PLASTIC DUCTS

INTRODUCTION

Plastic ducts continue to be the choice of many industries. The pulp and paper, electrical power generation, basic steel and electronics industries all have processes that produce corrosive atmospheres, which deteriorate most common metal ducts. Plastic ducts are also functionally desirable because of their lighter weight and ease of fabrication. However, fire can spread through the interior of plastic ducts where it is fully sheltered from the discharge of building sprinklers, and where it is extremely difficult to reach with extinguishers and hose streams. Manual fire fighting can be hampered further by the release of toxic smoke and the inability to exhaust both the smoke and the corrosive chemicals. Fire can also spread to associated equipment, such as scrubbers, de-misters and precipitators. Replacement of this equipment could take significantly longer than the duct replacement.

The consequences of a major fire in plastic ducts and associated environmental equipment are usually severe. This equipment is often custom built and can have long replacement times. Federal, state and some local governments are extremely concerned with pollution control, and will probably not grant a variance to run a process without this equipment. A lengthy interruption of production is inevitable. This can be further complicated when current laws require additional reductions in emissions.

Loss experience shows that plating rooms and wet chemistry areas of semiconductor fabrication facilities are the leading occupancies for fires involving ductwork. The most frequent cause of these fires is ignition by electric immersion heaters of plastic or plastic-lined tanks experiencing low liquid level. In many losses, low liquid level alarms and shutoffs failed due to the corrosive environments, internal shorting of wiring and inadequate maintenance and testing programs. Losses in this category are becoming less frequent but significantly more expensive.

Plastic ducts should only be used where materials being removed are not compatible with metallic ducts. Do not use plastic ducts for flammable gas or flammable and combustible liquid fume exhaust.

POSITION

Where fire is the primary concern, whenever possible use metallic ducts, including stainless steel. Use plastic ducts only for handling materials corrosive to metals. Confirm that plastic ducts have a flamespread rating of 25 or less when tested in accordance to ASTM E84. Since the ASTM E84 tunnel test cannot be used on materials that melt and drip when tested, nonreinforced polyolefin (polypropylene, polyethylene) ductwork cannot be tested and will not have a flame spread rating. Avoid use of these types of ducts wherever possible.

In semiconductor fabrication facilities and other cleanroom occupancies the losses from contamination can greatly exceed the potential fire loss. The use of metallic ducts is even more important in these occupancies. Further guidance can be found in PRC.17.11.1, PRC.17.11.0, and PRC.17.1.1. These sections further restrict the conditions in which plastic duct can be safely used.

Interior Duct Protection

Provide fixed automatic sprinkler or CO_2 protection inside all plastic ducts with cross-sectional area exceeding 100 in.² (645 cm²) (approximately 11.3 in. [28.7 cm] in diameter) whenever any of the following apply:

- Combustible dusts, combustible residues (including precipitation of combustible and flammable liquids) or oxidizing materials are likely to accumulate inside the ducts.
- Ducts are **NOT** one of these types:

    Factory Mutual listed as not requiring sprinklers. Ducts must be tested and approved in accordance with FM 4922.

    Unplasticized polyvinylchloride (PVC) ducts with walls less than ¼!/4 in. (6.3 mm) thick.

Some of the plastic duct arrangements allowed by this section may not be appropriate in some occupancies, such as cleanrooms, due to high values or a high level of required cleanliness. The loss from contamination could significantly exceed the expected fire loss in these occupancies. Some ducts use dampers or interrupters to obtain the FM listing. This would back-up chemicals from processes and contaminate the room. In ducts with CO_2 protection dampers are sometimes used to help retain the needed concentration of gas. While it is effective in containing the gas to help extinguish the fire, it shuts down the exhaust. The model building codes and NFPA 318 require maintaining the exhaust for hazardous processes in semiconductor manufacturing. For further examples, see PRC.17.11.1.

Protect the interior of ducts by one of the following methods:

Closed Head Sprinklers

Use pendent sprinklers with ½ in. (15 mm) nominal orifices. Select the temperature rating in accordance with NFPA 13 for the anticipated maximum temperature. Glass bulb types are preferred because the rating chosen can be closer to the maximum expected ambient temperature. Do not exceed 20 ft (6.1 m) between sprinklers in either vertical or horizontal runs.

Hydraulically size the sprinkler system piping for a minimum of 30 psi (2 bar) operating pressure at each of the five most hydraulically remote sprinklers for ducts with a diameter of 24 in. (610 mm) or greater, and 15 psi (1 bar) for ducts with diameter less than 24 in. (610 mm). Run piping outside the duct and extend only the sprinklers into the duct interior. Provide a readily accessible, indicating type control valve in the feed main to the duct sprinklers. Provide waterflow alarm supervision to the facilities alarm system.

