14th July, 1892.

A COMPARISON BETWEEN THE ADVANCEMENT MADE IN PUMPING ENGINES AND MARINE ENGINES DURING THE PAST FIFTY YEARS, AND A REVIEW OF THE DESIGNS SUBMITTED IN COMPETITION FOR WAVERLEY HIGH LEVEL SERVICE OF THE SYDNEY WATER SUPPLY.

By Norman Selfe, M.I.C.E.

This Association has very recently had under its consideration tion Mr. Blechynden's elaborate paper (read before the Institute of Mechanical Engineers), in which he reviews the progress of marine engineering during the past decade, and, as is well known to most of our members, a contract has just been let as the result of competition, to an eminent local firm of marine engineers, to manufacture a "High Duty" pumping engine for the highest levels of the City Water Supply. These two circumstances have suggested the idea that much profit might perhaps result from a comparison of the relative progress which these two important branches of engineering have made in the past, and their present relation to one another, and form the grounds for some consideration as to the future possibilities of pumping engines. Before awarding the contract just referred to, the Water and Sewerage Board invited tenders for a set of high duty pumping engines, under exceedingly stringent conditions, as shown by appendix; and, in response to the invitation, a number of designs accompanied by tenders were sent in by local manufacturers and importers, one of the former being accepted. By the courtesy of most of these contractors, the Association has obtained the loan of the different designs, now hung on the walls of the room. We have also here the designs of the old Crown-street engines, made years ago by Mort's Dock Company, and of the supplementary engines at Botany, made in sixty days by the Atlas Company.

It is not the object of this paper to discuss the policy of the Water and Sewerage Board in adopting the successful design, and it would be rather outside the general custom of our Association. Price is a most important factor in these matters as we know, and the design selected was tendered for at a price comparatively very much lower than any of the other ones we have before us, so that only very strong reasons would have justified its being passed by for another one. There are, however, several features in connection with this competition that will repay consideration in the interests of professional engineers, manufacturers, and the colony generally.

There is a growing practice, at any rate in New South Wales, to ask engine builders and contractors to tender for the construction of machinery, and at the same time to prepare and submit their own designs and plans for what they propose to supply, based upon a sort of skeleton specification, or outline of the requirements, often exceedingly indefinite. The author is aware of a recent case where a number of large Colonial and European firms, at very great trouble and expense, prepared plans, supplied information, and tendered for extensive works for an inland city, and where one of them was thrown out because the boiler was of the wrong sort; another one because the engines were of the automatic expansion type and not "compound," and so on. It would have been the simplest thing in the world to have first stated all the conditions that were absolutely essential or which were pre-determined upon, but such was not done, and in consequence there was an enormous amount of unnecessary expense incurred to prepare plans and specifications, and the tenderer's money was simply thrown away, because: First—the conditions were vague and indefinite, and secondly—there were certain foregone conclusions determined upon, or arrived at, of which they were never informed.

In the matter of these Sydney pumps, the manufacturers only tendered on their own designs, or on those which they conceived met the requirements of the indefinite specification; and it is certain from the variety in the designs around us that exact requirements were not stated, for in the majority of instances, as is evident, the specification has been understood by manufacturers to require a vertical and more costly machine (to say nothing of type) than the one that has been accepted, of horizontal construction. Two of the contractors were so uncertain as to the actual requirements of the outline specification that each of them sent in ten tenders, and one of them went to enormous expense and furnished a great number of special designs, all to no direct purpose. The special point to which your attention is directed is this: Suppose competition had first been called for the design alone, as in the case of Pyrmont Bridge competition; and say three of the designs sent in (if suitable) had been selected, and the contractors had been invited to tender on them, how much more satisfactory, from an economic point of view, the case would have been. As it is now, A's design is selected presumably because it is the cheapest, and Z's is thrown out because it is too costly; but we do not know and really have no idea what A's price for Z's design would be, and *vice versa* Z's price for A's design. Again, it is now open for Z to say that A's design is a cheap one; that it is not the type of machine that was implied by the very stringent conditions as to duty in the specification; or, had the specification not been so strict as to duty, &c., he could have supplied a still less costly machine, and so on.

