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Economic Feasibility of Fuel Conversion and Technical Considerations for Uprating Steam Generator Capacity

by

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ECONOMIC FEASIBILITY OF FUEL CONVERSION AND TECHNICAL CONSIDERATIONS FOR UPRATING STEAM GENERATOR CAPACITY

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INTRODUCTION

American homes and factories need an ample and reliable source of electricity. Tight regulatory constraints and scarce capital require innovation to provide this supply. Major issues facing the utility industry today deal, in part, with this problem.

Utilities and manufacturers are responding. A myriad of alternatives are being investigated and developed to solve today's problems, and address potential problems. The specific objectives are: to safely and economically generate the required power with acceptable risk to preserve capital and equipment, to reduce our dependence on foreign energy supplies and to maintain the quality of our environment. Two alternatives among the many concepts available are being considered to accomplish these objectives. These are: converting fuel from foreign to domestic sources and increasing the generating capacity of existing steam generators.

This paper addresses these subjects. It focuses on economic considerations associated with fuel conversion and on technical considerations of upgrading the capacity of oil/gas fired drum type units and supercritical steam generators.

FUEL CONVERSION

A major factor to be considered in any program to convert fuel sources is the impact it has on foreign fuel supplies. The 1978 Power Plant Industrial Fuel Use Act dictates that new units must be designed for coal firing, and previously enacted-now rescinded-legislation stipulating that natural gas shall not be used as a boiler fuel after 1990. This, combined with the present trend to coal, signifies that any reasonable conversion program must consider coal as being the sole or primary fuel source.

Partial results obtained from a 1980 study done by the Mitre Corporation for the Department of Energy quantify the status and magnitude of domestic oil firing in units designed only for oil. Figures 1 and 2, respectively, represent the size and age distribution of these units.

