THE HUNTINGTON PUMPING STATION

OF THE

SOUTH STAFFORDSHIRE WATERWORKS COMPANY.

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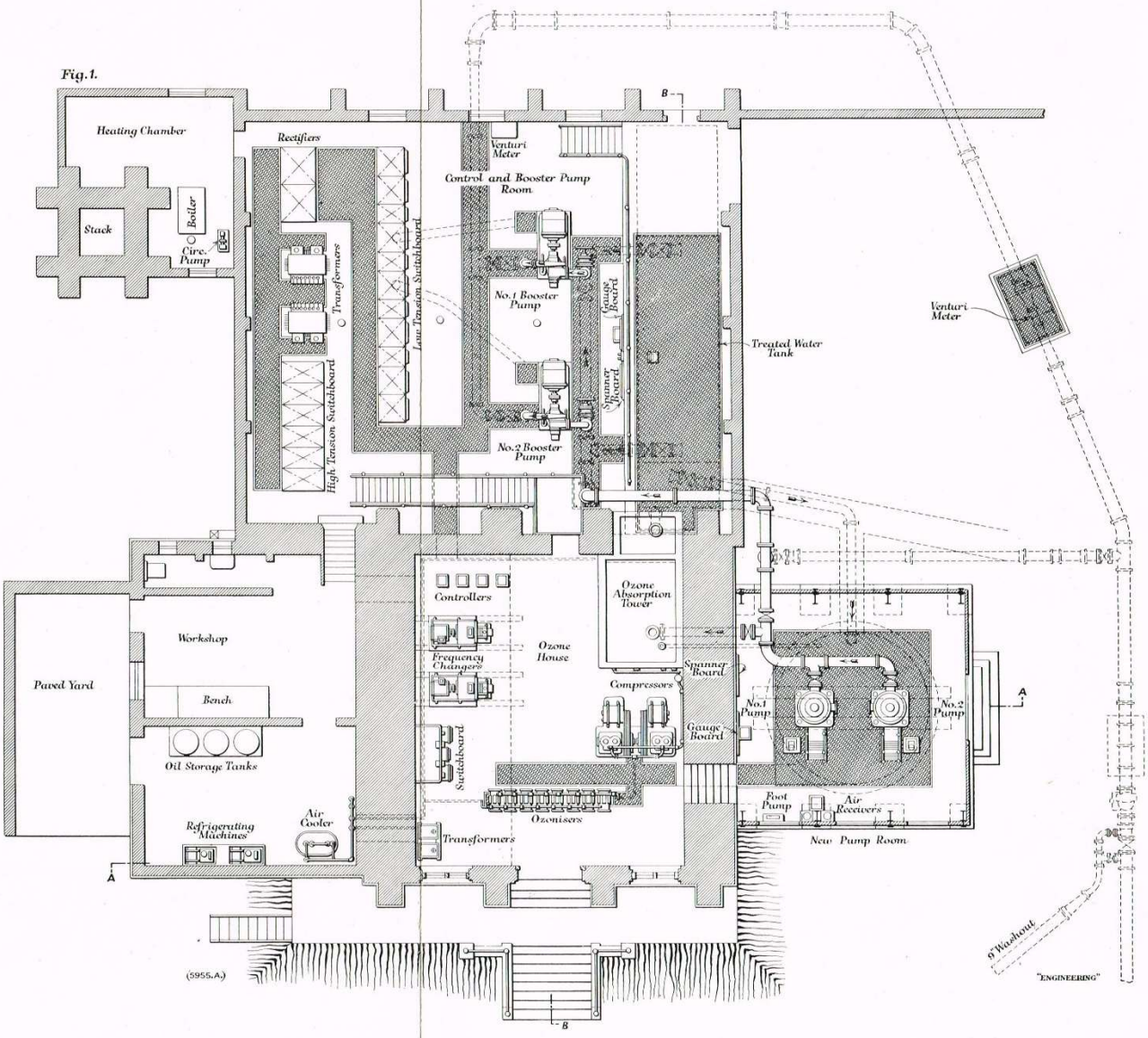
Fig. 1.



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THERE have appeared in these columns within recent years accounts of some of the pumping stations of the South Staffordshire Waterworks Company, all of them possessing an interest of their own. The description we give below of the Huntington Pumping Station deals again with a plant of individual character, as the station is a reconstruction of one which came into existence some sixty years ago, a water treatment plant also being incorporated in it. Our description is illustrated by Figs. 1 to 12 on the Plate and on the following pages, and it may be prefaced, by a brief note on the early history of the South Staffordshire Waterworks Company, which was incorporated by Act of Parliament in 1853. The original works were commenced in February, 1856, and consisted of impounding reservoirs in the Lichfield district, with a pumping station at Lichfield to deliver the water to a storage reservoir at Walsall, which supplied the immediate neighbourhood by gravitation, and also of a pumping station at Wood Green, Wednesbury. This station derived its supplies at a low pressure from Walsall reservoir and delivered the water to a reservoir at Dudley, which supplied the Black Country towns. The pumping plant at Lichfield was first brought into operation on October 26, 1858, and in 1864 the supply was extended to Burton-on-Trent.

As the company developed their area of supply, they obtained, at various times, parliamentary powers for additional works, but by 1873 the growing requirements of the company made it necessary to seek for new sources of supply. At this time, trial sinkings for coal were being made through the conglomerates at Huntington and Hednesford, and the volume of water liberated materially interfered with these operations. The company had these waters analysed, and, having found them to be admirably suited for town water supply, they decided to promote a Bill in Parliament. This provided for the construction of two pumping stations and a large storage reservoir, and was passed in 1875. The two pumping stations were to be situated at Huntington and Moors Gorse, respectively, and Scout House Reservoir, with a capacity of 42,000,000 gallons, was to be situated at Hednesford. This reservoir, it may be noted, was never wholly filled, and was finally abandoned, due to mining operations, in 1930. With the exception of the depth of the wells, the pumping plant at both stations was identical. The present account is, however, concerned only with that at Huntington. The necessary plans and specifications were prepared by the company's engineer, Mr. William Vawdrey, and in 1876 the several contracts were placed. Mr. E. Timmins, Bridgwater Foundry, Runcorn, was awarded the contract for sinking the well, which was originally 16 ft. 6 in. in diameter by 180 ft. deep, though it was later deepened to approximately 200 ft. A heading was at this time driven for a distance of 467 ft. It was 5 ft. 6 in. high by 3 ft. 6 in. wide, and was situated at a depth of 137 ft. below the engine house floor. At the end of the heading a borehole 3 in. in diameter was driven for a distance of 105 ft., inclined upwards at an angle of 17 deg. from the horizontal. A bore-hole 6 in. in diameter was sunk in the floor of the heading, 10 ft. from the end, to a depth of 74 ft.

The buildings were entrusted to Messrs. William Trow and Sons, Wednesbury, and were erected in the Gothic style to the designs of Mr. Henry Naden, Birmingham. The plan is substantially as shown in Fig. 1 on the Plate, and their appearance as originally constructed is shown in Fig. 2. The main building is the engine house which contained a pair of beam engines. In the background is the lower boiler house for four Lancashire boilers, and in the foreground a flag-covered pump room for the air pumps, condensers and force pumps. The latter were worked from the beams projecting from the engine house. The deep-well pumps were situated at the other end of the engine house, and were worked by auxiliary beams. It will be seen from Fig. 3 on page 5, which shows the buildings as they are now, that they retain much of their original appearance, though a new low building now occupies the site of the old pump room and the deep-well head has also been covered in.

The contract for the pumping machinery was placed with the historic firm of Messrs. James Watt and Company, Soho Foundry, Birmingham. There were two single-cylinder double-acting beam engines, the cylinders being 65 in. in diameter by 10 ft. stroke. As they have now been dismantled, the photographs now reproduced of characteristic parts will be of interest. The view of the cylinder covers and valve chests, Fig. 4 on page 6, shows the drop-valve gear, the valves being worked by the old method of plug rods attached to the beam and actuating wyper shafts on the lower platform. This gear is shown in Fig. 6 on page 8, in which the care spent on detail is evident, though perhaps still more striking in the view of the end of the beam given in Fig. 7, on page 9, in which the balustrade-like distance pieces in the parallel motion are typical of the taste of the times. The winged stop on the beam is a common fitting on non-rotative engines in which it acts as a safeguard in case of valve-gear failure, &c. An unusual

feature in this illustration is the secondary beam attached to the cylinder end of the main beam by a drag link. The secondary beam was pivoted on the engine-room wall, and its other end attached to the rods of the well pumps; the latter had buckets 22 in. in diameter with a stroke of 9 ft. The force-pump rams were attached, through parallel motion gear, as will be seen in Fig. 2, to the other end of the main beam. The rams were 21 in. in diameter, with a stroke of 9 ft.

The engines were supplied with steam from four Lancashire boilers, each 7 ft. in diameter by 32 ft. long. The working pressure was 20 lb. per square inch. Each engine had an output of 1,500,000 gallons per 24 hours at a speed of 8 strokes per minute. The total specified head was 500 ft., including a lift of 180 ft. by the well pumps. The latter delivered the water at the surface into open headboxes from which it gravitated to the force-pump suction tanks in which were placed the feed pumps, air pumps and tubular surface condensers. Pumping into supply commenced in April, 1878, and the whole of the works in the Cannock district, sanctioned by the Bill of 1875, were officially opened on July 21, 1880.

Passing now to the considerations determining the reconstruction of the station, it may be said that in recent years there have been traces of pollution in the Huntington water, and various methods of treatment have been under consideration to remedy this. Early in 1935 a cast-iron pipe in the rising main of No. 1 well pump fractured, a mishap which put the engine out of commission. There is a series of stagings in the well at distances of approximately 27 ft. and the rising mains have feet which are bolted to the staging girders. When the remaining engine was pumping at its maximum rate it was not able to lower the water level in the well sufficiently to permit men to go down and release the defective lift for withdrawal and the replacement of the damaged pipe. The installation of temporary pumping plant was considered in order to assist the remaining engine to unwater the well. For this, steam plant was ruled out owing to the low working pressure of the existing boilers and no electric supply was available; nor was suitable Diesel plant to be hired. There were, moreover, difficulties with temporary foundations due to weakness of the structure at the well top. Careful consideration of the conditions necessary for retaining this source of supply led, therefore, to the decision to reconstruct the whole station and to include plant for water treatment. Various types of prime mover were considered, and, after a favourable offer of an electric power supply had been received from the Cannock Urban District Council, it was decided to instal electrically-operated plant. An examination and comparison of different methods of and schemes

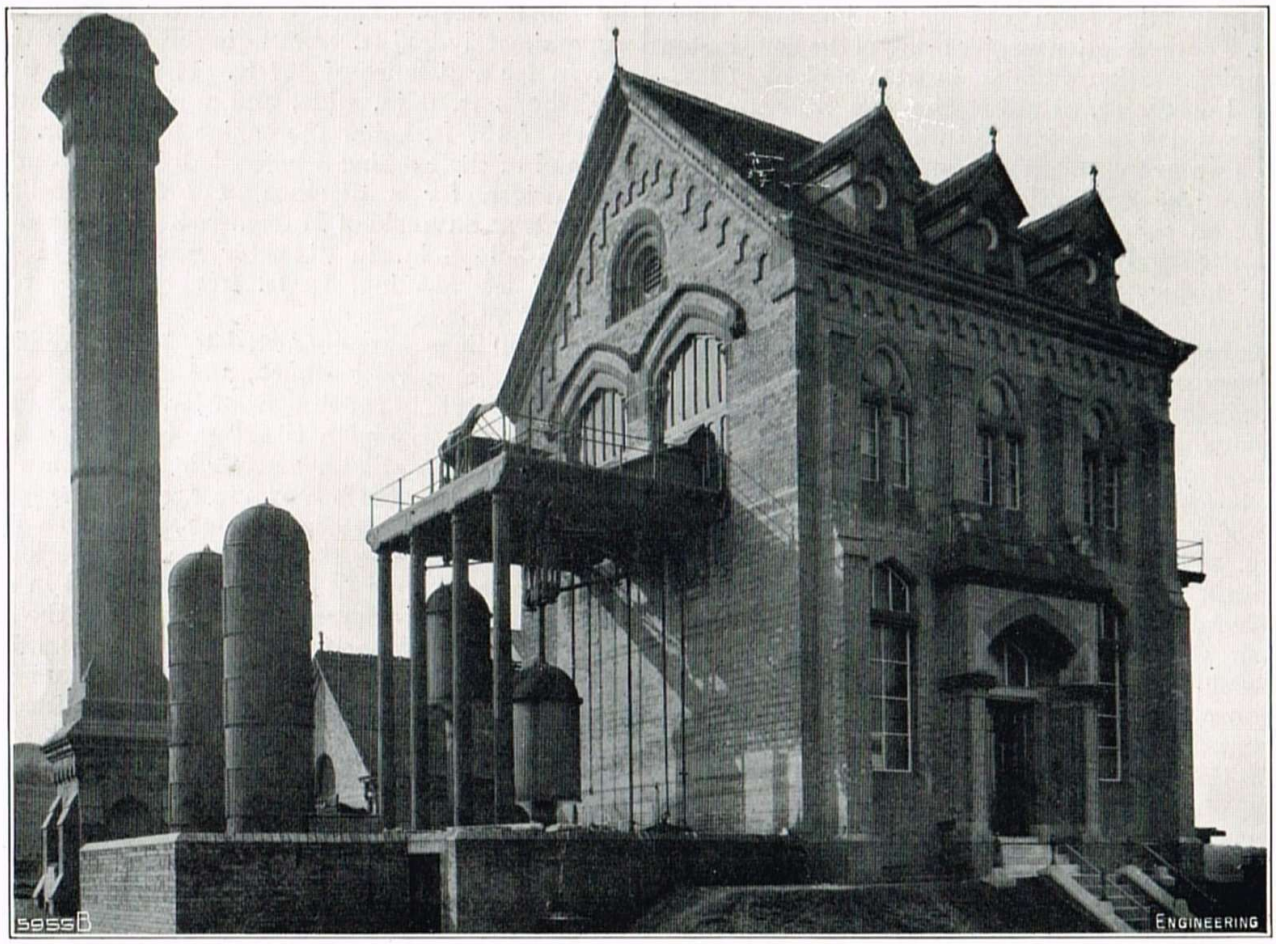


FIG. 2. PUMPING STATION AS ORIGINALLY BUILT.

for water treatment led to the adoption of ozone as a sterilising medium.

