AN ENVIRONMENTAL EVALUATION OF ACID SCRUBBERS
Building 628, McClellan AFB CA

By

Jerry W. Jackson, Capt, USAF, BSC
William E. Normington, Capt, USAF

August 1975

Approved for public release; distribution unlimited.
USAF ENVIRONMENTAL HEALTH LABORATORY
McCLELLAN AFB, CA. 95652
# An Environmental Evaluation of Acid Scrubbers; Building 628, McClellan AFB CA

## Authors
- Jerry W. Jackson
- William E. Normington

## Performing Organization Name and Address
USAFA Environmental Health Laboratory/CC
McClellan AFB CA 95652

## Control Office Name and Address
USAFA Environmental Health Laboratory/CC
McClellan AFB CA 95652

## Number of Pages
36

## Distribution Statement
Approved for public release; distribution unlimited.

## Key Words
- Acid scrubbers
- Perchloric acid
- Air pollution
- Hydrochloric acid
- Nitric acid

## Abstract
An environmental evaluation was conducted of an operation in which nitric, perchloric, and hydrochloric acid vapors and aerosols are generated. The evaluation was requested to determine why a visible white plume existed at the exhaust of a wet scrubber. The white plume was formed regardless of meteorological conditions when acid vapors and aerosols were generated. The evaluation included a scrubber efficiency study, an environmental assessment and an air pollution regulation compliance test.
AN ENVIRONMENTAL EVALUATION OF ACID SCRUBBERS
Building 628, McClellan AFB CA

Prof. Report No 75M-11
(Project No AAF-460)

August 1975

Prepared by:

HARRY W. JACKSON
Capt., USAF, BSC
Chief, Special Projects Branch

WILLIAM E. NORMINGTON
Capt., USAF
Special Projects Branch

Reviewed by:

JOHN J. GOKELMAN
Major, USAF, BSC
Chief, Environmental Protection
Engineering Division

Approved by:

DONALD D. HIGGINS
Lt Col, USAF, BSC
Commander

Approved for public release; distribution unlimited.
NOTICE

This report has been prepared by the Air Force for the purpose of aiding study and research. It is not to be used for promotional or advertising purposes and does not constitute an endorsement of any product. The views expressed herein are those of the author/reviewer and do not necessarily reflect the official views of the publishing agency, the United States Air Force or the Department of Defense.
ABSTRACT

An environmental evaluation was conducted of an operation in which nitric, perchloric and hydrochloric acid vapors and aerosols are generated. The evaluation was requested to determine why a visible white plume existed at the exhaust of a wet scrubber. The white plume was formed regardless of meteorological conditions when acid vapors and aerosols were generated. The evaluation included a scrubber efficiency study, an environmental assessment and an air pollution regulation compliance test.
# DISTRIBUTION LIST

<table>
<thead>
<tr>
<th>Distribution</th>
<th>No of Copies</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALC/DEE, McClellan AFB CA 95652</td>
<td>2</td>
</tr>
<tr>
<td>1155th TOS, McClellan AFB CA 95652</td>
<td>2</td>
</tr>
<tr>
<td>AFLC/SG, Wright-Patterson AFB OH 45433</td>
<td>3</td>
</tr>
<tr>
<td>AFLC/SGB, Wright-Patterson AFB OH 45433</td>
<td>3</td>
</tr>
<tr>
<td>HQ USAF/SGPA, Washington DC 20314</td>
<td>1</td>
</tr>
<tr>
<td>HQ US 20330</td>
<td>1</td>
</tr>
<tr>
<td>USAFEHL/CC, Kelly AFB TX 78241</td>
<td>1</td>
</tr>
<tr>
<td>AFWL/SUL, Kirtland AFB NM 87117</td>
<td>1</td>
</tr>
<tr>
<td>AFWL/DEE, Kirtland AFB NM 87117</td>
<td>1</td>
</tr>
<tr>
<td>IMSEW/SGB, APO San Francisco 96274</td>
<td>1</td>
</tr>
<tr>
<td>AFCEC/EQ, Tyndall AFB FL 32401</td>
<td>3</td>
</tr>
</tbody>
</table>
TABLE OF CONTENTS

1. Introduction................................................................. 1
2. Process Description......................................................... 1
3. Scrubber Description....................................................... 2
4. Scrubber Efficiency....................................................... 2
5. Discussion
   a. Environmental Nuisance or Annoyance................................. 6
   b. Environmental Injury or Detriment................................... 6
   c. Violation of Emission Standards................................... 6
6. Conclusions............................................................... 7
7. Recommendations.......................................................... 8
8. Apparatus and Materials................................................ 8
9. Procedures............................................................... 10
10. Data and Discussion...................................................... 11

REFERENCES.............................................................. 17

TABLES

I AAF COLAG Mist, Vapor & Fume Collector Efficiency.................. 13
II Acid Mass Balance............................................................ 14
III Moisture Characteristics of Exhaust.................................. 15
IV Impinger Acid Content...................................................... 16

FIGURES

1 AAF COLAG Scrubber.......................................................... 3
2 Scrubber Arrangement...................................................... 4
3 Sampling Train for Acids.................................................. 9

APPENDIX

I AAF Wet Dust and Fume Collectors........................................ 18
1. Introduction:

Laboratory procedures, conducted by the 1155th Technical Operations Squadron in Building 628, McClellan AFB, generate acid vapors and aerosols in sufficient quantity to require their control prior to release of the exhaust to the outside atmosphere. Control equipment (wet scrubbers) presently in place does not remove all of the acid vapors and aerosols. A white plume formed in the fume hood remains visible in the scrubber's exhaust gas. The white plume is visible regardless of atmospheric conditions and is characteristic of acid plumes (Ref. 1). The plume is not formed when only room air is being scrubbed.

DEE, McClellan AFB, through AFLC/SGB, requested USAFEHL-M to conduct a study to determine, (a) collection efficiency of the present control equipment, (b) the nature and quantity of pollution being released to the atmosphere, and (c) the need for additional control and how it can be obtained.

2. Process Description:

Acid vapors and aerosols are generated during a laboratory procedure in which a cellulose material ($C_6H_{11}O_5$) is digested with acid. Nitric acid (90% HNO$_3$), perchloric acid (70% HClO$_4$) and the cellulose material are combined in a beaker and the mixture is brought to a boil. The mixture boils at $120^\circ$C until the excess HNO$_3$ is evaporated and then boils at $200^\circ$C until the HClO$_4$ is evaporated. Hydrochloric acid (37% HCl) is added to the dry beaker and boiled at $140^\circ$C to dryness. The HCl procedure is repeated three times.

Chemical reactions during cellulose digestion are: (Ref. 2).

a. $6\text{HNO}_3 + (\text{C}_6\text{H}_{11}\text{O}_5)_{12} \xrightarrow{\Delta} \text{C}_{12}\text{H}_{14}(\text{ONO}_2)^6 \text{O}_4 + 6\text{H}_2\text{O}$

b. $6\text{HClO}_4 + \text{C}_{12}\text{H}_{14}(\text{ONO}_2)^6 \text{O}_4 \xrightarrow{\Delta} 12\text{CO}_2 + 6\text{HNO}_3 + 6\text{HCl} + 4\text{H}_2\text{O}$

c. $2\text{HCl} + \text{Residue} \xrightarrow{\Delta} 2\text{HCl} + \text{Negligible Products}$

The mass (volume) of digestion products generated by the chemical reactions is small compared to the acid vapors and aerosols generated since only 60 to 100 grams of cellulose are digested. The major contaminants are the acid vapors and aerosols. Less than 2.5% of the acids are decomposed to other products such as NO$_x$ and Cl (Ref. 2). The maximum acid vapor and aerosol mass loadings to each scrubber are: (a) 204
gms/min HNO₃, (b) 104 gms/min HClO₄ and 192 gms/min HCl. These mass loadings occur very infrequently. The digestion procedure itself occurs infrequently, less than 2 hours per week on the average (Ref. 3).

