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Comparison of Five Types of Low-Energy Scrubbers for Dust Control

By E. F. Divers and J. J. Janosik



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COMPARISON OF FIVE TYPES OF LOW-ENERGY SCRUBBERS FOR DUST CONTROL

by

E. F. Divers¹ and J. J. Janosik²

ABSTRACT

This Bureau of Mines report describes the results of a program to develop small, rugged mechanical dust collectors (scrubbers) with high dust collection efficiency and low energy consumption for controlling dust in coal mining operations. All of the scrubbers described are similar in configuration and are powered by 6-hp, 2,000-ft³/min vane axial fans. Air pressure differential is less than 6 inches water column. Height of the scrubbers including fan is less than 14 inches, width is less than 16 inches, and length is less than 45 inches.

The flooded fibrous-bed scrubber achieved respirable (less than approximately 7 μ m) dust collection efficiencies of 95 percent. The small-diameter-cyclone scrubbers showed about 92 percent efficiency and can be best where excess water is a problem. The wetted brush scrubber showed 88 percent efficiency at low cost, and the wetted fan scrubber showed a slightly lower efficiency (87 percent) but offered the smallest size and cost.

A suitable water droplet eliminator is described.

INTRODUCTION

Both the Government and private industry have been interested in scrubbers for coal mine dust control, especially for face operations, since the introduction of the continuous miner in the United States in 1948. Various types of scrubbers were designed by industry and evaluated in coal mines. With few exceptions, such as the Donaldson³ small-diameter cyclone type and the Gundlach wetted fan type, only a few of the early scrubber designs are in use today because of a combination of large size, misapplication, mechanical problems, and relatively low dust collection efficiency. However, field tests

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³Reference to specific trade names is made for identification only and does not imply endorsement by the Bureau of Mines.

with these scrubbers did generally point out at least three distinct advantages: A strong potential for the control of respirable dust, improved face visibility, and less rock dusting required in return airways.

More recent laboratory and field work at the Bureau of Mines Pittsburgh Mining and Safety Research Center has shown that scrubbers can offer a highly effective technique for dust control at coal mine face operations when properly combined with the face ventilation system. For the most effective applications, these scrubbers are usually mounted on or in the mining machine, and minimum scrubber size is essential for successful installation. Fortunately, field studies and laboratory modeling work of face ventilation systems by the Bureau indicate that, when properly applied, even relatively low volumes of air through the scrubber, 2,000 to 3,000 ft³/min, could do an effective job for dust control with room-and-pillar mining.

The low air volume presented an opportunity to develop a family of various types of very small scrubbers based on a 2,000-ft³/min vane axial fan that was commercially available for coal mine face applications. The scrubbers were selected from previous Bureau tests as being the most promising types. Surprisingly, these small and simple scrubbers frequently demonstrated high coal dust collection efficiency.

This paper summarizes the results of the Bureau's research and development program to develop these scrubbers.

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DUST COLLECTION EFFICIENCY REQUIREMENTS

If miners are exposed to the discharge from the scrubber, such as in sections using blowing ventilation and in longwall operations, the concentration of respirable dust out of the scrubber should be less than 2 mg/m³ (8-hour average, MRE⁴ equivalent) to meet Federal requirements.

The overall efficiency of the scrubber system in field application is the product of the scrubber's laboratory efficiency multiplied by its efficiency in capturing the dust cloud in the mine. Relatively high intake efficiencies (above 80 percent) can be readily achieved in room-and-pillar development where the dust cloud is largely contained by the face coal and machinery. Longwalls and retreat mining usually present much more difficult problems in dust cloud capture.

Bureau field tests to determine dust collection efficiency requirements have indicated that 8-hour average values of respirable dust concentration of up to 20 mg/m³ can be encountered at the face with ripper-type continuous-mining machines, and much higher dust levels are frequently encountered at the

⁴Mining Research Establishment, National Coal Board, Great Britain.

face with boring and auger machines and longwall shearers. A dust collector efficiency of 90 percent would reduce a 20-mg/m^3 value to 2 mg/m^3 in the effluent from the scrubber. However, a higher efficiency scrubber, ranging up to a maximum of about 98 percent, would provide a safety factor and also would be required to compensate for low dust cloud capture efficiency.

For most face applications, collection efficiency above 98 percent for respirable dust can frequently be prohibitive in terms of fan size and power and water use.

Note that a 98-percent-efficient scrubber would result in only 20 percent of the dust in the scrubber effluent than a 90-percent-efficient scrubber; 2 percent versus 10 percent of the dust penetrates the scrubber and is present in the effluent airstream.

LABORATORY TEST FACILITY

In 1971 a laboratory test facility was constructed at the Pittsburgh Mining and Safety Research Center, Bruceton, Pa., to evaluate prospective scrubbers, determine their maximum potential, and develop new scrubbers when required.

Full-size scrubbers up to $10,000\text{ ft}^3/\text{min}$ can be tested in the laboratory facility. A wide range of respirable dust concentrations and size distributions typical of coal mine face operations can be set up and maintained for long periods. The laboratory test facility saves considerable time and effort by reducing the need for the difficult and much more costly underground evaluation of scrubbers.

A flow chart of the dust collector test facility is shown in figure 1. Briefly, fine (minus $1/8$ inch) Pittsburgh seam coal (1.3 g/cm^3) is fed by a vibrator feeder to a commercial pulverizer which reduces it into a very fine dust with size distribution similar to that of airborne coal mine dust. The pulverizer feeds the dust to a variable airstream that is then ducted to the scrubber being tested. The scrubber is placed in the center of a horizontal section of duct approximately 45 feet long. The effluent air is ducted to a baghouse for cleaning prior to being discharged to the atmosphere or bypassed to the atmosphere when moisture might affect baghouse operation.

Airflow velocity and velocity gradients within the duct are probed with pitot tubes and a hot wire anemometer with a special sensor element resistant to damage from airborne particulate matter. The use of duct splitters minimizes velocity gradients.

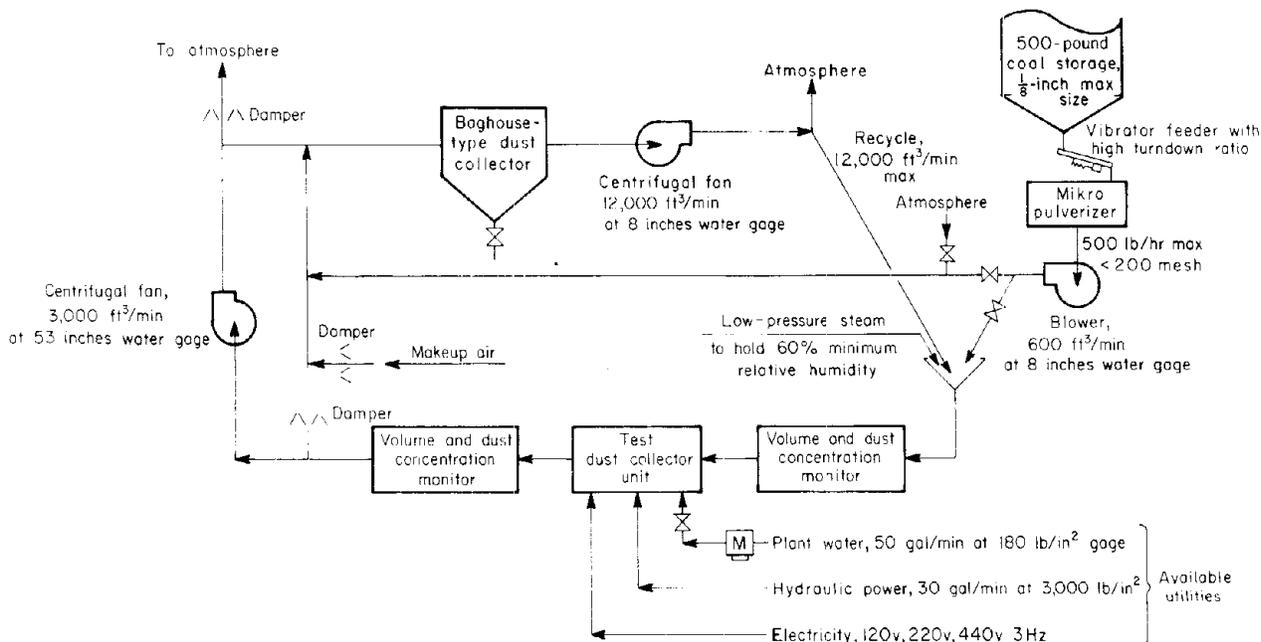


FIGURE 1. - Flow chart of dust collector test assembly.

EXPERIMENTAL PROCEDURE

Dust Sampling

The flow diagram of the dust-sampling system is given in figure 2. Iso-kinetic dust sampling probes were located in the center of the duct, 10 feet upstream and 15 feet downstream of the scrubber. The size distribution of the sampled dust cloud was measured with eight-stage Andersen cascade impactor ambient samplers. The airflow rate through the sampler was $1 \text{ ft}^3/\text{min}$, the manufacturer's recommended value. This type of sampler separates the airborne particulate into various size fractions in accordance with the aerodynamic behavior of the dust particles, and dust particles in specific size ranges are deposited on various stages (plates) of the sampler. Agglomerates of dust particles are deposited as such.

A 1-quart Mason jar was used as a water trap upstream of each impactor with both air connections terminating approximately 1 inch below the sealed lid.

