GB Building Research Board

POST-WAR BUILDING STUDIES

NO. 4

PLUMBING

BY

THE PLUMBING COMMITTEE OF
THE BUILDING RESEARCH BOARD OF THE
DEPARTMENT OF
SCIENTIFIC AND INDUSTRIAL RESEARCH

LONDON: 1944
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MINISTRY OF WORKS

POST-WAR BUILDING STUDIES

The series of Reports being published under the title of Post-War Building Studies owes its origin to a desire expressed by professional and other institutions connected with the building and civil engineering industries to assist and support the Ministry of Works in regard to post-war plans. During the latter part of 1941 the then Minister, in order to take advantage of these offers of assistance which he was receiving from all quarters, encouraged the establishment of a series of Committees to investigate and report on the major problems which were likely to affect peace-time building. He also offered, on behalf of the Ministry, to provide the necessary staff and organization to co-ordinate the various inquiries, in such a way as to avoid duplication of effort and to secure so far as possible uniform direction and policy.

A list of the Reports in this series is given on the back page of the cover.

The Committees were either appointed by a Government Department or convened by a professional institution, a research association or a trade federation, as seemed most appropriate in each case; they were so constituted as to ensure that the Reports contain the considered views of experts and others closely concerned with the subject. The Minister gratefully acknowledges the work of the Committees and the valuable assistance given both by the various convening bodies and by the individual members. The Reports are not official publications in the sense that the Government as such is responsible for or necessarily accepts the views expressed, but their contents are authoritative and must be of great value to all concerned with the national building programme.

LONDON: 1944

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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

THE PLUMBING COMMITTEE OF THE BUILDING RESEARCH BOARD

To The Building Research Board.

GENTLEMEN, We, the Plumbing Committee, beg leave to present a report on the inquiries which we were appointed by you in February 1942 to undertake under the following terms of reference:

i. To review existing scientific information and practice in this country and abroad on plumbing (including the underground drainage forming part of normal building works), with particular reference to the supply of cold and hot water in buildings and the removal of soil, rainwater, and waste therefrom.

ii. To make recommendations for practice in post-war building.

iii. To make such recommendations for further research as may suggest themselves in considering (i) and (ii).

MEETINGS OF THE COMMITTEE

We have held twenty-two meetings, in the course of which we have surveyed plumbing practice in this country, studied a number of special problems which seemed to call for our attention, and prepared certain recommendations for plumbing in post-war construction.

SPECIAL CONCERN WITH LOW-COST HOUSING

Bearing in mind the anticipated requirements of the immediate post-war period, we have attended particularly to low-cost housing. Concentration on this type of building—in respect of its plumbing layout, materials used for plumbing, and plumbing appliances—has made it impossible to give a balanced treatment to plumbing as a whole, and we have therefore devoted little of the time at our disposal to subjects which did not seem to us to promise such good returns in the form of useful recommendations on our part for immediate post-war use. Examples of such omissions or partial treatments are rainwater disposal from roofs, drainage below ground, and the plumbing of non-domestic buildings. As regards the last item, however, much of what we have had to say about low-cost housing should apply to plumbing generally.

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PLUMBING

A REPORT BY A COMMITTEE APPOINTED BY THE BUILDING RESEARCH BOARD OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

INTRODUCTION

DEFINITION OF PLUMBING

1. It may not be out of place at the outset to refer briefly to what we have considered to be the scope of our inquiries. The word "plumbing" as a description of a craft or trade is not very well defined. According to the Oxford Dictionary, the plumber is "an artisan who works in lead, zinc, and tin, fitting in, soldering, and repairing water and gas pipes, cisterns, boilers, and the like in buildings; originally a man who dealt and worked in lead." But, rightly or wrongly, the definition according to the ordinary parlance in the industry goes beyond that. For the purpose of this report we have taken the word as covering the provision of water supply from the water undertaking's main to the various washing and sanitary appliances used in domestic buildings, the removal of water and waste matter from appliances * (including the underground drainage forming part of normal building works) and the design of the appliances.

RESULTS OF PRELIMINARY SURVEY

2. Our preliminary survey showed us that there were a number of opportunities for greater efficiency and economy in plumbing practice in this country. Expressed in general terms these opportunities may be said to lie in:

a. Taking greater care in the installation of plumbing systems to remove hazards to health, and also to obviate inefficiency and breakdowns of service, which, besides causing inconvenience and discomfort to users, may lead to costly maintenance and renewals.

b. Securing more uniformity in practice throughout the country so that the work of all concerned with plumbing may be simplified and costs reduced.

c. Extending the standardization of plumbing appliances and fittings.

d. Taking measures for greater economy in construction, including carrying out in the workshop instead of on the site all work which may be dealt with more satisfactorily in the former.

3. In the course of our preliminary survey, and also at subsequent stages in our work, we noted a number of commonly occurring defects in plumbing practice. These have been instructive to us in preparing our recommendations, so we thought it advisable to record a few of them. We have done so in Appendix I.

BY-LAWS

4. At an early stage in our deliberations we discussed the question of by-laws, including the regulations of water undertakings. It was clear to us that more unification of by-laws and regulations was advisable in the interests of greater efficiency and economy. We felt, however, that our work would be hindered rather than helped by undue concern with the by-laws position. Our most important duty was to produce recommendations for improved practice, taking account of economy as well as efficiency, and without thinking too much as to whether the recommendations were in accord or conflicted with existing by-laws. Once a sound basis for improvement had been established in that way and the basis generally accepted, plumbing practice throughout the country would be influenced in the right directions, and the question of by-law revision could be viewed in clearer perspective by the competent authorities.

* See Glossary.

CONSULTATION WITH AUTHORITIES ON PLUMBING MATTERS

5. In order that our findings should be upon a broad basis we consulted, by personal interview or by correspondence, a considerable number of experts in various fields of our subject, including sanitary engineers, plumbers, architects, contractors, housing authorities, manufacturers, and others. One means adopted of obtaining the evidence we needed was to circulate to a number of Institutions, Associations, and other bodies interested in plumbing, an Interim Report, prepared in October 1942. The response to our request for comments on this report was very encouraging. Many valuable suggestions were received which have helped us considerably in formulating conclusions in the present report.

6. We have made a brief study of plumbing practice in America and have been in contact with American technicians on certain points. Opportunity has also been taken to discuss German and mid-European practice with German and other architects now resident in this country.

PLUMBING BASED ON PRACTICE RATHER THAN RESEARCH

7. We felt that the consultation of practical experience over as wide a field as possible was of special importance in view of the nature of our subject. Plumbing in this country has developed almost entirely on a basis of practice and suffers to some extent from the absence of research which might have resolved some of the variations in practice and given confidence for the more rapid introduction of improved methods. This disadvantage has been felt in a number of directions and present circumstances give little opportunity for carrying out a research programme. Any immediate recommendations have, therefore, to be based upon the considered views of experienced men in the industry. Their views would, in any case, be an essential element in any review of practice, but the absence of quantitative data sets a limit to changes that can safely be recommended.

DIFFERENCES OF OPINION ON PLUMBING MATTERS

8. We have found differences of opinion between experts on many plumbing matters. No doubt this is inevitable considering that in a plumbing problem one may be concerned with such diverse factors as hygiene, properties of materials, hydraulics, water supply, plumbing technique, the need for economy, and the general requirements and habits of the user of plumbing services. Our task has been to try to make reasonable recommendations for post-war use, in full realization that it is not possible to satisfy all desiderata at the same time. Safety from the sanitary point of view must take first place in all design for plumbing, but the need for special economy in certain classes of work may place limits on what can be done, for instance, in the way of securing good appearance and the full convenience of the user. Further, certain requirements may be to some extent mutually incompatible. For example, concealed piping pleases the housewife, simplifies cleaning and removes certain possibilities of accidental damage in use; but, on the other hand, visible piping is easier to repair and replace, it reveals leakages at an earlier stage and in some cases it may be safer in frosty weather. It is not surprising that experts, giving different weight to different factors, reach different conclusions as to detailed construction. The important thing is, we feel, to appreciate all the points concerned, to put essentials first and then to make as reasonable a balance as possible of the other requirements in any particular case.

We have tried to deal with this problem by formulating good principles in general terms and then giving examples to show ways in which these principles might work out in a particular case. Paragraph 11 of this Introduction refers to this matter again when describing the form and objective of Parts I and II of our report.

SPECIAL SUBJECTS CALLING FOR ATTENTION

9. Within our general scheme of concentrating on low-cost housing we have paid special attention to certain problems which, from the evidence given to us and from our own observation, seemed to call specially for attention. As already stated in paragraph 3, a few commonly occurring defects have been noted in Appendix I, but brief notes on the following subjects may be appropriate at this stage:

a. *Frost Precautions*. We have attached considerable importance to this subject. Frost precautions are dealt with, chiefly, in Part I.

b. *Planning for Plumbing*. We have been impressed by the need that buildings should, wherever possible, be planned so as to allow good and economical plumbing to be carried out. The location, in a building, of its plumbing equipment, including the washing and sanitary appliances, hot-water heaters, storage cisterns, etc., may have marked effects on the efficiency and cost of plumbing. We feel that many buildings in the past have been designed without sufficient regard to this factor and the plumbing has suffered accordingly. While it is not suggested that the plumbing of a building should be held to be of such relative importance as to control and restrict planning unreasonably, a fair compromise should be effected, bearing in mind the serious inconveniences to building users which may arise from an unsatisfactory plumbing system and the undue costs of installation and upkeep which may be incurred thereby. Early consideration of the layout of the plumbing installation should remove many of the disadvantages which have formerly arisen under this head. The diagrams discussed in Part I will, it is hoped, be of value in giving emphasis to this point and in illustrating in detail the benefits of close grouping of plumbing equipment.

c. *Noise in Plumbing*. We have considered the serious annoyance, and even ill effects on health, of undue noise caused by the operation of plumbing systems—particularly in the case of flats. Trouble may arise in connection with plumbing layout and the use of materials and also in the design of the appliances. These aspects of the problem are considered at appropriate stages in our report. In addition there is the problem of preventing the noises which may arise in a plumbing system from travelling to the various parts of the building through the structure. Your Committee on Acoustics and Sound Insulation of Buildings has been dealing with this matter.

d. *Concealment of Plumbing*. While realizing the advantages, from the point of view of the internal and external appearance of buildings, of concealing plumbing work within walls or ducts, we have had to take account in our recommendations of:

i. The need for safeguards in the event of leakages.
ii. Protection against frost (where pipes are buried in outside walls).
iii. The possible harbouring of vermin behind casings.

These considerations have led us to believe that in certain types of buildings accessibility of piping is essential, even if it means that pipes can be seen. This matter is dealt with in more detail in the appropriate sections of the report.

NO FUNDAMENTAL CHANGES PROPOSED

10. We have studied practices which have been basic to good plumbing in this country for a number of years and have tried to show how these practices may be used, economically, in the plumbing of low-cost houses. To this extent our recommendations are naturally orthodox in character. We have not ignored, however, the possibility that unorthodox methods might profitably be introduced; and, to make sure that opportunities in this direction should not be missed, we have considered a number of suggestions for new or unusual practices. For example, we have examined the possibilities of using a simplified one-pipe system for low-cost

housing. (Appendix II gives an account of our experimental work on some one-pipe installations. Part I includes some recommendations for the use of one-pipe systems in low-cost housing.)

In the main, however, we find it necessary to stress the achievement of efficiency and ultimate economy by good workmanship and suitable materials applied to familiar and orthodox design.

REFERENCE TO PRINCIPLES

11. It has seemed necessary to us to set down the fundamental principles which should be borne in mind by those responsible for designing the layout of plumbing installations and for selecting materials for plumbing purposes and specifying the methods of jointing to be employed. Parts I and II of our report contain a statement of these principles, applying to layout and materials respectively.

Constant reference to sound principles is, we feel, the surest way of maintaining good standards, guiding developments along the right lines and discouraging unwise departures from traditional practice.

Since, however, the implications of a principle are not always readily seen we have thought it advisable to make certain additional recommendations as to how these principles might be interpreted in typical cases. In each case these recommendations follow the statement of the principle to which they apply. They are necessarily of a selective character and may, therefore, be more open to differences of opinion than the principles themselves.

It may be felt in some quarters that it is not necessary to state plumbing principles, on the ground that they are well known in the trade, frequently referred to in the technical press and amply covered by courses of instruction in the technical schools and colleges. When, however, plumbing systems have, in the past, been found to be defective in operation, where stoppages have occurred, where material has corroded or failed under stress, or where unnecessary expenditure has been incurred, it has often been due to ignorance or disregard of rational principles. It seemed to us, therefore, that a restatement of plumbing principles in this report would serve a useful purpose.

THE STANDARDIZATION OF PLUMBING APPLIANCES AND FITTINGS

12. A greater measure of standardization of types and dimensions of plumbing appliances and fittings than obtains at present would facilitate the supply, installation and replacement of components.

At an intermediate stage in our inquiry we recommended that British Standards should be prepared for baths, washbasins, sinks, and water-closet suites for low-cost housing. We also made certain suggestions of a detailed character regarding these appliances. These suggestions were considered by the Standards Committee of the Ministry of Works; and, at their instigation, the British Standards Institution has now formed Committees to carry out this standardization work. After further study of the functions of these plumbing appliances we have prepared fuller recommendations regarding their design. These recommendations are given in Part III of the present report.

As regards the standardization of water-supply fittings, much has already been done, by the Health Departments and the British Waterworks Association, to lay down standards, but effect should be given to the co-ordinated recommendations of these authorities in the country as a whole.

Part V of the report contains a reference to further suggested items for standardization.

OVERALL ECONOMY

13. We have had regard to the possibility that after the war the utmost economy in construction may be required and that the question may then be asked: To what extent can principles be abandoned under the stress of necessity? The answer is that where a principle concerns health, adequate durability of materials,

prevention of damage due to frost, and similar essentials it cannot be abandoned without the likelihood of an eventual expenditure on the part of the community greater, sometimes considerably greater, than the initial saving which might have been made. When carefully examined we think it will be found that not a great number of the principles we have recorded can be ignored without an overall loss to the community on a cash basis alone. We feel it necessary to make this point because it may be found that plumbing installations designed on the basis of the principles in our report may in certain parts be more costly originally than if carried out according to some pre-war practice. On the other hand, we feel that the extension of standardization in plumbing, the carrying out of certain parts of the work in the workshop instead of on the site and other measures recommended in various parts of the report may redress the balance and sometimes result in greater overall economy in first costs.

