DISCUSSION.

Mr. L. C. Auldjo, in opening the discussion, stated that he agreed with the author in the statement that it would have been very much more satisfactory if designs had first of all been invited, and after the most suitable one had been selected to have then called tenders for the supply of the pumps, the engineers who submitted designs would then have furnished complete plans and specifications, and they would also have been responsible for the duty which the pumps were guaranteed to perform.

Any competent engineer who read the specification under which these designs were sent in would, he believed, agree with him that it was somewhat vague. The idea of making the builder of the pump responsible for the duty of a boiler, with which he had nothing to do, and about whose evaporative efficiency no information was supplied was peculiar, more especially as an elaborate analysis of the coal to be used during the supposed duty test was given. When one ponders over this he ceases to wonder at the facts brought forward by the author, which go to prove that the pumping engines built some fifty years ago were more economical than those being built at the present day.

To emphasise these facts it was only necessary to go to Crown Street Pumping Station and examine the mass of complicated machinery called the Worthington High Duty Pumping Engine. These pumps had no fly-wheel, and its place was supplied by two compensating cylinders, an accumulator, an air and a water pump, also various fittings. The compensating cylinders required close attention and regulation, as the pressure in them was constantly varying, and with all this complication the result was only a duty of some 65,000,000 foot lbs. per cwt. of coal burned. The same firm who built these pumps—Messrs. Simpson and Co., of London—also built some forty years ago the pumps at the Chelsea Water Works, London, which gave a duty of 111,000,000 foot lbs.; and also the pumps at the Berlin Water Works, which gave a duty of 117,000,000 foot lbs. Both these pumping engines were Woolf's type compound beam engines with fly-wheels, and the boiler pressure was from 30 to 40 lbs. The above tests were conducted by T. Hawksley, in London, and H. Gill, in Berlin. He believed these pumps were still at work and could show the same duty now as when they were first started.

The boilers in use at Crown Street are the Babcock and Wilcox, the working pressure being 90 lbs., so that the Worthington's had everything in their favor. No doubt the fact of the pumps only being run for some five to seven hours at a time was rather against them, but still this certainly could not account for the very low duty shown.

He would like to draw attention to the pumping engines recently erected at the Ryde Pumping Station. They were vertical compound fly-wheel pumps, not unlike the designs sent in by the Atlas Co., and Auldjo and Osborne. These pumps were as plain and substantial in design as could be desired, they could be handled by any ordinary mechanic, and it certainly was a pleasure to see them at work. They gave a duty on trial of over 120,000,000 of foot lbs. The boiler pressure was 90 lbs., and the piston speed about 160 feet per minute. They were built and erected by James Watt and Co., of Birmingham, and were certainly a very different piece of work to the pumps, by the same firm, at Cockatoo Dock, mentioned by the author, in which the speed of the plunger was greater than that of the piston.

The author, in his paper, referred to the pumping engines built to his designs by the Atlas Co., as auxiliary to the Botany pumps, and made a very strong point of the fact that they were built and started in 60 days, but the facts of the case were, that he (Mr. Selfe) only designed the pumps, and that was all the Atlas Co. constructed, as the engine portion complete was imported for some other purpose, but made use of to save time. The author stated that these pumps were similar to the Paris Waterworks, designed by M. Farcot, about the year 1872, pointed out the feature of the pointed plunger, and the large capacity of the pump chamber, which allowed the pump plunger to be run at a speed of 360 feet per minute. Now some eight or ten years previous to these Paris pumps being built, Messrs. Porter and Allan, of New York, had built the air pumps of three horizontal engines on this plan, the pump ram being a continuation of the piston rod. The piston speed of these engines was from 800 to 1,000 feet per minute, or rather more than twice the speed stated of the Paris pumps.