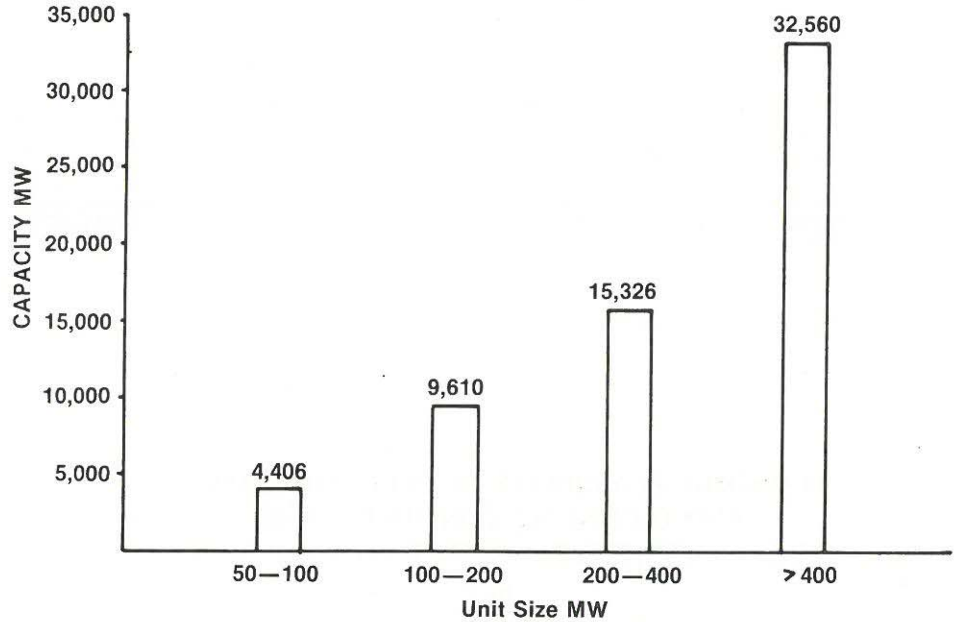


Figure 1 Size Distribution of Oil-Designed Units

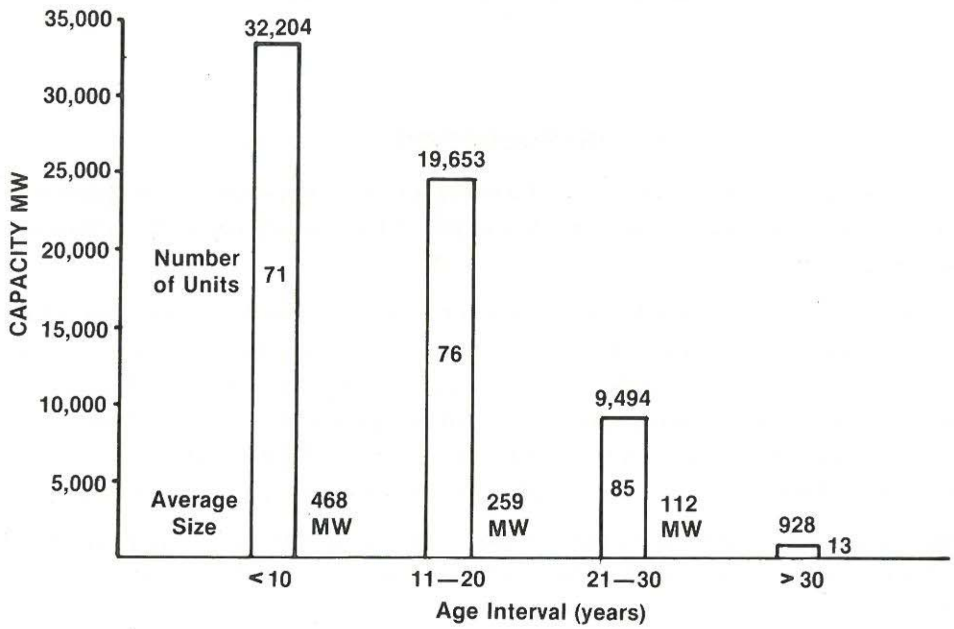
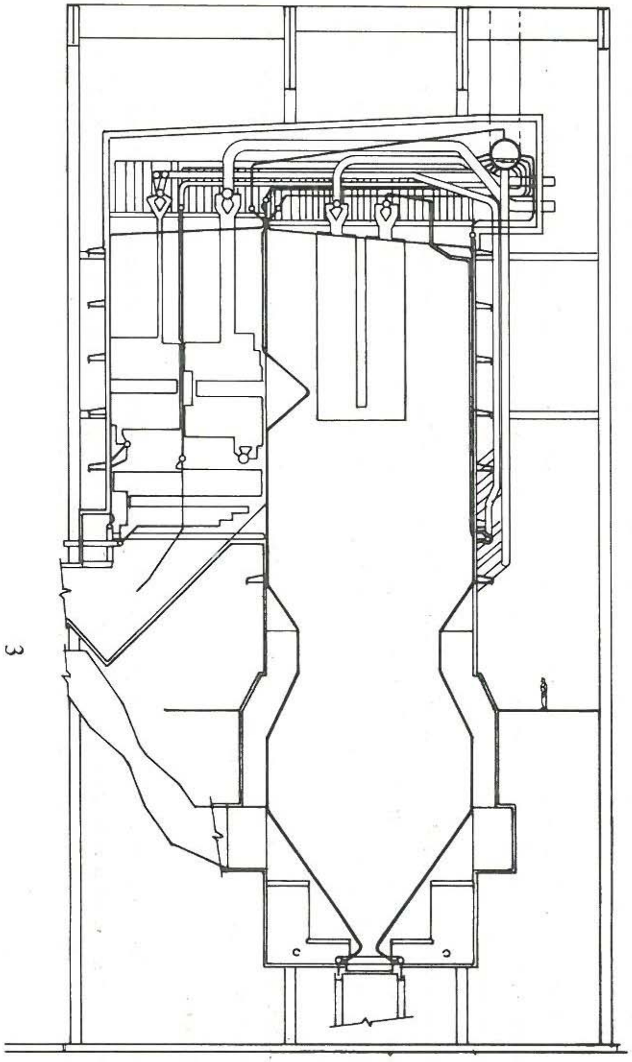


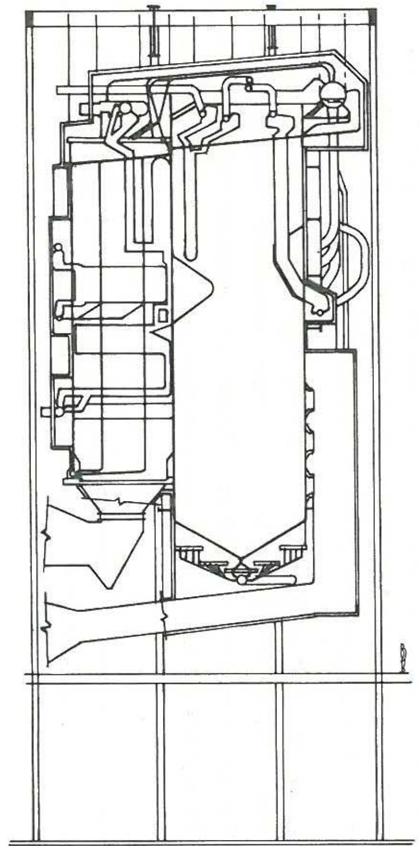
Figure 2 Age Distribution of Oil-Designed Units

Please note that over 50% of these units are less than 10 years old and the majority are rated at more than 400 MW. Additionally, the study indicates that another 220 units, representing over 30,000 MW, were originally designed for future firing of coal but are now burning oil.

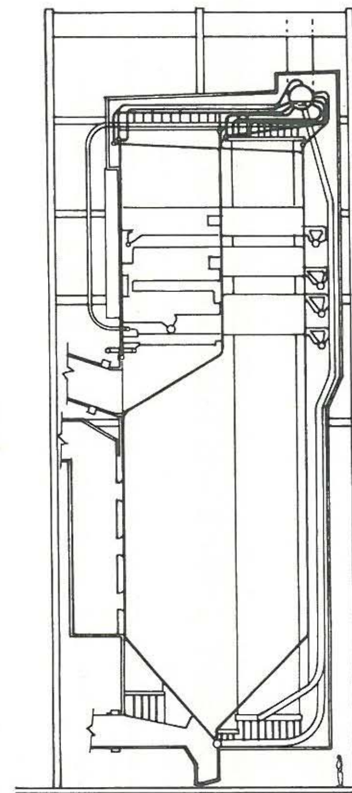
The nearly 100,000 MW represented forms a large pool of potentially convertible generating capacity. The feasibility of converting these units, especially to coal derived fuel, is dependent on the physical characteristics of the steam generator. Figure 3 depicts three types of designs; each is rated at approximately 400 MW.



