TESTING CAPABILITIES IN SUPPORT OF AVAILABILITY/RELIABILITY NEEDS

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INTRODUCTION

In 1974, the Riley Research Center was opened in Worcester, Massachusetts. The Center is located on a 101,000 m^2 (25-acre) site, near Riley Stoker's corporate and engineering headquarters, and includes 2053.2 m^2 (22,100 square feet) of office and laboratory test space. Initial capabilities included a test furnace for firing liquid and gaseous fuels and analytical laboratories for investigating fossil and synthetic fuels.

A recently-completed expansion of these facilities now allows the preparation and combustion of solid fuels, furthering state-of-the-art knowledge relating to NO_X, SO_X, and particulate emissions. Investigations underway include Company-sponsored programs and government contract work.

These experimental facilities were put in place to support the improvement in availability and reliability of both existing and new products. The facilities are also being offered to a variety of private organizations on a contract basis.

Riley Research facilities are dedicated to serving the needs of the utility and industrial boiler users for development of coal processing and combustion technology applicable both for new and retrofit steam generating/fuel burning projects. Through advancement of these coal-related technologies, we are striving to improve predictability of equipment operation, with the future benefit of higher equipment availability/reliability and lower atmospheric emissions. Ultimate customer goals include improvements in plant operating economics and a higher degree of social responsibility.

COAL BURNER TEST FACILITY

The Coal Burner Test Facility (CBTF), shown in Figure 1, supports technology advancements in both coal processing and combustion. It has an overall design capability of 29.3 (10^6) watts (100-million Btu/hr.). The sampling cycle from delivery to combustion to flue gas operates in the following manner:

Raw Coal Storage and Pulverization

Raw coal delivered to the CBTF is received in a below-ground vibrating hopper and conveyed to a 54.4-metric ton (60-ton) bunker which is fitted with a bin activator and inert gas blanketing. Also located in the coal preparation plant is a 3.2 metric tons-per-hour (3.5 tons-per-hour) attrition pulverizer, the Riley ATRITA® Model 350 (Figure 2), coupled with a 1.2 (10^6) watt (4-million Btu/hr.) natural gas fired vitiated air heater and primary air fan.

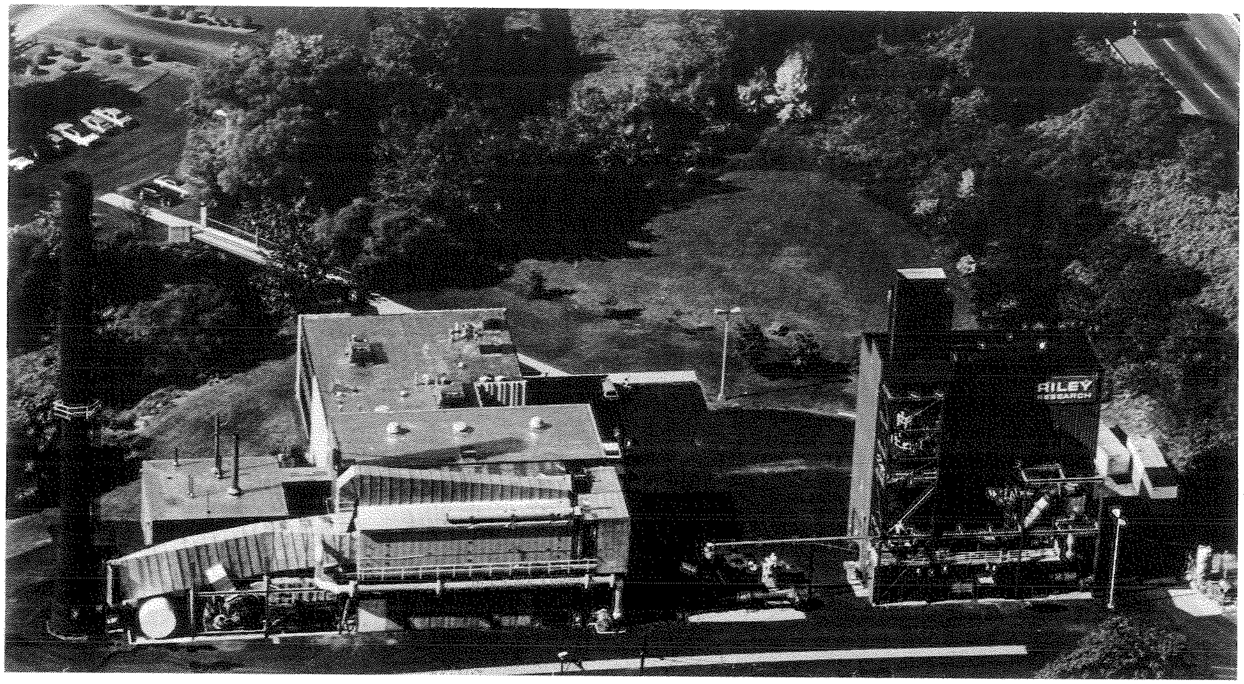

Figure 1 Riley Research Center; Coal Burner Test Facility is in Foreground

Figure 2 Riley ATRITA Coal Pulverizer

Pulverized Coal Transport and Storage

The system at the CBTF is designed to permit either (1) direct conveying of pulverized coal to the test furnace, or (2) intermediate pulverized coal storage. In case (1), raw coal is fed from storage onto a gravimetric weigh belt and then into a stream of vitiated air at 260°C (500°F) to the pulverizer. Transport to the test furnace of the pulverized coal/air stream is through a 254-mm (10-inch) line.

