HEAT TREATING OF MATERIALS USING OIL QUENCHING AND MOLTEN SALT BATHS

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1.0 SCOPE

This data sheet provides loss prevention guidance relating to the heat treating of metals by immersion or quenching in oil or other liquid quenching media. The majority of quench oils have flash points above 300°F (150°C); therefore, the guidance in this data sheet is focused on the protection of ignitable liquids with flash points greater than 200°F (93°C). This data sheet also covers heat treating by immersion in molten salt baths. A brief description of typical quenching processes is included.

This data sheet does not cover oil cookers, metal cleaning, or processes where materials are coated by immersion in dip tanks. These operations are covered in Data Sheets 7-20, *Oil Cookers*; 7-97, *Metal Cleaning*, and 7-9, *Dip Tanks, Flow Coaters, and Roll Coaters*; respectively.

1.1 Changes

January 2022. Interim revision. The following significant changes were made:

A. Lowered the flash point threshold of very high flash point (VHFP) liquids to be consistent with other ignitable liquid data sheets.

B. Reorganized Section 2.5, Equipment and Processes to improve readability.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

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

2.1.1 Ignitable Liquid Hazard Scenario

Recommendations for passive and active fire protection features in this data sheet vary depending on the severity of the potential fire hazard. The consequences of a quench tank fire are dependent on a number of factors, including the following:

- Quantity and type of ignitable liquid involved
- Exposed surface area of the quench tank
- Use conditions (e.g., temperature)
- Equipment arrangement (e.g., open, closed)
- Equipment location
- Equipment construction

The intent of this data sheet is to limit the amount of ignitable liquid that can become involved in a fire. In evaluating the hazard associated with a quench tank, the starting point is the exposed surface area of the tank. The severity of a quench oil tank fire is directly proportional to the surface area of the liquid. As such, the surface area and corresponding fire severity will be minimized if the ignitable liquid can be contained within the tank. A small tank that is properly designed (e.g., noncombustible equipment, piping, etc.) will present a minimal fire hazard due to the small surface area of the tank.

A tank with a larger surface area will result in an increased fire hazard, although damage can still be limited if overflow from the tank can be prevented. Safeguards such as overflow drains and emergency bottom drains may be provided for the equipment, designed to contain the liquid within the tank and piping systems. Damage to adjacent equipment will be minimized, while automatic sprinklers will limit damage to the building.

Regardless of the tank size, if safeguards are not provided to confine the liquid to the equipment, the potential exists for the liquid to be released into a room, and for a subsequent fire to extend well beyond the tank area. The fire size will grow exponentially, and the potential exists for a large fire that will operate all exposed sprinklers. Any equipment that is exposed to the burning pool will be damaged. However, if overflow from the tank is accounted for by designing the surrounding area as an ignitable liquid occupancy in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*, damage may be effectively limited. The includes containment and emergency drainage for the room area to limit the ignitable liquid fire exposure to the rest of the building, and properly designed automatic sprinkler protection that accounts for the larger pool fire outside of the quench tank.

2.1.2 Liquid Evaluation

2.1.2.1 Use a nonignitable liquid (e.g., water) or an FM Approved quench fluid rather than an ignitable liquid such as mineral oil. A liquid or mixture that does not exhibit a fire point can be treated as a nonignitable liquid.

2.1.2.2 Where FM Approved quench fluids are used exclusively, determine the need for protection and other safeguards, such as automatic sprinkler protection, based on the surrounding occupancy.

2.1.2.3 Where it is not possible to use a nonignitable liquid or an FM Approved quench fluid:

2.2 Construction and Location

2.2.1.1 Locate and arrange external heat exchangers that are remote from the heat treating operations in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*.

2.2.3 Construct all quench tanks of noncombustible material on supports of heavy metal, reinforced concrete, or masonry.

2.2.4 Arrange the top of any quench tank to be at least 6 in. (150 mm) above the floor of the room in which it is located. Where this arrangement cannot be provided, install a 6 in. (150 mm) noncombustible curb or lip, secured to the building floor surface around the perimeter of the tank.

2.2.5 Construct molten salt bath tanks of chrome-nickel-alloy steel or other material that is resistant to high temperatures and to attack by the salts.

2.2.6 Design, locate, and arrange quench tanks and associated equipment, piping, and storage tanks so they are protected against physical damage:

A. Locate equipment so the potential for vehicle impact damage is eliminated.

B. Provide noncombustible equipment and piping materials with high resistance to mechanical damage.

C. Locate piping overhead or in covered trenches in the floor.

2.2.7 Containment and Emergency Drainage

Containment and emergency drainage will limit the surface area of an ignitable liquid pool fire, as well as the corresponding fire size and severity. A quench tank designed to contain the liquid within the tank and piping systems will limit the fire size. However, a spill on the floor outside the tank could result in a much larger fire. If safeguards are not provided to confine the liquid to the equipment, containment and emergency drainage for the room area is necessary.

