15TH APRIL, 1909.

THE COOLGARDIE WATER SUPPLY SCHEME.

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About the early part of the year 1892 the people of Australia were roused to considerable excitement by the news from Western Australia that gold had been discovered in astonishing rich and vast quantities in the district of Coolgardie. Very soon after the news reached the Eastern States many hundreds, even thousands, of mining men, storekeepers, speculators, and others were making their way towards the new goldfields. As is usual with all "rushes," great and many hardships were met with. The greatest suffering was, however, due to the want of water. Nearly all the water found was extremely salt, and in its natural state quite unfit for drinking and washing purposes. Many private undertakings were established for condensing the water. The Government also took the matter up, and spent something like half a million of money in water works of every description. These works, both on the part of private speculators and the Government, whilst they produced potable water, could only produce it at extremely high rates per 1,000 gallons. In the earlier days men who returned from the fields stated that fresh water was often more expensive than whisky and rum. Man and beast had to be supplied. And it was about the middle of 1895 that the Government, under the leadership of Sir John Forrest, with the late C. Y. O'Connor as Engineer-in-Chief, took the matter up of a sound and unfailing water supply, not only for the goldfields, but for the route to the goldfields, over which man, beast, provisions, and necessaries of life and industries were to be carried. Water was then being sold for from £4 per thousand gallons to 25s. per thousand gallons. The cost to the railways alone for one year was £60,000.

The cost of £4 per thousand being for condensed water; the cost of 25s. only when sufficient rain fell to fill the tanks which were erected for the purpose of catching the rain. This cheap water was not often available, as the average rainfall for the year at Coolgardie was very little more than 3½in., and the evaporation extremely great. Also the excessive porous nature of the soil and its salinity rendered the rain water useless after it had fallen to the ground.

As before stated, the Government took up the question of a large permanent and reliable water supply scheme. Many schemes were proposed, and from about thirty alternative propositions three were left for final consideration. The scheme finally adopted was one for pumping a daily supply of 5,600,000 gallons from a point in the Darling Ranges to Coolgardie, the estimated cost to be £2,500,000. And it was in the latter part of the year 1896 that the West Australian Parliament decided to raise by loan £2,500,000 for this purpose. It was finally decided to build a weir at a place called Mundaring, on the Helena River, to instal a pumping main 30in. diameter, and to pump from eight pumping stations, distributed as follows:—

1st, at Mundaring, 650 feet down stream from the dam, or the storage reservoir, and to deliver through about 1½ miles piping to a height of 415 feet, to a storage tank at No. 2 station; from this through 22½ miles to Baker's Hill (a height of 340 feet), into a regulating tank, from which the water gravitated to a regulating tank at Northam (12 miles further on, a drop of 94 feet);

and from this point the water gravitated to the Cunderdin Reservior, a distance of 41 miles from Northam, a total length of 75¼ miles from No. 2 to No. 3 station.

No. 3 station pumps deliver the water through 62¾ miles of piping to the No. 4 station, the net lift being 215 feet.

From No. 4 station the water is pumped a distance of 32½ miles to a height of 333 feet at No. 5.

From No. 5 to No. 6, 46 miles; 52 feet.

From No. 6 to No. 7, 31¾ miles; 106 feet.

From No. 7 to No. 8, 45 miles; 56 feet.

From No. 8 to service reservoir at Bulla Bulling, a distance of 12¼ miles, and 183 feet above the No. 8 station.

All the "head" figures given are net.

From this point the water gravitates to Coolgardie and Kalgoorlie, distances between being—Bulla Bulling to Coolgardie, 21 miles; Coolgardie to Kalgoorlie, 23½ miles; a total distance of 351 miles, and an elevation of 1,295 feet from the Helena River.

