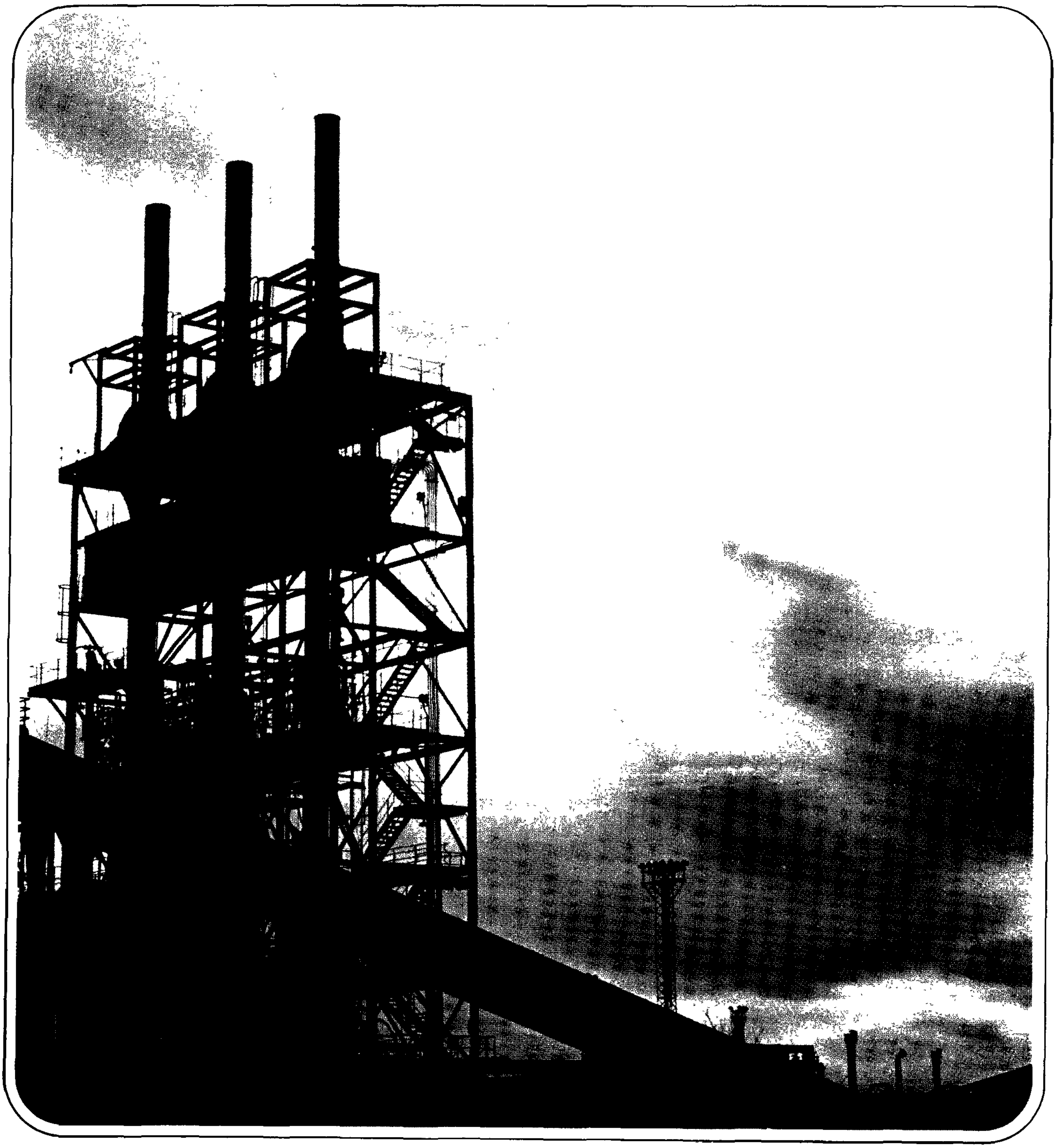
SECOND PROGRESS REPORT

TECHNOLOGY TRANSFER

CAPSULE REPORT

LIME/LIMESTONE WET-SCRUBBING TEST RESULTS AT THE EPA ALKALI SCRUBBING TEST FACILITY

U.S. EPA OFFICE OF RESEARCH AND DEVELOPMENT PROTOTYPE DEMONSTRATION FACILITY



1. INTRODUCTION AND SUMMARY

This capsule report describes a program conducted by The Environmental Protection Agency (EPA) to test prototype lime and limestone wet-scrubbing systems for removing sulfur dioxide (SO_2) and particulate matter (fly ash) from coal-fired boiler flue gases. The program is being carried out in a test facility which is integrated into the flue gas duct-work of a coal-fired boiler at the Tennessee Valley Authority (TVA) Shawnee Power Station, Paducah, Kentucky. Bechtel Corporation of San Francisco is the major contractor and test director, and TVA is the constructor and facility operator. This report describes a series of lime and limestone reliability tests conducted from March 1973 to December 1974. An earlier capsule report (EPA Technology Transfer Capsule Report No. 4) discussed the results of limestone factorial tests and initial limestone reliability tests. The results of an advanced program at the Shawnee test facility will be presented in future reports.

In a lime/limestone wet-scrubbing system, the flue gas is contacted (scrubbed) with a slurry of lime or limestone in water. SO_2 is absorbed into the liquor, where it reacts with the dissolved lime/limestone, forming the waste products of calcium sulfite and calcium sulfate (gypsum). Particulate is removed in the scrubber by impact with the slurry droplets.

The Shawnee test facility consists of three parallel wet-scrubber systems: a Turbulent Contact Absorber (TCA), a venturi followed by a spray tower, and a Marble-Bed Absorber. Each system is capable of treating approximately 10 MW equivalent (30,000 acfm at 300°F) of flue gas containing 1800 to 4000 ppm of SO_2 and 2 to 5 grains/scf of particulates. Testing of the TCA and venturi/spray tower is ongoing; testing of the Marble-Bed Absorber has been discontinued.

The following tests have been conducted:

- Limestone factorial tests on all three scrubbers to determine the effects of the independent variables (e.g., liquid-to-gas ratio, gas velocity, etc.) on SO_2 and particulate removal
- Limestone reliability verification tests on all three scrubbers to define regions for reliable (scale-free) operation of scrubber internals
- Lime and limestone reliability tests on the venturi/spray tower and TCA systems, respectively, to demonstrate long-term operational reliability

Test results have shown that scrubber internals can be kept relatively free of scale if the sulfate (gypsum) saturation of the scrubber liquor is kept below about 135 percent. This can be accomplished by proper selection of slurry solids concentration, effluent residence time, and liquid-to-gas ratio.

At the conditions tested, the mist elimination configuration presently used in the TCA appears to be successful in handling the problem of mist eliminator scaling and plugging – the most significant reliability problem encountered during the test program. This configuration consists of a wash tray (Koch Flexitray) followed by a chevron mist eliminator, both continuously washed on the underside with a combination of clarified liquor and makeup water. In a test run of over 3 months' duration in which the TCA operated in a closed liquor loop at a superficial gas velocity of 8.6 ft/sec and a slurry solids concentration of 15 percent, the system remained essentially clean.

A run of 3 months' duration is yet to be made with the venturi/spray tower mist elimination configuration, which consists of a chevron mist eliminator with provision for both underside and topside washing. With the system at a superficial gas velocity of 6.7 ft/sec and 8 percent slurry solids concentration, scale formation on the top mist eliminator vanes has been a constant problem. Underside washing by itself did not eliminate topside scale formation. But when the underside washing was combined with an intermittent high-pressure topside wash of a single section of the mist eliminator, that section remained essentially scale-free. This procedure seems promising and will be tested further.