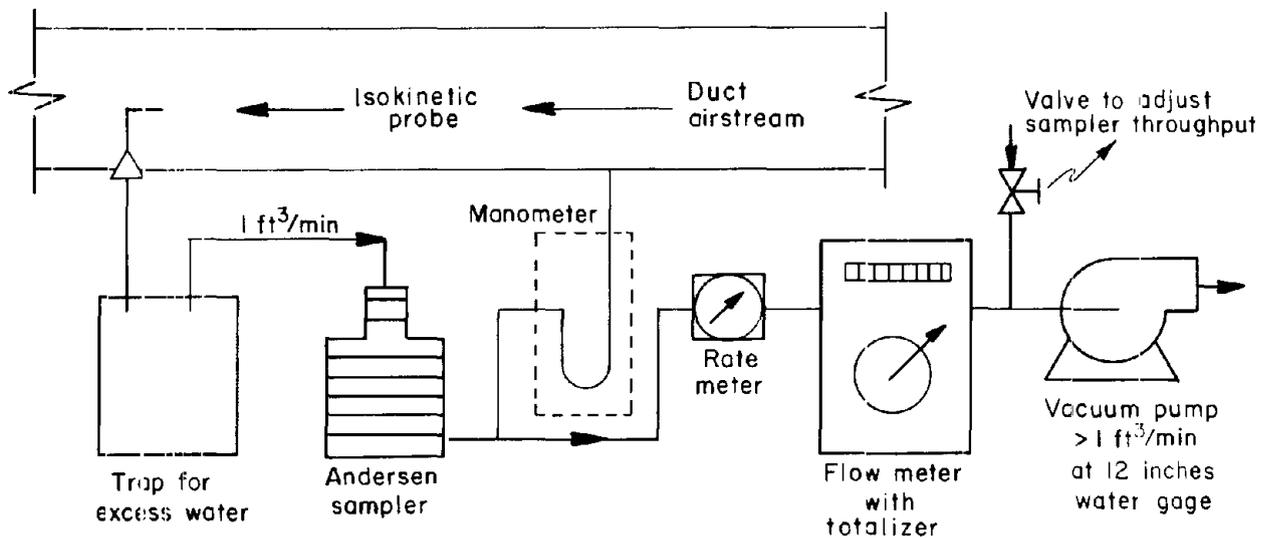


FIGURE 2. - Flow chart for Andersen sampling system. Identical system used at both sampling locations.

A preweighed, 80-mm-diameter, glass fiber Gelman filter was used to cover each plate of the Andersen sampler to increase the ratio of dust weight to tare weight and reduce dust blowoff from overloaded plates.⁵ The filters were desiccated for 30 minutes immediately before weighing.

Due to the large reduction in dust concentration downstream of the scrubber, the sampling time was extended to achieve reasonable dust sample weights. Upstream sampling time usually was about 12 minutes, and downstream sampling time was about 120 minutes. The upstream sampling time was divided into three intervals--at the beginning, middle, and end of the total 120-minute sampling time--to help compensate for possible long-term concentration drift.

Most tests were conducted at a concentration between 50 and 60 mg/m³ respirable coal dust. Tests with a special light-scattering dust monitor developed by Stanford Research Institute⁶ indicated occasional changes in the dust concentration at the upstream station of ± 10 percent for periods of less

⁵A paper by A. K. Rao and K. T. Whitby in the April 1977 issue of American Industrial Hygiene Association shows that while glass fiber collection surfaces reduce particle bounce, they also change the impactor collection efficiency characteristics; that is, the glass fiber reduces the size resolution of the impactor, especially in the smaller range. The net effect on the data presented is to slightly increase the efficiency reported for each size fraction.

⁶Lapple, C. E., and C. F. Schadt. Portable Mine Dust Concentration Instrument. BuMines Open File Rept. 6-73, 1972, 203 pp.; available for consultation at the Bureau of Mines libraries in Pittsburgh, Pa., Twin Cities, Minn., Denver, Colo., and Spokane, Wash.; at the Central Library, U.S. Department of the Interior, Washington, D.C.; and from National Technical Information Service, Springfield, Va. PB 215 150.

than 30 seconds. The total dust concentration into the scrubber normally ranged between two and three times the respirable concentration, when measured with the Andersen sampler.

Dust-Sampling Analysis

Federal regulations pertaining to the health hazards associated with coal mine dust are based only on the respirable fraction of the airborne dust cloud, which is defined as the percentage of the particles of a given aerodynamic size that penetrates into and deposits in the human lung. To determine the respirable fraction of a dust cloud, coal mine dust samplers have an initial or first-stage separator which passes only the respirable fraction.

The respirable fraction of coal mine dust can be determined by an MRE sampler, which uses a parallel-plate elutriator as the separator. The MRE penetration curve can be readily described by the formula:

$$\text{Percent MRE penetration} = \left[1 - \frac{(\text{equivalent diameter, micrometers})^2}{50} \right] \times 100.$$

The dust collection efficiency for the respirable fraction of the dust cloud can then be determined from the fractional breakdown data as measured by the cascade impactor by appropriate application of the MRE curve. The effective cutoff diameter [ECD] for unit-density spheres on each stage of the impactor was taken from tables supplied by the manufacturer (Andersen 2000 Inc., Atlanta, Ga.). The respirable fraction of the weight of dust collected by each stage is obtained by multiplying the weight by the percent MRE penetration factor for each stage. The respirable concentration (in milligrams per cubic meter) corresponding to each stage then is calculated by

$$\frac{35.31}{\text{sampling time}} \times \text{respirable weight},$$

where 35.31 converts cubic feet to cubic meters. The respirable concentration of the dust cloud is the sum of the respirable concentrations corresponding to each stage.

The collection efficiency of the test scrubber then is calculated:

$$\text{Collection efficiency} = \frac{\Sigma \text{upstream conc.} - \Sigma \text{downstream conc.}}{\Sigma \text{upstream conc.}}.$$

It should be noted that the overall dust collection efficiency of the scrubber given by this procedure is still dependent upon the size distribution of the test dust within the respirable range.

When evaluating fractional breakdown data on scrubbers for coal mine use, a very rapid analysis can be made by simply checking the fractional efficiency data approximately between and 1- and 2-um size range. Good scrubbers will show an efficiency well above 80 percent in this size range.

GENERAL DESCRIPTION OF SCRUBBERS

Based on commercially available hardware and applications that would be suitable for both low-coal and machine-mounted applications, the Bureau directed this program toward the development of a family of small, inexpensive, and rugged scrubbers. All of the scrubbers utilized a commercially available, MESA-approved,⁷ 2,000-ft³/min, two-stage vane axial fan (Joy Manufacturing Co. model 5112) powered by an internal 6-hp electric motor.

The height of these scrubbers including fan was held to less than 14 inches, width to less than 16 inches, and length to less than 45 inches excluding the droplet eliminator. Five types of scrubbers having a medium-high dust collection efficiency were investigated or developed: Two types of small-diameter cyclones, and wetted fan, wetted brush, and flooded fibre types. Data for two types of wire brushes are presented.

Our tests show that the Joy 5112 fan is capable of operating at pressures up to roughly 6 inches water gage (if scrubber spray water is kept out of the fan); fan stall occurs at pressures beyond this.

Tests have also shown that the fan will stall at spray waterflow rates greater than roughly 4-1/2 gal/min through the fan. Stall was somewhat arbitrarily defined as operation at less than 1,800 ft³/min for this fan.

Spray water was clean potable water for all tests.

These scrubbers can all be adapted to larger air volumes with appropriate design changes. Joy Manufacturing Co. is now designing a 4,000-ft³/min fan similar to the fan described in this report. This 10-hp fan will be 16 inches in diameter and 24 inches long. If space is available, greater air volumes are usually desirable. As the scrubber volumetric flow rate is increased, the dust cloud capture efficiency can be expected to increase. Once all of the dust cloud is drawn through the scrubber, additional flow will reduce the dust concentration into the scrubber; therefore, scrubber efficiency requirements are reduced.

DROPLET ELIMINATORS

Water droplet eliminators can be used to prevent problems associated with scrubber water draining to the floor, especially with clay bottom, or to reduce the quantity of water in the effluent airstream from the scrubber. Various types of eliminators were tested during the scrubber evaluation program. Effort was directed towards very small, high-face-velocity eliminators with minimum air pressure drop. Recent field and laboratory tests with the Euroform eliminator, manufactured by Munters Corp., Ft. Myers, Fla., have been especially encouraging. One- and two-layer units have been tested at face velocities of approximately 2,000 ft/min. Thus a 2,000-ft³/min scrubber would require 1 square foot of eliminator cross-sectional blade area plus frame and

⁷MESA became the Mine Safety and Health Administration (MSHA), U.S. Department of Labor, on March 9, 1978.

sump requirements. For these tests water elimination generally exceeded 90 percent of the spray water input to the scrubber, and the effluent airstream was free of visible drops. Air pressure drops were about 1 inch water gage across the eliminator.

Maintaining the high 2,000-ft/min face velocity through the eliminator not only reduces its size but also makes it compatible with the face velocity through the wetted wire, steel brush, and plastic brush media, thus reducing or eliminating the need for additional duct transitions and allowing a further reduction in scrubber size.

Even with the high face velocity, the droplet eliminator can be the largest and highest component of the scrubber. The eliminator illustrated in figure 3 is 16 inches wide, 18 inches high, and 10 inches long.

Another approach to the water problem is to develop scrubbers with very low water consumption. Tests at low water rates of the flooded-fibrous-bed, wetted-wire-brush, and small-diameter-cyclone scrubbers have been especially encouraging.

