T H E S I S

THE RELATION OF VOLATILE MATTER AND HEAT VALUE IN TENNESSEE COALS.

For the Degree of

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

By

J. B. Seagle

Under

Prof. Chas. E. Ferris

1915.

THE RELATION OF VOLATILE MATTER AND HEAT VALUE IN TENNESSEE COALS.

The object of this thesis is to produce an empirical formula from which the heat value of any coal (run of mines) in Tennessee may be calculated when the per cent of volatile matter and fixed carbon are known.

The first thing done was to collect eight samples of run of mine coal from different sections of the state and test them in the laboratory. The laboratory test consisted of a determination of the per cent of moisture, volatile matter, and ash. The heat value in B.T.U. was also found by means of a Parr Calorimeter. Three tests were made for each coal of ash, volatile matter, moisture, and heat value. The mean value was found by applying the theory of least squares to each set of three readings. The formula used in applying the theory of least squares is

$$E_o = \frac{.8453\ \Sigma\ v}{n\ \sqrt{n-1}}$$ Tracy's Plane Surveying Page 18.

where n = number of observations.

v = difference between any one observation and the mean value of all observations.

E_o = probable error of the mean of all the observations.

Σ = a symbol signifying sum of.

The method of sampling and making tests in the laboratory will now be explained.

Sampling.

The best way to sample coal would be to take a section of the vein, from top to bottom, from side to side, and as far back as the size of sample wanted dictates. This method was not followed

on account of the expense. The samples tested were taken from run of mine coal procured at various coal yards. Great care was taken in order that the sample should be as near run of mine as possible. About fifty pounds of coal of different size and from different parts of the coal pile was taken as a sample. The sample was then placed in a box and mashed with a hammer. The crushed coal was thoroughly mixed and quartered. The opposite quarters were thrown away to reduce the size of the sample. This crushing and quartering was carried on until the sample was only a quart in size, the largest pieces of coal being less than a pea in size. The sample was then sealed in a glass fruit jar and carried to the laboratory where it was crushed still further in a coffee mill. After mixing and quartering about fifteen grams were ground in a mortar so as to pass a 100 mesh sieve. The sample was then ready for test purposes.

Moisture Determination.

One gram of the finely ground sample was weighed and put in a porcelain crucible. It was then put in an oven where the temperature ranged from 215 to 225° F. The loss in weight of the coal in one hour was taken as the amount of moisture. The moisture was determined within 1/4 of one per cent.

Volatile Matter Determination.

The crucible of coal from the oven was placed over a bunsen burner for seven minutes. The lid was placed on the crucible loosely during the burning. The loss in weight of the coal was taken as the volatile matter. The volatile matter was determined within one per cent.

Ash Determination.

One gram of coal was placed on a crucible lid and burned over an intense flame until nothing remained but the ash. The flame was restricted by placing a clay funnel around the lid. The ash was determined to within 0.2 per cent.

Heat Value Determination.

The heat value was determined by means of a Parr Calorimeter. The method, in general, is to note the rise in temperature of two liters of water due to the ignition of a mixture composed of one half gram of coal and a quantity of sodium peroxide, $Na_2 O_2$. This test is described in detail in the pamphlet inclosed and will not be fully explained here. It is well to state however, that no accelerator was used and the method of ignition was by passing an electric current thru an iron wire. The heat value was determined within 1/4 per cent.

Development of Formula.

The formula was first written in the form

(1) B.T.U. = 14500 C + XV

where C is the per cent of fixed carbon, V the per cent of volatile matter, and X some number. The value of X was found for each coal by substituting the values of C, V and B.T.U. determined by the tests in the laboratory. The value of X was also calculated for five coals whose analysis is given in Bulletin 22 of the Bureau of Mines. These values of X were then plotted as ordinates and the per cent of volatile matter as abscissae as seen on the curve sheet. The value of X varied in a straight line as V varied. Equation (1) was now put in the form,

(2) B.T.U. = 14500 C + a V^m

(3) Let b = a V^m

(4) or log b = log a + m log V

Equation (4) is in the form y = mX + b

The value of (m) was found by placing equation (4) in the form,

(5) $y'' - y' = m (x'' - x')$

(6) or $(\log b_2 - \log b_1) = m (\log V_2 - \log V_1)$

By referring to the curve sheet we have,

Log b_1 = log 20 x 178 = log 3560 = 3.55145

Log V_1 = log 20 = 1.30103

Log b_2 = log 37.2 x 149 = log 5543 = 3.74374

Log V_2 = log 37.2 = 1.57054

From (6)

$$m = \frac{3.74374 - 3.55145}{1.57054 - 1.30103} = \frac{.19229}{.26951} = .713$$

To find (a) we have from equation (4)

Log a = log b_1 - m log V_1

= 3.55145 - .713 x 1.30103

= 2.62384

= 420.6

Thus equation (2) becomes

(7) B.T.U. = 14500 C + 420.6 $V^{.713}$

By use of equation (7) the heat value of the coals tested in the laboratory and also of the five coals tested by the Bureau of Mines was calculated as shown on the result sheet. The maximum variation in per cent between the heat value calculated from the formula and the heat value determined by the calorimeter was within

1.2 per cent for the coals tested by myself and within 2.3 per cent for the coals tested by the Bureau of Mines. This greater variation from the formula for the coals tested by the Bureau of Mines is probably due to the fact that the experimental conditions were not the same. A different gas pressure or different character of gas may cause a variation of 2 per cent in the volatile matter determination. When equation (7) was represented graphically as shown on the curve sheet it was seen that it is very nearly that of a straight line. As a first degree equation is more readily used equation (7) was changed to the form

(8) B.T.U. = 145(C-50) + 110.6 (V-25) + 11435 where 11435 is the heat value of a coal containing 50% fixed carbon and 25% volatile matter, 145 (C-50) is the heat value due to any addition of fixed carbon over 50%. 110.6 (V-25) is the heat value due to any addition of volatile matter over 25%. When the heat value was calculated for the various coals by means of equation (8) it was found that the values were practically the same as those given by equation (7) as is easily seen by a comparison of the result sheets showing those calculations.