He wished to describe the pump design submitted by Messrs. Auldjo and Osborne, for which he was mainly responsible. The pump end was, so far as he knew, original in design, and it appeared to him to possess several good features. The pump was single acting in suction, and double acting in delivery, the valve area was large and the valves could be inspected without any difficulty, all the castings were plain and cylindrical, the water passages large and direct, and no air could possibly be locked in the pump chamber. There was nothing special about the steam cylinders, they were jacketed all over, and both fitted with expansion valves to allow of cutting off the steam from $\frac{1}{8}''$ up to $\frac{7}{8}''$ of the stroke. The air and feed pumps were driven by an eccentric from the main shaft. Both the pumps and steam cylinders were so connected and fitted with sluice and stop valves that either engine could be run independent of the other, by removing one of the connecting rods, should a break down occur. Both steam cylinders were also connected to the condenser and air pump. The alteration from compound to high pressure condensing could be made in a few minutes. There was also a suction and discharge air vessel to each pump in addition to the main air vessel.

On examining the accepted design its resemblance to a Worthington pump would at once be observed, with the compensating cylinders omitted and a fly-wheel added. It had all the good and bad features of its prototype. The rectangular section of the pump chamber required that it should be strongly ribbed to withstand the heavy pressure that it had to contend with. Its best feature was the large number of small valves, giving a large port area with a low lift, also their accessability. There were no expansion valves fitted, which would lead to the belief that a high duty had not been aimed at. Although there were two separate pumps they could not be worked separately, as neither the steam or the pump ends had valves to allow of their being shut off in case of break down. This being so he considered that the pump could have been made at a much less cost, and more accessable if one high and one low pressure cylinder had been adopted in place of the tandem cylinders as shown.

The author, in drawing attention to the fact of there being no bed-plate, had pointed out the weakest feature of the whole design. In a Worthington pump proper, the strains were all in line, and were transmitted directly through the piston rods, consequently the bed-plate could be dispensed with, and this was one of the principal features in which this type of pump differed from the fly-wheel type.

The designers of the accepted plans, in aiming at cheapness, appeared to have overlooked the fact that the twisting strains set up by the fly-wheel and connecting rods required something to compensate them. He quite agreed with the author that it was a cheap pump, and he questioned if this cheapness was not attained with some considerable risk of a break down.

Mr. A. Christie said that the excellent paper the author had brought forward was one well worthy of our consideration, and was certainly deserving of being thoroughly discussed.

The figures quoted by him regarding the duty of pumping engines would appear to make out that the engines made previous to 1840 were equal to, if not more economical than those made at the present date, but we should remember that one swallow did not make a summer, and that although the engines mentioned might have performed the extremely high duties quoted, yet he was certain that the majority of the engines made at that time did not give a duty of more than half of that stated in the author's examples. His reason for saying so was that he had seen old pumping engines replaced by others of a more modern type, with satisfactory results, and yet the new engines were by no means able to do a duty of 100,000,000 ft. lbs., per 112 lbs. coal. He was aware that in 1840 Messrs Hocking and Loam erected an 85-inch cylinder engine at the United Mines, Gwennap, which beat all previous records and maintained the premier position for years. This engine was specially designed for a large range of expansion, greater than had been previously attempted, with the exception of Woolf's compound engines which had a range of expansion of 20.

The boilers were made smaller in diameter than the usual practice, and the plates stronger, to allow of a higher pressure, the working pressure being 40 lbs., and an extra number of boilers was also provided in order to increase the heating surface. This engine was first reported in December, 1840, to be doing a duty of 74,900,000, but rose rapidly, probably due to an alteration of the cut off. In July, 1841, it reached 100,000,000, thereby passing all previous records, except for short trials, and in September, 1842, it was reported at 107,500,000 ft. lbs. per bushel of coal, or 127,900,000 ft. lbs. per 112 lbs. coal. The range of expansion at this time was from 10 to 12.

