In selecting the various points of interest in connection with the sewering and draining of Dunedin, which are most likely to be profitable to record, we find that these group themselves under two distinct headings—"Matters of General Policy" and "Engineering Details of the Work."

For greater clearness it is better to deal with each of these separately.

1. **Matters of General Policy.**

To those familiar with sewerage works as carried out in the past in these States, and in New Zealand, it will be a surprise to learn that a community which, in wealth and population, probably ranks about the sixth largest of our cities, should be committed to a scheme which in extent and capacity ranks third, and which, although the immediate expenditure is not likely to exceed £400,000, will before completion embrace, directly and indirectly, works that will probably exceed one million pounds, and will serve a population of between three and four times the present.

Though this large excess of works over present requirements is somewhat in accord with the policy recommended by the late Mr. Mansergh for Melbourne, it would not under ordinary colonial conditions, where the money has to be borrowed at a comparatively high rate of interest, be an economical or wise policy; and, while I have followed Mr. Mansergh's lead in this respect, I do not wish it to be understood that I approve of the policy he recommended as compared with the more conservative policy which has been actually carried out by the Melbourne and Metropolitan Board of Works. There were, however, many circumstances in Dunedin which would have rendered anything less extensive than the present scheme not only inadvisable, but insufficient to meet some of the present requirements. Of these circumstances the most important was the topography of the inhabited area.

Photographs of Dunedin taken in 1862 and, from the same point, in 1904 show not only the steepness of many of the hills (which rise to an elevation of from 500 to 700 feet in less than a mile, and in many places in a couple of thousand feet), but also the substantial growth of the city, and that a large portion of it
has been built upon land which forty years ago was swamp or harbour.

At the present time, the swamps surrounding Dunedin have been almost entirely reclaimed, and the work of harbour reclamation is being steadily pushed on, along with the improvements of wharves, channels, and docks, which the policy of the Harbour Board is to gradually increase and deepen at a continual steady rate without adding appreciably to its public debt. Ultimately, the total area reclaimed from the harbour will reach about 400 acres, which will be reclaimed to a level of about five feet above the highest spring tide. The other area of flat land lies in a narrow tongue which connects the district known as the Peninsula with the mainland. The Peninsula forms a natural wall or barrier, dividing the harbour from the Southern Ocean, and at the narrow tongue of flat land adjoining Dunedin, the average width, from the end of the Harbour to the open ocean, is about one and one-half miles.

The general level of land on the Peninsula is considerable, the highest ridges averaging from 400 or 500 feet to over 1200 feet, and the formation being volcanic, the beauty of the harbour is greatly enhanced. It is hard to imagine a more entrancing picture than this land-locked sheet of water, which is protected on the inland side by a range of mountains rising to 2400 feet in elevation, and on the ocean side by this Peninsula of rich volcanic soil, where the emerald of the fields is set with occasional splashes of blood-red hematite, and the purples and browns of the volcanic escarpment; while glimpses of the brilliant blue of the deep ocean contrasted with the yellowish-green of the shoal waters which flank the shallower parts of the coast-line are seen between every hollow in the graceful curves which form the horizon.

In Dunedin, as in the case of Sydney Harbour, the growth and improvement of the city is likely to add fresh charms, since here the contrasts must of necessity always be strong and picturesque between Art and Nature. But in this respect, Dunedin will have the advantage over Sydney, in that Nature is here so rugged and bold, that it must always form the predominating feature, and the greatest effort of Art will not be able to obtrude itself further than to give that modest intimation of the teeming life inhabiting the sheltered spots, which gives soul to beautiful scenery.

No doubt it is an inestimable blessing to the city to be set in the midst of such beautiful surroundings, and surroundings which, at the same time, afford the opportunity for an almost unlimited expansion; but, unfortunately, these advantages greatly complicate the engineering problems, and make it impossible to follow precedents.

Thus it would be hard to imagine a more difficult problem
than to devise a sewerage system which will combine and embrace in one complete arterial system the steep streets of Dunedin, where the grades often exceed 14 per cent., with the reclaimed land and the fourteen or fifteen hundred acres of flat land forming the tongue of the Peninsula, the greater part of which is barely above ordinary highwater mark; and undoubtedly the easiest way to deal with the problem would have been by a series of different works, each independent of the other; and if the population were destined to remain stationary, this would probably be the cheaper way.

The growth and vital statistics of the district since the year 1878 suffice to indicate how steady has been the growth of Dunedin in the past, in spite of the vicissitudes of a land boom, followed by as severe a slump in prices as has perhaps been experienced by any British community in recent years. From regard to its past history, and the sound nature of its present enterprises, there can be little doubt that in the future, as in the past, the growth of Dunedin will follow the general growth of the colony. In fact, there are many reasons which would induce one to believe that it will grow more rapidly in population and wealth than the country district which it serves. For instance, it is a well-known fact that the tendency of modern life is that the leisured class should swell the city population, and in the particular case of Dunedin the enterprises which are on foot are such as not only to make the city attractive for such, but also to make Dunedin the manufacturing centre for the whole of New Zealand. Among the facilities for this latter, is the existence of considerable water power, as well as large deposits of coal in the neighbourhood. Waipori Falls illustrates one of the head works for water power which is being harnessed by the City Council, with a view to adding the distribution of power to its other municipal enterprises.

From consideration, then, of all the circumstances of the case, it is evident that no scheme of sewerage which would in any way cramp the growth of the district should be adopted. Two other factors existed which made the difficult scheme of combining all the sewers into one large system the only one which would satisfactorily meet the demands of the people. The first of these was that the existing sewers had been so constructed that they could not be satisfactorily utilised in connection with any distributed systems, and the second was that the interests of the harbour demanded that all solids and polluted liquids should be excluded therefrom. This latter provision I resisted, but, in spite of my opposition, it was embodied in the Board's amended Act in September, 1902; and, as I will subsequently point out, this provision has materially added to the amount of the works which will devolve on the Board. In the meantime, it will suffice to call attention to the fact that the
main outcome of this restriction was that the sewage had to be carried to the ocean, and, as a distance of two miles separated the nearest part of the city from the ocean, and the average level of the surface of this two miles was absolutely uniform and only just at highwater mark, there was no choice between either constructing a huge syphon (for the gravitation of such sewers as could be intercepted at a sufficiently high level), with a pumping system for pumping the lower level areas at different places under pressure into this syphon, or alternatively carrying all the sewers to one pumping-station at a considerable depth and thence pumping the sewage.

This latter scheme was the one adopted. The pumping station is known as Musselburgh Station. From thence the sewage is pumped to the dividing well, and flows naturally by gravitation. A large provision is made in the scheme for the admission of stormwater, and for economy two separate gravitation outfalls have been provided: one to the nearest point which could be used with impunity for discharging sewage into the ocean, where the combined stormwater sewage can be discharged when it is sufficiently diluted; and the other, at a distance of about two miles further, discharges into the main ocean current, where sewage to an almost unlimited quantity could always be discharged without any danger of polluting the beaches. This latter extension for ordinary sewage pumping has less than a third of the capacity of the stormwater outfall, or one-quarter of the total capacity for which the pumping station has been designed.

