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EPA
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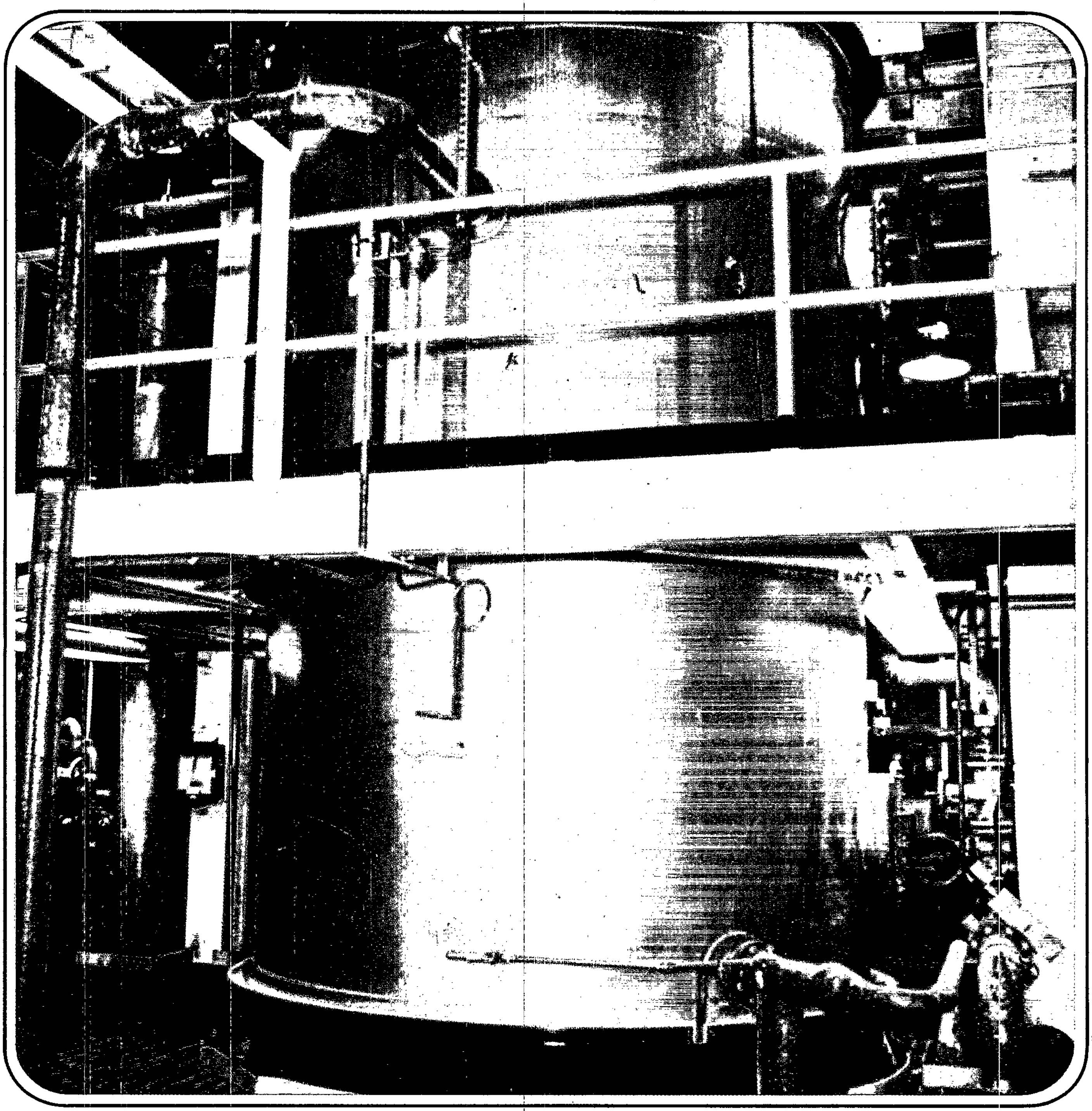
CAPSULE REPORT

DOUBLE ALKALI FLUE GAS DESULFURIZATION SYSTEM APPLIED AT THE GENERAL MOTORS PARMA, OHIO FACILITY

U.S. EPA
OFFICE OF RESEARCH AND DEVELOPMENT
INDUSTRIAL BOILER DEMONSTRATION FACILITY



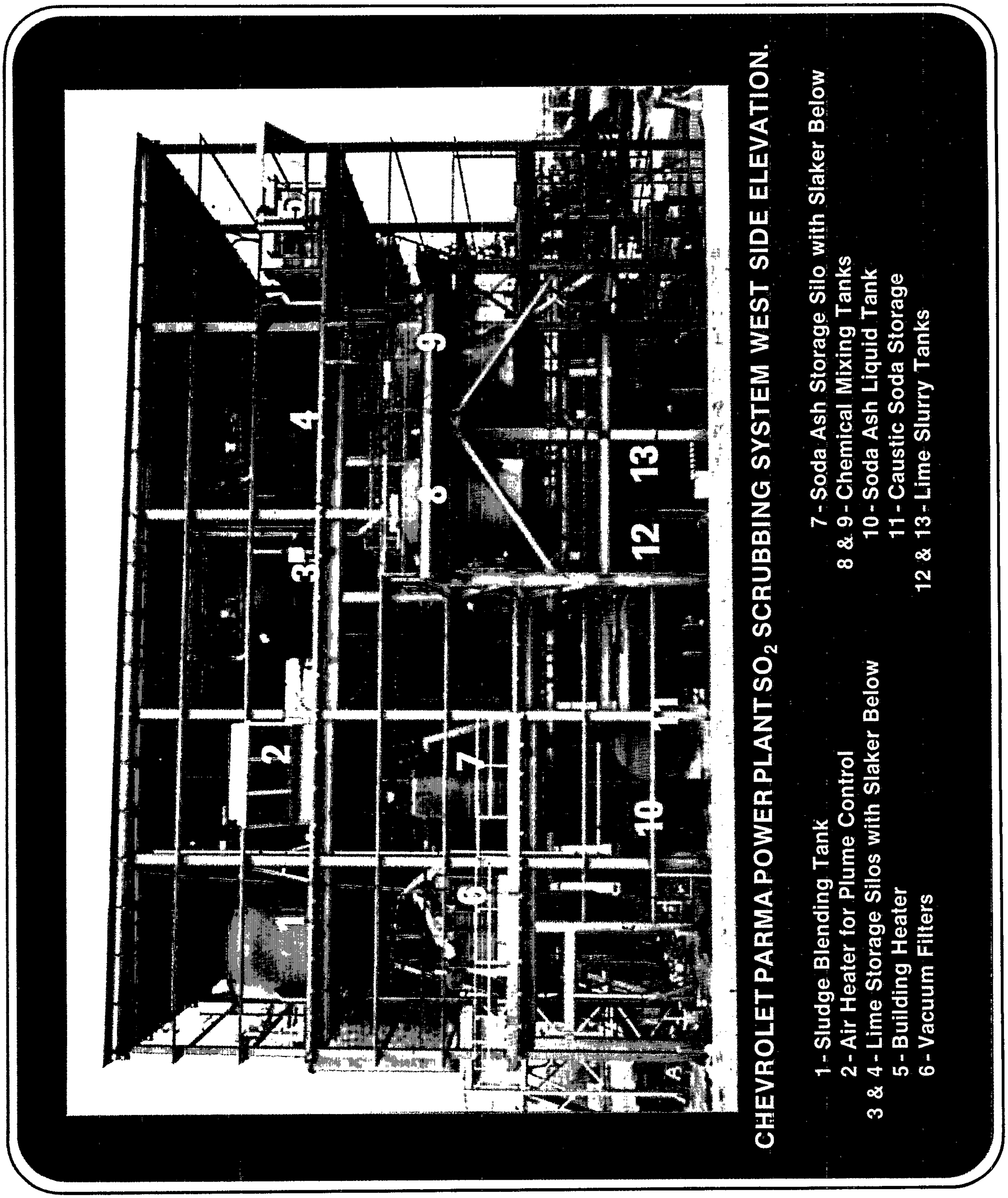
This report has been jointly prepared by the Environmental Research Information Center (Technology Transfer) and the Industrial Environmental Research Laboratory (Research Triangle Park). The EPA selected Arthur D. Little, Inc. to evaluate the General Motors' Chevrolet-Parma double alkali system located near Cleveland, Ohio. This final report, EPA-600/7-77-005, (or PB 263-469), is available from the National Technical Information Service, Springfield, Virginia, 22151, at a cost of $6.00 per copy.

