the water through the valves, as soon as the plunger, connected to any one of the three valve boxes, began to lift.

The valve seatings and covers were of cast iron, with valves of the multi-annular type of bronze, working on bronze removable seats, fitted with bronze spindles and phosphor bronze springs for accelerating their action. These valves were found to work very quietly and gave sufficient waterway with a maximum lift not exceeding 3/8in. Each valve was so formed that the water gave it ⅜in. Each valve was so formed that the water gave it a slight turn at the time of lifting, thus ensuring its rotating constantly on its seat. The usual sluice, relief and bye-pass valves were provided.

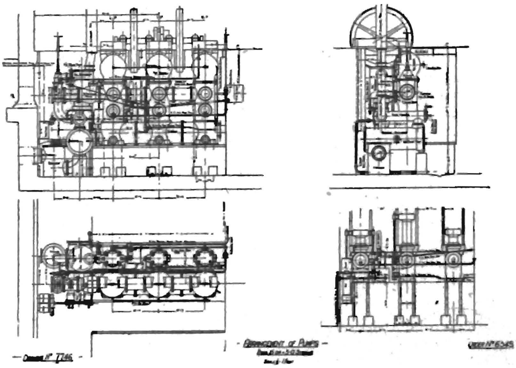


Plate No. 6A

PLATE 6A: A feed water heater was placed on the exhaust steam pipe between the low pressure cylinder and the condenser. having a number of solid drawn "U" tubes, expanded into a cast iron header. This heater had a capacity equal to heating all the feed water to within two degrees of the temperature of the exhaust steam, and was provided with the usual bye-pass valves for throwing it in and out of action.

An oil separator was inserted on the exhaust main between the low pressure cylinder and the condenser, provided with an oil extracting pump for handling the oil recovered from the exhaust steam. This oil separator was guaranteed by the makers that not more than one-half a grain of oil per gall. would remain in the condensed water after the steam had passed through the separator, and, on trial, it was found to act very satisfactorily indeed.

There were two feed pumps on this plant, each capable of handling from six to seven thousand lbs. of feed water per hour. One was worked by the engine, and had a ram 2in. dia. x 3in. stroke, connected to one of the ram heads, the pump being entirely bronze fitted, and it was with this pump that the major portion of feed water was pumped to the boilers.

There was also a bronze-fitted steam Weir pump of similar capacity, placed in position, as shown on the plan; this pump was used for pumping up the boilers at times when the main pumping engines were not in operation.

There were two feed tanks provided, upon one of which was mounted a Lea Recorder.

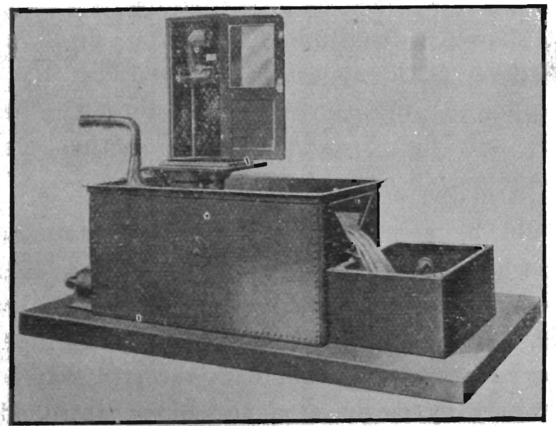


Plate No. 7.

Doubtless many of the Members were conversant with the operation of this machine, but, for the benefit of those who might not perhaps have been fortunate enough in having handled this instrument, a brief description of the same would not be out of place.

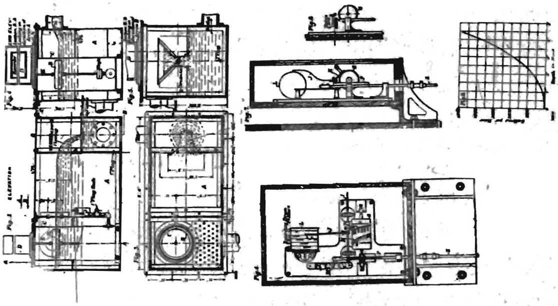


Plate No. 7A

PLATES Nos. 7 & 7A: Afforded views of one of these Recorders, the operation of which depended on the laws regarding the flow of water over weirs and notches, which laws had been found to work with great accuracy. They had been well known for a long time, but it was only comparatively recently that they had been turned to account in the ingenious manner embodied in this machine.

Fig. 2 showed a longitudinal elevation; fig. 3, a plant with the cover of the apparatus removed; fig. 4, a transverse section of the elevation and through the float chamber; and fig. 5, a transverse section elevation through the outfall chamber of the weir.

