SPRAY APPLICATION OF IGNITABLE AND COMBUSTIBLE MATERIALS

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1.0 SCOPE

This data sheet contains recommendations for the prevention of and protection against fires and explosions in the spray application of ignitable liquid coatings and combustible solid coatings (i.e., powder coatings).

The following areas associated with spraying operations are not covered in this document:

- Ignitable liquid mixing rooms (also known as paint kitchens); see Data Sheet 7-32, *Ignitable Liquid Operations.*
- Ignitable liquid storage in excess of a one-shift supply; see Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers.*
- Dust collection equipment; see Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires.*
- Exhaust systems; see Data Sheet 7-78, *Industrial Exhaust Systems.*

1.1 Hazard

1.1.1 Spray Application of Ignitable Liquids

The key hazards associated with the spray application of ignitable liquids are the spray itself, vapor, and residue. Spraying ignitable liquid makes ignition more likely and increases the heat release rate of the fire.

If the liquid being sprayed ignites, the spray fire can be the ignition source for any combustible materials within the spray booth/room (including the room's construction). The only way to prevent an uncontrolled spray fire is to shut off the fuel supply.

Vapor also increases the likelihood of ignition and, in an enclosed spray area, can support an explosion. Providing ventilation mitigates this hazard.

A fire growing in an unsprinklered spray booth is similar to a fire growing within a concealed space. Any combustibles (e.g., workpieces, overspray residue deposits, combustible construction of booth) will contribute to the fire.

Automatic shutoffs on pumping supplies, ventilation, and sprinklers within the spray area will minimize and protect from these hazards.

1.1.2 Spray Application of Combustible Solids

The key hazards associated with the spray application of combustible solids (i.e., powder coatings) are the spray itself and the overspray.

The ignition source for the fire is usually an arc from electrostatic spray equipment. If the powder supply is not shut down promptly, the fire can ignite the powder spray. This hazard is more prevalent in automatic spray booths if an automatic shutdown for the powder supply is not provided. With manual spray equipment, once the operator releases the trigger, the powder flow is interrupted.

A fire involving the powder spray can spread to involve any powder overspray present within the booth. If burning particles of powder are drawn into the associated dust collection equipment, an explosion or fire can result in that equipment. A secondary dust explosion can occur in the booth if fugitive dust is present.

During normal operation, the hazard of a dust explosion within the booth is minimized by keeping the interior below the minimum explosive concentration of the powder.

A fire growing in an unsprinklered booth is similar to a fire growing within a concealed space. Any combustibles (e.g., workpieces, combustible powder deposits, combustible construction) will contribute to the fire. Many powder booths are constructed of combustible plastic materials.

Automatic shutoffs for equipment, explosion venting on dust collection equipment, ventilation, and sprinklers will minimize and protect from these hazards.

1.2 Changes

April 2018. Interim revision. Minor editorial changes were made.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Spray Application of Ignitable Liquids

2.1.1 Introduction

Use FM approved equipment, materials, and services whenever they are applicable and available. For a list of products and services that are FM approved, see the *Approval Guide,* an online resource of FM Approvals.

2.1.2 Construction and Location

2.1.2.1 Construct spray booths/rooms of noncombustible materials. Do not use metal sandwich panels that have combustible plastic insulation. Use smooth surfaces to facilitate cleaning.

2.1.2.2 Locate spray operations that severely expose surrounding occupancies to fire, water, or smoke in a detached, one-story spray building or a 1-hour fire-rated cutoff room on an outside wall at grade level.

2.1.2.3 Do not locate spray operations in below-grade locations.

2.1.2.4 Use FM Approved ignitable liquid storage cabinets to store small amounts of ignitable liquid within the booth/room.

2.1.2.5 Construct and locate associated ignitable liquid mixing rooms (also known as paint kitchens) and storage areas in accordance with Data Sheets 7-32, *Ignitable Liquid Operations,* and 7-29, *Ignitable Liquid Storage in Portable Containers.* (See Figure 1.)

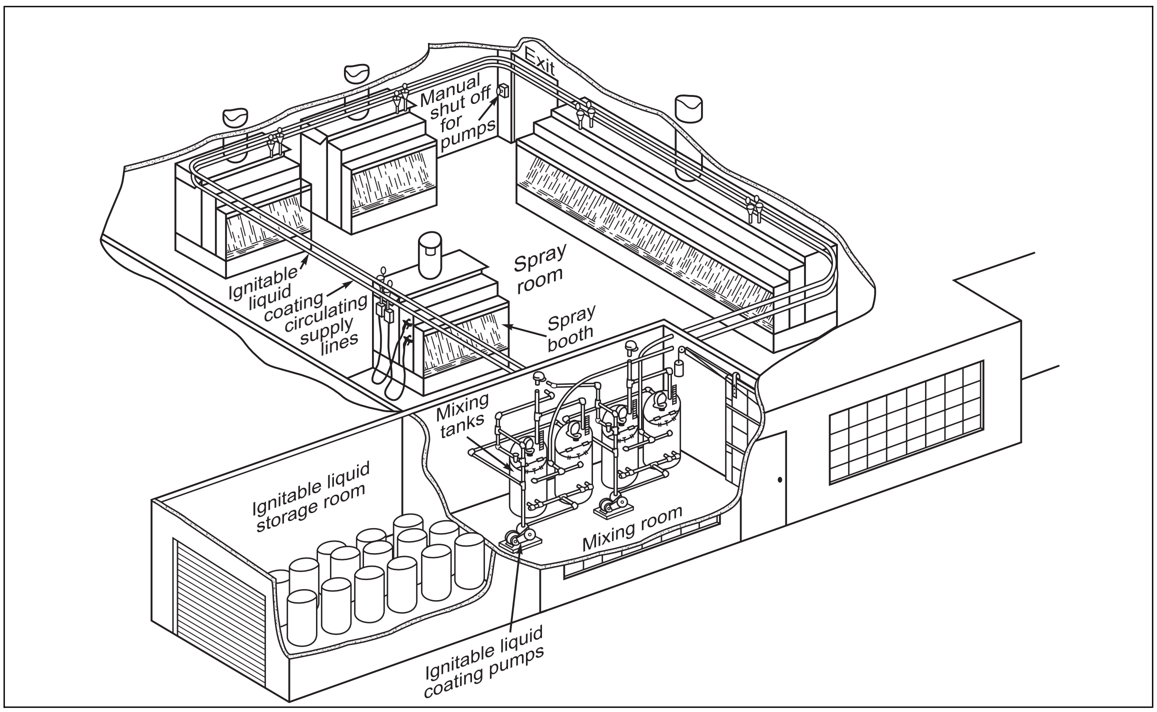

Fig. 1. Spray room with water wash spray booths, cut-off ignitable liquid mixing room, ignitable liquid distribution system and cut-off ignitable liquid storage room (sprinkler protection and automatically actuated remote shutoff for pumps not shown)

2.1.2.6 Design for uniform air movement toward the exhaust outlet to prevent pocketing of overspray residue.

2.1.2.7 If baffle plates are present in the booth, ensure they are easily removable or accessible for cleaning on both sides.

2.1.2.8 Construct exhaust ducts in accordance with Data Sheet 7-78, *Industrial Exhaust Systems.*

2.1.2.8.1 Do not install baffles in exhaust ducts.

2.1.3 Occupancy

2.1.3.1 General

2.1.3.1.1 Limit the quantity of ignitable liquid staged in or near the spray booth/room to a one-shift supply, but no more than 120 gal (450 L). Locate quantities in excess of this in a cutoff room in accordance with the recommendations in Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers.* (See Figure 1.)

2.1.3.1.2 Avoid using incompatible materials in the same spray area. If used, clean the area thoroughly each time the material is changed. Examples of hazardous combinations are the following:

A. Nitrocellulose materials may spontaneously ignite in contact with materials containing drying oils (e.g., varnishes, oil-based stains, air drying enamels, primers).

B. Oxidizing or bleaching compounds (e.g., hydrogen peroxide, hypochlorites, perchlorates) in contact with organic materials.

2.1.3.1.3 Do not use combination spray/cure booths for materials subject to spontaneous heating (i.e., avoid the use of materials mentioned in 2.1.3.1.2.A).

2.1.3.2 Ventilation

2.1.3.2.1 Design the mechanical ventilation system to dilute flammable vapor to a concentration not exceeding 25% of its LEL (see Data Sheet 6-9, *Industrial Ovens and Dryers,* for example calculations). Where spray booth exhaust air is recirculated, provide LEL detection to alarm at 25%, and interlocks to shut down spraying operations at 50%. (See Figure 2.)

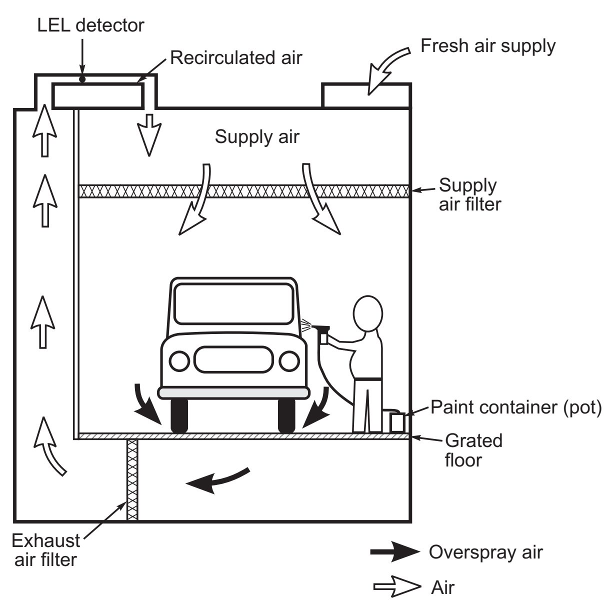

Fig. 2. Dry filter (down draft) spray booth with air being recirculated into booth; LEL detector is also shown (sprinkler protection is not shown)

2.1.3.2.2 Design the mechanical ventilation system to confine overspray residue to the spray area as follows:

A. Electrostatic spray operations: Provide a minimum average air velocity across booth openings of 60 ft/min (20 m/min).

B. Other spray operations: Provide a minimum average air velocity across booth openings of 100 ft/min (30 m/min).

C. Increase the minimum flow rates in (A) through (B) above to compensate for external conditions near the spray operation (e.g., drafts from windows and doors) that may reduce the flow rate.

D. Calculate the minimum flow rates in (A) and (B) above assuming worst-case filter conditions (i.e., just before the filter needs to be replaced). It may be necessary to increase the air velocity when a spray operation is new because gradual loading of the filter will decrease air flow.

E. For spray operations coating large objects, such as tank cars or trucks, calculate air velocity assuming the object to be coated is in place. If objects range in size, base the calculations on the smallest object.

2.1.3.2.3 In dry spray booths, install a device to activate an alarm (audible and/or visible) if air velocity falls below the recommended minimum. (See Figure 3.)

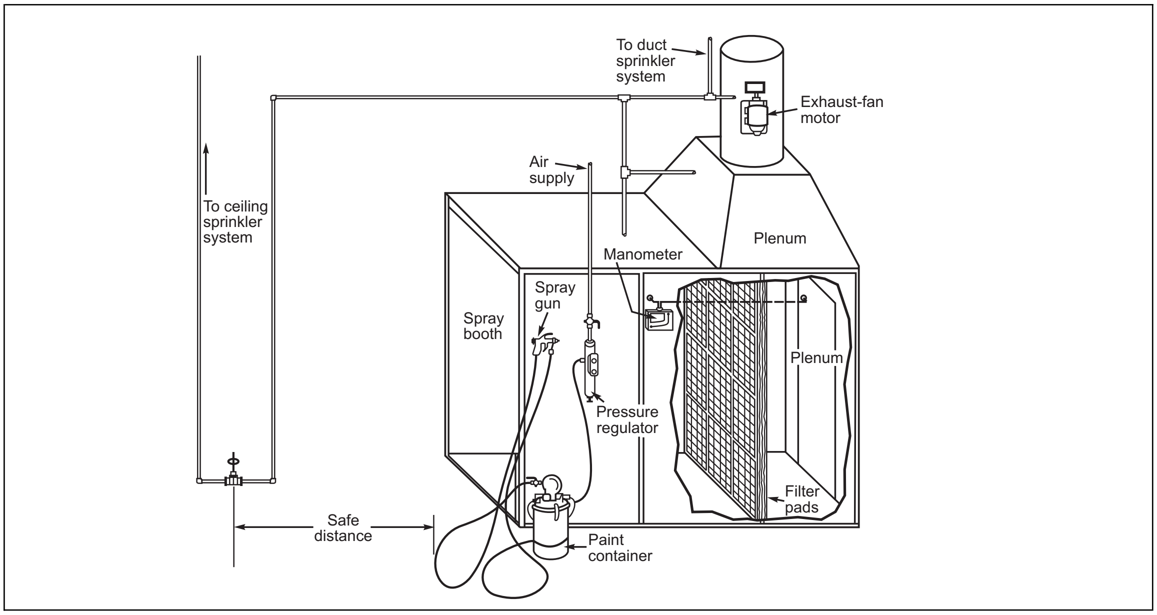

Fig. 3. Dry filter (open-face) spray booth equipped with filter pads; gauge used to indicate minimum air velocity is also shown

2.1.3.2.4 Design mechanical ventilation so the spraying equipment will not start up or run if the ventilation system is inoperable (e.g., using interlocks with airflow in the ductwork, interlock with compressed air supply or spray gun for manual paint pot operations, differential pressure across fans).