SUGGESTIONS FOR IMPLEMENTING THE REPORT

14. It should be clearly realized that the proper implementing of our recommendations would mean the general introduction of certain plumbing methods which are not yet permissible in every locality. Proposals to modify local by-laws and regulations, in the interest of greater economy and efficiency in plumbing, should receive sympathetic consideration.

The purpose of our report would also be more readily achieved:

a. If suitable measures were taken to encourage the phrasing of plumbing contracts and the organization of plumbing work so that sound principles, on the lines of those which we have recorded, are followed.

b. If new methods of fabrication, including work off the site, were given every facility for development, in so far as plumbing efficiency is not reduced by such methods.

c. If full use were made of standardized appliances and fittings in connection with specifications for plumbing work.

We have attempted to provide data and to make suggestions throughout the report which could serve to amplify the above proposals with the necessary detail.

FURTHER WORK

15. Some observations on what might be done by experiment and research to resolve certain differences of opinion among plumbing experts and to provide data for a progressive development of plumbing practice are given in Part V.

ACKNOWLEDGMENTS

16. Reference has already been made in paragraph 5 to the advice given to us by experts on all aspects of plumbing. All the comments made to us received careful attention in our discussions and we profited greatly from them. We wish, therefore, to express our gratitude to all those who helped us in this way and to record how much we appreciate the trouble that they have taken to do so and the ready way in which they responded to our request for advice.

We desire to place on record our appreciation of the valuable assistance we have received from the Building Research Station, and in particular from Mr. F. L. Barrow of this Station, who has been responsible for conducting the inquiries associated with the work and without whose indefatigable labour in conducting experiments and drafting documents we could never have completed our task in the time allotted.

PART I. THE LAYOUT OF PLUMBING INSTALLATIONS

Parts I and II consist of principles followed in each case (in smaller type) by recommendations for their application.

17. Our purpose in setting down a number of principles for the layout of plumbing installations has been explained in the Introduction. (See paragraph 11.)

To assist in making some recommendations on the application of these principles we have worked out, and illustrated in the drawings appended to this report, three examples of plumbing installations for low-cost houses. Differing conditions have been chosen for each of these cases so as to cover a range of normal requirements in this type of dwelling. The conditions assumed for the three cases are set out in the following table:

Level of Appliance	Case 1 Terraced House	Case 2 Semi-detached	Case 3 Semi-detached
Roof space	Cistern		
First floor	Basin Bath W.C.	Cistern Basin Bath W.C.	
Ground floor	Sink	W.C Sink	Cistern Basin Bath W.C. Sink

The drawings show only those parts of the house which directly affect the plumbing, but, in preparing them, house plans have been studied to the extent of making reasonably sure that normal planning requirements could be met with the plumbing space occupied as shown.

It should be stressed that these drawings are not meant to serve in any way as rigid plumbing models. They have been prepared simply to illustrate the principles and to observe some of the implications of these principles in practice. It is realized that further analysis could quite possibly lead to improvements in these layouts while maintaining equally well the general principles on which they are based.

18. The principles and applications are grouped under the heads of "Water Supply," "Exclusion of Foul Air from the Building," "Precautions against Vermin Infestation," "Safeguards against Boiler Explosions," "Frost Precautions," "Efficiency from the Standpoint of the User," "Precautions against Noise," "Appearance," "Corrosion and Encrustation," and "Economy." Applications are inset under principles.

WATER SUPPLY

19. Underground piping should be laid at such a depth that it cannot be damaged by frost or other means, and thus, by fracturing, lead to waste and contamination of water by substances in the soil, or by percolation of foul water from leaking drains, cesspools, etc., in the vicinity.

In the drawings service pipes are shown entering at 2 ft. 6 in. below ground level.

20. Storage cisterns should be provided with suitable and close-fitting covers to prevent the entry of dust, insects, vermin, etc.

See covers on storage cisterns. (It may also be noted that one outlet at least from these cisterns is on a side opposite to the inlet to obviate dead water.)

21. Taps should be so located in relation to appliances that back-flow of used water into the supply system cannot take place.

Back-flow may be guarded against by keeping the outlets of taps above the flood rim of the appliance. This is largely a matter of design of baths and washbasins and their fittings, but it affects layout in that piping cannot run to globe taps fixed to the walls of baths if this principle is accepted.

22. At least one tap in each separate dwelling should be supplied directly from the service pipe. If only one such tap is provided it should be in the kitchen.

The drawings show drinking water supply in the kitchen only. With little alteration of piping the cold tap on washbasins could also be supplied from the service pipe.

23. Cold-water pipes serving draw-off taps should be so located as not to be exposed to heating up by being placed too near to hot pipes, tanks, etc.

24. The size of cisterns and tanks, the bore of water pipes and the positions of pipe connections to hot-water tanks should be such that a good supply of both cold and hot water is available at the appliances.

a. 40-gallon hot-water tanks are used.

b. The cold-water cistern is at least equal in capacity to the hot-water tank, thus enabling the full capacity of the tank to be used if the mains pressure fails.

c. Note the pipe sizes shown in the drawings. Some distributing pipes in Cases 2 and 3 are larger than corresponding ones in Case 1, to compensate for lower head from the storage cistern.

d. i. The flow pipe from the boiler enters the hot-water tank at not more than three-quarters of the height of the tank in order to guard, as far as practicable, against reversed circulation.

ii. The flow pipe from the boiler enters at not less than two-thirds of the height of the tank in order that a small supply of adequately hot water shall be available soon after lighting up the boiler. The cold-water inlet from the storage cistern is located low so as to minimize the admixture of cold water with hot.

iii. The design is such as to encourage ready flow from the boiler to the tank, thus maintaining the temperature of the latter as high as possible in relation to that of the former.

iv. The cold feed from the cistern connects to the tank and a separate pipe connects from the bottom of the tank to the bottom of the boiler. This prevents a possible direct cold flow to the boiler which might occur if the cold feed were continuous to the boiler with a T branch to the tank.

EXCLUSION OF FOUL AIR FROM THE BUILDING

25. Disposal piping should be so designed that the water seals in all the traps are maintained under all conditions likely to arise in practice.

Both " one-pipe " and " two-pipe " disposal systems are shown in Cases 1 and 2. Trap seals are 3 in. for one-pipe and 1½ in. for two-pipe. Trap vents are omitted. Some full-scale tests (see Appendix II) have recently been carried out to determine to what extent and in what circumstances the omission of special anti-siphonage venting is justified (from the point of view of loss of seal by siphonage) in simple one-pipe systems for two-storey housing. The one-pipe systems shown for Cases 1 and 2 are based to some extent on the results of these experiments, but they are subject to amendment in the light of further experiments projected. (See Part V.) It is urged that, in view of the limited data on this subject so far available, any one-pipe systems not in accordance with accepted British practice (particularly as regards ventilation of traps) should be subjected to tests before use, pending more comprehensive investigations.

Case 3 is shown on the two-pipe system only. This case does not seem to lend itself to one-pipe treatment because the use of a separate compartment for the closet when all the appliances are on the ground floor makes close grouping difficult.

26. Disposal piping should be so placed in buildings that any leakages or other defects that may appear in course of time will cause as little damage as possible. Special care in this connection should be taken in the use of one-pipe systems, particularly those with internal stacks.

The safe use of one-pipe systems, particularly with internal stacks, depends upon the security of the joints and the quality and durability of the pipes. The external stack system is suggested for use when joints cannot be relied upon to remain gas-tight for the lifetime of the building. (The materials used will have a special importance in this connection.) Possible advantages of the one-pipe over the two-pipe system are (*a*) economy, (*b*) simplicity of erection by an appropriate use of pre-assembly.

27. Where practicable, waste systems should be so designed that accumulations of waste matter are not exposed to the open air in the immediate vicinity of doors, windows or other openings.

a. In the two-pipe systems waste and vent stacks are used in preference to hopper heads for receiving bath and washbasin discharges (Cases 1 and 2).

b. The objection to the use of gullies for sink wastes is appreciated, but they are shown in the one-pipe systems in Cases 1 and 2 for the following reasons :

i. Ease of clearance is provided should a stoppage occur due to the sink waste.

ii. If a stoppage occurs in the section of the drain between the sink connection and a manhole, closet discharges cannot back up into the sink.

iii. If waste water is taken into a rainwater gully it will serve to keep the gully trap filled in dry weather.

iv. In pre-assembled systems working tolerances in fitting may be easier to arrange if only bath, washbasin, and closet on the first floor have to be considered.

v. It may be preferable in some cases, for reasons of planning, to arrange the sink at a considerable distance (in plan) from the bathroom appliances.

c. Where gullies are used the waste discharges into a back inlet.

28. Accumulation of waste matter within the building should be avoided.

This question concerns, in the main, the design of appliances (dealt with in Part III), but note that waste tails are kept short.

29. Vent stacks should be carried to such heights and be so placed that their tops are at a safe distance from openings into buildings.

The need for carrying vent stacks to a sufficient height to prevent foul air from entering openings in buildings is one reason why we do not support the suggestion that rainwater may be taken into soil stacks as a general practice (though there may be special cases where it could be done satisfactorily, and there seems little objection to discharging certain isolated waste appliances into properly constructed rainwater stacks). We note the following paragraphs from Section 40 of the *Public Health Act 1936*:

"1. No pipe for conveying rainwater from a roof shall be used for the purpose of conveying the soil or drainage from any sanitary convenience.

"3. No pipe for conveying surface water from any premises shall be permitted to act as a ventilating shaft to any drain or sewer conveying foul water."

And in the Rules of the City of New York State, Rule 64 contains the requirement: " Rainwater leaders must not be used as soil, waste or vent pipes, nor shall any such pipe be used as a leader."

PRECAUTIONS AGAINST VERMIN INFESTATION

30. Plumbing pipes should be so located in buildings and the buildings be so constructed in their vicinity that "dead spaces" which cannot be cleaned, or can only be cleaned with difficulty, are avoided, except when properly built ducts are constructed for the housing of pipes, as in blocks of flats, etc. Where such ducts are provided they should be easily accessible for inspection, working, and repairs, and should incorporate means to prevent rats, etc. from climbing up the ducts from floor to floor.

Where it is impossible to eliminate uncleanable spaces behind appliances—*e.g.* behind baths—properly designed covers should be used.

In the drawings no casings to pipes are used except bath panels, and pipes are kept clear of walls. In the case of multi-storey flats ducts would be recommended.

SAFEGUARDS AGAINST BOILER EXPLOSIONS

31. Layout should be such as to provide adequate safeguards against boiler explosions under the conditions to which the system will be subjected.

a. Expansion, flow, return, and feed pipes are kept well within the building plan as a safeguard against closure by frost. In Case 1, where expansion and feed pipes run in the roof space, they are lagged.

b. The hot-water tanks cannot be emptied from taps on the appliances.

c. Safety valves and drain cocks to boilers are shown.

FROST PRECAUTIONS

32. Water-supply piping, cisterns, and tanks should be so located or so insulated that they are adequately protected against frost.

a. Note interior location of rising service pipe, flow, return, feed, and expansion pipes and storage cisterns and tanks. Where distributing pipes have to run along the inner face of external walls they are supported away from them on clips or pipe boards.

b. In Case 1, in the roof space, lagging of pipes and cistern is shown.

c. In Cases 2 and 3, the storage cistern is placed within the house on first and ground floor respectively.

33. Water-supply systems should be so designed that they can be completely emptied, and convenient provision should be made for carrying out such emptying. (This provision is also useful for easy repairing.)

Pipes fall to taps on appliances or to draw-off taps, drain cocks or drain plugs (falls not shown on drawings). In all three cases a draw-off tap is necessary to drain the rising service pipe, and this tap is placed immediately above the stop valve in the kitchen. Draining points not over appliances are avoided as far as possible; and this leads to both drinking water and cold supply from the cistern being shown at the sink in Case 1. If only one cold tap, supplied from the service pipe, had been provided here, a special draining point would have been necessary at the lowest level of the cold distributing pipe. In Case 2, the same problem does not arise because there is a flushing cistern on the ground floor. In Case 3, drain plugs for both hot and cold distributing pipes are provided.

EFFICIENCY FROM THE STANDPOINT OF THE USER (SPECIAL CONSIDERATIONS)

34. Stop valves should be provided in such positions that the effect of frost bursts if they occur can be minimized, and that repairs can be more readily effected.

Stop valves for these purposes are shown on the drawings.

35. The installation should be so designed that cleaning is facilitated as far as possible.

a. Bath panels are used

b. Pipes are kept clear of walls.

c. Where possible pipes are taken through hot-water tank cupboards.

36. It is recommended that, if there is only one water-closet in a house, it should be in a separate compartment.

37. Piping should be located in buildings so as to be reasonably secure against accidental damage.

a. Absence of casing (except bath panels) avoids danger of nails being driven into pipes through boarding.

b. Square head, not crutch, is shown on boiler drain cocks.

38. Layout should be such that faults, *e.g.* leakages, are likely to be detected by the occupants at an early stage.

a. Warning overflow pipes, of adequate diameter to prevent flooding, and suitably placed, are provided to storage and flushing cisterns.

b. Note position of drain cocks and plugs.

c. Most piping is visible.

39. All parts of a disposal system should be so designed as to minimize the risk of stoppages.

a. 4-in. diameter soil stacks are shown.

b. Pipe bends are of easy radius.

c. No " dead ends " occur.

d. Full bore traps are indicated: we do not recommend the use of special " re-sealing " or " anti-siphonage " traps in these examples, and, in this connection, we would call attention to the following comments made by American investigators (see Bibliography, item 66) on traps and trap siphonage :

" We have given attention to the subject of anti-siphon, non-siphon, or re-sealing traps, as they are called. Practically all traps, except the plain traps already mentioned, may be included in this class. There are many different kinds, many of them patented and more expensive than plain traps. They are supposed to resist siphonage better than plain traps by reason of having a deep seal, a greater area or volume, tortuous passages for the water, projecting lips, partitions, or, in some cases, moving parts. The best of the resealing traps, when clean, resist siphonage more than a plain trap of 2 to 4 in. seal, and this may be the case even when slightly fouled. When more completely fouled, this resistance to siphonage rapidly lessens. Properly designed resealing traps unvented and clean resist back pressure somewhat more than unvented plain traps of the same depth of seal, but the difference is not sufficient to justify their general use without vents. Their greater complexity causes them to clog more quickly than plain traps, and, if clogged, they are less easily cleaned by the householder and cannot be thoroughly cleaned by the usual method of using a force pump or plunger. Lack of standardization of these traps makes replacement more troublesome and expensive. The supposed advantages of a resealing trap lie in the fact that greater resistance to siphonage makes it possible to omit some of the vent pipes commonly installed, and to use longer horizontal unvented waste pipes and thus secure greater freedom in the location of fixtures. Long unvented horizontal runs, however, are in themselves objectionable.

