IMPROVE YOUR PULVERIZER PERFORMANCE

Today's demands on PC-fired unit flexibility are tremendous. Even very large units are now expected to park overnight at low loads before rapidly ramping up in the morning for another day of load swings. This combined with new requirements for NO_x reduction and a market-driven push for fuel flexibility has taxed coal pulverizing equipment to the limit. The utility staff can, however, hold its own against such odds if it takes the time to understand the pulverizers and properly set them up.

One of the most popular pulverizer designs in use today is the medium speed roll and race design, such as B&W's MPS, Foster Wheeler's MB or MBF, and ABB-CE's new HP. This type of design will be generically addressed here. All curves and examples presented are consistent with a theoretical, but practical example of an operating roll and race design.

Pulverizer set up and tuning will be addressed in three parts:

Part I - Pulverizer Capacity
Part II - Primary Air/Fuel Ratio Characterization
Part III - Pulverizer Controls

PART I - PULVERIZER CAPACITY - WHAT DOES IT REALLY MEAN?

When a pulverizer manufacturer rates capacity at 100,000 pph, there are strings attached. Associated with that rating are limits on coal grindability, moisture, feed size and output fineness, along with some reasonable PA/fuel ratio. Each of the parameters will affect the effective size of the machine.

For example, consider a 100 KPPH pulverizer which was designed for a Hardgrove Grindability Index (HGI) of 60, a surface moisture of less than 10%, and a feed size of 2.5". The 100 KPPH rating means that operating at those stated conditions the pulverizer product will have a fineness of 70% through a 200 mesh at a throughput of 100 KPPH. Figures No. 1 through 4 shows how the capacity of the pulverizer actually changes as each of the operating parameters change. Figures No. 1, 3 and 4 assume that rated fineness is being maintained, which in this case is 70% through 200 mesh.

Suppose a plant's fuels department has found a bargain on a local coal which has an HGI of 54, a surface moisture of 14% and a feed size of 2.75". Using the capacity correction curves, the pulverizers new effective capacity for delivering a 70% through 200 mesh product is:

(RATED CAPACITY) (HGI CORRECTION) (MOISTURE CORRECTION) (SIZE CORRECTION) = (100 KPPH) (.935) (.97) = 82.5 KPPH

Surprised? Now, if the operators simply must push 100 KPPH of this new fuel through the pulverizer, then Figure No. 2 indicates that the pulverizer will be running at 121% of the new rated capacity and the 200 mesh fineness will drop to about 52%. There goes LOI and boiler efficiency, not to mention an increase in equipment erosion and possible adverse effects on NO_X

The curves presented here are typical. Each pulverizer manufacturer should be able to produce similar curves upon request which are specific to the application.

Pulverizer performance will deteriorate any time the machine is operated above its effective rating. The above example of switching fuels is one illustration, but a similar effect may result from switching to a fuel with lower heating value or trying to sustain higher loads with fewer pulverizers operating. Both increase the required fuel throughput. It is a certainty that LOI goes up as fineness goes down.

The message then, is to thoroughly consider the rating and operating conditions of the pulverizer before firming up new fuel purchases or buying new pulverizers. Other fuels impacts such as fouling and slagging tendencies, fuel bound nitrogen, sulfur and ash should be considered as well.

PART II - PRIMARY AIR/FUEL RATIO CHARACTERIZATION

The primary air/fuel ratio characterization is a very critical but seldom understood curve. Even the manufacturer's start-up or service engineer sometimes fails to grasp the significance of the relationship as a whole, or the effect of each part of the curve. How the air/fuel ratio is characterized will have profound effects on flame stability, pulverizer load stability, turndown, response rate, burner eyebrows, NO_x generation, LOI, erosion and auxiliary power use.

Developing the Basic Air/fuel Characterization Curve

A typical PA/fuel flow characterization curve is shown in Figure No. 5. The exact values for a given pulverizer are a function of coal conduit size, fuel moisture and throat ring flow area. In any case the actual curve must be above a minimum allowable curve.

