

Retrofit options for controlling particulate emissions from a magnesium sulfite recovery furnace

William E. Powers, Michael W. Short, James A. Evensen, and
Bradford A. Dennison

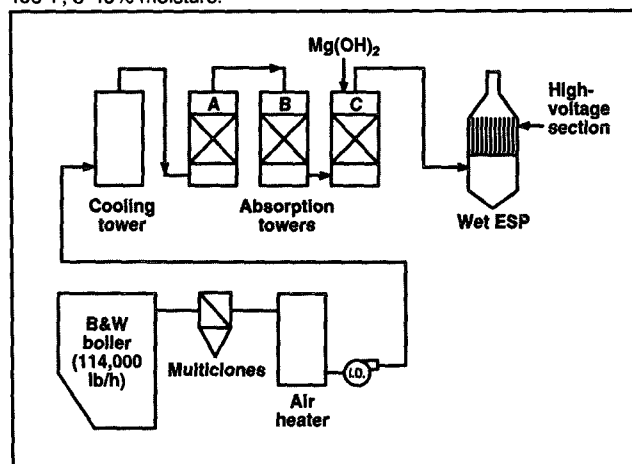
When emission of submicron particles became a problem, this magnesium sulfite mill evaluated the available control options by contacting every North American mill with similar emissions characteristics.

This report presents the results of a recent engineering study of retrofit options for controlling particulate emissions from three recovery furnaces at Alaska Pulp's magnesium sulfite mill in Sitka. Two of these recovery furnaces are equipped with wet electrostatic precipitators (ESP) installed between 1975 and 1980. The third furnace utilizes two chevron mist eliminators in series for particulate control. Particulate emissions from the recovery furnaces have periodically exceeded the emission limit of 2 lb/a.d. ton specified in the facility's operating permit. The engineering study was undertaken with the objectives of (a) identifying proven particulate-control options capable of maintaining furnace emissions below 2 lb/a.d. ton and (b) ranking the recommended control options for each furnace by cost.

Logs processed by the mill are soaked in salt water during transport to the facility in floating log "rafts." Salts accumulated during transport are eventually carried along with the spent sulfite liquor to the recovery furnace. When magnesium-base liquor is burned, a flue gas is produced from which magnesium oxide is recovered as fine white powder in a multiple cyclone. The magnesium oxide is then water slaked and used as circulating liquor in a series of absorption towers, which are designed to absorb sulfur dioxide from the flue gas and to form a bisulfite solution for use in the cooking cycle. Salts vaporized in the recovery furnace condense as submicron particulate in the exhaust ductwork and are only partially removed in the absorption towers. An emissions characterization study performed at the mill in the mid-1970s indicated the mean particle size of recovery-furnace particulate emissions was in the submicron range.

Powers is manager of air engineering, and Short is a senior environmental engineer. Both are affiliated with ENSR Consulting and Engineering, 1220 Ave. Acaso, Camarillo, CA 93012. Evensen manages environmental operations, and Dennison is a senior environmental engineer. Both are affiliated with Alaska Pulp Corp., 4600 Sawmill Creek Rd., Sitka, AK 99835-9798.

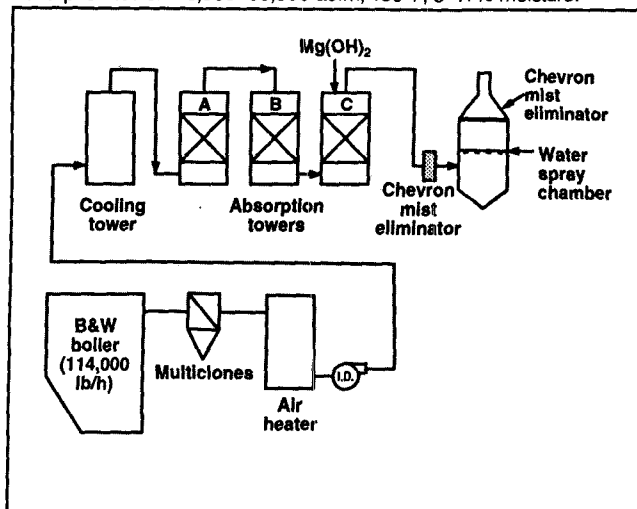
1. Exhaust-gas flow from Furnace 1. Conditions at outlet of last absorption tower: 35,000–50,000 acfm (actual cubic feet per minute), 100°F, 8–10% moisture.