Conclusions.

In conclusion I would say that if the coals were tested under the same conditions, especially the volatile determination, as the coals were in producing the formula that the heat value given by the formula should be within one per cent of the heat value given by the calorimeter. If the conditions are not the same the variation may be as much as 2 per cent or more.

Laboratory Tests.

Kind of Coal	Exper. Number.	Moisture %	Volatile Matter %	Ash %	Fixed carbon %	Temp.diff. on calorim.	Heat value B.T.U.
Chaska	1	2.90	36.16	2.46	58.48	4.48	
	2	2.34	37.20	2.44	58.02	4.50	
	3	2.66	37.26	2.40	57.68	4.50	
	Average (a)	2.63	36.87	2.43		4.493	
	(b)	2.63	37.16	2.43	57.78	4.493	14,005
LaFollette "Rex"	1	2.42	34.68	4.71	58.19	4.40	
	2	2.12	35.10	4.66	58.12	4.40	
	3	2.22	35.02	4.55	58.21	4.40	
	Average (a)	2.28	34.93	4.64		4.40	
	(b)	2.28	35.03	4.64	58.05	4.40	13,715
Jellico "Blue Gem"	1	2.88	36.84	4.40	55.88	4.37	
	2	2.72	36.84	4.50	55.94	4.36	
	3	2.85	36.39	4.64	56.12	4.35	
	Average (a)	2.81	36.69	4.51		4.36	
	(b)	2.81	36.81	4.51	55.87	4.36	13,590
Soddy	1	.92	26.40	5.28	67.40	4.49	
	2	.90	26.00	5.50	67.60	4.47	
	3	1.30	25.94	5.32	67.44	4.47	
	Average (a)	1.04	26.11	5.37		4.477	
	(b)	.94	26.00	5.32	67.74	4.477	13,955
Brushy Mt.	1	.90	32.80	7.35	58.95	4.38	
	2	1.32	34.00	6.89	57.79	4.36	
	3	1.05	32.99	7.16	58.80	4.40	
	Average (a)	1.09	33.26	7.13		4.38	
	(b)	1.09	32.97	7.13	58.81	4.38	13,652
Whitwell	1	1.65	26.90	7.74	63.71	4.40	
	2	1.16	26.76	7.90	64.18	4.37	
	3	1.14	26.96	7.86	64.04	4.39	
	Average (a)	1.32	26.87	7.83		4.387	
	(b)	1.17	26.92	7.87	64.04	4.387	13,674
Proctor "Bear Wallow"	1	1.05	33.37	7.73	57.85	4.34	
	2	1.12	32.90	7.82	58.16	4.36	
	3	1.00	33.94	7.54	57.52	4.36	
	Average (a)	1.05	33.40	7.70		4.353	
	(b)	1.05	33.40	7.76	57.79	4.353	13,568
Coal Creek	1	.82	32.66	9.20	57.32	4.30	
	2	.84	32.78	9.17	57.21	4.29	
	3	.70	33.04	8.81	57.45	4.31	
	Average (a)	.78	32.83	9.05		4.30	
	(b)	.81	32.74	9.15	57.30	4.30	13,503

Note: Average (a) is the arithmetical mean
Average (b) is the average found by use of the method of least squares
The average found by method (b) was used thruout.

Calculation of the value of x, which was used in drawing the curve as shown on the curve sheet, from the formula

B.T.U. = 14500 C + V X

Coals tested by J. B. Seagle.

Kind of coal	Volatile matter %	Fixed carbon %	Value of X
Chaska	37.16	57.78	151.4
LaFollette "Rex"	35.03	58.05	151.2
Jellico "Blue Gem"	36.81	55.87	149.1
Soddy	26.00	67.74	159.0
Brushy Mt.	32.97	58.81	155.4
Whitwell	26.92	64.04	163.0
Proctor "Bear Wallow"	33.40	57.79	155.3
Coal Creek	32.74	57.30	158.7

Coals from Bulletin 22 of Bureau of Mines.

Oliver Springs	32.32	51.76	156.9
Catliff "Regal Mine"	34.54	53.03	155.1
Fork Ridge	32.91	51.13	156.6
Yellow Creek	27.61	54.07	169.3
Brushy Mt.	33.62	51.03	161.5

Calculation of the Heat Value of the Various Coals Tested by means of the formula

$$B.T.U. = 14500\ C + 420.6\ V^{.713}$$ and a comparison with the calorimeter values.

Coals tested by J. B. Seagle

Kind of coal	Volatile Matter %	Fixed Carbon %	B.T.U.value from calorim. determination	B.T.U.value calculated from form.	B.T.U. diff.	% difference
Chaska	37.16	57.78	14005	13917	88	.63
LaFollette "Rex"	35.03	58.05	13715	13721	6	.04
Jellico "Blue Gem"	36.81	55.87	13590	13602	12	.09
Soddy	26.00	67.74	13955	14116	161	1.15
Brushy Mt.	32.97	58.81	13652	13612	40	.29
Whitwell	26.92	64.04	13674	13685	11	.08
Proctor "Bear Wallow"	33.40	57.79	13568	13514	54	.40
Coal Creek	32.74	57.30	13503	13368	135	1.00

The analysis of the following coals was taken from Bulletin 22 of the Bureau of Mines.

Oliver Springs	32.32	51.76	12578	12519	59	.47
Gatliff	34.54	53.03	13048	12947	101	.77
Fork Ridge	32.91	51.13	12569	12490	79	.63
Yellow Creek	27.61	54.07	12514	12319	195	1.56
Brushy Mt.	33.62	51.03	12841	12556	285	2.22

Calculations of the Heat Value of the Various Coals Tested by Means of the Formula.