"As before stated, the efficiency of traps should not be considered alone; plain traps should not be compared with 'resealing traps'; the true comparison is between a drainage system including plain traps and a drainage system including resealing traps. The experiments made by the Bureau of Standards have indicated that simplifications in venting are possible even when plain traps are used. Plain traps have the advantages of economy, simplicity, greater freedom from fouling, and greater ease of cleaning. For these reasons we favour having drainage systems designed on the basis of plain traps rather than on the basis of resealing traps, and are of the opinion that the plain-trap system, with simplified venting, affords ample range in the location of fixtures. Resealing traps should not be accorded any special privilege with respect to venting over plain traps, but their use cannot be prevented by regulation. In short, plain trapping with vents should be the prescribed rule, with resealing traps without vents permitted only under very restricted conditions."

PRECAUTIONS AGAINST NOISE

40. Layout should be such as to reduce the production and transmission of noise as much as possible.

In houses the chief requirement as regards reduction of plumbing noises is to install appliances which operate quietly (see Part III) and to plan the bathrooms and water-closets so that they are as remote from the living rooms as possible.

The part played by plumbing layout, as such, is more limited. For quiet, piping should obviously be confined to the rooms where the appliances are fitted or taken outside the building as directly as practicable. Also plumbing appliances should not be fixed against walls adjacent to living rooms. The piping itself should have easy bends and, where quiet is particularly desired, clips and brackets can be insulated from the pipe by suitable pads.

41. The layout of piping should be designed so as to avoid admixture of air with the water.

When water is being drawn from hot taps there is a tendency for the level of the water in the expansion pipe to be lowered. If it falls to a connection to a hot distributing pipe air may be drawn into the pipe and interrupt the flow. In the drawings it has been arranged that the length of the expansion pipe which contains water above the hot distributing pipe connection is sufficient to render this action unlikely.

The risk of air lock is minimized by sloping pipes continually to the refilling and emptying points and by avoiding U-shaped pipes in the system, except where drain cocks or plugs are situated at the lowest part of the U.

APPEARANCE

42. Regard should be had to the appearance of piping whenever it is exposed to view.

a. Visible piping is unavoidable when other important principles are applied. (See paragraphs 30, 32 and 38.)

b. Bath panels are used.

c. In Case 3, the overflow pipe from the cold-water storage cistern is run at such a height along the wall of the kitchen that it could be hidden by a shelf.

CORROSION AND ENCRUSTATION

43. Piping should be arranged in such a manner as to reduce the chances of encrustation and corrosion.

a. The length, slope, and general run of branch disposal pipes shown in the drawings is such that they should keep reasonably clean in use and thus not give rise to special corrosion effects.

b. It has not been thought necessary in the disposal installations shown to fit anti-siphonage piping for the special purpose of lessening the chances of corrosion.

c. The use of one-pipe systems has the advantage that stacks are kept cleaner by receiving discharges from a number of appliances. In particular, bath wastes help to clear solid matter coming from closets and sinks.

d. Adequate space between external stacks and walls facilitates painting.

ECONOMY

44. In view of the need to put good plumbing within the reach of all sections of the community, to conserve materials (including fuel and water) and to economize in labour, costs should be reduced to the minimum consistent with good sanitation, avoidance of frost troubles, adequate services, and reasonably tidy appearance. It is essential that costs should take account of maintenance as well as installation. Planning to avoid stoppages and to provide easy access should trouble arise from any cause is specially important. Plumbing installations should be designed with a view to reducing the amount of piping and the number of connections as much as possible, to facilitating fabrication off the site (where this leads to economy) and to minimizing the cutting of floors, roofs and walls. It should also allow for ease of access for inspection and repair at all parts and for the clearance of stoppages. Care should be taken to design disposal piping in respect of bore of pipes, falls, connections, etc., so that the system is self-cleansing.

a. One-pipe disposal systems may lead to economies if some pre-assembly of piping units is found to be practicable.

b. Close grouping of appliances shortens pipe runs.

c. Pipes are not run in floors.

d. Maintenance costs have been considered by recommending :

i. 40-gallon hot-water tanks, which should have a longer life in service than, say, 25-gallon tanks, other factors being equal.

ii. One-pipe systems, which may lead to more efficient clearance and thus minimize stoppages.

iii. Readily accessible pipes.

iv. Stop valves in positions convenient for use in repair work.

(See paragraph 39 on the elimination of causes of stoppages in disposal pipes.)

e. Economy in water has been considered. Storage cisterns are shown, also 2-gallon flushing cisterns. (Recommendation for the use of 2-gallon low level flushing cisterns is subject to satisfactory operation of low level flushing cisterns with this quantity of water. Trials are proposed.)

f. Economy in fuel has been considered. Flow and return pipes and hot-water tanks are shown insulated, and flow and return pipes are as short as possible.

PART II. THE USE OF MATERIALS FOR PLUMBING PURPOSES

45. This section of our report consists of some principles for, and some notes on, the selection and use of materials for plumbing purposes. The subject-matter is set out under the main headings of "Effect of Materials on Water," "Durability (General, Corrosion, and Mechanical Strength)," "Nature of Interior of Pipes," "Method of Support," "Economy," "Noise Prevention," "Appearance," "Ease of Cleaning" and "Insulating Materials."

EFFECT OF MATERIALS ON WATER

46. Materials used for pipes, pipe joints, cisterns, tanks, etc., should have no deleterious effect on the water.

Water may be adversely affected by the material of the inner surface of pipes, cisterns, tanks, etc., through which it flows. In general, soft waters are more likely to be affected, but this cannot be taken as a general rule. Each case should be considered on its own merits and reference made to practical experience in the district concerned. Precautions to avoid contamination may be (*a*) selection of materials not likely to give trouble with the water supplied, (*b*) modification of the character of the water, or (*c*) a combination of (*a*) and (*b*). Possible effects of water softening within the building itself should be considered.

DURABILITY—GENERAL

47. Materials used for all parts of plumbing installations should, as far as they are available, be adequately durable, *i.e.* they should, as far as is reasonable, function without permitting leakage of liquids or gases during the expectation of life of a normal building.

a. The conditions to which plumbing pipes are exposed in practice are often very complex, particularly in the case of disposal systems, and, until considerably more data are available, the choice of materials for adequate durability will depend chiefly upon practical experience of what has been satisfactory in the past. The way should not be closed, however, to the introduction of new materials into plumbing or to the use in new ways of the traditional plumbing materials when these would seem to be of benefit. Research into these matters should be encouraged, but the results of research are not likely, alone, to bring about developments of this character in plumbing practice; practical trial under normal service conditions is also essential. Perhaps a good plan would be to regard buildings of a non-domestic character as suitable for innovations as regards plumbing materials. In such buildings the results of a material not being as durable as expected would not be so serious as in housing, and regular inspections and, where necessary, replacements would be more practicable.

b. When materials are being specified for temporary buildings it should be borne in mind that a building is not necessarily temporary because it has been so labelled in the first instance. When a " temporary " building shows obvious defects, *e.g.* roof leaking or walls developing cracks, one may expect steps to be taken to prolong its life, or to demolish it and find alternative accommodation for the tenants. Defects in the plumbing, however, may not be detected until appreciable harm is done, say, by contamination of water supply or underfloor dampness, both of which might result from, for example, corroded piping. It is therefore recommended that short-life plumbing materials should not be used in " temporary " buildings without adequate safeguards.

c. In British Standards for plumbing pipes certain thicknesses have been laid down for different diameters and for various purposes. It is recommended that these specified dimensions should not be departed from without special reasons.

DURABILITY—CORROSION

48. When selecting materials to resist corrosion the following should be taken into account: Type of waste to be carried, character of supply water, corrosion leading to encrustation, use of different metals in the same installation, hot-water effects, alternate wetting and drying, weathering, condensation, materials in which pipes are embedded, special corrosive effects and durability of protective coatings. Notes on these matters follow under appropriate headings.

a. TYPE OF WASTE TO BE CARRIED. Waste may consist of human waste, urine alone, domestic waste, human and domestic waste together or trade waste. In public buildings, schools, etc., where large quantities of urine pass through the pipes, furring rapidly takes place. Such accumulations are sometimes removed by using a chemical solvent which is intended to attack the deposit of uric acid salts but to have no effect on the material of the pipes. Consequently, if it is considered likely that uric acid salts may be deposited to any large extent, the method by which it is intended to remove the deposit should influence the choice of materials.

Grease films in pipes carrying household waste are believed to afford some protection against corrosion, but as yet there seems to be no real evidence of this.

b. CHARACTER OF SUPPLY WATER. The relation between corrosiveness of water and its composition is a complex problem on which a considerable amount of research work has been done. It depends on many variables, *e.g.* acidity, the nature of the various salts in solution, the oxygen and carbon dioxide content. Each case has to be judged on its own merits and specific recommendations can only be made regarding the selection of materials when full data are available. The formation of a protective film or coating, also the character and stability of the film, is particularly important in this connection.

c. CORROSION LEADING TO ENCRUSTATION. A common cause of encrustation is the deposition of solids from temporarily hard water coming out of solution when the water is heated. Such actions are obviously independent of the material of the pipes, but the nature of their inner surfaces may control to some extent the deposition of this solid matter. Besides this, however, there are certain types of corrosion which encourage encrustation. It is therefore possible that encrustation may be greater with some pipe materials than with others even with the same kind of water.

d. USE OF DIFFERENT METALS IN THE SAME INSTALLATION. The use of the same material for cisterns and tanks and the pipes connected to them is an obvious safeguard against electrolytic action between dissimilar metals. One reason for laying all piping to falls is to prevent solid accumulations which may set up electrolytic action. All parts of a plumbing system should be left clean after installation or after repairs (especially cisterns and tanks) so that electrolysis cannot be set up by small particles of metal filings, sand, etc., resting therein. Possibilities of electrolytic action being set up between pipes and pipe clips and between clips and their holding screws should also be noted.

e. EFFECTS OF HOT WATER. Corrosion of pipes, etc. usually proceeds faster when they carry hot water, so that special precautions for such pipes should be taken. The increase in efficiency in hot-water supply systems in recent years has had a tendency to increase corrosion of pipes (in places where heat is a contributing factor in corrosion).

f. ALTERNATE WETTING AND DRYING IN DISPOSAL PIPING. A soil-and-vent stack is exposed to particularly severe conditions because, besides discharging gases and moist air and receiving a slight amount of (soft) rain-water, it also becomes dried from time to time. Any protective effect which waste pipes may enjoy by reason of being lined with grease films is not shared by the vent pipes. Anti-siphonage vent branches and vent stacks are exposed to rather less severe conditions.

Overflow pipes are also subject to wetting and drying because, besides receiving occasional discharges, the air within them must undergo some change in moisture content from time to time.

g. WEATHERING EFFECTS. Pipes on the outside of buildings may have to withstand polluted industrial and seaside atmospheres. Materials unsuitable for such exposure may be safe enough in country air, but it must be remembered that a district may become more industrialized during the lifetime of a building.

h. CONDENSATION. Special conditions in kitchens and bathrooms should be allowed for.

j. MATERIALS IN WHICH PIPES ARE EMBEDDED. Buried pipes may need protective coverings as a safeguard against corrosion in certain types of ground. Ashes, clinker and clay containing sulphates, in particular, should be taken account of in this connection. Materials for pipes should also be reviewed in relation to their behaviour when in contact with lime, concrete, gypsum plasters, "jointless flooring," damp wood, etc.

k. SPECIAL CORROSIVE EFFECTS. Flue gases, cooking fumes, domestic cleaning materials, etc., should be considered. It may be worth noting that developments in the use of fuel for domestic purposes may alter the composition of flue gases, and consequently their effects, if any, on materials used for boilers.

m. DURABILITY OF PROTECTIVE COATINGS. Where the resistance of a material depends on a protective coating, such coating should be adequately resistant to corrosive influences and to erosion by liquids and solids passing along the pipe.

When external coatings have to be periodically renewed in order to give the required protection, the likelihood of this being actually done at the correct intervals should be considered.

Data are lacking as to the durability of internal coatings in disposal piping under practical conditions, so that, in the absence of such information, there would seem to be some advantages in using materials which are not dependent upon coatings for their durability.

DURABILITY—MECHANICAL STRENGTH

49. All parts of an installation should be adequately strong to withstand pressures due to head of water, stresses in transport, handling, assembly (including fixing) and wear in use. An adequate margin should be allowed for anticipated corrosion during the required period of use.

PRESSURE. The selection of suitable water-supply pipes for given pressures has been simplified by the issue of British Standards. As regards heads of water which can be built up in disposal systems in the event of stoppages, the heads to allow for should relate to actual possibilities in the installation concerned.

TRANSPORT, HANDLING, AND ASSEMBLY. The possibility of damage to materials and components after being manufactured and before reaching a final position in the completed building should be carefully considered, especially in relation to proposals to use pre-assembled units. The cost of properly protecting plumbing materials and units should be allowed for when selecting materials for different purposes.

WEAR IN USE. Pipes made of ductile materials, or of relatively weak brittle materials, are subject to damage by the users of buildings. Where such pipes cannot be arranged to be out of harm's way they need to be protected, and cost comparisons relating to plumbing materials should take account of this.

50. Materials for plumbing purposes should be capable of withstanding fatigue stresses due to vibration in the building concerned.

51. When temperature stresses are likely to be produced too high to be taken by a particular material, it may be necessary to consider other materials or to design the system in such a way as to permit expansion and contraction to take place.

52. The liability of movement due to settlement of the parts of the structure to which the piping is attached and the subsequent stresses set up in the material should be allowed for in its selection.