The selection of a site for the reservior necessarily required grave consideration, and after the Darling Ranges had been thoroughly searched, and all possible investigations made, a spot on the Helena River, at Mundaring, was decided on. This spot appears to have been specially left by nature for the purpose, the granite rocks reaching outwards into the river from either bank as if desirous of connecting. By building the crest of the weir 106 feet above the lowest scouring outlet, viz., 426 feet above sea level, it was estimated that about 4,600 million gallons of water would be impounded, the area being about 800 acres. This large amount of water impounded may seem enormous for a daily supply of five million six hundred thousand gallons (5,600,000) per day on a catchment area where the average rainfall was about 37in. per annum. But it must be understood that this rainfall is not all collectable, inasmuch as during the rainy months between May and November, when the principal rains come, the rain does not fall in heavy cloud bursts generally, but in light showers, thus allowing on the catchment area (of 569 square miles) a tremendous soakage, many of the feeders and principal storm water channels not flowing at all, even though for days light rains fall. Then, of course, evaporation had to be considered, and this was estimated, and finally proved, at about 4½ feet per annum. This also included a slight amount for leakages in the surrounding country.

The weir is an overflow gravity dam built of concrete. (Plate II., Fig. 1).

The excavations for the dam gave rise to considerable anxiety. The principal cause was the discovery of a very ugly fissure on the site selected for the dam, almost in the middle of the river. This caused at that part of the site excavations to be carried down to about 90 feet below the general level of the bed of the river before the officials were satisfied. At this point the rock was subjected to a hydrostatic pressure of about 690 feet, and found to be perfectly water tight.

On the right bank of the river (Plate II., Fig. 2) great trouble was caused and expense incurred by proving a tremendous floater, with a large cavity under it. This, of course had to be taken out, and from the view it will be seen what this meant in excavating and filling in (Plate III., Fig. 1), concreting being commenced 190 feet below the proposed crest of the weir. The crest length of the weir is 755 feet. The section was designed so that the pressure on any portion of the wall should resist eight tons to the square foot with five feet of water overflowing. This overflow has not yet been reached. In the year 1903, during the rainy season (Plate III., Fig. 2), the water was for two weeks overflowing at a depth of 6in., the greatest depth of overflow being in August, 1904, when there was 18in. passing over the crest (Plate IV., Fig. 1). It will have been noticed that the flow of water on both these occasions was unbroken, the water clinging to the whole face of the wall in its descent, and although the dam overflows every year not the slightest damage has occurred to the down stream portions.

The spill water basin is lined with concrete, and is about 100 feet wide by 150 feet long, with a depth of about 10 feet, a bank of rock and rubble extending across the river bed below it. This is the highest gravity dam in existence. The crest of the weir is a parabolic curve. (Plate IV., Fig. 2). At the 320 feet R.L. there is a 30in. scouring pipe, built through the wall, and extending down stream to and through the outer valve tower, the scouring being regulated by two valves, one in the inner and one in the outer valve tower. From the outer valve tower the scour empties into the river. The arrangements made to draw off the water for the pumps (Plate V., Fig. 1) are a stand-pipe in the inner valve tower, connected by piping at three different levels, through the valve tower walls, to the reservoir at 225 feet 6 inches, 53 feet, and 88 feet respectively below the crest level. This water column is connected by two 24in. pipes led through the wall, and carried in common with the 30in. scouring pipe in a solid concrete viaduct to the outer valve chamber, and there connected up to one 30in. pipe leading to the pump suction. The usual type of valve arrangement is in use, the valves being operated from the crest by wheels and gearing, and from the outer valve tower by similar means.

Extraordinary care was taken in the selection and preparation of the cement used throughout the construction. Special slaking sheds were built, with space for handling two thousand casks. (Plate V., Fig. 2). Exhaustive tests were made with the cement purchased. Much of the cement (all imported) required very little air slaking. Provision was made in the slaking sheds for one thousand casks spread out on tables. All the cement was passed through fine-meshed sieves before passing to the concrete mixer. The sand used, with the exception of a very few tons, was brought from Bayswater principally (about 22 miles from Mundaring). Some also from a place called "Lions Mill," about eight miles from Mundaring. All the sand required washing, the Bayswater sand requiring only light washing. All the stone required for the weir was quarried from near the site. The proportions of the concrete were—Five parts of granite, 2½in. gauge; two parts of sand; one part of Portland cement.

Plums, or gibbers, up to two cubic yards in volume were also used, care being taken that they were well bedded and grouted and rammed. The total amount of cement used in the construction of the dam was 77,500 casks, 19,700 casks being German, the rest British. About 30,000 yards of spalls for concrete were used, a rough estimate of the total cubic contents of the dam being 50.000 yards. The dam took about 2½ years to complete—not long considering the extra work entailed due to faults. The cost of the construction of the dam was £250,000, and the cost for land resumptions and five miles of narrow-gauge railway £30,000.