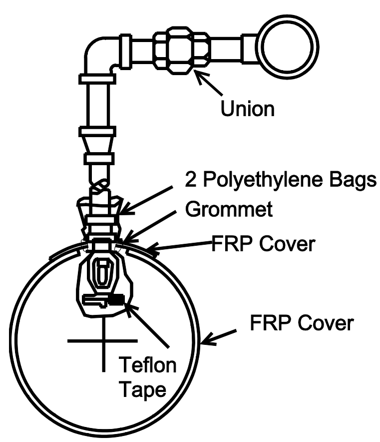

Figure 1. Method Of Protecting Sprinklers In Ducts Handling Corrosive Fumes.
Reprinted from the March 1978 Fire Journal (Vol. 72, No. 2).

In duct systems handling corrosive fumes, protect sprinklers against corrosion by one, or a combination, of the following methods:

- Use listed wax-coated or lead-coated sprinklers. Stainless steel sprinklers are also available and acceptable.
- Wrap two 1 mil (0.03 mm) thick polyethylene bags around each sprinkler. Cover deflector edges with Teflon® tape so they will not cut the bags. See Figure 1.
- Utilize the commercial bagging system specifically designed for listed flexible piping/ sprinklers head devices.
- Dip sprinkler heads and pipe drops into USP-grade liquid beeswax at least three times. Dip only sprinkler heads with a temperature rating of 212°F (100°C) or higher. Note: Dipping of a sprinkler in beeswax essentially loads the sprinkler and voids the listing. Contact the Authority Having Jurisdiction before this method of sprinkler protection is used.

In 1998 tests were performed at Underwriters Laboratories, Inc. to evaluate the response time of various sprinkler protection methods. Listed wax coated sprinklers; heavy and light bagging over ordinary sprinklers; heavy and light bagging over listed wax coated sprinklers and the commercially available bagging system were tested. All protection methods and reasonable response times were observed when installed in plastic duct. Dipped heads were not tested in this series of tests. They performed satisfactorily in earlier tests. These tests also showed the exhaust capacity in duct was reduced by less than 15% with one operating sprinkler.

Open Head Sprinklers

This mode of protection is recommended if closed head sprinklers might operate too slowly, such as when highly combustible deposits. e.g., wax, unusually high air flow rates (greater than 50 ft/s [15 m/s]), or high flamespread (greater than 75) duct material is expected or encountered. Actuate open sprinklers with fixed temperature detectors protected against corrosion, e.g., Teflon®-coated, and spaced in accordance with their listing for smooth ceilings or for use inside ducts. Fixed temperature detectors have faster response times and are available with lower temperature ratings than sprinkler heads.

Protect nozzles against plugging and corrosion with blow-off plastic covers or bags. Hydraulically size the system to provide a density of 0.15 gpm/ft^2 (6.0 L/min/m^2) over the protected area. Run piping outside the duct and extend only the nozzles into the duct interior. Control the deluge system in each continuous run of ductwork with a single valve. Install manual trips for the deluge systems at strategic, readily accessible locations.

Carbon Dioxide

Design CO_2 systems in accordance with NFPA 12 and PRC.13.3.1. Base the design on total flooding of any continuous run of duct. Provide double-shot protection. Actuate the system with fixed temperature detectors protected against corrosion, e.g., Teflon®-coated, and spaced in accordance with their listing for smooth ceilings or for use inside ducts. Install manual pull stations at strategic, readily accessible locations.

Allow for loss of agent through intake openings and during fan coastdown time. Interlock all duct system fans to shut down before agent discharge. Where exhaust fans must remain operating, consider other types of protective systems.

General Protection

Provide overhead sprinkler protection in areas containing plastic ducts as follows:

- In areas of combustible construction or occupancy, regardless of duct type.

- In all other areas, including concealed spaces, unless they contain only single runs of duct that are either sprinklered inside or an acceptable construction type (see page 2). However, no plastic ducts of any type should be run through air plenums.

Where automatic sprinkler or water spray systems protect the interior of ducts, arrange the duct systems so that water from the protective systems neither introduces a hazard nor presents unnecessary damage potential. To accomplish this:

- Slope ductwork away from tanks containing molten salt or other water-reactive materials, and away from high-temperature equipment. Provide duct to this equipment from connections entering the top of the main duct.
- Design duct hangers and the structure supporting the ducts to withstand the weight of the ductwork when filled with water.
- Provide low-point drains in main duct runs at intervals not exceeding 50 ft (15 m). Size the drains for the anticipated protective system discharge, or use 3 in. (75 mm) diameter drains, whichever is larger. Account for both horizontal and vertical duct runs in the drainage design. Seal the drains with spring-loaded or friction-retained caps that will release under the weight of accumulated water and discharge to a safe location.

Install quick-opening access panels for inspection, cleaning and firefighting purposes in major horizontal headers at intervals not exceeding 100 ft (30 m). Install panels at every sprinkler head or nozzle in protected ducts. Provide permanent ladders or platforms for reaching each panel.