2. THE TEST FACILITY

The test facility consists of three parallel scrubber systems, each with its own slurry-handling system. Scrubbers are of prototype size, each capable of treating approximately 30,000 acfm (at 300°F) of flue gas from the TVA Shawnee coal boiler No. 10. This corresponds to approximately 10 MW of power plant generating capacity. The equipment selected was sized for minimum cost, consistent with the ability to extrapolate results to commercial scale. Boiler No. 10 burns a high-sulfur bituminous coal, leading to SO_2 concentrations of 1800 to 4000 ppm and particulate inlet loadings of about 2 to 5 grains/scf in the flue gas.

The major criterion for scrubber selection was the potential for removing both SO_2 and particulates at high efficiencies (SO_2 removal greater than 80 percent and particulate removal greater than 99 percent). Other factors considered in the selection of the scrubbers were (1) ability to handle slurries without plugging or excessive scaling, (2) reasonable cost and maintenance, (3) ease of control, and (4) reasonable pressure drop.

On the basis of information available in the literature, the following scrubbers were selected:

- Turbulent Contact Absorber (TCA)
- Venturi followed by a spray tower
- Marble-Bed Absorber

The TCA, manufactured by Universal Oil Products, uses a fluidized bed of low-density plastic spheres that are free to move between retaining grids. The venturi, manufactured by Chemical Construction Co., contains an adjustable throat that permits control of pressure drop under a wide range of flow conditions. Although a venturi is ordinarily an effective particulate removal device, gas absorption is limited in lime/limestone wet-scrubbing systems by low slurry residence time. For this reason, the spray tower was included for additional absorption capability. The Marble-Bed Absorber, manufactured by Combustion Engineering Co., uses a packing of 3/4-inch glass spheres (marbles). Because of operating problems with the Marble-

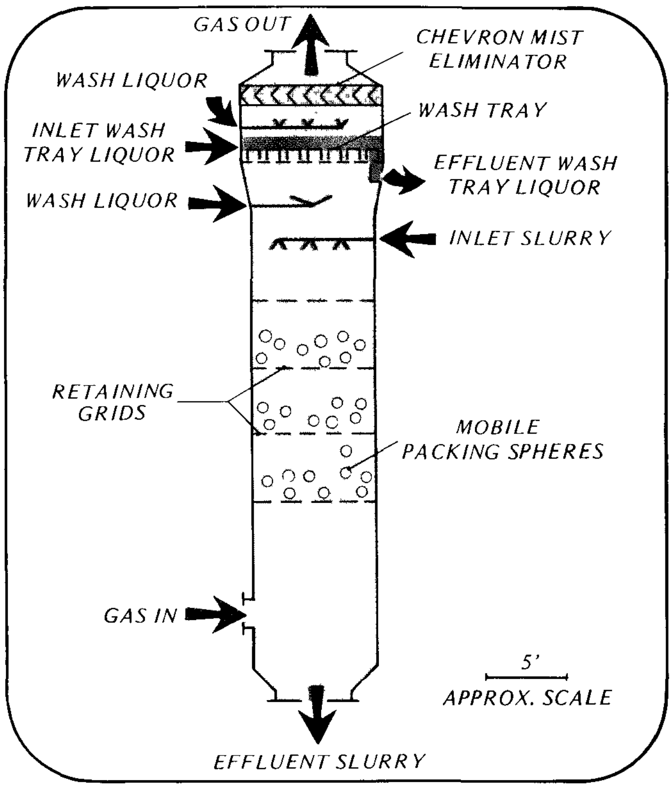


Figure 1. Schematic of Three-Bed TCA

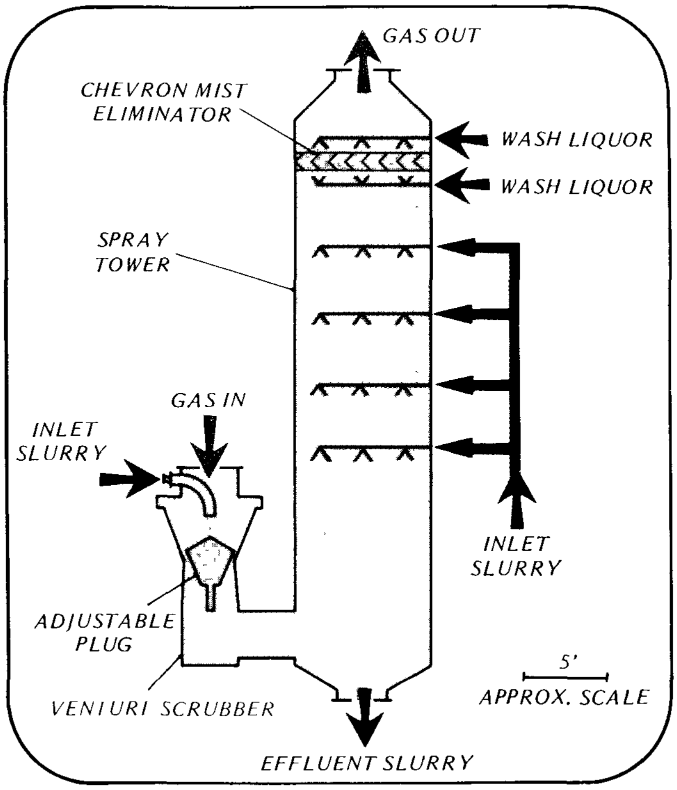


Figure 2. Schematic of Venturi/Spray Tower

Bed Absorber (i.e., nozzle failure and subsequent plugging of the bed), testing was discontinued on this system early in the program. Combustion Engineering has since developed an advanced Marble-Bed Absorber which has been operating reliably in full-scale commercial service at other locations. Figures 1 and 2, drawn roughly to scale, show the TCA and the venturi/spray tower, along with the mist eliminators selected for de-entraining slurry in the gas streams.