The minimum curve has four components which must be calculated and coordinated: Minimum line velocity, minimum A/F ratio, minimum slope, and the resulting inflection point.

The minimum line velocity is the velocity required through the coal conduits to keep the fuel in suspension. At lower PA flows the pulverized coal is in danger of falling out of suspension and laying out in the coal conduits, possibly resulting in fire or explosion. Minimum line velocity is thus affected by conduit size, number of conduits, altitude and temperature. Minimum line velocity is usually targeted at about 3000 fpm at sea level. The quantity of air required to maintain minimum line velocity is calculated as follows:

Air Flow = (3000fpm) (60 min/hr) (A) (N) (p) P_O/P_B

Where: A = Flow Area of one conduit, ft^2
N = No. Of conduits/pulverizer
P_o= Standard barometric pressure, psiu
P_b= Barometric pressure at plant altitude, psiu
p = Density of air at standard pressure, 150°F.

Note: Western fuels are often controlled to 135°F, which would also require a density correction for temperature.

Thus, for user example pulverizer, the PA flow required to support minimum line velocity is calculated at 150°F, elevation of 400 ft., and four 17" I.D. coal conduits per pulverizer:

$$\frac{(3000\text{fpm})\ (60\ \text{min/hr})\ \pi\ (17\ \text{in})^2\ (4)\ (0.00651\ \text{lb/ft}^3)\ (14.7\ \text{psia})}{(4)\ (144\ \text{in}^2/\text{ft}^2)\ (14.44\ \text{psia})} = 75{,}212\ \text{pph}$$

<u>The minimum allowable PA/fuel ratio</u> is somewhat subjective, and largely a function of moisture in the fuel. Figure No. 6 may be used in most instances as a guideline for minimum air/fuel ratio. Note also that minimum air/fuel ratio is achieved at maximum fuel flow. Thus, multiplying the maximum fuel flow by the minimum air/fuel ration results in the PA flow at maximum fuel flow. Continuing our example:

(100,000 pph fuel flow) (1.25 lb air/lb fuel) = 125,000 pph

We have now developed minimum PA flow and maximum PA flow. Figure No. 7 illustrates the two. Note that minimum PA flow is a constant at all fuel flow, while maximum fuel flow. Connecting the two can become a compromise, especially with oversized coal conduits. The two lines will meet at an angle (inflection point) followed by a slope up to maximum value. The inflection point would preferably be to the left of minimum pulverizer operating range to avoid the instability associated with passing through that point. Typical turndown ratio for this type of pulverizer is between 2-1/2 and 3 to 1, which would put minimum operating load at 33.3 to 40 kpph in the example. Thus, an inflection point of 33.3 kpph would seem in order. This is sufficient for establishing the minimum curve. Figure No. 8 indicates the resulting minimum curve.

Developing the actual operating curve involves balancing several performance parameters and guidelines:

1. Stay above the minimum characterization curve. (Figure No. 8)
2. Keep inflection point out of operating range.
3. Keep the slope of the operating curve steep enough for good response.

4. Lower air flow results in better fineness & less erosion.
5. Lower air flow can result in more pyrites, but fewer burner eyebrows.
6. Lower air flow means and a greater tendency to plug with wet coal.
7. Lower air flow leaves more reserve fines in the pulverizer.
8. Also note that lower air flow leaves a deeper bed depth of coal, and thus a higher pulverizer d/p.

Keeping the PA flow above minimum line velocity is a very important safety consideration. A good practice would be to set the minimum air flow about 20% higher than the calculated minimum line velocity to allow for control system error, overshoot, etc.