The lay-out of the new pumping plant is shown in Fig. 1, on the Plate, and in Figs. 8 and 9, on pages 10 and 11. It consists of two electrically-driven centrifugal well pumps, the motors for which are situated in a pump room built over the well head. These pumps raise the water from the well and deliver it to the base of the ozone absorption tower through which it rises and overflows into a treated-water tank in the booster-pump house occupying the old boiler house. There are two horizontal electrically-driven booster pumps which draw from the treated-water tank and deliver the treated water to Gentleshaw service reservoir. The well-pump motors are shown in Fig. 5, on page 7. The water delivered to the reservoir is measured by a Kent Venturi recorder, having its Venturi tube fixed in the new length of main connecting to the old pumping main. The discharge of the well pumps is not actually measured, but is regulated to maintain a relatively constant level in the treated-water tank, and a level indicator with high and low water level electrically-operated alarm bells is provided to assist the attendants in this respect.

In case the ozone plant is out of commission, the well pumps can deliver direct to the booster pumps by by-passing round the absorption tower and treated-water tank. In order to meet the various duties required due to varying lift in the well and varying quantities and heads on the booster pumps, it was necessary to instal variable-speed motors on both the well and booster pumps. The power supply is three-phase, 50 cycles, 6,000-volt current which could be transformed down to suit commutator motors at 400 volts. Alternatively, by the use of transformers and rotary converters or mercury-arc rectifiers, the supply might be converted to suit direct-current motors. On comparing the methods of conversion and performance of the two types of motors working under the varying load conditions required, it was finally decided to adopt the alternative method and to use mercury-arc rectifiers with direct-current machines. This point having been settled, the preliminary work involved in the change-over was begun.

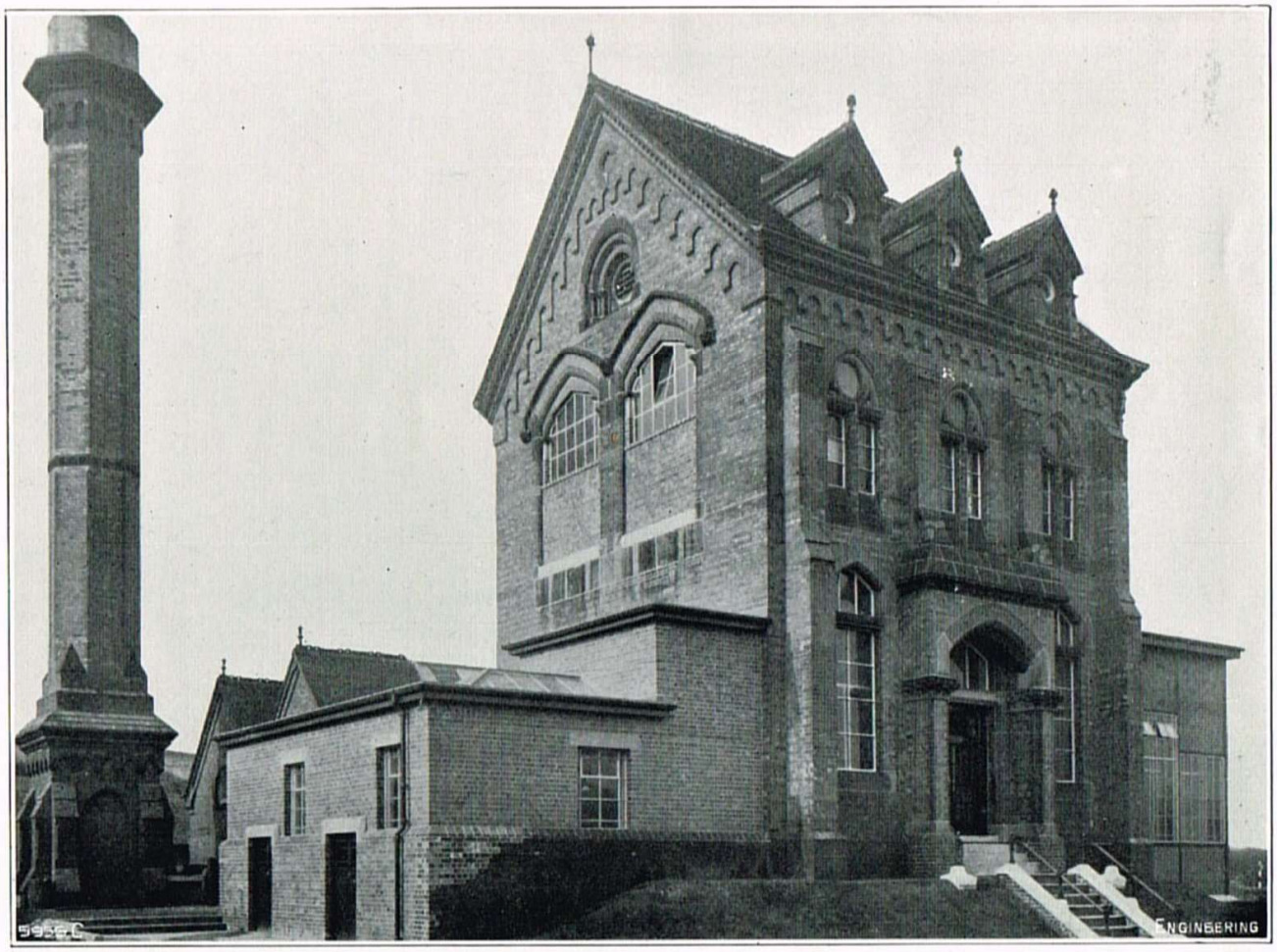


Fig. 3. Pumping Station as Now Re-Constructed.

It was necessary to remove the timber platforms on the various stagings to allow the new well pumps to be installed, and in order to do this some means had to be provided to give assistance to the remaining workable engine in lowering the water level in the well. By plumbing the well, it was found that it was possible to erect temporarily one of the new well pumps alongside the defective well pump and use it for that purpose. The power supply authorities undertook to lay one of the cables and arranged a direct-current supply from a neighbouring

colliery. The well top was open and as the new electric pump motors must work under cover, the construction of the well pump house was put in hand, the overhead crane erected, and a temporary roof provided. The head of the defective well pump was first removed, and the suspension girders for the new well pumps were temporarily fixed at the well top.

On completion of the first well pump at the maker's works, it was tested there to comply with the guarantees and then erected in its temporary position in the well. Suitable pipes were fixed to discharge into timber troughing leading to a large surface water drain connecting with a stream feeding to the River Penk. Continuous pumping operations started on May 8, 1936, with the sound beam engine pumping into supply and the new centrifugal well pump discharging to waste. The engine varied its rate of pumping to suit the district requirements, while, as each staging was cleared by the retreating water, the speed of the well pump was raised to increase the rate of discharge until the bottom staging was reached and cleared on May 11, when the centrifugal pump was stopped, allowing the water to rise to its normal level.

Pumping into supply ceased on May 17, and the work of dismantling the old plant commenced on the following day. The pump rods, bucket and clack of the second well pump were withdrawn, and the well top cleared for the new well pump foundations. At the same time, the cutting up of the old boilers was commenced to clear the boiler house for the reception of the main electrical equipment and the booster pumps, the intention being to resume pumping operations as soon as possible without the ozone installation. When the well pump foundations were prepared the complete well pump was lifted in its temporary position clear of the suspension girders, and the girder nearest the centre of the weld was moved into its permanent position. The complete pump was then moved by the crane into position and left slung by the crane while the second suspension girder was moved over and levelled up. The pump was then lowered into its final position on the girders and all was ready for the erection of the second pump. Meanwhile the old pump working beams and connecting rods had been removed and the permanent roof fixed on the house. The four boilers were removed by May 27, and the alteration of the boiler house commenced. The whole of the electrical equipment and the booster pumps were installed and the plant was brought into commission, pumping into supply, on November 22, 1936.

In the meantime, the engines and force pumps had been dismantled and the construction of the absorption tower and foundations for the ozone installation were in hand. The old force pump chamber was filled in and a new house constructed

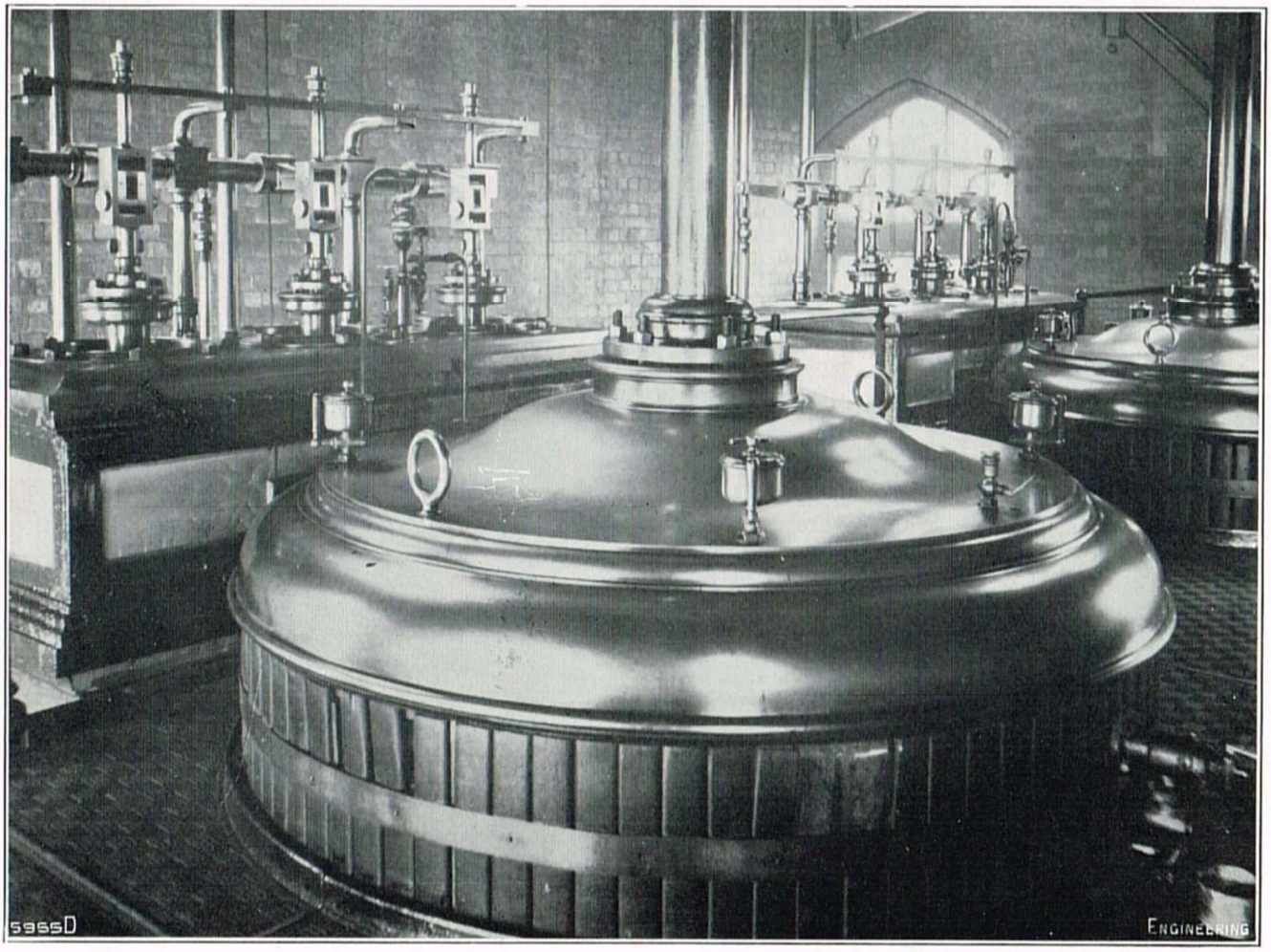


FIG. 4. CYLINDERS AND VALVE GEAR OF OLD BEAM ENGINES.

to receive the refrigerating plant and to provide workshop, stores, lavatory and boiler house for the heating installation. The ozone installation was completed and brought into commission on January 19, 1937. With the completion of the installation of the new plant, it is possible to unwater the well again and to remove the old well pumps, but for various reasons it has been decided to abandon them, at least for the present.