B.T.U. = 145 (C - 50) + 110.6 (V - 25) + 11435

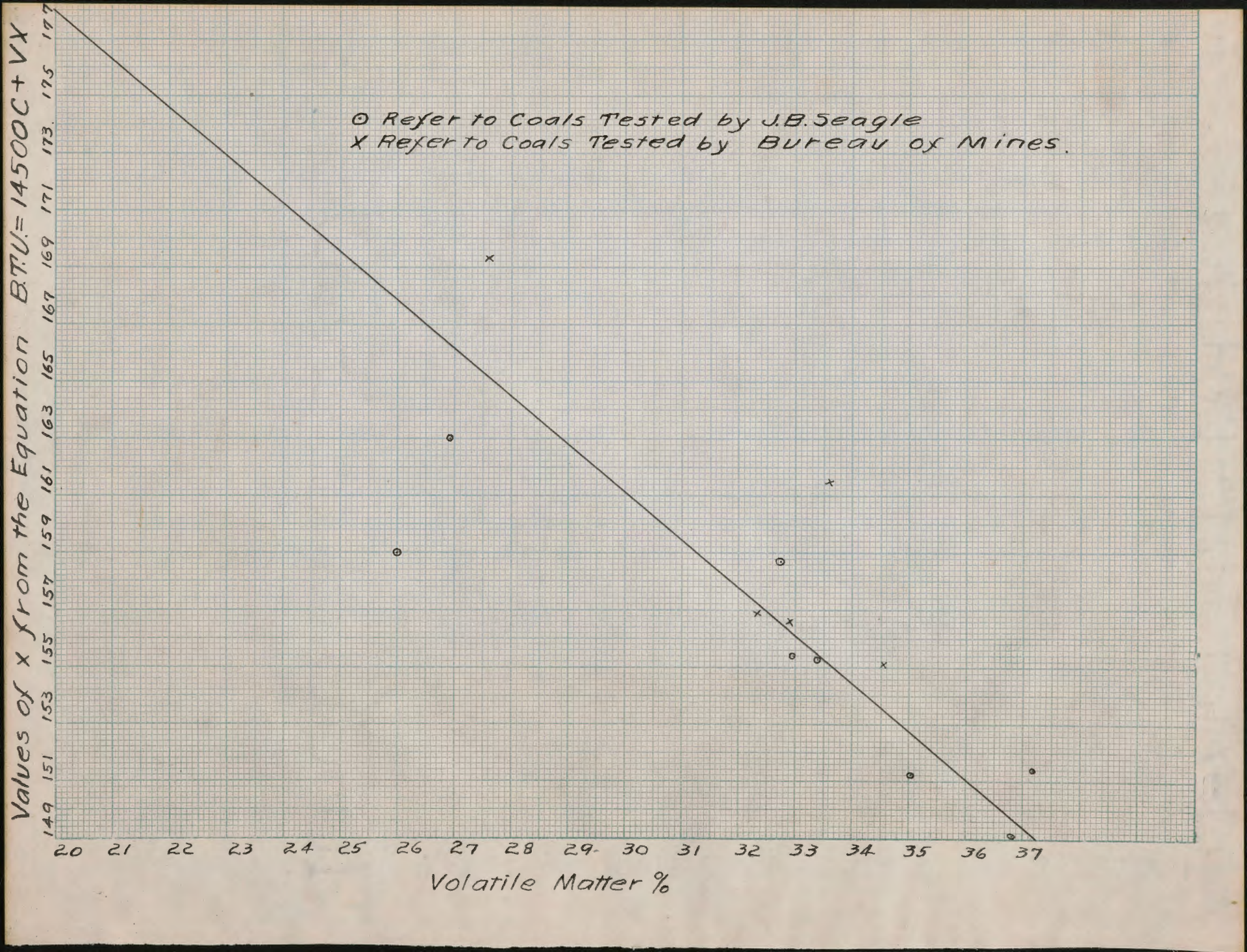
and a Comparison with the Heat Value Given by the Calorimeter.

Coals Tested by J. B. Seagle.

Kind of Coal	Volatile matter %	Fixed carbon %	B.T.U.value given by Calorimeter	B.T.U.value given by Formula	B.T.U. Difference	% Difference
Chaska	37.16	57.78	14005	13908	97	.69
LaFollette "Rex"	35.03	58.05	13715	13712	3	.00
Jellico "Blue Gem"	36.81	55.87	13590	13592	2	.00
Soddy	26.00	67.74	13955	14118	63	.45
Brushy Mt.	32.97	58.81	13652	13594	58	.42
Whitwell	26.92	64.04	13674	13683	9	.07
Proctor "Bear Wallow	33.40	57.79	13568	13494	74	.55
Coal Creek	32.74	57.30	13503	13350	153	1.13

The Analysis of the Following Coals was taken from Bulletin 22, Bureau of Mines.

Oliver Springs	32.32	51.76	12578	12500	78	.62
Gatliff	34.54	53.03	13048	12929	119	.91
Fork Ridge	32.91	51.13	12569	12473	96	.76
Yellow Creek	27.61	54.07	12514	12314	200	1.60
Brushy Mt.	33.62	51.03	12841	12538	303	2.36