For further information on the General Motors' double alkali system and other EPA-sponsored programs, write:

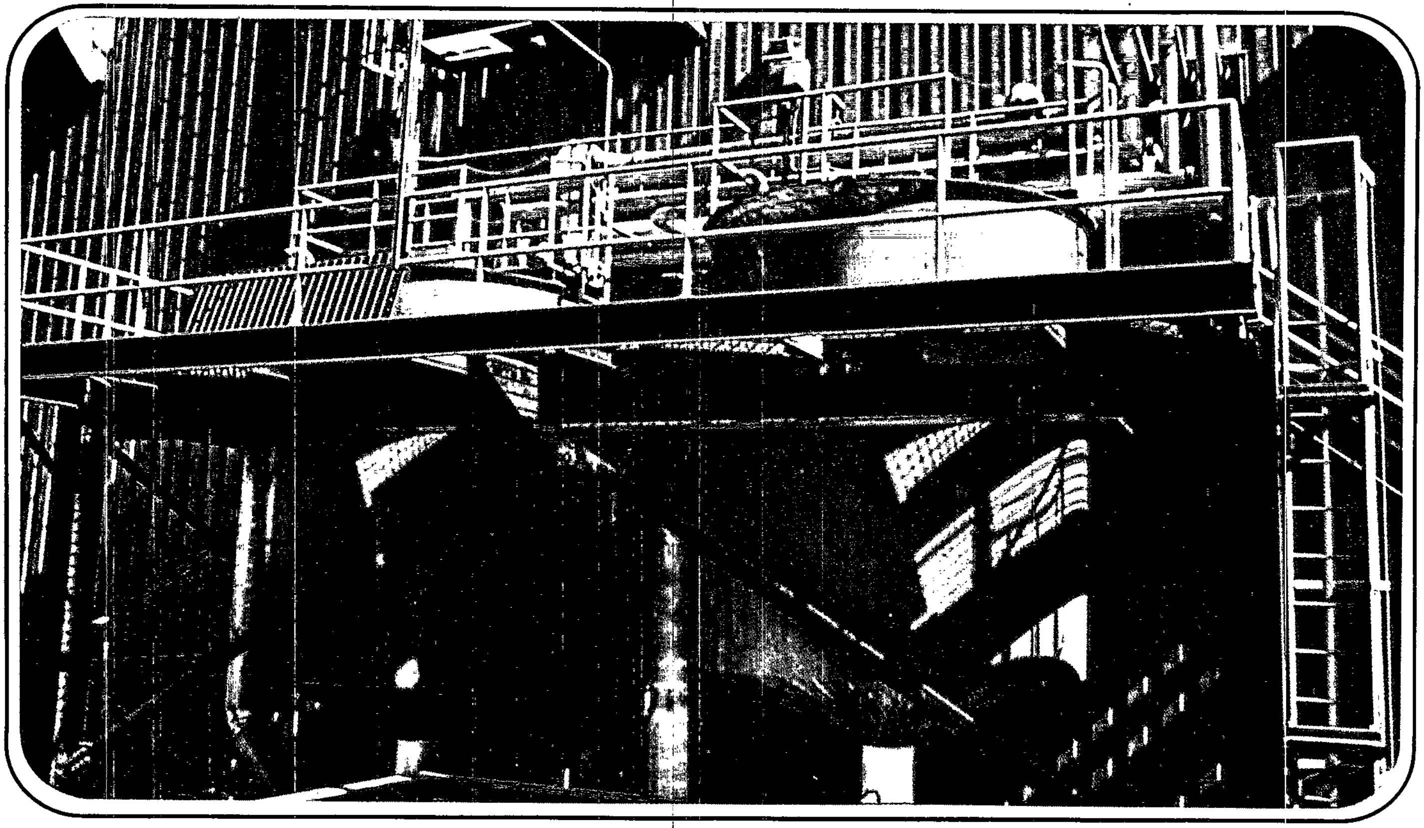
Utilities and Industrial Power Division
Industrial Environmental Research Laboratory
Research Triangle Park, N.C. 27711

