# Design, Operation, and Performance
# of a Modern Air Pollution Control System
# for a Refuse Derived Fuel Combustion Facility

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## ABSTRACT

The Robbins, Illinois refuse derived fuel combustion facility was recently placed into service. Large and new, the facility is designed to process 1600 tons of waste per day. Twenty-five percent of the waste, or 400 tons per day, is separated out in the fuel preparation process. The remaining 1200 tons per day is burned in two circulating fluidized bed boilers.

The system is designed to meet new source performance standards for municipal waste combustion facilities, including total particulate, acid gases (HCl, $SO_2$, HF), heavy metals (including mercury), and dioxins. The system utilizes semi-dry scrubbers with lime and activated carbon injected through dual fluid atomizers for control of acid gases. Final polishing of acid gas emissions, particulate control, heavy metals removal, and control of dioxins is accomplished with pulse jet fabric filters. This paper discusses the design of the facility's air pollution control system, including all auxiliary systems required to make it function properly. Also discussed is the actual operation and emissions performance of the system.

## INTRODUCTION

The air pollution control system for this facility consists of one semi-dry scrubber and pulse jet fabric filter for each of the two refuse combustion trains. Reagent preparation and delivery and compressed air for atomization of the reagent are provided in a system common to both air pollution control trains. A general system schematic is shown in Figure #1.

Each air pollution control system is designed to treat the flue gases from the combustion of 600 TPD of refuse derived fuel (RDF). This refuse firing rate translates to approximately 176,000 ACFM of flue gas at a temperature of 475°F. All of the system inlet design parameters are provided in Table #1.

To comply with new source performance standards for municipal waste combustion facilities, the system is designed to remove 95% of the HCl entering the system, or achieve an outlet emission rate of 25 ppm @ 7% $O_2$. $SO_2$ emissions are designed for 30 ppm @ 7% $O_2$ or an 85% reduction of the $SO_2$ entering the system. Particulate emissions are limited to 0.010 gr/DSCF @ 7% $O_2$. Mercury emissions are limited to 80 ug/Nm$^3$ @ 7% $O_2$ or an 85% reduction of the mercury entering the system. Dioxins are controlled to a maximum of 30 ng/Nm$^3$ @ 7% $O_2$. Certain heavy metals are also controlled. A summary of the mandated emission levels for the facility is provided in Table #2.

## SEMI-DRY SCRUBBER

The flue gas from the incinerator enters the top of the semi-dry scrubber through flow tubes. In each flow tube, calcium hydroxide along with a small amount of activated carbon for dioxin and mercury control is introduced through a dual fluid nozzle in a finely atomized liquid form. The calcium hydroxide mixes with the flue gas and reacts with the acid gases to form solid particulate. As the flue gas and reaction products flow downward in the scrubber, the reaction products are completely dried. Although some of the particulate drops into the hopper under the semi-dry scrubber, most of the particulate is carried to the fabric filter where it is removed from the gas stream.

The design of the semi-dry scrubber for this process necessitates the satisfaction of two major criteria. First, the reagent slurry must be atomized to produce a droplet spectrum that provides for the optimum acid gas absorption and reaction. Second, the vessel must be configured to ensure that the droplets evaporate and the reaction products produced dry before reaching the wall of the vessel or exiting the vessel. This prevents buildups which would impede the operation of the system.

The semi-dry scrubber utilizes dual fluid nozzles to atomize the lime slurry. A total of 10 nozzles per scrubber vessel were provided. The flue gas entering the vessel is equally divided into three gas streams. Each gas stream passes through a "flow tube" where a dual fluid nozzle sprays the atomized slurry concurrently downward with the gas flow. A sketch of this arrangement is shown in Figure #2. The cool liquid contacting the hot flue gas induces turbulence and mixing. At the same time, a gas velocity reduction of approximately 90% occurs as the flue gas enters the main body of the scrubber vessel. The combination of these two processes induces a thorough mixing of the reagent and acid gases. During this mixing, the acid gases are absorbed by the reagent, creating solid particulate and removing the acid gases from the flue gas stream.

In order for this reaction to occur efficiently, the droplet spectrum from the dual fluid nozzles must be such that the droplets are not too small and therefore flash dry nor are they too large, which reduces the surface area available for reaction and causes a problem with particle drying. A useful measurement of the droplet spectrum is the sauter mean diameter (SMD). The SMD is defined as the droplet diameter which has the same surface to volume population as the entire droplet population. This number helps define the size distribution of the droplets. A wide size distribution, which is not desirable for semi-dry scrubbing, will have a higher SMD than a narrow size distribution of droplets. Field testing on this process has shown that an SMD of 60 to 70 microns produces a droplet spectrum which does not have an excessive amount of large droplets and also does not have too many fine droplets. The theoretical drying profile for the droplet spectrum for the BELCO nozzle used in this installation is shown in Figure #3.

Overall geometry of the scrubber vessel is also an important consideration. The vessel must be designed so that the flue gas expands and utilizes as much of the vessel as possible for drying of the particulate. The unit must also be designed such that, considering the trajectory of any large droplets, no large droplets reach any wall surface before drying. The flue gas exit from the vessel is arranged so that the gas is turned out of the vessel without disturbing the gas flow patterns in the vessel and without the use of any internal turning devices which would create a point of buildup for solids. The key physical dimensions for this vessel, which incorporate the above items, are shown in Table #3.

