REDUCTION IN COST OF STEAM POWER FROM 1870 to 1897.*

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IN the year 1870 the most economical steam engine in use in mills was the Corliss simple condensing engine, which used 19 or 20 pounds of steam per horse power per hour. Previous to that time compound engines had been used in England in mill practice, and simple engines had in many cases been changed to compound. In this country compound pumping engines had been used to a very limited extent, notably the Worthington direct acting duplex compound, the first one of which was put in at the Charlestown, Mass., water works in 1863, and the installation of the Morris engine at Lowell and the Leavitt engine at Lynn are well known examples of them in the early part of the period which we are considering. The Lowell engine was of the Simpson type, so named from the Simpsons, of London, who originated the arrangement of two compound cylinders with different lengths of stroke under one end of a beam. It is known as the Morris engine from Henry G. Morris, the builder, but its design is due to the late Robert Briggs, of Philadelphia. The Pawtucket pumping engine, built by George H. Corliss, and started on June 30, 1878, is another important example of economical pumping engines, and probably was the most economical steam engine which had been built up to that time, having used less than 14 pounds of dry steam per indicated horse power per hour. While these engines are not mill engines, they influenced the practice of builders of mill engines, and can properly be considered with them. Pumping engines have heretofore been the leaders in economy, but at present the best pumping and mill engines are practically equally economical.

Of course the greatest single step in economy was the introduction of the compound engine. At the present time we may cite the Louisville pumping engine and several mill engines, one or more at Grosvenor Dale, Conn.; Natick, R. I.; West Boylston, Mass.; Berkley, R. I., and Lawrence, Mass., as being about on a par, and representing the best commercial economy. In 1873 the most economical compound engines used about 16½ pounds of steam per indicated horse power per hour, as shown by tests of the Lynn and Lawrence pumping engines, which then established new records for duty. Improvements in methods of using steam were made, until it is now as easy to design an engine to use less than 13 pounds of feed water per horse power per hour as it was to use as little as 16 pounds in 1875. At this date steam jackets were common, and were used in all engines which gave the most economical performances. The steps, however, that lowered the steam consumption of compound engines from 16 to 14 pounds per indicated horse power per hour were largely the introduction of a cut-off on the low pressure cylinder and a reheating receiver between the cylinders. Although the reheater was invented by the late E. A. Cowper, of London, in 1862, so far as I know it was first used in this country by E. D. Leavitt in his engines for the Calumet & Hecla Mining Company, and is regarded by him as one of the most important causes of the economy of his engines.

These features appear to have been the principal means of lowering economy to 14 pounds of steam; but to what are we to attribute the step to 13 pounds? Clearance is well known to be an important factor, and its reduction, especially in the last cylinder of a series, is important for economy. It is receiving constant attention from careful designers, and its reduction is a constant source of gain. The 13-pound mark has also been reached by an increase in steam pressure with resulting increase in the number of expansions. In some cases a reduction in the size of the high pressure cylinder has doubtless contributed toward economy, by means of which smaller surfaces are exposed to the boiler steam than would otherwise be the case. This carries with it a proportional reduction of initial condensation in the cylinder which is most prolific in this cause of waste. Still further, the 13-pound mark has, in general, been attained by engines which have a low pressure cylinder larger for the work to be done than is commonly the case, so that the mean effective pressure referred to the low pressure cylinder is in the vicinity of 21 pounds. There are occasional exceptions, as in the case of the Louisville engine, which worked with a mean effective pressure referred to the low pressure cylinder of 25 pounds. Such cases are exceptional, and their economy can be attributed to great perfection of detail.

It will in general be observed, however, whatever may be said of other causes, that most of the extreme cases of economy are those in which a good vacuum has been maintained. This leads me to say that the importance of good vacuum is often not appreciated, and that air pumps and condensers are as often too small.

There is a strong tendency nowadays to underrate steam jackets, but I believe that in every case where they have been wasteful, or where their economy is indifferent, at all events with ordinary speeds, an examination would show that the jackets are air bound, water logged, blowing through traps, or that the jacket piping is bare, and thus steam for heating the building is charged to the engine. Such an arrangement of pipes can furnish but indifferent material for giving up latent heat to the working fluid within the cylinders, and is, in fact, absurd.

