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BOILER MODIFICATIONS TO IMPROVE PERFORMANCE

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ABSTRACT

At various utilities steam generator production and plant heat rate has deteriorated because of worsening coal quality. The major effect of this coal degradation has been to reduce pulverizer capacity, which has, in some instances, made units either unable to achieve or sustain full steam capacity.

Even if pulverizer capacity can be restored, it is not always matched by the steam generator's ability to accept a higher level of coal flow, because, in some instances, steam production has also been affected due to exacerbated operating and maintenance problems. In addition coal degradation can cause lower boiler efficiency, higher plant heat rates, greater boiler forced outage rates, and reduced steam generator availability.

Since the wide range of problems that can be encountered varies from plant-to-plant, discussion of an actual case is not as informative as discussion of a composite, yet realistic model. Consider a vintage 400-MW, balanced draft, open furnace steam generator firing a Midwestern bituminous coal that has lost about 15 percent capacity because of a change in coal. Whereas at one time four mills could achieve MCR, now all five mills are required--and with little margin to spare.

The utility, possibly working with the vendor, establishes ground rules or objectives for restoring steam production and plant heat rate. A thorough fact finding and engineering analysis for the fuel feeding system and the steam generator is made by the vendor and presented to the utility. The analysis presents the options, including equipment downtime and estimated costs.

For the fuel feed system: replace existing mills with the same number of larger mills, add one more same size mill, or add a load regain system.

For the steam generator the option may include changes to sootblower system, superheater surface changes, and addition of slag fences and flue gas distribution baffles.

INTRODUCTION

Over the past ten years, C-E has been involved in a number of studies and steam generator modifications for different utilities on improving steam generator production and plant heat rate that had deteriorated because of worsening coal quality. The degradation in coal has manifested itself in reduced higher heating value (HHV) and Hardgrove grindability, higher moisture and ash, lower fusion temperatures, and greater proclivity toward slagging and fouling.

Table I is an example of the decline in coal quality that is common. And even more extreme deteriorations have been observed in individual coal properties. The major effect of this coal degradation has been to reduce pulverizer capacity, which has, in some instances, made units either unable to achieve or sustain full steam capacity.

TABLE I

ORIGINAL COAL VS DETERIORATED COAL

	Original Coal	Present Coal
Higher heating value, Btu/lb	11,800	10,500
Moisture, %	10	13
Hardgrove Grindability Index	55	50
Ash, %	9	12
Ash Loading, lb Ash/10^6 Btu Fired	7.6	11.5
Ash Fusion Temperatures - ^oF		
Initial Deformation	2,000	1,900
Softening	2,200	2,000
Fluid	2,400	2,100

Even if pulverizer capacity can be restored, it is not always matched by the steam generator's ability to accept a higher level of coal flow, because, in some instances, steam production has also been affected due to exacerbated operating and maintenance problems caused by furnace slagging, coutant throat plugging, slag falls, convection section fouling and plugging, and rapid tube erosion due to greater soot blower use and higher, more erosive ash loading.

Plant heat rate increases because of coal degradation. The more slag prone coals results in higher furnace outlet gas temperatures, greater use of superheater desuperheating spray flow, and in some cases, the introductuion of reheater desuperheating spray flow, as well, in order to control superheater and reheater outlet steam temperatures. If desuperheating spray flow, particularly reheater desuperheating spray flow is taken off the boiler feedpump discharge (bypassing the high pressure feedwater heaters), it tends to increase fuel firing rate, flue gas weight, and air heater exit gas temperature. Thus, the other effects of coal degradation are lower boiler efficiency, higher plant heat rates (Btu/kWh), greater boiler forced outage rates, and reduced steam generator availability.

