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The Role of Coal Characteristics in Boiler Operation

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THE ROLE OF COAL CHARACTERISTICS IN BOILER OPERATION

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Steam generating units for coal firing, and I am thinking both of pulverized coal units and stoker fired units, are designed to accept some range of fuel characteristics. Some units, of course, can accept fuels with wider ranges than other units, depending on the leeways built into the equipment by the manufacturer. In all cases, however, where the fuel deteriorates from the design fuel for which the equipment was selected, there will be some deficiencies in operation, or efficiency, or power requirements. And it is possible to have variations in coal characteristics such that satisfactory operation cannot be obtained. It is my purpose this morning to examine the effects of certain fuel variables on boiler operation and/or boiler efficiency. The coal characteristics or coal variables under consideration are: Btu value, moisture content, ash percentage, grindability index, volatile content, nitrogen content, sulfur content, ash slagging characteristics, and ash fouling characteristics.

BTU PER POUND VALUE

The coal heating value of coals in the United States can vary from 7800 Btu per pound for certain sub-bituminous coals to as high as 14,500 Btu per pound for some West Virginia coals. This is a variation of almost two to one. Within a single state, such as Illinois, it is easy to find coals with heating values from 10,000 - 12,000 Btu/lb. Steam generators of a given capacity operating at full load require a fixed heat input if all other things are equal. So if the purchasing agent buys his coal on a Btu basis, he may substitute 10,000 Btu per pound coal for a unit designed to fire 12,000 Btu per pound coal. This requires 20% more pounds of coal to be handled in the coal yard, the silo, the coal conveying and feeding equipment, the pulverizers, or the stoker. Somewhere along the line it would not be unusual to find a piece of equipment with a 10% margin and this would limit the output of the unit to about 91% capacity. Hopper fed traveling grate stokers usually have a limitation as to the pounds of coal that can be fired per foot of stoker width. Any radical change in the Btu per pound of coal requiring 20% more pounds of coal could easily exceed the burning capacity of the stoker such that output of the steam generator may be reduced.

In short, lower Btu coal will increase the pounds of coal to be handled and when the variations are large enough we can expect a reduction in boiler capacity. Higher Btu coal seldom gives any problems in boiler operation or performance. See Figure 1 for typical heating values of various coals found in the United States.