Dealing now in more detail with the new plant it may be stated that the pumping plant is in duplicate, each unit consisting of one transformer and one rectifier working in conjunction with one booster pump. The duties specified in Table I were to be easily capable of being fulfilled.

Duty D is that required of each unit under emergency conditions, when the two units are running in parallel.

The Power is supplied by the Cannock Urban District Council by dual feeders to a six-panel switchboard of the cubicle type, consisting of two incoming panels and one metering panel, with one outgoing panel belonging to the Council and two outgoing panels belonging to the waterworks company. The power supply, as already stated, is three-phase, 50-cycles, 6,000-volt. The two transformers, each of 229-kVA output, are of the oil-immersed self-cooled core type in boiler-plate tanks, with external cooling tubes. The primary winding is three-phase, delta-connected, with adjustable off-load tappings, plus or minus $2\frac{1}{2}$ per cent., 5 per cent. and $7\frac{1}{2}$ per cent. The secondary winding for the rectifiers is six-phase, 450-volt, star-fork connected, and, in addition, there is a tertiary winding, star-connected, giving a three-phase, 50-cycle, 400-volt supply, which is used for the rectifier auxiliaries, station auxiliary plant and lighting and for the ozone plant. The two rectifiers are each rated at 150 kW, 550 volt. One of them is shown in operation in Fig. 11, page 13. It was decided to use the pinch ignition method in preference to the dipper electrode method for establishing the main

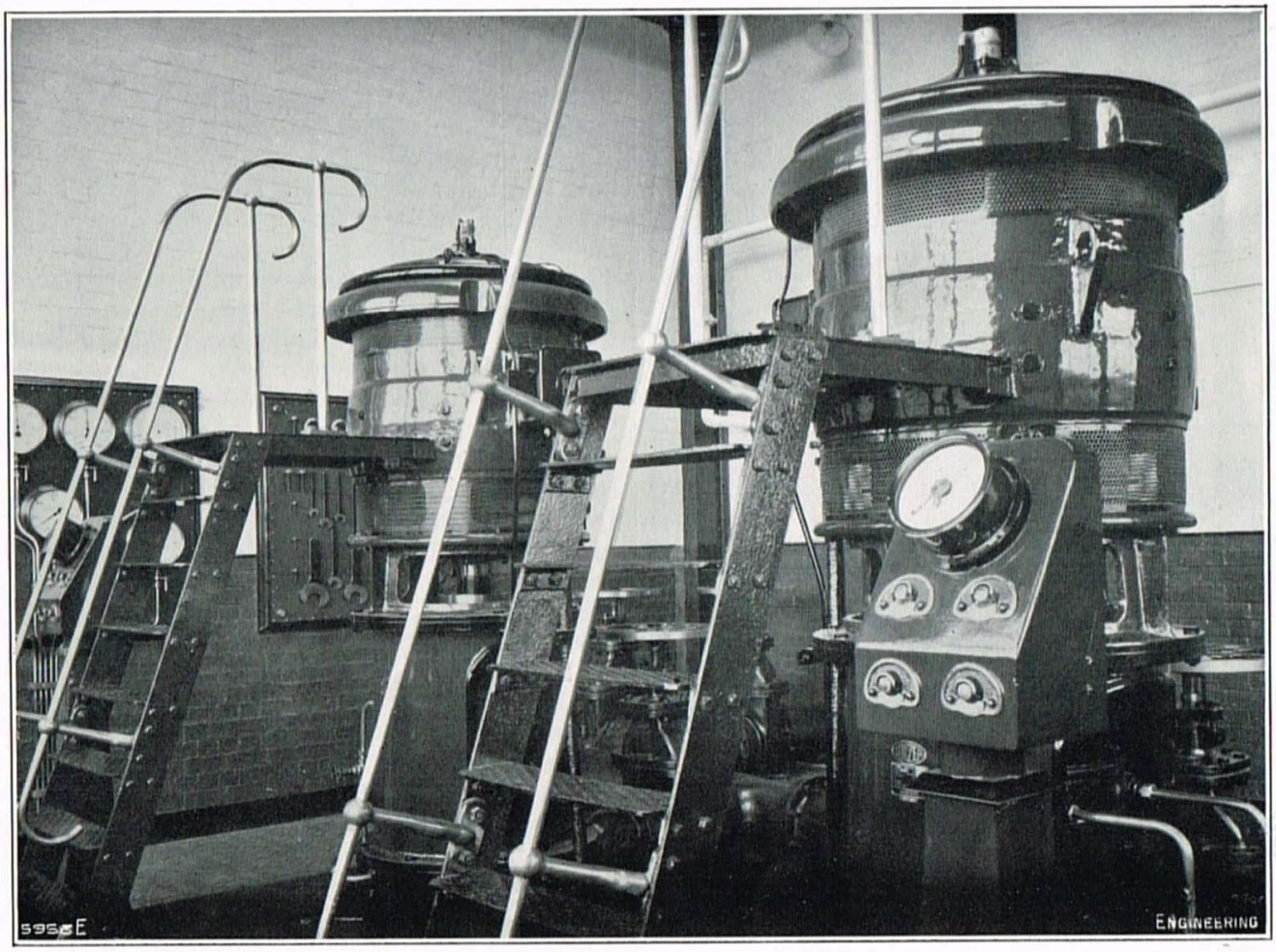


Fig. 5. Motors and Control Pedestals of New Deep-Well Pumps.

Table I.

	Duty A.	Duty B.	Duty C.	Duty D.
Well Pumps:				
Gallons per minute, net.	700	875	1,042	700
Water level in well below floor level, feet	60	90	120	180
Lift above floor level, feet	21	21	21	21
Total static head, feet	81	111	141	201
Booster Pumps:				
Gallons per minute, net.	700	875	1,042	700
Total head above floor level, including friction, feet	210	230	230	230
Total inclusive head on the two pumps, feet	291	341	371	431

current arc, as the absence of moving parts and the fact that the rectifier does not need to be tilted in the former method reduce the possibility of bulb failure.

The power factor of this type of rectifier depends on the number of rectifier phases. For three-phase rectifiers the power factor is about 0·83, whereas for six-phase rectifiers it is about 0·94. In this instance six-phase rectifiers were adopted and they have a good efficiency and power factor from half-load up to 25 per cent. overload. The rectifiers are housed in the upper portion of steel cubicles and can be readily withdrawn through hinged doors

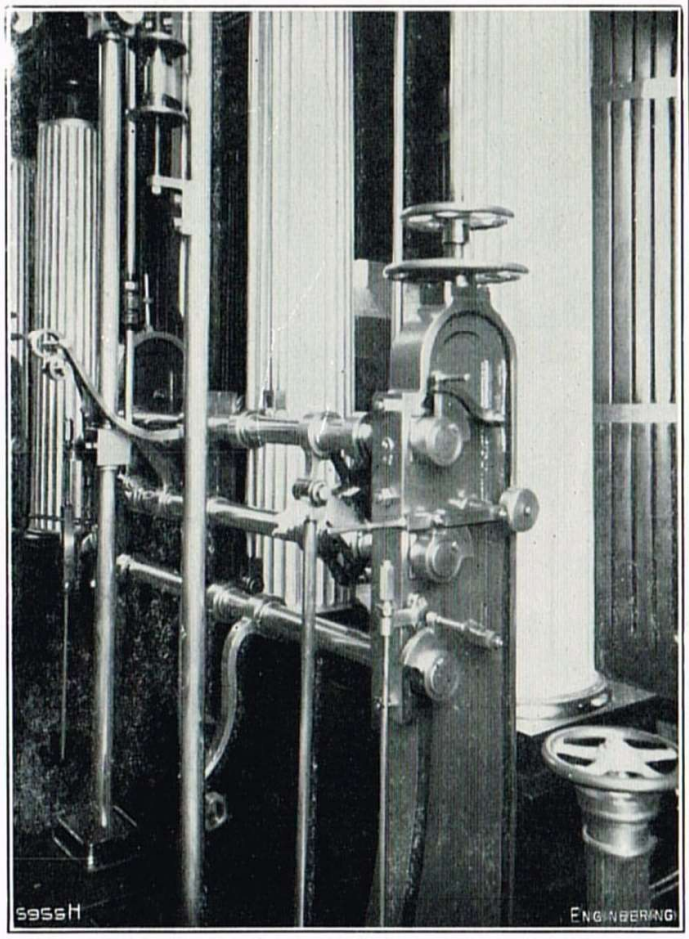


FIG. 6. BEAM-ENGINE VALVE GEAR.

provided with dark glass inspection windows. A motor-driven ventilating fan is fixed under each bulb, together with the auxiliary apparatus. The motors are of the three-phase type with speed control chokes for regulating the fan speed to suit the load conditions. In the view of the high-tension incoming and outgoing panels and metering panel given in Fig. 10, page 12, the rectifier cubicles can be made out beyond the transformers, which are identifiable by their kerb bases. The position of this equipment is indicated in the general plan of Fig. 1, as is also that of the low-tension incoming and control panels, a view of which is given in Fig. 12, page 14.

The low-tension panel follows a standard design adopted by the waterworks company for all its recently-constructed electrically-driven stations. The switchboard is of the cubicle type, built up of rolled-steel section framework and steel sheets, with hinged doors having wired-glass panels. It is highly finished and has chromium-plated beading. A similarly mounted electrically-wound seven-day clock is fitted. Hand-operated isolating switches are provided for each cubicle and the doors are interlocked, so that they can only be opened when the panel is dead. The actual control gear is of the contactor type, operated under push-button control. This type of switchgear has been adopted as it can be kept free of dust, is constantly under observation, and is simple to operate. The first six panels deal with the direct-current supply from the rectifiers, and comprises two incoming panels, two outgoing panels for the well pumps and two outgoing panels for the booster pumps. The seventh panel deals with the auxiliary three-phase low-tension supply for the auxiliaries, station lighting and ozone plant.

Each incoming panel is equipped with a double-pole isolating switch on the incoming and 'bus bar sides, double-pole circuit breaker, voltmeter, ammeter static earthing gap and watt-hour meter. The well-pump and booster-pump panels are each fitted with a double-pole isolating switch, ammeter, watt-hour meter, speed indicator, and push-button-controlled contactor equipment. On each pump motor panel there are four push-buttons, "Start," "Stop," "Raise Speed" and "Lower Speed." The speed is varied by a motor-operated field rheostat. Reference to Fig. 1 will show that the well pumps are some distance away from the main low-tension switchboard. To allow the attendant, after priming the pumps, to bring them into operation under observation while actuating the valves, control pillars with four push-buttons and a speed indicator are fixed near each well pump, thus giving full control from either position. Interlocks are provided so that in case either pump stops the other pump working in series with it is automatically shut down. The seventh panel of the switchboard is fed from the tertiary winding of either transformer, a change-over switch being provided for this purpose. The panel is provided with four outgoing circuits, the contactor switches being under push-button control. This panel feeds the ozone plant and the lighting circuits. All these circuits are metered separately. All the seven panels are provided with strip light interior illumination and have "Off" and "On" indicator lamps fixed above the glazed doors.

The vertical-spindle well-pump motors are standard drip-proof, continuously-rated machines, fitted with ball and roller bearings. The motors are shunt wound with compounding for stability, and have an output of 75 brake horse-power with a speed range of from 675 r.p.m. to 1,000 r.p.m. to meet the specified duties. As shown in Fig. 5, they are mounted on stools well above the pump room floor level. The control pillars referred to previously are well seen in this illustration. The horizontal-spindle booster-pump motors are standard protected-type, continuously-rated machines, fitted with ball bearings. The motors are shunt wound and have an output of 110 brake horse-power and a speed range of from 1,200 r.p.m. to 1,400 r.p.m.