The slope of the operating curve directly relates to ramp rate ability and stability. Approximately the first three to five minutes of a pulverizer load increase is accomplished solely form increasing PA flow, as it can immediately access reserve fines resident in the machine. By the time the reserve fines are depleted the pulverizer should be able to sustain the higher load by generating additional fines from higher fuel input. If the curve is too flat, then the change in air flow is not sufficient to pick up the required reserve fines, and ramp rate will be limited. Conversely if the slope is too steep the immediate response will be prompt, but the high initial PA flow has kept the pulverizer swept so clean that not enough fines are resident to sustain load until additional grinding is accomplished. Selecting the proper slope is difficult, but can be accomplished through a methodical series of tests to monitor resource, stability, pyrites, fineness, etc. Note that the only three curve components to work with in slope adjustment are:

- Maximum PA flow at maximum fuel flow (i.e., minimum PA/F ration)
- Minimum PA flow
- Location of reflection point

If possible, a reasonable initial PA/Fuel flow slope range could be about .6 to .9 lb air/lb fuel. The final slope may be a compromise, and can only be determined through field tests.

Lower PA Flow

The virtues of lowering PA flow are numerous. A brief summary of those already mentioned and others would include:

- Improved fineness
- Less component erosion
- More complete pyrite rejection
- Fewer or smaller burner eyebrows (via better pyrite rejection)
- Less PA fan capacity requirements
- Less PA system resistance (not including the pulverizer)
- More reserve fines available

- Greater opportunity for steeper characterization curve
- Easier to keep inflection point out of the operating range
- Aids in NO_X reduction

This discussion would not be complete, however, without observing the courteous of possibly creating other operational problems. Lowering PA flow could impose any of the following performance deficiencies if not implemented properly:

- Higher pulver d/p via increased bed depth
- Excessive pyrites & fuel rejection via low throat ring velocity
- Increased fire risk due to operating closer to minimum line velocity & minimum throat ring velocity
- Greater tendency to plug with wet coal
- Hotter inlet air temperature (i.e. constant BTU input) for the same fuel moisture

The higher d/p may be handled through additional PA fan head, if available. The increased fire risk is really not a factor if operated as described above. Wet coal pluggage with reduced PA flow can be avoided bias available until maximum biased air flow prior to the change (assuming this previous maximum air flow adequately avoided wet pluggage).

Excessive pyrites rejection is a matter of insufficient throat ring velocity, however, and may require mechanical modification of the throat ring flow area. Minimum throat ring velocity varies with pulverizer design, and even seems to be somewhat proprietary among manufacturers. Obviously, the proper minimum velocity is that which provides continued fuel through put while rejecting the majority of legitimate pyrites but very little fuel. Once again, field test at low pulverizer load will determine what needs to be done. If PA flow has been lowered then one good approach would be to add throat ring flow area restriction proportionally to maintain the same velocity. Subsequent adjustment may be required.

PART III - PULVERIZER CONTROLS

Basic pulverizer controls are well established, and will not be addressed here. There are, however, several tuning aspects which will be addressed for improved response and stability.

The Inflection Point, Again

The PA/fuel flow characterization curve inflection point has been discussed at length. If, however, it simply must be located within the operating range of the pulverizer due to excessively large coal conduit or some other reason, then tuning problems will result. As discussed in Part II, the initial response is a result of altered fines delivery through a change in PA flow for a given fuel flow change is different on either side of the inflection point is passed through) results in a similarly abrupt change in fuel delivery and finally an abrupt change in total loop gain. The traditional analog control system cannot easily handle a modulating loop gain. However, the new microprocessor-based systems can handle the change in two ways. The first is to replace the inflection point with a smoother regressed curve so that the loop gain change is not so abrupt. The second is to replace the constant controller gain with a variable gain, programmable as a function of the ?A/fuel flow characterization curve slope.

PA Flow Lead/Lag

A load-following unit with rapid load changes requires maximum pulverizer ramping capability. During a pulverizer load ramp the primary air will always lead the increase ramps (transferring additional fines to the burners) and lag the decrease ramps (to withhold fines from the burners). Once the new load is reached both fuel and air find a new equilibrium point as determined by the characterization curve. The faster the ramp, the more the primary air leads (or lags) the fuel.