⊙ Refer to Coals Tested by J.B. Seagle
X Refer to Coals Tested by Bureau of Mines.
Values of x from the Equation B.T.U.= 14500C + Vx
149
151
153
155
157
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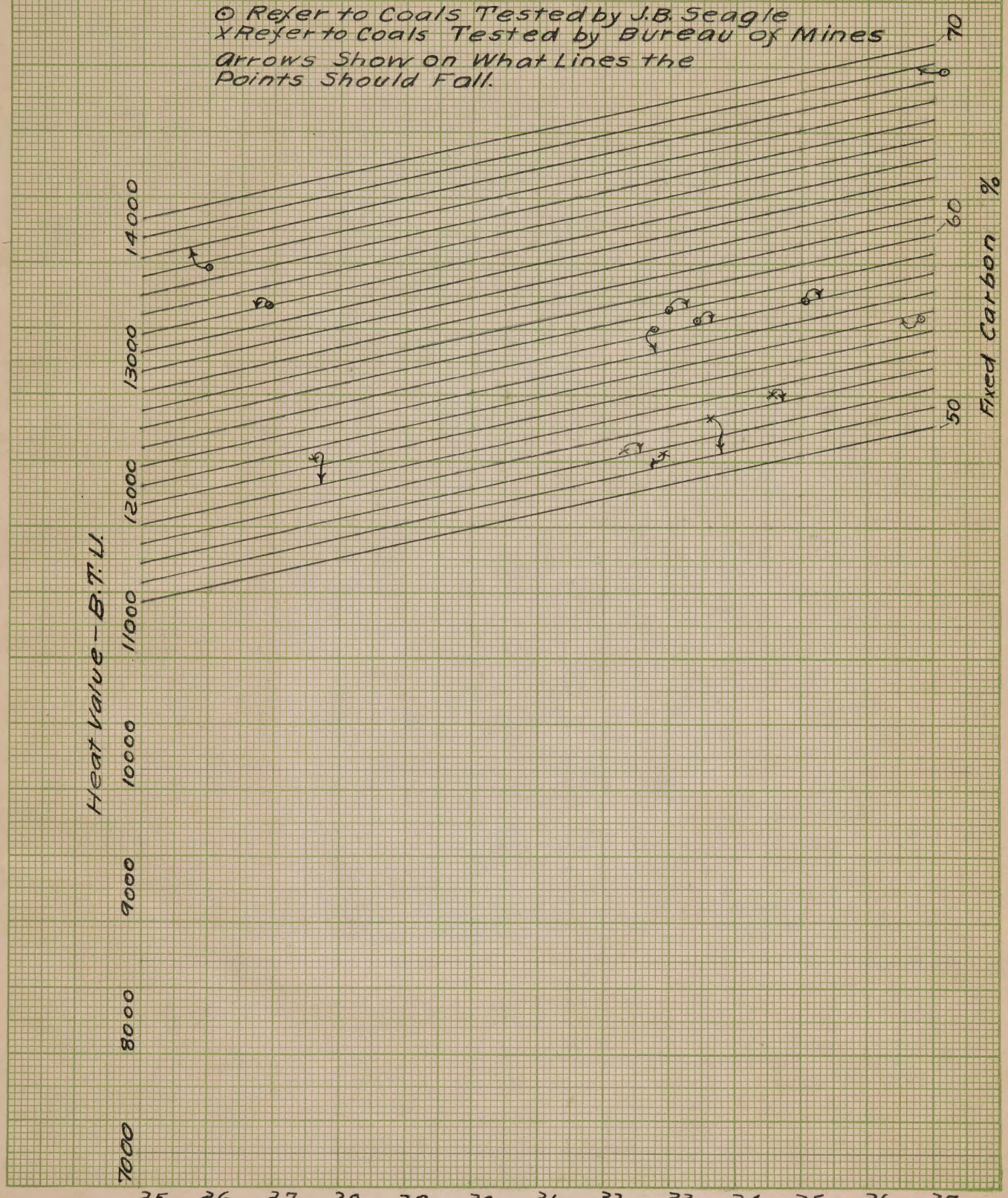
36
37
Volatile Matter %

Graphical Representation of the Formula, —

$$B.T.U. = 14500C + aV^{.713}$$

⊙ Refer to Coals Tested by J.B. Seagle
X Refer to Coals Tested by Bureau of Mines
Arrows Show on What Lines the Points Should Fall.



No. 792. KOLESCH & CO., NEW YORK.

DIRECTIONS

FOR USING

The Parr Standard Calorimeter



Manufactured by

The Standard Calorimeter Co.

East Moline, Illinois

DIRECTIONS
FOR USING
THE PARR STANDARD
CALORIMETER

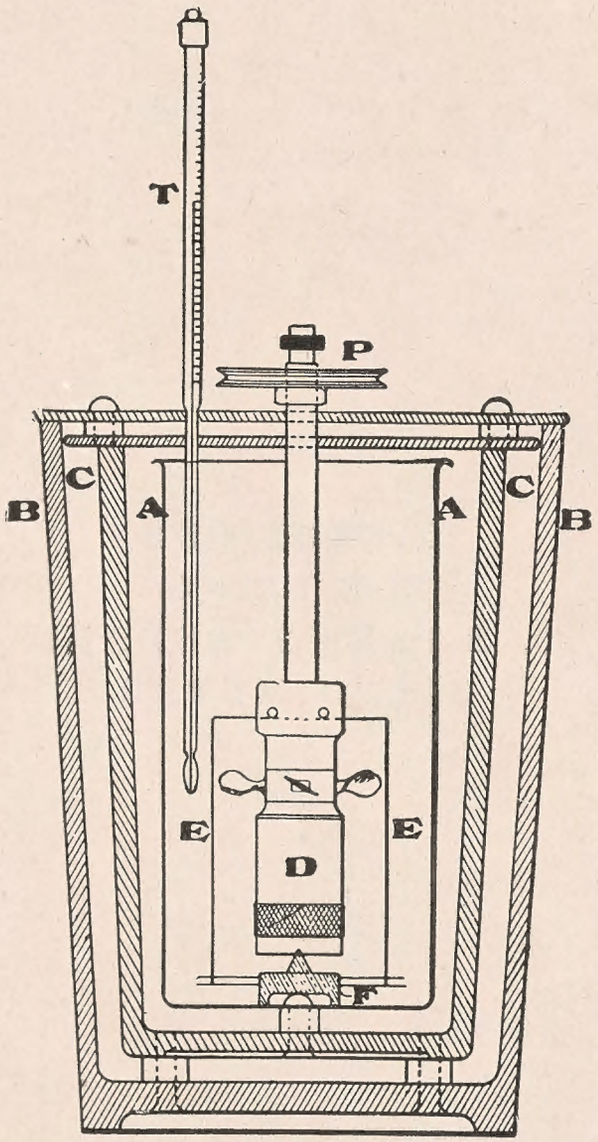


Fig. 1

DIRECTIONS FOR USING THE PARR STANDARD CALORIMETER

General Arrangement

The Calorimeter should be placed on a good, firm desk in a room where fluctuations of temperature may be avoided. The general arrangement of parts is shown in Fig. 1. However, it is better to remove the can AA from the instrument for filling with water. The outside of the can should be dry, and no water should be allowed to spill over into the air spaces of the insulating vessels.

