Works of sewage disposal : with some historical notes on problems arising in connection with the treatment of effluents from the textile industries, 1870-1931.

CITY OF BRADFORD

WORKS OF SEWAGE DISPOSAL

WITH

Some Historical Notes on Problems arising in connection with the Treatment of Effluents from the Textile Industries.

1870-1931

THIRD AND REVISED EDITION
1931

Presented by

The Sewage Works Engineer

December 1931

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WORKS OF
SEWAGE DISPOSAL

The Lord Mayor
Alderman Alfred Pickles, J.P.

CITY OF BRADFORD

WORKS OF SEWAGE DISPOSAL

WITH

SOME HISTORICAL NOTES ON PROBLEMS ARISING IN CONNECTION WITH THE TREATMENT OF EFFLUENTS FROM THE TEXTILE INDUSTRIES

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Councillor Jonas Pearson
Chairman

Councillor William A. Leach
Deputy Chairman

MEMBERS OF THE SEWAGE COMMITTEE 1930-31.

Savoy Studios

1. Councillor T. Ashworth, J.P.
2. Councillor J. Bailey.
3. Councillor E. T. Bolland.
4. Councillor W. Brooke, M.P.
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14. Councillor J. Stringer, J.P.
15. Councillor C. Watkin.

Chapter I

EARLY DIFFICULTIES

THE Esholt scheme is the culmination of many years of effort by the citizens of Bradford to deal with the problem of sewage disposal. The situation of the city, the history of its development, and the character of the industries in which a large proportion of its population is engaged are all factors which have combined to give to the local sewage problem almost unique complexity.

When three parts of the eighteenth century had passed Bradford still remained much as it had been from medieval times, a tiny market town of two or three thousands of inhabitants, with some traditional interest in the textile trade, but mainly of an agricultural character. At the end of the nineteenth century it had attained to the rank of a great industrial city of 280,000 persons. The settlement of the colonies has presented in recent years more impressive examples of town development, but those municipalities have been planned from the beginning, and in places presenting natural opportunities. These are the reverse of the conditions in Bradford, where the fortuitous cart-tracks and lanes of the past settled the lines and too often the widths of the streets, and where ancient legitimate and equitable interests presented a hundred awkward problems in town building. Moreover, the expansion of Bradford was probably unparalleled in this country in the time of its greatest activity. It was unforeseen and in no way provided for.

In the early days of small things a very simple sanitary ideal sufficed. The houses nearest the water-courses, the Bradford Beck and its tributaries, turned their sewage into those becks and it mattered nothing even to the trout. Householders at greater distance followed such course of sewage disposal as their ingenuity suggested, trusting the breezes to make good defects of science. When the factory system changed the whole face of the community Bradford was for a generation or two unable to realise all that the change involved. The nation as a

whole was slow in awakening. The principles of the conservation of the public health had not been evolved; municipal bodies were without adequate powers, without an understanding of their vast opportunities, and the daily growing burden of their duties was paralysing rather than stimulating.

Bradford in Village Days.

So until far into the nineteenth century the sanitary condition of Bradford was deplorable. An experienced government officer, who was engaged during some years in collating the material which resulted in the Public Health Act of 1848, came to Yorkshire in 1843, and he declared in his report that, bad as were many industrial communities, Bradford was "the most filthy town I visited." There was not a public sewer in the place. Prehistoric private drains served the houses in the principal streets, whilst the sewage of the inferior streets ran into open channels. The chief commercial advantage of the town, its canal, added to the insanitation. In the middle of the eighteenth century a branch of the Leeds and Liverpool Canal had been carried up the Bradford valley and had its terminal basin partly upon the site of what is now Forster Square. Here sluice-gates intercepted the water of the Bradford Beck. The consequence was that the stagnant pool became the recipient of vast quantities of sewage. "The water of the basin" said the officer already quoted "is often so charged with decaying matter that in hot weather bubbles of sulphuretted hydrogen are continually rising to the surface; and so much is the atmosphere loaded with gas that watch-cases and other materials of silver become black in the pockets of the workmen employed near the canal. The stench is sometimes very strong and fevers prevail all around." This was in 1843.

The Rivers Pollution Commission which sat for some years in the 'sixties described the canal-basin as "so corrupt that large volumes of inflammable gases were given off, and although it had usually been considered an impossible feat to 'set the River Thames on fire' it was found practicable to set the Bradford Canal on fire, as this at times formed part of the amusement of boys in the neighbourhood. They struck a match placed on the end of a stick, reached over, and set the Canal on fire, the flames rising six feet high and running along the surface of the water for many yards, like a will-o'-th'-wisp; canal boats had been so enveloped in flame as to frighten persons on board."

Before this rather sensational but probably not exaggerated description was published the inhabitants were alive to the dangers. A charter of municipal incorporation was secured in 1847, and very soon after the coming of cholera impressed on the new Town Council the necessity of attention to sanitation. In 1853 the Borough Surveyor, the late Mr. Charles Gott, M.Inst.C.E., laid down the line for a main trunk sewer, but from various causes it was not till nine years later that any progress was made with its construction. In 1862 the first mile of sewer was laid; in the next year, two miles; in the third year four miles, and by 1870 thirty miles of sewering had been completed. The work of sewering has since then never ceased, and Bradford has now no less than 118 miles of sewer in the area of the old borough, excluding the five townships last added to the City. Besides this the Corporation caused the Beck in its course through the town to be covered in, and in 1866 it dealt with that festering plague spot, the canal basin. Action was taken in Chancery to prevent the Canal Company utilising the sewage-charged waters of the Beck to feed their navigation water. For a while this involved the closing of the Canal to traffic, but eventually pumping stations were established, which enabled the higher reaches of the Canal to be fed with pure river water. It is, perhaps, worthy of note that the Canal was abandoned in 1922, pursuant to the Bradford Canal (Abandonment) Act of that year and has now been emptied.

A Sanitary Awakening.

But all these sanitary measures proceeded upon the primitive principle that the river was the natural place into which the sewage should be poured, and the more efficient the drainage of the town, the worse became the condition of the Beck and of the River Aire into which it flowed. That condition, of course, being intensified by the fact that other industrial communities on the banks of the Aire were rapidly rising and were also utilising the river for sewage disposal.

The woolcombing industry which developed with extraordinary rapidity in the town in the middle of the nineteenth century added peculiar difficulties. Wool and hair were, and still are, brought to Bradford from all parts of the world in the crude state in which they are clipped from the backs of the animals. Before being combed the wool is washed, and in

that process it loses in many cases as much as 60 per cent. of its weight, that 60 per cent. consisting partly of the natural fat and partly of the dirt and manure clinging to the fleeces. As a consequence the effluent from the woolcombing water is extremely "rich" in organic materials and it is also very offensive. It is indicative of the magnitude of the problem which this trade creates that no less than one-fifth of the wool produced in the whole world or four-fifths of the quantity grown in and imported into England is washed and dealt with in the area of this single municipality.

The Local Difficulties.

As the wool trade increased in Bradford protest was made by the residents on the river banks against the growing nuisance. In 1868 Mr. William Rookes Crompton Stansfield, the owner of Esholt Hall and estate about three miles from Bradford, took legal action in the Court of Chancery. He asked that the Corporation should be "restrained from causing or permitting to pass any sewage filth or other offensive matter either solid or liquid into the Bradford Beck in such a manner that the same may pass therefrom into the River Aire to the injury of the plaintiff, and from in any manner polluting the River in its course past the Esholt Hall estate."

The Corporation presented to the Court a view of the difficulties in which they found themselves. All schemes of precipitation or deodorization of sewage at that time invented had proved unworkable on a large scale. The Rivers Pollution Commission which had been severe on Bradford's sanitary condition, had been appealed to for useful advice and aid, but "the Royal Commissioners were at a loss how such cases should be dealt with," and it was argued "if the most able officers whom the Government can select are thus embarrassed it may readily be believed that Local Boards are in equal difficulty." The only project ingenuity could devise, an expedient of despair, was the construction of a vast sewer which should take the sewage of the whole of the industrial district of Yorkshire in the valleys of the Wharfe, Aire, and Calder, away down to the sea. But this was too big a scheme for the Government to sanction or aid.

The Court realised the difficulty and, without acceding to the demand that it should forbid the passage of Bradford sewage into the river at all, it attempted to forbid any intensification of

the nuisance. It prohibited under penalty of £10,000 "the opening or permitting to be opened any additional main or branch sewer or any house drain or sewer into the outfall sewer." This setting, Canute-fashion, of a line "Thus far and no further" to the tide of Bradford's commercial development satisfied nobody. It made the river no more tolerable to Mr. Stansfield, and it rendered Bradford's position very difficult. For no house could be erected and properly drained. In the ensuing year, as a result of negotiations between the Corporation and Mr. Stansfield, an Order was made by consent dissolving the Injunction, without prejudice to any question between the parties, and ordering the Corporation before the 11th January, 1872, to take practical measures for defœcating the sewage before passing it into the River.

Bradford entered upon an era of experiments in sewage treatment. These experiments were made at Frizinghall, the lowest point within the borough. Here eleven acres of land were purchased and certain works were constructed. The first effort was a private adventure. In 1871 a company undertook the treatment of the sewage free of cost. The Corporation undertook to construct works and provide them rent free, and a lease was granted to the company for twenty-one years. Their advisers proposed to filter the liquid through peat charcoal, and they calculated upon a handsome profit by the sale to the farmers of the residual as manure. But after losing £30,000 in their experiments the company came to grief. The Corporation then in 1874 took the works into their own hands, and appointed a manager to superintend the purification processes. The period of the Order made in 1869 had expired, and the owner of the Esholt Estate in 1875 obtained a perpetual injunction prohibiting the Corporation from discharging undefœcated sewage into the Bradford Beck and into the River Aire. The works which the Corporation had in hand were proceeded with, and at a very great cost completed. For some time the system answered satisfactorily, the effluent being practically colourless and odourless.

If the exceptional strength of the Bradford sewage in the common organic elements had been its only peculiar quality the task of sewage treatment would still have been difficult. But besides the dirt there was taken from the fleeces in wool-washing an immense quantity of wool fat, known in the refined state as

Lanoline. At one stage of the commercial development of the borough it paid the woolcomber to extract part of the fat from his effluent, but as the quantity of wool dealt with increased, the price of the residual fat or grease declined, and eventually nearly all the effluent was passed entirely untreated into the sewers, and the sewage works became inadequate to deal with the difficulty. The estimated quantity of this grease thus poured into the Beck was, in 1889, stated at twenty-five tons a day when the wool trade was suffering a bad time, and fifty tons a day or more in prosperous times. In addition, of course, vast quantities of soap and alkali were used in its removal from the wool. Lanoline fat is of a very peculiar nature. During the period when the late Alderman Robert Pratt was Chairman of the Sewage Committee, a great deal of work was done to reach an understanding of the problem which had to be dealt with. Elaborate analyses of the sewage were made by Mr. F. W. Richardson, F.I.C., the Borough Analyst, and following upon these analyses, the properties of lanoline were carefully investigated by Professor Dewar (later Sir John Dewar). At the request of the Corporation, Professor Dewar made experiments which resulted in his discovering that the lanoline fat, being of very nearly the same specific gravity as water, would not rise to the surface as ordinary fats might do, and could not be skimmed off. It remained in suspension in extremely minute globules. Professor Dewar found further that it had a peculiar property of adhesiveness to water, as he called it, which retarded the extraction of the water from the sewage sludge, so that even after prolonged precipitation the sludge contained 98 per cent. of water as compared with 90 per cent. in the sludge of ordinary town sewage. This state of dilution increased five times the amount of sludge to be dealt with, and made the production of a satisfactory sludge-cake very difficult.

The Trouble of Wool Fat.

One more difficulty arose from the presence in Bradford of many dyeworks, which also poured their effluents into the sewers, so that the sewage at one time ran acid, and at another strongly alkaline.

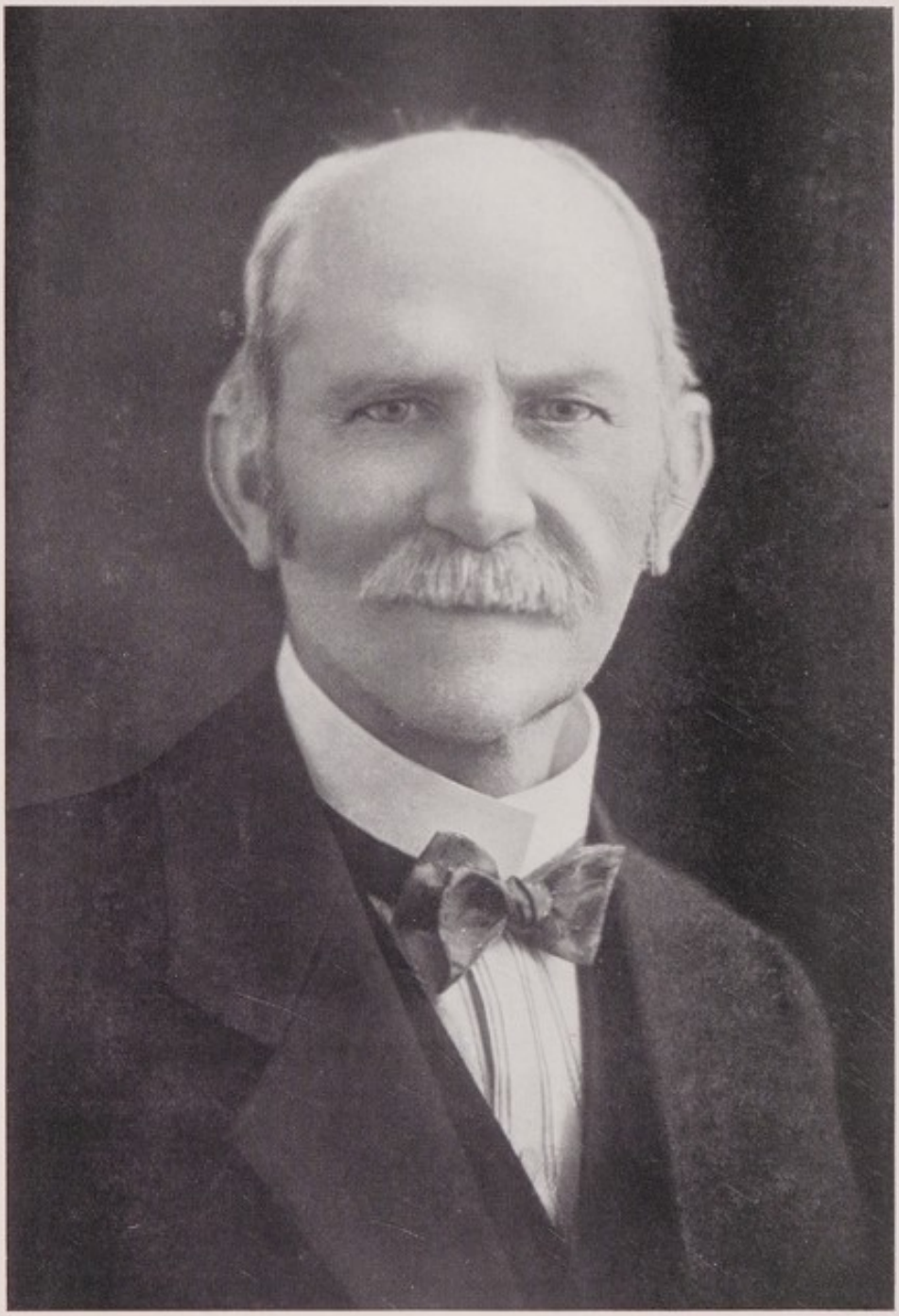
After many experiments the method adopted was to precipitate the solids with lime and the effluent then underwent a final purification by filtration through coke-breeze. The works were

so operated for many years. Only a portion of the sewage could be dealt with, however, and meanwhile the town was growing rapidly.

Subsequently the use of lime as a precipitant of the sewage was abandoned, and ferric sulphate was used. But this proving very expensive, sulphuric acid was substituted in January, 1901, and treatment by this chemical has been continued to the present time. After precipitation difficulties were conquered, it became necessary to dispose of the sludge, and experiments proved that this could be effected by means of filter presses. Through this treatment the grease is extracted and is marketable, as is also the dried sludge-cake. Since 1903 this process has been gradually expanded.

The condition of the Aire improved but slowly under the early experiments, and the West Riding of Yorkshire Rivers Board, which was formed in 1893, almost immediately brought pressure to bear on the Bradford Corporation to improve their effluent. The Corporation accordingly decided in 1894 to extend the Frizinghall works, and the consent of the Local Government Board was given to the scheme with the express intimation that it was accepted "very reluctantly," the Board evidently feeling that though it was the best devisable, any scheme of treatment in so limited an area, some 38 acres, as was at the utmost available at Frizinghall was necessarily far from satisfactory. Beck and road improvements were carried out, but before the new purification works at Frizinghall were commenced the scheme for the extension of the boundaries of the borough arose. In the course of the Local Government Board's Inquiry into that proposal the sewage disposal of Bradford was a good deal criticised, and eventually, when the extension was sanctioned, there was inserted, in the Extension Order of 1899, a stipulation that Bradford should proceed with a proper sewage disposal scheme within twelve months. By this extension an area of 12,067 acres was added to the borough. In these later days (1930) the Clayton Urban District with an area of 1,745 acres has been added to the City, making the total 24,625 acres, of which 20,156 acres drain towards the Aire Valley and the rest towards the Calder.

Meanwhile the feeling was growing that it was necessary to remove the works to the main valley of the Aire, and the only



The late Alderman Richard Johnson, J.P.
Chairman of the Sewage Committee for 21 Years

site there available seemed to be at Esholt on the estate of the successors of the gentleman whose legal proceedings first emphasised the gravity of the problem. Before they proceeded with an undertaking of such magnitude as the acquisition of the Esholt estate an alternative policy was tried by the Sewage Committee, of which at that time the late Alderman Robert Pratt was Chairman, and Councillor (later Alderman) Richard Johnson was Deputy Chairman. It was agreed that as the complexity of the problem and the costliness of treatment arose from the greasy "suds" from the woolcombing works, these should be dealt with separately. Two courses were suggested. One was that trade effluents should be conveyed to Frizinghall by a separate system of sewers to be constructed at the expense of the traders or the owners of their premises, and the other was that powers should be obtained to compel woolcombers to remove the grease from the effluent before it passed from their own works.

The Esholt Scheme Conceived.

These proposals were embodied in a Bill promoted in Parliament in 1897. Parliament, however, did not sanction the construction of a separate system of sewerage, and only allowed the woolcombers to be dealt with on certain lines. Many woolcombers had, it was held, acquired a prescriptive right to use the sewers for the disposal of their effluent. Power was given to compel them to deal with their own sewage on certain heavy payments to them by the Corporation, viz.: £18 per machine woolcomb in use, but they were only required to use the "best practicable and reasonably available" method, and they could only be coerced if they had sufficient and suitable space available for the erection and use of necessary plant and apparatus. As many of the woolcombers had little or no land available, it was evident that a certain amount of fatty matter would still go into the sewers, and would have to be dealt with before any land or bacterial treatment could be adopted. The policy of separate treatment for the woolcombers' suds was, therefore, not pursued.

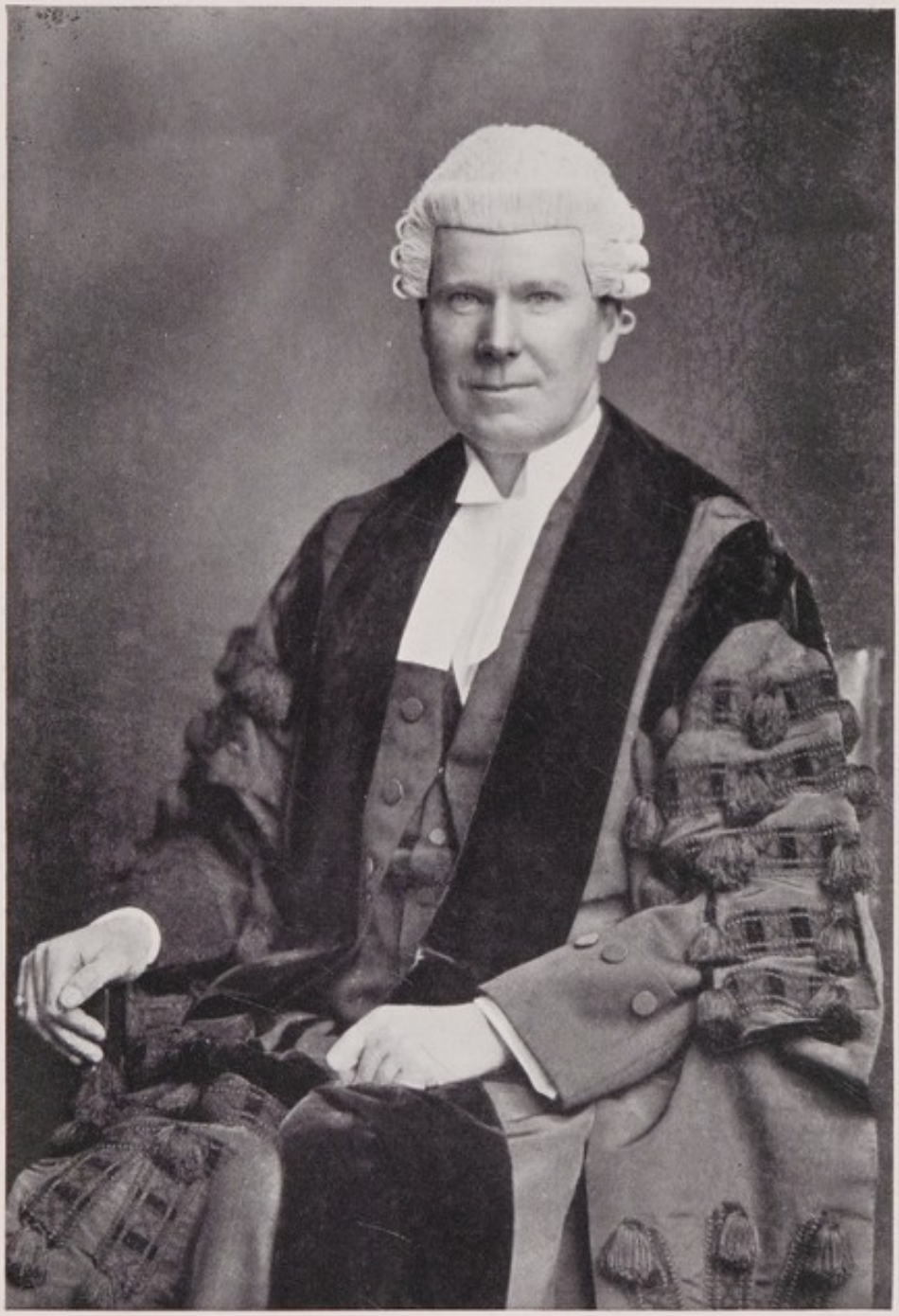
The Corporation were thus driven to the scheme for constructing works at Esholt, and the proceedings reveal almost at their worst our national machinery for controlling the operations of local bodies.