3. Scrubber Description:

Two different makes of scrubbers are presently in place (19 scrubbers). Fourteen scrubbers are old, worn out, and must be replaced. The remaining five scrubbers are relatively new and can be maintained. Only the newer scrubber make was evaluated.

The newer scrubber is manufactured by the American Air Filter Company, Inc. (AAF). The equipment is identified by the acronym COLAG meaning Contact of Liquid and Gas. AAF's catalog which describes this unit is included as Appendix I. The scrubber consists of a stack of three size 35 stages (Figure 1). Air enters each stage from below and is distributed by a perforated plate. Water supplied to the plate is entrained upward to a reaction pad. Liquid droplets which pass through the pad are trapped by sloped eliminator pads and flow to drainage channels, then out of the unit. Each scrubber serves two fume hoods (Figure 2). The mass loadings given above are for both hoods in operation.

The unit is designed to operate at 1900 to 3500 CFM air flow, 0.37 GPM water flow per stage and 4 to 13 inches of water gauge static pressure (Ref. 4). The unit when tested was operating at 2042 CFM air flow and 0.85 GPM water flow per stage. Static pressure could not be measured without damaging the unit.

4. Scrubber Efficiency:

Collection efficiencies were determined for nitric and perchloric acid vapor/aerosol under normal operating conditions. Collection efficiencies were 74 and 75% respectively for nitric acid loadings of 68.8 and 189.9 gms/min and 61% for a perchloric acid loading of 40.6 gms/min. The last loadings were chosen to best represent the normal operation.

5. Discussion

Thermally produced nitric acid aerosol in this situation has a mass median diameter (MMD) of 1.0 micrometer (μm) (Ref. 5). No reference could be found for perchloric and hydrochloric acid aerosol produced thermally.
Figure 2: Scrubber Arrangement, Bldg 628, McClellan AFB CA
Cleaning air that is contaminated with particles having a 1 \( \mu m \) MMD is very difficult, especially with low energy scrubbers such as the one under question. Ellison (Ref. 6) studied eight types of wet scrubbers and found collection efficiencies ranging from 42 to 80\% for 1 \( \mu m \) particles in low energy scrubbers. High energy scrubbers, venturi and wet dynamic, had much higher efficiencies (91 to 98\%) for 1 \( \mu m \) particles.

The AAF COLAG unit is a low energy scrubber but one of the best in the category. It has many characteristics similar to a flooded bed scrubber for which Ellison found a maximum collection efficiency of 80\% for 1 \( \mu m \) particles. Our collection efficiency tests show that the COLAG unit is functioning as well as can be expected for this particular application. AAF's catalog (page 9) shows an expected collection efficiency of 78\% for 1 \( \mu m \) particles and one stage.

Collection efficiency for the acid vapor/aerosol can be improved significantly, but it will require a high energy wet scrubber, of which many types are available, or electrostatic precipitation.

Types of wet scrubbers commonly used for this type operation are: (a) venturi, (b) wet dynamic, (c) packed tower and (d) wet fabric filtration (Ref. 2).

Electrostatic precipitation requires a high initial capital expenditure and intensive maintenance, especially in an acid environment. This method of control is not indicated for this small size operation.

Another approach commonly used in aerosol collection is physical growth of the aerosol to a much larger size and then collection by conventional low energy wet scrubbing. The method of aerosol growth depends on particle properties. In the case of hygroscopic acid particles, growth can be accomplished by humidification. As noted later in the report aerosol growth appeared to be occurring in the COLAG unit by humidification, but sufficient growth did not occur to improve collection efficiency. The second and third stages were added probably to effect particle growth and increased efficiency.

In addressing the question of whether additional collection efficiency is needed, three aspects were considered: (a) environmental nuisance or annoyance (b) environmental injury or detriment and (c) violation of air quality rules and regulations.
a. Environmental Nuisance or Annoyance:

No complaints of nuisance or annoyance have been registered against this operation since the present scrubbers have been installed (Ref. 7). In addition to the visible plume, other properties (in the absence of environmental injury) of the scrubber exhaust that would cause a nuisance or annoyance would be smell and/or mucous membrane irritation to exposed individuals. The exhaust is released ~40 feet above ground level and the area around Building 628 is parking space. The exhaust is diluted many times before it reaches any occupied area or an area where persons spend more than a few minutes in any given day. An estimate of the actual dilution at the closest location for exposure is impossible. One approach is to calculate the maximum expected acid concentration in the scrubber exhaust and determine the dilution required to lower the concentration to an acceptable level. Using 75% collection efficiency for HNO₃ and HCl (assumed) and 61% for HClO₄, and using the maximum loadings to the scrubber, the exhaust would contain ~2400 mg/M³ at the stack. As a reference point, the allowable exposure of workers to nitric acid vapor/aerosol is 10 mg/M³ for 15 minutes and 5 mg/M³ for an 8 hour/day exposure (Ref. 8). A dilution of 240 to 1 would lower the concentration to an acceptable level for 15 minutes of worker exposure. A dilution factor of 240 occurs rapidly in a turbulent atmosphere. Another approach is to estimate ground level concentration during stable (minimal turbulence) atmospheric conditions. Using a stack height of 12.2 meters, an acid mass flow of 2.39 gms/sec, F stability (lowest diffusion) and a wind speed 4 meters/second the maximum ground level concentration (470 meters downwind of the stack) is calculated to be ~0.4 to 0.5 mg/M³, a concentration well below the acceptable 8 hour per day exposure for workers.

b. Environmental Injury or Detriment:

The area surrounding Building 628 as well as the roof of the building was closely inspected for evidence of corrosion that might have been caused by acid emissions. No evidence was found even in the immediate area of the scrubbers. The scrubbers themselves showed signs of corrosion as would be expected but it was not excessive. No evidence of environmental injury or detriment was found in the area adjacent to the building.

c. Violation of Emission Standards:

An evaluation of the digestion procedure as it relates to Federal, State and Local emission regulations was conducted with assistance from the County of Sacramento Air Pollution Control District. They
stated that due to the type (laboratory) and intermittent nature of the operation the only State regulation that applied is the State of California Code 24242 which restricts plume opacity ... "A person shall not discharge into the atmosphere from any single source of emission whatsoever any air contaminant for a period or periods aggregating more than three minutes in any one hour which is: (a) as dark or darker in shade as that designated as No 2 on the Ringelmann Chart, as published by the US Bureau of Mines, or (b) of such opacity as to obscure an observer's view to a degree equal to or greater than does smoke described in subsection (a) of this section." The white plume was observed on five occasions during maximum activity. Plume opacity did not equal or exceed 40% (No 2 on the Ringelmann scale).