2.1.3.2.5 Maintain ventilation following completion of the spraying operation for a sufficient time to allow vapor and residue to be exhausted.

2.1.3.2.6 Shut down ventilation in the event of a fire in the spray booth/room in accordance with Section 2.1.5.3.

2.1.3.2.7 For ambient air drying (flash-off) areas associated with the spray operation, provide mechanical ventilation in accordance with Recommendation 2.1.3.2.1.

2.1.3.2.8 Remove exhaust air through a system of blowers, fans, and ductwork terminating outside away from equipment, air inlets, doorways, and other openings.

2.1.3.2.9 Provide independent exhaust ductwork for each spraying operation, and run the ducts as directly as possible to the outdoors with a minimum of bends.

2.1.3.2.10 Where it is not possible to provide independent exhaust ductwork for each spraying operation due to regulatory requirements, design manifolded exhaust systems as follows:

A. Do not use materials that are likely to react and cause ignition of residue in the duct.

B. Do not use nitrocellulose-based materials.

C. Adhere to the recommendations in Data Sheet 6-11, *Thermal and Regenerative Catalylic Oxidizers.*

2.1.3.2.11 Design make-up air systems as follows:

A. Use outside air as make-up air for spray operations.

B. If make-up air is taken from other facility areas, keep those areas free of ignitable liquids.

C. Separate air make-up units from booth exhaust outlets to prevent overspray being drawn into the air make-up units.

2.1.3.3 Control of Overspray

2.1.3.3.1 Establish and implement a housekeeping program for the spray area and areas exposed to overspray residue (e.g., booth/room, plenum area, exhaust ducts, and area on the roof around exhaust ducts). Clean up spills promptly. Do not store combustible materials in the spray area.

2.1.3.3.2 Establish cleaning frequencies so overspray residue deposits do not exceed approximately 1/8 in. (3 mm) in thickness. Frequency need not be greater than daily.

2.1.3.3.3 Apply aids such as strippable coatings and plastic films to the walls to assist with cleaning. Use nonferrous scraping tools to remove overspray residue. Keep residue wet with water while cleaning.

2.1.3.3.4 Monitor overspray residue accumulation within the spray area. Excess overspray residue is an indication of improper system operation. In this case, investigate and address the root cause by maintenance, as opposed to increasing cleaning frequencies.

2.1.3.3.5 If an ignitable liquid is used for cleaning, use a liquid that has as high a flashpoint as possible, but not below 100°F (38°C). Keep ventilation on when cleaning with ignitable liquids.

2.1.3.3.6 Do not use halogenated solvents to clean aluminum components.

2.1.3.3.7 For electrostatic spray operations, carry out cleaning operations with the following safeguards:

A. De-energize the power supply.

B. Ground the ignitable liquid cleaning container.

C. Ensure the ventilation system is in operation.

2.1.3.3.8 If large quantities of overspray are found outside spray booths, or if during spray operations overspray can be seen escaping the booth, evaluate facility operating procedures and booth ventilation systems. This may mean doing the following:

A. Limiting lengths of hose to spray guns so operators cannot spray outside the booth.

B. More frequently cleaning or replacing filters to maintain capture velocities.

C. Sealing openings in ducts such as penetrations for fan drives and automatic sprinklers.

D. Measuring air flow during normal spraying operations to determine whether fans are adequately sized, and replacing fan(s) not adequately sized to contain overspray.

2.1.4 Protection

2.1.4.1 Provide automatic sprinkler protection in the spray booth/room, in any associated drying areas (i.e., flash-off areas), and at ceilings above booths.

2.1.4.2 Design the sprinkler system as follows:

A. Protect the surrounding occupancy per the relevant data sheet.

B. Design the sprinkler system in the spray booth/room in accordance with Hazard Category 3 (HC3) per Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties.*

C. Where it is critical to limit fire damage to expensive spray equipment and minimize lengthy business interruption, in addition to the sprinklers recommended above for the spray booth/room, provide deluge sprinklers and position these over the critical specific equipment within the booth/room. Alternatively, provide a deluge system to protect the entire spray booth/room. Design the deluge sprinklers to provide 0.3 gpm/ft^2 (12 mm/min). Arrange the system so it is automatically actuated by optical detectors located to cover the discharge from all spray guns and at ceiling level.

2.1.4.3 Install the sprinkler system in accordance with Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers.*

2.1.4.4 Provide sprinkler protection designed for HC3 for all concealed spaces with combustible materials (e.g.,in housings and tracks containing ignitable liquid pipework).

2.1.4.5 Provide sprinklers designed for HC3 in all extract plenum areas where combustible residue could accumulate (e.g., in downdraft water wash tank areas below the booth's operating level). If corrosive coatings are used, install corrosion-resistant piping, pipe hangers, and sprinklers in these areas.

2.1.4.6 Provide sprinklers for combustible incoming and/or outgoing filters.

2.1.4.7 Cover automatic sprinklers that are subject to accumulation of overspray residue with thin plastic or paper bags. Replace covers frequently so heavy deposits of residue do not accumulate.

2.1.4.8 Protect ignitable liquid mixing and dispensing areas in accordance with Data Sheet 7-32, *Ignitable Liquid Operations.*

2.1.4.9 Protect ignitable liquid storage areas in accordance with Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers.*

2.1.4.10 Protect ovens in accordance with Data Sheet 6-9, *Industrial Ovens and Dryers.*

2.1.4.11 Protect ventilation ducts in accordance with Data Sheet 7-78, *Industrial Exhaust Systems.*

2.1.4.12 Provide indicating control valves for sprinkler systems in individual spray booths or rooms. Locate them in an easily accessible place.

2.1.4.13 Provide portable extinguishers. Use extinguishers appropriate for the expected fire hazard. Refer to Data Sheet 4-5, *Portable Extinguishers,* to determine effective sizes and locations for the extinguishers.

2.1.5 Equipment and Processes

2.1.5.1 General

2.1.5.1.1 Design and construct pressure vessels used to supply coating materials in accordance with all applicable local codes, standards, laws, and regulations, such as the ASME Boiler and Pressure Vessel Code or international equivalent. Guidelines are provided in Data Sheet 12-0, *Applicable Pressure Equipment Codes and Standards.*

2.1.5.1.2 Arrange manual handling of ignitable liquids in accordance with Data Sheet 7-32, *Ignitable Liquid Operations.*

2.1.5.2 Piping Systems

2.1.5.2.1 Locate and arrange ignitable liquid transfer equipment and piping in accordance with Data Sheet 7-32, *Ignitable Liquid Operations.*

2.1.5.2.2 For piping in the spray booth/room, use noncombustible fire-resistive components (e.g., metal). Where flexibility is required, use the following, in order of preference:

A. Corrugated metal hose.

B. Reinforced rubber hose with a synthetic liner and metal-braid covering.

C. Other hoses if adequately interlocked per Section 2.1.5.3.

2.1.5.3 Emergency Shutdown

2.1.5.3.1 For automatic spray operations and associated pumping or transfer systems, provide an automatically actuated means of shutting down the flow of ignitable liquid, conveyors, ventilation, and the high-voltage power supply (if applicable) in the event of a fire in the spray booth/room.

This may be accomplished using one or more of the following methods:

A. Actuation by use of detectors located within the spray area and any shielded areas. Ensure FM Approved optical or heat detectors are located as recommended in Data Sheet 5-48, *Automatic Fire Detection,* and the relevant FM Approval listing. Also consider factors specific to the spray operation, such as ventilation and make-up air systems, that could impact detector operation.

B. Operation of the automatic sprinkler system.

Additional guidance is contained in Data Sheet 7-32, *Ignitable Liquid Operations.*

2.1.5.3.2 If all of the following features are present, it is tolerable for ventilation to keep running in the event of a fire:

A. Where closed-type sprinklers are installed, the air velocity within the spray area is less than 300 ft/min (90 m/min) so there is no delay in sprinkler activation.

B. The spray operation has an independent exhaust system (i.e., no common ductwork shared between spray operations) and the exhaust goes straight to atmosphere.

C. There is sprinklered ductwork or noncombustible ductwork with no combustible residue.

D. Recirculated air is shut down.

2.1.5.3.3 For manual spray operations, provide the following:

A. A deadman-type control or self-closing valve (so release of the spray gun stops ignitable liquid transfer).

B. Normally closed solenoid valves on pressure pots.

C. Shut down ventilation in the event of fire in the spray booth/room unless all the features listed in Recommendation 2.1.5.3.2 are present.

2.1.5.3.4 Provide one or more emergency shutdown buttons or switches within the operation area (arranged for easy access by the operators and at points of egress from the building) and at accessible remote locations (e.g., control room, security station) to allow for manual shutoff of the ignitable liquid system.

2.1.5.4 Dry Spray Booths

2.1.5.4.1 Do not use incompatible finishing materials in a dry booth unless filters are replaced each time the finishing material is changed.

2.1.5.4.2 Use noncombustible overspray collector filter pads or rolls.

2.1.5.5 Water Wash Spray Booths

2.1.5.5.1 Where a water curtain is used, arrange the booth exhaust so it cannot be operated unless the pump is in operation.

2.1.5.5.2 Arrange water pan booths so the distance between the water level in the sump and the baffle is automatically maintained during spray operations.

2.1.5.6 Combination Spray/Cure Areas

2.1.5.6.1 Use FM Approved drying equipment for radiant drying equipment that is permanently located in the spray area.

2.1.5.6.2 Interlock spraying equipment and the drying apparatus to achieve the following:

A. The drying apparatus automatically shuts off if air temperature exceeds 200°F (93°C).

B. The drying apparatus cannot be energized with spray equipment in operation.

2.1.5.6.3 Provide explosion venting, ventilation, and fuel-fired equipment as recommended in Data Sheet 6-9, *Industrial Ovens and Dryers.*

2.1.5.7 Electrostatic Spray Application

2.1.5.7.1 Provide automatic electrostatic apparatus with interlocks to de-energize the high-voltage power supply in the event of the following conditions:

A. Loss of mechanical ventilating equipment.

B. Stoppage of the conveyor, unless stoppage is required by the spraying operation.

C. The occurrence of a ground or excessive current leakage at any point on the high-voltage system.

D. Fire

2.1.5.8 Catalytic Spray Application

2.1.5.8.1 Construct equipment that will be in contact with organic peroxides of stainless steel (300 Series), polyethylene, Teflon, or other material specifically recommended for this application.

2.1.5.9 Hot Spraying Systems

2.1.5.9.1 Use FM Approved Class I, Division 1 (Zone 1, Zone 0) electric resistance heaters to directly heat materials.

2.1.5.9.2 Locate heaters outside areas where they may accumulate overspray deposits.

2.1.5.9.3 Interlock heater controls with the exhaust fan so the material can only be heated while the exhaust fan is in operation.

2.1.5.9.4 Drain and clean heaters used for materials susceptible to spontaneous heating during idle periods.

2.1.5.9.5 Cover steam pipes that are within 10 ft (3 m) of a spray area with insulation. Provide a clearance of at least 1 in. (25 mm) between such insulation and any combustible material or construction.

2.1.5.10 Steam Spray Application

2.1.5.10.1 Cover steam pipes within 10 ft (3 m) of a spray area with insulation. Provide a clearance of at least 1 in. (25 mm) between such insulation and any combustible material or construction.