The late Joseph Garfield, M.Inst:C.E.
Sewage Works Engineer 1899–1925

In 1898 the Corporation decided to apply for compulsory powers for the purchase of the Esholt site. Negotiations to that end with the owners were unavailing, and the Corporation in the next session went to Parliament for compulsory powers. It was proposed to acquire the whole estate (1,700 acres), it being felt that this course was more fair to the owners than the acquisition of a part only, whilst it also obviated claims for deterioration and severance of lands. After an inquiry in which the owners of the estate, the Misses Stansfield, opposed any sale whatever, and maintained that the Frizinghall site could be made adequate, the Local Government Board came to the conclusion that Frizinghall was unsuitable for sewage works, and they granted a Provisional Order empowering the Corporation to purchase, not the whole estate asked for, but 529 acres, including Esholt Hall. The Provisional Order was opposed by the Misses Stansfield, and the Local Government Board intimated to the Bradford Corporation that they left it to the Corporation to support the Order. This the Corporation did, and after a long and costly fight in the Session of 1899 a Select Committee of the House of Commons refused to confirm the Provisional Order, no reason being given.

Parliamentary Troubles.

This decision did not, however, remove the compulsion which Parliament had previously confirmed that a complete sewage scheme should be proceeded with, and continued negotiations with the owners of the Esholt Estate having no effect, the Corporation were compelled to go to Parliament again in 1901. They asked now for power to acquire 814 acres in the Aire valley, of which 685 acres were the property of the Misses Stansfield. The Bill came first before a Select Committee of the House of Commons and met with strenuous opposition from the landowners. The Committee decided that the Frizinghall site was inadequate, and the chairman took a map of the Esholt district and traced an area of land which the Committee considered should be used. This was found to contain 310 acres, of which 210 were on the Esholt estate. The Bill thus modified passed to the House of Lords, but a Select Committee of that House decided that the area allowed by the House of Commons Committee was insufficient, and they rejected the scheme altogether. The Bradford Corporation Act, 1901, which emerged



N. L. Fleming
Town Clerk

from these proceedings, contained a section giving the Corporation till the 31st December, 1902, to carry out and execute works for the disposal of sewage as directed in Article xviii of the Extension Order of 1899.

The Purchase of Esholt.

In 1902 the Corporation, being still pressed by the Rivers Board, approached the Misses Stansfield again. Protracted negotiations ensued, and a Section was inserted in the Bradford Corporation Act, 1903, extending to 31st December, 1904, the time allowed to the Corporation for proceeding with a sewage disposal scheme. The negotiations terminated unsuccessfully in September, 1903, and the Corporation decided to apply for a Provisional Order, authorising the acquisition of the lands shown on the deposited plans in connection with the Bill submitted to Parliament in 1901. But in February 1904 the owners came forward with an offer to sell the whole of the Esholt estate to the Corporation. The Corporation eagerly seized the opportunity, and compulsory powers were subsequently obtained, without opposition, for the purchase of some subsidiary areas of lands, other lands in the same neighbourhood having been acquired previously by the Corporation from time to time. The price paid to the Misses Stansfield was decided by arbitration, and on 2nd February, 1906, the purchase price, £239,742, was handed over, and the estate became the property of the Corporation.

A detailed scheme for the utilisation of the estate was submitted to the Council by the then Chairman of the Sewage Committee (the late Councillor E. J. Smith), in December, 1906. It was finally approved in March, 1907, the cost of the Scheme then being estimated at £955,000. It was not until 23rd April, 1909, however, that the Local Government Board (after holding a Local Inquiry which commenced on the 22nd October, 1907, and lasted four days) gave permission for the work to be proceeded with.

TABLE.

Showing the districts within the City of Bradford draining to the Esholt and North Bierley works respectively, together with dates of abandonment of local sewage works; areas within the City draining to outside districts by agreement; outside Urban Districts draining to the Esholt works by agreement.

ESHOLT DRAINAGE AREA

Districts	Area in acres	Population	Works abandoned	Remarks
Central Area of City (to Frizinghall)	11,195	238,750	March 1926	Via Main Outfall Sewer
Sandy Lane ...	606	1,000	June 1913	
Thornton ...	1,361	6,980	May 1915	
Tong	2,380	1,500	—	
Tong	25	500	June 1904	
Clayton ...	1,745	5,520	December 1930	
Idle	1,570	6,500	April 1912	Via Intercepting Sewer
Greengates ...	162	2,200	May 1912	
Eccleshill ...	735	7,750	July 1912	
Thackley ...	377	2,300	—	
Total	20,156	273,000	—	

NORTH BIERLEY DRAINAGE AREA

District	Area in acres	Population	Remarks
North Bierley	3,532	23,500	—
North Bierley	128	Undrained	

AREAS WITHIN THE CITY DRAINING TO OUTSIDE DISTRICTS

District	Area in acres	Population	Date of agreement	Remarks
Frizinghall	40	500	July 1928	Drains to Shipley U.D.C.
Wyke ...	769	1,000	January 1905	Drains to Brighouse U.D.C.
Totals for City	**24,625**	**298,000**		

OUTSIDE URBAN DISTRICTS DRAINING TO ESHOLT

District	Area in acres	Population	Date of agreement	Remarks
Yeadon ...	1,110	7,000	October, 1908	—
Baildon ...	1,340	7,400	May, 1931	


MENSTON
GUISELEY
AREA 1556 ACRES
POPULATION 5607
CARLTON
HAWKSWORTH
AREA 2465 ACRES
YEADON
AREA 1724 ACRES
POPULATION 7671
ESHOLT
AREA 601 ACRES
POPULATION 990
RAWDON
AREA 1561 ACRES
POPULATION 4574
KEIGHLEY
RIVER AIRE
BAILDON AREA 2606 ACRES
POPULATION 11724
ESHOLT WORKS
BINGLEY AREA 9036 ACRES
POPULATION 18,131
MORTHORPE
AREA 2800 ACRES
POPULATION 11770
SHIPLEY AREA 2181 ACRES
POPULATION 30,243
CALVERLEY
AREA 2106 ACRES
POPULATION 3655
HAWORTH
WILSDEN AREA 2638 ACRES
POPULATION 2422
FARSLEY
AREA 821 ACRES
POPULATION 6170
OKENHOPE
DENHOLME
AREA 2536 ACRES
POPULATION 2662
ESHOLT DRAINAGE AREA 20,156 ACRES
POPULATION 273,000.
PUDSEY
AREA 2370 ACRES
POPULATION 14,762.
LEEDS
AREA 28,030 ACRES
QUEENSBURY
AREA 1492 ACRES
POPULATION 5763
NORTH BIERLEY DRAINAGE AREA
3532 ACRES POPULATION 23500
SHELF
AREA 1303 ACRES
POPULATION 6600
GILDERSOME
AREA 772 ACRES
POPULATION 2845
DEIGHLINGTON
AREA 1135 ACRES
POPULATION 9064
HUNSWORTH
AREA 1361 ACRES
POPULATION 1318
BIRKENSHAW
AREA 724 ACRES
POPULATION 2814
HALIFAX
AREA 13,584 ACRES
NORTH BIERLEY
WORKS
BIRSTALL
AREA 1234 ACRES
POPULATION 7705
MORLEY
HORWOOD GREEN
& COLEY
AREA 601 ACRES
CLECKHEATON
AREA 1756 ACRES
POPULATION 12,537
GOMERSAL
AREA 1100 ACRES
POPULATION 3628
HIPPERHOLME
AREA 1196 ACRES
POPULATION 5383
BATLEY
BRIGHOUSE
AREA 2231 ACRES
POPULATION 19,756
LIVERSEDGE
AREA 2136 ACRES
POPULATION 14,597
HECKMONDWIKE
SOUTHOWRAM
AREA 1820 ACRES
POPULATION 2570
RIVER CALDER
MARTHSHEAD
ELLAND
RASTRICK
MIRFIELD
HUDDERSFIELD
CITY BOUNDARY
BOROUGH & PARISH BOUNDARIES
OUTSIDE URBAN DISTRICTS DRAINING TO WORKS
WATERSHED BOUNDARIES
SCALE OF MILES.
5 MILES

Chapter II

DESCRIPTION OF THE ESHOLT WORKS

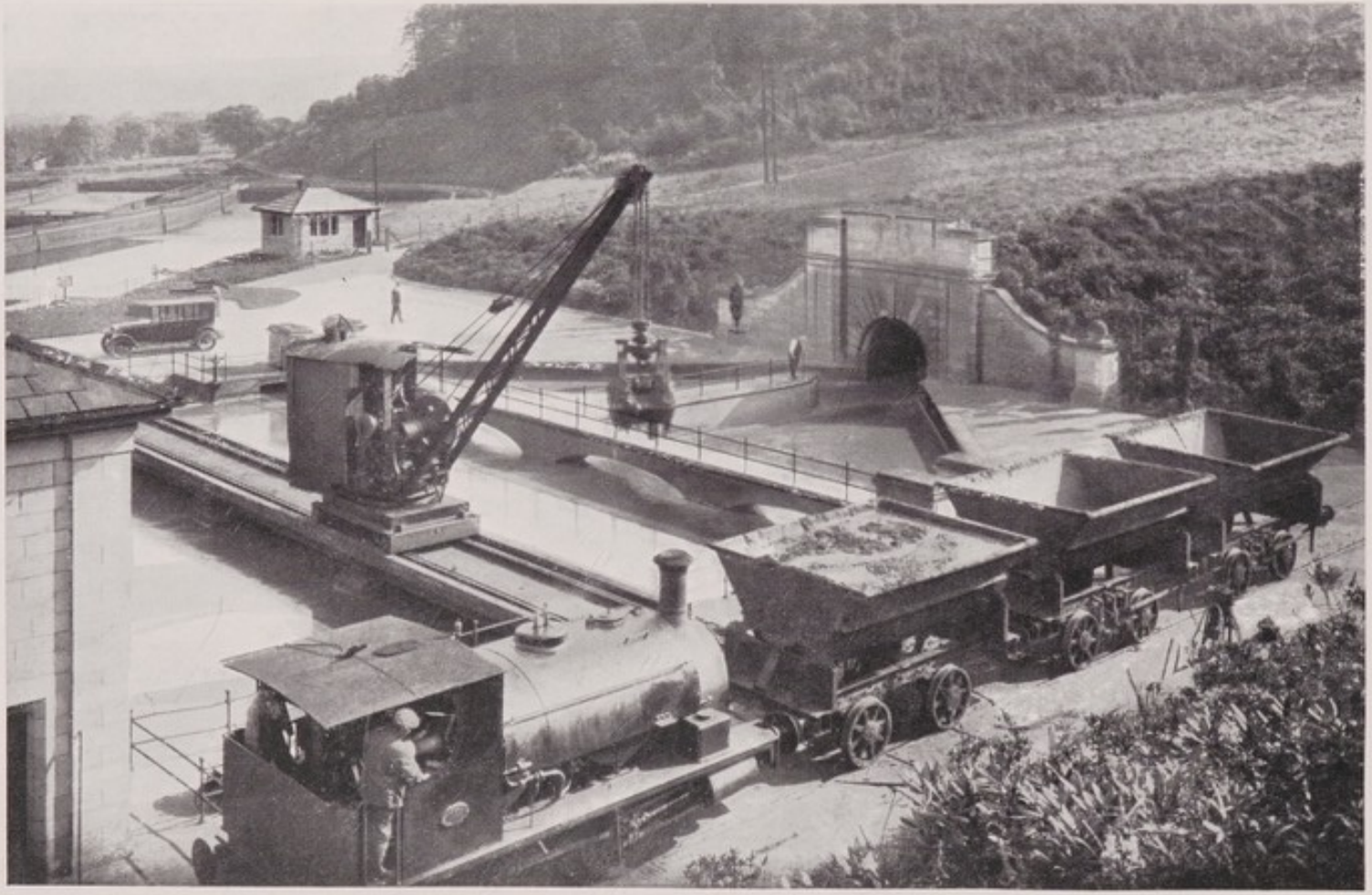
THE area of the City of Bradford is 24,625 acres. Of this area 20,156 acres drain to the new Esholt Works situated in the Aire Valley whilst most of the remainder drains to the North Bierley Works of the Corporation in the Calder Valley. There are, however, one or two small portions of the City which drain, as a matter of convenience, to outside Authorities. In addition to the area draining from Bradford to the Esholt Works there is an area of 1,110 acres from the Yeadon U.D.C. and an area of 1,340 acres from the Baildon U.D.C., these Councils having entered into Agreements with the Corporation whereby the latter take and treat their sewage for a term of 30 years with arrangements for extension.

Volumes to be dealt with.

The population of the City of Bradford according to the 1931 census is 298,000, of which the population draining to the Esholt Works is taken to be 273,000, added to which is a population of 7,000 from the township of Yeadon and 7,400 from the township of Baildon, making a total of 287,400 people. The dry weather volume of crude sewage flowing to the Esholt Works is shown by the gaugings to be approximately as follows:

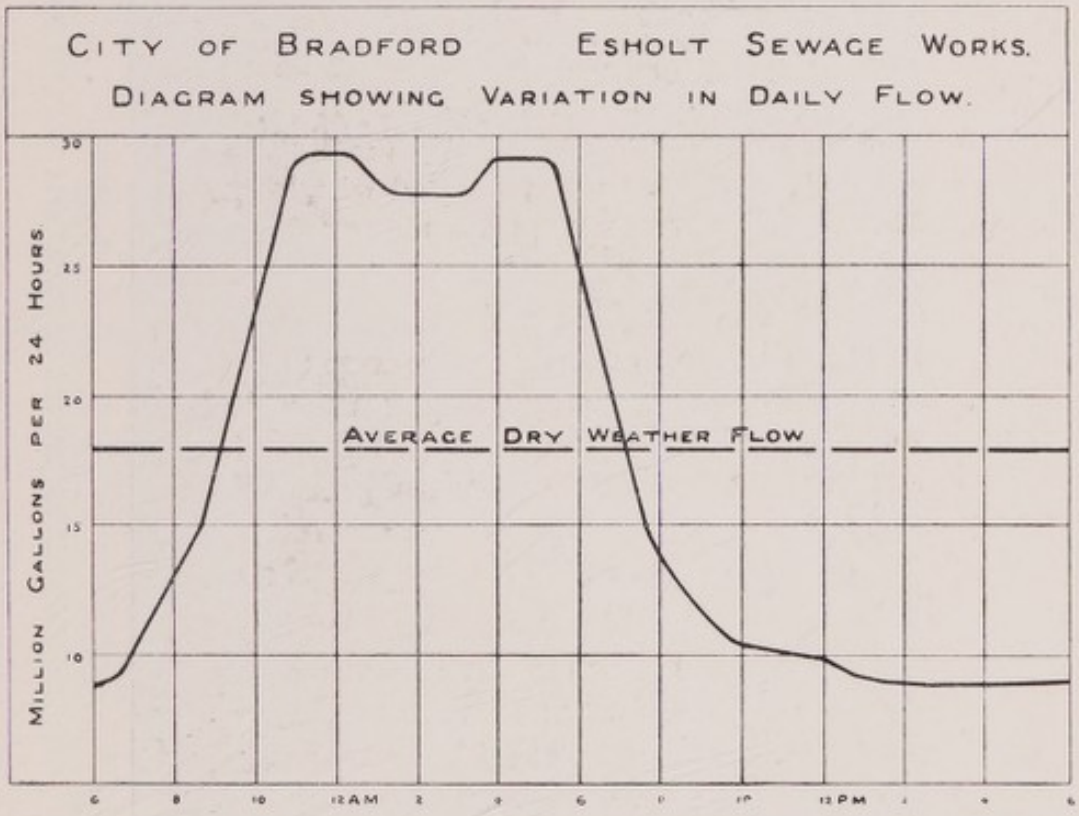
Million galls.	
15	From the central part of the City via the main outfall sewer in tunnel.
1	From the Eccleshill and Idle districts of the City via the intercepting sewer.
*1¼	From the township of Yeadon.
*¾	From the township of Baildon.
18	Total

*The sewage from the out-districts mentioned enter the Precipitation Tanks on the north side of the valley and have special balancing, grit-catching, and storm-water arrangements.



TUNNEL OUTFALL AND DETRITUS PIT.

Thus the dry weather flow of crude sewage amounts to 63 gallons per head per day of the population served, and is of a quality later described. The volume of sewage in wet weather, which is liable to flow to the Esholt Works, is at the rate of 96 million gallons per day, which figure has been reached on many occasions. The average flow treated throughout the year (taking 1929–30 as an example) amounts to $23\frac{3}{4}$ million gallons daily, the total flow for that year being 8,661 million gallons for Bradford alone without out-districts. One of the features of the Bradford flows is the high rate maintained during the working hours of the day as is shown by the following diagram:—



This is due mainly to the emptying of wash-bowls and vats at the various wool-washing and dyeing plants in the City.

The sewage entering the Esholt Works is composed of approximately half domestic and half trade waste. The latter

DETRITUS TANKS AND STORM WATER BAY.

consists of crude wool scouring effluents, seak tank effluents from wool scouring treatment plants and various dye liquors.

Quality of Crude Sewage.

Typical analyses of wool scouring liquors are as follows:—

Wool Scouring Effluent.

Grease . . .	2,220·0	parts	per	100,000
Suspended matter	3,030·0	,,	,,	,,
Oxygen absorbed.	234·0	,,	,,	,,
Alkalinity . .	612·5	,,	,,	,,

Treated Wool Scouring (Seak Tank) Effluent.

Grease . . .	144·0	parts	per	100,000
Suspended matter	315·0	,,	,,	,,
Oxygen absorbed.	117·9	,,	,,	,,
Acidity . . .	102·9	,,	,,	,,

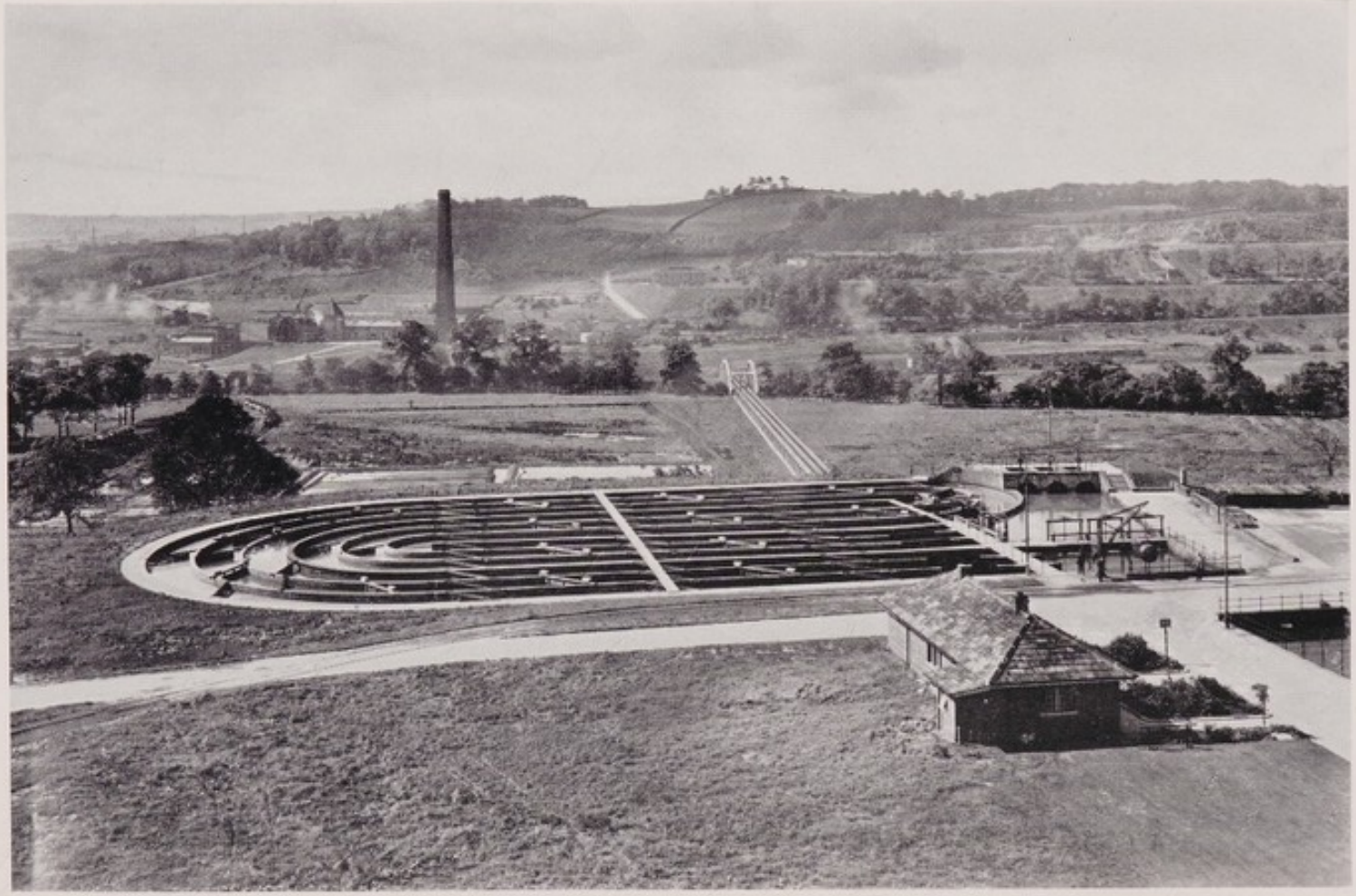
The dye liquors are too varied in character to enable separate analyses to be given, some being acid and some strongly alkaline, according to whether they are from the wool, cotton, or silk industries.

The strength of the combined liquor, i.e., the crude sewage of Bradford arriving at the works may be illustrated by giving the following average analysis over 12 months:—

Grease . . .	89·0	parts	per	100,000
Suspended matter	145·0	,,	,,	,,
Oxygen absorbed.	24·6	,,	,,	,,
Alkalinity . .	81·5	,,	,,	,,

The difficulty of the problem, however, is not fully measured by the consideration of average analyses because, owing to the nature of the staple industries of the City, the sewage during the working day contains a higher proportion of trade waste. On the basis, for instance, of oxygen demand the figure is often double the one given above.

The major portion of the sewage arrives at the Works by way of the new 10-ft. diameter main outfall sewer in tunnel through Idle Moor. This sewer has a discharging capacity of



MIXING TANKS.

about 180 million gallons per 24 hours. This is twice the capacity required at the present time and is expected to serve the needs of the City for at least 100 years. The intercepting sewer has a discharging capacity of 12 million gallons. These sewers discharge in the inlet bay of the new Works where the process of sewage purification begins.

Sewers.

