MINES BRANCH
DEPARTMENT OF MINES
OTTAWA, CANADA

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By

E. S. Malloch*

During 1930, 1931 and 1932, a series of tests was made in the Fuel Research Laboratories of the Department of Mines at Ottawa on twelve coals from British Columbia, with a view to obtaining data concerning these coals when burned in the pulverized state for the generation of steam and also with a view to correlating them one with another and with a so-called operating coal.

The investigation was made at the request of the British Columbia Government, the officials of which selected the coals to be tested. These were as follows: Pleasant Valley, Tulameen, Coalmont, Middlesboro, Wellington, Reserve, Comox, Cassidy, Telkwa, Michel, Corbin Birdseye and Corbin Washed Steam. Three complete tests were made on each of the above coals, as well as three on the operating coal - one test at high rate, one at medium rate and one at low rate of coal feed, in order to gather sufficient and reliable data necessary to the making of a fair comparison with each other and with the operating coal. This operating coal was selected as being a high grade of bituminous coal eminently suited for this method of burning in this type of equipment.

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Full reports of the tests have been prepared; these are very comprehensive, consisting of 84 items of information regarding each test of each coal, as well as numerous notes and comments. These reports have been sent to the coal operators who supplied the coal samples. They are of a highly technical nature and are intended primarily for the use of combustion engineers interested in the selection of a proper coal for their particular needs. The reports are perfectly intelligible to fuel engineers but it is realized that they may not be quite so intelligible to the layman or to the non-technical man interested in coal marketing only.

Table 1, which follows, shows the more salient results of the tests on each fuel at the high rate of coal feed.

The first four items of the table refer to the fuel as it is delivered to the pulverizer and give an indication of its inherent qualities. The next two items show: first, the fineness to which the coal was ground in the pulverizer, and secondly, the power required to attain that degree of fineness; these two items together may be taken as a measure of the so-called grindability of the fuel. The next two items following set forth the economic possibilities of the fuel when burned in this manner: the first of the two, viz. water evaporated per lb. of fuel fired, is, perhaps, of more interest to the operating engineers, and the second, viz. fuel fired per 1000 lb. of steam generated, to the power plant owner. The last two items in the table deal solely with the performance of the boiler and the rated boiler capacity developed.

The following is a brief resume of results of the tests for each coal.

TABLE I

Fuel Number	Item Number / Name of Item	7a: Moisture in fuel as fired (%)	7b: Ash in fuel as fired (%)	9a: Cal. Value of fuel, as fired B.T.U. (gross)	13b: Fusion temperature of ash (°F.)	20f: Pulverized Fuel passed through 200 mesh (%)	24g: K.W.H. required to pulverize 1 ton fuel	54d: Water evaporated per lb. of fuel fired (lb.)	18d: Fuel fired per 1000 lb. of steam generated (lb.)	73: % of rated boiler capacity developed	82: Thermal efficiency of boiler (%)
5-29	Pleasant Valley	22.9	13.3	8,110	2093	41.9	32.7	5.34	187.3	137	63.9
4-29	Tulameen	19.7	9.5	9,360	2118	40.4	33.4	6.29	159.0	160	65.2
8-30	Coalmont	7.9	10.3	11,450	2239	53.0	33.3	7.60	131.6	194	64.4
6-29	Middlesboro	9.3	11.3	11,230	2588	54.3	32.3	7.48	133.7	191	64.6
10-30	Wellington	5.3	17.2	11,330	2145	67.9	34.2	7.51	133.2	192	64.3
9-30	Reserve	3.9	13.5	12,140	2223	61.6	31.7	7.96	125.6	204	63.6
19-30	Comox	3.9	14.6	12,250	2459	65.0	30.8	8.05	124.1	206	63.8
17-30	Cassidy	3.0	11.6	12,630	2307	67.1	31.5	8.21	121.8	209	63.1
13-30	Telkwa	3.2	12.8	12,820	2170	66.1	32.4	8.49	117.8	216	64.3
20-30	Michel	1.7	7.7	13,950	2032	78.6	31.6	9.46	105.7	222	65.8
3-31	Corbin Birdseye	4.9	16.9	11,680	2700	78.7	48.7	7.99	125.2	201	66.4
2-31	Corbin Washed Steam	3.9	12.7	12,540	2490	80.9	46.1	8.54	117.1	219	66.1
7-30	Operating Coal	1.8	8.3	13,700	2593	69.5	30.9	8.69	115.1	223	61.6

