MSSA

FOLLOW UP DOCUMENT

Sodium training

METAUX SPECIAUX

SUMMARY

Présentation

The company :

MSSA also known as Métaux Spéciaux has been established since 1898 in Pomblière Saint Marcel in Savoie.

When the first tonne of sodium was produced at the site of Pomblière ?

☐ 1898 ☐ 1923 ☐ 1951

Sodium applications :

Sodium is used in many chemical and pharmaceutical processes, like :

Synthesis of indigo

Reducing Titanium and Tantalum salts

Na

Bleachning paper pulp

For manufacturing active ingredients used in medecine

Sodium is also used in the energy industry :

catalyst, as sodium methylate for production of biodiesel

energy storage via sodium-sulphur batteries.

Na

Silicon used in the photovoltaïc industry

Heat-transfer fluid in fast breeder nuclear reactors

Sodium properties

PHYSICAL PROPERITIES

Name : Sodium

Type : Chemical element

Family : Métaux alcalins

Atomic number : 11

Symbol : Na

What are the main hazards ?

☐ Corrosive ☐ Flammable

Sodium is indeed extremely reactive., and in particular, It slowly oxidises in atmosphere and reacts violently with water.

Density :

Is sodium denser than water ?

☐ Equal or Lower ☐ Higher

Sodium density is similar to water density, although slightly lower. Which means that if a bloc of sodium fall into a tank of water, it would float.

However, as sodium reacts violently with water, this experience should never be demonstrated

In which shape sodium has the higher density ?

☐ Liquid ☐ Solid

The solid density is greater than the liquid density which means a bloc of sodium would sink in a tank of liquid sodium.

In other terms, for a given weight of sodium, is the volume greater if the sodium is in its solid form or in its liquid form?

☐ Liquid ☐ Solid

As the density is lower when the temperature decreases, the volume of sodium increases as it is heated. For example, the volume would increase by 5% when sodium temperature is increased from 20°C (68°F) to 120°C (248°F), heating temperature must therefore be limited.

In the packaging supplied by MSSA, the heating temperature must be limited. Please indicate this temperature :

☐ 100°C (212°F) ☐ 130°C (266°F) ☐ 150°C (302°F)

In the packaging supplied by MSSA, the heating temperature must be limited to 130°C (266°F) to avoid any spillage due to sodium expansion.

Viscosity:

Liquid sodium viscosity is close to water viscosity, that is low. This has two advantages:

-As liquid sodium flows easily, low pressures are required to transfer the product.
-Thanks to a low viscosity, heat transfer, especially in nuclear processes, can be improved.

Heat capacity and latent melting heat:

Sodium melts at a temperature of 98.4°C (209°F) which requires large quantities of energy.

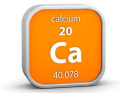
In your opinion, is more energy required to increase the sodium temperature from 10°C (50°F) to its melting point of 98.4°C (209°F) or to melt sodium at 98.4°C (209°F)?

☐ Yes ☐ No

Latent melting heat required to go from solid sodium to liquid sodium is very high. The same energy is required to melt sodium at 98.4°C than needed to increase its temperature from 10°C (50°F) to 98.4°C (209°F).

CHEMICAL PROPERTIES

Impurities :



Calcium is the main impurity in sodium because of the production process. As calcium particles are heavier, these tend to settle in the lower points of the pipelines, in the valves or at the bottom of tanks. This build-up is called “sludge” and can cause blockages requiring cleaning operations.

The calcium concentration is measured in a sample of liquid sodium. A cold sample taken from the surface of the packaging would return a skewed result as calcium mainly concentrates in the lower parts.

Oxidation :

Reaction of solid sodium with air
When in contact with air, sodium oxidises on the surface and forms sodium monoxide. The colour then changes from bright silver to dull white.
Moisture in the air will react with sodium to form sodium hydroxide and hydrogen.

What are the hazards ?

☐ Corrosive hazard ☐ Chemical burns

Sodium must always be kept in an inert atmosphere and contact with air must be limited to a strict minimum.

Corrosive hazard, risk of chemical burns due to the presence of sodium hydroxide. Risk of explosion. Even though the hydrogen production process is slow when sodium is in contact with air, there still is a risk of explosion in a confined space such as a drum or a tank.
Sodium must always be kept in an inert atmosphere and contact with air must be limited to a strict minimum.

Spontaneous combustion :

Reaction between liquid sodium and air.

When liquid sodium comes in contact with oxygen in air, it can spontaneously ignite when temperatures are greater than 120°C/250°F. Combustion generates extremely dense white smoke and forms a superficial layer of sodium oxides (sodium monoxide and sodium peroxide) on the surface.

Sodium monoxide is the main product of this reaction; sodium peroxide, a yellow substance, is formed during a second stage where sodium monoxide is oxidised.
During the decomposition stage of sodium peroxide, oxygen is produced which allows combustion to continue in a closed container with no addition of external oxygen.

Explosion :

$Na + H2O = NaOH + ½ H2$: Reaction between sodium and water.