FLOODED FIBROUS-BED-TYPE SCRUBBER

In December 1974, the Bureau of Mines initiated tests on a prototype flooded fibrous-bed scrubber, using a fiber developed by E.I. du Pont de Nemours & Co.² During these tests the wire fiber was tested at air pressure differentials ranging from 2½ to 20 inches water gage, and at spray waterflow rates up to 6 gal/min per 1,000 ft³/min.

The 3-month test program showed that the prototype scrubber had a significantly higher dust collection efficiency than any other device previously tested. It also appeared to offer the advantages of minimum size and simplicity. Based on a Bureau design, du Pont then fabricated the scrubber tested in this report.

Description

The basic scrubber (fig. 3) consists of the Joy fan, a short duct transition at the fan inlet, and a rectangular housing that holds a 1-foot by 1-foot by 1/4-inch-thick bed (approximately 32 double layers) or mat of knitted wire mesh. The wire is 0.0035-inch-diameter, type 430 stainless steel. Dusty air is drawn through the bed of wire mesh at a velocity of 2,000 ft/min. The wire mesh was positioned approximately 15 inches upstream of the fan for all tests. Spray nozzles are installed in the duct upstream of the mesh to insure reasonably complete and uniform wetting of the mesh. Nozzle type is listed on test sheets A1, A2, and A3 (appendix).

Spray water rates can exceed 4 gal/min if the droplet eliminator is placed upstream of the fan. Slurry drain slots with appropriate pipe

²R. L. Lucas and others. Process and Apparatus for Wet Scrub Removal of Dust and Mist From Gases. U.S. Pat. 3,370,401, Feb. 27, 1968.

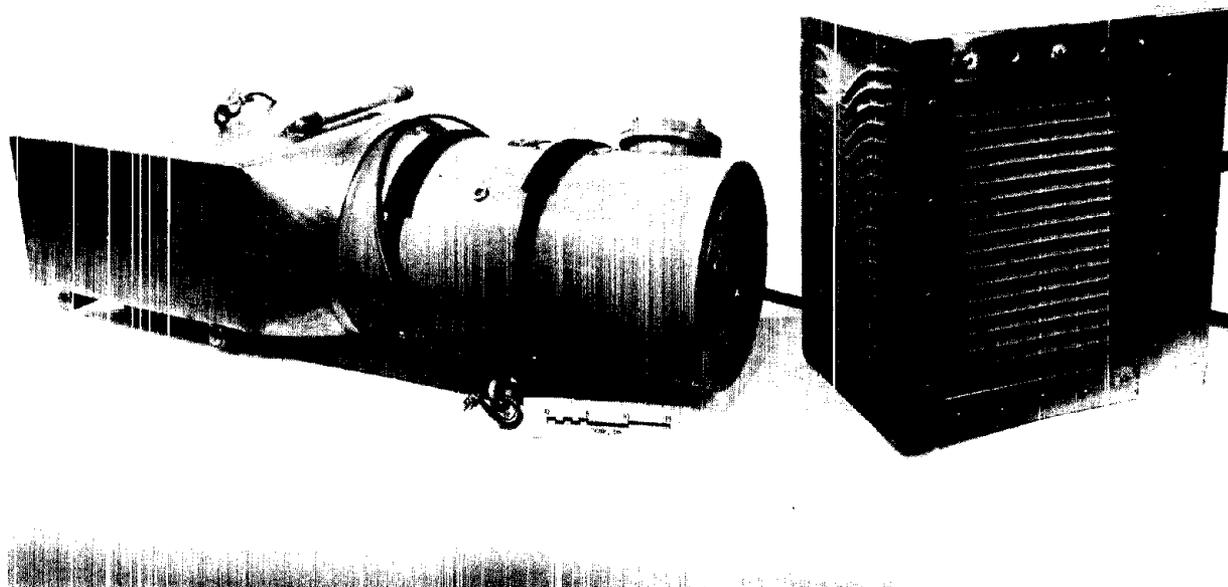


FIGURE 3. - Flooded fibrous-bed scrubber. A suitable 2,000-ft³/min eliminator (Euroform) on right with top removed to show curved blades.

connections are installed on both bottom sides of the wire mesh housing. The basic scrubber is 13 inches high, 12-1/2 inches wide, and 42 inches long, including the fan and excluding the eliminator. The Euroform droplet eliminator was added to the scrubber for some tests.

Results

Five different conditions were tested and three laboratory tests were run for each condition (table 1) to determine the maximum dust collection efficiency and also to determine the impact of two locations of the droplet eliminator on efficiency and fan performance. The water sprays and mesh were located upstream of the fan for all tests. Raw data sheets (A1, A2, and A3) for the three tests showing the highest efficiency are given in the appendix.

Condition 3 with the sprays, wire mesh, and Euroform droplet eliminator upstream of the fan showed a dust collection efficiency averaging 89 percent on respirable coal dust.

Condition 2 with the droplet eliminator downstream of the sprays, mesh, and fan showed a much higher efficiency of 95 percent, but at a significant sacrifice in fan volumetric flow rate. This test indicates that the water

flow rate through the fan has a significant impact on dust collection efficiency, especially at higher pressure differentials across the fan.

TABLE 1. - Summary sheet--2,000-ft³/min flooded fibrous-bed scrubber

Test	Air volume, ft ³ /min	Water rate, gal/min	Water pressure, lb/in ² gage	Differential pressure across fan, inches of water	Dust collection efficiency, percent	Comments
Condition 1:						
2/14.....	2,190	5.2	140	6	93	} Eliminator upstream.
2/15.....	2,190	5.2	140	6	93	
2/16.....	2,190	5.2	140	6	92	
Average.	-	-	-	-	93	
Condition 2:						
1/21.....	1,880	2.6	120	4-1/2	94	} Eliminator downstream.
1/24.....	1,880	2.6	120	4-1/2	95	
1/25.....	1,880	2.6	120	4-1/2	96	
Average.	-	-	-	-	95	
Condition 3:						
2/4.....	2,190	2.7	120	6	87	} Eliminator upstream.
2/7.....	2,190	2.7	120	6	90	
2/8.....	2,190	2.7	120	6	89	
Average.	-	-	-	-	89	
Condition 4:						
4/5.....	1,950	3.5	60	4-1/2	86	} No eliminator.
4/7.....	1,950	3.5	60	4-1/2	87	
4/9.....	1,950	3.5	60	4-1/2	85	
Average.	-	-	-	-	86	
Condition 5:						
3/31.....	2,200	1	45	5	83	} Do.
4/1.....	2,200	1	45	5	81	
4/2.....	2,175	1	45	5	80	
Average.	-	-	-	-	81	

Conditions 4 and 5 were conducted without using the eliminator--that is, with just the fan, wire mesh, and sprays. This basic arrangement results in minimum size and cost. Disadvantages are that the dust-laden water droplets go through the fan and are present in the effluent airstream from the scrubber.

Comments

One distinct advantage results from the effort to develop 2,000-ft/min face velocities through the media and droplet eliminator; transitions from the media to the eliminator or air duct can be very simple 1-to-1 ratios, thus allowing the mesh to be placed immediately upstream of the eliminator.

Waterflow rates typically range from about 1 to 3 gal/min per 1,000 ft³/min for coal mine applications, although recent tests indicate that a

fairly high dust collection efficiency can also be achieved with less than 1/2 gal/min per 1,000 ft³/min with this type of scrubber.

At a face velocity of 2,000 ft/min a bed thickness of roughly 1/4 inch will result in an air pressure differential of approximately 2-1/2-inch water gage. Air pressure differentials can be changed by adding or removing layers of mesh until a desired pressure differential is achieved.

While this type of scrubber has the highest collection efficiency measured to date, it may be more susceptible to clogging than other types of scrubbers. Coarse particulate would obviously clog the mesh, but it is felt that appropriate design changes, such as back-flushing sprays or a design that permits rapid replacement of clogged mesh, would resolve the problem.

Somewhat to our surprise, several underground tests to date have not shown a clogging problem. The only clogging problem encountered during the Bureau tests occurred when a single hollow cone spray was used in the bottom fitting located very close to the mesh in the scrubber housing. This resulted in a distinct doughnut-shaped pattern on the mesh, with caked coal dust clogging the center and periphery of the mesh; uniform wetting normally prevents this.

Total costs of the flooded fibrous-bed scrubber can be fairly high, roughly \$2.50 per cubic foot per minute of volumetric capacity.

TWO SMALL-DIAMETER CYCLONE SCRUBBERS

Two types (Donaldson Co., Minneapolis, Minn., and Merix Corp., Wellesley, Mass.) of small-diameter cyclone scrubbers were tested. Next to the wetted fan type the small-diameter cyclone type is the most popular scrubber used in underground applications. The Donaldson scrubber is commonly used in many coal applications. The Merix cyclone scrubber is new for coal applications.

Description

The small-diameter cyclone scrubber (figs. 4-5) consists of a bank or panel of side-by-side cylindrical cyclone tubes. Tube diameter is usually less than 4 inches. Each tube has an air volume capacity roughly from 50 to 250 ft³/min, depending on the tube diameter and air pressure differential across the tube. Air pressure drops normally range from 2 to 5 inches water gage.

Stationary vanes in each tube create a spinning action to the airstream. Particulate matter is thrown to the side of the tube where it can either be bled off in a separate airstream or impact on the wetted vanes or side wall of the tube. Water sprays are placed upstream of the panel to insure complete wetting. Water spray nozzle flow rates usually range from 1/4 to 3 gal/min per 1,000 ft³/min of scrubber capacity. For these tests both panels had a cross-sectional area of roughly 1-1/2 square feet.