Michel Coal:

This coal was the best coal tested in the series. It had the lowest moisture content, the lowest ash content, and the highest calorific value - (see items 7a, 7b, and 9a). Besides these merits it was the most economical fuel when burned under the B. & W. boiler at the Fuel Research Laboratories, Ottawa, for the high rate of coal feed. This is shown by items 54d, 18d, and 82. Although the percentage of fines passing through a 200 mesh sieve, after pulverizing, was greater for Michel coal than for any of the other fuels tested, with the exception of the Corbin coals, slightly more power was required, and no difficulty was experienced in maintaining a high rated load on the boiler. Item 73 shows that the average load carried was 222% of its rated capacity. The one demerit of Michel coal as tested in this series was the low temperature at which the ash fused (see item 13b). This fault is offset, partially or wholly, by the low ash content of the coal, as is shown by the fact that no trouble was experienced from this characteristic during the tests.

Operating Coal:

This coal was entirely satisfactory and might be listed in this series second to Michel. It has low moisture and ash contents, a high calorific value, and a very high ash fusion temperature. The grindability of this fuel was very good: a fairly large quantity passed through a 200-mesh sieve, and the power required was low. The evaporation per pound of coal was high, and the average load developed during the test was 223% of the rated capacity of the boiler.

Cassidy Coal:

Cassidy coal was distinctly of lower class than either of the two coals described above. It contained, as fired, nearly twice as much moisture, considerably more ash, and the calorific value was about 9 1/2% lower than that for Michel coal. Also, the ash fusion temperature was slightly lower than the average for the fuels tested in this series. The fineness of this coal after pulverization was very satisfactory, and the power required to pulverize it was lower than the average for these fuels. From an economic viewpoint, Cassidy was an excellent coal, and this is shown by items 54d and 18d, both of which are better than the average. A load of 209% of the rated capacity of the boiler was carried without difficulty and it may be stated that the Cassidy coal, as tested, is a very satisfactory fuel to burn in the pulverized state for steam raising.

Telkwa Coal:

This coal was very similar to Cassidy coal. It was a little higher in both moisture and ash, and on the other hand, its calorific value was slightly higher, but the ash fusion temperature was lower by 130°F. The grindability was rather poor in comparison with Cassidy coal - one per cent less passed through a 200-mesh sieve, after pulverization, and the power required was higher. Items 54d and 18d in the table show the economic value of this fuel to be above the average for the series. No difficulty was experienced in carrying a load of 216% of the rated boiler capacity. From the above it may be noted that this coal is an excellent fuel when prepared and burned in this manner.

Comox Coal:

Comox coal, although low in moisture, was high in ash. However, this was offset by the high ash fusion temperature, and in consequence, the ash did not slag on the walls and bottom of the furnace. The calorific value was well above the average for the thirteen coals tested. This coal was easily ground, the power requirements were the lowest for the series, and the percentage passing through a 200-mesh sieve was just a little above the average. Its so-called economic value was very good in comparison with the other fuels (see items 54d and 18d). The average load carried by the boiler for this test was 206% of its rated capacity and was easily maintained. Comox coal proved itself to be a good fuel for this method of steam raising, and was particularly economical as regards the power required for pulverization.