The couplings between the pumps and motors in both the well and booster units are of the flexible rubber buffer type.

The well pumps are of the four-stage bore-hole type, each stage being separate and of cast-iron with integral guide vanes. The impellers are of bronze and the pump bearings are of bronze lined with rubber. The neck rings and packing bushes are of bronze. The suction pipe is furnished with a cast-iron strainer covered with sheet brass $\frac{3}{16}$ in. thick and perforated with holes $\frac{1}{4}$ in. in diameter at $\frac{3}{8}$ in. pitch, giving an effective area of eight times that of the suction pipe. The foot valve is of the mushroom type, with top and bottom spindle guides. The delivery or suspension pipes, in 20 lengths to each pump, are of mild steel and have double-riveted steel flanges recessed to receive the intermediate guide bearings. The transmission shafts are of mild steel and are protected with renewable bronze sleeves in the bearings. The intermediate shaft bearings consist of flanged cast-iron spiders spigoted to centre them in the suspension pipe flanges, and they are fitted with rubber-lined bronze sleeve bearings. The transmission shaft couplings are of mild steel and are of the double-cone type with bronze securing nuts and lock nuts.

The suspension pump head is of cast steel and is provided with suitable feet for securing to the suspension girders and with a pump delivery branch. The compound suspension girders consist of H-section rolled-steel joists with top and bottom strapping plates securely riveted together. They form a massive and rigid support for the pumps and are provided with machined steel pads to suit the suspension pump heads. The motor stool is of cast-iron and in it is embodied the Michell bearing carrying the whole of the rotating parts. The stool is attached to the pump head and is provided with spigoted flanges to ensure proper alignment of the pump and motor. The Michell bearing is provided with a large water-cooled oil reservoir. The well top is covered with rolled-steel chequer plating supported on steel channels, and is divided up into sections to permit of access to the well and also to allow for the dismantling of one pump without interfering with the other.

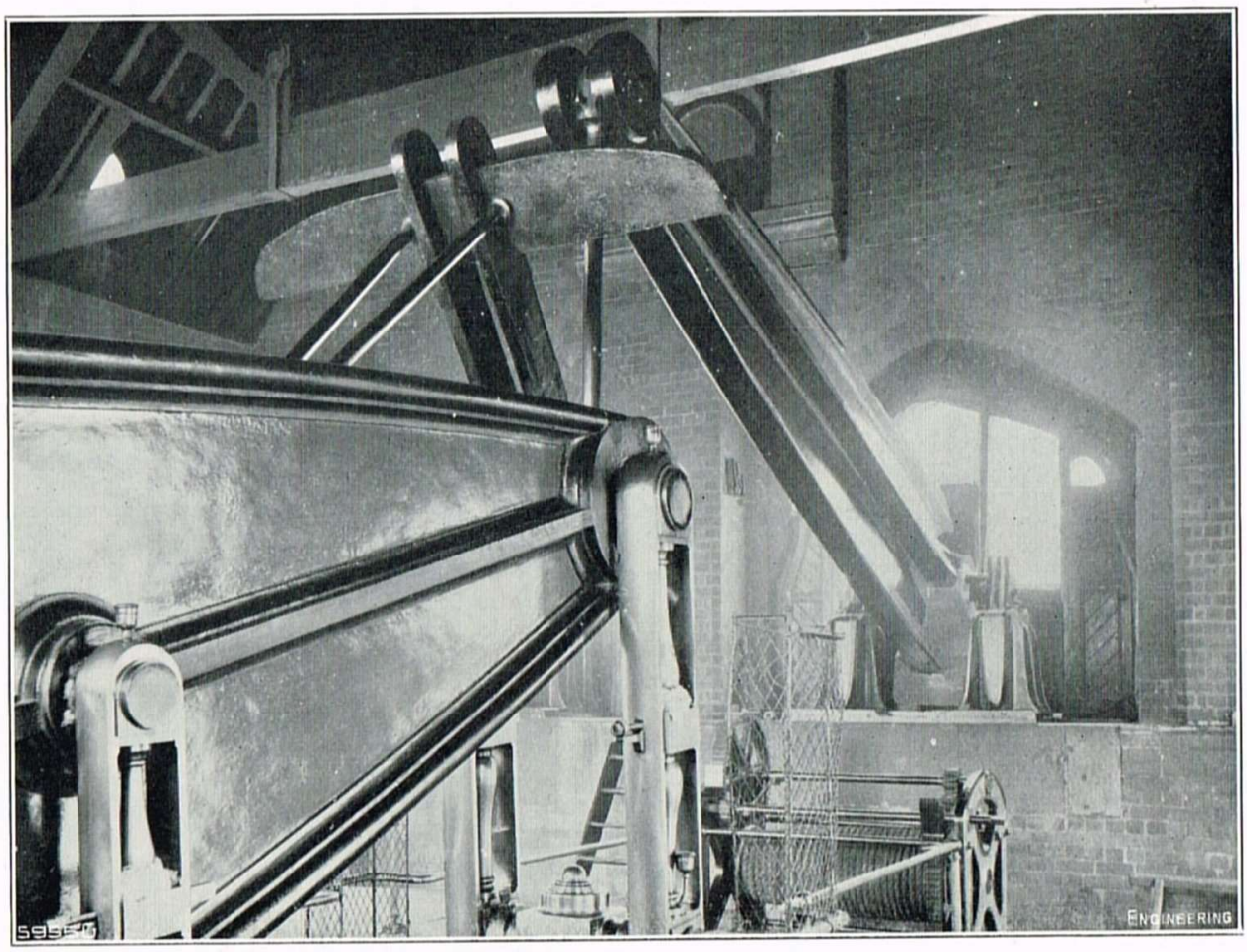


Fig. 7. Secondary Beam for Old Deep-Well Pump.

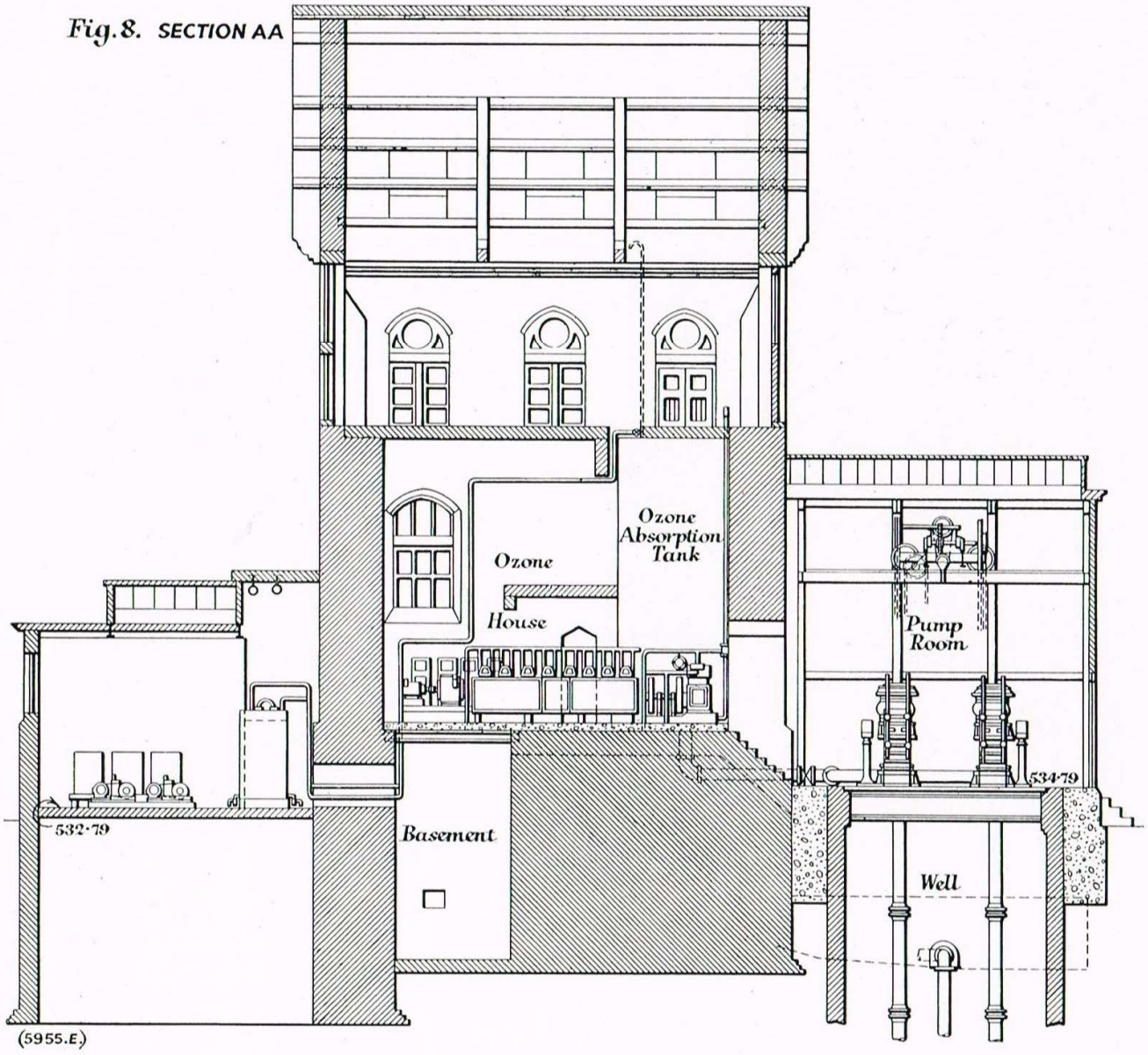
The first part of this account of the reconstruction of the Huntington Pumping Station of the South Staffordshire Waterworks Company, though it dealt in the main with the deep-well pumping plant shown in Figs. 8 and 9 on pages 10 and 11 and Fig. 1 on the Plate, these drawings also showed the booster pumps and the water-treatment plant, and it is therefore necessary to refer to these illustrations in connection with the photographs of these units reproduced in Figs. 13 to 19 on pages 15 to 19 and on the Plate.

The general appearance of the booster pumps is shown in Fig. 13. They are of the two-stage type

with single inlet impellers. The casings are of cast-iron and the impellers and guide passages of bronze with bronze renewable neck rings. The second stage impeller delivers into a spiral volute discharge formed in the pump casing. The motor and pump of each unit are mounted on a common cast-iron baseplate of box section. The pump bearings are of the ring-lubricated type, that at the suction end being water-cooled. The cooling water is taken from the first stage and returned to the suction inlet of the pump. A relief valve with test lever is provided on the cooling water pipes to prevent excess pressure on the water jacket when priming the pump from the delivery main or when the pump is running with a closed delivery valve.

