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Project Summary

Economic Evaluation of Advanced Limestone, Davy S-H, and Dowa Gypsum-Producing FGD Processes

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The economics of three gypsum-producing flue gas desulfurization processes were evaluated: advanced limestone (in-loop forced oxidation with adipic acid additive), Davy S-H (lime, and Dowa (aluminum sulfate, limestone). For a 500-MW power unit burning 3.5% sulfur coal and meeting the 1979 New Source Performance Standards, capital investments in 1982 costs are $93 million ($186/kW) for the advanced limestone process, $116 million ($231/kW) for the Davy S-H process, and $121 million ($243/kW) for the Dowa process. First-year annual revenue requirements in 1984 costs for these processes are $26, $33, and $32 million (9.4, 11.9, and 11.7 mills/kWh), respectively. The lower capital investment and annual revenue requirements of the advanced limestone process are due in part to the use of adipic acid, which allows partial scrubbing at 95% removal. The Davy S-H process has slightly higher annual revenue requirements than the Dowa process because lime is used instead of limestone. Changes in power unit size and coal sulfur content affect the costs of all three processes similarly. The Davy S-H process is more sensitive to raw material costs because lime is used. Landfill waste disposal is a minor cost element in all three processes.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Since 1967, the Tennessee Valley Authority (TVA) has been evaluating the economics of flue gas desulfurization (FGD) processes and related technology of electric utility power plants. Many of these evaluations have been sponsored by the U.S. Environmental Protection Agency (EPA) as part of its FGD research and development program. The major objective of each evaluation is to prepare economic analyses that are representative of current U.S. utility power plant conditions on a consistent basis that allows equitable process comparisons.

This study for EPA is the fifth in a series begun in 1977 to evaluate the economics of advanced FGD processes that have promise of commercial development. Three gypsum-producing FGD processes with landfill disposal are evaluated in this study: a limestone scrubbing process with adipic acid addition and forced oxidation (the advanced limestone process), the Davy S-H (Saarberg-Holter) process, and the Dowa process.

Although the technology is not new, production of gypsum (rather than calcium sulfite sludge) in limestone scrubbing is an emerging FGD technology which has only recently attracted wide commercial interest in the U.S. In Japan, many limestone and lime FGD systems produce gypsum by the forced-oxidation method since there are few natural gypsum deposits and the byproduct FGD gypsum can be sold to the wallboard and cement industries. In the U.S., the major emphasis has not been on producing gypsum for sale, but to solve the waste problems associated with disposal of calcium sulfite sludge. Calcium sulfite sludge forms an unstable semiliquid when disposed of in a pond, is difficult to dewater, and must be stabilized to be disposed of by landfill. Gypsum slurries are easier to dewater, can be disposed of in a landfill without stabilization, and can be dewatered to 80% to 85% solids with a conventional vacuum filter. The filter cake, resembling a moist soil, is easily handled by conventional solids-handling equipment. Although some byproduct FGD gypsum can probably be sold to U.S. wallboard and cement manufacturers, this evaluation assumes that all waste gypsum is landfilled.

Process Description

The advanced limestone process is similar to the basic limestone slurry process except that: (1) adipic acid is added to the scrubbing liquid to enhance SO_2 removal and increase limestone utilization, and (2) forced oxidation by air-sparging is incorporated to produce gypsum. The design and operating conditions are based in part on data from EPA-sponsored tests at TVA's Shawnee test facility. The process uses a counter-current spray tower with a presaturator and a chevron-type mist eliminator. The presaturator cools the entering gas from 300°F to 124°F.* The absorbent liquid is an 8% solids slurry of finely ground (90% minus 325 mesh) limestone prepared onsite by crushing and ball milling. A stoichiometry of 1.07 mols $CaCO_3$/mol (SO_2 + 2HCl) absorbed is used. The liquid-to-gas (L/G) ratio is 4 gal./1000 acf for the presaturator and 80 gal./1000 acf for the absorber. An adipic acid concentration of 1,500 ppm is maintained in the absorption loop by metering adipic acid into the makeup limestone slurry tank. Air, at a stoichiometry of 2.5 lb atoms O/lb mol SO_2 absorbed, is injected into the absorber effluent tank to oxidize the sulfite. A bleedstream is pumped to a thickener and rotary vacuum filter for dewatering. The dewatered gypsum is trucked to a landfill 1 mile from the FGD facility.