New Unit Firing Pulverized Coal
Radiant Heating Surface: 57,700 ft^2
Furnace Volume: 295,000 ft^3



Existing Unit, Capable of Future Coal Firing
Radiant Heating Surface: 21,600 ft^2
Furnace Volume: 122,700 ft^3
Note: Vertical space available for furnace modifications



Existing Unit Capable of Only Oil Firing - No Future Coal Capability
Radiant Heating Surface: 19,800 ft^2
Furnace Volume: 156,000 ft^3

Figure 3 Steam Generator Designs

Previous studies have shown that unless a steam generator was originally designed for coal that capacity reductions of up to 50% can result, in addition to numerous and major design changes being required. Conversion under such circumstances is not feasible nor practical. Many of the units designed for possible future coal firing considered only high rank, low ash and low moisture fuel; not the fuels considered economically available today.

Because a utility scale conversion project to coal gasification or coal liquifaction is likely to have significant economic or technical barriers associated with implementation, these alternatives were not considered. Because of the deratement issue, oil designed units were also not considered in this study. Only units originally designed to burn coal now firing oil, representing over 30,000 MW, were evaluated.

Since the main goal is to reduce or eliminate oil as the primary fuel, the following fuels were evaluated:

1. Pulverized coal.
2. Coal-oil mixture (COM) comprised of a 50-50 percent by weight mix of No. 6 oil and good quality Eastern bituminous coal.
3. Coal-water slurry (CWS). A 75-25 percent mix of pulverized coal and water

Generally, steam generator modifications are required with the above fuels because of the following parameters:

1. *Heat releases.* Reduced area and volumetric heat releases require larger furnace cavity surface and volume. In some cases, this can be accomplished by deepening and/or increasing the height of the furnace in combination with the additional waterwall platen or radiant superheater surface.

2. *Fouling and gas velocity.* Increasing the clear space between tubes in the convection section reduces the probability of a serious fouling problem and also reduces particulate erosion by reducing gas velocity. However, higher flue gas quantities, coupled with design considerations regarding heat transfer, pressure drop and tube bundle depth may require the convection pass to be deepened and/or heightened to maintain performance level.

3. *Steam temperatures.* Because of furnace and convection pass modifications, increases in both superheater and reheater heating surface are required to achieve design terminal temperatures. Economizer surface requirement is lessened, because of added surface doing evaporative duty in the furnace.

4. *Ducts and breeching.* Addition of primary air ducts is normally a requirement. Breeching design must also incorporate ash hoppers and larger sizing due to flue gas velocity limitations.

5. *Fuel burning equipment.* Burners and windbox must be replaced or modified to meet performance requirements and NO_x emission limits. Fuel storage, handling, preparation and transport systems must also be installed.

6. *Structural steel.* Furnace and convection pass modifications, along with the addition of auxiliary equipment such as soot blowers, affect the existing structural steel and associated column foundations. Design changes are usually required.

7. *Auxiliary equipment.* Components such as F.D. and I.D. fans and drives, air heater, soot blowers and digital and analog control systems probably will require modification. Precipitators to meet 0.1 lb. per 10^6 Btu particulate emission limit are always required and constitute a major capital investment in converting fuels.

8. *Scrubbers.* Depending on fuel type/quality available SO_2 regulations may require the installation of scrubbers, which is also a significant investment.

Economic Feasibility

The economic feasibility of converting fuel sources, or incorporating a dual fuel mode of operation, is very site specific. Factors such as inadequate land area for fuel storage, inadequate means of fuel transportation to the plant, or improper physical plant layout can be serious stumbling blocks to an otherwise economically attractive project. The relative cost of coal--less than 50% of oil on a Btu basis--and the impending deregulation of natural gas also weigh heavily in the economic equation to convert.

Table I lists the major factors affecting each alternative to straight heavy oil firing.

	Pulverized Coal	COM	CWS	Oil
Plant Equipment and Associated Labor				
Coal Handling and Storage	X			
Boiler and Auxiliary Equipment Modification	X	Minor	X	
Particulate Collection Equipment	X	X	X	
Ash and Sludge Disposal	X	X	X	
Additional Operating and Maintenance Costs	X	X	X	
Off Site Preparation Plant Costs		X	X	
Fuel Costs	Minimum	Relatively High	Relatively Low	Very High

Table I Major Factors Affecting Economics of Alternative Fuels to Oil

The coal handling and storage facilities in the Pulverized Coal alternative is the only item not common with COM and CWS, since these are transported directly into existing tanks at the plant site.

Considering that the costs of fuel oil for a 400 MW unit that has a 60 percent capacity factor is over 100 million dollars a year, and fuel cost differential between coal and oil is so significant, the pulverized coal and CWS options are favored. Because a majority of the fixed costs still exist and only 40 percent of the oil is displaced on a Btu basis, any recommendations to convert to COM should be scrutinized very closely.

In summary, the economic feasibility of converting fuel types is very much site specific. Unless oil is displaced to the maximum degree, there may be no economic justification for converting to COM. Because of the state of technology and the dearth of suppliers for CWS, the thrust to convert should be directed at pulverized coal, preferably of good grade or cleaned to minimize deratement and boiler modifications.