Exactly two liters of water (preferably distilled) are used, and it should have a temperature of 1 or 2 degrees F. below that of the room. The thermometer T should extend a little over half way to the bottom of the can. The pulley P is connected by a light, flexible cord with a small electric or water motor. Stirring is effected by the spring clips with turbine wings placed on the cartridge D. The pulley P must be made to revolve at a rather brisk rate. About 150 revolutions per minute, uniformly maintained, will insure a complete equalization of temperature throughout the water. The pulley should turn to the right or as the hands of a watch.

The Chemical: Sodium Peroxide Na_2O_2

It is absolutely necessary that the chemical employed (sodium peroxide) be kept free from contamination. It has special avidity for moisture, and

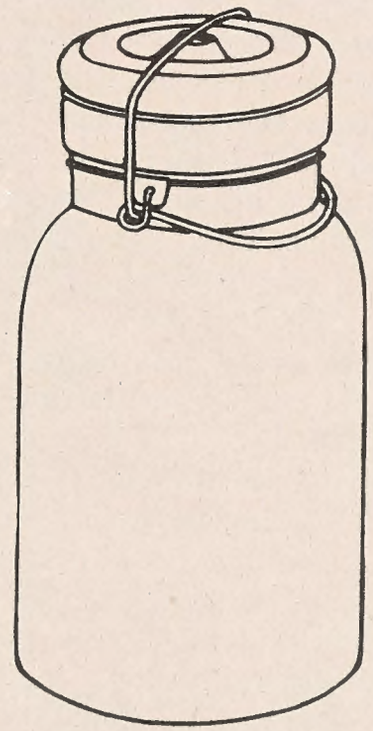


Fig. 2

the glass jar with lever fastener, as shown in Fig. 2, has been found best adapted as a container for this material. A pint size is used so that the measuring cup and handle entire may be enclosed within the jar. The sodium peroxide is furnished in small sealed tins, and the entire contents of a can, upon opening, should be transferred completely to the jar. The contents of a half-pound tin when emptied into a jar will leave room for convenient handling of the measuring cup. If sodium peroxide is procured in one-pound tins there should be available two glass jars for dividing the material between them, thus permitting the complete emptying of the container. Commercial sodium peroxide or material that has been much exposed to the air so that any considerable amount of moisture has been absorbed, will give variable and uncertain results. The sodium peroxide furnished by the Standard Calorimeter Company has been especially prepared under uniform conditions, and enclosed in solder-sealed tins in order that the material may come to the user in the best possible condition.

The Accelerator
Potassium Chlorate, $KClO_3$

In order to secure a combustion that shall be uniformly complete, it has been found desirable to use an accelerator for the purpose of increasing or intensifying the oxidizing effect of the sodium peroxide. While numerous chemicals and mixtures have been tried, a very extended experience has made it evident that potassium chlorate is best adapted for this purpose. It is supplied in finely

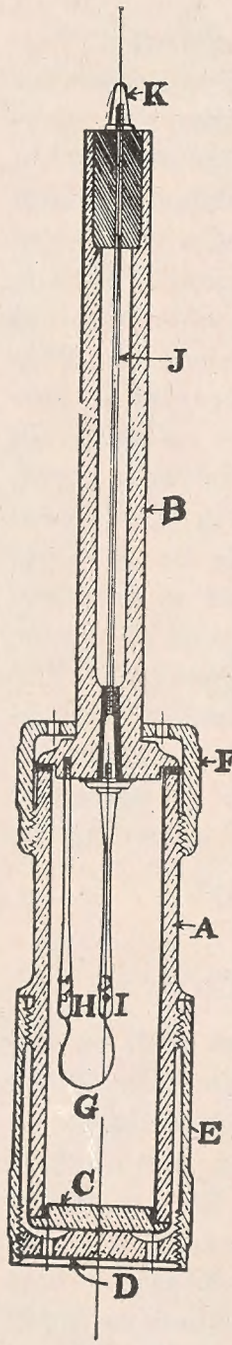


Fig. 3

divided form, thoroughly dried, chemically pure and standardized, as is indicated by the correction values printed on the labels. The amount needed for each charge is weighed out in the same manner as for coal. One gram is the usual amount for coals of all types.

Preparation of the Sample

If the sample of coal contains water in any considerable amount, it should be air-dried to a point where the moisture content is below 3 or 3½ per cent. The usual method for determining loss on air-drying is followed. The unground sample, usually of buckwheat or pea size and 2 or 3 pounds in amount, is weighed and spread out in a shallow tray over night, or for a few hours, in a current of air raised somewhat above the ordinary temperature, say 100 to 120 degrees F. The sample thus air-dried is weighed again and the difrence taken as the loss on air-drying. Two or three ounces of this air-dried sample are ground to pass a 100-mesh sieve, and placed in a stoppered bottle to prevent variation in the moisture content. From this sample are weighed out the quantities for moisture, ash, etc., as well

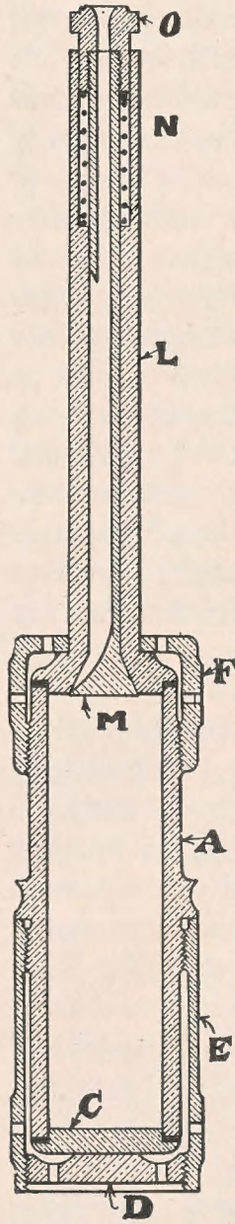


Fig. 4

as the samples for Calorimeter determinations. With the sample thus prepared, oven-drying is unnecessary.

Making Up the Charge

To prepare the bomb for filling, dry all the parts perfectly, inside and out. To accomplish this the metal should be thoroughly cleaned of chemical by rinsing with hot water. Further drying on a hot plate or radiator is recommended as being more effective than wiping with a cloth. See that the inner bottom C, Fig. 3, with gasket, is properly seated, screw on the outer bell E, then with the spanner-wrench screw up firmly the outer bottom D, and place on a sheet of white paper.

