INDUSTRIAL EXHAUST SYSTEMS

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1.0 SCOPE

This data sheet provides guidelines for reducing fire and explosion hazards inherent in industrial exhaust systems and preventing fire spread via these systems, whether within buildings or between adjacent buildings.

The provisions of this standard are not intended for chimneys (see Data Sheet 1-13, *Chimneys*), nor for noncombustible ducts handling noncombustible products. Refer to Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires,* for additional information on ducts conveying combustible dusts. Specific recommendations for use and protection of industrial exhaust systems in clean rooms and semiconductor fabrication facilities are presented in Data Sheets 1-56, *Cleanrooms*, and 7-7/17-12, *Semiconductor Fabrication Facilities.* Arrange and protect heating and air conditioning ducts per Data Sheet 1-45, *Air Conditioning and Ventilating Systems.* In some cases the recommendations in those data sheets are more conservative than the guidelines presented here.

This standard is **not** intended to cover metallurgical smelters, refineries, or acid plants. Specific recommendations for these facilities and their plastic exhaust systems and associated equipment can be found in Data Sheet 7-12/17-17, *Mining and Ore-Processing Facilities.*

1.1 Hazard

Refer to *Understanding the Hazard: Fire in Industrial Exhaust Systems,* FM Global publication P0351, for loss lessons, general loss information, and an explanation of the fire hazard.

1.2 Changes

January 2017. Revisions were made to Table 1 and Table 2 based on more current editions of the ACGIH®, *Industrial Ventilation Manual*.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Construction and Location

2.1.1 Ducts: General

2.1.1.1 Except as recommended in Section 2.1.2, use ducts constructed of metal or other noncombustible material, and of adequate strength and rigidity to meet service conditions and installation requirements. If plastic ducts must be used, ensure they are FM Approved.

When exterior insulation is necessary on duct systems, use a material that is noncombustible or Class 1, such as FM Approved duct materials (Class 1) or mineral wool (note: kraft facing on glass fiber insulation is combustible; however, if it is the only combustible in the area, sprinkler protection usually will not be warranted). Combustible insulation on indoor duct systems is acceptable if ceiling sprinkler protection is adequate, except for foamed plastic. Where foamed plastic insulation is used, refer to Data Sheet 1-57, *Plastics in Construction,* for guidance in providing thermal barriers and surface treatments.

2.1.1.2 Construct the entire duct system to be self-contained and independent, and ensure it is designed by a licensed engineer.

2.1.1.3 Locate ducts as follows:

2.1.1.3.1 Extend vertical portions of ducts through the roof unless specifically FM Approved for long vertical runs (15 ft [4.6 m] is maximum unless specifically Approved for longer runs). An alternative to this is to provide automatic sprinkler protection in the vertical portion of FM Approved plastic ducts per Section 2.2.1

2.1.1.3.2 If it is not possible to extend the vertical portion through the roof, protect penetrations of fire barriers by ducts. Possible designs are shown in Data Sheet 1-45, *Air Conditioning and Ventilating Systems.*

2.1.1.3.3 Where vertical metal and plastic ducts pass through floors, protect the penetrations from liquid damage from external spills or leaks spreading to lower floors in accordance with Data Sheet 1-24, *Protection Against Liquid Damage*.

2.1.1.4 Locate vapor-removal inlets as close to the point of vapor liberation as is practical. Give consideration to the potential for condensation of vapor due to changes in temperature, especially for uninsulated ducts. Such systems may consist of hoods or enclosures connected to ducts.

In the area where vapor is liberated, maintain a capture in-draft velocity sufficient to convey vapor to the hood opening and prevent outward escape. Capture velocities for typical operations are listed in Industrial Ventilation by the American Conference of Governmental Industrial Hygienists (Table 1). Lack of adequate capture in-draft velocities allows high concentrations of combustible material.

Use adequate design transport velocities throughout the ductwork system to prevent material from settling in the ducts. The recommended duct airflow-conveying velocities for typical operations are listed in Table 2.

Base design velocities on the greatest resistance to airflow that would normally be tolerated before changing or cleaning the filters (see Recommendation 2.4.4).

*Table 1. Recommended Capture Velocities**

Energy of Dispersion	*Examples*	*V_x fpm [m/s]*
Little motion	Evaporation from tanks, degreasing	75–100 [0.38–0.51]
Average motion	Intermittent container filling; low speed conveyor transfers; welding; plating; pickling	100–200 [0.51–1.02]
High	Barrel filling; conveyor loading; crushers	200–500 [1.02–2.54]
Very high	Grinding; abrasive blasting; tumbling	500–2000 [2.54–10.2]
Factors Affecting Choices within Ranges Strength of crossdrafts due to makeup air, traffic, etc. Need for effectiveness in collection: ° Toxicity of contaminants produced by the source ° Exposures from other sources that reduce acceptable exposure from this source, quantity of air contaminants generated - i.e., production rate, volatility, time generated *see also ANSI Z9.2-19917		

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Table 2. Range of Minimum Duct Design Velocities

Nature of Contaminant	*Examples*	*Design Velocity*
Vapor, gases, smoke		Any desired velocity (economic optimum velocity usually, 1,000–2,000 fpm) [5.08–10.16 m/s]
Fumes, metal smokes	Welding	2,000–2,500 fpm [10.16–12.70 m/s]
Fine light dust	Cotton, lint, wood flour, litho powder	2,500–3,000 fpm [12.7–15.24 m/s]
Dry dusts and powders	Fine rubber dust, Bakelite molding powder dust, jute lint, cotton dust, shavings (light), soap dust, leather shavings	3,000–3,500 fpm [15.24–17.78 m/s]
Average industrial dust	Grinding dust, buffing lint (dry), wool jute dust (shaker waste), coffee beans, shoe dust, granite dust, silica flour, general material handling, brick cutting, clay dust, foundry (general), limestone dust, packaging and weighing asbestos dust in textile industries	3,500–4,000 fpm [17.78–20.32 m/s]
Heavy dusts	Sawdust (heavy and wet), metal turnings, foundry tumbling barrels and shakeout, sand blast dust, wood blocks, hog waste, brass turnings, cast iron boring dust, lead dust.	4,000–4,500 fpm [20.32–22.86 m/s]
Heavy or moist dusts	Lead dust with small chips, moist cement dust, buffing, lint (sticky), quick-lime dust.	4,500 fpm [22.86 m/s] and up

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2.1.1.5 Arrange ducts so as not to be continuous over/around maximum foreseeable loss (MFL) fire walls. If penetration of MFL fire walls cannot be avoided, arrange protection according to Data Sheets 1-42, *MFL Limiting Factors.*

Do not allow ducts to penetrate other fire-rated partitions. If this is necessary for new construction, provide dampers with a fire rating suitable for the wall at the point of penetration. Building code requirements may not allow the use of dampers in ducts conveying hazardous materials. In these cases, reroute the duct to avoid penetration of the fire partition, or do the following: For FM Approved ducts or ducts and duct contents that need sprinkler protection and are adequately protected, construct a shaft with a rating equal to the wall around the duct for 25 ft (7.6 m) on each side of the partition. Allow no inlets to the duct within this distance. This arrangement is not acceptable for MFL wall penetration.