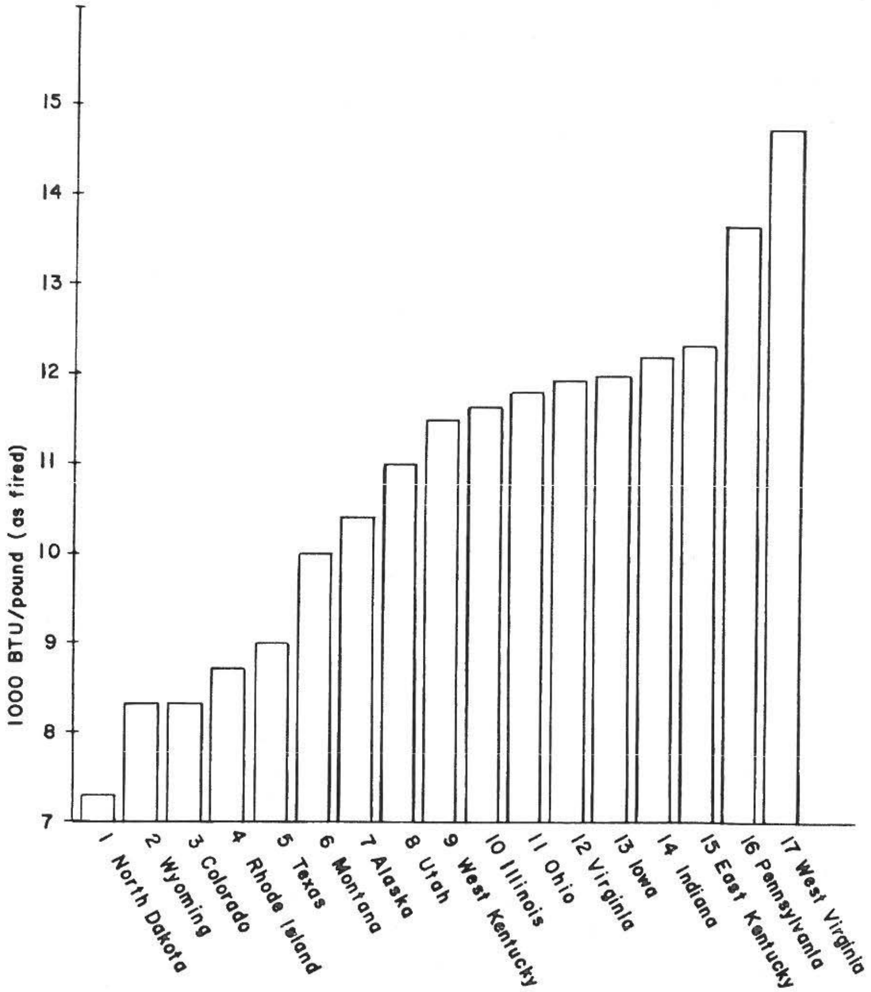

Figure 1 Typical Heating Value of United States Coal

MOISTURE CONTENT

Increased moisture coal content has all the problems of lower Btu value in that more pounds of fuel must be fired for the same heat input to the unit. Wet coal may require special additional equipment such as coal dryers or bunker vibrators to avoid coal pluggage in the feed chutes to the pulverizer. But in addition to the problems of handling more fuel because of increased moisture, we can also expect a reduction in efficiency. Nine percent additional moisture, say a change from 9% to 18% moisture in the fuel, will drop the efficiency approximately 1%, even more on units that do not have heat recovery equipment. With a drop in efficiency of 1% we have 1% more air and gas flow which means 2% more air pressure drop and gas draft loss which translates to 3% more fan horsepower requirement on the forced draft and induced draft fans.

Pulverizer capacity is particularly sensitive to coal moisture. An increase in coal surface moisture from 5% to 14% can reduce the output of the pulverizer to 74% of its original capacity. The Riley Stoker Corporation has found it desirable to use crusher dryers ahead of its ball tube mill pulverizers to overcome this problem. See Figure 2 for pulverizer capacity plotted against surface moisture for the reduction in the capacity for ball tube mills both with and without crusher dryers. Our approach has been to insist on a crusher dryer whenever the surface and inherent moisture total more than 10%. On the other hand, if the customer insists that he will never have more than 10% total moisture in the fuel, we simply do not believe it and add the crusher dryer anyway.

In short, increasing coal moisture beyond the amount for which the equipment selected has all the problems of lowering the Btu content and in addition may reduce the efficiency, increase the fan horsepower, and limit pulverizer output.

