PLASTIC AND PLASTIC-LINED TANKS

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1.0 SCOPE

This data sheet provides loss prevention guidance relating to construction, fire protection, and electrical safeguards for plastic and plastic-lined tanks containing non-ignitable liquids. These tanks are commonly found in metal treatment processes such as pickling and electroplating, and electronics manufacturing.

Specific guidance relating to the fire hazards of metal treatment processes, such as treating and finishing, are provided in Data Sheet 7-104, *Metal Treatment Processes.*

Specific guidance relating to heat treatments, such as annealing, are provided in Data Sheet 6-10, *Process Furnaces.* This data sheet (DS 7-6) does not cover treatment or finishing processes for non-metal materials.

Refer to Data Sheet 7-32, *Ignitable Liquids Operations,* for guidance on tanks containing ignitable liquids.

Refer to Data Sheet 7-78, *Industrial Exhaust Systems*, for guidance on fume exhaust systems.

1.1 Changes

April 2017. This document has been completely revised. Major changes include the following:

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

B. Updated the fire protection guidance.

C. Added guidance on human factors, including emergency response procedures and pre-incident planning.

D. Incorporated relevant guidance from Data Sheet 7-104, *Metal Treatment Processes,* to ensure consistency between the two data sheets.

E. Updated the loss history, including the addition of recent illustrative losses.

1.2 Hazards

In pickling and electroplating processes, the equipment is typically constructed of plastic and fiberglass-reinforced plastic (FRP). This is necessary to sustain longevity of equipment due to the corrosive nature of the acids that are typically involved. However, these materials are combustible and, without adequate fire protection, a fire involving a plastic tank can propagate to adjacent combustibles and interconnected equipment, resulting in an uncontrolled fire.

Where plastic or plastic-lined tanks are used to contain corrosive liquids, release from a tank can expose nearby equipment and the building structure to corrosive attack. If the liquid release is not controlled, the liquid can spread to adjacent production areas or floors below.

For a description of the hazards associated with plastic-lined tanks, see the FM Understanding the Hazard brochure *Heated Plastic Tanks* (P0038).

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

2.1.1 If noncombustible materials are used for tank construction, tank lids, hoods, enclosures, exhaust ductwork, and downstream fume treatment equipment, the recommendations in this data sheet do not apply.

2.1.2 Use FM Approved sprinklers, controls, interlocks, sensors, valves, and other equipment and materials, when applicable and available. Use FM Approved immersion heaters for hazardous locations. For a list of FM Approved products, see the Approval Guide, an online resource of FM Approvals.

2.2 Construction and Location

2.2.1 Where plastic materials are needed for process compatibility, use plastics that are FM Approved to the Class 4910 FM Approval Standard.

2.2.2 Provide a minimum 1-hr fire separation between plastic tanks and the surrounding occupancy.

2.2.3 Provide FM Approved scrubbers, fume/smoke exhaust duct systems. Scrubbers and fume/smoke exhaust system should be independent of other plant areas. Refer to Data Sheet 7-78, *Industrial Exhaust Systems*.

2.2.4 If liquid release has the potential to cause contamination, provide containment to limit exposure to the surrounding equipment or occupancy (e.g., a curb at the door to the area).

2.3 Protection

2.3.1 Protect combustible plastic and plastic lined tanks containing nonignitable liquids as follows:

A. Where smaller tanks used in batch type processes are in place, protect in accordance with HC-3 in Data Sheet 3-26, *Fire Protection Water Demand for Nonstorage Sprinklered Properties.*

B. Where larger tanks that may span an entire room are in place (e.g., tanks used for chemical pickling lines), provide protection in accordance with Data Sheet 7-104, *Metal Treatment Processes.*

2.3.2 Provide protection under any enclosure or other obstruction that exceeds 3 ft (0.9 m) in width or diameter, or 10 ft^2 (0.9 m^2) in area.

2.3.3 Follow the sprinkler installation guidelines indicated in Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers.*

2.3.4 Provide a minimum 500 gpm (1900 L/min) allowance for hose streams.

2.3.5 Ensure the water supply is capable of providing the design sprinkler discharge flow rate plus hose streams for 60 minutes.

2.3.6 Protect tanks containing ignitable liquids per Data Sheet 7-32, *Ignitable Liquids Operations.*

2.3.7 Protect combustible exhaust ductwork in accordance with Data Sheet 7-78, *Industrial Exhaust Systems.*

2.3.8 Protect combustible scrubbers and exhaust stacks in accordance with Data Sheet 7-78, *Industrial Exhaust Systems*.

2.3.9 Use automatic sprinklers or nozzles that are appropriate for the corrosive environment (such as FM Approved corrosion-resistant sprinklers).

