Analyses of Iowa Coals

With a Discussion of their Physical and Chemical Properties from the Industrial View Point

BY

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ANALYSES OF IOWA COALS.

BY A. W. HIXSON.

Introductory.

During the summer of 1909 samples of Iowa coals were collected and proximate analyses were made. The results of these analyses were published in the Annual Report of the Iowa Geological Survey (Vol. XIX, pp. 476-519).

After the Report had gone to press it was decided that ultimate analyses of these samples should be made so that the chemical properties of the coals could be studied in greater detail. The following facts brought about this decision: (1) The samples had been taken with great care according to approved scientific methods. (2) The samples had been taken from producing mines in ten different counties, so that practically the whole Iowa coal field was represented. (3) The samples had been taken under the same conditions so that the analytical results could be compared. (4) The samples had been collected at considerable cost. (5) Ultimate analyses of samples of Iowa Coals taken under uniform conditions had never been made. (6) Such information was needed for calculations in power and heating problems, and for use in writing specifications for the purchase of coals.

The ultimate analyses were made by the same chemist who made proximate analyses, the conditions being the same except that the ultimate analyses were made at a little later date.

It has been considered wise to republish the proximate analyses along with the ultimate analyses so that all of the analytical data will appear together in a more useful condition.

Slight errors have been detected in the "analysis corrected to sample as received" as published. The calculations are corrected in this work. A quite complete analysis of the ash of each sample has been made.

Collection of Sample.

The samples were collected by Mr. James H. Lees, Assistant State Geologist of Iowa. Mr. Lees' description of the methods he employed is as follows: Practically the same method of mine sampling was used as was employed by the United States Geological Survey in collecting the samples which were analyzed at its coal-testing station at the Louisiana Purchase Exposition at St. Louis in 1904. The method was about as follows: The room or entry selected for sampling was one from which coal was being mined at the time the sample was taken and thus a fresh face was assured. A portion of the face was cleaned to remove powder smoke or coal which had been exposed to the air for any considerable period of time. A strip was then cut across the seam from floor to roof about three inches wide and one inch deep. All bony streaks or sulphur bands over one-fourth inch thick were thrown out. The coal cut down in this way was collected, as it fell, upon a rubber cloth to avoid any danger of mixture with dirt or moisture on the floor. Immediately upon arrival above ground, the sample was broken up, on a clean hard surface, into fragments one-half inch or less in diameter. It was then thoroughly mixed and quartered, alternate quarters rejected, and the remaining quarters mixed and further pulverized and again quartered, until about a quart remained. This was put into a clean can with a tight fitting lid, which was driven down solid and the joint sealed by wrapping with tire tape, so that it would be air tight. In short, every effort was made to the end that the sample should represent as closely as might be, the commercial output of the mine, and the original characteristics of the coal should be preserved until it was analyzed.

A slip of paper giving the number of the sample together with the name and location of the mine was enclosed in the can to render identification certain. The sample number was also marked on the outside of the can. The sample was later shipped by express to the laboratory at Iowa City.

Proximate Analysis.

Laboratory Methods.—The methods followed in the analytical work were essentially those adopted in the report of the committee on coal analysis of the American Chemical Society and those employed in the laboratory of the coal testing plant of the United States Geological Survey at the Louisiana Purchase Exposition in 1904.

The analytical work consisted of the proximate and ultimate analysis of the coal samples with the determination of Specific gravity and Calorific value in addition. A complete analysis of the ash of each sample was also made.

Preparation of the Sample.—When the sample arrived at the laboratory it was immediately given a serial number for identification purposes in the laboratory. The number and description on the tag were compared with the number and description on the slip of paper within the can to make sure they agreed. The number and description were then entered in a book for permanent record together with notes concerning the condition of the sample when it arrived.

The coal was then poured out upon a well cleaned bucking board, crushed, mixed and quartered down to one pint. One-half of this was spread out upon a shallow tinned iron tray ten inches in diameter. After weighing, this portion was set aside for air drying. The other half was run through a coffee mill. A portion of the well mixed ground sample was placed in a tightly stoppered bottle for the moisture determination. The crushing, quartering and grinding of the sample were done as quickly as possible to prevent loss of moisture.

The coal was air-dried for ninety-six hours and weighed. The time at which the weighing was done together with the temperature and humidity of the air were recorded. The air-dried sample was crushed and quartered down to 150 grams. The final crushing was to 100 mesh. This sample was then placed in a tightly stoppered bottle and was used for the proximate and ultimate analyses and calorific value determinations.

All samples were mixed on a rolling cloth before weighing out for each determination, to insure a perfectly homogeneous sample. All determinations were made in duplicate.

Moisture.—One gram of coarsely ground fresh coal was dried in a weighed porcelain crucible at 105° C. for one hour, in a double walled, electric oven. The covered crucible and its contents were cooled in a dessicator and weighed. Moisture in the air dried sample was determined in like manner.

It was found that the moisture determination cannot be made with any degree of accuracy if the sample is finely ground. This is due to the fact that the fresh sample loses moisture rapidly during the grinding operation. For this reason the fresh sample for the moisture determination was ground in a coffee mill.

Ash.—A portion of powdered coal used for the determination of moisture in the air-dried sample was burned at first over a Bunsen burner with a very low flame until all of the volatile matter was driven off. The final burning was done in a gasoline muffle furnace, the temperature being kept at that of low redness. Ignition was continued until constant weight was obtained.

If the volatile matter is expelled too quickly, as will be the case if too high a temperature is employed at first, considerable difficulty will be experienced in obtaining complete ignition.

Volatile Combustible Matter.—One gram of the air-dried sample was weighed into a previously ignited and weighed platinum crucible with a tightly fitting cover. This was heated for seven minutes over the full flame of a Bunsen burner, then cooled in a dessicator and weighed. The crucible was supported on a pipe clay triangle resting upon a tripod, the bottom of the crucible being seven centimeters above the top of the burner. The burner when burning freely gave a flame from seventeen to twenty centimeters high.

Fixed Carbon.—Fixed carbon is the difference, in percentage, between the sum of the percentages of the other constituents determined and 100. No correction was made for the sulphur which goes partly into the volatile combustible matter and partly into the coke. Fixed carbon may also be found by subtracting the percentage of ash from the percentage of residue left after expelling the volatile matter.

Sulphur.—This was determined by the Escka Method. One gram of the finely powdered air-dried coal was weighed into a platinum dish of 100 cc. capacity. To this was added one and five-tenths grams of an intimate mixture of one part dry sodium

carbonate and two parts of magnesium oxide. The coal and the mixture were well mixed together by stirring with a glass rod. The contents of the dish were then heated over a Bunsen burner very gently until all of the volatile matter was expelled. This required about thirty minutes. Then the heat was increased until all traces of carbon disappeared. To prevent any sulphur from the gas from contaminating the determination, the platinum dish was fitted in a hole in a piece of asbestos board.

After all traces of carbon were removed, the contents of the dish were transferred to a numbered beaker and digested with 75 cc. of water for thirty minutes. The solution was then filtered and the residue washed twice by decantation with 50 cc. of boiling water. The residue was then transferred to the filter paper and again washed with hot water until the filtrate gave only a slight opalescence with nitric acid and silver nitrate. The filtrate at this point amounted to about 200 cc.

Ten cc. of saturated bromine water and 3 cc. of concentrated hydrochloric acid were added to the solution, which was then boiled slowly until all of the bromine was expelled. Then the sulphur was precipitated by adding to the boiling solution 10 cc. of a ten per cent barium chloride solution. This was added drop by drop and the solution was vigorously stirred. The solution was allowed to stand two hours at a temperature slightly below boiling. The barium sulphate was then filtered off and washed with hot water until free from chlorides. The filter with the moist precipitate was transferred to a weighed porcelain crucible which was heated over a low flame until the paper was burned off. The heat was then raised until the precipitate became a dull red. The heating was continued until the carbon was burned out. The crucible with the precipitate was then cooled in a dessicator and weighed. Careful ignition was repeated until constant weight was obtained.

Blank determinations were made, using all of the reagents in the same quantities and the determination was carried out exactly as with the coal. Any barium sulphate found was subtracted from that obtained in the coal determination. The true weight of barium sulphate multiplied by 0.1373 gave the weight of sulphur.

Ultimate Analysis.

Carbon and Hydrogen.—The carbon and hydrogen determinations were made in a twenty-seven burner Bunsen combustion furnace. The burners were adjustable so that the temperature in different parts of the furnace could be varied. Kavalier glass combustion tubes, seventeen millimetres in diameter were used. The tubes were cut long enough to project about ten centimetres beyond the ends of the furnace. The rear end of the tube was closed with a single hole rubber stopper into which a branching tube with a two way cock was fitted. The two way cock was used for the alternate admission of air and oxygen into the combustion tube. The rear end of the tube for a distance of thirty centimetres was left empty. The next forty centimetres was filled with wire copper oxide. This was held in place by acid washed, ignited asbestos plugs. Following the copper oxide the tube was filled for a distance of fifteen centimetres with granular fused lead chromate. This also was held in place by an asbestos plug.

The purifying train through which the oxygen and air were passed before entering the combustion tube, was arranged in duplicate, one part for oxygen and the other for air. The purifying apparatus used was Tauber's. The first jar contained concentrated sulphuric acid, the next jar contained potassium hydroxide solution, one limb of the U tube contained fused calcium chloride and the other small pieces of KOH. The potassium hydroxide and fused calcium chloride were separated by glass wool. This arrangement removed carbon dioxide and moisture from the air perfectly.

The absorption apparatus consisted of a glass stoppered U tube which contained concentrated sulphuric acid and a Geissler bulb which contained a potassium hydroxide solution. The Geissler bulb and the sulphuric acid tube were connected by means of a small piece of shellaced rubber tubing. Wherever rubber tubing was used in the combustion train it was shellaced on the outside to prevent leakage from outside. The absorption tubes were protected by a pair of glass stoppered U tubes one of which contained concentrated sulphuric acid and the other

potassium hydroxide solution. The absorption tubes were connected to the front end of the combustion tube by a glass tube which was tightly fitted into a well rolled cork.

After the combustion train was assembled it was tested for leakage. No difficulty was experienced in removing all of the CO_2 and moisture from the gas and air drawn through the apparatus.

The analysis in detail was as follows:

Two-tenths of a gram of the well mixed air-dried sample was weighed into a previously ignited and weighed platinum combustion boat. After weighing, this was quickly transferred to the combustion tube and pushed up close to the rear end of the copper oxide. The amount of time required for mixing and weighing sample was two and one-half to three minutes. This part of the operation was hurried as much as possible to avoid change in moisture content. The burners underneath the copper oxide and lead chromate were then lighted. The burners were so adjusted that the copper oxide was brought to bright redness and the lead chromate to low redness before the burners were turned on under the coal. The coal was slowly heated, first by turning the burners on behind the boat and then underneath, to prevent the volatile constituents being driven off too quickly. If the volatile constituents are driven off too quickly a great deal of time is required for complete combustion. The final temperature was kept below that of the fusion point of the ash. While combustion was going on air was slowly pulled through the train. When combustion was almost complete oxygen was passed through the tube to insure complete combustion. After the combustion was complete air was again passed through the train to sweep out the last traces of moisture and carbon dioxide. After complete combustion the temperature of the tube and its contents was slowly lowered to prevent the tube from breaking and to prepare for another combustion.

After cooling for several minutes in the balance case, the absorption apparatus was weighed and the gain in weight of each tube noted. From the gain in weight of the sulphuric acid

tube and potash bulbs the hydrogen and carbon contents were calculated.

Nitrogen.—The Kjeldahl method was employed for the determination of nitrogen. One gram of the well mixed air-dried sample was placed in a 200 cc. Kjeldahl digestion flask and was digested for about an hour and a half with 30 cc. concentrated sulphuric acid and about .65 gm. mercury. The time required for the digestion varied slightly with different samples, the digestion being continued in each case for at least forty minutes after oxidation was apparently complete. The vapors from the distillation flask were condensed in a tin condensing coil which was connected to the digestion flask by means of a glass tube and a close fitting rubber stopper. The coil of the condensor was surrounded by cold water.

The ammonia found was absorbed in 10 cc. standard sulphuric acid of which 1 cc. was equivalent to .005 N. The remaining acid was titrated with standard ammonia (1 cc.=.0025 gm. N.).

