stage of the actual design. Fuel properties and plant design tie-in at many points, as diagrams on pages 110 and 111 show. Attention to this angle at the drafting-board stage keeps some small limitation from creeping into the plans. Such a restriction might look big when the time comes to operate the plant.

## SPENDING THE FUEL DOLLAR

So much for fuel selection as a factor in plant design. Let's turn now to the problem of buying fuel for an existing plant—one that was, in all probability, designed without benefit of a fuel survey. "Needle-in-the-hay-stack" purchasing leads to high steam cost and operating headaches. Responsibility for proper selection rests squarely on the shoulders of the power engineer. He is the only man, aside from the independent fuel consultant, who understands all the facts needed to spend the fuel dollar wisely. The purchasing agent can help with his knowledge of market conditions and buying procedure, the salesman and fuel-service engineer can supply facts about their fuels, but the power engineer must coordinate these with plant requirements and *make the choice.*

Because coal is a complex substance, selection cannot be reduced to a simple formula. What follows is an outline of a sound procedure which can be followed in most plants. Because it involves a minimum of testing and a maximum of "horse-sense," it comes closest to meeting small-plant needs.

The right coal for any plant is the one that will carry the load, meet all reasonable operating requirements and produce lowest over-all steam cost. While any coal can be burned in any plant, after a fashion, every practical engineer knows that many plants have design and equipment limitations that bar certain coals, either because they will not carry the load, because reliability will be seriously impaired, or because intolerable operating difficulties will be encountered.

To eliminate a lot of unorganized trial-and-error testing, the power engineer must examine every part of his plant from coal pile to ashpit and stack, with but one thought in mind, to locate and evaluate every factor affecting coal selection. Even the engineer *familiar with his plant will find such a* fuel-engineering analysis reveals limitations he wasn't aware of or puts the finger on the exact cause for some limitation only vaguely recognized.

Of equal importance, he will find that some limitations thought to exist will disappear on close examination. By removing false restrictions on coal choice, the analysis may actually lead to savings from wider buying latitudes.

The check list on this page gives some idea of the questions the power engineer must ask and answer. Experience and records will furnish some of the answers definitely and easily; others will have to be determined by trial. For example, a low boiler setting causes smoke trouble at high burning rates with high-volatile coals. The engineer knows this but has no records that would indicate the maximum amount of volatile matter that will permit operation at high rates without exceeding the smoke requirements. A few tests with sample shipments of coal will give the answer.

Limiting factors on coal use will take various shapes in different plants; in many cases the limitation will occur outside the furnace. For example, inadequate ash-handling equipment may require putting a limit on the ash content of fuels burned. A plant equipped with considerable air-heater surface, which produces low exit-gas temperature, may find it necessary to limit sulphur content to avoid rapid and expensive corrosion.

In considering furnace and firing equipment, it will be found that each factor of the design must be considered in relation to burning rates encountered and nature of load; that is, whether it is steady or fluctuating. For example, *minimum ash-fusion temperature for clinker-free operation* on an underfeed stoker depends largely on combustion rate. Likewise, nature of load affects importance of caking qualities of coals; a fluctuating load may bar a strongly caking coal from use on a stoker with inadequate agitation of the fuel bed, or from a hand-fired grate.

The engineer must also remember that one property of a coal may modify another. Thus presence of excessive fines may aggravate clinkering tendencies, producing trouble with a coal having apparently satisfactory ash-fusion characteristics.

Finally, in making the fuel analysis of his plant, the engineer must distinguish between limitations and preferences. For example, in a plant with barely enough pulverizer capacity, if grindability drops below a definite point, the load can't be carried; coals with lower grindabilities are worthless. However, if pulverizer capacity is ample, the engineer may still prefer high-grindability coals since grinding costs will be somewhat less. Saving in power consumption and cost of replacing wearing parts will indicate how much can be paid for higher grindability.