## REAGENT PREPARATION AND DELIVERY

A critical part of the system design is the delivery slurry, dilution water, and compressed air for liquid atomization. The slurry must be prepared, stored, and delivered in a manner that avoids the typical operating and maintenance problems that are associated with slurry handling and delivery.

For system redundancy, two 100% capacity lime storage and slurry preparation systems were provided. Each lime storage silo has a capacity of 143 tons of pebble lime which represents 7 days of storage at maximum acid gas loadings. The pebble lime is slaked in a detention type slaker, each of which is rated at 7,000 lb/hr. The lime slurry produced is stored in a tank, each tank having a capacity of approximately 24,000 gallons of slurry.

Activated carbon for the system is stored in a silo. This silo has a capacity of approximately 15 tons, or one truckload of activated carbon. The activated carbon is added to the lime slurry in a batch type process. When the slaker operates and lime slurry is added to the storage tank, activated carbon is mixed with water and transported to the slurry storage tank. The amount of activated carbon added is adjustable and coordinated with the slaking operation so that the desired concentration of activated carbon in the slurry can be maintained. A schematic of the slurry and activated carbon preparation system is shown in Figure #4.

Slurry from the storage tanks is delivered to the scrubber vessel through a series of pumps. The first pumps deliver slurry to the atomization level of the scrubber. Most of the slurry pumped is recirculated back to the lime slurry storage tank. This allows for a slurry velocity of approximately 4 to 7 ft/sec in the piping which avoids erosion from high velocity or settling from low velocity. Redundant pumps and recirculation loops were provided to ensure the ability to continuously deliver slurry to the scrubbers. Slurry is delivered to the vessel by diaphragm type pumps. The speed of these pumps is variable and controlled by a signal from the acid gas monitor. This ensures that the proper and optimum amount of slurry is continuously delivered to the scrubber. Again, redundant pumps were provided to ensure continuous operation. A schematic of the slurry delivery is provided in Figure #5.

Dilution water is added for temperature control, assuming that the liquid in the slurry is insufficient to reduce the gas temperature to the desired level. A control valve regulates the amount of dilution water, which is mixed with the slurry in a small manifold just prior to entering the nozzles. The amount of compressed air delivered to the nozzles is controlled to ensure optimum atomization of the liquid. This entire system is shown in Figure #6.

## PULSE JET FABRIC FILTER

A modular pulse jet fabric filter with roof access doors was selected for this facility. The use of full roof doors allows for easy accessibility and a large area for storage when maintenance or filter bag changeout is required. Flue gas enters each module in the hopper area where a manual damper is provided for insulation. A series of vanes turn the gases up toward the filter bags. Gas is drawn through the filter bags, removing particulate and provided a surface for secondary removal of acid gases. The clean gas exits the module through a poppet valve which is used for module isolation during off line cleaning or module maintenance. Compressed air for cleaning the filter bags is provided through pulse pipes located above the filter bags. Cleaning air is controlled by Goyen valves located on each pulse pipe. A general schematic of a filtering module is shown in Figure #7.

The pulse jet fabric filter for this facility has a total of eight modules. The eight modules allow for maintenance to be performed in one of the modules at the same time one module is off line for cleaning, with the remainder of the modules in service to filter the particulate from the flue gas. Each module has a total of 256 bags, with each bag 6 inches in diameter by 16.5 feet long. This results in a net-net air to cloth ratio of 4:1 at maximum design conditions. The filter bags are constructed of 16 oz/yd$^2$ fiberglass with 10% Teflon B coating. The cages are 20 wire cages constructed of mild steel with a light galvanized coating. A summary of the fabric filter specifics is provided in Table #4.

## SYSTEM OPERATION AND PERFORMANCE

This facility was first placed into operation in October, 1996. Facility acceptance testing was performed in January, 1997. To date, operation of the air pollution control system has been excellent. The scrubber has operated without any problems, except for some minor issues with the strainers and slurry hoses. There is no evidence of buildups inside the vessel and there have been several internal inspections during outages for boiler related issues. The fabric filter has operated reliably, with pressure drops typically ranging from 5 inches to 5.5 inches.

The first formal emissions testing from the facility showed excellent performance, with emissions well below the permitted levels. A summary of this test is provided in Tables #5 and #6.

## SUMMARY

Well designed refuse incineration facilities with state of the art air pollution control systems provide an efficient and effective method of reducing waste volume. Semi-dry scrubbers utilizing dual fluid atomizers have been developed to a state of the art technology whcih provides excellent performance and low emission levels. The emissions from this facility show that environmentally sound emission levels are readily achievable, allowing a facility such as this to be a "good neighbor" at the same time that it helps to solve the problem of waste disposal.

