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“Machinery for Steel-Making by the Bessemer and the Siemens Processes.”

By BENJAMIN WALKER, M. Inst. C.E.

IN this Paper it is not intended to make any comparison between the Bessemer and the Siemens processes, as both are inventions for which the world must ever be grateful, and one should never be put in opposition to the other.

Much has been done to render easy the manipulation of steel in the molten state, as well as in the solid but heated state. In bringing the subject before the Institution, the endeavour will be to explain some of the appliances with which he himself has been connected. Hydraulic machinery plays a most important part in these processes, and the larger portion of the Paper will be devoted to this class of work. So extensive is the use of pressure by water, and so gigantic are the machines worked by this power, that it has become indispensable that the water employed as the vehicle of pressure should be produced and used economically. The Author has carefully considered the question, and has come to the conclusion, from actual practice, that in order to attain the former condition the boilers must be of first-class material and workmanship, and be worked at fairly high pressures, say 80 lbs. to 90 lbs. per square inch; that the most advantageous hydraulic pressure is from 600 lbs. to 750 lbs. per square inch, and that the engines for pressing the water should be compound, highly expansive, and fitted with surface condensers. Large accumulators are also necessary, and where the distances are considerable there should be several accumulators. If possible, the engines should be kept going, and not be allowed to stop and start again, as this causes great waste. This is not difficult where the machinery is extensive and the work pretty regular. The engines are much more economical when driven at from 150 to 180 feet per minute than at a lower speed, and this has been proved by frequent experiments. The valves and waterways, especially for the inlet, should be large, the valves having but little lift. Cup-leathers and all packing which cannot be easily got at, and where leakage cannot at once be detected, should be avoided, rams being always preferable to buckets.

It is not proposed to enter into an argument as to the relative merits of compound and simple engines for pumping at high pressures, but reasons will be given why they should be compound: 1st. The expansion is put to a great extent beyond the control of the workman; 2ndly, Simple piston or slide-valves can be employed, and elaborate and complicated cut-off gear avoided; 3rdly, The cooling effect is less in the compound than in the simple engine; and 4thly, In the Author's thirty years' experience, the compound engine has always proved to be the more economical.

In his opinion, some of the strongest arguments in favour of compound engines are contained in a Paper by Mr. F. J. Bramwell, M. Inst. C.E., read before the Institution of Mechanical Engineers at Liverpool;¹ and a pair of cylinders on this system, designed by Mr. Bramwell, is the neatest and the most compact arrangement he has ever seen. The clearance between the high-pressure and the low-pressure cylinders is reduced to a minimum; and by having three separate slides, one to admit the high-pressure steam, one between the high and the low-pressure cylinders, and one from the low-pressure cylinder to the condenser, the valve-setting is exactly adjusted for each operation. The engines so designed are most economical.

Figs. 1 and 2, Plate 1, represent the elevation and plan of a pair of pumping engines of about 300 indicated HP. at the pumps. These engines are compound. The high-pressure cylinder is 30 inches in diameter, and the low-pressure cylinder is 50 inches in diameter, the stroke of each being 30 inches. To the piston-rod of each cylinder is coupled a double-acting pump, the larger ram of which is 9 inches in diameter, and the smaller $6\frac{1}{2}$ inches in diameter, or half the area of the larger. The action of the pump is similar to the ram-and-bucket pump, except that instead of a liner and cup-leathers being used ordinary packing is available. This kind of pump has been in use for several years, and has given great satisfaction; the expensive gun-metal liner is dispensed with, the construction is simple and cheap, and there is practically no leakage. The engines are fitted with a surface condenser, air-, circulating and boiler pump. The circulating pump acts as a tank pump, sending its water through the condenser tubes to the overhead tank for the supply of the feed pumps. The circular slide-bar has been adopted, as it combines lightness with strength and cheapness. It can, of course, be bored

¹ *Vide* Proceedings, 1872, p. 125.

out, which is simpler than planing, and if the crosshead is adjustable, and the wearing surfaces are large, it works remarkably well. The cylinders are steam-jacketed, and the valves and pistons, and in fact all details connected with the engines, are similar to a first-class marine engine. It is not intended that these engines should be stopped and started by the rise and fall of the accumulator, but provision is made for rendering them automatic by admitting steam direct from the boiler at a reduced pressure into the low-pressure cylinder, and by an arrangement in connection with the accumulator, shutting this off when the engines have been set in motion. Engines of this class have been found most economical, not only from the indicator cards, but from the number of boilers used in comparison with simple engines, which they have in some cases superseded, and in the consumption of coal.