One gram of accelerator is first weighed out and added to the cartridge, then ½ gram of coal properly prepared and dry (not over 3 or 3½% moisture) is added. The two are stirred with a glass rod or otherwise mixed to insure that no lumping of the two substances has occurred.*

(*This is very important, since if lumps form or if for any reason there is a failure to secure an even mixture a violent reaction may result from possible concentration of combustible matter. By thus mixing the first two ingredients, the subsequent even dissemination throughout the sodium peroxide is easily and surely effected by shaking as described.)

Then one full measure of sodium peroxide is poured directly from the measuring cup into the cylinder. In filling the cup with peroxide, it should be tapped against the side of the jar to insure against the formation of air pockets.

The false top, with burnished face and no ignition arrangement, is first put in position and the cap F screwed firmly in place. By shaking the cartridge thoroughly the ingredients of the charge are evenly mixed. In the process of shaking it may be well to invert the cartridge and tap it sharply upon the desk to make certain that none of the material has lodged at the bottom. When the mixing is complete, tap the cartridge lightly to shake all the material from the upper part of the cylinder. Remove the false cap and put in its place the regular cap with stem and ignition device. Screw the cap F firmly in place, using the spanner-wrench.

In screwing on the cap F, as well as in all handling of the cartridge after the regular cap has been put on, care should be observed to keep the cartridge in an upright position. The object being to prevent the chemical mixture from coming in contact with the inner face of the cap and ignition arrangements. By observing this procedure much trouble from short circuiting will be avoided.

Put on the spring clips with vanes and assemble the parts as shown in Fig. 1.

Ignition

There are two methods of ignition which make use of slightly different cartridges, as shown in Figs. 3 and 4. In Fig. 3, ignition is effected by means of

an electric current passing through a loop of fine iron wire, which acts as a fuse. In Fig. 4, a red hot slug of soft iron or nickel wire is dropped through the stem, and by means of a spring valve, as at M, is admitted into the chamber.

Where the electric method is used the iron wire, about 4 inches long, is fastened to the terminals so as to form a loop extending below about $\frac{3}{4}$ of an inch and dipping well into the charge.

The wire should be of about 32 or 34 American gauge. A special fuse wire of proper size and by winding on a card measured into convenient lengths sufficient for 500 determinations, is furnished with each outfit.

The current required is from two to four amperes, and is readily obtained by placing in parallel five 16-candle power lamps in an ordinary lighting circuit of 110 volts. It is well to have the fifth lamp of 32-candle power. By this means a suitable current is readily obtained.

Make a number of preliminary tests by fastening a loop to the terminals and passing the current without assembling the parts. In this way the behavior of the fuses can be observed. Make a trial with three or four lamps in the circuit. If the wire does not come very quickly to incandescence, increase the resistance until it melts with but little delay upon closing the circuit.

When the hot wire slug is used, the spring valve must work smoothly and be free from chemical, which will be the case if the false cap has been used in shaking, as already described. The red hot slug is dropped into the stem and first lodges at the

valve M, Fig. 4. Then, by pressing down quickly with the curved forceps at O, the slug is released and the valve springs back into place. *Do not press down on the valve with the finger. Use the forceps.* Too quick a motion may result in catching the slug before it has cleared the valve. Too leisurely a movement is also to be avoided. Make a few preliminary trials without connecting up the stem.

Temperature Readings

The thermometer is inserted so that the lower end of the bulb will be about midway toward the bottom of the can. The pulley should be allowed to revolve a few minutes before reading the thermometer, in order to equalize the temperature throughout the apparatus. Take readings one minute apart for two or three intervals before igniting the charge, and continue the same for nine or ten minutes subsequent to ignition. The first three or four readings after ignition are roughly taken, but after the fourth or fifth minute the temperature should be nearly equalized, and the readings must be carefully taken in order to ascertain the exact maximum and to furnish the necessary data for making a correction for radiation. If the temperature of the water before ignition is 1 or 2 degrees below that of the room, the temperature at the end of the first minute after ignition will be something above that of the room, and radiation for that period may be considered as self-correcting. Ordinarily the rise in temperature will continue for about four minutes more, at which time the maximum temperature will have been reached. The radiation for this period is found as

follows: Read the fall in temperature for each minute for four minutes after the maximum has been reached. The average drop per minute represents the correction to be added to each minute preceding the maximum, except for the minute immediately following ignition. The final temperature thus corrected for radiation, minus the initial reading before ignition, represents the total rise in temperature due to the reaction in the cartridge.

Calculations

From the total rise in temperature, as above obtained, subtract the correction factors for the heat due to the chemical, fuse-wires, etc., as indicated on the small bottle of accelerator, and multiply the remainder by 3117. The product will be the number of British thermal units per pound of coal (see notes *a* and *b*, page 22).

Some illustrative examples of readings and calculations are given on the following pages.

The above constant is adapted to the amount of metal as now employed in making the bomb, which has a weight, including the stirring vanes, but not the pulley, of 550 grams. If an earlier bomb of different weight is employed, the water equivalent may be found by multiplying the weight of all the metal, omitting the pulley, by 0.092, which is the specific heat of the alloy used. Thus, total weight

$$1470 \times .092 = 135,$$

the water equivalent.

For the method of deriving the constant from the water equivalent, see note (*a*).

It is to be noted that the heat value as derived, refers to the coal in the form in which it is weighed out for making the determination. That is to say, if a coal having 5% of moisture is taken and ½ gram of the same weighed out and dried in the oven at 212° for 1 hour, then burned in the calorimeter, the results obtained refer to the coal on the basis of 5% of moisture and not to the coal as in the oven-dry state.

To calculate values to "dry coal," divide the number by 100% minus the per cent of moisture present. Thus, a coal having 5% moisture and indicating 11000 B. T. U. would have

11000÷.95=11579 B. T. U.

on the "dry coal" basis.

Example No. 1

May 15, 1909.