Reference to the illustration on page 16 will show the discharge end of the main outfall sewer to an apron, the object of which is to spread out the waters to the full width of the detritus pit over which a grab is seen at work. This pit is necessary in order to retain not only the coarse grit but also lumps of clotted cotton waste, wool, and rags of a size likely to cause stoppage in the pipes and damage in the sludge treatment processes. This material is dredged from the tanks as required. The waters pass forward through a screening plant (not at the present time in use) to the two detritus tanks which retain the finer mineral matter whilst floating matters are prevented from going forward by deep scum boards. An illustration on page 18 shows the detritus tanks in the foreground and a recording house where the whole of the flow of sewage is measured by Lea recorders. All the sewage (including storm water) passes forward to the storm water bay, which will be seen in the same picture where the excess water is diverted down a cascade to the storm water tanks, one of which can be seen behind the detritus tanks in the foreground. The sewage undergoing full treatment flows from the storm water bay to the syphon head which is controlled by penstocks seen in the picture.

Grit-catching, Detritus and Storm Water Overflow Arrangements.

The sewage flows across the Aire Valley in three lines of 48-inch diameter pipes constructed in the form of inverted syphons, each of the three pipe lines being capable of passing 30 million gallons per day. Two of these pipe lines are in constant use and one is kept in reserve. Reference to the illustration on page 28 will show the pipe lines crossing the valley to the north side where the precipitation tanks and other plant are situate. At the point of discharge sulphuric acid, as a precipitant, is added to the sewage.

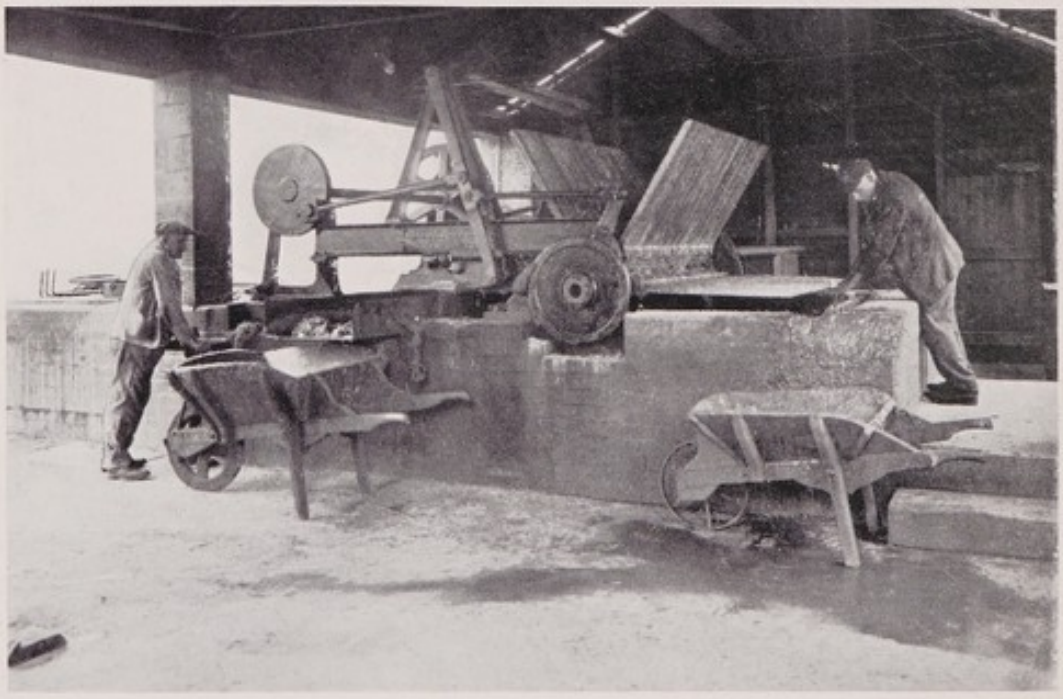
Aire Valley Crossing by Syphons.

The acidified sewage then passes through a specially designed mixing tank of 445,000 gallons capacity, illustrated on page 20, where the precipitate is kept in circulation, being gently turned over by means of baffle boards suitably placed across the natural flow. An improved cracking of the soaps and a reduction of the colloidal content is thus obtained. As a matter of fact, the visible effect in comparing the crude sewage after cracking with acid and the same after passing through the mixing tanks, where there is a delay period of half an hour, is very pronounced. This improvement measured in terms of oxygen absorbed represents a 14% purification. Laboratory experiments, however, indicate that this is not the maximum improvement possible. An increase of suspended solids in the liquor still further improves the effluent and for this reason arrangements have been made to pump back the sludge from the secondary tanks to mix with the incoming sewage.

Mixing Tanks.

After mixing, the sewage flows forward to the precipitation tanks which are arranged in two series, there being twenty tanks for the acid cracking process and a further twenty for secondary precipitation. These tanks will be seen in the

Precipitation Tanks.



SLUDGE SCREENS.

illustration on page 26 and the sulphuric acid plant which supplies some of the Department's requirements in acid on page 30.

Bacterial Filters.

The tank effluent passes by way of the main eastern conduit to 53 acres of bacterial filters, some of which may be seen in the illustration on page 36. From the filters the effluent passes down the main effluent conduit to the River Aire at a point 1 mile above Apperley Bridge.

Sludge Disposal.

The sludge from the detritus tanks and the precipitation tanks gravitates in sealed mains to the screening plant where the sludges are blended and screened in a plant which is illustrated on the opposite page. From this plant the sludge is lifted to the sludge disposal building, a general view of which will be seen on page 44. Here the sludge is treated for the extraction of grease and water, leaving a residue of value as manure.

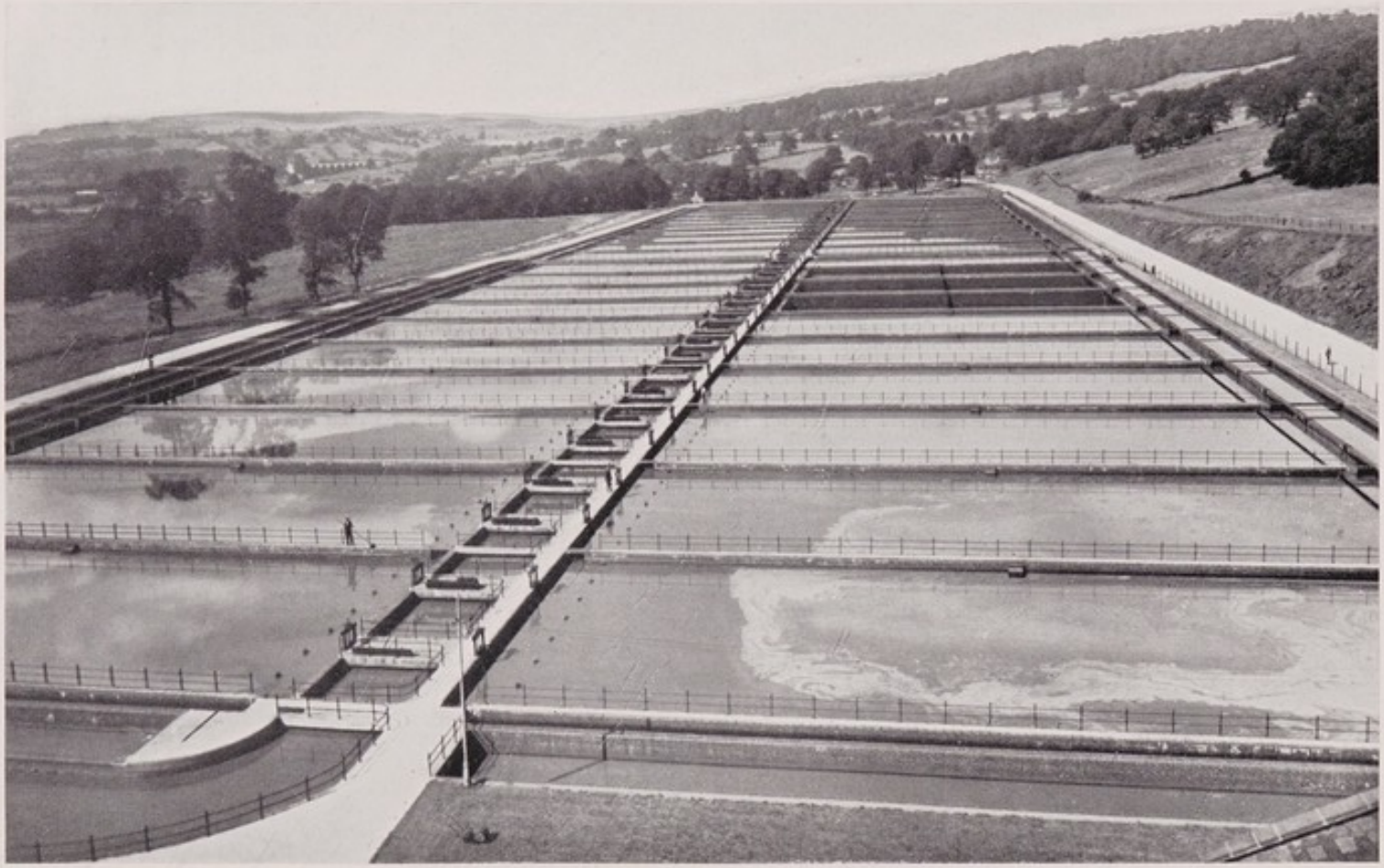
H. WONTNER-SMITH, M.INST:C.E.
Sewage Works Engineer

Chapter III

OPERATION OF THE SEWAGE DISPOSAL WORKS

WHILST these Works are operated mainly for the efficient purification of sewage, they are also worked for the collection of valuable by-products and there are many features of the works which are of considerable interest. Put shortly, Bradford has no sludge problem. The whole of the sludge (with one small exception), both from the detritus and precipitation tanks, is treated in the press-house for the extraction of grease. Subsequently the grease and also the residual cake are sold on the market at prices which pay all the working expenses of this part of the process. The only material tipped to waste is that from the detritus pit (or grit chamber) at the end of the tunnel. The quantity of this material does not amount to more than 25 tons per day. In fact this dredging is kept within very narrow limits, the object being to allow as much of the fine sand as possible to go forward to the main detritus tanks. The gritty sludge produced in these tanks is valuable as one of the component parts of the sludge pressing compound. For a similar reason not only is the fine sand required, but all the paper and fibrous floating matter is found to be so helpful that the battery of screens, which was installed as part of the process following the detritus pit, is not as a rule, used. It is found that if the floating matters are allowed to go forward through the detritus tanks, which will be seen on the illustration on page 18, these matters become entangled in the scum which collects behind the scum-boards guarding the outlets to these tanks. Thus they go down and become part of the sludge when the supernatant water is pumped off from these tanks. As no precipitant is used on this side of the valley it is necessary to operate the detritus tanks at frequent intervals for the removal of the sludge, in order to prevent smells. The arrangement is that the two detritus tanks are cleaned alternately and the sludge removed

Working of Detritus Tanks and Sludging Arrangements.



PRECIPITATION TANKS.

from each within seven days and rather oftener in the hot summer months. The tanks are fitted with floating arms placed beyond the scum-boards, the water contents of each tank being pumped from one to the other as required, leaving the sludge exposed for removal to the press-house. Each of these tanks contains half a million gallons of liquid, the velocity being such as to cause, as far as possible, only mineral matters in suspension in the sewage to be settled out. The sludge from here gravitates to the sludge screening house for mixture with the greasy sludge from the precipitation tanks. It is found by the use of this plant that even in times of high flow all the floating matter, and all the heavy and medium qualities of sand together with wool and cotton residues are retained, and the liquor going forward to the next part of the process is of the nature required, the screens being out of action and scum-boards, assisted by entangling greasy scum, taking their place.

Measurement of Flow.

Before going forward to the storm water bay all the sewage passing over two weirs each 33 feet long, is gauged by means of Lea Recorders. A third recorder measures the volume of storm water before it passes down the cascade on an elliptical weir 160 feet long. By this means a continual record can be kept in the books of the Department of the amount of storm water treated and also of the quantity of sewage undergoing the full process.

Storm Water.

The storm water tanks have a capacity of 11½ million gallons. It was originally intended and agreed by the Authorities to fully treat three times the domestic and 1$\frac{1}{10}$ times the trade sewage, which was equivalent to fully treating 32 million gallons and partially treating in storm water tanks 64 million gallons. Experience has shown, however, that owing to the high flows during the working hours of the day (see diagram of flows, page 17) a slight amount of rain causes very strong sewage to flow to the storm water tanks. This storm water is very foul, containing a good deal of grease. Moreover, difficulties were experienced in removing the sludge over so large an area with such quickness as to prevent aerial nuisance. Now, therefore, the amounts have been reversed, the 64 million gallons being carried forward to the

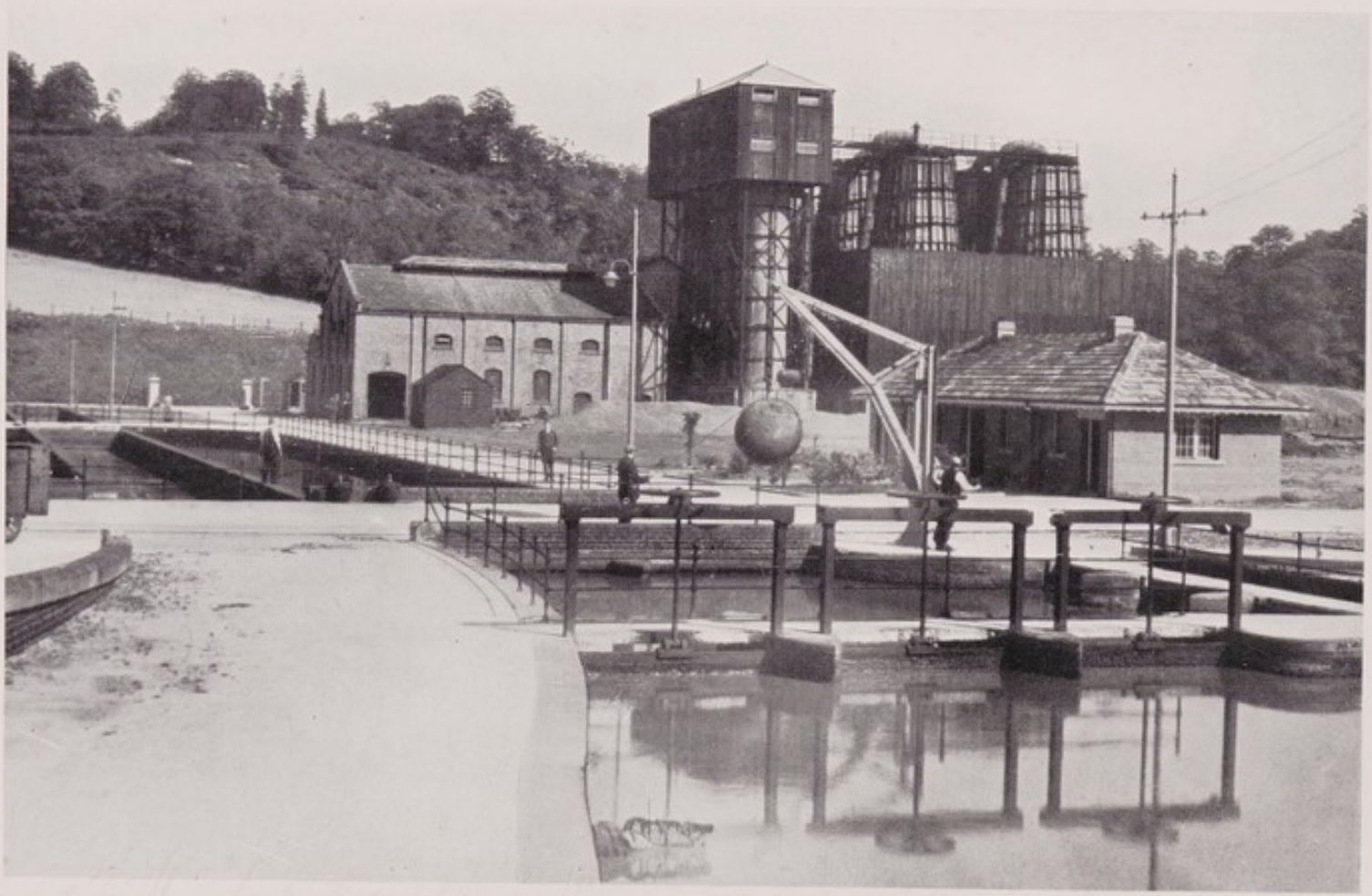
main precipitation tanks and the remainder only, flowing to the storm water tanks, which thus only come into use occasionally. By this means some of the gross pollution of the river has been eliminated, and has much facilitated the working of the scheme generally. The supernatant water from the storm water tanks is passed by way of a 20-inch main to an area of land which has been suitably prepared for its reception. The sludge from the limited area of storm water tanks used, is passed to the press-

REINFORCED CONCRETE BRIDGE CARRYING SYPHON PIPE LINES.

house in a fresh condition, it being very necessary to see that it is not allowed to lie in the tanks for more than a few days.

Syphons Crossing Aire Valley.

The crossing of the Aire Valley by means of inverted syphons was a matter concerning which there was a great deal of discussion. This method was only adopted ultimately because of the heavy expense of erecting the overhead aqueduct which before the war was the accepted design. Owing to the high cost of materials and labour after the war the committee decided that they must, even at some risk, reduce the cost of this portion of the undertaking. Thus it was agreed that syphons should be provided subject to safeguards against blockage. This is the more necessary because the velocity through these pipes owing to the restricted head often falls below 2 feet per second. To guard this position three lines of defence were adopted. (1) The operation of a wooden ball on the lines of that seen working in the syphons under the Seine during the visit to Paris by a deputation from the Committee in 1923. The ball at Bradford consists of a solid wooden sphere, in four segments bolted together, of home-grown timber and weighing 15 cwts. (See illustration on page 30.) This ball floats low and just about displaces its own weight of water. By this means it is found that without any help, except guidance to the particular line of pipes it is intended to clean, the flow of water draws the ball down the vertical leg 68 feet deep at the head of the syphon, after which the ball passes along the pipe line on a slightly ascending gradient with finally a sharp gradient at the delivery end. The retardation of the ball, which is 3 in. less in diameter than the pipe through which it passes, owing to friction in rubbing along the top (intrados) of the pipe, causes an increase in the velocity of the liquid underneath the ball and therefore all the sediment is stirred up and moved forward. The ball travels the distance across the valley of 712 yards in 7 minutes under normal conditions. Each pipe line in use is thus cleaned once a week. Although this work has been in operation now for five years the mains are free from deposit. (2) The syphons were arranged to cross above the river on a reinforced concrete bridge which will be seen in the illustration on the opposite page (although very much fore-shortened in appearance, this bridge being 130 feet span). This made it possible to arrange wash-out pipes into the river in order that, in case of necessity, the pipe

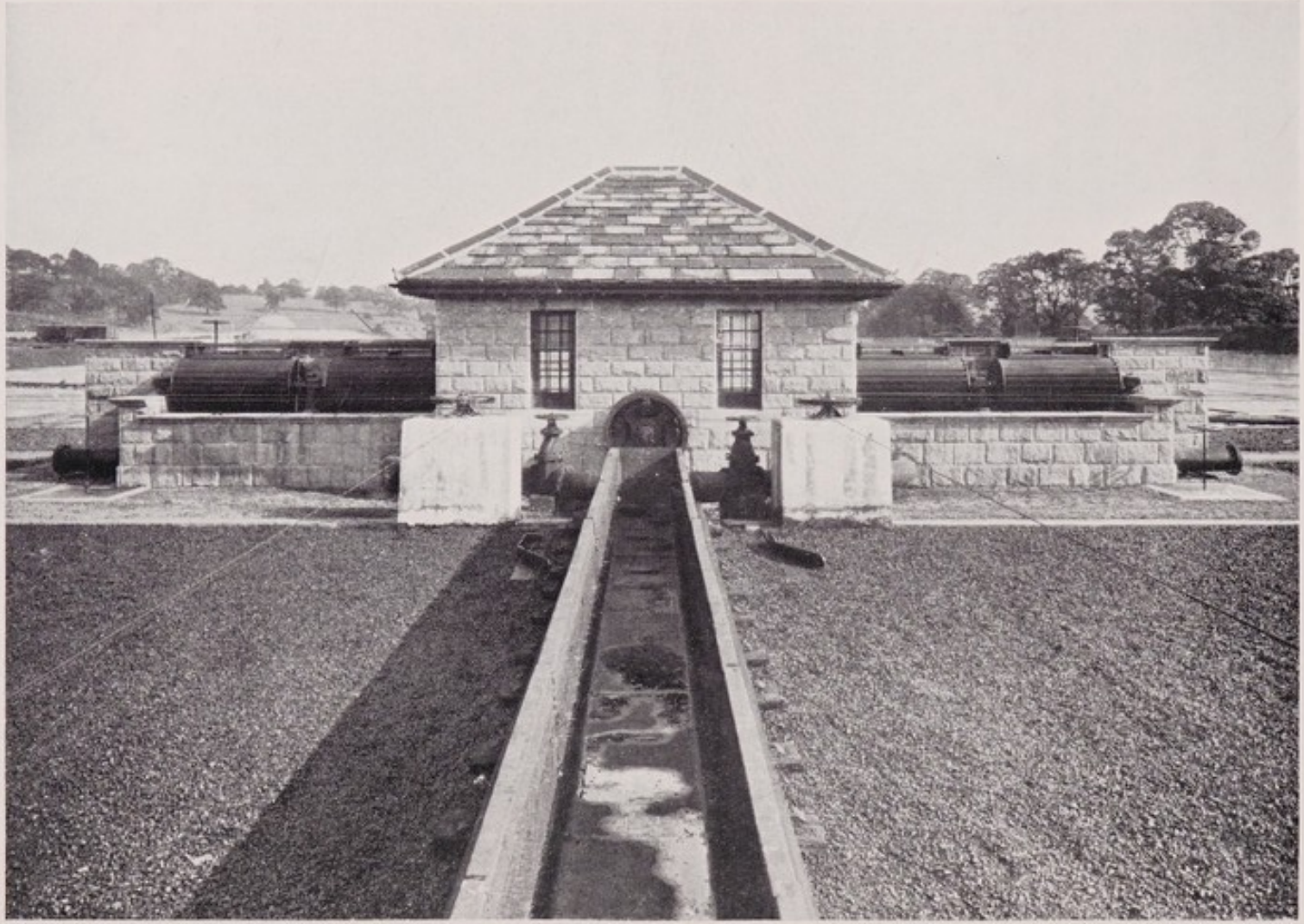


RECEIVING BAY TO PRECIPITATION TANKS AND SULPHURIC ACID PLANT.

lines could be emptied. (3) Lastly, cast iron access doors (hatch boxes) were arranged in each pipe line at suitable points so that, in case of necessity, workmen could get into the pipes and dig them clear after the water had been removed.

Mixing and Precipitation Tanks.