It would be seen that the tank of chamber "A," through which the water flowed, contained a float, "B," which was free to rise and fall, as the water level varied. The float was enclosed with inner chamber or pipe "C," which was in communication with the still water above the weir only by means of a 1in. pipe, controlled by a valve, the object of which was to prevent any surface agitation of the water in the tank affecting the float, as it was important that the water inside the cylinder "C" should be kept perfectly still, except for its rise and fall of level.

The float was usually made about 12in. in dia., and was connected to the recording instrument in the box "D" by means of the rod or spindle "E." This spindle, after passing through a patent anti-vapour gland, was connected to and actuated a rack "F." The rack "F," geared with a small pinion, which actuated the drum "G," upon the body of which there was wound screw thread "H," the contour of which was similar to the line formed by the curve of flow, as shown in the diagram Fig. 8. Above the drum "G" there was a sliding bar "I," which carried the pen-arm "J" and rested on small pivoted rollers, as shown in fig. 6, so that the slightest force would move it sideways.

It would be seen from this that, as the float rose, a rotary motion was given to the drum "G," which. by means of the spiral on its surface and the saddle-arm "K," caused the pen on the end of "J" to trace a line on the cylinder "L."

A small guard-arm prevented saddle-arm from being displaced with regard to the coil. This arrangement was shown in Fig 7A.

It would be noticed that at first the pitch of the coil in the drum "G" was very slight, but that it increased rapidly towards the left hand end of the drum, and that finally, after the maximum limit was reached, became zero again.

The movement of the pen was in this way limited, and no damage could happen to the pen at either end of its travel. No excessive motion of the rod "E" was allowed, either up or down, for the coupling between the rod and the rack, formed a stop in one direction, and the rack itself the stop in the other direction.

The scale "M," shown on the left-hand side of fig. 6, indicated the actual rise and fall of the water in tank "A" in inches.

The result of this mechanism was that the instrument could be employed to produce daily or weekly records from which the total quantity of water passed in a given time might be easily deducted.

It was found, when running duty trials of this pumping plant, that the Lea Recorder installed at the pumping station registered within .71 per cent. of the total steam consumption, which was first checked by careful tank measurement.

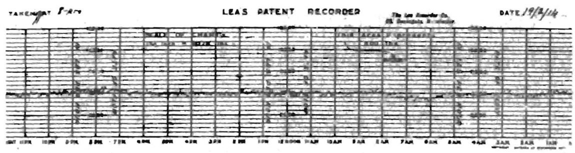


Plate No. 8

PLATE No. 8: Showed an actual card taken off the Recorder installed at the Walka Pumping Station.

(PLATE No. 4): To do the required duty of 150,000 galls. per hr., after allowing for slip, the engine was run at 38 revs. per minute, which was equivalent to a pump piston speed of 228ft. per minute. This speed rather conflicted with the contract specification, which stated that the speed of the plungers must not exceed 135ft. per minute, but, as in this instance the plungers were directly connected to the main crossheads, and the work, therefore, was not put through the crankshaft and connecting rods, the engine was capable of running perfectly steady and quietly at the speed named.

The really important point in this connection was not the speed of the engine, but the waterway through the pumps and valves. This was proportioned from the builders' experience in other cases. The actual speed of the water through the valves was only 250ft. per minute, and the speed through the suction less than 200ft. per minute. The internal vacuum vessels, which were provided immediately below each set of suction valves, enabled the engines to work quietly, at speeds considerably above their normal rate.

A small feed water filter was provided on the plant, but this was used for filtering some two or three thousand lbs. of additional feed, which came in from the old beam engine pumping plant.

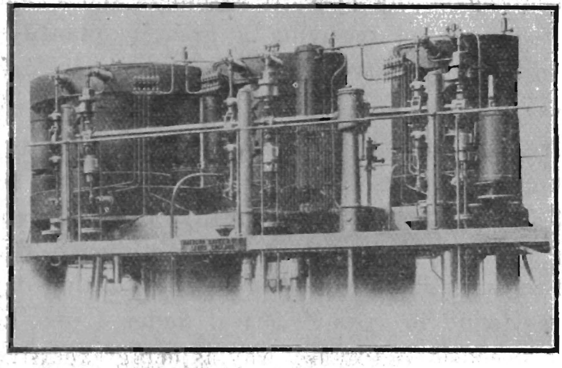


Plate No. 9.