Calorific value.—This was determined with a Parr Standard Calorimeter, which was installed in a room as free as possible from fluctuations in temperature. The apparatus was carefully standardized, the water equivalent being determined by different methods as follows: (1) Calculation of the water equivalent from weights and specific heats of the different parts of the calorimeter. (2) By burning resublimed naphthalene in the bomb. (3) By burning pure cane sugar in the bomb. The results of the three different determinations agreed closely. The correction components used for the chemicals, iron wire and for the varying compositions of the different coals were those determined by Prof. S. W. Parr, of the University of Illinois. The thermometers used were standardized by the Bureau of Standards in Washington.

One gram of the powdered air-dried coal was weighed into the bomb of the calorimeter. To this was added one gram of accelerator (potassium chlorate) and fifteen grams of perfectly dry pure sodium peroxide. The false cap was then put into position and screwed firmly into place and the ingredients

mixed by shaking the bomb thoroughly. The material was then shaken to the bottom of the bomb, the false top removed, the ignition device inserted and firmly screwed in place. The bomb now complete was put in place into the can which contained exactly two litres of distilled water. The lid was then placed on the calorimeter, pulley attached and the thermometer inserted so that the bulb was half way to the bottom of the can. The water was stirred by metal wings attached to the bomb which was revolved by a belt from a small motor.

The motor was started and apparatus allowed to run for five minutes before ignition in order that the rate of change of temperature might be noted by taking a reading each minute. At the end of the fifth minute the charge in the bomb was ignited by closing a switch which allowed an electric current of four and one-half amperes to quickly fuse a thirty-four gauge iron wire, four inches long, which extended into the charge in the bomb. The temperature was read each minute until the maximum was reached, then each minute for five minutes to obtain the rate of change of temperature due to radiation.

The apparatus was then taken apart, each piece dried thoroughly, and prepared for a new charge. The room temperature was taken during each determination.

The calorific value was calculated by multiplying the number of British Thermal Units corresponding to one degree increase in temperature by the total rise of temperature obtained after the correction factors had been subtracted. The calorific value was also calculated in calories. Corrections other than those noted above were made for the formation of nitric acid and combustion of sulphur to sulphuric acid.

Specific Gravity—The true specific gravity of the coal substance was determined by the method described by Stanton and Fieldner in Bureau of Mines Technical Paper, Number 8. The procedure was as follows: Three and five-tenths grams of the finely pulverized coal was dried at 105° C. for one hour. This was placed in 50 cc. pycnometer with 35 cc. of distilled water. The contents of the flask were boiled slowly under reduced pressure on a water bath. To prevent loss of solid particles

during boiling, a six inch two bulb drying tube was fitted into a well rolled cork stopper in the neck of the pycnometer. The other end of the drying tube was connected to an aspirator. The boiling was continued under reduced pressure for several hours to insure complete removal of all air. The drying tube was removed from the neck of the pycnometer which was nearly filled with boiled, cooled, distilled water. The pycnometer with contents was allowed to cool to room temperature in the balance case, stoppered and weighed. The temperature of the contents was taken at time of weighing. The pycnometer was emptied, dried and filled with boiled, cooled, distilled water and placed in the balance case until the temperature of the contents was the same as that of the balance room. The pycnometer was then stoppered and weighed. The true specific gravity was then calculated as follows:

$$\text{True specific gravity} = \frac{W}{W-(W^1-P)}$$

W = weight of coal.
W^1 = weight of pycnometer + coal + water to fill.
P = weight of pycnometer + water to fill.

Analysis of Ash of Coal Samples.

Quite complete analyses of the ash of the coal samples examined, were made. The procedure was as follows: 100 grams of the air-dried coal sample was placed in a well cleaned, previously ignited, fire clay crucible. Only crucibles which had a perfectly smooth inner surface were used. The crucibles used were furnished by the Denver Fire Clay Company of Denver, Col. The crucible was placed in the cool muffle of a gasoline assay furnace. The temperature was raised very slowly until all of the volatile matter was driven off. The muffle was then heated to low redness and kept at that temperature until ignition was complete. The ash was removed, cooled in a dessicator, well mixed and a small portion weighed into a weighed platinum crucible. The content of the platinum crucible was ignited, cooled and weighed to determine if the ignition in the muffle had

been complete. If the ignition in the platinum crucible showed a loss in weight the sample was returned to the muffle and heated until ignition was complete. This method allows large samples of coal to be ashed and a large number of samples to be run at one time, and has the further advantage that the temperature can be easily controlled. After complete ignition in the muffle furnace the samples were cooled in a dessicator and transferred to a previously dried, glass stoppered bottle. The well mixed samples for analysis were weighed out from the bottles as they were needed. CaO, Fe_2O_3, Al_2O_3, SiO_2, MgO, P_2O_5, and SO_3, were determined.

The methods used for these determinations were standard methods and inasmuch as complete analyses of coal ash are rarely ever made, it has not been thought necessary to give details of procedure other than those already given.

Calculation of Results.

The actual determinations were those made upon the air-dried sample. The results tabulated under the heading, "Results corrected to sample as received," were not obtained by analysis of the original sample, but were calculated from the results of the analysis of the air-dried sample. The only determination made on the original sample was moisture.

The calculations from "air-dried" to "as received" conditions were made according to the following formulæ: (Method of statement of formulæ taken from Bureau of Mines Bulletin, No. 22, page 26.)

"Air-dried" condition.		"As received" condition.
Moisture at 105° C.	$\times \frac{100-\text{air-dry loss}}{100} + \text{air-dry loss}$	=moisture.
Volatile matter	$\times \frac{100-\text{air-dry loss}}{100}$	=volatile matter
Fixed Carbon	$\times \frac{100-\text{air-dry loss}}{100}$	=fixed carbon
Ash	$\times \frac{100-\text{air-dry loss}}{100}$	=ash
Sulphur	$\times \frac{100-\text{air-dry loss}}{100}$	=sulphur
Hydrogen	$\times \frac{100-\text{air-dry loss}}{100} + \frac{\text{air-dry loss}}{9}$	=hydrogen
Carbon	$\times \frac{100-\text{air-dry loss}}{100}$	=carbon
Nitrogen	$\times \frac{100-\text{air-dry loss}}{100}$	=nitrogen
Calorific value	$\times \frac{100-\text{air-dry loss}}{100}$	=calorific value

The heat values obtained from the ultimate analyses were calculated by DuLong's formula. The form of the formula used is:

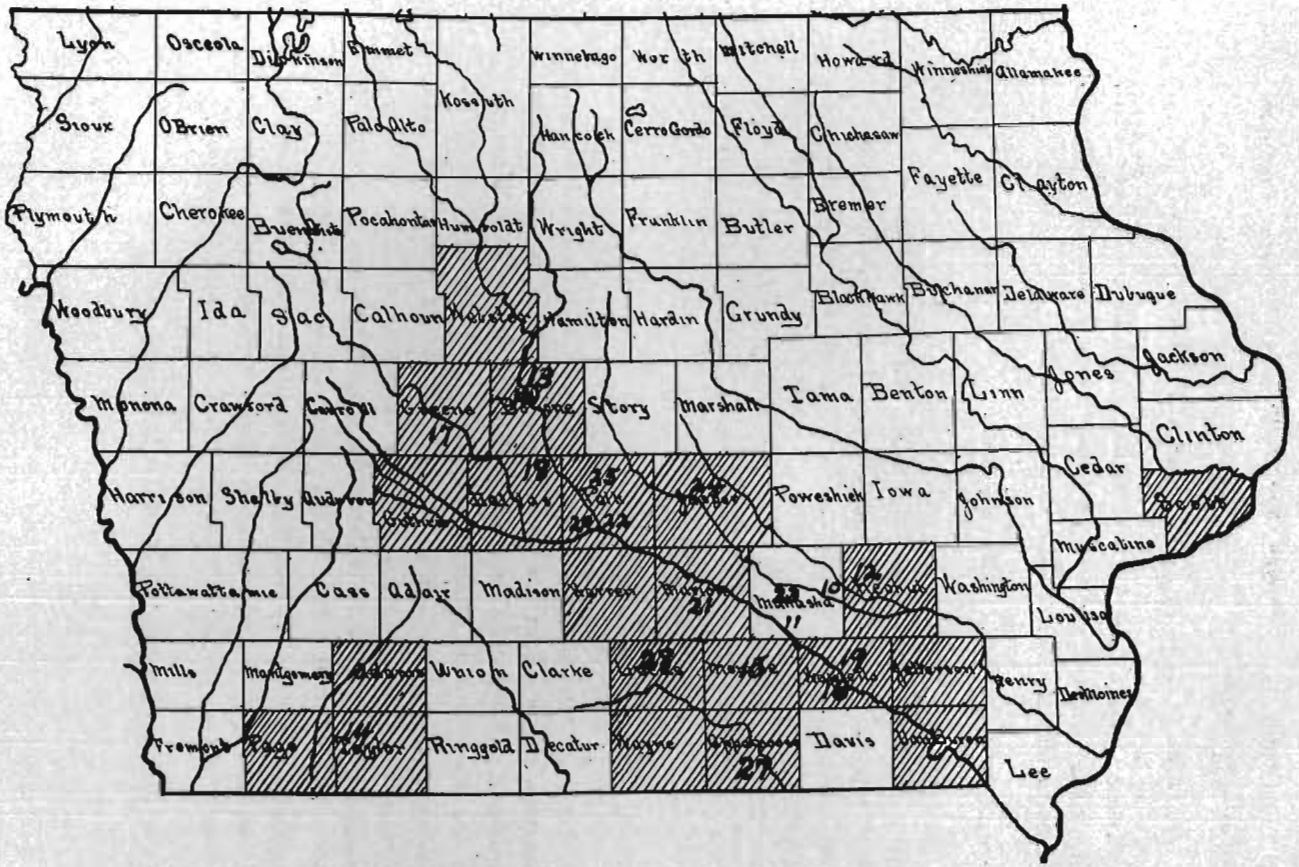
$$\text{Weight carbon} \times 8080 + \left(\text{weight hydrogen} - \frac{\text{weight oxygen}}{8}\right) \times 34460 + \text{weight sulphur} \times 2250 = \text{Calories per gram.}$$

Calories $\times$ 1.8 = British Thermal Units.

The sulphur values in the ultimate analysis were obtained by deducting the amount of sulphur found in the ash from the amount of total sulphur.

Description of Mines Sampled.

The descriptions of the mines sampled, which appear on pages opposite the analyses, were written by Mr. James H. Lees, Assistant State Geologist, who collected the samples. These descriptions are taken from Vol. XIX, pages 482-487, Annual Report Iowa Geological Survey.



Map showing coal producing area and locations from which samples were taken. The numbers on the map correspond to sample numbers used in the following pages with the exception of 27 and 28. 27 is Iowa coal No. 4 and 28 is Iowa coal No. 5, described on pages 79 and 80 and 224 and 225, Professional Paper No. 48, United States Geological Survey. Shaded areas indicates coal producing sections.

Sample Number 10.

Description of Mine.

Operator. Atwood Coal Company, What Cheer.

Mine. Blyth mine, three miles northwest of Rose Hill, Mahaska county, on long switch from Knoxville branch, Chicago, Rock Island and Pacific Railway.

Sample collected. May 18, 1909.

Description. The mine was sampled in the fifth north entry on the west side of the mine, 840 feet from the shaft. The vein dips steeply in this entry. It shows a thickness of 5 feet 1 inch where sampled. The coal is very clean-looking, without sulphur bands or rock. Only one vein is present. The mine when sampled had been running four years and employed 100 men. (See Vol. XIX, page 202, Annual Report of Iowa Geological Survey.)

Discussion of Analytical Results.

Although the coal in place showed no sulphur bands, the analysis shows this element to be present in quite large amount. The presence of so large an amount of sulphur would undoubtedly cause this coal to be more destructive to grates and fire boxes than the average Iowa coal. The loss of moisture on air-drying is that of the average Iowa coal. Slagging will be more noticeable with this coal, if firing is forced, than with some of the other coals examined, due to high pyrite content. The ash contains an abnormal amount of sulphur. The heat value is above average. The oxygen content is one of the lowest found in the coals examined.

Sample Number 10.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	9.53		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	5.58		14.57
Volatile combustible matter	36.34		32.88
Fixed Carbon	44.30		40.08
Ash	13.78		12.47
	100.00		100.00
Total sulphur	6.51		6.00
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	4.95		5.53
Carbon	62.90		56.90
Nitrogen	1.40		1.27
Oxygen	10.93		18.37
Sulphur	6.04		5.46
Ash	13.78		12.47
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11814 / Calories 6563
Calorific value corrected to sample as received	B. T. U. 10688 / Calories 5938
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11619 / Calories 6455
Calorific value corrected to sample as received	B. T. U. 10512 / Calories 5840
Specific gravity of air-dried sample	1.295

Analysis of ash from air-dried sample.