COMPOSITE REFERENCE MODEL

Since the wide range of problems that can be encountered varies from plant-to-plant, discussion of an actual case is not as informative as discussion of a composite, yet realistic model. Consider a vintage 400-MW, balanced draft, open furnace steam generator firing a Midwestern bituminous coal. Such a unit would have a typical cross-section as shown in Fig. 1. Its maximum capacity rating

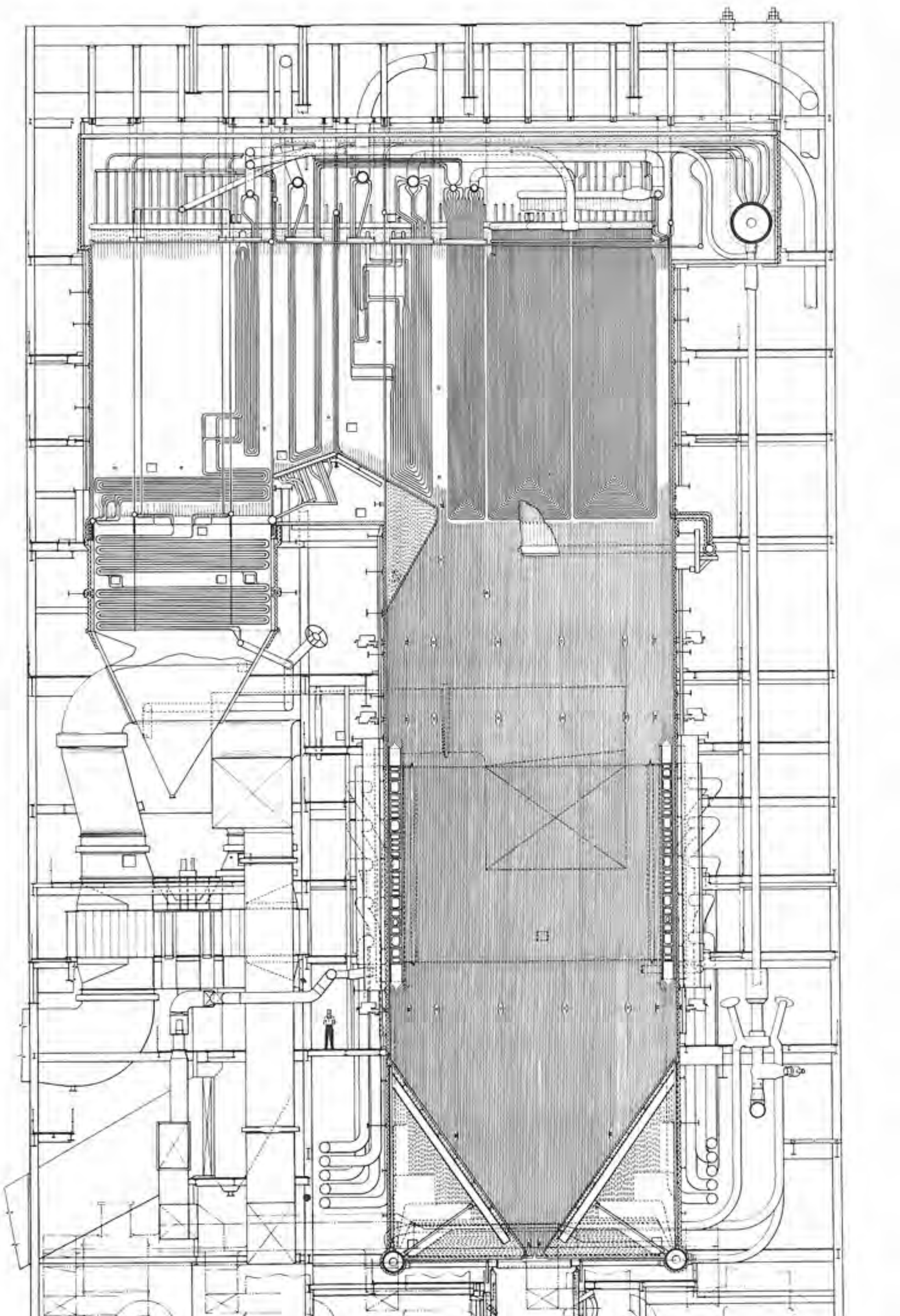


Fig. 1 Composite unit (400 MW)

(MCR) main steam flow would be on the order of 3×10^6 pounds per hour with a superheater outlet temperature and pressure of 1005 F and 2520 psig. The reheater outlet temperature and pressure would normally be about 1005 F and 600 psig. Based on the original coal shown in Table I, four 803 RS exhauster type C-E bowl mills would be used to achieve maximum capacity operation with one spare for backup.