The effect of reheaters in drying out steam which issues from a preceding cylinder and in superheating it to 60 or 90 degrees, as is often the case, for use in the next cylinder, cannot be otherwise than advantageous, for, as Prof. Thurston shows in his paper of 1894 before this society, heat so added to the working fluid saves much more steam than was condensed to liberate this heat. While these considerations are very general, they are necessarily so, for nobody can attribute to any one of the features named its proper effect. Moreover, their combinations are very varied. Whatever may be said pro and con on this subject, it cannot be denied that the best results have been obtained from engines equipped with jackets and reheaters.

Considering economies effected, it is safe to say that without including triple expansion engines steam economy has steadily decreased from 20 to 12½ pounds per

indicated horse power between 1870 and 1897. This corresponds to a saving of 37½ per cent.

Within this period of 27 years the use of exhaust steam has extended in various mills, such as cotton, woolen and paper mills, so that in some mills the cost of steam power is next to nothing. Economies of this kind are not confined to the use of the exhaust of non-condensing engines, for since 1895 the writer's firm have had installed at the Washington Mills, Lawrence, Mass., a large surface condensing vertical compound engine, the rejected heat of which is utilized. In this mill large quantities of warm water are used in the dye-house, which has heretofore been heated by exhaust and direct steam. Now the circulating water of the new engine is sent from the condenser to the dyehouse by the circulating pump at about the temperature required. In this case the rejected heat of the engine is just as effectively used up as it would be if the engine were noncondensing and sending its exhaust to the dyehouse. There are advantages, moreover, in the compound surface condensing engine, for there is less rejected heat to use, with consequent diminished chance for waste, and there is less heat lost by radiation from a pipe full of warm water than from one of full steam. This constitutes one of the latest forms of recent economies. It may be mentioned incidentally that by the surface condensing engine oil is kept out of the dyehouse and away from the cloth. The air pump discharge, being small in volume, and containing all of the cylinder oil, can be easily taken care of in any way which appears to be advantageous.

What is there to be said concerning boilers within the period that we are considering? The horizontal return tubular boiler is still the standard of the country, and will probably so remain. It is cheap, and if properly built it is safe. As its tube heating surface can be effectively blown with steam with the certainty that the jet will strike every part thereof, and as, furthermore, its tubes can be effectively scraped at any time without taking the boiler out of service, it must necessarily be more economical than any of the numerous water tube boilers which are now being introduced. The fire surfaces of the latter can only be indifferently blown, and they cannot be scraped at all unless the boiler is cooled down, and in general it cannot then be done with anything approaching thoroughness. There is scarcely any improvement to be noted in the horizontal return tubular boiler during the last twenty-seven years as far as economy is concerned, but I believe that grates have been improved to a measurable extent, resulting in an economy of perhaps 2 per cent. My own experience teaches me that the internally fired boiler, either of the locomotive or vertical type, will save under equal conditions some 7 per cent. of coal compared with the horizontal return tubular boiler, besides causing an important economy in doing away with brick work.

Bryan Donkin, in a recent paper before the Institution of Civil Engineers, in discussing boiler economies says: "Generally speaking, internally fired boilers give a higher efficiency than those externally fired. The old and well known locomotive type, with smoke tubes and induced draught, stands high as a very economical steam generator." Praise from so careful an investigator as Mr. Donkin should carry great weight.

Within 27 years economizers for heating feed water in smoke flues have become common. Although subject to a rather large depreciation, in the general case they will save about 7 or 8 per cent. of coal.

There are economies to be obtained from the use of vertical engines. These come from reduction of friction, reduction of repairs to cylinders and pistons and diminished cylinder oil consumption. It would not surprise me if there were a net saving of 5 per cent. by reduced friction of a vertical compound compared with a horizontal engine.

