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THE UTILIZATION OF FUEL IN LOCOMOTIVE PRACTICE

BY

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THE UTILIZATION OF FUEL IN LOCOMOTIVE PRACTICE.

By W. F. M. Goss.

INTRODUCTION.

The locomotives in service on the railroads of this country consume more than one-fifth of the total coal production of the United States. The amount is so large that any small saving that can be made effective in locomotive practice at once becomes an important factor in conserving the fuel supply of the nation. For this reason the United States Geological Survey has given attention to the special problems of combustion in locomotive boilers. It has approached this task from several different directions. The facts presented herewith constitute one series of results.

In the fall of 1906 the locomotive-testing laboratory of Purdue University, at Lafayette, Ind., entered on a series of tests, one purpose of which was to determine in precise terms the degree of efficiency with which a modern high-class American locomotive utilizes the heat energy of the fuel supplied to it. The general interest in the subject, the elaborate plans which had been formulated for conducting the work, and the substantial character of the support which had been pledged to maintain it justified the Geological Survey in aiding the investigation.[a] The cooperation of the Survey consisted in detailing experts to assist the regular staff of the laboratory in the chemical and calorific work of the tests. These experts, working under the general supervision of the director of the Purdue laboratory, became responsible for the sampling of smoke-box gases, of the fuel used, of the cinders caught in the front end, of the sparks discharged by the stack, and of the refuse caught in the ash pan. The gas analyses were made by them at the university laboratory. The analyses of all solid samples and the calorific tests of the fuels were made at the government fuel-testing plant at St. Louis. The representatives of the Survey were not concerned with other phases of the work.

[a] At the time mentioned the laboratory, aided by a grant from the Carnegie Institution, of Washington, D. C., was engaged in a general research concerning the value of superheated steam in locomotive service. See "Superheated steam in locomotive service," in press by the Carnegie Institution.

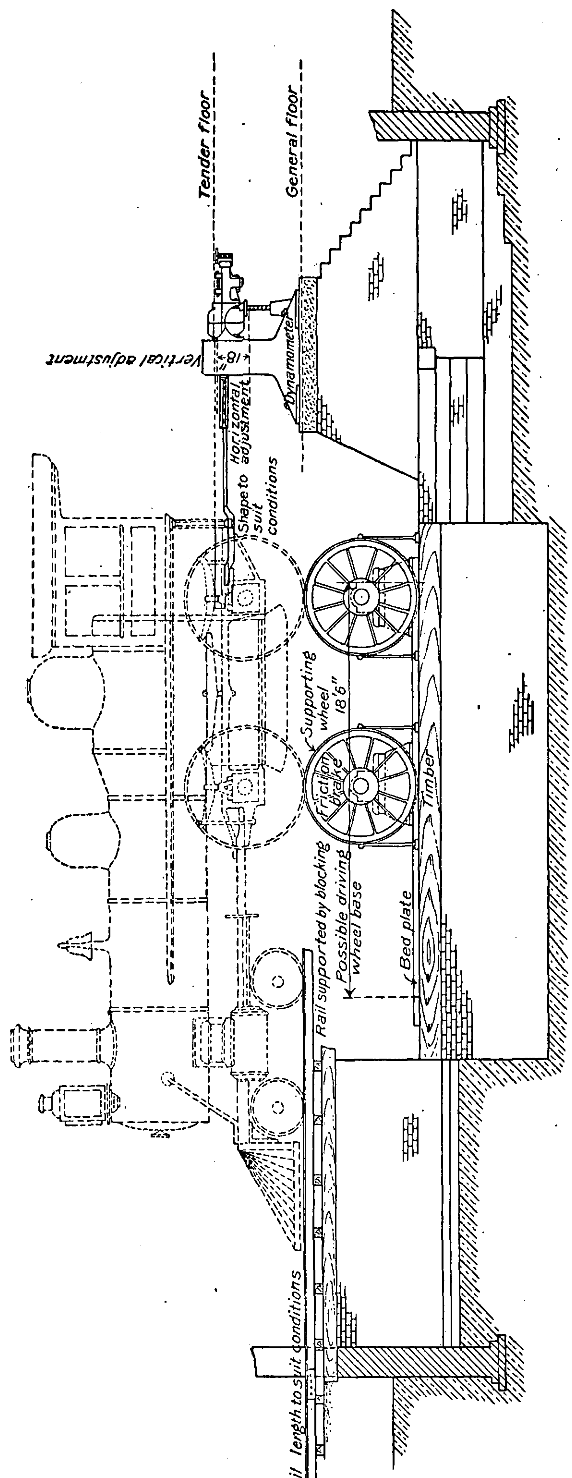

FIGURE 1.—Elevation of the testing plant.

THE TESTING PLANT AND LOCOMOTIVE.

The locomotive laboratory of Purdue University includes a plant for mounting a locomotive for experimental purposes, involving (1) supporting wheels carried by shafts running in fixed bearings to receive the locomotive drivers and to turn with them; (2) brakes mounted on the shafts of the supporting wheels, having sufficient capacity to absorb continuously the maximum power of the locomotive; (3) a traction dynamometer to indicate the horizontal moving force, all as shown by figure 1. Assume an engine thus mounted to be running in forward motion, the supporting wheels, whose faces constitute the track, revolving freely in rolling contact with the drivers. The locomotive as a whole being at rest, the track under it (the tops of the supporting wheels) is forced to move backward. If now the supporting wheels are retarded in their motion, as, for example, by the action of friction brakes, the engine must as a

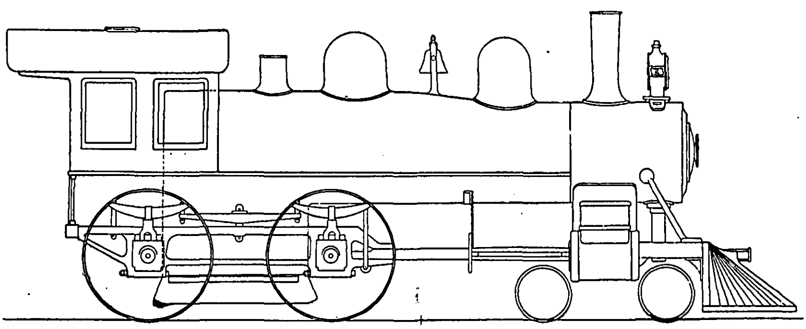

FIGURE 2.—Outline elevation of the test locomotive.

result tend to move off them. If they are stopped, the drivers must stop or slide. Whether the resistance to be overcome in turning the supporting wheels is great or small, the force to overcome it is transmitted from the driver to the supporting wheel and will reappear as a stress on the drawbar, which alone holds the locomotive to its place upon the supporting wheels. The dynamometer constitutes the fixed point with which the drawbar connects and serves to measure the stresses transmitted. It is evident from these considerations that the tractive power of such a locomotive may be increased or diminished by simply varying the resistance against which the supporting wheels turn, and that the readings of the traction dynamometer will always serve as a basis for calculating the work done at the drawbar.

The locomotive used in the experiments is a simple superheating locomotive of the American type, and is shown in general outline by figure 2. Its boiler is designed to operate under pressures as high as 250 pounds. Horizontal seams are butt jointed with welt straps inside and out and are sextuple riveted. The superheater is of the return-tube type and was built and installed in the summer of 1906.

The principal characteristics of the locomotive are as follows:

Type	4-4-0
Total weight ... pounds..	109,000
Weight on four drivers ... do....	61,000
Total wheel base ... feet..	23
Cylinders:	
Diameter ... inches..	16
Stroke ... do....	24
Drivers, diameter outside of tire ... do....	69¼
Boiler:	
Type	Extended wagon top.
Length of fire box ... inches..	72$\frac{1}{16}$
Width of fire box ... do....	34½
Depth of fire box ... do....	79
Number of 2-inch tubes	111
Number of 5-inch tubes	16
Length of tubes ... feet..	11½
Heating surface in fire box ... square feet..	126
Heating surface in tubes, water side ... do....	897
Total water-heating surface, including water side of tubes ... square feet..	1,023
Superheater:	
Type	Cole return tube.
Outside diameter of superheater tubes ... inches..	1¼
Number of loops	32
Average length of tube per loop ... feet..	17.27
Total superheating surface based upon outside surface of tubes ... square feet..	193
Total water and superheating surface, including water side of boiler tubes ... square feet..	1,216

DISCUSSION OF TESTS.

PURPOSE.