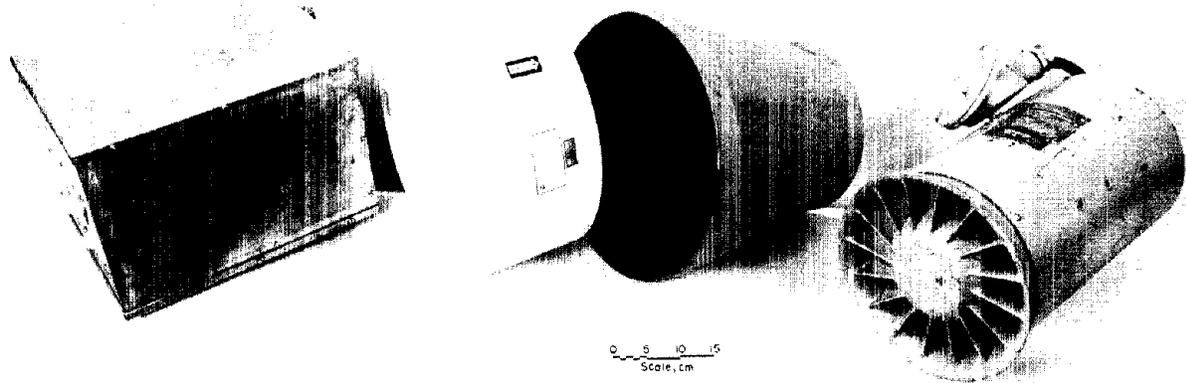


FIGURE 4. - Small-diameter cyclone scrubbers. Merix panel on the left, Donaldson panel on right. Transition for the Donaldson and an appropriate 2,000-ft³/min Joy fan are also shown. Airflow would be from left to right.

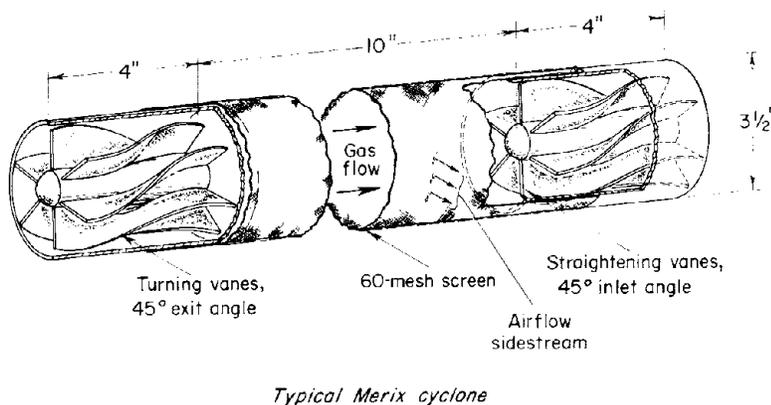
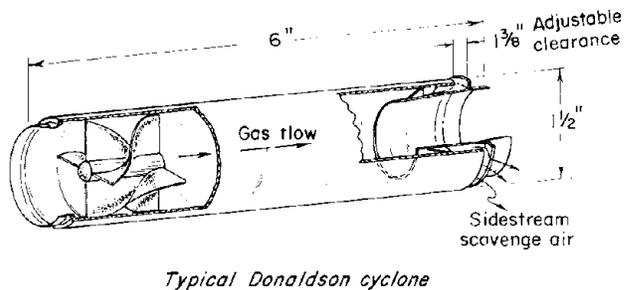


FIGURE 5. - Donaldson and Merix cyclone detail.

percent of the scrubber spray water input. The Donaldson cyclone can remove up to approximately 60 percent.

Results

Five conditions were examined with each of the small-diameter cyclone scrubbers; three different tests were made with each condition. Results are summarized in tables 2 and 3.

The highest efficiency (92 percent, condition 1) was achieved with the Merix panel. However, previous testing programs have indicated that the dust collection efficiencies of the Merix and Donaldson cyclones are about equal, both peaking at about 93 percent when high-pressure, high-flow-rate sprays are used with maximum air pressure differentials.

These tests have indicated that the Merix cyclone can typically remove over 80

TABLE 2. - Summary sheet--Merix cyclone scrubber

13

Test	Air volume, ft ³ /min	Water rate, gal/min	Water pressure, lb/in ² gage	Differential pressure across fan, inches of water	Dust collection efficiency, percent
Condition 1:					
4/1.....	1,970	5-1/2	65	5	91
4/2.....	1,970	5-1/2	65	5	90
4/9.....	1,970	4	65	5	93
Average.....	-	-	-	-	92
Condition 2:					
3/6.....	2,100	5-1/2	75	3	85
3/10.....	2,100	6	70	3	83
3/11.....	2,100	6	70	3	89
Average.....	-	-	-	-	86
Condition 3:					
3/12.....	2,100	1	70	3	80
3/13.....	2,100	1	70	3-1/2	79
3/14.....	2,100	1	70	3-1/4	78
Average.....	-	-	-	-	79
Condition 4:					
2/28.....	2,100	2	70	3	82
3/3.....	2,100	2	70	3	78
3/5.....	2,100	2	70	3	82
Average.....	-	-	-	-	81
Condition 5:					
3/26.....	2,100	2	70	3-1/2	81
3/31.....	1,970	2	70	3-1/2	83
Average.....	-	-	-	-	82

TABLE 3. - Summary sheet--Donaldson cyclone scrubber

Test	Air volume, ft ³ /min	Water rate, gal/min	Water pressure, lb/in ² gage	Differential pressure across fan, inches of water	Dust collection efficiency, percent
Condition 1:					
6/10.....	2,065	5-1/2	70	5	92
6/11.....	2,065	5-1/2	70	5	87
6/12.....	2,065	5-1/2	70	5	88
Average.....	-	-	-	-	89
Condition 2:					
4/25.....	2,100	5-1/2	70	3	86
4/28.....	2,100	5-1/2	70	3	83
4/29.....	2,100	5-1/2	70	3	84
Average.....	-	-	-	-	84
Condition 3:					
5/22.....	2,100	1/2	40	3-1/4	78
5/27.....	2,100	1/2	40	3-1/4	76
5/28.....	2,100	1/2	40	3-1/4	81
Average.....	-	-	-	-	78
Condition 4:					
6/2.....	2,065	1/2	40	5	76
6/3.....	2,065	1/2	40	5	84
6/5.....	2,065	1/2	40	5	82
Average.....	-	-	-	-	81
Condition 5:					
5/9.....	2,100	1-1/2	70	3-1/4	86
5/15.....	2,100	1-1/2	70	3-1/4	76
5/21.....	2,100	1-1/2	70	3-1/4	77
Average.....	-	-	-	-	80

Comments

The small-diameter cyclone scrubber has one distinct advantage: it can be both scrubber and eliminator. Thus, it is a logical choice where an eliminator is needed and minimum size is essential. It is also a wise choice where minimum use of water is essential, and in previous tests has demonstrated reasonable efficiency (80 percent) at spray water rates as low as 1/4 gal/min per 1,000 ft³/min.

Underground tests have shown some clogging problems when clay is present in the seam and when the scrubber is operated at low water flow rates.

Maximum pressure differential for these tests was limited to approximately 5 inches water gage. This is a rough maximum for small-diameter cyclones; if higher efficiency is desired and higher fan pressure is available, it would be beneficial to select another scrubber type such as the flooded bed or venturi.

Cost of the small-diameter cyclone scrubber is fairly high, averaging about \$2 per cubic foot per minute of volumetric capacity.

WETTED FAN SCRUBBER

Description

In general the wetted fan scrubber (fig. 6) consists of a heavy-duty fan, centrifugal or vane axial type, with a water spray into the fan inlet. Fan

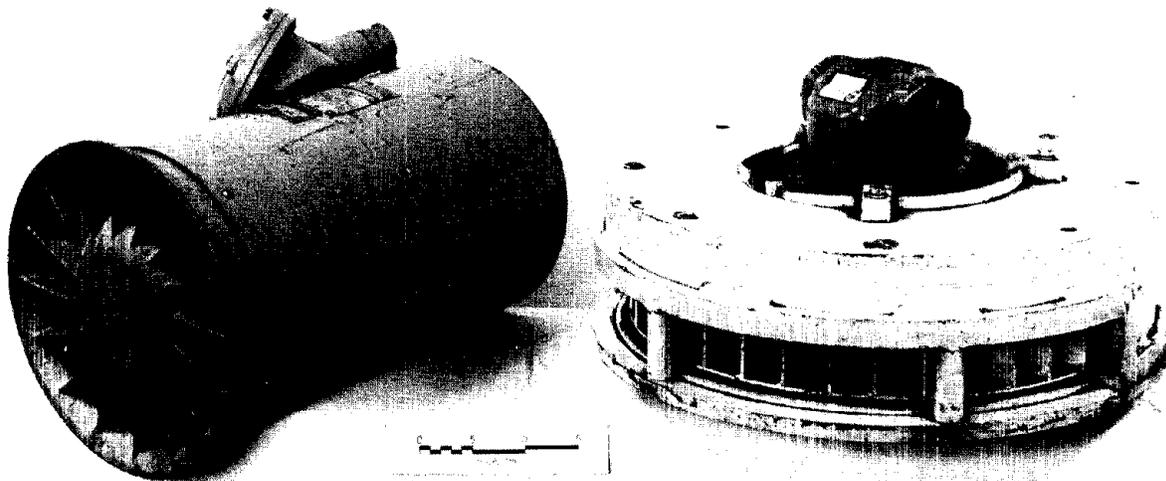


FIGURE 6. - Wetted fan scrubbers. The 2,000-ft³/min internal-electric-motor-driven Joy 5112 vane axial fan on the left can be readily converted to a wetted fan scrubber by adding water sprays, less than 4 gal/min, to the fan inlet. The 2,000-ft³/min hydraulically driven Gundlach centrifugal fan on the right was designed as a wetted fan scrubber.

differential pressures normally range from 1 to 5 inches water gage. Water-flow through the spray nozzles generally ranges from 1 to 3 gal/min per 1,000 ft³/min of scrubber air volume capacity.