Further, the County of Sacramento as the enforcement agency for the State of California in the county has an "Exceptions" rule that applies to this activity. Rule 30, Air Pollution Control District Rules and Regulations states, ... "Exceptions. Provisions shall not apply to any activity which is for the purpose of investigation and

a. The Air Pollution Control Officer has granted a permit to conduct said activity, with conditions of said activity specified therein; and

b. The terms of said conditions are met; and

c. The Health Officer of Sacramento County has been consulted and has concurred with such permit and the conditions contained therein; and

d. Said activity does not result in violation of any ambient air quality standard set by the California Air Resources Board or the Federal Environmental Protection Agency."

The cellulose digestion procedure is an investigatory procedure that does come under the provisions of Rule 30 and the activity does not violate any ambient air quality standard.

6. Conclusions:

a. Collection efficiency of the AAF COLAG size 35 (75% for HNO₃ and 61% for HClO₄) is, for this application, as good as can be expected.

b. During the period of greatest activity, the scrubber exhaust
will contain ~ 2400 mg/M³ (2.39 gms/sec) acid vapors and aerosols. This emission will not last for more than an average of two hours per week.

c. Additional collection efficiency can be obtained but not with low energy wet scrubbers. High energy wet scrubbers (venturi, wet dynamic, wet fabric filtrations, etc.) must be used for improved efficiency.

d. Additional collection efficiency does not seem warranted from an environmental standpoint. No environmental damage or detriment is occurring, complaints of nuisance or annoyance have not been registered and the operation is investigative in nature and falls under the provisions of Rule 30, Exceptions. It is unlikely that a violation of air pollution regulations will occur.

7. Recommendations:

a. From an environmental standpoint, the AAF COLAG units should be maintained as is.

b. In the event that a violation of air pollution regulations does occur, a longer period of time should be used for the digestion procedure, thus decreasing the density of aerosol and consequently plume opacity. This procedure would not be considered illegal circumvention.

c. Specifications for replacement scrubbers should contain:

(1) A through discussion of the cellulose digestion procedure.

(2) A performance bond (installer or manufacturer) requirement.

(3) A pilot plant study requirement.

d. The Air Force should conduct acceptance tests.

e. This evaluation was not concerned with operating costs, maintenance problems, etc. The user (1155th TOS) and Civil Engineering should consider these aspects of the operation prior to any decision to replace them.

8. Apparatus and Materials:

Acids were absorbed in doubly distilled, deionized water. A series of four Greenburg-Smith impingers (Figure 3) was used. The first three impingers (fritted insert) each contained 250 ml of absorption
Figure 3: Sampling Train For Acid
medium (water). The last impinger contained silica gel to dry the sample before it entered the pump and dry gas meter. The volume flow rate was measured with a dry gas meter (with temperature sensor) calibrated to a wet test meter.

9. Procedures:

Ideally, acid mist (aerosol) should be sampled isokinetically from a representative cross-section of the stack, preferably according to the EPA Method 8 - Determination of Sulfuric Acid Mist and Sulfur Dioxide Emissions from Stationary Sources. In this particular case, the EPA Method 8 procedures could not be strictly adhered to without expensive modifications to the stack. Therefore, the procedures were modified, and to verify accuracy of data, a material balance of acid evaporated versus acid found in the scrubber water plus that found in the scrubber exhaust gases was performed.

One point sampling was conducted at 6 inches from the inside wall of the 20 inch diameter stack. Since the sampling point was located only one diameter above the fan, no attempt was made to sample isokinetically, instead the largest sample size possible was obtained. The sampling rate was generally 200 to 300% of isokinetic flow, based upon calculated stack velocity as explained later.

Each test consisted of two samples. One sample was taken when acid was being scrubbed and another identical sample was taken when only room air was being scrubbed (blank). The blank sample was used to obtain the background level of contaminants. The background level was subtracted from the sample to give the true level.

The solution in each impinger was analyzed individually. This was done to evaluate the possibility of bleeding (movement) of acid from one impinger to the next and/or the breakthrough of acid to and through the last impinger.

When nitric acid was sampled the impinger solution was analyzed for nitrate ($\text{NO}_3^-$) and nitrite ($\text{NO}_2^-$).

When perchloric acid was sampled the impinger solution was analyzed for perchlorates ($\text{ClO}_4^-$). Analysis was done by the specific ion electrode method.

Sampling was conducted for 20 minutes. The sampling rate ranged from 0.65 to 1 cubic foot per minute (CFM).
The volume of gas scrubbed could not be measured at the scrubber exhaust due to turbulence. Instead, the flow through one fume hood duct (Figure 2) was measured (six point pitot traverse) and the value multiplied by two. Both fume hoods and the connecting ducts were identical and the assumption that flows in each were equal seemed justified.

To establish a known acid vapor and aerosol concentration, acid was placed in beakers and boiled until a preselected volume of acid remained in the beakers. At this point, sampling was begun and continued for 20 minutes. At the end of sampling, the beakers were removed from the heat (they were near dryness) and the volumes of acid lost during sampling were measured. The volumes lost were converted to mass (specific gravity) and the mass was multiplied by the percentage of acid to arrive at the mass of acid lost. Since 90% nitric acid was used, the loss rate of nitric acid (gms/min) was greater in the early phase of boiling due to azeotrope formation at 70% acid/30% water. To avoid an excessive error in calculating the mass of acid loss, the beakers were boiled to near dryness so that 90% of the total mass lost was acid.

Scrubber water samples were taken each five minutes during sampling. Each individual stage could not be sampled, just the combined drainage from all three stages. It would have been interesting to test each stage for its efficiency. The scrubber water samples were analyzed in the same manner as the impinger solution. Blanks were taken as explained earlier.

Data and Discussion:

Collection efficiencies and scrubber operating parameters are presented in Table I. Collection efficiency for nitric acid did not change noticeably with an increase in loading of 300%. The lesser collection efficiency for perchloric acid was probably due to the formation of smaller particles upon cooling of the perchloric acid vapor. Perchloric acid, due to its higher boiler point, condenses more readily than nitric acid.

A mass balance is presented in Table II. The balance was used to verify accuracy of data and procedures. As the data indicate, anisokinetic sampling produced reasonably accurate results, probably because the particle size in the stack effluent had not grown sufficiently to have a significant inertial mass. Scrubber water samples were not taken during test 1, therefore a mass balance could not be
Moisture characteristics of the scrubber exhaust gases are presented in Table III. These data show that an increase in moisture content of the exhaust gases occurred when acid was scrubbed. This indicates that acid particle growth was occurring in the scrubber.

