a large amount of cold air. This latter loss is increased by an increase of draught. The remedy for this lies in care being taken with the boiler setting and the adoption of up-to-date methods, such as an iron plate air-tight case enclosing a carbonate of magnesia lining outside the brickwork. For the tubular boiler the leakage is less than for the water-tube type, owing to the smaller number of joints in the water space. This advantage is offset by the increased difficulty of construction and the danger of using large boilers of the tubular type, especially with high-pressure steam.

The importance of getting the feed-water to the maxi mum temperature obtainable is generally recognized, and would seem to indicate that all auxiliaries should be steam-driven, so that the exhaust may be utilized in the feed-water heater. In this way the auxiliaries may operate at about 80 per cent thermal efficiency.

(5) In regard to electricity-driven versus steam-driven auxiliaries, the two considerations are economy and reliability. The economy of the steam-driven is greater than of the electricity-driven auxiliaries, and the only objection that can be raised is the extensive piping required for the steam-driven auxiliaries. This piping will have considerable radiation, which cannot be avoided, and if the steam piping to the auxiliaries becomes too great the loss from this cause may be greater than the amount of inherent economy. Pipe radiation is best taken care of by the use of two-layer pipe covering, each layer being approximately one-fifth of an inch thick, and sections put on in such a manner that all joints are broken. This covering of steam pipes reduces losses about 80 per cent. Relative values of several coverings are given here as regards reduction in losses:—

	Per cent.
Mineral wool	90
Asbestos sponge	89
Air felt	87
Magnesia	87
Asbestos navy	86
Asbestos air cell	83

(6) I do not believe that either system will prevail to the exclusion of the other. A very good arrangement seems to be direct-acting steam boiler feed pumps, and possibly centralize vacuum pumps with all the smaller and scattered auxiliaries, such as service pumps, oil pumps, etc., driven by electric motors, the power supply for the motors to be furnished by separate steam-driven exciter sets of sufficient capacity to carry the exciter, plus the motor load, and exhausting into feed-water along with the boiler feed pumps and vacuum pumps. The exciter sets should be located near the boiler and feed water heater so that there will be a maximum of steam and exhaust pipes to and from them to maintain. It is difficult to explain the expense of a piping system for a small steam plant; a steam plant when it is once installed has to be kept hot and drained all the time, so that it appears that the trouble is far greater than the expense.

The motor drive for the other auxiliaries permits of direct connection to the centrifugal pumps making very compact, cheap, efficient and easily maintained sets, and entirely eliminates the maze of hot pipes which permeates the ordinary power plant basement, and are a continuous source of trouble and expense to keep covered. Motor-driven sets also do away with the necessity of cylinder lubrication oil cups, and greatly reduce stuffing box and packing expense. Since the exciter sets must furnish the power there is no diminution in the supply of exhausts or feed-water, and, since the power is direct current, there is every opportunity for efficient speed regulation to meet all variable load demands. From these arguments there appear to be valid reasons why steam-driven auxiliaries should not be used exclusively.

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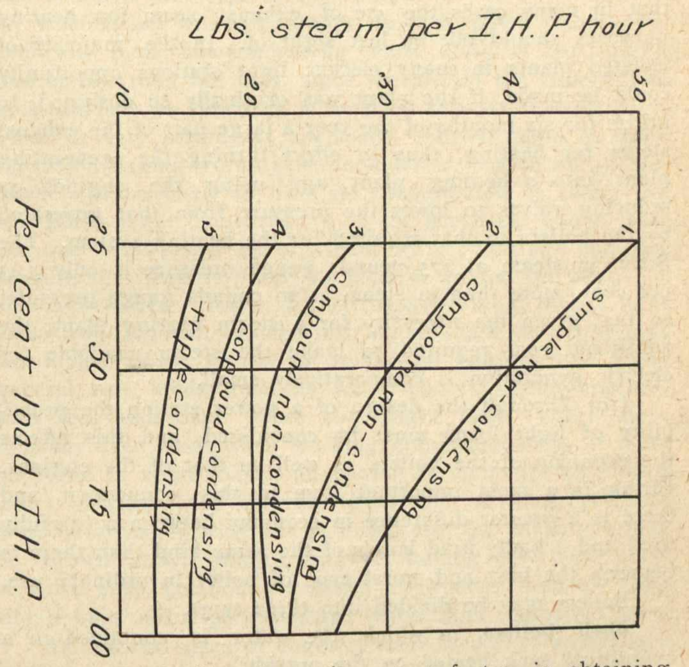
(5) P. M. Lincoln, A.I.E.E., February 13th, 1906.
(6) W. E. Moore, A.I.E.E., February 13th, 1906.

(7) Owing to the difficulty of pumping water at temperatures above 150° F., when under pressure, it becomes necessary to install economizers for the purpose of increasing the feed water temperature to 200 or 250° F. As the increase of temperature is obtained from the waste gases at no expense of fuel, it only is necessary to consider the load factor in order to determine whether economizers should be installed or not. The size of the economizer to be installed depends upon the influence of the economizer upon the available draught due to the obstruction it offers, and also due to reduced slack temperature. The second consideration is to equate the interest and depreciation changes against the saving in fuel, and thus determine the amount of investment justified in each particular case.

In regard to the loss in leakage, this should, and can be made very slight, and the high-pressure drips can be returned to the boiler, so that the actual loss from this source is very small. In considering these small losses we might also note that such losses as that delivered to small auxiliaries, heating, and to house auxiliaries are probably unavoidable, and of so small a magnitude as not to merit much consideration.

Recent tests on some reciprocating engines show a mechanical efficiency of 93.65 per cent. at full load, or an engine friction of 6.35 per cent. As this forms only .3 per cent. of the total thermal loss it is relatively unimportant.



The method of oiling is an important factor in obtaining this good result. The method used is what is called the flushing system, whereby a large quantity of oil is put through all the bearings by gravity feed from elevated oil reservoirs common to all the units. The oil, after passing through the bearings, is collected in the basement and pumped to the tanks again with a loss of only .5 per cent.

Engine radiation losses are probably as low as it is possible to bring them, due to the improved methods of heat insulation.

In considering the heat rejected to the condenser, we become involved in the thermal dynamics of the steam engine, a subject so broad that it can only be touched on here. The efficiency of any heat engine: $E = \frac{T1 - T2}{T1}$ where T is the absolute temperature of the steam entering the engine and T2 is the absolute temperature of the steam leaving the engine. If the united pressure is 175 pounds gauge and the vacuum at low pressure exhaust is 28 inches, then the maximum thermal efficiency is $\frac{837 - 560}{837} = 33$ per cent. In a particular example the point of maximum

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(7) "Power Plant Economics." Stott, A.I.E.E., January, 1906.