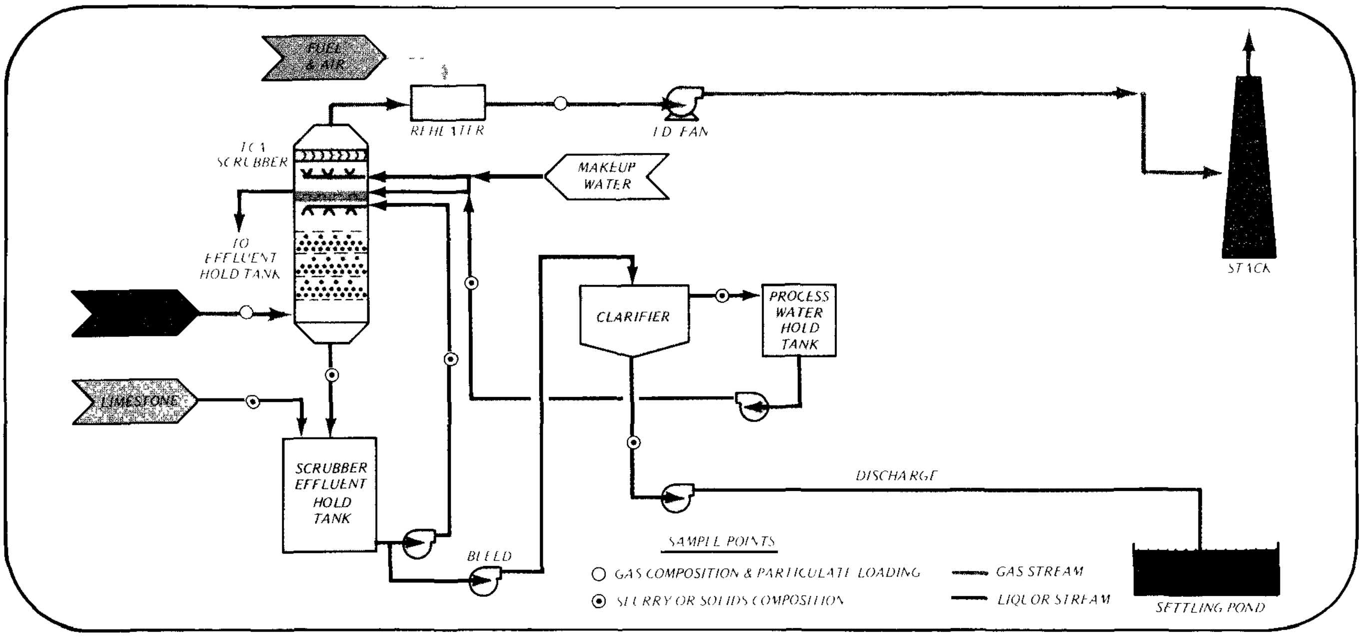


Figure 3. EPA Test Facility – Typical Process Flow Diagram for TCA System in Limestone Service

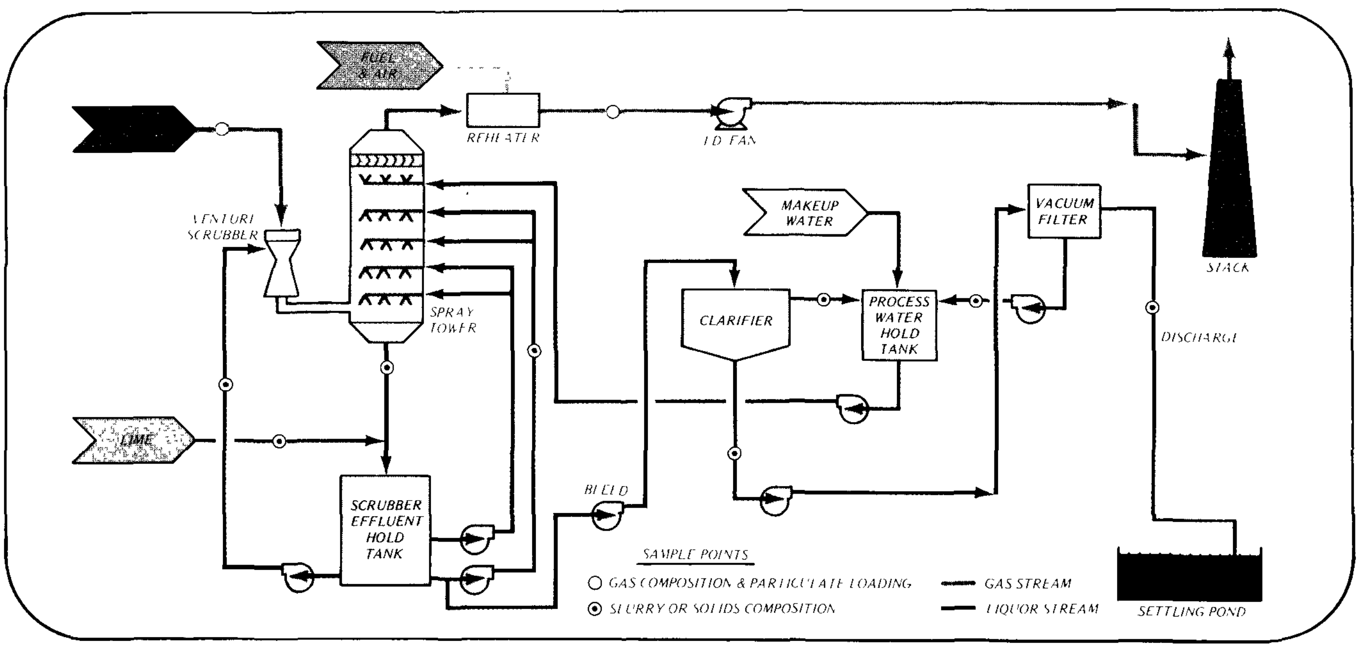


Figure 4. EPA Test Facility – Typical Process Flow Diagram for Venturi/Spray Tower System in Lime Service

The test facility was designed to allow a number of different scrubber internals and piping configurations to be used with each scrubber system. For example, the TCA can be operated as a one-, two-, or three-bed unit, and solids separation can be achieved with a clarifier alone or with a clarifier in combination with a filter or a centrifuge.

A typical TCA system configuration used during limestone testing and a typical venturi/spray tower system configuration used during lime testing are shown in Figures 3 and 4, respectively. Process details, such as flue gas cooling sprays, are not shown.

For all configurations, gas is withdrawn from the boiler ahead of the power plant particulate removal equipment so that entrained fly ash can be introduced into the scrubber. The gas flow rate to each scrubber is measured by venturi flow meters and controlled by dampers on the induced-draft fans. Concentration of SO_2 in the inlet and outlet gas is monitored continuously by Du Pont photometric analyzers. Inlet and outlet gas particulate concentrations are measured periodically using a modified EPA particulate train.

Control of the scrubbing systems is carried out from a central graphic panelboard. An electronic data acquisition system is used to record the operating data. The system is hard-wired for data output directly on magnetic tape, and on-site display of selected information is available. Important process control variables are continuously recorded, and trend recorders are provided for periodic monitoring of selected data sources.

Views of the scrubber structure, TCA, spray tower, and control room are shown in Figures 5, 6, 7, and 8, respectively.