When case (2) is selected, the coal flow is directed to the intermediate pulverized coal storage bin. The coal from this bin can be extracted over a wide range of feed rates for entry into the coal pipe for combustion tests. This bin mounts on load cells for weighing the amount of coal entrained. Primary air flow can also be varied, thereby allowing a wide range of air/coal ratios. The entire fuel supply system is protected by an explosion suppression system.

Burner Test Furnace

The water-cooled test furnace (Figure 3) is approved for firing rates of 29.3 (10^6) watts (100-million Btu/hr) on coal by the U.S. Environmental Protection Agency. It has an ultimate capacity of 87.9 (10^6) watts (300-million Btu/hr) when firing gas or oil.

Test burners are mounted on one end of the furnace, and the products of combustion are exhausted at the opposite end. A 406.4-mm (16-inch) wide water jacket surrounds the entire furnace compartment. Water vapor produced in the jacket is collected in a large plenum at the top of the furnace and mixed with the products of combustion at the furnace exit. Additional cooling of the flue gases is provided by water sprays in the furnace exhaust duct. Both generated water vapor and combustion products pass through a scrubber before venting to the atmosphere.

The inside surface of the test furnace (Figure 4) is partially covered with insulating refractory to simulate the overall thermal environment experienced in operating furnaces. The furnace is equipped with many access points for wide angle viewing, video recording, temperature probing, gas sampling, and other data collection.

Stack Gas Scrubber

Test furnace exhaust gases are cleaned of particulate and SO_2 by intimate contact with a sodium hydroxide solution in a venturi rod scrubber (Figure 5), manufactured by Ducon Company, a sister Ashland Technology Company. The unit is capable of 90% SO_2 removal from combustion of 29.3 (10^6) watts (100-million Btu/hr) on Illinois #6 coal with 4.2 % by weight sulfur.

Control Center

All burner test facility functions and input flow streams are monitored and controlled from the control center (Figure 6) adjacent to the test furnace. This area also houses data acquisition and processing equipment (with time averaging or instantaneous readout), continuous gas analysis equipment, and multi-camera circuit video monitoring, with recording capability, of the entire installation.

