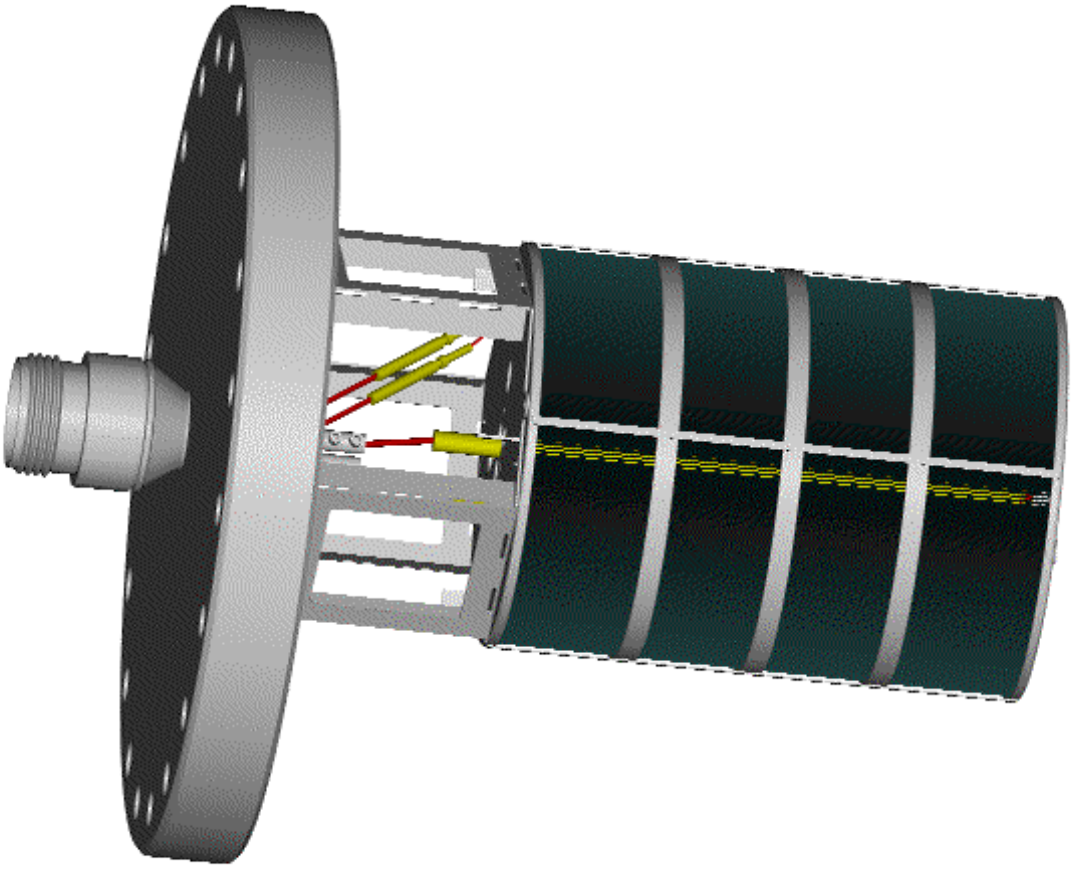
OPERATING INSTRUCTIONS FOR

SORB-AC® CARTRIDGE PUMPS

MK5 Type



Prep.: MAP	Chk.: GS	Appr.: CT

SORB-AC® Cartridge Pumps MK5 Type are types of vacuum pumps manufactured by SAES GETTERS S.p.A., which sorb active gases with a non-evaporable getter material. They are used alone or in combination with other vacuum pumps in several applications in the high and ultrahigh vacuum fields (HV and UHV).