The Davy S-H process is a lime-based process using a clear alkaline absorbent liquid buffered with formic acid. The SO_2 is removed in a Rotopart absorber (a patented modular-design cocurrent spray column with an integral gas/liquid separator). Each module consists of two absorption tubes containing liquid-shedding rings (venturi throats) connected to a single gas/liquid separator (Rotopart) section. The buffering action of formic acid acts to slow and control the pH drop to 4.5 to 5.0, ensuring formation of bisulfite. The concentrations of both the formic acid and a ferric chloride catalyst and the absorber L/G ratio are proprietary information. The lime stoichiometric ratio is 1.02 mols (CaO/mol (SO_2 + 2HCl) absorbed. The absorber effluent is oxidized by air-sparging in an oxidizer vessel at a stoichiometry of 5 lb atoms O/lb mol SO_2 absorbed. The gypsum slurry overflows from the oxidizer to the thickener through a mixing trough. Lime slurry and makeup formic acid are added to this trough. The thickened slurry is dewatered in a rotary vacuum filter. The dewatered gypsum is trucked 1 mile to a landfill.

The Dowa process is a double-alkali process that uses a basic aluminum sulfate—$Al_2(SO_4)_3$—solution to absorb SO_2 and limestone to precipitate gypsum and regenerate the scrubbing solution. A packed-bed countercurrent absorber with a fresh-water wash on the wall at the gas/liquid interface is used for SO_2 removal. The absorber is packed with Ecodyne Poly-Grid packing. An L/G ratio of 45 gal./1000 acf is used. The absorber effluent is oxidized by air-sparging in an oxidizer vessel in the absorber liquid loop at an air stoichiometry of 4 lb atoms O/lb mol SO_2 absorbed. A chloride purge prevents an excessive buildup of chlorides in the system. A bleedstream from the oxidation tank is neutralized with limestone to regenerate the basic $Al_2(SO_4)_3$ solution and precipitate gypsum. A stoichiometry of 1.03 mols $CaCO_3$/mol of (SO_2 + 2HCl) absorbed is used. The gypsum slurry is dewatered in a thickener and a rotary vacuum filter, and the gypsum is trucked 1 mile to a landfill for disposal.

Design and Economic Premises

The economic evaluations are based on a conceptual design developed from the design premises and engineering data such as flow diagrams, material balances, and equipment costs. The Davy S-H and Dowa processes are based on vendor-supplied data; the limestone process is a generic design. A base-case, new 500-MW power unit burning a 3.5% sulfur, 16% ash (both are dry basis) bituminous coal, and complying with the 1979 New Source Performance Standards (NSPS) is used as the primary basis of comparison.

Design Premises

The coals used are three eastern bituminous coals containing 5.0%, 3.5%, and 2.0% sulfur (dry basis). The coals have a heating value of 11,700 Btu/lb as fired. The compositions of the coals are shown below. The 3.5% sulfur coal is the base-case coal.

Coal	Sulfur, % Dry basis	Sulfur, % As-fired basis	Ash, % As-fired basis	Moisture, % As-fired basis	Heat content, Btu/lb
Eastern bituminous	5.0	4.80	15.10	4.0	11,700
Eastern bituminous	3.5	3.36	15.14	4.0	11,700
Eastern bituminous	2.0	1.92	15.08	4.0	11,700

The power plant site is assumed to be in the north-central region of the U.S. The base-case power unit is a new, single 500-MW, balanced-draft, horizontally fired, dry-bottom boiler burning pulverized coal. Power unit size variations consist of similar 200- and 1,000-MW units. The power units have a 30-year life and operate at full load for 5,500 hr/yr for a total lifetime operation of 165,000 hours. Existing power units with 20 years of remaining life at 5,500 hr/yr of full-load operation are also evaluated. This operating schedule is equivalent to a total remaining lifetime operation of 110,000 hours.

Flue gas compositions are based on a total air rate equivalent to 139% of the stoichiometric requirement, including 19% air leakage. It is assumed that 80% of the ash in the coal is emitted as fly ash and 92% of the sulfur is emitted as SO_x. Three percent of the sulfur emitted as SO_x is SO_3, and the remainder is SO_2. Cold-side electrostatic precipitators (ESPs), sized to meet the 0.03 lb/10^6 Btu 1979 NSPS, are assumed for particulate control. Costs for ash collection and disposal are not included in the economic evaluation.