There are, of course, many other things to be considered in the design of a pumping engine besides the smallest consumption of steam; but it is, or should be, the part of the designer to weigh all these points, and give to each its due share of consideration; and it is, or should be, the part of the manufacturer to put the work so designed into execution. To enable members to estimate the relative importance attached to these points by the different tenderers, a table of comparative dimensions and particulars is appended.*

It has seemed to the author of this paper that the manufacture of pumping engines in past years has been in a much more limited number of hands than have been concerned in marine engine building, and that perhaps improvements may have been somewhat retarded by the conservatism of favoured firms, and the manifest advantages of adhering to old patterns; this may or may not be the case, but there is certainly plenty of room for a discussion which is specially invited on the following propositions:—

First.—Has the improvement of the pumping engine, during the past half century, advanced with the times, in the same way that the marine engine has done? If it has not done so, what is the reason, or are the principal reasons?

Secondly.—What are the most important factors that should be combined in order to secure a high duty in steam pumps?

Thirdly.—Has a due consideration been given to the whole of these factors in the best pumping engines, with the designs of which we have illustrations or records in the regular engineering works or scientific journals?

It will not be necessary to lengthen this paper by devoting any consideration to boilers. It is quite true that some recent specifications have made the pumping engine builder responsible

* Appendix No. 1.

for coal consumption, although the steam was to be supplied from another manufacturer's boilers; but such a connection is never now made in any modern scientific investigation into engine duty. The duty of a boiler is quite distinct from that of the engine and is measured by—

(*a*) The evaporative power in lbs. of water per lb. of coal, and

(*b*) The relative dryness of the steam supplied.

The duty of the engine is measured by the number of pounds of steam which it consumes per horse power per hour. A good boiler is just as available to supply the cylinders of a pumping engine as it is to supply a marine engine, and therefore all consideration of the various types of boilers may be left out of the question before us. It may be assumed for the purposes of this paper that steam boilers at the present day evaporate from 8 to 10 lbs. of water per lb. of coal, and that 30 to 50 years ago they seem to have evaporated about 8 lbs. both on land and at sea. It must at the same time be admitted that, with the much greater room available on shore, the evaporation need never be less in the boilers for a pumping engine than it is in the boilers of a marine engine.

In order to ascertain the condition of the pumping engine fifty years ago, reference has been made to Mr. Wicksteed's well-known work published in 1841, where there are tables giving the duties of Bolton and Watt, and Cornish engines, with Newcastle and Welsh coals. From Tredgold's large work we can ascertain the condition of the marine engine sixty years ago. As the duty of pumping engines expresses the pump horse-power, in the foot-lbs. of useful or actual work done by a given weight of coal; and the efficiency of marine engines is recorded by the consumption of coal per *Indicated* horse-power per hour, there must be a common standard adopted before we can make the comparison; and further, the duties of some pumping engines are recorded in bushels of 94 lbs., some in cwts., and some in 100 lbs. weight of coal. Again, with the slower speeds, or ordinary pumping engines, and the more direct connection of the power to the work, the ratio of efficiency in the whole machine is probably much higher than it is with the greater friction of a rotative marine engine, transmitting all its power through the shaft to a screw propeller. It, therefore, appears to be the simplest method to take the indicated horse-power as the standard for comparison.

The efficiency in the different pumps to be referred to or the duty will be taken as 85 per cent. of the indicated horse-power; in some trials that are recorded, makers have claimed the exceptional efficiency of 90 per cent., which would give only 5 per cent. for the friction of the engine, 5 per cent. for the friction and loss in the pumps, and no doubt there are many that do not give 80 per cent., but 85 per cent. seems to be established as the average in high class work.

Coming to the comparison of "Duty" and "Horse-power," 1 lb. of coal per horse-power per hour is equal to 1,980,000 foot-lbs. of work performed per lb. of coal, *i.e.*, 33,000 x 60 minutes; this is of course 198 millions duty with 100 lbs of coal, and therefore 221,760,000 with 112 lbs. of coal.