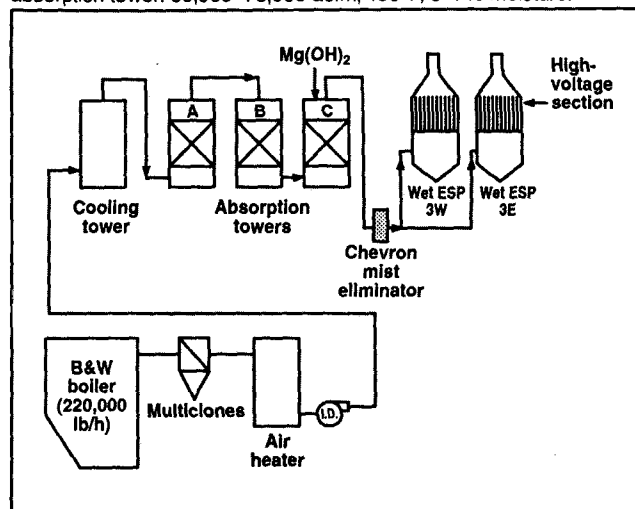
Of the nine magnesium sulfite mills operating in North America, only two are processing saltwater-soaked logs. Given the small number of such mills, the scope of this investigation was expanded to include particulate-control technologies in use at other mills with similar emissions characteristics, i.e., in mills discharging submicron particulate emissions in saturated, low-temperature gas streams.

Saturated, low-temperature exhaust-gas streams are also characteristic of ammonium sulfite mills, since a chemical recovery step is included in the process after the recovery furnace. Unlike the magnesium base in the magnesium sulfite process, the ammonia base liquor is consumed in the recovery furnace, though the sulfur dioxide from the flue gas is used to form a bisulfite solution in a series of absorption towers using fresh ammonia as the circulating liquor. A saturated, low-temperature exhaust gas is present at the outlet of the absorption towers. Several studies have characterized the particulate emissions from ammonium sulfite mills, generally known

2. Exhaust-gas flow from Furnace 2. Conditions at outlet of last absorption tower: 40,000–60,000 acfm, 100°F, 8–11% moisture.



3. Exhaust-gas flow from Furnace 3. Conditions at outlet of last absorption tower: 60,000–75,000 acfm, 100°F, 5–7% moisture.



as "blue haze," as submicron fumes. For this reason, the particulate-control technology used at ammonium sulfite mills was included in the engineering study for the magnesium sulfite mill.

The study included the following components:

- Identify the particulate concentration and mean particle size at the recovery-furnace outlet for magnesium sulfite and ammonium sulfite mills in North America.
- Evaluate the particulate-control technologies used on the recovery furnaces at these mills on the basis of control efficiency, outlet particulate concentrations, and maintenance history.
- Identify the factors contributing to the performance degradation of the wet ESPs in use at the Alaska Pulp mill.
- Identify proven particulate-control technologies capable of achieving the performance standard of 2 lb/a.d. ton.
- Rank the proven alternatives in the order of estimated annualized cost.

Process description

The mill operates three recovery furnaces. Furnaces 1 and 2 are similar Babcock & Wilcox (B&W) units that were installed when the mill was built in the mid-1950s. Each is rated at 114,000 lb/h of 860-psig (pounds per square inch gauge) steam. Furnace 3 is a B&W/Mitsubishi unit rated at 220,000 lb/h of 860-psig steam. This unit was installed in 1972, when the mill's production capacity was expanded. In all cases, the recovery-furnace exhaust gases pass through a magnesium oxide recovery system composed of a mechanical cyclone, air heater, cooling tower, and three absorption towers. Process-flow diagrams for exhaust gas from Furnaces 1, 2, and 3 are provided in Figs. 1–3, respectively.

Vertical, single-field wet ESPs serve as the final particulate-removal devices on Furnaces 1 and 3. The wet ESP on Furnace 1, installed in 1975, was the first permanent installation of a wet ESP on a sulfite recovery furnace of any type. Two single-field wet ESPs were in-

stalled in parallel on Furnace 3 in 1980, along with a chevron mist eliminator upstream of the wet ESPs. There are differences between the design of the wet ESPs installed on Furnace 3 and the design of the wet ESP on Furnace 1, primarily related to the water-distribution header that continuously cleans the ESP collecting plates. All three of the wet ESPs were manufactured by Fluid-Ionics Systems, now a subsidiary of Dresser Industries.

A chevron mist eliminator/spray chamber/chevron mist eliminator combination (in series) serves as the final particulate-removal device on Furnace 2. The control system for this setup was designed, built, and installed by mill personnel in 1976.

The Alaska Department of Environmental Conservation (ADEC) has established two performance-based particulate emissions limits for the mill's recovery furnaces: 2 lb/a.d. ton averaged across all three furnaces, and individual emission rates for each furnace. These permitted emissions limits are presented in Table I, along with emission rates and exhaust-flow rates determined during the most recent set of source tests. The highest emission rates measured on each unit during the lifetime of the control equipment are also included in Table I. Original performance specifications for the wet ESPs on Furnaces 1 and 3, obtained from installation data provided by the manufacturer, are also included in Table I for purposes of comparison.

Major overhauls were performed on all three of the mill's recovery furnaces in May 1991, during the mill's annual maintenance outage. Approximately 45% of the air-heater tubes in Furnace 3 were plugged with particulate, and these tubes were cleared during the outage. Leaks in both the furnace shell and the air heater on Furnace 2 were also repaired. Furnace 1 had no significant air-leakage problems prior to the outage.