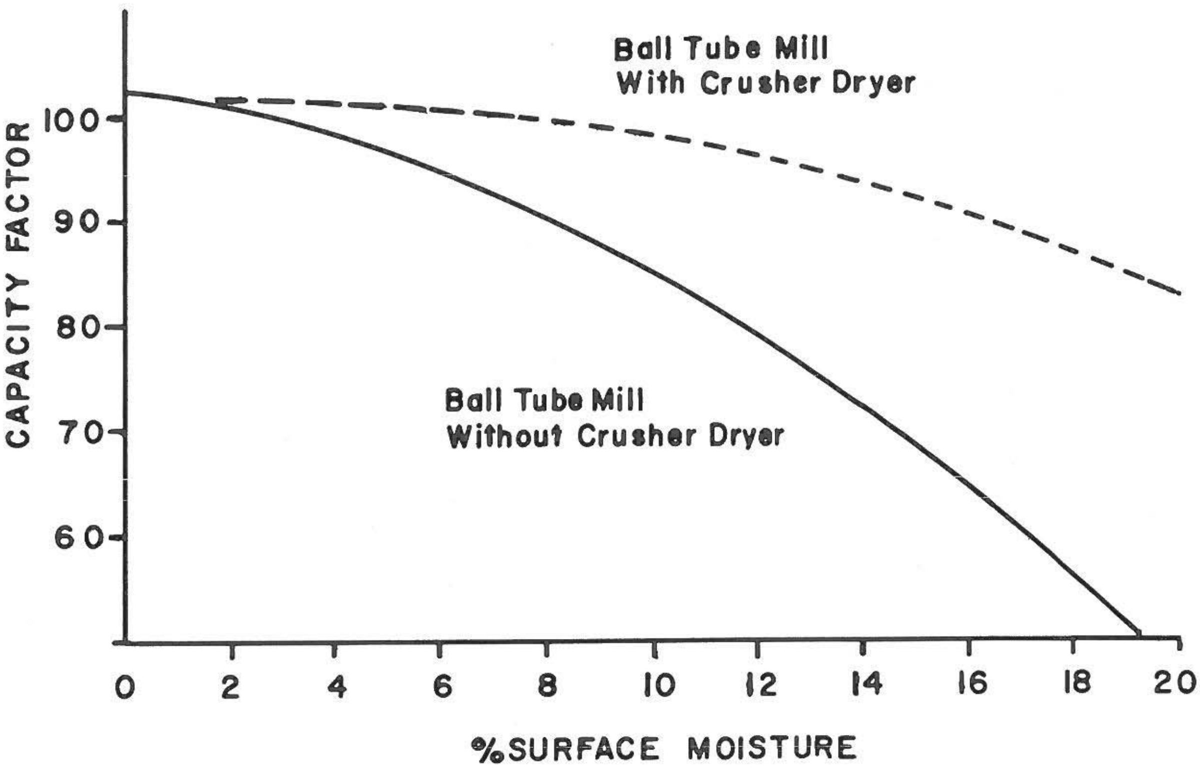

Figure 2 Pulverizer Capacity vs. Surface Moisture

ASH PERCENTAGE

Ash quantity in American coals normally varies from 3 to 20% and somewhere in the design process an ash quantity has to be considered for the design of the ash handling equipment, boiler hopper, precipitators or dust collectors, pulverizers, and coal handling equipment. Increasing the ash beyond the design figure will give us all the problems of lower Btu per pound of coal and larger fuel quantitites. In addition, carbon loss increases with ash content. On a spreader stoker, if we move from 5% ash to 15% ash we can expect the carbon loss to go from 2% to 3% when reburning the dust collector catch or from 3.5% to 5% without reburning the dust collector catch. A more serious problem occurs with the dust collector or electrostatic precipitator. For pulverized coal firing, the Riley Stoker Corporation makes the very simple and conservative assumption that all the ash in the coal is delivered to the electrostatic precipitator. In actual practice, probably 20% of the ash is caught in the boiler furnace hopper, so we have built in to the precipitator a 25% margin. But if the ash in the coal increases from 5% to 10%, we have doubled the loading to the precipitator and in all probability the flyash in the flue gas leaving the precipitator would quickly exceed the EPA limitation of 0.1 pounds of flyash per million Btu fired. In short, when ash content increases beyond the design figure, we can assume that the air pollution regulatory body will order the unit shut down and excessive ash in the coal beyond the design point can be said to result in zero capacity.

COAL GRINDABILITY

Coals in the United States can vary from approximately 35 to 100 on the Hardgrove grindability index. It must be remembered that on this grindability index a high figure indicates a coal easy to grind and a low figure indicates a coal diffcult to grind. Anthracite and petroleum fluid coke are even more difficult to grind than bituminous and sub-bituminous coal. Unless otherwise specified, a pulverizer is usually selected for a 50 grindability coal and if the coal characteristic varies such that the operator is asked to burn coal with a 40 grindability index, his pulverizer capacity will be reduced to 78% of the design figure. See Figure 3 for the capacity reduction that may be expected in pulverizers attributed to lower Hardgrove grindability index figures.