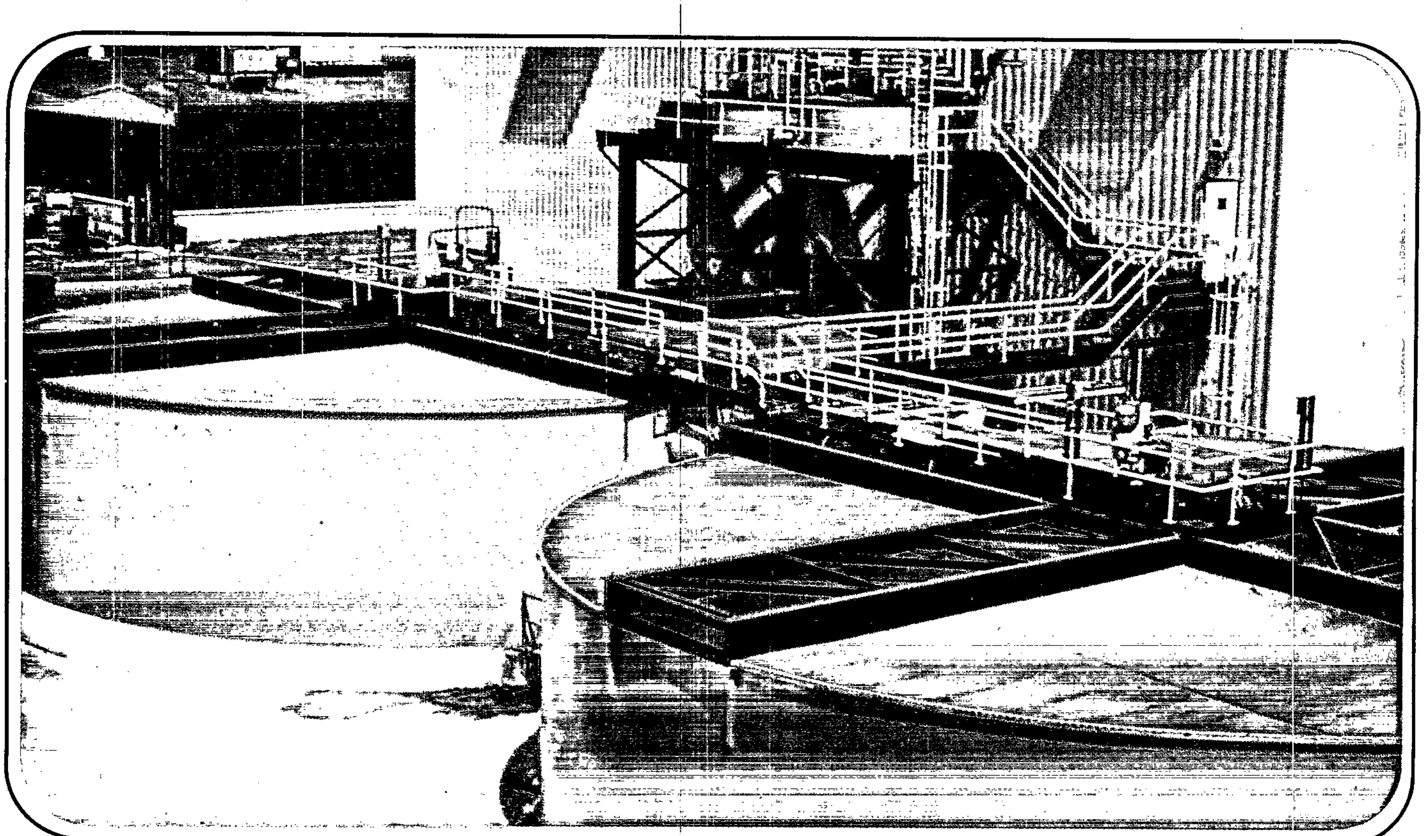
Photographs in this capsule report were supplied by the General Motors Corporation, Environmental Activities Staff.

View of equipment during construction.



Chemical mix tanks.





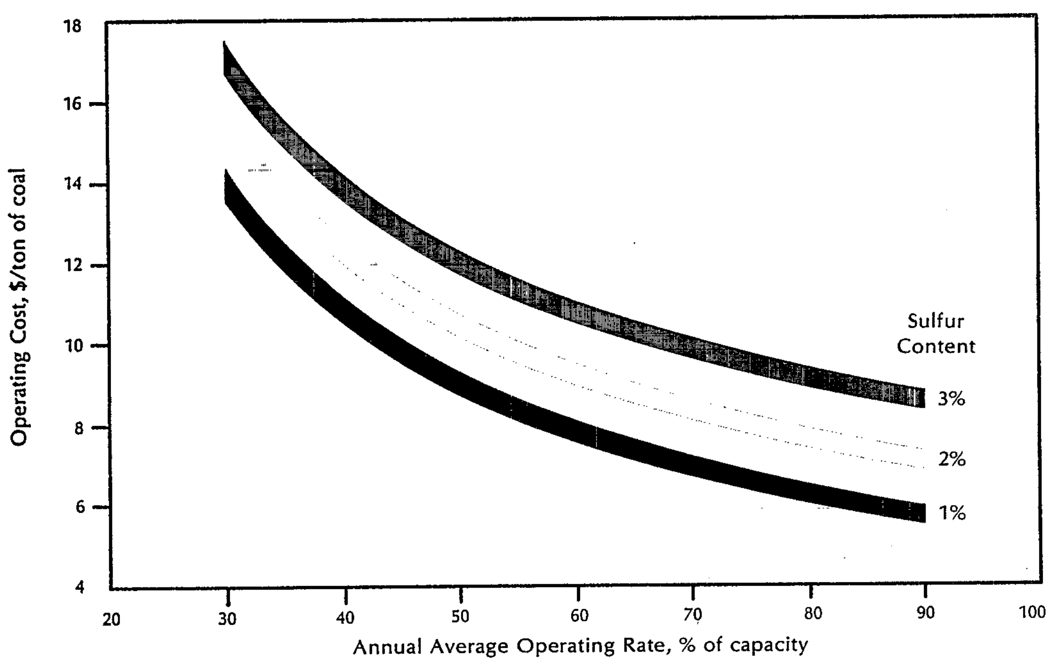
Clarifiers.

Table 4
Estimated Double Alkali Economics
Total Capital Cost = $3.2 Million (1975$)

Parameter	Scrubber operating costs (1976$) Total $	$/ton of coal
Capital Charge	250,000	6.90
Chemicals	26,500	0.73
Utilities	33,800	0.94
Solid Waste	46,100	1.27
Labor	113,400	3.13
Maintenance	77,200	2.13
Totals	547,000	15.10

Based upon burning 36,000 TPY coal (i.e., approximately 31% load factor).

Figure 4. Effect of Sulfur Content and Operating Rate on Operating Cost



5. ECONOMICS

The costs of constructing and operating a Double Alkali System, as they are for any flue gas desulfurization system, are quite variable depending primarily on:

- coal properties and boiler characteristics,
- whether the system is constructed along with a new boiler or retrofitted to an existing power plant,
- space availability,
- specific plant requirements such as spare capacity or provision for expansion,
- size and operating rate, and
- geographic location.

This section presents the overall economics of the Chevrolet-Parma system and describes some of the unique aspects of the facility which affect its cost of operation.