Source test data (1) from June 1991 indicated that particulate loading in the exhaust gas from Furnace 3 had decreased significantly compared with earlier test results. Water flow to the water-distribution header serving the collection plates on one of the wet ESPs following Furnace 3 had been reduced in March 1991, resulting in a markedly stronger electrical field.

The particulate-control devices for each of the recovery

I. Performance characteristics of the mill's three recovery furnaces

Recovery furnace no.	Design exhaust flow rate, acfm ^a	Actual exhaust flow rate, acfm	Design outlet particulate loading, grains/dscf ^b	Actual outlet particulate loading, ^c grains/dscf ^c	Highest outlet particulate loading, ^d grains/dscf	Permitted outlet particulate loading per furnace, grains/dsacf	Outlet particulate loading ^e required to meet 2 lb/a.d. ton full capacity, grains/dsacf
1	45,000	42,000	0.050	0.122	0.122	0.080	0.057
2	NA	40,000	none	0.112	0.166	0.085	0.061
3	72,000	73,000	0.030	0.006	0.112	0.042	0.030

^aacfm = actual cubic feet per minute
^bdscf = dry standard cubic feet
^cJune 1991 test results at rated steam output for each recovery furnace
^dThe highest outlet particulate loading was determined from the available source test data record
^eThe 2 lb/a.d. ton emission standard is applied to recovery furnaces as a group and is more stringent than emission limits established for the individual recovery furnaces

II. Particulate controls used for recovery boilers in magnesium sulfite and ammonium sulfite mills

	Process	Particulate control device ^a	Outlet particulate loading, ^b grains/dscf
Mill 1	Mg	chevron ME, wet ESP	0.01–0.12
Mill 2	Mg	mesh pad ME, fiber = bed = ME (polyester fibers)	0.02
Mill 3	Mg	none	
Mill 4	Mg	chevron ME	no data
Mill 5	Mg	venturi scrubber	0.03
Mill 6	Mg	chevron ME, mesh pad ME, fiber = bed ME	no data
Mill 7	Mg	none	
Mill 8	Mg	none	
Mill 9	Mg	none	
Mill 10	Mg	none	
Mill 11	NH ₄	Dynawave scrubber, fiber = bed ME	no data
Mill 12	NH ₄	Fiber = bed ME (glass fibers)	no data
Mill 13	NH ₄	no data	no data
Mill 14	NH ₄	tray scrubber, chevron ME, fiber = bed ME (polyester fibers)	<0.01
Mill 15	NH ₄	fiber = bed ME	no data
Mill 16	NH ₄	wet ESP	0.04–0.06
Mill 17	NH ₄	fiber = bed ME (polyester fibers)	no data

^aME: mist eliminator
^bNo data: either no testing has been performed on the source, or test data had not been received before the conclusion of the evaluation.

furnaces were also inspected during the May 1991 outage. Internal and external inspections were performed on the wet ESPs and on the mist eliminator/spray chamber/mist eliminator system. All related wet-ESP subsystems—transformer/rectifier sets, water filtration/supply system, and the purge air system—were inspected. In addition,

mill personnel responsible for maintenance of the wet ESPs and recovery furnaces were interviewed, and the maintenance and source test records for the wet ESPs were reviewed.

Characteristics of particulate emissions from magnesium and ammonium recovery furnaces

Each of the magnesium sulfite or ammonium sulfite mills operating in North America (2) was contacted for information about the type of particulate-control equipment in use on the mill recovery furnaces. The responses enabled the mill to document the outlet particulate concentrations from these sources. The results of this investigation are provided in Table II. We also requested data on particulate concentration and size distribution at the inlet to the recovery furnace's particulate-control device. These data are presented in Table III.

Fiber-bed mist eliminators and wet ESPs are the two devices of choice for high-efficiency particulate control on this source type. Wet scrubbers are in use at two installations, and though these units do provide limited particulate control, they were installed for SO₂ removal.

The use of fiber-bed mist eliminators and wet ESPs as the devices of choice in this application has evolved over time. Many other technologies have been evaluated over the past 20 years as part of the effort to achieve consistent, high-efficiency particulate removal (>90%) from recovery-furnace exhaust gases at magnesium sulfite and ammonium sulfite mills. The following devices were evaluated during the mill's engineering study:

- Fiber-bed mist eliminator
- Wet ESP
- Ionizing wet scrubber
- Venturi scrubber
- Wet scrubber.

Fiber-bed mist eliminator

The fiber-bed mist eliminator is composed of a series of densely packed cylinders, or "candles," of glass or polyester

fibers that remove particulate through direct interception, impaction, or diffusion. Entrained liquid flowing down the surface of the fiber-bed continuously removes captured particulate. Typically, several fiber-bed candles are grouped together in a single vessel, which is periodically filled with water to clean the candles. While this device is capable of achieving very high collection efficiencies on submicron particulate, it is subject to several potential limitations (3).