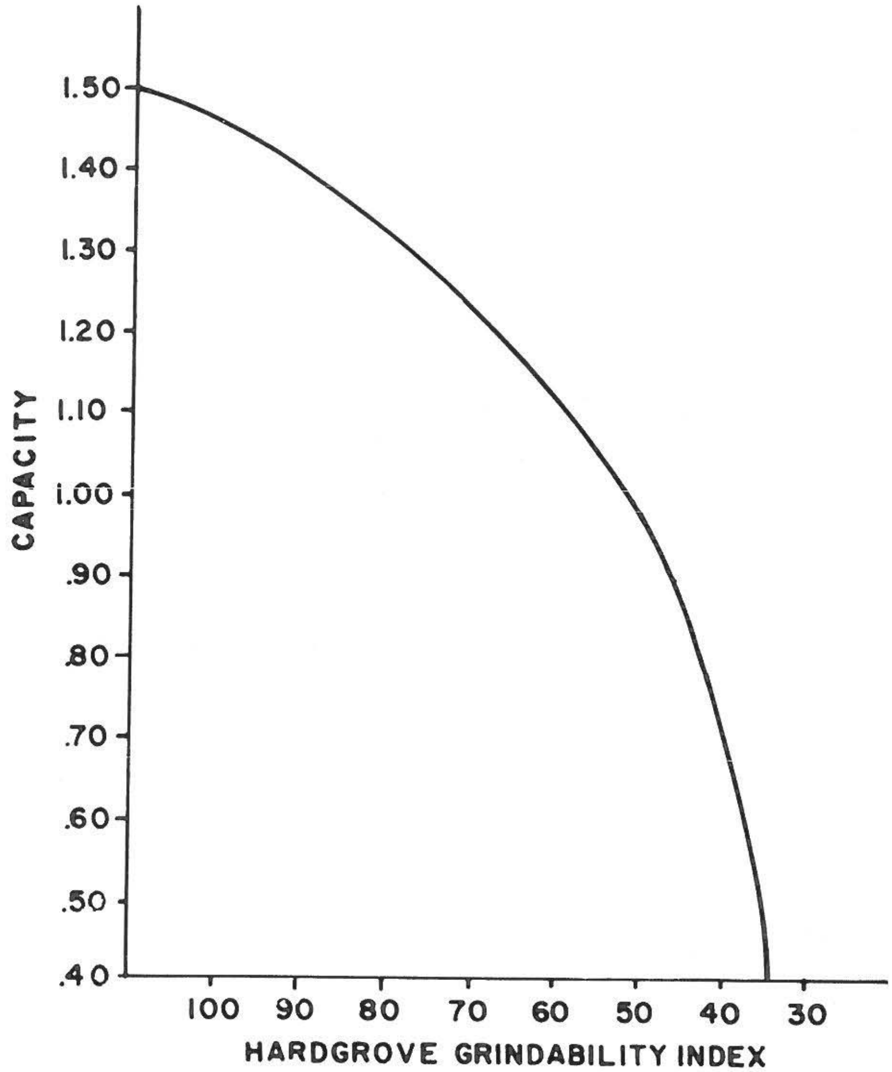

Figure 3 Pulverizer Capacity vs. Coal Grindability

PERCENT VOLATILE CONTENT IN COAL

American coals have a volatile content range on a dry and ash free basis of anywhere from 2 to 50%. The 2% lower limit, of course, is anthracite coal. This coal characteristic directly effects the combustibility of the pulverizer product. With lower volatile content, the required fineness increases. For medium volatile coals, it is usual to pulverize the fuel such that 70% will pass a 200 mesh screen. For low volatile coals, it is recommended that the size of the pulverized coal be finer, or 75% through a 200 mesh screen. And for anthracite fuels with volatile content down to the 2 to 10% range, we would recommend 85 to 90% through a 200 mesh. In addition some sustaining fuel (oil) may be required for good combustion. If the boiler designer knows he is designing for an extremely low volatile bituminous coal or an anthracite fuel, he will look for greater retention time in the furnace. Taller furnaces with lower volumetric heat releases are used to increase retention time. In general, however, for normal volatile content variations between 25% and 50%, there is little effect on boiler operation or furnace design. The extremely low volatile fuels can give us problems. See Figure 4 for pulverizer capacity reduction when extra fineness is required. In short, pulverized anthracite cannot be fired in a furnace designed for bituminous coal.

