English version

ULTIMHEAT® MUSEUM

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Technology of components used in heating.

Chapter 12

Technical introduction to flexible heating elements

1st edition 2019/08/12

First part :
Various reheating tests

1. What are the differences between industrial warming jackets and blankets and domestic warming blankets?

Vocabulary:
- An industrial jacket heater heating has a clamping system for attaching it to the vertical wall of a container
- An industrial blanket heater is intended to be placed on a horizontal surface, it does not have straps, but only rings around its perimeter for possible fixing.
These are the only differences between these two products.
Although these devices look like household warming blankets, their design and performance are far more complicated and their technology much more sophisticated. In particular, the following points of difference may be mentioned:
1 / - A wider operating temperature range, from -40 to + 120 °C (and up to 200 °C for some models) instead of +20 to + 50 °C
2 / - A pitch of the heating wire network tighter to 20mm instead of 50 to 70mm, giving a better homogeneity of temperature and avoiding local overheating if the thermal transfer is bad
3 / A higher power range: 50 to 150W which corresponds to a surface power density from 0.04W/cm² to 0.06W/cm² for domestic blankets, compared to 140 to 4400W, ranging from 0.05W/cm² to 0.135W/cm² for industrial covers and coats
4 / Strong thermal insulation to prevent losses to the outside and improve their energy performance
5 / A design of thermal and electrical insulation resistant to heat, water absorption, and resistant to water jets (IP65), very rarely achieved in most domestic models
6 / Electrical insulation resistance at least 10 times higher than domestic blankets
7 / A total grounding by a metal braid external to the heating cords, forming a mechanical protection and ensuring the earthing in case of perforation or short circuit. This protection is non-existent on domestic blankets.
8 / A thermal protection of the surface temperature with anticipatory action to prevent overheating of the wall, to allow use on containers made of glass, plastic or metal
9 / A fixation on the containers by straps and safety loops for an effective tightening, easy to adjust, and incorporating a soft hood closing above, ensuring the maintenance in position without sliding.
10 / A variety of temperature control methods:
- Heating according to the outside temperature (antifreeze function),
- Heating according to the surface temperature of the tank,
- Heating according to the temperature in the center of the volume of product to be heated (To be used in addition to the heating according to the surface temperature.
These temperature control systems, in their electronic versions ensure a steady and optimized temperature rise without overheating

11 / A wide range of accessories: insulating covers, ground thermal insulator, adjustable speed stirrer, GFCI.

2 / Parameters acting on the duration of the rise in temperature

The most common question users ask is: «How long does it take for your blanket to heat my drum or container?»
To answer this question a number of parameters must be studied and the main ones are:
- The total volume heated.
For a given power a large volume will heat less quickly than a small volume.
- The total power applied.
Higher power will normally heat up faster.
- The distribution of power.
Heating distributed over the whole mass or on all the walls will heat up **faster than**

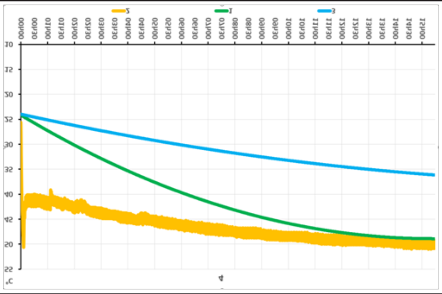
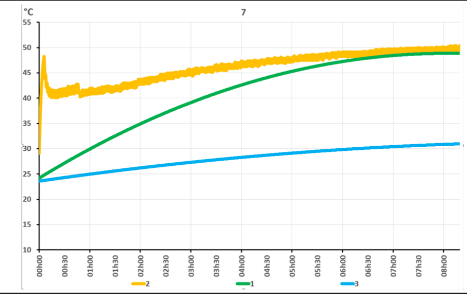
heating located on a small surface of the tank.
- The thermal conductivity of the liquid.
The higher the thermal conductivity of the liquid, the faster the heat is transmitted to the whole mass.
- The heat capacity of the liquid.
Since the heat capacity represents the energy that must be applied to a mass of liquid to heat it, liquids with a low heat capacity (oil for example) will heat up, at equal power, faster than those with a high heat capacity like water).
- The kinematic viscosity (ν)of the liquid.
The more viscous a liquid, the fewer convection currents exist. So the heat energy is transmitted less quickly. It may be necessary in some cases to add a mixing apparatus for viscous, low-conductive products.
- The thermal insulation.
By eliminating heat losses to the outside, the heat energy is concentrated on the tank. An insulated tank will heat up faster. The addition of cover and insulating pedestal also reduces the heating time.
- The starting temperature of the product, and of course the temperature to reach. The greater the difference between the two, the longer the heating time is.
- The type of temperature control:
The temperature control can reduce the power delivered to the tank near the set point (PID control), and thus slow down the heating, but it suppresses overheating. An On-Off action control will not slow down the rise in temperature, but may cause overheating. In most cases, and because the regulation is done according to the temperature of the wall, the best regulation will be On-Off type with anticipation. In particular a poor positioning of the temperature sensor, for example in the middle of the heated liquid, increases the risk of overheating of the walls, due to the time taken by the heat energy to reach the center of the container.
- The maximum admissible temperature on the wall:
The thermal safety limiters installed in the heating blankets limit the temperature reached by the heating element or the wall of the container in order to prevent their destruction by overheating. This limitation can increase the duration of the heating, in particular when the thermal exchanges with the liquid are bad, because of the thermal conductivity of the wall of the container, that of the liquid or its viscosity.
- The type of heating:
It can be, according to the suppliers, by conduction, by radiation, and even by induction.
The conduction solution is the most common and the most economical.
- The material of the walls of the container:
Barrels and drums can be metal, like painted steel or stainless steel. Although having a very different thermal conductivity, these materials withstand surface temperatures above 100°C.
There are more and more barrels and containers made of thermoplastic material, obtained by different modes of molding, but all of them have in common their softening when the temperature increases. The most common in barrels, drums and IBCs for industrial use is HDPE (high density polyethylene), often given for a maximum temperature of 80°C, but also Polypropylene, Polyamide, PBT and many other thermoplastics. As a general rule, for plastic containers, the surface temperature must not exceed 70°C and 50°C for glass carboys.
- Access to the surface of the container:
The best case scenario is when the heating blanket is in direct contact with the container wall. The worst case occurs when there is a layer of air between the wall of the cover and that of the container. This latter configuration is most often observed in IBCs, as these are often reinforced by an external metal cage that prevents direct contact with the wall.
- Thermal gradient between the center and the bottom of the tank:
This thermal gradient can reach 20°C, and the temperature is commonly 15 to 17°C lower in the tank bottom in the case of 55 gallons metal drums heated between 80 and 100°C without mixing. When the metal containers are placed on the ground without thermal insulation of the soil, this difference is increased by several degrees.