**Table 1. System Design Parameters**

| | |
|---|---|
| Refuse Firing Rate | 600 tons per day per train |
| Flue Gas Flow to APC Equipment | 176,026 acfm |
| Flue Gas Temperature | 475 °F |
| Maximum Inlet HCl | 1,500 ppm @ 7% $O_2$ |
| Maximum Inlet $SO_2$ | 600 ppm @ 7% $O_2$ |

**Table 2. System Design Emissions**

| | |
|---|---|
| HCl Emissions | 25 ppm @ 7% $O_2$ or 95% removal |
| $SO_2$ Emissions | 30 ppm @ 7% $O_2$ or 85% removal |
| Particulate Emission | 0.010 gr/dscf @ 7% $O_2$ |
| Mercury Emissions | 80 $\mu$g/Nm$^3$ @ 7% $O_2$ or 85% removal |
| Cadmium Emissions | 10 $\mu$g/Nm$^3$ @ 7% $O_2$ |
| Lead Emissions | 100 $\mu$g/Nm3 @ 7% $O_2$ |
| Dioxin Emissions | 30 ng/Nm$^3$ @ 7% $O_2$ |

### Table 3. Semi-Dry Scrubber Design

| | |
|---|---|
| System Type | Downflow |
| Atomizers | Dual Fluid Nozzles |
| Number of Atomizers | 10 |
| Scrubber Diameter | 30.0 feet |
| Scrubber Cylindrical Height | 40.0 feet |
| Residence Time at Design Flow Rate | 11.7 seconds |

### Table 4. Fabric Filter Design

| | |
|---|---|
| Fabric Filter Type | Pulse Jet |
| Number of Modules | 8 |
| Number of Bags per Module | 256 |
| Total Number of Bags | 2048 |
| Bag Dimensions | 6" diameter by 16.5 feet long |
| Total Cloth Area | 51,343 $ft^2$ |
| Net-Net Air to Cloth Ratio | 4.00 : 1 |
| Bag Material | 16 $oz/yd^2$ Fiberglass with 10% Teflon B Coating |

**Table 5. Emission Test Results (100% RDF Firing)**

| Pollutant | Emissions Uunit A | Emissions Unit B | Permit Limit |
|---|---|---|---|
| HCl (ppm) | 4.6 | 6.2 | 25 |
| $SO_2$ (ppm) | 1.0 | 0.5 | 30 |
| Particulate (gr/dscf) | 0.0015 | 0.0056 | 0.010 |
| Arsenic (µg/dscm) | 0.2 | 0.2 | 10 |
| Cadmium (µg/dscm) | ND | 0.3 | 40 |
| Chromium (µg/dscm) | 4.8 | 5.6 | 120 |
| Lead (µg/dscm) | 3.6 | 30.9 | 490 |
| Mercury (µg/dscm) | 15.8 | 2.9 | 80 |
| Nickel (µg/dscm) | 3.1 | 3.1 | 100 |
| Total Dioxin-Furans (ng/dscm) | 2.1 | 4.9 | 30 |

Notes:

All concentrations are at 7% $O_2$.
ND-below detection limits.

**Table 6. Emission Test Results (50% Residential Waste & 50% Wood)**

| Pollutant | Emissions Unit B | Permit Limit |
|---|---|---|
| HCL (ppm) | 2.4 | 25 |
| $SO_2$ (ppm) | 0.6 | 30 |
| Particulate (gr/dscf) | 0.0047 | 0.010 |
| Arsenic (µg/dscm) | 0.3 | 10 |
| Cadmium (µg/dscm) | 0.1 | 40 |
| Chromium (µg/dscm) | 5.9 | 120 |
| Lead (µg/dscm) | 22.1 | 15.8 |
| Mercury (µg/dscm) | 0.5 | 80 |
| Nickel (µg/dscm) | 3.1 | 100 |
| Total Dioxin-Furans (ng/dscm) | 2.1 | 30 |

Note:

All concentrations are at 7% $O_2$.