The system of timbering the dam during construction can readily be appreciated from the view shown, and it may be of interest to know that no facing was required after the timber was removed, the faces appearing quite smooth, the only thing necessary being to take out the bolts and cement up the holes. The finished dam and its surroundings is now one of the favourite picnic resorts of the people of Fremantle, Perth, etc., to which the

Government run many excursion trains during the hot weather. The people greatly appreciate the manner in which the administration have cleared the rough bush, and erected little bowers and many pathways, with flower beds on either hand. This, coupled with the natural beauties of the country surrounding, tempting numbers of people to visit the site.

There are seven suction tanks used, one at each station excepting the No. 1 station. The view (Plate VI., Fig. 1) shows a picture of the machinery sheds or engine houses, with the wall of one side of the suction tank and the water in it. Six of these are concrete-lined excavations, 20 feet 6 inches x 145 feet x 73 feet, with batters above the ground; capacity half a million gallons. The seventh is a reservoir with a capacity of ten million gallons, 77 miles from No. 2 station, at Cunderdin. This reservoir was taken over from the Railway Department, who constructed it in the old days, and used it for storage water for the engines.

The regulating tanks at Baker's Hill and Northam are also concrete-lined, and much the same section as the suction tanks. The service reservoirs are three in number—one of one million gallons capacity at Coolgardie, and one at Kalgoorlie of a capacity of two million gallons, similar in construction to the others, but fitted with bye-pass arrangements to allow for the tanks being cleaned or repaired in case of accident. The main service reservoir at Bulla Bulling is of special construction, the concrete being reinforced with barbed wire, 12in. spaces in bottom, 9in. spaces in batter, and 8in. spaces in top wall. The bottom was built of two layers of concrete, the bottom layer eight inches thick, with a smooth top face, and the top layer four inches thick, thus allowing the top layer to slide on the bottom layer. At the junction of floor and sides a bituminous joint was made six inches deep by half-inch wide. The sides and walls were built in sections, also jointed with bitumen. This was done to avoid the certain destruction, had these precautions not been taken, owing to contraction and expansion.

The service reservoirs and regulating tanks cost £60,000.

In a long distance pumping scheme such as this (351 miles of pipe line), the question of piping was a matter for careful and thorough investigation. It had been decided to sell water at from 3s. 6d. to 7s. 6d. per 1,000 gallons. Necessarily, the initial cost, with its interest on capital, and the working costs, had to be closely considered. Cast-iron piping was not to be thought of, owing to its high capital cost, both for material, freight, and handling charges. Other piping had to be considered. After calling tenders in Australia, America, and Europe for welded, rivetted, and locking-bar pipes, exhaustive comparison led to the adoption of the locking-bar type of pipe, and although the initial cost of this piping showed something like 11½ per cent. more than the rivetted pipes would have been, there was a frictional resistance of 25 per cent. in favour of the locking-bar type. Also, the difference in life of the pipes was estimated at nearly 40 per cent. in favour of the locking-bar pipe (Plate VI., Fig. 2), due to the estimated safe working load of the rivetted and locking-bar pipe being as two to three in pipes of equal thickness. Also the fact was obvious that the locking-bar pipe was less subject to leakage than the rivetted pipe, with its hundreds of thousands of rivets. All these points brought about the decision to instal locking-bar pipes, 30in. diameter, ¼in. thick, and 28ft. in length, weighing about 1¼ tons each; also a considerable number of pipes made of 5-16in. plated pipes for such portions of the system as were exposed to the greater head pressures. The total number of pipes of all thicknesses was, roughly, 60,000. At every five miles or so along the line scour and stop valves were placed, and on long gradients reflux action valves were placed, and at all summits air valves of the Glenfield pattern were placed. Whilst most of our members are fully conversant with the locking-bar pipe, a brief description of the method of manufacture may be of interest. The contract for the pipes was divided between Messrs. Mephan Ferguson and G. and C. Hoskins. Mephan Ferguson put up works at Falkirk, about three miles from Perth, and Messrs. Hoskins at Midland Junction, about twelve miles from Perth. The system of manufacture was similar at both works.