Assume the unit had a reasonably good history of performance and availability, but over the past five or six years, the coal quality has deteriorated to something comparable to the "present" coal shown in Table I. Whereas at one time four mills could achieve MCR, now all five mills are required--and with little margin to spare. In addition, lack of a spare mill means that the steam generator must operate at reduced load for pulverizer maintenance.

Furthermore, periods of excessive furnace slagging have become more common; and during spells when particularly poor or wet coal is being fired, MCR cannot be maintained. Many other problems related earlier also affect the unit in varying degrees. To help overcome these difficulties, heating surfaces are cleaned using a combination of nightly load drops and considerable sootblowing.

Coal degradation has increased the forced outage rate due to more frequent pressure parts failures, and consequently, made greater demands on plant maintenance crews.

UTILITY'S LOAD RECOVERY GOALS

Given these circumstances, the pressure from regulatory bodies to hold the line on rate increases, the high cost of borrowing money, and the high cost of replacement power; the affected utility is impelled to find low cost expedients to regain capacity. The first logical approach is to try to increase the capacity of the existing pulverizers by increasing airflow capacity. Examples of means of doing this are switching to larger diameter exhauster wheels that would fit in the same casings and shaving the rims of the grinding bowls.

Although such changes can produce some gain in capacity, the resulting increase in mill airflow tends to be marginal or, at best, modest because of the consequential, counteracting rise in system resistance offered by the existing coal piping. Replacing the coal piping with larger diameter piping will help offset the increase in system resistance, but the need for sufficient space and adequate structural support limits this option.

In situations in which the load to be recovered is small, for example, 2 to 5 percent, such relatively minor changes to pulverizer equipment may suffice. It probably would not, however, for the composite example chosen, because of the size of the load to be recovered (approximately 15 percent) and the impact that the "new" coal quality has on--not just pulverizer capacity, but also--furnace performance. Thus, after it was determined that increasing airflow capacity and changing the coal piping would not suffice or could not be done, a more comprehensive engineering study involving the milling system and steam generator would be required. The initial "ground" rules set by the utility for the study often require (to the extent possible):

1. Restoring full steaming capability with a spare mill.
2. Retaining existing feeders, coal piping, mill motors, and other equipment.
3. Avoiding pressure part changes and minimizing them if they are required.
4. Retaining, high load carrying oil-or gas-firing capability.
5. Improving boiler efficiency, plant heat rate, boiler availability, and forced outage rate.
6. Minimizing unit downtime; scheduling downtime to coincide with certain preferred times (usually in the fall or spring).
7. Making pulverizer changes with the unit on line.

These guidelines represent a formidable challenge. Depending on the severity and complexity of the problems involved, the conclusions of the study may indicate that not all goals can be achieved; in which case, a reassessment by the utility is necessary. In some cases, the most satisfactory solution may be to switch to a different coal, perhaps a beneficiated one.

C-E'S PROBLEM SOLVING STRATEGY

Before developing "solutions" to problems, the C-E analytical strategy requires that the problems, which have been generally outlined, be more clearly defined and quantified. This initial phase is particularly important for forming a perspective regarding the dimensions of the problems and their relative ranking in order of importance. To expedite the investigation, the C-E in-house records of recent operating data, coal analyses, field service reports, the C-E Availability Data Program and other resource material are researched thoroughly. Other information, especially site specific information, is obtained from the utility's plant engineering, operating, and maintenance personnel, including: (1) the latest boiler operating data and a complete coal analysis, if needed; (2) plant layout drawings, particularly in the pulverizer bay area; and (3) steam generator equipment failure and maintenance repair reports.

