at any time it was necessary to serve a notice upon an occupier, the notice would have to be drawn up and served in accordance with the requirements of Section 259 of the Birmingham Corporation (Consolidation) Act, 1883.

Part III. Trade Refuse.

1. Public Health Act, 1875, Section 42.

It will be remembered that when the provisions of Section 42 of the Public Health Act, 1875, were discussed previously (page 2), it was pointed out that there is nothing contained in that section which directs that a Local Authority shall remove trade refuse. In districts where no special local enactment authorising a charge being levied for trade refuse removal is in force, the fact that Section 42 does not require a Corporation to remove trade refuse might be used as an authority for demanding payment. This may be termed a negative authority, however, and in actual practice might not invariably prove satisfactory, particularly in the larger cities and towns, where organised associations of traders are usually found, who are always alive to the protection of their members. To place the matter on a sounder footing, therefore, many Local Authorities have obtained powers under local Acts definitely authorising the levying of charges for trade refuse removal, or have adopted other legislation which is referred to later.

2. Birmingham Corporation Act, 1903, Section 80.

As far as Birmingham is concerned, power to demand payment for removal of trade refuse is contained in Section 80, Birmingham Corporation Act, 1903, as follows :—

"No trade refuse, building materials or rubbish of a like description shall be deposited in any closet, privy, cesspool, ashpit or ashtub, and if any such refuse, materials or rubbish be so deposited the Corporation may make a reasonable charge for the removal of the same, which charge shall be paid to the Corporation by the occupier of the premises in respect of which the charge is made."

3. Public Health Acts Amendment Act, 1907, Section 48.

A charge for trade refuse removal is authorised also under Section 48, Public Health Acts Amendment Act, 1907, as follows :—

" *Removal of Trade Refuse.*

If the local authority are required by the owner or occupier of any premises to remove any trade refuse (other than sludge), the local authority shall do so, and the owner or occupier shall pay to them for doing so a reasonable sum, to be settled in case of dispute by order of a court of summary jurisdiction; and if any question arises in any case as to what is to be considered as trade refuse, that question may be decided on the complaint of either party by a court of summary jurisdiction, whose decision shall be final."

The latter Act is an adoptive Act, that is, an Act which can be adopted in part or whole by a Local Authority at their discretion, subject to the approval of the Ministry of Health. If a Corporation had adopted Section 48 of this Act, they would be obviously obliged to abide fully by its provisions, and would, therefore, have no power to decline removal of trade refuse (other than sludge), no matter what the nature of the trade refuse might be. From a Cleansing or Salvage Department's standpoint, this is not desirable, as certain classes of trade refuse are very difficult to dispose of. For instance, refuse produced by some trades is not combustible; refuse of other trades is offensive, and its treatment might bring a Department into disrepute; and again, certain classes of trade refuse are dangerous to deal with. A Corporation is, therefore, in a happier position if they can discriminate between the classes of trade refuse they shall remove.

4. Public Health (London) Act, 1891, Section 33.

This section, which refers, of course, to the Metropolis only, reads as follows :—

" If the Sanitary Authority are required by the owner or occupier of any premises to remove any trade refuse, that Authority shall do so, and the owner or occupier shall pay to that Authority a reasonable sum for such removal, such sum in case of dispute shall be settled by the order of a petty sessional court."

5. Definition of Trade Refuse.

From the above remarks it will be gathered that Local Authorities usually have ample power to recoup themselves for the cost of trade refuse removal, and the student might begin to wonder where the difficulties, which he has probably heard referred to, arise in charging for this service. The answer lies in the question : " What is ' house ' refuse and what is ' trade ' refuse ? " Perhaps the best definitions of the two terms are contained in Section 30, Public Health (London) Act, 1891 :—

" The expression ' house refuse ' means ashes, cinders, breeze rubbish, nightsoil and filth, but does not include trade refuse.

" The expression ' trade refuse ' means the refuse of any trade, manufactory or business or of any building materials."

The definitions contained in the above section are, of course, not necessarily binding on Authorities other than Metropolitan Authorities, but it may be reasonably assumed that regard would be paid to the definitions in any action affecting a provincial Authority. No legislation, however, has proved sufficient to prevent legal proceedings being taken with reference to trade refuse removal, and the question of what may be legitimately termed trade refuse has apparently vexed the minds of members of the legal profession and of Corporation officials ever since cleansing services were instituted. The subject has become so complicated that a really intelligent and complete definition of trade refuse is to-day perhaps one of the greatest needs of Departments responsible for the removal and disposal of refuse.

It was probably the intention of the promoters of legislation dealing with trade refuse that all refuse produced in the course of trade should be regarded as trade refuse. Be this as it may, legal decisions have been given from time to time to the effect that refuse produced in certain trades (although these trades are ostensibly carried on solely for making profit) must be regarded as house and not trade refuse by reason of the nature of the refuse, and Local Authorities undertaking removal of refuse have no option but to remove without payment. In a trade refuse case tried in 1909, in which a firm of caterers were concerned, Lord Alverstone stated that :—

> " If the principle could be accepted that all refuse produced in a trade was trade refuse, we should have a clear and safe guide to the decisions of these cases, but that having regard to previous decisions, the Court could not accept the principle."

6. Traders Receiving Free Refuse Removal.

Traders who are able to claim this preferential treatment in the removal of refuse produced in their businesses are engaged in such undertakings as hotels, refreshment rooms, and similar catering establishments, and their claim is based on the argument that they are carrying on a domestic undertaking to supply a domestic necessity for persons who would otherwise produce similar refuse in their own dwellings. As an instance, hotel proprietors claim that if hotel residents were living in private houses they would produce refuse exactly similar in nature to that produced in hotels, and that if the refuse had accumulated at private dwellings, it would be removed by the Local Authority without question.

However logical this argument may appear from the viewpoint of the hotel proprietor, it seems palpably unfair that one trader, because he happens to make his profits from the sale of such articles as eatables, should be in a position to demand free refuse removal, whilst his neighbour, who may trade in some other useful commodity, must pay for the removal of every bin of trade refuse produced on his premises.

It is also unfortunate from the point of view of the Local Authority that catering businesses usually produce larger quantities of refuse than traders engaged in other directions. Theatres, cinemas and other places of amusement are another class of business generally allowed refuse removal free of charge, owing to the nature of the refuse produced.

Notwithstanding the legal decisions which have been given from time to time to the effect that refuse produced in the businesses mentioned must be removed free of charge, it appears possible that payment at least on a reduced scale to a Local Authority's normal charge for trade refuse removal could be demanded in many cases. Under Section 43 of the Public Health Act, 1875, a Local Authority is not in default for non-removal of house refuse until after the expiration of seven days' notice to remove has been received from an occupier, and a Corporation cannot therefore be compelled to remove refuse more frequently than once weekly. It has been stated already that hotels and other catering establishments usually produce large quantities of refuse, and apart from the quantity produced, the nature of the refuse is such that frequent removal is necessary. A weekly service is not generally sufficient therefore for such businesses, and where a more frequent removal is demanded, there appears to be good grounds for a Local Authority to require payment of at least a portion of the expenses incurred. When recently reading through a paper entitled " Trade Refuse," read by Sir William E. Hart, Town Clerk of Sheffield, at the annual conference of the Institute of Cleansing Superintendents (now The Institute of Public Cleansing) in June 1920, the writer was interested to find that this opinion is held by such an eminent authority on the subject.

7. Legal Decisions.

A paper devoted largely to the legal position regarding trade refuse removal was read by Mr. Leigh Turner, the Town Clerk of Blythe, at a meeting of the Institute of Municipal and County Engineers in September 1926, and the following decisions given in a number of trade refuse cases are referred to in this paper :—

(a) *Lyndon v. Stainbridge* (1857).

House refuse does not extend to dust and ashes, the exclusive produce of manufactories.

(b) *Holborn Union* (*Guardians of*) v. *St. Leonards'* (*Vestry of*) *Shoreditch* (1876).

Local Authority was bound to remove refuse from a workhouse, although such workhouse was by local Act rated at a less amount than other property in the parish.

(c) *Gay* v. *Cadby* (1877).

Ashes arising from coals burnt in the furnace of a steam engine used for the purpose of sawing and lifting timber and other materials for carrying on business of a pianoforte manufacturer were held not to be house refuse, but were the refuse of a trade, manufactory or business within Section 128 of the Metropolis Management Act, 1855.

(d) *Collins* v. *Paddington* (*Vestry of*) (1879).

Not all refuse from a house is "house refuse," as it was held that broken glass, shoes and other articles of a similar character, which it might not be convenient otherwise to get rid of, thrown into the dustbin of a house were improperly placed there, and the Local Authority were not bound to remove them. This decision was given under the Metropolis Management Act of 1855, which requires the Local Authority to remove "rubbish," and it was considered that what the Vestry were required to remove were dirt and dust, which would be prejudicial to health if allowed to accumulate, and not such things as broken glass, bottles or disused garments. Where such articles were removed and were afterwards appropriated by servants of the Local Authority it was held that the contractor who had purchased and undertaken to dispose of the house refuse was not entitled to compensation in respect of them, on the ground that his contract only included such refuse as the Authority were bound to remove.

(e) *St. Martin's Vestry* v. *Gordon* (1890).

Clinkers produced in furnaces of boilers belonging to an hotel used to generate steam for the purposes of supplying power for electric lighting and for warming and cooking and other purposes of the hotel were held not to be refuse of a trade, manufactory or business within the Act (Metropolis Management Act of 1855).

(f) *London and Provincial Laundry Company* v. *Willesden Local Board* (1892).

Clinkers produced in furnaces of boilers belonging to a steam laundry for the purpose of heating the water used and also for heating laundry were not house refuse within the meaning of Section 42 of the Public Health Act, 1875, although the laundry comprised a dwelling-house for the persons in charge, which had a separate receptacle for house refuse.

(g) *Westminster Corporation* v. *Gordon Hotels Ltd.* (1906).

Ordinary refuse of an hotel, comprising such things as ashes from the grates, sawdust strewn on the kitchen floors for the sake of cleanliness, empty sauce bottles and preserve tins, straw packing-cases for bottles, tea leaves, waste paper, egg-shells, lemon peel, the dust from the rooms and staircases, and from time to time quantities of broken crockery ware and glass, was "house refuse" within the meaning of Section 30 of the Public Health (London) Act, 1891. In this case the Court expressed the opinion that in considering whether refuse is "house refuse" or "trade refuse" *regard must be had to its physical nature and character, and not to the process or circumstances by which it is accumulated.*

(h) *Lyons & Co., Ltd.* v., *City of London Corporation* (1909).

It was held that where premises (upon which no one slept at night) were used as a teashop for providing customers with refreshments and food for consumption on the premises (some of the food being cooked or prepared on the premises), the refuse, consisting of ashes and clinkers, coffee grounds, newspapers, cabbage leaves, egg-shells, dust and general dirt, broken crockery, tea leaves, potato parings, scrapings from the sink and sweepings from the rooms, but not including scraps left by customers, which were given away in charity, was "house refuse" and not "trade refuse," within Sections 39 and 141 of the Public Health (London) Act, 1891, and that the Sanitary Authority were under an obligation to secure its due removal. In this case, Lord Alverstone stated that "if the refuse is 'house' refuse in fact—if that is its character, then it is not a good answer to say, 'But that refuse has been produced in the course of carrying on a trade.'"

In the same case, Mr. Justice Jelf made the following statement:—

"Now there are many cases which clearly fall on one side of the line and many which clearly fall on the other. For example, in a carpenter's shop, the sawdust and shavings are clearly trade refuse; the snippings from a tailor's business would clearly be trade refuse; and so would be the hair cut by a hairdresser from the heads of his customers. On the other hand, there are certain incidents common to all houses, whether used for trade purposes or not, which would clearly not be trade refuse—dust blown in by the wind, soot from chimneys and dirt brought in on the boots of persons entering the house. These fall clearly on the other side of the line. The description of the refuse in this case included many things which are merely house refuse, and other things which might be considered trade refuse; and it seems to me that, having regard to its character as distinct from the place in which it was produced, it is not 'trade refuse,' but is 'house refuse.' "

The above decisions clearly show the serious confusion which has arisen on the question owing to the contradictory legal findings which have been given from time to time, and also demonstrates how the legal mind is capable of confusing the original meaning of plain language and intent.

As stated previously, it was presumably the intention of promoters of legislation dealing with trade refuse that all refuse produced in the course of trade should be regarded as trade refuse, but the legal mind sees things differently, and what to the lay mind appears to be a plain question has been the subject of numerous contradictory legal findings, thus rendering the position full of complications.

A consideration of the decisions delivered in the cases quoted demonstrates that the subject is almost hopelessly confused, and it appears that the only way of placing the matter on a satisfactory basis from a Local Authority's standpoint is by fresh legislation being passed which would definitely lay down the principle that all refuse produced in the course of trade for profit, is to be regarded as trade refuse.

8. Unsatisfactory Legal Position.

The unsatisfactory and uncertain legal position in which Local Authorities are placed in the matter of enforcing charges for trade refuse removal has led some Corporations to take the line of least resistance and to shirk their responsibilities of requiring traders to pay the cost of trade refuse removal and disposal. A return incorporated with Mr. Leigh Turner's paper shows that a number of Authorities remove trade refuse free of cost. The list of Corporations who follow this practice is not confined to small Rural Authorities, but includes a number of fairly large Corporations. Other large Corporations charge very small sums for the removal of trade refuse, a charge which can be regarded as a small acknowledgment only for the service given, and cannot possibly cover their expenses. These methods are grossly unfair to the general body of ratepayers, as the businesses concerned are being subsidised to some extent out of the rates. A real difficulty is also created for cities where an endeavour is made to obtain the approximate cost of service given in trade refuse removal, particularly when dealing with refuse produced by multiple businesses possessing branches in different towns, as when requiring payment for trade refuse removal from such businesses a complaint is frequently made that at branches in other towns free service is given, or a small payment only is required.

9. Instructions issued by Birmingham Salvage Department.

In view of the problems which arise from time to time in deciding whether different classes of refuse are to be regarded as trade refuse, it has been found advisable in the Birmingham Salvage Department to issue to all persons concerned a list of instructions showing how the main classes of refuse which the Department is called upon to remove from businesses are to be dealt with, *i.e.*, whether payment is to be required or whether free service should be given. The essentials of these instructions are as follows :—

(*a*) " Under the Public Health Act, 1875, it is the duty of the Corporation to remove house refuse from premises. It is not the duty of the Corporation, however, to remove trade refuse as a charge against the rates, and the Corporation have power, under Section 80 of the Birmingham Corporation Act, 1903, to make a reasonable charge for the removal of trade refuse, building materials or rubbish of a like description."

(*b*) The following will serve as a general definition of trade refuse :—

All refuse other than house refuse from premises where business is carried on.

(*c*) Even so, it is sometimes difficult to decide whether a certain kind of refuse is house refuse or trade refuse. Each case must be dealt with on its merits and the endeavour to obtain payment for the removal of any suspected trade refuse should not be abandoned until advice has been obtained from a superior officer.

(*d*) In the case of a shop to which there is attached a dwelling-house occupied by the proprietor or manager of the shop, and where the shop refuse and house refuse are deposited in the same bin, the removal of one bin of refuse per week may be allowed as a charge on the rates. Any refuse above this quantity should be charged for as trade refuse.

(*e*) In the case of a lock-up shop, all refuse except the assistant's fire and cooking refuse should be regarded as trade refuse, and its removal charged for.

Speaking generally, the following classes of refuse (among others) fall under the heading of trade refuse :—

Ashes, clinkers and hops from home-brewed beer-houses.
Ashes, clinkers and other refuse from pork shops.
Bakers' ashes, clinkers and refuse.
Factory and workshop ashes, clinkers, refuse and sweepings.
Garage refuse.
Heating apparatus ashes (except from offices).
Jewellers' refuse.
Machinery cotton waste and rags.
Metal waste.
Packing waste.
Polishers' sand, etc.
Sawdust.
Shavings.
Shopkeepers' refuse, packings and sweepings, including :—

Barbers'	refuse.	
Butchers'	,,	(including sawdust).
Fruiterers'	,,	
Grocers'	,,	
Tobacconists'	,,	etc., etc.

Straw refuse.
Waste paper, including waste paper from offices.

(*f*) The following refuse generally falls under the heading of house refuse, and is removed without charge :—

Refuse from hotels, lodging houses, restaurants and public houses.
Refuse from theatres, music halls, picture houses and other places of amusement.

Providing these instructions are faithfully observed, the main classes of trade refuse at least are dealt with on a uniform basis, whereas prior to the instructions being issued there was always a danger that an inspector of one district was allowing free removal of a class of refuse, while in another district of the city a charge was being made for the collection of the same class of refuse.

10. Suggested Definition of Trade Refuse.

Students sitting for the examination of the Institute of Public Cleansing may be asked to give a definition of trade refuse, and the following answer is perhaps as satisfactory as could be given under present circumstances :—

"Trade refuse consists of all refuse other than domestic refuse, from premises where business for profit is carried on. Alternatively, it may be defined as any waste or useless material produced in the course of a manufacturing process or as a result of any profit-making business. In considering whether refuse is house or trade refuse, regard must be paid to its physical nature and character, and not to the process or circumstances by which it is made."

11. Removal of Manure from Mews, Stables and other Premises.

Manure produced at mews, stables, etc., does not fall under the usually accepted designation of trade refuse, but attention might be usefully drawn to the provisions of Section 50 of the Public Health Act, 1875, which provides that notice may be given by any Urban Authority (by public announcement in the district or otherwise) for the periodical removal of manure or other refuse matter from mews, stables, or other premises; and where any such notice has been given, any person to whom the manure or other refuse matter belongs who fails to remove the same or permits further accumulation, and does not continue such periodical removal at such intervals as the Urban Authority direct, shall be liable to a penalty not exceeding 20*s*. for each day of the continuance of the offence.

12. Garden Refuse.

The removal of this refuse is dealt with in different ways by various Corporations, some Authorities requiring payment for removal, others removing free of charge. Probably the more general custom is to remove without making any charge. The Birmingham Salvage Department does not knowingly undertake free removal of garden refuse, although this fact now seems to be so well known by many occupiers of houses possessing gardens that it is not an uncommon occurrence for garden refuse to be deposited at the bottom of dustbins and for a quantity of house refuse to be placed carefully on the top. The refuse collector, no matter how keen he may be to obey his instructions not to remove garden refuse unless the collection be paid for, is therefore not infrequently deceived.

There is no legislation dealing actually with payment for garden refuse removal, but in Birmingham the view is held that garden refuse cannot be regarded as legitimate house refuse, and its removal is therefore subject to the same charge as that levied for trade refuse collection.

CHAPTER II

ACCOUNTANCY

ACCOUNTANCY may be described as the science of accurately recording monetary transactions so that at any time you may be able to ascertain the exact state of your financial affairs, *i.e.*, whether you are solvent or insolvent. This is very desirable, as it affords the information by which you will be able to protect yourself against excesses and generally keep control over your business affairs.

I propose to explain the system practised in a Salvage Department and to show by means of a diagram the various stages which lead up to the final result, *i.e.*, the Statement of Income and Expenditure compared with estimates. This is the means by which the Chief Executive Officer is able to keep a close watch on the financial affairs of the Department and thereby check undue expenditure under any particular heading.

1. *Wages Sheets* are ruled with columns to give the following information :—

Pay check number.
Registered number.
Name.
Occupation.
Time worked.
Rate.
Gross amount due.
Deductions for superannuation.
Health insurance, etc.
Net amount due.
Employers' contributions (Health and Unemployment Insurance).
Employers' contributions (Superannuation Fund).

These wages sheets are made up to each Wednesday night at the Depot, from time cards, etc., and are checked at the Central Office.

2. *Wages Summary.*—The totals of each column of the Depot Wages Sheets are transferred to this summary, thus giving the total wages bill per week. This summary is completed by Thursday afternoon and after being certified by the Chief Executive Officer is forwarded to the City Treasurer, who draws a cheque on a special Wages Advance Account at the bank. The Treasurer's advance account is reimbursed the following week. A certificate is passed forward for payment on the Monday following, against which the Treasurer draws a cheque on the Borough Fund Account, which is paid into the wages advance account. A Wages Chart or graph is prepared each week showing the comparison of the total wages to the estimate together with those of the previous year.

3. *Periodical Payment Book.*—This is the record book of such items as Rents, Rates and Taxes, etc., and contains the following information :—

Head of Expenditure to which the charge is to be allocated.
To whom due—Address.
Nature of Charge.
Contract dated—Minute numbers.
When Payable—On.
Commencing.
Amount payable per annum, £ .

4. An account must be rendered by the creditor and particulars should be entered in the Periodical

Payment Book when passing for payment. The account should then be certified by completing the following certification stamp :—

Certification of Periodical Payments.

Authority ....   Checked by ....   Certified by ....
Nominal Account.

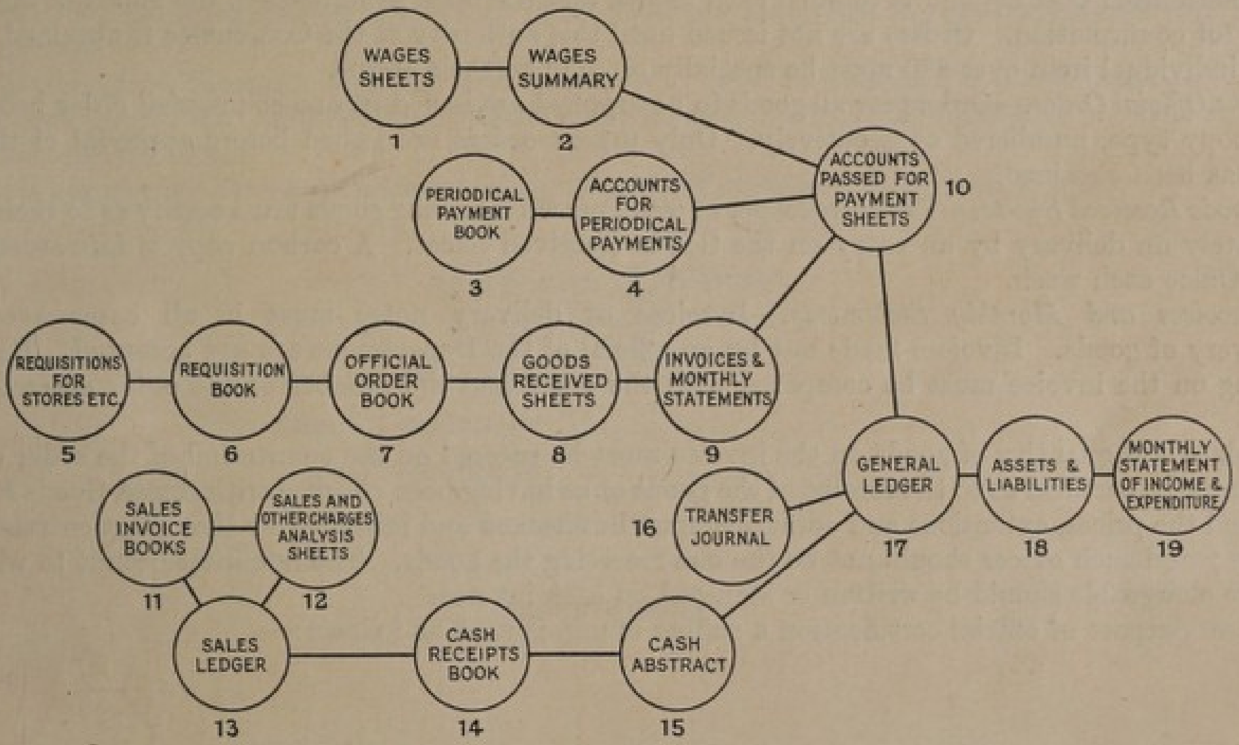

Fig. 2.—Diagram showing Accounting System.

5. *Requisitions for Stores,* work to be done or service to be rendered are forwarded to the Chief Executive Officer by the Storekeeper or others for approval.

The form of requisition is :—

Requisition from Depot. No. Date

Name of goods, etc., reqd.	Quantity.	To be used for.

Approved by General Manager. Signature of Requisitioning Officer.

Order issued. Date. No.

Accounts Clerk's Initials.

6. *The Requisition Book.*—When requisitions have been approved by the Chief Executive Officer they are entered in this book under the following headings :—

Consecutive number.
Requisition number.
Description of Goods or Work.
Quantity.
To be purchased from or carried out by.
Estimated cost.
To be used for.
Order number.
Actual cost.
Remarks.

The Estimated Cost column is totalled each month and the book submitted to the Monthly Committee Meeting for confirmation. Orders are not issued until this authority of the Committee is obtained.

Any individual item over £50 must be specially brought to their notice.

7. *The Official Order.*—Orders for all goods to be supplied are issued from a counterfoil order book of the carbon copy type, numbered consecutively. Only urgent orders are issued before approval of the Committee has been obtained.

8. *Goods Received Sheets.*—The storekeeper or other person receiving goods must certify as to their receipt immediately on delivery by an entry on the Goods Received Sheet. A carbon copy is forwarded to the Central Office each week.

9. *Invoices and Monthly Statements.*—Invoices or delivery notes must in all cases accompany the delivery of goods. Invoices made out by an official of the Department are not accepted. Each item appearing on the invoice must be compared with the order and the number of the order entered on the invoice.

The date and quantity of goods on the invoice must be entered on the counterfoil of the order. Every invoice must be certified as to the receipt of the goods or as having been checked with signed Goods Received Sheets and the prices, extensions and additions must be checked and initialled by the officer entrusted with this duty; and such officer should not be the one receiving the goods. The nominal account to which the goods are chargeable should be written or stamped on each invoice.

For the purpose of official certification a rubber stamp is used as follows :—

Certification of Invoice.

Order No. ....
Compared by ....
Goods rec'd. by ....
Prices checked by ....
Extensions checked by ....

Nominal Account.

Rev. ....
Cap. ....

Accounts due for charges other than goods supplied or Periodical Payments are checked as follows :—

Nature of Charges.	*Checked by.*
Horse Keep, Hired Horses	Horse Returns.
Contractors' Carting	Depot Clinker Books.
,, Boating	Boating Returns.
Tonnage Charges	Canal Tickets.
Gas, Water, Electricity	Register of Consumption.

Statements of accounts must be obtained at the end of each month and entries on such statements be compared with the invoices and certified, and the deductions or discounts be checked by the officer responsible. No invoice should be passed for payment unless it appears on the statement rendered and such statement must bear upon its face a summary of the amounts chargeable to the nominal accounts as shown on the invoices.

The Statement of Account, together with the Invoice, must be attached to a certificate or "jacket," which is certified by the Chief Executive Officer and also certified by the Chairman or other authorised member of the Committee.

For the purpose of Official Certification of the statement, a rubber stamp is used :—

Certification of Statement.

Checked with invoices by ....

Discounts checked by ....

Arithmetic checked by ....

Certified by ....

Nominal Account.

Analysis of Stores Purchased.—This is a subsidiary analysis of the heading—Plant, Materials, Tools, Repairs and Maintenance. The expenditure under this head is large enough to make it desirable to split it under sub-heads, such as Bricks, Lime, Cement, Brooms, Brushes, Petrol, Paint, Iron and Steel, Timber, Manure Bags, Tyres, Wagon Sheets, etc.

The comparison with the estimate can then be more closely watched each month.

10. *Accounts passed for Payment Sheets.*—The Wages Certificate for wages paid the previous Friday, together with any urgent accounts for payment, are prepared for signature of the Chairman of the Finance Committee each Monday.

Other accounts are prepared for submission to the Committee each month by attaching to the front of each account a certificate or "jacket" bearing the name, what the account is for and the summary of the nominal account to be debited. This is certified by the Chief Executive Officer and signed by the Chairman. All accounts are entered on the Accounts Passed for Payment Sheet, which is ruled with a column for each head of expenditure. The amounts shown on the "jacket" or certificate against each nominal head are entered in the appropriate column.

The whole of the expenditure of the Department is allocated to one of the following nominal heads :—

Salaries.
Wages.
National Insurance :—
    Health.
    Unemployment.
Workmen's Compensation.
Workmen's Clothing.
Hired Haulage.
Horse Keep and Bedding.
Other Stable Expenditure.
Purchase of Horses.
Plant—Vehicle Renewals.
    Machinery Renewals.
    Materials, Tools, Repairs and Maintenance.
    Additions to.
Rents and Acknowledgments.
Rates and Taxes.
Telephones and Postages, etc.
Gas, Water, Electricity and Fuel.
Printing, Stationery and Advertising.
Fire and Other Insurances.
Railway and Canal Charges.
Tipping Charges.
Travelling and Conveyance.
Incidental Disbursements.
Licences.
Superannuation :—
    Equal Annual Charge.
    Equivalent Contributions.
    Supplementary Pensions.
Ashbin Scheme—Purchase of Bins.
Contributions—Conversion of Ashpits, etc.
Central Depot Site.
Contributions to Hospitals.
Loan Charges.

Having been approved by the Committee and signed by the Chairman, the original sheet is forwarded to the City Treasurer with the accounts for payment and the duplicate retained in a binder forming an Expenditure Journal.

11. *Sales Invoice Book.*—All credit sales at Depots are made out in this book and a receipt for goods is taken in exchange for the official invoice. A copy of each invoice is forwarded to the Central Office weekly. Cash Sales are made out in a special book and the amount is paid in each week.

12. *Sales Analysis Sheets.*—Each invoice is entered on these sheets and analysed under one of the following headings of Income :—

Sale of Manure.
 ,, ,, Grease.
 ,, ,, Clinker.
 ,, ,, Mortar.
 ,, ,, Slabs.
 ,, ,, Sand.

Sale of Bottles, Waste Paper, Rags, etc.
,, ,, Scrap Metals.
,, ,, Ashbins, etc.
,, ,, Plant and Materials.
,, ,, Horses.
Trade Refuse Charges.
Cleansing Markets.
Rents and Acknowledgments.
Steam Sold.
Central Depot Site.
Tipping Charges.
Ashbin Scheme—Repayments.
Miscellaneous.
Government Grant towards Loan Charges.

13. *The Sales Ledger* is kept in the Treasurer's Department. A duplicate of the sales ticket or invoice is forwarded to the Treasurer for posting to the debit side of the Sales Ledger.

14. *The Cash Receipt Book*, from which receipts are given for all payments from debtors. The credit posting is made in the Sales Ledger from these Receipt Books, or when a receipt is given by the Department from the "Paying in Form" which shows each receipt in detail.

15. *Cash Abstract.*—Total of cash receipts dissected in accordance with analysis of sales and paid into bank under the appropriate income headings.

16. *Transfer Journal*, is used for making transfers between nominal heads. It is also used for recording direct charges debited to the Department by the City Treasurer such as :—

Postage stamps.
Fire and other insurances.
Superannuation equal annual charge.
Contributions to hospitals.
Loan charges, etc.

17. *The General Ledger* is ruled in the same form as the Accounts Passed for Payment Sheets with a column for each nominal head of expenditure or income.

Expenditure.—Debit monthly totals from Accounts Passed for Payment Sheets, or Expenditure Journal as analysed under nominal heads. Also liabilities unpaid at the end of the period (par. 18). Credit liabilities outstanding at the commencement of the period, the balance being the total expenditure.

Income.—Credit Cash received and paid into bank in accordance with the cash abstract under the income headings mentioned previously. Credit assets accrued but not received at end of period, *i.e.*, a list of debtors extracted from the Sales Ledger and analysed under income headings (par. 18). Debit Assets at commencement of period. The resulting balance is the total income.

18. *Liabilities.*—In preparing a Statement of Expenditure for any period, it is most important that a correct and complete list of liabilities should be compiled. This list should include all items of expenditure which have been incurred but not paid. It should include all creditors, whether due for payment or not and may be compiled from various sources as follows :—

Invoices.
Goods Received Sheets.
Periodical Payment Book.
Depot Clinker Books.
Boating Returns.
Canal Tickets.
Gas.
Water.
Electric Current.
} Register of Consumption.

Assets.—A list of assets or debtors must be extracted from the Sales Ledger and analysed under the appropriate headings of Income mentioned previously.

19. *The Income and Expenditure Statement* is an account showing on the credit side the total income earned during the period, whether actually received or not and on the debit side the expenditure incurred during the period, whether actually paid or not. This account should not be confused with a Receipts and Payments Account, which would only be a summary of accounts paid and cash received. It should be noted that the Income and Expenditure Account embodies the outstanding assets and liabilities at the commencement and end of the period, as will be seen by referring to the General Ledger. It will be noted that the debit postings (*i.e.*, the accounts paid) commence from the first day of the period, in this case from April 1st. It will be seen that these amounts must include the liabilities unpaid for the previous period, therefore these items must be credited or deducted. Similarly, the liabilities outstanding for the period must be debited.

In January each year an estimate of the requirements for the ensuing year, set out in accordance with the nominal headings is prepared, and after approval of the Salvage Committee, submitted to the Finance Committee of the Council. When finally approved by the City Council, these estimates form the basis upon which the City rates are levied, and it is therefore expected that Committees will endeavour to keep their net expenditure within these estimates.

A statement of income and expenditure compared with estimates is submitted to the Chief Executive Officer and the Committee each month, thus enabling a close check to be kept that the estimates are not exceeded.

CHAPTER III

COSTING

AS APPLIED TO CLEANSING WORK

I PROPOSE to give in the course of this chapter, the history of costing as applied to cleansing work, its objects, requirements and benefits, the lay-out of a simple system and a brief description of its working methods.

The word " Costing " means, as its name implies, any method used to obtain the cost of making some specific article, or performing some specific service. It may also be described as the scientific application of statistics to finance.

I believe I am correct in stating that Costing in the Cleansing Services is quite a modern innovation.

In pre-war days, except in a very few instances, costing was only considered a necessity by private manufacturers.

During the last ten years, however, new methods of collection and disposal have come into use in cleansing work, and Salvage has become an important factor. These new methods have brought in their train an increased desire to know what things are costing, not only in main unit costs, but also in detail.

Another factor in bringing costing into the limelight is the tightness of money and the ever-increasing quest on the part of the ratepayers and the Press as to where and how the money goes.

These various factors led up to and culminated in the appointment by the Ministry of Health of an expert Committee to consider methods of keeping costing accounts for public cleansing work.

After exhaustive consideration of the subject, the Committee issued their Report, which I may here state has filled a long-felt want.

The Report contains the outline of a costing system suitable for application to cleansing work, and thus becomes a text-book for the guidance of cleansing officials who are about to commence costing, or who are seeking a remedy for weakness in their present system.

At the time of writing, I have yet to hear of a text-book other than this Report which touches particularly on the costing of cleansing work, neither have I seen any reference to cleansing costing methods in the recognised costing journals.

When I tell you that the cleansing services of England and Wales entail an annual expenditure of approximately £10,000,000 you will see that there is great scope for any methods of control that will lead to greater efficiency at less cost.

The Ministry of Health have now published a summary of the first year's returns, and this gives food for thought, and in some cases for not a little concern. The publicity, however, is all to the good and cannot do otherwise than further key up official staffs and bring about a real endeavour to reduce their costs.

This first publication has already led to improvements in the form; the original one did not call for particulars of methods of collection or percentages of refuse tipped, pulverised or incinerated. These details, of course, add to the value of comparative figures.

Before leaving the subject of the Costing Returns furnished to the Ministry of Health, I would like to point out that these returns only deal with certain unit costs. The principal ones are as follows :—

COST OF COLLECTION AND DISPOSAL.

Cost per Ton.
,, ,, 1,000 Population.
,, ,, 1,000 Premises.

These costs give a valuable comparison from year to year and between town and town, but they are taking what one may call the large view.

Of course, all reductions or increases in cost are reflected in these bulk figures, but the management and costing staff have to concentrate their attention on the individual sections of their work in the search for efficiency and economy. The results from individual sections may not be great, but however small, they are worth while, and the cumulative results are shown in the published comparison of unit costs.

Having briefly outlined the history of costing in the Cleansing Services, I will now pass to the objects and methods of costing.

The main objects of Public Cleansing Costing are as follows :—

1. To keep a check on expenditure and by analysis show how and when it is possible to curtail expenses without losing efficiency.
2. To give controlling officials a closer grip on the work of their department.
3. To act as one of the deciding factors in comparing the merits of various methods of collection and disposal of house refuse and street cleansing.

Effective costing should be, and is rapidly becoming, a great aid to management. It is primarily a function of management and not a function of finance.

The financial accounts bring into range the whole series of individual transactions of an undertaking, whilst the cost accounts deal with its production and afford the detailed information requisite to the successful conduct of the business or undertaking.

The cost accountant must, like a poet, have a certain latitude or licence granted to him, and be allowed to exercise imagination within certain defined limits, and his methods, even if unorthodox, should not be condemned if they lead to the shortest, cheapest and most efficient road to the desired end.

Before considering the lay-out of his system, the cost accountant should bear in mind a number of points, a few of which are as follows :—

1. The thing that matters is the works itself and not his system. The costing system is an auxiliary to the works, and therefore must be woven round the works organisation. He must not expect the works to be re-organised to suit his requirements. He may show at a later date where some change in the organisation would be effective.

2. To ensure that the system is laid out in such a way that future developments will be absorbed into it without any marked disturbance.

Under the system that I shall shortly outline, two new depots costing £100,000 each have been opened, new processes have developed and fresh types of mechanical plant have been brought into use. It has only been necessary to allot a fresh series of code and cost numbers, notify the people concerned and the flow of information to the Cost Office commenced immediately.

3. To bear in mind the expense of costing, and that the benefits to be expected should be commensurate with the outlay.

I believe that the Ministry of Health consider that anything up to 1*d.* per ton of refuse dealt with is a reasonable price to pay for costing. In Birmingham the cost is approximately 0·6 pence.

4. The percentage of accuracy and detail to be aimed at.

5. The mere fact of costing a process has no effect in itself, it does no work and effects no saving. The figures produced must be presented in such a way that they can be effectively used by the management.

6. He must acquire a thorough knowledge of the organisation of the works, and at least some knowledge of the workings of every plant and process, and, like the small boy, must constantly display a curiosity as to what makes the wheels go round.

7. He must not be too ambitious at the outset, but model his system on such lines that will first give him costs of the main sections of work, and if the system is well thought out, these first efforts will of themselves show the way to future developments and more detailed analysis.

Whilst on the subject of points to be borne in mind by the cost accountant, I will instance a few more that are applicable when the system is in operation. These points are in the nature of axioms for cost clerks :—

(*a*) Costs, to be of any value, must be prepared as each job progresses, so that each week a computation can be made as to the progress. Costs must also quickly follow the completion of the work.

(*b*) Bear in mind that, however quickly your cost figures are ready, they cannot always be put to good use until other sections of the Department have completed their statistics. It is therefore up to the cost accountant to be always at the other fellow, Smith, Brown or Robinson, seeking for information.

(*c*) Closely study your returns, otherwise they can serve no useful purpose.

(*d*) Costs must be "all in." Do not give someone a chance to say something has been left out. It shakes confidence.

(*e*) Do not accumulate a lot of useless figures; cut them out when you are sure you can do so with safety.

(*f*) Never think your system is perfect; it is not. Study it sufficiently and you will find you still have a lot to learn.

(*g*) Use mechanical means whenever you can do so to advantage.

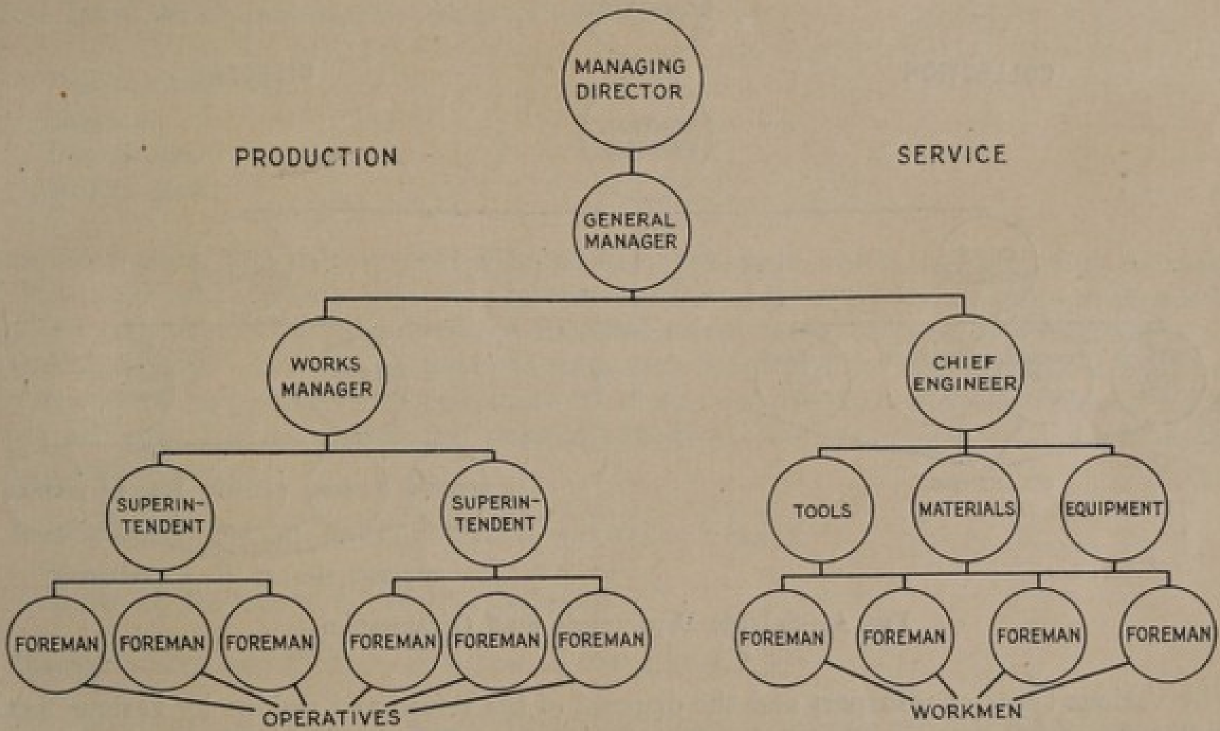

Fig. 3.—Line and Staff System of Works Organisation.

Before describing the lay-out of a Costing System, I will make a comparison of the Staff Organisation of a commercial works and that of a Salvage Department.

Figs. 3 and 4 show the similarity between the two organisations.

It would appear at first that the similarity between a works and a Salvage Department only exists so far as staff organisation is concerned.

As a matter of fact, I suggest it can be carried further; for instance, the function of a factory is usually to manufacture goods and sell them. Is not this also the function of a Salvage Department? The answer appears to be so, a Salvage Department collects refuse and disposes of it. Another point of view can be taken, however, that is, that a Salvage Department, by means of its organisation, renders a service to the ratepayers which is invoiced to them in the rates that are levied.

The manufacturer gets his return for careful organisation and control in his profits. A Salvage Department by applying the same careful control and business methods to its work can also get some form of profit, *i.e.*, the good opinion of the public and a high place in the cleansing world.

I will now describe the lay-out of a Costing System.

The system which I shall outline is that in use in the Birmingham Salvage Department. I may mention that the use of Hollerith posting and tabulating machines has obviated a lot of the routine posting and balancing, but as these machines are not available in many towns, I will describe the system as it existed prior to their introduction.

I consider that the costing of cleansing work is best carried out by the adoption of code numbers covering the various activities of the Department.

This is quite a simple matter in towns which have one depot only, but in a large town like Birmingham with many depots, the position is easily met by the adoption of prefix letters or numbers representing the names of the various depots.

These prefix letters enable the items of cost to be gathered together under Depot Headings.

There are a series of permanent Cost Numbers from 1 to 50 for use at all depots, covering the collection

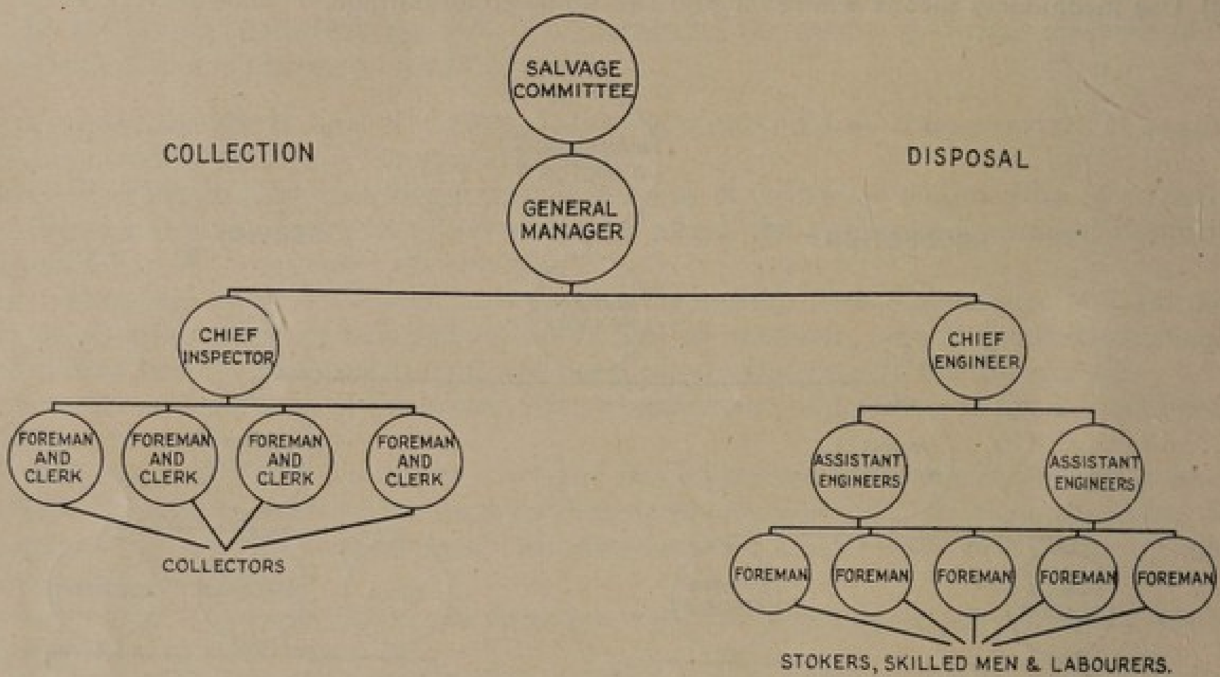

Fig. 4.—Salvage Department Staff Organisation.

of refuse by various types of transport and the disposal of the refuse and residue by various methods. A few examples are as follows :—

RP/1. Collection of refuse by horse wagons at Rotton Park Street Depot.
RP/2. ,, ,, ,, by hired horses at Rotton Park Street Depot.
RP/3. ,, ,, ,, by electric vehicles at Rotton Part Street Depot.
RP/8. Disposal of refuse (burning) at Rotton Park Street Depot.

For the same work at other depots it is only necessary to change the prefix letters thus :—

M/1. Collection of refuse by horse wagons at Montague Street Depot.

In the same way, all transport cost numbers are prefixed by some suitable letter such as E.V. for electric vehicle, P.D.V. for petrol dumbwell vehicle, M.V. for Morris van.

This method enables the cost numbers to be kept within reasonable bounds. In Birmingham there are only 500 numbers in constant use. The next series of numbers runs from 200 upwards and can be used at all depots, coupled with a prefix letter. These numbers are used for salvage processes, maintenance and repairs of various salvage plants, clinker crushing, canteens, collection of tins, etc.

The next series commences at 500 and is allotted to work of a transient nature. These numbers are used for obtaining the cost of special jobs, such as annual repairs at disposal works, installing new concentrators in the manure plant, installing a weighbridge and other such similar work. They are closed off when the job is completed, and having served their purpose, no longer exist, and the costs are transferred to the section of work to which they rightly belong.

Estimates of the cost of these special jobs are obtained from the Engineering Staff before the work is commenced, and a weekly progress report is placed before the General Manager, so that the cost of the job can be closely watched against the estimate whilst the work is in progress.

All mechanical vehicles have two cost numbers, one for the running charges and one for maintenance and repairs. There are also special numbers for tips, and for departmental charges.

Some of the last-mentioned cost numbers are a duplication of the permanent collection or disposal numbers, but confusion is avoided by the use of the prefix letters.

The items of expense with which the system has to deal may be classified under four headings, Wages, Materials, Special Charges and Loan Charges.

I will first deal with *Wages*, this item being of the first importance, representing as it does approximately 60% of the total expenditure of the Department.

This item I will divide into four headings as follows :—

Refuse Collectors.
Stokers.
Labourers.
Skilled Men.

The first three groups are easy to deal with, as the work upon which they are employed varies very little, and it is quite an exception for a man in these grades to be employed upon more than one sort of job during any one week. Cost numbers are allocated to the wages of these men in a wages dissection book by the Depot Clerk. It is not necessary to enter each individual man's name in this book, but it can be done by grades of employment; for instance, if there are, say, 40 refuse collectors at Rotton Park Street Depot and they had all worked full time on collection, one item would cover them for the week. It would read as follows :—

" Refuse Collection, 240 days @ 8/11$\frac{5}{6}$*d.* = £107.16.8 R.P.1."

A similar item for 12 Stokers would read as follows :—

" Disposal (burning), 72 days @ 9/7$\frac{5}{6}$*d.* = £34.15.0 R.P.8."

From this dissecting time book, a Wages Dissection Sheet is written up, the total balanced with the Wages Sheets and sent to the Cost Office.

When the dissection sheets are received at the Cost Office, the totals are checked with a summary of wages paid, which is furnished by the Accounts Department, and they then become the Wages Journal, from which the items are posted to the appropriate cost accounts.

When the postings are complete, the entries on the cost cards are totalled, and balanced with the Journal as a check that all items have been entered.

The wages of the skilled tradesmen are not so easy to deal with, owing to the fact that it is not unusual for a man to work on as many as twenty different jobs in a week. It will be obvious, therefore, that a dissecting time book would be too unwieldy a method to deal with this section.

The position is met by having a combined clock card and time sheet, as illustrated on p. 33.

By this means every tradesman dissects his own time each day, and it is one of his foreman's duties to examine daily and initial weekly his card, and see that the work is properly described, and that the appropriate cost numbers are filled in. The cards are also initialled by the engineer in charge of the work.

I might here mention that each foreman is in possession of a schedule of cost numbers and is also notified in writing of the number of any special job upon which his men will be employed.

At the end of the week, the hours shown against each job are extended at the man's hourly rate of pay and the total time and money balanced with the entry shown against each man's name on the wages sheet.

The cards are then analysed and all the items for each cost number are grouped together, and then copied on to a dissection sheet, which in turn becomes part of the Cost Office Wages Journal.

After the initial difficulty of training the workmen in dissecting their time, this method is found to work quite smoothly, and it soon becomes looked upon as part of their day's routine.

Materials.—There are in the Stores of the Birmingham Salvage Department approximately 5000 different items of material; you will see, therefore, that the first essentials are a good system and a good storekeeper.

It is a sound principle that all goods should go through the Stores, and that issues should only be made against a requisition signed by an official or foreman.

As before mentioned, each foreman has a copy of the schedule of cost numbers, and it is a strict rule that all requisitions shall show in the column provided the prefix letter and cost number of the job for which the material is required. Should more material be drawn from Stores than is ultimately used on the job, a somewhat similar form, printed in red, is used when the material is returned to Stores. Both requisitions and returned to stores forms have columns provided for cost number, description of stores, quantity, price and total value.

At the end of each day the price and total value columns are filled in, and at the end of each week they are analysed and the items for each cost number gathered together, written up on a materials dissection sheet, and then sent to the cost office, where they become the Materials Journal, from which the issues of material to each job are posted to the appropriate cost accounts.

When the posting is completed, the total entries on the cost cards are balanced with the totals of the requisitions.

The original requisitions on stores are also sent to the cost office, and are subjected to careful scrutiny before the items are posted. You can usually tell whether the description of the job and the material shown as issued to it bear some relation one to the other. For instance, if through an error in the cost number you find steam coal being issued to an electric vehicle, even a novice would sit up and take notice.

These checks are made in order to reduce the percentage of error.

From the Wages and Materials Journals, a weekly Progress Report is prepared and this enables the cost of special work in hand to be checked against its estimated cost while the work is still in progress.

Special Charges.—The items included under this heading are horse keep, purchase of horses, hired haulage, canal tonnage charges, tipping charges, rents, rates, taxes, gas, water, electricity, salaries, stationery, insurance, workmen's compensation and superannuation. Particulars of these items are obtained from the Accounts Department at the time they are passed for payment by the Committee. The items are entered on a special form which shows the account number, name of the person to whom the account is payable, name of depot to which the account refers, date and amount. Cost numbers are allocated to these items by the Cost Office. When this has been done, the lists become the Special Charges Journal. The entries are then transferred to the cost accounts. The totals as shown on the cost cards are balanced with the Accounts Passed for Payment Sheet.

The majority of the items included in special charges are quite easy to allocate to their appropriate cost numbers. The description on the invoice usually makes it quite clear to which depot the charge should go and also to what section of work. There are, however, exceptions to this, and I will mention one or two. The first is horse keep. The charges for this item are debited to the Salvage Department by the Veterinary Department at the end of each quarter, but this account gives no clue as to what service the horses have been employed on.

This item, therefore, has to be analysed extensively. The clerk at each depot sends to the Central Office a weekly Horse Return showing the number of horses at the depot, separating work from play, and also showing the section of work upon which they have been employed. These returns are summarised at the Central Office and a quarterly return is made to the Cost Office. This quarterly return is called the Horse Keep Journal and is made up in terms of horse-weeks. It is divided between collection and disposal, also working and resting. The next step is to find the cost per horse-week. This is ascertained by dividing the total charge for horse keep by the total horse-weeks. It is desirable that each section of work upon which horses are employed should not only bear its cost of horses that have worked, but the cost of those that are off work. It follows, therefore, that to get the full cost of horse keep for any particular section, the cost per horse-week should be multiplied by the total weeks booked against it on this return, whether worked or otherwise. In working out costs which are required in between these quarterly periods, the horse cost per week for the previous quarter can be used. The other large items of expense which require extensive analysis are—Canal Tonnage Charges and Hired Haulage Accounts. The invoices that are rendered for these items always show the nature of the material carried, its destination and the depot from which it was taken. From these particulars the Cost Office can summarise these items and allot and post them to their correct cost accounts.

There now remains one more item of expense, and that is *Loan Charges*. Any Cleansing Department to which this item does not apply is indeed fortunate, as at the present time it is not always possible to increase the activities of a department or modernise its methods without having recourse to borrowed money.

In Birmingham these charges are paid by the Treasurer direct and debited against the Salvage Department periodically. The Treasurer's Department supply a detailed statement showing the amount due for the year on each loan. From the known circumstances in the Department, these are allocated to depots and divided between collection and disposal. A detailed summary is prepared from which the items are posted to the Cost Accounts.

The next step is to prepare a periodical summary of the cost accounts summarised under Depot Headings.

It is on this summary that the allocation has to be made between collection and disposal. It is in this division that labour can be wasted. It is not necessary in this allocation to split hairs, bearing in mind that these figures will ultimately, in arriving at unit costs, be subject to division by very large figures. It follows, therefore, that a matter of £5 or £10 in allocating between collection and disposal may only represent a fraction of a penny when reduced to unit costs.

I do not wish to convey the impression that an extreme of accuracy is never required, for there are many occasions when it is necessary to work a cost out to the third or fourth decimal point of a penny, because in some subsequent calculation it may be necessary to multiply this cost by a very large number.

In the course of allocating expenditure between collection and disposal there are many questions which have to be decided by the Head of the Department. It is advisable, therefore, to have these decisions recorded in a book kept for the purpose. They are then available for reference, and also constitute the authority for your allocations. Decisions on other points can also be recorded in this book.

The majority of the cost numbers clearly indicate by their description to which heading the item should go, but quite a number of the accounts have to be divided. Of course, the particular circumstances existing in any department have a great bearing on the dividing of items of this nature, but an example of the division in this department may be instructive. For instance, there are a number of canteens in the department. An approximate division of the department's employees is two-thirds collection, one-third disposal. This item is therefore divided in these proportions. Weighbridge expenditure would, of course, follow the extent to which it was used for collection or disposal.

Having completed our periodical summary of Cost Accounts, there is still an important point to deal with before we can say definitely what the cost of collection or disposal is at any particular depot. This point is the transfer of our transport and departmental charges to Depots.

The transport charges have been kept separate, so that vehicle costs can be prepared, but having served this purpose, they must be debited to the depots for which they have performed work. I will take as an example our Electric Vehicle Fleet. Assume for the purpose of illustration that the total drivers' wages, maintenance, repairs, etc., amounted to £73,000 and that the total number of vehicle days worked during the period was 21,000, the cost per vehicle day worked would be £3 9*s.* 6*d.* It is then only necessary to multiply this cost per day by the number of vehicle days worked at each depot and make the necessary transfers.

With regard to the Departmental Account, this is made up of general items that cannot in the first place be allocated direct to any particular depot or section of work. These may be transferred to depots in proportion to the amount of wages expended at each depot. Wages are the most stable factor for this purpose, as they so closely follow the amount of work performed. This disposes of departmental and overhead charges so far as depot totals are concerned. In preparing individual costs, however, such as transport, treatment of waste tins, etc., it is usual to adopt a definite percentage to be added to labour costs. This percentage can be ascertained by taking the percentage of overhead charges to the total wages paid for the year.

Having now completed the Cost Accounts, such unit costs as are required by the Ministry of Health and also costs under similar headings in respect of each depot can be furnished.

The system outlined provides for the balancing of all items of expense except materials. An annual stock is taken of materials and a Stores Ledger is kept, the records of which form a check balance on this item.

For the purpose of obtaining costs of individual sections or processes, it is only necessary to extract from the detailed summary the items recorded against the cost numbers relating to the work which is being costed.

Transport Costs are one of the most expensive items in cleansing work, and this section is one that should have a great amount of time and thought expended on it.

It is desirable to show the cost per day and cost per ton of each separate item of expense. To find the cheapest and most efficient type of collection vehicle for any particular town is one of the greatest problems with which controlling officials are faced to-day, and the closest comparison of individual cost items is useful to show where any difference in cost occurs.

The difference in cost may only be small, but it is important to know what has brought it about. For instance, it may only be caused through a less capital cost or, on the other hand, it might be that a lower loading line or some such similar refinement in design had brought about an increase in output.

I think the cost of transport is so important that I must put forward a plea for standardisation. I do not mean standardisation of results, that is not desirable—nor can it be obtained. What can be aimed at, however, is standardisation of principles in costing and of expense headings of transport.

As an example of expense headings for transport, I will quote those in use for electric vehicles in Birmingham.

Service Data.

Work engaged upon.
No. of loaders employed in addition to driver.
Days worked.
Journeys.
Loads.
Miles run.
Weight carried (tons).
Average loaded mileage per journey.
Energy used, in units.
Premises visited.
Units used per mile.

Running Charges.

	£. s. d.	Cost per day.	Cost per ton.
Wages and insurance (drivers only).			
Tyres.			
Electrical energy. . . . Pence per unit.			
Garage expenses and sundries (including wages of attendants, charging, lubricants, etc.).			
Repairs and renewals.			
Total running charges.			

Carried Forward

MONTAGUE STREET DEPOT.

4

Cost.		Description of Work Done.	WED. Over Time.	THUR.	FRI.	SAT.	SUN.	MON.	TUES.	WED.	TOTAL HOURS.	RATE.	£	s.	d.
Letter.	No.														

Cost Clerk .... Foreman or Engineer ....

(Note.—On the actual cards, the reverse side is used for clocking in and out.)

STANDING CHARGES.

Brought Forward	£ *s.* *d.*	Cost per day.	Cost per ton.
Depreciation.			
Proportion of tax and licence.			
Insurance.			
Total standing charges.			
Total exclusive of loaders' wages.			
Loaders' wages and bonus.			
Tools and materials (including skeps, scuttles, brooms, etc.).			
Overhead charges.			
GRAND TOTAL.			

I do not suggest that this is the perfect list, but I do say that if some such headings could be agreed on, comparisons of transport costs in various towns would be of much greater value and would bear the hall mark " All in."

If it is considered that the costing out per ton of each item is going too far with detail, I would at least advocate a dividing line between Running Charges, Standing Charges and General Charges. These are easily defined. Running charges are those incurred through the running of the vehicle, standing charges are those that continue when the vehicle is not in use, and general charges would include such items as loaders' wages, overheads, etc.

CHAPTER IV

STATISTICS

Part I.—Collection of Refuse.

Statistics is the scientific study of enumerated and tabulated facts. Its application to all large undertakings is essential, indeed it may be said to be the foundation upon which a large business is based.

There is increasing evidence that chief officials and committees responsible for the cleansing services are beginning to realise, not only the necessity for keeping reliable data relating to past experiences, but also the invaluable assistance which such records can contribute to their work.

In compiling statistics relating to cleansing, it is essential that careful consideration is given to the object for which the data are required and so avoid the accumulation of unnecessary records and the consequent waste of time.

Briefly it may be stated that the object of the collection and tabulation of data is to ascertain the extent of any variation between past and present results. If the information thus obtained shows a speeding up or slackening off in the amount of work performed, etc., the cleansing official concerned is given an opportunity of locating the reasons for such variations and can take immediate steps to encourage or counteract such tendency in the future.

To establish an efficient and useful statistical system, careful attention must be given to the following important points :—

(*a*) Decide beforehand the exact nature of the information required and also the purpose to which it is to be put.

(*b*) Ascertain that the source from which the data are to be collected is reliable, *e.g.*, it is of little use to tabulate figures relating to the tonnage of refuse unless facilities are available for accurate weighing.

(*c*) The person responsible for compiling the statistics should be conversant with the nature of the work to which such records relate.

(*d*) Considerable care should be exercised in laying out the heading and ruling of the required stationery, in order that the data may be collected and co-ordinated in a convenient form and without unnecessary overlapping.

(*e*) Having once decided upon the object in view, all the relative information should be collected and recorded.

(*f*) To be of practical value, statistics should be prepared so that they can be put to immediate use. It must be remembered that figures themselves are of little value—it is the correct method of utilising them which will repay the time and expense incurred in their tabulation.

The collection of refuse is generally found to be most economically performed by units of 2 or 4 men, and it is therefore impossible to keep their work under constant personal supervision, but by an adequate and well-conceived method of recording work done, the cleansing official may obtain an efficient control and detect at once any variation in output.

There are still a number of towns which do not weigh their refuse, although this fact does not prevent them publishing data relating to the tonnage of refuse collected and disposed of. Such data may be regarded as purely hypothetical and of no practical value; indeed, in most cases it is entirely fallacious and their publication results in many misleading conclusions being drawn.

A weighbridge is a very necessary adjunct to the efficient working of a cleansing department, and its initial cost is a small item compared with the advantages to be derived from its proper use.

The following notes are intended to describe briefly the method of tabulating, in a convenient form, the statistics relating to the collection of refuse as adopted in one large city, and whilst they may not be suitable for use in towns where local conditions are not the same, they can be adjusted to meet the requirements of most towns with very slight alterations.

On entering the depot, the weight and time of arrival should be recorded in the *weighings book* (*specimen ruling No.* 1).

SPECIMEN RULING No. 1.

Salvage Department..................................*192*.........

Vehicle No.	Round No.	GROSS.			TARE.			NETT.			TOTAL WEIGHT PER DAY.			Time Out.	Time In.	REMARKS.
		T.	C.	Q.	T.	C.	Q.	T.	C.	Q.	T.	C.	Q.			
(1)	(2)		(3)			(4)			(5)			(6)		(7)	(8)	(9)

Column No. 1 refers to the departmental number of the vehicles. All vehicles should be numbered consecutively, commencing at No. 1 for each type of transport, *i.e.*, electric, petrol, horse-drawn, etc., and when a vehicle is replaced, the new vehicle should be allotted the next highest number to the previously installed vehicle of the same type. For instance, the first electric to replace a scrapped vehicle in a fleet of 16 electrics should be No. 17, the second replacement No. 18 and so on. This system of numbering will prevent confusion when referring to past records of various vehicles.

The remaining columns are self-explanatory, and it is only necessary to state that the weight should be recorded in the weighings book immediately each load is weighed. In the event of an exceptionally light or heavy load, the weighman should be instructed to use the remarks column for denoting the reason for such abnormal weighing.

At the end of each day, the weights should be totalled up and summarised and then transferred to the *Record of Work done by Refuse Collection Vehicles* (*specimen ruling No.* 2).—It will be noticed that this sheet is for use in recording the work done by electric vehicles. By substituting "quantity of petrol used" for column No. 7 a similar sheet would serve the purpose of petrol vehicles.

A more simple form of return will, of course, suffice for horse-drawn vehicles.

Columns numbered 1, 3, 4 and 6 should be filled in at the end of each day's work, the information being extracted from the Weighings Book (No. 1).

Column No. 1, *Sheet No.* 2, refers to the number of the round or collecting unit, and the weekly totals will give the record of work done on such rounds, not necessarily the work of any particular vehicle.

Column No. 4 (*Vehicle Days*).—If, through accident, or any other cause, a vehicle is taken off a round before completing a full day's work and is not replaced by another vehicle, only the fraction of the day worked should be entered in the column, *i.e.*, $\frac{1}{3}$, $\frac{1}{2}$, $\frac{2}{3}$, etc., likewise, any additional work above one normal working day should be recorded.

Column No. 5 (*Men Days*).—Particular care should be taken that the exact number of men days worked is recorded correctly, as it is man power which, more than any other factor, affects the amount of

CITY OF BIRMINGHAM

RETURN OF WORK DONE BY ELECTRIC VEHICLES WORKING AT...DEPOT

SALVAGE DEPARTMENT

SPECIMEN RULING No. 2.

Week Ending..192.......

Round No.	Driver's Name.	THURSDAY. Vehicle No.	Vehicle Days.	Men Days.	Weight Collected. Lbs.	Tons.	C.	Charging Units.	Miles Run.	Premises Visited.	FRIDAY. Vehicle No.	Vehicle Days.	Men Days.	Weight Collected. Lbs.	Tons.	C.	Charging Units.	Miles Run.	Premises Visited.
(1)	(2)	(3)	(4)	(5)		(6)		(7)	(8)	(9)									

Round No.	SATURDAY. Vehicle No.	Vehicle Days.	Men Days.	Weight Collected. Lbs.	Tons.	C.	Charging Units.	Miles Run.	Premises Visited.	MONDAY. Vehicle No.	Vehicle Days.	Men Days.	Weight Collected. Lbs.	Tons.	C.	Charging Units.	Miles Run.	Premises Visited.

Round No.	TUESDAY. Vehicle No.	Vehicle Days.	Men Days.	Weight Collected. Lbs.	Tons.	C.	Charging Units.	Miles Run.	Premises Visited.	WEDNESDAY. Vehicle No.	Vehicle Days.	Men Days.	Weight Collected. Lbs.	Tons.	C.	Charging Units.	Miles Run.	Premises Visited.

Round No.	TOTALS. Vehicle No.	Vehicle Days.	Men Days.	Weight Collected. Lbs.	Tons.	C.	Average per Load. Tons.	C.	Q.	Charging Units.	Miles Run.	Premises Visited.	Collection (Days Old.)
													(10)

DISTRIBUTION OF REFUSE.

Loads Tipped as follows :—

Depot.	Lbs.	Tons.	C.	Q.
E'. Park St.				
Shadwell St.				
Montague St.				
Holliday St.				
Nechells				
Handsworth				
Brookvale Rd.				
Lifford				
Tyseley				
Tips				
TOTAL				

Loads Received from Other Depots :—

Depot.	Lbs.	Tons.	C.	Q.
E'. Park St.				
Shadwell St.				
Montague St.				
Holliday St.				
Nechells				
Handsworth				
Brookvale Rd.				
Lifford				
Tyseley				
Harborne				
TOTAL				

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Vehicle No.	Garage.	Where Worked.	Description of Work.	Particulars of Work Performed.											Remarks.	Particulars of Driver's Absence.					Remarks.
				Days Worked.	Man Days Worked.	Weight Collected.			Average per Load.			Charging Units.	Miles Run.	Premises Visited.		Name.	Round No.	No. of Days Lost.	Reason Given.	Action Taken.	
						Lds.	Tons.	C.	T.	C.	Q.										

Signed..*Clerk.*

Countersigned .... *Inspector or Foreman.*

work performed. The following table indicates the method of arriving at the number of men days worked :—

Vehicle days worked.	No. of Men Days Worked.		
	2 Men units.	3 Men units.	4 Men units.
$\frac{1}{3}$	$\frac{2}{3}$	1	$1\frac{1}{3}$
$\frac{1}{2}$	1	$1\frac{1}{2}$	2
$\frac{2}{3}$	$1\frac{1}{3}$	2	$2\frac{2}{3}$
1	2	3	4
$1\frac{1}{2}$	3	$4\frac{1}{2}$	6

or—vehicle days worked × number of men engaged per vehicle.

Columns Nos. 7 *and* 8.—The information required for these two columns is first ascertained by the garage attendant, who records it on

Vehicle Log Sheet (*specimen ruling No.* 3).—The information extracted from columns 1, 2, 8 and 9 of this return should be transferred to columns 2, 5, 8 and 7 respectively of Sheet No. 2, and it will generally be found more practicable to transfer this information at the end of each week and not daily.

Record of Premises Visited (*specimen ruling No.* 4).—To obtain a reliable record of premises visited it is, of course, essential that the system of refuse collection in operation should provide for this information being readily ascertained.

The "continuous" system enables this to be done in a very convenient form by utilising the Specimen ruling No. 4.

Note.—The method of ascertaining the number of premises visited is explained in detail in Chapter V.

The following summary will, perhaps, indicate more clearly the method of co-ordinating the various information collected on Sheets Nos. 1, 3 and 4 for the purpose of completing Sheet No. 2, *i.e.*, Record of Work done by rounds or collecting units.

Col. No. (specimen ruling No. 2).	Information extracted from		Original Source of Information.
	Sheet No.	Col. No.	
1	1	2	Departmental number of collecting unit.
2	3	1	The driver should write his name in the column provided before the commencement of each day's work.
3	1	1	The departmental number allotted to vehicle. This can be checked with the number of vehicle denoted on Sheet No. 3.
4	1	5	No. of vehicle days worked usually indicated by number of loads collected.
5	3	1 and 2	See previous description of ascertaining correct number of men days worked.
6	1	5 and 6	Weighbridge.
7	3	9	K.W.H. Meter.
8	3	8	Milometer.
9	4	5	See Chapter V for correct method of ascertaining this information.
10	"Interval between collection."		Average period in days between two collections of refuse.

The tabulation of the above return provides practically all the data required relative to refuse collection in any particular area, but in this form it is not, of course, convenient for comparative purposes.

To enable a comparison to be made between present and past results on any particular round, the total columns of each round shown on specimen ruling No. 2 are transferred each week to specimen ruling No. 5.

From the information collected on this sheet, any variation in the amount of work performed may be easily detected and action can immediately be taken to ascertain the cause of such variation.

The " Grand Total " of the work recorded on Sheet No. 2, *i.e.*, the whole of the work done by all rounds at any particular depot, is transferred (in cases where refuse is collected by two or more depots) to summary Sheet No. 6. This latter sheet can be used for weekly, monthly, quarterly and yearly totals, or any other period in which the cleansing official may desire the information to be tabulated.

To obtain a comparison of the quantity and variation in refuse collected at any particular depot, the totals of Sheet No. 6 are transferred to Sheet No. 7.

The effect of seasonal changes may be clearly ascertained from the latter return.

Return of Work Done by Vehicles.—It frequently happens that a vehicle may work for a week or more entirely on one particular round, and in such cases the record of work done for such rounds as shown in the total column of the front page of Sheet No. 2 also indicates the work of one particular vehicle, but it often becomes necessary, either through breakdown or other causes, to transfer a vehicle to another round.

It is, however, necessary in the case of mechanical vehicles to keep a complete record of the work done by each vehicle. A method of collecting this information is indicated on the back of Sheet No. 2, the summary of such information being tabulated for comparative purposes, etc., on Sheet No. 8.

In small departments, it may be convenient to combine two or more of the refuse collection returns on to one sheet, for instance, Sheet No. 4 could be incorporated with the Weighings Book (No. 1). In Birmingham it has been found that by keeping all the returns in the manner indicated, it is possible to obtain practically all the information required in relation to the work of refuse collection, particularly that information which is essential for the Cost Accountant. It must be remembered that the foundation of Cost Accounting is the utilisation of recorded information of past work done.

Having briefly described a method of presenting refuse collection statistics, it is possible to enumerate some of the chief relative facts which may be extracted from such data, and to which it is essential that the cleansing official should give careful consideration if he requires to keep an efficient check upon the work of his department :

1. Output of work per man.
2. ,, ,, ,, ,, horse.
3. ,, ,, ,, ,, vehicle.
4. ,, ,, refuse per house.
5. ,, ,, ,, ,, round or district.
6. ,, ,, ,, ,, 1000 population.
7. Average haul between collection districts and disposal point (for mechanical vehicles).
8. Variation in refuse due to seasonal or other effects.
9. Average interval between collection of refuse.
10. Distribution of refuse at various depots and tips.

The above-mentioned items can, of course, be split up into more detail, for instance, item No. 3 may be analysed as follows :—

(*a*) Tonnage of refuse collected per vehicle, per hour, day, etc.
(*b*) Premises visited per vehicle, per hour, per day, etc.
(*c*) Average weight per load collected.
(*d*) Number of B.Th.U. consumed per ton, per mile, etc.
(*e*) Number of ton miles worked.
(*f*) Number of visits per ton collected, per mile run, etc.

In compiling statistics relating to refuse collection, regard should be had to the following :—

1. *All* weekly returns should, as far as is practicable, commence and terminate on the same date as the wages week, *i.e.*, if wages are paid from Thursday morning to Wednesday evening, the statistical returns should relate to the same period. This will greatly facilitate the work of the Costs Department.

2. Where Saturday is reckoned a full day for the payment of wages, it must be remembered that only

Specimen Ruling No. 5.

……………………………DEPOT. ……………………………DRIVER ROUND No………… QUARTER ENDING…………………192

WORK DONE BY REGULAR VEHICLES.														ASSISTANCE BY SPARE VEHICLES.										TOTALS.							
Week Ending.	Driver's Name.	Vehicle Number.	Vehicle Days.	Men Days.	WEIGHT.			Average Per Load.			Charging Units.	Miles Run.	Premises Visited.	Driver's Name.	Vehicle Number.	Vehicle Days.	Men Days.	WEIGHT.			Charging Units.	Miles Run.	Premises Visited.	Vehicle Days.	Men Days.	WEIGHT.			Charging Units.	Miles Run.	Premises Visited.
					Lds.	T.	C.	T.	C.	Q.								Lds.	T.	C.						Lds.	T.	C.			
(1)	(2)	(3)	(4)	(5)		(6)			(7)		(8)	(9)	(10)																		

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SPECIMEN RULING No. 6.

COLLECTION AND DISTRIBUTION OF

......................................ENDING......................................192......... ....

COLLECTION DEPOTS.	NUMBER OF Men Days.		Vehicle Days.		Horse Days.	
	Dept.	H'rd.	Dept.	H'rd.	Dept.	H'rd.
ROTTON PARK ST.						
SHADWELL ST.						
MONTAGUE ST.						
HOLLIDAY ST.						
TYSELEY						
NECHELLS						
HANDSWORTH						
BROOKVALE ROAD						
LIFFORD						
HARBORNE						
TOTAL REFUSE RECEIVED AT DEPOTS & TIPS						

COLLECTION DEPOTS.	LOADS TAKEN TO DEPOTS. ROTTON PARK ST.				SHADWELL ST.				MONTAGUE ST.				HOLLIDAY ST.				TYSELEY.			
	Lds.	T.	C.	Q.	Lds.	T.	C.	Q.	Lds.	T.	C.	Q.	Lds.	T.	C.	Q.	Lds.	T.	C.	Q.
ROTTON PARK ST.																				
SHADWELL ST.																				
MONTAGUE ST.																				
HOLLIDAY ST.																				
TYSELEY																				
NECHELLS																				
HANDSWORTH																				
BROOKVALE ROAD																				
LIFFORD																				
HARBORNE																				
TOTAL REFUSE RECEIVED AT DEPOTS & TIPS																				

COLLECTION DEPOTS.	NECHELLS				HANDS-WORTH.				BROOKVALE RD.				LIFFORD.			
	Lds.	T.	C.	Q.	Lds.	T.	C.	Q.	Lds.	T.	C.	Q.	Lds.	T.	C.	Q.
ROTTON PARK ST.																
SHADWELL ST.																
MONTAGUE ST.																
HOLLIDAY ST.																
TYSELEY																
NECHELLS																
HANDSWORTH																
BROOKVALE ROAD																
LIFFORD																
HARBORNE																
TOTAL REFUSE RECEIVED AT DEPOTS & TIPS																

HOUSE AND TRADE REFUSE

....ENDING ....192.........

	Total Refuse Taken to Depots.				Average Weight Per Load Collected.			LOADS TAKEN TO TIPS.																	Total Refuse Taken to Tips (Weight Estimated).				Total Refuse Collected by Depots.				Miles Run.	Premises Visited.	Coll'n. Days Old.
	Lds.	T.	C.	Q.	T.	C.	Q.																		Lds.	T.	C.	Q.	Lds.	T.	C.	Q.			
		(1)				(2)																				(3)				(4)			(5)	(6)	(7)

[*To face Specimen Ruling No. 6.*

Specimen Ruling No. 7.

....DEPOT

COMPARISON TABLE SHOWING QUANTITY OF REFUSE COLLECTED BY..

Year ending.....................................

Month.	No. of Working Days.	Refuse Collected and Taken to Depots.							No. of Loads and Estimated Weight taken to Tips.				Total Weight of Refuse Collected.			
		Weight.				Average per Load.										
		Lds.	T.	C.	Q.	T.	C.	Q.	Lds.	T.	C.	Q.	Lds.	T.	C.	Q.
APRIL	(1)		(2)				(3)				(4)			(5)		
MAY																
JUNE																
1st Quarter																
JULY																
AUGUST																
SEPTEMBER																
2nd Quarter																
OCTOBER																
NOVEMBER																
DECEMBER																
3rd Quarter																
JANUARY																
FEBRUARY																
MARCH																
4th Quarter																
1st Quarter																
2nd ,,																
3rd ,,																
4th ,,																
Year's Totals																

Year ending.....................................

Month.	No. of Working Days.	Refuse Collected and Taken to Depots.							No. of Loads and Estimated Weight taken to Tips.				Total Weight of Refuse Collected.				General Manager's Remarks.
		Weight.				Average per Load.											
		Lds.	T.	C.	Q.	T.	C.	Q.	Lds.	T.	C.	Q.	Lds.	T.	C.	Q.	
APRIL																	
MAY																	
JUNE																	
1st Quarter																	
JULY																	
AUGUST																	
SEPTEMBER																	
2nd Quarter																	
OCTOBER																	
NOVEMBER																	
DECEMBER																	
3rd Quarter																	
JANUARY																	
FEBRUARY																	
MARCH																	
4th Quarter																	
1st Quarter																	
2nd ,,																	
3rd ,,																	
4th ,,																	
Year's Totals																	

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SPECIMEN RULING No. 3.

CITY OF BIRMINGHAM—SALVAGE DEPARTMENT

Weekly Log Sheet, Electric Vehicle No......... Week ending..............................192.........

		Thursday.	Friday.	Saturday.	Monday.	Tuesday.	Wednesday.
(1) Driver's name							
(2) Loaders' names							
(3) Work done (Round No. etc.)							
(4) Depot where Loaded or Tipped	1						
	2						
	3						
	4						
		T. | C. | Q.	T. | C. | Q.	T. | C. | Q.	T. | C. | Q.	T. | C. | Q.	T. | C. | Q.
(5) Weight carried	1						
	2						
	3						
	4						
TOTAL							
(6) Depot where charged							
(7) Milo before charging							
(8) Miles run							
(9) Charging units							

TOTALS: (5)............tons............cwts.............qrs.; (8)...........miles run; (9)...........units.
Transferred to Weekly Summary by...Clerk.......................................Depot.

NOTES as to breakdowns, repairs, topping-up, cleaning controller, etc., etc.

Date.	Particulars.	Initials of Garage Attendant.

DRIVER'S REPORT

to be filled in and signed every day. If nothing to report, write "All Correct"

Date, 192 .	Accidents, Repairs Required, etc. Reported by Driver.	Signature of Driver.	Signature of Garage Attendant.	Repaired by.
Thurs.				
Fri.				
Sat.				
Mon.				
Tues.				
Wed.				

Detailed Report of Accident

Date.	Time.	Place.	Particulars.

Witnesses' Names and Addresses

(1)

(2)

(3)

Signed ....*Depot Clerk.*

Countersigned ....*Foreman.*

about one-half the normal day's work is done by the refuse collectors, and this should be particularly noted where any comparison of work is being made. In this connection it should also be remembered that once in every five or six years, according to the incidence of leap year, the financial year will contain 53 weeks and that one quarter will therefore consist of 14 weeks.

SPECIMEN RULING No. 4.

PROGRESS BOOK.

WORK DONE ON REFUSE COLLECTION ROUNDS.

ROUND No......................

DATE. 192....			ADDRESS AT WHICH VEHICLE FINISHED WORK. (NOTE.—Assistance given by spare Vehicles to be shown in RED).	Page No.	No. of Houses on Round.	No. of Houses Visited.	
						Daily Total.	Progressive Total.
Thurs. Fri. Sat. Mon. Tues. Wed.	(1)		(2)	(3)	(4)	(5)	(6)

Assuming that a satisfactory system of collecting and tabulating data has been installed for recording the work of refuse collection, the cleansing official is able to control more effectively the work of the refuse collectors, and by applying to present conditions the recorded experiences of past achievements, it will be possible to ascertain what are the requirements for dealing with current problems.

Every abnormal increase or decrease in the yield of refuse or any other phenomenal results which may be revealed by statistical records has a cause and the change resulting in such variation should be immediately analysed in order to ascertain such cause, so that if similar changes are likely to occur in the future, the official is able to make provision to meet them. In some cases statistical methods have been brought into disrepute, largely due to the fact that proper care has not been exercised in the method of presenting them.

PART II.—DISPOSAL AND GENERAL.

The cost of refuse collection in England and Wales is approximately £5,000,000 per annum. The disposal of refuse is responsible for a further expenditure of approximately £2,500,000.

Generally speaking, it is possible to maintain a more direct supervision upon the work of disposal than is practicable in the case of refuse collection.

In towns where refuse is dealt with by screening, incineration and tipping, specimen ruling No. D1 (facing p. 44) will be found a useful return for recording particulars of work done. Columns Nos. 1 to 6 refer to the tonnage of refuse dealt with at the disposal depot. Columns Nos. 7 and 8 are used for recording the quantity of crude refuse boated from the depot to tip. Columns Nos. 9 to 14 indicate the various facilities available at the depot for the incineration of refuse.

In the weekly summary (shown on D1) the first four items are totalled in order to arrive at the total quantity of refuse available for treatment. The remaining items indicate the tonnage of various grades of material not dealt with by incineration. The total of the latter material is then subtracted from the total tonnage of refuse available for treatment and the difference represents the total tonnage burnt.

The totals are transferred weekly from D1 to D2 (facing p. 46) for comparison purposes.

In a cleansing department, one of the chief points to be watched is the effect of seasonal variations upon the output of refuse.

The following table shows the daily yield of refuse in Birmingham during the twelve months ended March 1927, together with the mean temperature recorded during each month.

Month.	Average daily yield of refuse.	Mean Temperature.
	tons.	degrees F.
April	928·08	48·02
May	886·93	49·61
June	771·83	56·05
July	723·11	62·14
August	692·56	61·87
September	694·62	58·45
October	788·99	46·8
November	918	42·5
December	913·15	39·85
January	948·22	40
February	955·19	38·91
March	935·56	44·56

These data have been plotted in graphic form and are reproduced in Fig. 5, which portrays in a very striking manner, the variation in yield of refuse consequent upon seasonal changes. In this diagram, two

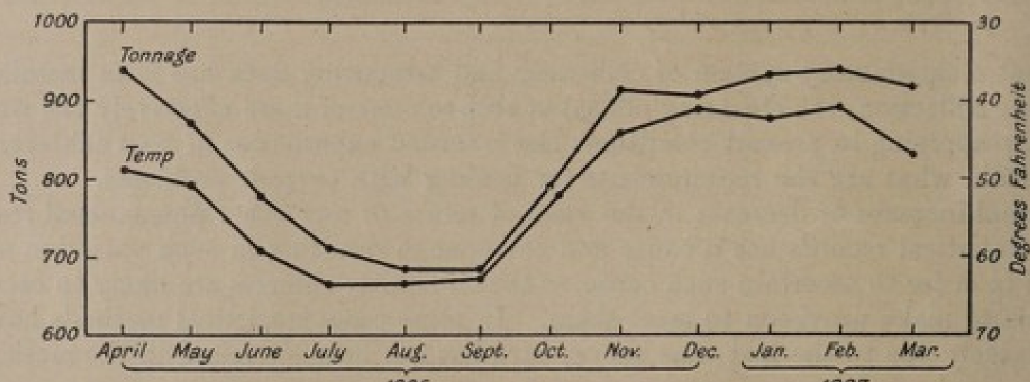


Fig. 5.—Chart showing the average daily output of refuse in tons, and atmospheric conditions during the year ended March 31st, 1927.

different scales have been introduced, the left hand one to indicate the average daily output of refuse in tons and the right hand one the mean temperature in degrees Fahrenheit. In order to show more clearly the rise in yield following upon a fall in temperature, the latter scale is shown inversely.

As in the case of the table, the data may be recorded for the current year from month to month as the figures become available. It will be found extremely useful to superimpose the current year's diagram upon a chart containing the graphs of one or perhaps two previous years. Comparison can by this means be made month by month of the results of the current year with those obtained during the corresponding period of the previous year, and the causes of any divergency can be investigated immediately.

The reasons for any abnormal fluctuations should always be noted for future reference. For instance, in the case of the coal dispute of 1921, it was observed that in Birmingham the effect of the dispute was substantially to decrease the tonnage of refuse produced. In 1926, when similar circumstances were again present, the knowledge obtained in 1921 enabled the General Manager to anticipate an abnormally low output of refuse, with the result that steps were immediately taken to exploit the opportunity offered for reducing costs due to the decrease in the tonnage of refuse to be disposed of.

There are, of course, numerous other instances where the use of the graphic method of presenting data

Specimen Ruling No. 8.

RETURN OF WORK PERFORMED BY ELECTRIC VEHICLE No. .... **QUARTER ENDING 192**

Week Ending.	Depot Garaged at.	Depot Worked at.	Refuse Collection.											Miscellaneous Work.													Reasons for Time Lost.
			Vehicle Days.	Men Days.	Weight.			Average per Load.			Charging Units Used.	Miles Run.	Premises Visited.	Description of Work.	Vehicle Days.	Men Days.	Weight.			Average per Load.			Charging Units.	Miles Run.	Premises Visited.	
					Lds.	T.	C.	T.	C.	Q.							Lds.	T.	C.	T.	C.	Q.				
(1)	(2)	(3)	(4)	(5)		(6)			(7)		(8)	(9)	(10)													(11)

[To face p. 42.

enables the cleansing official to obtain a comparison between past and present results without having to wade through a mass of tabulated statements.

A very useful graph which records the output of work by stokers and chargemen is shown in Fig. 6. The top portion of the figure is utilised for showing the quantity of refuse burnt per week and the bottom portion indicates the average wages cost per ton of burning.

It is, of course, impossible in this chapter to describe in detail all the various returns and statements which a Cleansing Department may require, as in many cases they are peculiar to each individual department, but by carefully studying the various specimen forms which have been provided, and which, generally speaking, are suitable for recording the work of refuse collection and disposal in most departments, it should be possible to obtain a useful knowledge of a method of collecting data.

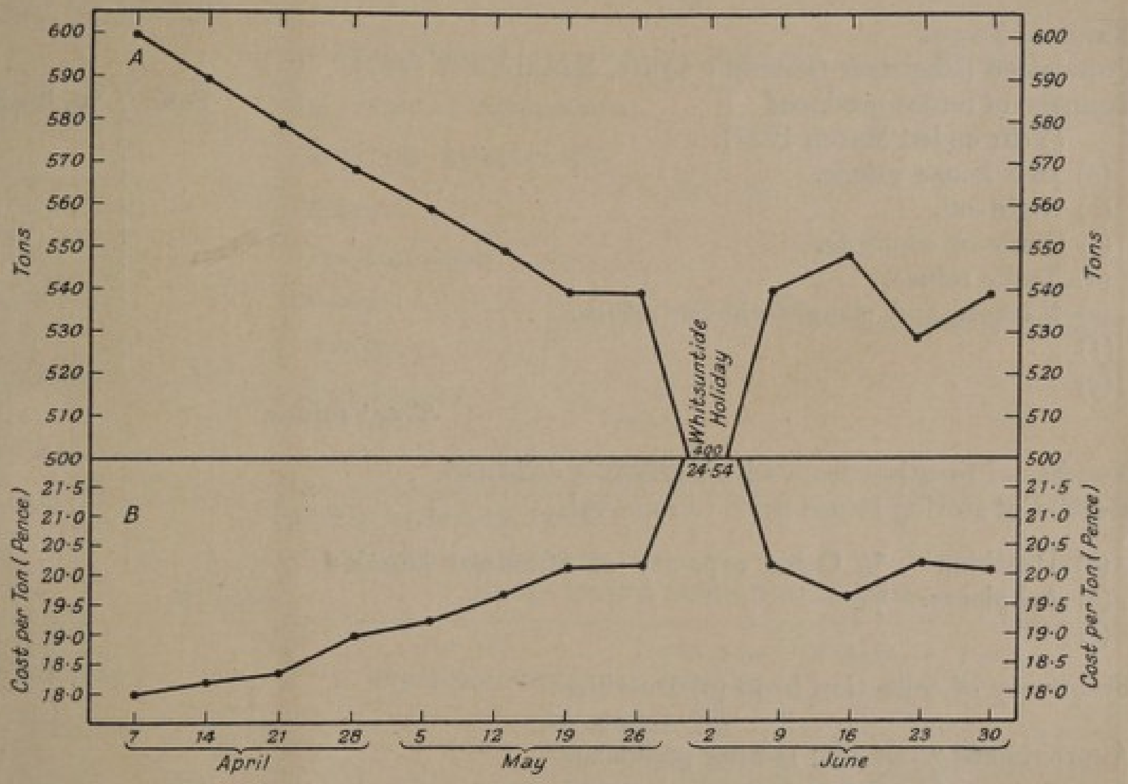


FIG. 6.—Chart showing (A) weekly tonnage of refuse incinerated, and (B) wages cost per ton for incineration.

Comparison of Data Relating to Different Towns. Questionnaires.—It often occurs that a cleansing official who is contemplating some change in methods requires to compare the present results of his own department with those obtained in other towns, and for this purpose he sends out a list of questions or questionnaire.

Unfortunately, in a number of cases, the questionnaires, after being duly completed and returned to the sender, are misleading either because the questions have not been drawn up in a clear and concise manner, or else the conditions in the various towns are not comparable.

In sending out a questionnaire, careful thought should be given to the following important points if it is desired to avoid misunderstanding and mistakes :—

(*a*) The nature of the information required should be concisely but clearly stated.

(*b*) The questions should be short and to the point.

(*c*) Where an opinion is required, the question should be so framed that the answer " Yes " or " No " may be given without qualification.

(*d*) If the conditions existing in any of the towns to which the questionnaire is addressed are subsequently found to be incomparable, the greatest care should be taken in coming to any decision based upon such information.

(*e*) As an assistance both in drafting and in answering a questionnaire, the questions should be first answered by the draftsman in respect of his own town, and those answers should be circulated with the questionnaire *in the first place.* If this were always done, questions and replies would frequently be more intelligible than they are. The courtesy of replies to queries is fittingly and gracefully acknowledged by the circulation among correspondents of tabulated results.

Assuming that it was desired to compare the output of refuse per thousand of population in various towns together with the reasons for abnormal fluctuations, the following would be a suitable form of questionnaire:—

1. Name of Town.
2. Population (Registrar-General's figure, Midsummer 1927).
3. Tonnage of refuse produced (Year ended March 1927).

	Tons	*% Weighed.*
(*a*) Dry house refuse.		
(*b*) Nightsoil.		
(*c*) Cesspool contents.		
(*d*) Trade refuse.		
(*e*) Markets and slaughterhouse refuse.		
(*f*)		
(*g*)		
Total refuse.		

4. Number of premises from which refuse is collected.
5. Method of storing refuse prior to removal.

   (*a*) Dustbins % Cubic capacity of Standard Dustbin ......
   (*b*) Ashplaces. %
   (*c*)

6. Frequency of collection from (*a*) Dustbins.
   (*b*) Ashplaces.
7. Approximate % of coal mining population.
8. Approximate % of use of gas or electric cookers and radiators.
9. Has any propaganda work been undertaken?
10. Are you of the opinion that such propaganda has reduced the yield of refuse?
11. Factors influencing production in your particular town.

In analysing the data supplied by means of the questionnaire, more reliable deductions are likely to be made by a comparison of a few correct returns than by attempting to compare a large number of unreliable returns. Thus assuming that twenty of the above completed questionnaires are returned and it is ascertained that only ten of the towns weigh more than 50% or 60% of their refuse, it will be far safer to ignore the figures supplied by the remaining ten towns whose figures are largely estimated.

There is a noticeable dearth of reliable published statistics relating to cleansing, but as the result of a report issued in 1925 by a conference of cleansing and other officials, there are prospects of more trustworthy data being available in the near future.

In pursuance of the recommendation made by the above-mentioned conference, the Ministry of Health now incorporates in its annual report a series of statistical tables relating to Cleansing Departments. The data supplied are mainly concerned with costs, but as it is the first serious attempt to present more or less reliable comparative statistics of cleansing work, an extract from the report for 1927 is reproduced.

In considering these statistics, attention should be paid to the comments made by the Ministry in the

SPECIMEN RULING No. D. 1.

CITY OF BIRMINGHAM—SALVAGE DEPARTMENT

....Depot. *Week Ending*...*192*

DATE. Day.	Month.	House Refuse and Night Soil. Tons.	Market Refuse. Tons.	Trade Refuse. Tons.	Tons.	Total Quantity of Refuse Received. Tons.	Boated to Tip. By Contractors' Boats. Tons.	By Corporation Boats. Tons.	No. of Grates in use.	Grate Area in use. Sq. Ft.	Total Working Hours of Furnace.	Total No. of Clinkerings.	No. of Stokers.	No. of Chargers.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
THURS.														
FRI.														
SAT.														
MON.														
TUES.														
WED.														
Totals . . .														

Total No. of Grates ....

Total Grate Area ....Sq. Ft.

Normal Ashpit Pressure ....Ins. W.G.

(15)

Average Rate of Burning per Grate per 24 hours...............Tons.

Flue Dust mixed as Disinfectant ....

WAGES SUMMARY.

	£ s. d.	
.........Foremen . . .		Must include Holiday Pay.
.........Leading Stokers .		
.........Stokers . . .		
.........Chargers . . .		
.........Flue Cleaners . .		

Cost per Ton to Burn (in Pence) . . . .

WEEKLY SUMMARY.

	Tons.	Tons.
Total Refuse Received		
Quantity on Yard at commencement of week . . .		
Quantity in Hopper Do. Do. . . .		
Scrap Metals, &c. (from Refuse) received from other Depots		
Boated { Refuse.................Tons / Salva ....Tons }		
Treated in Fish Plant		
Treated in Meat Plant		
Quantity on Yard at end of week		
Quantity in Hopper Do. Do.		
Scrap Metals, &c. (from Refuse) Disposal of . . .		
Quantity Burnt (to Balance)		

	T.	C.	Q.
Estimated quantity of Tins, Scrap Metals, &c., sorted from Refuse . . . . =			

Remarks.

THURSDAY {

FRIDAY {

SATURDAY {

MONDAY {

TUESDAY {

WEDNESDAY {

Reasons for Decreased or Increased Burning MUST be stated.

Scrap Metals taken from Refuse.

RECEIVED.

Date, 192....	Depot received from.	Ticket or Receipt No.	Weight. T. C. Q.

DESPATCHED.

Date, 192....	Name of Purchaser.	Ticket or Receipt No.	Weight. T. C. Q.

(*Signed*)...............................*Clerk*...............................*Foreman.*

[*To face p. 44.*

1926 report upon the methods employed by the various Municipalities concerned in the preparation of the data. The second paragraph particularly emphasises the need for caution being exercised in using the figures to compare the working results in different towns.

It is probable, however, that as the value of the Ministry's return becomes more widely recognised, subsequent editions will be found to contain statistical information of a more reliable nature, especially if some system of grouping is inaugurated in lieu of the present alphabetical arrangement. By this means it would be possible more easily to compare and analyse the data relating to those towns which operate under similar conditions, *i.e.*, mining, industrial and coastal towns.

Public Cleansing

Extracts from the Annual Report of the Ministry of Health for 1926–7

Costing Returns from County Borough Councils.

The report issued in March, 1925, of the conference which considered the keeping of costing accounts for public cleansing, recommended that annual costing returns should be obtained by Local Authorities. The Minister asked the Councils of County Boroughs to furnish returns for the year 1925–26; returns have been received from 79 of the Councils, and are summarized in the tables in Appendices I and II (pages 48 to 53).

The Minister wishes to make it clear that it is not suggested that towns can be compared simply on these figures. Account has to be taken of local conditions, and these differ greatly in different towns.

Proper costing accounts are, however, essential for economy of service. There is still room for a good deal of saving in this branch of work, and it has to be remembered that it is responsible for a large part of the expenditure of Local Authorities, the amount spent in England and Wales on the collection and disposal of refuse and on street cleansing being over £10,000,000 for the last year for which information is available.

It may be mentioned that the net expenditure on these services in 1925–26 in the 79 towns from which returns were obtained was approximately £4,200,000, equivalent to about 6*s*. 7*d*. per annum, or a little over 1½*d*. per week, per inhabitant.

Inaccuracies in Returns.—As was to be expected, this being the first occasion on which returns of this nature have been obtained, there are many shortcomings in them; and the principal defects are mentioned in order that they may be avoided in future returns.

(1) Some Councils have not kept separate accounts for collection and for disposal. This should be done.

(2) In some cases, there is neither a record nor a reliable estimate of the weight of the refuse. Instances have come to the notice of the Department in which statistics of cost have been wholly misleading because of the absence of any proper record or estimate of the weight of the refuse.

(3) In some cases, the cost of tipping has been included in that of collection. The cost to the point of discharge should be included in collection, but all subsequent costs should be charged to disposal.

(4) Different numbers of days in the year have been adopted in calculating the weight of refuse per day per 1000 of the population. The number taken should be the actual number of days in the year; and the figures in the summarized tables in the Appendices have been amended on this basis.

(5) The returns for street cleansing were generally not satisfactory. It has not been properly understood that, as was set out in the report of the conference, the unit costs per 10,000 square yards for street cleansing and per 1000 gullies for gully cleansing should be based on the number of cleansings, so that, to give a purely hypothetical illustration, if there were two towns with the same expenditure and the same area for street cleansing and the number of cleansings in the one were twice that in the other, the unit costs in the former would be half those in the latter.