SO_2 emissions from new coal-fired utility plants are regulated by the revised 1979 NSPS. SO_2 emissions from existing units are based on a representative state implementation plan (SIP) emission standard of 0.6 lb SO_2/10^6 Btu. The controlled outlet SO_2 emission and SO_2 removal

*Nonmetric units are used in this report for convenience. Readers more familiar with metric units may use the conversion factors at the end of this Summary.

efficiencies for new plants for each of the coals are shown below.

Coal	Equivalent SO_2 content of coal, lb SO_2/10^6 Btu	Overall equivalent SO_2 reduction required, %	Equivalent SO_2 removal required in FGD system, %	Controlled outlet emission, lb SO_2/10^6 Btu
Eastern bit., 5.0% S	8.21	90.0	89.1	0.82
Eastern bit. 3.5% S	5.74	89.6	88.7	0.60
Eastern bit. 2.0% S	3.28	81.7	80.1	0.60

The FGD systems are coupled to the power unit by a plenum into which the power plant ID fans discharge. Separate ID fans are provided for the FGD system. FGD costs include ductwork and associated equipment between the power plant ID fans and the stack plenum. Costs for the stack plenum and the stack are excluded. Absorption trains are sized for a maximum of 125 MW of flue gas (513,000 scf/min). Spare trains are provided for a minimum of 25% redundancy, and provision for emergency bypass of 50% of the scrubbed gas is included. For all of the advanced limestone cases, partial scrubbing of the flue gas at an SO_2 removal efficiency of 95% SO_2 is used. Partial scrubbing of 89% of the flue gas at 90% SO_2 removal is used for the 2.0% sulfur coal cases for the Davy S-H and the Dowa processes. This corresponds to the quantity of gas bypassed shown below. Indirect steam reheat to 175°F is provided as necessary. The dewatered gypsum cake is disposed of in a landfill, 1 mile from the FGD facilities. The gypsum disposal area includes loading, trucking, spreading, and compaction operations, and general landfill maintenance and reclamation.

	Flue gas bypass, %		
Coal	Advanced limestone	Davy S-H	Dowa
Eastern bit., 5.0% S	6.2	--	--
Eastern bit., 3.5% S	6.7	--	--
Eastern bit., 2.0% S	15.7	11.0	11.0

Economic Premises

A 3-year construction period, from early 1981 to late 1983, is used for both new and existing units. Mid-1982 costs are used for capital investment. Mid-1984 costs are used for annual revenue requirements.

Capital investment consists of direct investment, indirect investment, and other capital investment. Direct investment consists of the installed costs of all process equipment, including provisions for services, utilities, and miscellaneous, and costs associated with the landfill. Indirect capital investment consists of fees for engineering design and supervision, architect and engineering contractor, construction expense, contractor fees, and contingency. An allowance for start-up, modifications, and interest during construction is included. No royalty charges are included for the advanced limestone and Dowa processes. Royalty charges for the Davy S-H process were obtained from the process vendor. Process and waste disposal area land is charged at $5,000 per acre.

For existing plants, a capital investment retrofit factor of 1.3 is assigned to cover the additional investment required for fitting the equipment into the available space. Each area investment (e.g., material handling) is multiplied by the retrofit factor. The remaining investment costs are calculated in the same manner as for new units.

Annual revenue requirements consist of various direct and indirect operating and maintenance costs and capital charges. Both first-year and levelized annual revenue requirements are reported. Levelized capital charges are used in both first-year and levelized annual revenue requirements. Levelized operating and maintenance costs are determined by multiplying the first-year operating and maintenance costs by a 30-year levelizing factor of 1.886, representing an annual inflation rate of 6% and a discount rate of 10%.