For this report the scrubber consisted of the 2,000-ft³/min Joy 5112 vane axial fan with water spray nozzles located approximately 15 inches upstream of the fan inlet. Nozzle type is listed on scrubber test sheets A10, A11, and A12.

Scrubber size can be as small as 12 inches in diameter by 32 inches long if a droplet eliminator is not used.

Results

Four different conditions were examined, three tests for each condition. Results are summarized in table 4.

TABLE 4. - Summary sheet--Four conditions with wetted fan scrubber

Test	Air volume, ft ³ /min	Water rate, gal/min	Water pressure, lb/in ² gage	Differential pressure across fan, inches of water	Dust collection efficiency, percent	Comments
Condition 1:						} Droplet eliminator downstream of fan.
2/25.....	2,150	2.6	140	1	87	
2/28.....	2,150	2.6	140	1	87	
3/1.....	2,150	2.6	140	1	87	
Average.	-	-	-	-	87	
Condition 2:						} Fan near stall. No eliminator.
8/12.....	1,880	5.5	70	1-1/2	66	
8/13.....	1,880	5.5	70	1-1/2	85	
8/14.....	1,880	5.5	70	1-1/2	62	
Average.	-	-	-	-	71	
Condition 3:						} Do.
8/1.....	2,400	.5	40	1-1/2	57	
8/4.....	2,400	.5	40	1-1/2	71	
8/5.....	2,400	.5	40	1-1/2	60	
Average.	-	-	-	-	61	
Condition 4:						} Droplet eliminator in front of fan.
3/3.....	2,400	5.1	140	3	30	
3/4.....	2,400	5.1	140	3	42	
3/7.....	2,400	5.1	140	3	44	
Average.	-	-	-	-	39	

For these tests the highest efficiency, 87 percent (condition 1), was achieved with relatively high (140 lb/in² gage) spray water pressure and when the Euroform droplet eliminator was placed downstream of the fan.

The lowest efficiency, 39 percent (condition 4), occurred when the droplet eliminator was placed in front of the fan, thus keeping most (over 90

percent) of the water out of the fan. This showed that the eliminator had a relatively small effect on efficiency.

Conditions 2 and 3 were conducted without the droplet eliminator to demonstrate the effect of spray waterflow rate, 5-1/2 gal/min versus 1/2 gal/min, on dust collection efficiency.

Comments

The wetted fan scrubber (centrifugal or vane axial) is the smallest and simplest scrubber. It is normally used where minimum size is essential. This has made the wetted fan scrubber very popular for underground use. All of the major continuous-mining-machine manufacturers can supply these scrubbers as an accessory to their machines. Most of these scrubbers are hydraulically driven centrifugal-type fan scrubbers, which are especially suitable for auger support frame (boom) mounting. The inlet to the scrubber is located in the bottom of the boom, and the discharge from the scrubber is directed either inby or outby, depending on the desired arrangement.

More wetted fan scrubbers have been tested at the Pittsburgh Mining and Safety Research Center than any other type of scrubber. Most of these were centrifugal fan types and included Jeffrey, Joy, Gundlach, and Vortex units.⁹

These tests indicate centrifugal wetted fan scrubbers generally have a slightly higher dust collection efficiency than vane axial wetted fan scrubbers. Typical respirable coal dust collection efficiencies range from about 70 percent to 90 percent. The tests also show that the efficiency increases with increased spray waterflow rate, spray water pressure, and increasing pressure differential across the fan.

The wetted fan scrubbers have several problems including fan blade erosion, mechanical damage from oversize material, and fan stall or motor overload when water throughput is excessive. Utilizing a droplet eliminator upstream of the fan can reduce these problems but at the cost of a drastic decrease in dust collection efficiency and significant increase in size.

For maximum dust collection efficiency wetted fan scrubbers should be operated at the highest waterflow rate that will not significantly impair fan performance. Wetted fan scrubbers usually have the lowest cost, approximately \$1.50 to \$2 per cubic foot per minute of volumetric capacity.

WETTED BRUSH SCRUBBERS

A bed of wire or plastic brushes was added to the basic wetted fan scrubber in an effort to improve the efficiency by capitalizing on the dust impaction benefits of the small-diameter wire target of the flooded fibrous-bed scrubber.

⁹Reports of these tests are available from Mine Safety and Health Administration, 4800 Forbes Avenue, Pittsburgh, Pa. 15213, Attention: Mr. T. Tomb.

A layer of approximately 28 stainless steel brushes was added to the inlet side of the fan (fig. 7). The brushes (Beco Engineering, Glenshaw, Pa.) were similar to those commonly used to wash bottle interiors: 2- to 4-inch outside diameter, length of several inches, with radial wires extending from a central rod. Wire diameter was 0.010 inch. The brushes can be purchased commercially.

The brushes were located in a fan inlet transition and held in place by a wire screen, 3/4-inch mesh, located approximately 14 inches upstream of the fan inlet. Inside dimension of the transition at this location was 12 inches high by 13 inches wide. Overall length, excluding the eliminator, was 38 inches.

Water sprays were located upstream of the brushes to insure complete wetting. A small sump with a 3/4-inch drain connection was located immediately behind the brushes to capture the water that usually flows along the bottom of the transition.

For the second series of tests the stainless steel brushes were replaced with 30 polypropylene brushes of identical overall dimensions. Wire diameter was approximately 0.015 inch.

Stainless Steel Brushes

Table 5 contains results of tests with the wetted brush scrubbers. Maximum efficiency (88 percent) occurred with the stainless steel brushes and the

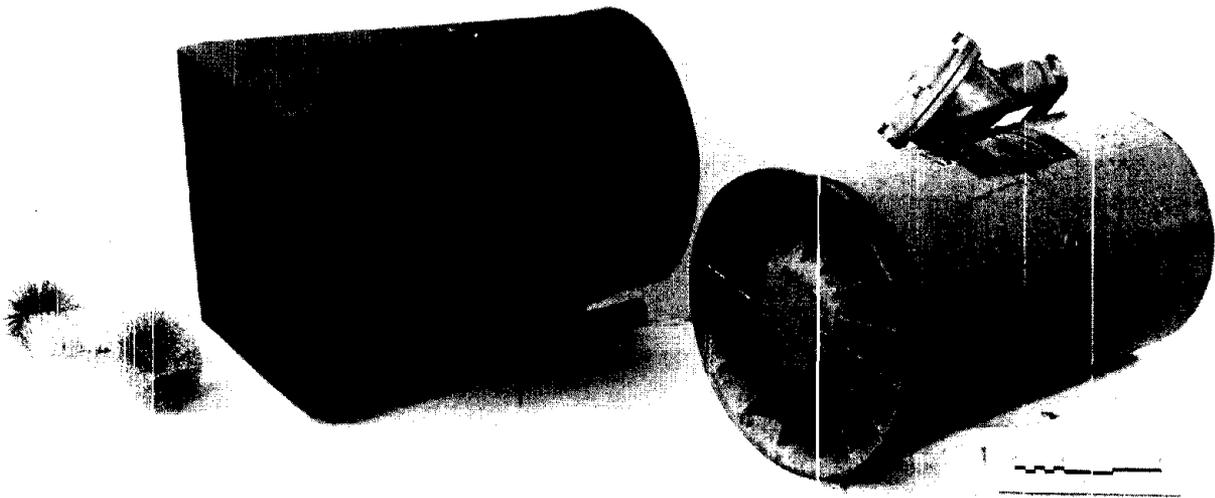


FIGURE 7. - Wetted brush scrubber. Typical brushes, transition with drain, and 2,000-ft³/min fan are shown. A wire mesh retainer in the transition holds approximately 28 stainless steel brushes in this scrubber. Water sprays not shown.

fan operating near the stalled condition, 1,750 ft³/min (condition 1). Spray water rate, 4 gal/min, was near the maximum acceptable by the fan.

TABLE 5. - Summary sheet--Wetted brush scrubbers

Test	Air volume, ft ³ /min	Water rate, gal/min	Water pressure, lb/in ² gage	Differential pressure across fan, inches of water	Dust collection efficiency, percent
STAINLESS STEEL BRUSHES					
Condition 1:					
10/17.....	1,750	4	45	3-1/2	88
10/21.....	1,750	4	45	3-1/2	88
10/22.....	1,750	4	45	3-1/2	89
Average.....	-	-	-	-	88
Condition 2:					
10/30.....	2,000	2	60	4	90
10/31.....	2,000	2	60	4	84
11/5.....	2,000	2	60	4	84
Average.....	-	-	-	-	86
Condition 3:					
11/7.....	2,050	1/2	40	4-1/2	79
11/10.....	2,050	1/2	40	4-1/2	82
Average.....	-	-	-	-	80
PLASTIC BRUSHES					
Condition 4:					
9/4.....	2,000	2	20	4-3/4	87
9/5.....	2,000	2	20	4-3/4	80
9/8.....	2,000	2	20	4-3/4	79
Average.....	-	-	-	-	82

Decreasing the spray waterflow rate to 2 gal/min (condition 2) brought the fan up to its normal performance, 2,000 ft³/min, at only a slight decrease in efficiency, which averaged 86 percent.