The purpose of the tests was to determine the performance of the boiler and superheater of a normal locomotive while developing such rates of power as are common in locomotive service. The process involved a careful study of the various channels through which the heat energy of the fuel is absorbed or dissipated. The purpose of the work is best disclosed by Tables 1 to 13, which give the results of eighteen complete tests.

GENERAL CONDITIONS.

The general conditions under which the several tests were run are set forth in Table 1. The "laboratory designation" given in column 2 consists of three factors, the first of which represents the speed of the locomotive during the test, the second the position of the reverse lever as expressed in terms of the notches forward of the center, and the third the boiler pressure. For example, test 1 (30–5–240) was made at a speed of 30 miles an hour, with the reverse lever in the fifth notch from the center, and under a boiler pressure of 240 pounds. Columns 1 and 2 are repeated in the succeeding tables.

The maximum power of the boiler may result from engine conditions involving a long cut-off and slow speed or a shorter cut-off and higher speed. The engine merely served during the tests to absorb the steam which the boiler generated and to supply, through the action of its exhaust, the draft necessary to stimulate the fire. This being the case, the conditions of speed and cut-off under which the engine of the locomotive was operated during the tests are not important to the present study.

The tests may be grouped into four series, for each of which the boiler pressure was the same. The first four tests were run under a boiler pressure of 240 pounds, the next five under a boiler pressure of 200 pounds, the next three under a boiler pressure of 160 pounds, and the remaining six under a boiler pressure of 120 pounds. The results of each series are presented in the order of the rate of combustion. Thus test 1 is the test of highest power and test 4 the test of lowest power in the 240-pound series.

COAL AND REFUSE.

Data concerning coal and refuse and certain other dependent factors are presented in Tables 2 and 3. Column 11 shows the total weight of coal fired for each test, and column 18 the coal fired per hour, which is a measure of the rate at which the coal was burned. For example, this rate for the first test was 1,975 pounds an hour and for the fourth test 1,210 pounds an hour.

The results represent work done with two grades of coal that will be designated as coal A and coal B. Both are of excellent quality. The greater part of the tests were run with coal A, which, for purposes of discussion, will be regarded as the standard for the tests. Tests which were run with coal B are indicated by a star preceding the number in column 1 of the tables. The chemical characteristics and the calorific value of samples taken from the fuel of each test will be found in detail in the tables, but the following summarized statement will be convenient at this point.

Composition and calorific value of coals A and B.

	Coal A.	Coal B.
Moisture ... per cent..	1.89	3.10
Volatile matter ... do....	31.94	15.23
Fixed carbon ... do....	57.71	72.75
Ash ... do....	8.46	8.92
Heating value per pound of dry coal ... B. t. u..	14,047	14,347
Heating value per pound of combustible ... do....	15,372	15,802

The cinder record, as presented in columns 23 and 24, showing the extent to which fuel passes over the heating surface of the boiler to find lodgment in the front end or to pass out of the top of the stack during each hour of the locomotive's operation, will be of more than ordinary interest to those who have not especially studied the processes which go on within a locomotive fire box.

RATES OF COMBUSTION, DRAFTS, AND SMOKE-BOX TEMPERATURES.

Rates of combustion, draft values, and smoke-box temperatures are set forth in Table 4. These are closely related factors. The rate of combustion, as expressed in terms of coal fired per square foot of grate surface per hour (column 25), is for most tests about 100 pounds. This factor, when compared with the burning of 10 to 12 pounds per foot of grate, which is common practice in stationary furnaces, well illustrates the activity of locomotive processes.

The draft is the regulator which in any boiler furnace determines the rate at which fuel shall be burned. To sustain the high rates of combustion necessary in locomotive service, high drafts are required. The drafts used in these tests are shown in column 31.

Column 32 (temperature of the smoke box) expresses the temperature at which the waste gases from the boiler are discharged. Efficient boiler action demands that the temperature of these gases shall be as low as possible, but under the high rates of combustion at which locomotive boilers are forced, the smoke-box temperatures are necessarily high, ranging in these tests from above 800° to a little less than 600° F., depending on the rate of combustion.

WATER AND STEAM.

The record of water delivered to the boiler, the boiler pressure, and the quality of the steam appear in Table 5. Thermal quantities involved in the computation of other results are given in Table 6, and the equivalent evaporation in Table 7. Column 44 shows the hourly rate at which water was actually delivered to the boiler, and column 48 the equivalent evaporation represented by the output of boiler and superheater. For most of the tests the rate of evaporation exceeded 10,000 pounds per hour, and for a considerable number it was 50 per cent or more in excess of this amount.

EVAPORATION AND HORSEPOWER.

Rates of evaporation and horsepower of boiler are shown in detail by Table 8, column 55 giving the total output of power. This value is the sum of two factors—the output of the boiler (column 53) and that of the superheater (column 54). The figures show that the normal output for the boiler and superheater is about 400 horsepower, the maximum being 482 horsepower.

EVAPORATIVE EFFICIENCY.

The evaporative efficiency is shown by Table 9. In column 56 will be found the equivalent evaporation per pound of coal as fired. The equivalent evaporation per pound of dry coal (column 57) is a usual measure of performance. The results of this column, platted with the rate of evaporation (column 51), are represented by figure 5 (p. 13). By the slope of the lines representing the experimental points for coals A and B in this figure, it will be seen that as the rate of evaporation increases the amount of water which can be evaporated per pound of coal diminishes. These lines may be accepted as fairly representing the performance of the boiler and superheater tested under all rates of power. A study of the data will show that boiler pressure, within the limits employed in the experiments, has very little influence on boiler efficiency. The evaporation per pound of combustible fired and per pound of combustible burned appears in columns 58 and 59, respectively. The significance of these two items grows out of the fact that, as will appear more plainly later, all the coal thrown into a locomotive fire box is not consumed, a considerable proportion of it finding a way of escape before complete combustion has taken place. The efficiency of the boiler is the ratio of the heat absorbed by the water to the heat available in the coal as fired. The efficiency of the boiler and grate is the ratio of the heat absorbed by the water in the boiler to the heat of combustion in the fuel fired. It appears from column 60 that the efficiency of the boiler ranged from 68 to 75 per cent; that is, the boiler and its superheater were successful in transforming these percentages of the heat energy of the fuel burned into heat energy of steam. Column 61 shows that the efficiency of the boiler and superheater, based on coal fired, ranged from 47 to 69 per cent.

CHEMICAL AND CALORIFIC VALUES.

Chemical and calorific values are given in Tables 10 to 12. These factors include the results of analyses of the smoke-box gases (columns 62 to 65); the ratio of air supplied to that required for combustion (column 70); the results of proximate and ultimate analyses of the coal used (columns 71 to 80); the percentage of combustible material found in the cinders caught in the front end, in the cinders and sparks passing out of the stack, and in the fuel dropping through the grate with the ash (columns 81 to 83); and calorific values of the coal used, of front-end and stack cinders collected, and of refuse caught in the ash (columns 84 to 88).

HEAT BALANCES.

Heat balances representing the action of locomotive boilers have justly been regarded as difficult to formulate. In the present tests efforts were made to procure complete data on which such a balance could be based. The preceding discussion has purposely been kept

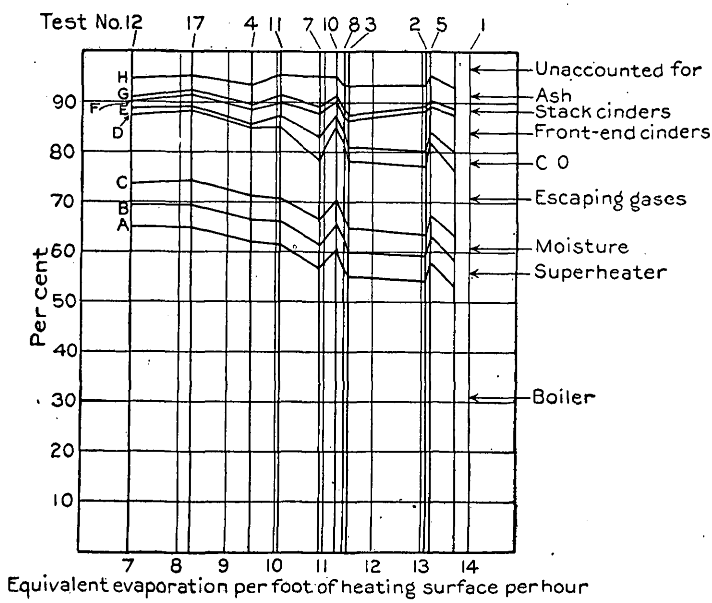

FIGURE 3.—Heat balance of combined boiler and superheater as derived from tests using coal A.

