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# FLUE GAS DESULFURIZATION SYSTEM MANUFACTURERS SURVEY

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

# FLUE GAS DESULFURIZATION

# SYSTEM MANUFACTURERS SURVEY

Prepared by

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# 1.0 INTRODUCTION

The purpose of this study is to assess the capability of manufacturers of pollution control equipment to meet current and future demands for flue gas desulfurization (FGD) systems. Both regenerative and nonregenerative FGD systems are considered in the study.

A survey form was prepared and sent to 18 representative manufacturers of FGD systems. The following information was requested:

- Type of FGD system manufactured.
- Capability of companies to design and install various sizes of FGD systems.
- Future use pattern of FGD systems.
- Manufacturers' guarantees.
- Raw material availability and specifications.
- Manpower and equipment availability for installing FGD systems.
- Willingness of manufacturers to provide for operation and maintenance services.

Thirteen of the 18 manufacturers contacted either completed or partially completed the form and returned it.

Table 1-1 lists them and the FGD systems they produce. The information they furnished is found throughout the balance of the report.

Table 1-1. MANUFACTURERS RESPONDING TO THE SURVEY AND THE FGD SYSTEM(S) OFFERED BY EACH

| Manufacturer | Type of FGD System Offered | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Regenerative system | | | | | Nonregenerative system | | | | | |
| | Magnesium oxide | Phosphate | Wellman-Lord | Catalytic oxidation | Citrate | Double alkali | Lime | Limestone | Chiyoda thoroughbred 101 | Sodium carbonate | Hydro |
| 1. Babcock & Wilcox Company | | | | | | | X | X | | | |
| 2. Chemico Air Pollution Control Company | X | X | | | | X | X | X | | | |
| 3. Chiyoda International Corp. | | | | X | | | | | X | | |
| 4. Combustion Engineering, Inc. | | | | | | | X | X | | | |
| 5. Davy Powergas, Inc. | | | X | | | | | | | | |
| 6. Environeering, Inc. | | | | | | | X | X | | | |
| 7. Flakt, Inc. | | | | | | | X | X | | | X |
| 8. FMC Corp. | | | | | | X | | | | X | |
| 9. Peabody Process Systems, Inc. | | | | | X | | X | X | | | |
| 10. Pullman, Inc. | | | | | | | X | X | | | |
| 11. Research-Cottrell, Inc. | | | | | | | | X | | | |
| 12. UOP, Inc. | | | | | | X | X | X | | X | |
| 13. Zurn Air Systems | | | | | | X | | | | | |

## 2.0 CAPABILITIES OF MANUFACTURERS

Presently more than 10 different processes are available for desulfurization of boiler flue gas (Table 1-1). These processes can be broadly separated into two classes, regenerative and nonregenerative.

A regenerative FGD system removes the sulfur dioxide ($SO_2$) and converts it to a marketable by-product, usually elemental sulfur, sulfuric acid, or a concentrated $SO_2$ gas stream. Magnesium oxide (MgO) scrubbing, the Wellman-Lord process, the citrate process, the phosphate process, the ammonium bisulfate process, charcoal adsorption, and the Shell FGD system are examples of regenerative systems.

A nonregenerative system removes the $SO_2$ from flue gas by reacting it with a compound. This reaction produces a sludge which must be disposed of in an environmentally sound manner. Lime scrubbing, limestone scrubbing, the sodium carbonate process, the Hydro process, the double alkali process, and the Chiyoda Thoroughbred 101 process are examples of nonregenerative systems.

Only the following FGD systems are considered in this report:

- Lime scrubbing
- Limestone scrubbing
- Double alkali
- Wellman-Lord
- Magnesium oxide

Table 2-1 summarizes the projected number of FGD systems that manufacturers can design and install over three 5-year periods. These figures are broken down into size categories and the use of the present staff versus an expanded staff. The manufacturers were also queried regarding their sources of personnel to perform various stages of FGD system design and installation. Table 2-2 summarizes the information they provided.

The survey form included a request for estimates of the time required to design, install, and start up the FGD systems. Table 2-3 presents average times and the ranges of times submitted for various sized systems.

The future use pattern of the various FGD systems was calculated by PEDCo. Table 2-4 presents this information.

Responses to questions in this section of the survey were received from 12 manufacturers. The non-responding manufacturers posses a small share of the total market. Therefore the numbers shown in the following tables are judged to be low by about 15 percent.