2.1.5.10.2 Do not locate the boiler within the steam spray operation area.

2.1.5.11 Airless Spray Application

2.1.5.11.1 Equip positive displacement pumps with a relief valve discharging to a safe location (coating material container). Provide compressed-air-driven pumps with a relief valve on the air supply line set so the air supply cannot produce a pump discharge pressure in excess of 125% of the system working pressure. (Maximum pressure must not exceed design pressure.)

2.1.5.11.2 Do not convert existing low-pressure systems designed for less than 100 psi (7.9 bars) for use as high-pressure systems.

2.1.5.12 Spraying Inside Membrane Enclosures

2.1.5.12.1 Do not conduct spraying operations within membrane enclosures. Provide a properly designed and constructed spraying area.

2.1.6 Operation and Maintenance

2.1.6.1 General

2.1.6.1.1 Regularly maintain equipment and follow manufacturers' instructions.

2.1.6.1.2 Function-test system interlocks in accordance with manufacturers' recommendations or at least annually. Visually confirm proper position and response of safety devices prior to and following the trip test (e.g., valve position open in operation then closed after functional testing an interlock-trip).

2.1.6.1.3 Monitor overspray residue accumulation within the spray area and address excess overspray by maintenance to correct the cause, as opposed to increasing cleaning frequencies.

2.1.6.2 Water Wash Spray Booths

2.1.6.2.1 Follow manufacturers' recommendations for the use of chemical additives. Test the chemical additive used to control the pH of the water on wet overspray residue to ensure it will not result in spontaneous ignition (e.g., when nitrocellulose is used).

2.1.6.2.2 Inspect and clean the water wash tank area below the booth operating floor level (see Fig. 4). These areas can develop significant accumulation of combustible residue on the baffles.

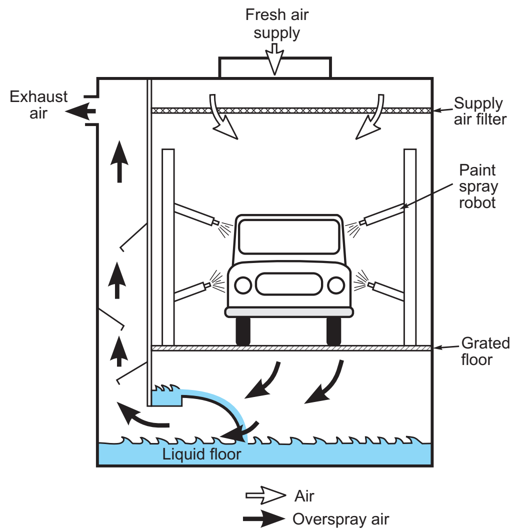

Fig. 4. Water wash (downdraft) spray booth

2.1.6.3 Electrostatic Spray Application

2.1.6.3.1 Shield contact points on workpiece hangers from buildup of paint overspray and clean at regular intervals. Make periodic checks to ensure the workpiece is properly grounded.

2.1.6.4 Catalytic Spray Application

2.1.6.4.1 Store and handle organic peroxide catalysts in accordance with Data Sheet 7-80, *Organic Peroxides,* and Data Sheet 7-81, *Organic Peroxides-Hazard Classification.*

2.1.6.4.2 Limit quantities of organic peroxides in the spray area to that needed for one day's operations unless the guidance from the above mentioned Data Sheets is more stringent.

2.1.6.4.3 Prevent contamination of organic peroxides with dust or overspray residues. Clean spills of peroxide using a noncombustible absorbent.

2.1.6.5 Hot Spraying Systems

2.1.6.5.1 Drain and clean heaters, used for materials susceptible to spontaneous heating, during idle periods.

2.1.6.6 Airless Spray Application

2.1.6.6.1 Inspect and test hose frequently and replace as necessary.

2.1.7 Training

2.1.7.1 Train equipment operators in accordance with the recommendations in the training section of Data Sheet 7-32, *Ignitable Liquid Operations.*

2.1.8 Human Factor

2.1.8.1 Establish an emergency response plan that focuses on the following items:

A. Prompt fire service notification.

B. Shutdown of equipment.

C. Availability of the provided fire protection features, including identification of sprinkler valve location(s) relative to each spray operation.

D. Notification of facility management and emergency response team.

E. Spill response procedures aimed at limiting the ignitable liquid release size (e.g., prompt shutdown of flow), containing released fluid, and eliminating all ignition sources that may be exposed by the release.

F. Methods to mechanically exhaust smoke from the building once the fire has been confirmed as extinguished.

2.1.8.2 Adopt proper fire protection impairment management procedures for spray equipment automatic interlocks activated by fire protection/alarm systems in the spray booth/room.

2.1.8.3 Establish a formal audit process to confirm the following:

A. All fire protection interlocks for spraying equipment are being maintained in service.

B. Adequate housekeeping conditions are being maintained within spraying areas.

C. Ignitable liquid handling procedures are being followed.

D. Equipment maintenance is being conducted with prompt corrective action for all abnormal operating conditions.

2.1.9 Ignition Source Control

2.1.9.1 Eliminate or control ignition sources in accordance with the recommendations in Data Sheet 7-32, *Ignitable Liquid Operations.*

2.1.9.2 Avoid locating electrical equipment in spray areas and associated exhaust ductwork where possible. If this is not possible, do the folowing:

A. Ensure electrical equipment is kept clean so heat can be dissipated and the equipment will not overheat. Establish a formal inspection and maintenance procedure for all hazardous rated electrical equipment.

B. Use electrical components that are FM Approved for use with flammable vapor and combustible deposits. Refer to Data Sheet 5-1, *Electrical Equipment in Hazardous Locations.*

2.1.9.3 For areas adjacent to the spray area, use Class I, Division 2 (Zone 2) electrical equipment as follows:

A. For an enclosed spray operation, provide this within 3 ft (1 m) in all directions from any openings.

B. For an unenclosed spray operation, see Figure 5.

C. For a closed-top, open-face, or front-spray operation, see Figure 6.

D. For an open-top spray booth, see Figure 7.

2.1.9.4 Provide vapor-tight panels for light or observation that are constructed of wired glass, hammered wired glass, heat-treated glass, laminated glass, or impact-resistant glass. Locate panels so they are not subject to overspray residue.

2.1.9.5 Do not locate space-heating appliances, unprotected steam pipes, or any other equipment with surfaces heated above 200°F (93°C) within the Class I, Division 2 (Zone 2) area or within 10 ft (3 m) of an open spray area.

2.1.9.6 Ground all metal parts of spray booths, agitators, exhaust ducts, and piping systems that convey ignitable liquids.

2.1.9.7 Electrostatic Spray Systems

2.1.9.7.1 Use FM Approved electrostatic spray systems.

2.1.9.7.2 Ground all conductive objects that are in the vicinity of spraying operations.

2.1.9.7.3 Ground grids, disks, and charging electrodes through the power supply so residual charge is removed after the power supply has been shut off.

2.1.9.7.4 Support the workpiece on a conveyor or hanger in such a way that the following criteria are met:

A. The workpiece is grounded.

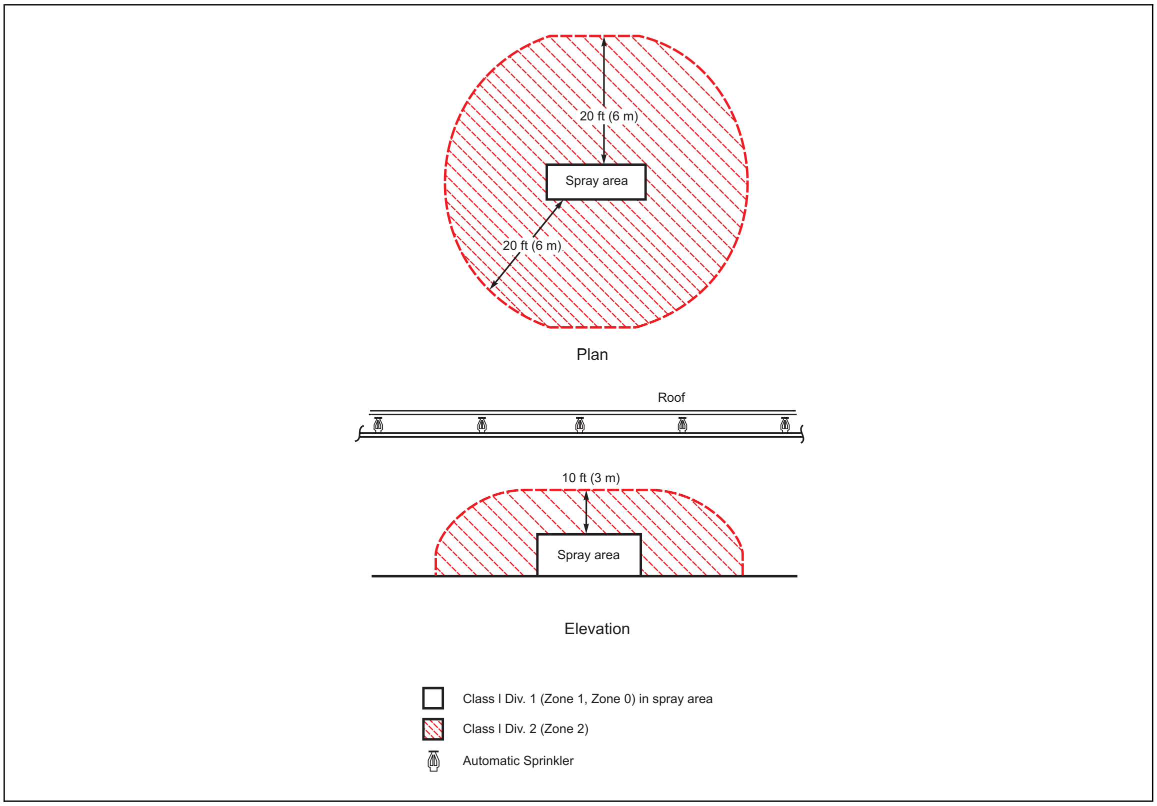

Fig. 5. Class I Division 2 (Zone 2) areas adjacent to an unenclosed spray operation

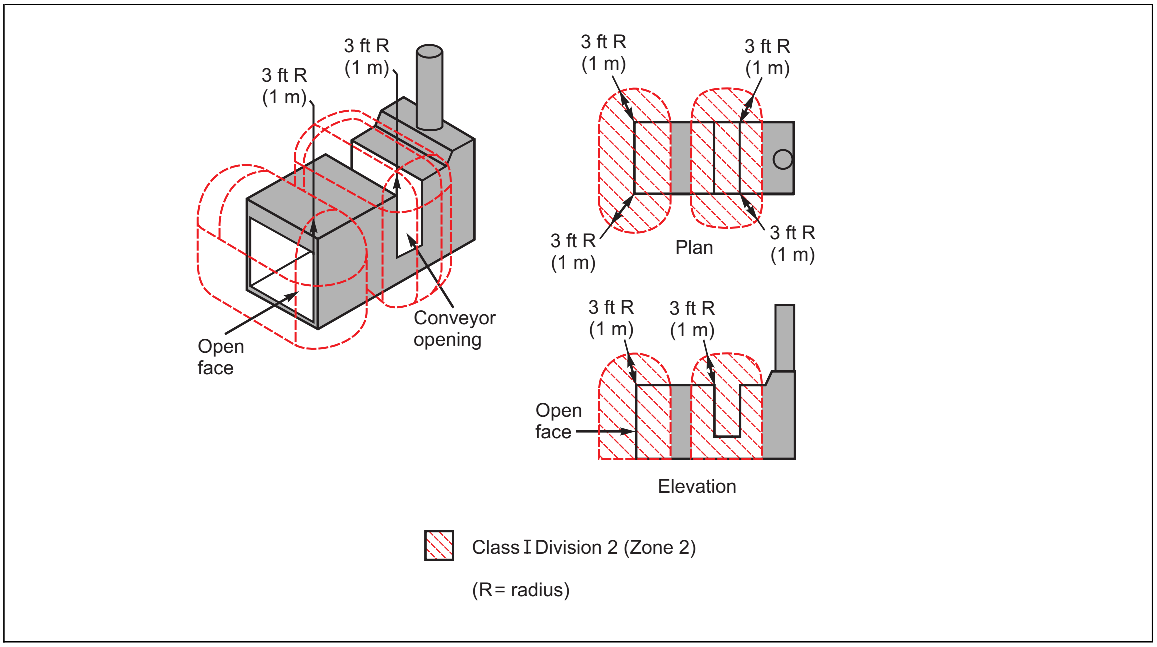

Fig. 6. Class I Division 2 (Zone 2) areas adjacent to a closed-top, open-face or open-front spray operation

B. The workpiece is located at least twice the sparking distance from the grid, disk, or charging electrode. (This does not apply to FM Approved equipment of nonincendive design.) If not indicated in manufacturer's instructions, use a minimum of 12 in. (30 cm).