Middlesboro Coal:

This coal was high in moisture; the ash content was moderate, being a little lower than the average for all the coals in this series of tests; and the calorific value was a little lower than the average. When burning this coal in the pulverized state no troubles should arise due to the ash fusing, as the ash fusion temperature was high, higher than for any of the other fuels, with the exception of the "operating coal" and Corbin Birdseye. Items 20f and 24g show that only 54.3% of the pulverized coal would pass through a 200-mesh sieve, which is below the average, while 32.3 K.W. Hours were required to pulverize one ton of coal - this figure is a little lower than the average for the fuels in the series when tested at the high rate of coal feed. The figure given in the table for pounds of steam per pound of fuel is low, while the thermal efficiency of the boiler when fired with this coal was good, being just a little higher than the average at this rate of coal feed. Although this coal was of a distinctly lower grade than the average, no difficulty was encountered in operating at 191% of the rated boiler capacity.

Coalmont Coal:

Coalmont coal had a slightly higher moisture content than the average. The ash content was quite low - 2% lower than the average - the calorific value was also low, and the ash fusion temperature was a little lower than the average for this series of coals. This coal did not pulverize easily:

only 53% of the coal, as fired, passed through a 200-mesh sieve, and the power required was a little lower than the average. The economic values - (items 54d and 18d) - for Coalmont were not quite up to the average for the series at high rate of coal feed. The load carried on the boiler was 194% of the rated boiler capacity. After considering all the points noted above, Coalmont coal may be classed as a fairly satisfactory fuel to burn under a steam boiler in the pulverized state.

Reserve Coal:

This coal was low in moisture and high in ash - 3.8% and 13.5% respectively. While the calorific value was quite high, the ash fusion temperature was slightly lower than the average value for the series of tests. This latter factor, coupled with the high ash content, caused a little trouble in the removal of the refuse from the bottom and walls of the furnace. On the other hand, the grindability was very good and more than an average amount of coal passed through a 200-mesh sieve after pulverization, and the power required was low. The pounds of steam per pound of fuel was fairly high, and the average load carried by the boiler was 204% of its rated capacity. This coal proved itself to be an excellent fuel for this purpose, even when its comparatively high ash content is considered.

Wellington Coal:

The moisture content of this fuel was nearly 2% lower than the average for the coals in the series, but the ash content was very high and the calorific value, as well as the ash fusion temperature, was lower than the average. After pulverization, 67.9% passed through a 200-mesh sieve, which is high for these fuels, but the power required was very high. Item 54d, viz: (7.51 lb. of water per lb. of fuel) is a little below the average. Although the refuse was hard to remove at this rate of coal feed, no apparent difficulty was found in maintaining 192% of the rated capacity of the boiler.

Tulameen Coal:

Tulameen fuel, as supplied for these tests, was very high in moisture, 19.7% and low in ash, 9.5%; the average values for these two items were 7.0% and 12.3% respectively. The calorific value was very low, as was also the ash fusion temperature. The grindability was poor, only 40.4% passed through a 200-mesh sieve, after pulverization, and the power required was 33.4 K.W. hours per ton. This coal, when fired under the boiler used for these tests, only evaporated 6.29 lb. of water per lb. of fuel, which figure is much lower than the average for the series. Although the efficiency of the boiler was high only 160% of the rated capacity of the boiler was developed. This coal is undoubtedly of low grade in comparison with the other fuels in the series. However, no difficulties were encountered in burning this fuel in the installation used, and on one especially designed for Tulameen coal it might prove to be an admirable fuel.

Pleasant Valley Coal:

This fuel was of a markedly lower grade than the other coals tested in the series. The moisture content and the ash content were 22.9% and 13.3% respectively, the former being exceedingly high. This lowered the calorific value which was only 8,110 B.T.U./lb., whereas the average for the series was 11,950 B.T.U./lb. The ash fusion temperature was very low also, but fortunately, this characteristic caused no trouble in the furnace. The grindability was poor, only 41.9% passed through a 200-mesh sieve, after pulverization, and the power required was 32.9 K.W. hours per ton of fuel ground. From an economic consideration, disregarding fuel costs, Pleasant Valley coal, as tested, was of a very low grade in comparison with the other fuels tested, as indicated by item 54d, which shows that only 5.34 lb. of water were evaporated per lb. of fuel fired, whereas, 9.46 lb. were evaporated per lb. of the highest grade of coal tested in the series. Providing Pleasant Valley coal could be purchased at a low price it may in certain installations prove to be an economic fuel to use.