Upon arrival at the precipitation tanks site on the north side of the valley, as before-mentioned the sewage is treated with sulphuric acid (B.O.V.). The object here is, of course, to crack the soaps in the sewage and precipitate a good deal of the dissolved organic matter, the wool waxes and the suspended matter being carried down in the process. This means that a varying quantity of acid is required ruled by the alkalinity of the incoming sewage at various periods of the day. The process is controlled by an assistant who takes samples frequently (about every quarter of an hour) during the day and regulates the amount of acid in order to produce a sewage which is about 10 parts per 100,000 acid, using methyl orange as an indicator. It was the custom until recently to acidify the sewage during the whole of the 24 hours and when this was done the amount of acid used by the Department in twelve months amounted to some 20,000 tons. This was not only a great expense but it was found that the filtration of an acid sewage had limits, and that probably considerable sums of money could be saved and better final results obtained if the grease could be collected by the use of less quantities of acid. After exhaustive experiments it was found that the best results in filtration were obtained when the P.H. value of the tank effluent was about 6, and therefore with this in view a reduction of the amount of acid used has been standardised without prejudicing the amount of grease collected. In this way it is now the custom to only use acid when actual wool suds are arriving at the works. This means that at certain periods during the night, on Saturday afternoons, Sundays, on Monday mornings, and during very wet weather no acid is added. The effect of this is, that instead of using 20,000 tons of acid per annum, 12,000 to 13,000 tons is sufficient. This alone has saved the department a considerable sum of money. Moreover, the *average* acidity of the primary tanks is reduced to a very low figure, almost to the neutral point. Having achieved this the second series of twenty tanks, which were designed either for primary or secondary use as might be required, are now used for secondary precipi-



POWER UNIT. BACTERIAL FILTERS

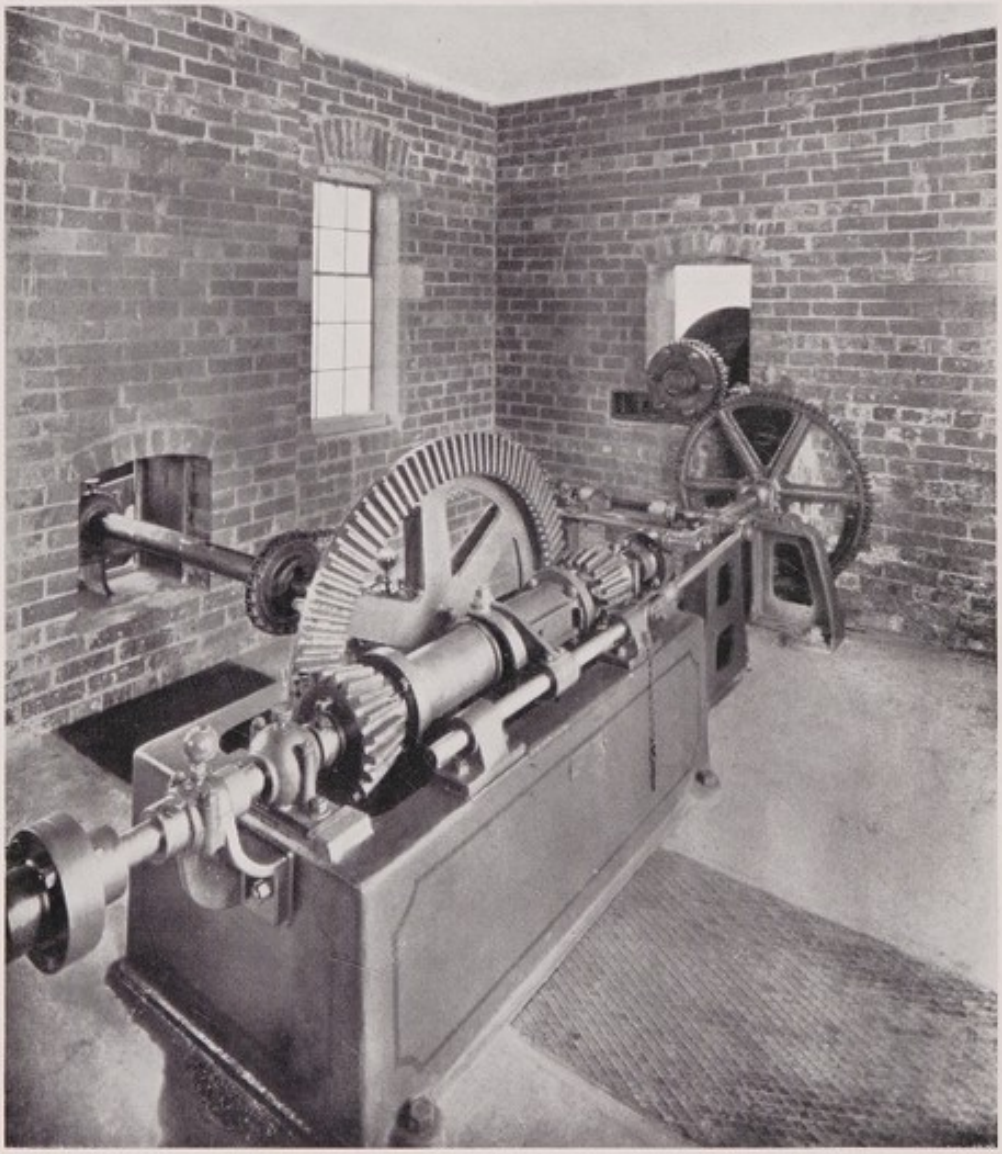
tation and advantage is taken of discharging to them alkaline sewage from the out-districts of Yeadon and Baildon. Possibly the sewage of others with whom the Corporation are now negotiating will be added in order to produce a tank effluent of higher alkalinity. The effect to-day is that instead of the feed to the filters being acid to methyl orange it is alkaline and in consequence better results are being obtained. It is expected within measurable time to produce a tank effluent with a P.H. not of 4·5 to 5·0 as now, but up to the figure of 6 without any expense in the use of chemicals. Moreover, since considerable value is attached to the use of the mixing tanks at the discharge end of the syphon, arrangements have now been made, as before mentioned, to pump the secondary sludge (this is a very small expense) back to the starting point. This increase in the amount of suspended matter passing through the mixing tanks has the effect of arresting more of the colloidal matter present in the incoming sewage.

The design of the tanks at Esholt is an extremely satisfactory one for the purposes required. They are so designed that they may be worked either in parallel or in series. Inlet and outlet weirs the full width of the tanks are arranged so that the film of water flowing into and out of the tanks is very regularly and quietly governed throughout the whole length of flow. In this way excellent settlement is secured and it is seldom that the suspended solids passing from these tanks exceed 7 parts per 100,000, with only minute traces of grease. One of the values of the acid cracking process is the preservation of the sludge collected in the tanks which secures entire freedom from smell and enables dense sludge to be collected. This is a very great asset when dealing with sludges because, whilst Bradford works up a sludge in the neighbourhood of 80% water, some other towns are unable, owing to the necessity for frequent emptying, to produce a sludge of less than 90%. Thus, in the case of Bradford, the bulk of sludge to be handled is halved, the value of this being obvious. The sludge is drawn from the tanks and passed through the press-house as required, an average of approximately 75 tons of cake being produced daily, having a percentage of moisture of about 26. It should be remembered that in order to provide an 80% sludge, it must be built up over a period and thus three months commonly passes before any unit part of the sludge arrives at the press-house. This position

can be faced without danger of smells arising; in fact the sludge has been kept for much longer periods without offence.

Sulphuric Acid Plant.

The Sulphuric Acid used in the Department is practically all made by the Corporation. It is obtained from two sources, first from a plant erected at the Esholt works in the years 1927–8, about to be referred to, and secondly from the Gas Department which produces 5,000 tons of B.O.V. per annum using a bye-product of gas manufacture, viz., spent oxide, as the raw material.



DRIVING GEAR. FILTER DISTRIBUTION.

The installation at Esholt is a Mills-Packard Chamber process plant of modern design capable of producing equivalent to 9,000 tons of 140° Twaddle Sulphuric Acid (77·17% H_2SO_4) per annum. About 5,000 tons of Iron Sulphide (in the form of pyrites, imported from Spain) is roasted in mechanically-operated furnaces for the production of the sulphur di-oxide gas. The sulphur content of the raw material is 48–49% of which 46–47% is available for acid making. The oxidation of the sulphur di-oxide to tri-oxide is effected by means of nitric oxide gas produced by the action of sulphuric acid on nitrate of soda, some 65 to 75 tons of the latter being used annually.

The plant is situated in a convenient position near the precipitation tanks, the acid being delivered direct from the plant to the storage tanks by gravitation.

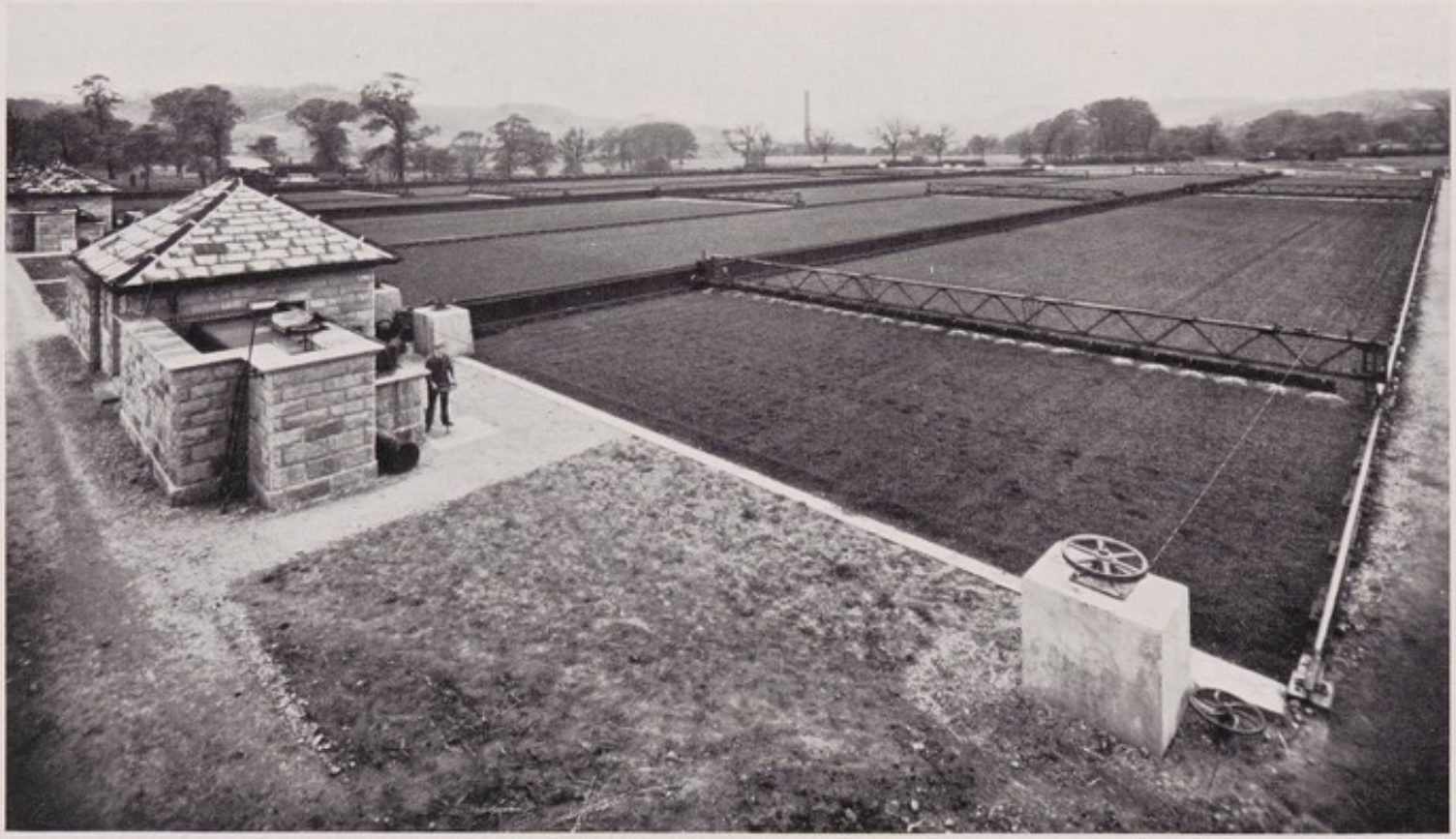
Compactness and economical working are two big features of the plant and since its erection large savings have been effected owing to the Committee's policy of being self-suppliers.

Tank Effluent.

The tank effluent passing by way of the main eastern conduit to the filters, a distance of 920 lineal yards, has an analysis something as follows:—

Oxygen absorbed	12·8	parts per	100,000
Grease	6·0	,, ,,	,,
Suspended matter	7·4	,, ,,	,,
Alkalinity	5·9	,, ,,	,,
Ammonia, free	2·3	,, ,,	,,
Ammonia, albumenoid	1·2	,, ,,	,,

One of the difficulties encountered at this stage is the growth of certain fungi, which appear to be much encouraged by the mineral acid used for precipitation. It may be said, however, that the amount of fungus has much decreased since the P.H. value of the effluent was increased. The fungi (*fusarium aqueductum* and others) are more pronounced in winter and thrive particularly on the length of the underground conduit leading to the filters. It is necessary, therefore, to pass the tank effluent through a series of three fine screens in order to eliminate as far as possible the fungoid growths which have broken away from the walls and floors of the channels. The screens are also

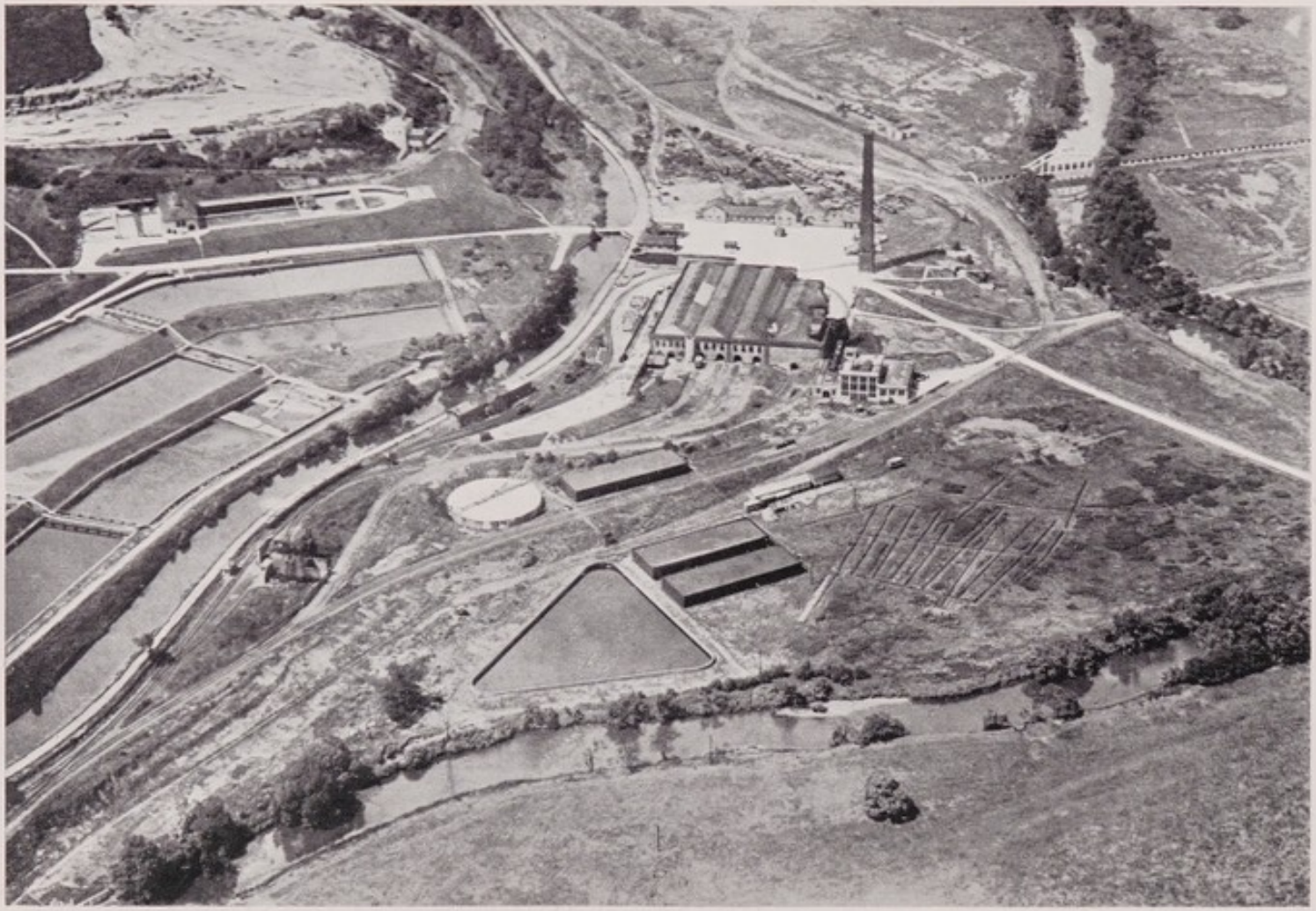


BACTERIAL FILTERS.

of use in preventing leaves and any other extraneous matter passing on to the filters.

Bacterial Filters.

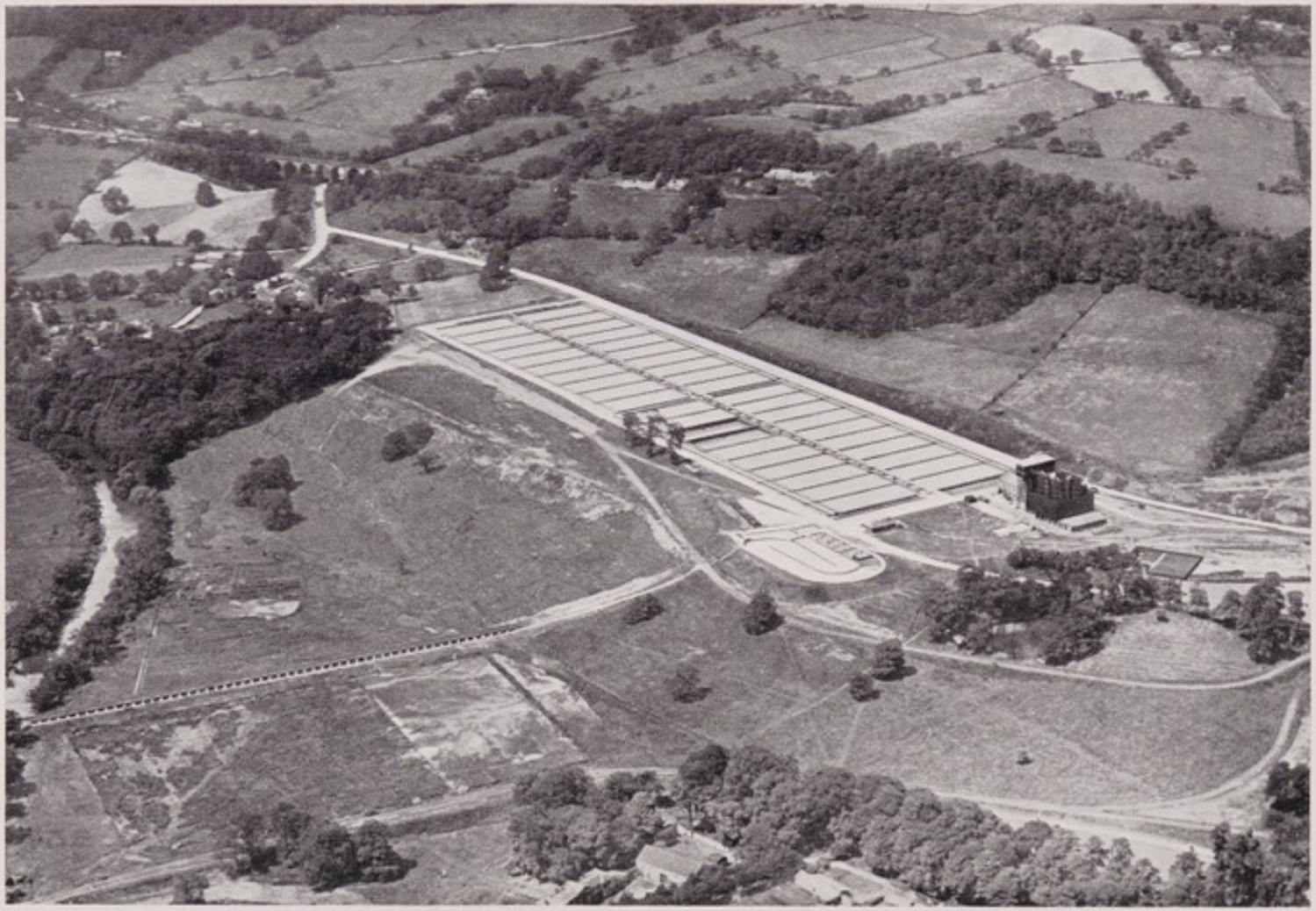
The filters cover an area of 53 acres and they deal with a dry weather flow of 18 million gallons per day which is equivalent to 340,000 gallons per acre, 70 gallons per square yard or 35 gallons per cubic yard, the filters being 6 feet deep. Owing to the high flow, however, for ten hours during the working day, the filters are then called upon to function at a considerably greater rate. It is not uncommon for the flow during the day to be maintained at the rate of about 30 million gallons per day for very long periods, this being equivalent to 556,000 gallons per acre, 117 gallons per square yard or 58 gallons per cubic yard. The filtering material is coal of a size from ¾ in. to about 1¼ in. known in the trade as washed singles. The hard Yorkshire coals have proved to be a very satisfactory filtering material for the type of sewage which has to be dealt with at these works. Moreover, it is extremely valuable as a business asset, having always a potential market value which might well be of service in times of national emergency. On one occasion already, owing to the general strike in the year 1926, the whole of the gas and electrical services of Bradford were maintained at full output by means of this coal. In addition, factories in Yorkshire and Lancashire, and also householders in the City were supplied. In this way 200,000 tons were sold and afterwards replaced. Again, coal is a cheap form of material owing to its lightness in weight, 1 cubic yard of coal weighing only 11 cwts. Thus coal is actually cheaper than other forms of material that could be thought of. Should the coal in future years become dirty, which is not anticipated, it would be cheaper to sell it when the market was favourable and thus save washing charges. The coal does not appear to suffer as regards its calorific value by long years in the beds, although it might be thought to do so. The filter floors are laid entirely flat so as to facilitate the loading and unloading of coal, it being necessary to keep them so in order that the railway lines may be slued to any position desirable. Openings have been left in every section of the filter beds to permit the entry, at short notice, of the necessary railways and plant for the removal of the coal. Cranes fitted with grabs handle this coal excellently and twenty-five trucks of coal loaded or unloaded in eight hours per machine is con-



AERIAL VIEW SHOWING THE DETRITUS TANKS, STORM WATER TANKS, SLUDGE DISPOSAL WORKS, AND AIRE VALLEY CROSSING.

sidered to be a reasonable day's work. This is equivalent to about 200 tons, and the cost is approximately 9d. per ton for unloading, including levelling the coal into its final position.