Clayware appliances are liable to be fractured in the settlement of buildings. A typical case is that of a closet pan situated on a timber floor in an upper storey of a building. If the floor settles (one cause could be shrinkage of the floor joists) and the pan is rigidly connected, it may in time become fractured. It is desirable to allow for some flexibility—either in the outgo joint or in the piping assembly to which the closet is fixed. In selecting piping materials, therefore, the need for flexibility of the assembled unit or parts thereof should be borne in mind.

Another example is in the laying of underground piping. If, owing to the nature of the ground, settlement has to be anticipated, the piping should be made either strong enough to resist the stresses involved or flexible enough not to become unduly stressed. If brittle, relatively weak materials are used in such cases and rigidly connected together, fracture of the pipes or parting of the joints is likely to occur.

NATURE OF INTERIOR OF PIPES

53. Interior surfaces of pipes should be sufficiently smooth not to give rise to the collection of deposits or to undue restriction of flow. Pipe sizes for given purposes may have to vary according to the material used. Specially smooth and corrosion-resisting materials may give opportunities for using smaller sizes.

It is possible for small projections on the inside of pipes or fittings to lead ultimately to a stoppage. If a few particles of fibre etc. are caught and held they may in turn collect further solids and eventually, under certain conditions, build up a complete blockage.

Data are available on the rate of flow of water through new pipes of various materials and on the reduction in flow which takes place with age in service, due to increased roughness and diminution in bore. Such data should be considered when selecting piping materials for plumbing purposes and when making any necessary allowances for conditions after years in service. Reduction in flow in pipes to such a degree as seriously to affect the efficient working of plumbing systems has often occurred.

When taking advantage of opportunities to reduce the bore of pipes when they are of specially smooth materials, it should be noted that the velocity of flow through the pipes will be increased if the bore is reduced and that high velocity of flow is a cause of noise in plumbing systems. In disposal systems pipe sizing is governed by other factors besides capacity to take flow. For example, one has to consider the advantages of (*a*) making certain soil and waste pipes large enough so that they are not completely filled with water at critical points during the discharge from appliances—this being a precaution against siphonage of traps which may be necessary even with the conventional provision of anti-siphonage pipes—and (*b*) providing a certain amount of passage way in soil pipes for foreign matters which sometimes find their way down closet pans.

54. Methods of jointing pipes to pipes and pipes to cisterns, tanks, appliances and fittings should not give rise to projections or recesses in the pipe lines liable

to lead to stoppages in disposal systems, or noise or undue loss of flow in water-supply systems.

It is usually desirable that when a change of bore occurs in a pipe the change should be gradual, not abrupt. Burrs should be removed from pipe ends before finally making a connection. Joints between pipes which give rise to annular spaces between the pipe ends may possibly give trouble. Exposed screw threads within pipes may give opportunities for material to collect. In spigot and socket (caulked or filled) joints care is required to obviate the protrusion of materials inside the connection. The same applies to welded and soldered joints.

In water-supply systems the general effect of an obstruction or a sudden change in diameter is to produce turbulent flow resulting in a loss of head and sometimes noise.

METHOD OF SUPPORT

55. Pipes made of materials which are liable to flow under stress (creep) need to be supported at short intervals (or continuously). This fact should be borne in mind in selecting materials for given purposes.

The cost of properly supporting pipes in a plumbing installation should be considered in relation to particular types of job. In a small house with a compact plumbing layout the number of supports required for piping, other than connections to appliances and fixings when passing through walls and floors, may be small, so that materials requiring support at short intervals are in such cases in a more favourable position than when used in other installations with, say, long horizontal runs. Costing estimates for pipe runs, supplied and fixed, at a constant figure, irrespective of the type of job, may therefore be misleading in some cases.

56. Clips and brackets connecting pipes to the inner faces of outside walls should have a minimum of heat conductivity, taking account also of any packing material between pipe and clip.

Low-heat conductivity of clips and brackets is necessary as a frost protection measure, but if insulating material is inserted between the clip or bracket and the pipe then the heat conductivity becomes of less importance.

57. Clips and brackets should be of such material and design as to reduce the likelihood of corrosion between the clip or bracket and the piping which it supports.

Paragraph 48 (d) has mentioned the possibility of electrolytic action at pipe clips.

Owing to the fall on pipes, water formed by condensation tends to collect at the junction of a pipe with its clip or bracket.

ECONOMY

GENERAL ECONOMY

58. The cost of plumbing should be regarded as a total of installation and maintenance. Allowance should also be made for the effect of alternative methods of plumbing on the cost of other work in the same building.

The estimation of maintenance costs likely to be incurred in any given plumbing installation, using given materials, is a difficult matter. The essential point, however, is that in seeking low initial costs the importance of estimating maintenance charges as accurately as possible should not be forgotten.

It is clear that plumbing affects all other building trades in some degree, so that any appreciable general changes in plumbing practice, *e.g.* pre-assembly (coupled perhaps with installation of plumbing work at earlier stages in the construction of a building), may have effects on the other trades. It is not sufficient, therefore, to show that a certain method of plumbing costs more or less than another method—reference should also be made to consequent changes in labour or material costs in other directions.

PRE-ASSEMBLY

59. Shop assembly [1] should be used instead of site work wherever it can be shown that it is more efficient to do so.

a. Shop assembly is often done under better conditions for work, supervision and testing, and gives opportunities for the use of special factory methods of rapid and economical construction.

Jointing of pipes on the site is frequently done in confined situations, creating more difficulties in the case of welded, soldered or caulked joints.

Supervision of site work is difficult and sometimes impossible to do satisfactorily.

Test pressures on disposal piping erected on the site must be limited. Bench test methods applied to pre-assembled piping give a better guarantee of long-period, as well as initial, gas-tightness.

Site welding limits the technique which can be employed.

b. Pre-assembled units above a certain size and weight may be cumbersome to transport and handle. They may also be liable to damage between shop and final position on the site. Some forms of such damage might be detected and remedied on the site, but it is possible that other forms, *e.g.* springing of joints, might not be attended to, and this could lead in some cases to serious plumbing defects. Well-made metal-to-metal joints (especially if welded or screwed) may be expected to remain intact during transport; but clayware-to-metal (spigot and socket) joints are more vulnerable to impact and vibration stresses.

c. It may be found that for some cases a combination of shop and site fabrication would lead to the most satisfactory and economical construction (See drawings discussed in Part I.) In these cases it may be possible to pre-assemble, for example, parts of the disposal system, parts of the water-supply piping and a hot-water tank cupboard with tank and piping.

Partial pre-assembly has often been used by plumbing contractors. It seems to be successful provided the problems of job organization can be solved, such as finding constant employment for the men on the site. If generally and systematically used it should reduce costs and speed up construction.

Other examples of partial pre-assembly are: Cutting pipes to dead lengths and threading them off the site, and the use of trap and short branch pipe in one piece to save a joint between trap outgo and branch.

d. In pre-assembled units certain problems arise in connection with the working tolerances required in fitting waste and supply piping to appliances. Some difficulties due to variation in positions of outlets of closets, baths, etc., should be removed when the proposed British Standards for these appliances have been implemented. As regards the connection of a pre-assembled disposal piping unit to standard appliances, the following points call for consideration. The position of the bath is more or less fixed in relation to the walls of the bathroom, and thus the bath outlet constitutes a fixed point. The closet pan, however, can be moved laterally to enter the socket of the branch pipe, and the washbasin might be of such a design as to allow a certain amount of lateral movement on its brackets. Sinks are adjustable laterally on their supports. The use of the more ductile or of thin walled piping materials in the pre-assembled units would help to meet the need for tolerances in fitting because slight bending and springing could be done simply on the site.

When pre-assembled units are made up in a material which depends on a coating for its protection, note should be taken of the practicability and cost of coating after all welding, screwing, etc., has been done. Coating of units above a certain size and complexity may be difficult and expensive, and local facilities for doing it may sometimes be lacking.

e. The degree of pre-assembly which contractors may find it desirable to adopt may depend upon:

i. The job in question, flats giving perhaps better opportunities than houses, and compact groupings of appliances better than dispersed ones.

[1] By "shop assembly" is meant work carried out anywhere except in the final position of the plumbing in the building. It would therefore include assembly of piping units etc. in a site workshop, which may in some circumstances be found to be the best place for such work.

ii. Whether pre-assembly methods are being applied to other components of the building concerned as well as to the plumbing.

iii. The facilities available to the plumbing contractor and the size of his contract.

iv. The type of labour available.

v. The materials available.

It is therefore not desirable to recommend any specific degree of pre-assembly for general application, but every opportunity should be taken to seek plumbing economies in this field. Practical trials with the construction, transport, handling and fitting of pre-assembled units should lead the way to the most efficient and economical methods.

ALTERATIONS, REPAIRS AND REPLACEMENTS

60. In the selection of materials and methods of jointing preference should be given, other factors being equal, to those which permit of economical removal or cutting and refitting.

The softer metals are more easily cut. Compression, union, and some capillary joints, etc. are readily detached and remade.

REDUCTION IN NUMBER OF JOINTS

61. In the interests of economy connections should be eliminated when practicable.

Pipes obtainable in long lengths and capable of being easily bent in a satisfactory manner may need fewer joints and thus present opportunities for economy. The number of pipe fixings will be reduced in proportion to the rigidity of the material.

WEIGHTS OF PIPE WORK, ETC.

62. Preference should be given, other factors being equal, to materials with a high strength/weight ratio, in view of their economy in transport and handling.

The weight of material used may influence the economical size and complexity of pre-assembled units.

EXTERNAL DIAMETER OF PIPES

63. Consideration should be given to the fact that, for a given bore, thin-walled piping occupies less space within buildings and also requires less lagging material (where this has to be used).

METHODS OF JOINTING

64. In general, and in so far as is consistent with efficiency, economy should be secured by reducing the amount of material in joints and by simplifying the jointing process as much as possible.

STANDARDIZATION

65. Standardization of certain manufactured components is desirable in the interests of economy.

A good deal of standardization of pipes, pipe junctions, bends, tees, etc., has already been done. (See relevant British Standards.) It would be an advantage if this standardization, and a limitation of manufactured types, could be extended to other fittings. (See suggestions in Part V, paragraph 123.)

USE OF DETACHABLE JOINTS FOR ACCESS

66. It may be economical to use detachable joints at certain points in a disposal system and thereby save the cost of providing special access doors, eyes or screw caps. This factor may influence the selection of the piping material in certain cases.

When waste piping is connected by means of mechanical joints such joints may sometimes serve for access.

PAINTING

67. Exterior surfaces of exposed piping, etc. should be such as to require the minimum cost of painting. Special consideration should be given in this connection to materials not requiring painting.

FUEL ECONOMY

68. Other factors being equal, piping material of low thermal capacity and conductivity is preferable for carrying hot water.

NOISE PREVENTION

69. Piping, appliances, etc. should be so fixed as not to cause undue noise to be transmitted to the structure.

Pipes should be fixed rigidly to supports holding the pipe firmly at frequent intervals, especially if the pipe is of " hard " material, likely to " ring."

When necessary, sound-insulating materials should be placed between appliances, pipes, etc. and the floors, walls, etc. with which they are in contact. For example, pads may be necessary under closet pans and flushing cisterns and pipes may need to be wrapped when passing through interior walls and suspended concrete floors.

Washers for taps should be of such material and so fitted that the possibility of water hammer, etc., arising in water systems is eliminated as far as possible. It is important to select washers correctly for the purpose required, not only in the original installation but also in replacements. The particular requirements of (*a*) draw taps and stop valves, (*b*) ball taps, and (*c*) hot-water taps should be met in the selection of the material for washers. The fixing and housing of a washer should be such as to prevent it spreading or distorting. Correct sizing is important ; slightly oversized washers can in some cases give rise to noise.

APPEARANCE

70. Where plumbing work is exposed to view, piping materials and methods of jointing should be so chosen as to give a neat appearance.

Appearance is usually improved when the size of visible pipe connections is made small compared with the size of the pipes being connected. Reduction in external diameters which accompanies the use of the thinner-walled pipes is also an advantage from the point of view of appearance.

It seems possible that piping assemblies built up on the bench may be neater in appearance than *in situ* work.

EASE OF CLEANING

71. Where plumbing work is not encased, materials for piping, etc., and methods of jointing should be so chosen as to leave the minimum of uncleanable spaces between piping and structure, and the exterior surfaces of the pipes and fittings should be such as to be easily cleanable.

INSULATING MATERIALS

72. Selection of type and thickness of materials for insulating pipes, cisterns, tanks, etc., against freezing effects, against loss of heat and against warming up of cold water should be made on the basis of the actual conditions obtaining.

73. Insulating materials should be durable, *i.e.* they should perform their required functions for the life of the piping, etc., which they cover.

74. Insulating material should not be such as to form food or nesting material for, or be capable of being damaged by, vermin.

PART III. STANDARD APPLIANCES FOR HOUSING

RECOMMENDATIONS OF A GENERAL CHARACTER FOR THE STANDARDIZATION OF BATHS, WASHBASINS, SINKS, AND WATER-CLOSET SUITES

(The purpose of these notes is to indicate the general lines along which standardization should proceed. For the actual fixing of appropriate dimensions co-operation with the manufacturing side is essential. Committees representing the various interests involved have now been formed by the British Standards Institution for the purpose of preparing the detailed specifications.)

BATHS

HEIGHT

75. The commonly used internal height of 17 in., or thereabouts, over the outlet is acceptable.

76. There should be sufficient clearance under the bath at the outlet to allow for the trap and waste pipe to be above the floor. In the case of one-pipe systems a trap with a 3-in. seal should be allowed for.

(The purpose of the above recommendation is to give ready access to the screw cap at the side of the bottom of the trap and to secure simplicity and economy of labour in fixing trap and wastes. It is true that in certain cases access to the screw cap could be in the ceiling of the room below, but this could only normally apply to a kitchen ceiling of a two-storey house and not to flats, one-storey buildings or ground-floor bathrooms. There might also be some difficulty in the case of concrete floors. Since in standardization the demand is for a bath suiting the general case it seems desirable to proceed on the basis of keeping the whole of the piping mentioned above the floor, in spite of the disadvantages of installing baths which may be as much as 24 in. from floor to rim. It is agreed that a lower height, such as 18 in., is preferable for elderly people, but in view of the need for access and economy in installation it is recommended that the standard bath be provided with feet to give the necessary clearance beneath it.)