2.1.1.6 If exhaust ducts of combustible construction, FM Approved plastic and plastic-lined metal duct, or noncombustible ducts handling combustibles pass through or run near combustible construction, insulate the duct exteriors with 1 in. (25 mm) vermiculite or perlite plaster on metal lath or an appropriate thickness of an FM Approved cementitious fire-retardant coating. The chosen method of insulating the duct exteriors needs to provide a minimum of 10 to 15 minutes of delay for ignition. An alternative to coating is a 6 in. (152 mm) minimum clearance around the duct with an appropriate metal collar closure.

2.1.1.7 Locate exhaust ducts so their discharge outlet is not less than 6 ft (1.8 m) from any combustible construction, including the wall from which the duct protrudes. Additionally, ensure the exhaust duct discharge outlet is not less than 25 ft (7.6 m) from any combustible construction or unprotected openings in noncombustible exterior walls associated with nearby buildings or structures.

2.1.1.8 To reduce the possibility of duct collapse due to accumulation of sprinkler water, provide low-point drains shown in Figure 1, or a comparable releasing mechanism. A 4 in. (102 mm) drain with a capacity of approximately 150 gpm (565 L/min) is typically used. Other sizes are acceptable. Determine capacity per Table 3, assuming a 4% (1/2 in./ft, 13 mm/305 mm) slope. Also, locate branch-duct inlets to main horizontal ducts near the top of the main duct to lessen the possibility of sprinkler discharge flowing back through the branches into critical processes. In cases where drainage would not cause water damage, use friction-retained caps or equivalent drainage arrangements. Ensure the drains are tight to minimize air leakage into the ducts.

Where the occupancy is susceptible to water damage, arrange drains to discharge at a safe location. In ducts where hazardous residue is present, arrange drains for proper disposal of wastes in the drain water.

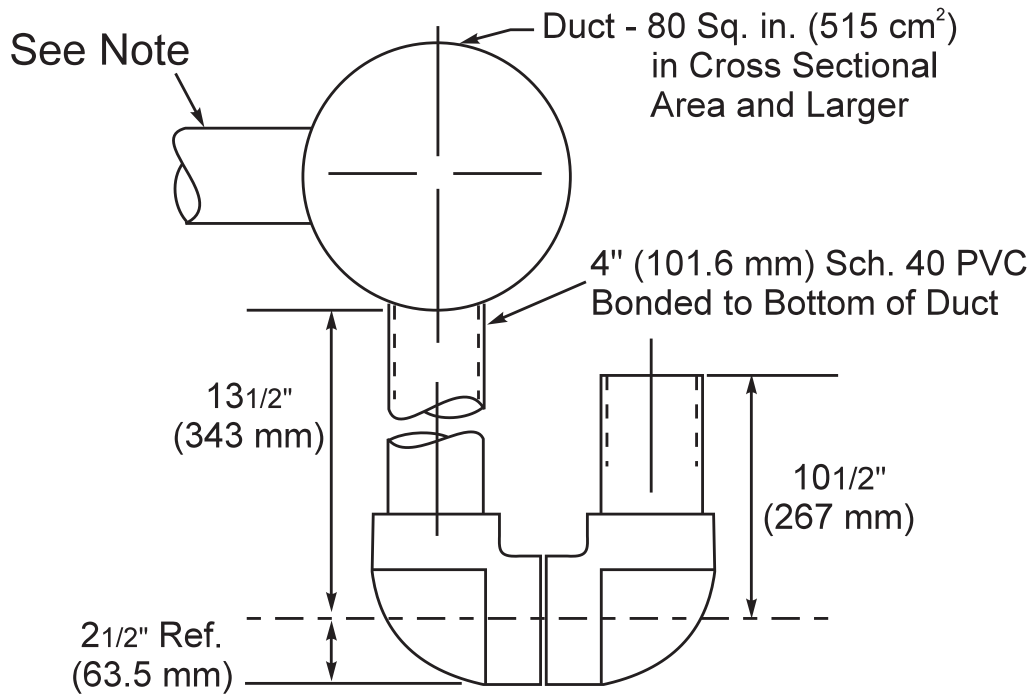
2.1.1.9 Protect exposed outdoor exhaust intake and discharge openings with substantial metal screens or gratings to prevent the entry of foreign material such as leaves or tree branches. If there is a sufficient fire exposure (such as a wildland fire) to warrant it, provide these openings with automatic fire doors or solid-type dampers of an appropriate fire rating. Locate the fire doors or dampers at the opening to the room where the equipment is situated.

Table 3. Flow Capacity for Low-Point Drains

English Units		
Diameter of Drain or Pipe (in.)	Low-Point Drains (gpm)	Horizontal Drainage Piping (gpm) Slopes ½ in./ft - 4% Slope
3	90	69
4	180	157
5	360	278
6	540	446
Metric Units		
Diameter of Drain or Pipe (mm)	Low-Point Drains (L^3/min)	Horizontal Drainage Piping (L^3/min) 4% Slope
75	340	260
100	680	595
125	1360	1050
150	2040	1690

2.1.2 Plastic and Plastic-Lined Ducts

2.1.2.1 Do not use ducts of plastic material or plastic-lined ducts (whether FM Approved or not) to handle combustible environments. An effluent air stream containing less than 25% of the LEL (lower explosive limit) of a flammable vapor is not considered a combustible environment. Do not handle Class 3 and Class 4



Note: Inlets to main horizontal runs should be located on side or top of main duct to provide invert elevation for sprinkler water to prevent drainage backflow into the equipment.

Fig. 1. Four in. (102 mm) drain

oxidizers in these ducts. If Class 1 and Class 2 oxidizers are to be handled in these ducts, take proper measures to prevent intermingling of the resin with the oxidizer. (See Data Sheet 7-82N, *Storage of Liquid and Solid Oxidizing Materials.*)

2.1.2.2 Where plastic or plastic-lined ducts are needed, use FM Approved ducts for all new construction and retrofit applications provided they are available and suitable for the process involved. Follow the limitations of the FM Approval. FM Approved materials are required to have the FM Approval mark on the packaging or the material itself. Do not accept materials without proper labeling.

2.1.2.4 When a corrosion-resistant duct is needed for handling combustible environments, use FM Approved coated metal duct and provide the sprinkler protection described in Section 2.2.1 inside the duct.

2.1.2.5 In occupancies susceptible to smoke damage, do not use thermoplastic ducts such as PVC, polypropylene, or flexible-type ducts because these types are more susceptible to collapse in a fire. Only FM Approved ducts for use in semiconductor occupancies should be used to minimize smoke damage potential.

2.1.2.6 Do not use dampers or interrupters in smoke control systems. Their presence will defeat the smoke-control system.

2.1.3 Fans

2.1.3.1 Use fans of noncombustible construction. For additional information, see Data Sheet 13-24, *Fans and Blowers.*

2.1.3.2 Use housings or casings of substantial construction to prevent distortion and loss of alignment under operating conditions. Use blades, impellers, and shafting designed with adequate clearance to prevent contact with casings and to prevent distortion under conditions of deposit loading.