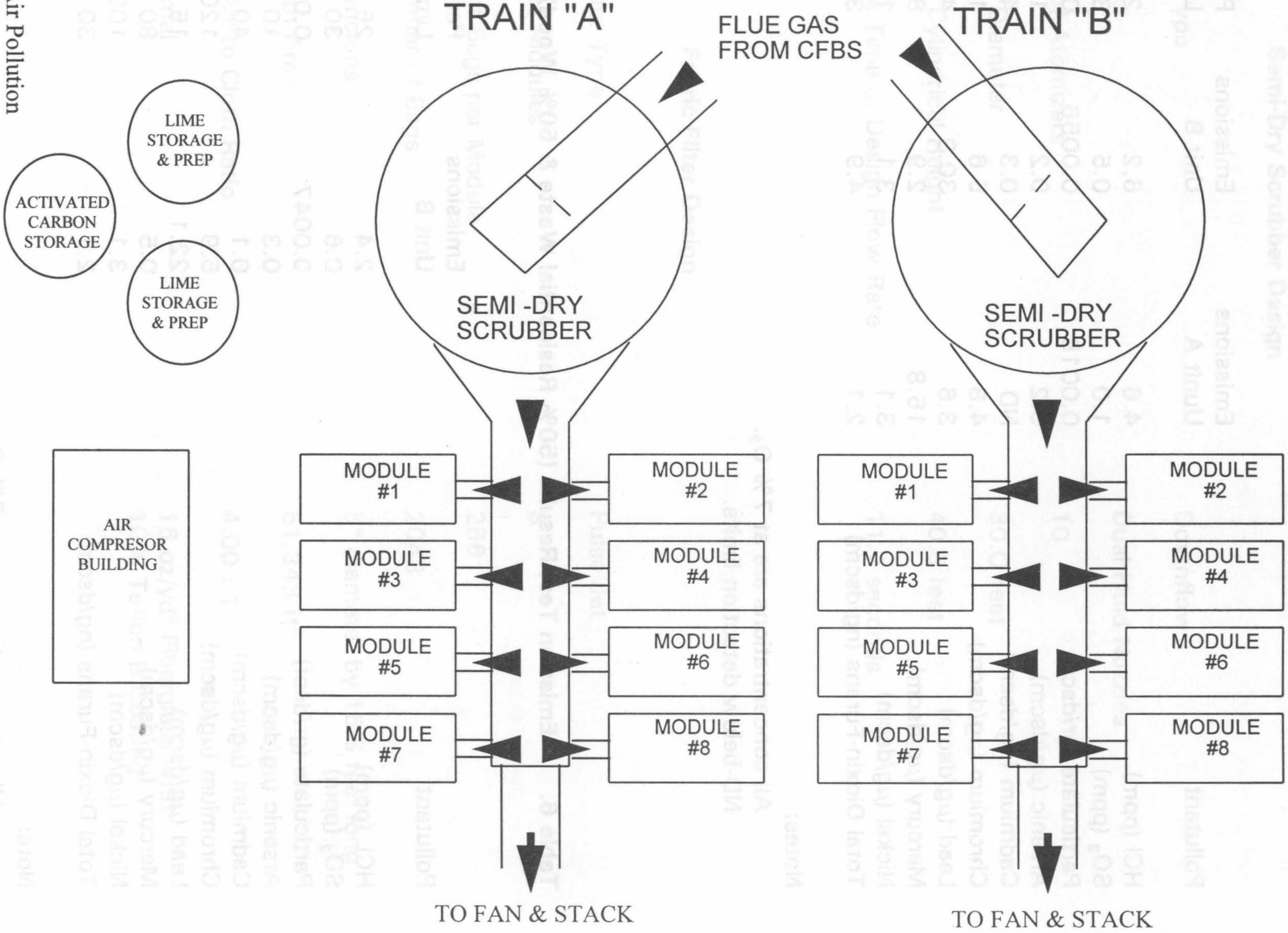

Figure #1- Air Pollution Control System

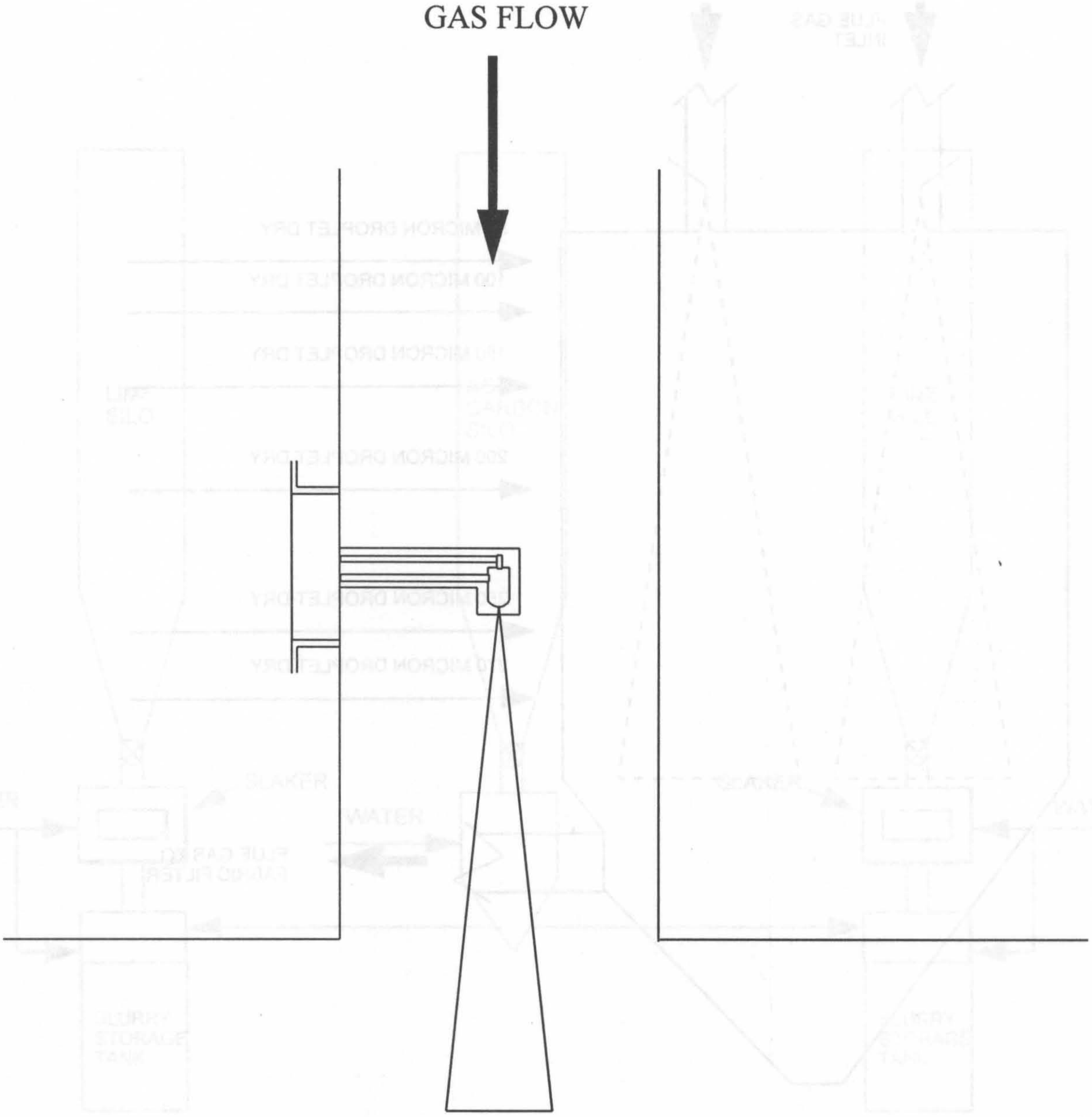

