FGD Mist Eliminator Replacement Guide

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REPORT SUMMARY

In wet flue gas desulfurization (FGD) systems, mist eliminators (ME) remove entrained scrubbing slurry from flue gas before it leaves the wet scrubber and exits the stack. Such systems are historically problem-prone. To assist utilities replacing mist eliminators on existing FGD systems, this guide contains a systematic methodology to determine the best replacement. It also contains the latest information on performance, construction materials, and installation and structural properties.

Background

Mist elimination system (MES) problems have plagued FGD units since their installation on utility boilers in the late 1960s. MES failures are the second most common cause of FGD system outages. MES problems can result in particulate emissions, stack "rain," and additional operating and maintenance costs. Higher operating costs frequently result from difficulties in keeping a MES clean in the reactive environment of lime- and limestone-based FGD systems.

EPRI R&D activities have concentrated on evaluating and solving problems on real-world, full-scale FGD systems and in simulating actual commercial installations in a large-scale air/water modeling facility. The results of this project represent an updated guide to existing ME replacement along with recently collected data on construction materials and techniques.

Objectives

- To develop a comprehensive guide to existing ME replacement.
- To collect, synthesize, and document information on ME construction materials and structural properties.

Approach

Investigators collected information from utilities, ME suppliers, materials suppliers, and FGD vendors on construction materials, structural properties, and costs. They combined this information—along with previously collected information on performance and causes of problems—with ME systems to develop this guide.

Results

Information in the guide covers all aspects of selecting a replacement ME, including performance (Æp and mist removal efficiency), materials selection (such as mechanical damage resistance, temperature resistance, corrosion resistance), installation and structural properties (such as assembly weight, structural support, load bearing capacity), and relative costs. The guide presents enough information to effectively select replacement mist eliminators.

EPRI Perspective

These results represent the best information available on the issues of replacing an existing mist eliminator. The guide is complementary to the EPRI *FGD Mist Eliminator Design and Specification Guide* (TR-102864, December 1993) and the EPRI *FGD Mist Eliminator Troubleshooting Manual* (GS-6984, October 1990). This new guide contains the most recent information on construction materials and structural aspects of MES. Using all three MES guides will enable utilities to replace an existing ME with confidence; the guides will help utilities achieve the maximum useful life of the new mist eliminator while minimizing or eliminating many of the factors that limit ME life.

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Interest Categories

Air emissions control

Keywords

Air pollution control
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Fossil fuel boilers
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Wet scrubbers

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INTRODUCTION

Background/Objective

The objective of this manual is to provide a simple, brief reference that will help utilities select the best replacement mist eliminator for their application. The manual describes an approach to the selection process aimed at avoiding the types of problems that originally led to the need for replacement. Included in the manual is technical information regarding mist eliminator performance specifications and materials selection. Materials selection in particular is of increasing importance to many utilities, since this is the primary factor affecting mist eliminator longevity once any scaling problems have been corrected.

This manual is not intended to replace current vendor information or other existing mist eliminator references. Much useful information has already been published on mist eliminator design and troubleshooting in references such as the EPRI Mist Eliminator Design Guide and the EPRI Mist Eliminator Troubleshooting Guide. Instead, this manual supplements these previous works with an emphasis on the practical aspects of mist eliminator replacement.

Summary

Selecting a replacement mist eliminator is not necessarily an easy decision. There are a number of factors that should be considered in selecting a replacement mist eliminator, and it is not always easy to evaluate these factors. Examples of issues that should be considered in the selection process include:

- Are the mist eliminators lasting as long as they should?
- If they are not lasting as long as they should, why are they failing early?
- How can early failures be avoided?

The objective of this manual is help guide a utility through the replacement process. This guidance and experience should enable a utility to select a mist eliminator that will perform better and last longer than the one which is being replaced.

A guide to the selection process is provided in Section 2. The selection process is divided into three basics steps. The first step, initial analysis, is simply identifying why the mist eliminator is being replaced. According to vendors, mechanical damage (including temperature excursions and corrosion), scaling, and carryover account for virtually all replacements. The second step involves identifying the underlying cause of the failure. For instance, a damaged mist eliminator may have failed because of a temperature excursion, because of corrosion, or because of damage associated with scale removal. Once the failure mode is identified, the options available for preventing similar failures in the future become more evident. These options generally involve either avoiding similar operating or process conditions in the future or selecting a mist eliminator that can better tolerate these conditions. The manual provides guidance both on how to identify the underlying cause of the failure and how to address the problem so that similar failures do not occur in the future. The final step in the process is to identify other factors, such a load bearing capacity and fire retardant properties, that may also be desirable to the utility.

A technical discussion of factors important to mist eliminator replacements is presented in Section 3. The factors discussed in this section include:

- Mist removal performance,
- Pressure drop,
- Materials selection, including:
  - Mechanical damage resistance,
  - Temperature resistance,
  - Corrosion resistance (for both plastics and alloys)
- Fire Retardance,
- Installation and structural factors, including:
  - Span length
  - Assembly weight,
  - Structural support/wash systems,
  - Load bearing capacity

- Plugging and scaling resistance, and
- Relative costs

The objective of Section 3 is to provide the technical background information necessary to evaluate those factors important to selecting a replacement mist eliminator.

The manual also includes a glossary and bibliography as Sections 4 and 5.

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REPLACEMENT MIST ELIMINATOR SELECTION PROCESS

This section presents a general approach to selecting a replacement mist eliminator. The selection process outlined here focuses on addressing the underlying problem which led to the need for replacement. The selection process is illustrated in the flow diagram shown in Figure 2-1; a discussion of this process follows below.

Initial Analysis

The initial analysis simply involves identifying the reason for replacement. According to vendors, mechanical damage, scaling, and carryover account for virtually all replacement mist eliminators. However, since it is possible that different sorts of problems lead to a single mode of failure (e.g. there are several different problems that can lead to mechanical damage), it is necessary to investigate further to determine the underlying reason that the mist eliminator needs replacement.

Identifying the Underlying Causes and Potential Solutions to Mist Eliminator Failures

Simply knowing that a mist eliminator is being replaced because it allows excessive carryover or because it is damaged does not enable a utility to select a better replacement. First, it is necessary to take a more detailed look at the underlying problem that ultimately led to the mist eliminator failure. Once this has been done, it is then possible to examine ways in which similar failures can be avoided in the future. A discussion of the possible causes of mist eliminator failures and potential solutions to these problems is presented below. The discussion is organized according to failure cause: mechanical damage, scaling, and carryover.

Mechanical Damage

Mechanical damage can be a difficult problem to assess. Plastic mist eliminators do not usually last the life of the plant, so it must first be determined if the existing mist eliminators have failed prematurely. If not, then the underlying cause of the failure

