PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Public Health Engineering in the External Environment: Water Supply and Re-Use, Waste Disposal and Pollution Control

D. G. M. Roberts

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Public health engineering in the external environment: water supply and re-use, waste disposal and pollution control

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INTRODUCTION

Healthy living conditions require pure and adequate supplies of air and water, the satisfactory and hygienic disposal of solid liquid and gaseous wastes, and the control of all forms of pollution.

Public Health Engineering, or Environmental Health Engineering as it is sometimes called, comprises the construction and operation of the works needed to maintain such conditions.

Whether we be dealing with the supply of water, the disposal of garbage, or the suppression of noise or smoke, a combination of internal and external works is almost invariably needed to obtain the required results, and I think this paper will be found to be very largely complementary to the other papers heard today.

The principal public health engineering services inside buildings include water storage and distribution systems, sanitary installations, space-heating systems, air-conditioning installations, and refuse-collection systems.

The major external works include schemes for the abstraction, treatment and distribution of water, for foul and storm drainage, for the disposal of sewage and trade effluents, and for the conveyance and disposal of refuse.

Public health engineering works have been built since the dawn of the earliest civilizations 10000 or so years ago, and are essential to civilized communal life. Indeed, when the water and irrigation works serving Babylon and Ur were destroyed, those ancient civilizations perished.

The sanitary installations and sewers discovered in excavations in Babylonia and Assyria, the aqueducts that supplied Rome, and the under-floor warm air central heating systems of Roman villas, such as that at Fishbourne in Sussex, all demonstrated a high technical competence which was unfortunately lost and has had to be reacquired during the past century or so.†

What is making our problems in this country so acute today is that the same basic resources of land, air and water that served our forefathers must satisfy the needs of a much larger population with very much higher living standards at a time when those standards are increasing at an unprecedented rate, and the population is showing no signs of stabilizing, and certain of the resources – especially around our larger cities – are already fully utilized.

It is frequently not fully appreciated that what happens inside a building can profoundly affect the external environment and the magnitude of external public health engineering works.

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† The following is a description of what archaeologists found when excavating at the Sumerian town of Mari in northern Mesopotamia: 'As for the drainage, it was effected by means of brick gutters laid under the pavement and of bitumen-lined clay pipes going down thirty feet underground. The whole system had been so skilfully planned and installed that the waters of a violent rainstorm which burst one day during the excavations were evacuated within a few hours, the drains having worked again, most efficiently, after forty centuries of disuse.' (G. Roux 1964 *Ancient Iraq* (chap. 13). London: George Allen and Unwin.)

The greatest pollutant of urban atmosphere, for instance, is smoke from domestic fireplaces, and the widespread introduction of central heating, coupled with the use of smokeless fuels, can transform the position; and in Central London, where there has been strict enforcement of the 1956 Clean Air Act, the hours of winter sunshine have increased by 75 % over the last 20 years (see figure 1).

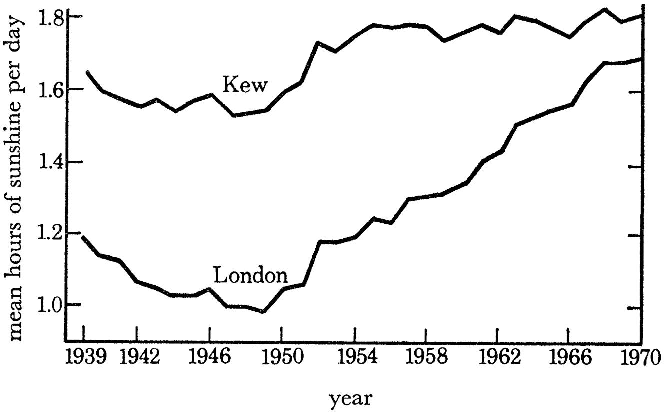


Figure 1. Trend of winter sunshine (December to February) at London Weather Centre and Kew Observatory. (Taken from the First Report of the Royal Commission on Environmental Pollution (February 1971), H.M.S.O.)

Likewise, the introduction of air conditioning can significantly increase water usage, while the installation of sink disposal units increases water demand and sewage flow, and also changes materially the characteristics of the sewage. Their wide scale introduction would, therefore, considerably affect the size and nature of water supply works, of sewers, and of sewage purification plants.

Although we have major environmental problems here, we should not forget that those overseas are even greater; and it is salutary to remember that 80 % of the population in developing countries has neither piped water nor access to standpipe supplies; that the vast majority of the world population lives in substandard conditions, and that most major cities overseas are doubling in size every 15 years. A recent study by the World Health Organization into the provision of improved water supplies in 75 developing countries showed that, because of the continuing growth in population, real advances were being made only in six. I sincerely believe that, if our own civilization is to flourish, solutions to these problems overseas must also be found in the years ahead.

Water supply

Of the future problems facing the public health engineer, the biggest are those of water supply and sewage disposal. Although domestic water consumption per person is currently only some 160 l/day (35 gallons/day) industry uses about twice as much, and the total demand per person is about 450 l/day (100 gallons/day). In addition, power stations use the equivalent per person of a further 600 l/day (130 gallons/day) for cooling purposes, and although this is normally returned to the rivers unaffected, apart from a rise in temperature, this can seriously affect the fish and plant life in the river.

Due to our improving living standards and population growth, the demand from all these sources is steadily increasing, and for a long time now has been growing at about 3 % per year.

The indications are that this growth rate will continue, and it is estimated that, by the end of the 1980s, consumption will be 60 % higher than it is today, and that by the end of the century it will be double today's figure (see figure 2).

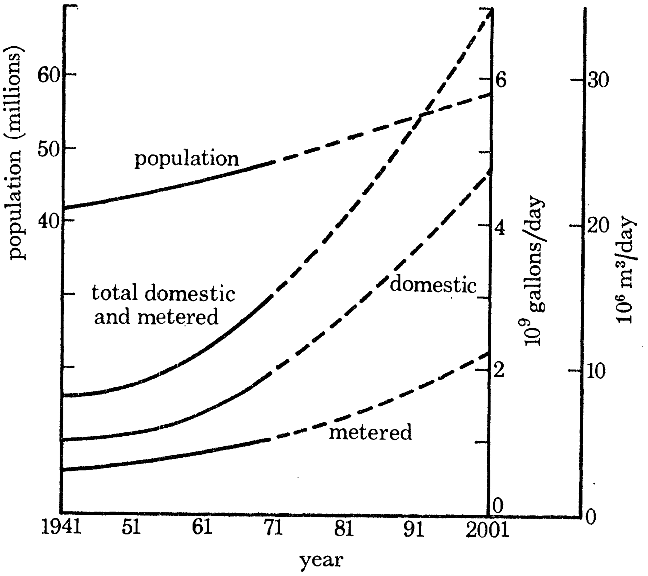


Figure 2. Growth of population and water demand in England and Wales, 1941–2001.

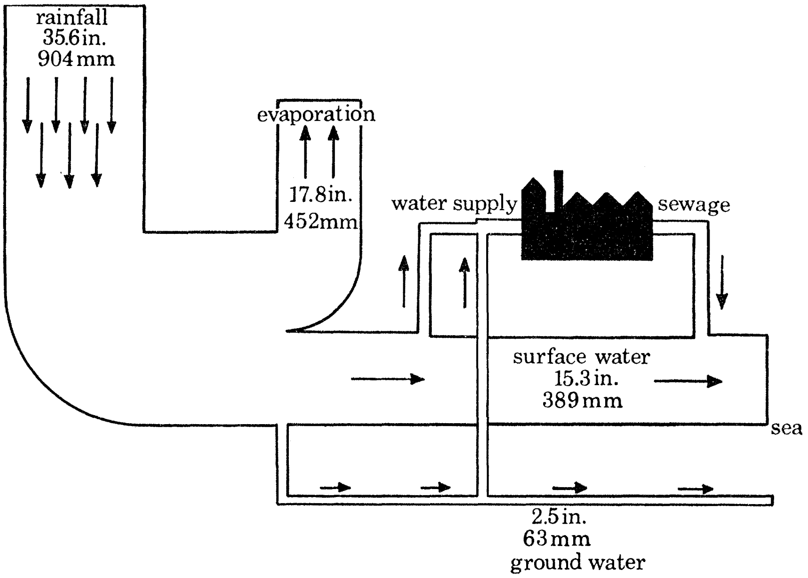


Figure 3. Water balance, England and Wales, average year. (Source: Water Resources Board.)

This means that within the next 30 years we will have virtually to duplicate all the reservoirs and other works that have been built over the past 100 years or so.

Fortunately, in the country as a whole there is no shortage of water (see figure 3), but most of our population lives away from the areas of highest rainfall; demand is highest in the summer when rainfall is least, and some major rivers are too polluted to be used for supply purposes. Put another way, too much of our water is in the wrong place at the wrong time, and sometimes of the wrong quality; and we must find the most economical means of harnessing and purifying it.