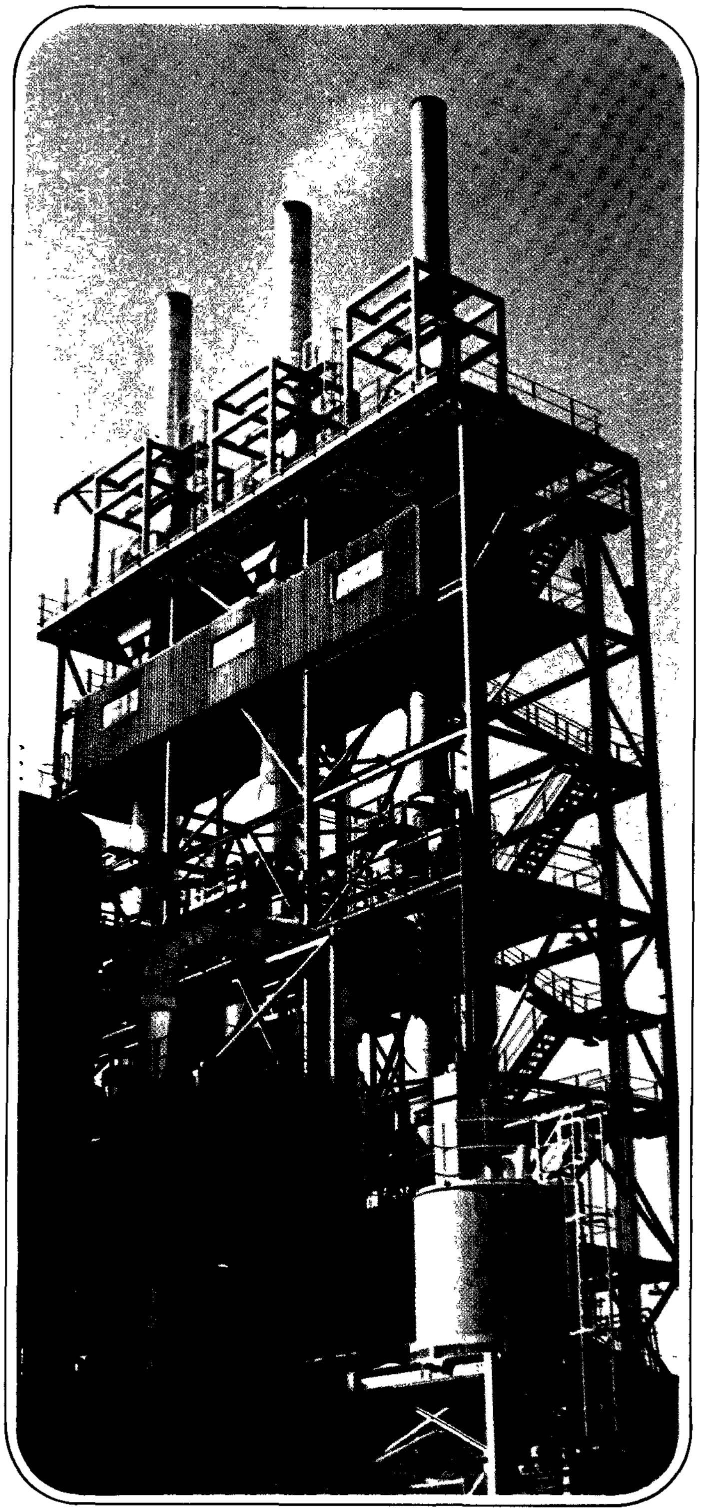


Figure 5. Scrubber Structure

Figure 6. TCA with View of Fluidized Spheres during Air/Water Tests

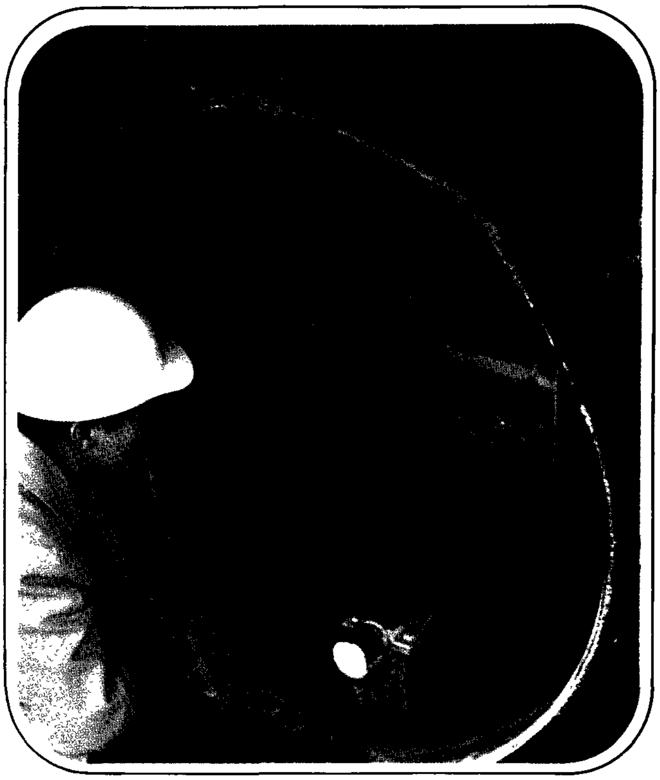


Figure 7. Inspection of Spray Tower

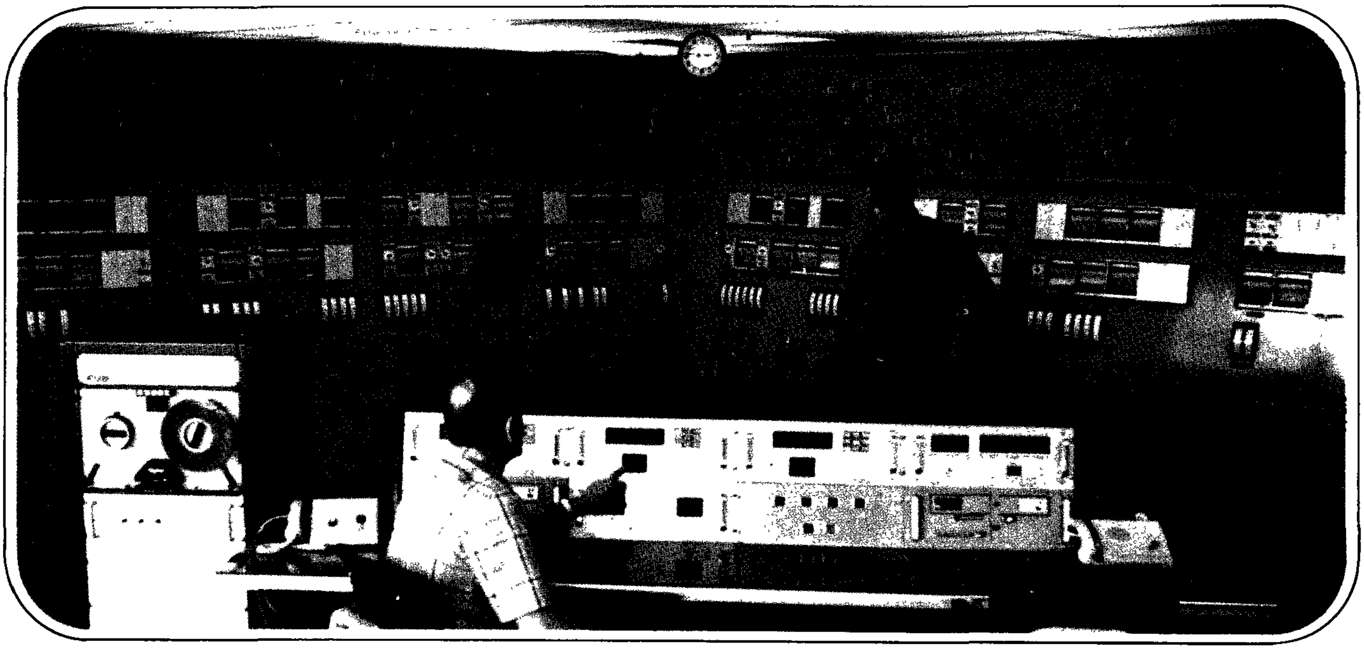


Figure 8. Control Room

3. THE TEST PROGRAM

The following sequential test blocks were established for the test program:

(1) Air/water tests
(2) Sodium carbonate tests
(3) Limestone wet-scrubbing tests
(4) Lime wet-scrubbing tests

The test program schedule from March 1972 through December 1974 is shown in Figure 9. Detailed test results have been presented in EPA Progress Reports EPA-650/2-73-013 and EPA-650/2-74-010. A third report will be issued in mid-1975.

AIR/WATER TESTS

These experiments, which used air to simulate flue gas and water to simulate alkali slurry, were designed to determine pressure drop model coefficients and to observe fluid hydrodynamics for all three scrubbers under clean conditions.

SODIUM CARBONATE TESTS

These tests, which used sodium carbonate solutions to absorb SO_2 from flue gas, were designed to determine coefficients within mathematical models for predicting SO_2 removal.