In some cases, also, the cost of street cleansing has been partly included in the expenditure on the maintenance of highways.

Summary of Returns.—The following summaries are given in illustration of the figures in the Appendices. It has been thought well not to attempt any detailed analysis of the figures until there has been more experience of them, and until there has been opportunity to avoid present inaccuracies.

I.

Quantity of Refuse per 1000 *of Population per Day for the Year* 1925–26.
Number of County Boroughs with Quantity as stated in first column.

Quantity per 1000 of Population.	Number of County Boroughs.
Cwts.	
Under 10	2
10 and over, under 13	14
13 ,, ,, 16	24
16 ,, ,, 19	17
19 ,, ,, 22	8
22 and over	9
Total	74

Average of the towns . . . 16 6 cwts.

II.

Cost per Ton of Refuse Collection for the Year 1925–26.
Number of County Boroughs with Cost as stated in first column.
(*Loan or depreciation charges and expenditure for new plant out of revenue included; income deducted.*)

Cost per Ton.	Number of County Boroughs.
Under 6*s.*	8
6*s.* and over, under 8*s.*	15
8*s.* ,, ,, 10*s.*	21
10*s.* ,, ,, 12*s.*	13
12*s.* and over	9
Total	66

Average of the towns . . . 9*s.* 1*d.*

III.

Cost of Refuse Collection per 1000 *of Population for the Year* 1925–26.
Number of County Boroughs with Cost as stated in first column.
(*Loan or depreciation charges and expenditure for new plant out of revenue included; income deducted.*)

Cost per 1000 of Population.	Number of County Boroughs.
Under £90	10
£90 and over, under £120	18
£120 ,, ,, £150	21
£150 ,, ,, £180	16
£180 and over	5
Total	70

Average of the towns . . . £130

Specimen Ruling No. D 2.

....DEPOT

Particulars of Refuse Received.						Particulars as to Disposal of Refuse Received.													Burning Costs.												
Week ended, 192....	House Refuse.	Market Refuse.	Trade Refuse.		Total Quantity Received.	Boated.		"Salvo" Dust Boated.	Treated in Fish Plant.	Treated in Meat Plant.	Scrap Metals taken from Refuse.	Salvage Sundries.	Paper Baled.	State of Yard.		State of Hopper.		Quantity Burnt.	Wages of Foreman, Stokers, Chargers and Flue Cleaners (including Holiday Pay).		Remarks.	Number of Shifts Worked.	Average No. of Stokers.		Average No. of Chargers.		Fan Hours Worked.	Grate-foot Hours Worked.	Total No. of Clinkerings.	Average No. of Clinkerings per Shift.
						By Contractors' Boats.	By Corporation Boats.							Added to.	Taken from.	Added to.	Taken from.		£ s. d.	Cost per Ton. d.			Per Day.	Per Shift.	Per Day.	Per Shift.				
	Tons.	Tons.	Tons.		Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.			Tons.	Tons.	Tons.	Tons.	Tons.												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)

[To face p. 40.

The figures show large differences. As already indicated, some of the differences are to be attributed to errors in the returns, and a great deal is due to the different conditions in the different towns; in this connexion, it may be stated (*a*) that the weight of refuse per inhabitant is usually high in mining towns, and (*b*) that the figures for some towns include dealing with a large quantity of nightsoil.

Making, however, full allowance for these facts, the returns indicate that there is need for further investigation. It will pay all Local Authorities with a large expenditure on this branch of service to obtain, and carefully to scrutinize, adequate costing records; and the periodical publication of returns should be of material assistance to them in the examination of their expenditure.

The Minister proposes to ask for returns for the year 1926–27 from all Urban Authorities in areas with a population exceeding 30,000 persons.

APPEN

APPEN

WEIGHT OF REFUSE AND COST OF COLLECTION AND DISPOSAL OF

RETURNS RECEIVED FROM

[*Loan or depreciation charges and expenditure for new plant out of revenue included (except in column 7, where*

Name of County Borough.	Population.	Weight, actual or estimated, per 1,000 of Population per Day.	Net Expenditure per Ton per Annum.						Total net expenditure per ton per annum *excluding* loan charges and expenditure for new plant out of revenue.	
			Collection.		Disposal.		Total.			
1.	2.	3.	4.		5.		6.		7.	
		cwts.	s.	d.	s.	d.	s.	d.	s.	d.
Birmingham	961,222	14·9	9	10	5	7	15	5	14	0
Liverpool	856,000	20·0	9	10	8	1	17	11	16	9
Manchester	761,389	15·8	8	5	8	7	17	0	16	8
Sheffield	526,900	13·1	13	10	8	11	22	9	17	8
Leeds	472,900	18·5	7	9	2	11	10	8	10	3
Bristol	385,700	18·0	8	3	3	9	12	0	11	5
West Ham	318,500	10·0	10	10	3	9	14	7	14	7
Kingston-upon-Hull	297,300	17·4	8	8	2	1	10	9	10	6
Bradford	290,200	18·4	9	10	2	10	12	8	11	3
Newcastle-upon-Tyne	286,300	20·5	8	1	1	2	9	3	8	11
Stoke-on-Trent	278,900	15·7	7	7	3	7	11	2	9	11
Nottingham	270,600	16·0	10	2	5	5	15	7	12	9
Portsmouth	250,100	15·9	5	0	4	4	9	4	8	2
Salford	244,700	14·4	14	0	5	8	19	8	18	4
Leicester	242,100	12·3	11	9	5	10	17	7	16	2
Cardiff	227,300	16·6	10	3	0	11	11	2	10	5
Croydon	199,300	11·2	14	5	3	0	17	5	17	2
Plymouth	192,100	15·9	10	8	2	6	13	2	12	5
Bolton	180,400	25·2	5	8	1	4	7	0	6	5
Southampton	168,600	16·6	—		—		6	10	6	8
Sunderland	166,000	18·3	6	5	2	0	8	5	7	9
Birkenhead	155,500	15·3	—		—		12	0	11	4
East Ham	147,200	8·8	7	6	9	6	17	0	16	0
Oldham	146,200	11·4	8	10	7	8	16	6	14	10
Brighton	138,300	14·2	11	9	3	11	15	8	15	5
Middlesbrough	136,200	14·0	8	3	2	8	10	11	10	0
Derby	134,700	15·8	10	0	4	2	14	2	14	2
Coventry	133,500	11·4	9	10	5	2	15	0	14	5
Gateshead	129,000	22·0	6	11	3	7	10	6	8	11
Blackburn	126,900	11·8	6	8	10	8	17	4	15	9
Norwich	124,000	No data	—		—		—		—	
Preston	122,900	13·1	9	0	5	10	14	10	13	4
Huddersfield	112,100	13·1	13	10	4	10	18	8	17	9

DICES

DIX I

REFUSE DURING THE YEAR ENDED ON THE 31ST MARCH, 1926

COUNTY BOROUGH COUNCILS

the figures are given, for comparison, exclusive of loan charges and such revenue expenditure); income deducted.]

Net Expenditure per 1000 Population per Annum.			Net Expenditure per 1000 Houses per Annum.			Rate in £.			Expenditure for New Plant out of Revenue.	Method of Disposal. I. = Incineration. P. = Pulverization. S. = Separation. T. = Tipping.
Collection.	Disposal.	Total.	Collection.	Disposal.	Total.	Collection.	Disposal.	Total.		
8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
£	£	£	£	£	£	*d.*	*d.*	*d.*	£	
134	76	210	610	345	955	6·03	3·41	9·44	—	S., I. and T.
179	151	330	929	784	1713	6·43	5·43	11·86	379	I. and dumping at sea.
121	124	245	526	538	1064	3·49	3·58	7·07	—	I. and T. Land reclamation.
165	109	274	746	491	1237	9·00	5·90	14·90	—	S. and I.
131	52	183	517	207	724	5·20	2·10	7·30	600	I. and T.
133	61	194	652	301	953	6·15	2·84	8·99	—	I. and T.
101	34	135	543	186	729	5·80	2·00	7·80	—	T.
138	32	170	585	139	724	6·66	1·60	8·26	—	I. and T.
165	47	212	624	179	803	5·30	1·52	6·82	—	T. and I.
151	21	172	711	101	812	4·70	0·60	5·30	—	T.
109	51	160	535	251	786	6·67	3·14	9·81	461	S., I. and T.
148	80	228	600	322	922	6·40	3·50	9·90	6601	I. and S.
73	63	136	190	164	354	3·68	3·16	6·84	—	I.
184	74	258	895	364	1259	8·40	3·40	11·80	—	I. and T.
132	70	202	558	297	855	5·80	3·10	8·90	—	I.
156	13	169	888	78	966	5·57	0·60	6·17	1721	T. and I.
148	31	179	614	129	743	5·32	1·12	6·44	—	P. and I.
152	36	188	882	211	1093	6·37	1·52	7·89	—	I., T. and dumping at sea.
130	31	161	539	127	666	5·39	1·26	6·65	1150	I. and T.
—	—	103	—	—	483	—	—	4·64	263	Dumping at sea.
106	34	140	706	225	931	5·87	1·88	7·75	—	Dumping at sea.
—	—	167	—	—	939	—	—	7·95	—	I. and T.
60	77	137	314	399	713	3·68	4·69	8·37	—	I. and P.
95	87	182	372	341	713	4·50	4·00	8·50	465	S., I. and T.
152	51	203	808	272	1080	5·29	1·78	7·07	—	I.
108	35	143	512	165	677	6·50	2·25	8·75	—	Dumping at sea.
148	71	219	662	316	978	6·50	3·00	9·50	—	T. and P.
102	54	156	449	239	688	6·29	3·34	9·63	—	I.
139	71	210	640	328	968	10·26	5·25	15·51	—	Dumping at sea.
73	116	189	289	460	749	3·42	5·45	8·87	—	S., I. and P.
102	61	163	404	242	646	5·38	3·22	8·60	109	T.
108	70	178	477	310	787	5·70	3·70	9·40	746	S., I. and T.
165	58	223	513	181	694	5·51	1·95	7·46	—	I. and T.

APPENDIX

Name of County Borough.	Population.	Weight, actual or estimated, per 1000 of Population per Day.	Net Expenditure per Ton per Annum.			Total net expenditure per ton per annum *excluding* loan charges and expenditure for new plant out of revenue.
			Collection.	Disposal.	Total.	
1.	2.	3.	4.	5.	6.	7.
		cwts.	s. d.	s. d.	s. d.	s. d.
Wolverhampton	108,800	15·0	11 3	5 5	16 8	14 11
Burnley	105,000	12·5	6 2	4 8	10 10	9 7
St. Helens	104,900	16·3	9 6	1 10	11 4	11 2
Walsall	102,300	17·0	5 0	1 9	6 9	6 9
Halifax	98,750	11·0	14 11	9 11	24 10	19 2
Southend-on-Sea	98,060	16·8	—	—	17 2	16 2
Newport (Mon.)	96,420	19·3	5 4	3 4	8 8	8 2
Northampton	94,000	16·0	8 5	3 7	12 0	11 6
Reading	94,000	12·5	—	—	11 0	10 6
Rochdale	92,190	13·0	9 7	8 2	17 9	15 3
Wallasey	91,720	14·0	10 3	4 3	14 6	13 5
Wigan	91,010	20·5	—	—	11 1	11 1
Grimsby	86,810	13·2	13 7	4 10	18 5	16 4
York	86,380	11·9	10 9	3 5	14 2	14 0
Bournemouth	85,840	No data	—	—	—	—
Bootle	83,260	12·0	11 8	4 6	16 2	15 3
Ipswich	83,120	7·5	12 1	10 3	22 4	17 7
Merthyr Tydfil	82,920	40·1	—	—	4 3	4 2
Blackpool	80,750	22·4	9 3	5 10	15 1	13 8
West Bromwich	79,490	13·9	6 1	5 5	11 6	8 11
Smethwick	78,790	12·5	9 0	4 4	13 4	12 2
Warrington	78,260	23·2	14 0	3 10	17 10	14 5
Southport	74,260	No data	—	—	—	—
Barrow-in-Furness	73,470	15·7	5 11	3 9	9 8	7 11
West Hartlepool	71,620	12·4	7 2	4 5	11 7	11 5
Barnsley	71,170	25·8	7 0	2 1	9 1	8 3
Rotherham	70,600	21·0	8 4	3 2	11 6	10 6
Darlington	69,450	20·7	7 9	0 9	8 6	8 6
Bath	69,050	14·5	9 7	5 4	14 11	12 3
Lincoln	66,790	13·1	13 1	7 2	20 3	18 4
Hastings	66,496	No data	—	—	—	—
Tynemouth	66,180	29·6	6 6	1 10	8 4	8 4
Exeter	60,410	10·5	9 6	5 11	15 5	13 10
Dudley	58,810	37·4	3 11	0 7	4 6	4 5
Great Yarmouth	57,890	14·1	8 3	3 1	11 4	11 4
Oxford	57,090	18·0	—	—	9 7	9 7
Bury	56,700	16·0	8 7	2 10	11 5	9 3
Carlisle	55,360	20·7	5 6	1 0	6 6	6 3
Eastbourne	55,060	16·8	11 3	5 10	17 1	16 1
Dewsbury	55,020	21·5	—	—	10 2	9 8
Wakefield	54,428	22·0	6 10	1 0	7 10	7 10
Gloucester	53,060	No data	—	—	—	—
Burton-upon-Trent	49,530	18·4	10 10	4 3	15 1	14 9
Worcester	49,160	15·6	5 3	0 6	5 9	5 8
Chester	41,670	17·1	6 5	1 3	7 8	7 8
Canterbury	24,000	14·5	7 8	2 9	10 5	7 10
Total population and average of columns 3 to 16	12,613,055	16·6	9 1	4 3	13 0	12 0

I (*continued*)

Net Expenditure per 1000 Population per Annum.			Net Expenditure per 1000 Houses per Annum.			Rate in £.			Expenditure for New Plant out of Revenue.	Method of Disposal. I. = Incineration. P. = Pulverization. S. = Separation. T. = Tipping.
Collection.	Disposal.	Total.	Collection.	Disposal.	Total.	Collection.	Disposal.	Total.		
8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
£	£	£	£	£	£	*d.*	*d.*	*d.*	£	
157	75	232	711	339	1050	8·29	3·95	12·24	—	I.
71	53	124	287	216	503	2·80	2·10	4·90	—	I. and T.
141	27	168	778	154	932	8·76	1·71	10·47	—	T.
78	27	105	380	131	511	5·90	2·03	7·93	—	T.
147	99	246	518	347	865	5·94	3·98	9·92	667	S., I. and T.
—	—	263	—	—	1036	—	—	7·45	—	I.
95	58	153	558	344	902	3·70	2·30	6·00	—	T. and I.
120	50	170	478	202	680	6·23	2·60	8·83	—	I. and T.
—	—	126	—	—	537	—	—	5·62	595	T.
114	99	213	423	369	792	4·83	4·20	9·03	—	S. and I.
138	56	194	553	221	774	4·69	1·88	6·57	—	I.
—	—	208	—	—	1045	—	—	11·50	—	I. and T.
163	58	221	750	267	1017	9·50	3·40	12·90	—	I. and P.
117	37	154	526	169	695	5·82	1·87	7·69	—	I. and T.
—	—	316	—	—	1158	—	—	6·75	—	I. and T.
123	47	170	762	293	1055	4·70	1·81	6·51	343	I. and T.
84	71	155	365	312	677	3·99	3·40	7·39	—	I.
—	—	157	—	—	823	—	—	12·70	—	T.
189	120	309	663	423	1086	3·77	2·41	6·18	587	I.
77	68	145	384	342	726	5·88	5·25	11·13	—	S. and I.
103	50	153	470	224	694	6·90	3·30	10·20	—	I. and T.
296	81	377	1484	405	1889	14·75	4·02	18·77	—	I. and T.
205	21	226	834	87	921	5·21	0·54	5·75	—	T. and P.
85	54	139	404	254	658	4·17	2·62	6·79	290	I.
81	53	134	395	256	651	5·12	3·32	8·44	—	I. and T.
163	49	212	771	231	1002	11·01	3·30	14·31	—	I., S., P. and T.
162	62	224	792	302	1094	8·68	3·31	11·99	—	I. and T.
149	15	164	664	67	731	5·73	0·57	6·30	—	T.
125	68	193	576	315	891	5·00	3·00	8·00	532	I.
155	86	241	681	375	1056	8·00	4·40	12·40	54	I. and T.
167	19	186	680	81	761	5·03	0·60	5·63	—	I. and dumping at sea.
177	49	226	795	224	1019	9·06	2·55	11·61	—	Dumping at sea.
92	58	150	382	238	620	3·20	2·00	5·20	—	T.
134	20	154	605	91	696	9·86	1·49	11·35	—	I. and T.
107	39	146	440	162	602	5·94	2·20	8·14	—	I.
—	—	158	—	—	702	—	—	4·50	—	T.
126	40	166	487	157	644	5·20	1·69	6·89	1296	P. and S.
105	18	123	485	86	571	4·77	0·85	5·62	314	T.
173	90	263	883	461	1344	4·39	2·29	6·68	—	I.
—	—	199	—	—	633	—	—	9·60	—	T. and I.
137	20	157	584	87	671	5·93	0·88	6·81	—	I. and T.
90	20	110	408	90	498	3·55	0·79	4·34	—	T.
181	72	253	770	306	1076	7·60	3·02	10·62	—	I.
74	18	92	292	69	361	3·40	0·81	4·21	—	T.
100	20	120	458	91	549	4·49	0·90	5·39	—	T.
104	35	139	435	148	583	4·75	1·66	6·41	—	I.
130	56	187	588	252	838	5·97	2·62	8·50	—	

APPENDIX II

EXPENDITURE ON STREET CLEANSING, INCLUDING STREET SWEEPING AND WATERING, GULLY CLEANSING, AND SNOW REMOVAL, FOR THE YEAR ENDED ON THE 31ST MARCH, 1926

SUMMARY OF RETURNS FROM COUNTY BOROUGH COUNCILS

(Loan or depreciation charges and expenditure for new plant out of revenue included; income deducted.)

Name of County Borough. 1.	Total net Expenditure. 2.	Expenditure per 1000 of Population. 3.	Net Cost: equivalent Rate in £. 4.	Expenditure for New Plant out of Revenue. 5.
	£	£	d.	£
Birmingham	108,199	112·6	4·97	1483
Liverpool	89,737	104·8	3·76	—
Manchester	155,886	204·7	5·90	—
Sheffield	56,075	106·4	5·78	2461
Leeds	65,083	137·6	5·4	1065
Bristol	67,494	174·9	8·1	—
West Ham	45,976	144·4	8·2	—
Kingston-upon-Hull	40,615	136·6	6·58	—
Bradford	37,777	130·2	4·18	—
Newcastle-upon-Tyne	60,757	212·2	6·56	548
Stoke-on-Trent	28,832	103·4	6·34	—
Nottingham	43,720	161·6	6·88	—
Portsmouth	29,017	116·0	5·82	—
Salford	22,461	91·8	4·11	—
Leicester	24,215	100·0	4·46	—
Cardiff	32,782	144·2	5·07	—
Croydon	24,879	124·8	4·49	1125
Plymouth (b)	32,140	167·3	7·03	—
Bolton	15,093	83·7	3·45	—
Southampton	18,462	109·5	4 92	—
Sunderland	16,867	101·6	5·59	—
Birkenhead	13,722	88·2	4·2	—
East Ham	18,251	123·9	7·37	—
Oldham	23,485	160·6	7·50	—
Brighton (b)	18,591	134·4	4·68	—
Middlesbrough	11,741	86·2	5·29	—
Derby	16,350	121·4	5·5	—
Coventry	10,232	76·6	4·74	—
Gateshead	13,972	108·3	7·95	—
Blackburn	9,171	72·3	3·39	—
Norwich	18,645	150·4	7·93	—
Preston	12,215	99·4	5·25	—
Huddersfield	13,113	116·9	3·9	—

(b) The return did not include any expenditure on snow removal.

APPENDIX II (*continued*)

Name of County Borough. 1.	Total net Expenditure. 2.	Expenditure per 1000 of Population. 3.	Net Cost: equivalent Rate in £. 4.	Expenditure for New Plant out of Revenue. 5.
	£	£	*d.*	£
Wolverhampton	10,120	93·0	4·92	—
Burnley	13,494	128·5	5·1	—
St. Helens	7,533	71·8	4·47	—
Walsall	5,609	54·7	3·85	—
Halifax	17,123	173·4	6·99	—
Southend-on-Sea (*a*)	24,312	247·9	7·03	—
Newport (Mon.)	12,733	132·1	5·23	70
Northampton	13,102	139·4	7·26	—
Reading	11,143	118·5	5·3	—
Rochdale	12,777	138·6	5·87	—
Wallasey	11,805	128·3	4·3	—
Grimsby	12,226	140·8	8·22	—
York	12,523	145·0	7·22	—
Bournemouth	23,501	273·8	6·0	—
Bootle (*a*) (*b*)	11,224	134·8	5·15	140
Ipswich (*a*)	6,996	84·2	4·03	—
Merthyr Tydfil	7,216	87·0	7·11	—
Blackpool (*b*)	15,639	193·7	3·77	—
West Bromwich	5,766	72·5	5·58	—
Smethwick	5,594	71·0	4·76	—
Warrington (*b*)	5,559	71·0	3·54	—
Southport	7,347	98·9	2·51	—
Barrow-in-Furness (*b*)	3,878	52·8	2·59	—
West Hartlepool	4,923	68·7	4·07	—
Barnsley (*a*)	6,490	91·2	6·69	—
Rotherham	5,826	82·5	4·4	—
Darlington (*a*)	8,463	121·9	4·7	—
Bath (*a*)	9,675	140·1	5·8	1008
Lincoln	6,466	96·9	4·97	52
Hastings (*a*)	10,271	154·4	6·2	—
Tynemouth	7,281	110·0	5·64	—
Exeter (*b*)	9,203	152·3	5·32	—
Dudley	6,584	112·0	8·22	—
Great Yarmouth	12,258	211·9	11·84	—
Oxford (*a*)	10,163	178·0	5·13	—
Bury	5,930	104·6	4·326	—
Carlisle	6,527	117·9	5·47	—
Eastbourne	8,925	162·1	4·13	—
Dewsbury	8,258	150·1	7·16	—
Wakefield	7,375	135·5	5·9	—
Gloucester	5,441	102·5	4·03	—
Burton-upon-Trent	8,000	161·5	6·735	—
Worcester (*b*)	6,012	122·3	5·62	—
Chester	4,479	107·5	4·81	—
Canterbury	3,187	132·8	6·04	—
Total expenditure and average of columns 3 and 4	1,614,512	125·3	5·56	

(*a*) The cost of gully cleansing was not included in the return.
(*b*) The return did not include any expenditure on snow removal.

CHAPTER V

REFUSE COLLECTION

Part I. Storage and Loading.

1. General.

Approximately 11 million tons of house and trade refuse are produced annually in England and Wales, and the cost of collection of this refuse amounts to something like £5,000,000 per annum. The annual tonnage of house and trade refuse removed in Birmingham is about 254,000 tons, necessitating more than eleven million separate calls and the whole time employment of about 450 men. These statistics are quoted in order to emphasise the necessity of well-organised collection services, and a brief consideration of the figures mentioned will render obvious the grave danger of waste of public moneys if collection services are not efficiently organised. A simple calculation shows that an increase or decrease of only one penny per ton in the cost of collecting the house and trade refuse of the country would entail a difference in expenditure of over £45,000 per annum.

The importance of collection of house refuse from the health standpoint cannot be over-estimated, and the dangers attendant upon putrefying refuse being allowed to remain on premises for indefinite periods are apparent. It will be agreed that every household should have its refuse removed once weekly at least. A disgruntled ratepayer was once credited with having facetiously remarked that, after the annual municipal elections have taken place, the only representative of the Corporation with whom the ratepayers come into regular touch is the humble dustman ! This gentleman presumably meant that the refuse collectors attended his premises with unfailing regularity, and he was probably not aware that he had paid a nice compliment to the Cleansing or Salvage Department of the Corporation concerned.

The writer has heard the remark made on a number of occasions that, as compared with refuse disposal, the problem of refuse collection is not difficult, but he considers that such a dogmatic statement is open to doubt. The scientific disposal of refuse certainly calls for highly qualified technical skill, but it is submitted that the problem of refuse collection, with its many phases, calls for an equally high standard of training and administrative ability, especially in the case of large centres of population. Further, a Local Authority's collection service, however efficiently organised, may be $1\frac{1}{2}$ to 5 times greater than the cost of disposal, varying mainly according to the disposal method in force.

The average cost per ton quoted in the annual report of the Ministry of Health for 1926–1927 is 9*s*. 1*d*. for refuse collection and 4*s*. 3*d*. for refuse disposal, a difference of 114%.

In support of the writer's contention, the following passage relating to the importance of refuse collection is taken from a publication entitled " Collection and Disposal of Municipal Refuse," written jointly by Rudolph Hering, D.Sc., New York, and Samuel A. Greeley, Chicago :—

> " The foregoing statements show the great need for efficiency and economy in the collection of refuse materials, because it is frequently the most important and costly single element of the entire refuse problem, and one where improvement, chiefly in equipment, can most readily be made. The collection requires well organised and effective co-operation between householder and collector, and a Cleansing Department which operates along thoroughly business-like lines.
>
> " The equipment should be carefully adjusted to the specific needs of the locality, and standardised as much as practicable.
>
> " The collections should be regular. They should be along well-planned routes, studied carefully to get the largest loads in the shortest time along the easiest roads. The frequency of collection should depend on the method of final disposal, on the season of the year, and on the geographical location of the town. The time of collection should be selected so as to give the least inconvenience to people and traffic moving on the streets. The manner of collection should be such as to remove the refuse

from house to wagon in the least objectionable way. The loading should be done so that it will produce the least possible dust and noise, and the wagons should be kept covered for as much of the time as practicable."

2. Accommodation for Storage at Premises.

In Chapter I the various kinds of storage accommodation are briefly referred to. The two types of receptacle mainly in use to-day are fixed ashpits and portable dustbins. In that chapter, fixed ashpits are referred to as relics of an insanitary past, and their abolition should be proceeded with by every well-ordered Authority as quickly as finances and circumstances permit. It is generally admitted that it is almost impossible for ashpits to be kept in a sanitary condition, and after emptying, they are frequently as great a nuisance as before the refuse was removed. The frequency of emptying an ashpit usually depends mainly upon its size, and may vary from weekly to quarterly, which alone is a sufficient reason to condemn the fixed ashpit as a sanitary convenience. Ashpits are not generally situated in positions accessible to collection vehicles, and the filth has usually, therefore, to be loaded into a barrow and wheeled to the pavement, where the refuse is dumped, to be once more picked up and re-shovelled into the vehicle, thus causing double work and annoyance.

The emptying of ashpits is also a degrading and unpleasant task to the workmen responsible for the work, and the cleansing of certain types of ashpits, particularly where men have to crawl through small apertures (and there are ashpits of this kind in use) may be described as almost inhuman. There is no necessity to emphasise further the disadvantages of this type of receptacle, as sufficient has been said to show that whether regarded from the economy, efficiency, or public health viewpoint the fixed ashpit stands condemned.

It is now generally accepted that the best method of domestic refuse storage is by means of portable dustbins. These receptacles possess the advantages of being easily cleaned and emptied and they also keep refuse dry, providing lids are kept fitted, thus facilitating treatment of the refuse at the disposal works.

A dustbin should be of sufficient capacity to hold the refuse produced by an average household between the collection periods during the period of the year when the output of refuse is greatest, but it should not be so large that an average man cannot easily handle and carry it when the bin is completely filled. A dustbin should be also sufficiently strong to withstand the somewhat rough treatment to which it is liable when being emptied, as if the refuse does not leave easily, the dustman usually bangs the receptacle on the side of the vehicle in order to loosen the contents. This particularly applies in the case of bins from houses where the misguided occupants persist in depositing liquid matter into bins in spite of bye-laws which may be in force making such action an offence. If the bin is not made strongly, and if the "bump" is over-vigorous, the result is a badly dented side, probably quickly followed by a letter of complaint from an irate landlord or tenant. In passing, it may be mentioned that to obviate or lessen damage to dustbins in this way, refuse collection vehicles in Birmingham are provided with rubber strips which are attached to the top edges of the sides of vehicle bodies. Even this precaution, in many cases, is insufficient to prevent damaged bins, and the only sure remedy is to educate householders to refrain from depositing liquid matter into dustbins. Reference was made in a previous chapter to the bye-law in operation in Birmingham relating to liquids being thrown into dustbins, but the prosecution of offenders is frequently a matter of some difficulty, and it is appreciated that the co-operation of the citizens is of much greater value than methods of compulsion. With the view of securing the co-operation of citizens in this respect, lids of dustbins in use in Birmingham are embossed with the wording "FOR DRY REFUSE ONLY," and in addition, every bin issued under the Salvage Department's Hiring Scheme has the following appeal affixed to the lid :—

Birmingham Corporation Salvage Department.

HOUSEHOLD REFUSE.

Help to Reduce the Rates.

Riddle your Ashes and use the Cinders again.
Bundle all your Old Papers and hand them to the Refuse Collectors.
Burn all Vegetable Waste and other Combustible Refuse.
Keep the Lid on Your Bin and use it for Dry Refuse Only.

Referring to the use or misuse of refuse receptacles, it may be mentioned in passing that, since the war, many Corporations have experienced trouble through explosives being deposited amongst house refuse. It was found that these explosives had been brought home by ex-Service men as souvenirs, and after a time were deposited in bins for removal. This action was obviously extremely dangerous, particularly where refuse is passed through incinerator cells, and in the writer's Department several employees received injuries owing to explosives bursting in the incinerator cells, one man losing the sight of an eye owing to this cause. In order to impress upon the public the grave danger of discarding explosives by depositing them in refuse intended for removal, appeals were made in the Press, and a window display was arranged at the Central Offices of the Department of explosives recovered from refuse. The display included a large number of cartridges, high explosive shells, aërial torpedoes, and various other kinds of explosives, and was accompanied by notices appealing to the public to refrain from depositing explosives in bins. The publicity given to the matter in the directions mentioned immediately resulted in a diminution of the number of explosives recovered from house refuse, and it was obvious that, generally speaking, the explosives had been put out for removal owing to thoughtlessness, as the persons concerned had not apparently realised that the bulk of refuse collected passed through furnaces.

FIG. 7.—Explosives found in refuse.

It was found necessary, however, to take legal proceedings against one person who had deposited a number of "live" cartridges with refuse after the above-mentioned publicity had been given to the matter, and even at the present time explosives are occasionally discovered in refuse.

In order to obtain a satisfactory receptacle, many Local Authorities have adopted a standard dustbin, and in districts where this has been done, bins of the approved type only are accepted.

In Birmingham, two types of standard dustbin have been adopted, one having a capacity of 3½ cubic feet and the other of 2⅓ cubic feet.

The essential details of the two standard bins are as follows :—

	Large Bin.	Small Bin.
Height	24 in.	20 in.
Diameter	18 ,,	16 ,,
Body	22 B.W.G. Sheet Iron.	22 B.W.G. Sheet Iron.
Bottom	21 ,, ,,	21 ,, ,,
Weight without lid . . .	25 lb.	19 lb.
,, with lid	28 ,,	21½ ,,

The Birmingham standard dustbins are retailed by ironmongers at 9*s*. 5*d*. for the large bin and 8*s*. 5*d*. for the small bin, with a reduction for quantities.

The small bin was adopted as standard in May 1927, and in October 1928 there were approximately 4000 of these bins in use. Its adoption was not carried out until tests over a long period had been completed in order to ensure that this smaller bin possessed sufficient capacity to hold the output of refuse between collection periods at selected properties. Theoretically, the bin possessed ample capacity for single house property in Birmingham, but it was decided to try it out under actual working conditions before arriving at a definite decision. About thirty of the small bins were therefore distributed to the private addresses of various members of the staff, mainly occupying small self-contained houses, and they were requested to keep close observation as to whether the bin was sufficiently large. The result of this test proved that, under all normal conditions, the small bin has ample capacity for small self-contained properties, and since its adoption as standard, the small bin has been installed at the majority of small houses requiring new dustbins. It is considered that the small bin will prove an important factor in still further reducing the output of refuse throughout the City, as it is the general experience of cleansing officials that the larger the receptacle allowed, the greater is the output of refuse. The smaller bin has also the advantage of a lower cost as previously shown, and this is a point which particularly appeals to property owners. It should be added that the Department specifies which type of bin is to be installed at any property, and the installation of the large bin is now usually confined to premises where the use of bins is shared between two or more houses, such as courtyard properties. The latter bin is used also as standard for trade refuse contracts.

In some districts, a bucket-shaped bin is used, and bins of this shape possess the advantage of being more easily stored in bulk. It is also claimed that a bucket-shaped bin is easier to empty. The circular bin is, however, the type most generally adopted.

3. Dustbin Sheds.

It has been mentioned that one advantage obtained from the use of dustbins is that refuse is kept dry, but obviously this is only so when lids are replaced after bins have been used. It sometimes happens, however, that careless householders fail to replace the lid, or that the lid becomes displaced, with the result that refuse becomes wet in rainy weather unless the bin itself is kept under cover. It is therefore an advantage if dustbins are kept in bin-sheds, and apart from the double assurance thus obtained against the refuse becoming saturated with rain, a bin contained in a simple dustbin-shed presents a tidier appearance than a receptacle standing in the open. A further advantage obtained where a dustbin-shed is provided, is that in the event of an unusually large quantity of refuse being produced, which could not be entirely accommodated in the dustbin, the "overflow," which would probably be thrown on the floor of the shed, is kept reasonably dry, whereas under similar conditions in the case of premises provided with a dustbin only, part of the refuse would be thrown down in an open yard near to the dustbin, from where the "overflow" would perhaps be distributed to neighbouring properties by the wind, or become saturated with rain. The Birmingham Corporation has no legal power to demand the provision of bin-sheds although 83,268 were in use on 31st March, 1928, of which about 35,000 have been converted from ashplaces, the cost of conversion having been borne partly by the Corporation.

4. Means for Obtaining Installation of Dustbins.

The legal powers of the Birmingham Corporation to require the installation of dustbins at all properties have been dealt with in a previous chapter, and the property owner, having received a statutory notice requiring him to provide bins (stating whether small or large), has the option of taking one of two courses, *i.e.*, to purchase a standard bin outright from a retailer, or to enter the Department's Hiring Scheme. A property owner deciding to enter the scheme is required to pay a deposit varying from 1*s.* 6*d.* to 10*d.* per bin, according to the month of entry, and to sign an agreement form undertaking (amongst other things) to pay the sum of 1*s.* 11*d.* for each large bin and 1*s.* 6*d.* for each small bin on April 1st of each year.

After a hired standard dustbin of the larger capacity has been in use for a period of five years, the annual charge is reduced from 1*s.* 11*d.* to 1*s.* 6*d.* It may be added that to suit the convenience of dustbin hirers, payments of the annual instalments can be made at any branch of the Birmingham Municipal Bank. Accounts not paid through the latter are collected by the Salvage Department.

Until the year 1919 the Birmingham Salvage Department sold dustbins direct to the public, but in that year an agreement was entered into with the local branch of the Ironmongers' Federated Association, under which the Corporation undertook not to sell dustbins direct to the public, the Association on their part agreeing to sell standard dustbins only, at a profit which is controlled by the Corporation. The Hiring Scheme was inaugurated in April 1923, and it is entirely optional upon any owner whether he hires bins from the Corporation or purchases them outright from a retailer.

The success of the scheme can be judged from the following table :—

	No. of Owners.	No. of Bins.		Replacements.
		Large.	Small.	
1/4/23 to 31/3/24	940	5,465	—	—
1/4/24 to 31/3/25	931	6,889	—	—
1/4/25 to 31/3/26	1,066	8,414	—	6
1/4/26 to 31/3/27	967	6,911	—	—
1/4/27 to 31/3/28	745	5,696	786	43
1/4/28 to 30/9/28	374	801	2,390	57
Total to Sept. 30, 1928	5,023	34,176	3,176	106

Replacement of burnt and damaged bins, for which extra payment has been received, is not included in the above figures.

There are now a number of Corporations which supply bins on yearly payments, and in a few cases Parliamentary powers have been obtained whereby property owners are compelled to hire bins from the Corporation concerned.

In one large city, bins are made by the Cleansing Department, who supply the first bin on payment of the sum of 10*s*., subsequent renewals being supplied by the Corporation as a charge against the rates.

5. Position of Dustbins at Premises.

It is perhaps unnecessary to mention that dustbins should be kept on premises in a convenient position for emptying, so that the length of " carry " is reduced to a minimum. This is a particularly important point in the case of houses having long gardens and where access to the premises for the removal of refuse is by means of an entrance at the end of the gardens. In such cases, occupiers are sometimes prone to keep dustbins near to the house, and this results in extra travelling and carrying for the dustmen. It was mentioned in a previous chapter that a bye-law is in force in Birmingham which empowers the Corporation to require dustbins to be kept in a convenient position for emptying.

6. Waiting Time.

Waiting time is probably the most important factor affecting the cost of refuse collection, and is a matter over which a Cleansing Department has unfortunately little control. In the planning of most districts, no consideration appears to be given to facilities for refuse removal, with the result that the department responsible for this important service has to frame its methods to fit the conditions prevailing, and in districts where refuse has to be carried long distances to the collecting vehicle, the waiting time may be as much as three times greater than actual travelling time. In some towns in the North of England, refuse is loaded in back lanes situated between the backs of the houses fronting adjacent streets, the refuse being stored in special receptacles which are generally fixed to the wall at the end of back yards. The collecting vehicle is loaded from each side simultaneously, without the collectors entering the premises, as access to the refuse receptacles is obtained by means of small doors in the wall. It is obvious that towns possessing these facilities for loading have a tremendous advantage over those areas where portable bins have to be carried down long passages or pathways to the front street, and returned to their usual position after being emptied.

With a view to reduce waiting time to a minimum, some Authorities have passed bye-laws requiring occupiers to carry their bins to the kerb and to remove them from the pavement when emptied, but while this method reduces costs, the disadvantages attached to it probably outweigh any saving effected. The average person has a strong objection to being employed as an amateur dustman, and if a Corporation suddenly decided to compel occupiers to remove their refuse to the kerb after having previously carried out the removal by the employees of the Corporation, strong opposition and criticism would undoubtedly be encountered. Quite apart from objections of ratepayers against the removal of bins to the kerb, the method leaves much to be desired from other points of view. Bins would probably be left to await the collecting vehicle without lids being fitted, and on windy days waste paper, dust, etc., would be broadcast into the streets. Another objection is that in the event of the collecting vehicle being delayed for any reason, such, for example, as a breakdown, bins might be left standing on the kerb for indefinite periods. Even if the collecting vehicle is punctual, there is no guarantee that the emptied bins would be removed promptly by householders.

A further disadvantage attached to this method is that it is essential for collecting vehicles always to visit each house on the same day and time, so that occupiers would know when to deliver their bins to the kerb. It would be impossible, therefore, for a Department to take full advantage of the lighter output periods of the year, where the practice of householders removing bins to the kerb is in force.

Another practice employed by various Corporations is to leave loaders in the collecting area while the collecting vehicle is travelling to and from the disposal point. These loaders bring bins (with lids fitted) to the kerb, so that when the vehicle returns after tipping its load, less time is lost in completing the next load. The bins, after being emptied, are returned by the loaders to the premises to which they belong. The objections to this system are not nearly so great as those attached to the method mentioned previously, as providing the loaders carry out their instructions, no bins without lids are allowed to stand on the kerb, and after being emptied, the bins are promptly removed from the pavement.

From the æsthetic viewpoint, the appearance of a pavement lined with dustbins is certainly not pleasing under any conditions, but if consideration of economy is the primary factor, the consequent saving in cost probably justifies any disadvantages attached to the practice, provided it is operated in quiet suburban areas, particularly where the collection area is a considerable distance from the disposal depot. The delivery of bins to the kerb in busy thoroughfares cannot be recommended, however, under any circumstances.

Another method of loading involves the use of skeps or scuttles into which the refuse is emptied from the bins. This system saves a return journey with the empty bin, and also obviates damage to dustbins through being banged on the side of vehicles to loosen contents. Its disadvantages are that the refuse is subjected to a double disturbance, involving greater risk of dust being blown about, and also that a careless workman in transferring refuse from the bin to the skep is liable to spill part of the refuse on the ground.

The most sanitary method of loading, and incidentally the most costly, is for the bin and its contents to be taken direct to the collecting vehicle, emptied, and immediately returned to its usual position.

7. Rate of Loading.

The rate of loading per man is closely allied to waiting time and is mainly dependent upon local conditions, as in districts where long carries are general the rate of loading will be obviously slower than in areas where refuse has to be carried short distances only.

The rate of loading was estimated at 9 cwts. per man per hour in a paper read at the annual conference of the Institute of Cleansing Superintendents in 1925, but the figure varies very considerably in different districts, and may be as low as 4 cwts. per man per hour in summer, and as high as 12 cwts. per man per hour in winter.

It is a very important factor, however, and must be taken into consideration before adopting any particular type of transport, as it obviously largely determines the tonnage which can be removed and the number of premises which can be cleared by a collection unit in a given time. The following figures showing the number of premises cleared per week by average collection rounds in Birmingham are given for the information of students, but it cannot be borne in mind too strongly that a satisfactory output for a particular area can be determined only when the whole of the conditions attached to the area have been fully considered, as it is easily possible for a collection unit in one area to give a higher output with less effort than that expended by a unit clearing a lower number of premises per week from a different area, even in the same city.

Premises Cleared once Weekly by Average Rounds in Birmingham.

(*a*) Horse drawn wagon with two men operating in inner areas—1000 to 1200 premises per week.
(*b*) Electric vehicle with four men operating in outer areas—2300 to 2500 premises per week.
(*c*) *Container System.*—Units of four men—2400 to 2700 premises per week.

8. Frequency of Collection.

The frequency of collection varies in different towns from daily upwards, and the period between collections may also vary in the different districts of one Authority, but the service given by most Corporations is a weekly collection. In the case of a daily collection, it is essential, unless the cost be prohibitive, that householders should deliver their bins to the kerb, and some of the disadvantages of this practice have already been dealt with. Further, where a daily collection is in force, the output of refuse is liable to be greater than in districts where refuse is removed less frequently.

The most suitable intervals between collections must be decided upon in full consideration of local circumstances, as a satisfactory collection period for a scattered rural district might be quite unsuitable for a congested industrial area. In most cases, however, it is doubtful whether a collection service from ordinary dwelling houses of a higher frequency than once per week is not an expensive luxury, although in the case of business premises, located in the centre of towns, a daily removal is often essential. Where a weekly collection is suitable, it is questionable whether a more frequent service, with its attendant extra cost, due to duplication of travelling, etc., can be justified by any extra sanitary advantage which may be obtained.

Part II. Transport.

1. Methods of Transport.

The most efficient method of transport for the collection of refuse in any district can be properly determined only after full consideration has been given to the conditions operating in the district concerned. The chief determining factors are as follows :—

(*a*) Receptacles for storage of refuse.
(*b*) Frequency of collection.
(*c*) Whether bins are brought to kerb by occupiers.
(*d*) Length of carries (if bins are removed from premises by dustmen).
(*e*) Waiting time.
(*f*) Rate of loading per hour per man.
(*g*) Length of haul from collecting area to disposal depot.
(*h*) Gradients and surface of roads.
(*j*) Facilities for quick discharge of loads at disposal points.
(*k*) Average output of refuse per premises.

No two towns possess identical conditions and after due consideration has been given to the various factors affecting the question, it will probably be decided that no uniform class of transport will satisfactorily meet all the conditions applicable to any one town.

It has until recently been a usually accepted principle that a well-organised horse-drawn transport when employed on hauls up to about 1¼ miles gives better results than mechanical transport, and that mechanical vehicles are more economical for hauls in excess of that distance. The experience of the writer with both classes of transport has certainly proved that the horse cannot compete with mechanical vehicles on the longer hauls, and the results of recent tests conducted by the Birmingham Salvage Department point to the probability that the superiority of the horse is challenged even on short hauls.

The two 2-ton electric vehicles employed in the above-mentioned tests were specially designed for the purpose of contesting the previously accepted sphere of horse-drawn wagons, and in addition to a lower loading line, the electrics possessed greater carrying capacity than the horse wagons. Another feature of the electrics is their small overall dimensions, which renders them capable of negotiating narrow passageways with even greater ease than a horse and wagon. The two electrics are both employed in areas previously cleared by horse-drawn wagons, and during the twelve months ended June 1928 the vehicles proved superior to horse wagons on all counts. The actual results shortly summarised were as follows :—

Reduction in total expenses	8·43%
Increase in weight collected	3·29%
Increase in visits made	5·5 %
Reduction in men days worked	14·38%

These tests have resulted in further vehicles of similar type being acquired by the Department for employment on other short "haul" rounds, and so long as the electrics continue to show superior results to horses, the policy of the Department will be that of a gradual replacement of horses by mechanical vehicles.

The experience of low loading mechanical vehicles proving themselves more economical than horses for short "hauls" is not confined to the Birmingham Salvage Department, and the results of carefully conducted tests recently made in a North Country borough showed definitely superior results by low loading petrol vehicles as compared with horses when employed on exactly similar work within an average radius of 0·75 mile from the disposal depot.

The above-mentioned tests are not referred to in order to create the impression that horse-drawn transport employed on refuse collection is necessarily invariably uneconomical. There are many towns where, owing to peculiar local conditions, it is probable that well-organised horse-drawn transport may always prove most suitable, but it is submitted that the hackneyed principle of horses being the only economical proposition for short "hauls" should not be blindly accepted.

The forms of traction used for refuse collection are as follows :—

(*a*) Horse-drawn.
(*b*) Electric vehicles.
(*c*) Petrol vehicles.
(*d*) Container system (combined horse and mechanical).
(*e*) Steam vehicles.

In the "Municipal Year-book" for 1928 the proportion of horse and mechanical transport engaged upon house refuse collection in 93 municipalities is stated to be as follows :—

Population per Town.	No. of Towns.	Total Population.	Proportion of Horse and Mechanical Transport Engaged.				
			Electric.	Petrol.	Horse.	Container System.	Steam.
			%	%	%	%	%
500,000 to 1,100,000	5	4,245,000	29·96	9·40	63·18	0·46	—
250,000 to 500,000	9	3,019,000	8·78	4·36	76·56	10·30	—
100,000 to 250,000	35	5,392,000	13·18	24·36	57·88	2·91	1·71
50,000 to 100,000	44	3,144,296	14·82	20·38	59·87	4·65	0·28
Totals	93	15,800,296	16·37	15·73	63·27	4·01	0·61

A brief review of the various types of transport is given below :—

(a) *Horse Traction.*—This type of traction is still the most extensively used, and has, in the past, been generally accepted as being the most economical form of transport for short hauls. Four-wheeled wagons are usually employed, although in hilly and rural districts two-wheeled carts are still frequently used. The objections against two-wheeled carts are that the loading line is necessarily high, and the carrying capacity is not sufficient. Cleansing Departments employing horse-drawn transport are sometimes regarded as being obsolete in their methods, but this criticism not infrequently emanates from persons who do not fully understand the problems attached to refuse collection. The fact is, that refuse collection is not such a simple matter as it appears on the surface, and the mistake usually made by persons having no actual experience in cleansing work is to compare refuse collection with point to point haulage. It is impossible to make any fair comparison, however, as the collection of house refuse usually entails about 30 stops to the ton against one stop only in the case of ordinary haulage.

(b) *Electric Vehicles.*—Electric vehicles have proved themselves eminently suitable for refuse collection provided they are operated under suitable conditions, and as shown in the above table are fairly extensively employed in the larger towns. They are extremely reliable in performance, and the percentage of running efficiency obtained from the fleet of 86 vehicles employed by the Birmingham Salvage Department was 93 for the year ended 31st March, 1928. It may be stated that in calculating this figure time lost through all causes, including painting, repairs due to road accidents, etc., is taken into consideration. Other advantages claimed for the electric vehicle are as follows :—

(*a*) Maintenance costs are low.

(*b*) Does not require such a skilled driver as the petrol vehicle. (In the Birmingham Salvage Department every electric vehicle driver has been promoted from a dustman, after passing through a short course of instruction arranged by the Department.)

(*c*) Suitable for frequent stopping and starting.

(*d*) Starts easily under all conditions.

(*e*) Uses no energy when stationary.

(*f*) Its motive power can be obtained as a by-product from the burning of refuse.

(*g*) Amenable in the streets as it is practically noiseless in running and does not give off fumes from exhaust.

(c) *Petrol Vehicles.*—These vehicles have not found general favour in the larger towns for house refuse collection, although they are employed to an appreciable extent in towns having a population up to 100,000, and good results are claimed for them. The initial cost of small motor vehicles is comparatively low, and they possess the advantage of extreme flexibility. One of the main objections against petrol vehicles is that they are not so suitable for frequent stopping and starting as compared with other types of transport. It is an illegal practice to allow the engine of a petrol vehicle to remain running whilst the vehicle is unattended, so that in house refuse collection a considerable portion of the time of a petrol vehicle driver is necessarily taken up in constantly starting the engine.

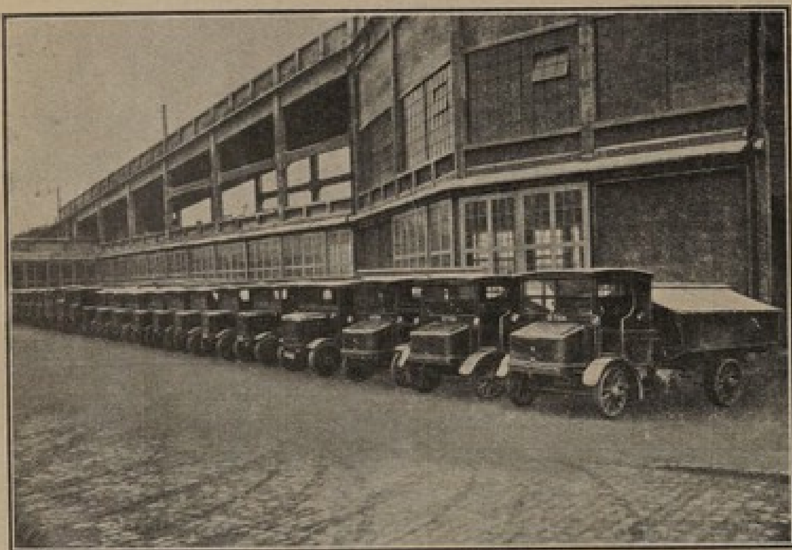


Fig 8.—Part of Electric Vehicle Fleet.

In several towns, petrol vehicles are utilised in connection with relay systems, which are designed to keep the loaders fully employed. Under this method, a vehicle and loading gang leave the depot for each collection area, and are followed by a second vehicle after sufficient time has elapsed for the first vehicle to be loaded. The empty vehicle is left for loading, while the loaded vehicle and driver proceed to the disposal point. After the load has been discharged, the vehicle is returned to be again loaded, and so on, throughout the day.

(d) *Petrol Traction* (*Container System*).—This system was introduced about five years ago and is designed to utilise horse and mechanical traction in their most advantageous spheres, on the principles that :—

(*a*) For slow house to house collection the horse is most suitable.

(*b*) For the rapid conveyance of the loaded containers to depot, mechanical transport is most efficient and economical.

Each petrol lorry serves three or four horse sections, and by means of inclined rails deposits an empty container (which has a very low loading line) in the street, and picks up a loaded container for haulage to the place of disposal. A horse is harnessed to the empty container left by the lorry and loading is then recommenced. After the loaded container taken to the disposal point has been emptied, it is hauled to the next horse section, where it is deposited, and the full container from that section is then picked up and taken away.

The fact that a number of large Corporations are at present employing the Container System proves that it possesses attractions, although it has certain disadvantages which may be briefly reviewed as follows :—

(*a*) In order to obtain the best results, it is necessary for horses to be stabled as near as possible to the collecting area, thus involving the use of several stables. This makes it difficult for the district inspector to keep in close touch with the various sections, and in the event of a workman failing to report for duty, or if a horse is unfit for work, considerable time may be lost before the district inspector is informed.

(*b*) It is advisable that workmen should not return to the stabling depot from the time they turn out in the morning until they arrive there at night for leaving work. This implies their staying away from their depots at dinner time and taking their meals as best they can.

(*c*) The gross weight of a loaded container may be over 4 tons, and the system is therefore unsuitable for hilly districts.

(*d*) The necessity for changing containers in the street renders the system unsuitable for congested areas such as main streets and narrow roads.

(*e*) The dislocation in case of breakdown of a motor lorry is considerable if a spare is not available, and unless several units are employed, the cost of keeping a spare for emergency use would be excessive.

In some districts, the container system is employed in conjunction with tractors. In this case, the containers are hauled behind the tractor instead of being carried on the chassis of the lorry.

(e) *Steam Wagons.*—These vehicles are not employed to any great extent in refuse collection, although they have found considerable favour for point-to-point haulage of heavy loads such as clinkers. Two 5-ton steam wagons were used by the Birmingham Salvage Department upon refuse collection for several weeks during the summer of 1926, when owing to the low calorific value of the refuse, due to the coal strike, difficulty was experienced at one depot of the Department in raising sufficient steam to enable electric vehicles to be properly charged. The experiment was not a success and it was deemed advisable to take other measures in order to surmount the difficulty, although it should be stated that the steam wagons were not designed for refuse collection, being normally employed upon clinker haulage.

2. Carrying Capacity of Vehicles.

Whatever form of transport is decided upon, it is usually good policy to provide vehicles of ample capacity and this particularly applies in districts where it is the practice for collection teams to remove a specified number of loads per day. In Birmingham, three loads per full working day are usually collected by each collection unit, and wherever 5-ton mechanical vehicles with a body capacity of from 11 to 13 cubic yards have been substituted for 2½-ton vehicles, with a collecting team of 4 men in each case, it has been the general experience that costs are reduced.

It is not suggested that the larger vehicles are necessarily completely filled on each occasion of returning to depot for unloading, but it has been found that during certain periods of the year, owing to the refuse being more bulky and the output greater, smaller vehicles are not infrequently filled when there is still time to spare for the collection of more refuse. Under such circumstances, a team of conscientious workers may endeavour to pack the refuse in the vehicle in order to provide further space for loading, but even if this is done, time and energy are expended which could be more profitably employed if a vehicle of greater capacity were provided. Further, where refuse is tightly packed in vehicles, time is wasted in unloading, as the refuse usually has to be partly pulled out before the load will leave the vehicle.

It appears to be the general experience throughout the country that the composition of house refuse is undergoing a considerable change, in that while there is a tendency towards a reduction in the weight collected, the reduced tonnage is not accompanied by a corresponding reduction in bulk. A few years ago the average weight of a cubic yard of house refuse was usually considered to be approximately 9 cwts., whereas at the present time, the average weight per cubic yard in many towns does not exceed 7 cwts. This increase in bulk and reduction in weight may be partially attributed to the following reasons :—

(*a*) The more general use of dustbins instead of fixed ashpits, resulting in refuse pending removal being kept in a drier condition.

(*b*) The increase in the use of gas and electric cookers and heaters in place of coal fires. The heavy cinder content of refuse is thereby reduced and the facilities provided by the open fire for burning light refuse such as waste paper, etc., are lessened.

With regard to (*b*) the following data are submitted showing the development in Birmingham in the use of gas and electrical heating and cooking appliances :—

Year.	Gas Fires.	Gas Cookers.	Electric Radiators.	Electric Cookers.
1914	19,000	116,300	945	11
1927	92,000	195,700	7,000	295

The increase in bulk in house refuse obviously calls for vehicles of larger cubic capacity, although the size of vehicles employed must be governed largely by local conditions, such as width of streets, etc., as the employment of large 5-ton vehicles, for example, would obviously prove uneconomical in districts where narrow back passages are available, giving access to the backs of houses, which could be negotiated by smaller vehicles. In such cases, refuse might have to be carried considerable distances if a large vehicle were employed, and this would result in waiting time being greatly increased.

The width of vehicles is limited to 7½ feet by law and the overall length should not exceed 20 feet.

An important consideration in the design of any refuse collection vehicle is the loading line, which should be kept as low as possible.

3. Cleanliness of Vehicles.

The cleanliness of refuse collection vehicles is a matter which frequently does not receive the consideration it deserves, and in many towns there appear to be no arrangements in operation for the systematic cleaning of vehicles. The composition of average present-day house refuse is not usually of such an offensive nature that collection vehicles should be permitted on the streets in a perpetually filthy condition, and a thorough weekly washing is normally sufficient to ensure vehicles being kept in a reasonably clean state.

After experimenting with several types of vehicle-washing apparatus, including overhead spray washers, the writer has found that a cyclone washing plant is the most suitable for refuse collection vehicles, for the reason that water can be applied either as a fine spray, or as a direct jet, up to a pressure of 300 lb., which ensures the rapid removal of caked mud, grease, etc., and the complete washing of a vehicle can be comfortably accomplished in 10 minutes.

A Vehicle Prize Scheme was introduced in the Birmingham Salvage Department about five years ago with a view to encourage drivers of mechanical vehicles to maintain their vehicles in a cleanly condition. The vehicles are subjected to a thorough examination at regular intervals, points being awarded for maintenance and cleanliness. Prizes varying in amounts from £6 to £1 10*s.* per vehicle are awarded annually to drivers obtaining the highest points, and it is considered that the money expended in connection with the scheme has been more than justified by the additional cleanliness of the vehicles. It may be mentioned that a number of the Department's vehicles always participate in the local annual vehicle parade of the Commercial Motor Users' Association, and without exception the vehicles entered have obtained awards. In the parade for the year 1926 a team of four vehicles belonging to the Department was successful in obtaining the premier award in competition with vehicles entered by many of the leading traders in the city.

4. Seasonal Variation in Output of Refuse.

The quantity of refuse produced daily in any area varies considerably during the course of the year, and a series of charts kept by the Birmingham Salvage Department over a number of years shows that the daily output at the heaviest period of the year is more than 60% greater by weight than during the lightest period of the year. The charts also show that the heaviest output occurs during the months of January or February and that the lightest output is during the months of July or August.

This variation is chiefly due to the difference in climatic conditions during the various periods of the year, resulting in a greater or lesser use of coal fires at the different seasons, and a consequent variation in the quantity of ashes which the Department is called upon to remove. Rainfall also has some effect upon the daily weight of refuse removed, and this particularly applies where dustbins are not in general use, as in such circumstances refuse becomes wet and heavy in rainy weather. Another cause affecting the output of refuse which may be mentioned is coal strikes, resulting in inferior fuel being used, which gives a larger ash residue, or if the dispute lasts sufficiently long, it may result in the refuse output being reduced below normal, as coal of even a low quality may become almost unobtainable. A temporary suspension of work due to a public holiday, a breakdown in transport or disposal arrangements are other factors affecting the daily quantity of refuse to be removed.

5. Necessity for Elastic Organisation.

It will be apparent from the remarks made in the preceding paragraph that if the work of collection is to be efficiently and economically performed, the organisation of the collection system must allow of full advantage being taken of the low output periods, and at the same time be sufficiently elastic to be capable of rapid expansion in order to deal with the output during the heavy period of the year.

6. "Continuous" System of Refuse Collection.

Until about eight years ago, the "block load" system of refuse collection was in operation in Birmingham, and under this method, blocks of premises were allocated to each load collected by every vehicle, the "blocks" allocated to each collection unit not necessarily being in the same area of the district. In view of the disjointed lay-out of the collection rounds, this method proved unsuitable, as during heavy output periods of the year it was difficult to prevent collection teams becoming in arrears with their work and full advantage could not be taken of low output seasons. A method known as the "continuous" system was therefore devised, the whole of the refuse collection work of the Department now having been reorganised on the latter system.

Under the "continuous" system, a self-contained area calculated to provide a week's work during the summer months of the year is allotted to each collecting team, who are provided with a working list showing the exact order in which each house or shop is to be visited. As far as possible, the route of the collecting vehicle is planned in an unbroken line from beginning to end of the round, and it is usually arranged that the commencement of the round lies at the farthest point from the disposal depot, so that the vehicle is gradually working towards "home." The vehicle commences work at the first house on the working list and proceeds from house to house and street to street in the order laid down in the working list until a full load is obtained or until it is time to return to the depot. The load is then taken to the disposal depot, and, after tipping, the vehicle proceeds to the next house on the working list and recommences loading. This process of loading continues until the round is cleared or if during the heavy output period of the year the team is unable entirely to clear the round in a week, the vehicle can, if it is thought desirable, be turned back to recommence work at the first house on the working list, assistance being given to clear that portion of the round not attended to by the regular vehicle. It will be seen that under the "continuous" system the refuse collectors can never plead in excuse of a small load that they had completed their load or day's work, or that it was too far to travel to the next job—a plea which was frequently put forward when the "block load" system was in operation.

At the end of the day's work, the driver in charge of the vehicle reports to the weigh clerk the last address attended to, and by means of a simple table with which each clerk is supplied, a quick calculation is made giving the number of premises attended to by the collecting vehicle during the day. The number of premises cleared is then recorded by the clerk in graph form on what is known as a progress chart.

A separate chart is kept in respect of each round, and in actual practice the day's work of each round is recorded daily on the progress charts by the depot clerk before he leaves at night. By means of these charts the Inspector in charge of the district is able to see at a glance before each day's work commences the progress made by each collection team during the previous day.

The main advantages claimed for the "continuous" system are :—

(a) Control is entirely in the hands of the management.

(*b*) Collection is carried out at a minimum of cost, as by reason of the elasticity of the method the collection staff can be rapidly expanded or reduced in accordance with the varying output of refuse.

(*c*) Complaints are practically eliminated.

7. Compilation.

A necessary preliminary before the "continuous" system can be installed is that a complete record has to be obtained of all premises in the area concerned, showing their situation, access, receptacle for refuse storage, etc. One man can record the necessary particulars of about 1000 houses per week.

8. Charts Kept Under "Continuous" System.

Reference has been made previously to progress charts which show the daily progress of each collecting team. The average weight of each load is also recorded weekly on these charts, so that a check is provided on both the number of premises attended to and also upon the weights collected.

Other weekly records kept which may be mentioned are :—

(a) *Arrears of Collection Chart* shows the number of loads the whole of the collection teams employed in the city are in arrears. For purposes of comparison, the details of arrears in respect of corresponding weeks of the two preceding years are also recorded.

(b) *Assistance for Arrears Chart* shows the number of loads assistance given to the regular collecting teams. Particulars of corresponding periods of the previous two years are also shown.

(c) *Complaints and Applications for Removal of Refuse Chart.*—Records the total applications received from all sources, the total being divided under the headings of "Justifiable" and "Unjustifiable" complaints.

Part III. Yield of Refuse.

1. Unit of Work.

Until a few years ago the tonnage of refuse collected was considered to be the best and perhaps the only reliable check obtainable upon work performed by refuse collectors, but it is now recognised by many officers that consideration of weight to the exclusion of every other factor may lead to wrong conclusions. A given weight of refuse may be collected from properties possessing common backyards, with the expenditure of perhaps half the time and energy required to collect the same weight of refuse from single house property where long "carries" are the rule. Further, where the gospel of weight is being always preached to collection employees, they are tempted to disobey their instructions by removing builders' rubbish and heavy trade refuse as an easy means of improving the average weight of their loads. The number of premises attended to is now, therefore, frequently regarded as providing a more reliable check upon work performed. This information is readily ascertainable where the "continuous" system is in force, thus providing a further argument in favour of the latter system, for unless the number of premises attended to by the individual collection units can be quickly calculated, practically the only check upon work performed is the record of weight collected.

The unit of count or number of premises attended to could not invariably be used with safety for the purpose of comparing one round with another, as any individual round may contain premises such as institutions, schools, etc., which each count as one premises only, whereas another round may consist entirely of ordinary dwelling-houses. A comparison on the basis of premises visited would be quite sound, however, in reviewing the work of any particular round with the results obtained from the same round in a corresponding period to that under review. It is, of course, an additional help if, when forming an opinion regarding the output of work performed by refuse collectors, the tonnage figure is also available, as in the case of rounds including institutions, etc., while the number of premises cleared may be low, the tonnage removed should be greater in comparison to rounds consisting of dwelling-houses only, thus justifying a low output figure based on premises visited.

2. Variation in Output of Refuse.

The annual yield of house refuse per thousand persons in eighteen large towns in England and Wales having a population of more than 200,000 for the year ended March 31st, 1928, varied from 373 tons to 190·4 tons, the average annual yield for the eighteen towns being 290·1 tons, or nearly 16 cwts. per thousand persons per day.

The average yield of house refuse may also vary within wide limits, in any one town, and the following table shows the average annual yield of dry refuse per premises in the nine collecting districts of Birmingham for the year ended 31st March, 1928 :—

District.	Average Annual Yield per Premises. Cwts.
Holliday Street	31·93
Shadwell Street	30·97
Montague Street	29·32
Rotton Park Street	22·53
Nechells	19·59
Brookvale Road	18·47
Handsworth	18·36
Lifford	15·66
Tyseley	14·61
Average for city	20·59

The fact that average yield figures, both in respect of separate towns and also in separate districts of one city, show such great variation, provides conclusive proof that the yield of house refuse throughout the country is capable of considerable reduction if only the co-operation of the public could be obtained, and it is perhaps unnecessary to add that, if the yield of refuse was considerably reduced, the cost of cleansing work could be materially lessened.

To what extent the yield of refuse could be reduced if Corporations possessed the assistance of a public sympathetic to their aims in connection with reduction of output of refuse is a matter upon which opinion may vary, and in a paper entitled " Suggestions for the Reduction of House Refuse at its Source," which was read by the General Manager of the Birmingham Salvage Department at the annual conference of The Institute of Cleansing Superintendents, held at Swansea in June 1925, it was stated that with the necessary care on the part of the housewife, an average reduction of 40% by weight throughout the country is a modest estimate of what could be achieved.

A first consideration of this estimate may lead to doubt as to whether this figure is not somewhat over-estimated, but when it is appreciated that half-burnt coal alone, in the form of cinders, accounts for 30% to 35% of house refuse, the estimate of an average reduction of 40% must be regarded as reasonable. In passing, it may be mentioned that cinders contained in house refuse possess a calorific value of about 7000 B.Th.U. per pound against approximately 14,000 B.Th.U. obtained from coal, so that it will be conceded that such valuable fuel should never be consigned to the dustbin.

Whatever reduction in yield is considered reasonable of achievement, however, it must not be assumed that working expenses will necessarily show a corresponding decrease.

3. Collection.

A reduction in the average yield per house would increase the number of calls per ton, so that the collection cost per ton would increase, but if the refuse reduction were appreciable, the collecting vehicle should visit more houses per load, and this would result in a reduction in the collection cost per house and per 1000 population. Further, in the case of premises where the output is exceptionally excessive, a reduction in yield would probably result in the refuse collectors being required to make one journey only between the premises and the collection vehicle, whereas two or more journeys may be necessary under existing circumstances, particularly during the " heavy " output periods of the year. Providing the collection system is capable of adjustment in order to take advantage of any yield reductions achieved, the total collection cost should, therefore, be decreased, and if the total cost is reduced, the fact that an increase is shown on a unit cost such as cost per ton can be disregarded.

4. Disposal.

When the disposal of refuse is considered, the effects of a reduced yield may be even more pronounced, according to the method of disposal in force. Where refuse is disposed of by barging to sea, or pulverisation, the reduction in cost should diminish almost proportionately with the yield. Where disposal is by incineration, the change in the constitution of the refuse which would accompany a large reduction in yield, *i.e.*, the elimination of the majority of cinders, waste paper and organic waste, might result in existing disposal depots and salvage plants becoming to some extent unsuitable for the changed conditions. Refuse disposal and salvage plants have been designed to meet existing circumstances, however, and if the need arises, cleansing officials will be undoubtedly sufficiently ingenious to adjust their methods to meet the different conditions.

5. Estimated Saving.

In the paper already referred to it was estimated that a yield reduction amounting to 40% should make possible a saving of 20% in working expenses. The removal and disposal of house refuse costs the country approximately £7,500,000 per annum, so that a 20% saving in working expenses would amount to no less a sum than £1,500,000 per annum, which is equal to about £40 per 1000 persons per annum.

Sufficient has been said to show the desirability of yield reduction, and it now remains to be considered as to how best it can be brought about. The following remarks are intended to describe methods and practices which are calculated to assist in promoting yield reduction.

6. Adoption of Standard Dustbins.

The advantages attached to the use of standard dustbins have already been referred to. There is no necessity to discuss this matter further except to say that the absence of covered receptacles results in the removal of tons of moisture.

7. Cinder Sifters.

Mention has been made of the fact that household refuse contains a very large proportion of good fuel in the form of partly burned coal, so that if Local Authorities could induce the general public to recover this useful fuel by the use of cinder sifters, considerable progress would be made towards the end in view. A number of Local Authorities have had a cinder sifter designed for use with the standard dustbin adopted.

8. Demand for Payment for Removal of all Refuse other than House Refuse.

Few methods are likely to be more effective in reducing yield than the imposition of a charge for the removal of trade refuse and garden refuse. In this connection it may be mentioned that where a bonus scheme based upon the number of premises visited is in operation, refuse collectors may be generally relied upon not to surreptitiously remove trade, garden or builders' refuse, as besides risking punishment for disobeying instructions, they are quick to realise that they are performing work for which they receive no credit.

9. Bye-Laws.

The adoption of bye-laws making it an offence to deposit liquid or fæcal matter in dustbins is another aid which should assist in reducing the weight of refuse to be removed.

10. Publicity.

Whatever action a Local Authority takes in endeavouring to obtain a reduction in yield of refuse, good results are not possible unless the interest of householders is awakened to the benefits which lie in their power to confer, both upon themselves and the community at large, in reducing their output of house refuse to a minimum by burning all combustible refuse on the house fires. In order to obtain the necessary co-operation between the householder and Local Authorities, a number of salvage and cleansing departments now undertake publicity work as a part of their regular activities, with a view to encourage the public to reduce the yield of house refuse, and also to give guidance as to how yield reduction can be best accomplished. The methods which have usually been employed in the past are as follows :—

(*a*) Lectures (sometimes illustrated by lantern slides) to school children, educational institutions, clubs and the general public, usually followed by visits of inspection to salvage and disposal works.

A fascinating story can be woven round the operations and aims of a modern salvage or cleansing department, and if lectures are skilfully delivered, they invariably hold the interest of audiences. Apart from the value of lectures and visits of inspection in regard to the promotion of yield reduction, they also materially assist in educating citizens to regard the work of public cleansing with the consideration it deserves.

(*b*) Prizes for best essays written by school children, after lectures or visits to works. The child of to-day will be the citizen of to-morrow, and no field is likely to prove more fruitful if it could be assiduously cultivated. In the case of a large town, however, it is almost impossible for the ordinary staff of a Cleansing Department to devote the time necessary to this branch of publicity work. If success is to be achieved, it is essential that the effort shall be sustained, and this applies perhaps even more particularly in the case of lectures to school children than to any other sphere of propaganda work.

(*c*) The exhibition of slogans such as " Burn your Refuse—Reduce your Rates " on refuse collection vehicles. Some time ago, a lady resident of Birmingham interpreted this slogan, which is exhibited on all mechanical vehicles employed by the Salvage Department, too literally. This good lady forwarded a communication to the local Rates Department, stating that she had observed this notice on the vehicles, and as she made a practice of disposing of her own refuse, she would be glad to hear what allowance off her rates she was entitled to receive !

(*d*) Daylight signs with the wording " Save your Cinders " are now fitted to many refuse collection vehicles employed in Birmingham.

(*e*) Window displays and exhibits at industrial exhibitions, etc.

(*f*) Distribution of " Don'ts " cards, leaflets and pamphlets.

(*g*) Insertion of matter in Municipal calendars. The Birmingham Estates Department issue to tenants of all Municipal houses a calendar giving gardening information and hints upon the proper care of houses, drains, fittings, etc. During the past three years the Birmingham Salvage Department has joined the Estates Department in the production of this calendar, and the monthly notes contain helpful information upon the subject of house refuse, and especially upon the reduction of yield of refuse. The calendar is used also for the purpose of advertising by-products of the Salvage Department, such as manures, clinker, paving slabs, etc.

11. Results Obtained from Publicity.

The results obtained in those towns where a real effort has been made to induce reduction in yield are distinctly promising, but the time has probably arrived when something beyond local efforts should be attempted, and for a National Campaign to be inaugurated.

The question of obtaining the necessary funds for conducting such a movement appears to be the chief difficulty, and at the annual conference of The Institute of Cleansing Superintendents, held in 1926, Mr. Jas. Jackson, O.B.E., who was then President of the Institute, announced that the Birmingham Salvage Department would be willing to provide the sum of £100 towards the cost of a National Publicity Campaign if a satisfactory number of other Local Authorities would agree to donate a sum in the same ratio, based on population, but although a number of Corporations agreed to subscribe to the movement, sufficient support was not forthcoming to ensure its success.

12. Newspaper Advertising.

The extent of a publicity campaign obviously must depend largely upon the funds available, and newspaper advertising, which is too costly for a single Local Authority to undertake to any extent, is one avenue of publicity which has not yet been explored. It is now recognised by most big advertisers that newspaper advertising, providing it is well done, is productive of excellent results, and if at any future date it is decided to embark upon a National Campaign for the reduction of yield in house refuse, this method of advertising will doubtless receive careful consideration by the persons responsible for the methods to be adopted.

13. Broadcasting by Wireless.

Wireless lectures upon certain phases of cleansing work have been broadcast in the past, but this is another method which could probably be more efficiently exploited through a national rather than a local movement.

14. Cesspools.

The cleansing of cesspools is a duty delegated by the City Council to the Birmingham Salvage Department, although in other towns this work does not generally appear to be carried out by the department responsible for the removal and disposal of house refuse.

Fig. 9.—Fleet of "Halley" Cesspool Emptiers.

Cesspools are usually attached to houses situated on the outskirts of a city where no sewer is available. They are underground chambers and generally sewage, in addition to waste sink and bath water, are drained to them.

Cesspools are recognised as very insanitary arrangements and almost invariably give rise to complaints, whether emptied frequently or otherwise. The occupants of premises possessing cesspools usually insist upon frequent emptying, and notwithstanding that the most efficient plant obtainable may be employed on the work, cesspools are productive of frequent complaints regarding nuisance from offensive smells created during the process of emptying and discharging.

Quite apart from the hygienic aspect, the work of emptying cesspools is an extremely expensive operation, and in Birmingham it is a not infrequent circumstance that the expenditure incurred in the cleansing of a cesspool exceeds the total sum paid in rates in respect of the premises concerned. The average cost of emptying cesspools in Birmingham during the year ended 31st March, 1928, was £14 6*s*. 7*d*. per cesspool, the cost per house served being £8 12*s*. 7*d*.

In Birmingham there are 558 cesspools serving 709 premises on the records of the Salvage Department, no fewer than 348 of these cesspools being located in one small unsewered district which was annexed to the City in April 1928.

The Department possesses five 35 h.p. "Halley" vehicles for cesspool emptying, each being fitted with an 800-gallon cylindrical tank body, this type of vehicle being adopted as standard after experimenting with several other makes of vehicle. The tank is exhausted of air by a rotary air pump, which also, by the operation of a single lever, applies internal pressure for quick discharge. Each vehicle carries 100 yards of 4-inch armoured suction hose in 12 feet lengths, and the same hose is used for suction and discharge.

General.

The writer has frequently referred in this chapter to methods in operation in Birmingham, but he is anxious that the impression shall not be created that such remarks have been made for the purpose of unduly stressing the activities of the Birmingham Salvage Department.

Birmingham, like every other Authority, has its own local conditions and problems, and the organisation of the Birmingham Salvage Department has been devised solely to meet the local conditions.

The writer, being in the service of the Birmingham Corporation Salvage Department, is obviously more familiar with Birmingham methods than those employed by other Authorities, and having access to all data and information compiled in the Department, considers that his conclusions being formed from actual data and personal experience are more reliable than if he were to attempt to treat the subject from a wider angle.

CHAPTER VI

ORGANISATION OF REFUSE COLLECTION

1. Introduction.

Reference has been made in the preceding chapter to the great variation which takes place in the output of refuse at different seasons of the year and the consequent need for a flexible system of refuse collection was stressed.

The " block load " system, by which the work of each collecting vehicle is arranged so that a definite block of premises is allocated to each load, does not possess that elasticity which is so essential for rapid expansion and contraction to meet varying conditions.

The " continuous " system of refuse collection, which has also been described in the preceding chapter, possesses the advantage of extreme flexibility and was devised mainly with the view to full advantage being taken of low refuse output periods of the year. This chapter is intended therefore to describe the organisation of refuse collection upon the " continuous " system.

2. Compilation of Area to be Organised.

Before organisation can be satisfactorily commenced, it is essential for a complete compilation or census of the whole area to be made, the following particulars being recorded in respect of each separate premises :—

(a) Name of road and name or number of premises.
(b) Access for purposes of removal of refuse.
(c) Storage accommodation.
(d) Class of premises (stating whether private dwelling-house or business premises).

One man can record approximately 1000 premises per week, and the initial cost of obtaining the necessary particulars will be amply repaid. The information obtained will prove invaluable, and will provide the foundation on which an efficient system of refuse collection can be established.

3. District Boundaries.

After the compilation of the area has been completed, the whole area proposed to be organised must be divided into collection districts, definite boundaries being laid down. The term " district " is used as meaning a defined area from which refuse is collected and taken to one disposal centre.

In deciding the position of the district boundaries, the main governing factors are :—

(a) The position of the disposal centre.
(b) The capacity of the disposal centre.

In passing, it should be stated that, subject to (a) and (b), it will be usually found that up to reasonable limits one large collection district is preferable to two small separate areas, as the work of supervising the collection employees is simplified. Fewer supervisory officials are required and it becomes economically practicable to employ district refuse collection inspectors of a better type.

4. Position of Disposal Centres.

Assuming that a district is reasonably developed over its entire area, the ideal position for the refuse disposal centre would be as near the centre of the district as possible, in order to avoid the necessity of collection vehicles having to make long journeys to and from their rounds. The gradients to the disposal depot should be easy, and an alternative method of transport such as a railway-siding or canal should be available. It has to be admitted, however, that in spite of the fact that modern salvage and refuse disposal plants can be operated entirely without nuisance, there still exists a strong prejudice in the minds of the public against such works being erected in congested areas.

For this reason it may not be practicable to obtain a site located in the centre of the collection district which possesses all the above-mentioned features, and a site not centrally situated may have to be decided upon. In these days of mechanical traction, the disadvantages attached to long hauls are not nearly so important as was the case when horse-drawn vehicles were practically solely employed upon the work of house-refuse collection, and the disadvantage of longer hauls for a section of the collection fleet may be therefore more than compensated by the selection of a site not centrally situated, but possessing other advantages.

5. Capacity of Disposal Centre.

This is the most important factor governing the size of the district and position of the boundaries.

The weekly tonnage capacity of the disposal centre must be ascertained, and possessing this information, the estimated number of houses required to give this tonnage is easily obtained. The most reliable method of ascertaining the number of houses estimated to produce the tonnage required is, of course, to base the calculations on the output per premises during the heavy period of the year in the particular district concerned, but if this information is not available, a ready means of estimating the number of premises required to produce a given tonnage is to allow 0·5 cwt. of refuse per week to each premises. This figure is probably on the high side (Birmingham's average figure being 0·398 cwt. per premises per week), but allows a margin for heavy output periods. The boundaries of the collection district can then be decided, in order to give the number of houses estimated to produce the tonnage capacity of the disposal depot at the heaviest output period of the year.

6. "Continuous" System of Refuse Collection.

When the "continuous" system of refuse collection was commenced in Birmingham, each round was set out independently of any other round, but all rounds are now set out on the "Continuous Circle" system. In the latter method, each round to be organised is commenced at the finishing point of the previous round, and the entire area of one district is thus organised in one or more large circles, each circle being composed of a number of rounds. This allows of much easier adjustment which may become necessary, for reasons such as the addition of a large number of new houses, or re-arrangement consequent upon alteration to the type of collecting vehicle employed. All that is necessary in such cases is to add the unattached premises to the appropriate round or rounds, which will, in the case of a round already constituting a full week's work, result in a portion of the original round being unattached. This unattached work is transferred to the adjoining round, and so on until the end of the circle is reached. Instead of a portion of several rounds requiring revision, the whole of the premises left unattached to specific rounds are therefore brought together at the end of the circle. The collection of refuse from these premises can be then organised as a part or whole of an additional round, as necessary.

7. Mapping Out of Rounds.

The importance of rounds being carefully mapped out cannot be over-emphasised, as time wasted owing to waste runs, or badly set-out routes, will occur on each occasion refuse is removed subsequent to organisation. If by carefully setting out the route of a round a saving of one hour's loading time per week, only, can be effected, the extra loading time thus obtained represents, during one year, the equivalent of a week's work for the entire team, in the case of a weekly collection.

The commencing point of the first round is most important and care must be taken in its selection. Local conditions are the deciding factors in fixing this point, and as an example, if there is a main road running through the district, a good starting place would be the point where the boundary of the area meets the main road. This would allow of the collection vehicle working up the main road on the left-hand side, taking all side roads as they are reached, until arriving at the boundary at the other side of the district and then turning back to work similarly along the other side of the main road.

The direction of travel as a general rule will be along the left-hand side of the road. There are times, however, when this rule can be altered with advantage so as to avoid a waste run, or in order to decrease the mileage of the vehicle.

There may be certain roads in the district with houses on one side only, and by working along the wrong side of the road (that is, against the traffic) a waste run may be avoided. This practice should not be followed more than is necessary, and certainly not on main roads.

Again, there are occasions when it is advantageous to collect from both sides of a road at the same time. In many of the new Corporation estates, some of the side roads are very suitable for collecting refuse in this way. Generally speaking, however, the only instances where this practice can be worked with advantage are in narrow side roads, in thinly-populated areas, which are little used by traffic, and also on steep hills. More will be said later regarding the latter point.

The advantages gained from collecting simultaneously from both sides of a road are that mileage and the number of stops and starts of the collecting vehicle are greatly reduced. Unless roads are narrow and little used by other traffic, however, the time lost due mainly to the extra distance refuse has to be carried (as the vehicle must stand on the left-hand side of the road) more than outweighs any gain. There is also the possibility of refuse collectors being involved in accidents with passing traffic.

In the case of a collection team consisting of an uneven number of men, *i.e.*, 3 or 5, the method is unsuitable, as obviously more men would be working one side of the road than the other, probably resulting in the men employed on one side of the road wasting time, while those clearing the opposite side caught up.

If horse vehicles are employed, it is necessary to work out the route of collection so that all gradients too steep for horses are worked downhill as loading proceeds. This usually entails one side of the road being cleared on the wrong side, although if the road is suitable, it will be more advantageous to clear both sides at once. In the case of mechanical vehicles, hills are of considerably less importance, but if a hill is very steep, it is advisable, if convenient, to organise the work so that the vehicle does not have to work up the hill, as continual stopping and starting are a strain on the mechanism.

When the collection vehicle enters a road, the whole road should be cleared, that is, the vehicle should work straight up the left-hand side as far as possible, turn round, and return straight down the other side. Only such side roads which have no other entrance should be turned into. By this means, time wasted by turning the vehicle in the road is reduced to a minimum.

If possible, the work should never be set out so that the collecting vehicle has to be turned on a main or busy thoroughfare to work in the opposite direction, as in turning, there is a possibility of accidents and time may be lost in waiting for a break in the traffic to allow of the vehicle being turned.

8. Setting Out of Rounds.

A rough working list of the area to be cleared should be written up in accordance with the foregoing methods. This list must contain every house to be visited in its correct sequence, and must show the exact route to be followed.

In drawing up the list, care must be taken that only houses with access in the road in which the vehicle will work are included, as although the fronts of certain houses may be located in one road, access for refuse removal may be in another road. In such cases, houses should be included in the working list embracing the road in which access is situated.

9. Competent Foremen to Set Out Round.

The rough working list having been prepared and the vehicle and team decided upon, an experienced foreman should be detailed to accompany the team. The duties of this foreman are as follows :—

(*a*) To see that the round is worked strictly in accordance with the working list.

(*b*) To check particulars of the premises visited, and to verify all details of the list with the conditions he finds.

(*c*) In towns where charges are levied for the removal of trade refuse, to note all such refuse removed and to inform the District Inspector of his observations, in order that the latter may verify that an arrangement is in force for the removal of such refuse.

(*d*) To make suggestions for any improvement in the way in which the working list is set out.

(*e*) To report to the District Inspector any dustbins or other storage receptacles which are worn out or require attention.

(*f*) To see that the refuse collectors give a fair day's work.

The premises on the working list being visited in a different sequence from that previously in operation, it follows that if a weekly collection is usually given, a portion of the work will be overtime, while other premises will be reached before a full week has elapsed since the last collection. In order to ensure that the round is set out fairly and that the work is a week old only, it is necessary for the foreman to accompany the team for a second week. At the end of the first week, the collection should therefore be recommenced at the beginning of the list, a separate vehicle being sent to attend to any premises included on the working list and not cleared during the first week. The house on the list at which the collection team finishes after the second week's work will be the recognised end of the round.

It is not suggested that the team should never complete the round as set out in less than a full week's work, as it is a frequent experience in Birmingham that a team of keen workers who are anxious to earn bonus will complete their list in less than a week. In such cases, teams are diverted to other work, such as to assist other teams which may be unavoidably in arrears with their work. The number of premises cleared at the end of the second week that the team is accompanied by the foreman should be regarded, however, as a definite minimum output required from the team at the period of the year in which the round is set out, and any falling off from this standard must be quickly inquired into. As explained in the description of the "continuous" system included in the preceding chapter, the number of premises cleared by each collection unit is charted daily, so that where this system is in operation any reduction in output is readily discernible.

10. Working Lists.

During the second week of the round being set out, at least three copies of the rough working list (which will by then have received any necessary corrections) should be typed, *i.e.*, one copy for Head Office, one copy for the Depot Office, and one copy to be carried by the refuse collectors.

On the depot copy of the working list, each page is totalled separately, a progressive total being also made showing the total number of premises included on the working list.

Record of Work Performed by Refuse Collectors.

A point of paramount importance is that any deviation in the collection of refuse from the order laid down in the working list immediately disorganises the system, and refuse collectors must therefore be warned that disciplinary action will be taken if they are found departing from the sequence of their list.

It is absolutely essential that working lists be kept strictly up to date. All new houses reported by refuse collectors as being occupied subsequent to organisation should, after verification by the District Inspector, be entered immediately on each copy of the working list concerned, in their correct position, and the totals adjusted.

If a charge is made for the removal of trade refuse, particulars of the quantity of such refuse to be removed should be indicated on the working lists against the premises concerned.

CHAPTER VII

REFUSE DISPOSAL

Part I. Barging : Pulverisation.

Preamble.

The earliest record of refuse disposal appears to be a reference to the burning of the refuse outside Jerusalem at a site known as Gehenna, previously the scene of Molochian sacrifices. Subsequently, Gehenna allegorically represented the ancient Jewish corruption of "Hell" (a fact which appears to have escaped the attention of not a few of our Borough Engineers and Directors of Cleansing). The Romans and Greeks, according to ancient history, are also credited with the disposal of refuse by burning, and it is stated that the Turkish baths of Cairo have been heated for many centuries by the heat generated from the refuse of the city.

Charles Dickens, in his "American Notes" refers to the hog's part in refuse disposal in Broadway, New York. For instance, "Take care of the pigs" . . . "Two portly sows are trotting behind this carriage, and a select party of half-a-dozen gentlemen hogs have just turned round the corner," . . . "here a solitary swine. He leaves his lodgings every morning at a certain hour, throws himself upon the town and regularly appears at the door of his own house again at night, grunting down to the kennel, turning up the news and small talk of the city in the shape of cabbage stalks and offal"—this gentleman swine must have known something about the "Continuous" system of refuse collection. "Just as evening is closing in, you will see the hogs roaming towards bed by scores, eating their way to the last." . . . "They are the city scavengers."

Again, take the pariah-dogs of Constantinople and other Eastern cities. These also act as scavengers. In fact, the animal world appears to have been largely interested in the subject matter. Even at this day valuable food for pigs is derived from the proper treatment of certain constituents of our refuse, and we find the animal as a public utility agent still not quite distinct from our present-day mechanical practice.

It is not my intention, however, to labour the animal's part in refuse disposal, but to confine my remarks to those of Barging to Sea, Pulverisation, Incineration and Salvage Utilisation.

Barging to Sea.

Many river-side towns and also towns on the seaboard resort to this means of disposal, which compares very favourably from a cost point of view with any other method and is to a certain extent effective, excluding the danger of floating residue being returned to the shore. Moderately large dumping barges are employed in the service, which are towed to sea and there discharged, and assuming a suitable position be selected, the danger referred to is not likely seriously to affect the Authority responsible in most cases for the accumulation.

The nuisance of the lighter refuse being washed up on the beaches is always prevalent. Take the river Tyne, for instance—Gateshead barge approximately 40,000 tons per annum, other neighbouring boroughs more or less likewise, it needs little imagination to visualise the state of affairs should any of this débris be washed ashore. It therefore follows that if dumping were carried out indiscriminately a good deal of nuisance would be caused, but to minimise this trouble the River Commissioners require that refuse barges shall not tip in less than 20 fathoms of water.

It will be appreciated that the conditions of towns using this method vary considerably, *e.g.*, the barges working from Gateshead have to travel a distance of 9 miles to the mouth of the river and a further 3 miles out to sea before discharging, whereas from Middlesbrough a distance of 14 miles from berth is necessary before the required depth is reached. From other towns on the seaboard, a journey of from 2 to 5 miles is sometimes necessary before reaching a permissible dumping area.

Another point which must be observed is that no tipping is allowed near to the fairways approaching rivers or ports on the seaboard. Barges or hoppers used in this service differ in size and construction, but, generally speaking, a barge having a carrying capacity of 300 tons of refuse is mostly favoured.

One of the latest barges constructed for the Middlesbrough Corporation has a gross tonnage of 300 tons, an overall length of 120 feet, and a 27 feet 6-inch beam; the holding capacity of the wells is approximately 300 tons of household refuse calculated at 8 cwts. per cubic yard. The barge is made up of four separate wells, each well containing four drop doors with only sufficient bulkhead between wells for safety's sake. The vessel is kept afloat by means of air-tight compartments. The barges in use at Gateshead are also built on similar lines.

Owing to the nature of the material for disposal it is essential that the sides of the hopper wells are perpendicular to obviate any choking when dumping; it has also been found from experience that the section of the keel should be minimised as much as possible, as this also has a tendency to cause choking. To release the refuse from the hoppers, the doors, which are hinged from the centre, are lowered by chains attached to hand cranes fixed on deck.

The doors of the hopper are not water-tight, and when the refuse is dumped the hopper returns to the loading berth with approximately 4 feet of water in the wells. This water is not pumped out, but the refuse is just tipped into it, and as the doors, as stated, are not water-tight, the water is displaced by the refuse which is tipped in. It is of interest to note that until there is a big sea of approximately 7 feet running, that is, the waves are at least 7 feet high, the hopper does not get rid of such floating matter as tins, bottles, etc. All this sort of light floating material is brought back again for a further trip and is only got rid of when tipping commences again, thereby sinking the same to the bottom of the wells.

It will be seen from the above information that the doors, hinges and part of the chains are always below water and therefore out of sight, and before any repairs can be carried out the hopper has to be berthed on the slipway, or the services of a diver have to be obtained.

The main disadvantage of barging refuse to sea is the long delays that sometimes occur in carrying out this work, as it will readily be understood the barges cannot travel out to sea in very rough weather; this means storing the refuse until the weather conditions improve, and in consequence a second handling is necessary unless sufficient barges are available. On the contrary, should the sea be very smooth then there is not sufficient swell or motion to allow the refuse to drop from the bottom of the barges and very considerable delays take place; in fact, on some occasions it has taken 23 hours to discharge one of these barges; a work which under normal conditions would be completed in 1 hour. The best condition for carrying out this work quickly is when there is a good swell on the water.

As regards cost, hoppers can be hired at Gateshead to carry out this work at a charge of £16 10*s*. per trip and carrying approximately 300 tons of refuse per journey: to this, of course, must be added wages of the loaders, and this, taking a fair average, will give a cost of about 1*s*. 9*d*. per ton, not including capital expenditure. Middlesbrough disposes of approximately 20,000 tons of refuse per annum by barging to sea and their cost is something in the region of 2*s*. 8*d*. per ton.

It will be seen that the greatest argument in favour of refuse disposal by barging to sea is the low cost per ton.

Pulverisation.

The pulverisation of house refuse is a mechanical method of disposal which has been adopted by a number of towns with varying degrees of success. The object of this method is to reduce the heterogeneous mass constituting refuse, to a finely-divided material of uniform texture which in this state possesses certain valuable properties as a fertiliser, the principal constituents being nitrogen, phosphates and potash.

Some difficulty was experienced in convincing agriculturists of the manurial value of pulverised refuse, but time and experience have evidently overcome this prejudice, and the value, more especially for dressing heavy soils and growing root crops, is now more or less generally acknowledged.

The cost of this method is claimed to be lower than most disposal methods, but, as in other cleansing problems, each town has its own particular local conditions to contend with and the success or failure of pulverisation in any town is very largely dependent on those conditions. Hence it is impossible to dogmatise as to the success of this method in general.

Action of the Pulveriser.—The machine for disintegrating the refuse is known as a pulveriser and, briefly, a pulverising machine consists of an outer steel casing and cast iron side plates through which passes a driven central shaft; to the latter are attached loose beater arms (or hammers) which are caused to rotate rapidly. As the rough matter is introduced to the machine it is struck by the hammers whilst in suspension and sharply beaten forward against the inner corrugated lining and grids (as they are called) attached to the steel case of the machine. This causes some disintegration of the larger particles, which rebound and are again struck successive blows by the hammers carrying it round in the machine, and gradually breaking the particles down. Those sufficiently fine now pass through the grids in the bottom of the machine, the rest continuing under the action of the swinging hammers until sufficiently reduced. The degree of fineness of the material can be regulated by varying the grids to suit any particular requirement. Owing to the

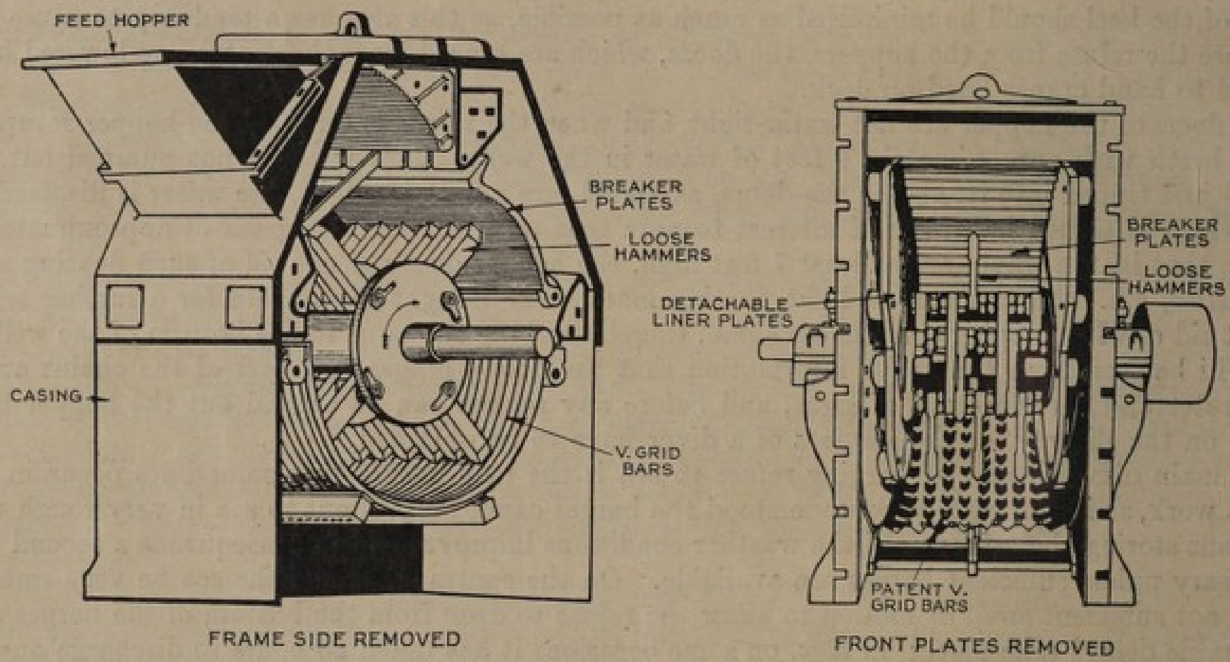


Fig. 10.—A Gannow Pulveriser.

hammers being loosely attached to the shaft from which they are suspended, hard material, such as pieces of steel, cause no damage to the machine, the mass of steel simply forcing back successive rows of hammers and causing sufficient noise to indicate its presence; the machine can then be stopped and the foreign matter removed.

Owing to the rapid revolution of the hammers, a strong current of air is constantly passing through the machine; this comes in contact with the finely-divided matter inside the machine, thoroughly permeating its substance and by its oxidising action largely removing the smells usually associated with refuse.

It is interesting to see the pulveriser at work and to note how large quantities of refuse can be fed into the machine and emerge almost instantaneously in the form of a uniform brown mould practically free from unpleasantness and ready for use as a fertiliser.

A Gannow Pulveriser is shown (Fig. 10) and the power required to drive such a machine varies from 30 to 35 B.H.P.

A typical lay-out of a plant dealing with the pulverisation of house refuse is shown (Fig. 11). It will be noted that the refuse is fed on to a picking belt from which any article desired to be salvaged can be picked out as the pulveriser is being fed. The refuse after being disintegrated falls into the jubilee wagon and is transported to the desired position.

The working of the plant is quite simple, and with the exception of minor adjustments very little mechanical attention is necessary. It should be mentioned that the chief renewals in connection with the pulveriser are the beaters.

Pulverisation of Dry Refuse for Tipping.—In many towns a plant is installed for the pulverisation of dry ashbin refuse for tipping. By this means the refuse is very much reduced in bulk (losing about one-third of its volume in the process). It is also practically odourless after treatment, will not harbour flies and vermin and when tipped does not become unsightly, nor is it liable to fire.

One of the products (frequently nearly one-half of the contents of dry or ashbin refuse) consists of fine ash. This, if utilised as a base for mixing with offal, garbage, etc., makes a good fertiliser for lightening heavy soils. Cinders, paper, rags, tins, etc., may be salvaged and are marketable, thus helping to reduce the costs of disposal.

Many towns adopt this method of disposal.

Pulverisation of Wet Refuse.—This method is in use for the treatment of the refuse from privy middens and pail closets.

In the former case the refuse consists of excreta and ashes, in the latter it consists of excreta only. When mixed with ashes the refuse after pulverisation makes a fairly good fertiliser especially suitable for heavy soils. The addition of fish offal, abattoir offal, street sweepings and vegetable waste also assists further to enrich the manure.