Given the necessary funds, these technical problems can generally be solved, and it is on the administrative side that the greatest difficulties usually occur. This is because water resources development and river regulation can only properly be tackled on a comprehensive and regional basis, and, hitherto, the water and river authorities have mostly been too small, and have been entirely divorced from the sewerage authorities.

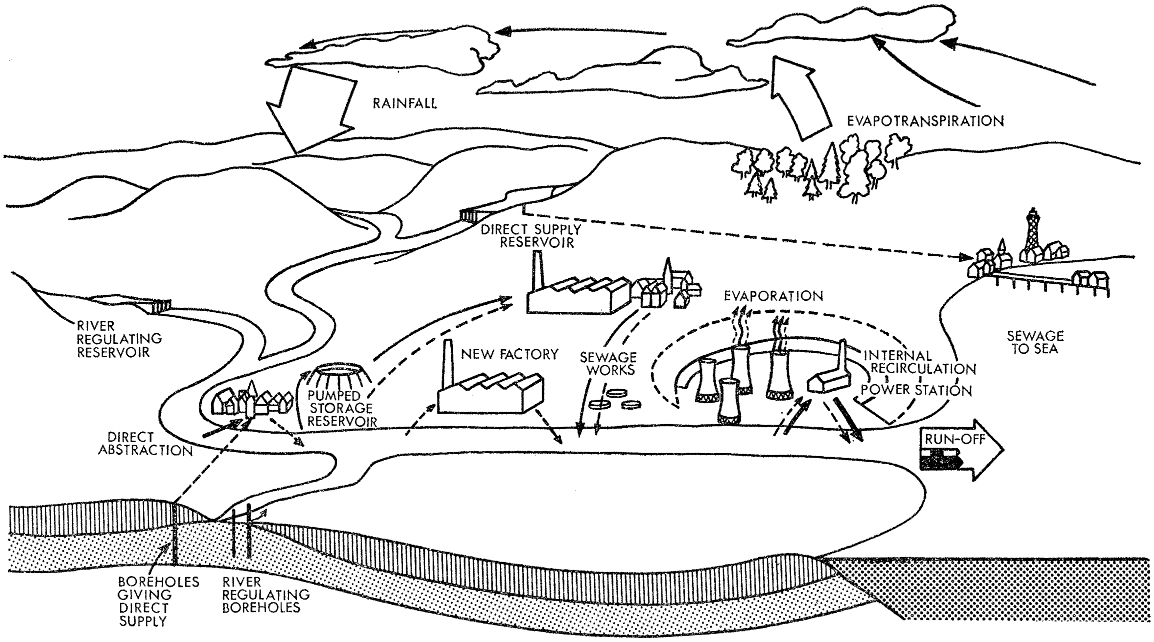


Figure 4. Hydrological cycle and re-use of water. (Source: Water Resources Board.)

Figure 5. Hawkridge Dam and Reservoir of the West Somerset Water Board, near Bridgwater. 27 m (90 ft) high concrete gravity dam retaining 860000 m^3 (190×10^6 gallons) of water over an area of 13 ha (33 acres) and providing a reliable yield of 7500 m^3/d (1.65×10^6 gallons/day).

Frequently a reservoir is the only practical way of increasing supplies, and even though it could be an attractive addition to the landscape and used for various recreational pursuits, plans to build one often raise strong opposition; and three important schemes supported by the Water Resources Board were recently rejected by Parliament.

Proposals for the reorganization of the river, water and drainage authorities will shortly be published by the Government.† These will almost certainly be based on a regional river basin

† Subsequently published as D.o.E. Circular 92/71 on 2 December 1971

concept and recognize the interdependence of water supply and drainage as component parts of the water cycle, and it is greatly to be hoped that these will end the present state of impasse, otherwise water shortages are inevitable – and will happen very soon if we get a succession of dry years.

Rivers and underground aquifers must continue as our main future sources of supply, but new techniques for abstraction will be introduced (see figure 4).

In the past, river water has been mainly abstracted from impounding reservoirs, which store water from times of plenty to times of low rainfall, and from which the water is piped to the town the reservoir serves (see figure 5).

Future developments will concentrate on regulating reservoirs, which are sited higher up the catchment and pass a regulated flow down the river for abstraction nearer the town, thus maintaining a bigger flow in the river during the summer, often enabling the reservoir to be sited in poorer agricultural land, and effectively increasing water availability by allowing it to be used by smaller towns *en route*.

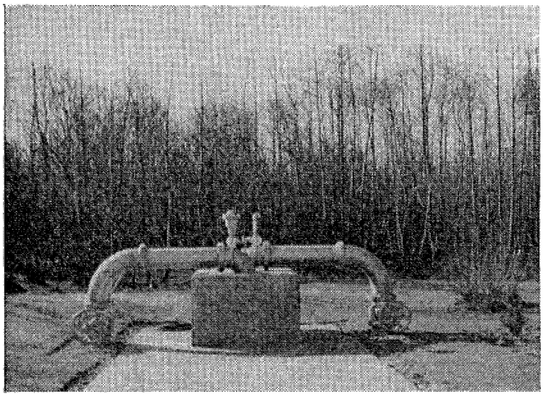


FIGURE 6. Headworks of 0.85 m diameter borehole at Godmersham, Kent, extending 60 m into the chalk and containing two submersible pumps delivering a total of 13 600 m^3/d (3×10^6 gallons/day). (Source: Mid Kent Water Company.)

Abstraction from underground aquifers will continue (see figure 6), but new developments which are envisaged include schemes such as that for the augmentation of the summer flow in the Thames by water abstracted from the chalk near Newbury, it then flowing along the Kennet and Thames before being abstracted again at London.

The artificial winter recharge of underground aquifers with surface water for abstraction during the following summer is also likely, and there are indications that this may also be an effective way of purifying polluted discharges.

Estuarial barrages, which are currently being studied for the Wash, Morecambe Bay and the Dee Estuary, are also likely to be developed (see figures 7 and 8). Such schemes would increase water supplies by making the run-off from the whole river basin available, improve land communications by enabling roads to be built across the barrage, and facilitate the reclamation of estuarial land. They would, however, cost hundreds of millions of pounds, and could only be justified when cheaper alternatives are not available.

Plants to desalinize sea water are also probable and a number of major distillation plants have been operational in the Middle East for some time, and those in Kuwait have a capacity that could supply Newcastle upon Tyne. At home two smaller plants have recently been built

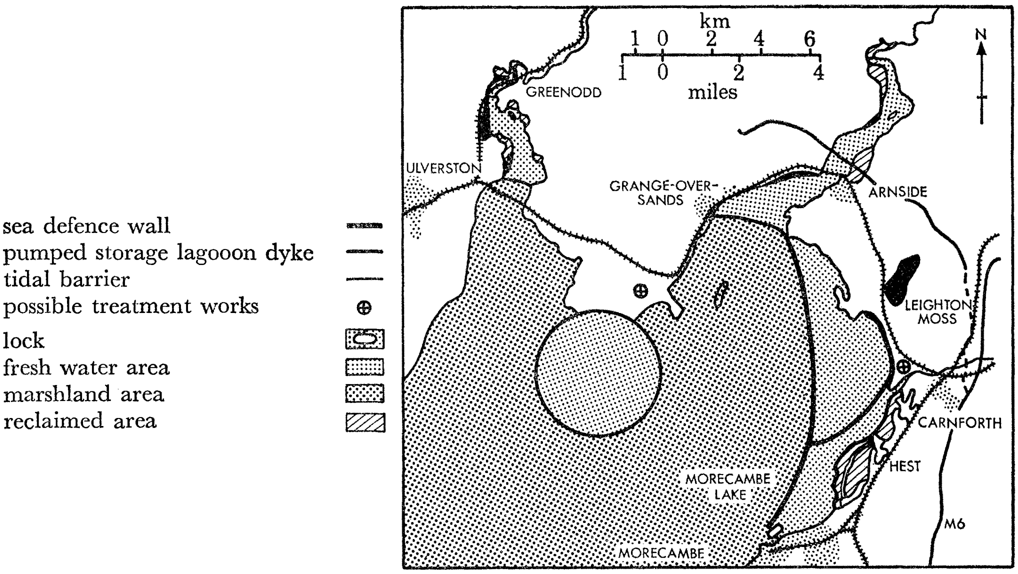
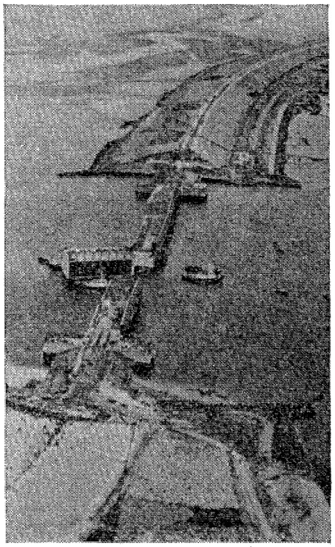


FIGURE 7. Possible estuarial storage development in Morecambe Bay. (Source: Water Resources Board.)



