

Oil Quenching and Molten Salt Baths

Oil-quenching operations are heat treatment processes that both harden and temper metals. Molten salt baths are used for heat treatment of metals, ceramics, or polymers to increase their hardness.

OIL AND POLYMER QUENCHING

One process in the heat treatment of metals is a controlled cooling or quenching of heated materials by immersion in a liquid-quenching medium. This process hardens and tempers the metal by imparting metallurgical changes to its surface. *Due to the combustible nature of quench oils, the process presents serious fire hazard potentials.*

Contributing to the hazards of oil quenching are

1. Requirements for a special atmosphere (a flammable gas blanketing the surface of the oil)
2. Temperature requirements of the quench medium
3. Physical properties of the quench medium
4. Volume limitations of the quench medium
5. Size and configuration of process materials
6. Locations of furnaces and quench tanks
7. Mutual exposure between quenching and other processing or storage facilities

Whether the quenching is automatic and continuous, semiautomatic, or a batch operation, it will involve elevators, conveyors, hoists, and cranes, either individually or in combination, to immerse the work in, move it through, and remove it from the oil bath (Figure 6.9.1). Although all three steps are important to the process, the one that is critical to safety is the entrance of the work into the quench.

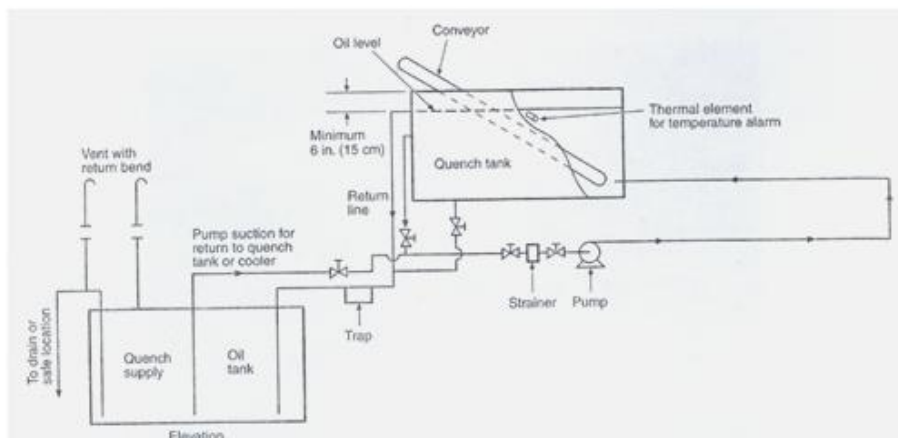


FIGURE 6.9.1 Typical Continuous-Type Oil Quench Tank

Quenching Oils

In most cases, mineral oils are used for quenching, but specific metallurgical requirements sometimes dictate the use of mixtures, with animal or vegetable oils. In addition, wetting agents might need to be blended with certain oils or oil mixtures. In any case, it is important to use quenching oil with a low viscosity.

Essential quench oil properties include the ability to remain stable over periods of extended usage and to retain fluidity. For unheated quenching, operating temperatures between (38 and 93°C) are considered normal. Standard quench oils for use in this temperature range usually have flashpoints somewhat above (149 °C). For heated quenching, operating temperatures between (93 and 204°C) are common. Quench oils used at these temperatures generally have a flashpoint above (260 °C).

QUENCH TANKS

A quench tank should allow proper quenching under normal conditions and provide for minor variations in equipment control functions and operator error. The designs of the tank free board, overflow drains, and liquid level control **are all critical**. A fire that is confined to the liquid surface within a tank is **much more readily controlled** and extinguished than a fire involving quench oil that has overflowed the tank.

The distance from the quench surface to the top of the tank, with tank loaded to capacity, is known as free board. Free board should take into account the splashing to be expected when the maximum workload is immersed with maximum speed. The distance between the liquid level with the work load submerged and any openings in the tank wall should be not less than (152 mm) below the door or any opening into the furnace.

Adequately sized, fully trapped overflow drains are important safety features for all oil quench tanks. They should direct the overflow to a safe location outside of buildings or into special tanks. As a practical matter, small quench tanks frequently can be installed without overflow drains. However, quench tanks with a liquid capacity of 150 gal (570 L) or a liquid surface area of (0.93 m²) or larger should be provided with overflow drains.