Figure #2
Atomization and Mixing

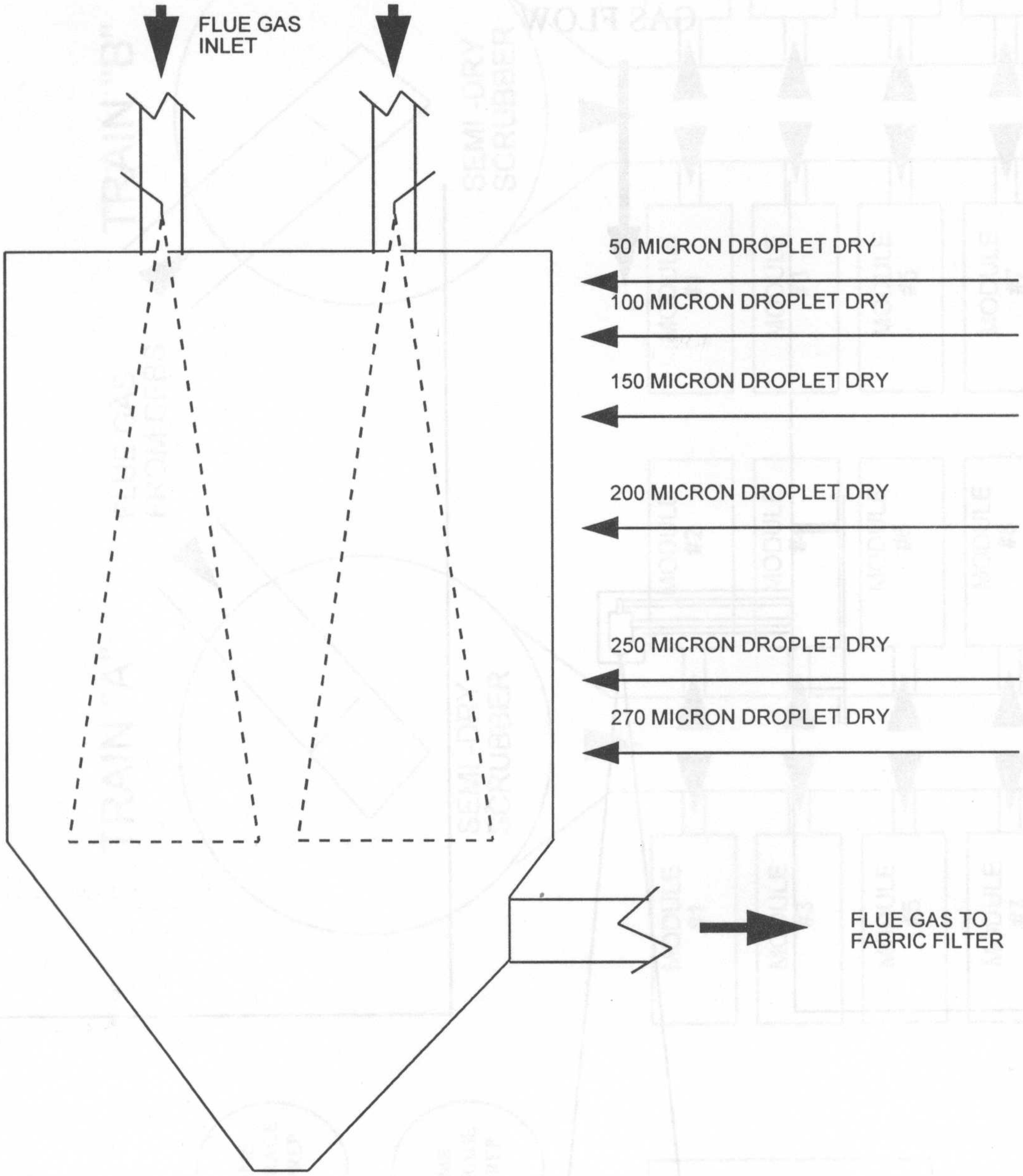

Figure #3
Typical Drying Profile