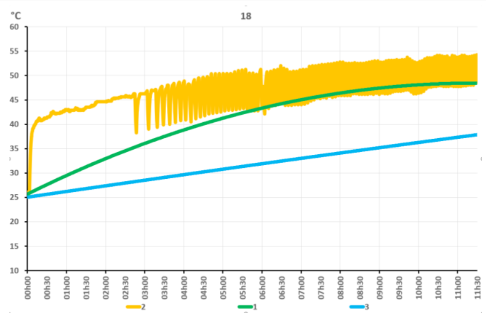
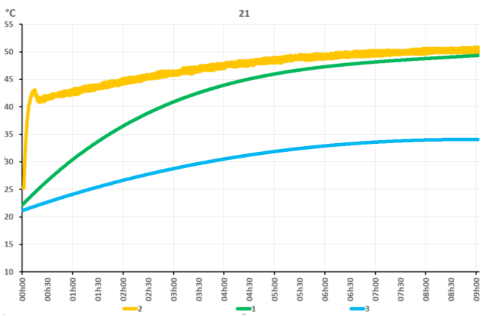
- Thermal gradient between wall temperature of the heating blanket and the center of the tank:

This thermal gradient is a function of the conductivity of the tank wall, the thermal conductivity of the liquid and the heating or temperature maintenance time and convection currents in the liquid. In the absence of stirrer, or temperature-corrected control in the center of the liquid, differences of 10 to 30°C are commonly observed. This is the reason why we did some of the tests with stirrer. The regulation according to the temperature in the center makes it possible to stop a reheating cycle when the product has reached a precise temperature in its center, but cannot substitute for reheating according to the temperature of the walls.

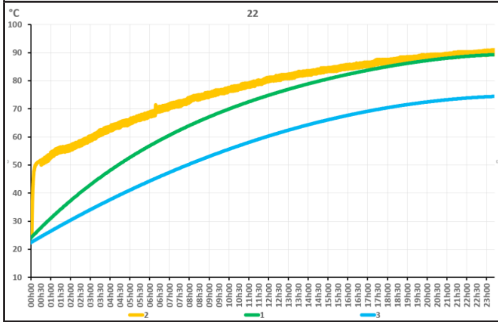
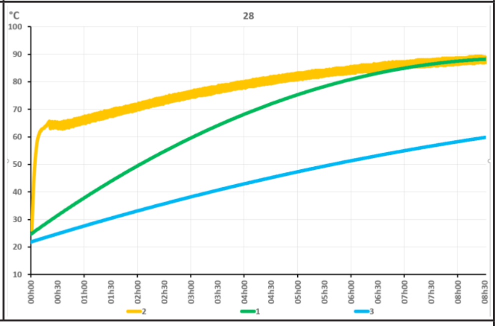
3. Examples of the most usual containers heating time in different configurations.

3-1. With small plastic containers

Fluid: Water **Container:** 20 liter HDPE plastic can **Power:** 150W (Surface Load 0.05 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** no **Insulating base:** no **Electronic control:** On-Off with anticipation, with set point set at 60°C **Surface temperature:** Limited to 60 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 50 °C **Heating time:** 15h29 min	**Fluid:** Hydraulic oil HF 24-6 **Container:** 20 liter HDPE plastic can **Power:** 150W (Surface Load 0.05 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** no **Insulating base:** no **Electronic control:** On-Off with anticipation, with set point set at 60 °C **Surface temperature:** Limited to 60 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 50 °C **Heating time:** 8h 19 min
	
1: Temperature of the liquid, at the geometric center of the tank, at half height 2: Average temperature, measured at 5 points, of the inner wall of the heating blanket 3: Liquid temperature, in the center, 50mm from the bottom	

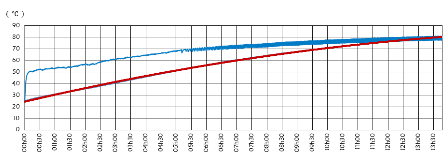
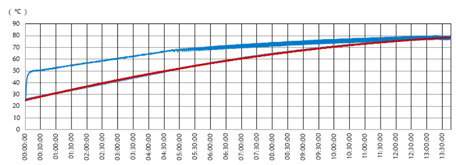
Fluid: Water **Container:** 60 liter HDPE plastic can **Power:** 150W (Surface Load 0.05 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** no **Insulating base:** no **Electronic control:** On-Off with anticipation, with set point set at 60 °C **Surface temperature:** Limited to 60 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 50 °C **Heating time:** 11h 30 min	**Fluid:** Hydraulic oil HF 24-6 **Container:** 60 liter HDPE plastic can **Power:** 150W (Surface Load 0.05 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** no **Insulating base:** no **Electronic control:** On-Off with anticipation, with set point set at 60 °C **Surface temperature:** Limited to 60 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 50 °C **Heating time:** 9h 03 min
	
1 : Temperature of the liquid, at the geometric center of the tank, at half height 2 : Average temperature, measured at 5 points, of the inner wall of the heating blanket 3 : Liquid temperature, in the center, 50mm from the bottom	

3-2 With steel containers

Fluid: Water **Container:** 30 gallons steel drum (110 liters) **Power:** 1100W (Surface Load 0.09 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** no **Insulating base:** no **Electronic control:** On-Off with anticipation, with set point set at 100 °C **Surface temperature:** Limited to 135 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 90 °C **Heating time:** 23h 24 min	**Fluid:** Hydraulic oil HF 24-6 **Container:** 30 gallons steel drum (110 liters) **Power:** 1100W (Surface Load 0.09 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** no **Insulating base:** no **Electronic control:** On-Off with anticipation, with set point set at 100 °C **Surface temperature:** Limited to 135 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 90 °C **Heating time:** 8h 32 min
	

1 : Temperature of the liquid, at the geometric center of the tank, at half height
2 : Average temperature, measured at 5 points, of the inner wall of the heating blanket
3 : Liquid temperature, in the center, 50mm from the bottom

Incidence of use of thermally insulated lid and botttom

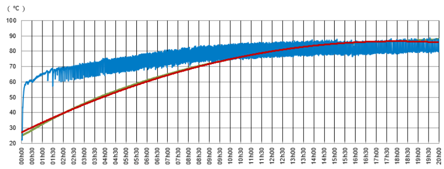
Fluid: Water **Container:** 55 gallons steel drum (210 liters) **Power:** 1500W (Surface Load 0.09 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** yes **Insulating base:** yes **Electronic control:** On-Off with anticipation, with set point set at 100 °C **Surface temperature:** Limited to 135 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 90 °C **Heating time:** 13h 46 min **Power consumption:** 16.4 kw	**Fluid:** Water **Container:** 55 gallons steel drum (210 liters) **Power:** 1500W (Surface Load 0.09 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** no **Insulating base:** no **Electronic control:** On-Off with anticipation, with set point set at 100 °C **Surface temperature:** Limited to 135 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 90 °C **Heating time:** 14h 54 min **Power consumption:** 17.5 kw
	