Emergency Drains

Under serious fire conditions, it might be necessary to empty a quench tank in order to reduce the amount of quench fluid available. This can be performed readily through adequately sized, fully trapped and valved bottom drains directed to safe locations.

Emergency drains must be used only under the guidance and control of well-trained and experienced personnel, as improper usage can result in greater hazards. Whenever a flammable gas processing atmosphere is maintained above the quench oil, removal of the oil can create a negative pressure that can result in explosion, an increase in fire severity, or both.

Tank Location

Heat-treating operations involving combustible quench oils should be housed in fire-resistive buildings and should be well separated from exit areas, combustible materials, valuable stock, power equipment, and important process equipment.

The safest location for quench tanks is at grade level. Boilover from tanks above grade can be expected to spread fire to floors below, thereby making fire control more difficult and significantly increasing the potential fire loss. Fires in below grade locations will make manual fire fighting difficult and result in significant increase in fire loss.

Fire Protection

Fire protection for combustible oil-quenching requires a detailed evaluation of the inherent fire potentials. *One of the most effective forms of area protection is automatic water spray.* Experience has shown *that ceiling-mounted sprinkler systems* will limit building and equipment damage from quench oil fires whether they are confined to the quench tank surface or spread over a large area by a quench oil boil over.

Specific protection for open quench tank surfaces and oil drainage areas is also important. Most oil fires can be extinguished by fixed carbon dioxide or dry chemical systems. In some operations, foam fire-fighting systems can also be effective. However, the suitability of foam will be determined by the quenching oil used and the temperatures involved. These systems designed to operate automatically, well in advance of any potential sprinkler system discharge.

MOLTEN SALT BATHS

Molten salt baths have become increasingly popular for the heat treatment of metals, ceramics (e.g., glass), or polymers (e.g., Teflon) because they provide rapid and precise heat transfer and the required equipment is relatively inexpensive. *A molten salt bath is defined as any heated container that holds a melt or fusion of one or more chemical salts in a fluid state.* The work to be treated is immersed in the bath. There are many kinds of salt baths that use various salts and salt mixtures and that operate at various temperatures, depending on the results required.

As work is immersed fully into a salt bath, the salt serves as a protective environment. Heat is transferred more rapidly than by any other type of furnace heating. Moreover, because of the constant convection currents in the heated liquid medium, uniform temperature distribution is more easily attained.

Types of Salt Baths

The various types of salt baths available today can be classified by the heating method, application, or the particular salt mixture utilized.

Salt baths can be electrically heated or fuel fired. Electrically heated baths have electrodes introduced through the top surface of the molten salt or through the sides of the furnace below the salt surface (Figures 6.9.5 and 6.9.6). In some instances, ribbon-type resistance elements are used around a metal pot or container (Figure 6.9.7).

