It will be noticed that in the example given above, cooling tower conditions were assumed in calculating the power of the circulating pump. Their absence would have reduced the power for the pump from 100 h.p. to perhaps 60 h.p., depending on the location of the source of water. Natural-draft towers are responsible, therefore, for an appreciable increase in the motive power installation, and fan-draft towers for a considerable increase.

Economizers.

The question of economizers is almost entirely one of thermal efficiency. It is interesting, therefore, to note that they have been excluded from much important American practice. They are, on the other hand, used extensively in British and Continental work, though to very different degrees. Heating surface may be arranged for either in a boiler or outside it, with the qualifications that if in a boiler, it must be made of steel; but if outside, it can be made of cast-iron; and further, that gases cannot, in a boiler, be cooled below the temperature of saturated steam at working pressure, or in some cases superheated steam. In most designs of boiler these limitations result in a standard form, and a temperatutre of outgoing gases between 450 deg. and 600 deg. F. Such a standard form is accepted—and properly so—as being the outcome of the boiler-maker's experience; and the additional heating surface is arranged for apart from the limitation due to the presence of saturated or super-heated steam. But, while a certain uniformity is to be found in boiler surface provided for a given output, the number of economizer pipes may vary from nothing up to 12 per 1,000 lbs. evaporated. This variation in practice may be accounted for by the space available; but it is often influenced by consideration of the draft necessary.

Draft.

Draft may be created either by a fan or by a chimney. Where there are peculiar conditions such as the existence of long and tortuous flues, or the absolute necessity for drafts upwards of 1½ in., the question is settled automatically in favor of the mechanical method, practical considerations making it impossible to create a high draft by chimney alone. With a chimney the gases cannot be cooled below a certain temperature; otherwise insufficient draft will result. On the other hand, with a fan, gases may be cooled to any degree desired. Practical limitations are soon set in this direction by the space occupied by the economizer; and the result is that, though at first it might be expected that natural draft would necessarily be associated with smaller economizers than mechanical draft, in practice examples can be found of natural draft stations employing as large an economizer surface as even modern fan-draft installations. The mechanical arrangement has, however one advantage in facility of regulation independently of the weather, and in rendering a short chimney practicable.

The value of control over the draft cannot be assessed except in general terms by those who have had extended experience with both methods. Apart from this, the cost of power absorbed by the fans much outweighs the difference in capital charges due to a high natural-draft stack, as the following illustration, applicable to installations of about 10,000 kw. shows:—

For natural draft—	
Cost of chimney 250 feet high, with foundations	£3,000
For mechanical draft—	
Cost of chimney 100 feet high, with foundations	£1,200
Cost of fans and motors and extra flues........	1,400
	£2,600
Balance of capital expenditure in favor of mechanical system	£ 400
Representing an annual charge, at 15%., of........	£ 60
Against this is to be set running costs of motors, calculated on 200 h.p. for 5,000 hours at 0.25d. per unit	£ 780

The circumstances of load may, however, demand great elasticity in the steam-raising plant, in which case mechanical draft takes the place of additional boilers, and so may justify itself. Moreover, under normal conditions combustion is effected more economically with a high draft, if boiler and economizer surfaces are ample, less air of dilution being required per pound of coal.

The foregoing discussion is applicable only in cases where very moderate drafts are sufficient; and little variation is called for. The more usual case with an installation supplying power for general uses is that a certain latitude of draft is necessary for the purposes of the load, but the obstruction due to large economizers, coupled with the reduction at the chimney caused by lowering the temperature of the gases would result in insufficient difference of air pressure at the grate. In such cases the choice must be between natural draft with small economizer, or mechanical draft with large economizer; and the following treatment is put forward as being applicable.

The conditions assumed are as follows:—

Gases issue from boilers at....................	550° Fahr.
Air per lb. of coal, on average....	23 lbs.
Temperature of atmosphere	60° Fahr.
Specific heat of products of combustion.........	0.25

In the case of fan draft, it is further assumed:—

Gases leave economizer and enter fan at..	320° Fahr.
Maximum water gauge required at fan.........	3 inches.
Usual water gauge required at fan............	2 inches.
Efficiency of fan, 50% per cent. on average.	

In the case of chimney draft:—

Gases leave economizer at...........	450° Fahr.
Height of chimney	220 feet.

Then heat rejected from boiler per ton of coal fired is $(2{,}240 \times 24 \times 0.25) \times 490$, or 6,585,600 B.T.U. In the case of chimney draft the economizer absorbs $(2{,}240 \times 24 \times 0.25) \times 100$, or 1,344,000 B.T.U., and of this amount about 70 per cent., i.e., 940,800 B.T.U., is conveyed to the feed water, the balance being dissipated in flues, radiation and influx of cold air through economizer chain holes. In the case of fan draft, the power of the fan to create 3 in. water column, with an assumed efficiency of 50 per cent., may be found to be 16.6 h.p. per ton of coal burned per hour.* The usual h.p. required is, therefore, $16.6 \times \frac{2}{3}$, or 11 h.p. per ton of coal per hour. The number of B.T.U. required to produce this energy, by way of boiler, turbine, alternator, transformer, and motor, with a combined assumed efficiency of 10 per cent., is $\frac{2{,}545 \times 11}{0.1}$ or 280,000 B.T.U. The quantity of heat usefully absorbed by economizer is $(2{,}240 \times 24 \times 0.25) \times 230 \times 0.7$, or 2,170,000 B.T.U. Consequently, of the total heat rejected from the boilers per ton of coal burned per hour, viz., 6,585,600 B.T.U., the natural-draft

* Height of column of heated products of combustion equivalent to 3 inches water column = 306 feet. Maximum horse-power required, with efficiency of 50%—

$$\frac{306 \times 24 \times 2{,}240}{60 \times 33{,}000 \times 0.5} \text{ or } 16.6 \text{ h.p. per ton per hour.}$$