2.2 Protection

2.2.1 General Protection for Ducts, Scrubbers, and Associated Equipment

2.2.1.1 In locations where the combustible duct exteriors (non-FM Approved ducts) are exposed to ceiling sprinklers, no other exterior protection is needed. If combustible ducts are located in an unsprinklered area and are of sufficient concentration or size to generate a self-propagating fire, install sprinklers over or near the duct spaced not more than 12 ft (3.7 m) on center. Generally, one line of sprinklers over the duct will suffice. Base water supply on 20 gpm (75 L/min) per head over a maximum of 100 lineal ft (30 m) of duct, 165°F (74°C) rated heads are satisfactory. When ducts are wide, sprinklers will also be needed below if there are combustibles below the duct. See Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers,* for details. If the duct is covered with foam plastic insulation (polyurethane, polystyrene, etc.), follow the surface treatment and sprinkler protection recommendations in Data Sheet 1-57, *Plastics in Construction.*

2.2.1.2 Install sprinklers inside all ducts that have cross-sectional areas greater than or equal to 80 in^2 (516 cm^2), or that have diameters greater than or equal to 10 in. (254 mm), and which:

A. are combustible (including non-FM Approved plastics; treat plastic-lined ducts the same as plastic ducts)

-or-

B. contain combustibles sufficient to cause a damaging fire.

Carefully consider the potential for oily deposits; even frequent thorough cleaning of duct interiors may only reduce the frequency of a fire, not the potential severity should one occur without sprinklers in the ducts. In almost all cases, duct accumulations should be eliminated by increasing the air velocity, not by installing automatic sprinklers inside otherwise noncombustible ducts. In either case, regular interior inspections of ducts where such potential exists is an important aspect of maintaining a well-protected plant.

Use judgment in determining if sprinklers should also be provided in smaller ducts that offer serious exposures.

2.2.1.3 For ducts described in Section 2.2.1.2, install sprinklers as follows:

A. Space sprinklers no more than 12 ft (3.7 m) on center in horizontal and 24 ft (7.4 m) on center (preferably at top of) in vertical ducts. Use sprinklers with a temperature rating of at least 50°F (27°C) above the temperature of the environment inside the duct. Use pendent sprinklers. Base the water supply on 20 gpm (75 L/min) per head over an area equal to the projected area of the duct, but not exceeding 100 lineal feet (30 m) of the duct. Make sure this operating area includes all sprinklers inside the duct within the 100 ft horizontal length traversed by the duct, including the first head in each connected vertical section.

B. An option to protect combustible ducts (rather than combustible residue) is as follows: Space sprinklers not more than 20 ft (6.6 m) on center in horizontal ducts if a density of at least 0.50 gpm/ft^2 (20 mm/min) over the projected area of the duct (not exceeding 100 lineal feet [30 m]) can be provided.

C. To protect horizontal combustible ducts (including non-FM Approved plastic), intermediate spacing (option A and B) with interpolated demands also are acceptable.

In all three cases, the following also apply:

D. When the duct width or diameter is greater than 12 ft (3.7 m), provide an additional line of automatic sprinklers at the same spacing inside the duct. For rounded ducts, position the lines of sprinklers at 2 o'clock and 10 o'clock.

E. In systems with branch ducts, provide one sprinkler in each branch duct, regardless of size, within 3 ft (0.9 m) of its point of entry into a main duct system. Several smaller ducts may be manifolded and a single sprinkler provided before the manifold enters the main duct system. Where not practical due to size limitations, provide a sprinkler in the main duct at the point where the smaller branch duct enters.

F. Equip the supply line to the duct sprinklers with an accessible FM Approved control valve. If there is more than one exhaust duct system, and they can be operated independently, control sprinklers to each system with separate valves. Lock all sprinkler control valves in the wide open position per Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance and Other Fire Loss Prevention Inspections.* Use a separate water flow alarm for duct system protection in large installations.

G. Use a minimum flow of 20 gpm (75 L/min) per sprinkler within the 100 ft (30 m) limit. In most cases, this will yield a density over the projected area much larger than the minimum 0.20 gpm/ft^2 specified previously. Include a 250 gpm (945 L/min) hose stream demand.

Example: In an 8 ft (2.4 m) dia. by 200 ft (60 m) long duct, the projected design area will be:

8 ft x 100 ft (max) = 800 ft^2 (2.4 m x 30 m = 74 mset$^{2)}$.

H. Use wet systems for sprinkler protection where possible. If the ducts or associated equipment are subject to freeze, arrange these fire protection systems on a dry-pipe, deluge, or non-freeze system.

2.2.1.4 Do not use steam or gaseous extinguishing systems as the primary protection system for ducts in lieu of automatic sprinklers.

2.2.1.5 When large indoor ducts, plenums, scrubbers, laboratory collection hoods, or other associated equipment contain fixed arrays of filtering or pollution control features, that are combustible or could accumulate combustible materials, provide automatic sprinklers in accordance with Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties,* for the appropriate hazard level. Place sprinklers so structural components are cooled during sprinkler operation.

2.2.1.6 Provide sprinkler protection for long runs of exterior combustible ductwork.

2.2.1.7 Arrange and protect plastic scrubbers as follows:

2.2.1.7.1 Install automatic sprinklers inside near the openings of outdoor scrubbers (above the packing, but below the exhaust stack). Design each sprinkler to flow a minimum of 25 gpm (95 L/min). Open sprinklers or waterspray nozzles supplied by a deluge valve and actuated by a heat detector may also be used.

Intermediate level protection should be provided in scrubbers with multiple packed beds.

2.2.1.7.2 Protect outdoor plastic scrubbers with open sprinklers or water spray protection. Design the system in accordance with the following specifications:

A. Locate the sprinklers or water spray nozzles to provide coverage over exposed tank surfaces.

B. For pilot sprinklers, use FM Approved quick response sprinklers within 6 in. (150 mm) of the scrubber surfaces.

C.Use a discharge pressure of 20 psi (1.4 bar) for open sprinklers or nozzles greater than or equal to ½ in. (13mm). Use 30 psi (2.1 bar) for smaller nozzles.

2.2.1.7.3 For indoor scrubbers, install protection only as needed to protect large shielded areas because the combustible plastic scrubbers are adequately protected from ceiling-level sprinkler protection. Sprinklers are not needed within the plastic scrubbers themselves.

2.2.1.7.4 Design the interconnecting ducts and chambers between the process unit and the fume incinerator to prevent deposits, vapor, and gas from accumulating. It will also usually be necessary to provide drip legs, traps, knockout pots or scrubbers, and insulate and heat the ducts and chambers. Locate the process unit and fume incinerator to provide the shortest possible length of connecting ducts.

Specific guidance for combustible scrubbers installed in semiconductor facilities is given in Data Sheet 7-7/17-12, *Semiconductor Fabrication Facilities.*

Specific guidance for combustible scrubbers associated with fume incinerators is given in Data Sheet 6-11, *Thermal and Regenerative Catalylic Oxidizers.*

2.2.1.8 Arrange and protect plastic vessels / tanks as follows:

2.2.1.8.1 Provide sprinkler protection over both indoor and outdoor plastic vessels.

2.2.1.8.2 Fire protection may also be warranted for the interior of indoor or outdoor plastic vessels depending on the size and geometry of the vessel, and how critical it is to production. Conduct a risk assessment to determine the need for protection.

2.2.1.9 FM Approved corrosion-resistant sprinklers are effective in certain environments; use them where applicable. Consult the manufacturer. For other applications in corrosive environments, protect the sprinklers as recommended in Section 3.6.

2.2.1.10 Run sprinkler piping outside the ductwork and support it independently of the ductwork system.

2.2.1.11 Ensure sprinklers are readily accessible for inspection, maintenance, and replacement. Flexible sprinkler fittings allow for easier inspection. Ducts equipped with readily accessible inspection ports will increase the likelihood and frequency of duct interior inspection and cleaning.