Instability will result if the leading PA flow bumps the PA flow calibration limits, or the PA flow capability limits. The solution is threefold. Expand the PA flow calibration to cover the maximum PA flow on a load ramp, and be sure the minimum PA flow is outside the pulverizer operating range. Both of these "fixes" are within the practical capabilities of an analog control system. A DCS system could also monitor individual pulverizer load and load ramp direction, and impose corresponding ramp rate limits. The limits would allow maximum increase ramps that taper to minimum at full load and the reverse on the way down.

Air Flow & Temperature Control Interference

Hot air and tempering air mixing requirements vary as fuel moisture varies and as primary air bias varies. A properly set up pulverizer temperature control system will not impact primary air flow, even temporarily.

The hot and tempering air damper characterizations are usually a linear "scissors" - type arrangement, with full open hot air damper corresponding to a fully closed tempering air damper, and full open tempering air corresponding to a fully closed hot air damper. Each damper and damper installation has its own flow coefficient characterization, and it would be an unlikely coincidence if this "generic" hot/cold air damper program ever results in a combined constant flow coefficient. If the combined temperature control damper movement does not always result in a constant flow coefficient. The characterization curves are not likely to be linear, although a linear approximation can sometimes be used. The characterization curves may be easily determined through field testing.

CONCLUSION

In most cases the pulverizer utilizes relatively obscure applications of simple engineering principles. The diligent results engineer should be able to successfully optimize pulverizer performance through methodical testing and analysis. This discussion should provide at lease some enlightenment on the pulverizer internal performance relationships and their dependence upon externally controlled parameters.

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Figure No. 1
Grindablitiy vs Capacity