- Any settling or porosity in the fiber-bed results in a rapid degradation in performance.
- Undersizing the number of candles and containment vessels results in a rapid increase in pressure drop and high sensitivity to process upsets.
- Loads up to 1000 lb/ft² are generated on the containment vessel's support structure during a cleaning cycle.
- Pressure drop of 6–8 in. wg (water gauge) is typical, resulting in a significant penalty in exhaust-fan energy.

Wet electrostatic precipitator

In the wet ESP, a high voltage is applied across the gas space between a discharge electrode and a collecting plate to induce electron flow (4). Negatively charged gas molecules attach themselves to particulates in the gas stream, and the particulate matter is driven to the collecting plate by the force of the applied voltage. In the wet-ESP design, collecting plates are continuously irrigated to remove collected particulate and to provide a conductive, grounded surface that completes the electrical circuit (5).

The wet ESP is capable of high-efficiency particulate collection, and the collection efficiency can be further improved by adding ESP fields in series. A principal advantage of the ESP is low pressure drop (<1-in. wg), which reduces consumption of exhaust-fan energy. However, this device has several limitations.

- Loss of irrigation water to any portion of the collecting plate surface results in significant performance degradation.
- The support insulators for the discharge electrodes are subject to cracking if the flow of hot, dry purge air is interrupted.

Ionizing wet scrubber

The ionizing wet scrubber (IWS) functions by charging incoming particulate for subsequent collection in a packed-bed scrubber section. An opposite electrical charge can also be maintained across the packed-bed scrubber section to augment collection efficiency. A pilot-scale IWS was tested at Ketchikan Pulp Co. in 1974. The device could not maintain adequately high collection efficiencies because of the rapid loss of electrical charge on the water droplets in the packed-bed section of the unit. At present, there are no IWS particulate-control installations on magnesium sulfite or ammonium sulfite recovery furnaces.

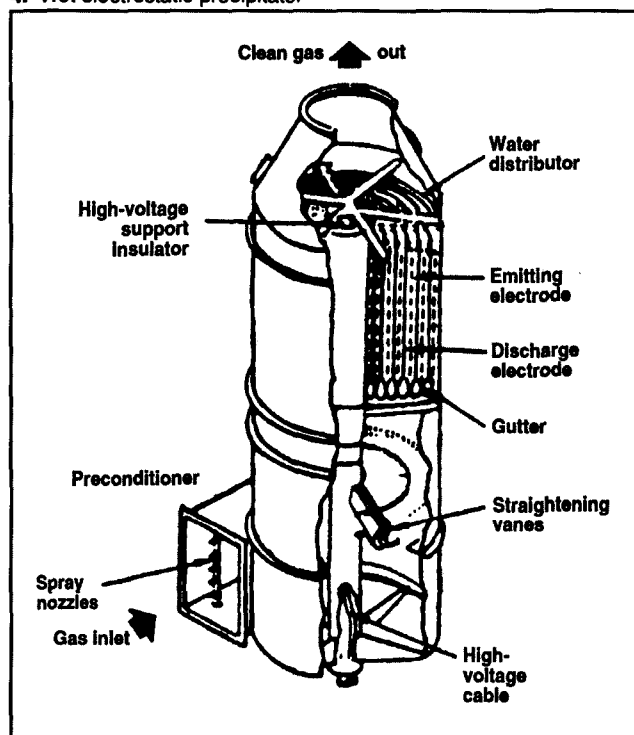
Venturi scrubbers

Venturi scrubbers and packed-bed, or "packed-tower," scrubbers are typically used upstream of the recovery furnace to absorb flue-gas SO₂ and form a bisulfite solution with the base process chemical in the circulation liquor.

III. Uncontrolled particulate-grain loading and particle size distribution for recovery boilers in magnesium sulfite and ammonium sulfite mills

	Date	Uncontrolled grain loading, grains/dscf	Uncontrolled particle size distribution (mass mean diam.), μm
Mill 1	1976	0.35	0.5
	1980	0.30	...
Mill 2	1973	0.18	...
Mill 11	1989	0.2–3.1	0.8
Mill 14	1972	0.25	submicron
Mill 16	1980	0.4–0.6	0.1–0.5

4. Wet electrostatic precipitator



These scrubbers also have a limited ability to remove fine particulate. They are generally low-pressure-drop devices, with a typical pressure drop of 2–4 in. wg. A low-pressure-drop venturi scrubber is in use at the Weyerhaeuser mill in Cosmopolis, WA, although this unit was installed for final SO₂ removal only. The manufacturer of this scrubber recommended a high-pressure-drop conventional venturi scrubber for control of submicron particulates.

A conventional venturi scrubber functions by injecting scrubbing liquid laterally into a venturi throat, creating a highly turbulent gas-liquid contact zone. A pilot high-pressure-drop venturi scrubber was effective in removing submicron particulate during a study carried out at the Finch Pruyn mill in 1972. For moderate removal efficiency on submicron particulate (70–85%), the estimated pressure drop for a conventional venturi scrubber is 20–26 in. wg.