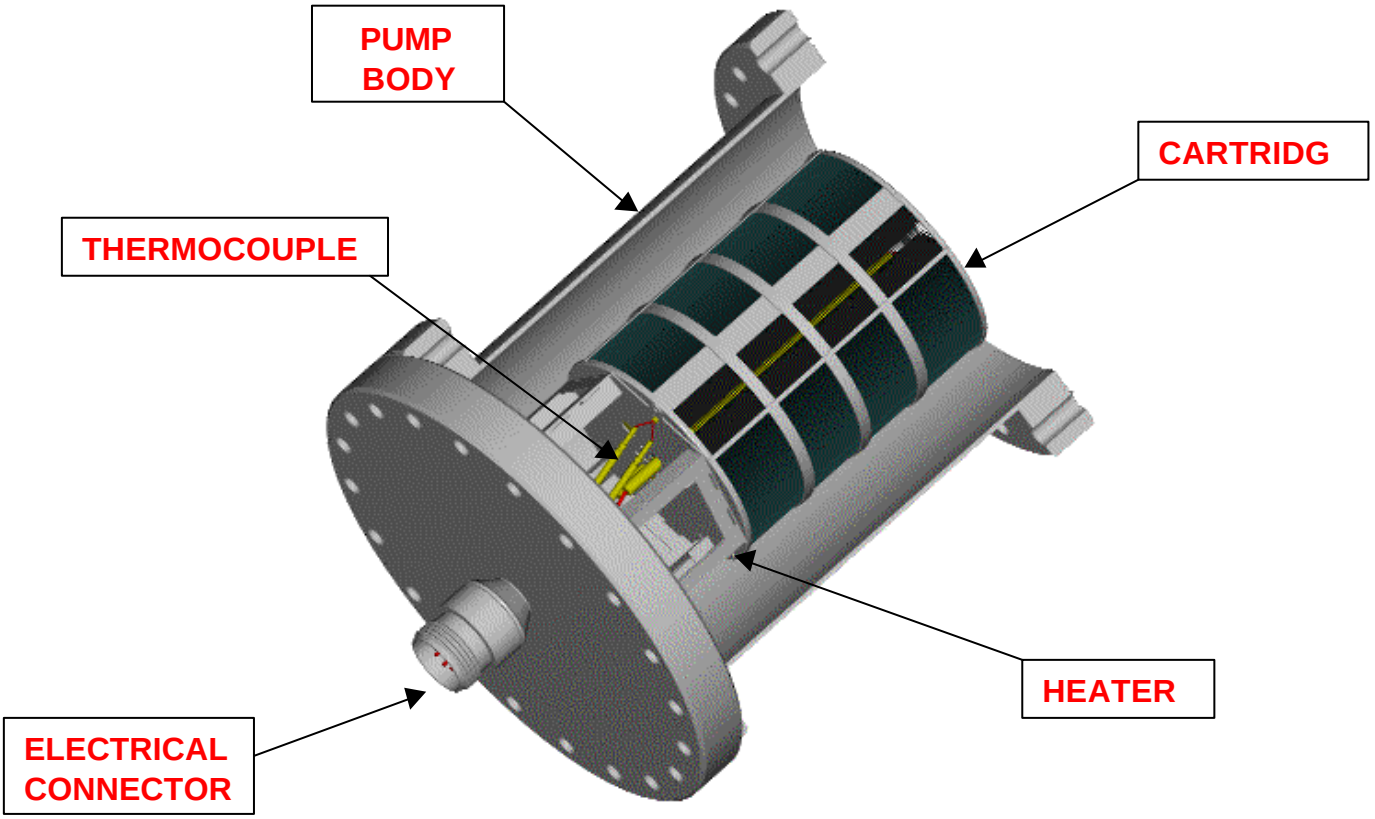


Fig.1

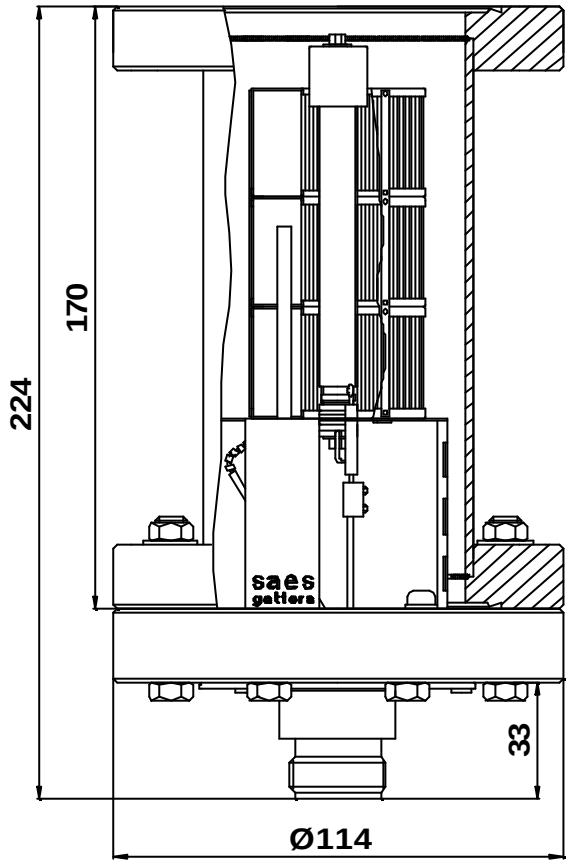
DESCRIPTION OF SORB-AC® Cartridge Pumps MK5 Type

A typical SORB-AC® Cartridge Pumps MK5 type is shown schematically in fig. 1.