within narrow limits in the belief that the summation of the results of the tests can be most completely set forth in connection with the

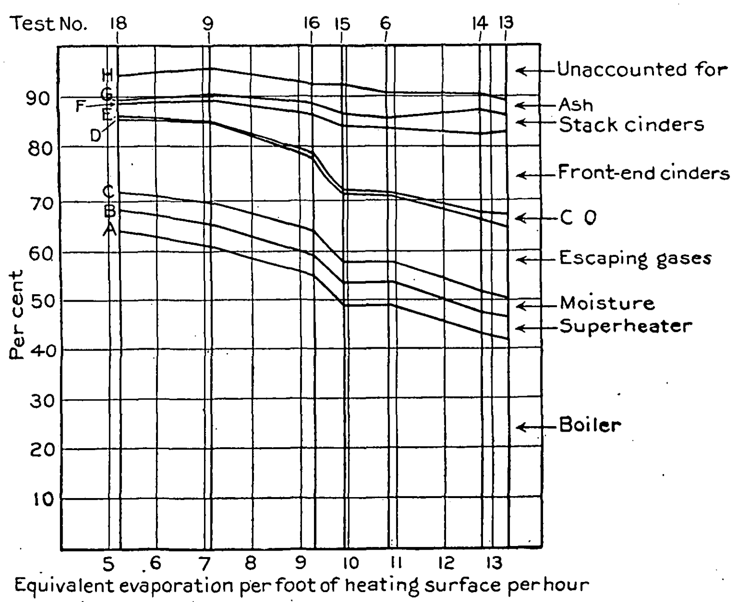

FIGURE 4.—Heat balance of combined boiler and superheater as derived from tests using coal B.

heat balances. The data making up these balances are presented in Table 13, but can be most easily understood by reference to figures 3 and 4, which show the results obtained with coal A and coal B, respectively. It is the purpose of the heat balance, as the term implies, to account for all heat represented by the coal supplied to the fire box, not only the heat which is utilized, but that which is lost, and to point out the various channels through which losses occur. In the diagrams the term "heating surface," as applied to the abscissas, includes the heat-transmitting surface of both boiler and superheater. The ordinates of the diagrams represent the percentage of heat in the fuel supplied. Distances measured on ordinates between the axis and the first broken line, A, represent the percentage of the total heat supplied which is absorbed by the water of the boiler. The line A is, in

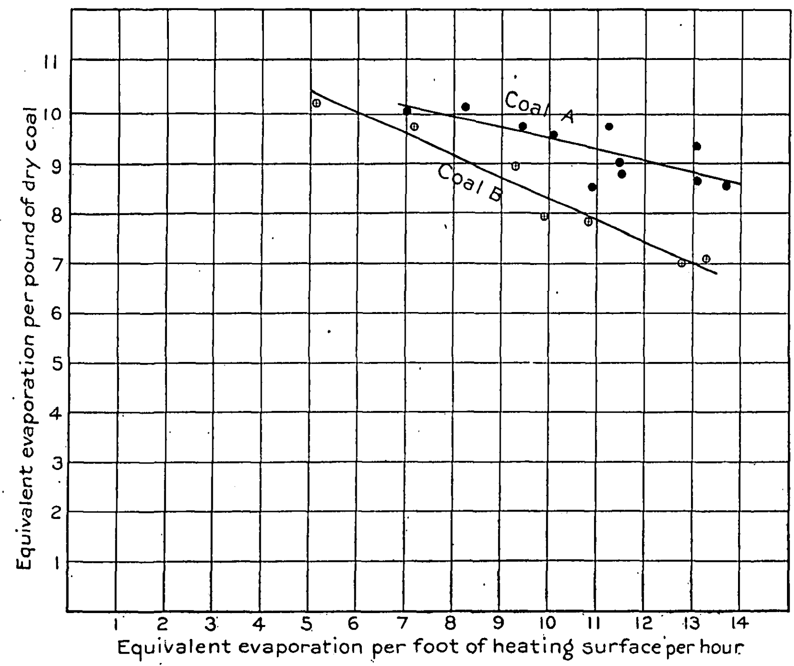

FIGURE 5.—Equivalent evaporation per pound of dry coal under all conditions of pressure.

fact, a definition of the efficiency of the boiler under the varying rates of evaporation represented by the tests. Though based on a different unit, it is, as it ought to be, similar in general form to the lines defining the evaporative efficiency of the boiler in terms of pounds of water water evaporated per pound of coal used (fig. 5). The inclination of all such lines shows the extent to which the efficiency of the boiler suffers as the rate of evaporation is increased. The nature and extent of the losses leading to decreased efficiency are to be found in the areas above the line A. The fact that the points representing different tests through which this line is drawn do not result in a smooth curve is due to irregularities in furnace conditions that were beyond the vigilance of the operator, an explanation which applies equally to other lines of the same diagram. Again, where the points on which the line A is based fail to form a smooth curve, the reason therefor is to be found in the location of the lines above.

The percentage of the total heat which is absorbed by the superheater is measured by distances on ordinates between lines A and B. It is apparent that this quantity is practically constant, whatever may be the power to which the boiler is driven; that is, this superheater is a device of constant efficiency. The normal maximum power of a locomotive may for present purposes be taken as represented by an evaporation of 12 pounds of water per square foot of heating surface per hour. At this rate the superheater, which contains 16 per cent of the total heat-transmitting surface, receives approximately 8 per cent of the total heat absorbed. Distances between the broken line B and the axis represent the efficiency of the combined boiler and superheater, and distances above the line B account for the various heat losses incident to the operation of the furnace, boiler, and superheater.

Losses of heat arising from the presence of accidental and combined moisture in the fuel, of moisture in the atmospheric air admitted to the fire box, and of moisture resulting from the decomposition of hydrogen in the coal are represented by distances measured on ordinates between lines B and C. It is of passing interest to note that the heat thus accounted for is practically equal to that absorbed by the superheater.

Losses of heat in gases discharged from the stack are represented by distances measured on ordinates between lines C and E. The distances between lines D and E represent that portion of these losses which is due to the incomplete burning of the combustible gases. The record shows that the stack loss (C–E), while necessarily large, increases with increased rates of combustion far less rapidly than has been commonly supposed. In other words, the loss in evaporative efficiency with increase of power (line B, figs. 3 and 4) occurs only to a very slight degree through increase in the amount of heat carried away with the smoke-box gases. That portion of this loss which is chargeable to incomplete combustion (CO) is small under low rates of combustion (column 104, Table 13), but may increase to amounts of some significance under the influence of very high rates of combustion, as will be seen from the record of coal A.

Losses of heat through the discharge from the fire box of unconsumed fuel are represented by distances measured on ordinates between lines E and H. The loss thus defined is separated into three parts—the heat loss by partly consumed fuel in the form of cinders collecting in the front end (E–F), the heat loss by partly consumed fuel in the form of cinders or sparks thrown out of the stack (F–G), and the heat lost by partly burned fuel dropping through the grate into the ash pan (G–H). The first two of these losses increase with the rate of power developed. They are, in fact, the chief cause of the decrease in the evaporative efficiency of a locomotive boiler with increased rates of power. This is well shown by a comparison of the two diagrams. In the tests with coal B (fig. 4) the cinder loss is comparatively heavy and the boiler efficiency diminishes in a marked degree under high rates of power, while tests under similar conditions with coal A (fig. 3), involving less loss

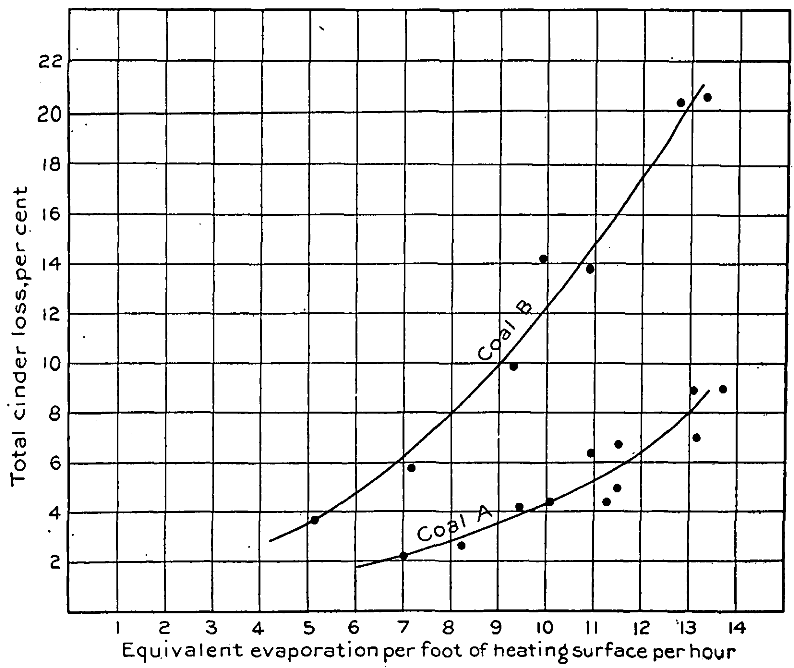

FIGURE 6.—Stack and front-end cinder loss, per cent of coal fired.

by cinders, show an efficiency of the boiler under high rates of power which is much better sustained.