This method is in operation at Bury, where several thousand tons of manure are sold annually (Bury Corporation estimate their total all-in costs of refuse pulverisation at 2*s*. 4*d*. to 2*s*. 10*d*. per ton). These figures show a great saving when compared with the cost of refuse disposal by burning.

Pulverisation of Refuse to an Even Grade for Burning.—This is another method, which is in operation at Glasgow. The Corporation have recently installed a plant in which by means of screening and pulverisation before disposal a constant even feed to the disposal plant is assured and it is hoped by means of such plant an even pressure of steam will be maintained.

It can be easily understood that a refuse disposal plant, one of whose principal objects is the raising of steam, needs constant watching and stoking when fed with refuse, the mass of which is a heterogeneous collection of almost every conceivable nature. If, however, the refuse is pulverised to an even grade before it is fed into the furnaces the above difficulties should be lessened. This scheme is entirely new and the Authority hope that by its successful operation great possibilities may be opened whereby pulverisation and incineration may be combined, with valuable results. Reports from Glasgow on this method should be very interesting when available.

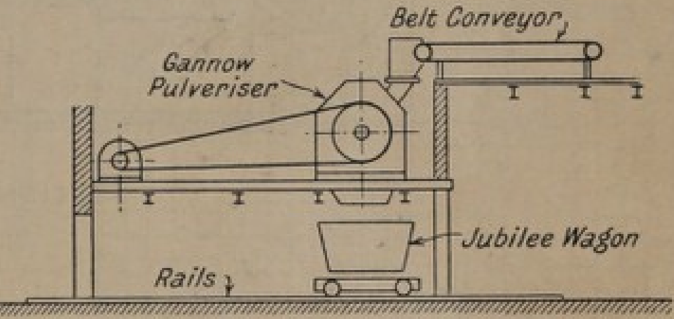


Fig. 11.—Lay-out of pulverisation plant.

Part II. Incineration and Salvage Utilisation.

The true function of a refuse furnace is to render innocuous house, trade and other refuse, and if in the process of incineration, after salvable articles have been withdrawn, the available heat can be utilised, a source of revenue is created to offset to a certain degree the cost of transforming the refuse to the resulting residue. The residue, a vitreous mass of clinker, is innocuous, germ-free and, what is also of importance, valuable, so that its accumulation at the disposal point rarely presents serious difficulty. Other material, such as paper, rags, glass, bottles, metal, rubber, etc., can also be salvaged to form a lucrative part in the disposal of refuse.

The refuse having a fuel value is also of great importance and much useful power can be developed, but the primary object of disposing of the refuse in a sanitary and efficient manner should be the first consideration.

It is, therefore, not surprising that this method is now very largely adopted and is perhaps the most hygienic system of refuse disposal.

Disposal Plant.—The modern refuse disposal plant consists of a rectangular furnace with simple arched roof, fitted with a single grate—in trade nomenclature a continuous grate—divided beneath by a series of

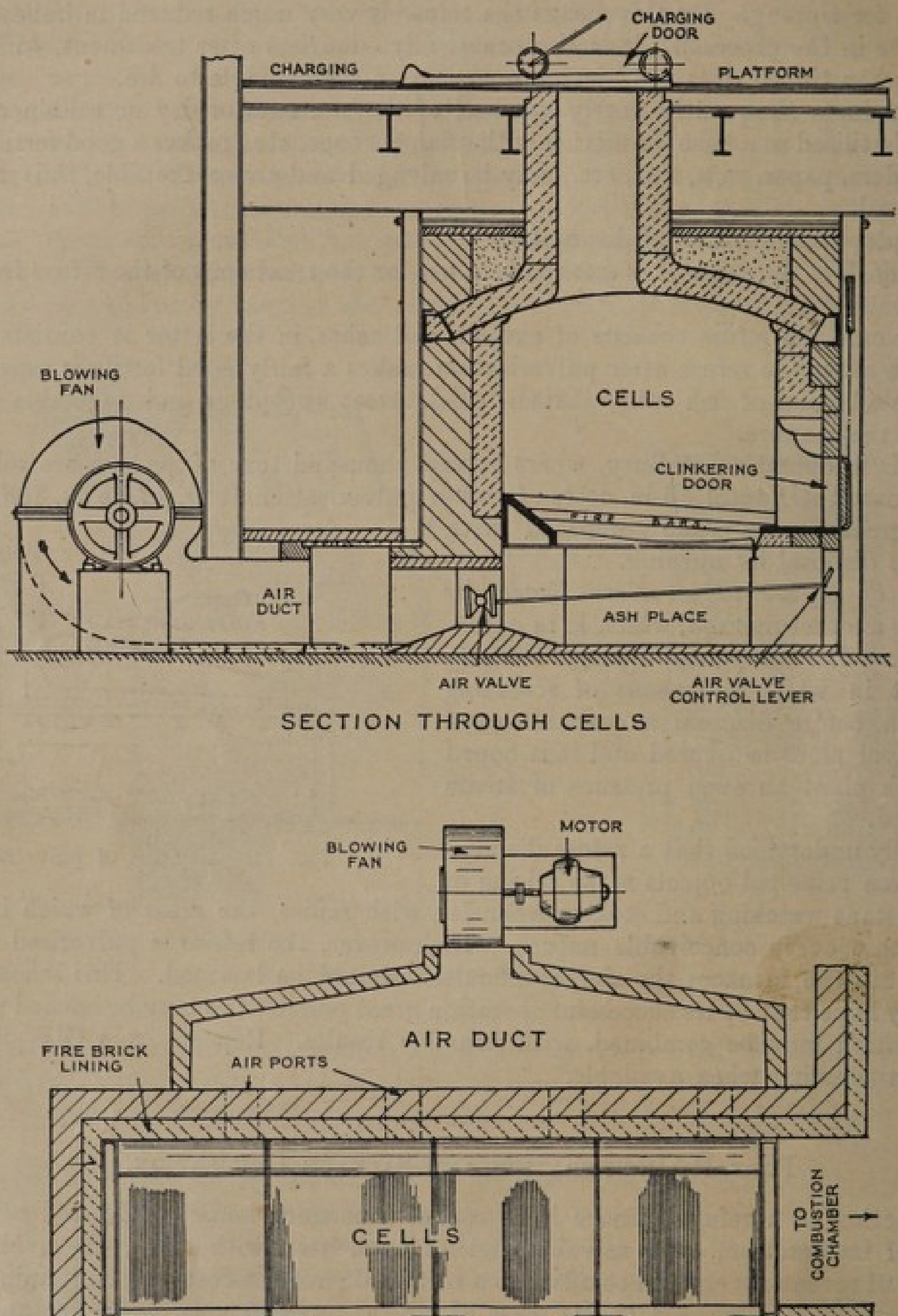


FIG. 12.—Simple type of incinerator.

division walls in order to control combustion over a relatively large grate area. Fig. 12 shows a simple arrangement. Its evolution is traced with some difficulty, and commences with the simplest of grates and a refractory lined cell. The relatively high moisture content evidently induced older engineers to evolve outer drying hearths where the refuse received a preliminary heating. The resultant nuisance led to closed-feed hoppers, with indirect heating, and then to hearths within the cells, where the material was swept by the hot combustion products before being pushed on to the bars. The drying hearth is partly evidenced by the massive curbs which are still a feature, but these are retained for a slightly more useful objective.

The operations of working the furnace are known as Charging and Stoking. The former operation includes the feeding of the furnace with the necessary amount of refuse and the preparation of the charges to follow. Stoking is the actual manipulation of the fires and includes the pulling down and levelling of the charges, slicing and clinkering. Steady temperatures should be the aim of the stoker, but as the process requires alternate charging and clinkering this is rather difficult. The stoker should, however, minimise fluctuations as much as possible and try to maintain a temperature ranging between 1300° and 2000° F., so that the refuse is rendered thoroughly innocuous. Stoking is a skilful operation, and only those having the necessary training and skill should be employed to do this class of labour.

It would appear that a system whereby the refuse could be dumped direct into the furnaces from the collecting vehicles would be the simplest method of charging, but many disadvantages prohibit this procedure.

Clinkering is perhaps the most laborious work. The clinker which forms in a solid mass on the bars has to be broken up by means of heavy bars and drawn out into wagons or barrows and removed whilst in a highly heated state. In addition, this work is performed by hand labour in front of a hot furnace. Many systems of transporting the clinker from the fires are in use, such as wheelbarrows, trackless jubilee wagons, jubilee wagons on rails, skeps on monorails, and conveyors to storage hoppers. Advantages are claimed for each system, but in the case of the monorail, storage room is limited. The charging and clinkering of the fires should be performed to a time-table, thus tending to promote efficiency, as in common with industrial plants the operation may mean success or failure.

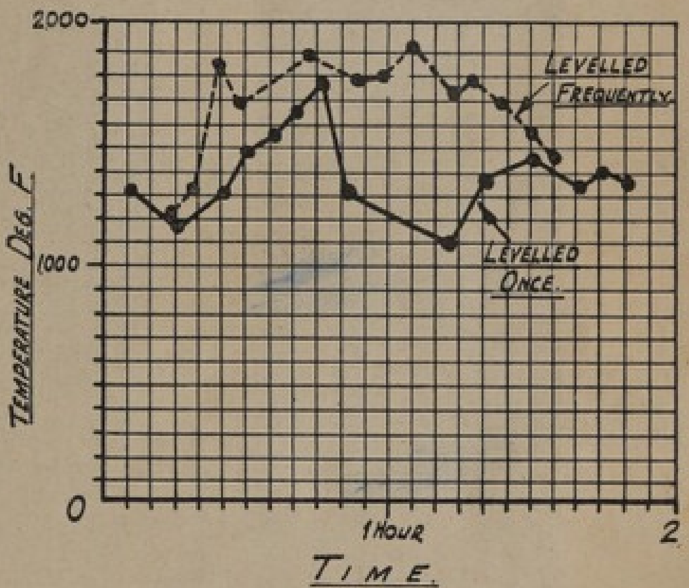


FIG. 13.—Chart showing comparative temperatures attained in a refuse furnace.

In its present form the disposal plant presents many features which are classified by the combustion engineer as inefficient, laborious and objectionable. It must be admitted that the charge is substantially true, and yet improvement has not been simple. How easy for the critic to contrast modern boiler practice with even a top-charged feed incinerator and 80% heat absorption, with a 30% heat absorption; clinkering by hand *versus* automatic and continuous removal; the accumulation of dust and débris, and yet the function of the disposal plant is exactly defined by its term, and it satisfactorily discharges the principal duty. If we visualise the production of power, this is purely a by-product of the operation, and as we strive to simplify and improve the handling of one of the most difficult materials extant, we must not lose sight of the final objective.

The present inventive trend is towards simplification of the charging and clinkering arrangements. Various mechanical clinkering devices have been tried but have left much to be desired. As regards clinkering, there are mechanical grates by Messrs. Heenan and Froude, Ltd., which are being installed at Glasgow and Fulham. The grate has been designed to minimise manual labour and loss of temperature through open doors, etc., causing inrush of cold air; it will, so the makers state, undoubtedly provide far better and more hygienic conditions of working than have hitherto been obtained.

On the old-fashioned type of incinerator there is usually a distinct drop in temperature during clinkering and feeding operations owing to the long periods the doors have to remain open. This affects the rate of burning and also the steam-raising capabilities, with a consequent lowering of the efficiency of the plant.

In the new design of grate these drawbacks will be considerably curtailed, as the period of clinkering, it is stated, will take only about three minutes compared with ten minutes with hand clinkering on ordinary grates.

Fig. 15 shows the arrangement of the plant which has been erected at Fulham. It will be noted that the top feed doors are hand operated, and that the clinker is transported by means of a suitable conveyor. In the Glasgow plant, however, the top feed doors are hydraulically operated and the refuse is fed to the furnaces by a special arrangement of container which determines the quantity of refuse deposited on the grate at each charging operation. The storage hoppers are located immediately over the furnaces and no manual labour is required for feeding the containers, this being carried out mechanically by the movement of the top feed doors.

At Glasgow, to enable this mechanical device to function satisfactorily with crude refuse, the refuse is first reduced to a uniform consistency by screening and pulverisation. This should improve the burning in so much as it is possible to maintain more regular fires without blow holes, which are formed by the presence of bulky material such as paper, rags, etc., when burning. When the top feeding doors are hydraulically operated they are inter-connected with the valve for operating the grates, and also with the air control valve to maintain the sequence of operations.

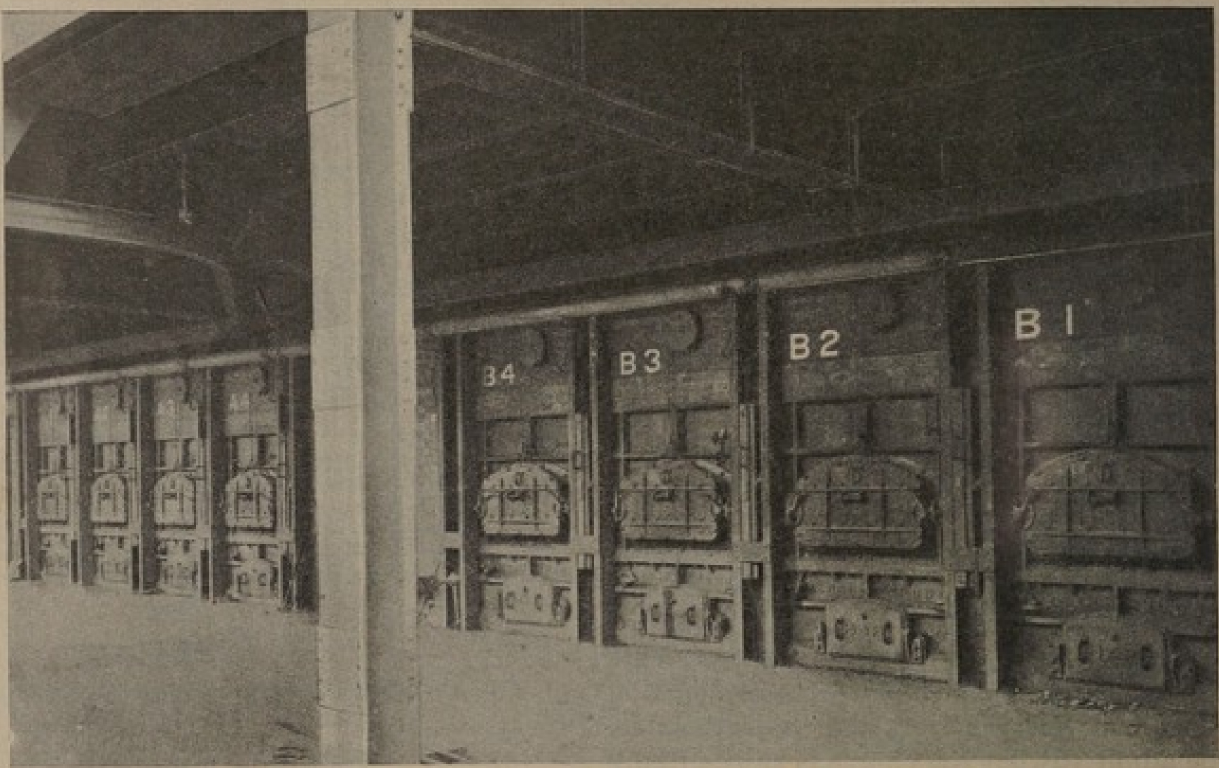


Fig. 14.—View of incinerators, Brookvale Road Depot, Birmingham.

The grates consist of ordinary cast iron firebars carried in cast iron frames on wheels running upon suitable rails forming part of the furnace structure, and they are arranged to travel backwards and forwards by power-driven gearing, or alternatively by hydraulic power.

At the back of each cell, and above the level of the grate bars, a substantial cast iron bar is provided, which, during the backward movement of the grate, pushes the clinker off the grate bars and allows it to fall on to a grid, or auxiliary grate below. When the grate moves forward again, the hanging scrapers drag over the clinker lying on the bottom grate without disturbing it, and fall into approximately a vertical position behind the clinker when the grate completes its forward travel. During the next clinkering operation these scrapers engage with the clinker lying on the bottom grate and it is dragged forward and discharged down the shoot shown at the rear. The hot clinker from a previous clinkering operation, therefore, lies on the lower grate during the whole subsequent burning period, and the air from the forced draught fans is passed through it. The air is thus heated, which assists the burning of the new charge of refuse;

the clinker is also cooled, and, moreover, is thoroughly burnt out. The heat from the clinker is also fully recovered, and this should prove a very important feature of the grate.

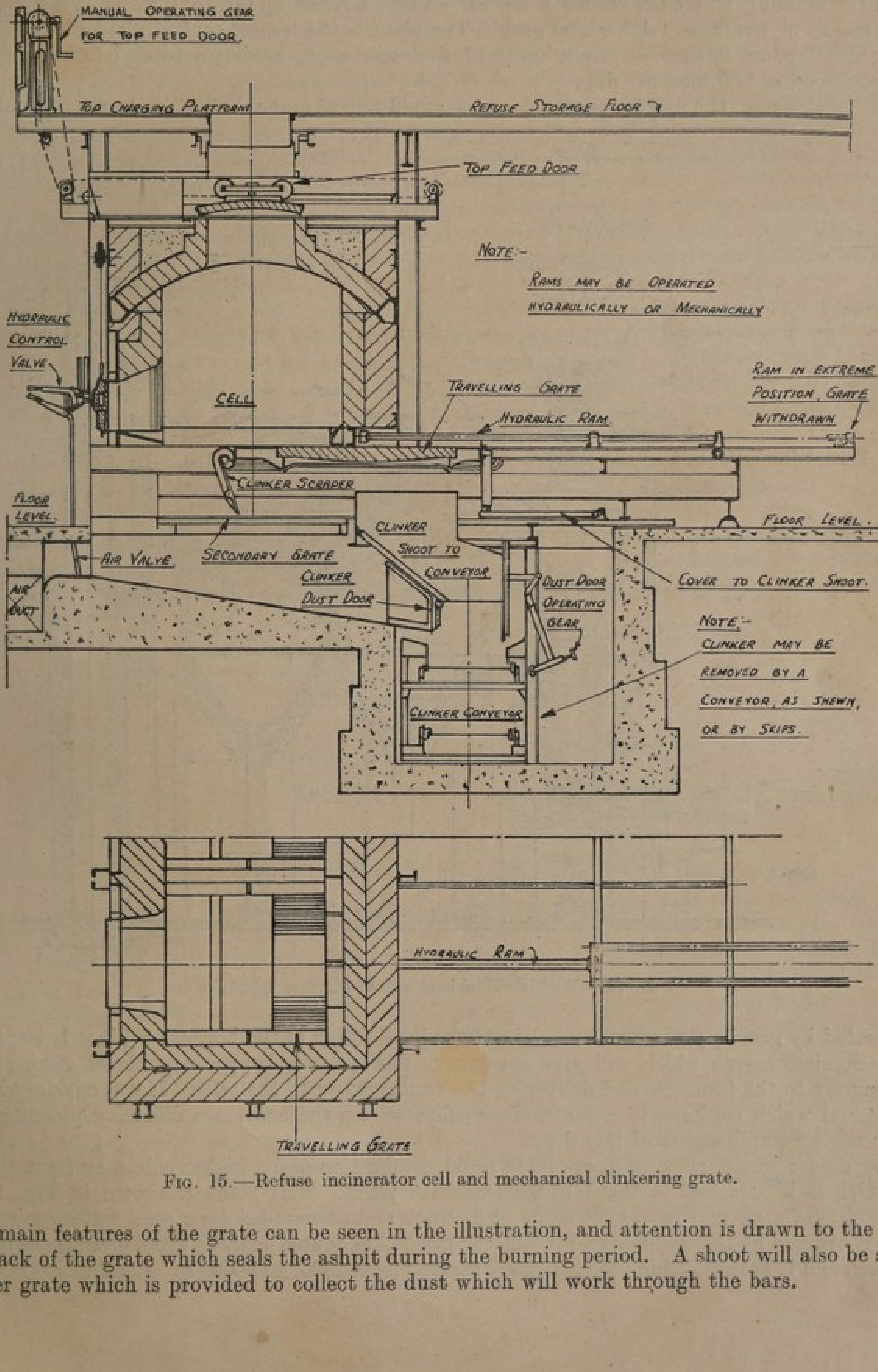


FIG. 15.—Refuse incinerator cell and mechanical clinkering grate.

The main features of the grate can be seen in the illustration, and attention is drawn to the door fixed at the back of the grate which seals the ashpit during the burning period. A shoot will also be seen below the lower grate which is provided to collect the dust which will work through the bars.

At Glasgow, the clinker is discharged into a type of jubilee wagon which runs upon a light gauge railway and is moved about by an electric battery locomotive. The wagons containing the clinker are taken out at the end of the building, where the clinker is discharged into a receiving pit, from which it is moved in due course by means of overhead telpher and grab. The plant is the largest central plant of its kind in the country, consisting, as it does, of eight units of five cells each, having a total burning capacity in the neighbourhood of 500 tons per day.

Concerning charging, the nearest approach to the avoidance of manual effort is the use of certain doors

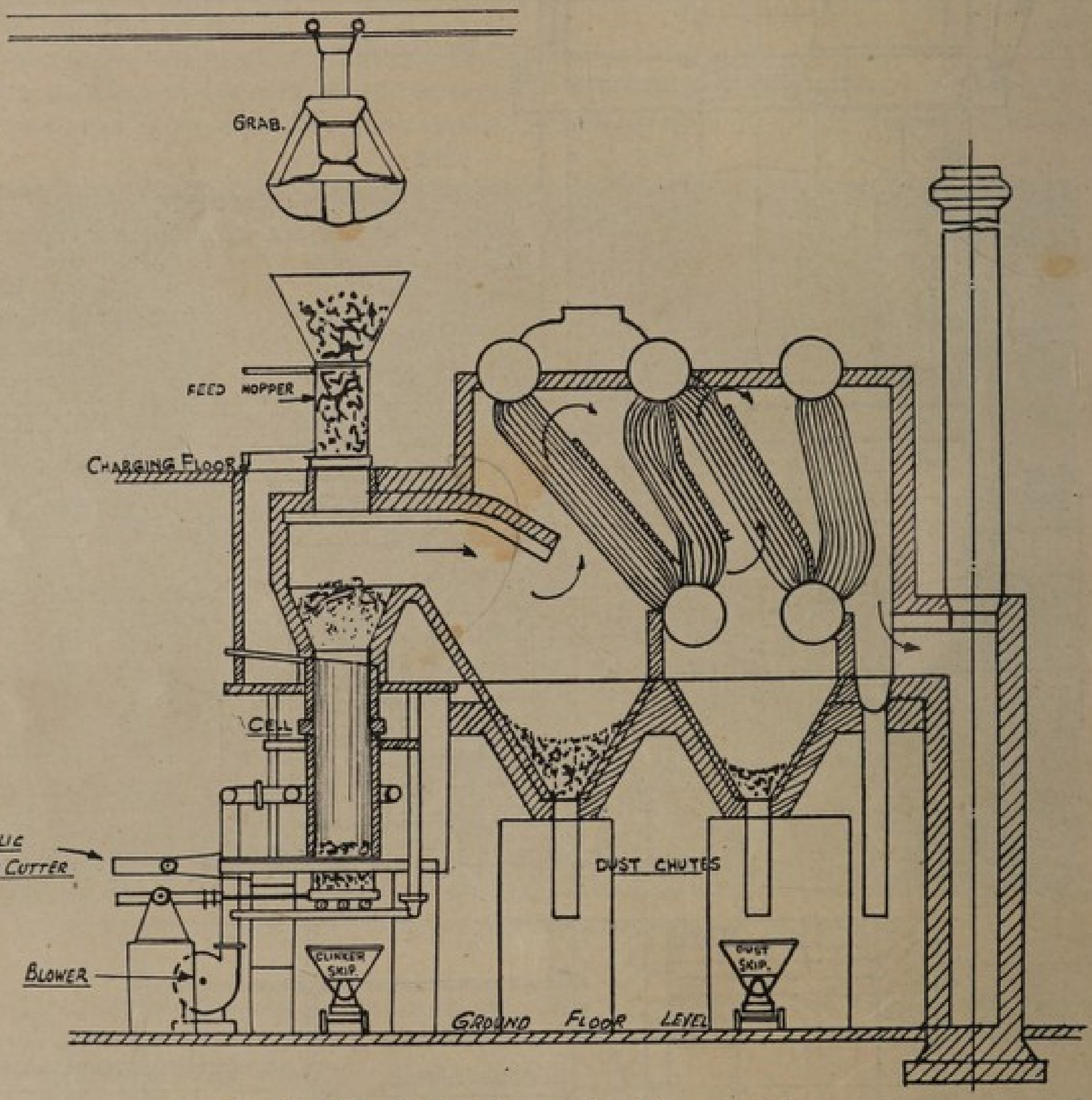


Fig. 16.—Woodall-Duckham refuse disposal plant.

partly operated by gravity; these still necessitate the hand filling of the hoppers. What is wanted is, of course, mechanical means which will give continuous flow from a hopper capable of storing at least 24 hours' supply to the furnaces, and delivering this continuously to the cells. If we consider the nature of the material which we have to move mechanically, we see the enormous difficulty presented to the engineer in the accomplishment of this duty.

Another device which aims to secure more rapid combustion and a higher efficiency from the boiler unit to which it is attached is the Woodall-Duckham plant. This plant is shown in Fig. 16. The furnace consists of a circular receptacle made of firebrick and surrounded by a steel water-cooled casing. The refuse is charged by the well-known "producer" method of double doors to avoid emission of gas or the ingress of air, and is burned at high temperatures ranging from 2500° to 3000° F. Combustion is aided by air at a pressure of 28-inch W.G., supplied by means of a rotary blower, thus aiming at molten clinker being formed during combustion, when it can be separated by a special knife hydraulically operated and dropped into a receiving cart. The operation of slicing the clinker occupies less than a minute, and it is reported that owing to this almost negligible time, no undue temperature effect is produced on the knife. The water cooling of the furnace is obtained by keeping a supply of water circulating in the jacket by a small rotary pump and this water is afterwards transferred to the boiler for steam-raising purposes.

We see that the best results at present obtained are in the existing type of horizontal grate bar furnaces, fitted with forced draught fans, by firing intermittently and at regular periods with a moderately thin fire. Combustion in this case is assisted with air supplied at 2-inch to 3-inch draught gauge

In recent years, considerable advantage has been obtained by the removal of the dust from the refuse before charging the furnaces. This has given better combustion with increasing thermal efficiency, and it will be obvious that the removal from the material of débris containing about 50% ash, before it enters the furnace is a step in the right direction. Another important benefit is the prevention to a large degree of dust emission from the chimney.

Scientific instruments also play an important part, and if results are carefully interpreted, are capable of giving useful information to those responsible for the management of the works. In other words, they may be termed the *Scientific Watchmen* in addition to producing a very useful record of events.

In some instances where a large percentage of the refuse consists of cinders from household grates, the salvage of this material provides a profitable adjunct, as such cinders can be disposed of for many purposes and incidentally for firing the boilers.

Refuse Conveyance and Storage.

One of the most serious problems confronting cleansing officials is the bulk movement of crude refuse, a heterogeneous collection of almost every conceivable nature, varying in mass, possessing an entirely unknown angle of repose, and carrying a high percentage of fine dust usually more or less moisture-laden.

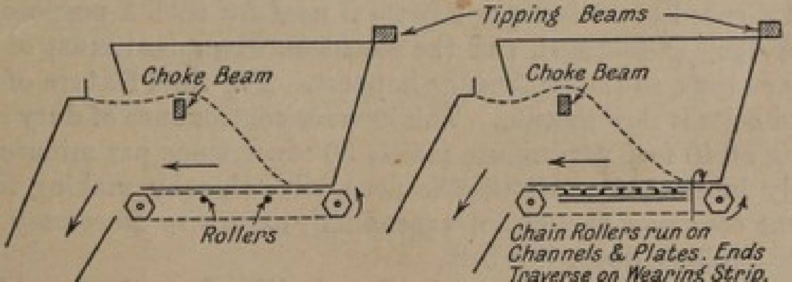


Fig. 17.—Refuse receiving hoppers and conveyors.

For this duty our present apparatus is the steel plate conveyor and a hopper for containing the mass. Fig. 17A is a diagrammatic illustration showing the refuse-receiving hopper and conveyor which proved more or less unsatisfactory until the choke beams introduced by this Department became a feature of their construction. It will be noticed that the choke beams prevent the obstruction of the refuse at the outlet, forcing back the bulky mass into the trough and preventing the choking of the mouthpiece.

The belt, if unstretched, would form the usual catenary curve between the tumblers, but by inserting rollers as shown, excessive curvature is avoided.

So far, our improvements have been limited to a superior design of chain fitted with rollers, the adoption of case-hardened chain bushes and dust-proof lubrication of every moving pin and link. The rollers run on channels, there is no curvature of the belt, wearing strips are fitted to the channel slat guides and it is hoped by these means to secure greater durability. The device is illustrated diagrammatically in Fig. 17B.

The writer looks for further improvements to take place in the design of the refuse conveyor embodying minimisation of frictional parts, more solid platform belt, avoidance of choking and variable flow.

Now let us follow the flow graph of a plant treating 200 tons of refuse per day of 24 hours. At the point of reception, viz., the refuse-receiving hoppers, the flow is irregular and intermittent, so it continues to the first process in the cycle, namely, screening, thereafter regularity is the order, but there is a halting point—the storage of tailings adjacent to the charging hoppers of the furnaces. The collection vehicles may discharge at a speed of anything up to 100 tons per hour. The maximum velocity whilst screening with plants under our control is, say, 30 tons per hour, so that the inflow is readily dealt with in a single shift of 8 hours, which includes the salvage and baling of material; but the capacity of the plant is equivalent to the incineration of the daily tailings over a period of 24 hours, and thus an accumulation of 16 hours' stock has to be provided for, and, in many instances, the wise provision of a considerable amount of excess storage is included.

Now the secondary graph supplies us with the flow speeds of each element in the conveying system, and we observe initially, that it is desirable to have two speeds for the conveyor moving crude refuse in bulk within the reception hopper (*a*) to coincide with the reasonable discharge of incoming vehicles, and (*b*) to provide equilibrium for the screen feed. In the alternative, we waste power, but, of far greater import, we imperil or strain the conveying unit, and may jamb the progress completely, involving a stoppage, with consequent increment in the process charges. Screening is the second stage, and in this operation up to 45% by weight of dust is removed and discharged. Thus at the screen exit, allowing for the separation of salvable material, the flow has declined to 110 tons over the 8 hours, or, say, 14 tons hourly. If the screen capacity can be increased without loss of efficiency, this will tend to lessen the discrepancy and promote truer harmony.

Consider a cylindrical screen 6 feet inner diameter, fitted with a helix pitch 2 feet at 10 r.p.m., the peripheral speed is 190 feet/min. and the material will occupy a segment, the chord being inclined in the direction of rotation. If we increase the screen plate surfaces by 50% it does not follow that 50% more material can be effectively dealt with, and it is probable that, to secure such a gain, an increment of not less than 75% would be demanded. Generally, we observe that in this direction some improvement may be looked for.

From the screen exit to the tailings storage bunkers, or hoppers, the system of conveyance is by rubber-surfaced belts, or by a combined system of belts and elevators. The belts, which may be used as picking belts, should not exceed a speed of 40 feet per minute if used for such a purpose, so that efficient sorting of all materials to be salvaged is obtained, and the elevators when used must of necessity run at a speed to cope with the tailings *en route* to the bunkers or hoppers. The chief feature of successful conveyance of refuse by rubber-surfaced belts is slow motion. This ensures continuance of duty and durability. A 5-inch idler with a belt running at 40 feet per minute makes 30 revolutions per minute and thus a simple dust-proof bearing adequately lubricated is all that is necessary, thereby making for low initial cost. The angle of inclination of the conveyor should not exceed 22°, otherwise there may be the danger of articles such as bottles, tins, etc., rolling down the belt.

Effective and uniform distribution within the bunkers is difficult, and even aided by movable discharge carriages the problem has not yet been solved satisfactorily. Simple storage is purely a question of the proper use of capacity at the disposal depot. Owing to the nature of the material, however, and its tendency to coalesce, the tailings are just as difficult to segregate, and involve just as much labour in movement as in the initial stage.

Assuming 80 cubic feet of refuse to the ton, a set of four cells having a total grate area of 144 square feet requires 4800 cubic feet of material per 24 hours, and thus one man must be able to remove 200 cubic feet per hour to charge the furnaces. The difficulties of charging the cells grow as the mass recedes from the charging hopper by consumption, so that eventually the 200 cubic feet has to be raked or barrowed over a floor space of approximately 10 feet to 20 feet.

To avoid this, we see that any device capable of moving the mass evenly to the charging point lessens the duty and brings us nearer to the solution of the problem of mechanical charging, still greatly involved owing to the cohesion of the composite articles.

Part III. Screening Refuse.

The various types of screen projected or now in service are so numerous as to warrant the belief that any novel system to-day is almost certain to have been anticipated. Refuse contains a very large percentage of fine material, probably 45% passing through a $\frac{3}{8}$-inch mesh, and 55% through a $1\frac{1}{4}$-inch mesh, the former being largely mineral ash, with relatively little combustible matter, whereas above that size the combustible matter exceeds the ash and the product becomes of value.

Now let us consider a mass of unit cube upon its arrival at the screen entrance. We will assume the fines to be evenly distributed, and we apply primarily the rotary screen separator. As the mass passes, either by gravitation or mechanical means, forward, the movement is gradual, the larger particles tend to occupy the lower position, and the fines are to some extent prevented from passing the screen perforations. This is depicted by (Fig. 18a), and we may assume that the efficiency is in the neighbourhood of 80% only. Fig. 18b shows the reciprocating screen, and the same objection applies, there being probably a slightly decreased efficiency in contrast with the rotary method. Thus we see that some very definite movement of the mass is essential if we are to secure stratification in the order which will assist the separation process.

Now consider how we proceed to separation by hand sieving. The vibration that we convey to the mass is such that large particles come to the surface. The same is evidenced by sudden motion imparted to any vessel containing materials of different sizes. Fig. 18c depicts what the writer will term a pulsating screen. The motion imparted is at right angles to the screen surface. By making the pulsations sufficiently rapid, definite stratification is possible precisely as in the case of the hand sieve, and by inclining the screen plate at a suitable degree the mass moves gradually over the surface.

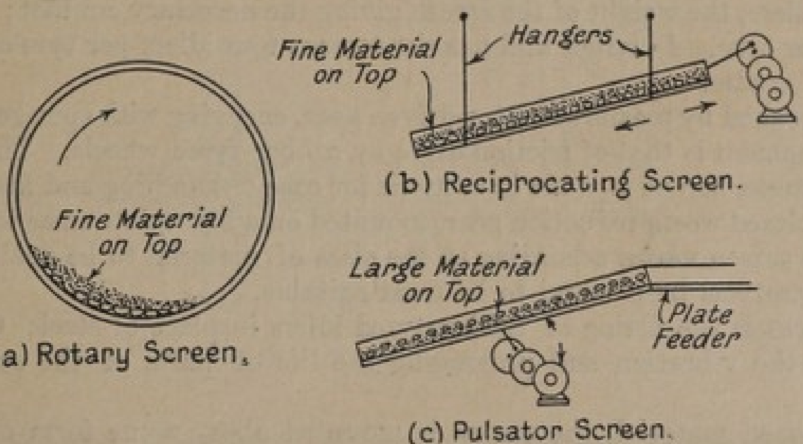


FIG. 18.—Types of screen.

The number of pulsations per unit of time, and the degree of inclination, would be a matter of experiment, and if we apply the data derived from similar screens we should expect that in contrast with the rotary screen the screen surfaces could be reduced by at least two-thirds, the power by one-half, whilst the efficiency could be raised nearly to parity.

Rotary Screen.—The screen which has found favour in this Department is the rotary type, although many improvements should be looked for in this type of screen. For instance, it should not be impossible to impart a pulsating movement to increase the efficiency of the screen. Another addition might be a steam or waste heat jacket to dry the tailings and assist combustion. Combinations of shakers and rotaries, grids and rotaries are also worthy of thought for promoting efficiency.

The rotary type in use consists of a cylinder, approximately 18 feet in length by 6 feet diameter, built up of mild steel sections and plates to form a rigid structure; into an inner frame are fitted plates perforated with circular holes to some prescribed dimension. These plates are of a size convenient for handling to facilitate replacement, as it will be readily seen the screening surface wears rapidly, due to the material passing over and through the holes.

The perforations in common use for house refuse are $\frac{3}{8}$-inch diameter, which have been found in practice sufficiently large to extract up to 45% of the original weight of material.

The cylinder above described is rotated about its axis at from 10–15 revolutions per minute with an even and steady turning motion. This carries the material up the side of the screen a distance of approximately one-third of the circumference, at which point it falls back due to gravity and then brings fresh material into contact with the screening surface. If the material were not mechanically moved through the screen it would remain indefinitely in its original position, but it will be appreciated that we are also concerned with a treated output or quantity, and we must in consequence provide automatic means to make room for further material entering. This may be accomplished in several ways; probably the most common is the inclination of the screen from 3 to 4 degrees to the horizontal, the lowest end being the discharge end. With this method of motion, there is a combination of two movements, viz., the natural tendency for the material to slide down the inclined plane, which whilst not being sufficient to disturb it if the screen is standing, will on slight agitation follow this path, and the side travel of the screen as previously mentioned, its path being upwards and forwards, as will be seen on reference to the figure. In falling vertically it meets the plates at a distance nearer to the discharge or lower end, the distance being dependent upon the inclination and the diameter of the screen.

Let us now consider how the screen is supported. There are two methods commonly employed for rotary screens.

1. A central shaft with screen mounted on what are known as spiders on which is erected the screen cylinder. This is employed for relatively small screens.

2. Larger screens are usually mounted upon two or more tyres, and have no central shaft; the tyres are of fairly heavy construction in order to prevent any distortion and should be turned on the face. These tyres run upon idlers, the weight of the screen giving the necessary contact; for light work it is usual to fit two idlers only per tyre. In larger and heavier screens four idlers per tyre are employed, these being mounted in pairs in a cradle.

The drive is accomplished by means of motor-driven gear, engaging with spur gearing fitted to the screen, although a later development is that of friction drive by rubber-tyred wheels. The spur ring in the former drive on the larger diameter screen is made in sections for ease of handling and fitting. The motor is direct coupled to a totally enclosed worm reduction gear, mounted on a base-plate so as to form a complete driving set. The speed of the screen varies according to the class of material to be dealt with. In house refuse, a speed of 10 to 20 r.p.m. has been found to be most suitable.

A recent development is the fitting of rubber-tyred idlers in place of steel; this has had the effect of considerably reducing the vibration and prolonging the life of parts of the screen subjected to heavy wear.

To collect the screened material, the screen is mounted above some form of hopper into which the material descends, or in the case of fine dust screenings, such as that from house refuse, it is usual to enclose the complete screen to prevent the exit of the dust. Where it is necessary mechanically to remove the dust to some distant point, it is desirable to bring the screened material to one point before discharge from the casing. This may be done in various ways, such as a casing, fitted with transporting helix, made of larger diameter than the screen. Another very effective method is to have the outer casing made of conical shape with the base of the cone towards the point of discharge.

It will be appreciated that a certain amount of fine floating dust is liberated by the agitation of the refuse; much of this dust may be collected by connecting the forced draught fans of the furnaces to the casing by means of ducts. These fans extract the fine dust and force it beneath the fires, where it is burnt, thus serving a dual purpose. The collection of this dust adds much to the comfort of the screening-room and also makes the process of salvage much more hygienic.

Concentric Cylindrical Screen.—This type has been used with some measure of success for grading broken clinker. It consists of three or four cylindrical wire or plate screens fitted one within the other, usually cased with an unperforated cylinder, the whole inclined at a suitable angle and delivering at the lower end. Each cylinder within the case has the delivery end so extended as to bring the delivery point over the appropriate collecting hopper. The screen is compact, and permits of some economy in housing. If a magnetic separator be fitted to the front end, it may be that its efficiency will fall as the angle of inclination increases, unless some special means of accumulating is employed.

Gannow Patent Screen.—This is a rotary screen of the cylindrical type, suspended and driven by a shaft running through the centre line of the cylinder. On the shaft are mounted four sets of arms. Each set consists of four (in this particular case) channel-section steel bars set into a cross-section cast iron hub, keyed to the shaft. This arrangement gives four segmented spaces, each separated by the width of the channel iron. In these spaces are fitted four individual screens with the space of the above-mentioned channel iron between, and this space allows the screened dust to leave the screen. Herein lies the value of this screen.

The four separate screens consist of two perforated plates (*b*) and (*c*) and one plain plate (*a*) which is also fitted with guide plates pitched to facilitate the travel of the material along the screen. *a* and *b* are flat plates, while *c* is curved to form the periphery of the screen. It will be seen very readily what a wonderful increase in screening area can be obtained by this form of screen as compared with the ordinary perforated cylinder used for screening. The mechanical advantage is also a very big factor in its favour, in that it is much stronger than the hollow cylinder and balance is more perfect.

This screen would be suitable for grading clinker; no experiments have been tried on the screening of house refuse, but it may be that undue choking would take place.

By reference to the figures shown, the description will be made clear.

General.—If we accept the theory of stratification applicable to either rotary or horizontal reciprocating screens, it is obvious that means for imparting other than strictly lineal sliding motion to the particles is necessary. This feature has been recognised by screen designers recently, and a rotary screen for grading broken coke and incidentally separating the dust and fines, has the inner wires so arranged as to turn over the material when it has reached the limiting height.

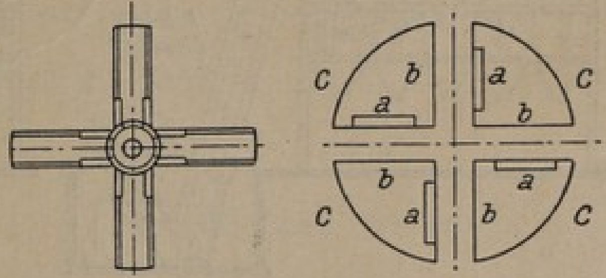


FIG. 19.—Gannow patent screen.

An objection to this is the wear on the mesh, but the angular velocity is low and apparently the durability is assisted by the use of a relatively soft metal for the screen wires.

A mathematical analysis of the well-known Hummer Screen was undertaken to discover the critical vibratory speed. This yielded some rather peculiar results. With a lift of 1 inch the completed upward and downward movements were limited to 425 per minute. At any vibratory speed in excess, the gravitational force was insufficient to permit the screen surface and the material to descend the full permissible stroke.

If the screen surface be automatically depressed by a spring at a speed greater than that due to gravity, the material would be subjected to a series of rapid shocks, which would assist the stratification. Thus advantage has been taken of this feature in the preliminary designs of a pulsating screen, the stroke susceptible to minute regulation being arranged to give a definite clearance between material and screen surface. It is, of course, more than probable that the action is well known, but in my opinion it accounts for the high efficiency of the Hummer on certain ores. I am not sure, however, that on moist materials the screen would be an unqualified success. It may be that the enforced limitation of the vibrations with a spring (if used) which could not be regulated would result in moist fines adhering to and clogging the screens, whereas greater freedom in stroke fixation with a spring which could be regulated would obviate the defect.

Triangular section bars *versus* wire mesh or perforated plates for screening refuse has on many occasions formed a problem for the writer's investigation. To a certain extent one is bound by accepted practice and must move warily in any innovation. String, rope, wires, metallic residues, rags, etc., in lieu of a more or less uniform mixture, hamper all theoretical considerations. Unfortunately, practice gives little assistance, being wedded to a common form which gives more or less satisfactory results and presumably little trouble.

It may be asserted with truth that we are moving towards improvement when we submit a design which permits such accessibility as to render the change of plates or removal of obstacles a matter of minutes instead of hours.

Clinker Crushing, Screening and Storage.—The burning of refuse in furnaces results in a valuable by-product known as clinker.

This material is greatly in demand for the many uses and purposes to which it can be put. In the crude state it is used for road-making and filling, and in the crushed and graded state the different graduations or sizes are used as aggregate for concrete; for clinker asphalt; for clinker concrete bricks, paving slabs, kerbs and channels, and for a variety of other purposes in connection with the building trades.

If the clinker is of good quality, and graded to the proper size, it makes admirable paving material when used in the construction of asphalt roads. Excellent examples of its use in this direction can be

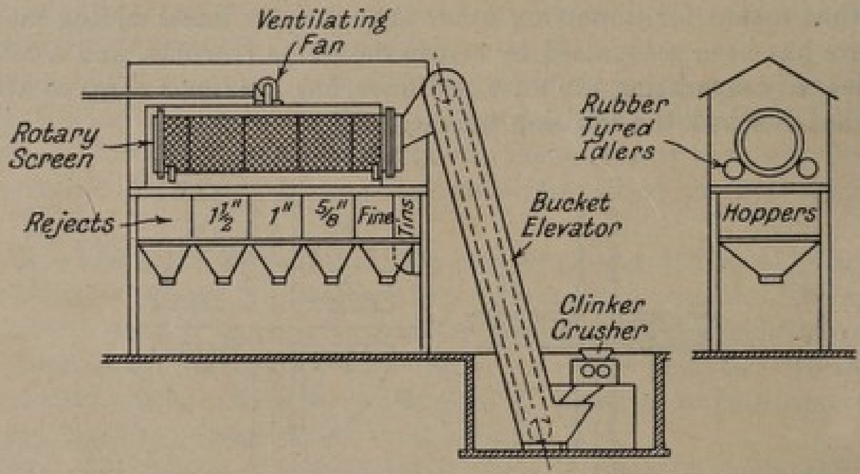


FIG. 20.—Clinker crushing, screening and storage plant.

found in the work carried out by the Fulham Borough Council, Hornsey Borough Council and Surrey County Council.

Trinidad Lake Asphalt, the cementing agent or matrix for all forms of asphalt paving, enters very largely into the work executed by these Authorities.

On removal from the furnaces the clinker is usually deposited in the open for cooling, a process frequently hastened by means of a water spray. It is sometimes advisable to allow clinker which is to be used for concrete aggregate a short period in the open for what is generally known as "weathering."

The modern crushing and storage plant is a simple and compact apparatus, occupying but little ground space and capable of handling large quantities of crude clinker.

The crusher is generally placed in a pit just below the ground level and into the small receiving hopper fixed at ground level the clinker is shovelled by hand. This system does not necessitate the lifting of the clinker by the man in charge of the plant, and consequently the output of the plant is considerably greater than would be the case if each shovelful of material had to be lifted off the ground to a height for feeding into the crusher-hopper. As the limiting capacity of the average crusher plant is the capacity of the man to feed material into the crusher, it will be at once appreciated how important a point is the foregoing. It should be explained that it is an undoubted advantage to feed the crusher by hand, since in this way the operator can mostly prevent such articles as flat irons and other domestic and foreign accessories, which would cause injury to the crusher rolls or jaws, from being fed into the machine. Moreover, crude clinker is such an irregular material as regards shape and size that it would in any case be desirable to have an attendant constantly watching the machine, even if the form of mechanical feed were employed, to ensure that stoppage did not occur through large clinkers jamming in the feeding hopper.

The crushed material falls by gravity to the boot of an inclined bucket elevator, by means of which it is raised and discharged to a circular screen arranged above the storage bunkers.

The screen grades the crushed clinker into the desired sizes, these usually being 0–$\frac{1}{4}$, $\frac{1}{4}$–$\frac{3}{4}$, $\frac{3}{4}$–$1\frac{1}{2}$, $1\frac{1}{2}$ inches and over, each grade falling direct from the screen into its appropriate division of the storage bunkers.

The capacity of storage bunkers is largely a matter of choice, depending to some extent upon the local demands for graded clinker. The bunker is provided with a simple form of outlet door and is arranged at a sufficient elevation to allow the contents to be discharged direct to vehicles.

The space on the ground floor beneath the storage bunker is frequently occupied by one or more mortar-mills, these being fed direct from the bunkers by shoots and valves, connected with the bunker division containing the grade of material it is desired to employ for mortar-making.

It is frequently considered advisable, before screening the crushed clinker, to remove the magnetic content, and this is done by means of a magnetic separator fixed between the elevator discharge point and receiving end of the screen. The magnetic material is deposited either in a special compartment of the storage bunker or by shoot to ground level.

A housing over the storage bunker and screen, and cover to the crusher, together with an exhaust fan, completes the whole plant, access being given to the screen and elevator head by means of a suitably arranged stairway.

The pit in which the crusher is housed is floored with chequer plates, and a hatchway and ladder provide access to the crusher and elevator foot.

The drive is usually by means of a motor at the ground level for the crusher, and a second motor arranged above the screen for the elevator and screen. The screen is mounted on idlers fitted with rubber tyres and rotated by spur gearing.

Fig. 20 shows a typical lay-out of a plant.

Part IV. Belt Conveyors.

Screen Dust.

The removal of the fine dust residues from the screen after it has passed through the perforations seems, *prima facie*, a subject requiring little thought and less investigation. The pneumatic system with a totally enclosed pipe from the fan to the point of exit may at first thought be considered ideal. In practice, however, such was not the case with the trial plant erected for the Birmingham Salvage Department, as the pipes were quickly choked with the dust. Many experiments were tried to free the material, but none was satisfactory and the makers eventually had to remove the plant. A vacuum system of transportation was also experimented with and this likewise proved to be unsatisfactory.

The uniformly distributed moisture, together with the free lime of the dust, without any positive binding material, would, in the writer's opinion, speedily choke any tubular system, even if the latter were subjected to vibratory action. Thus any metallic surface with which the ash comes in contact ought to be finished preferably with a suitable corrosive resisting enamel. One instinctively turns to a graphite paint, but the objection to this will be the very short life of the surface. Again, a stove enamel with a hardened surface is unlikely to prove really durable. What is required is a metal of the nitro-steel variety; a metal with an almost glass-like surface inert to either alkaline or acid corrosives.

Belt Conveyor.

The belt conveyor provides a simple and inexpensive means of transport for the dust, and, unlike the tubular system, requires little power for driving, and large overloads can be accommodated without any undue ill effect. A belt conveyor may be described as a moving endless belt running over two pulleys fixed at each end of the structure with carrying rollers interposed to support the belt for the top and bottom travel. The belt which supports the material and by its travel transports the latter from one place to another is driven by a pulley actuated by means of mechanical power. The material may be fed on the belt by hand, shovel, chute or other means, and is removed from the belt by discharging it over the end pulley or by deflecting it at some point along the run of the conveyor. There is no greater item of importance in connection with the belt conveyor than that of the belt and it is advisable to install first class belts only, and should the belt be of textile manufacture great care should be exercised in the selection.

The elements of the belt conveyor are, therefore :—

(1) A belt to carry the material and transmit the pull.
(2) Means to support the belt, usually rollers or pulleys.
(3) Means to drive the belt, usually a pulley or pair of pulleys.
(4) (*a*) Accessories for maintaining belt tension, such as "take-ups."
(*b*) Accessories for loading the belt, such as a chute.
(*c*) Accessories for discharging the material, such as a chute or a tripper.
(*d*) Accessories for cleaning and protecting the belt, such as housings, decks, covers, cleaning brushes, etc.

The belt is a flexible, jointless structure which runs quietly at any speed; it is not ordinarily harmed by the actual conveying of the material it carries. Since the material does not come into contact with the moving surface of pulleys and shafts in which there are friction losses, these losses are relatively small and the power required for the transfer of the material is generally less than in other forms of conveyors. The belt with its rollers weighs less per foot of run than other types of conveyors doing the same or similar work, and hence frames, bridges and other supporting structures are relatively lighter and cheaper.

Belt conveyors are suited to the carrying of all sorts of material, wet or dry, from the lightest to the heaviest, and in any quantity. They have been known and used for over a hundred years, but the most rapid development in their design and use has probably occurred in the last thirty years.

The belt must have a certain flexibility in order to wrap around the pulleys, width enough to carry the required quantity of material, and strength enough to bear the weight of the load and transmit the pull in the conveyor. These conditions can be met by bands of metal, leather or woven fabric. Leather belts are expensive and do not resist wet and abrasion well enough in conveyors and elevators to justify their greater cost. Belts of hemp fibre are used to some extent in Europe, but in this country practically all conveyor and elevator belts are made of cotton fibre. They are of several forms :—

1. Rubber-covered belts are made of layers or plies of cotton duck cemented together by an elastic compound. In "friction surface" belts the outside of the belt is covered by the thin layer of compound adhering to the outer plies; in rubber-covered belts an extra layer of rubber is attached to the outer plies beyond the thin coating of "friction rubber." No attempt is made to waterproof the individual cotton fibres, the layers of rubber being depended upon to keep moisture out of the belt.

The choice of this type of belt may be narrowed down to :—

(*a*) Ordinary canvas duck belts with no special thickness of rubber on carrying face.

(*b*) Full or straight ply canvas duck belts with extra thickness of rubber along the whole face of belt.

(*c*) Graduated type, which is similar to No. 2 except that the plies graduate down in number to give increased rubber thickness at the centre of the belt for troughing purposes.

The strength of the belt lies in the duck, a cotton fabric which for conveyor and elevator belts differs from ordinary sail duck, or canvas, in the fact that the strength of the warp threads is considerably greater than the weft threads. The strength of duck depends, not only on its weight, but also on the degree of twist in the threads, and the cementing action of the rubber depends upon the openness of the weave as well as on the quality of the rubber.

2. Stitched canvas belts are made of layers or plies of cotton duck folded together to give the required width and thickness, and then sewed through and through with strong cotton twine. To waterproof the fibres and to reduce internal wear, the made-up belt is impregnated with a mixture of oil and gum.

3. Balata belts are made of duck with the fibres of the cotton waterproofed by impregnation with a

liquid solution of balata, a tree gum similar in some respects to rubber. The impregnated duck is folded and rolled under pressure to make a belt of the required width and thickness, the balata gum acting as a cement to hold the plies together.

4. Solid woven belts consist of a number of layers of warp (lengthwise) threads and weft or filler (crosswise) threads woven and interbound together in a loom to make a structure of fabric of the necessary width and thickness. Most of them are waterproofed liké stitched canvas belts, but some are impregnated with a rubber solution and then covered with a rubber sheathing.

Supporting idlers consist of cast iron rollers in various forms and combinations. The idlers for each width of conveyor belt are made up in sets or units, each set consisting of a complete troughing idler mounted upon its batten board, or a complete return idler with its side bracket. With this design of idler it is possible to arrange the spacing of the idler sets on both the loaded and return sides of the belt to the greatest advantage, and is a great improvement over all conveyor systems where the return idlers are fixed to the underside of the troughing idler batten boards.

The troughing idler sets consist of a series of cast iron rollers with bored and faced hubs, and turned on the outside of the rim, mounted upon solid drawn hollow steel spindles, which are fixed in bored cast iron brackets bolted to the batten board. The number of rollers per set and the width of face of the individual rollers are dependent upon the width of the conveyor belt. The upper ends of the inclined side

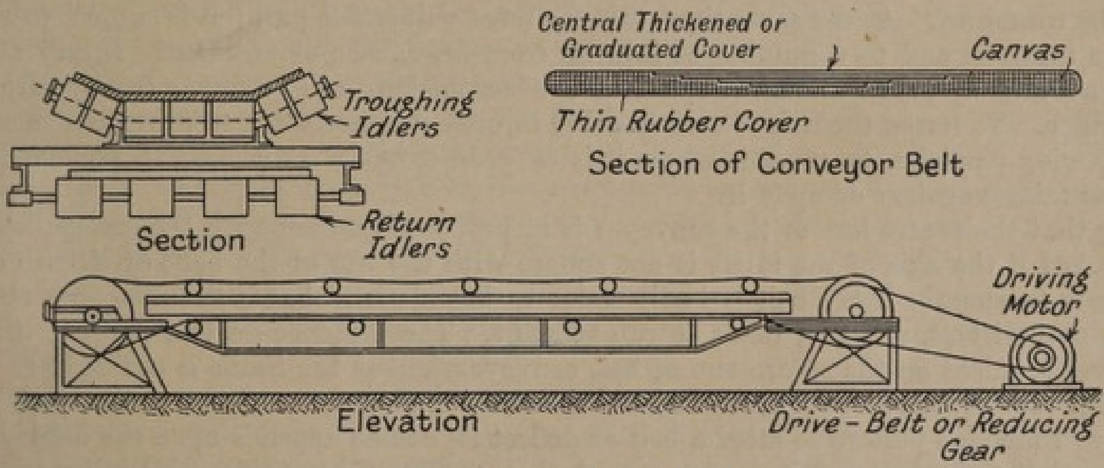


Fig. 21.—Conveyor belts and idlers.

roller tubes are provided with special nipples to be used in connection with grease guns or specially designed large size compression grease cups of cast iron, which force the grease through the hollow spindles to the centres of the loose roller hubs, where holes are drilled through the wall of the tube to allow of its emission. Distance pieces are provided to maintain the spacing between the rollers where necessary. The batten boards are usually of machine-dressed deal and provided with holes at either end ready for fixing to the conveyor stringers. The angle of the inclined troughing rollers is preferably reduced to 25°, which has the effect of prolonging the life of the conveyor belt by reducing the internal stress, and the gaps between the rollers are in every case reduced to a practical minimum in order to lessen the tendency of the belt to crack along the line formed by squeezing the belt between the rollers when it is running fully loaded.

The return idler sets consist of a series of cast iron rollers with bored and faced hubs, turned on the outside of the rim, and mounted upon horizontal spindles, which for all widths of conveyor belt up to and including 24 inches wide is a solid drawn hollow tube supported in fixed bearings of cast iron and for all sizes above this width is a solid spindle supported in bored bearings of cast iron of the ball and socket type which allows for any settlement that may take place in the conveyor framework during the life of the conveyor. These ball and socket bearings are lubricated by means of independent Stauffer lubricators and the rollers are fixed upon the spindle.

Fig. 21 shows the type of idler, belt and method of drive usually found in conveying installations.

The drive for a belt conveyor consists of one or two pulleys around which the belt wraps, suitably mounted on shafts and bearings, and driven from a source of power through belts, chains, gears or other means of power transmission. The simplest drive is that in which the belt wraps half-way round the end pulley; this is usually at the head or delivery end of the conveyor toward which the material moves, but it may be at the foot or loading end of the conveyor. If 180° of belt wrap is not enough to drive the conveyor, it may be necessary to get a greater wrap on the driving pulley by the use of a snub or reverse bend pulley. For still greater driving contact, the belt may be led around two pulleys, both of which are drivers.

Conveyor belts in service stretch more or less, and it is necessary to have means to " take up " or remove the slack as it is formed. At some point in the conveyor, a pulley is mounted on a shaft running in bearings which are adjustable in position either by a screw or by a weight. The usual position for the " take up " is at the foot end, where the belt is under less tension.

The simplest discharge is over the end pulley; sometimes a chute may be required there, often it is not. If the discharge is to be at some point short of the end of the conveyor, the material may be deflected sideways from the conveyor by a scraper set diagonally across the belt; more frequently this is done by inverting the belt or running it in S form through a tripper. In the tripper or " throw-off," as it is called, the material leaves the belt as it reaches the top of the upper pulley and is caught in a chute which directs it to one side, or by means of a by-pass gate, back on to the belt again if the material is to be carried past the tripper. Trippers may be fixed or movable, or travelling and self-reversing, and may be operated by hand or power.

The belt is the most expensive part of a belt conveyor, often costing more than all the rest of the machinery and accessories combined. At the same time, it is the most vulnerable part; it is subject to abrasion from impact of the material and to a number of injuries from negligence or accident. Injury at the loading point can be avoided by proper design of the chute; other mishaps can be prevented by care in operation and maintenance. To lessen the risk of certain other injuries it is necessary to provide means to clean the belt from adhering particles, to cover it where it is exposed to the weather and to prevent it from being cut by objects falling against or upon it.

Assuming that the centre line of the conveyor is in proper alignment with the end pulleys, a flat belt may run crooked if the axis of the idlers is not square with the run of the belt, or if both edges are not under the same tension, or if the belt is badly made to begin with; but if the idlers are set square with the travel, a normal belt, run flat, tends to run straight. The evidence on this point is that side guide idlers are never required on the return run of belt conveyors unless the frame is out of line.

However, if the belt is run over troughing idlers of any kind, there comes a tendency to run crooked. The tendency of inclined pulleys to steer a belt or deflect its course depends upon the angle of inclination and the proportion of the belt width in contact with them. The effect of side guide idlers is generally bad. They wear the belt at its most vulnerable place and open the way for dirt and wet to get between the plies of fabric. If the belt is badly out of line, the pressure against the idler may be enough to bend or fold the belt for an inch or two all along the edge so that a crack develops there and splits the belt. In general, the right way to make belts run straight is to use flatter troughing. Just as 30° troughing is better than 45° troughing, so is 20° better than 30° in keeping the belt centred on the idlers and running straight.

Besides the normal duty of conveying material, a belt has to check the impact of material at the feed point and impart to it the belt's own velocity in the direction of travel. It is therefore of importance that proper attention should be given to the design of the feeding chutes.

If belts could be fed with material moving at belt velocity, cutting and abrasion would be at a minimum, but this is seldom possible in practice. The best that can be done is to deliver material through a chute pointing in the direction of belt travel and at such an angle that the horizontal component of the velocity in the chute will be equal to belt speed.

The slope of an inclined conveyor is usually limited by the tendency of the material to roll down hill; hence, screened or sized material cannot be carried on angles as steep as where the lumps in a mixture rest on a bed of fines. An intermittent feed is objectionable when the angle approaches the maximum, single lumps fed to the belt may not be picked up promptly, but may tumble around between the skirt boards for a time, until a flat surface happens to rest on the belt. Conditions like these have fixed the angles at which it is practicable to convey various materials. They may be determined by experiment with some of the material and a piece of belt, but it is well to remember that when the angle of incline approaches the maximum for any material, there is a danger that the material may at times slip.

The simplest discharge from a belt conveyor is over the head pulley. When belts handle materials like wood chips, fine coal, etc., which are not abrasive, and can be carried with little or no troughing, it is possible to discharge them at various places along the run by plough or scrapers set diagonally across the belt. This method of discharge is not recommended when the belt is handling refuse, as the wear and tear on the belt is too great. A better arrangement for discharging the material at any point on the run of the belt is a travelling tripper in which the travelling motion can be done by power or hand, depending on the frequency at which the tripper is to remove.

To reduce the wear and tear on the belt due to its passing round the pulleys on the tripper, it is advisable to keep the pulleys as large a diameter as possible and a good proportion is 4 to 5 inches in diameter for each ply in the belt.

Some materials cling to the belt and it is desirable to install some method to clean it. Stationary brushes are not a success, they fill up with dirt and fine stuff and soon become useless. Strips of belting set diagonally against the under side of the return belt have been found satisfactory on some belts feeding certain materials. Revolving brushes are more satisfactory, but means must be provided for adjusting the brush against the belt, and it must work against the travel of the belt and at a speed sufficient to throw the fine stuff out of the bristles and keep the brush clean. Where the belt is handling crude refuse, tailings or screened dust, it is not usually necessary to provide any special cleaning arrangements and generally they are to be avoided if possible as they are subject to rapid wear and need regular attention.

In order to prevent material from dropping on to the return belt, it is advisable to cover the space between the conveyor stringers by a floor or deck of plank or light sheet steel.

All drive drums, tension drums and snub drums should be crowned on the face, the crowning to be at least $\frac{1}{8}$ inch per foot of face; they should also be 2 inches wider on the face than the belts up to about 18-inch belts and 3 inches for 24- or 30-inch belts and 4 inches more in wider belts.

Generally, the speed and capacity of belt conveyors depend entirely on the nature of material to be handled and the width and shape of the belt. Materials like grain could be conveyed at the highest speeds, as such materials would not be damaged by being delivered at the highest velocity. The limit of speed is, therefore, only set by the resistance of the air to the passage of material. Speeds of 300 to 500 feet per minute are common for such materials. For conveyance of dust we have found 100 to 150 feet per minute a suitable speed.

In general, great care should be taken in the installation and maintenance of the belt. The absorption of oxygen by rubber causes what is known as drying, the effect of which is loss of tensile strength and stretch of rubber, and this manifests itself by fine cracks in the surface of the belt. Belts also deteriorate rapidly when exposed to heat or when carrying hot materials. Other important points to observe are the splice not being square with the belt, speed of belt too fast, pulleys too small at drive, wide gaps between idlers, belt too thick for its duty, alignment not correct, too many side guide idlers, excessive "take up" tension, lack of decking, etc., all of which tend seriously to interfere with the efficient service of the belt conveyor.

Aërial Ropeway.

Another mechanical means of transporting the dust is that of the aërial ropeway. Like the band conveyor, it is not expensive to run, and large quantities of material can be transported at minimum cost. Fig. 22 shows a plan and profile of the aërial ropeway installed at Tyseley Works.

The ropeway is 775 feet long, with a capacity of 15 tons per hour, in 5 cwt. net loads, involving a dispatch of 60 loads per hour, or one load every minute, and with a hauling rope speed of 200 feet per minute the carriers are therefore spaced 200 feet apart along the line.

The average gradient against the load is about 1 in 18, whilst the steepest gradient against the load is about 1 in 17.

The loading, driving and tension terminal, which is about 30 feet long, complete with steel framing, together with the necessary driving gear, including driving, fleeting wheel, vertical and horizontal shafts, bevel gearing, and also special reduction gear, is joined up direct to the electric motor shaft by a suitable coupling. The main driving gear including bevel gearing, with reduction gear and motor, is placed at the top of the terminal framing, so as to be well out of the way of floor traffic.

The ropeway carrier boxes are loaded by gravity from a hopper by means of a suitable chute and valve, and as soon as the carrier box has been loaded, the man in charge allows it to run along the fixed loading rail, down the inclined part of the loading rail, and near the outgoing end of the terminal where the ropeway carriers automatically engage with the hauling rope, a suitable engaging ramp and special guard being provided for the purpose, so as to ensure automatic attachment of the rope gripper to the hauling rope.

Automatic tipping gears are provided on the ropeway, one on each side, so that loaded buckets can be tipped either on the forward or return side of the ropeway as required. These tipping gears are absolutely self-contained, requiring no guy ropes or other means for anchoring them down to the ground, such as is necessary with other types of tipping gears.

The carriers on this ropeway are all fitted with a rope gripper, which is made for automatic negotiation of any angle stations there may be *en route*, also automatic return around the return terminal, and automatic engaging with the hauling rope when sent away from the loading station as already named, as well as automatic disengaging from the hauling rope when each carrier comes back empty to the loading station, and after being automatically disengaged from the hauling rope each carrier is then run by gravity to the loading point as required.

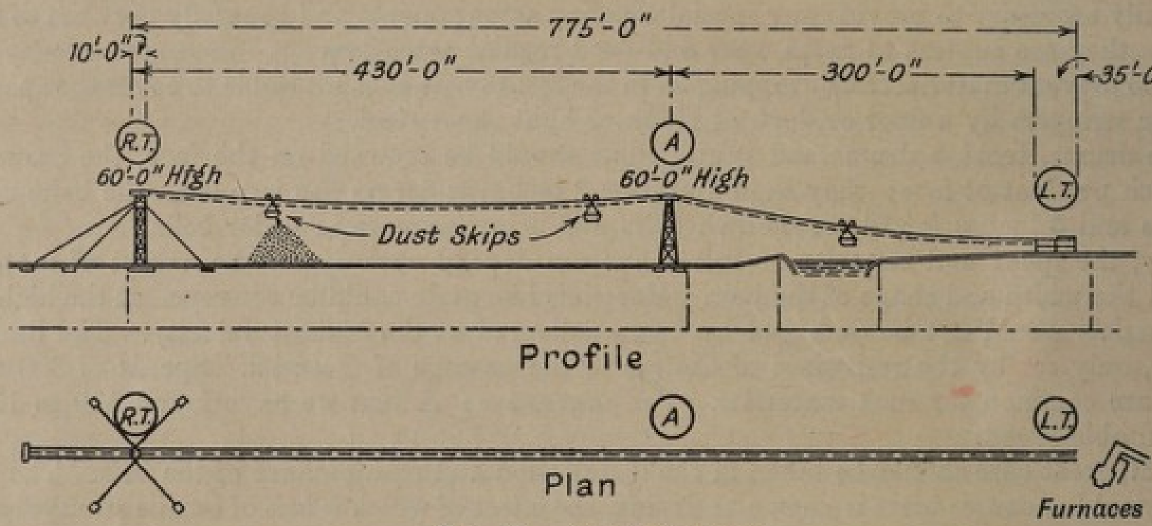


Fig. 22.—Aërial ropeway.

It will be readily understood what a large saving this means in labour and attendance generally, as the carriers are never touched by hand from the time of leaving the loading point until they arrive back again empty and stand ready for the next load. The chief item of renewal is the carrier rope, but with care and particular attention to the lubrication and guide rollers, efficient and economical service is assured.

General.—Other forms of transport include electric, steam, petrol and horse-drawn vehicles, jubilee wagons, each being useful in their sphere and according to existing conditions.

Magnetic Separation of Ferrous Metals.

A magnetic separator provides us with a means for removing ferrous metal at a point before salvage by hand of other material is attempted.

A brief description of an electro-magnetic separator will be of interest. By reference to Fig. 23, *A* is a soft iron core wound with many turns of insulated wire, *B*. If now a current of electricity is passed through the wire, the core, *A*, becomes magnetised and capable of picking up pieces of iron. The magnetism lasts so long as the current is passed through the wire. In practice, magnetic separation assumes a variety of forms. Fig. 24 shows a simple separator. It consists of a drum, mounted and rotated about a horizontal axis. Within are placed magnets as shown in Fig. 23 and so arranged that part only of the circumference is magnetised when the current is switched on. This magnetic field remains stationary in space in spite of the rotation of the drum. Therefore, if any material containing iron, such as tins, etc., is passed under the drum, it is picked out at *C*, transferred by the rotation of the drum to *D*, and here discharged into a chute or other receptacle.

There are two types of magnetic separators used in the Birmingham Salvage Department, known as the "Rapid Patent Screen Type Separator" and the "Rapid Pulley Type Separator." Either type is suitable for extracting magnetic materials from house refuse or clinker, but the screen type, which has been developed by this Department in conjunction with the Rapid Magnetting Machine Co., Ltd., is more efficient with regard to cleanliness and percentage of extraction than the pulley type.

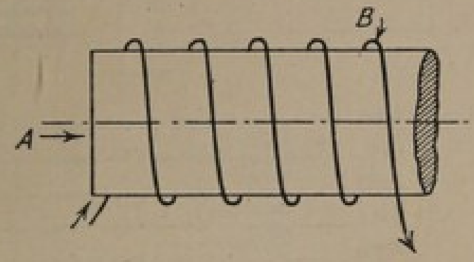


FIG. 23.

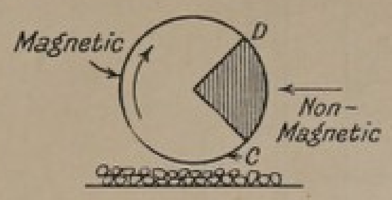


FIG. 24.

Principles of magnetic separation.

The following description will be more clearly understood by referring to Fig. 25, in which the screen type separator is shown. It is fitted about the non-magnetic extension plate of a rotary screen and half envelops the extension. The magnetic substance when passing in the vicinity of the magnet is attracted to the inside face of the rotary extension, carried upwards and automatically discharged into a chute which diverts the tins and other ferrous metals. It may also be mentioned that extraction is aided by means of magnetic feelers fitted to non-magnetic slats fixed to the inside face of the extension plate, whilst the discharge can be regulated by specially designed throw off magnetic feelers.

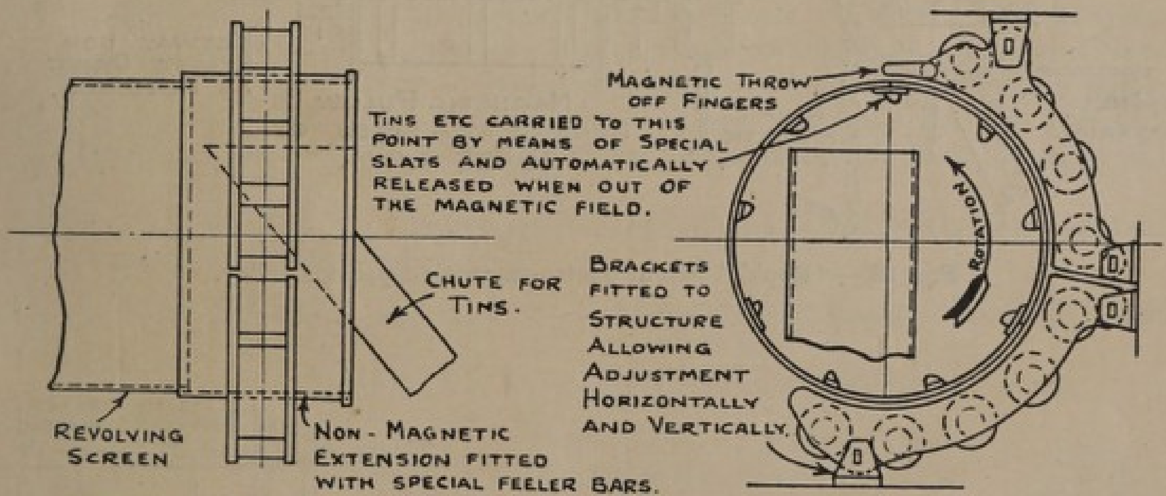


FIG. 25.—"Rapid" patent screen type electro-magnetic separator.

In connection with this type of screen, a combined electric blower and motor can be fixed on an adjustable platform so that an air current can be directed at an opening in the tins discharge chute. This opening is roughly about the centre line of the screen and any paper or straw, etc., which may be carried down by the tins is blown back into the screen and discharged on to the picking belt. The combined electric blower is arranged with a fantail mouthpiece which is directed at the opening in the chute and this opening is made adjustable to suit the required conditions.

The arrangement of the switchboard for controlling the Rapid Patent Screen Type Separator is shown in Fig. 26. Fig. 27 shows the connections of the Rapid Patent Potentiometer Pattern "Drum Type Crank Handle Operated Controller" of the totally enclosed type. This controller is known as the "Midget" non-

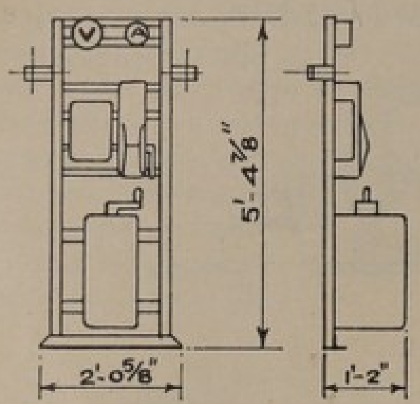


Fig. 26.—Arrangement of switchboard for electro-magnetic separator.

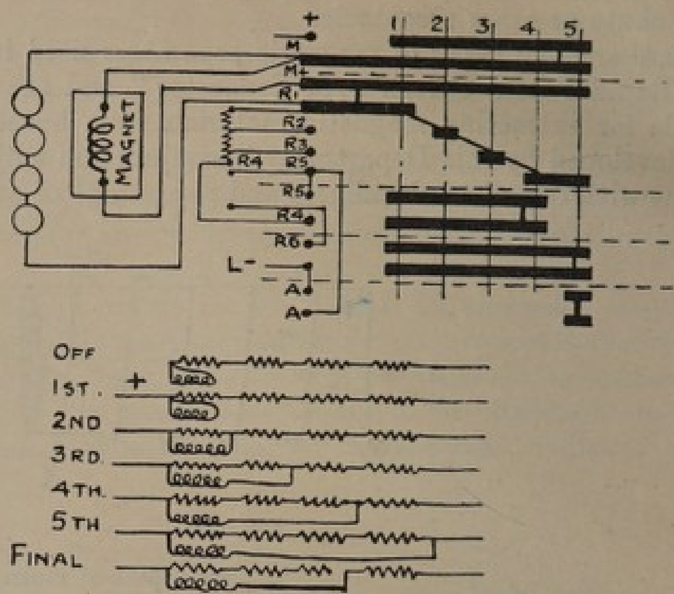


Fig. 27.—Diagram of patent improved 5M8E, potentiometer controller for highly induced currents.

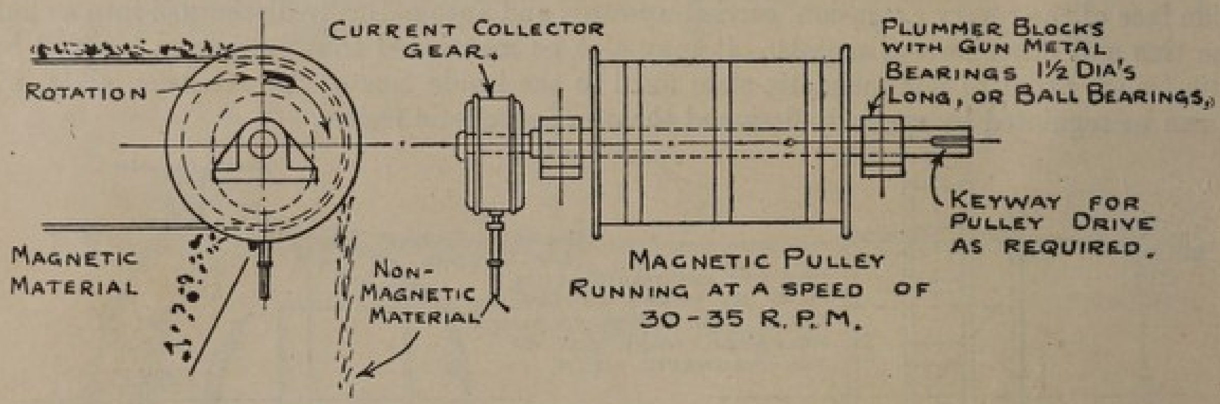


Fig. 28.—"Rapid" patent electro-magnetic separator pulley.

Fig. 29.—Outline of shunt break switch and pilot lamp.

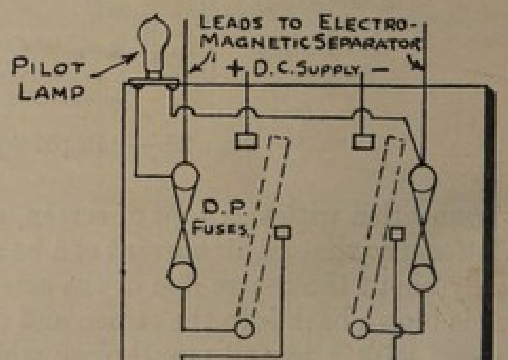


Fig. 30.—Diagram of switch connections.

reversing type and is arranged with four points in one direction fitted with spring return and complete with all necessary series of non-inductive resistance units. It will be noticed that the mains are connected to + terminal and − terminal and that the magnetic separator is across terminals M and M_1, all other switch and fuse gear, etc., being connected to the mains.

With regard to the pulley type of separator, the action is somewhat different. In this case, the terminal head pulley is replaced by a magnetic pulley. When material is in the vicinity of the magnetic pulley at the discharge end, the ferrous metal is attracted to the face of the belt and carried to the back bottom position, whereas the non-magnetic material, such as paper, bones, clinker, bottles, cinders and the like, is discharged, due to gravity, in the front of a diverting chute placed in a suitable position under the pulley, for separating the iron from the non-magnetic material. Fig. 28 shows this design and application.

When using high permeability steel, the field collapses very quickly when the current is broken, and this produces a high discharge voltage which very often breaks down the insulation.

In certain cases where the induction kick is high and there is a possibility of damage being caused, the installation of a patent controller instead of the shunt break double pole switch is advocated. The latter is shown in outline in Fig. 29, and diagram of connections in Fig. 30.

With regard to the patent controller, advantage is taken of the retentivity in the specially high permeability steel used, which forms the magnetic circuit, and it is claimed that a greater magnetic strength on contact surfaces is obtained, which would not be possible with any other type of control.

Part V. Baling Plants.

Hydraulic Scrap Baling Plant.

It has been shown how the scrap tins and other metals are separated from the house refuse and it will be readily appreciated that their bulk is relatively large when compared with their weight. The present practice is to compress recovered tins into bales of convenient size either with or without the removal of the tin, and then pass to the smelting furnace for further treatment to make commercial steel.

To achieve the compressing of scrap tin, some form of press is used, which may be mechanical or hydraulic. The hydraulic system is economic, moving parts are relatively small and there is little or no danger in overloading the presses. Mechanical plants are also manufactured, which have the merit of being simple and economic.

To understand the principle of hydraulic methods of pressing, it will be necessary to consider some of the underlying principles of hydraulics :—

First—water (which is the fluid used on the hydraulic plants under discussion) is to all intents and purposes incompressible.

Secondly, the pressure exerted at any one point is exerted equally on all surfaces.

By reference to Fig. 31, assume box Y is fitted with two plungers, A and B, the area of A being twice that of B and the box being completely filled with water. Now suppose a known weight, W, is placed on the plunger B, it would be found that in order to keep plunger A stationary, it would be necessary to place on top of it a weight equal to twice W.

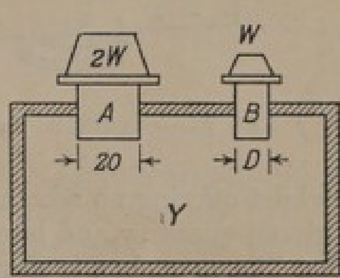


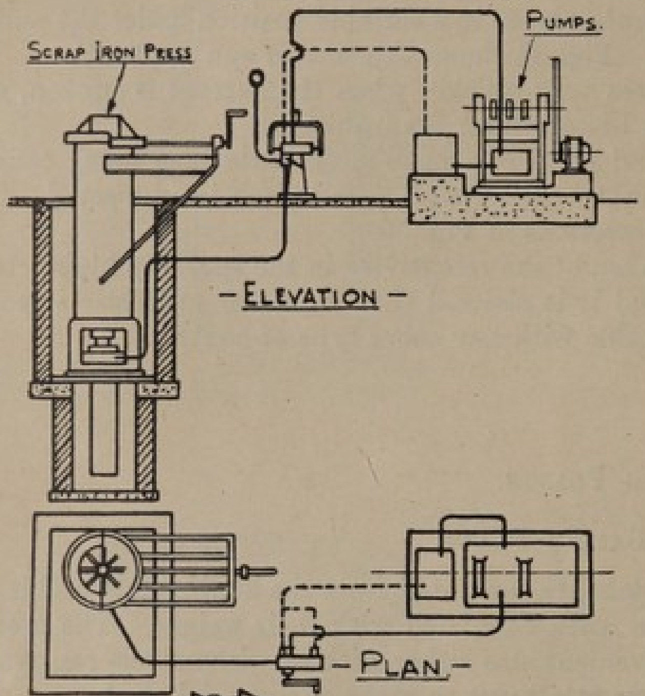
Fig. 31.—Principle of the hydraulic press.

To carry this still further, any number of plungers the size of A may be put in the same box and without increasing the size or number of plungers B, each plunger of size A would sustain a weight equal to twice W. That is, supposing in the box Y there are 1 plunger B and 6 plungers A, the total weight which the weight W on plunger B would sustain would be 12 times W.

Hitherto, the weight has been considered to be stationary; now let it be supposed that it is desired to raise the weight on A some definite amount, it would be found that the plunger B would have to be moved down by an amount equal to twice that which it is desired to raise the weight on A, and in the second case, viz., 6 plungers, 12 times as much. Thus the weight remains constant but the distance passed through alters in direct ratio to the weight to be lifted or sustained.

The simplest plant consists of a set of pumps and press box as shown in Fig. 32. The hydraulic pump for an installation of this size would be of the two-plunger type, a larger diameter plunger for the early stage of compression, that is, a plunger which is capable of pumping a large quantity of water against a small pressure head, and a second plunger of lesser diameter for the final compression. This type of pump,

Fig. 32.—Simple type of scrap baling plant.



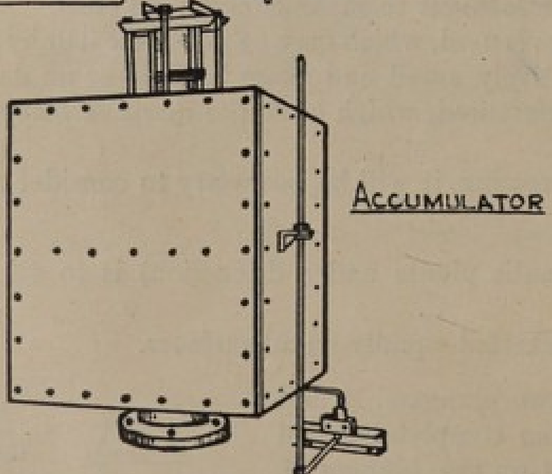


Fig. 33.—Hydraulic accumulators for baling plant.

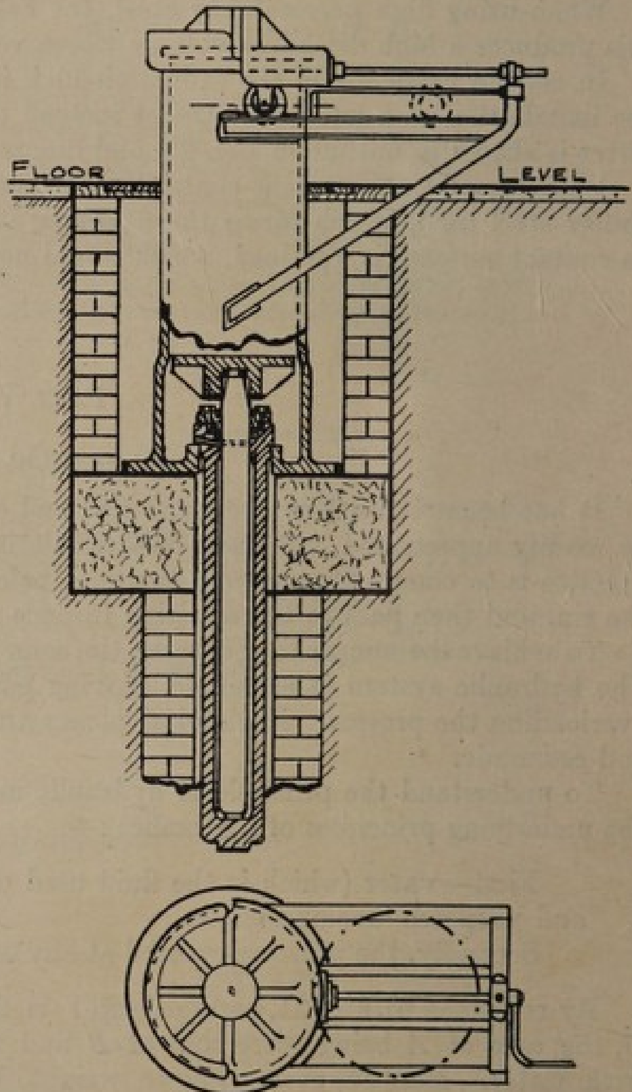


Fig. 34.—Scrap metal baling press.

whilst offering no advantage in power economy, has the advantage in the early stage of compression of giving quantity and later reduced quantity and increased pressure.

The press box is shown in Fig. 34. It consists of a cast steel or cast iron box approximately 4 feet deep by 26 inches in diameter, or such area and depth as would hold roughly 18 cubic feet of loose scrap. Into this box a table is fitted and connected to the hydraulic ram. It is usual to arrange this box below ground level, so that the top of the box may be at a convenient height above the floor for ease in handling bales.

Rigidly connected to the box or container is the hydraulic cylinder, into which water is pumped by the pumps mentioned previously, exerting pressure on the hydraulic ram connected to the table.

The method most commonly adopted to make a water joint capable of withstanding the heavy pressure imposed, is by means of a U leather either fitted into a groove turned in the cylinder or into a recess with a covering gland. The size of the hydraulic ram is determined by the pressure at which it is desired to work the pumps, but it may be taken that the total pressure on a bale having an area of about 3½ square feet should not be less than 50 tons to ensure a satisfactory bale, that is, one which will hold together by compression alone, without the aid of wires or other binding material.

The output of a plant of this description using a 6 h.p. motor to drive the pumps should be about 3 tons per day of 8 working hours. It is possible to obtain a much larger output from the press by increasing the

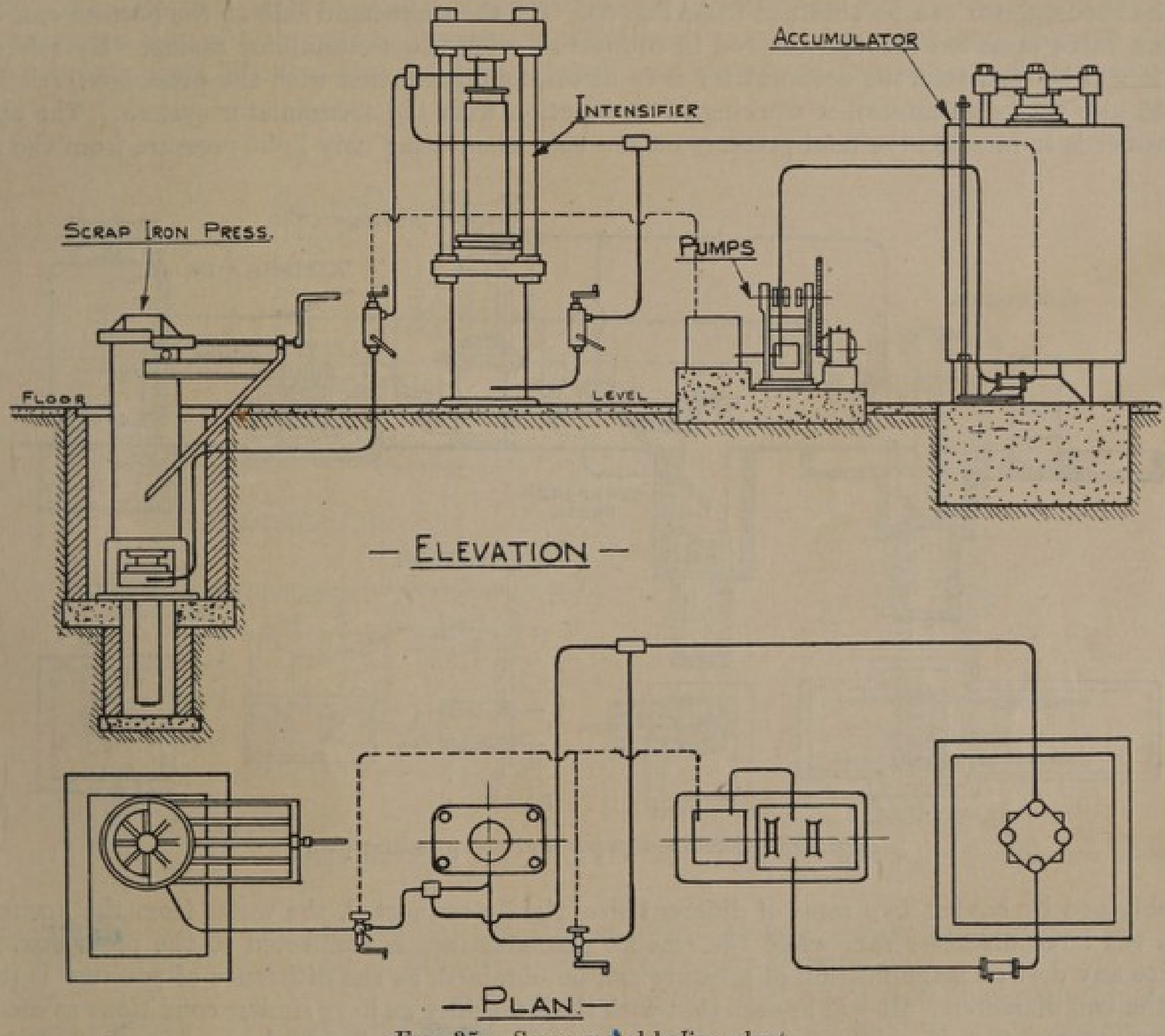


Fig. 35.—Scrap metal baling plant.

size of the pumps and with the addition of an accumulator and intensifier. This system is shown in Figs. 35 and 36. Fig. 36 shows the scheme, into which is incorporated a paper baling press in addition to the scrap press. On reference to Fig. 35 it will be seen that the pumps do not pump the water direct to the scrap press as shown in Fig. 32, but into the accumulator.

The accumulator, whose function is to absorb the work done by the pumps when the presses are at rest, consists of a cylinder and ram much the same as the press box, but usually of somewhat larger dimensions in order to obtain sufficient capacity for water. The ram is loaded with heavy weights, against which the pumps must work when filling the cylinder, and the maximum working pressure obtainable is determined by the amount of loading placed upon the ram.

An accumulator may be built to give any desired pressure, but that most used in scrap bundling plants is between 700 and 2000 lb. per square inch, the pressure used depending upon the size of the rams employed in the scrap bundling press. To the accumulator is fitted a duplex valve which when the accumulator has reached a predetermined height is full of water; the valve opens by means of a tappet arrangement and allows the pumps merely to return the water to the suction tank until such time as the accumulator falls, due to some of the water being used, when the valve closes and the pumps again pump into the accumulator. By this means much power is saved, as when the stored quantity of water is sufficient the pumps are pumping against atmospheric pressure only and not against the weight of the accumulator.

It may be mentioned that when an accumulator is employed it is usual to install a pump having two or more plungers of equal diameter, and not of different diameters as in the previous scheme. A general idea of the accumulator can be obtained from Fig. 33. On the right-hand side at the bottom can be seen the duplex valve operated through the rod in connection with the accumulator casing. By reference to Fig. 35, it will be seen that the accumulator is in direct communication with the press box.

Fig. 35 also shows an intensifier working in conjunction with the accumulator system. The object of the intensifier is to increase the final pressure on the bale when using only light pressure from the pumps.

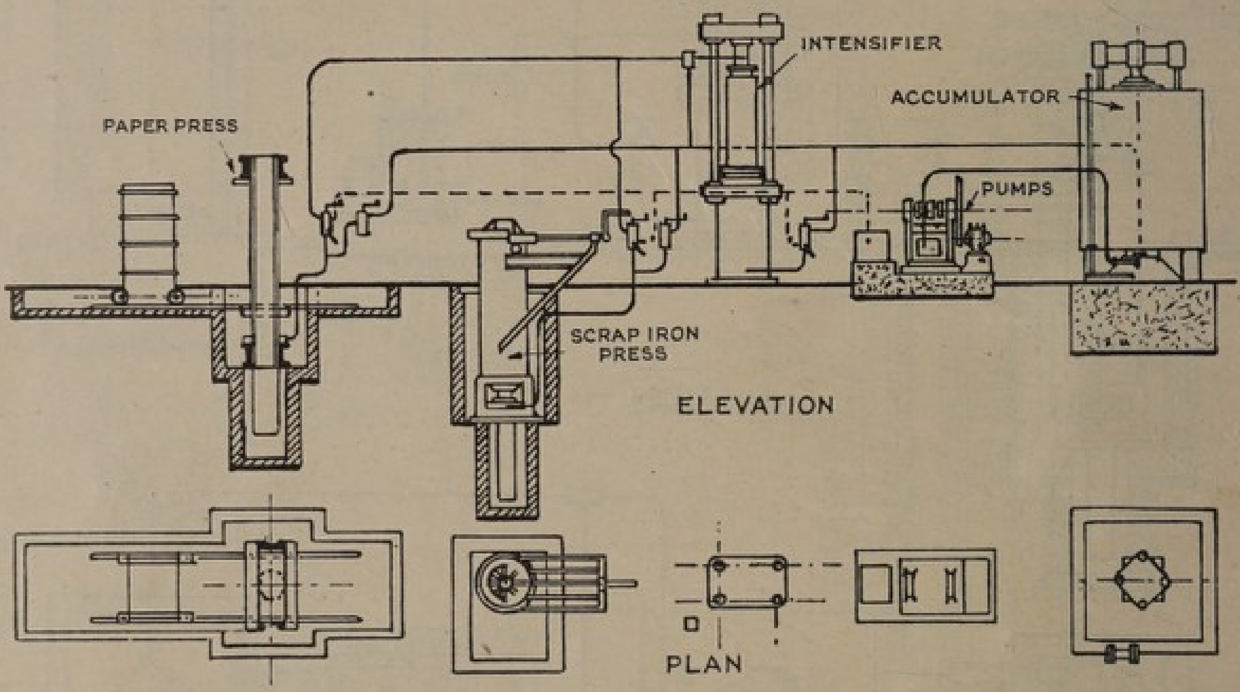


FIG. 36.—Combined paper and scrap baling plant.

This is obtained by having two rams of different size, rigidly connected, the water from the accumulator being on the large diameter ram while the smaller diameter ram is connected to the press box. With this device any desired magnification of pressure can be obtained, as the difference of pressure is in direct ratio to the two diameters. It will be seen that with the intensifier we have similar conditions as mentioned in the first scheme, that is, a large quantity of water at low pressure (large plunger) for first compression and high pressure, and small quantity (small plunger) for final compression. A general idea of the intensifier can be obtained from Fig. 38.

The operation of the accumulator and intensifier is controlled by valves which are placed near to the press box in order to be easily manipulated by the attendant.

Assuming the press box to be full of tins, the operation of the valves is as follows: the valve is opened which connects the accumulator to the press box, thus admitting water under the pressure of the accumulator.

When the tins have been reduced in bulk by this pressure, the intensifier is charged by opening another valve, which brings the large ram into communication with the atmosphere, thus allowing the smaller cylinder to fill with water from the accumulator. This being done, the valve is closed and another valve opened which connects the larger diameter ram with the accumulator; this causes the pressure on the smaller diameter ram to increase and be forced out into the pipe leading from the accumulator to the press box, in which main it is prevented from returning to the accumulator by a non-return valve which is self-operating, being placed between the intensifier and the accumulator. After the tins have been fully compressed the valve which was first opened is closed, also the valve from the accumulator to the intensifier, and the valve is opened which connects the press box with the exhaust or return main. This allows the press ram to fall. It is usual to allow the ram to fall a short distance only, sufficient to allow of the lid being opened and the valve closed again, the lid of the press box removed and the valve connecting the accumulator with the press box opened to push the bale out of the box for removal. The exhaust valve is then opened and the ram allowed to fall to its full depth ready for recharging.

In Fig. 36 is shown a plant in which is incorporated a paper baling press. The operation of this is exactly similar to that of a scrap baling press, the difference being in the container. The size of the container is approximately 50 cubic feet, having an area about 8½ square feet and a depth of 6 feet. The

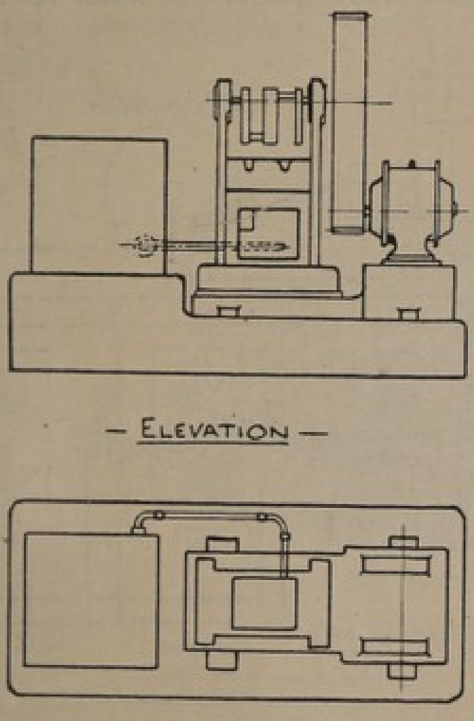


FIG. 37.—Vertical pumps.