2.3.10 Arrange automatic sprinklers or deluge nozzles installed within equipment (under lids, hoods, ducts, or enclosures) to enable periodic visual inspection and replacement. One solution may be to install mounting brackets and flexible hose connections to facilitate removal of the sprinkler or nozzle from outside the equipment.

2.3.11 Provide portable extinguishers in accordance with Data Sheet 4-5, *Portable Extinguishers.* Do not use dry chemical or foam extinguishers where contamination of tank contents is a concern.

2.4 Equipment and Processes

2.4.1 Liquid Heating Systems

2.4.1.1 Where tanks are heated using a heat transfer system, design and protect the system in accordance with Data Sheet 7-99, *Heat Transfer by Organic and Synthetic Fluids.*

2.4.1.2 Where tanks are heated using immersion heaters, mount and secure the heaters in a fixed position in accordance with the manufacturer’s mounting recommendations to account for adequate clearance from the walls and bottom of the tank.

2.4.1.3 Protect immersion heaters from mechanical impact.

2.4.2 Tank Alarms and Interlocks

2.4.2.1 Shut off heaters during idle periods.

2.4.2.2 Upon fire detection, perform the following interlock actions:

A. Shut down the ventilation fans for the fume exhaust system.

B. Activate the dynamic braking system to fume exhaust system fan motors, if applicable.

C. Shut down heaters

2.4.2.3 Provide each heated tank with the following sensors or limit switches.

A. Low-liquid-level sensors or limit switches. Interlock these to shut down the heaters and sound an alarm. Restore heater operation when the process level sensor is satisfied.

B. High-liquid-level sensors or limit switches when tanks are filled from a bulk supply system. Interlock these to stop the flow of chemical, shut down the heaters, and sound an alarm. Restore operation when the process level sensor is satisfied.

C. Over-temperature alarm and interlock for the heater. Locate temperature sensors as close as possible to the heater or make them an integral part of the heater. Interlock the tank heating system to shut down at or below the maximum operating temperature specified by the heater manufacturer or sufficiently below a temperature that creates a potentially dangerous situation (e.g., the boiling or thermal degradation temperature of the liquid being heated).

D. High liquid temperature limit sensor or limit switch. Set the high liquid temperature limit to 25°F (14°C) above normal operating temperatures, or set at a temperature that does not create a potentially dangerous situation (e.g., the boiling or thermal degradation temperature of the liquid being heated), whichever is less. Interlock these to shut down the heaters and sound an alarm. The interlock should have a manual reset.

Note: The liquid temperature and level interlocks should operate independently of normal process controls. Often, the process and safety interlocks are connected to the same controller but, for example, the process liquid temperature control should not do double duty as the safety high liquid temperature interlock. Similarly, the process liquid level control should not double as the low-liquid-level interlock. The safety interlocks are frequently referred to as the high-high-temperature interlock and the low-low-level interlock in order to differentiate them from the process interlocks.

E. Low-liquid-flow alarm and interlock. Interlock the tank heating systems and pumping systems to shut down if the liquid circulation falls below the minimum required flow per the heater manufacturer. Restore heater operation when the process level sensor is satisfied.

F. If applicable, interlocks that shut down the tank heating system upon actuation of a tank's drain system. Restore heater operation when the process level sensor is satisfied.

2.4.2.4 Wire the interlocks listed in Section 2.4.2.3 so a fault signal shuts down power to the heaters and places the system in a safe condition.

2.5 Operation and Maintenance

2.5.1 Visually inspect accessible electrical and mechanical components, heaters, operating controls, and safety devices weekly. Capture any deficiencies and generate work orders to address any necessary corrective actions.

2.5.2 Conduct quarterly visual inspections of the fire protection system (sprinklers, valves, pipe work, and detectors) for signs of corrosion. Replace components as needed. (Figure 1 shows examples of corrosion-damaged fire protection components.)

2.5.3 Inspect internal and external tanks, and conduct tank repairs or alterations per the tank manufacturer's guidelines.

2.5.4 Test all system interlocks in accordance with the manufacturer's recommendations at least quarterly. Document the scope and results of the testing.

2.5.5 Physically check the tightness of electrical connections. Alternatively, conduct an infrared scan annually.

2.5.6 Refer to Data Sheet 10-3, *Hot Work Management,* for guidance when conducting hot work around or within the tank.

2.5.7 Manage safety interlocks using an impairment-management program in accordance with Data Sheet 10-8, *Operators.*

2.6 Human Factor

2.6.1 Develop formal emergency response procedures. Include procedures for operator actions during a fire, which may include opening tank lids, draining liquid from the tank, shutting down tank-heating systems, and shutting down the fume exhaust system.