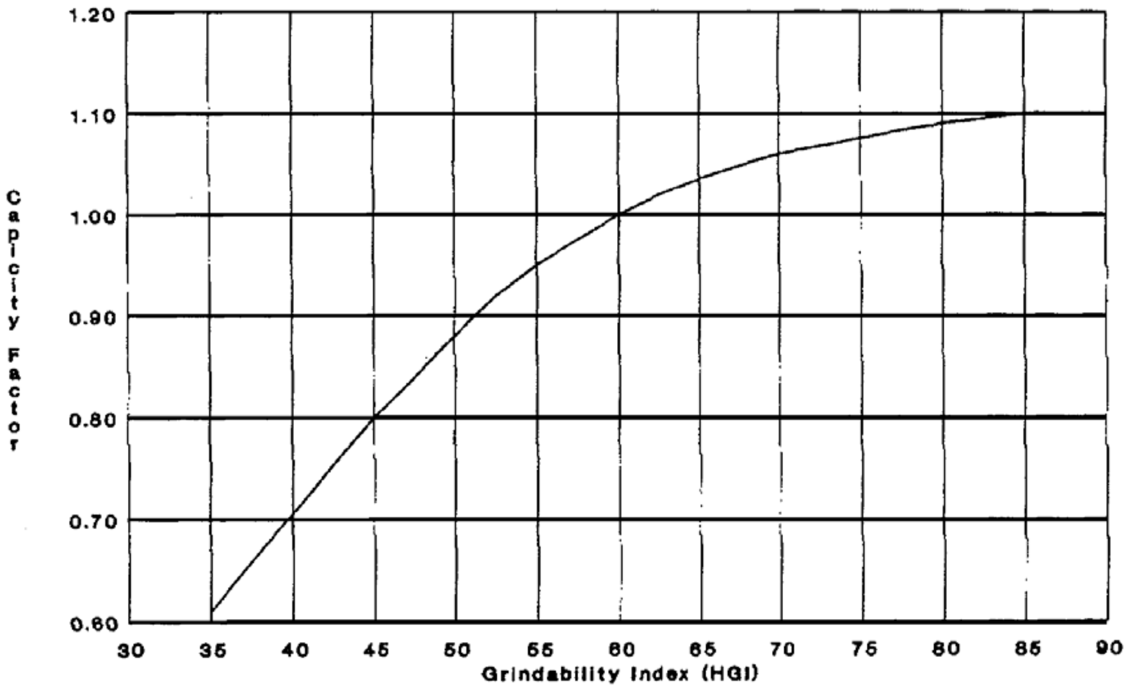

Figure No. 2
Fineness vs Capacity

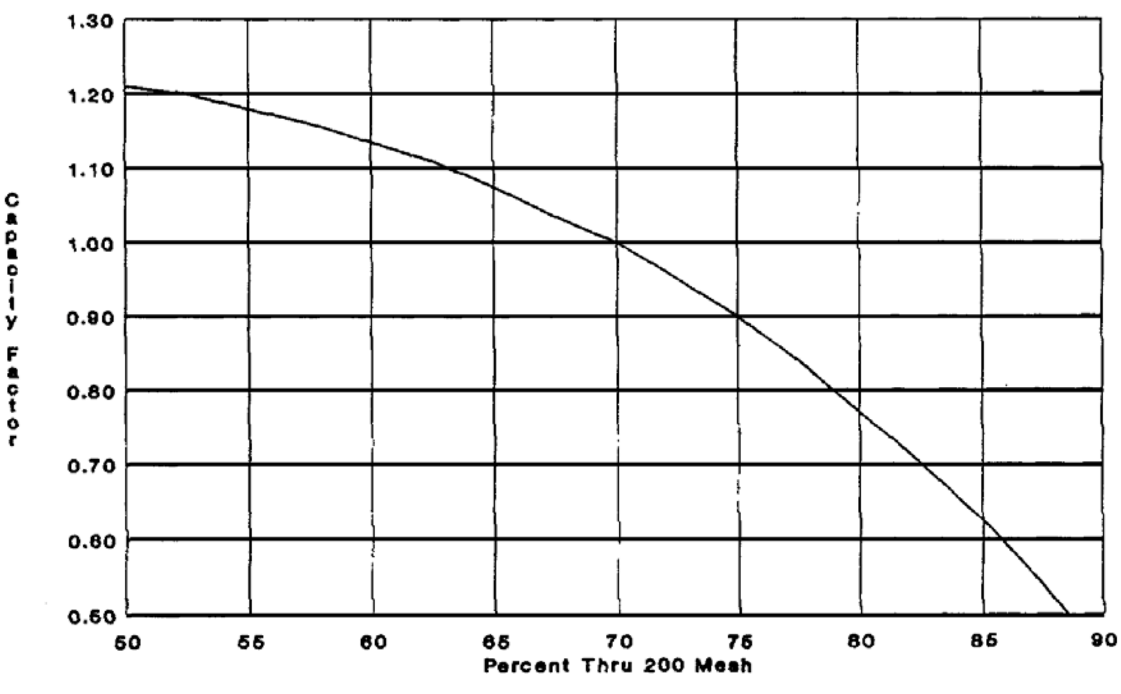

Figure No. 3
Surface Moisture vs Capacity