Individual impinger acid content is presented in Table IV. These data are included to show the efficiency of the sampling procedure. In tests 1 and 2, over 90% of the acid was collected in the first impinger. However, in test 3, just over 50% was collected in the first impinger. These data support the findings that water scrubbing in a low energy system is not as effective for perchloric acid as for nitric.
TABLE I
AAF COLAG MIST, VAPOR & FUME COLLECTOR EFFICIENCY FOR NITRIC (HNO₃) & PERCHLORIC (HClO₄) ACIDS

<table>
<thead>
<tr>
<th>Test</th>
<th>Acid</th>
<th>Collector Operating Parameters</th>
<th>Acid Load</th>
<th>Collector Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Water Usage £/min</td>
<td>Air Flow M³/min</td>
<td>Acid Loading+ gms/M³</td>
</tr>
<tr>
<td>1</td>
<td>HNO₃</td>
<td>9.6</td>
<td>57.79</td>
<td>1.19</td>
</tr>
<tr>
<td>2</td>
<td>HNO₃</td>
<td>9.3</td>
<td>57.79</td>
<td>3.29</td>
</tr>
<tr>
<td>3</td>
<td>HClO₄</td>
<td>9.3</td>
<td>57.79</td>
<td>0.70</td>
</tr>
</tbody>
</table>

* Nitric & perchloric acids were boiled off in beakers - no chemical reactions occurred. The acid loading was determined in two ways; (1) measuring the volume of acid lost in a given time and (2) sampling before the scrubber. These acid loadings represent the design information given to AAF. A mass balance of acid lost from beakers and acid collected by the scrubber water plus that penetrating the scrubber is presented in Table II.
<table>
<thead>
<tr>
<th>Test</th>
<th>Acid Lost gms/min</th>
<th>Acid Found gms/min</th>
<th>Ratio Found/Lost %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Scrubber Water</td>
<td>Exhaust</td>
</tr>
<tr>
<td>1</td>
<td>68.8</td>
<td>-</td>
<td>18.1</td>
</tr>
<tr>
<td>2</td>
<td>189.9</td>
<td>118.9</td>
<td>47.9</td>
</tr>
<tr>
<td>3</td>
<td>40.6</td>
<td>24.5</td>
<td>15.8</td>
</tr>
</tbody>
</table>
### TABLE III

**MOISTURE CHARACTERISTICS OF EXHAUST GASES**

AAF COLAG MIST, VAPOR & FUME COLLECTOR

<table>
<thead>
<tr>
<th>Test</th>
<th>Acid Load gms/min</th>
<th>Moisture Content of Exhaust Gas (%)</th>
<th>Increase+ %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Room Air Thru Collector</td>
<td>Acid Gas Thru Collector</td>
</tr>
<tr>
<td>1</td>
<td>68.8</td>
<td>Not measured++</td>
<td>1.9</td>
</tr>
<tr>
<td>2</td>
<td>189.9</td>
<td>1.4</td>
<td>2.4</td>
</tr>
<tr>
<td>3</td>
<td>40.6</td>
<td>0.7</td>
<td>1.7</td>
</tr>
</tbody>
</table>

* Total gain in impinger weight assumed to be water mass - acid mass constituted less than 5% of weight gain in all cases.

** During test 1 samples were taken simultaneously before and after the scrubber. The moisture content of the fume hood exhaust (prescrubber) was < 0.1%.  

### TABLE IV

**Impinger Acid Content**

**Sample Volume**

**Acid Load**

**AAF Colag Collector Efficiency Study**

<table>
<thead>
<tr>
<th>Test</th>
<th>Impinger Acid Content mg</th>
<th>Sample Volume Liters</th>
<th>Acid Load** mg/Liter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1-A**</td>
<td>1282.5</td>
<td>11.6</td>
<td>0.5</td>
</tr>
<tr>
<td>1-B**</td>
<td>184.1</td>
<td>6.8</td>
<td>0.5</td>
</tr>
<tr>
<td>2-A</td>
<td>396.0</td>
<td>33.8</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>2-B</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>3-A</td>
<td>10.4</td>
<td>6.1</td>
<td>5.5</td>
</tr>
<tr>
<td>3-B</td>
<td>71.9</td>
<td>26.9</td>
<td>17.3</td>
</tr>
</tbody>
</table>

* Includes probe rinse acid content.

** Tests done simultaneous pre and post-scrubber. Tests 1-B, 2-A and 3-B done post-scrubber during acid scrubbing. Tests 2-B and 3-A done when no acid vapor was being generated: for baseline data.

♦ Concentration in one duct - equal flow but no acid in the other duct. Acid concentration to scrubber = 1.19 mg/L.

** Out of scrubber except for 1-A. 1-A is load to scrubber.
REFERENCES


7. Mr Ray Theep, Personal Communications: Bioenvironmental Engineering Services, McClellan AFB, 10 July 1975.

8. The American Conference of Governmental Industrial Hygienists, Threshold Limit Values, 1974.

APPENDIX 1

AAF WET DUST AND FUME COLLECTORS
DUST CONTROL BULLETIN NO 304
AAF WET DUST AND FUME COLLECTORS

American Air Filter COMPANY, INC
215 Central Avenue, Louisville, Ky. 40208, U.S.A.
American Air Filter, a pioneer in the design and development of wet dust collectors, offers the largest and most flexible line of wet dust and fume collection equipment available today. From small nuisance dust problems to large process gas cleaning applications, AAF has the right collector for the job — whether the contaminant is dust, fume, mist, or vapor.

AAF wet collectors have earned a reputation for quality, durability, and dependability. Equally important is the technical "know-how" of AAF engineers. This ability — gained from over 15,000 wet dust collector installations — is not limited to the selection of proper equipment type; it embraces the entire field of dust control — the entrapment of dust at its source, transportation to the collector, removal of contaminant from the air stream, and disposal of collected material.

Wet dust collectors provide a comparatively simple, low-cost solution to many dust control and air pollution problems. Space requirements are generally less than for other collector types. Because equipment size is in relation to air cleaning capacity, most collectors can be shipped from the manufacturer completely assembled or in major sub-assemblies, simplifying installation and reducing erection costs.

Wet collectors are capable of cleaning hot, moist gases which are difficult or even impossible to handle with other collector types. Since solids are collected in a wetted form, secondary dust problems during material disposal are avoided. In addition, wet collectors are often able to eliminate or substantially reduce the hazards associated with the collection of explosive or highly flammable materials.

Wet collectors are commercially available in a wide variety of designs, shapes, and sizes. The collection principles employed are centrifugal force, impaction, and impingement, either separately or in combination.

Independent investigators studying wet collector performance have developed the Contact Power Theory, which states that for well-designed equipment, collection efficiency is a function of the energy consumed in the air to water contact process, and is independent of the collector design. On this basis, well-designed collectors operating at or near the same pressure drop can be expected to exhibit comparable performance.

All wet collectors have a fractional efficiency characteristic; that is, their cleaning efficiency varies directly with the size of the particle being collected. In general, collectors operating at a very low pressure loss will remove only medium to coarse-size particles. High efficiency collection of fine particles requires increased energy input, which will be reflected in higher collector pressure loss.

High-efficiency wet collection of sub-micron particulate, fume, and smoke has been made possible largely by the development of the high-energy venturi type collector. Venturi designs are now used on a large number of applications formerly limited to fabric or electrostatic collectors. In accordance with the Contact Power Theory, venturi type collectors require substantial energy input to achieve high collection efficiency on sub-micron particles.

Collector water requirements represent a continuing operating cost which must be evaluated when selecting specific equipment. When required water rates are high, substantial savings can usually be realized by using a recirculating water system. Such systems usually employ a settling tank or pond to separate the collected material by gravity. Since the water returned to the collector will invariably contain some solids, it is advantageous to choose a collector which does not require spray nozzles or other small water orifices.

Corrosive substances are often present in typical wet collector applications. Modern construction materials are capable of providing satisfactory protection against nearly all corrosive agents, but the chemical compounds present must be correctly anticipated and identified in order to make the proper material selection.

