economy shows a steam consumption of 17 pounds per kilowatt-hour, which is equivalent to 20349 B.t.u. per hour. One kilowatt-hour is equal to 3412 B.t.u. per hour, so that the actual efficiency of the steam engine and generator is equal to $\frac{3412}{20349} = 16.7$ per cent. As the generator efficiency is approximately 98 per cent. at this load, the net thermo dynamic efficiency is 17 per cent.

The difference between the theoretical efficiency and the actual is then 33 — 17 = 16 per cent., of which 6.35 per cent. is accounted for as engine friction, leaving the balance due to condensation radiation and incomplete expansion. These last three must be considered in order to obtain any improvement, and the use of superheated steam is the only remedy at hand. With its use an improvement of probably 5 or 6 per cent. may be effected by using such a degree of superheat in the boilers that dry steam will be had at the point of cut-off in the low-pressure cylinder. Any greater amount of superheat than this will result in loss to condenser, for cylinder losses increase with the difference in temperature. This would seem to point to the use of more cylinders, but this involves additional first cost and higher maintenance charges.

(9) Considering the table, we note that 60 per cent. of heat units are rejected to condenser. It is clear from this that in many cases the use of exhaust seam for heating purposes should not be lost sight of. In the majority of isolated plants in many electric light stations opportunity could be made, if the plant was originally so designed, to utilize for six months of the year a large part of the exhaust steam for heating, thus in effect turning the generating plant into a heating plant, and using the engines as reducing valves to lower the pressure from that generated by the boilers to that required for the heating system. The B.t.u. in steam at 175 pounds gauge pressure is only 5.45 per cent. more than in steam at 10 pounds gauge pressure, so that given the necessity for a steam heating plant, the additional coal required to make the steam available for electric generation is comparatively small.

(10) Through the design of a power station the probability of light loads must be considered, and this affects the economy of the boilers as well as that of the engines. Firing is a most important item in this connection, and there is a greater difference in economy between a carefully fired and a badly fired boiler of the same kind than there is between the best and worst type of boiler in ordinary use.

Boilers may be divided into three types:—

Shell boilers, in which the water is contained in a cylindrical tank heated on the outside.

Tubular boilers, in which there are tubes running lengthwise of the boiler shell, and serving as channels for the heated gases from the fire; and, lastly,

Water-tube boilers, in which the water is contained in a group of metallic tubes, around which the heat of the fire burns freely.

As to the merits of these different types opinions differ very widely, but it is clear from experience that the simple shell boiler is decidedly inferior to either of the others in economy, despite its simplicity and cheapness. Of late years it has been the fashion to employ water-tube boilers under all sorts of conditions on account of their supposed high efficiency as steam producers. Safety and compactness as tests under experiment show phenomenal efficiency, but tests under working conditions hardly give as good results.

Altogether, the subject of boiler efficiency is a very difficult one, since conditions are constantly changing, and the best guides are found from long practical tests than from the theory of combustion. Boiler tests, with the condition of economy in view, are of great importance, and are likely to pay for themselves many times over in a few months of operation. Forcing a boiler usually injures its efficiency, as it increases the consumption of coal for grate area. Therefore, it follows that a boiler is more efficient at moderate loads than high ones. It may occur in central station practice that despite these facts it is better to force the boilers at hours of heavy load than to keep a relay of boilers banked ready for use.

The best fuel is not always that of the highest thermal value, for, in fact, a grade of coal only moderately good is often the most economical. Good boilers should with careful firing utilize from 70 per cent. of the thermal value of the coal. In regard to actual tests under boilers, examples show from 8 to 13 pounds of water evaporated from and at 212° F. per pound of combustible. As average good steam coal contains from 8 to 13 per cent. of ash and moisture, these results correspond to from 7 to 11¾ pounds of water per pound of coal. Generally speaking, from 10 to 15 pounds of coal are consumed per hour per square foot of grate surface.

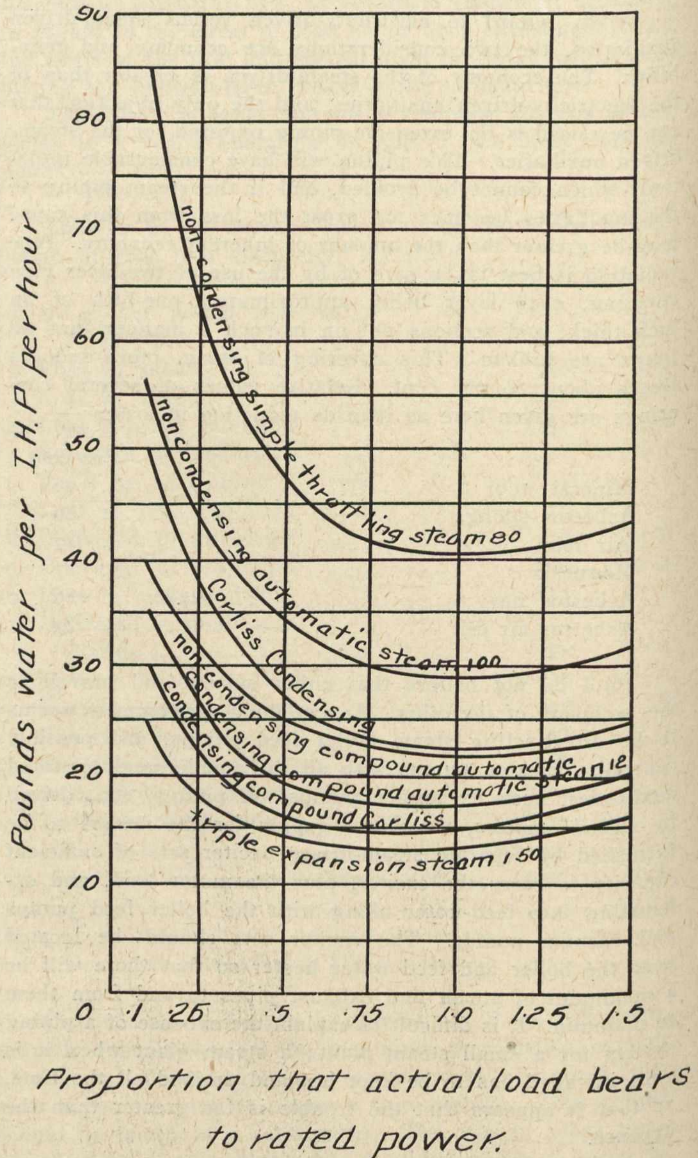

Fig. 2.

(11) The following table gives a general idea of the results of several boiler tests, good, bad and indifferent:—

Kind of Boiler.	Kind of Coal.	Evaporation.
Return tubular	Welsh steam	13.12
Water-tube	Bituminous	13.01
Return tubular	Cumberland	12.47
Verticular tubular	Cumberland	12.29
Marine	Newcastle	11.44
Water-tube	Anthracite	11.31
Plain tubular	Cumberland	10.98
Marine	Anthracite	10.88
Locomotive	Welsh steam	10.44
Cylinder	Coke	10.39
Cylinder	Anthracite	9.22
	Cumberland	8.74

(8) "Power Plant Economics." Stott, A.I.E.E., Jan., 1906.
(9) Calvert Townley, A.I.E.E.
(10) "Electric Power Transmission." Bell. Page 326.
(11) "Electric Power Transmission." Bell. Page 330.