2.2.7.1 Design the equipment to contain the liquid within the system. Quench tanks that are provided with one or more of the design features or safeguards listed in Table 1 are not expected to create a pool outside the equipment footprint, provided any automatic filling or circulation systems are properly arranged and no other sources of ignitable liquid release exist in the area (e.g., improperly designed piping systems).

Table 1. Design Options to Contain Ignitable Liquid within a Quench Tank

Closed-Cup Flash Point, Liquid Type, and/or Equipment Configuration	*Design Options*
≥ 200°F (93°C)	Provide emergency bottom drains to prevent overflow by quickly removing the exposed ignitable liquid from the equipment and fire area. Design the emergency bottom drains in accordance with Section 2.5.11.
	Design the sprinkler protection at the ceiling and/or under any obstructions (e.g., exhaust hoods, process enclosures) to extinguish the fire (refer to Data Sheet 7-32, *Ignitable Liquid Operations*). In addition, provide enough freeboard to contain the sprinkler discharge for the duration of the fire.
	Design the sprinkler protection at the ceiling and/or under any obstructions (e.g., exhaust hoods, process enclosures) to extinguish the fire (refer to Data Sheet 7-32, *Ignitable Liquid Operations*). In addition, provide overflow drains to prevent overflow due to discharge from sprinklers or other installed extinguishing systems, or froth-over. Design the overflow drains in accordance with Section 2.5.10.
	Provide a special protection system over the equipment. Design the system in accordance with Section 2.4.2. In addition, provide enough freeboard to contain the sprinkler and special protection system discharge for the duration of the fire.
Specific gravity >1	Provide at least 1 in. (25 mm) of freeboard.

2.2.7.2 Provide either containment (if using a sprinkler protection option that has been shown to extinguish a pool fire) or a combination of containment and emergency drainage (or an alternative to emergency drainage) in the room or building in accordance with the recommendations in Data Sheet 7-32, *Ignitable Liquid Operations* when the prevention of the release liquids into the room is not possible.

2.2.7.2.1 Design the containment and emergency drainage in accordance with Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids*.

2.2.7.3 The provision of safeguards specified in Table 1 is not practical for enclosed quench tanks integral with special-atmosphere furnaces. Provide either containment (if using a sprinkler protection option that has been shown to extinguish a pool fire) or a combination of containment and emergency drainage (or an alternative to emergency drainage) external to the equipment, as described in Section 2.2.7.2.

2.3 Occupancy

2.3.1 Establish good standards of housekeeping. Remove oil deposits frequently from floors, under hoods, and on ceilings that are near quenching operations. Keep records of these housekeeping inspections on file.

2.3.2 Develop and implement a housekeeping audit program completed at least semiannually. Ensure facility management reviews audit reports and takes action to promptly address any identified issues.

2.4 Protection

2.4.1 Room Protection

2.4.1.1 Provide automatic sprinkler protection over quench tanks and associated equipment that use ignitable liquid.

2.4.1.2 Design and install the sprinkler protection in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*, based on the flash point of the ignitable liquid in use.

2.4.1.2.1 For open tanks designed to prevent the release of the liquid into the room and where the sprinkler protection is designed to extinguish the pool fire, use the exposed liquid surface of the dip tank to determine the sprinkler operating area.

2.4.1.3 In addition to sprinklers at the ceiling, provide automatic sprinklers under any obstruction that exceeds 3 ft (0.9 m) in width or diameter and 10 ft^2 (0.9 m$^{2)}$ in area (e.g., under tanks, exhaust hoods, obstructed pit areas, etc.), and in all enclosures. Use sprinklers at least 50°F (28°C) above the highest ambient operating temperature, to avoid premature operation from localized flashing.

2.4.1.4 In noncombustible buildings where molten salt baths are in use, automatic sprinklers are not needed.

2.4.1.4.1 Provide automatic sprinkler protection if combustible material or combustible construction is in the vicinity of the salt baths. Automatic sprinkler protection is not required in the salt bath area.

2.4.1.5 Interlock the quench oil system, including any heating system, to shut down in the event of sprinkler system operation.

2.4.2 Equipment Protection

2.4.2.1 Automatic sprinkler protection may be supplemented with an FM Approved fixed special protection system in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*, to limit fire damage or as an alternative to an emergency drainage system (either within the room or locally over or within the quench tank). In selecting an appropriate system, give consideration to the potential contamination of oil by the agent, which would require oil disposal or cleaning.