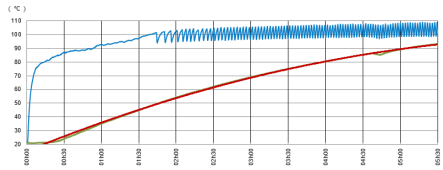
In red: Liquid temperature, at the geometric center of the tank, at half height
In blue: average temperature, measured in 5 points, of the inner wall of the heating blanket

Analysis of the results : the use of an insulating pedestal and an insulating lid reduces the heating time by 1h 8 minutes and the consumption by 1.1kw, i.e. 6.3%

Differences in heating time between water and oil

Fluid: Water **Container:** 55 gallons steel drum (210 liters) **Power:** 2250W (Surface Load 0.135 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** yes **Insulating base:** yes **Electronic control:** On-Off with anticipation, with set point set at 120 °C **Surface temperature:** Limited to 135 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 95 °C **Heating time:** 13h 27 min **Power consumption:** 23.2 kw	**Fluid:** Hydraulic oil HF 24-6 **Container:** 55 gallons steel drum (210 liters) **Power:** 2250W (Surface Load 0.135 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** yes **Insulating base:** yes **Electronic control:** On-Off with anticipation, with set point set at 120 °C **Surface temperature:** Limited to 135 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 95 °C **Heating time:** 5h 48 min **Power consumption:** 10.5 kw



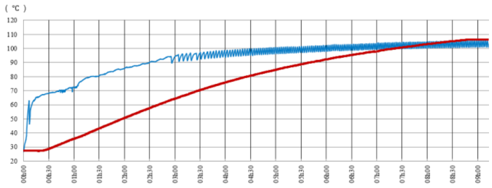


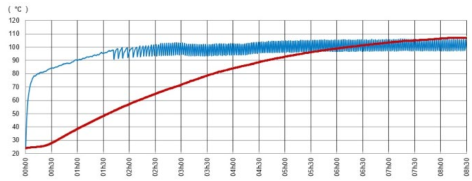
In red: Liquid temperature, at the geometric center of the tank, at half height
In blue: average temperature, measured in 5 points, of the inner wall of the heating blanket

Analysis of results: under the same conditions of power and adjustment, it takes 807 minutes to heat water and 348 minutes to heat oil, a ratio of 0.43. The power consumption is decreased in a ratio of 0.45

Effect of heating power on heating time

Fluid: Hydraulic oil HF 24-6 **Container:** 55 gallons steel drum (210 liters) **Power:** 1500W (Surface Load 0.09 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, **covering the entire cylindrical surface.** **Insulating lid:** yes **Insulating base:** yes **Electronic control:** On-Off with anticipation, with set point set at 120 °C **Surface temperature:** Limited to 135 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 108 °C and stabilize during one hour **Heating time:** 9h 14 min **Power consumption:** 11.7 kw	**Fluid:** Hydraulic oil HF 24-6 **Container: 55 gallons steel drum (210 liters)** **Power: 2250W (Surface Load 0.135 W/cm²)** **Thermal insulation: 20mm of NBR-PVC foam, covering the entire cylindrical surface.** **Insulating lid:** yes **Insulating base:** yes **Electronic control: On-Off with anticipation, with set point set at** 120 °C **Surface temperature: Limited to 135 °C by a safety thermostat.** **Test conditions: start at 25 °C, stop when the temperature at the center of the tank reaches** 108 °C and stabilize during one hour **Heating time: 8h 32 min** **Power consumption: 12.7 kw**





In red: Liquid temperature, at the geometric center of the tank, at half height
In blue: average temperature, measured in 5 points, of the inner wall of the heating blanket

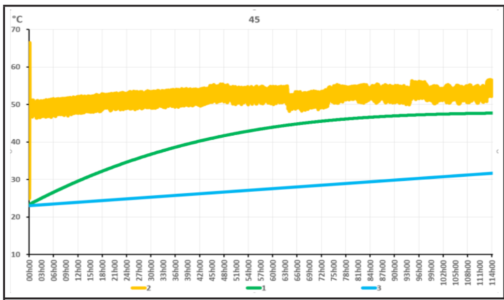
Analysis of results: increasing the power from 1500 watts to 2250W, being a coefficient of power increase of 1.5, heating time decrease from 554 to 512 minutes to reach the same temperature of 108 °C, a ratio of 0.92.The power consumption is increased in a ratio of 1.085

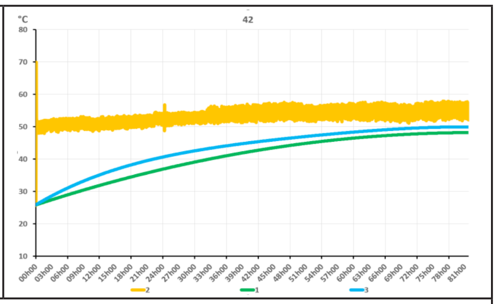
3-3 1000 liters IBC with HDPE reservoir and tubular protective grid in steel

Influence of an insulating cover and an insulating base on the heating time of an IBC

The IBCs are particularly long to heat because in addition to the large mass of the container, the jacket heaters are not in direct contact with their wall, because of their protective cage. As a result, the air circulates between the cage and the wall, and the hot air is quickly evacuated from above. We therefore recommend the use of a wraparound lid in addition to the standard hood to block this air circulation. A good insulation of the pedestal, when its placement is possible also significantly reduces the heating time.

Fluid: Water **Container:** 1000 liters HDPE container with tubular frame **Power:** 4400W in 2 zones (Surface Load 0.09 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** no **Insulating base:** no **Electronic control:** On-Off with anticipation, with set point set at 70 °C **Surface temperature:** Limited to 80 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 50 °C **Heating time:** 121h	**Fluid:** Water **Container:** 1000 liters HDPE container with tubular frame **Power:** 4400W in 2 zones (Surface Load 0.09 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** yes **Insulating base:** yes **Electronic control:** On-Off with anticipation, with set point set at 70 °C **Surface temperature:** Limited to 80 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 50 °C **Heating time:** 81h 45 min





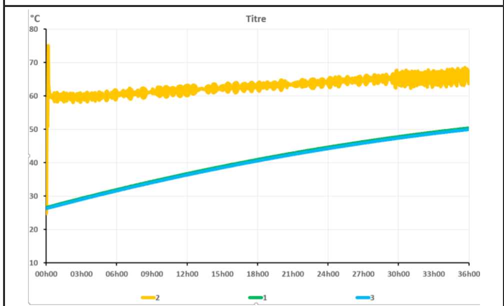
1 : Temperature of the liquid, at the geometric center of the tank, at half height
2 : Average temperature of the inner wall of the heating blanket, measured in 16 points
3 : Liquid temperature, in the center, 50mm from the bottom

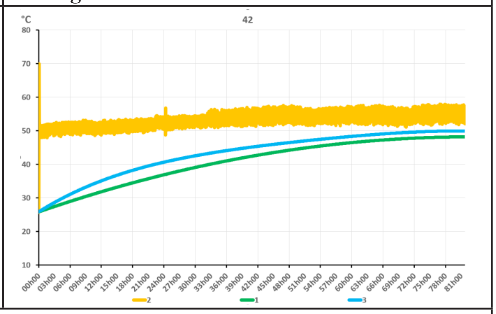
Analysis of results: insulation of the lid of a 1000-liter IBC makes it possible to reduce the heating time from 121 hours to 81.45 hours, a very important saving of time, with a ratio of 0.67

Incidence of stirrer on heating time

The use of a stirrer, circulating a cooler liquid on the walls increases the heat exchange. Insulating lid and pedestal allow full use of heat produced.