LENGTH

77. In the planning of bathrooms for low-cost housing the length of the bathroom is frequently made the same as the overall length of the bath (with a small allowance for building in). If, when this occurs, a choice has to be made between lengths of approximately 5 ft., 5 ft. 6 in. and 6 ft., the 5 ft. 6 in. dimension seems to be the most suitable. To use 5 ft. would restrict space unduly, and it is questionable whether one can justify 6 ft. in low-cost housing. The recommendation is, therefore, that in standardization priority should be given to the 5 ft. 6 in. length overall.

WIDTH

78. Baths should be wide enough inside at the head end for comfort in use. A minimum of 24 in. (inside measurement) at this part (at top level of bath) is suggested.

SHAPE

79. a. For the safety of users baths should be as flat-bottomed as practicable.

b. The fall along the bottom of the bath from head end to outlet should be adequate for drainage.

c. The foot end of bath should be so shaped that:

i. There is adequate space between the end of the bath and the wall for easy connection of supply and waste pipes.

ii. Taps will not drip on to the end wall of the bath, causing staining, but on to the bottom. Also it should be made possible for vessels to be filled easily from the taps. (This is partly a matter of design of taps, which is not dealt with in these notes, but the slope of the end wall of the bath is a contributory factor.)

d. The front side of bath should be so shaped that water-supply pipes can, if desired, be run horizontally behind a panel covering this side of the bath.

e. The slope at the head end of the bath should be such as to make for comfort in use. A slope of about 25° from the vertical is suggested.

f. The rims of the bath at the ends and back should be designed for good joints to walls.

WASTE OUTLET

80. Outlets should be such as to suit a trap of 1½-in. internal diameter and should be located sufficiently far from the wall to allow for easy fixing of overflow, trap, and waste piping.

OVERFLOW OUTLET

81. a. A fully cleanable overflow passage is preferable to the non-cleanable type, but the practical difficulty of providing such an overflow for baths which is at the same time simple and economical is appreciated. It is also realized that even when overflow channels are cleanable the cleaning may not be done. The usual type of bath overflow fitting in which connection is made to a vertical grid on the wall of the bath at the foot end is, therefore, acceptable. The height of this grid should be such that when a heavily built person enters a bath which has been filled to the overflow there is room for displacement without flooding. The actual position for the outlet grid will obviously depend upon the shape of the bath, but presumably it will be about 13 in. above the level of the waste outlet and thus about 4 in. below the rim.

b. The hole for the grid should be such that an overflow waste pipe 1¼ in. in internal diameter can be used.

TAP HOLES

82. a. The size of the (squared) holes should be suitable to take ¾-in. taps.

b. The spacing of the tap holes should be such that they are far enough apart for ease of manipulation (6-in. minimum suggested) but not so wide apart that a vessel resting on the bottom of the bath cannot be filled from either tap (9-in. maximum suggested). It follows from the above that taps in the corners of the bath are not recommended.

c. As a precaution against back-flow it is recommended that the outlets of the taps should be above the flood rim (*i.e.* top edge) of the bath. It will be noted that this recommendation cannot be followed if the normal globe tap, fixed to the wall of the bath, is used.

d. Taps fixed to walls and not to the bath may in some cases be required. Cover pieces should, therefore, be provided for closing tap holes when necessary.

PANEL

83. a. It is recommended that priority be given to the panelled bath. The advantages of the panelling are:

- i. Appearance is better.
- ii. Less floor covering (*e.g.* lino) is required.
- iii. Cutting of lino round feet of bath is avoided.
- iv. "Dead space" under a bath is liable to collect dirt because it is difficult to clean, and it may also be used as a depository for cloths, brushes, etc. which is undesirable from the point of view of general cleanliness.
- v. Cleaning of the bathroom is simplified.
- vi. It enables water-supply piping to be run parallel to and in front of the bath just behind the panel.

b. The panel should be of a strong and durable material, should be capable of being rigidly and easily fitted and should be easily removable for getting access to pipes. It may be necessary, to avoid burying pipes in external walls (a practice which is undesirable from frost and access standpoints), to bring piping through the panel at the foot end. The panel may be recessed where it meets the floor to provide adequate toe space. It would be sufficient, and perhaps more convenient for fixing, to recess only between the feet of the bath. Panels should be so fixed to the side of the bath (and the flange so formed) that a good grip can be obtained by users in getting in and out of the bath.

c. Allowance should be made for end panels in cases where the head end of the bath is not fitted against a wall.

FEET

84. The feet of the bath should be so placed that they do not obstruct or make it difficult to connect a 1½-in. diameter trap and a 2-in. waste pipe carried out parallel to the foot end of the bath, if this should be desirable in any layout.

SOAP TRAYS

85. It would seem preferable not to make soap trays integral with the bath.

OVERFLOW FITTING

86. It is recommended that, if the standardization of waste fittings is carried out in conjunction with the standardization of baths, provision should be made for a standard connection between the overflow outlet and the waste trap.

WASHBASINS

FORM

87. a. The surface under the edge of the rim at the sides should be wide enough to give play on the brackets, thus allowing sufficient tolerance if it is required to fit the basin to pre-assembled disposal piping.

b. All edges and corners should be rounded for convenience of cleaning.

c. The back of the basin should be so shaped that tap connections can be easily made.

OUTLETS

88. a. Outlets should be bevelled and not rebated. Bevelling makes a much neater joint and ensures the waste fitting being fixed concentric with the opening.

b. The diameter of outlets should be suitable for a fitting of 1¼-in. (internal) diameter.

c. The position of the outlet on plan should be such as to allow for easy connection of the waste.

WASTE FITTING

89. The waste fitting should be 1¼-in. diameter and the flange bevelled on the underside to suit the countersinking of the outlet.

OVERFLOW

90. An easily cleanable type of overflow is desirable.

TAPS AND TAP HOLES

91. a. Taps should discharge above the flood rim of the basin, consequently the design of the basin should be such as to facilitate this, though this requirement may chiefly concern the design of taps.

b. Tap holes should be squared.

c. Tap holes should be in such a position that the taps will project sufficiently over the basin to enable a vessel to be filled.

SOAP TRAYS

92. Soap trays should be designed so as to enable the soap to dry.

SUPPORTS

93. Brackets should be standardized with the basin.

TOWEL RAILS

94. Towel rails on the sides of the supports often abut too closely on the bath or the closet or the wall for them to be useful. They should be arranged at the front, but not to project beyond the basin. A wider rail can be provided in this position and the towel is more accessible.

HEIGHT FROM FLOOR

95. It may be necessary to specify the height if legs or pedestals are used. 30 in. to 32 in. is recommended.

SINKS

TYPE

96. It is suggested that the following types should be standardized initially:

a. Single sink.

b. Combined sink and wash tub with single outlet.

FORM

97. a. The form of the sink should be rectangular with rounded edges and corners and with the bottom sloping to the outlet.

b. A back shelf is not regarded as essential, but, if it is used, pillar taps should not be incorporated in the shelf.

DEPTH (INSIDE)

98. 8½ in. is suggested for the single sink and for the sink of the combined sink and wash tub.

OUTLET

99. a. The diameter of the outlet of the sink should be suitable for a 1½-in. waste.

b. If the outlet is placed at back centre care should be taken to allow ample room for accommodating the trap which runs waste out through the wall. The centre-end position is considered generally preferable to the back-centre position, provided that the draining board is not fixed over the overflow channel opening. It may be advisable to standardize draining boards and their connection to the sink.

OVERFLOW

100. An easily cleanable weir overflow is recommended.

WATER-CLOSET SUITES

SUITE AS ONE UNIT

101. It is recommended that a closet suite, consisting of flushing cistern, flush pipe and closet pan, be standardized as one unit and that a standard of performance be applied to the suite as a whole.

PERFORMANCE OF SUITE

102. a. The contents of the pan should be cleared with a flush of 2 gallons and tests for performance should be prescribed.

b. It would be advisable also to standardize suites for 2½- and 3-gallon flushes to meet the case where such a flush is allowed.

c. The suite should be designed to operate as quietly as possible.

d. Particular attention should be paid to connections between the various parts —cisterns, flushpipe, and pan—and flushing should not cause a splash over the edge of the pan.

FLUSHING CISTERN

103. a. TYPE. The low-level flushing cistern has the following advantages:

i. It has a better appearance, is simpler to install and to attend to.

ii. It permits the storage cistern to be placed at a lower level than would otherwise be the case, giving in some cases better protection against frost.

b. MATERIALS. The specification should allow for the use of galvanized cast iron, vitreous enamelled cast iron, vitreous enamelled pressed steel, copper, plastics, asbestos cement, wood with sheet-metal lining, clayware, etc.

c. SHAPE. The shape of the cistern can be rectangular in elevation. Tapered sides are not necessary for its function in use.

d. LID. A lid which covers the cistern should be provided.

e. BALL VALVES. Ball valves should be designed to refill the cistern within a certain specified time, not exceeding, say, one minute.

A variety of valves should be standardized to suit various pressure ranges. The range should be stamped on the body of the valve.

Valves should be rigidly fixed to cisterns.

The quality of ball valves should be good to reduce maintenance. A silencing pipe should be fitted and the body of the tap should be perforated with an anti-siphonage hole.

f. FLOAT AND ARM. Clearance should be allowed to prevent sticking. The design should be such as to ensure efficient closure of the ball valve.

g. SIPHON MECHANISM (INCLUDING LEVER AND HANDLE). The mechanism should be non-clanking and of the "siphon," not the "dome and discharge pipe" type. Noise (gurgle) due to the breaking off of the siphonic action at the end of a discharge should be prevented, *e.g.* by boring a small hole just above the bottom of the inlet arm of the siphon.

There should be a minimum of working parts.

h. OVERFLOW. A proper overflow should be provided.

The position of the overflow hole in the cistern should be such that the overflow pipe will take away the full discharge under any pressure likely to arise without flooding the body of the valve.

j. SUPPORTING BRACKETS. These should be included in the specification and be of the cantilever type or suitable for fixing on the wall face, as may be required.

FLUSH PIPE

104. a. MATERIAL. The flush pipe should be of non-corrodible material.

b. CONNECTION TO PAN. A simple and satisfactory method of connecting the flush pipe to the flushing arm is by means of a lead cone and red-lead packing, but there are other methods which are almost as satisfactory.

CLOSET PAN

105. a. OUTLET. The following types of outlet should be included:

i. Straight P-trap.

ii. S-trap.

iii. 45° turned P-trap (P-traps turned more than 45° from the straight position are not recommended for the proposed specification).

b. SHAPE. To minimize fouling the following suggestions are made:

i. Pans should be so formed that a vertical line from the back of the inner edge of the rim falls within the water surface.

ii. The water surface itself should be about 7 in. long (back to front on centre line).

In general, the shape should be such that adequate flushing occurs. (See paragraphs 101 and 102.)

c. HEIGHT. The maximum height should be 15 in. from base to top of rim, but a lesser height, down to 13½ in., is desirable.

d. TRAP SEAL. Depth of seal should be at least 1¾ in.

e. OUTLET:

i. *Height.* 7 in. to centre of outlet for P-trap is suggested.

ii. *Inclination to Horizontal* (*P-trap*). This should be such as to suit standard cast-iron, also asbestos cement, branches.

iii. *Diameter* (*Internal*). It is suggested that 3½ in. be used for washdown closets and 3 in. for the siphonic type.

iv. *Diameter* (*External*). This should be included in the specification as it affects the size of socket to be used on the closet branch; it will, of course, vary with the thickness of the material used.

v. *Form.* The spigot should be corrugated and unglazed for security of jointing.

vi. *Anti-siphonage Pipe Connection.* This should not be on the pan but on the branch pipe or connector.

f. BOLTING DOWN. The number and size of holes for bolts, also their positions, should be included in the specification.

g. SUPPORT. If pads are to be inserted between the base of the pan and the floor for sound insulation these pads should be covered in the specification. They should be non-absorbent.

SEAT

106. a. MATERIAL. This should be non-absorbent.

b. FORM. The seat should be flat on the underside.

c. HINGES. The spacing of hinges should be standardized to fit standard lug spacing on the pan. Hinges should be of non-corrodible metal.

d. BUFFERS. The number of buffers required, their type and the method of fixing should be specified. Screws to buffers should be of non-corrodible metal.

e. COVER. When the closet is placed in the bathroom, it is recommended that a seat cover should be provided; consequently the specification should include a seat cover to meet this case. If the closet is in its own compartment, a seat cover is not considered necessary.

NOTE ON FLUSHING VALVES

107. In the section of our report which deals with flushing cisterns it seems appropriate to mention flushing valves. It has been suggested to us that we should recommend the replacement of cisterns by valves for post-war plumbing because of the advantages of the latter (particularly appearance) and in view of their wide use in America and Europe. After careful consideration we find that we cannot recommend a change over from normal British practice in this respect at the present time, because of the excessive consumption of water which defective valves may entail and because it does not seem to us that a flushing valve proof against waste of water has yet been developed in, or introduced into, this country. Our conclusion has been influenced by the following observations:

a. The construction of flushing valves, of the types known to us, often includes narrow passages liable to become blocked by small particles carried in suspension in the water supply or arising from corrosion or lime deposits. When these passages become blocked the result may be to permit a continuous flow of water.

b. When valve seatings in the mechanism become imperfect through corrosion or wear the same defect may develop.

c. When flushing valves get out of adjustment (as they seem to do at short intervals—sometimes less than six months) they may discharge quantities of water considerably in excess of the designed flush, and readjustment to the correct discharge may require dismantling of the valve.

d. It may be noted that maintenance of flushing valves in low-cost housing would probably be difficult. When comparing valves with cisterns on the score of cost, it should be noted that flushing valves normally require larger supply pipes than flushing cisterns, and it is most undesirable that they should be supplied directly from service pipes on account of the risk of contamination.

e. The problem of noise set up by certain types of flushing valve needs to be solved before the general use of the valves could be recommended.

f. The above observations concern flushing valves which are intended to deliver automatically a definite quantity of water when the lever is pressed. Types of mechanism which discharge water as long as pressure is applied are obviously liable to excessive use of water.