Sodium reacts violently with water to produce sodium hydroxide and hydrogen while releasing large amounts of heat as the reaction is exothermic.
Because of the heat produced by this reaction, the mix of hydrogen and oxygen may explode if the lower explosive limit is reached.

Dangers

HAZARDS AND FIRST AID

Corrosive and heat hazard :

Sodium reacts with moisture from the skin to produce sodium hydroxide which is very corrosive to mucous membranes.
The severity of chemical burns is proportional to the quantity of sodium in contact with skin/tissues. Furthermore, as the reaction is exothermic, the heat produced may cause additional thermal burns.

In case of contact with the product, wash thoroughly with large amounts of water. What is the minimum amount of time required for rinsing the product:

☐ 20min ☐ 40min ☐ 60min

In case of contact with the product, rinse thoroughly with large amounts of water for at least 20 minutes and seek immediate medical advice.

Burns :

Spattering of liquid sodium, which temperatures may reach 800°C (1500°F), will cause serious burns in case of contact with the body.

In the event of sodium spattering, is it better to : try and put out the fire or to remove clothing ?

☐ Try and put out the fire ☐ Remove clothing

In this case:
-Immediately remove all contaminated clothing.
-Remove the sodium from the skin with a dry cloth or a wooden spatula.
-Rinse thoroughly with large amounts of water for at least 20 minutes and seek immediate medical advice.
If sodium is burning, it is always more efficient to remove it immediately than to try and put the fire out. Do not forget to comply with the length of time required to rinse off the product.

Inhalation :

Liquid sodium may ignite spontaneously when in contact with oxygen in the air and produce corrosive and toxic vapours. In the event of inhalation, place the victim in a smoke-free room.
If the victim is having difficulty breathing, administer oxygen under medical supervision.

Explosion :

The reaction between sodium and water is more or less reactive depending on the quantities involved, the size and state of the sodium particles, mainly:

- The smaller the sodium particles, the more violent the reaction will be.
- The hotter the sodium, the more violent the reaction, as liquid sodium is more reactive than solid sodium.
- The reaction will also depend on the water / sodium concentration. Temperature and pressure will be at their highest when the quantity of water is 10 to 30 times greater than the quantity of sodium.

For this type of reaction, temperatures can reach 1400 °C / 2200 °F and pressure approximately 1200 bars / 120Mpa / 17.4 ksi.

Reaction products :

Products from the reaction will vary depending on the temperature conditions and the water/sodium concentration. However, in all cases, the reaction will be explosive because of the hydrogen produced.

SODIUM FIRE, SPECIFICATIONS

Ignition temperature :

From what temperature is there a risk of sodium igniting spontaneously ?

☐ 50°c ☐ 80°C ☐120°

The risk of spontaneous ignition for sodium exists above temperatures of 120°C (250°F) although different parameters may affect this auto-inflammation temperature.

The ignition temperature will depend on various parameters:

- The sodium state: When sodium is dispersed as droplets (spray fire), it will be more reactive than a sodium spill (pool fire).
- Sodium quality: Low impurity refined sodium is more reactive than standard sodium.
- The environment: in the event of a fire on premises, the ignition temperature will depend on the amount of moisture in atmosphere, on the ventilation rate, etc… In the event of a fire in a confined space, like a storage, the risk of ignition mainly depends on the oxygen concentration in the atmosphere of this confined space. Above an oxygen concentration of 3%, the risk of ignition exists.

Mechanism :

At the beginning of the reaction, oxygen from air diffuses into the liquid sodium. Following this, a crust of sodium monoxide and sodium peroxide forms on the surface.
The oxide layer is heterogeneous and temperature gradients appear during the oxidation process.
Gradients in the surface tension and convection movements appear in the liquid because of these confined temperature increases.
These movements create cracks in the crust and sodium droplets appear on the surface by capillary action.
These high temperature sodium droplets will oxidise faster than the rest of the surface and are considered as the ignition trigger point.
The droplets vaporise and react with oxygen in the air while producing orange flames and oxide particles.

The flame temperature reaches 1350°C (2380°F), whereas the sodium temperature during combustion stabilises around 700 - 800 °C (1290 – 1470 °F). The evaporating temperature (881.4°C / 1618°F) is not reached in the sodium layer.
The combustion rate can be estimated at approximately 30 kg of sodium /m²/h (6lbs/ in²/h) with a proportion of aerosol equal to 40 % of the weight of burnt sodium.

The combustion rate and the probability of ignition are conditioned by the quality of the oxide crust.

Indicate the different reactions for each temperature :

At low temperature ○	○ The crust will crack but prevents oxygen diffusing into the sodium.
At average temperature ○	○ Oxides form a protective layer and limit combustion.
At high temperature ○	○ The oxide crust is inefficient and oxygen diffuses into sodium.