2.4.2.2 A fixed water spray system may be installed over the quench oil tank to limit fire damage. Design the system in accordance with Data Sheet 4-1, *Fixed Water Spray Systems for Fire Protection*.

2.4.2.3 Automatically actuate special protection systems using FM Approved flame and/or heat detectors that are compatible with the extinguishing system and arranged in accordance with Data Sheet 5-48, *Automatic Fire Detectors*.

2.4.2.4 Provide capability for remote manual activation of special protection systems from an area that will be accessible during a fire.

2.4.2.5 Interlock the alarm signaling systems to automatically shut down the quench oil system, including any heating system.

2.4.3 Manual Protection

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

2.4.3.2 Where small hose (1 1/2 in. [38 mm]) stations are provided, space them to allow full coverage of the area being protected. Add a water demand of 50 gpm (190 L/min) to the combined sprinkler and hydrant demand for a single hose station. Add a water demand of 100 gpm (380 L/min) when more than one hose station is provided.

2.5 Equipment and Processes

2.5.1 General

2.5.1.1 Design and arrange all work transfer equipment and processes, piping systems, and other auxiliary quenching system equipment in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*.

2.5.1.2 Provide automatic safeguards and interlocks arranged to shut down all ignitable liquid flow in and to the impacted building or room in the event of a fire. Design the operation of these safeguards to prevent damage to the equipment or partial submersion of work.

2.5.1.3 Provide high liquid level switches for automatic filling operations to prevent overflow of the tank.

2.5.1.3.1 Provide a high liquid level switch a maximum of 2 in. (51 mm) below the lip of the tank, arranged to sound an alarm.

2.5.1.3.2 Provide a second switch at a higher level designed to shut down all ignitable liquid flow to the tank.

2.5.1.3.3 Tanks with properly designed overflow drains do not need a second liquid level switch arranged to shut down filling. A high liquid level alarm is still needed to ensure operators are alerted.

2.5.1.4 Provide a low-oil-level interlock in tanks integral with heat-treating furnaces, arranged to sound an alarm and shut down quenching equipment in the event the oil level is below safe limits.

2.5.1.5 Provide a water detector for oil quenching integral with heat-treating furnaces, arranged to sound an alarm and shut down quenching equipment in the event the water content in the oil exceeds 0.35% by volume.

2.5.1.5.1 Locate the detector in accordance with the manufacturer's instructions.

2.5.1.6 Provide a high-temperature-limit switch independent of operating temperature controls on all oil quench tanks where any of the following conditions exist:

A. The surface area exceeds 25 ft^2 (2.3 m^2).

B. Incoming or outgoing work is handled by conveyor.

C. Artificial cooling is required to maintain the oil temperature at least 50°F (28°C) below the flash point.

D. The tank is equipped with a heating system.

2.5.1.6.1 Set the limit switch slightly higher than the normal operating temperature and at least 50°F (28°C) below the flash point of the oil. Interlock the switch to provide an audible alarm, shut down any quench oil heating system, and if not in operation, start up oil recirculation or agitation and the tank cooling system. Where sudden stoppage will not damage the feed conveyor or result in partial submergence of work, arrange the limit switch to also shut down the conveyor. A dual-contact limit switch may be used, arranged to actuate the alarm prior to the other operations.

2.5.1.7 Locate cooling-oil nozzles below the oil surface of the quench tank to prevent spraying into the air or causing excessive spattering if the oil level drops.

2.5.1.8 Arrange for rapid and complete immersion of work. Transfer hot parts to the quench tank without splashing and with minimal possibility of hang-up. Construct chutes so they are smooth and of sufficient size and pitch.

2.5.1.9 Where elevator mechanisms are used, provide sides or guides on elevator platforms. Where cranes or hoists are used, install guides or limit switches arranged to properly position the crane or hoist.

2.5.1.10 Install controls of transfer equipment in a safe location so the operator can complete the immersion in the event of oil flash while the work is being lowered.

2.5.1.11 Where multiple loads are quenched in series, design the conveyor loading controls to prevent a load from extending beyond the end of the quench tank while successive work is moved into the tank. Design the controls to prevent manual overriding of these load stops.

2.5.1.12 Where sudden stopping will not damage the equipment or result in partial submersion of work, interlock the conveyor drive to shut down with the operation of the automatic fire protection system. Avoid locating conveyor motor drives, take-up mechanisms, and similar devices in the immediate vicinity of the quench oil tanks.

2.5.1.13 Route process piping, building roof drains, and similar items away from open quench oil tanks.

2.5.1.14 Locate motors, controls and electrical wiring for furnaces and quench tanks to minimize damage by fire, water, or oil.

2.5.1.15 Where possible, avoid locating such equipment in the same pit as the quench tank.

2.5.1.16 Install any wiring that is exposed to oil vapor, drippings, or splashing in rigid conduit with oil-resistant insulation.