AAF engineers have the experience necessary to insure a satisfactory and successful wet collector installation. AAF can provide technical assistance in equipment selection, choosing proper materials of construction, design of recirculating water systems, or any other aspect of wet collector dust control.
For medium concentrations of fine particles

dynamic precipitator

The Type W Roto-Clone combines the scrubbing effect of water with the basic principle of dynamic precipitation — the result is a highly efficient, low-cost dust collector and air mover in one complete, shop-assembled package.

The Type W is used to collect light to medium concentrations of granular dusts, oil mists, and certain fumes. Because of its compact size and low water requirement, the Type W is often the equipment of choice when space is severely limited or water consumption must be kept to a minimum.

The Roto-Clone is designed to operate continuously at peak efficiency without interruption for reconditioning or servicing of any kind. It is ideally suited for processes requiring continuous ventilation and constant exhaust volume.

The Type W Roto-Clone is manufactured in twelve sizes with capacities ranging from 1,000 to 50,000 CFM. Water consumption is limited to the small amount required to maintain a flowing film on all collecting surfaces — normally ½ to 1 gpm per 1,000 CFM of air cleaned. The collected material is discharged in the form of a slurry. Since the Roto-Clone serves as both collector and air mover, it has no pressure drop as such. The energy input required to effect collection is reflected in a moderately lower blower efficiency.

Type W Roto-Clones can be fabricated of many materials, including stainless steels, monel, and aluminum. Corrosion resistant internal coatings are also available.

ADVANTAGES

- Compact — Basically no larger than a centrifugal exhauster, and as simple to install.
- Low Water Consumption — ½ to 1 gallon per 1,000 CFM of air cleaned on most applications.
- Versatile — Operating flexibility and compact size permit easy relocation to keep pace with changes in process or plant layout.
- Economical — Factory assembly reduces installation costs, low water requirement cuts operating cost.

REQUEST DUST CONTROL BULLETIN 274
For heavy loadings of all particle size

hydrostatic precipitator

The Type N Roto-Clone is a heavy-duty orifice type collector which has established an enviable reputation for rugged dependability.

The heart of the Type N is its unique stationary impeller, where air is cleaned by the combined action of centrifugal force and thorough intermixing of air and water. Cleaning action is induced by air flow, which creates a heavy, turbulent sheet of water that traps even very fine particles. Although the required supply water rate is very low, the quantity of water in motion is quite high - approximately 20 gallons per 1,000 CFM, all of which is continuously recirculated. Simplicity of both design and operation enable the Type N to handle the toughest dust control applications.

The Type N Roto-Clone is available in three basic hopper arrangements:

Arrangement B is a flat bottom design for manual removal of collected material. It is often used for the exhaust of buffing, polishing, and metalworking operations; fumes and vapors, and packaging, sorting, and weighing of chemicals and food products. It is frequently used to reclaim small to moderate quantities of valuable materials. Arrangement B is offered in eleven sizes for exhaust volumes of 750 to 32,000 CFM.

Arrangement C incorporates a drag-type sludge ejector for automatic removal of collected material. It is commonly used for abrasive cleaning and tumbling mill dust control, foundry sand systems, and for many dryer, cooler, kiln, and materials handling operations in the chemical, mining, and rock products industries. Arrangement C is available in fifteen sizes with capacity ratings ranging from 750 to 48,000 CFM.

Arrangement D utilizes a pyramidal hopper for continuous sluicing of collected material to a disposal point or back to process. Arrangement D is applied to kilns, dryers, and coolers in the chemical and rock products industries; to materials that can be periodically sluiced to process or to a disposal point; and to crushers, screens, and transfer points in the mining industry. Arrangement D can be furnished in eleven sizes for exhaust volumes of 750 to 32,000 CFM.

Collector pressure drop is 6" w.g. at nominal capacity, and varies only slightly with fluctuations in volume handled. Extra-heavy ¼" plate construction is available in sizes above 8,000 CFM capacity. Corrosion resistant interior construction, such as stainless steel or rubber coating, is available for all sizes and arrangements.

- Engineered Simplicity — Cleaning action is induced by the air flow, and water is continuously reused. No pumps, nozzles, or internal moving parts are required.
- High Efficiency — Cleaning action is so thorough that even very fine particles are removed from the air stream.
- Low Water Consumption — Requires water only slightly in excess of evaporative losses or sluicing requirements. Arr B and C seldom require over 1 gallon per minute, excluding evaporative loss.
- Compensating Water Level Control — Exclusive AAF water level control maintains constant collector performance regardless of fluctuations in air volume.
- Low Maintenance — Designed for continuous operation with minimum service. Fabricated of heavy gauge steel for long life.
For low cost cleaning of large exhaust volumes

wet centrifugal dust collector

The Type R Roto-Clone utilizes a number of specially designed, double-inlet tubes to separate and trap dust particles by centrifugal force and impingement. Water introduced to each tube is carried to the periphery by high velocity dust-laden air entering the two tangential tube inlets. Centrifugal force causes dust particles to impinge against the wetted peripheral surfaces. Water and collected solids are separated from the air stream by the tube, eliminating the need for entrainment chevrons or baffles.

The Type R is used for light to heavy loadings of all size granular dusts. It is very popular for such applications as metal mining, coal handling, chemical processing, fertilizer manufacture, and foundry sand systems. Standard sizes contain from one to twenty-four tubes, each having a nominal capacity of 4500 CFM. The multiple-tube design permits great operating flexibility — tubes can be added or removed to suit changes in process or exhaust requirements. Such flexibility is extremely advantageous for installations where future expansion is planned.

Pressure loss through the Type R varies with air volume. At the nominal rating of 4500 CFM per tube, pressure drop is 5.8" w.g. Typical water requirement is 3.5 gallons per 1,000 CFM of air cleaned. It is usual practice to recirculate water to the Type R from a settling tank or pond, adding only enough fresh water to compensate for evaporative loss. Since there are no spray nozzles or small orifices to plug, the Type R can use water having high solids content.

Standard Type R Roto-Clones have 10 gauge HRS housings and Type 304 stainless steel tubes. Optional construction materials include 1/4" plate, all stainless steel, monel, and internal protective coatings.

- No moving parts
- No entrainment eliminators
- No water in suspension
- No spray nozzles

- Small space requirement
- Light weight
- Flexibility in arrangement
- Wide range of capacities

Acid pickling
Brake shoe grinding
Chemical processing
Coal handling
Fertilizer dryers and coolers
Food products
Foundry sand systems
Lead battery plants

Lightweight aggregate kilns
Metal mining
Municipal incinerators
Ore pelletizing plants
Paper dust
Pharmaceuticals
Sandblasting
Sugar granulators
For ultra-high cleaning efficiency

**kinetic scrubber**

The AAF Kinpactor utilizes kinetic energy to collect very small dust and fume particles by the principle of impaction. The contaminated gas stream is accelerated to high velocity in the venturi shaped throat section — water introduced to the throat is atomized by the high velocity gas, and the contaminant particles collide with and are trapped by millions of small water droplets. The gas stream is decelerated - and maximum static pressure regained - in the long diverging section behind the Kinpactor throat. Entrained water droplets are removed from the gas stream by a Type R Separator or cyclonic separator.

Gas-water contact is so thorough that even submicron particles are removed. The degree of cleaning is a direct function of energy input, which is reflected by the pressure drop across the Kinpactor. Throat pressure drop ranges from 8" w.g. to 100" w.g. depending on the contaminant particle size and desired degree of cleaning. Usual water requirement is 8 gallons per 1000 CFM of gas cleaned.