The construction cost of General Motors' Double Alkali System was 3.2 million, reported in 1975 dollars. This figure includes all construction-related activities including engineering which was performed by the Argonaut Division of General Motors. Table 3 summarizes the major factors which contribute to this capital investment. One important factor which affects the capital investment for any retrofit situation is the space availability for scrubbers and auxiliary equipment. At Parma the retrofit was relatively easy and most equipment is housed in a large multi-level building.

The operating costs of the double alkali system per ton of coal burned are shown in Table 4.

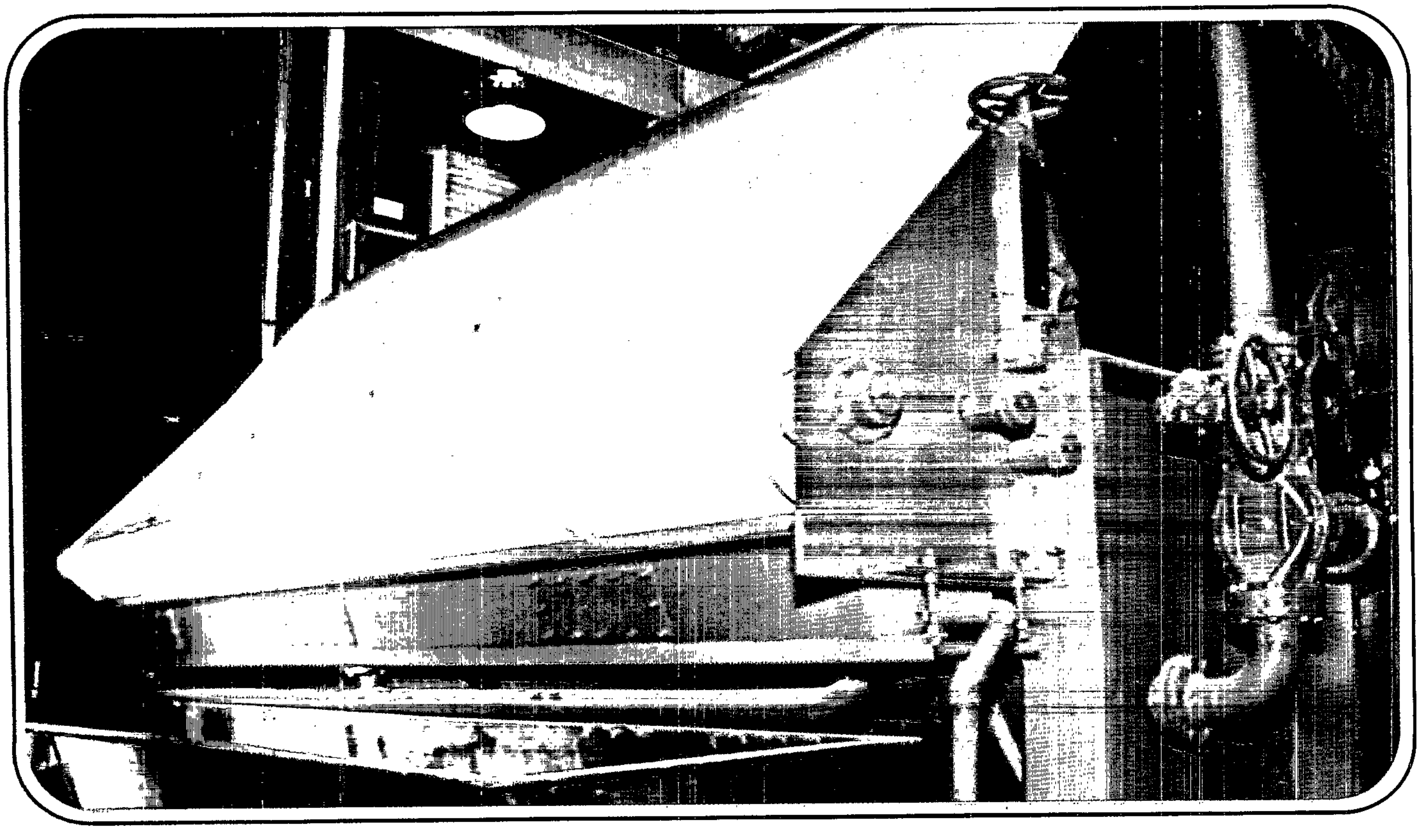
One operating cost factor requiring special note is the capital charge. Industrial firms will use differing capital charge rates depending on their own capital structures and the specific method of financing the plant. The rate of less than 10% used in this instance by General Motors is perhaps lower than most. However, the capital costs are probably somewhat higher than would be typical of future installations, as they would not generally incorporate all the operating flexibility afforded in this first design. Therefore, the capital charge of $6.90 per ton of coal would be a reasonable figure in many instances.