### TYPICAL QUESTIONS FOR PLANT FUEL SURVEY

**FUEL AND ASH HANDLING**

Is coal stored long enough to make its weathering characteristics important?
Need to watch heating tendencies?
Would wet coal cause handling troubles?
Would dust from excessive fines constitute a nuisance?
Does rough handling bar friable coals?
Do segregation difficulties put premium on close sizing?
Does inadequate handling limit ash?
What is coal- and ash-handling cost per ton, including labor?
How much does ash disposal cost?

**LOAD CONDITIONS**

What burning rate results from maximum load? What is duration of peak?
What is lowest load to be carried for any length of time?
Is load fluctuating or fairly steady?
Is spare boiler capacity available?

**SMOKE AND DUST EMISSION**

Is smoke restricted by law? How?
Is there any specific restriction on fly-ash? If so, what?
Does plant have effective dust collectors?

**OPERATION**

To what extent is combustion controlled automatically?
Are operators experienced, competent?
Does plant have adequate metering and facilities for testing?

**FURNACE**

Volume ample, heat release conserv[illegible]
Is setting height adequate?
Does lack of refractory surface make [illegible]tion difficult?
What is furnace temperature just [illegible] of first tube row?
What is temperature in combustion [illegible]
Does furnace promote turbulence[illegible]
How much air preheat, if any?

**STOKER SYSTEMS**

How much agitation does fuel bed [illegible]
How well can underfire air be dis[illegible] and controlled?
Is there enough overfire air at the [illegible] places, with enough velocity?
How much do coal size and caking [illegible]ties affect fuel-bed structure?
What is limit on ash-fusion [illegible] to avoid clinkering trouble?

**PULVERIZED-FUEL SYSTEMS**

Is mill capacity ample for low gri[illegible] coals?
What is grinding cost per ton [illegible] parts replacement?
Does inadequate drying limit [illegible]
Does amount and location of wa[illegible] surface restrict volatile content[illegible]
Is furnace dry-bottom or slag-tap[illegible] range of ash fusion can be [illegible]
Does furnace bar high-ash fuels [illegible] long flame travel?



Some properties of coal have importance only as limits, never as preferences. For example, once the minimum ash-fusion temperature for trouble-free operation has been determined, any increase has no actual value.

The completed plant analysis boils down primarily to a set of limitations expressed as far as possible in coal properties that can be measured (ash content, fusion temperature, sulphur content, etc.) with properties that still defy exact expression (caking quality, weathering properties) stated as clearly as possible. Armed with this analysis, the power engineer can tackle the list of coals available, eliminating immediately those that fail to meet minimum requirements.

At this point relative prices enter the picture. The list of coals remaining after the first elimination should be *set up on the basis of delivered-cost-per-Btu.* This will immediately permit a second elimination, divided into two parts: (1) of the coals meeting all requirements, eliminate all but the best two or three from the delivered cost standpoint, and (2) from the coals exhibiting one or more undesirable qualities, eliminate those where low cost seems insufficient to compensate for undesirable properties.

Note that up to this point the only testing required has been of a simple sort and that even such trials as mentioned for setting the upper limit of volatility are only needed where plant records and observations are lacking on a particular point. Elimination can be carried even further without need *for full-fledged evaporation tests.* Each of the coals whose cost per Btu is low should be studied to determine how much weight must be given to the undesirable properties which pull its price down. High ash content may make no difference in a plant where ash can be sold; in a plant where removal must be paid for every increase in ash content involves a definite cash outlay. Thus, more coals may be eliminated.

For the small plant without test instruments, this may be enough. What looks like the best value among the remaining coals can be used for a short period. If it behaves satisfactorily and there is no apparent increase in operating troubles or maintenance it can be used with a fair degree of confidence.

If the plant has equipment for evaporation testing, plant trials will help verify the analysis up to this point and further sort out the remaining coals. By avoiding hit-or-miss plant testing, a large number of coals can be given consideration and the necessary careful *testing can be given those worthy of* it, all without excessive expense.