The cinder loss expressed as a percentage of the total weight of coal fired is shown by figure 6, and the heating value of the material thus accounted for by figure 7. It will be seen that cinders from coal B have more than double the weight and that each pound has nearly double the heating value of those from coal A, a result doubtless due in part to the large percentage of fine material in coal B and to the absence of such material in coal A. The stack cinders from both coals have a higher calorific value than those caught in the smoke box. Under the practice of the laboratory, the coal was not wetted previous to being fired. Concerning the general significance of the cinder loss as recorded here, it should be remembered that the fuel used in all the tests was of high quality. Lighter and more friable coals are as a rule more prolific producers of stack and front-end cinders.

Radiation, leakage, and all losses not previously accounted for are represented by distance ordinates between line H and the 100 per cent line of the diagrams. The radiation losses are probably not much in excess of 1 per cent, so that the remainder of this loss—from 3 to 8 per cent of the total heat available—represents leakage of steam or water, or inaccuracy in determining the value of one or more of the quantities already discussed.

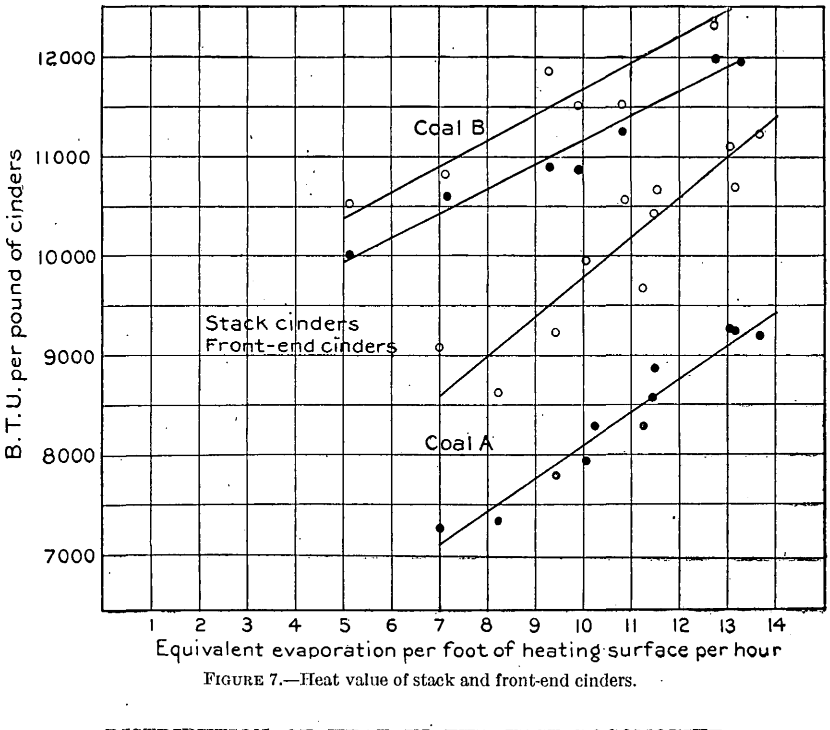

FIGURE 7.—Heat value of stack and front-end cinders.

DISTRIBUTION OF HEAT IN THE TEST LOCOMOTIVE.

It is sometimes convenient to have an elaborate statement of fact summarized into a few representative figures, the relation between which may be easily apprehended. Such a summary may be framed for the present case by assuming that the normal maximum power of the locomotive tested is that which involves a rate of evaporation of 12 pounds of water per square foot of heating surface per hour, and by averaging from the diagrams (figs. 3 and 4) the values of the various factors entering into the heat balance for this rate of power. The result may be accepted as showing in general terms the action of such a locomotive as that tested when fired with a good Pennsylvania or West Virginia coal. It is as follows:

Averaged heat balance for test locomotive.

[Percentages of total heat available.]

Absorbed by the water in the boiler	52	
Absorbed by the steam in the superheater	5	
Absorbed by steam in the boiler and superheater		57
Lost in vaporizing moisture in the coal		5
Lost through the discharge of CO		1
Lost through the high temperature of escaping gases, the products of combustion		14
Lost through unconsumed fuel in the form of front-end cinders		3
Lost through unconsumed fuel in the form of cinders or sparks passed out of the stack		9
Lost through unconsumed fuel in the ash		4
Lost through radiation, leakage of steam and water, etc		7
		100

GENERAL CONCLUSIONS.

There were in 1906, on the railroads of the United States, 51,000 locomotives. It is estimated that these locomotives consumed during the year not less than 90,000,000 tons of fuel, which is more than one-fifth of all the coal, anthracite and bituminous, mined in the country during the same period. The coal thus used cost the railroads $170,500,000.[a] That wastes occur in the use of fuel in locomotive service is a matter which is well understood by all who have given serious attention to the subject, and the tests whose results are here presented show some of the channels through which these wastes occur. These results are perhaps more favorable to economy than those attained by the average locomotive of the country, as the coal used in the tests was of superior quality, the type of locomotive employed was better than the average, and the standards observed in the maintenance of the locomotive were more exacting. But the effect on boiler performance arising from these differences is not great and, so far as they apply, the results may be accepted as fairly representative of the general locomotive practice of the country. They apply, however, only when the locomotive is running under constant conditions of operation. They do not include the incidental expenditures of fuel which are involved in the starting of fires, in the switching of engines, and in the maintenance of steam pressure while the locomotive is standing, nor do they include a measure of the heat losses occasioned by the discharge of steam through the safety valve. Observations on several representative railroads have indicated that not less than 20 per cent of the total fuel supplied to locomotives performs no function in moving trains forward. It disappears in the incidental ways just mentioned or remains in the fire box at the end of the run. The fuel consump-

[a] Rept. Interstate Commerce Commission, 1906.

tion accounted for by the heat balance on page 17 is, therefore, but 80 per cent of the total consumed by the average locomotive in service. Applied on this basis to the total consumption of coal for the country, the heat balance may be converted into terms of tons of coal as follows:

Summary of results obtained from fuel burned in locomotives.

	Tons.
1. Consumed in starting fires, in moving the locomotive to its train, in backing trains into or out of sidings, in making good safety-valve and leakage losses, and in keeping the locomotive hot while standing (estimated)	18,000,000
2. Utilized, that is, represented by heat transmitted to water to be vaporized	41,040,000
3. Required to evaporate moisture contained by the coal	3,600,000
4. Lost through incomplete combustion of gases	720,000
5. Lost through heat of gases discharged from stack	10,080,000
6. Lost through cinders and sparks	8,640,000
7. Lost through unconsumed fuel in the ash	2,880,000
8. Lost through radiation, leakage of steam and water, etc	5,040,000
	90,000,000

These amounts, together with the corresponding money value, are set forth graphically by figure 8. It is apparent from this exhibit that the utilization of fuel in locomotive service is a problem of large proportions, and that if even a small saving could be made by all or a large proportion of the locomotives of the country it would constitute an important factor in the conservation of the nation's fuel supply. On examining the diagram with reference to such a possibility the following facts are to be noted: The amount of fuel consumed in preparing locomotives for their trains, etc. (item 1), is dependent only to a very slight extent on the characteristics of the locomotive, being in large measure controlled by operating conditions, by the length of divisions, and by the promptness with which trains are moved. Under ideal conditions of operation much of the fuel thus used could be saved, and it is reasonable to expect that the normal process of evolution in railroad practice will tend gradually to bring about some reduction in the consumption thus accounted for.

The fuel required to evaporate moisture in the fuel (item 3) and that which is lost through incomplete combustion (item 4) are already small and are not likely to be materially reduced.