A team of boiler design engineers, equipment layout draftsmen, component failure analysts, construction specialists and other technical specialists review this information to determine if it is consistent and sufficient for the project. Information gaps, anomalies, and any technical questions are pursued with the utility through the appropriate C-E regional technical service group and assigned project management personnel. On occasion, the quality and scope of the data is judged inadequate and comprehensive boiler performance tests are conducted with the special emphasis on mill performance, steam generator section-by-section heat absorption, tube-to-tube steam temperature profiles, draft losses, furnace waterwall and radiant/convection section slagging and fouling patterns, and sootblower use and effectiveness.

Only after the extent and interrelationships of the boiler problems are well understood, are specific engineering solutions developed. Proven state-of-the-art design improvements are first considered; when necessary, innovative solutions are developed.

Complex retrofits of operating units require special attention and concern by specialists experienced in engineering modification projects. When incorporating a new or revised system to an existing unit, the project management team strongly emphasizes working within plant design, operational, and economic criteria. Many utilities stipulate these in their goals, as indicated in the previous section. Those that do not, however, can benefit from the incorporation of these standards in the project management strategy.

Once an optimal solution has been chosen, the project management team, drawing upon the skill and expertise of specialists in plant layout design, construction, and manufacturing, begin developing a carefully coordinated and synchronized schedule. Because projects of this nature are generally "fast track," special considerations must be given to procedures that reduce the overall project time.

To accomplish this, the team develops a composite schedule drawn from the analyses of the individual specialists. Then using computer-based techniques, the schedule is analyzed for its compatibility with project requirements. Once the "first cut" at a schedule is completed, team members re-evaluate information flow, material manufacture, and construction techniques for compatibility with design, production, and erection requirements of the project. The final product is reviewed with the utility and/or the architect/ engineer to determine if the needs of all parties are met.

During the execution phase of the project, the project management team closely monitors the established schedule and updates based upon actual work progress. Periodic meetings are held with the owner and/or architect/engineer to review project progress and to ensure that the needs of all parties are met.

PULVERIZER ALTERNATIVES

Based on the magnitude of the coal degradation shown in Table I and the capability of existing mills, approximately 15 percent of MCR is lost when operating with four out of five mills in service. With all five mills in use and in condition, full MCR is still attainable, though with only a small margin of reserve. To attain full MCR coal delivery with spare mill capability, the following options are available, presuming certain space requirements:

1. Replace the five existing 803 RS exhauster mills with five larger capacity 863 RS exhauster mills.
2. Add another 803 RS exhauster mill to the existing five 803 RS mills.
3. Add a remotely located pulverized coal bin storage C-E Load Regain System to transport dense phase coal into the existing coal pipes.

Figure 2 shows the existing system and Figs. 3 through 5 show the various options. Table II shows a comparison of the alternatives, the major replacement components required, certain affected areas, approximate equipment cost in 1982 dollars per kW recovered, unit downtime estimates to make modifications, and general comments.

