Dynalene Molten Salts

engineering guide

DYNALENE

Tomorrow's Solutions **Flow** Through Us

Contents

Product Overview

Dynalene molten salts are environmentally friendly heat transfer salt fluids designed for ultra-high temperature applications. They are specifically engineered to safely withstand excessive heat loads far above the boundaries of most alternative heat transfer fluids. They exhibit negligible vapor pressures near peak operating temperatures and are safe-to-use and non-flammable. The salts are odorless and appear off-white to slightly yellow. They are compatible with steel and stainless steel alloys.

Dynalene heat transfer salts must surpass stringent quality inspections prior to shipment. It is essential that all personnel handling this product review and understand this manual and the Dynalene molten salt material safety data sheets (MSDS). Do not hesitate to contact Dynalene for more information.

There are three variations of molten salt to choose from, with each salt providing a different melting point and maximum operating temperature. These salts are Dynalene MS-1, Dynalene MS-2, and Dynalene MS-450. Custom blends can also be formulated depending on your system requirements.

Melting Temperature

Dynalene's molten salts have the following melting points:

Table 1. Melting temperatures of Dynalene molten salts.

Product	Melting Temperature
Dynalene MS-1	225°C (437°F)
Dynalene MS-2	130°C (266°F)
Dynalene MS-450	120°C (248°F)

Vapor Pressure

Dynalene molten salts exhibit negligible vapor pressures even near peak operating temperatures. This reduces the need for high-pressure plumbing materials and greatly reduces pressure-related system failure. Vapor products include N_2, O_2, NO, NO_2, N_2O_3, N_2O_4, and N_2O_5, with the latter decomposition products slowly produced at excessive temperatures. Due to the oxidative products that are released upon decomposition of the salts when used near peak operating temperatures, airtight containment is recommended to reduce safety hazards.

Thermal Stability

Each Dynalene molten salt has a different maximum operating temperature based on the chemistry of the salt blend. The maximum operating temperatures and recommended operating temperature ranges are given in Table 2. Upon exceeding the maximum operating temperature, the salt will slowly evolve into nitrogen and nitrogen oxides.

When the salt decomposes, white salt oxides will precipitate out into the molten salt fluid. As long as the maximum salt temperature is not exceeded, Dynalene molten salts will remain stable for years.

Table 2. Maximum operating temperatures and recommended use ranges of Dynalene molten salts.

Product	Max Operating Temp	Recommended Use Range
Dynalene MS-1	585°C (1,085°F)	250°C to 565°C (482°F to 1,050°F)
Dynalene MS-2	500°C (932°F)	140°C to 485°C (284°F to 905°F)
Dynalene MS-450	460°C (860°F)	150°C to 450°C (302°F to 842°F)

Materials Compatibility

Dynalene molten salts are compatible with carbon steel, stainless steels, Inconel, iron aluminides, nickel aluminides, and most alloy steel materials up to their maximum operating temperatures. 304, 316, and 321 stainless steels have been used up to 550°C (Dynalene MS-1) with minimal corrosion. At lower operating temperatures, the corrosion rate is drastically reduced.

Carbon steel can be used for temperatures below 400°C, however it is strongly recommended to use higher-alloy steels. Commercially available aluminized products showed little to no corrosion protection due to surface cracking of the aluminum layers. Porous ceramics and cast iron are not advised due to salt uptake and crumbling which can enhance the corrosion rate.

System Compatibility

Valves

Due to thermal expansion and contraction, interior parts of the valves may become misaligned over time. It is strongly recommended to use valves made of stainless steel (316, 321 advised) with stainless steel ferrules to prevent corrosion at high temperatures. High temperature sealant should be used with NPT fittings. Valves must be selected so that there is sufficient reduction in thermal conduction to the packing material to eliminate leakage.

Bellows-sealed, mechanically operated, poppet valves have also shown reliable performance in larger-scale systems. Molybdenum against tungsten or copper and several titanium or tungsten carbide-cermets mating with each other also proved to be satisfactory valve materials that showed minimal signs of corrosion. Always consult your valve manufacturer's recommendations before selecting a valve to be used with Dynalene molten salt.