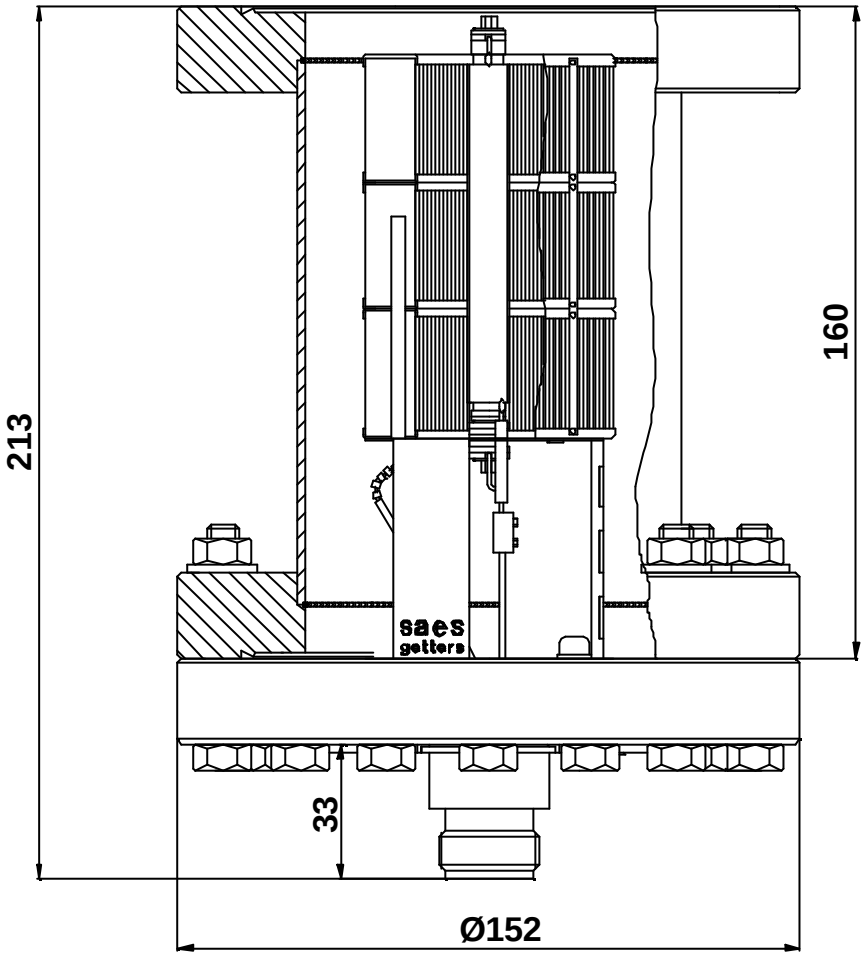
The essential components are:

- Cartridge containing the getter material
- Heater assembly
- Heater support flange
- Thermocouple
- Electrical connector
- Removable pump body (water cooled version available)

