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FUEL TESTS WITH ILLINOIS COALS

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BULLETIN NO. 7 OF THE UNIVERSITY OF ILLINOIS ENGINEERING EXPERIMENT STATION

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THIS BULLETIN is the seventh of a series of bulletins published by the Engineering Experiment Station of the University of Illinois. The Engineering Experiment Station was established by action of the Board of Trustees December 8, 1903. It is the purpose of the Station to carry on investigations along various lines of engineering, and to study problems of importance to professional engineers and to the manufacturing, railway, mining, constructional and industrial interests of the state.

The control of the Engineering Experiment Station is vested in the heads of the several departments of the College of Engineering. These constitute the Station Staff, and with the Director, determine the character of the investigations to be undertaken. The work is carried on under the supervision of the Staff; sometimes by a Fellow as graduate work, sometimes by a member of the instructional force of the College of Engineering, but more frequently by an investigator belonging to the Station Corps.

The results of these investigations will be published in the form of bulletins, and will record mostly the experiments of the Station's own staff of investigators. There will also be issued from time to time in the form of circulars, compilations giving the results of the experiments of engineers, industrial works, technical institutions and governmental testing departments.

The volume and number at the top of the title page of the cover refer to the general publications of the University of Illinois; at the bottom is given the number of the Engineering Experiment Station bulletins or circulars.

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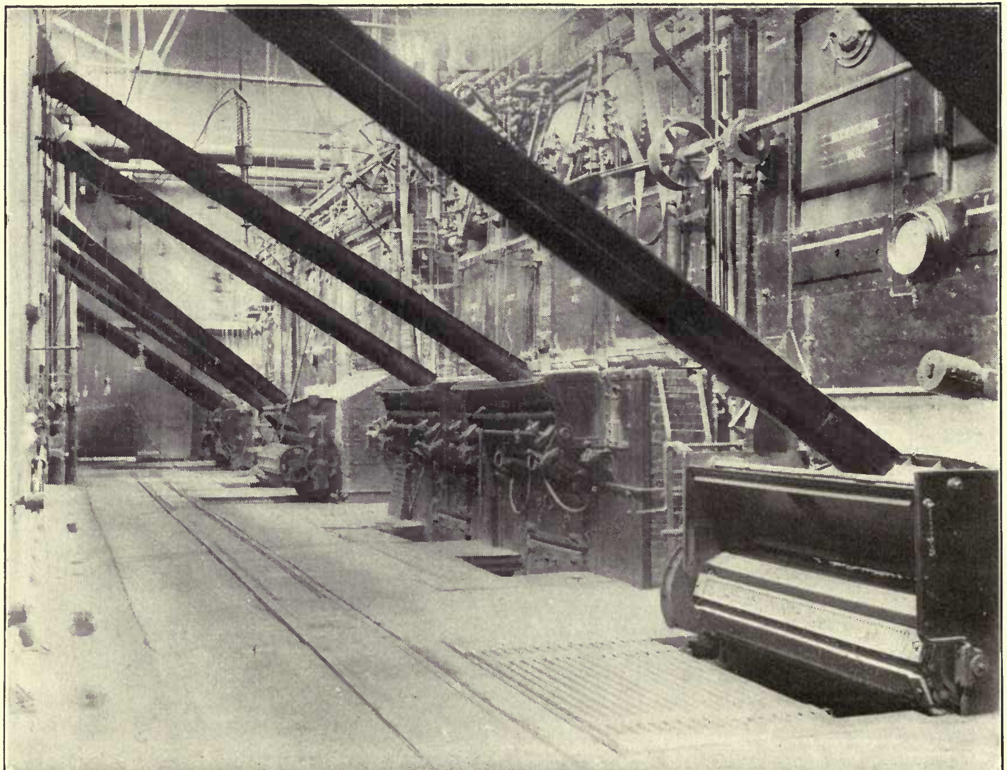

View in Central Heating Station University of Illinois

UNIVERSITY OF ILLINOIS

ENGINEERING EXPERIMENT STATION

BULLETIN No. 7 AUGUST 1906

FUEL TESTS WITH ILLINOIS COALS

BY

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During the last ten years a considerable number of boiler trials have been made at the University of Illinois. Many of these have been made under the boilers in the power plant of the University. Still other trials have been made with boilers in use at the plants in neighboring cities. In some instances experts representing several special stoker and furnace companies have been present at these trials and operated the devices in which they were interested. For the most part, however, the tests have been made in order to instruct students in the usual methods of boiler testing, and the boilers themselves have been operated under such usual conditions as happened to obtain. In some of the earlier tests all of the data relating to the heating value of the coals were not obtained, and for such tests several items depending on these values are necessarily omitted. While in most cases these tests have not been made with the object of making a comparison of coals or of appliances, nevertheless, it has seemed wise to publish the results obtained and also to exhibit these results side by side as they apply to various forms of furnaces, types of boilers or kinds of coal. It is entirely probable that the results obtained are equal to those generally obtained under the varying conditions of plants using Illinois coals. Many more boiler trials have been made than are here reported, but only such are included in this report as appear to be free from any indications of errors in methods or results. For the purpose of this bulletin all of the results of the tests have been carefully rechecked.

The work of the department of Applied Chemistry has not only supplemented the work relating to boiler trials by furnishing the composition and heating value of the coals used in these trials, but it has also examined and tested a large number of Illinois coals not yet tested under boilers. In connection with this subject this department has perfected several new devices very useful to chemists and engineers, designed for making the ordinary determinations of the heating values and composition of coals. The Parr calorimeter, one of these devices, has found ready sale among the operators of many of the power plants of the country as well as among the consulting chemists and fuel experts. It is expected that a separate bulletin will soon be published setting forth in detail many of the new methods which have been developed by this department, and giving the complete results of its investigations relating to Illinois coals. It is hoped that the tables of the chemical composition and heating values of Illinois coals, which form a part of this bulletin, will furnish engineers and manufacturers with useful information in this important field.

With the above somewhat general statement in explanation of the character of this bulletin, it may now be advisable to refer more in detail to the special features which are intended to be brought out in the following pages.

Boiler Testing

For many years engineers have been making "boiler tests" with the object of finding out how many pounds of water in the boiler could be evaporated with one pound of coal. In order that the results of the tests might be comparable, it became evident that some common method of making tests should be agreed upon and also that the tests made should be reported in a uniform manner. A committee of the American Society of Mechanical Engineers recommended to that Society in 1899 a method of testing boilers and also a method of reporting such tests. These methods have been largely used since their recommendation at that time. The many expert engineers who are to-day so familiar with these methods will probably not be interested in the pages immediately following. Having in mind the owners and operators of power plants as well as manufacturers and young technical students, it has seemed worth while to present somewhat in detail the following subjects:

(1) Observations to be made during a boiler trial.

(2) Appliances used during a boiler trial.

(3) Form of report, methods of operation and explanation of computations.

I Observations to be Made During a Boiler Trial

In the report of the committee of the American Society of Mechanical Engineers,[1] 1899, on the revision of the standard code for conducting steam boiler trials, two forms of report are submitted, a Complete Form and a Short Form. These are both shown in Section III, page 21. The observations necessary to complete either of these forms are given in Table I. An explanation of some of the methods used in obtaining these observations and the forms used in recording them follow.

Coal, Water and Ash

The two fundamental points to be determined in every test of a steam boiler or furnace, regardless of the special or specific purpose of such test, are the pounds of water evaporated by the boiler and the pounds of fuel necessary to produce such evaporation. To determine these two points it is necessary to know the number of pounds of water fed into the boiler and the pounds of fuel fed into the furnace. The possibility of an error in either throws doubt upon all the indications of the test. Each item, therefore, should be ascertained in a manner that proves its own correctness, and the records must be such that if errors are made, they will be clearly exposed.

Coal.—The weight of the coal is best obtained by means of a barrow or car with a capacity of 500 pounds. The car should be loaded uniformly each time and weighed on platform scales in front of the furnace. The total weight and the time of weighing should be recorded in the log. From the car the coal should be fired directly into the furnace and the weight of the separate

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1 See Trans. A. S. M. E, Vol. XXI, p. 34.

TABLE I

OBSERVATIONS TO BE MADE DURING A BOILER TRIAL

Short Trial	Standard Trial	Observations
1	1	Weight of water fed to boiler
2	2	Weight of coal as fired (sample)
3	3	Weight of ash and refuse (sample)
4	4	Moisture in coal
5	5	Steam pressure by gage
6	6	Force of draft: between damper and boiler
7	7	in furnace
	8	in ash-pit
8	9	Temperature: of feed water entering boiler
9	10	of escaping gases from boiler
	11	of external air
	12	of fire-room
	13	of steam
	14	of feed water entering heater
	15	of feed water entering economizer
	16	of escaping gases from economizer
	17	of gases in furnace
10	18	Moisture in steam by calorimeter
	19	Analysis of flue gases
	20	Smoke observations
	21	Average thickness of fire, intervals of firing

charges and time of firing entered in the log. After the entire car-load of coal has been fired, the weight of the empty car and the time should be recorded. The sum of the separate charges must then be equal to the difference in weight of the car when loaded and empty. A convenient form for recording the coal fired is shown in Form I. From each car-load of coal fired an average sample of coal should be taken for moisture determination and chemical analysis. The sample of course must be taken before the coal is weighed and should be about two per cent of every car-load, or about ten pounds. At the end of the test these samples from the different cars are mixed, pounded into small sizes, and then quartered until enough is left to fill a two-quart jar. The jar should then be sealed, to prevent loss of moisture, and sent to the chemist.

Feed Water.—The water fed to the boiler should be both weighed and measured, as dependence upon measuring alone will introduce errors due to uneven filling and variations in temperature; for the latter, however, corrections may be made. The measuring tank or preferably two tanks should be set on scales in such a position that the water can be delivered directly into the suction or settling tank as shown in Fig. 1. The measuring tanks should be filled and emptied alternately, the time of each weighing to be noted when the tank is empty, the tanks being designated as No. 1 and No. 2. In no case should a simple tally be recorded for

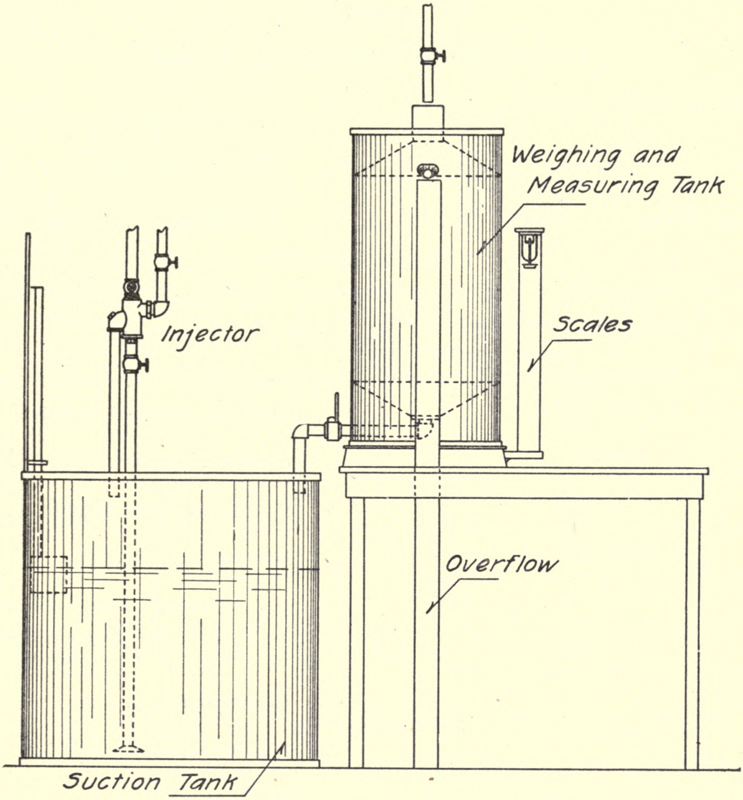

FIG. 1 ARRANGEMENT OF TANKS AND SCALE FOR MEASURING FEED-WATER FED TO BOILER

each tankful, as the liability of error is thereby increased. When the boiler tested is of small capacity, one weighing tank will be sufficient. A convenient form for recording the feed water measurements is shown in Form II.

To guard against the loss of all data, due to accidents, it is best to have coincident records of the water and coal fed to boiler. For this reason it is well to have a float in the suction or settling tank, and each time an entire car-load of coal has been fired, the time on the feed water log should be recorded, also the height of water in the boiler and in the settling tank. This will also provide a check on the uniformity of operations.

Ash.—The ashes and refuse should be weighed dry. The time of each raking of the fire and cleaning of the ash-pit and the weight

FORM I

LOG OF BOILER TRIAL NO ....

Made at........................

Date........................... By.....................

Boiler No....................... Fireman..... ....

COAL SHEET

TIME	COAL DELIVERED TO SCALES POUNDS	COAL ON SCALES AFTER EACH FIRING POUNDS	COAL FIRED EACH TIME POUNDS	FUEL
....	....	....	....	Moist coal consumed, pounds ....
....	....	....	....	Moisture in coal, per cent ....
....	....	....	....	Dry coal consumed, pounds ....
....	....	....	....	Wood consumed, pounds ....
....	....	....	....	Coal equivalent of wood (=wood x-4) lb ....
....	....	....	....	Total dry coal consumed including wood equivalent, pounds ....
....	....	....	....	Total dry refuse, pounds ....
....	....	....	....	Total dry refuse, per cent ....
....	....	....	....	Total combustible ....
....	....	....	....	DESCRIPTION OF FUEL ....
....	....	....	....	*Commercial Name* ....
....	....	....	....	Commercial size ....
....	....	....	....	Lumps, per cent ....
....	....	....	....	Small coal, per cent ....
....	....	....	....	Slack, per cent ....
....	....	....	....	Appearance of coal ....
....	....	....	....	Record the times when fires are cleaned ....
....	....	....	....	....

FORM II

LOG OF BOILER TRIAL NO............

Made at..........................

Date.......................... By......................

Boiler No...................... . Fireman..................

FEED WATER SHEET

TIME	WATER DELIVERED TO FEED TANK POUNDS	TEMP. OF WATER IN TANK	TIME	WATER DELIVERED TO FEED TANK POUNDS	TEMP. OF WATER IN TANK	REMARKS
						Test began at ....
						o'clock M.
						Date
						Test closed at ....
						o'clock M.
						Date,

FORM III

LOG OF BOILER TRIAL NO..........

Made at..........................

Date.......................... By ....

Boiler No...................... Fireman...............

TIME	PRESSURES			TEMPERATURES					HEIGHT OF WATER IN GLASS GAGE	REMARKS
	STEAM GAGE	DRAFT GAGE	BAROM-ETER	BOILER ROOM	EXTERNAL AIR	FLUE GASES	FEED WATER	STEAM		
....	....	....	....	....	....	....	......	......	....	Test began at ....
....	....	....	....	....	....	....	......	......	....	o'clock M. ....
....	....	....	....	....	....	....	......	......	....	Date, ...
....	....	....	....	....	....	....	......	......	....	Test closed at ....
....	....	....	....	....	....	....	......	......	....	o'clock M. ....
....	....	....	....	....	....	....	......	......	....	....
....	....	....	....	....	....	....	......	......	....	....
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....	....	....	....	....	....	....	......	......	....	....
....	....	....	....	....	....	....	......	......	....	....

FORM IV

LOG OF BOILER TRIAL NO............

Made at.........................

Date............... .... By.....................

Boiler No.... .... Fireman...............

TIME	CALORIMETER			DRAFT			HEIGHT OF WATER IN TANK	HEIGHT OF WATER IN GLASS GAGE	REMARKS
	GAGE PRESSURE	STEAM DISCHARGE OR CALORIMETER TEMP.	WATER SEPARATED OR CALORIMETER PRESSURE	BETWEEN DAMPER AND BOILER	IN FURNACE	IN ASH PIT			
....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....
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....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....

FORM V

LOG OF BOILER TRIAL NO............

Made at.........................

Date........................ .. By.......... ....

Boiler No...................... Fireman................

FLUE-GAS SHEET

TIME	CO_2	O_2	CO	HYDROGEN AND HYDROCARBONS	TOTAL	REMARKS
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
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....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....

of ash removed should be recorded in the same log as the weight of coal, Form I. A representative sample of ash should be taken at every cleaning and saved in order to determine the principal characteristics of the ash, a proximate analysis giving the actual amount of incombustible material being made of each sample.

General Observations

Although the main points to be determined in a boiler trial are the weight of water evaporated and the amount of fuel burned, the general observations of pressures, temperatures, etc., under which this evaporation takes place and which tend to secure the accuracy of these two measurements must not be overlooked. It is necessary that all available data be obtained and recorded in the log for use in making comparisons. The value of the observation will depend primarily upon its correctness and the greatest care should be exercised in obtaining and recording observations. Too often the observer is guided by personal opinion and former readings, and the value of the observation as an indication of some specific occurrence is entirely lost.

All general observations should, as nearly as possible, be taken at the same instant, the exact time in all cases being recorded in the log. As a rule all observations should be recorded in duplicate, this being necessary especially where several persons are concerned with the results. Duplicates are easily obtained by placing carbon copying paper below the original log. The duplicates are then obtained as the results are originally recorded. Forms for recording the general observations are shown in Forms III to V.

For convenience it is best to have the log sheets tacked to a board, which may be suspended on the wall at some convenient point. This avoids the accumulation of dust and dirt when the sheets are lying around unattached in a horizontal position.

Sufficient time should elapse between temperature measurements if only one thermometer serves for taking several observations, in order to allow the thermometer to assume the new temperature. Where the range of temperature is large, however, this should never be practised, and it will be preferable in most cases to take only the most important of the readings, being certain of its correctness.

Determinations of the moisture in the steam are necessary to make corrections in the amount of water evaporated, and should be made at regular intervals and entered in the log.

The analysis of the flue gases is important as it indicates to some extent the progress of combustion in the furnace. Notwithstanding, the general use of this analysis is still very limited, although in some instances a record of the CO_2 in the flue gases is regularly kept. The value of the analysis consists in its being an indication of the amount of excess air being used. The flue gas to be analyzed should be an average sample taken continuously over a considerable period of time. This is necessary as the composition of the gases varies from minute to minute. Under ordinary conditions an analysis every half-hour is sufficient; special readings, however, may be taken more often. The apparatus for sampling will be explained in the following section.

II Appliances Used During A Boiler Trial

Since the corrections to be applied to the weights of fuel and water fed to the boiler are dependent on the general observations, the appliances necessary for their determination must be considered. The correctness of the observations will depend primarily on the instruments used and their location. In the following paragraphs these are discussed to some extent.

Description of Appliances

A list of the apparatus necessary to take the observations given in Section I is shown in Table II. The apparatus required

TABLE II

Appliances for Observations Given in Table I

Short Trial	Standard Trial	Appliances
1	1	Measuring and suction tanks for measuring water
2	2	Platform scales for weighing water
3	3	Car or barrow for handling coal
4	4	Platform scales for weighing coal
5	5	Standard calibrated steam gage
6	6	Draft gages, U tubes or otherwise
7	7	Thermometers according to observations made
8	8	Flue gas thermometer
	9	Pyrometer for furnace temperatures
9	10	Throttling or separating calorimeter
	11	Orsat apparatus for flue gas analysis
	12	Smoke charts

in the determination of the weights of coal and water was discussed in the previous section and needs no explanation other than that the scales used should be calibrated so that a correction may be applied if necessary. The suction tank should also be calibrated so that the contents of the tank are known for all positions of the float.

For measurement of the steam pressure an ordinary steam gage calibrated by comparison with a standard gage or other means will suffice. A good recording steam gage carefully adjusted and compared at frequent intervals with the steam gage provides a good check. Various forms of draft gages are used to determine the draft pressure. The ordinary U tube is the most common form and gives very satisfactory results. A gage of the type shown in Fig. 2 has been extensively used at the University and gives results which can be read with greater accuracy than the U tube.

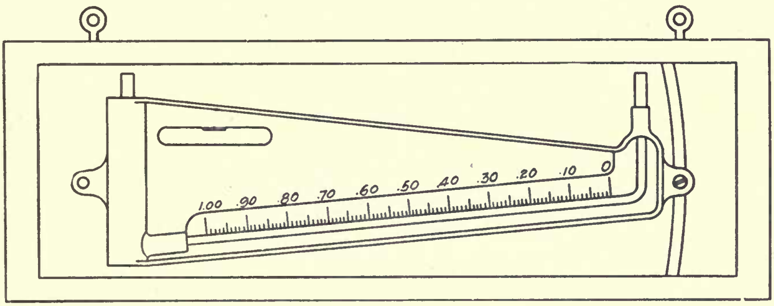


FIG. 2 DRAFT GAGE

In the choice of thermometers care should be taken that the range of readings will fall within that of the thermometer. Where thermometers are likely to be handled constantly, a metal casing is desirable. Where temperatures within a pipe are required, as in steam or water pipes, thermometer cups, as shown in Fig. 3 will need to be used.

Either mercury or a heavy cylinder oil may be used in these cups; the former, however, is preferable both for cleanliness and accuracy. For the measurement of flue gas temperatures a special mercury thermometer is used, reading up to 1000° F., with nitrogen compressed above the mercury.

The thermometer should be calibrated from time to time to insure its correctness. The location of the thermometer will be discussed in the following section.

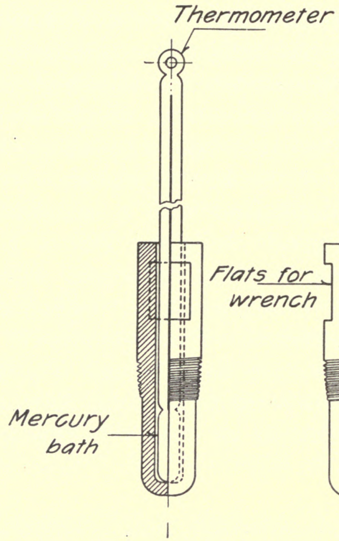


FIG. 3 THERMOMETER CUP, USED TO OBTAIN TEMPERATURES WITHIN A PIPE

The measurement of furnace temperatures is very difficult, and no especial form of pyrometer has proved to be entirely satisfactory. The Wanner optical pyrometer is being used at the Government Coal-Testing Plant at St. Louis, and seems to be giving fair results.