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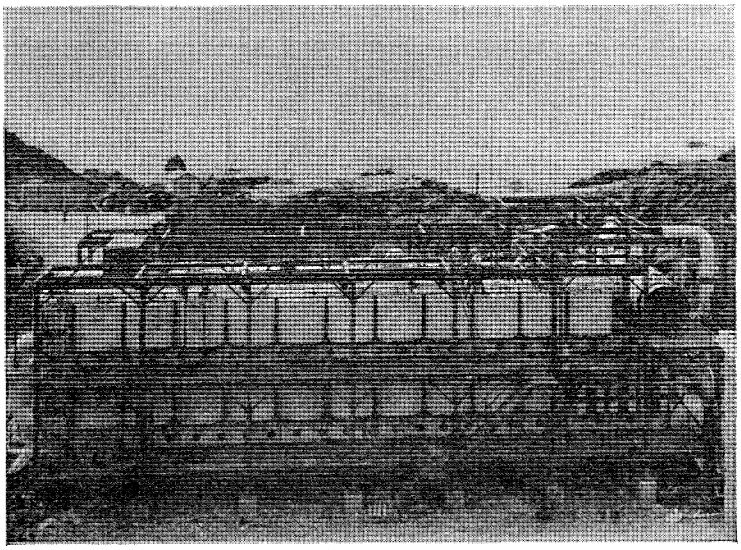


FIGURE 9. New multi-stage flash evaporator desalination unit at Jersey, Channel Islands, producing 6800 m^3/d (1.5×10^6 gallon/day) of fresh water from the sea. (Source: The Weir Group Ltd, Glasgow.)

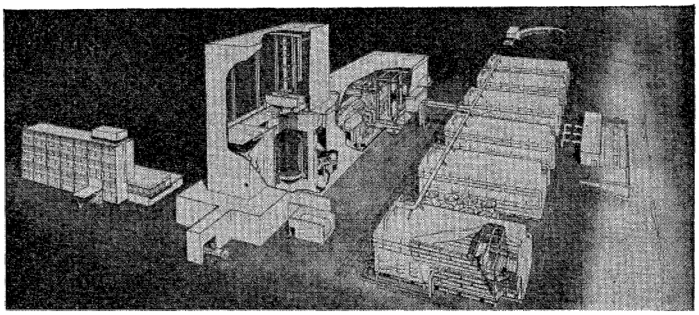


FIGURE 10. Artist's impression of possible future nuclear-powered electricity and water generating complex (advanced gas-cooled reactor and multi-stage flash distillation plant producing 400 MW (e) and 270000 m^3/d (60×10^6 gallons/day). (Source: U.K. Atomic Energy Authority.)

in the Channel Islands (see figure 9), while the construction of an experimental plant near Ipswich, working on a freezing technique, was recently authorized. The commercial application of reverse osmosis and electrodialysis for desalination is also being investigated.

In the Middle East plants, high-pressure steam is first utilized for power generation before passing to the water-producing units, and, if major units are built here, I expect they will form part of a nuclear powered electricity and water generating complex (see figure 10).

Water re-use

So far I have dealt with means of increasing the availability of raw water, but there is another fundamentally different way of tackling the problem, and that is by using the same water more than once, i.e. by the recirculation of water by industry, and the re-use of purified sewage effluents.

If every unit of water could be used twice over, our demand on raw water sources would obviously be halved. While I believe there is considerable scope along these lines, let me add that it could not eliminate the need for new sources, partly for geographic reasons, but also because increases in dissolved salts gradually occur.

Already sewage effluents from Swindon, Oxford and Reading are returned to the Thames upstream of London's intakes, but the best existing examples of re-use are probably in the River Lee and at Bristol.

The Luton Sewage Works now forms the headwaters of the River Lee, while the Rye Meads Sewage Works, which serves 300000 people in Stevenage, Harlow and Welwyn, is the other major source. In a dry summer their flow can comprise half the total river flow, and the annual average dilution is only $3\frac{1}{2}:1$. Despite this, the Lee provides nearly 20% of the Metropolitan Water Board's supply to London.

At Bristol, the town's sewage used to discharge into the River Avon after partial treatment only, but a plant for full purification of part of the flow was built recently, and is providing process water for a smelting factory very economically.

Before the end of the 1980s, I believe there will be many more such developments, and some of the 1.8×10^3 m^3/day (400 million gallons a day) of fully purified effluent that London now discharges to the tidal Thames may well be utilized in some way.

Water conservation

Whatever means may be adopted to increase water supplies, it behoves all of us – whatever our profession – to ensure that all reasonable economies in water usage are made, so that our available resources, both natural and economic, are used to the best overall advantage.

The designers of buildings, domestic as well as industrial, have considerable scope for ensuring that the devices they specify do not use excessive water, and the Building Research Station has carried out much research into equipment that economizes in water.

Other possible ideas include the use of domestic meters – as is the practice in many overseas countries – but I doubt whether they would be worth while here. Water is cheap – it costs only about 3p a ton delivered to the house – and most households pay only about £10 per year for water, and the incentive to reduce consumption is too small.

Two classes of water, one of high purity and the other of inferior quality, have also been suggested. Cisterns and distribution mains would need duplication, however, and there would also be the risk of making connexions to the wrong pipe, and I doubt whether it would prove advantageous.

What would help considerably is the better education of the public in scientific and environmental matters – and especially in the dangers of pollution and the need for conservation of our various natural resources, including, of course, water. Conservation Year may be behind us, but the principles of conservation of matter and of energy are still with us, and govern our lives; yet what proportion of our population has even heard of them – let alone appreciate their implications.

SEWAGE PURIFICATION

Efficient sewage purification is, of course, essential for water re-use, and there will be even greater increases in sewage plant capacity than in water works because, not only must the future increase in water consumption be matched; but increased future abstractions will reduce the natural flow in the rivers, and the returned effluents will therefore have to be even purer than now; and, also, the existing deficiency in treatment capacity which exists in some districts will have to be made good.

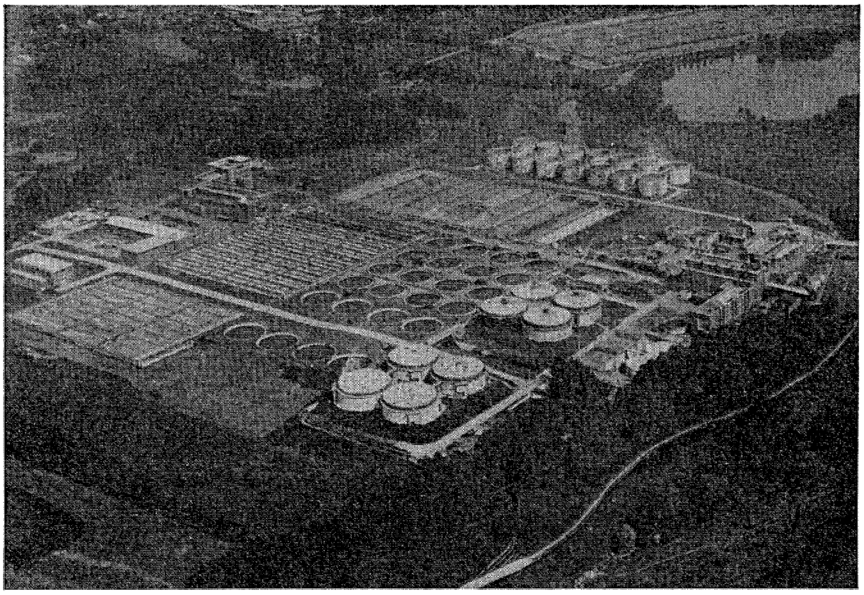


FIGURE 11. Maple Lodge sewage treatment works of the West Hertfordshire Main Drainage Authority at Rickmansworth, which treats the flow from over half a million people to a very high degree of purity. (Source: West Hertfordshire Main Drainage Authority.)

Fortunately, our existing purification processes are sufficiently developed to enable any desired degree of effluent purity to be met efficiently and economically. Similarly, most liquid industrial wastes can be treated satisfactorily, those that cannot being mostly from factories sited on estuaries.

Sewage purification normally consists of the separation of settleable matter by sedimentation, followed by the microbiological oxidation of dissolved impurities into a form in which they too can be separated out by sedimentation (see figure 11).

The disposal of the settled matter, or sludge, is the most difficult part of the process, and unless it can be disposed of in liquid form to farmland or the sea, it must be dewatered, either by evaporation or mechanical means, to a state where it can be tipped or burnt (see figure 12).

Unless, say, the introduction of new detergents, or the widespread use of sink-disposal units, should change significantly the composition of domestic waste water, our existing purification processes will, I believe, continue well into the 1980s. Among refinements which I foresee, however, are more reliable techniques for sludge dewatering, and that new works will increasingly resemble modern chemical process plants, with a high degree of automation.