The Kinpactor may be equipped with either a Type R Separator or a Cyclonic Separator. The Type R Separator is a modification of AAF’s Type R RotoClone dust collector. It requires less space and provides more positive separation than any other centrifugal type eliminator. If the collected material is cementaceous or extremely sticky, a cyclonic separator is recommended for ease of service.

Kinpactors and separators can be fabricated of mild steel, stainless steel, rubber-lined steel, monel, and fiberglass-reinforced polyester.

---

**For Iron and Steel**
- Cupolas
- Blast furnaces
- Basic oxygen furnaces
- Open hearth furnaces
- Electric arc furnaces
- Scarfing machines
- Sintering machines

**For Chemical Process**
- Fertilizer dryers and coolers
- Fertilizer ammoniators
- Acid concentrators
- Spray dryers
- Flash dryers
- Roasting kilns

**For Pulp and Paper**
- Lime kilns
- Black liquor recovery boilers

**For Non-Ferrous Metals**
- Aluminum furnaces
- Lead blast furnaces
- Reverberatory furnaces
- Induction furnaces
- Sintering

**For Other Processes**
- Asphalt plants
- Coal processing
- Salt bath paint stripping
- Incinerators
- Boiler flue gas
- Wire insulation burning
- Galvanizing kettles
- Plastic and resin fumes

REQUEST DUST CONTROL BULLETIN 294
AAF designs and manufactures custom-engineered kinetic scrubber systems for larger volume process gas applications. Custom systems are normally used to clean hot gas volumes above 50,000 CFM. Kinetic scrubber systems commonly include:

- Quencher to initially cool process gas
- Kinpactor kinetic scrubber
- Gas cooling tower to further cool cleaned gas and recover the water evaporated in the quencher and Kinpactor
- High pressure fan
- Separator to remove any entrained water droplets
- Water cooling tower to remove heat absorbed from the gas stream
- Water recirculation system to remove collected solids from the effluent slurry and return clean water to the scrubber

Systems can be designed to reduce exit dust concentration to 0.05 grains per cubic foot or less. The Kinpactor can be equipped with an automatically controlled variable throat damper which maintains the same high cleaning efficiency regardless of fluctuations in process gas volume.

AAF offers complete turnkey design and installation of the entire kinetic scrubber air pollution control system.
For chemical fumes, mist, and vapor

fume scrubber

The unique COLAG fume scrubber is the result of AAF's search for a better means to collect chemical fumes, mists, and vapors.

The COLAG uses a specially designed scrubbing pad arrangement to thoroughly clean the contaminated air. Air enters the unit at high velocity and is evenly distributed by a special perforated plate. The reaction pad, located just above the plate, is constantly saturated with water to create millions of flooded, bubbling contact surfaces which scrub and re-scrub the air. Liquid droplets which pass from the reaction pad are trapped by sloped eliminator pads.

The COLAG is ideal for the collection of inorganic and organic acids, alkalies, water-soluble solvents, halogens, and ammonia. Because of its high collection efficiency and low water rate, the COLAG acts as an excellent concentrator and is often utilized as an important part of a process system.

The COLAG is available in seven sizes for air volumes of 1150 to 25,000 CFM. Arrangements utilizing one, two or three collection stages can be furnished. Units can be fabricated of mild steel, stainless steel, monel, solid PVC, and fiberglass-reinforced polyester. Protective coatings are also available.

Operation and maintenance is simplified by a large plexiglass observation window which provides easy access to the pads and plate. Disposable type pads slide out of the observation window for quick, low-cost replacement.

Highest Efficiency — The collection efficiency of the COLAG cannot be exceeded by any other fume scrubber operating at a comparable pressure loss and water rate.

Lowest Water Usage — The unique design of the COLAG allows operation at a lower water rate than any other collector of this type — as low as 0.1 gallons per 1,000 CFM of air cleaned.

Smallest Size — The COLAG operates at a substantially higher air velocity than other packing-type scrubbers.

<table>
<thead>
<tr>
<th>TYPICAL APPLICATIONS</th>
<th>Electro-polishing</th>
<th>Metal etching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum anodizing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pickling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electroplating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coating stripping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid dipping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal cleaning</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There are no liquid storage tanks, recirculating pumps, or heavy eliminator sections required — as a result the COLAG weighs less and requires less space than conventional collectors.
Collector performance is usually stated in terms of collector efficiency, which may be calculated by the equation

\[
\text{Efficiency (\%) } = \left( \frac{M_i}{M_o} \right) \times 100
\]

where \(M_i\) is the contaminant mass flow rate at the collector inlet and \(M_o\) is the contaminant mass flow rate at the collector outlet. Air pollution regulations normally establish the allowable rate of contaminant emission. Where no regulation exists, the user must determine the desired exit level, possibly by referring to regulations in nearby locales. The value of \(M_i\) is fixed by the application, and can be determined accurately by isokinet sampling of the gas stream. If the process is not yet in operation, \(M_i\) can be estimated on the basis of test data from similar applications.

Because wet collectors have a fractional efficiency characteristic, the stated efficiency for a given collector is only meaningful when it is based on particle size, usually expressed in microns. There are many ways of determining particle size, and the results vary widely. One method might indicate a particle diameter of 5 microns while a second method could give a value as low as 3 microns. It should be readily apparent that collector efficiency curves can be misleading if the method of particle size analysis is not stated.

In accordance with the Contact Power Theory (see page 21), Curve A represents the typical efficiency of any well-designed wet collector operating at a 5 to 6” w.g. pressure drop, when particle size is determined by the Whitby Centrifuge (liquid sedimentation) method. Published curves for such collectors may deviate appreciably from the curve shown. When appropriate corrections are made to compensate for the method of particle size analysis, the deviations will almost invariably disappear and the curves found to coincide.

Curves B, C, and D show collection efficiency vs. particle size for a kinetic scrubber operating at pressure drops of 10”, 20”, and 30” w.g., respectively. Efficiency is substantially higher in the small particle size range due to the additional energy expended to improve air-water contact.

