As the gases pass onward through the tubes they become cooled, but those of higher temperature part most readily with their heat, and at the same time their volume and consequent velocity are reduced, still further facilitating heat transmission. On the other hand the gases of lower initial temperature transmit their heat less rapidly and the final result is that within practical limits the temperature of the escaping gases is least with the greatest excess of the air supply. The fact just presented points toward the economy to be secured by comparatively high rates of combustion, when the proper rate of heating surface to grate surface is provided. A high combustion rate manifestly requires a thicker fire, which in turn presents a better opportunity for contact between fuel and air with consequent economy in the supply of the latter. Less air results in a more intense fire, a higher furnace temperature, a greater transmission of heat to the water within the boiler, and a resultant higher evaporative efficiency. But a thicker fire requires a greater intensity of draft to overcome the increased resistance, while the relatively smaller area for passage of air necessitates a higher velocity of that air, and furthermore, the increased intensity to produce this velocity must be proportional to the square of the rate of flow. This condition is most readily met by the fan, which, under normal conditions, produces an intensity exceeding that of an ordinary chimney, and which can without trouble maintain the highest practicable rate of combustion.

The loss resulting from the formation of smoke is absolute, for it is equivalent to directly robbing the fire of a part of the fuel from which not only has no heating effect been secured, but upon which heat has actually been wasted in raising it to the temperature of the escaping flue gases. For the prevention of smoke, sharp, intense draft is necessary, properly regulated and capable of furnishing the required amount of air, both below and above the coal at the very moment when it is most needed. This result can be best secured by the introduction of mechanical draft which is ordinarily so regulated that the decrease in steam pressure resulting from the opening of the fire doors, the charging of the furnace, or the clearing of the fires, instantly causes an increase in the speed of the fan and in the intensity of the draft and the volume of air. A loss incidental to poor draft is that due to the formation of carbonic oxide. The formation of this gas instead of the complete product of combustion, carbonic acid, results from a lack of air. Sufficient air can best be secured by some means like the fan, which under automatic regulation increases both the intensity of the draft and the volume of the air when required. As a result, the pressure forces the air in sufficient quantity to all spaces between the fuel, and renders the combustion practically perfect.

By far the most important of the factors connected with the operating expense of a boiler plant is the cost of the fuel. When burned under suitable conditions, the decrease in its cost far outstrips its decrease in efficiency, so that the solution of the problem involves itself with the provision of the proper conditions. As a rule the cheap fuels, like the fine anthracites, require for their combustion an intensity of draft which the ordinary chimney is incapable of producing. The draft actually required under given conditions is clearly shown by these results of tests by Coxe:

RESULTS OF TESTS OF PEA AND BUCKWHEAT COAL.

Kind of Coal	Rate of combustion per square foot of grate per hour.	Pounds of water evaporated from and at 212° per pound of coal.	Air pressure in inches of water.	Maximum limit to size of coal in inches.
Oneida Pea Coal.	13.63	[illegible]6	0.375	7-8
Oneida No. 1 Buckwheat	13.58	7.94	0.5	9-16
Oneida No. 2 Buckwheat	11.40	8.60	0.625	3-8
Oneida No. 3 Buckwheat	11.34	8.65	1.04	3-8
Eckley No. 3 Buckwheat	9.44	8.75	1.125	3-16

These coals, which are among the smallest in size, were burned on a special form of traveling grate, and the air pressure was maintained in the chamber beneath. It is noticeable that with practically constant combustion rate and evaporative efficiency, the draft increases very rapidly as the size of the coal decreases.

RELATIVE EFFICIENCIES OF VARIOUS COALS.

Kind of Coal.	Water evaporated from and at 212° by one lb of Dry Coal.	Relative efficiency in p.c. Cumberland =100.	Cost of coal per ton	Fuel cost of evaporating 1,000 lbs. of water from and at 212°.	Relative efficiency in per cent measured by cost to evaporate 1,000 lbs. Cumberland =100.
Cumberland	11.04	100	$3.75	$0.1698	100
Anthracite, broken...	9.79	89	4.50	0.2297	74
Anthracite, chestnut.	9.40	85	5.00	0.2660	64
Two parts Pea and Dust and one part Cumberland	9.38	85	2.58	0.1375	123
Two parts Pea and Dust and one part Culm	9.01	82	2.58	0.1432	119
Anthracite, Pea.....	8.86	80	4.00	0.2259	75
Nova Scotia Culm..	8.42	76	2.00	0.1187	156

The comparative efficiency of various coals as determined by Barrus is indicated in the accompanying table, which speaks for itself. The evidence in favor of burning low grade fuels is conclusive. Such results can, however, only be secured by positive and intense draft. It is true that as the quality of coal grows poorer and the size of the particles less, it becomes more necessary to provide some special form of grate or stoker for its proper burning. But even without an economizer to utilize the waste heat, the burning of cheap fuel by mechanical draft will, under perfect conditions, show a decided saving, after due allowance is made for fixed charges on the special furnace arrangements and for the cost of operating the fan:

Water evap. from and at 212° per lb. of coal.	ANNUAL SAVINGS RESULTING FROM BURNING CHEAP FUEL—COST PER TON.														
	$0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00
11.00											4,892	3,669	2,446	1,223	0,000
10.50										5,474	4,193	2,912	1,630	349	
10.00									6,115	4,770	3,424	2,079	734		
9.50							8,240	6,823	5,407	3,991	2,575	1,159			
9.00						9,105	7,610	6,115	4,621	3,126	1,631	136			
8.50					10,074	8,491	6,909	5,326	3,743	2,160	578				
8.00				11,180	9,478	7,797	6,115	4,433	2,752	1,070					
7.50			12,393	10,599	8,805	7,012	5,218	3,424	1,630						
7.00	15,724	13,803	11,881	9,959	8,037	6,115	4,193	2,272	350						

The possible savings with low grade fuels and mechanical draft are still further evidenced by the accompanying tables, which show for a 1,000 h.p. plant, the annual saving, based on 312 days of 10 hours each, which would result from the substitution of a cheaper fuel for say Cumberland coal, costing, in round figures, $4 per ton, and evaporating 11 pounds of water from and at 212° per pound of coal. Under these conditions the annual fuel expense would be $19,568. If the assumption be made that a coal costing $2.50, and evaporating only 9 pounds of water is substituted, the annual saving would be $4,621. The cost of operating the fan even if the exhaust steam was not utilized, and it required 1½ per cent. of the total coal burned, would be only $224, and if this were charged against the saving it would still amount to $4,397, a sum sufficient to show a most