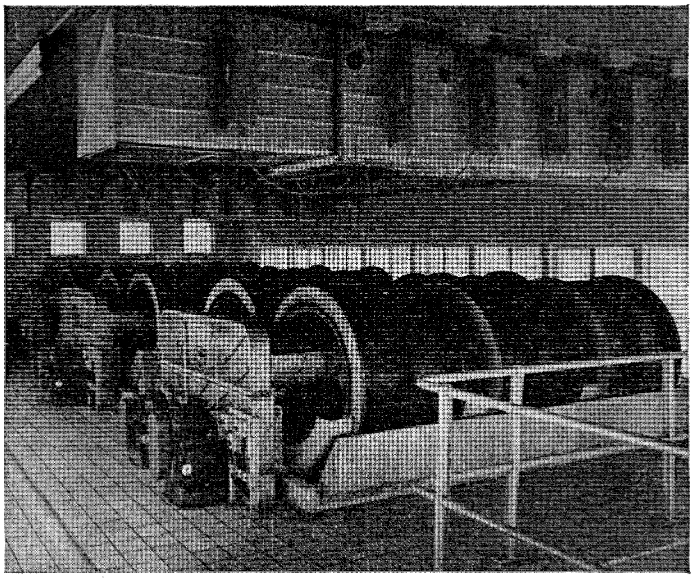


Figure 12. Mechanical sludge de-watering plant at Chertsey serving 80000 people. (Source: English Electric Diesels Ltd, Colchester.)

Solid wastes

Excluding colliery waste and power-station ash, solid wastes for disposal consist annually of some 11 million tonnes of industrial waste, partly toxic, but mostly inert, and some 14 million tonnes of domestic garbage. Although the weight of garbage is not increasing appreciably, it is getting bulkier, and it now contains much more plastic and paper and much less ash than before.

Refuse collection is still mainly via the dustbin, which was surely old fashioned even at the start of this century. Mechanical means of collection must come, and one possibility is the sink disposal unit which, despite what I said earlier, has many attractions.

Another possibility is a Swedish system which sucks refuse through a network of pipes at a speed of about 100 km/h to a central collecting point – and which will shortly be tried in a new housing development in London (see figure 13). Although in both the Swedish and London cases the collected refuse is pulverized and then incinerated, it could equally well be transported from the collecting point for ultimate disposal elsewhere.

Further practical research by the construction of estates with mechanical refuse collecting systems, instead of dustbins, is surely desirable.

Once collected, refuse has generally been tipped, and after decomposition to an inert form, has been useful in land reclamation. Although tipping is now being superseded in many districts, because there are no more suitable sites available locally, because of nuisance, or because of

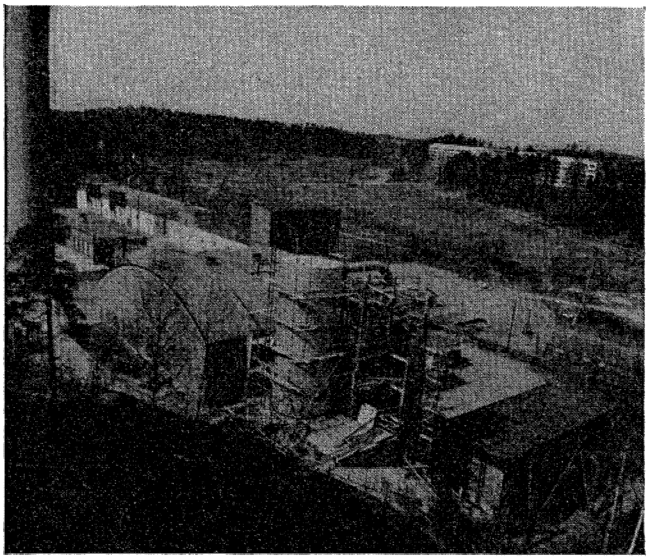


Figure 13. Mechanical refuse collection and disposal system, Sweden. Refuse is conveyed by pipeline from flats in background to silo and incinerator in foreground. (Source: Photocentralen, Sweden.)

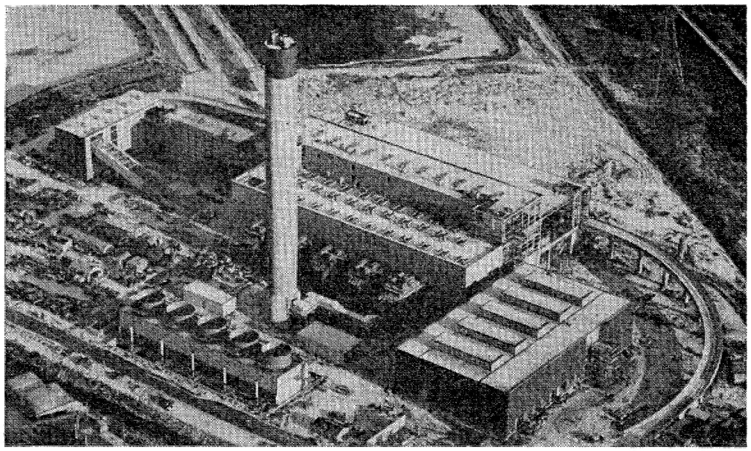


Figure 14. The new G.L.C. incinerator at Edmonton, which disposes of the refuse from approximately one million people. (Source: Public Health Engineering Department, Greater London Council.)

the risks of pollution of water courses, it might with advantage still be used in reclaiming semi-derelict industrial areas, possibly by using liner trains as the means of transport from a major city and, overall, there are more potential tipping sites than refuse to fill them.

Composting is unlikely to become an economic means of disposal, and, where tipping is no longer possible, our larger towns are increasingly turning to incineration (see figure 14), a trend which will be accelerated by the impending reorganization of Local Government. As the heat generated could be used for power generation or for industrial or district heating purposes, and as the incinerator could also dispose of dewatered sludges and industrial wastes, there are obvious opportunities for imaginative planning.

The future will also see much more pre-disposal separation and reclamation of reusable wastes.

AERIAL POLLUTION

Smoke is our greatest aerial pollutant, and because so much of industry now uses gas, oil or electricity instead of coal, 80 % of the smoke in our atmosphere today comes from domestic fireplaces. I should add, however, that, over the last 20 years, despite a 17 % increase in the total energy consumed, the smoke and sulphur dioxide contents of the lower atmosphere have steadily decreased, and, as already mentioned, this has had a very beneficial effect in many of our cities (see figures 1 and 15).

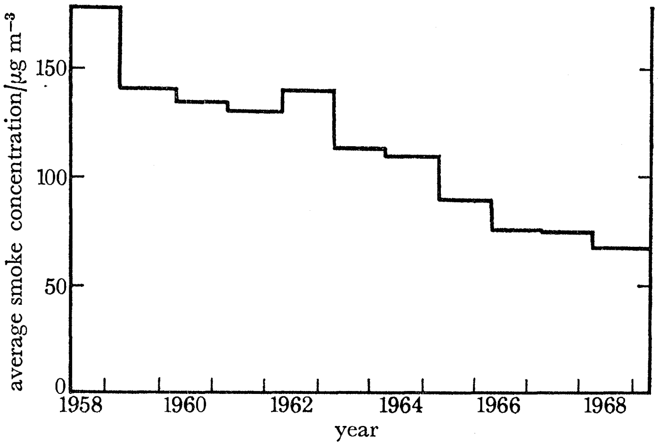


FIGURE 15. Average smoke concentration near ground level in the U.K. 1958 to 1968. Taken from the First Report of the Royal Commission on Environmental Pollution, H.M.S.O.

The main improvement in the SO_2 reading has been due to the use of very high chimneys by power stations and factories, rather than by the use of sulphur-free or de-sulphurized fuels, and the Swedes have suggested that what we discharge to the upper atmosphere finally falls there – but this has not been established.

The other main source of atmospheric pollution is the internal combustion engine, but the Royal Commission on Environmental Pollution recently stated that there was no firm evidence that car exhausts were, at the present time, 'a hazard to health, even in busy city streets, although smoke from diesel engines can be very offensive'.

More information is undoubtedly required regarding the long-term effects of car exhausts and, with the inevitable future increase in car numbers, we cannot be complacent.

Significant improvements can only happen through better engine design, but the problem is not easy, because, unlike industrial furnaces and domestic boilers, which mostly operate at steady rates, a car engine has to operate under very variable conditions, e.g. idling, crawling in a traffic jam, accelerating, and driving at high speed along a motorway. Nevertheless, much progress has aready been made and will undoubtedly continue.

Investigations are also being made to see whether the increased discharges of carbon dioxide – a product of all forms of combustion – and of dust and aerosols, are having any long-term effect (see figure 16).