2.5.1.17 Provide lighting fixtures, motors, and control equipment similarly exposed with tight enclosures designed to prevent the entrance of oil or oil vapor.

2.5.2 Cooling Systems

2.5.2.1 Design the tank and cooling system with sufficient capacity to keep the oil temperature at least 50°F (28°C) below its flash point under maximum workload conditions.

2.5.2.1.1 Interlock the controls to prevent starting the feed conveyor or elevator before the agitator or recirculation pump is started.

2.5.2.2 Interlock the controls to shut down the feed conveyor or elevator in the event of failure of the cooling system, agitator, or pump.

2.5.2.3 Design the cooling system with an external heat exchanger and pressure differentials maintained so that any leakage will be oil-to-water, not water-to-oil. Avoid the use of water-cooling coils within or above the tanks.

2.5.3 Heating Systems

2.5.3.1 On all tank heating systems, provide automatic temperature controls to maintain the oil at the desired working temperature, and at least 50°F (28°C) below the flash point of the oil.

2.5.3.2 Interlock the controls to provide an audible alarm and shut down the equipment, and prevent starting the heating system before the tank agitator or recirculation pump is in operation.

a. Provide a high-temperature limit switch independent of operating temperature controls. Set the limit switch slightly higher than the normal operating temperature and at least 50°F (28°C) below the flash point of the ignitable liquid. Interlock the switch to provide an audible alarm, shut down the heating system, and, if not in operation, start up oil recirculation or agitation. A dual-contact limit switch may be used, arranged to actuate the alarm prior to the other operations.

b. Provide a low-liquid-level interlock arranged to sound an alarm and shut down the heating system in the event the liquid level is below safe limits.

2.5.3.3 Design automatic controls to shut down on loss of operating electrical or air supply.

2.5.4 Overflow Pipes

2.5.4.1 Route overflow pipes back to the source of supply or to a point of safe discharge such as a salvage or separator tank.

2.5.4.2 Locate the center line of the overflow connection at least 6 in. (150 mm) below the top of the tank.

2.5.4.3 Provide traps so discharged ignitable liquid will not continue to burn at the collection point. Keep the traps sealed with liquid to prevent passage of vapor.

2.5.4.4 Size the piping to prevent tank overflow from ceiling sprinkler discharge, water-spray nozzles, and other fixed fire protection systems. Refer to the recommendations for catch basins and horizontal discharge piping design in Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids*, to determine the necessary capacity of the overflow drains.

2.5.4.5 Provide fittings and ports to facilitate inspection and cleaning.

2.5.4.6 Install a sheet metal guard where necessary to prevent splashing into the overflow pipe, but arranged so the liquid may flow unobstructed into the overflow pipe.

2.5.5 Emergency Bottom Drains

2.5.5.1 Pipe emergency bottom drains back to the source of supply or to a point of safe discharge such as a salvage or separator tank.

2.5.5.2 Design the emergency bottom drain pipe sizes in accordance with the recommendations for floor drains in Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids*.

2.5.5.3 Where the bottom drain is not arranged for gravity flow, provide an automatically operated pump to empty the quench tank. Interlock the pump to operate simultaneously with the opening of the bottom drain valve. Ensure the pump and electrical supply to the pump are located away from the fire area. Provide a means for manual operation of the bottom drain valve from a safe location.

2.5.5.4 Actuate the bottom drain valve independently of any automatic special protection systems. Operation of the bottom-drain valve may be by a fusible link having a temperature rating higher than that of a fixed-temperature fire detection device actuating the fire protection system or suitable electrical control from a water-flow alarm on the sprinkler system. If fusible links are used, center them over the quench tank on a spacing not exceeding that of the sprinklers in the building.

2.5.6 Salvage Tanks

2.5.6.1 Arrange overflow pipes and emergency bottom drains to discharge to a storage location for recovery of ignitable liquid and waste water treatment.

2.5.6.2 Size emergency drainage system impounding basins or collection facilities to hold the total drainage system discharge for the duration of the sprinkler operation.

2.5.6.3 Design and locate salvage and separator tanks in accordance with Data Sheet 7-88, *Ignitable Liquid Storage Tanks*, including the following:

A. Provide pipe connections and vents for salvage and separator tanks; terminate vent lines outside the building.

B. Equip the vent on the salvage or separator tank with a flame arrester.

C. Provide an overflow pipe from the salvage or separator tank to a safe location.

D. Provide a normally locked open valve in the bottom drain line between the quench tank and the quick-opening valve, and install a plugged tee immediately after the quick-opening valve. By closing the valve, the automatic operation of the quick-opening valve may be tested without discharging the contents of the quench tank. By removing the plug, the interior of the quick-opening valve is readily accessible for cleaning. For accessibility, install plugged tees at the trap and bends in the drain line.