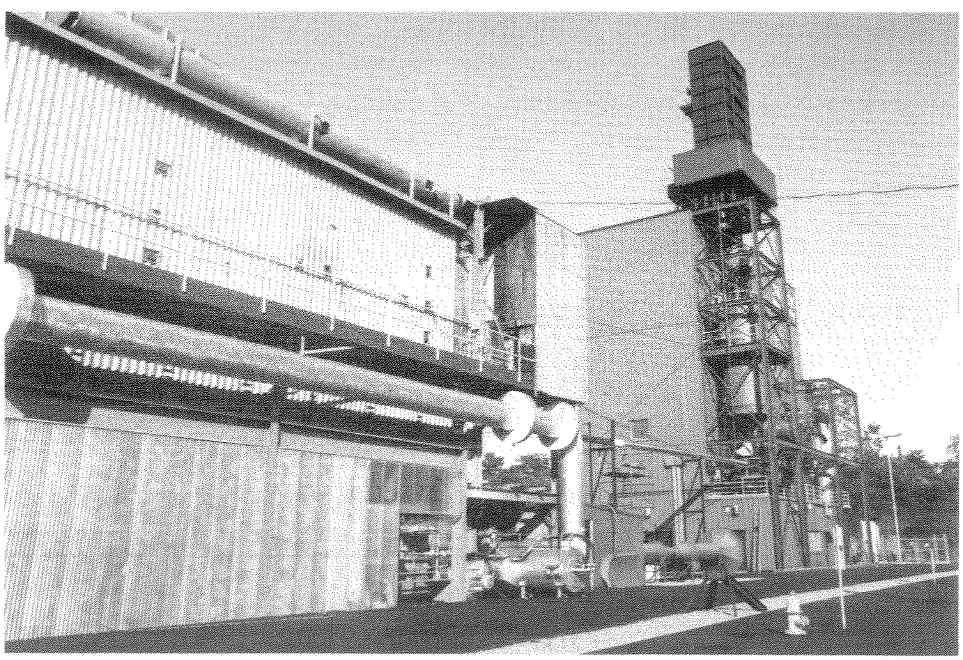

Figure 3 Burner Test Furnace

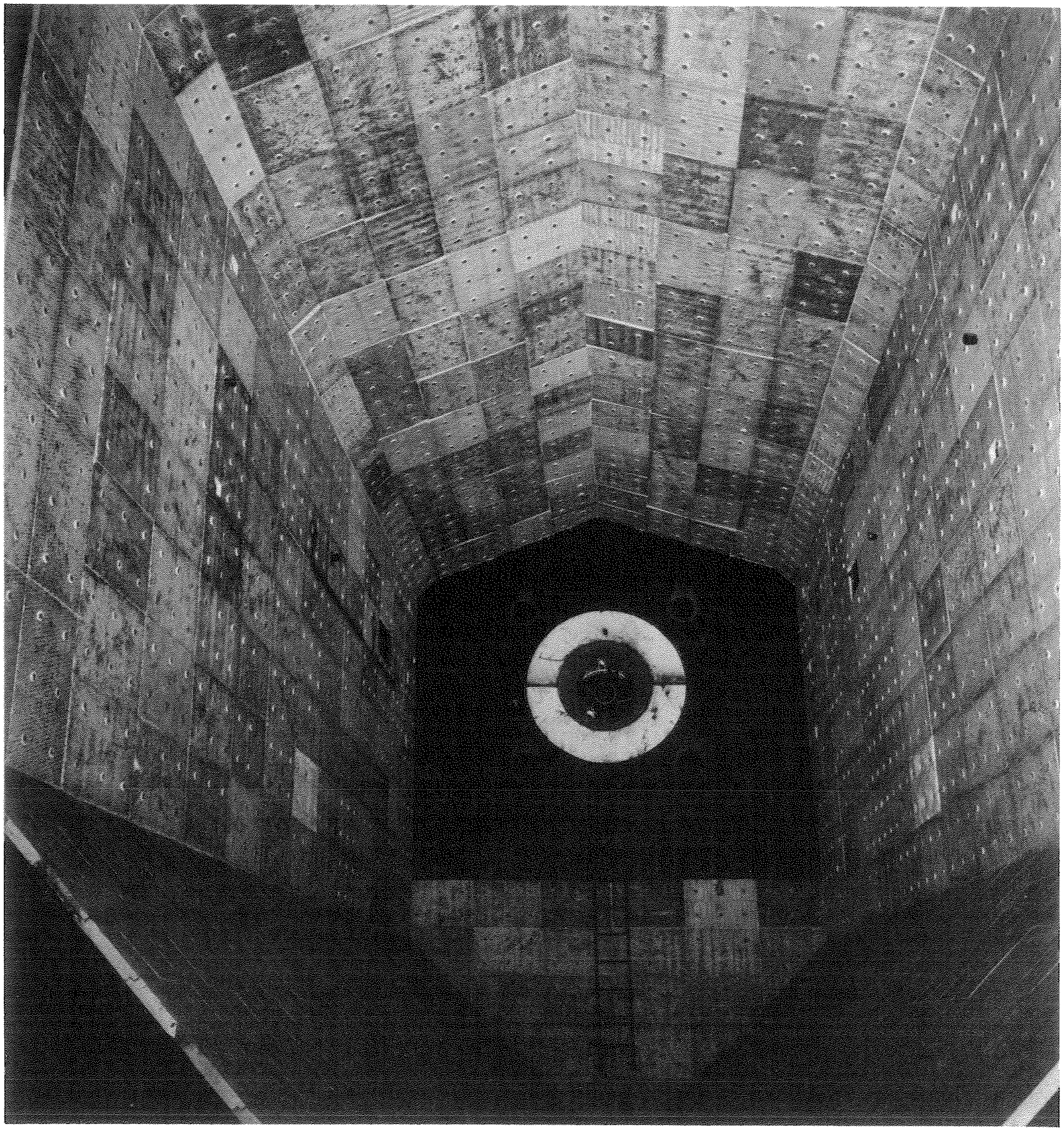

Figure 4 Interior View of Test Furnace Showing Refractory Lining and Burner Front