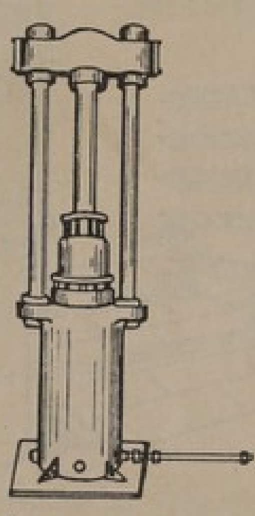


FIG. 38.—Hydraulic intensifier for baling plant.

final size of this bale when under a total pressure of about 30 tons would be approximately 3 feet 6 inches × 2 feet 6 inches × 1 foot 6 inches and would weigh about 2½ cwts.

The box or container for holding the loose paper is usually built up of mild steel plates and sections, and not as is the case with the scrap press of cast iron or cast steel. This is not made so strongly, as the pressure is not taken up by the box but by a beam across the top against which the paper is pressed. Unlike the metal scrap, the paper will not hold together without some method of binding. This binding is done while the bale of paper is still under pressure. The binding is usually of soft iron wire passed round the bale and the ends are twisted up so as to prevent the bale opening. A paper-baling press is shown in Fig. 39.

In the operation of this plant it will be understood that there must be considerable movement of water from place to place, for while the pressure is applied with a stationary column of water, the various vessels have to be filled and to do this water must pass along the pipes. The velocity of the water in these pipes should not exceed 100 feet per minute at 700 lb. pressure per square inch. Owing to the great pressure which is employed, large diameter pipes are not generally used, as the thickness of metal necessary becomes excessive.

There is another consideration to be made with regard to high velocities, *i.e.*, that due to shock. Let us imagine a column of water which weighs perhaps 5 cwts. moving at a high velocity, to be suddenly stopped, it will be seen that this would impose a tremendous strain on all parts of the machinery.

Again, let us suppose that the accumulator, weighing, say, 30 tons, is at the top of its travel, perhaps 12 feet above ground. Open a large pipe suddenly and allow it to remain open until the accumulator is 2 feet from the ground, close the pipe suddenly, and try to imagine the enormous blow that the 30 tons would strike. From this it will be readily understood that it is advisable to have hydraulic machinery moving at slow speeds.

A real evil to hydraulic work is that of grit and dirt in the water system, and every precaution should be taken to guard against it. Not only do these impurities cut the valves and seatings, but should a very small piece of grit get below a valve, the high pressure on one side against a low pressure on the other allows a high velocity to be attained by the water and it is almost impossible with normal capacity plants for the pumps to keep pace with the attendant leak. This evil also has the effect of allowing the water, where it passes through, to wear away the valve in the form of small grooves, known as water cuts.

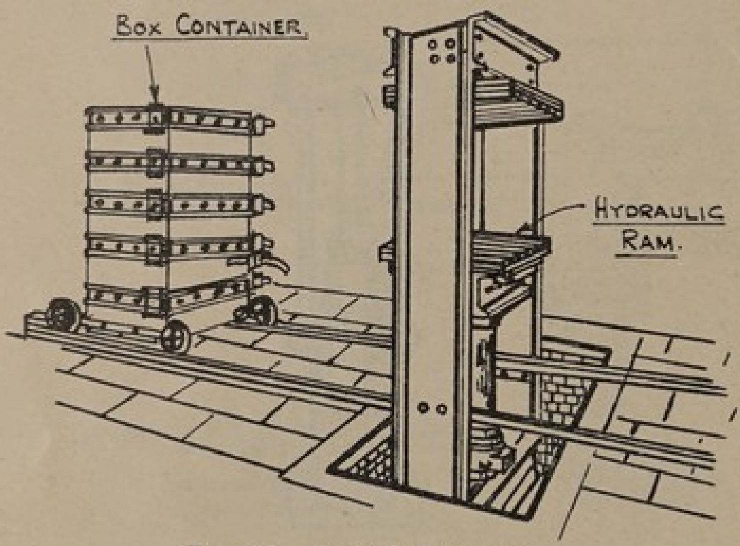


Fig. 39.—Paper baling press.

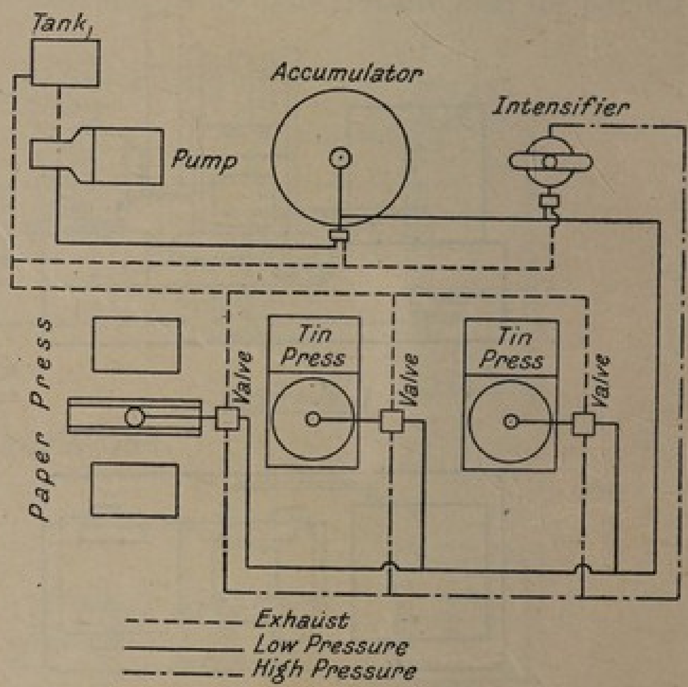


Fig. 40.—Diagrammatic arrangement of paper and scrap baling plant.

It is therefore most important that all the water for hydraulic plants should be soft, thoroughly strained or filtered, the strainers or filters kept clean, and every precaution taken to avoid dust and dirt getting into the system at any point. To the water should be added a soluble lubrication so as to reduce the wear and tear of leathers, packings, rods, rams and valve-faces to a minimum.

Another important point in the design of the presses is a coppered ram enclosed in a protector of Chinese lantern pattern. The ram being coppered lessens the wear and tear on the leathers and the crinoline prevents grit or other foreign material from scoring the ram. The plant described is the one fitted at the Montague Street Works of the Birmingham Salvage Department and is made by Messrs. John Shaw and Sons (Salford), Ltd.

A diagrammatic arrangement of the hydraulic baling plant at the Tyseley Works is illustrated in Fig. 40. The plant in this case was made by the Leeds Engineering and Hydraulic Co., Ltd., Rodley.

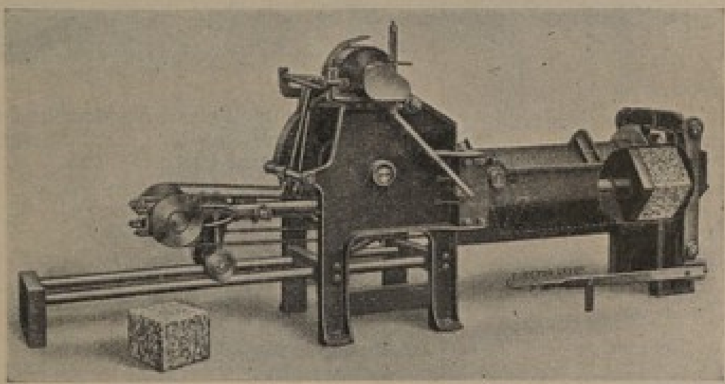
Mechanical Presses.

The mechanical press, as its name implies, is operated by suitable mechanical means as distinct from hydraulic pressure, the most usual form being that of a belt drive.

Fig. 41 illustrates a mechanical press, from which it will be seen that it consists of a press box fitted with a hinged lid, centred at one end and balanced. When closed it is effectively locked with a hinged bar. The box is cast diagonally to provide a larger opening for filling than would obtain with a horizontally cast box. A press box, size 3 feet 8 inches × 12 inches × 12 inches, makes a bale of cans 12 inches × 12 inches × 8 inches up to 12 inches thick, and weighing approximately 40 lb.

The ram has a cast-iron or steel head at one end, and a hinged crosshead at the other to carry sets of pulleys on each side of the ram. Steel hausers are fitted over these pulleys and form the equivalent of two sets of pulley blocks, one on each side of the ram. On the winding shaft three scrolls are fitted, two of which are for pressing, and one for returning the ram. The ends of the pressure hausers are attached to the larger pressure scrolls at the commencement of the pressure operation, and on the smaller scrolls at the finish, thereby exerting a greater pressure as the bale is compressed, and thus offering a greater resistance to the ram (this takes the place of an intensifier in a hydraulic plant). The return scroll at the conclusion of the pressing operation returns the ram to its original position. Automatic stops at each end of the stroke and brakes are provided to prevent over-winding. The stops can be adjusted to allow the ram different lengths of travel, thereby giving bales of 8 inches, 10 inches and 12 inches thick, according to a predetermined setting.

After the lid is raised, a handle is moved to put a friction pulley in action to return the ram, and a lever on



[*By courtesy of Messrs. Spencer and Cook, Ltd.*

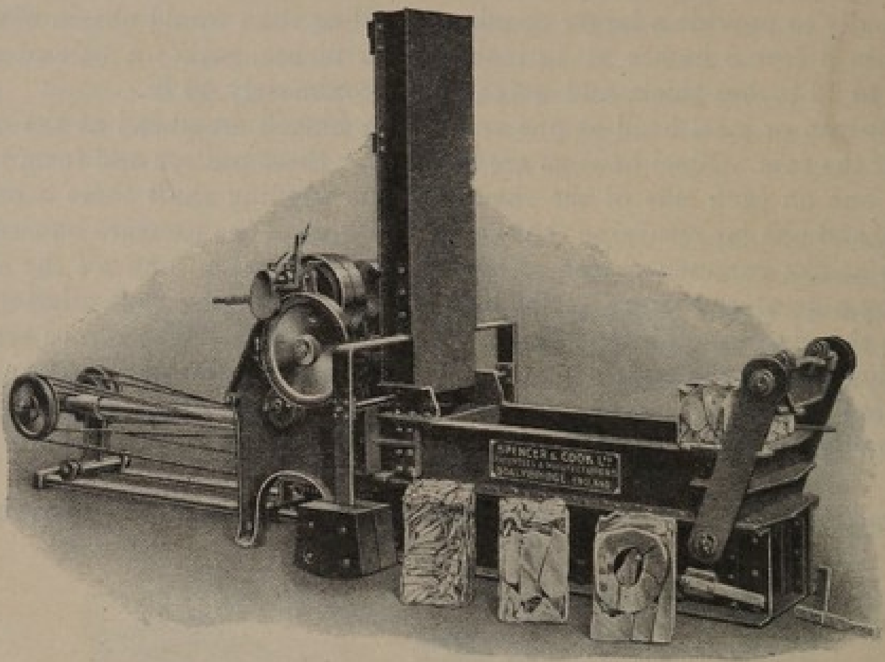
FIG. 41.—Standard scrap metal baler.

the side of the press is used to lift the bale into position for the operator to remove it. The whole operation of filling, pressing and removing one bale occupies approximately $2\frac{1}{2}$ to 3 minutes, but the manufacturers state that in practice the output is about fifteen bales per hour, if the tins are placed conveniently. A leather belt is used for driving from the motor, engine or shafting. The belt cannot exert a breaking pressure on the mechanism, and acts as a safety device, in that if any undue pressure is applied, the belt will either slip or break. The stress on the gear wheels, which are machine cut, is very gradual and repairs are therefore reduced to a minimum. The ropes require renewal when they fray, but this is only a minor cost.

The power required for driving this press reaches a total of 3 H.P. when the compression of the bale is reached, but previous to this state of compression the horse power exerted varies from $\frac{1}{2}$ to 1. Fig. 42 shows a press similar in construction to the one described above, but is of larger capacity, and therefore constructional details are of more generous dimensions. This particular press will handle from 2 to $2\frac{1}{2}$ tons of tins per day of 8 hours. Presses of larger capacity are also made to suit requirements.

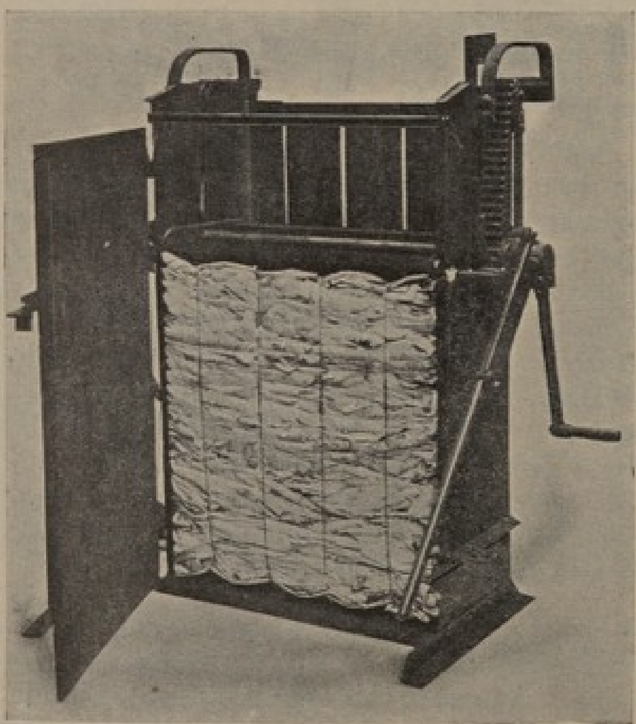
PAPER AND RAG PRESSES.

Hand or power presses may be used for paper or rag baling. A press of this type is illustrated in Fig. 43, and such presses are simple, quick and powerful. When the quantity of paper or rags assumes sufficient importance to warrant it, a mechanical press will, of course, be more efficient. These presses are capable of producing a bale weighing 2 or 3 cwts., and two operators can produce five such bales per hour. The presses work on the same principle as the tin presses, but are vertical and are filled from the front. After



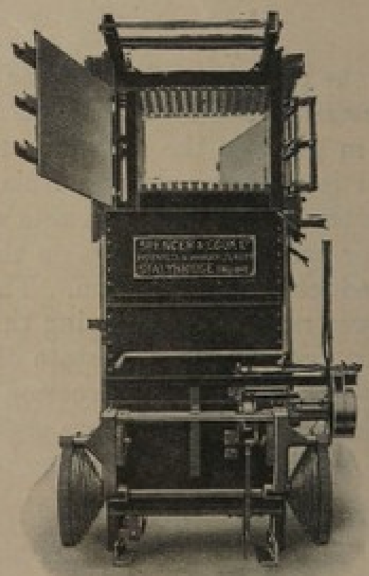
[*By courtesy of Messrs. Spencer and Cook, Ltd.*

FIG. 42.—Heavy scrap metal baler.



[*By courtesy of Messrs. Spencer and Cook, Ltd.*

FIG. 43.—All steel hand baler for paper and rags.



[*By courtesy of Messrs. Spencer and Cook, Ltd.*

FIG. 44.—Power baler for paper and rags.

the door is closed, the remainder of the material is filled in from the top, the lid wheeled over, and the bale pressed. The doors are then opened and the wires fastened round the bale. Bales cannot easily be removed from box presses even if the sides are tapered, unless adjacent sides of the bale are freed. On

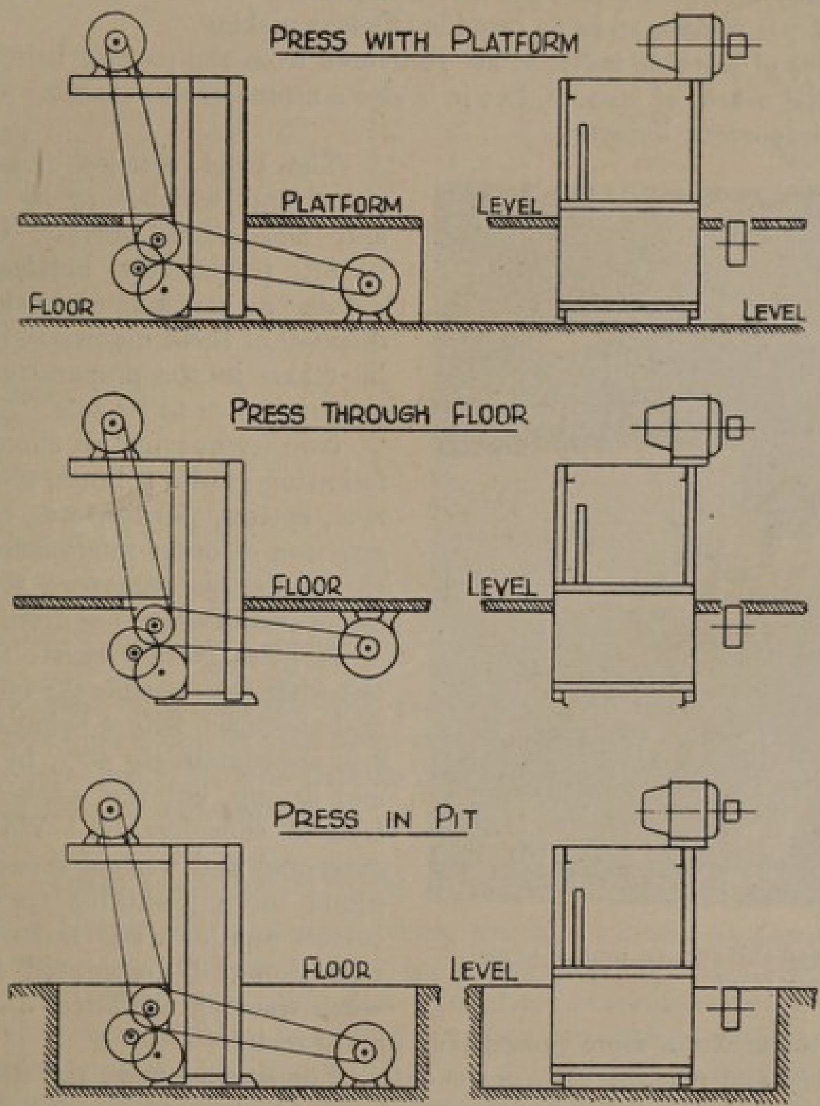


FIG. 45,—Lay-out of paper and rag baling plant.

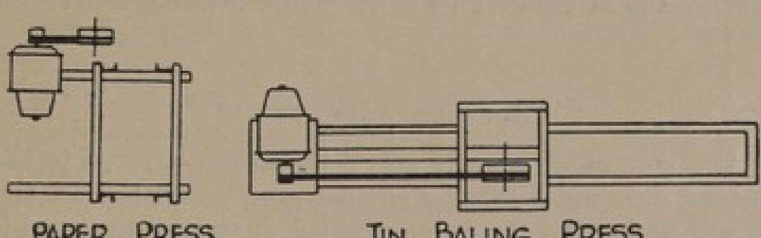


FIG. 46.—Lay-out of tin and paper presses.

the presses illustrated in Fig. 44, the front and back are freed when the doors are opened. One end is released by raising a lever, which allows an end of the box to fall away and thus leave the bale free for removal.

A typical layout is shown in Fig. 45. Fig. 46 shows a simple layout of tin and paper presses.

Such mechanical presses are made by Messrs. Spencer & Cook, Ltd., Stalybridge, nr. Manchester.

Picking Belt.

The picking belt is usually a band conveyor and as such has already been described. Other forms, such as the steel plate, tray and grid types, are also successfully used. The speed, however, of any type should not exceed 40 feet per minute so as to provide efficient picking.

Considerable quantities of saleable material are recovered from the picking belt, and this material not only provides a substantial source of income, but it is also a means of maintaining a continuous supply of raw material to several important industries.

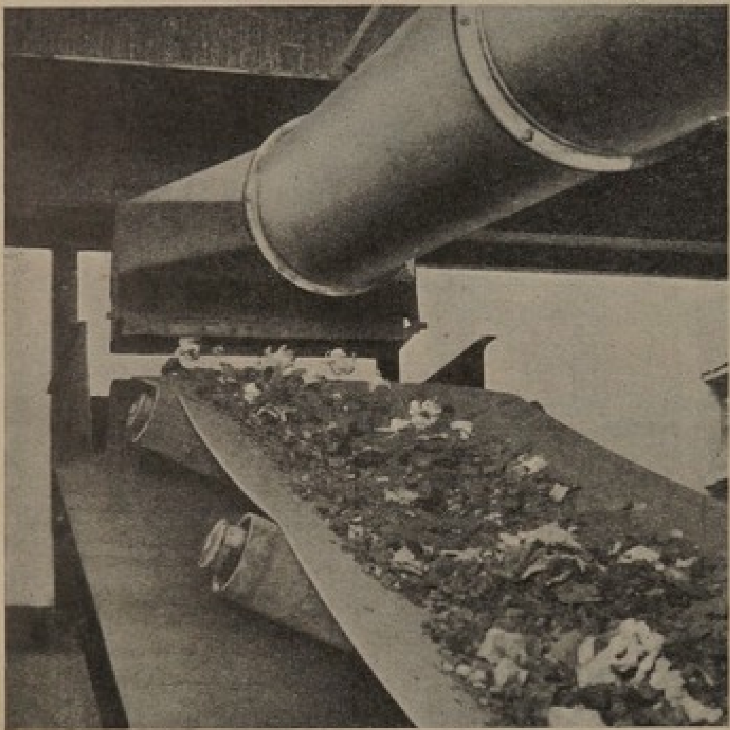


Fig. 47.—Adjustable hood and suction pipe of paper recovery plant.

The chief articles possessing a marketable value and which may be recovered are ferrous and non-ferrous metals, bones, rags, bagging, paper, proprietary bottles and jars, etc. To obtain a continuous outlet for the profitable disposal of these materials, it is essential that care be taken in the preparation and packing of the material prior to its sale.

Non-ferrous metals should be sorted into the following grades: brass, aluminium, lead, copper, zinc, spelter, pewter, etc., care being taken that any iron or other inferior metal is not mixed with the grades, as otherwise the customer will want considerable allowance from the amount charged.

A good market exists for rags and bagging, but wherever possible the former should be washed and sterilised before being sold. Unwashed rags lose approximately 40% by weight after washing and drying, but the market value is thereby increased considerably. Woollen rags should be extracted and washed separately, and it may be found more profitable to collect all good-sized cotton rags and sell them for wipers. Coloured rags should be separated from white rags and when washing the latter a quantity of bleaching powder should be used to impart a more presentable appearance.

The profitable recovery and packing of paper is entirely dependent upon the state of the waste paper market, as it frequently happens that merchants are not able to pay a price sufficient to repay the cost of recovery and packing.

Bagging, old carpets, etc., should be thoroughly dried before pressing into suitably-sized bales, ready for the market.

Bottles, Jars, etc.

Proprietary bottles and jars command a ready sale if they are delivered to the packers in a clean condition. Where the Department does not wash the bottles, etc., before selling, they should only be sold to a reputable merchant who will undertake the responsibility of thoroughly washing them before they are passed on to the merchants for re-use.

There are other saleable articles which may be recovered and sold, including skins, rubber, broken glass, etc., but a great deal depends upon the state of the waste markets if their recovery is to show a profit.

The following table shows the actual quantity of material recovered and sold at one Salvage Depot in Birmingham during the year ended March 31st, 1928. Total amount of refuse dealt with 37,736 tons.

	Quantity.				Price Realised.		
					£	s.	d.
Bottles and Jars	12,845 doz.				165	5	8
Skins	161 ,,				17	2	1
	T.	C.	Q.	Lb.			
Brass	7	4	0	11	243	18	6
Lead	1	0	3	0	23	4	6
Aluminium	2	6	2	0	151	2	6
Copper	1	8	2	11	66	8	3
Zinc	2	9	2	0	45	13	0
Pewter		3	3	1	21	1	0
Spelter	1	19	0	0	40	19	0
Rubber	1	6	0	8	18	5	1
Rags	105	19	0	0	235	6	9
Paper	83	5	0	0	60	14	9
Bagging and Carpets	69	11	3	0	197	14	0
Bones	100	3	0	0	491	18	6
Woollen Rags		1	0	0	1	0	0
Light Iron	92	18	2	0	113	0	5
Woollens	8	15	0	0	106	16	0
Broken Glass	44	6	0	0	16	5	11
Gold	–	–	–	–	1	12	0
Silver	–	–	–	–	12	5	1
Miscellaneous	–	–	–	–		10	0
	522	17	2	3	£2030	3	0

One man and four youths were engaged upon the recovery of these materials and a bonus was paid to them upon sales; it is interesting to note that so effective is the bonus scheme in eliminating petty pilfering, etc., that during a period of nine months over 170 ounces of silver and 4 ounces of gold were recovered and sold from the picking belts.

Utilisation of Garbage and Vegetable Refuse.

The scarcity of fats in almost every country during the late war was responsible for quite a number of suggestions and processes having for their object the extraction of oils and the preparation of fertilisers from garbage—note the distinction—purposely separated either at some cost or as an act of implied duty. It may at once be said that current values of oil and fertilisers are such as effectively to prohibit such processes now, except in a few instances. Usually the refuse was carefully sorted and the separated garbage dried in suitable apparatus, whereupon low grade solvents were admitted, the mass was digested and finally the solvent and abstract were withdrawn and separated by distillation in the usual way. The residue after grease abstraction was ground and sold for fertilising purposes, its value being a matter of pure speculation. Within the same category, mention may be made of steaming processes which liberate certain oils which can be isolated in the usual way, but the difficulty of the waste effluent is by no means easy, and if allowed to accumulate this forms a very objectionable product.

The raw material referred to above is usually termed "garbage," which term is generally understood to cover such organic food wastes as occur in, say, houses and hotels. In America the treatment of such garbage even to-day is the basis of many highly successful businesses.

The subject matter of this item is totally distinct from organic wastes such as meat and fish-market refuse.

Atmospheric Pollution.

Atmospheric pollution in its various forms is a problem which has engaged the attention of responsible authorities for a considerable time. One form of such pollution which is constantly becoming more intense is that of dust issuing from industrial chimneys. So serious has this become that Local Health Authorities have now acquired powers for taking legal action against parties causing such pollution. Smoke abatement

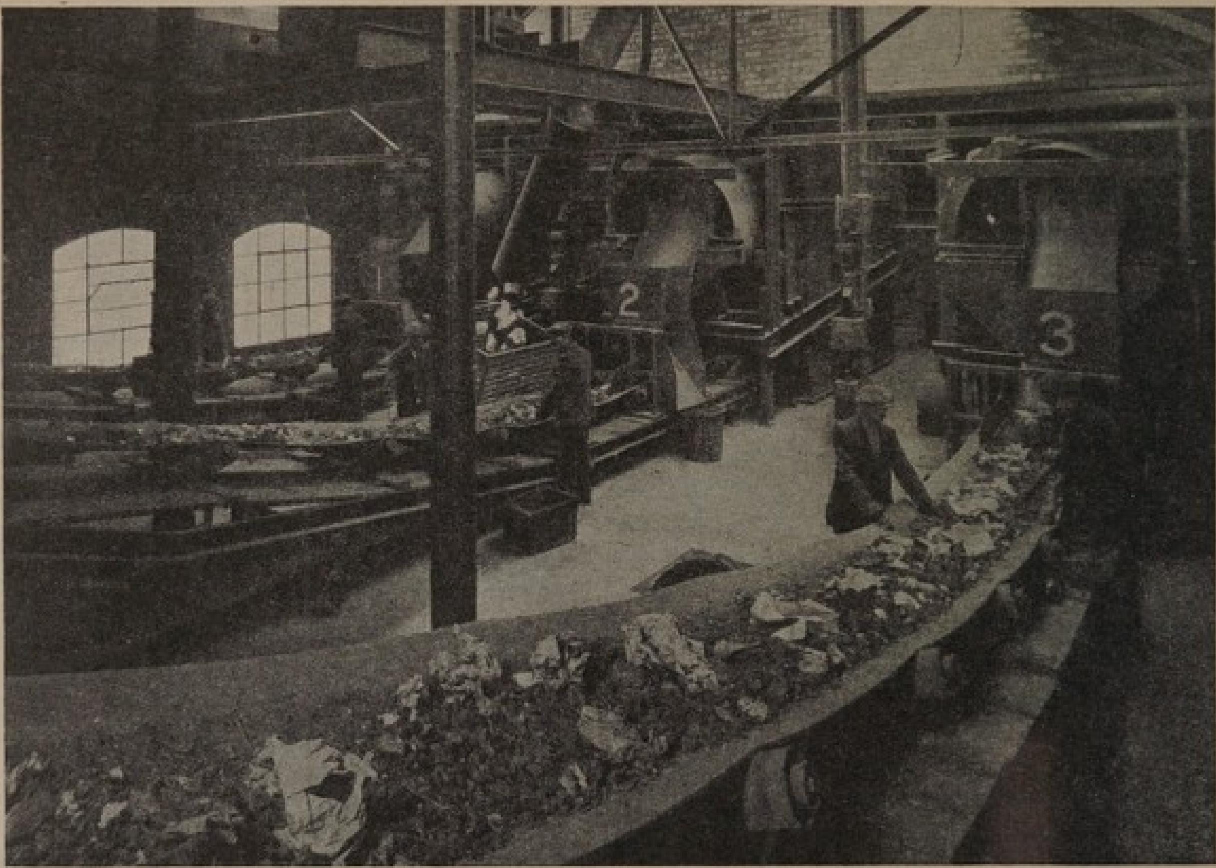


Fig. 48.—View of picking belts, Brookvale Road Depot, Birmingham.

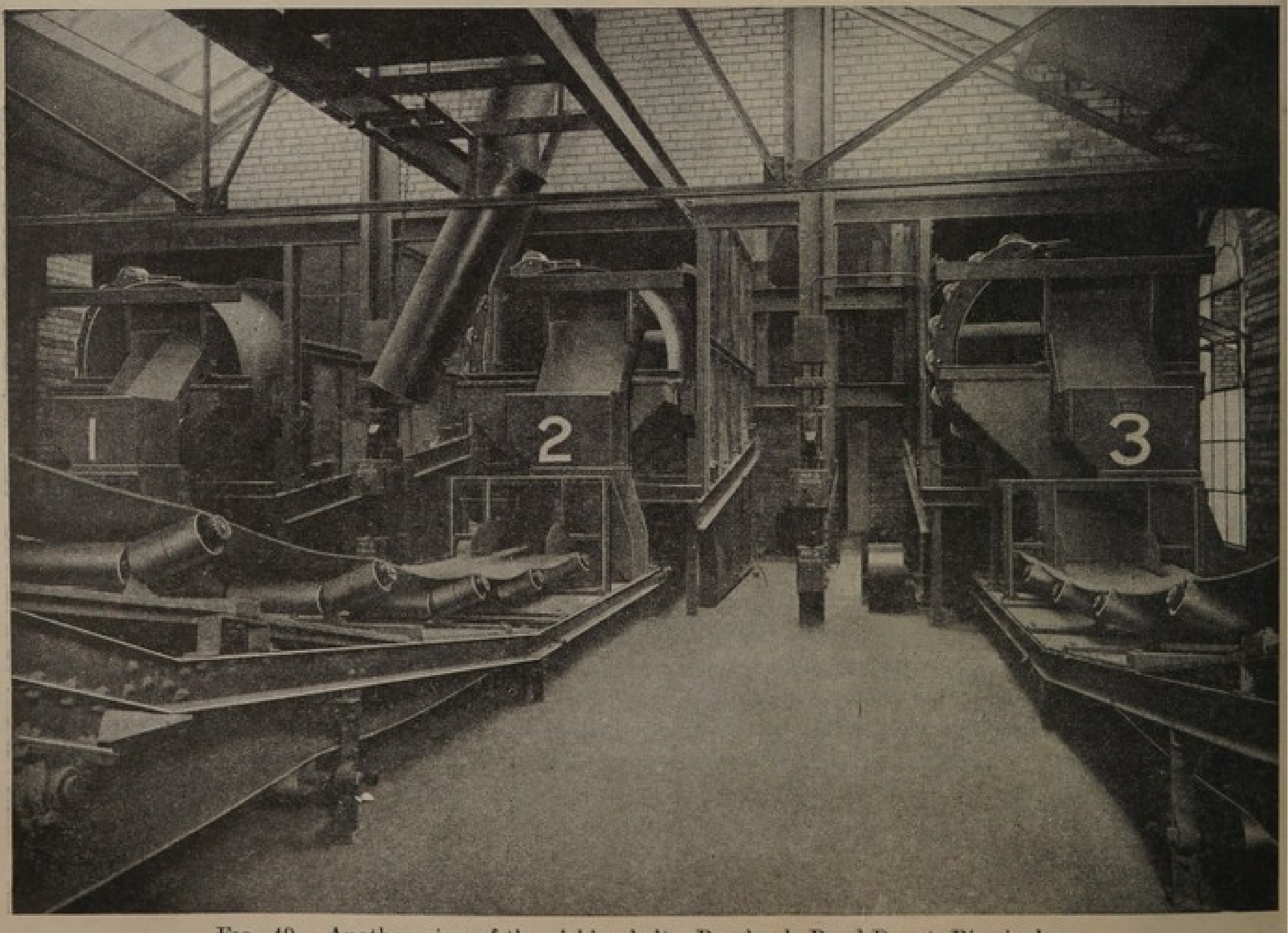


Fig. 49.—Another view of the picking belts, Brookvale Road Depot, Birmingham.

has already received considerable attention and much ingenious apparatus is in operation to prevent the nuisance of excessively heavy smoke emission. Interest is now centred on the control or elimination of the dust which, issuing from industrial chimneys, causes both inconvenience and monetary loss in the environments, besides constituting a nuisance in the legal sense.

Obviously one contributor to this atmospheric pollution is the refuse disposal works, where the nature of the refuse destroyed, consisting principally of ashes, paper, vegetable matter, etc., collected from all sources, is such as to make the production of dust and grits unavoidable, and although high chimney stacks are usually provided to convey the gases from the burning refuse to the atmosphere, the dust particles carried in the gases are not sufficiently dissipated in the atmosphere to prevent their settlement, particularly in congested areas, where considerable nuisance is caused.

As an experiment, therefore, the Davidson Grit Collector was applied to a four-cell refuse disposal plant fitted with a forced draught fan and connected to a Babcock and Wilcox water-tube boiler. The grit collector is of the "shunt suction" type, and consists of two elements—a primary separator of volute shape, and a secondary collector inter-connected by relatively small ducts, and all of steel construction.

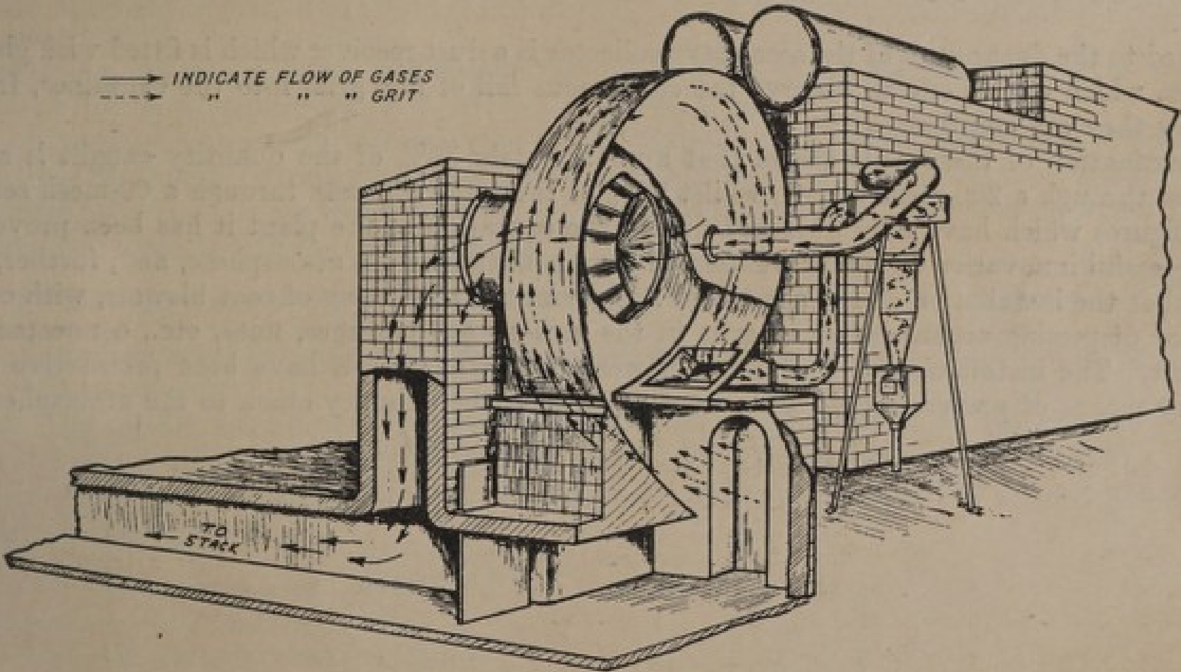


FIG. 50.—Grit collector, as installed at the Montague Street Depot of the Birmingham Corporation Salvage Department.

The inlet of the primary separator makes connection to the main flue, after the gases at a temperature of about 500–700° Fahr. have passed through the Babcock and Wilcox boiler. Under the action of the draught power set up by a 265 feet chimney stack, the gases naturally try to follow a path represented by the shape of the primary separator, the casing of this separator being of volute formation. Due to centrifugal force the dust particles, which are heavier than the gases, are forced out against the periphery of the volute casing, and as the radius of the casing decreases, the centrifugal force increases until it attains a maximum at the minimum radius. At this point a tangential slot is arranged, connecting with a pocket from which a steel plate duct communicates with the secondary dust collector, and as the term "shunt suction" implies, a certain quantity of the gases is shunted through this duct from the primary separator to the secondary collector. This collector is also of volute formation, and a similar action takes place in this as in the primary separator, with the exception that the grits which have been gas-borne from the primary separator, and forced down partly by gravity and partly by the conical formation of the casing attached to the volute into which the grits are first discharged, follow a spiral path to the dust outlet at the bottom of the collector, leaving the gases which have borne the grits, and form a vortex in the centre of the collector, to pass upwards through a gas outlet, and through a further steel duct making connection to the side of the primary separator. This dust comes under the action of the draught power exerted by the chimney stack over the primary separator. The volume of gases which enters the primary separator, apart from the small quantity which passes through the slot in the same for the purpose of conveying the grits to the secondary collector, passes through the side of the primary separator through a brick connection joining up to the main flue running to the chimney stack.

As will be understood from this description and the perspective (Fig. 50), the action of the grit separator is entirely controlled by centrifugal force and the natural draught of the chimney, and there being no moving parts whatever in the plant, upkeep and attention are reduced to a minimum.

Naturally, the interposing of this apparatus between the boiler and the chimney stack could not be effected without a loss in draught power on the refuse burning plant. Normally an induced draught fan would have been required to overcome the resistance to the flow of gases set up by the collecting apparatus. In this case, the Salvage Department were fortunate in having a high chimney stack, producing a margin of draught over their requirements, which margin was sufficient to cover the resistance set up by the collecting apparatus, which is about 0·6 inch water gauge with a volume of approximately 40,000 cubic feet of waste gases flowing per minute. This feature has eliminated any running cost for the collecting apparatus.

Attached to the dust outlet of the secondary collector is a dust receiver which is fitted with glass inspection covers, which enable one to observe the continuous fall of fine grits into the container, from which periodically they are emptied.

An examination of these grits shows that approximately 35% of the quantity caught is sufficiently fine to pass through a 200-mesh screen, whilst 92% of the total will pass through a 60-mesh screen.

From figures which have been obtained during the operation of the plant it has been proved to be a highly successful innovation in the prevention of dust pollution of the atmosphere, and, further, it should be noted that the installation of the apparatus has permitted the fitting of soot blowers, with consequent facilities for dispersing accumulation of grits in the various gas passages, flues, etc., connected with the refuse plant. The installation of these soot blowers would, of course, have been prohibitive without a satisfactory means of preventing the grits from passing up the chimney stack to the atmosphere.

CHAPTER VIII

APPLIED MECHANICS

Professor Jamieson has said that applied mechanics is that branch of applied science which not only explains the principles upon which machines are designed, made and act, but also describes their construction and application.

Another authority says, "Mechanics is that science which treats of the action of forces upon bodies and the effects which they produce."

The foregoing, the writer thinks, will be sufficient explanation of this science to enable us to recognise it in the various forms of engineering, etc., dealt with in this book.

Units of measurement are first necessary before calculations, etc., can be carried out, and though many interpretations of these have been put forward from time to time by various authorities, I think the rendering by Professor Jamieson in his elementary treatise on applied mechanics, and which the writer recommends all to study, is simple and to the point, viz. :—

"*Force* is any cause which produces or tends to produce motion in the matter upon which it acts."

Again, force is that which changes or tends to change the state of rest of a body or of its uniform motion in a straight line (Strong).

British Engineering has adopted the pound avoirdupois as the Unit of Force, and the measurement therefore of a force of 9 lb. means a force equal to the weight of a mass which contains 9 lb.

Matter.—Anything that affects any of our senses we define as matter, and it is found under three conditions, viz :—

Solids—Iron, wood, steel, glass.
Liquids—Water, mercury, oil.
Gases—Air, oxygen, coal gas, steam.

We recognise solids by the fact that, unless acted upon by some extraordinary influence, such as heat or percussion, they have a tendency to keep their original shape and size.

Liquids, on the other hand, alter their shape continually, to suit the vessel in which they may be contained.

Gases have no size or shape.

Matter is composed of minute portions called particles, molecules and atoms, particles being larger than molecules, molecules larger than atoms, and atoms the smallest or indivisible portions of matter.

Some idea of the size of a molecule is obtained when we imagine that we can continue dividing and re-dividing matter in this case, say water, until one more division alters the state of the body, the composition of water being 2 parts of hydrogen gas to 1 part of oxygen gas. When we come to the division where liquid water turns into gas we can assume that we have reached the portion called a molecule. In other words, that point where water is liquid and one more division forms a gas will give us a molecule of water.

There are many properties of matter, some of the important ones being as follows :—

Weight, tenacity, elasticity, divisibility, hardness, porosity and impenetrability.

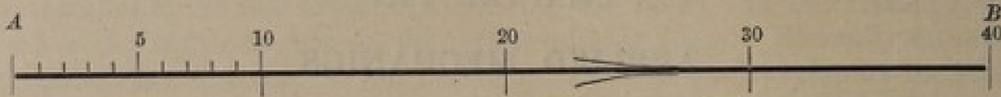
These properties are possessed by solids.

In liquids we have viscous and mobile, and gases—heavy gas, such as fire damp in coal pits, or light gas, such as hydrogen.

Forces can be shown graphically by lines, the direction of the line representing the direction of the force, and the length of line to some particular scale giving its magnitude.

In addition, we must locate the point of application. The following diagram shows all the essentials for graphically showing a force.

Draw a line *A B*, 4 inches long, assuming that each inch represents 10 lb. and parts of a lb.—we have a force equal to 40 lb.



Place an arrow-head anywhere on the line to represent the direction. Then either *A* or *B* could represent the point of application.

Several forces can be shown acting in any direction by adopting the above method, in addition, one force can represent the combined action of several forces, or, conversely, several forces can be components of a single force.

If we replace the action of several forces acting on a body by a single force, we are said to have found

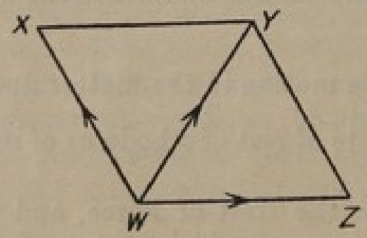


Fig. 51.

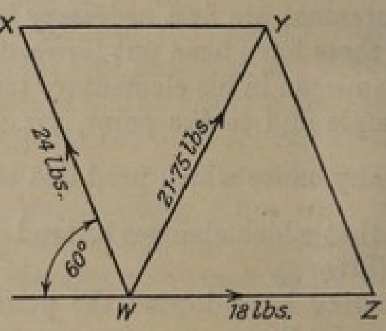


Fig. 52.

Force diagrams.

the resultant of the sum of the forces, and by splitting up the single force into other forces or components we deal with the Composition of Forces.

Parallelogram of Forces.—Let WX and WZ (Fig. 51) represent in magnitude and direction two forces acting upon a point.

Suppose we complete the parallelogram $WXYZ$, we find the diagonal WY which represents a force equal to WX and WZ combined.

By drawing these lines or forces to some particular scale, say $\frac{1}{8}$ inch equals 1 lb., we shall be able to see what force acting along the diagonal WY will place the series in equilibrium (Fig. 52).

$$WZ = 2\tfrac{1}{4} \text{ inches} = 18 \text{ lb.}$$
$$WX = 3 \quad ,, \quad = 24 \text{ lb.}$$

and at an angle of 60 degrees to the horizontal.

We find after completing the parallelogram that the diagonal WY when measured by scale = 21·75 lb.

By combining the first resultant with a third force and finding a second resultant which we combine with a fourth force, and so on, we can find the resultant of any number of forces which enter into the problem. We must, however, remember that all forces acting upon any body must be in equilibrium to prevent that body having any tendency to revolve, and the line of action of all forces must meet in a point.

A very important force is the force of gravity, or the attraction of the earth to all other bodies.

All bodies, as a matter of fact, attract each other with forces directly proportional to their masses and inversely proportional to the squares of the distance between them.

The attraction of the earth practically overwhelms all others, and as the direction of attraction is towards the centre of the mass, under the action of gravity all things tend to fall towards the centre of the earth.

We have in a body a point through which the resultant of the gravities would pass—no matter what position the body assumes—this point we call the centre of gravity. Regular bodies have their centre of gravity in the centre of their mass, but it is not always necessarily situated in a solid portion of a body, but is simply the mean central point of the mass.

Should we support a body at its centre of gravity it will be in equilibrium.

Centre of gravity of triangle—bisect two sides, draw to opposite angles, and where they intersect is the centre of gravity (Fig. 53).

Square.—Draw lines to opposite angles; intersection equals centre of gravity (Fig. 54).

The centre of gravity of any irregular-shaped body can be found by cutting the profile of the body

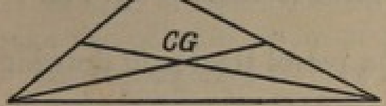


Fig. 53.

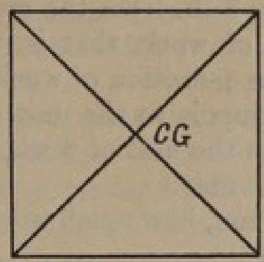


Fig. 54.

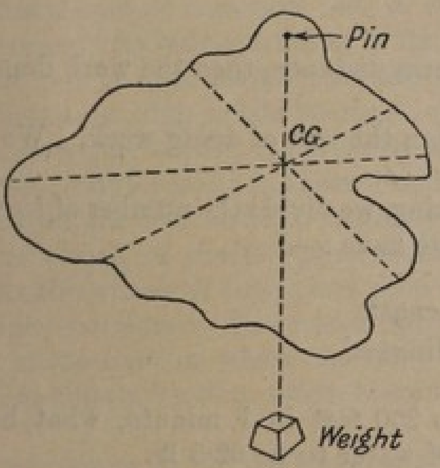


Fig. 55.
Centres of gravity of plane figures.

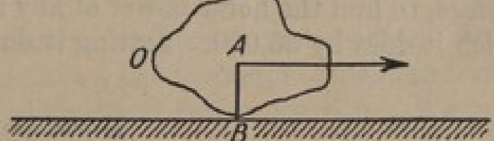


Fig. 56.—Moment of force.

out of cardboard and suspending the latter from several points, at the same time hanging a piece of cotton weighted by a small weight from the point of support and carefully marking a line on the piece of cardboard along the line taken up by the cotton. Continue doing this at the several points of support and where the marks all cross each other is the centre of gravity of the section (Fig. 55).

Other forces which the student should become acquainted with are cohesion, adhesion, and capillary attraction.

The attraction of the molecules to one another of the same or in the same body is *cohesion.*

The attraction of molecules or particles of different bodies one to another is *adhesion* (*e.g.*, chalk on a blackboard).

Capillary attraction is a form of adhesion in liquids and it is made use of in the wick of an ordinary oil lamp or candle.

Moments of force are used in the design of machines, and, in fact, in all structures. That is, the force acting in any particular direction is multiplied by the *perpendicular* distance from its line of action.

Suppose we take a body of any shape resting on the point B and we apply a force O in the direction shown, the moment of the force as applied to that point is equal to $AB +$ force O (Fig. 56).

If we use scales or measurements to represent the force and distance AB we can very easily find out any particular moment we require. In structural engineering we invariably use inches for distance AB and tons or lbs. for force O. Our answer, therefore, would be in ton-inches, or pound-inches, whatever the case might be.

If we have two equal forces acting in opposite directions such as is found in motor-car steering wheels, letter presses, or capstans, we have what is known as a couple, and the moment in this particular case would be equal to the product of one of the forces multiplied by the length of arm from one force to the other.

The student should make himself conversant with examples of composing and resolving forces, triangle of forces, etc.

Work.—If a person lifts a package weighing 8 lb. from the ground to a height of 3 feet, we say that that person has accomplished 24 foot-pounds of work, that is, the pressure exerted, multiplied by the space passed through in any direction gives us a definition of work.

In British practice we use the pound avoirdupois as the unit of weight and the lineal foot as that of distance. These two multiplied together give us the unit of work, that is, the force × distance *e.g.* 1 lb. × 1 foot = 1 foot-pound. It is a very convenient unit.

If the resistance on a level road is 100 lb. per ton, how much work is done by a petrol tractor in drawing a load of 10 tons 200 yards?

We know the tractive force is 100 lb. per ton,

$\therefore$ the total pull is 100 lb. × 10 tons, and the distance = 200 yards × 3 = 600 feet.

$\therefore$ the work done is Force × Distance.

$= 100 \times 10 \times 600 = 600{,}000$ foot-pounds.

Should the distance vary whilst the force acts through a known distance, then the work done will equal the product of the average resistance and distance.

We now come to Power, and this is nothing more or less than the *rate* of doing work. We use 33,000 foot-pounds per minute as our unit and call it a Horse Power.

Therefore, to find the horse power of any machine when working, we divide the number of foot-pounds of work which it does by 33,000. Setting it down as a formula, we have :—

$$\text{Horse power} = \frac{\text{Force} \times \text{Length}}{33{,}000 \times \text{Minutes}}.$$

Example.—If we require to raise 80 cubic feet of water to 250 feet in 1 minute, what horse power engine will be required? Assume the weight of a cubic foot of water to be 62·5 lb.

80 cubic feet of water will weigh 62·5 × 80.

$$\text{Work done per minute} = \frac{F \times L}{M} = \frac{5{,}000 \times 250 \text{ ft}}{1}.$$

$$\therefore \text{Horse power} = \frac{F \times L}{33{,}000 \times M} = \frac{5{,}000 \times 250}{33{,}000 \times 1} = 37{\cdot}8, \text{ say, } 38 \text{ h.p.}$$

The Three Laws of Motion.

The basis of the science of kinetics consists of three laws, described, or rather formulated, by Sir Isaac Newton, one of the greatest mathematicians England, or the world for that matter, has produced. Unfortunately, much of his work was destroyed by accidental burning, but in his chief work, called "The Principia," he gives us his three laws of motion, as follows :—

1. If a body be at rest, it will remain at rest unless it is compelled by some external force to change its state, and if in motion, it will continue to travel in a straight line unless acted upon by some outside force.

2. Every motion, or change of motion, is proportional to the acting force, and takes place in the straight line along which the force acts.

3. To every action there is always opposed an equal and contrary reaction.

Briefly stating the above, we have :—

1. Change of state is due to external force.
2. Every force produces its own result.
3. Action and reaction are equal.

Motion itself is opposite to rest. The parts or molecules composing all bodies are in continual agitation, and the hotter a body becomes, the more violently are its molecules agitated.

Our next important item is :—

Friction, or the resistance that a body meets from the surfaces on which it moves. It is a well-known fact that trying to push a packing case loaded with material and lying directly on the pavement or warehouse floor is very much harder than if the case was supported on rollers; and much harder on a rough road than on a boarded floor. The reason is that the rough road or pavement has much larger protuberances than the boarded floor, and these interlock with the protuberances on the packing case. Even if we take two polished pieces of glass, place them under a microscope and examine them closely, we shall notice a minute roughness all over the surface, though we may not be able to locate this by touching, and I think we may take it for granted that no substance exists which can have a perfectly smooth surface.

Friction destroys motion it cannot generate, and always acts in a contrary direction to that in which a body is moving. Now the latter quality is very useful to the engineer when used in the form of braking power on motor-cars or tramcars, but, of course, in the bearings of wheel spindles or any revolving shaft, it is very necessary to reduce friction to its utmost. For this purpose we well grease or oil the bearings, or otherwise we should soon realise that friction produces heat, and if allowed to continue, the shafts would become so hot as to cling to the bearings, or, in engineering parlance, would " seize."

Other cases where friction is a friendly agent is in the action of driving ropes, pulleys and driving wheels of locomotives; but for friction, these would slip and make no progress. Neither could a person walk but for friction between the feet and the roadway.

In the revolving of shafts, spindles, cart wheels and motor-car wheels we have rolling friction, and should we fix the wheels of a cart and slide downhill, we should have a good example of sliding friction. It is quite simple therefore to distinguish the difference between sliding and rolling friction. We might also notice that static friction, where the force tends to prevent the setting in motion of two bodies at rest, is different from kinetic friction, where there is a resistance tending to arrest the motion of one body over the other.

Should we require to find the static or kinetic friction between two bodies, we can do so by a very simple experiment, by taking a weight, say, of 20 lb., which we call W and attaching a thin cord, pass the same over a pulley and affix a small scale pan (see Fig. 57).

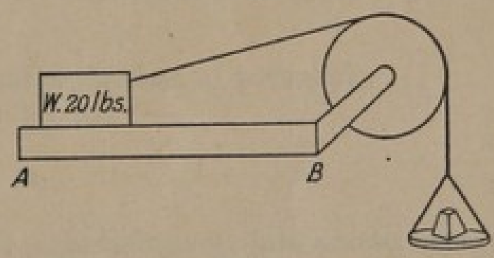


Fig. 57.—Method of ascertaining coefficient of friction.

Assume the surface AB is an oak board. We now add small weights to the scale pan until the weight W just starts moving. The weights required to do this measure the friction between the surfaces, that is, the weight in the pan equals the frictional resistance. Supposing that the weight in the pan amounts to 8 lb., then the ratio between the friction and the weight is $\frac{8 \text{ lb.}}{20 \text{ lb.}} = 0{\cdot}4$. We call this fraction the coefficient of friction, and if the 20 lb. weight and surface on which it acts were oak, then we would speak of the coefficient of oak, on oak, as 0·4.

There is something else to remember while on the subject of friction, especially with regard to tip-up wagons, and that is—the angle of friction. This is the angle made by a plane with a horizontal surface at the moment when a body that is placed on the inclined plane begins to slide. The following examples are taken from a well-known work on the subject, but I should advise the student to experiment for himself with various materials and surfaces :—

	Coefficient of Friction.	Angle of Friction.	
		Degrees.	Minutes.
Oak on elm fibres parallel to motion .	0·25	14	3
Wrought iron on brass	0·17	9	39
Steel on cast iron	0·20	11	19
Brass on cast iron	0·22	12	25
Hard on soft limestone	0·67	33	50

House refuse usually requires an angle of at least 45 degrees before it will slide.

Laws of Friction :—

1. Friction is independent of the extent of the surfaces in contact.
2. The amount of friction is proportional to the pressure between the two surfaces in contact.
3. For ordinary velocities friction is independent of the velocity with which one body moves over the other.
4. Statical friction is greater than kinetic friction.
5. Statical friction is increased after the two surfaces have been in contact for some little time.
6. Rolling friction is less than sliding friction.
7. In rolling friction, the resistance is proportional to the weight, and inversely proportional to the radius of the wheel.
8. The work done in overcoming friction is transformed into heat or energy.

CHAPTER IX

HEAT

The Nature of Heat.—When we stand in the sunshine or in front of a fire it feels hot. If we take hold of some ice or snow it feels cold. Heat is the name given to the cause of these and the like sensations. In the first case, heat enters our body, in the second, it leaves it, and our sensations make us aware of its transference. What, then, is the nature of heat? This question can be more fully answered when we have studied some of the effects which heat causes and some of the methods by which heat can be produced, and we shall then be able to appreciate the meaning of the statement that—HEAT is one form in which ENERGY becomes known to us. We will, however, at once consider this statement a little more in detail.

Work and Energy.—If a body, under the action of a force, moves in the direction in which the force acts, work is done on the body. Thus, when a man lifts a weight he applies force to it and does work; when a cannon ball penetrates a target it exerts force on the target and does work, being itself stopped in the process.

The capacity that a body or system of bodies has for doing work is called Energy.

Thus, the statement that heat is one of the forms of energy, implies that heat is one form which the capacity of a body for doing work may take.

Now a body may have energy because of its position relative to other bodies and of the forces which act on it. Energy in this form is called Potential—a stone at the top of a cliff—the weight of a clock which has just been wound up, or the coiled mainspring of a watch, all possess potential energy.

Again, a moving body possesses energy; a falling stone can do work. Energy in this form is called Kinetic.

Transformation of Energy.—Energy can change from kinetic to potential or *vice versa.*

A stone at the top of a cliff has no kinetic energy; relative to the cliff its energy is all potential. As the stone falls it loses potential energy, for this is proportional to its height above the earth, being measured by wz, where w is the weight of the stone, z its height; at the same time it gains kinetic energy, for this is measured by $\frac{\frac{1}{2}wv^2}{g}$, where v is the velocity, and this increases until the stone reaches the ground, g is the acceleration due to gravity and is equal to 32·2 feet per second.

We can show that for any body the gain in kinetic energy is equal to the loss of potential.

Assume a weight of 10 lb. to be at a height of 50 feet above the ground :—

$$\text{Potential energy} = wz = 10 \times 50 = 500 \text{ ft. lb.}$$

Now let us allow this stone to fall to the ground; that is, convert its potential energy into kinetic energy, in other words, transform the energy.

We have given above the formula for kinetic energy as :—

$$\frac{\frac{1}{2}wv^2}{g}.$$

First of all we must find the velocity of the stone on impact, that is, when it strikes the ground or when, in this case, it has fallen 50 feet :—

The velocity is found as follows :—

$$v^2 = 2\,gs,$$

where s = space passed through, therefore,

$$v^2 = 2 \times 32{\cdot}2 \times 50.$$

Now substituting the above for v^2 and returning to our formula for kinetic energy, we get

$$\frac{\frac{1}{2}10 \times 2 \times 32{\cdot}2 \times 50}{32{\cdot}2}$$

$$= \frac{10 \times 2 \times 32{\cdot}2 \times 50}{2 \times 32{\cdot}2}$$

cancelling out we get 10×50

$$= 500 \text{ ft. lbs.}$$

We thus see that although the stone has lost all its potential energy in falling, it has converted it all without loss or gain into kinetic energy.

When the stone has reached the ground it has apparently lost its energy, for it has no potential energy, as it can fall no further; it has no kinetic energy, as it is at rest. Careful observation would show, however, that another change has taken place, the stone has been heated, and were we able to measure this heat, we should find that all the kinetic energy has been converted into heat energy, again without loss or gain.

Heat and Work.—Various experiments can be made to show that there is some connection between heat and work. Thus, when a man hammers a piece of metal for a short time we find that the metal has become heated. You may rub a piece of steel with emery paper until it is too hot to hold, the work which you have expended having been converted into heat.

We have seen that there is no loss of energy due to conversion, and also we have previously stated that heat is one form of energy a body may have for doing work, we may, therefore, safely say that "Heat and work are convertible one into the other."

This rule is a very important one in our study, and should be firmly impressed as it forms a basis of almost all our work in this subject.

Effects of Heat.—When heat is applied to bodies it produces, amongst other effects, the following :—

(1) Change of dimensions.
(2) Change of internal stress.
(3) Change of state.
(4) Change of temperature.

We will briefly consider each of these.

1. Change of Dimensions.

Most bodies expand or increase in volume on being heated. In laying down the rails of a railway a space is left between the ends of each rail to allow for this. The tyre of a cart is put on hot; as it cools it contracts and holds the wheel tightly together.

2. Change of Internal Stress.

Many of these changes of volume are accompanied by changes in the stresses or internal forces between the molecules of the body. As the wheel tyre contracts, it is subject to great force. An air balloon placed in front of a fire expands, and the pressure the contained air exerts on the india rubber covering increases and bursts the covering.

3. Change of State.

Many substances can exist in the three states of matter—solid, liquid and gaseous—changing from one to the other on the application or withdrawal of heat. A lump of ice melts and becomes water when sufficient heat is applied; apply more heat and the water becomes warmer and after a time it boils, being converted into steam.

4. Change of Temperature.

Place the hand in a bowl of cold water, it feels cold; apply heat to the water it gets warmer; in scientific language its temperature is said to rise. Or, again, put a red hot piece of iron into a vessel of water, the iron is cooled and the water heated, heat passes from the hot iron to the water, or the temperature of the iron has been decreased and the temperature of the water increased.

Temperature.—" Temperature is the condition of a body on which its power of communicating heat to, or receiving heat from other bodies depends."

If, when two bodies (*a*) and (*b*) are put into communication, heat passes from (*a*) to (*b*), then (*a*) is said to be at a higher temperature than (*b*), and should there be no transference of heat, then both bodies are at the same temperature. We can thus determine which of the two bodies is at the higher temperature. We cannot, however, yet say whether the difference is greater or less than between two other bodies, neither can we compare the temperature observed at one point with another observation of temperature made elsewhere, unless we can transport the same thermometer. For such purposes, we need a scale of temperatures.

The Fixed Points on a Thermometer.—The temperature at which ice melts is found to be always the same.

The temperature of steam emanating from boiling water is also constant when under atmospheric pressure, and thus we have two fixed or unvarying points on a scale which we may use.

Scale of Temperatures.—The difference in temperature between these fixed points is very considerable and we need some means of sub-dividing it so that we may compare any two temperatures more closely; these sub-divisions are called degrees.

Definition.—" A rise of temperature of 1° is that rise of temperature which causes the mercury to expand by some definite fraction of the total expansion between the freezing and boiling points of water."

There are three scales of temperature in more or less common use :—

1. *The Fahrenheit.*—The number of degrees between the two fixed points is 180, thus the temperature changes by 1° F. when the volume of the mercury of a mercurial thermometer alters by 1/180th part of the total increase between freezing and boiling point. On Fahrenheit's scale the freezing point is marked 32 degrees; the boiling point is thus 32° plus 180°, = 212°.

2. *Centigrade Scale.*—The number of degrees between the two fixed points is 100. On the Centigrade scale, freezing point is marked 0°, boiling point 100°.

3. *Réaumur's Scale.*—The number of degrees between the two fixed points is 80. On Réaumur's scale freezing point is marked 0°, boiling point 80°.

The Fahrenheit scale is the scale most commonly used in engineering; the Centigrade is used for scientific work, while the Réaumur scale is still largely employed on the Continent.

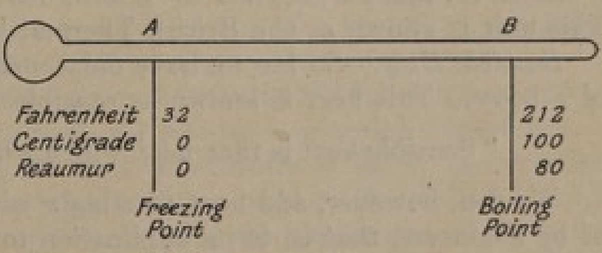


Fig. 58.—Temperature scales.

Comparison of Scales.—As we shall often meet with the Fahrenheit and Centigrade scales, we must know how to compare one with the other. The Réaumur scale may be dismissed from mind, as in this country it is rarely met with.

From Fig. 58 it will be seen that the distance between *A* and *B* is the same for each scale, and this will apply when we take any point between *A* and *B*. We see then that each scale has some definite relation to the other.

To convert F. to C. :—

$$\frac{(F^\circ - 32) \times 5}{9}.$$

Example.—Convert 212° F. into a corresponding reading on the C. scale.

$$\frac{(212 - 32)}{9} \times 5 = \frac{180 \times 5}{9} = 100^\circ \text{ C.}$$

To convert C. to F. :—

$$\frac{(C^\circ \times 9)}{5} \text{ plus } 32.$$

Example.—Convert 100° C. into a corresponding reading on the F. scale.

$$\frac{(100 \times 9)}{5} \text{ plus } 32 = 180 \text{ plus } 32 = 212^\circ \text{ F.}$$

This method applies for any temperature above zero point on the F. scale.

Sources of Heat.—Among the sources of heat available for our use, we may reckon :—

(*a*) The Sun.
(*b*) Chemical action.
(*c*) Mechanical sources.
(*d*) Electrical currents.
(*e*) Change of physical state.

(*a*) *The Sun.*—Of the above, the sun is by far the most important. Directly or indirectly the sun is the source of nearly all the available energy we possess.

(*b*) *Chemical Action.*—Many chemical actions are accompanied by the production of heat; first among these we place combustion.

(*c*) *Mechanical Sources.*—Of these, friction is the chief.

(*d*) *Electrical Currents.*—When an electric current passes through a conductor the latter is heated.

(*e*) *Change of Physical State.*—Just as it requires heat to melt ice, so heat can be obtained by freezing water. The molecules of the substance in the liquid form possess more energy than in the solid; absorb this energy and the liquid becomes solid. When steam condenses to water, heat is given out.

Heat—a Quantity.—Heat is a physical quantity; if it requires a definite amount of heat to raise 1 lb. of water from 39° F. to 40° F. it will require the same quantity to raise a second pound. If the two pounds be mixed, they require twice the amount of heat previously required to raise the temperature of each separate pound. We can add together the two amounts of heat as we could add the two pounds of water; we are justified then in speaking of an amount or quantity of heat.

The Unit of Heat.—We must measure the quantity of heat by some one of the effects it produces. Water is chosen for this purpose and the unit of heat is "The amount of heat required to raise 1 lb. of water 1° F." This unit is known as the British Thermal Unit and is written B.Th.U.

Sensible Heat.—So far we have only considered that heat which when applied, raises the temperature of a body. This heat is known as sensible heat, so we may say that—

"Sensible heat is that heat which when applied to a body, raises the temperature of that body."

We can, however, add heat to a body without raising its temperature and this heat is made much use of by engineers, that is, in its application to power, as we shall see presently.

Latent Heat.—"The heat which when applied to a body changes the state of that body without changing its temperature is known as 'Latent Heat.'" Thus, if we place a pan of water over a burner we shall notice that the temperature rises until 212° F. is reached, and even though the heat of the burner is still being applied, the temperature does not rise. The water, however, is gradually converted into steam. This heat is that which is known as latent heat.

Latent heat is always expressed as so many B.Th.U. per pound of the substance being considered.

Mechanical Equivalent of Heat. Joule's equivalent.—Doctor Joule after many years' experimental work found that 772 foot-pounds of work was done in raising 1 lb. of water through 1° F. This figure has since been checked by various people and it is now generally agreed that Dr. Joule's value was a trifle low, and the figure of 778 foot-pounds of work for 1 B.Th.U. is taken. It is still, however, known as Joule's equivalent. Thus, whenever 1 B.Th.U. of heat is given to or taken from a body, 778 foot-pounds of work have been done by the agent giving this heat, or by the body if giving up the heat to another body.

Steam.—The action of heat in the formation of steam may be illustrated by diagrams (Fig. 59).

Let the cylinder (stage one) contain 1 lb. of water at 32° F. and let the pressure of the atmosphere be represented by a weighted piston, then, if the heat be applied to the water, the temperature will rise higher and higher, though the piston will remain stationary until the temperature of the water reaches 212° F.

On continuing the heat, the water shows no further increase of temperature by the thermometer, but steam begins to form, and the piston commences to ascend in the cylinder (stage two), rising higher and higher as more and more steam is formed, until the whole of the water is converted into steam. In stage one the steam did not begin to form until the temperature reached 212° F. Evidently, therefore, this is the lowest temperature at which steam can exist under atmospheric pressure.

In stage three, as soon as the last drop of water disappears we have 1 lb. of steam occupying the least possible space or volume at the given pressure, *i.e.*, atmospheric pressure.

If the steam be surrounded by a vessel containing an indefinite supply of cold water (stage four), then the heat will be extracted from the steam by the surrounding water, and the steam will be condensed to water, the same in every particular as to weight and properties as the water with which we started. If the temperature of the water is now the same as its temperature before starting, then the whole of the heat taken away when the steam is condensed is equal to the whole of the heat added during the operation. The series of changes has, therefore, been brought about by the addition or subtraction of heat only.

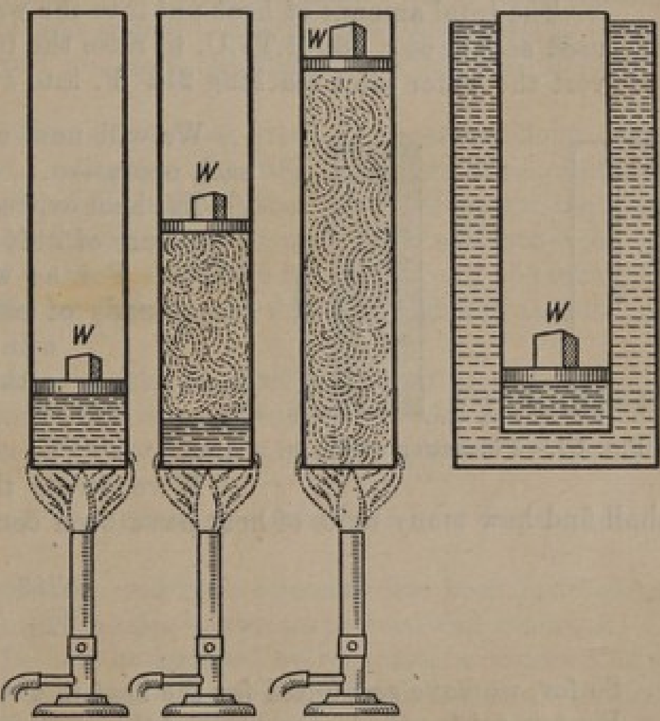


Fig. 59.—Formation of steam.

No heat having been lost, the gain of heat of the surrounding water must equal the loss of heat by the steam and water in the cylinder.

All the heat from the steam passes into this water, raising its temperature by an amount corresponding to the loss of heat of the steam; *i.e.*, loss of heat of steam and water equals gain of heat of water.

We have so far been content with the general statement of the action of heat and the formation of steam; we will now consider what quantities of heat are required to perform the several stages of the operation.

Work done by Steam During Formation.—Referring to Fig. 60 let 1 lb. of water at 32° F. be contained at the bottom of a cylinder 1 square foot or 144 square inches in sectional area, then first find the height of the water in the cylinder; since the area of the vessel is 1 square foot and the weight of 1 cubic foot of water is 62·5 lb.

62·5 lb. of water will stand 1 foot high.

1 lb. ,, ,, $\frac{1}{62\cdot5}$ feet high.

$= 0\cdot016$ foot.

Let the pressure of the atmosphere be represented by a piston resting on the surface of the water and loaded with a weight of 14·7 lb. per square inch (this being the pressure of the atmosphere).

The area of the piston being 1 square foot, the total weight on the piston will be 14·7 × 144 = 2116·8 lb.

1. On applying heat to the water it will at first gradually rise in temperature from 32° to 212° F. before evaporation commences as previously explained.

Then 212 — 32 = 180 = the number of heat units or B.Th.U. required to raise 1 lb. of water from 32° F. to boiling point under atmospheric pressure, since from our previous definition it required 1 B.Th.U. to raise 1 lb. of water through 1° F.

2. Steam now begins to form and the piston to rise; and on continuing the heat the water is eventually converted into steam at a temperature of 212° F. and the piston continues to rise until the steam occupies a volume, under the pressure of the atmosphere, of 26·36 cubic feet as found by experiment.

The heat expended in evaporating 1 lb. of water into steam after the water has been raised to 212° F. is found to be 966 B.Th.U. This is known as the latent heat of steam at atmospheric pressure.

The total amount of heat put into the water is therefore 180 + 966 = 1146 B.Th.U. and has been used as follows: 180 B.Th.U. to raise the temperature from 32° to 212° F. and 966 B.Th.U. to convert the water after reaching 212° F. into steam.

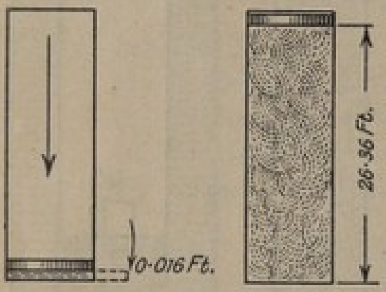


FIG. 60.—Formation of steam.

We will now consider what share of the heat has been expended on each operation.

The heat expended in doing the external work of raising the piston under a pressure of 2116·8 lb. through a height of 26·36 — 0·016 foot = 2116·8 × 26·344. For as we saw at the commencement of the chapter, $w \times z$ = foot-pounds of energy.

w in the above being represented by 2116·8 lb.

z the height the weight has been raised

= 55,765 foot.-lb. of work.

If we divide this by the mechanical equivalent of heat, *i.e.*, 778, we shall find how many units of heat have been converted into work.

$$\frac{55765}{778} = 71{\cdot}6 \text{ B.Th.U.}$$

So far, we have accounted for the heat in two of the operations.

First, in raising the temperature of the water from 32° to 212° F. Secondly, in raising the weight through 26·344 feet.

We have, therefore, only accounted for 180 + 71·6 B.Th.U = 251·6 B.Th.U.

Now we know that the total amount of heat applied was 1146. Subtracting 251·6 from 1146 we get the amount of heat used in overcoming the internal resistance of converting the water into steam = 894·4.

The heat has therefore been used as follows:—

1. In raising temperature of water from 32° to 212° F.	180
2. In overcoming the internal resistance	894·4
3. In raising piston	71·6
Total Heat	1146·0 B.Th.U.

CHAPTER X

COMBUSTION

1. *Introduction.*—The question of Combustion should be carefully considered by all who have to deal with the disposal of refuse by burning. When combustion is good, many advantages accrue as against when combustion is moderate or bad. For instance, more heat is available for sundry works purposes and there is less danger of polluting the atmosphere with soot and smoke. Again, when the refuse is burnt and good combustion prevails, the clinker so produced will be hard, innocuous, and suitable for many industrial purposes.

Combustion may be defined as the combination of dissimilar substances, producing heat and light. One of these substances is oxygen and the other the fuel used. A given quantity of oxygen is required for every pound of fuel, so as to burn the fuel completely, and with different fuels the amount of oxygen required varies. With an insufficient supply of oxygen complete combustion is prevented, while with an excess of oxygen, heat is wasted to that amount required to raise the excess air to the temperature of the escaping gases from the chimney. It should also be stated that different fuels require different furnaces and no one furnace or grate bar is equally good for all fuels.

2. *Matter.*—Matter is anything that occupies space and can exist in three forms, viz.: solids, liquids and gases. Matter is the substance of which all bodies consist and is composed of *molecules* and *atoms*.

3. *Molecule.*—A *molecule* is the smallest possible portion of matter which is capable of separate existence without changing its nature.

4. *Atom.*—An *atom* was formerly defined as "the smallest particle of matter which so far has never been split up into anything simpler."

Chemists always keep the proviso "so far" in the definition, and their reticence has been justified in that now it is well known that the atom is composed of simpler bodies known as protons and electrons.

The relation between the atom and the molecule may be best understood by regarding a molecule as a brick wall and the atoms as the bricks composing the wall. If a drop of water were divided and sub-divided until it could only just be seen by the most powerful microscope, even then it would still consist of thousands of molecules forming a tiny drop. If we could separate one of these molecules it would still be water, although invisible to the most powerful microscope—it would still be the brick wall. But this brick wall (*i.e.*, the molecule of water) would be composed of three bricks (or atoms) two of the bricks being exactly alike, *i.e.*, hydrogen atoms, and one brick different—the oxygen atom. So that we have, by further division of the molecule, broken it down into two entirely different substances—oxygen and hydrogen.

Some idea of the size of the average atom may be obtained in the following manner. Assume it to be possible to puncture an electric light bulb so that 1 atom per second could rush in, it would take approximately 14 years to fill it.

5. *Elements.*—An element is a substance composed of one kind of matter only and cannot be changed into anything else, except by the addition of some other body. For example, iron, carbon, chlorine, aluminium and sulphur cannot be decomposed or changed into anything else other than by adding something else to them.

6. *Compounds.*—Compounds consist of two or more elements chemically united, which can be broken down by suitable means into simpler elementary bodies composing them. For example, water under the influence of electrolysis is broken up into two gases entirely dissimilar from each other, and from the water which they formerly composed.

7. *Chemical Combination.*—Chemical combination is essentially different from mere mixture, and is not

only accompanied by a change of appearance, but also by an evolution of heat. The term mixture will be explained later. Hence the chemical combination of two or more elements results in the production of a substance whose chemical properties, and generally speaking its physical properties, are completely different from those of the elements entering into its composition. Thus when carbon is heated in oxygen they combine to form a compound of totally different properties from either, viz., carbon dioxide = CO_2.

Again, hydrogen and oxygen when exploded, by an electric spark, say, combine to form water vapour; suitable analysis of this reveals the fact that the water vapour molecule is composed of two atoms of hydrogen combined with one atom of oxygen; so in the original gases one volume of oxygen must have combined with two volumes of hydrogen. Hence, the molecule of water is indicated by the symbol H_2O.

8. *Combination by Weight.*—Under similar conditions of pressure and temperature equal volumes of all gases contain the same number of molecules. From this it follows that at the same temperature and under the same pressure the volume of any gaseous molecule is the same, whatever may be the nature and composition of the gas. An equal number of atoms may now be said to be contained in a cubic foot of oxygen and a cubic foot of hydrogen, and as oxygen is 16 times heavier than hydrogen it is safe to assume that the weight of an atom of oxygen is 16 times greater than an atom of hydrogen. The atomic weight of an element is said to be the ratio between the weight of an atom of that element compared with the weight of an atom of hydrogen, the latter being stated as 1.

The following table gives the symbols and atomic weights of the constituents of most fuels :—

Element.	Symbol.	Atomic Weight.
Hydrogen . . .	H	1
Carbon	C	12
Nitrogen . . .	N	14
Oxygen	O	16
Sulphur	S	32

Amongst other uses the atomic weights of the elements enable us to determine the composition by weight of any compound, *i.e.*, its molecular weight.

For instance :—

1 atom of C × atomic weight, 12 = 12 parts by weight of C.
2 atoms ,, O × ,, ,, 16 = 32 ,, ,, ,, ,, O.
44 ,, ,, ,, ,, CO_2.

$$\therefore \quad CO_2 \text{ comprises } \frac{12}{44} \text{ or } 27{\cdot}3\% \text{ carbon and } \frac{32}{44} \text{ or } 72{\cdot}7\% \text{ oxygen.}$$

Molecular weight of CO_2 = 44.

9. *Mixtures.*—Substances which when mixed together do not chemically combine are said to be mixtures as distinct from chemical compounds and the mixture so produced may be separated into its constituent parts by *mechanical* means; the properties of the mixture are essentially the specific properties of the substances composing it. For example, if finely divided iron and sulphur are mixed together a grey powder results; but this can be proved to be only a mixture by treating it with carbon disulphide, when the sulphur dissolves, leaving the iron behind. On evaporating the CS_2 (carbon disulphide) the sulphur is also left unchanged.

10. *Union of Elements.*—The process of burning or combustion is an everyday occurrence, but very few realise that this process is a chemical reaction which follows definite laws.

It has already been stated that when chemical combination takes place between two substances heat is produced, and the student may verify this by the simple experiment of adding a little water to a quantity of sulphuric acid. The water and acid unite with each other and a rise in temperature is caused.

A great affinity exists between the atoms of certain elements, and when brought together under favourable conditions chemical union is unavoidable. For instance, oxygen combines very readily with carbon, and when these two elements unite so that heat and light are evolved, combustion is said to have taken place. The resultant gas, which may be either carbon dioxide or carbon monoxide, is termed the product of combustion. If in the oxidisation of the carbon the oxygen is taken from the air, as is usual when burning coal in a furnace, then the nitrogen of the air passes off with the gases in its natural state and is termed a product of combustion, although in itself it does not aid combustion.

It may now be stated that when the heat caused by chemical combination is such as to raise the resultant substances to a temperature at which light is produced, the act of combination is said to be Combustion.

11. *Weight of Air.*—Carbon dioxide, as already mentioned, is chemically united in the proportion by weight of 12 parts carbon and 32 parts of oxygen. From this it will be seen that $\frac{32}{12}$ or $2\frac{2}{3}$ lb. of oxygen are required to oxidise completely a pound of carbon. The theoretical amount of air required to supply the $2\frac{2}{3}$ lb. of oxygen is calculated on the basis of air containing 23% by weight of oxygen, therefore, $\frac{100}{23} \times \frac{32}{12} = 11{\cdot}6$ lb. of air per lb. of carbon burnt.

The chemical combination of 1 lb. of carbon and 11·6 lb. of air may be shown as follows :—

$$\begin{matrix} 1{\cdot}0 \text{ lb. of carbon} \\ 11{\cdot}6 \text{ lb. of air} \end{matrix} = \left\{\begin{matrix} 1{\cdot}0 \text{ lb. C} \\ 2{\cdot}7 \text{ lb. O} \\ 8{\cdot}9 \text{ lb. N} \end{matrix}\right\} = \begin{matrix} 3{\cdot}7 \text{ lb. } CO_2. \\ 8{\cdot}9 \text{ lb. N.} \end{matrix}$$

From this it is obvious that 11·6 lb. of air completely combines with 1 lb. of carbon. In this amount of air there is present 2·7 lb. of oxygen, which is that constituent of the air which actually combines with a pound of carbon, giving 3·7 lb. of CO_2. The other constituent of the air, *i.e.* the 8·9 lb. of nitrogen it contains, is inert and passes off with the CO_2 unchanged.

So much for complete combustion, but it is possible that the combustion may be incomplete. If there is an insufficiency of air, or, what is the same thing, an insufficiency of oxygen, a lower oxide of carbon CO, known as carbon monoxide, may be formed.

One pound of carbon burning to CO obviously requires only half the oxygen necessary to form CO_2, that is, one atom of carbon combined with only one atom of oxygen, whereas in CO_2, two atoms of oxygen are so required.

In other words, 1 lb. of carbon oxidised to CO_2 requires 11·6 lb. of air as against only 5·8 lb. to produce the lower oxide CO.

In practice, however, it is usually found that twice as much air is used per pound of fuel over that required theoretically.

12. *Calorific Value.*—The calorific value of a fuel is determined by its chemical composition, and the quantity of heat developed by the complete combustion of such fuel is known as its calorific or heating value. This value is measured in heat units called British Thermal Units (B.Th.U.) and a British thermal unit is defined as being the amount of heat required to raise the temperature of 1 lb. of water through one degree F. House refuse has a calorific value ranging from 3000 to 6000 B.Th.U. per pound.

By means of an instrument called a calorimeter the heat value of a fuel can be determined.

The figures below give the value of one pound of the elements.

Carbon burnt to carbon dioxide,	14,500	B.Th.U.
Carbon ,, ,, ,, monoxide,	4,400	,,
Hydrogen ,, ,, water,	62,000	,,
Sulphur ,, ,, sulphurous oxide,	4,030	,,

It will be seen by reference to the above figures that a great loss of heat is experienced when carbon is burnt to carbon monoxide, CO, instead of to carbon dioxide, CO_2.

For calculating the calorific values of fuels, Dulong's formula is generally accepted. It is expressed as follows :—

$$145(C + 4{\cdot}28\left(H - \frac{O}{8}\right) + 0{\cdot}28S) = \text{B.Th.U.}$$

Example.—What is the calorific value of a pound of fuel the analysis of which is as follows :—

Carbon	78 per cent.
Hydrogen	4 ,,
Oxygen	6 ,,
Nitrogen	1 ,,
Sulphur	1 ,,
Ash	10 ,,

Solution :

$$145(C + 4{\cdot}28\left(H - \frac{O}{8}\right) + 0{\cdot}28S.) = \text{B.Th.U.}$$

$$145(78 + 4{\cdot}28\left(4 - \frac{O}{8}\right) + 0{\cdot}28 \times 1)$$

$$145(78 + 13{\cdot}91 + 0{\cdot}28)$$

$$145 \times 92{\cdot}19$$

$$= 13{,}367 \text{ B.Th.U.}$$

13. *Theoretical Evaporative Power.*—The theoretical heating value of fuel is the heat which such fuel develops when burnt under ideal laboratory conditions and is stated in heat or thermal units. In England and America the British thermal unit is adopted and, as previously stated, is the amount of heat required to raise the temperature of 1 lb. of water through 1° F. On the Continent of Europe the " Calorie " is used. This is expressed as the amount of heat required to raise the temperature of 1 kilogramme of water 1° C. To convert British thermal units per pound of fuel into calories per kilogramme of fuel, multiply by five and divide by nine.

A common evaporative standard is desirable when carrying out fuel tests so as to obtain comparative evaporation values, as in many cases the temperatures of the feed water and steam pressure vary considerably. It is usual to express the evaporation in " number of pounds of water evaporated per pound of fuel from and at 212° F.," and this expression is known as the theoretical evaporative value of the fuel. To find the evaporative value of any fuel it is necessary to divide the calorific value of the fuel in British thermal units by 966, the latter figure representing the latent heat of steam at atmospheric pressure. From this it will be gathered that 966 B.Th.U. are required to convert 1 lb. of water at 212° F. into steam at atmospheric pressure.

Example.—A certain coal has a heat value of 13,793 B.Th.U. State the theoretical evaporative value of a pound of such fuel.

Total heat units of coal = 13,793 B.Th.U.

Latent heat of steam at 212° F. = 966 B.Th.U.

$$\frac{13{,}793}{966} = 14{\cdot}28 \text{ lb. evaporation.}$$

14. *Temperature of Combustion.*—Under ideal theoretical conditions the temperature, above zero, of burning carbon should be approximately 5000° F. and that of burning hydrogen 5800° F. It is practically impossible, however, to obtain these temperatures owing to heat losses, the chief of which is due to the large excess of air passed to the fire, usually about 100% more than that theoretically required to maintain complete combustion. This excess air entering the fire at a temperature of outside air passes up the chimney at a temperature varying from 350° to 700° F. It is thus seen that a great deal of valuable heat is lost and a high furnace temperature, which would naturally result had perfect conditions been maintained, is reduced considerably. Furnace temperatures vary according to the setting of the boilers. For instance, a temperature from 2000° to 2800° F. may be expected when the boiler is away from the furnace providing the latter is well insulated with good firebrick, but a temperature of 1600° to 2000° F. is considered good in the case of a boiler the furnace of which is placed within, and is surrounded by water. It has been stated that heat lost is never regained, it is therefore important to maintain as high a temperature as possible as by so doing the water of the boiler will take up heat much faster than otherwise, and gases of combustion are completely oxidised, and there is less danger of producing soot and smoke.

CHAPTER XI

SMOKE PREVENTION AND DRAUGHT

Introduction.—Fuel is the commercial source of energy, therefore a study of the combustion of fuel, and the means of preventing a waste of heat by guarding against those conditions that tend toward incomplete combustion, is most desirable. Heat lost by imperfect combustion is a total loss, and ignorance and carelessness in the stoke-hold should be avoided. The Power Engineer has a most serious problem to overcome successfully in the burning of soft fuels without the formation of black smoke, and this problem depends for its solution chiefly upon the intelligence and education of the stoker in performing his duties.

Coal is the fuel most generally used, and owing to its varying composition its behaviour in the furnace, like house refuse, varies considerably. Anthracite, which contains only a small percentage of volatile matter, is difficult to ignite, and a keen draught is therefore required. Bituminous fuels contain a large percentage of volatile matter from which smoke is readily formed unless correct conditions prevail. They are easy to ignite, consequently a lesser draught will be sufficient. House refuse, having a lower calorific value than most other grades of fuels, can be successfully burned at a high rate of combustion under suitable draught conditions.

Changes During Combustion.—Bituminous coal, which consists of liquid, gaseous and solid substances, gives off, when heated to a sufficiently high temperature, water, tar, oils, ammoniacal liquors, hydrocarbons and compounds of hydrogen and oxygen. These are called volatile substances, and the remaining portion of the coal which is not vaporised by the application of heat is coke and ash, the coke being referred to as the fixed carbon of the coal. The process of separating the gases and vapours from the solid matter is called distillation.

Volatile Substances and their Combustion.—The volatile substances comprise combustible and non-combustible matter.

The principal constituents of the non-combustible class are water, oxygen and nitrogen, which, when the coal is burned, are liberated as water vapour and the respective gases.

The combustible matter comprises the various hydrocarbons occurring in coal and is driven off in the application of heat as gases or vapours, principally as methane and ethane gas and the vapours as tar, naphtha and sulphur.

There are several varieties of coal having widely different compositions and the quantity and quality of the volatile matter released on coal distillation are, of course, dependent on this feature and on the conditions under which the coal is distilled. For instance, in high or low temperature carbonisation the presence or absence of air greatly modifies the composition of the resultant products.

In an ordinary boiler furnace, sulphur, water, etc., vaporise and mix with the gases to form a readily combustible mixture. This combustion may be either complete or incomplete and to attain the former it is essential that :—

1. There should be a sufficiently high initial temperature.
2. Plenty of air (for the supply of oxygen).
3. An intimate mixture of the volatile substances with the air supplied.

The structure of a flame may be studied by observing a jet of coal gas burning or that of a candle.

Take a candle flame as an example. The body of the candle is composed of tallow or wax, which is a hydrocarbon. When heat is applied this hydrocarbon melts and travels up the wick by capillary attraction. Heat having been applied to the wick, the hydrocarbon now vaporises into the inner blue cone shown at *C* (Fig. 61). Air mixes with the flame on all sides, providing the oxygen which combines with the hydrocarbons at *C*, which latter undergo incomplete combustion; in other words, there is not sufficient oxygen for the complete combustion of the hydrocarbons; the hydrogen combines with all the oxygen to form water, H_2O, and the carbon is left as tiny glowing particles which supply the luminosity of this part of the flame, *B*. These incandescent carbon particles rise, combine with more air and are oxidised to CO_2. This CO_2 mixed with the water vapour produced at *B* forms the faintly luminous mantle, *A*.

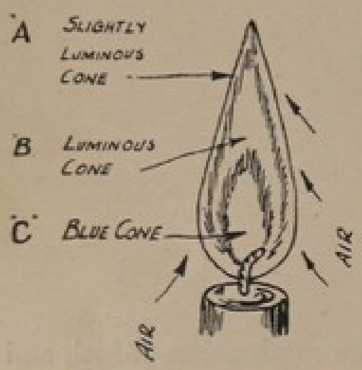


Fig. 61.—Structure of candle flame.

Similar conditions obtain in the burning of a jet of coal gas, excepting in this case the portion *A* of the divisions contains a quantity of the unburnt gas giving the somewhat black colour in contrast to the surrounding cones.

If a glass tube is placed in the centre of the flame *C* some of the unburnt gas may be drawn off; this cools down before it emerges from the tube and does not ignite owing to loss of temperature; if, however, the gas is heated, it may be lighted at the end of the tube.

This illustrates two vital principles of good combustion in a boiler furnace :—

1. A combustible gas cooled below its ignition point cannot be burned by the addition of air.
2. A combustible gas when supplied with sufficient air can be burnt if its temperature is raised sufficiently.

Burning of Carbon.—As already explained, the burning of carbon is its chemical combination with oxygen, and to bring about this union a temperature of about 1800° F. is required. The temperature in refuse furnaces being about 1800/2000° F. it is obvious that care is needed in stoking to see that this temperature does not fall in order to ensure proper combustion. The temperature of the furnace can be ascertained approximately, by studying the colour and temperature table which follows. Assuming that a temperature of 1800° F. is maintained together with a sufficient air supply, the carbon burns to CO_2. If there is not sufficient air CO is formed. Manifestly, therefore, in the latter case, the carbon is capable of uniting with a further atom of oxygen and forming the higher oxide, CO_2.

In an ordinary fire grate the air rises through the bars and the oxygen combines in the lower layers of the fire with the carbon of the coal to form CO_2. As the CO_2 and more oxygen of the air continue to rise through the fire, there is thus a progressive formation of CO_2. If the refuse is fed on the bars of an incinerator in too thick a layer, in parts there will not be sufficient oxygen to form CO_2, and as a result of such, only CO will be formed.

The passage of CO_2 over the red hot carbon results in the reduction of 1 molecule of CO_2 and the resulting formation of 2 molecules of CO as illustrated in the following equation :—

$$CO_2 + C = 2CO.$$

The reduction of CO_2 requires as much heat as is developed when CO is oxidised to CO_2, hence the net production of heat is the same whether the carbon is directly oxidised to CO or part of it is oxidised to CO_2 and finally reduced to CO.

As to whether carbon monoxide passes from the furnace in that form or as carbon dioxide is directly dependent on the temperature. If the latter is sufficiently high the CO will combine with more oxygen to form CO_2 and will pass from the furnace in that state.

Good furnace work, therefore, comprises the following axioms :—

1. Good combustion is complete combustion.
2. To obtain this, there must be enough air to supply the requisite amount of oxygen.
3. This oxygen must be distributed uniformly throughout the furnace fuel bed.
4. A sufficiently high temperature is essential.

Colour and Temperature Table.—The following table shows the appearance of the fire in relation to its temperature :—

1300° F.	Dull red.
1835° F.	Bright red.
2200° F.	Orange.
2380° F.	White.

Smoke.

Smoke is the result of bad combustion and may be the partly condensed vapours of the fuel produced by distillation, or the residue produced when the hydrocarbons are incompletely carbonised. In the latter case, infinitesimal parts of carbon are liberated, and mix with the air, and are emitted as smoke. This state of affairs is very objectionable and many authorities take drastic steps to stop such nuisance.

The formation of smoke is due to :—

1. A restricted supply of air.
2. Too low a furnace temperature, which prevents the chemical association of hydrogen and carbon with the oxygen.
3. Heavy firing of green fuel, thus cooling the furnace.

It is well known that hydrogen has a greater attraction for oxygen than carbon, and this being the case, if the full supply of oxygen for oxidisation is not available or the temperature of the furnace is too low, then the carbon is liberated in minute particles and passes up the chimney as smoke. If, however, sufficient oxygen is available and the correct temperature applies, then the particles of carbon will burn to complete combustion, and in so doing give out a bright flame.

The conditions involved in the production of smoke may readily be studied by the aid, when burning, of an ordinary paraffin lamp. Under favourable conditions, such as a clean and trimmed wick, a suitable glass which acts as a chimney, and a regulated flame, then a state of complete combustion is effected, and a bright luminous flame is obtained. This state of affairs shows that the correct temperature and a sufficient supply of oxygen are available. Under these conditions no smoke is produced, but interfere with these conditions by restricting the air supply (on most burners there is an air regulator) and smoke is produced. Again, smoke may be produced by turning the wick too high, in which case the supply of air is not sufficient for the gases produced, or by taking away the glass, which allows an unrestricted supply of air to be distributed unevenly, thereby lowering the temperature and liberating the carbon in the form of smoke.

Prevention.—Smoke which is caused by heavy firing may be prevented in two ways :—

1. By keeping the fuel in a layer sufficiently thin so that carbon monoxide as formed is completely burned to CO_2 or its formation is prevented altogether.
2. By admitting enough air over the fuel bed to oxidise completely the rising CO to CO_2.

This necessitates a brisk fire, for if the temperature is too low no oxidisation of the CO will take place; thus heat is lost by the escaping CO and by the admission of excess air. That the CO is being properly burned to CO_2 may be detected by the presence of the lambent blue flame occurring over a brisk fire when this condition is being maintained. In the case of a large grate area and slow combustion owing to the low temperature, there is usually a considerable amount of CO present. Lessening the grate area to speed up the combustion will remedy this. There is danger in admitting more air, as it is obviously probable that the temperature will be lower. Smoke caused by the escape of unburnt hydrocarbon is observed at the chimney as being yellowish in colour, the flame in the furnace having a similar appearance.

Oxidisation of Hydrocarbons.—In the complete oxidisation of hydrocarbons the following conditions are necessary :—

1. A sufficiently high temperature.
2. A sufficient supply of air.
3. An intimate mixture of the air with the gaseous hydrocarbons.

The presence of thick volumes of black smoke is not necessarily evidence that a large amount of carbonaceous matter is escaping unburnt and represents no great loss of efficiency.

This can be explained by the fact that the hydrocarbons were burnt to CO or CO_2 and the products rendered invisible; but in so doing the air took away more heat from the furnace than would have been formed by the small amount of carbon that would have appeared in the smoke.

The presence of smoke itself, although not producing a serious loss of heat, is indicative of conditions under which poor combustion is taking place. As has been previously pointed out, a low temperature in the furnace, or a thick layer of fuel in the furnace, are conditions appertaining to the production of black smoke, and these are the conditions representing imperfect combustion.

Draught.

Natural Draught.—The primary object of a chimney is to provide sufficient draught under natural draught conditions to facilitate the burning of a fuel, and the intensity of the draught is governed by the height of the chimney and the difference in density between the gases in the chimney and the outside air. It is well known that hot gases are lighter than cool gases, consequently the path of the air will be through the chimney by way of the furnace. Natural draught usually demands a high chimney and is influenced largely by outside atmospheric conditions. Take the following example. The gases within a stack 200 feet high have a temperature of 500° F. The weight of a full column of this gas having a cross-section of 1 foot is approximately 8·67 lb., and the weight of a similar column of outside air at 60° F. is about 15·3 lb. The difference between the weights of these two columns, viz., 15·3–8·67 = 6·63 lb. per square foot. Draught pressure is the name given to this difference of pressure.

The pressure of the draught is usually expressed in inches of water, and by dividing the weight of a cubic foot of pure water, viz., 62·2786 lb. by 1728, the weight of a cubic inch is obtained,

$$\frac{62{\cdot}2786}{1728} = 0{\cdot}03604 \text{ lb.}$$

Thus, 1 inch of water corresponds to a pressure of 0·036 lb. per square inch. The draught pressure is measured by means of a draught gauge, one form of which is shown herewith (Fig. 62).

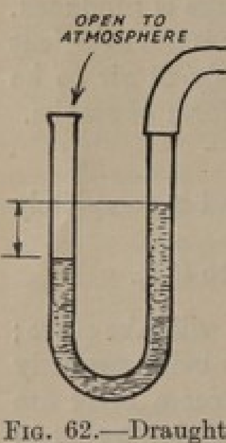


Fig. 62.—Draught gauge.