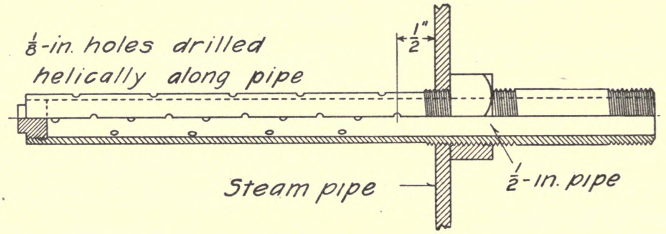


FIG. 4 SAMPLING NOZZLE FOR STEAM CALORIMETER

For determining the moisture in the steam, as long as the moisture remains below three per cent, any one of several forms of calorimeters may be used with good results. Above this point, all calorimeters are inaccurate, owing to the inability to obtain an average sample of the steam. The sampling nozzle, Fig. 4, should be made of ½-in. pipe, and should extend across the diameter of the steam pipe to within half an inch of the opposite side, being closed at the end, and perforated with not less than twenty ⅛-in. holes equally distributed along and around its cylindrical surface, but none of these holes should be nearer than ½ inch to the inner side of the steam pipe. The calorimeter and pipe leading to it should be well covered with felt. When a separating calorimeter with attached gage for determining the amount of steam passing through the calorimeter is used, such gage should be calibrated by taking readings over twenty minutes in length, and condensing the steam passing through the calorimeter during that time, the weight of condensed steam being compared with the indication on the gage. This should be repeated for the entire range of the gage. Superheating should be determined by means of a thermometer placed in a mercury well, inserted in the steam pipe.

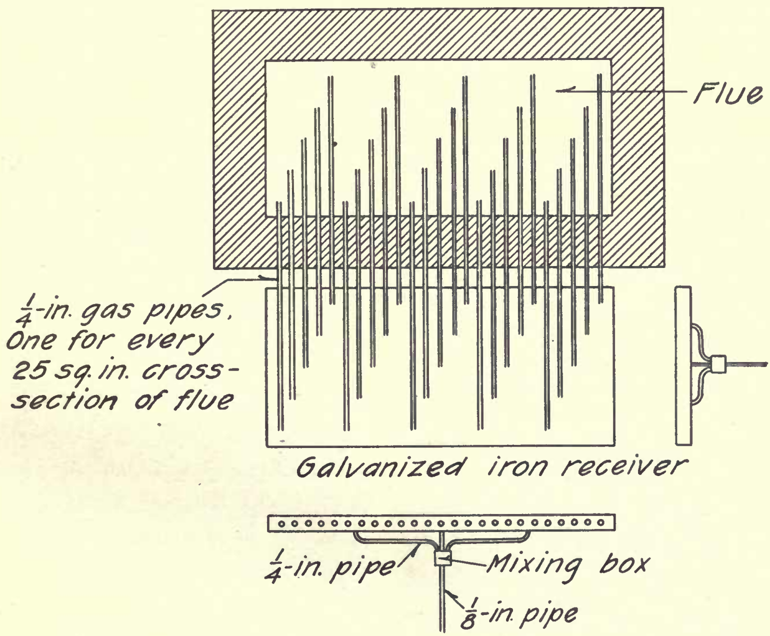


FIG. 5 FLUE GAS SAMPLER, ADVISED IN THE A. S. M. E. STANDARD CODE FOR CONDUCTING STEAM BOILER TRIALS

For determining the composition of the flue gases a sampling tube for drawing the sample of gas from the flue is necessary, also apparatus for analyzing the gas. There has been a great diversity of opinion regarding the method to be used in obtaining the

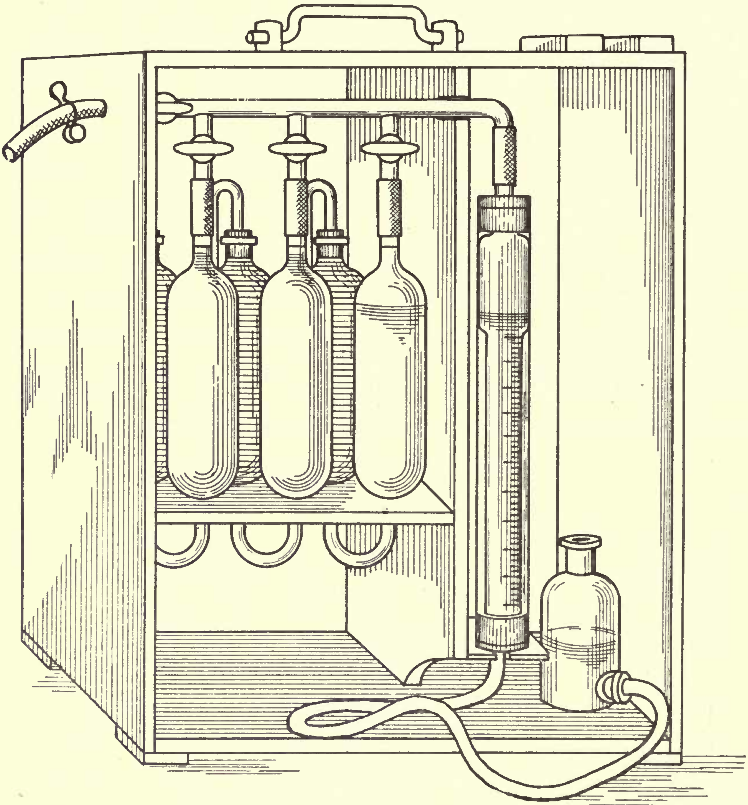


FIG. 6 ORSAT APPARATUS FOR ANALYZING FLUE GAS

sample, due probably to the varying conditions in different boiler settings and at different points in the same flue. In the trials carried on by the United States Geological Survey at St. Louis, both the sampler advised in the A. S. M. E. code, Fig. 5, and an ordinary pipe closed at the end and perforated with holes equally spaced along its entire length have been used. The results indicate the advisability of using the latter, and it has been adopted for use in all future trials. To get a uniform flow through all the perforations, they are made of such size and number that the sum of the areas of the perforations is less than the cross sectional area of the sampling tube. The Orsat apparatus is the one mostly used for analyzing the flue gases, as it is simple in operation, and with a little care gives reliable results. To insure the

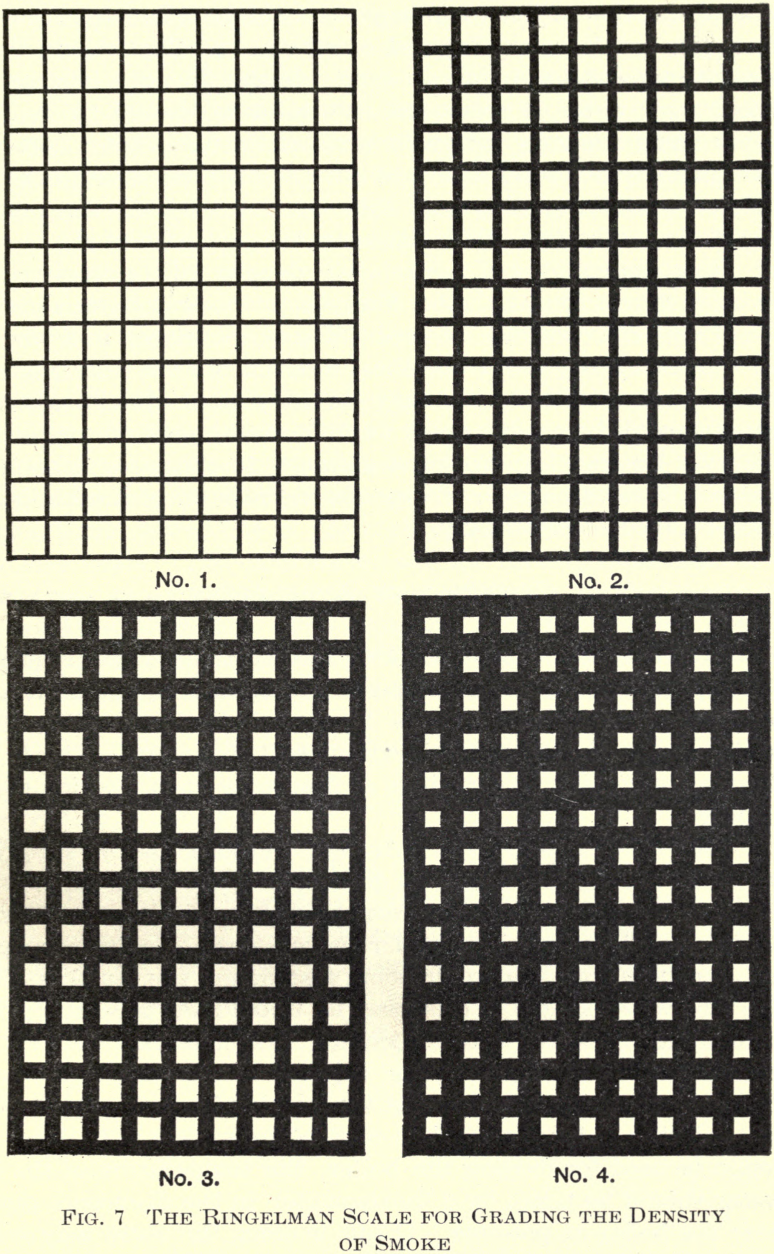


FIG. 7 THE RINGELMAN SCALE FOR GRADING THE DENSITY OF SMOKE

total absorption of the various gases, care must be taken that the absorbing solutions are in good condition, and they should therefore be renewed from time to time. If the flue gas is to be collected over water, a saturated salt solution should be used, as water has a tendency to retain some of the CO_2 when a considerable quantity is present, and to give it up later when there is a smaller quantity of this gas, thus causing errors in the results. Fig. 6 shows the type of Orsat apparatus generally used.

If determinations of the relative density of the smoke are to be made during the trial, the Ringelman smoke charts shown in Fig. 7 may conveniently be used. These are placed in a horizontal row about fifty feet from the observer, and as nearly as convenient in line with the chimney. At this distance the lines become invisible and the cards appear as different shades of gray. The observer by glancing from the chimney to the cards determines which card most nearly corresponds to the color of the smoke and makes a record accordingly.

Location of Appliances

Of prime importance in taking observations is the location of the apparatus used. On account of the variation in different types of boiler settings it will always be necessary to describe clearly in the report of the test the location of all apparatus. This is best done by indicating on drawings or diagrams their position on the setting.

Feed Water Temperature.—As the methods used in supplying feed water to a boiler vary, so does also the location of the thermometer for the temperature measurement of such feed water. If an injector be used, it should receive steam directly through a covered pipe from the boiler being tested, and the temperature of the feed water should in this case be taken from the supply tank furnishing the water to the injector. It is here assumed that the heat of the steam operating the injector is returned to the boiler from which it was taken, so that the supply pipe between the boiler and injector, if long, should be covered to prevent radiation. If a pump be used for feeding the boiler, the temperature of the feed water should be taken by a thermometer in the discharge pipe as near the boiler as possible. If this is done, the water may or may not be pumped through a feed water heater after leaving the pump.

It is always essential that the heat carried into the boiler by the feed water should be known, and it is well to record its temperature before and after it passes through any kind of heater or economizer in order that the effect of such device may be given proper credit.

The location of thermometers for the determination of boiler room and external air temperatures should be such that drafts or heat rays will be avoided. The flue gas temperature should be taken at a point where the gases leave the boiler and pass into the breeching on their way to the stack. As the temperature in a transverse section of the flue will vary, several readings should be taken at different points of the same section. Observations of the draft are usually made at several points of the setting. The one between the damper and the boiler is, however, the more important, and should be taken at a point close to the flue gas thermometer or possibly in the same transverse section. The force of draft in furnace and ash-pit may be taken through the firing and ash-pit doors, but is preferably taken through holes left in the side walls. The calorimeter and the thermometer cup for determining superheat should be attached to the vertical steam pipe as it leaves the boiler. The sampling tube for the flue gas was explained in the last section. It should be inserted in the flue at the point where the flue gas temperature and draft are obtained.

III REPORT OF THE TRIAL

Forms.—The data and results of a boiler trial should be reported in the manner given in Form VI, which is the complete form advised by the Boiler Test Committee of the American Society of Mechanical Engineers, Code of 1899. The items printed in italics correspond to the items in the "Short Form" of report recommended for commercial tests. For more elaborate trials the code recommends that the full log of the trial be shown graphically by means of a chart, Fig. 8.

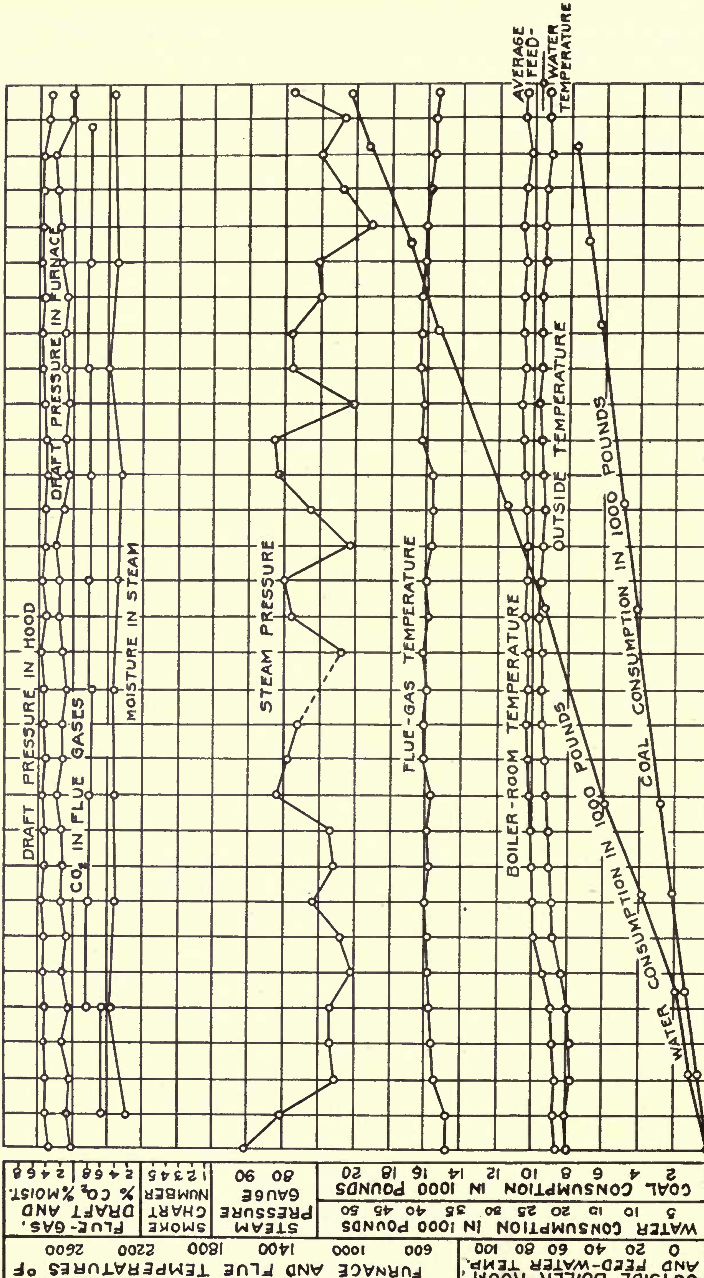


Fig. 8 Chart Showing Log of Boiler Tests

FORM VI

Data and Results of Evaporative Tests

Arranged in accordance with the Complete Form advised by the Boiler Test Committee of the American Society of Mechanical Engineers. Code of 1899.

Made by............................of.......................boiler at ....to determine..
....
Principal conditions governing the trial...
....
....
*Kind of fuel**...
Kind of furnace..
State of the weather..
Method of starting and stopping the test ("standard" or "alternate")
1. *Date of trial*...
2. *Duration of trial*.. hours

Dimensions and Proportions

(A complete description of the boiler and drawings of the same if of unusual type, should be given on an annexed sheet.)

3. *Grate surface*............*width*.............*length*.............*area*............ sq. ft.
4. Height of furnace.. in.
5. Approximate width of air spaces in grate.................................... in.
6. Proportion of air space to whole grate surface.............................. per cent
7. *Water-heating surface*... sq. ft.
8. *Superheating surface*.. sq. ft.
9. Ratio of water-heating surface to grate surface.............................. —to 1
10. Ratio of minimum draft area to grate surface................................ 1 to—

Average Pressures

11. *Steam pressure by gage*...lbs. per sq. in.
12. *Force of draft between damper and boiler*...................................in. of water
13. Force of draft in furnace..in. of water
14. Force of draft or blast in ash pit...in. of water

Average Temperatures

15. Of external air.. deg.
16. Of fireroom.. deg.
17. Of steam... deg.
18. Of feed water entering heater.. deg.
19. Of feed water entering economizer.. deg.
20. *Of feed water entering boiler*... deg.
21. *Of escaping gases from boiler*... deg.
22. Of escaping gases from economizer.. deg.

Fuel

23. Size and condition... ....
24. Weight of wood used in lighting fire... lbs.
25. *Weight of coal as fired*... lbs.
26. *Percentage of moisture in coal*.. per cent
27. *Total weight of dry coal consumed*... lbs.
28. *Total ash and refuse*.. lbs.
29. Quality of ash and refuse.. ....
30. Total combustible consumed... lbs.
31. *Percentage of ash and refuse in dry coal*.................................... per cent

Proximate Analysis of Coal

	Of Coal.	Of Combustible.
32. Fixed carbon........................	per cent	per cent
33. Volatile matter.....................	per cent	per cent
34. Moisture............................	per cent	——
35. Ash.................................	per cent	——
	100 per cent	100 per cent
36. Sulphur, separately determined......	per cent	per cent

*The items printed in italics correspond to the items in the "Short Form of Code."

Ultimate Analysis of Dry Coal

		Of Coal.	Of Combustible.
37.	Carbon (C)	per cent	per cent
38.	Hydrogen (H)	per cent	per cent
39.	Oxygen (O)	per cent	per cent
40.	Nitrogen (N)	per cent	per cent
41.	Sulphur (S)	per cent	per cent
42.	Ash	per cent	—
		100 per cent	100 per cent
43.	Moisture in sample of coal as received	per cent	per cent

Analysis of Ash and Refuse

44. Carbon .... per cent
45. Earthy matter .... per cent

Fuel per Hour

46. *Dry coal consumed per hour* .... lbs.
47. Combustible consumed per hour .... lbs.
48. *Dry coal per square foot of grate surface per hour* .... lbs.
49. Combustible per square foot of water-heating surface per hour .... lbs.

Calorific Value of Fuel

50. *Calorific value by oxygen calorimeter, per lb. of dry coal* .... B. T. U
51. *Calorific value by oxygen calorimeter, per lb. of combustible* .... B. T. U
52. Calorific value by analysis, per lb. of dry coal .... B. T. U
53. Calorific value by analysis, per lb. of combustible .... B. T. U

Quality of Steam

54. *Percentage of moisture in steam* .... per cent
55. *Number of degrees of superheating* .... deg.
56. Quality of steam (dry steam =unity). (For exact determination of the factor of correction for quality of steam see section on computation of results.) ..

Water

57. *Total weight of water fed to boiler* .... lbs.
58. Equivalent water fed to boiler from and at 212 degrees .... lbs.
59. *Water actually evaporated, corrected for quality of steam* .... lbs.
60. Factor of evaporation .... lbs.
61. Equivalent water evaporated into dry steam from and at 212 degrees. (Item 59 × Item 60.) .... lbs.

Water per Hour

62. *Water evaporated per hour, corrected for quality of steam* .... lbs.
63. *Equivalent evaporation per hour from and at 212 degrees* .... lbs.
64. *Equivalent evaporation per hour from and at 212 degrees per square foot of water-heating surface* .... lbs.

Horse-Power

65. *Horse-power developed. (34½ lbs of water evaporated per hour into dry steam from and at 212 degrees, equals one horse-power.)* .... H. P.
66. *Builders' rated horse-power* .... H. P.
67. *Percentage of builders' rated horse-power developed* .... per cent

Economic Results

68. *Water apparently evaporated under actual conditions per pound of coal as fired. (Item 57÷Item 25.)* .... lbs.
69. *Equivalent evaporation from and at 212 degrees per pound of coal as fired. (Item 61÷Item 25.)* .... lbs.
70. *Equivalent evaporation from and at 212 degrees per pound of dry coal. (Item 61÷Item 27.)* .... lbs.
71. *Equivalent evaporation from and at 212 degrees per pound of combustible. (Item 61÷Item 30.)* .... lbs.

(If the equivalent evaporation, Items 69, 70 and 71, is not corrected for the quality of steam, the fact should be stated.)

Efficiency

72. *Efficiency of the boiler; heat absorbed by the boiler per pound of combustible divided by the heat value of one pound of combustible* .... per cent
73. *Efficiency of boiler, including the grate; heat absorbed by the boiler, per pound of dry coal, divided by the heat value of one pound of dry coal* .... per cent

Cost of Evaporation

74.	*Cost of coal per ton——lbs. delivered in boiler room*	$.........
75.	Cost of fuel for evaporating 1,000 lbs of water under observed conditions.....	$.........
76.	*Cost of fuel used for evaporating 1,000 lbs. of water from and at 212 degrees*.....	$.........

Smoke Observations

77.	Percentage of smoke as observed..	per cent
78.	Weight of soot per hour obtained from smoke meter.........................	ounces
79.	Volume of soot per hour obtained from smoke meter.........................	cu. in.

Methods of Firing

80. Kind of firing (spreading, alternate, or coking)...................................
81. Average thickness of fire...
82. Average intervals between firings for each furnace during time when fires are in normal condition...
83. Average interval between times of levelling or breaking up...................

Analyses of the Dry Gases

84.	Carbon dioxide (CO_2)..	per cent
85.	Oxygen (O)...	"
86.	Carbon monoxide (CO)..	"
87.	Hydrogen and hydrocarbons..	"
88.	Nitrogen (by difference) (N)..	"
		100 per cent

HEAT BALANCE, OR DISTRIBUTION OF THE HEATING VALUE OF THE COMBUSTIBLE
TOTAL HEAT VALUE of 1 lb. of Combustible..............................B. T. U.