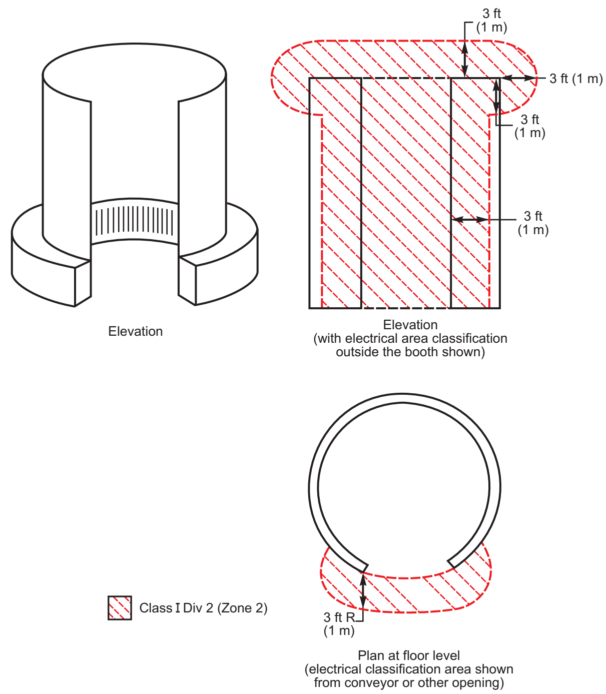

Fig. 7. Class I Division 2 (Zone 2) areas adjacent to an open-top spray booth

C. The workpiece is prevented from movement that would reduce the clearance to less than that specified above.

2.1.9.7.5 The following applies to grid, disk, and bell electrostatic systems:

A. Use FM Approved electric motors driving rotating disks or bells located in the spray area, and suitable for use in Class I, Division 1 (Zone 1, Zone 0) locations.

B. Install grids in fixed locations, effectively insulated from ground.

C. Ensure fine wire elements used in grids are under tension at all times. Use unkinked, hardened steel or materials of comparable strength.

2.2 Spray Application of Combustible Solids (Powder Coatings)

2.2.1 Introduction

Use FM Approved equipment, materials, and services whenever they are applicable and available. For a list of products and services that are FM Approved, see the *Approval Guide,* an online resource of FM Approvals.

2.2.2 Construction and Location

2.2.2.1 Construct spray booths of noncombustible materials. Do not use metal sandwich panels that have combustible plastic insulation.

2.2.2.2 Locate and construct dust collection equipment that handles combustible dust, and any associated explosion vents, in accordance with Data Sheet 7-73, *Dust Collectors and Collection Systems,* and Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires.*

2.2.2.3 For an enclosed fluidized bed, provide explosion protection in accordance with Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosions and Fires.*

2.2.2.4 Design spray operations to eliminate places on which overspray will accumulate (e.g., ledges, pipes).

2.2.2.5 Design for uniform air movement toward the exhaust outlet to prevent accumulation of overspray residue.

2.2.3 Occupancy

2.2.3.1 Ventilation

2.2.3.1.1 Design the mechanical ventilation system to keep the interior of the booth below the minimum explosive concentration (MEC) of the powder coating used. Design the system using the following formula:

$$V = \frac{W}{0.50L}$$

Where:

V = ventilation rate, ft^3/min (m^3/min) at standard conditions.
W = maximum powder discharge from spray gun(s), oz/min (kg/min).
L = minimum explosive concentration (MEC) oz/ft^3 (kg/m^3).

If the MEC is not known, use 0.030 oz/ft^3 (0.030 kg/m^3).

2.2.3.1.2 Design the mechanical ventilation system to confine overspray residue to the spray area as follows:

A. Electrostatic spray operations: Provide a minimum average air velocity across booth openings of 60 ft/min (20 m/min) unless the ventilation rate calculated using the formula in Recommendation 2.2.3.1.1 is higher.

B. Other spray operations: Provide a minimum average air velocity across booth openings of 100 ft/min (30 m/min) unless the ventilation rate calculated using the formula in Recommendation 2.2.3.1.1 is higher.

C. Increase the minimum flow rates in items (A) and (B) above to compensate for external conditions near the spray operation (e.g., drafts from windows, doors) that may reduce the flow rate.

2.2.3.1.3 Interlock failure of the ventilating fans to cut off the power and stop the introduction of powder.

2.2.3.1.4 Maintain ventilation following completion of the spraying operation for a sufficient time to allow powder to be exhausted.

2.2.3.1.5 Shut down ventilation in the event of a fire in accordance with the recommendations in Section 2.2.5.2.

2.2.3.2 Control of Overspray

2.2.3.2.1 Control fugitive dust/powder accumulations around the spraying operation in accordance with Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosion and Fire.* Any fugitive dust/powder accumulation conditions within a powder coat booth is a sign of improper booth/powder system operation requiring prompt repair per OEM requirements.

2.2.3.2.2 If suspended ceilings are installed in booths, include the area above the suspended ceiling in housekeeping inspections.

2.2.3.2.3 Control ignition sources and de-energize the booth as required for cleaning operations.

2.2.4 Protection

2.2.4.1 Provide automatic sprinkler protection in the spray booth (including in FM Approved booths), at ceilings above booths, and for recovery systems.

2.2.4.2 Design the sprinkler system as follows:

A. Protect the surrounding occupancy per the relevant data sheet.

B. Extend the ceiling sprinkler system to the booth. Design sprinklers within the booth to provide a minimum pressure of 7 psi (0.5 bar).

2.2.4.3 Provide sprinkler protection for all concealed spaces that contain combustible materials.

2.2.4.4 Protect dust collection equipment in accordance with Data Sheet 7-73, *Dust Collectors and Collection Systems.*

2.2.4.5 Protect ovens in accordance with Data Sheet 6-9, *Industrial Ovens and Dryers.*

2.2.4.6 Protect ventilation ducts in accordance with Data Sheet 7-78, *Industrial Exhaust Systems.*

2.2.4.7 Provide portable extinguishers. Use extinguishers that are appropriate for the expected fire hazard. Refer to Data Sheet 4-5, *Portable Extinguishers,* to determine effective sizes and locations for the extinguishers.

2.2.5 Equipment and Processes

2.2.5.1 Dust Collectors

2.2.5.1.1 Design dust collection equipment (including integrated) in accordance with Data Sheet 7-73, *Dust Collectors and Collection Systems,* and Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosion and Fire.*

2.2.5.2 Emergency Shutdown

2.2.5.2.1 Interlock failure of the ventilating fans to cut off the power and stop the introduction of powder.

2.2.5.2.2 For automatic spray booths and associated transfer systems, provide an automatically actuated means of shutting down the supply of powder, conveyors, ventilation, and the high-voltage power supply (if applicable) in the event of fire. This may be accomplished using one of the following methods:

A. Infrared detection

B. Ultraviolet detection

2.2.5.2.3 For manual spray operations, provide a deadman-type or self-closing valve (so that release of the spray gun stops the supply of powder).

2.2.5.2.4 Interlock the air supply for fluidized and electrostatic fluidized beds and the power supply for electrostatic fluidized beds with the exhaust system. This is to ensure the electrodes cannot be energized and the fluidizing air cannot be introduced unless the fan is in operation.

2.2.6 Operation and Maintenance

2.2.6.1 Regularly maintain equipment and follow manufacturers' instructions.

2.2.6.2 Function-test system interlocks in accordance with manufacturers' instructions or at least annually. Visually confirm proper position and response of safety devices prior to and following the trip test (e.g., valve position open in operation then closed after functional testing an interlock-trip).

2.2.6.3 Correct fugitive dust/powder accumulation by maintenance.

2.2.7 Training

2.2.7.1 Train operators in accordance with the recommendations in Data Sheet 10-8, *Operators.*

2.2.8 Human Factor

2.2.8.1 Establish an emergency response plan with a focus on the following items:

A. Prompt fire service notification

B. Shutdown of powder supply and power supply

C. Availability of the provided fire protection features, including identification of sprinkler valve location(s) relative to each spray operation

D. Notification of facility management and emergency response team

2.2.9 Ignition Source Control

2.2.9.1 Keep the surface temperature of a preheated part 50°F (28°C) below the autoignition temperature of the powder.

2.2.9.2 Use the following equipment:

A. FM Approved electrostatic spray equipment

B. FM Approved equipment suitable for use in Class II, Division 1 areas for other electrical equipment in the booth, recovery system, associated ductwork, or any other area where powders are likely to accumulate during normal operation

C. For areas adjacent to the booth, FM Approved equipment suitable for use in Class II, Division 2 areas within 3 ft (1 m) of any opening (Figure 8 shows this for a closed-top, open-face, or open-front booth)

D. For fluidized beds, use FM Approved electrical equipment suitable for use in Class II, Division 1 areas

E. Use FM Approved Class II, Division 2 electrical equipment in the following areas:

1. For a fluidized bed with an open top, the area extending 10 ft (3 m) horizontally in all directions from the bed and floor above the highest part of the object coated

2. For an enclosed fluidized bed, the area extending 3 ft (1 m) from conveyor openings

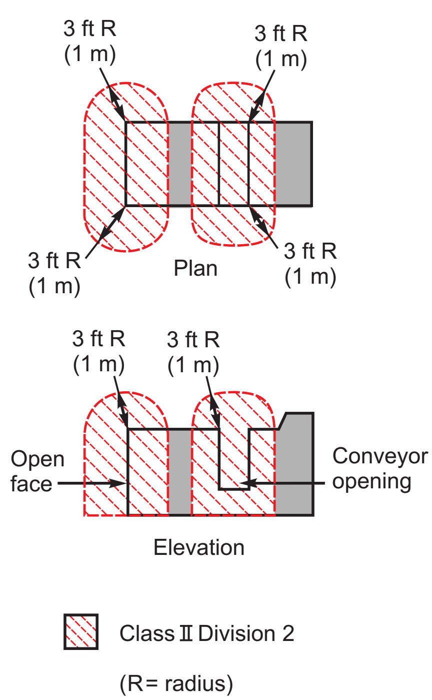

Fig. 8. Class II, Division 2 area equipment adjacent to a closed-top, open-face, or open-front spray booth

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

3.1.1 Spray Application of Ignitable Liquid

The spray application of ignitable liquid coatings may lead to a serious fire and explosion hazard because of the presence of easily ignitable liquid, vapor, and combustible overspray residue. The following general safeguards are recommended:

- Automatic shutoffs on ignitable liquid systems

- Automatic sprinkler protection
- Ventilation to control overspray and vapors
- Elimination of the ignition sources in the vicinity of spray operations
- Limitation of staged ignitable liquids within the spray area
- Regular maintenance and cleaning to prevent overspray residue

3.1.2 Ignitable liquid Coatings

Coatings may be applied by hand-held or fixed equipment. Fixed equipment may be stationary, mounted on a reciprocator, or mounted on a robot. Reciprocators are usually limited to one dimension of movement, up and down being most common. Robots may be programmed to duplicate any of the movements of a human operator. Robots consist of at least two major components: the operating arm and the electronic control. The operating arm holds the spray gun or applicator and, through a system of hydraulic or electric drives, can move the applicator in a number of programmed directions. Robots may be arranged so that air pressure, coating supply (both quantity and color change), and electrostatic voltage levels may be controlled by the computer.

“Coating” means any factory-applied finish. Coatings such as varnish, shellac, and some clear lacquers are not pigmented. However, most coatings include the following:

A. Pigment: an organic or inorganic powder(s) that provides color and hiding power.

B. Binder, resin or vehicle: a film-forming organic polymer or natural resin.

C. Special additive: a material that enhances a characteristic of the finished coating such as weathering, solvent resistance, flexibility, etc. This material may be solid or liquid, organic or inorganic.

D. Solvent, thinner, or volatile: a combination of organic liquids used to control viscosity and drying rate. Most solvent evaporates during and shortly after application, and does not form a part of the dried film.

3.1.3 Water-Based Coatings

In previous versions of this standard (prior to 2016) water-based coatings (i.e., up to 20% ignitable liquid in a water base) were treated differently than ignitable liquid coatings. This is no longer true for the following reasons:

A. Where any water-based coating that has an organic content is used, the overspray residue from the spraying operation that accumulates within the booth/room and ductwork will burn. It presents the same combustible hazard as the overspray residue of an ignitable liquid coating. Therefore, the same recommendations regarding ignitable liquid overspray residue apply to a water-based overspray residue.