It is quite a simple affair, consisting in its simplest form of a smooth bore glass tube bent into the form of a U, the length of the legs depending upon the pressure to be measured. In service, it is partly filled with cold water and fixed in a vertical plane, one leg being coupled to the pipe or duct in which pressure is to be read and the other end being left open to the atmosphere. The measure of pressure, if positive, is indicated by the water being depressed in the leg coupled up to the pipe, and elevated in the other leg, which, being open, has only atmospheric pressure acting on its surface. The difference in level of the surface of the two columns of water is the measure of pressure in inches of draught gauge. The reverse would of course apply if the pressure in the pipe were negative; the water in the leg open to atmosphere would be depressed and the water in the leg connected to the pipe raised.

Draught Calculation.—The rate of flow of hot gases within the chimney is dependent upon the height of the stack and the difference in weight between a column of these gases and a similar column of outside air. To find the draught of a chimney, divide 7·6 by the absolute temperature of the outside air and 7·9 by the absolute temperature of the hot gases; the difference between the two multiplied by the height of the chimney in feet gives the draught in inches of water. Expressed as a formula this would read :—

$$d = H\left(\frac{7{\cdot}6}{t} - \frac{7{\cdot}9}{T}\right).$$

where

d = Draught pressure in inches of water.
H = Height of chimney in feet above grate.
t = Absolute temperature of outside air.
T = Absolute temperature of chimney gases.

Absolute temperature is obtained by adding 460 to the observed temperature.

Example.—A chimney is 200 feet high; what is the intensity of the draught, the external air being 60° F. and the gases within the chimney 600° F.

Proceed by the formula

$$200\left(\frac{7{\cdot}6}{60 + 460} - \frac{7{\cdot}9}{600 + 460}\right)$$

$$= 200\left(\frac{7{\cdot}6}{520} - \frac{7{\cdot}9}{1060}\right)$$

$$= 200(0{\cdot}0146 - 0{\cdot}0074)$$

$$= 1{\cdot}44 \text{ inches.}$$

Artificial Draught.—Modern practice has shown that with the more intense draught produced by mechanical means not only can a greater evaporation be obtained per pound of fuel burnt, but that other fuels which have been regarded as unsuitable for steam generating purposes can be successfully and economically used. Shortage of steam, emission of black smoke from the chimney and difficulty in burning some fuels can also be overcome.

The emission of black smoke is a clear indication that the combustion conditions are faulty, and the shortage of steam may be due to inefficient combustion. Difficulty in burning the fuels may also be the result of faulty draught conditions. Artificial draught in many cases is resorted to in order to make the plant more successful in dealing with these troubles.

Artificial draught is produced by means of fans, blowers, air compressors or steam jets, and is known as *forced draught* or *induced draught*, according to the manner in which it is employed. In a forced draught installation the air is forced into the furnace or ashpit by suitable means; in an induced draught system a partial vacuum is created in the root of the chimney or uptake.

An artificial draught plant not only provides adequate draught to enable thicker fires to be used with a consequent greater rate of combustion per square foot of grate area, but also increases the temperature of combustion in the furnace or cells. The thick bed of fuel will tend to increase the efficiency of the boiler plant, since the time taken for the air to pass through a thick bed of incandescent fuel will be longer than with a thin bed, consequently the air will mingle more intimately with the fuel, thus allowing more of the oxygen in the air to combine with the combustibles in the fuel, and thereby reducing the amount of air required per pound of fuel.

Forced Draught.—In the induced draught system the air for combustion is drawn through a fuel bed, whereas forced draught sets up a pressure under the fires, thus forcing the air through the fuel. With this system, the function of the fan ends when the air for combustion has been forced through the fuel bed, the remaining duty of overcoming the resistance of boilers and flues being performed by natural draught. With a forced draught system the pressure that can be maintained below the fires is governed by the necessity of preserving a slight vacuum above the fires. Unless this condition is maintained, flames, smoke and hot air will be blown through every opening and crevice in the combustion chamber. This not only results in a considerable heat loss, but makes the vicinity of the fronts of the furnaces and boilers uncomfortably hot. The pressure usually required at the fan outlet for forced draught is between 2- and 3-inches draught gauge, but where the duct is unusually long and of curtailed area, slightly higher pressures are required to overcome the additional resistance.

Forced Draught System (*Steam Jets*).—The main advantage of steam jets is the low first cost, but against this must be set the high steam consumption involved, amounting to a figure of 4 to 5% of the total steam generated.

An application of the steam jet principle is one used in connection with the Meldrum furnace. By means of a specially designed blower the steam is forced into the ashpit, which is of the closed type, and a pressure from a 1- to 3-inch draught gauge can easily be obtained.

The fire bars used in the furnace vary in thickness according to the class of fuel being burned, so as to prevent the fine parts of the fuel from falling into the ashpit. The Meldrum furnace and steam jets are well known to the cleansing profession in connection with the burning of house refuse.

Ejector Draught.—In this system the draught power is produced indirectly and the power consumption is higher for a given duty than with induced or forced draught. The chimney is constructed with a throat of reduced area, through which the average velocity is between 8000 and 10,000 lineal feet per minute as against an average velocity of 1500 to 1800 lineal feet per minute with ordinary parallel chimneys. A result of this is that the dust trouble is accentuated, and also a loss of power is represented by this very high velocity.

Induced Draught.—In this system, as the name implies, the gases are induced to the stack by way of the furnace boiler and flues by means of a steam jet or fan placed at or near the base of the stack. Another system to increase the draught is by increasing the height of the chimney, but this is usually expensive and in many cases the foundation of the existing stack will not allow of such increase of height. Usually the steam jet system is operated by means of exhaust steam, as live steam for this purpose is too expensive. A common form of an induced draught system worked by exhaust steam is that of the locomotive, and this system is also employed on transport vehicles having the locomotive type of boiler. The fan, however, is the means usually employed for induced draught and the intensity of the draught can be governed to meet most conditions providing the fan is of sufficient capacity.

Certain rules are necessary for the successful application of induced draught, such as :—

1. The path of the gases to and from the fan should be as easy as possible.
2. A suitable velocity is most desirable and sudden changes of velocity and direction of gases should be avoided.
3. Infiltration of air should be prevented.

If the flues are of ample size and the path to the fan is easy, there is less resistance to the flow of gases, consequently there is a greater efficiency. Sudden changes of velocity and direction should be avoided, as a change of velocity means a loss of heat equal to the difference of pressure required to set up these velocities, as measured by the draught gauge, and a change of direction necessitates overcoming the inertia of the gases in the original direction and the establishment of the velocity in the new direction.

One of the chief causes of a low boiler plant efficiency is infiltration. By infiltration is meant air passing through faulty brickwork, dampers, etc., the intensity of the draught is usually higher with induced draught than with natural conditions, therefore any leakages in the brickwork will allow a greater quantity of air to flow through the flues. The brickwork should be pointed carefully, and the dampers should be a good fit, otherwise the draught power will be lessened, and the power consumed increased.

Balanced Draught.—The balanced draught system possesses the advantages of both forced and induced draught, and is used largely in modern power stations. The forced draught takes care of the fuel bed resistance, and the induced draught takes up the load from the top of the fuel bed, and thus only deals with the resistance of the boiler and heat-saving devices, if fitted. Balanced draught provides a means of burning fuels under the best conditions, the draught over the fire being balanced, and all that is necessary is to maintain a slight vacuum in the combustion chamber to prevent the escape of gases. In large stations it is usual to make each boiler unit self-contained, that is, to provide each boiler with its own forced and induced draught fan.

Comparison of Natural and Mechanical Draught.

Natural Draught.

1. A high chimney is necessary for a moderate draught.
2. The gases usually leave the boiler at a high temperature with consequent heat losses.
3. Weather conditions affect the intensity of the draught.
4. Natural draught is usually of low intensity, thereby :—
    (*a*) Limiting the application of economisers and other efficiency increasing accessories.
    (*b*) Requiring thin fires, thus limiting the rate of combustion per square foot of grate area.
    (*c*) Preventing the efficient combustion of low grade fuel.

Mechanical Draught.

1. Does not require a high chimney.
2. Is not dependent on the temperature of the waste gases.
3. Is not affected by weather conditions.
4. Can be adjusted to suit the varying steam demands.
5. Can be adjusted to suit the intensity of the draught required for the economical combustion of low grade fuel.
6. Can successfully deal with the high draught required by modern boilers with their economisers, air heaters and re-heaters.

Advantages of Mechanical Draught.—Providing the mechanical draught system is correctly designed and installed, and completely under control, inferior fuels can be successfully and economically burnt, and, furthermore, the system can be varied for different rates of combustion. Owing to greater intensity and uniformity of draught, much more steam can be generated per hour than would be the case with natural draught. Again, less air is used, being somewhere in the region of 17 lb. against 21 lb. per pound of fuel used. It naturally follows that, owing to this less quantity of air, a higher furnace temperature is obtainable, with a consequent result of more effectual combustion and economy of fuel. Climatic conditions affect the draught produced by a chimney, but such is not the case where mechanical means are provided for draught purposes.

CHAPTER XII

BOILERS AND BOILER PLANT

There are almost endless types of boilers, and it is not within the scope of this chapter to deal fully with all or any of them.

One of the earliest of boilers was that invented by Newcomen in 1711, which on account of its shape was called the Haystack or Balloon boiler (Fig. 63). It was formed with a hemispherical top and an arched bottom, and unlike earlier types, which were made of cast iron, was made of wrought iron. The fire was placed beneath the arched bottom, the hot gases surrounding the lower part of the boiler.

To increase still further the heating surface, James Watt made his wagon boiler (Fig. 64). In this boiler the top was cylindrical and the sides curved inwards.

The hot gases passed from the grate, underneath the boiler to the rear, through the left-hand flue to

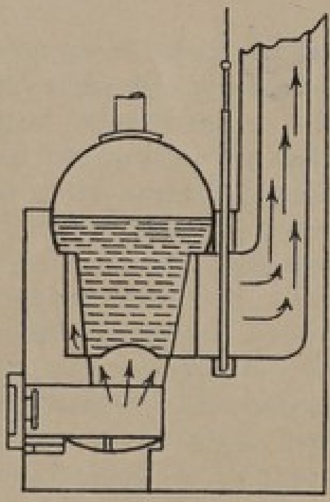


Fig. 63.—Haystack boiler.

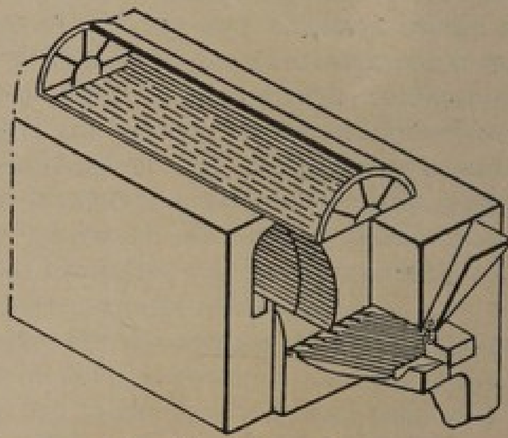


Fig. 64.—Wagon boiler.

the front, then through the right-hand flue to the rear, and so to the stack. This was called the " wheel draught " by reason of the gases passing completely around the boiler.

In the larger sizes a flue was placed within the boiler. The products of combustion first passed beneath the boiler to the rear, thence through the centre flue to the front; on reaching the front the gases divided and passed to the chimney by the side flues. This form of draught was called the " split draught."

Although such boilers as the above gave excellent results for the duties imposed on them, they could not stand the higher pressures that became common. In fact, to-day we are finding difficulty in getting material for boilers to withstand the increasingly high pressures which are becoming popular.

About the beginning of the nineteenth century the cylindrical boiler was introduced, and as to shape this boiler brings us almost to present-day practice.

The earliest forms were the plain cylindrical and the egg-ended boiler, the difference being in the form of the ends—those of the former were flat and of cast iron, the latter hemispherical and of wrought iron. These boilers, like those previously mentioned, were externally fired.

Still the pace for steam demands could not be maintained, and the demand for increased heating surface led to the introduction of the internally fired boiler. The introduction of this boiler we owe to a Cornish engineer named Trevithick, and his boiler was and is still known as the Cornish boiler (Fig. 65). It is interesting to note that not only are many of this type of boiler still working, but that they are giving results which compare favourably with many of the more recent designs of boiler.

The coal is burnt on the grate bars, *C*, passed through the flue to the back, where they divide and return to the front end by means of the side flues, *L*, in the brickwork. At the front, the hot gases uniting pass

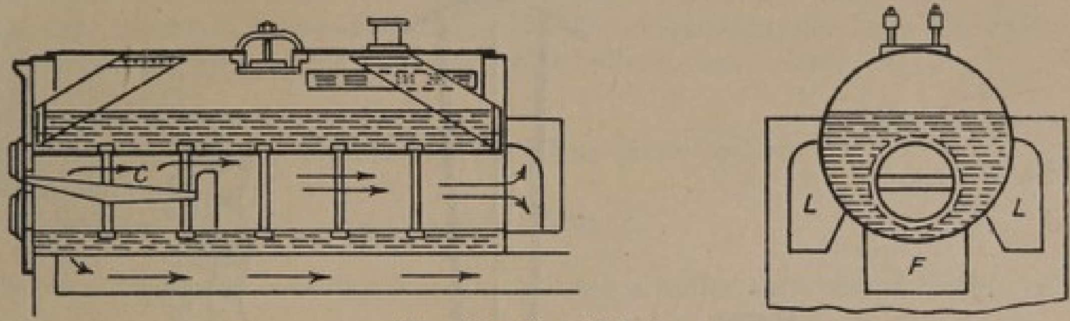


Fig. 65.—Cornish boiler.

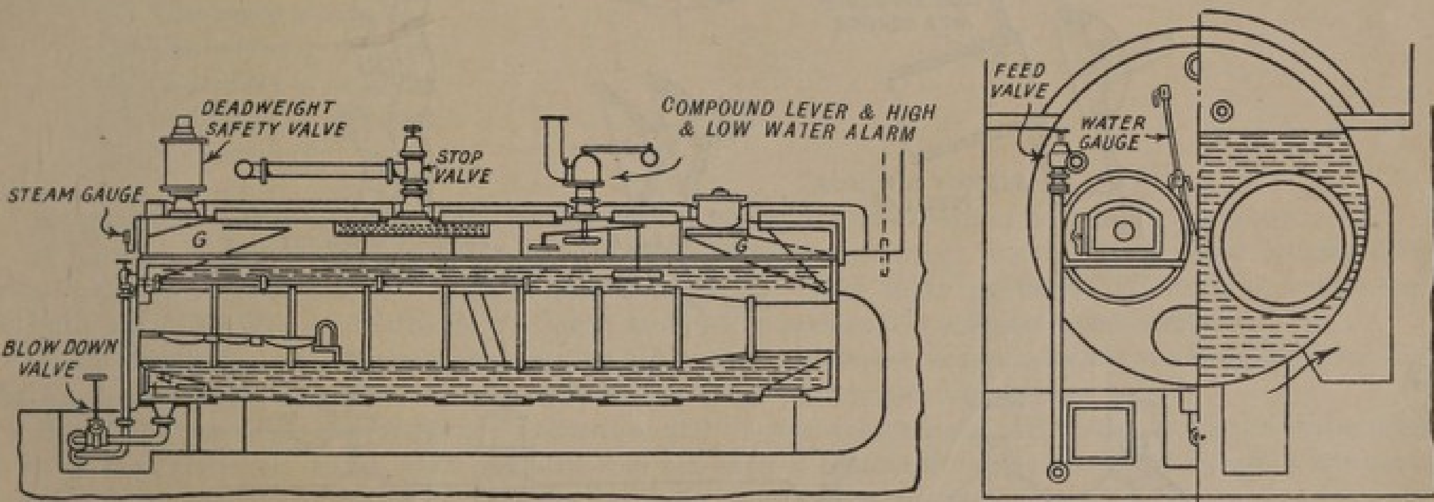


Fig. 66.—Lancashire boiler.

downwards and through the flue, *F*, in contact with the bottom of the boiler. This arrangement reduces the temperature of the gases before they come into contact with the bottom of the boiler, where sediment collects.

Even this boiler did not satisfy the demand for power, and to obtain more heating surface and grate area, a second flue tube was inserted. This type is known as the Lancashire boiler (Fig. 66), and to-day is a great favourite where pressure up to 160 lb. per square inch is sufficient.

The shell is made of courses of plates each about 3 or 4 feet wide and so arranged that each course is alternatively an outer and inner belt. Each end plate is cut in one piece. The front plate is joined to the shell by angle rings and the back plate flanged to join the shell. The end plates are stayed to the shell by what are known as gusset stays, *G*.

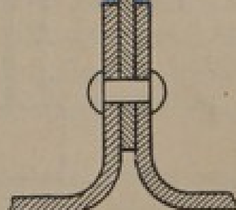


Fig. 67.—"Adamson" ring joint.

The plates forming the flue are generally flanged outwards and connected together as shown in Fig. 67, a ring being inserted between the flanges. This form of joint is known as the " Adamson Ring Joint," from the name of the original inventor.

The Lancashire boiler is sometimes modified in order to obtain more capacity. This form resembles the Lancashire boiler from outward appearance; the difference in construction is that after the furnace, the two tubes join into one, shaped something like a kidney, and is often referred to as the kidney tube; in this tube are arranged a number of conical tubes known as Galloway tubes (Fig. 68).

Next came the Water Tube boiler, still in an endeavour to meet modern steam requirements. These boilers are built with much larger steaming capacities than any of the former types, chiefly on account of the good circulation of the gases and water, and also by reason of the fact that it is possible to get a much larger heating surface into the same space. They are also able to withstand much higher pressures than the shell or flue type by reason of the much smaller diameter of the parts.

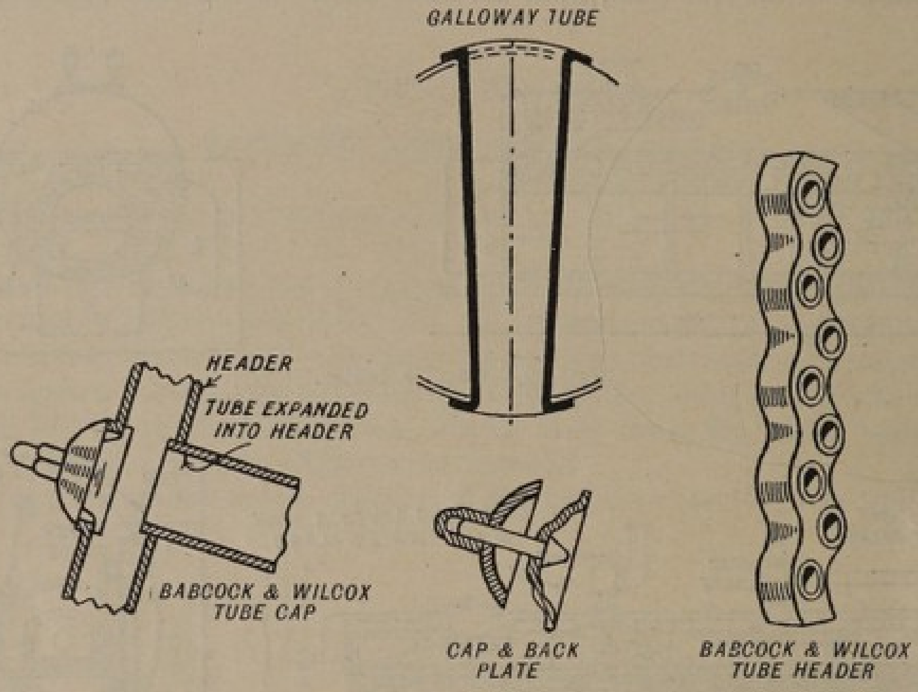


Fig. 68.

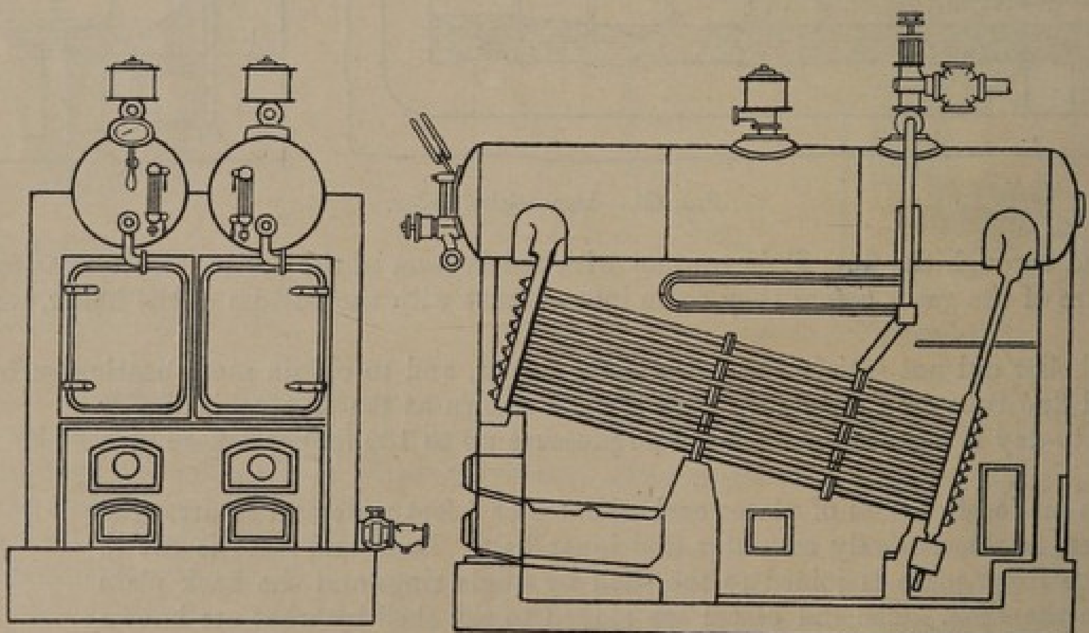


Fig. 69.—Babcock and Wilcox Boiler.

Water tube boilers may generally be divided into two classes, those with vertical or nearly vertical tubes and those with horizontal or nearly horizontal tubes. Fig. 69 shows a Babcock and Wilcox boiler which falls within the horizontal or nearly horizontal class.

This boiler consists of a number of mild steel tubes placed in an inclined position and connected with each other and with a horizontal steam and water drum by vertical passages at each end, while a mud drum is connected to the rear and lowest point of the boiler.

The boiler is suspended entirely independent of the brickwork from wrought iron girders resting on columns. This does away with straining from any unequal expansion and permits the brickwork to be removed, if necessary, without disturbing the boiler.

The furnace is placed under the front and higher end of the tubes, and the products of combustion pass up between the tubes, down through them again, then once more up through the spaces between the tubes and so to the chimney.

As the water inside the tubes is heated, it tends to rise towards the higher end, and rises through the vertical passages into the drum above the tubes, where the steam separates from the water.

Some of the advantages claimed for the water tube boiler are as follows :—

(1) Better circulation.
(2) Safety (bursting of one portion does not affect entire boiler).
(3) Better combustion.
(4) Small space occupied for large steaming capacity.

Choice of Boilers.—The main considerations in choosing a boiler may, stated briefly, be :—

(1) The amount of water to be evaporated.
(2) The space available.
(3) The working pressure.
(4) Character of fuel.
(5) Character of demand.
(6) Water supply.

Evaporation.—It is usual to state the amount of water to be evaporated in pounds per hour.

A Lancashire boiler can evaporate up to 9000 lb. of water per hour; above this size they become somewhat large and difficulties of transport and manufacture make their use rare. Water tube boilers may be built up to 30,000 and 40,000 lb. per hour, and, being sectional, transport is not difficult.

Space Available.—For a given evaporation the water tube boiler occupies much less ground space than the Lancashire type, although more head-room is required for water tube boilers.

Working Pressure.—For working pressures of 180 lb. per square inch and above, the water tube boiler is to be recommended, as for high pressures the plates of a Lancashire type have to be made very heavy due to the large diameter, whereas with the small diameter of the component parts of the water tube, much less thickness of metal is required, added to which is, of course, the greater safety of the water tube.

Character of Fuel.—The Lancashire boiler is admirably suitable for low rates of combustion, that is, anything up to 25 lb. of coal per square foot of grate surface per hour, and with this rate of combustion it will be seen that, owing to the restricted grate area, good fuel must be used in order to obtain maximum evaporation. On the other hand, with the larger grate area permissible with the water tube and the greater space available for combustion, a much higher rate of combustion may be employed, with the consequence that a much lower grade of fuel may be burnt without lowering the efficiency of the boiler.

Character of Demand.—Where the demands for steam are irregular and heavy for short duration, the Lancashire is ideally suitable, as the large steam space allows of sudden draw of steam without decreasing the pressure to any large extent. In cases where quick steaming is of first consideration, that is, where the demand or time of demand can be anticipated, the water tube would be recommended, as an idle boiler of this type can much more quickly be got under steam.

Character of Water Supply.—If the water with which it is proposed to feed the boiler contains a considerable amount of scale-forming salts (commonly known as " hard water "), the Lancashire boiler has a distinct advantage owing to it being more accessible for cleaning, and further it can take a much greater thickness of scale without impairing the boiler.

It is essential that good water should be used for the water tube and, of course, this has undoubted advantage when applied to the Lancashire type.

Water Supply.—Before using any water for feed purposes, have an analysis made by a competent chemist, as often water which appears excellent is totally unsuitable for boiler feed water and its use might easily be attended with disastrous results.

Care of Boilers.—The law demands certain requirements regarding the care of boilers and it would be well if everybody who is in charge of boilers paid special attention to these requirements. By being in charge is meant those actually responsible and not of necessity the man working the boiler, *i.e.*, the stoker.

The following is an extract from the Factory and Workshop Act 1901 :—

"(1) Every steam boiler used for generating steam in a factory or workshop or in any place to which any of the provisions of this Act apply must, whether separate or one of a range (*a*) have attached to it a proper safety valve, and a proper steam gauge and water gauge to show the pressure of steam and the height of water in the boiler; and (*b*) be examined thoroughly by a competent person at least once in every fourteen months.

(2) Every such boiler, safety valve, steam gauge and water gauge must be maintained in proper condition.

(3) A report of the result of every such examination in the prescribed form, containing the prescribed particulars, shall within 14 days be entered into or attached to the general register of the factory or workshop, and the report shall be signed by the person making the examination."

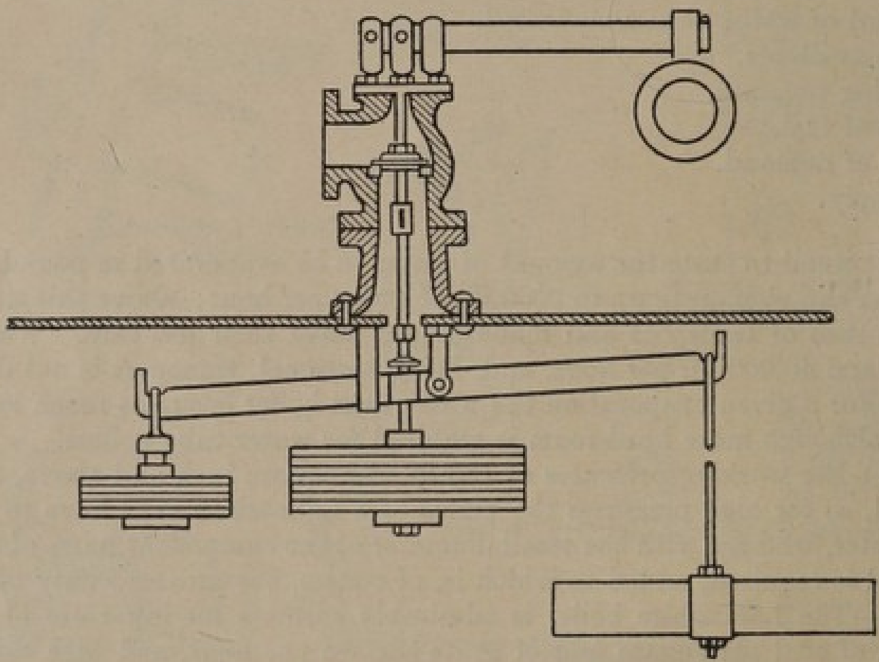


Fig. 70.—Lever weight safety valve.

Whilst the above are fairly stringent rules they do not in any way cover the care of a boiler.

Before proceeding with the care of boilers it will be as well if we get some idea of the various fittings which are mentioned in the above Act, together with several others which are to be found on almost any boiler.

Safety Valves.—These are of various designs, lever weight, dead weight, and spring loaded, and are shown in Figs. 70, 71, and 72.

With the former is incorporated a high and low water alarm, that is, should the water get too low in the boiler the float sinks and causes the safety valve to open. The same applies when the water reaches too high a level, the other float rises and again opens the safety valve, when the blowing off of the steam at once attracts the attention of the attendant and he is able to act before any serious damage results.

Fig. 71 shows a spring loaded valve; these valves are invariably used on boilers which are subject to any movement, such as locomotive boilers, marine boilers and steam wagon boilers.

Fig. 72 shows a dead weight valve. Safety valves should be lifted by the steam at least once per day, for if they are not worked regularly, they are liable to become set either through corrosion or dirt, and when required will not blow off at the desired pressure, which may have fatal results.

It is essential that the safety valve should not in any way be tampered with, things should not be hung on the lever end, or dead weights, and any adjustments should be made by a competent person.

Boilers are often fitted with two safety valves of different types, in which case one should be set a little in advance of the other. This is a practice to be recommended.

Steam Pressure Gauge.—This is shown with dial removed in (Fig. 73). It is fitted in the steam space of the boiler at or near the highest point and consists of a bent tube which the pressure tends to straighten

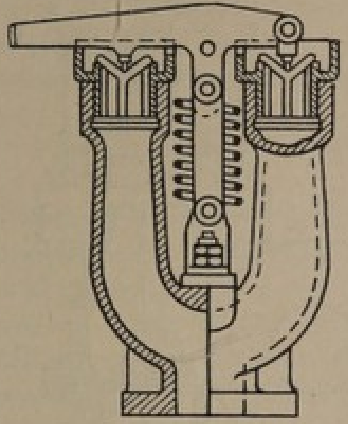


Fig. 71.—Spring loaded safety valve.

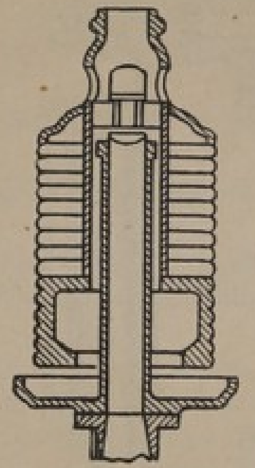


Fig. 72.—Deadweight safety valve.

and so operates the pointer through the quadrant. These should be occasionally checked against a standard gauge as only a small variation is allowed.

Water Gauge.—(Fig. 74) shows the usual form of water gauge. It consists of three cocks, a top or steam cock, a bottom or water cock and a try cock. The top or steam cock is connected with the bottom or water cock by a glass tube. The top fitting is in communication with the steam space of the boiler, and the lower fitting in communication with the water space. When both steam and water cocks are open as shown, water flows into the glass tube and shows the level at which the water is standing in the boiler. The try cock is normally closed but should be periodically opened to try the fittings. It is also advisable to blow through the fittings systematically two or three times each day. This should be done in the following manner: First close the water cock and open the try cock, allow this to blow through until satisfied that a clear passage exists, next close the steam cock and open the water cock, allowing this to blow through to remove any sediment which may have become lodged in the passages. When confident that all is clear, close the water cock and try cock, then open the steam cock and finally open the water cock, when water should rise fairly quickly in the glass. Any reluctance on the part of the water to rise should be investigated, as false levels are perhaps the most fruitful source of accidents to boilers.

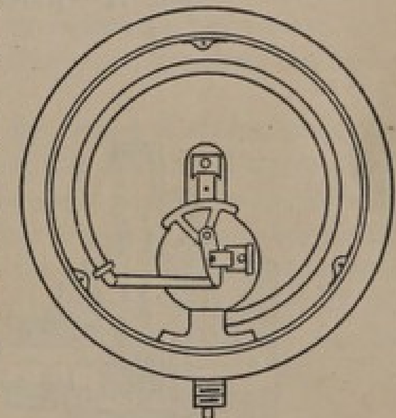


Fig. 73.—Steam pressure gauge.

Feed Check Valve.—This fitting is shown in Fig. 75. It is connected to the boiler just below the working water level and the water is conveyed by an internal pipe some distance into the boiler, usually about 8 or 10 feet beyond the furnace tubes in the Lancashire or flue tube type, and a short distance beyond the front headers of the Babcock type.

This valve is so arranged that whilst water may enter the boiler it is impossible for the water to be forced out by the pressure of steam in the boiler. It is also possible to close the valve so that nothing can enter the boiler. By control of this valve the supply of feed water is regulated.

Blow Down Valve.—Fig. 76 shows a common type of valve for this purpose; it is placed at the lowest part of the boiler, and is used for emptying the boiler and also for blowing out any sediment during the working of the boiler. This procedure is very necessary when the feed water contains salt, as the only method of reducing the concentration is by blowing down. It is advisable to blow about 1–2 inches of water out of the boiler each day, in order to remove a considerable amount of the sediment. This practice would not, of course, be adopted if it is known that the water does not contain impurities, as it is wasteful of heat.

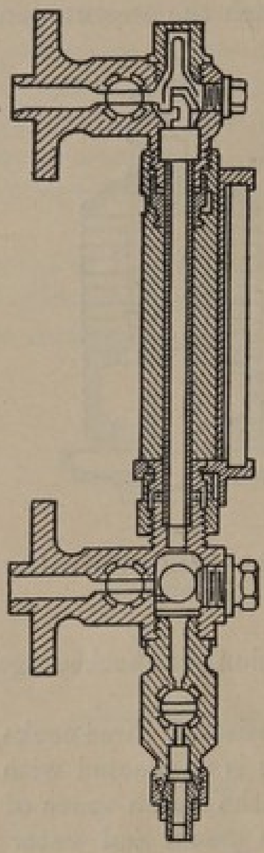


Fig. 74.—Water gauge.

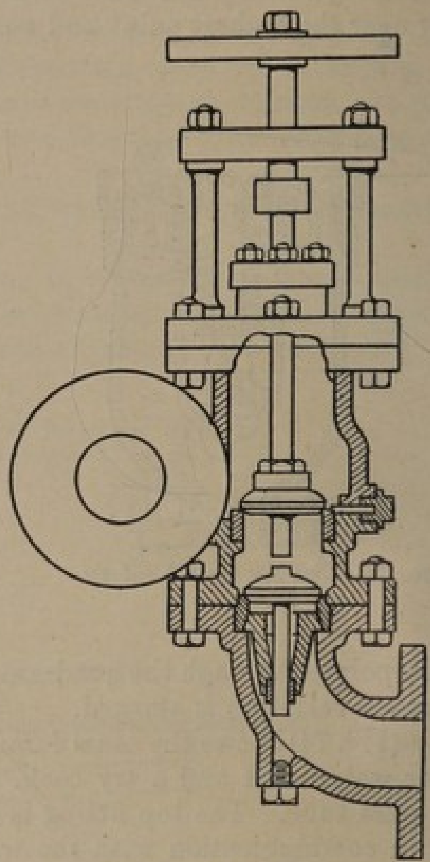


Fig. 75.—Feed check valve.

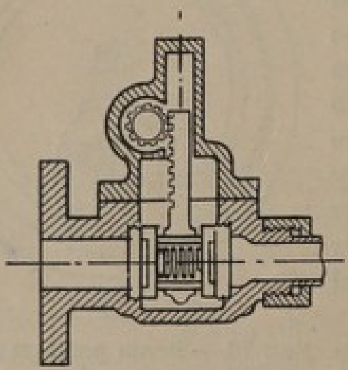


Fig. 76.—Blow down valve.

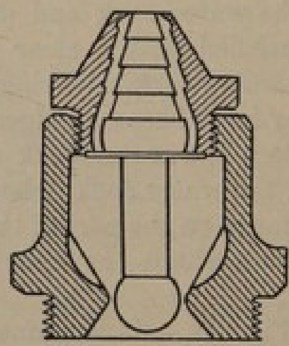


Fig. 77.—Fusible plug.

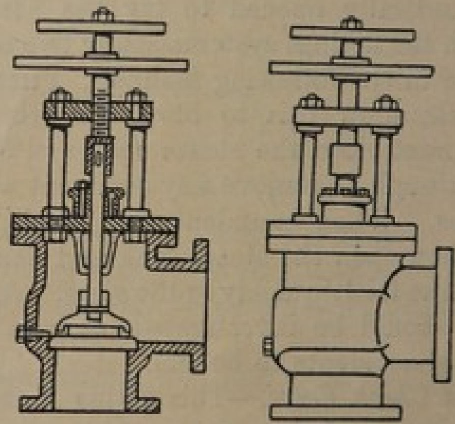


Fig. 78.—Main stop valve.

Fusible Plug.—Fig. 77 shows a fusible plug which is inserted in the furnace crown of the boiler. It is composed of a metal cone held in place by a metal having a low melting or fusion point. Should the furnace crown become dangerously hot, this metal melts, allows water to damp the fire and at the same time relieves pressure in the boiler.

Covering of Boiler and Pipe Surfaces.—The bare top of a boiler and steam pipes are a source of great heat loss. To overcome some of this loss the pipes should be covered with some non-conducting material, magnesia covering with a protection of canvas is commonly employed, sometimes a more fibrous material is used on account of its greater mechanical strength.

A bare pipe will radiate heat at the rate of 3 B.Th.U. per hour for each square foot of uncovered surface for each degree F. difference of temperature between the steam and the surrounding air. This loss is considerable in even a small station when taken over the year.

General.

The first duty of an attendant when taking over a boiler which is working is to see that the water is at its proper working level.

Feed pumps and/or injectors should be tried and if not working properly, steps should be taken to have them put right.

Never empty a boiler while the brickwork is hot. Avoid if possible pumping cold water into a hot boiler.

Do not allow dampness to get into flues as this causes pitting and corrosion of the shell. If any pitting or redness is found at times of cleaning, the parts should be thoroughly cleaned and limewashed at regular intervals; this will generally arrest the corrosion.

Internal Corrosion.—This results from the chemical action of impure feed water. It may occur in several forms such as general wasting of the boiler plates, which it is difficult to detect and if suspected should be confirmed by the drilling of a small hole in order to gauge the thickness of the plates; or it may occur as pitting or local wasting.

Grooving is also a common form of corrosion. This is the result of combined chemical and mechanical action, and is most commonly found in boilers of the Lancashire and Cornish types. It appears at the edge of the angle iron on the front plate around the furnace tubes or in the root of the angle ring at this point.

Grooving is not readily detected, and what may appear but a fine crack may extend for a considerable depth and if allowed to continue is likely to produce serious results.

Incrustation.—This is the formation of a scale or sludge by the impurities in the feed water which are precipitated by the rise in temperature or left behind as the result of evaporation of the water.

A thin coating of scale may not be harmful to the boiler, but if a thin coating will form, so will a thicker one in course of time, and being a poor conductor of heat, not only causes considerable wastage of fuel, but also allows the plates next the furnace to become overheated, and if this takes place to excess the boiler will collapse with fatal results to boiler, surroundings, and possibly life.

This incrustation may be prevented by seeing that the water entering the boiler contains no scale-forming salts. This is done by chemical treatment before the water enters the boiler. This method, however, whilst having everything to recommend it, is hardly worth the expense, where there is passably good water, and very small plant. In this case the boiler should be thoroughly cleaned of scale regularly, the period between cleaning being determined by experience. Never loosen the scale by blowing down a boiler under pressure and filling up with cold water. This does undoubtedly loosen the scale, but at the same time it will cause serious injury to the boiler and is therefore a practice which should not be tolerated.

CHAPTER XIII

SCIENTIFIC INSTRUMENTS AS AN AID TO REFUSE DISPOSAL WORKS MANAGEMENT

To cover the entire subject in this chapter would be to attempt the impossible; it is therefore my object to stress the extent by which steam raising plant efficiencies can be increased in refuse disposal works by the introduction of suitable instruments, providing always that such apparatus receives the attention which it demands and deserves. Appreciating the advantages to be derived from instruments during the raising of steam, it will be apparent that their further introduction for use with the main power plant and its various auxiliaries will have most beneficial results.

Modern refuse disposal works practice is undoubtedly incomplete unless scientific instruments are in use. The introduction of these has covered a lengthy period, in view of which considerable losses have been, and are still being, constantly incurred.

Recent developments demand that the efficient operation of any important unit shall be governed by the results obtained from a sequence of suitable instruments, whereas in the past many engineers have been satisfied with the occasional installation of pressure gauges.

The object of this chapter is to emphasise the use of these instruments in connection with undertakings such as the City of Birmingham Salvage Department, at the same time showing how efficient control and operation can be procured with reasonable ease by their introduction.

Admittedly refuse incinerator plants are installed to render innocuous refuse from innumerable sources, and, after salvable articles have been withdrawn, if the inherent heat can be utilised in the process of incineration a valuable source of revenue is created. This substantially affects operating costs, but it is essential that the primary object of refuse incinerators, *i.e.*, the disposal of refuse in an efficient and sanitary manner, should not be lost sight of.

The inception of refuse disposal plants was the simple form of furnace in which refuse was burned to destroy its offensive nature and reduce its bulk. This process was not only slow, but expensive and wasteful, no consideration being given to the recovery or use of the heat which the material possessed.

To overcome these objections, and with a view to expeditious incineration, high chimneys were introduced, thus increasing the draught at their base, at the same time materially assisting in the dispersion of the products of combustion in a manner which reduced fume nuisance to a minimum.

Mechanical draught appliances were introduced at a later period, these being responsible for the more rapid incineration of the refuse and the creation of higher temperatures. These improved conditions were responsible for the appreciation that a considerable amount of heat could be extracted from the gases and utilised for steam raising and power generation to drive forced or induced draught-fans, and other important auxiliary machinery.

Further, with the advent of the electric vehicle, the demand for cheap electric current was increased by the necessity of regular charging at a reasonable cost, this being naturally responsible for a heavier steam consumption.

To-day, it is universally acknowledged that instruments are essential to efficient steam production, the function of such apparatus being to produce regular and reliable data relating to pressure, temperature, carbon dioxide (CO_2), draught, fuel consumption and steam production. These two latter are doubtless the most important features, inasmuch as they definitely indicate whether results are efficient or otherwise.

The average working efficiency of industrial boilers in this country is below 60 per cent., which statement is made on good authority and cannot be seriously questioned. It will be appreciated that much remains to be done in connection with the introduction of instruments, it being the exception rather than the rule to find boiler houses equipped with a comprehensive range of apparatus for producing data. Few people are acquainted with the output and leaving losses of steam raising plant, hence efficiency is an unknown quantity, and it is undoubtedly an apt illustration of "where ignorance is bliss, etc."

The importance of measuring the output of steam raising plant consuming high grade coal will be readily admitted, also the necessity of arriving at the vital ratio: "lb. of water evaporated per lb. of fuel burnt." Further, steam generation is equally important when refuse is used as fuel, the calorific value of which constitutes its most important asset. It may be argued that refuse does not cost anything, but nevertheless, the fact that labour, capital and depreciation charges are ever present cannot be denied, such costs being substantially reduced when the inherent heat of the material is recovered. In explanation, one should possibly stress that these charges remain stationary whatever the amount of the steam generated may be, in view of which the greater steam production is responsible for the lowering of the overall cost per ton produced. Those in charge of refuse disposal plants will appreciate from the foregoing the necessity of the selection and arrangement of a comprehensive sequence of instruments.

Pressures.—The pressure gauge, as the name implies, indicates pressures of boilers, steam and water mains and other auxiliary equipment. Gauges of the most popular type are of the Bourdon design, consisting of a bent tube, elliptical in cross-section, one end of which is closed and connected to a quadrant by means of a lever. The tube is filled with a suitable fluid, and when pressure is exerted upon this, the tube tends to straighten, and through a pinion and quadrant gears movement is transmitted to the pointer proportionate to the pressure, this being indicated on the gauge dial. An instrument of this type is illustrated by Fig. 79. Dials should preferably be of a generous size, and in particular cases, illuminated. A feature which should not be overlooked, is that connecting pipes should be at least ½-inch in diameter.

Coming to the question of recording pressure gauges, these serve an exceptionally useful purpose in providing the engineer-in-charge with a continuous check upon his stokers. A dual advantage is forthcoming by the introduction of this recorder, first, inasmuch as the engineer is in a position to criticise the previous day's operations, and secondly, the instrument has a wonderful moral effect upon the stokers, who feel that they are under constant automatic surveillance, realising that the production of indifferent results will undoubtedly entail, *metaphorically*, the heaping of coals of fire upon their heads. Alternatively, boiler attendants producing good results have reason for self pride, and a certain amount of appreciation in such instances on the part of those in authority would undoubtedly be well placed.

The harmful effects of a rapidly fluctuating boiler pressure are probably common knowledge, but nevertheless it should be stressed that, quite apart from the loss of efficiency experienced, unnecessary strains are set up, these often being responsible for leaky seams. A specimen chart taken from a pressure recorder at the Birmingham Salvage Department's Brookvale Road works is reproduced in Fig. 80. The diagram is admittedly by no means perfect, nevertheless it will be seen that the changes have been gradual, and have not occurred at relatively short intervals.

Regarding the installation of gauges in connection with high pressure services, the advisability of providing for suitable bosses on steam and other mains should be borne in mind. These should be of such size as to ensure the entire absence of leaky connections.

Evaporation.—One of the principal features in every section of the industrial world is undoubtedly "Output," and in connection with steam raising plant "Production" is not one whit less important. Output in connection with boiler plants can be determined by one of two methods, these being either by measurement of the water fed into the plant or the steam leaving it. The former is by far the simpler proposition and the one for which a decided preference has been shown up to the present time. Nevertheless, whether water or steam be measured, the instruments installed for the purpose should be capable of producing a record of production throughout the day, at the same time providing a definite indication of the total quantity of water or steam measured.

Records from meters of this description, together with a knowledge of the heat value of the refuse burnt, serve not only to promote further steam production, but are also useful when comparing the varied methods of firing, or types of furnaces, and the efficiency of one shift with another. The efficiency of a stoker can be more readily estimated by the joint consideration of records appertaining to pressure obtained and water

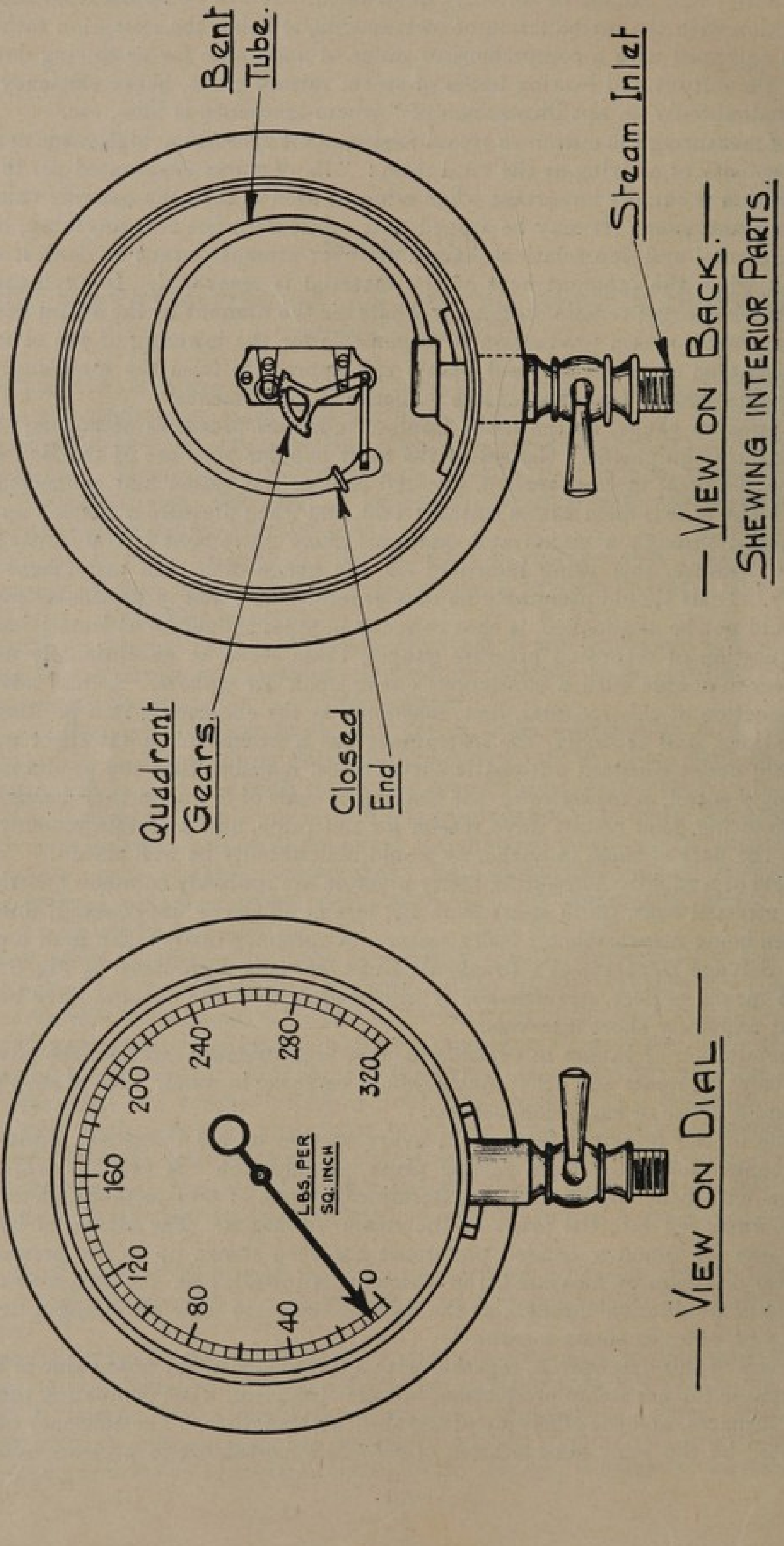


Fig. 79.—Bourdon pressure gauge.

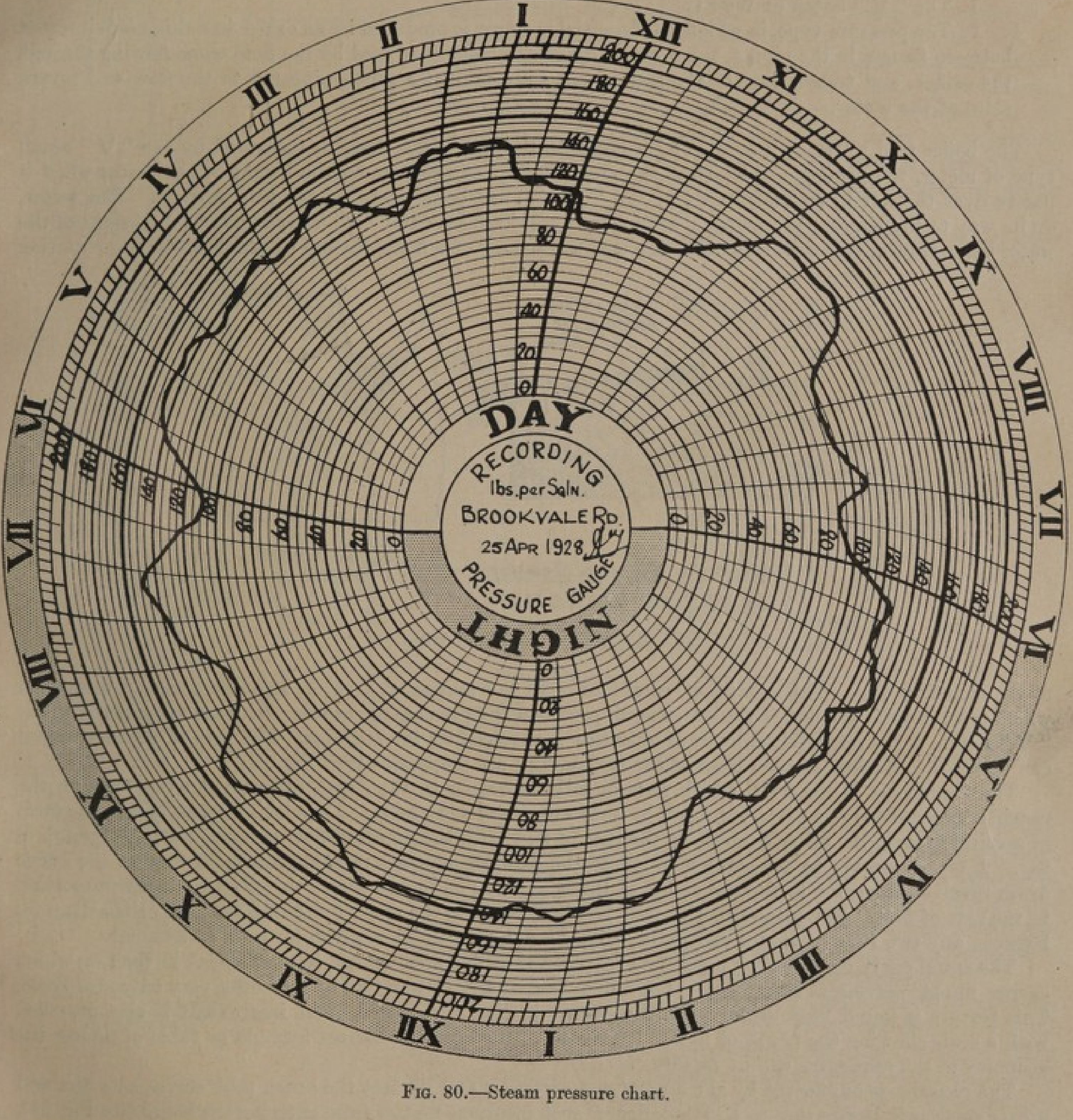


Fig. 80.—Steam pressure chart.

evaporated during his shift than by the former alone, though the value of the pressure record should not be discredited.

The types of meters in general use are :—

1. The "V" notch or Weir type.
2. The pressure type, in which a differential pressure is produced by an orifice in a thin plate inserted between flanges in the piping, the pressure difference being produced by the fluid when flowing through the orifice, and transmitted to the instrument by means of a pipe connected to the flow and return sides of the meter.

The boiler feed water at the City of Birmingham Salvage Department is measured by the "V" notch type of meter, the principle of which is the measurement of the flow by the height of the water when it passes over the notch, an instrument of the "Lea" type being installed for this purpose. The water, on its way to the boiler feed pumps, is arranged to gravitate over the "V" shaped notch, the height of the water being transmitted to the recorder through the agency of a float, the rod of which controls the motion

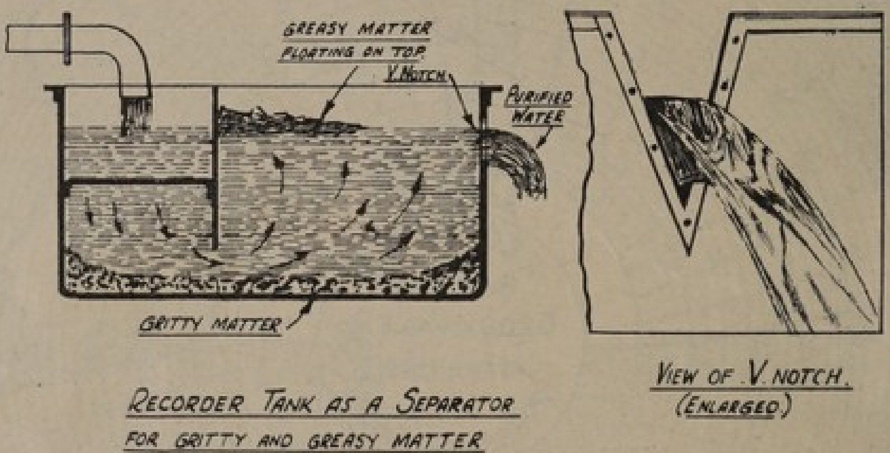


FIG. 81.—Lea recorder tank.

of the recording pen. This operation, combined with the motion of a clock, also operating an integrator which totals up the amount of the water used, produces the permanent record. No wear takes place on the "V" notch, and a negligible amount of attention is required by the recorder. The zero of the instrument can be readily checked at such time as the feed pumps are stopped. (See Fig. 81.)

The movement of the float, which rises or falls according to the depth of water flowing through the notch, is transmitted to a revolving drum by means of a rack and pinion. Upon this drum is cut, in the form of a spiral groove, the curve connecting the rate of flow with the depth of flow through the "V" notch in use. A pin connected to the same member as the pen-arm engages in this groove, so that as the curve drum revolves according to the rise or fall of the float, the pen moves across the chart in direct proportion to the rate of flow. The total quantity may be obtained from the chart by taking the area of the diagram between any two time ordinates and multiplying by a factor, which is given for each instrument.

The spiral curve on the revolving drum is calibrated in lb. per hour, and with the beak in the arm which carries the pin serving as an indicator, the rate of feed at any instant can be read off a very extended scale. This feature is found very useful when conducting a short boiler test. The instrument is also provided with a scale showing the depth of flow. By means of this and the correct formula or table of figures the accuracy of the apparatus can be rapidly checked.

The recorder is unaffected by the hottest and dirtiest water, in fact the notch tank serves as a dirt and grease separator, preventing to a certain degree such injurious matter from entering the boiler (see Fig. 81). The accuracy of the apparatus is guaranteed by the makers to within 1%.

Professor James Thompson of Belfast, in papers read before the British Association in the year 1858, pointed out the accuracy of the "V" notch method, and later this has been substantiated by many scientists.

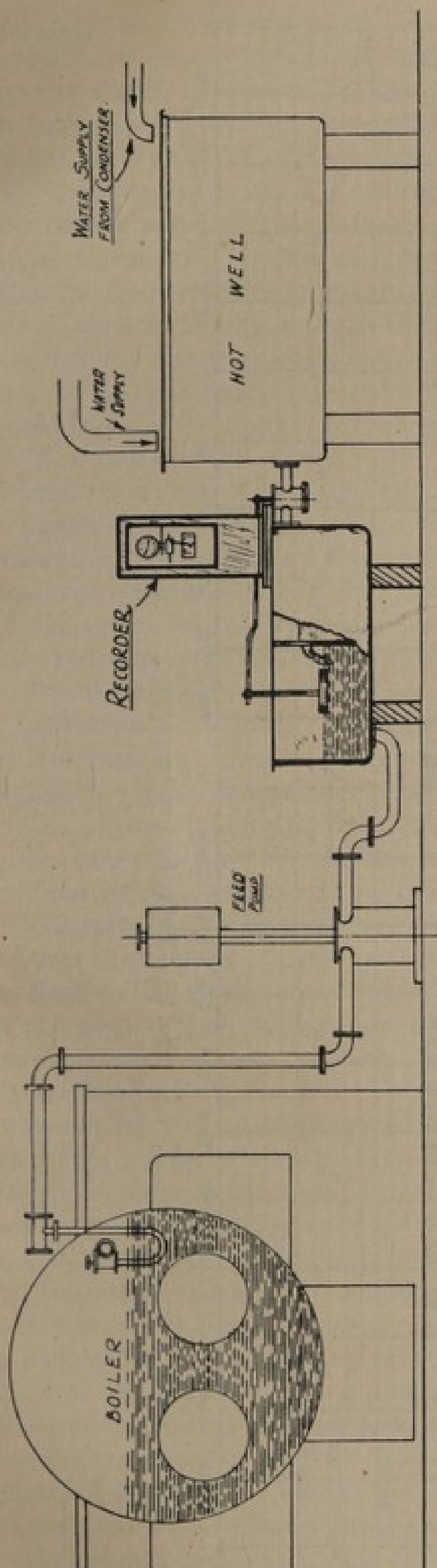


Fig. 82.—Arrangement of boiler feed recorder.

Reference to Fig. 82 will make clear the arrangement relative to other parts of the boiler plant, while Fig. 83 illustrates the apparatus itself.

The flow through the notch tank is automatically controlled in accordance with the demands of the feed pump by means of a double beat equilibrium valve, actuated by lever and float in the hot well end of the tank. By this arrangement, not only is the water integrated as in ordinary meters, but a permanent diagram is produced by the instrument which gives a record indicating the times at which varied demands for steam take place, also indicating the manner in which the operator has regulated the feed supply. Briefly, a complete daily record is produced so far as steam production is concerned.

The chart record is invaluable to the engineer-in-charge, inas-

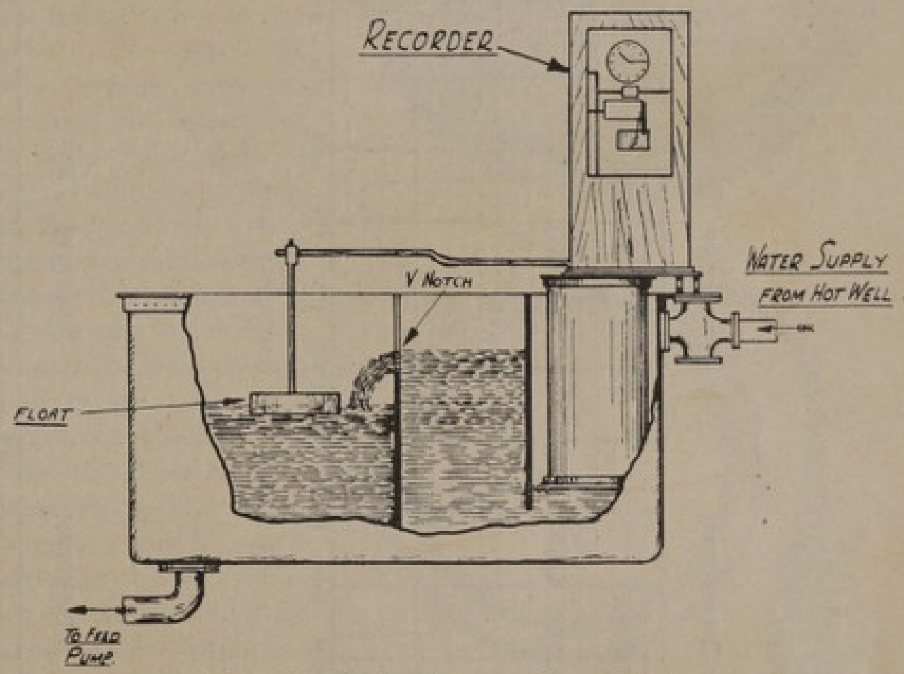


Fig. 83.—Feed water recorder and tank.

much as it shows him at a glance the regularity or otherwise with which the boilers have been fed, and if the instrument is placed within easy access of the stoker, he can readily observe the degree of success of his efforts to maintain a constant feed. It may also be mentioned at this juncture that water fed into the boilers at a rate greater than the heat units are dissipated in the furnaces is invariably responsible for a drop in the steam pressure.

The two specimen charts were taken on the recorder installed at the Brookvale Road Works of the City of Birmingham Salvage Department. Fig. 84 is an example of irregular feeding, showing that the speed of the feed pump has been varied considerably, while round 8 a.m. it was stopped for half-an-hour. Fig. 85 shows how the boiler feeding has been much improved, being more or less constant according to the load on the boiler, this undoubtedly promoting efficiency. A feed water regulator is of course an ideal way of maintaining a regular feed, and with one of these installed the meter record would approximately follow the boiler load. The total

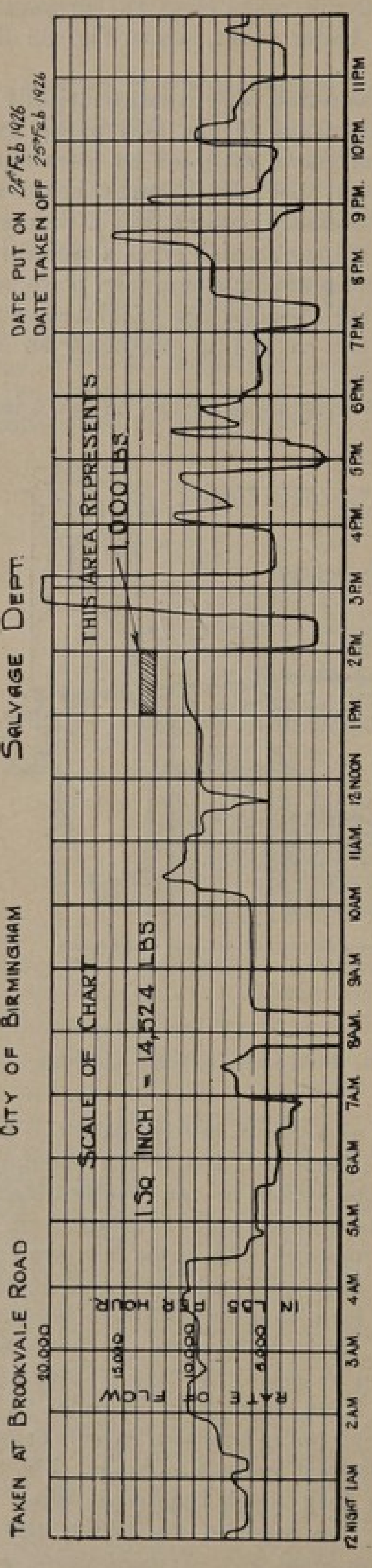


FIG. 84.—Boiler feed water chart.

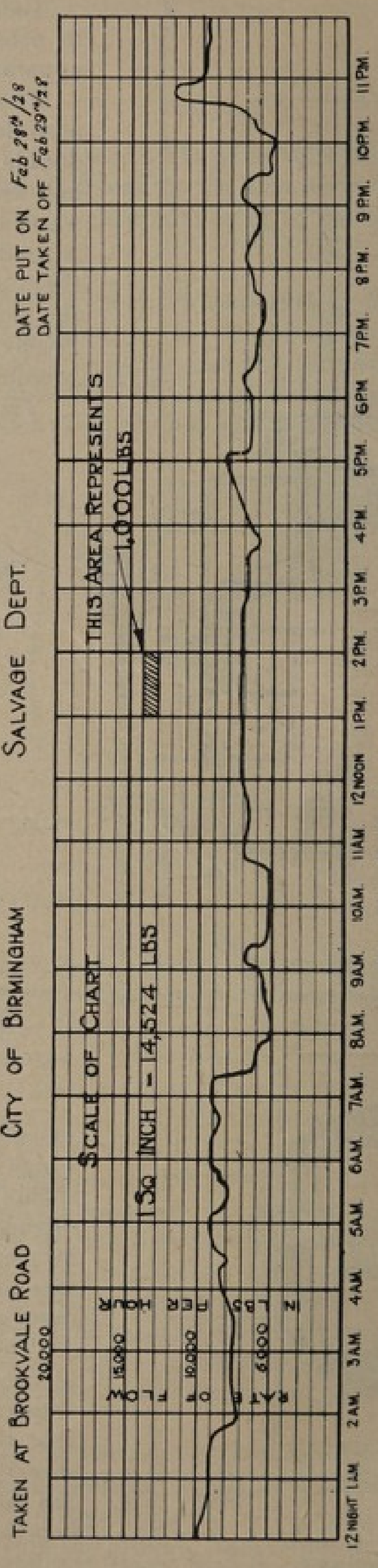


FIG. 85.—Boiler feed water chart.

quantity of water fed to the boilers is represented by the area of the diagram, each square inch equalling so many pounds of water. The area may be calculated by means of a planimeter or stated approximately by counting the number of small rectangles, each of which represents 1000 lb. For instance, in Fig. 84 the area is 11·82 square inches and one square inch = 14,524 lb. therefore 11·82 × 14,524 = 171,674 lb. of water fed to boilers.

The recorder fulfils the useful rôle of policeman over the feed water regulator; any erratic behaviour of the latter, such as a sudden rise or fall of line, would indicate immediately that the feed water regulator required attention. This instrument appeals chiefly to the engineer-in-charge by virtue of its extreme robustness and the simplicity of its mechanism. It is in no sense a delicate piece of apparatus and it is hardly possible for it to break down or get out of adjustment.

For boiler feed purposes the instrument is usually calibrated in lb. weight, in preference to gallons. This being so, it might be thought that with a change in temperature of the water the accuracy would be seriously affected. The apparatus, however, possesses an unique compensative action, owing to the fact that when the temperature increases, the density of the water is reduced, consequently the float sinks slightly, and thus the instrument records a less weight, which is correct. Alternatively, when the temperature falls, the float rises owing to the increased density of water, and the instrument records a slightly greater weight, which is also correct. This automatic action of the float tends to produce true records, by weight, over a large range of temperatures. The compensation, though not absolutely perfect, suffices for all practical purposes.

Temperatures.—Further recent developments in the scientific operation of steam raising plant include the collection of data relating to the temperature conditions at various points on the boiler plant. The measurements of temperature may be taken continuously or at regular intervals, according to the particular demands of an installation. Temperatures can be continuously recorded by the introduction of instruments of the transmitting type, these being arranged with daily or weekly charts, while for occasional readings thermometers of the ordinary stem type, or preferably dial type, can be installed. Such instruments are illustrated by Figs. 86 and 87.

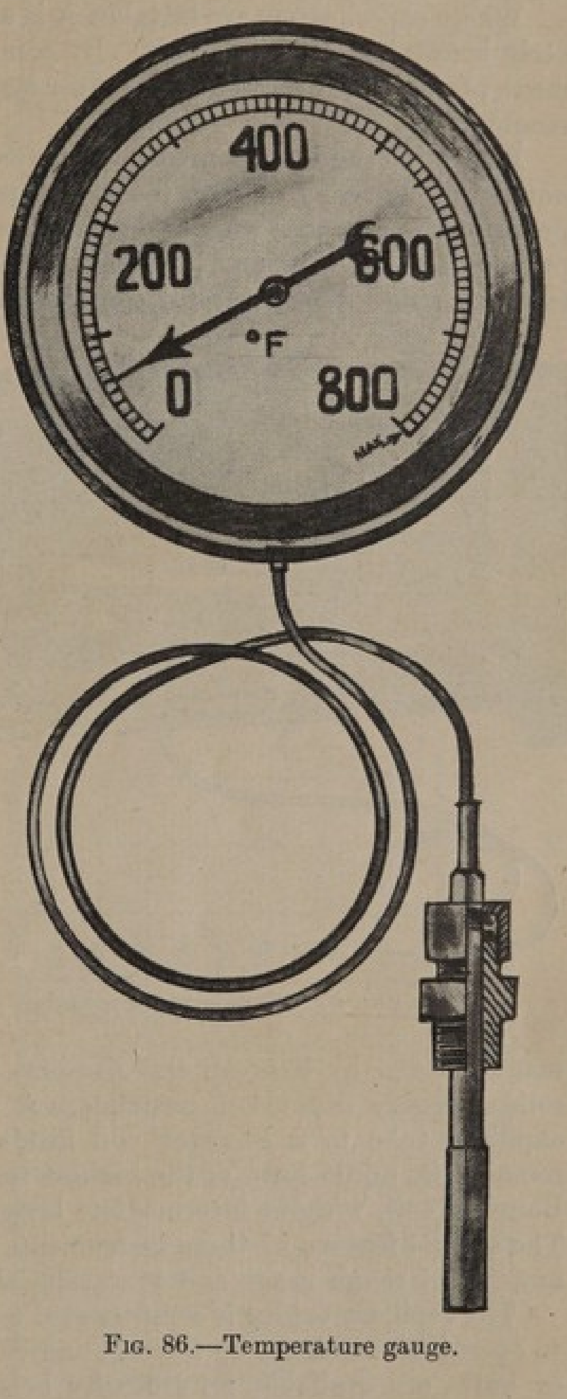


Fig. 86.—Temperature gauge.

Recording instruments are recommended for use with feed water before it reaches and on leaving the economiser, also in connection with flue gas temperatures at the inlet and outlet ends of the latter. A two-pen recorder can be utilised with distinct advantage for these purposes, such arrangement being recommended in view of the fact that two diagrams are obtained on one chart, allowing of more ready comparison than would otherwise be possible.

Information should be secured appertaining to the temperature of the gases on the way to the chimney after leaving the boiler plant, which, when considered in conjunction with the percentage of CO_2 obtaining at the same point, enables the engineer-in-charge to determine his "leaving losses."

Temperature indications, as distinct from records, are usually found sufficient for such points as the side flues of Lancashire boilers, and the different passes of water tube boilers. Distance thermometers with their dials placed in accessible positions are much to be preferred to the ordinary mercury-in-glass instruments. Readings should be secured and logged periodically. At this juncture it should be stressed that conveniently located dials are obviously responsible for much more accurate readings than stem thermometers, which, for observation purposes, necessitate scrambling over the tops of boilers and other obstructions, usually with the aid of a duck lamp. A further disadvantage of the glass stem instrument is its liability to breakage.

Where superheaters are installed it is an advantage to fit an indicating thermometer in the pass immediately before and after this unit. By comparison of the readings at these points and that from the instrument placed in the superheater steam main, it will be readily apparent whether efficient results are being secured.

Possessing the data secured by the introduction of the aforementioned instruments and having carefully noted the efficiency of each individual portion of the plant, the heat balance can be determined. This provides the engineer with information enabling him to consider the plant in the nature of a commercial proposition, *i.e.*, in pounds, shillings and pence, which, it will be agreed, is the most important feature in steam raising. Given careful consideration of the various readings obtained, faults can be located and rectified immediately, and, in many cases, substantial economies effected, in view of the fact that on many plants the inefficiency of the economiser, superheater, or the presence of air leaks is not detected until the plant is taken off load for periodical inspection.

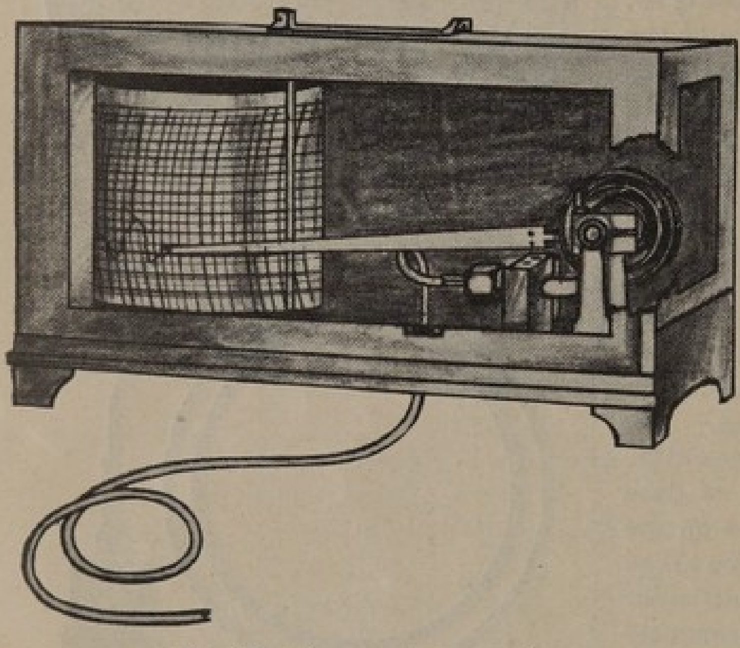


Fig. 87.—Temperature recorder.

Instruments installed should be reliable and accurate, and capable of maintaining such efficiency over a long period of working without constant repairs or adjustments. One instrument out of commission often destroys the usefulness of the whole sequence and an inaccurate unit may render a comprehensive boiler test ineffective, from which the importance of selecting first-class instruments will be appreciated.

The disadvantages of the glass stem thermometer for boiler house work have already been commented upon, and it may be said that these are rapidly losing favour in modern steam practice. Several types of distance thermometers are marketed, and one highly appreciated is that manufactured by Negretti and Zambra. This is known as the mercury-in-steel type and operates on the solid mercury expansion principle. A steel bulb containing mercury is connected by a fine bore steel capillary tube to a Bourdon coil inside the dial. The mercury is introduced under high pressure and remains in liquid form at the highest temperature of the range. Connected directly to the centre of the Bourdon coil, without intermediate levers or gears, is the pointer, or pen-arm in the case of a recorder. The special feature of these instruments is their robust nature, enabling them to withstand a maximum amount of rough usage and vibration, their guaranteed accuracy being within ½% under all conditions.

The capillary tubing is compensated to counteract temperature changes, and instruments can be arranged to operate at distances up to two hundred feet from the bulb without affecting the accuracy. Many designs of bulbs are available, no difficulty being experienced in procuring suitable fitments for either piping or flues. This type of instrument is quite suitable for temperatures up to and including 1000° F., but to ascertain the temperatures of furnaces and combustion chambers approximating 2500° F., it is necessary to use a thermometer of the thermo-couple type.

The principle upon which this latter instrument operates is the employment of a thermo-couple in connection with a sensitive galvanometer. One end of the thermo-couple is exposed to the temperature to be measured, the other terminating in a suitable socket and connected to a calibrated millivoltmeter by a suitable electric circuit. Low voltage currents are generated by the thermo-couple and translated by scales to record or indicate the temperature. Instruments of this type can be located at convenient points for observation at considerable distances from the thermo-couple, this constituting no mean advantage.

Carbon Dioxide (CO_2).—The chief constituent of fuel is carbon—the introduction of oxygen in a suitable ratio being necessary to effect combustion. Chemical action is said to take place when the various elements combine or decompose with the evolution of heat. Combustion is said to occur when chemical action takes place with the evolution of light and flame as well as heat. When fuel is thrown upon a fire the volatile matter is the first to be expelled, this consisting of gases, liquids and solids, which are members of a large class of compounds known as hydrocarbons.

The application of sufficient heat results in the breaking-up of the constituent elements, the carbon vapour combining with the oxygen in the atmosphere to form first, carbon monoxide (CO), which in the process of combustion combines with more oxygen, forming carbon dioxide (CO_2). Given perfect combustion the resultant percentage of carbon dioxide would be 21%, but in actual practice this is unattainable, 12% to 15% being considered quite satisfactory when using coal as fuel.

The introduction of insufficient air is responsible for incomplete combustion and inefficient burning of refuse, which, in this case, is fuel. Excess air results in the oxygen passing through, and in doing so, a considerable amount of heat is absorbed and the gases are diluted without further aiding combustion. Nevertheless, it is preferable to pass a slight excess of air rather than the reverse, to ensure the quantity of oxygen essential to the complete combustion of the carbon.

Household refuse can hardly be regarded as good fuel, and must receive air at a good pressure, particularly on account of the thick fires and low calorific value. When a fire is charged, the percentage of carbon dioxide falls, owing to a considerable amount of excess air passing through the open doors into the furnace instead of through the fuel bed, resulting in a substantial temperature reduction and dilution of the gases as previously mentioned.

Boiler plants are designed to generate steam from the products of combustion of the available fuel, and economical operation can only be secured by conservance of the maximum available heat in the fuel, it therefore being most important that, first, the fuel—refuse—be completely burnt, and secondly, the maximum heat transference be effected.

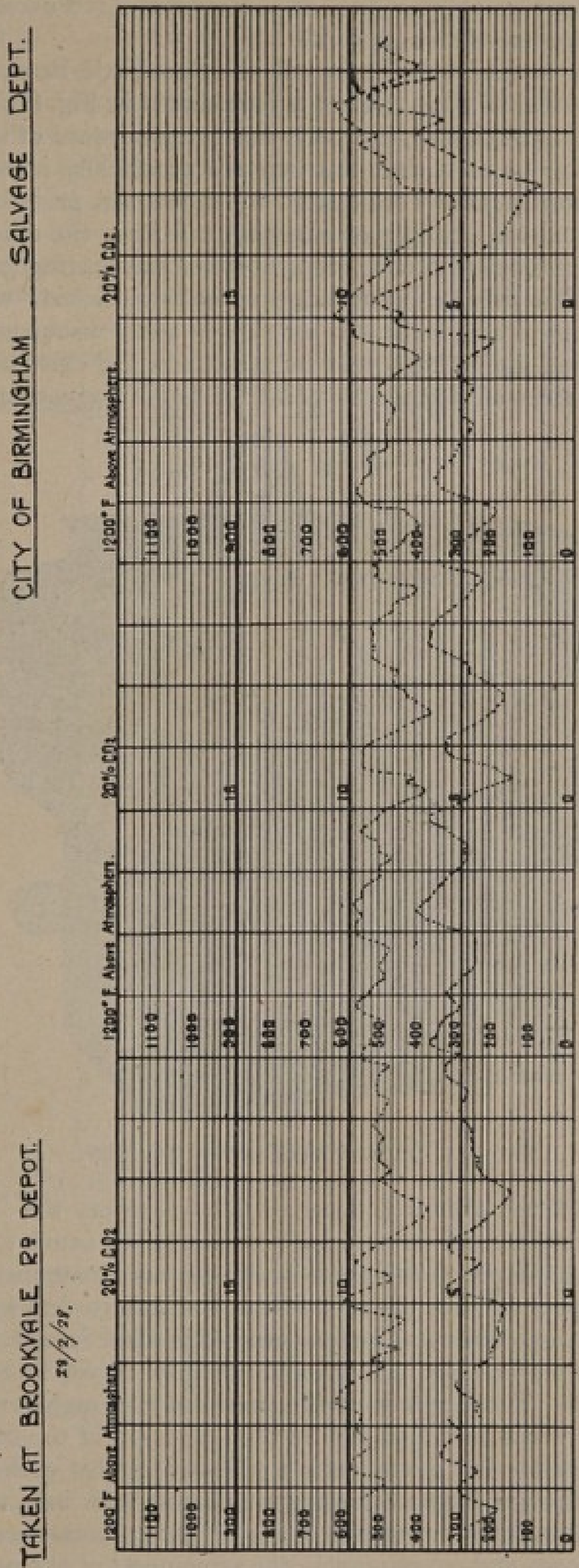


Fig. 88.—CO_2 and Temperature Chart.

Having in mind the foregoing, the advisability of analysing the combustion gases will be readily admitted. Instruments normally selected for this duty are CO_2 recorders of the electrically conductive or chemical absorption type, which in some cases have attachments enabling the user to determine the amount of carbon monoxide present.

A typical record taken at the Brookvale Road works from a "Cambridge" combined temperature and electrical CO_2 instrument is reproduced in Fig. 88, the upper trace representing the temperature of the gases leaving the boiler, the lower one being a record of the carbon dioxide percentage obtaining at the same point. It will be seen that the two are practically identical in character, indicating that the variations in the carbon dioxide were caused by excess air, probably admitted through the furnace doors when these were opened for cleaning or charging the fires, the existence of such conditions obviously being responsible for the reduction in the temperature of the leaving gases.

The reduced percentage of carbon dioxide with an approximately constant temperature indication points to an insufficient air supply and consequent incomplete combustion, in which case a fair amount of carbon monoxide would be present in the exit gases. In view of the foregoing it will be appreciated that the most advantageous point for the introduction of a CO_2 recorder is in the main flue before reaching the chimney as previously mentioned when dealing with temperatures.

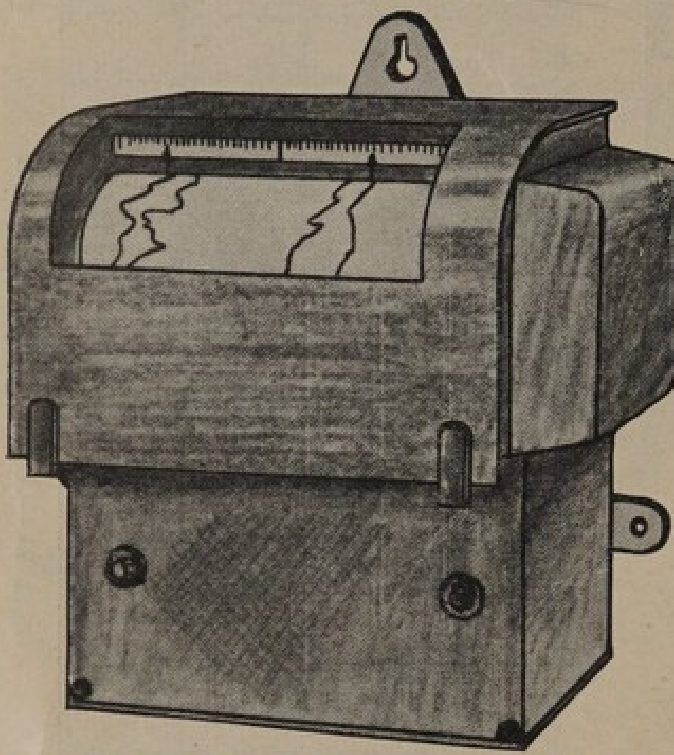


Fig. 89.—CO_2 and Temperature Recorder.

The "Shakespear" patent apparatus made by The Cambridge Instrument Co. is one of the electrical carbon dioxide type of instruments, and is shown in Fig. 89.

This particular instrument contains two platinum wire spirals which are individually encased in metal—one coil being surrounded by air which is saturated with water vapour and the other exposed to the flue gases. The two spirals form two arms of a Wheatstone bridge. On closing the circuit the spirals are heated and dissipate their heat to the metal casing forming the cells; it is obvious that these respective resistances of the spirals depend on the thermal conductivity of the gas surrounding them. Therefore a change in the amount of CO_2 in the gas surrounding the open spiral will affect its resistance, which will be recorded by the kick of the galvanometer needle, the scale of which is calibrated to read the percentage of CO_2. The flue gases are aspirated through the soot filter and over the meter. The indicator is enclosed in a metal casing, thus protecting it from dust and fumes and the galvanometer needle is visible in the upper half of the case.

Of the chemical types of CO_2 recorders the "Hays," which is briefly described below, is typical, the principle in all cases being practically the same, *i.e.*, the absorption of the CO_2 gas by caustic potash.

A sample of flue gas is drawn into the instrument by means of a water aspirator, after first being cleaned by passing through soot filters. A definite known volume of gas at atmospheric pressure is dealt with at each operation. The gas sample is then forced into the absorption bulb, where the CO_2 is absorbed by coming into contact with the freshly exposed surfaces of steel wool which is packed into the absorption bulb. The surfaces of the wool are thoroughly wet by the caustic solution with which the bulb is filled, and which is forced out by the operation of the instrument into the caustic solution container.

Inside this container is a rubber bag filled with water and connected to bellows which operate a pen-arm. As the gas forces the caustic solution back into the container, some of the water in the bag is forced out, creating an air pressure in the bellows, which moves the pen over the chart. The extent of pressure in the bellows, and consequently the movement of the pen, are determined by the amount of absorption that takes place, since that will govern the amount of caustic returned to the container.

The cycle of operations is repeated at regular intervals and a series of radial lines is traced on the chart.

This particular instrument is also fitted with mechanism for recording the draught on the same chart, and the relationship between the draught and CO_2 may thus be seen for any period of the day.

Draught.—Draught constitutes a very important factor in efficient power production, since it is responsible for the introduction of the oxygen necessary to combustion. Natural draught usually necessitates the construction of high chimneys and high capital expenditure, producing only a moderate draught which precludes, or at least limits, the adoption of many heat-saving devices, leaving the steam user no option but to work the boilers with thin fires. Further, such conditions are largely influenced by the elements, and on not a few occasions the greater demand for steam coincides with the worst natural draught conditions, *e.g.*, the theoretical draught of a chimney stack 125 feet high, with the atmosphere at 60° F., and gases, after passing through an economiser, at, say, 350° F., is five-eights of an inch draught gauge only.

Mechanical draught admits of a considerable variation in accordance with the desired rate of combustion. Under such conditions it is possible to carry thicker beds of fuel than with a natural draught, and it should be borne in mind that owing to a greater resistance, the air passes through the bed of incandescent fuel at a reduced velocity, mixing more intimately with the fuel, allowing the oxygen to combine more completely with the combustibles, thus promoting a greater furnace efficiency.

"Forced Draught Fans" can be introduced, these supplying air to the system at a pressure below the furnace grates. Alternatively "Induced Draught Fans" (normally located adjacent to the base of the chimney) can be installed, these units drawing air through the fires. In many generating stations it is not unusual to find a combination of the two, to obtain the condition generally known as "Balanced Draught." Standard practice with furnaces burning refuse includes the provision of mechanical draught by forced draught fans, normally designed to create pressure varying from $1\frac{1}{2}$ inches to 3 inches draught gauge beneath the grates, a chimney of sufficient height producing the necessary negative draught above the grates. This latter is essential to promote the flow of waste gases given off by the burning refuse.

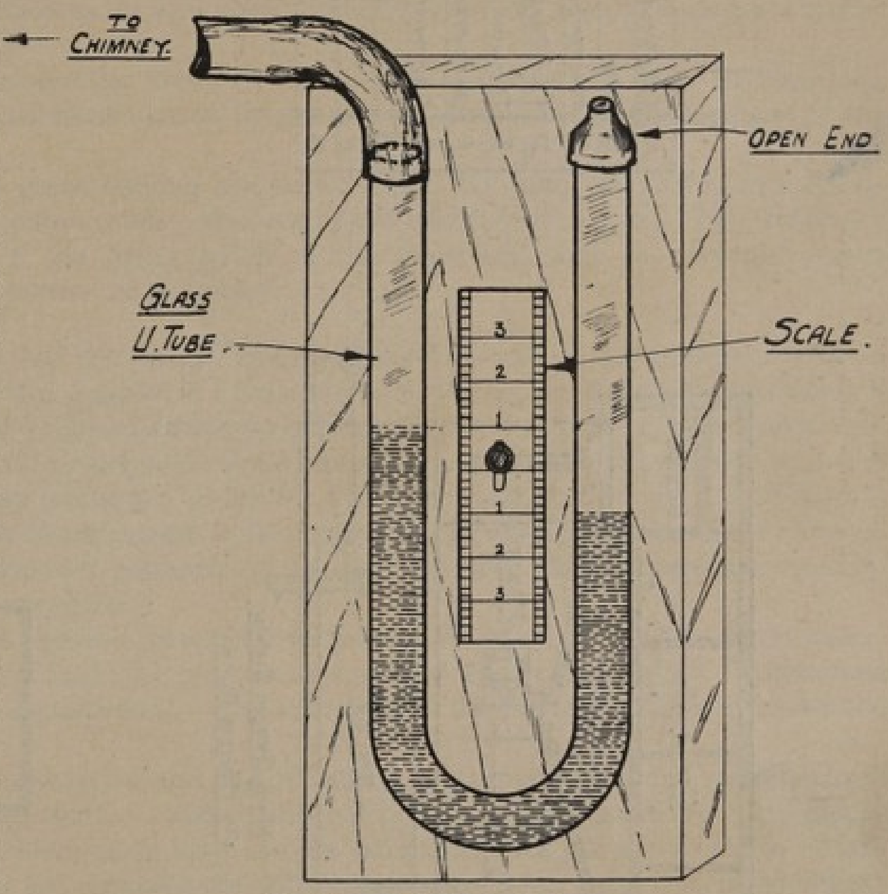
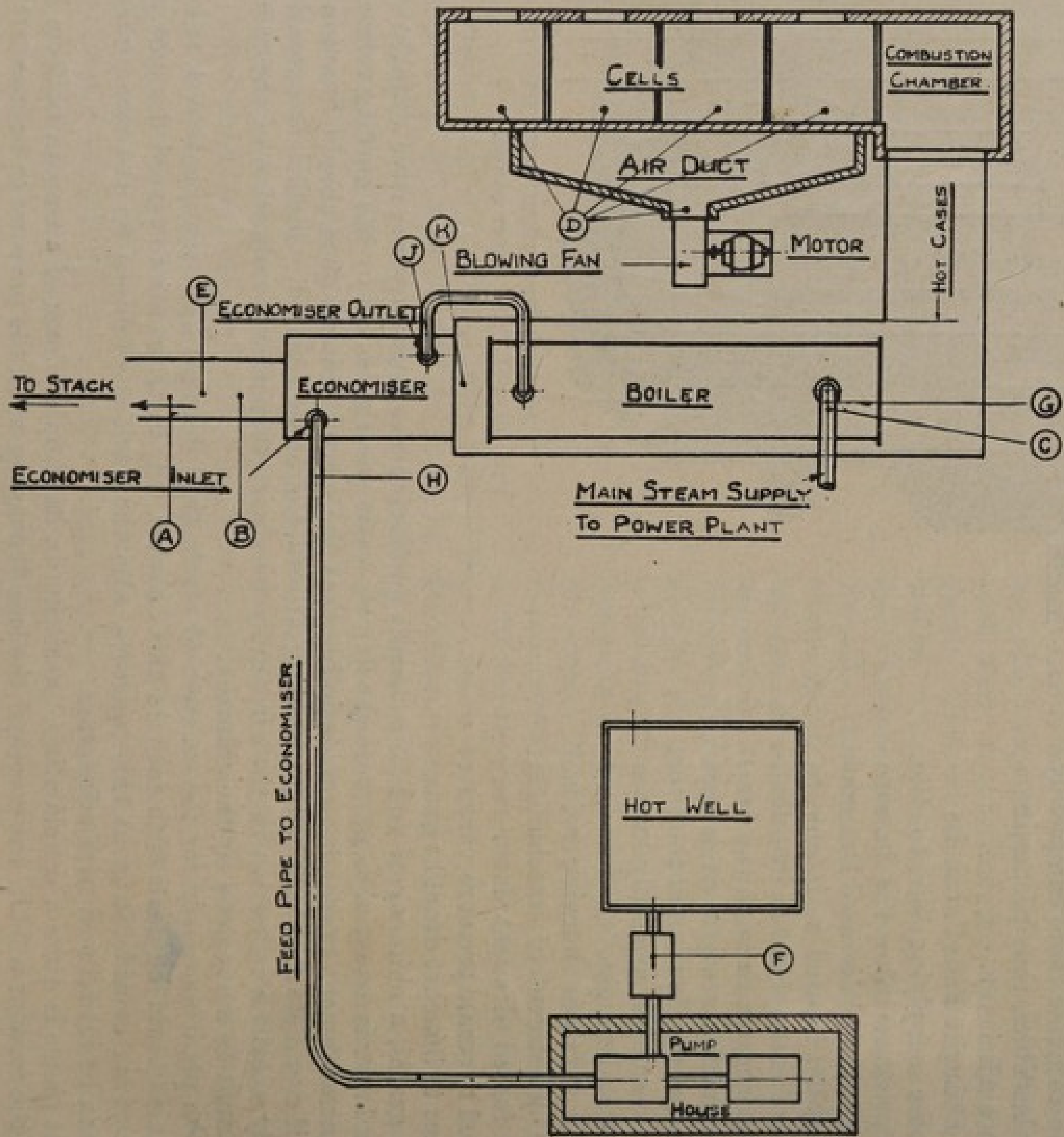


FIG. 90.—U-Tube water gauge.

Such an arrangement makes it very desirable that the forced draught fans should function correctly at all times if complete and satisfactory burning of refuse is to be secured. Inefficient operation of the fans naturally entails a reduction in the air supply necessary to perfect combustion of the refuse, which deficiency cannot be made good by the chimney.

Though the plant necessary for the creation of mechanical draught has been mentioned, it is not proposed that this should be dealt with fully in this chapter, but instruments to record draught power can doubtless be given consideration at this juncture, also the various positions on the steam-raising plant where they can be introduced with advantage.

A draught gauge is quite a simple affair, consisting in its simplest form of a smooth uniform bore glass tube bent in the form of a "U," the length of the legs depending upon the pressure to be measured, Fig. 90 indicating this type of gauge. In service it is partly filled with water and fixed in a vertical plane, one leg



A	CO_2 Recorder } on gases leaving
B	Temp. - } Economiser.
C	Recording Steam Pressure Gauge
D	Fan Pressure Gauge
E	Draught Gauge
F	Lea Recorder for measuring Boiler Feed Water.
G	Thermometer for Superheat
H	" for Feed Water Temp. before Economiser.
J	" for Feed Water Temp. after Economiser.
K	" for Gases entering Economiser.

FIG. 91.—Lay-out of instruments.

being coupled to the pipe or duct in which the pressure is to be read, the other being left open to the atmosphere. The measure of pressure, if positive, is indicated by the water being depressed in the leg coupled up to the pipe and elevated in the other, which, being open, has atmospheric pressure acting upon its surface. The difference in the levels of the surfaces of the two columns of water indicates the pressure difference in inches of water, 1 inch of water corresponding to a pressure of 0·036 lb. per square inch. The reverse would of course apply if the pressure in the pipe were negative, the water in the leg open to the atmosphere being depressed, and that in the leg connected to the pipe raised.

Draught gauges may be fixed in any or all of the following positions :—

1. Beneath the fire grates, thus enabling the responsible engineer or boiler attendant to locate any fault in connection with the forced draught fans, often responsible for reduced boiler steam capacity, probably owing to a temporary restriction in the air supply main from the fan, *e.g.*, a dirty fan wheel or reduced fan speed.

2. At the front end of the boiler where the waste gases enter after leaving the fires—the purpose, in this instance, being to indicate restrictions caused by grit accumulation in the gas passages of the boiler.

3. At the point where the waste gases leaving the boiler enter the main flue—this to indicate draught loss owing to further grit accumulations, also restricted effective flue area. The difference between this gauge and the one at the firing point of the plant indicates the draught power necessary to operate from the major portion of the plant.

Lay-out.—Having described in some detail the various instruments which can be advantageously used, it will probably be a useful conclusion to this chapter if I summarise the foregoing by briefly describing a lay-out comprising the various instruments in their relative positions. Fig. 91 is intended to represent such a lay-out in diagrammatic form. Taking the instruments in a consecutive sequence, at the points marked *D* the fan pressure gauges are installed, giving indication of the fan efficiency, and at *E* in the flue leading to the stack is the draught gauge. *K* is the thermometer indicating the temperature of the gases entering the economiser, whilst at *A* and *B* are situated respectively the CO_2 recorder and temperature recorder giving readings of the gases leaving the economiser.

G, *H* and *J* are thermometers. *H* is on the feed water pipe to the economiser. *J* gives the temperature of the water on exit from the latter, whilst *G* reads the temperature of the steam in the main. On the same line as the latter is the main steam pressure gauge at *C*. The actual water flow to the boiler is given by the "Lea" recorder at *F*.

Thus I have endeavoured to show the operation and use of various instruments which I consider have undoubted advantage in the efficient management of a refuse disposal plant. Probably I have by no means exhausted their number, and no doubt much ingenuity can be exercised in their provision to attain certain objects, but whatever instruments are installed the salient feature of their operation is intelligent use. Columns of readings in prettily bound books are no doubt impressive, but the logical deductions from these readings are of real service.

CHAPTER XIV

ELECTRICITY AND ITS APPLICATIONS

Part I.—Elements of Electrical Theory.

The ancient Greeks discovered that amber had a special property not known to be possessed by any other substance at that time. It was found that amber when rubbed by wool attracted small particles of dust and fluff, and the Greeks took advantage of this in so designing their spinning wheels that the thread passed through a block of amber, which, rubbed by the thread, generated an electric charge on the amber and collected all the dust and fluff from the thread, leaving the latter clean.

This appears to be the first authentic record of the practical application of electricity to industry. At a later date it was discovered that furs, flannel, glass, cotton, silk, metals, sealing wax, resin, sulphur, rubber and ebonite have the same properties in different degrees. When any two of these substances are rubbed together, electricity will be generated and the electricity thus generated resides on the surface of the substance in the form of a static charge. This particular form of generation of electricity is known as "Frictional Electricity," and although it has a practical use it is not the commercial method of generation. The latter is mentioned in order to dispel any false idea that may exist regarding the modern generation of electricity, which consists of passing a series of wires or conductors across a magnetic field in such a manner as to cut the lines of force. In order to understand this it is first of all necessary to know something regarding the laws of magnetism.