	B.T.U.	Per Cent
1. Heat absorbed by the boiler = evaporation from and at 212 degrees per pound of combustible × 965.7.		
2. Loss due to moisture in coal = per cent of moisture referred to combustible÷100 × [(212 — t)+966+0.48 (T — 212)] (t = temperature of air in the boiler room, T = that of the flue gases)		
3. Loss due to moisture formed by the burning of hydrogen = per cent of hydrogen to combustible÷100 × 9 × [(212—t)+966+0.48(T—212)]		
4.* Loss due to heat carried away in dry chimney gases = weight of gas per pound of combustible × 0.24 × (T—t).		
5.† Loss due to incomplete combustion of carbon = $\frac{CO}{CO_2 + CO} \times \frac{\text{per cent C in combustible}}{100} \times 10{,}150$.		
6. Loss due to unconsumed hydrogen and hydrocarbons, to heating the moisture in the air, to radiation, and unaccounted for. (Some of these losses may be separately itemized if data are obtained from which they may be calculated.)		
Totals..		100.00

*The weight of gas per pound of carbon burned may be calculated from the gas analyses as follows:

$$\text{Dry gas per pound carbon} = \frac{11\,CO_2 + 8O + 7\,CO + (N)}{3\,(CO_2 + CO)}$$

, in which CO_2, CO, O, and N are the percentages by volume of the several gases. As the sampling and analyses of the gases in the present state of the art are liable to considerable errors, the result of this calculation is usually only an approximate one. The heat balance itself is also only approximate for this reason as well as for the fact that it is not possible to determine accurately the percentage of unburned hydrogen or hydrocarbons in the flue gases.

The weight of dry gas per pound of combustible is found by multiplying the dry gas per pound of carbon by the percentage of carbon in the combustible, and dividing by 100.

†CO_2 and CO are respectively the percentage by volume of carbonic acid and carbonic oxide in the flue gases. The quantity 10,150 = Number of heat units generated by burning to carbonic acid one pound of carbon contained in carbonic oxide.

Starting and Stopping the Test

Standard Method.—Steam being raised to the working pressure, remove rapidly all fire from the grate, close the damper, clean the ash-pit, and as quickly as possible start a new fire with weighed wood and coal, noting the time and the water level while the water is in a quiescent state, just before lighting the fire. At the end of the test, remove the whole fire, which has been burned low, clean the grates and ash-pit, and note the water level when the water level is in a quiescent state, and record the time of hauling the fire. The water level should be as nearly as possible the same as at the beginning of the test. If it is not the same a correction should be made by computation, and not by operating the pump after the test is complete.

Alternate Method.—The boiler being thoroughly heated by a preliminary run, the fires are to be burned low and well cleaned. Note the amount of coal left on the grate as nearly as it can be estimated; note the pressure of steam and the water level. Note the time and record it as the starting time. Fresh coal, which has been weighed, should now be fired. The ash-pits should be thoroughly cleaned at once after starting. Before the end of the test the fires should be burned low, just as before the start, and the fires cleaned in such a manner as to leave a bed of coal on the grates of the same depth and in the same condition as at the start. When this stage is reached, note the time and record it as the stopping time. The water level and steam pressure should previously be brought as nearly as possible to the same point as at the start. If the water level is not the same as at the start, a correction should be made by computation, and not by operating the pump after the test is completed.

The two methods given above for starting and stopping the test are taken from the A. S. M. E. Code for conducting steam boiler trials. When the alternate method is used, several precautions regarding the observations are necessary. The time of starting and stopping should be noted when the smallest amount of fuel is on the grate, and when it is in the most burned-out condition, i. e., just before firing fresh coal after cleaning, and when the water level is in its most quiet condition and the least raised by ebullition. This condition of fire and of water level can be duplicated immediately after cleaning the fire, but there is no certainty of duplication of any condition when there is a bright fire and consequent rapid steaming. If the water level is noted at the starting of the test when it is raised by a bright fire, and at the end of a test when it is depressed by the stoppage of violent ebullition or of rapid circulation due to the cooling of the fire, the boiler will be credited with more water than was really evaporated. As such a fall in water level is easily produced by opening fire doors and checking draft, it should be guarded against especially when using bituminous or flaming coals. The greatest care should also be taken that the bed of coal at the end does not contain more waste material, which belongs to the ash, than it did at the beginning.

Computation of Results

On account of the variations in the types of boilers and furnaces, no specific directions can be given for the measurement of grate surface, height of furnace and other furnace proportions. The heating surface should be computed from the surface of shells, tubes and fire-boxes in contact with fire or hot gases. The outside diameter of water tubes and the inside diameter of fire tubes should be used in this computation. All surfaces below the mean water level which have water on one side and products of combustion on the other are to be considered as water-heating surface, and all surfaces above the mean water level which have steam on one side and products of combustion on the other are to be considered as superheating surface.

The following directions show how some of the results to be derived from a boiler trial may be obtained. The calculation of other items is self-evident.

Item 26, the moisture in the coal, should be obtained by the chemist by drying the sample collected during the test, for one hour in a sand or air bath at a temperature between 240° and 280° F. Sometimes the moisture is obtained by drying a known quantity of the coal above the boiler; however, if this method is used, it should be so stated in the report. The first method is always to be preferred. (See Section VI, page 48).

Item 27=Item 25×(100−Item 26)

Item 30=Item 27×(100−Item 42)−(Item 28×Item 44)

As this is dependent upon the ultimate analysis of the coal, which is not always available, the following may be used:

Item 30=Item 27−Item 28

The latter, however, is in error, due to the unaccounted-for ash passing over the bridge wall.

Item 51=Item 50÷(100−Item 42)

or =Item 50÷[Item 27−(Item 28×Item 45)]

in which the former depends again upon the ultimate analysis of the coal.

$$\text{Items 52 and 53} = 14{,}600\ C + 62{,}000\left(H - \frac{O}{8}\right) + 4{,}000\ S,$$

in which C, H, O and S refer to the proportions of carbon, hydrogen, oxygen and sulphur respectively, as determined by the ultimate analysis.

$$\text{Item 54} = 100 \times \frac{H - 1146.6 - 0.48\ (T - 212)}{L}$$

$$\text{or} \quad = 100 \times \frac{\text{lbs. of moisture separated}}{\text{lbs. of steam} + \text{lbs. of moisture separated}}$$

in which H=total heat and L=latent heat per pound of steam at the pressure in the steam pipe, and T=temperature of the throttled and superheated steam in the calorimeter. The first formula applies to throttling and the second to separating calorimeters.

Item 55 should be taken as the difference between the reading of the thermometer for superheated steam and the readings of the same thermometer for saturated steam at the same pressure as determined by a special experiment and not by reference to the steam tables.

Item 56=100−Item 54

For the exact determination of the factor of correction for quality of steam we have the following:

For wet steam, $F = Q + P\left(\frac{T_1 - J_1}{H - J_1}\right)$, and

For superheated steam, $F = 1 + \frac{0.48K}{H - J_1}$, in which

F = factor of correction

Q = quality of steam

P = per cent of moisture in steam

K = degrees of superheating in steam

H = total heat of the steam due to the steam pressure

T_1 = total heat in the water at the temperature due to the steam pressure

J_1 = total heat in the feed water due to the temperature

Item 59 = Item 57×Item 56

Item 60 $=\frac{H-h}{965.7}$, in which H and h are respectively the total heat in the steam of the average observed pressure and in water of the average observed temperature of the feed. This item may usually be obtained directly from steam tables giving the factors for different pressures and feed water temperatures.

Item 61 = Item 59 × Item 60
Item 62 = Item 59 ÷ Item 2
Item 63 = Item 61 ÷ Item 2
Item 64 = Item 63 ÷ Item 7
Item 65 = Item 63 ÷ 34.5

This is held to be equivalent to 30 pounds of water evaporated from 100° F. into dry steam at 70 pounds gage pressure. The former equals 33,317 B. T. U. per hour and the latter 33,305 B. T. U. per hour.

Item 66.—This item should give besides the rated horsepower the basis (square feet of heating surface) upon which this rating is made.

Item 67 = Item 65 ÷ Item 66

The necessary computations for economic results and efficiency, items 68 to 73, are indicated in the form of report.

IV Report of Boiler Tests with Illinois Coals

The following tables contain a summary of the results of boiler tests made by the department of Mechanical Engineering at the University of Illinois. For the most part these tests have been made, as stated in the introduction, for purposes of instruction in the method of boiler testing, although a considerable number were made for investigational purposes or as thesis work. As a rule, they have been conducted under the direct supervision of a member of the instructional staff of the department, but at times when experiments were being made with special appliances, the representative of the company interested was present to take charge of the test.

Coals Tested

The coals used in these tests were mostly those purchased under the yearly contracts of the University. In a few cases, special coals were purchased, while other tests were made on coals sent to the University by various coal companies and manufacturing concerns to determine the evaporative efficiency or their behavior on various kinds of stokers.

35 coals were tested, representing 14 counties of Illinois. These are given in the list below together with the commercial size of the coal.

	County	*Town*	*Commercial Size*
1	Christian	Pana	Lump
2	Christian	Pana	Slack
3	Christian	Pana	Srceenings
4	Coles	Paradise	Lump
5	Gallatin	Junction	Pea
6	Macon	Niantic	Nut
7	Macoupin	Mt. Olive	Lump
8	Madison	Glen Carbon	Lump
9	Marion	Odin	Lump
10	Marion	Odin	Pea
11	Marion	Odin	Slack
12	McLean	Bloomington	Lump
13	McLean	Colfax	Lump
14	Menard	Athens	Lump
15	Perry	Du Quoin	Lump
16	Perry	Du Quoin	Pea
17	Perry	Du Quoin	Slack
18	Sangamon	Barclay	Pea
19	Sangamon	Dawson	Pea
20	Sangamon	Divernon	Lump
21	Sangamon	Lowder	Slack
22	Sangamon	Ridgely	Pea
23	Sangamon	Riverton	Pea
24	Sangamon	Sringfield	Pea
25	Sangamon		Lump
26	Shelby	Moweaqua	Lump
27	Vermilion	Catlin	Screenings
28	Vermilion	Fairmount	Screenings
29	Vermilion	Muncie	Slack
30	Vermilion	Oakwood	Lump
31	Vermilion	Oakwood	Pea
32	Vermilion	Oakwood	Screenings
33	Williamson	Carterville	Washed Pea
34	Williamson	Herrin	New Kentucky Pea
35	Williamson	Herrin	New Kentucky Screenings

Boilers Tested

The tests were made at the power plants of the University and the neighboring towns, under water-tube and fire-tube boilers of the following types:

Stirling water-tube boiler.............. 2 settings
National water-tube boiler............. 2 settings
Heine water-tube boiler. .... 1 setting
Babcock & Wilcox water-tube boiler..... 8 settings
Horizontal tubular boiler ....11 settings

The settings of these boilers include the following:

1 Murphy smokeless furnace
2 Roney automatic stokers
2 Green chain grate stokers

1 Babcock & Wilcox chain grate
1 Brightman stoker

The remainder of the furnaces were hand-fired with plain or rocking grates.

Results of Tests

The results of these tests are shown in Tables III and IV, arranged according to the counties in which the coal was mined. Table III gives the conditions of temperature, pressure, heating surface and grate area under which the tests were made, and Table IV gives a few of the most important results. In some cases the heat value of the coals used was not obtained and several of the columns dependent upon it are left vacant. The headings of the tables are self-explanatory. Where a series of tests was made with the same coals under like conditions, the average of the series is reported together with the number of tests in the series. Where the coal and steam have been assumed moisture free and when the moisture in the coal was obtained by drying a known amount above the boiler, indications have been made in the tables.

In the computation of results, the usual correction for quality of steam by proportional weights of steam and water was used. The combustible was computed from the weights of coal and ash and not from the ultimate analysis of the coal, and it is, therefore, in slight error to the extent of the ash which passed over the bridge wall. The basis for the rating of the boilers varied from 10 to 15 square feet of heating surface per horse-power according to the different types of boilers used. The B. T. U. of the coal, given in the table, were obtained from an analysis of the sample taken during the test.

Discussion of Results

On account of the wide variation of conditions obtaining in the tests reported, an exact comparison was hardly possible. A general comparison of results with different types of boilers and grates has, however, been attempted. Such a comparison is shown in Table V, which contains the general average of the results of all trials made with the same type of boiler and grate, irrespective of all other conditions. It also shows the average of

TABLE III BOILER TESTS WITH ILLINOIS COALS MADE BY THE MECHANICAL ENGINEERING DEPARTMENT, UNIVERSITY OF ILLINOIS, 1894-1905. GENERAL DESCRIPTION AND PROPORTIONS

Number	Description of Coals: County	Description of Coals: Town	Description of Coals: Commercial Size	Type of Boiler and Grate	Location of Boiler	Date of Trial	Duration of Trial	Grate Surface	Water Heating Surface	Steam Pressure, Gage	Force of Draft between Damper and Boiler	Temperature of Feed Water	Temperature of Escaping Flue Gases
							Hours	Sq. ft.	Sq. ft.	Lbs. Sq. in.	Inches, Water	°Fahr.	°Fahr.
				A. S. M. E. Code No.		1	2	3	7	11	12	20	21
1	Christian	Pana	Slack	B. & W. No. 1 & 2, plain grate	Urbana & Cham. Elec. Light Pl'nt.	June 1894	10.12	52.1	2340	90.2	.220	59.1	498
2	.... do	.... do	Pea	.... do	... do	June 1894	10.00	51.0	2264	91.3	.220	60.9	484
3	.... do	.... do	Screenings	.... do	.... do	June 1894	10.00	51.0	2264	95.9	.200	60.0	464
4	.... do	.... do	Lump and slack	.... do	.... do	June 1894	10.18	51.0	2264	95.0	.325	60.7	529
5	Coles	Paradise	Lump	Hor. Tub. No. 2, plain grate	Univ. of Illinois, M. E. Lab.	Feb. 1897	8.00	18.7	533	82.1	.405	47.5	549
6	Gallatin	Junction	Pea	National W. T. No. 4 Murphy furnace	Univ. of Illinois, Cent. Heat. Pl'nt.	Mar. 1899	7.25	60.7	2579	108.1	.580	49.1	481
7	Macon	Niantic	Nut	B. & W. No. 5, plain grate	.... do	Jan. 1895	10.00	51.0	2450	59.5	.300	49.6	485
8	Macoupin	Mt Olive	Lump	Hor. Tub. No. 2, plain grate	Univ. of Illinois, M. E. Lab.	Feb. 1897	8.00	18.7	533	75.8	.470	47.0	567
9	Madison	Glen Carbon	Lump	B. & W. No. 2, chain grate	Univ. of Illinois, Cent. Heat. Pl'nt.	May 1901	8.00	28.0	1486	108.4	.600	60.0	571
10	Marion	Odin	Lump	Hor. Tub. No. 1, plain grate	Univ. of Illinois, M. E. Lab.	Apr. 1894	7.74	18.7	533	70.3	.262	56.3	489
11	.... do	.... do	Lump	Hor. Tub. No. 2, plain grate	.... do	Apr. 1895	10.10	18.7	533	59.0	.200	53.7	680
12	.... do	.... do	Pea	.... do	.... do	June 1896	9.50	18.7	533	67.8	.163	61.1	508
13	.... do	.... do	Pea	Hor. Tub. No. 1, plain grate	.... do	Oct. 1896	8.00	16.6	547	73.0	.200	59.6	494

14	.... do	.... do	Pea	Hor. Tub. No. 3, 4, plain grate........	Urbana & Cham., Water Works.....	Jan. 1897	8.00	45.0	2260	70.8	.394	128.0	359
15	.... do	.... do	Lump	Hor. Tub. No. 4, rocking grate.....	Univ. of Illinois Cent. Heat. Pl'nt.	Mar. 1895	9.38	30.0	1010	69.4	.219	52.2	560
16	.... do	.... do	Lump	B. & W. No. 5, plain grate	.... do	Jan. 1895	8.71	51.0	2450	67.8	.330	50.9	478
17	.... do	.... do	Pea	.... do	.... do	Mar. 1899	8.00	51.0	2450	103.7	.600	49.7	518
18	.... do	.... do	Lump	Stirling No. 3, plain grate........	.... do	Nov. 1896	7.85	13.5	525	82.0	.250	21.8	544
19	.... do	.... do	Lump	B. & W. No. 2 plain grate........	Urbana & Cham. Elec. L. & P. Co..	June 1894	10.00	51.0	2264	98.5	.210	59.5	482
20	.... do	.... do	Slack	.... do	.... do	Dec. 1896	8.00	51.0	2264	106.4	.730	45.0	462
21	.... do	.... do	Duff	Stirling No. 7 & 8, plain grate........	.... do	Mar. 1905	23.60	50.9	2587	110.6	.650	178.5	591
22	.... do	.... do	Pea	Nat. W. T. No. 4, Murphy furnace..	.... do	Jan. 1899	8.00	60.7	2579	84.7	.515	53.0	502
23	McLean.......	Bloomington....	Lump	Hor. Tub. No. 2, plain grate.......	Univ. of Illinois, Cent. Heat. Pl'nt.	Feb. 1895	10.76	18.7	533	65.6	.243	52.2	578
24	.... do	.... do	Lump	B. & W. No. 5, plain grate..	Univ. of Illinois, M. E. Lab........	Dec. 1894	6.00	51.0	2450	53.6	.300	53.6	......
25	.... do	Colfax..........	Lump	B. & W. No. 1, plain grate........	Univ. of Illinois, Cent. Heat. Pl'nt	May 1902	8.00	35.0	1486	106.3	.500	70.5	.....
26	Menard	Athens..........	Lump	Hor. Tub. No. 2, plain grate........	.... do	Mar. 1897	7.83	18.7	533	77.5	.190	50.6	523
27	Perry	Du Quoin	Lump	Hor. Tub. No. 1, plain grate........	Univ. of Illinois, M. E. Lab........	Oct. 1895	8.00	16.6	547	63.1	.236	63.6	528
28	.... do	.... do	Lump	Hor. Tub. No. 2, plain grate........	.... do	June 1896	9.25	18.7	533	69.0	.180	61.6	503
29	.... do	.... do	Slack	Hor. Tub., plain grate........	.... do	Apr. 1898	8.00	22.5	870	93.0	.320	177.7	535
30	.... do	.... do	Lump	Hor. Tub. No. 4, rocking grate.....	Twin City Ice & Cold Storage Co...	Feb. 1895	9.00	30.0	1010	65.6	.257	48.4	519
31	.... do	.... do	Lump	B. & W. No. 5, plain grate........	Univ. of Illinois, Cent. Heat. Pl'nt	Feb. 1895	9.50	51.0	2450	68.3	.303	49.8	515
32	.... do	.... do	Pea	B. & W. No. 2, plain grate........	.... do	Mar. 1901	12.00	51.0	2264	108.5	.700	69.2	420
33	Sangamon	Barclay	Pea	Hor. Tub. rocking grate.....	Urbana & Cham. Elec. L. & P. Co..	Apr. 1898	7.50	25.0	......	88.8	.300	100.1	403
34	.... do	Dawson	Pea	B. & W. No. 5 & 6, plain grate........	Decatur, Illinois, Water Works.....	Mar. 1899	8.00	51.0	2450	105.8	.600	53.4	539
35	.... do	.... do	Pea	Nat. W. T. No. 4, Murphy furnace	Univ. of Illinois, Cent. Heat. Pl'nt	Mar. 1899	8.00	60.7	2579	104.3	.540	52.1	503
36	.... do	Divernon........	Lump	B. & W. No. 2, chain grate.......	.... do	May 1901	8.00	28.0	1486	102.3	.600	60.6	512
37	.... do	Lowder	Slack........	.... do	.... do	Apr. 1904	8.00	28.0	1486	119.0	.325	78.5	453
38	.... do	Ridgely	Pea..........	Nat. W. T. No. 4, Murphy furnace..	.... do	Feb. 1899	8.00	60.7	2579	106.5	.550	49.5	495

TABLE III (*Concluded*)

Number	Description of Coals: County	Town	Commercial Size	Type of Boiler and Grate	Location of Boiler	Date of Trial	Duration of Trial	Grate Surface	Water Heating Surface	Steam Pressure Gage	Force of Draft between Damper and Boiler	Temperature of Feed Water	Temperature of Escaping Flue Gases
							Hours	Sq. ft.	Sq. ft.	Lbs. Sq. in.	Inches, Water	°Fahr.	°Fahr.
				A. S. M. E. Code No.		1	2	3	7	11	12	20	21
39	Sangamon	Riverton	Pea	Nat. W. T. No. 4, Murphy furnace	Univ of Illinois, Cent. Heat Pl'nt.	Mar. 1899	8.00	60.7	2579	110.8	.420	48.3	462
40	do	do	Pea	B. & W. No. 5 & 6, Roney stoker	do	Jan. 1904	24.00	51.0	2353	119.4	.270	60.6	559
41	do	do	Pea	B. & W. No. 2, chain grate	do	Dec. 1903	8.00	28.0	1486	113.7	.700	63.7	530
42	do	do	Pea	do	do	Jan. 1904	8.00	28.0	1486	113.7	.670	63.2	535
43	do	do	Pea	do	do	Feb. 1904	8.00	28.0	1486	115.0	.630	72.0	435
44	do	do	Pea	do	do	Mar. 1904	8.00	28.0	1486	118.7	.580	73.5	441
45	do	do	Pea	do	do	Jan. 1904	8.00	28.0	1486	114.4	.170	65.2	464
46	do		Lump	Hor. Tub. No. 2, plain grate	Univ. of Illinois, M. E. Lab.	Feb. 1897	8.51	18.7	533	75.2	.306	48.0	519
47	do			B. & W. No. 2, chain grate	Univ. of Illinois, Cent. Heat. Pl'nt.	Apr. 1904	8.00	28.0	1486	121.6	.145	72.3	492
48	do			Nat. W. T. No. 4, chain grate	do	Jan. 1905	9.77	59.0	2513	117.8	.360	79.8	635
49	do			do	do	Apr. 1905	10.02	55.8	2513	122.9	.370	73.6	584
50	do	Springfield	Pea	B. & W. No. 2, plain grate	do	Apr. 1901	8.19	35.0	1486	104.9	.620	63.5	462
51	do	do	Pea	B. & W. No. 2, chain grate	do	Apr. 1901	8.00	35.0	1486	102.8	.640	57.4	519
52	do	do	Pea	B. & W. No. 6, Roney stoker	do	Nov. 1905	10.00	51.0	2353	128.4	.290	61.5	608
53	Shelby	Moweaqua	Lump	B. & W. No. 5, plain grate	do	Jan. 1895	10.00	51.0	2450	55.0	.300	51.5	489
54	Vermilion	Catlin	Screenings	Murray hor. tub. No. 1, 2, 3, rocking grate	Urbana Light, Heat & Power Co.	Mar. 1905	47.66	33.0	1456	98.9	.640	130.6	393