PLATE No. 9: In the matter of external lubrication, all the principal bearings were continuously and automatically fed with oil by gravity supply from a tank on the staging, which was fitted with adjustable visible drop lubricators and copper pipes. The oil, after being used, was caught, strained and pumped back into the overhead tank, filtered under pressure, and so used over and over again.

The internal lubrication was supplied from a tank also fitted on the staging, which held about 3 galls. of cylinder oil, which was forced into the cylinders and steam chests by a positive pump, which stopped with the engine. Each cylinder was provided with six visible adjustable sight feeds and the necessary copper pipe connections.

It was possible to disconnect this pump and work the same by hand, and, experience had gone to show that the latter system of operation was much more satisfactory than when the pump was mechanically operated.

The oil feed was regulated to the respective cylinders and steam chests, by means of adjustable valves, and it would at once be readily seen the difficulty of getting anything like a proper feed under this arrangement. The oil naturally took the path of least resistance, and the intermediate and low pressure cylinders and steam chests were found to be receiving a greater quantity of oil pumped by the pump when being mechanically driven.

It was proposed to fit special control valves on the high pressure and intermediate circuit, so to speak, to enable the supply of oil to be regulated with more accuracy whilst the pump was mechanically operated, and thus ensure a continuous supply of oil being given.

The consumption of cylinder oil per working day of 24 hrs. was found to average out at under 4 pts., and this cannot be considered in any way as being excessive, when taking into consideration the high degree of superheat employed.

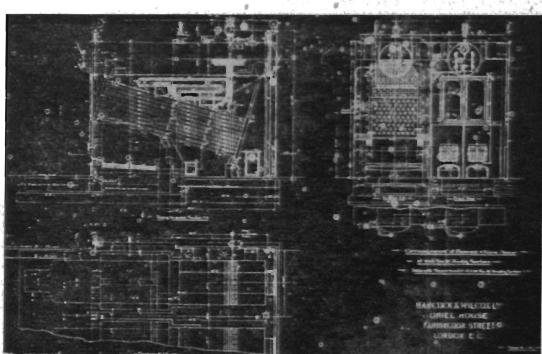
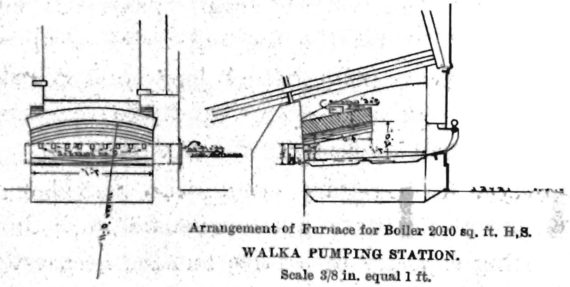


Plate No. 10.

PLATE 10: The boiler plant consisted of two water tube boilers made by Messrs. Babcock and Wilcox, Ltd. Each boiler had a heating surface if 2,010 sq. ft., and a grate area of 49½ sq: ft., and had a capacity of supplying steam for the Hathorn Davey pumping engines and all accessories. together with 2,500 lbs. of steam per hr. for the existing old plant. The boilers were worked at 180 lbs. pressure per sq. inch above the atmosphere, with a superheat of 150 deg. at the engine stop valve; each superheater had 440 sq. ft. of heating surface, and consisted of 32 welded steel tubes 1½in. dia., bent into "U" shape and connected at both ends by expanded joints to wrought steel boxes or manifolds. The general arrangement and design of the Babcock & Wilcox boilers were so well known as to need no detailed description here. The boilers were guaranteed to evaporate 7.75 lbs. of steam per lb. of coal, with a calorific value not less than 12,500 B.T.U.'s, the coal being that supplied by the Leith Collieries and known as commercial slack.



Arrangement of Furnace for Boiler 2010 sq. ft. H.S.
WALKA PUMPING STATION.
Scale 3/8 in. equal 1 ft.

Plate No. 11.

Some difficulty was at first experienced in implementing this guarantee, and, owing to the volatile nature of the coal, it was found necessary to alter the furnaces, as shown by the design, plate No. 11. This alteration had for its special purpose the supplying of a considerable quantity of air at the back of the fire-grate, and was found to considerably improve the evaporative performance of the boilers.

It was estimated that the excess air admitted by this method was approximately 20 per cent. above that taken in through the fire-grate in the ordinary way.

The water actually evaporated per lb. of coal was 7.63 lbs. with a calorific value of 11,590 B.T.U's. of the coal used.

The equivalent evaporation with coal at 12,500 B.T.U's., as provided for in the guarantee, was 8.2 lbs. of water per lb. of coal.

The efficiency of the boilers (with economiser) runs out at a shade just below 72 per cent.