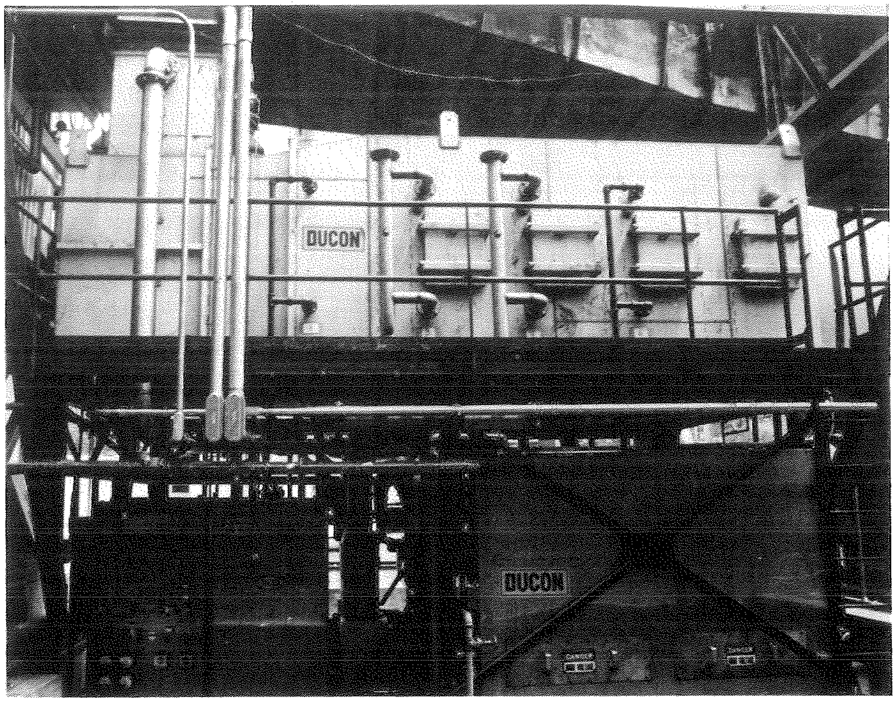

Figure 5   Sodium-based Regenerative Scrubber for Particulate and SO_2 Removal

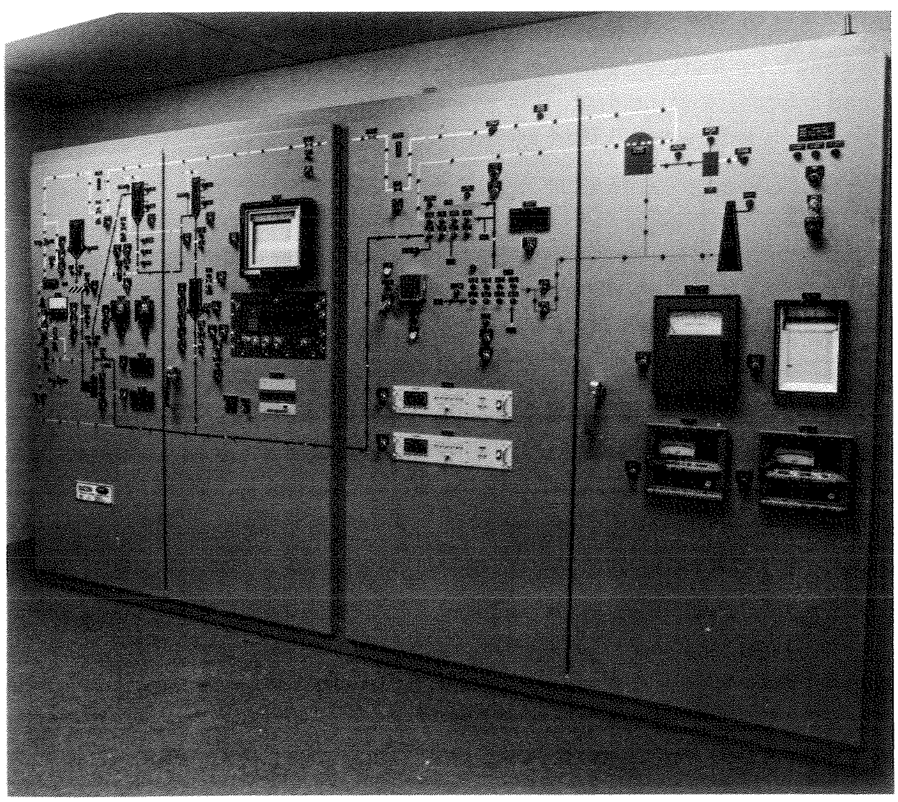

Figure 6   Master Control Panel

Flue Gas Sampling System

This system provides continuous analysis of combustion products. All materials in contact with the sample have been selected for non-reactivity. Sampling probes are water-cooled, and small cyclones remove particulate matter and condensed water. A heated line transports the sample to the control center where final conditioning (filtration and drying) is performed. The analysis equipment measures O_2, CO_2, CO, NO/NO_x, and SO_2. Certified calibration gases are used to maintain equipment calibrations.

Furnace Instrumentation

The facility is equipped with a number of velocity, gas sampling and high temperature probes for post-flame analysis. A cascade impactor is available for determining particle size distribution of entrained particulate matter. In addition, a color television camera and a 3/4-inch video tape system can be used to record flame shape.

The largest effort currently underway at the CBTF involves full-scale testing of advanced low NO_x pulverized coal burners. The main objectives are to determine ignition, stability, turndown and emission characteristics that will reduce potential operating problems and meet emissions requirements. Experience gained in operating pulverized coal burners in this facility will be incorporated into future coal burners for both new and retrofit applications. These efforts are expected to significantly advance efforts to improve plant reliability and availability.

FLOW MODELING LABORATORY

Another major area of Riley Research is the Flow Modeling Laboratory (Figure 7), where various air, water and steam flows are simulated for a wide variety of experimental studies. Large-size test assemblies and burners as well as laboratory and pilot scale combustion test facilities are employed for this research.

Both two- and three-dimensional modeling capabilities are available in this laboratory. They are used to investigate complex flow patterns in burners, furnaces, ductwork and breeching configurations, and various power and process plant equipment. The laboratory is well-equipped with air and water supplies, water tables, metering and measuring equipment, flow visualization equipment, and photographic and television monitoring equipment for experimental flow model test programs.

The prediction and design verification of actual flow processes in water tubes, steam drums, burner systems, convection banks and furnaces are conducted through model testing combined with computer analyses. These tools are enhanced with sub-scale and full-scale component tests as required. Improvements in design verification and performance predictability will lead to clearer definition of operating limits of boiler components as well as the entire boiler operation.

An air-flow measurement robot provides accurate and repetitive testing of air flow patterns from three-dimensional burner models. Both direction and magnitude of flow can be monitored and recorded, and the identical planes checked before or after model modifications.

A steam-water loop, calibrated to steam drum separation equipment from 1724 to 18,961 kPa (250 to 2750 psig), is installed in another portion of the laboratory. The system includes a forced circulation liquid return loop. Instrumentation provides measurements of liquid "carry over" and vaporous "carry under."

Water tables (Figure 8) are available for two-dimensional flow studies of ductwork, breeching, furnace, heat recovery, and fuel burning configurations. The water tables utilize simple surface tension-type pumps to provide the necessary head for flow. Aluminum powder floating on colored water allows visual observation or photographic recordings of the flow patterns within the configuration being tested.