The two well pumps have each a controlling sluice valve 10 in. in diameter on the delivery branch, and discharge into a common delivery main 12 in. in diameter leading to the ozone absorption tower. There is a sluice valve to shut off the absorption tower, and in front of this is a branch with a sluice valve controlling the by-pass main direct to the booster pumps for use when the ozone plant is out of commission. The water passing up the ozone absorption tower discharges over a submerged weir into a chamber, from which a pipe leads down to the treated-water tank in the booster pump house. The booster-pump suction branches, which are provided with sluice valves 10 in. in diameter, are connected to the by-pass main from the well pumps, and, in addition, each pump has a separate suction pipe connection from the treated-water tank and fitted with a sluice valve and non-return valve 10 in. in diameter. There is also a dividing valve between the two pumps. Each booster pump has a sluice valve and non-return valve on its delivery branch, and the two pumps discharge into a common delivery main, which is connected up to the existing pumping main at Gentleshaw. In the new section of the 15-in. delivery main are fixed the Venturi tube, a retaining valve and a sluice valve, each valve being fitted with a by-pass and from the sluice valve by-pass a washout connection is coupled to a storm-water drain. On the pump side of the retaining valve there is an anchor pipe embedded in a mass of

Fig. 8. SECTION AA



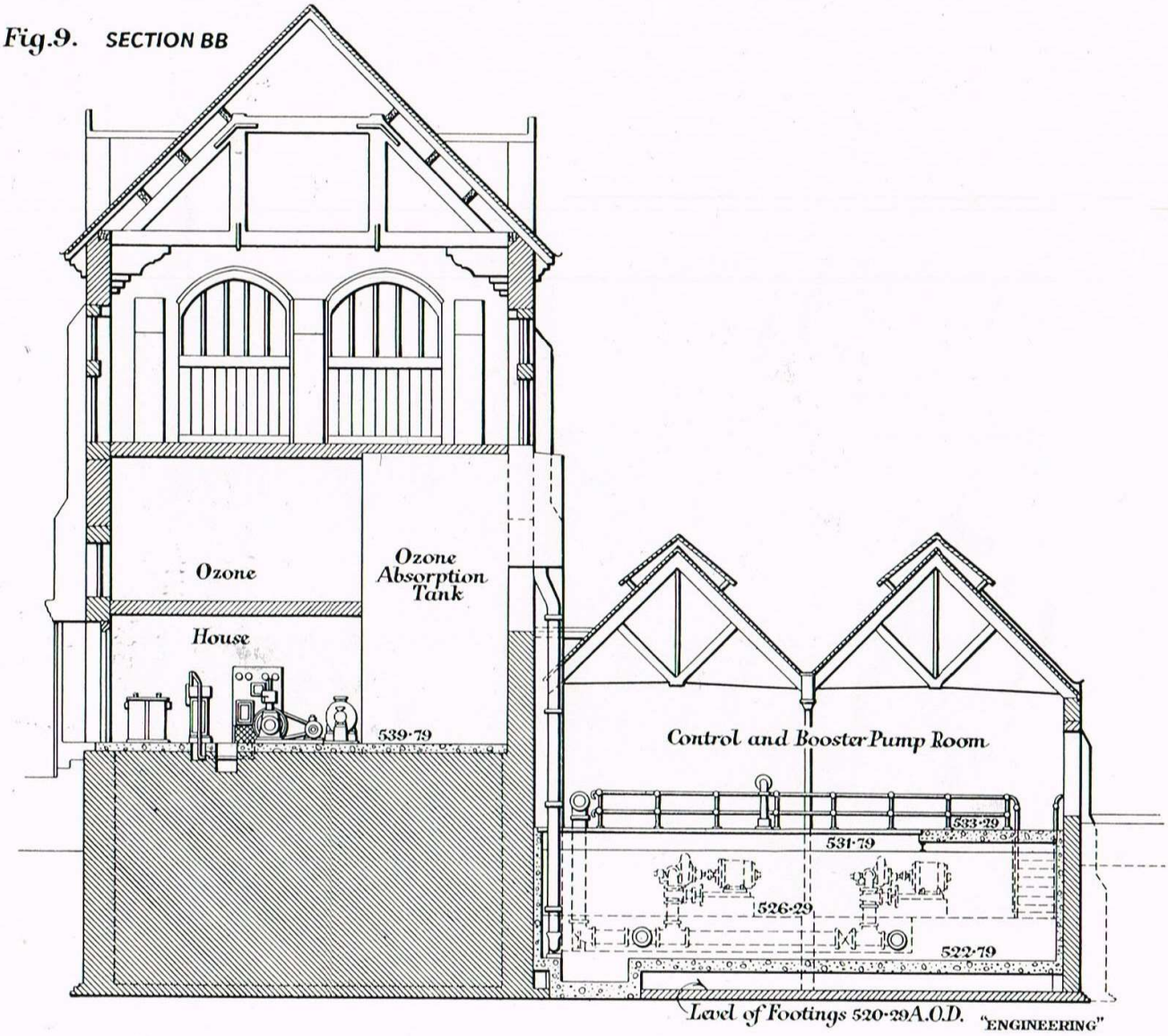
(5955.E.)

concrete to prevent any strain being thrown on the booster-pump casings in the event of a sudden stoppage due to a power failure causing a heavy recoil on the retaining valve.

The Venturi recorder is a Kent " A " mercurial-type instrument with an equal space chart, rate of flow indicator and integrating counter. The instrument is fitted with a continuous-pressure recorder. The water level indicator on the clear-water tank is also a Kent instrument and is provided with high and low water electrically-operated signal lamps and alarm bells. A drain 10 in. in diameter, fitted with a sluice valve, is provided between the treated-water tank and the well so that the treated water can be returned to the well if it is desired to empty the tank for examination. Further, should the well pumps exceed the output of the booster pumps the excess water is discharged by an overflow to waste. A connection 10 in. in diameter is provided between the well pump by-pass main and the booster pump delivery main, so that the well pumps can be run alone, if desired, to empty the well should the water become dirty due to the flow from the adit being such as to disturb the silt at the bottom of the well. Under these conditions the well pumps discharge to waste. The treated-water tank has a capacity of about 20,000 gallons, and was made by building a brick wall, 18 in. thick, across the old boiler house and lining the walls where they formed part of the tank with fresh brickwork.

The bottom of the tank was filled in with rubble to the desired level and then covered with concrete. Both bottom and sides were then lined with asphalt and the sides were protected with a brick wall $4\frac{1}{2}$ in. thick. The major portion of the tank is covered with rolled-steel chequer plates supported on steel joists. That portion of the tank roof nearest the entrance door from the yard is in reinforced concrete, strong enough to take the weight of any part of the plant which may require to be passed over it. The tank is seen in the background of Fig. 13. The treatment involves the use of ozone and the plant was supplied, with various sub-contractors, by Messrs. Paterson Engineering Company, Limited, 83,

Fig.9. **SECTION BB**



Kingsway, London, W.C.2. This firm employs the Van der Made process of ozonisation, which is operated on a closed circuit. Ordinary atmospheric air is dried in coolers and drawn by the suction of an air compressor through the ozonisers. The ozonised air is delivered by the compressor into the base of the absorption tower where it bubbles upwards through the water and sterilises it. The water from the well being pumped through the tower is discharged over a submerged weir. The surplus ozonised air is trapped in the top of the tower from which it is then led back by a pipe to the coolers for further use, any make-up air being drawn into the pipe leading to the coolers through a special breather valve.

It may not be out of place to refer to the principle of the apparatus before dealing with it in detail. The ozone is produced by subjecting the atmospheric air to a high-tension high-frequency electrical discharge, which causes a change in the molecular constitution of the contained oxygen from O_2 to O_3. The additional molecule is easily given off and the oxidising activity resulting is thus used for sterilisation. The ozonisation process is, of course, only employed for final decolorisation and sterilisation, and water containing solids and dissolved organic matter must be first treated by coagulation and filtration. The nitrogen contents of the air pass through the water, but are not dissolved in it, being trapped in the top of the tower with such oxygen as may have escaped ozonisation and withdrawn for re-circulation with fresh air.

The ozonising apparatus is shown in Figs. 14 and 15 on page 16. There are 8 units, each consisting of 6 horizontal electrodes arranged in the triangular form seen in Fig. 14. The electrodes proper consist of stainless-steel tubes which are inserted in glass tubes and so supported in them that there is an uninterrupted annular passage between the two. The passages open at each end of the element into a sealed chamber with which the inlet and outlet pipes communicate. The pipes to the right of Fig. 15 are the inlet pipes admitting cooled air to the ozoniser tubes, while those to the left are the ozonised air outlets and are coupled up to the suction of the compressors. The electrical terminals of the electrodes are contained in the inlet chamber and are visible, through the glass-fronted covers, in Fig. 14. The glass tubes in between the inlet and outlet chambers are immersed in water and are also visible through glass-fronted covers as shown in Fig. 15. The water is electrically earthed. The high-voltage high-frequency current supplied to the electrodes is discharged silently across the

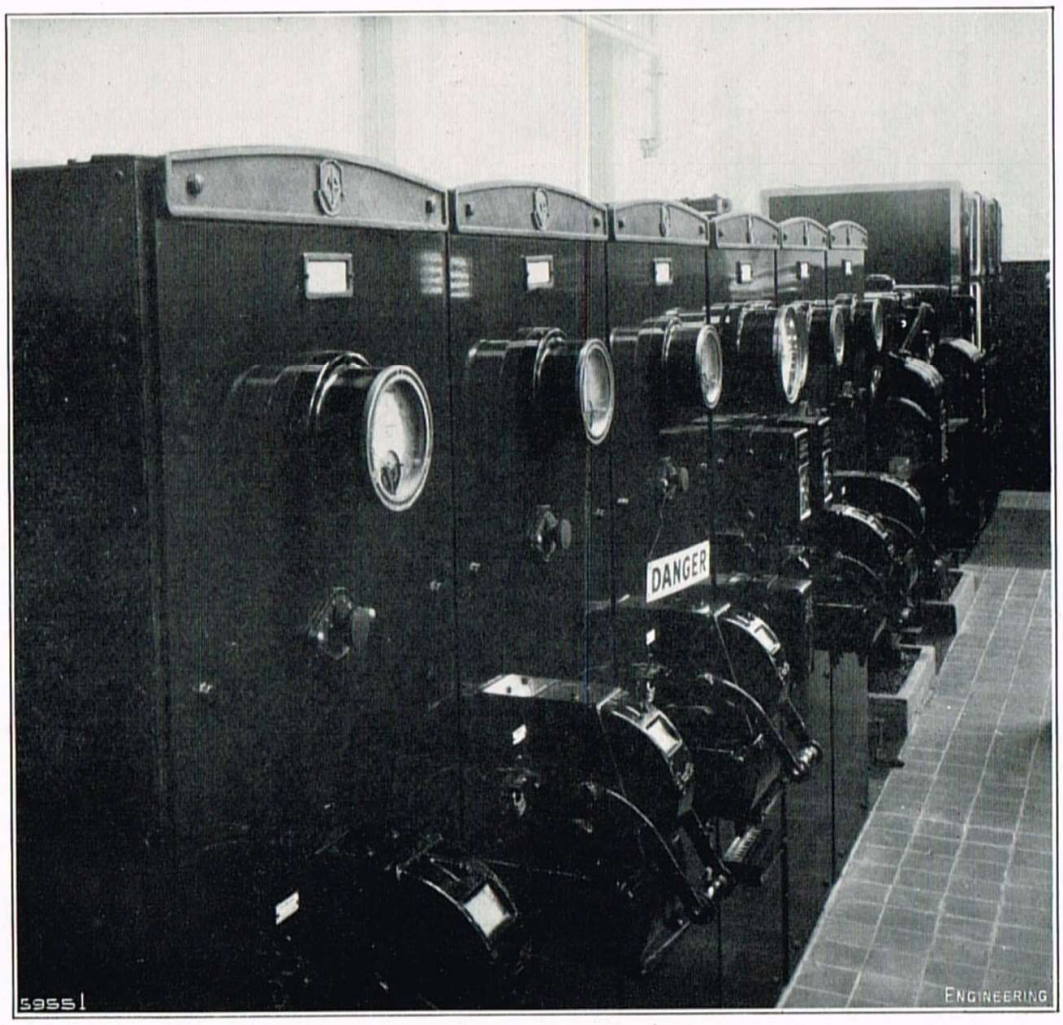


Fig. 10. High-Tension Switchboard.

annular gap through the walls of the glass tubes to the water. The discharge passes, in consequence, through the air which is being aspirated along the annular passages and converts the oxygen into ozone. The casings are provided with a water control valve and drain, and each cell is fitted with a Neon warning lamp to show when it is in use. The supporting steel structure is surrounded by a perforated metal screen with doors to give access to the high-tension isolator and selector panel. These doors are interlocked so that, should the operator open one with the plant in operation, the frequency changer on the electrode circuit is stopped and the ozoniser is de-energised.

Some comments may be here fittingly introduced on the considerations determining the choice of the other parts of the ozonising equipment. To obtain the best results from the ozonisers it is necessary to supply them with dry air, as moisture in the air has a tendency to foul the electrodes, thus reducing their efficiency, and it creates the possibility of the formation of certain oxides of nitrogen which could be taken into solution by the water. Three methods of removing the moisture from the air before ozonising were considered. The first of these, viz., the passing of the air through desiccator chambers containing calcium chloride for absorbing the moisture involved the disposal of the spent solution from the desiccators. The local authority would not permit the waterworks company to discharge this into the sewers, and a proposal to evaporate it on trays in an electrically-heated chamber was not economically feasible. The solution contains about half its weight of calcium chloride and the recovered chloride would have an absorptive capacity of about 75 per cent. only, compared with fresh material. The cost of the necessary current for recovery wiped out any economy resulting from the re-use of the material. The second method considered involved the use of silica gel as an absorbent for the moisture and meant that the desiccators would have to be duplicated. Each desiccator would work over a period of four hours at maximum output, while the other was being re-conditioned by forcing electrically-heated air through the medium. This method called for electric heaters with duplicate electrically-driven fans and cooling water to bring down the air temperature before reaching the ozonisers.

FIG. 11. MERCURY-ARC RECTIFIER IN OPERATION.