LIMESTONE WET-SCRUBBING TESTS

The objectives of these tests, in which limestone ($CaCO_3$) slurry was fed to the scrubber circuit were:

(1) To determine the effect of important variables on particulate and SO_2 removal
(2) To identify and resolve operating problems, such as scaling and mist eliminator plugging
(3) To identify regions of reliable operation of the three scrubber systems, consistent with reasonable SO_2 removal, and to choose economically attractive operating configurations from within these regions
(4) To establish long-term operating reliability for one or more of the scrubber systems and to develop definitive process economics data and scale-up factors

A large number of short-term limestone factorial tests, of about 4 hours each, were made on each scrubber system to accomplish the first objective. The major independent variables were gas rate, liquor rate, scrubber inlet liquor pH, and number of grids and height of spheres in the TCA. The results of these tests and of the air/water and sodium carbonate tests are reported in EPA Technology Transfer Capsule Report No. 4.

A relatively small number of longer term limestone reliability verification tests, of about 3 weeks per test, were made on each scrubber system to accomplish the second and third objectives. In these tests, the dependent variable was the scaling and plugging potential of the scrubber internals, and the major independent variables were gas rate, liquor rate, scrubber inlet slurry pH, effluent residence time, solids concentration in the scrubber recirculation slurry, and solids concentration in the discharge sludge. The results of these tests are reported in Section 4.

Long-term limestone reliability tests, of up to 3 months in duration, were run on the TCA system to accomplish the fourth objective. The results of these tests are reported in Section 5.

LIME WET-SCRUBBING TESTS

The objectives of this test sequence, in which hydrated lime ($Ca(OH)_2$) slurry was fed to the scrubber circuit, were identical to those for the limestone wet-scrubbing sequence just described. Originally, the testing was to be divided into the same three categories: (1) short-term factorial tests, (2) longer term reliability verification tests, and (3) long-term reliability tests. Subsequently, it was decided to begin the lime testing with long-term reliability tests on the venturi/spray tower system and to perform the factorial and reliability verification tests at a later date (after December 1974). The results of the long-term reliability tests on the venturi/spray tower system are reported in Section 6.

ANALYTICAL PROGRAM

Samples of slurry, flue gas, limestone, and coal were taken periodically for chemical analyses, particulate size sampling, and limestone reactivity tests. Locations of slurry and gas sample points for the TCA and venturi/spray tower systems are shown in Figures 3 and 4.

To meet the formidable analytical requirements of the facility at reasonable costs, equipment was selected to minimize manpower. For example, an X-ray fluorescence unit was used for comprehensive slurry analyses. All analytical computations and recording of results were handled by an on-site minicomputer.

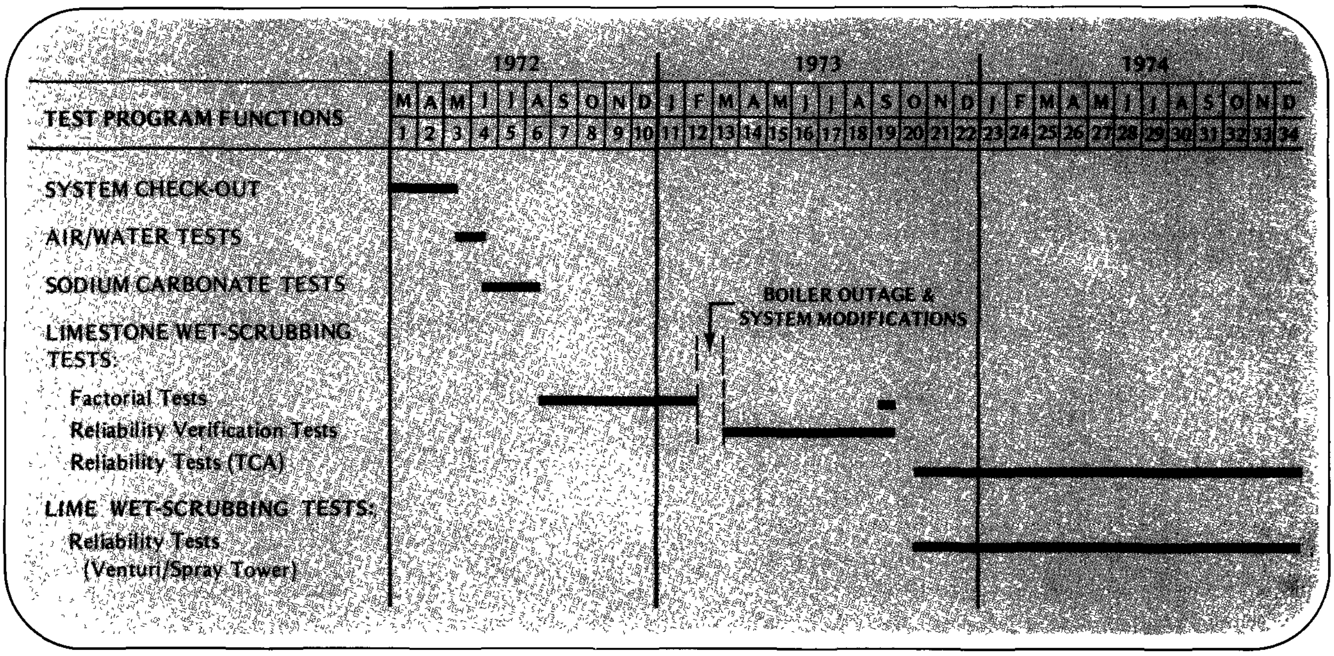


Figure 9. Shawnee Test Schedule

4. LIMESTONE RELIABILITY VERIFICATION TEST RESULTS

The primary objectives of the limestone reliability verification tests were to identify and resolve operating problems and to identify regions of reliable operation of the three scrubber systems. Emphasis was placed on solving the problem of scaling of scrubber internals. The reliability verification tests averaged approximately 500 hours (3 weeks) each.

SCALING OF SCRUBBER INTERNALS

The rate of scaling of the scrubber internals was found to be sensitive to the supersaturation of the calcium sulfate (gypsum) in the circulating scrubber liquor. Results of the limestone reliability verification tests showed that scrubber internals can be kept relatively free of scale if the sulfate saturation is kept below about 135 percent at 50°C (i.e., below 35 percent supersaturation).

The limestone tests showed that, generally, the sulfate saturation in the scrubber liquor decreases (i.e., scaling potential decreases) with (1) increasing slurry effluent residence time, (2) increasing solids concentration in the scrubber slurry, (3) decreasing solids concentration in the discharge sludge, (4) increasing scrubber slurry pH, and (5) increasing liquid-to-gas ratio.

Figure 10 shows the sulfate saturation of the scrubber liquor as a function of slurry solids concentration and effluent residence time for the TCA reliability verification tests. All these tests were operated in closed liquor loop. In these tests, the slurry pH ranged from 5.2 to 6.1, tending to increase with increasing slurry effluent residence time. Included are two data points from TCA long-term reliability runs at 10 and 15 minutes residence time.

As seen in Figure 10, the sulfate saturation of the scrubber slurry was 190 percent at 4.4 minutes effluent residence time and 8 percent slurry solids concentration. Severe sulfate scaling of the bottommost TCA grid occurred under these conditions after 500 hours of operation. At 20 minutes residence time and 15 percent slurry solids concentration, the sulfate saturation was about 110 percent, and no significant scaling of the TCA grids occurred after 500 hours of operation. In the reliability test at 10 minutes residence time and 15 percent slurry solids concentration, sulfate saturation was about 130 percent, and less than 15 mils of sulfate scale formed on the bottommost TCA grid after 1200 hours of operation.

The calcium sulfate (gypsum) saturations of the scrubber liquors were obtained with the use of a chemical equilibria computer program. Using laboratory-measured liquor compositions, the equilibria program calculates the activities of the calcium and sulfate ions. The degree of saturation is equal to the product of the activities divided by the solubility product of calcium sulfate at the specified temperature. Calculations of sulfate saturations in this report were based on a solubility product for $CaSO_4 \cdot 2H_2O$ of 2.2×10^{-5} $gmole^2/liter^2$ at 50°C.

