a small stock of spare parts. The type of engine was a difficult matter to decide. Tenders were called for in America, Europe, and Australia, and as, in the case of the pipes, the actual decision was based on operation costs rather than on the first cost, various types of engines were submitted. The flywheel was first disregarded, on account of initial first cost, excessive cost of foundations, the proved augmented annual cost for repairs and up-keep, and the decreasing efficiency from year to year. Of the direct acting type (which were eventually selected), the established reputation of the economy in up-keep, with engines of this type built by Messrs. James Simpson and Co., together with their guarantee of steam consumption per P.H.P. and duty per "N." Thermal units, showing a saving per annum equal to a capitalisation of some thousands of pounds, and turned the scale in their favour, with the result that the order was placed with Messrs. J. Simpson and Co., London, for 20 sets of pumping engines, boilers, etc. In each of the first four stations was to be installed three triple-expansion, high-duty Worthington pumping engines of the following sizes:—

H.P. Cylinder, 16in. diameter.
I.P. Cylinder, 25in. diameter.
L.P. Cylinder, 46in. diameter.
Double-acting Plungers, 15in diameter.
(All having a common stroke of 36in.).

Together with three Babcock and Wilcox boilers.

The boilers adopted each contain 1,800 square feet of heating surface, the grate area being 33 square feet. The drums are 4 feet in diameter, by 24 feet 3 inches long. Nine tubes wide and nine tubes high, 18 feet long, four inches in diameter.

Each boiler is capable of evaporating, under normal conditions, 6,000lbs. of steam per hour from and at 212 degrees Fah. The super-heaters are of the integral type, each containing 276 square feet heating surface, and suitable for 120 degrees superheat.

GREEN'S ECONOMISERS.—The economisers are of two different sizes. Where three boilers are installed the economiser, Green's type, contains 120-10ft. tubes, being arranged 6 wide and 20 long. Where two boilers are installed the economiser consists of 96 tubes, 6 wide and 16 long; two feed pumps; and a Webster feed water-heater. The feed pumps, and all piping, steam, exhaust, etc., and suction and delivery to outside the building, complete and erected and maintained in good running order for twelve months from date of completion of erection. In the last four pumping stations there were to be provided two sets of triple-expansion, high-duty Worthington pumping engines, the steam ends being identical with those of the first four stations, but the water ends to have plungers 21in. in diameter, together with two Babcock and Wilcox boilers, Green's economisers, Webster's feed water-heaters, pumps, piping, etc., erected and maintained for twelve months under a guarantee that each of the pumping units should maintain *a duty of 135 million feet lbs. of effective work done per million British Thermal units supplied to the engines,* which would not be returned to the boiler in the ordinary course of working. Also that any one unit should be capable of delivering from its station to the reservoir at the next station 2,800,000 imperial gallons of water in twenty-four hours, and that the duty of such group (Plate IX., Fig. 1) would be not less than 135 million ft. lbs. for every 160lbs. of coal consumed, the coal used to be what is known as the "Collie" coal, which had a value of, nominally, 10,000 b.t.u. per lb. The piston speed of the pumps was not to exceed 150ft. per minute.

Where two boilers are installed the economiser consists of 96 tubes 6 wide and 16 long. Bye-pass arrangements were made to allow of overhauling the economiser when necessary. Suitable scrapers attached to the nests of tubes, driven by small engine. The chimney stacks (Plate VI., Fig. 1) are of steel, 5 feet in diameter and 130 feet in height at the first four stations, and 90 feet in height at the last four stations.

With the exception of the special tube and arch bricks, and sufficient fire bricks to line the furnaces (one half of which were imported), it is a matter of interest to know that all the other bricks were made in Western Australia.