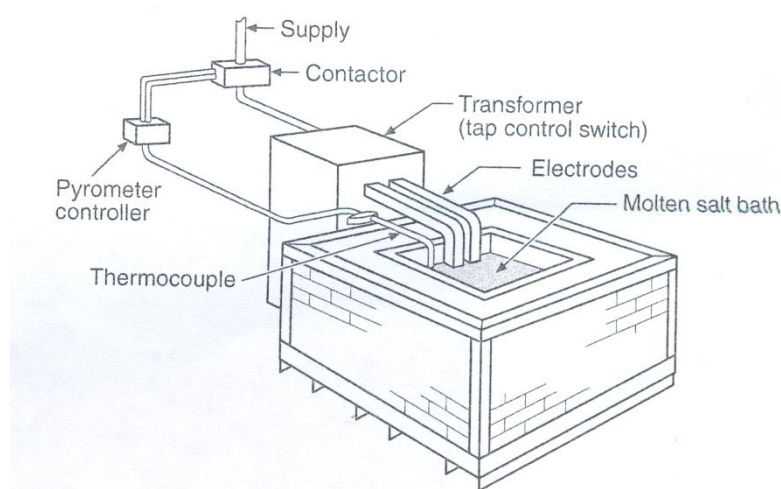


FIGURE 6.9.5 Typical Electrode Immersion-Type Electrical Heating Arrangement

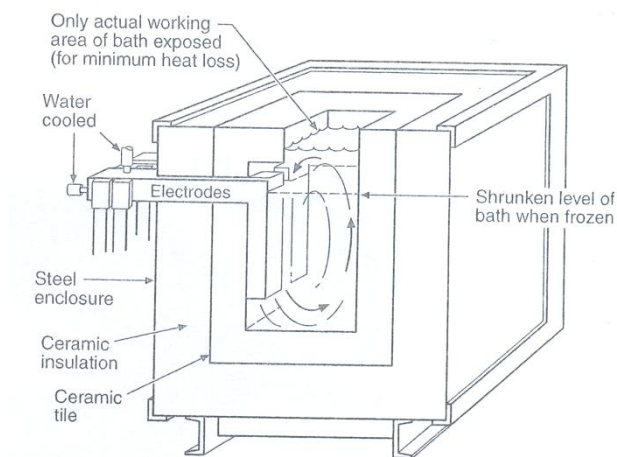


FIGURE 6.9.6 Submerged Electrode- Type Salt Bath

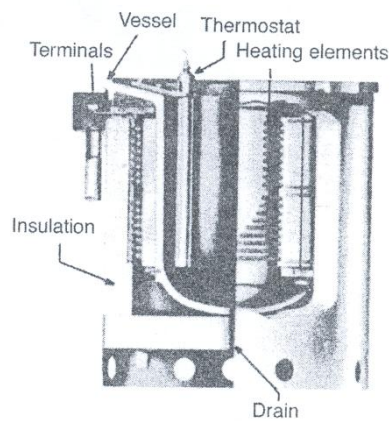


FIGURE 6.9.7 Resistance Heated Salt Bath with Pot (Source: SECO/WARWICK Corp.)

There are two types of fuel-fired salt baths. In one, the burners are fired directly outside a retort containing the salt. In some instances the burners are fired in metal tubes, known as *radiant tubes*, and the tubes are immersed in the molten salt (Figure 6.9.8).

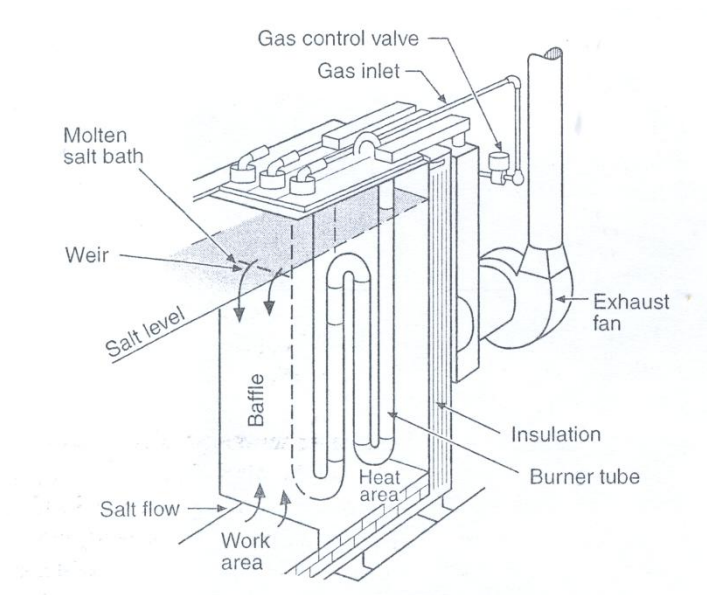


Figure 6.9.8 Gas-Fired Radiant Tube Salt Bath Heating Section

Salt Bath Hazards

The hazards common to salt bath furnaces can be divided into following three types:

1. Fire caused by contact of molten salt with combustibles
2. Explosion of the salt mixture due to physical or chemical reaction
3. The danger to operating personnel

Since salts are used at temperatures from 149 to 1316 °C, the ejection of salt by popping, spattering, or spilling will create a fire hazard if it comes in contact with anything combustible, including wood floors. Since molten salts have relatively little surface tension and low viscosities, any minor physical disturbance or chemical reaction can result in salt being ejected. When liquids (water, oil, etc.) or materials reactive to the particular salt utilized penetrate the surface of the salt bath, a violent ejection can result. Table 6.9.3 lists common salts and their melting points. Table 6.9.4 lists common salt mixtures and their melting points. Proprietary mixtures of these salts are formulated for specific applications and temperatures. Intermixing of certain salts is hazardous (e.g., nitrates and cyanide). Consult suppliers for recommendations.

