Use of the Low Pressure Steam Turbine*

Instances of Where the Output of a Power Station Has Been Increased Without Increasing the Boiler Capacity by Installation of Low Pressure Steam Turbine and, in Case of Non-Condensing Engines, Condensing Equipment; Thus Reducing Materially the Cost of Power.

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In this period of keen competition, when the profit in almost every line of manufacture is represented by the value of what was discarded as worthless but a few years ago, it becomes not only desirable but absolutely essential to the success of any undertaking to carefully investigate each item which goes to make up the cost of the finished product.

To analyze and discuss all of the items which when combined represent the manufacturing cost is beyond the scope of this paper. The writer will, however, endeavor to present for your consideration some facts which it is hoped may be of material assistance in reducing to a minimum one of these items, the importance of which varies materially with the class of goods manufactured, namely, the production of the power for operating the producing machinery.

You will agree with me that this desirable result can be accomplished if every pound of steam generated in your boilers can be so utilized as to deliver in useful work from 25 to 100 per cent. more available power than is at present being obtained under such conditions as not to increase the cost of the other items.

The prime object of this paper is, therefore, to call to your attention a recent engineering development which will effect immense gains in capacity and economy in existing power plants without involving any sacrifice or abandonment of any part of the present equipment, accomplishing this result with a minimum of additional investment.

While the reciprocating steam engine is a highly efficient piece of apparatus for utilizing the available energy of steam between boiler pressure and atmospheric pressure, it is a comparatively inefficient piece of apparatus for utilizing the available energy of the steam in its lower ranges below atmospheric pressure.

On the other hand the supremacy gained by the steam turbine has been largely due to the fact that it as efficiently utilizes the available energy of steam in the lower as in the higher pressure ranges, and there being as much available energy in steam below the atmospheric line as there is above it we are led to the investigation of the results to be obtained from the use of the reciprocating unit in its most economical field (the higher pressure ranges) combined with the turbine for the most economical transformation of the low pressure ranges.

THE LOW PRESSURE TURBINE.

The low pressure turbine is designed to take steam at one pound gauge pressure and efficiently utilize its energy in the lower ranges to one-half pound absolute, or, in other words, a 29-inch vacuum, at water rates from 30 to 50 pounds per kilowatt-hour at the switchboard, in accordance with size and local conditions.

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The low pressure turbine can be advantageously applied in any case where reciprocating engines are now used, and their application will always afford a large improvement of economy and increase the power output without increase of boiler plant.

This applies whether engines are now operated condensing, or non-condensing, delivering their output electrically or mechanically, and also applies to engines which operate on intermittent loads, since the delivery of low pressure steam can be equalized by suitable steam regenerating apparatus.

In many existing plants engines are operated non-condensing because cooling water is not conveniently available.

Such practice may be legitimate with reciprocating engines because the gain by condensation with engines is comparatively small and, in many cases, may not pay for the additional complication and expense incident to the installation and operation of cooling towers or condensers.

If low pressure turbines are used, however, we can expect to obtain about as much power from the turbine working below the atmosphere as we do from the engine above the atmosphere, and with this great gain obtainable there can be no question as to the economy of installing condenser facilities and low pressure turbines, even where cooling towers would be required.

There are already in existence plants where low pressure turbines have been installed in connection with engines previously used non-condensing, and by such installation with cooling towers, the output of the plant has been practically doubled without any addition to fuel consumption or attendance. Permit me to be specific in this statement and cite a 1,000 h.p. non-condensing engine plant operating 3,000 hours per year at 2.5 pounds of fuel per h.p., or 3,750 short tons of coal per year.

By the addition of a 1,000 h.p. low pressure turbine with a suitable cooling tower, made necessary by local conditions, capable of maintaining a 28-inch vacuum, the plant was made to deliver 2,000 h.p. 3,000 hours per year at 1.25 pounds of fuel per h.p. hour, or 3,750 short tons of coal per year. The plant as doubled in output required no addition to the boiler equipment, nor was any additional labor made necessary.

The most ready field for the introduction of low pressure turbines is found in existing condensing plants which operate with reciprocating engines. In such plants immense gains can be accomplished by the use of low pressure turbines either with existing condensers or with improved condensing facilities. The gain by high vacuum in turbines is so much greater than in engines that it will generally be worth while to install condensing facilities of the most improved kind with the most improved pumping facilities. Where low pressure turbines are installed, the exhaust pressure of engines will be above the atmosphere. There will, therefore, be no air leakage around piston rods and valve stems, and it will be possible to maintain better degrees of vacuum than those which are generally experienced in condensing engine plants where there is more or less leakage of air and little incentive for the production of high vacuum.

The possibilities of the low pressure will be more readily understood if we consider the available work in different ranges of steam pressure. If saturated steam operates from a pressure of 150 pounds gauge to a pressure of one pound above the atmosphere, the available energy is about 132,000 foot pounds per pound, and if saturated steam operates from a pressure of one pound of steam above the atmosphere to a vacuum of 28½ inches, the available energy is 146,000 foot pounds per pound of steam. In a mixture of steam and water issuing from an ordinary steam engine exhausting at a pressure of one pound above the atmosphere, the above available energy is reduced to about 132,000 foot pounds per pound if we work to a vacuum of 28½ inches. Thus under these very ordinary conditions there is as much work available in the low pressure ranges as in the high. In a turbine properly proportioned for such work the efficiency in these low pressure ranges is better than the high pressure part, while in the reciprocating engine the return from the low pressure steam is relatively very small.

In most condensing engines the gain over non-condensing conditions does not exceed 30 per cent. even under the most favorable conditions of load, and under overload conditions the gain by condensing is much smaller. In most cases a reciprocating engine which is operated condensing will give at least 75 per cent. of the output with the same steam used non-condensing. This steam being taken into a low pressure turbine with good condensing facilities will add nearly, if not quite, as much work as it gives in the engine. We can, therefore, under ordinary conditions get a net gain of 50 per cent. over existing condensing engine service by installing low pressure turbines, and under overload conditions where the efficiency of the engine falls off and where its gain by vacuum is greatly diminished, the rate of improvement will be much better.

AN EXAMPLE OF POWER GAINED.

The Philadelphia Rapid Transit Co., in 1905, installed at its power station on Thirteenth and Mt. Vernon streets an 800 kilowatt Curtis low pressure turbine. This station was equipped with four 1,500 h.p. and one 2,200 h.p. Wetherill Corliss engines which had always been operated non-condensing for the reason that cooling water was not available.

An Alberger condenser having 8,000 square feet of cooling surface together with a cooling tower, was installed for use with the low pressure turbine.