So much is known of the Babcock boilers (Plate IX., Fig. 2) that very little can be said, except that they have given every satisfaction. The water from the hot well was passed through a Webster feed water-heater, purifier and filter combined (Plate X., Fig. 1), in which the feed water, besides being purified, was heated to 180 degrees Fah. From this apparatus the feed pumps (horizontal pressure-feed, Worthington pot-valve pattern) forced the water through the Green's economiser to the boilers, the water entering the boilers at a temperature of 380 degrees. The Webster heater gained its heat units from the exhaust steam from the feed pump, these pumps being driven by the steam passing through the re-heaters on I.P. and L.P. cylinders and the cylinder jackets. All condensation from re-heaters and jackets was collected and forced into a hot well by a small Worthington duplex pump. The main pumps (Plate X., Fig. 2) were of the Worthington triple-expansion, high-duty, surface-condensing type. The view on the sheet shows the engine in side elevation. One of the first things to strike one about this view is the simplicity and small cost for foundation work, and although it may not be quite clear in the picture the fact remains that only the water ends are bolted down to the foundations, the steam ends being supported (high and intermediate) on the pipe column shown, and the low-pressure cylinders on rollers under the feet of the cylinders, suitable plates being introduced between the rollers and the foundation stone. The H.P. and I.P., on the supporting columns, are allowed free movement on the square flanges. This allows of the free elongation of the engines by expansion when heating up; also a free movement accommodating the elongation due to stress under working conditions. Thus everything is free, and no binding occurs, reducing the friction of the working parts to a minimum. Certainly this calls for perfect alignment, but this is not difficult to accomplish. Plate XI., Fig. 1, shows the pumping engine in sectional elevation. One can see at a glance from this view of the engine what might at first not be apparent, viz., the facility of drawing the pistons for examination of pistons and cylinders. It will be seen that the intermediate pressure piston and the low-pressure piston are connected by a central piston rod; the high-pressure cylinder by a rod connecting in the centre of the engine cross head. The high and intermediate pressure cylinders have their covers in the same aperture, and can easily be removed. There is ample space to draw either the high or intermediate pressure pistons, and it is surprising how little time it takes to do this. The low-pressure piston, however, as will be seen from Plate XI., Fig. 2, is carried by three piston rods. The two outside rods, being connected to the cross head, and passing through the glands to the piston, therefore transmit motion to low and intermediate pressure pistons. In the previous view the manner in which this was done was not apparent. These three rods, besides being necessary in this design to transmit motion, form a great support for the heavy low-pressure piston, allowing the disuse of tail rods, which might otherwise be found necessary. Again referring to the section, Plate XI., Fig. 1, members will notice that the distance piece between the L.P. and I.P. cylinders is provided with a bush only. This bush keeps itself absolutely steam tight. He desired members to specially note this fact when viewing diagrams taken off these engines after five years' work. Members will also notice that the cylinders are all jacketed (Plate XII., Fig. 1), and that there are no liners in the cylinders, the jackets being cast with the cylinders. This, of course, necessitates special care in the foundry, and in design also, to avoid foundry strains. The plate shows a low-pressure cylinder in section.

The following five diagrams show the work on cylinders which may be of interest:—