As will be explained later on, the greatest possible pains have been taken to make these outfall works as economical as possible; and drawings were even prepared to determine the comparative cost of septic tank treatment, to enable all the sewage to be treated, so that it could with impunity be discharged at the same point as was chosen for the stormwater discharge. Consideration was also given to the question of the establishment of a sewage farm along the sand-banks in that vicinity, but for this latter proposal the areas available would have been insufficient.

The other factor which influenced the decision to construct the main intercepting sewer, pumping-station, and outfall of comparatively large size, was that by so doing, the existing system of sewerage, which is one combining the stormwater and sewage in the same sewers, could be maintained and embodied as part of the new scheme, and thereby works which were probably worth over £40,000 would be retained, and also a considerably larger sum of money saved to the householders in enabling them to maintain the greater part of their existing appliances and connections.

In adopting this comprehensive scheme, which, to a large
extent, enables house connections to be made on the combined sewerage and stormwater system, the most important question was—to what extent stormwater should be allowed into the sewers? To have constructed the sewers of sufficient size to accommodate the maximum floods would probably mean making the sewers at least forty times as large as would be necessary to meet merely the demand for domestic sewage. What has been done is to construct the sewers of six times the capacity for the calculated mean sewerage flow, so that ordinary domestic sewage will be diluted to the extent of six times before there is any danger of it overflowing by the stormwater outlets, which are provided at various places—into the water of Leith River, the Lindsay Creek, and the harbour. In adopting this proportion, regard was paid to the regulations of the British Home Government. At the same time, to satisfy the demands of the Harbour Board, and also to admit of the almost indefinite growth of population, which it is desirable to allow for, without radically altering the scheme, aseptic depositing tanks, somewhat on the lines of the celebrated Dortmund Tanks, were provided for on the overflows. Full details of these will be given in the second part of this paper. In the meantime, the following brief explanation will show the very considerable economy which will ultimately arise from the use of these tanks.

As has already been stated, the stormwater discharges are in many cases forty times the capacity of the main sewers. With the increased growth in density of population, whereby roofs and impervious pavements will take the place of gardens and green fields, both the quantity of sewers, and also the volume of flood water will be greatly increased beyond anything which can now be provided for; and the chief function of these aseptic tanks is that, whatever increased provision may hereafter be made for stormwater discharges, the sewers proper will continue to have ample capacity for every possible increase in the volume of the sewage. Obviously, this would mean that the proportional amount of stormwater which will dilute the sewage will gradually become less and less, and in consequence also, the occasions on which the overflows will act will gradually become more and more frequent, with the result that the one-sixth pollution, which is at present the utmost anticipated, will in time be considerably exceeded, with the result that these overflows will eventually become almost as troublesome and offensive as the sewers which formerly flowed to the harbour (now being intercepted) have been in the past. It is here that the advantage of the depositing tanks will come in. On experiment it was found, when using the first two of these tanks which have been constructed, that they remove 70 per cent. of the solid matter passing through them.

The following is the broad line of policy which is being
carried out. On the steep and hilly portions of the district, where, owing to the steepness of the grades, sewers combining a large measure of stormwater discharge can be used, all the house connections are made on the combined system; while on the flatter portions of the area the separate system is adopted on similar lines to that used in Melbourne. The surface water flows through its own channels into the harbour.

In time a good many of the present sewers on the hilly portion will have to be retained for stormwater only, and the stormwater provisions all over the district will require to be considerably extended; but, for the present, the financial restrictions of the Board, which forbid a greater rate than one shilling in the pound, prevent the possibility of providing for stormwater to the full extent that is adopted in such large cities as Paris, New York, and Melbourne. What is being done in Dunedin is to make the sewers on the same basis as Sydney, capable of carrying off a rainfall of from two to three inches in the twenty-four hours; and constructing as large stormwater sewers in addition as will relieve the inhabitants from the frequent floodings which in certain districts have been such as to convert large areas into swamps during weeks and sometimes months at a time. The construction of large sewers, such as those which are now being built in New York and Brooklyn capable of taking stormwater up to two inches in one hour, would at present be extravagantly absurd, but may possibly, with changed conditions and increase in density and values, be some day within the region of practical politics.

A difficulty which will suggest itself is that, by constructing the sewers as they are at present being made on the flat portions of the district, of six times the capacity, the ordinary flow would be quite insufficient to give self-cleansing velocities. The means, however, of obviating this difficulty are being carefully worked out in the case of each individual branch. In the case of the main intercepting sewer and the St. Kilda main sewer no difficulty will arise, seeing that the level of these sewers places them within the range of the pumping operations, and as the capacity of any one of the pumps will be three times the average sewage flow, it will be seen that the pumps must work intermittently. Thus, for a total sewage discharge at the rate of four and a half million gallons a day, one pump would be required to work twice in the twenty-four hours for an aggregate of eight hours' pumping out of the twenty-four, and, instead of the main sewers flowing with only one-sixth of their full capacity, while the pump is running, the sewer will discharge with an average flow of one-half of its full capacity; and for a portion of this time, say the first half-hour after starting the pumps, the greater part of these sewers will be discharging at very nearly their full capacity, because the sewage will during the period of rest have
backed up into the feeding branches. In the feeding branches, in most cases, the rainfall can be relied upon to give a sufficient scour at least once a month, the district being exceptionally favoured in rainfall.

The records from 1868 show that probably no three consecutive months have yet passed without a rainfall of one-eighth of an inch in twenty-four hours. In two or three cases, however, it will be necessary to introduce flushing tanks, and in other cases provision is made for introducing the natural flow of the rivers and creeks.

The peculiar difficulty in giving effect to this policy is found from the fact that a very large area is built over with the ground floor of the houses only a few inches above high-tide, and in many cases the back yards are no higher than the highest recorded tide-level. Consequently, if the ordinary method of a diversion weir, whereby the ordinary fine weather flow of the sewers is entirely diverted into the intercepting sewer, and the stormwater flows over a weir, were adopted, the result would be that in flood time the great increase in the "head" of the water discharging from the hills would be such that, even with the pumps working at full capacity, and keeping the level of the water at the outlet of the main intercepting sewer below the invert level into the suction well, the hydraulic head would be such that, in the low parts of the district, some of which are situated nearly three miles distant from the pumping-station, there would not only be no opportunity for the sewage to flow away, but for a short time the flow would actually be in the reverse direction, regurgitating back into the back yards, and out of the gullies on to the surface. To obviate this the leaping weir, as originated by the late Mr. F. La Trobe Bateman, has been adopted wherever it can be used. With this contrivance the greater the flood the less the quantity of water that will find its way into the sewer. At other places, where this device is not used, such contrivances as removable stop planks are provided; while in one case, by the stormwater overflow discharging on to the St. Clair Beach, provision is made to enable a great portion of the hilly district, which up to now has not been sewered, to be treated on the separate system, as is done in Melbourne and in most cities in these colonies, and in States where water-carriage sewerage provision has been made.

Sufficient has, I think, been said to show how difficult and highly technical have been the questions of policy which have had to be decided, and these have been further complicated by the necessity to provide a modus vivendi during the carrying out of the works. Such difficulties as the following having had to be provided for: the St. Clair intercepting stormwater channel described on page 142 being independent from the rest of the work, and being a work which would bring an immediate bene-
DUNEDIN DRAINAGE AND SEWERAGE.

fit to a large and influential area, was naturally among the first of the works ordered to be carried out. If now this work were finished before the completion of the sewerage system, the sewage which at present finds its way into the natural water channels, and for which even now but little provision has been made by branch sewers, would become exceedingly offensive, since the natural water-flow in these channels would entirely be cut off, and the undiluted sewage be left there to stagnate. What has been done therefore has been to only partially use this intercepting sewer for stormwater, and, to a considerable extent, to divert sewage also into it, which will ultimately be carried into the main sewers.