Wet scrubbers

Mills use a variety of thin-bed, packed-tower scrubber

designs for SO₂ control. These units use countercurrent liquid flow through the packed bed to absorb SO₂ in the flue gas. In particulate-control applications, the primary removal mechanism involves inertial impaction of particles on water-washed collection beds composed of either loose packing, mesh pads, or chevron blades (6). As noted earlier, these units have a limited ability to remove submicron particulates. When used for particulate control (7), these units generally serve as precleaners to high-efficiency control devices such as fiber-bed mist eliminators or wet ESPs.

Monsanto manufactures a scrubber technology known as the Dynawave that is in use at the Scott Paper mill in Everett, WA. The Dynawave is a gas-to-liquid contactor that creates a zone of intense mixing. The feed gas stream enters the top of a vertical duct and collides with the scrubbing liquid, which is injected upward through a large-bore injector. A standing wave of highly turbulent flow is created at the point where the liquid flow is reversed by the gas. The high rate of liquid surface renewal in this zone effectively removes particulate and absorbs SO₂. Pilot testing of the Dynawave scrubber at Scott Paper indicated a particulate collection efficiency of 80% at a pressure drop of 7 in. wg. The collection efficiency of this device can be improved by adding additional contactors, or "stages," in series. A Dynawave scrubber is now on line as a precleaner to the existing fiber-bed mist eliminator installation at Scott Paper.

Performance degradation of wet ESPs at Alaska Pulp

Figure 4 is a schematic of the wet ESPs in use at the mill. Several problems were encountered while attempting to attain the design outlet particulate grain loading of 0.05 grains/dscf on the original wet ESP (8) that was installed on Furnace 1 in 1975.

- Low conductivity of the water on the water walls, which limited the strength of the electric field
- Incomplete coverage of water wall because of nozzle pluggage or residue buildup on cylinders (collecting plates)
- Premature failure of high-voltage insulator.

The mill's local water supply is primarily snow melt and is thus very low in impurities. As a result, this water has poor natural conductivity and serves as an effective insulator. The water-conductivity issue was addressed during the pilot test program for the wet ESP in 1975. Fortified H₂SO₄ was added to the water to maintain a minimum conductivity of 1000 μ mho. This system has worked adequately since then.

The collecting-plate water distributors in ESP 1 are a bottom-flow design, with 15-psig water supplied to the collection cylinders through 1/8-in.-diam. holes evenly spaced along the base of the distributor. However, this design is susceptible to pluggage, and the mill chose a top-flow design for the two wet ESPs installed on Furnace 3 in 1980.

Flowmeters are used to monitor flow to the water distributors on each ESP. Water flow to the distributors must be balanced to ensure complete coverage of the

cylinders while avoiding excessive flows that can spray onto the high-voltage cages. A considerable difference in average power levels was observed over time between the two identical wet ESPs (3E and 3W) arranged in parallel on Furnace 3. The principal difference in operating characteristics between these two units was the quantity of water flow to the water distributors. The water flow to the distributor in ESP 3W was reduced to match the flow to the ESP 3E distributor in early 1991. The reduction in flow to the distributor in ESP 3W resulted in a marked improvement in collection efficiency.

A mesh-pad mist eliminator was installed above the straightening vanes in ESP 1 during acceptance testing in 1975. The pad was intended to serve as a precleaner that would improve the collection efficiency of the unit by reducing the buildup of carbon on the cylinders during recovery-furnace upset conditions and soot blowing. However, the mesh pad was not specifically designed for this application and was, instead, customized by mill personnel. While the mesh pad did allow the unit to reach the outlet target of 0.05 grains/dscf, the rapid buildup of carbon on the mesh pad caused it to become a maintenance problem. On at least one occasion, a high pressure drop across the mesh pad caused an unplanned shutdown of Furnace 1. The pad was removed in 1987.

The single high-voltage insulators supporting the high-voltage cages in the mill's three ESPs are protected from moisture and particulate by a constant flow of hot, dry purge air. The high-voltage insulators must remain clean and dry, since moisture and dirt on the insulator surface act as high-resistance ground paths that limit peak voltage by permitting electrical tracking across the insulator. Electrical tracking induces a thermal stress that eventually cracks the insulator. The crack serves as an electrical fault line, and no useful voltage can be maintained across the insulator once it has been cracked.

A steady flow of hot, dry purge air is essential for a high-voltage insulator sitting unprotected in the middle of a moist, particulate-laden gas stream. Even with a continuous flow of purge air to the insulator, moisture and dirt can readily deposit on the insulator shroud and bucket, creating a high-voltage ground path. As a result of the inherent shortcomings in the insulator location and insulator shroud design, the manufacturer introduced externally mounted high-voltage insulators in the early 1980s.

Identifying proven particulate-control technologies

Several control technologies have demonstrated moderate- to high-efficiency removal of submicron particulate emitted from magnesium sulfite or ammonium sulfite recovery furnaces. The following technologies have been provided on a pilot scale or a full scale by one or more vendors:

- Wet ESP: Fluid-Ionics; Beltran
- Fiber-bed mist eliminator: Monsanto; Koch
- Dynawave scrubber: Monsanto
- Conventional venturi: Airpol.