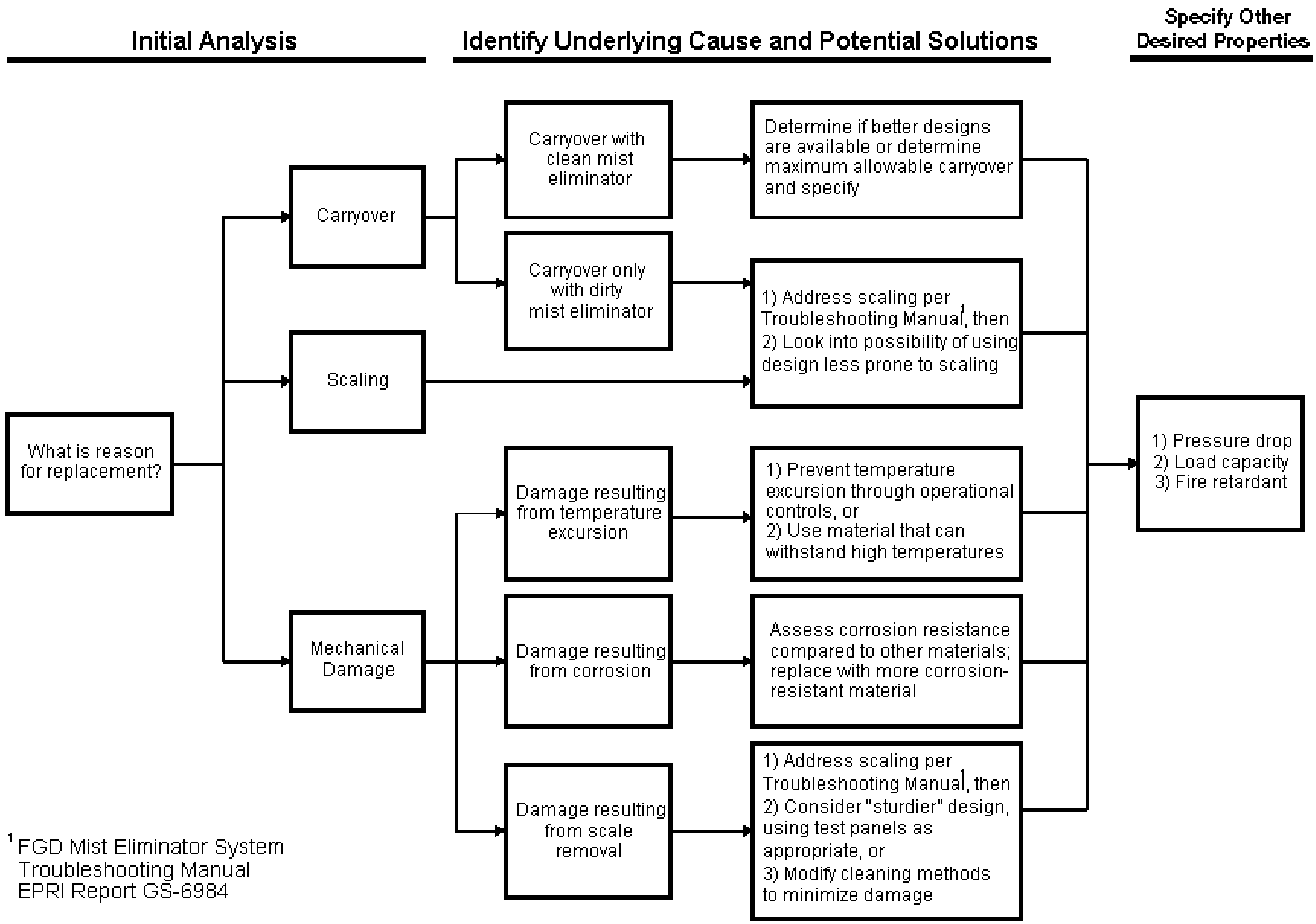

Figure 2-1
Mist Eliminator Replacement Flow Diagram

must be determined. Temperature excursions, corrosion, and damage from wash system malfunction (wash nozzle blowoff) or mechanical cleaning are all ultimately manifested as some form of mechanical damage. Only after the underlying cause of the failure is determined can a utility effectively address replacing the mist eliminator. If the mist eliminator has lasted as long as it should, and its performance is judged satisfactory, then replacement with an identical mist eliminator is appropriate.

The expected life span (according to vendors) of properly operated and maintained mist eliminators is summarized below.

Material	Expected Life Span
Alloys	Decades - Life of plant
Polypropylene	5 to 10 years, have seen 12 year life spans in Europe
Engineered Thermoplastics	5 to 10 years
Polysulfone	Currently only 2-3 years actual experience; expected to last 10 years
FRP	5 to 10 years

If the mist eliminator did not last as long as expected, the next question to ask is why did it fail early. Possible causes of failure include temperature excursions, chemical corrosion, and damage from scale removal (mechanical cleaning or high-pressure washing) or wash system malfunction. Distinguishing between these different failure modes will help the utility either select a replacement mist eliminator which can tolerate the environment or modify the system so that the environment is not as harsh to the mist eliminators. Based on information from mist eliminator vendors and plastics suppliers, the primary "symptoms" of mechanical failures are as follows.

> Temperature excursion - Temperature excursions most commonly occur when slurry recycle pumps trip. For thermoplastics, sagging and warping are likely results of temperature excursions. For thermosets, delamination is a likely result of temperature excursions. Degradation of the material, manifested as visible changes in appearance (such as surface cracks, or loss of gloss), brittleness, or loss of strength, may also result from temperature excursions.
>
> Chemical corrosion - For plastics, in the absence of temperature excursions, changes in surface appearance are signs of chemical corrosion. Brittleness and loss of strength may also result from corrosion. For alloys, pitting and/or weight losses are signs of corrosion.
>
> Damage from Scale Removal - This category covers damage resulting from mechanical cleaning and high pressure washing in the absence of other factors which weaken or damage the mist eliminators. If temperature or corrosion weaken the mist eliminator (thus leading to damage), then the temperature excursion or corrosion problem is what should be addressed.

Once a failure mechanism has been determined, it is then possible to look into ways of avoiding future failures. For temperature excursions, the options are straightforward: either prevent future temperature excursion (through operational controls), or purchase a replacement mist eliminator constructed of a material that can withstand the excursion temperatures. Information on both the continuous and short-term temperature limits for many common mist eliminator materials is provided in the technical discussion (Section 3).

Corrosion problems are a little more difficult to assess. In particular, it can be difficult to determine whether or not a material will be able to survive in a given environment. For plastics, suppliers generally assess corrosion by exposing a sample of the material to the environment for an extended period of time (preferably six months to one year). Evaluation of the material's performance is based on visible evidence of corrosion or sometimes on physical properties of the exposed material (see the technical discussion for more information on these evaluations). While these methods have been used extensively within the plastics industry, there is little experience in applying them to mist eliminator applications. Consequently, it is not possible to provide quantitative recommendations regarding the level of corrosion resistance necessary for mist eliminator applications. Plastics corrosion tests can, however, be useful in comparative analyses, such as in determining if a potential replacement material is more or less corrosion resistant than the material being replaced.

For alloys, corrosion resistance can be evaluated by using test panels. Since alloys are expected to last the life of the plant, any evidence of corrosion found after a six to twelve month period should be considered an indication that the alloy is not satisfactory for the application. Alternately, an alloy can be selected based on scrubber pH and chloride levels. Guidance on alloy selection is provided in the technical discussion and in Appendix A.

In some instances, corrosion may be known to have occurred as a result of a chemical excursion. In these cases, preventing future excursions may also be an option for addressing corrosion problems.

Damage from scale removal generally occurs during mechanical cleaning and high-pressure washes. If regular mechanical cleanings or high-pressure washes are required, a first step in preventing continued mist eliminator damage is to address the underlying scaling problem. Information on addressing mist eliminator scaling problems can be found in the FGD Mist Eliminator System Troubleshooting Manual. Once scaling problems have been addressed, the need for mechanical cleaning/high pressure washing should be substantially reduced. If mechanical damage problems persist, then the utility may want to consider looking into other mist eliminator designs. Information on designs is presented in the technical discussion section of this report. Test panels can be a valuable tool in assessing whether or not potential replacement designs are capable of withstanding the mechanical cleanings/high pressure washes typical for the system.

Damage may also occur when loss of a wash nozzle allows wash water to impinge directly on a section of the mist eliminator. This will typically result in a small, localized area of damage.

Scaling/Plugging

Scaling and plugging are usually caused either by an inadequate wash system or by chemistry problems in the scrubber. Information on addressing mist eliminator scaling and plugging problems can be found in the FGD Mist Eliminator System Troubleshooting Manual. Mist eliminator design can also affect scaling (although design factors are generally secondary to wash system and chemistry effects); information on how mist eliminator design factors can affect scaling is presented in the technical discussion.

Carryover

Carryover may be seen either as buildup in the outlet duct and stack or as local fallout, as excessive particulate emissions from the stack[1]. Carryover results from fine droplets which penetrate through the mist eliminator or from large droplets which are stripped from the mist eliminator vanes by high gas velocities. Under normal gas velocity conditions, if the carryover occurs when the mist eliminator is clean, then the utility should look into the possibility of replacing the mist eliminator with a different design which better controls carryover. Keeping in mind that every mist eliminator allows at least some carryover, a reasonable question to ask is: How much carryover can our plant tolerate? An example calculation used to estimate a maximum allowable carryover rate is shown in the technical discussion section. While calculations can provide estimates of maximum allowable carryover rates, vendors report that most utilities select carryover specifications based on the achievable carryover rates reported by vendors (i.e., utilities select a mist carryover specification based on the capabilities of current technology). Typical ranges are presented in the technical discussion. It can also be useful to know how well the existing mist eliminator compares to others which are available on the market. Information on measured carryover rates for various mist eliminators is presented in the technical discussion; additional information on carryover rates is presented in the FGD Mist Eliminator Design and Specification Guide.

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[1] If excess particulate emissions from the stack are the underlying problem, the utility should confirm that FGD solids are the actual source of the excess emissions prior to replacing the mist eliminator. Information describing how this can be done is provided in EPRI's Utility Stack Opacity Troubleshooting Guidelines.