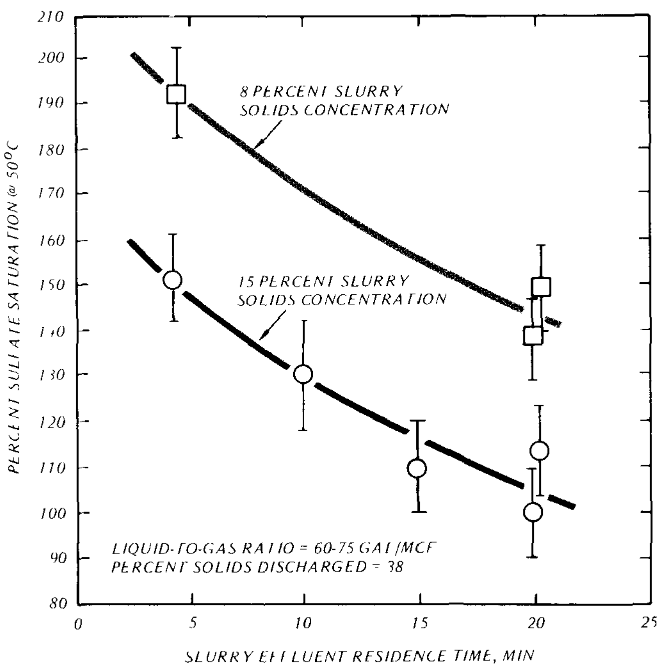


Figure 10. Effect of Effluent Residence Time and Slurry Solids Concentration on Sulfate Saturation for TCA Limestone Tests

5. LIMESTONE RELIABILITY TEST RESULTS WITH THE TCA

The major objective of the limestone reliability tests was to demonstrate long-term (2 to 5 months) operability of the TCA system, with emphasis on mist elimination and scrubber internals. This was achieved in TCA Run 535-2, terminated in December 1974, which ran with little scale and an essentially clean mist eliminator over a 3-month operating period (2325 hours on-stream). A summary of the operating conditions for this run is given in Table 1.

MIST ELIMINATION SYSTEM

The TCA mist elimination system consists of a six-pass, closed-vane, stainless-steel, chevron mist eliminator preceded by a wash tray (Koch Flexi-tray). (See Figure 1.)

The underside of the mist eliminator was sprayed continuously (0.3 gpm/ft^2) with clarified liquor diluted with makeup water.

A 2-inch depth of liquor on the wash tray (0.5 gpm/ft^2 combined rate from mist eliminator sprays and additional clarified liquor) was used to intercept the solids in the entrained mist. Entrained droplet solids concentration was reduced from 15 wt % to less than 0.5 wt %.

Initially in Run 535-2, the underside of the wash tray was intermittently steam sparged (125 psig, 1 minute/hour). At 2000 hours, the steam sparge was replaced by a continuous underside spray (0.3 gpm/ft^2) using wash tray effluent liquor.

A view of the top of the wash tray and underside of the mist eliminator after 1350 hours of TCA Run 535-2 is shown in Figure 11. It appears that this mist elimination system can be operated for a year or more at the run conditions tested.

Future plans include testing the TCA mist elimination system (1) at increased gas velocity (10 and 12 ft/sec) and (2) with the wash tray removed.

SCRUBBER INTERNALS

As demonstrated during limestone reliability verification testing, scrubber internals can be

Table 1

OPERATING CONDITIONS FOR TCA RELIABILITY RUN 535-2

Operating Time, hr	2325
Gas Velocity, ft/sec	8.6
L/G, gal/mcf	73
Pressure Drop (including Mist Elimination System), in. H_2O	6.5
Slurry Solids Concentration, percent	12-15
Effluent Tank Residence Time, min	15
Inlet SO_2 Concentration, ppm	2000-4000
Percent SO_2 Removal (controlled)	75-88
Scrubber Inlet Liquor pH	5.7-6.0
Percent Limestone Utilization (100 x moles SO_2 absorbed/moles $CaCO_3$ added)	65
Percent Sulfate Saturation @ 50°C	110
Percent Oxidation of Sulfite to Sulfate	10-28
Percent Solids in Discharge Cake	35-42
Dissolved Solids, ppm	6000

kept relatively free of scale if the sulfate (gypsum) saturation of the scrubber liquor is kept below about 135 percent. For TCA Run 535-2, the sulfate saturation of the scrubber slurry was 110 percent, and less than 20 mils of sulfate scale formed on the bottommost TCA grid during 2325 hours of operation. This scale growth rate would not interfere with normal scrubber operation over a 1-year operating period. Figure 12 shows the bottom bed of the TCA after 1350 hours of Run 535-2.

Until recently, the operating life of the 1½-inch-diameter, 5-gram plastic spheres has been a significant limiting factor in the long-term reliability of the TCA scrubber. High-density polyethylene (HDPE) spheres had an operating life of about 2000 hours before eroding through and filling with slurry. Thermoplastic rubber (TPR) spheres showed a weight loss of only 6 percent after 2500 hours. The TPR spheres tend to dimple, however, and can slip through the supporting bar-grids presently used in the TCA. This can be corrected by respacing the bar-grids.

There has been no evidence of significant erosion of the bar-grids in the TCA after more than 5000 hours of operation. The original wire mesh grids deteriorated during approximately 3000 hours of operation owing to vibrational wear at the points of contact.

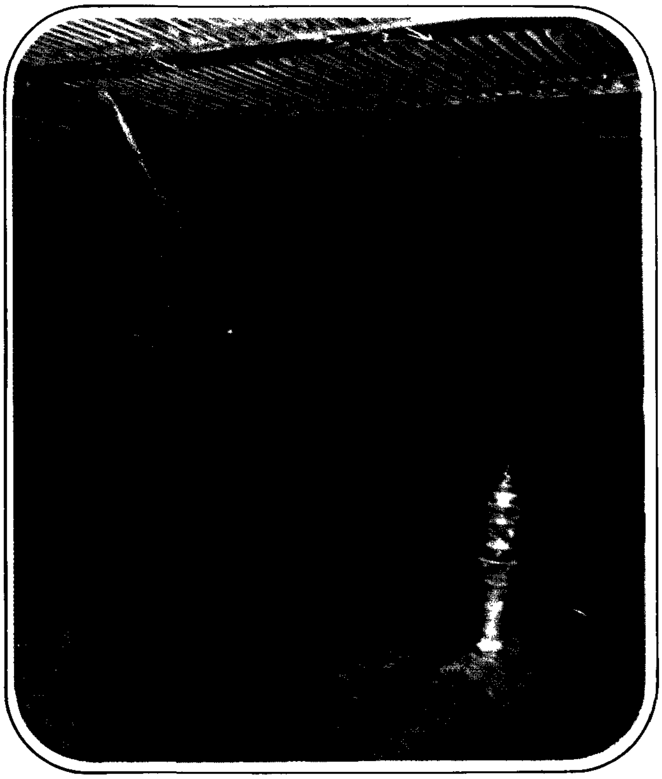


Figure 11. Wash Tray and Mist Eliminator after 1350 Hours of Operation during TCA Reliability Run 535-2