B. Water-based coatings can burn in spray form.

3.1.4 Types of Spray Booths for Ignitable Liquid

Spray booths confine overspray, and filter as much of the overspray residue as possible before flammable vapor is exhausted. Booths have mechanical ventilation systems to maintain air velocity through all openings, and to keep flammable vapor air concentrations below the lower explosive limit. Various types of filters may be used to remove solid particulate. The booth designation is frequently based on the type of filter (e.g., dry spray booth) or direction of air flow (e.g., downdraft). Further details on different types of spray booths are provided in Appendix C.

3.1.5 Spray Application of Powder Coating

Plastic polymers can be applied in dry powder form by means of a spray gun or fluidized bed. The workpiece may be heated and/or the powder may be electrostatically charged. Powder coatings can be used for most applications when protective or finish coatings are applied.

3.1.6 Powder Coatings

Both thermoplastic and thermosetting plastic polymers are used. Thermosetting powders include epoxy, hybrid epoxy, polyester and acrylic resin-based materials. Epoxies are currently the most widely used. Polyester and acrylic polymers, in use to a limited extent, are available both as thermoplastic and thermosetting coatings. Thermoplastic powders include polypropylene, polyethylene, nylon, polyvinyl chloride, and cellulose acetate butyrate. Thermosetting coatings can be applied directly to the surface without a primer. Thermoplastic coatings usually require a primer for the coating to adhere properly. The primer coat may be liquid-based or powder. Both types of coatings contain, in addition to the thermoplastic or thermosetting resin, a curing agent or hardener, pigment and/or filler, and flow control additives.

The particle sizes of the powder vary depending on the desired coating thickness and method of application. Coatings of from 1 mil (25 microns) to 10 mils (250 microns) in thickness normally involve particle sizes ranging from 1250 mesh (10 microns) to 125 mesh (120 microns). Coatings of from 10 mils (250 microns) to 40 mils (1000 microns) normally involve particle sizes ranging from 350 mesh (40 microns) to 60 mesh (250 microns).

Tests have been conducted by FM on 13 samples of powder coating. Test results are included in Table 1.

As noted in Table 1, MEC ranged from 0.045 to 0.115 oz/ft^3 (0.045 to 0.115 kg/m^3).

Autoignition temperatures ranged from 835°F to 932°F (446°C to 500°C).

In general, ignition energies for plastic powders are higher than for ignitable liquid coatings by a factor of approximately 100. Ignition temperatures are approximately the same.

Table 1. Test Results for Powder Coatings

Type	*Sample No.*	*Kst*	*Pmax*		*MEC*		*Autoignition Temperature*	
		(m bar/s)	(psig)	(bar)	(kg/m^3)	(oz/ft^3)	°F	°C
Epoxy	1	152	97.2	6.7	0.095	0.095	932	500
	2	194	108.8	7.5	0.060	0.060	891	477
	3	228	117.5	8.1	0.045	0.045	882	472
Polyester	1	204	120.4	8.3	0.075	0.075	856	458
	2	154	117.5	8.1	0.065	0.065	855	457
	3	70	94.3	6.5	0.070	0.070	835	446
	4*	177	117.5	8.1	0.065	0.065	845	452
	5*	148	110.2	7.6	0.060	0.060	867	464
	6*	184	116.0	8.0	0.050	0.050	860	460
Epoxy-polyester	1	149	110.2	7.6	0.045	0.045	882	472
	2	101	94.3	6.5	0.115	0.115	892	478
	3	152	104.4	7.2	0.115	0.115	887	475
	4*	189	118.9	8.2	0.045	0.045	899	482

*Powder contains less than 10% bonded or blended aluminum pigments.

4.0 REFERENCES

4.1 FM

Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers*
Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties*
Data Sheet 4-5, *Portable Extinguishers*
Data Sheet 5-1, *Electrical Equipment in Hazardous Locations*
Data Sheet 6-9, *Industrial Ovens and Dryers*
Data Sheet 6-11, *Thermal and Regenerative Catalylic Oxidizers*

Data Sheet 7-2, *Waste Solvent Recovery*
Data Sheet 7-29, *Ignitable Liquid Storage in Portable Containers*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-78, *Industrial Exhaust Systems*
Data Sheet 7-80, *Organic Peroxides*
Data Sheet 7-81, *Organic Peroxides-Hazard Classification*
Data Sheet 7-88, *Storage Tanks for Itnitable Liquids*
Data Sheet 10-8, *Operators*

4.2 Other

National Fire Protection Association (NFPA). *Standard for Spray Application Using Flammable or Combustible Materials.* NFPA 33.

APPENDIX A GLOSSARY OF TERMS

Flash-off Area: An open or enclosed area after the spray operation where vapors are released due to exposure to ambient or a heated atmosphere.

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.

Spray area: An area in which flammable or combustible vapor, mist, residue, dust, or deposits are present due to the spraying process operation. The spray area includes the following:

- Any area in the direct path of the spray
- The interior of the spray booth or room
- The interior of ducts exhausting from spraying operations

The spray area can be fully enclosed, partly enclosed, or unenclosed.

Spray booth: A power ventilated enclosure for a spraying process that limits and confines the escape of the material being sprayed. Vapor, mist, dust, and residue produced by the spraying process are directed to an exhaust system via ventilation. Spray booths are manufactured in a variety of forms, including dry, water wash, and combination.

Spray room: A power ventilated enclosed room used for open spraying, usually of large workpieces. Vapor, mist, dust, and residue produced by the spraying process are directed to an exhaust system via ventilation.

APPENDIX B DOCUMENT REVISION HISTORY

April 2018. Interim revision. Minor editorial changes were made.

July 2016. The entire document was revised. The following major changes were made:

A. Changed the title of the data sheet from *Spray Application of Flammable and Combustible Materials to Spray Application of Ignitable and Combustible Materials.*

B. Revised terminology and guidance related to ignitable liquids to provide increased clarity and consistency. This includes the replacement of references to “flammable” with “ignitable” throughout the document.

C. Reorganized the document to provide a format that is consistent with other data sheets.

D. Deleted the section for water-based coatings. These are now treated the same as ignitable liquid coatings. See Section 3.0 for further details.

E. Revised the recommendation for 1-hr fire resistance for walls of spray rooms. Noncombustible construction is acceptable unless the spray operation severely exposes the surrounding occupancy.

F. Deleted the recommendations relating to drainage for ignitable liquid spraying operations. The intention in the previous version was to control water discharge.

G. Deleted the recommendation for draft curtains and automatic vents. There is no clear evidence on the value draft curtains would provide for this operation.

H. Added guidance about shutting off ventilation in the event of a fire.

I. Deleted the recommendations for oil wash and traveling spray booths as these are rarely seen.

J. Added a recommendation for spraying within membrane enclosures.

K. Deleted the sections relating to furniture, aircraft, and automobile occupancies. Recommendations that still apply have been incorporated into other sections as they apply generally and are not specific to these occupancies.

L. Added a recommendation to provide sprinkler protection within an FM Approved powder coating booth.

M. Revised the recommendation for detectors in an automatic powder booth. Only automatic detectors are recommended.

January 2007. Clarification was made to the recommendation 2.1.8.3.3.3.

September 2004. Cross-reference to recommendation numbers in section 2.2.6.1.2.1 were corrected.

January 2001. Table 1, Sprinkler Protection Criteria for Flammable Liquid Spraying, has been included. Previously the information was located in Data Sheet 3-26, *Fire Protection Water Demand for Non-storage Sprinklered Properties.*

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

June 1989. The following changes have been made to Data Sheet 7-27.

Section 2.1 Flammable Solvent Base Coatings

1. Added recommendations for combination spray/cure booths (Section 2.1.8.1.6).

2. Added recommendations for aircraft finishing in Section 2.1.8.3.1, furniture plant finishing in Section 2.1.8.3.2 and automobile plant finishing in Section 2.1.8.3.3.

Section 2.2 Water Base Coatings

1. Recommendations regarding storage of finishing material in spray area revised (Section 2.2.7.2).

Section 2.3 Powder Coating

1. Explosion protection recommendation for dust collector revised to allow venting only to outside, or use of explosion suppression systems for dust collectors (Section 2.3.2).

APPENDIX C TYPES OF APPLICATION METHODS AND SPRAY BOOTHS

C.1 Spray Application Methods for Liquid

Spray equipment is designed to atomize and direct coating material onto the object to be coated. The most common and earliest method used compressed air. Other methods have since been developed to improve coating efficiency, reduce solvent usage, and improve the quality of the coating.

C.1.1 Conventional Spray Systems

Conventional spray systems use compressed air to atomize and carry coating material to the object.

C.1.2 Electrostatic Spray Systems

Electrostatic spray systems apply electrically charged, atomized coating material to a grounded conductive workpiece or a nonconductive object prime coated with a conductive coating. The major advantage of this method is increased efficiency. Particles of coating material that would otherwise miss the workpiece are attracted to the edges and back of the workpiece by their electrical charge.

C.1.2.1 Types of Electrostatic Applicators

Three types of applicators are commonly used:

1. Spray guns using external grids or electrodes. This system was one of the first methods for electrostatic application of ignitable liquid based coatings. It is now most widely used for the application of conductive liquid coatings. This method of application does not require isolation from ground of the paint supply

system; the system is grounded at the applicator. A high voltage grid is located adjacent to the workpiece. The coating material, discharged between grid and workpiece, is charged by the grid. The grid is electrically isolated from the applicator. It is a fixed system with the spray gun(s) and grid(s) stationary.

2. Electrostatic spray gun. The gun atomizes particles of coating material by pneumatic or hydraulic pressure. These particles are charged by an electrode near the discharge nozzle. Power is supplied through a cable from a high voltage DC power supply. The gun may be hand held, fixed or mounted on a reciprocator or robot.

3. Disk or bell system. Coating material is fed to a rotating disk or bell, and carried uniformly to the edge by centrifugal force. When the system is charged, particles of coating material are pulled from the edge and carried to the object (Fig. 9). The disk system is an automatic system. The bell system may be either automatic or hand held (manual). In the automatic system, the disk or bell is either fixed or mounted on a reciprocator or robot. Electrostatic bell and disk applicators are increasingly used to improve the efficiency of paint transfer, and thereby reduce volatile organic coating (VOC) emissions.

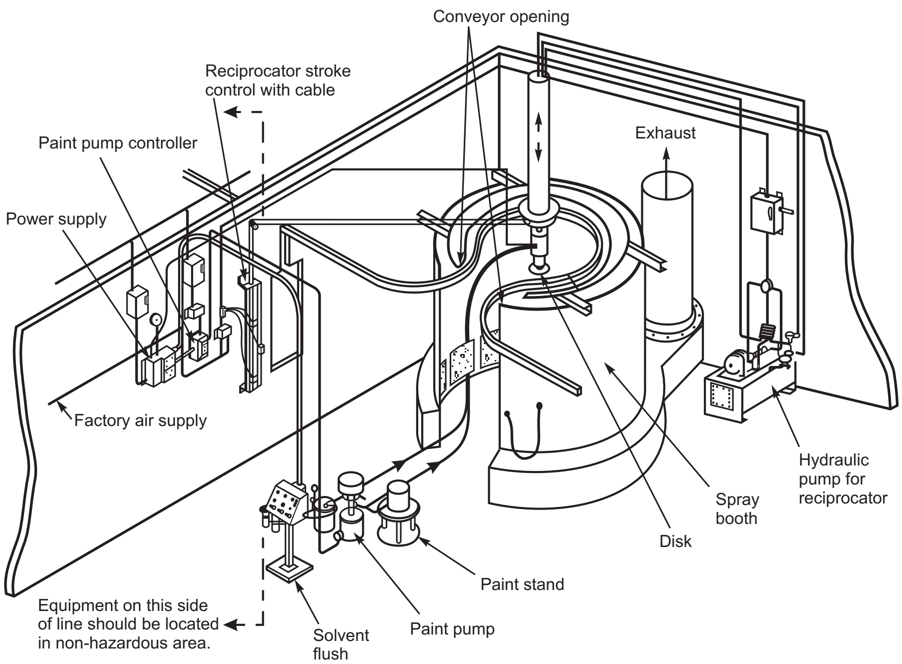

Fig. 9. Electrostatic spray system, rotating disk type

C.1.2.2 Nonincendive and Stiff Electrostatic Spray Equipment

Both nonincendive and “stiff” electrostatic spray equipment are used in industry. Presently only nonincendive spray equipment is FM Approved. Electrical ignition may occur from an arc to a grounded object such as workpiece swinging on the conveyor.

