Wet Flue Gas Desulfurization (FGD)

In most developed countries, wet scrubber (flue-gas desulfurization; FGD) technology is a well-established process for removing SO_2. Also, costs have been reduced significantly from 150-200 $/KW in the 1980s to 70-150 $/kW in the late 1990s.

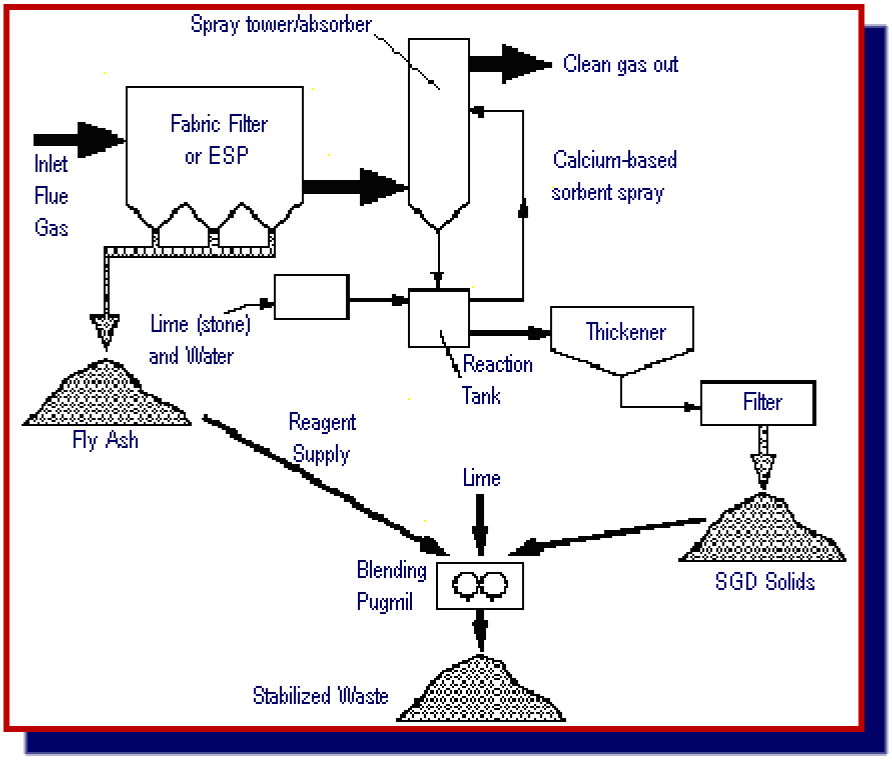
Wet FGD Technology

A simplified process flow diagram of a conventional wet scrubber is shown in the figure below. In wet scrubbers, the flue gas enters a large vessel (spray tower or absorber), where it is sprayed with water slurry (approximately 10 percent lime or limestone). The calcium in the slurry reacts with the SO_2 to form calcium sulfite or calcium sulfate. A portion of the slurry from the reaction tank is pumped into the thickener, where the solids settle before going to a filter for final dewatering to about 50 percent solids. The calcium sulfite waste product is usually mixed with fly ash (approximately 1:1) and fixative lime (approximately 5 percent) and disposed of in landfills. Alternatively, gypsum can be produced from FGD waste, which is a useful by-product.

Note that "mist eliminators" installed at the spray tower outlet or downstream ductwork collect slurry droplets and remove moisture from the flue gas. In some installations, the flue gas is reheated to avoid corrosion downstream in the power plant. Many scrubbers have gas-bypassing capability, which can be used for gas reheating. Also, gas-to-gas reheating may be used, which does not have a penalty on plant efficiency.

The figure shows conventional limestone/lime flue-gas desulfurization. After leaving the particulate removal device- ESP or a fabric filter (top left)-the gas enters a spray tower or absorber (top center), where it is sprayed with a calcium-based water slurry. The calcium in the slurry and the SO_2 in the flue gas form calcium sulfite or calcium sulfate, which are removed by dewatering and settling into a thickener (center). The FGD wastes are usually mixed with the fly ash collected in the fabric filter or ESP and lime in a pug mill (bottom center), and they are disposed of in landfills.

Conventional Limestone/Lime Flue-Gas Desulfurization



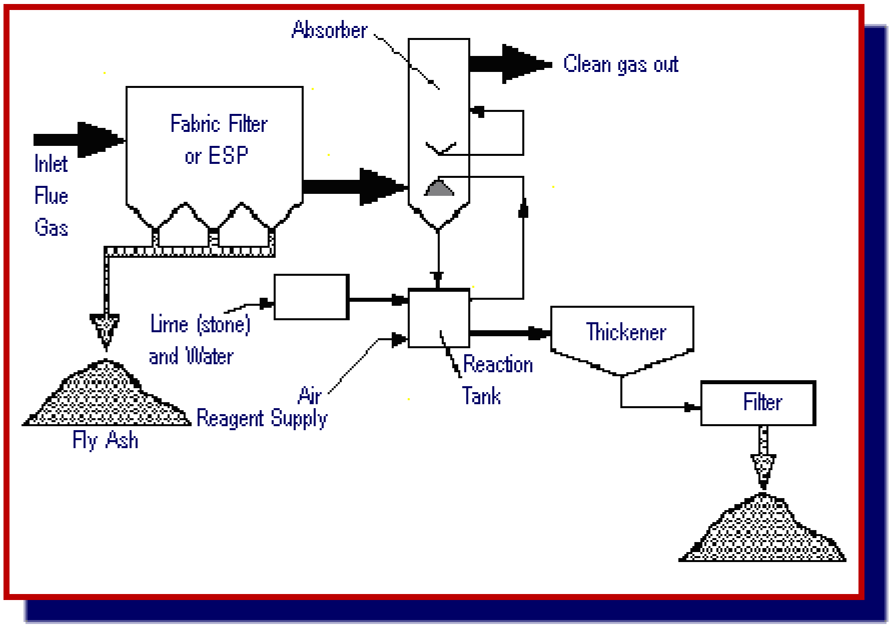
Note:
ESP = electrostatic precipitator
FGD = flue-gas desulfurization