2.6 Operation and Maintenance

2.6.1 Oil Quenching

2.6.1.1 Develop and implement a formal operator audit procedure to ensure compliance with established standard operating and emergency response procedures. Conduct these audits at least semiannually.

2.6.1.2 Implement a management of change program. Have a full review of all planned changes conducted by qualified loss prevention consultants and other authorities having jurisdiction before the project begins.

2.6.1.3 Create a series of routine checkpoints with normal condition limits to be inspected by the operator for prompt detection of abnormal conditions. Conduct frequent inspections to detect and repair leakage. Determine the frequency of the checks based on the process conditions and severity of the consequences of a process upset.

2.6.1.4 Maintain hydraulic-control mechanisms and water-cooling systems in good repair to prevent leakage and faulty operation. Give particular attention to cooling coils submerged in quench tanks. Check tanks monthly for possible water accumulation and keep records of these inspections

2.6.1.5 Maintain and test all system interlocks at least quarterly or in accordance with manufacturer's recommendations, if more frequent.

2.6.1.5.1 Maintain records of these tests.

2.6.1.6 Maintain work transfer equipment in dependable operating condition. Check the integrity of the equipment monthly and keep records of these inspections.

2.6.1.7 Maintain the proper level of oil in quench tanks to ensure complete submergence of work, to ensure an adequate ratio of oil volume to workload, to prevent spattering of oil discharge nozzles, to prevent overflowing, and to keep the bottoms of chutes submerged. Maintain records of inspections of the oil level.

2.6.1.8 Add make-up oil to the tank only when the oil temperature in the tank is below 212°F (100°C) to avoid violent frothover if the make-up oil is contaminated with water.

2.6.2 Molten Salt Baths

2.6.2.1 Suspend stock in the bath, but do not allow it to rest on the tank bottom. Be certain that stock accidentally dropped to the bottom is not allowed to remain.

2.6.2.2 Completely clean stock of dust, chips, oil, and other foreign material before immersion.

2.6.2.3 Use the bath for its intended purpose only.

2.6.2.4 Observe extra precautions with nitrate baths. Do not operate nitrate salt baths used for aluminum and aluminum alloys in excess of 1000°F (538°C), as this may lead to an explosive reaction. Do not heat-treat aluminum alloys containing more than 1% to 2% of magnesium in nitrate baths. If cyanide heat treating is followed by nitrate heat treating, thoroughly wash the stock as a dangerous reaction between the two chemicals is likely to occur.

2.6.2.5 Observe extra precautions when heat treating titanium parts. Inspect the integrity of aluminum liners used with steel baskets each time they are used prior to loading with titanium parts and quenching. If there are any holes or thin spots in the aluminum liner, it should be replaced.

2.6.2.6 Check and clean salt baths frequently to prevent any accumulation of scale or other sediment and maintain the proper level of salts. Necessary additions will vary with operating temperature and severity of use. Permit only authorized personnel, who are familiar with the hazards of introducing the wrong material or excessively moist material, to make salt additions to the bath.

2.6.2.7 When re-melting a cold or solidified salt bath, raise the temperature of the entire bath slowly to the melting point. Overheating could result in an explosion caused by gas evolved from decomposition of the molten salts at the bottom. When baths are taken out of service, remove the salt before it solidifies, or immerse tapered steel rods in the solution to provide vent holes for gas when reheating is started.

2.7 Training

2.7.1 Train operators in the hazards of the process, and develop safe standard operating and emergency response procedures in accordance with Data Sheet 7-32, *Ignitable Liquid Operations*. Train operators thoroughly in the prevention and handling of quench oil fires, with particular attention given to the following:

A. Where hot work is handled or controlled manually, lower the work load rapidly and continuously into the oil until completely submerged. Avoid splashing and stops that leave the work partially above the surface.

B. Stop quenching operations immediately if the water detector or temperature alarm sounds, if the oil temperature rises to within 50°F (28°C) of the flash point, or if the cooling or recirculating system is not functioning properly.

C. Follow proper procedures for filling the tank to prevent splashing or overfilling.

2.8 Ignition Source Control

2.8.1 Control all ignition sources in accordance with the recommendations in Data Sheet 7-32, *Ignitable Liquid Operations*.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 Oil Quenching and Molten Salt Baths

3.1.1 Quench Oil Characteristics

Various types of quench oil are used, most having flash points above 300°F (150°C). Straight mineral oils are most common, but mixtures of mineral and vegetable or animal oils compounded to close specifications also are widely used. Compounded mixtures are subject to more serious contamination by extinguishing agents.