If carryover occurs only when the mist eliminator is dirty or scaled, then scaling/plugging is the underlying problem. The scaling/plugging problem must be corrected in order to prevent carryover, since any mist eliminator will allow carryover once it scales. Scaling and plugging are usually caused either by an inadequate wash system or by chemistry problems in the scrubber. Information on addressing mist eliminator scaling and plugging problems can be found in the FGD Mist Eliminator System Troubleshooting Manual. Mist eliminator design can also have an effect on the tendency of a mist eliminator to scale or plug. Information on how design factors can affect scaling/plugging is presented in the technical discussion. It is important to note that the scrubber chemistry and wash system are the primary factors affecting scaling; any mist eliminator is likely to scale or plug if it is not washed adequately or if there are underlying problems with the scrubber chemistry.

Other Desirable Properties

Once the utility has determined the underlying cause of their mist eliminator failures and has decided on how to address the problem, the one remaining task is to determine what other properties are desirable in the replacement mist eliminator. Properties that may be of interest include things such as pressure drop, fire retardant properties, load bearing capacity, and other structural/installation factors. Information regarding these properties is included in the technical discussion.

3

TECHNICAL DISCUSSION

The technical discussion section provides information about the various factors that can affect how well a mist eliminator performs in its environment. The discussion is organized into five subsections: 1) performance factors (covering mist removal performance and pressure drop), 2) materials selection (covering mechanical damage resistance, temperature resistance, corrosion resistance in plastics, corrosion resistance in alloys, and fire retardant properties), 3) installation and structural properties (covering span length, assembly weight, structural support/wash system, and load bearing capacity), 4) plugging and scaling resistance, and 5) relative cost.

Performance Factors

Mist Removal Performance

Mist removal is obviously a key performance parameter for mist eliminators. In selecting replacement mist eliminators, utilities typically specify a maximum carryover rate that is required of the replacement. How do most utilities select maximum carryover rates? In many cases, the specification is based on the capabilities of current technology. Sometimes performance information is collected directly from the vendors. Other times the information is obtained from other utilities, although often this information ultimately comes from the vendors as well. But regardless of the source, typical specifications fall in the range of 0.02 gr/acf to 0.07 gr/acf (0.045 g/m^3 to 0.16 g/m^3). [Note: a carryover rate of 0.02 gr/acf is roughly equivalent to 0.0002 gpm/sq.ft. (0.008 liters/min/square meter) at a gas velocity of 10 ft/s (3.04 m/s)]. Vendors typically determine the carryover performance of their mist eliminators through laboratory testing.

Is it always best to select a mist eliminator with the lowest available carryover rate? The short answer is no. Low carryover rates are generally achieved by mist eliminators with tight blade spacings or a high number of passes. These mist eliminators will tend to be more difficult to clean, will have higher pressure drops, and may also cost more, since more material is required to manufacture them.

The experience with the performance of previous mist eliminator installations can be of great use in determining an appropriate carryover specification. If a plant has not experienced any significant carryover problems, it is appropriate to specify that carryover from the replacement mist eliminator must not exceed carryover from the previous mist eliminator. Specific data regarding carryover rates for some commonly used mist eliminators is shown in Figure 3-1; the corresponding blade configurations and stage spacings for these mist eliminator are shown in Figure 3-2. The information shown in Figures 3-1 and 3-2 represent data collected in an EPRI test program. It does not include all commercially available mist eliminators. Additional carryover information (also from the EPRI test program) is available in EPRI's FGD Mist Eliminator System Design and Specification Guide starting on page 2-73.

If a plant has experienced carryover problems, a maximum allowable carryover rate can be selected based on calculations of duct buildup or particulate emissions rates. An example calculation assuming a specific particulate emission rate follows.

EXAMPLE – Carryover That Could Cause Significant Particulate Emissions

<u>Assumptions</u>:

- Particulate emissions of 0.015 lb/MMBtu (6.5 ng/J) [half of the New Source Performance Standard (NSPS) limit] caused by slurry carryover are significant.

- For the purpose of this calculation, all slurry carryover is assumed to be carried out the stack, water in the carryover is assumed to be evaporated, leaving only the solids, and carryover from washing is assumed to cause insignificant particulate emissions.

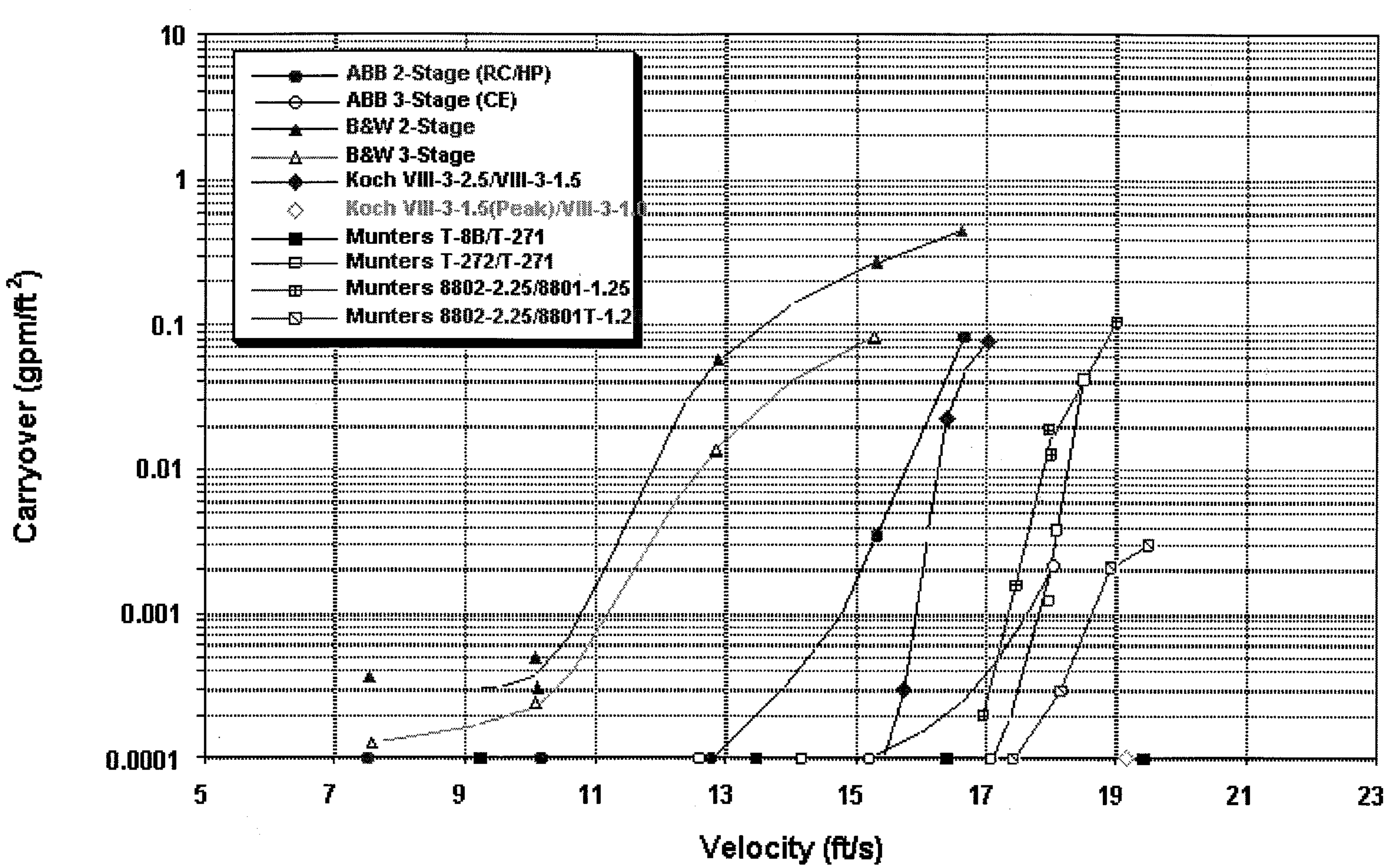
<u>Example Process Information</u>:

- 18,600 acf/MMBtu (4.99×10^{-7} m^3/J) at 130°F (54°C) passes through the mist eliminator.

- 10% total suspended solids (TSS) and 50,000 ppm total dissolved solids (TDS) in the slurry.

- 10 ft/s (3.04 m/s) superficial velocity in the tower and 12.5 ft/s (3.81 m/s) actual velocity through the mist eliminator (20% blockage by supports).

- Slurry density is 9.34 lb/gal (1.12 g/cm^3).



To convert gpm/ft ^{2} to L/min/m ^{2}, mulitply by 40.74.
To convert ft/s to m/s, multiply by 0.3048.