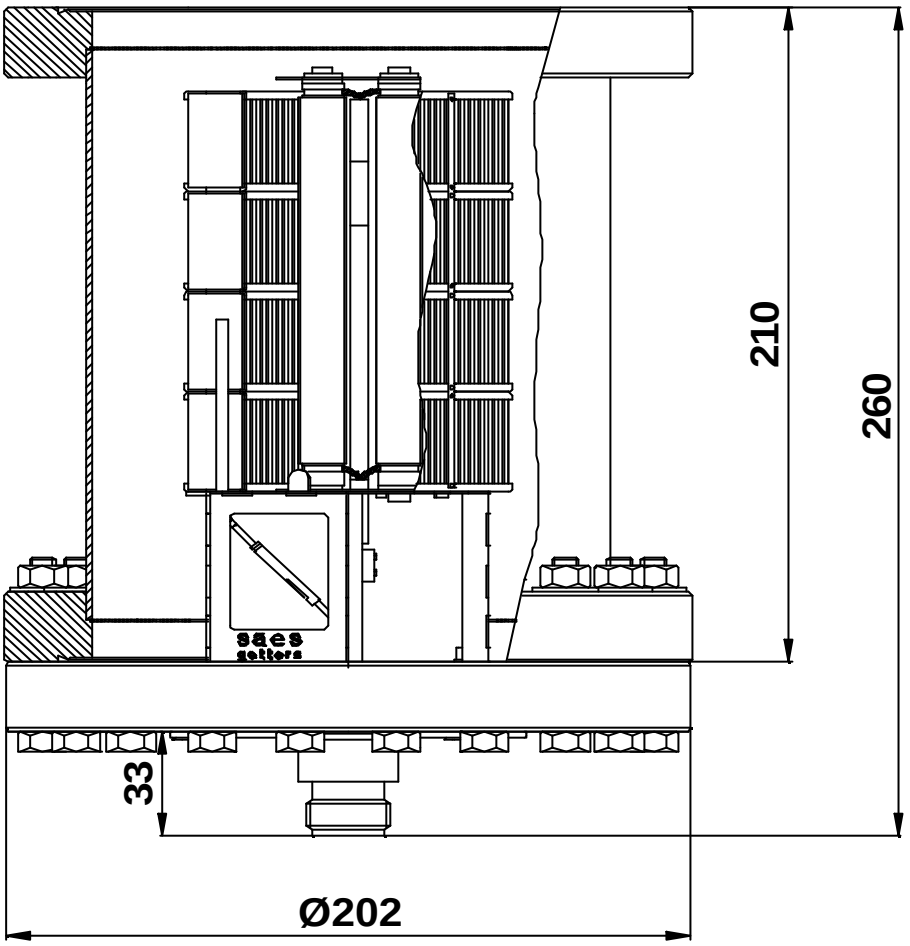
Characteristics of the SORB-AC® Cartridge Pumps MK5 Type



GP 100 MK5		
Alloy Type		ST 707
Getter Alloy Mass (g)		100
Getter Surface (cm^2)		2600
Pumping Speed (l/s)	H_2	240
	CO	85
Sorption Capacity (Torr l)	H_2 Room Temperature	1000
	H_2 High Temperature	Depends on the equilibrium pressure
	CO Room Temperature	1.7
	CO Total	900



GP 200 MK5		
Alloy Type		ST 707
Getter Alloy Mass (g)		170
Getter Surface (cm^2)		4470
Pumping Speed (l/s)	H_2	500
	CO	180
Sorption Capacity (Torr l)	H_2 Room Temperature	1700
	H_2 High Temperature	Depends on the equilibrium pressure
	CO Room Temperature	2.7
	CO Total	1530



GP 500 MK5		
Alloy Type		ST 707
Getter Alloy Mass (g)		540
Getter Surface (cm^2)		14290
Pumping Speed (l/s)	H_2	1200
	CO	500
Sorption Capacity (Torr l)	H_2 Room Temperature	5400
	H_2 High Temperature	Depends on the equilibrium pressure
	CO Room Temperature	8
	CO Total	4860

Cartridge

The cartridge is made by coating the getter alloy onto Costantan strips which are then pleated in concertina fashion and formed into cylinders which make up the cartridge.

For the SORB-AC® Cartridge Pumps MK5 Type, only cartridges made with ST 707 getter material are available.

A stainless steel separator is inserted in the cartridge to facilitate the correct positioning of the thermocouple.

Heater

The heater consists of a tantalum wire spiral wound on an allumina element supported by a stainless steel rod. The heater assembly also includes the cartridge and the thermocouple positioning (stainless steel tube) and securing components.

Flange

The support flange is a standard CF type flange in which one Special Connector equipped with six conductors for electrical and thermocouple connections is TIG welded.

The pump flange is leak tested to 1.5×10^{-10} scm^3/s.

Thermocouple

The thermocouple is a K type electrically insulated within an allumina tube.

The thermocouple is assembled on the support flange and connected to the connector thermocouple conductors with compensated contact terminations.

Electrical connector

The Special Connector allows the connection of the pump to the power supply and control unit. The connector is bakeable up to 400°C.

Pump Body

The optional pump body is a simple double flanged nipple. If desired, the pump can be mounted nude inside the vacuum system to fully exploit its pumping speed. The pump body can be supplied with a water cooled jacket, but it should be noted that water cooling is not necessary for the pump to function efficiently. Both the pump body and the pump flange are leak tested to 1.5×10^{-10} scm^3/s.

INSTALLATION OF A SORB-AC® Cartridge Pumps MK5 Type

The SORB-AC® Cartridge Pumps MK5 Type can be mounted connecting it to a suitable CF type flange, available in the vacuum system to be pumped. The pump cam be mounted "nude" inside the vacuum system directly connecting the heater supporting flange to the port of the vacuum system. In alternative the pump can be mounted in appendage, using the double flanged body which can be optionally supplied with a water cooling jacket.