Fluid: Water **Container:** 1000 liters HDPE container with tubular frame **Power:** 4400W in 2 zones, surface Load 0.09 W/cm² **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** yes **Insulating base:** yes **Stirrer:** yes **Electronic control:** On-Off with anticipation, with set point set at 70 °C **Surface temperature:** Limited to 80 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 50 °C **Heating time:** 36h	**Fluid:** Water **Container:** 1000 liters HDPE container with tubular frame **Power:** 4400W in 2 zones (Surface Load 0.09 W/cm²) **Thermal insulation:** 20mm of NBR-PVC foam, covering the entire cylindrical surface. **Insulating lid:** yes **Insulating base:** yes **Stirrer:** no **Electronic control:** On-Off with anticipation, with set point set at 70 °C **Surface temperature:** Limited to 80 °C by a safety thermostat. **Test conditions:** start at 25 °C, stop when the temperature at the center of the tank reaches 50 °C **Heating time: 81h 45 min**





1 : Temperature of the liquid, at the geometric center of the tank, at half height
2 :Average temperature of the inner wall of the heating blanket, measured in 16 points
3 : Liquid temperature, in the center, 50mm from the bottom

Analysis of the results: The addition of an insulating pedestal and a stirrer greatly reduces the heating time, since one goes from 81h 45 minutes to 36h, a remarkable ratio of 0.44. Compared to the model without insulating cover, this time goes from 121h to 36h, an extraordinary ratio of 0.3. We can only recommend the use of these accessories.

4. Comparison of heating times required for different liquids currently heated by jacket heaters and electric blankets

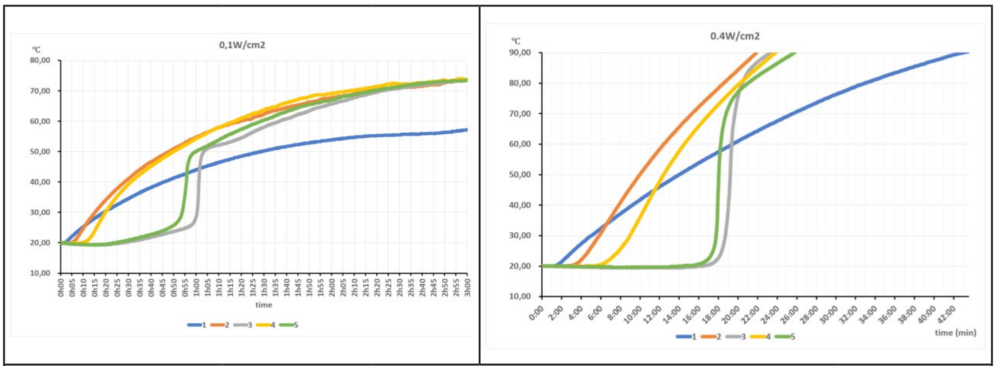
Testing equipment

In order to give an idea to the users heating specific products, we carried out, under identical test conditions, comparative tests by recording the necessary time and the evolution of the temperature during the heating of a liter of product, from 20 °C to 90 °C (measured at the geometric center of the tank).

These tests were made with two different values of surface power load: 0.1W/cm^2, as it is an usual value of industrial electric jacket heaters, and 0.4W/cm^2, which is maximum value achievable in this type of device.

Test conditions: Heating performed in a cylindrical tank diameter 76 mm height 280 mm, flat bottom, red copper 2 mm thick, the entire cylindrical portion filled with the product (250 mm) is heated by a flexible silicone heater, insulated with 20mm of PVC-NBR foam. The heating is made without temperature control or safety temperature limiter. The ambient temperature is maintained at 20 °C. in a climatic chamber. The test is stopped when the temperature at the center of the product has reached 90 °C.

Characteristics of the products used in the tests				
Products	**Thermal conductivity W/m.K**	**Specific heat capacity (kJ/kg.K)**	**Kinematic viscosity at 20°C mm^2/s**	**Specific gravity Kg/m3**
Water	0.597@20°C	4.182	1.006@20°C	0.998@20°C
Olive oil	0.189@15°C	1.25	91.5@20°C	0.922 @20°C
Lard	0.407@25°C	2.1	Frozen (melting between 35 and 42 °C)	0.924-0.930
Mineral oil ISO VG680	0.134@40°C	1.99	4000@20°C	0.850
Butter	0.197 @46°C	2.3	Frozen (melting between 27 and 32 °C)	0.87-0.93
With a surface load of 0.1W/cm^2 (60W)			**With a surface load of 0.4W/cm^2 (240W)**	



1: Water; **2:** Olive oil; **3:** Lard; **4:** ISO VG680 Mineral oil ; **5 :** Butter

Analysis of the results: The water, with a heating capacity of 2 to 4 times greater than the other products, thus requires more energy to warm up and thus heats up much less quickly. Products frozen at room temperature (butter, animal fat) retain for a long time a central cold part for lack of convection currents, before quickly reaching the temperature of the other oils when they liquefy.

5. Energy balance

To heat from 25 to 80 °C a barrel of 55 gallons (220 Liters), with a 1500W electric heater, the theoretical calculation without heat losses gives a duration of 9 hours 23 minutes and a consumption of 14 kw.

In the real energy balance, the losses to the external environment, which depend on the quality of the thermal insulation, are involved. In the case of our tests, insulation is made by a NBR-PVC foam with an insulation coefficient ≦ 0.036 w / m.k.

For 55 gallons drum (220l) with thermal insulation on all sides, an average total consumption of 16 to 17 kw is measured for reheating water. The energy yield is then around 88%.

Under the same conditions, the measured times range from 13 hours 45 minutes to 14 hours. This is 1.5 time the theoretical time.

The heating time is extended by the heat transfer conditions between the blanket and the product to be heated and by the homogenization of the temperature in the container, which can be very long to take place, because temperature differences between the bottom and the upper part can reach 25 to 30 °C during the heating period.

A temperature homogenization system such as a stirrer will therefore reduce the heating time, but its power consumption will add to that of the heating.