SiO_2	18.21	per cent
CaO	17.74	per cent
MgO	1.10	per cent
Fe_2O_3	35.17	per cent
Al_2O_3	17.36	per cent
P_2O_5	.575	per cent
SO_3	8.53	per cent
Undetermined	1.315	per cent
	100.00	

Sample Number 11.

Description of Mine.

Operator. Crescent Coal Company, Oskaloosa.

Mine. Crescent No. 5, White City, Mahaska county, on Buxton branch Chicago and North Western Railway.

Sample collected. May 9, 1909.

Description. This sample was cut from the first room on the eighth north entry on the east side of the mine about one mile from the shaft. The coal was 7 feet 8 inches thick with about 8 inches of slaty coal near the roof. It was dipping steeply away from the entry. (See Vol. XIX, page 216, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

The analysis shows the air-dried coal to contain an average amount of moisture, high total sulphur, high sulphur in ash and a lower than average moisture content in sample when taken from mine. The heat value is slightly lower than that of the average Iowa coal. The coal when completely burned gives a brick red ash with higher than average Fe_2O_3 content. The ash content of this coal probably varies considerably in car samples due to presence of varying amounts of the slaty material at the top of the vein. The analysis shows a high ash content.

Sample Number 11.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	6.82		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	6.17		12.56
Volatile combustible matter	36.71		34.21
Fixed Carbon	41.72		38.88
Ash	15.40		14.35
	100.00		100.00
Total sulphur	5.87		5.47
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.00		5.41
Carbon	61.40		57.21
Nitrogen	1.23		1.14
Oxygen	11.56		16.85
Sulphur	5.41		5.04
Ash	15.40		14.35
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11497 Calories 6387
Calorific value corrected to sample as received	B. T. U. 10713 Calories 5952
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11353 Calories 6308
Calorific value corrected to sample as received	B. T. U. 10579 Calories 5877
Specific gravity of air-dried sample	1.261

Analysis of ash from air-dried sample.

SiO_2	17.49	per cent
CaO	16.40	per cent
MgO	1.35	per cent
Fe_2O_3	36.02	per cent
Al_2O_3	18.88	per cent
P_2O_5	.692	per cent
SO_3	7.47	per cent
Undetermined	1.698	per cent
	100.00	

Sample Number 12.

Description of Mine.

Operator. Armstrong Brothers Coal Company, What Cheer.

Mine. Armstrong, one mile east of What Cheer, Keokuk county. No railroad connections.

Sample collected. May 19, 1909.

Description. The sample was taken from the first north entry off the west main entry. The coal here showed a thickness of 4 feet 2 inches and was clean and free from impurities. (See Vol. XIX, page 288, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

Although the total sulphur content is well above that of the average Iowa coal, the sulphur content shown in the ultimate analysis is normal. The reason for this is that a considerable part of the sulphur is present in such condition that it went into ash. The average SO_3 content of ash of Iowa coals is 6.00 per cent. An abnormal amount of MgO in the ash is also to be noted. Loss of moisture on air-drying is below average. The ash content is above average.

Sample Number 12.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	7.83		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	7.43		14.68
Volatile combustible matter	38.21		35.22
Fixed Carbon	41.10		37.88
Ash	13.26		12.22
	100.00		100.00
Total sulphur	5.15		4.75
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	4.88		5.36
Carbon	62.75		57.84
Nitrogen	1.42		1.32
Oxygen	13.01		18.95
Sulphur	4.68		4.31
Ash	13.26		12.22
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11410 / Calories 6339
Calorific value corrected to sample as received	B. T. U. 10517 / Calories 5843
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11322 / Calories 6289
Calorific value corrected to sample as received	B. T. U. 10435 / Calories 5797
Specific gravity of air-dried sample	1.259

Analysis of ash from air-dried sample.

SiO_2	20.81	per cent
CaO	17.50	per cent
MgO	2.06	per cent
Fe_2O_3	32.30	per cent
Al_2O_3	15.85	per cent
P_2O_5	.641	per cent
SO_3	8.53	per cent
Undetermined	1.829	per cent
	100.00	

Sample Number 13.

Description of Mine.

Operator. The Fort Dodge, Des Moines and Southern Railway Company (electric) own controlling interest.

Mine. Ogden No. 1, two miles north of Ogden, Boone county, on switch from main line of Minneapolis and St. Louis Railroad.

Sample collected. May 14, 1909.

Description. The sample was taken from the fourth northeast entry. The coal is here 4 feet 4 inches thick, free from sulphur bands or balls as well as from rock. It is the "lower vein" of the Boone county mines and averages 4½ to 5½ feet. The "upper vein" is about 50 feet above and is about 3½ feet thick.

The shaft is 275 feet deep. It was completed in August of 1907. The mine at the time the sample was taken had an output of 400 tons, of three grades, lump, range and steam. The Minneapolis & St. Louis Railroad Company at that time used about 125 tons daily. About 200 men are employed in the mine. The haulage is done by electricity. (See Vol. XIX, page 74, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

This coal is one of the best examined. The ash content is low for an Iowa coal, although the sulphur content is high. The heat value is well above the average. The iron content in the ash is quite high and it is quite probable that this coal will not stand forced firing on account of slagging. All Iowa coals slag, however, under certain conditions. The cause and nature of slagging is discussed at another place. The lime and alumina values in the ash are low.

Sample Number 13.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	10.65		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	8.91		18.61
Volatile combustible matter	37.81		33.78
Fixed Carbon	43.31		38.70
Ash	9.97		8.91
	100.00		100.00
Total sulphur	6.10		5.45
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.18		5.81
Carbon	63.80		57.01
Nitrogen	1.63		1.46
Oxygen	13.48		21.49
Sulphur	5.94		5.31
Ash	9.97		8.92
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11894 / Calories 6608
Calorific value corrected to sample as received	B. T. U. 10627 / Calories 5904
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11687 / Calories 6493
Calorific value corrected to sample as received	B. T. U. 10442 / Calories 5801
Specific gravity of air-dried sample	1.283

Analysis of ash from air-dried sample.

SiO_2	23.76	per cent
CaO	15.54	per cent
MgO	.67	per cent
Fe_2O_3	43.49	per cent
Al_2O_3	11.09	per cent
P_2O_5	.627	per cent
SO_3	4.13	per cent
Undetermined	.693	per cent
	100.00	

Sample Number 14.

Description of Mine.

Operator. Campbell Coal Company, New Market.

Mine. Campbell No. 1, nearly one mile east of New Market, on the Keokuk, Shenandoah and Red Oak division of the Chicago, Burlington and Quincy Railroad.

Sample collected. May 22, 1909.

Description. The sample was collected from the second west entry off the second north entry. The bed was 16 inches thick where sampled. It varies from 16 to 20 inches in thickness in different parts of its extent. In some places it shows thin streaks of sulphur or clay one-eighth to one-half inch thick. The coal is brittle and breaks easily with angular fracture. The mine is on the right-of-way and is served by a short siding. (See Vol. XIX, page 383, Annual Report of Iowa Geological Survey.)

Discussion of Analytical Results.

This coal, like several of the other Iowa coals examined, loses more than an average amount of moisture on air-drying. With the exception of the heat value this coal is about an average coal from the Iowa field. The coal has the appearance of one that would weather badly. Appearance, however, is not always a good basis for the judgment of this property. Analysis shows the coal to be better than its appearance indicates.

Sample Number 14.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	10.97		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	9.24		19.11
Volatile combustible matter	34.17		30.45
Fixed Carbon	43.60		38.86
Ash	12.99		11.58
	100.00		100.00
Total sulphur	4.78		4.26
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	4.73		5.43
Carbon	63.80		56.80
Nitrogen	1.59		1.41
Oxygen	12.51		20.90
Sulphur	4.38		3.90
Ash	12.99		11.56
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11494 / Calories 6385
Calorific value corrected to sample as received	B. T. U. 10233 / Calories 5685
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11422 / Calories 6346
Calorific value corrected to sample as received	B. T. U. 10169 / Calories 5649
Specific gravity of air-dried sample	1.272

Analysis of ash from air-dried sample.

SiO_2	20.97	per cent
CaO	20.79	per cent
MgO	1.10	per cent
Fe_2O_3	30.17	per cent
Al_2O_3	17.11	per cent
P_2O_5	1.22	per cent
SO_3	7.58	per cent
Undetermined	1.06	per cent
	100.00	

Sample Number 15.

Description of Mine.

Operator. Wapello Coal Company, Hiteman.

Mine. Wapello No. 4, three miles northwest of Hiteman, Monroe county, on branch from the main line of the Chicago, Burlington and Quincy Railroad.

Sample collected. May 21, 1909.

Description. The sample is from the seventeenth room off the tenth west entry off the sixteenth north entry. The vein measured, where sampled, 5 feet 4 inches and is free from sulphur and rock. The average thickness is 5½ feet.

The mine uses tail rope haulage for about a mile under ground and the entries run in one-half mile farther. The output was 900 tons daily. (See Vol. XIX, page 242, Annual Report of Iowa Geological Survey.)

Discussion of Analytical Results.

The noticeable feature of this coal is its low sulphur content. The sulphur is present in such condition that much of it goes into the ash. This coal should have little destructive effect upon grates and fire boxes and should stand forced firing better than many Iowa coals. The oxygen content is above average. Silica in the ash is high and iron is low. The ash is lighter colored than most of samples examined. This is probably due to the iron content. The appearance of the coal indicates a higher thermal value than the analysis shows. The amount of moisture retained after air-drying is higher than the average.

Sample Number 15.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	8.21		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	8.40		15.92
Volatile combustible matter	36.26		33.28
Fixed Carbon	42.80		39.29
Ash	12.54		11.51
	100.00		100.00
Total sulphur	2.10		1.93
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.10		5.59
Carbon	64.10		58.84
Nitrogen	1.88		1.73
Oxygen	14.55		20.64
Sulphur	1.83		1.68
Ash	12.54		11.52
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11564 / Calories 6424
Calorific value corrected to sample as received	B. T. U. 10615 / Calories 5897
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11437 / Calories 6351
Calorific value corrected to sample as received	B. T. U. 10498 / Calories 5832
Specific gravity of air-dried sample	1.274

Analysis of ash from air-dried sample.

SiO_2	30.87	per cent
CaO	16.25	per cent
MgO	1.31	per cent
Fe_2O_3	28.05	per cent
Al_2O_3	16.12	per cent
P_2O_5	.663	per cent
SO_3	5.41	per cent
Undetermined	1.357	per cent
	100.00	

Sample Number 16.

Description of Mine.

Operator. Phillips Fuel Company, Ottumwa.

Mine. Bear Creek mine, at Bear Creek, Wapello county, four miles southwest of Ottumwa, on the Chicago, Milwaukee and St. Paul Railway.

Sample collected. May 20, 1909.

Description. The sample is from the first south entry. Here the coal is 4 feet 6 inches thick and is in the main clean and free from rock except near the roof, where some bowlders occur. One of these near the place of sampling measured ten inches in thickness.

The mine was opened in the fall of 1908. At the time of sampling forty miners were employed and tail rope haulage was installed. Hoisting is done by duplex engine geared to the drum. (See Vol. XIX, page 302, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

The moisture in sample "as received" is low for an Iowa coal. The moisture in the air-dried sample is also considerably below the average. The ash content is high, due mostly to earthy material. The ash is dark in color and quite high in iron oxide. The iron in the ash of this sample does not come entirely from pyrites (FeS_2) which is present in considerable quantities in all Iowa coals, but also from earthy material with a dark soily appearance. The heat value is a little below that of the average coal from the Iowa field. The writer is convinced that washing would greatly improve this coal.

Sample Number 16.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	7.49		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	4.79		11.92
Volatile combustible matter	37.59		34.78
Fixed Carbon	43.22		39.98
Ash	14.40		13.32
	100.00		100.00
Total sulphur	6.63		6.13
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.19		5.63
Carbon	62.04		57.40
Nitrogen	1.39		1.29
Oxygen	10.64		16.49
Sulphur	6.34		5.87
Ash	14.40		13.32
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11695 Calories 6497
Calorific value corrected to sample as received	B. T. U. 10819 Calories 6011
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11674 Calories 6486
Calorific value corrected to sample as received	B. T. U. 10800 Calories 6000
Specific gravity of air-dried sample	1.269

Analysis of ash from air-dried sample.