Systems Estimated

All three processes are divided into materials handling, feed preparation, gas handling, SO_2 absorption, reheat, oxidation, solids separation, and disposal areas. In the Dowa process two additional areas, neutralization and chloride purge, are included. There are no equivalent areas in the other processes. The materials handling and feed preparation areas consist of equipment to receive, store, and prepare absorbent slurry. Limestone is crushed and wet ball milled. Lime is slaked and slurried. For processes that use additives, supplemental equipment is included in the preparation area for addition. The gas handling area consists of a feed plenum that distributes the flue gas to the individual absorber trains, ductwork, and one ID fan per absorber train. Two emergency bypass ducts are included to handle 50% of the scrubbed gas and to serve as bypass ducts if some of the flue gas is normally bypassed. The absorption area consists of the absorbers and the absorbent liquid recirculation system. All FGD systems are designed for a flue gas temperature of 175°F at the entrance to the stack. Reheat is provided by indirect, inline steam reheat with provisions to account for compression by the ID fans and heating by bypassed flue gas. The oxidation area consists of air compressors, the oxidation tank, a sparging ring, and an agitator. The neutralization and chloride purge areas in the Dowa process include tanks, agitators, pumps, and limestone addition equipment to precipitate gypsum and aluminum hydroxide. The solids separation area consists of thickeners and rotary vaccum filters to generate an 85% solids gypsum waste. Trucks are used to transport the filter cake to the landfill.

Results

The economics developed consist of capital investments and first-year and levelized annual revenue requirements for the three processes, based on the design and economic premises and the specific process designs.

Capital Investment

Capital investments for each process are summarized in Table 1. The advanced limestone process has the lowest capital investment, followed by the Davy S-H process (25% higher in the base case) and the Dowa process (31% higher in the base case).

Direct capital investments by process area for the base-case processes are shown in Table 2. The Davy S-H process has the highest gas handling area cost (due to the limited but costly use of 316 stainless steel ducting) and oxidation cost (due to a unique sparger constructed with 316 stainless steel). The Davy S-H process has the lowest feed preparation area cost (due to the use of lime) and SO_2 absorption area cost (due to the modular Rotopart). However, the high cost areas of the Davy S-H process are not offset by the lower cost areas and, therefore, result in the Davy S-H process having the second

Table 1. *Capital Investment Summary*

	Advanced limestone		Davy S-H		Dowa	
	10^6	\$/kW	10^6	\$/kW	10^6	\$/kW
New Units[a]						
200 MW, 3.5% S	54.4	272	63.0	315	66.4	332
500 MW, 2.0% S	79.1	158	99.8	200	102.6	205
500 MW, 3.5% S	92.8	186	115.5	231	121.3	243
500 MW, 5.0% S	97.9	196	121.4	243	130.3	261
1,000 MW, 3.5% S	155.5	156	206.7	207	216.1	216
Existing Units[b]						
200 MW, 3.5% S	59.8	299	80.6	403	85.4	427
500 MW, 3.5% S	118.5	237	148.1	296	156.2	312
1,000 MW, 3.5% S	211.7	212	268.1	268	281.3	281

[a]*New FGD facilities are constructed simultaneously with the power plant and have a 30-year remaining life.*
[b]*Existing FGD facilities are retrofit installations on existing power plant facilities and have a 20-year remaining life.*

highest capital investment. The Dowa process has only two major areas (SO_2 absorption and solids separation) that are lower in cost than the advanced limestone process; and they are only marginally lower in cost. The higher costs in the other processing areas result in the Dowa process having the highest capital investment for the base case.

Case Variations

As shown in Table 1, the capital investment ranking remains the same for all case variations as that of the base cases. The capital investment approximately doubles as the power unit size increases from 200 to 500 MW and triples as the size increases from 200 to 1,000 MW. For existing units, the cost relationships are essentially the same as for new units. The capital investment increases 15% to 18% as the coal sulfur increases from 2.0% to 3.5%. The increase is 22% to 27% as the coal sulfur increases from 2.0% to 5.0%.

The 200-MW units have a 50% spare capacity because only two operating absorption trains (arbitrarily used as the minimum) are required, while the 500- and 1,000-MW units have only 25% spare capacity. The additional capital required for the 200-MW unit increases the cost (in dollars per kilowatt), resulting in an exaggerated economy of scale as the power unit size increases from 200 to 500 MW. Partial scrubbing is used in all processes for the 2% sulfur coal. For advanced limestone, the SO_2 absorption and gas handling equipment are sized to handle 84.3% of the total gas; the remaining 15.7% is bypassed. For Davy S-H and Dowa processes, the SO_2 absorption equipment and gas handling equipment are sized to handle 89% of the total gas; the remaining 11% is bypassed. The reduction in equipment size and materials because of the bypass further reduces the capital investment for the 2.0% sulfur coal, compared with the 3.5% and 5.0% sulfur coal for the Davy S-H and the Dowa processes. For the advanced limestone process, where partial scrubbing is used in all cases, the corresponding reductions are not as significant.