Second part :
Construction features and performance validation

1. IP tests (Resistance to water ingress)

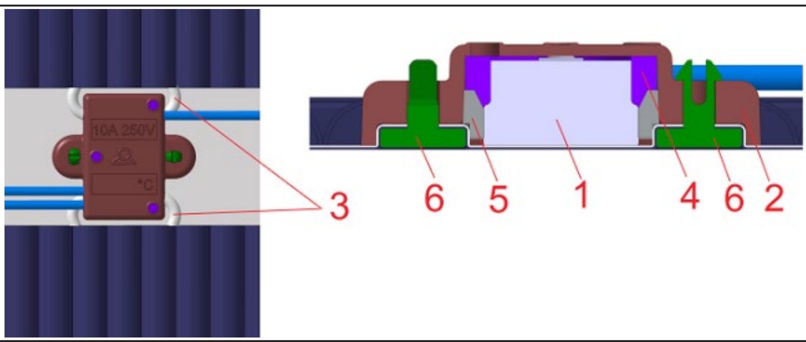
Protection against water ingress is an essential parameter of industrial heating blankets and jacket heaters, which may be subject to overflows and various projections. Everything in the design of these devices has been implemented to continue to ensure the protection of users in the harshest conditions. In the heating part, the electrical connections between heating cables, connecting conductors, thermostats, limiters, connectors and other components are sealed and meet the IP66 classification. Control and connection boxes, accessible by users, are IP69K. However, although the fabrics used are waterproof, although the zippers are watertight, limited water penetration into the heating zone can occur, most often through seams. All the inner wiring of this part being waterproof, this penetration of water does not question the electrical insulation of the devices.

IPx6 testing of jacket heaters

Insulation resistance measurement after IPx6 tests

2. Thermal safety and temperature limiter. Maximum wall temperature and use on empty containers.

One of the conditions of critical use of industrial flexible heating blankets is related to their use on containers full, but also partially or totally empty. When the temperature limiter is in contact with a wall behind which there is no more liquid, or when it is not in contact with a surface with which the heating blanket can exchange its calories, it must react to overheating of heating elements. For this reason, it is in contact with them thanks to two heating wire loops, via a patented flexible thermal semiconductor. This system then switches off the heating when the local temperature becomes too high, and then limits the amount of energy supplied to the heating elements.

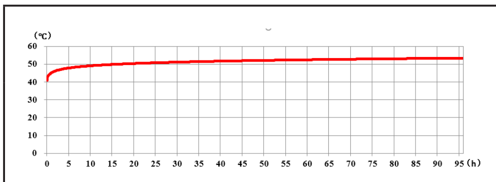


1 : Limiter — 2 : PA66 enclosure — 3 : Heating wire loops
4 : Resin filling — 5 : Thermal semiconductor — 6 : Clips for fabric surface mounting

3. Tests for permanent and peak temperature insulation of the insulating foam, measurement of the retraction rate after heating, tests for water recovery after heating.

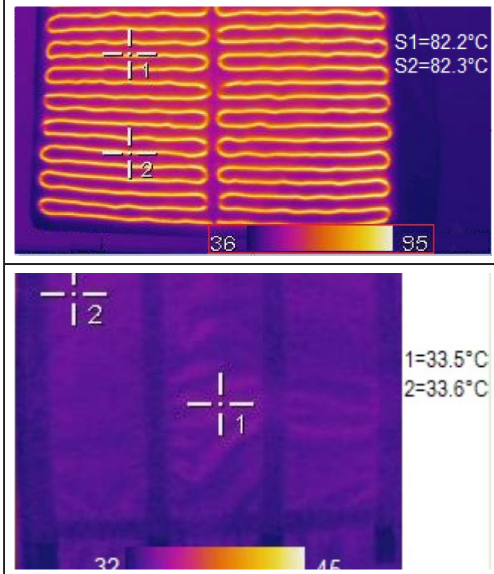
The selection of an effective thermal insulation over the range of temperature of the blanket and jacket heaters eliminates most of the flexible thermal insulation available on the market:
- The glass wool, rock wool, ceramic wool, because of their permeability and their «sponge» effect
- Polyurethane and polyethylene foams because of their flammability and poor temperature behavior
- The carbon fiber felts because of their inflammability and their «sponge» effect
- NBR and NR foams because of their flammability.
- Silicone foams because of their prohibitive price.

From intensive tests made on these different materials, only the PVC-NBR foam appeared adapted to the use. It combines the insulating effect of closed-cell NBR foam (thus without sponge effect) with the self-extinguishing properties of PVC.
For these tests, the foam is placed around a heating barrel set at 120 °C (maximum permanent temperature of the heating blanket), for 96 hours. After this period, the variation of its insulating power, and its size change (elongation or shortening) are measured, then its porosity is evaluated by weighing after immersion in water for 8 days.
Another test is also performed, the verification of the peak temperature resistance. Subjected at 300 °C for 30 minutes, the PVC-NBR foam does not ignite, but loses its flexibility and cracks.
However, higher temperatures, impossible to achieve in normal operation, initiated by the supply of energy external to the process, can initiate the slow combustion of the foam

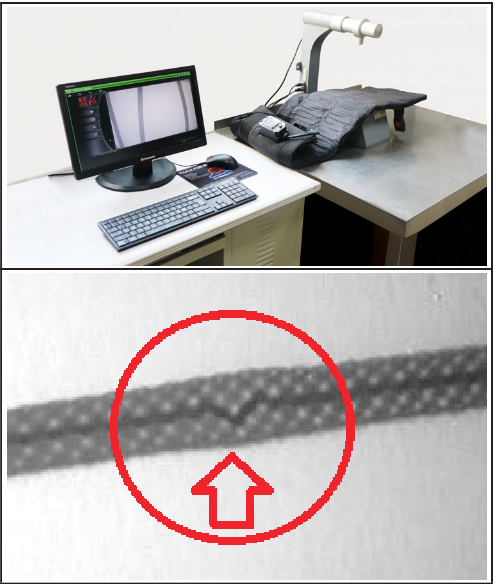
	Heating barrel for measuring the maximum temperature of the foam (protective cover and fume hood removed for shooting)	
		
Variation of the average outside surface temperature of the foam during the test of 96h at 120 °C (constant ambient temperature at 32 °C). No change in the external temperature is measured. The insulation characteristic of the foam remains constant	Foam after 96 hours at 120°C Length shrinkage: - 4,7% Water absorption: 9%	Foam after 30 minutes at 300°C

4. Search for hot spots in heating cables

During the manufacture of the heating conductors, it happens that splices are made to butt the conductors when changing wire coils. These splices are then taken up under the silicone insulation, they remain invisible. But a poorly executed splice may add additional electrical resistance to the heating cable where it is made. This type of fault then causes a hot spot. This hot spot is detected by thermal imaging during the final test of the cover. An additional X-ray hot spot check then verifies the cause of the fault and replace the heating cable prior to use.