SiO_2	21.70	per cent
CaO	15.29	per cent
MgO	1.92	per cent
Fe_2O_3	38.62	per cent
Al_2O_3	15.63	per cent
P_2O_5	.259	per cent
SO_3	4.95	per cent
Undetermined	1.731	per cent
	100.00	

Sample Number 17.

Description of Mine.

Operator. Willow Grove Coal Company, Angus.

Mine. Willow Grove mine, on northwest border of Angus in Greene county. No railroad connections.

Sample collected. May 14, 1909.

Description. This sample was taken from the fourth east-south entry. The seam is here 4 feet 2 inches thick. The coal breaks with angular fracture and shows bright clean faces. Thin films of lime occur along stratification planes. The vein worked is called the lower vein. Its thickness ranges from 4 to 5½ feet. The middle vein is separated from the lower by a sandstone roof 3½ to 20 feet thick, with an average of 14 feet. Owing to the character of the roof the mine is very wet. (See Vol. XIX, page 361, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

Although this mine is wet the sample as received did not show high moisture content. After air-drying the moisture value is lower than that of the average coal. The carbon content is lower than that of any coal examined. The ash is high, due to the lime bands mentioned above. The ash is light in color, low in iron oxide and the magnesia content is the highest found in any of the samples examined. This constituent is undoubtedly present in the lime bands mentioned. The calorific value is lower than that of any of the samples in this group. Washing would undoubtedly increase the value of this coal. Much of the ash-forming material could be removed. This treatment would also remove much of the sulphur, thereby decreasing whatever destructive effect the coal has upon grates and fire boxes.

Sample Number 17.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	8.08		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	5.57		13.20
Volatile combustible matter	38.73		35.60
Fixed Carbon	40.40		37.14
Ash	15.30		14.06
	100.00		100.00
Total sulphur	5.37		4.94
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.14		5.62
Carbon	60.48		55.59
Nitrogen	1.45		1.33
Oxygen	12.53		18.71
Sulphur	5.10		4.69
Ash	15.30		14.06
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11234 Calories 6241
Calorific value corrected to sample as received	B. T. U. 10326 Calories 5737
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11219 Calories 6233
Calorific value corrected to sample as received	B. T. U. 10313 Calories 5730
Specific gravity of air-dried sample	1.262

Analysis of ash from air-dried sample.

SiO_2	26.50	per cent
CaO	18.21	per cent
MgO	2.11	per cent
Fe_2O_3	27.77	per cent
Al_2O_3	18.44	per cent
P_2O_5	.996	per cent
SO_3	4.35	per cent
Undetermined	1.624	per cent
	100.00	

Sample Number 18.

Description of Mine.

Operator. High Bridge Coal Company, Madrid.

Mine. High Bridge mine, High Bridge, Dallas county, on Boone division of the Chicago, Milwaukee and St. Paul Railway.

Sample collected. May 12, 1909.

Description. The sample was collected from the face of the west entry about 1,300 feet from the shaft. The coal is here 3 feet 11 inches thick. It has a clay roof and about three inches of black shale on the floor. This is underlain by gray fire clay. The capacity of the mine at the time of sampling was 300 tons daily. (See Vol. XIX, page 89, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

The sample as received was high in moisture, much of which was lost on air-drying. The air-dried sample, however, retained about two per cent more moisture than the average. This coal has the lowest sulphur content of any of the coals examined. A considerable part of the sulphur went into the ash. The ash is light in color. The lime content is high. Iron oxide is low as might be expected from the low amount of sulphur. The thermal value is about average. Fixed carbon is above and volatile combustible matter is below the average.

Sample Number 18.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	10.47		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	8.68		18.21
Volatile combustible matter	33.14		29.67
Fixed Carbon	45.00		40.29
Ash	13.21		11.83
	100.00		100.00
Total sulphur	2.75		2.46
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	4.69		5.36
Carbon	65.92		59.03
Nitrogen	1.67		1.50
Oxygen	12.17		20.18
Sulphur	2.34		2.10
Ash	13.21		11.83
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11675 / Calories 6486
Calorific value corrected to sample as received	B. T. U. 10452 / Calories 5807
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11648 / Calories 6471
Calorific value corrected to sample as received	B. T. U. 10428 / Calories 5793
Specific gravity of air-dried sample	1.275

Analysis of ash from air-dried sample.

SiO_2	23.34	per cent
CaO	25.03	per cent
MgO	.76	per cent
Fe_2O_3	24.28	per cent
Al_2O_3	17.10	per cent
P_2O_5	.329	per cent
SO_3	7.90	per cent
Undetermined	1.261	per cent
	100.00	

Sample Number 19.

Description of Mine.

Operator. Phillips Fuel Company, Ottumwa.

Mine. Rutledge No. 5, at Rutledge, Wapello county, on the Chicago, Milwaukee and St. Paul Railway.

Sample collected. May 20, 1909.

Description. The mine was sampled in the seventeenth west entry on the north side of the shaft, about one mile from the bottom. The seam is here 3 feet 10 inches thick and is free from rock, although there are some sulphur concretions. The average thickness of the bed is 42 inches. (See Vol. XIX, page 298, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

The sulphur content is high. Ash is low for an Iowa coal. The ash was a dark brick red due to the iron oxide content. The carbon value is high and as a result the thermal value is correspondingly high. Moisture in sample as received is lower than the average. Except for the large amount of pyrite present this coal has an excellent appearance.

Sample Number 19.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	7.53		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	5.84		12.93
Volatile combustible matter	38.78		35.86
Fixed Carbon	44.14		40.82
Ash	11.24		10.39
	100.00		100.00
Total sulphur	6.26		5.79
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.09		5.54
Carbon	64.20		59.36
Nitrogen	1.67		1.54
Oxygen	11.80		17.63
Sulphur	6.00		5.54
Ash	11.24		10.39
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 12010 / Calories 6672
Calorific value corrected to sample as received	B. T. U. 11106 / Calories 6170
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11822 / Calories 6568
Calorific value corrected to sample as received	B. T. U. 10931 / Calories 6073
Specific gravity of air-dried sample	1.293

Analysis of ash from air-dried sample.

SiO_2	13.61	per cent
CaO	14.49	per cent
MgO	.97	per cent
Fe_2O_3	47.81	per cent
Al_2O_3	15.53	per cent
P_2O_5	.677	per cent
SO_3	5.80	per cent
Undetermined	1.113	per cent
	100.00	

Sample Number 20.

Description of Mine.

Operator. Keystone Coal Mining Company, Des Moines.

Mine. Keystone mine, Des Moines, Polk county, at west city limits, on Chicago, Milwaukee and St. Paul Railway.

Sample collected. June 21, 1909.

Description. The sample was taken from the face of the second north entry, where the vein has just risen from a swamp to the top of a hill. Where sampled the vein measured 4 feet 3 inches. In the swamp it was seven feet thick. It will vary from 3 feet 8 inches to 7 feet in different parts of the mine. Some thin sulphur streaks were present in the face, but no rock or thick sulphur bands.

The shaft is 165 feet deep. It was sunk July, 1908. The mine at the time of sampling was not well opened, but had an output of 75 to 80 tons daily, and employed 23 men. (See Vol. XIX, page 114, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

The sample as received was lower in moisture than the average Iowa coal. Ash and sulphur contents are high. The ash is a dark buff colored mass and contains more than the average amount of phosphorus. In this coal as in nearly all of the Iowa coals a large amount of sulphur goes into the ash. The lime content in the ash is noticeably low. The thermal value is a little below the average.

Sample Number 20.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	8.64		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	4.78		13.01
Volatile combustible matter	38.06		34.77
Fixed Carbon	41.83		38.22
Ash	15.33		14.00
	100.00		100.00
Total sulphur	6.26		5.72
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.12		5.64
Carbon	61.10		55.82
Nitrogen	1.37		1.25
Oxygen	11.20		17.91
Sulphur	5.88		5.37
Ash	15.33		14.01
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11481 / Calories 6378
Calorific value corrected to sample as received	B. T. U. 10483 / Calories 5824
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11433 / Calories 6352
Calorific value corrected to sample as received	B. T. U. 10445 / Calories 5803
Specific gravity of air-dried sample	1.256

Analysis of ash from air-dried sample.

SiO_2	23.15	per cent
CaO	10.83	per cent
MgO	1.26	per cent
Fe_2O_3	35.87	per cent
Al_2O_3	19.59	per cent
P_2O_5	1.04	per cent
SO_3	6.26	per cent
Undetermined	2.00	per cent
	100.00	

Sample Number 21.

Description of Mine.

Operator. English Creek Coal Company, Oskaloosa.

Mine. Hawkeye mine at Hawkeye, about two miles east of Knoxville, Marion county, on Washington and Knoxville line of the Chicago, Rock Island and Pacific Railway.

Sample collected. June 16, 1909.

Description. The sample is from room 5, thirteenth entry east. The coal here showed a face of six feet, with some thin streaks of sulphur and occasional bowlders. The mine at time of sampling employed 125 men. (See Vol. XIX, page 192, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

This coal contained a large amount of moisture in the "as received" condition and lost a very large amount of the moisture on air-drying. The hydrogen content is high and oxygen is unusually low. Although this coal has a high ash content its thermal value is above average. The sulphur content is also high.

Sample Number 21.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	13.80		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	4.50		17.68
Volatile combustible matter	36.37		31.35
Fixed Carbon	44.36		38.24
Ash	14.77		12.73
	100.00		100.00
Total sulphur	6.03		5.20
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.21		6.02
Carbon	63.42		54.67
Nitrogen	1.21		1.05
Oxygen	9.71		20.62
Sulphur	5.68		4.90
Ash	14.77		12.74
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11939 Calories 6633
Calorific value corrected to sample as received	B. T. U. 10291 Calories 5717
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11932 Calories 6629
Calorific value corrected to sample as received	B. T. U. 10285 Calories 5725
Specific gravity of air-dried sample	1.289

Analysis of ash from air-dried sample.

SiO_2	26.01	per cent
CaO	18.68	per cent
MgO	1.22	per cent
Fe_2O_3	32.84	per cent
Al_2O_3	14.03	per cent
P_2O_5	.382	per cent
SO_3	6.11	per cent
Undetermined	.728	per cent
	100.00	

Sample Number 22.

Description of Mine.

Operator. Bennett Brothers Coal Company, Des Moines.

Mine. Bennett mine, Des Moines, Polk county, south side Raccoon river. No railroad connections.

Sample collected. June 21, 1909.

Description. The mine was sampled at the end of the fourth west entry. The vein here measured 4 feet 6 inches. Its average thickness is 4 feet 4 inches, with occasional portions up to 5 or 6 feet. The coal is clean, without rock or sulphur bands and breaks into angular fragments. The mine is 125 feet deep and employed 100 men who put out 100 to 300 tons daily. The mine at time of sampling had been running six years and supplied a large local trade. (See Vol. XIX, page 120, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

This coal is high in hydrogen and carbon and as a result has a high calorific value. The coal in the "as received" condition was low in moisture for an Iowa coal. Much of this was lost on air-drying. The ash is light gray in color. The iron oxide content is low. Magnesia, alumina, and silica are high. The appearance of the coal is good and the analyses from it show it to be better than the average Iowa coal.

Sample Number 22.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	8.77		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	4.62		12.99
Volatile combustible matter	38.88		35.47
Fixed Carbon	44.20		40.32
Ash	12.30		11.22
	100.00		100.00
Total sulphur	5.15		4.70
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.32		5.83
Carbon	64.82		59.14
Nitrogen	.98		.90
Oxygen	11.68		18.42
Sulphur	4.90		4.48
Ash	12.30		11.23
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 12139 Calories 6744
Calorific value corrected to sample as received	B. T. U. 11064 Calories 6147
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 12020 Calories 6678
Calorific value corrected to sample as received	B. T. U. 10965 Calories 6092
Specific gravity of air-dried sample	1.277

Analysis of ash from air-dried sample.

SiO_2	26.13	per cent
CaO	17.04	per cent
MgO	2.09	per cent
Fe_2O_3	26.99	per cent
Al_2O_3	20.66	per cent
P_2O_5	.458	per cent
SO_3	5.58	per cent
Undetermined	1.482	per cent
	100.00	

Sample Number 23.

Description of Mine.

Operator. Bolton-Hoover Coal Company, Oskaloosa.