55	.... do	Fairmount......	Screenings..	B. & W. No. 2, plain grate........	Urbana & Cham. Elec. L. & P. Co.	Dec. 1896	8.00	51.0	2264	108.2	.740	54.0	487
56	.... do	Muncie..........	Slack........	Hor. Tub. No. 2 & 3 plain grate........	Urbana & Cham. Water Works.....	Nov. 1895	10.00	22.5	1060	74.8	.430	140.0	301
57	.... do	Oakwood........	Lump	Stirling No. 7 & 8, plain grate........	Urbana & Cham. Elec. L. & P. Co.	Mar. 1905	24.00	50.9	2587	112.3	.790	182.8	634
58	.... do	... do	Screenings..	.... do	.... do	Apr. 1905	10.80	50.9	2587	110.7	.790	200.0	616
59	.... do	.... do	Screenings..	B. & W. plain grate........	.... do	Apr. 1905	10.33	64.0	2860	102.0	.330	178.0	565
60	.... do	.... do	Screenings..	Heine chain grate........	.... do	May 1905	8.03	72.0	3160	111.9	.710	63.5	592
61	.... do	.... do	Pea	B. & W. No. 6, Roney stoker.....	Univ. of Illinois. Cent. Heat. Pl'nt.	Nov. 1905	10.00	51.0	2353	133.2	.226	98.3	593
62	Williamson ...	Carterville	W. Pea& duff	.... do	.... do	Nov. 1905	10.00	51.0	2353	132.9	.236	61.0	609
63	.... do	Herrin	New Ky. Pea	B. & W. No. 2, chain grate.......	.... do	Apr. 1904	9.33	28.0	1486	117.0	.490	65.0	529
64	.... do	.... do	do W. Scre'n	.... do	.... do	Apr. 1904	20.00	28.0	1486	120.1	.540	62.0	534
65	.... do	.... do	do W. Scre'n	B. & W. No. 5 &6, Roney stoker......	....do	Feb. 1904	12.00	51.0	2353	117.9	.166	57.8	657

TABLE IV BOILER TESTS WITH ILLINOIS COALS MADE BY THE MECHANICAL ENGINEERING DEPARTMENT

UNIVERSITY OF ILLINOIS 1894-1905

AVERAGED RESULTS

Number	Description of Coals: County	Description of Coals: Town	Description of Coals: Commercial Size	Type of Boiler and Grate	Number of Tests Averaged	Dry Coal per sq. ft. of Grate Surface per hr.	Horsepower Developed by Boiler	Percentage of Rated Horsepower Developed	Equiv. Evaporation from and at 212° Fahr.: Per sq. ft. of Waterheating Surface per hr.	Equiv. Evaporation from and at 212° Fahr.: Per pound of Dry Coal	Equiv. Evaporation from and at 212° Fahr.: Per pound of Combustible	B. T. U. per pound of Dry Coal	Efficiency of Boiler including Grate
					See Note	lbs.		%	lbs.	lbs.	lbs.		%
				A. S. M. E. Code No.		49	65	67	64	70	71	50	73
1	Christian	Pana	Slack	B. & W. No. 1 & 2, plain grate	4†	15.10	108.5	51.7	1.60	4.90	6.38	....	......
2	.... do	.... do	Pea	.... do	1†	13.80	110.8	52.8	1.69	5.44	6.63	....	......
3	.... do	.... do	Screenings	.... do	1†	14.90	114.9	54.7	1.75	5.21	6.18	....	......
4	.... do	.... do	Lump and Slack	.... do	1†	20.40	196,4	93.5	2.99	6.50	7.44	....	......
5	Coles	Paradise	Lump	Hor. Tub. No. 2, plain grate	2	13.56	52.0	130.0	3.37	7.05	7.78	11430	59.6
6	Gallatin	Junction	Pea	National W. T. No. 4 Murphy furnace	4†	18.43	206.3	82.5	2.76	6.36	7.09	....	......
7	Macon	Niantic	Nut	B. & W. No. 5. plain grate	1*	18.74	135.4	61.5	1.19	4.89	5.95	....	......
8	Macoupin	Mt. Olive	Lump	Hor. Tub. No. 2. plain grate	2	13.79	52.1	130.2	3.38	6.96	7.53	....	......
9	Madison	Glen Carbon	Lump	B. & W. No. 2, chain grate	3	32.40	135.1	90.1	3,14	5.15	7.17	....	......
10	Marion	Odin	Lump	Hor. Tub. No. 1, plain grate	5	10.38	36.6	91.5	2.37	6.48	7.73	....	......
11	.... do	.... do	Lump	Hor. Tub, No. 2. plain grate	5*	13.63	45.9	114.7	2.97	6.19	7.44	....	......
12	.... do	.... do	Pea	.... do	3*	8.41	24.6	61.5	1.59	5.38	6.25	....	......
13	.... do	.... do	Pea	Hor. Tub. No. 1, plain grate	1	11.99	35.5	88.7	2.24	6.13	7.32	11070	53.5

14	.... do	.... do	Pea	Hor. Tub. No. 3 & 4 plain grate	3	10.31	84.6	47.0	1.29	6.29	7.49	......	....
15	.... do	.... do	Lump	Hor. Tub. No. 4 rocking grate	2*	22.49	135.0	135.0	4.61	6.91	7.87	......	....
16	.... do	.... do	Lump	B & W No. 5 plain grate	5	20.20	176.4	80.2	2.48	5.91	7.00	......	....
17	.... do	.... do	Pea	.... do	1	27.10	555.7	126.3	3.91	6.92	8.82	......	....
18	.... do	.... do	Lump	Stirling No. 3 plain grate	7	19.91	51.2	85.3	3.37	6.57	7.63	11633	54.5
19	.... do	.... do	Lump	B & W No. 2 plain grate	1†	15.20	129.1	61.5	1.97	5.74	6.51	......	....
20	.... do	.... do	Slack	.... do	1	23.51	205.8	98.0	3.14	5.92	6.83	......	....
21	.... do	.... do	Duff	Stirling No. 7 & 8 plain grate	1	20.78	382.6	73.6	2.55	6.24	8.11	11185	53.8
22	.... do	.... do	Pea	National W. T. No. 4 Murphy furnace	2†	21.04	216.9	86.8	2.90	5.86	7.13	......	....
23	McLean	Bloomington	Lump	Hor. Tub. No. 2 plain grate	10*	11.34	40.7	101.7	2.64	6.64	8.01	......	....
24	.... do	.... do	Lump	B & W No. 5 plain grate	1*	24.76	194.2	88.3	2.73	5.30	6.26	......	....
25	.... do	Colfax	Lump	B & W No. 1 plain grate	2	22.70	116.3	77.5	2.70	5.06	6.64	12025	4.06
26	Menard	Athens	Lump	Hor. Tub. No. 2 plain grate	2	11.63	41.0	102.5	2.66	6.49	7.09	......	....
27	Perry	Du Quoin	Lump	Hor. Tub. No. 1 plain grate	4*‡	10.66	28.6	71.5	1.80	5.54	6.49	11250	47.6
28	.... do	.... do	Lump	Hor. Tub. No. 2 plain grate	2	7.37	24.6	61.5	1.59	6.15	6.85	......	....
29	.... do	.... do	Slack	Hor. Tub. plain grate	1	15.96	73.9	123.2	2.93	7.10	8.60	......	....
30	.... do	.... do	Lump	Hor. Tub. No. 4 rocking grate	1*	18.24	117.0	117.0	4.00	7.38	8.30	11250	63.4
31	.... do	.... do	Lump	B & W No. 5 plain grate	2*	19.59	190.3	86.5	2.68	6.57	7.52	......	....
32	.... do	.... do	Pea	B & W No. 2 plain grate	2	16.06	118.5	56.4	1.81	5.00	5.87	......	....
33	Sangamon	Barclay	Pea	Hor. Tub. rocking grate	2	24.31	118.7	.....	....	6.74	7.75	......	..
34	.... do	Dawson	Pea	B & W No. 5 & 6 plain grate	1	29.00	543.7	123.6	3.83	6.34	7.64	......	....
35	.... do	.... do	Pea	National W. T. No. 4 Murphy furnace	3	15.95	152.2	60.9	2.04	5.42	6.21	......	....
36	.... do	Divernon	Lump	B & W No. 2 chain grate	3	28.60	125.9	83.9	2.92	5.42	6.98	......	....
37	.... do	Lowder	Slack	.... do	2	22.40	103.5	69.0	2.41	5.69	7.06	11700	....
38	.... do	Ridgely	Pea	National W. T. No. 4 Murphy furnace	6	18.00	179.7	71.9	2.40	5.68	6.33	......	....

*Steam assumed dry. ‡Coal assumed dry. †Moisture obtained by drying coal above boiler.

TABLE IV (*Concluded*)

Number	Description of Coals: County	Town	Commercial Size	Type of Boiler and Grate	Number of Tests Averaged	Dry Coal per sq. ft. of Grate Surface per hr.	Horsepower Developed by Boiler	Percentage of Rated Horsepower Developed	Equiv. Evaporation From and at 212° Fahr.: Per sq. ft. of Waterheating Surface per hr.	Per pound of Dry Coal	Per pound of Combustible	B. T. U. per pound of Dry Coal	Efficiency of Boiler including Grate
					See Note	lbs.		%	lbs.	lbs.	lbs.		%
				A. S. M. E. Code No.		48	65	67	64	70	71	50	73
39	Sangamon	Riverton	Pea	National W. T. No. 4 Murphy furnace	3	19.21	205.2	82.1	2.75	6.07	6.76		
40	do	do	Pea	B. & W. No. 5 & 6 Roney stoker	1	24.30	463.1	105.3	3.39	6.43	8.12	9975	62.2
41	do	do	Pea	B. & W. No. 2 chain grate	4	34.30	165.7	110.4	3.85	5.96	7.39	11152	51.7
42	do	do	Pea	do	3	34.90	185.1	123.4	4.30	6.53	7.95	11152	56.7
43	do	do	Pea	do	4	17.90	89.1	59.4	2.07	6.15	8.26	11152	53.3
44	do	do	Pea	do	4	19.90	114.9	76.6	2.67	7.11	8.93	11152	62.2
45	do	do	Pea	do	5	20.50	91.4	60.9	2.12	5.49	6.23	11287	47.0
46	do		Lump	Hor. Tub. No. 2 plain grate	4	13.00	48.3	120.7	3.13	6.84	7.83	11980	55.1
47	do		Pea	B. & W. No. 2 chain grate	2	21.84	114.6	76.4	2.66	6.47	7.44	11930	52.4
48	do		Pea	National W. T. No. 4 chain grate	4	30.52	335.8	134.3	4.61	6.43	8.21	12162	51.5
49	do		Pea	do	4	30.73	331.2	132.5	4.55	6.67	8.10	11537	55.9
50	do	Springfield	Pea	B. & W. No. 1 plain grate	2†	25.70	111.3	74.2	2.58	4.27	5.18		
51	do	do	Pea	B. & W. No. 2 chain grate	2†	28.20	176.3	117.5	4.09	6.16	7.75		
52	do	do	Pea	B. & W. No. 6 Roney stoker	2	24.37	238.4	101.4	3.44	6.51	7.79	12591	49.9
53	Shelby	Moweaqua	Lump	B. & W. No. 5 plain grate	1*	20,78	164.4	74.7	2.32	5.35	6.27	13026	39.7
54	Vermilion	Catlin	Screenings	Murray Hor. Tub. No. 1, 2, 3. rocking grate	1	11.27	100.1	66.7	1.58	6.19	8.15	12369	48.3

55	.... do	Fairmount......	Screenings......	B. & W. No. 2 plain grate................	1	30.67	230.1	109.6	3.51	5.08	5.95	12413	39.5
56	.... do	Muncie..........	Slack............	Hor. Tub. No. 2 & 3 plain grate	1‡	13.62	107.9	63.5	1.76	6,07	7.50	......	......
57	.... do	Oakwood........	Lump............	Stirling No. 7 & 8 plain grate	1	25.42	497.6	95.7	3.32	6.63	8.07	12503	51.0
58	.... do	.... do	Screenings.....	...... do	1	25.09	507.4	97.6	3.38	6.85	8.39	11427	57.9
59	.... do	.... do	Screenings......	B. & W. plain grate	1	17.91	166.9	64.2	2.01	5.02	6.59	10299	47.1
60	.... do	.... do	Screenings......	Heine chain grate	2	23.94	382.7	109.3	4.18	7.66	9.64	11067	66.8
61	.... do	.... do	Pea..............	B. & W. No. 6 Roney stoker...............	2	22.40	230.9	98.3	3.39	7.15	8.58	13251	52.1
62	Williamson......	Carterville......	W. Pea & Duff..	...... do	3	19.96	240.2	102.2	3.52	8.14	8.89	13408	58.6
63	.... do	Herrin	New Ky. Pea....	B. & W. No. 2 chain grate....	3	32.93	196.0	130.7	4.55	7.34	8.74	12769	55.5
64	.... do	.... do	... do W. Screen	...... do	1	34.60	210.3	140.2	4.88	7.50	8.89	13156	55.0
65	.... do	.... do	... do W. Screen	B. & W. No. 5 & 6.. Roney stoker.......	1	26.55	620.7	132.1	4.55	7.75	9.21	12364	60.5

*Steam assumed dry. ‡Coal assumed dry. †Moisture obtained by drying coal above boiler.

NOTE: Column headed "Number of Tests Averaged" gives the number of boiler tests, the average of whose results is recorded in the Table.

the results of the ten highest tests together with the single highest result obtained. The basis of comparison is the equivalent pounds of water evaporated from and at 212° F. per pound of dry coal. The same table also contains the average of the results of six tests with Illinois coals made by the Boiler Division of the Fuel Testing Plant of the United States Geological Survey at St. Louis. It is interesting to note that in these latter tests in which hand-firing and plain grates were used, the results obtained are better than any of the others recorded, including the results of tests in which mechanical stokers were used. This fact may be taken to indicate that the maximum efficiency of Illinois coals is rarely obtained under present average conditions. It is probable that with a closer study of furnace conditions, even these results may be improved. The general tests reported in Tables 3 to 5 include a number of trials made with special objects in view. Several of these trials are described as follows:

1. Tests of a small horizontal tubular boiler of 40 horsepower, to determine its performance with varying rates of combustion. The results of these tests are given below.

RESULTS OF A BOILER TRIAL SHOWING EFFECTS OF RATE OF COMBUSTION ON THE PERFORMANCE OF HORIZONTAL TUBULAR BOILER

Dry coal per square foot of grate surface per hour	6.80	9.30	11.00	12.00	14.00
Equivalent evaporation from and at 212° F. per pound of dry coal	6.20	6.55	6.57	6.37	5.75
Horse-power in per cent of rated capacity (40)	52 50	87.50	107.50	115.00	122.50
Temperature of escaping gases	432.00	447.00	501.00	516.00	553.00

The same kind of coal was used in all these tests, and conditions remained nearly constant. It is evident that the maximum results were obtained with the boiler running at its rated capacity, with the flue gas temperature about 500° F. With an increase in the rate of combustion, the capacity and flue gas temperature increased and the evaporation dropped off.

2. Tests to determine the effect of soot deposits on the evaporation of a small horizontal tubular boiler. These tests were made on the same boiler as the preceding series and with results as follows:

RESULTS OF BOILER TRIALS MADE TO DETERMINE THE EFFECT OF SOOT DEPOSITS ON THE EVAPORATION OF A HORIZONTAL TUBULAR BOILER

	First Series (5 days) Soot allowed to remain on tubes	Second Series (5 days) Tubes cleaned each morning	Third Series (5 days) Soot allowed to remain on tubes
Equivalent evaporation from and at 212° F. per pound of dry coal	6.20	7.04	6.23
Dry coal per sq. ft. of grate surface per hour	13.40	9.09	13.40
Horse power in per cent of rated capacity	111.00	99.00	115.00
Temperature of escaping gases	627.00	546.00	698.00

It is evident from the results that the effect of the soot deposit on the evaporation is not very marked. It is interesting to note that in the first and last series, in which the soot was allowed to remain on the tubes, the soot burned upon reaching a certain thickness, leaving but a very thin layer. In all three series the conditions were held as nearly constant as possible, although in the second series the load fluctuated somewhat on the different days.

TABLE V COMPARISON OF RESULTS OF BOILER TESTS WITH ILLINOIS COALS ON HORIZONTAL TUBULAR AND WATER-TUBE BOILERS

Type of Boiler and Grate	No. of Tests Aver.	No. of Coals Aver.	Aver. Force of Draft	Aver. Flue Gas Temp.	Dry Coal per sq. ft. of Grate Surface Per hr.	Horse-power: Develop'd by Boiler	Horse-power: Per cent of rating Dev'p'd	Equiv. Evap. F. and A. 212°: Per sq. ft. of Heating Surface per hr.	Equiv. Evap. F. and A. 212°: Per lb. of Dry Coal	Equiv. Evap. F. and A. 212°: Per lb. of Combus-tible	B. T. U. Per lb. of Dry Coal	Eff. of Boiler and Grate
A. S. M. E. Code No.			12	21	48	65	67	64	70	71	50	73
Water-Tube Roney stoker	9	5	.214	605	22.7	305	105	3.57	7.32	8.53	13034	54.2
	9	5	.214	605	22.7	305	105	3.57	7.32	8.53	13034	54.2
	Highest Single	1	.166	656	26.5	....	132	4.55	7.75	9.21	12364	60.5
Water-Tube chain grate	46	9	.493	521	27.2	180	98	3.43	6.29	7.82	11562	52.5
	Highest 10	4	.571	507	26.1	202	106	3.76	7.33	9.01	11821	59.9
	Highest Single	1	.710	592	23.9	....	109	4.18	7.66	9.64	11067	66.9
Hor. Tubular rocking grate	6	4	.323	473	20.5	121	113	3.70	6.81	7.95	11809	55.7
	6	4	.323	473	20.5	121	113	3.70	6.81	7.95	11809	55.7
	Highest Single	1	.257	519	18.2	117	117	4.00	7.38	8.30	11250	63.4
Hor. Tubular plain grate	45	10	.267	534	11.5	45	95	2.45	6.38	7.48	11532	53.4
	Highest 10	5	.354	542	13.4	52	123	3.16	6.91	7.85	11797	56.6
	Highest Single	1	.405	549	13.6	....	130	3.37	7.05	7.78	11430	59.6
Water-Tube plain grate	39	19	.400	509	20.6	176	79	2.62	5.75	6.67	11608	47.8
	Highest 10	4	.404	552	21.6	220	92	3.28	6.64	7.85	11728	54.7
	Highest Single	1	.790	616	25.1	507	98	3.38	6.85	8.39	11427	57.9
Water-Tube Murphy Furnace	18	5	.530	488	18.3	189	76	2.53	5.87	6.64	......	....
	Highest 10	4	.516	481	19.1	205	82	2.75	6.11	6.92	......	....
	Highest Single	1	.580	481	18.4	205	82	2.76	6.36	7.09	......	....
U. S. G. S. Tests Water-Tube plain grate	6	4	.527	595	22.3	198	94	3.36	7.55	8.84	12293	59.3
	Highest Single	1	.580	637	21.2	201	96	3.41	8.04	9.53	12857	60.4

3. Tests of a water-tube boiler with chain grate stoker to determine the relative economy of a 6-inch and an 8-inch fuel bed with various rates of combustion.

The results of these tests are best shown by the curves in Fig. 9.

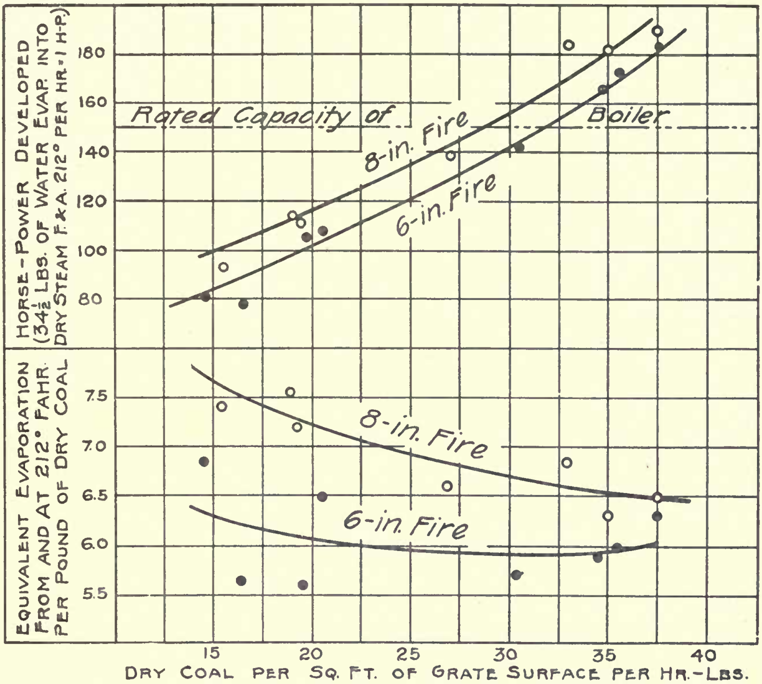


Fig. 9 Curves Showing the Relative Economy of a 6-inch and 8-inch Fuel Bed in a Chain Grate Stoker

They show that under the conditions of the test, the 8-inch fire was the more efficient, giving an equivalent evaporation per pound of dry coal 10 per cent greater than the 6-inch fire, when operating at the rated capacity of the boiler. The same coal was used throughout this series. The averages of the results of these tests are reported in Tables III and IV, viz., Nos. 41, 42, 43 and 44. In Figs. 10, 11 and 12 are shown a few of the characteristic results of boiler trials made on water-tube boilers with chain grate stokers. These diagrams are plotted from the results of 38 trials, and each point on the diagram represents the average of 5 trials. It is safe to assume, therefore, that the results represent average conditions.