Figure 3-1
Carryover Rates for Multiple-Stage, Vertical-Flow ME Systems Tested by EPRI at 1.5 gpm/ft^2 Mist Loading

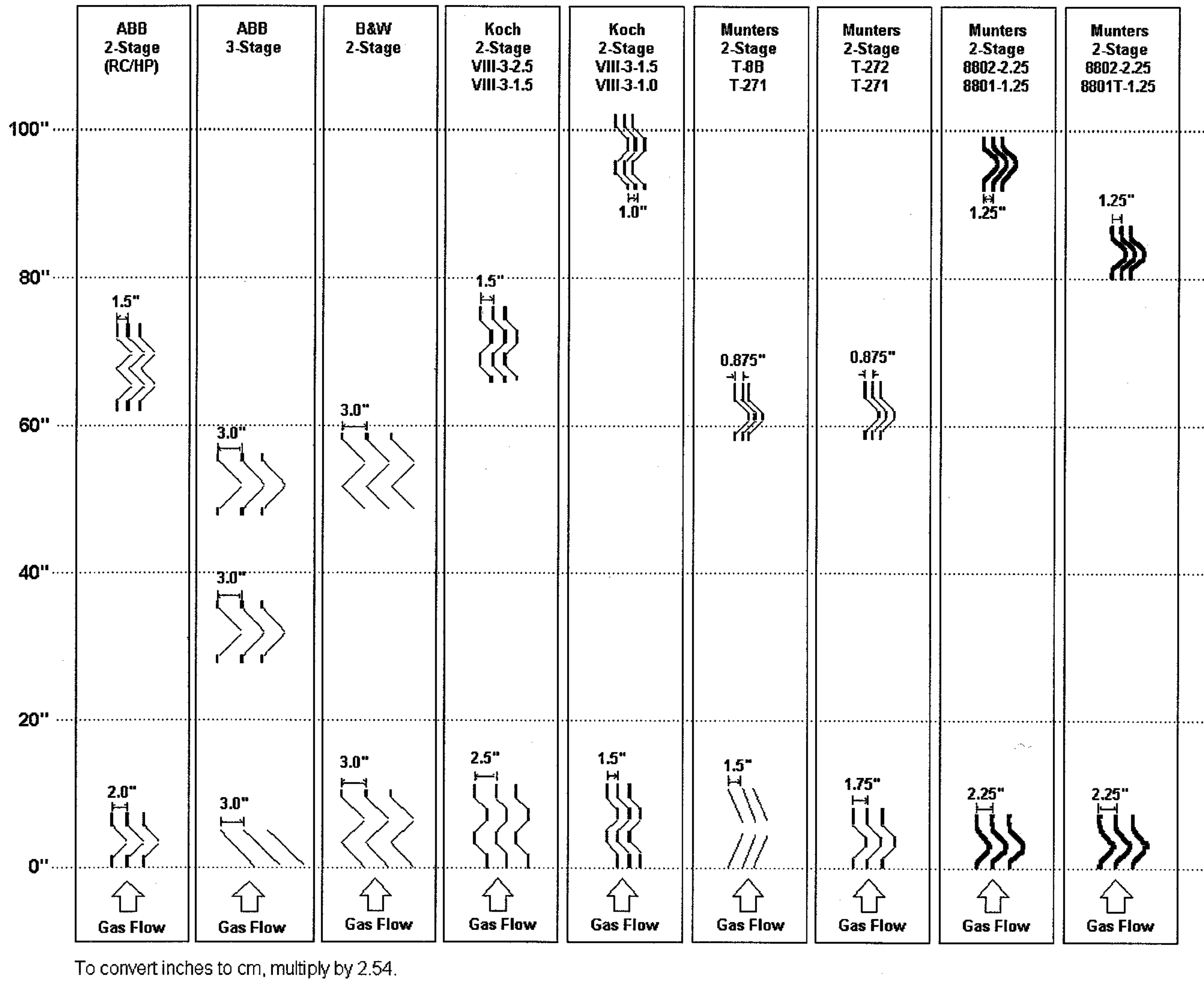


Figure 3-2
Blade and Stage Spacings for Multiple-Stage Vertical-Flow ME Systems Tested by EPRI

Calculation:

$$\frac{(0.015\ lb\ solids/MMBtu)\ x\ (12.5\ ft/s)\ x\ (60\ s/\min)}{(9.34\ lb/gal\ slurry)\ x\ (0.15\ lb/solids/lb\ slurry)\ x\ (18{,}600\ acf\ /MMBtu)} \qquad \textbf{(eq. 3-1)}$$

= $0.0004\ gpm/ft^2\ (0.018\ liter/min/m^2)$

= Point at which FGD mist eliminator carryover becomes significant from a particulate emissions standpoint.

Additional information on calculations used to determine maximum carryover rates can be found in EPRI's FGD Mist Eliminator System Design and Specification Guide on pages 2-93 through 2-98.

Though utilities usually do specify maximum allowable carryover rates, mist eliminator vendors report that it is fairly infrequent that a utility will attempt to measure carryover rates. According to vendors, most utilities that do measure carryover rates do so using the Army Insecticide Measurement System (AIMS) probe. It should be noted, however, that the AIMS probe does not measure large droplet contributions accurately, so measured carryover rates may be understated when large droplets, such as these generated when reentrainment occurs, are present. The AIMS probe accuracy improves when large droplets are not present, i.e., when there is no reentrainment. (See the FGD Mist Eliminator System Design and Specification Guide starting on page 2-42 for more information regarding performance of various carryover measurement methods including the AIMS probe.). Overall, the video droplet analyzer is a better technique, although it is more expensive and access limitations may prevent its use in some areas.

Pressure Drop

In most replacement situations, pressure drop is not a critical factor in the selection process. The approach to evaluating pressure drop varies among utilities. Some simply specify a maximum pressure drop; typical values specified range from 0.5 in H_2O to 1 in H_2O. Vendors typically do not have any difficulty in meeting these requirements; a summary of pressure drops for the previously referenced mist eliminators is shown in Figure 3-3. Figure 3-3 presents information collected under an EPRI test program; it does not include all commercially available mist eliminators. Other utilities request that the vendor supply pressure drop information in the bid package. These utilities can consider the impact (if any) that differences in pressure drop will have on plant operating costs; these costs can then be considered during the bid evaluation process.

Pressure drop information for many commonly used mist eliminators is available in the FGD Mist Eliminator System Design and Specification Guide starting on page 2-60.