The listed vendors were invited to provide quotes for new equipment capable of attaining various levels of

particulate control for the exhaust gases from Furnaces 1 and 2. The manufacturer of the wet ESPs in use at the mill provided a separate quote for upgrading (a) the existing single-point internal high-voltage insulator system to a four-point externally mounted system on each ESP and (b) the bottom-flow water distributors in ESP 1 to the top-flow design used in ESPs 3E and 3W.

Costs for retrofit options

Feasible control-technology alternatives for each recovery furnace are listed in ascending order of cost in Table IV. The anticipated outlet particulate grain loading achieved with each alternative is also shown. The annualized cost of each alternative was calculated assuming an equipment life of ten years and an average annual interest of 10%.

The mill's engineering consultants assumed a maximum allowable pressure drop across the retrofit particulate-control devices of 8-10 in. wg. This is the approximate pressure drop across the fiber-bed mist eliminator systems in use at several of the mills listed in Table II. An 8-in.-wg pressure drop provides a good starting point for balancing operating costs (primarily in the form of electrical requirements for the ID fan and water pump) and capital investment. Because of the high pressure-drop requirement of a conventional venturi scrubber, this device was eliminated from further consideration as a retrofit option.

The method of calculating the annualized cost of each retrofit alternative is based on a factored method of determining direct and indirect installation costs (9). This approach is a modified version of the Lang method, where installation costs are expressed as a function of known equipment costs. The cost-calculation technique assumes that the removal/site-preparation cost for replacing an existing particulate-control device will equal approximately 25% of the capital cost of the retrofit alternative selected. The assumed removal/site-preparation cost may be somewhat higher or lower than the actual cost, depending on the retrofit alternative chosen. However, as a rule, the removal/site-preparation cost amounts to only 15% of the annualized cost. The accuracy of this cost-calculation method is estimated to be $\pm 20\%$. For the purposes of this evaluation, the assumption that removal/site-preparation costs will equal 25% of capital costs is adequate for grouping the feasible retrofit alternatives in general cost ranges. To select between two options that are very close in annualized cost, a more-detailed analysis of site-specific retrofit costs should be performed in conjunction with input from a qualified vendor representative.

Vendors quoted an anticipated minimum useful service life of 20 years for new equipment, which is typical for equipment in industrial service. The length of useful service life beyond 20 years depends on the effectiveness of preventive maintenance programs, the compatibility of materials of construction with the service environment, and operating loads.

Conclusion and recommendations

The ADEC has established individual performance limits for each recovery furnace, as well as a limit of 2 lb/a.d.

IV. Feasible options for controlling particulate emissions from the mill's recovery furnaces

Option	Description	Anticipated outlet particulate loading, grains/dscf
<u>Recovery Furnace 1</u>		
1	ESP upgrade: top-flow water distributors, external high-voltage insulators	0.04
2	Single-stage Dynawave scrubber to replace two absorption towers, ESP upgrade	0.015
3	Single-stage Dynawave scrubber after existing absorption towers, booster fan, upgrade ESP	0.015
4	New ESP	0.04
5	Single-stage Dynawave scrubber after existing absorption towers, new ESP	0.015
6	Single-stage Dynawave scrubber after existing absorption towers, booster fan, new ESP	0.015
7	Two new ESPs in series	0.015
<u>Recovery Furnace 2</u>		
1	Single-stage Dynawave scrubber	0.10-0.12
2	Single-stage Dynawave scrubber, booster fan	0.06-0.10*
3	New ESP	0.03-0.04
4	Single-stage Dynawave scrubber, new ESP	0.015
5	Single-stage Dynawave scrubber, booster fan, new ESP	0.015
6	Two new ESPs in series	0.015
<u>Recovery Furnace 1 and 2 (Combined Exhaust)</u>		
1	Chevron or mesh-pad mist eliminators on each exhaust steam as precleaners followed by combined exhaust stream to six mist-eliminator candle canisters. All existing absorption towers remain in service.	<0.02
2	Single-stage Dynawave scrubbers on each exhaust stream, followed by combined exhaust stream to six mist-eliminator candle canisters. Dynawave scrubbers replace last two absorption towers on each recovery furnace.	<0.02
<u>Recovery Furnace 3</u>		
1	Existing internal high-voltage insulator support system is replaced with external HV insulator support system.	0.03

*Depends on pressure drop across scrubber, ranging from 8 in. wg to 14 in. wg

ton for the combined particulate emissions from the three recovery furnaces. These limits were provided in Table I and are summarized again in Table V.