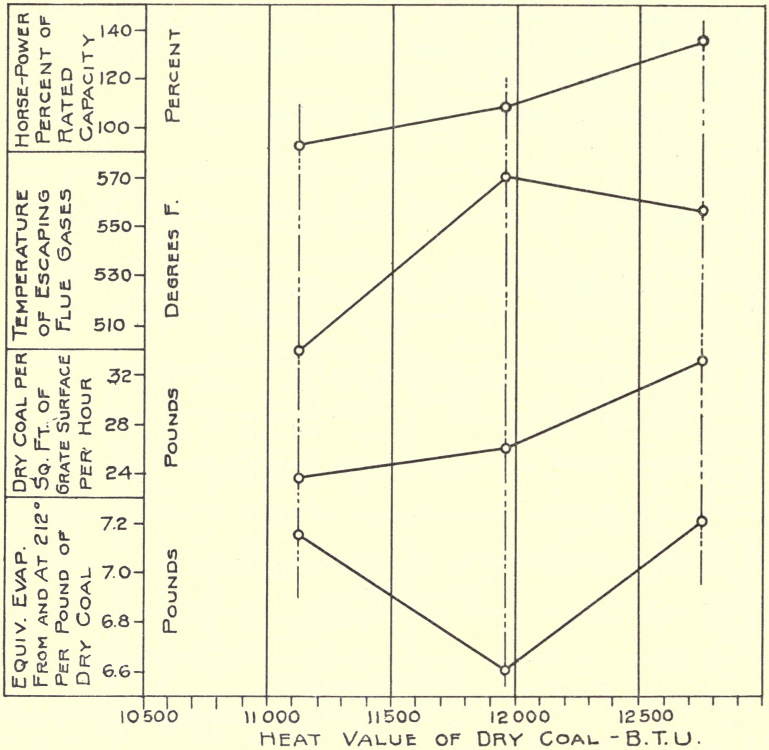


FIG. 10 CHART SHOWING VARIATION IN BOILER PERFORMANCE WITH COALS OF DIFFERENT HEAT VALUE

Fig. 10 shows the results of trials, in which coals of highest, lowest and mean heat values were used, plotted on a basis of heat value. The sudden drop in the equivalent evaporation per pound of dry coal, with coals of low and medium heat value is no doubt due to the large increase in the flue gas temperature with constant rate of combustion and capacity. With coals of medium and high heat value the equivalent evaporation increases with increasing rate of combustion and capacity, the flue gas temperature remaining constant. It is evident from the diagram that the effect of the heat value of the coal is not very marked, a large increase, however, other conditions remaining constant, causing an increase in the evaporation per pound of coal, as will be seen in Fig. 12.

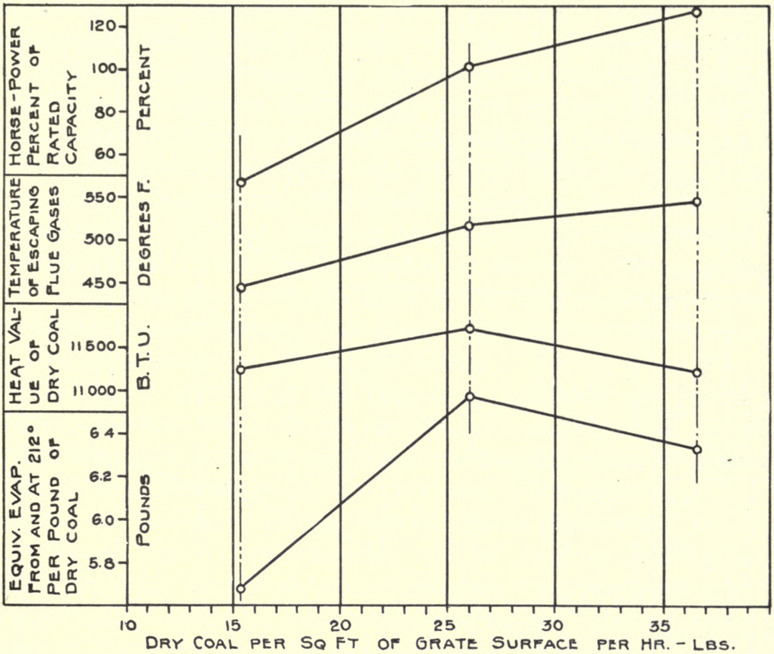


FIG. 11 CHART SHOWING VARIATION IN BOILER PERFORMANCE WITH VARYING RATES OF COMBUSTION

In Fig. 11 the results of a boiler trial are plotted on a basis of rate of combustion. It is evident from the diagram that the equivalent evaporation per pound of dry coal increases with the rate of combustion until the capacity reaches 100 per cent, or the rated capacity, the heat value of the coal remaining approximately constant, the flue gas temperature at this point being 500° F. With a further increase in the rate of combustion the capacity and flue gas temperature still increase but the equivalent evaporation per pound of coal decreases. This curve, if it may be called such, might be named the characteristic curve of the boiler, and is important because it shows the rate of combustion above which the evaporation per pound of coal decreases.

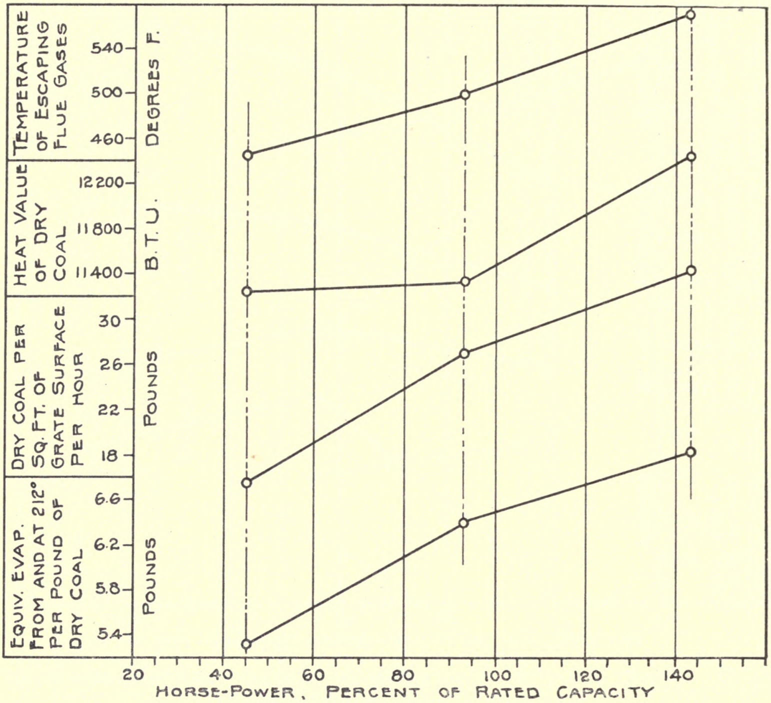


Fig. 12 Chart Showing Variation in the Performance of a Boiler Working at Different Capacities

The effect of capacity on the evaporation is shown by the diagram in Fig. 12. It is seen that here as in the previous figure the evaporation per pound of dry coal again increases with an increase in the capacity due to an increased rate of combustion. However, instead of attaining a maximum at 100 per cent capacity, it increases with a further increase of capacity and rate of combustion. At first sight this seems contradictory to the previous diagram, Fig. 11; however, it is evident that this increase is not due to this further increase in the rate of combustion and capacity, but is due to the sudden increase in the heat value of the coal (about 10 per cent) used.

V Arrangements For Future Fuel Tests

In publishing this bulletin it has been the desire to record the results of the most important tests of boilers fired with Illinois coals, that have been made up to date. During the year 1906 the Engineering Experiment Station at the University purchased and installed a plant designed especially for conducting a series of fuel tests of Illinois coals. The plant consists of a 210 H. P. Heine water-tube boiler together with a Green chain grate stoker and a Sturtevant economizer and induced draft fan and engine. This boiler is a duplicate of the boilers used by the United States government in the fuel tests in progress at St. Louis under the direction of the United States Geological Survey. It was thought that in this way the fuel tests here at the University would be in a measure comparable with the tests made by the government on coals from all parts of the United States.

The rapid growth of the industrial interests of Illinois demands a careful study of the great fuel supply, and no effort should be spared in the introduction and promulgation of improved methods and processes in the production, treatment and consumption of its coal. In the tests of Illinois coals which it is now proposed to make, less attention will be paid to routine boiler tests, familiarly known as such, and more attention will be given to a scientific study of fuel treatment before burning and to a study of those furnace constructions and conditions which give promise of maximum results. In order that future tests may be conducted along lines which will meet with the general approval of the various interests of the state, a Conference Committee on Fuel Tests has been appointed consisting of the members named below and representing the organizations indicated:

H. Foster Bain, Director State Geological Survey, Urbana, Ill., representing the State Geological Survey;

A. Bement, Consulting Engineer, Chicago, the Western Society of Engineers;

Edwin H. Cheney, President Fuel Engineering Co., Chicago, the Building Managers' Association of Chicago;

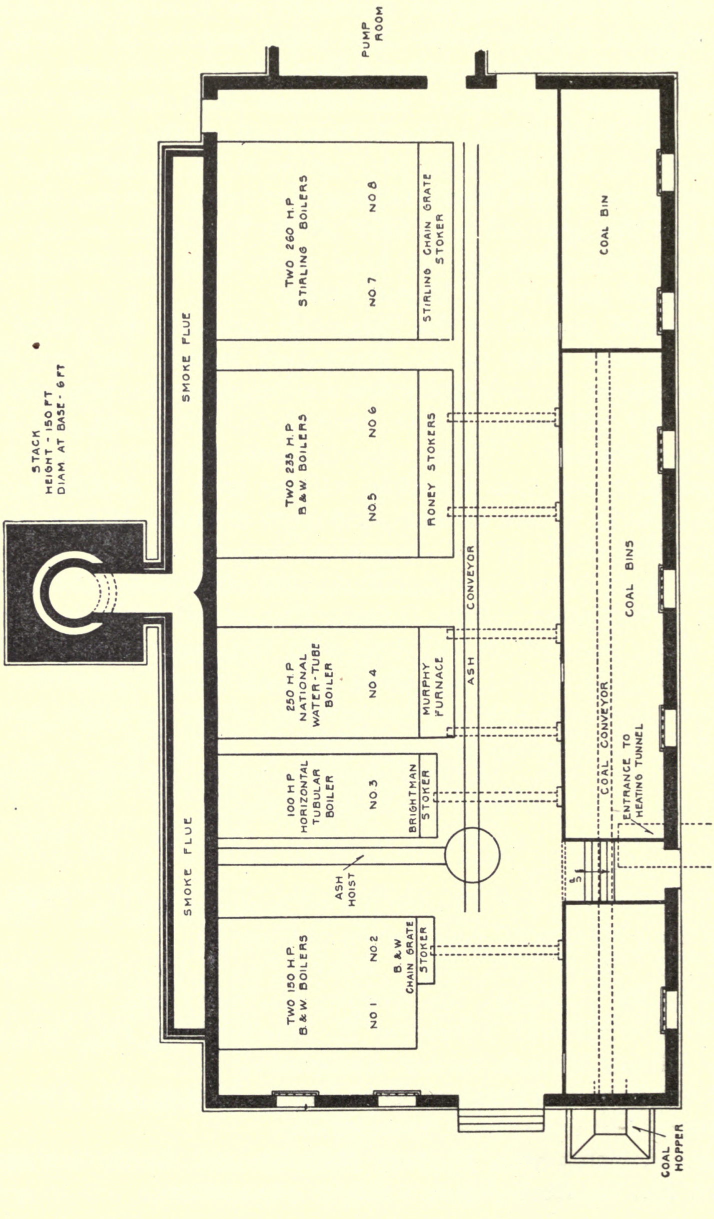
F. H. Clark, Gen. Supt. Motive Power Burlington Road, C. B. & Q. Ry., Chicago, the Western Railway Club;

Adolph Mueller, President H. Mueller Mfg. Co., Decatur, Ill., the Illinois Manufacturers' Association;

Carl Scholz, President Coal Valley Mining Co., Chicago, the Illinois Coal Operators' Association;

A. V. Schroeder, Decatur Railway and Light Company, Decatur, Ill., the State Electric Light Association;

Wm. L. Abbot, Chief Operating Engineer, Chicago Edison Co., Chicago, the Board of Trustees University of Illinois;



PLAN OF CENTRAL HEATING STATION
UNIVERSITY OF ILLINOIS
SCALE 0 5 10 15 FEET

L. P. Breckenridge, Director Engineering Experiment Station, University of Illinois, Urbana, Ill.

Reference has been made to the government fuel tests at St. Louis. It should be stated that the work of the boiler division of these tests has been carried on under the direction of the Director of the Illinois Engineering Experiment Station, who will also have charge of the tests made at the University of Illinois. Copies of Professional Paper No. 48, containing a report on the operations of the government coal testing plant at St. Louis may be obtained upon application to a member of Congress or to the Director of the United States Geological Survey, Washington, D.C.

It is not the intention of this bulletin to discuss the subject of fuel testing. A future bulletin will take up that subject and will also describe in full the plant provided for such tests at this University. Attention is called, however, to the facilities now offered for this important work. It is hoped that mine owners and manufacturers will find it advantageous to cooperate with the Engineering Experiment Station in the proposed tests. The Station Staff will always be glad to receive such suggestions concerning this work as those interested may desire to offer.

VI CHEMICAL ANALYSIS AND HEAT VALUES OF ILLINOIS COALS

By S. W. PARR, Professor of Applied Chemistry

The accompanying results of chemical analyses of Illinois coals may be divided into three classes: first, those which were directly connected with the boiler tests conducted by the department of Mechanical Engineering, and which are listed in a separate table, covering such work from the year 1894 to 1905; second, in connection with thesis work by Mr. F. C. Koch in 1901, there were assembled by him the results of all analyses of Illinois coals which had been made by the department of Chemistry previous to that date. These results were published together with his own work in a bulletin through the courtesy of Secretary Ross of the Bureau of Labor Statistics in the report of that Bureau in 1902. They are designated in the tables by the letters B. L. S. The third series of results comprises the work on one hundred fifty samples of Illinois coal collected in 1904 and published in a separate bulletin in connection with the exhibit of mines and minerals at the St. Louis Exposition. These results are designated in the tables by S. W. P. The sum total of data which has thus resulted, while of a somewhat desultory nature, constitutes a very considerable contribution to our knowledge of the constituents of Illinois coals. It is to be noted that the processes employed in connection with this series were confined almost exclusively to the method of proximate analysis. In the future the more exacting demands of modern methods will require extended data such as are furnished by both proximate and ultimate analysis, including of course the determination of calorific units. It may be well therefore, at the present time, to assemble the information obtainable up to the present date, compiling it as in the accompanying tables, and also to discuss briefly some of the terms which are used in connection with the chemical work on coals. The chemist employs terms and processes which are also used by the engineer, but it does not always follow that their use of terms is in accord.

Moisture.—Moisture in coal is constantly undergoing a change as to quantity. The percentage contained at the time of breaking out the coal from the vein is greater than at any subsequent stage of its history, unless possibly it be under the conditions of rain or snow or drenching with the hose. Some of this moisture which is normally contained in the coal is lost when the coal is exposed to the air, being in this respect like water which has been poured upon the coal. But there remains moisture in the coal after air-drying and which is removed only at the temperature of boiling water. This moisture is described as hygroscopic. If now the chemist works upon a sample which is overcharged with moisture, as is the condition when the sample is freshly mined, it will be constantly losing in weight and modifying his results. Similarly, if he works upon a sample which has been completely dried in the oven, it will have great avidity for moisture and be constantly gaining in weight throughout his work. He, therefore, proceeds in his determinations, as a rule, with the coal in that condition which is least affected by external conditions, viz., in the air-dry state with the normal amount of hygroscopic moisture present, but without the excess of water, which might be termed water of saturation.

Therefore, we have three distinctly different conditions: first, the wet coal; second, the air-dry coal; and third, the oven-dry state. The engineer, however, not having to do with the conditions under which the chemist works, recognizes only the two phases, either the wet or dry, and by this latter term he means the oven-dry state. The failure on the part of the engineer and the chemist to recognize these terms often leads to misinterpretation of results. The chemists, therefore, should agree to such use of terms relating to water as have become firmly established in engineering literature: viz., that dry coal refers to moisture free coal or to the oven-dry state, and second, that wet coal refers to the condition as received or previous to any process of air-drying, and that it is one or the other of these conditions that is of interest to the engineer, regardless of how important it may be to the chemist to proceed upon the basis of the air-dry condition.

It may not be out of place further to indicate how results may be transferred from one basis to the other. It is not an uncommon practice for the chemist to report his results on the air-dry basis, in which case he should also report the amount of moisture lost upon air drying, provided his sample comes to him sealed in such a way as to make this factor possible. Suppose, for example, that the loss of moisture upon air-drying is 4 per cent, then all his results reported on the air-dry basis would be changed to the wet coal basis by multiplying each by 96 per cent; not by dividing by 104 per cent as is often erroneously done. This will make small difference in a constituent which has a low percentage factor, but the error is very considerable in a factor like the fixed carbon which is from 40 to 50 per cent. This may seem like a simple arithmetical problem to mention in this connection, but it is one not always correctly interpreted.

Conversely, if it is desired to change factors to the dry coal basis, each factor should be divided by 100 minus the percentage content of water in that condition from which the transfer is being made. For example, if we are calculating this coal from the *air-dry* state, supposing it to have 6 per cent of moisture present, each factor should be divided by 94 per cent, but it should be noted that if we are calculating from the *wet-coal* condition our divisor will not be 100 per cent minus the sum of the two factors, 6 and 4, as in the above illustration, but 100 minus 96 per cent of 6 plus 4, or 90.24. Here again is a not uncommon place for stumbling in what might seem to be a simple arithmetical problem.

Volatile Matter.—When coal is subjected to high temperature out of contact with the air, a considerable amount is driven off as volatile matter. This includes, also, of course, any moisture in the sample, if we start with a portion which has not been dried in the oven. Now an even greater discrepancy in the use of terms has come into use in connection with this constituent than is the case with different forms of water. One of the oldest terms is that of volatile carbon. This is both incorrect and meaningless because carbon is not volatile, and because the constituents of this material are numerous and complex. The term that is perhaps most frequently met designates this material as volatile combustible. This again is incorrect and misleading, as this material in the ordinary bituminous type of coal has from one-third to one-half of its weight made up of non-combustible material. It is evident, therefore, that the only proper term among those commonly in use for this constituent is that of *volatile matter*. The only restriction indeed in connection with this term is to understand, as is the uniform custom, that the moisture of the coal is not included. A word may be in place here in connection with a term which is occasionally met, and is likely to be more frequently used than formerly. This term is intended to designate that part of the volatile matter which does not burn. This constituent is sometimes referred to as "water of composition". It is not included in any of the results listed in the following tables, and hence its use does not enter into any of the discussions in this bulletin. It is noted in this connection, however, in order that it may not be confused with any of those terms which are intended to designate the water in its ordinary form and which are capable of being driven off at the temperature of boiling water. This property does not belong to the water of composition, as this substance like the other part of the volatile matter, requires a red heat for its dissociation.

Fixed Carbon and Ash.—Concerning these constituents there is no disagreement as to the use of terms unless it be the occasional use of the word coke. Coke in its proper and technical sense should apply to the residue including the ash after subjecting the coal to destructive distillation. It is, therefore, not proper to designate the fixed carbon as coke, though it would be proper, of course, to use the term "coking carbon" in this connection. The preferable term and the one commonly employed, however, for this material is that of fixed carbon.

Methods of Analysis.—The methods of analysis employed are those in common use and their description is so easily accessible that no repetition is necessary here. Reference may be made to the report of the committee of the American Chemical Society on coal analysis.[1]

Calorific Value.—The determination of heat units in coals is, of course, a necessity in connection with any well conducted boiler test. Two systems of units are employed, viz., the kilo calories and the British Thermal Units, designated as B. T. U. Each unit is the measure of heat imparted to the water by an equal weight of coal. They would, therefore, be identical if it were not for the fact that the one is read on the Centigrade scale and the other on the Fahrenheit scale. The transfer, therefore, of calories per kilo over to B. T. U. per pound is effected by multiplying by the ratio of 9:5 or 1.8.

There are four types of instruments in use for measuring the heat value of coals. The first and most elaborate is the Mahler instrument which has numerous modifications as to detail, but which embodies the use of a steel bomb capable of maintaining oxygen from twenty to twenty-five atmospheres pressure. The next in the order of time is the Fisher calorimeter which burns the sample of coal in a small chamber supplied with oxygen at atmospheric pressure. The third type may be designated as the L. Thompson calorimeter, wherein the coal is mixed with a chemical which in itself supplies the oxygen for carrying on the combustion and in which the gaseous products are allowed to bubble up through the water, thus imparting their heat to the liquid. The fourth type may be designated as the Parr calorimeter which also employs a chemical having its own supply of oxygen, but which absorbs the gaseous products, thus retaining all the heat of the reaction for more accurate measurements by the thermometer. Of the second and third types, it may be said that owing either to incompleteness of combustion or to loss of heat by transmission of the gases, results are obtained which are not of sufficient accuracy for reliable work. Results from the Thompson calorimeter are reported by certain authorities to admit of variations amounting to 15 per cent. The Mahler type of calorimeter is accurate when operated by one thoroughly familiar with such processes. The Parr calorimeter is the one used in connection with the analyses in these tables of all coals made since 1900, and is now the instru-

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[1] Jour. Am. Chem. Soc. Vol. XXI. p. 1130.

ment most commonly used in technical work. A brief description of this apparatus follows:

Fig. 13 shows the relative position of parts. The can A.A. for the water has a capacity of 2 litres. The insulating vessels B.B. and C.C. are of indurated fiber. The charge of coal and chemical is put in the cartridge D. Upon ignition, the heat generated is imparted to the water and the rise in temperature is indicated on the finely graduated thermometer T. The cartridge or bomb rests on the pivot F and is made to revolve, and by aid of the small turbine wings attached effects a complete circulation of the water and equalization of temperature.