In the early years of introduction of FGD technology, a spare absorber was included to allow full-load operation with one absorber out of service. Recent improvements in reliability have contributed to the elimination of the spare module in most installations. Presently, the largest capacity scrubber module can handle flue gas approximately equivalent to that of a 1,000 MW coal power plant.

Limestone with forced oxidation (LSFO) is a variation of the traditional wet scrubber (see below) in that it utilizes limestone instead of lime. In the LSFO process, the calcium sulfite initially formed in the spray tower absorber is nearly 100 percent oxidized to form gypsum (calcium sulfate) by bubbling compressed air through the sulfite slurry in the tower recirculation tank or in a separate vessel. Because of their larger size and structure, gypsum crystals settle and dewater better than calcium sulfite crystals, reducing the required size of by-product handling equipment. The high gypsum content also permits disposal of the dewatered waste without fixation. Gypsum also has a commercial value, and this needs to be incorporated into the overall assessment of the FGD processes.

The figure below shows the limestone with forced oxidation (LSFO) process. It differs from the wet FGD process described in Figure 3.4 in that calcium sulfite formed in the absorber is oxidized to form gypsum by introducing compressed air into the slurry tank. The final FGD waste is wallboard-grade gypsum.

Limestone Forced Oxidation Flue-Gas Desulfurization Process



Note: FGD = flue-gas desulfurization

By controlling the gypsum quality in the dewatering step, a wallboard-grade gypsum can be produced. The majority of scrubber installations in Europe and Japan generate gypsum for reuse. In the United States, sale of gypsum depends on local markets for wallboard, cement, and agricultural soil amendments.

The LSFO process with throwaway by-product is the standard process against which other FGD processes are compared.

Wet FGD Performance

Wet scrubbers are usually designed for efficiency of 80 to 95 percent SO_2 removal. Additives (e.g., magnesium-enhanced lime or adipic acid) improve the process efficiency by 5 to 10 percent, raising it to a total 95 to 99 percent. These performance levels have been proven for both high- and low-sulfur coals in many commercial applications in Europe, Japan, and the United States.

Approximately 1 to 2 percent of the unit's generating capacity is consumed to meet the power requirements of the scrubber. An additional 1 percent is consumed for gas reheating (when available). When gas-to-gas heating is used, there is no additional efficiency penalty.

Wet FGD Commercial Availability

The following points describe the commercial conditions under which wet scrubber technology is available today.

Technology Readiness

Wet scrubber technology is the most proven and commercially established SO_2 removal process in most developed countries (Europe, Japan, and the United States). At the end of 1993, there were more than 132 GWs of installed capacity operating worldwide. Approximately 40 GW (installed in the late 1980s) are in Germany and more than 62 GW in the United States. Of the 9,200 MW of coal-fired capacity in Japan, approximately 93 percent use scrubbers (mostly wet type).

Cost Effectiveness

Wet scrubbers are the technology of choice for retrofit applications requiring more than 80 to 90 percent SO_2 removal. FGD cost projections are shown in the table below.

Wet FGD Lead Time for Construction

Retrofitting an existing power plant with wet scrubbers requires 3 to 6 weeks of outage to connect the FGD with the boiler ducts and to construct the scrubber itself (provided that space is available).

Cost Projections for Retrofit and New Construction of Flue Gas Desulfurization Units

Cost Factor	Retrofit	New Plant
Capital costs (US$/kW)	100 - 150	70 - 150
Variable O&M (USmills/kWh)	1.5 - 3.3	1.3 - 3.2
Total O&M (USmills/kWh)	6.6 - 12.0	7.4 - 13.0

Note: Costs are expressed in 1990 US$. These costs reflect market conditions and design specifications used in OECD countries. Recent cost estimates (1995-1997) of FGD systems in both OECD and developing countries indicate a general reduction of costs.

Wet FGD Suitability to LDCs

In general, wet scrubber technology is suitable for power plants in developing countries, but additional demonstration and adaptation of specific FGD processes may be required depending on the coal quality in each case.

Wet FGD Deployment Issues

Demonstration and adaptation of the technology may be needed for some coals found in developing countries (e.g., Indian and Chinese coals). In general, deployment issues that need to be addressed by most developing countries are as follows.

- The cost of FGD equipment puts an additional strain on the already limited financial resources of developing countries.
- In case FGDs are not manufactured domestically, the required hard currency needs to be considered.