The loss represented by the heat of gases discharged from the stack (item 5) offers an attractive field to those who would improve the efficiency of the locomotive boiler. So long as the temperature of the discharged gases is as high as 800° F. or more there is a possibility of utilizing some of this heat by the application of smoke-box superheaters, reheaters, or feed-water heaters, though thus far the development of acceptable devices for the accomplishment of this end has made little progress.

The fuel loss in the form of cinders collecting in the front end and passing out of the stack (item 6) is very large and may readily be reduced. The results here recorded were obtained with a boiler having a narrow fire box; the losses in the form of cinders would probably be smaller with a wide fire box. A sure road to improvement in this direction lies in the direction of increased grate area.

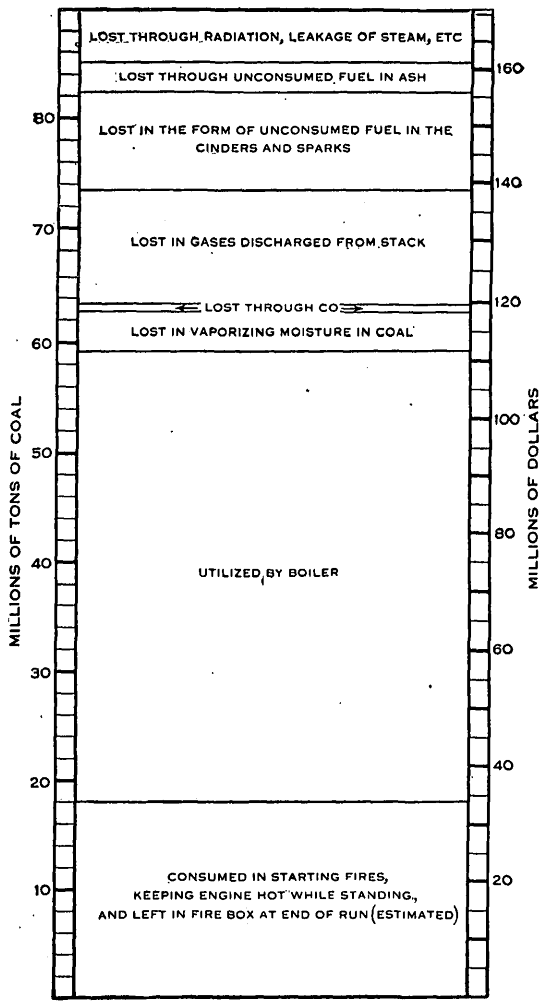

FIGURE 8.—Utilization and accompanying wastes of one year's coal supply for locomotive service in the United States.

Opportunities for incidental savings are to be found in improved flame ways such as are to be procured by the application of brick arches or other devices. Such losses may also be reduced by greater care in the selection of fuel and in the preparation of the fuel for the service in which it is used. It is not unreasonable to expect that the entire loss covered by this item will in time be overcome.

The fuel which is lost by dropping through grates and mingling with the ash (item 7) is a factor that depends on the grate design, on the characteristics of the fuel, but chiefly on the degree of care exercised in managing the fire. More skillful firing would save much of the fuel thus accounted for.

The radiation and leakage losses (item 8) may in part be apparent rather than real, owing to possible inaccuracies in the process of developing the heat balance. On the assumption that the values are correct as stated, however, it is not likely that under ordinary conditions of service they can be materially reduced.

Locomotive boilers are handicapped by the requirement that the boiler itself and all its appurtenances must come within rigidly defined limits of space, and by the fact that they are forced to work at very high rates of power. Notwithstanding this handicap, it is apparent that the zone of practicable improvement which lies between present-day results and those which may reasonably be regarded as obtainable is not so wide as to make future progress rapid or easy. Material improvement is less likely to come in large measures as the result of revolutionary changes than as a series of relatively small savings in the several items to which attention has been called.

TABLES.

In the tests summarized in the following tables four different boiler pressures were employed—240, 200, 160, and 120 pounds. Throughout each test the engine was operated under constant conditions, the speed and power developed being changed from test to test in accord with a fixed programme. The engine conditions were under observation, but, as has been stated, a discussion of these conditions and of the results derived from them does not come within the scope of this paper. It will be apparent to those who study the data, however, that the running conditions for tests under each of the four pressures were so chosen as to give boiler results covering a wide range of power.

TABLE 1.—*General conditions.*

No. of test.	Laboratory designation.	Date (1907).	Duration in minutes.	Duration in hours.	Temperature (°F.).				Atmospheric pressure (pounds per square inch).
					Laboratory.	Wet-bulb thermometer.	Dry-bulb thermometer.	Feed water.	
1	2	3	4	5	6	7	8	9	10
1	30-5-240	June 6	65	1.08	88.1	73.0	83.6	62.0	14.44
2	40-4-240	May 20	100	1.67	81.5	53.3	61.0	59.6	14.55
3	30-4-240	June 7	120	2.00	81.8	74.2	77.8	60.2	14.31
4	30-2-240	May 27	120	2.00	77.8	58.4	66.2	61.8	14.50
5	40-6-200	Apr. 22	150	2.50	84.5	66.7	78.1	55.3	14.42
*6	50-4-200	Apr. 12	50	.83	75.2	61.0	66.3	59.1	14.31
7	40-4-200	June 8	120	2.00	86.7	75.2	77.5	59.9	14.46
8	30-6-200	Apr. 19	150	2.50	79.3	59.1	65.6	57.2	14.45
*9	30-2-200	Mar. 18	150	2.50	72.9	64.7	73.7	55.1	14.55
10	30-8-160	Apr. 29	150	2.50	73.9	53.6	55.7	56.9	14.34
11	40-6-160	May 3	150	2.50	72.9	56.4	61.0	57.2	14.43
12	30-4-160	June 5	150	2.50	82.4	66.2	71.4	62.7	14.37
*13	40-12-120	Feb. 22	90	1.50	75.5	64.8	72.0	58.0	14.72
*14	30-14-120	Feb. 18	120	2.00	78.4	55.0	61.0	58.0	14.20
*15	30-10-120	Feb. 15	120	2.00	68.4	57.0	66.0	54.1	14.40
*16	40-8-120	Mar. 4	150	2.50	73.0	57.7	66.4	59.0	14.35
17	30-8-120	May 31	150	2.50	80.8	64.9	67.6	62.9	14.31
*18	40-4-120	Mar. 15	150	2.50	76.9	61.9	70.6	55.5	14.58

TABLE 2.—*Total coal and refuse.*

No. of test.	Laboratory designation.	Duration (hours).	Total weight (pounds) of— Coal as fired.	Dry coal fired.	Combustible fired.	Combustible consumed.	Refuse.	Front-end cinders.	Stack cinders.
1	2	5	11	12	13	14	15	16	17
1	30-5-240	1.08	2,139	2,107	1,929	1,656	157	212	29.5
2	40-4-240	1.67	3,106	3,057	2,800	2,428	210	308	44.3
3	30-4-240	2.00	3,241	3,190	2,925	2,530	360	222	45.0
4	30-2-240	2.00	2,419	2,353	2,173	1,979	206	99	57.3
5	40-6-200	2.50	4,374	4,294	3,934	3,470	324	338	73.5
*6	50-4-200	.83	1,436	1,405	1,250	989	169	293	31.6
7	40-4-200	2.00	3,157	3,099	2,741	2,385	381	195	56.8
8	30-6-200	2.50	3,918	3,859	3,529	3,153	415	211	50.8
*9	30-2-200	2.50	2,324	2,239	2,015	1,785	256	127	45.3
10	30-8-160	2.50	3,574	3,515	3,239	2,962	269	195	43.8
11	40-6-160	2.50	3,281	3,208	2,909	2,652	256	135	74.8
12	30-4-160	2.50	2,163	2,121	1,950	1,826	195	38	40.7
*13	40-12-120	1.50	3,518	3,415	3,164	2,353	231	664	157.5
*14	30-14-120	2.00	4,609	4,449	4,025	3,005	294	774	274.2
*15	30-10-120	2.00	3,119	3,030	2,742	2,135	327	454	82.2
*16	40-8-120	2.50	3,248	3,156	2,890	2,444	254	300	84.8
17	30-8-120	2.50	2,527	2,469	2,263	2,114	190	83	40.5
*18	40-4-120	2.50	1,583	1,523	1,392	1,259	205	53	24.0