About two years ago the Author's firm made for the East and West India Docks Company two pairs of compound surface-condensing pumping engines of about 150 indicated HP. at the pumps for pumping into accumulators. The boilers are of the Lancashire type, 7 feet in diameter and 26 feet long, and are capable of being worked at a pressure of 75 lbs. per square inch. The engines have two high-pressure cylinders, each $20\frac{1}{2}$ inches in diameter, and two low-pressure cylinders, each 32 inches in diameter, cast together and mounted on one bed-plate, but independent. They are fitted for surface condensation. Trials have been made with these engines, and the mean result of a large number of diagrams shows a consumption of coal of $2\frac{1}{4}$ lbs. per indicated HP. per hour. The boilers are clean and free from incrustation. The large amount of water, which is very dear in London, formerly necessary to feed the boilers is now almost entirely dispensed with; only the small quantity required to make up for loss at the head box and gland of the boiler pump having to be supplied. The high-pressure engines in the same house have been made surface-condensing by a separate engine; only one-third of the boiler power formerly needed is now required, and, consequently, only one-third of the coal. During the trials these engines were maintained at a nearly uniform speed, a Harding's counter was fixed, and the coal, which was of fairly good quality, was carefully weighed, the boiler pressure was kept uniform and the feed gradual. The vacuum was $13\frac{1}{2}$ lbs. per square inch. The Author has collected a large number of indicator diagrams from non-condensing pumping engines working into accumulators, and finds that the average amount of water evaporated per indicated HP. per hour is about 35 lbs.; while in some of them, with no expan-

sion, it is as high as 50 lbs. per indicated HP. per hour; whereas in the compound highly-expansive surface-condensing pumping engines only 12 lbs. per indicated HP. per hour of water were required to be evaporated.

The cost of giving to 1,000 cubic feet of water a pressure of about 700 lbs. per square inch, or, in other words, the cost of getting the same into the accumulator and pressure main, in the case of the cranes shown in the drawings (assuming that the boilers already exist), is for the ordinary high-pressure, non-condensing, non-expansive accumulator pumping engine, about 6s. 7d., and for the economical highly-expansive surface-condensing engine about 4s. 3d. For this computation the coal is taken at 8s. per ton, the price paid in Leeds, next the attendant's wages, then the interest at 5 per cent. per annum on the capital expended on the engine-house, foundations, engines, boilers, accumulator and pipes, the oil, etc., and the water evaporated in the boilers in producing the steam, which in the former case is not condensed. In a large works where other power is used, and the steam required for the accumulator pumping engines is generated in the same boilers that drive the works, the above cost would be reduced. If they are well constructed at the beginning, with the wearing surfaces large, without cup leathers, and, consequently, with very little renewal, accumulator pumping engines require practically no repairs, and are in this respect more economical than any other power producers.

There seems to be no reason why accumulator pumping engines should not be as economical as any other engines. It was in pumping engines on the Cornish plan that economy first began to be considered, and some of these engines have approached perfection in the way of duty, and the Author knows no reason why the class of engines here dealt with, now so extensively used, should not be as economical. Economy must lead to more frequent use of hydraulic power. A high pressure of steam, and a high rate of expansion, independent if possible of the attendant, are necessary to ensure cheap working. Steel in its present advanced state has helped in this last-named respect, so great has been the progress made of late years. It is not only in the engine- and boiler-shop that the great advantage of steel has been found; shapes can now be rolled and manufactured of steel that formerly could not have been made in puddled iron, and no man, not having a practical knowledge of steel made by these processes sixteen to twenty years ago, can have any idea of the great improvement in its uniformity, quality, ductility and strength.