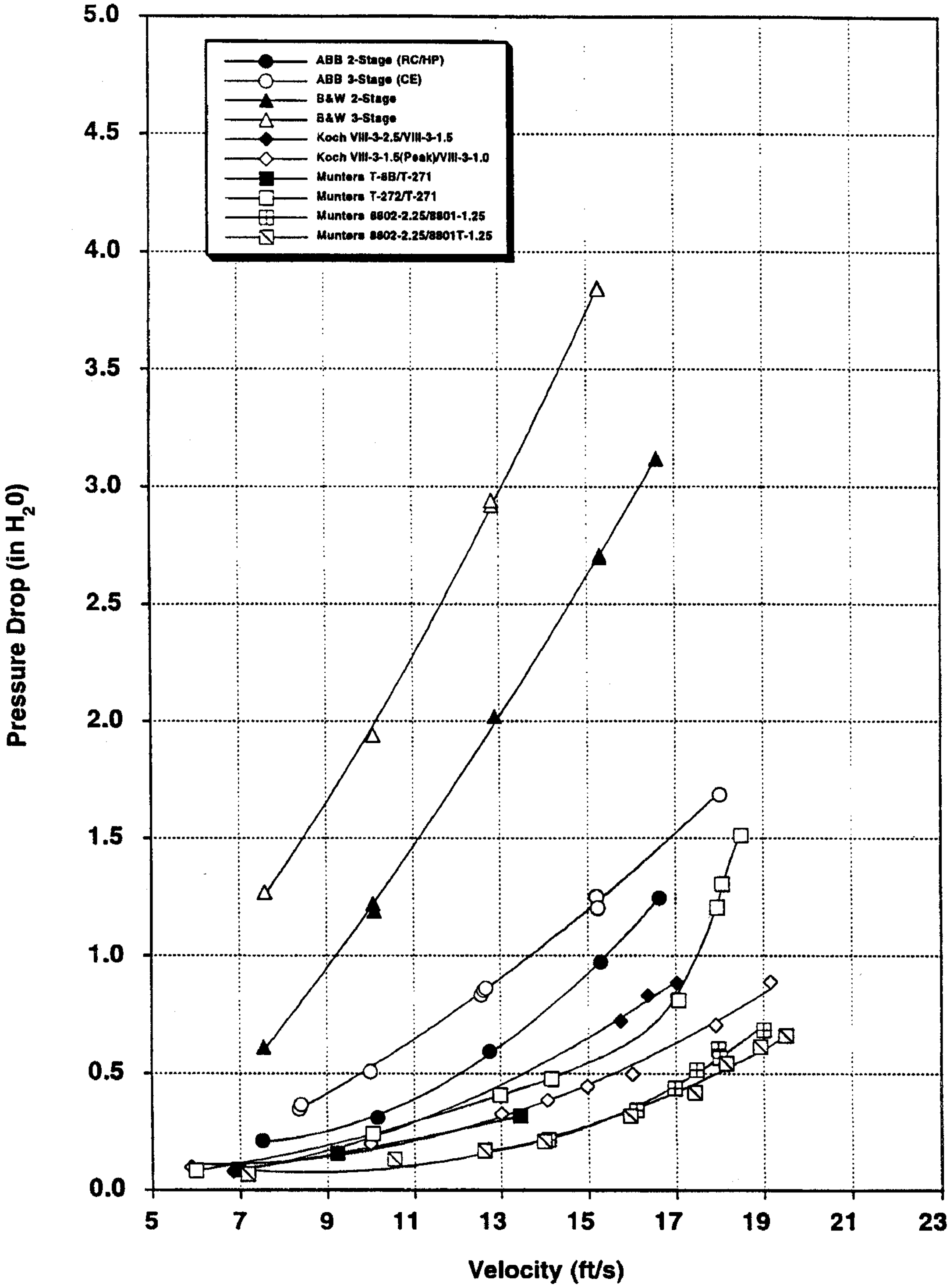


Figure 3-3
Pressure Drop Results at 1.5 gpm/ft² (61.1 L/min/lm²) Mist Loading for the Multiple-Stage, Vertical-Flow ME Systems Tested by EPRI

Materials Selection

Mist eliminator vendors typically avoid making materials recommendations. They will, if asked, provide general guidance about the various materials, but ultimately material selection is done by the utility. For alloy selection, the primary issue is corrosion. Selection of an alloy is thus typically done based on experience with alloys in FGD service or through the use of corrosion test panels. For plastics, there are several issues influencing the selection process including mechanical damage resistance, corrosion resistance, temperature resistance, and fire retardant properties. Approaches to assessing materials performance in each of these categories are summarized in the following sections.

Mechanical Damage Resistance

According to mist eliminator vendors, the most common reason for replacing a mist eliminator is mechanical damage. Damage typically occurs as a result of mechanical cleaning (i.e. physically knocking scale out of the mist eliminators), walking on the mist eliminators, or high-pressure washing. Note that the damage resistance discussed here refers only to mechanical damage. If mist eliminators are weakened by corrosion or temperature excursions, then the reader should refer to the sections discussing corrosion or temperature resistance. Damage may also result from losing a wash nozzle, but this damage is usually fairly localized.

Mist eliminator damage can occur through a number of different mechanisms including impact, tensile or flexural failure, and being cut (by high-pressure wash). Because of the different mechanisms involved, there is no single property which can be used to assess how well a mist eliminator will survive in a particular environment.

Virtually all mechanical damage results from the need to remove scale from mist eliminators. Accordingly, the first step in addressing mechanical damage is to ensure that the mist eliminators are being kept as clean as possible. Guidelines on addressing wash system recommendations, scaling and plugging problems are addressed in the FGD Mist Eliminator Troubleshooting Guide.

If mechanical damage problems persist after scaling and plugging problems have been addressed, there may be the option to use a “sturdier” mist eliminator. Unfortunately, it is not easy to determine how well a mist eliminator will resist mechanical damage. Sturdiness depends on a number of factors, including blade thickness, overall panel design and construction, and the type of damage being sustained (e.g. resistance to being “cut” by a high pressure wash is different than resistance to being damaged by the impact from a hammer used to knock out scale). Vendors can provide information regarding how various materials have performed with respect to mechanical damage resistance, and can also provide information regarding how well different mist eliminators within their own product line can withstand mechanical damage.

A more accurate assessment of mist eliminator sturdiness can be obtained by installing test panels. The test period should last an extended period of time (vendors suggest six months to a year) and should include several cleaning cycles. Vendors report that roughly one fourth of their customers have installed test panels, and that those who are diligent about tracking the test panels have been satisfied with their use in evaluating sturdiness. However, vendors note that a number of utilities that have installed test panels lost track of them before testing was complete. As an alternate approach, if time is not available to evaluate a test panel in service, some utilities have elected to evaluate test panels out of service. Basically, this is done by allowing maintenance personnel to "simulate" the sort of wear and tear that will occur during actual use. Typically this would entail subjecting the test panel to a high-pressure wash or mechanical cleaning as is normal practice for the existing mist eliminator.

In general terms, thermosets (because of the strength resulting from the glass fiber reinforcement) and engineered thermoplastics have better mechanical damage resistance than does polypropylene. However, mist eliminator design and construction play a large role in its ability to resist damage. Thus the entire panel assembly should be evaluated (as through the use of test panels) when selecting a damage resistant mist eliminator.

Another alternative to minimize damage is to modify cleaning methods. Examples include using planking for all foot traffic and using lower pressure wash water. These actions may increase the amount of time required to clean the mist eliminator, but they can also reduce the amount of damage incurred during the cleaning.

Temperature Resistance

The temperature resistance of alloy mist eliminators is high (considered an advantage) and usually not an issue when selecting replacements. However, the temperature resistance of the various plastics used in mist eliminator manufacturing varies widely. A summary of the maximum operating temperatures recommended for common plastic materials utilized by mist eliminator vendors is provided in the following table.

	Continuous	30 Minute
Polypropylene	165°F to 170°F (74°C to 77°C)	180°F to185°F (82°C to 85°C)
Glass coupled polypropylene*	265°F (129°C)	300°F (149°C)
Fiberglass reinforced plastic**	250°F (121°C)	300°F (149°C)
Ultem	300°F (149°C)	350°F (177°C)
	Continuous	30 Minute

Ryton	400°F to 450°F (204°C to 232°C)	
Polysulfone	300°F (149°C)	350°F (177°C)

* Some vendors do not use glass coupled polypropylene because of concerns that the underlying resin begins to soften at 170°F (77°C).
** Damage to the outer veil of fiberglass reinforced plastic can expose fibers to moisture and thus accelerate moisture to penetration into the mist eliminator. If this occurs, temperatures exceeding 212°F (100°C) can damage the mist eliminator (delamination) as the absorbed moisture vaporizes.

The lower temperature resistance of polypropylene is one of its primary drawbacks; temperature excursions caused by losing the recycle slurry pumps will damage polypropylene mist eliminators. Glass-coupled polypropylene can withstand higher temperatures (up to 265°F), although some manufacturers prefer to avoid this material because the underlying resin softens at 170°F (77°C). Fiberglass mist eliminators can also be subject to damage from temperature excursions, especially if there is any damage to the surface veil which allows moisture to penetrate the mist eliminator. The remaining materials (all engineering thermoplastics) can generally withstand the temperatures commonly seen in FGD systems, even during a temporary loss of slurry recycle pumps.

Corrosion Resistance in Plastics

Though the mechanisms by which plastics corrode are different than mechanisms by which metals corrode, plastics are subject to corrosion. Plastics corrosion in mist eliminators can be manifested as changes in the surface characteristics (such as appearance of surface cracks and loss of gloss), embrittlement, and loss of strength. (The surface changes are what give the appearance of "aging" that can sometimes be seen in mist eliminators).

The changes described above are signs that the plastic has deteriorated. However, it is important to note that this deterioration can also be caused by temperature excursions; plastics which can survive indefinitely at normal temperatures may degrade rapidly at higher temperatures. Yet if the mist eliminator appears to degrade in the absence of temperature excursions, corrosion is likely to be the cause.

While plastics suppliers have been doing corrosion testing for years, there is very little experience in actually applying corrosion testing results to utility mist eliminator applications. As a result, it is not possible to make specific recommendations regarding the level of corrosion resistance necessary for mist eliminator applications. On the other hand, test used by plastics suppliers should be helpful is determining relative corrosion resistance between materials, and thus should be useful in selecting a mist eliminator material that will perform better than one which had previously been found to corrode.