TABLE 6.9.3 Melting Points of Common Chemical Salts

Salt	Melting Point	
	°F	°C
Barium chloride ^a	1764	963
Barium fluoride	2336	1280
Boric oxide (anhydride)	1071	578
Calcium chloride ^a	1422	773
Calcium fluoride	2480	1360
Calcium oxide	4662	2572
Lithium chloride ^a	1135	613
Lithium nitrate	491	255
Magnesium fluoride	2545	1396
Magnesium oxide	5072	2800
Potassium carbonate ^a	1636	891
Potassium chloride ^a	1429	776
Potassium cyanide ^a	1174	634
Potassium fluoride	1616	880
Potassium hydroxide ^a	716	380
Potassium nitrate ^a	631	333
Potassium nitrite ^a	567	297
Sodium carbonate ^a	1564	851
Sodium chloride ^a	1479	804
Sodium cyanide ^a	1047	564
Sodium fluoride ^a	1796	980
Sodium hydroxide ^a	605	318
Sodium metaborate	1771	966
Sodium nitrate ^a	586	308
Sodium nitrite ^a	520	271
Sodium tetraborate	1366	741
Strontium chloride	1603	873

^aMost common salts.TABLE 6.9.4 Melting Points of Common Salt Mixtures^a

Mixture and Proportion	Melting Point	
	°F	°C
Lithium nitrate 23.3, sodium nitrate 16.3, potassium nitrate 60.4	250	121
Potassium hydroxide 80, potassium nitrate 15, potassium carbonate 5	280	138
Potassium nitrate 53, sodium nitrate 7, sodium nitrite 40 ^b	285	141
Potassium nitrate 56, nitrite 44	295	146
Potassium nitrate 51.3, sodium nitrate 48.7	426	219
Sodium nitrate 50, sodium nitrite 50 ^b	430	221
Sodium hydroxide 90, sodium nitrate 8, sodium carbonate 2	560	293
Lithium chloride 45, potassium chloride 55	666	352
Barium chloride 31, calcium chloride 48, sodium chloride 21 ^b	806	430
Calcium chloride 66.5, potassium chloride 5.2, sodium chloride 28.3 ^b	939	504
Calcium chloride 67, sodium chloride 33	941	505
Potassium chloride 35, sodium chloride 35, lithium chloride 25, sodium fluoride 5 ^b	960	516
Potassium chloride 40, sodium chloride 35, lithium chloride 20, sodium fluoride 5 ^b	990	532
Barium chloride 48.1, potassium chloride 30.7, sodium chloride 21.2 ^b	1026	552
Sodium chloride 27, strontium chloride 73	1049	565
Potassium chloride 50, sodium carbonate 50 ^b	1086	586
Barium chloride 35.7, calcium chloride 50.7, strontium chloride 13.6	1110	599
Barium chloride 50.3, calcium chloride 49.7	1112	600
Potassium chloride 61, potassium fluoride 39	1121	605
Sodium carbonate 56.3, sodium chloride 43.7 ^b	1177	636
Calcium chloride 81, potassium chloride 19	1184	640
Barium chloride 70.3, sodium chloride 29.7 ^b	1209	654
Potassium chloride 56, sodium chloride 44 ^b	1220	660
Sodium chloride 72.6, sodium fluoride 27.4	1247	675
Barium fluoride 70, calcium fluoride 15, magnesium fluoride 15	1454	790
Barium chloride 83, barium fluoride 17	1551	844
Calcium fluoride 48, magnesium fluoride 52	1738	948

^aLowest constant melting points given; proportions are percentages by weight.^bMost common salt mixtures.

Nitrates are particularly hazardous due to their ability to start and support combustion. When nitrates are overheated to temperatures in excess of 593°C, rapid *dissociation* with the release of nitrous oxide fumes occurs. These fumes are injurious to operating personnel and are corrosive to the adjacent equipment. Explosions can occur if nitrate salt leaks from an externally heated container (pot) into a superheated combustion chamber. The overheating of nitrates can be caused by temperature controls that malfunction, an accumulation of sludge in the bath or by operator errors. If the operating temperature of a nitrate or nitrite bath exceeds the maximum limit, the following emergency action should be taken:

1. Shut off the heat supply.
2. Remove all work from the bath.
3. Move employees to a safe location.