The author mentioned the report of a trial of the Fowey Consuls engine when the duty of 130,248,000 ft. lbs. was reached, but he (the speaker) found this was much higher than was usually obtained. In 1834-5-7 and 9 the Fowey Consuls engine headed the list of Cornish engines. The duty obtained in these years were 115,500,000, 114,000,000, 101,000,000, and 92,500,000, respectively; very good results indeed, but still a long way under 130,000,000. But if we wished to know what Cornish engines were really capable of doing we must not take any particular engine, but take a fair average. The accompanying table gave the reported duties of the pumping engines in Cornwall from 1822 to 1843.

The results recorded of the working of 52 engines in 1822 was 34,391,000 ft. lbs., and the highest recorded duty was 56,100,000 ft. lbs. In 1827, 51 engines were reported on, giving an average duty of 38,200,000 ft. lbs., and the highest duty reached 74,000,000 ft. lbs. In 1832, the average of 59 engines rose to 53,950,000 ft. lbs., and the highest duty to 108,700,000 In 1837, the average duty of 58 engines was 55,930,000, and the highest duty recorded was 101,100,000 ft. lbs. In 1842, the average of 49 engines was 64,000,000 ft. lbs. per 112 lbs. coal, and the highest recorded duty was 127,900,000, so that in 20 years the average duty was nearly doubled.

The author had selected certain pumping engines and compared them with the engines of the "Medea," engines which were using about 8 lbs. coal per I.H.P per hour. Now he (the speaker) failed to see how a proper comparison could be made as the two types of engines were working under totally different conditions. The marine engines at that time were of low pressure jet-condensing type often working at about atmospheric pressure, so that the range of expansion of steam was small. The boilers were difficult to construct and were seldom tight. They were also fed with salt water, which entailed continued blowing off, which, of course, resulted in a very serious loss of heat. Another great source of loss was the scale in the boilers. It was also seldom that sufficient steam could be obtained, so that there was certain to be a large waste of fuel. In the attempt to force the fires few, if any, of the

ABSTRACT OF THE DUTY OF PUMPING ENGINES IN CORNWALL FROM 1822 TO 1843 INCLUSIVE.

Year.	Number of Engines Reported.	Best Engine.			94 lb. Coal.	112 lb. Coal.	94 lb. Coal.	112 lb Coal.
		Name of Mine.	Description.	Engineers.	Highest Duty.	Highest Duty.	Average Duty.	Average Duty.
1822	52	Wheal Abraham	Double Cylinder	Woolf	47,200,000	56,100,000	28,900,000	34,391,000
1823	52	" "	" "	"	51,000,000	60,600,000	28,200,000	33,558,000
1824	49	Polgooth	80-inch Cylinder	Sims	46,900,000	55,800,000	28,300,000	33,677,000
1825	56	"	" "	"	54,000,000	64,200,000	32,000,000	38,000,000
1826	51	Wheal Vor	" "	Sims & Richards	50,000,000	59,500,000	30,500,000	36,295,000
1827	51	Wheal Towan	" "	Grose	62,200,000	74,000,000	32,100,000	38,200,000
1828	57	" "	" "	"	87,000,000	103,500,000	37,000,000	44,000,000
1829	53	" "	" "	"	82,000,000	97,500,000	41,700,000	49,623,000
1830	56	" "	" "	"	77,900,000	92,700,000	43,300,000	51,527,000
1831	58	" "	" "	"	77,700,000	92,400,000	43,400,000	51,646,000
1832	59	Wheal Vor	" "	Richards	91,400,000	108,700,000	45,000,000	53,550,000
1833	56	" "	" "	"	88,500,000	105,300,000	46,600,000	55,454,000
1834	52	Fowey Consols	" "	West	97,900,000	115,500,000	47,800,000	56,882,000
1835	51	" "	" "	"	95,800,000	114,000,000	47,800,000	56,882,000
1836	61	Wheal Darlington	" "	Eustis	95,400,000	113,500,000	46,600,000	55,454,000
1837	58	Fowey Consols	" "	West	85,000,000	101,100,000	47,000,000	55,930,000
1838	61	Wheal Darlington	" "	Eustis	78,100,000	92,900,000	50,000,000	59,500,000
1839	52	Fowey Consols	" "	West	77,800,000	92,500,000	55,000,000	65,450,000
1840	54	Wheal Darlington	" "	Eustis	81,700,000	97,200,000	54,000,000	64,260,000
1841	56	United Mines	85-inch Cylinder	Hocking & Loam	101,900,000	121,200,000	54,700,000	65,000,000
1842	49	" "	" "	" "	107,500,000	127,900,000	53,800,000	64,000,000
1843	36	" "	" "	" "	96,100,000	114,300,000	60,000,000	71,400,000