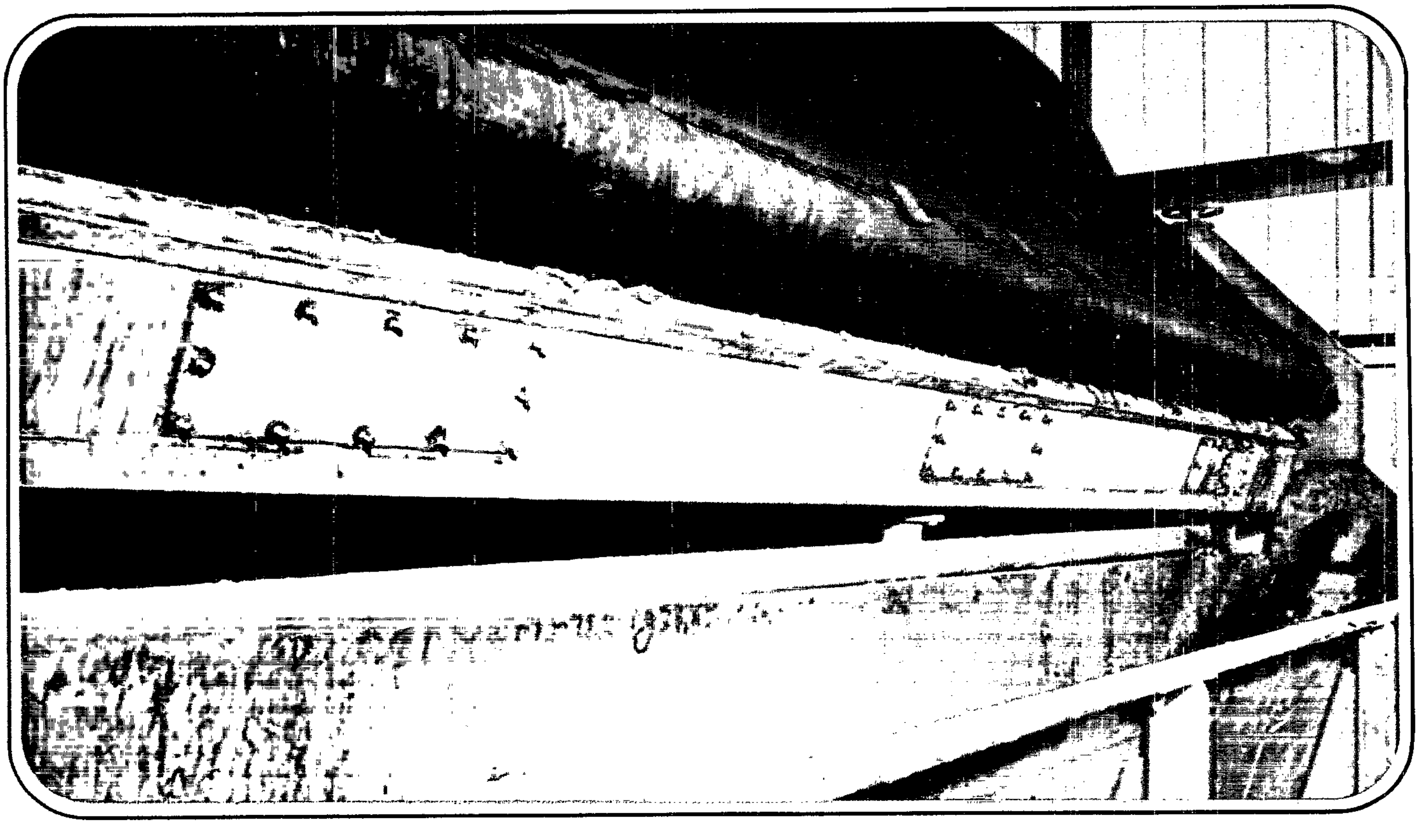
Further affecting the capital charge would be the relative values of installed capacity and annual operating load. General Motors' Chevrolet-Parma average annual load factor is 31% of capacity based on 33 x 10^6 kg/yr (36,000 tons/yr) coal. If the steam load were to increase and quantity of coal burned increased accordingly, the capital charge (per ton of coal) would drop. Figure 4 generalizes the operating costs for double alkali to consider the effect of operating rate (load factor).

Table 3
Factors Impacting Double Alkali System Capital and Operating Costs

Plant Investment	$3.2 million (1975 dollars)
Capacity	Scrubbers: 4 scrubbers @ total equivalent 32 Mw Reactors and sludge handling; capable of expansion to 5 scrubbers @ total equivalent 40 Mw Annual coal burn: 107x10^6 Kg (118,000 tons) capacity
Operating Rate	Annual coal burn: 33x10^6 Kg (36,000 tons) average
Process Building	Spacious, four-level building houses: absorbers, all other process equipment and storage silos excluding the large clarifiers and reactors
Excess Capacity	Fully-spared vacuum filter All equipment and piping conservatively designed for this first-of-a-kind installation
Sulfur Removal	Design: 90% based on 3% sulfur coal Average operating: 90% based on 2% sulfur coal
Operating Requirements	Consumptions based on best sustained operation to date Cost based on local market conditions

Vacuum filter.





deliberately to increase oxidation. Consistent with expectation, the higher oxidation rates produced improved solids because of the prevalence of gypsum crystals.

Entrainment

Isolated instances of high entrainment from the scrubbers were evidenced by considerable dense mist emerging from the scrubber stacks and carrying down from the roof to the ground. An entrainment test showed that, although the carryover was significant, entrainment of scrubber liquor was within the design specifications.

A contributing factor to the periodic entrainment problem is the location of the demister relative to the transition piece at the top of the scrubber. Immediately above the full-diameter demister pad is a square reducer through which the outlet gas passes into a high velocity duct. Inspections of solids buildup on the pad indicate that the gas is not utilizing the full cross section of the demister as it contracts to flow into the duct. A future design would probably include larger overall vertical distances both below and above the demister pad to ensure its effective operation. Since the demisters are relatively free of plugging in a double alkali application, there is no need for continuous washing of the demister pad.