The fractional efficiency characteristic of wet collectors presents an additional problem in evaluating performance. Efficiency is commonly expressed on a weight basis. An efficiency of 98 to 99 percent by weight does not necessarily ensure that the contaminant discharged to atmosphere will not be visible. Visibility is a function of light reflectance, which in turn is directly proportional to the surface or reflective area of the particles emitted. Since a unit weight of small particles represents considerably more total surface area than an equal weight of large particles, it is entirely possible to collect over 90% of the particles by weight (by capturing the larger sizes) yet remove less than 30% of the total reflective area. It should be kept in mind that collection efficiency and discharge appearance are only remotely related.
<table>
<thead>
<tr>
<th>OPERATION</th>
<th>Dust Loading</th>
<th>Particle Size</th>
<th>Type W Rate Class</th>
<th>Type N Rate Class</th>
<th>Type E Rate Class</th>
<th>Rinsewater</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CERAMICS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials Handling</td>
<td>Light</td>
<td>Fine</td>
<td>USUAL</td>
<td>USUAL</td>
<td>USUAL</td>
<td>Not Req'd</td>
<td></td>
</tr>
<tr>
<td>Filling and Grinding</td>
<td>Med Hvy</td>
<td>Fine Med</td>
<td>Emergency</td>
<td>Frequent</td>
<td>Frequent</td>
<td>Not Req'd</td>
<td>1</td>
</tr>
<tr>
<td>Spraying</td>
<td>Lt Med</td>
<td>Medium</td>
<td>USUAL</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Not Req'd</td>
<td>2</td>
</tr>
<tr>
<td><strong>CHEMICALS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials Handling</td>
<td>Lt Hvy</td>
<td>Varies</td>
<td>Frequent</td>
<td>USUAL</td>
<td>USUAL</td>
<td>Rare</td>
<td>3</td>
</tr>
<tr>
<td>Crushing and Grinding</td>
<td>Med Hvy</td>
<td>Varies</td>
<td>Occasional</td>
<td>USUAL</td>
<td>USUAL</td>
<td>Frequent</td>
<td>4</td>
</tr>
<tr>
<td>Weighing and Screening</td>
<td>Lt Med</td>
<td>Fine Med</td>
<td>USUAL</td>
<td>Frequent</td>
<td>Not Req'd</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Roasters, Kilns, Dryers</td>
<td>Heavy</td>
<td>Medium</td>
<td>Occasional</td>
<td>USUAL</td>
<td>USUAL</td>
<td>Frequent</td>
<td>4, 5, 6</td>
</tr>
<tr>
<td>Bin Ventilation</td>
<td>Light</td>
<td>Fine Med</td>
<td>USUAL</td>
<td>Occasional</td>
<td>Occasional</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td><strong>FERTILIZER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screening and Handling</td>
<td>Med Hvy</td>
<td>Fine Med</td>
<td>Occasional</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Dryer Cooler</td>
<td>Heavy</td>
<td>Fine Med</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Occasional</td>
<td>USUAL</td>
<td>5</td>
</tr>
<tr>
<td>Ammoniator</td>
<td>Lt Med</td>
<td>Fine</td>
<td>Rare</td>
<td>Occasional</td>
<td>Rare</td>
<td>USUAL</td>
<td>5</td>
</tr>
<tr>
<td><strong>COAL MINING AND POWER PLANT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials Handling</td>
<td>Moderate</td>
<td>Medium</td>
<td>Frequent</td>
<td>USUAL</td>
<td>USUAL</td>
<td>Not Req'd</td>
<td>7</td>
</tr>
<tr>
<td>Bunker Ventilation</td>
<td>Light</td>
<td>Fine</td>
<td>Frequent</td>
<td>Rare</td>
<td>Not Req'd</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Dedusting and Coating</td>
<td>Heavy</td>
<td>Medium</td>
<td>Frequent</td>
<td>Rare</td>
<td>Not Req'd</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Dryers</td>
<td>Heavy</td>
<td>Fine Medium</td>
<td>No</td>
<td>Frequent</td>
<td>USUAL</td>
<td>USUAL</td>
<td>5</td>
</tr>
<tr>
<td><strong>FOUNDRY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abrasive Cleaning</td>
<td>Med Hvy</td>
<td>Fine Med</td>
<td>No</td>
<td>Occasional</td>
<td>Rare</td>
<td>Not Req'd</td>
<td>6</td>
</tr>
<tr>
<td>Shakeout Enclosed Hood</td>
<td>Moderate</td>
<td>Fine</td>
<td>Rare</td>
<td>Frequent</td>
<td>USUAL</td>
<td>Rare</td>
<td>6</td>
</tr>
<tr>
<td>Shakeout Side Hood</td>
<td>Light</td>
<td>Fine</td>
<td>USUAL</td>
<td>Rare</td>
<td>USUAL</td>
<td>Rare</td>
<td>6</td>
</tr>
<tr>
<td>Sand Handling</td>
<td>Moderate</td>
<td>Fine Med</td>
<td>Rare</td>
<td>Frequent</td>
<td>USUAL</td>
<td>No</td>
<td>6</td>
</tr>
<tr>
<td>Tumbling Mills</td>
<td>Heavy</td>
<td>Medium</td>
<td>Rare</td>
<td>USUAL</td>
<td>No</td>
<td>USUAL</td>
<td>5, 6, 8</td>
</tr>
<tr>
<td>Cupola</td>
<td>Moderate</td>
<td>Varies</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>USUAL</td>
<td>5, 6, 8</td>
</tr>
<tr>
<td>Non Ferrous Melting</td>
<td>Varies</td>
<td>Fine</td>
<td>No</td>
<td>Occasional</td>
<td>No</td>
<td>USUAL</td>
<td>5, 6, 8</td>
</tr>
<tr>
<td><strong>PHARMACEUTICALS AND FOOD PRODUCTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixing, Grinding, Weighing, Blending, Packaging</td>
<td>Light</td>
<td>Medium</td>
<td>USUAL</td>
<td>Frequent</td>
<td>Frequent</td>
<td>Not Req'd</td>
<td>6</td>
</tr>
<tr>
<td>Coating Pans</td>
<td>Varies</td>
<td>Fine Med</td>
<td>USUAL</td>
<td>No</td>
<td>Frequent</td>
<td>No</td>
<td>6</td>
</tr>
<tr>
<td>Sugar Handling</td>
<td>Light</td>
<td>Fine Med</td>
<td>Frequent</td>
<td>Occasional</td>
<td>Frequent</td>
<td>No</td>
<td>6</td>
</tr>
<tr>
<td>Sugar Granulators</td>
<td>Moderate</td>
<td>Fine Med</td>
<td>USUAL</td>
<td>Frequent</td>
<td>Frequent</td>
<td>No</td>
<td>6</td>
</tr>
<tr>
<td><strong>ROCK PRODUCTS AND METAL MINING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials Handling</td>
<td>Med Hvy</td>
<td>Fine Med</td>
<td>Occasional</td>
<td>USUAL</td>
<td>USUAL</td>
<td>Not Req'd</td>
<td>6</td>
</tr>
<tr>
<td>Crushing and Screening</td>
<td>Heavy</td>
<td>Medium</td>
<td>Occasional</td>
<td>USUAL</td>
<td>USUAL</td>
<td>Rare</td>
<td>6</td>
</tr>
<tr>
<td>Dryers and Kists</td>
<td>Med Hvy</td>
<td>Fine Med</td>
<td>Rare</td>
<td>USUAL</td>
<td>USUAL</td>
<td>USUAL</td>
<td>5, 6</td>
</tr>
<tr>
<td>Coolers</td>
<td>Moderate</td>
<td>Coarse</td>
<td>Rare</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Not Req'd</td>
<td>5, 6</td>
</tr>
</tbody>
</table>