2.2.1.12 Space hose connections (equipped with 1-1/2 in. (38 mm) FM Approved fire hose with combination spray nozzles) at appropriate intervals to provide adequate coverage to all access doors or panels in the ductwork. (See Data Sheet 4-4N, *Standpipe and Hose Systems.*) Provide FM Approved fire extinguishers suitable for the occupancy. (See Data Sheet 4-5, *Portable Extinguishers.*)

2.2.1.13 Arrange sprinkler protection in exhaust ducts containing baffles so the sprinkler distribution pattern is not obstructed.

2.2.2 Protection for Ducts in Extremely Corrosive Environments

2.2.2.1 Install FM Approved coated duct nozzles suitable for use in extremely corrosive environments. Space nozzles no more than 12 ft (3.7 m) on center in horizontal ducts, and not more than 24 ft (7.4 m) on center (preferably at the top) in vertical ducts. Base the water supply on a design of 20 gpm (75 L/min) per nozzle for ducts up to 4 ft (1.2 m) diameter or width. Design for 30 gpm (110 L/min) per nozzle for ducts 4 ft (1.2 m) to 8 ft (2.4 m) diameter or width. Design for 20 gpm (75 L/min) each for two nozzles installed for ducts 8 ft (1.2 m) to 16 ft (4.8 m) diameter or width. Any ducts larger than this need special design considerations; evaluate them on a case-by-case basis.

2.2.2.2 Install FM Approved linear heat detection suitable for use in extremely corrosive environments to activate the sprinkler nozzles installed on a deluge sprinkler system.

2.2.2.3 Install the linear heat detection wire inside the duct. Install a loop of linear heat detection wire at the top of the duct on the same spacing as the nozzles. Locate the loops within 3 ft (1 m) horizontally of the nozzles. (See Figure 2.)

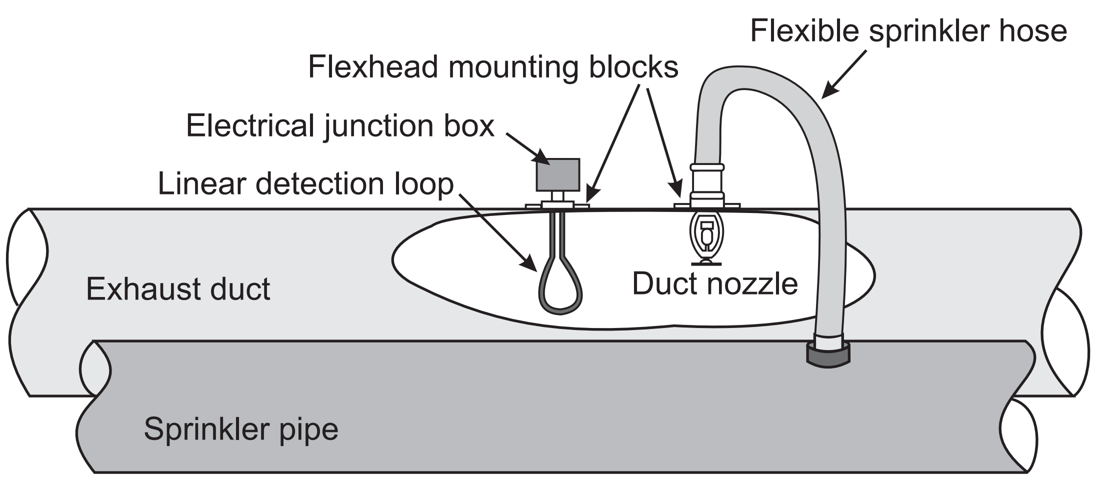


Fig. 2. Typical location of duct nozzle and linear heat detection wire in exhaust duct

2.2.2.4 Install duct nozzles on FM Approved flexible sprinkler hose suitable for use in extremely corrosive environments. (See Figure 6.)

2.2.2.5 Provide an FM Approved deluge valve to supply the open nozzles. Ensure the water delivery time does not exceed one minute (water delivery time for the deluge system is the time from initial detector activation to full discharge from all nozzles).

2.2.2.6 Visually inspect a sampling of at least six sprinkler nozzles and six linear heat detectors annually for any significant deposition on the devices or deterioration of the nozzle coating or detector jacketing. The flexible sprinkler hose allows for easy device removal. Light device deposition can be readily removed with a plastic brush and tap water and the devices can be reinstalled for continued use. If the sampled devices show signs of significant deterioration, replace them with new FM Approved devices and increase visual inspection frequency of devices to every six months.

2.2.2.7 Use a special plastic wrench (furnished by the sprinkler manufacturer) for installation and removal of the sprinkler nozzles in a manner that will not damage the nozzle coating.

2.2.2.8 Provide a low-point drain line for system installation arranged as described in Recommendation 2.1.1.8.

2.2.2.9 Provide a low-air-flow alarm switch for situations in which a reduction in air velocity will cause solids in the airstream to settle onto the bottom of the exhaust ductwork.

2.3 Operation and Maintenance

2.3.1 Make periodic checks of the entire system, including each fan, motor, blower unit, operating control panels, fume scrubbers, flexible connections, and especially any dampers to prove tightness when closed. Use a maintenance inspection form. Ensure this form fits the system involved, listing the items needing attention.

2.3.2 Establish inspections on a regular schedule to determine the amount of dust, lint, and waste material in the duct system. The interval between cleanings will depend upon the character of the deposits and the accumulation rate. (As a general rule, remove combustible deposits thicker than 1/8 in. [3 mm].)

2.3.3 The method of cleaning will vary with the nature of the deposits. Remove lint and dust with brushes. Soft, gummy deposits are commonly scraped with safety tools. Where the deposits are exceptionally hard, it may be necessary to melt them with steam. Do not use open flames.

2.3.4 Clean or replace filters when their resistance to air flow exceeds the manufacturer's specifications. Provide a draft gauge to indicate when excessive accumulations are present. In some cases, a low-flow or excessive loss of pressure alarm may be desirable.

2.3.5 For ducts with combustible deposits, perform any cutting and welding operations on ductwork with the duct section removed and cleaned, if practical. If not practical to remove the duct section, clean the duct prior to welding or cutting. In either case, use the FM Global Hot Work Permit System.

2.3.6 Replace sprinklers covered with deposits or corrosion. Forward samples of questionable sprinklers to FM Approvals for evaluation of suitability for continued service.

2.3.7 Familiarize the emergency response team (ERT) and the public fire service with the installations and have them plan duct system firefighting tactics. This is especially important in ducts handling noxious or corrosive materials where self-contained breathing apparatus and other emergency equipment must be readily available for use. It is also important for any exterior runs of combustible ductwork.

2.3.8 Keep concentrations of flammable vapor or gas within ducts and associated equipment below 25% of its lower explosive limit. Refer to Data Sheets 5-49, *Gas and Vapor Detectors and Analysis Systems,* and 6-9, *Industrial Ovens and Dryers.* Above 25% may require a vapor detection system.

2.3.9 When flammable vapor is liberated in such a way that it cannot be readily picked up at the source, employ general ventilation through a system of suction ducts with inlets from the room or area. Locate inlets to produce a sweeping or purging effect that will eliminate pockets in which vapor may accumulate.

Where heavier-than-air vapor or mixtures are handled, locate intake openings near floor level. Conversely, for gases lighter than air, locate intake openings near the ceiling.