UPRATING OIL/GAS-FIRED STEAM GENERATOR STEAMING CAPACITY

The high cost of money for plant expansion, siting and other regulatory problems, and the conservative load growth forecast warrants utilities to look closely at modifying generating capacity to best meet demand.

As indicated in Figures 1 and 2, the large units are of rather young vintage -- young enough so that many of them were originally designed for peaking service and, as such, may have been specified with minimum conservatism. Also, boiler manufacturers, having improved substantially on the science of boiler design and watching product costs, did not provide the inherent conservatism that existed in older steam generators.

Generally, increasing the steaming capacity from 10 to 15 percent over the original rating of the unit rating will affect performance; that is relatively easy to evaluate. But, much more difficult to determine is the effect on long-term reliability and the life of the unit. There are risks involved with uprating.

The potential effects to increasing steaming capacity 10 to 15 percent, without reducing pressure on 2400 psi drum type and 3500 supercritical units are discussed. The many other possible modes of operation possible to increase the rating of the unit are beyond the scope of this paper.

Subcritical; 2400 psi Drum Type Units

Prior to discussing the specific effects on operation, it is worthwhile to review the trend of several operating parameters as a function of load for this type unit. Figure 4 depicts these trends for a 2400 psi, 400 MW oil fired unit, with gas recirculation; the curves have been extrapolated to indicate the predicted trends as a function of steaming beyond rated capacity.

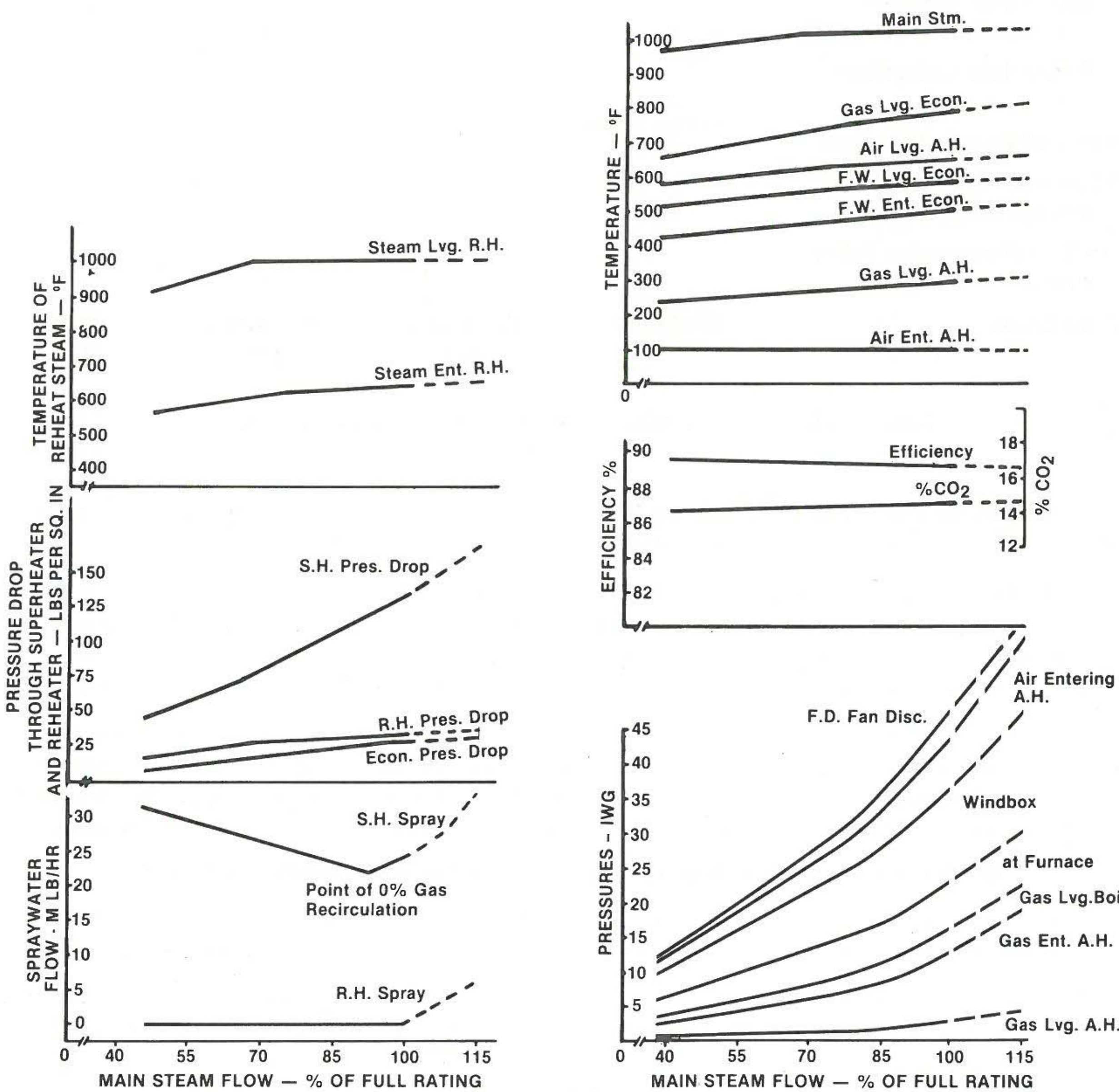


Figure 4 Trends in Operating Parameters vs. Percent Rating

As illustrated, some components/systems are drastically affected. In addition to considering operation, effects on reliability and equipment life must also be evaluated. The following items must be thoroughly analyzed:

1. *Circulation.* Increasing capacity increases the firing rate, which raises the heat flux to radiant heating surface. On natural circulation oil-fired units this is critical. As flow, emulsion quality and heat flux increase, the circulation ratio decreases, resulting in a possible departure from nucleate boiling (DNB) condition, which can result in waterwall tube overheating and failure. Modifications to correct this problem can be extensive. Some likely modifications are:

   - installation of rifled tubing in susceptible areas of the furnace,
   - addition of downcomers to reduce pressure drop or improve distribution,
   - extensive revisions to drum internals to reduce carry-under (steam entrained in water entering lower furnace) to increase subcooling of water entering furnace.