Low viscosity is necessary for a uniform rate of heat transfer and for reduced oil consumption. Small quantities of wetting agents are blended with some oils to increase surface activity and to improve quenching characteristics. Oils must have sufficient stability to retain their initial properties for a long period.

3.1.2 Quench Tank Equipment

Quenching systems vary widely in size and arrangement according to the type of workload, quenching technique used, rate of production, and other technical and economic factors. In addition to the quench tank, quenching medium, and the work-transfer equipment, systems often include equipment to agitate, filter, cool, and heat the oil; pumps to circulate the oil; and a supply tank (See Figure 1).

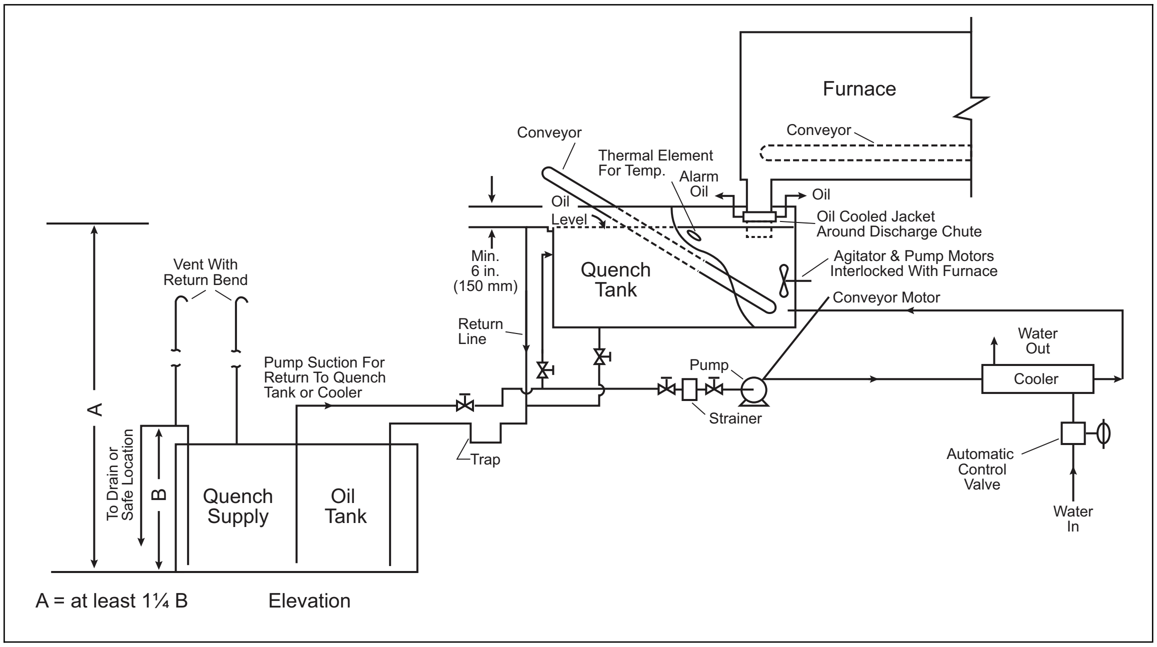

Fig. 1. Typical continuous oil-quench tank arrangement.

Equipment is either the batch or continuous-conveyor type. Tank dimensions and capacity depend mainly on the size of the work being quenched, the method of handling and the rate of production.

Most quench-oil tanks are operated in the temperature range of 100°F to 200°F (38°C to 90°C). Tanks having a large oil volume per unit of load quenched may be cooled adequately by agitation alone or by recirculation of the oil. To conserve space and increase production, modern installations usually have a small volume of oil per unit of workload, and require forced cooling of the oil by circulating cold water through submerged coils or by circulating the oil through an external heat exchanger. Large installations commonly have a central cooling system and a storage reservoir to supply all quench tanks. Some tanks are equipped with steam coils to bring the oil to the desired temperature when starting up, before any work is quenched.

Many modern oil quench tanks are fully enclosed; they form an integral part of a heat-treating furnace. Work can be lowered directly from a chamber in the furnace into the quench tank by an elevator or conveyor.

3.1.3 Automatic Sprinklers at Quench Tanks

Automatic sprinklers at ceiling or roof level are basic protection for quench oil tanks. They provide protection not only for the tank itself, but if installed throughout the heat-treating department, for all possible overflows, for leaks in oil distribution or hydraulic systems, and for any other combustibles, including the building construction. Sprinkler water may cause oils heated above 212°F (100°C) to froth over, but it protects the building and equipment against serious fire damage and extinguishes the oil fire on the floor and in the tank.