Condition 3 showed a reasonably high efficiency, 80 percent, at a very low spray waterflow rate of 1/2 gal/min.

Polypropylene Brushes

The tests with polypropylene brushes (condition 4) showed an efficiency of 82 percent.

Comments

Dust collection efficiencies were somewhat higher than expected for the wetted-brush-scrubber tests. It was anticipated that the low wire density of the packed brushes might result in only a modest improvement in efficiency. Previous tests on other types of wetted fan scrubbers had shown that efficiency increases with increasing water use and scrubber air pressure

differential. Part of the increase in efficiency for this scrubber can probably be explained by the increased fan pressure differential caused by the brushes.

It was also anticipated that the larger wire diameter of the polypropylene brushes would result in slightly lower efficiency. The test (condition 4) appears to indicate this.

The "loose" wire density of the brushes probably may allow coarse particulate to pass through that might clog a flooded fibrous-bed scrubber.

Since the wire brush bed does not significantly increase the size or cost of a wetted fan scrubber, its use is recommended as an improvement on the wetted fan scrubber. Cost of the wetted brush scrubber should be between \$1.50 and \$2 per cubic foot per minute of scrubber air volumetric capacity.

CONCLUSIONS

1. Recent underground tests have tended to confirm the use of scrubbers as an especially successful dust control technique for coal mines.
2. Several types of small, safe, and rugged scrubbers with adequate dust collection efficiency are available for various coal mine applications.
3. The flooded fibrous-bed scrubber demonstrated a marked superiority in dust collection efficiency. This superior dust collection efficiency was maintained during other comparative tests with other types of scrubbers at much higher air pressure differentials.
4. For maximum dust collection efficiency, the scrubber spray water rate and/or scrubber air pressure differential should be increased until the fan volumetric flow rate falls to minimum acceptable levels.

Table 6 summarizes efficiency advantages, disadvantages, and recommended use for each type of scrubber.

TABLE 6. - Summary comparison of maximum dust collection efficiency

Scrubber type	Differential pressure across fan, inches of water	Water rate, gal/min	Water pressure, lb/in ² gage	Average maximum efficiency, <7 μm	Advantages	Disadvantages
Flooded bed.....	4-1/2	2.6	120	95	Highest dust collection efficiency.	May clog where large (>25 μm) particulate is encountered
Small-diameter cyclone: Merix.....	5	5.5	70	91	Can be used as both scrubber and eliminator; thus gives minimum size if eliminator must be used.	Dust collection efficiency is limited.
Donaldson.....	5	5.5	70	89		
Wetted fan.....	1	2.6	140	87	Minimum size and cost.	Spray water and particulate can cause fan blade erosion. (Component layout of other scrubbers can prevent this problem.)
Wetted brush.....	3-1/2	4.0	45	SS = 88 PP = 82	Small size and low cost. Higher efficiency than wetted fan, or lower water use than wetted fan.	Fan blade erosion.

SS = Stainless steel; PP = polypropylene.

Special requirements	Recommended scrubber type	
	1st choice	2d choice
High efficiency.....	Flooded fibrous bed...	Small-diameter cyclone
Minimum size.....	Wetted fan.....	Wetted wire brush.
Coarse or sticky particulate.....	Small-diameter cyclone with maximum water.	Wetted wire brush with maximum water.
Low water consumption (less than 1 gal/min per 1,000 ft ³ /min).	Small-diameter cyclone	Flooded fibrous bed.

APPENDIX.--SCRUBBER TEST SHEETS
MRE EFFICIENCY ANALYSIS

TEST NUMBER 1/21 DUST FEED NUMBER 30

SCRUBBER MANUFACTURER AND TYPE Du Pont flooded fibrous bed

AIR VOLUME FLOWRATE (CFM) UPSTREAM 1,830 DOWNSTREAM 1,880

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 4-1/2 FINAL 4-1/2

WATER FLOWRATE, GPM 2.6 PRESSURE AT NOZZLE 120 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-5 QUANTITY 2

NOZZLE LOCATION 16 inches from Du Pont medium

SLURRY PUMP yes GPM NA DROPLET ELIMINATOR yes

DUCT INLET AIR TEMP., °F 72 R.H. 62% OUTSIDE °F 22 R.H. 32%

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD μ m Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>12 min</u>			DOWNSTREAM SAMPLE TIME <u>120 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	% Effic.
8	0.4	100	0.02	0.02	0.06	1.64	1.64	0.482	-
7	.7	100	.43	.43	1.3	2.27	2.27	.667	49
6	1.1	98	2.69	2.64	7.76	4.39	4.30	1.26	84
5	2.1	92	5.33	4.90	14.4	2.25	2.07	.609	96
4	3.3	78	10.30	8.03	23.61	1.11	.87	.256	99
3	4.7	56	7.63	4.27	12.6	.39	.22	.06	100
2	7.0	2	5.58	.11	.323	.31	.006	.002	99
1	>11.00	0	31.36	-	0	.30	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			60.1			3.34			

RESPIRABLE DUST COLLECTION EFFICIENCY = 94%

SHEET A1

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 1/24 DUST FEED NUMBER 30

SCRUBBER MANUFACTURER AND TYPE Du Pont flooded fibrous bed

AIR VOLUME FLOWRATE (CFM) UPSTREAM 1,830 DOWNSTREAM 1,880

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 4-1/2 FINAL 4-1/2

WATER FLOWRATE, GPM 2.6 PRESSURE AT NOZZLE 120 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-5 QUANTITY 2

NOZZLE LOCATION 16 inches from Du Pont medium

SLURRY PUMP yes GPM NA DROPLET ELIMINATOR yes

DUCT INLET AIR TEMP., °F 75 R.H. 60% OUTSIDE °F 28 R.H. 34%

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>12 min</u>			DOWNSTREAM SAMPLE TIME <u>120 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	% Effic.
8	0.4	100	-	-	-	0.83	0.83	0.24	-
7	.7	100	0.33	0.33	0.97	2.17	2.17	.637	34
6	1.1	98	2.54	2.49	7.32	3.47	3.40	1.00	86
5	2.1	92	5.61	5.16	15.2	1.99	1.83	.538	96
4	3.3	78	9.61	7.50	22.1	.77	.60	.18	99
3	4.7	56	6.72	3.76	11.1	.02	.01	.003	100
2	7.0	2	5.77	.12	.353	-	-	-	-
1	>11.00	0	38.14	-	0	-	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			56.2			2.60			

RESPIRABLE DUST COLLECTION EFFICIENCY = 95%

SHEET A2

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 1/25 DUST FEED NUMBER 30

SCRUBBER MANUFACTURER AND TYPE Du Pont flooded fibrous bed

AIR VOLUME FLOWRATE (CFM) UPSTREAM 1,830 DOWNSTREAM 1,880

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 4-1/2 FINAL 4-1/2

WATER FLOWRATE, GPM 2.6 PRESSURE AT NOZZLE 120 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BL-5 QUANTITY 2

NOZZLE LOCATION 16 inches from Du Pont medium

SLURRY PUMP yes GPM NA DROPLET ELIMINATOR yes

DUCT INLET AIR TEMP., °F _____ R.H. _____ OUTSIDE °F _____ R.H. _____

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>12 min</u>			DOWNSTREAM SAMPLE TIME <u>120 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	% Effic.
8	0.4	100	0.25	0.25	0.74	1.49	1.49	0.438	41
7	.7	100	.61	.61	1.8	2.52	2.53	.74	59
6	1.1	98	2.88	2.82	8.30	4.15	4.07	1.20	86
5	2.1	92	5.65	5.20	15.3	2.37	2.18	.641	96
4	3.3	78	8.45	6.59	19.4	1.40	1.09	.320	98
3	4.7	56	9.80	5.49	16.1	.27	.15	.04	100
2	7.0	2	8.85	.18	.529	.19	.004	.001	100
1	>11.00	0	-	-	0	.10	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			62.2			3.38			

RESPIRABLE DUST COLLECTION EFFICIENCY = 96%

SHEET A3

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 4/1 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Merix eliminator and Joy fan

AIR VOLUME FLOWRATE (CFM) UPSTREAM 1,970 DOWNSTREAM 1,970

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 5 FINAL NA

WATER FLOWRATE, GPM 5-1/2 PRESSURE AT NOZZLE 65 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION 18 inches upstream of panel

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR NA

DUCT INLET AIR TEMP., °F 55 R.H. 65% OUTSIDE °F 50 R.H. 37%

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM			DOWNSTREAM			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	% Effic.
8	.4	100	0.3	0.3	1.1	2.2	2.2	0.6	94
7	.7	100	.8	.8	2.8	4.6	4.6	1.4	50
6	1.1	98	3.0	3.0	10.6	10.0	9.8	2.9	73
5	2.1	92	6.0	5.5	19.4	7.9	7.3	2.1	89
4	3.3	78	11.0	8.6	30.4	3.3	2.6	.8	97
3	4.7	56	12.2	6.8	24.0	.9	.5	.1	100
2	7.0	2	8.7	.2	.7	.7	.01	.003	70
1	>11.00	0	25.1	-	0	.3	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			89			7.9			

RESPIRABLE DUST COLLECTION EFFICIENCY = 91%

SHEET A4

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 4/2 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Merix eliminator and Joy fan

AIR VOLUME FLOWRATE (CFM) UPSTREAM 1,970 DOWNSTREAM 1,970

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 5 FINAL NA

WATER FLOWRATE, GPM 5-1/2 PRESSURE AT NOZZLE 65 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION 18 inches upstream of panel