2. *Steam purity and water level stability.* Modern drum internals utilize physical principles for steam water separation that has velocity as a governing criteria. Overloading these components may result in less than required steam purity, which will eventually result in superheater damage caused by the insulating effect of solids depositing out in the tubing and erosion or corrosion to turbine components. Water level stability can affect steam purity, circulation, and cause a myriad of problems with feedwater controls and valving.

3. *Superheater and reheater systems.* Increased steam flow, and convective and radiant heat transfer have significant impact on these components:

   - Tubing and Headers. Tubing and header metal temperatures will tend to rise, generally. This is especially important in the primary and high temperature superheaters with much of the tubing requiring at least a one grade improvement in metallurgy. Headers may likewise be affected. The high temperature reheater outlet tubing may require upgrading to stainless steel to minimize exfoliation and long-term overheating problems.

     Surface removal may be an alternative, although steam temperature control range will be reduced.
   - Safety Valves. Increased pressure drop will likely affect safety valve selections and settings and may have implications regarding Code compliance. Reheater pressure drop and spray flow also may negatively affect the reheater cycle thermodynamic efficiency.
   - Spray Attemporator. The increased convective effect associated with higher gas mass flows will likely have a serious impact on the spray attemporator capacity to maintain main steam and hot reheat temperatures. A change in spray water piping and nozzle selection, or a booster pump, will likely be required for reheater and superheater protection.

4. *Burners.* Increased air and fuel flow all have an effect on burner performance and flame placement within the furnace. Operating burners beyond rated capacity can cause flame impingement on furnace walls, which may lead to tube failures, and initiate a vibration condition resulting in damage to other sections of the boiler. Modifications can include simple oil gun or gas burner modification to extensive burner/register replacement and windbox alterations.

5. *Structural components.* Higher air and flue gas pressures may jeopardize existing structural integrity of the steam generator and ducts. Buckstays may be altered and levelers added to the furnace/convection pass enclosure and stiffeners added to ducts and breeching.

6. *Auxiliary Equipment.*

- Fans and Drives. Because there is a square relationship of pressure (head) with flow, the duty on forced draft fans and induced draft fans (if any) and their drives is significantly increased.

Depending on existing operation, the respective margins on the flow, static pressure, and horsepower may be exceeded. Modifications having a large impact on performance for these components are not very likely. Therefore, changeout is probably required.

- Sootblowers. Because gas and metal temperature profiles change in the unit, the addition and relocation of sootblowers may be required to prevent excessive convection pass ash fouling and possible plugging.

7. Instruments and Controls. Flow, temperature and pressure sensing elements will likely require recalibration or replacement. Transmitting and recording devices, in some cases, may be operating outside of their recommended range with inaccuracies resulting in data acquisition and function control.

8. Nitrogen Oxide Emissions. Increasing the steaming capacity by 15% results in a similar increase in furnace heat release. Depending on the method of firing and fuel type used, thermal NO_X production can increase from 15 to 100 ppm. In some cases this may result in employing off-stoichiometric firing methods, require burner modification, or replacement with low NO_X burners to ensure compliance with applicable regulations governing.

Supercritical Design; 3500 psi Operating

Riley's experience with supercritical designs extends to twin 400 MW coal-fired steam generators at the Wateree Station of South Carolina Electric and Gas Company. Having been in service for ten years, their demonstrated operation and reliability has been excellent.

The Riley design differs from the conventional once-through concept in that recirculating pumps provide for varying the fluid flow through the furnace and convection pass sections independent of through--flow. This is depicted in Figure 5.