**NOTES:**
1 Dust released from bin filling, weighing, mixing, pressing, and forming Refractory products screening and dry pan operations more severe
2 Operations found in vitreous enameling, wall and floor tile, and pottery
3 Includes conveying, elevating, mixing, and packaging
4 Category covers so many different materials that specific recommendations are difficult to report
5 Corrosion protection normally required
<table>
<thead>
<tr>
<th>OPERATION</th>
<th>Dust Loading</th>
<th>Particle Size</th>
<th>Type W Rate Clone</th>
<th>Type N Rate Clone</th>
<th>Type R Rate Clone</th>
<th>Kinpacter</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUBBER AND PLASTIC PRODUCTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixture</td>
<td>Moderate</td>
<td>Fine</td>
<td>Frequent</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Not Req'd</td>
<td>6</td>
</tr>
<tr>
<td>Batch out Rolls</td>
<td>Light</td>
<td>Fine</td>
<td>Rare</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Not Req'd</td>
<td>6</td>
</tr>
<tr>
<td>Tire Drying</td>
<td>Moderate</td>
<td>Medium</td>
<td>Frequent</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Not Req'd</td>
<td>6</td>
</tr>
<tr>
<td>Grinding and Buffing</td>
<td>Moderate</td>
<td>Coarse</td>
<td>Frequent</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Not Req'd</td>
<td>6</td>
</tr>
<tr>
<td>Plastics Molding</td>
<td>Moderate</td>
<td>Medium</td>
<td>Frequent</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Not Req'd</td>
<td>6</td>
</tr>
<tr>
<td>Plastic Finishing</td>
<td>Light</td>
<td>Fine</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Not Req'd</td>
<td>6</td>
</tr>
<tr>
<td>STEEL MILLS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic Oxygen Furnace</td>
<td>Med Hvy</td>
<td>Fine Med</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>USUAL</td>
<td>5.6</td>
</tr>
<tr>
<td>Electric Arc Furnace</td>
<td>Light</td>
<td>Fine Med</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Frequent</td>
<td>5.6, 9</td>
</tr>
<tr>
<td>Open Hearth</td>
<td>Med Hvy</td>
<td>Fine Med</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>USUAL</td>
<td>5.6</td>
</tr>
<tr>
<td>Blast Furnace</td>
<td>Heavy</td>
<td>Varies</td>
<td>No</td>
<td>Rare</td>
<td>No</td>
<td>USUAL</td>
<td>5.6</td>
</tr>
<tr>
<td>Scouring</td>
<td>Light</td>
<td>Fine Med</td>
<td>No</td>
<td>Rare</td>
<td>No</td>
<td>USUAL</td>
<td>5.6</td>
</tr>
<tr>
<td>Coal and Coke Handling</td>
<td>Moderate</td>
<td>Medium</td>
<td>Frequent</td>
<td>USUAL</td>
<td>USUAL</td>
<td>Not Req'd</td>
<td>6</td>
</tr>
<tr>
<td>Rolling Machines</td>
<td>Medium</td>
<td>Fine Med</td>
<td>No</td>
<td>Rare</td>
<td>No</td>
<td>Rare</td>
<td>5</td>
</tr>
<tr>
<td>Steel Exit</td>
<td>Heavy</td>
<td>Fine Med</td>
<td>No</td>
<td>USUAL</td>
<td>Rare</td>
<td>Frequent</td>
<td>5</td>
</tr>
<tr>
<td>Hot Strip Mills</td>
<td>Light</td>
<td>Fine</td>
<td>No</td>
<td>USUAL</td>
<td>Rare</td>
<td>Frequent</td>
<td>5</td>
</tr>
<tr>
<td>Coke Screening</td>
<td>Med Hvy</td>
<td>Medium</td>
<td>Rare</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Frequent</td>
<td>6</td>
</tr>
<tr>
<td>Materials Handling</td>
<td>Med Hvy</td>
<td>Fine Med</td>
<td>Rare</td>
<td>Occasional</td>
<td>Occasional</td>
<td>Frequent</td>
<td>6</td>
</tr>
<tr>
<td>MISCELLANEOUS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid Mills</td>
<td>Light</td>
<td>Fine</td>
<td>Frequent</td>
<td>Frequent</td>
<td>Occasional</td>
<td>Not Req'd</td>
<td>5.10</td>
</tr>
<tr>
<td>Acid Pickling</td>
<td>Moderate</td>
<td>Fine</td>
<td>Frequent</td>
<td>USUAL</td>
<td>USUAL</td>
<td>Occasional</td>
<td>5</td>
</tr>
<tr>
<td>Asphalt Plant Dryers</td>
<td>Heavy</td>
<td>Fine Med</td>
<td>No</td>
<td>Frequent</td>
<td>Frequent</td>
<td>USUAL</td>
<td>5</td>
</tr>
<tr>
<td>Brake Line Grinding &amp; Sanding</td>
<td>Heavy</td>
<td>Medium</td>
<td>Frequent</td>
<td>Rare</td>
<td>No</td>
<td>USUAL</td>
<td>5</td>
</tr>
<tr>
<td>Lead Battery Plants</td>
<td>Light</td>
<td>Fine Med</td>
<td>Occasional</td>
<td>USUAL</td>
<td>Frequent</td>
<td>Not Req'd</td>
<td>5</td>
</tr>
<tr>
<td>Leather Buffing</td>
<td>Moderate</td>
<td>Medium</td>
<td>USUAL</td>
<td>No</td>
<td>Occasional</td>
<td>Not Req'd</td>
<td>5</td>
</tr>
<tr>
<td>Leather Sanding</td>
<td>Moderate</td>
<td>Fine Med</td>
<td>Frequent</td>
<td>No</td>
<td>Occasional</td>
<td>Not Req'd</td>
<td>5</td>
</tr>
<tr>
<td>Metal Buffing and Polishing</td>
<td>Light</td>
<td>Varies</td>
<td>USUAL</td>
<td>No</td>
<td>No</td>
<td>USUAL</td>
<td>5</td>
</tr>
<tr>
<td>Newspaper Lead Pots</td>
<td>Light</td>
<td>Fine</td>
<td>USUAL</td>
<td>Rare</td>
<td>No</td>
<td>No</td>
<td>5</td>
</tr>
<tr>
<td>Offset Spray</td>
<td>Light</td>
<td>Fine</td>
<td>USUAL</td>
<td>Rare</td>
<td>No</td>
<td>Occasional</td>
<td>5</td>
</tr>
<tr>
<td>Paint Stripping (Salt Bath)</td>
<td>Light</td>
<td>Fine Med</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>5</td>
</tr>
<tr>
<td>Paper Cutting</td>
<td>Moderate</td>
<td>Medium</td>
<td>Occasional</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>5</td>
</tr>
<tr>
<td>Paper Grinding</td>
<td>Mod Hvy</td>
<td>Medium</td>
<td>Occasional</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>5</td>
</tr>
<tr>
<td>Wood Sanding</td>
<td>Moderate</td>
<td>Fine</td>
<td>Occasional</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>5</td>
</tr>
</tbody>
</table>

6. Fabric collectors (AAF AMERplus, AMERpulse, AMERtherm) are frequently used.
7. High efficiency dry centrifugal collectors (AAF Type D RoToClone) are frequently used.
8. AAF AMERclone high efficiency dry centrifugal can be used where codes permit 0.20 grains per cubic foot in discharge.
9. Many furnaces now use direct shell evacuation instead of old style hood.
10. AAF COLAG fume scrubber frequently used.

The listings under "Dust Loading" and "Particle Size" are averages and will vary from job to job. The ranges are as follows:

**Dust Loading**
- **Light**: 1/2 to 2 Grains/Cu Ft
- **Medium**: 2 to 3 Grains/Cu Ft
- **Moderate**: 3 to 5 Grains/Cu Ft
- **Heavy**: Over 5 Grains/Cu Ft
- **Extremely Fine**: 50% in 1/2 to 2 Micron Range
- **Fine**: 50% in 2 to 7 Micron Range
- **Medium**: 50% in 7 to 15 Micron Range
- **Coarse**: 50% Above 15 Microns

**Particle Size**
- **Medium**: 50% in 7 to 15 Micron Range
- **Coarse**: 50% Above 15 Microns