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR NA

DUCT INLET AIR TEMP., °F 53 R.H. 67% OUTSIDE °F 45 R.H. 39%

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>10 min</u>			DOWNSTREAM SAMPLE TIME <u>120 min</u>			% Effic.
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	
8	0.4	100	0.3	0.3	1.1	2.6	2.6	0.8	20
7	.7	100	.6	.6	2.1	4.6	4.6	1.4	33
6	1.1	98	2.7	2.6	9.1	11.7	11.5	3.4	63
5	2.1	92	6.6	6.0	21.2	8.8	8.1	2.4	89
4	3.3	78	12.4	9.7	34.2	4.3	3.4	1.0	97
3	4.7	56	11.0	6.1	21.5	1.1	.6	.2	99
2	7.0	2	8.8	.1	.4	1.2	.02	.006	98
1	>11.00	0	37.4	0	0	.6	0	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			89.6			9.2			

RESPIRABLE DUST COLLECTION EFFICIENCY = 90%

SHEET A5

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 4/9 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Merix eliminator and Joy fan

AIR VOLUME FLOWRATE (CFM) UPSTREAM 1,970 DOWNSTREAM 1,970

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 5 FINAL 5

WATER FLOWRATE, GPM 5-1/2 PRESSURE AT NOZZLE 65 lb/in² gage

NOZZLE MANUFACTURER Sprahing Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION 18 inches upstream of panel

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR NA

DUCT INLET AIR TEMP., °F 53 R.H. 68% OUTSIDE °F 34 R.H. 34%

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>10 min</u>			DOWNSTREAM SAMPLE TIME <u>120 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	% Effic.
8	0.4	100	0.2	0.2	0.706	2.0	2.0	0.588	16.71
7	.7	100	.5	.5	1.77	4.9	4.9	1.44	18.64
6	1.1	98	2.4	2.35	8.30	2.5	2.45	.720	91.32
5	2.1	92	4.1	3.77	13.31	.8	.736	.216	98.37
4	3.3	78	8.7	6.79	23.97	6.0	4.68	1.375	94.26
3	4.7	56	8.2	4.59	16.20	1.6	.896	.263	98.37
2	7.0	2	8.3	.166	.586	1.1	.022	.006	98.98
1	>11.00	0	5.7	-	0	.7	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			64.842			4.608			

RESPIRABLE DUST COLLECTION EFFICIENCY = 93%

SHEET A6

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 6/10 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Donaldson eliminator and Joy fan

AIR VOLUME FLOWRATE (CFM) UPSTREAM 2,065 DOWNSTREAM 2,065

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 5 FINAL NA

WATER FLOWRATE, GPM 5-1/2 PRESSURE AT NOZZLE 70 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION 18 inches upstream of panel

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR NA

DUCT INLET AIR TEMP., °F 75 R.H. 55% OUTSIDE °F 55 R.H. 100%

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	MCD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>8 min</u>			DOWNSTREAM SAMPLE TIME <u>75 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	% Effic.
8	0.4	100	0.1	0.1	0.4	1.2	1.2	0.6	-
7	.7	100	.2	.2	.9	2.6	2.6	1.2	-
6	1.1	98	2.0	2.0	8.8	5.6	5.5	2.6	70
5	2.1	92	4.6	4.2	18.5	3.3	3.0	1.4	92
4	3.3	78	8.6	6.7	29.5	.9	.7	.3	99
3	4.7	56	7.2	4.0	17.6	.2	.1	.05	100
2	7.0	2	5.7	.1	.4	.2	.004	.002	100
1	>11.00	0	22.9	-	0	.1	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			76.1			6.152			

RESPIRABLE DUST COLLECTION EFFICIENCY = 92%

SHEET A7

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 6/11 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Donaldson eliminator and Joy fan

AIR VOLUME FLOWRATE (CFM) UPSTREAM 2,065 DOWNSTREAM 2,065

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 5 FINAL NA

WATER FLOWRATE, GPM 5-1/2 PRESSURE AT NOZZLE 70 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION 18 inches upstream of panel

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR NA

DUCT INLET AIR TEMP., °F 65 R.H. 72% OUTSIDE °F 72 R.H. 100%

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD μ m Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>8 min</u>			DOWNSTREAM SAMPLE TIME <u>75 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	% Effic.
8	0.4	100	0.1	0.1	0.4	1.0	1.0	0.5	-
7	.7	100	.3	.3	1.3	2.2	2.2	1.0	23
6	1.1	98	1.2	1.2	5.3	4.6	4.5	2.1	60
5	2.1	92	2.3	2.1	9.3	2.9	2.7	1.3	86
4	3.3	78	4.5	3.5	15.4	1.2	.9	.4	97
3	4.7	56	4.3	2.4	10.6	.4	.2	.09	99
2	7.0	2	3.6	.07	.3	.4	.008	.004	99
1	>11.00	0	10.5	-	0	.4	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			42.6			5.394			

RESPIRABLE DUST COLLECTION EFFICIENCY = 87%

SHEET A8

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 6/12 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Donaldson eliminator and Joy fan

AIR VOLUME FLOWRATE (CFM) UPSTREAM 2,065 DOWNSTREAM 2,065

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 5 FINAL NA

WATER FLOWRATE, GPM 5-1/2 PRESSURE AT NOZZLE 70 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION 18 inches upstream of panel

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR NA

DUCT INLET AIR TEMP., °F 65 R.H. 72% OUTSIDE °F 72 R.H. 100%

DUST SAMPLING ANALYSIS--ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD μ m Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>8 min</u>			DOWNSTREAM SAMPLE TIME <u>75 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	% Effic.
8	0.4	100	0.3	0.3	1.3	1.5	1.5	0.7	46
7	.7	100	.4	.4	1.8	2.9	2.9	1.4	22
6	1.1	98	1.7	1.7	7.5	5.0	4.9	2.3	69
5	2.1	92	3.6	3.3	14.6	3.4	3.1	1.5	90
4	3.3	78	5.7	4.4	19.4	1.9	1.5	.7	96
3	4.7	56	3.9	2.2	9.7	.7	.4	.2	98
2	7.0	2	12.6	.3	1.3	.3	.006	.003	100
1	>11.00	0	13.7	-	0	.2	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			55.6			6.803			

RESPIRABLE DUST COLLECTION EFFICIENCY = 88%

SHEET A9

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 2/25 DUST FEED NUMBER 30

SCRUBBER MANUFACTURER AND TYPE Wetted fan

AIR VOLUME FLOWRATE (CFM) UPSTREAM 2,100 DOWNSTREAM 2,150

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 1 FINAL 1

WATER FLOWRATE, GPM 2.6 PRESSURE AT NOZZLE 140 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-5 QUANTITY 2

NOZZLE LOCATION Center

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR yes

DUCT INLET AIR TEMP., °F 68 R.H. 60% OUTSIDE °F 52 R.H. 40%

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>12 min</u>			DOWNSTREAM SAMPLE TIME <u>60 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	% Effic.
8	0.4	100	0.2	0.2	0.6	0.2	0.2	0.1	80.5
7	.7	100	.3	.3	.9	1.1	1.1	.65	28.1
6	1.1	98	1.7	1.7	4.9	3.2	3.1	1.8	62.4
5	2.1	92	3.4	3.1	9.2	2.9	2.7	1.6	82.9
4	3.3	78	6.0	4.7	14	1.4	1.1	.6	95.3
3	4.7	56	5.7	3.2	9.4	.3	.2	.1	98.9
2	7.0	2	5.7	.1	.3	.3	.01	.004	98.7
1	>11.00	0	-	-	0	-	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			39			5.0			

RESPIRABLE DUST COLLECTION EFFICIENCY = 87%

SHEET A10

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 2/28 DUST FEED NUMBER 30

SCRUBBER MANUFACTURER AND TYPE Wetted fan

AIR VOLUME FLOWRATE (CFM) UPSTREAM 2,100 DOWNSTREAM 2,150

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 1 FINAL 1

WATER FLOWRATE, GPM 2.6 PRESSURE AT NOZZLE 140 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-5 QUANTITY 2

NOZZLE LOCATION Center

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR yes

DUCT INLET AIR TEMP., °F 55 R.H. 60% OUTSIDE °F 34 R.H. 36%

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>12 min</u>			DOWNSTREAM SAMPLE TIME <u>60 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	% Effic.
8	0.4	100	0.1	0.1	0.3	0.2	0.2	0.1	61
7	.7	100	.2	.2	.6	.8	.8	.5	22
6	1.1	98	1.5	1.5	4.3	2.4	2.4	1.4	68
5	2.1	92	2.4	2.2	6.5	2.2	2.0	1.2	82
4	3.3	78	5.1	4.0	12	1.2	.9	.6	95
3	4.7	56	3.7	2.1	6.1	.4	.2	.1	98
2	7.0	2	4.7	.1	.3	.3	.01	.004	99
1	>11.00	0	-	-	0	-	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			30			3.8			