A) Unpacking

The pump is contained in two packs: one for the pump (flange/heater assembly) and the second for the corresponding SORB-AC cartridge sealed under dry nitrogen. The pack which contains the pump may be opened immediately on arrival. A special protection body preserve the pump from possible shock. To remove the body protection, put the pump horizontally, remove the polyethylene bag and back off the three screws. Take the pump by the electrical connector and pull it out of the body.
It also contains a copper gaskets for flange connection.

CAUTION : Do not open the cartridge pack until final assembly. The getter material may be harmed by a long exposure to air, especially if stored for several days in a humid atmosphere.

B) Installation

As for all UHV type equipment, clean lint free gloves should be used for handling the parts of the pump exposed to vacuum. All operation should be conducted on a clean dust-free bench. All tools used for the assembly should be cleaned before use.

Stand the pump vertically with the heater to the top and refer to fig. 2.

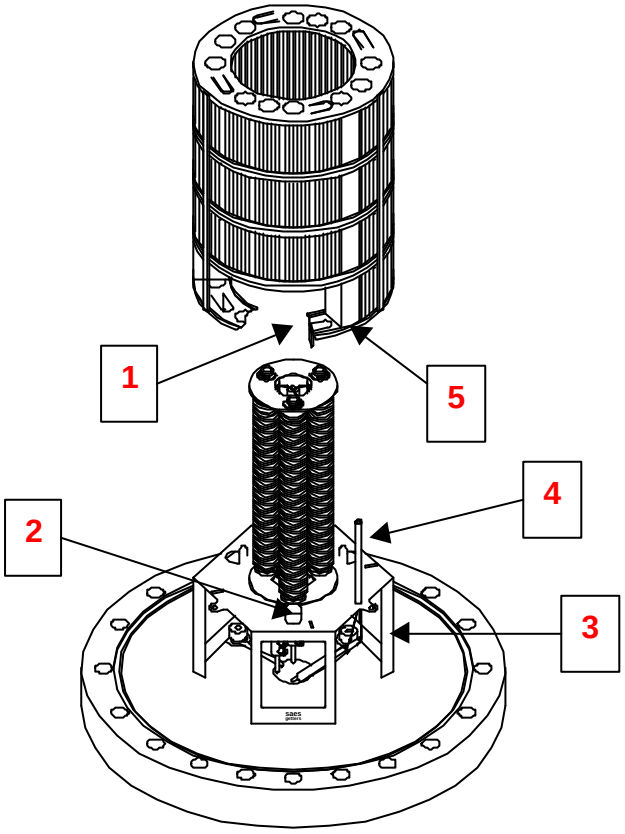
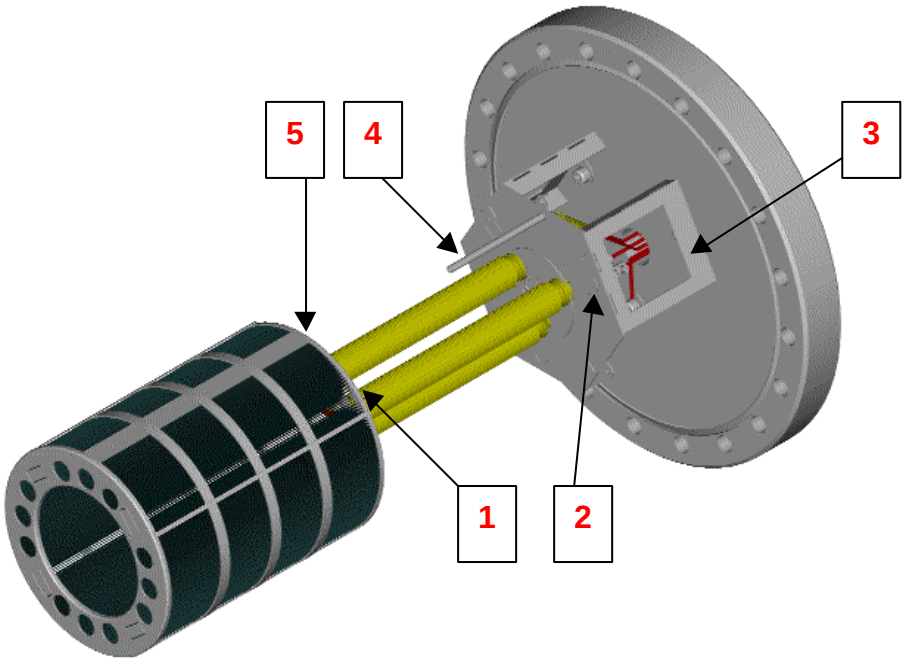