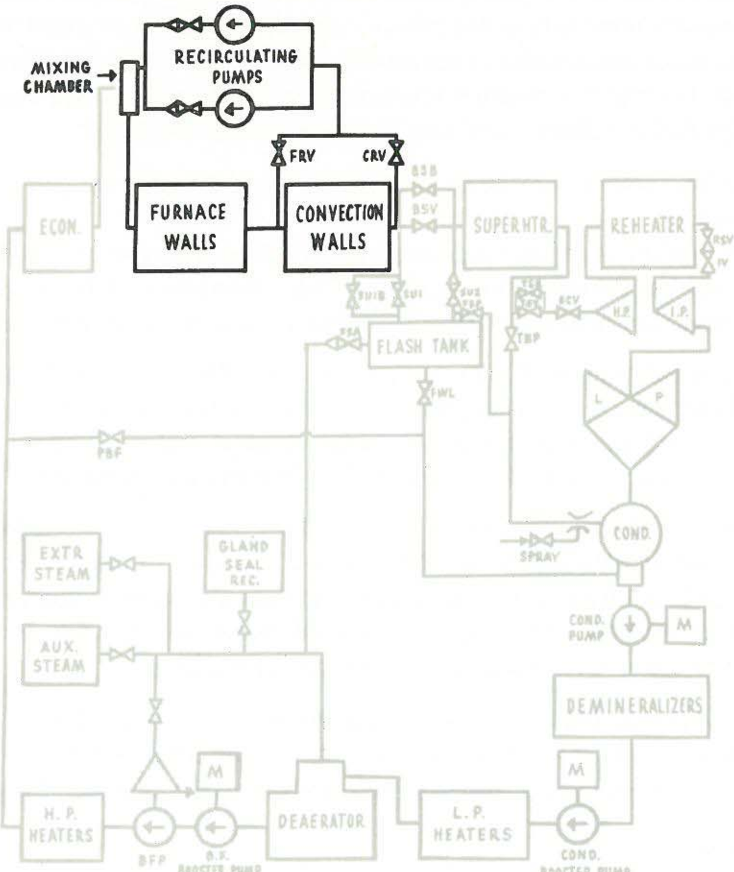


Figure 5 Startup System for Supercritical Recirculation Boiler

There are many advantages associated with this concept: reduced feed pump power at full load because pressure drop requirements are substantially lower, very close control of furnace outlet fluid temperature level and uniformity, and the through-flow required at minimum load is a maximum of only 10 percent of full load rating.

The potential problems with uprating supercritical units are essentially the same as that on subcritical drum type units except for circulation, steam purity, and water level stability. Replacing these concerns are the effects of higher fluid pressure and heat flux on furnace performance and the capability of the pre-boiler system to furnish the quantity and quality of water required to prevent steam generator and turbine damage.

Because of the rapid change of specific heat and fluid density with temperature and pressure in the supercritical range, it is extremely important to be able to accurately control furnace outlet fluid temperature. This has a major impact on furnace performance and superheater duty. Refer to Figure 6, which depicts some salient operating features of the recirculation boiler.