Fig. 1. Corrosion-damaged fire protection components

2.6.2 Prepare a pre-incident plan with the fire service and any other responding agencies to ensure an agreeable plan of action is in place in the event of a fire or other incident. Factors to be addressed include issues of chemical exposure, potential plating solution reactivity (e.g., with water), and ignitable liquid handling (if any). Annually, conduct a joint exercise (drill) involving the facility and the public agencies that would normally respond to emergencies. Review and update the plan as necessary following these exercises.

2.6.3 Develop, implement, and audit a formal standard operating procedure plan. Include operation and maintenance, plus procedures that manage changes in processes.

2.6.4 Conduct initial operator training and periodic refresher training on standard operating procedures and emergency response procedures.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Introduction

Plastic (usually polypropylene, polyethylene, polyvinyl chloride, or glass-fiber-reinforced plastic) and plastic-lined tanks are used extensively in metal processes, the electronics industry for cleaning, plating, and etching of circuit boards and electronic components. They are also used in metal finishing and electroplating operations.

Although solutions in these tanks are usually not ignitable, fire involving the combustible tank and/or tank lining can cause considerable damage to contents and surroundings. Plastics, such as polypropylene, are chosen for their corrosion resistance and lower cost compared to stainless steel. Plastic materials can easily ignite and, without adequate fire protection, rapidly propagate to adjacent plastic tanks, into the combustible exhaust systems, and to nearby combustible materials. Severe damage to equipment and the structure (in both combustible and noncombustible construction) may result from such fires. Fires occur frequently in plastic tanks because the liquids they contain are typically heated as part of the process. The heaters ignite the plastic tanks because of electrical faults, low liquid levels, etc.

3.2 Fluid Heating Types

3.2.1 Electrical Resistive Element Heaters

These types of heaters use the energy generated by the resistance to the passage of electrical current through a conductor to directly heat a liquid. These heaters can be either non-flow or flow systems. Non-flow systems do not require agitation or flow in order to operate properly and safely. Flow systems require forced convection through either flow or agitation of the liquid being heated to prevent overheating of the liquid.

3.2.1.1 Electric Immersion Heaters

An outer sheathing that acts as a corrosion and electrical barrier typically protects the heating element on these heaters. This type of heater transfers energy to the liquid by means of conduction.

3.2.1.2 External Heaters (Bonded Heaters)

External heaters are normally bonded to the outside of the tank. This type of heater also transfers heat to the liquid by conduction.

3.2.1.3 Infrared Heaters

These are heaters that emit infrared energy and heat the liquid by absorption of radiant energy. Infrared heaters are usually resistive element devices separated from the liquid by a nonconductive material, typically quartz glass.

3.2.2 Heat Exchangers

The most common type of heat exchanger uses a separate heating device that may be remote from the heated tank. This heat source may use a heat transfer fluid that is delivered by noncombustible tubing to the tank and then recirculated back to the heater. A similar design uses a dual loop system and counter-flow type heat exchanger.

3.3 Loss History

Between 2006 and 2016, the majority of FM plastic tank losses occurred in occupancies classified as machine shops or electronics manufacturing, with most taking place in plating operations.

Two-thirds of the losses involved plastic tanks equipped with electric immersion heaters. The heater was identified as the cause of the loss in 34% of the instances (see Table 1). Immersion heaters are normally submerged in the processing solution. If the tank leaks or if the liquid level drops below the heater and the heater is left energized, the tank wall or liner can be ignited. Several of the fires occurred when heaters were either left energized during idle periods or were activated by a timer several hours before the beginning of operations.

Table 1. Causes of Plastic Tank Fire Losses, 2006 to 2016

Cause	*Percentage of Losses*
Immersion heater	34%
Electrical (arc, short, etc.)	26%
Hot surface	13%
Overheating	13%
Unknown	11%
Leakage	3%

A major factor in many of the losses was a lack of or malfunctioning of low-liquid level interlocks and/or high-temperature limit switches. These interlocks were often poorly maintained and as a result did not function properly when needed. A complete list of contributing factors is provided in Table 2. This table does not include information pertaining to fire protection, which is included in Table 3. Note that many losses included more than one contributing factor.