TABLE 3.—*Coal and refuse per hour.*

No. of test.	Laboratory designation.	Duration (hours).	Weight per hour (pounds) of— Coal as fired.	Dry coal fired.	Combustible fired.	Combustible consumed.	Refuse.	Front-end cinders.	Stack cinders.
1	2	5	18	19	20	21	22	23	24
1	30-5-240	1.08	1,975	1,944	1,780	1,528	144	196.0	27.3
2	40-4-240	1.67	1,863	1,834	1,680	1,457	126	185.0	27.0
3	30-4-240	2.00	1,621	1,595	1,463	1,265	180	111.0	22.5
4	30-2-240	2.00	1,210	1,177	1,087	989	103	49.7	28.6
5	40-6-200	2.50	1,750	1,718	1,574	1,388	130	135.1	29.4
*6	50-4-200	.83	1,722	1,685	1,498	1,186	203	244.5	37.8
7	40-4-200	2.00	1,578	1,549	1,370	1,193	195	97.3	28.4
8	30-6-200	2.50	1,567	1,544	1,412	1,261	166	84.6	20.3
*9	30-2-200	2.50	930	896	806	714	102	50.9	18.1
10	30-8-160	2.50	1,430	1,406	1,296	1,185	108	78.2	17.5
11	40-6-160	2.50	1,312	1,282	1,163	1,060	102	54.1	29.9
12	30-4-160	2.50	866	849	780	730	78	15.3	16.3
*13	40-12-120	1.50	2,345	2,277	2,109	1,569	154	443.0	105.0
*14	30-14-120	2.00	2,304	2,224	2,012	1,502	147	387.0	137.1
*15	30-10-120	2.00	1,559	1,515	1,371	1,067	163	227.0	41.1
*16	40-8-120	2.50	1,299	1,262	1,156	978	102	120.0	34.0
17	30-8-120	2.50	1,011	988	905	846	76	33.3	16.2
*18	40-4-120	2.50	633	610	557	504	82	21.0	9.6

TABLE 4.—*Combustion, draft, and smoke-box temperature.*

No. of test.	Laboratory designation.	Duration (hours).	Dry coal fired per square foot of grate surface per hour.	Combustible fired per square foot of grate surface per hour.	Combustible consumed per square foot of grate surface per hour.	Dry coal fired per square foot of heating surface per hour.	Combustible fired per square foot of heating surface per hour.	Combustible consumed per square foot of heating surface per hour.	Draft in smoke box (inches of water).	Temperature in smoke box (°F.).
1	2	5	25	26	27	28	29	30	31	32
1	30-5-240	1.08	114.4	104.6	89.9	1.599	1.463	1.257	5.18	815.4
2	40-4-240	1.67	107.9	98.8	85.7	1.508	1.381	1.198	5.15	798.1
3	30-4-240	2.00	93.8	86.0	74.4	1.312	1.203	1.040	4.28	774.5
4	30-2-240	2.00	69.2	63.9	58.2	.968	.894	.814	3.09	725.9
5	40-6-200	2.50	101.1	92.6	81.6	1.413	1.294	1.141	5.60	824.2
*6	50-4-200	.83	99.2	88.1	69.7	1.386	1.232	.975	3.85	778.1
7	40-4-200	2.00	91.1	80.6	70.1	1.274	1.127	.981	3.69	747.1
8	30-6-200	2.50	90.8	83.1	74.2	1.270	1.161	1.037	4.37	787.0
*9	30-2-200	2.50	52.7	47.4	42.0	.737	.662	.587	2.04	661.0
10	30-8-160	2.50	82.7	76.2	69.7	1.156	1.066	.975	4.56	764.4
11	40-6-160	2.50	75.4	68.4	62.4	1.054	.956	.872	3.50	722.1
12	30-4-160	2.50	49.9	45.9	42.9	.698	.642	.601	2.25	669.6
*13	40-12-120	1.50	133.9	124.1	92.3	1.872	1.735	1.290	5.74	781.9
*14	30-14-120	2.00	130.8	118.4	88.4	1.829	1.655	1.235	5.65	771.6
*15	30-10-120	2.00	89.1	80.6	62.8	1.246	1.127	.878	3.22	701.6
*16	40-8-120	2.50	74.2	68.0	57.5	1.038	.950	.804	3.10	691.5
17	30-8-120	2.50	58.1	53.2	49.7	.812	.744	.694	3.00	676.0
*18	40-4-120	2.50	35.8	32.7	29.6	.501	.458	.414	1.25	579.1

TABLE 5.—*Water and steam.*

No. of test.	Laboratory designation.	Duration (hours).	Total water delivered to boiler.	Steam pressure by gage (pounds).	Steam temperature by thermometer (° F.).	Steam temperature corresponding to pressure (° F.).	Superheat (° F.).
1	2	5	33	34	35	36	37
1	30-5-240	1.08	13,752	236.6	552.6	401.3	151.3
2	40-4-240	1.67	20,150	239.7	556.4	402.5	153.9
3	30-4-240	2.00	21,316	238.9	554.6	402.1	152.5
4	30-2-240	2.00	17,600	241.0	540.7	402.9	137.8
5	40-6-200	2.50	30,205	200.0	565.2	387.7	177.5
*6	50-4-200	.83	8,372	201.1	547.4	388.0	159.4
7	40-4-200	2.00	20,266	199.4	540.0	387.4	152.6
8	30-6-200	2.50	26,448	200.2	556.8	387.7	169.1
*9	30-2-200	2.50	16,754	200.1	519.3	387.7	131.6
10	30-8-160	2.50	26,123	160.1	543.3	370.4	172.9
11	40-6-160	2.50	23,432	160.0	535.3	370.4	164.9
12	30-4-160	2.50	16,585	160.2	512.4	370.5	141.9
*13	40-12-120	1.50	18,483	120.6	540.5	350.2	190.3
*14	30-14-120	2.00	23,664	120.2	541.1	349.7	191.4
*15	30-10-120	2.00	18,415	119.9	524.5	349.6	174.9
*16	40-8-120	2.50	21,755	120.2	520.4	349.8	170.6
17	30-8-120	2.50	19,475	120.2	505.9	349.7	156.2
*18	40-4-120	2.50	12,231	120.1	470.6	349.8	120.8

TABLE 6.—*Thermal units.*

No. of test.	Laboratory designation.	British thermal units absorbed— Per pound of steam. By boiler.	By superheater.	By boiler and superheater.	Per minute. By boiler.	By superheater.	By boiler and superheater.
1	2	38	39	40	41	42	43
1	30-5-240	1,166.0	100.6	1,266.6	246,697	21,283	267,980
2	40-4-240	1,167.9	103.0	1,270.9	235,336	20,752	256,088
3	30-4-240	1,168.0	101.3	1,269.3	207,477	17,996	225,473
4	30-2-240	1,165.8	93.2	1,259.0	170,992	13,665	184,657
5	40-6-200	1,170.8	110.7	1,281.5	235,772	22,273	258,045
*6	50-4-200	1,165.5	101.6	1,267.1	195,152	17,012	212,164
7	40-4-200	1,165.3	96.7	1,262.0	196,787	16,339	213,126
8	30-6-200	1,168.1	106.5	1,274.6	205,963	18,775	224,738
*9	30-2-200	1,169.4	85.2	1,254.6	130,610	9,516	140,126
10	30-8-160	1,166.5	100.2	1,266.7	203,141	17,455	220,596
11	40-6-160	1,165.3	96.6	1,261.9	182,032	15,091	197,123
12	30-4-160	1,159.8	83.7	1,243.5	128,243	9,257	137,500
*13	40-12-120	1,157.4	109.9	1,267.3	237,691	22,564	260,255
*14	30-14-120	1,158.1	109.6	1,267.7	228,381	21,615	249,996
*15	30-10-120	1,160.3	102.2	1,262.5	178,053	15,694	193,747
*16	40-8-120	1,155.9	99.0	1,254.9	167,637	14,363	182,000
17	30-8-120	1,152.4	91.1	1,243.5	149,617	11,829	161,446
*18	40-4-120	1,159.8	71.6	1,231.4	94,572	5,842	100,414