Comparison with hydrocarbon fire :

Please indicate flame characteristics for each type of fire, sodium or hydrocarbon

Sodium fire ○	○ 1 à 2 cm high
Hydrocarbon fire ○	○ 4m high

Sodium flames are small and localised, no more than 1 or 2 cm high (1 inch), with an important decrease in temperature above the flame. At a distance of 1 meter (3.3 feet) from the flames, the temperature is below 100°C (212°F) whereas for a hydrocarbon fire, the flames may reach heights up to 4 meters (13 feet) and a temperature of 800°C (1470°F) at a distance of 1 meter (3.3 feet) from the flames.

On a scale of 1 to 100, indicate what is the energy produced from combustion for each type of fire, sodium or hydrocarbon :

Sodium fire ○	○ 25
Hydrocarbon fire ○	○ 100

The energy produced from the combustion of sodium is 4 times lower than the energy produced from a hydrocarbon fire.

On a scale of 1 to 100, indicate the combustion rate for each type of fire, sodium or hydrocarbon

Sodium fire ○ ○ 100

Hydrocarbon fire ○ ○ 33

The mass of burnt sodium per surface unit is 3 times lower than for a hydrocarbon fire. It can therefore be deduced that the heat produced from a sodium fire is much lower than from a hydrocarbon fire.
However, this does not mean a sodium fire is easier to extinguish, as it generates extremely dense smoke, it is often difficult for the fire services to localise the fire itself.

In order to avoid all hazards, an accurate assessment of the situation must be carried out before any intervention.

⇒ Use specific aluminised protective clothing.
⇒ Never handle sodium in a damp area.
⇒ Always use dry tools.
⇒ Use a dry and appropriate fire agent.

In a confined space such as a drum, a sodium fire can be put out by covering the openings with a metallic lid to prevent air from entering the drum. Caution, the lid must only be fixed to the drum once the sodium is cold.

SODIUM FIRE, EXTINCTION

What is the best way to extinguish a sodium fire?

☐ Water ☐ CO2 ☐ Halogens ☐ Hydrates ☐ Mineral powders

Warning: to put out a sodium fire, never use water, CO2, halogens or hydrates which react with sodium. The best method to extinguish a sodium fire following a spill is to smother this fire by applying dry mineral powders. Different powders have been assessed, only a small number have been efficient. We have tested them for you.

Dry powder extinguisher :

Class A, B and C powder extinguishers are prohibited. Powder is inefficient and the propellant used is CO2. The sprayed carbon dioxide will support combustion and may even explode when in contact with sodium as a solid form.
Class D fire extinguishers contain a powder mainly composed of 80 to 90% of sodium carbonate or sodium chloride, the remaining 10 to 20% include calcium phosphate, magnesium, mica or silica. They can be used to handle metal fire as long as certain precautions are taken during their use:

- Inert gas, not CO2, must be used as a propellant.
- The gas spray pressure must be low to avoid any spattering which may worsen the situation: burns or spraying of extremely reactive sodium droplets over a wider area.
- Finally, the capacity of a single extinguisher is low and will not be sufficient to smother the fire.

As a conclusion, only class D extinguishers can be used and these should only be used on small fires in remote areas.

Vermiculite :

Vermiculite is a natural incombustible mineral that expands with the application of heat. However, its relatively large particle size (0.5 to 5 mm) allows oxygen to be diffused through the particles which makes this substance inefficient against a sodium fire.

NaCl :

Sodium chloride is recognised as a fire fighting method because of its chemical stability. However, it has some drawbacks :

- One of the properties of the salt crystal structure is that it may contain traces of water. For example, before using the salt required for producing sodium, MSSA heats this salt at high temperature to reach moisture content below 400 ppm.
- The salt density is twice the sodium density. In the event of a deep pool, it tends to flow and sodium on the surface will continue burning.

In summary, the salt can be used to extinguish a sodium fire once its moisture content has been checked. However it is better used on small fires only.

Mineral powder containing graphite : Marcalina powder or Graphex

Powders known under their commercial name of Marcalina or Graphex contain graphite and alkaline carbonates (sodium and lithium).

The powder is fluidised by the addition of graphite. Graphite also expands with heat and the alkaline carbonates smother the fire.
The efficiency of these graphite powders is widely recognised. Only 0.5 to 1 kg (1 to 2 lbs) of powder per kg of sodium is required. However, their cost remains high.
The powder reacts by forming a liquid and inert layer on the surface of the burning sodium. This layer is lighter than sodium and non miscible and works by creating a barrier preventing oxygen from diffusing in the metal.
When cool, this layer solidifies at approximately 500°C (930°F) and forms a crust. However, as its thermal expansion coefficient is different to that of sodium, cracks can appear in the crust where sodium can return to the surface by capillarity and reignite.

Sodium carbonate :

Sodium carbonate is the fire agent most commonly used by MSSA. Its low density combined with sodium surface tension allows it to float on the surface of a sodium pool and preventing oxygen from diffusing into the sodium.
As the flames from a sodium fire are small, carbonate can be added with a shovel which limits further air mixing as opposed to the use of extinguishers.

Warning : sodium carbonate has the disadvantage of absorbing moisture, it is therefore vital to store it in waterproof bags which must only be opened when needed at the last minute. Once a bag has been opened, it should be removed and must not be used.