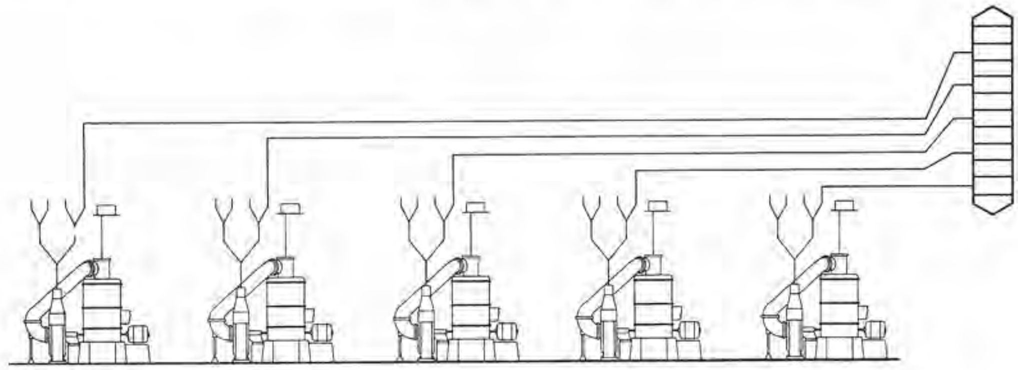


Fig.2 Existing pulverizers: Five 803 RS bowl mills

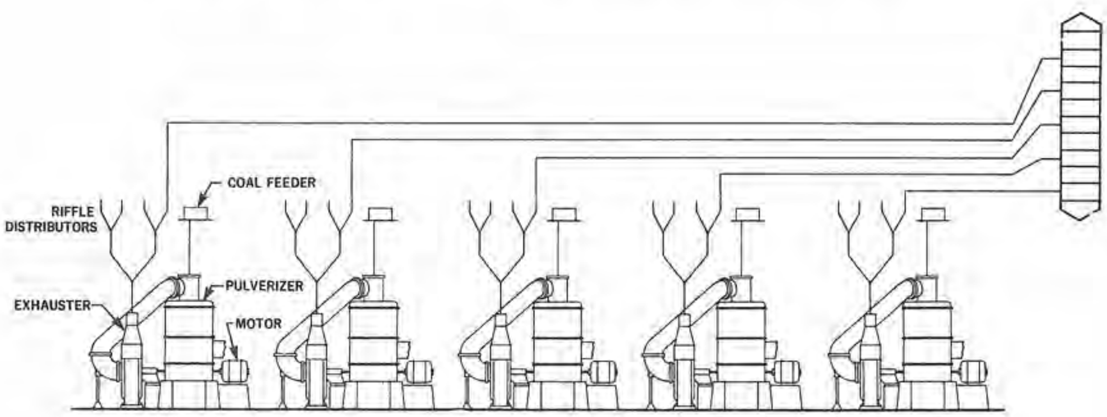


Fig.3 Alternative No. 1, complete pulverizer replacement: Five 863 RS bowl mills

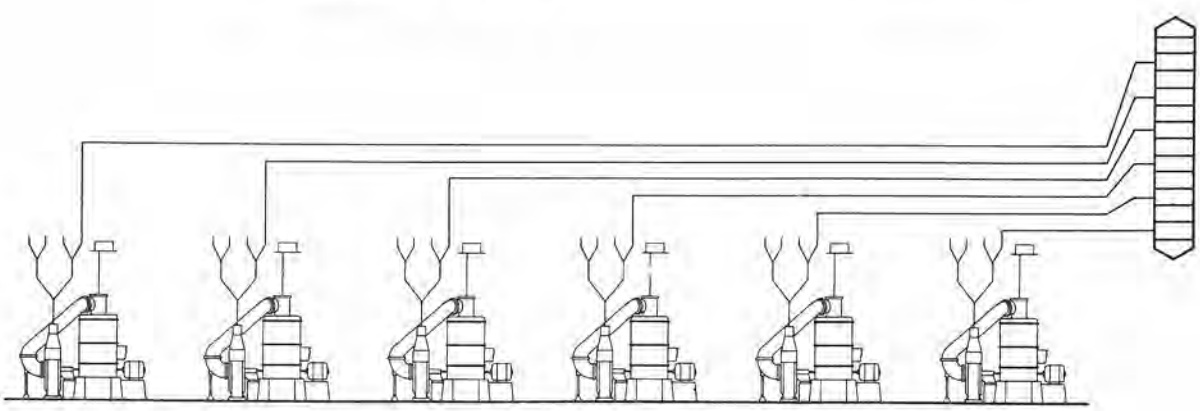
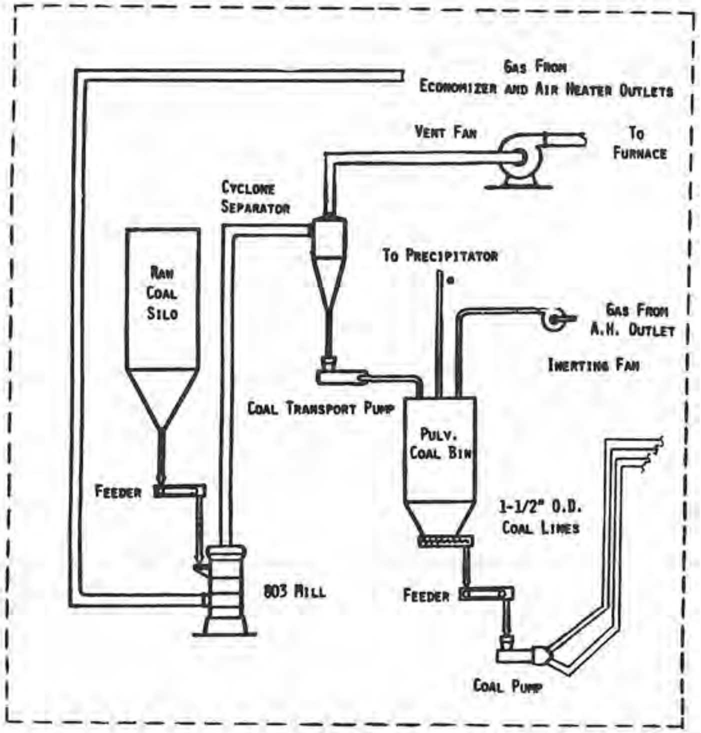
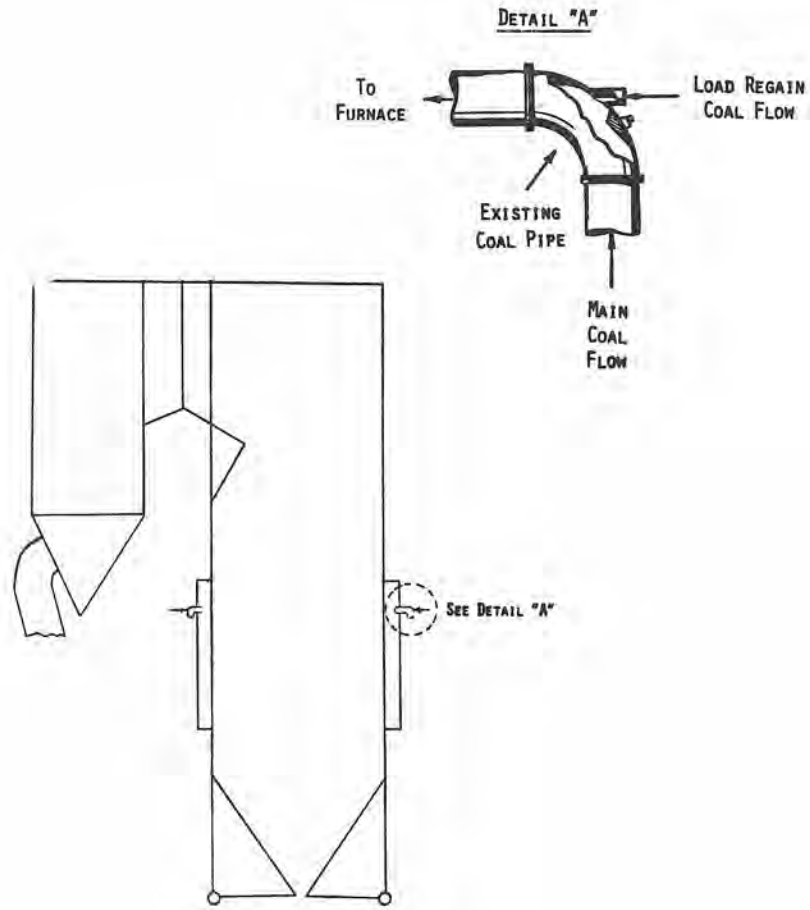


Fig.4 Alternative No. 2, add one same size pulverizer leaving: Six 803 RS bowl mills



THE C-E LOAD REGAIN SYSTEM* - Remotely Located
*Patented under U.S. Patent 4,263,856



EXISTING UNIT

Fig.5 Alternative No. 3, add Load Regain System to existing setup leaving: Five 803 RS bowl mills plus Load Regain System, which includes one 803 RS bowl mill