The third method, viz., that of refrigeration, was ultimately adopted and it was decided to instal two coolers in series and duplicated refrigerating machines consisting of compressors with condensers, this scheme giving the cool dry air desired. The

capital cost of the plant was higher than that called for by either of the other two methods, but the operating costs as regards electric power and cooling water were lower. The air compressors are seen at the left of Fig. 15 and the refrigerating plant in Figs. 16 and 17, Plate XXXV. The general lay-out of the whole ozonising equipment is shown in Fig. 1, Plate XXXII, *ante*. Referring to Fig. 16, the two air coolers are seen in the corner of the room, being identified by the oval lagged casing in which they are both contained. The casing is of steel and is fitted with an internal baffle to direct the air over the coils, through which the refrigerant is passed, first in a downwards and then an upwards direction on its way from inlet to outlet. It is understood that the air circuit is a closed one, the cooler being inserted in the pipe line between the top of the absorption tower and the compressors on the suction side of the compressor. The ozonisers are also inserted in this part of the pipe line. The remaining part of the circuit is formed by the delivery pipe from the compressors to the absorption tower.

The interruption of the pipe line on both sides of the cooler is shown by the U-shaped pipes at the left hand of Fig. 16. The lowest of the two pipes coming through the wall is the return pipe from the absorption tower, and is distinguished by the breather valve, for making up any deficiency in the air supply, seen just inside the arched recess. This pipe is branched to one leg of each U-pipe. The other pipe is the connection to the air compressor, and is branched to the other legs of each U-pipe. These legs are each provided with a valve operated by a small motor which is automatically controlled from a panel. The object of the U-pipe arrangement is to reverse the flow of air through the cooler. The two cooling coils are made of solid-drawn steel tube, and are connected to the refrigerating plant by the lagged pipes seen in the upper part of Fig. 16, towards the right hand. These pipes can again be identified in Fig. 17, Plate XXXV, in which the duplicate refrigerating sets are shown.

Each set consists of a twin-cylinder compressor with a steel cylindrical condenser casing fitted with a copper cooling coil. The compressors are driven by $1\frac{1}{2}$-brake horse-power motors through adjustable Vee-belt drives. The working medium is methyl chloride. Each refrigerating machine is connected with one of the cooler coils, and has valves on both the suction and delivery branches. Isolating valves permit either machine to be used in conjunction with either cooler in case of a breakdown. The valves are mounted on a board enclosed in a wood cabinet fixed above the refrigerating machines. The cooling water supply to each machine is only in use during the time the machine is running, and is controlled by an electrically-operated valve. Each machine is also provided with a cut-out switch in case of overload on the compressor. The motor-driven air valves on the U-pipes and the refrigerating machines are controlled by an electric clock. This is housed in the cabinet seen to the left of Fig. 17, along with the contactor switches it controls. Pilot

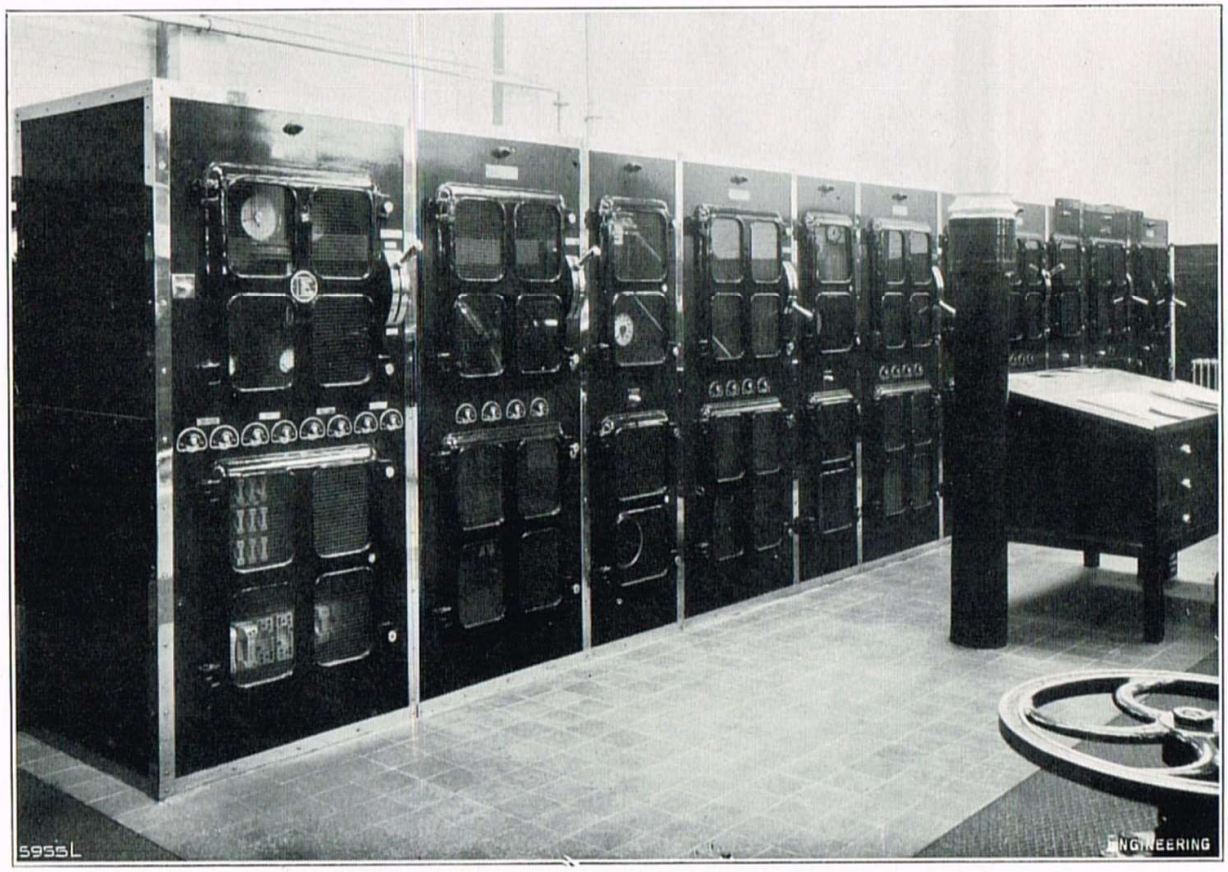


Fig. 12. Low-Tension Switchboard.

lights are provided to show which air valves are open.

The automatic controls operate in the following manner. The cycle of operations is first determined by the time required under various load conditions for the cooling coil of the second air cooler to be covered by an accumulation of snow from the moisture in the air, and the clock is set accordingly. Assuming the coils to be clear at the start, the snow begins to form on the second cooler, and at the predetermined time the clock stops the refrigerator serving this cooler and starts the other refrigerator. The motor-driven valves are also set so as to reverse the air flow through the cooler, and the relatively warm air from the absorption tower melts the snow, the resulting water being discharged through a trapped drain with a visible outlet. In the meantime snow begins to accumulate on what was previously the first cooler, and the previous conditions occur in the reverse order when the clock again changes the mechanism. The refrigerators were supplied by Messrs. J. and E. Hall Limited, Dartford.

The air compressors into which the cooled and dried air is drawn are in duplicate and were supplied by Messrs. Broom and Wade, Limited, High Wycombe. They are of the twin-cylinder type, and are driven by direct-current shunt-wound motors of 10 brake horse-power, through Vee-belts. The plant has to deal efficiently with any quantity of water between the limits of 42,000 gallons and 84,000 gallons per hour, and variable-speed motors were adopted to enable the volume of ozonised air to be adjusted to suit the quantity of water being pumped. The motors have a speed range of from 600 r.p.m. to 1,200 r.p.m., and are controlled from a Brookhirst switchboard with glass panels. The panels are each equipped with a circuit breaker, notching starter and shunt regulator for speed control.

The absorption tower is constructed in reinforced concrete, and is 22 ft. 6 in. high by 10 ft. 6 in. by 7 ft. 6 in. in cross-section. At the bottom there are three ribs 1 ft. 6 in. deep, extending for the full length. There is a space between the outer ribs and the walls. These spaces communicate with the two central ones by means of slots at the bottom of all three ribs, 12 in. long by 6 in. deep. The centre rib has also slots in the top, 6 in. long by 2 in. deep. The spaces are bridged over by carborundum plates resting on the ribs. The well pumps discharge into the compartments between the spaces through a bell-mouth pipe with a horizontal diffusing plate above it. The water flows outward through the slots and rises between the outer ribs and the walls. The air compressors deliver to ozonised air into the base of the tower through two perforated pipes extending the full length and lying in the two central compartments. The ozonised air is trapped in the compartments above the level of the bottom slots in the ribs, the top slots in the centre rib equalising the pressure in the compartments. The compressor delivery pressure is sufficient to force the ozone through the carborundum plates, in passing which it breaks up into small bubbles which rise through the water and provide a maximum surface contact for sterilising. As already stated, the water is discharged over a submerged weir, so trapping the excess ozonised air for further use.

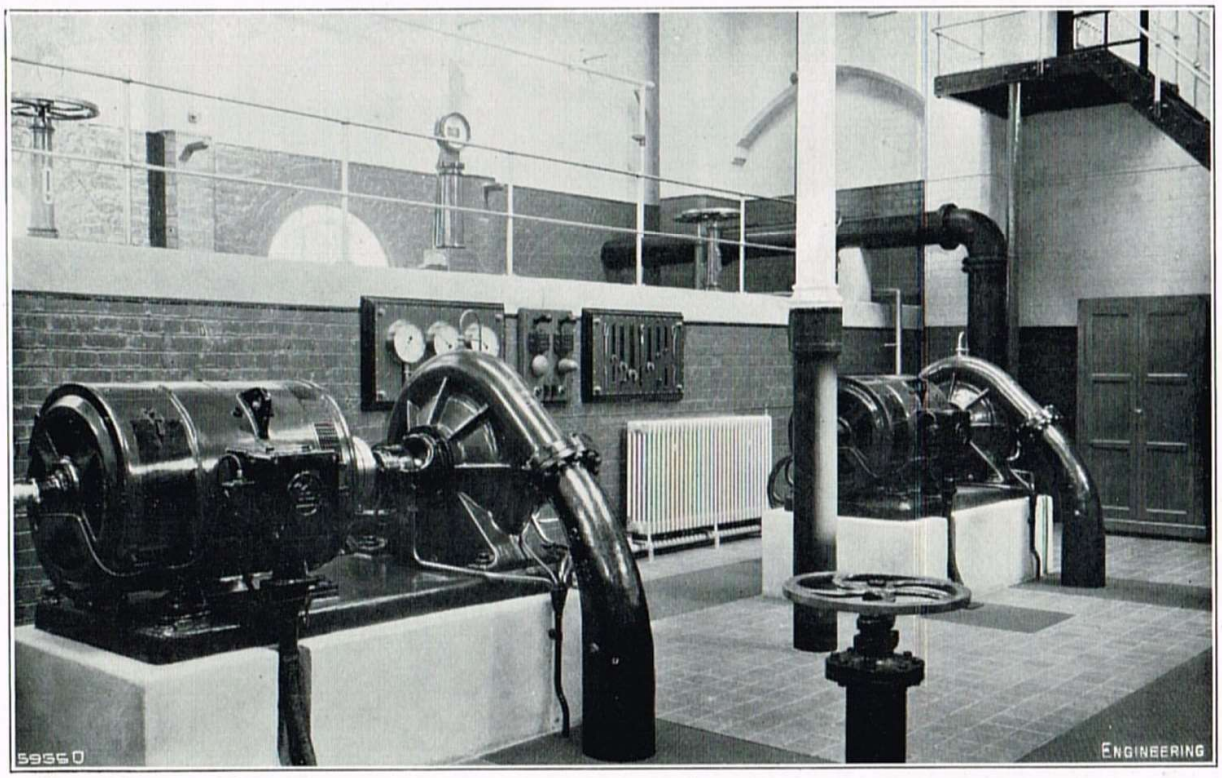


Fig. 13. Booster Pumps and Treated-Water Tank.