One approach used by plastics suppliers in evaluating corrosion resistance is to put a material sample (for mist eliminators, either a test coupon or, preferably, a test panel) in service for an extended period of time, preferably six months to one year. Visual examination of the test piece should be made at the end of the exposure period; any changes in surface appearance (such as cracking or loss of gloss) are signs of corrosion. (A control piece should be kept to use for comparison purposes). Testing can also incorporate an evaluation of the physical properties of the coupon, such as flexural strength and flexural modulus. A protocol for measuring physical properties of corrosion test coupons is provided in American Society for Testing and Materials (ASTM) C-581. (The ASTM protocol involves looking for changes in flexural strength, flexural modulus, Barcol hardness, and appearance in exposed test coupons).

Plastics suppliers use the methods described above (or minor variations thereof) to develop chemical compatibility charts for their products. Suppliers of thermoplastics use visible inspection of exposed pieces to prepare chemical compatibility charts for their products (some suppliers also put the plastic under strain during the chemical exposure, to more accurately simulate end use conditions). Any change in appearance makes the plastic “suspect” for the chemical environment. The thermoset suppliers use ASTM C-581 to evaluate the corrosion resistance of their products. These suppliers use a minimum of 50% retention of flexural strength and modulus as criteria for determining if the thermoset is compatible with the chemical environment.

The limited data from actual utility applications suggest that there can be significant differences in corrosion resistance. One utility which has performed corrosion tests reported that for a test of three materials, one retained 90+% flexural strength (for a one month exposure period), while the two others retained only 50% to 60% for the same exposure period. This led the utility to select the material that better retained its flexural strength, although it remains to be seen how well the new material performs in comparison to the material being replaced. If time permits, corrosion testing for plastics may be prudent in that it may be help the utility eliminate from consideration some obviously unsuitable materials.

Corrosion in Alloys

According to vendors, alloy mist eliminators are used in approximately 10% of all FGD system applications. The primary reason for alloy mist eliminator failures is corrosion, although these failures are uncommon. Most utilities considering alloy mist eliminators already have experience with alloys in FGD service. However, in most cases this experience is with alloys used either in the absorber section or in the outlet duct area. The severity of the environment for mist eliminators falls between that of the absorber and outlet duct. Therefore, while experience in the absorbers and outlet duct can help establish limits in terms of the alloy requirements, the experience may not be directly applicable. Yet since alloy mist eliminators are usually expected to last for decades, it is essential that the selected alloy be able to withstand the chemical environment, including process excursions, without experiencing any corrosion.

When adequate time is available, a good approach for evaluating corrosion resistance of an alloy is to install an alloy test panel in the mist eliminator section for a 6 month to 1-year period. Any evidence of corrosion found after the test period should be considered an indication that the alloy is not satisfactory for the application. (A small sample of the alloy should be saved - not exposed to the scrubber - to provide a basis for comparison with the test panel).

If there is not time for evaluation of a test panel, then an alloy can be selected based on scrubber pH and chloride levels. Guidance on alloy selection is provided in Appendix A.

Fire Retardant Properties

Fires in the mist eliminators are not a concern during normal operation, but they can be a serious concern during an outage, especially if welding or cutting is to be done in the vicinity of the mist eliminators. While plastics typically do not ignite as easily as cellulose based materials (such as wood), their behavior once ignited poses a number of significant concerns. These include vigorous burning and rapid flame spread, large quantities of smoke generated, production of toxic gases, and production of flaming drips. There are a number of standard tests which can be used to evaluate the behavior of materials in fires. Unfortunately, small-scale tests do not accurately predict the behavior of plastics under actual fire conditions. Even larger scale tests, such as the Steiner Tunnel Test, do not accurately predict the burning characteristics of plastics under all conditions. (Further information regarding the behavior of plastics in fires and the applicability of test results to actual behavior in fires can be found in the National Fire Protection Association's (NFPA's) Fire Protection Handbook).

Although standard tests cannot predict behavior under actual fire conditions, they do provide a sense of the wide range of flammability/flame retardant properties of the various plastics used in mist eliminators. A test commonly referenced is the Steiner Tunnel Test [also known as ASTM E-84, NFPA 255, and Underwriters Laboratory (UL) 723]. This is a relatively large-scale test which measures the relative rate at which a flame spreads across the surface of the material. The result of this test is a number called the flame spread (FS) index; reference values for flame spread are asbestos-cement (FS=0) and red oak (FS=100). Flame retardant plastics are available with FS< 25, while non-flame retardant plastics may have flame spreads exceeding 300. To help further put this in perspective, one plastics supplier has indicated that the industry standard practice for ducts, hoods, and other fume handling equipment limits the flame spread rating to less than 25.

Mist eliminator vendors can improve the fire retardant properties of mist eliminator materials through the use of additives; they generally can meet flame-spread limits requested by the customer. Some vendors prefer not to use these additives as their experience has shown that these additives can detract from the impact and corrosion resistance of the material. Other vendors report that they generally add fire retardant additives to their mist eliminators, even when not specifically requested, since the additives are relatively inexpensive. (Polypropylene is an exception; fire retardant polypropylene is typically 30% to 50% more expensive than regular polypropylene, and is not offered by all vendors). Vendors report that specific flame spread requirements in utility mist eliminator specifications are still relatively uncommon.

As mentioned earlier, no standard test can accurately predict the behavior of plastics under full-scale fire conditions. Determining whether or not the flame-retardant properties of the mist eliminator are satisfactory is a matter of individual testing and evaluation. In a similar situation, a utility evaluated their tower packing plastic materials options by setting fire to test specimens.

Installation and Structural Properties

Span Length

Mist eliminators are generally fabricated in custom lengths to meet the customer's requirements. Typical unsupported maximum spans available from the mist eliminator vendors are indicated below; longer spans can often be accommodated by the use of secondary supports. (The cost and effect on performance of any required secondary supports should be included as a separate line item in the bid). In replacement applications, existing supports are virtually always close enough together that span length is not a deciding factor.

Polypropylene - up to 5 feet (1.5 meters)
FRP - up to 8 feet (2.4 meters)
Advance thermoplastics - up to 8 feet (2.4 meters)
Alloys - up to 8 feet (2.4 meters)

Factors other than allowable span length generally control the maximum size that can be used for a particular application. Limitations in access (such as manways or elevators) or live load requirements can limit the size of the individual assemblies to sizes smaller than those indicated above. The practical limitation on span length differs for each plant; the utility engineer should consider any factors which may restrict the maximum allowable panel size and make this information known to bidders.

Assembly Weight

"Assembly weight" refers to the weight of the mist eliminator panel (plugged or unplugged), not to the amount of weight it can support (as in someone walking on the mist eliminator). The amount of weight a mist eliminator can support is addressed under the subheading "Load bearing capacity".

A common request of utilities is that the mist eliminator assembly can be lifted by hand when fully plugged. Although utilities often try to include this requirement, vendors generally take exception to the requirement, because it is often difficult or impossible to meet.

Consider the following example. A rough estimate of the density of solids plugging a mist eliminator is 120 lb/cubic foot (1.9 g/cm^3). Thus, for a mist eliminator panel that is 2' x 4' x 6" (0.6 x 1.2 x 0.15 meters), the fully plugged weight of the assembly would be approximately 480 lb (218 kg). Restricting the plugged weight to an amount that could be lifted by hand would therefore require unrealistically small mist eliminator assemblies. Plugged assembly weight restrictions are therefore not recommended.

Structural Support/Wash Systems

Since mist eliminators are generally custom made to fit the existing tower and support structures, replacement of the support structure is not typically required. The main reason for avoiding changes to the support structures is cost: costs for replacing the supports could equal or exceed the costs for the mist eliminators themselves. Some vendors have reported that secondary supports may be required in some instances; however, these secondary supports usually represent a fairly minor added expense (i.e. 10% or less of the cost of the mist eliminator).

Instances do exist when changes to the structural supports are required. Because of the substantial expense involved, this usually only occurs when the existing mist eliminator configuration is unable to meet required performance specifications (such as allowing unacceptable amounts of carryover). Revisions to the wash systems are likely to be required in these instances as well. Vendors will typically provide the general layout design of both the structures and wash systems in these cases.

Load Bearing Capacity

Load bearing capacity refers to the amount of weight that a mist eliminator can support, not the weight of the mist eliminator panel itself. The weight of the mist eliminator panel itself is addressed under the subheading "Assembly weight".

With one exception, vendors do not recommend walking on the mist eliminators. Planking is generally recommended; the more conservative of the vendors recommend that the planking span two structural supports.

Many utilities will specify a load that the mist eliminator must be capable of supporting. Requirements are specified either as ability to support a concentrated load (typically 300 to 600 lb, or 136 to 273 kg) at mid-span, or a live load capacity ranging from 100 lb/square foot to 300 lb/square foot (490 to 1470 kg/m^2) when scaled. Utilities usually develop these requirements based on one (or possibly two) men carrying toolboxes standing at mid-span on the mist eliminator. The tradeoff for specifying higher load bearing capacities is cost: mist eliminators that can support more load generally require more material or possibly more supports and are correspondingly more expensive.