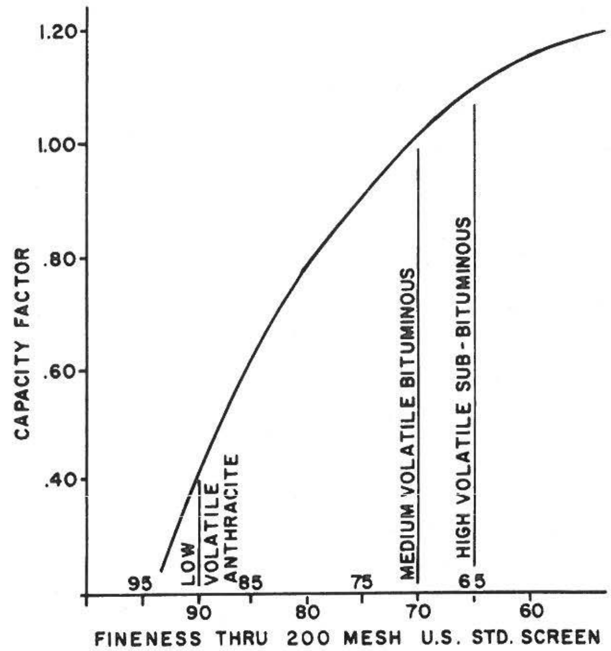

Figure 4 Pulverizer Capacity vs. Coal Fineness

COAL NITROGEN

Until a few years ago, boiler designers and operators were not concerned with NO_X emissions. But with Federal Legislation limiting nitric oxides emissions to a maximum of 0.7 pounds per million Btu fired, and with the proposed new rules of 0.5 pounds or 0.6 pounds, the nitrogen content is a very important fuel characteristic. On a dry basis, the nitrogen usually varies from 0.6 to 1.6% and although the exact conversion of fuel nitrogen to NO_X varies somewhat among experts, most agree that high fuel nitrogen results in high NO_X emissions. Unfortunately, several methods of reducing NO_X generated from the combustion air are not effective in reducing NO_X generated from fuel nitrogen. Such methods as gas recirculation, larger furnace areas, and lower combustion air temperature have little if any effect on NO_X from fuel nitrogen. If the nitrogen content on a dry basis goes much above 1% it becomes necessary to use off-stoichiometric firing to keep the NO_X emissions acceptable. This requires some of the combustion air introduced above the burners and is frequently referred to as two-stage combustion. Unfortunately, two-stage combustion gives lower gas temperatures from the furnace and this in turn gives lower steam temperature from the superheater. Moreover, if we move to two-stage combustion to reduce NO_X, there is a good possibility that CO emissions and carbon loss will increase. If the regulations on emissions are altered from 0.7 pounds to 0.6 pounds per million Btu, it is approximately equivalent to calling for a reduction of 1/4 of 1% in the coal nitrogen content. In the area of nitrogen content, a very small change in a coal characteristic, such as moving from 1.25% nitrogen coal to 1.5% nitrogen coal, can cause emissions to go beyond the Federal limit.

SULFUR CONTENT

Somewhere between 80% and 90% of the sulfur in the coal will usually be converted to sulfur dioxide in the flue gas. A good rule of thumb is to plan on 85% conversion. Sulfur dioxide has twice the weight of the sulfur in the oxide so if we start with 1.5% sulfur in the coal, and if we are firing 10,000 Btu per pound coal (requiring 100 pounds of fuel per million Btu), the SO_2 emission per million Btu will be 100 x 0.015 x .85 x 2, or 2.55 pounds of SO_2 per million Btu fired. Assuming we are required to meet the EPA limit of 1.2 pounds of SO_2 per million Btu, we then have to remove 53% of the SO_2 of the flue gas. On the other hand, if the sulfur content in the fuel doubles to 3% sulfur, we can expect 5.1 pounds of SO_2 in the flue gas requiring 77% removal. This can certainly be a burden on boiler operation.