The rectangular type of distribution adopted throughout the works, although it might be considered to be expensive in first cost, is not unduly so when all the factors are taken into consideration. Certainly for the difficult type of tank effluent to be dealt with at Bradford this form of distribution has proved to be the right one. As the object throughout the design of the works has been to make the greatest use of the natural forces provided, advantage has been taken of the head of water available, owing to the difference in level between the screening house and the filter beds, to obtain power. Thus the sewage operating overshot water-wheels provides all the power, free of cost, before going forward itself for purification on the beds. The illustrations on pages 32, 34 and 36 show the general and detail designs and it will be noted that the distributors are run in pairs, balanced as well as drawn along, by wire ropes. This is a very important feature as it secures uniformity of distribution in all weathers and counteracts the inequalities of wind pressure. The distributors have simple automatic reversing gear and need very little attention. The troughs conveying the sewage across the beds are made of cast iron. These rest on the top of the coal without any solid support except that at the leading end of each trough when laid, two wooden pit props of the correct length are driven with a mallet into the coal and rest on the concrete bottom of the bed. There is no difficulty in driving these props, and this has the effect of steadying the troughs from any chance of settlement. The rails are laid on sleepers in accordance with ordinary railway practice. The object of this, of course, is that if at any time the coal is required to be taken out of the bed there is no obstruction whatever in the way of the cranes and railways. As the coal is removed, the troughs and rails slide down the slopes and are picked up by the cranes and put aside without trouble or much expense. The nozzles discharging on the bed being large ($\frac{11}{16}$-in. diameter) tend to prevent choking from fungus or any other obstruction, and the fact that the jet of water impinges on a porcelain plate causes an excellent umbrella spray which has been found to be most satisfactory. It is necessary, however, to see that the distance from the porcelain plate to the coal is not too great, about 5 inches being the practice here.



AERIAL VIEW SHOWING THE SYPHONS, MIXING TANKS, PRECIPITATION TANKS, AND SULPHURIC ACID PLANT.

The filters at Bradford are hard worked even at the comparatively low rate of 58 gallons per cubic yard owing to the nature of the liquor to be dealt with, and have to be used with a good deal of care and thought. On the whole, however, the effluents are good considering the strength of the original sewage and the large amount of colloidal matter inseparable from this type of sewage.

Up to the present, humus tanks have not been considered necessary owing to the large filter area and the consequent slow rate of filtration. There are, however, ample areas of land available below the level of the filters should further works become necessary. The final outlet to the River Aire will be seen by reference to the illustration on page 60.

Flies.

In common with most other sewage works, Bradford has during the summer months a certain number of flies (*psychoda*) on the percolating filters. These are not much in evidence, being mostly confined to the filter media and do not cause a nuisance. In no other part of the process is there any quantity of flies, this again, like the absence of smell, being attributable to having no septic sewage or sludge in any part of the process.

Sludge Disposal.

The handling of the sludge is a very important part of the process of dealing with the sewage of the City, and a great deal of research work has been done in this direction. The method of working has been continuously improved in detail over many years past and the plant is working to-day more economically and more smoothly than ever in the past. The process of sludge disposal is necessarily a hot process because only by this means can the grease be successfully expelled. The daily supply of 80-83% sludge after being mixed with its due proportion of gritty sludge from the detritus tanks in the proportion of 1 to 6, is passed to large 7-ton vats where it is heated by means of steam coils. The temperature is there raised to as high a point as possible (about 170° Fahr.) at which point it rather tends to froth. When at the required heat the sludge passes to large displacement vessels in the basement from whence it is forced up by compressed air to 128 presses in the press-house. Here the sludge is filter-pressed through

cotton cloths by alternately feeding-in hot sludge and superheated steam (to keep up the temperature). Liquid grease and water are discharged in the process. Some 40,000 cotton filter-press cloths are used annually for this purpose, the life of a cloth being under good conditions from 6 to 8 weeks. The presses are operated for varying times according to the nature of the sludge to be pressed, but 64 hours' pressing is the usual practice. In that time the grease content of the cake is reduced to about 16% on the dry solids as compared with 40% in the original sludge, the water content of the cake being about 26%. When the presses are opened the cake falls into railway wagons in the basement and the cake then passes down to a drying area in the open where it remains for about 12 months to mature.

It is of interest to note in regard to the dewatering of this sludge by mechanical means that in two or three days equal or better results are obtained, with far less nuisance, than would be the case by natural methods in twelve months.

STORAGE AND DRYING GROUND FOR PRESS CAKE.

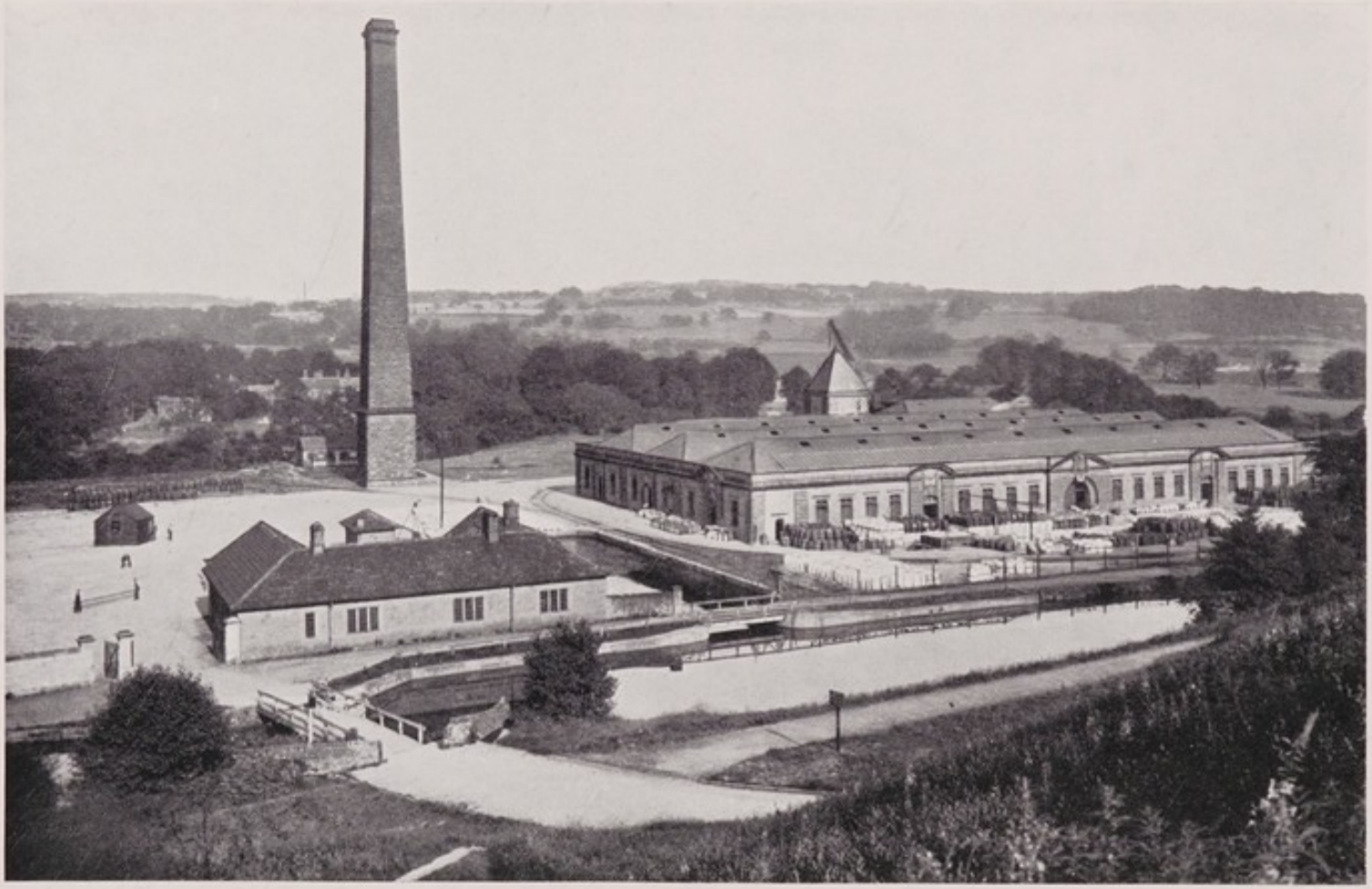
The sludge disposal buildings are a self-contained unit. The boiler plant consists of four Stirling water tube boilers each evaporating 15,000 lb. of water per hour, and being designed to burn low grade fuels, either slacks or a mixture of slack and pressed cake (this cake owing to its grease content having a calorific value of about 7,500 B.T.U^{s}) or liquified grease, although this has seldom been used. The Engine House contains three air compressors together capable of compressing 2,500 cubic feet of free air per minute. The works have their own water supply, there having been sunk a bore hole 300 feet deep from which the water is raised by an air lift into an overhead covered concrete tank. Electric current from the Corporation's supply is used throughout, the cost including delivery and transformer charges being 0·65d. per unit. This figure varies, however, according to the amount used which in the case of this department is relatively small. The price would be reduced on increased consumption. The grease is treated in sixteen grease vats in the grease-house for the removal of impurities and is barrelled and sold to customers as required. The liquors resulting from the purifying of the grease and also the liquors passing from the presses, after separation of the grease, are returned to the precipitation tanks and thus again pass through the process.

A further plant, detached from the main building, was laid down some years ago for the extraction of the grease from the pressed cake, which as before-mentioned contains about 16% of grease on the dry solids. This plant extracts by means of solvents (benzine) the remaining grease, but it is not usually operated and is not considered to pay unless the price of grease is relatively high.

Reference has already been made to the comparative absence of smells on the works generally. This, as has been pointed out, is due largely to the acid treatment which precludes the formation of septic sewage or sludge in any part of the process.

Smells.

Various precautions have been taken to prevent offensive odours being emitted from the hot process of sludge disposal. Thus the vats for heating up the sludge have each been covered with a hood and pipes to convey the gases away. These have been made of special stainless metal. The gases are drawn away by means of a fan and passed up a tower



SLUDGE DISPOSAL BUILDINGS AND WORKS.

filled with brushwood through which a constant stream of water is falling. The gases are thus scrubbed and most of the smell removed. In addition to the above an ozone plant is installed so that there is a constant circulation of ozone in the press-house and also in the grease-house. The ozone is allowed to escape at various points in the apex of the roof where it mingles with the gases from the process thus oxidising many of the compounds having obnoxious odours.

Manure.

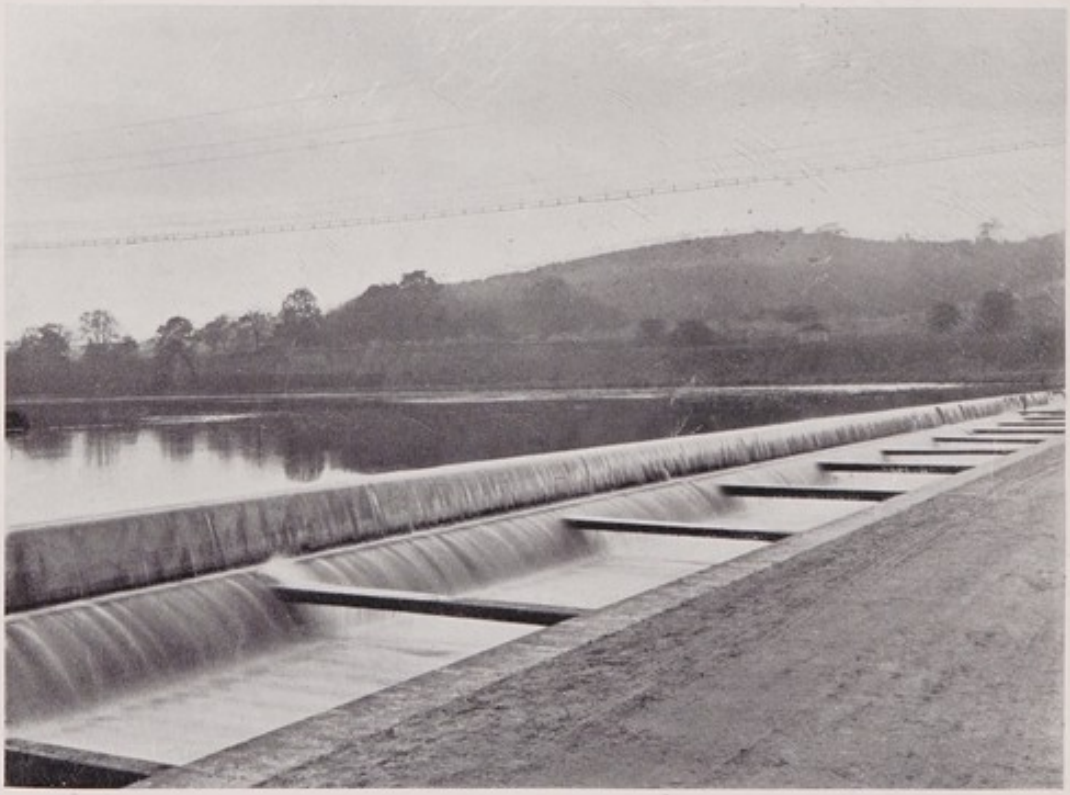
The cake from the presses and still in its hot condition is stored in large heaps in the open. In this way it is found that the grease content is reduced due to the "heating" of the material which is really a chemical action bound up with the growth of moulds. Also this hot condition melts some of the grease which tends to settle to the bottom of the heaps. No buildings are necessary in connection with this work which is not affected by ordinary weather conditions. At the end of twelve months these heaps are broken into by grab as will be seen in the illustration on page 42 and the material passed through a disintegrator which grinds the dried cake into a fine powder. This product finds a ready sale on the market. The land set aside for sludge storage is only a few acres in extent (about 5 acres) and no nuisance whatever is created. As a rule endeavour is made to send out manure not exceeding 15% of moisture although the figure is often down to 10%. As this material contains a very small trace of grease it makes it very nice to handle being free from light dust. Usually one year's supply is kept in stock, although there are times when, owing to sales, it is difficult to keep that amount in hand. At the present time stocks are low.

Experimental Works.

The description of these works would not be complete without some reference to the years of experimental work which has been carried out in the department, and reference is now made particularly to the question of activated sludge and sludge digestion as applied to the treatment of this particular sewage.

Although activated sludge treatment is not used in any part of the process, its action has been investigated in very minute detail in many large scale experiments. One particular experi-

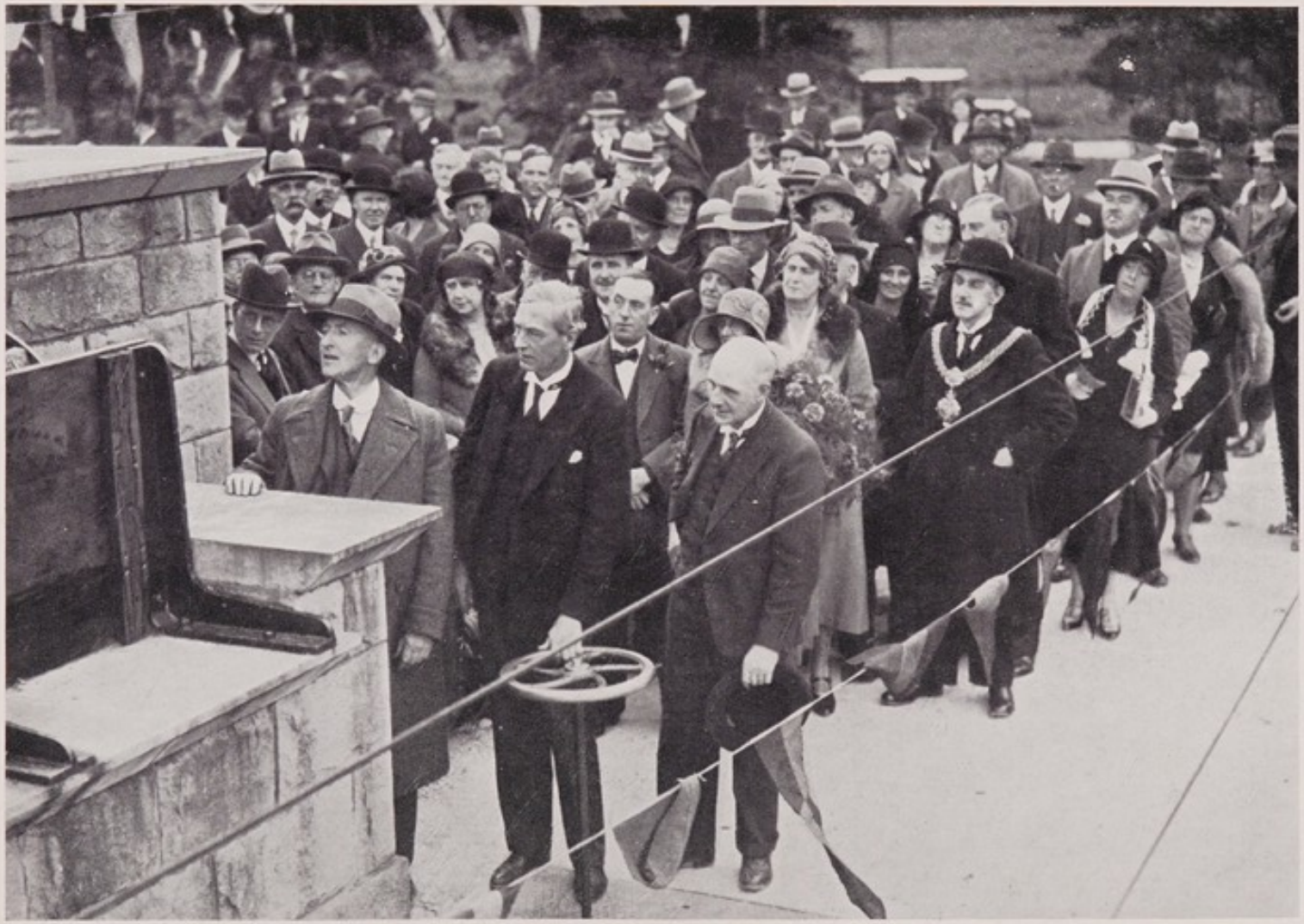
ment, where the crude sewage was treated by means of air-blowing in a deep cylindrical tank, necessitated no accumulation of sludge as in the ordinary activated sludge process. The sewage was merely pumped into the tank and the effluent containing the sludge removed from a point two-thirds the depth of the tank. The effluent on settlement was always satisfactory from a bio-oxygen demand stand-point. There are certain evident drawbacks, however, to the activated sludge method of treatment at Bradford, viz. (1) The sludge to be dealt with would not only be approximately ten times the volume, but of a more difficult nature for subsequent disposal. (2) A large quantity of the grease content in the original sewage would be destroyed in the process whilst any grease remaining would be of very little value on the market. From an economic stand-point, therefore, this would not be advantageous compared with the processes now in operation in the department, especially when the cost of the enormous volume of air required is taken into account.



LAKE, 10 ACRES IN EXTENT, RECEIVING FILTER EFFLUENT BEFORE DISCHARGE TO RIVER.

With regard to the use of activated sludge as a partial treatment of the effluent from the tanks prior to filtration, this matter has received some attention of late with a view to reducing the colloidal content of this liquor. The experiments have shown that with the present tank effluent of relatively low P.H. values the results are not particularly encouraging but more in this direction may be done later when the tank effluent becomes more alkaline. The matter is not pressing at the present time partly because the many nuisances often associated with filter feed waters do not arise.

On the subject of sludge digestion, for long periods a closed digestion tank containing 2,000 tons of sludge was in operation. The results obtained were in accordance with those of other wofks and the gas evolved was used for running a gas engine, 20 brake H.P. being developed. With a view to using this gas, should the process of sludge digestion be adopted at Bradford in the future, a clause has been inserted in the agreement with the Baildon U.D.C. providing that the Corporation may use gas (generated from the fermentation of sewage sludge) or electricity at their option as power for pumping the sewage of this township, 20 cub. ft. of gas to equal 1 unit of electricity. The disposal of the sludge and water from the digestion tank presented certain difficulties in this method of treatment and all things taken into consideration, especially as the grease is destroyed in the process, no advantage could be found. On the contrary, the process is not to be compared in this particular case with the efficient method of filter-pressing now in operation.



OPENING OF THE 53rd ACRE OF BACTERIAL FILTER BEDS BY
THE RIGHT HONOURABLE ARTHUR GREENWOOD, M.P., SEPTEMBER 28th, 1931.

Chapter IV

CONSTRUCTION DETAILS

THE works first undertaken, apart from the canal basin and a branch line of railway from the London, Midland, and Scottish system, were those in connection with the disposal of sludge because it was thought that by this means effect could be given to improvement in the river in the shortest possible time. The construction of the press-house was therefore commenced at the Esholt Works in the year 1910, and completed and brought into use in the year 1912, thereby allowing the sludge to be drawn from the precipitation tanks at the old Frizinghall Works in sufficient quantities and thus reducing the amount of sludge finding its way into the Bradford Beck and thence to the River Aire. The sludge was forced by compressed air a distance of 4·12 miles along an 8-in. diameter main and this method was continued until the spring of the year 1926, when the Main Outfall Sewer came into operation for the passage of the crude sewage into the new Esholt Works.

The buildings are substantially built of sandstone with brick internal facings and have a handsome appearance. The general elevations will be seen in the illustration on page 44. Care was taken in laying out these works to provide for every contingency with regard to transport, and canal, 4 ft. 8½ in. gauge railway, and road are available at the works in order to provide the cheapest possible transport. A large amount of excavation was necessary on the site as a hill known as Strangford Hill had to be removed. The main building covers an area of 1¾ acres and consists of grease-house (237 ft. × 50 ft.), press-house (237 ft. × 92 ft.), engine-house (115 ft. × 40 ft.), and boiler-house (80 ft. × 68 ft.). A basement is provided under the press-house for the accommodation of railway trucks, which receive the press-cake from the presses, and a basement also covers the whole area of the grease-house where are provided grease storage tanks, press liquor tanks, grease separating tanks, and so forth. These two buildings have specially designed reinforced concrete floors, the total weight

on the press-house floor being 2,100 tons. The chimney (8 feet square inside dimension × 200 feet high) is detached from the main building and placed on a solid rock foundation 78 yards distant. The flue laid outside from the boiler-house to the chimney is 5 ft. wide × 8 ft. 6 in. high. Since the erection of the main building other units have been added to complete the works. A Chemical Laboratory, Mess room, and Lavatories for the workpeople, constructed in 1914, which can be seen in the foreground of the illustration on page 44; a block of workshops accommodating blacksmiths, joiners, and stores to the left of the picture; also the main electrical transformer station which transforms the current (alternating, 3 phase, 50 cycles) passing from Apperley Bridge and also that by way of the overhead transmission line crossing Idle Moor to the Works (originally put up for the construction of the tunnel) from 6,600 volts to 400 volts for power purposes and 230 volts for lighting.