Summing up the various items that have been mentioned, the following may be presented as the economies of the period from 1870 to 1897:

	Per cent.
Saving due to compounding, jackets, reheaters, higher pressures and greater expansions.....	37
Due to vertical engines.....	5
Due to vertical internally fired boilers.....	7
Due to economizers.....	7
Due to improved grates.....	2

As these economies could not be simultaneously applied to the original condition of a mill, their sum is not a result that could have been realized in any case. With these important economies having been brought about during 27 years, the question arises, Are there any compensating disadvantages?

It is easy to show that there are not, for

1. The first cost of a cross compound condensing engine is no greater than that of a pair of simple condensing engines 27 years ago, on account of improved tools and processes and reduced prices of materials.
2. Interest charges are less than they were 27 years ago.
3. The depreciation of engines is less than it was 27 years ago, on account of better materials, better workmanship, better oil and better means of applying oil. Vertical engines will render the depreciation of cylinders, pistons, piston rods, piston rod packing and cross heads less than similar parts in horizontal engines.
4. The reduction in the number of boilers required by some 33 per cent. for a given power within 27 years carries with it many reduced charges, such as first cost, interest, repairs, depreciation, insurance, taxes, cost of boiler houses, cost of attendance, and various lesser items.
5. Present boiler building practice is superior to the old, so that high pressures are now as safely and comfortably carried as the lower pressures of 1870. Better materials, longer plates and fewer joints, butt joints of high efficiency and maintaining the circular form with changes in pressure, drilled holes, hydraulic riveting and round tool calking render it as safe to carry 200 pounds or more as any lower pressure.
6. I might include reductions in cost due to handling coal by conveyors for large plants and by mechanical stokers. Conveyors are in some cases very economical, but mechanical stokers are of doubtful value, speaking generally. The greatest efficiency of the conveyor is to be found in connection with the mechanical stoker.

So far the only steam engine considered is the compound engine. This engine has recently been found

capable of utilizing the higher pressures much more economically than was formerly suspected. It has therefore diminished the advantage of the triple expansion engine to such an extent that the latter has met with something of a setback. I believe, however, that the triple engine is still to be common when pressures begin to exceed 160 pounds of steam, and its undoubted advantage at sea gives evidence that it will be no less on land. Within a year or two an interesting and instructive comparison can be made between two pumping engines, one compound and one triple, both to use 185 pounds of steam and designed on the same lines by Mr. Leavitt. It seems probable that the relative economies of the compound engine, using 160 pounds, and the triple, using 185 pounds of steam, are to-day represented in the very best practice by 12½ pounds of steam and 11¼ pounds of steam respectively per indicated horse power per hour. This corresponds to a saving of 8.16 per cent., which is a paying saving.

Very careful attention should be paid to the kind of steam valves used in engine cylinders, for leaky valves can readily nullify the advantage which may be derived by anything which can be done to contribute to economy in the general design. It is the writer's experience that the gridiron valve, properly designed with ample lap, and originally made strictly tight by scraping, will remain so far longer than any other kind.

The future, so far as we can now see, offers us highly superheated steam for further means of economy. The technical papers have frequent accounts of the use of such steam in Germany, and published tests (see Engineering, pp. 113, 391, 1895) show that a small Schmidt "motor" has used 10.17 pounds of steam per indicated horse power per hour. It would seem that we have a right to anticipate in the early future a steam rate of 10 pounds by means of superheated steam in the best designed engines. Compared with the lowest rate thus far mentioned, this corresponds to a saving of 11.11 per cent.

We have also in anticipation the use of very high steam pressure and quadruple expansion engines as built experimentally at Cornell University and described by Prof. Thurston last year before this society. If, however, steam can be so highly superheated that expansion in one cylinder will not cause condensation or even the saturated condition until the time of exhaust, as was the case in the Schmidt motor, extreme economy may be obtained without resort to the multiple expansion engine.

The economies thus far mentioned relate to improvements in engines and boilers; but one of the greatest economies results from the low cost of coal at present in Lowell, Lawrence and similarly located towns.

The price of coal in these places has fallen from \$7.10 per ton, in 1870, to \$3.85 per ton, in 1895.

These prices show a saving from 1870 to 1895 by themselves of about 46 per cent.