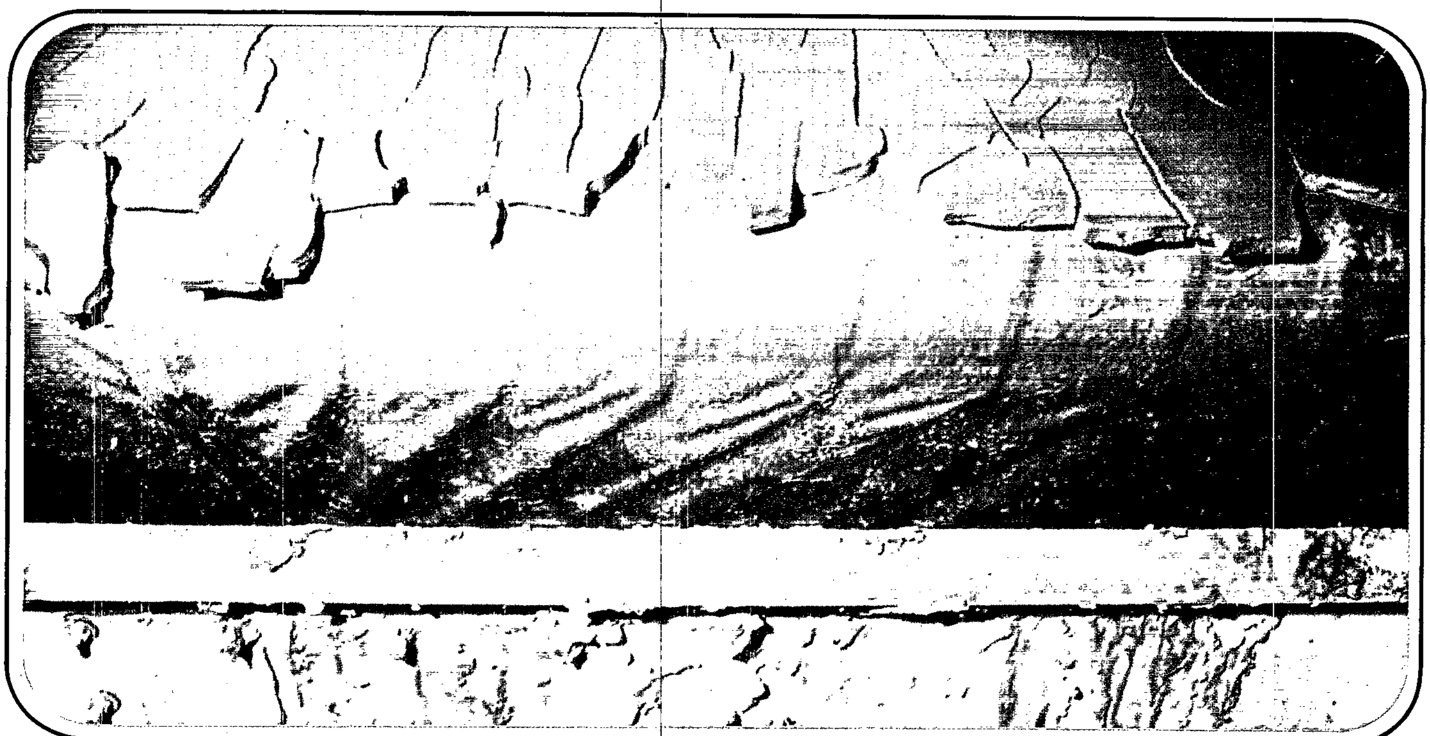
Reliability

During the 21-month test program the scrubbers ran a total of 37.5% of the boiler operating hours and were available for an additional 23.5%. The maximum potential then was 61.0% over this period. When downtime for major system modifications is excluded, the total was 77.9%.

These major modifications involved four periods:

- October 7, 1974 to November 12, 1974, when a number of changes were implemented. Included were instrument recalibration, cleaning of control valves, installation of sample petcocks, installation of cake wash nozzles, and investigation of chemical mix tank and clarifier overflow plugging problems.
- March 14, 1975 to April 15, 1975, when General Motors was investigating the sulfite plugging problem in the scrubbers. Ultimately, the scrubber operating mode was changed, requiring some repiping of the recirculating and regenerated liquor lines.
- June 27, 1975 to September 8, 1975, when open trough lines were installed in the overflows of both chemical mix tanks and clarifier number 1, all of which had plugged seriously at various times.
- March 5, 1976 to March 29, 1976, when a section of the regenerated liquor line was replaced along with a new orifice plate. Both were intended to afford accurate flow monitoring at low flow rates relative to the original system design. At the same time the instrumentation on the lime feed line was replaced to permit better control of the lime stoichiometry.

Although the operation of the General Motors Double Alkali System has not yet achieved an availability in the 90% range over several months, General Motors has gained considerable experience in equipment and process operability and is continuing to make modifications to improve its plant. This experience should be a valuable resource to any prospective user of dilute double alkali technology.



Filter cake.

2. PROCESS DESCRIPTION

The double alkali process in general consists of four major sections, as shown in Figure 1: Absorption (or scrubbing); Regeneration; Solids Dewatering; and Calcium Control.

Absorption Section

In the Absorption Section an alkaline solution of aqueous sodium hydroxide and sodium sulfite are contacted directly with the dirty flue gas leaving the boiler. SO_2 is removed from the gas by reaction with these sodium compounds to form additional sodium sulfite plus some sodium bisulfite:

$$2\ NaOH + SO_2 \rightarrow Na_2SO_3 + H_2O$$

$$Na_2SO_3 + SO_2 + H_2O \rightarrow 2NaHSO_3$$

Simultaneously, some sodium sulfite reacts with the oxygen in the flue gas to produce sodium sulfate:

$$Na_2SO_3 + 1/2\ O_2 \rightarrow Na_2SO_4$$

Thus, the scrubber effluent solution consists of a mixture of Na_2SO_3, $NaHSO_3$, and Na_2SO_4.

Regeneration Section

The capacity of the scrubbing solution to absorb SO_2 is depleted as it passes through the scrubber. Therefore, a portion is continuously withdrawn to the regeneration section to begin reactivating the absorbent solutions so that it may be reused.

This regeneration is accomplished by reaction with lime:

$$Na_2SO_3 + Ca(OH)_2 \rightarrow 2\ NaOH + CaSO_3\downarrow$$

$$2\ NaHSO_3 + Ca(OH)_2 \rightarrow Na_2SO_3 + 2\ H_2O + CaSO_3\downarrow$$

$$Na_2SO_4 + Ca(OH)_2 \rightarrow 2\ NaOH + CaSO_4\downarrow$$

The reactor effluent, then, is a mixture of soluble sodium species and insoluble calcium salts.

Solids Dewatering Section

To separate the solids from the liquor, the reaction products are taken to the Dewatering Section, which serves three major purposes: (1) to remove all traces of insoluble solids from the regenerated scrubbing liquor to avoid the chance of solids plugging the scrubber; (2) to concentrate the solids to a low level of moisture to minimize the tonnage of waste material; and (3) to wash the waste solids to reduce the soluble solids content and minimize sodium losses and makeup requirements. With low solubles content the solids have minimal impact on the environment when landfilled, and sodium is conserved within the double alkali process.

The major pieces of equipment included in the Dewatering Section are a clarifier to separate the solids by gravity from the regenerated liquor and a rotary vacuum filter to further concentrate the solids from the clarifier underflow and wash them before they are discharged for disposal.

The filtered solids are usually washed with fresh water to remove the solubles from the filter cake to as low a level as possible. Since there is no liquid purge from the system, the quantity of this fresh water makeup is limited by the need for water in the system to replace evaporation losses in the scrubber.

Calcium Control Section

Although the insoluble calcium is effectively removed from the regenerated liquor in the Solids Dewatering Section, some soluble calcium remains. Depending on process conditions, this soluble calcium can combine with SO_2 or CO_2 from the flue gas to produce $CaSO_3$ or $CaCO_3$. These compounds, if present in sufficient quantity, can then precipitate and build up on surfaces within the scrubber and seriously affect its operation.

The concentration of soluble calcium depends on the operating mode of the system. In the "concentrated mode", the concentration of the active species is greater than 0.15 molar and the concentration of the soluble calcium is quite low. However, in the "dilute mode", the total molarity of the active species is less than 0.15 molar and the soluble calcium concentration is considerably higher, requiring softening with carbonate,

$$Ca^{++} + CO_3^{=} \rightleftarrows CaCO_3\downarrow$$

The insoluble $CaCO_3$ is removed from suspension in a second clarifier of a design similar to that used in the Solids Dewatering Section. The clarified overflow is then returned to the Absorption Section while the concentrated solids are sent to the Dewatering Section to be filtered along with the sulfur salts.