Piping

It is recommended to use seamless piping where available to prevent flaws that can be worsened by thermal expansion and molten salt corrosion. Thermal expansion effects can be minimized by pre-stressing the piping or by using expansion loops and joints. Only select materials that are compatible with Dynalene molten salts as recommended by Dynalene.

Pump Selection

Pneumatic stainless steel vertical submersible pumps have been successfully used by Dynalene. Vertical cantilever and centrifugal pumps have demonstrated satisfactory performance in larger scale systems. Ensure the pump motor is isolated sufficiently far away from the molten salt to reduce thermal conduction from the pump shaft to the pump motor. Choose pumps which isolate bearings and sealants from direct contact with the molten salt. Thermal barriers and radiant shields are strongly recommended to prevent pumping components from excessive heat sources. Metal or high-density ceramic mechanical seals should be used throughout the pumping assembly to reduce salt leakage. Liquid cooling of internal pump surfaces is another method that can be used to prevent overheating.

Storage & Handling

Keep Dynalene molten salts in tightly sealed containers and store in cool and dry environments with adequate ventilation. Avoid storing near organic and other combustible materials that can be readily oxidized. Avoid walking on the salt in prill form as it could create a slippery surface. Protect against physical damage and moisture and isolate from any source of heat or ignition. Dynalene molten salts ship within hazard class 5.1 (packing group III) in the USA.

Installation & Operating Guidelines

The following recommendations are provided by the Dynalene Technical Support Group to assist the installer or end user in achieving a proper installation. Only qualified personnel with expertise in safely handling potentially hazardous liquids within the compliance of all local, state, and federal regulations should be involved in the work process.

Pre-cleaning

Materials from welding operations, excess pipe joint compound, oils, and other unwanted contaminants must be removed completely prior to installing Dynalene molten salts. Ensure all other foreign contaminants are removed.

Pressure Testing

Ancillary equipment designed with mechanically jointed sealing surfaces must be able to withstand a vapor tight seal when exposed to positive and/or negative pressures. This is commonly performed by subjecting the system or individual component to a leak test.

Inert Gas Blanket

It is recommended to use an inert gas, preferably nitrogen, in the head space to prevent oxidative degradation of the molten salt. An inert gas blanket also has the additional benefit of reducing the corrosion of metals exposed to the salt.

Salt Loading

It is advised to only use materials compatible with molten salt for the storage tank. Begin by inspecting the tank to make sure there are no foreign contaminants and evidence of cracking which could propagate with thermal expansion. As a general heuristic for the initial loading phase of the solid salt into the tank, the average volume of the prill form is generally twice that of the liquid volume due to air gaps. If the tank is not big enough to accommodate all prill form, it may be necessary to add the solid salt and melt down in stages until the desired amount is achieved. As the salt melts, it may be mixed or manually pushed around to evenly heat the molten salt near the burner tubes or resistance heaters. Ensure the tank drain valve is preheated and working properly before addition of the salt and prior to running the system. Thermally conductive materials (such as metal rods or slabs) should be added to the tank to allow for more uniform salt melting. Never add more salt than necessary as overflow may result. Always wear the proper personal protective equipment when charging the system with salt. For large-scale solar thermal storage applications, contact Dynalene for a detailed consultation.

System Heating

Immersion heaters provide the most uniform method of tank heating and have the added benefit of reducing problems caused from thermal expansion and contraction. Gas-fired tube burners or resistance heating methods are the two most common ways of heating a salt tank. Due to the high operating temperatures of the salt, material stability at these temperatures must always be taken into account. For gas-fired heaters, always use flame detectors

and immediately close all gas lines in case of a fire. Resistance heaters should be grounded and covered to reduce exterior exposure.