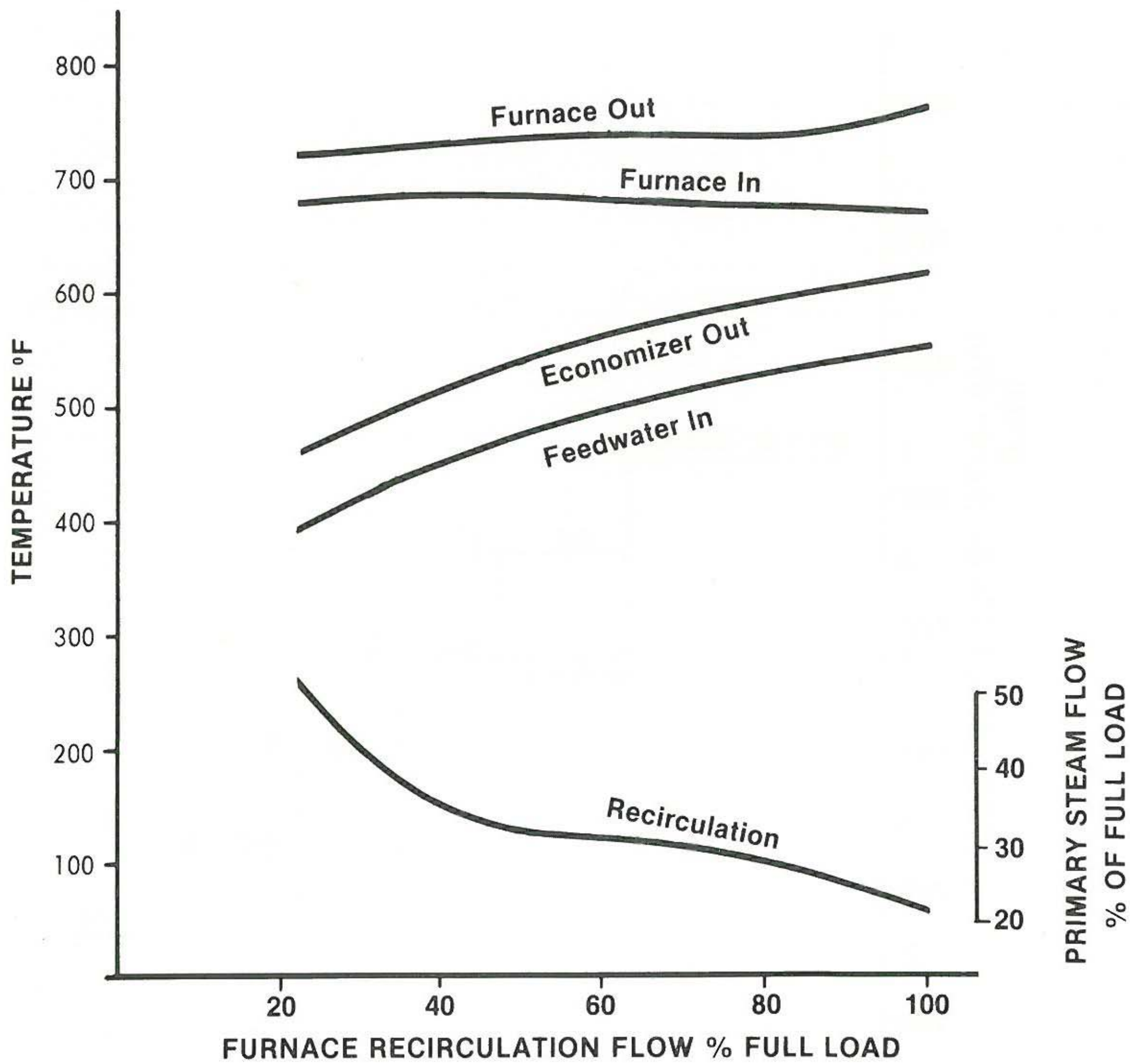


Figure 6 Fluid Temperature and Recirculation Performance vs. Load

The recirculation system, as installed on the Riley Units, can provide for the flexibility required to minimize furnace and superheater modifications. Units not already equipped with this feature may require the installation of such a system and furnace modifications to effect the hydraulic performance required for operation.

The quality of steam in a supercritical unit is the same as the quality of the feedwater entering. Thus, water treatment is extremely important to prevent steam generator and turbine damage. Additives are ineffective with this type unit since it has no storage capacity. Condenser tube leaks cannot be tolerated and condensate polishers must be capable of maintaining 0.05 ppm total solids at the higher rating.

The above indicates that the potential problems associated with uprating can deal with the operation of the unit and can affect long-term reliability and the life of the boiler. Studies performed indicate that a general approach to the subject cannot be made; each unit must be evaluated individually. As with fuel conversions, uprating the unit's steaming capability without changing other operating conditions such as pressure or feedwater temperature, requires a thorough analysis and evaluation.

NO_X was identified as a major potential concern in converting fuels or uprating the capacity of oil-fired units. It is also a major design consideration in new coal-fired steam generators. Additionally, anticipated New Source Performance Standards (NSPS) for coal are expected to become increasingly stringent, as indicated in Figure 7.

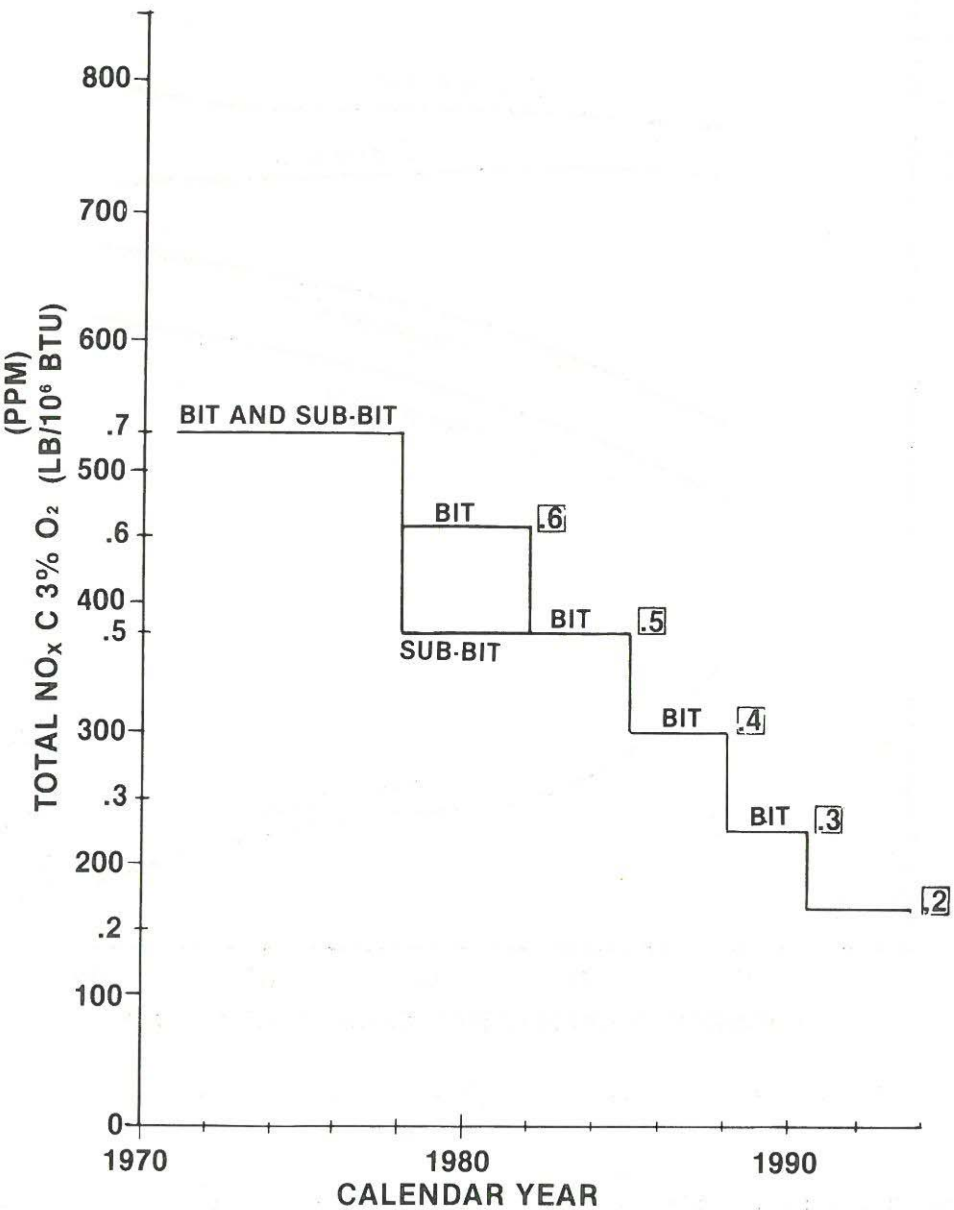


Figure 7 Utility Coal Fired Boilers - Anticipated New Source Performance Standards (NSPS)

These factors, combined with the "bubble" pollution control strategy expected to be issued soon by the EPA, which would sanction higher-than-allowed emissions at some existing plants if they are balanced with lower-than-allowed emissions at other plants, may be key in formulating future generation strategies.