Sulfur content also has an effect on airpreheater protection. With 1.5% sulfur in the coal, the airpreheater manufacturer may recommend that the sum of the gas exit temperature and the air entering temperature equal 310°. But for 3% sulfur the airheater manufacturer will call for gas out and air in temperatures to total 360°. On a zero degree day, this may make the difference between using the steam coil or not using the steam coil. And of course, if the sulfur content in the coal is beyond the design figure for which the steam coil was originally sized, we may find that the coil is not adequate for higher sulfur fuel.

ASH SLAGGING CHARACTERISTICS

Coals in the United States have shown wide variations in the slagging characteristics of the ash when fired in a pulverized coal furnace. It is customary to classify a coal in one of four ash slagging categories, either low, medium, high, or severe slagging. Ash fusion temperature is one variable that helps determine the slagging characteristic. Another indication can be taken from the temperature required to give the ash a viscosity of 250 poises. Off hand I can think of no more severe problems in boiler operation than those that usually result when trying to fire a severe slagging coal in a furnace designed for low or medium slagging coal. Figure 5 indicates furnace exit temperature variation for the four grades of ash slagging factors. Steam temperature can be expected to jump with furnace exit temperature, perhaps well beyond the ability of the temperature control system to function. Furnace wall blowers if selected for medium slagging coal will not be sufficient for severe slagging coal. A change in the slagging factor from medium to severe could easily reduce the capacity of the unit by 20%.

On the other hand, we cannot assume that firing a low or medium slagging coal in a furnace designed for severe slagging coal is without problems. We would not overload the sootblower system but we would certainly drop the furnace exit temperature and on a superheater designed for 950 or 1000°, we can expect to lose 50° of superheat or more.