Fig.2



Open the cartridge pack and place the cartridge over the heater, taking care not to damage the heater assembly and ensuring that the tabs (1) provided in the base of the cartridge fit inside the slits (2) in the support (3), and the thermocouple (4) fits in the fins separator provided in the cartridge (5).
It is not necessary for the tabs to be bent completely (90 degree). This fixing method has been tested through several tens of heating cycles, carried out with different mounting orientations of the cartridges, to simulate activation processes and proved to be efficient and reliable.
Bend the tabs under the plane of the support, as shown in Fig. 3.

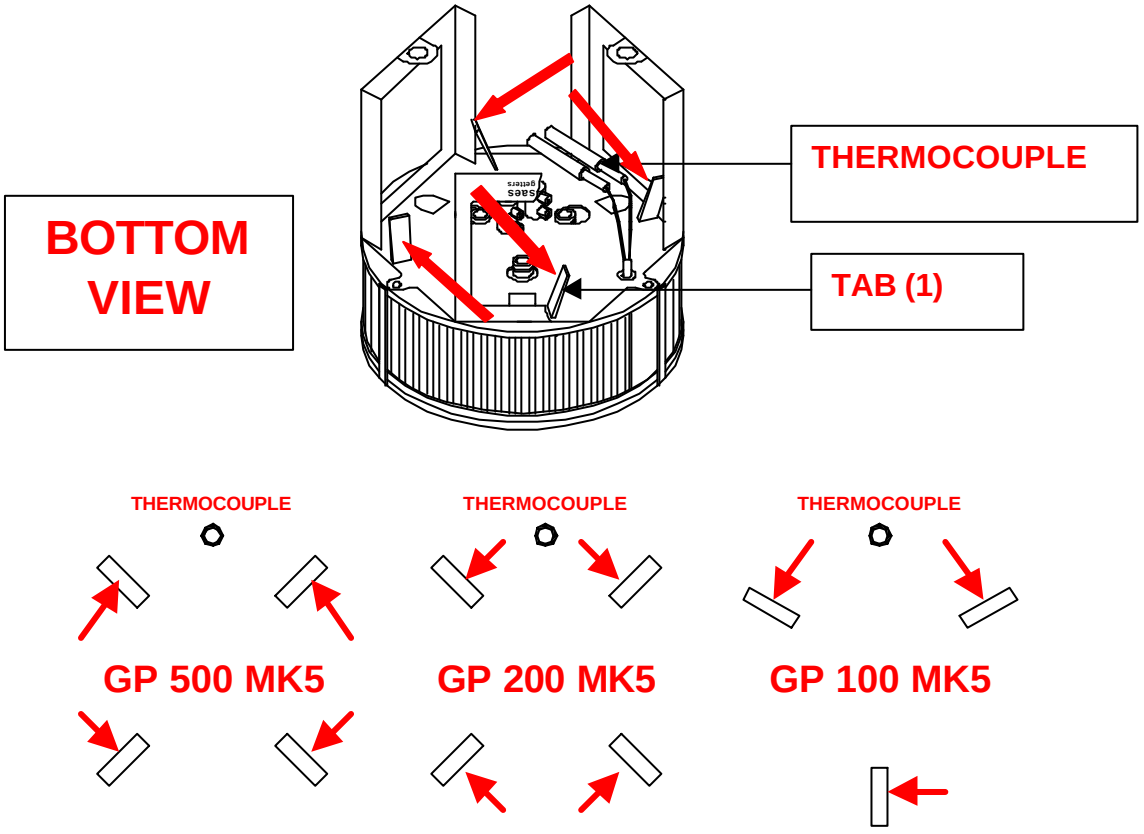


Fig. 3.

CAUTION : During this operation take care not to bend or damage the tube of the thermocouple

Check that the cartridge is properly seated.

Check, with an ohm-meter, at the electrical connector (see fig. 4) that the heater shows continuity and is insulated from the flange.

Nominal cold resistance:

- GP 500 MK5 2
- GP 200 MK5 4.1
- GP 100 MK5 3.7

Pump without Body. Connect the heater supporting flange to the vacuum system using the gasket supplied.