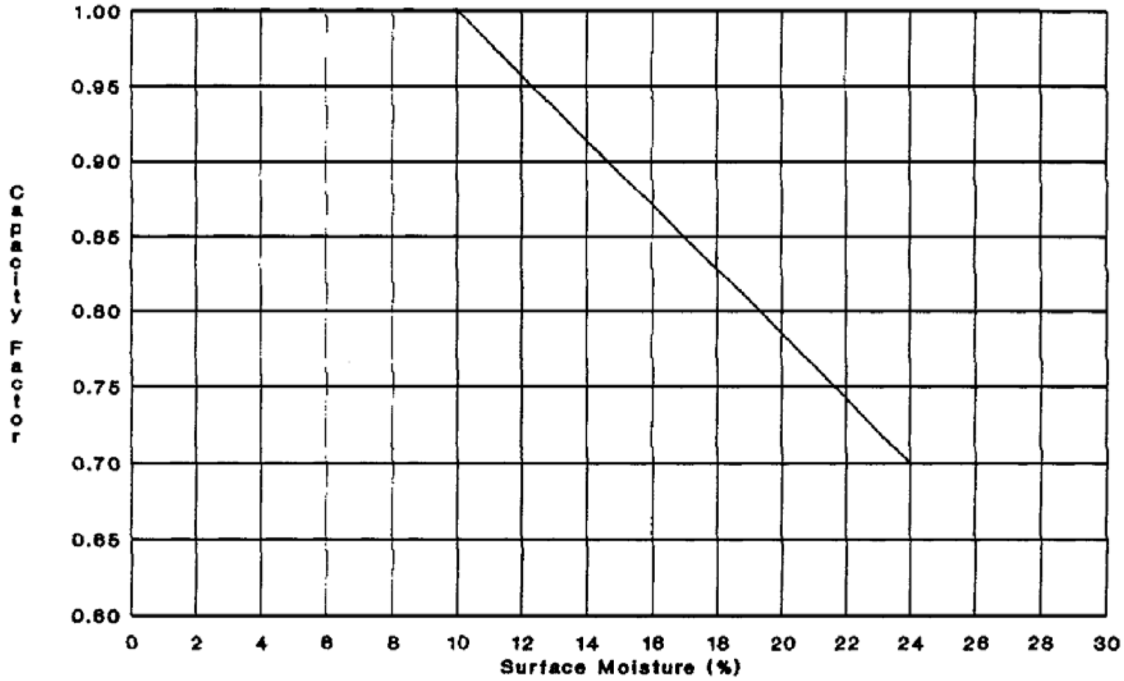

Figure No. 4
Feed size vs Capacity

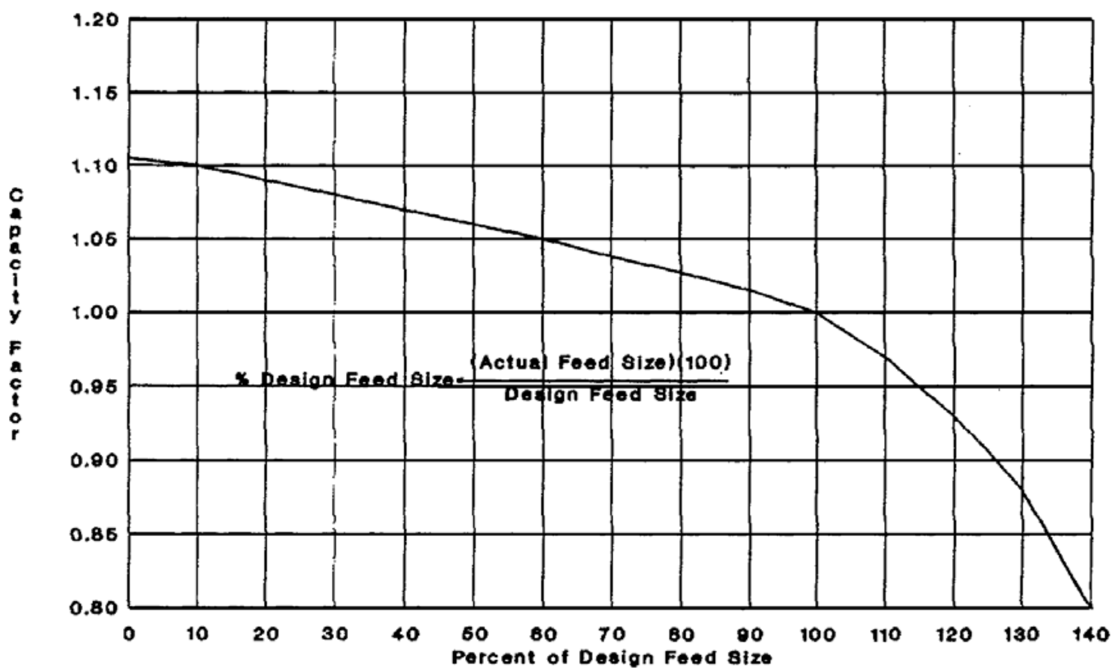

Figure No. 5