There are two kinds of magnets, *i.e.*, Natural and Artificial.

The Natural magnet consists of a certain iron ore which, when freely suspended by a thread, is found to come always to rest in the same position, pointing approximately north and south; the same end always pointing to the north. This property was found to be very strongly marked in the iron ore known as *magnetite* which comes from Magnesia in Asia Minor, hence the name "magnet." This ore was also known in England as a "lodestone" or "leading stone."

A striking feature of the lodestone is that when a piece of iron or steel is rubbed with it the latter will impart its magnetic properties to the iron or steel without losing its own magnetism. A steel needle or bar treated in this way is called an "Artificial Magnet," and if this magnetism is retained for a long time it is called a "Permanent Magnet." Soft charcoal iron is much more susceptible to magnetism than steel, but it does not retain its magnetism for any length of time.

When a magnet is suspended freely by a thread, and one end of another magnet is brought close to the end of the suspended magnet, attraction takes place between the two magnets, but when the opposite end of the suspended magnet is approached by the same end of the movable magnet, repulsion takes place.

The end of the magnet which points to the north is known as the North Seeking Pole, and the other end is known as the South Seeking Pole. The first law of magnetism is therefore as follows :—

Like poles repel each other (*i.e.*, two north seeking poles or two south seeking poles).

Unlike poles attract each other (*i.e.*, one north seeking pole and one south seeking pole).

When a piece of unmagnetised iron is placed in the vicinity of a magnet, attraction takes place, so that it will readily be seen that attraction is not a test for magnetism in a piece of iron which is brought near to a testing magnet or a compass needle. Repulsion is the only test, and this can be obtained when two like poles are brought into close proximity.

The force exerted between two magnetic poles is directly proportional to their pole strengths and inversely proportional to the square of the distance between them.

Written algebraically, the above law is as follows :—

$$F = \frac{M_1 M_2}{d^2},$$

where F represents the force, M_1 and M_2 represent the pole strengths of the two magnets, and d represents the distance between them. If the distance between the two poles is increased to twice the original distance, the force is reduced to one-quarter, and if the distance is increased three times, the force is reduced to one-ninth.

The magnetic field surrounding a magnet is stated to consist of a number of magnetic lines of force, and these lines of force flow from the north seeking pole to the south seeking pole of a magnet outside the magnet, but inside the magnet they flow from south to north. The direction of flow is determined by the direction in which the north pole of a compass needle would point if placed at any point in a magnetic field. Lines of force radiate in all directions from the poles of the magnet, and are measured in thousands of lines per square centimetre, and this is often referred to as the Magnetic Flux. The flux density varies considerably in different qualities of iron and steel, and this property guides the choice of material for any particular purpose.

It was found by Ampère that, when an electric current was passed from a battery through a conductor, a magnetic field was set up around the conductor. The lines of force in this field take the form of a series of concentric circles with the axis of the conductor as their common centre. For example, imagine the conductor as a curtain rod and the lines of force as a number of curtain rings of all sizes packed tightly together on the curtain rod. The lines of force are, of course, far more numerous than the curtain rings. Moreover, Ampère discovered that the direction of flow of the current in a conductor had a definite relation to the direction in which the lines of force were flowing.

Ampère's rule states :—

> " Imagine a man swimming in the current, with the current, and looking at a compass needle, then the north pole of the needle will turn to his left."

If a straight conductor is placed above a compass needle (which lies in the magnetic meridian) and the current flows from south to north, the north pole of the compass needle will turn to the west. In applying Ampère's rule the man would be swimming on his face and looking downwards, and his left hand would be towards the west. If the conductor was placed below the needle and the current flowed from south to north, the north pole of the needle would turn to the east, because in this case the man would be swimming on his back in order to look at the needle.

Another rule for ascertaining the direction of the lines of force round a conductor is to imagine yourself standing at the end of a conductor in which a current is flowing away from you. The resulting magnetic force would tend to urge a magnetic north pole in a clockwise direction. If the current was flowing towards you, the magnetic north pole would be urged in an anti-clockwise direction.

The conventional method of indicating a current flowing away from the observer is by putting a cross on the conductor ⊕. A current flowing towards the observer is shown ⊙.

Electro Magnetic Generators.—If a conductor is arranged to work in such a way that it will be constantly cutting across the lines of force in a magnetic field, and also some device arranged for connecting up the ends of this conductor to a circuit or enclosed path, a current of electricity will flow through the conductor. The direction of travel of this current in the conductor will depend upon the direction in which the conductor is cutting across the magnetic field, and the magnitude of the current will depend upon the rate of cutting the lines of force in the field.

Mechanical work is done by moving the conductor through a magnetic field, this mechanical work being transformed into electrical energy.

Figs. 92 and 93 show a conductor being rotated in a magnetic field in such a manner as to cut the greatest possible number of lines of force. The ends of the conductor are connected to two slip rings upon which press the brushes or collectors. The coil is being rotated in a counter-clockwise direction when looking at the slip ring end of the coils. From a few moments' consideration of the figure it will be clear that at a certain period of the revolution of the conductor (which is arranged as a rectangular coil), the coil sides *X* and *Y* will be travelling along the lines of force and not cutting them. During this brief period, which occurs when the plane containing the two coil sides is at right angles to the lines of force, no current will be generated in the conductor, but immediately the conductor begins to move across the lines of force, a current will be generated. This occurs as soon as the plane containing the coil ceases to be at right angles to the lines of force, and if the coil is rotated at a uniform rate, it will cut the lines of force more rapidly as the plane containing the coil moves into a position parallel to the lines of force. Here the current in the coil will reach a maximum value, and as the coil rotates out of this plane the value or *E.M.F.* of the current generated will begin to fall off until it reaches zero again, when the condition referred to before occurs, *i.e.*, the plane containing the coils is at right angles to the lines of force. This has taken place during the rotation of the coil through 180°, and the same process would occur in both coil sides, with this exception, that the current generated in each coil side would flow in opposite directions when observed from one end.

A good rule for remembering the direction of the current induced in a conductor by moving the latter across a magnetic field is Fleming's right-hand rule, which is as follows: "Let the first finger point in the

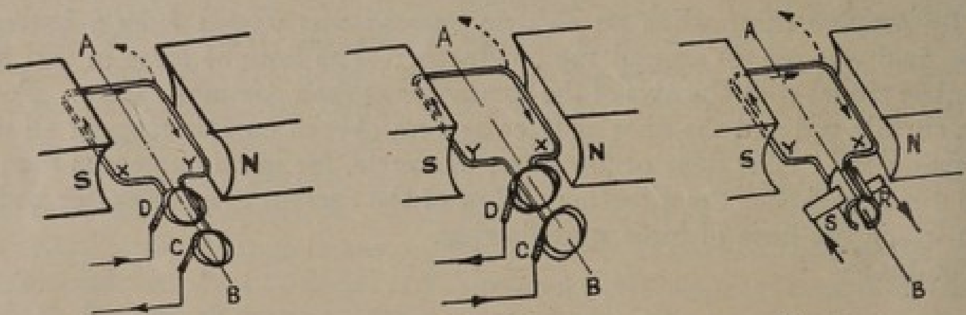


Fig. 92. Fig. 93. Fig. 94.

Diagrams of a simple electric generator.

direction in which the lines of force are travelling (from the north pole of magnet to the south pole of magnet); let the thumb point in the direction in which the conductor is being moved, then the middle finger and thumb will indicate the direction of the induced *E.M.F.*" This is illustrated in (Fig. 95).

In Figs. 92 and 93 the small arrows on the conductor indicate the direction in which the current is flowing at the moment.

In Fig. 92 slip ring *D* is connected to coil side *X* and slip ring *C* is connected to coil side *Y*. The current generated is flowing from slip ring *D* to slip ring *C*. In Fig. 93 the current is flowing from slip ring *C* to slip ring *D*, so that when the coil sides move in opposite directions across the lines of force, the direction of the current in the coil is reversed. On one revolution of the coil the current has risen to a maximum value in one direction, dropped down to zero, risen to a maximum value in the other direction and dropped down to zero again. This is known as an alternating current, on account of its change of direction. It is also a pulsating current.

Alternating current delivered to the external circuit was not of much use to the early investigators who desired a current which would flow continuously in the same direction, but as the generator, by reason of its construction, could generate no other kind of current, some device had to be resorted to to commute the current, hence the name commutator. The commutator consists of a split tube as in Fig. 94, each end of the rotating coils being connected to a segment of the split tube upon which press the brushes or collectors. As the coil is revolved, the commutator moves with it, and at the moment when no current is flowing in the coil, *i.e.*, when the coil has revolved through 90°, the segment *R* leaves the top brush and passes under the opposite brush, immediately after which a current is started in the coil.

This current flows from *X* to *Y* instead of from *Y* to *X* as in Fig. 94, and still leaves the current flowing out of the top brush in the same direction as before, so that the object of a current flowing in one direction continuously is obtained. By making a number of coils revolve in the magnetic field, each one of the coils being connected to the segments of a multi-segmented commutator, a current is obtained which is unidirectional and non-pulsating, *i.e.*, a continuous current with a steady *E.M.F.* or voltage. The rotating coils are laid in slots in a soft iron core, which has the effect of increasing the flux or number of lines of force which the coils are to cut. The whole arrangement of coils and iron-core is spoken of as the armature, and the latter rotates between the poles of a strong electro-magnet. This magnet is supplied with current from the armature, of which only a small amount is required for magnetisation purposes, the remainder being used in the external circuit for whatever purpose is intended. There are variations of the methods of supplying the magnetic flux, but the principle described is the same.

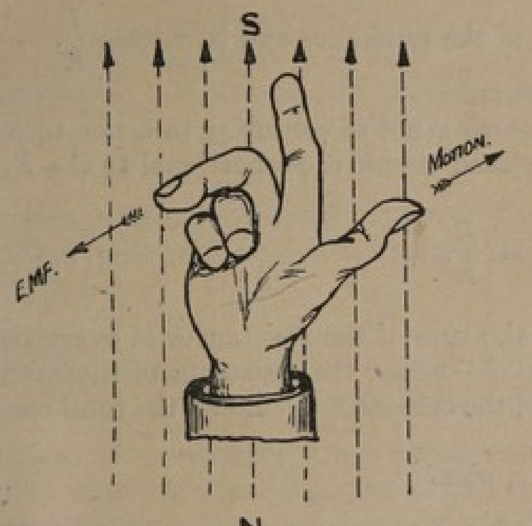


FIG. 95.—Illustration of Fleming's right-hand rule.

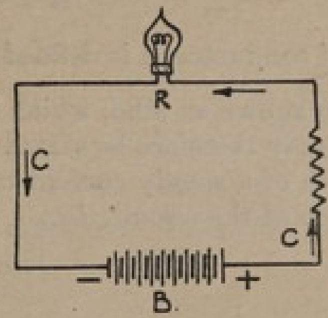


FIG. 96.—Series circuit.

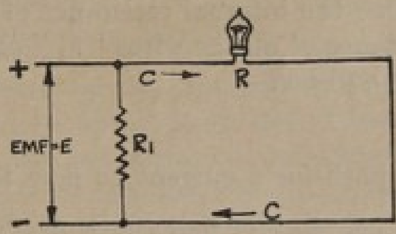


FIG. 97.—Shunt circuit.

UNITS USED IN THE MEASUREMENT OF ELECTRICITY.

Units are named after some of the early investigators in physics :—

Ohm.
Ampère.
Volta.
Watt.
Joule, etc.

The International *Ohm* is the unit of resistance, and is the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice, 14·4521 grammes in mass, of a constant cross-sectional area, and of a length of 106·300 centimetres.

The International *Ampère* is the unvarying electric current which, when passed through a solution of silver nitrate in water, deposits silver at the rate of 0·00111800 gramme per second.

The International *Volt* is the electrical pressure which, when steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampère.

These units are often represented by letters or symbols, and sometimes one unit may have more than one symbol, thus :—

Current in ampères is usually represented by the letter *I*. Volts by "*E.M.F.*" or "*E.*" Resistance by "*R*" or "*r*," and watts by "*W.*"

The *Watt* is the unit of power and is obtained by multiplying the current in ampères by volts, viz., $I \times E = W$.

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The *Kilowatt* is 1000 watts and is written "KW."

The *Joule* is the unit of work and is represented by "J," viz. :—

$$J = E \times I \times t = W \times t, \text{ where } t \text{ is the time in seconds.}$$

The joule is often referred to as a Watt-Second.

"Ohm's law" plays a very important part in electrical work. The law is as follows :—

> "The strength of a steady direct current of electricity in a closed circuit is proportional to the *E.M.F.* and inversely proportional to the resistance of the circuit."

Written in symbols it is $I = \frac{E}{R}$.

The unit of conductance is defined as the reciprocal of the resistance and is written $\frac{1}{R}$.

This unit is known as Mho, which is ohm spelt backwards.

Ohm's law may therefore be stated in another way, which is not so confusing to a non-technical mind.

The strength of a steady current of electricity in a closed circuit is proportional to the *E.M.F.* and to the conductance of the circuit, *i.e.*,

$$I = E \times \frac{1}{R} = \frac{E}{R}.$$

The total resistance of a simple undivided circuit is the sum of the resistances of every part of it. In Fig. 96, assume the internal resistance of the battery is "b" ohms, the resistance of the lamp "r" ohms, and the resistance of all the wires "r_1" ohms, then when the current "C" flows, the total resistance "R" of the circuit will be :—

$$R = b + r + r_1 \text{ ohms.}$$

The only path for a current to flow is through all the resistances in series, the conductance being $\frac{1}{R}$.

From Ohm's law we can find the *E.M.F.*

$$E = R \times I.$$

If we have a current flowing through a divided circuit or through parallel paths, as in Fig. 97, the only way to arrive at the total current flowing when an *E.M.F.* is applied to the circuit is by adding all the conductances together, *e.g.*, let $r =$ the resistance of the lamp, and r_1 the resistance of the coil, then the total conductance will be :—

$$\frac{1}{R} = \frac{1}{r} + \frac{1}{r_1} = \frac{r_1 + r}{rr_1}.$$

∴ The total resistance will be $$R = \frac{rr_1}{r_1 + r}$$

and by Ohm's law the total current will be

$$I = \frac{E}{R} = \frac{E}{\frac{rr_1}{r_1 + r}}$$

or :—

$$\begin{aligned} I &= E \times \text{Conductance} \\ &= E \times \frac{1}{R} \\ &= E \times \frac{r_1 + r}{rr_1}. \end{aligned}$$

Returning to the units previously mentioned, we must have some link between the electrical units of power and work, and the mechanical and heat units of power and work.

1 Horse power = 33,000 ft.-lb. of work *per min.*

The time factor enters here, the work being done over a period of 60 seconds. Therefore, in 1 second 1/60th only of the work will be done.

$$= \frac{33,000}{60} \text{ ft.-lb. of work } \textit{per sec.}$$

The horse power is merely a rate of doing work.

1 Horse power	= 746 watts.
1 Joule	= 1 watt for 1 second.
1 Watt hour	$= 1 \times 60 \times 60$ joules = 3600 joules or watt-seconds.
	= 2655·2 ft.-lb.
	= 3·415 B.Th.U.
1 Kilowatt hour	$= 3600 \times 1000$ joules.
	$= 2655{\cdot}2 \times 1000$ ft.-lb.
	$= 3{\cdot}415 \times 1000$ B.Th.U.

The kilowatt hour is the British Board of Trade unit for consumption of electricity and it is upon the number of these units that current is charged for by the electric supply companies.

Part II.—Electricity: its Generation, Distribution and Utilisation for Power and Lighting Purposes at Refuse Disposal Works.

Introduction.—At any depot where house refuse is burnt, steam can be produced and may be used for the generation of electricity. The production of electricity and its distribution and utilisation for power purposes throughout a refuse disposal plant are simple matters, and yet certain circumstances, such as the class of labour available, the poorness and variable calorific value of the fuel, the gritty, corrosive nature of the dust that pervades the whole atmosphere, and so on, tend to introduce certain difficulties despite the simplicity. The writer spent some time at this problem and ventures here to record some of those things which he found by experience gave satisfactory results in practice.

Steam Raising.—Nowadays so much is heard about reverberatory arches and continuous grates, and so much about this, that and the other system of blowing, etc., that one is almost tempted to suppose that for the production of steam the equipment is the important thing, and to forget that it is the system and the *personnel* that really matter. Steam is your first requirement in the production of electricity, and even if you do not possess the very latest type of furnace and boiler there is no need to be discouraged. Commence operations by cleaning your boiler inside and out, and then look to your flues and method of stoking.

Stoking.—The test of your work on the furnace side is the percentage of carbon dioxide in the flue gases as they leave the boiler, and, within limits, the higher that percentage the better the combustion. Now there are two ways in which the percentage of carbon dioxide may be improved. A charge of refuse placed on a furnace quickly ignites and in parts burns rapidly away. As soon as this happens, craters form and cold air rushes through, reducing the temperature of your furnace and spoiling your steam raising. This state of affairs is clearly indicated by a fall in the percentage of carbon dioxide, and the remedy is to level the fire directly such a crater forms. Endeavour to get an average 12% of carbon dioxide in the gases leaving the boiler. This is a difficult matter, but it is a reasonable possibility, so do not be satisfied with an average figure of less than 10%. How advantageous from a steam-raising point of view frequent levelling is, Fig. 13 clearly shows. It gives the furnace temperatures obtained from a refuse incinerator cell with once levelling only, and the temperature from the same cell when the fire is levelled frequently.

Flues.—The other important step is to prevent the temperature of the hot gases from being reduced by the leakage of cold air through cracks in the flues and boiler setting. To do this, take a candle and hunt all over the boiler setting and flues, and at every point where you find the candle flame sucked in there is an air leak. Stop it by filling the crack with cotton waste soaked in fireclay. So much for steam raising. Attention to these points will usually result in the production of an ample supply of steam.

Section 1.—The Generating Plant.

The Supply.—The first matters to be decided are the nature and voltage of the supply. In deciding these points it is as well to bear in mind :—

(1) That it is very desirable to have your supply similar to that of the town main so that when you are unable to generate all the electricity you require, you can, by simply operating a switch, transfer part of your load to the town supply.

(2) That the electric vehicle is proving itself a suitable and economical vehicle where well organised collection methods are in operation. Where electric vehicles are employed, the supply of electricity generated should be suitable for vehicle charging, that is, direct current at 120, 240 or 480 volts.

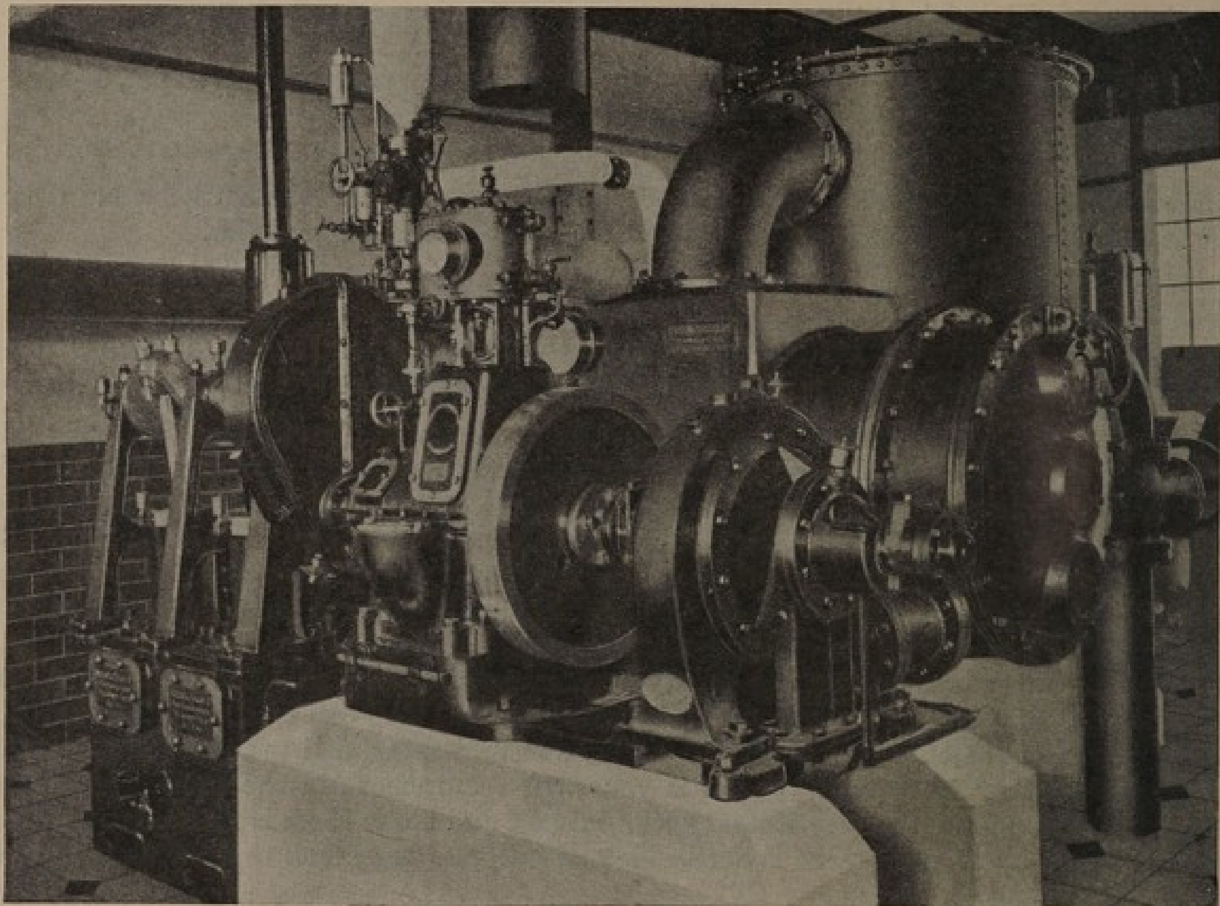

Fig. 98.—Condensing plant.

If the town supply is alternating, the conditions (1) and (2) may be reconciled by generating alternating current on the works plant, and by using mercury arc rectifiers for vehicle charging.

The Engine.—In selecting the engine the choice lies between a turbine and a reciprocating set. If your output is to be 750 h.p. or more per engine, then the economy in steam consumption of the turbine as compared with the reciprocating engine is sufficiently marked to make its adoption advisable, but below this output experience generally is in favour of the high speed forced lubrication reciprocating engine. As very few refuse disposal depots can either produce or require more than 750 h.p., it is reasonable to suppose that most depots have installed or will install reciprocating sets. Economy in the consumption of steam amounting to some 20% for both reciprocating and turbine sets may be effected by installing a condensing plant, and where economy in steam consumption is necessary a condenser should be installed, provided a suitable supply of cooling water is available. (See Fig. 98.)

The Generator.—Because of its accessibility and the ease with which it may be coupled to a high speed engine, an open (pedestal) type of generator will be found suitable for almost all cases. With direct current generators, the writer finds that compound winding to give 2 or 3% rise in voltage on full load is advantageous where the current is used for vehicle charging. It compensates automatically for armature drop and loss of voltage in transmission cables, and therefore ensures that the charging current given to the batteries will remain practically constant and independent of the load on the generator. This compounding is open to a very grave objection which it is said renders it inadmissible, but the writer has found in practice that properly designed switchgear gives to the electrical equipment adequate protection from all the evils of compound winding, and that no inconvenience or ill results arise from its use. Figs. 99 and 100 show good direct current generating sets.

The Switchboard.—The switchboard is an important part of the plant, and each piece of apparatus

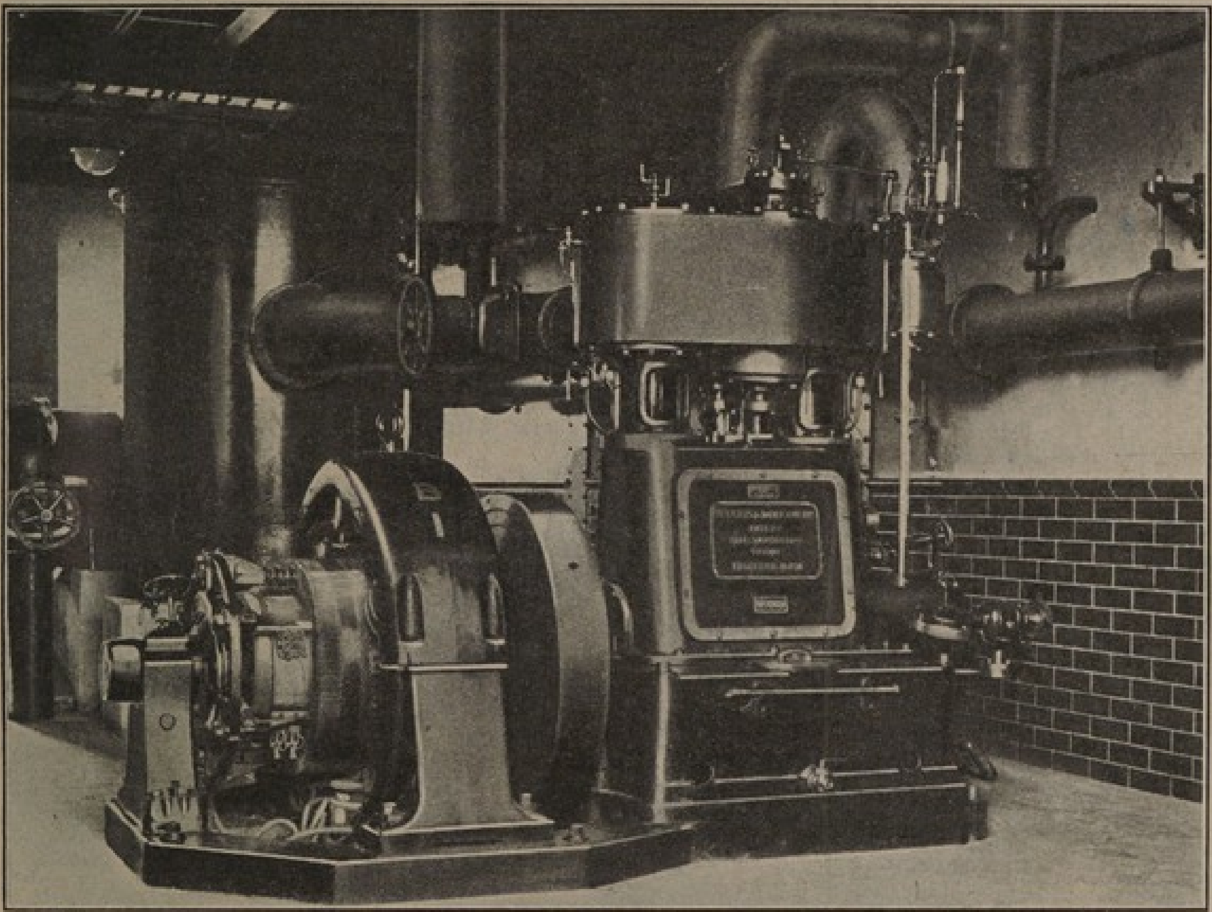

Fig. 99.—Steam-driven generating set.

should be robust and of good design. Allow plenty of space behind the board so that a man may have room enough to work there on any repairs necessary. See that every connection made with any form of cable (as distinct from copper strip) is provided at both ends with a proper cable eye or socket. Good connections cannot be made without. In direct current installations, particularly if used for battery charging, protect each generator by a double pole overload and reverse current circuit breaker. The soft iron type of ammeter and voltmeter, though cheap, is liable to considerable errors and should not be used on alternating or direct current switchboards. Knife switches, in addition to fitting well into the clips or jaws, should be of the quick break type and the quick break action should be operated by a helical spring. The writer has not found the spiral spring action satisfactory. Liberal voltage variation by means of shunt regulators should be provided, as it often happens that this regulation is very useful. This is especially so in the case of electric vehicle charging. For a 440-volt machine, I should specify regulation from 420 to 500 volts.

The Distributing Panels.—The circuits to the various motors on the works should be fed from a distribution panel, the bus bars of which are supplied with electricity from the works power plant. Every circuit leaving the panel should be equipped with a descriptive label, a double pole knife switch and, if considered necessary, double pole fuses. If a supply of electricity at the correct voltage is available from the town mains, it is convenient to provide this distributing panel with an additional set of bus bars fed from the town mains. In this case, double pole change-over knife switches should be provided instead of simple knife switches, and with such an arrangement the load on any or all circuits may be transferred from the works power plant to the town mains. In this way it is possible to assist the works power station

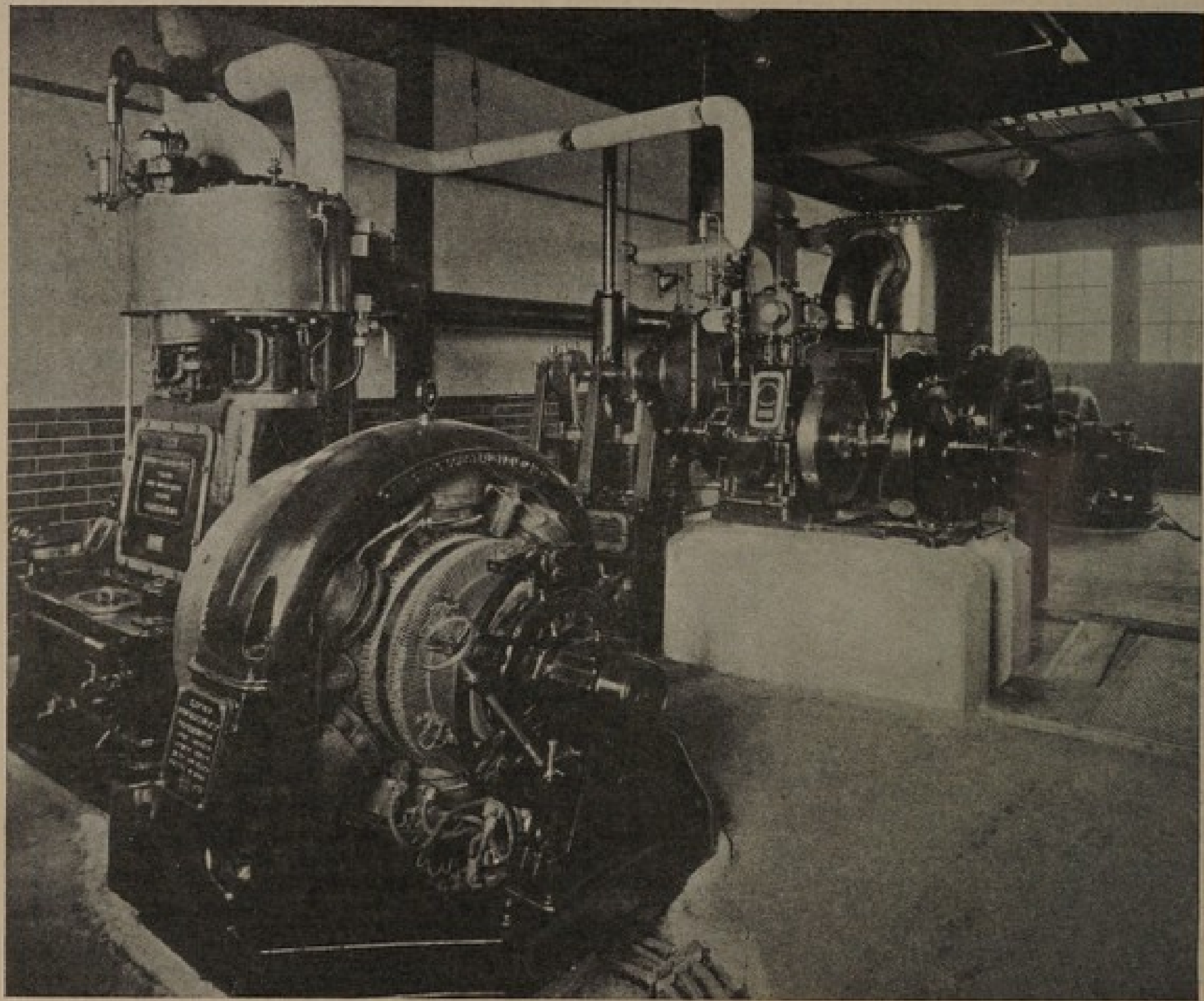

FIG. 100.—Steam-driven generating set.

by transferring some or all of the load to the town's mains, and thus to keep the whole of the electrical equipment running during periods of low steam.

Cost of Generating Electricity.—To show how economical it can be to generate your own electricity, I give the cost of generating electricity at the Montague Street disposal works of the Birmingham Corporation.

The power station here comprises two 100-kw. reciprocating condensing sets which supply all the power required for driving the plant, charging twenty-two electric vehicles and lighting the depot. There are three engine attendants, each of whom does an eight-hour shift per twenty-four hours.

For Year ending March 31st, 1928.

		£ s. d.
Depreciation of plant on a 20 years' life		441 15 8
Running Charges.		
Wages	£498 18 1	
Materials (oil, etc.)	60 15 11	559 14 0
Maintenance and Repairs.		
Wages	£74 8 1	
Materials	76 11 3	150 19 4
Amount paid to Electric Supply Dept., in respect of "stand by" guarantee		144 2 6
		1296 11 6
Overhead charges, 14·38% on all items except depreciation		122 18 4
		£1419 9 10
Total units generated	660,388	
Total cost per unit	0·516*d.*	

In calculating this cost, the writer has assumed that the steam is supplied free of charge. This assumption is justifiable, because in this case the boilers existed long before the power plant was installed, and the generating plant was put down to utilise the excess steam generated by the boilers and blown daily to waste. Even if allowances are made for the depreciation and maintenance of the three boilers and the pumps necessary to produce this steam, the cost per unit is still under one penny. There are very few electric supply authorities in this country at present who can supply electricity at less than one penny per unit at your bus bars.

Section 2.—The Distributing System.

Mains.—When a main runs in a dry place and is not exposed to mechanical damage, then vulcanised rubber cable run along boards on china cleats gives very satisfactory results, and this system possesses the very great advantage that every part is visible and can therefore be easily inspected and readily repaired. For damp situations vulcanised indiarubber cable is not suitable, and it should be replaced by cab-tyre sheathed cable, which again has the advantage that every part is visible. If in certain places the cable is liable to be damaged, as, for example, when it passes through a floor, it should be run just for this particular portion in conduit. The writer has not found conduit to be a very satisfactory method of wiring because damp clinker dust will settle on the tubing and fittings and rapidly corrode them.

Protection from Damp.—One of the most frequent causes of electrical breakdown results from the presence of water and therefore no steps that can be taken to keep out moisture should be omitted. For cab-tyre sheathed cables the writer recommends the use of sealed junction boxes and sealed ceiling roses, and with all cables, in order to prevent moisture creeping in between the wire and the sheathing, it is advisable to serve them with Chatterton compound at the ends where the copper conductor projects from the rubber insulation.

Section 3.—Utilisation of Electricity for Power Purposes.

Type of Motor.—In all refuse disposal works there is a large amount of very fine dust and a great number of rats, and both get inside motors and cause trouble. Totally enclosed motors, of course, are immune from both difficulties, but they are much too expensive to use in any but exceptional places. Pipe ventilated motors are less expensive and are inaccessible to rats, but not so to dust. They are not readily inspected, so that dust may lodge inside without being seen, and unless the supervision is very good it is likely to remain undisturbed until it causes trouble. The least expensive type of motor, namely, the enclosed ventilated motor, is quite well suited for use in any dry and ordinarily dusty situation provided that it is attended to daily. A small mesh covering on the end shields will effectually keep out all rats, and by blowing out the motor once a day with a pair of hand bellows, all dust within can be cleared away. An additional advantage of the enclosed ventilated motor is that the brush gear, commutator and commutation may be inspected at any moment without having to undo anything.

Type of Winding.—For most ordinary purposes, the simple shunt wound direct current motor or the squirrel cage alternating current motor is at once the simplest and best, but in cases where at times a heavy torque is required, then compound wound direct current motors or alternating current induction motors with wound rotors are necessary, but such cases are really quite rare.

Standardisation.—Where a number of motors are being installed, all should, if possible, be exactly the same horse-power and speed, so that a minimum of spares only is required, and one spare armature or motor can be used as a replacement anywhere on the works. This is not such an extravagant proposal as it may at first appear, for it must be remembered that a 50 h.p. motor, for example, driving a 10 h.p. load takes from the mains only a fraction over 10 h.p. and not 50 h.p.

The Starting Gear.—All except very small alternating current motors should have a starting panel comprising a switch, a protective device (which in some cases may also act as the switch) and a starter, and each of these items will be dealt with in turn.

The Switch.—For currents up to 100 ampères at 550 volts direct or alternating current, totally enclosed ironclad quick air break switches will be found satisfactory in most cases. It should be remembered, however, that the kilowatt capacity of the switch is not the only thing that matters. Due consideration should be given to the possible short circuit current that may flow and which the switch may be called upon to break. If this current is found to be very heavy, a greater degree of safety will be obtained by using quick break switches with carbon breaks for direct current work, and oil switches for alternating current circuits. It should be noted that in ironclad air break switches, ample space must be provided between the live parts and the cast iron box as well as in the break itself. To give a large break and yet to bring live parts close to the iron box is manifestly ridiculous.

The Protective Device.—All electrically operated plant should be protected, and by a protective device as applied to a motor circuit is meant some piece of apparatus which will open the circuit when the current exceeds a certain pre-determined amount. Usually it will take the form of a fuse or circuit breaker and whatever may be the type, it certainly is a very important piece of apparatus which needs, not only very careful selecting, but also careful daily inspection.

For circuits carrying over 100 kilowatts, automatic circuit breakers are undoubtedly the safest device to use. They should be so designed that it is impossible to hold them " in " on an overload and they should be placed high enough to ensure that the operator cannot be burnt by any flash that may occur across the contacts. Six feet high is a safe distance. They should be inspected daily to see that all parts are working properly, and that the trip is set at the proper current value. They may be used for any current from 10,000 ampères to 10 ampères or less. Unfortunately, they are open to two grave objections; they are expensive and they can be tampered with by ignorant folk.

Fuses.—For circuits carrying up to 100 kilowatts, fuses form a simple, reliable and cheap method of protection. The simplest form is the porcelain replaceable fuse. These are liable to abuse through workmen putting in pieces of copper wire ⅛ inch or more in diameter, but if by every fuse is placed a box such as that shown in Fig. 101, in which is kept always a good supply of fuse wire of the correct gauge, then, when the fuse blows, the workman concerned will use only the proper gauge wire provided. He will do this because it is easier for him to use that provided and on the spot, than it is for him to go and find other wire. Such fuse-wire boxes should have painted on them clearly the number of the motor to be served and the correct gauge of fuse wire.

A surer method is to use cartridge fuses, and of these the Zed fuse manufactured by Siemens seems as good as any. With this fuse it is impossible to insert any but the proper size of cartridge and therefore it cannot be abused. Spare cartridges ready for replacement should be kept in a fuse-cartridge box alongside the fuse in a manner similar to that recommended for fuse wire.

If when a fuse blows you find that it shatters the porcelain holder, the only solution is to provide a much heavier pattern. Fuses are like switches, their size is determined, not only by the kilowatt capacity, but also by the short circuit current that may flow, and probably will be flowing, at the moment they operate.

The Starter.—The proper function of a starter seems to be but rarely understood and the average work-

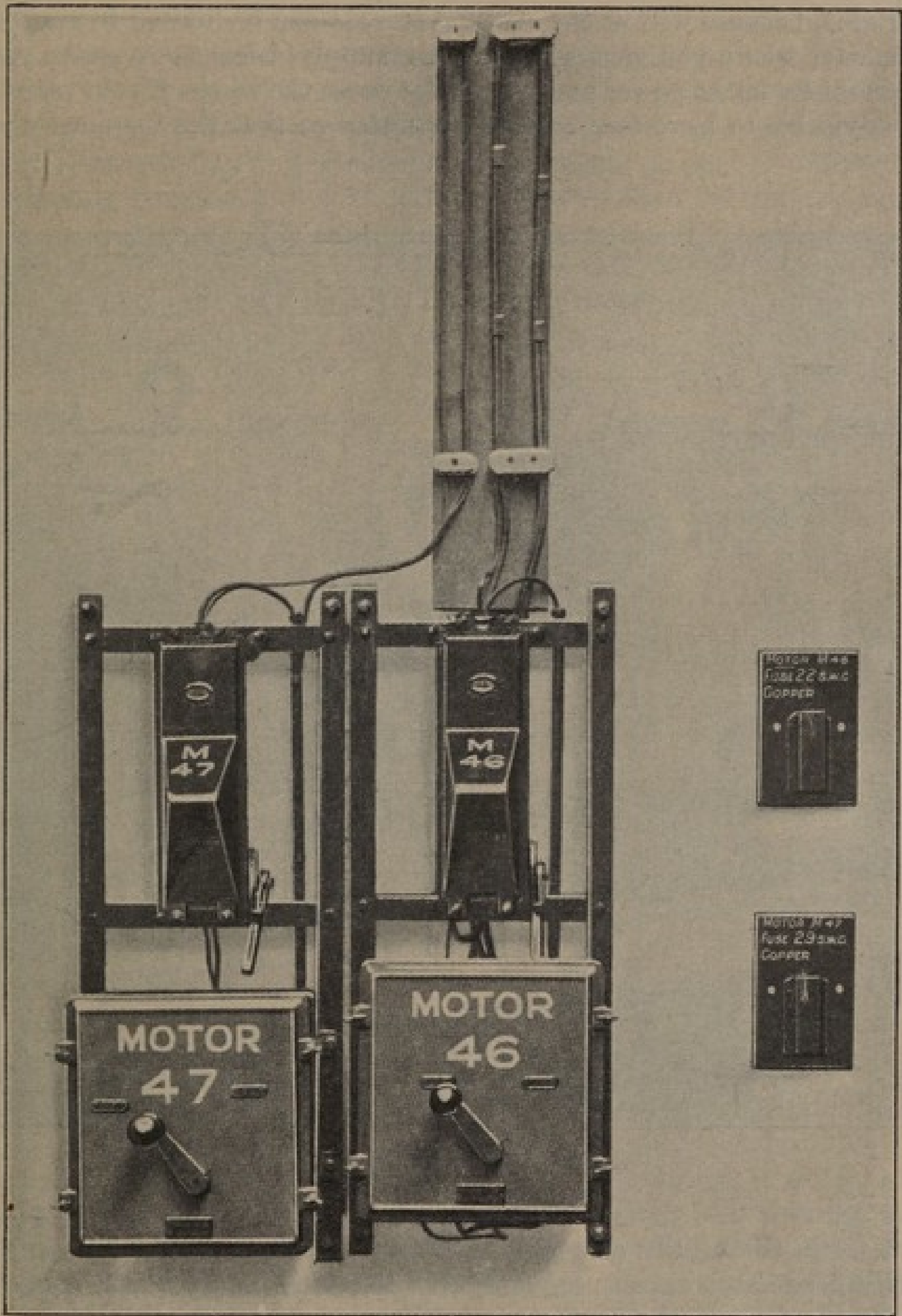

Fig. 101.—Motor starting panels with fuse wire boxes.

man, instead of taking perhaps 30 seconds to run the motor up, regards the starter as a switch and pulls the handle sharply over, with results which, to say the least, are annoying. For this reason, the writer regards as a very necessary feature some sort of slow motion device such as that made by the Electrical Apparatus Co., Ltd., of London, which compels the operator to start slowly step by step. See to it that your starter is liberally rated if operating a motor driving a machine which has a heavy fly-wheel effect, such as a clinker crusher. Specify that once in every 10 minutes the starter must start the motor against full load torque with a starting period of 60 seconds. Such a starter will cost a little more than the standard type, but you will be amply repaid by the freedom from breakdown that will result. Where motors are required to make many starts per hour, automatic starters with push bottom control offer many advantages over hand-operated starters, for by their use much time and much wear and tear on the starter can be avoided.

For the alternating current work, the oil immersed auto-transformer starter with no-volt release only will be found very suitable, because with it the starting current can be limited to anything you choose, and this is an important matter where you generate your own supply, because excessive starting currents may open the main circuit breakers in the power house and shut down the whole of your plant. With alternating current starters it is advisable to have fuse connections fitted so that the fuses are short-circuited during the starting period.

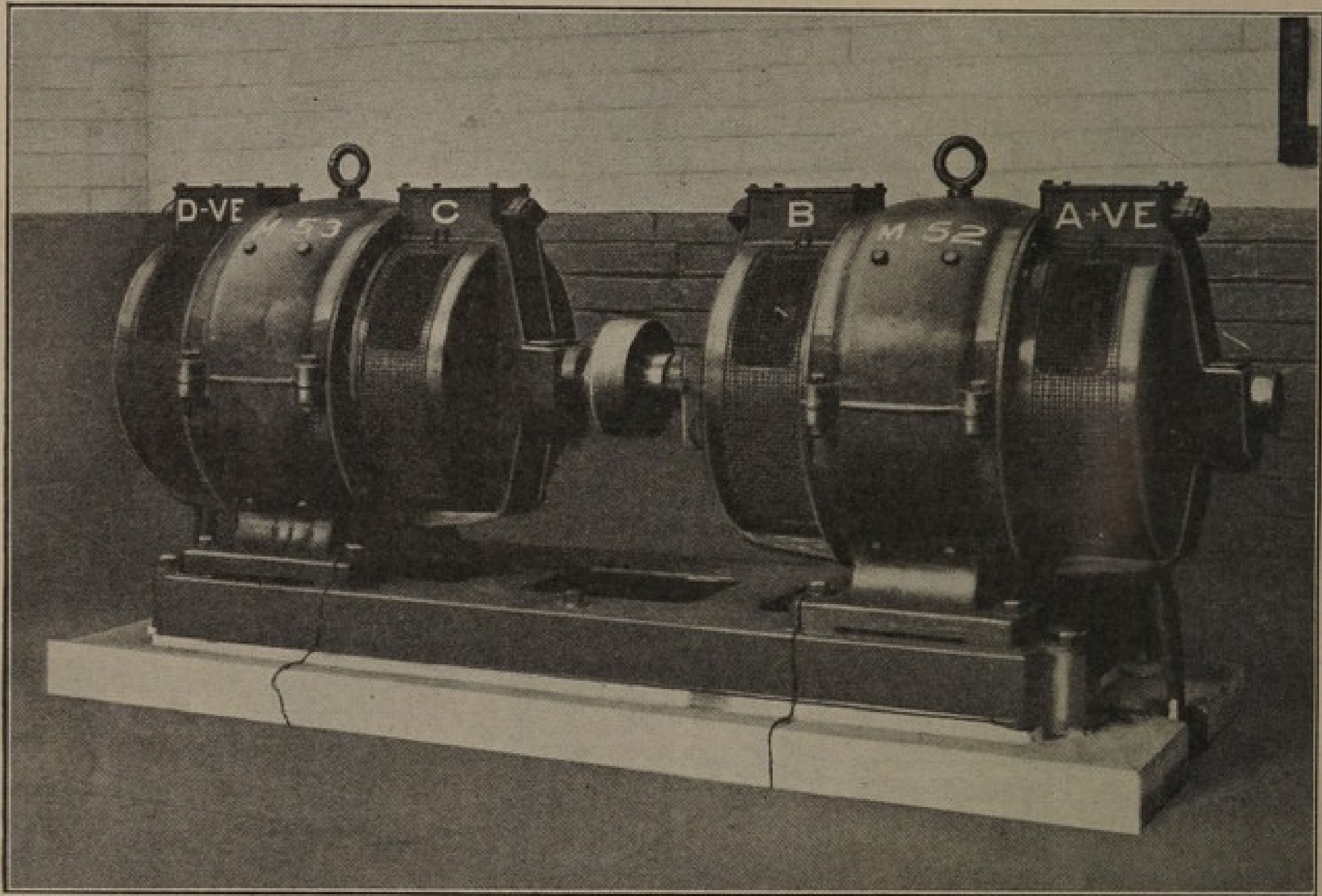

Fig. 102.—Five-wire balancer set.

For direct current work, the totally enclosed starter with no-volt release only is greatly to be recommended, but where this type is too expensive, ventilated resistances may be used, but the front should be totally enclosed to keep the dust off the contacts. Avoid overload releases both for alternating and direct current work. They are troublesome and since they only duplicate the work of the fuses or circuit breakers, they are quite unnecessary.

Vehicle Charging.—About vehicle charging very little need be said. Charging by means of a motor generator set is a very simple and straightforward matter and needs very little comment. On charging from alternating current circuits by means of mercury arc rectifiers the writer is not qualified to speak, for he has had no experience with this type of plant. Vehicle charging by means of a 5-wire balancer was the subject of an article by Mr. J. P. Kemp, published in the *Electric Vehicle* in October and December 1922, and for any information on this subject the reader is referred to that paper. In passing, however, it may be said that experience with 5-wire balancers has proved that the following points are of importance: (1) That a maximum out-of-balance current of 100 ampères (*i.e.*, a maximum armature current of 80 ampères) is frequently met with in practice where 12 or more vehicles are charged at one station and the balancer should be able to carry this armature current continuously; (2) that where double-wound armatures are used, owing to the difficulty of arranging a cooling fan on the armature the machine should be liberally rated to prevent overheating; (3) that when any armature winding is carrying its full load the voltage drop across that armature and its brushes when hot should never exceed 5 volts. If it is allowed to exceed this figure, then in working, much inconvenience arises from the variation of the voltage with the load on each leg; (4) that for large lead plate batteries (44 cells) 110 volts is not a sufficient pressure for charging; 115 volts pressure (460-volt supply) at the least is necessary; (5) shunt regulation is very desirable; (6) that vehicles charged from a 5-wire balancer set should be (and for safety's sake must be) fitted with some form of switching device so arranged that the vehicle cannot be charged unless on both poles the motors are completely isolated electrically from the batteries and from the charging supply; (7) that the neutral point itself should not be earthed. Instead, four 220-volt carbon filament lamps should be connected across the outers and the middle point of these four lamps should be earthed. Under normal working, all four lamps will glow similarly, but if an earth occurs on either side of the neutral, the pair of lamps on the faulty side will go out and the other pair will burn more brightly, thus indicating at once to the attendant that there is an earth on the circuit. (See Fig. 102.)

Section 4.—The Utilisation of Electricity for Lighting Purposes.

Supply Voltage.—If you generate at a pressure exceeding 240 volts, then for lighting purposes the voltage will have to be reduced by a transformer or by a static balancer in the case of an alternating current supply, and by a 3-wire balancer in the case of a direct current supply. In all three systems, it will be found that there is a particular condition of affairs which will arise in every-day working under which the voltage on the lamps will fall below normal. It should therefore be specified that with the most unfavourable conditions of loading the voltage will not vary by more than 5% from the normal.

The Wiring System.—In wiring an installation, vulcanised india-rubber cable in screwed conduit is well suited for offices, but on works, the writer has come to the conclusion that cab-tyre sheathed cable run on boards and properly fitted with sealed ceiling roses and junction boxes gives the best results. In cost there is practically no difference between vulcanised india-rubber cable with screwed conduit, and cab-tyre sheathed cable installations. Where it is necessary to use flex of any kind, use cab-tyre sheathed flexible cord only. It is more expensive but will last many times longer than ordinary cotton-covered flex, particularly in a corrosive atmosphere.

Fittings.—In perfectly dry situations standard tumbler switches and wall plugs are satisfactory, but if there is the least suggestion of moisture, use water-tight fittings only. Wall plugs are very handy things, therefore see that plenty of them are provided.

Fuses.—The fuses should be regarded as most important accessories. Use a standard size of fuse in a cast iron case all over the works, and place your boxes in accessible positions 4 feet or so from the floor, and not up against the roof or ceiling, as is so frequently done. It is foolish to expect a man to get a ladder every time a fuse blows and to climb in the dark to some lofty corner of a building to replace it. Whenever a lighting circuit fuse blows in a works it is a serious matter and everything that can be done to quicken the restoration of the light should be done, because in those few moments whilst it is dark a man making a false step, or slipping, may get caught in some machinery and be injured. Number all the fuse boxes and in the power house keep a large chart showing:—

(*a*) The number of every fuse box.
(*b*) The exact position of every fuse box.
(*c*) A list of the circuits supplied from each box.

Inside the lid of each box paste another list showing the circuits supplied from each fuse. Every man on the works then has at his disposal a simple means of finding out where the fuse is that controls any light in the works.

Intensity of Illumination.—In planning extensions to lighting, a very good rule given in Trotter's "Elements of Illuminating Engineering" is

$$\text{Candle Power} = \frac{\text{Floor Area} \times \text{Foot Candles}}{5 \times \text{Number of Lamps}}$$

and with white-washed ceilings of moderate height and with light-coloured walls, the following illuminations will be found satisfactory :—

Room.	*Foot Candles.*
Drawing office	9
Office desk	6
Workshop	6
Tipping sheds	1 to 2
Depot yards	0·1 to 0·5

The tendency nowadays is to use in workshops a degree of illumination even higher than that given in the table above. The intensity of illumination should be uniform and free from glare, and this result can be best obtained by using properly designed reflectors and frosted or enamelled lamps. It must be remembered that so far as internal lighting is concerned, the illumination obtained is dependent upon the cleanliness of the walls and ceilings. For example, if you allow your ceilings to become dirty until equal to No. 2 shade of Ringleman's Smoke Chart (that is, about as grey as a sheet of newspaper viewed at 50 feet) the reflection from the ceiling will be reduced by some 25% and as a consequence the degree of illumination will be materially lessened.

Section 5.—Maintenance.

Having touched briefly upon some of the details relating to the generation, distribution and utilisation of electrical energy, I will conclude with a few remarks upon the question of maintenance. Every day, send a man round to blow the dust out of every motor and to clean it, oil it and see that it is in good order as far as can be judged by a visual examination. The commutation should be sparkless, and if it is not the cause should be determined and removed. Innumerable tiny white sparks rotating with the commutator usually indicate that the mica is high and it should be undercut, or the commutator should be rubbed with fine emery cloth. The writer has not found glass paper satisfactory as it does not cut down the mica so well as the emery. White sparks can usually be stopped by reseating the brushes or by adjusting the brush position, and long green sparks as a rule indicate a broken connection between the armature winding ând the commutator. The action of the no-volt release on the starter should be checked daily, and at the same time the supply of fuse wire should be replenished if necessary. Every month, the insulation resistance to earth of every motor with its starter and supply cable should be taken with a megger and if below 100,000 ohms the circuit should be tested in detail and the fault repaired. The carbon dust which collects between the connections to the commutator should be removed at the same time. Lighting circuits should be tested similarly. At rarer intervals, that is to say, only when necessary, brushes should be renewed, commutators turned or ground, and the contacts of starters and switches should be overhauled. It should always be remembered that no electrical installation will run indefinitely without a breakdown unless it receives regular attention, and if the maintenance is carried out in a systematic manner, no very great amount of labour or expense is involved, and much loss from breakdown will be avoided.

CHAPTER XV

BOILER FEED WATER

WATER comes very near to being a universal solvent, as very few things will not dissolve in it to some extent. For boiler-feed purposes a variety of sources of supply is drawn on, such as rivers, canals, ponds and so on. Generally speaking, such waters at some part of their passage have been in contact with the minerals of the earth and have taken some of these salts into solution. Now water also has the capacity of holding the gas, carbon dioxide, in solution, and such a solution is of a weak acid character known as carbonic acid. When this weakly acid solution comes in contact with limestone and magnesium rocks some will be dissolved, and this results in the water becoming hard. It is so called on account of the difficulty in getting soap to lather with such water. On the other hand, rain water, which contains no salts in solution, very easily forms a lather with soap and is spoken of as soft. Water containing only small quantities of lime and magnesium salts in solution lathers freely with soap and is likewise called soft. To measure the degree of hardness of a water, soap solution is employed. The soap in contact with the hard water throws out of solution or precipitates the salts causing the hardness; the greater the quantity of such salts present, the greater the quantity of soap solution required. When all the salts have thus been thrown out, the water lathers freely. Using a standard soap solution of known strength, the amount of soap required to produce a lather with a specified volume of the water under test can be ascertained and serves as a measure of hardness. The result is then expressed in "degrees of hardness." Each degree of hardness corresponds to 1 grain of calcium carbonate per gallon of water. Hardness is also expressed as parts of calcium carbonate per 100,000 parts of water. A water of less than 5° of hardness is soft; 20° hardness is moderately hard; above 30° hardness is very hard.

Salts causing Hardness.

Calcium bicarbonate	$Ca(HCO_3)_2$
Magnesium bicarbonate	$Mg(HCO_3)_2$
Calcium sulphate	$CaSO_4$
Magnesium sulphate	$MgSO_4$

There are two kinds of hardness—

1. Temporary.
2. Permanent.

Temporary hardness is caused by the presence of magnesium and calcium bicarbonates. If water containing these salts is boiled, the bicarbonate is decomposed and calcium carbonate precipitated.

$$\underset{\text{Bicarbonate}}{Ca(HCO_3)_2} = \underset{\text{Carbonate}}{CaCO_3} + \underset{\text{Water}}{H_2O} + \underset{\text{Carbon dioxide}}{CO_2}$$

The water is then soft, but such a method would not do for boiler work, as, irrespective of the expense, the boiler would soon be choked with the precipitated carbonate.

Permanent hardness is largely due to the presence of the magnesium and calcium sulphates, and these salts cannot be precipitated by boiling.

Boiler Scale.—If the salts causing the hardness of water are not removed from the water prior to its use in the boiler, owing to certain chemical reactions and the evaporation there taking place, the salts are deposited as "Scale." This scale is a poor conductor of heat, and therefore the boiler efficiency is lowered. Secondly, the scale and the metal of the boiler have different rates of expansion. If the water in the boiler gets low and the metal overheats, some of the scale may leave the metal, or the scale may crack, leaving the hot metal exposed. On cold water now entering, it comes in contact with the hot metal, and owing to the sudden generation of a large volume of steam an explosion may occur.

Corrosion.—This is usually produced by soft waters containing organic acids in solution from water which has been polluted by mineral acids and by water which contains magnesium or calcium chlorides and nitrates. These latter salts very often are decomposed in the boiler with the production of mineral acids.

Softening Boiler Water.—Probably the process most generally used is Clark's. As explained, the temporary hardness is due to the presence of the soluble calcium and magnesium bicarbonates. If either of these carbonates is treated with lime, the insoluble carbonate is precipitated.

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O,$$

hence an analysis of the crude water is first made and the amount of the bicarbonate per 1000 gallons of water is found. The amount of lime necessary to precipitate this as carbonate is then added to every 1000 gallons of water. The process, of course, is carried out mechanically in a water-softening plant.

There now remains the permanent hardness to deal with, due, as already explained, to the sulphates of magnesium and calcium.

Again a precipitation process is used. It is found that if sodium carbonate is added to these sulphates in solution, the calcium or magnesium is precipitated as an insoluble carbonate and sodium sulphate is left in solution.

$$\underset{\text{Calcium sulphate}}{CaSO_4} + \underset{\text{Sodium carbonate}}{Na_2CO_3} = \underset{\text{Calcium carbonate}}{CaCO_3} + \underset{\text{Sodium sulphate}}{Na_2SO_4}$$

The presence of a small quantity of sodium sulphate, however, is not objectionable.

The sodium carbonate is usually added as "Soda Ash." Again it is a matter of calculation following analysis as to how much soda ash to add per 1000 gallons.

Usually the two operations of the lime water and the soda ash are carried on at the same time in the water-softening plant.

So that from the original hard water there is now a considerable precipitate formed of scale-forming salts, and before the water is allowed to enter the boiler these precipitates are filtered out. These filters, however, rarely clear the water of the precipitates, and sufficient space should be allowed in the settling tank for the remainder to settle out. It is very rare to find a softener plant of sufficient size to allow a 24 hours' supply of boiler water completely to settle out its precipitates, therefore a certain amount of scale-forming material finds its way into the boiler.

Colloidal Treatment of Boiler Water.—This is a method of treating boiler water which is growing in popularity.

A Colloidal Solution is one having a substance in it whose particles are so small as to be only visible by the ultramicroscope, and these particles never settle out. If the particles were only in suspension in the liquid, then if the liquid were allowed to stand long enough they would ultimately settle out, but the particles of a colloidal solution never settle out. Examples of colloids are starch and gelatine.

Colloids present a very large surface area.

Imagine a substance like calcium carbonate to be powdered as finely as possible. If this were placed in some water and shaken up, it would mix with the water and be suspended in it as thousands of tiny particles. Therefore, each of these tiny particles is exposing a certain surface area to the water. But however finely we powdered the carbonate we should never get it so fine as that assumed by a colloid in solution. Hence the colloid will expose far more surface area.

Adsorption.—When one substance fixes itself over the surface of another without being dissolved, the phenomenon is spoken of as adsorption.

Absorption means the solution of one body into another very often with chemical reaction.

A colloid is capable of adsorption. If, therefore, a colloid is present in sufficient quantity in a boiler water, it will adsorb all the solid particles of the salts present in the water and as adsorption implies entrance into the surface of a colloid, it follows that each particle will be covered by a film of the colloid and will be unable to grow any bigger by crystallisation. It is now seen how valuable is the large surface area exposed by the colloid, in that a large area is exposed for adsorption to take place. It will also be appreciated that scale cannot form, as scale is crystalline growth. All that needs to be known is the total amount of solids, say per 1000 gallons of water, and the right amount of colloid added to effect the adsorption.

Enough has now been said to give an elementary idea of the principle underlying colloidal treatment of boiler water.

The particular colloid used must be such as will not coagulate when the temperature is raised to the boiling point of water, otherwise it will be useless in effecting the adsorption of the solids present.

CHAPTER XVI

FERTILISERS AND FEEDING STUFFS

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To obtain an intelligent conception of the preparation and sale of fertilisers and feeding stuffs, it is essential that a few elementary terms used in this connection should be understood.

Broadly speaking, fertilisers can be divided into two classes—Organic and Inorganic. By an organic fertiliser is meant one which is composed of animal, fish or vegetable matter; an inorganic fertiliser being, of course, composed of mineral matter. Each class has its own particular use, and whether one or the other is used depends entirely on the conditions under which it is to be applied.

All fertilisers, whether organic or inorganic, contain one or more of the three main elements of plant food—Nitrogen, Phosphorus and Potash. Plant life requires all three elements for its growth, but differing in their relative proportions according to the plant. For example, some plant life requires relatively large amounts of nitrogen compared to its requirements of potash and phosphorus; whilst another class of plant life may require very little nitrogen and much phosphorus. Hence, fertilisers are mixed to provide these elements in the necessary proportions to suit particular cases.

Nitrogen is actually a gas, but this gas also enters into the composition of certain salts used as fertilisers, *e.g.*, nitrate of soda ($NaNO_3$), where nitrogen is combined with sodium (Na) and oxygen (O); ammonium sulphate $(NH_4)_2SO_4$, where nitrogen is combined with hydrogen (H), sulphur (S) and oxygen. Such salts as the above are either available for plant food as soon as they are dissolved in the soil water or are quickly rendered so by some chemical action with the constituents of the soil.

Nitrogen occurring as above we may regard as *inorganic nitrogen*.

On the other hand, nitrogen occurs in many animal and vegetable tissues as a highly complex series of compounds, known as *albuminoids*. One albuminoid may have a formula $C_{55}H_7O_{24}N_{17}S_5$, where it is seen that nitrogen is combined with carbon (C), hydrogen, oxygen, and sulphur. This nitrogen can be regarded as Organic Nitrogen. Before such nitrogen as this can become available for plant food, this highly complex molecule above has to be broken down into a much simpler substance. This change is brought about by organisms in the soil known as Nitrifying Bacteria, which by a series of biochemical changes produce from the albuminoid matter a simple chemical substance such as a nitrate.

Now this biochemical change is a form of fermentation and depends on the presence of moisture. If the applied fertiliser containing the organic nitrogen contains fat or oil in any quantity it is obvious that the moisture cannot gain access, with the result that the fermentation is delayed and the food is not easily available to the plant. Hence the importance of having a fertiliser as fat free as possible. Fish manure and meat manure provide examples of fertilisers containing organic nitrogen.

Phosphorus.—In fertilisers this is usually found in combination with lime as calcium phosphate. Most of the naturally occurring phosphates are insoluble or nearly insoluble in water and are therefore not immediately available for plant food; but such phosphates can be chemically prepared to render them soluble, or after they have been in the ground some time, chemical changes there take place which function in the same way. Hence in a fertiliser analysis it is usual to find expressed the soluble phosphates and insoluble phosphates, so that we can see how much of the total phosphates is immediately available as plant food and how much will lie dormant in the ground for some time before becoming so. Examples of Phosphatic manures are Basic Slag, Superphosphate and Bone.

Potassium.—This occurs in such materials as wood ashes, and banana stalks; it occurs naturally as salts in the great deposits at Stassfurt in Germany. These salts are sold under such trade names as Kainite, Sylvinite and so on.

Humus.—This is a term very frequently used in connection with fertilisers. Humus is the organic portion of the soil and serves very largely in retaining moisture and heat, and to bind the loose soil particles together. In connection with this latter property it is interesting to note that the cementing power of humus is eleven times that of clay. Humus can be looked on as the decomposition product of animal and vegetable tissues, and as such can be supplied to the soil by fertilisers of the farmyard manure class.

Albuminoids.—This is a term met with in a feeding-stuff analysis; it is sometimes spoken of as protein. It is an essential constituent of foods.

Fats.—A brief explanation of a few terms generally used in connection with the evaluating and sale of fats may be helpful.

Moisture and Dirt.—Fats are sold as a rule on a basis of containing less than 2% moisture and dirt, hence in the production of fats it is obvious that great care must be taken to see that proper settling of the dirt takes place in the clarifying operation and that the fat is subsequently effectively dried.

Saponification Value.—This is the soap-forming value of a fat and forms a basis of sale.

Titre.—The melting point of the fatty acids. The higher the melting point the harder the fat, and *vice versa.* Hence a fat of high titre simply means a good hard fat.

Free Fatty Acids.—A decomposition product of fats. The greater the quantity of free fatty acids present, the more rancid the fat and the less value it has. A fat can become decomposed in several ways. For instance, assume that the fat is being produced from condemned meat; the longer the meat is kept before treatment the further has putrefaction advanced and the more decomposed the fat has become, hence the importance of treating such materials as freshly as possible.

Prolonged heating and contact with steam will produce a similar result, and the importance of this and its bearing on the quality of the fat obtained will be appreciated in what follows.

Processes for Organic Waste Utilisation.—It is proposed in the following discussion simply and briefly to summarise the plant and methods at present in everyday use for the treatment of organic waste from the special viewpoint of a Corporation Department.

Digester.—In many parts of the country this type of plant is still in operation, and in almost every case is causing grave nuisance in the surrounding districts owing to the bad smells attendant on this process. In addition, inferior types of products result from this treatment as compared with those from the modern dry process. It will be interesting at this point to examine this older process as once practised by the Birmingham Corporation Salvage Department.

Two types of digester were employed—one using open steam and the other steam-jacketed. The results in both cases were much the same. Carcases of meat were cut up into sizes suitable for introduction to the digester and loaded through the charging door on the top of the vessel. When fully charged the digester was sealed and the steam opened up. The contents were then subjected to the high temperature and pressure of the steam—some 60 lb. per square inch—for 7 or 8 hours.

During this period, owing to the high temperature and pressure, the fat cells were broken up and the fat was liberated. Unfortunately the process did not stop at this point. One of the most valuable constituents of meat is the protein which it contains, and this protein is soluble in water. It is therefore obvious that in the digester process the soluble protein will be washed from the meat, and ultimately found dissolved in the water. At the end of the digestion period, the contents of the vessel were allowed to settle undisturbed, just sufficient steam being left on to keep the freed fat in a molten condition. Situated about a quarter of the way up from the bottom of the digester was a false perforated bottom, and during the settling process the liberated fat and aqueous solution of protein settled through this plate to the bottom of the digester—the fat, of course, remaining as a distinct layer on the top of the protein liquor. The solid residue rested on the false bottom. Several hours' settling was required, and then a tap was opened in the bottom of the digester and the protein liquor run off. This liquor was very offensive smelling, so one can well imagine the nuisance arising whilst this operation was in progress. From the digester the liquor was run to large tanks fitted with steam coils and situated on the floor below, where it was partly

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evaporated (again a very offensive process) and ultimately barrelled as a sticky, viscous mass and sold for size.

Alternatively, the evaporation could be carried one stage further in special ovens producing a brownish, sticky powder which, of course, commanded a better price. As stated above, the valuable constituent of the meat was here in the form of liquor or powder, and irrespective of the extra time, labour, and other expense of producing it in this condition, its value as size could not be compared to its value if the protein matter had remained in the meat. In very many cases the liquor was not treated at all, but simply run away down the drain as useless. It seems almost incredible at this time that such waste should have been allowed to occur.

When all the liquor had been run off, the fat flow was next commenced, and passed to the floor below, where it entered the fat-clarifying tanks. These were large wooden vessels fitted with steam coils, in which the fat was treated with steam and water, or boiled with acid solutions, in an endeavour to improve its quality. No small amount of the liquor was often left entangled with the fat, and in the open steam digestion, as the fat was subjected to prolonged treatment with hot water, certain chemical changes often took place in its composition; these two factors alone resulted in the production of rancid, evil-smelling fat which no subsequent treatment ever greatly improved.

Finally, the perforated bottom had to be moved out of the way to allow the charge of meat to be dropped. This false bottom was permanently connected to chains, which, through the top charging lid of the digester, could be attached to a crane. On hauling up, the false bottom could be pulled clear, allowing the solid residue to fall through the bottom door, which had previously been unbolted, and swung clear. This was providing one of the chains did not break—a not infrequent occurrence—in which case a man had to descend into the filthy mass and shovel the residue out. The solid residue then fell from the digester. This residue, which naturally was very wet, had to be transferred to another machine for drying; it was then ground and bagged, and sold as a fertiliser. Remembering that the bulk of the valuable protein had been removed, and that the protein is the source of the most valuable ingredient in this fertiliser, viz., nitrogen, one can appreciate that its analysis was not very high, and consequently it did not command a very high price.

Another type of plant which finds favour in many quarters is the *Vacuum Pan System*. This bears many points of resemblance to the steam-jacketed digester; in fact, the essential point of the vacuum system is a steam-jacketed upright cylindrical pan whereby the contents can be raised to the required temperature and arranged so that during the digestion period the interior is under vacuum—usually about 25 or 26 inches of vacuum are employed. The obnoxious vapours produced are usually brought through a water condenser, where the bulk of them are condensed and passed to the sewers, the uncondensable gases being destroyed in the furnace. The object of working under a vacuum is, of course, that lower temperatures can be used to accomplish the same object, which means cheaper production and less loss of valuable material. Also the vapours as formed are removed, and so prevent any injurious action due to prolonged contact of steam with the fat. These, of course, are distinct moves in the direction of economy and hygiene as contrasted with the older system. Finally, when digestion is complete, the fat and liquor are blown out by pressure into settling tanks, where, after standing and cooling some time, the fat is run off. Subsequent processes are much the same as in the older method.

The next type of plant which is of interest is the *Benzene Process*. Benzene is an excellent solvent for grease and will not mix with water. A general idea of the operation of this plant can be gathered from Fig. 103, which with slight modifications of procedure is the principle adopted in all these plants.

Tank B is the storage tank for the benzene and is fitted with a steam coil. A is the still, also fitted with a steam coil, from which the benzene is distilled. D is a cooling tank from whence the benzene runs to C, which is the container for the material under treatment. This is fitted with steam coil and agitator and a condenser, Y, to prevent the escape of benzene vapour. Z is a syphon connecting C to tank L, which is also connected to A. Consider a charge of fatty material in C to be treated. All steam is turned off except that in coil A.

Open taps G, N, Z and Q, the others all being closed, and turn on steam to A. Benzene distils to D, where it is condensed and runs to C, where it percolates through the mass of raw material being agitated. When the benzene has risen to the height R it syphons into L and A. C is open to atmosphere *via* Q in order to prevent air locks in the system, and benzene vapour is prevented from escaping by means of the water condenser at *Y*. While the benzene is in contact with the raw material in *C*, it exerts a solvent action on the fat, which is carried in solution *via* the syphon back to the still *L*. Here the benzene is distilled off once more and the circuit completed again and again. Ultimately a sample of the benzene is run from tap *S*. If there is any fat in solution, on test the benzene will show a different density from pure benzene. If this is the case, the process is continued until a sample taken from *S* shows the gravity of benzene. This proves that there is no more fat in the raw material to be extracted, and the distillation concludes. We are now left with the fat-free raw material in *C* and a little benzene, and a solution of fat in benzene in *A* and *L*. All taps with the exception of *X* and *I* are closed and the benzene from *C*, *A* and *L* is distilled into the storage tank, *B*, where it can be condensed by cooling. The residue of fat in *A* can now be run off and the solid residue in *C* is heated up and the agitators set in motion to dry it.

By this process it is almost impossible to eliminate a slight odour of the solvent in the finished dry product, and users have found that if used as a feeding meal for pigs and poultry it is not very palatable. The fat also, in many cases is not of the best quality.

In operating a solvent extraction plant it is obvious that skilled labour and fairly involved plant are required. Rigorous rules have to be adhered to during its operation to safeguard against any risk of fire or explosion, and the annual losses of solvent are also very high.

The next process to be described is the one adopted in Birmingham, known as the Iwel Dry Rendering Process, and in the writer's opinion this is the process most eminently suited to the needs of municipalities. In deciding on this type of plant we carefully considered its advantages and disadvantages as compared with other types of plant. Without going into any detailed considerations which influenced our views, some of which, from what has been stated, will be readily deduced; it may be said that it is simple in operation, therefore demanding no high order of intelligence amongst the men—this means cheaper labour—there is no danger; the treatment is economical in both time and labour—6 men run the plant; finally the upkeep is low.

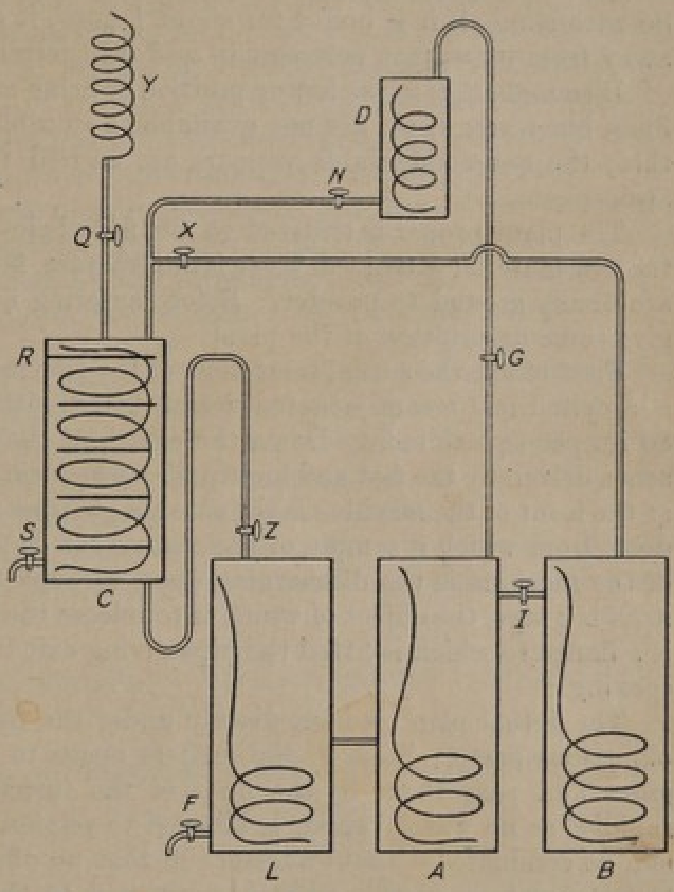


Fig. 103.—Diagram of a benzene fat extraction plant.

The raw material as received is tipped in a room where the atmosphere is being constantly changed by a suction duct scheme. These ducts in the wall are connected up to powerful fans which are constantly exhausting the atmosphere, so that any offensive gases are carried away in the constant inrush of fresh air, and conveyed *via* the ducts to the hot flues of the fires, where at a temperature of about 1500° F. they are dissociated and rendered odourless prior to passing up the stack to the atmosphere. Care is also paid to the cleanliness of the floor, which is swilled down every day and disinfected so that, these precautions being observed, there is no cause for complaint about any offensiveness arising here.

The first operation as soon as the load is tipped is its separation into such individual classes of material as it contains. As previously stated, we divide the raw material into meat, offal, slime and fish. In addition we collect a considerable quantity of bone from dustbin refuse. The carcases of meat are first chopped into suitable pieces to pass through a crusher, where they are broken down. It is obvious that by so preparing the meat, in the subsequent treatment by heat, the cooking is done much more quickly and the fat cells are more completely broken down. A charge of meat to the melter is about 12 cwts., and uniformity of charging is secured by having a trolley wagon suitably calibrated for the correct charge of every type of material.

The manifolds are prepared for treatment by passing through a cutting machine where rapidly rotating knives slice them up finely and the drum underneath conveys the chopped material to the trolley. It is then mixed with the intestines and is ready for charging. House refuse bones are prepared by crushing in the bone crusher, whilst fish receives no preliminary treatment. Slime as we receive it is an evil-smelling, emulsified mass, from which it seems impossible to separate the water effectively by any mechanical means. When it is known that 2 tons of slime as we get it usually contain about 1 ton 18 cwts. of water, it will be understood that it would not pay to evaporate all this water. Yet there is a very simple solution. The solid part of the slime is albuminous in character, and, chemically speaking, is analogous to the white of an egg, although, of course, it looks totally different. If an egg is boiled, the white or albumen sets hard. So with slime, if it is boiled for about ½ hour, it coagulates into a rubbery mass which can easily be lifted away from its watery partnership and transferred to the melter for cooking.

Birmingham is in the happy position of being able to discharge the noxious fumes direct to the incinerator flues, but where these are not available, a suitable condensing plant is fitted, and the vapour condensed in this; the non-condensable vapours are carried to the boiler flue or chimney and in some cases to the atmosphere.

The plant proper is situated on the floor below and consists of nine melters, *i.e.*, the machines in which the raw material is treated, three fat extractors, fat clarifying tanks, and the plant in which the dry products are finally ground to powder. Before entering into the actual working operations, it will be advisable to give some description of the plant.

First of all, the actual treatment of the raw material takes place in a machine known as a melter, which is a cylindrical steam-jacketed vessel, fitted with safety valve and steam trap. The working pressure is 80 lb. per square inch. Down the centre of the machine is a square shaft to which are attached beater arms, driven by the fast and loose pulley which can be brought into operation by means of a lever. Situated at the front of the machine is the charging hopper for the raw material, and immediately below it the testing door, from which a sample of the charge can be examined from time to time. Lower down on the front of the machine is the discharging door, through which the finished product is extracted, and in the door itself is a pipe, the object of which is to release the bulk of the fat from the charge. Attached to the hopper is a flange to which is fitted the pipe giving exit to the water vapour and obnoxious gases produced during cooking.

The actual plant is immediately under the tipping floor. Fume pipes, connected to fans, convey the obnoxious gases. Each of the melters opens to a common fume pipe. The fans constantly extract the gases and pass them to the flues of the furnaces. Thus the charge in the machine is cooked more rapidly, as no water vapour is allowed to remain in contact with it, and at the same time the operation can be conducted without nuisance in that no offensive smell can escape to the atmosphere. In addition, the atmosphere of this room is connected to the ventilation ducts in exactly the same manner as in the tipping room.

For the purpose of following the method of treatment, let us assume that a charge of 12 cwts. of meat has been fed into a melter. The steam is turned on to the melter jacket and the beater arms are set in motion. This results in the contents of the machine being constantly stirred up and forced in thin layers against the hot plates of the shell. The temperature gradually rises, the water is evaporated and the fat cells burst. So that soon the original raw meat is broken down and is a more or less dry, lumpy mass, floating in fat; the temperature constantly rises, and it has been found that if the contents of the melter are discharged at a temperature of 248° F. the best quality products are obtained. This temperature applies to fatty material only.

The steam consumed during this cooking operation is on the average about 1 ton per ton of raw material treated. The charge of meat we are considering takes about 2 hours to finish, and after running off the bulk of the fat through a cock in the discharging door, the solid product itself is partly discharged automatically by rotating the beater arms, and partly raked out into suitable vessels. The fat run off is transferred to the clarifying tanks and the solid residue is then subjected to fat extraction. For this purpose a turbine centrifugal fat extractor is employed, and it would be advisable at this stage to examine the structure of this machine.

This consists of an outer steel vessel with a hinged lid. Inside is a perforated steel cylinder, known as a rotor, free to rotate on ball bearings. Attached to the bottom of the rotor are a number of small vanes, and on to these impinge two steam jets. A pressure of 90 lb. of steam exists at the jet, and the steam playing on these vanes causes the rotor to revolve rapidly, so that four minutes after starting up it is whizzing round at 800 r.p.m. A charge of the meat weighing about 1 to 1½ cwts. is loaded into a perforated steel basket lined with a filter cloth, the basket is placed inside the perforated rotor, and the machine closed down. Steam is turned on, and owing to the rapid revolution of the basket, the contents are subjected to an extremely high pressure due to centrifugal force. This combined with the heat of the steam causes the fat to be squeezed out of the meat and to flow through the filter cloth, the perforated basket and the perforated rotor into the space surrounding the latter, whence it issues from the machine *via* a pipe. After twenty minutes' fat extraction, the brake is applied to stop the machine, the latter opened up and the basket removed. The contents are spread on the floor to cool, and are then ready for subsequent grinding down to a powder. The fat so secured is transferred to fat-clarifying tanks, where it is purified and finally run off into barrels. The tanks are fitted with steam coils; to this fat is added a quantity of water, and the whole boiled up for some time and allowed to settle. The wash water, together with the impurities washed out of the fat, is then run off. After this process has been repeated once or twice, most of the impurities will have been carried away. The fat is then heated up without the addition of water, for the purpose of driving off any remaining moisture. This process is important in that two of the factors on which a fat is sold depend on the moisture and dirt content. The bulk of this fat is sold for soap and candle-making and 70 to 80 tons per annum are so produced by the Birmingham Salvage Department.

Comparing this treatment of meat with digester treatment, we see that in the Iwel process :—

(1) Owing to the water vapour being removed by suction as it is formed, the protein matter is not dissolved out and therefore a higher percentage of product is obtained.

(2) We may therefore regard the heat of the melter as "dry" heat, which results in the protein matter "setting" in the same way as the white of an egg, and then becoming insoluble in water. We are therefore preserving in the meat, where it is wanted, its most valuable constituent.

(3) In the same way, the fat is not kept in contact with hot water and steam as in the digester process, which again preserves the fat value in that it is of good colour and high titre, and is much lower in free fatty acids.

The offal treatment varies somewhat from the above procedure. The raw material is separated into two grades :—

(1) That portion which contains a fair amount of fatty tissue and will therefore pay for fat extraction.

(2) The non-fatty portion.

The fatty portion is treated in the same way as meat, whereas the non-fatty offal is simply cooked in the melter until it is dried, and is then ready for its final treatment prior to selling.

As the fatty offal is treated with the ingesta intact, and as this ingesta consists very largely of undigested food, mainly grass fibre, the green colouring matter of the latter, known as chlorophyll, is very prominent in the resulting product. Unfortunately, this green colouring matter stains the fat produced from the offal, and this fat is often a deep green colour. However, this is not very important, as the colour ultimately disappears in the manufacturing processes for which this fat is used, but at the same time it is of advantage to the buyer in that he can offer a lower price owing to the colour.

The slime, after the preliminary coagulation treatment, previously described, is usually added in with a meat charge as the final product; although much richer than meat, in other features it closely resembles it. Fish is likewise divided into two classes. :—

(1) Oily—such as herrings, mackerel, etc.

(2) Non-oily—all the white fish.

The first class is treated in the melter, and the oil then extracted in the turbine extractors, and the latter class simply dried down to a powder in the melter without any oil extraction. Fish oil is thus another valuable product, being extensively used in industry for currying leather, adulterating paint oils, steel tempering, soft soap manufacture, and linoleum making. This extraction of oil and fat is both an economic and an essential operation. As the solid products are used for either fertiliser or feeding-stuffs, if the fat or oil is left in, it is sold at the price realised for the fertiliser. The fat taken from the solid product sells at three or four times this value. Again, if fish oil is left in the fish in any quantity, the resultant fish meal is degraded for feeding purposes, and sometimes causes considerable trouble and loss amongst the stock fed with it. In the case of fertilisers, fat left in these resists the action of the water in the soil, with the result that the decay of the fertiliser and its consequent fertilising action are seriously delayed, in addition to which the fat under certain conditions exercises a souring and poisonous effect on the soil.

During the treatment of bones the liberation of the fat is rather a difficult matter, and the efficacy of the operation is largely dependent on how finely they are crushed prior to treatment in the melter. In any case, it is necessary to raise the temperature higher than in the case of the other raw material. In the case of, say, offal, although the pressure of steam in the melter jacket results in a temperature of 162° C., this temperature is not attained by the offal under treatment, for as long as there is water present the temperature will not rise above 100° C. Therefore, in the case of streeter bones, which are fairly dry in the first instance, a quantity of fat is added to the charge in the melter, and this results in their being cooked at a higher temperature, and consequently the running of the bone fat is facilitated. The subsequent fat extraction results in an inferior grade of fat being produced, which is kept separate from the best meat fat.

Old Streeter Bones always present a somewhat difficult problem to the Dry Rendering Process, although the new "Laabs Process" overcomes this. At the same time, a number of Municipal Salvage Departments dispose of the bones sorted from household refuse to such large concerns as British Glues and Chemicals, Limited. There is a steady demand from such firms, who, on account of the intensive processes employed, and the diversity of products extracted, such as fats, greases, glues, fertilisers, feeding meals, etc., etc., are able to pay prices which often show a more satisfactory return than can be obtained by Departments treating the bones themselves.

It is not generally realised that bones form the raw material of a large industry, and that the efficient sorting of bones, and supply to the trade, are of national benefit.

Reverting now to the treatment of offal, it must be remembered that the stomachs and intestines are treated just as received, with all the manurial matter or ingesta still in them. The resulting dry product is used for a fertiliser. On opening up a manifold, the ingesta can be seen as a green-looking material—the green colour being produced by the chlorophyll in the grass which the beast has eaten. Now the ingesta of the offal is largely undigested food, grass, etc., and a large quantity of water; therefore this part of the offal contains very little of fertilising value. The main value of the offal lies in the stomach and intestine walls. Before treatment, the offal should therefore be cleansed of all this useless material and only the valuable part used. Obviously far less material is treated, which means less treatment expenditure, and although we receive less dry product it is far more valuable. Experience shows that out of 1500 tons of offal no less than 1000 tons consist of this comparatively useless ingesta. The raw offal is passed through the cutting machine previously mentioned, which finely divides it, and it is then fed into an offal washing machine. This consists of a long cylindrical perforated vessel slowly rotated by a chain drive. The cutting machine delivers the prepared offal into one end. Inside the machine near the top is fitted a perforated water pipe capable of delivering a fairly fierce spray of water. The machine has a gentle slope away from the feed end, and as it rotates, the finely divided offal passes along under the water spray. Large quantities of water are thus swilled around the offal, and the ingesta rapidly mixes with it and passes through the perforations, the cleared portion passing along the cylinder, and is finally discharged at the lower end, when it is ready for treatment and is subjected to the same process as meat.

It is extremely important in the treatment of the various classes of raw material that fertilisers should be kept entirely clear of feeding stuffs, and feeding stuffs not allowed to contaminate each other. For instance, most meat meals and fish meals are required to be of nice light brown colour, and contamination with a dark coloured fertiliser would degrade this. Fish meal must not come in contact with meat meal, or buyers quickly protest. For these reasons, certain melters are kept for meat only, some for fish only, and the rest reserved for fertilisers. From the condemned carcases, meat and bone meal is produced; the fish provides fish meal—certain qualities of fish are turned into fish manure; offal is turned into a fertiliser, as is also the streeter bone.

From meat, 30% of meat and bone meal is produced, together with 12 to 15% of fat; fish gives 26% of meal and varying quantities of oil; offal yields 25% of fertiliser and varying quantities of fat; slime gives about a 5% recovery of its total weight, but it will be remembered that its total weight includes a huge percentage of water which is not treated. Bone produces 70% of fertiliser, together with some 10% of fat, the recovery varying very much with the quality of the bone. So that from slaughterhouse and market waste there are produced two feeding meals, a fertiliser, fat and fish oil.

Grinding.—So far, in the course of treatment of this waste we have only got as far as melter treatment and fat extraction. In all cases, the solid product is now ready for its last phase of treatment. Meat and bones are directly ground to a fine product—the former for a feeding meal and the latter for a fertiliser. Fish as we receive it contains such foreign matter as shells, hooks, weights, glass, wood and so on, which it would be hopeless to sort. Hence, after melter treatment and fat extraction, before being finally ground up, all this foreign matter is screened from it by means of a shaking screen. The pure fish which passes through the screen is then ground up for a feeding meal. The foreign matter, which passes off the screen as the tailings, naturally contains quite an appreciable amount of fish. Hence these tailings are not wasted, but ground up in a suitable mill into a low grade fertiliser, the principal ingredients being shell and fish.

Offal, as at present treated, contains, of course, all the ingesta, and the offal fertiliser comes from the melter as a mixture of hairy-looking material and a dark powder. The hairy-looking material is the undigested fibrous portion of the beasts' food; the dark powder is mainly the meaty portion of the offal, discoloured by the chlorophyll. If left in this condition the farmer experiences great difficulty in using it, as owing to the hairy material clogging his machine he cannot drill it. Hence the two portions are separated on the shaking screen, the powder which passes through being bagged separately. The hairy tailings are also bagged and sold as a fertiliser for hops and fruit, for which it is eminently suitable.

We now logically come to the process of grinding down the meals. The material to be ground is tipped on to the floor and then shovelled into a hopper below. At the bottom of the hopper is an endless belt working over two rollers back and front, and moving forward. As it slowly travels forward it carries with it the material in the hopper, and at the end of its travel delivers it in a uniform stream into a large funnel which gives access to a pipe. At the end of the pipe is a high-speed blowing fan projecting an air stream up the pipe with a velocity of 50 m.p.h. As the material to be ground, say meat, enters this air stream, it is carried forward along the pipe to the top of the building, where the grinding plant is situated. Now any pieces of iron which may be invisibly entangled with the meat, when they reach this bend in the pipe, owing to their large weight and comparatively small volume, are not carried any further, but remain at the bend. Hence they cannot reach the grinding machines and probably wreck them. A hinged door is placed on the pipe at this bend, and occasionally the operator opens it and allows whatever has accumulated to fall out. The pipe delivers the meat into a cone-shaped arrangement known as a cyclone. The function of this is to dissipate the air blast, which it achieves by a mechanical arrangement, and thus prevents dust; the meat therefore falls down the cyclone by gravity and enters the top grinding machine. This grinding machine is of the hammer mill type, and its function is to break down the larger pieces of meat. The mill delivers the roughly ground meat down a pipe to the next machine, where it is very finely ground, whence it passes down a chute to meet a bucket elevator. The bucket elevator consists of a moving endless belt to which are attached a number of small buckets, each of which picks up its quota of ground meat from the boot of the elevator and passes it on to the rotary screen. This screen is merely a rotating cylinder of wire meshing 12 holes to the inch, which allows to pass that portion of the meat which has been sufficiently finely ground, and delivers it into the bags attached to the bottom of the case. The tailings are delivered separately at the end of the machine, and go through the whole process again until they are sufficiently fine. The bags are then weighed up in cwts., stitched, and can be delivered down the chute to the waiting transport wagon below.

If the ground material is not immediately required for sale, instead of bagging it, it can be transferred to a store-room by shutting a valve which closes the way to the grinding machines and opens another air-conveying path direct to the store-room. The ground material is then fed through a hopper in the flue into the air pipe, and so transferred to the store-room. Cyclones dissipate the air blast, and as there are four large bays to accommodate the different classes of material, meat meal, say, can be blown to its appropriate heap by closing the valves to the other three cyclones, and only leaving open the one over the meat meal bay. In connection with this large store-room I should point out that the fertiliser trade is seasonal in character, as will be understood, therefore we have to make provision for storing large quantities of fertiliser in readiness for the selling season, and this store-room in addition to one other, meets our requirements. In connection with a large by-product plant of this character, a laboratory is a most valuable adjunct. Stringent regulations under the Fertilisers and Feeding Stuffs Act require that all feeding stuffs and fertilisers shall be sold under definite guarantees of quality as indicated by their analysis. This implies the frequent analysis of all products sold, and also reacts to the advantage of the producer in that, knowing the exact analysis of the product, he is in a position to secure the best market value.

In addition to this side of the work, laboratory control of the various manufacturing operations reveals errors in treatment and tends to secure uniformity of production. Also, many problems arise in this work whose solutions can only be found in the chemist's laboratory—the study of the fats alone, and their methods of production and treatment is an immense science. In the Birmingham Salvage Department's laboratory, all this analytical work is accomplished and the various problems arising receive attention.

Let me give one very simple illustration of the value of laboratory control. Suppose one of the melters springs a tiny leak in the steam jacket; under our system of sampling this would be at once revealed, as the moisture test in the laboratory would show up much higher than usual. The cause of this high moisture is at once sought and tracked to its source. The leak is found and repaired at once, instead of being allowed to become steadily worse. Without this system the first notification of something wrong might occur weeks later, when some buyer raises a protest against the quality of the product, or the product is found to be going bad, and probably by this time the originally small repair has assumed large proportions.

The fertilisers are sold on what is known as the "unit basis," by which is meant the respective percentages of the various fertilising constituents. There are the nitrogen, phosphates and potash, and the prices of these different constituents fluctuate from week to week. At the moment, nitrogen is worth 12*s.* per unit, which means that every 1% of nitrogen per ton of fertiliser is worth 12*s.* Phosphates are worth 1*s.* 10*d.* per unit; potash about 3*s.* 6*d.* per unit. The principal fertilisers sold by the Birmingham Corporation Salvage Department are fish manure, slaughterhouse manure and bone manure.

The *Fish Manure* has the following average analysis :—

Moisture	8·3%	Total phosphates . . .	19·0%
Organic matter	67·4%	Potash	0·5%
Ash	24·3%	Nitrogen 9% . . =Ammonia	11·0%

Slaughterhouse Manure, i.e., the fertiliser made from offal :—

Moisture	7·6%	Total phosphates . . .	6·0%
Organic matter	82·7%	Potash	0·5%
Ash	9·7%	Nitrogen 6% . . =Ammonia	7·2%

Bone Manure :—

Moisture	5·8%	Phosphates	40·0%
Organic matter	40·2%	Nitrogen	5·0%
Ash	54·0%	Ammonia	6·1%

These manures are purchased by local farmers and gardeners, in addition to which considerable trade is done with wholesale buyers.

The feeding meals produced are extensively used in the feeding of pigs and poultry. Much controversy exists about the question of the advisability of feeding fish meal to pigs and poultry, on the ground that it taints the flesh and eggs respectively, and in some cases even causes loss of stock. Now in the writer's opinion the principle is not at fault, but there is, and I suppose always will be, a large number of inferior meals on the market, and the average buyer is not in the position to determine the actual quality of a meal. Although a meal may have a perfect appearance in that it is a good colour, finely ground and so on, it does not follow that it is a good meal to feed to stock. As far as has been ascertained at present, the offending constituent in fish meal is the oil; meals with a high percentage of oil are not suitable for feeding purposes. Those who have had the opportunity of smelling fish oil will know that it has a particularly pungent odour and they will therefore appreciate this point. A further factor which has antagonised many users of fish meal lies directly under their own control. This type of user commences by using an excellent meal and according to instructions, viz., that he shall mix a certain percentage with the rest of the food ration. He achieves excellent results and then proceeds to argue illogically that as a little has done so much good, a lot will do so much better. He carries this fallacious argument into practice, attains ill results, and at once condemns fish meal instead of himself. A good quality fish meal, used in the proper proportion, does give excellent results, as far as the writer's experience goes, and other chemists who have conducted feeding trials on sound lines are in agreement with this. First, it is essential that a good quality product should be insisted upon, especial attention being given to a low oil content, say 5% at the most. Secondly, in the writer's experience not more than 6 to 7% of the total feed should be used, and if this be followed out, no ill results need be anticipated.

The writer cannot pretend, of course, to discuss such a huge subject here as the science of feeding such meals and the various food values of the different ingredients. Briefly, all that can be said is that the essential feeding value in meat and fish meals lies in the albuminoids, the fat, the mineral matter and the carbohydrates. Each has its own particular value to the animal organism, but it has been discovered that the proportions relative to each other of these three items have a large bearing on the results obtained. For instance, on the proportion which the albuminoids bear to the carbohydrates will depend the digestibility of the albuminoids, and on this factor will depend how much of the food is used, and how much will be wasted. The mineral matter also has a very important bearing on the value of a food, yet this is often a factor entirely ignored. The animal utilises this mineral matter in two ways :—

1. As formative materials—for the bones, teeth, etc.
2. As necessary for various physiological processes, *e.g.*, the blood contains iron; the saliva, gastric juice, etc., contain potassium. Chlorine and hydrogen are ingredients of the gastric juice and the thyroid gland contains iodine.

An analysis of the meat meal as produced by the Birmingham Corporation Salvage Department is as follows :—

Moisture	8·5%	Ash	20·0%
Fat	12·0%	Nitrogen	8·2% = NH_3 10·0%
Albuminoids	51·3%	Phosphates	15·7%

It is interesting to compare this analysis with one of a meat product produced under the old digester system :—

Moisture	4·0%	Ash	37·6%
Fat	24·5%	Nitrogen	4·7% = 5·7% Ammonia
Albuminoids	29·2%	Phosphates	30·28%

Reckoned on the unit basis, the difference in value is at once seen; in addition, the meat meal is of a golden-brown colour, and can be used for feeding whereas the digester product was almost black, vile smelling, and could only be used as a fertiliser. It will be appreciated, of course, that higher prices can be commanded for feeding meals than for fertilisers.

Actually the meat meal as sold is much richer than the above analysis would indicate, as it is mixed with the extremely rich product of the slime.

The slime analysis is as follows :—

Moisture	7·8%	Ash	10·4%
Fat	9·9%	Nitrogen	10·3% = 12·5% Ammonia
Albuminoids	64·4%	Phosphates	6·0%

When this material is mixed with the pure meat meal, the result produced analyses as follows :—

Moisture	9·5%	Ash	19·3%
Fat	12·8%	Nitrogen	9·0% = 11·0% Ammonia
Albuminoids	56·3%	Phosphates	17·6%

which indicates a meat and bone meal of high quality.

The question is sometimes raised regarding the sterility of these products as they are used for feeding purposes. Bacteriological tests which we have conducted have never indicated the presence of any living virulent organism, and although such tests are not absolutely conclusive evidence, taken in conjunction with the fact that these meals are subjected to a high temperature for several hours, the writer thinks little doubt remains as to their complete sterilisation. The only conclusive evidence would be actual feeding tests combined with bacteriological diagnosis, and as the meals are being fed daily to animals and birds with beneficial results, little doubt can be entertained as to their being sterilised.