Having pressed the water to the degree required, the next question is how most economically to use it. Perhaps in no kind of hydraulic machinery has there been a greater waste of water than in the hydraulic engine, whether used for cranes or capstans. From careful experiments made during the last eighteen years, it is believed that Figs. 3 and 4, Plate 1, represent a fairly economical engine. The manner of operation will be easily understood from the figures. The two smaller rams are half the area of the larger, and are always in communication with the accumulator, the larger being brought into communication with it alternately by means of a small slide valve. The cranks being at right angles, and an hydraulic valve requiring neither lap nor lead, it occurred to the Author that the crosshead of one ram might be made to move the valve of the other. Such is the arrangement shown in Figs. 3 and 4, which represents a machine for hauling heavy weights in operation at his works in Leeds. Having made a large number of capstan engines with three cylinders, he has come to the conclusion, after careful examination and experiment, that the double-acting engine, with cranks at right angles, is as good as any, and that it has many advantages in simplicity and cheapness over the three-cylinder engine. It takes up little room, the connecting rods are long, the rams well guided, the valves and gear are simple, and the whole is readily accessible, not requiring a foundation when used as a capstan for hauling.

As a double-power engine, to exert a strain of 5 tons at about 70 feet per minute, the Author has employed a similar arrangement, but instead of a double crank, a three-throw with six rams, three and three, and with forked connecting rods. The valve for admitting the water is double-ported, and the arrangement is such that water can be admitted to either three or six rams. Engines of this class are in operation at the eastern extension of the East and West India docks for pulling the ships, and they are found to be very economical.

Figs. 5 and 6, Plate 1, illustrate a single form of ingot crane, which is very economical in the consumption of water. Most of the cranes of this type made by the Author have had the centre ram or pillar to take the weight and act as a guide, not being under pressure, the side rams doing the duty of lifting and balancing, one ram being always, and the other alternately, in communication with the accumulator. The original ingot crane was the same as shown in Figs. 5 and 6 without the side cylinders, and the centre ram had to be made large enough to lift not only the ingot, but its own weight and that of the top and jib of the crane. The two side rams

represent economy in pressure-water. The crane above alluded to not only has the water on the circular area of the centre ram, but also on the side rams, the centre ram doing the duty of balancing the dead weight, and the side rams being used either singly or together, making the crane double power. This is a great improvement over the old style of ingot crane. On the old plan, with one centre ram which acted both as guide and lifting power, there was a risk of breakage if safety and greater capacity for work were aimed at. The dead weight to be lifted was increased enormously, and consequently water was wasted. With the plan of balancing by the centre ram, which is put in constant communication with the pressure-main and accumulator, and by employing side-lifting rams, the crane may be made of any strength and power without sacrificing economy in pressure-water.

Fig. 7, Plate 1, represents an 8-ton ingot crane in operation at Messrs. Bolckow, Vaughan and Company's new steel works at Eston, where it is used in connection with the new process of making steel from Cleveland iron. This crane is extremely strong, and, unlike most cranes of this class, it is fitted with power-turning and racking-in-and-out gear. The turning is effected by a small hydraulic engine similar to that described under Figs. 3 and 4, but made to reverse. To enable this to be done, the ordinary valve is three-ported, and the admission of water to either one port or the other determines the direction in which the engine has to run. The reversing is effected instantaneously, the parts are few, and the whole is simple. The centre rams in these cranes are 18 inches in diameter, 3 inches thick, and about 30 feet long, having a stroke of 9 feet 6 inches.