The reaction accompanying the combustion may be represented by the equation:

$$56Na_2O_2 + C_{25}H_{18}O_3 = 25\ Na_2CO_3 + 18\ NaOH + 22\ Na_2O$$

Sod. perox.   Coal   Sod. carb.   Sod. hydrate   Sod. oxide

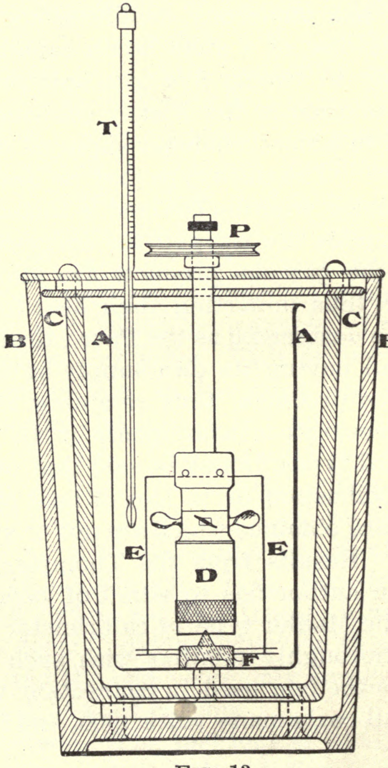

FIG. 13

With certain substances such as coke, anthracites, petroleums, etc., a more strongly or vigorously oxidizing medium is needed than exists in the peroxide alone. This may be secured by various additions. The most effective are: A mixture of potassium chlorate and nitrate in the proportion of 1 to 4 and this mixture used in the ratio of 1 to 10 of the sodium peroxide; another effective mixture is an addition of potassium persulphate in the ratio of 1 to 10 of the sodium peroxide. Other substances facilitate the oxidation, notably ammonium salts and certain organic substances, as tartaric or oxalic acid, benzoic acid, etc. In the work on Illinois coals, while ordinarily no extra chemical would be necessary, still in certain cases, such as extra slaty coals and coals with excessive volatile matter, and also to guard against variations in the quality of the sodium peroxide, a mixture as first described above, of chlorate and nitrate, has uniformly been used throughout these tests.

Further extension of the use of the instrument to other types of coal and to petroleum has made it necessary to extend still further the oxidizing power of the chemicals employed beyond what is afforded by the chlorate mixture. In addition to this the use of the residue for determining the total carbon and sulphur has made it highly desirable in such additional chemicals to avoid the use of compounds containing carbon or sulphur. To meet these conditions, the so-called "boro-mixture" has been devised. It consists of:

Boric acid	11 parts
Potassium chlorate	4 parts
Magnesium powder	1 part

Its correction factor is found by trial with a pure chemical of known heat value, such as napthalene or by burning with a coal whose heat value is already accurately known. This mixture has the further advantage of carrying on a combination with material so low in carbonaceous matter as to be non-burning by ordinary methods, such as ashes and coals of very high ash content.

Still further modifications relate to the bomb as shown in Fig. 14, and have to do mainly with the avoidance of screw threads on the interior of the combustion chamber, especially in the upper part, where particles tend to lodge and thus escape combustion; also in jacketing the lower part of the chamber to avoid direct contact with the water, thereby avoiding rapid cooling of the parts and extending somewhat the period of high temperature, thus securing a more perfect combustion.

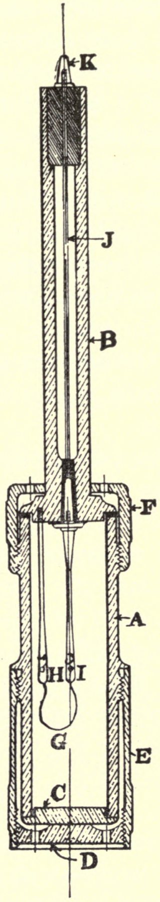

FIG. 14

Calorific Values By Calculation.—Numerous methods for calculating the calorific value of coal have been proposed, but no method can be said to have any value which is not based on a knowledge of the percentage constituents of the total carbon, available hydrogen and sulphur. Even under these conditions the results by calculation are not always in agreement with the indicated results by means of the calorimeter, and in any event, of course, results from proximate analysis do not furnish the necessary data for this calculation. When this method is used the Dulong formula is considered the most nearly accurate and is as follows:

$$\text{Cal.} = 8080 + 34{,}500\ H + 2250\ S$$

In the results here recorded the necessary factors were not always available for applying this formula, but it is the one used wherever calorific values by calculation are included.

TABLE VI CHEMICAL ANALYSIS AND HEATING VALUES OF ILLINOIS COALS USED IN STEAM BOILER TRIALS AT UNIVERSITY OF ILLINOIS 1894-1905

No.	Source of Coal		Description of Coal	Date of Analysis	Boiler Test No.	Proximate Analysis—Air-Dry Coal					B. T. U. per lb. of Total Dry Coal
	County	Town				Fixed Carbon	Volatile Matter	Moisture	Ash	Sulphur	
1	Christian	Pana	Slack	June '94	1	.....	.....	.....	.....	......	......
2	Christian	Pana	Pea	June '94	2	.....	.....	.....	.....	......	......
3	Christian	Pana	Screenings	June '94	3	.....	.....	.....	.....	......	......
4	Christian	Pana	Lump Slack	June '94	4	.....	.....	.....	.....	......	......
5	Coles	Paradise	Lump	Feb. 26 '97	5	48.33	34.56	10.72	6.39	......	11,430
6	Gallatin	Junction	Pea	Mar. 20, '99	43,52	43.52	37.04	9.91	10.33	3.65	......
7	Macon	Niantic	Nut	Jan. 16, '95	7	40.55	34.25	4.44	20.79	......	11,203
8	Macoupin	Mt. Olive	Lump	Feb. '97	8	.....	.....	.....	.....	......	......
9	Madison	Glen Carbon	Lump	May 13, '01	9	40.66	39.13	7.85	12.36	4.87	12,522
10	Marion	Odin	Lump	Apr. '94	10	.....	.....	.....	.....	......	......
11	Marion	Odin	Lump	Apr. '95	11	48.09	34.90	7.10	9.91	......	12,110
12	Marion	Odin	Pea	June '96	12	42.30	37.93	5.09	14.68	......	11,569
13	Marion	Odin	Pea	Oct. 6, '96	13	45.23	41.25	7.28	6.24	......	11,070
14	Marion	Odin	Pea	Jan. 16, '97	14	39.54	31.95	6.48	22.03	......	......
15	Marion	Odin	Lump	Mar. 6, '95	15	44.45	37.73	6.32	11.56	......	......
16	Marion	Odin	Lump	Jan. '95	16	46.02	40.25	6.20	7.53	......	12,665
17	Marion	Odin	Pea	Mar. 14, '99	17	46.70	34.65	6.70	11.95	3.43	......
18	Marion	Odin	Lump	Nov. 14, '96	48	45.10	37.06	8.02	9.83	......	11,880
19	Marion	Odin	Lump	June '94	19	.....	.....	.....	.....	......	......
20	Marion	Odin	Slack	Dec. 9, '96	20	42.26	34.31	8.00	15.43	......	12,130
21	Marion	Odin	Duff	Mar. 28, '05	21	45.14	31.79	7.21	15.86	2.12	11,185
22	Marion	Odin	Pea	Jan. 26, '99	22	46.70	34.65	6.70	11.95	3.43	......
23	McLean	Bloomington	Lump	Jan. '95	23	.....	.....	.....	.....	......	......
24	McLean	Bloomington	Lump	Dec. '94	24	43.50	43.90	3.80	8.80	......	......
25	McLean	Colfax	Lump	May '02	25	42.58	41.35	8.02	8.05	1.80	12,025
26	Menard	Athens	Lump	Mar. '97	26	41.95	35.18	12.11	10.76	......	13,824
27	Perry	Du Quoin	Lump	Oct. '95	27	47.53	35.77	7.59	9.11	......	12,174
28	Perry	Du Quoin	Lump	June 16, '98	28	48.59	33.15	8.13	9.21	......	......
29	Perry	Du Quoin	Slack	Apr. '98	29	41.60	35.95	6.05	16.40	5.14	11,761
30	Perry	Du Quoin	Lump	Feb. '95	30	45.10	39.81	7.43	7.66	......	12,174
31	Perry	Du Quoin	Lump	Feb. '95	31	45.10	39.81	7.43	7.66	......	12,174
32	Perry	Du Quoin	Pea	Mar. 12, '01	32	.....	.....	.....	.....	......	......
33	Sangamon	Barclay	Pea	Apr. '98	33	45.19	38.15	3.76	12.90	......	......
34	Sangamon	Dawson	Pea	Mar 13, '99	34	41.40	33.65	12.54	12.41	5.63	......
35	Sangamon	Dawson	Pea	Mar. 4, '99	35	41.40	33.65	12.54	12.41	5.09	......
36	Sangamon	Divernon	Lump	May 6, '01	36	38.59	34.72	8.69	18.00	6.03	11,239
37	Sangamon	Lowden	Slack	Apr. '04	37	45.02	35.00	6.92	12.55	1.73	11,700
38	Sangamon	Ridgely	Pea	Feb. '99	38	40.04	37.33	9.80	12.83	4.19	......

39	Sangamon........	Riverton..........	Pea...........	Mar. ......'99	39	40.57	36.51	8.83	14 10	4.22	......
40	Sangamon.........	Riverton..........	Pea...........	Jan ......'04	40	33.98	36.27	8.23	21.52	....	9,975
41	Sangamon........	Riverton..........	Pea	Dec. ......'03	41	43.20	36.96	3.38	16.46	1.01	11,152
42	Sangamon.........	Riverton..........	Pea...........	Jan. ......'04	42	43.20	36.96	3.38	16.46	1.01	11,152
43	Sangamon........	Riverton..........	Pea...........	Feb. ......'04	43	43.20	36.96	3.38	16.46	1.01	11,152
44	Sangamon.........	Riverton..........	Pea...........	Mar. ......'04	44	43.20	36.96	3.38	16.46	1.01	11,152
45	Sangamon........	Riverton..........	Pea...........	Jan. ......'04	45	43.20	36.96	3.38	16.46	1.01	11,287
46	Sangamon.........	....	Lump..........	Feb. ......'97	46	40.57	35.44	12.47	11.52	4.10	11,980
47	Sangamon........	....	....	Apr. ......'04	47	43.52	37.04	9.11	10.33	....	11,930
48	Sangamon.........	....	....	Jan. ......'05	48	41.57	36.56	8.79	13.08	3.65	12,162
49	Sangamon........	....	....	Apr. ......'05	49	41.33	32.28	9.19	17.20	3.42	11,537
50	Sangamon........	Springfield........	Pea...........	Apr. ......'01	50	.....	.....	.....	.....	3.76	......
51	Sangamon.........	Springfield........	Pea...........	Apr. ......'01	51	.....	.....	.....	.....	.....	......
52	Sangamon........	Springfield........	Pea...........	Nov. ......'05	52	42.44	36.59	5.42	15.55	.....	12,591
53	Shelby............	Moweaqua........	Lump..........	Jan. 19, '05	53	43.75	39.58	9.18	7.49	6.14	13,026
54	Vermilion..........	Catlin.............	Screenings....	Mar. ......'05	54	43.40	29.62	7.41	19.57	.....	12,369
55	Vermilion..........	Fairmount........	Screenings....	Dec. ..... '96	55	39.85	36.46	10.67	13 02	2.12	12,413
56	Vermilion..........	Muncie...........	Slack.........	Nov. 26, '95	56	.....	.....	.....	.....	.....	......
57	Vermilion..........	Oakwood..........	Lump.........	Mar. ......'05	57	45.13	37.40	6.80	10.67	.....	12,503
58	Vermilion..........	Oakwood..........	Screenings....	Apr. ......'05	58	42.19	35.55	8.24	14.02	3.40	11,427
59	Vermilion..........	Oakwood..........	Screenings....	Apr. ......'05	59	38.88	33.43	6.02	21.67	3.23	10,299
60	Vermilion..........	Oakwood..........	Screenings....	May ......'05	60	41.76	35.25	6.08	16.91	3.21	11,067
61	Vermilion.........	Oakwood..........	Pea...........	Nov. 25, '05	61	41.47	39.85	5.62	13.06	3.14	13,251
62	Williamson........	Carterville........	W. Pea, Duff..	Nov. ......'0[illegible]	62	55.52	32.40	3.33	8.76	3.63	13,408
63	Williamson........	Herrin............	New Ky. Pea..	Apr ......'04	63	53.32	33.10	2.94	10.64	1.97	12,769
64	Williamson........	Herrin............	N. Ky. W. Scr.	Apr. ......'04	64	53.32	33.10	2.94	10.64	1.42	13,156
65	Williamson........	Herrin............	N. Ky. W. Scr.	Feb. ......'04	65	53.26	31.12	5.00	10.62	1.42	12,364

TABLE VII CHEMICAL ANALYSIS AND HEATING VALUES OF ILLINOIS COALS

No.	Source of Sample		Description		Date of Analysis	Analysis Obtained from	Proximate Analysis—Air-Dry Coal					B. T. U. per lb. of total Dry Coal
	County	Town	Size	Geol. Seam			Fixed Carbon	Volatile Matter	Moisture	Ash	Sulphur	
1	Adams	Elm Grove	Drill Core		Mar. 28 '06	Chem. Dept.	47.00	35.83	4.62	12.55	2.45	12,966
2	Adams	Elm Grove	Drill Core		Mar. 28 '06	Chem. Dept.	50.57	36.89	3.52	9.02	2.68	13,915
3	Bureau	Ladd	W. Nut	2	'04	S. W. P. '04	45.67	38.30	7.04	8.99	2.10	12,247
4	Bureau	Ladd	W. Slack	2	'04	S. W. P. '04	46.75	38.61	6.60	8.04	2.70	14,117
5	Bureau	Lombardville	Vein Sample		'78	B. L. S. '02	51.74	31.38	9.42	7.46	2.46	......
6	Bureau	Spring Valley	W. Screen		May '99	B. L. S. '02	39.01	35.58	12.40	13.01	2.81	......
7	Champaign	Ivesdale	Drill Core		Jan '02	B. L. S. '02	49.27	35.89	5.68	9 16	......	12,638
8	Christian	Assumption			'89	B. L. S. '02	50.10	41.20	3.90	4.80	......	13,598
9	Christian	Assumption	Block			B. L. S. '02	47.86	37.76	7.25	7.13	2.94	......
10	Christian	Assumption	Lump			B. L. S. '02	43.56	37.24	7.97	11.23	5.21	......
11	Christian	Assumption	Nut	1	'04	S. W. P. '04	48.16	38.30	8.46	5.08	1.58	13,739
12	Christian	Assumption	Slack	1	'04	S. W. P. '04	43.28	36.26	7.74	12.72	2.60	12,621
13	Christian	Pana			'89	B. L. S. '02	46.95	36.37	7.22	9.46	......	12,513
14	Christian	Pana	Slack		Mar. '98	B. L. S. '02	39.35	35.45	8.55	16.65	4.77	10,727
15	Christian	Pana	Nut		Dec. '02	B. L. S. '02	46.04	39.43	5.30	9.23	......	12,522
16	Christian	Pana	Screen		Apr. 17 '06	Chem. Dept.	39.11	33.75	8.76	18.38	4.10	11,233
17	Christian	Pana	Lump	6	'04	S. W. P. '04	41.28	41.42	9.00	8.30	3.20	12,849
18	Christian	Pana	Slack	6	'04	S. W. P. '04	37.44	35.84	8.06	18.66	3.45	10,915
19	Christian	Pana	Lump	6	'04	S. W. P. '04	39.74	43.72	7.80	8.74	2.96	12,902
20	Clinton	Breese	Slack	6	'04	S. W. P. '04	43.66	34.00	8.10	14.24	3.40	12,181
21	Clinton	Breese	Nut	6	'04	S. W. P. '04	46.96	35.24	8.83	8.97	3.17	12,631
22	Clinton	Buxton	Lump	6	'04	S. W. P. '04	46.21	36.69	7.95	9.15	3.24	12,777
23	Clinton	Trenton	Nut	7	'04	S. W. P. '04	43.05	28.00	8.76	20.19	1.32	11,065
24	Clinton	Trenton	Slack	7	'04	S. W. P. '04	45.27	29.98	9.47	15.28	1.12	11,371
25	Coles	Paradise	Lump		Feb. 26 '97	Chem. Dept.	48.33	34.56	10.72	6.39	......	11,430
26	Crawford	Flatrock			Jan. 10 '05	Chem. Dept.	36.14	35.74	2.22	25.90	2.00	10,699
27	Franklin	Benton	Lump		May 4, '05	Chem. Dept.	51.12	36.23	3.04	9.61	2.62	12,983
28	Fulton	Astoria	Average		Jan. '98	B. L. S. '02	39.40	40.00	12.26	8.34	3.16	12,566
29	Fulton	Astoria	Lump	5	'04	S. W. P. '04	46.67	36.75	7.94	8.46	2.18	12,953
30	Fulton	Astoria	Slack	5	'04	S. W. P. '04	36.24	34.46	9.34	19.96	3.50	11,285
31	Fulton	Canton	Lump	5	'04	S. W. P. '04	38.56	35.98	11.10	14.36	3.67	12,217
32	Fulton	Canton	Nut	5	'04	S. W. P. '04	41.40	38.72	10.00	9.88	2.67	12,825
33	Fulton	Cuba			July '98	B. L. S. '02	40.96	36.93	10.42	11.69	4.60	12,056
34	Fulton	Cuba	Slack	5	'04	S. W. P. '04	43.34	39.19	7.70	9.77	3.10	13,035
35	Fulton	Cuba	Lump	5	'04	S. W. P. '04	41.38	38.26	9.23	11.14	1.50	12,622
36	Fulton	Cuba	Lump	5	'04	S. W. P. '04	43.26	41.01	5.55	10.18	2.22	12,905
37	Fulton	Cuba	Slack	5	'04	S. W. P. '04	40.71	36.33	7.28	15.68	3.35	11,988
38	Fulton	Dunfermline			June '98	B. L. S. '02	36.54	34.80	10.95	17.71	3.13	11,623
39	Fulton	Farmington			July '98	B. L. S. '02	36.50	35.93	11.12	16.25	3.98	11,847
40	Fulton	Farmington	Vein Sample		'78	B. L. S. '02	50.48	29.28	8.52	11.72	3.28	......
41	Fulton	Farmington	Lump	5	'04	S. W. P. '04	41.79	35.75	10.25	12.21	1.97	12,497
42	Fulton	Farmington	Slack	5	'04	S. W. P. '04	37.16	33.04	9.62	20.18	3.02	11,234
43	Fulton	Fiatt			July '98	B. L. S. '02	40.04	35.86	12.54	11.56	4.67	12,451

44	Fulton	Norris	Lump	5	'04	S. W. P. '04	40.84	33.20	11.78	14.18	1.93	11,767
45	Fulton	Norris	Slack	5	'04	S. W. P. '04	37.18	33.68	9.44	19.70	1.98	11,379
46	Fulton	St. David	Nut No. 2		Feb. 28, '06	Chem. Dept.	41.94	36.43	10.25	11.38	2.63	12,061
47	Fulton	St. David	Drill Core		May 12, '06	Chem. Dept.	50.96	40.21	3.08	5.75	3.23	13,941
48	Fulton	St. David	Drill Core		May 12, '06	Chem. Dept.	48.06	39.05	2.90	9.99	6.80	12,588
49	Gallatin	Junction	Pea		Mar. 20, '99	Chem. Dept.	43.52	37.04	9.11	10.33	3.65	......
50	Grundy	Braceville	Slack	2	'04	S. W. P. '04	32.24	26.88	9.70	31.18	3.55	9,574
51	Grundy	Braceville	Lump	2	'04	S. W. P. '04	46.80	37.32	11.86	4.02	2.18	13,797
52	Grundy	S. Wilmington	Slack	2	'04	S. W. P. '04	34.01	28.84	7.80	29.35	3.98	9,847
53	Grundy	S. Wilmington	Lump	2	'04	S. W. P. '04	46.11	37.09	11.44	5.36	2.10	13,531
54	Hamilton	Delafield	Drill Core		Jan. 31, '06	Chem. Dept.	48.01	38.46	.31	13.22	3.20	12,967
55	Hamilton	McLeansboro			July '05	Chem. Dept.	50.51	34.34	5.04	10.11	2.77	13,402
56	Hancock	Augusta			July '98	B. L. S. '02	41.32	44.37	10.78	3.53	2.48	13,164
57	Henry	Briar Bluff	Vein Sample		'78	B. L. S. '02	48.54	28.96	12.60	9.90	4.62	......
58	Henry	Galva			Oct. '98	B. L. S. '02	36.54	36.72	10.39	16.35	3.26	11,249
59	Henry	Kewanee	Vein Sample		'78	B. L. S. '02	49.66	27.60	15.60	7.14	2.22	......
60	Henry	Kewanee	Nut	6	'04	S. W. P. '04	45.87	37.33	10.16	6.64	2.50	12,560
61	Henry	Kewanee	Slack	6	'04	S. W. P. '04	44.99	37.99	9.99	7.03	2.57	12,523
62	Jackson	Carbondale	Vein Sample		'78	B. L. S. '02	59.88	26.40	6.32	7.40	.80	13.154
63	Jackson	Carbondale				B. L. S. '02	57.50	33.65	4.25	4.60	....	13.140
64	Jackson	Carbondale			May '96	B. L. S. '02	46.22	39.78	6.08	7.92	....	11,787
65	Jackson	Carbondale			May '96	B. L. S. '02	49.12	34.10	6.18	10.60	....	12,183
66	Jackson	De Soto	Mine Run		Nov. '99	B. L. S. '02	51.18	34.08	4.32	10.42	1.46	......
67	Jackson	De Soto	No. 1 W		Nov. '99	B. L. S. '02	52.04	34.63	5.27	8.06	1.73	......
68	Jackson	De Soto	No. 2 W		Nov. '99	B. L. S. '02	51.62	35.72	4.34	8.32	2.03	......
69	Jackson	De Soto	No. 3 W		Nov. '99	B. L. S. '02	49.40	36.76	4.32	9.52	1.70	......
70	Jackson	De Soto	No. 4 W		Nov. '99	B. L. S. '02	52.46	35.77	3.82	7.95	2.98	......
71	Jackson	De Soto	Refuse From Water		Nov. '99	B. L. S. '02	28.65	22.71	2.88	45.76	2.80	......
72	Jackson	Mt. Carbon	Vein Sample		'78	B. L. S. '02	66.58	24.68	6.12	2.70	.60	13,535
73	Jackson	Murphysboro	Lump		Mar. '00	B. L. S. '02	56.37	35.61	3.26	4.76	.76	......
74	Jackson	Murphysboro	Lump	1	'04	S. W. P. '04	56.03	34.62	4.96	4.39	.62	13,978
75	Jackson	Murphysboro	Lump	1	'04	S. W. P. '04	54.78	34.29	6.21	4.72	.62	13,955
76	Knox	Etherly	Lump	6	'04	S. W. P. '04	42.74	36.66	12.74	7.86	1.56	12,816
77	Knox	Etherly	Slack	6	'04	S. W. P. '04	33.65	31.19	10.16	25.00	2.48	10,218
78	Knox	Soperville	Drill Core		Feb. 21, '06	Chem. Dept.	46.46	42.51	5.17	5.86	2.97	12,945
79	La Salle	Kangley	Lump	7	'04	S. W. P. '04	44.88	38.94	7.68	8.50	3.24	13,258
80	La Salle	Kangley	Slack	7	'04	S. W. P. '04	38.54	33.05	5.81	22.60	4.96	11,137
81	La Salle	La Salle	Lump	2	'04	S. W. P. '04	42.06	45.30	7.54	5.10	3.04	13,476
82	La Salle	La Salle	Slack	2	'04	S. W. P. '04	39.02	38.91	7.87	14.20	3.35	11,821
83	La Salle	La Salle	Pea	2	'04	S. W. P. '04	42.58	41.78	7.56	8.08	3.92	13,046
84	La Salle	La Salle			'89	B. L. S. '02	43.95	39.40	8.22	8.43	....	13,259
85	La Salle	Oglesby	2nd Vein	2	'78	B. L. S. '02	49.32	30.84	12.12	7.72	2.02	......
86	La Salle	Oglesby	3rd Vein	3	'78	B. L. S. '02	55.88	30.34	10.06	3.72	2.27	......
87	La Salle	Oglesby	Egg	2	'04	S. W. P. '04	43.60	42.03	10.28	4.09	2.62	13,185
88	La Salle	Oglesby	Slack	2	'04	S. W. P. '04	38.26	35.92	8.28	17.54	4.66	11,253
89	La Salle	Peru			'89	B. L. S. '02	47.20	37.19	9.00	6.61	....	12,999
90	La Salle	Peru	Vein Sample	2,3	'78	B. L. S. '02	51.26	33.90	10.30	4.54	3.05	......
91	La Salle	Streator	Slack	2	'04	S. W. P. '04	43.52	36.03	8.47	11.98	4.30	12,474
92	La Salle	Streator	Lump	2	'04	S. W. P. '04	45.85	39.84	7.96	6.35	3.38	13,597
93	La Salle	Streator	Slack	7	'04	S. W. P. '04	44.81	38.74	6.88	9.57	3.66	13,096
94	La Salle	Streator	Lump	7	'04	S. W. P. '04	46.98	42.10	5.52	5.40	3.07	13,824