Based on the design parameters of the system, line and drain valves may need to be preheated to allow salt to flow through narrow orifices and fittings which can cause cold pockets and block the system lines. Straight tube furnaces and induction heating methods provide more uniform heating than traditional resistance heating through metal bands. Heating around irregular shapes and bends can be accomplished by tightly wrapping high-temperature heating tape or induction coil around the section. Preheating the system to 70-100°C above the melting point of Dynalene molten salts provides a sufficient temperature differential to eliminate cold pockets and allow the molten salt to flow through piping and plumbing. Use caution when opening a salt tank during the heating process as molten eruption can suddenly occur if the downward pressure of the solid material forces the molten phase through the cracks and potentially to the surface of the salt.

Draining

All drain valves should be preheated with a heat source to allow the molten salt to flow without freezing in the orifices of the valves. If salt freeze up occurs in the valves, slowly reheat to avoid sudden melting and splashing caused by solid pockets formed inside the valves. Ensure there is an adequate storage vessel that can safely handle the temperatures of the molten salt leaving the outlet of the drain valve. The connection to the drain vessel should be sealed to avoid splashing and drain tank overflow.

Cleaning the Tank Interior

Sufficiently drain the tank of all hot molten salt and ensure all heating elements are off and the system is allowed to cool. Clean the interior of the tank with water and scrub out any salt residue that remains on the tank walls and immersion heaters. Using distilled water will prevent foreign minerals from depositing on the tank. Prior to re-charging the system with salt, clean out any other contaminants and boil off all moisture.

Maximum Surface Temperature

Surface temperatures of all system components should not exceed the maximum operating temperature of the molten salt. Contact at the liquid-wall interface can promote degradation of the molten salt fluid after prolonged exposure.

Volumetric Expansion upon Re-melting

A 5% expansion upon melting from room temperature has been observed with Dynalene molten salts. Systems should be designed to prevent damage caused by volumetric expansion upon re-melting in case of in-line freeze up. It is advised to re-heat the system starting with the sections closest to the drainage container to reduce pressures built up from the melting expansion. Thermally conductive rods and slabs can be placed in the bulk salt to enhance heat distribution in the tank.

System Safety

Systems using Dynalene molten salts should be designed and constructed with integrally safe methods of preventing exposure to excessive heat sources. Not using excessive pump velocities, insulating all heat sources, and eliminating flammable vapors are all common practices in molten salt convection skids. For precautionary measures, all metal components used in the manufacture of heat transfer fluid systems with the intent to use Dynalene molten salts should be properly grounded as per the governing electrical codes. Proper engineering practices should also endorse methods to prevent sparks generated by energy such as eddy current, Foucault current, static discharges, etc., as the liquids mentioned above flow in the system. Unauthorized personnel should never be allowed near the molten salt system unless specifically instructed by an authorized employee.

Dynalene molten salt dust can cause irritation by contacting the skin, eyes, or throat. If salt contacts the skin, rinse with water and consult medical help for all burns. Respirators should be used if there is excessive salt dust present. In case of inhalation, remove the person to fresh air and provide oxygen if necessary. In case of ingestion, drink large amounts of water and seek medical attention.

Use caution when water is present near molten salt as any wet residue can readily vaporize and can cause the molten salt to violently splash. Because of this, avoid using water to quench the salt. In case of a leak, allow sufficient time for the salt to solidify and come to room temperature before cleaning.

High-Temperature Protective Equipment

Always use the proper personal protection equipment when dealing with Dynalene molten salts at its operating temperatures. Operating personnel should always wear long sleeved clothing, a face shield, gloves, and heavy-duty footwear. Wool, cloth, and other light clothing may not provide adequate protection in case of molten splash. Heavy aluminized clothing is recommended to reduce radiant exposure as well as conduction caused from potential molten salt splashing. Steel or composite toe boots with aluminized shielding are recommended for footwear. Ensure there is no skin or light clothing exposed prior to running the system. Facial protection should be made of heavy aluminized material that extends down to the shoulders to reduce injury due to molten splash. Full Nomex suits or heavy shielding is recommended for additional body protection. Showers and eye wash stations should be located within close proximity to the operating system.