Table 2-1. PROJECTED NUMBER OF FGD SYSTEMS THAT MANUFACTURERS CAN DESIGN AND INSTALL OVER A 15-YEAR PERIOD[a]

| | Number of units | | | | | |
|---|---|---|---|---|---|---|
| | 1978-1982 | | 1983-1987 | | 1988-1992 | |
| Systems designed[b] | Present staff | Expanded staff | Present staff | Expanded staff | Present staff | Expanded staff |
| 5 MW[c] | 202 | 342 | 221 | 412 | 226 | 424 |
| 20 MW[c] | 195 | 332 | 209 | 394 | 213 | 406 |
| 50 MW | 212 | 375 | 224 | 427 | 327 | 439 |
| 200 MW | 171 | 307 | 177 | 348 | 179 | 359 |
| 1000 MW | 156 | 283 | 161 | 321 | 161 | 331 |
| Systems installed[b] | | | | | | |
| 5 MW[c] | 155 | 243 | 184 | 327 | 192 | 332 |
| 20 MW[c] | 148 | 232 | 172 | 309 | 179 | 314 |
| 50 MW | 167 | 284 | 187 | 335 | 193 | 348 |
| 200 MW | 121 | 197 | 134 | 244 | 140 | 253 |
| 1000 MW | 108 | 179 | 120 | 220 | 124 | 228 |

[a] Represents the responses of 12 manufacturers. The manufacturers indicated that the size range of 200 to 800 MW would not have a great impact on their capability to design or install units; however, other sizes would affect their capabilities. The capability shown in this table refers to both regenerative and nonregenerative systems.

[b] The difference between the number of systems designed and the number installed results from the long lead time required for installation of FGD systems.

[c] One of the 12 responding manufacturers indicated that they would not bid on 5- and 20-MW units, which is reflected in the fewer units shown for these two sizes than for a 50-MW unit.

Table 2-2. SOURCES OF PERSONNEL TO ACCOMPLISH VARIOUS STAGES OF FGD SYSTEM DESIGN AND INSTALLATION[a,b]

| Item | Number of manufacturers using in-house personnel | Number of manufacturers using outside labor |
|---|---|---|
| Process design | 12 | 1 |
| Detailed engineering design | 11 | 3 |
| Equipment fabrication | | |
| Scrubber vessels/tanks | 4 | 9 |
| Fans/pumps | 1 | 11 |
| Sludge disposal | 0 | 11 |
| System installation | | |
| Supervision | 10 | 3 |
| Crafts | 1 | 11 |

[a] Some manufacturers indicated that they use both in-house personnel and outside labor to accomplish the different stages of FGD system design and installation.

[b] Represents the responses of 12 manufacturers.

Table 2-3. TIME REQUIRED FOR FGD SYSTEM DESIGN, INSTALLATION, AND START-UP[a]

| Size, MW | Time required for design and installation, months | | Time required for start-up, months[b] | |
|---|---|---|---|---|
| | Average | Range | Average | Range |
| <100 | 22.2 | 6 to 36 | 1.8 | 0.5 to 6 |
| 100-400 | 24.4 | 8 to 36 | 2.3 | 0.5 to 6 |
| 400-800 | 30.1 | 18 to 42 | 2.4 | 0.5 to 7 |
| >800 | 33.1 | 20 to 42 | 2.7 | 0.5 to 7 |

[a] Represents the responses of 12 manufacturers.

[b] "Start-up" is defined as the time between completion of plant construction and the capability of the plant to operate at an acceptable level of capacity.

Table 2-4. PROCESS DISTRIBUTION OF PLANNED FGD SYSTEMS ON NEW COAL-FIRED UTILITY BOILERS[a]

| FGD process | Percent distribution |
|---|---|
| Lime | 38 |
| Limestone | 52 |
| Double alkali | 3 |
| Wellman-Lord | 3 |
| Magnesium oxide | 2 |
| Other | 2 |
| Total | 100 |

[a] The following assumptions were used to calculate this distribution:

- Units coming on line through 1980 have been committed to a specific $SO_2$ control device due to the long lead times for FGD system installation.
- All New England (U.S. EPA, Region I) utilities will use regenerable systems.
- The distribution is applied to new units through year 2000.