For grounded objects, nonincendive devices do not have enough energy at the charging electrode to cause an arc of sufficient intensity to ignite the ignitable liquid coating material.

Stiff systems do have enough energy, and rely on prevention of ignition by 1. maintaining the spray gun at twice the sparking distance from the workpiece, and 2. proving current-limiting and/or arc-detection features to shut off the power supply and ground the charging electrode to prevent an arc. Sparking distance in dry air is well known. It is not clearly defined during the spray operation, and will depend on such things as coating material (conductivity of solvent and solids content); rate of spraying; and shape and speed of approach of the workpiece.

The interlock used to shut off the gun depends on detection of rate of current increase or on current exceeding a preset value. These settings should be properly set by the manufacturer’s representative when the system is installed. If interlocks actuate, every attempt should be made by the operator to find out why, rather than pressing the reset button or adjusting to less sensitive settings.

Most hand-held (manual) spray equipment is nonincendive. This design feature is important for a hand held device subjected to random operator movement. Automatic electrostatic spray equipment is either nonincendive or capable of ignition.

Even with properly designed and maintained equipment, if a conductive object near the applicator is not properly grounded, a charge can build up on the surface of the object. The energy of the charge is dependent on the surface area and shape of the object. An electrical discharge may occur from the object to any other grounded object. The energy of the discharge may be sufficient to ignite ignitable liquid vapors regardless of the design features of the electrostatic system. The ungrounded or improperly grounded object may be a can of ignitable liquid brought into the spray area to clean the system. It also may be the workpiece that has been insulated from ground by overspray residue accumulating on the support hanger.

Loss prevention during cleaning operations is a matter of proper operator training. Improper grounding of the object being coated can be avoided by preventing overspray from accumulating on the contact point between the workpiece and the hanger, and the hanger and the conveyor. The point between the hanger and the conveyor can be kept free of overspray by shielding it. The point where the workpiece is attached to the hanger can be shielded when not in use, or the hanger can be cleaned frequently. Hangers need to be cleaned or replaced at a frequency adequate to ensure good electrical contact.

Examples of continuous cleaning methods:

A. Wet systems. The conveyor line includes a tank of stripping compound which dissolves overspray residue from the hooks.

B. Burn off. An excess air burner is used to burn residue off the hooks without formation of char.

C. Mechanical systems. Rotary wire brushes are used on either side of the hook to brush off the residue.

D. High pressure water. A water spray at from 10,000 to 50,000 psi (70,000 to 340,000 kPa; 680 to 3400 bar) is directed at the hangers.

E. Cryogenic cleaning systems. Liquid nitrogen is used to clean hangers.

C.1.3 Catalytic Spray Systems

Catalytic spraying, also called dual-component coating, involves discharging two components through the same spray gun.

The second component may act as a catalyst to initiate a chemical reaction between compounds in the first component. Glass fiber-reinforced plastics are formed by the reaction (copolymerization) of an unsaturated polyester alkyd and styrene; both are contained in one of the components. This reaction is initiated by a second component, usually an organic peroxide. The most widely used is methyl ethyl ketone peroxide (MEKP). The fiber may be injected into the spray pattern as chopped strands or may be on a mold in front of the spray pattern in the form of a mat. As the reaction proceeds, heat is generated which further increases the reaction rate.

The second component also may take part in the reaction. Polyurethane foam can be made by discharging an isocyanurate and a glycol through a spray gun into a mold. These components react to form the polyurethane foam.

The components may be kept in separate pressure containers and conveyed to the spray gun through separate hoses. One component is expelled through the fluid tip in the conventional manner, while the second is admitted into the atomizing air through a metering venturi. The two components are mixed in the gun or most commonly in the spray pattern after discharge from the gun.

These coatings are cured by a chemical reaction; in many cases this reaction can occur without the external application of heat. In some cases, however, low temperature curing ovens are used. Heat is usually generated during the curing reaction. Cleanup may be a problem with this type of coating unless strippable coatings or plastic films are used to cover exposed surfaces in the spray area.

C.1.4 Hot Spray Systems

Hot spray equipment (Fig. 10) is used to heat finishing material either before it reaches the spray gun or as it leaves. Steam, hot water, or electric resistance heaters may be used. This method uses little solvent and a heavier film may be deposited on the object.

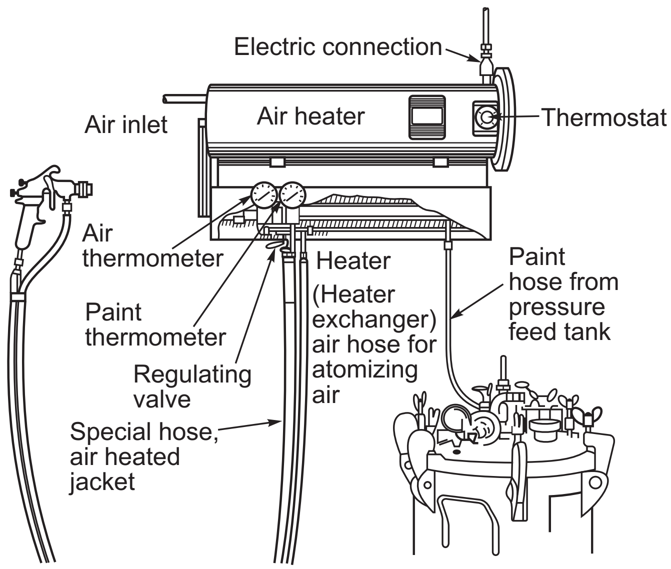

Fig. 10. Hot spraying system; this type heats both atomizing air and coating material

C.1.5 Air-Assisted Airless Systems

Coating material is supplied to the atomizer by a pump with fluid pressures from 300 to 500 psi (20 to 35 bar). The coating is discharged through an airless-type spray nozzle. Air pressure also is used as in a conventional system to provide pattern control.

C.1.1.6 Airless Spray Systems

Coating material is atomized by hydraulic pressure instead of air pressure. Equipment consists of a hydraulic paint pump and spray gun (Fig. 11). The pump supplies coating material to a spray nozzle at pressures from 300 psi to 3500 psi (20 to 250 bar). The coating material may be heated or at ambient temperatures.

C.2 Types of Spray Booths

C.2.1 Dry Spray Booths

Dry spray booths are equipped with baffles, filter pads, or filter rolls to prevent excessive quantities of residue from entering the exhaust system. Their efficiencies vary greatly. Baffle booths (Fig. 12) are the least efficient. A properly maintained dry filter booth (Fig. 3) is one of the most efficient methods of collecting overspray residue. Some residue will pass through the filter and coat the plenum and exhaust duct downstream. A high filter efficiency does not eliminate the need for protection in the plenum and exhaust duct. A highly efficient, well-maintained filter, however, will reduce cleaning frequency.

C.2.2 Water Wash Booths

Water wash booths replace the dry filter with a water curtain or mist. In the water curtain booth, water is pumped from a sump at the bottom of the booth to perforated pipes, troughs, or nozzles in the top rear of the booth. Coating operations are directed so that overspray residue comes in direct contact with the curtain or is drawn by the booth's exhaust system through the curtain (Fig. 13).