TABLE 7.—*Equivalent evaporation.*

No. of test.	Laboratory designation.	Duration (hours).	Water delivered to boiler per hour (pounds).	Quality of steam in boiler.	Superheat in steam delivered (°F.).	Equivalent evaporation per hour (pounds). By boiler.	By superheater.	By boiler and superheater.
1	2	5	44	45	37	46	47	48
1	30-5-240	1.08	12,698	0.990	151.3	15,326	1,322	16,648
2	40-4-240	1.67	12,090	.989	153.9	14,620	1,289	15,909
3	30-4-240	2.00	10,658	.990	152.5	12,889	1,118	14,007
4	30-2-240	2.00	8,800	.989	137.8	10,623	849	11,472
5	40-6-200	2.50	12,082	.993	177.5	14,647	1,384	16,031
*6	50-4-200	.83	10,038	.991	159.4	12,114	1,056	13,170
7	40-4-200	2.00	10,232	.992	152.6	12,225	1,015	13,240
8	30-6-200	2.50	10,579	.992	169.1	12,795	1,166	13,961
*9	30-2-200	2.50	6,702	.991	131.6	8,114	591	8,705
10	30-8-160	2.50	10,449	.996	172.9	12,620	1,084	13,704
11	40-6-160	2.50	9,373	.995	164.9	11,309	938	12,247
12	30-4-160	2.50	6,634	.995	141.9	7,967	575	8,542
*13	40-12-120	1.50	12,322	.994	190.3	14,766	1,402	16,168
*14	30-14-120	2.00	11,832	.995	191.4	14,188	1,343	15,531
*15	30-10-120	2.00	9,208	.993	174.9	11,061	975	12,036
*16	40-8-120	2.50	8,702	.994	170.6	10,414	892	11,306
17	30-8-120	2.50	7,790	.994	156.2	9,295	735	10,030
*18	40-4-120	2.50	4,892	.994	120.8	5,875	363	6,238

TABLE 8.—*Rate of evaporation and horsepower.*

No. of test.	Laboratory designation.	Equivalent evaporation per hour (pounds). Per square foot of boiler heating surface.	Per square foot of superheating surface.	Per square foot of total heating surface.	Ratio (column 50÷column 49).	Horsepower developed per hour. By boiler.	By superheater.	By boiler and superheater.
1	2	49	50	51	52	53	54	55
1	30-5-240	14.98	6.85	13.69	0.457	444.2	38.3	482.5
2	40-4-240	14.29	6.67	13.08	.467	423.8	37.4	461.2
3	30-4-240	12.59	5.79	11.51	.460	373.6	32.4	406.0
4	30-2-240	10.39	4.40	9.43	.423	307.9	24.6	332.5
5	40-6-200	14.32	7.18	13.18	.501	424.6	40.1	464.7
*6	50-4-200	11.84	5.47	10.82	.462	351.1	30.6	381.7
7	40-4-200	11.95	5.26	10.89	.440	354.3	29.4	383.7
8	30-6-200	12.51	6.04	11.47	.483	370.9	33.8	404.7
*9	30-2-200	7.92	3.06	7.16	.386	235.2	17.1	252.3
10	30-8-160	12.33	5.61	11.26	.455	365.8	31.4	397.2
11	40-6-160	11.05	4.86	10.07	.440	327.8	27.2	355.0
12	30-4-160	7.79	2.98	7.02	.382	230.9	16.7	247.6
*13	40-12-120	14.43	7.26	13.30	.503	428.0	40.6	468.6
*14	30-14-120	13.87	6.96	12.77	.502	411.2	38.9	450.1
*15	30-10-120	10.81	5.05	9.90	.467	320.6	28.3	348.9
*16	40-8-120	10.18	4.62	9.30	.454	301.8	25.9	327.7
17	30-8-120	9.09	3.81	8.25	.419	269.4	21.3	290.7
*18	40-4-120	5.74	1.88	5.12	.328	170.3	10.5	180.8

TABLE 9.—*Economy and efficiency.*

No. of test.	Laboratory designation.	Duration (hours).	Equivalent evaporation per hour (pounds). Per pound of coal as fired.	Per pound of dry coal fired.	Per pound of combustible fired.	Per pound of combustible consumed.	Efficiency of boiler (per cent).	Efficiency of boiler and grate (per cent).
1	2	5	56	57	58	59	60	61
1	30-5-240	1.08	8.43	8.56	9.36	10.89	68.3	58.7
2	40-4-240	1.67	8.54	8.67	9.46	10.92	68.4	59.3
3	30-4-240	2.00	8.65	8.79	9.58	11.07	69.4	60.1
4	30-2-240	2.00	9.48	9.75	10.55	11.59	72.9	66.4
5	40-6-200	2.50	9.16	9.34	10.18	11.55	71.7	63.2
*6	50-4-200	.83	7.65	7.82	8.79	11.11	68.2	53.9
7	40-4-200	2.00	8.39	8.55	9.66	11.10	70.5	61.4
8	30-6-200	2.50	8.91	9.04	9.89	11.06	69.7	62.3
*9	30-2-200	2.50	9.36	9.72	10.80	12.19	74.1	65.7
10	30-8-160	2.50	9.59	9.75	10.57	11.57	72.4	66.2
11	40-6-160	2.50	9.34	9.55	10.53	11.55	72.6	66.2
12	30-4-160	2.50	9.87	10.06	10.95	11.70	73.8	69.0
*13	40-12-120	1.50	6.89	7.10	7.67	10.30	62.7	46.7
*14	30-14-120	2.00	6.74	6.98	7.72	10.33	63.5	47.4
*15	30-10-120	2.00	7.72	7.95	8.78	11.27	68.9	53.6
*16	40-8-120	2.50	8.70	8.96	9.78	11.56	70.9	60.0
17	30-8-120	2.50	9.92	10.16	11.08	11.87	74.7	69.7
*18	40-4-120	2.50	9.85	10.23	11.20	12.38	75.3	68.1

TABLE 10.—*Dry-gas analyses and air supply.*

No. of test.	Laboratory designation.	Gas analyses.				Weight (pounds) of—				Ratio of air supplied to theoretical requirement.
		CO_2.	O.	CO.	N.	Dry gas per pound of carbon burned.	Dry gas per pound of combustible fired.	Air per pound of carbon burned.	Air per pound of combustible fired.	
1	2	62	63	64	65	66	67	68	69	70
1	30-5-240	14.63	2.98	1.06	81.33	16.18	11.31	15.71	10.98	1.16
2	40-4-240	13.95	3.81	.99	81.25	16.95	11.96	16.48	11.63	1.22
3	30-4-240	14.11	4.32	.77	80.80	17.04	12.32	16.45	11.89	1.25
4	30-2-240	14.27	4.05	.12	81.55	17.63	13.41	17.17	13.06	1.23
5	40-6-200	13.90	3.87	.40	81.83	17.70	13.09	17.54	12.98	1.22
*6	50-4-200	13.59	5.16	.10	81.15	18.49	12.64	17.96	12.28	1.32
7	40-4-200	14.63	3.01	1.39	80.97	15.85	11.36	15.32	10.98	1.16
8	30-6-200	13.64	4.72	.27	81.37	18.20	13.52	17.73	13.17	1.28
*9	30-2-200	11.70	7.40	.01	80.90	21.47	16.95	20.94	16.53	1.53
10	30-8-160	13.48	5.14	.31	81.07	18.35	14.13	17.82	13.73	1.32
11	40-6-160	12.85	5.81	.35	80.99	19.12	14.58	18.59	14.18	1.37
12	30-4-160	12.47	6.11	.29	81.13	19.75	15.32	19.27	14.94	1.40
*13	40-12-120	12.05	6.34	.27	81.33	20.41	13.08	20.00	12.81	1.42
*14	30-14-120	11.82	6.77	.16	81.25	21.01	13.66	20.58	13.37	1.46
*15	30-10-120	11.57	7.15	.15	81.12	21.43	14.33	20.97	14.02	1.50
*16	40-8-120	11.99	7.43	.04	80.51	20.92	15.45	20.27	14.97	1.54
17	30-8-120	12.20	6.15	.19	81.46	20.31	15.67	19.92	15.37	1.40
*18	40-4-120	10.81	8.82	.11	80.26	22.96	17.88	22.26	17.35	1.71