Animals which have succumbed to or are known to be suffering from such diseases as anthrax and swine fever are not treated by this plant at all, but destroyed by fire in a special cremator maintained for this purpose, although the writer understands that in Holland they are seriously contemplating treating even such carcases as these in a similar plant.

Laabs Process.

For a considerable period it has been felt that despite its manifest faults, amongst the principles employed in the digester process there were several of undoubted advantage. If therefore we could eliminate the faults whilst retaining the advantages and at the same time we could incorporate the obvious advantages of the dry rendering process, then I think it will be agreed a very efficient combination will have been secured. This dream has, I understand, now materialised, and we have in the Laabs Process an extremely interesting and efficient machine for the treatment of organic waste.

In outward appearance the Laabs machine is very similar to the ordinary melter, being a steam-jacketed cylindrical vessel fitted with the usual agitator shaft. The essential difference lies in the fact that it is constructed to withstand the high pressures characteristic of the digester process, and is safe for a pressure up to 100 lbs. per square inch. In the ordinary digester process the raw material under treatment is digested and disintegrated by steam pressure and agitated by live steam being blown through the tank. In the Laabs process no live steam is blown into the material being rendered. The raw material is heated by steam in the jacketed shell and steam generated from the products being treated. This generated steam is continuously allowed to escape from the machine, but the amount escaping is retarded. The steam is produced inside faster than it escapes, and a pressure therefore develops. The usual working pressure thus developed is about 40 lbs. to the square inch, and under the combined influence of this and the agitator shaft, disintegration of the largest bones will be accomplished in from one to two hours. It is obvious, therefore, that no preliminary crushing of the raw material is necessary, as in the ordinary dry rendering process; in consequence large sides of meat can be charged directly to the machine.

This ends the preliminary operation—the pressure period. We now come to the vacuum period. The object of this is to remove the last traces of moisture in the material under treatment without darkening the colour of the fat or allowing it to become contaminated with the albuminous or gluey material. In ordinary dry rendering, the high temperatures, as already stated, are detrimental to animal fats. This applies particularly when such other materials as bones or certain fibrous products containing protein matter are present. As drying proceeds, the gluey material parts from the water which is driven off, and if the fat present is hot it will absorb much of the freed gluey matter with consequent degradation of the fat; on the other hand, at lower temperatures this absorption does not take place. It therefore becomes necessary to remove the moisture at a low temperature and this can be accomplished by lowering the steam pressure in the shell and maintaining a vacuum in the interior.

As a result of using this process, it has been established that the dry residue is 50 per cent. more in weight than from digesters and has a much higher protein content, analysing 75 per cent. more in ammonia. The product is of good odour and colour, and has an average protein digestibility of over 95 per cent. Similarly, the fat is of excellent colour, high titre, low free fatty acids and keeps well.

CHAPTER XVII

MATERIALS

Part I. Materials used in Constructional Work

The materials generally used in constructional work are as follows :—

Cement and limes.
Various aggregates for making concrete.
Bricks and stones.
Lead, iron, steel.
Timber.
Slates (natural and artificial), tiles.
Asphalt.
Earthenware drain pipes, etc.
Glass.
Paint.

Cement.—Two kinds of cement are generally used, the ordinary British Standard Portland Cement, which takes from four to six weeks to complete its setting, and the New Rapid Setting Cement, which is a fairly recent invention and which will give the same results at the end of three days as the ordinary cement will give in a month.

During the building of the Birmingham Corporation Salvage Department's Brookvale Road Depot, most of the ferro-concrete piles used in the foundation work were made with ordinary cement, but six of them were made with the new cement, and these were cast or moulded on Monday morning before noon, and were driven on the following Wednesday without any trouble or sign of fracture; in fact, during excavation work two months later, two of them were exposed, and they were found to be in perfect condition.

To convey some idea of the strength of these piles, the following information is given :—

The weight of the monkey or hammer was 2 tons.

The average number of blows per pile was 300, and the free fall of the monkey 1 foot 6 inches, although falls of 3 feet and 3 feet 6 inches were frequently given. For the final test the last ten blows of the monkey had not to sink the pile more than $\frac{3}{8}$ inch.

All the piles were driven to this test.

The greatest objection to this cement is that the cost is nearly double that of ordinary.

Concrete Work.—The usual mixture used for work in the Birmingham Salvage Department is: 1 cubic yard of gravel, broken bricks or clinker, evenly graded from $1\frac{1}{2}$ to $\frac{1}{4}$ inch, $\frac{1}{2}$ cubic yard of fine ashes or sand, and 6 cwts. of cement made to the requirements of the British Standard Specification, and any cement which will pass the various tests of this specification will be quite satisfactory in ordinary use.

The above amounts will give 33 cubic feet of finished concrete.

The most important thing to watch in concrete work is to get a full and solid mass with no hollows or voids, and to do this it is necessary to ram it hard during the filling, and all concrete should be placed in its final position and not touched again within twenty minutes of being mixed.

Excessive water makes the ramming easier, but the resulting concrete is very much weaker. For a rough test of the proper amount of water to use, take a handful of the mixture, and it should be possible to make a ball of it similar to the making of a snowball.

The amount of cement required to be used depends upon the size of the aggregate; sufficient cement must be used to give a coating to every piece of material used, otherwise there will be no adhesion—the smaller the materials the more cement to be used, as the outer area of a large number of small stones, etc., is greater than that of a smaller number filling up the same cubic capacity.

A good practical way of finding the amount of cement to be used in a mixing is to fill a measured receptacle with ballast, then pour in water until it overflows; afterwards drain off the water, find its volume, and use the same amount of mortar made of 1 part of cement to 2 parts of sand, each by measure.

It is essential that all concrete should be mixed thoroughly, and the most important mixings are the first three times turning over dry, as the cement falls on to the gravel and sand and a thin layer stops on each piece, whereas a wet ball of cement will probably never break, and the cement will therefore be used as a filling and not as a cementing material for the other parts.

Two wet mixings are sufficient.

Machine mixing in an efficient mixer is the best, one of the reasons being that the machine does not get tired, and gives equal consistency all the day long.

In the Hennebique specification for reinforced concrete, an addition of 10% of cement must be made if hand mixing is allowed.

Portland cement is a mixture of lime and clay ground in water to a fine slurry, dried and burnt to a hard clinker. This is re-ground to such a fineness that not more than 10% fails to pass through a sieve containing 32,400 meshes to the square inch.

The following are the results of two recent tests :—

1. Test taken April 1927, on *England Cement.*

Fineness.	Percentage left on sieve 5776 meshes to square inch	Specification not to exceed	1·0%
		Actual	0·12%
	Percentage left on sieve 32,400 meshes to square inch	Specification	10·0%
		Actual	5·50%

		Quick.	*Slow.*
Setting Times.	Specification not less than	5 mins.	30 mins.
	Actual	—	1 hr. 40 mins.
Final Set.	Specification not more than	30 mins.	10 hrs.
	Actual	—	3 hrs. 15 mins.

Test on *Holberough Cement*, February 1927.

Fineness.	Residue on 180 × 180 Sieve (32,400)	2·8%
Setting Time.	Initial	145 mins.
	Final	3 hrs. 20 mins.

Mortar.—Ordinary mortar is formed by mixing together lime, sand and water, and is that ordinarily used for general work, for bedding bricks and stones. The mortar made by the Birmingham Salvage Department is of good quality, and is suitable for factory building, foundation work, etc., and as it is made with *hydraulic lime* it is extremely valuable in *damp* situations or in positions *unexposed to the air.*

Best work nowdays is usually executed with mortar composed of Portland cement and sand (compo), and it is always specified where great strength is required.

In furnace work the above mixtures are not suitable. A cementing material called fireclay is used instead, and this clay is usually mined from the same bed as the clay used for making firebricks. The latter are set with as fine a joint as possible, the firebricks being dipped in a mixture of the consistency of cream, and the key bricks gently hammered into position.

The heat generated in the furnace burns the whole work into a solid mass.

When used for plaster work, the mortar should be composed of a fatty lime such as Buxton. For the finishing coat, adamant or plaster of Paris is good and sets very quickly.

Keen's cement should be used for all external angles.

Bricks.—The local bricks as used in Birmingham are :—

(1) The ordinary common red building brick.

(2) The famous Staffordshire blue and brindled bricks which are used where great durability and strength are required.

(3) Firebricks, usually from the Stourbridge district. These bricks are very suitable for furnace work.

Firebricks are used for the linings of all cells, flues, chimneys, etc., and are also used to protect ordinary bricks from direct flames or high temperatures.

Bond.—When laying bricks, great care should be taken to arrange them in such a manner as will prevent the occurrence of continuous vertical joints. The lap should be even, so that the different portions of the wall are well tied or bonded together.

There are various methods of bonding, but these are dealt with in the chapter on building construction.

Damp-proof Courses.—These are inserted to prevent damp rising from the ground by capillary attraction to walls and rooms.

There are various materials used for this purpose, the best being sheet lead, but this is too expensive, except in cathedrals and buildings of a like nature.

Two courses of slates with lapped joints and bedded in cement mortar are good, and some of the various bitumen damp courses are excellent, but care must be taken that these are of such a nature that they do not crack in winter or soften in summer.

Natural asphalt makes a good damp course.

Lead.—Lead is a metal largely used in building work for covering flat roofs, lining cisterns, for gutters, pipes, flashings, ridge coverings, and soakers.

This metal is very soft and malleable, very easily melted, but has little tensile strength. It adapts itself readily to any irregularity between surfaces, and is very often used between the bottom flange of a girder and the bearing stone. It can be obtained in the forms known as cast lead or milled lead, the latter being more often used, though it is not quite so durable as cast lead.

The use of lead is specified by its weight per square foot, that weighing 6 lb. per square foot being used for gutters and good flat roofs, whilst 4 lb. lead is quite suitable for top flashings.

Iron.—This metal exists in three states, viz., cast iron, wrought iron, and mild steel.

In the manufacture of cast iron, iron ores are first smelted in a blast furnace. The slag, consisting of impurities, floats on the top of the charge and is run off, and the metal, which owing to its greater weight sinks to the bottom of the furnace, is run into sand troughs, forming, when cold, the crude pig iron.

Cast iron is obtained by remelting the pig iron, and then forming castings—which may be of any shape—by running the molten metal into moulds of sand.

This metal is used for innumerable purposes, *i. e.* : columns, engine beds, engine cylinders, fly-wheels, tooth-wheels; and in refuse disposal plant work : furnace doors, fire-bars, furnace fronts, furnace grates, dampers and balance weights, etc.

Where the heat of a furnace impinges directly upon it, cast iron is much better than either wrought iron or steel, as it resists distortion.

Cast iron has little tensile strength and cannot be bent, but its compressive strength is very great, which makes it an ideal metal for large bearing blocks for bridges. On buildings, rain-water pipes, tanks, gutters and various covers are all made of this useful material. It is brittle and when it breaks, gives way suddenly, and without warning.

Malleable Iron.—Malleable cast iron is iron which has been annealed and partly decarbonised by being heated in contact with some oxidising material in an annealing oven.

It is much more tensile than cast iron, and is an excellent material when subjected to repeated shocks.

Americans are great makers and users of the malleable casting.

Wrought Iron.—Wrought iron is now very seldom used, as mild steel is cheaper and can be used in nearly all cases where wrought iron was formerly used.

Steel.—Steel lies intermediate between cast iron and wrought iron, being pure iron combined with carbon and other elements. Cast iron contains much carbon; wrought iron contains very little carbon.

The hardest steels contain about 1·2 to 1·6% of carbon, and the mildest about 0·25 to 0·4%.

There are two processes of making steel: the *Bessemer* and *Siemens-Martin* or *Open Hearth*.

Mild steel is made by either of the above processes, and is usually worked up into bars, angles, plates, etc.

Mild steel does not harden perceptibly when heated and quenched afterwards in cold water. It contains a low percentage of carbon and resembles wrought iron, and, like the latter, can be welded.

It has taken the place of wrought iron for many purposes—such as rolled steel joists, angle iron, boiler plates, bolts, shafting and many engine parts. Its ultimate tensile strength is between 30 and 34 tons per square inch.

There are many kinds and qualities of steel used for various purposes. The Great War did much to encourage the use of steel of special hardness and high tensile strength. Some idea of the strength of present-day steel can be obtained when it is realised that twenty years ago the main shaft of a 300-horse-power gas engine was 10 to 12 inches diameter, whilst that of a 300-horse-power aeroplane engine to-day is 2 inches diameter with a hole ⅞ inches diameter bored in the centre.

Part II. Timber, Slates, etc.

The selection of timber of any kind is a matter of experience, chiefly, and the subject can only be treated in a general manner in a short chapter such as this.

For all work the heart-wood is the best, and this only should be used, the outer portion, or sapwood, being inferior in strength or durability.

The annular rings should be regular, close and narrow. When freshly cut, the wood should have a sweet smell—a disagreeable smell usually indicates decay.

Any knots should not be large in number or in size, nor should they be loose.

Shakes of any kind should automatically condemn any timber. Ring or cup shakes running parallel to the annular rings are the worst, as they absolutely split any planks in which they occur. It is possible to cut most trees so that a star shake occurs in one plank only, the other portion cutting into good timber, but a cup shake generally spoils the whole tree. (See Fig. 104.)

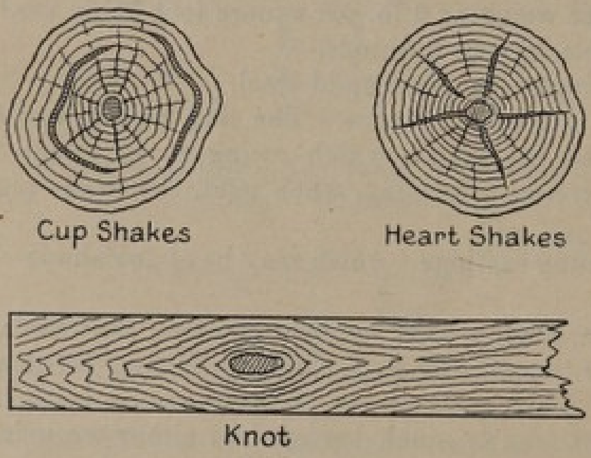


Fig. 104.—Timber sections.

Varieties of Timber.—*Baltic Pine* has hard and soft annular rings, a strong resinous odour, is easily worked, and is a good timber for most constructional work.

American Red or *Yellow Pine* is clean and free from defects, but is not so strong as the Baltic. It is used chiefly for joinery work.

Pitch Pine is obtained from the Southern States of America, and is largely used on account of its strength and durability. It is very hard and heavy, contains a very large proportion of sapwood, and is full of resin; is very difficult to work and is subject to upshakes. It is obtainable up to 80 feet long, and from 10 inches to 18 inches square. This is a very useful timber for heavy constructional work.

Oak. English oak is the hardest and most durable of Northern timbers, and is used where strength and durability are required. It is, however, very expensive.

American oak is freer in the grain, being quicker in the growing, but it is not so strong or durable as English oak.

Ash is very strong and resilient, and is used for cart shafts, shovel and pick handles, etc.

American Hickory is also used for hammer shafts, shovel handles, etc., and is very serviceable.

Elm. English elm possesses great strength and toughness. It has a close fibrous grain, and does not rot under water. It is, however, difficult to work, and is liable to warp.

Red Elm grows to a larger size, but is not so tough as English elm.

Beech is a hard and heavy wood. It is suitable for use in either a wet or dry position, but very quickly rots in a spot that is alternately wet and dry. A large amount of cheap furniture is made of beech.

Poplar is a soft wood, and is often used for cart and wagon bottoms and barrow boards. It will withstand a fair amount of fire, as it chars instead of burning.

Decay of Timber.—Dry rot is caused by the confinement of gases produced by warmth and stagnant air. It produces a fungus which feeds upon the wood and very quickly spreads to any other wood in the vicinity.

Thorough seasoning, ventilation, and protection from damp are the best preservatives.

Wet rot is caused by water and general decay. It is not infectious except by actual contact.

Seasoning is a preventative, and is effected by stacking under cover with free ventilation all round. If the sap be driven out by steam or water, the time required for seasoning is very much reduced. Creosote is a good preservative for rough timber and good oil for dressed timber.

Timber is bought in various market forms, viz.

Log. The tree as felled, with the branches lopped off.

Balk. A log roughly squared.

Plank. Any timber more than 10 inches wide by 2 inches thick.

Deal. Any timber less than the above, but more than 2 inches thick.

Board. Any timber less than 2 inches thick.

Scantling. Timber, squared.

Square. One hundred super feet. Matchboard, floorboards and roofing boards are usually sold by the square.

Standard. There are two standards used for buying timber in bulk : the St. Petersburg, 165 cubic feet; the London, 270 cubic feet.

A special form of timber used at present for many purposes, especially for lining and panelling rooms, is plywood, which consists of three or more layers of timber glued together by waterproof glue, each layer having its grain running at right angles to the adjacent layer.

Slates.—Slates are of various kinds and qualities, and are mostly used for roof coverings. They should not be used at a less angle than 26° to the horizontal. Westmorland Green are a good sound slate, and are used chiefly on churches and like buildings. They are, however, expensive.

Slates from the North Wales quarries of Velinheli or Penrhyn are a good, sound, all-purpose slate.

Port Madoc slates can be split very thinly, and lie very flat on a roof, but are too soft and not at all suitable for the Birmingham district.

Architects and contractors sometimes require a cheaper form of roofing than natural slates, and there is at present on the market a very useful form of slate composed of asbestos and cement. The manufacture of these has become a very important branch of the roofing industry. There are several brands, and all are fairly reliable. These asbestos slates are light for handling and transport, easy to fix, and cause a big saving in roofing costs. Several colours can be obtained, but for the present the writer regards the natural colour as best.

The South Wales and Cornish Slates are chiefly green and mottled, and are mostly used for their appearance. A good colour effect can be obtained by their use.

Grey slates are about 1 inch thick. They are generally used in close proximity to the quarries from which they are obtained, usually in Yorkshire and Lancashire. They make a good roof, but require heavier supporting timbers. They help to keep a house warm in winter and cool in summer. Carriage is very expensive, on account of their weight.

Tiles are burnt clay, and are not often used on refuse disposal plants.

For temporary buildings, galvanised corrugated iron sheets are frequently used; they require constant painting and attention.

Asbestos sheets are better, but more expensive.

Asphalt is used for damp-proof courses, covering flat roofs, making gutters, etc., and is a natural product not to be confused with tarred macadam.

Natural asphalt is also very useful for the flooring of lavatories, and places such as manure rooms, which require frequent washing out.

Glass is sold in accordance with its weight per sq. foot. It weighs 14 ozs. at $\frac{1}{16}$ inch thick.

Roof glass is generally about $\frac{1}{4}$ inch thick. It is generally opaque, and is called rough rolled plate. It is usual to fix it in about 2 feet widths.

For roof-lights and any glazing likely to be broken, wired glass is best, as even if cracked, the pieces do not fall.

Paints are used for covering other materials to keep them from rusting or rotting, or as a decoration. All paints are composed of three constituents: the base, the pigment and the vehicle. For work where paint is used as a preservative, as distinct from a decorative, the base is usually oxide of lead.

The pigment is any colouring matter, and may be either mineral, vegetable or animal.

The vehicle is generally oil.

In the case of distemper, the vehicle is water.

Drains.—These are generally made with glazed earthenware pipes, and are jointed, first with a ring of tow, and afterwards with a two-to-one mixture of cement and sand. The tow is inserted to prevent the mortar from passing through to the inside of the pipe.

For fresh-water drains, clay joints and second-quality pipes are good enough. These pipes are all marked with a black ring.

All manholes should have half pipes in the bottom, and should be built of hard impervious bricks with cement mortar.

CHAPTER XVIII

ELEMENTARY BUILDING CONSTRUCTION AND DRAINAGE

PART I. BUILDING CONSTRUCTION.

In this chapter, some of the elementary principles employed to obtain a sound and dry building will be discussed.

One of the first things to be done before the erection of any building is to examine the site. There are so many different kinds of ground met with in various parts of the country that this examination is most essential. Firm gravel and water-laden material may be found within a very short distance of each other, or there may be an underground river or a layer of running sand.

London is mostly built on clay, Birmingham (especially in the Warwick area) on gravel—practically two opposites and extremes. Whatever is met, methods appertaining to each must be used. Therefore, after examining the ground carefully, digging trial holes, if necessary, to see whether the ground is the same for the usual depths used for foundations, it is then necessary to estimate what is known as the bearing pressure the earth will stand. Sometimes this information can be gained by inquiring of local builders who have done excavations round about.

SAFE LOADS.

Material.	Bearing Power per Sq. Ft.	
	Minimum.	Maximum.
	Lb.	Lb.
Rock	30,000	40,000
Very dry clay	8,000	12,000
Moderately dry clay	4,000	8,000
Made ground	2,000	4,000
Gravel	16,000	20,000
Sand compact	8,000	12,000

Safe Bearing Powers of Soils.—All buildings settle more or less, but precautions must be taken to secure uniformity of settlement.

Heavy portions such as stacks or towers should not be bonded into the walls of the building.

The foundation bed should be horizontal, and should vary in width to suit the height, thickness and weight of the wall, etc., it has to support. In Fig. 105 is shown the usual foundation for a 9-inch brick wall on a fairly firm soil.

It will be noticed that the thickness of the wall is increased in offsets on either side, not more than $2\frac{1}{4}$ inches at one time, until twice the thickness of wall is reached, and the width of concrete is made to suit the bearing capacity of the particular ground.

The thickness of concrete should not be less than twice the offset marked X. The same methods would be adopted in walls of $1\frac{1}{2}$-, 2- or 3-brick construction, but the design of concrete would have to be slightly different, so as to save material.

Referring to Figs. 108 and 109, we have examples of walls built in Flemish and English bond.

By bond is meant the arrangement of placing bricks during building so as to form a tie, one with the other, by preventing the occurrence of continuous joints (as in Fig. 106). There are several bonds adopted to obtain this tieing or locking of the bricks, but English bond and Flemish bond are the most common.

Headers are bricks laid lengthwise across the thickness of the wall as *d* in Fig. 105.

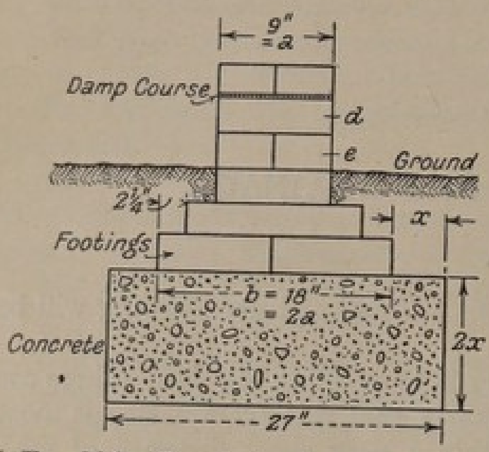


Fig. 105.—Foundation for a 9-in. wall.

Stretchers are bricks laid with their length parallel to the direction of the wall—*e* in Fig. 105 is an end view of a stretcher.

In English bond, the headers and stretchers are laid in alternate courses, and in Flemish bond headers and stretchers are placed alternately in every course (*see* Figs. 108 and 109). English bond is the stronger of the two, but Flemish bond has rather a better appearance and sometimes works out cheaper.

All bricks are porous, some very much more so than others, therefore some method of preventing capillary attraction of moisture must be introduced, otherwise the walls, etc., will be damp. Several methods have been used, and nowadays it is a bye-law all over the country that a damp course, consisting of some non-absorbent material, be placed at least 6 inches above the ground and below any woodwork. A very good method is to build two courses of slate in cement, breaking joints. Ruberoid, asphalt, or sheet lead is also used, the latter, however, being very expensive.

Corbelling.—Sometimes it is necessary to support the end of a piece of timber from the face of a wall, and it then becomes necessary to build an *Offset* or *Ledge*. This takes many bricks. As an alternative, corbelling, with projecting courses, can be resorted to (see Fig. 107). It is advisable, however, that the

Fig. 106.

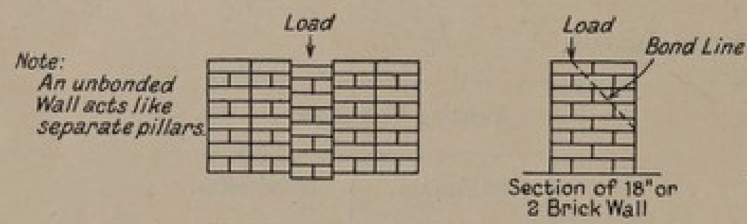
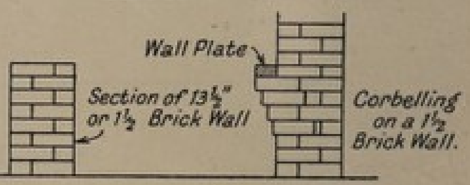


Fig. 107.



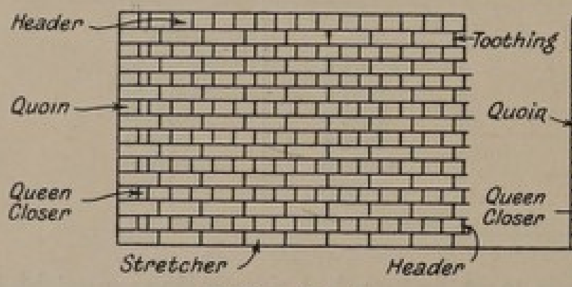


Fig. 108.

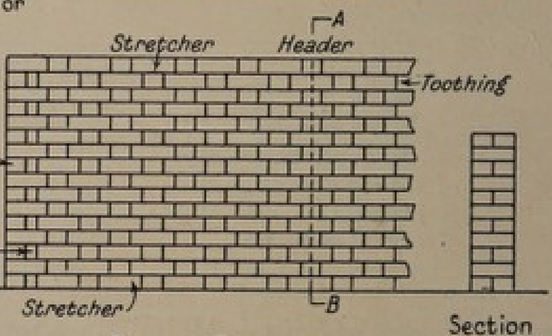


Fig. 109.

Brickwork bonding and corbelling.

amount of projection of each course beyond the one below, does *not exceed* 2¼ inches. It is better if it can be kept less, but always remember to keep it some multiple of the size of a brick.

Bricks for ordinary purposes are approximately 9 inches long, 4½ inches wide and 3 inches deep. A good brick should be burnt thoroughly and should give a good ringing sound when struck against another.

Very many terms are used in brickwork, but the above are amongst the most important. The student, however, should make himself conversant with the following: heading courses, stretching courses, queen closers, bats, copings, jambs, sills and air bricks.

Air bricks are used for the purpose of allowing a current of air to pass through a building. They are absolutely necessary under a timber floor, and should never be omitted. The chief causes of rot under floors are lack of ventilation and lack of damp course, and in passing, the writer would like to say that *Damp* is the bugbear of building, and may be caused in several ways. Once in a building, it is difficult to remove, and slowly but surely it causes decomposition of mortar, plaster, timber and brickwork. It is unhealthy for the occupant, and may cause disease. Never skimp money on providing damp courses.

One of the methods put forward in building to prevent surface damp, is to build the outside walls hollow —that is, two separate walls with a cavity between. These walls, to be stable, should be tied by means of brick or galvanised iron ties. It is very necessary when building these walls that the men do not drop mortar, etc., between, or the whole theory is upset, and, in addition, air bricks must be inserted at the bottom and top of the wall in order that there shall be a constant circulation of air.

Floors may be divided up as follows: single, double and framed.

A *single* floor consists of common joists and floor-boards.

A *double* floor consists of binders, common joists and floor-boards.

A *framed* floor consists of girders, binders, common joists and floor-boards.

If a ceiling is supported under any of the above floors, ceiling joists for carrying same have to be added.

Single floors are only suitable for small spans, or at any rate nothing exceeding 18 feet, and then it is necessary to strut the joists to prevent deflection, and to distribute the load.

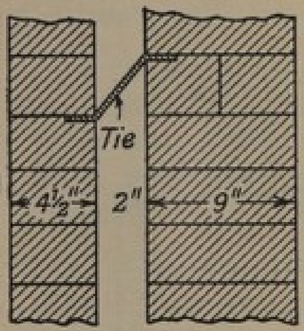


Fig. 110.—Diagram showing method of preventing surface damp.

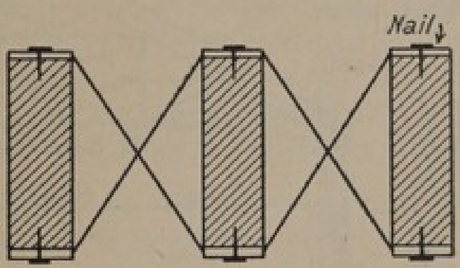


Fig. 111.—Hoop iron strutting.

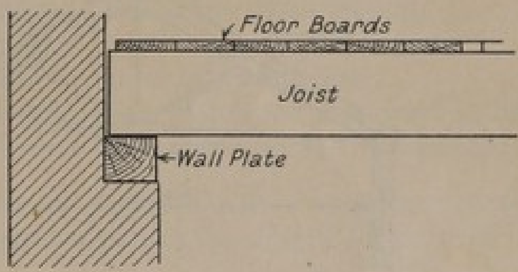


Fig. 112.—Method of supporting floor joists.

Fig. 111 shows a form of strutting known as hoop-iron strutting, and has the advantage of all members being in tension.

It should be noted that the ends of joists should not be built in the wall, but should if possible be carried on a wall plate supported by a brick corbel or set off as is shown in Fig. 112.

The modern tendency in refuse disposal plant buildings is to form the floors of concrete and steel, which are not only stronger but also have the advantage of being fire-proof.

Doors.—The majority of doors used in buildings can be divided into the following classes:—

1. Ledged doors.
2. Ledged and braced doors.
3. Framed and ledged doors.
4. Framed, ledged and braced doors.
5. Panelled doors.
6. Sash doors (or glazed).

Doors are of various widths and heights, but the minimum width of any door should not be less than 2 feet 3 inches and 6 feet 3 inches in height.

Various types of doors are used for different purposes, the simplest being the ledged door, which is composed of vertical boards nailed to cross-pieces, termed ledges, and used for back doors of kitchens or out-houses, and the framed door fitted with panels, used for main entrance and most internal work. Some are hung on solid framing, and others on jamb casing or lining, according to requirements and location. Sliding doors are very useful where it is necessary to economise space, but are liable to be draughty.

Windows.—These may be of any particular design or material.

For small offices and dwelling-houses, the ordinary wooden windows of either the solid frame type or box-frame type are quite suitable. Large buildings require something different, and these can be obtained made in pressed steel or cast iron.

The solid-frame window is very similar to an ordinary door and frame, the glazed portion, which is hinged and fits in a rebate in the frame, is known as a casement, and can be made to open either outward or inward. It is very difficult, however, to make the latter weather-proof. The box-frame type is composed of light-section timber built up to form a box section. There are two sliding sashes or windows suspended by weights, which work up and down. This type of window is certainly better for controlling ventilation, but whatever kind is adopted, care must be taken during building operations that all windows are bedded so as to exclude all rain and draught.

Roofs.—Roofs all more or less satisfy the requirement for which they are intended, that is the covering of a building, but to be satisfactory, a roof must be water-tight, resist changes in temperature, resist wind pressure, must carry off rain and snow as quickly as possible, and be easy to repair.

Slates at present predominate for covering roofs, and special kinds of slating suit certain conditions. A new form of slate composed of asbestos and cement is making great headway amongst builders; it is

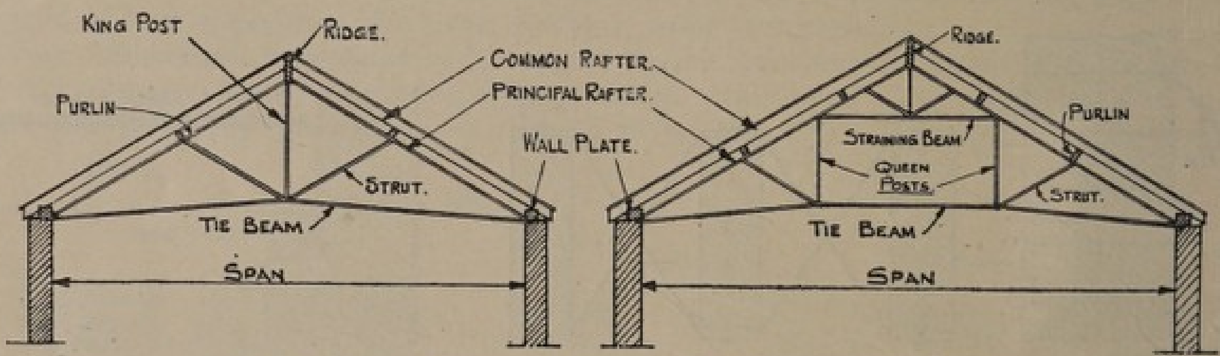


Fig. 113.—Line drawings of king post and queen post roof trusses.

cheap and serviceable. Tiles have been in use for very many years on the Continent and in England, and a good English tile is a splendid roof covering, both in appearance and lasting qualities.

For buildings of small widths, wood trusses are quite suitable, but for larger buildings steel principals are necessary, and are now used very considerably. There are several forms of roofs, but the names of a few will suffice :—

1. The Lean-to roof.
2. The King-post roof.
3. The Collar roof.
4. The Queen-post roof.
5. The Mansard roof.

The lean-to roof is a roof with one slope only, and is used for small buildings, sheds, etc. The two main forms of roof trusses are the King-post and Queen-post. These are shown diagrammatically in Fig. 113. The King-post is used up to 25 feet span, and the Queen-post for more than this. For large spans the steel principal is used, and can be designed in a great variety of forms.

The pitch of roofs is a very important point in building. For a slated roof the rise would be about a fourth of the span, but for a roof covered with tiles a much steeper pitch is desirable, and is sometimes as much as half the span.

Slates are obtained from Westmorland and various places in Wales, those from Penrhyn quarries, Bangor, being acknowledged as the best. Welsh slates may be of a blue grey or purple colour, and are cut to uniform sizes.

Westmorland slates are of a greenish colour, and vary in size; they are usually heavier than Welsh slates. Various sizes are used, but 24 × 12 inches, 20 × 10, or 16 × 8 inches are most serviceable.

Slates may be secured at the head or waist by two copper or galvanised iron nails to each slate.

They can be laid direct on battens, but for good work, and especially in exposed positions, they should be laid on felt and boards.

The next operation is draining the roof. This is usually accomplished by the use of gutters and down pipes, made of galvanised iron, cast iron or zinc. Cast iron is preferable. Any section of gutter can be obtained, but it is always better to adopt makers' standards. For down pipes, allowance is usually made for 1 square inch of bore to every 60 square feet of roof surface, and the pipes should be placed not more than 20 feet apart.

Gutters should not be less in width than the diameter of down pipes; they are usually made too small, no allowance being made for silt débris, etc.

Always fit feet to down pipes, so as to carry rain water from the walls.

Part. II. Drainage.

Drainage is one of the most important branches of building, and, unfortunately, very often the most neglected.

Most drains are buried out of sight, and are forgotten until nuisances arise.

Essentials.—The essentials of a modern system of drainage are as follows :—

1. To convey the sewage without contaminating the land through which the drain passes.
2. Must be self-cleansing by allowing sufficient fall in the line of drains.
3. Must be easily accessible, in order to ascertain and remove the cause of a stoppage.
4. Must be so constructed that it is impossible for any poisonous gases which are generated in the drains to enter buildings. (In other words, adequate arrangements must be made for ventilation.)

It has already been stated that the major part of a drainage system is buried, and it is important therefore that very severe tests should be carried out on all drain installations before the drains are covered in and put into actual use.

The drains of a building are nothing more or less than a series of tubes through which the sewage or matter for disposal is conveyed, and discharged into the public sewer, cesspool or otherwise dealt with.

System.—In many towns there is often a double system of drainage : one for the purpose of carrying rain-water, and the other for conveying the discharge from water closets, urinals, sinks, baths and lavatory basins. The latter are usually termed foul water or soil drains. The circumstances of different buildings may vary, but whether the case is one of the town house or the detached country house, the principles are the same.

The preparation and laying of the drains come under the scope of either the bricklayer, concrete man or drain layer.

Land Drainage.—Before any building is erected, pains should be taken to ensure that the foundations are placed on ground which has been well drained.

Many houses are cold and damp through being erected on water-logged land.

Fig. 114A shows sections taken through ground of this nature. As long as this liquid is allowed to remain, the house will always be cold and damp. Condensation will take place on the walls; fungus will grow under the floors, and if there are cellars, these will always feel cold and clammy. The necessary preparations must therefore be made for draining the site.

Fig. 114B shows an area with the ground drainage arranged.

Fig. 114C shows a cross section of what is known as a French drain.

Fig. 114D shows a modern land drain section. It will be noticed that a pipe is shown in this figure. These are called agricultural drain pipes, and are short tubes from 2 to 6 inches in diameter, formed of earthenware without sockets and unglazed.

These pipes are of rough finish, and in Fig. 114F it will be seen that they are so laid that the water which percolates through the ground can enter the drain through the open joints at any point.

Surface Water and Soil Drains.—The pipes used for these must be absolutely impervious to water, quite straight, and not easily broken; the inner surface should be smooth and not affected by acids. There is now a British Standard make, which it is always advisable to specify. They are usually made of glazed stoneware, and one end is fitted with a socket which takes the other or spigot end. The length of these pipes is about 2 feet and they are of varying diameter.

It is usual to adopt as small a diameter pipe as possible, provided it is large enough for the maximum flow.

Fig. 114E shows a lay-out of land drains around the site upon which it is proposed to build. The water is conducted to catchpits, where the mud or sludge settles, and is thus prevented from entering the sewer or brook.

It will be noticed that the house drains are quite distinct from the land drains. Fig. 114G shows a section through a catchpit.

Fig. 114H shows an arrangement of drainage for a house. The following details should be observed.

1. *Bends.* These are pipes formed to change the direction of flow. If possible they should never be used in soil drains, and very rarely in rain-water drains.

2. *Junctions.*—Where one range of pipes joins up with another range, Y pipes or junctions are used. Junctions should only be used in rain-water drains.

3. *Channels.*—These are open or semi-circular pipes, and are of special use in the floors of manholes and inspection chambers.

Channels are also frequently used as an open-surface drain for stables.

Foul Gases.—Traps. One of the most important devices in drains is that which is known as a "trap." This is an arrangement to prevent the obnoxious gases which form in the pipes from reaching the atmosphere or building.

The water seal is the simplest form of trap, and is now used exclusively.

Fig. 114I shows a trap or seal on an ordinary gully. The passage of foul air is barred by the water seal shown in the figure.

If possible, all drains should be self-cleansing, and this is arranged for by giving them sufficient fall.

As drain-laying is so important, very careful attention should be given to the laying of them to ensure the easy flow of the matter and liquids within the drain. Sufficient fall in the range of the pipes must be allowed, and where this is not possible, a system of *Automatic Flushing* must be resorted to.

Gradients.—The following gradients are found to answer very well in practice :—

4-inch diameter drain should fall	1 in 40.
6-inch ,, ,, ,, ,, ...	1 in 60.
9-inch ,, ,, ,, ,, ...	1 in 90.

These falls give a velocity of from $2\frac{1}{2}$ to 5 feet per second. The ideal velocity should be somewhere in the region of $4\frac{1}{2}$ feet per second.

All soil drains should be laid on a bed of concrete, the concrete being filled in on either side (see Fig. 114I).

Any stoneware drains passing under a building should be surrounded with concrete at least 6 inches thick, but cast-iron pipes are far superior. In fact, it should be a rule that none but cast-iron pipes should be used for drains passing under any building.

Easy bends should be used everywhere, and connections made on the sides only.

The approximate quantity of sewage and waste water for all purposes from dwellings varies from 25 to 40 gallons per person per twenty-four hours, and the drains should be large enough to remove half the estimated daily quantity in six hours.

Ventilation.—All drains should be ventilated, to ensure that they act efficiently and in order to avoid the accumulation of foul gases.

The system usually adopted is to have a fresh-air inlet pipe at the lower extremity and a tall outlet pipe at the head of the drain.

Stable Drains.—These drains must be kept quite separate from house drains, and if possible carried

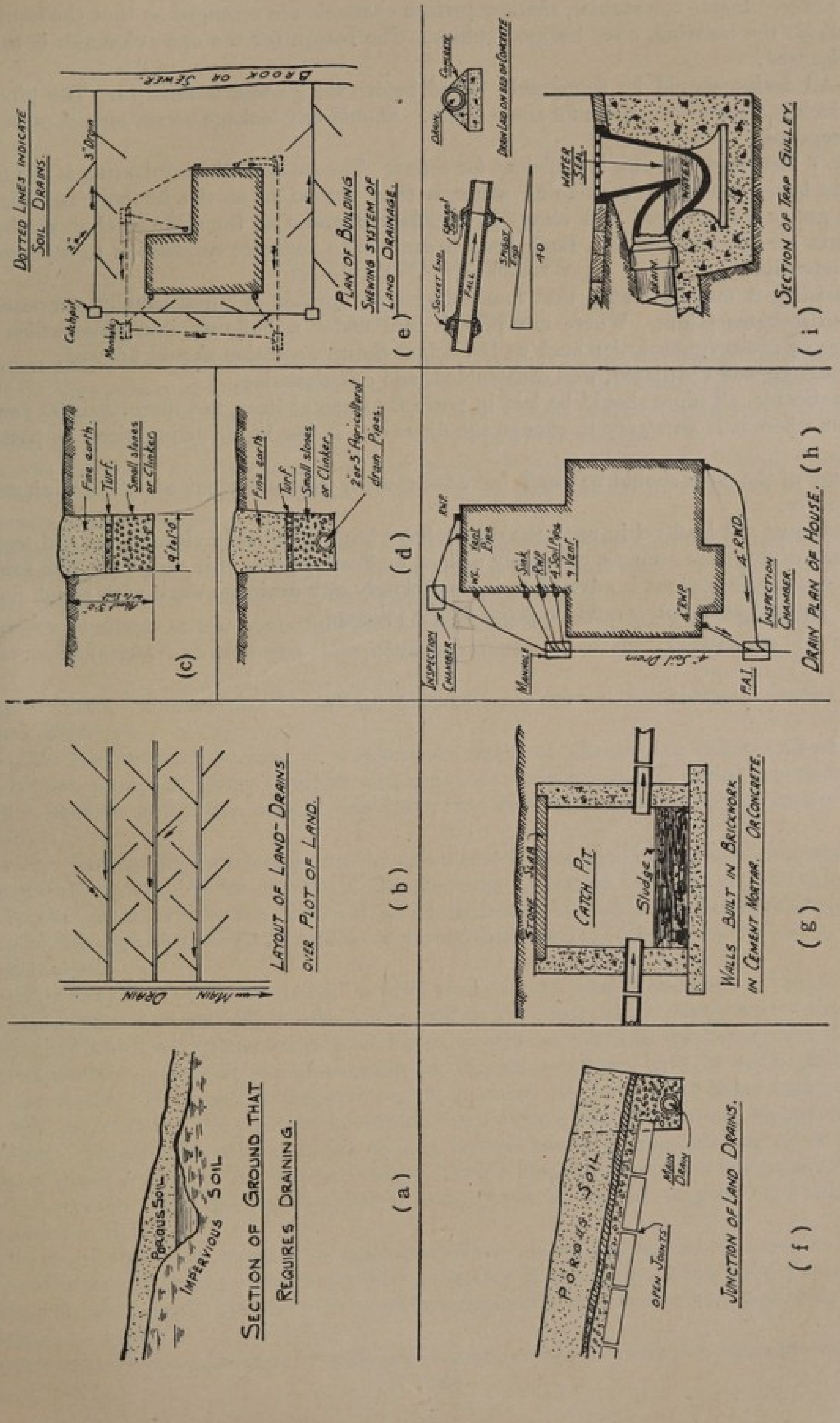


Fig. 114.—Drainage methods.

direct to the sewer. Inside the stables, shallow surface channels are arranged so that the liquid matter is discharged *outside* the building, over trapped gullies. The reason for the open channels is that they are more easily cleansed.

Testing.—All drains should be thoroughly tested before the ground is filled in. The pipes are filled with water which is allowed to remain for some hours. Should any leakage occur, repairs must be effected and the test repeated.

About 4 to 6 feet head of water is sufficient for a test. The usual method of testing is to insert a drain stopper at the lower end in the man-hole; water is then poured in at the furthest and highest gulley trap, and the gulley trap plugged with clay. If the water remains at the same level at the bend for one hour, the joints are all water-tight. Each branch drain with separate connection to man-hole must be tested independently.

In summarising, it may be stated that house drains are formed of pipes usually composed of glazed stoneware with socketed joints. Where any pipe is laid under a building, iron pipes which have been treated with some preserving solution such as Dr. Angus Smith's solution should be used.

Drains should be well ventilated, well constructed, and self-cleansing.

Where practicable, all pipes should be laid in perfectly straight lines, not more than 30 yards between man-holes, but where it is necessary to change the direction, as few bends or junctions as possible should be used.

The diameter of the pipes should be small, but adequate for the work required. The minimum diameter should be 4 inches.

The ground must not be filled in until the drains have been thoroughly cleaned out and tested.

Many details of drainage schemes obviously cannot be dealt with in this chapter. The main rules are given, however, and the student is advised to inspect closely any drainage work with which he may come into contact. Special attention should be given to the jointing.

CHAPTER XIX

ELECTRIC VEHICLES

PART I. BATTERIES.

THE electric vehicle has proved itself to be eminently suitable for the work of refuse collection, and this is borne out by the number of Local Authorities who have adopted this method of transport.

Whilst the type and size of electric vehicle are admittedly important factors, a very essential part is the battery, which has been termed, and rightly so, "the heart of the vehicle."

There are two kinds of batteries in general use on electric vehicles, viz., the "Lead Plate" or "Lead Sulphuric," and the "Edison" or "Alkaline" type. A battery consists of a number of cells or accumulators, generally joined together in series.

It is very necessary for the proper understanding of the electric accumulator to explain that this apparatus does not accumulate or store up electricity. It only apparently does this. It is much nearer the truth, but still not quite accurate, to say that it stores up or accumulates a certain amount of energy. It approximates more closely to the truth, however, to say that the electrical energy by means of which the accumulator is "charged" is converted into chemical energy which in "discharging" is reconverted to electricity.

Although the term "accumulator" is not correct (as already shown), neither are the terms "secondary" or "storage" batteries.

A lead-plate accumulator consists of a container made of ebonite, or other acid-proof insulating material, with two groups of plates (positive and negative). Each group is joined together by a common bar, and the positive group has always one plate less than the negative group, except in two-plate accumulators.

The life of a battery depends largely on the treatment it receives both in charging and discharging, which consists of so many cycles of charge and discharge, a certain chemical action taking place inside the cell. To the extent which this chemical action is carried out when the battery is being charged, in particular, and the attention which is paid to it during this time, the life of the battery is probably prolonged or shortened.

Before explaining the "*chemical action*," a brief study of the term "electrolysis" may be of interest. Obtain a small glass vessel and fill it with water, add a few drops of sulphuric acid, and then place the ends of two wires which are connected to a source of electric supply into the liquid, and it will be found that when an electric current is passed through the circuit, small gas bubbles will form and rise to the surface of the water. If these bubbles were tested, it would be found that those which came from the end of the wire connected to the positive pole would be of oxygen, and those from the negative pole would be of hydrogen. This action, or electrolysis as it is termed, results in the splitting up of the water into its constituent parts, hydrogen and oxygen; water being a combination of two volumes of hydrogen and one volume of oxygen. The chemical symbol of hydrogen is H, that of oxygen O, so that the chemical symbol of water is H_2O.

The mixture of these two gases in definite proportions, is explosive, and this can be illustrated if a light is placed near any of these bubbles whilst a battery is on charge, when quite a formidable report or explosion will take place. Therefore every precaution should be taken to keep naked lights away from batteries when on charge.

"Sulphuric acid" is a combination of water and sulphur compound, and this forms the solution in which the positive and negative active materials are immersed. This solution is termed "electrolyte," and forms the medium through which the electric current produces the chemical changes on which the action of the cell depends. The chemical symbol is H_2SO_4. The active materials consist of the following :—

"*Positive Active Material.*"—Lead peroxide, which is a fairly hard substance, dark-chocolate in colour, is a combination of lead and oxygen, the chemical symbol being PbO_2.

"*Negative Active Material.*"—Spongy lead, which is pure lead in spongy or porous condition. The chemical symbol is Pb.

The combination of lead (Pb) with sulphuric acid (H_2SO_4) is called lead sulphate, the chemical symbol being ($PbSO_4$).

All the foregoing are the chemical symbols used in connection with the action of a battery, and when an accumulator is fully charged, these chemical symbols are arranged as follows :—

Positive.	*Electrolyte.*	*Negative.*
PbO_2.	H_2SO_4.	Pb.

If the circuit is closed, and the accumulator or battery commences to discharge, the acid in the electrolyte combines with the active material in the plates and forms "lead sulphate." This is shown by the fall of specific gravity of the electrolyte, and if this action was carried to absolute exhaustion, the electrolyte would be reduced to water (a position which does not arise in practice). The situation would then be :—

Positive changed to lead sulphate.	*Electrolyte reduced to water.*	*Negative changed to lead sulphate.*
$PbSO_4$.	H_2O.	$PbSO_4$.

On the cell being recharged, the action of the current reduces the negative plates to spongy lead, the acid returning to the electrolyte, and at the same time the sulphated positive is oxidised, the acid likewise returning to the electrolyte. This continues, until at the end of the charge the situation is again :—

Positive.	*Electrolyte.*	*Negative.*
PbO_2.	H_2SO_4.	Pb.

This chemical action cannot be carried to absolute exhaustion, and it will therefore readily be understood that there must be some indication to show how far it can be carried with safety. It is only by careful and intelligent use of the various instruments and meters that this state can be ascertained.

As long as the plates can absorb the current, everything is in order, but the positive and negative plates are not necessarily fully charged in the same time, so that the electrical energy must be dissipated in some other way than in charging those plates which are already fully charged. Remember the action which takes place when two wires are put into a glass of water through which an electric current is passed. This is exactly what happens at the end of a charge or during an equalising or extended charge. The water being split up into hydrogen and oxygen, numbers of bubbles give the electrolyte an appearance of boiling or being milky. If this is carried to excess, it is not only a waste of current and electrolyte, but it is also detrimental to the plates. The whole process of charge and discharge may thus be summarised as follows :—

Discharge.—Lead sulphate forms on the positive and negative plates, hence a fall in specific gravity and voltage takes place, and the cells give out energy.

Charge.—The lead sulphate is converted into lead peroxide at the positive, and spongy lead at the negative plates. This causes a rise in the specific gravity and voltage, and the cells absorb energy. On discharge there is a fall, and on charge a rise of specific gravity or density of the electrolyte.

To ascertain the extent of this rise and fall, the garage attendant must be supplied with a hydrometer, thermometer and cell-testing voltmeter.

The hydrometer is a small glass tube with a graduated scale inside. The lower end is of larger diameter, and weighted with small shots at the bottom, which causes it to float upright in the accumulator. For vehicle batteries, however, it is placed in a long glass tube which has a rubber bulb at the top and a small piece of rubber tube at the bottom. The tube is put into the "pilot cell" or cell to be tested, and as the electrolyte is drawn into the glass tube the hydrometer floats upright, and the reading is taken at that point where the top of the electrolyte cuts the point on the graduated scale.

The temperature of the electrolyte should be taken at the same time as the specific gravity readings, the latter being ascertained as follows: For the rise or fall of temperature of 2½° F. above or below 60° F., there is a variation of 1 degree of specific gravity, *i.e.*,

Specific gravity 1262 at 60° F. = 1250 at 90° F. = 1264 at 55° F.

The batteries in service in the Birmingham Salvage Department have a rise and fall of specific gravity ranging from about 1265 or 1275 when fully charged to about 1165 or 1175 when discharged at a temperature of 60° F.

The voltage of a lead-plate battery rises or falls according to the state of charge or discharge of the battery. Readings should always be taken on closed circuit, and these will be found to vary at the end of charge according to the age of the battery, temperature of electrolyte, etc. When the battery is first installed the readings should be about 2·7 volts at a temperature of 60° F. As the battery gets older, however, the voltage at the end of the charge falls below this figure. During discharge the voltage drop is slight and gradual, becoming greater near the end, and the limit of discharge is reached when the voltage drops to between 1·8 and 1·9 volts per cell.

The cell-testing voltmeter is a small portable low-reading meter generally marked from 0 to 3 volts, positive and negative, and is used to read the difference of potential across one single cell. It should be of the dead beat pattern, and should be fitted with a device to set the needle at zero.

The capacity of a battery is that amount of energy it is capable of storing, and is usually expressed in ampère-hours. A cell is said to have a certain capacity which is based upon the amount of current it will give for a specified time, at a certain rate of discharge, and this can be measured by an instrument called an ampère-hour meter. An ampère-hour meter, therefore, is a meter which indicates the state of battery either on charge or discharge. The capacities of several of the different types of batteries are as follows :—

Lead Plate 40-Cell Batteries.	Capacity at the 5-hour rate of discharge.
IMV 8	258 ampère-hours.
IMV 10	323 ,, ,,
IMV 12	387 ,, ,,

Evaporation.—It has already been stated that electrolyte consists of dilute sulphuric acid and water, and although evaporation takes place in all storage cells, the sulphuric acid is not affected. It is the water only which evaporates, and this causes the specific gravity to become higher and the level of the electrolyte lower. To make up for this evaporation, it is essential to add water at frequent intervals, so as to prevent the tops of the plates from becoming exposed, and to maintain the electrolyte at its proper level, *i.e.*, about ½ inch above the tops of the plates. This should be done when the specific gravity is lowest.

The adding of this water is called " topping up," and pure distilled water only should be used for this purpose, as ordinary tap water may contain mineral matters which would be detrimental to the accumulators. In this connection it is wise to submit a sample of the water to the battery makers for their analysis and approval. The acid also should be added only under the directions of the makers. During use, a certain amount of sediment gets to the bottom of the containers, and it is advisable to take the elements out of the containers and flush this sediment out, reconditioning the battery when it is nearly two years old.

The Edison cell consists of a container and positive and negative plates in electrolyte, but instead of lead and lead peroxide in sulphuric acid, nickel and iron oxide in alkaline are used. Great care must be taken that these electrolytes do not become mixed in any way. Separate hydrometers and thermometers should be used always.

The Edison batteries are known as types A 8, A 10, and A 12. The container is nickel-plated, the positive plates consisting of a number of tubes of thin steel, strengthened by ferrules and containing active material of " nickel oxide."

The negative plates consist of a number of flat pockets of nickel-plated steel which are filled with oxide of iron, which in appearance, is not unlike iron rust. All the positive plates are connected to the positive pole, and all the negative plates are connected to the negative pole, the whole being placed in electrolyte consisting of 21% of caustic potash in distilled water. The top of the container is fitted with a water-tight cap, which can be opened for "topping up" and washing out.

The normal working voltage is 1·2 volts per cell. The specific gravity of the electrolyte is about 1200, and this does not alter materially with charge or discharge, but becomes lower with use, and when down to 1160 should be renewed.

The capacities of Edison batteries are as follows :—

"Alkaline" 60-Cell Batteries.	Capacity at the 5-hour rate of discharge.
A 8	300 ampère-hours.
A 10	375 ,, ,,
A 12	450 ,, ,,

A "pilot cell" is one which is used for taking the readings of density, voltage and temperature, and should be a cell in the centre of the battery, preferably one showing low specific gravity and high temperature readings, as compared with the remainder of the battery.

Part II. Charging Methods.

There are several methods of charging accumulators, but if alternating current only is available, then some suitable apparatus must be supplied to change it to direct current.

Cells for charging can be arranged in any manner suitable to the current and voltage available, but it is the general practice to join them in series, that is, the positive of one cell is coupled to the negative of the next, and so on. This, of course, leaves a positive terminal at one end of the battery and a negative terminal at the other, and it is essential that the positive wire of the charging circuit should be connected to the positive terminal, and the negative wire to the negative terminal of the battery, respectively. This is in order to maintain "correct polarity" during charging, and a reversal of this polarity will cause serious damage to the cells. The battery makers usually attach a plate to the outside of the battery boxes showing the number of cells, type and charging rates. There are invariably three rates of charging shown. The higher one is called the "starting rate," the lower one the "finishing rate" and the other, which is about half the "finishing rate," is called the "equalising rate." The "starting rate" can be used to give the greater amount of the charge, but should be reduced to the "finishing rate" when gassing begins to take place in the cells, or if the temperature rises quickly. If the temperature should rise to 110° F., charging should be stopped immediately. There are two methods of charging generally recommended by the battery makers, one being termed the "constant current" method, and the other the "constant potential" method.

The "constant current" method of charging is recommended if there is plenty of time to finish the charge. A pressure or voltage of about 2·15 to 2·2 volts per cell, that is, about 86 to 88 volts for a 40-cell battery will be required at the start, the charge then being adjusted to the "starting rate," that is, the higher rate as shown on the plate. As the charge is continued at the "starting rate," it will be necessary to raise the voltage so as to maintain this rate, and when the voltage is raised to 2·3 volts per cell—that is, 92 volts for a 40-cell battery—the current should be allowed to taper off until it reaches the "finishing rate," after which, the voltage should be so adjusted as to keep the charge at this rate until the specific gravity of the "pilot cell" rises to about 10 points below that reached at the last "equalising charge," or until the hand of the ampère-hour meter returns to zero. The alternative method is termed the "constant potential," and although this certainly needs less attention than the "constant current" method, the battery is not fully charged, consequently more "equalising" charges are necessary. For the "constant potential" method, a voltage across the battery terminals of 2·3 volts per cell, *i.e.*, 92 volts for a 40-cell battery, is required, and the charge can be commenced at any rate the battery will take, without exceeding the voltage of 2·3 per cell. The charge should be continued at this voltage until the charging current tapers off to the "finishing rate," when the voltage should be adjusted so as to retain this rate until the specific gravity of the "pilot cell" reaches about 10 points below the last "equalising" charge, or until the hand of the ampère-hour meter returns to zero. At this point the voltage will have risen to about 2·6 or 2·7 volts per cell.

Whilst either of these methods can be adopted, it will be found that with a large fleet of vehicles having various types of batteries, it is not practicable to lay down any hard and fast method of charging, and with a certain amount of care and attention, a combination or modification of the two methods can be adopted in order to obtain the most satisfactory results.

"*Equalising Charges.*"—The makers issue instructions which should be specially adhered to with regard to these charges, and the readings which have to be written up in the "Fortnightly Returns" should be scrutinised and checked. With the "constant current" and "constant potential" methods, the procedure has already been explained until the charging has reached the "finishing rate," and the specific gravity has risen to 10° below the last "equalising charge" or until the ampère-hour meter pointer has returned to zero. At this stage the hand of the ampère-hour meter should be put forward 75 or 100 ampère-hours (being careful that it is again returned to zero when the "equalising charge" is finished), an ampère-hour meter key being supplied for this purpose. The charging current should be allowed to taper off until it is half the "finishing rate," and this rate should be maintained until the voltage and specific gravity of the "pilot cell" show no increase over four consecutive hourly readings. "Equalising charges" should be given every fortnight, the readings of the "pilot cell" being recorded carefully, and once a month the reading of every cell should be taken at the end of an "equalising charge," notes being made of any cells showing signs of low voltage, loss of specific gravity or high temperature. No notice should be taken of ampère-hour meter readings during the time the "equalising charge" is being given.

"*Boosting*" *or* "*Quick Charging.*"—It will sometimes be found necessary to give a battery a boost up, or, in other words, to give it a quick charge, and this can safely be done up to a certain degree. The more nearly a battery is discharged, the higher rate of charging will it take, and by starting the charge at a higher rate according to the time available, and then allowing it to taper off, a great deal of the discharge can be replaced in a short time. The following formula is a good guide to ascertain the maximum rate at which the battery may be charged, *i.e.*,

$$\text{Charging current in ampères} = \frac{\text{ampère-hrs. discharge}}{1 + \text{hrs. available}}.$$

Example.—Ampère-hours discharge, 200. Time available for charging, $1\frac{1}{2}$ hours.

$$\frac{200}{1 + 1{\cdot}5} = 80.$$

Maximum charging rate 80 ampères.

The foregoing refers to lead plate batteries only. In the case of the Edison or alkaline battery, the charging rate remains constant during the whole time of charge. The specific gravity does not alter, and overcharging does not damage the cell, but necessitates "topping up" the cells more frequently. There is no fear of sulphating or buckling of plates.

Motor Generators.—The motor generator consists actually of two machines, a motor and a generator with their shafts direct coupled together and mounted on one bedplate. This machine receives direct current of high voltage and low ampèrage, and generates a current of low voltage and high ampèrage, suitable for battery charging. This is termed a direct-current motor generator. There is a certain amount of loss; the efficiency being approximately 65 to 70%.

Five-wire Balancer.—A five-wire balancer consists of four armatures in series, or, to be more correct, two double-wound armatures connected to four commutators, which are equivalent to four dynamos or motors coupled to one common shaft. Across the positive and negative mains there is a 440-volt supply; between the neutral and positive or neutral and negative 220 volts, and this is again divided into what is termed four "legs," with 110 volts supply on each leg. If the loads on the four legs are evenly balanced, the balancer runs as four unbalanced motors running in series across the 440-volt mains, but as soon as one leg becomes more heavily loaded than another, *i.e.*, if two batteries are being charged on one leg and one only on the other legs, or if the batteries are being charged at different rates, the motors connected across the more lightly loaded legs restore the balance by inserting a load equal to the difference in the load between them and the more heavily loaded legs. This equalising of the "out-of-balance" current consists of driving the motors on the heavier-loaded legs as generators and so maintaining the voltage on these legs. In other words, if *A* leg is heavily loaded, then *B*, *C* and *D* legs assist *A* to keep up the heavier load. The shunt fields are cross-connected, and the balancing needs very little attention up to "150 ampères out of balance." Any number of vehicles can be charged by this method, the number only being limited to the carrying capacities of the supply mains. This machine has a higher standard of efficiency than other machines such as the motor generator, and the more vehicles there are being charged at the same time, the greater the efficiency.

When alternating-current supply only, is available, which, as already explained must be converted into direct current before it can be used for the purpose of battery charging, it is necessary to install a transformer which reduces the voltage from very high to a voltage suitable for running what is termed a "rotary converter."

A rotary converter is similar in construction to a continuous-current dynamo, but on the end of the

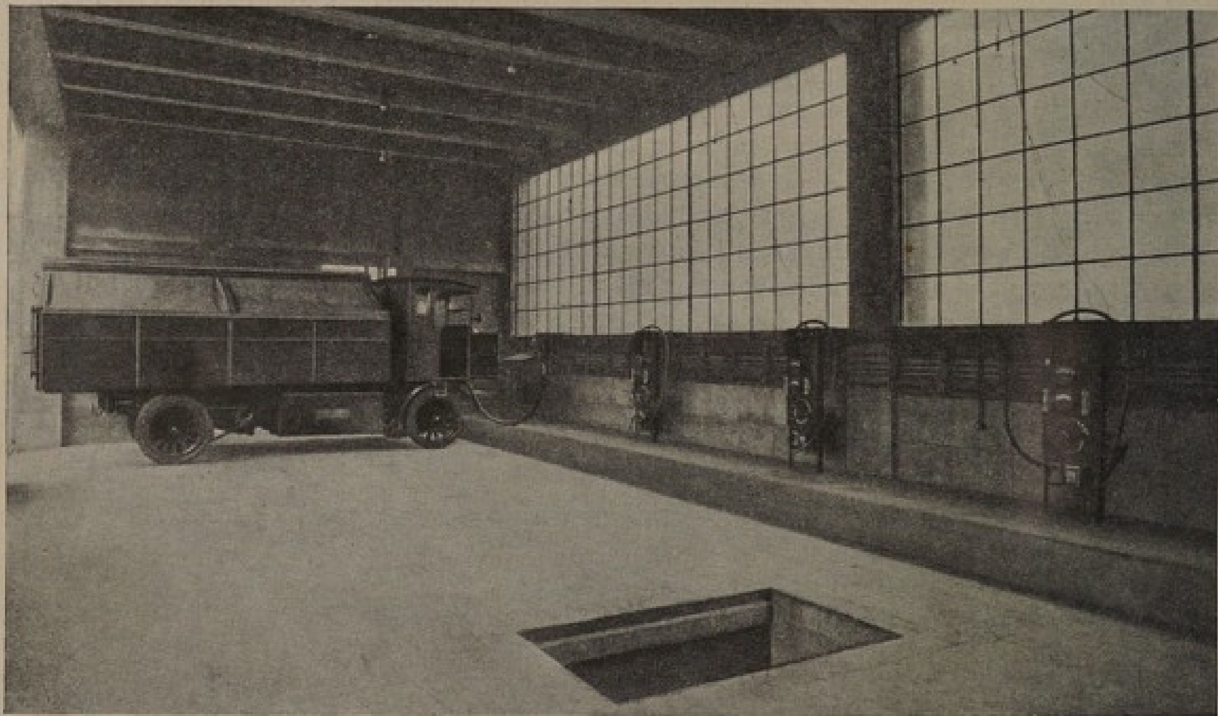


Fig. 115.—Electric vehicle charging panels.

armature shaft opposite to the commutator, are a number of slip rings. This is a dual purpose machine. It can either be supplied with direct current and deliver alternating current, or it can be supplied with alternating current and deliver direct current.

Control Panels and Charging Panels.—"Control Panels" consist of a panel, fitted with voltmeter, ammeter, motor starter, main fuses, automatic breakers, and earth lamps. Charging panels, of which there should be one for every charging circuit, should be fitted with a switch, circuit breaker, with overload and reverse current attachment, fuses, ammeter, voltmeter, kilowatt-hour meter, and regulating rheostat. There should also be a pair of terminals to which can be permanently attached a suitable charging cable terminating in a standard charging plug, to fit the standard receptacle attached to the vehicle. (See Fig. 115.)

Hints on Charging Batteries.

"Lead Plate" Batteries.

1. Charge the battery only as frequently as the circumstances of the service require it.
2. Avoid charging at high rates when cells are gassing. Reduce to "finishing rate" when cells commence to gas freely.

3. Keep cells " topped up " and use distilled water only.
4. Give " equalising charges " in accordance with makers' instructions, and note carefully all the readings of the cells.
5. Avoid high temperatures, and never exceed 110° F.
6. Use " direct current " only.

Edison or Alkaline Batteries.

1. Always keep cells " topped up " and use distilled water only.
2. Do not allow the temperature to rise above 115° F.
3. Use only the electrolyte supplied by the makers.
4. Occasionally fully discharge the battery, short circuit, and then recharge it.
5. Avoid charging at less than the normal charging rate.
6. If the battery is cold, give a short " boost " to warm it up before the vehicle is used.

General.—Keep the cells and connections clean, and never use the same electrolyte, thermometer, or hydrometer for both types of batteries.

Part III. Motors and Controllers.

Motors, Controls, Drives, etc.—For propelling electric vehicles it is necessary to have mechanical energy, and to convert the electrical energy into mechanical energy a machine which is called a motor is used.

There are three kinds of motors known as the :—

1. Series wound.
2. Shunt wound.
3. Compound wound.

These are shown diagrammatically in Figs. 116, 117 and 118.

The series-wound motor has the field magnet coils in series with the armature, and is used where a

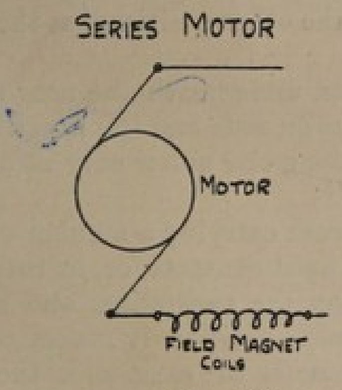


Fig. 116.

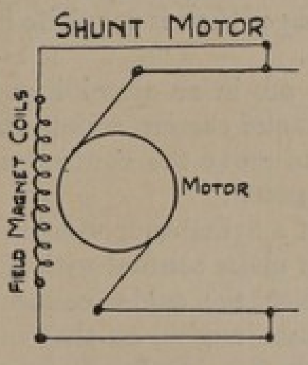


Fig. 117.

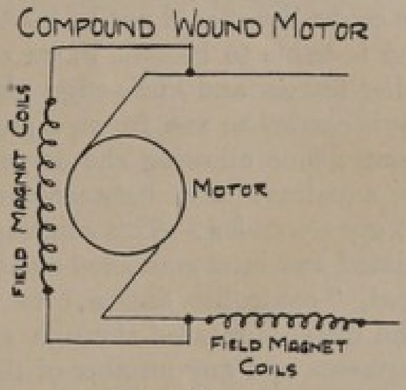


Fig. 118.

strong starting torque is required. The torque increases rapidly with increased current, and this is taken advantage of in traction work, where this type of motor is used to give the high starting torque required. By torque, is meant the exertion required to start the armature revolving. For electric vehicles, the series-wound motor is most generally used.

The shunt-wound motor has a shunt circuit from the armature circuit to excite the field magnets. This type of motor is used where constant speed is required.

The compound-wound motor has both shunt and series windings.

A motor consists of an outside casting, which is termed the *Yoke*. Bolted to the yoke are the pole pieces, around which are placed the field magnet coils, and inside these is placed the armature, which consists of a core around which are wound a number of coils of wire, the ends of which are brought out and sweated into a segment of copper. These segments are placed around one end of the armature shaft, and are termed the commutator. Inside the yoke at the one end, and placed around the commutator, there is mounted a rocker which has attached brush-holders, inside which are placed carbon brushes kept in position by adjustable springs. The rocker with brush-holders is termed the brush gear. The armature shaft is fitted into bearings having suitable means of lubrication.

Care and Maintenance of Motors.

1. Motors should be kept free from oil and dust.
2. Commutators should be kept clean and free from carbon dust.
3. Lubricators should be kept filled and screwed down.
4. Brushes should be kept bedded in, and springs so adjusted that the brushes make good contact with the commutator.

"Undercutting" the Commutator.—When the copper segments forming the commutator are fixed, strips of mica are placed between, to insulate one from the other, and after the commutator has been turned up, this insulation has to be cut down so as to be just clear of the face of the commutator. This is called "undercutting."

Controllers.—Motors on vehicles must be so arranged that they may revolve slowly or quickly in either direction as necessary, and for this purpose a controller is used. The controller is a device used to control the speed and direction of rotation of a motor.

There are several types in use, but the principle is the same in each case.

The Flat-type Controller.—This consists of a number of segments on a flat plate, which is called a knife-edge plate. The segments are so placed that when the controller handle is moved forward, the plate moves and the segments engage between half round finger tips, which are on the end of a number of fixed controller fingers. This gives five speeds forward. There is a reverse switch placed at the rear end of the controller, and by pulling the controller handle up, the connections are made, so that when the controller handle is moved forward the motor armature revolves in the opposite direction, and this gives five speeds in the reverse.

Although there are actually five notches in the controller, the only two running positions are the third and fifth. The controller should not be kept longer than is requisite in the other positions, as the resistance is in circuit and is liable to become burnt out.

The controller fingers and knife-edge plate are in an aluminium box underneath the near side of the cab. The plate is carried to and fro on a gun-metal carrier, which works on rods and has a pawl rack with pawls and springs, thus allowing the driver to move the controller along one notch only at a time, and there should be a distinct pause between each notch.

The Drum Type Controller.—This consists of a cylinder or wooden drum carrying a number of segments which are insulated and interconnected so as to make contact with the fixed contacts, or, as they are more commonly called, "controller fingers," to which the cables connecting the resistances and motors are connected. The drum is rotated through certain angles, so that in each position it makes connections between the segments and any number of the fixed controller fingers, exactly the same as in the Flat type controller.

For reversing, a separate drum is used, and this is operated in different ways, according to the design of the controller. In the Garrett 5-ton vehicles there is a lever under the driver's feet, whilst with the General Vehicle, Orwell and Electromobile 5-ton vehicles the handle is put back in the reverse position.

There is a special feature on the controller of the Garrett 3½-ton vehicle, consisting of an auxiliary foot-pedal device, which is provided for starting the vehicle on hills. It is operated with the left foot, and when the pedal is pressed down its function is to cause a small amount of current to be passed through the motor, so that if on a steep incline, there is sufficient current passing through the motor to start the vehicle as soon as the brakes are released, and so prevent the vehicle running backwards before the driver operates the main controller. It is impossible, however, for sufficient current to pass to damage the motor.

The Care and Maintenance of Controllers.

1. Controllers need frequent and special attention, and should be examined at least once per week.
2. Fingers and segments should be kept clean by wiping with a clean rag, and then being smeared over with a little vaseline or clean oil.
3. All contacts should be kept good, tight and clean.

Drives.—The three principal methods are:—

1. Direct drive with cardan shaft.
2. Chain drive.
3. Worm drive on back axle.

Edison vehicles are fitted with direct drive, which consists of a pinion on the armature shaft, working a silent chain on one end of the cardan shaft. The other end of the shaft is fitted with a bevel pinion, which in turn engages in the teeth of a crown wheel attached to the hubs of the rear wheels. Each end of the cardan shaft is fitted with a universal ring, the object of which is to partially absorb road shocks.

The universal ring consists of a steel ring having four ball-races set at equal distances apart, a tee-piece at the end of the cardan shaft being fitted into this ring.

As with the cardan shaft so with the chain drive—the motor transmits its power through a silent chain to a counter-shaft, the chain being totally enclosed, and running in an oil bath. The driving-chain sprockets are keyed to the end of the counter-shaft, and the power is transmitted to the driving wheels through roller driving chains. These chains should be kept properly adjusted by shortening or lengthening the tie rods, and there should be a slight up-and-down movement in the chain of about 2 inches. Lastly, there is the worm drive on the rear axle, the axle being fitted with "differential gear," the function of which is to permit the two rear wheels to travel at different speeds when necessary.

Tipping Gears.—There are several kinds of tipping gears, which generally consist of either an horizontal or a vertical screw or a pair of screws worked by a small tipping motor. They are so constructed that should the electrical gear fail, the bodies can be tipped up or down by hand.

Fuses.—All electrical circuits are fitted with safety devices, such as automatic breakers, fuses, etc. When replacing fuse wires either for the main, tipping, or lighting fuses, it is important to remember that only the wire supplied for the purpose should be used, as this has been found to carry a specific amount of current, and if the circuit is overloaded, will fuse before any damage is done to electrical apparatus.

CHAPTER XX

HORSE MANAGEMENT

Part I.—The Selection of Horses.

The Class of Horse required.—In town salvage work, two different types of horses are employed :—

(1) The heavy draught horse for refuse collection and clinker haulage.
(2) The boat horse for canal work.

The heavy draught horse should be a sound, upstanding, and active horse, with a fine quality head, muscular neck, good shoulders, short back, well-developed ribs, giving plenty of heart room, strong muscular loins and quarters, and should possess sound legs with plenty of fine bone and good, sound, well-developed feet. The height of this horse should be about 16·2 hands—that is, 66 inches—measuring from the withers at the top of the shoulder. The age of the new horse should be 5 to 6 years. Horses put to work in towns at a younger age do not wear long, because they are not fully matured, and the leg bones and joints are soft; consequently disease soon arises in these parts, from continued concussion on hard town paving. The weight should be about 1729 lb.

The boat horse should be of a similar type, but smaller in size, lighter in bone, with smaller feet. The most useful height is about 15 hands (60 inches). In order to pass safely under canal bridges, the boat horse must not be too high. The colour of the horse is of no great importance, although it should be borne in mind that the grey-coloured horse can never be kept so clean looking as the horse of any other colour.

The Purchase of New Horses.—When purchasing horses it is advisable to buy from horse dealers of good repute, who will supply horses on say seven to fourteen days trial, and if for any reason the new horse is not suitable, it can be exchanged. It is also advisable to have the horse examined by a qualified veterinary surgeon before purchase, to ascertain that it is sound.

The Trial of New Horses.—New horses should be given a careful and searching trial by an experienced and competent driver. By searching, I mean that the new horse should be put to every class of work which is likely to be required of it. These new horses come from country districts, and suddenly to put them into an entirely strange environment, surrounded by traffic, faced with unaccustomed sights, and continually startled by nerve-racking noises is not fair play to them.

It would not be surprising to find that a horse purchased for clinker carting would not stand the noise and sight of steam escaping from a leaking pipe, or the sight of an overhead crane, or that a horse purchased for refuse collection would not stand quietly in the street while the wagon was loaded.

Class of Horse to Avoid.—Horses to be avoided are those showing nervousness, irritability, vice, biting or kicking, and even the horse which is too slow. This latter class of horse is not only a constant source of irritation to the good honest driver who desires to earn his weekly wage, but also an uneconomic proposition for the owner. The man trying the young horse must exercise good judgment to ascertain whether any nervousness is due to strangeness of surroundings, which will ultimately disappear with usage, or to inherent nervousness, which will always be present and will hinder efficient work and may sometimes lead to a serious or fatal accident.

From the point of view of disease it is also advisable to avoid horses growing too much hair on the legs, as such horses are liable to develop a disease of the skin called " Grease."

Care of the Young Horse.—The young horse which has proved itself suitable on trial should be worked carefully and lightly for the first few months. This gives the horse a chance to harden in muscle and tendon, and although the writer fears it is not always realised, it is in the end a very economic procedure, since the risk of lameness is not only reduced, but the working life of the horse is prolonged.

Stable Buildings.—The stables should be well-constructed buildings of brick or stone, with tile or slate roof according to the locality. The site should be dry or, if such a site is not available, it should be thoroughly and deeply drained to ensure freedom from damp. The lay-out of the buildings should comprise: stable with stalls, loose box or boxes, harness-room, food storage-room, shoeing forge, and manure receptacle.

Ventilation of the Stables.—It is most important that horses should have a plentiful supply of pure air, if they are to remain healthy. The minimum cubic space for each horse should be 1200 cubic feet, and the ground area about 87 square feet, provided the ventilation, paving and drainage are good.

To the mind of the writer, the simplest form of ventilation is the best, and *is not so costly to install as some of the scientific appliances advocated*. In the act of breathing, carbon dioxide is given off from the lungs. When cool this gas is heavier than air, but when given off from the lungs it is hot, so that, mixing with the hot air of the stable, it expands, becomes lighter than air, and so rises to the highest point of the stable. To get rid of this gas, the outlet ventilators must therefore be placed at an elevated point on the ridge of the roof.

There are various forms of outlet ventilators, but the form is of no great moment so long as there is the necessary opening, without back draught. The louvred ventilator is very simple and effective. A series of small ventilators placed equidistant along the ridge of the roof or, better still, running the whole length is more effective and gives less back draught than a large one placed centrally. The area of the outlet ventilation should be about 4 square feet per horse.

The inlet ventilators for the entrance of fresh air may consist of air bricks placed in the wall below the manger of each stall and windows, the upper portion of the latter opening inwards, forming a hopper-shaped ventilator. Windows fitted thus, placed on opposite walls of the stable, can be opened or closed according to atmospheric conditions, and so regulate, to some extent, the flow of air through the stables. Wherever possible, it is advisable to build the stable with an open roof, that is to say without a loft or room above. The stable will be much cooler, but the ventilation will be much more effective. Stables with lofts or compartments above are very difficult, it might be said almost impossible, to ventilate effectively, for the reasons already mentioned, even when fitted with the most elaborate ventilating tubes and gadgets. These stables are always much warmer, and if not thoroughly and frequently cleaned out, the air becomes pungent with ammonia from manure and urine. If one compares the horse housed in the closed-roof stable with that in the open-roof one, one will find the former carries a finer, sleeker coat, and looks better, but is more liable to cold when brought into the open air. On the other hand, the horse from the open-roofed stable grows a much thicker and coarser coat, and though never looking quite so well groomed, is nevertheless the hardier and healthier animal.

Lighting.—It is essential that stables should be well lighted, both from the point of view of the health of the stud and the cleanliness of the stable. If the stable is dark, grooming is not carried out so thoroughly, and the horse-keeper may even overlook signs of injury or disease. The windows should therefore be sufficient, and so placed that light may penetrate to every corner of the stable; the area of window space to each horse being about 6 square feet. A window should be placed in the wall above each horse's head, and where the stable is a single one—that is to say, where there is only one row of horses—gable windows may also be provided. As already mentioned, the upper portion of each window should open inwards, for ventilating purposes.

During the winter months, the grooming and feeding of the stud are carried out during the dark hours in the early morning and at night. It is therefore most essential that provision should be made for efficient artificial lighting of the stables.

Doors.—Each door should measure 8 feet high by 4 feet 6 inches wide. The doors should be made in two portions, which should open outwards. The position of the doors will depend on the plan of the building chosen.

Water Supply.—Water should be laid on, both inside and outside the stables. The water pipes and taps in the stable should be fixed in the most convenient positions, but should be well protected from risk of injury from horses' feet. A galvanised or other trough should be provided outside the stable for watering the horses.

Fittings.—The stalls, which measure 11 feet long by 7 feet wide, are divided by partitions. These partitions may be constructed wholly of wood or of an iron framework filled in with wood, oak or good red deal $1\frac{1}{2}$ inches thick being suitable. The lower portion to a height of 5 feet may consist of wood, while the upper portion is formed by open ironwork. The height of this partition at the front should measure about $7\frac{1}{2}$ feet, to prevent horses biting at each other, and at the rear $5\frac{1}{2}$ feet. The top rail may have a straight fall to the rear, or it may take the form of a curve. The heel posts should be round. Kicking plates, which consist of sheet iron, $\frac{1}{8}$ inch thick, should be fixed on each side of every stall partition to a height of 2 feet 6 inches. If these are not provided, considerable damage will ultimately be done to the woodwork through horses kicking the partitions. The passage behind the stalls should measure at least 5 feet 6 inches wide in the single-line stable, and 8 feet wide in the double-line stable.

Mangers.—These should be made of iron, the whole fitting extending completely across the stall. The dimensions of the actual manger are 3 feet 6 inches long, 15 inches across, and 10 inches deep. An iron bar should be fixed across the manger about 9 inches from each end, and the front top boarder of the manger should project inwards about $1\frac{1}{2}$ inches. This prevents the horse throwing the food out of the manger and wasting it. The height of the manger from the ground should be about 3 feet 6 inches. Some mangers are constructed with two portions, one for food and the other for water. It is not advisable to have a receptacle for water in the manger, as it gets filled up with food and dust, cannot be properly cleaned out, and is therefore insanitary. At one time, hay-racks were a standard fitting, but it is now realised that feeding long hay is not economical for town studs, and so hay-racks are now quite unnecessary. Horses are tied up to the mangers by tie ropes or chains, which pass either through holes in the framework or rings fixed to the manger.

Drainage.—The stable paving should be constructed with material which is impervious to moisture, durable, easily cleaned and non-slippery. There are various materials in common use for stable paving—concrete, hard-burnt bricks, blue vitrified bricks, granite cubes, etc. Good concrete made non-slippery is very useful and cheap. Granite cubes, although more costly, are without doubt the most suitable paving material for heavy draught horse stables. Whatever material is chosen, the work of laying it should be carried out very carefully. The materials should be laid in cement, on a 6-inch bed of concrete, as this paving must be not only impervious to moisture, but also strong enough to sustain a large moving weight.

Drains.—All drains in the stable must be of the surface type; underground drains soon get choked, and become insanitary. In stables where an absorbent bedding is used, such as sawdust and turnings, or peat moss litter, no drains are required, the liquid excreta being absorbed by the litter, and removed with it in the process of cleaning out.

In stables where straw is used as litter, a simple drainage system should be provided. The stall paving should fall gradually from each side to a shallow centre channel, which in turn falls toward the rear of the stall, connecting with another shallow channel placed well back from the heel-post, and running the whole length of the stable. This channel in turn discharges finally on to a trapped gully placed outside the stable and to one side of the wall opening. The fall of the stall and main drain should be about 1 inch in 80 inches. Should the stable be exceptionally long, the main channel may be made to fall from the centre to each end of the stable. The level of the stable floor should be about 8 inches above the outside ground level.

Loose Box.—This is a very essential structure in connection with a stable of any size. In any stud of horses, sickness occurs, and this can only be successfully treated in a loose box. The provision of a loose box is an economic proposition, as the disease may be of a contagious nature and spread from one horse to another, thus rendering part of the stud useless for the time. By removing such a case to the loose box, this risk is minimised considerably. It is especially important in regard to new purchases. Young horses are very liable to influenza, strangles, etc., and as they pass through dealers' stables they may become infected, so that when a new purchase arrives, he may bring the infection with him, and develop the disease some days after arrival. This then is a special use for the sick-box: the housing of the new-comer, until one can safely say that no contagious disease will develop.

The loose box will be found very useful for the treatment of horses suffering from colic, a trouble which sometimes makes the patient very violent, when it would be dangerous both to horsekeeper and horse to remain in the ordinary stall.

The treatment of throat and lung diseases can only be carried out successfully in a dry, airy loose box.

The dimensions of the loose box should be 14 feet long, by 12 feet wide, by 12 feet high. Special attention should be given to lighting and ventilation, as plenty of sunlight and fresh air are essential for the treatment of sick horses. At the same time, one must make sure that the ventilation does not cause draughts. Small iron mangers should be fitted in opposite corners so that one can be used for food and the other for the water bucket. By this method the water is kept clean and free from fodder. The floors may be paved as in the main stable, the drainage being of the surface type. The door should be divided into two portions. A hinged iron-barred gate the same size as the top half of the door should be provided, so that when the top portion of the door is left open, the horse will be unable to make any attempt to get out.

Harness-room.—The compartment in which the harness is placed after work should be a roomy one. Its actual dimensions will be governed by the number of horses in the stud. Many harness-rooms are much too small; the drivers have not elbow room and are hampered in the operation of harness cleaning. This leads to careless work. The harness-room should be well lighted, naturally and artificially. One cannot expect harness to be thoroughly cleaned when the man cannot see clearly what he is doing. Heating and ventilation are also of great importance, both from the point of view of the health of the horse and the wear of the harness. Wet harness causes sore shoulders and sore backs, and the harness itself wears out much more quickly. For the same reason, harness should never be kept in the stable. The harness-room fittings consist of iron brackets placed round the walls at a height of 7 feet from the floor. There should be a space of at least 3 feet 6 inches between each bracket. A strong table or bench with small cupboards underneath should be placed in the centre of the room for harness-cleaning utensils, etc.

The heating of the harness-room may be carried out by means of an open fire grate; by a stove, with or without a hot-water system; or by steam pipes, where steam is available. Either method is good so long as ample provision is made for the egress of damp air.

Food-storage Room.—With a small stud of horses, it is necessary to have a stock of provender for at least a week. When the stud is a large one, it may be necessary to provide storage for three weeks' supply. The size of the food-storage room will therefore be governed by the number of horses in the stud, and by the method of procuring the horse rations. Should the stud be a small one, it may be a better method to buy the provender cut and mixed ready for feeding to the horses. On the other hand, the size of the stud may make it more economical to purchase hay and grain in bulk, when room would have to be provided for the storage of bulky hay: for the necessary installation of hay-cutting and grain-mixing machinery with dust-extracting plant.

It may suffice for the moment to say that unless the stud exceeds twelve horses, it is more economical to purchase the provender cut up ready for mixing and feeding. The food-room should be of a size sufficient to hold, say, forty to fifty bags of provender. A room 18 feet long by 14 feet wide would accommodate this amount of provender, and give space also for store cupboards, for spare harness, and sundries. This room should be thoroughly dry, with good ventilation and lighting.

Shoeing Forge.—This should consist of a blacksmith's shop, containing the fire, bellows, anvil, tools, etc. A separate compartment should be provided for the work of shoeing the horse.

Manure Receptacle.—A manure receptacle should be provided, with a good concrete floor.

Part II. Feeding and Watering of Horses.

The feeding of a stud of horses should be carried out scientifically and economically. The provender purchased should be sound and suitable for the class of horse and work done.

When the writer says economical, he does not suggest buying the cheapest provender on the market. One might purchase an inferior class of hay or grain at less money than the better-quality article: this would not be economy. Not only would the horses do badly; they would also suffer from digestive and other troubles. One can economise in feeding the stud, however, by the judicious and often forward purchase of good sound hay and grain, and by the selection and mixing of grain, the price of which rules cheapest on the market. For example, oats might be dear, with barley and maize cheaper. By using more maize and barley and fewer oats in the rations, costs will be reduced.

The principal foodstuffs used for working horses are: hay, straw, oats, maize, barley, beans, peas, wheat, bran, oatmeal, linseed, hay, and green forage. Carrots are used principally in sick horse rations.

Hay.—A good sample of hay is one grown on good land, cut at the proper time of year, and well dried or cured. It should be sweet smelling, of a green colour, have a dry, crisp feel, and not be too coarse or too soft. It should contain a variety of good-class herbage; the flowering heads of the grasses should be in abundance. A mixture of weeds in hay is objectionable and the hay is less palatable to the horse. The presence of flowers which have not lost their colour, such as buttercups and the flowers of trefoil and clover, shows that the crop has been cut early in the season, before the grasses had lost their juices and nutriment. Hay is at its best for feeding when about one year old. Good hay is clean. Mouldy or dusty hay shows that the hay has not been well made, and should be avoided.

Hay forms the bulk ration of the horses' diet and is essential for digestion. The weight of hay in a heavy-draught-horse ration is about 15 lb. per day. Boat horses require slightly less. The most economical way to feed hay is by chopping it into short lengths with a machine called the chaff-cutter. The hay is then mixed with the grain to form the ration.

The feeding of long hay to heavy draught horses is extravagant. Some of the hay drops to the floor when the horse is helping himself from the hay-rack; this portion becomes soiled with litter and is thrown out on to the manure heap.

Straw.—There are various straws—oat, wheat, barley—but oat straw is the only one suitable for draught-horse food. Straw contains a large amount of fibre, and should only form a small portion of the bulk ration, and then only to reduce costs in a bad season when hay is very dear. In a good season, straw is dear compared with hay, as it does not contain nearly so much nutriment.

Oats.—As a rule, oats form the bulk of the grain diet. A good sample of oats should be dry, hard, clean, heavy, full of flour, and free from any adulteration with other small seeds. Oats may be pale-coloured or black—both varieties are good if they correspond with the above description. Good oats should weigh 38 to 40 lb. per bushel. Should they weigh less than this, the oat skin or husk will be thicker, there is less flour present in it, and it is less valuable as a foodstuff. It is an economy to purchase a good sample of oats at more money than a poor sample at less money. In purchasing oats, the following should be avoided:—

Kiln-dried Oats.—These oats are kiln-dried to get rid of dampness or softness. They can be recognised by their reddish colour and by a loose, shrivelled appearance at the end of the husk.

Foxy-Oats.—The term applied to oats which have been heated and fermented when kept in bulk, through not being perfectly dry. They also, are reddish in colour, have a bitter taste, and are unfit for horse food. This class of oats causes kidney trouble and loss of condition.

Dampness and softness in oats are also objectionable. Musty and mouldy oats are quite unfit for horse food, being in the first stages of decomposition.

New oats which have been recently harvested and thrashed are distinguished from old oats by their earthy smell, bright shining appearance and softness. Old oats, which are best for feeding purposes, are hard, somewhat dull in colour and slightly bitter in taste.

Oats are sometimes cracked or crushed before feeding. This ensures more complete digestion, especially in cases where the horse is a greedy feeder, and bolts his food without mastication.

The heavy-draught horse on full work would require 16 lb. of oats per day, along with the hay ration, where oats is the sole grain constituent of the food.

Foreign oats are used extensively in this country for feeding purposes. They are harder than the English oat, and make a first-class ration for horse food; moreover they are cheaper than English oats. Foreign oats come principally from South America.

Maize.—This grain, which is also grown abroad, is suitable only for horses doing slow work. It is best fed in conjunction with oats, but may be used with other grains. The grain should be cracked before mixing with the provender, and should be fed in the proportion of about 5 lb. to 9 lb. of oats.

Barley.—This grain is only suitable for horses doing slow work. It should be used carefully, as it has a tendency to produce skin troubles. Only sound hard grain should be used, and at the rate of 4 lb. to 10 lb. of oats.

Beans.—This grain is very rich in nitrogenous matter, and should therefore only be used for horse rations in comparatively small proportions. For heavy draught horses, used in the proportion of 1 lb. beans to 13 lb. oats, it makes a very excellent item. English beans are preferable to foreign beans, as the skin is not so tough. The grain should be hard, dry, sound and sufficiently matured, weighing 60 lb. to the bushel. Beans, like maize, should be cracked before mixing with the provender.

Peas are very similar to beans, and should be fed in the same way, in the same proportion. The grain should be dry and sound, and should also be cracked before mixing with the other rations.

Wheat.—This grain should not be fed to horses if other grain can be procured. It should be partially ground before using, and should only be used with the greatest care, as it is liable to cause very serious digestive troubles.

Process of Digestion.—It may be useful to describe very briefly the course of the food in the digestive system. The food is gathered by the front teeth and lips, passes to the back of the mouth, and is ground into pulp by the back teeth or molars, meanwhile being thoroughly mixed with saliva, which is a digestive juice. The food is then swallowed and passes down the gullet into the stomach. The stomach is a muscular pouch, lined with a digestive membrane which secretes the digestive material known as gastric juice. The food, entering the stomach, stimulates the nerves, which, acting on the muscular wall, cause contraction of those muscles, thereby producing a rotatory movement of the stomach. The food thus reaches a further stage of digestion by mixing with the gastric juices. As the process of digestion goes on, the liquid portion of the food gradually passes into the small intestines, where it is mixed with the secretions from the liver, pancreas and intestinal fluids. These juices complete the digestive process, and absorption of the food takes place by the blood vessels lining the walls of the intestines, and is by this means conveyed to the various tissues of the body which require rebuilding. The food not absorbed in the small intestines, which is now mainly waste product, passes to the large intestines, where a further absorption takes place. The residue then passes along to the rectum and is evacuated as dung.

Water does not take quite the same course as food. It passes quickly through the stomach to a portion of the large intestine called the cæcum, and remains there until absorbed by the blood vessels; through these blood vessels it reaches the lungs, kidneys and skin.

The class and amount of food which a horse will require depend on the size and weight of the horse and the nature of his work.

The heavy draught horse will require a somewhat more bulky ration than the boat horse, which does faster and proportionately heavier work.

Some horses will eat a greater quantity of fodder than others doing the same work.

The rations for horses at rest should not only be reduced in quantity, but also in concentrates.

Digestion Coefficient.—This is the term applied to the percentage of each nutrient digested in a feeding stuff. It is necessary to know the digestion coefficients of the various nutrients in a feeding stuff when computing balance of rations.

Nutritive Ratio in any food is the proportion or ratio between the digestible crude protein, which serves special uses in the body, and the combined digestible carbohydrates and fats.

The nutritive ratio of a food is ascertained in the following way :—

The digestible fat in 100 lb. of the given food is multiplied by 2·25, because fat will produce 2·25 times as much heat on being burned in the body as do the carbohydrates.

The product is then added to the digestible carbohydrates, and the sum is divided by the amount of digestible crude protein.

The nutritive ratio of oats is computed as follows :—

$$\frac{\underset{\text{Digestible Fats.}}{3{\cdot}8} \times \underset{\text{Heat Equivalent.}}{2{\cdot}25} + \underset{\text{Digestible Carbohydrates.}}{52{\cdot}1}}{\underset{\text{(Digestible Crude Protein.)}}{9{\cdot}7}} = 6{\cdot}25.$$

The nutritive ratio of oats is therefore 1 : 6·25 (read 1 to 6·25).

A narrow nutritive ratio is one in which the proportion of crude protein is high compared with the carbohydrates and fats combined.

A wide nutritive ratio is the reverse.

Oat straw.—1 : 44·6 shows a wide nutritive ratio.

Oats.—1 : 6·25 shows a medium nutritive ratio.

Linseed meal.—1 : 1·6 shows a very narrow nutritive ratio.

A balanced horse ration is one which has a correct nutritive ratio for the amount and class of work done.

A maintenance ration is one which is sufficient to maintain the body tissues when the animal is at rest.

The nutritive ratio for the horse at medium work should be 1 : 6·2. This nutritive ratio should be narrower when the work is greater, and wider when the work is less.

The following table shows suitable daily diets for heavy draught and boat horses at work :—

Heavy Draught Horses, weighing 1729 *lb.*

1.	Oats	13 lb.
	Beans	1 lb.
	Hay	16 lb.
2.	Oats	8 lb.
	Barley	6 lb.
	Hay	16 lb.
3.	Oats	10 lb.
	Barley	3½ lb.
	Beans	1 lb.
	Hay	15 lb.
4.	Oats	9 lb.
	Barley	3 lb.
	Maize	2 lb.
	Hay	16 lb.
5.	Oats	5 lb.
	Barley	4 lb.
	Maize	4 lb.
	Beans	2 lb.
	Hay	14 lb.
	Straw	2 lb.

Similar rations can be used for boat horses by reducing the quantity of grain by 2 lb. and hay by 3 lb. each. Roughly speaking, the amount of food required for horses in hard work should be about 2 lb. per 100 lb. of horse.

Sick Horse Foods.—The most common articles of food for sick horses are bran, linseed, oatmeal, hay, green forage, and carrots.

Bran, which is the husk from the wheat kernel obtained from the process of flour manufacture, is a common item in sick horse diet. It may be fed dry or made into a bran mash. The latter is the more common way of using it. The bran mash is made by putting a quantity of bran into a clean stable bucket and pouring over this as much boiling water as the bran will absorb. A bag is placed over the top of the bucket to retain the heat and steam, and when the whole is sufficiently cool it is ready for use.

Linseed is the seed of the flax plant, and is a valuable sick horse food. It is fed either boiled and mixed with bran mash, or in the form of a gruel—1 lb. of linseed boiled with 2 gallons of water; it should then be strained and the liquid portion given as a drink and the solid portion as a mash.

Oatmeal.—This makes a valuable sick horse ration when fed in the form of gruel. It is very refreshing and palatable to the sick horse, and is, moreover, easily digested and assimilated by the stomach and intestines. Good gruel is made by putting a double handful of oatmeal into a bucket and mixing this thoroughly with a quantity of cold water—$1\frac{1}{2}$ gallons of hot water, not boiling, should then be added, stirring the mixture the while. Before feeding the temperature should be reduced to that of new milk.

Hay.—The very best hay only should be used for the feeding of sick horses. It may be fed dry or steamed. Steaming is done by placing a quantity of hay in a bucket and pouring boiling water over it. The whole is covered with a bag until sufficiently cool to feed to the animal.

Green Forage.—This forms another excellent item in sick horse diet, when procurable, but should only be used when absolutely fresh. Grass, clover, lucerne, sainfoin and vetches are the most commonly used.

Carrots also form a very useful adjunct to sick horse diet, and are especially valuable at the time of year when green forage is not procurable. Only sound roots should be used and should be cut lengthwise. If cut transversely they are liable to cause choking. They may be given alone or mixed with crushed oats.