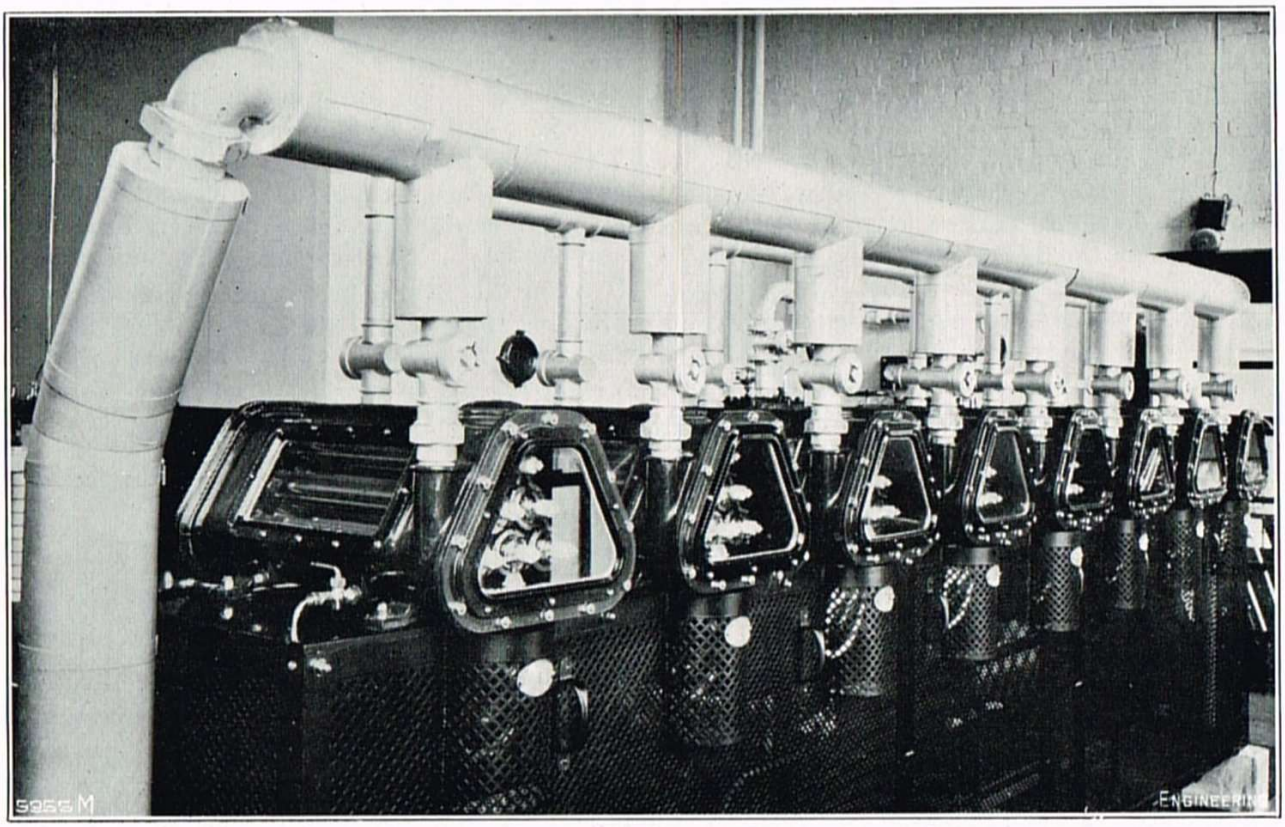


FIG. 14. OZONE PLANT.

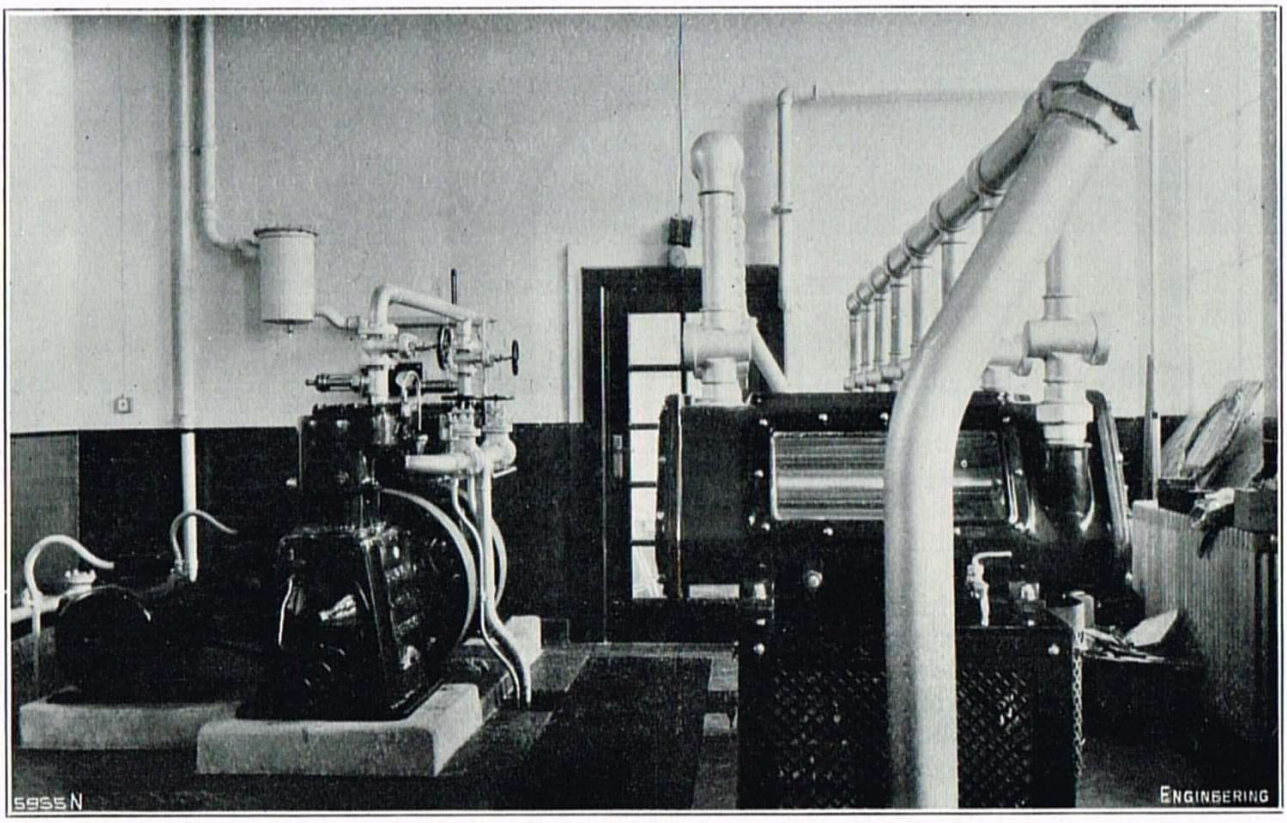


FIG. 15. AIR COMPRESSORS AND OZONE PLANT.

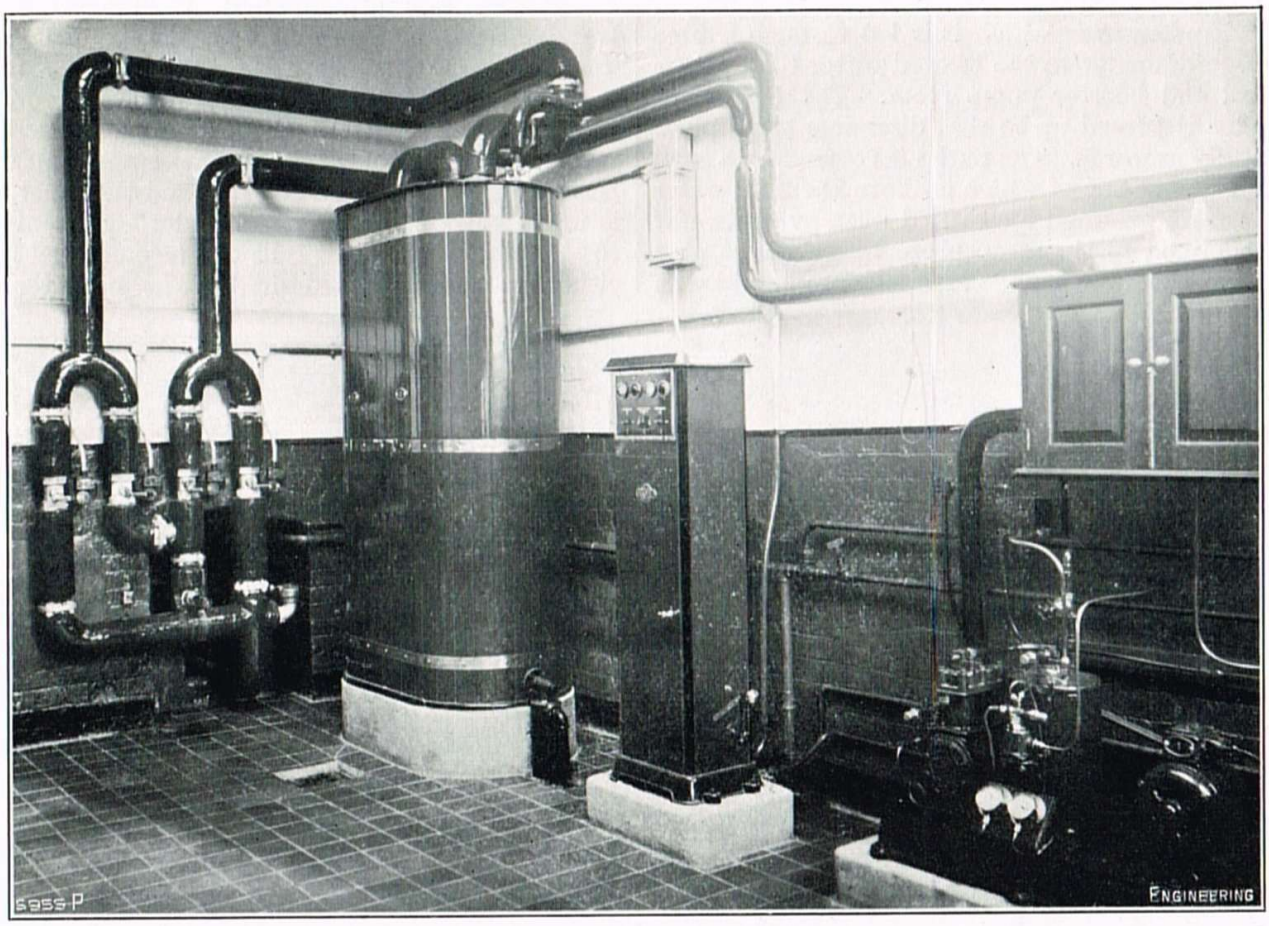


Fig. 16. Air Coolers and Motor-Driven Control Valves.

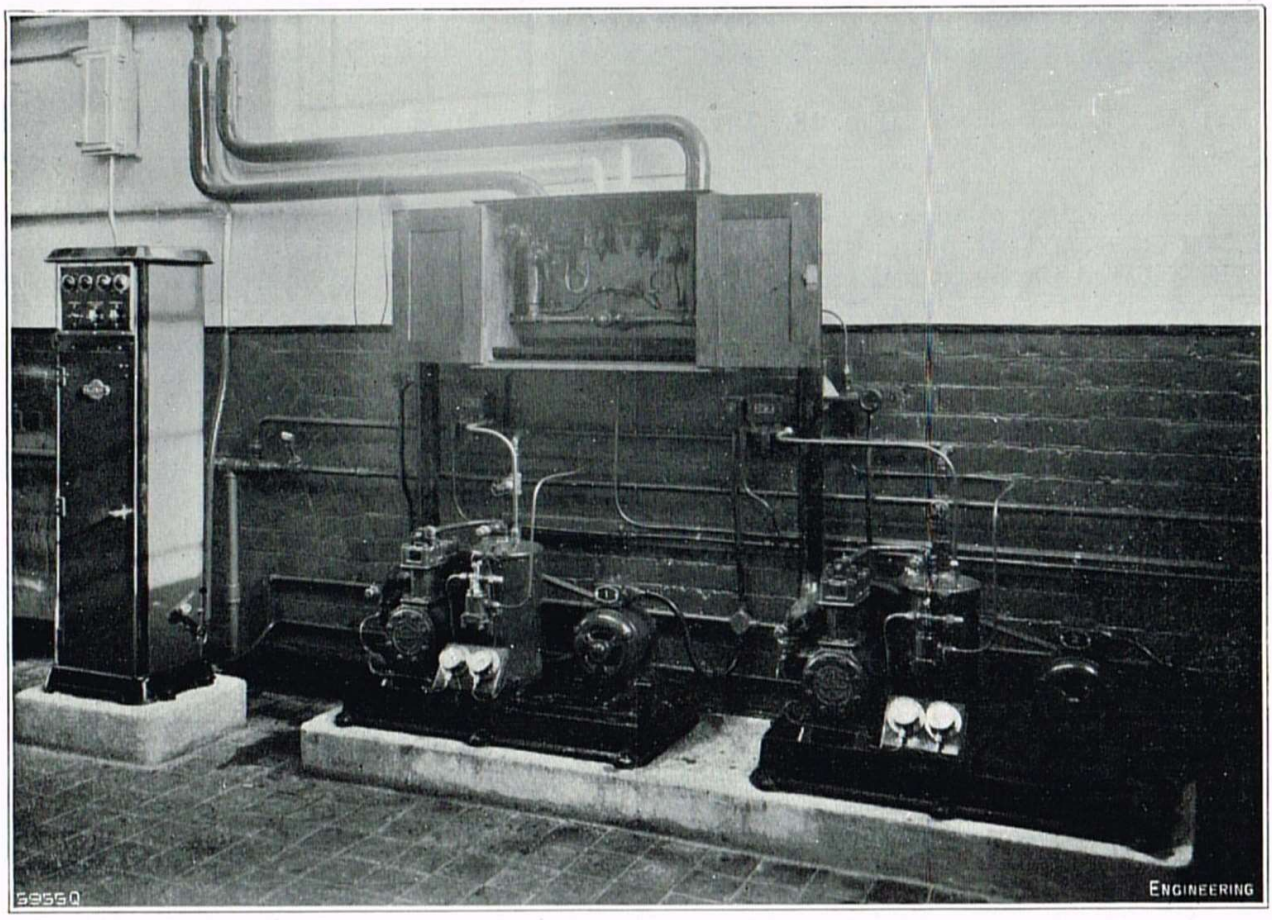


Fig. 17. Refrigerating Units and Valve Cabinet.