TABLE II

Alternative Pulverizer System Retrofit Modifications

Proposed Alternative	Major Replacement Components Required and Other Affected Areas	Approximate Equipment Cost in $/kW Regained	Approximate Unit Down-Time in Weeks	Additional Comments
Alternative 1 Replace existing 5 - 803RS mills with 5 - 863RS mills	5 863RS mills and exhausters, 5 levels of coal piping 5 mill motors, possibly 5 feeders, some additional hot and cold air ductwork, and structural support steel	100 - 120	5 - 7 Depending on how much equipment can be installed with unit on line	Sufficient mill bay area required to fit 863 mills and motors. Sufficient space to fit larger diameter coal piping required. Existing mill/exhauster/motor foundations and pyrite removal system must be adequate. Some economizer surface removal may be required to increase hot air temperature to mills.
Alternative 2 Add another 803RS mill to the existing 5 - 803RS mills	1 - coal bunker and feeders 1 - 803RS mill/exhauster/ motor 1 - level of coal piping windbox modifications, additional controls, hot and cold air ductwork, and structural steel	20 - 50	4 - 6 Depending on whether the windbox has to be extended.	Sufficient space required to add coal bunker, feeder, mill/exhauster/motor and coal piping. Restructuring of windbox compartments probably will result in some loss of oil or gas load carrying capability. Otherwise, extending the windbox will require furnace pressure part modifications. Similar economizer changes may be required as outlined above in Alternate 1. Depending on space involved, it may be possible to use coal from an adjacent bunker with an extended feeder.
Alternative 3 Add a dense phase load regain system	Add a remotely located pulverizer coal bin storage system using 1 - 803RS mill and motor, dense phase transport pumps and piping, flue gas fans, ductwork, controls and structural support steel.	75-100	1.5 - 3 Depending on the amount of equipment that can be installed with the unit on line	Space requirements much less stringent than on Alternative 1 and 2. No windbox changes required. Small amount of economizer flue gas used for drying coal. Four new furnace openings (pressure parts included) will be required to vent the exhaust of the LRS.

Note that the equipment costs for each alternative varies to reflect lesser or greater equipment scope. Erection costs were not provided because of the large number of variables involved; nevertheless, it is estimated that the erection costs would roughly span from 0.4 to 0.6 of the equipment cost. The unit downtime also varies depending on how much equipment can be installed with the unit on line, considering the available space for equipment demolition, removal and reconstruction.

Of the three alternatives given, the addition of another mill (alternative 2) is substantially lower in equipment cost than replacing all the mills (alternative 1) for approximately the same amount of downtime. However, while adding a mill is again much lower in equipment cost than the load regain system (alternative 3), the much shorter downtime (1.5 to 3 weeks) of the latter may well favor that choice economically, depending on the specific replacement power cost for the unit involved.

While adding a mill appears to be superficially the most attractive path to follow, it is predicated on sufficient plant space being readily available. In most instances, adequate space is not available; and whatever space is useable may be so confined as to compromise mill performance and maintainability.

Depending on the space issue, complete mill replacement, (alternative 1) and particularly the load regain system, (alternative 3) may provide greater flexibility than alternative 2. In some extreme cases, the load regain system may be the only option. Comparing complete mill replacement and load regain system in terms of equipment cost, no allowance was made in mill replacement for salvaging the existing 803 RS mills for spare parts on similar mills on other units in the system. Therefore, depending on the salvage factor, the equipment costs for mill replacement should be closer to the load regain system than shown. Nonetheless, the load regain system still retains a considerable advantage in terms of shorter downtime.

With regard to downtime, the estimates provided are not necessarily continuous time periods, but rather approximate, cumulative totals subject to considerable upward revision if certain site specific problems are present. For example, the 5 to 7 week time span shown for mill replacement is based on working on one mill at a time with the unit on line, presuming that adequate space and support for new and larger OD coal piping is available. Similar remarks apply to the outage time estimates for alternatives 2 and 3.