I shall now consider the actual figures making up the cost of a mill steam plant and its cost of operating, say of 1,000 horse power, in most mill towns in the State of Massachusetts away from tidewater. The very best steam plant of this power 27 years ago, including a pair of simple condensing engines using 20 pounds of steam, boilers evaporating 8 pounds of water on total coal used, buildings, chimney and all accessories, cost \$70 an indicated horse power. The fixed charges on such a plant were interest at 6 per cent., depreciation at 4 per cent., repairs at 2 per cent., insurance at 1 per cent., or a total of 13 per cent.

13 per cent. of \$70 is.....	\$9.10
Coal at 2.50 pounds per I. H. P. per hour, at \$7.10 a ton.....	24.40
Attendance, boilers—3 day men at \$1.50, 1 night man at \$1.50.....	1.85
Attendance, engine—1 engineer at \$3.00, 1 assistant at \$2.00.....	1.54
Oil, waste and supplies.....	1.25
	<hr/> \$38.14

The very best plant of 1,000 horse power can be installed to-day complete, including buildings, chimney, compound engine using 12½ pounds of steam, boilers evaporating 9 pounds of water on total coal used, economizers and all accessories for \$57 per indicated horse power. Such a plant can run on 14 pounds of coal per indicated horse power per hour for total coal consumed. The fixed charges are: Interest at 5 per cent.; average depreciation, 3½ per cent.; repairs, 2 per cent.; insurance and tax, 1 per cent., or a total of 11½ per cent.

11½ per cent. of \$57 is.....	\$6.55
Coal at 1.4 pounds per I. H. P. per hour at \$3.85 a ton.....	7.41
Attendance, boilers—2 day men at \$1.50, 1 night man at \$1.50.....	1.39
Attendance, engine—1 engineer at \$3.50, 1 assistant at \$2.00.....	1.69
Oil, waste and supplies.....	.80
	<hr/> \$17.84

Saving in 27 years in first cost, per cent.	18.6
Saving 27 years in operation, per cent.....	53.0

On the supposition that superheated steam can reduce the steam consumption to 10 pounds per indicated horse power per hour, and that the combined efficiency of boilers and economizers is not affected thereby, the cost of installation of 1 horse power can still be taken at \$57.

The cost of coal per I. H. P. will be.....	\$5.88
Other charges will be.....	10.43

Total \$16.31

This makes a saving of yearly charges, compared with the best present plant, of 8½ per cent.

Some actual costs of a yarn mill in Massachusetts built in 1889 are as follows:

Cost per horse power of engine (compound).....	\$60.50
Total coal burnt per year, tons	2,674
Average I. H. P. for the year.....	1,132
Total coal burnt for power, heating mill and banking fires, per I. H. P. per hour, pounds.....	1.75
During the six months when no heating was done the coal used per I. H. P. per hour was, pounds.....	1.65

* Paper presented at the New York meeting of the American Society of Mechanical Engineers.

The cost of operating a horse power per year was as follows, assuming 11½ per cent. fixed charges:

Total cost of plant, \$66,600, at 11½ per cent. \$7,659.00
 Coal, 2,674 tons, at \$4.75 per ton 12,701.00
 Attendance \$8.85 a day × 308 days ... 2,725.80
 Oil waste and supplies ... 312.00

Total cost of power..... \$23,397.80

Average horse power per year, I. H. P.... 1,132
 Cost per I. H. P. per year ... \$20.67
 Cost corrected for coal used in heating mill..... 20.01

The following figures were given in The Engineering Record for March 14, 1896, for the Stevens linen mill, Webster, Mass. The engine is a compound, and was indicated morning and afternoon every working day throughout the year, and the coal is that used for all purposes throughout the year:

	1893.	1894.	1895.
Average I. H. P. for the year.....	381	393	396
H. P. hours for the year....	1,042,221	893,792	1,076,134
Coal, pounds for the year....	1,831,700	1,493,243	1,775,720
Average coal per I. H. P. per hour, pounds.....	1.76	1.67	1.65

THE IMPERIAL NAVY YARD AT KIEL.