TABLE 11.—*Coal analyses.*

No. of test.	Laboratory designation.	Proximate analysis.				Ultimate analysis of dry coal.					
		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.
1	2	71	72	73	74	75	76	77	78	79	80
1	30-5-240	1.54	31.67	58.53	8.26	77.02	4.66	7.24	1.52	1.17	8.39
2	40-4-240	1.56	31.16	59.01	8.29	76.83	4.62	7.44	1.57	1.14	8.40
3	30-4-240	1.63	31.74	58.49	8.14	78.70	4.73	5.67	1.51	1.11	8.28
4	30-2-240	2.72	32.19	57.63	7.46	78.45	5.25	6.10	1.50	1.03	7.67
5	40-6-200	1.83	32.85	57.09	8.22	78.60	4.76	5.64	1.52	1.10	8.38
*6	50-4-200	2.16	15.88	71.18	10.77	79.45	3.92	3.69	1.03	.94	11.00
7	40-4-200	1.84	30.70	56.13	11.33	74.91	4.89	6.02	1.45	1.19	11.54
8	30-6-200	1.51	32.78	57.27	8.44	77.76	4.71	6.48	1.50	1.08	8.57
*9	30-2-200	3.68	15.56	71.10	9.66	81.30	4.09	2.52	1.04	1.04	10.00
10	30-8-160	1.65	32.94	57.70	7.71	78.90	4.88	5.68	1.54	1.16	7.84
11	40-6-160	2.24	32.33	56.28	9.15	77.09	4.82	6.12	1.52	1.09	9.36
12	30-4-160	2.01	31.39	58.67	7.93	77.14	4.52	7.43	1.55	1.27	8.09
*13	40-12-120	2.93	15.27	74.66	7.14	83.14	4.16	3.52	1.08	.75	7.35
*14	30-14-120	3.44	14.55	72.80	9.21	81.72	4.17	2.67	1.00	.91	9.54
*15	30-10-120	2.85	14.70	73.26	9.19	80.54	4.10	3.90	1.05	.95	9.46
*16	40-8-120	2.82	15.11	73.86	8.21	81.74	4.11	3.83	1.02	.84	8.44
17	30-8-120	2.30	31.53	58.03	8.14	76.65	4.61	7.58	1.57	1.26	8.33
*18	40-4-120	3.79	15.55	72.39	8.27	79.93	3.87	5.57	1.05	.98	8.60

TABLE 12.—*Chemical analyses and calorific values.*

No. of test.	Laboratory designation.	Per cent of combustible— In front-end cinders.	In stack cinders.	In refuse from ash pan.	Calorific value (British thermal units). Per pound of dry coal.	Per pound of combustible.	Per pound of stack cinders.	Per pound of front-end cinders.	Per pound of refuse from ash pan.
1	2	81	82	83	84	85	86	87	88
1	30-5-240	79.83	66.08	53.76	14,097	15,388	11,239	9,211	7,849
2	40-4-240	78.03	63.89	49.03	14,121	15,416	11,113	9,275	7,160
3	30-4-240	81.98	61.86	51.94	14,124	15,398	10,673	8,881	7,583
4	30-2-240	66.10	60.61	45.88	14,174	15,352	9,245	7,812	6,698
5	40-6-200	76.30	65.52	48.85	14,262	15,566	10,699	9,265	7,132
*6	50-4-200	80.63	80.24	41.81	14,009	15,744	11,534	11,261	6,103
7	40-4-200	73.61	70.33	44.14	13,457	15,214	10,571	9,949	6,444
8	30-6-200	73.84	60.12	45.73	14,018	15,332	10,442	8,599	6,677
*9	30-2-200	74.14	74.79	39.85	14,283	15,875	10,832	10,615	5,820
10	30-8-160	64.82	57.02	46.94	14,216	15,425	9,293	8,305	6,853
11	40-6-160	69.97	56.38	47.19	13,914	15,351	9,959	7,960	6,890
12	30-4-160	64.87	57.47	39.25	14,062	15,300	9,090	7,272	5,730
*13	40-12-120	87.95	82.51	41.73	14,690	15,857	12,627	11,980	6,092
*14	30-14-120	86.42	83.13	41.87	14,215	15,714	12,337	12,000	6,114
*15	30-10-120	80.55	75.38	54.73	14,305	15,799	11,534	10,875	7,984
*16	40-8-120	83.09	75.52	51.82	14,421	15,752	11,875	10,903	7,565
17	30-8-120	68.50	59.27	35.81	14,070	15,348	8,640	7,349	5,228
*18	40-4-120	74.74	70.00	37.60	14,507	15,872	10,546	10,115	5,490

TABLE 13.—*Heat balances.*

No. of test.	Laboratory designation.	Calorific value (British thermal units per pound of combustible).	British thermal units absorbed per pound of combustible fired.	British thermal units lost per pound of combustible fired. Due to H_2O in coal.	Due to H_2O in air.	Due to H_2O formed by H in coal.	Due to escaping gases.	Due to incomplete combustion.	Due to front-end cinders.	Due to stack cinders.	Due to refuse in ash pan.	Unaccounted for.
1	2	85	89	90	91	92	93	94	95	96	97	98
1	30-5-240	15,388	9,040	24	70	632	1,975	576	1,235	141	639	1,056
2	40-4-240	15,416	9,136	24	33	625	2,057	565	1,224	147	537	1,068
3	30-4-240	15,398	9,252	25	82	633	2,049	451	886	137	933	950
4	30-2-240	15,352	10,189	41	39	688	2,087	72	432	205	634	965
5	40-6-200	15,566	9,832	28	62	649	2,325	243	918	173	588	748
*6	50-4-200	15,744	8,489	34	55	544	2,133	66	1,882	284	823	1,434
7	40-4-200	15,214	9,330	29	75	671	1,801	746	750	206	895	711
8	30-6-200	15,332	9,552	23	47	637	2,297	167	625	124	785	1,075
*9	30-2-200	15,875	10,430	56	58	541	2,392	8	670	243	738	739
10	30-8-160	15,425	10,209	25	42	653	2,342	195	561	112	570	716
11	40-6-160	15,351	10,170	34	42	646	2,272	229	463	205	604	686
12	30-4-160	15,300	10,575	28	57	581	2,160	194	178	152	573	802
*13	40-12-120	15,857	7,408	45	55	556	2,217	199	2,654	596	445	1,680
*14	30-14-120	15,714	7,456	54	44	568	2,272	122	2,373	817	446	1,562
*15	30-10-120	15,799	8,480	43	43	547	2,178	116	1,910	326	948	1,208
*16	40-8-120	15,752	9,446	42	44	538	2,294	30	1,233	320	665	1,140
17	30-8-120	15,348	10,701	34	59	597	2,239	130	270	132	439	747
*18	40-4-120	15,872	10,817	55	46	486	2,145	89	400	174	807	833

TABLE 13.—*Heat balances*—Continued.

No. of test.	Laboratory designation.	Percentage of heat— Absorbed by boiler and superheater.	Due to H_2O in coal.	Due to H_2O in air.	Due to H_2O formed by H in coal.	Due to escaping gases.	Due to incomplete combustion.	Due to front end cinders.	Due to stack cinders.	Due to refuse in ash pan.	Unaccounted for.
1	2	99	100	101	102	103	104	105	106	107	108
1	30-5-240	58.75	0.16	0.46	4.11	12.83	3.74	8.02	0.92	4.15	6.86
2	40-4-240	59.28	.15	.20	4.05	13.35	3.67	7.94	.95	3.48	6.93
3	30-4-240	60.08	.16	.53	4.11	13.31	2.93	5.75	.89	6.06	6.17
4	30-2-240	66.37	.27	.25	4.48	13.58	.47	2.81	1.34	4.13	6.30
5	40-6-200	63.16	.18	.40	4.17	14.93	1.56	5.00	1.11	3.78	4.81
*6	50-4-200	53.90	.22	.35	3.45	13.32	.42	11.96	1.80	5.23	9.37
7	40-4-200	61.34	.19	.49	4.41	18.86	4.90	4.95	1.35	5.88	4.63
8	30-6-200	62.34	.15	.31	4.16	14.98	1.09	4.08	.81	5.12	6.96
*9	30-2-200	65.70	.35	.37	3.41	15.07	.05	4.22	1.53	4.65	4.65
10	30-8-160	66.16	.16	.27	4.24	15.18	1.27	3.64	.73	3.70	4.65
11	40-6-160	66.25	.22	.27	4.21	14.79	1.49	3.02	1.33	3.93	4.49
12	30-4-160	69.12	.18	.37	3.80	14.11	1.27	1.16	.99	3.74	5.26
*13	40-12-120	46.72	.28	.35	3.51	13.98	1.26	16.74	3.76	2.81	10.59
*14	30-14-120	47.45	.34	.28	3.61	14.46	.78	15.10	5.20	2.84	9.94
*15	30-10-120	53.67	.27	.27	3.46	13.78	.73	12.09	2.06	6.00	7.67
*16	40-8-120	59.97	.26	.27	3.42	14.56	.19	7.82	2.03	4.22	7.26
17	30-8-120	69.73	.22	.38	3.89	14.58	.85	1.76	.86	2.86	4.87
*18	40-4-120	68.14	.35	.29	3.06	13.58	.56	2.52	1.10	5.09	5.31

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PROFESSIONAL PAPER 48. Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904; E. W. Parker, J. A. Holmes, M. R. Campbell, committee in charge, 1906. In three parts. 1,492 pp., 13 pls. $1.50.

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