From regard to the extremely complex and difficult nature of the problem involved it is in no way surprising that there has been extreme difficulty with a Board consisting entirely of laymen, and great credit is due to the various members of the Board for the unremitting attention they have given to the matter and all the points which I have tried to elaborate. Now, however, that the work is well under way and portions of it have come into operation, there will be less labour, and the members of the Board should have little difficulty in agreeing and intelligently adhering to the lines of policy they may adopt.

2.—ENGINEERING DETAILS OF THE WORK

The earliest of the works which had to be carried out was the repair of the old sewers. In two different classes of work these had failed: in one, where the sewers had been constructed in soft mud, insufficient provision had been made for the thrust of the arched cover, with the result that in many cases the arches had come down and were threatening to collapse. The arches were replaced by covers of a cheap reinforced concrete construction. The other class of failure was due to the sewers in the steep ground being constructed so that too great a velocity in flood time caused the inverts to be knocked to pieces. This difficulty was remedied by adopting a series of drops, and paving the bottom with the hardest procurable Diorite pitchers.

Stormwater Outlets.—Where these were made into the ocean special provision was necessary to prevent the waves from washing into the sewers and meeting the land water, causing a water hammer effect. One example, on a boulder beach, has been constructed of cone-shape, with a ventilating opening at the top to prevent the entrapping of air, and heavily strengthened on the shore side over the mouth of the tunnel where it discharges into it. In the choice of sites, so as to prevent the outlets being blocked by boulders which the waves everywhere pile round any obstruction on the coast, it is necessary to either discharge, as in the case of these stormwater outlets, at a level of two or three feet above highest tide-level, or else to discharge (as is
now proposed at the sewer outlet) by a submerged orifice. Most of the stormwater outlets discharging into the harbour, all of which are below high-water mark, are being protected by a semi-circular wall in front of the discharge, and within this wall is hung a flood-gate, which prevents seaweed and harbour deposit finding its way in at high-tide; and in case of the wooden overflows from the plain intercepting sewer being left open, prevents sea-water from flowing back up the stormwater channel and into the main intercepting sewer.

Detritus Tanks.—To facilitate precipitation, and also cleaning out, these tanks have been made with conical bottoms. To prevent the formation of upward currents, in addition to the ordinary radial spreaders for the water at entry, and catching trays at the surface on the parallel system, interlaced bamboo grids are placed horizontally. The most novel appliance introduced, however, is the detritus elevator. This appliance is fitted with six nozzles, which are connected with the city water supply, and when the water is turned on, these nozzles flush out the conical bottom by discharging six jets radially along it. After the detritus is well flushed out by this action the ejector nozzle is turned on, and the material, at the consistency of pea soup, is ejected into the sewer, from whence it flows to the pumping-station, and so the solids which otherwise would find their way into the harbour through the stormwater outlets, are caught in these detritus tanks, and are periodically flushed out into the main sewer and pumped with the sewage to the ocean.

Fig. 1.—Detritus Intercepting and Treating Tank.
Sewers in the Hilly Districts.—As explained above, these are mainly on the combined principle. In some cases the stormwater channel is constructed over the sewer. The sewer, which is a 15 in. pipe, is set in a bed of concrete, and the concrete is carried up so as to form the invert of the stormwater drain above the sewer. In other cases the sewer is simply diverted from its old channel in the natural watercourse, that being left as it was before. One of the great difficulties in places like this lies in the fact that such natural watercourses are often situated in private property, and the owners seeing that the ordinary flow has been diverted assume that they are at liberty to level up the old watercourse, with the result that when an exceptional storm comes down they are “inconvenienced.”

Sewers on the Flat.—In sharp contradistinction to the hilly district comes the large flat area which lies at the foot of the hills, and which over nearly three square miles in extent has a dead level of only a few inches above ordinary springtide level. This portion of the district is not only unusually difficult for sewerage because all sewer gradients must be obtained artificially, but because the subsoil consists of fluid mud. So fluid is this mud that in places the workmen have to stand on planks in the excavation to prevent their sinking in the soft bottom. It is only within the last twenty-three or twenty-four years that any buildings were erected on this area, and the work of reclaiming it from a morass was then undertaken; but large areas of it remained unbuilt over until two or three years ago. Since the Board’s operations, however, public confidence in the ability of the Board to prevent serious flooding of this district has resulted in a considerable population taking up and occupying these areas.

It will be quite obvious that in dealing with such an area the sewerage must be on the separate system, unless very extensive pumping provision is made. Consequently over almost the whole of this area the present surface or shallow sewers will be retained for dealing with stormwater. As, however, these drains can only discharge into the harbour during a few hours at low tide, the intention is to utilise the pumping machinery of the Board, when the tide is up, for giving a relief to flood water, and consequently while the sewers proper are intended to only take sewage from dwellings and stables, certain places are left on the main intercepting sewer where the stormwater drainage can at will be turned into this main sewer and pumped to the ocean. The organisation for properly and intelligently using this provision is not yet complete, but something has been done in the last flood to give this relief, and also a start has been made on the new method of keeping the stormwater drains cleansed by the greater velocity which can be obtained in them when they are discharging into the main intercepting sewer.
The first condition, of course, for bringing this system into vogue was that the outlets should be so constructed with tidal flaps that the salt water would not find its way into the main intercepting sewer. About half these flaps have been constructed to date, and most of the connections between the storm-water drains and the main intercepting sewer have been made by means of wooden stop planks.

Details of Construction.—Where these sewers are in such treacherous ground, it has been necessary to prepare a bed of macadam, somewhat similar to a railway permanent way, to carry the sewer, and owing to the very heavy nature of the ground it has often been necessary to work day and night continuously, and to get the ground covered in as soon as possible. Where, owing to broken weather or any other cause, delay has been occasioned, the nature of the ground has been such that the fluid pressure has gradually increased, so that anything less than 3 in. blue-gum sheeting, supported by walings every 3 ft., has proved unable to carry the weight, and the walings, which are strutted every 6 ft. 6 in., have had to be increased to 9 in. x 6 in. section, and even at that, only the best blue-gum has sufficed. To prevent delay, the only construction which could be used is Monier pipe construction. Where the ground has been favourable for rapid work, as much as 514 ft. 1 in. of those pipes have been laid in one fortnight, working on a single shift. In double shift and continuous work, however, owing to the difficulties of organising and supervising night work, and the fact that this class of work is only undertaken where the ground is exceptionally difficult and requires heavy packing, no records have been made, and the maximum for the fortnight under such conditions is about 25 per cent. below that given above.

With reference to the use of macadam in the bed, great care has to be taken to put in frequent check walls of concrete, as otherwise the discharge of water, which would run through this macadam like a “French drain,” would tend to undermine the macadam and cause the formation to collapse. My practice is to place one of these stops every 80 ft. and carry the concrete to a depth of 2 ft. 6 in. below the bottom of the macadam formation.