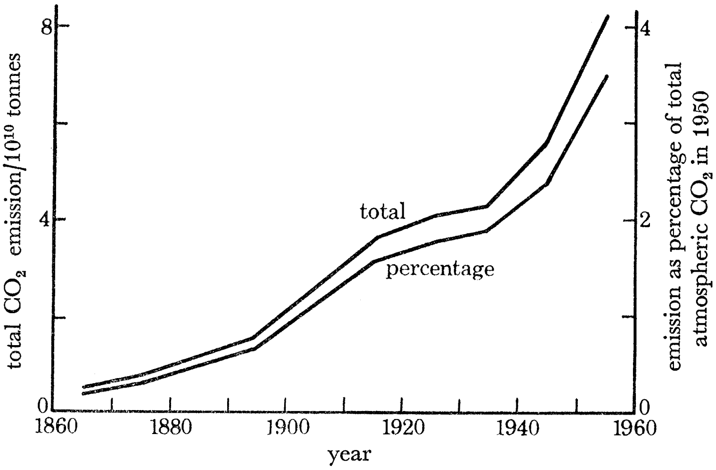


FIGURE 16. Carbon dioxide from the combustion of fuels in the World 1860–1959. Taken from the First Report of the Royal Commission on Environmental Pollution, H.M.S.O.

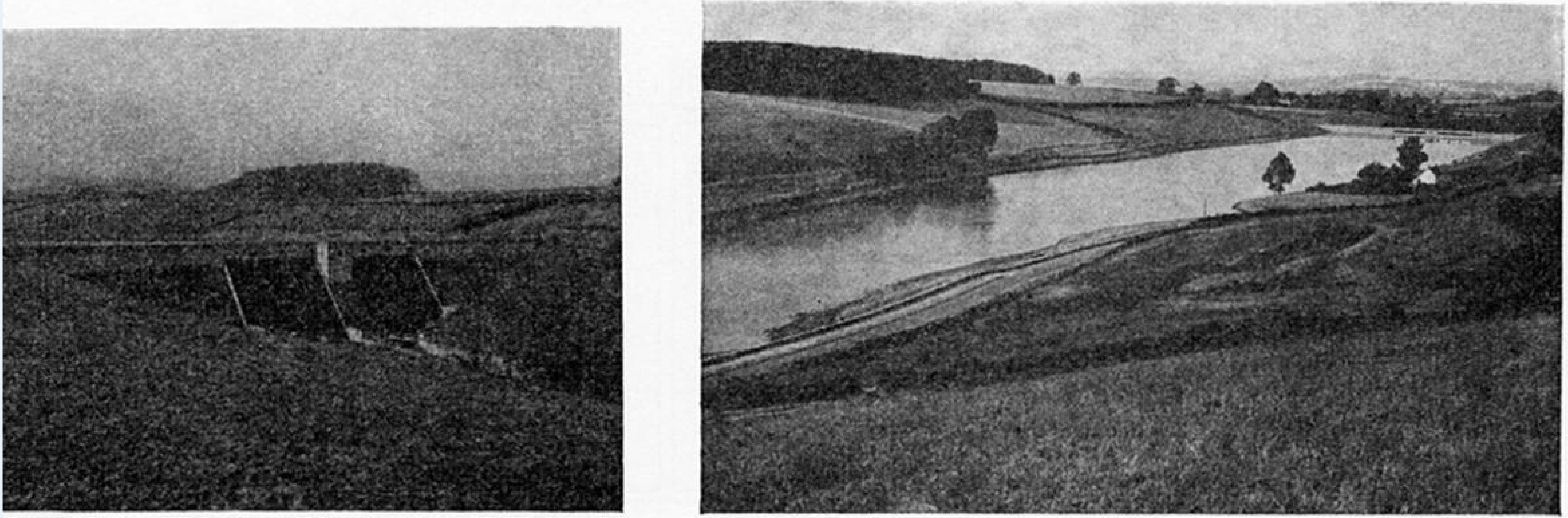
CONCLUSION

An awareness of the need for conservation is not new – indeed, as long ago as the 4th century B.C., Plato bemoaned the deforestation of Attica brought about by the demand for fuel for metal smelting – but it is only very recently that the public at large has realized its importance.

All conservation problems stress the interdependence of the internal and external environments. They are also essentially interdisciplinary and, in order to achieve success: politicians must allocate the necessary funds; scientists, of many disciplines, must establish the underlying scientific principles; and engineers, of many specializations, must develop the necessary equipment – whether it be newer means of refuse collection and disposal, quieter aero-engines, better building services, nuclear-powered desalination plants, more efficient sewage purification works, improved car engines, or techniques for reducing marine pollution, one of the problems to which I have not had time to refer today.

Engineers have a vital role to play in environmental conservation, and this has possibly not been sufficiently realized in the past. Indeed, there are many who find it strange that there should be no professional engineer on the Royal Commission on Environmental Pollution, and that engineering aspects should appear to play so little part in next year's Stockholm Conference on the Human Environment – and I am, therefore, particularly happy to have been given this opportunity to describe today some aspects of the part engineers are playing in environmental conservation and generally in improving the quality of life.

We are all dependent for our continued existence and well-being on the three basic elements of land, air and water. Public health engineers are fortunate that their work deals with the utilization and conservation of all three; and with their colleagues in other branches of engineering, in the Building Industry, and in the various scientific disciplines, will continue to strive to ensure that the buildings of the 1980s will provide the future population of this country, and of the world, with the healthy living conditions to which I referred at the start of this address.



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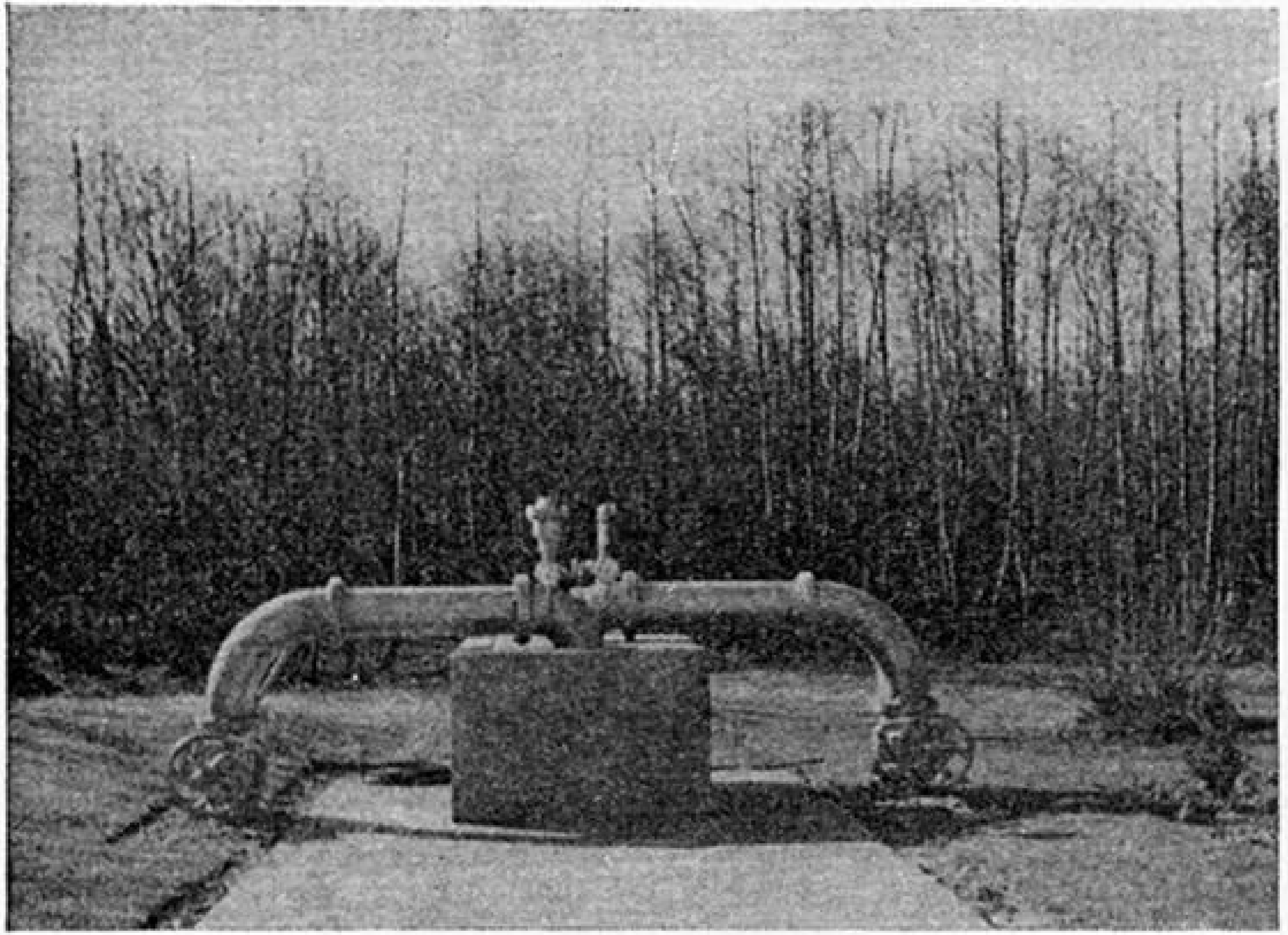