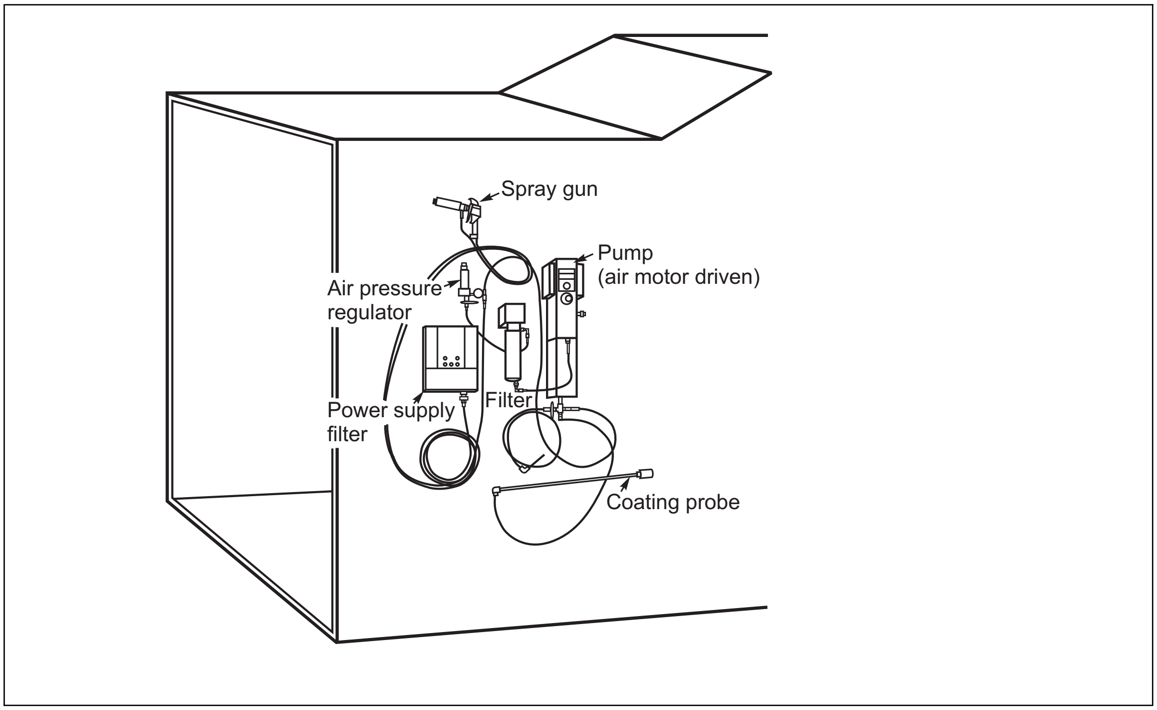

Fig. 11. Airless electrostatic spray system

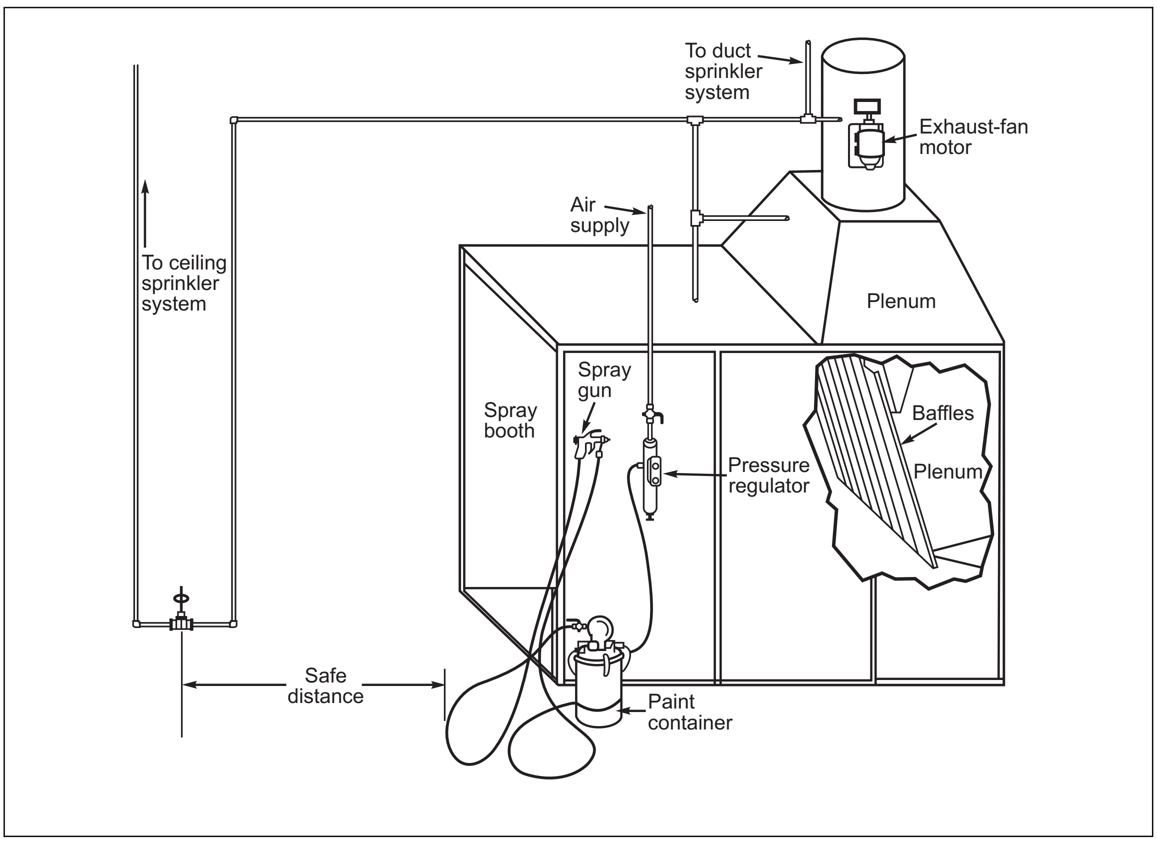

Fig. 12. Dry filter spray booth equipped with baffles

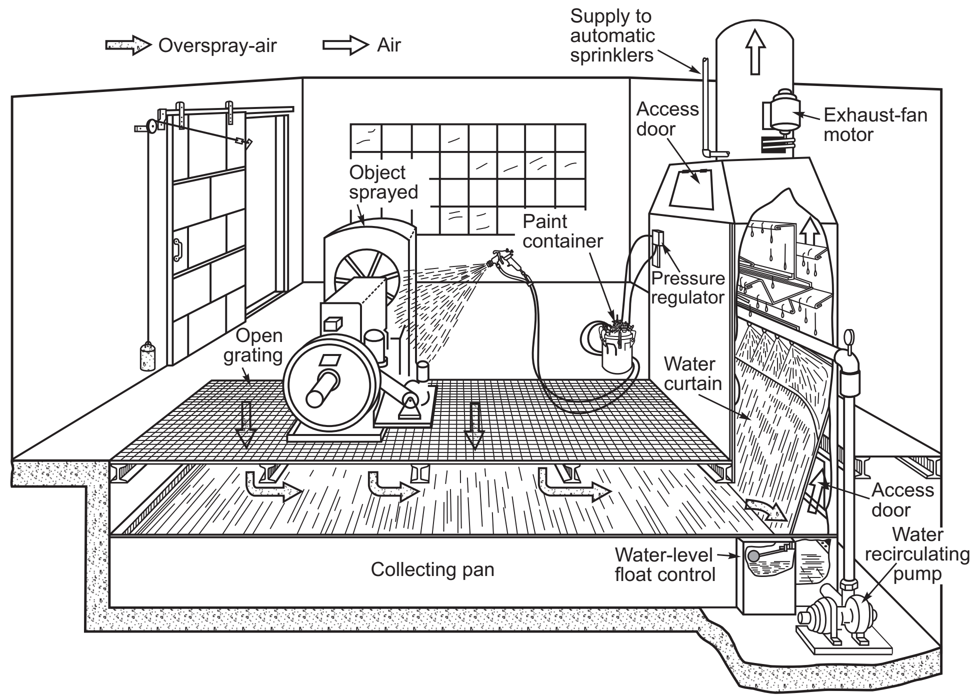

Fig. 13. Downdraft water wash spray booth (room sprinkler system not shown)

Water pan booths use mist to collect overspray. The mist is formed by air at high velocity passing between the surface of the water in the sump and a baffle located a few inches above the surface, or by spray nozzles discharging water at 50 to 100 psi (345 to 690 kPa). The distance between the surface of the water in the sump and the baffle is critical. If the space is too large, the mist is not formed and residues are carried into the exhaust duct; if too small, the increased pressure drop across the opening reduces air flow. This is normally automatically controlled by measuring air velocities between the baffle and the sump, and either raising or lowering the water level.

Chemical additives are used to precipitate the residues so that they may be skimmed off the top or removed from the bottom of the sump. In the curtain-type booth, it is important that the perforated pipes, troughs or nozzles are not plugged with residue. If these are plugged, open areas in the water curtain decrease collection efficiencies and result in residue accumulations in the exhaust duct. In the water mist booth, residue accumulations on the surface of the water in the sump may reduce formation of mist or block the spray nozzles, also decreasing collection efficiencies.

Water wash booths are preferred when quantities of overspray residue are heavy. They reduce fuel loading since most residue is collected in the sump. The water curtain also helps to confine a fire occurring in the exhaust duct from spreading to the booth and vice versa. The use of a water wash booth does not eliminate the need for protection in the plenum area behind the water mist or curtain, or in the exhaust duct. Overspray residue will build up in these areas. When residues are wet, the chance of ignition is minimal. However, residues dry quickly when booths are shut down.

C.2.3 Combination Spray/Cure Booths

Combination spray booths are used largely for automotive refinishing operations. They are designed so that the coating can be applied and cured at elevated temperature in the same booth. Some coatings in use in the automotive market require above-ambient cure temperatures. Heating systems on booths may be direct-fired or indirect-fired gas or oil, with the burner systems located outside the booth, or infrared (IR) with the IR heating units mounted on the walls of the booth.

Where oil-fired or gas-fired burner systems are used, the exhaust arrangement for paint spray operations is separate from the booth heating system, and is not in operation when spraying operations are carried out in the booth. The concern is prevention of overspray residue on surfaces that would be exposed to flame or flame temperature during the cure cycle.

C.3 Spray Application Methods for Powder Coatings

C.3.1 Spray Application

Powder may be applied by spray gun onto a workpiece that has been preheated to a temperature above the melting point of the powder. This process is called fusion bonding. Pipe coating is the most typical example of this coating process. More commonly powder is applied by electrostatic spray gun using a combination of air pressure and electrostatic charging to direct the powder onto a workpiece at elevated or room temperature. Coatings of from less than 1 mil (25 microns) to 20 mils (500 microns) may be applied by spraying.

Both operations may be done manually or automatically. In an automatic booth, the guns may either be stationary or mounted on a reciprocator or robot. The spray guns may be arranged to discharge continuously when the conveyor is in operation, or intermittently when the workpiece passes in front of them. Spraying is carried out in an enclosure similar in design to the downdraft spray booth used in liquid spraying. Air movement is usually designed to carry powder overspray to the bottom of the booth.

There are two basic booth designs relating to location of powder recovery equipment. In one design powder recovery equipment is separate from the booth. In this design powder recovery may be by cyclone and bag collector in series or by a bag collector (Fig. 14). In the integrated design the powder collection equipment is part of the booth.

Cartridge filters may be located in the upper part of the booth hopper to remove overspray (Fig. 15). In the integrated design, the filter system may be a permanent part of the booth.

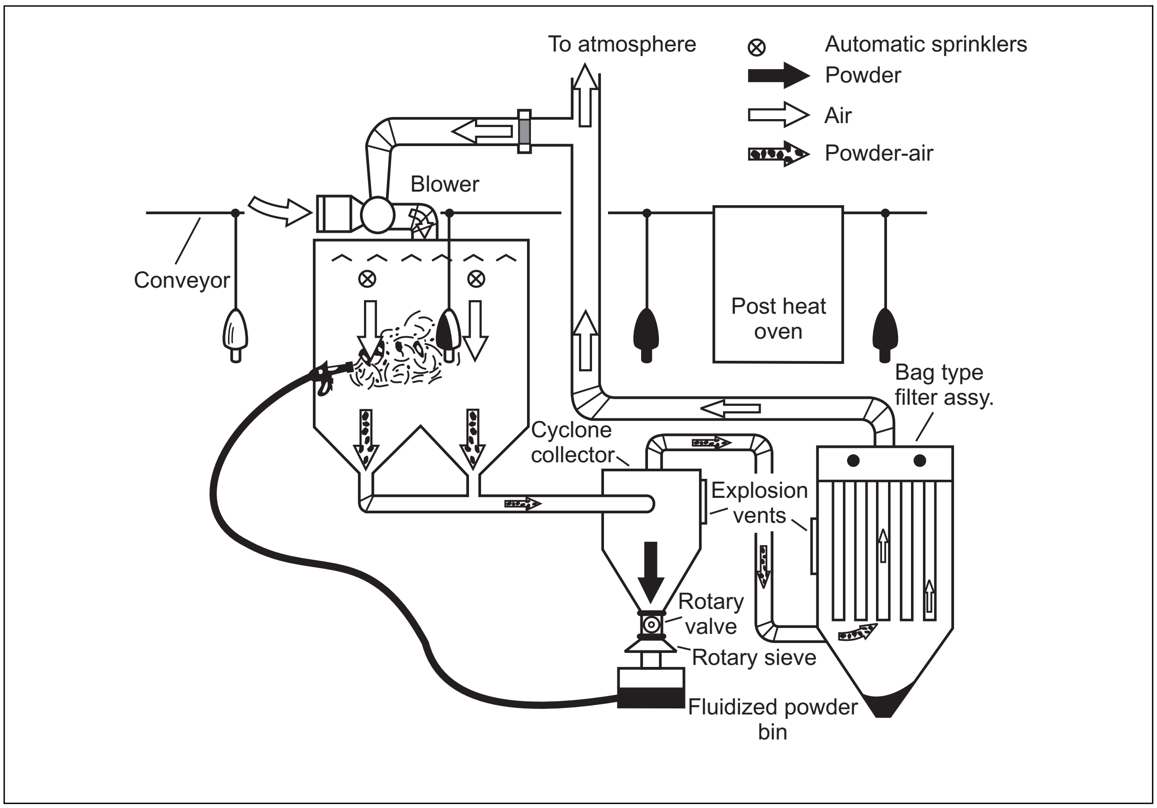

Fig. 14. Manual spray booth with partial recirculation of filtered air

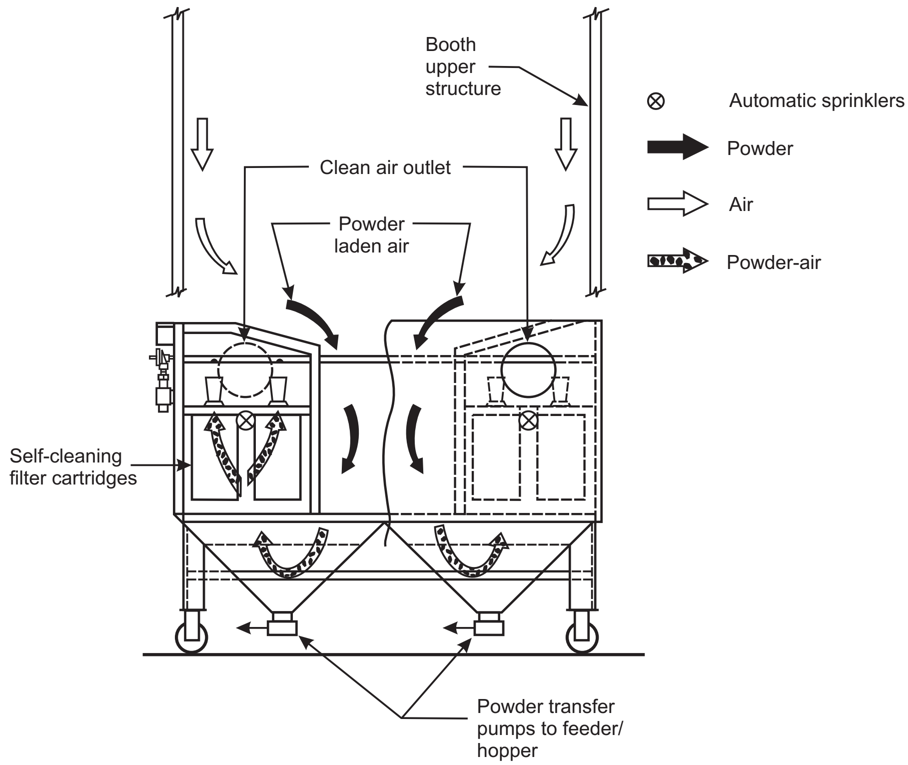

Fig. 15. Integrated booth design with cartridge filter system in upper part of booth hopper

If color changing capability is needed, it may be arranged to be detachable from the booth. When changing from one color to another, the filter and hopper section may be detached and replaced with the filter and hopper system of the new color.

In the powder coating of pipe, fixed spray guns may be arranged around the circumference of the pipe. Spraying is conducted inside an enclosure resembling a collar, that completely surrounds and is only slightly larger than the diameter of the pipe. A combination of construction and venting may be provided so that the enclosure can withstand an internal dust explosion. In this case, air velocities that would give the highest transfer efficiencies may be used.