Table 2. Contributing Factors to Plastic Tank Fire Losses, 2006 to 2016

Factor	*Percentage of Losses*
Lack of or failure of Protective device (e.g., interlock)	50%
Equipment issue	32%
Human Factor	29%
Lack of segregation, space separation	26%
Combustible building construction	21%
Inadequate inspection and maintenance	11%
Contamination	11%
Presence of ignitable liquid in area	8%

Over half the losses involved unsprinklered occupancies. Several of the losses included some sprinkler protection, but the design was identified as inadequate or sprinkler were not installed in key areas such as below obstructions. For example, the loss identified in Section 3.4.1 had ceiling sprinklers installed throughout the building, but sprinklers were not provided within a combustible equipment enclosure. The fire was therefore shielded from the provided sprinkler protection, resulting in a significant fire loss. Table 3 provides further details regarding the impact of sprinkler protection.

Table 3. Automatic Sprinkler Protection in Plastic Tank Fire Losses, 2006 to 2016

Factor	*Percentage of Losses*
Sprinklers adequate	32%
Sprinklers missing or inadequate	66%
Unknown	2%
Total	100%

3.4 Illustrative Losses

3.4.1 Aircraft Manufacturing Facility

The facility had plastic tanks heated by electric immersion heaters. The heaters were controlled by temperature probe systems, and equipped with interlocked liquid level switches. Maintenance and testing of these controls and interlocks was not conducted on a regular basis.

The molten salt bath process was used to clean parts. It includes three, 400 gallon (1500 l) plastic tanks. The molten salt bath operation was surrounded by a 3/8 inch polypropylene plastic enclosure designed to capture the fumes associated with the process. A PVC exhaust hood near the tanks fed a 16 inch diameter PVC exhaust duct which ran vertically up through the roof. Sprinkler protection was not present within the enclosure, nor were they provided in the exhaust ductwork.

A plant employee noticed a fire beginning in a molten salt bath cleaning area. Sprinklers operated and the fire department arrived within 8 minutes of the initial alarm. A total of 76 sprinklers operated in production area, and six sprinklers operated in the office mezzanine area overlooking the original fire area.

Although the fire area was contained to 400 ft^2 (40 m^2, the plant experienced heavy smoke damage, damaging the manufactured products. In addition to the smoke damage, there was some buckling of building structural steel directly over the fire area. About 25,000 ft^2 (2300 m^2) of the metal roof cladding sustained heat damage.

The most likely cause of the fire was arcing in an electrical heating bundle in a plastic tank. Another major contributing factor was the hot water tank heating system was normally left on and unattended during the weekends. Also, the heated tanks were located in a main production area, rather than in a separated cut-off room. There was no testing or maintenance program for the electric immersion heaters. There were no sprinklers within the polypropylene enclosure surrounding the plastic tank operation, nor were they provided in the 16 in (40 mm) PVC exhaust duct, which ran 24 feet vertically through the roof. Ceiling sprinklers directly above the plastic tank enclosure were obstructed by a 4 ft. wide (1.3 m), steel ventilation duct.

3.4.2 Metal Wiring Manufacturing

A fire occurred in an unsprinklered reinforced concrete building with brick walls. The facility had a polyurethane insulated roof panel. The facility manufactured steel wires. The plating process included four lines, each line was approximately 200 ft long, 5 ft wide and 2.5 ft deep (60 m long, 1.5 m wide and 0.7 m deep). Each line was separated by approximately 2.5 ft (0.7 m). Each line consisted of 5 tanks. The lines were located on the second floor of a manufacturing facility. The tanks were constructed with polypropylene with a polyurethane core for insulation purposes. Immersion heaters were provided to heat the liquid. An immersion heater caused the fire within one of the tanks, and the fire spread along the entire second floor within 30 minutes. Flames extended beyond the windows of the second floor and ignited the roof panels. The fire department suppressed the fire approximately four hours later. The time needed to restore the plating building was approximately eight months.

3.4.3 Metal Hardware Manufacturer

A fire started in a plating line located on the ground floor of a manufacturing facility. The manufacturing facility was noncombustible construction (brick walls and steel roof). The plating line was not adequately separated from the rest of the manufacturing facility (i.e., in a 1-hour cutoff room). It was separated from the rest of the facility by a partial-height plastic sheeting wall. Sprinklers were provided at the perimeter of the plating area, however the area was not sprinklered. The plastic tanks were electrically heated and the heaters were surface mounted on the tanks. The fire department arrived at the site 10-15 minutes after notification and were able to suppress the fire an hour after they arrived. The fire involved the entire plating area, including electrical damage, equipment, and structural damage to the roof.