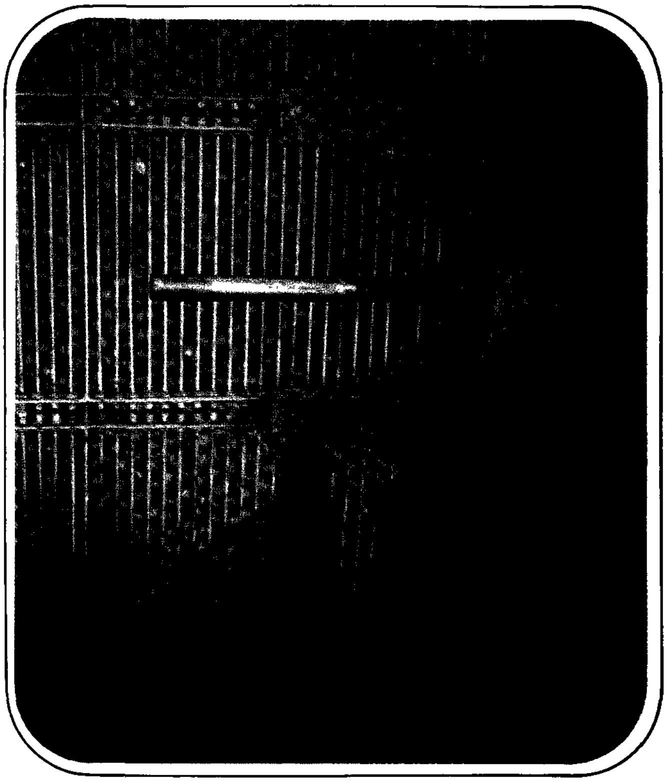


Figure 12. Internal View of TCA Showing Bottom Support Grid and Spheres After 1350 Hours of Operation during TCA Reliability Run 535-2

6. LIME RELIABILITY TEST RESULTS WITH THE VENTURI/SPRAY TOWER

The major objective of the lime reliability tests was to demonstrate long-term (2 to 5 months) operability of the venturi/spray tower system, with emphasis on mist elimination and scrubber internals. A successful run of long-term duration has not yet been achieved because of scale formation on the spray tower mist eliminator.

MIST ELIMINATION SYSTEM

The spray tower mist elimination system consists of a three-pass, open-vane, stainless-steel, chevron mist eliminator which has provision for underside and topside washing (see Figure 2). In tests of this system at a superficial gas velocity of 6.7 ft/sec and 8 percent slurry solids concentration, scale formation on the top mist eliminator vanes (of 100 to 200 mils/month) has been a constant problem. A variety of washing configurations have been tried in order to alleviate this problem.

Underside washing only, either continuously with low-pressure water at 0.3 gpm/ft^2 or intermittently with high-pressure water at 3 gpm/ft^2 (9 minutes every 4 hours at 45 psig), was unsuccessful in eliminating scale formation on the top vanes.

A combination of topside and bottomside washing was studied during venturi/spray tower Runs 609-1 and 610-1. A summary of the operating conditions for these runs is given in Table 2. The entire underside of the mist eliminator and a small area of the topside (14 ft^2) were washed intermittently (8 minutes every 4 hours) at high pressure (45 psig) with makeup water at a rate of 2.7 gpm/ft^2 for the underside and 1.0 gpm/ft^2 for the topside. At the termination of these runs, after 530 operating hours, the washed area was essentially clean, with less than 1 mil of solids accumulation, compared with an average of 70 mils scale buildup on the rest of the topside surfaces. Figure 13 shows the topside wash nozzle and the relatively clean mist eliminator

Table 2

OPERATING CONDITIONS FOR VENTURI/SPRAY TOWER RELIABILITY RUNS 609-1 AND 610-1

Total Operating Time, hr.	530
Spray Tower Gas Velocity, ft/sec	6.7
L/G, gal/mcf	90*
Pressure Drop, in. H_2O	12**
Slurry Solids Concentration, percent	8
Effluent Tank Residence Time, min.	24
Percent SO_2 Removal	80-98
Scrubber Inlet Liquor pH (controlled)	8.0
Inlet SO_2 Concentration, ppm	1800-3600
Percent Lime Utilization, (100 x moles SO_2 absorbed/moles CaO added)	86
Percent Oxidation of Sulfite to Sulfate	12-30
Percent Solids in Discharge Cake	43-52
Dissolved Solids, ppm	10,000

*60 for spray tower and 30 for venturi
**9 inches across venturi and 3 inches across spray tower and mist eliminator

surface beneath it. It is anticipated that the chevron mist eliminator can be operated for a year or more with underside and topside washing at the run conditions tested.

Carryover of water from the topside sprays caused reheater overloading during the runs. *This problem might be reduced by a sequential* sectional topside wash or by the use of a second mist eliminator to catch the entrainment from the topside sprays. These concepts will be studied during future testing.

SCRUBBER INTERNALS

As with limestone, the lime reliability tests have shown that scrubber internals can be kept relatively free of scale if the sulfate (gypsum) saturation of the scrubber liquor is kept below about 135 percent. Again, this can be accomplished with increased slurry solids concentration and/or with increased effluent residence time. The lime system was found to differ from limestone, however, in that sulfate saturation of the scrubber liquor is a strong function of inlet gas SO_2 concentration (i.e., SO_2 absorption rate).

The lime reliability tests have also shown that severe scale formation within the spray tower *does not necessarily limit scrubber operability.* Figure 14 shows a view of the spray tower internals (looking upward) after approximately 1 month of operation at a scrubber liquor sulfate saturation of 180 percent. The white gypsum scale on the scrubber internals did not noticeably interfere with the spray tower operation.

Initially, nozzles in the spray tower frequently plugged, but dual strainers installed in the circulating slurry lines greatly reduced this problem. Stainless-steel spiral-tip nozzles were badly eroded after about 4300 hours in service. Stellite-tipped nozzles have shown no measurable signs of erosion after approximately 4000 hours in service.

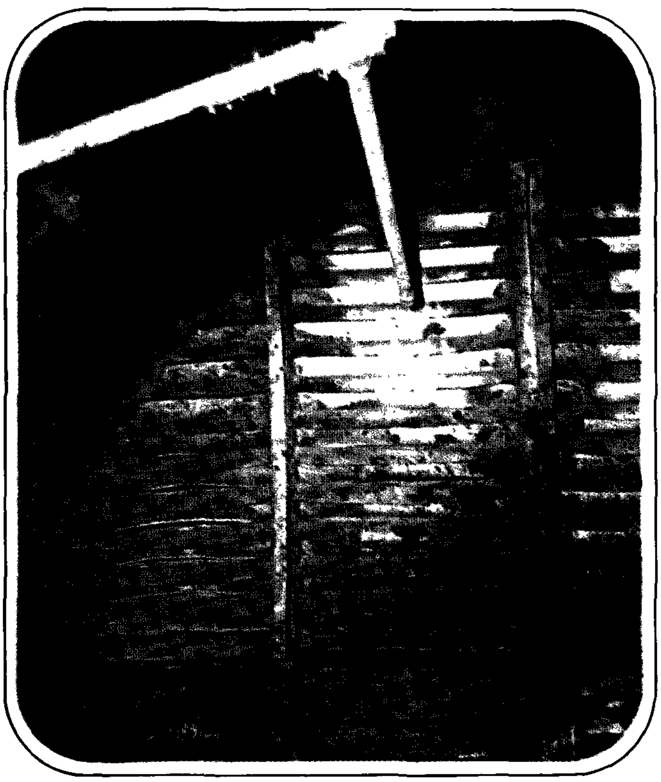


Figure 13. Topside of Spray Tower Mist Eliminator at Conclusion of Runs 609-1 and 610-1