3.1.4 Quench Oil Fires

When hot metal is quenched in oil, an envelope of vapor forms around the piece. Large vapor bubbles, which may be above the autoignition temperature, rise to the surface and sometimes flash momentarily into flame. Additional localized surface flashing also occurs around the work as it enters the oil, but is extinguished readily by normal agitation of the oil.

There are three types of quench oil fire that may reach serious proportions in the absence of appropriate safeguards such as sprinkler protection:

A. The most common type of fire occurs with the oil at its normal temperature below the flash point. The red-hot work hangs up, partially submerged at the surface, heating the oil locally above its flash point. The fire develops slowly, and if the work is promptly submerged or removed from the tank, it can be extinguished with portable extinguishing equipment or by agitating the oil.

B. The second type of fire occurs when the main body of oil is heated above its flash point because of the failure or inadequacy of the tank's cooling system, or introduction of an excessive work load. This fire reaches full intensity in only a few seconds and is very difficult to extinguish with portable equipment. Above 212°F (100°C), the heated oil turns water to steam. The impact of sprinkler discharge on the oil should be minimal, but water from hose streams discharged on the fire may cause the oil tank to froth over. Fire spreads suddenly over the adjacent floor area, and firefighters are forced back by intense heat and smoke. (Water spray discharged from sprinklers penetrates the oil surface less readily than the solid hose stream and consequently will cause less violent frothover.)

C. The third type of fire is caused by oil contacting the hot furnace as a result of the following:

1. Overfilling the tank.
2. Splashing caused by the discharge from recirculation nozzles under conditions of low oil level.
3. Steam formation if water gets into the tank and the temperature reaches 212°F (100°C) or the hot work penetrates the water layer. In open tanks, formation of steam below the surface causes foaming and frothover. In enclosed tanks, pressure builds up and oil or flammable furnace atmosphere shoots out of openings. Intense burning can occur over a wide area.

3.1.5 Tempering Oil Tanks

Following quenching, steel parts are usually heated at temperatures below the transformation range and are then cooled at the desired rate. This tempering operation serves to remove internal stresses and to produce the desired mechanical properties. The operation is usually conducted in furnaces at relatively low temperatures, although molten salt baths are also used.

Heated oil baths are occasionally used for tempering metals, but usually in small systems involving low production tool steel items. Because of their limited size and infrequent use, only a few fires have been reported in tempering oil tanks. Applicable safeguards recommended above for quench tanks may be considered a general guide to safe practice for tempering oil tanks.

3.1.6 Molten Salt Baths

3.1.6.1 General

Chemical salts, melted to form a liquid bath, are used in industry for immersion heating of steel and other metals. Their principal application is heat treating of metal to modify its physical properties for specific uses. Other important applications include heating metals for forging, forming, brazing, de-scaling, cleaning, and coloring.

A variety of salts and mixtures may be used, depending on the specific treatment and temperature required for the work at hand. Nitrates, for example, are commonly used for temperatures of 500°F to 1100°F (260°C to 593°C), cyanides for temperatures between 1450°F and 1750°F (788°C and 954°C), and chlorides of sodium, potassium, or barium for temperatures between 1100°F and 2450°F (593°C and 1340°C). Most frequently encountered are the nitrates and cyanides.

The salts themselves are not combustible. However, they create the hazard of a continuous ignition source for combustibles in the vicinity if the salt spatters or otherwise escapes from the bath. Water introduced with work or with salt additions may turn to steam with explosive effects. Some compounds decompose violently when overheated or if the wrong salt is added. Introduction of foreign matter may cause spattering, decomposition of the salts, or serious overheating due to the formation of interior crusts on the tank. Titanium metal and its alloys form a galvanic reaction when in contact with carbon steel while immersed in salt baths. If contact is continuous and uniform, titanium may undergo a complete anodic dissolution. Nitrates, by furnishing oxygen, increase ease of ignition and intensity for burning of combustibles. Cyanides in contact with acids or moisture evolve highly toxic and flammable hydrocyanic acid gas.

Molten salt baths in heat treating areas are not a reason to omit sprinklers if combustible construction or combustible occupancy is present. Salt baths should always be in noncombustible occupancies and noncombustible construction. Sprinkler discharge onto typical molten salt baths is not expected to result in spattering of any significance if installed to protect local combustible materials or combustible construction.

In the absence of sprinklers, a serious fire must ultimately be fought with hose streams; there is record of personnel being driven from the building by spattering when a solid hose stream was accidentally directed into a salt bath. Hose streams cause more severe spattering than does the relatively gentle discharge from sprinklers. A noncombustible hood may be installed over the baths to prevent sprinkler water from contacting them directly.

3.1.6.2 Nitrate Salt Baths

The most commonly used nitrate bath, a mixture of equal amounts of sodium and potassium nitrate, has a lower melting point than either of the salts alone.