Further, a solvent plant was erected near the existing buildings towards the end of the War, out of revenue, for the purpose of degreasing sludge cake.

TUNNEL SEWER—ADVANCE HEADING.

In 1909 the Eccleshill and Idle Intercepting Sewer was constructed, together with a small pumping station at Apperley Bridge, to deal with the low-lying area of Greengates and also certain of the storm water tanks, in order to enable preliminary treatment to be given to the Eccleshill, Idle, and Greengates sewage.

Also in that year two of the precipitation tanks were constructed in order to give temporary treatment to the Yeadon sewage, an out-district of Bradford which the Corporation were under agreement to take.

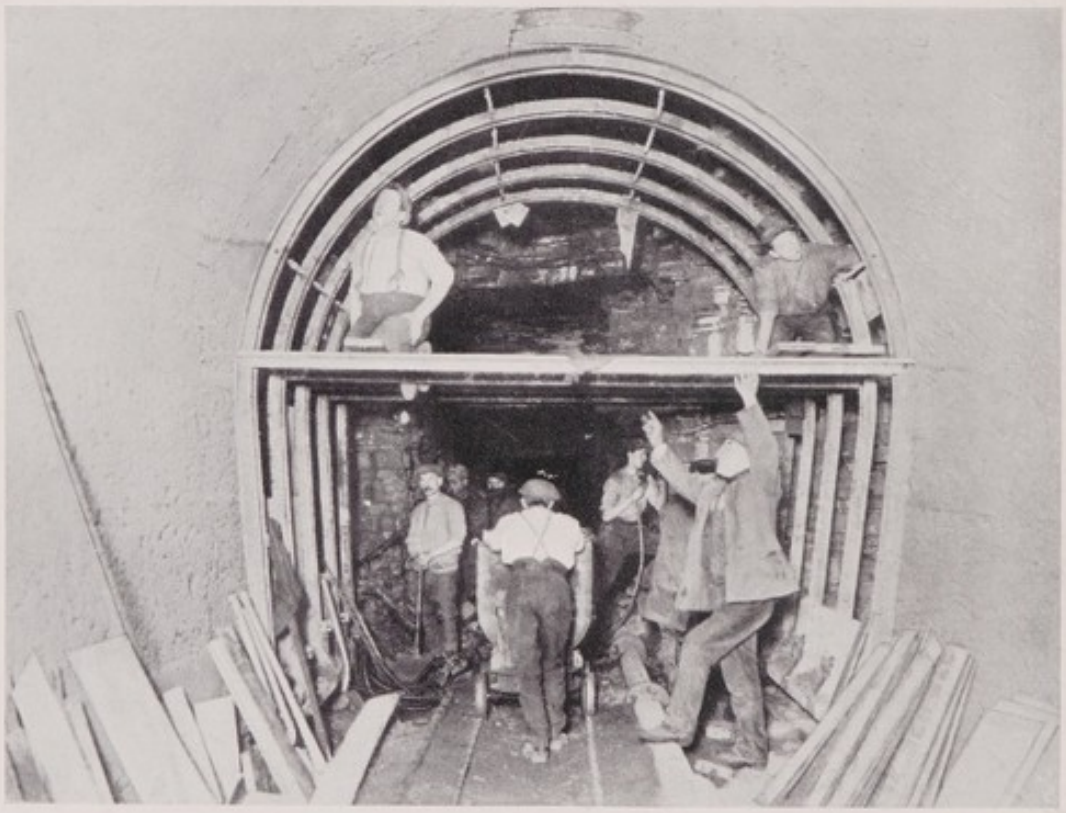
Main Outfall Sewer in Tunnel.

In the year 1913 a commencement was made with the construction of the main outfall sewer in tunnel. It should be mentioned that the construction of this tunnel was decided upon because only by taking the shortest route could full use be made of the lands available at Esholt by gravitation. With a total fall of only 12 feet, it was found possible whilst providing self-cleansing velocities to pass the sewage from the Frizinghall district of the City by way of the tunnel and across the Aire valley, a distance of more than 3 miles, to the only natural site available for the precipitation tanks, on the north side of the valley, and thus permit the use of 800 acres of land for works by gravitation. The tunnel was first let to a contractor for the sum of £113,971 who commenced the preliminary works necessary before the driving of the actual tunnel commenced. However, this contractor was unfortunate and became bankrupt after very little of the work had been done. Borings had previously been sunk on the line of the tunnel but the Committee decided that before they let a further contract they would sink the two shafts, Nos. 1 and 2 (position of which can be seen by reference to the section of the tunnel at the end of the book) by administration. This work was therefore proceeded with and completed in 1914. By this means it was thought that contractors could learn something more of the geology of the undertaking with a view of giving closer tenders.

In 1914, a few days before the commencement of the War, a further contract was let in the sum of £121,616. However, this contractor was not able to proceed long with the work unhindered and hampered by restrictions in the supply of materials

and the difficulty of retaining his men who were being constantly taken away from him for war service, he was glad when the Corporation, in consequence of Treasury restrictions upon borrowing, decided to shut down the works in 1916. This contractor was afterwards paid off and his plant and materials sold, nothing further being done until after the War. In the year 1919 the Corporation resolved to undertake the work by direct labour. Incidentally, it may be said that since the War contractors have not been employed on these works, everything (that is the great bulk of the Esholt Scheme) has been done by direct labour, the Engineer acting throughout as Administrator.

In the autumn of 1919 a bottom heading about 7 ft. × 7 ft., in the clear was started from both the Frizinghall and Esholt ends in order to open up the ground and for the first twelve months nothing else was done. It was decided to abandon the proposal to work from the bases of shafts Nos. 1 and 2, owing to the high costs of carrying materials up the hills to these points.



TUNNEL SEWER. CONCRETE LINING ON TRAVELLING STEEL CENTRES.

The shafts had previously been sunk and the tunnel eye formed at their base and these were subsequently accurately junctioned from the two ends. The bottom headings having been well advanced, arrangements were made in November, 1920, to open up the full-sized tunnel, but in doing this it was resolved for traffic reasons not to put in the invert of the sewer but to concrete the arch and the two side walls only. For this purpose special steel centres were constructed in order to carry the super-imposed weight of the wet concrete and the ground in dealing with each section. The lengths dealt with were 12 ft. long each net. The centres were provided with wheels at the base so that they could easily be moved forward, and a row of jacks on each side were built into the foot of the structure so that when fixed roughly in position they could be levelled in place accurately for the next length. By this means, the headings being well advanced, the tunnel was carried on by enlargement on a system of break-ups which was pursued until the final junction in the centre of the hill was made in July, 1923. A picture well illustrating this method of construction will be seen on the opposite page. When the whole $2\frac{3}{4}$ miles was made safe in this way by the concrete arch and side-wall lining, the completion of the circular section was commenced from the centre of the hill and worked backwards. This consisted of putting in the concrete invert and at the same time a complete ring of blue bricks $4\frac{1}{2}$ in. thick to complete the section with an internal diameter of 10 ft. This method worked admirably and as the work proceeded backwards the complete tunnel swept out and clean was left in front of the men. It will be noticed that the side-walls of the concrete lining were left splayed so that the invert was locked in position when completed. All the tunnel junctions were accurate, and the alignment of the tunnel was within the thickness of a candle both at the centre of the hill and also when the lines were produced, a full 3 miles from the Esholt Transit Station. The greatest error in level after careful instrument work over difficult country across Idle Moor for 3 miles, including transferring the levels down the shafts and afterwards picking up the points underground at the various junctions, was $\frac{3}{8}$-inch. On completion the tunnel was watertight.

The tunnel workings passed through the lower coal measures and all sorts of experiences were met with in excavating the

ground. They went through coal seams and old workings were found in one section at the Frizinghall end which caused the Corporation considerable expense in foundations. The tunnel passed also through ironstone which was only bored with difficulty, through treacherous shales, and through many faults, one of them more than 100 feet wide consisting of mud and water. The Corporation were fortunate in not tapping the large quantities of water known to be overhead in the old abandoned stone mines on Idle Moor. Progress was entirely made by means of compressed air drills and the use of explosives. The ponies used for underground haulage by the contractors were soon abandoned owing to the danger and also because of atmospheric conditions. Electric traction was installed which made the conditions very much better. The excavation and bricklaying was let to mining sub-contractors on a piece work basis and the amount of work done was extraordinarily good and increased as the men got more used to the work. The following table shows the progress made in driving the main tunnel and putting in the arch and side walls for each of the four years or part of years during which the tunnel was under construction:—

1920	25 ft. per week.
1921	74 „ „ „
1922	93 „ „ „
1923	99 „ „ „

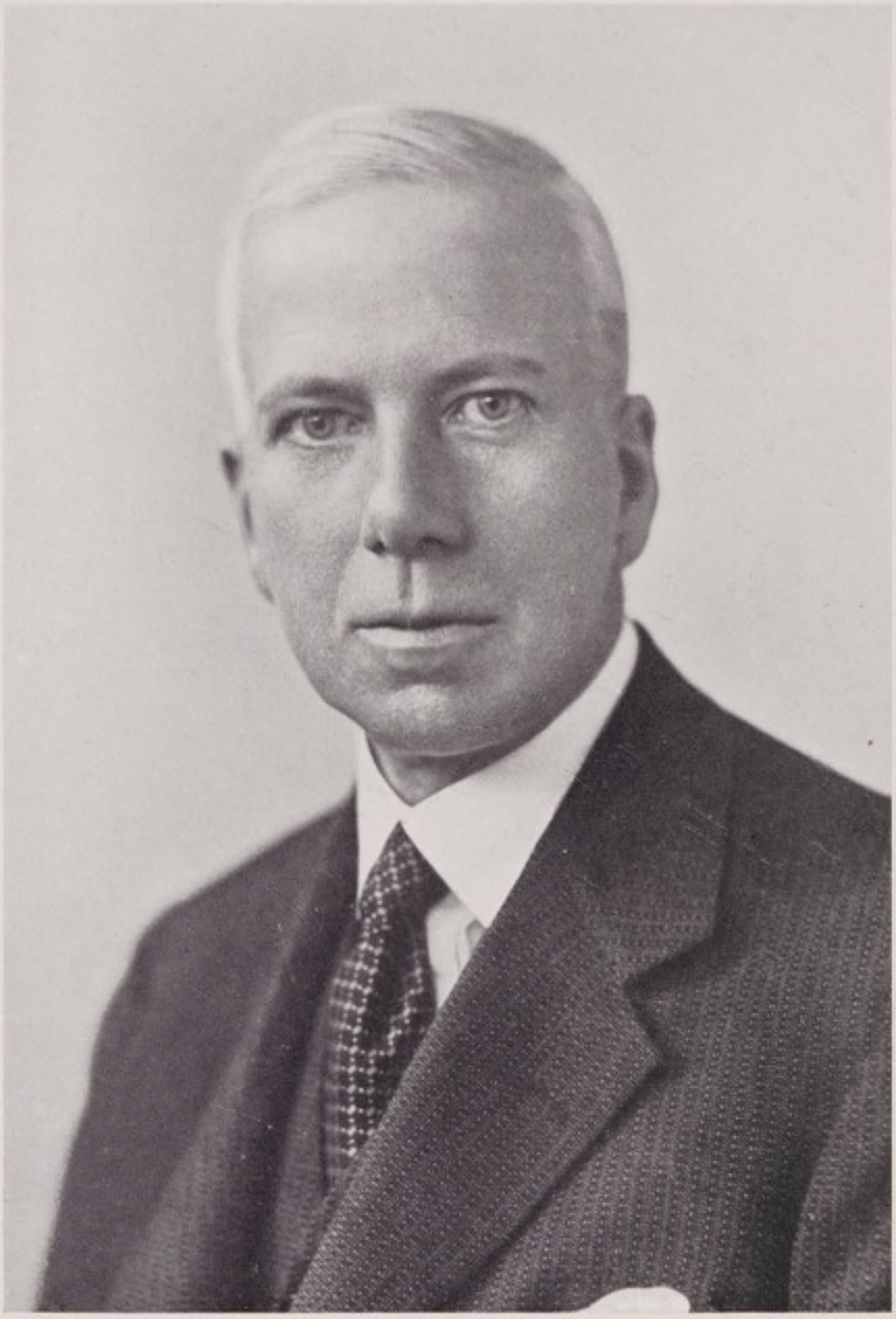
This was obtained in spite of the difficulties inseparable from the ever-growing distances to the working faces which operated against output. As instances may be mentioned (1) the traffic problem, and (2) the atmospheric conditions.

In July, 1923, the sub-contractors commenced the concrete tunnel invert and the blue brick lining and they entirely completed this work in the autumn of the year 1924. During this time, apart from the concrete, 2¼ million bricks were laid in the 4½-inch brick lining and the men laid as many as 860 bricks per man per 8 hours' shift on piecework on the complete circular section, including turning the water, cleaning down the brickwork, and all complete. When finished motor cars were driven through the tunnel for final inspection, an illustration of which may be seen on the opposite page.

Intercepting Sewer.

The intercepting sewer from the Eccleshill and Idle districts of Bradford was commenced in August, 1909, and completed in June, 1910. The sewer for a length of 2,092 yards is egg-shaped, 2 ft. 4 in. × 3 ft. 6 in. high with a gradient of 1 in 630 and has a discharging capacity of twelve million gallons per day. This section of the sewer is in tunnel for one-third of a mile. The total length is 3,000 yards, the upper end consisting of 24-in. stoneware pipe sewers together with manholes, storm water overflow chamber, and sewer connections. The alignment and levels of the tunnel were accurate.

MOTOR CARS IN FINISHED TUNNEL SEWER.



H. I. Fleming
Resident Engineer

As soon as the work of lining the main tunnel was launched in 1920–21, the Corporation had to seriously consider the question of proceeding with other important sections of the work, namely the detritus and storm water tanks on the south side of the valley and the precipitation tanks and the filters on the north side of the valley. The Minister of Health in March, 1921, urged upon the Corporation "the importance of proceeding as rapidly as practicable with the construction of the aire valley aqueduct, precipitation tanks, and bacterial filters, and of having the aqueduct, tanks, and at least 30 acres of filters constructed in time to be brought into use concurrently with the tunnel outfall sewer." Thus followed the commencement of the precipitation tanks in the year 1921, the filters in 1922, and the detritus and storm water tanks in 1923.

The construction of the storm water tanks, two of which had previously been provided to take the Eccleshill, Idle, and Greengates sewage temporarily, the detritus tanks and other works on that site were duly completed in 1926–7.

Detritus Pit and Detritus Tanks.

The detritus pit measures 55 ft. × 83 ft. 9 in., and is 11 ft. deep. The detritus tanks are two in number each 150 ft. long by 40 ft. wide and have together a capacity of one million gallons. These works are substantially built with blue brick facings.

Storm Water Tanks.

The storm water tanks are of various sizes, seven of them covering 6 acres. The average depth is 6 ft. 6 in., the walls being built of concrete finished with a blue brick coping. The sludge from the detritus tanks and from the storm water tanks pass in sealed mains under gravity to the press-house.

Precipitation Tanks.

The precipitation tanks were completed in 1926. The primary tanks are 140 ft. long by 60 ft. wide with an average depth of 7 ft. 4 in. and contain 7½ million gallons in twenty tanks and the secondary tanks are 140 ft. long by 65 ft. wide with an average depth of 10 ft. 2 in., and contain 11½ million gallons making the total volume 19 million gallons, which is rather more than a day's dry weather flow. The walls are built with blue brick facings, one row of headers to three rows of stretchers

with a concrete hearting, whilst the channel walls are of red faced with blue brickwork. The walls have been well preserved and the action of the very dilute acid has not affected the brickwork or the cement joints appreciably. The reason for this is that a greasy scum forms on the walls, acting as an excellent protection.

Bacterial Filters.

The construction of the filters is due for completion this year, (1931) being 53 acres in extent. The filters have flat concrete bottoms 6 in. thick with drainage channels formed in the concrete floor 18 in. wide and from 3 in. to 21 in. deep the fall being on the bottom of the channel itself. The channels are covered with reinforced concrete flags supported on blue bricks. The coal is 6 ft. deep and 5,000 tons is required per acre of bed, so that the stock of coal held is about 265,000 tons. The walls are of concrete and there is no blue brickwork on this site. Before the coal strike of 1926 the late Engineer had provided 6 acres of filters 10 ft. deep and another 6 acres 15 ft. deep and when the works were first started up the opportunity occurred of trying these various depths of coal under good conditions. It was found, however, with our particular type of sewage that very little benefit was experienced from the greater depth of bed, certainly not commensurate with the cost of the material and therefore the coal in these beds was sold out during the strike and replaced with coal 6 ft. deep.

Syphons Crossing Aire Valley.

The low level syphons were constructed partly in tunnel and partly in cutting whilst a portion of the pipe lines rest on piers above ground level. In passing (in tunnel) underneath the Leeds and Liverpool Canal considerable difficulty was met with as the roof of the heading was within 4 feet of the canal bottom. Special C.I. segments were designed for the work and progress was necessarily slow as it was necessary to bogee with lime each section, 2 feet in length, as the work progressed. In spite of the greatest care, the water burst in on one occasion but the men escaped. Precautions had been taken against risks of emptying the canal. Although the three syphon headings were only completed with the greatest difficulty another tunnel under the canal only 170 yards away and of 11 feet internal diameter and equally near the canal bottom,

constructed for the purpose of accommodating various pipes, was completed without any trouble, although the risk was great. Two of the pipe lines were completed in March 1926 and a third pipe line was completed in November 1929. The net cost of this section of the work totalled £41,000, against the cost of the proposed overhead aqueduct estimated to cost, before the War, £75,000, and which would certainly have cost, after the War, more than double that amount. The pipes are 4 feet in internal diameter, 700 yards long, and convey each about 30 million gallons of sewage per 24 hours. The vertical depth of the loop in the pipes is 68 feet as before stated.

Bridges.

Reference must also be made to certain River Crossings, there being four very fine bridges of 130 feet span and over. One bridge is of reinforced concrete carrying the three syphon pipe lines, two railway bridges of steel construction, and one road bridge of similar construction seen in the illustration below. Some 22 miles of 4-ft. 8½-in. gauge railway cover the works and enable material to be dumped at the necessary points.

ROAD BRIDGE ACROSS THE RIVER AIRE.

It is difficult to give details of the whole of this work but it may be said that the cost of the complete scheme is rather more than two million pounds sterling for works, and including land, about £2,350,000. This sum is largely accounted for by the increase in the cost of labour and materials in the years following the War, when, for a period, labour was three and a half times and materials from three to four times pre-war prices.

Administrative Side.

For instance the following examples of labour and materials show the comparison between pre-war prices, the peak (1920), and the present day:—

	Pre-war	Peak (Post-war)	Present Day
Labour (per hour)	7d.	259%	100%
Red Engineering Bricks (per 1000)	27/–	335%	104%
Sand (per ton)	4/1	261%	98%
Cement (per ton)	28/9	248%	49%

MAIN EFFLUENT CONDUIT DISCHARGING TO RIVER AIRE.

As the works were originally estimated to cost £955,000 and will have been completed for little more than twice the original figure in spite of the fact that the great bulk of the work was done when prices were very high, up to 1,000 men being employed in those days, it would appear to show that the works have been economically administered.

In dealing with the administrative side of the venture an enormous amount of work had to be undertaken which is not now apparent. Taking excavation alone, some 1⅓ million cubic yards had to be moved and for this purpose five steam diggers were at work, two being Ruston Hornby machines on rails with 2½ cubic yard buckets, and three of a smaller type. There were six 4-ft. 8½-in. gauge steam and one petrol locomotive in úse, and four electric and three petrol 2-ft. gauge locomotives. Also thirteen steam cranes capable of lifting 5 tons and under, with and without grabs, and nine machine concrete mixers. Altogether some £96,000 was expended on plant with which to carry out the works. The Corporation's own sandstone quarry has provided all the stone for building as well as broken stone for concrete and sand, which has been prepared in its own plant. Altogether some 300,000 tons of stone have been used in these works.

The new works, although not finished, were brought into partial use in the spring of the year 1926, this being made possible by the completion of the tunnel sewer as beforementioned. Since this time the treatment of the volume of sewage has been gradually extended to embrace the whole. As a complete new installation these works have functioned wonderfully well and in accordance with plan. The engineering details throughout, including lines and levels, have shown no appreciable errors. It should be noted that the Esholt Sewage Disposal Works have the unusual feature of being set on the hills (overlooking the Aire Valley) and therefore both the works and the control of such large volumes of water in elevated positions had to be designed with some care. All the sewage and the liquid sludge is passed from point to point by gravitation and pumps, air lifts and the like are little used and then only for subsidiary purposes. The greatest care has been taken in designing the works for economical operation.

CORPORATION VILLAGE OF ESHOLT. WORKMEN'S DWELLINGS.

The workmen are mostly accommodated on the Corporation's own estate either in Esholt village, an illustration of which appears on the opposite page, or in the houses built on the lands around. The Corporation have 146 workmen's dwellings on the estate of which 34 were built after the War.

Housing.

PRESS HOUSE CONTAINING 128 SLUDGE PRESSES.

Chapter V

THE BUSINESS SIDE OF THE UNDERTAKING

FROM the outset of sewage treatment in Bradford, it appears, efforts have been made to produce some commercial asset. Clauses were inserted in the Bradford Corporation Gas and Improvement Act, 1871 *re* the defæcation of sewage, and Clause 46 states "The Corporation may upon such terms and conditions as may be fixed by agreement with the owners or occupiers of any lands contiguous to sewage works of the Corporation supply to such owners or occupiers respectively sewage for the fertilisation of such lands."

In 1873 when the first sewage works in Bradford was completed it was handed over by the Corporation to the Peat Engineering & Sewage Filtration Co. Their idea was to strain the sewage through peat in order to purify the effluent and extract its manurial properties at one and the same time, afterwards drying the peat under cover, and recovering the cost of the process by selling the product as a manure for agricultural purposes. This, like many admirable theories, broke down utterly in practice. Various other processes were tried by companies and persons, but with no greater success. Consequently, in 1874 the Corporation took over the works and commenced treatment themselves, with some success, by means of lime and subsequent filtration.

The cost of treatment was reduced from £6,276 in 1876 to £4,000 in 1880. At this period there was little or no complaint in regard to the effluent, but from this time on, the population and trade increased to such a degree that the works were inadequate. Large quantities of lime sludge were being produced the disposal of which proved difficult. This state of things obtained until the year 1899. Experiments and remedies were tried by Companies and individuals but were either too costly or deemed unsatisfactory.

In the year 1901 the change to sulphuric acid precipitation took place. Later, in 1902, to deal with the sludge and extract

GREASE HOUSE.

the grease it contained, a French company at their own expense provided and worked a solvent plant on the system known as the "Delattre." This apparatus did not prove a commercial success.