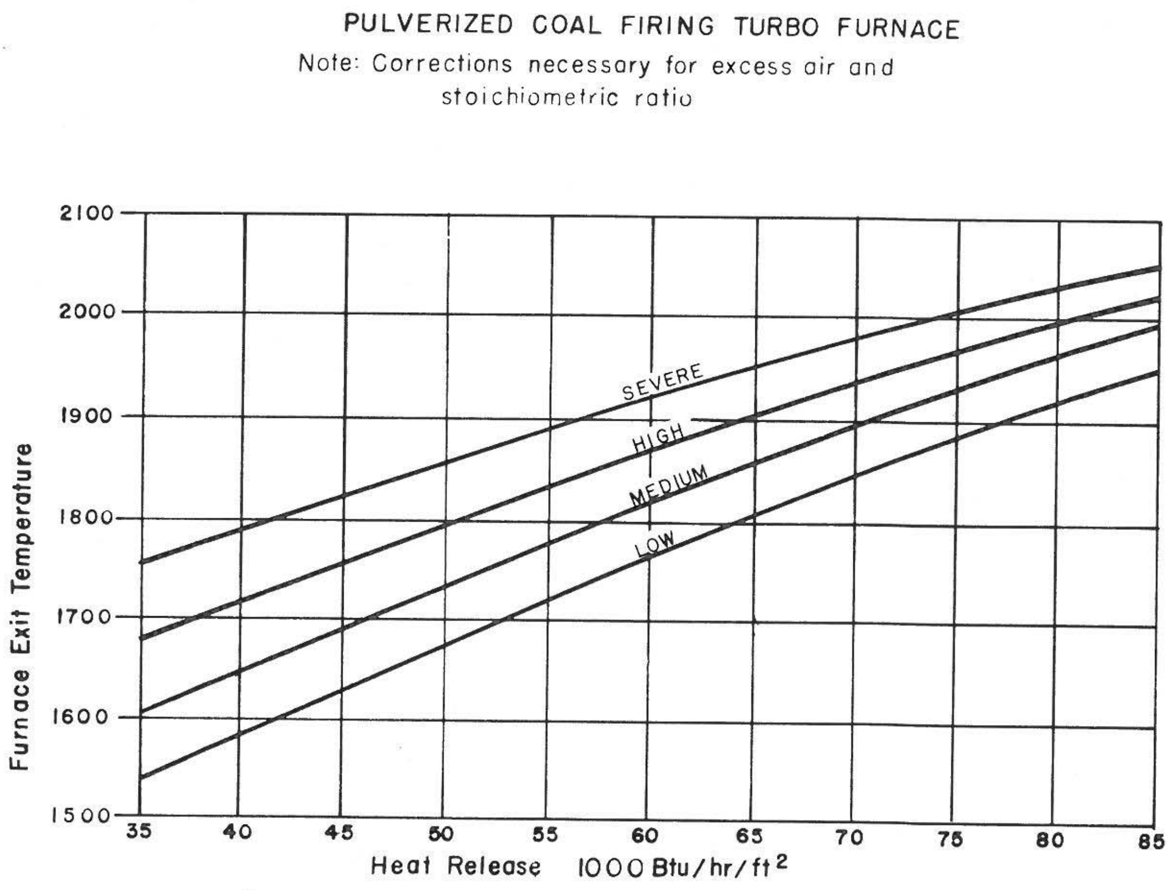

Figure 5 Effect of Coal Slagging Index on Furnace Exit Gas Temperature

ASH FOULING CHARACTERISTICS

Another coal characteristic we are interested in is the fouling potential or fouling index of the ash. Again, it is usual to classify coals into four levels and they are said to be either low, medium, high, or severe fouling coals. There are several indicators that permit us to predict the fouling index. Perhaps the most commonly used is the percentage of sodium oxide in the ash. If the boiler designer knows that he is designing for a severe fouling coal, he will use wider spacing between tubes in the superheater, reheater, boiler, and economizer tube bundles. Figure 6 shows a recommended tube clearance as a function of coal fouling index and gas temperature. Moreover, sootblowers will be more numerous. If we try to fire a severe fouling coal in a unit designed for low or medium fouling, we can expect bridging over of the ash deposits in the convection zone to the point where gas velocity and pressure drop may increase beyond the capacity of the induced draft fan, and the unit will have to come off the line for cleaning. On the other hand, if we fire medium fouling coals, in a unit designed for severe fouling coal, the only disadvantage is the extra investment in the unit.

CONCLUSION

I have tried to cover the more important coal characteristics that have an adverse effect on boiler operation. It is important to know as much as possible about the fuel under consideration when a change in fuel supply is contemplated. Figure 7 is an excellent coal check list. It is the American Boiler Manufacturer's Association coal specification form and will serve as an excellent check list to compare several possible fuels with original fuel for which the steam generating unit was designed. Any wide variation between a contemplated fuel and a known satisfactory fuel will indicate an area requiring more thought or study.