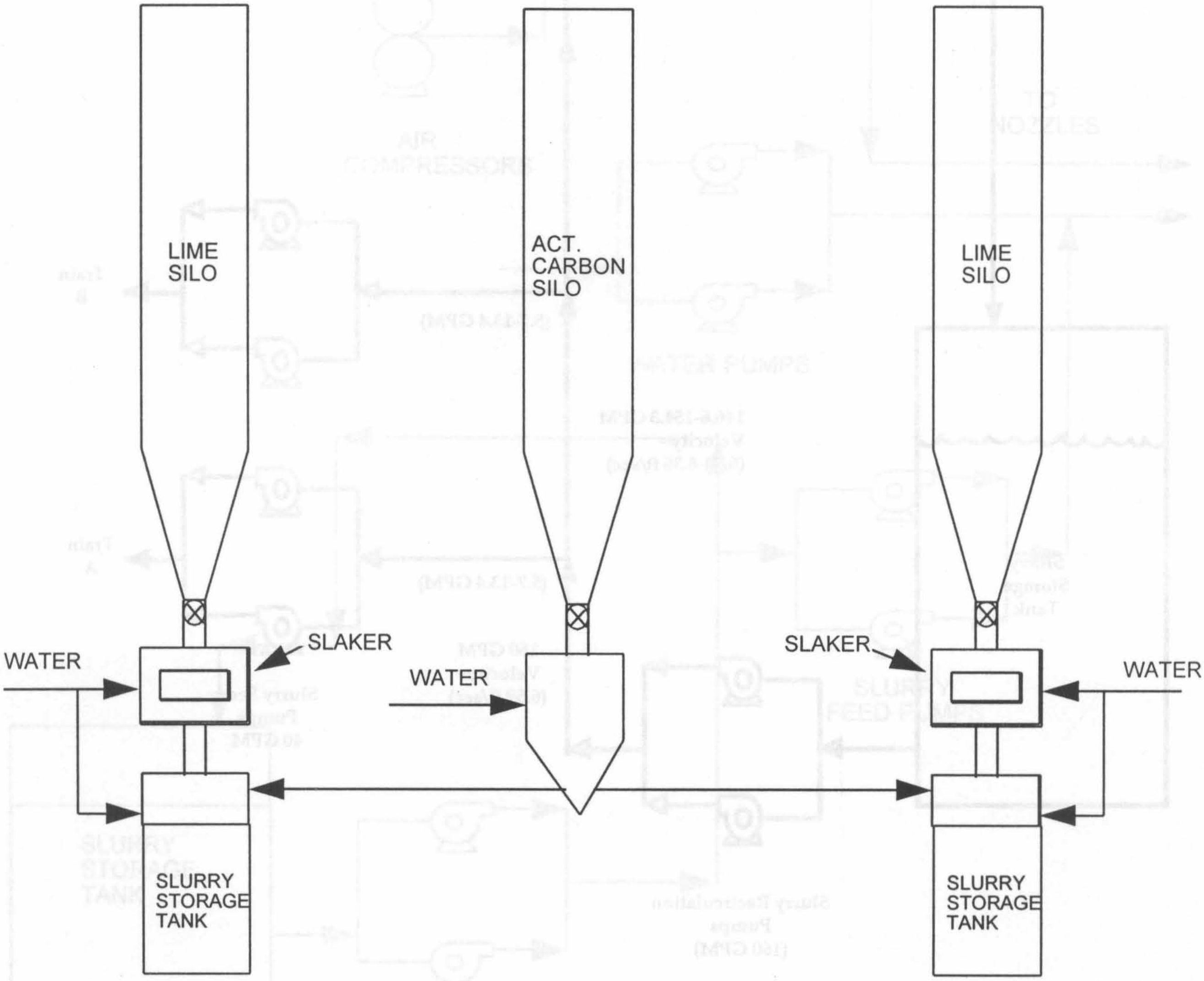

Figure #4
Slurry and Activated Carbon
Preparation