In October 1902, the method of sludge disposal by filter pressing was put into operation. This process, including chemical precipitation with sulphuric acid still in operation to-day, was the beginning of an era of commercial enterprise. From October 1902 to the end of March 1903 grease to the value of £222 had been sold. The following year this had increased to £2,371. In the years 1908–9 a second press-house was erected doubling the number of presses to 64 which gave a subsequent increase in production and the sales had passed the £20,000 per annum mark. Prior to the War, nearly £200,000 had been obtained from the sale of grease alone. In 1912 the new press-house at Esholt was opened, having double the capacity of that at the Frizinghall Works, the presses from the latter place being transferred to the new works.

Grease Sales.

In the year 1918 the sale of grease reached the colossal figure of £126,658. This was the result of abnormal circumstances, but the sales for the three years, 1918, 1919, and 1920, contributed to relieving the rates to the extent of £81,453.

In the first twelve years of post-war period, the sales produced over half a million pounds sterling, or 2½ times as much as in the equivalent pre-war period.

The total value of grease produced has now reached £1,250,000.

At the moment (1931) the market is certainly depressed from the instability of currency, over-production, and a general lack of confidence, but unlike the ordinary manufacturer who closes down his plant, the sewage works still has to purify the sewage of the City, and treat the sludge, which means the recovery of grease in the face of unfavourable markets. The efforts of the department in trying to find new outlets, and new markets for grease in any and every part of the world, however, do not cease. Previous experience has shown that there are periods when the production of grease is much in excess of the demands and also periods when the contrary applies. When large stocks have

accumulated, experiments have been conducted to find outlets other than the usual channels. For example, during the year 1923 the recovered grease was used by the department as fuel oil for the boilers, and quantities have been sold to many firms for this purpose during coal disputes. Again, it was used on the works as fuel oil for diesel engines, this having been done on many occasions during periods of emergency. The grease has a calorific value of 17,300 B.T.U^{s}. and a flash point 313° Fahr. Although the grease is solid at ordinary temperatures and consequently cannot be quite so conveniently handled as many fuel oils without warming it, the melting point is very low and thus the grease on gentle warming readily becomes fluid, then proving an excellent fuel oil.

The recovered grease is largely composed of wool grease discharged in the effluents from the scouring of raw wool, as previously described. It also contains certain fatty acids which are liberated from the various soaps in the sewage, by acid precipitation. In addition there is also a certain amount of dark colouring matter present in a colloidal form which is also the source of the distinctive odour. Both odour and dark colour can be removed by treatment with various activated earths or carbons leaving a product very similar in appearance and smell to an ordinary wool grease.

The following is a typical analysis of the grease, the constitution of which is very constant:—

Moisture		1·0%
Mineral matter		trace
Saponifiable matter		
Free Fatty Acid	28·3%	
Neutral Grease	34·3%	62·6%
Unsaponifiable matter . . .		36·4%

The free fatty acids consist of the acids occurring naturally in wool grease with those liberated by decomposition of the waste soaps by the sulphuric acid. The neutral grease is the glycerides of various fatty acids, these being present in the wool fats. The neutral grease, with the free fatty acids is the portion of the grease capable of saponification. This is usually from 60–65%. The unsaponifiable matter consists of a small quantity of mineral oil along with the various wool waxes, e.g. cholesterol

and iso-cholesterol. The grease is usually sold for distillation, the main products of which are stearine, oleine, and pitch. The stearine is repurified and used in candle making, leather dressing, and also in the manufacture of low-grade soaps. The oleine is used principally in the woollen industry for lubrication of the wool prior to combing, carding, and spinning operations. The pitch is in great demand for use in the insulation of electric cables. It also finds use in the manufacture of black enamels.

Manure Sales.

In the year 1902, when the method of pressing the sludge after precipitation by sulphuric acid commenced, many difficulties had to be overcome. By constant experiment and attention to detail however, these difficulties were gradually dispelled, and eventually a cake was produced with about 30% of moisture but containing some 20% grease. It was thought at the time that on account of the grease the cake had little or no manurial value. The cake was tipped at Frizinghall, varying from 40 to 80 tons per day, and early in the year 1904 about 12,000 tons of cake had been disposed of in this manner. It became the cause for general complaint from people passing along the road. In consequence it was decided to instal a Wilton Patent Furnace, fitted to the Lancashire boiler. By means of this furnace a large portion of the sludge cake then being made was burnt, and a saving of coal effected.

Also in 1904, the Committee decided after much experiment to engage Dr. Grossmann to prepare plans and specifications for a process of distillation to recover the remaining grease and produce a saleable manure.

Sales of the dried sludge did fructify, amounting to approximately £30 for each of the first two years. After working for a period, this plant, not proving wholly satisfactory, was abandoned to make room for press-house extensions in 1908.

However, a start had been made in selling the dried sludge. A local firm who specialised in the degreasing of woolcomber's sud cake, commenced taking deliveries of sewage cake for the same purpose, but the quantities were only small. Compounders of artificial manures were taking small quantities of cake to grind up as a base for the more expensive chemical fertilisers. With the resulting demand for a ground sludge, a pan grinding

machine was installed. Grinding the cake was a difficult operation as the material containing both grease and moisture had a more or less plastic composition. However, it was found by exposing to the atmosphere and air drying, it could be ground more readily, and a steady increase in the demand for this powder developed. Experiments in grinding finally decided in favour of a "bar disintegrator" comprising two cages of different sizes, the smaller revolving inside the larger, the two travelling in opposite directions, as being the most practical. This type is still in use to-day.

With the advent of the new press-house at Frizinghall, and an increased production of cake, experiments were made with a "Mason's Gas Producer," burning the cake by slow combustion and making a producer gas to fire a Babcock and Wilcox boiler. Steam was raised in this manner for the sludge pressing plant for a period, but as there were considerable troubles from clinkering, firing, etc., it was abandoned.

About this time, early in the year 1908, a more insistent demand for a dried sludge led to experiments with the installation on trial of a mechanical drying machine, but this after many tests did not meet requirements.

However, in spite of the difficulties of finding a standard material, the demand was steadily increasing. In the year 1909 an order for ground sludge, packed in bags, for export to France was booked. Undoubtedly a milestone in progress when one considers the cost of freight in relation to a low grade commodity.

In 1910 a "Ruggles Cole" rotary kiln drying machine was erected at Frizinghall. Immediately an order was received for 700 tons of the "machine dried and ground cake." This was followed up by an order for a further 2,000 tons, the result being that the £1,000 mark in sales of sludge per annum, was reached. The year 1912 found the sales were more than doubled, £2,259 being realised. Efforts were being made at this time to find further outlets, and two Ovoid Briquetting machines were put into operation at Esholt. The briquettes were about the size of small soap tablets, and were used as boiler fuel on the chain grate stokers in conjunction with coal. In December 1913 an order was booked for 10,000 tons of the briquetted sludge.

Sales were now increasing year by year. The year ending March 1915 produced sales of £3,825, being a five-fold increase in five years. The War period was responsible for the disposal of the rotary kiln dryer, also the Briquette machines, but the substitution of natural drying in the open air did not cause any diminution in the demand for the material. For the years 1918 and 1919 the tonnage sold exceeded the production by a value of £10,000 per annum. The year 1921 realised no less than £13,655, the highest figure obtained in one year, this exceptional demand it should be stated being largely due to the shortage of artificial chemical manures following the War, and the high prices obtaining at this period. The years 1920–30 were noteworthy, although a period of falling prices and abundant supplies of chemical manures, for a fairly constant demand, and almost the whole production has been regularly sold, realising £40,000. The material unsuitable for manure, of which there is only a small quantity, is being ground into powder, mixed with the coal, and used for stoking the boilers at Esholt, thereby creating a saving in the cost of fuel.

During the post-war years no opportunity has been wasted of further extending the scope of the usefulness of the manure, or increasing the area of distribution. Indeed, many thousands of tons of the cake have been shipped to France in recent years. Experiments have been carried out in compounding with the more expensive chemical manures, and a consignment was bagged and shipped to the United States of America, overcoming most stringent regulations *re* the importation of fertilisers into the States. This was carried through in spite of the heavy freight rates obtaining. Indeed, the greatest difficulty of the department has been the heavy railway rates, unduly heavy in respect of this class of material, the carriage being much the greater part of the cost to the farmer and market gardener. Much effort has been spent with the railway authorities, endeavouring to obtain specially reduced rates, compatible with the value of the material. Undoubtedly the farmers would welcome the material and no doubt all the supply could be disposed of to better advantage to the department if the railway rates were lowered to a level commensurate with the real value. In spite of exceptional difficulties, the total sales of manure have realised £108,352, which represents an average income of about £4,000 per annum over nearly 30 years.

A typical analysis of Bradford Sewage Manure is as follows:—

Moisture	14·6%

Data on dry solids:—

Mineral matter	53·7%
Organic matter (Humus)	46·3%
Total nitrogen (equals Ammonia 3·05%)	2·51%
Phosphates (P_2O_5)	0·30%
Potash	trace

The total value of the grease and manure produced since the process of sludge pressing was adopted in October 1902 amounts to the figure of £1,358,000, and from a sewage which was considered almost untreatable at one time.

Some idea of the income derived from the sales of the bye-products having been given, it is natural that one should turn immediately to the cost of their production.

Costs of Production. In the first instance, the most important expenditure is in regard to the precipitant. At the outset, experiments were carried out with various chemicals. Originally lime only was used, then lime and copperas, afterwards ferric-sulphate, but these not only added to the quantity of sludge produced, but were unsuitable for the extraction of grease. Eventually sulphuric acid was used solely, successfully neutralising the alkali and releasing the grease.

In the year 1905 efforts were made to reduce the cost by almost 50%, it was thought, by the use of sulphurous acid. An experimental SO_2 plant, or in reality furnaces roasting spent-oxide (a bye-product of the Gasworks) was used for the production of gas, which in contact with the water formed sulphurous acid. The experiment was tried on a large scale, and at one period was thought would prove satisfactory. Certainly it would have been much cheaper as it would have obviated the installation and upkeep of the large leaden chambers, and the supply of nitric oxide which contributes so largely to the cost of oxidising sulphur dioxide to the trioxide in the manufacture of sulphuric acid. Time proved that the use of sulphurous acid was not wholly successful and it was necessary to revert to sulphuric acid.

The difficulty of buying large quantities of sulphuric acid at sufficiently cheap rates meant that competition had to be

created amongst the acid manufacturers of the North of England. Indeed, Bradford-made acid was so high in price that the department purchased the bulk of their requirements from Lancashire. Even then the cost was so heavy that it was proposed as an integral part of the original scheme of the new Esholt sewage works to include a self-contained plant to manufacture the acid on the site. Largely owing to the prosperity of the wool trade in pre-war days, the amount of acid used was a gradually increasing quantity year by year. At the same time this increasing demand also shows an annual hardening tendency as regards cost.

In 1906 short of 6,000 tons were required at an average price of 25/7 per ton.

In 1908 nearly 8,000 tons were required at 28/4 average per ton.

In 1913 nearly 10,000 tons at 31/8 average per ton.

In 1914 requirements had increased to 11,124 tons at 34/7 average price per ton.

During the war, difficulty was experienced in obtaining supplies. Eventually large quantities of nitre cake and waste acid from munition works had to be used, acid being unobtainable. It was not until the year ending 1922 that the consumption and supplies of acid approached the tonnage of the year 1914, being 10,974. An enormous increase in the consumption took place in the year 1923, being 20,008 tons or almost double the preceding year. The following year 20,240 tons were consumed, and 18,876 tons in the year 1925.

One of the reasons for this enormous rise was due to certain woolcombers discharging their untreated suds into the sewers. This matter was subsequently the subject of an action in the Chancery Division where the Corporation obtained an Injunction restraining defendants from discharging to the city's sewers trade wastes which, by the Corporation's local Act of 1897, were expressly forbidden if by reason of the nature of the liquor it could be held to "interfere with the treatment and utilisation of sewage." At this period the total cost of acid was in the neighbourhood of £60,000 per annum. The price of acid was being controlled by an association of the acid manufacturers;

this, coupled with increased transport costs entirely eliminated other than local supplies. With the opening of the new precipitation tanks at Esholt, additional costs of transport were added to the cost of acid and also by reason that *all* the sewage, which in times of storm is increased to three times the volume, had to be treated at the new works, it was apparent that a cheap acid supply on the site was essential. The Ministry of Health sanctioned the construction of a Sulphuric Acid Plant on the 30th August, 1926. The plant was started up in February 1928. This plant, although not capable of producing the whole of the Department's requirements, proved its worth in the first year by being one of the factors in reducing the cost of acid from £46,522 in the year 1928 to £37,219 in the year 1929, and up to the present has been the means of maintaining the reduced average purchasing price per ton.

The treatment and disposal of the wet sludge after precipitation is naturally a costly process in consequence of the amount to be dealt with daily. The main items of expenditure are filter cloths and fuel. Filter cloths of various materials have been tried from time to time with a view to economy, e.g., hemp, jute, cotton, asbestos, flax, etc. It has been found, however, that up to the present, cotton is the best material when all factors are taken into consideration, i.e., life, cost, and rate of filtration. A cotton cloth usually lasts for about 6 weeks of continuous filtration, and about six cloths are used in the production of 1 ton of grease. These cloths were purchased at from 2/2 to 2/5 each in pre-war days. The cost was doubled in the year 1924, yet at the moment we are able to contract at below pre-war prices. The number of cloths used, approximate 35,000 to 40,000 per annum.

Fuel has already been referred to in dealing with the sales of manure. The Committee has been in a favoured position in the purchase of fuel, advantage having been taken of purchasing in conjunction with coal supplies for the artificial filters. Seven to eight thousand tons of coal are used per annum in the boilers.

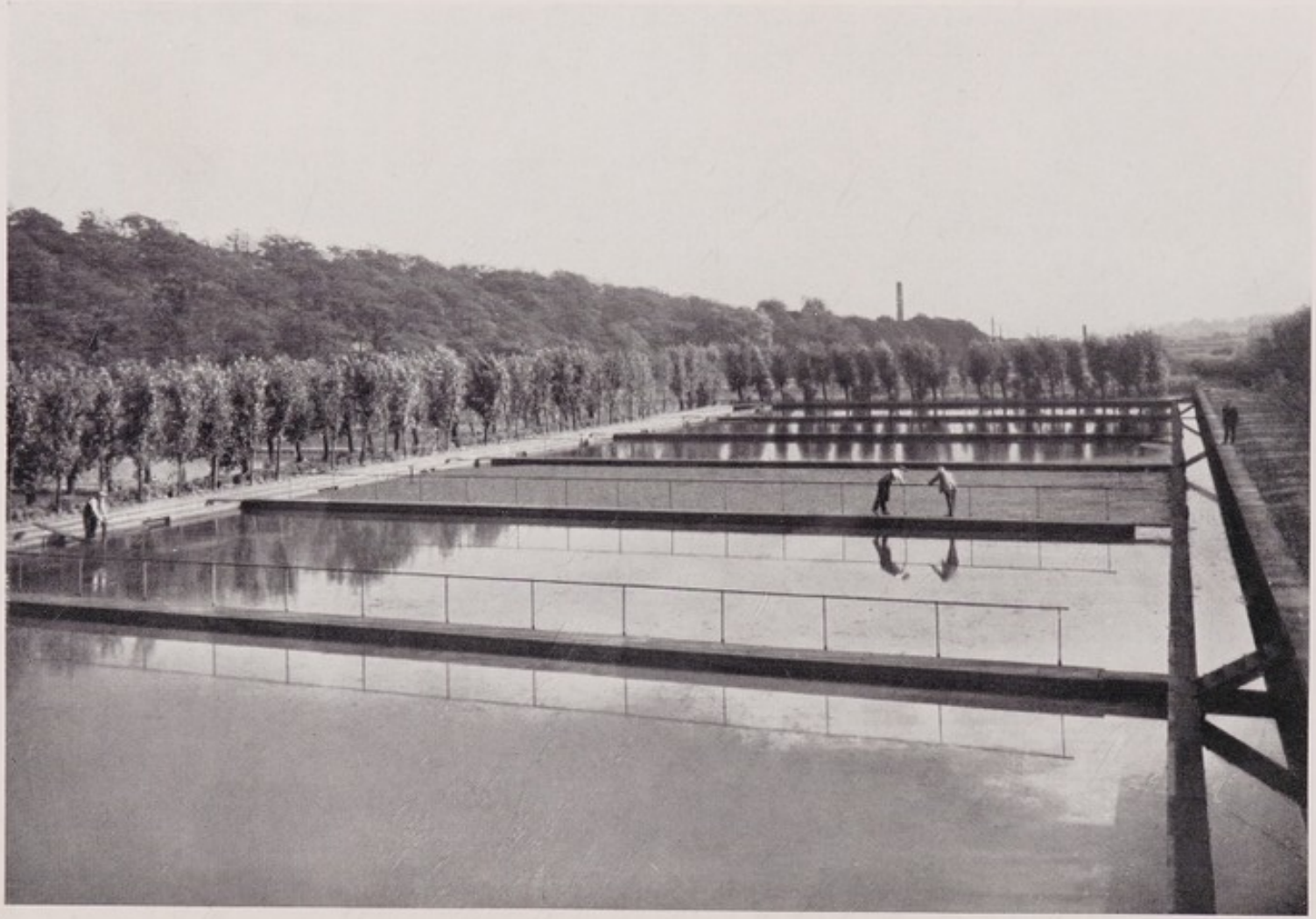
Although the cost of sludge disposal and pressing is at present in the neighbourhood of £35,000 per annum, and has been as high as £65,700, it is a matter of no small wonder to realise that costly as the precipitants and process of sludge disposal

are, yet the whole of this expenditure is more than covered by the sales and recovery of grease and manure.

However, the revenue from sales of grease and manure does not altogether cover the cost of the whole treatment as there are in addition to sludge disposal, expenses for filtration, management, rates and taxes, sidings maintenance, general repairs, etc. etc. Indeed, upon examination of the net costs of treatment since the year 1903 when the cost was nearly £12,000 for the partial treatment then possible, it is really surprising to find there was actually an income in excess of expenditure for the seven years 1910, 1911, and 1916 to 1920, in spite of a gradual increase in treatment as the process and construction of the works developed. On the other hand, following the War period, the net expenditure increased to £120,000 in the year 1921 and the following year reached the highest point of nearly £140,000. With the fall in the cost of various commodities these costs were reduced by approximately 50%. The year 1926 saw the consolidation of the process at the newly constructed works at Esholt. Whilst there was intensification of the treatment and a larger volume of sewage actually dealt with, many economies were possible, and the cost was again reduced by more than a third. The new works even in the face of trade depression that has become worse each year, have been conspicuous by an annual decrease in the cost of treatment, so that the present net cost is only a little more than twice that of the year 1903.

The construction of the new works has been responsible for a very heavy capital outlay. The repayment of the loans is a heavy burden that has to be faced.

In the year 1903 the interest and sinking fund payments were approximately £10,000, or less than the cost of treatment. This figure has increased annually; the year 1908 saw the payments pass the £20,000 mark, but not till the year 1921 did it pass £30,000 per annum. Then it went up by leaps and bounds as the construction of the works developed. By 1926 it was nearly £100,000. In 1929 it had reached £130,000 per annum. At the present moment the annual cost is about 5 times the net cost of treatment. This expenditure has no doubt reached the high water mark, which it is hoped in the near future will be considerably reduced.



NORTH BIERLEY SEPTIC TANKS.

Chapter VI

NORTH BIERLEY SEWAGE WORKS

THESE works deal with the sewage of that side of the City which naturally drains to the river Calder. The area draining to these works is 3,532 acres with a population of 23,500. The dry weather flow of sewage is 1¼ million gallons, which is equal to 53 gallons per head per day of the population served. Whilst the sewage is largely domestic in origin it contains some wool-washing wastes with a good deal of soapy liquor from cloth scouring processes and a fairly large volume of dye liquor.

At these works the old-fashioned, but in this case very effective septic treatment is used the liquor afterwards being treated on percolating filters. The sewage arrives at the works by way of a 3 ft. × 2 ft. egg-shaped sewer and passes first through a detritus tank measuring 60 ft. × 9 ft. × 7 ft. with a capacity of 23,600 gallons. The detritus is regularly grabbed and deposited on to a tip. The sewage is then screened through a self-cleansing perforated screen worked by an under-shot water-wheel in the flow of sewage and passes forward through a balancing and mixing tank of 117,000 gallons capacity. The septic tanks are arranged in a battery of six, the sewage flowing from one to another and finally away to the percolating filters. The tanks are each 89 ft. long × 45 ft. wide × 6 ft. deep and have a capacity of 900,000 gallons. The storm water is allowed to flow to a storm-water filter. The bacterial filters cover an area of six acres and the tank effluent is distributed over the area of the beds by means of fixed spray jets, the alternate rows of which are given working and resting periods of one hour. The filter media is quite novel in the case of these works, being the shale removed as residue from the local coal mines. This shale has no market value. So effective has the filter media been, that no humus tanks have been constructed or considered necessary, although the works have been in existence for many years. The filters have no concrete walls

NORTH BIERLEY BACTERIAL FILTERS.

or bottoms and the under-drains are few and far between. The effluent discharges into a small clean stream and although in the summer months the volume of effluent is greater than the stream, the quality is never questioned. At these works the sludge disposal problem is only of small importance as so little is removed in the process, since only two of the six tanks are emptied every twelve months. The sludge is put into sludge lagoons and allowed to dry, there being no accumulation as the farmers in the neighbourhood remove it quickly, they themselves digging it off and loading it into carts at their own expense. These works, although by many considered out of date, continue to do their work as efficiently as they have done for the last thirty years. The works have no outstanding debt and the cost of treatment is extremely low, being under £3-10-0 per million gallons of sewage treated. The total area of the works is 22 acres.

There is a tendency for building work on this side of the City to grow and it may be necessary shortly to increase the area of the filters to comply with modern requirements.

ESHOLT HALL, THE OFFICES OF THE DEPARTMENT.

Chapter VII

HISTORY OF THE ESHOLT ESTATE

THE estate of Esholt possesses no little historic interest. The name of the place implies "Ashwood," and that name in itself curiously links the past with the present. Ash trees are not very common upon the Coal Measure rocks which prevail in Mid-Airedale. The native woodland, the primeval jungle which clothed the hillsides of Aire and its tributaries before mân cut into them a multitude of "royds," was of oak. Ash trees flourish only upon soil well supplied with lime, and if such trees were in this little bend of the Aire valley so numerous as to attract the special notice of the early settlers, we may find the reason in the circumstance that in the Great Ice Age a glacier from the mountains at the head of Airedale brought down from the Craven crags by Settle abundant limestone debris. In the river valley itself few limestone boulders remain. For centuries they were collected and burnt for lime for building and for the fertilisation of peaty land, but in the Boulder Clay which lies up on the northern flank tracing the line of the lateral moraine of the glacier, there is still much limestone, and ash trees find the conditions suitable, so that the Esholt woods have many fine specimens.