Three-dimensional models (Figure 9) are generally made of plexiglass so that visual and photographic records can be obtained. The flow mediums utilized are air, water, or a combination of the two. Various standard means of flow visualization such as tufts of yarn or entrained solids are available for use.

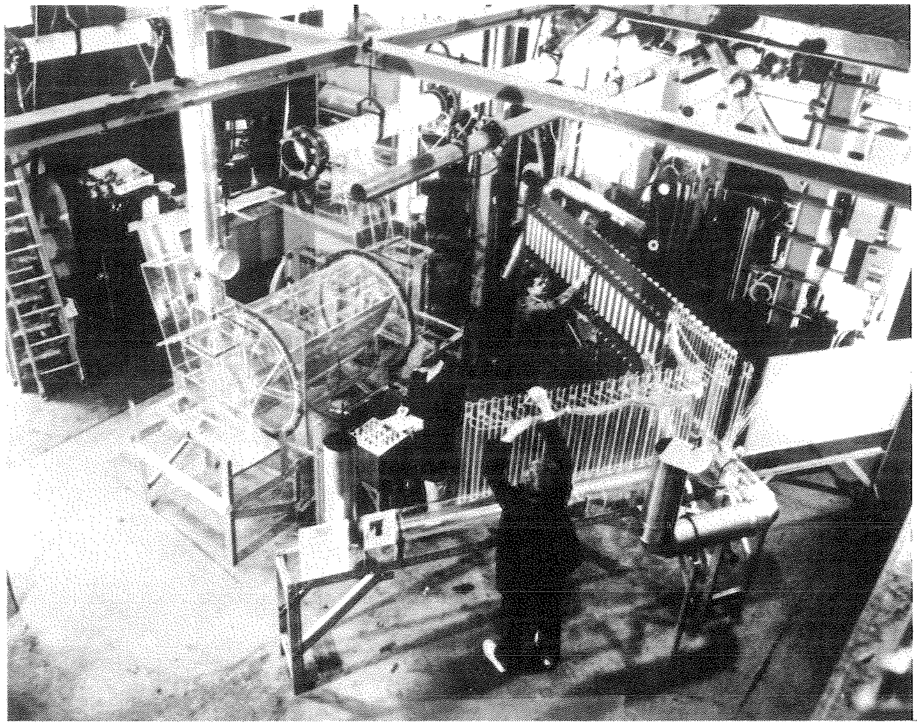

Figure 7 Flow Modeling Laboratory

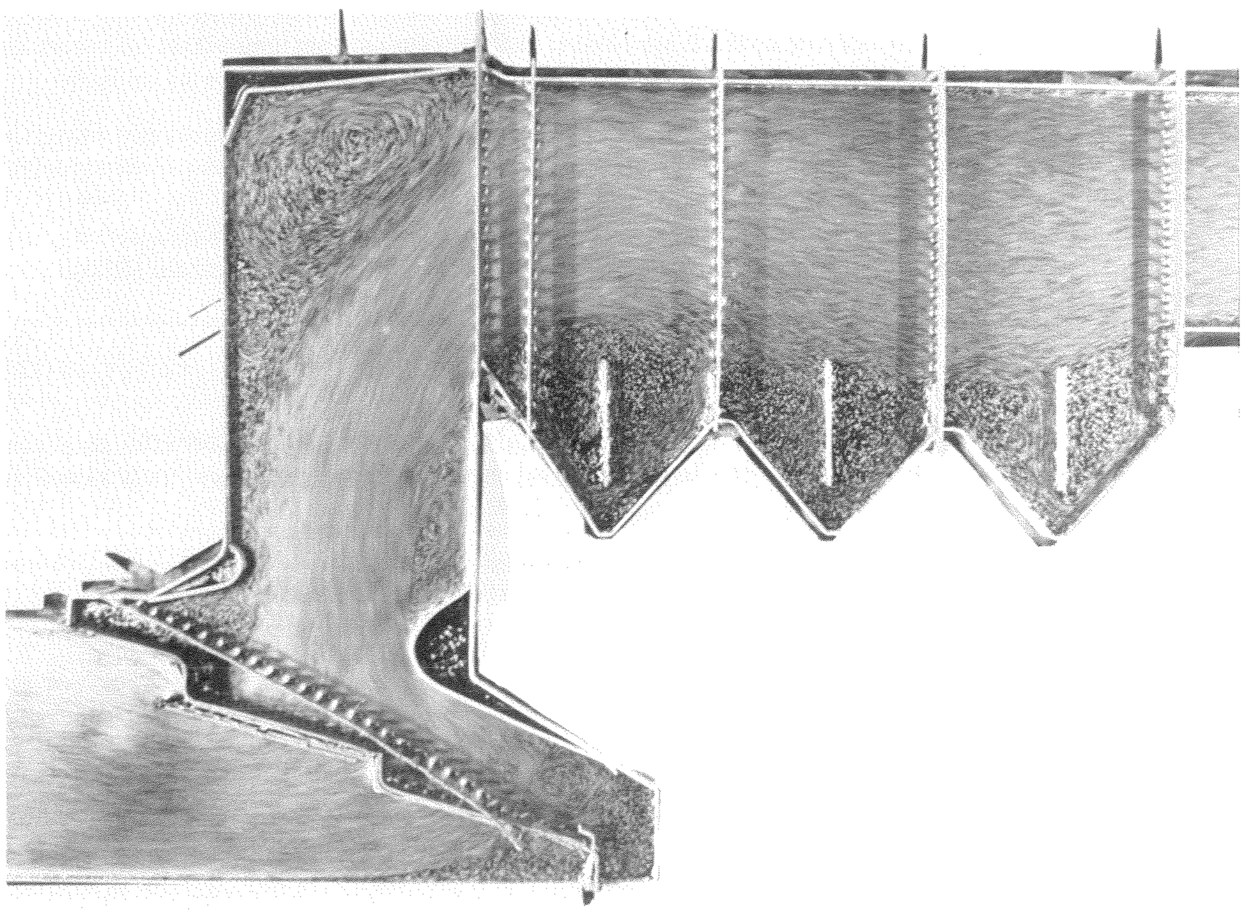

Figure 8 Water Table Setup for Flow Modeling

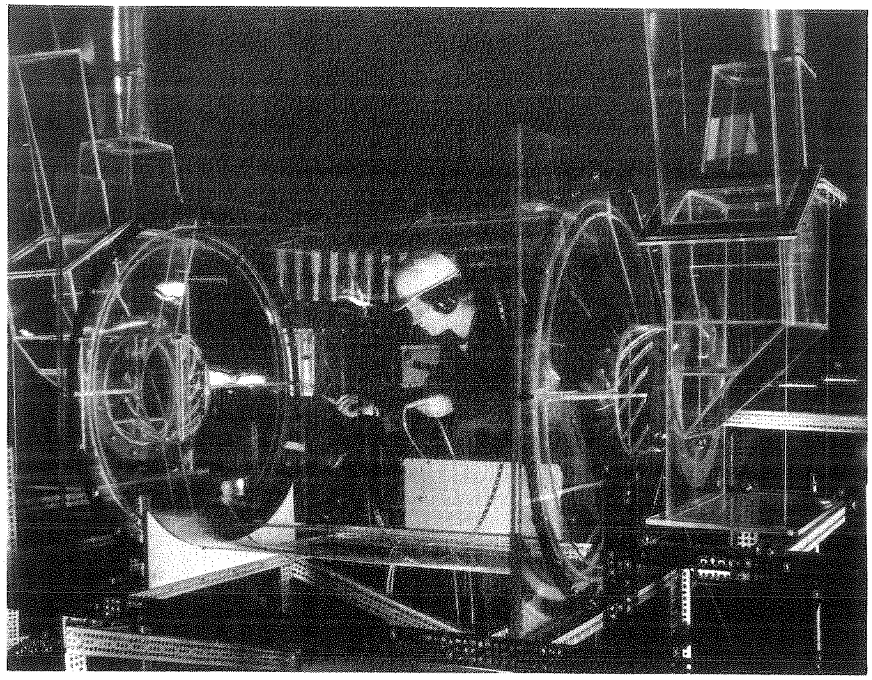

Figure 9 Ball Tube Mill Flow Model

The laboratory is equipped with a range of blowers rated from 1.7 to 850 m^3 (60 to 30,000 cfm) with static pressures up to 2032 mm (80 inches) of water. Air flow model studies utilize a helium bubble generator and a high intensity arc lamp with special optical shroud to observe and track flow stream lines within the model. In addition, an orientable 5-hole pitot tube can be used to measure magnitude and direction of air flow.

The laboratory also has a water flow loop capable of delivering 3785 liters (1000 gallons) per minute at 275.8 kPa (40 psi). A 37,854 liter (10,000 gallon) storage reservoir and flow distribution manifold are an integral part of the system.

In addition to standard manometers and pressure gauges, the laboratory has numerous high accuracy, high resolution pressure transducers. Lighting, photographic, and closed circuit television equipment are available for recording flow stream lines.

ANALYTICAL LABORATORIES

The Riley Research Center has two separate, yet complimentary, laboratories (Water Chemistry and Fuels Characterization) which support the test work being carried out at the Center on outside contracts as well as project work for several Riley divisions.

The Water Chemistry Laboratory (Figure 10) is equipped to perform detailed physical and chemical analyses of boiler water and steam condensates. An atomic absorption spectrophotometer (Figure 11) is used to determine these low levels of impurities. This equipment is also used for major, minor, and trace elemental analyses of coal ash.

The Fuels Characterization Laboratory (Figure 12) is equipped to perform analyses on solid, petroleum and gaseous fuels, both conventional and unconventional, following ASTM testing procedures. The laboratory is capable of performing full grind and burning analyses in addition to determining the chemical and physical properties of the fuels. Particle size and particle size distribution of pulverized coal can be determined by ASME-accepted sieve analysis techniques or by a particle size analyzer with a range of 2.9 to 300 microns (Figure 13). The lab includes equipment such as an adiabatic bomb calorimeter for heating value determination, furnaces for ash fusion temperature and sample preparation, pulverizers for fuel preparation, a hardgrove index machine, and the necessary support equipment.