RESPIRABLE DUST COLLECTION EFFICIENCY = 87%

SHEET A11

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 3/1 DUST FEED NUMBER 30

SCRUBBER MANUFACTURER AND TYPE Wetted fan

AIR VOLUME FLOWRATE (CFM) UPSTREAM 2,100 DOWNSTREAM 2,150

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 1 FINAL 1

WATER FLOWRATE, GPM 2.6 PRESSURE AT NOZZLE 140 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-5 QUANTITY 2

NOZZLE LOCATION Center

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR yes

DUCT INLET AIR TEMP., °F 69 R.H. 60% OUTSIDE °F 33 R.H. 38%

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>12 min</u>			DOWNSTREAM SAMPLE TIME <u>60 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	% Effic.
8	0.4	100	0.2	0.2	0.6	0.1	0.1	0.1	90
7	.7	100	.4	.4	1.2	1.1	1.1	.6	46
6	1.1	98	1.7	1.7	5.0	2.7	2.6	1.6	69
5	2.1	92	3.4	3.1	9.2	2.9	2.7	1.6	83
4	3.3	78	4.8	3.7	11	1.4	1.1	.6	94
3	4.7	56	4.9	2.7	8.1	.2	.1	.1	99
2	7.0	2	4.7	.9	.3	.2	.004	.002	99
1	>11.00	0	19.1	-	0	.2	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			35.4			4.5			

RESPIRABLE DUST COLLECTION EFFICIENCY = 87%

SHEET A12

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 10/17 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Joy fan and stainless steel brushes

AIR VOLUME FLOWRATE (CFM) UPSTREAM 1,750 DOWNSTREAM 1,750

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 3-1/2 FINAL 3-1/2

WATER FLOWRATE, GPM 4 PRESSURE AT NOZZLE 45 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION NA

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR NA

DUCT INLET AIR TEMP., °F 47 R.H. 52% OUTSIDE °F NA R.H. NA

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	HCD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>8 min</u>			DOWNSTREAM SAMPLE TIME <u>60 min</u>			% Effic.
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	
8	0.4	100	0.2	0.2	0.9	0.3	0.3	0.2	78
7	.7	100	.3	.3	1.3	.5	.5	.3	77
6	1.1	98	.7	.7	3	1.4	1.4	.82	73
5	2.1	92	1.0	1.0	4.4	.9	.8	.5	89
4	3.3	78	1.8	1.4	6.2	.5	.4	.2	97
3	4.7	56	1.4	.8	3.5	.3	.2	.1	97
2	7.0	2	1.9	.04	.17	.4	.008	.04	76
1	>11.00	0	5.6	-	0	.3	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			19			2.1			

RESPIRABLE DUST COLLECTION EFFICIENCY = 88%

SHEET A13

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 10/21 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Joy fan and stainless steel brushes

AIR VOLUME FLOWRATE (CFM) UPSTREAM 1,750 DOWNSTREAM 1,750

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 3-1/2 FINAL 3-1/2

WATER FLOWRATE, GPM 4 PRESSURE AT NOZZLE 45 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION NA

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR NA

DUCT INLET AIR TEMP., °F 55 R.H. 45% OUTSIDE °F NA R.H. NA

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>8 min</u>			DOWNSTREAM SAMPLE TIME <u>60 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	% Effic.
8	0.4	100	0.1	0.1	0.4	0.3	0.3	0.2	50
7	.7	100	.1	.1	.4	.6	.6	.4	-
6	1.1	98	.8	.8	4	1.8	1.8	1.1	73
5	2.1	92	1.3	1.2	5.3	1.2	1.1	.65	88
4	3.3	78	2.3	1.8	7.9	.6	.5	.3	96
3	4.7	56	2.0	1.1	4.9	.2	.1	.006	99
2	7.0	2	1.2	.02	.09	.4	.008	.04	56
1	>11.00	0	6.7	-	0	.7	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			23			2.8			

RESPIRABLE DUST COLLECTION EFFICIENCY = 88%

SHEET A14

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 10/22 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Joy fan and stainless steel brushes

AIR VOLUME FLOWRATE (CFM) UPSTREAM 1,750 DOWNSTREAM 1,750

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 3-1/2 FINAL 3-1/2

WATER FLOWRATE, GPM 4 PRESSURE AT NOZZLE 45 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION NA

SLURRY PUMP NA GPM NA DROPLET ELIMINATOR NA

DUCT INLET AIR TEMP., °F 63 R.H. 49% OUTSIDE °F NA R.H. NA

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	HCD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>12 min</u>			DOWNSTREAM SAMPLE TIME <u>90 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	% Effic.
8	0.4	100	0.1	0.1	0.3	1.1	1.1	0.43	-
7	.7	100	.2	.2	.6	2.0	2.0	.8	-
6	1.1	98	1.6	1.6	4.7	3.8	3.7	1.5	68
5	2.1	92	3.2	2.9	8.5	1.9	1.7	.66	92
4	3.3	78	5.8	4.5	13	.8	.6	.2	98
3	4.7	56	4.1	2.3	6.8	.5	.3	.1	99
2	7.0	2	3.2	.06	.18	.4	.008	.003	98
1	>11.00	0	9.4	-	0	.5	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			34			3.7			

RESPIRABLE DUST COLLECTION EFFICIENCY = 89%

SHEET A15

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 9/4 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Joy fan and plastic brushes

AIR VOLUME FLOWRATE (CFM) UPSTREAM 2,000 DOWNSTREAM 2,000

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 4-3/4 FINAL 4-3/4

WATER FLOWRATE, GPM 2 PRESSURE AT NOZZLE 20 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION NA

SLURRY PUMP None GPM NA DROPLET ELIMINATOR no

DUCT INLET AIR TEMP., °F 70 R.H. 74% OUTSIDE °F NA R.H. NA

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>8 min</u>			DOWNSTREAM SAMPLE TIME <u>90 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	% Effic.
8	0.4	100	0.3	0.3	1.3	0.5	0.5	0.2	85
7	.7	100	.4	.4	1.8	1.1	1.1	.4	78
6	1.1	98	.8	.8	3.5	2.2	2.2	.9	74
5	2.1	92	1.3	1.2	5.3	2.8	2.6	1.0	81
4	3.3	78	2.2	1.7	7.5	2.1	1.6	.6	92
3	4.7	56	1.9	1.1	4.9	.8	.4	.2	96
2	7.0	2	3.2	.06	.3	.8	.02	.008	97
1	>11.00	0	8.7	-	0	.6	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			25			3.3			

RESPIRABLE DUST COLLECTION EFFICIENCY = 87%

SHEET A16

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 9/5 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Joy fan and plastic brushes

AIR VOLUME FLOWRATE (CFM) UPSTREAM 2,000 DOWNSTREAM 2,000

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 4-3/4 FINAL 4-3/4

WATER FLOWRATE, GPM 2 PRESSURE AT NOZZLE 20 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION NA

SLURRY PUMP None GPM NAp DROPLET ELIMINATOR no

DUCT INLET AIR TEMP., °F 67 R.H. 69% OUTSIDE °F NA R.H. NA

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>8 min</u>			DOWNSTREAM SAMPLE TIME <u>90 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	% Effic.
8	0.4	100	0.2	0.2	0.9	0.5	0.5	0.2	78
7	.7	100	.1	.1	.4	1.3	1.3	.5	-
6	1.1	98	.4	.4	1.8	2.4	2.4	.9	50
5	2.1	92	.7	.6	2.6	1.7	1.6	.6	77
4	3.3	78	1.3	1.0	4.4	1.1	.9	.4	91
3	4.7	56	1.1	.6	2.6	.2	.1	.04	98
2	7.0	2	1.5	.03	.1	.3	.006	.002	93
1	>11.00	0	4.5	-	0	.3	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			13			2.6			

RESPIRABLE DUST COLLECTION EFFICIENCY = 80%

SHEET A17

SCRUBBER TEST SHEET
MRE EFFICIENCY ANALYSIS

TEST NUMBER 9/8 DUST FEED NUMBER 24

SCRUBBER MANUFACTURER AND TYPE Joy fan and plastic brushes

AIR VOLUME FLOWRATE (CFM) UPSTREAM 2,000 DOWNSTREAM 2,000

AIR DIFFERENTIAL PRESSURE, INCHES WATER GAGE INITIAL 4-3/4 FINAL 4-3/4

WATER FLOWRATE, GPM 2 PRESSURE AT NOZZLE 20 lb/in² gage

NOZZLE MANUFACTURER Spraying Systems Co. TYPE BD-8 QUANTITY 3

NOZZLE LOCATION NA

SLURRY PUMP None GPM NAp DROPLET ELIMINATOR no

DUCT INLET AIR TEMP., °F 67 R.H. 87% OUTSIDE °F NA R.H. NA

DUST SAMPLING ANALYSIS-ANDERSEN CASCADE IMPACTOR DATA:

Plate No.	ECD µm Particle Size	% MRE Penetr.	UPSTREAM SAMPLE TIME <u>8 min</u>			DOWNSTREAM SAMPLE TIME <u>90 min</u>			
			Wt. (mg)	Resp. Wt. (mg)	Resp. Concent. (mg/m ³)	Wt. (mg)	Resp. Wt. (mg)	Resp. Concen. (mg/m ³)	% Effic.
8	0.4	100	0.1	0.1	0.4	0.2	0.2	0.08	80
7	.7	100	.1	.1	.4	.4	.4	.2	50
6	1.1	98	.2	.2	.9	1.2	1.2	.5	44
5	2.1	92	.2	.2	.9	.2	.8	.3	67
4	3.3	78	.5	.4	1.8	.3	.2	.08	96
3	4.7	56	.5	.3	1.3	.1	.1	.04	97
2	7.0	2	.7	.01	.04	.2	.004	.002	95
1	>11.00	0	2.4	-	0	.01	-	0	-
TOTAL RESPIRABLE DUST CONCENT, mg/m ³ (MRE)			5.7			1.2			

RESPIRABLE DUST COLLECTION EFFICIENCY = 79%

SHEET A18