To be worthwhile, plant tests must be carefully made and the results must be analyzed properly. The errors involved in casual tests will often exceed the differences in coal quality. Every *effort must be made* to keep load conditions the same from test to test. Boiler surfaces should be equally clean. Finally, each coal should get equal attention and skill from the operating force. This does not mean each should be fired the same way; it means each should be fired to get best results, allowing for its peculiarities on the given equipment. This, in turn, means that each test should be preceded by a "warm-up" period to give the operating force a chance to get acquainted with the coal and its behavior. During this warm-up and the test itself, everything connected with the coal's performance should be studied and checked against the plant analysis.

## LOWEST-COST COAL

If none of the coals display any markedly unsatisfactory operating characteristics, *final selection will depend* on over-all steam cost indicated for each. This will be made up of fuel cost, as calculated from the evaporation results, and maintenance and labor costs as estimated from observation.

Differences in evaporation results *must be taken with a grain of salt* since relative coal values are not the only factors affecting evaporation. Operation of other factors can often be determined and allowed for by calculating a boiler heat balance.

Unless plant testing extends over a fairly long period, it is difficult to estimate any differences in operating costs due to different coals. Items like increased power cost for handling or pulverizing can be measured but differences in maintenance costs will not show up for some time and then must be analyzed carefully to be sure they result from some property of the coal.

Normally analysis and testing will yield several coals having nearly the same value, any one of which will prove economical.

Once the job is done, the engineer must stay with it, for fuel values change and so do plant conditions. For example, improved preparation has raised ash-fusion temperature of West Kentucky coals enough to make them "available" to many midwestern plants formerly unable to use them. The vigilant engineer will keep his eyes open *for such changes. He will also* constantly revise his fuel specifications as changes in equipment and amount and nature of plant load so require.

### ACKNOWLEDGMENTS

The editors wish to express their sincere appreciation to the many engineers who helped to insure the completeness and accuracy of this material by making technical data available and offering constructive comments. POWER is also indebted to the following manufacturers of firing equipment who furnished information used in preparation of this special section:

American Coal Burner Co
American Engineering Co
Babcock & Wilcox Co
W N Best Combustion Equip Co
Blaw-Knox Co, Power Piping Div
Wm Bros Boiler & Mfg Co
Brownell Co
Canton Stoker Corp
Combustion Engineering Co
Combustion Equipment Co
Coppus Engineering Corp
Denver Fire Clay Co
Detroit Stoker Co
C H Dutton Co
Eclipse Fuel Engrg Co
Engineer Co
Enterprise Engine & Fdry Co
Erie City Iron Works
Faber Engineering Co
Fairbanks, Morse & Co
Fisher Industrial Co
Flynn & Emrich Co
Foster Wheeler Corp
Hammel Oil Burner Co
Hammel Oil Burning Equip Co
Hoffman Combustion Engrg Co
Illinois Stoker Co
Iron Fireman Mfg Co
Johnston & Jennings Co
Kennedy-Van Saun Mfg & Engrg Corp
Laclede Stoker Co
James Leffel & Co
Lee B Mettler Co
National Airoil Burner Co
Peabody Engineering Corp
Petroleum Heat & Power Co
Preferred Utilities Mfg Co
Ray Oil Burner Co
Riley Stoker Corp
W S Rockwell Co
Schutte & Koerting Co
Simplex Oil Heating Corp
Staples & Pfeiffer
David Stout & Sons
Strong-Scott Mfg Co
Superior Combustion Industries
Surface Combustion Co
Timken Silent Automatic Div, Timken-Detroit Axle Co
Todd Shipyards Corp, Combustion Equipment Div
Webster Engineering Co
Westinghouse Electric Corp
C H Wheeler Mfg Co
Whiting Stoker Co
York-Shipley Inc, Industrial Div
John Zink Co