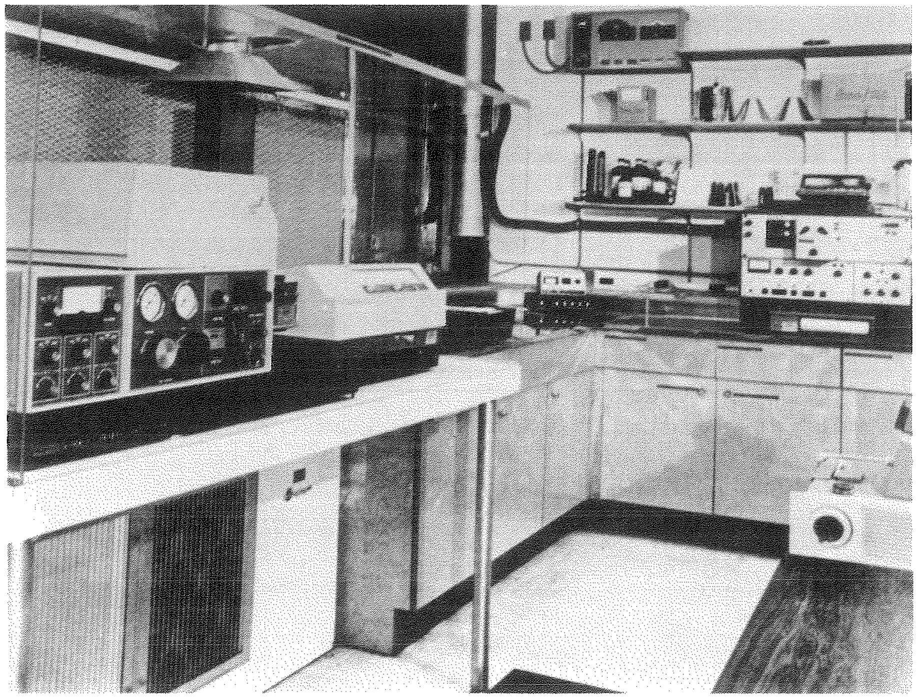

Figure 10 Water Chemistry Laboratory; Flame Spectrophotometer is at Left

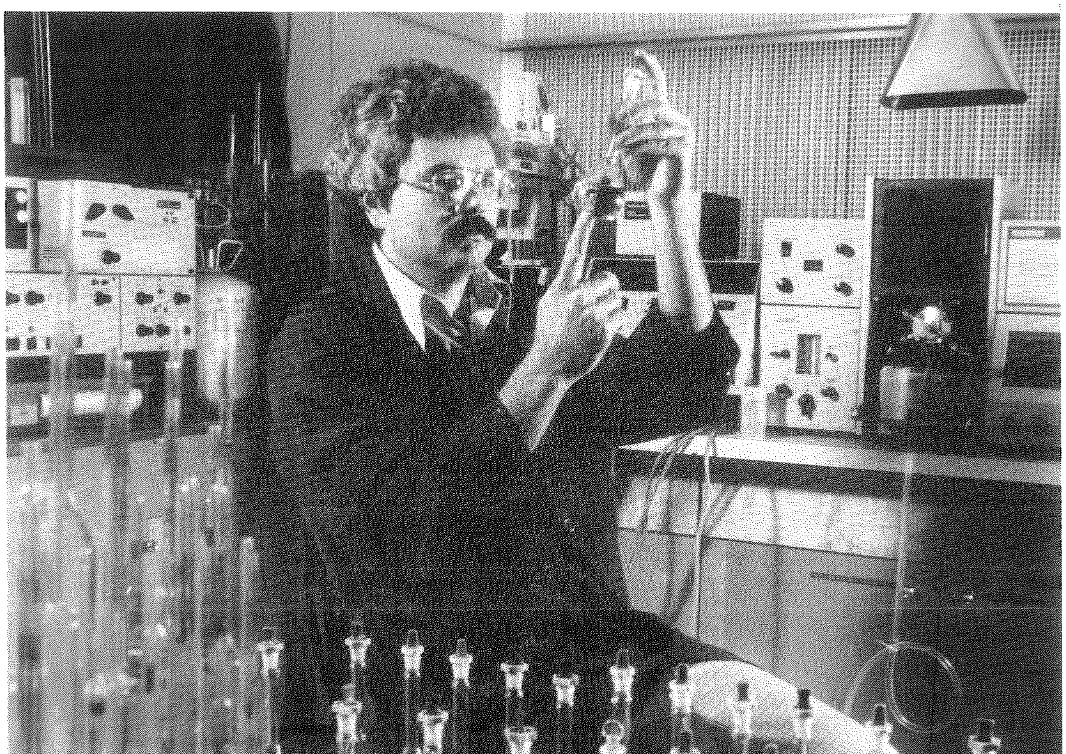

Figure 11 Atomic Absorption Spectrophotometer in Water Chemistry Laboratory

Figure 12 Fuels Characterization Laboratory Showing Initial Examination of Coal Samples