2.3.10 Do not handle dissimilar materials through a common exhaust system if their intermingling could create a fire or explosion hazard in the duct. Do not manifold operations generating sparks, such as sanding machines or grinding wheels, with the same exhaust system that handles other combustible material unless inherent to the process, such as in woodworking occupancies. Refer to Data Sheet 7-73, *Dust Collectors and Collection Systems,* for protection recommendations against sparks.

2.3.11 Where ducts or contents are combustible, install quick-opening access doors or panels for inspection, cleaning, and firefighting at all sprinklers (except for FM Approved flexible sprinkler connections) and where necessary at individual ducts leading from equipment.

2.3.12 Inspect sprinklers at least annually, unless local conditions dictate a more frequent inspection. Where duct environments are known to be corrosive, increase the inspection frequency to every 6 months.

2.3.13 Inspect and test water supply deluge valves in accordance with Data Sheet 2-81, *Fire Protection System Inspection,* Testing and Other Fire Loss Prevention Inspections.

2.3.14 Inspect and test fire detection systems in accordance with Data Sheet 5-48, *Automatic Fire Detection.*

2.4 Ignition Source Control

2.4.1 Electric Wiring and Equipment

2.4.1.1 Ensure electrical installation is in accordance with the *National Electrical Code*, or equivalent code or standard outside the United States.

2.4.1.2 Locate motors outside rooms in which flammable vapor or combustible dust is generated. If inside the room, ensure motors are properly classified for the environment. See Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations.* Provide remote control of all fans, or at least identify breakers that could be used to isolate fans, in addition to controls located close to the equipment.

If combustible dust or vapor is passed through fans, use a rotating element of nonferrous or non-sparking material; ensure the casing consists of or is lined with such material. If ferrous material must be used, maintain clearances sufficient to ensure no contact between fan and shroud. Where there is a possibility of solid foreign material producing a spark while passing through the fan, use a nonferrous or lined rotating element and casing.

2.4.1.3 Electrically bond all metal parts of ducts or other apparatus used for the removal of flammable gas or vapor, or for conveying combustible dust, stock or refuse, and ensure the duct system is grounded. When metallic contact is broken at duct joints or at other points, install metal straps to afford effective bonding connections. Conduct at least annual checks of bonding adequacy during initial startup or after equipment revisions. Less-frequent checks can be made after good results are obtained for 3 to 5 years, assuming no equipment changes are made.

2.4.2 Control of Static Charge

If accidents or malfunctions can cause the environment to reach the explosive range, precautions will be needed to limit static electricity.

2.4.2.1 Provide a conductive lining in the duct.

2.4.2.2 Extend metallic tabs through the flanges and ensure they lead to ground at suitable intervals.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Duct Applications

Ducts are critical to many facility operations. Removal of flammable vapor, noxious fumes, dust, or lint is usually so vital that production stops if the duct system is damaged. Costly fires have occurred in large duct systems that were not adequately protected, forcing operations to shut down.

The inaccessibility of duct interiors makes fire prevention and protection difficult. Combustible deposits are hidden, and the hazard can be overlooked. Fires are difficult to extinguish because they travel rapidly and extensively through the ducts, feeding on deposits. Interconnected ducts carry fire to locations remote from its origin, often involving other equipment.

Collapsible fabric ductwork is becoming much more common, although it is typically only being used in building HVAC systems to transport conditioned air, and is not being used in industrial exhaust systems. This subject is addressed in Data Sheet 1-45, *Air Conditioning and Ventilating Systems.*

3.2 Causes of Duct Fires

Most duct fires are started by one of the following ignition sources: electrical short circuits, cutting or welding, static electricity, spontaneous ignition of deposits, friction, burner flames, and electrical immersion heaters in process equipment.

Spontaneous ignition of deposits is the most prevalent cause of fire in ducts that handle ventilation from coating and finishing processes. The longer a deposit is allowed to build up and the greater the accumulation, the greater the chance of spontaneous ignition.

Friction heat from fan bearings or stock being processed is the source of most fires in ducts handling dust and lint. Overheating, burner flames, and sparks cause about half of all oven duct fires and about a third of those in flammable vapor removal ducts.

Plating tank systems require exhaust systems with manifold ducts to exhaust corrosive vapor. It is a common practice to equip plating tanks with electric immersion heaters. Experience shows these tanks are easily ignited by immersion heaters when not properly protected and the tank liquid level becomes excessively low. (Refer to Data Sheet 7-6, *Plastic and Plastic-Lined Tanks.*)

3.3 Duct Collapse-Explosion

It is possible to collapse duct work inward on the pressure side of the fan in a high-velocity system. The conditions for this type of duct failure can be initiated by a fire damper slamming shut. The rapidly moving air mass develops a tremendous vacuum behind this sudden tight shutoff. This may be possible in duct systems with transport velocities greater than 3600 ft/min (1100 m/min). If necessary, the duct system can be protected against the possible collapse from this type of stress by pressure relief vents as shown in Figure 3.

All ducts handling airborne finely divided solids with considerable calorific value are potentially explosive. Ducts handling flour starch, grain sugar, milk powder, ground spices, phenolic molding powder, pulverized fuel, wood flour, aluminum buffings, and hard rubber dust are in this category. Explosion doors, as shown in Figure 4, can be effective in reducing the amount of damage caused by an explosion. Refer to Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires,* for additional information.

3.4 Condensation of Flammable Vapors

When a duct passes through a zone of lower temperature, condensation of vapor within may occur. If the vapor is flammable, a fire hazard exists. Methods to prevent condensation in ducts are outlined in Section 3.7.

3.5 Plastic and Plastic-Lined Ducts

Increased emphasis on air pollution control has resulted in the need for highly corrosion-resistant duct materials. The cost of acceptable metals and alloys usually prohibits their extensive use. Plastics usually prove to be the most satisfactory for corrosion resistance. These plastics may be used in ducts, hoods, fans and blowers, scrubbers, absorbers, and mist eliminators.