SODIUM, EXTINCTION BASIC RULES

Veuillez indiquer si un risque est présent à utiliser un produit d'extinction :

☐ Dry ☐ Slightly damp ☐ Damp ☐ Very damp

*A fire agent must indeed be always dry before application. It must be stored in waterproof bags or in chemically inert drums. Once opened, a bag of fire agent becomes **unusable.***

Accurancy :

-Applied the fire agent **carefully** to avoid any splashing or to avoid fanning the fire
-With a shovel or with a low pressure extinguisher
-The tools required to apply the product must also be **dry**.
- The fire agent must be available in sufficient quantities in the sodium storage building so as to put out the beginning of a fire. A larger stock of fire agent must also be available and easily transported to the area in the event of a serious accident.

The fire agent creates a barrier preventing oxygen from diffusing in the sodium.
However, care must be taken as below this barrier, sodium remains hot and in its liquid state and the sodium fire can reignite. Once extinguished, the fire must be supervised until the sodium has completely cooled down.

PERSONAL PROTECTIVE EQUIPMENT

Surround the minimum required PPE for using with sodium

For conventional interventions, operators must wear:

- *Nomex fibre clothing.*
- *Gloves or mittens, (solid sodium can be handled without risk with dry gloves. Gloves must be oversized in order to be easily removed, with gauntlets covering the sleeves).*
- *Safety goggles. (For certain operations, a face shield must be worn over goggles in order to protect the face from potential projections.)*

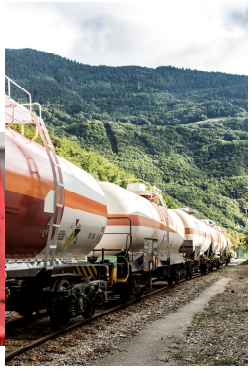
For specific interventions: In the event of liquid sodium or sodium fire risk, specific equipment must be used.

- *Aluminised clothing*
- *Ankle boots to protect ankles*
- *Respiratory protection to protect from smoke which is extremely irritant. A protective mask equipped with a cartridge filter or an SCBA, a self-contained breathing apparatus is used as opposed to an aluminised hood with integrated face shield which does not include an independent air source.*

Packaging presentation

MSSA has a unique range of packaging for shipping sodium throughout the world in the most varied forms: from 12g pieces delivered in drums up to bulk supplies in 60-tonne railcars. All our packaging complies with transport regulations and is approved for transporting hazardous substances of group 4.3.





What are the essential documents needed for large-capacity packaging approved for transport ?

☐ An identification number
☐ A name plate
☐ A certificate exemption
☐ An analytical report of the content
☐ A periodic inspection certificate

Large-capacity packaging, such as containers or wagons, has:
- An identification number
- A nameplate
- A periodic inspection certificate

Moreover, MSSA provides its customers with a simple guide to using each type of packaging, including information related to the connections, technical specifications and safety data.

Delivery in ingots :

The ingots are shipped in fully-opening drums, in compliance with regulations for transporting dangerous goods (UN approval code X).

The ingots are packed in a plastic bag, which is itself placed within the drum. The bag is put in a neutral atmosphere, then vacuumed and finally heat-sealed to prevent contamination of the sodium during transport.

By special request, doses weighing between 12g to 100g can be wrapped in a sheet of heat-sealed aluminium to facilitate storage and handling.

What are the benefits of delivering sodium in ingots?

☐ The personnel do not need to be trained in sodium hazards
☐ A limited investment
☐ Simplification of engineering for the sodium building
☐ The quality of the sodium is better in this form
☐ Ease of handling the product

Delivering sodium in ingots limits investment costs.
Sodium is also easier to handle in this form.
However, be careful and make sure that the ingots are always kept under an inert atmosphere, to avoid contact with air. If a drum is stored for a long period without inerting, the moisture in the air reacts with the sodium to form sodium hydroxide and hydrogen.

Do not use this sodium under these conditions.

Bulk delivery :

What is the capacity of the various packaging for bulk sodium?

Railcars	Containers	Disposable drums	Shuttle drums
☐90Kg / 200lb ☐400Kg / 882lb ☐20Tonnes / 44 092lb ☐60Tonnes / 132 277lb	☐90Kg / 200lb ☐400Kg / 882lb ☐20Tonnes / 44 092lb ☐60Tonnes / 132 277lb	☐90Kg / 200lb ☐400Kg / 882lb ☐20Tonnes / 44 092lb ☐60Tonnes / 132 277lb	☐90Kg / 200lb ☐400Kg / 882lb ☐20Tonnes / 44 092lb ☐60Tonnes / 132 277lb

Sodium can be delivered in bulk in:
-Disposable drums of 90 kg
-Shuttle drums of 400 kg
-Containers of 4 to 20 tonnes
-Railcars of 50 to 70 tonnes
-Special packaging

Bulk sodium is supplied solid and must be put in a liquid form to be transferred under pressure through a dip tube.