Laboratory, No. 2090.

Coal from Williamson County, Illinois.

Room temperature, 72° F.

Readings:

Minute	1	70.11	
"	2	70.12	
"	3	70.12<—	
"	4	73.55	
"	5	74.00	
"	6	74.15	
"	7	74.25	
"	8	74.460<—	
"	9	74.450	.010
"	10	74.440	.010
"	11	74.440	.000
"	12	74.435	.005
		Rad.	.025

Max	74.460
Initial	70.120
Rise	4.340
Radiation Loss	.025
Corrected for Radiation	4.365
Correction for Accelerator, Fuse, etc.	.377
Corrected Rise	3.988

3.988×3117=12431 B. T. U.

The correction factor, .377, indicated for the accelerator, fuse, etc., is derived from a number of components, as follows:

The analysis of Coal, No. 2090, shows:

Moisture in Air-dry Coal	2.32%
Ash	11.60
Sulphur	2.67
Loss of Moisture upon Air-drying	8.5

The correction components, therefore, are made up as follows:

Per cent of Ash, 11.60×.005° =	.058° F.
" " " Sulphur, 2.67×.010°=	.026° "
Electric Fuse Wire	.014° "
1 gram Accelerator	.234° "
Hydration	.045° "
Total	.377° "

Example No. 2

Laboratory, No. 2111.

Coal from Kanawha District, West Virginia.

(Omitting the readings at minute intervals.)

Maximun Reading	75.38
Initial Reading	70.70
Rise	4.68
Radiation	.02
Corrected for Radiation	4.700
Correction for Accelerator	.319
Corrected Rise	4.381

4.381×3117=13656 B. T. U.

The correction factor, .319, indicated for the accelerator, fuse, etc., is derived as follows:

The analysis of Coal, No. 2111, shows:

Moisture	0.88
Ash	10.70
Sulphur	1.82
Loss of Moisture on air drying	.00

The correction components are therefore:

Per cent of Ash, 10.70×.005=	.053
" " Sulphur, 1.82×.010=	.018
Electric Fuse Wire	.014
1 gram Accelerator	.234
Total	.319

Correction Factors

The method for obtaining the correction for radiation has already been described under Temperature Readings. The other correction components are listed for convenient reference as follows:

Per cent Ash is multiplied by	.00275° C. or .005° F.
" " Sulphur is " "	.005° C. or .010° F.
1 gram Accelerator equals	.130° C. or .234° F.
Electric Fuse Wire equals	.008° C. or .014° F.
Ignition by Hot Slug equals	.012° C. or .022° F.
Hydration Factor equals	.025° C. or .045° F.

The "hydration factor" is applied in the case of bituminous coals because of the oxygen compounds present, frequently referred to as hydroxyl constituents or water of composition as distinguished from free moisture. These bodies unite with the chemical to form a small increment of heat, but do not produce heat in the ordinary process of combustion.

For bituminous coals having over 30% of volatile matter, including black lignites, this excess of heat is accounted for by the hydration factor for ½ gram of .025° C. or .045° F.

Hydration factors for other substances, when ½ gram is used, are as follows:

Brown lignites	.050° C. or .090° F.
Wood	.111° C. or .200° F.
Sugar	.145° C. or .262° F.
Benzoic Acid	.124° C. or .223° F.

To Dismantle

Remove the thermometer, pulley and cover; then take out the can and contents entire, so that the lifting out of the cartridge will not drip water into the dry parts of the instrument. Remove the spring clips and unscrew the end caps. It is better to loosen the bottom D, Fig. 2, and unscrew the entire outer bell E for greater convenience in cleaning. The fused mass is easily driven out at the bottom by means of the short metal rod with enlarged ends supplied with each outfit for this purpose. Wash out the interior of the bomb thoroughly, as also the faces of the caps and electric terminals. For this purpose a jet of hot water or submerging in boiling water is advisable, as the metal is thus left clean and hot, the latter facilitating the drying out of the parts. Place the parts on a radiator or near a hot plate to insure thorough drying. If the stem with valve-method of ignition is used, be sure that no water remains inside of the stem or about the valve. By unscrewing the knurled top the valve parts can be easily removed.

Anthracites and Coke

In the case of Anthracites and Coke it is well to use 0.2 grams of benzoic acid along with the 1 gram of accelerator and $\frac{1}{2}$ gram of fuel. This substance facilitates ignition as well as the ultimate combustion. The heat resulting from the combustion of this extra 0.2 gram of benzoic acid, which is to be corrected for along with the other correction components, is 1.550° F.

For Petroleum Oils

The amount of oil used for a charge should not exceed about $\frac{1}{3}$ gram; from 0.20 to 0.30 gram giving the proper combustion. The weight of oil is best obtained by means of a small light 15 c. c. weighing flask provided with perforated cork and dropping tube with common rubber bulb-cap. Weigh the flask and contents, and by means of the dropping tube discharge 20 to 30 drops of oil and re-weigh, thus obtaining the weight of oil taken by difference. Determine, by experiment, the height in the dropping tube required for the approximate amount of oil desired so as to avoid trial weighings. One full measure of chemical (sodium peroxide) and 1 gram of accelerator are taken as already indicated. Also, to facilitate the ignition of all oils and at the same time promote the ultimate combustion, it is recommended that a small amount (0.2 gram) of benzoic acid be used as described under *Anthracites and Coke*. Note, however, that thorough mixing by shaking is not easily accomplished in the case of thick, viscous oils. By means of a glass stirring-rod the accelerator, benzoic acid and oil may be readily mixed in the bottom of the bomb before adding the measure of chemical. With very viscous oils, part of the sodium peroxide may also be stirred in to advantage before adding the complete amount. Finally, complete the full measure of chemical, close with the false cap, shake and continue in the usual manner.

Compute by means of the formula as follows:

Correcting as under coals for radiation, accelerator, benzoic acid and fuse-wire, and letting "r" rep-

resent the rise in temperature; then $\frac{\text{"r"}\times 0.73\times 2135}{\text{Wt. of oil}} =$ B. T. U. per pound of oil.

Gasolene, Etc.