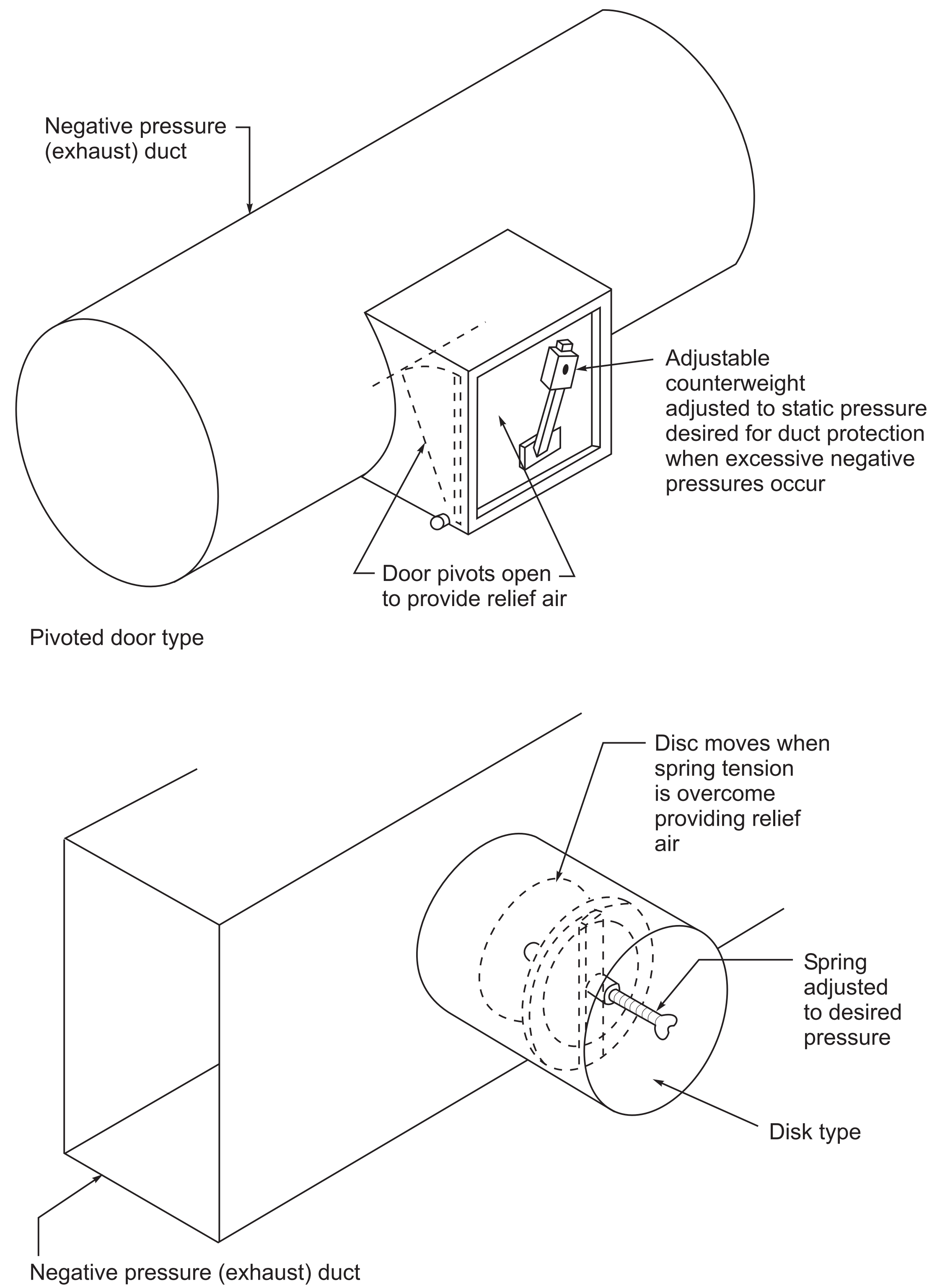
Corrosion-resistant hoods frequently are fabricated of rigid thermoplastics such as polypropylene, polyvinyl chloride (PVC), etc. These may include thermosetting resin linings. Due to low fabrication costs relative to corrosion-resistant alloys, rigidity, ease in handling, and generally good corrosion and solvent resistance, PVC and FRP are receiving wide application in large fume removal systems.

Most plastics, including those containing fire-retardant additives, will burn, decompose, melt or distort under exposure to continuous flame. Consequently, in order to lessen the loss potential, protection should be provided as recommended in this data sheet.

Duct environments are often highly corrosive. Ordinary sprinkler heads used in these ducts will have very short life spans unless protected.

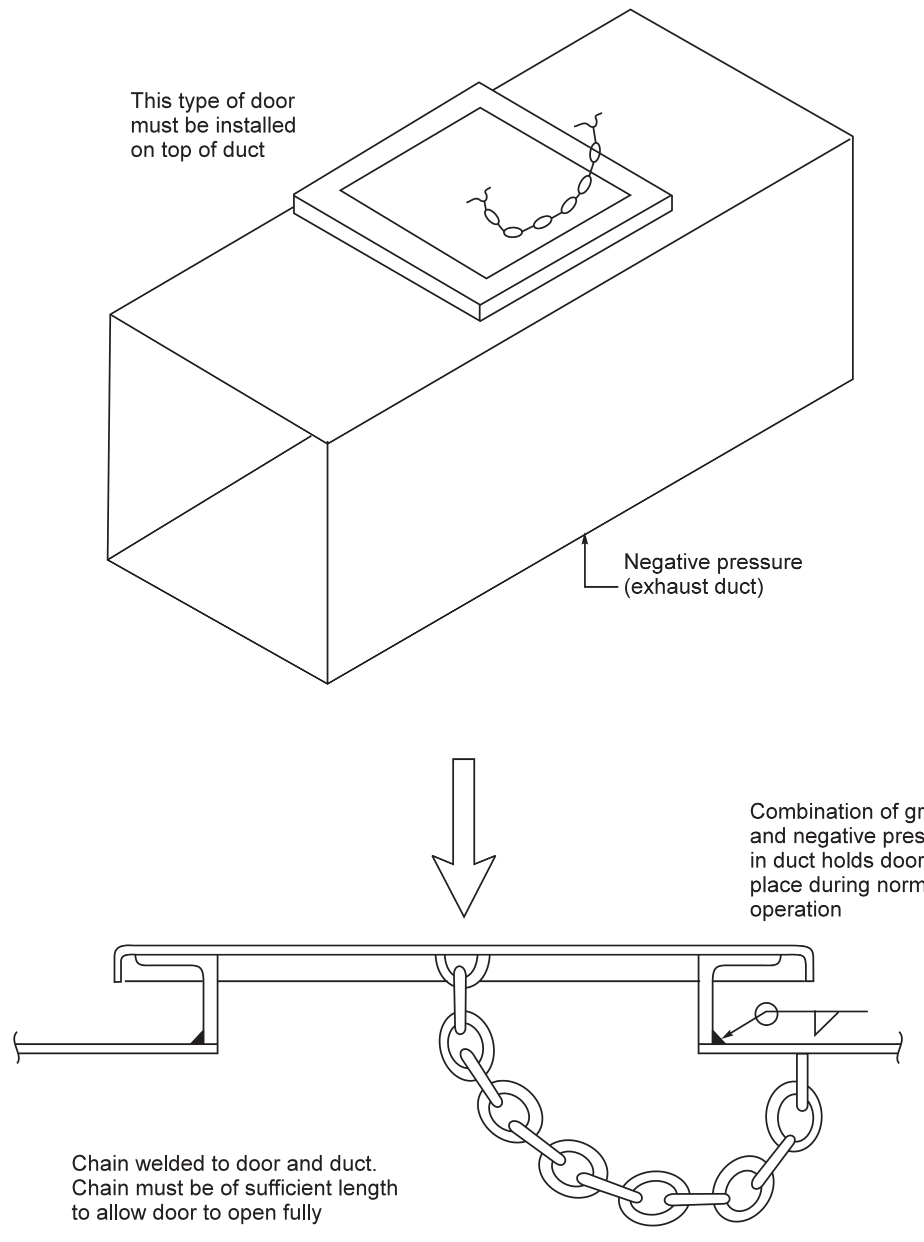
3.6 Corrosion Protection for Duct Sprinkler Systems

The best way to approach a corrosion problem is to first determine what corrosive media are formed by the process. The proper corrosion-resistant material can then be selected either to protect the base metal or to fabricate the whole sprinkler for mildly corrosive environments. Extremely corrosive acidic environments warrant a specialized protection approach as described in Section 2.2.2.



(Sheet Metal and Air Conditioning Contractors' National Association, Inc. Used with permission.)

Fig. 3. Pressure relief vents



(Sheet Metal and Air Conditioning Contractors' National Association, Inc. Used with permission.)