Corbin Birdseye Coal:

This coal sample was one of two sent by the Corbin Collieries Limited, and upon test proved to be a fairly good fuel when burned in the pulverized state. The moisture was lower and the ash content higher than the average for this series of fuels. The ash fusion temperature was higher than for any other coal in the series and in consequence even with the high ash content no slagging of the ash was observed in the furnace. A higher degree of pulverization was obtained than with any of the other fuels, with the exception of Corbin Washed Steam coal, but at a cost of the highest power consumption per ton of coal pulverized for the series. The economic features of this coal as shown by items 54d and 18d class it as being just a little above the average; while the thermal efficiency of the boiler when testing it was the highest of the series. After considering all the items in the table, Corbin Birdseye coal may be said to be a fairly good fuel to burn in the pulverized state in any equipment similar to that installed at the Fuel Research Laboratories at Ottawa.

Corbin Washed Steam Coal:

This sample of coal from the Corbin Collieries was decidedly better than the other sample shipped at the same time, viz: Corbin Birdseye. It was 1% lower in moisture; 4.2% lower in ash and its calorific value was higher. When compared with the other coals of the series Corbin Washed Steam ranked as being the second best of the British Columbia coals and third best when the operating coal is included. It had a high ash fusion temperature, thus even with a fairly high ash content no trouble was experienced due to ash slagging in the furnace. The highest degree of pulverization was obtained with this coal but the power required was very great. Item 54d gives the water evaporated per lb. of fuel fired and for this fuel is 8.54 lb. a figure which is well above the average for this series of coals. No trouble was experienced in developing 219% of the rated boiler capacity. The thermal efficiency of the boiler when burning this coal sample was 66.1%, the highest efficiency for the series of British Columbia coals with the single exception of the other coal sample shipped from the Corbin Collieries, Ltd. From the tests made at the Fuel Research Laboratories on Corbin Washed Steam it may be said that it is a very good fuel when utilized in the pulverized state and in such equipment as is installed in those laboratories.

Notes On
Pulverized Fuel Fired Steam Generators
Vs. Other Types.

by

B. F. Haanel*

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The results obtained in the tests on British Columbia Coals and summarized by Mr. Malloch under the title "Summary of Tests on British Columbia Coals When Used as Pulverized Fuel" are largely comparative and will enable the steam engineer to evaluate the different coals for burning in the pulverized state in a steam boiler. The factors determined do not afford a basis of comparison of this method of burning coal with other methods. For such a comparison, results of the burning of all the coals in a boiler or boilers equipped with mechanical stokers of different types would have been required.

In making such comparisons the fact that the cost of generating steam depends on size of boiler plant, heat saving appliances and other factors, in addition to quality and cost of coal used, must be kept in mind, and also that the ultimate consideration in the generation of steam is the cost of the steam which is sold for industrial, power or heating purposes - consequently, the method selected for burning coal, and the coal itself, will be so chosen that the lowest cost of steam will result.

The Pulverized Fuel Fired Steam Generator has made spectacular progress in the last decade, especially in the field of very large central station plants, and also for

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marine purposes. The tendency today, when electrical energy is generated in a steam turbine electric generator plant, is to construct the steam generators and steam turbines on an almost gigantic scale in order that the fullest advantage of the economies made possible through the most efficient use of the fuel, reduction in heat losses, and reduced cost per unit of power installed, may be realized.

A single steam generator unit supplying an 80,000 K.W. steam turbine is not uncommon today, and it is possible to design and install even larger units. For units of this character the pulverized fuel fired generator appears to possess distinct advantages over other types. When high peak loads must be provided for, a steam generator which will rapidly respond to increased steam demand and operate without difficulty over long periods at high ratings, will naturally be given serious consideration when the design and installation of a steam power plant is contemplated, and a boiler installation which is capable of burning the largest possible quantity of coal per cubic foot of combustion space, or per square foot of grate area, will naturally be selected on account of the lower capital cost and smaller floor space required for generator and primemover.