In the tables of Mr. Blechynden—before referred to—deduced from the actual working at sea of twenty-eight steamers, the average coal consumption is set down at 1·522 lbs. coal per horse-power per hour, or 1·336 lbs. with forced draught; and in No. 24 ship it is is as low as 1·242. And, as stated before, what can be done at sea ought to be done on land, so if we take 1½ lbs. coal per I.H.P. as a standard consumption, or what is the same ⅔ horse-power per lb., then as a horse-power is 33,000, and ⅔ of that is 22,000 foot-lbs. per minute, this multiplied by 60 minutes gives 132,000,000 foot-lbs. as the gross or indicated duty of the engine per 100 lbs. coal, and 147,840,000 with 112 lbs.; 85 per cent. of this latter amount would give a net or pump duty of 125,664,000 per cwt. of coal. How close the duty of the best pumping engines, both past and present, approaches to this will now be shown.

The tables appended to Mr. Wicksteed's work show that before the year 1840 there were engines attaining the following duties:—

Evaporation.	Class of Fuel.	Consumption.	Duty.
8,534 lbs.	Newcastle Coals	112 lbs.	97,146,000
9,277 „	Best Welsh „	112 lbs.	108,198,000
9,493 „	McLean Bros.'	112 lbs.	105,664,000
—	—	—	102,726,000

While in the Fowey Consuls Cornish Engine with a $24\frac{1}{2}$ hours' trial, cylinder 80-inch, stroke 10 ft. 4 in., the high duty was reached of 130,248,000
and with the Holmbush Engine 122,376,000
the highest being something above the mean of the best modern marine results above referred to, viz., 125,664,000.

From an account in "Tredgold," of H.M.S. "Medea," we find that about the year 1834 this early steam vessel consumed from 7 or 8 lbs. of coal per horse-power per hour. If we take a mean of $7\frac{1}{2}$ lbs. as a basis, and take as before 85 per cent. for the efficiency of the machine, it will be found to give a duty of only 25,132,800, or not much more than two-thirds of the lowest duty recorded in Wicksteed's tables of Boulton and Watt Engines with the poorest coal (Derbyshire), and only about one-third the mean of the highest and lowest duties of pumping engines there tabulated, say 77 millions.

If these figures are correct it is safe to assert that 50 years ago the pumping engine was at least three times as efficient as the marine engine was, or, in other words, required but one-third the consumption of coal for a given duty.

Coming to another decade. The establishment of the Lambeth Water Works, in the author's native town of Kingston-on-Thames, about 1850, for the London supply was an epoch in the history of pumping engines, and the oft-illustrated engines erected there by Messrs. Simpson, of Pimlico, were tested in 1854 by the late Joshua Field, of Maudsley and Field, and the duty recorded was 104,000,000, or about the mean of the Cornish engines already quoted.

It is unnecessary to trace the marine engine through all the decades from the days of the old "Medea," but missing the "forties," "fifties," and "sixties" and taking the records for 1872, 1881, and 1892, it will be found that since 1834, when the consumption per horse-power was, say $7\frac{1}{2}$ lbs., it has been gradually reduced year by year until in the three latter 10-year periods it stood at 2·1 lbs., then 1·8 lbs., and may now be set down at 1·5 lbs., or actually 80 per cent. less—that is, only one-fifth of what it required in its infancy. The coal consumption in marine engines has in fact been reduced 16·7 per cent. within the last ten years, and 27·9 per cent. in the last nineteen, as shown by figures which have only recently been printed on the records of this Association.

In 1884, thirty years after Messrs. Simpson had made the Lambeth Water Works engines at Kingston, they made engines for the Brixton Hill station of the same company. From particulars recorded in the proceedings of the Institute of Civil Engineers on the authority of Mr. Mair, of the builders' firm, the following information is derived:—

The engines are compound, having H.P. cylinder 24 in. x 3 ft. stroke, L.P. cylinder 32 in. x 6 ft. stroke, pumps $16\frac{1}{2}$ in. and $21\frac{1}{2}$ in diameter x 4 ft. stroke; revolutions, 30 per minute; horse-power, 123 to 150; efficiency, 85 to 86 per cent.; and the duty with 112 lbs. coal, 106·7.