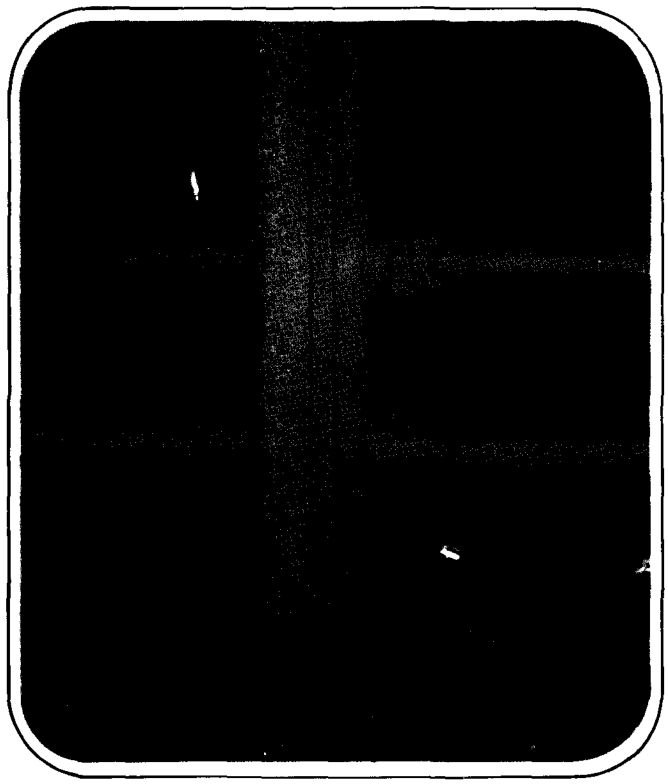


Figure 14. Spray Tower Internals Showing Gypsum Scale after One Month of Operation at 180 Percent Sulfate Saturation

7. OPERATING EXPERIENCE

This section highlights the operating experience during both lime and limestone wet-scrubbing tests at the Shawnee facility. Mist elimination systems and scrubber internals have been discussed previously and will not be described in this section.

CLOSED LIQUOR LOOP OPERATION

Most commercial scrubber systems are required to maintain a closed liquor loop. A closed liquor loop is achieved when the raw water input to the system is equal to the water normally exiting the system in the settled sludge and in the humidified flue gas. For lime/limestone wet-scrubbing systems, the solids concentration in the settled sludge is normally equal to or greater than 38 percent by weight.

Scaling potential is significantly affected by the quantity of raw water makeup, and meaningful reliability data can be obtained only by operating with a closed liquor loop. Because of excess water input, closed liquor loop operation was not achieved early in the test program during limestone factorial testing. Sources of excessive water included pump seal water, flue gas presaturation sprays, and water in the 10 to 20 wt % limestone slurry feed. To reduce water input, water seals were converted to air purge, slurry was substituted for water on the presaturation sprays, and the slurry feed concentration was increased to 60 wt % solids. As a result of these modifications, all testing in both lime and limestone systems has been in closed liquor loop operation since March 1973.

HOT-GAS/LIQUID INTERFACE

During the limestone reliability verification testing, there was a continual problem of soft solids buildup at the hot-gas/liquid interface in the TCA scrubber inlet duct, where the hot flue gas is cooled by slurry sprays to protect the vessel's rubber linings. The problem was solved by selecting the proper size, location, and orientation of the slurry spray nozzles and by soot blowing in the direction of the flue gas flow only.

The venturi scrubber is an extremely reliable gas-cooling device and does not require presaturation sprays.

REHEATERS

Fuel-oil-fired reheaters with external air supply and direct combustion in the flue gas stream were originally installed on the scrubber systems. They were hard to start, had frequent flame-outs, and generated considerable soot. Field modifications to provide an isolated combustion zone and installation of mechanical atomizing nozzles improved combustion, but burner flame-out continued to be a problem.

A fuel-oil-fired external combustion reheat system was installed on the venturi/spray tower system in March 1974. This unit has performed satisfactorily with high reliability for over 4000 operating hours.

FANS

Erosion, corrosion, pitting, scaling, etc., have been negligible on all three fans. Operation has been with 125°F flue gas reheat to give a fan inlet temperature of 250°F.

PUMPS

The major pumps used in alkali slurry service at the Shawnee test facility are rubber-lined variable-speed centrifugal pumps. In general, the rubber linings have shown excellent erosion-corrosion resistance and have remained in good condition. The original pumps had water-sealed packing, but were converted to air-purged packing during a boiler outage in February 1973.

LININGS

The neoprene rubber linings on the agitator blades and in the spray tower, TCA, process water hold tanks, pumps, and circulating slurry piping have usually been found to be in excellent condition, except for slight wear on some of the rubber-coated agitator blades. Hairline cracks have been noted in the glass flake lining on the effluent hold tanks and clarifiers, but the cracks did not appear to penetrate the entire thickness of the lining.

WASTE SOLIDS HANDLING

The test facility is equipped to study alternative methods of waste solids dewatering and disposal. Separate clarifiers are provided for each scrubber system. A belt-type rotary-drum vacuum filter and a horizontal solid-bowl centrifuge are common to the three systems.

The venturi/spray tower system has a 20-foot-diameter clarifier, while the TCA unit is 30 feet in diameter. The solids concentration in the underflow of the larger TCA unit has approached the expected final settled sludge concentration (approximately 38 wt %), but the underflow from the smaller unit has averaged only about 25 wt %. To achieve closed liquor loop operation, the smaller clarifier has to be used in series with the filter or centrifuge.

Under normal operations, the belt-type rotary-drum vacuum filter produces a filter cake containing 50 to 55 wt % solids from limestone and 45 to 50 wt % solids from lime slurries. Filter operation has been significantly hampered by the short life (usually less than 260 hours) of the filter cloth.

The continuous solid-bowl centrifuge produced a cake with 55 to 65 wt % solids from limestone slurry, and the centrate solids averaged 0.5 to 1.0 wt %. However, erosion made a major repair of the unit necessary after about 1400 hours of operation. It was concluded that the centrifuge was not an acceptable solids dewatering device for the Shawnee test conditions.

INSTRUMENTS

Two types of pH meters have been used in slurry service: (1) in-line flow-through meters and (2) submersible electrode meters. The performance of the in-line flow-through meters has been unsatisfactory because of the erosion and high rate of failure of the glass cells and the frequent plugging of the sample lines. The submersible electrode meters have been free of such problems during approximately 9000 hours of operation.

Operating experience has been obtained with three types of density meters in slurry service: (1) radiation meters, (2) differential pressure (bubbling tube) meters, and (3) vibrating U-tube meters. The radiation meter has a continual calibration shift which is accelerated by scale formation. The gas line on the differential pressure meter plugs frequently and requires significant maintenance, but the meter is accurate when clean. The vibrating U-tube meters were installed in September 1973 in two locations. The performance of this type of density meter has thus far been encouraging.

Slurry flow rates have been measured by both magnetic and differential pressure (both orifice and Annubar) flowmeters. Performance of the magnetic flowmeters and the orifice flowmeters has generally been adequate. Annubar meters plugged frequently and required excessive maintenance.

Operating experience with control valves in slurry service has generally been unsatisfactory. Severe erosion and frequent plugging result from the throttling operation. This has been observed with stainless-steel plug valves, stainless-steel globe valves, and rubber pinch valves. Satisfactory and trouble-free flow control has been experienced only with variable-speed pumps.

For further information:

Detailed progress reports, EPA-650/2-73-013 and EPA-650/2-74-010, are available from the National Technical Information Service, Springfield, Va. 22151.

A third detailed report is currently being prepared. If you wish to be notified when this report is available write:

Technology Transfer
Environmental Protection Agency
Washington, D.C. 20460