Fig. 8, Plate 2, is a plan of Siemens-steel furnace, with the necessary hydraulic cranes, as in operation at the works of Messrs. John Brown and Company (Limited), Sheffield, and at the West Cumberland Iron and Steel Company's works at Workington, where this process is used for making heavy plates, bars, and forgings. There is one centre crane, similar to the centre lift used in the Bessemer pit, capable of lifting 14 tons, and which is employed in receiving the molten steel. This crane is fitted with a centre ram 18 inches in diameter, and with two side rams, each 14 inches in diameter, one being for balancing and the other for lifting the weight. The centre casting or sleeve is fitted with live rollers, and carries the jib, formed of two wrought-iron bars 3 inches thick and 24 inches deep. Gearing is provided for turning the crane round, moving the ladle on a strong carriage in and out, and tipping it. The other cranes are for lifting the

ingots, and are in all respects similar to those used in the Bessemer pit. These cranes are fitted with double rams for saving water. Over the whole pit there is a power travelling crane, worked by an engine and square shafting, capable of lifting 50 tons. The blocks and screw barrel, with common chain, are replaced by a pitch chain formed of thin steel plates and pins, and a pitch pulley of cast steel with a box for collecting the chain. The chain, formed of steel bars 3 inches in diameter and plates $\frac{1}{4}$ inch thick, is entirely machined, and is fitted accurately throughout, pains being taken that no part of it comes near the fire. All the gearing is of steel, as well as the plates and rails out of which the crane girders are formed.

The next machine to be described is the centre crane, illustrated in Figs. 9 and 10, Plate 3. This crane is large, massive, and of a somewhat novel construction. It consists of a centre ram or pillar 24 inches in diameter, and about 48 feet long, working in a cylinder with a stroke of 18 feet. It is to lift 10 tons of molten steel. The jib, with provision for a ladle at both ends, is movable on rollers, and is drawn in and out by an apparatus similar to the ordinary jigger. The crane is made to rotate by a small hydraulic capstan (Figs. 3 and 4). A ring of live rollers is introduced at the top of the ram to take the downward pressure, and a similar ring of larger rollers surrounds the ram at the part where the sleeve-casting, constructed to carry the jib, presses. The extreme range of the jib is 20 feet, but it can easily be altered, the length being about 10 feet when the metal is being poured out of the converter into the ladle, and 20 feet when the ingots are run.

Figs. 11 and 12, Plate 3, represent a 10-ton Bessemer converter, four of which were recently made by the Author's firm for Messrs. Bolckow, Vaughan and Company, to be used in connection with the process of making steel from Cleveland iron. The weight of one of these converters is about 40 tons; they are formed of wrought-iron plates 1 inch thick, riveted with 1-inch rivets with strong straps. The belt and trunnions are in two pieces, formed of cast-iron box section; the trunnions are 21 inches in diameter and 15 inches long. One belt weighs 11 tons, and is 10 feet 8 inches in internal diameter bored to fit the converter, but room is allowed for expansion. Air is introduced into the converter, according to the plan of Sir Henry Bessemer, F.R.S., M. Inst. C.E.; but the shape of the vessel is very different from the ordinary one, resembling a "Scotch haycock." As far as making goes it is simpler in this shape, and it is considered more suitable for the dephosphorization

process, where a large quantity of lime will probably be required to be blown through. The arrangement and apparatus for tipping the vessel are new. A strong and powerful double-acting hydraulic engine, similar in construction to the one shown by Figs. 3 and 4, working a steel worm and worm-wheel about 8 feet in diameter and $4\frac{1}{2}$ feet pitch, is employed, and this engine can be reversed from the pulpit as in the ingot crane, by changing the direction of the water. Had a movable slide been employed, this could not have been done conveniently from the pulpit. The man in the pulpit has complete control over the vessel, which can be turned over and over and reversed at a good speed.