Annual Revenue Requirements

As shown in Table 3, the advanced limestone process also has the lowest annual revenue requirements, but there is little difference between the Davy S-H and Dowa processes. Although the Dowa process has a higher capital investment, it has marginally lower annual revenue requirements because it uses limestone (at \$8.50/ton) whereas the Davy S-H uses lime at \$75/ton. The Davy S-H process lime cost is 4.0 and 3.3 times higher than the limestone costs of the advanced limestone and Dowa processes. Other raw material costs (adipic acid, formic acid, and aluminum sulfate) are minor.

The largest component of the first-year annual revenue requirements (as shown in Table 4 for the base-case application) for all processes is capital charges, which are over 50% of the total. Except for raw material cost, all processes have the same order of major cost components: levelized capital charges, maintenance, plant and administrative overheads, and electricity, in order of decreasing importance. Raw material cost, however, is the second highest component of annual revenue requirements for the Davy S-H process; whereas, it is the fifth highest component for the advanced limestone and Dowa processes.

Table 2. *Base-Case Capital Investment Summary by Processing Areas*[a]

	10^6		
	Advanced limestone	Davy S-H	Dowa
Materials handling	2.6	3.5	2.9
Feed preparation	4.3	1.2	5.3
Gas handling	10.5	18.6	14.3
SO_2 absorption	17.7	14.7	17.6
Reheat	2.3	4.2	4.0
Oxidation	3.2	5.0	4.7
Neutralization	–	–	0.6
Chloride purge	–	–	0.8
Solids separation	3.5	2.6	2.7
Total process capital	44.1	49.8	52.9
Total direct investment	51.0	57.0	60.3
Total capital investment	92.8	115.5	121.3

[a]*500 MW, new power unit, 3.5% sulfur coal, 1982 dollars.*

Table 3. Annual Revenue Requirement Summary

	Advanced limestone				Davy S-H				Dowa			
	First year		Levelized		First year		Levelized		First year		Levelized	
	$10^6	mills/kWh	$10^6	mills/kWh	$10^6	mills/kWh	$10^6	mills/kWh	$10^6	mills/kWh	$10^6	mills/kWh
New Units[a]												
200 MW, 3.5% S	15.3	13.95	21.9	19.86	17.7	16.06	25.1	22.83	18.0	16.33	25.2	22.94
500 MW, 2.0% S	21.6	7.86	30.4	11.07	26.7	9.69	37.3	13.55	26.8	9.76	37.2	13.54
500 MW, 3.5% S	25.8	9.38	36.6	13.31	32.7	11.88	46.5	16.93	32.3	11.74	45.1	16.39
500 MW, 5.0% S	27.7	10.07	39.5	14.36	35.9	13.08	52.0	18.90	34.8	12.65	48.6	17.68
1,000 MW, 3.5% S	42.8	7.78	60.4	10.99	57.4	10.44	81.4	14.80	56.1	10.21	77.7	14.13
Existing Units[b]												
200 MW, 3.5% S	17.1	15.53	22.0	20.04	21.9	19.87	27.8	25.28	22.7	20.66	28.7	26.14
500 MW, 3.5% S	32.5	11.83	41.5	15.10	40.2	14.63	51.2	18.62	40.9	14.86	51.4	18.71
1,000 MW, 3.5% S	56.9	10.34	72.1	13.12	71.6	13.02	90.6	16.48	71.9	13.08	90.0	16.36

[a]*New FGD facilities constructed simultaneously with the power plant and have a 30-year remaining life.*
[b]*Existing FGD facilities are retrofit installations on existing power plant facilities and have a 20-year remaining life.*

Table 4. Major Cost Components for Base-Case Annual Revenue Requirements

Process	Major operating cost components (% of first-year annual revenue requirements) 1	2	3	4	5
Advanced limestone	Levelized capital charges 52.7	Maintenance 14.7	Plant and adm. overheads 12.0	Electricity 6.6	Raw materials 4.3
Davy S-H	Levelized capital charges 52.0	Raw materials 14.1	Maintenance 10.1	Plant and adm. overheads 8.3	Electricity 6.7
Dowa	Levelized capital charges 55.3	Maintenance 14.3	Plant and adm. overheads 10.9	Electricity 6.2	Raw materials 4.3

Capital investments play a major role in the ranking of the annual revenue requirements because levelized capital charges are a direct function of total capital investment and maintenance costs are a function of direct investment. In addition, overheads are a function of maintenance costs.