The Parma Facility

Boilers

The steam plant at Parma contains four boilers, two with a nominal steaming capacity of 27,000 kg/hr (60,000 lbs/hr) and two of 45,000 kg/hr (100,000 lbs/hr). They are spreader stoker fired with traveling grates and operate with variable excess air rates in the 100% range. The two larger boilers are equipped with economizers with resultant lower flue gas temperatures than the smaller boilers. Each boiler was equipped with existing mechanical dust collectors for primary particulate control. Normal burning of medium and high sulfur (2-3%) eastern coal plus occasional lower sulfur waste oil results in flue gas generally containing 800-1300 ppm by volume of SO_2.

Absorption System

Figure 2 is a flow schematic of the General Motors dilute mode system. In the scrubber, SO_2 removal is effected by contact of saturated flue gas with a sodium solution circulating through the scrubber at a rate of 2.7 liter/m³ (0.02 gal/ft³) of flue gas.

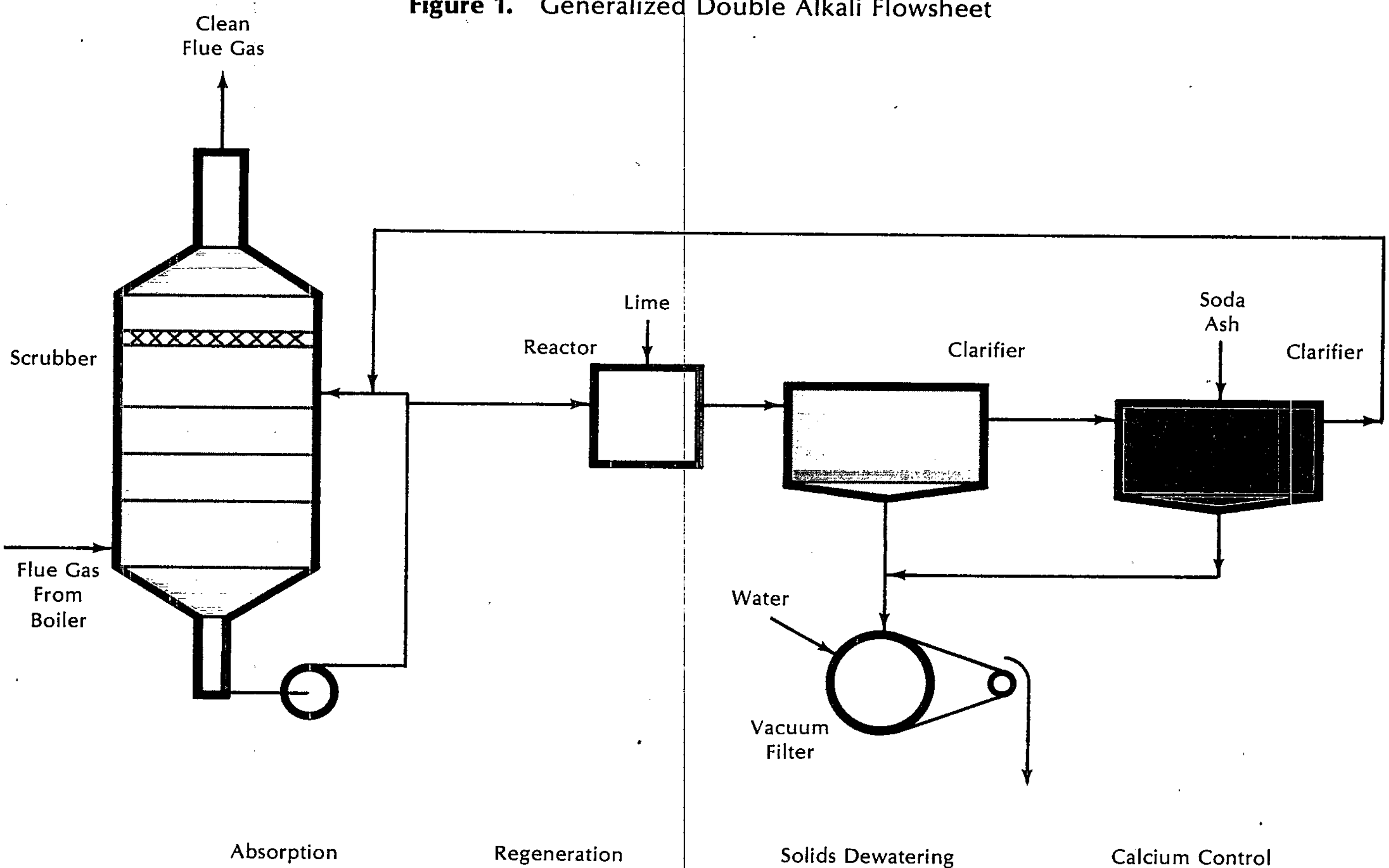
Each scrubber was installed to control the emissions from its respective boiler, i.e., no provision was

Table 1
Summary of Operational Double Alkali Scrubbing Processes

Owner	Location	Size Mw Equiv.	No. Boilers	Startup Date
General Motors Corp.	Parma, Ohio	32	4	March, 1974
Caterpillar Tractor Co.	Joliet, Ill.	18	2	September, 1974
Caterpillar Tractor Co.	Mossville, Ill.	57	4	October, 1975
Gulf Power/Southern Services, Inc.	Sneads, Fla.	20	1	February, 1975

Table 1 summarizes the double alkali systems which have been operated in the United States.

Figure 1. Generalized Double Alkali Flowsheet



1. SIGNIFICANCE

Much of the emphasis regarding the application of flue gas desulfurization processes has been in connection with utility coal and oil fired power plants. However, a significant growing segment of high sulfur fuel consumption is in the industrial production of steam and electric power. Industrial use of coal, other than utility and metallurgical, was about 61 megatonnes (67 million tons) in 1975 in the United States. This represents 12% of the coal consumed for all purposes in that year.

Low sulfur fuels are becoming less available to industrial consumers, and synthetic fuels will not be available on a significant scale for many years. New federal regulations may require even users of low sulfur coal to reduce sulfur emissions by requiring the best available control technology. Therefore, it is likely that flue gas desulfurization (FGD) will be the most widely implemented technique for control of sulfur dioxide (SO_2) emissions.

FGD processes are generally categorized as either "regenerable" or "throwaway" processes. The regenerable processes absorb SO_2 and recover its sulfur value for sale in some form, usually as sulfuric acid, elemental sulfur, or liquid SO_2. On the other hand, throwaway processes produce a solid waste material consisting of calcium sulfite and sulfate for disposal. The choice between these approaches depends on the comparative economics including the local market conditions for byproduct sulfur values and the cost of sludge disposal.

There are two types of throwaway systems producing solid wastes: (1) direct contact lime or limestone scrubbing; and (2) double (or dual) alkali. Generally, double alkali is capable of high SO_2 removal efficiencies and better alkali utilization and may be more economical in many high sulfur coal applications. Further, if on-site sludge disposal is not possible, the superior dewatering properties of the double alkali waste would enhance its transportability and disposability.