Examples of thermal imaging of a heating blanket. Top photo taken on the inside, heated side, and photo of the underside, non-heated outside (ambient temperature 32 °C)

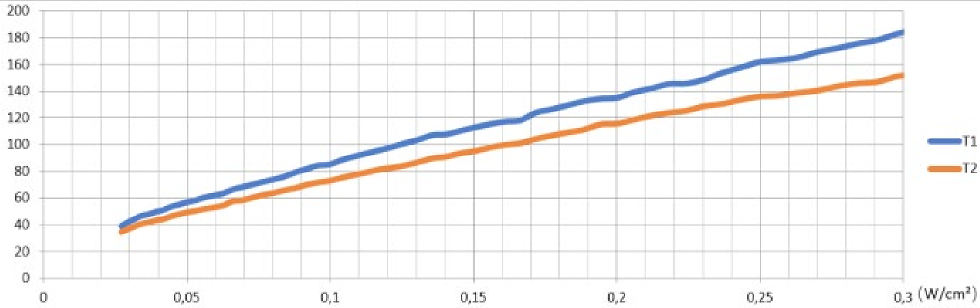


Detection of connection faults or hot spots of X-ray heating wires (protective screen removed for shooting). Example of hot spot detected: splice between the heating conductors.

5. Surface temperature of heating wires for a heating blanket without contact with a wall, as a function of the watt-density

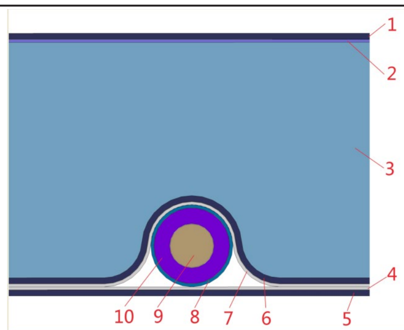
Apart from any temperature control, a heating wire embedded inside a blanket heater or a jacket heater will reach, in a calm air without mechanical ventilation, a stabilizing temperature depending on its external surface and its power.
The design of an industrial blanket heater or jacket heater must take into account this factor so that the temperature reached in the worst operating conditions can not destroy or melt the fabric of the structure, and retains an electrical insulation guaranteeing the safety of the people, including when two heating layers are superimposed or when it is not in contact with the surface of the container.
It is by using heating wires with low surface watt density, by using a heating net with compact heating wires pitch, that the temperature of the surface of the heating blanket will be more homogeneous, without hot spots. In the most common models (220 liters drum, 1000 liters IBC), this results in significant lengths of heating wire from 80 to 160 meters per device. But it is the sine-qua-non condition of reliable professional devices.
The surface watt density values of the heating blankets are divided into 4 classes, depending on the types of containers used and the maximum temperature that can be reached in the container.
- **Low temperature class:** 0.05W/cm². This class allows the heating of plastic tanks, for example polyethylene. The maximum temperature reached by the heating cable, without temperature control, is 50 °C. This is the most common solution for antifreeze applications.
- **Middle temperature class:** 0.095W to 0.1W/cm². This class allows the heating of metal containers containing water or a liquid not to exceed 80 °C. The maximum temperature reached by the heating cable, without temperature control, is 85 °C
- **High temperature class:** 0.135W/cm². This class allows the heating of metal containers containing a liquid not to exceed 110 °C. The maximum temperature reached by the heating cable, without temperature control, is 110 °C
- **Very high temperature class:** 0.25W/cm². This class allows the heating of metal containers containing a liquid not to exceed 150 °C. The maximum temperature reached by the heating cable, without temperature control, is 160 °C. This particular class requires enhanced thermal protection of fiberglass and kapton heating cables. Control systems mounted on the surface of the cover are not possible, and PID control with Pt100 sensor and remote mounting box is the only possible temperature control.

Equipment for measuring the surface temperature as a function of the surface W/cm² of the blanket heater or jacket heater

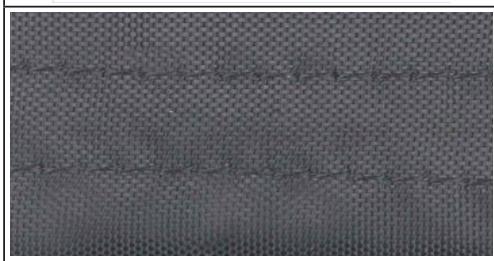


Surface temperature, in °C, in an environment at 20 °C, of heating wires with metal protection braiding, for different surface watt density values of the heating blanket or jacket heater.
T1 = surface temperature of the heating wire.
T2 = outer surface temperature of the blanket or jacket.

Deterioration of the surface as a function of the temperature reached on the heating wires, for blankets or jackets heaters with wires embedded under PA66 fabric with PTFE protective film (Standard low, medium and high temperature versions)



Cut view of the heating cord embedded between the flexible walls (standard version)
1, 5, 6: High resistance polyamide fabric
2: Polyurethane sealing layer of the outer polyamide fabric
3: Insulating PVC-NBR foam
4, 7: Ptfe film (overheating protection)
8: Tinned brass braid (mechanical protection and grounding)
9: Heating wire
10: Silicone insulation 300V, thickness 1.1mm

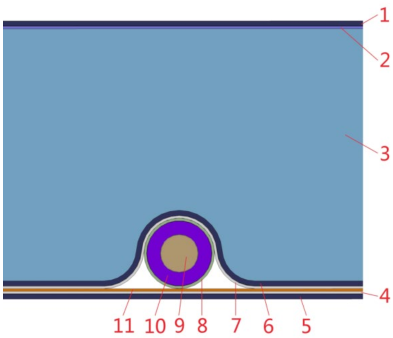
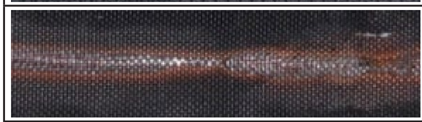


96 hours at 120 °C on the heating cable: no color change, no insulation melting, no change in characteristics

1h at 220 °C on the heating cable: the PA66 starts to change color

	
1h at 235 °C on the heating cable: The PA66 begins to melt	5 minutes at 245 °C on the heating cable, the PA66 has melted, and reveals the protective layer of PTFE which is not deteriorated. The protection of the heating cord is always done by PTFE and silicone insulation.

Deterioration of the surface as a function of the temperature reached on the heating cord, for covers with heating resistors mounted on fiberglass fabric and Kapton film, and covered under PA66 fabric with PTFE protective film (very high temperature version)

	Cut view of the heating cord embedded between the flexible walls 1: High resistance polyamide fabric 2: Polyurethane sealing layer of the outer polyamide fabric 3: Insulating PVC-NBR foam 4: Ptfe film (overheating protection) 5: High resistance polyamide fabric 6: Non-combustible fiberglass fabric 7: heat reflective aluminium film 8: Tinned brass braid (mechanical protection and grounding) 9: Heating wire 10: Silicone insulation 300V, thickness 1.1mm 11: Additional thermal protection and electrical insulation by kapton film
	5 minutes at 250 °C on the heating cable, the external temperature at the PA66 fabric layer causes its color change
	5 minutes at 320 °C on the heating cable, the external temperature at the PA66 fabric layer causes its melting
	5 minutes at 350 °C on the heating cable, when opening of blanket heater, we can see that the holding and insulation to the outside of the heating cable is still provided by fiberglass and Kapton. A further increase in temperature causes deterioration of the silicone sheath of the cord, and puts its live parts in contact with the metal braid which then switch off the power supply, without an electrical loss to the outside is possible.