High-pressure cylinder showing header, Plate XII., Fig. 2; core for intermediate-pressure cylinder, Plate XIII., Fig. 1; shows method of building up jacket core on a runner for intermediate-pressure cylinder, Plate XIII., Fig. 2; core for L.P. cylinder, without main core, Plate XIV., Fig. 1; L.P. cylinder, showing header, Plate XIV., Fig. 2. In Plate XI., Fig. 1, you will notice the method in which the exhaust from high and intermediate cylinders is reheated before going into the intermediate and low-pressure cylinders. Superheated steam direct from the boilers is passed through these re-heaters, also through the jackets, and goes out to the feed pumps, to drive same thence to the Webster heater, and here gives itself up to the feed water with its heat units. You will notice that the exhaust pipe is fitted with an expansion joint. This is essential, due to the working lengthways of the engine when pumping and the length of the pipe. The exhaust steam passes through an exhaust steam oil separator of the Webster type, 80 per cent. to 90 per cent. of extraction effected. The condenser, which is of the surface type, is placed on the main suction to the pumps, therefore all the water pumped passes through same. The quantity of water is so great that the difference in temperature between inlet and outlet water is scarcely appreciable. The air pumps are worked by bell cranks from the cross head of the engines, and are of ample capacity to maintain a vacuum of 27in. at the highest station. They are of the D.A. piston type or S.A. bucket type. It will be noticed that the pumps proper are of very simple construction. The plungers are outside centre-packed, and referring to Plate X., Fig. 2, of the side elevation, it will be seen how the water ends are divided up, and ample arrangements made for getting easily to any valves in any parts of the water ends. Two especially interesting features in these pumping engines are the high-duty attachment and the special vacuum breaking safety attachment. The high-duty attachment (Plate XV., Fig. 1) is the application of the idea of storing up energy at a part of the stroke where it can be spared, and giving it off at the end of the stroke, where it will be most valuable. The arrangement and the working of the high-duty gear is as follows:—To the cross heads of the engine are attached by knuckle joints the rods of the plungers of the compensating cylinders, or pots, as they are commonly called. The plungers work through glands and stuffing boxes, at top and bottom of the cylinders respectively. These compensating cylinders, which are filled with oil, are designed to oscillate in hollow trunnions. These hollow trunnions are connected by pipes to the bottom end of a differential accumulator, and are also filled with oil. An air compressor supplies the bottom cylinder of the differential accumulator with a small quantity of air to give the necessary cushioning, and regulates the difference in pressure required between this lower cylinder and the upper cylinder. The bottom cylinder of the accumulator is fitted with a ram passing through a gland, and connected to the piston of the upper, or air, cylinder of the accumulator. The upper end of the air cylinder is connected by piping to the top of the air vessel on the delivery main, thus always being open to the pressure in the delivery main.

Going back to the compensating cylinders, or pots (Plate XV., Fig. 2), it will be seen that when a cross head is at the extreme end of the stroke the plungers are extended, so that the oil, under pressure from the accumulator, fills the pots. When the cross head starts on its stroke, actuated by the pressure of steam on the pistons, it arrives at the middle of the stroke, and brings with it the pot plunger rods in a vertical line, which causes the plungers to displace all the oil in the cylinders, and store up energy in the differential accumulator, compressing the air in the lower one; then passing onward, allows the stored up energy in the accumulator to be given to the plungers as they are going out, and these plungers give off their energy to the moving cross head when the expansive power of the steam in the cylinder is at its lowest, and, so to speak, pushes the water plungers to the end of their arranged stroke, giving the pumps their normal displacement, and so on during the return stroke. The pots, it will be seen, make two oscillations for each single stroke of one plunger. In the differential accumulator it will, therefore, easily be seen that any sudden loss in head due to the sudden release of water in the delivery main will decrease the pressure in the air vessel and air cylinder, and therefore the pressure in the pots, and consequently the engine will make a short stroke, according to the pressure taken off, and prevent any accident. This apparatus was invented by Mr. C. C. Worthington many years ago. (Plate XVI., Fig. 1.).

The other safety attachment, called the vacuum breaking attachment, is actuated by either loss or increase of pressure in the main by means of trip gear and levers, which are loaded on either side for certain pressures to be agreed upon. As an illustration of the value of these two safety apparatus, at one of the pumping stations on the Coolgardie scheme two pumps were both on full load pumping, when some blasting operations caused a large piece of rock to break through the delivery main. The engines stopped dead, without the slightest damage to anything in the engine-room. To illustrate the splendid results of the high-duty attachment, Plate XVI., Fig. 2, shows sets of diagrams taken of the engines of two different stations about eighteen months ago—after five years working.

Although the shipping arrangements of a considerable amount of machinery have only to do with the commercial side of engineering, it might yet be of interest to know that by the method of marking carried out with these twenty sets of engines, boilers, etc., as shown by Plate XVII., Fig. 1, not an ounce of machinery was overcarried, and not one pound's worth of apparatus was lost. Most of the engines and boilers were erected under difficulties, no engine-house being available until all of the boilers and most of the engines were erected, thus losing to the contractors the valuable use of the 10-ton travellers erected in each engine-house. Plate XVII., Fig. 2, shows a cylinder being hauled into position, men working in extremes of weather, and machinery exposed to same.