Partly in response to the expected changes in emission regulations, Riley Stoker has developed a coal-fired Controlled Combustion Venturi burner (CCV) capable of significantly reducing NO_X emissions, while maintaining unit operation, performance and efficiency. The concept responsible for producing a successful design is optimum air/fuel mixing to accurately control the combustion process and rate.

Performance data taken on a 400 MW front fired PC unit and an opposed fired 350 MW unit indicate NO_X reduction of 37% and 56%, respectively. Refer to Figure 8.

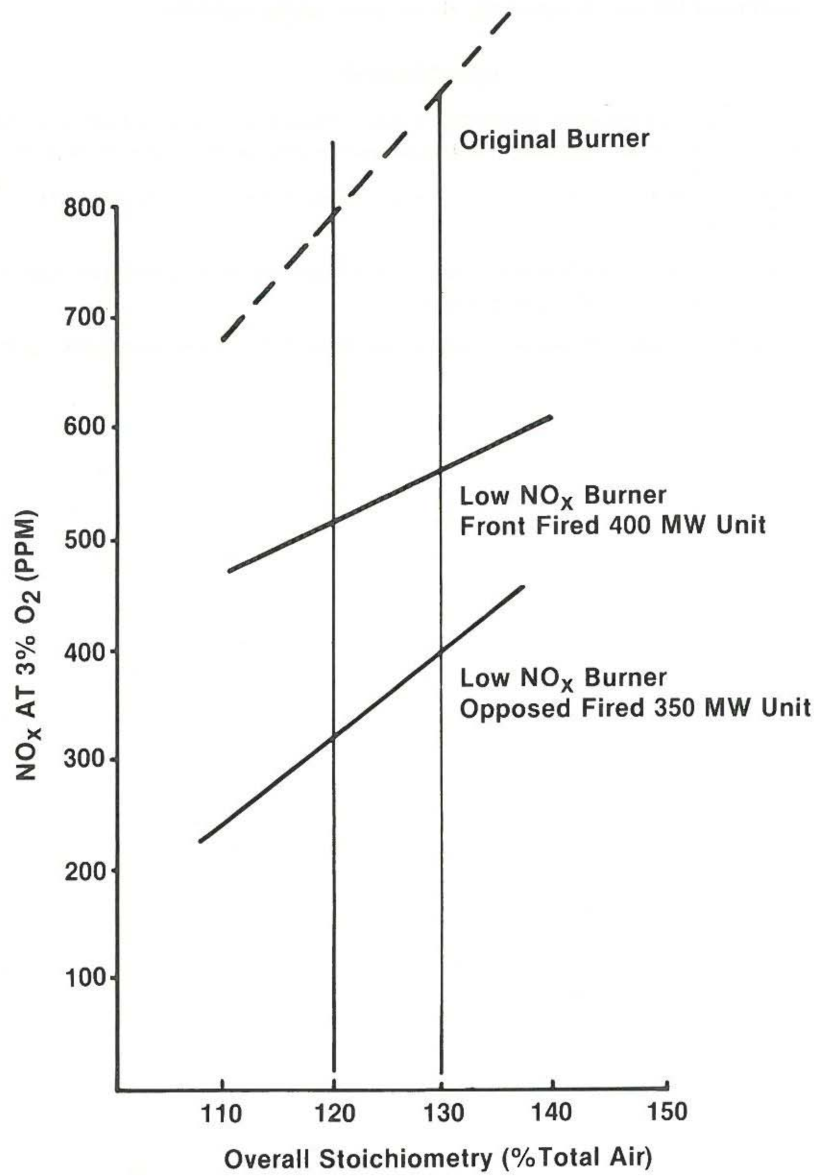


Figure 8 Retrofit Test Results with Low NO_X Riley CCV Burner

These burners corrected the specific emission problems on these units.

The simplicity of design make these burners attractive for retrofit to lower NO_X emissions, if limits are exceeded, on a fuel conversion or boiler uprating project.

CONCLUSION

Regulatory and financial pressures are causing utilities and those suppliers serving them to develop methods to optimize the utilization of existing equipment and resources to meet electricity demands. Two potentially viable methods worthy of consideration are fuel conversion -- to coal -- and uprating the steaming capacity of steam generating units.

Specific and judicious evaluations must be made prior to implementing a program of fuel conversion or uprating. Although the programs can result in significant short-term operating cost reductions, the effects on long-term reliability must be considered for each specific unit.

NO_X regulations are likely to become more stringent. Reforms expected from the EPA with the "bubble" concept, and developments in burner design, can result in strategies which will allow possible conversions to coal and eliminate a potential barrier to uprating steam generating capacity.

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