The macadam is always prepared for the pipes by being covered with concrete, and well bedded in this formation are 8 in. x 3 in. Jarrah sleepers, which extend across the trench from sheeting to sheeting and are rigidly held in place by the pressure on the sheeting transmitted to them by the walings. This bottom portion of sheeting and the bottom length of walings are permanently left in the work, and the level of the invert of the sewer is got by wedging up from longitudinals laid on these sleepers. The Monier pipe is then bedded flush in compo. and surrounded to the level of the haunch of the arch (say 9 in.
above the horizontal diameter) in 7 to 1 concrete, which completely fills the cavity between the pipe and the side sheeting of the excavation.

Where the sheeting of the main outfall sewer (Fig. 4) passes through running sand, there was, of course, very much less difficulty than with the fluid mud which has just been described. It was an unlucky circumstance that all the trial shafts (four in number) sunk in this ground happened on the best portion, and consequently the costliness of this work was greatly underestimated. This is a good example of how unsafe it is to rely on the result of bores, because the four shafts which were sunk in this flat ground were supplemented by over a hundred 3 in. diameter trial bores. The only practical information which was obtained from these bores was the location of some rocky dykes, and the position of some running sand. From these, however, the best location for the pumping station was chosen, and the pumping station is situated on the rocky dyke most remote from the city, so as to shorten the length of the rising main as much as possible. The length of the main intercepting sewer from where it takes in the furthest main sewer, viz., the Frederick Street sewer, which serves the extreme north of the city and the suburbs of Maori Hill and North-east Valley, is two and three-quarter miles, and it gradually increases from 3 ft. in diameter to 5 ft. 6 in. in diameter, the grade falling from 1 in 1200 to 1 in 3000 over the last seven furlongs, and finishing in a pumping well, where a drop of 2 ft. to augment the discharge to this flat portion is given. The level of the suction for the pumps—i.e., the lowest level from which water can be pumped—is 19 ft. below high tide level of ordinary spring tides, and the average depth of this main intercepting sewer from the surface is about 18 ft.

All the old sewers passed in the course of this main intercepting sewer are at a level which enables it to pass entirely underneath them, and one of the most important features of the scheme is the retention of these old sewers for carrying off the storm-water discharges from the hilly portion of the district. In four cases this is done by the device of a leaping weir, the sewage falling through an opening in the invert into the intercepting sewer. These, however, are not placed immediately over the main intercepting sewer, because to work satisfactorily they must be placed above the tidal influence, that is to say, 3 ft. or 4 ft. higher up in level than the highest tide level, where the gradient and circumstance of the sewer are such that at all hours and states of the tide a sufficient velocity during flood time can be obtained to enable heavy floods to leap over this hopper arrangement. In consequence of this requirement these leaping weirs are placed at a considerable distance higher up the main sewers than where they pass over the main intercepting
sewer. At other places where these circumstances cannot be obtained without interfering with the general policy outlined above, the ordinary diversion weir is used.

Various modifications of diversion weir have been adopted in some cases, such as the new storm-water discharge which has been made from Caversham Hills to St. Clair; the old sewers are simply restricted in area, and when the stormwater causes them to discharge under pressure an overflow is provided into the stormwater drain.

Pumping Station.—The very imposing front which has been erected to this station (Fig. 2) has been subjected to considerable criticism on the grounds of extravagance, but in point of fact the total expenditure on architectural embellishments out of £21,000—which is the cost of this station, including machinery, suction well, etc.—is only about £300. The handsome style of classical architecture is rendered possible by the use of Diessel engines, which do not require the ordinary chimney, and which give off no smoke to blacken the precincts. The cheapness of the ornamentation is due to the adoption of modern reinforced concrete methods, which enable classic ornaments—which could otherwise only be made with the finest marble or granite in immense blocks—to be constructed of ordinary cheap concrete. The ground on which this pumping station is placed is a little over four acres in extent, and is being fenced by a handsome iron lattice-work fence and protected by a holly hedge, so that this pumping station should form one of the handsome garden reserves of the district. It is at least due to the Drainage Board, which will spend a vast sum of money underground, that the portion of its work which is exposed to view should bear for public opinion some relation to the other solid and expensive work which it represents.

Rising Mains and Outfalls.—So far-reaching and ambitious a drainage scheme would only have been within the limits of the present means of the district by the adoption of every possible economy in construction. In no way will the economies adopted be better appreciated than by the methods adopted to make a double-deck sewer serve for the stormwater outfall and the sewage outfall; the level of the latter being 4 ft. above the level of the former (Fig. 3).

Again, in the case of the rising mains, two in number, and each of 3 ft. diameter internal capacity, are 1700 ft. long. These (Fig. 5) have been constructed as follows:

The sewer rising main is of Jarrah timber, with the joints carefully planed and caulked, while the stormwater rising main is of ironbark timber, also carefully caulked; these are surrounded by a wool-felt and 4 in. of concrete. The reason for this latter precaution was that in accordance with law it was necessary that any sewer passing through private ground should
DUNEDIN DRAINAGE AND SEWERAGE.

Fig. 2.—Pumping Station during Erection.

Fig. 3.—Combined Sewer.
Fig. 4.—Cutting for Main Outfall Sewer in Sand.

Fig. 5.—Rising Mains.
be constructed of masonry material. The reason for placing wool-felt between the wooden pipes and its concrete casing was that it was feared that the wood might expand so much on being saturated that it would burst its iron bands and break the concrete. These mains have now been in operation continuously for more than four months, and there has been no sign of any such accident, consequently there is little doubt but that the oakum caulking and the wool-felt have sufficed by their compression to take up any expansion which may have occurred in the timber.

The success experienced with these timber rising mains induced an experiment to be tried by using timber pipes instead of Monier construction in the St. Kilda 3 ft. diameter main sewer, and some 500 ft. of this construction was made. It was, however, found that that mode was not only 50 per cent. more expensive than the Monier pipe construction, but had a serious objection in being so light that in the fluid mud it required a heavy weighting down by concrete surrounding and covering to prevent its rising by its own flotation. In point of fact a length of about 100 ft. of it rose from 18 in. to 2 ft. out of level, and had to be taken up and replaced at a cost of some £700. Roughly speaking, the average cost of this 3 ft. diameter sewer, which was about 19 ft. 6 in. deep, was £4 per running foot, exclusive of the replacement mentioned above; while the 5 ft. 6 in. diameter main intercepting sewer running through exactly the same ground, cost about £5 5s. per running foot, and a 30 in. diameter sewer in Monier work, under practically the same conditions as this 3 ft. diameter wooden sewer, cost an average of about £2 10s.