Typical PA/Fuel Flow Characterization

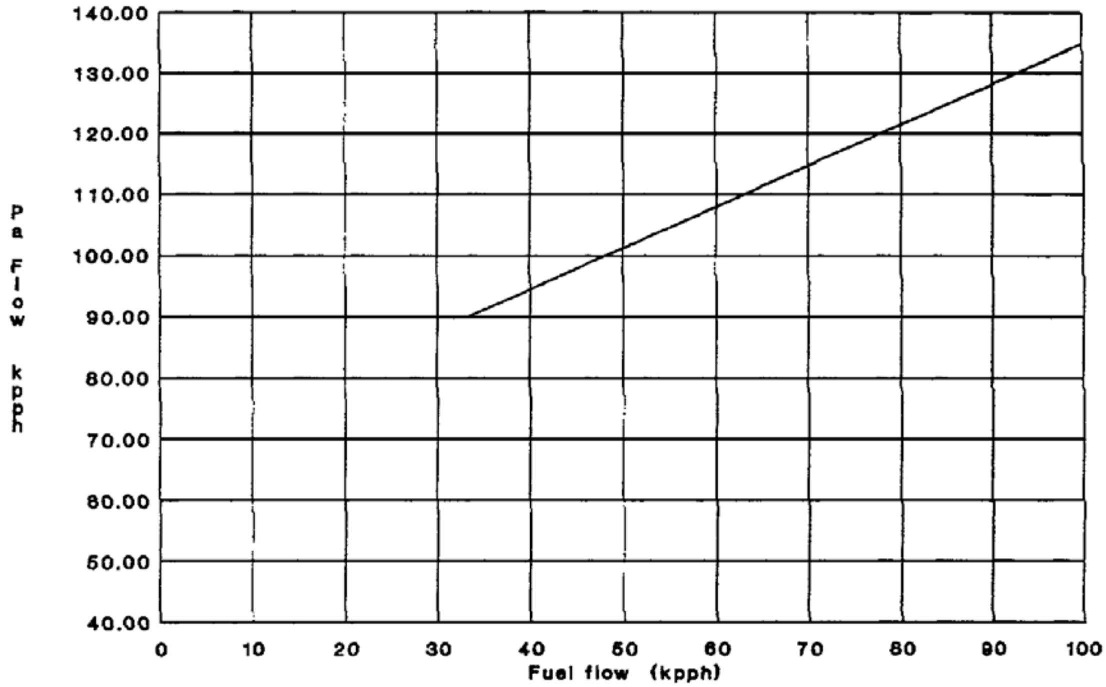

Figure No. 6
MINIMUM Primary Air/Fuel Ratio

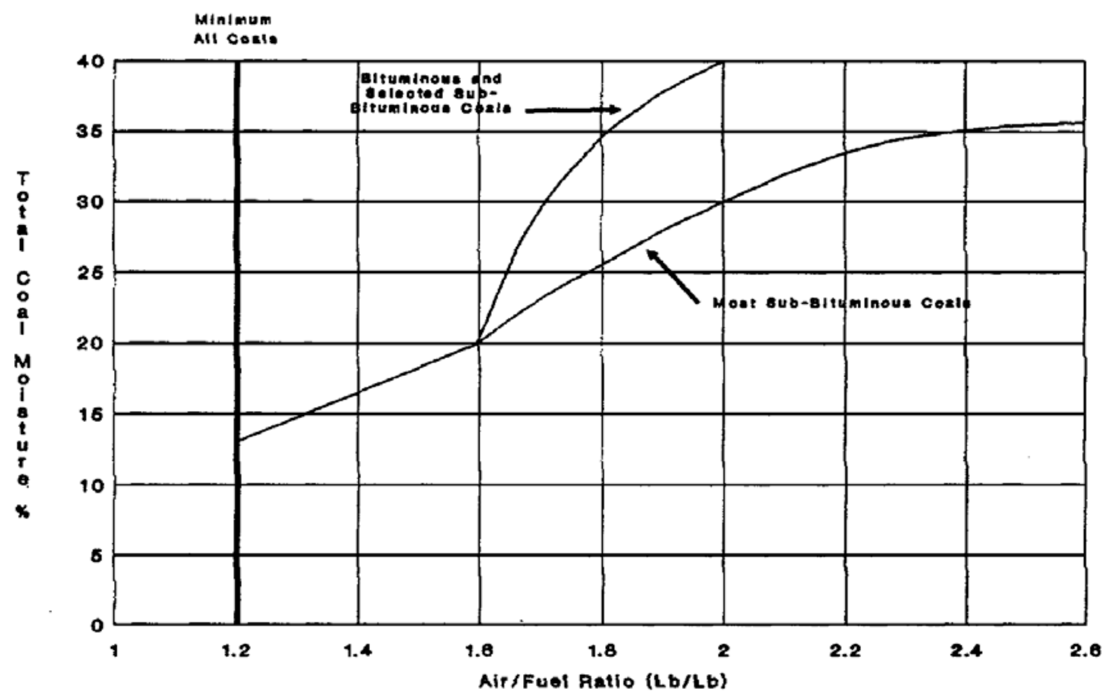