Mine. Bolton No. 2, Bolton, Mahaska county, on a long switch from the Oskaloosa and Tracy line of the Chicago, Burlington and Quincy Railroad.

Sample collected. June 15, 1909.

Description. The sample is from the first room on the fifth north, about 1,200 feet in from the mouth of the slope and seventy feet below the surface. The face was here 5 feet 3 inches in height. It showed a few thin sulphur streaks, some up to 1½ inches in thickness, and a few bowlders. The mine at time of sampling had a daily capacity of 400 tons. The coal is hauled out of the mine and overland to the top works, about 1,200 feet distant, by rope. The top works are located on the railroad at the old slope. The haulage engine is located here also and serves both slopes. The tail rope runs on the surface nearly one-fourth mile beyond the mouth of the slope and enters the mine through an old drill hole. (See Vol. XIX, page 205, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

Volatile combustible matter is high. The total carbon content is unusually high for an Iowa coal. This fact largely accounts for the high thermal value. Ash and sulphur are low. Silica in the ash is very high.

Sample Number 23.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	9.16		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	5.48		14.14
Volatile combustible matter	40.15		36.48
Fixed Carbon	44.88		40.77
Ash	9.49		8.61
	100.00		100.00
Total sulphur	3.26		2.96
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.30		5.82
Carbon	67.01		60.87
Nitrogen	1.41		1.28
Oxygen	13.64		20.55
Sulphur	3.15		2.86
Ash	9.49		8.62
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 12183 / Calories 6768
Calorific value corrected to sample as received	B. T. U. 11067 / Calories 6145
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 12102 / Calories 6724
Calorific value corrected to sample as received	B. T. U. 10993 / Calories 6107
Specific gravity of air-dried sample	1.30

Analysis of ash from air-dried sample.

SiO_2	35.34	per cent
CaO	16.60	per cent
MgO	.56	per cent
Fe_2O_3	28.56	per cent
Al_2O_3	14.03	per cent
P_2O_5	.710	per cent
SO_3	3.00	per cent
Undetermined	1.20	per cent
	100.00	

Sample Number 24.

Description of Mine.

Operator. Colfax Consolidated Coal Company, Colfax.

Mine. Mine No. 8, four miles southeast of Colfax on the Colfax Northern Railway.

Sample collected. June 17, 1909.

Description. The sample was cut from the end of the main west entry, 1,700 feet west from the shaft. The seam was here 5 feet 7 inches thick and presented a clean face except for a half inch sulphur band one foot from the bottom.

The shaft is 164 feet deep and penetrates the "first vein," one or two feet thick, eighty feet from the surface. The mine employed 400 men at time of sampling and had an output of 800 to 900 tons per day. (See Vol. XIX, page 159, Annual Report Iowa Geological Survey.)

Discussion of Analytical Results.

This coal in the "as received" condition contained a large amount of moisture. Air-drying removed much of this. The sulphur content is quite low for an Iowa coal and but little of this constituent went into the ash. The oxygen content is above the average. The ash is dark buff in color and high in iron oxide. The thermal value is a little below average.

Sample Number 24.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	12.68		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	5.47		17.46
Volatile combustible matter	39.17		34.20
Fixed Carbon	42.94		37.49
Ash	12.42		10.85
	100.00		100.00
Total sulphur	3.49		3.05
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.02		5.79
Carbon	63.60		55.53
Nitrogen	1.53		1.33
Oxygen	14.09		23.58
Sulphur	3.34		2.92
Ash	12.42		10.85
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U.	11588
	Calories	6438
Calorific value corrected to sample as received	B. T. U.	10119
	Calories	5620
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U.	11407
	Calories	6337
Calorific value corrected to sample as received	B. T. U.	9961
	Calories	5533
Specific gravity of air-dried sample		1.249

Analysis of ash from air-dried sample.

SiO_2	21.13	per cent
CaO	19.27	per cent
MgO	1.66	per cent
Fe_2O_3	35.34	per cent
Al_2O_3	17.55	per cent
P_2O_5	.247	per cent
SO_3	3.12	per cent
Undetermined	1.683	per cent
	100.00	

Sample Number 25.

Description of Mine.

Operator. Enterprise Coal Company, Des Moines.

Mine. Mine No. 2, Enterprise, Polk county, on the St. Paul and Kansas City Railway.

Sample collected. June 22, 1909.

Description. This sample was cut from the break-through near the face of the second west entry off the first south entry. The coal was 5 feet thick here and carried a two-inch sulphur band one foot from the top. Clay slips are present in places. The mine is considered to be in the second vein and was the only one working in this horizon with the possible exception of the Bennett mine. A daily output of 400 tons is maintained. (See Vol. XIX, page 143, Annual Report Iowa Geological Survey.)

Discussion of Results.

This coal is characterized by a high carbon content, the highest of any coal of this series. The volatile combustible matter is high. Ash is very low for an Iowa coal. Total sulphur is below average. The ash is gray in color and quite flaky. Alumina is high. The calorific value is the highest found in any Iowa coal examined.

Sample Number 25.

	Per Cent.		Per Cent.
Loss of moisture on air-drying	8.61		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	6.08		14.17
Volatile combustible matter	41.01		37.48
Fixed Carbon	44.17		40.36
Ash	8.74		7.99
	100.00		100.00
Total sulphur	3.79		3.46
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.23		5.73
Carbon	68.11		62.24
Nitrogen	1.58		1.44
Oxygen	12.78		19.35
Sulphur	3.56		3.25
Ash	8.74		7.99
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 12454 / Calories 6919
Calorific value corrected to sample as received	B. T. U. 11382 / Calories 6320
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 12303 / Calories 6835
Calorific value corrected to sample as received	B. T. U. 11244 / Calories 6247
Specific gravity of air-dried sample	1.301

Analysis of ash from air-dried sample.

SiO_2	23.12	per cent
CaO	17.10	per cent
MgO	1.86	per cent
Fe_2O_3	26.41	per cent
Al_2O_3	23.30	per cent
P_2O_5	.293	per cent
SO_3	6.72	per cent
Undetermined	1.197	per cent
	100.00	

Average Coal.

The data on the opposite page, which have been termed "average coal," were not obtained by the analysis of a sample, but by averaging the corresponding values obtained from analyses of the sixteen Iowa coals discussed in the preceding pages.

The coal dealer is seldom furnished with analyses of the particular coals he is handling and about the only information he can furnish the consumer is that it is an Iowa coal. In such a case the analytical data of the "average coal" will be of value. It will also be valuable when coal from the Iowa fields in general is to be compared with that of other fields.

A discussion of the average Iowa coal is unnecessary. The data will speak for themselves.

Average Coal.

	Per Cent.		Per Cent.
Loss on air-drying	9.33		
Analysis of air-dried sample: Proximate—		Analysis corrected to sample as received: Proximate—	
Moisture	6.34		15.07
Volatile combustible matter	37.60		34.09
Fixed Carbon	43.24		39.21
Ash	12.82		11.63
	100.00		100.00
Total sulphur	4.67		4.52
Analysis of air-dried sample: Ultimate—		Analysis corrected to sample as received: Ultimate—	
Hydrogen	5.07		5.64
Carbon	63.71		57.77
Nitrogen	1.47		1.33
Oxygen	12.27		19.42
Sulphur	4.66		4.23
Ash	12.82		11.61
	100.00		100.00

Calorific value determined on air-dried sample	B. T. U. 11754 Calories 6530
Calorific value corrected to sample as received	B. T. U. 10657 Calories 5921
Calorific value calculated from ultimate analysis of air-dried sample	B. T. U. 11650 Calories 6472
Calorific value corrected to sample as received	B. T. U. 10563 Calories 5865
Specific gravity of air-dried sample	1.27

Analysis of ash from air-dried sample.

SiO_2	23.26	per cent
CaO	17.31	per cent
MgO	1.38	per cent
Fe_2O_3	31.10	per cent
Al_2O_3	17.02	per cent
P_2O_5	.548	per cent
SO_3	6.00	per cent
Undetermined	1.372	per cent
	100.00	

General Discussion and Conclusion.

Coal is composed of two classes of substances, viz., (1) those which have heat value and (2) those which do not. In the first class carbon and hydrogen are the important ones. Sulphur on oxidation does evolve heat but the amount of heat contributed by this element is practically negligible. In the second class are ash, moisture, nitrogen and oxygen. Of these moisture and ash are the most important. These two substances not only displace their own weights of combustible matter but they absorb a large amount of the heat of the fuel in being heated up to the temperature of the fire box or furnace. Each per cent of moisture and ash displaces twenty pounds of combustible matter per ton. Both ash and moisture increase the cost of handling the coal for the producer and consumer. If the ash contains slagging or clinkering constituents the efficiency of the furnace is decreased and the cost of handling greatly increased. Sulphur which was mentioned above as having heat value, is also classed as an impurity on account of its low heat value and its injurious properties when coals are used for certain purposes.

The physical and chemical properties of Iowa coals are discussed under the following headings:

Moisture.—Coals from the Iowa field before mined contain a high percentage of moisture. In this respect they are similar to many coals in other fields of the mid-continental regions, averaging a little higher in this component than Illinois coals and about the same as Missouri coals. The loss of moisture on air-drying is practically the same as that of Illinois and Missouri coals. The Iowa coals are compared with those of Illinois and Missouri for the reason that they must compete in the market with these coals.

A study of the analyses reveals the fact that the loss of moisture by air-drying is not uniform in Iowa coals. This difference, the writer believes, is due to difference in structure. A microscopic examination was not made, but it is believed that such an examination would reveal differences in structure.

Iowa coals as they exist in the mine contain a little over fifteen per cent of moisture. When air-dried they contain 6.34 per cent

of moisture on the average. The importance of allowing the coal plenty of time to air-dry is here evident. In this work, ninety-six hours was the time allowed for air-drying. The coal was crushed much finer than is used in practice and for that reason the loss of moisture was more rapid than it is when the coal is in the lump sizes. Averaging the moisture content of the five mine samples and car samples of the same Iowa coals analyzed at the coal testing plant of the United States Geological Survey in 1904 (See Professional Paper No. 48, page 151, U. S. G. S.), we find that the difference in moisture in the mine samples and in the car samples after shipping to St. Louis is 2.42 per cent. From extensive studies at the Coal Testing Plant in St. Louis in 1904, the following conclusion was reached: "In sampling coals which run 5 per cent or over in the mine sample, the probable amount of moisture in the commercial sample can be obtained by multiplying by the coefficient 0.915." (See reference above.) In other words the moisture content of the commercial sample will average 91.5 per cent of that of the mine sample. This value is too high for Iowa coals. The coefficient of decrease of moisture from mine samples, calculated from the five Iowa coals referred to above is .844, or in other words the moisture content of the commercial sample of Iowa coal will average about 84.4 per cent of that of the mine sample.

The amount of moisture lost on air-drying after mining depends upon (1) the fineness of the coal, (2) atmospheric conditions, (3) time that elapses between mining and consumption, (4) conditions of storage. The finer the coal, within certain limits, the more rapid and greater will be the moisture loss. It is plain that weather conditions, such as variations in temperature and moisture content in atmosphere, will affect air-drying. Other things being equal the sooner the coal is used after mining the less will be the air-drying loss. This is true only within certain time limits. If coal is stored immediately after mining, the rate at which air-drying will take place may be affected by the condition of the bins. A bin with good ventilation will naturally give better drying conditions than one with poor ventilation. As mentioned before, the structure of the coal will undoubtedly have something to do with the rate of air-drying.

Volatile Combustile Matter.—This includes the volatile matter of coal with the exception of moisture. This term is objected to as being misleading, for the reason that not all of the volatile matter of coal, exclusive of moisture, is combustible. However, the term is in such general use in the coal trade that it has seemed wise to continue its use.

Iowa coals generally average quite high in volatile combustible matter. The exact nature of the volatile constituents has not been carefully studied. An investigation along this line is being planned.

Like most mid-continental and western coals, a large portion of the volatile matter is distilled off at rather low temperatures. This is one of the causes of a serious heat loss in the burning of these coals. Many furnaces in which Iowa coals are burned are not properly designed and as a result too often the fuel is blamed instead of the furnace. Better results would be obtained if greater combustion space or means of furnishing an ample supply of heated air be provided. The economic combustion of the volatile combustible matter in these coals is an important factor too often overlooked or neglected in furnace design. The low efficiency obtained from many western coals is often due to the fact that combustible volatile matter escapes from the flue unburned.