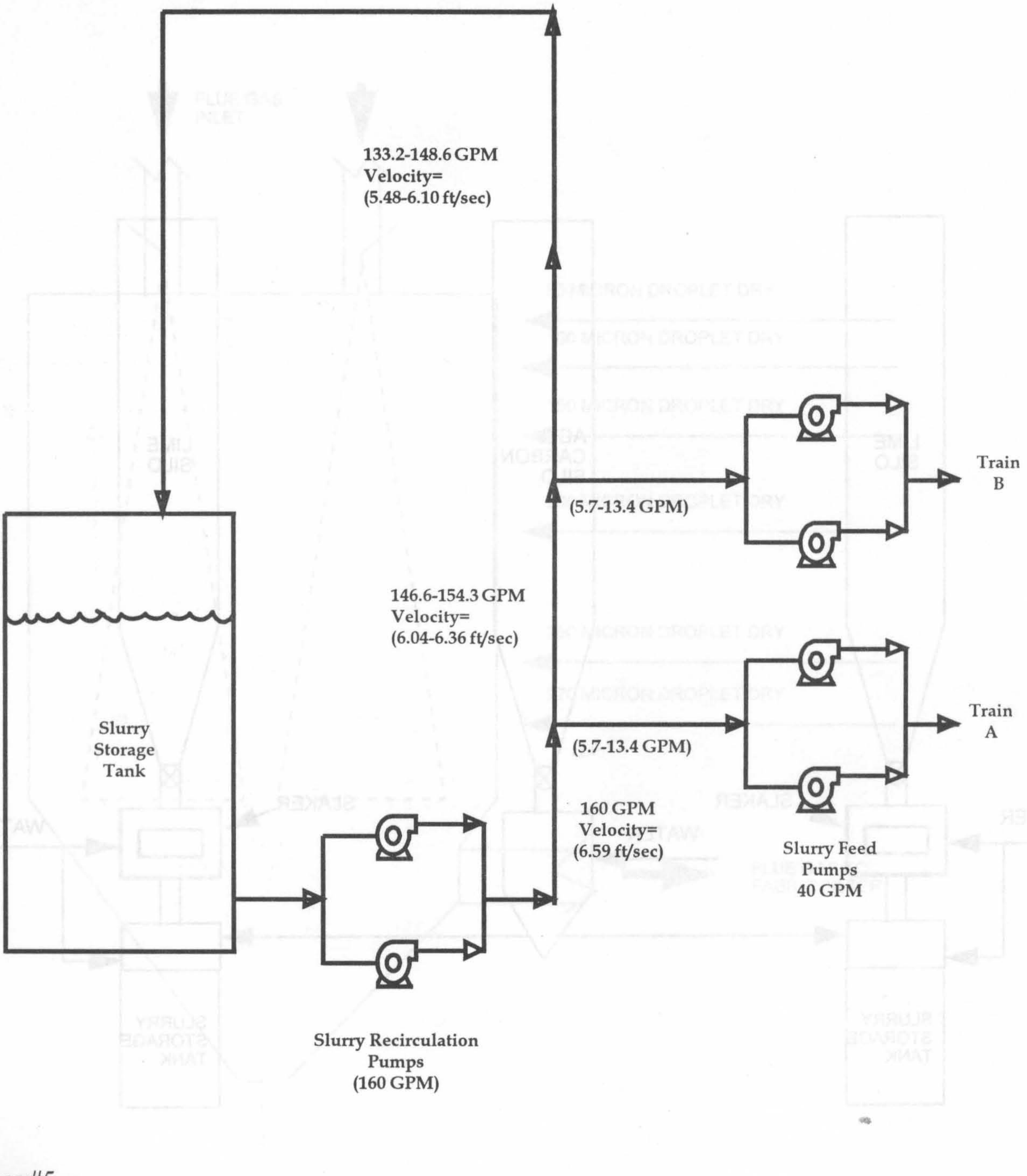

Figure #5
Slurry Recirculation

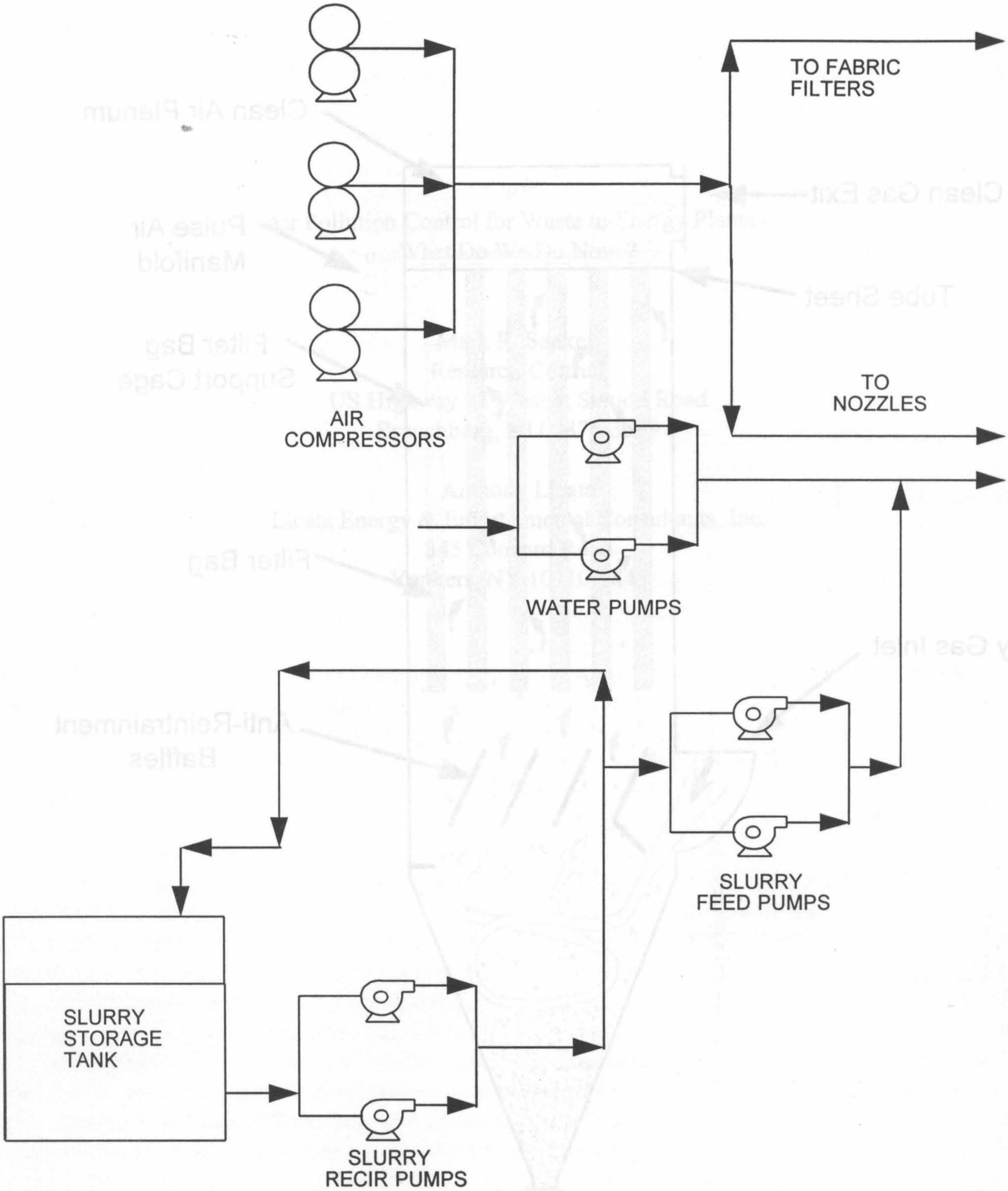

Figure #6