Existing Sewer Appliances.—The water carriage sewerage system had been anticipated in Dunedin to the extent of upwards of 3000 houses, the majority of which discharge solid sewage matter into the stormwater sewers, and thence into the harbour, but to a very large extent septic tanks have been used. The experience with these has been quite satisfactory as far as liquefaction of solids is concerned. Unfortunately, however, the bacterial filters give continual trouble. Where the "Exeter System" has been adopted the parties in charge have not appreciated the necessity of keeping the mechanism in good working order. The result is that the Dunedin experience of the magic of the septic tank corresponds with that of those authorities who speak sceptically of this magic as "black magic," and some of the Dunedin contractors have dubbed the system the "Sceptic tank system." At the same time the experience is quite sufficient to show the very great value of the system for places where land is too expensive for the establishment of a sewage farm, or where, as in Dunedin, the water-courses are too limited and the people are too civilised to tolerate sludge treatment methods.
The existence of so extensive a water carriage system of sewerage in the district has proved a very great inconvenience and a heavy handicap in the carrying out of the new system. In the first instance, it was impossible to ignore the existing conditions, and from the outset my attention was distracted from the large works I had in hand, and my labour greatly increased, by the necessity of keeping a close supervision over all the sanitary work in progress in connection with the ordinary building operations of the district. How much attention this involved may be gathered from the fact that during the last two years the number of notifications to be dealt with have increased from a rate of about 550 to over 700 per annum. As a somewhat similar condition existed in the case of Sydney, the by-laws used by the Sydney Water Supply and Sewerage Board were adopted for use in Dunedin with some slight variations. However, it would seem that Sydney builders have the critical faculty less keenly developed than their brethren in Dunedin. In any case, these by-laws required very careful administration, and were the source of so much difficulty that we have had to carefully draft entirely new by-laws based on the experience of the last three years. In these I have been careful to avoid confusion by recommending separate by-laws to embody:

1. Drainage questions.
2. Sewage questions.
3. Statutory powers and legal questions.

The Diesell Engines and Centrifugal Pumps.—Within the compass of the present paper I cannot hope to do justice to this novel and important feature of the work. I would, however, mention that the only feature in these engines which, after four months' continuous use, I would be prepared to criticise, is the location of the air compressor attached to the back of the engine. To my mind, the arrangement of taking the power for so vital a adjunct as the air compressor from the crank shaft is likely to at some time give trouble.

I am thankful to say that the Board has provided means that enable me to make the most accurate tests, both of the engines and of the pumps. For the former, as I have already mentioned, a Froude friction brake is provided; and for the latter it is possible to measure, by mercury gauges, both the suction and the head on the pumps. As to capacity, this, of course, can only be inferred from the sewer velocities. The proximity of manholes will enable these to be determined with accuracy.

For determining invert velocities, I have had a set of balls made from ironbark, which is slightly heavier than sewage. These are caught on a net at the outlet of the main sewer into the suction well. So far, however, the main sewer has not been
Sufficiently completed to get enough water to give a continuous flow of sufficient duration for the purposes of reliable velocity tests. But the discharge with sewage occupying from one-third to one-half of the area of the main intercepting sewer has been carefully investigated, and gives a result about two per cent. better than Kutter's formula, giving a co-efficient of roughness equal to .011. It must be remembered that this sewer, though constructed of Monier, has been constructed on the French style, which gives a much rougher internal surface than the Austrian or "Wayss" system adopted in Australia.

**NOTE I.**

**Comparison between sewer capacity for sewage on the separate system, and sewer capacity for the combined system; if the latter is to take the maximum possible rainfall.**

Separate System.—On an average, the maximum dry weather flow of the sewage from the most densely peopled part of the district is about 120 cubic feet per hour from each acre built over. Adding 25 per cent. for contingencies, this may be taken as the discharge which branch sewers for the separate system should be calculated for, or, say, 150 c. ft. per minute per acre of thickly populated ground.

The maximum recorded rainfall has been about 4.6 inches in twenty-four hours. Hourly records have only been taken during the last three years, and consequently the maximum hourly rainfall can only be computed in regard to what it is in parts of Great Britain and America, where similar weather conditions prevail. On this basis it is possible that 1 1/2 inches may fall in one hour. As portions of Dunedin are extremely steep, and as heavy rainfalls are often preceded by long periods of wet weather, it is possible that nearly 90 per cent. of this hourly rainfall may find its way into the sewers from certain districts. Consequently the capacity of the branch sewers on the combined system should exceed the capacity on the separate system by a flow equal to 1 1-3 inches of rainfall from the area served.

This, over one acre, will give 4840 c. ft. per second; and as there is at least 25 per cent. unoccupied area in each branch sewer district, this capacity must, for comparison with the separate system sewer, be increased by 25 per cent., or the 4840 becomes 6050 c. ft. per minute. The comparison, then, between the size of branch sewers under the two systems will be as 6200 c. ft. per minute is to 150 c. ft. per minute; or the one would require to be forty-one times the other.

On deciding to limit the combined capacity to little over one-seventh part of this calculated maximum capacity, regard was paid to the recorded rainfalls, which made it appear that it was unlikely that the stormwater capacity of the sewers would be
overtaxed, at the utmost, more than five or six times during the year, and then only to a very slight extent. Several sewers and drains, serving on the aggregate nearly 400 acres, made on this basis have now been in operation for about one and a half years, and only on one occasion has any overflow from any of them been noticed, viz., on September 2, 1905; rainfalls of nearly half an inch have been recorded, which have not overtaxed the sewers.

NOTE II.

ON TOTAL CAPACITY OF THE MAIN SEWERS.

The maximum capacity of the main sewers is limited by the capacity of the pumps, because all main sewers are made capable of carrying water under pressure, and when they are overflowing at the stormwater relief overflows, the quantity of water which they will abstract is strictly limited by the capacity of the pumps. Thus, assume the main intercepting sewer to be headed up by stormwater to such an extent that the main overflow, which is approximately two miles distant from the pumping station, is acting, and neglecting the minor branches which it receives between that point and the suction well at the pumping station. Now the level of the main overflow is about 14 ft. above the level of the sewer where it discharges into the suction well; consequently the maximum discharge of this sewer, if the pumping engines were able to take it, would be that calculated from an hydraulic head of 14 ft. in two miles. This would give a discharge of about 36,000,000 gallons a day. As there are at present two other main sewers to be served, the present capacity of the pumps will not suffice to take this limit, and consequently what will happen is that the water will rise in the suction well to such a level that the capacity of the pumps and the discharge of the sewer will balance.

NOTE III.

ON THE CAPACITY OF THE PUMPS.

From previous experience elsewhere, I was satisfied that centrifugal pumps properly designed will adapt themselves to a very great variation of head, and consequently variation of speed, without any such fall in mechanical efficiency as would prevent their economical use in the case of occasional flood conditions, and consequently I specified for the service here three centrifugal pumps designed to work at best advantage under a head of 26 ft., and at that to discharge not less than 1400 c. ft. per minute—say twelve and a half million gallons per diem each—and when raising the water 18 ft. (the minimum possible) to have a discharge capacity of eighteen and a half million gallons per diem each.
The pumping station has been designed to accommodate four such pumps. In the meantime three have been installed, and two have been attached direct to Diessel engines; the third will shortly be fitted with a 100 kilo. electric motor, and will be driven through a variable speed-belt drive. It will be seen that as at present laid down, so soon as the electric motor is installed, the gross capacity of the pumps will be about 55,000,000 gallons a day.

NOTE IV.

The Ultimate Capacity of the System.