Application of the double alkali concept evolved in part as a result of successful sodium scrubbing applications in the early 1970's such as those at Nevada Power Company and General Motors' St. Louis Assembly Plant. To minimize the difficulty of treating and disposing of the sodium liquor waste and to conserve its sodium value, the double alkali process regenerates the active SO_2 absorbing species by reaction of spent absorbent with lime, producing insoluble calcium-sulfur waste salts. Thus, no liquid stream (other than the liquor wetting the washed solids) needs to be purged from the system.

Double alkali systems may be operated in either a dilute or concentrated mode. The concentrated mode generally allows lower flow rates with a consequent reduction in plant investment and operating cost. Further, this mode requires no special precautions to prevent scaling in the scrubber. However, operation in a concentrated mode is limited to applications where the oxidation rate of absorbed SO_2 is less than about 25%. This may be a constraint common among industrial boilers — particularly older ones — operating with relatively high excess air and/or burning low or medium sulfur coal. On the other hand, operation in a dilute mode is not constrained by an upper level of oxidation; in fact, high oxidation rates usually enhance the properties of the waste sludge in the dilute mode.

In 1969 General Motors began pilot operations of its Double Alkali SO_2 Control System to determine the applicability of stack gas scrubbing to its industrial powerhouses. General Motors chose Double Alkali Scrubbing on the basis of four criteria:

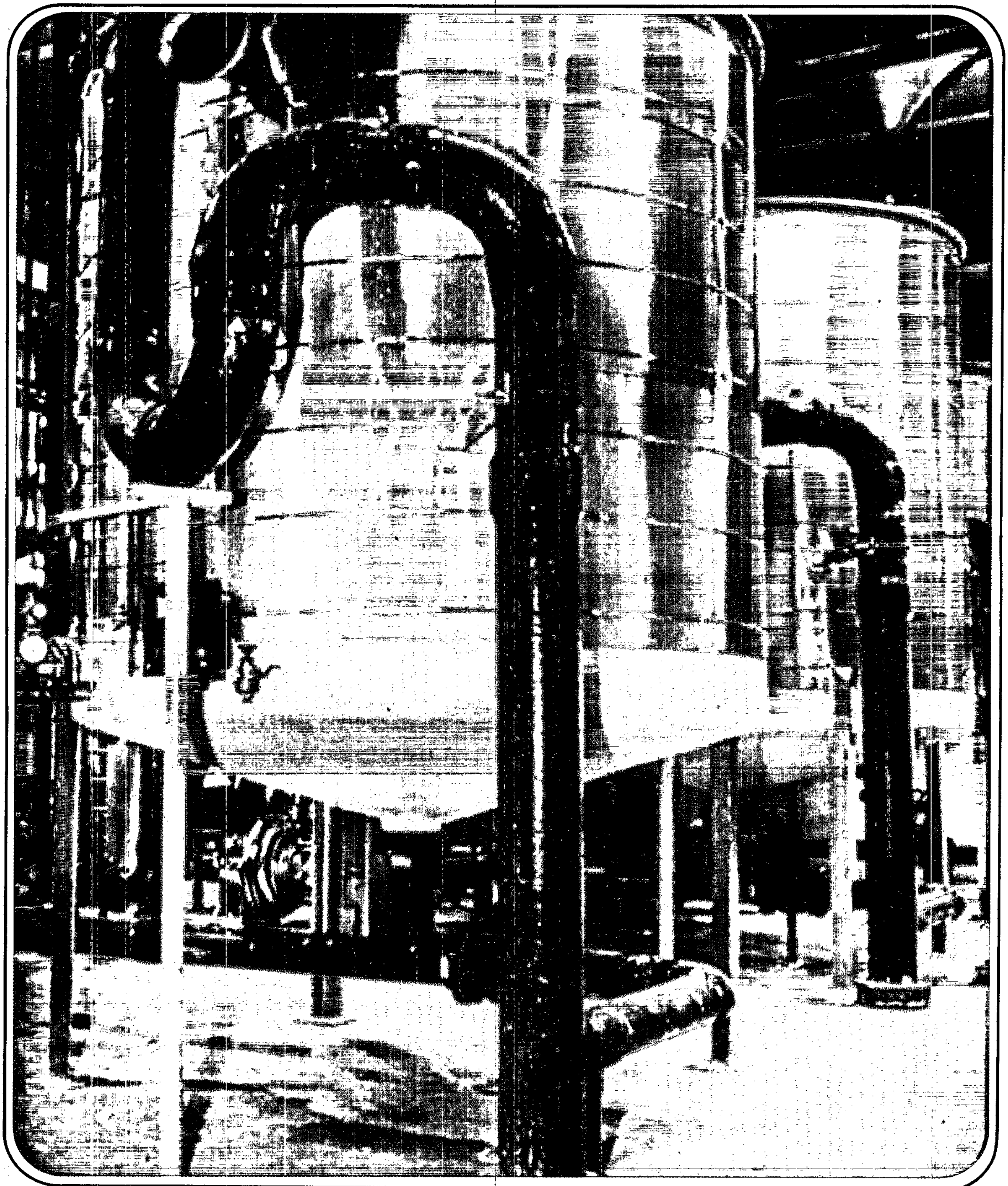
- high potential reliability of process and equipment
- simplicity permitting freedom of powerhouse operation
- byproduct readily disposed
- economics competitive with other options

Using data from its two-year pilot plant development program, General Motors designed and constructed a complete industrial-scale demonstration plant capable of handling the emissions from all four coal fired boilers at the Chevrolet-Parma plant near Cleveland, Ohio. The Parma steam plant has a combined steam generating capacity of 145,000 Kg/hour (320,000 lbs/hour). The design provides for incorporation of a future, fifth 36,000 Kg/hour (80,000 lbs/hour) boiler by addition of a single additional scrubber.

The prototype system was placed in operation in March, 1974. After an initial startup period, General Motors and EPA began a cooperative program in which Arthur D. Little, Inc., as contractor to EPA, observed the extended operation of the facility from August, 1974 to May, 1976 and tested it intensively over three one-month periods.

This report describes the results of the test program at Parma. In summary, the system has demonstrated a consistant 90% SO_2 removal capability. Operating reliability has improved during the test program after some difficulties, principally in the early months of operation. A more detailed description of the test program results are available in an EPA report entitled, "Evaluation of the General Motors Double Alkali SO_2 Control System" (EPA-600/7-77-005) published January, 1977 (NTIS Report No. PB 263-469).

Scrubber recycle tanks.



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