Do not penetrate any rated floor wall or partition with plastic duct. Where needed, provide a chase of equal rating until the duct leaves the building.

Where plastic ductwork serves tanks containing heated solutions, such as plating or pickling tanks, steam or hot water immersion heaters or external heat exchangers are preferred. Arrange tanks with electric immersion heaters in accordance with PRC.9.5.1.

Locate 1 in. (25 mm) hose connections equipped with 50 ft (15 m) of 1½ in. (40 mm) woven-jacket, lined fire hose and adjustable spray nozzles to provide coverage for all access panels in the ductwork. Provide at least two self-contained breathing apparatus units for use by trained personnel in fighting a fire involving plastic ductwork.

DISCUSSION

Fiberglass-Reinforced Plastic Ducts

Fiberglass-reinforced plastic (FRP) ducts should not be confused with the fibrous-glass ducts used in air conditioning systems. The latter are designed to handle building air efficiently while deadening sound transmission and providing a high degree of insulation. Usually available in ¼ in. – 1 in. (6 mm – 25 mm) thickness, fibrous-glass ducts are constructed of fiberglass mats containing only enough resin binder to achieve sufficient rigidity and resistance to external penetration. The exterior may be coated with a vinyl film or other thin covering. Both Underwriters Laboratories Inc. and Factory Mutual list this type of duct for use in air conditioning systems.

The FRP duct, on the other hand, is basically a plastic product with glass fibers added to increase strength. These ducts are designed to overcome the corrosion problems of metallic ductwork in hostile environments and usually have wall thickness of ⅛ in. – ¼ in. (3 mm – 6 mm). Unfortunately, there is a tendency to assume these ducts are noncombustible because they contain glass fibers. However, the glass fibers constitute only 20% – 35% of the finished material. Also, larger diameter ductwork may have an inner lining and outer facing of glass-reinforced plastic, with a 1 in. or 2 in. (25 mm or 50 mm) annular ring between them filled with polyurethane foam.

The resin in most corrosion-resistant FRP ducts is polyester. Four different types of polyesters are commonly used:

- Chlorinated resins

- One hundred percent Bisphenol-A resins
- Resins containing Bisphenol-A and Isophthalic acid
- Hydrogenated Bisphenol resins

Polyester resin glass fiber-reinforced ductwork can therefore have a wide range of combustibility. One manufacturer's ducts, for instance, exhibit flamespread ratings anywhere between 25 and 250.

Small quantities (usually 5%) of antimony trioxide may be added to any of these duct formulations to increase fire retardancy. However, the ducts must still be considered combustible. Fire retardants make ducts harder to ignite, but once ignited, the ducts may burn like untreated ducts. Also, fire retardancy tends to decrease with age.

Flamespread ratings are the result of ASTM E84 tunnel tests on flat specimens of the FRP material. The basic weakness in this standard test is that it does not reflect the effects of reradiation, air movement and elevated temperatures that can be expected in an actual duct.

The lack of documentation correlating automatic sprinkler operation with fire propagation in ducts has led to full scale testing of specific duct materials and methods of protection. FM Global Corporation, for instance, uses a full scale test array (Approval Standard 4922) consisting of 24 ft (7.3 m) of the duct in question with an exhaust fan at one end and a 1 ft^2 (0.09 m^2) pan of burning heptane exposing the other end.

A minimum of two tests are run with varying air velocities, one of which is 600 ft/m (183 m/min). The duct passes the 15-min test if flame does not spread the full length of the duct and if the temperature does not exceed 1000°F (538°C) inside the duct 23 ft (7 m) from the exposed end.

The protection arrangement shown in Figure 1 was also subjected to full scale testing by Texas Instruments in 1976. The results of this test work were the subject of a paper presented by D. L. McLaughlin at the NFPA Fall Meeting in 1977 and of an article published in the March 1978 *Fire Journal*.

It is advisable to leave exhaust fans running where interior sprinkler protection has been provided. Loss experience and test results indicate that operating sprinklers will intercept the interior duct fire. Leaving the exhaust fans in operation will help maintain control of any toxic gases given off during normal operations while also channeling off gases and smoke from the fire scene, thus assisting manual extinguishing efforts.

Polyvinylchloride Ducts

Despite indications that a major segment of all ductwork is made of PVC, no significant losses can be identified in which PVC ductwork was the major contributor to flamespread or fire intensity. PVC duct has been consumed or damaged by exposing fires, but normally this has been of secondary importance in the loss.

Analyses of all available losses and some large-scale testing suggest that ducts made of this thermoplastic halt fire spread by collapsing ahead of any flame propagation in the duct. This phenomenon, coupled with an inherent degree of fire retardancy, seems to limit the degree to which PVC ducts become involved in a fire situation.