Bulk deliveries of sodium require specially-designed installations.

4 tonnes containers : Presentation

The total capacity of the container is about 4 190 litres with a quantity of sodium between 3 and 4 tonnes.

Do you know the equipment present on this type of container ?

- ☐ An immersed coil
- ☐ A dummy valve
- ☐ A man lid
- ☐ A relief valve
- ☐ A rupture disc

The 4 tonnes container is fitted with:
- An immersed coil with an oil circulation for remelting the sodium
- A man lid for the connections
- A relief valve and a rupture disc to protect against overpressure
The maximum operating pressure is 4 bar.
However, to limit the risk of leak, it is preferable to carry out transfer at lower pressure.

On receiving the container, you should check the internal pressure on the manometer on the man lid; the pressure must be positive in order to avoid oxidation of the sodium.

Connections on 4-tonne containers

After this first inspection, you can make the connections.

The container must first be decompressed. To do this, you connect the vent of your installation on the container's gas connection, which is fitted with a ball valve.

To avoid entry of air during the heating phase, you must sweep with an inert gas through this same opening.

The containers are all fitted with a sodium valve. The sodium line is connected to the container via a tongue and groove flange to reduce the risk of leak.

It is important to note that the end of your sodium line, usually a flexible hose, must be fitted with a flange with a tongue end, which compresses the gasket in its throat. The gasket must be replaced for each discharge.

Be careful when connecting your sodium line to the container; it must be purged with an inert gas to prevent the entry of air.

The temperature of the sodium is monitored by a thermocouple, which should be inserted into the thermowell provided on the man lid.

When all connections are made, the container is heated.

The oil coil of the container consists of an inlet and an outlet connection located on the container's man lid.

The recommended oil is a mineral oil, reference TOTAL ETA 32, functioning at 130°C

Discharging of 4 tonnes containers :

What is the order of actions for a safe discharge ?

Action n°	Entitled
1 o	o Slowly pressurise the container to the desired transfer pressure
2 o	o Connect the heating cable of the dip pipe 1h before transfer
3 o	o Open the sodium valve
4 o	o Check that there are not cold spots
5 o	o Rethighten the sodium connection when hot

When the temperature reaches the desired value, you must carry out certain operations before starting the transfer:
- Connect the heating cable of the dip pipe1 hour before
- Retighten the sodium connection when hot
- Make sure there are no cold spots by adding a layer of insulation at the connection between the drain line and the container
- Slowly pressurise the container to the transfer pressure; it generally should be under 2 bar
- Then open the sodium valve to start transfer

The average draining time for a container is about 1 hour.
When the container is empty, the gas escapes through the dip tube with a whistling noise and shaking of the flexible hose. This marks the end of the transfer.

Caution: If there is a leak during the transfer, decompress the container immediately by closing the inert gas supply and opening the vent.

What is the order of actions to achieve the end of discharge safely ?

Action n°	Entitled
1 ○	○ Close the sodium valve and the inert gas supply
2 ○	○ Pressurise the container with inert gas at 1 bar (14 psi)
3 ○	○ Open the vent and sweep with gas
4 ○	○ Replace the cover
5 ○	○ Blow through the sodium line with gas and disconnect all heat tracing
6 ○	○ Blow through the container's double jacket with gas

To finish the discharging, use the following procedure :

- Close the sodium valve and the container's gas supply.
- Open the vent to depressurise the container and sweep with a low flow of inert gas,.
- Blow through the sodium line from the highest point to avoid sodium remaining in the line. The container must be returned with the dip pipe completely empty of sodium.
- Disconnect the heating cable from the dip pipe, the valve and from the flexible hose .
Be careful not to disconnect the sodium before the hose temperature is below 60°C so as to avoid any risk of liquid sodium and burns.
- Blow through the container's oil coil with gas for 5 minutes from the container's outlet. The container's oil coil must be absolutely empty before returning, in order to avoid mixing oils from different installations.
- Pressurise the container with gas at a pressure of 1 bar before returning, in order to maintain a residual pressure when the container is completely cold.

ISO container : Presentation

The total capacity of ISO containers is about 23 000 litres / 6075 gallons with a sodium quantity between 18 et 20 tonnes / 39 683 et 44 092lb.

Can you identify the different equipment on an ISO container ?

- ☐ A water inlet nozzle
- ☐ A jacket with a circulation of oil
- ☐ An electromagnetic pump
- ☐ A relief valve
- ☐ A ruptur disc
- ☐ A man lid with connections for transferring the sodium

The tank is fitted with a jacket with a circulation of oil, to re-melt sodium, a relief valve and a rupture disc. and also a main lid with connections for transferring the sodium. The maximal pressure for use is about 4 bar. However to limit risks, transfers must be carry out at a low pressure.

What should be checked when receiving the container ?