Fig. 4. Explosion door

Method 1. FM Approved Sprinklers

FM Approved wax, lead, or wax-over-lead coated sprinklers can be used with or without plastic bags (Method 2). The temperature of the environment in the duct should not exceed 150°F (66°C). FM Approved corrosion-resistant sprinklers are described under Method 4.

Method 2. Plastic Bags

Each FM Approved sprinkler in the duct can be protected with double polyethylene bags. Each bag should be maximum 4 mils (0.1 mm) thick and arranged to open to the outside, as shown in Figure 5. Teflon tape can be applied around the sprinkler deflector to limit abrasion of the bag.

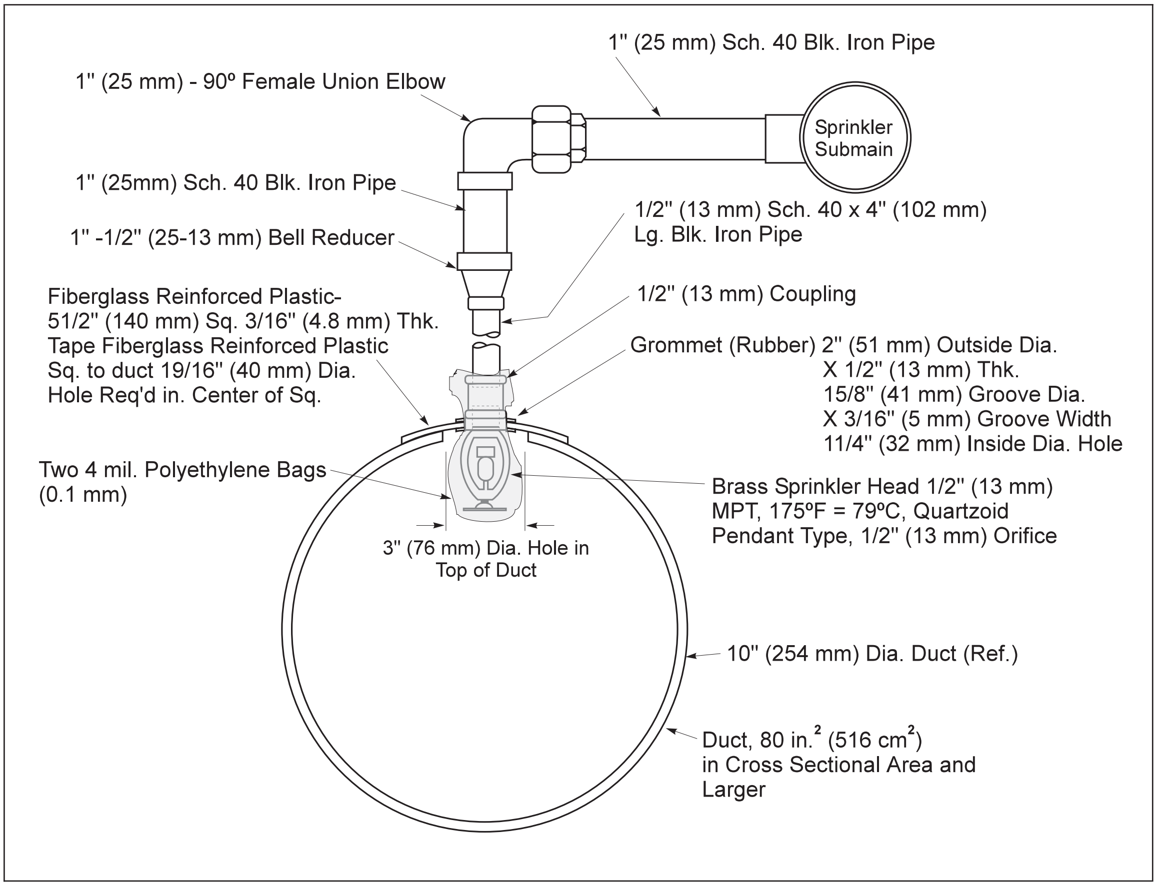


Fig. 5. Typical hard-piped sprinkler installation

The temperature of the environment in the duct should not exceed 150°F (66°C).

Method 3. Plastic-Coated Sprinklers

Sprinklers and piping can be coated with epoxy, tetrafluoroethylene (TFE) resin, or some other plastic resistant to the more mildly corrosive atmosphere.

The fusible element of the sprinklers should be of the center-strut, glass-bulb, or quartzoid type. The fusible element should not be coated because the temperature rating would be affected. The exposed surface of the center-strut fusible assembly, if used, should be made of a metal alloy resistant to the exposing corrosive medium. To ensure durability, the coating should be minimum 5 mils (0.13 mm) thick. The sprinkler manufacturer can select the best coating thickness if provided with the concentration and temperature of the corrosive environment involved. Special care must be used during sprinkler installation so the finish is not chipped or scratched.

When open coated sprinklers are installed, the heat detectors should be fabricated of corrosion-resistant metal alloys such as Hastelloy, stainless steel, Inconel, or their equivalent. The sprinklers should be covered with blowoff caps, or corrosion-resistant piping should be used.

The temperature of the environment in the duct should not exceed 250°F (121°C).

The two coatings most frequently used on sprinklers are epoxy resins and TFE. Epoxy resins are resistant to most alkalis and to many other chemical media. They adhere well to metal surfaces. Like other plastics, they are attacked by ketones, aromatics, and chlorinated hydrocarbons.

TFE is also resistant to a wide variety of chemicals. It is known to react only with elementary fluorine and with molten sodium. Some slight discoloration may occur in the TFE coating after extended periods at up to 250°F (121°C), but this will not affect the corrosion resistance.

Fig. 6. FM Approved flexible sprinkler hose connection, courtesy of Flexhead Industries, Inc.

Method 4. Special Alloy Sprinklers (Corrosion Resistant)

Sprinklers of metal alloys (such as Inconel, Monel, Hastelloy, etc.) or FM Approved sprinklers of stainless steel (Figure 7) can be used. These are effective against certain mildly corrosive environments, but not for extremely corrosive acidic environments. The manufacturers' specifications should be consulted. Sprinkler manufacturers also need to be consulted on their ability to produce sprinklers out of these special metal alloys, which may then be candidates for FM Approval.

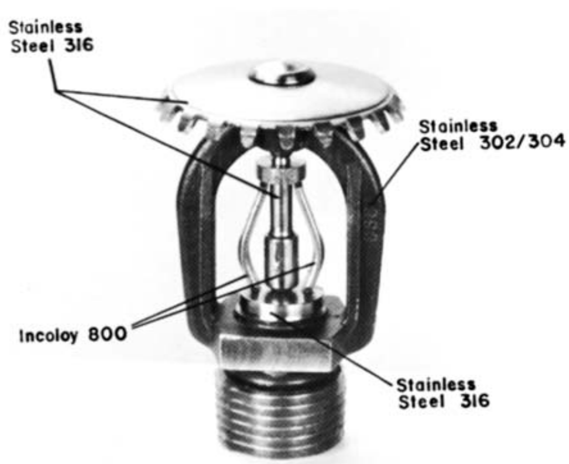


Fig. 7. Corrosion-resistant sprinkler.

The fusible assembly for these heads should be of the center-strut, glass-bulb type or any equivalent arrangement resistant to the environment. The valve cap of the head should be made of the same material as the sprinkler frame. The sealing between the sprinkler frame orifice and the valve cap can be provided with an O-ring arrangement made of a compound resistant to the exposing corrosive medium, or equivalent sealing arrangement.