Times for Feeding.—The horse has a small-capacity stomach, and therefore requires to be fed fairly frequently. This is even more important in horses doing hard work than in horses at rest. The horse should be fed not less than three times per day, and with regularity. The largest feed should be given in the evening, when the horse is at rest. When long hay is fed, it should be given in the evening, when there is more time for the horse to masticate it thoroughly.

Where possible, it is best to feed five times per day. Two small feeds with half-an-hour between in the morning before leaving the stable, one feed at mid-day, and two feeds in the evening, with an interval of one to one and a half hours. This method is not possible where each individual driver feeds his own horse, but in a stud where a horse-keeper is in attendance this method can be successfully applied. Hard work with irregularity in feeding is the most common cause of gastric troubles in the horse, and is often attended by heavy mortality.

Watering of Horses—Under normal conditions horses should be given water to drink frequently, and should be allowed as much water as they care to have.

It is important to remember that at meal times water should be given first. If water is given after feeding, there is a tendency for undigested food to be washed out of the stomach into the intestines, where further digestion of this food cannot take place. This food, acting as a foreign body, sets up fermentation, with consequent gastric trouble and colic. It is not advisable to give cold water *ad lib.* to a horse which is very hot and tired. The horse should first be rested and allowed to " cool off," or he may be given a small quantity of tepid water. Fresh, pure, clean water only should be used. Water should never remain in buckets in the stable, as, to a certain extent, it absorbs foul gases from the stable excreta.

Bedding.—Horses doing hard work require one item of comfort, and that is a good bed. The principal materials used for horse bedding are wheat straw, peat moss litter, sawdust and turnings. The first two items make very good bedding, especially when used together, but the cost for commercial heavy horses will be found to be prohibitive. The most economical and useful bedding, therefore, is sawdust and turnings. These should be used in the proportion of one bag of sawdust to four bags of turnings. The amount required per horse, per week, is about two bags of the mixed litter. When this form of litter is used, no drains are required in the stable, as the liquid portion of the excreta is absorbed by the bedding. Only the very wet portions of the bed and the droppings are removed, and new litter is added to make up the required amount.

Grooming of Horses.—Horses very well fed and doing hard work require thorough grooming, as the secretions from the skin glands are enormously increased, and without grooming, the skin pores become blocked up and the health deteriorates. The greater the action of the skin, the greater the attention that must be paid to it. This is why hunters and racehorses, which are trained to such a high pitch, require more grooming than the heavy cart-horse doing slow work and fed on rations not so highly nutritious. Excretion of worn-out body materials through the skin takes place also in a horse at grass in a state of nature, but as the food is not highly nutritious and the horse does not use up much energy, it remains healthy without grooming.

For heavy horse grooming, the cleaning utensils used are the dandy-brush—a brush with long stout bristles—a curry-comb, which is a flat iron comb with very short teeth; a body-brush, which is a brush with soft bristles; a comb or drag with long teeth, and a rubber or cloth.

The dandy-brush and curry-comb are used together, the curry-comb stirring up the hair and breaking up congealed perspiration and dried mud, and the dandy-brush removing this débris.

The body-brush is used when the bulk of the dirt and skin excreta have been moved by the dandy-brush and curry-comb. A long-toothed comb is used on mane and tail. The rubber is then used to finish off and give a polish to the coat.

The thorough cleaning of the skin is an operation requiring skill and hard labour. This operation should be carried out night and morning.

In some large studs, cleaning the horses is carried out by vacuum-cleaners. This answers very well for the parts of the body where the suction nozzle can be laid flat upon it, but when applied to the limbs it loses a great deal of efficiency.

Clipping and Singeing.—Twice in the year, namely spring and autumn, the horse sheds his coat. The old hair falls out and is replaced by new hair. The hair of the new coat in autumn is longer than that of the new coat in spring. This is Nature's provision against cold. This coat is, however, too heavy for the horse doing hard work, and causes him to sweat even in the coldest weather. It is necessary, therefore, to reduce this heavy coat. With light carriage and van horses, this is done by clipping. With heavy draught horses the object is achieved either by clipping the hair on the lower part of the body, leaving a long coat on the withers, back, loins, quarters and rump, or by singeing the long hairs over the whole of the body with a paraffin or gas-singeing lamp. The second method is not so speedy, and is a dirtier operation than the first, but is, in the writer's opinion, preferable, especially with heavy horses employed on refuse collection. These horses have to stand about a great deal, and are therefore not so liable to get chilled as the partially clipped animal.

Horse Attendants.—In large studs it is usual to employ a horse-keeper to look after a number of horses. The work for each horse-keeper should be the care of twelve horses, and he should carry out the feeding, grooming, singeing and cleaning of stables.

In small studs the driver may feed, groom and look after his own horse. This is, in the writer's opinion, the better system. The driver then takes an interest in the animal, both in regard to grooming and working. When, however, the animal is handed over to the care of another individual on its return to the stable, it seems to have a deleterious effect on the driver's interest, which is so essential for the welfare of a horse.

Harness and Clothing.—The question of harness forms a very important economic item in connection with the working of a stud of horses. Many days of useful work may be lost to the owner through badly fitting harness, or harness not properly cleaned and taken care of.

The heavy draught harness consists of bridle and bit, collar and hames, with shaft tugs, saddle, breeching, reins, and bellyband; and in winter a loin cloth.

The boat-horse harness consists of bridle and bit, collar and hames, rope traces with bobbins, back-bands, spreaders, reins, and in winter, shoulder and loin cloths.

New harness should be well made and of best material obtainable. The purchase of cheap harness is a false economy.

Old harness should be kept in a thorough state of repair; neglect to do so may cause delay through breakage, and in some cases may even lead to serious accidents. It is most important that the linings of collars and saddles should be kept not only thoroughly clean, but also in a high state of repair. Neglect to do this causes a great economic loss to the owner, as sore crests, shoulders and backs will be prevalent. These sores are not only painful to the horse, but also will put him out of action for long periods.

When a horse is in heavy draught, there is considerable pressure and friction on the shoulders and on the back when working in a cart. It therefore behoves us to see that the pressure is kept as even as possible and friction reduced to a minimum. This can only be done by having collars which are well padded and which fit absolutely; by saddles well padded and level, and last, but not least, by ensuring that the linings of each are kept scrupulously clean. The leather part of the harness should be kept thoroughly clean and well blacked with some wet-resisting compo. In wet weather, harness should be well dried overnight.

Spare sets of harness should always be available, so that the horse is not held back from work while repairs to harness are being carried out.

Loin-cloths are lined waterproof covers which cover the horse from saddle to tail. These are indispensable in the winter time, as they keep the horse dry along the back and warm enough to prevent chills. These cloths can be rolled up and fastened to the saddle, should the weather be warm.

Boat-horse cloths are indispensable for the same reason; the shoulder cloth which covers the collar prevents the wetting of the shoulders, and so, sore shoulders.

Sleeping rugs are a necessary item of clothing where horses are clipped, but with heavy draught and boat horses, where only partial clipping or singeing is carried out, they are not necessary. One or two rugs, however, should be provided, as they will certainly be required for sick horses.

Shoeing of Heavy Draught and Boat Horses.—The horse's foot is a sensitive vascular structure, surrounding bones, the whole being enclosed within a horny capsule which is the hoof. The hoof consists of a horny wall which can be seen when the foot is on the ground. On lifting the foot it will be found that the lower surface is formed by a horny sole and a horny frog, which is the bulbous, wedge-shaped structure.

Wear of the Hoof.—The essential of good shoeing is to preserve the outer case, or hoof, which acts as a protection to the more delicate structure. Under natural conditions the hoof coming in contact with soft or smooth ground does not suffer any undue wear, and Nature supplies the required new horn by growth of the hoof. This growth of horn is in proportion to the amount of wear. Under artificial conditions—that is, working on the city streets or county roads—the friction of the hoof on the hard road wears the horn down much faster than Nature can provide the new horn. The inevitable result is the wearing of the hoof right down to the underlying sensitive structure, with consequent lameness. To prevent this undue wear it is necessary to provide a shoe for the lower surface of the foot. With the shoe in position, no wear of the hoof takes place and the hoof grows too long. This is corrected by the shoeing smith cutting down the excess horn when fitting the new shoe. The shoeing smith must be a highly skilled workman. Faulty preparation of the foot for the shoe, if continued, may in time lead to deformity of the feet, with consequent incurable lameness.

The shoe is applied to the foot to prevent undue wear of the horn, to prevent injury to the hoof, and so to the underlying sensitive structure—to give the horse a foothold on the slippery streets and roads.

Malleable iron has been found to be the most suitable material for the manufacture of horse-shoes. Horse-shoes may be either machine made or hand made. Machine-made shoes are principally used in the army. For commercial work, hand-made shoes are most suitable.

The Horse-shoe.—The shoe consists of a somewhat circular piece of iron, which, when applied to the lower surface of the foot, covers the lower end of the wall and a small portion of the sole. It follows the contour of the foot, fitting flush with it. The thickness of the iron used for shoe-making depends on the weight of the horse and the class of work the horse is doing. For heavy draught horses, iron measuring $1\frac{1}{4} \times \frac{5}{8}$ or $1\frac{1}{4} \times \frac{1}{2}$ inches will be found suitable, the weight of the finished shoe being about 4 lb., and for boat horses, iron measuring $1 \times \frac{5}{8}$ or $1\frac{1}{8} \times \frac{1}{2}$ inches, the weight of the finished shoe being 2 lb. 8 ozs.

The Prevention of Slipping.—It is preferable, where possible, to have the front feet shod with flat shoes and the hind feet with shoes having small heels or calkins, to give a good foothold. The condition of the streets and roads to-day is such that the majority of heavy horses cannot get a sufficiently good foothold without heels on the front shoes also.

Pads, which are small rubber blocks fitted to a metal plate and fastened across the heels of the shoe, are used to prevent slipping, but are found to be too expensive for heavy horse wear.

In winter-time the shoeing has to be adapted to give the horse a good foothold on streets and paving covered with snow and ice. This is carried out by making the winter shoes with holes, into which fit chisel pointed studs on the front shoes and chisel screws on the hind shoes.

The Fitting of the Shoe to the Foot.—The shoe is held to the horse's foot by nails, which, passing through holes in the shoe, are driven into the wall of the hoof in a slanting direction, the points of the nails emerging about one third up the wall. The points of the nails are twisted off and the ends are then turned down on the hoof to form clenches, thus fixing the shoe securely to the foot. Great care must be taken that the nail does not pierce or touch the underlying sensitive structure. Should this be done and remain unnoticed, suppuration will follow, with consequent lameness.

Wear of the Shoe.—On the average, horses should be shod every four weeks. Some horses, however, will wear their shoes out in fourteen days, when the shoes must be renewed. Others will carry their shoes six weeks, but in this case the shoes ought to be removed in twenty-eight days, the hoof reduced to normal length and the shoes re-made and applied again.

Heavy Draught Work.—Provided that a horse is sound and in good condition, the weight which he can draw depends on the size and weight of the horse and the gradients along which he has to travel.

In hilly counties, like Devon and Cornwall, very small carts are used and small loads are carried. In city work, where the gradients are not too severe, an average load would be 28 cwts. in wagons weighing 24 cwts., making a total load of 52 cwts.

In clinker work the load would average 30 cwts., and the weight of the cart 20 cwts., making a total of 50 cwts. The distance travelled per day would average 12 miles.

Boat Horse Work consists of the drawing of barges along the canal. This is very heavy work, as the horse is constantly in the collar. The load carried in the canal boat averages 28 to 30 tons, and the distance travelled per day may range from 15 to 30 miles.

Speaking generally, the horse should be selected to suit the work required of him, and he must be matured, sound, and in fit condition.

The driver is a most important factor in the work of the horse. To-day, on account of the great increase in mechanical transport, good horse drivers are scarce. The horse of the good driver wears better, lasts longer, and is always in better condition than that of the bad driver.

The driver should not only be thoughtful, having the welfare of his horse always in mind, but should also possess some nerve and not be afraid of the animal he is driving, whatever fix they get into. Many a timid horse has been rendered quite unworkable through the driver showing fear, and this fear is quickly conveyed to the horse, increasing its feeling of nervousness. This leads sometimes to the horse running away and doing some material damage, and once a horse runs away, one is never quite sure of him again. I know that the problem to-day of securing useful, experienced horse-drivers is a difficult one. In past years many of the drivers came from country districts as young men and those men made excellent drivers, their experience in horse-driving dating from a very early age.

Before leaving the subject of work, the writer would like to say a word on vehicles. The vehicles used to-day seem to be heavier than necessary. The lighter the vehicle commensurate with durability, the greater the load of material the horse can draw. Where possible, four-wheeled vehicles should be used in preference to two-wheeled vehicles. When working in a two-wheeled vehicle the horse has a heavy pressure on the back, and especially in downhill work. This naturally puts an extra strain on legs and tendons, and should he slip, a still greater strain is placed on these parts in regaining his equilibrium—with the consequent risk of sprained tendons. With the four-wheeler, there is no weight on the horse's back, and, moreover, those vehicles are provided with brakes, which assist the horse to hold the load back when going downhill. The vehicles should be kept in thorough repair, with axles well greased and oiled.

Part III. Diseases of Heavy Draught and Boat Horses.

In health the horse should have a good appetite, normal pulse, temperature and respiration. The normal pulse, which is really the impulse of the heart pumping the blood through the blood vessels, is thirty-four to thirty-eight beats per minute. The pulse is most easily taken by placing the fingers over the sub-maxillary artery, just inside the border of the lower jaw, or over the radial artery which lies just inside the forearm. The temperature is taken by lifting the tail and placing a thermometer in the rectum, which is the most posterior part of the intestines. The normal temperature is 101° Fahrenheit.

The normal respirations when the horse is at rest are about eight to twelve per minute, and these can easily be counted by observing the rise and fall of the horse's flank.

Every experienced horse-keeper should be able to take pulse and temperature and note respiration, and by knowing what these should be in health, he is at once in a position to say when the horse is "off colour," and to call in the necessary professional advice.

The following are some of the most common ailments of horses :—

Colic.—This ailment is the most common, and is recognised by the animal showing signs of abdominal pain, intermittent or constant. The horse becomes very restless, getting up and down, kicks at the abdomen with the hind feet, and looks round to his flank. The attack of colic may be due to indigestion with flatulence, or to stoppage of the intestines, when it should soon respond to treatment. When the colic, however, is due to ruptured stomach or twist of the intestines, the trouble is quite incurable, and death will ensue in 24 hours or less.

Colic is caused by over-feeding, irregular feeding, feeding with bad food, and irregular watering of horses.

The fatal cases of colic are more prevalent when the horse is doing extraordinarily hard work or working exceptionally long hours. This is easily explained, because under these conditions the horse has long fasts, and when he comes into the stable, dead tired and hungry, he is given an extra large feed, or he may bolt his food ravenously, with the same result.

To eliminate attacks of colic, watering and feeding must be carried out regularly, and with care.

Sore Throat.—This is an inflammatory condition of the throat tissues. It may be of a simple nature, due to draught in the stables or from exposure to very cold winds. This form, as a rule, soon responds to treatment. On the other hand, the sore throat may be of a contagious or an infectious nature, when recovery is rather prolonged. Both conditions are recognised by a throaty cough, but the contagious form is accompanied by a yellowish discharge from both nostrils and a persistent high temperature and pulse. The horse affected with the contagious form of sore throat should be immediately isolated from the others, as this is a disease which spreads quickly. It will be found most prevalent in young horses, newly purchased, these horses being infected, as already mentioned, in the dealers' stables before purchase.

Strangles.—A contagious disease also prevalent in young horses. This disease can be easily recognised by a swelling of the lymphatic glands inside the angle of the jaw. As a rule, abscess formation takes place, and recovery is rapid when this abscess matures and bursts, or is lanced. Isolation of affected animals is here also of great importance.

Pneumonia and Pleurisy.—These diseases may occur singly or together. They may be due to simple chill or be of microbial origin, as in sore throat. Whatever the cause, this is a very serious complaint, and the horse can only be saved by the most careful nursing and treatment. Complete isolation, in a roomy, well-ventilated loose box, free from draughts, is absolutely essential.

Cough and Cold.—The first is really a symptom of the second, which is a simple sub-acute inflammation of the lining membrane of throat or lungs, due to exposure to a draught or inclement weather. The complaint, as a rule, soon responds to treatment, but care must be taken that the animal does not get a further chill, as it may lead to some trouble much more serious.

Influenza.—This is a very serious disease of microbial origin, which is generally brought to the stable by the newly purchased young horse. The disease is characterised by high pulse and temperature, increased respirations and great nervous prostration. Several organs of the body may be affected, usually the throat, lungs, heart, and sometimes the liver and bowels. It is a very infectious disease, and quickly spreads from animal to animal. Recovery is very protracted, even in the most favourable cases. Should the disease be of a virulent nature, mortality from pneumonia and heart failure is very high. The affected animal should be at once isolated in the loose box, and given the greatest care.

Rheumatism.—This is a disease which is not uncommon in the horse. As a rule, horses affected are housed in a damp stable. Rheumatism may be of an acute form, giving a rise in the animal's temperature and affecting the heart. This form of the disease is, however, rare. The more common form, which is sub-acute, attacks principally the muscles, tendons, ligaments and bones.

Rheumatism is easily recognisable by the irregularity of the symptoms. The animal may at one time show lameness from rheumatism, and a few hours later the symptoms have entirely disappeared, to recur again at intervals. One limb may be affected one day, and another the next. The horse should be housed in a dry stable, should always have a dry, comfortable bed, and the legs should on no account be washed.

Sprains.—A sprain is an inflammatory condition of some tissue, due to violent usage. Sprains usually occur in ligaments or tendons. Ligaments are the structures which hold the bones together, tendons are the ropes which join the muscles to the bones, and by contraction of the muscles, move the bones. Sprains *usually* occur below the knee in the fore-leg, in the hock, or below it in the hind limb, but they may also occur in other parts—shoulders, loins, etc. Sprain of tendons or ligaments is one of the most common ailments in heavy draught and boat horses, and is recognised by the animal showing lameness in the affected limb. In the primary stage, the parts affected show heat and swelling. When the sprain becomes chronic, the heat disappears, but the thickening of the tissue remains. Sprain, as has already been said, is caused by an extra strain put on the part, and results often from slipping in the street or even in the stable. The animal suffering from a sprain must be completely rested until the part has recovered. If put back to work too soon, the result is a chronic sprain from which the animal will not recover.

Diseases of Bone and Cartilage.—When horses are put to very hard work or work on hard town paving at an early age, the concussion from the foot coming to the ground induces disease of the bones and cartilages.

Ring Bone is an inflammatory disease of the bones in the foot, in which the bone becomes enlarged, and, when present, this enlargement can be easily felt with the fingers, at the top of the front part of the hoof. In young horses, there is always lameness present during the acute inflammatory stage of the disease. Lameness may disappear with treatment, leaving the horse with a blemish, but workable, or it may continue; this depends on whether the joint is affected.

Side Bone.—This is an inflammatory disease affecting the lateral cartilages. These lateral cartilages are two in number, one placed on either side of the foot. They can be felt under the skin above the hoof and they also extend down inside the hoof itself. As the inflammatory process continues, these cartilages are gradually turned into bone. In good, wide, feet lameness is not often produced.

Both Ring Bone and Side Bone constitute an unsoundness in the horse, and no young horse suffering from either disease should ever be purchased for the stud.

Laminitis.—This is an inflammatory disease of the sensitive structures underlying the hoof or horny capsules. It usually occurs in the front feet, and the horse becomes very lame from the pressure of the increased amount of blood in the foot. The cause may be due to chill, but more often to over-feeding, feeding on unsuitable foodstuffs, or to overwork. This disease usually responds to treatment. In some cases, however, deformity of the feet results, this rendering the animal unsuitable for town work, although still useful for work on the land.

Foot Lameness may be caused by a nail, picked up by the sole or frog when the horse is at work, which pierces the horny part of the foot, injuring the sensitive structure underneath, with a consequent formation of matter in the foot, or the shoeing-smith, when fastening the shoe on, may drive the nail out of its proper course, and so injure the sensitive underlying structure. When this happens, lameness may appear at once or very soon after. In either case, withdrawal of the nail, and treatment, as a rule, soon effect a cure, but should the nail be left in for some time, or penetrate to the bone or joint, the condition becomes much more serious, and sometimes fatal, the horse succumbing to septic poisoning.

Grease.—This is a disease of the glands of the skin in pastern and fetlock joints, and occurs in both fore and hind limbs. It is a gradually progressive disease, which commences with a slight, evil-smelling, watery discharge. With treatment, the progress of the disease may be retarded, but in time it spreads around these joints, thickening the skin and forming nodular tumours, which render the horse's legs so unsightly that it becomes impossible to work him on the public highway. This disease has a dietetic origin, and develops in young horses when they have been fed for some time in town on a highly nutritious diet. It does not often affect young horses on the farm, where the diet is, as a rule, not so highly nutritious. Mud and wet hasten the disease. Horses with thick, hairy legs, are more predisposed to it than horses with fine bone and little hair on the legs.

Sore Crests—Shoulders and Backs.—These form a common cause of trouble in heavy draught and boat horses.

Sore crests occur on the top of the neck where the collar rests, and are usually due to badly fitting collars or those out of repair and not sufficiently padded.

The heavy draught horse working in a cart is more subject to sore shoulders and back than the horse working in a wagon. This is due to the weight on the horse's back and the swaying action of the cart while in motion.

Boat horses are very subject to sore shoulders.

These sores take a long time to heal up. Prevention is better than cure. Collars and saddles therefore should fit well, should be kept well padded, in a good state of repair, and thoroughly dry and clean.

Young horses are very liable to sore shoulders, because the shoulder skin is not yet hardened with work. A solution of salt or alum applied to the shoulders, hastens this hardening process.

Eczema.—This disease is not common in a well-cared-for stud. It is caused by neglect in grooming, or by unsuitable feeding. The hair falls out and the skin assumes a dry scaly appearance. Treatment of the skin, with good grooming and feeding, will soon cure this trouble.

Mange.—This disease is due to a parasite which burrows under the skin, causing great irritation. The parts affected are the head, neck and body. The hair falls out, showing skin covered with scaly material. This is a serious disease in a stud of horses, as the horse affected is, by order of the Ministry of Agriculture, prohibited from working on a public highway. The parasites soon pass from one animal to another, and the greatest care must be taken in isolating the affected animal and carrying out thorough disinfecting measures in the stable. The woodwork of the stable, cleaning utensils and harness must be thoroughly treated with some parasiticide. The treatment of mange is a tedious one, and it may take weeks to make a complete cure.

Leg Mange.—This disease is also due to a somewhat similar parasite, but the parasite lives on the skin of the legs. It causes intense irritation, making the animal stamp and kick. Not only does the horse suffer, but shoes are twisted and broken, and this means an economic loss. The best method of treating this disease is by the construction of a leg bath. This bath is filled with a solution of disinfectant, and the horse stands in it two or three times a week, thus killing the parasites.

The Care of Sick Horses.

Loose Box.—Good nursing and attention are of primary importance in the treatment of disease. As a rule, the first procedure is to place the sick animal in a well-ventilated and well-lighted loose box, as already described. In affections of the eyes or nervous system, the loose box should be darkened and the animal kept as quiet as possible. It is most essential that the loose box, although well ventilated, should be free from draught. The temperature of the box should be cool, but not positively cold. The box must be kept perfectly clean, dry, and sweet with some disinfectant powder.

Rugs, etc.—The warmth of the patient must be kept up by the use of hood rugs, and bandages on the legs. According to the weather, the clothing should be increased or decreased. A second set of rugs should be available, as the patient may break out into an excessive perspiration, wetting the clothing, which must then be changed immediately. Bandages which are made of flannel should be wrapped *loosely* round the lower extremities of the legs. If too tight, they retard the circulation.

Grooming.—When grooming the sick animal, only part of the body should be exposed at one time. Further chills are thus avoided.

Water.—Drinking water should be kept in the box at all times, and should be changed frequently, to ensure freshness.

Food.—The appetite of the sick horse is very often capricious and small. Small feeds should therefore be given, and if the food is not soon cleared, it should be removed and replaced by a fresh feed later on. Mangers, buckets and cleaning utensils must be kept scrupulously clean. The sick-horse attendant should be thoroughly experienced and attentive, and should be most observant, quickly noticing any change of symptoms which the sick patient may develop.

CHAPTER XXI

STREET CLEANSING

Part I. The Law Relating to Street Cleansing.

Definition.—By street cleansing is meant broadly the removal of mud, dust, manure and refuse from the surface of streets, and the operations incidental thereto. In certain cases, the service extends to footpaths, alleys, courts and steps.

Composition of Street Refuse.—The matter deposited on the streets varies, both in kind and in quantity, according to circumstances. It comprises, *inter alia* :—

Dust arising from the attrition of the road surface;

Horse droppings, though with the growth of motor transport the streets are becoming more and more free from this material;

The pulverised residue of granite chippings, shingle, sand, and other material spread by the Local Authority to counteract slippery road surfaces;

Paper, straw, and other matter falling from passing vehicles, or surreptitiously swept out of shops;

Tram and bus tickets, cigarette and sweet wrappings, fruit skins, and other litter cast aside by a careless public.

Each town will have its peculiarities. For instance: in Rochdale, cotton, both in its raw state, fallen from the bale in transit by road, and in the form of "fluff," escaping from the mill during the first stages of manufacture, may often be seen in the streets, in spite of efforts to prevent its dissemination. Also, mud from unadopted and unpaved streets and back passages is carried by the wheels of vehicles and the shoes of pedestrians and deposited on the paved streets.

Street Cleansing, a Maintenance and Public Health Service.—The significance of street cleansing as a maintenance service, *i.e.*, the maintenance of the streets in such a condition as to make possible the safe and convenient passage of vehicles, animals and pedestrians, is fairly obvious. Its significance as a public health service may not be immediately apparent, but is more readily understood when we compare the state of our streets to-day with that which existed in former times. Macaulay in his "History of England" gives an illuminating description of the condition of London streets some two hundred and fifty years ago. He says :—

> "If the most fashionable parts of the capital could be placed before us, such as they then were, we should be disgusted by their squalid appearance, and poisoned by their noisome atmosphere. In Covent Garden a filthy and noisy market was held close to the dwellings of the great. Fruit women screamed, carters fought, *cabbage stalks and rotten apples accumulated in heaps* at the threshold of the Countess of Berkshire and of the Bishop of Durham.
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> "The centre of Lincoln's Inn Fields was an open space where the rabble congregated every evening, within a few yards of Cardigan House and Winchester House, to hear mountebanks harangue, to see bears dance, and to set dogs at oxen. *Rubbish was shot in every part of the area.* . . .
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> "*Saint James's Square was a receptacle for all the offal and cinders, for all the dead cats and dead dogs of Westminster.* An impudent squatter settled himself there, and built a shed for rubbish under the windows of the gilded saloons in which the first magnates of the realm gave banquets and balls. It was not till these nuisances had lasted through a whole generation and till much had been written

about them, that the inhabitants applied to Parliament for permission to put up rails, and to plant trees.

"When such was the state of the region inhabited by the most luxurious portion of society we may easily believe that the great body of the population suffered what would now be considered as insupportable grievances. The pavement was detestable; all foreigners cried shame upon it. The drainage was so bad that in rainy weather the gutters soon became torrents. Several facetious poets have commented on the fury with which these black rivulets roared down Snow Hill and Ludgate Hill, bearing to Fleet Ditch a vast tribute of animal and vegetable filth from the stalls of butchers and greengrocers. This flood was profusely thrown to right and left by coaches and carts. To keep as far from the carriage road as possible was therefore the wish of every pedestrian. The mild and timid gave the wall. The bold and athletic took it. . . .

"When the evening closed in, the difficulty and danger of walking about London became serious indeed. *The garret windows were opened, and pails were emptied*, with little regard to those who were passing below. Falls, bruises, and broken bones were of constant occurrence. For, till the last year of the reign of Charles the Second, most of the streets were left in profound darkness."

We have certainly progressed since those days! Our streets are not now regarded to the same extent as the natural dumping ground for refuse and filth of all kinds, but progress has been gradual.

Supplementing the improvement (voluntary or enforced) of the habits of the people and the better street surfaces with which we are familiar, organised street cleansing is now an accepted duty of the Local Authority. Not the least of the blessings resulting from this service are the improved amenities afforded to dwellers in crowded areas, whose houses border the street. In such cases, effective street cleansing lightens the task of home cleaning, safeguards the health of the children whose principal playing space is in the street, and makes for greater atmospheric purity in districts where breathing space is all too meagre.

Streets, therefore, must be cleansed for reasons of personal comfort, cleanliness and health, as well as for the convenience and safety of pedestrians and traffic.

Law.—A Local Authority is empowered or required, as the case may be, to cleanse the streets of its district, by virtue of *Section* 42 *of the Public Health Act*, 1875, which also deals with the removal of house refuse and the cleansing of privies, cesspools, etc.

Section 44 *of the same Act* empowers a Local Authority who do not themselves undertake or contract for the cleansing of footways and pavements (*i.e.*, footpaths) adjoining any premises, to make bye-laws imposing the duty of such cleansing, at such intervals as they think fit, on the occupier of any such premises.

"An urban authority may also make bye-laws for the prevention of nuisances arising from snow filth dust ashes and rubbish. . . ." This power is extended by Section 26 of the Public Health Acts Amendment Act, 1890, to include the making of bye-laws for preventing the dropping or spilling on streets of offensive or noxious matter or liquid from receptacles or vehicles, and for compelling the cleansing of any place whereon such matter or liquid shall have been dropped or spilt.

Bye-laws made in this connection by the Rochdale Corporation in 1912 include the following :—

2. The occupier of any premises fronting, adjoining or abutting on any street shall, as soon as conveniently may be after the cessation of any fall of snow, remove or cause to be removed from the footways and pavements adjoining such premises all snow fallen or accumulated on such footways and pavements in such a manner and with such precautions as will prevent any undue accumulation in any channel or carriageway or upon any paved crossing.

3. Every person who shall remove any snow from any premises shall deposit the same in such a manner and with such precautions as to prevent any undue accumulation thereof in any channel or carriageway or upon any paved crossing.

If in the process of such removal, any snow be deposited upon any footway or pavement, he shall forthwith remove such snow from such footway or pavement.

4. Every person who shall throw salt upon any snow fallen or accumulated on any footway or

pavement shall forthwith effectually remove from such footway or pavement the whole of the product resulting from the mixture of the salt with the snow.

5. The occupier of any premises who shall remove or cause to be removed any filth, dust, ashes, or rubbish produced upon his premises shall not, in the process of removal, deposit such filth, dust, ashes, or rubbish, or cause or allow such filth, dust, ashes, or rubbish to be deposited upon any footway, pavement, or carriageway. Provided that this bye-law shall not be deemed to apply in any case where an offence is committed against Section 98 of the Town's Improvement Clauses Act, 1847.

6. (*a*) Every person who shall remove any filth, dust, ashes or rubbish from any premises, or from any cart, carriage or other means of conveyance across or along any footway, pavement or carriageway, shall use a suitable vessel or receptacle properly constructed and furnished with a sufficient covering so as to prevent the escape of the contents thereof; and shall adopt such other precautions as may be necessary to prevent any such filth, dust, ashes, or rubbish from being slopped or spilled, or from falling in the process of removal upon such footway, pavement, or carriageway.

(*b*) Every person who shall convey any filth, dust, ashes, or rubbish through or along any street shall use a cart, carriage, or other means of conveyance, properly constructed and furnished with a sufficient covering so as to prevent the escape of the contents thereof.

(*c*) If in the process of such removal or conveyance as aforesaid any filth, dust, ashes, or rubbish be slopped or spilled, or fall upon any footway, pavement or carriageway, he shall forthwith remove such filth, dust, ashes, or rubbish from the place whereon the same may have been slopped or spilled or may have fallen, and shall immediately thereafter thoroughly sweep or otherwise thoroughly cleanse such place. Provided that this bye-law shall not be deemed to apply in any case where an offence is committed against Section 98 of the Town's Improvement Clauses Act, 1847.

16. Every person who shall offend against any of the foregoing bye-laws shall be liable for every such offence to a penalty of five pounds, and in the case of a continuing offence to a further penalty of forty shillings for each day after written notice of the offence from the Council.

Provided nevertheless, that the justices or court before whom any complaint may be made or any proceedings may be taken in respect of any such offence may, if they think fit, adjudge the payment as a penalty of any sum less than the full amount of the penalty imposed by this bye-law.

Certain bye-laws "for the good rule and government of boroughs" made pursuant to *Section* 23 *of the Municipal Corporations Act*, 1882, have a bearing on the cleanliness of streets, as witness these extracts from bye-laws made in that behalf by the Rochdale Corporation in 1914:

3. No person shall for the purpose of advertising throw about or deposit in any street or public place any bill, placard, or other paper.

4. No person shall (i) sweep or otherwise remove from any shop, house or other premises into any street any waste paper, hay, straw, shavings, or other refuse, or being a pedlar, hawker, newsvendor or other street trader throw down and leave in any street any waste paper, hay, straw, shavings or other refuse; (ii) throw down and leave in any street any bill, placard or other paper which shall have been torn off or removed from any bill-posting station.

5. No person shall in any street or public place throw or leave any orange peel, banana skin or other dangerous substance on any footway.

6. No persons shall throw, place or leave, any bottle or any broken glass or other sharp substance (not being road material) on or in any street or public place in such a position as to be likely to cause injury to passengers or damage to property.

8. (*a*) The owner of a vehicle shall not allow such vehicle to be used in a street for the purpose of carrying coal, coke, lime, mortar or building material, unless it be so constructed and kept in such repair that it will carry its load without the repeated dropping of any part or parts thereof.

(*b*) Every person loading a vehicle with coal, coke, lime, mortar or building material shall load it in such a manner as to prevent as far as possible the repeated dropping of any part or parts of the load.

20. If any person offends against these bye-laws he shall be liable to a penalty not exceeding forty shillings and in the case of a second or subsequent conviction to a penalty not exceeding five pounds.

Note that under *Section* 16 *of the Local Government* (*England and Wales*) Act, 1888 :—

1. A county council shall have the same power of making bye-laws in relation to their county, or to any specified part or parts thereof, as the council of a borough have of making bye-laws in relation to their borough under section twenty-three of the Municipal Corporations Act, 1882, and section one hundred and eighty-seven of the Public Health Act, 1875, shall apply to such bye-laws :

2. Provided that bye-laws made under the powers of this section shall not be of any force or effect within any borough.

Bye-laws applied for recently by the Bristol Corporation include the following, which, in some respects, is an improvement on others already quoted :—

1. No person shall throw down or deposit and leave in any street or public place any newspaper or any paper bag, wrapping or sheet such as is likely to create or tend to create a litter in or to affect or tend to affect injuriously the amenities of the street or public place.

In most towns the law relating to the cleansing of footpaths (except of snow) appears to be unwritten. The Corporation usually cleanse pavements adjoining public buildings, municipal property and vacant lands, but the remainder is left to the occupiers of the adjoining properties, except that the orderly men and sweeping gangs remove any large pieces of paper or other litter as they proceed along their appointed streets. In 1910, out of twenty-nine of the larger English and Scottish cities and towns, it was found that in only eleven of such towns did the Corporation carry out the work of footpath cleansing.

The duty of regularly cleansing footpaths could be imposed on the occupiers of premises adjoining such footpaths by bye-laws made under Section 44 of the Public Health Act, 1875, but the writer is not aware of any such bye-law. The Corporation of Swansea proposed to make such a bye-law in 1921, but for some reason it was not approved.

In London the cleansing (including after a fall of snow) of the footways of streets which are repairable by the inhabitants at large is placed upon the sanitary authority by *Section* 29 *of the Metropolitan Management Act*, 1855.

In the case of streets not repairable by the inhabitants at large, the duty of cleansing footways after a fall of snow is placed on the occupier of the adjoining premises by the Metropolitan Boroughs (General) Bye-laws.

Section 45 *of the Public Health Act*, 1875, empowers any urban authority to provide, in proper and convenient situations, receptacles for the temporary deposit and collection of dust, ashes and rubbish; they may also provide fit buildings and places for the deposit of any matter collected by them under Section 42.

This section appears to cover the provision in streets of orderly bins and litter baskets for the temporary deposit of street refuse, but not of orderly bins for the storage of sand, grit, or shingle; so the deficiency is remedied by:

Section 13, *Public Health Act*, 1925 :—

(1) The local authority may provide and maintain in or under any street, orderly bins or other receptacles, of such dimensions and in such position as the local authority may from time to time determine, for the collection and temporary deposit of street refuse and waste paper, or the storage of sand, cinders, grit or shingle.

(2) Nothing in this section shall be taken as empowering the local authority to hinder the reasonable use of the street by the public or any person entitled to use the same, or as empowering the local authority to exercise their powers under this section in such a way as to create a nuisance to any adjacent owner or occupier.

This latter Act is an adoptive one (so far as relates to our subject); the Rochdale Corporation have not adopted it, but have a similar power under the Rochdale Corporation Act, 1925.

Section 27 *of the Public Health Acts Amendment Act*, 1890, reads :—

(1) Where any court, or where any passage leading to the back of several buildings in separate occupations, and not being a highway repairable by the inhabitants at large, is not regularly and

effectually swept and kept clean and free from rubbish or other accumulation to the satisfaction of the urban authority, the urban authority may, if they think fit, cause to be swept and cleaned such court or passage.

(2) The expenses thereby incurred shall be apportioned between the occupiers of the buildings situated in the court or to the back of which the passage leads in such shares as may be determined by the surveyor of the urban authority, or (in case of dispute) by a court of summary jurisdiction, and in default of payment any share so apportioned may be recovered summarily from the occupier on whom it is apportioned.

Street Litter.—The degree of cleanliness of the streets of a town has a marked effect on the impression formed by visitors. The unnecessary littering of streets betokens a lack of civic responsibility on the part of the offender. It is both foolish and a breach of good manners, because every piece of paper or other refuse dropped in the street has to be collected at the expense of the ratepayers, *i.e.*, the public, and, until it is collected, is an offence to the eye, helping to spoil the amenities of the place for those who are more sensitive and observant.

Bye-laws are helpful only if they are vigorously enforced by the appropriate authority, and in this connection it is interesting to note that the Home Secretary, in a recent case, before approving the making of a bye-law intended to prevent street litter, required an assurance that the Local Authority (Bristol Corporation) would (*a*) make a continued effort to bring and keep the bye-law before the public notice, and to educate public opinion in the matter; (*b*) make a liberal provision of receptacles in the streets in which the public must be encouraged to deposit waste paper; and (*c*) do everything to uphold the bye-law and prevent it becoming a dead letter. But all the existing bye-laws dealing with street litter fall short of the maximum usefulness, in that they leave untouched the scattering in the streets of tram and bus tickets, one of the most prolific present-day sources of street litter. The Englishman is jealous of his liberty, even of his liberty to be a nuisance to others, and does not like restrictions. In Vienna, the authorities are not so diffident about hurting the feelings of the tram-ticket fiend. There, we are told, the police have power to collect an immediate fine of 2*s*. from any person who litters the streets. One imagines that the streets of our towns would be practically free from preventable litter very soon after the adoption of such a rule.

Publicity.—In the absence of effective measures for the suppression of preventable litter by pedestrians, the active cleansing officer has to resort to publicity in varying forms and intensity. In Rochdale, this publicity takes the following forms :—

Instruction to schoolchildren by teachers: the Education Secretary circularises all schools on this subject at the request of the Cleansing Director.

Slogans painted on Cleansing Department vehicles: "Don't litter the streets."

Enamelled signs on wire litter-baskets attached to tramway standards and lamp-posts. "Help to keep the town tidy. Please deposit paper, tram-tickets, etc., in this basket."

Notices painted on orderly handcarts. "Don't litter the streets. Please deposit waste paper, match boxes, etc., in here, or the wire baskets on standards."

A specially designed device printed in colours, on the envelopes used by the Cleansing Department. This device, which displays the departmental slogan (and a view of Rochdale's famous Town Hall, to give it local colour), is also printed on adhesive stamps, which are attached, in suitable cases, to correspondence and other documents emanating from the department.

Artistically printed notices displayed in tramcars:

"Keep Rochdale tidy and be proud of it.
Don't drop your ticket in the street."

Immediate personal appeal by members of the Cleansing Department staff, to persons seen to litter the streets.

Reference to the subject during lectures on "Public Cleansing" by the Cleansing Director or his assistants.

Street Surfaces.—Following the advent of the motor, the re-asserted supremacy of the road has come to the assistance of the Cleansing Officer. The laying of improved street surfaces, such as tar macadam, asphalt and concrete, has in recent years very greatly facilitated the work of street cleansing. In the days of the old water-bound (or mud-bound) street, enormous quantities of mud in winter, and dust in summer, had to be removed from the street surfaces at heavy total costs.

Water-bound macadam requires a big expenditure if it is to be kept clean, and if the surface is of soft stone, or uneven and full of potholes, it becomes an impossibility to maintain it clean. Such streets have to be swept with hand-brooms, as horse-drawn or machine brushes draw out the mud binding, with consequent quick breaking up of the surface. Happily, this type of street is fast disappearing in towns. It is being replaced by more stable and impervious materials.

The smoother and more impervious the street surface, the more sanitary it becomes, since it is more easily maintained in a state of cleanliness. Graded according to hygienic merit, street surfaces may be arranged as follows :—

1. Asphalt.
2. Tar macadam, with closely sealed surfaces.
3. Wood paving.
4. Granite setts.
5. Water-bound macadam.

Closely associated with its sanitary merit is the amount of labour required to cleanse a street surface; and the efficiency for this purpose of the various kinds of surface follows generally the same grading, subject to the proviso that the labour required for cleansing a given area of every kind of street surface increases, as the condition of the surface deteriorates. Thus, an asphalt street in poor condition will require more labour than a wood-paved street in good condition.

It should not be overlooked, however, that on the smoother surfaces, such as asphalt and concrete, every particle of dirt is apparent, so that, if they are to look well, such surfaces require more frequent and thorough cleansing than, say, sett paving, which hides much refuse in its crevices. In certain situations, too, the work of cleansing smooth-surfaced streets is increased by the fact that grit or shingle, put down to counteract slipperiness, becomes crushed by traffic and must soon be removed.

Wood-block paving occupies a position midway between asphalt and granite setts, generally calling for more cleansing than the former and less than the latter. This form of paving is being replaced to an increasing extent by more modern and impervious forms of paving, but it is worth while here to say that wood blocks used for this purpose might be either hard woods of the Jarrah type or soft creosoted deals. From a cleansing and sanitary point of view, the hard woods are good, if properly seasoned and well shrunk before being laid, but failure to observe this condition has caused much trouble, through the blocks becoming twisted, loosened and rocked from their foundations in course of time by the continued wear of traffic.

Good dry deal can be made almost impervious to moisture by forcing into the planks before cutting a saturating quantity of creosote under pressure. After a time, however, continual heavy traffic causes a crushing of the top crust, and the opening fibres permit dung and other refuse to be ground in, with consequent deterioration of its hygienic properties.

According to Mr. T. P. Francis, City Surveyor of Bangor, " wood-block paving has in some quarters been condemned, in consequence of an attributed liability for the dust, occasioned by wear, to irritate the eyes and lungs. It should only be used on wide, sun-dried streets; it absorbs liquids and manures and, at times, gives off a disagreeable smell in narrow streets."

Water-bound macadam occupies the lowest place in the scale of cleansable street surfaces, for reasons already explained.

For their satisfactory cleansing, street surfaces, of whatever kind, must be kept in a good state of repair; the breaking open of streets for work on mains and sewers greatly increases the difficulties of cleansing.

Local Conditions.—The work of street cleansing in towns can be divided into the following classes :—

1. Gritting.
2. Washing, swilling or flushing.
3. Watering or sprinkling.

4. Sweeping, and removal and disposal of sweepings.
5. Gully cleansing, and removal and disposal of gully contents.
6. Snow clearance.

The exact manner in which the work is executed in different towns will vary according to their size, situation, climate, industry or class, road gradients, type and condition of road surfaces, preponderant type of transport, character of the population and administration of the district. The standard of street cleanliness maintained may be affected by the demands of the public; it may have to be modified for reasons of cost; and, further, it is dependent on the ability of the executive officer to give value for money. Generally, the standard of cleanliness is rising; what would pass without notice a few years ago will now raise a storm of protests.

Whatever method we adopt or practise, it is our duty to cleanse the streets in the best possible manner, at the lowest possible cost, and with the least inconvenience, both to vehicular traffic and to pedestrians; and therefore the Cleansing Director must be always observant, and fully informed of modern developments, so that he may choose the methods best suited to his town and circumstances.

Part II. Methods of Cleansing.

Operations and Methods.—The variety of local conditions, and therefore of methods, in different towns is so great as to make it hardly possible for any one officer to have experience of either all conditions or all methods. Therefore, the preparation of such a chapter as this necessitates an examination and comparison of experiences and views from many quarters, and their consideration in the light of one's own experience and judgment. It is in this attitude that the writer has approached his task.

All the estimates of output and cost of work given in this chapter should be regarded merely as approximations, the variations in circumstances alone being sufficient, in many cases, to render comparison at least misleading, if not impossible; further, it has to be admitted that the accurate measurement of work done in street cleansing is a difficult matter, and reliable costing of the various processes a rare event.

Gritting.—Road-construction engineers have long sought a road surface which, while being sufficiently strong, durable and even for modern requirements, should be non-slippery under normal conditions, especially on gradients. But practically all impervious road surfaces become slippery under certain conditions (especially when they are not perfectly clean), and are then unsafe for horses, to a less extent for motor vehicles, and in extreme cases for pedestrians. Generally, the remedy is the spreading of granulated material of suitable hardness.

A heavy shower of rain usually precludes any need of sand or grit, but a very slight shower, a mere damping process, renders the surface greasy and difficult to all types of traffic. Roads are usually in a dangerous condition immediately following a mist, which causes the surfaces, especially those paved with hard wood or asphalt, to become speedily coated with a slippery film, not sufficiently wet or substantial to be removed by a squeegee or brush. Frost preceding, accompanying or following mist or fog will cause sudden slipperiness, while a week's continued hot sunny weather will give an almost glassy smoothness to well-worn hard road surfaces which are subject to heavy traffic.

The process known as "gritting" or "shingling" (or if sand be used, "sanding") should be carried out as sparingly as is consistent with safe road conditions, for two reasons :—

1. Economy of material, labour and transport.
2. The grit is reduced ultimately to dust or mud, and, as such, becomes a nuisance and calls for further treatment.

The choice of material depends on several factors, viz., the type of road surface, the specific cause of slipperiness and the availability (including cost) of various kinds of material suitable for the purpose.

Material used for gritting must :—

(*a*) Give a ready grip to the feet of horses.
(*b*) Not crush too easily.
(*c*) Not be so hard as to damage the road surface.

Granite chippings, of $\frac{3}{8}$ or $\frac{1}{4}$ inch down, but without dust, are good. Also good, but not quite so hard, is spar gravel of similar size—both are clean in use. The price per ton of these materials, in truck loads to user's station, will be in the region of: granite chippings, 20*s*., spar gravel, 15*s*.

Sand, which must be dry, for effective spreading, and sharp, to serve its purpose, is the best material to use for the safety of pedestrians on slippery footpaths, slopes, steps and crossings, and will be shovel-spread by hand.

Grit may be shovel-spread by hand from carts or motors; or by means of special gritting machines, which may be either :—

(*a*) Horse-drawn or trailer vehicles, specially constructed for the purpose; or

(*b*) Special machines, such as the "Simplex," which, in use, is towed behind a horse-cart or motor lorry, the container or hopper of which is hand-fed from the towing vehicle. The relatively low cost of this machine (£35 10*s*.) is one of its attractions.

The distribution of grit from a machine is by means of a revolving plate, on to which the grit is delivered by gravity at the required rate, and from which it is thrown by centrifugal force. In the case of (*a*) the material is fed towards the distributor either by hand or by a wooden conveyor or brattice, chain-driven from one road wheel, while the distributor is similarly driven. In both cases (*a*) and (*b*), the width of the cast or spread and the rate of feed are adjustable.

The quantity of grit required for a given area, and the cost of spreading, will vary according to circumstances, but may be taken approximately as follows :—

	Hand Spread.	Simplex Machine Spread.
Per 1000 square yards		
Grit required	0·75 cwt. to 1·25 cwts.	0·5 cwt. to 0·75 cwt.
Cost, including grit, labour and haulage . .	8*d*. to 16*d*.	6*d*. to 8*d*.

Machine users claim as further advantages a more even distribution of the material, which probably accounts for the smaller quantity required, and greater speed. In this latter connection, we must know that when gritting is necessary it is required *at once*.

Advocates of hand spreading claim that a man spreading by hand can regulate his distribution of shingle to meet the varying requirements of different stretches or patches of road during one journey, *e.g.*, gradients or flats, exposed places or sheltered, wide places or narrow, smooth paving or rough, and when passing standing horses and vehicles, but hand-spreading, to be satisfactory, requires trained men, possessing the necessary dexterity and speed in the use of the shovel, and intelligence to gauge the varying requirements. Further, they must be reliable and must spread evenly, as an irregular distribution is generally ineffective.

Whichever method is used, a motor lorry is more suitable than a horse as the hauling unit, being in less danger on the unshingled portion of the road, which of necessity both must travel, and being speedier in transit between the depot and the point of operation.

For immediate application at dangerous or important points at a distance from the cleansing depot, it is usual to store a quantity of suitable material, either in shingle bins or on private property by arrangement with the occupier. Such material is spread as required, by the appropriate employees, or in some cases may be available for use by private carters using the particular road.

Washing, Flushing, or Swilling.—Experts agree that the most thorough cleansing of street surfaces can be accomplished by washing such surfaces with water applied under pressure, either from hand-hose connected to street hydrants or by special machines. But this method can only be applied extensively and regularly, if :—

(*a*) The water supply of the town is ample, and not subject to curtailment in dry periods.

(*b*) The sewerage and sewage disposal systems are adequate to deal with the additional water and refuse resulting from this process.

(*c*) The road surfaces are sufficiently well made and maintained to withstand the searching effect of water so applied.

The great advantage of this process, which is known variously as washing, flushing or swilling, is that it effectively gets rid of all dust and slime, and of oil from motor vehicles; further, the need for gritting is greatly reduced. In the summer it has a refreshingly cooling effect.

The work must be done at night, when the streets are free from traffic and people. An important preliminary to this work is first of all to remove, by sweeping and picking up, all loose material. If this plan were always adopted there would be little objection to street washing, but the custom does not appear to be prevalent. Consequently a quantity of material which should be picked up is deposited in the sewers, to the annoyance of the officials responsible for their cleansing. Any practice that wilfully removes the work from one department, to cause it to devolve upon another, is to be deprecated.

[*By courtesy of Dennis Brothers, Ltd., of Guildford.*

FIG. 119.—"Dennis" street washing and sprinkling machine.

The Borough of Lambeth owns two of these 1100-gallon combined street washing and watering machines and gully emptiers.

Given the necessary pre-requisite of comparative freedom from loose refuse, the effect of street washing is substantially that of a heavy rainstorm, therefore it is not usual to wash streets which do not require the service more often than twice a week, except in periods of dry weather; the English climate usually obliges at least twice a week! This means in effect that washing is done on important streets only.

Of the two alternatives, hose-washing by hand is the more effective, but this calls for a sufficient number of hydrants at distances of not more than 100 to 200 yards apart. A hose-gang of two men, with a reel barrow carrying three 50-feet lengths of hose and a stand-pipe, is capable of washing about 2500 square yards (about 250 yards of 30-feet road) per hour, at a cost of, say, 1*s*. to 1*s*. 3*d*. per 1000 square yards for washing only. The pressure at the end of a hose, varying from 40 to 90 lb. per square inch, will loosen most of the refuse adhering to the road. Any caked mud or manure clinging to the surface in spite of the flushing must be removed by scrapers. The cleansing must be thorough if it is to serve its purpose. Immediately following the hose-gang there should be two men armed with brooms and squeegees to move slime to the channels and sweep it into the gullies. They should also be provided with tools for opening gratings and letting off any choked gullies which they encounter.

Where hose-washing is for any reason impracticable, recourse must be made to mechanical washing machines. These usually carry one or two circular rose sprays or fish-tail jets, low in the front of the vehicle. The vehicle may be provided with special side jets for washing channels, especially when the front jets are not controllable. A powerful pump is fitted, which forces the water through the jets. Such machines may be pêtrol driven or electrically propelled. A tramway flushing and watering car, of 2000 gallons capacity, is used in dry periods over the tramway routes at Rochdale. It is generally admitted that mechanical washing machines do not work as efficiently as the hose and reel under manual labour, but the machines are being continually improved and rendered more economical in working.

Sweeping.—Sweeping may be manual, or mechanical, or a combination of both.

Hand sweeping, which is mostly a daytime service, is usually practised in streets of secondary or less importance. It may be carried out either on the length system, otherwise known as the beat, or patrol system; or on the gang system; or by a combination of both. In the former, each man is assigned a section of street (or streets) the length of which is determined by its width, amount and kind of traffic, importance of the street and the nature of its surface. The condition of a lengthman's street or streets is a constant index of his efficiency. Under this system a fair output would be from $\frac{3}{4}$ to 1 mile of 30-feet street per day, variable according to the amount of work.

Sweeping by the gang system is done, as its name implies, by gangs, usually consisting of from five to seven men, including a leading hand or working ganger. All the gang except two, sweep transversely across the road, commencing in the middle, and pushing the refuse into the channels. One or more of these sweepers should be provided with a scraper, fixed to the top of his brooms tail, with which to remove any caked refuse. The remaining two sweepers follow on, sweeping along the channels, and forming the refuse into small heaps to be loaded into carts.

An approximate output for satisfactory sweeping would be one-twentieth of a mile per man per hour; but by what is known as "picking," *i.e.*, sweeping the dirty places and missing the clean portions, twice this output could be achieved.

Where the gang system is worked in conjunction with mechanical sweepers, the gang is reduced to not more than four sweepers, whose work consists of "rucking" or making into heaps, near the channels, the "trail" left by the machine; in sweeping the channels, which the average machine sweeper cannot do, and crossings, *i.e.*, the paved ends of abutting streets; removing the more noticeable litter from footpaths and any refuse dropped on the carriageway since the passage of the sweeping machine, and opening any choked gully grates. Machine sweepers are of two types: (*a*) horse-drawn, and (*b*) self-propelled. Both have rotary brushes so arranged as to sweep obliquely to the line of travel. As the brush revolves, the sweepings are pushed outwards towards the rear end of the brush, and deposited in a line at the side of the machine. The brush can be lifted off or lowered on to the road by means of a lever under the control of the driver.

It is generally admitted that horse-drawn sweeping machines impose such a strain on horses as to shorten materially their working life.

A good mechanically operated sweeper will do the work of from ten to twelve men. The machine starts with the off-side wheel just over the middle of the road, thus sweeping to a line on the near side. It then returns, sweeping down the other side, and comes back over the first side, sweeping the line of dust still nearer the channel. The process is repeated until, when the machine has finished, two lines of sweepings lie on the street, one near each channel. Two sweepers follow and form this into small heaps, which are afterwards picked up by the carts. By this method, a good petrol machine will sweep from $\frac{3}{4}$ to 1 mile of 30-feet road per hour.

Approximate costs of sweeping secondary roads by hand and machine are:—

		Per 1000 square yards. *s.* *d.*
Hand sweeping and rucking	1*s.* 3*d.*	1 6
Picking up	3*d.*	
Machine sweeping	6*d.*	
Rucking by hand	3*d.*	1 0
Picking up	3*d.*	

A development of the sweeping machine is the combined sweeper and collector, a machine which not only sweeps the streets, but picks up the sweepings at the same time. Where the street surfaces are sufficiently good to allow the machine to do its work well, this combination of operations is ideal in the hygienic aspect, eliminating the possible scattering of dust, with its consequent irritant effect on humans, and the contamination of food stuffs. A diagonal road brush is set to sweep the refuse from the channel or curb to the centre of the road, directly opposite to the practice with non-collecting sweeping machines. At the rear end of this broom there is a casing having an opening through which the sweepings are thrown. This casing contains a series of rotors, or transfer brushes, which lift the refuse and deposit it through another opening at the top end of the casing into the body, which is capable of holding about 3 tons of refuse and of being tipped. The reason for the alteration in the direction of sweep is that the greatest proportion of street refuse is found in or near the channel or gutter, and by sweeping this first, any surplus not immediately removed by the rotary brooms is left for the next traverse, when the amount of material will be considerably reduced and the rotors will be able to deal with it in an efficient manner.

As the depth of the channels varies considerably, even in the same town, it is essential that the utmost freedom should be allowed the road brush near the curb, and the designers of this machine have met the conditions by fixing the operation of collection on the off side as being least subject to variations in the road surface.

The all-in cost of operating this outfit varies according to local conditions from 8*d*. to 1*s*. 3*d*. per 1000 square yards.

For completeness, mention should be made of sweeping machines constructed for use over tram routes, and towed during night time behind tramway tractive units, which may also be watering cars. The system is falling out of favour, on account of its being limited to tramway routes, of its cumbersomeness and consequent inconvenience to night motor traffic.

The "Orderly" System.—"Street Orderlies" (either boys or men) are allocated definite lengths of busy or important streets to keep clean during the day. They are provided with brooms, squeegees for use in wet weather, bags for paper, and hand-carts or barrows in which to load their sweepings. The orderly works up and down his length as circumstances require, but usually four or five times a day, collecting the miscellaneous litter which each day brings to his "beat." He empties his paper sack and hand-cart at some convenient dump or small depot, to be removed at suitable intervals by cart or motor to the appointed tip. Alternatives to this procedure are the depositing of such sweepings in—

(*a*) Street orderly bins, sunk into the footpath and emptied at night.

(*b*) Bins carried on a bin-truck or carrier. Such trucks usually carry two bins, and may take the place of barrows or hand-carts. These bins are emptied as often as necessary during the day into a visiting motor vehicle, which tours the district and relieves all orderlies of the collected matter.

The orderly service in busy thoroughfares is usually a day-time adjunct of night cleansing, and about three orderlies per mile are required for 30 feet streets.

Collection of Sweepings.—Where the collection, picking up, or "lifting" of sweepings is done manually, the horse-drawn cart is still the most-used vehicle. By reason of the greatly reduced quantity of street refuse removable these days, motor vehicles have less advantage over horse-drawn vehicles than in most other occupations. The horse can move continually, the driver is the picker up, and on the casual tips frequently used for the deposit of sweepings, the horse-cart is usually more manageable than a motor.

Disposal of Sweepings.—The disposal of the matter collected from the streets is especially dependent on local conditions. In former days, street sweepings were easily disposable to gardeners and farmers, but with their smaller manure content, and the addition of oil and petrol from motor traffic, they are now more difficult to get rid of. Apart from such outlets as remain in that direction, the principal method is tipping or dumping. According to circumstances, the scavenging carts may tip their contents either on suitable tips, or failing this, at a depot, for subsequent removal to the ultimate tip by road vehicles, aërial ropeway, canal barge or railway, as the case may be.

Sprinkling and Watering.—Incidental to sweeping in dry weather, is the process of sprinkling, *i.e.*, the spraying of water, under slight pressure only, on the street surfaces to be swept, the object being to damp the dust and so prevent its dissemination while sweeping and lifting are in progress.

For hand or horse-broom sweeping, the operation is performed by a watering machine, *i.e.*, a vehicle either horse-drawn or self-propelled, carrying a tank of suitable capacity (varying from 350 to 2000 gallons), and fitted with a sprinkling device controlled by the driver.

All modern self-propelled sweepers are equipped with water tanks and sprinkling devices, and sprinkle as they sweep. The performance of both operations by one unit at the same time has its advantages. Under modern conditions, *i.e.*, of fast-moving traffic and less street refuse, there is a distinct tendency in dry weather for such refuse to be wafted to the channels, so that sprinkling (and sweeping) on the crown of the road becomes less of a necessity, and this is especially applicable to asphaltic surfaces, which are free from joints or interstices which tend to hold the refuse; instead it is found useful to " water " the channels and the adjacent strip of street surface. The term " watering " implies the use of more water to a given area, *i.e.* its application under rather more pressure than mere " sprinkling."

Small hand-drawn water carts are available for sprinkling in or near the channels, and in certain circumstances may be very useful in connection with street orderly work.

In very hot weather watering may proceed quite independently of sweeping, for the purposes of preventing the dissemination of dust, counteracting the softening and lifting of pitch grout and tar binding, and in making town conditions more tolerable for the general public.

As an emergency measure, for the sprinkling of places where dust becomes a nuisance during the day following a change in the weather, and when it is difficult to obtain hired horses for drawing the water vans, one Cleansing Director has provided his length-men with large watering cans, which they store in convenient places and use as required.

In coastal towns, sea water may provide an alternative to fresh water for street watering. On account of the affinity of salt for moisture, streets watered with salt water remain damp for a much longer time; and one authority states that one watering with sea water is as effective as three waterings with fresh water, so that if sea water can be procured and laid on the road at any cost less than three times the fresh water cost, it is preferable. However, it must be applied carefully, as it damages varnish, *e.g.*, of vehicles and shop fronts.

The management should devote some attention to the care of water-carrying vehicles, particularly at the close of the watering season. The intermittent application of water upon the iron tanks, together with the action set up by the use of disinfectants, speedily cause a rust to collect in the pipes, iron fittings and tanks. It is therefore advisable to scrape thoroughly the exposed portions of the tank, etc., and to give the surfaces thus cleaned a coat of good lead paint; they can then be put by until required for early spring painting. All repairs should be taken in hand during winter months, it being usual to overhaul a few at one time, so as to retain as many as possible for snow purposes, etc.

The interior should be scraped, cleansed and treated with bitumastic or other similar preparation. The pipes should be painted on the outside and freed from rust, corrosion and scale on the inside. Such precautions taken in time materially lengthen the life of the vans and fittings.

Gully Cleansing.—It is one of the duties of the cleansing department to make general arrangements for the regular removal of all refuse from gullies, together with an efficient system of flushing, to keep them clean and properly trapped. Gullies are receptacles placed at convenient intervals in the channels of streets to permit a ready escape of the surface water into the sewers. They may be constructed of bricks, rendered in cement on the surface, of glazed baked earthenware, or of cast iron, and are so made that the means of outlet into the sewer is brought near the top, thus providing a deep receptacle for the settling of any refuse matter that may be washed down and preventing such refuse from passing into the sewers.

It is this refuse that requires to be removed periodically, as in the first place it is likely to become offensive if allowed to remain long, and secondly, if not emptied it is likely to accumulate so as to stop the outlet, thereby preventing the passage of surface water into the sewer and causing the overflow of the gully. Immediately a gully is emptied it should be flushed thoroughly with clean water. This ensures thorough trapping and forces into the sewer the stale water, which may have become so highly charged with gases as to become useless as a seal.

It must always be remembered that a water seal is only effective so long as it does not become logged with gases. A given quantity of water can only carry a fixed measure of gas, consequently when the maximum quantity of gas has been absorbed, it will allow any further addition that may be thrust upon it to pass through. It thus becomes imperative at all times to flush the gullies thoroughly, to ensure renewing of the water seal. This also becomes an urgent necessity in very dry weather, as the heat of the atmosphere combined with the heat of the sewers tends to dry up the water rapidly, thus causing a direct opening between the street and sewers, whereby offensive smells arise, causing serious trouble to the health of the people, more especially to the children who make the streets their playground.

A gully is protected on the top by means of an iron grid, placed so as to permit of a ready flow of water and at the same time prevent any large articles of refuse from passing into it. Care should be taken that the bars of the grid be kept free from all accumulation of filth, so as to permit of a free flow of surface water in times of flood.

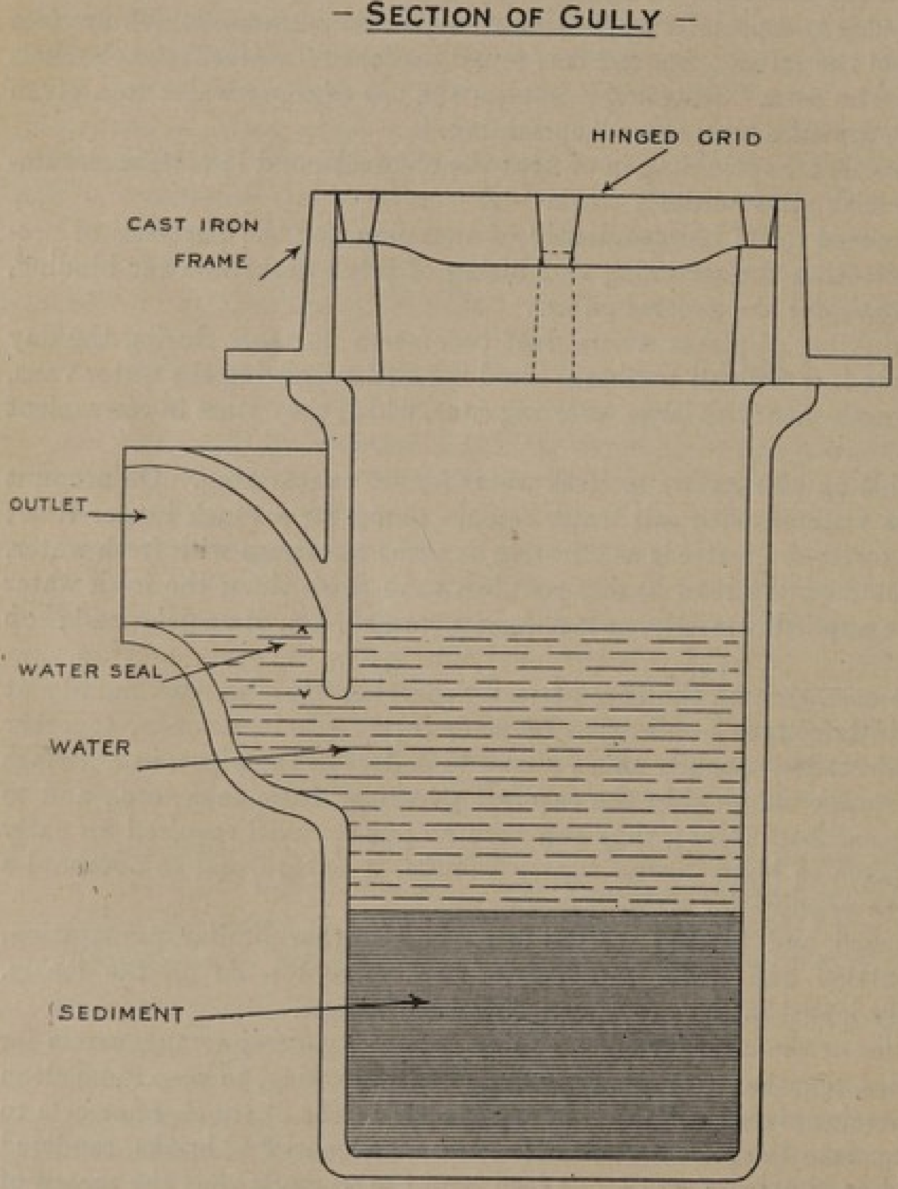

Fig. 120.

A street gully should be so constructed as to meet the following requirements :—

(*a*) It should be strong, simple and able to be cleaned easily, with smooth sides and bottom.

(*b*) It should possess a deep water seal.

(*c*) It should be of sufficient capacity to serve the requirements of the road surface in which it is placed.

(*d*) The outlet should be made so that it is in no danger of being damaged by heavy traffic passing over it.

(*e*) It should be so constructed as not to be easily choked by the washing down of ordinary road litter.

Where there are not sufficient gullies to warrant the employment of a mechanical gully emptier, or where the gullies are so small as to make it impracticable, the work has to be done by hand; the method being to lift out the sludge by means of a scoop attached to a long handle, and deposit it either (*a*) direct into a vehicle, (*b*) into buckets which are emptied into the vehicle or (*c*) on the street surface, to be picked up and put into the vehicle later. Methods (*a*) and (*b*) are preferable to (*c*), but where (*c*) obtains, the place where the gully contents have been put to await picking up should be swilled and brushed afterwards.

The vehicles used for the removal of gully contents are either tumbler carts, or, if an ordinary scavenging cart is used, it should be lined inside with sheet iron or steel, and the tail door properly fitted to prevent the escape of the semi-liquid contents.

A water cart should follow to flush the gully and re-seal it with clean water. An approximate cost for the complete operations of hand-emptying, lifting and carting away of contents, flushing the gully and swilling and sweeping the surrounds, is from 9*d*. to 1*s*. per gully per emptying.

During recent years several makes of mechanical vehicles of all types, steam, petrol and electrically operated, have been developed for gully emptying, with considerable success. These machines withdraw the contents from the gully by suction; in the case of the petrol and electrically operated vehicles, a vacuum is created in the sludge tank by a high-speed rotary air exhauster. In the case of the steam-operated vehicles, the vacuum is created in the mud tank or, better still, in a special vacuum dome, by means of a steam ejector. The preference lies with the steam vehicles, as the vacuum is obtainable more quickly, and it is available for use instantly upon the arrival of the machine at the gully. The mechanical gully emptiers are provided with tanks for carrying fresh water for flushing and re-sealing the gullies after emptying. The cost of machine emptying of gullies varies from 5*d.* to 8*d.* per gully, according to circumstances.

Naturally, the frequency of emptying will affect both the cost per gully and in total. With the reduction in the quantity of refuse produced in the streets, gullies do not now require to be emptied as often as formerly. Once a month may be a quite reasonable interval, but it depends on the circumstances. A gully at the bottom of a steep hill will silt up more quickly than the average.

Where the gully contents are small in quantity, they may be deposited at the local tip, provided that they are covered with street sweepings, screened refuse dust, or other less offensive material. Where there is a large quantity of this material, a good plan is to deposit it at the depot in a special tank or pit, so constructed that most of the water drains away. At convenient intervals the solid matter or sludge is removed, either by hand or by gravity, according to the construction of the pit or tank, and is taken to the tip.

Part III. Organisation.

Effects of Weather on Street Cleansing.—The routine work of street cleansing is always subject to emergency calls by reason of sudden weather changes and storms. Typical cases are:—

(*a*) Gritting, in the circumstances already explained.

(*b*) The clearance of channels, gullies and grates choked with débris washed down during a rainstorm.

(*c*) Watering, necessitated by dry wind or sudden heat. This liability necessitates provision for a rapid change-over. Depots and sub-depots must be near the work, and preferably in the centre of the districts they serve. Sub-depots may be merely lock-up tool sheds containing orderly barrows or trucks, brushes, shovels, squeegees, scrapers, gully tools, paper sacks and a supply of salt, sand and grit.

Rapid changes of climatic conditions also call for experience on the part of officials and workers.

Tools and Implements.

(*a*) *Brooms.*—There is no tool of such importance to the scavenger as a good broom. For the bristles, pure Bahia bass is preferable to, but more expensive than African bass. The latter is stiff and brittle, it soon breaks, and does not sweep as clean as does Bahia, which is more elastic. The life of a broom varies according to the way it is used, the weather (a broom wears away quicker in wet weather than in dry) and the type of road surface, but under average conditions should last about a month. For machine brooms a mixture of selected Bahia and African bass is found to be the most suitable. If the machine is in regular use, a refill will last from 4 to 6 days or from 65 to 140 brush miles, according to circumstances.

(*b*) *Squeegees.*—A good squeegee, which is an extremely useful tool for use on footpaths and smooth carriageway surfaces in wet weather, should clean the surface and leave it almost dry. Correct thickness and elasticity of the rubber govern its effectiveness. A composition rubber containing about 15% of pure rubber is suitable, its thickness varying from ⅜ inch down, according to the length of the frame, which may be from 18 inches to 3 feet. The rubber overlaps the ends of the frame about 1 inch, for channel-cleaning purposes. The weight of the frame governs the amount of rubber protruding, as it must always be somewhat rigid and resistant to do effective work.

(*c*) *Litter Baskets.*—Strong, well-made baskets, about 17 inches deep of 14-gauge wire, ¾-inch diamond mesh on ¼-inch frames, heavily galvanised, and suitable for attaching to tramway standards and lamp posts, cost about 10*s*. each in lots of three dozen or more. Enamelled plates containing appropriate wording for attaching thereto cost extra, from about 8*d*. to 2*s*. each.

Employees.—The scattered location of the street cleaners and the difficulty of measuring their output accurately make supervision difficult, so that efficiency is rather to be sought from dependable and conscientious workers carefully trained and fairly treated. Modern conditions demand a better type of employee than we have grown to connect with scavenging. A higher standard of street cleanliness and the use of mechanical appliances call for more intelligent workers; while modern traffic conditions rule out the employment of old or disabled men who are no longer useful on other work. In this latter connection the following figures, showing the traffic census for one week on three streets in Leicester in 1925, will support the contention that in busy places, the street cleaner needs to be young, observant and agile :—

Motor vehicles and trailers	15,885	27,526	32,932
Horse-drawn vehicles	1,514	2,752	5,304
Tramcars, cycles, cattle, handcarts, barrows, etc.	27,528	48,708	21,412
Totals	44,927	78,986	59,648

Organisation.—Method and sound organisation are vital to success in street cleansing. Speaking broadly, the cleansing official must accept his local conditions as he finds them, and must shape his system to suit them.

It is necessary first to classify all the streets which have to be cleaned in three or four grades, according to their importance from the cleansing view-point, *e.g.* :—

(*a*) Shopping centre, business streets, steps and main traffic routes : daily cleansing and continuous orderly work.

(*b*) Business and warehouse back streets, suburban business streets : daily cleansing.

(*c*) Same as (*b*), but less used : cleansing on alternate days.

(*d*) Suburban residential streets, by-streets : weekly or twice-weekly sweeping.

Having determined from observation the frequency and kind of service required for each grade, it will then be necessary to decide whether any portion of the work is to be done at night. Against night work we have the well-known difficulty of insufficient light for either good work or proper supervision; disturbance of light sleepers is another, but minor, objection. On the other hand, traffic conditions are such as to make it difficult, and in some cases impossible, to attempt thorough cleansing of busy streets in the daytime. A compromise is frequently resorted to, *e.g.*, for main thoroughfares machine sweeping and the collection of sweepings or, alternatively, flushing or swilling will be done at night or in the early morning, and be supplemented by orderly service during the day—while for less-used streets daytime sweeping service will suffice. An advantage of machine sweeping at night is that a machine can have frequent attention during the day, with little interference to its night work. Where night work is done, it may be possible to work one machine (sweeper or gully emptier) both day and night, provided there is sufficient work for it.

The grade (*a*) and (*b*) streets will probably require tidying on Sunday morning as a result of litter dropped by the Saturday night crowds. This work usually occupies a number of orderlies and length-men for about three hours.

According to the size of the town it will be necessary to split up the area into districts and sub-districts for cleansing purposes, with inspectors, foremen and gangers in charge of the various sections as circumstances may require.

Statistics.—If the street-cleansing service is to be efficiently controlled and reliable data are to be available for the preparation of periodical reports, an accurate system of returns and costing must be at the service of the controlling officer. The observations contained in Chapters III and IV, as to the need for such a system for controlling the collection and disposal of house and trade refuse holds good for street cleansing. In this connection, the Ministry of Health Conference on Costing realised the difficulty of finding suitable units by which to express the cost of street cleansing.

Finally they agreed on :—

(*a*) For sweeping and watering 10,000 square yards (Area multiplied by times cleansed).

(*b*) For gully cleansing, 1,000 gullies. (Number of gullies multiplied by times of emptying.)

(*c*) In the case of snow removal they failed to discover a suitable unit beyond the net cost in terms of rates in the pound, because of the variability in the volume of work undertaken from time to time.

The allocation of time, materials, transport and overhead charges will follow the lines suggested in the Conference Report, or in Chapter III. For the purpose of recording the amount of work done, it will be necessary to prepare and keep up to date an alphabetical list of all the streets and places which the department has to cleanse. This record should give, in addition to the name of the street or place, its locality; situation (from and to); length; average width, or actual width by sections, both for carriageways and footpaths; area; type of paving; classification for cleansing; number and types of gullies, litter baskets and orderly bins; and notes as to any special circumstances. Such a record implies the accurate measurement of all the streets concerned.

Daily records must be devised which will give the area of street and number of gullies cleansed, the important point being that such returns must refer to work actually done; they must not be vague estimates, nor mere repetitions of quantities originally planned for periodical execution, but the actual performance of which is dependent on the honesty or capacity of the scavenger, or the vigilance of his supervisor.

It is a striking commentary on the lack of adequate data kept by Local Authorities in connection with street cleansing that, in the return published by the Ministry of Health summarising the cost returns of County Boroughs for the year 1925–6, no figures relating to the selected units were included. The only figures printed were: total net expenditure, expenditure per 1000 of population, net cost equivalent rate in £, and expenditure for new plant out of revenue.

Interesting features of this return are :—

	Highest.	Lowest.	Average.
	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
Expenditure per 1000 of population . .	273 16 0	52 16 0	125 6 0
Net cost equivalent rate in £	11·84*d.*	2·51*d.*	5·56*d.*

Obviously the greatest caution should be exercised in making comparisons of cost between towns, because of the tremendous variation in conditions.

Snow Clearance.—Snow clearance, being a relatively infrequent requirement (perhaps thrice a year), is a thing apart from the daily routine of street cleansing, but the great inconvenience which a fall of snow causes to pedestrians and vehicular traffic, demands that the streets shall be cleared as speedily as is practicable, and consistent with a reasonable return, in terms of work done, for the expenditure incurred.

Such a desideratum necessitates the preparation of a comprehensive scheme, the main features of which are here indicated :—

1. Division of area into districts and sub-districts for snow-clearance purposes; fixing of headquarters for, and appointment of supervisors (inspectors and foremen with sufficient clerical assistance) to take charge of such districts and sub-districts.

2. Arrangement for the calling up of supervisors in the event of a fall of snow at night, where street-cleansing operations are not usually carried on at night. It is usually possible to arrange for the police to give help in this connection.

3. Provision of means of communication between, and transit for, supervisors, making possible the rapid notification and satisfaction of particular needs as they arise, and the reporting of progress, changing weather conditions, etc.

4. Classification of streets for priority of treatment, and preparation on cards of short lists of such streets, to be handed by the supervisors to their various teams and gangs.

5. Preparation of lists of suitable places for tipping snow, and of instructions as to such tipping.

6. Rules for guidance of supervisors as to the diversion of transport and labour from other employment, *e.g.*, refuse collection and the engagement of additional transport and labour.

7. During September in each year, permission should be sought anew for the tipping of snow :—

(*a*) On land, from the owner or agent.
(*b*) In sewers, from the borough surveyor or other appropriate officer.
(*c*) In rivers, from the river commissioners.

Also, during September, and in addition after every snowfall :

(i) The scheme in force should be reviewed, and, if necessary, amended in the light of any developments of new roads, streets, or traffic routes, and of experience gained during previous snowfalls.

(ii) Stocks of salt, tools, and equipment should be examined, and brought up to the approved standards of quantity and condition.

8. Where there is a bye-law imposing on occupiers the duty of removing snow from the footpaths adjoining their premises, a notice should be advertised in the local press, early in November, reminding such occupiers of the duty, and emphasising the need for keeping clear the channels in front of their premises.

A fall of snow 3 inches deep, on streets 36 feet wide (including footpaths) is equal to 1 cubic yard of snow per yard run of street. Taking a two-wheeled cart to hold about 2½ cubic yards, such a fall would give 700 cart-loads of snow per mile of street, or for every 50 miles of street controlled by the Local Authority, 35,000 loads. Assuming that with adequate fillers and facilities of near and rapid discharge of loads each cart could remove twelve loads per day, each mile of street would provide sufficient snow to employ 58 carts a whole day.

From these figures it is apparent that it would be impossible to lift and cart the snow from all the streets of a borough or district with that promptitude which the average layman seems to expect. In the first place, sufficient men and vehicles could not be obtained; and even if they could, the expense would be prohibitive.

It therefore becomes necessary to resort to some more workable process, and this is found in the spreading of salt, which melts the snow. One ton of soiled white salt, obtainable for about 30*s*. per ton in bulk at user's station, will effectively treat about 15,000 square yards of surface covered with snow 3 inches deep. The spreading of salt follows the same lines as the spreading of shingle, grit and sand described previously. In some towns, objections are made to the use of salt, in that its application to snow creates a freezing mixture which is dangerous to the health of the people, particularly to those ill-shod or underfed; but if the operations are performed rapidly, this condition is only temporary, and the brief discomfort is preferable to that of allowing the snow to lie about the streets for many days. The statement that salt damages horses' feet is not true. It will cause a horse with cracked heels to go lame, but this does good, causing the owner to rest the animal, while the salt assists in cleaning and hardening the wound. It will never make a sound horse go lame, or in any way affect it detrimentally.

In the event of a snowfall occurring outside the ordinary working hours, the supervisors should come on duty as soon as the snow begins to fall. It is for the senior supervisor to use his discretion when to call the gangers or the men and transport. A premature call means needless expenditure for men's time, etc. If an early cessation and thaw seem likely, little need be done except to prepare for sweeping away the melting snow; but if a continuance appears probable, with no indication of thaw, it will be well to summon drivers and attendants for salt-spreading, which may be commenced while the snow is still falling, provided that motor traffic is likely soon to be running and so work up the snow and salt. Subject to this proviso, the salting schedule should be worked to with all possible speed.

If, before salting is done, the snow reaches a depth of say six inches or more, it may be considered advisable, especially on flat streets, to remove the bulk of the snow by snowploughs before salting, so as to reduce the amount of slush.

After giving the salt reasonable time to act, the gangs of men, each in charge of a responsible ganger, may now be sent out with snow shovels, scrapers and brooms to clear the footways and channels. Gullies should receive special attention, to see that the grids are kept quite clear and open. The footpaths adjoining public buildings and vacant plots (or where the Local Authority undertake the duty, the footpaths of all busy streets) will also require early attention. The sweeping-machine brooms are now brought into use as soon as practicable, to assist in clearing the centre of the roads, all the water vans being brought into service likewise. As far as is practicable, the snow should be arranged in orderly sections along the breasts of the road, as long and flat as the quantity to be dealt with will permit. The large area thus exposed to the atmosphere assists the melting process, whereas the formation of big heaps retards it and consolidates the snow. The channels should be kept thoroughly clear for drainage. At varying intervals, crossings should be made, and the sections, although long, should have cross cuttings made at distances of about 30 feet apart, to assist drainage. These sections should be neither unsightly nor cause any nuisance, and having been treated with salt should, under normal conditions, melt away.

The complete melting process being somewhat slow for town requirements, the removal of the snow is assisted by the flushers and water carts. Water is applied freely, and soon the whole is worked into a liquid state and passed down the gullies and other sewer entrances. It is usual to have a large staff of men with squeegees and brooms to help break up any heaps of snow and mix well with water; this enables the flushers to get over a much greater area than they otherwise would.

The method just described, however, is not suitable for all circumstances. For instance, in a narrow and flat but much-used street the splashing of pedestrians and shop fronts by motors running through the snow-brine during the busy hours would not long be tolerated, although if the snow ceased to fall so that salting could be performed in the early hours, allowing the streets to be cleaned by 9 or 10 a.m., little inconvenience would be caused. It is all a question of circumstances. Where the melting and flushing process is not adequate, resort must be had to removal of the snow by carts, in which case the snow should be shovelled well to the roadsides and formed into heaps in readiness for loading. The distance snow has to be transported is usually small, a condition which favours the use of "horse, cart and man" as the mode of conveyance. The carter is available for loading, and two extra shovelmen will make up a useful team. Wherever practicable, it should be arranged for a second cart to be loaded while the first one goes to tip its load. The loads of snow may be tipped on vacant land, into docks or rivers, or through manholes into sewers.

There are occasions when it is advisable to spread a mixture of rough grit and salt, *e.g.*, when a severe frost after rain or thaw has covered street surfaces with sheer ice; then the grit provides immediately a grip for horses, until the salt has had time to do its work.

A word as to the effects of motor traffic on snow will not be out of place. If the temperature is above freezing point, with a decided tendency to thaw, the action of motor wheels helps materially to break down the snow to a liquid state. On the other hand, with a temperature at or below freezing point, the effect is to consolidate the snow, giving a dangerously slippery surface, and retarding its liquefaction.

During every fall and clearance of snow a detailed log should be kept recording in chronological order: Commencement, cessation and depth of fall, and all climatic variations, attendance of supervisors, calling of men, turning out of vehicles, performance of processes, reports of progress, complaints from public, observations of supervisors and all relevant happenings, concluding with a statement of number of men, vehicles and tools employed (casuals and hired vehicles being stated separately), quantity of salt, etc., used, cost of operations, and suggestions for future guidance. Such a record is of the greatest possible value in reviewing the scheme, as suggested in paragraph 7 (1).

CHAPTER XXII

TIPS

Tipping or dumping crude household refuse is the most primitive of all methods of disposal. The practice is still continued in many places, particularly in small urban and rural districts, where the amount of refuse to be dealt with does not justify the cost of erecting a mechanical plant.

Removal and Tipping of Dust from House Refuse.—In large cities, it is generally considered that the best way of dealing with house refuse is to extract the fine dust content by passing the crude refuse through screens, usually of $\frac{3}{8}$-inch mesh; the dust extracted by a screen of this mesh amounting to approximately 45% of the whole. The refuse, after passing through these screens, is usually passed forward by means of travelling belts, from which articles of commercial value are removed by belt attendants.

The dust extracted from house refuse can be tipped without risk of nuisance, and is, in fact, used frequently as a covering material on tips where house refuse or street sweepings are deposited in a crude state.

The City of Bradford disposes of nearly all its house refuse by tipping, and has, the writer understands, more than forty tips, most of which are disused quarries. These tips are situated in the city and so facilitate easy collection and disposal.

The Bradford method is to tip in layers 3 feet deep, each layer being covered by street sweepings, or other suitable material. This process continues until the required level is reached, when the surface of the tip is either turfed or seeded down with grass seed. The ground is afterwards used as sports fields, etc.

Precautions to be Observed at Refuse Tips.—The tipping of refuse on land is likely to create nuisance unless very strict precautions are taken, and in July 1922 the Ministry of Health issued a statement of suggested precautions to be observed in the use of tips. A copy of these precautions follows :—

Ministry of Health Suggested Precautions.

26th July, 1922.

" 1. Every person who forms a deposit of filth, dust, ashes or rubbish, of such a nature as is likely to give rise to nuisance, exceeding * cubic yards must, in addition to the observance of any other requirements which are applicable, comply with the following rules :—

(*a*) The deposit to be made in layers.

(*b*) No layer to exceed * feet in depth.

(*c*) Each layer to be covered, on all surfaces exposed to the air, with at least nine inches of earth or other suitable substance; provided that during the formation of any layer not more than * square yards may be left uncovered at any one time.

(*d*) No refuse to be left uncovered for more than 72 hours from the time of deposit.

(*e*) Sufficient screens or other suitable apparatus to be provided, where necessary, to prevent any paper or other débris from being blown by the wind away from the place of deposit.

2. Every person who deposits any filth, dust, ashes or rubbish likely to cause a nuisance if deposited in water must, so far as practicable, avoid its being deposited in water.

* Figures should be inserted to meet local conditions. The writer considers that a depth of 8 feet for each layer, and not more than 100 square yards to be left uncovered at any time, would be reasonable.

3. Every person who deposits any filth, dust, ashes or rubbish, must take all reasonable precautions to prevent the breaking out of fires and the breeding of flies and vermin on or in such deposit.

4. If the material deposited at any one time consists entirely or mainly of fish, animal or other organic refuse, the person making such deposit must forthwith cover it with earth or other equally suitable substance at least 2 feet in depth.

5. Every person who deposits any filth, dust, ashes or rubbish must take all practicable steps to secure that tins or other vessels or loose débris likely to give rise to nuisance are not deposited in an exposed condition on or about the place of deposit.

6. Sufficient and competent labour must be provided in connection with the deposit to enable the necessary measures to be taken for the prevention of nuisance.

7. So far as practicable, each layer of refuse which has been laid and covered with soil must be allowed to settle before the next layer is added.

8. Wherever practicable, the person making the deposit must avoid raising the surface of the tip above the general level of the adjoining ground.

9. All refuse must be disposed of with such dispatch and be so protected during transit as to avoid risk of nuisance."

Site of Tips.—In looking for suitable tips, the Ministry of Health's suggested precautions should be borne in mind. The following points must also be considered :—

(1) The distance of the proposed tip from the collecting district.
(2) From where the covering material is to come.
(3) The close proximity of houses, buildings, etc.

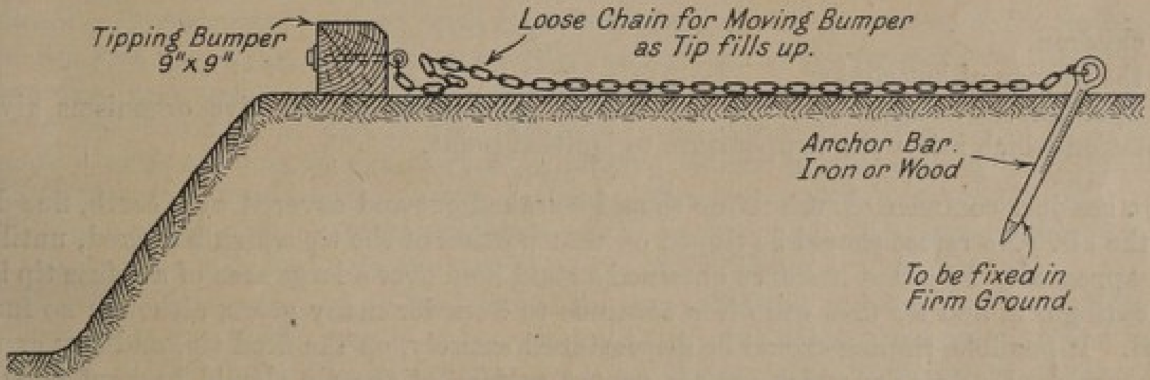

FIG. 121.—Sketch of tipping bumper for use on tips, showing method of anchoring bumper. Two chains and anchors to each bumper.

It is not wise to tip crude house refuse in water, nor on to land where there is a likelihood of water coming into contact with the tipped material, as, sooner or later there may be trouble owing to the pollution of a water-course.

A tip that is not seen by the public will not as a rule cause trouble. " If the eye does not see, the nose does not smell," or, in other words, if the public know there is a likelihood of any smell arising from a tip, they imagine it is much worse than it actually is.

It is well to consider the prevailing wind in the summer time—generally south-west—on account of the trouble that is caused by paper and dust being blown about.

Roadways.—The road to a tip needs constant attention, and should be excavated 10 feet wide, then filled in with ashes not less than 9 inches deep. An ash road must be kept well up in the centre, so that no water can lie on it. The ruts or wheel tracks must be kept filled in, as they form.

In some cases it will be found necessary to put down a sleeper road similar to that advised on the top of a tip, but without the cross pieces.

A sleeper track can be made with 10-inch sleepers put end to end and fastened together with iron dogs, the sleepers being so placed that the wagon wheels will run down the centre of each sleeper.

Surface of Tips.—The top of a tip needs constant attention, as it will sink in places. These cavities must be filled up in order to keep the tip as level as possible.

Bumpers.—These are pieces of wood or iron girders usually 9 by 9 inches and 3 feet longer than the width of vehicles to be tipped, and are needed so that the vehicles do not get too near to the edge of the tip, which is always loose.

The bumpers should be chained to land anchors or posts, placed well back from the edge of the tip. There should be a hook at one end of the chain, and large links or rings at intervals so that the bumper may be moved as required, without the land anchors being taken up as the tip is extended. (See Fig. 121.)

Tipping Platform.—It is often necessary to put down a sleeper track so that the vehicles can get to the edge of the tip—old wooden railway sleepers are very useful for this purpose. In putting this track down, it is advisable to place two or three sleepers at right angles to the face of the tip, then place others across these, so as to make a good platform for the vehicles to tip off.

In the case of heavy transport, such as electric vehicles, or steam wagons, it is advisable to use larger timbers underneath the sleepers, say 6 × 8 inches, and of such length that the whole of the vehicle is on them when tipping.

Covering of Tips.—The dust screened from house refuse, flue dust, or clinker, does very well for this purpose. Soil is the best, but will be found to be very expensive.

In some districts it may be possible to obtain excavations from sewers, foundation material, etc.

Road sweepings are generally easily obtained, and make good covering, but care has to be taken that the paper found in all street sweepings is either covered, or burnt.

When a tip has been covered with soil or sweepings it should be seeded down with grass seeds.

Tip Fires.—Great care has to be taken to prevent fire on tips. The following are a few of the ways that a tip may be fired :—

By children.

By the tipping of hot clinker.

By spontaneous combustion, which is caused by minute putrefactive organisms giving rise to fermentation which raises the temperature to ignition point.

If the fire has just commenced, the refuse should be raked out and covered with earth, flue dust or sand to exclude the air. No refuse should be tipped on that portion of the tip which has fired, until all signs of fire have disappeared. Fire that has once obtained a good hold over a large area of a refuse tip is extremely difficult to extinguish, and tip fires will often continue to burn for many years, although no further refuse be deposited. If possible, tipping should be discontinued entirely, on the fired tip, and any exposed refuse should be covered. Fire cracks which appear on the surface of the tip should be kept filled with sand, and pressed. It may be necessary for measures to be taken to prevent the fire from spreading to adjoining property, in which case, a trench should be cut down to the solid ground and filled with sand. The trench should be at least 1 yard wide, and must be continued along the whole length of the tip.

Prevention of Nuisances.—The paper nuisance on a tip may be overcome by erecting 2-inch mesh wire netting around the tip, to a height of 8 feet, the top of the wire being turned in towards the tip.

It is advisable to burn all paper, but care must be taken not to fire the surface of the tip, and in this connection, a small portable incinerator is worthy of consideration.

Rats.—The Ministry of Agriculture conduct an annual Rat Week, which is usually held in November. During this week, many Local Authorities endeavour to obtain the co-operation of householders, shop-keepers, proprietors of business premises, etc., in a combined effort to rid their property of vermin. Many proprietary rat poisons are on the market, but care must be exercised in their purchase.

The following two recipes were recommended for use in a circular which was issued in Birmingham in connection with the National Rat Week :—

(*a*) Barium carbonate (commercial)	6 ozs.
Meal (Cereal)	16 ,,
Dripping	4 ,,
Salt	½ oz.

This will make 1000 baits, the size of a hazel nut.

(*b*) Barium carbonate (commercial)	4 ozs.
Biscuit or oatmeal	4 ,,
Oil of aniseed	5 drops.

The rat is an extremely wily customer, and quickly detects the scent of human hands. Neither the ingredients nor the finished baits should, therefore, be handled with uncovered hands.

The above recipes have been proved effective for use at depots, workshops, etc., but the most efficient method employed in connection with tips has been in the use of chlorine gas. While the latter method has been extremely successful, it is essential that the use of the gas should be in the hands of a person who is qualified to use it, as otherwise the method is dangerous. Chlorine gas is not, under any circumstances, suitable for use in buildings, as it has been found that the gas does not escape readily from inside the buildings, and therefore causes inconvenience to persons employed therein. When used in the open, however, the gas escapes quickly.

Flies.—Starting in the month of April, when the fly commences to lay its eggs, the surface of refuse tips should be sprayed with an emulsion of the following ingredients :—

Paraffin	$2\frac{1}{2}$ gallons.
Soft soap	2 lb.
Water	5 gallons.

Spraying should be continued throughout the summer, as frequently as possible, but in any case, not less than once per week.

Agriculture.—House refuse covered with road sweepings or soil is often used for reclaiming low-lying land. For the first year or so the crops are earlier, on account of the fermentation causing heat.

Screened dust from house refuse forms a manure which on analysis is as good as stable manure, but the action of the two materials on land is very different. The stable manure contains more organic matter and produces a large amount of humus-forming matter, which enriches the soil. Fine dust contains a smaller percentage of organic matter, and the action of the dust is rather of aëration than of fertilisation of the soil, and for this purpose is especially beneficial to clay land. The dust makes the land easier to work, and results later in better drainage and therefore better crops.

When crude house refuse is put on land, it has the same effect as fine dust. Although the house refuse contains as a rule more organic matter, it also contains tins, and unless these are ploughed in deeply, they will cause a good deal of trouble in working the land, hoeing, etc. It is found that most tins, such as tomato and fruit tins, will rust away in twelve months, but galvanised tins and earthenware must be picked out.

In a previous chapter, information was given about the use of dust as a carrier for excreta, and manure from slaughter-houses, etc. This makes a very good fertiliser, and is largely used by market gardeners for growing crops of the brassica family.

Pulverised House Refuse.—The action of this material is the same as crude house refuse, but it is much more easily spread on to the land, and the trouble of tins, etc., is avoided. The best results from the use of house refuse and dust will be found in the crops of cabbages and mangolds.

Site of Boat Tips.—(1) The conditions with regard to water troubles and proximity to houses and roads are the same with boat tips as cart tips.

(2) The prevailing wind must be considered with regard to the unloading, because if the wind is blowing off the tip on to the boat, it makes it bad for the unloaders, the wind blowing the dust into their eyes.

(3) The distance from the water's edge to the faces of the tip is a very important point, on account of the cost of unloading.

Building on Refuse Tips.—The law relating to the erection of buildings on land which has been used as a refuse tip, is contained in Section 25 of the Public Health Acts Amendment Act, 1890, which reads as follows :—

"It shall not be lawful to erect a new building on any ground which has been filled up with any matter impregnated with fæcal, animal or vegetable matter, or upon which any such matter has been deposited, unless and until such matter shall have been properly removed by excavation or otherwise, or shall have been rendered or become innocuous."

When tipping house refuse, etc., the bye-laws in force in each local district must also be observed.

Decomposition of Tipped Refuse.—Organic matter exposed to the air undergoes decomposition, which takes place most rapidly in the presence of moisture and at a slightly elevated temperature. This biochemical change is known as fermentation. It is now generally accepted that fermentation cannot occur without the presence of certain living organisms or of chemical substances derived from these organisms; for example, certain bacteria and fungi. The bacterium feeds on its own particular food, and produces certain decomposition products, these latter as a rule characterising the particular form of fermentation. For instance, in house refuse one form of fermentation which goes on is known as putrefactive fermentation. A further form of fermentation occurs through the influence of such ferments as the moulds.

Fermentation can be accelerated or retarded by altering certain physical conditions, such as temperature, or can be altogether arrested by certain bodies known as antiseptics or antiferments.

The term bacteria covers a group of minute plant growths—malignant and benign—which are very widely distributed in nature.

Generally speaking, they can attack and feed on any matter containing carbon or nitrogen, resulting in very complex chemical and physical changes in the substance attacked; hence such putrescible matter as house refuse forms a highly satisfactory ground for the activities of certain classes of bacteria. The classes of bacteria most likely to be found in house refuse are putrefactive and pathogenic. It is with the former class alone we need concern ourselves. The putrefactive bacteria may be regarded as Nature's minute scavengers, as apparently their function is to break down the highly complex organic matter into much simpler substances, which process is accompanied by a considerable rise in temperature. This is used to advantage in the Beccari process in Italy, where house refuse is fermented in huge cells with the object of reducing the putrescible organic matter.

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