Plugging and Scaling Resistance

Plugging/scaling is one of the more common reasons that mist eliminators must be replaced. The primary factors that affect mist eliminator plugging and scaling, however, are unrelated to the mist eliminator itself. Utilities with significant scaling problems are encouraged to refer to the "FGD Mist Eliminator Troubleshooting Manual" prepared in 1990 (EPRI GS-6984). This manual can provide guidance on how to identify and correct most mist eliminator scaling problems.

Even though mist eliminator design has only a secondary effect related to plugging and scaling, some general tendencies have been observed over the years. These general observations follow:

> Mist eliminators with many passes (i.e. three or more) tend to be more difficult to keep clean as compared with those that have fewer passes. This appears to result from inadequate washing of the internal areas of the mist eliminators with multiple passes.
>
> Mist eliminators with many "nooks and crannies" tend to scale more quickly than those that are smooth. The "nooks and crannies" seem to provide locations for scaling to start; scaling/pluggage can then spread to other areas of the mist eliminator.
>
> Mist eliminators with hard, glossy surfaces (such as many of the thermoplastics) tend to resist scaling and plugging better than those with flat or porous surfaces (such as many FRP laminates).

It is important to remember that these general tendencies are only secondary effects. If the FGD system has an inadequate wash system or scrubber chemistry problems, the mist eliminator will have a high likelihood of plugging/scaling regardless of the design or material of construction. Problems with scrubber chemistry or mist eliminator wash systems should be addressed first before considering mist eliminator replacement alternatives.

Relative Costs

The relative costs of mist eliminators constructed of various materials are provided below. These rough estimates of cost and are based on the cost of polypropylene = 1. It should be noted that while plastics costs are relatively stable, alloy costs can vary dramatically based on metals markets. These relative costs reflect the current cost of the constructed mist eliminators.

Polypropylene	1.0
Fire retardant polypropylene	1.3 to 1.5
FRP	1.4 to 2.5
Polysulfone	2.0 to 2.5
Other engineering plastics (Noryl, Ultem, etc.)	1.5 to 2.0
Stainless Steel (316, 317L)	1.5 to 3.2*

* Note: the price for alloys (including stainless) can vary dramatically depending on metals markets. Higher alloys (e.g., Hastelloy, Inconel, etc.) may be substantially more expensive.

Polypropylene is one of the more common materials of construction, largely because it usually provides satisfactory resistance to chemical and mechanical damage at a favorable price. The primary reason that engineered plastics are not more commonly used is price. Some utilities have, however, been able to justify the increased cost based on the predicted durability of these materials, although there are currently no comparative data which indicate under what conditions this would be true.

As with any utility plant, price, total cost and evaluation factors are site specific and subject to variable situations. Ultimately, each utility will use their own criteria to select their individual replacement FGD mist eliminator system.

Conclusion

This guide is intended to complement existing mist eliminator reference materials. Combined with the experience gained in operating a mist eliminator system, the guide should help utilities select the best replacement mist eliminator for their specific application.

4

GLOSSARY

ASTM C-581 - The ASTM method compares the properties of a test coupon before and after exposure to the chemical environment. Properties that are evaluated include flexural strength, flexural modulus, Barcol hardness and appearance. For flexural strength and modulus tests, results are reported as percent retention of these properties after exposure to the chemical environment. The "appearance" portion of the test documents any changes in appearance; generally these changes are indicative of some form of chemical attack. The ASTM method is written specifically for thermosets (i.e. the properties measured in the test are almost always important in thermoset applications). It should be noted that Barcol hardness, often used to verify that a thermoset has cured properly, may not be a useful indicator of thermoplastic performance.

Engineered Thermoplastic - Engineered thermoplastics are a group of thermoplastics which generally have improved strength, impact resistance, temperature resistance, and chemical resistance characteristics as compared to *commodity thermoplastics* (which includes polypropylene) and *intermediate thermoplastics* (which are not used in mist eliminator construction). Polysulfone, Ryton, Noryl, Kynar, and Ultem are all considered engineering thermoplastics. A fourth group, called *advanced thermoplastics*, has properties which generally exceed those of engineered thermoplastics, although advanced thermoplastics have not been used in mist eliminator construction.

Flexural Strength - The maximum stress (at the point of breakage) in the outer fibers of a sample under flexural load. This is determined by resting a sample on two supports and subjecting it to a load at the center of the span between the two supports. Flexural strength is the stress in the outer fibers at the point the sample breaks. Flexural strength is reported in units of psi.

Flexural Modulus - Flexural modulus is the ratio of stress (psi) to strain (in/in) of a sample subject to flexural load (see test description in flexural strength definition above). The stress and strain are determined by the load applied to the sample and the deflection of the sample. The flexural modulus is determined at the steepest straight-line portion of the load/deflection curve. (The steepest straight-line portion of the load/deflection curve will fall within the elastic limit of the material, not at the point of breakage). Basically speaking, flexural modulus is a measure of stiffness.

Thermoplastic - A plastic that can be softened by heating and hardened by cooling. Polypropylene, Noryl, Ultem, Ryton, and polysulfone are examples of thermoplastics. Thermoplastics may be filled with materials such as glass, talc, or other fillers to improve the properties of the plastic or reduce the amount of resin used in forming the plastic.

Thermoset - A plastic that, after having been cured, will not melt. Thermosets include the materials typically thought of as fiberglass reinforced plastics (FRP). Some vendors prefer to use the term reinforced thermoset plastic (RTP) to describe these materials to avoid any confusion with the thermoplastics.

5

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A

SELECTION OF ALLOYS FOR MIST ELIMINATOR SERVICE

The mist eliminators act as the separator between the absorber spray zone and the outlet duct. Below the mist eliminators, the absorber surfaces are continuously washed with slurry, which provides a constant source of alkalinity and maintains the pH. Beyond the mist eliminators, duct wall surfaces remain moist but there is no significant refreshment of alkalinity. Residual acid gases in the outlet duct continue to be absorbed, lowering the pH of the moisture film on the duct walls, making the outlet duct moderately more corrosive than the spray zone. If raw, hot flue gas is mixed with the treated flue gas, extremely corrosive conditions are created where the gases mix. Even the most corrosion resistant alloys, C-class alloys[2] and titanium, have occasionally experienced severe corrosion in such direct-bypass mixing zones. However, even in systems without direct bypass reheat, there has been a trend over time of upgrading alloy ducts to C-class alloys, often by retrofitting alloy wallpaper lining.

The service conditions of the mist eliminators are intermediate between those of the spray zone and those of the outlet duct. Some refreshment of alkalinity probably occurs on some surfaces but not on others. Mist eliminators are made of thin sheet material and can tolerate less corrosion than vessel walls, and roughening by corrosion can seriously impair performance. Because of the environment, mist eliminators are prone to scaling, and conditions under scales are more corrosive than on unscaled surfaces. (This is because electrochemical differences between the exposed metal and the environment under the scale - where oxygen is quickly depleted - cause chlorides to migrate to the area under the scale. The combination of reduced oxygen and increased chlorides result in more corrosive conditions towards stainless steels and nickel based alloys).

The alloys that have commonly been used in FGD mist eliminators are austenitic stainless steels and nickel-based alloys containing chromium and molybdenum. They owe their corrosion resistance to the spontaneous formation and regeneration of an extremely thin (few nanometers) passivation film which acts as a kinetic barrier to

[2] C-class alloys include Alloy C-276 and C-22, Haynes C-2000, VDM Alloy 59, and INCO Alloys 622 and 686.

further corrosion. As long as this film remains intact, the corrosion of the alloy will be negligible, and properly selected alloy mist eliminators can probably last for the design life of the plant. However, if the passivation film breaks down, then severe and rapid pitting and/or crevice corrosion may occur, destroying the alloy mist eliminators in a short period of time.

Thus the austenitic stainless steels and chromium-molybdenum-nickel-base alloys rarely exhibit mediocre performance. They perform very well up to the limits of their corrosion resistance, but very poorly beyond these limits. Unfortunately, clear guidelines for selection of alloys for FGD applications are lacking, and specification of alloys for FGD mist eliminators is left to the purchaser.

The primary factors which dictate the stability of the passivation film in FGD service are:

- Composition of the alloy, particularly the concentrations of chromium, molybdenum, tungsten, and nitrogen;
- Chloride concentration and pH of the liquids contacting the alloy;
- Temperature; and
- Mechanical crevices or scale deposits.