TABLE VII (*Continued*)

No.	Source of Sample: County	Source of Sample: Town	Description: Size	Description: Geol. Seam	Date of Analysis	Analysis Obtained from	Proximate Analysis of Illinois Coal: Fixed Carbon	Volatile Matter	Moisture	Ash	Sulphur	B. T. U. per lb. of Total Dry Coal
95	Livingston..	Cardiff.........	Lump	2	..........'04	S. W. P. '04...	44.52	39.36	11.28	4.84	2.41	13,301
96	Livingston..	Cardiff..........	Slack	2	..........'04	S. W. P. '04...	41.18	36.54	10.26	12.02	2.96	12,053
97	Livingston..	Fairbury.......	Slack	5	..........'04	S. W. P. '04 ..	39.44	33.76	5.30	21.50	4.36	10,870
98	Livingston..	Fairbury.......	Lump	5	..........'04	S. W. P. '04...	43.67	39.07	6.57	10.69	2.20	12,999
99	Livingston..	Forest..........	Drill Core.....	1	Oct. ......'98	B. L. S. '02...	42.99	39.37	5.19	12.45	2.81	......
100	Livingston..	Forest..........	Drill Core.....	2	Oct. ......'98	B. L. S. '02...	40.04	44.83	4.36	10.77	3.76	......
101	Logan.......	Lincoln	....	......	....	B. L. S. '02...	46.88	34.19	8.36	10.57	2.59	......
102	Logan.......	Lincoln	....	......	..........'89	B. L. S. '02...	44.55	34.99	8.45	12.06	....	12,312
103	Logan.......	Lincoln	....	......	..........'89	B. L. S. '02...	49.50	31.30	7.50	11.70	....	12,668
104	Logan.......	Lincoln	Vein Sample..	......	..........'78	B. L. S. '02...	46.64	27.60	10.92	14.84	4.99	......
105	Logan.......	Lincoln	Lump	5	..........'04	S. W. P. '04...	37.58	36.78	10.64	15.00	3.17	12,161
106	Logan.......	Lincoln	Nut............	5	..........'04	S. W. P. '04...	42.10	38.88	10.44	8.58	2.44	12,247
107	Logan.......	Mt. Pulaski....	Lump	5	..........'04	S. W. P. '04...	42.28	33.64	11.98	12.10	2.73	12,308
108	Logan.......	Mt. Pulaski....	....	......	....	B. L. S. '02...	46.53	35.82	7.68	9.97	....	12 305
109	McDonough.	Colchester	....	......	July......'98	B. L. S. '02...	40.09	34.07	9.04	16.80	1.16	11,653
110	McLean......	Bloomington ...	Vein Sample..	......	..........'78	B. L. S. '02...	53.12	34.02	7.90	4.96	1.97	13,375
111	McLean	Bloomington ...	Lump	......	..........'96	B. L. S. '02...	43.50	43.90	3.80	8.80	....	12,443
112	McLean	Bloomington ...	....	......	..........'89	B. L. S. '02...	45.20	35.99	4.10	14.71	....	11,797
113	McLean	Bloomington ...	Slack..........	2	..........'04	S. W. P. '04...	35.63	34.05	6.77	23.55	4.14	10,884
114	McLean	Bloomington ...	Lump	2	..........'04	S. W. P. '04...	40.60	40.06	7.56	11.78	3.14	12,680
115	McLean	Bloomington ...	Slack..........	3	..........'04	S. W. P. '04...	39.84	38.06	5.64	16.46	3.10	12,069
116	McLean	Bloomington ...	Lump	3	..........'04	S. W. P. '04...	43.84	44.06	6.98	5.12	2.48	13,751
117	McLean	Colfax..........	Lump	......	May .....'02	Chem. Dept...	42.58	41.35	8.02	8.05	1.80	12,025
118	Macon.......	Decatur	Lump	5	..........'04	S. W. P. '04...	44.97	38.56	8.46	8.01	2.13	12,264
119	Macon.......	Niantic.........	Nut............	5	..........'04	S. W. P. '04...	44.01	36.47	10.38	9.14	3.27	12,056
120	Macon.......	Niantic.........	Slack..........	5	..........'04	S. W. P. '04...	39.32	34.51	11.01	15.16	3.35	11,175
121	Macon.......	Niantic.........	Nut............	......	Jan. 16 '95	B. L. S. '02...	40.55	34.25	4.44	20.79	....	11,203
122	Macon.......	Niantic.........	....	......	..........'89	B. L. S. '02...	47.80	36.25	7.88	8.47	....	12,515
123	Macon.......	Niantic.........	....	......	..........'89	B. L. S. '02...	45.50	34.15	11.85	8.50	....	13,079
124	Macoupin ...	Brighton.......	Lump	......	Dec. 30, '04	Chem. Dept...	49.54	35.43	7.87	7.16	2.68	13,230
125	Macoupin ...	Green Ridge ...	Lump	6	..........'04	S. W. P. '04...	44.50	39.96	10.24	5.30	1.98	13,581
126	Macoupin ...	Green Ridge ...	Slack..........	6	..........'04	S. W. P. '04...	37.50	32.98	8.38	21.14	3.00	10,990
127	Macoupin ...	Mt. Olive.......	Lump	6	..........'04	S. W. P. '04...	43.78	42.39	9.30	4.53	3.80	13,066
128	Macoupin ...	Mt. Olive.......	Slack..........	6	..........'04	S. W. P. '04 ..	41.62	34.21	9.62	14.55	3.86	11,433
139	Macoupin ...	Mt. Olive.......	....	......	..........'89	B. L. S. '02...	44.49	36.43	7.97	11.11	...	12,432
130	Macoupin ...	Mt. Olive.......	....	......	..........'89	B. L. S. '02...	51.50	35.00	5.30	8.20	....	12,431
131	Macoupin ...	Mt. Olive.......	....	......	Feb......'95	B. L. S. '02...	44.51	38.59	7.99	8.91	. ..	......
132	Macoupin ...	Mt. Olive.......	Lump	......	May .....'01	B. L. S. '02...	40.22	38.33	9.63	11.82	6.78	12,252
123	Macoupin ...	Palmyra	Drill Core.....	......	Feb. 9, '05	Chem. Dept...	51.30	35.28	6.63	6.79	2.44	13,024
134	Macoupin ...	Palmyra	Drill Core.....	......	Feb. 9 '05	Chem. Dept...	49.44	35.82	6.39	8.35	4.13	13,063
135	Macoupin ...	Palmyra	Drill Core.....	......	Feb. 9 '05	Chem. Dept...	42.07	42.26	6.22	9.45	2.48	12,818
136	Macoupin ...	Virden	Nut............	6	..........'04	S. W. P. '04 ...	43.40	38.25	10.27	8.08	1.50	12,826
137	Macoupin ...	Virden	Slack..........	6	..........'04	S. W. P. '04 ...	42.32	37.60	10.21	9.87	2.80	12,184

138	Madison	Collinsville	Nut	6	'04	S. W. P. '04	42.34	38.34	8.26	11.06	3.09	12,802
139	Madison	Collinsville	Pea	6	'04	S. W. P. '04	38.67	35.91	7.74	17.68	4.08	11,440
140	Madison	Donkville	W. Nut	6	'04	S. W. P. '04	44.66	39.86	8.08	7.40	3.00	13,059
141	Madison	Donkville	W. Pea	6	'04	S. W. P. '04	45.53	40.83	4.87	8.77	2.96	12,997
142	Madison	Edwardsville	Nut	6	'04	S. W. P. '04	40.91	36.93	7.76	14.40	4.74	11,928
143	Madison	Edwardsville	Slack	6	'04	S. W. P. '04	39.33	36.37	8.54	15.76	4.00	11,895
144	Madison	Glen Carbon	Lump	......	May '01	B. L. S. '02	40.66	39.13	7.85	12.36	4.87	12,522
145	Marion	Centralia	......	......	'89	B. L. S. '02	45.50	38.18	8.28	8.04	....	......
146	Marion	Centralia	Duff	......	......	B. L. S. '02	36.00	36.10	1.50	26.40	4.04	......
147	Marion	Centralia	Slack	6	'04	S. W. P. '04	40.76	34.13	6.75	18.36	4.36	11,620
148	Marion	Centralia	Nut	6	'04	S. W. P. '04	43.99	38.17	5.43	12.41	3.60	12,327
149	Marion	Kinmundy	......	......	'97	B. L. S. '02	42.78	33.63	6.15	17.44	7.25	......
150	Marion	Kinmundy	......	......	......	B. L. S. '02	47.45	34.00	7.00	11.15	....	12,542
151	Marion	Odin	Lump	......	Jan. '95	B. L. S. '02	46.02	40.25	6.20	7.53	....	12,665
152	Marion	Odin	Lump	......	Feb. '95	B. L. S. '02	44.45	37.73	6.32	11.50	....	......
153	Marion	Odin	Lump	......	Apr. '95	B. L. S. '02	48.09	34.90	7.10	9.91	....	12,110
154	Marion	Odin	Pea	......	July '96	B. L. S. '02	42.30	37.93	5.09	14.68	....	11,569
155	Marion	Odin	Pea	......	Oct. '96	B. L. S. '02	45.23	41.25	7.28	6.24	....	12,619
156	Marion	Odin	Lump	......	Nov. '96	B. L. S. '02	45.77	40.76	7.24	6.23	....	11,195
157	Marion	Odin	Lump	......	Nov. '96	B. L. S. '02	45.57	38.39	7.92	8.12	....	13,293
158	Marion	Odin	Lump	......	Nov. '96	B. L. S. '02	44.62	35.73	8.11	11.54	....	12,537
159	Marion	Odin	Slack	......	Dec. '96	B. L. S. '02	42.26	34.31	8.00	15.43	....	12,609
160	Marion	Odin	Lump	......	Jan. '97	B. L. S. '02	47.35	38.30	3.50	10.85	....	12,777
161	Marion	Odin	Pea	......	Jan. '97	B. L. S. '02	44.23	36.22	4.20	15.35	....	12,307
162	Marion	Odin	Lump	......	Feb. '97	B. L. S. '02	41.85	34.07	8.42	15.70	....	12,874
163	Marion	Odin	Lump	......	Feb. '97	B. L. S. '02	44.15	36.10	8.55	11.20	....	12,597
164	Marion	Odin	Pea	......	Mar. '97	B. L. S. '02	42.44	35.43	7.71	14.42	....	12,482
165	Marion	Odin	Pea	......	Mar. '98	B. L. S. '02	42.23	38.17	7.25	11.35	3.61	11,741
166	Marion	Odin	......	......	Mar. '95	B. L. S. '02	44.45	37.73	6.32	11.50	....	11,684
167	Marion	Odin	Pea	......	Mar. '97	B. L. S. '02	39.54	31.95	6.48	22.03	....	......
168	Marion	Odin	Pea	......	Mar. '99	B. L. S. '02	46.70	34.65	6.70	11.95	3.43	......
169	Marion	Odin	Pea	......	'99	B. L. S. '02	46.05	33.78	4.70	15.47	4.80	......
170	Marion	Odin	......	......	'89	B. L. S. '02	50.86	33.99	6.07	9.08	....	12,726
171	Marion	Odin	Lump	......	Feb. '96	B. L. S. '02	47.22	36.46	9.10	7.22	....	12,574
172	Marion	Odin	......	......	'89	B. L. S. '02	46.90	41.10	5.90	6.10	....	13,457
173	Marion	Odin	Pea	......	'97	B. L. S. '02	39.54	31.95	6.48	22.03	4.31	......
174	Marion	Odin	Lump	......	'97	B. L. S. '02	44.23	37.05	6.81	11.91	2.68	......
175	Marion	Odin	Pea	......	May '00	B. L. S. '02	42.96	35.76	7.27	14.01	3.88	12,072
176	Marion	Odin	Nut	6	'04	S. W. P., '04	44.55	37.11	8.52	9.82	3.00	12,175
177	Marion	Odin	Slack	6	'04	S. W. P., '04	40.97	36.16	6.92	15.95	3.80	11,566
178	Marion	Odin	Duff	......	Mar. 28, '05	Chem. Dept.	45.14	31.79	7.21	15.86	2.12	11,185
179	Marion	Sandoval	Vein Sample	......	Oct. 30, '05	Chem. Dept.	45.89	36.41	5.03	12.67	8.05	12,249
180	Marion	Sandoval	Lump	6	'04	S. W. P., '04	45.74	36.81	5.51	11.94	2.60	12,721
181	Marion	Sandoval	......	......	'89	B. L. S., '02	50.86	35.07	7.19	6.88	....	12,885
182	Marshall	Toluca	......	......	July '98	B. L. S., '02	41.32	33.07	8.95	16.66	4.64	11,861
183	Marshall	Wenona	Lump	2	'04	S. W. P., '04	50.15	36.59	10.94	2.32	.79	13,630
184	Marshall	Wenona	Slack	2	'04	S. W. P., '04	43.06	33.49	10.31	13.14	2.67	12,230
185	Menard	Athens	Lump	5	'04	S. W. P., '04	42.32	39.32	9.32	9.04	4.44	12,685
186	Menard	Athens	Slack	5	'04	S. W. P., '04	38.46	34.82	10.10	16.62	4.20	11,444
187	Menard	Athens	......	......	'97	B. L. S. '02	43.60	35.57	10.01	10.82	2.40	......
188	Menard	Athens	......	......	Mar. '97	B. L. S. '02	41.95	35.18	12.11	10.76	....	13,824
189	Menard	Greenview	......	......	July '00	B. L. S., '02	41.21	39.20	10.94	8.65	3.15	12,443

TABLE VII (*Continued*)

No.	Source of Sample		Description		Date of Analysis	Analysis Obtained from	Proximate Analysis—Air-Dry Coal					B. T. U. per lb. of Total Dry Coal
	County	Town	Size	Geol. Seam			Fixed Carbon	Volatile Matter	Moisture	Ash	Sulphur	
190	Menard	Greenview	Lump	5	'04	S. W. P., '04	44.81	37.62	9.46	8.11	2.41	12,757
191	Menard	Greenview	Slack	5	'04	S. W. P., '04	39.88	36.28	9.58	14.26	3.04	11,863
192	Menard	Middletown	Lump	5	'04	S. W. P., '04	43.17	36.89	10.04	9.90	2.43	12,550
193	Menard	Middletown	Slack	5	'04	S. W. P., '04	37.31	33.12	10.37	19.20	3.13	10,933
194	Menard	Petersburg	Slack		Dec. 17, '04	Chem. Dept.	39.54	33.32	4.69	22.45	5.68	10,806
195	Menard	Petersburg	Lump		Dec. 17, '04	Chem. Dept.	50.89	35.04	6.30	7.77	2.40	13,027
196	Mercer	Cable	Lump	1	'04	S. W. P., '04	40.78	39.34	9.02	10.86	3.93	12,588
197	Mercer	Cable	Slack	1	'04	S. W. P., '04	41.43	37.77	9.02	11.78	4.00	12,508
198	Mercer	Gilchrist			July, '98	B. L. S., '02	35.32	36.94	7.48	20.26	4.86	11,479
199	Mercer	Sherrard	Lump	1	'04	S. W. P., '04	42.22	39.36	9.60	8.82	3.02	13,136
200	Mercer	Sherrard	Slack	1	'04	S. W. P., '04	37.05	36.72	7.84	18.39	4.78	11,004
201	Montgomery	Litchfield	Slack	2	'04	S. W. P., '04	41.88	36.34	7.94	13.84	3.10	12,104
202	Montgomery	Litchfield	Lump	2	'04	S. W. P., '04	46.08	38.74	9.22	5.96	1.77	13,329
203	Peoria	Elmwood			July, '98	B. L. S., '02	40.76	44.45	9.38	5.41	2.61	13,606
204	Peoria	Elmwood	Vein Sample	3	July, '98	B. L. S., '02	41.30	43.63	8.70	6.37	2.75	13,603
205	Peoria	Elmwood	Vein Sample	5	July, '98	B. L. S., '02	42.30	26.78	10.55	10.37	1.29	12,879
206	Peoria	Elmwood	Vein Sample	6	July, '98	B. L. S., '02	43.90	35.50	9.30	11.30	3.16	12,403
207	Peoria	Elmwood	Vein Sample		'78	B. L. S., '02	55.30	27.60	7.60	9.50	2.18	......
208	Peoria	Holles	Lump	2	'04	S. W. P., '04	41.80	42.66	7.86	7.68	2.41	12,893
209	Peoria	Holles	Nut	2	'04	S. W. P., '04	43.03	41.13	8.04	7.80	3.13	12,956
210	Perry	Du Quoin	Lump		June 16, '98	Chem. Dept.	48.59	33.15	8.13	9.21	....	......
211	Perry	Du Quoin			'97	B. L. S. '02	49.51	33.15	8.13	9.21	.83	......
212	Perry	Du Quoin	Vein Sample		'78	B. L. S. '02	60.60	23.54	8.86	7.00	1.88	12,355
213	Perry	Du Quoin				B. L. S. '02	44.60	35.03	7.03	13.34	....	11,820
214	Perry	Du Quoin				B. L. S. '02	53.69	32.03	6.84	7.44	....	13,064
215	Perry	Du Quoin				B. L. S. '02	54.08	30.35	6.67	8.90	....	13,279
216	Perry	Du Quoin	Lump		Feb. '95	B. L. S. '02	45.10	39.81	7.43	7.66	....	......
217	Perry	Du Quoin	Lump		Sept. '95	B. L. S. '02	47.53	35.77	7.59	9.11	....	12,174
218	Perry	Du Quoin	Lump		June '96	B. L. S. '02	50.85	34.61	9.14	5.40	....	13,273
219	Perry	Du Quoin	Slack		May '98	B. L. S. '02	41.60	35.95	6.05	16.40	5.14	11,762
220	Perry	Du Quoin			Jan. '95	B. L. S. '02	44.56	35.03	7.02	13.39	....	11,819
221	Perry	Du Quoin	Nut	6	'04	S. W. P. '04	49.07	35.97	8.44	6.52	1.82	13,055
222	Perry	Du Quoin	Nut	6	'04	S. W. P. '04	44.00	38.72	7.24	10.04	3.04	12,710
223	Perry	DuQuoin	Lump		Mar. 27, '06	Chem. Dept.	48.45	34.28	7.15	10.12	.71	12,248
224	Perry	Muddy Valley	Lump		July '96	B. L. S. '02	48.23	40.37	7.11	4.29	....	12,790
225	Perry	Pinckneyville	Lump	6	'04	S. W. P. '04	45.96	39.20	7.54	7.30	1.88	13,067
226	Perry	Pinckneyville	Slack	6	'04	S. W. P. '04	39.16	31.36	7.26	22.22	3.10	10,784
227	Perry	St. John	Lump		July '96	B. L. S. '02	51.10	37.00	9.63	2.27	....	13,245
228	Perry	St. John	Lump		Feb. '97	B. L. S. '02	48.34	34.56	10.72	6.38	....	13,104
229	Randolph	Sparta	Lump	6	'04	S. W. P. '04	46.28	37.64	7.44	8.64	2.40	12,738
230	Randolph	Sparta	Nut	6	'04	S. W. P. '04	47.23	36.75	7.09	8.93	3.45	12,744
231	Randolph	Tilden	Slack	6	'04	S. W. P. '04	44.98	34.70	7.17	13.15	3.13	12,313