This shows only about two per cent. reduction in coal consumption by eminent makers of pumping engines in the course of thirty years, during which same time the corresponding reduction in the marine engine has been say 60 per cent.

It is unfortunate with regard to the best modern pumping engines that there appears to be an absence of reliable records of continuous working available, from which we may ascertain their regular duty in ordinary work, apart from experiment, or the coal burnt say in a year, and the foot-pounds raised. Records do not appear to be kept of waterworks as was the case with the reports of the old Cornish engines. It is all very well to get up a special trial of a pumping engine, or any other machine, with everything combining to secure the most favourable returns for an hour or two, and call that the duty realised; but such a test may give quite different results to those deduced from a whole year's trial of the same machinery; a reference to the coal consumption of the original Botany engines presently will show this. The steamship owner, on the contrary, does not care a straw, comparatively, how much coal the builder of his vessel uses on the trial trips of the ship; what he wants to know is the consumption in actual work, and his engineer logs every day's work in miles that the ship runs, and the weight of coal that is burnt. The figures given in Mr. Blechynden's paper are no fanciful results obtained from jockeyed trials with selected fuel, like some of the races recorded of American river steamers when they fired with sides of bacon while they made a nigger sit on each of the safety valves till they passed the rival boat; or like the trial of locomotives in Egypt we have read of where they had mummies for fuel, and the driver dissatisfied with the progress he was making, told his fireman to leave the common fellows alone and chuck in a king. The records of marine engines referred to are taken from reliable trials *at sea* in twenty-eight steamers.

The three waterworks engines at Botany are of a standard English type, and would be expected to be fairly economical, having large boilers, beam engines, expansion gear, and slow speed, say 192 feet per minute of the steam piston at 12 revolutions, but in the year 1879 they were charged with 6,365 tons of coal—consuming 15 cwt. per hour, and as reported upon by the author to the Mayor and Aldermen in 1880, the actual duty was found from such consumption to be less than 25,000,000 per 112 lbs. coal. At the same time the colonial-made engines at Crown-street, by Messrs. Mort & Co., as per illustration, were found to have a duty of 62,000,000, or two-and-one-half times as high as the engines at Botany.

Mort's engines cost £4,680 without the house, say £6,500 complete, and the contract was to deliver 2,000,000 gallons in 12 hours at $20\frac{1}{2}$ revolutions, but they were constantly run at 24 and 25 revolutions, being 20 to 25 per cent. over contract speed. The Botany engines, it is believed, cost over £70,000, which would be say three times the relative cost of the colonial engines.

In 1886 some supplementary engines were constructed and erected at Botany in a remarkably short time (60 working days) by the Atlas Co., and have been before referred to in this room. They are non-condensing 12 and 20 inch cylinders by 3 ft. stroke, and had plungers of 50 inches effective area. They pump their contract amount (which was $1\frac{1}{2}$ millions in 24 hours) at less than 48 revolutions a minute for 20 hours, but have run noiselessly up to 60 revolutions. At 54 revolutions a minute they do the same work as one of the old Botany beam engines when making 10 revolutions, and work quite as quietly.

So far as could be ascertained during the short time they were at work, the duty of these emergency pumps ran out to between 49 and 50 millions The designs are before you, and it will be seen that they are not steam jacketed. The price erected complete, including engine-house, foundations, and painting, was £3,498, or perhaps one-sixth of the relative cost of the Botany establishment. The contract for these supplementary pumps was let on March 6th, and they were started on May 24th of the same year by the Mayor and Aldermen. Since that date there have been three most notable examples of pumping engines erected in Sydney, viz. :—

The High Duty Worthington Engines at Crown Street, the Low Lift Pumps for the Sutherland Dock, and the new Ryde Engines for the high levels of North Shore.* The interest of this Association will only attach to the first and third, perhaps. For some reason which the author has not yet been able to

* Appendix No. 2.