Case Variations

As shown in Table 3, the levelized annual revenue requirements for new units increase 70% to 85% as the power unit size increases from 200 to 500 MW, and 175% to 225% as the power unit size increases from 200 to 1,000 MW. For existing units, the costs increase 80% to 90% for the 200- to 500-MW power unit size increase, and 215% to 230% for the 200- to 1,000-MW range.

Although the Davy S-H process has the highest base-case levelized annual revenue requirements, this relationship is not true of all power unit sizes. At the 200-MW size, the levelized annual revenue requirements for the Dowa process are slightly higher than those of the Davy S-H process. As the power unit size increases, the levelized annual revenue requirements for the Davy S-H process increase more rapidly than those of the Dowa process. This is due to the relationship between the variable raw material costs and the fixed-percentage capital-related costs (maintenance and levelized capital charges). Since the Dowa process has the highest total capital investment in every case, its maintenance cost and capital charges are also highest; but the Davy S-H process has the highest raw material cost for all cases. As the power unit size increases, the effect of raw material cost surpasses the effects of maintenance cost and capital charges.

As the coal sulfur increases from 2.0% to 3.5%, the levelized annual revenue requirements increase 20% for the advanced limestone and Dowa processes and 25% for the Davy S-H process. As the coal sulfur increases from 2.0% to 5.0%, the increases are 30% and 40%. The levelized annual revenue requirements of the Davy S-H process are equivalent to the Dowa process for 2.0% sulfur coal, but they are higher for 3.5% and 5.0% sulfur coal. As in the power unit size variation, this trend is due to the relationship of raw material costs and capital-related costs.

The sensitivity of the Dowa process economics to changes in the absorber L/G ratio was evaluated since the base-case costs were calculated using an L/G ratio of 45 gal./1000 acf; whereas, recent tests indicate that an L/G ratio of about 80 gal./1000 acf is required for 90% SO_2 removal. The higher L/G ratio increases the capital investment 4%, primarily because larger pumps and piping were required, and increased the levelized annual revenue requirements about 5% because of the higher electricity cost and the higher levelized capital charges. The levelized annual revenue requirements for the Dowa process became slightly higher than those of the Davy S-H process, but the cost differences between the two processes remain small.

Conclusions

The capital investment relationships among the processes remain the same for all power unit sizes and coal sulfur contents. Landfill capital investment is a minor element of capital investment and is similar for all processes.

The capital investment and annual revenue requirements of the advanced limestone process are substantially lower (about 25% and 10%, respectively) than those of the Davy S-H and Dowa processes. This is largely the result of more extensive use of partial bypass for the advanced limestone process, which is possible because using adipic acid allows scrubbing at 9% removal, compared with 90% for the other processes. The capital investment and annual revenue requirements of the Davy S-H and Dowa processes do not differ appreciably: the Davy S-H process is slightly lower in capital investment and slightly higher in annual revenue requirements. The cost relationships of the three processes hold true for different power unit sizes and coal sulfur contents, except that the Davy S-H process annual revenue requirements increase slightly more rapidly with increasing power unit size and coal sulfur content.

The Davy S-H process is most sensitive to raw material cost changes because lime is used as the ultimate absorbent. The processes using limestone have absorbent costs three to four times lower. Other raw material costs (adipic acid, formic acid, and aluminum sulfate) are insignificant.

Approximately doubling the L/G ratio (from 45 to 90 gal./1000 acf) increases the capital investment and annual revenue requirements of the Dowa process 4% to 5%, which has no large effect on the cost relationships of the processes. Using a chloride purge in the Dowa process, which is not used in the other processes, has no material effect on the costs.

Landfill is a minor element of the capital investment and annual revenue requirements of all processes.

Conversion Factors

Readers more familiar with metric units may use the following factors to convert from the nonmetric units used in this report.

Nonmetric	Multiplied by	Yields metric
acre	4047	m^2
Btu	1.055	kJ
°F	5/9(°F-32)	°C
ft^3	0.283	m^3
gal.	3.785	1
lb	0.454	kg
mi	1.609	km
ton	907.2	kg

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The complete report, entitled "Economic Evaluation of Advanced Limestone, Davy S-H, and Dowa Gypsum-Producing FGD Processes," (Order No. PB 85-143 253; Cost: $17.50, subject to change) will be available only from:
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