It will always be expedient to retain one pump and motor as a standby; consequently the ultimate capacity of the pumping station may be taken as the capacity of three out of the four pumps which it will contain. This means an ordinary sewage discharge capacity of thirty-seven and a half million gallons, working continuously throughout the twenty-four hours. But owing to the fluctuations which are experienced in sewers, even after allowing for the large storage capacity of the main sewers, which will allow of a fluctuation of two and a half million gallons, this will probably mean about twenty-four million gallons of sewage as the maximum daily capacity of the station. When all four pumps are installed, their total capacity for stormwater discharge will exceed that of the sewers which feed them, and will be equivalent to the maximum possible capacity of the outfalls into which their rising mains discharge (these capacities are 14 and 46 million gallons respectively), namely, about 60 million gallons in twenty-four hours. It has been suggested that the rising mains (which are two, of only 3 ft. diameter) should be increased to give these pumps an opportunity of assisting the stormwater discharges to a greater extent than they do at present. Such a step would require also the increase of the capacity of the outfall sewers. In the meantime, the additional head due to increased friction when all pumps are discharging at the same time through the two rising mains, will reduce this maximum capacity and suffice to prevent the pumps from discharging more than the outfall sewers can accommodate. I mention this to illustrate one of the weak points in providing a large margin of power; because nothing is more likely than that some future engineer in charge of these works might strive to obtain the full advantage of all the pumps for use in flood times, without taking the precaution to check all the calculations of sewer discharge, and the result of the “improvement” would be that the main outfall sewers would be blown up, since they are only constructed to carry a pressure due to a water head of about three feet above the level of the reinforced concrete cover of the upper sewer. Such an accident might be attended by very serious consequences.
The system will be, if left alone, as far as possible free from any complications, and all mechanisms have been designed to be "fool proof," but owing to the unusual features of much which it contains, it will be obvious that it is a system that will not admit of tampering with, or altering, except by an engineer who fully understands and appreciates its limitations. And, unfortunately, its apparent simplicity will always prove a trap to tempt the superficial to make "improvements." Thus nothing could be simpler, nor more usual than the precaution of the extra or standby pump, and at the same time no contrivance has given rise to more trouble from a similar abuse to that I have here anticipated. The rising mains have been made with a large margin of power, so that no danger need be feared from them, as they now are, in case anyone should incautiously try to run four pumps simultaneously; and the extra friction head due to the increased velocity of the discharge through them will so operate against the pumps that in no case will they be capable of discharging more than the total of sixty million gallons rate, which is the practical limit of the outfall sewers into which they discharge.

NOTE V. ADDITIONAL COST OF PUMPING RAINFALL ALONG WITH SEWAGE

One of the arguments raised against this system was, that the cost of pumping the rainfall would be excessive. The total rainfall of the hilly part of the district is about 36 inches in the year, while that of the flat portion is probably less than 30 inches in the year. It is therefore quite safe to assume that not more than 18 inches on the area served by the sewers will even be pumped in the year.

On the completion of the scheme, as being carried out, an area of about 2500 acres will be served, and this area will carry a population of about 56,000 people, discharging into the sewers about four and a half million gallons of sewage daily, or, say, 1600 million gallons a year.

If the whole 18 inches of rainfall estimated were to find its way from this area at the same time it would increase this discharge to 2600 million gallons.

If it be conceded that the large size of sewers, etc., is warranted from other considerations, then the chief increase in the cost of pumping this additional rain water is the fuel consumed by the engines, because almost every other item is either insignificant, or else uninfluenced by the duration of pumping.

This cost of oil has been shown to approximate one farthing per horse-power per hour, and after allowing for all contingencies, such as efficiency of pumps, would be equivalent to one halfpenny per pump horse-power per hour. This, on a basis of 26 ft. lift, costs approximately 5s. 6d. per million gallons, or an
increase in the annual fuel bill of from £440 to £715. This addition of £275 per annum is obviously inconsiderable in so large a scheme, and with such large interests depending on the system adopted.

NOTE VI.

THE BOARD'S FINANCIAL POSITION

As compared with most cities, Dunedin has a less value for rating power, and consequently the rate must be heavier, owing to the very socialistic and modern policy of municipal and State ownership having here exempted from rating what would elsewhere be heavy ratepaying enterprises for a Drainage and Sewerage Board; these include the following: gasworks, tramways, power installations, telephones, Government railways, Government insurances (both fire and life), schools, and the harbour works, sheds, etc.

The following table will show the extent to which the municipality of Dunedin City, which represents about three-quarters of the population of the district, has entered into socialistic enterprises:

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total municipal loan</td>
<td>£294,225</td>
</tr>
<tr>
<td>Total water loans</td>
<td>£278,100</td>
</tr>
<tr>
<td>Total gas loan</td>
<td>£100,000</td>
</tr>
<tr>
<td>Total abattoir loan</td>
<td>£11,000</td>
</tr>
<tr>
<td>Total tramways loan</td>
<td>£300,000</td>
</tr>
<tr>
<td>Total Waipori (power distribution loan)</td>
<td>£72,500</td>
</tr>
</tbody>
</table>

Towards the extinction of this, sinking funds have accumulated to the extent of about £230,000.

Leaving a net indebtedness of, say £825,000. All of these earning ventures, except the first, are on a paying basis. Consequently it will be seen that so long as the administration of its earning ventures is in the hands of similar long-headed gentlemen to those who have represented Dunedin in the past, the position of the district is singularly sound. Thus the nett debt for the non-revenue earning portion, after deducting its proportion of sinking funds, is only £178,000.

To which will have to be added for drainage and sewerage works 300,000.

And for unremunerative works in municipalities of St. Kilda, Mornington, North-East Valley, and Maori Hill 30,000.

And the total nett indebtedness will be £508,000.

* A further provision of £25,000 for advances to householders for house connection work is, of course, excluded from this figure.
Whereas the total annual rateable value within the same district is nearly £500,000, so that the total loan commitment of the district has hardly yet exceeded half of the recognised standard, namely, two years' annual valuation.

To return, however, to the drainage and sewerage rate. The following is the rate as struck last year:

- £209,769—Properties connected to sewers, at 6d. £5,233 19 6
- £229,150—Properties drained, but not sewered, at 4d. 3,819 3 4
- £7,570—Properties to be drained shortly, at 2d. 63 1 8

£9,116 4 6

The last estimate of revenue and expenditure to be met next year was as follows:

**Revenue.**

City (including Caversham)—
- £285,000, at 10d. £11,875 0 0
- £50,000, at 4d. 833 6 8
- £14,000, at 2d. 116 13 4

Other suburbs—
- £84,000, at 10d. 3,500 0 0
- £16,000, at 4d. 262 13 4
- £42,000, at 2d. 350 0 0

£16,937 13 4

**Expenditure.**

Interest on capital, £200,000, at 4½ per cent. £9,000
Interest on value of drains taken over, £40,000, at 4 per cent. 1,600
Amortisation and maintenance 1,270
Pumping station charges 1,280
Office expenses 1,250
Stationery, legal, travelling, etc. 350
Sewer cleaning 300
Sewer replacing 800
Inspectors and draughtsman 580

£16,430
NOTE VII.

Best Theoretical Efficiency obtained by the Diesel Engines on their Trials

In developing one brake horse-power (Froude brake), the No. 1 engine used .397 lbs. of oil per hour with a calorific value of 19,300 B.T.U. per lb. Taking Joule's equivalent as one B.T.U. = 780 ft. pounds on the Froude brake, this would give the following efficiency:

\[
\text{One horse-power for one hour} = \frac{1,980,000}{19,300 \times 0.397 \times 780} = 5,976,438
\]

or one-third, very nearly, of the heat of the fuel is turned to actual work on the engine shaft.