Table VI lists the retrofit particulate-control recommendations for each of the mill's three recovery furnaces. Upgraded wet ESPs are recommended for Furnaces 1 and 3. Assuming that upgraded ESPs can consistently maintain outlet particulate loadings of 0.030 grains/dscf or less, which is likely in light of the recent performance of ESPs 3E and 3W, Furnace 2 has a practical particulate

V. Particulate limits for the mill's three recovery furnaces

Recovery furnace no.	Permitted outlet particulate loading per furnace, grains/dscf	Maximum outlet particulate loading ^a allowable to meet 2 lb/a.d. ton full load, grains/dscf	
		Hypothetical	Practical
1	0.080	0.057	0.030
2	0.085	0.061	0.085
3	0.042	0.030 ^b	0.030 ^b

^aThe 2 lb/a.d. ton emission standard is applied to the recovery furnaces as a group and is more stringent than emission limits established for the individual recovery furnaces.

^bThe Recovery Furnace 3 particulate emission rate has been assumed to be 0.030 grains/dscf to facilitate estimation of allowable particulate loadings for Recovery Furnaces 1 and 2.

VI. Retrofit recommendations for the mill

Recovery furnace no.	Recommendations
1	<ul style="list-style-type: none"> ● Upgrade existing wet ESP ● Perform detailed inspection and subsystem performance check (by vendor representative) to determine present condition of components, and the realistic remaining useful life of the ESP and the support steel
2	<ul style="list-style-type: none"> ● Install Dynawave wet scrubber with booster fan ● Perform pilot testing of Dynawave after first and third absorption towers.
3	<ul style="list-style-type: none"> ● Upgrade existing ESPs ● Perform detailed inspection and subsystem performance check (by vendor representative) to determine present condition of components and the realistic remaining useful life of the ESPs and the support steel

loading limit of 0.085 grains/dscf. Using this emissions-limit scenario, a single-stage Dynawave scrubber is a feasible particulate-control alternative for recovery Furnace 2. This scrubber is significantly less costly than competing alternatives.

ESP upgrade

The two design deficiencies that limit performance in ESP 1 are bottom-flow water distributors and an internally mounted, single high-voltage insulator. Over time, the performance of this unit has been erratic, with outlet grain loading ranging between 0.04–0.12 grains/dscf. Upgrading ESP 1 to include top-flow water distributors and four externally mounted high-voltage insulators will address inherent design deficiencies, essentially converting ESP 1 to the current wet-ESP design by Fluid-Ionics. A four-point high-voltage insulator support system will also facilitate alignment of high-voltage electrodes. This conversion should result in a maximum outlet particulate loading of 0.03–0.04 grains/dscf, assuming that regular preventive maintenance is performed.

ESPs 3E and 3W are presently performing better than design at an outlet particulate loading of less than 0.01 grains/dscf, although past source tests indicate that outlet

particulate loading has been as high as 0.11 grains/dscf. Upgrading these units to externally mounted high-voltage insulators will address the major deficiency in the existing design. Assuming regular preventive maintenance is performed, a consistent maximum outlet particulate loading of 0.03–0.04 grains/dscf can be expected.

The original service life of the wet ESPs was estimated at 20 years by the manufacturer without any operational data available. The manufacturer inspected the units in 1987 and found the fiberglass-reinforced plastic (FRP) shell and preconditioner on all units to be in good condition. Another inspection by the mill's consulting engineers in 1991 indicated that these components remain in good condition. The manufacturer estimates that a minimum additional service life of 10–15 years is reasonable to expect, assuming no serious damage to any of the principal FRP components has occurred.

Dynawave scrubber

The particulate-control efficiency of the Dynawave scrubber is directly dependent on the pressure drop across the turbulent gas-liquid contact zone. A pressure drop of 8 in. wg across a single-stage unit provides an approximate particulate-control efficiency of 70% based on the vendor quote provided. A pressure drop of 14 in. wg provides an efficiency of approximately 80%. Adding a second stage to the Dynawave and distributing a pressure drop of 14–16 in. wg across two stages would provide an expected collection efficiency of approximately 85%. □

Literature cited

1. Source test results records 1974–91, Alaska Pulp Corp., Sitka, AK.
2. Lockwood-Post's Directory of Pulp, Paper and Allied Trades, Miller Freeman Publications, New York, 1989.
3. Hayes, A. L., Recovery stack particulate control—wet filtration method, Ketchikan Pulp Co., Environmental Dept., Ketchikan, AK, 1975, unpublished manuscript.
4. White, H. J., Industrial Electrostatic Precipitation, Addison-Wesley Publishing, Reading, MA, 1963, pp. 38–40 and 180–81.
5. Parker, K. R., The wet ESP and its role in modern pollution control, Lodge-Cottrell Division of Dresser U.K. Ltd., Birmingham, U.K., 1986, unpublished manuscript.
6. Control techniques for particulate emissions from stationary sources, Vol. I, EPA-450/3-81-005a, USEPA, Washington, DC, Sept. 1982.
7. Teller, A. J., Yu, K. M., Ernst, C., and Johnson, W. D., Pulp Paper Can. 78(2): T37(1977).
8. Corporate correspondence record between Fluid-Ionic Systems and Alaska Pulp Corp. 1974–87, Alaska Pulp Corp., Sitka, AK.
9. Vatauvuk, M. V., and Neveril, R. B., Chem. Eng. 87(Nov. 7): 157(1980).