Closely associated with the volatile combustible matter of coals is the smoke nuisance problem. "Visible smoke* consists of solid carbon particles and solid or liquid hydrocarbon particles or tar vapors." These result from the incomplete combustion of the volatile matter of the fuel. The black particles of the smoke are free carbon deposited by the cooling of hot dissassociated gases. This carbon is evidence of a great waste of fuel. "Flame† is a phenomenon accompanying the chemical union of certain gases, one of which is usually oxygen; and the incandescent solid particles make a flame visible. If some of these particles in the flame are carbon, formed by the dissociation of hydrocarbons, luminosity results, and if the temperature of these particles is reduced below the point at which they combine with oxygen, or if sufficient oxygen is not at hand to effect

*Bureau of Mines bulletin, No. 1, page 9, Volatile Matter of Coal.
†Bureau of Mines bulletin, No. 1, page 9, Volatile Matter of Coal.

the union, they fail to unite with oxygen, and pass off as solid carbon in smoke." "The essential requirements of smokeless combustion are, therefore, three—(1) sufficient combustion space, (2) sufficient air at a high temperature, and (3) sufficient thorough mingling of gases and air—these three conditions to be adapted to the type of fuel and nature of its volatile products."

The property that many coals possess to disintegrate and change in heat value, known as "weathering," is associated to a certain extent with the volatile matter of the coal. Parr* and Wheeler found that upon liberation of coal from the vein immediately an exudation of hydrocarbons began, followed by an absorption of oxygen. The loss† of hydrocarbons caused a loss in calorific value averaging about one per cent for the first week and three to three and five-tenths per cent for a year. Iowa coals no doubt are very similar to Illinois coals in this respect. Weathering will be further discussed under sulphur.

For the manufacture of illuminating gas, coals with high volatile matter content are usually preferred. Experience has shown, however, that not only the percentage of volatile matter is important, but also its composition. Careful studies have shown that the composition of the volatile matter of coals varies greatly. Concerning the value of coals in general for coal gas manufacture, Fuhlweiler‡ states:

It is notable that some of the newer Western coals yield considerably less gas than the Eastern coals having the same content of volatile matter. The ultimate analysis of a coal does not throw very much light on its suitability for the manufacture of gas, although certain general indications may be derived from it. In general, increasing percentages of hydrogen result in more volatile constituents, and high percentages of oxygen apparently decrease the yield of gas and increase the yield of tar. The higher percentages of nitrogen usually result in more ammonia. The presence of sulphur is to be avoided as far as possible, yet its manner of occurrence is important in determining whether it will be volatile and go off in the gas and have to be removed, or whether it will remain in the coke. Where the

*University of Illinois bulletin, No. 32.
†University of Illinois bulletin, No. 38.
‡Indust. Chem. for Student and Mfg.—Rogers & Aubert, page 418.

coke is to be used for the manufacture of water gas, the composition and fusion point of the ash is important, while in case it is to be used for foundry work the absence of sulphur and phosphorus is essential.

In the manufacture of coal gas four commercial products are obtained. They are coal gas, ammoniacal liquor, coal tar and coke. The value of these products, as has been stated, depends upon the coal from which they are obtained. Iowa coals are high in oxygen, consequently large yields of tar may be expected. In this respect they differ very little from Illinois and Missouri coals. The oxygen content of Eastern coals is very much lower. The hydrogen and nitrogen contents of Iowa, Illinois and Missouri coals are about the same. Sulphur in Iowa coals is high and much of this substance, as will be seen by examining the analyses, will go into the gas and will have to be removed. The coke, which is very poor, will be high in ash and consequently high in sulphur, which will prevent its use for forge and metallurgical purposes.

For the manufacture of gas a good grade of marketable coke is essential. In Iowa a coal for gas purposes that will not yield a good coke cannot be used. The yield of gas from Iowa coals is low compared with Pennsylvania and West Virginia coals. Illinois and Missouri coals are much the same in this respect. Iowa coals are not used for gas purposes for the reasons given above and the additional reason that the ash-disposal problem is very difficult. The cost of operation of a gas plant using Iowa coal is very much higher than one using Pennsylvania or West Virginia coals. Specifications for gas coals usually call for a maximum of not more than one per cent of sulphur. This excludes all Iowa coals.

Fixed Carbon.—Experience has shown that in bituminous and semi-bituminous coals the steam values are proportional to the percentage of fixed carbon. Although the fixed carbon evaporates less water than an equivalent weight of volatile combustible matter when properly burnt, so much of the latter is lost through careless firing and faulty furnace construction

that the relative steam value of a coal may be approximated by assuming the fixed carbon to be the only useful constituent. For steam tests of Iowa coals see Vol. XIX, pages 417-458, Annual Report Iowa Geol. Surv. Usually the fixed carbon is the principal constituent of the coke produced by the destructive distillation of the coal. Coke produced from Iowa coals has little value. It has little strength and is high in ash and sulphur.

Ash.—Iowa coals are high in ash. This is the most detrimental of the inert constituents. From each ton of coal burned from 200 to 300 pounds of ash are produced. When the fact that the ash is quite fusible under certain conditions is taken into consideration the ash problem is more serious. The labor charge, in a power plant burning Iowa coal, against handling the ash, is high.

The fact that Iowa coals clinker and slag is due very largely to the high iron content. An examination of the analyses of Iowa coals reveals a high ash content. Further examination shows that the iron content in the ash is high. The ash analysis shows the iron to be present as ferric oxide. The fact is that much of the iron is present in the coals as pyrite (FeS_2).

When the furnace temperature approaches low redness the pyrite breaks up as follows:

$$FeS_2 + heat = FeS + S.$$

Oxygen from the air then reacts with the sulphur ($S + 2O = SO_2$) to form sulphur dioxide. It will also react with FeS to form ferrous oxide (FeO) and sulphur dioxide (SO_2). The equation is $FeS + 3O = FeO + SO_2$. If the temperature of the furnace does not get too high the ferrous oxide will go over to ferric oxide.

$$2FeO + O = Fe_2O_3.$$

If the iron stays in the form of ferric oxide little or no slagging or clinkering will take place. In the case where the furnace temperature is high, the ferrous oxide will react with the silica (SiO_2) to form a ferrous silicate. The silicate formed will depend upon the temperature and the amount of constit-

uents present. The following reactions take place when firing is pushed:

$$\underset{\text{Ferrous oxide}}{FeO} + \underset{\text{silica}}{SiO_2} = \underset{\text{ferrous silicate}}{FeSiO_3}$$

$$\underset{\text{Ferrous oxide}}{2FeO} + \underset{\text{silica}}{SiO_2} = \underset{\text{ferrous silicate}}{Fe_2SiO_4}$$

Both of these silicates have comparatively low formation temperatures, and these temperatures are readily obtained in furnace or boiler firing. The above silicates at their formation temperatures are sticky viscous masses which when cooled are clinkers. If the temperature is raised above the formation temperature of these silicates the mass will fuse and run through the grates, forming when cool, either a glassy or stony slag. If the temperature is high enough, as is often the case, the ferrous sulphide (FeS) mentioned above will fuse and cause clinkering. In the presence of carbon (C) at temperatures above 1000 degrees C ferric oxide will be reduced to ferrous oxide, which will then react with silica to form a slag. The formation temperatures of calcium and aluminum silicates are very high, but in some cases calcium silicate will be formed and clinkering will result. The reaction is

$$\underset{\text{Lime}}{CaO} + \underset{\text{Silica}}{SiO_2} = \underset{\text{Calcium silicate}}{CaSiO_3}$$

In most cases the lime and alumina will dissolve in the ferrous silica to form a complex slag.

If Iowa coals are to be used for the manufacture of producer gas, it is probable that the slagging type of gas producer will work well. At any rate this method of getting rid of the ash seems feasible.

Few gas-producer tests have been made on Iowa coals. Those which have been made indicate that a much higher fuel efficiency can be obtained by using the coal in a producer plant. One test made "*showed that to produce one electrical horsepower hour with this coal in the producer required 1.73 pounds of dry coal, whereas under the steam boiler it required 4.95 pounds to produce the same result, a gain in efficiency for the producer of 186 per cent. As this coal ran nearly 17 per cent

*Vol. XIX, page 411, Annual Report Iowa Geol. Surv.

of ash in the car sample, the great advantage of using it in the producer plant will be apparent, and these results seem to open the way to a much better utilization of Iowa coals."

No thorough washing tests of Iowa coals have been made. The writer believes that thorough experiments along this line would give valuable results. Much of the ash and sulphur content could no doubt be removed and the value of the coal thereby be greatly increased.

Sulphur.—Iowa coals are noted for their high sulphur content. This constituent renders them practically valueless at the present time for the manufacture of gas. Iron and sulphur at a temperature above low red heat react to form FeS. This is the principal cause of the corrosion of grates and fire boxes when coals high in sulphur are burned. Not all of the sulphur in Iowa coals is present as FeS_2. Some of it is present as calcium sulphate ($CaSO_4$), magnesium sulphate ($MgSO_4$), and as organic sulphur. The sulphate sulphur does little damage, and unless very high temperatures are reached, goes into the ash.

Deterioration and spontaneous heating of coal in storage is thought by some authorities to be due to a large extent to the oxidation of pyrite. Other authorities attribute spontaneous combustion to oxidation of the available hydrogen and a small part of the carbon by occluded oxygen. This causes an evolution of heat. When the sulphur of the pyrite (FeS_2) oxidizes, heat is also given up. If the coal is fine and the pile is large, there is little chance for the heat so generated to escape. The temperature having been raised the velocity of the oxidation of the sulphur, hydrogen and carbon increases and a correspondingly large amount of heat is evolved. The increase in temperature followed by increased velocity of reaction takes place until the ignition temperature of the coal is reached. The rise in temperature causes an increased amount of volatile matter to be distilled off. Unless this volatile matter can escape, it will ignite and burn. A certain amount of moisture seems to aid in spontaneous combustion. Lump sizes are not as liable to ignite by spontaneous combustion as finer coal. The larger the

pile and the poorer the ventilation, the greater is the tendency to ignite by spontaneous combustion.

Storing large amounts of fine coal in large piles is not to be recommended. Storing under water will prevent spontaneous combustion and the disintegration of the coal. However, the storage of coal in larger sized lumps than is to be used will overcome the difficulties of spontaneous combustion to a great extent. The storing of Iowa coal in large lumps for a very long time is not recommended, for the reason that disintegration takes place due to the taking up of oxygen, part of which oxidizes the available hydrogen and a little carbon, as has been stated before. In time the coals will almost completely slack. Then the danger of spontaneous combustion is great. This danger is not greater in Iowa coals than in many Illinois and Missouri coals. There is a great deal of difference of opinion concerning the factors that are most important in spontaneous combustion. An excellent summary of the opinions of many investigators is given in Illinois University Bulletin No. 46, entitled, "The Spontaneous Combustion of Coals," by Parr and Kressman.

Summary.—Iowa coals on account of their high ash and moisture contents have correspondingly low heat value. Their high sulphur content excludes them from the manufacture of coal or water gas, and renders them destructive to grates and fire boxes. Their tendency to disintegrate by weathering prevents their being stored for a great length of time. The experimental evidence at hand indicates that from 100 to 150 per cent greater efficiency can be obtained by the manufacture of producer gas. This method of use should create a preference for Iowa coal for steaming purposes in Iowa. Washing will undoubtedly increase the value of Iowa coals by removing much of the ash and sulphur content. Whether this can be done economically has not been demonstrated, but it is thought that an experiment on an industrial scale would yield favorable results. The use of Iowa coal at the present time is confined to steam and household use in the immediate vicinity of the mines. The use of Iowa coals for power purposes is discussed in Bulletin No. 29, of the En-

gineering Experiment Station of Iowa State College at Ames. Iowa coals are of little value for the manufacture of coke on account of their high sulphur content and low crushing strength. Iowa coals compare favorably with those of Northern Illinois and Missouri.

Purchase Of Coal Under Specification.

The purchase of coal under specification depending on the heating value of the coal, its content of ash and of moisture, rather than upon the reputation of the coal dealer or the trade name of the coal, is recommended. The United States Government has been purchasing coal for a number of years under specification with great profit. The specifications used are quoted below and may be adapted, by the Iowa coal consumer and dealer, to Iowa coals. Only that part of the specification which deals with Bituminous coal is given. For complete specifications for different types of coal, consult Bureau of Mines Bulletin, No. 63, entitled, "Sampling Coal Deliveries and Types of Government Specifications for the Purchase of Coal," by George S. Pope.

Specifications and proposals for bituminous coal for steam power plants.