# 3.0 AVAILABILITY OF MANPOWER AND EQUIPMENT FOR DESIGN AND INSTALLATION OF FGD SYSTEMS

Construction of power plants and their FGD systems requires the services of the same types of craftsmen. The key crafts required for power plant and FGD system installation are:

- Boilermakers
- Carpenters
- Electricians
- Ironworkers
- Laborers
- Millwrights
- Pipe fitters
- Welders

The domestic construction industry is currently in a slump. Therefore, short-term growth requirements could be met with few problems in most regions, except for the highly skilled mechanical craftsmen (including welders). As of mid-summer 1977, the following selected areas reported existing or anticipated shortages of skilled craftsmen:

| Location | Craftsmen |
|---|---|
| Denver, Colorado | Carpenters<br>Ironworkers |
| Detroit, Michigan | Boilermakers<br>Pipe fitters |
| Boston, Massachusetts | Electricians |
| Missouri and Nebraska | Boilermakers<br>Pipe fitters |
| North Carolina | Carpenters |

A selected number of large national power plant contractors who were contracted indicated that a shortage of skilled craftsmen in all disciplines is possible, indeed probable even under the present New Source Performance Standards (NSPS). Unskilled laborers, on the other hand, will be plentiful. Even a 10 percent annual increase in the number of craftsmen would be very difficult to maintain over an extended period of time. Moreover, the shortage of craftsmen is anticipated to be more acute in areas remote from high-population centers.

Another survey was made of major component manufacturers to determine if the future demand for FGD system components could be met under the alternative new source performance standards. The following components were of concern:

- Ball mills
- Clarifiers

- Fans
- Pumps
- Vacuum filters

Table 3-1 lists the manufacturers contacted and the equipment they manufacture. The demand for additional FGD system components for various sized plants was projected through the year 1998 using standard engineering calculations. Tables 3-2 through 3-6 present data on each component. In calculating the demand, a 500-MW capacity was assumed for power plants coming on line in 1986 or later, which would make the demand negligible for certain smaller sized equipment. This is evident in Tables 3-2 through 3-6.

The results of this latter survey indicate that the capacity to manufacture components far exceeds the demand. Table 3-4 shows a shortfall in the supply of large fans during the 1978-82 and 1988-92 periods. The shortages would not be as great as the data indicate, however, because all the manufacturers did not respond. The data are further qualified by the assumption used in calculating demand that all new units coming on line after 1986 will be 500 MW or greater in capacity. This assumption slants the requirements for equipment to larger capacities, whereas the manufacturers' responses covered a wide size range. An examination of the

Table 3-1. MAJOR MANUFACTURERS OF FGD SYSTEM COMPONENTS

| Manufacturers | FGD System Component Manufactured | | | | |
|---|---|---|---|---|---|
| | Fans | Ball mills | Pumps | Vacuum filters | Clarifiers |
| 1. Allis-Chalmers | | x | x | | |
| 2. American Air Filter | | | | | |
| 3. Bird Manufacturing Co. | | | | x | |
| 4. Buffalo Forge Co. | | | x | | |
| 5. Combustion Engineering | x | | | x | |
| 6. Denver Equipment Co. | | x | | x | x |
| 7. Dorr-Oliver Inc. | | | x | | x |
| 8. Environeering Inc. | x | | | | |
| 9. Envirotech Corp. | | | | x | x |
| 10. FMC Corp. | | | | x | x |
| 11. Goulds Pump Inc. | | | x | | |
| 12. Ingersoll-Rand Co. | | | x | | |
| 13. Joy Manufacturing Co. | x | | | | |
| 14. Kennedy Van Saun Corp. | | x | | | |
| 15. Koppers Co. Inc. | | x | | | x |
| 16. UOP Engineering Products Corp. | x | | | | |
| 17. Worthington Pump Inc. | | | x | | |
| 18. Zurn Industries Inc. | x | | | | |

Table 3-2. MANUFACTURERS CAPABILITY TO MEET THE DEMAND FOR BALL MILLS[a]

| Years (Inclusive) | Size (tons/hr) | | | | | |
|---|---|---|---|---|---|---|
| | 0-8 | | 8-16 | | 16-24 | |
| | Demand[b] | Capacity | Demand[b] | Capacity | Demand | Capacity |
| 1978 to 1982 | 131 | 662 | 99 | 594 | 186 | 448 |
| 1983 to 1987 | 20 | 860 | 13 | 710 | 86 | 560 |
| 1988 to 1992 | 1 | 860 | 0 | 710 | 426 | 560 |

[a] Represents the responses from 2 manufacturers.

[b] The very low demand during certain time periods was derived based on the assumption that the plants coming on line after 1986 will be 500 MW units; therefore these plants will require larger equipment.