PART IV. NOTE ON BUILDING DRAINAGE

GENERAL

108. The study of the underground drainage forming part of normal building works is one of the subjects to which we have been able to give only partial treatment. (See p. 1, last paragraph.) It is clear that this particular problem merits more detailed consideration and that, moreover, some of the proposals we have made for above-ground pipes need to be taken in conjunction with alterations to the drains, *e.g.* the adoption of the combined soil and waste pipe system with omission of gully traps. However, we have arrived at certain general conclusions which are presented here.

109. Too little attention has been paid in the past to building drainage, especially that for low-cost houses, with the result that money has been spent on work which is not only unnecessary but is frequently difficult to maintain in good order. Good materials, skilled workmanship, and simplicity of design are the essentials, but the importance of these requirements is not always realized, and consequently drains are frequently laid by men with insufficient skill in this particular kind of work, and supervised by others who have not studied the principles of good drainage. The result is that the most hygienic and economical methods are frequently not used.

All pipes, bricks, and other materials should be as specified by the appropriate British Standard, or should otherwise be of first-class quality.

PIPES

110. In the past there was a tendency to use unnecessarily large pipes with the wrong idea that these were less liable to become choked, but it should be emphasized there is no necessity to use a pipe larger than 4 in. internal diameter for the foul drainage of any ordinary house.

111. There are many stoneware and fireclay pipes on the market which are of poor quality. Rough surfaces, excrescences, and bad joints are frequent causes of stoppages.

JOINTING AND LAYING

112. Jointing, gradient, and alignment are not simple matters, particularly in water-logged trenches or bad ground, and the laying of pipes should only be executed by properly trained operatives. Much damage, too, is often caused in back filling the trenches, and as such damage generally occurs in deep drains it is not easy to detect or remedy when the trench is filled in.

Not infrequently pipes have been laid without a concrete bed or flaunching and, although this may be justifiable for strictly temporary huts in camps, etc., and where the ground consists of rock or stiff clay, the practice of omitting the concrete bed for even low-cost housing is to be discouraged.

Laying of stoneware drains by "self-centring" methods, to save time and secure better joints, should be considered.

VENTILATION

113. Thorough ventilation of the system is important to prevent back pressure on the traps of the appliances and also air locking. The mica-flap air inlet is obviously unsatisfactory, and there is no reason why the inlet should not be at or near the ground level with a simple bar grating. A dirt tray may be added in some situations.

BENDS AND TRAPS

114. The setting of bends and traps is an important matter, and it is generally agreed that the joint between the iron soil pipe and stoneware upturn bend is the weakest spot of any sanitary system.

MANHOLES

115. The commonest defects found in manholes are poor brickwork badly rendered, branch drains brought in at improper angles, bad benching, and light covers easily broken or which fit imperfectly.

116. Properly constructed manholes are an expensive item and are only necessary at main junctions, not at easy bends and 45° Y junctions.

117. It is in buildings of the lowest cost, where the drains are liable to be misused and stoppages occur, that there is the greatest temptation to provide inferior manholes and covers. Stoppages can often be removed by extending the head of the disconnecting trap to the surface and "plunging," or by rodding through

an access on the down pipe or a specially provided rodding eye. Since badly formed manholes are themselves a common source of obstruction to the natural flow, it is a matter for serious consideration whether drains would not function more satisfactorily without manholes, and also whether this course would not result in a vast saving to the community in general, even if on very rare occasions the ground had to be opened up. Buried access covers on the drains are not to be recommended, as they can seldom be found when needed and the covers are liable to be improperly fixed or broken.

TESTING

118. The testing of all drains by a competent person is a deterrent to scamped workmanship which may otherwise be rapidly covered up and escape unnoticed.

PART V. RECOMMENDATIONS FOR FURTHER INVESTIGATION AND RESEARCH

119. SOIL AND WASTE PIPE SYSTEMS. We have thought it advisable to study possibilities of greater economy in respect of waste and soil disposal systems for low-cost houses. Appendix II summarizes the results of some of our practical trials on one-pipe systems for such buildings, but it has not been possible in the time available and with the facilities at our disposal under war-time conditions to do more than carry out preliminary experiments of this nature. It would seem advisable that a systematic investigation of this subject be put in hand, because we feel that in many cases a rationally designed and constructed one-pipe system, even for small housing, may prove to be more economical, and sometimes more efficient in operation, than a two-pipe system. Further research would establish more exactly the conditions under which trap ventilation (by special anti-siphonage pipes) can safely be omitted from simple one-pipe systems. Possibilities in this direction may have an important bearing on costs.

Further investigation, including experimental work, seems also desirable in connection with one-pipe systems of a more complex character, such as for flats and multi-storey buildings generally. American investigators have carried out extensive experiments on this subject. (See Bibliography, items 66, 80, and 81.) This work merits more careful study than we have been able to give to it, and experiments on the same lines could profitably be done here to secure data for the more scientific design of disposal systems for British practice.

Similar work for obtaining or correlating data for the economical and efficient design of water-supply systems might be undertaken.

120. DURABILITY OF MATERIALS. A good deal of the data has been obtained by various investigators on the behaviour of plumbing materials under certain conditions of exposure, but the corrosive and other influences to which plumbing pipes, etc. are subjected in practice are very complex. More research is needed to give reliable data for the selection and use of materials (including methods of jointing), so that piping may be installed with more certainty of its durability for the periods and conditions required than is the case at present. Such research would be particularly useful in relation to certain materials, new to plumbing, which are now claiming attention on the score of economy but about which practical experience as to their behaviour for plumbing purposes is lacking or limited. There is a natural reluctance to use a comparatively untried material for plumbing purposes owing to the serious consequences which may result if the material becomes defective. Research may help in introducing the newer materials into plumbing where they are suitable for such use.

121. FIELD OBSERVATIONS. We have felt the need for reliable statistics on the behaviour of plumbing systems over long periods of service, *e.g.* the incidence of stoppages, the need for manholes, effects of settlement of buildings, durability of materials under various conditions, etc. It seems likely that some differences in the opinions of experts on what is desirable in plumbing would be resolved and practice made more uniform throughout the country if statistical data on performance were available in a suitable form. Field observations would be a guide to rational design, because, although suitable precautions must be taken for conditions likely to arise, it is not reasonable to make costly provision in all plumbing installations for contingencies which only arise in a very small proportion of cases. This applies, for example, to the provision of access doors, rodding eyes, and manholes. Some authorities favour a more limited use of these than others, on the basis that overall economy is better served by cutting and repairing pipes, etc. in isolated cases of stoppage than by providing expensive means of access in all cases.

Reliable statistics obtained in the field would not only be a useful guide to rational practice in such matters, but also be invaluable in connection with further research into the economical and efficient design of plumbing systems and the durability of plumbing materials.

122. NOISE. We recommend that an experimental investigation into plumbing noises be put in hand.

123. STANDARDIZATION. The work already completed, or in hand, on the standardization of plumbing appliances and fittings is referred to in other parts of this report. It is suggested that standardization be extended to cover other units such as hot-water boilers, precast manholes, certain piping assemblies, cast-iron rainwater gutters and outlets, gullies, etc., and smaller fittings such as brackets, wire balloons, domical gratings, sleeves, thimbles, etc.

Standardization of plumbing equipment should be kept continuously under review to take advantage of any improvements in design and manufacture which may be developed from time to time.

124. PLUMBING SUBJECTS NOT COVERED IN THIS REPORT. For reasons given elsewhere in this report (see p. 1, last paragraph) we have not studied all the branches of plumbing to the same extent. It might be useful at some stage for an inquiry to be conducted into possibilities for greater economy and efficiency in relation to rainwater disposal from roofs, the special plumbing of non-domestic buildings, and other matters to which we have been unable to give much attention.

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APPENDIX I

COMMONLY OCCURRING DEFECTS IN PLUMBING PRACTICE

In the course of our studies we have noted a number of commonly occurring defects in plumbing practice which have been instructive to us in preparing recommendations for improvements. It was thought that it might be of interest to record a few examples of these defects in an appendix. They are listed below under appropriate headings.

FROST EFFECTS

1. Laying service pipes too near to ground level at the point of entering a building, and also exposing them to cold draughts under ground floors.

2. Running service and distributing pipes within external walls or against them in cold parts of the building.

3. Installing piping and storage cisterns in roof spaces too near to the eaves or the roof surface, or without lagging or covering, or without other protection by way of roof boarding, felting and beam filling.

4. Laying water piping in such a way that it cannot be emptied completely, including insufficient support to horizontal runs of lead piping so that sags develop. Also, in this connection, the omission of necessary drain cocks or drain plugs.

5. Omission of a stop valve for handy use by the occupiers of individual dwellings. Omission of stop valves on distributing pipes from cold-water storage cisterns.

CONDITIONS ENCOURAGING COLLECTION OF DIRT AND HARBOURING OF VERMIN

6. Avoidable dead spaces behind pipes and in the fitting of appliances.

7. Holes for pipes not sleeved.

INSANITARY CONDITIONS

The following are the insanitary conditions most frequently complained of:

8. Inefficient flushing of closets.

9. Accumulation of waste on gully gratings.

DEFECTIVE WATER SUPPLY

10. Uncovered storage cisterns.

11. Inadequate supply at cold taps, for which a contributory cause is piping of too small a bore or piping reduced in bore by corrosion and encrustation.

12. Inadequate supply at hot taps for above reasons and on account of incorrect layout of the system.

CORROSION AND WEAR

13. Corrosion of galvanized hot-water tanks. (This often occurs because the choice of materials to meet the given conditions has been incorrectly made in the first place.)

14. Disappearance of wire balloons.

15. Fixing of external pipes so close to walls that they cannot be easily painted.

FRACTURE OF CLOSET PANS IN SERVICE

16. Fracture of closet pans due to outgo connection or branch connection being too rigid.

NOISE

17. Excessive velocity of water flow in pipes due to the use of piping of small bore in conjunction with high pressure. Sharp changes of direction in pipes, sudden changes of diameter and burrs on interior ends of pipes at connections.

18. Incorrect selection of ball valves in relation to pressure.

19. Badly designed or maintained draw-off taps or ball-valves.

20. Use of washers of incorrect material and incorrect size. Also washers incorrectly housed.

21. Flushing cisterns operating noisily on account of inferior design and finish.

DIFFICULTY OF ACCESS

22. Piping so fixed that repairs and replacements are difficult and expensive to make.

STOPPAGES

23. Layouts encouraging the building up of solid material in pipes.

INFERIOR MATERIALS

24. Use of tap washers of inferior quality and unsuitable material which rapidly wear.

25. Early deterioration of closet seat hinges and buffers.

26. Screw caps under traps of washbasins and sinks which cease to be watertight after a few removals.

27. Early deterioration of glazed finish on appliances.

SIPHONAGE OF TRAPS

28. Self-siphonage of traps of sanitary appliances.

AIRLOCK IN PIPES

29. Systems which give airlock trouble in refilling, commonly arising with piping so arranged that it cannot be completely emptied.

In relation to "defects" it seems appropriate to refer in this appendix to the following:

MULTIPLICITY OF TYPES OF THE SAME KIND OF EQUIPMENT

30. While making full allowance for different local conditions we have noted a degree of variety in different types of flushing cisterns, taps, ball valves, compression joints, sanitary ware, lead pipe weights, rainwater goods, etc., which seems unnecessary.

Variety arises to some extent from a desire to cater for individual tastes and from the natural effects of competition between manufacturers handling new designs. Up to a point this operates beneficially in bringing about improvements. On the other hand, the cost of plumbing to the consumer must be unnecessarily high with such variety, because it means that:

a. Costs of manufacture and marketing are likely to be higher when many different types have to be handled.

b. Replacements may have to come from one source only, thus involving delay in delivery and additional transport.

c. Additional time has to be spent by architects and in the order departments of plumbing contractors so as to provide correctly for various local requirements.

APPENDIX II

TESTS FOR SIPHONAGE OF TRAPS CARRIED OUT ON SIMPLE ONE-PIPE INSTALLATIONS

The one-pipe system of plumbing has been in use in this country in a number of multi-storey buildings erected during the past ten years. At an early stage in our inquiry the question arose as to whether any advantages would accrue from the extension of the system to low-cost housing of one and two storeys. The chief reason why we considered this matter was that, at first sight, a one-pipe system, in which soil and waste branches discharged into a common stack, seemed to be more amenable to fabrication in units off the site than a two-pipe system. We thought that, if it were found at a later stage that pre-assembly of one-pipe plumbing units for housing was practicable and desirable under post-war conditions, it would be useful to have data available for the economical and satisfactory design of such systems. We realized that a one-pipe system for a small house might be uneconomical if constructed with a special anti-siphonage vent connection to each trap. Certain investigations in America, and accepted practice in that country and elsewhere, suggested that in some simple one-pipe systems for a small house (particularly with the appliances reasonably well grouped together) most, if not all, of the special venting pipes could be omitted without risk of siphonage of the trap seals. We felt it necessary, however, to confirm this by doing such practical trials, to full scale, as war-time facilities permitted. Facilities afforded by the Ministry of Works, Mr. H. J. Manzoni and Mr. D. E. E. Gibson in London, Birmingham and Coventry respectively, enabled these trials to be made. The results we obtained are given in summarized form on Plate I. More details of the installations than are shown on this chart have been recorded, which can be made available if required.

We do not regard these trials as anything but preliminary, as the conditions under which they were carried out precluded a systematic programme of research such as might have been carried through under peace-time conditions. They are included in this report, because of the interest they may have for those concerned with plumbing generally, and because it seems to us that they enable one to draw certain general conclusions, which are as follows:

a. Simple one-pipe systems for one- and two-storey housing can be designed to operate under practical conditions of use without siphonage of traps in spite of the absence of special trap ventilation (but see paragraph 25).

b. The size of stacks and branches has a controlling influence on the liability to siphonage, the use of 4-in. stacks with 2-in. waste branches giving safer conditions than obtain with smaller stacks and branches.

c. When the washbasin branch is run directly to the common stack it is much less liable to siphonage of its trap than when dropped vertically to the bath branch.

It may be possible to draw further conclusions from the test results after further study and repeated experiments with such modifications of layout as seem desirable.