Figs. 13 and 14, Plate 3, illustrate a pair of vertical compound blowing engines, to be used in the process of making Bessemer steel. The steam cylinders are 42 inches and 78 inches in diameter respectively, and 60 inches stroke; the air cylinders are each 54 inches in diameter and 60 inches stroke. The high-pressure cylinder is fitted with expansion-slides on the back of the main slide, and the low-pressure with piston valves. These engines are intended to have a separate engine for condensing, but they can also be worked non-condensing. The boiler pressure is 90 lbs., and the air pressure 25 to 30 lbs. per square inch. The crank-shaft is of wrought iron 14 inches in diameter and 20 inches long in the neck; the cranks, also of wrought iron, are placed at an angle of 225° . There are piston inlet valves for the air-cylinders, and several small wrought-iron circular automatic valves for the delivery. The steam cylinders are jacketed, and there is an arrangement for admitting steam from the boiler into the low-pressure cylinder when starting the engines. The Author has compared these engines with simple engines of the same power blowing the same size of converter, and found that considerably less steam was required for the compound than for the simple engines. Mr. Martin, general manager of the Blaenavon Works, has informed the Author that when these engines are doing full work with condensation, the coal used per ton of steel is only 168 lbs. This includes the coal required for driving the hydraulic engines for moving the Bessemer apparatus. The Author believes this is the smallest quantity on record for this class of engine.

Formerly the iron used in the converter had to be very free from phosphorus, and only the ores found in Cumberland, and to a small extent in other places, were available for use in the converter. Now by the invention of Messrs. Thomas and Gilchrist, known as the dephosphorization process, aided by Mr. E. Windsor Richards, the manager for Messrs. Bolckow, Vaughan and Company,

steel can be made in the converter from Cleveland and other cheap and widely-spread ores. New energy has been given to the trade, and a cheaper and in all probability as good an article will be produced. In the dephosphorization process large quantities of metal are dealt with in the converter, and this necessitates the whole of the machinery being heavy, and to some extent complicated, rendering economy in steam and water an absolute necessity, as well as simplicity in construction and such reduction in weight as is consistent with strength and efficiency. There seems to be no limit to the production of steel, and it is the duty of the engineer to keep pace with the supply and demand by introducing simple, effective and economical appliances for its manipulation.

The machinery above described does not deal with the hammering and rolling. The Author may, however, mention his opinion that in rail rolling, the two-high mill, with compound reversing engines, is the most economical, and that in cogging it would be better to abolish wheels, increase the sizes of cylinders, jacketing them, and in fact to work direct as in roughing and finishing. It is obvious that the wheels do not make power; they cause trouble, and the sweep of the piston must be the same with or without wheels. Moreover, in the manufacture of steel plates, instead of casting small ingots and cogging with staff and tongs under the hammer, the Author would prefer large rolls and large ingots, and after cogging these ingots, to cut them into pieces, and reheat and roll them in the ordinary way.

The communication is accompanied by ten diagrams, from which the figures forming Plates 1, 2 and 3 have been reduced and engraved.

Fig: 1.

Fig: 2.

HORIZONTAL HYDRAULIC PUMPING ENGINE.

Fig: 3.

Fig: 4.

HYDRAULIC CAPSTAN.

Fig: 5.

Fig: 6.

FOUR TONS INGOT CRANE.

Fig: 7.

EIGHT TONS INGOT CRANE.

Scale for Fig: 1, 3, 5, 6, 7 - $\frac{3}{16}$ Inch = 1 Foot.
10 0 1 2 3 4 5 10 15 20 Feet.
Scale for Fig: 3 & 4 - $\frac{3}{16}$ Inch = 1 Foot.
10 0 1 2 3 4 5 10 Feet.

MACHINERY FOR STEEL MAKING,
BY THE BESSEMER AND THE SIEMENS PROCESSES.

PLATE 2.

MACHINERY FOR STEEL MAKING.

BY THE BESSEMER AND THE SIEMENS PROCESSES.

PLATE 3.

Fig: 9.

Fig: 10.

Fig: 13.

Fig: 14.

Scale $\frac{1}{16}$ Inch = 1 Foot.
12 6 0 1 2 3 4 5 10 15 Feet

TEN TONS CENTRE CRANE.

Fig: 11.

Fig: 12.

TEN TONS CONVERTER.

VERTICAL COMPOUND BESSEMER BLOWING ENGINE.

THOS KRIEGER & SON, LITH. 40, KING ST COVENT GARDEN.