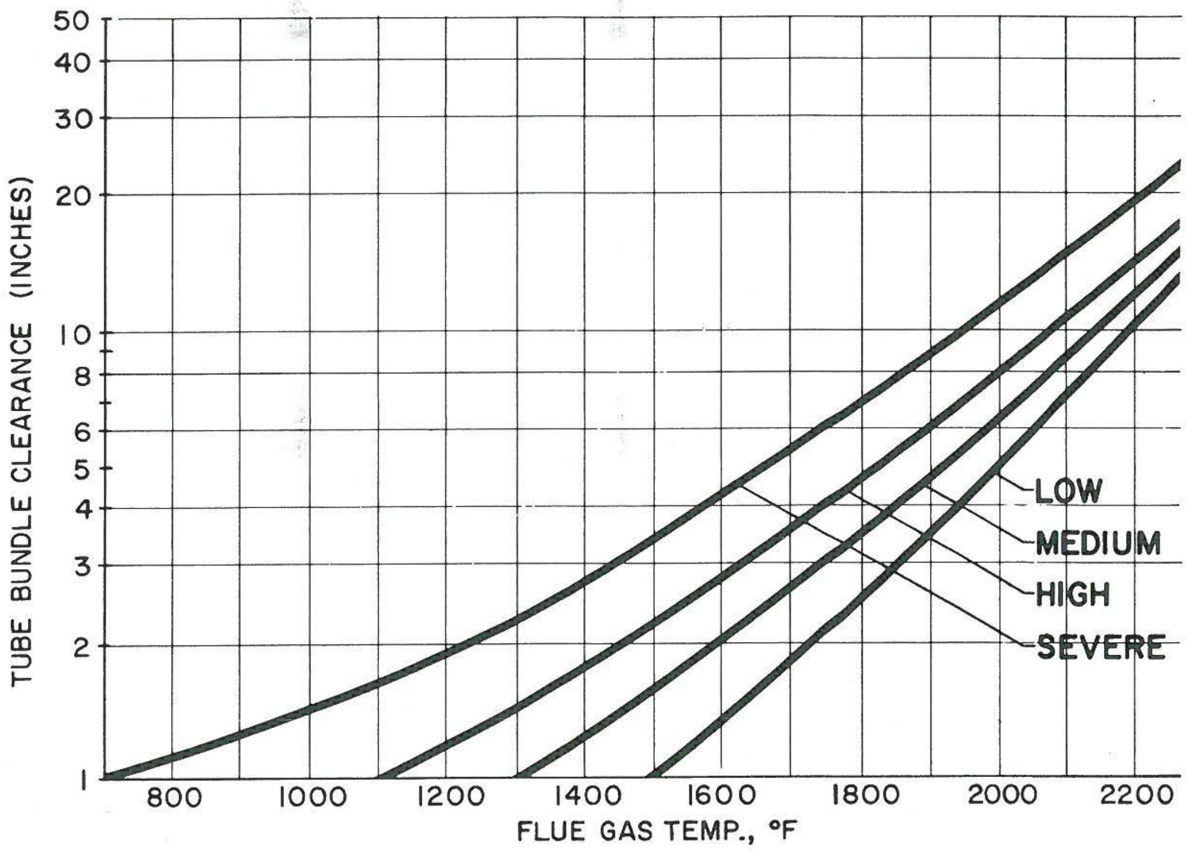

Figure 6 Convection Tube Spacing as a Function of Coal Fouling Index and Gas Temperature

RECOMMENDED ABMA*
COAL GUIDE SPECIFICATION FORM

SOURCE (STATE/COUNTY/COMPANY/MINE/SEAM) ____________

____

CLASSIFICATION BY RANK____________

Proximate Analysis—as received (percent by weight)

Volatile Matter	________
Fixed Carbon	________
Ash	________
Moisture (Total)	________
Equilibrium Moisture	________
	________

Grindability—Hardgrove ________

Feed Size (Sieve Analysis)

Sulfur

Forms of Sulfur

Pyritic	________
Organic	________
Sulfates	________

Heating Value—BTU/lb.
as received ________

Ultimate Analysis—as received (percent by weight)

Moisture	________
Carbon	________
Chlorine	________
Hydrogen	________
Nitrogen	________
Oxygen	________
Sulfur	________
Ash	________

Float Sink Fraction (1.6 sp.gr.) ________

Ash Fusion Temperatures (°F)

	Reducing	Oxidizing
Initial deformation	________	________
Softening (H=w)	________	________
Hemispherical (H=½w)	________	________
Fluid	________	________

Ash Analysis (percent by weight)

SiO_2	________
Fe_2O_3	________
Al_2O_3	________
CaO	________
MgO	________
P_2O_5	________
Na_2O	________
K_2O	________
TiO_2	________
SO_3	________
NAF	________
Viscosity	________

Burning Profiles ________

Bulk Density (as delivered) ________

Free Swelling Index ________

Reactivity Index ________

* Please use one form for *each* coal specification; do not list property ranges or composite properties.

Figure 7 ABMA Coal Guide Specification Form