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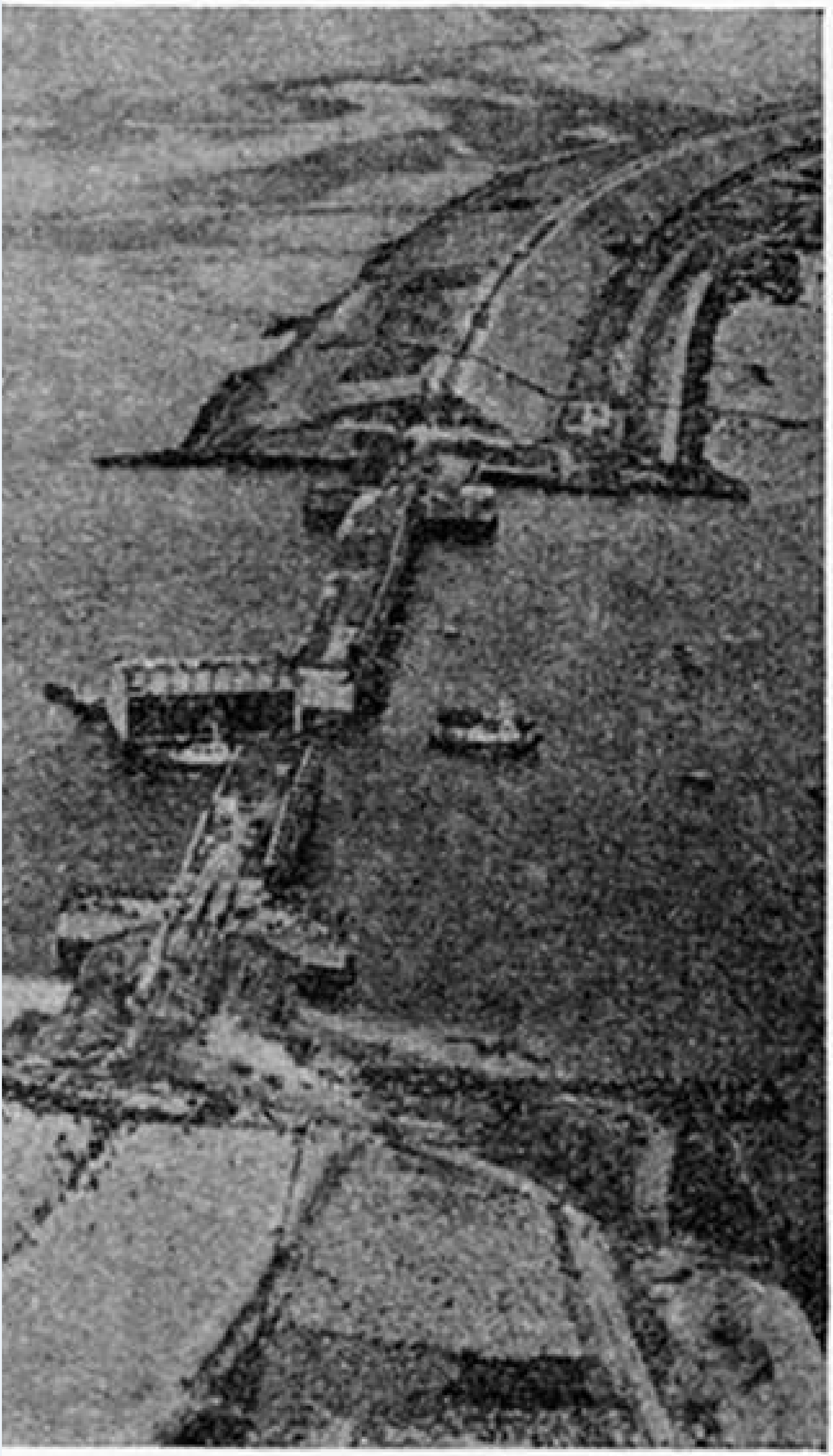

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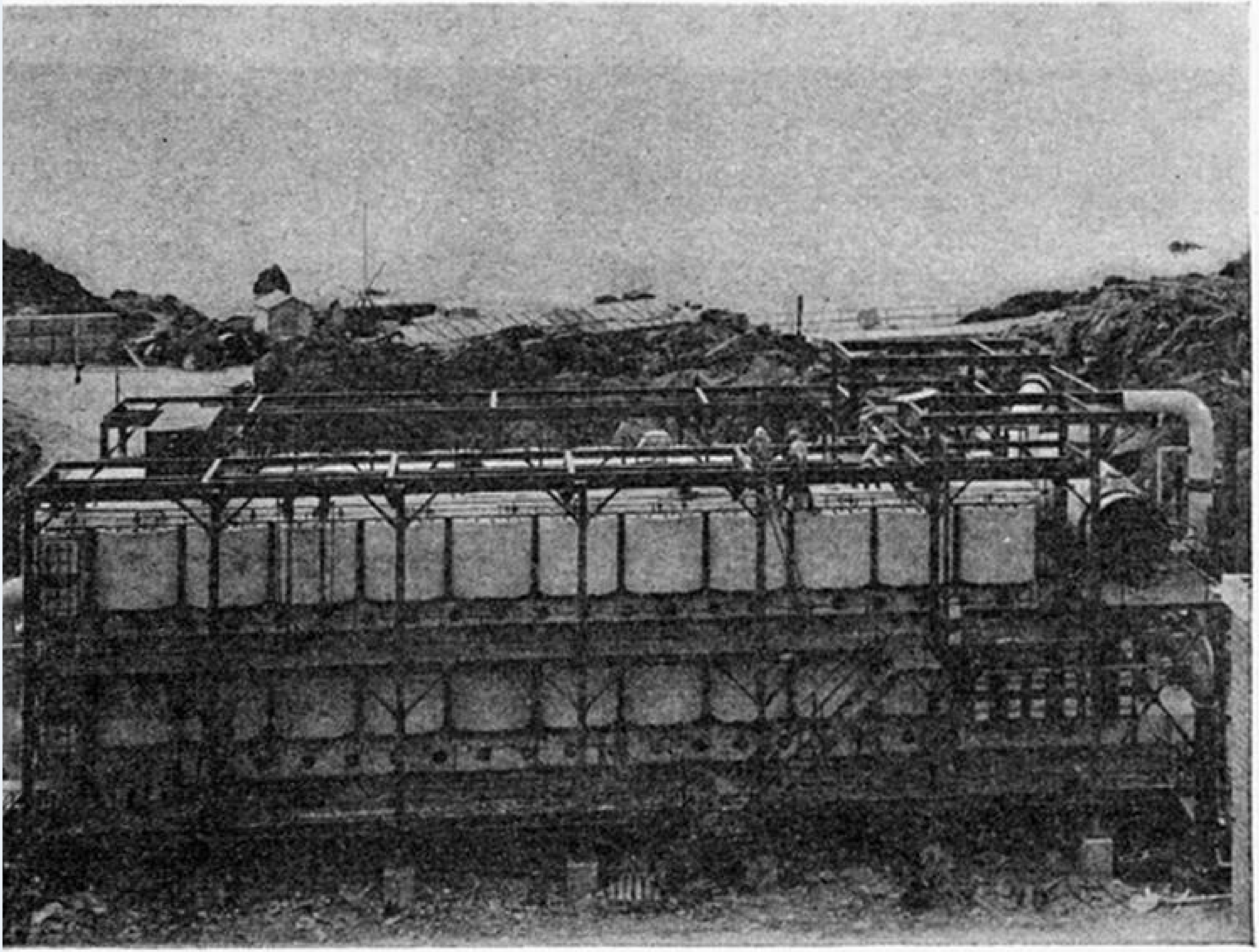