Spill Clean-up

Always wear the proper personal protective equipment when cleaning up a spill. Allow the salt to come to a safe temperature before any clean-up tasks are performed. Small molten salt spills will usually solidify quickly on contact with a room-temperature surface, however larger spills will take a much longer time to cool. Barricade the spill and clear out all personnel that are not authorized to clean the salt. Alkali compounds can attack leather material, so it is advised to use rubber boots and gloves during cleaning. Ensure the area is sealed off and well ventilated and there are no fumes or sources of ignition which may ignite the salt. Use water on the spill to absorb the salt and reduce the amount of dust that can be distributed to the air. Clean up and dispose the salt into containers for waste processing or recovery. If water is used during spill clean-up and needs to be discharged into the sewer system, contact your local sewer authority.

Sampling Procedure

Always wear the proper personal protective clothing when taking a sample of molten Dynalene molten salt. With the salt still molten, dip a cleaned, dried steel rod into the molten salt and slowly remove it to prevent salt splashing. The salt will solidify quickly (depending on the operating temperature) and should be gently scraped off as to not affect the sample. Deposit the salt solids into a clean, dry glass container and send to Dynalene for analysis.

Dynalene MS-1 Properties: SI Units

Properties of Dynalene MS-1 vs. temperature in SI units are given in Table 3.

Table 3. Properties of Dynalene MS-1.

Temp	Viscosity	Thermal Cond.	Specific Heat	Density
°C	mPa·s	W/m·K	kJ/kg·K	kg/m³
230	6.78	0.486	1.385	1,939
240	6.30	0.488	1.387	1,933
250	5.86	0.490	1.390	1,928
260	5.45	0.492	1.392	1,922
270	5.08	0.494	1.394	1,917
280	4.73	0.496	1.396	1,911
290	4.41	0.498	1.399	1,906
300	4.12	0.500	1.401	1,900
310	3.85	0.502	1.403	1,894
320	3.61	0.504	1.405	1,889
330	3.39	0.506	1.407	1,883
340	3.19	0.508	1.410	1,878
350	3.01	0.510	1.412	1,872
360	2.85	0.512	1.414	1,867
370	2.71	0.514	1.416	1,861
380	2.58	0.516	1.418	1,855
390	2.46	0.518	1.421	1,850
400	2.36	0.520	1.423	1,844
420	2.19	0.524	1.427	1,833
440	2.04	0.528	1.432	1,822
460	1.92	0.532	1.436	1,811
480	1.81	0.536	1.441	1,800
500	1.69	0.540	1.445	1,789
520	1.56	0.544	1.449	1,777
540	1.40	0.548	1.454	1,766
560	1.20	0.552	1.458	1,755
580	0.95	0.556	1.463	1,744
585	0.88	0.557	1.464	1,741

US to SI Conversions:

Viscosity: 1 cP = 0.001 Pa·s
Thermal Cond.: 1 Btu/hr·ft·°F = 1.73 W/mK
Specific Heat: 1 Btu/lb·°F = 4,186 J/kg°C
Density: 1 lb/ft^3 = 16 kg/m^3

Dynalene MS-2 Properties: SI Units

Properties of Dynalene MS-2 vs. temperature in SI units are given in Table 4.

Table 4. Properties of Dynalene MS-2.

Temp	Viscosity	Thermal Cond.	Specific Heat	Density
°C	mPa·s	W/m·K	kJ/kg·K	kg/m^3
130	27.0	0.559	1.579	2,010
140	23.2	0.562	1.579	2,004
150	20.0	0.564	1.580	1,997
160	17.3	0.566	1.581	1,990
170	15.0	0.569	1.581	1,983
180	13.0	0.571	1.582	1,976
190	11.4	0.574	1.582	1,969
200	10.0	0.576	1.583	1,962
210	8.87	0.578	1.583	1,955
220	7.91	0.581	1.584	1,949
230	7.11	0.583	1.585	1,942
240	6.44	0.586	1.585	1,935
250	5.88	0.588	1.586	1,928
260	5.39	0.590	1.586	1,921
270	4.98	0.593	1.587	1,914
280	4.61	0.595	1.587	1,907
290	4.29	0.598	1.588	1,900
300	4.00	0.600	1.589	1,893
320	3.49	0.605	1.590	1,880
340	3.04	0.610	1.591	1,866
360	2.65	0.614	1.592	1,852
380	2.31	0.619	1.593	1,838
400	2.05	0.624	1.594	1,825
420	1.86	0.629	1.595	1,811
440	1.75	0.634	1.597	1,797
460	1.69	0.638	1.598	1,783
480	1.63	0.643	1.599	1,770
500	1.48	0.648	1.600	1,756