Efficiency on Basis of Indicated Horse Power.

As the usual mode of expressing the efficiency of an engine is by fuel consumption per indicated horse-power, and as the Froude brake is only used on rare occasions, and chiefly to determine the economic value of the fuels offered, the following average figures taken from random indications during ordinary running may be taken:

I.H.P. = 165.
Fuel consumption, about 53.5 lbs. per hour.

This gives an efficiency of about 40 per cent., and at the Dunedin delivered price of the oil (8d. per gallon) costs for fuel 4s. per hour, so that the fuel cost is about one farthing per horse-power per hour. Cheaper crude oils may be got for half this price in Australia, but heavy oil in New Zealand is subject to a duty of 6d. per gallon.

NOTE VIII.

Cost of Scheme to Date, Chargeable Against Loan Account

The following are approximately the expenditures on the different items of work to date:

1. Preparing house to house plan of district. (say) £2,500
5. Pumping station, including rising mains (say) £26,000
6. Main intercepting sewer, to date £27,000
7. Branch sewers £19,000
7a. Ditto., incomplete £5,000
8. Stormwater channels, including two de-tritus tanks, and sundry minor works £14,000
9. Minor branch and reticulation sewers £16,000
10. Replacing old stormwater drains £3,000
11. Plant acquisition £8,000
12. Engineering, clerical, and sundry £12,000
13. Expenditure not yet allocated between loan and maintenance £6,000

£160,000

Since then, a further loan of £100,000 has been authorised, so that by the year 1907, or 1908 at latest, the interest on this—say £4,500—will have to be met. This will increase the expenditure to about £21,000, which it will be seen can be about met by rates of 1s., 6d., and 2d., with small fees to repay the salaries of inspectors.

NOTE IX.

MISCELLANEOUS PRACTICAL HINTS.

The following practical points were evolved from trial during the progress of the work:

1st. To prevent the well-known damage which results from sea water permeating concrete. The best way is to sheet the cement—by making the lagging water-tight that the sea water will have no opportunity of coming in contact with the concrete until long after it has set and become sufficiently mature to resist changes which probably only occur during the period of setting. In two cases where this precaution was not taken—one just beside the work just referred to, and the other where concrete was exposed to sewage within six days of its being placed in situ—a large part of the mass was some months subsequently found to be quite rotten, part of the cement having been displaced by a white milky magnesium salt. Consequently, where possible, only such methods as the Monier, where the cement is well set before being laid, or brick, set in hydraulic lime, or concrete when the timber lagging can be left in, are now used by me in sewer construction for such places as the lower half of a sewer section.

2nd. Another practical point of some moment is the necessity, in connection with pumping sewerage, to provide on the rising mains ample means for the sewer gases to escape.
The ventilation provided at first for the rising main was a 6 in. ventilating shaft placed at the higher end. This was connected with each 3 ft. diameter main by a 4 in. diameter pipe. In spite of this water-hammer occurred, giving a pressure in the rising main of more than four times the normal total head. To prevent this, 2 in. pipe connections were made on the lower or pump end, and even these were found insufficient to entirely remove the trouble, and were eventually supplemented by two 3 in. F.P.S. on standpipes, situated beside a curve, about 200 ft. from the pumping station, and a set of half inch snifting valves on the valve-boxes where sewer gas could accumulate. By this means the water-hammer effect has been practically removed.

This water-hammer effect, and a slight leakage, where the timber portion of the rising main connected with the iron work have been the only disappointments experienced, and these have never delayed the pumping, or caused any appreciable inconvenience. The leakage was removed by substituting pure Portland cement grout for the asphaltum which had been used to give a water-tight collar in the first place.

3rd. A third practical wrinkle—and this is one which probably all sanitary engineers now insist on—is as follows: Where earthenware pipes of 12 in. and upwards are used they cannot be obtained of sufficiently uniform shape to entirely prevent lipping, and consequently the grades of the sewers must be made steeper than would otherwise be necessary. The best way to prevent trouble is to use studs (at least three) of stoneware, placed under the barrel of the pipe where it rests in the socket, and by careful judgment the pipelayer can, with this expedient, lay earthenware pipes free from lipping. With larger sizes Monier pipes are to be preferred, and much flatter grades can be obtained.

Cement pipes, made on the Kirberg principle, can be used where only stormwater and not continual sewage matter has to be dealt with.
DISCUSSION—DUNEDIN DRAINAGE AND SEWERAGE.

VISIT.

On November 9th a number of the members of the Institute, accompanied by visiting members of the Association of Gas Engineers, inspected the Melbourne and Metropolitan Board's Pumping Station at Spottiswoode, under the guidance of Mr. C. E. Oliver.

The engines are numbered from 1 to 6, and are of three types. In numbers 1 to 4 the H.P. cylinders are $16\frac{1}{4}$, the I.M. cylinders $26\frac{1}{4}$, and the L.P. cylinders 44 inches in diameter; stroke, 33 to 36 inches; average mean pressure, 26 to 27 lbs.; steam, 15 to 16 lbs. per P.H.P.; efficiency, 96%.

No. 5 engine has cylinders respectively 20, 36, and 51 inches in diameter, by 42 inches stroke; average mean pressure, 24.6 lbs.; steam per P.H.P., 13.3 lbs.; efficiency, 93%.

No. 6 engine has cylinders of 21, 37\(\frac{1}{4}\), and 57 inches diameter, by 36 inches stroke; average mean pressure, 22 lbs.; steam per P.H.P., 14.1; efficiency, 95%.

The lift is 126 feet, and the cost of raising 1000 gallons 100 feet is, including all charges save interest, 0 31d.

The President (Mr. Geo. A. Turner), after the inspection, tendered the thanks of the Institute to Mr. Oliver for the invitation he had accorded members, and for his and Mr. Robertson Smith’s (Resident Engineer) courtesy during the visit.

Mr. R. O. Thompson, on behalf of the Gas Engineers, concurred.

Mr. Turner said that it was at all times a pleasure for engineers to see expensive and highly-efficient machinery, especially when cared for in the manner of that just viewed. The cleanliness, smoothness of working, and perfect repair were marked, in view of the constant service required. The perfect pumping engine had yet to be invented, but in the case of some later designs economy might be dearly bought, and it was well to wait until time had tested the matter.

On the motion of Mr. J. A. Smith, a hearty vote of thanks was accorded to Mr. W. Davidson (Chief Inspector of Public Works) for the use of a steam launch to convey members to the Station.

DISCUSSION.

The President, in continuing the discussion of Mr. J. T. Noble Anderson’s paper on the “Drainage and Sewerage of Dunedin,” said the paper was a valuable one. Mr. Anderson was to be congratulated upon the success he had accomplished. The town was especially difficult to deal with, and he had reason to know that in the initiation of the scheme unusual opposition had to be met. With reference to the detritus tanks, he had had considerable experience of their use in sugar refining, and could corroborate Mr. Anderson as to the amount of solids they removed. They should be especially useful when the solids could not be run into the sea.
Mr. Anderson's adoption of the oil engine was, he thought, a step in the right direction, although it might seem peculiar to some, as it had been stated that valuable coal seams were being opened up in the vicinity. The figures given for the Diessel engines corresponded very closely with English results, and denoted that some 40 per cent. of the heat was utilised.