For gasolene, benzine and very volatile liquids, the difficulty of securing an accurate weight of the material taken is met by the following procedure: By the use of very thin-walled glass tubing of about

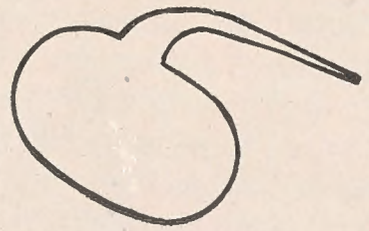


Fig. 5

5-32 inch in diameter, a light bulb with capillary tip may be blown of approximately the size and shape shown herewith, Fig. 5. After a little practice it is not difficult to blow such bulbs to weigh less than 0.2 gram. These may be also made from a capillary obtained by softening an ordinary piece of tubing in the flame, and drawing out the same to a filament about the size of a knitting needle. By fusing the end of such filament bulbs of the desired size and weight may be blown. When so blown they may be used as follows: Weigh the bulb carefully, then by dipping the capillary end into the liquid and alternately warming gently and cooling the bulb a quantity of oil is drawn into the bulb. When about 0.3 gram is obtained, seal the capillary in the flame and weigh accurately. Place the bulb and contents in

the bottom of the bomb and add the other ingredients of the charge. Seal with the false cap and strike the bomb sharply on the desk. This will break the bulb and permit of the complete mixing by shaking in the usual manner. The subsequent operations are already described.

In calculating, a correction is necessary, in addition to those normally observed, on account of the heat of fusion due to the glass present. This amounts to 0.03° F. for each 0.1 gram of glass used in the bulb. This should be subtracted along with the correction for accelerator and fuse-wire. The corrected rise, "r", is then used in the formula as above given for petroleums.

The use of 0.2 gram of benzoic acid as under oils will be found advantageous. It should be mixed with the accelerator as there described and corrected for in the calculation by subtracting along with the other correction factors the rise in temperature due to the reaction, viz: 1.55° F.

Notes

(*a*) The factor 3117 is deduced as follows: The water used plus the water equivalent of the metal in the instrument amounts to 2135 grams. In the reaction 73 per cent of the heat is due to combustion of the coal and 27 per cent is due to the heat of combination of CO_2 and H_2O with the chemical. If now $\frac{1}{2}$ gram of coal causes 2135 grams of water to rise "r" degrees, and if only 73 per cent of this is due to combustion, then $.73\times 2135\times 2\times$"r"=rise in temperature that would result from combustion of an equal weight (2135 grams) of coal. $.73\times 2135$

×2=3117.00. The factor 2 is used instead of the divisor 0.5, the weight of coal taken.

(*b*) With the electrical method of ignition, the fine wire is wrapped firmly and with good contact around the ends of the terminals, and bent U-shaped so as to extend below about ¾ to 1 inch. The wire should come very quickly to incandescence. If the heating up of the wire is too leisurely, the cooling effect of the chemical will still further retard that portion of the loop which dips below the surface, the result being that the wire will fuse in two near the terminal and above the mixture, thus resulting in a failure to ignite the charge.

In the other method of starting the combustion the ignition wire is of soft iron or nickel 2½ m. m. in diameter or No. 11 gauge and 1 c. m. long. It should weigh approximately .330 gram. It loses a very little by use. When by oxidation the weight falls much below .300 gram a new wire should be substituted. The correction for the hot wire may be calculated thus: Taking .114 as the specific heat and 1200—1300° F. as the temperature at a red heat, then

$$\frac{1250 \times 330 \times 114}{2135} = .022$$

Hence the value of the hot wire approximates closely to .022° F.

(*c*) Do not bring the instrument from a cold room to work at once in a warm room or *vice versa*. Sufficient time should be given for equalization of temperatures. Dry the bomb thoroughly inside before putting away. Dry it before using if it has stood

for some time, as moisture condenses on the surfaces.

(*d*) Do not throw a mixture of chemical and unburned coal into water. It may ignite violently. Similarly a drop of water left inside the valve may work into the charge and ignite it prematurely.

(*e*) Combustions are sometimes required of material too low in carbonaceous matter to support combustion, such as ash residues, etc. If the combustible matter is below thirty or forty per cent, double the quantity taken and use ½ of the temperature rise in calculating. Correct also for the ash, etc., as indicated under the heading of "calculations", page 13. Or use the usual ½ gram of material and 0.2 gram of benzoic acid as indicated under **anthracites and coke.**

(*f*) In measuring water from the two-liter flask read the mark at the *bottom* of the meniscus. Where two marks are etched on the neck the upper mark shows the volume at which the required quantity will be *discharged* from the flask, and of course is the one to be used in measurement.

(*g*) If it is found difficult to differentiate between readings for radiation that are made one minute apart, extend the periods to two or three minutes, making the final adjustment to cover the time actually to be corrected for.

For Reuniting the Mercury Thread of a Thermometer

FIRST METHOD

(*h*) If the upper cavity is only partially filled with mercury see that the globule is lodged in the

lower part of the expansion bulb next to the capillary outlet. Heat the upper end of the thermometer very gradually in the flame of an alcohol lamp or of a Bunsen burner turned rather low. Keep the end of the thermometer moving in the flame so that the heat will be imparted evenly to the outer or upper end of the thermometer. Begin at the tip and carry the heat thus applied gradually down to the enlarged space where the mercury has lodged, until the mercury in the upper portion of this space begins to volatilize, which is indicated by the globule of mercury being driven out of the enlarged cavity into the capillary tube. Do not heat longer than is necessary to drive out a few inches of filament or a thread long enough to flow by gravity, thus pulling the globule of mercury from the upper to the lower chamber. Allow the tip to cool down gradually, being especially careful not to bring the hot end of the glass in contact with a cold surface until same has become cold.

SECOND METHOD

By making a pocket of strong canvas sufficient to entirely envelop the thermometer, and extending beyond a distance of two or three feet, a sling is provided which can be whirled rapidly. By this means the globule of mercury is driven out of the upper end of the capillary tube. This method avoids the use of heat, and it is only necessary to avoid striking the thermometer against an obstruction in the process of whirling the same.