3.4.4 Fire in Unsprinklered Electroplating Line

A fire started in a plastic tank utilized for surface treating metal parts. It is believed that the fire was likely caused by overheating of a corroded electrical connection supplying power to the tank heater.

The facility was of noncombustible construction, but sprinkler protection was not provided. One area of the building contained two electroplating lines and the other housed a galvanization line. The electroplating process included plastic tanks in which liquid plating solutions were heated by immersed electric resistance heaters.

The tanks were not provided with independent high-temperature shutoffs. Over the weekend, while the facility was idle, a fire detection alarm was received early one morning, indicating a fire in the electroplating area. The fire department arrived soon after and began fire fighting efforts, eventually fully extinguishing the fire later that afternoon.

Although the building wall construction was noncombustible, the fire spread throughout the electroplating area due to the lack of sprinkler protection and the presence of plastic equipment such as tanks, ductwork, and pipes.

A significant portion of the electroplating area was severely damaged. The metal frame deformed and one area of the building collapsed. Most of the equipment in the building suffered fire damage and was beyond repair, including electrical supply equipment, motors, and cables. Fire did not spread into the galvanization line, but corrosive smoke and soot contaminated the area due to openings in the wall. Decontamination efforts were required to limit potential corrosion of the equipment.

3.4.5 Aircraft Component Plant

A fire originated in the unsprinklered plating room of an aircraft component manufacturing plant at approximately 3:00 p.m. The 2500 ft^2 (233 m^2) plating room contained four plating lines (two tin plating, one nickel plating and one gold/silver) plating. Some of the plating tanks were heated using immersion heaters; all were reportedly equipped with high temperature and low-level alarms and interlocks. The fire occurred over the Labor Day Holiday weekend so there were limited operations taking place at the plant. It was normal procedure for the plant to leave the plating equipment operating even when the plant was unoccupied.

Sprinklers had recently been installed in the building, though not in the plating room due to the plant's fear of sprinkler water reacting with cyanic solutions in the baths and creating toxic gases. The local fire department reportedly conducted annual pre-fire planning visits to the facility.

An employee notified an on duty policeman who was conducting hourly visits of the facility, as mandated by the local Fire Marshal Office since the newly installed fire alarms were not yet connected. The fire department responded to the location at 3:15 p.m. and connected a pumper truck to the fire department connection. No further fire fighting efforts were initiated by the fire department, reportedly due to the nature of chemicals located in the plating area (cyanides and acids) and the possibility that, when combined with water, cyanide gas could be evolved. The fire continued to burn until 11:00 p.m. when Hi-Ex foam concentrate was applied.

The fire resulted in severe damage to the plating room area and contents. An adjacent cleanroom used for assembly and packaging suffered smoke and soot damage.

The likely cause of the fire was determined to be the ignition of the polyethylene-plating tank by an immersion heater.

4.0 REFERENCES

4.1 FM

Data Sheet 1-57, *Plastics in Construction*
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 6-10, *Process Furnaces*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-78, *Industrial Exhaust Systems*
Data Sheet 7-83, *Drainage and Containment for Ignitable Liquids*

FM Approvals Standard *Cleanroom Materials Flammability Test Protocol* (Class 4910)

APPENDIX A GLOSSARY OF TERMS

FM Approved: A product or service that has satisfied the criteria for FM Approval. Refer to the *Approval Guide,* an online resource of FM Approvals, for a complete list of products and services that are FM Approved.

Ignitable liquid: Any liquid or liquid mixture that is capable of fueling a fire, including flammable liquid, combustible liquid, inflammable liquids or any other term for a liquid that will burn. An ignitable liquid is one that has a fire point.

APPENDIX B DOCUMENT REVISION HISTORY

April 2017. The entire document has been revised. Major changes include the following:

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

B. Updated the fire protection guidance.

C. Added guidance on human factors, including emergency response procedures and pre-incident planning.

D. Where applicable, incorporated guidance from Data Sheet 7-104, *Metal Treatment Processes,* to ensure consistency between the two data sheets.

E. Updated the loss history, including the addition of recent illustrative losses

January 2012. Terminology related to ignitable liquids has been revised to provide increased clarity and consistency with regard to FM Global's loss prevention recommendations for ignitable liquid hazards.

September 2000. The document has been completely revised to include additional recommendations for tank construction, electrical safeguards, heating system interlocks, updated loss information and descriptions of different heating system types.

January 2000. This revision of the data sheet was reorganized to provide a consistent format.

June 1986. This revision of the data sheet emphasized that the high temperature limit switches and the electrical contactor should be independent of the normal operating controller and electrical contactor. Also, the loss experience was updated.