Mr. J. A. Smith said that Mr. Anderson had left with him the plans (exhibited) of the scheme, and also a book of diagrams of the oil engines. Members would recognise that these latter were extremely interesting. In connection with the pumping equipment, the overall efficiency was good, but that was due to the high efficiency of the internal combustion engines. The pumps alone, he understood, were giving about 62 per cent., and that was not high as compared with results claimed for the most modern types. Considered commercially, the combination gave a good result, but when electric motors were eventually connected to the pumps, then the efficiency would depend largely upon the latter, and it would not be so high. Mr. Anderson had said that although the head varied, his experience was that the effect on efficiency was not vital. In this particular case, when an occasional flood only had to be dealt with, doubtless this was true, but it would not hold as a general statement. A centrifugal would only give the best efficiency when worked near the limits for which it was designed.

Professor W. C. Kernot said he was in Dunedin at the time of the early struggles in this scheme, and, in fact, took part in them. There was a good deal of criticism upon Mr. Anderson's doings, and a good deal was prompted apparently by trade interests; however, he seemed to have fought his way through all the difficulties, and to have the scheme in good working order. It would be very interesting if one could visit Dunedin now and see how the thing was working. If the scheme were working well, of course the opposition would soon die. It was lucky of Mr. Anderson to put in these Diessel engines, and he had shown himself to be in the forefront of progress by adopting theoretically the most perfect engine known. Whether he used these engines or steam engines, he presumed, would not affect the finances of the scheme generally. It was an object lesson to all. The engines would be watched with interest. It was a question of economy in fuel, and it could be seen in the course of a year or two whether these Diessel engines had a good all-round economy. He did not know that he had any reason to doubt them. The pistons must be kept in splendid order. He knew of a surprise visit to test a Diessel engine. The engine had been set up and working for some time at the factory, and the owners took a surprise test of the engine as they found it, "with all its imperfections on its head." The result was very fine and encouraging. The only question was whether working at such a high pressure the maintenance was likely to be enormous. In Melbourne Mr. Thwaites had carte blanche, and he went in for a severely and extremely separate system, but Mr. Anderson had found himself in an extremely different position. He found himself in possession of a number of sewers that he could not throw away.
and which he had to utilise. Much the same thing had to be done in
London some years ago, and they had to do the best they could with
the old system in conjunction with the new. The case in a very small
way compared with the London scheme. It seemed that it was a
reasonable course for Mr. Anderson to take, and he (the speaker)
was glad to hear that everything was working satisfactorily. A great
deal of fuss was made about the sea outlet. He saw the place, and
examined it, and he thought that they were frightening themselves
unnecessarily. It seemed to him that the question of the pollution of
the sea at the outlet need not be taken into account, for some years
to come at any rate. Dunedin was magnificently situated for a sea
outfall. Mr. Anderson seemed to be very much given to putting in
armoured concrete. He would be very glad if Mr. Anderson would give
in three or four years his experience with it, and his troubles, if any.
He thought that a paper like that, when the scheme had been working
for some time, would be of very great value.

Mr. Geo. Higgins said he had only had opportunity to glance at
the paper. One or two questions might, however, throw light on
some points. An intercepting tank was provided for collecting de-
tritus, and an elevator was used to transfer it to the sewer. Now one
of the first objects in many places was to exclude detritus from the
sewer. Had Mr. Anderson allowed sufficient fall in the sewers to
enable the flow to move along the detritus? If the detritus could
only be washed by the rain, and caught in pits before reaching the
sewer, it was valuable material; but if admitted into the foul water
of the sewer, it was of no use whatever. The rock in the neighbour-
hood of Dunedin was basalt, and it was known that excellent mortar
and concrete were obtained by mixing the powdered basalt with cement
and broken gravel and stone. Was the water from the street mains
used for elevating? The south of New Zealand was the home of
hydraulic elevating, and he had seen it very successfully used on the
St. Bathan's claim and elsewhere in Central Otago in New Zealand.
As far as he could estimate, the highest lift there was about 90
feet, the head available being about 400 feet. Mr. Ewing, the
owner of St. Bathan's, first lifted the material 30 feet; then, by
another nozzle, lifted it 90 feet. He had heard that Mr. Ewing was
going to lift it in one lift, 120 feet. The question then arose, with
the comparatively small head in the city main at Mr. Anderson's dis-
posal in Dunedin, what amount of water would be added to that
already in the sewer? It would be a considerable amount, he knew,
and the cost of the water had to be considered, as well as the cost of
pumping it. The efficiency of the elevator would only be some 30
or 40 per cent. On page 133 of his paper Mr. Anderson said:
"... There was no choice between either constructing a huge
syphon (for the gravitation of such sewers as could be intercepted
at a sufficiently high-level), with a pumping system for pumping the
lower level areas at different places under pressure into this syphon,
or alternatively carrying all the sewers to one pumping station at a
considerable depth, and thence pumping the sewage." He thought
there were other possible schemes, e.g., the following: Instead
of pumping all the sewage, to send as much as possible by gravitation to the sea without a syphon. The greater part of the city of Dunedin was at a higher level than the sea. Often with the best pumping schemes that could be introduced there might be stoppages; therefore, it was better not to rely solely upon pumping.

Mr. J. A. Smith said that, presumably, the ejector was used only to create a flushing current after occasional floods. Under these circumstances the efficiency, commercially considered, might suffice.

Mr. Turner said the sewerage rate in Dunedin was lower than here. What was the reason?

Mr. Elliott said it seemed to him that the system of running a large quantity of rain water through the sewers, and then pumping it, would be more expensive than that which we had in Melbourne. He would like to know from Mr. Anderson whether he could give further information on the subject.

Mr. Clarke said he was very interested in this paper, but had not time to go into it fully. He knew Dunedin well, as he had been there for several years a few years back. The commencement of the scheme was hampered by the Harbour Board. Mr. Anderson evidently was compelled to take his sewage out to sea. Formerly Dunedin was about half-sewered, and the sewage was then carried out into the harbour. Mr. Anderson had not stated that the rise and fall of the harbour tide was considerable. He could quite understand that the discharge of the sewerage into the harbour would affect the mud flats, so there was reason for the strictness of the Harbour Board. At Douglas, in the Isle of Man, Adams' sewerage lift was used, and Dunedin was situated in a rather similar way to Douglas. Had it ever been proposed to use such an apparatus as this lift in Dunedin? He would like to hear from Mr. Anderson regarding this, as he had no doubt studied the subject fully. In Dunedin there were liberal clauses in the Act respecting trespassing on private property in sewerage operations. In Melbourne people objected very much to sewerage trespassing on their property. From remarks made in the course of Mr. Anderson's lecture, there were probably liberal clauses in the Dunedin Drainage Act respecting easements over private property required for constructing public sewers. Information on this point would be interesting. In Melbourne property owners often protested against easements being taken for sewers across their land.

**PAPER.**

**ECONOMY IN FRAMED STRUCTURES.**

Read by Professor W. C. Kernot

Framed structures are those which present to the view a series of comparatively large openings or meshes separated by relatively narrow bars or portions of solid material. They are structures, in other words, through which the wind can blow freely, and at which if a bullet were aimed from a distance, it would most likely pass through without touching any solid material. Such structures are largely used
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