- ☐ The good operation of the heating cable
- ☐ The sodium draining nozzle is not blocked
- ☐ The internal pressure on the manometer

On receiving the container, it's necessary to check container's pressure, read on the manometer. It must be positive. Sodium is transported under a gaseous atmosphere to avoid any risk of pollution from the air. The good operation of the heating cable permitting to heat the deep tube and the sodium valve should be checked. The current should be about 10 amps.

ISO container connections :

When this initial inspection has been done, you can start connecting.

Do you think the container should be compressed or decompressed ?

☐ Compressed ☐ Decompressed

First, the container must be decompressed. To do this, you connect the vent of your installation to the gas connection on the container, which is fitted with a ball valve.

To avoid entry of air during the heating phase, you need to sweep with a low-pressure inert gas through this same opening.

The sodium connection varies according to the design of the man lid. Some containers are fitted with sodium isolation valves, others with a butterfly valve, depending on the needs of each customer.

If the container is fitted with a sodium valve, it has a high level of safety due to a double-seal system, using :

- The sodium seal created thanks to the cooling fins
- The mechanical packing made of graphite braids.

In both cases, the connection specification is the same. Connection is made using tongue and groove flange to minimise the risk of leak. It is important to note that the end of your sodium line, usually a hose, must be fitted with a flange with a tongue end (male), which compresses the gasket in the groove. This gasket must be replaced for each discharge.

Be careful when connecting your sodium line to the container; it must be purged with an inert gas to prevent the entry of air.

The temperature of the sodium is monitored by a thermocouple, which should be inserted into the thermowell provided on the man lid.
When these connections have been made, the container is heated.
The oil jacket of the container consists of two inlets at the bottom and two outlets at the top.
The oil circuit is common to all connections; only a single inlet and a single outlet need to be connected.
The oil flow through the jacket is about 20 m^3/h with a maximum pressure of 3 bar.

The recommended oil is a mineral oil, reference TOTAL ETA 32, operating at 130°C with low viscosity (32 centipoise at 40°C) and a flash point above the heating temperature of the sodium (220°C).
The oil used must have specifications consistent with those recommended by MSSA; mixing different oils can cause clogging problems.
The time for melting the 20-tonne ISO container is relatively long; it is estimated at about 16 hours. Eight hours are needed to reach the melting temperature of sodium; and eight hours are needed to melt the sodium and reach a temperature of 120°C.
The temperature of the sodium in the ISO containers should be 130°C maximum to avoid the risk of overflowing due to the expansion of the liquid.

Discharging the ISO container :

What is the order of actions to discharge safely ?

Action n°	Entitled
1	Close the manhole cover and put lead seals on the cover
2	Open the vent and sweep with gas
3	Close the sodium valve and the inert gas supply
4	Blow through the sodium line with gas and disconnect all electrical tracing
5	Pressurise the ISO container with inert gas at 1bar /14Psi
6	Blow through the ISO container's oil jacket with gaz

At the end of discharge, you should use the following procedure :

- Close the sodium valve and the container's gas supply
- Open the vent to depressurise the container and sweep with a low flow of inert gas,
- Blow through the sodium line with gas from the highest point to avoid sodium remaining in the line. The ISO container must be returned with the dip pipe completely empty of sodium
- Disconnect the heating cable from the dip pipe, the valve and also from the flexible hose. Caution: Do not disconnect the sodium before the flexible hose temperature is below 60°C so as to avoid any risk of liquid sodium and burns.
- Blow through the oil jacket of the ISO container with gas for 5 minutes from the outlet of the container located at the highest point; the ISO container's jacket must be absolutely empty before returning, in order to avoid mixing oils from different installations.
- Pressurise the ISO container with gas at a pressure of 1 bar before returning, in order to maintain a residual pressure when the ISO container is completely cold.
- Close the manhole cover and affix lead seals before shipment.

Maintenance

Unblocking a sodium line: checking phase

Various factors may explain a clogging issue in the sodium pipes :

- A technical problem (a faulty or inefficient heat tracing, a stuck valve or an insufficient level of insulation)
- Misuse of the facility (e.g. pipes not blown through after transfer; or air inlets creating oxides)

Disassembling a sodium installation is a complicated operation; it should be done as infrequently as possible.

Before considering disassembling, several checks must be carried out, can you identify them ?

☐ The insulation
☐ The pressure in the line
☐ The heat tracing
☐ The temperature on the control panel
☐ The sodium analysis report

There must be a complete check to ensure that no cold spot is responsible for the clogging, for this, you must:
- Check on the good condition of the insulation along the sodium line, and especially flanges, connections, wall duct , and pipe support
- Check that the heating system operates correctly
- Carry out further temperature measurements with a portable thermometer paying particular attention to the flanges, valves, connection points and supports
If a cold spot is discovered, increase the heating set point in the area concerned and try to re-melt the pocket of solid sodium.
When the line is unblocked, reset the installation operating parameters to their standard values.

Unblocking a sodium line: using a pressurised gas or a metal rod

If full verification of the installation does not give satisfaction, the line must be unblocked. There are several techniques for this and in particular injection of pressurised gas or also insertion of a metal rod in the line. The design of the sodium installation must therefore provide connection points for performing these operations.