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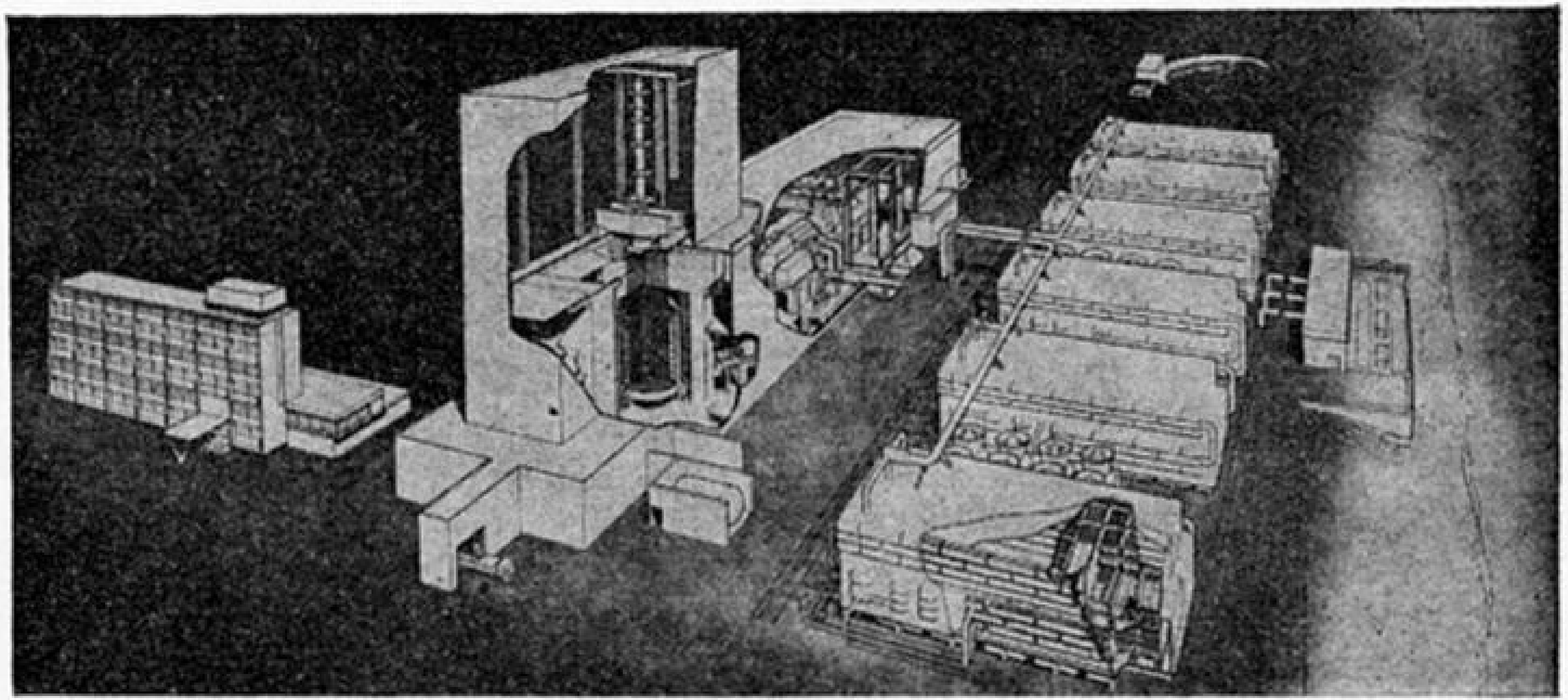

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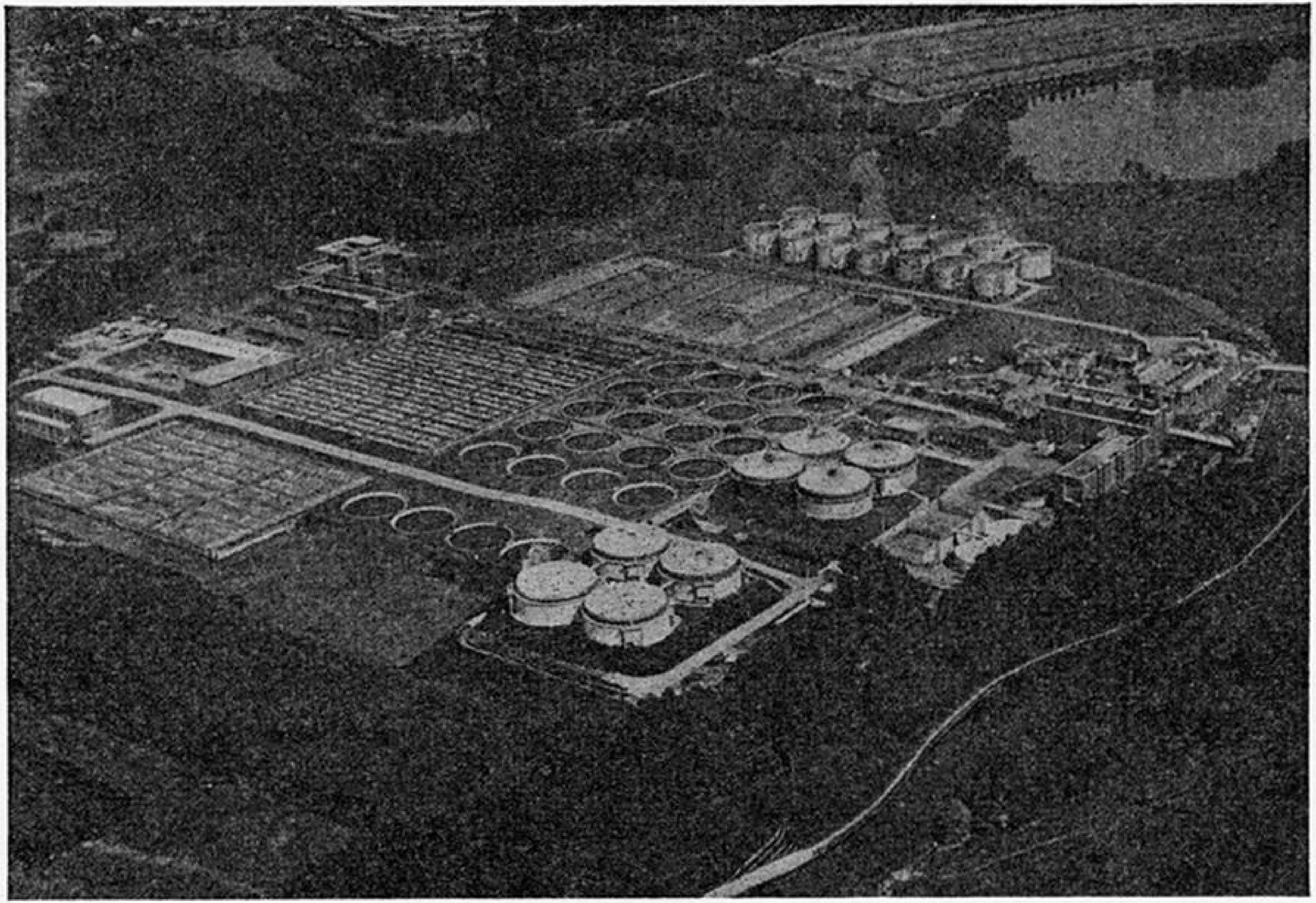
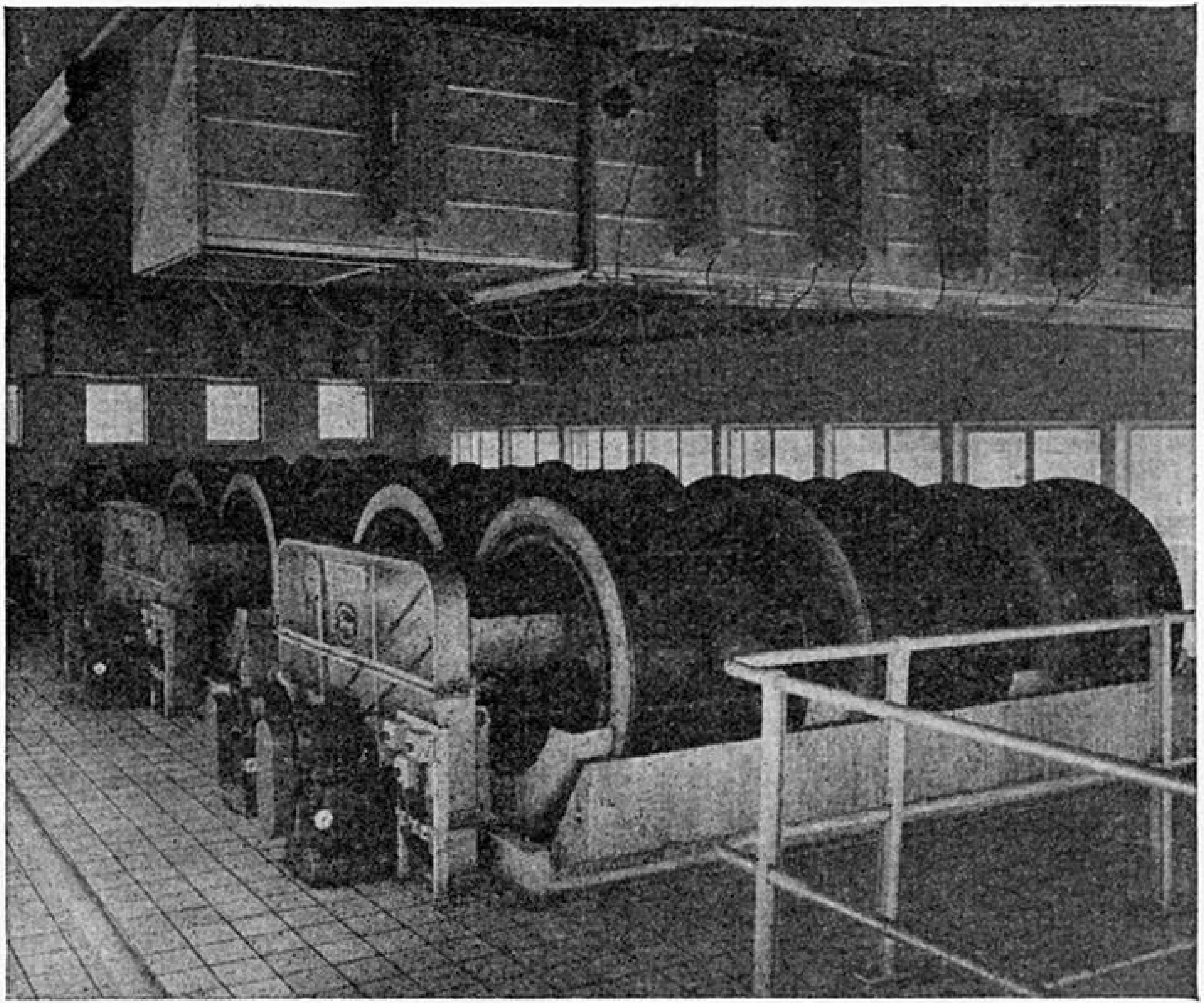


IGURE 11. Maple Lodge sewage treatment works of the West Hertfordshire Main Drainage Authority at Rickmansworth, which treats the flow from over half a million people to a very high degree of purity. (Source: West Hertfordshire Main Drainage Authority.)