Pump with Body. Assemble the heater flange to the pump body, using one of the gasket supplied.
Connect the free flange of the pump body to the vacuum system using the other gasket supplied.

C) Water Cooling

For all pumps fitted with A Body with includes a water jacket, the minimum cooling water flow is 0.5 liter/min. The water should not be connected (after baking) until the pump body has cooled to below 100°C.

D) Powering

The pumps can be powered using the dedicated NEG Pump Controller V1.1. For details see the instruction manual that comes with the Controller.

In case the Controller is not available, other DC or AC power sources can be used. Details of the pump connector terminals are shown in Fig. 4.

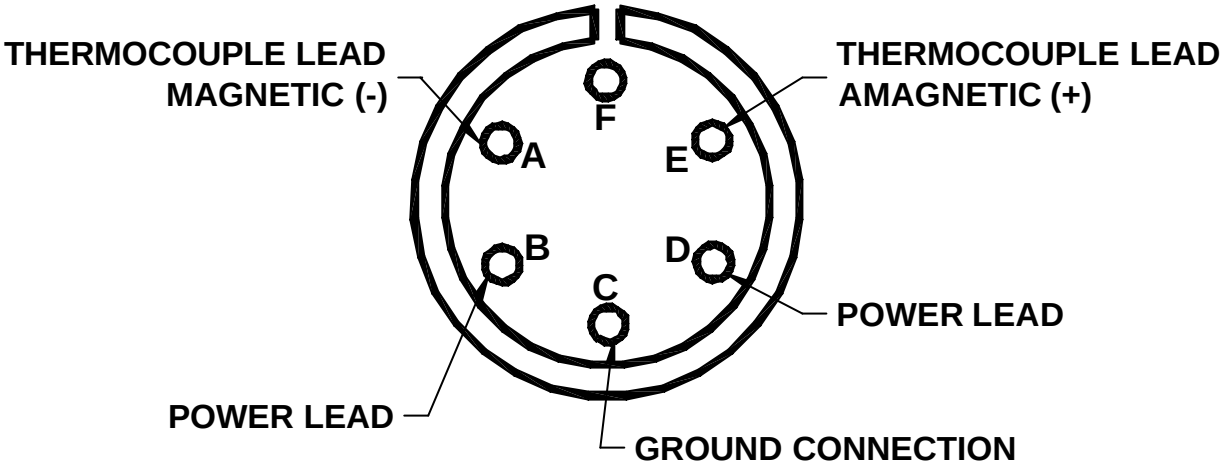


Fig.4

In case the temperature cannot be recorded it is possible to refer also to the heating curves in **Appendix A**.

ACTIVATION OF SORB-AC® Cartridge Pumps MK5 Type

The non-evaporable gettering material used in the getter cartridge develops its pumping characteristics after an **activation** process, i.e., after heating it to a suitably high temperature under dynamic vacuum for an appropriate time.

The heat treatment diffuses the thin protective layer, formed on the surface of the getter particles by air exposure during manufacture, into the bulk and makes the surface of the getter clean and able to sorb the gas molecules of the vacuum system in which it is operated.

The efficiency of this activation process is related to the diffusion coefficient of the getter material, which in turn depends on an exponential function of the temperature: $D=D_o\exp(-E/T)$. It is also related to the square root of time, as all the diffusion process.

In first approximation, the activation efficiency, considered to be related to the quantity of passive species removed from the surface of the getter particles, can be expressed by the following formula:

$$\textit{Activation efficiency} \propto \sqrt{Dt}$$

The suggested temperature/time combination for the best (100%) activation for the ST 707 based cartridge used in the SORB-AC® Cartridge Pumps MK5 Type pumps is :

450°C for 45 minutes

Fig. 5 gives other usable time/temperature combinations.

The curves show that in order to obtain the same final efficiency a shorter duration must be compensated by a higher temperature of the treatment and vice versa. Both these parameters are limited by practical and physical reasons to the range of values indicated in the figure.

However, in practical cases it is not always possible to use the "ideal" time/temperature combinations. Suitable operation modes can be programmed where only a "partial" activation is considered sufficient. This results in a condition where the getter surface develops less than full pumping speed. The condition which gives 60% of the optimum pumping speed is also shown in fig. 5.
The activation process should be carried out after a pump down of the vacuum system to a pressure of 10^{-4} Torr or less. After having reached this pressure, the heater can be energized to reach the desired temperature.