STEAM GENERATOR ANALYSIS

Careful review is made of furnace combustion conditions: the pattern of furnace slagging, i.e., the extent, surface condition and rate of buildup, and the ash deposition pattern in the upper furnace/division panel/platen/front pendant area. Operating steam/ water temperatuares, draft loss data, recorded sootblower use and unit outage inspection reports provide valuable information on loss of thermal performance, the presence of localized tube erosion and other problems on superheaters, reheaters, economizers and airheaters caused by excessive flyash fouling and plugging.

Of particular interest is the condition of the existing sootblower system, its frequency of use, and its cleaning effectiveness. Other concerns include sampling the pulverized coal fineness of each mill to determine the percent coal left on a +50 mesh and the percent passing through a 200 mesh screen; noting any indications of incandescent flyash "sparklers" leaving the furnace; noting the percent carbon in the flyash; obtaining O_2 and gas temperature traverse leaving the economizer and airheater; corner-to-corner windbox fuel and air damper settings, fuel nozzle tilt position, and SH/RH element steam temperature profiles across the unit.

Based on extensive field test data, analytical work, and operating experience, C-E has developed sophisticated computer programs that enable it to model the heat absorption characteristics of all gas touched heating surface. These programs are inputted with field data to determine gas temperatures, heat transfer rates, surface effectiveness factors and other information. With these analytical tools and engineering judgement, conservative estimates can be made of the maximum load carrying capability of the boiler with the present degraded coal and the probable effectiveness of relocating and adding sootblowers, changing sootblower pressures and blowing schedules, including programmable controls, and changing corner-to-corner windbox damper settings, excess air levels, fuel nozzle tilt positions and coal fineness.

A portion of this overall analysis is to improve the plant operator's ability to control furnace slagging, reduce furnace outlet gas temperature, lower convection section heat absorption and lessen SH and RH desuperheating spray flow requirements. Curtailing the volume of molten flyash to convection sections decreases fouling, plugging, tube erosion and long retract sootblower use. These relatively modest changes in equipment and operating procedures may be adequate to achieve full MCR given the planned increase in pulverizer capacity with no major pressure parts changes to the superheater, reheater, or economizer.

If the engineering analysis shows that, even with the prescribed sootblower/operational changes, the superheater/reheater desuperheating spray flows would still be above predetermined acceptable target levels, then superheater/reheater surface changes would be required. However, any surface reductions must consider the effects on the entire steam generator and not just the particular sections modified. Surface removal in one area results in gas temperature increases to downstream sections. As a consequence, these sections absorb more heat, steam or water leaving temperatures increase, and higher metal temperatures will occur in tubing, header and mechanical supports.

C-E's computer assisted design technology can analyze the influence of localized surface changes on other boiler components. This capability enables C-E to predict what the effect on boiler performance will be and decide what changes are needed to other components and systems, such as tubing, headers and support systems. In situations where ash plugging and tube erosion have occurred, serious thought is given to rehabilitation through repair and replacement, the addition of slag fences, the addition of flue gas and flyash distribution baffles; and the relocation and addition of retractable sootblowers. Some sections may require complete redesign to wider transverse spacings in order to lower gas velocities, improve sootblower "cleanability," and provide easier access for maintenance. In the case of airheater plugging, the addition of woven steel mesh slag screens at the economizer outlet may be necessary to limit large size ash carryover to the airheater.

Because of the numerous combinations of boiler modifications possible, it is impractical to tabulate the different scope changes, equipment cost, delivery schedules, downtime estimates, and predicted improvements in boiler performance, except for a specific case.

CONCLUDING REMARKS

The feasibility report submitted to the utility defines the objectives of the engineering study, states the conclusions and recommendations, and provides documentation and technical justification for the alternatives offered. The report includes material scope, material delivery, and installation schedules, for the various recommended options. Cost estimates and cost-benefit analysis of the various alternatives are provided either as part of or as addenda to the basic report. After the report is presented to and reviewed by the utility, C-E will assist the utility in studying other possible options as well.

As the quality of coal continues to degrade, retrofits of the kind discussed here will increase. C-E's objective will continue to be to provide the utility industry with sound, practical engineering advice; well designed, reliable equipment; and broad expertise and capability in project management, construction services and field technical services.