Slurry, Dilution Water & Compressed Air

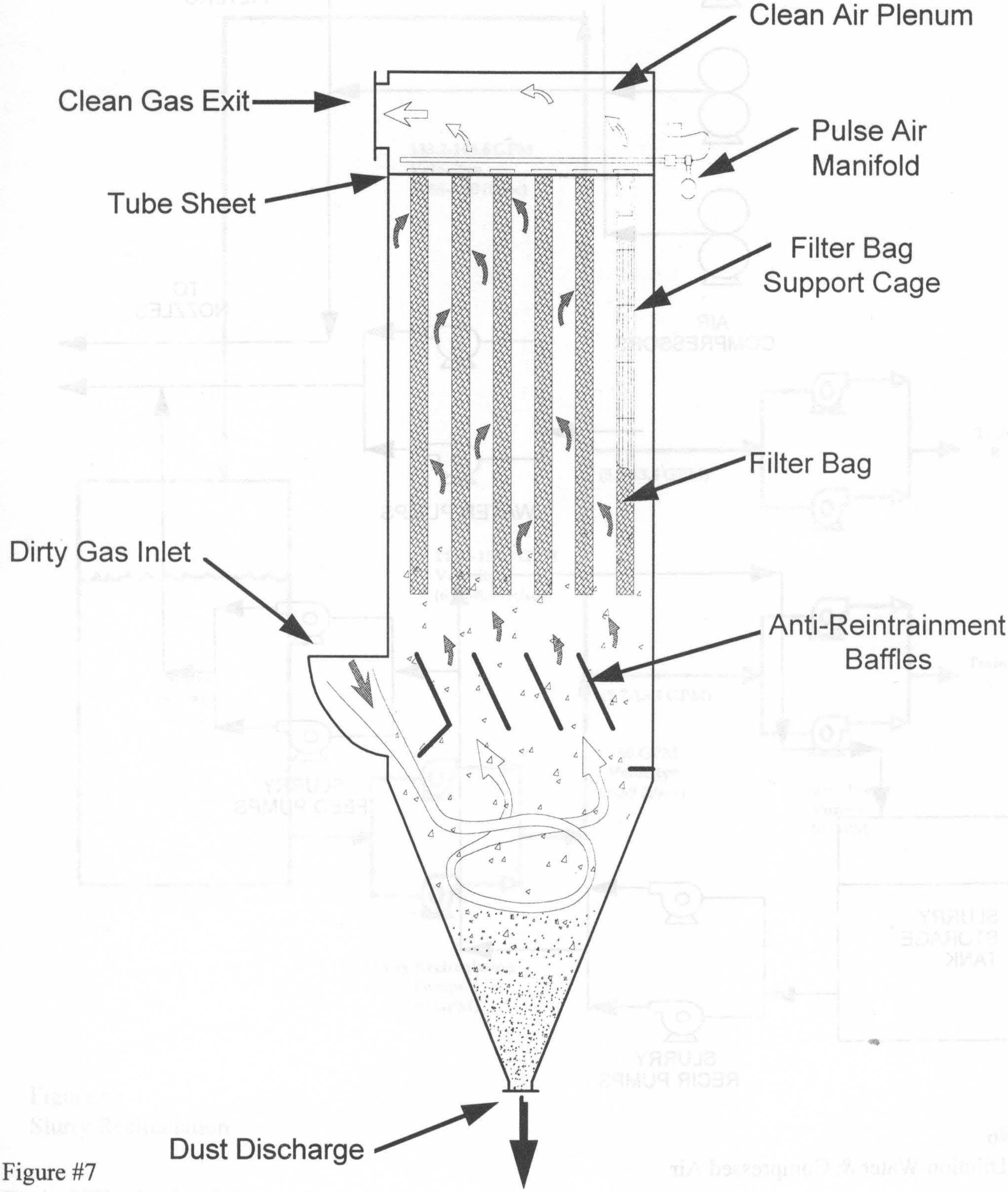

Figure #7
Typical Filtering Module