Why do you think the blow points must be located at the highest point ?

☐ For safety
☐ To facilitate access
☐ To limit a sodium leak when opening circuit
☐ To avoid returns of hot sodium after unblocking

We shall present the method used and recommended by MSSA for unblocking sodium pipes. In fact, using a pressurised gas or a metal rod is a delicate operation that requires special precautions.

To unblock safely, using a metal rod, it is important to respect the following order:

- You must wear personal protective equipment suitable for liquid sodium, as detailed before
- Check the absence of pressure on both sides of the blocked area to avoid projection
- Stop the heating from the area concerned (in fact, the temperature must not exceed 60°C)

To unblock safely, using pressurised gas, proceed as follows:

- You must wear the personal protective equipment suitable for liquid sodium, such as visor, aluminised garments and gloves
- Purge the gas line before connecting it to the sodium pipes to verify the absence of moisture.

Disassembling operations :

What is the order of actions to dismantle a blocked area or an equipment for maintenance safely ?

Action n°	Entitled
1 ○	○ Stop the heating and remove the insulation
2 ○	○ Fit caps or blind flanges
3 ○	○ Check the absence of pressure and sweep the line with inert gas
4 ○	○ Blow through the line with an inert gas

In all situations, whether the line is blocked or for maintenance, the actions to be implemented for disassembling are:
- You must wear suitable personal protective equipment
- Blow through the line with an inert gas when it is not blocked (this step evacuates the maximum residual sodium in the equipment to be disassembled)
- Stop the heating
- Remove the insulation and wait until the temperature is below 60°C
- Check the absence of pressure inside the circuit
- Sweep the pipe with a low-pressure inert gas to prevent air entering when disassembling
- Remove the area concerned by means of the connection flanges. If impossible, use cold cutting tools such as a pipe cutter or sabre saw to avoid igniting the residual sodium.
- Fit blind flanges or caps to prevent air entering the rest of the line

When removed, the equipment should be cleaned in a special decontamination area located away from the production area.

For safety reasons, the equipment removed must be decontaminated straightaway.

Maintenance of equipment : decontamination by melting and burning

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When removed, the equipment should be cleaned in a special decontamination area located away from the production area.
For safety reasons, the equipment removed must be decontaminated straightaway.

If this is impossible, how should it be stored ?

☐ In packaging of drum or box type ☐ On a pallet in fresh air ☐ Perfectly identified
☐ In a plastic bag ☐ Inerted

To store equipment safely, it must be put into drums or boxes according to its shape, inerted and perfectly identified.
Caution: Equipment stored in unsuitable conditions should be considered suspect.

Their complex shape is likely to promote the retention of sodium, which in contact with the humidity of the air forms soda, and also hydrogen, which increases the risk of explosion.

When the equipment has been disassembled, the residual sodium should be remelted using a torch.
When cleaned, the equipment must be placed above a dry metal receptacle to collect the molten sodium. This receptacle must contain dry sodium carbonate to prevent any risk of ignition.

Why must the heating be done from the bottom up?

☐ To allow the molten sodium to flow into the receptacle ☐ To facilitate the operation
☐ To prevent excess pressure

Heating is done upwards to allow the molten sodium to flow into the receptacle and prevent excess pressure. A dry metal rod can be used to encourage the flow of sodium.

It is therefore essential to observe the following guidelines:
- Never store uncleaned equipment outside, and limit storage time.
- Use an explosimeter before any work and then re-inert.
- If the equipment contains hydrogen or caustic soda, do not clean it with heat.

Maintenance of equipment : hydrolysis

When the residual sodium has been evacuated, the equipment must be cleaned by hydrolysis; i.e. convert the sodium oxides into caustic soda by reaction with water.

To lessen risk and achieve hydrolysis safely, several steps are necessary, what is the order ?

Action n°	Entitled
1 ○	○ Wash the part with water
2 ○	○ Hydrolyse the equipment with steam after purging the line
3 ○	○ Hydrolyse the equipment in the air using a fan
4 ○	○ Inject steam as long as there remains sodium, which is reconised by crackling or whithish vapour

Hydrolysis in the air is used to start the reaction slowly, which significantly reduces the risk of explosion. After 24 hours, the injection of steam is the most sensitive stage of cleaning; it is also the most effective. When the risk of explosion is zero, a water rinse removes all traces of soda.

When thoroughly cleaned, the equipment must be put in an oven to remove all traces of water before reuse.

Destruction of sodium residues

Sodium residues can be destroyed by chemical reaction with alcohol, by combustion or by reaction with steam or water.
The disposal of sodium residues is a dangerous operation and must only be carried out by qualified staff, correctly informed on the hazards involved and the required safety precautions.

Destruction with alcohol :

The reaction between sodium and alcohol forms a sodium alcoholate and hydrogen with a large production of heat.

In the event of bad practise, could this reaction be explosive ?