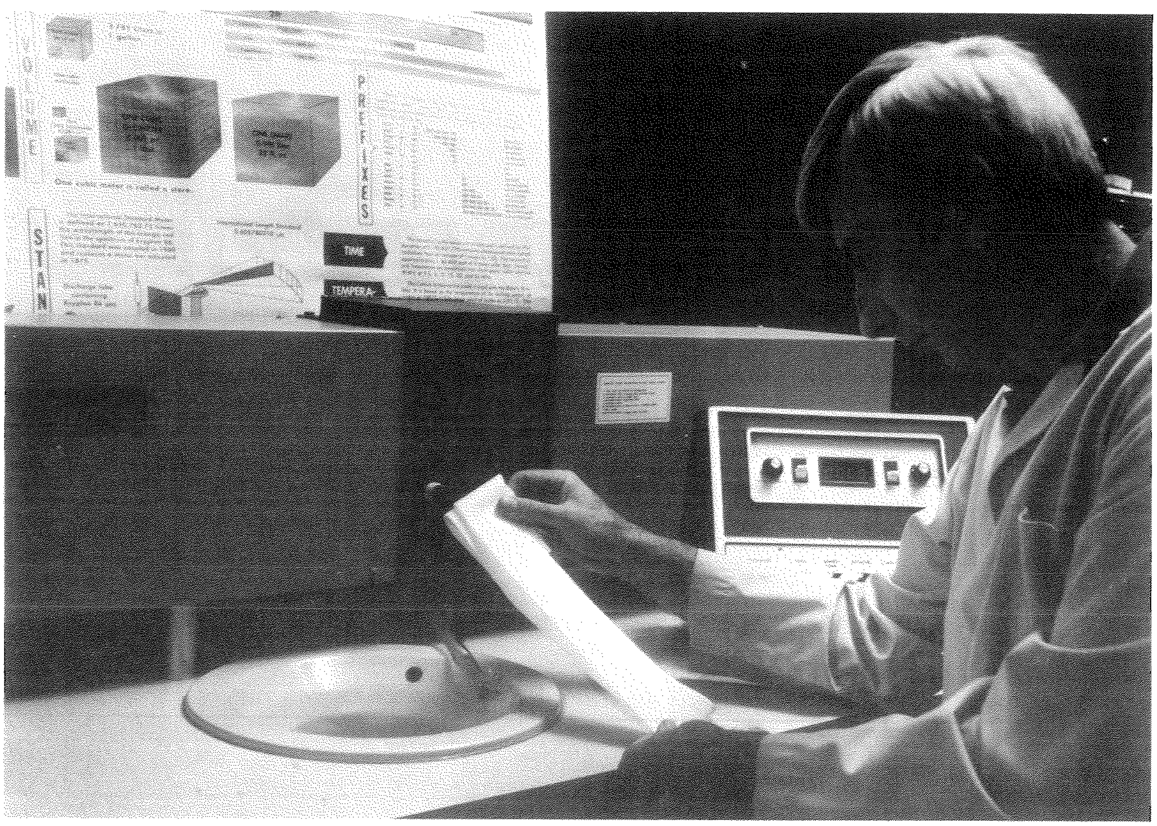

Figure 13 Particle Size Analyzer for Coal and Ash Samples

OTHER AREAS OF INVESTIGATION

Riley test facilities are designed to address numerous other technical areas which are also relative to boiler availability and reliability:

- Fire side corrosion
- Combustion efficiency
- Tube erosion
- Slagging/fouling
- Combustion control systems
- Flame stability and scannability
- Process data for development of design standards
- Component failure analyses
- Boiler safety code compliance
- Mechanical and thermal testing of structural components
- Performance testing and evaluaton of auxiliary equipment
- Field test services

The Riley Research Center has contracts with government and private research groups. The work encompasses analytical engineering, model studies, materials analyses, and combustion tests in the various Center facilities. Some of the R&D contracts are funded by:

- EPRI–The Electric Power Research Institute
- EPA–The United States Environmental Protection Agency
- EERC–Energy and Environmental Research Corporation

Riley Stoker has two contracts with EPRI. One entitled "Detection, Prevention and Control of Pulverizer Fires and Explosions," will culminate with recommendations for suppression alternatives to prevent mill system explosions in a generic way and not specifically relate to any single manufacturer's pulverizer type. The other is "Evaluation of Retrofit Low NO_X Combustion Process," the main objectives of which are to develop a confident design basis for retrofitting low NO_X burners and advanced fuel and air combustion staging, and to demonstrate the commercial feasibility of these technologies.

Two contracts have also been received from EPA. Both relate to low NO_X emissions from power boilers and further involve reductions of SO_X emissions using sorbent injection techniques. The first, entitled "Prototype Evaluation of Commerical Second Generation Low NO_X Burner Performance and Sulfur Capture," will optimize the Riley Stoker distributed mixing burner with limestone injection for combined NO_X/SO_X control. The second contract is "Boiler Design Criteria for Dry Sorbent SO_X Control with Low NO_X Burners." A major objective of this program is to assess the impact of Limestone Injection Multistage Burner (LIMB) technology on utility boiler design for both retrofit and new unit designs.

Two contracts have been received from EERC. Both eminate from the EPA and deal with low NO_X/SO_X programs. One entitled "Evaluation of In-furnace NO_X Reduction and Sorbent Inject on NO_X/SO_X Emissions of U.S.-designed Coal-fired Boilers" deals with staged fuel combustion. The other contract calls for Riley Stoker to evaluate the adequacy of computer codes (our own included) as analytical tools for sorbent injection performance. In addition, we will coordinate and aid in testing a wall-fired unit and compare predictive procedures with field data. The program is entitled "Evaluation of Time/Temperature History of Gases and Particles in the Radiant Furnace Zone of Pulverized Coal-fired Steam Generators."

SUMMARY

The laboratory/test facilities described here are now available for contract work at the Riley Research Center in Worcester. A variety of engineering design and analysis capabilities are also offered. These resources support Riley Stoker's corporate committment to meeting the availability/reliability needs of the electric utility industry.