(PLATE No. 4): A Green's economiser was installed, as being considered necessary to the obtaining of the guaranteed results from the boiler plant. This economiser was placed between the main flue and the chimney with the necessary valves and dampers for putting same in and out of action. It consisted of 120 tubes, 9ft. long, 4 9-16in. dia., with top and bottom headers forced together in sections, with hydraulic pressure, metal to metal joints. The usual self-acting treble scrapers were fitted to the tubes with lifting bars and guards with wrought iron rods and chains, and the scrapers were driven by a small horizontal steam engine.

An overhead travelling crane was provided in the engine room to facilitate any repairs, &c., &c.; this crane had a lifting capacity of 5 tons, but the heaviest weight to be dealt with in one part did not exceed three tons.

The total weight of the whole plant amounted to approximately 200 tons, so it might be accepted as being designed and built on liberal lines.

The plant was provided with the usual accessories, in the way of automatic recording gauges, for boiler pressures, temperatures, &c., &c., but these fittings were so well known as not to require anything but passing mention.

A guarantee had been given by the makers, that the steam consumption per thousand galls. pumped into the reservoir, would not exceed 22.5 lbs. of steam, and, as economy was the determining factor in the selection of the plant installed, it was hardly necessary to mention that very careful tests were made to ascertain if the plant complied with the guarantee given.

As already stated, the pumps had to deliver 150,000 galls. per hr. in the Buttai Reservoir, through a delivery main 9,800 yds. in length, 20¾in. internal dia., with a total lift—including friction—of 336ft.

Owing to the fact that supplies were constantly being drawn off in the surrounding district from the Buttai Reservoir, it was decided to test the capacity of the pumps by measurements taken at the filter tank, from which the pumps were drawing their supply. This tank was of circular design and had a dia. of 100ft. with a depth of 10ft., and, from very careful calculations made, 1in. in depth was found to represent 4,074 galls. The capacity of this tank was approx. a quarter of a million galls.

With pumps of this capacity it was necessary that the measurements taken at the tank should coincide to the fraction of a second with the readings taken at the revolution counter on the engine, and arrangements were made accordingly, the measurement of the water being ascertained per medium of the hook gauge, which gave very accurate readings.

For the duty test on the pumping engines a trial of 8 consecutive hrs. was run, and the following were the results obtained:—

Mean steam pressure at the engine stop valve, 177.2.

Mean steam temperature at the engine stop valve, 441.1 F.

Mean degree of superheat, 62.8.

Mean steam pressure at boiler, 182.3.

Mean steam temperature at boiler, 503 Fahr.

Mean degrees of superheat at boiler, 118.3 F.

Mean feed water temperature leaving economiser, 208 deg. Fahr.

Total revs. of engine, 8 hrs., 18,015.

Mean revs. of engine per minute, 37.53.

Total water pumped in 8 hrs., 1,221,957 galls.

Water pumped per rev., 67.83 lbs.

Total displacement of pump plunger per rev., 68.85 galls.

Slip per rev., 1.02 galls.

Percentage of slip of pump, 1.48.

Mean head against pump in ft., 335.3.

Total work performed in 8 hrs., 4,098,200,728 ft. lbs.

Pump H.P. in water actually lifted, 258.72.

Total steam consumption in 8 hrs., per tank measurement, 25,148 lbs.

Total steam consumption in 8 hrs., by Lea Recorder, 25,327 lbs.

Total steam consumption per thousand galls. pumped, based on tank measurements, 20.58 lbs.

Steam consumption per thousand galls. pumped, by Lea Recorder, 20.726 lbs.

Steam consumption per pump H.P., 12.15 lbs (this included all engine losses).

Mean vacuum, 27.44.

Total coal consumed per pump H.P. per hour, 1.76 lbs.

Duty of plant per cwt. of coal consumed, 125,866,068 ft. lbs.

From the above it would be noted that the actual steam consumption obtained was nearly 10 per cent. less than that guaranteed by the makers, whilst the guaranteed capacity of the pumps was exceeded by 1.8 per cent.

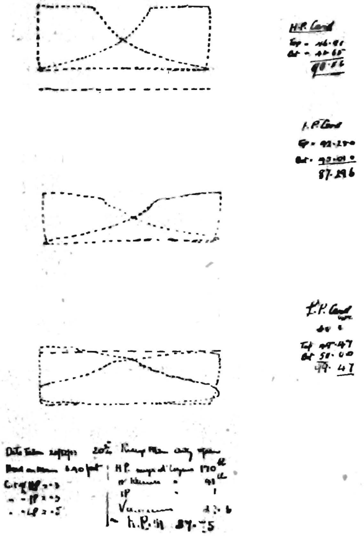


Plate No. 12.