6. Insulation resistance and breakdown voltage

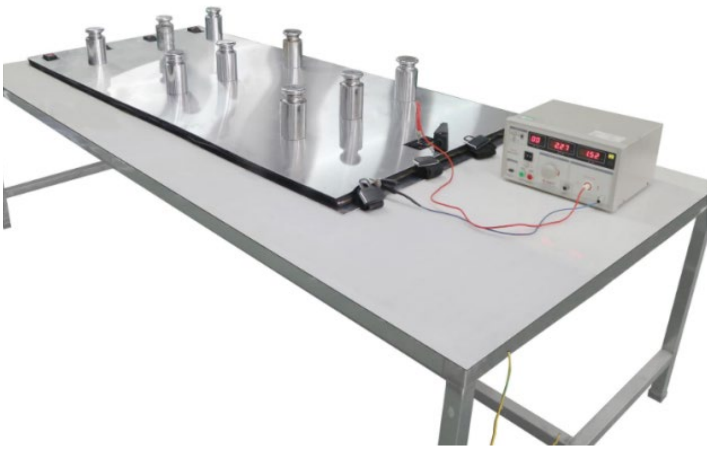
The insulation resistance decreases with the length of heating wire used. If this length can go down to a few meters in the small heating blankets and jacket heaters, it can exceed more than 160 meters on the 1000 liters IBC jackets heaters.
In production, the insulation values are 100% measured at ambient temperature. Our minimum acceptance limit for any condition (dry, hot, or after IP65 test) is 0.1Gohms (100x the limit of EN60335-2-17§ 19.112.3).

This measurement is carried out with the heater sandwiched between two metal sheets covering the entire surface and pressed against each other with a load of 35 DaN / m².

Device for measuring the insulation resistance.
The measured values are always greater than 0.1Gohm

Electric strength at cold conditions

In all protected heating elements, there is a leakage current passing through their insulation. This leakage current increases with the applied voltage.
In the case of heating blankets, a production test for measuring the total leakage current is performed by placing the heater between two metal plates and applying a voltage of 1750 volts between the conductors and the metal plates according to 60-335-2 -17 § 22.115. In application of the EN60519-1 standard, the maximum leakage current allowed during 1 minute is a function of the nominal ampacity of the jacket or blanket heater, it is 3mA for ampacities less than 7A (1600W in 230V) and 0.5mA per ampere for higher currents (eg 10mA for 2000W, 15mA for 3000W). For 1000 liter IBC heaters with 2 independent heating zones, this measurement is performed independently for each zone.
The large value of the leakage current on the large dimensions jacket heaters requires their connection to a power supply circuit protected by a differential circuit breaker calibrated at 20mA.



Measuring equipment for total current leakage at cold condition

Leakage current at operating temperature

Leakage current measurement on hot and accessible surfaces is a parameter intended to verify the safety of an appliance to avoid electric shock when touched while it is in operation. This is a way to check that its electrical insulation does not degrade and remains sufficient when the operating temperature is reached. The tests consist, in accordance with the articles of standards EN60335-1-13.1 and 13.2, to place a metal plate of 10 x 20 cm (simulating the size of a hand) on the blanket or jacket heater, and to measure the current passing between this plate and the live conductors when the heating blanket has reached its maximum temperature. The maximum limit value is 0.75mA at 240V. Our tests are validated by an average value of 6 measurements made at different locations, under a power equal to 1.15 times the nominal power.

Measuring equipment for total current leakage at hot condition

7. Tightening and holding systems for jacket heaters on tanks

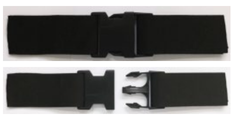
Holding and tightening the jacket heaters on the containers is an important parameter in the regularity of heating. It is therefore important to use the best way to ensure the best heat transfer at all temperatures. For this different means are implemented:

- Velcro tape tightening: easy to use and economical, it does not withstand high temperatures and its regular use deteriorates when external contaminants clog the tape. Adjustment of the tightening is impossible after pressing the 2 bands on each other.
Breaking load at room temperature on 50mm wide strips, with 100mm contact between the two hanging parts: 26 DaN
Breaking load at high temperature under load of 15 DaN: 120 °C
Withstand 15 DaN load without breaking at -50°C

- Plastic snap buckles: economic, but not resistant in temperature, and their opening can happen unexpectedly when the tightening force is too important.
Breaking load at room temperature: 44 DaN
Breaking temperature under 15 DaN load: 100 °C
Withstand 15 DaN load without breaking at -50°C

- The «automotive» type metal safety buckles: they are more expensive than plastic buckles, they resist very well to temperature, they allow a great tightening even after their closing, and they are easy and quick to open.
Breaking load at room temperature: 240 DaN
Breaking temperature under load of 15 DaN: withstands 150 °C without breaking
Withstand 15 DaN load without breaking at -50°C

- Scarf: Sewn on the upper part of the jacket heater, it is intended to be tightened above the container, or around the neck of the bucket or the carboy. It prevents the jacket heater from slipping down. It also serves to keep the insulation lid in place when used, and limits heat loss upward by blocking airflow. It is the indispensable complement of the clamping systems.

Velcro	Plastic snap buckles	Metal « Automotive » buckles	Scarf
			

8. Fabrics tear strenght

The fabrics chosen for industrial blankets and jacket heaters were selected to provide exceptional tear resistance. This resistance is tested on laser cut specimens with dimensions in accordance with EN 60335-2-17§21.110.1. Depending on their location and the type of covers, their resistance ranges from 44N to 107N (4 to 9 times the value of 12.5N required)

	Sample used for testing
	Tear strength testing equipment

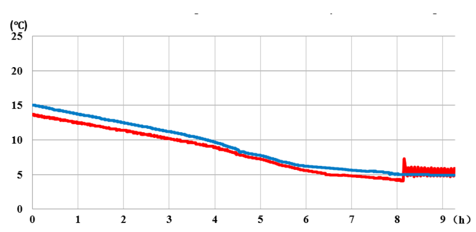
9. Minimum power for use in anti-freeze protection