Esholt is not mentioned by name in that first and greatest of national records, Domesday Book, the taxing assessment made by William the Conqueror's orders in 1086. But there were in the wide manor of Otley two different subordinate manors (berewicks) both called "Hawksworth." One of these, it is fairly evident, must have been really Esholt. But Domesday tells us much of interest relative to the locality. The estate which the Bradford Corporation now own extends far beyond the border of the township of Esholt into Hawksworth (proper), Guiseley, Yeadon, Baildon, and Rawdon. All those places, except Rawdon, lay in the lordship of the Archbishop of York, and their dues had before the Conquest contributed to the

upkeep of the splendour and the civilising influence of the Northumbrian see. But at the dread coming of William the Conqueror to wreak vengeance upon the inhabitants of this hill-country for their fierce opposition to his arms the district had been utterly devastated. In the eighteen years which had elapsed between William's awful campaign in Yorkshire and the Domesday survey, a few poor farmers and their labourers had crept back to their ruined homesteads and had rebuilt them, but most of the locality still lay desolate. It was indeed the very limit of cultivation, for the Sheriff of Yorkshire did not, when the survey was drawn up, discover a living soul from Bradford to the mountains.

Rawdon had perhaps even more interesting ownership than that of the Archbishop, for it was the property of Robert Bruce, to adopt the modern spelling, the ancestor of his famous namesake, the unfortunate King of Scotland, whose constancy in a struggle against a sea of troubles has been the admiration of ages. It is curious to link up great romantic figures like the Bruces with this busy industrial district, and to look upon them as a Yorkshire family. But so they were before Scotland knew them, for they had their castle at Skelton, to the north of Whitby, and the old priory at Guisborough which they founded, and the abbeys of St. Mary at York and Whitby, to the riches of which they largely contributed, testify to their local patriotism and devotion. Airedale must, consequently, have shared with Cleveland a curious interest in the scraps of news which came through of the great doings in Scotland in the early fourteenth century.

Esholt itself comes into history under that name in 1172, when Sir Simon Warde, of Guiseley, gave some of his land beside the Aire to the Syningthwaite Priory, a little Cistercian nunnery which had been founded a dozen years or so earlier in the fertile plain between Wetherby and York. The Wardes seem to have been a family of some interest, but in early days of no great wealth locally. They were good friends, however, to the Cistercians, then establishing their hold of the Yorkshire Dales, and they gave many gifts to Fountains Abbey and some to Kirkstall Abbey.

How long the Syningthwaite nuns retained their Esholt interest and how they lost it no one knows, but just before

Richard I ("Richard Yea and Nay") commenced his erratic course through Europe a nunnery at Esholt is found in existence. One, Galfred Haget, of whom there is nothing to say, and the Wardes were honoured as founders. The early interest of the latter family was continued thenceforth. As successive generations of Wardes grew in wealth they gave rich gifts to the little nunnery, and several members of the family directed that they should be buried there, and one at least of the prioresses bore the name of Warde.

A Cistercian Nunnery.

After its establishment the little convent enjoyed for three and a half centuries the happiness which is asserted to belong to the community without history. Nearly all we know of its affairs consists of the names of a few of those who proved themselves benefactors, and a hardly less imperfect list of the prioresses who ruled within the walls of the little establishment. The stirring events of the times passed this little retreat by. But some ripples must have been raised in the pool in passing. The place was the refuge for, among the others, the daughters of a good many of the important local families, viz. the Wardes, Calverleys, Chellerys, Woodhalls, Pudseys, Plumptons, and, austere as was the Cistercian rule the nuns cannot have gone unmoved when brothers and cousins lost their estates in the Magna Charta campaign of the Barons against King John, as did the Wardes temporarily, or were captured or fell fighting at Bannockburn or Flodden.

The Cistercians were no literary order. They wrote no chronicles, and took no care to transcribe and preserve the ancient classics. But they were splendid farmers, and their great abbeys of Fountains, Kirkstall, and Rievaulx, gave to Yorkshire a farming tone which it has never lost. The nuns of Esholt took their share in this agricultural work as supervisors and directors of their retinue of servants, and among the few documents which have survived is a bundle of farmers' and foresters' accounts in the Public Record Office, which shows with how much care, a care excelling that of most modern farmers, the bailiffs accounted for their receipts and payments and the foresters recorded the dates of their various plantings. There is some hint, however, that Esholt suffered the decay which overcame monasticism generally in the fifteenth century. It

probably had at the height of its prosperity eighteen nuns, that being the number of the nuns' stalls in the church, but it had only six when Henry VIII's commissioners travelled here to demand and receive the surrender of the little community of their home and property, and to dissolve the house.

We get a glimpse of the convent as it stood in its latter days through a description made by a surveyor of the Exchequer immediately after the Suppression. The writer was interested only in recording the saleable building materials, such as lead, timber, stone, and slate. He cared nothing for archæology, and it was somebody else's business to take account of the plate, valuable reliquaries, and so forth, so that the description does not answer all the questions one would like to have settled. But through all the confusion of this description we get hints which enable us to form a pretty clear conception of the little house. Let us start with its situation:—

> "Item the seid monastery is sett vpon a Ryuer callid Heyer. And she is lady of the same water vpon bothe sydes, that is to sey by the space of iij quarters of a myle vpon the north syde and half a mile vpon the southe syde. And ther is ouer that Ryuer a ffayre brigge, which the lady must maynteyn in reparacon.
>
> "Item she may fishe in the said Ryuer at her pleasure from the lorship of West Essholt vnto Apperley Brigge, which is by the space of half a myle or more."

The Convent Buildings.

The conventual buildings themselves evidently followed generally the ordinary Cistercian plan, but the smallness of the house involved a reduction of the number of apartments usual in larger houses like Kirkstall. The church was quite small, being but 72 feet long and 18 feet broad. It was divided into two equal parts by a rood loft. The choir contained eighteen stalls for the nuns, and the nave beyond the rood, which was allotted to the servants of the convent, was also provided with seats, a somewhat rare furnishing. The window above the High Altar was of three lights with "viij other partes of glass aboue," from which we may infer that it was of Geometrical or Decorated design. This may possibly indicate the rebuilding of the choir in the fourteenth century, since the other windows

of the choir were also of three lights each. The nave was lighted only by six little windows each 2 feet in height and half a foot broad, proportions which suggest the Early English style, so that the nave probably belonged to the original building. We are not told whether the church had aisles, possibly not, nor whether it had transepts, which is probable. Upon the church was a "stepulle of litle thack bordes couer'yd with slate." This must have been a bell turret such as was once common, but to find an existing example of which we must go to Hubberholme Church in Wharfedale.

From the church one passes to the cloister, in the eastern walk of which was the chapter house, the business council chamber of the little community. This was a room 15 feet square. Next to it was a little chamber the purpose of which is not known though in some big abbeys it is supposed to have been used as a mortuary-chapel. Then came a passage-way to the eastward. This led out into the orchard, for there was not at Esholt such a suite of infirmary buildings as occupies the ground eastward of the cloister court of Kirkstall and Fountains. These two apartments and passage being all that touched the eastern wing of the cloister, there must have been plenty of room for the existence of a south transept.

Over this eastern range of rooms was, of course, the dormitory of the nuns, which was 15 feet broad, and 40 feet long. It did not retain its primitive simplicity, but had been divided into seven cells. At the south end of the dorter were three little rooms "callid the ladyes parlers." Two of these rooms had fireplaces and all had windows looking across the river to the wooded hills of Idle and Thackley, a very fair prospect. One of the parlours had a "litle kychyn," so that this may have been used for the eating of flesh meat on the occasions when, through ill-health, a nun was permitted to add to her diet meat, a luxury not admitted to the monastic kitchen proper. These comfortable apartments would obviously belong to a period when the austerity of the rule was becoming a little relaxed, and they would undoubtedly utilise the space saved in the dormitory when the number of nuns was reduced.

In the south walk of the cloister, and at the eastern corner was the door of the great parlour, the one room in the building which in early severe days had a fire in the winter, and in which

was relaxed the rule of absolute silence prevailing elsewhere. This room had a "ffayr chimney of stone" 6 feet wide. Looking into the orchard was a bay-window "glasid." Next in the south aisle was the refectory, the "hall" as it is called here, a building of 35 feet × 20 feet. This stood with its long axis north and south, as at Fountains and Rievaulx. On the west side towards the north end was a "fayre bay window" with an upright window above it. Within this bay window doubtless stood the pulpit from which during meals a book was read to the diners, according to the custom of the Order. The bay window may be compared with those at Rievaulx and Fountains. On the opposite side of the room was a large wood and plaster fireplace.

The pantry and buttery seem to have been at the south end of this hall with the customary screens fitted with two sliding doors and one "shutting door." Close by was a "kychyn of the olde ffasshyon" with a louvre roof. Those who have seen the kitchen of Glastonbury Abbey will recognise the "old fashion," the custom of the Benedictines, for the position of the kitchen usual with the Cistercians, adjoining the south walk of the cloister, was at Esholt impossible because of the smallness of the cloister court. In this detached kitchen which may have been octagonal, was a fire-range 12 feet in width, very ample proportions, and two "fair ovens," in one of which could be baked two stones of bread, and in the other one stone. Adjoining the south end of the "hall" was a pantry (for the bread), a buttery (for the drink), a larder, a malt-house, and a brew-house.

There was also an "old hall" occupied in the latter days of the convent, by a man and his wife who were in effect lodgers, the right of food and lodging having been conferred upon them either by the patron of the house, or by the nuns as a benevolence or for payment. To purchase of a convent such a "corrody" as that right was called, was a favourite way of providing a refuge for old age.

On the west side of the cloister were a wood-house, a coal-house, a garner, and three "fair chambers" probably used as workshops, for the convent was self-supporting in everything, even spinning and weaving its own habit cloths. Over this range was the dormitory for the servants, who would probably be twice as numerous as the nuns.

Outside this compact little block of buildings was a yard, and beyond it a considerable range of farm-buildings, a lime-kiln, and a mill. There was also a "gate howse over the gate, wherein there ys a prati lodgynge." The imagination will seek aid in picturing the place from the gatehouse of Kirklees, famous in tradition as the place of the death of Robin Hood, and the comparison will be appropriate, for the Esholt gateway, like that at Kirklees, had a lower storey of stone and the upper storey half-timbered in panels. A good many of the other subsidiary buildings at Esholt were also in this manner of building.

It has been inferred that the place suffered abject poverty, the recorded income in money at the Dissolution being only £35 18s. 11d. a year. But this must have been equal to at least £1,500 or £1,600 of the money of our time, and it has to be remembered that nearly all the needs of the place could be met by the products of the farm-lands and the river.

A Soldier's Home.

After the Dissolution the place lay for some years ruined and deserted. Then the site was granted to one of the officials of the royal court, one Henry Thompson, gen d'armes to the King. Thompson had displayed considerable gallantry at the siege of Boulogne in 1544. For this he was rewarded with the confiscated property of an ancient hospital, the Maison Dieu in Dover. In the last months of the King's life an arrangement was made for an exchange by which the Dover hospital reverted to the Crown and Thompson took the lands of the nunnery at Esholt. Airedale thenceforward became his residence. Possibly for a time his family continued to reside in the monastic buildings. There are in the cellars of the existing hall considerable portions of the outer walls and windows of a building which, though it has been supposed to have been a part of the priory, cannot, judging from the debased character of the architecture, date farther back than about 1600, and this probably formed a part of the Thompsons' home.

For about 150 years the estate remained in the ownership of the Thompsons, but it passed through vicissitudes during the ownership of a grandson and namesake of the first grantee. One of his servants drew his sword in a street quarrel in York and struck "one Mr. Blackiston unto the brains, so that he was

hardly saved alive." Some sort of "employer's liability" seems to have been proved, and Thompson was ordered to pay £1,000. To evade payment he made his estate over to his father-in-law, Walter Stanhope, of Horsforth, and disappeared into Cumberland, but when in some legal way not quite clear the verdict was set aside, Thompson was "sore put to it to get his estate again from Stanhope, and was not quite loosed till later end of Mr. Calverley's time, after Stanhopes had gotten vast sums out of it." This at least is one gossip's account of the matter.

This Henry Thompson left his estate to an only daughter, Frances, who married Walter Calverley, of Calverley, and it was their son Walter who erected the existing hall. A very interesting Memorandum Book kept by the latter Walter, and now in the British Museum, was edited by Mr. Samuel Margerison some years ago for the Surtees Society. This gives us much interesting material for a picture of the local life of the early eighteenth century. In 1700 Walter's mother, then a widow, made the property over to him, and in 1706, when Walter was 33 years of age, he set about building a new hall on the site of the nunnery. The old buildings had been much lower than the existing ground level and had apparently been subject to floods. The level was consequently raised very considerably, a circumstance which would probably account for the fact that so few relics of the nunnery have been turned up in the gardens, and encourages the expectation that considerable remains lie awaiting some day the spade of the antiquarian excavator, beneath the lawns and shrubberies. It is interesting to notice that Walter Calverley did not engage the services of an architect, a profession then growing into general recognition, but followed the medieval plan of committing the work of his new house to a "chief mason," who in this case was one Joseph Pape, of Farnley. The Renaissance style, which was only just then in West Yorkshire overcoming the traditional debased Gothic, was followed.

The Erection of the Hall.

In the first week of May, 1706, the foundations of the new house were laid, and a few weeks later Walter, as his note-book shows, "went towards Newcastle" with the task of seeking the hand of Mistress Julia Blackett, the eldest daughter of the late Sir William Blackett, Bart., of Wallington, Northumberland, a

wealthy benefactor of the borough of Newcastle. The note-book gives us curious details of the "labyrinth of difficultyes" which beset the matrimonial arrangements, arising partly out of "my lady's [Blackett's] greatness and magnificence," but mainly out of questions of settlement. In the following January the marriage took place, but it was not till September, 1707, that Walter Calverley made entertainment to "all the neighbouring gentlemen and their ladyes" and two days later to "my tenants and neighbours and wives" "upon the account of my wife's coming to Esholt." So that probably that date marks the completion of the house.

Thoresby, the Leeds antiquary and historian, came over to Esholt, or, as it was then called, "New Calverley," in September, 1711, and noted in his diary "the noble and beautiful house lately erected, to which Mr. Walter Calverley is adding gardens and waterworks, etc." Thoresby, of course, searched for relics of the monastery but was too late. "He could hear of none save Elizabeth Pudsey, the last prioress." A stone bearing that lady's name and some insignia still exists and is built into the wall of the laundry at the back of the hall. Towards the end of that same year 1711, Walter Calverley was made a baronet. For the rest his memoranda are mainly records of hospitality offered at Esholt to the great folk of the time, Ferdinando Lord Halifax (in the old building), Dr. Richard Richardson, the botanist and antiquary of Bierley Hall, Dr. Sharp, Archbishop of York, the heads of the families of Fawkes, Arthington, Dyneley, Hawkesworth, and others.

The only stirring passage in the history was the visit in disguise of Sir William Blackett, brother of Lady Calverley, in 1715. It was the time of the Jacobite rising, and the incident shows us the difficulties of the times. Sir William was "pursued by Mr. Forster and a great many Northumberland gentlemen who were then in arms against King George," readers of Sir Walter Besant's "Dorothy Forster" will remember the part which the Forsters played in this trouble. Their design was to force Sir William to join them, but "he was as much pursued by the King's forces, who suspected him to be in the rebels' interest." "He told me," says Sir William Calverley, "he was no ways concerned nor under any obligations to them, but was not willing to be taken for fear of being committed to prison." Calverley

too, seems to have been suspected of Jacobite tendencies, for on one or two occasions he was pointedly challenged to drink "A confusion to the Pretender, and all his adherents, and to all his open and secret friends," and on one occasion Esholt Hall was searched by the King's officers. It was unsafe ground, and Sir William Blackett was hurried off to security in London in the disguise of a countryman. He tramped across to Wyke, but was so tired when he got there that he bought a horse and took the risk such a possession carried with it.

The Blackett interests in Northumberland, which came by the marriage of Sir Walter into the Calverley family, so greatly exceeded in importance the Airedale interest that the son of the diarist became wholly a Northumbrian. He adopted his mother's surname and even sold his Yorkshire estates. The Calverley properties, including the ancient home of the family which had been the scene of the terrible happenings of the pseudo-Shakespearian drama "A Yorkshire Tragedy," were sold to Thomas Thornhill, of Fixby, near Huddersfield.

Purchase by the Stansfields.

For the Esholt estate he found, in 1755, a purchaser in Mr. Robert Stansfield, the youthful son and heir of a then very well-known and lately deceased Bradford drysalter, who for some years had been a keen competitor of Sir Walter Calverley in the acquisition of Idle and Thackley properties coming into the market. Robert Stansfield had previously been the owner of the Paper Hall, in High Street, Barkerend, but this he sold upon entering upon the more imposing home at Esholt. He died without issue, and the Esholt estate passed to a sister Anne, wife of William Rookes, of Royds Hall, and from them to a daughter Anna Maria, who married Joshua Crompton, of Derby. Their son, William Rookes Crompton, took the surname of Stansfield, but he had no children and at his death in 1871 it passed to a nephew, General William Henry Crompton Stansfield, whose daughters were the vendors of the estate to the Corporation.

It is rarely that a century-and-a-half of the history of a great landed estate sees so many descents by the female line. The circumstances are peculiarly interesting because of the old superstition, recorded by the antiquary Spelman, that the possessors of the properties of the dissolved monasteries were

commonly "cursed" by the failure to continue their family through the male line. It is a superstition which has not sustained statistical examination, but such a line of descent as that shown by the lands of the Esholt nunnery is the sort of case to make the lover of the old fables fancy "there may be something in it after all." At all events, it may be hoped that the "curse" will not continue to operate in the case of the present owners, the citizens of Bradford.

The fine old oak staircase and the oak panelling "carved by a master hand" which were formerly in the hall are said to be now at Barrowby, Kirkby Overblow.

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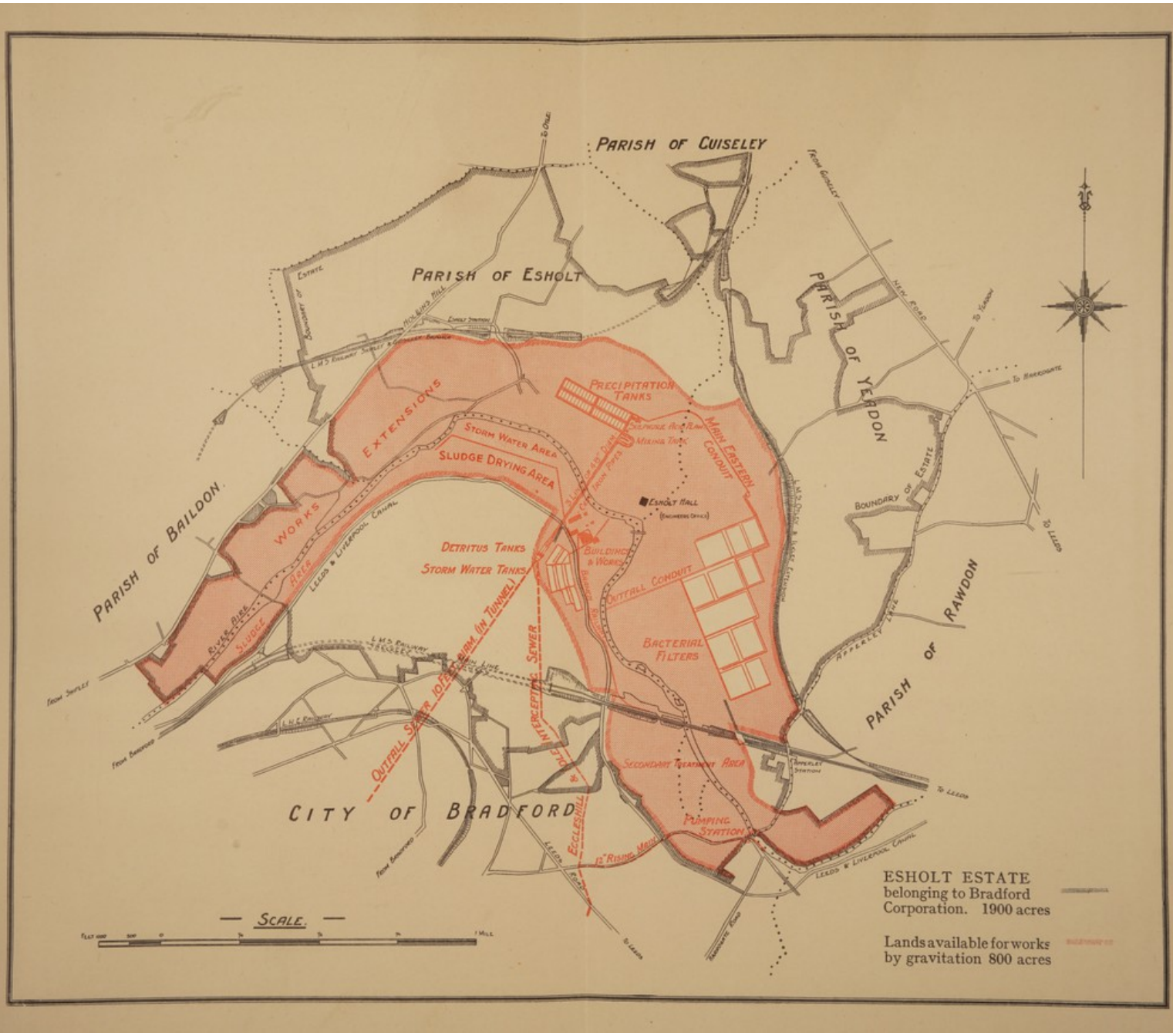
PARISH OF CUISELEY
PARISH OF ESHOLT
PARISH OF BAILDON
PARISH OF YEADON
PARISH OF RAWDON
CITY OF BRADFORD
EXTENSIONS
WORKS AREA
PRECIPITATION TANKS
STORM WATER AREA
SLUDGE DRYING AREA
MAIN EASTERN CONDUIT
ESHOLT HALL
(ENGINEERS OFFICE)
BUILDING & WORKS
DETRITUS TANKS
STORM WATER TANKS
OUTFALL CONDUIT
BACTERIAL FILTERS
OUTFALL SEWER 10FT. DIAM. (IN TUNNEL)
INTERCEPTING SEWER
ECCLESHILL
12" RISING MAIN
SECONDARY TREATMENT AREA
PUMPING STATION
BOUNDARY OF ESTATE
RIVER AIRE
SLUDGE
LEEDS & LIVERPOOL CANAL
— SCALE. —
ESHOLT ESTATE
belonging to Bradford
Corporation. 1900 acres
Lands available for works
by gravitation 800 acres

CITY OF BRADFORD. — ESHOLT SEWAGE WORKS.

Drawing No 653C

Plan and Section of Outfall Sewer from Frizinghall to Esholt.