I. Proposals.

1. Sealed proposals, in duplicate, to furnish the quantities of coal specified in the schedule herewith, required for the use of (the name of the department, bureau, or institution) for the fiscal year ending June 30, 19.., will be received until 2 o'clock p. m., ... 19.., at the office of ..... and then opened.

2. Each bidder shall have the right to be present either in person or by attorney when the bids are opened.

II. Address of Proposals.

3. Proposals, in duplicate, must be forwarded to.....
....., postage prepaid. Addressed envelope for mailing is inclosed herewith.

III. Proposals—Guaranty.

4. *Signature.* Proposals must be made in duplicate on the form furnished by ....., and must be signed by the individual, partnership, or corporation making the same; when made by a partnership, the name of each partner must be signed. If made by a corporation, proposals must be signed by the officer thereof authorized to bind it by contract, and be accompanied by a copy, under seal, of his authority to sign.

5. *Cash or Certified Check.* The proposals must be accompanied by cash or by a certified check drawn payable to the order of the Secretary of the....., in an amount equal to 2 per cent of the estimated cost of the items for which bids are submitted, the minimum amount in any case to be $10. This requirement is solely to guarantee, if an award is made on the proposal, that within 10 days after notice is given that an award has been made, the bidder will enter into a contract in accordance with the terms of the proposal and execute a bond for the faithful performance thereof, with good and sufficient sureties as hereinafter required. In the event of the failure of the bidder to enter into contract or execute bond, the cash or check guaranty will be forfeited.

IV. Contractor's Bond.

6. *Sureties.* Each contractor shall be required to give a bond, with two or more individual sureties or one corporate surety duly qualified under the act of Congress approved August 13, 1894, in which they shall covenant and agree, in case the said contractor shall fail to do or perform any or all of the covenants, stipulations, and agreements of said contract on the part of the said contractor to be performed as therein set forth, the said contractor and his sureties shall forfeit and pay to the United States of America any and all damages sustained by the United States by reason of any failure of the contractor fully and faithfully to keep and perform the terms and conditions of his contract to be recovered in an action at law in the name of the United States in any proper court of competent

jurisdiction. Such sureties (except corporate sureties) shall justify their responsibility by affidavit showing that they severally own and possess property of the clear value in the aggregate of double the amount of the above-mentioned forfeiture over and above all debts and liabilities and all property by law exempt from execution; the affidavit shall be sworn to before a judge or a clerk of a court of record or a United States attorney, who must certify of his own personal knowledge that the sureties are sufficient to pay the full penalty of the bond.

7. *May be waived.* If the estimated amount involved in the contract does not exceed the sum of $200, then the bond may be waived with the consent of the department involved.

V. Reservations.

8. *Rejection and annulment.* The right will be reserved by the Secretary of.....to reject any and all bids, to waive technical defects, and to accept any part of any bid and reject the other part, if, in his judgment, the interests of the Government shall so require; also the right to annul any contract, if, in his opinion, there shall be a failure at any time to perform faithfully any of its stipulations, or in case of a willful attempt to impose upon the Government coal inferior to that required by the contract; and any action taken in pursuance of this latter stipulation shall not affect or impair any right or claim of the United States to damages for the breach of any of the covenants of the contract by the contractor. Bidders are cautioned against guaranteeing higher standards of quality than can be maintained in delivered coal (this applies more especially to bituminous coal), as the Government reserves the right to reject any and all bids if the analyses and test results which the Government may have on record indicate that higher standards have been offered than can probably be maintained.

9. *Estimated quantity.* The estimated quantity of coal to be purchased will be based upon the previous annual consumption, but the right will be reserved to order a greater or less quantity, subject to the actual requirements of the service.

10. *Tests.* The right will be reserved by the Government to purchase, for the purpose of making boiler tests, other coal than that herein contracted for, provided the amount so purchased does not exceed five per cent (5 per cent) of the coal used at the plant during the period covered by this agreement.

11. *Lowest bids may not be considered.* If it should appear to the best interests of the Government to do so, the right is reserved to award the contract for supplying coal at a price higher than that named in a lower bid or in lower bids, on the basis of the quality of the coal offered.

12. *Failure to contract.* If the bidder to whom the award is made should fail to enter into a contract as herein provided, then the award may be annulled and the contract let to the next most desirable bidder without further advertisement, and such bidder shall be required to fulfill every stipulation expressed herein, as if he were the original party to whom the contract was awarded.

13. *Contracts non-transferable.* No contract can be lawfully assigned.

14. *Default.* No proposal will be considered from any person, firm, or corporation in default of the performance of any contract or agreement made with the United States, or conclusively shown to have failed to perform satisfactorily such contract or agreement.

VI. Description of Coals Desired.

15. *Coal desired.* Bids are desired on coal as specified below:

The coal must be a good steam..... { coking { run-of-mine / slack / lump (give size) } / noncoking { run-of-mine / slack / lump (give size) } }, bituminous coal, free from bone, slate, dirt, and excessive dust, and adapted for successful use in the particular furnace equipment.

16. *Lowest quality acceptable.* Bituminous coal that shows on analysis a quality lower than that indicated below will not be considered:*

Moisture in "delivered coal".....	....per cent
Ash in "dry coal".....	....per cent
Volatile matter in "dry coal".....	....per cent
Sulphur (separately determined) in "dry coal"	....per cent
British thermal units in "dry coal" below	.....

17. *Information to be supplied by bidder.* Bidders are required to specify the coal offered in terms of moisture, "as received"; ash, volatile matter, sulphur, and British thermal units, "dry coal"; which values become the standards for the coal of the successful bidder. In addition, the bidders are required to give the name and location of the mine producing the coal, the name or other designation of the coal bed, name of operator of mine, and the trade name of the coal. This information to be furnished in spaces provided under section 57 (A).

VII. Award.

21. *Considerations.* Bids will be considered on each item separately; and in determining the award of the contract consideration will be given to the quality of the coal (expressed in terms of ash in "dry coal," of moisture in coal "as received," and of British thermal units in "dry coal") offered by the respective bidders, to the operating results obtained with the coals on previous Government contracts, as well as to the price per ton.

22. *Method of comparing bids.* In order to compare bids as to the quality of the coal offered, all proposals will be adjusted to a common basis. The method used will be to merge all four variables—ash, moisture, calorific value, and price bid per ton—into one figure, the cost of 1,000,000 British thermal units, so that one bid may readily be compared with another. The procedure under this method will be as follows:

*The percentages and the heating value to be filled in by the office inviting bids.

(*a*) All bids will be adjusted to the same ash percentage by selecting as the standard the proposal that offers coal containing the highest percentage of ash. Each 1 per cent of ash content below that of this standard will be assumed to have a positive value of 2 cents per ton, and the price will be accordingly increased 2 cents, the amount of premium that is allowed under the contract for 1 per cent less ash than the standard established in the contract. Fractions of a per cent will be given proportional values. The adjusted bids will be figured to the nearest tenth of a cent.

(*b*) To reduce bids to a common basis with respect to the moisture in the coal offered, the price quoted, adjusted in accordance with the above, will be divided by the difference between 100 per cent and the per cent of moisture guaranteed in the proposal. The adjusted bids will be figured to the nearest tenth of a cent.

(*c*) On the basis of the adjusted price, allowance will then be made for the varying heat values by computing the cost of 1,000,000 British thermal units for each coal offered. This determination will be made by multiplying the adjusted price per ton by 1,000,000 and dividing the result by the product of 2,240, multiplied by the number of British thermal units guaranteed.

23. *Service results and test.* If from practical service experience or by test any of the coals have in the past proved unsuited for the furnace and boiler equipment, or have failed to meet the requirements of the city smoke ordinances, the bids thereon may be eliminated from further consideration, regardless of their calculated costs per million B. t. u. The selection of the lowest bid of the remaining bids on the basis of the cost per million B. t. u. will be considered as a tentative award only, the Government reserving the right to have practical service test or tests made under the direction of the Bureau of Mines, the results to determine the final award of contract. The interested bidder or his authorized representatives may be present at such test.

25. *Service test.* Before making final award of contract, practical service tests, under the direction of the Bureau of

Mines, will be made of selected coals to determine the suitability and adaptability of the coals for the particular furnace and boiler equipment concerned. The interested bidders or their authorized representatives may be present at such tests. Samples will be collected from the coals tested, and complete analyses and calorimetric determinations will be made, as well as determinations of the fusing temperature of the coal ash.

26. *Test results part of contract.* The results of the service test of the coal that proves a satisfactory fuel and the results of the analyses and tests of the samples of that coal will become a part of the contract establishing the standard of the coal offered by the bidder to whom the final award is made. The results become the basis for determining rejectable coal during the life of the contract.

VIII. Delivery.

27. *Quantity.* The coal shall be delivered in such quantities at such times as the Government may direct.

28. *Rapidity.* All the available storage capacity of the Government coal bunkers will be placed at the disposal of the contractor to facilitate delivery of coal under favorable conditions. When an order is issued for coal, the contractor upon commencing a delivery on that order shall continue the delivery with such rapidity as not to waste unduly the services of the Government inspector. Information is furnished in the schedule herewith in relation to the several places, etc., for the delivery of coal, but the bidder is invited to visit those places and inspect the conditions for his own information.

29. *Notices.* After verbal or written notice has been given to deliver coal under this contract, a second notice may be served in writing upon the contractor to make delivery of the coal so ordered within 24 hours after receipt of said second notice. Should the contractor, for any reason, fail to comply with the second request, the Government will be at liberty to buy coal in the open market and for coal so purchased to charge against

the contractor and his sureties any excess in price over the contract price.

30. *Hours.* The contractor will be allowed to deliver coal during the usual hours of teaming, that is, between 8 a. m. and 5 p. m.

31. *Weighing.* The coal will be weighed by representatives of the Government without expense to the contractor.

IX. Sampling.

32. *Imperative for bituminous coal.* As payment for bituminous coal is based upon the quality of coal delivered as shown by analyses of representative samples, it is imperative that samples representing every order of coal be taken and that the proper official of the Government buildings see that such samples are obtained. The Bureau of Mines will have general direction of sampling, giving instructions in the methods of obtaining representative samples, and lending all practicable assistance.

33. *Contractor may be present.* If desired by the coal contractor, permission will be given to him or his representative to be present and witness the collection and preparation of the samples to be forwarded to the Government laboratories.

34. *During unloading.* The coal will be sampled at the time it is being loaded or unloaded from railroad cars, ships, barges or wagons, or when discharged from contractors' supply bins, except as provided for in section 27 of the specifications for anthracite broken, egg, stove, and chestnut.

35. *Size of increments.* When the coal is being unloaded, a shovel or specially designed tool will be used for taking portions or increments of 10 to 30 pounds of coal. For slack or small sizes of anthracite increments as small as 5 to 10 pounds may be taken. The size of the increments depends on the size and weight of the largest pieces of coal and impurities.

36. *Collection of gross sample.* The increments will be regularly and systematically collected, so that the entire delivery

will be represented proportionately in the gross sample. The frequency of collecting the increments should be regulated so that a gross sample of not less than 1,000 pounds will be collected. If the coal contains an unusual amount of impurities, such as slate, and if the pieces of such impurities are very large, it will be necessary to collect gross samples of even 1,500 pounds or more. For slack coal and for small sizes of anthracite, if the impurities do not exist in abnormal quantities or in pieces larger than three-quarters of an inch, a gross sample of approximately 600 pounds may prove sufficient. The gross sample should contain the same proportion of lump coal, fine coal, and impurities as is contained in the coal delivered. As the increments are collected, they will be deposited in a receptacle having a tight-fitting lid and provided with a lock.

37. *Preparation of gross sample.* After the gross sample is collected, it will be systematically crushed, mixed, and reduced in quantity to convenient size for transmittal to the laboratory. The crushing will be done by a mechanical crusher or by hand with an iron tamping bar on a smooth and solid floor. In the absence of a smooth, tight floor, the crushing may be done on a heavy canvas, to prevent the accidental admixture of any foreign matter. The mixing and reduction will be done by hand with a shovel, or mechanically by means of riffles or sampling machines.

38. *Hand preparation.* When prepared by hand the pieces of coal and impurities will be crushed to the approximate size indicated in the table below before each reduction:

Weight of sample to be divided	Size to which coal and impurities should be broken before each division
1,000 pounds or more	1 inch
500 pounds	¾ inch
250 pounds	½ inch
125 pounds	⅜ inch
60 pounds	¼ inch

The 60-pound sample will then be reduced by quartering, or by the use of riffles or sampling machines, to the desired quantity for transmittal to the laboratory.