US to SI Conversions:

Viscosity: 1 cP = 0.001 Pa·s
Thermal Cond.: 1 Btu/hr·ft·°F = 1.73 W/mK
Specific Heat: 1 Btu/lb·°F = 4,186 J/kg°C
Density: 1 lb/ft^3 = 16 kg/m^3

Dynalene MS-450 Properties: SI Units

Properties of Dynalene MS-450 vs. temperature in SI units are given in Table 5.

Table 5. Properties of Dynalene MS-450.

Temp	Viscosity	Thermal Cond.	Specific Heat	Density
°C	mPa·s	W/m·K	kJ/kg·K	kg/m³
130	1089.0	0.435	1.252	2,035
135	666.5	0.436	1.252	2,031
140	436.4	0.437	1.252	2,028
145	302.0	0.438	1.253	2,025
150	220.3	0.439	1.253	2,022
155	167.1	0.440	1.253	2,018
160	131.2	0.441	1.253	2,015
165	106.0	0.443	1.254	2,012
170	88.1	0.444	1.254	2,008
175	74.6	0.445	1.254	2,005
180	64.3	0.446	1.254	2,002
185	56.1	0.447	1.255	1,999
190	49.7	0.448	1.255	1,995
195	44.4	0.449	1.255	1,992
200	40.0	0.450	1.255	1,989
220	28.2	0.455	1.256	1,976
240	23.2	0.459	1.257	1,963
260	17.8	0.464	1.258	1,949
280	14.2	0.468	1.259	1,936
300	11.7	0.473	1.260	1,923
320	9.8	0.477	1.261	1,910
340	8.5	0.481	1.262	1,897
360	7.5	0.486	1.263	1,884
380	6.7	0.490	1.264	1,871
400	6.0	0.495	1.265	1,858
420	5.5	0.499	1.266	1,844
440	5.1	0.504	1.267	1,831
460	4.7	0.508	1.268	1,818

US to SI Conversions:

Viscosity: 1 cP = 0.001 Pa·s
Thermal Cond.: 1 Btu/hr·ft·°F = 1.73 W/mK
Specific Heat: 1 Btu/lb·°F = 4,186 J/kg°C
Density: 1 lb/ft^3 = 16 kg/m^3

Toxicological Report

For complete toxicological information regarding Dynalene molten salts, consult the MSDS. The MSDS for Dynalene molten salts should be understood prior to use.

Product Disclaimer

The information contained in this entire publication is presented in good faith at “no charge” and is believed to be correct as of the date indicated no representations or warranties are made as to its completeness or accuracy. The information listed is supplied upon the condition that the persons receiving it will make their own determination as to its suitability for their purposes prior to use. In no event will the seller be responsible for damages of any nature whatsoever resulting from the use of, or reliance upon, this information or the product to which this information refers. Nothing contained on this page is to be construed as a recommendation to use the product, process, equipment or formulation in conflict with any patent. No representation or warranty, expressed or implied, is made that the use of this product will not infringe any patent.

No representations or warranties, either expressed or implies, of merchantability, fitness for a particular purpose or for any other nature are made with respect to the information, or the product to which the information refers.

Locations & Contact Information

Corporate Headquarters
Dynalene, Inc.
5250 West Coplay Road
Whitehall, Pennsylvania 18052
Phone: 610-262-9686 / 1-877-244-5525
Fax: 610-262-7437
Email: info@dynalene.com
Website: www.dynalene.com

Midwest Location
648 Bennett Road
Elk Grove Village, IL 60007
1-855-216-7639

West Location
1701 S 5350 W
Salt Lake City, UT 84104
Phone: 1-877-244-5525