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19. *Lead Pipes for other than Chemical Purposes*	602	1939
20. *Lead Pipes* (B.N.F. Ternary Alloy (No. 2))	603	1941
21. *Lead Alloy Pipes* (War-Emergency Issue)	1085	1943
22. *Cast-iron Pipes (vertically cast) for Water, Gas and Sewage and Special Castings for use therewith*	78	1938
23. *Cast-iron Spigot and Socket Drain Pipes*	437	1933
24. *Schedule of Cast-iron Drain Fittings, Spigot and Socket Type for use with Drain Pipes to B.S.* 437 (1933)	1130	1943
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28. *Wrought-iron Tubes and Tubulars, Gas (light), Water (medium), Steam (heavy) qualities*	788	1938
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31. *Steel Spigot and Socket Pipes and Specials for Water, Gas and Sewage*	534	1934
32. *Galvanized Mild Steel Cisterns, Tanks and Cylinders* (War-Emergency Specification)	417	1940
33. *Pressed Steel Galvanized Rainwater Gutters, Pipes and Fittings*	1091	1942

		B.S. No.	Year
34.	*Copper Tubes and their Screw Threads (primarily for domestic and similar work)*	61	1913
35.	*Light Gauge Copper Tubes*	659	1936
36.	*Copper Cylinders for domestic purposes* (Grades 1, 2 and 3)	699	1936
37.	*Copper-alloy Pipe Fittings, Screwed, for low and medium pressure B.S. Copper Tubes*	99	1922
38.	*Soft Solders* (War-Emergency Issue) (Memo. PD 48 and PD 76)	219	1942
39.	*Dimensions of Drain Fittings, Salt-glazed Ware and Salt-glazed Glass (vitreous) Enamelled Fireclay* (Amendment slip PD 54)	539	1937
40.	*Salt-glazed Ware Pipes, including Taper Pipes, Bends and Junctions*	65	1937
41.	*Salt-glazed Glass (vitreous) Enamelled Fireclay Pipes, including Taper Pipes, Bends and Junctions*	540	1937
42.	*Asbestos Cement Spigot and Socket Rainwater Pipes, Gutters and Fittings (Dimensions and Workmanship of)*	569	1934
43.	*Asbestos Cement Spigot and Socket Soil, Waste and Ventilating Pipes and Fittings*	582	1943
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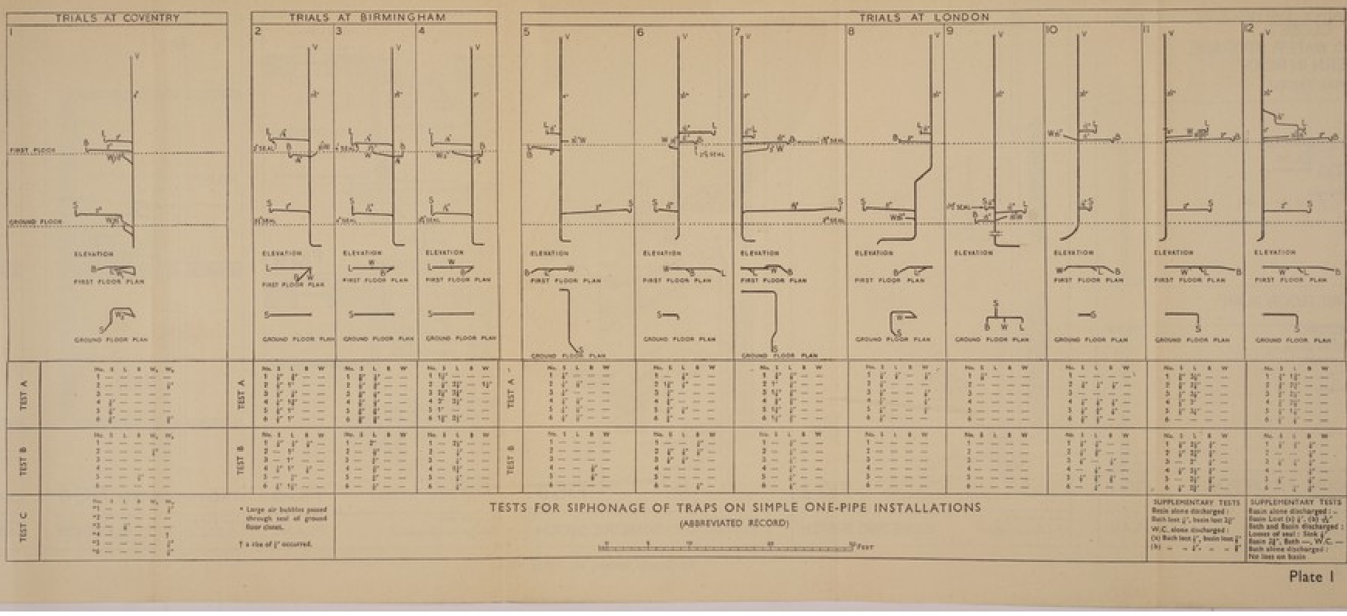
NOTES

DRAWINGS

1. For simplicity the elevations show developed lengths of branches and not their actual elevations.
2. Waste seals are 3" except where otherwise stated.
3. Dimensions shown at W.C. connections give diameter of outgo.
4. Reference:
   W. W.C. set.
   B. Bath.
   L. Washbasin.
   S. Sink.
   V. Vent.

TESTS

5. Each test was carried out 6 times.
6. Figures in tables give losses of seal on trap.



TEST A

"DRY SINK" TEST

1. Washbasin and bath filled to overflow.
2. 6 pieces of newspaper 8" × 6" placed in each closet pan.
3. Plugs removed from waste outlets and 2 galls. water tipped into each pan.
4. Pans flushed from cisterns immediately after discharge from buckets.

TEST B

"DRY BATH" TEST

As Test A, but reading sink for bath.

TEST C

"DRY GROUND FLOOR CLOSET" TEST

1. Washbasin, bath and sink filled to overflow.
2. 6 pieces of newspaper 8" × 6" placed in upper closet pan.
3. Plugs removed from waste outlets and 2 galls. water tipped into upper closet pan.
4. Upper pan flushed from cistern immediately after discharge from bucket.

TESTS FOR SIPHONAGE OF TRAPS ON SIMPLE ONE-PIPE INSTALLATIONS

(ABBREVIATED RECORD)

SUPPLEMENTARY TESTS (11)

Basin alone discharged:
Bath lost ¼", basin lost 3⅛"
W.C. alone discharged:
(a) Bath lost ¼", basin lost ⅝"
(b) " " ¼", " " ⅝"

SUPPLEMENTARY TESTS (12)

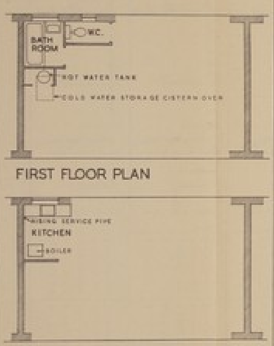
Basin alone discharged:
Basin Lost (a) ⅛", (b) ¹⁄₁₆"
Bath and Basin discharged:
Losses of seal: Sink ⅛"
Basin 2⅜", Bath —, W.C. —
Bath alone discharged:
No loss on basin

Plate I

UPSTAIRS BATHROOM AND CLOSET. COLD WATER STORAGE CISTERN IN ROOF.

CASE I

DISPOSAL SYSTEM.



GROUND FLOOR PLAN (TERRACED HOUSE) FIG 1

SCALE OF FEET — KEY PLAN

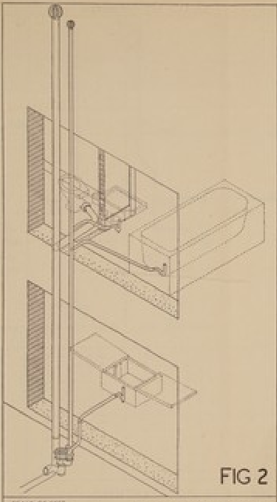


FIG 2

SCALE OF FEET — ISOMETRIC SKETCH

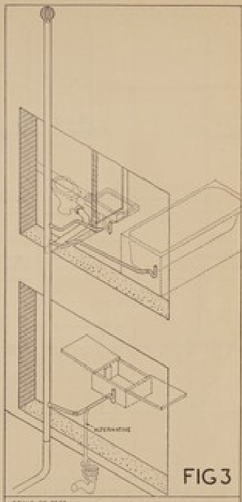
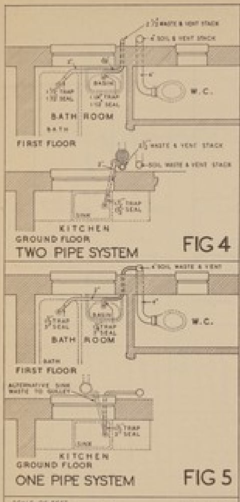


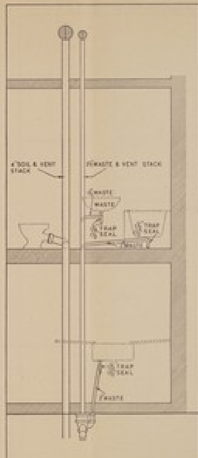
FIG 3

SCALE OF FEET — ISOMETRIC SKETCH



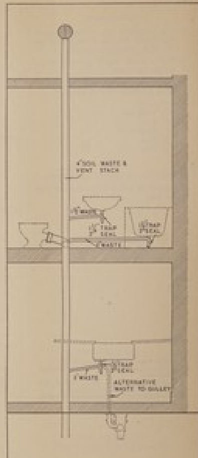
ONE PIPE SYSTEM FIG 5

SCALE OF FEET — PLANS



TWO PIPE SYSTEM FIG 6

SCALE OF FEET — ELEVATION



ONE PIPE SYSTEM FIG 7

SCALE OF FEET — ELEVATION

For Supply System, see Facing Plate

UPSTAIRS BATHROOM AND CLOSET. COLD WATER STORAGE CISTERN IN ROOF SPACE

CASE I

WATER SUPPLY SYSTEM

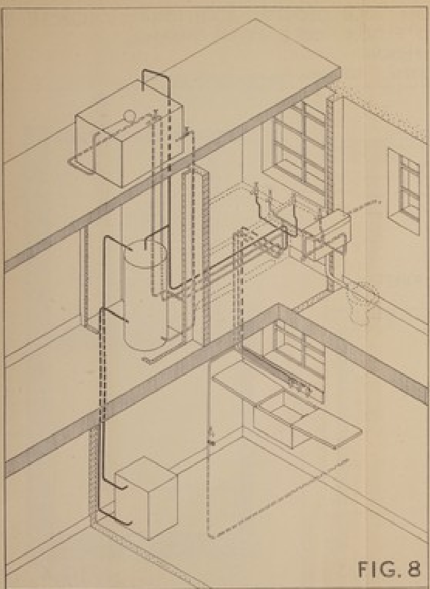
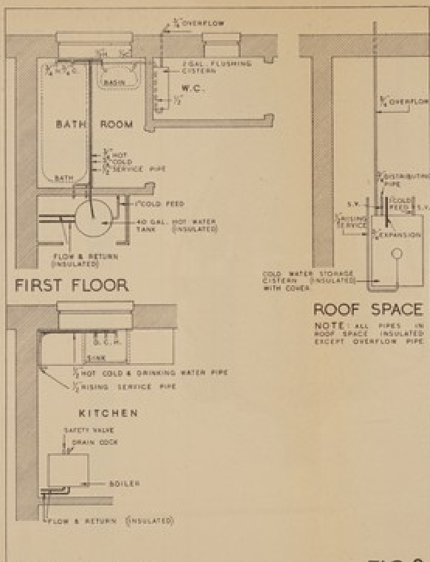


FIG. 8

SCALE OF FEET

ISOMETRIC SKETCH



GROUND FLOOR

FIG. 9

SCALE OF FEET

PLANS

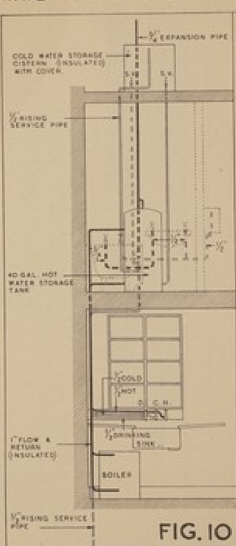


FIG. 10

SCALE OF FEET

ELEVATION

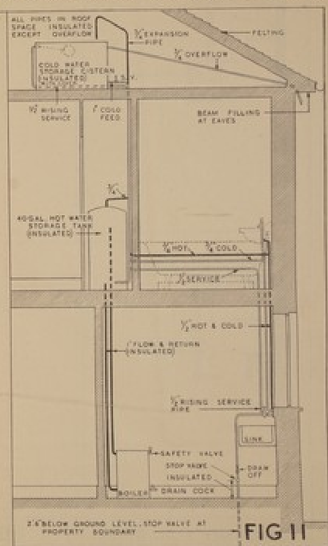


FIG 11

SCALE OF FEET

ELEVATION

For Disposal System, see Facing Plate

UPSTAIRS BATHROOM WITH CLOSET. ADDITIONAL CLOSET ON GROUND FLOOR. COLD WATER STORAGE CISTERN ON FIRST FLOOR.