PLATE No. 12: Showed a set of cards taken off the engines whilst under duty. The H.P. cylinder showed 90.56 I.H.P., the Intermediate Pressure 87.29, and the low pressure cylinder 99.47, which gave a mechanical efficiency of 93.2 per cent.

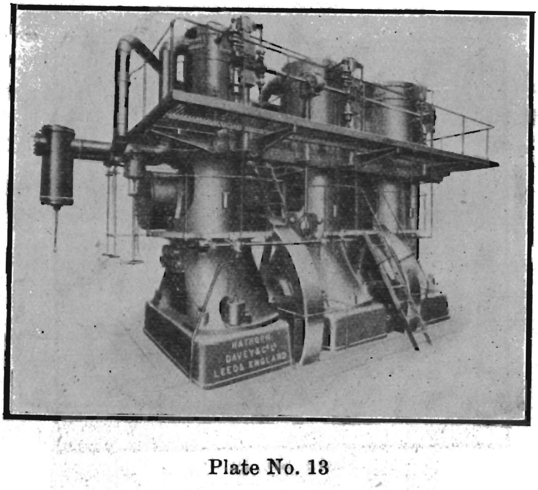


Plate No. 13

As reference had been made in this paper to the pumping engines supplied to the Rand Water Board, Johannesburg, it would probably be of interest for Members to know that these sets practically established a world's record at the time of their being tested by Professor Orr.

The pumps had a capacity of 100,000 galls. per hour, with a lift of 960ft. The steam consumption per pump H.P. was 10.78 lbs.; the overall mechanical efficiency was 93.1 per cent; the slip of pumps, when running at 240ft. speed per minute was 2.45 per cent.

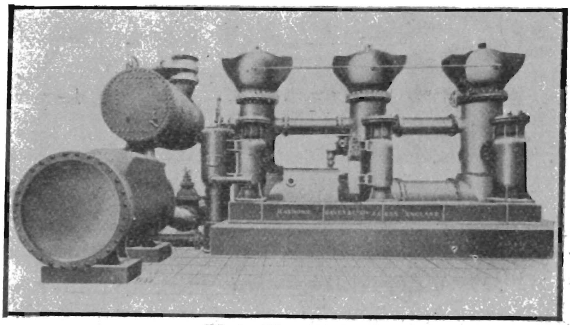


Plate No. 14.

PLATES Nos. 13 & 14: Showed the engine and pump, respectively, of this plant.

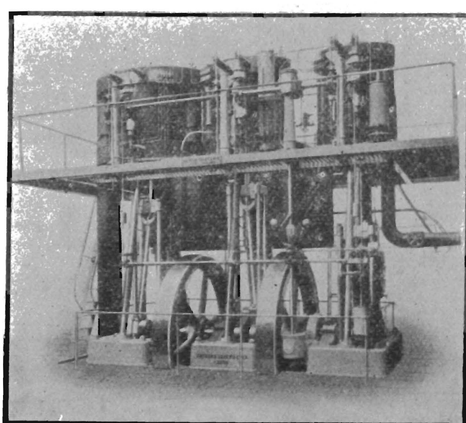


Plate No. 15

PLATE No. 15: Showed a pumping plant of the same type, supplied to the Lahore Waterworks, India, the duty of which was to raise 200,000 galls. of water per hour against a total lift of 125ft. from 12 wells, 1,650ft. distant, together with supplying 65,000 galls. per hr. through existing main, the remainder being taken from a well close to the engine house.

In this plant steam consumption was 11.8 lbs. of steam per H.P. per hr., whilst the slip of the pumps was only 1.73 per cent.

The author had to acknowledge information supplied by Mr. J. T. Rutter, engineer-in-charge of the pumping station.

In conclusion, the author recognised that probably much more could be said upon the subject of this paper, but calls upon his time in other directions prevented his giving little more than a brief summary, which, whilst intended to be comprehensive, must necessarily include many faults and omissions; he, however, submitted it to the Association in the hope that it might prove interesting, and possibly instructive to the Members.

Discussion.

MR. A. J. ARNOT said, like himself, everyone who had the privilege of listening to the very interesting paper which had been read by Mr. Saunders was filled with a sense of the keenest pleasure, and was also deeply grateful for the facts which had been so efficiently placed before them. The illustrations which appeared upon the screen had enabled them to grasp the various points of interest in connection with the plant at Walka, for which Mr. Saunders had been responsible. and the information supplied by the author was of the real vital nature that we, as engineers, were naturally interested in, and he