Selection of the optimum construction material requires careful analysis of corrosion resistance, material cost, practicability of fabrication, installation, and maintenance.

Alloy manufacturers have researched the corrosive action of over 500 corrosives. A list of metal alloys has been selected that presumably would withstand the attack of approximately 90% of these. The following alloys are resistant to the greatest variety of corrosives:

- Inconel
- Types 316, 304/345, and 20Cb3 stainless steel
- Hastelloy
- Monel
- Incolloy

Method 5. Special Coated Duct Nozzles (Extremely Corrosive Environments)

An FM Global short-range research project (SRR), ″Corrosion Resistant Alloys for Fire Protection Nozzles,″ was initiated due to the need to find suitable alloys or materials that would stand up to some of the highly corrosive environments encountered. These ductwork systems designed to remove or filter these hazardous wastes can be found in large industrial metallurgical smelters for copper, lead, nickel, and zinc, where corrosive sulfur-based waste gases are collected, cleaned, dried in a gas cleaning plant, and then converted into sulfuric acid. They are also found in steel industry pickling lines, semiconductor fabrication facilities, pulp and paper plants (including bleach plants), inorganic chemical facilities, and the mining industry. These extremely corrosive environments typically involve acids such as sulfuric, hydrochloric, nitric, or hydrofluoric.

Feedback from the industries indicated that the types of corrosion-resistant sprinklers currently FM Approved and on the market were very limited in their application and generally not suited for the types of environments typically found in these highly corrosive atmospheres. Additionally, the end users have indicated that for a sprinkler alloy to be a viable product it would need to be able to stand up to the corrosive environments for at least one year or longer. Phase 1 of this SRR project dealt with alloys that had been found to be able to perform favorably in sulfuric acid environments, and this research was concluded with a technical report issued during early 2006. Research was unable to find any alloys that will stand up in the hydrofluoric/nitric acid environments. As such, further study was needed on this phase 2 area of work to focus on materials or metals with anti-corrosion coatings for these environments.

The completed phase 1 research work tested coupons of ten stainless steel and high-nickel alloys in a flue gas simulant for corrosion performance using crevice assembly immersion tests and electrochemical techniques in the laboratory. Four alloys (C22, C276, I686, and CW6M) were selected for field evaluation based on laboratory results. Eight coupon test racks were assembled, and sent to four different industrial exhaust systems for field testing. Field coupon exposures included both a sulfuric acid environment and a hydrofluoric/nitric acid environment. The results indicated that C22, C276, and I686 performed well in sulfuric acid pickling atmospheres; however, all four alloys suffered localized corrosion in the hydrofluoric/nitric acid atmosphere, with C22 ranked the best with the least corrosion among them.

The completed phase 2 research work focused on evaluating various coating systems on high nickel alloy C22 to ensure these devices would withstand severe hydrofluoric/nitric acid environments. This work also involved assembling test racks with various coated coupons evaluated at several field sites within their acidic industrial exhaust systems. Research concluded in 2007 and indicated that prototype nozzles fabricated from alloy C22 coated with ECTFE and ETFE coatings would be best suited for this environment.

The next step involved partnering with duct nozzle and linear heat detection manufacturers to develop prototype devices that would effectively withstand the extremely corrosive environments. This was satisfactorily done, and the final step to validate the technology was to install a small pilot corrosives sprinkler system. This was done in 2010 at an FM Global client site involving industrial exhaust ductwork housing mixed nitric/hydrofluoric acids. The system and its duct nozzles and linear heat detectors were satisfactorily function tested, and the testing and research program was concluded during late 2010.

To date (2016), only one sprinkler manufacturer has submitted a nozzle for FM Approval. The corrosion-resistant duct nozzle is now FM Approved and commercially available. This is an open, directional spray nozzle designed for use in water spray fixed systems for fire protection applications in extremely corrosive duct environments.

3.7 Control of the Corrosive Action of a Wet Environment

The corrosive action of an environment is increased when the moisture content is high. Should a duct system carrying a moist corrosive agent enter a zone of lower temperature, condensation may occur. If the condensate is corrosive, it will rapidly deteriorate the sprinkler system, other equipment in the duct, and possibly the duct itself. One of the preventive procedures outlined below may be helpful in lessening these effects:

A. Use an FM Approved plastic duct that does not require sprinklers.

B. Heat the environment in the duct system to a temperature above the dew point of the corrosive medium and/or insulate the duct system to prevent cooling of the corrosive medium to its dew point.

C. Cool the corrosive medium below its dew point before it enters the duct, and drain it to a safe location.

4.0 REFERENCES

4.1 FM Global

Data Sheet 1-13, *Chimneys*
Data Sheet 1-24, *Protection Against Liquid Damage*
Data Sheet 1-42, *MFL Limiting Factors*
Data Sheet 1-45, *Air Conditioning and Ventilating Systems*
Data Sheet 1-54, *Roof Loads for New Construction*
Data Sheet 1-56, *Cleanrooms*
Data Sheet 1-57, *Plastics in Construction*
Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 2-81, *Fire Protection System Inspection, Testing and Maintenance and Other Fire Loss Prevention Inspections*
Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*
Data Sheet 4-4N, *Standpipe and Hose Systems*
Data Sheet 4-5, *Portable Extinguishers*
Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations*
Data Sheet 5-48, *Automatic Fire Detection*
Data Sheet 5-49, Gas and Vapor Detectors and Analysis Systems
Data Sheet 6-9, *Industrial Ovens and Dryers*
Data Sheet 6-11, *Thermal and Regenerative Catalylic Oxidizers*
Data Sheet 7-6, Plastic and Plastic-Lined Tanks
Data Sheet 7-7/17-12, *Semiconductor Fabrication Facilities*
Data Sheet 7-12/17-17, Mining and Ore Processing Facilities
Data Sheet 7-73, *Dust Collectors and Collection Systems*
Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires*
Data Sheet 7-82N, *Storage of Liquid and Solid Oxidizing Materials*
Data Sheet 13-24, *Fans and Blowers*

Understanding the Benefit: *FM Approved Fume and Smoke Exhaust Ducts* (P10224)
Understanding the Hazard: *Fire in Industrial Exhaust Systems* (P0351)

4.2 Other

NFPA 70, *National Electrical Code*

APPENDIX A GLOSSARY OF TERMS

Extremely corrosive environment: Highly acidic process environments such as those found in flue gas desulphurization systems, metal acid pickling ducts, chemical industry exhaust systems, metallurgical gas cleaning, and acid plants. The corrosive environments encountered are typically sulfuric, hydrochloric, nitric, or hydrofluoric acids, and can also include a mixture of these acids.

FM Approved: Products and services that have satisfied the criteria for FM Approval. Refer to the Approval Guide, an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

APPENDIX B DOCUMENT REVISION HISTORY

January 2017. Revisions were made to Table 1 and Table 2 based on more current editions of the ACGIH®, *Industrial Ventilation Manual*.

July 2016. A complete review of this document was performed and editorial changes were made. Recommendations were added for the protection of runs of exterior combustible ductwork, plastic scrubbers, and plastic vessels.

July 2011. Recommendations have been added for the protection of combustible duct systems exposed to extremely corrosive environments.

January 2007. Editorial corrections were made to this document.

September 2000. This revision of the document has been reorganized to provide a consistent format.