The water after passing over the weir is collected in a chamber from which it is led through a pipe 12 in. in diameter to the treated water tank in the control and booster pump room. The bottom of the pipe is turned up so that discharge takes place vertically upwards. The outlet is covered by a steel plate bell, the top of which is above the tank water level. Any ozonised air carried over by the water is discharged to the atmosphere by an outlet pipe from the top of the bell. Manholes are provided in the tower at the top, at the end above the carborundum plates, and over the discharge chamber. Sampling pipes at the centre and top are brought down to a basin in the ozone room seen at the right-hand of Fig. 18 on this page. Circular observation windows with hinged doors are provided at one end and on one side, and the interior is illuminated so that the actual working of the process can be easily seen. One of the windows is visible in the wall near the desk.

The electrical equipment for the ozonising plant consists of duplicate frequency changers, switchgear and duplicate step-up transformers. The frequency changers supplied by Messrs. Laurence, Scott and Electromotors, Limited, Norwich, and shown in Figs. 18 and 19, each consist of a 15-brake horse-power 3-phase, 400-volt, 50-cycle squirrel-cage motor driving a single-phase, 300-volt, 500-cycle alternator with exciter, both mounted on a common bedplate and running about 1,500 r.p.m. The motors for the frequency changers are provided with Brookhirst control panels. These are seen, along with the panels for the air compressors at the right-hand of Fig. 19. The current from the frequency changers is stepped up in two transformers supplied by Messrs. Ferranti, Limited, Hollinwood. The transformers are of the single-phase type of 12 kVA and step up the voltage from 300 volts to a value ranging from 3,000 volts to 4,500 volts, according to the requirements of the ozonisers. The high tension winding of each of the transformers is permanently earthed on one side and the other side is taken to the isolator panel under the ozonisers, so that any of the eight cells can be energised from either transformer as desired. The high tension switchgear, seen at the left-hand of Fig. 18, consisting of two incoming double-pole switch-fuse units feeding common 'busbars, off which is taken the supply through a four-pole change-over selector switch, also two controlling rheostats, ammeters and voltmeters. This gear allows for either frequency changer to operate with either transformer to provide the high-frequency current required, while the rheostats provide for the voltage variation of the convertor to suit the load on the ozonisers.

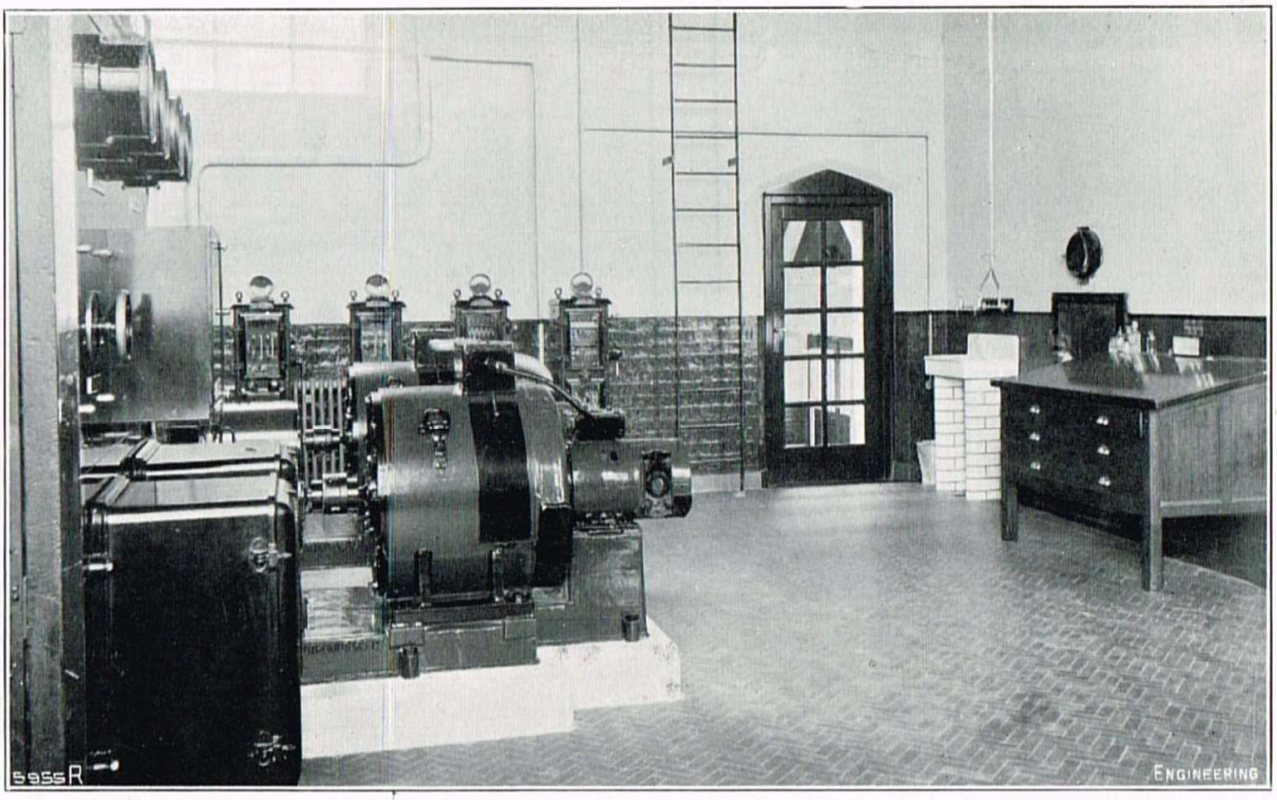


Fig. 18. Interior of Ozone House.

The supply for the internal and external lighting of the station and five adjoining cottages for the operating staff is taken off the tertiary winding of the transformers in the booster pump room. Separate meters are provided for the station and cottage lighting systems. The whole of the station is heated by a low-pressure hot water heating system. Owing to the considerable variation of levels in the different rooms of the station, it is necessary to accelerate the circulation by means of a small electrically-driven pump. The heating boiler is coke-fired.

As regards performance, the official trials of the pumping plant were carried out on February 20 and 21, 1937, the results obtained being given in

Table II. The plant was specified to be tested to comply with a guaranteed high-tension input in kilowatts per water horse-power hour when pumping under the specified conditions "A" and "C" of Table I, page 7. Owing to water level conditions in the well, it was not possible to carry out the tests under duty "A," but tests were made on both units under duty "C." Unit No. 2 was also tested under duty "D" of Table I. Each trial was over a period of three hours.

Subject to a tolerance of 3 per cent. above or below the given guarantees, there was a penalty or bonus of 150*l.* for each complete 1 per cent. by which each unit exceeded or reduced the average of the guarantees for duties "A" and "C," plus or minus the 3 per cent. tolerance, subject to a maximum penalty or bonus of 250*l.* per unit. It will be noted from Table II that the contractors for the pumping plant, who were Messrs. Sulzer Brothers (London), Limited, London, with Messrs. The English Electric Company, Limited, London, as sub-contractors for the electrical equipment, have earned the maximum bonus on both units. The work of reconstructing the buildings to accommodate the new plant was carried out by the staff of the waterworks company.

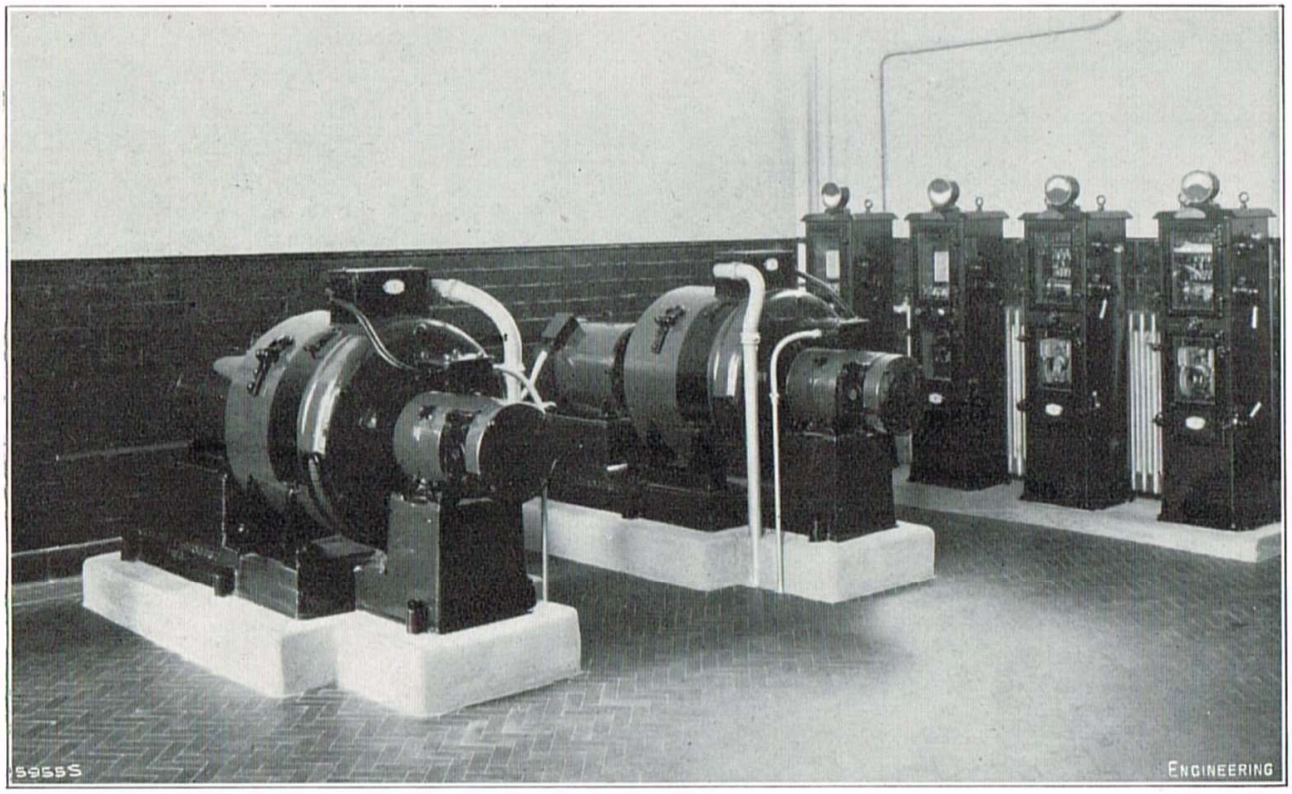


Fig. 19. Frequency Changers and Control Panels.

Table II.

	Set No. 1.	Set No. 2.	
	Duty C.	Duty C.	Duty D.
Gallons per minute	1,034	1,034	704·3
Total head on well pumps, feet	142·86	142·78	200·51
Total head on booster pumps, feet	234·70	228·12	231·80
Total inclusive head, feet ..	377·56	370·90	432·31
Equivalent water horse-power	118·30	116·20	92·30
Corrected high tension input, kilowatts	134·80	133·55	115·713
Equivalent E.H.P.	180·60	179·00	155·00
Overall efficiency, per cent. $\frac{\text{W.H.P. output}}{\text{H.T. input}}$	65·5	64·9	59·55
Guaranteed kilowatts per water horse-power hour..	1·234	1·234	1·345
Actual kilowatts per water horse-power hour.. ..	1·14	1·15	1·254
Percentage gain over guarantee	7·6	6·8	6·8

The Huntington station is one of seven stations on the Hednesford system, and, due to pumping conditions, it has only been possible to pump continuously at the rate of 38,000 gallons per hour. For this reason it has not been possible to carry out full range tests on the ozonisation plant, but the results obtained so far have been highly satisfactory.

The whole of the work has been carried out to the designs and specifications of the Engineer-in-Chief of the South Staffordshire Waterworks Company, Mr. Fred J. Dixon, M.Inst.C.E., M.I.Mech.E., to whom we tender our thanks for his courtesy in permitting publication of this account and for providing material on which to base it.

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