CASE 2

ONE PIPE DISPOSAL SYSTEM. NOTE: FOR TWO PIPE SYSTEM SEE CASE I

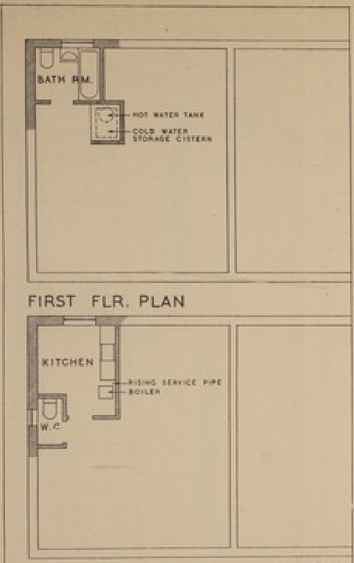


FIG. I
SCALE OF FEET
PLANS
DISPOSAL SYSTEM

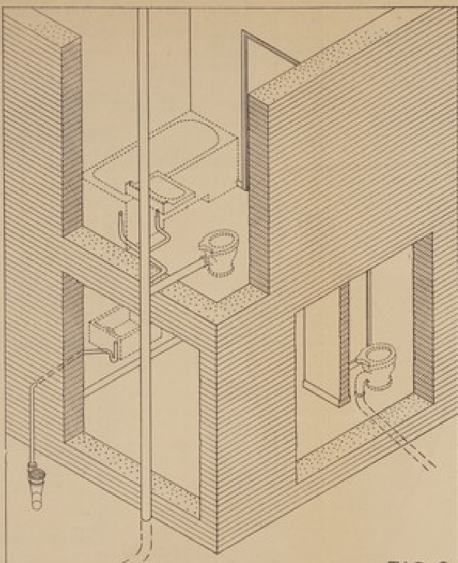


FIG. 2
SCALE OF FEET
ISOMETRIC SKETCH
DISPOSAL SYSTEM

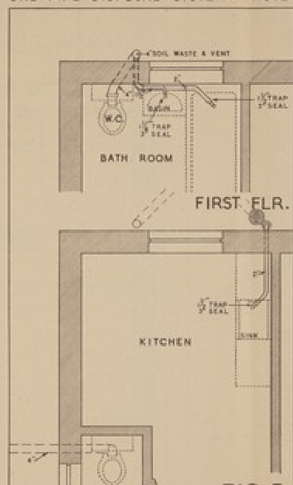


FIG. 3
SCALE OF FEET
GROUND FLR.
DISPOSAL SYSTEM

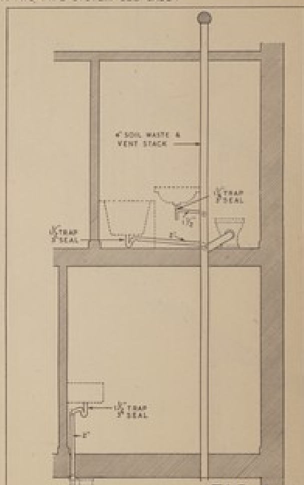


FIG. 4
SCALE OF FEET
ELEVATION
DISPOSAL SYSTEM

Plate 4

For Supply System, see Facing Plate

CASE 2

UPSTAIRS BATHROOM WITH CLOSET. ADDITIONAL CLOSET ON GROUND FLOOR. COLD WATER STORAGE CISTERN ON FIRST FLOOR.

WATER SUPPLY SYSTEM.

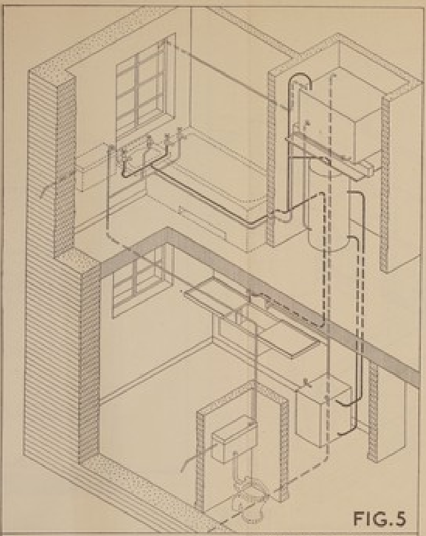


FIG.5

SCALE OF FEET

ISOMETRIC SKETCH

WATER SUPPLY SYSTEM

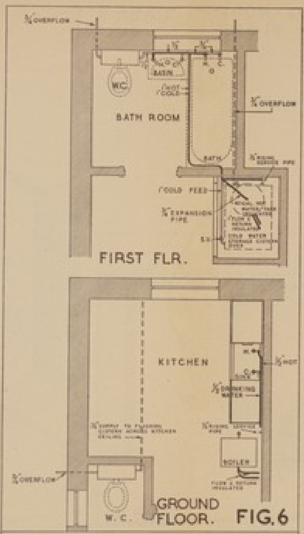


FIG.6

SCALE OF FEET

PLANS

WATER SUPPLY SYSTEM

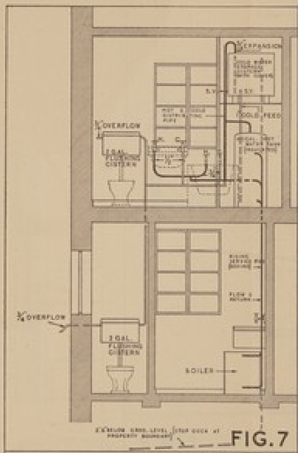


FIG.7

SCALE OF FEET

ELEVATION

WATER SUPPLY SYSTEM

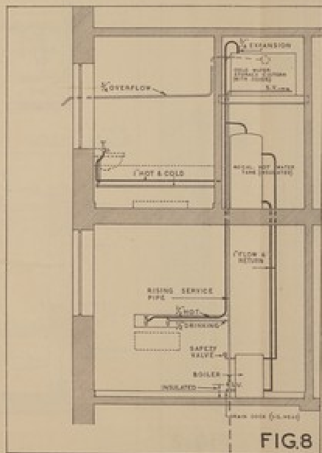


FIG.8

SCALE OF FEET

ELEVATION

WATER SUPPLY SYSTEM

For Disposal System, see Facing Plate

ALL PLUMBING WORK ON GROUND FLOOR

DISPOSAL SYSTEM.

CASE 3

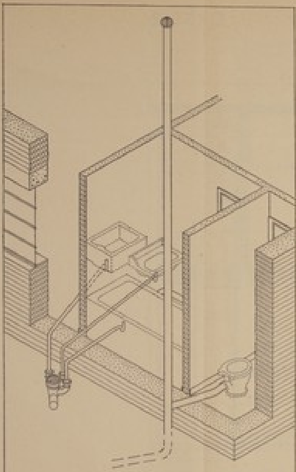


FIG. 2

ISOMETRIC SKETCH
DISPOSAL SYSTEM

SCALE OF FEET

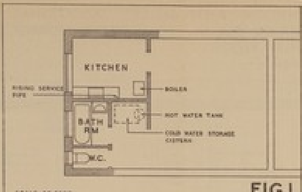


FIG. 1

SCALE OF FEET

KEY PLAN OF GROUND FLOOR

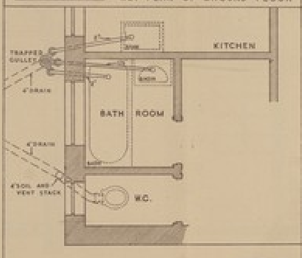


FIG. 3

GROUND. FLR. PLAN
DISPOSAL SYSTEM

SCALE OF FEET

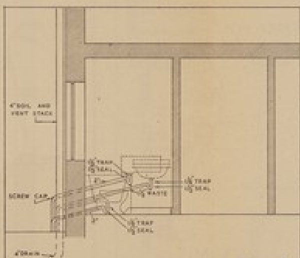


FIG. 4

ELEVATION
DISPOSAL SYSTEM

SCALE OF FEET

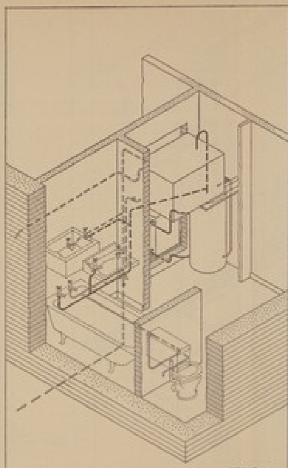


FIG. 5

ISOMETRIC SKETCH
WATER SUPPLY SYSTEM

SCALE OF FEET

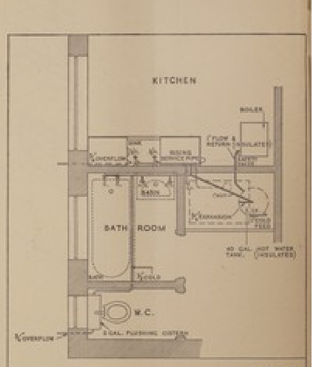


FIG. 6

GROUND FLR. PLAN
WATER SUPPLY SYSTEM

SCALE OF FEET

Plate 6

For Supply System, see Figs. 5, 6, and 7

For Disposal System, see Figs. 1, 2, 3, and 4

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    - c. *Threaded Pipe Fittings of Brass, Bronze, Cast Iron and Malleable Iron.*
    - d. *Seamless Tubing of Copper, Brass, Aluminium and Aluminium Alloys.*
    - e. *Unions of Malleable Iron or Steel, Brass or Bronze.*
    - f. *Angle, Globe, Gate and Radiator Valves of Brass or Bronze.*
    - g. *Asbestos-cement, Clay and Concrete (non-pressure) Pipes.*
    - h. *Setting Compound, Gaskets and Packing.*

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ALL PLUMBING WORK ON GROUND FLOOR

CASE 3

WATER SUPPLY SYSTEM.

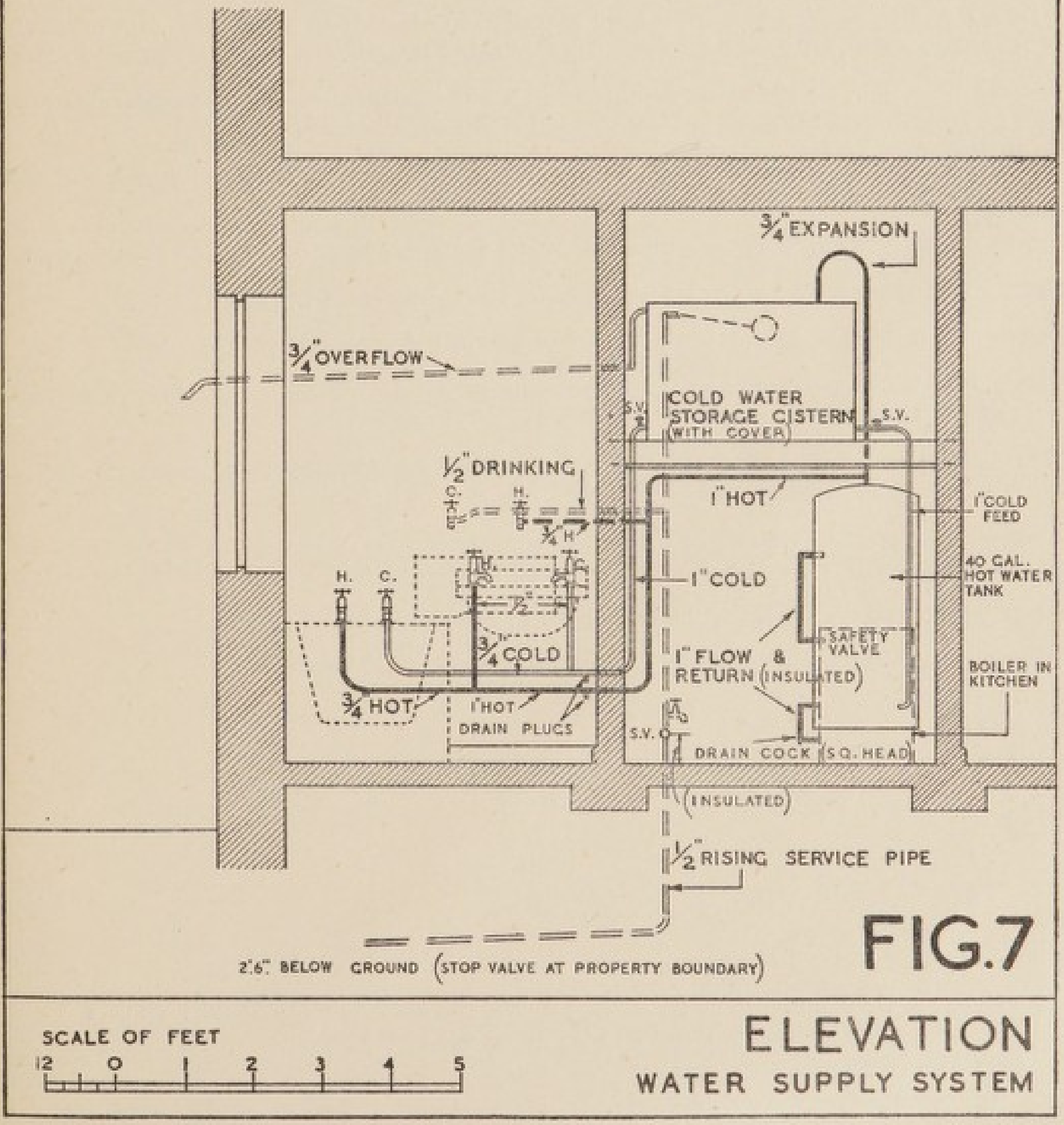

FIG.7

ELEVATION

WATER SUPPLY SYSTEM

GLOSSARY

APPLIANCE. Recipient forming part of a plumbing installation to which water is supplied for human use and from which water passes to the disposal system, such as bath, washbasin, sink or water-closet.

BACK-FLOW. Passage of water by suction or flow from appliance into water-supply system through a tap or valve.

BRANCH PIPE. Soil or waste pipe from trap outlet of appliance to stack.

CISTERN. A container for water the free surface of which is under atmospheric pressure.

DISPOSAL SYSTEM. System of piping conveying discharge from appliances to sewer.

DISTRIBUTOR PIPE. Pipe conveying water from a storage cistern or hot-water apparatus and under pressure from such cistern or apparatus.

DRAIN. Underground conduit forming part of a disposal system.

FITTING. Component of a plumbing installation other than appliance, pipe, cistern, tank, water heater, and similar—in general, a component relatively small in size.

MAIN. Pipe laid by the water undertaking for the purpose of giving a general supply of water as distinct from a supply to individual consumers.

ONE-PIPE SYSTEM. System of piping between appliances and drain in which soil and waste flow down the same stack.

SERVICE PIPE. Pipe directly subject to water pressure from the undertaking's main.

SOIL. Effluent from water-closets, urinals, slop sinks, and the like.

STACK. The principal vertical pipe, or pipes, in a disposal system.

TANK. A permanently closed or sealed container used for the circulation or storage of hot water.

TRAP-VENTING. Employing subsidiary piping for air passage to or from the outgo end of an appliance trap to prevent air pressure or siphonage.

TWO-PIPE SYSTEM. System in which (*a*) separate stacks are used for waste and soil, and (*b*) waste pipes are trapped off from the soil drain and separately vented.

VENT PIPE. Pipe providing flow of air to or from a disposal system.

WASTE. Used water from baths, washbasins, sinks, and the like.

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i. To review existing scientific information and practice in this country and abroad on plumbing (including the underground drainage forming part of normal building works), with particular reference to the supply of cold and hot water in buildings and the removal of soil, rainwater, and waste therefrom.

ii. To make recommendations for practice in post-war building.

iii. To make such recommendations for further research as may suggest themselves in considering i. and ii.

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