A minimum of 12% chromium is required to form passivation films on stainless steels, and all of the alloys currently used for FGD mist eliminators contain at least 15% chromium. Additions of molybdenum and nitrogen result in much more robust passivation films. Tungsten is added to a few of the nickel-based alloys primarily for metallurgical reasons, but also contributes to the robustness of the passivation film. Naturally, increasing chromium, molybdenum, and tungsten also increases the cost of the alloy.

Different lots of the same alloy have different compositions within set limits, so different lots will have slightly different passivation properties. In addition, variations of minor constituents in the FGD slurry, for example dissolved iron and copper, can cause significant variations in behavior. However, if enough experiences are examined, it becomes apparent that each alloy has a pH- and temperature-dependent chloride limit below which significant pitting or crevice corrosion is not likely to occur. Some

GENESIS OF THE CHLORIDE LIMIT DIAGRAM (Figure A-1)

The chloride limits shown in Figure A-1 are based on the published works of Michels and Hoxie [1978], Schillmoller and Kohlert [1982], and Sorell and Schillmoller [1990]. Michels and Hoxie and Schillmoller and Kohlert independently defined the relationship between pH and threshold chloride concentration for austenitic stainless steels. Schillmoller and Kohlert published a pH-Chloride limit diagram for a small number of stainless steels in FGD service. By 1990, Sorell and Schillmoller had expanded this diagram to include a number of more highly alloyed austenitic stainless steels and several nickel-base alloys, including Alloy C-276. Sorell and Schillmoller also related the chloride limits in their diagram to the Pitting Resistance Equivalent (PRE) of the alloys, defined as PRE = %Cr + 3.3(%Mo), providing a link between alloy composition and corrosion resistance.

In 1996, Schillmoller explained that the diagram was intended to provide guidance for pH-chloride limits of tightly creviced (or heavily scaled) components. Schillmoller also indicated that the chloride limits expressed by the diagram included a 30% safety factor. Based on FGD industry experience, the Sorell-Schillmoller diagram appears quite conservative for most FGD applications even without this 30% safety factor.

In the generation of Figure A-1, pH dependent chloride limits extracted from the Sorell-Schillmoller diagram were increased by 30%. To allow incorporation of alloys not included by Sorell and Schillmoller, modified PRE values, defined as PRE_{mod} = %Cr + 3.3(%Mo) + 1.15(%W) + 16(%N) were assigned to the alloy limit lines in the Sorell-Schillmoller diagram. These values of PRE_{mod} were based on typical compositions of the alloy, i.e., with alloying element concentrations toward the low ends of the specified ranges. The chloride limits for alloys not addressed by Sorell and Schillmoller were then interpolated.

In Figure A-1, the pH which is listed is the pH in the absorber slurry. Though the pH at the mist eliminator will typically be lower than in the absorber slurry, Figure A-1 is should be sufficiently conservative to account for the lower pH.

H.T. Michels and E.C. Hoxie, 1978, "How to Rate Alloys for SO_2 Scrubbers," Chemical Engineering, 5 June, p161ff.

C.M. Schillmoller and G. Kohlert, 1982, "Aspects of Alloy Selection for Flue Gas Desulfurization Scrubber Systems," ACHEMA 82, Frankfort am Main, 9 June.

G. Sorrel and C.M. Schillmoller, 1990, "High Performance Alloy Applications for Waste Incineration Air Pollution Control Equipment," paper 19, Proceedings of the Sixth International Seminar: Solving Problems in air Pollution Control Equipment Louisville, KY, 17-19 October.

C.M. Schillmoller, 1996, personal communications with Peter Ellis, Radian International LLC.

successes will be observed at considerably higher chloride concentrations, but the probability of severe corrosion also increases.

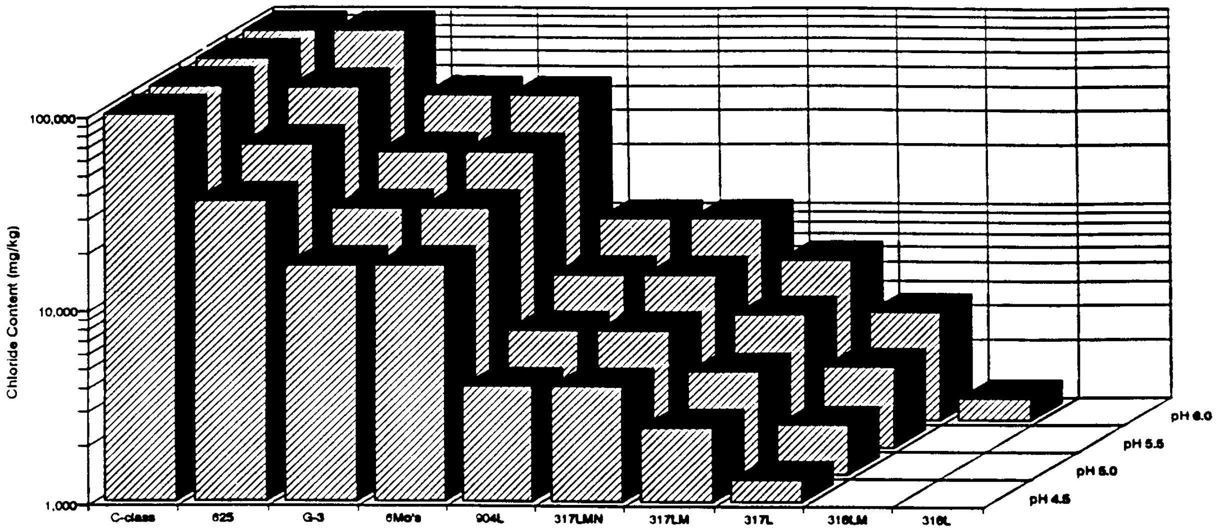
Figure A-1 provides the best current guidance for selection of alloys for FGD mist eliminator service. The derivation of this figure is discussed in the sidebar. This figure is conservative in that it assumes an objective of no corrosion under scale deposits or at tight mechanical crevices that can be expected in alloy mist eliminators. However, this figure should be considered only as general guidance. The specifier should consider carefully prior experience with alloys in the FGD system for which alloy mist eliminators are being specified.

Figure A-1 clearly demonstrates the decrease in chloride tolerance with decreasing pH. This figure indicates that there are probably few FGD systems today in which Type 316L or Type 316LM stainless steel would be expected to provide long-term mist eliminator service. Nonaustenitic stainless steels, i.e., 400-series stainless steels, should not be specified for FGD mist eliminator applications. Most of the 400-series stainless steels have less resistance to chlorides than Type 316L stainless steel, and few have chloride resistance comparable to Type 317L.

The workhorse stainless steels for current FGD applications are Type 317LM, Type 317LMN, and Alloy 904L, as well as a number of European and Japanese analogs all containing between 4 and 5% molybdenum. For mist eliminator applications, these alloys should probably be restricted to systems having only a few thousands of ppm chloride.

The 6% molybdenum superaustenitic stainless steels are iron-based analogs of Alloy G-3. They have become of increasing interest in the last decade, but experience in FGD applications is limited. All of these alloys contain 6-7% molybdenum, and many also contain nitrogen. Examples include Alloys 6XN, 20Mo-6, 1925hMo, UR SB8, and 254 SMO. For mist eliminator applications, these alloys may be suitable up to about 20,000 ppm chloride.

The C-class alloys should all be suitable for mist eliminator service up to at least 100,000 ppm chloride. Alloys 625 and H-9M have slightly lower chloride resistance limits than the C-class alloys but cost about the same. Selection of these alloys over C-class alloys will generally be based on formability concerns, not cost or corrosion resistance.



Limiting Chloride Concentration (mg/kg)

	316L	316LM	317L	317LM	317LM N904L	6Mo-Super-ustenitics, Alloy G-3	625, H-9M	C-class (C-276, C-22, 59, 622, 686)
pH 6.0	<1,000	1,300	3,600	6,700	10,900	46,000	100,000	100,000
pH 5.5	<1,000	<1,000	2,600	4,800	7,700	32,900	70,800	100,000
pH 5.0	<1,000	<1,000	1,800	3,400	5,500	23,300	50,100	100,000
pH 4.5	<1,000	<1,000	1,300	2,400	3,900	16,500	35,500	100,000

Significant corrosion of thin-walled, heavily scaled or tightly creviced components, such as alloy mist eliminators, is unlikely at bulk chloride concentrations below the indicated levels.

Figure A-1
Conservative Chloride Limits for Alloy Mist Eliminators in FGD Service