The amount of powder collected on the surface in relation to the amount discharged by the spray guns expressed as a percentage is termed the transfer efficiency. It can range from 10% to more than 90%, depending on the shape of the object coated. A recovery system is used so that oversprayed powder can be collected and reused, substantially increasing the efficiency of the operation. The recovery system may be a filter system designed as part of the booth (integrated system), or a bag collector located near the booth.

With an integrated system the recovery system may be a permanent part of the booth hopper. The hopper may be fixed to the booth or detachable. The former would be used for extended runs involving the same powder coating. The latter would be used in coating operations where color change capability is needed. Each filter system would be arranged for a different color.

When a bag collector is used, it is generally located adjacent to the spraying area. The powder may be recovered and used again, as is normally done in automatic spray booths, or discarded. The filtered air may be partially recirculated to the plant or spray booth, as is frequently done in automatic operations, or discharged to the atmosphere.

In applications in which filtered air is used in the plant, a second filter system is installed as a final filter in the duct discharging air to the booth or plant. The pressure drop across it can be monitored and an alarm installed to indicate when the filter needs to be serviced. This also acts as a safeguard to prevent the discharge of powder into the booth or plant from a leaking filter bag in the collection system.

C.3.2 Fluidized Bed Application

Powder may be applied by preheating the object and dipping it into an aerated bed of powder (fluidized bed). It may also be applied by grounding the object and electrostatically charging the powder so that when the object is dipped into or supported just above the aerated bed, the powder clings to it (electrostatic fluidized bed, Fig. 16). Perimeter exhaust systems or exhaust hoods are normally used to remove powder overspray. If thick coatings are desired in electrostatic bed systems, the object may be preheated. Coatings of from 6 mils (150 microns) to 40 mils (1000 microns) may be applied by these methods.

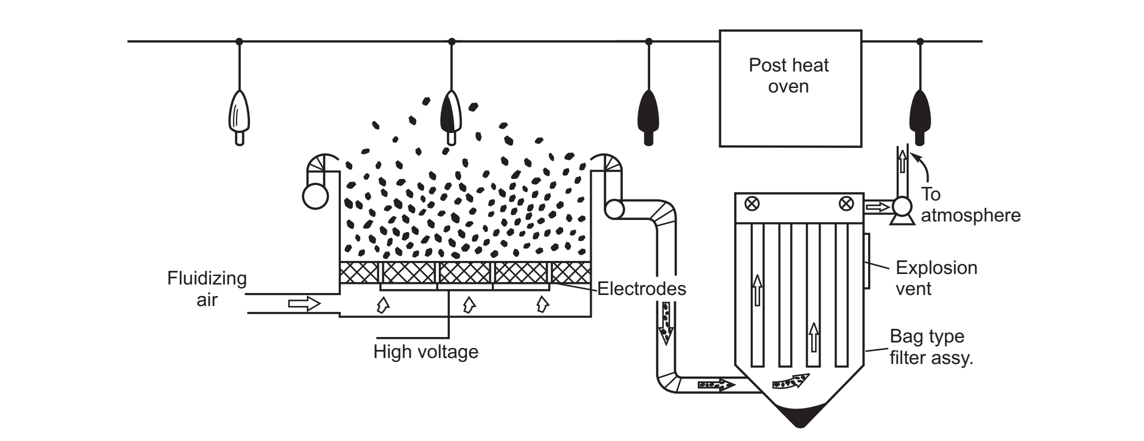

Fig. 16. Electrostatic fluidized bed with perimeter exhaust system

Powder also may be applied using a cascading electrostatic fluidized bed. This is essentially two separate electrostatic beds with space between wide enough to pass an object on a conveyor. Both beds are enclosed except for an opening at the top of the conveyor side of each bed. Charged powder passes through the openings and coats the grounded object. An exhaust system removes powder overspray. Coatings of from 1 to 7 mil (25 to 175 microns) may be applied by this method.

Cyclone collectors and/or bag-type filters similar to those employed in powder spraying may be used to recover powder overspray. The filtered air may be discharged to the plant or recirculated to the bed.

C.4 Exhaust Treatment

While the use of powder coatings has significantly reduced the use of ignitable liquid coatings in recent years, ignitable liquid coatings are still commonly used to produce high volume, high quality surface finishes such as those commonly found in the automotive and furniture industries. When ignitable liquid coatings are used, environmental regulations typically limit the amount of volatile organic compounds (VOCs) that may be discharged to atmosphere. Water scrubbers in conjunction with secondary filters, wet electrostatic precipitators, fume incinerators, thermal oxidizers and/or carbon bed adsorbers are provided. See Figure 17 for an example. Air recirculation may also be used to reduce VOC emissions. However, the need to remove fine particulates (e.g., overspray) from the recirculation stream and maintain VOC concentrations safely below the lower explosive limit has limited use of this as a stand-alone strategy. Loss prevention guidance for off-gas treatment equipment can be found in Data Sheet 6-9, *Industrial Ovens and Dryers;* Data Sheet 6-11, *Thermal and Regenerative Catalylic Oxidizers;* Data Sheet 7-2, *Waste Solvent Recovery;* and Data Sheet 7-78, *Industrial Exhaust Systems.*

C.4.1 Dry Scrubber Technology

Dry scrubber technology is a technique that combines the use of a dry filter module (as opposed to secondary filtration) with partial air recirculation. Overspray is exhausted from the spray booth through ductwork to a dry filter module coated with a binder. Part of the filtered exhaust is recirculated while part is exhausted to limit the VOC concentration.

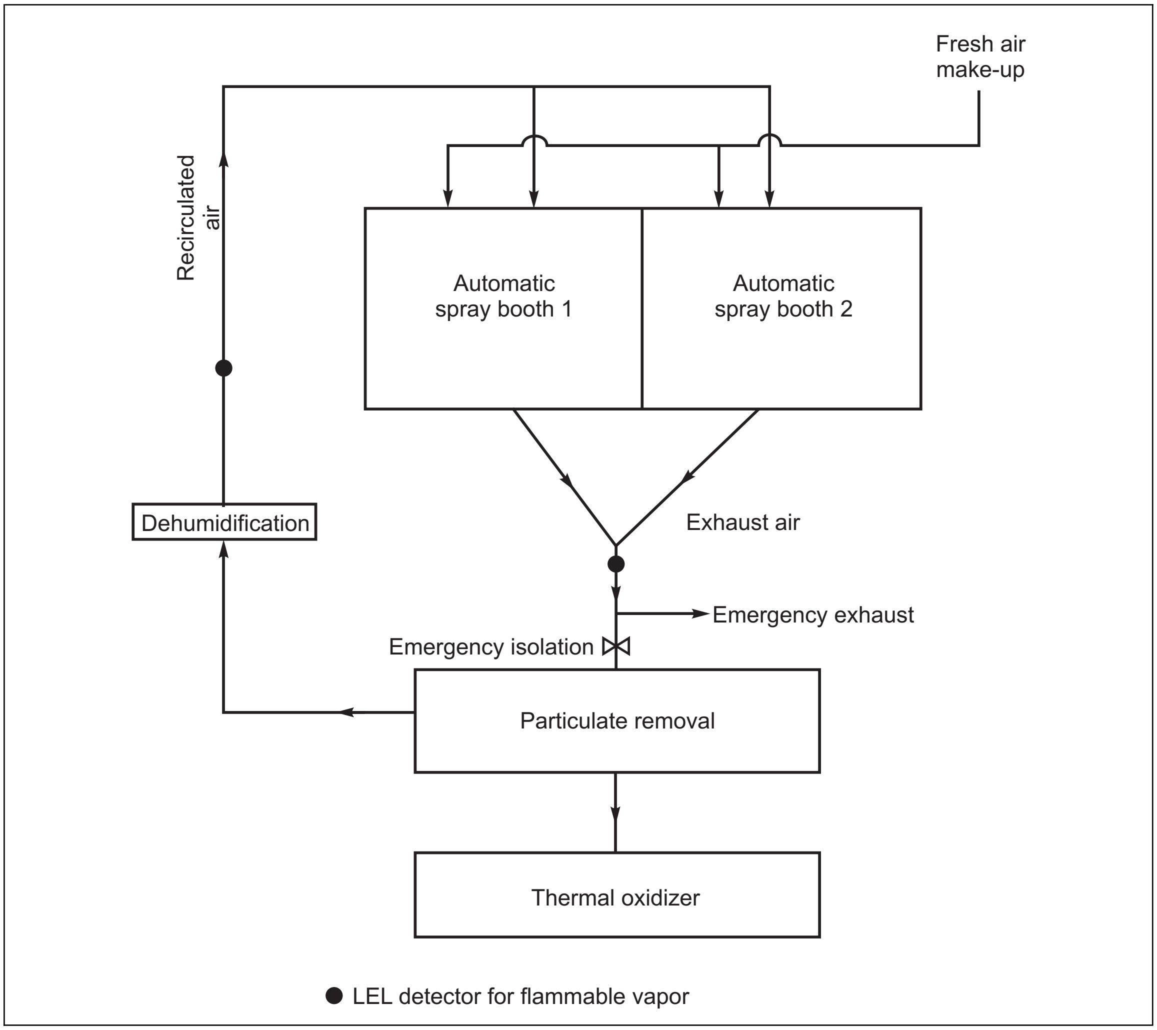

Fig. 17. Example of an off-gas treatment system for a multiple automatic ignitable liquid spray booth operation

The binder protects the filter media and facilitates removal of the particulates. Once a pre-defined filter differential pressure is reached, the filter cake (overspray and binder powder) is blown off the filter and is collected in a hopper below. The saturated binder is then removed from the hopper. Fresh binder is added and circulated to recoat the filters.

C.5 Thermal Spray Coating Processes

Thermal spraying is a group of coating processes in which finely divided metallic or nonmetallic materials are deposited in a molten or semi-molten condition to form a coating on a workpiece. The coating material may be in the form of a wire, powder, ceramic-rod, or molten materials. In general, each process consists of a heat source used to melt the coating material into liquid form. The coating material is then atomized and sprayed at high velocity, using a compressed gas, onto the workpiece surface to create the coating.

The following are the different types of thermal spraying:

Flame spraying: This process uses the chemical energy of combusting fuel gases to generate heat. Oxyacetylene or oxyhydrogen are commonly used to produce the high combustion temperatures. Via a spray gun, the coating material is introduced into the flame. This melts the coating material and it is accelerated towards the workpiece at speeds of up to 200 to 800 ft/s (60 - 240 m/s). Various coating materials can be sprayed using this method; these include metal, powder, wire and ceramic rod.

Detonation gun flame spraying: Pre-encapsulated shots of powder coating material are fed into a long barrel (3 ft [1 m]) with oxygen and a fuel gas (such as acetylene). The mixture is ignited by a spark and this produces a controlled explosion that propagates down the barrel length. The generated high temperatures and pressures (150 psi [10.3 bar]) blast the particles at speeds of up to 2625 ft/s (800 m/s) out the barrel and towards the workpiece. After each detonation, nitrogen is used to purge the barrel.

High-velocity oxyfuel (HVOF) spraying: Oxygen and other fuel gases (such as hydrogen, propane, acetylene) or kerosene are fed into a combustion chamber (barrel). In the chamber, the burning by-products of the gases heat and expel the powder or wire coating material outward through a small diameter orifice at high velocities of up to 4500 ft/s (1400 m/s). Air or water are used in the associated cooling systems.

Cold spraying: This process uses jets of compressed gas to accelerate particles at high velocities (up to 3,000 ft/s [1000 m/s]). Due to the velocity, the unmelted powder particles deform and consolidate on the workpiece on impact, to create the coating. The gas is heated to achieve higher flow velocities, which results in a higher particle impact velocity.

Electric arc spraying: Two consumable wire electrodes are connected to a direct current power source and fed into a spray gun. An arc is established where they meet that melts the tips of the wires. The molten metal is propelled, by compressed air or gas, onto the work piece. This process is different from other thermal spray processes as the particles are not indirectly heated using gas jets. Oxygen and/or a flammable gas are not used.

Plasma arc spraying: Plasma is formed using a gas such as argon, nitrogen, hydrogen or helium either alone or in combination. The powder coating material is accelerated towards the work piece by the plasma jet. Cooling water is used to cool the plasma generator during operation.

C.6 NFPA 33, Standard for Spray Application Using Flammable or Combustible Materials (2016)

The major difference between the NFPA standard and this DS is as follows:

Protection: NFPA 33 allows fixed automatic fire extinguishing systems (e.g., carbon dioxide, chemical, gaseous agent) to protect spray areas. FM recommends sprinklers.