The marked success achieved by a pulverized fuel fired steam plant in the United States in 1920, proved to be the turning point for this type of plant. From 1920 to 1924 several plants were designed and erection begun, and in 1928 most of these new plants were placed in operation. But from that time to the present new installations have fallen off, principally on account of the marked improvements in mechanical stokers by manufacturers of this type of plant who were stimulated to action by the success of the pulverized fuel fired boiler, which resulted in a decrease in the sales of their product. As a consequence of the activity displayed by the manufacturers of mechanical stokers, manufacturers of boiler plants are in a position to offer either type. Mechanical stokers for the efficient burning of almost every rank and grade of coal are now available and many of the largest central station power plants are equipped with this type of stoker, and the efficiencies obtained are not inferior to those which can be obtained with the former method. It is not possible to refer to either of the two methods for burning coal under boilers as being superior; each has its special advantages and the choice of plant will depend on local conditions, class and cost of fuel available, its suitability for the particular purpose for which it must be used, and character of load. The attendance required to operate either of the plants is practically the same but the cost of pulverizing plant and the cost of operating and maintaining it in repair must not be disregarded, since this represents an item of capital expenditure, upkeep and cost of operation, which is not present in the mechanical stoker plant.

Insofar as the application of pulverized fuel firing to locomotive boilers is concerned, the progress made to date is not sufficient to warrant special consideration. It is doubtful whether this special application of pulverized fuel firing has passed the experimental stage, although reports are issued from time to time in the technical press which would lead one to believe that this method of burning a solid fuel in a locomotive boiler has been developed to a point commensurate with that achieved in marine steam plants.

The application of pulverized fuel firing to marine plants is not in a similar position. Ships equipped with this type of boiler plant are regularly making long voyages without mishap, and it appears that the reduced fuel costs, together with the higher speeds made possible, have justified the introduction of such installations in certain ships, but nevertheless, its application to marine service is as yet very limited.

Size of Steam Plants:

According to opinions of prominent combustion engineers, the minimum size pulverized boiler unit which can be economically and efficiently operated is 1000 H.P., although there are others who hold the opinion that even a 500 H.P. unit can be operated to advantage. Pulverized fuel fired boiler installations, however, show to the greatest advantage when the individual units are of large capacity and the steam load demand is several times the normal boiler rating. This, of course, applies also to properly designed mechanical stoker plants equipped with a type of stoker suited for burning the fuel it is found most economical to use, but in the case of the mechanical stoker plant smaller boiler units can be economically operated than obtains in the case of the pulverized fuel fired plant.

Fuels:

All ranks and grades of coals can be efficiently burned in a modern pulverized fuel fired boiler plant, but the grade which can be most economically burned depends not only on the relative costs per one million B.T.U. of high and low grade coals, but also on the percent of the boiler rating at which the plant is to be operated and on the rank and grade of coal the plant is designed to burn. For example, if a steam plant is designed to operate at 300% rating when burning a high grade coal, such a rating cannot be maintained if the grade of coal is seriously lowered by high ash content. In order to produce the desired quantity of steam in this case, certain of the dimensions of the boiler, pulverizer, and coal and ash handling plant would have to be increased. This also applies to a mechanical stokered plant. It is evident, therefore, that given a steam plant of a definite capacity, when operating at high ratings and burning a high grade coal, a low grade coal cannot be economically burned, even though its cost per unit of heat energy is considerably less than that of the high grade coal, since additional boiler capacity would have to be installed to maintain the steam load.

Power Situation in Canada:

Unlike Great Britain and European Continent, Canada is endowed with great water power resources, located in industrial and more thickly populated areas, and during the past two decades many of these have been developed on an extensive scale. Industrial centres are, consequently, served with hydro-electric energy instead of steam generated electrical energy, as obtains in Great Britain, parts of Europe and to a very large extent in the United States, even though that country is possessed of very large water power resources. Since these hydro-electric developments are capable of supplying most of the requirements for power, Canada does not possess super-steam electric central stations. The largest industrial user of steam in Canada is the pulp and paper industry, and it is in this field that the pulverized fuel fired steam boiler has found its widest application.