39. *Mixing and reduction by "alternate shovelfuls."* After each crushing, the sample will be thoroughly mixed before reduction in quantity, the procedure being as follows:

The crushed coal will be shoveled into a conical pile. A new long pile will then be formed by taking a shovelful at a time and spreading it out in a straight line (8 to 10 feet long for a shovel holding 15 pounds). Each new shovelful will be spread over the top of the preceding one, beginning at opposite ends, and so on, until all the coal has been formed into one long pile. By walking around the long pile and systematically taking shovelfuls, and shoveling the coal to one side, alternate shovelfuls being discarded, the sample will be halved in quantity.

40. *Mixing and reduction by "quartering."* The above "long-pile" and "alternate-shovel" method of mixing and reducing the sample will be followed with samples of 125 to 250 pounds or more. Samples smaller will be mixed on a canvas about 8 feet square by raising first one end of the canvas and then the other, thereby rolling the sample back and forth. After thoroughly mixing in this manner, the sample will be formed in a conical pile and reduced in quantity by quartering.

41. *Crushing of increments.* Whenever the different increments of samples are collected throughout some considerable period of time, each increment may be crushed as soon as taken and the pieces of coal and impurities broken sufficiently small to permit two or three reductions of the total accumulated sample before further crushing is necessary.

42. *Special moisture sample.* In the reduction of the gross sample to the sample for transmittal to the laboratory the gross sample will unavoidably lose moisture. To determine the moisture content in the coal delivered, a separate special moisture sample must be taken. This will be accumulated by placing in a hermetically sealed receptacle small parts of the freshly taken increments of the gross sample.

43. *Moisture samples discretionary.* The collection of special moisture samples shall be discretionary with the Government. Special moisture samples will be taken if in the opinion of the Government inspector the coal contains moisture in excess of the amount guaranteed by the contractor. The special moisture samples will be taken so as to represent the coal with respect to the moisture contained at time of weighing.

44. *Extended deliveries.* If deliveries extend over any considerable period, what would otherwise be a gross sample may be worked down in successive stages to samples of a size suitable for transmittal to the laboratory, and the samples representing the several equal parts of a delivery may be analyzed and the several analyses averaged, or the several samples may later be mixed (at the delivery point or in the laboratory and reduced to one sample) and one analysis made.

X. Analysis.

45. Immediately on receipt of a sample in the laboratory it will be analyzed and tested by the Government in accordance with the method recommended by the American Chemical Society, and by the use of a bomb calorimeter.

XI. Causes for Rejection.

46. *Character.* All coal delivered during a fiscal year is expected to be of the same character as that specified by the contractor. It should, therefore, be supplied as nearly as possible from the same mine or group of mines.

47. *Quality.* It is important that the standards furnished with bids shall not establish a higher value than can be actually maintained under the terms of the contract. In this connection it should be recognized that the small "mine samples" usually indicate a coal of higher economic value than that actually delivered in carload lots, because of the care taken to separate extraneous matter from the coal in the "mine samples." It is evident, therefore, that it will be to the best interests of the contractor to furnish a correct description with average values of

the coal offered, as a failure to maintain the standard he establishes will result in deductions from the contract price, and may cause a cancellation of the contract, whereas deliveries of coal of higher grade than quoted will be paid for at an increased price per ton.

48. *Unsatisfactory fuel.* Coal containing percentages of volatile matter or sulphur higher than the limits indicated under "Description of Coals Desired," or having a moisture content in excess of that guaranteed, or containing percentages of ash greater than indicated in the column "Maximum limits for ash" in the table in the section entitled "Price and Payment," or failing to give satisfactory results because of excessive clinkering or a prohibitive amount of smoke, or proving for any other cause to be an undesirable fuel, will be subject to rejection, and the Government will have the right to cause the contractor to remove such coal at no cost to the Government. Such event may result in the Government purchasing in the open market, or through competitive bidding, such quantity of coal to supply the deficiency caused by such failure, or annulling the contract by giving notice in writing to that effect to the contractor, and the Government, in its discretion, purchasing such coal in the open market or by contract upon competitive proposals; the contractor to remain liable for all damages sustained by the United States on account of such failure, including the difference, if any, between the cost of purchasing and delivering said coal and the price at which the contractor agreed to furnish it. The contract price must be understood to be the corrected price per ton based upon analysis, as hereinafter described under the section entitled "Price and Payment." If it shall be impracticable to cause the contractor to remove coal subject to rejection, the Government may use such rejectable coal, deducting penalties as determined under the section entitled "Price and Payment," and may in addition, as circumstances warrant in the opinion of the Government, deduct a further penalty of twenty-five (25) per cent of the amount of the bill, based on the tonnage of the coal under question and at the contract price per ton.

XII. Price and Payment.

52. *Prompt payment.* Payment will be made promptly upon receipt of a report from the Bureau of Mines on the quality of the coal under consideration. The Bureau of Mines will furnish such report in not more than fifteen (15) days after the receipt of the sample or samples.

53. *Determination of price.* Payment for coal specified in the proposal will be made upon the basis of the price therein named, corrected as follows for variations in heating value, ash, and moisture from the standards specified in the contract (see section 48 for an additional deduction on coal subject to rejection):

(*a*) Considering the coal on a "dry-coal" basis, no corrections in price will be made for variations of 2 per cent or less in the number of British thermal units from the guaranteed standard. When the variation in heat units exceeds 2 per cent of the guaranteed standard, the correction in price will be a proportional one and will be determined by the following formula:

$$\frac{\text{B. t. u. delivered coal ("dry-coal" basis)}}{\text{B. t. u. ("dry-coal" basis) specified in contract}} \times \text{bid price} = \text{price resulting from B. t. u. corection.}$$

For example, if coal delivered on a contract guaranteeing 14,000 British thermal units on a "dry-coal" basis at a bid price of $3 per ton shows by calorific test results varying between 13,720 and 14,280 British thermal units, there will be no price correction. If, however, the delivered coal shows by calorific test 14,300 British thermal units on a "dry-coal" basis for example, the price for this variation from the contract guarantee is, by substitution in the formula:

$$\frac{14{,}300}{14{,}000} \times \$3 = \$3.064$$

The correction will be figured to the nearest tenth of a cent.

(*b*) For all coal that by analysis contains less ash on a "dry-coal" basis than the percentage specified herein, a premium of 2 cents per ton for each whole per cent less will be paid. An increase in the ash content of 2 per cent above the standard established by the contractor will be tolerated without exacting a penalty. When such excess is greater than 2 per cent, deductions will be made in acordance with the following table:

Ash as established in proposal	No deduction for limits below—	Cents per ton to be deducted							Maximum limits for ash*
		2	4	7	12	18	25	35	
		Percentages of ash in dry coal							
Per Cent	*Per Cent*								
4	6, inclusive	6.01– 7.00	7.01– 8.00	8.01– 9.00	9.01–10.00	10.01–11.00	11.01–12.00	12.01–13.00	11
5	7, inclusive	7.01– 8.00	8.01– 9.00	9.01–10.00	10.01–11.00	11.01–12.00	12.01–13.00	13.01–14.00	12
6	8, inclusive	8.01– 9.00	9.01–10.00	10.01–11.00	11.01–12.00	12.01–13.00	13.01–14.00	14.01–15.00	13
7	9, inclusive	9.01–10.00	10.01–11.00	11.01–12.00	12.01–13.00	13.01–14.00	14.01–15.00	15.01–16.00	14
8	10, inclusive	10.01–11.00	11.01–12.00	12.01–13.00	13.01–14.00	14.01–15.00	15.01–16.00	16.01–17.00	14
9	11, inclusive	11.01–12.00	12.01–13.00	13.01–14.00	14.01–15.00	15.01–16.00	16.01–17.00	17.01–18.00	15
10	12, inclusive	12.01–13.00	13.01–14.00	14.01–15.00	15.01–16.00	16.01–17.00	17.01–18.00		16
11	13, inclusive	13.01–14.00	14.01–15.00	15.01–16.00	16.01–17.00	17.01–18.00	18.01–19.00		16
12	14, inclusive	14.01–15.00	15.01–16.00	16.01–17.00	17.01–18.00	18.01–19.00	19.01–20.00		17
13	15, inclusive	15.01–16.00	16.01–17.00	17.01–18.00	18.01–19.00	19.01–20.00			18
14	16, inclusive	16.01–17.00	17.01–18.00	18.01–19.00	19.01–20.00	20.01–21.00			19
15	17, inclusive	17.01–18.00	18.01–19.00	19.01–20.00	20.01–21.00				19
16	18, inclusive	18.01–19.00	19.01–20.00	20.01–21.00					20
17	19, inclusive	19.01–20.00	20.01–21.00	21.01–22.00					21
18	20, inclusive	20.01–21.00	21.01–22.00	22.01–23.00					22

*These limits are used in determining rejectable coal, see section 48, marginal heading "Unsatisfactory fuel."

As an example of the method for determining the deduction in cents per ton for coal containing ash exceeding the standard by more than 2 per cent, suppose coal delivered on a contract guaranteeing 10 per cent ash on the "dry-coal" basis shows by analysis between 14.01 and 15 per cent (both inclusive), or, for instance, 14.55 per cent, the deduction according to the table is 7 cents per ton (reading to the right on line beginning with 10 per cent on the extreme left, which in this case is the standard, to the column containing "14.01-15," the deduction at the top of this column is seen to be 7 cents).

NOTE.—If the ash standard is an uneven percentage, the table will be revised in order to determine deductions on account of excessive ash. For example, if the ash standard is 6.53 per cent, each percentage value beginning with 6 in the left-hand column and all figures in the line reading to the right of 6 will be increased by 0.53. There would be no deduction then in price for ash in delivered coal up to and including 8.53 per cent, while for coal having an ash content, for instance, between 11.54 and 12.53 per cent the deduction would be 12 cents per ton.

(*c*) The price will be further corrected for moisture content in excess of the amount guaranteed by the contractor, the deduction being determined by multiplying the price paid by the percentage of moisture in excess of the amount guaranteed. The correction will be figured to the nearest tenth of a cent. For example, if coal delivered on a contract guaranteeing 3 per cent moisture with bid price of $3.50 per ton shows by analysis 4.65 per cent moisture, the bid price is multiplied by 1.65 (the excess moisture), which gives 5.8 cents ($0.058) as the deduction per ton.

[$3.50×(4.65—3.00=1.65 per cent)=5.775 cents.]

XIII. Information to be Supplied.*

55. Estimated quantity of coal required,———tons (2,000 or 2,240 pounds).

56. (The point of delivery, method of delivery, capacity and facilities for storage, etc., are here furnished.)

57. The bidder must insert in the blank space below the information called for on the coal he proposes to furnish, without which information the proposal will be informal:

(*a*) Commercial name of the coal.....

(*b*) Name of the mine or mines.....

(*c*) Location of the mine or mines (town, county, state).....

.....

(*d*) Railroad on which mine is located.....

(*e*) Name or other designation of the coal bed or beds.....

....

(*f*) Name of operator of mine or mines.....

(*g*) British thermal units per pound of "dry coal".....

(*h*) Percentage of ash in "dry coal".....

(*i*) Percentage of sulphur in "dry coal".....

(*j*) Percentage of volatile matter in "dry coal".....

(*k*) Moisture in coal "as received".....

(*l*) Additional description of coal as deemed of importance by bidder .....

....

(*m*) Price per ton of....pounds (this price is understood to be the bid price per ton, see section 53 for method of determining price for delivered coal).....

....

*Bidders are cautioned against specifying higher standards than can be maintained, for to do so may result in the bid being rejected (sec. 8), or may result in rejection of delivered coal or cancellation of the contract and the Government purchasing coal in the open market and charging against the contractor the difference in cost (see secs. 47 and 48).

THE SECRETARY OF THE ..... DEPARTMENT:

The undersigned hereby propose.. to furnish and deliver to .....the coal as above specified, and at the price stated above, for the fiscal year commencing on the 1st of July,..... and ending on the 30th of June,.....

The undersigned ha... read the specifications and proposal and agree.. to comply therewith in every particular.

Signature of each member of the firm and firm name. If a corporation, its name, and signature of the officer authorized to sign for the corporation, together with a copy, under seal of his authority to sign; also, the name of the state in which incorporated.

.....
.....
.....
.....

Doing business under the firm name of.....

Place of business, ...

.....

NOTE.—Owing to the difficulty in deciphering signatures, a typewritten copy of same should be attached.