☐ Yes ☐ No

As for any reaction between sodium and water, the heat produced by the reaction may lead to the mixture H2/O2 exploding if the Lower Explosive Limit is reached (LEL is 4%). Furthermore, alcohol generates vapours which may ignite at low temperature. For example, methanol flash point is only 11°C (52°F).

Disposal of sodium with alcohol can only be implemented in certain conditions:

- Small quantities of sodium to be destroyed
- Alcohol in excess
- Ethanol or isopropanol must be preferred to methanol as they are less volatile and their reaction rate is slower.
- Hydrogen vapours must be extracted from the working area.
- The equipment must be cooled during disposal process.

Combustion :

Using a combustion process, sodium is transformed into sodium oxides. This reaction produces large quantities of smoke which require treatment by filtration to avoid any atmospheric contamination.

Hydrolysis :

The destruction of residues using steam or water can be safely carried out in a dedicated area.

The decontamination area must be equipped with the following :

- A steel grid floor to allow runoff water to be discharged to an effluent treatment plant where its pH is corrected.
- Concrete walls equipped with safety sight windows and nozzles to inject steam or water from the outside of the bunker.
- A mesh roof to release the pressure to the outside of the building in the event of an explosion.
- A forced ventilation system to remove and dilute the hydrogen produced during the reaction.

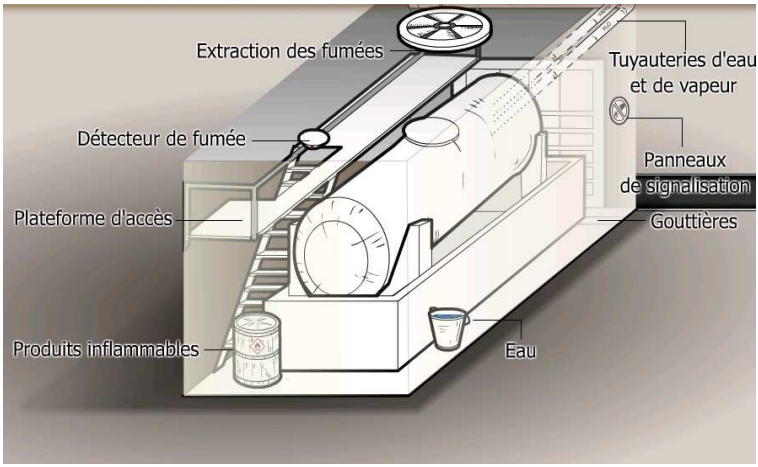
Operators in charge of the residue destruction using hydrolysis must always intervene from the outside of the decontamination area by using the safety sight windows and hose nozzles.

Information signs must always be displayed to inform all staff working in the surrounding area.

Guidelines

Sodium building :

Surround the items banned in a sodium storage building :



Water and steam pipelines as well as a sprinkler system are proscribed. Access platform to equipment at height, to storage or other must not be equipped with gratting, (in event of a spill on the grid floor, sodium may flow to the lower decks, causing further damage or injuring staff). Furthermore, when in contact with grid floor, sodium splits into small droplets which are more reactive and harder to extinguish.

- The sodium plant must be installed in a dry building, constructed with non-flammable material such as metal siding or roofing.
- The building must not contain flammable products other than sodium.
- The sodium building must be raised to prevent any flood risks. The floors should always be kept dry. Gutters which could hold water are also banned.
- Information signs displayed on each access door will inform all users about the ban on using water.
- To recover potential sodium spills, a pan will be provided for all equipment containing sodium. In the event of a leak, the pan will contain the sodium. The fire will then be easier to extinguish by the application of sodium carbonate.
- Smoke detectors must be installed to inform site staff of a fire start. A smoke extraction system linked to the fire detection system allows the smoke to be extracted to ease the fire fighting work.
- Natural ventilation must also be provided at higher points of the building to avoid hydrogen retention.

Design of sodium pipelines :

For temperatures below 300 °C (572°F), carbon steel pipes are preferred, above this temperature, stainless steel is required, why ?

☐ Corrosion ☐ Flammability ☐ Explosion

Above this temperature, the corrosion risk is higher, the use of stainless steel is recommended.

The diameter of sodium pipes varies between 1 and 2 inches, do you know why ?

☐ Blockages may occur at lower diameters
☐ Larger diameters require a greater heating capacity.
☐ A larger diameter requires more expensive material

Blockages due to impurities or cold spots are more likely in lower diameter pipes. On the contrary, the larger the diameter, the more expensive the associated equipment (valve, instrumentation) and the larger the heating system.

What type of material must be used for sealing with sodium ?

☐ Metallic seal ☐ Graphite seal ☐ Teflon seal

Sealing systems must never include Teflon as it contains fluorine which would react with sodium. MSSA recommends the use of graphite seals with a metallic reinforcement depending on the application.

Sodium transfer characteristics

Sodium can be transferred using different methods : by vacuum transfer, by pressure or by pumping.

For each method, please indicate the advantages ans disadvantages.

Vacuum transfer :

Advantages	Disadvantages

Pressure :

Advantages	Disadvantages

Pumping :

Advantages	Disadvantages

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