Figure No. 7
PA/Fuel Characterization Limits

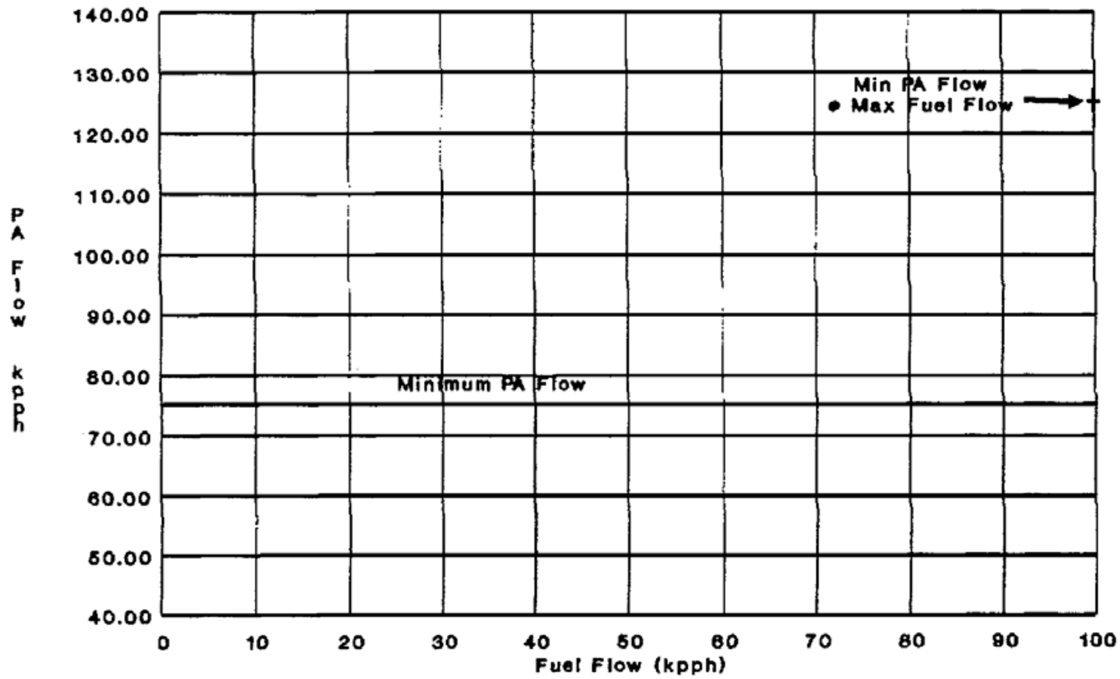

Figure No. 8
MINIMUM Allowable Characterization Curve