Nitrates start to decompose slowly at about 750°F (400°C), forming nitrites and hydroxides, but decomposition does not proceed with sufficient rapidity to prevent their use continuously at temperatures up to about 1100°F (593°C). Above this temperature, decomposition is increasingly rapid until a critical temperature of about 1300°F (704°C) is reached. At this point, violent decomposition is likely to occur, with formation of corrosive nitrogen oxides that will attack ordinary steel containers and the alloy being heat treated.

Aluminum alloys, particularly when they contain magnesium, may react strongly with the available oxygen in the nitrate at high temperature. A thermite reaction may occur between aluminum alloy particles in the bath and iron oxide sludge.

3.1.6.3 Cyanide Salt Baths

Cyanide baths are used most often for producing a case-hardened surface on steel and for reheating high-carbon steel. In general, baths contain from 30% to 75% sodium or potassium cyanide, the balance being varying proportions of sodium chloride and sodium carbonate. It is critical that the stock be free of foreign material, particularly acids or moisture.

4.0 REFERENCES

4.1 FM

Data Sheet 4-5, *Portable Extinguishers*
Data Sheet 5-48, *Automatic Fire Detection*
Data Sheet 7-9, *Dip Tanks, Flow Coaters, and Roll Coaters*
Data Sheet 7-20, *Oil Cookers*
Data Sheet 7-32, *Ignitable Liquid Operations*
Data Sheet 7-83, *Drainage and Containment Systems for Ignitable Liquids*
Data Sheet 7-97, *Metal Cleaning*
Data Sheet 7-99, *Heat Transfer by Organic and Synthetic Fluids*

APPENDIX A GLOSSARY OF TERMS

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.

Ignitable liquid: Any liquid or liquid mixture that has a measurable flash point. The hazard of a liquid depends on its ability to sustain combustion or create a flammable vapor-air mixture above its surface. Flash point is one way of understanding if a liquid can create that flammable vapor-air mixture. For a liquid to burn in a pool, it must have a fire point as well as a flash point. Ignitable liquids include flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn.

Very high flash point (VHFP) liquid: Liquids that meet the definition specified in Data Sheet 7-32.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

January 2022. Interim revision. The following significant changes were made:

A. Lowered the flash point threshold of very high flash point (VHFP) liquids to be consistent with other ignitable liquid data sheets.

B. Reorganized Section 2.5 to improve readability.

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

July 2013. The following major changes were made:

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

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

C. Provided information to assist in evaluating the fire hazard scenario associated with quench tanks, including the need to minimize the surface area of a fire by confining the ignitable liquid within the tank area.

D. Expanded the guidance on FM Approved quench fluids.

E. Expanded the guidance on the construction and location of quenching operations, including FM Global’s current recommendations for ignitable liquid operations.

F. Updated the recommendations for containment and emergency drainage.

G. Provided information on protection of piping and equipment from mechanical damage.

H. Added reference to Data Sheet 7-32, *Ignitable Liquid Operations,* for the appropriate design of piping systems.

I. Revised the sprinkler protection recommendations for areas containing quench tanks.

J. Updated guidance associated with special protection systems for alignment with current technologies and FM Global recommendations.

K. Expanded the information on the design of overflow drains and emergency bottom drains based on recent research.

L. Added information related to human factor, ignition source control, and housekeeping.

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

APPENDIX C RECLAIMING CONTAMINATED QUENCH OILS

Removal of water may be difficult, particularly with straight mineral oil. However, the following information on the reclamation of quench oils that have been contaminated by water or other fire extinguishing agents can be used as general guidance. Before attempting to reclaim any quench oil, contact the manufacturer regarding the suitability of reclaiming methods.

1. Operate the oil-recirculation system for approximately two hours after water contamination occurs to ensure thorough cooling of the oil.

2. Allow the oil and water to separate for at least 12 hours.

3. Pump out the water and sufficient oil at the water level to ensure removal of all large globules of water in the oil. The remaining oil will contain a small amount of water in suspension (approximately 0.5% by volume in mineral oils and 1% by volume in compounded oils).

4. Heat the remaining oil to 180°F to 190°F (82°C to 88°C) and blow compressed air through it for 10 to 12 hours. The oil should then be suitable for reuse.

5. If facilities are not available at the plant, local power company equipment for reclaiming transformer oils may be utilized.

Removal of foam and dry-chemical agents from contaminated oils may be difficult. In compounded oils, the presence of alkaline contaminants and water will cause saponification of the animal or vegetable oil and adversely affect the desirable properties of the original oils. If the oil has considerable value, contact the supplier to determine if economical salvage is possible. In some cases, dry chemical can be filtered out with no apparent effect on the performance of the oil as a quenching medium.