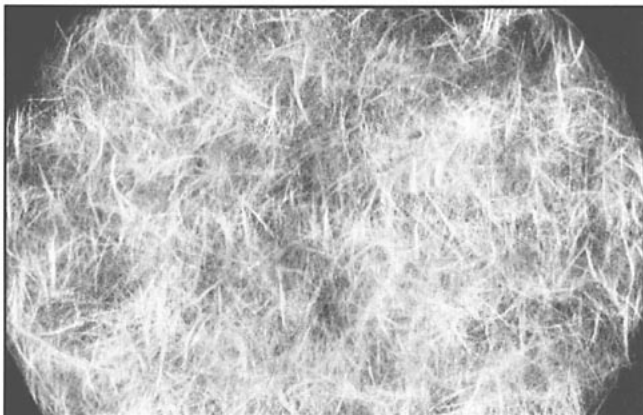
Received for review Dec. 24, 1991.

Accepted Jan. 17, 1992.

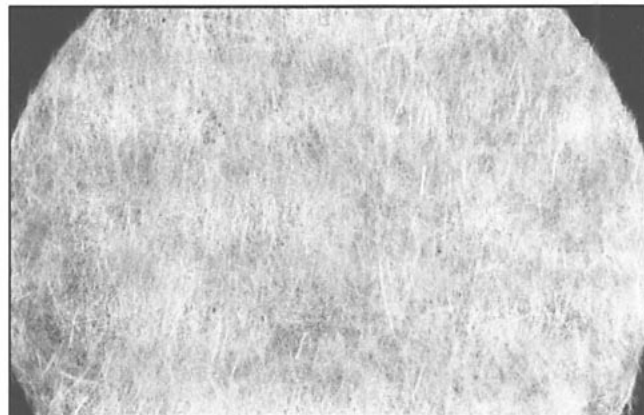
Presented at the TAPPI 1992 Environmental Conference.

Keywords: Air pollution, Alaska, ammonium sulfite, control systems costs, evaluation, magnesium sulfite, maintenance, North America particulate emissions, performance, recovery furnaces.

1. Handsheet made with no polyester dispersant



2. Handsheet made with 10 lb/ton polyester dispersant



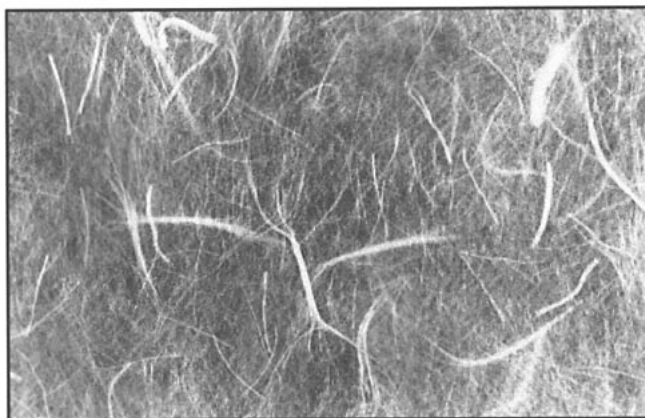
I. Polyester dispersant evaluation

<i>Dispersant dose, lb/ton</i>	<i>Formation index</i>	
	<i>Disp. no. 1</i>	<i>Disp. no. 2</i>
Blank	36.2	36.2
1	42.8	44.1
2	46.4	51.6
6	58.1	65.7
10	65.3	67.2

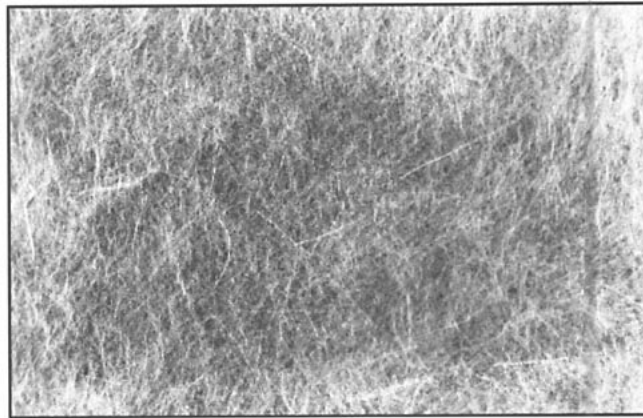
II. Formation aid evaluation: handsheets

<i>Viscosity modifier dose, ppm</i>	<i>Formation index</i>
0	54.4
25	63.3
50	69.0
100	70.1
250	81.6

3. Handsheet made with no viscosity modifier



4. Handsheet made with 250-ppm viscosity modifier



III. Formation aid evaluation: pilot machine

<i>Viscosity modifier dose, ppm</i>	<i>Formation index</i>
0	70.2
200	96.7

IV. Basis weight variation

<i>Basis weight, g/m²</i>	<i>Formation index</i>
12.5	95.5
25.0	77.8
50.0	74.1
100.0	65.3