Table 3-3. MANUFACTURERS CAPABILITY TO MEET THE DEMAND FOR CLARIFIERS[a,b]

| Years (Inclusive) | Size (diameter-ft) | | | | | |
|---|---|---|---|---|---|---|
| | 0-50 | | 50-100 | | 100-150 | |
| | Demand[c] | Capacity | Demand[c] | Capacity | Demand | Capacity |
| 1978 to 1982 | 50 | 200 | 119 | 360 | 130 | 400 |
| 1983 to 1987 | 2 | 250 | 21 | 450 | 64 | 500 |
| 1988 to 1992 | 0 | 250 | 2 | 450 | 426 | 500 |

[a] Assume maximum height of 10 foot.

[b] Represents the response of 1 vendor.

[c] The very low demand during certain time periods was derived based on the assumption that the plants coming on line after 1986 will be 500 MW units; therefore these plants will require larger equipment.

Table 3-4. MANUFACTURERS CAPABILITY TO MEET THE DEMAND FOR FANS[a,b]

| Years (Inclusive) | Size (acfm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 180,000 | | 300,000 | | 360,000 | | 420,000 | |
| | Demand[c] | Capacity | Demand[c] | Capacity | Demand[c] | Capacity | Demand | Capacity |
| 1978 to 1982 | 19 | 450 | 66 | 410 | 287 | 370 | 800 | 330 |
| 1983 to 1987 | 1 | 625 | 9 | 575 | 41 | 525 | 263 | 475 |
| 1988 to 1992 | 0 | 625 | 3 | 575 | 13 | 525 | 852 | 475 |

[a] Assume $\Delta P$ = 18", temperature = 300°F.

[b] Represents the response from 1 manufacturer.

[c] The very low demand during certain time periods was derived based on the assumption that the plants coming on line after 1986 will be 500 MW units; therefore these plants will require larger equipment.

Table 3-5. MANUFACTURERS CAPABILITY TO MEET THE DEMAND FOR PUMPS[a,b]

| Years (Inclusive) | Size (gpm) | | | |
|---|---|---|---|---|
| | 0-5,000 | | 5,000-10,000 | |
| | Demand[c] | Capacity | Demand | Capacity |
| 1978 to 1982 | 56 | 112 | 3,132 | 6,264 |
| 1983 to 1987 | 3 | 6 | 850 | 1,700 |
| 1988 to 1992 | 0 | 112 | 2,342 | 4,684 |

[a] Assume specific gravity = 1.06 and $\Delta H$ = 150 ft.

[b] Represents the responses of 2 manufacturers.

[c] The very low demand during certain time periods was derived based on the assumption that the plants coming on line after 1986 will be 500 MW units; therefore these plants will require larger equipment.

Table 3-6. MANUFACTURERS CAPABILITY TO MEET THE DEMAND FOR VACUUM FILTERS[a]

| Years (Inclusive) | Size, $ft^2$ | | | | | |
|---|---|---|---|---|---|---|
| | 0 to 279 | | 279 to 588 | | 588 to 833 | |
| | Demand[b] | Capacity | Demand[b] | Capacity | Demand | Capacity |
| 1978 to 1982 | 141 | 244 | 47 | 260 | 114 | 260 |
| 1983 to 1987 | 21 | 340 | 8 | 260 | 46 | 260 |
| 1988 to 1992 | 1 | 352 | 1 | 260 | 212 | 260 |

[a] Represents the responses from two manufacturers; 1 of the 2 manufacturers did not predict the capacity in the size range 279 to 833 sq. ft.

[b] The very low demand during certain time periods was derived based on the assumption that the plants coming on line after 1986 will be 500 MW units; therefore these plants will require larger equipment.

capacities on a total volume basis shows a demand of 954 million acfm, whereas the capacity is 1822 million acfm.

Most manufacturers stated that the demand could be met without expanding the number of production shifts or hours. It should be noted that a response was received from only half of the manufacturers contacted.

The manufacturers responding to the FGD survey reported ample availability of the raw materials used in their FGD systems. Table 3-7 shows raw material specifications for the five FGD systems.

Table 3-7. RAW MATERIAL SPECIFICATIONS FOR VARIOUS FGD SYSTEMS

| FGD system | Raw materials | |
|---|---|---|
| | Type | Specifications |
| 1. Lime | Calcium oxide | 90% CaO |
| 2. Limestone | Calcium carbonate | 90% $CaCO_3$, pass 200 mesh |
| 3. Magnesium oxide | Magnesium oxide | 98.5% MgO |
| 4. Double alkali | Sodium carbonate | 98% $Na_2CO_3$ |
| 5. Wellman-Lord | Caustic soda | 50% NaOH, 50 ppm maximum chloride concentration |

# 4.0 GUARANTEES

The current new source performance standard for coal-fired power plants is 1.2 lb $SO_2/10^6$ Btu. The following alternative standards are being considered:

- 90 percent $SO_2$ removal
- 0.5 lb $SO_2/10^6$ Btu.