Plate VI., Fig. 2, shows a section of the locking-bar before closing and after closing. A section showing sleeve for joint and two bars jointed, but with the sleeve cut through to show the ends of the two pipes. The pipes each consist of two plates and two locking bars. The plates, half of which were imported from America and half from Germany, were, after tests, specified to have a tensile strength of from 22 to 26 tons per square inch.

The locking-bars, all imported from England, were of a section of, for the ¼in. pipes 7lbs. and for the 5-16in. pipes 8¼lbs. per lineal foot, with the same tensile strength as the plates specified.

The plates, a little longer than 28 feet and 4 feet in width, after being examined and weighed, were first passed through horizontal rollers, to take out all kinks and make them straight. They were then cut square and exactly 28 feet long, and then passed through the planing and dove-tailing machine, the machine being fitted with cutters set to the exact position to cut the plates the required width, the cutters being followed up by rollers for forming the dove-tail. The plates then passed into a horizontal press, and the edges were given the correct curve. Again they were passed to the rolls for bending to an exact semi-circle. The plates were then assembled to the locking-bar, and securely cramped together with powerful cramps, the cramps being pulled together by driving the cotter pins tight in the cramps. Thus assembled the pipes were passed along to the hydraulic closing machine or press, where the locking-bar was closed on to the plate under a pressure of 1,200lbs. to the square inch. The whole of the operations were carried out without heating plates or bars. The pipes were then tested to 400lbs. to the square inch, after which they were passed along to the coating bath, where they were, after being heated to a temperature of 300 degrees Fah., dropped in the bath, containing a solution of ordinary gas tar and Trinidad asphaltum in equal quantities by measurement. After being taken out of the bath the pipes were spun round in a lathe and air blown through them, and the outside sprinkled with fine sand. After being again weighed and marked, the pipes were ready for the trucks. The work both at Falkirk and Midland Junction were capable of turning out from 160 to 150 pipes per day of eight hours respectively. Some days Falkirk turned out as many as 180 in eight hours, the average time thus taken, being from the weighing machine to ready for truck, averaging 2.75 minutes; the machinery being laid out in such a manner that there was no bringing material back to any point, the growth of the pipe continuing from the commencement to finish in a continuous and almost automatic movement. The sleeve joints need no comment, excepting that all were imported from England. The jointing material was special soft lead, and the usual yarn on the inside. Due to the thinness of the plates, the usual method of caulking was looked upon doubtfully, and the work was carried out with caulking machines devised by a local firm, who proved that the machine-caulked joint stood the pressure better than the hand-caulked joint. A description of this machine will take too much time to-night. Running the lead was found to be very troublesome, until a special lead-melting device (Plate VII., Fig. 1) was brought into operation, which got rid of the troubles (honeycombing and wants, etc.). The parts of the joints at the locking-bar, you will readily see, necessitated hand-caulking. An average day's work was about 30 joints. The work of laying the pipes in their trenches, putting on sleeves, adjusting, running lead, hand and machine caulking, and finishing was carried out with systematic regularity.

Plate VII., Fig. 2, shows the lowering of pipes into trench. Plate VIII., Fig. 1, pipes crossing a gully. Same method was adopted for swamp. The total cost of the delivery main, including all specials and valves, etc., trenching, jointing, and covering in, was £1,870,000.

The amount of water per day having been decided at five million six hundred gallons, and the diameter of the main at 30in., the style of pipe determined on, it remained to fix on the style and horse-power of the pumping engine. A liberal estimate for friction head per mile was taken at 3.76 feet, and the mileage to Bulla Bulling being 307 miles the total friction head was apparently 1,156 feet. The static head being 1,290 feet, gave an apparent total of 2,446 feet. To this, however, had to be added 122 feet for loss of head in suction reservoirs, in seven stations, bringing the total to 2,568 feet. But on the delivery line the natural contour of the country between stations Nos. 2 and 3 necessitated raising the water another 87 feet, thus bringing the total head, including suction and friction, to 2,655 feet. Dividing up the total head into stages of eight pumping stations, in order to keep the pumping units to uniform size as much as possible, it was decided to create the stations at such distances apart that at the first four stations the head would be equal to 450 feet each, and the last four stations 225 feet. This slightly increased the estimated head to 2,700 feet total, a waste head of 1¾ per cent. This apparent waste head was more than compensated for by having interchangeability of parts and