232	Randolph	Tilden	Lump	6	'04	S. W. P. '04	46.53	37.06	8.68	7.73	3.07	12,620
233	St. Clair	French Village	Lump	6	'04	S. W. P. '04	42.24	41.30	8.08	8.38	3.35	12,564
234	St. Clair	French Village	Slack	6	'04	S. W. P. '04	40.23	35.44	8.12	16.21	4.00	11,443
235	St. Clair	Marissa	Lump	6	'04	S. W. P. '04	44.10	40.78	7.78	7.34	3.23	12,670
236	St. Clair	Marissa	Slack	6	'04	S. W. P. '04	41.21	37.87	7.15	13.77	3.93	11,760
237	St. Clair	Marissa	Nut		Feb. 22 '05	Chem. Dept.	48.45	33.35	3.92	14.28	3.00	12,074
238	St. Clair	Marissa	Lump		Apr. 1 '05	Chem. Dept.	56.79	31.90	5.67	5.64	1.53	13,305
239	Saline	Eldorado	Lump	5	'04	S. W. P. '04	52.10	33.32	5.68	8.90	1.18	13,431
240	Saline	Eldorado	Slack	5	'04	S. W. P. '04	42.70	29.36	4.36	23.58	2.00	10,874
241	Saline	Eldorado	Lump	7	'04	S. W. P. '04	49.72	34.36	5.04	10.88	4.00	12,825
242	Saline	Eldorado	Slack	7	'04	S. W. P. '04	44.34	30.78	4.00	20.88	3.70	11,379
243	Saline	Eldorado	Lump		Apr. '04	Chem. Dept.	55.27	34.75	2.31	7.67	.53	12,978
244	Saline	Galatia			July '05	Chem. Dept.	48.73	33.91	5.44	11.92	2.96	13,009
245	Saline	Harrisburg	Lump		Apr. 26, '05	Chem. Dept.	56.39	31.12	6.01	6.48	.48	13,603
246	Saline	Harrisburg	Lump		Apr. 1, '05	Chem. Dept.	56.29	34.06	4.29	5.36	1.15	14,113
247	Saline	Harrisburg	Lump	5	'04	S. W. P. '04	53.18	37.12	4.20	5.50	1.64	13,886
248	Saline	Harrisburg	Lump	5	'04	S. W. P. '04	53.12	36.11	3.76	7.01	1.81	13,665
249	Saline	Harrisburg	Slack	5	'04	S. W. P. '04	47.36	33.14	3.70	15.80	2.40	10,993
250	Saline	Harrisburg	Lump	5	'04	S. W. P. '04	51.97	37.17	4.10	6.76	1.55	13,503
251	Saline	Harrisburg	Slack	5	'04	S. W. P. '04	48.28	32.72	4.72	14.28	2.70	11,913
252	Sangamon	Auburn	Lump	6	'04	S. W. P. '04	42.91	38.96	10.46	7.67	2.60	13,022
253	Sangamon	Auburn	Slack	6	'04	S. W. P. '04	39.75	34.50	9.38	16.37	3.50	11,602
254	Sangamon	Auburn	Nut	6	04	S. W. P. '04	43.60	39.52	6.46	10.42	2.73	12,228
255	Sangamon	Auburn	Slack	6	04	S. W. P. '04	40.00	35.78	10.10	14.12	3.02	11,831
256	Sangamon	Barclay				B. L. S. '02	46.20	35.70	7.40	10.70	....	12,100
257	Sangamon	Barclay	Vein Sample		'78	B. L. S. '02	45.60	27.32	10.08	17.00	3.21	.....
258	Sangamon	Barclay	Pea		Apr. '98	Chem. Dept.	45.19	38.15	3.76	12.90	....	.....
259	Sangamon	Cantrall	Nut	5	'04	S. W. P. '04	43.45	38.31	10.02	8.22	1.54	12,821
260	Sangamon	Cantrall	Slack	5	'04	S. W. P. '04	40.78	36.94	9.64	12.64	3.45	12,095
261	Sangamon	Dawson	Nut	5	'04	S. W. P. '04	43.41	34.10	12.56	9.93	2.14	12.699
262	Sangamon	Dawson	Slack	5	'04	S. W. P. '04	42.44	29.18	11.44	16.94	3.13	11,319
263	Sangamon	Dawson	Pea		Mar. 4, '99	B. L. S. '02	41.40	33.65	12.54	12.41	5.09	.....
264	Sangamon	Dawson	Pea		'99	B. L. S. '02	43.17	35.25	9.38	12.20	2.83	.....
265	Sangamon	Divernon	Lump		May '01	B. L. S. '02	38.59	34.72	8.69	18.00	6.03	11,239
266	Sangamon	Lowder	Slack		Apr. '04	Chem. Dept.	45.02	35.00	6.92	12.55	1.73	11,700
267	Sangamon	Ridgely			Feb. '99	B. L. S. '02	41.44	36.94	9.41	12.21	4.09	.....
268	Sangamon	Ridgely	Pea		Mar. '99	B. L. S. '02	40.04	37.33	9.80	12.83	4.19	.....
269	Sangamon	Riverton			'89	B. L. S. '02	48.45	35.39	6.38	9.78	....	12,426
270	Sangamon	Riverton			'89	B. L. S. '02	44.30	38.45	11.10	6.15	....	13,606
271	Sangamon	Riverton	Pea		Mar. '99	B. L. S. '02	40.56	36.51	8.83	14.10	4.22	.....
272	Sangamon	Riverton	Slack	5	'01	S. W. P. '04	43.20	36.96	3.38	16.46	4.10	11,818
273	Sangamon	Riverton	Pea		Jan. '04	Chem. Dept.	33.98	36.27	8.23	21.52	....	10,870
274	Sangamon	Riverton	Pea		Dec. '03	Chem. Dept.	43.20	36.96	3.38	16.46	1.01	11,542
275	Sangamon	Spaulding	Lump		Feb. '97	B. L. S. '02	40.57	35.44	12.47	11.52	....	12,544
276	Sangamon	Springfield			'97	B. L. S. '02	41.68	35.89	10.45	11.98	2.99	.....
277	Sangamon	Springfield	Lump	5	'04	S. W. P. '04	47.28	36.64	4.74	11.34	2.90	12,571
278	Sangamon	Springfield	Lump	5	'04	S. W. P. '04	38.64	37.08	11.32	12.96	3.90	12,032
279	Sangamon	Springfield	Slack	5	'04	S. W. P. '04	41.74	34.54	11.56	12.16	4.08	12,217
280	Sangamon	Springfield	Pea		Nov. '05	Chem. Dept.	42.44	36.59	5.42	15.55	6.14	12,591
281	Sangamon	Springfield			Sep. 23, '05	Chem. Dept.	44.52	35.15	8.55	11.78	3.55	12,364
282	Sangamon	Springfield	Lump		Feb. 2, '00	Chem. Dept.	34.35	32.33	.99	32.32	1.07	11,098
283	Sangamon	Springfield	Pea		Apr. 27, '06	Chem. Dept.	41.12	34.26	10.95	13.67	2.90	11.939

TABLE VII (*Concluded*)

No.	Source of Sample		Description		Date of Analysis	Analysis Obtained from	Proximate Analysis—Air-Dry Coal					B. T. U. per lb. of Total Dry Coal
	County	Town	Size	Geol. Seam			Fixed Carbon	Volatile Matter	Moisture	Ash	Sulphur	
284	Sangamon	Springfield Jc.			Feb. '99	B. L. S. '02	43.52	37.04	9.11	10.33	3.65	......
285	Sangamon		Lump		Feb. '97	Chem. Dept.	40.57	35.44	12.47	11.52	....	11,980
286	Sangamon				Apr '04	Chem. Dept.	43.52	37.04	9.11	10.33	3.65	11,930
287	Sangamon				Jan. '05	Chem. Dept.	41.57	36.56	8.79	13.08	3.42	12,162
288	Sangamon				Apr. '05	Chem. Dept.	41.33	32.28	9.19	17.20	3.76	11,537
289	Shelby	Moweaqua	Lump		Jan. '95	B. L. S. '02	43.75	39.58	9.18	7.49	....	13,026
290	Shelby	Moweaqua	Lump	1	Dec. '95	B. L. S. '02	45.57	36.57	8.77	9.09	....	......
291	Shelby	Moweaqua	Lump	2	Dec. '95	B. L. S. '02	42.14	42.80	7.08	7.98	....	......
292	Shelby	Moweaqua	Lump	5	Dec. '95	B. L. S. '02	46.00	39.53	8.00	6.47	....	......
293	Shelby	Moweaqua				B. L. S. '02	42.09	37.00	7.17	13.74	....	11,185
294	Shelby	Moweaqua	Nut	5	'04	S. W. P '04	44.01	37.14	8.07	10.78	3.30	12,157
295	Shelby	Moweaqua	Slack	5	'04	S. W. P. '04	43.83	36.82	9.19	10.16	3.27	12,401
296	Vermilion	Catlin	Lump	7	'04	S. W. P. '04	45.75	38.18	10.36	5.71	1.47	13,203
297	Vermilion	Catlin	Slack	7	'04	S. W. P. '04	44.33	40.75	9.90	5.02	2.00	11,487
298	Vermilion	Catlin	Vein Sample		'78	B. L. S. '02	48.42	31.08	7.80	12.70	3.96	......
299	Vermilion	Catlin	Screen		Mar. '05	Chem. Dept.	43.40	29.62	7.41	19.57	2.12	12,369
300	Vermilion	Danville	Vein Sample		'78	B. L. S. '02	44.56	31.20	9.60	14.64	2.72	......
301	Vermilion	Danville				B. L. S. '02	45.37	43.70	4.78	6.15	....	13,134
302	Vermilion	Danville				B. L. S. '02	46.42	37.07	5.62	10.88	....	12,349
303	Vermilion	Danville				B. L. S. '02	53.00	32.35	11.00	3.65	....	13,803
304	Vermilion	Danville	Screen		May '96	B. L. S. '02	34.20	33.30	9.40	23.10	....	10,331
305	Vermilion	Danville	Lump		Mar. '00	B. L. S. '02	40.50	47.47	7.56	4.47	3.62	......
306	Vermilion	Danville	Lump		Mar. '00	B. L. S. '02	47.37	40.64	8.06	3.93	1.27	......
307	Vermilion	Danville	Slack	7	'04	S. W. P. '04	48.14	35.06	3.44	13.36	3.38	12,333
308	Vermilion	Danville	Lump	7	'04	S. W. P. '04	43.01	45.96	8.38	5.65	2.88	13,740
309	Vermilion	Danville	Slack	7	'04	S. W. P. '04	37.70	34.83	8.00	19.47	3.40	11,525
310	Vermilion	Danville	Lump	6	'04	S. W. P. '04	41.80	41.84	9.30	7.06	2.40	12,552
311	Vermilion	Fairmount	Slack	7	'04	S. W. P '04	37.25	36.47	7.59	18.69	3.67	11,134
312	Vermilion	Fairmount	Screen		Dec. '96	B. L. S. '02	39.85	36.46	10.67	13.02	....	12,191
313	Vermilion	Fairmount	Screen			B. L. S. '02	47.05	31.80	8.10	13.05	....	12,438
314	Vermilion	Grape Creek	Vein Sample		July '78	B. L. S. '02	51.32	28.34	9.74	10.60	3.63	......
315	Vermilion	Grape Creek	Lump	6	'04	S. W. P. '04	46.76	35.49	11.85	5.90	2.43	13,120
316	Vermilion	Grape Creek	Lump	6	'04	S. W. P. '04	48.48	34.81	11.57	5.14	.75	13,186
317	Vermilion	Oakwood			'89	B. L. S. '02	46.00	37.55	7.80	8.65	....	13,587
318	Vermilion	Oakwood	Lump		Mar. '05	Chem. Dept.	45.13	37.40	6.80	10.67	3.40	12,503
319	Vermilion	Oakwood	Screen		Apr. '05	Chem. Dept.	42.19	35.55	8.24	14.02	3.23	11,427
320	Vermilion	Oakwook	Screen		Apr. '05	Chem. Dept.	38.88	33.43	6.02	21.67	3.21	10,299
321	Vermilion	Oakwood	Screen		May. '05	Chem. Dept.	41.76	35.25	6.08	16.91	3.14	11,067
322	Vermilion	Oakwood	Pea		Nov. 25, '05	Chem. Dept.	41.47	39.85	5.62	13.06	3.63	13,251
323	Vermilion	Westville	Mine Run		Mar. 12, '00	Chem. Dept.	48.19	39.86	8.02	3.94	1.27	14,384
324	Vermilion	S. Westville	Lump	6	'04	S. W. P. '04	47.12	35.86	11.20	5.82	.83	13,315
325	Vermilion	S. Westville	Slack	6	'04	S. W. P. '04	46.30	35.34	11.06	7.30	.84	13,078

326	Wabash.....	Sugar Creek....	Hand Sample..	....	Jan. ......'01	B. L. S. '02...	48.79	41.30	6.03	3.88	1.73	......
327	Will.........	Braidwood.....	Lump	2	...........'04	S. W. P. '04...	48.02	36.28	11.44	4.26	1.95	12,760
328	Will.........	Braidwood.....	Slack..........	2	...........'04	S. W. P. '04..	40.53	32.57	10.52	16.38	2.34	10.812
329	Will.........	Joliet...........	No. 1	....	Sept. ....'05	Chem. Dept...	45.55	38.05	11.98	4.42	2.24	13,866
330	Will.........	Joliet...........	No. 2	....	Sept. ....'05	Chem. Dept...	48.94	36.57	10.35	4.14	2.01	14,014
331	Will.........	Joliet...........	No. 3	....	Sept. ....'05	Chem. Dept...	47.94	36.26	11.52	4.28	2.43	13,844
332	Williamson..	Bush	Lump	7	...........'04	S. W. P. '04..	49.14	35.00	5.90	9.96	1.97	12,829
333	Williamson..	Bush	Slack..........	7	...........'04	S. W. P. '04..	47.20	35.64	4.92	12.24	1.15	12,477
334	Williamson..	Carterville.....	Slack..........	7	...........'04	S. W. P. '04..	53.16	33.18	6.04	7.62	1.03	13,422
335	Williamson..	Carterville.....	Lump	7	...........'04	S. W. P. '04..	54.99	32.58	6.32	6.10	1.00	13,563
336	Williamson..	Carterville.....	W. Nut.........	7	...........'04	S. W. P. '04..	56.20	32.00	3.28	8.52	.89	12,986
337	Williamson..	Carterville.....	Mine Run......	....	May. ....'00	B. L. S. '02..	52.17	34.11	4.87	8.85	.85	12,839
338	Williamson..	Carterville.....	W. No. 1......	....	May. ....'00	B. L. S. 02..	54.21	33.99	4.66	7.14	.74	12,886
339	Williamson..	Carterville.....	W. No. 2.....	....	May. ....'00	B. L. S. '02..	55.01	35.12	4.31	5.56	.86	13,517
340	Williamson..	Carterville.....	W. No. 4......	....	May. ....'00	B. L. S. '02..	55.29	33.26	4.86	6.59	1.15	12,976
341	Williamson..	Carterville.....	W. No. 2......	....	Mar. ....'29	B. L. S. '02..	57.32	30.25	5.76	6.67	1.18	13,179
342	Williamson..	Carterville.....	W. No. 2......	....	Mar. ....'29	B. L. S. '02..	52.34	34.20	7.35	6.11	1.05	12,716
343	Williamson..	Carterville.....	W. Nut No. 2.	....	May. 26, '05	Chem. Dept...	49.98	35.15	5.00	9.87	2.10	13.352
344	Williamson..	Carterville.....	W. Nut No. 2.	....	Dec. 19, '05	Chem. Dept...	56.30	32.00	3.28	8.52	.89	12,986
345	Williamson..	Carterville.....	W. Pea Duff..	....	Nov. .....'05	Chem Dept...	55.52	32.40	3.33	8.76	1.97	13,408
346	Williamson..	Herrin..........	N Ky. Pea...	....	Apr. .....'04	Chem. Dept...	53.32	33.10	2.94	10.64	1.42	12,769
347	Williamson..	Herrin..........	N. Ky. W. Scr	....	Feb. .....'04	Chem. Dept...	53.26	31.12	5.00	10.62	......	12,364
348	Williamson..	Herrin..........	W. Slack......	7	...........'04	S. W. P. '04..	52.62	31.76	5.00	10.62	2.22	12,974
349	Williamson.	Herrin..........	W. Nut.........	7	...........'04	S. W. P. '04..	54.24	33.53	5.87	6.36	.83	13,498
350	Williamson..	Herrin..........	W. Slack......	7	...........'04	S. W. P. '04..	52.41	30.96	5.46	11.17	1.85	12,846
351	Williamson..	Herrin..........	Lump..........	7	...........'04	S. W. P. '04..	56.22	32.32	6.00	5.46	.82	13,590
352	Williamson..	Herrin..........	Vein Sample..	....	Oct.......'00	B. L. S. '02..	51.49	34.66	4.22	9.63	2.78	12,508
353	Williamson..	Lake Creek....	....	....	Mar......'98	B. L. S. '02..	53.20	39.30	3.42	4.08	1.72	12,673
354	Williamson..	Lauder.........	Slack..........	7	...........'04	S. W. P. '04..	35.04	40.81	6.35	17.80	1.14	11,221
355	Williamson..	Sunnyside......	W. No. 2......	....	Jan ......'02	B. L. S. .02..	55.28	33.86	3.97	6.89	......	13,004

TABLE VIII

List of Illinois Coals Analyzed. Arranged by Towns

Town	County	Ref. Number in Table of Analyses
Assumption	Christian	8-12
Astoria	Fulton	28-30
Athens	Menard	185-188
Auburn	Sangamon	252-255
Barclay	Sangamon	256-258
Benton	Franklin	27
Bloomington	McLean	110-116
Braceville	Grundy	50-51
Braidwood	Will	327-328
Breese	Clinton	20-21
Briar Bluff	Henry	57
Brighton	Macoupin	124
Bush	Williamson	332
Buxton	Clinton	22
Cable	Mercer	196-197
Canton	Fulton	31-32
Cantrall	Sangamon	259 260
Carbondale	Jackson	62-65
Cardiff	Livingston	95-96
Carterville	Williamson	334-345
Catlin	Vermilion	296-299
Centralia	Marion	145-148
Colchester	McDonough	109
Colfax	McLean	117
Collinsville	Madison	138-139
Cuba	Fulton	33-36
Danville	Vermilion	300-310
Dawson	Sangamon	261-264
Decatur	Macon	118
Delafield	Hamilton	54
De Soto	Jackson	66-71
Divernon	Sangamon	265
Donkville	Madison	140-141
Dunfermline	Fulton	38
Du Quoin	Perry	210-223
Edwardsville	Madison	142-143
Eldorado	Saline	239-243
Elm Grove	Adams	1-2
Elmwood	Peoria	203-207
Etherly	Knox	76-77
Fairbury	Livingston	97-98
Fairmount	Vermilion	311-313
Farmington	Fulton	39-42
Fiatt	Fulton	43
Flatrock	Crawford	26
Forest	Livingston	99-100
French Village	St. Clair	233-234
Galatia	Saline	244
Galva	Henry	58
Gilchrist	Mercer	198
Glen Carbon	Madison	144
Grape Creek	Vermilion	314-316
Greenview	Menard	189-191
Greenridge	Macoupin	125-126
Harrisburg	Saline	245-251
Herrin	Williamson	346-352
Holles	Peoria	208-209
Ivesdale	Champaign	7
Joliet	Will	329-331
Junction	Gallatin	49
Kangley	La Salle	79-80
Kewanee	Henry	59-61
Kinmundy	Marion	149-150
Ladd	Bureau	3-4
Lake Creek	Williamson	353

TABLE VIII (*Concluded*)

Town	County	Ref. Number in Table of Analyses
La Salle	La Salle	81–84
Lauder	Williamson	354
Lincoln	Logan	101–106
Litchfield	Montgomery	201–202
Lombardville	Bureau	5
Lowder	Sangamon	266
McLeansboro	Hamilton	55
Marissa	St. Clair	235–238
Middletown	Menard	192–193
Moweaqua	Shelby	289–295
Mt. Carbon	Jackson	72
Mt. Olive	Macoupin	127–132
Mt. Pulaski	Logan	107–108
Muddy Valley	Perry	224
Murphysboro	Jackson	73–75
Niantic	Macon	119–123
Norris	Fulton	44–45
Oakwood	Vermilion	317–322
Odin	Marion	151–178
Oglesby	La Salle	85–88
Palmyra	Macoupin	133–135
Pana	Christian	13–19
Paradise	Coles	25
Peru	La Salle	89–90
Petersburg	Menard	194–195
Pinckneyville	Perry	225–226
Ridgely	Sangamon	267–268
Riverton	Sangamon	269–274
St. David	Fulton	46–48
St. John	Perry	227–228
Sandoval	Marion	179–181
Sherrard	Mercer	199–200
Soperville	Knox	78
Sparta	Randolph	229–230
Spaulding	Sangamon	275
Springfield	Sangamon	276–283
Springfield Junction	Sangamon	284
Spring Valley	Bureau	6
Streator	La Salle	91–94
Sugar Creek	Wabash	326
Sunnyside	Williamson	355
Tilden	Randolph	231–232
Toluca	Marshall	182
Trenton	Clinton	23–24
Virden	Macoupin	136–137
Wenona	Marshall	183–184
Westville	Vermilion	323
S. Westville	Vermilion	324–325
S. Wilmington	Grundy	52–53

Publications of The Engineering Experiment Station

Bulletin No. 1. Tests of Reinforced Concrete Beams, by A. N. Talbot. 1904.

Circular No. 1. High-Speed Tool Steels, by L. P. Breckenridge. 1905.

Bulletin No. 2. Tests of High-Speed Tool Steels on Cast Iron, by L. P. Breckenridge and Henry B. Dirks. 1905.

Circular No. 2. Drainage of Earth Roads, by Ira O. Baker. 1906.

Bulletin No. 3. The Engineering Experiment Station of the University of Illinois, by L. P. Breckenridge. 1906.

Bulletin No. 4. Tests of Reinforced Concrete Beams, Series of 1905, by A. N. Talbot. 1906.

Bulletin No. 5. Resistance of Tubes to Collapse, by A. P. Carman. 1906.

Bulletin No. 6. Holding Power of Railroad Spikes, by R. I. Webber. 1906.

Bulletin No. 7. Fuel Tests with Illinois Coals, by L. P. Breckenridge. 1906.