The manufacturers surveyed indicate that they are willing to offer guarantees of 90 percent $SO_2$ removal. Many of them are prepared to offer guarantees of better than 90 percent on a case-by-case basis. Table 4-1 presents a brief summary of various guarantees offered.

More than half the surveyed manufacturers indicated a willingness to guarantee the performance (availability) of their systems. Ninety percent was the typical level of performance guaranteed. Table 4-2 summarizes information on performance guarantees.

All manufactuers responding to the survey were willing to guarantee the cost of their FGD systems. Four manufacturers would guarantee their costs subject to an escalation clause, and one would negotiate the terms of his guarantee. None of the others specified the provisions of their guarantee.

Table 4-1. GUARANTEES OFFERED BY MANUFACTURERS FOR $SO_2$ REMOVAL[a]

| Company[b] | Level of $SO_2$ removal guaranteed | | |
|---|---|---|---|
| | <90% | 90% | >90% |
| A | | Minimum guarantee given. | Is willing to offer 95% guarantee on case-by-case basis. |
| B | | Minimum guarantee give. | Guarantee of >90% is based on inlet $SO_2$ concentration. |
| C | | | Would guarantee 95% in all cases. |
| D | | Minimum guarantee given. | Have guaranteed up to 92% in the past. |
| E | | | Have guaranteed >90% in the past. |
| F | | This guarantee is normally given. | Depending upon the process, they would guarantee >90%. |
| G | | This guarantee is given where $SO_2$ inlet concentration is 500 to 4000 ppm. | Have guaranteed up to 95% in the past. |
| H | Would normally guarantee 80 to 85%. | This guarantee is given where low-sulfur coal is fired. | |
| I | | Minimum guarantee given. | Are prepared to offer better than 90% when either low- or high-sulfur coal is burned, but would not guarantee less than 50 ppm $SO_2$ concentration in exit stream. |
| J | | This guarantee is usually given when coal with 3 to 4% sulfur is burned. | |
| K | | This guarantee is normally given when either low- or high-sulfur coal is burned. | In many cases they guarantee 95% when high-sulfur coal is burned. |
| L | | Minimum guarantee given. | May guarantee up to 95% on a case-by-case basis. |

[a] Represents the responses of 12 manufacturers.

[b] Company names are deliberately withheld.

Table 4-2. SUMMARY OF PERFORMANCE GUARANTEES OFFERED BY MANUFACTURERS[a]

| Company[b] | Guarantee offered | |
|---|---|---|
| | Yes (level) | No |
| A | Normally better than 90% | |
| B | | X |
| C | Typically 90% during performance testing; sometimes up to 95% | |
| D | Maximum of 90% based on boiler hours | |
| E | Yes (level of guarantee not disclosed) | |
| F | Have guaranteed in excess of 90% | |
| G | Normally 85 to 90% for 1 or 2 years | |
| H | | X |
| I | | X |
| J | Maximum of 90% on a case-by-case basis | |
| K | | X |
| L | | X |

[a] Represents the responses of 12 manufacturers.

[b] Company names are deliberately withheld.

The manufacturers were asked whether they would be willing to contract for the operation and maintenance of the FGD system after installation. Table 4-3 summarizes their responses.

Table 4-3. WILLINGNESS OF MANUFACTURERS TO PROVIDE OPERATION AND MAINTENANCE SERVICE FOR FGD SYSTEMS[a]

| Company | Provide operation and maintenance service | |
|---|---|---|
| | Yes | No |
| A | X | |
| B | | X |
| C | | X |
| D | X | |
| E | | X |
| F | X | |
| G | X | |
| H | X | |
| I | X | |
| J | | X |
| K | X | |
| L | X | |

[a] Represents the responses of 12 manufacturers.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

A survey of manufacturers of flue gas desulfurization equipment was conducted to determine the industry's capability to meet the demand for control equipment required by a change in the $SO_2$ emission standards for boilers. The report details the processes available, the capability of companies to design and install various sizes of FGD systems, manufacturers' guarantees, raw material availability and availability of equipment and manpower.

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