The total cost of engines, boilers, etc., was, including spares, freight, and erection, £290,000.

The pumping stations (Plate VI., Fig. 1) were designed by the Government. The railway sidings, suction tanks, and employees' quarters cost a total of £140,000. All along the line is a telephone service line independent of the Government lines or railway service, and connecting up the different stations one to another, so that a message from Perth to Kalgoorlie on the water supply service could be transmitted in a few minutes. This service, with a few other contingencies, cost £20,000, thus bringing up the grand total of this scheme to £2,660,000.

As to the results of the decisions arrived at among engineers, and the selections of material and machinery, it is sufficient to say that the dam is to-day a structure that must be looked upon as one of the finest south of the line. The pipe line has come out as well as was anticipated, with the exception that in some few places, due to the action of the soil principally, the pipes have eaten away. The machinery is apparently, after more than six years' continuous working, as good as new; and the results of the pumping engines themselves gave 144.4 million ft. lbs. at No. 2 station and 148 million ft. lbs. at No. 8 station, the guaranteed duty being 135 million ft. lbs. of work for 160lbs. of Collie coal, with 10,000 B.T.U. per lb., or an equivalent of 112lbs. of Welsh coal, worth 16,000 B.T.U. (Plate XVIII., Fig. 1). The slip of the pumps was established, after exhaustive tests and measurements, at as .6 per cent. at No. 8 station. The quantities delivered during twelve hours' tests were at the rate of 6,093,000 gallons per day at No. 2 and 6,177,000 gallons per day at No. 8 station, the contract quantities being 5,600,000 gallons. The average cost of pumping for year 1906-7 being .327 pence per 1,000 gallons per 100ft.; 1905-6 being .34 pence.

Altogether Australia is to be congratulated on having taken on and so successfully carried out such an engineering work.

A word or two as to the financial results of the scheme. It is very difficult to estimate what really should be chargeable to the scheme. In order to show what the calculations as to the worth of the undertaking have been borne out. Bringing the price of water down from £4 and 25s. per 1,000 gallons to—

	Mundaring.	Kalgoorlie.
Domestic supplies and ..	2/- ..	4/-
Market gardens	2/- ..	3/-
Mines, if using scheme water only	3/- ..	3/6
If retaining right to use any other supply but scheme water	6/6 ..	7/-

naturally conferred a boon on the people using the water.

Then, considering that many intermediate townships were benefited with a good, permanent water supply, created a position that was beneficial. Again, many otherwise unprofitable portions of the country are now revenue-producing to the Government, and are giving work to some hundreds of people, thus directly and indirectly benefiting the State. A much more direct benefit was gained by the Government, inasmuch as the railways were paying as much as £60,000 per annum for water for the train services. From the latest report he had in his possession (1906-7, June), the total water consumed was 688,548,000 gallons; daily consumption, 1,886,433 gallons; total revenue, £167,146; total cost of operations, £64,928, including £11,000 held in reserve; gross profit, £102,218.

From gross profits must be taken £13,989, made up by interest, at 3½ per cent. on £267,000, the first capital raised by the administration, and 2 per cent. sinking fund on same; leaving £88,229 available to the general revenue of the State. The interest on main capital expenditure, however, amounts to £91,700, and sinking fund on main capital to £81,100, showing a bookkeeping deficiency of £84,571.

In this year the railways only paid the administration £16,871. It is, therefore, evident that when the Goldfields Water Supply Administration can sell the quantity of water they were originally led to believe would be used, the scheme will undoubtedly prove a success in all ways, and from all points of view. He trusted this paper had been of interest. By the courtesy of Messrs. James Simpson and Co. he was able to produce all the pictures shown to-night, and also by the courtesy of Mr. Reynoldson, Engineer-in-Chief of the Goldfields Water Supply, the indicator diagrams and the financial statement.

It is to be hoped that the scheme would prosper, and be an incentive to others, when necessity arises, to

"GO AND DO LIKEWISE."