IGURE 12. Mechanical sludge de-watering plant at Chertsey serving 80000 people. (Source: English Electric Diesels Ltd, Colchester.)

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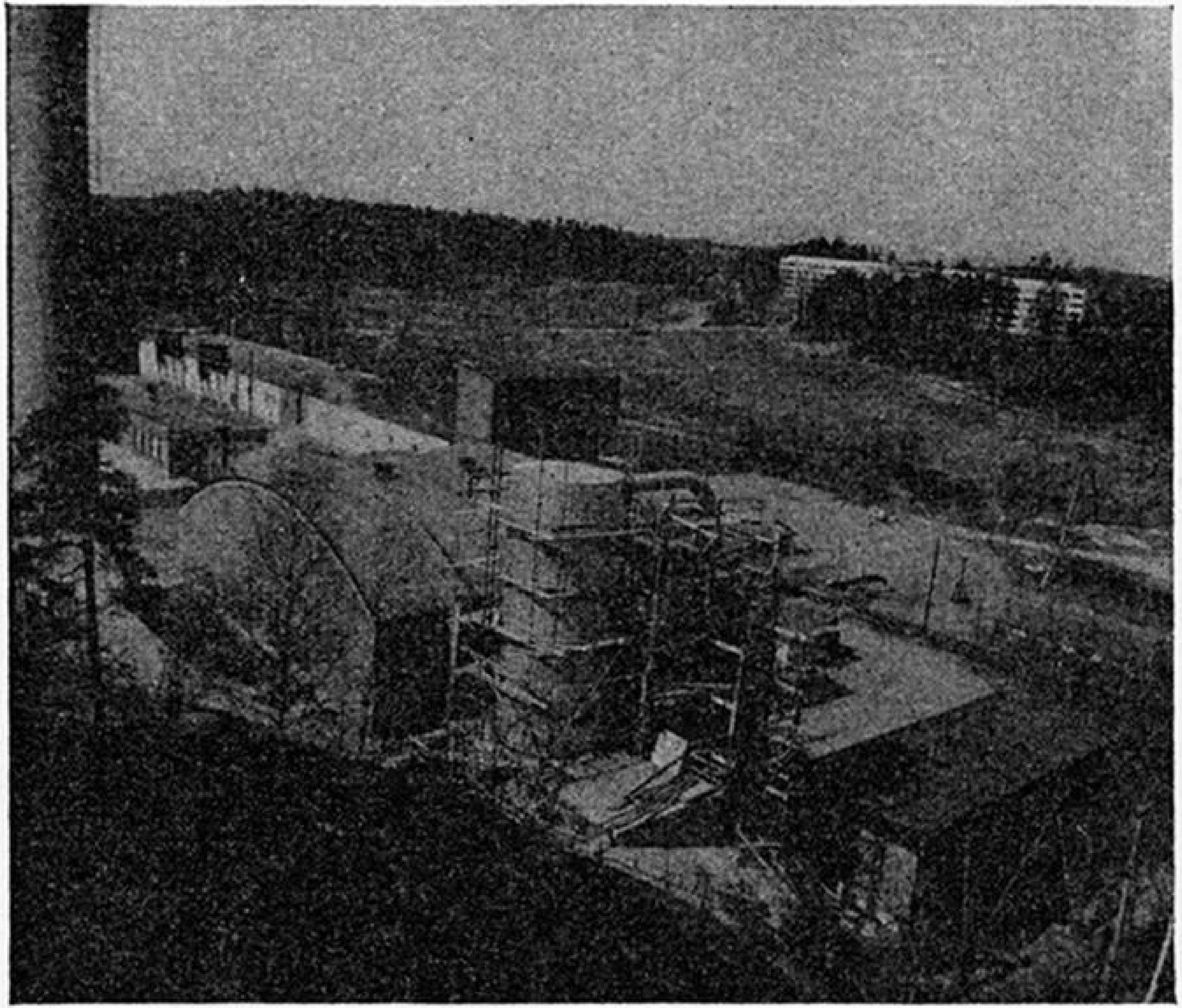
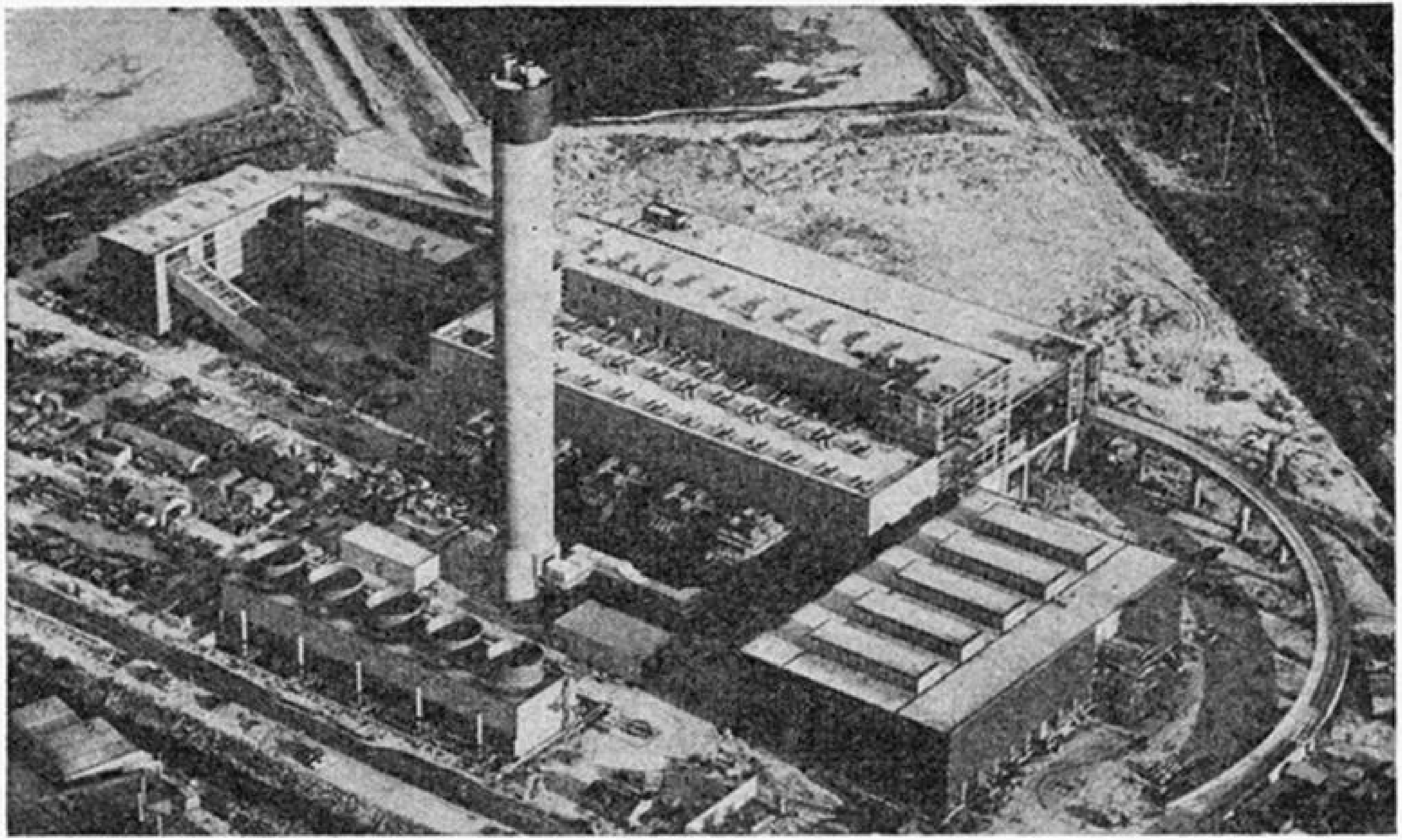


IGURE 13. Mechanical refuse collection and disposal system, Sweden. Refuse is conveyed by pipeline from flats in background to silo and incinerator in foreground. (Source: Photocentralen, Sweden.)



IGURE 14. The new G.L.C. incinerator at Edmonton, which disposes of the refuse from approximately one million people. (Source: Public Health Engineering Department, Greater London Council.)