In many applications, jacket heaters are used to prevent containers from freezing. But the information given by the different manufacturers is often inaccurate or incorrect.
We conducted systematic climate chamber tests to determine the surface power in W/cm² required to prevent a container from freezing as a function of ambient temperature.
These tests were carried out on fully insulated tanks (sides, bottom, lid) by heating blankets with insulating walls of 10 or 20mm. The set point of the on-off electronic temperature controller for heating the cover is set to 5 °C and the differential set to 2 °C

	
Climate chamber, with temperature adjustment range from -90 to + 150 °C, relative humidity adjustment range 1 to 100%	**Jacket heaters during climate tests in negative temperatures**

Tests with 10mm insulation foam thickness

(In blue the temperature of the liquid in the center of the tank. In red the wall temperature of the tank under the insulation)

<table>
<tr>
<td>
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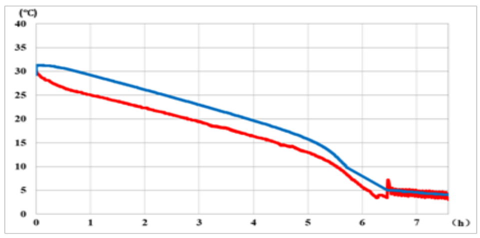
<td>
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</tr>
<tr>
<td>Variation of the water temperature in the container, while the ambient temperature is -10 °C, with a surface load of 0.05 W/cm² (150W).
It can be seen that the internal temperature of the container stabilizes at 5 ° C.</td>
<td>Variation of the water temperature in the container, while the ambient temperature is -35 °C, with a surface load of 0.1 W/cm² (300W).
It can be seen that despite the increased heating power, the internal temperature of the tank continues to fall slowly</td>
</tr>
</table>

Tests with 20mm insulation foam thickness

(In blue the temperature of the liquid in the center of the tank. In red the wall temperature of the tank under the insulation)

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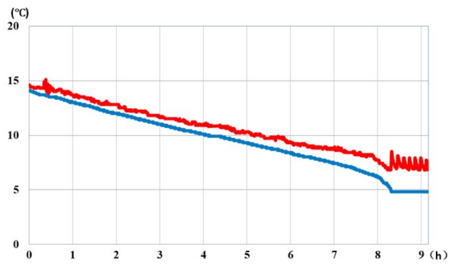
<td>
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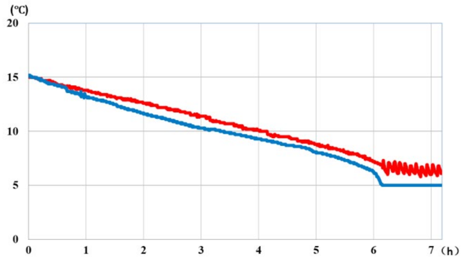
<td>
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<tr>
<td>Variation of the water temperature in the container, while the ambient temperature is -10 °C, with a surface load of 0.05 W/cm² (150W)
It can be seen that the internal temperature of the container stabilizes at 5 ° C.</td>
<td>Variation of the water temperature in the container, while the ambient temperature is -15 °C, with a surface load of 0.05 W/cm² (150W)
It can be seen that the internal temperature of the container stabilizes at 5 ° C.</td>
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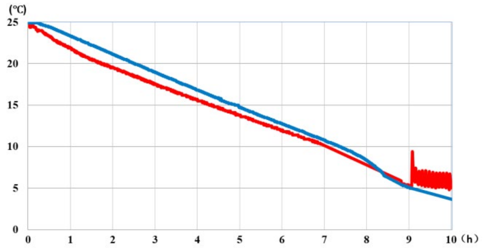
<td>
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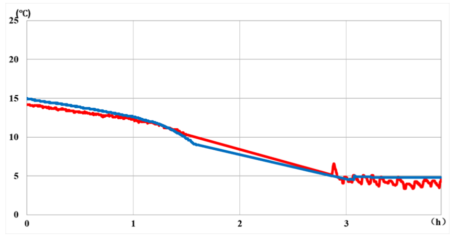
<td>
</td>
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<tr>
<td>Variation of the water temperature in the container, while the ambient temperature is -20 °C, with a surface load of 0.05 W/cm² (150W)
It can be seen that the internal temperature of the tank continues to drop sharply</td>
<td>Variation of the water temperature in the container, while the ambient temperature is -35 °C, with a surface load of 0.1W/cm² (150W)
It can be seen that the power increase allows to stabilize the internal temperature of the container at 5 ° C.</td>
</tr>
</table>

Analysis of the results: With an insulation thickness of 10mm on all sides, the surface charge of 0.05W/cm²is sufficient to protect against freezing an insulated tank up to ambient temperatures of -10 ° C. By increasing the surface load up to 0.1W/cm²the protection exists up to - 15 ° C.

With an insulation thickness of 20mm on all sides, the surface load of 0.05W/cm²is sufficient to protect an insulated tank from freezing up to ambient temperatures of -15 °C. By increasing the surface load up to 0.09 to 0.1W/cm²the protection exists up to - 35°C.

10. Temperature controls

All jacket and blanket heaters use the same waterproof connector on their control module. This connector exists for 10 or 20mm thickness of thermal insulation. The earth connection is realized, as well as the earthing of the container when it is metallic.	
Simplified connection box, for fixed temperature jacket and blanket heaters. The surface temperature measurement is then performed by a bimetal limiter embedded in the heating wires network. Power supply "on" and heating "on" are displayed by 2 pilot lights. This control box version is not interchangeable with models of blanket or jacket heaters with built-in NTC sensor, intended for electronic control.	
Fixed temperature mechanical room thermostat incorporated in the cover of the connection box. Automatic activation of the heating when the temperature drops below 5 °C, with pilot lights indicating power on and heating on. This control box version is not interchangeable with models of blanket or jacket heaters with built-in NTC sensor, intended for electronic control.	
Electronic thermostat for NTC sensor. On-Off action with anticipation, adjustment by knob, with pilot lights indicating power on and heating on. Mounting on the blanket heater or jacket heater connector. Temperature control according to the container wall temperature.	

Electronic thermostat for NTC sensor. On-Off action with anticipation, digital display. Direct mounting on the jacket or blanket heater connector. Temperature control according to the container wall temperature	
Electronic thermostat for NTC sensor. On-Off action with anticipation, digital display. Remote control with connection by cable on the jacket or blanket heater connector. Temperature control according to the container wall temperature	

Electronic thermostat for NTC sensor. On-Off action, digital display. Remote wall mounting. Features a long temperature sensing probe for immersion in the liquid. Can be used in addition to surface temperature control, to end the reheating process when the core temperature of the liquid is reached. Attention: it cannot be used directly for the control of the heating, without it already exists a regulation of surface temperature, because it does not replace it. Also available with Pt100 temperature sensor.	
Electronic temperature controller, Pt100 sensor input, autotune PID action. Dual digital display: measured temperature and set point value. Temperature control according to the container wall temperature. Available only with remote control box. This version, using a Pt100 type sensor is not interchangeable with the models of blanket and jacket heaters with built-in NTC sensor