VERY few tourists who visit Germany's naval city and its beautiful bay are willing to leave the vicinity without first inspecting at least one of the armored vessels anchored in the harbor, as well as the works where some of these colossi have been built. Of course, the duty of guarding technical secrets makes it impossible to grant too close an inspection of the workshops and storerooms, and closes many doors to the visitor, but what he sees and learns from the guide assigned to him at the entrance is sufficient to give him an idea of the extent of the navy yard, which is now one of the best equipped in Europe.

From a strategic point of view, however, its importance does not depend on the perfection of all its arrangements, but on its location, which is so sheltered that disabled vessels can always be repaired there and vessels that have been held in reserve can be provisioned, no matter how fierce a battle may be raging outside of the harbor; for the works are so far back from the strongly fortified entrance to the bay that neither the eye nor the shots of the enemy can reach them, and as long as the German army holds the land there will be communication with the interior of the country by rail. The importance of the navy yard at Kiel was greatly increased by the opening of the Kaiser Wilhelm Canal, for this will always enable vessels operating on the Elbe during a blockade to reach the docks for repairs or for a fresh supply of provisions or ammunition.

In order to prepare the shore opposite Kiel for use as a shipyard, extensive changes had to be made, such as leveling some hills and filling in places on the shore with the earth thus obtained. Many cubic yards of earth were removed, but a steep ledge still remains just across the road that runs along the outside of the wall around the navy yard and connects Gaarden and Ellerbek, and from this ledge the fine view reproduced in our engraving was taken.

Referring to the latter, we see, on the western shore of the harbor, the city of Kiel, which has grown very rapidly since it became the headquarters of naval affairs. In about the center of the city, embedded in the mass of houses, stands the church of St. Nicholas, the oldest and most beautiful house of God in the whole city, and to the left of this, close together, rise the spires of St. Jacobi and of the new Catholic church, while at the right, on a hill, is the beautiful new Gothic "Garrison Church." Close to the bank stands the royal palace, utterly bare of all architectural ornament and built on the foundation of the old "Wasserburg" of Graf Adolf IV., of Schauenburg, the conqueror of Bornhöven and founder of "tom Kil" (Kiel). It is now the residence of Prince-Admiral Henry, whose flag flies from the tower. A celebrated promenade begins at this palace and passes through Düsternbrook, ending near the imposing buildings of the Naval Academy at Bellevue. Beyond, the water spreads out into a wide bay, but contracts again to a narrow passage at the fortifications at Friedrichsort, and then joins the open sea.

After the conclusion of the naval maneuvers in the autumn the squadron entered the bay, and our engraving shows them arranged in a long chain extending from the inner end of the harbor to the bay, some of them under steam. The vessels farthest away from us, in the second line, are the high-masted cadet and school ships; in front of them, fourth class armored vessels of the "Siegfried" type, which are easily recognized by the shape of their hulls; next comes the "König Wilhelm" with its two smokestacks between the two military masts and the short signal mast, and against its long hull the sharp lines of the imperial yacht, the "Hohenzollern," stand out clearly. This side of the latter are three powerful men-of-war of the "Brandenburg" type, and two vessels of the old "Saxon" type end the line. Some of the vessels of the squadron are not in this line, as they have already entered the yard, which has an area of 150 acres, 96,000 square yards of which are covered with buildings which lie just at our feet, on this side of the harbor.

The entrance to the repair basin, between the coal yard and the gun and artillery storehouses, is 328 feet wide and is closed at night by having a chain stretched across it. Lying by the wharf of the coal yard we see the gigantic floating crane, capable of lifting 100 tons and propelled by its own power, and at the farther side of the basin, in the right hand corner of the picture, is the "Kurfürst Friedrich Wilhelm," distinguished by the admiral's pennant with the black cross. The basin is about 33 feet deep and is surrounded by so-called "ships' rooms," long sheds in which the supplies for the ships of the Baltic Sea squadron are kept. On this side of the basin, where we see the two smokestacks and masts of the dispatch boat "Blitz," is the chain testing station fitted up with a hydraulic chain testing machine of 200 tons and a torsion machine of 250 tons pulling power; and on the same shore, but at the opposite corner, the smaller floating crane, of 40 tons

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