cylinders were jacketed, and they were poorly clad, and he believed the boilers were not clad at all.

According to Dr. Denny, the marine boilers of 1845 carried a steam pressure of "7lbs. when you could get it, if not, as much as you could." He also says: "I remember the boilers of that time with the splendid stalactites of salt on their fronts and elsewhere, and when under trial the comforting assurance of the foreman boilermaker that they would soon 'tak up,' which they did in a way, with the assistance of horse manure" With the Cornish engine a different state of things existed. The boilers were cylindrical and carried a comparatively high pressure. They were arranged in batteries set in brickwork, carefully covered with clay and bricked over, so that the loss of heat by radiation was small. The boiler power was extremely large so that the fires were not forced, and the waste of fuel reduced to a minimum. In the engine we find that the cylinder was carefully steam jacketed and clad with about 12 inches non-conducting material, and built round with brickwork, so that the loss of heat was small indeed. Owing to this and the high pressure carried, a long range of expansion was made possible, and the engineers of that period were not slow in availing themselves of this advantage

Looked at all round the Cornish engine of fifty years ago was really a most economical machine, and certainly did not leave much room for improvement. But it could not be said that no improvement had been made in pumping engines, because although we had perhaps not exceeded the best previous performances, still the average duty at the present time was certainly better than it was fifty years ago.

If the author had selected, for his examples, pumps similar to those at Botany, he would have found that the average performance had increased almost at the same rate as the progress made in marine engines.

He would now pass on to the designs of the pumping engines for Waverley Water Supply, and in doing so he felt himself in a rather awkward position, as he was the author of the accepted design—Plates XXIX, XXX, and XXXI. It would be bad taste on his part to criticise the designs of the unsuccessful competitors. He would therefore confine himself to a few remarks in defence of his design. It was very questionable whether he would have said anything on this subject had it not been for remarks made by the author when speaking of this particular engine.

The author stated that the design was a cheap one, therefore the other competitors were at a disadvantage, they not knowing that a cheap pump was wanted. He also discovered that there was no soliplate, and he had also heard that the guaranteed duty was low, only some 60,000,000 ft. lbs., per 112 lbs. coal.

He further stated that it was not according to the specification, and that a vertical pump was implied. These, he thought, were the principal charges laid by the author against the Mort's Dock design. Several months ago he read the specifications carefully over, and since hearing the author's remarks he had done so again, but he could not find anything therein that could be construed to mean that a vertical pump was what was wanted, this point being left open to the designer, and he had no doubt that if the Water and Sewerage Board had particularly wanted a vertical engine they would have said so.

The conditions laid down in the specifications were :—

1st.—The duties required of the engines will consist in raising 100,000 gallons of clean water per hour through a rising main of the following diameters and lengths :—Delivery connection, 60 feet of 15 inch new cast iron pipe ; 10,000 feet of wrought iron pipe 24¾ inches in diameter, assumed for the purpose of calculation of friction, to be only 24 inches in diameter, to allow for the effects of rivet heads, and 5,800 feet of new 18-inch cast iron pipe. The actual difference between top water level in Crown Street reservoir,