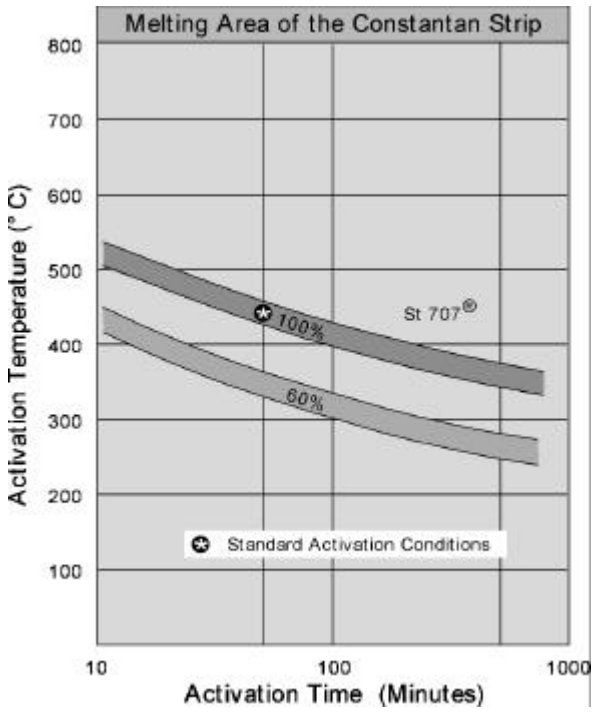


Fig.5

During the heating phase there is a desorption of gases from the getter cartridge. This is due to the physisorbed gases which form the external monolayers covering the surface of the getter material, while the internally chemisorbed layers are diffused into the bulk of the getter material.

Desorbed gases include H_2, H_2O, CO, CO_2, CH_4, and eventually H_2, due to the behavior of the getter material toward this gas.
In order to minimize this gas evolution, baking the system, with the getter cartridge maintained at a relatively higher temperature than the other components of the system, has been found to be effective. This procedure minimizes the migration of the gases desorbed from the wall of the system toward the getter cartridge which has a real surface area much larger than the system walls themselves.

During activation it is advisable not to exceed pressures in the 10^{-3} Torr range to avoid phenomena of corrosion of the heater wire, r.f. discharges between the heater and other pump elements and contamination of the gettering material due to the sorption of active gases during the activation process.

For this purpose and depending on the backing pump pumping speed, it may be advisable to activate the getter cartridge by successive steps, not applying the full power to the heater at the beginning of the activation process. In this case, reaching the activation temperature may take a few hours compared to 30 minutes usually needed if full power is applied at the beginning.

OPERATION OF SORB-AC® Cartridge Pumps MK5 Type

When activated, the SORB-AC® Cartridge Pumps MK5 Type can be operated at various temperatures according to the load of active gases, taking into account two main facts: First, the higher the temperature, the higher the diffusivity of the sorbed gases into the bulk of the getter material. Second, the higher the temperature, the higher the H_2 equilibrium pressure.

High temperature operation is preferred when high gas loads are present. In this way it is possible to maintain a high diffusion rate and consequently a constant pumping speed for all the active gases. Temperatures in the range of 280° C is typically suggested for St 707. High getter temperature is usually not compatible with UHV operation due to the desorption of hydrogen from the getter material. For example the use of an St 707 cartridge at 280°C will cause a hydrogen equilibrium pressure on the getter material in the range of 10^{-7}-10^{-8} Torr due to the residual H_2 content of the alloy and depending on the presence of additional pumping devices.

Room temperature operation is indicated when the gas load is low and, for the reason mentioned above, it is mandatory when the operating pressure is below 10^{-8} Torr. When pumping high purity hydrogen, operation at room temperature is also possible with high gas loads, due to the high diffusivity of H_2 at that temperature. In this latter case, a careful evaluation of the gas load and the quantity of gas sorbed is necessary to avoid possible embrittlement.

The pumping speed curves of the pumps are shown in Appendix B. The curves refer to the pump configuration with body, standard activation conditions.

REACTIVATION OF SORB-AC® Cartridge Pumps MK5 Type

The reactivation of the getter cartridge of a SORB-AC® Cartridge Pumps MK5 Type is necessary when the cartridge is exposed to air or when its pumping speed falls below acceptable limits. In both cases the surface of the getter material becomes covered by a passivation layer of mainly carbides and oxides.
If reactivation is preceded by an air exposure and a successive pump down cycle, it should follow the same procedure and has the same characteristics of the first one.
If the reactivation follows normal operation in vacuum without air venting, it may be shorter and carried out at a lower temperature (indicatively 20% lower). Moreover, during a reactivation which follows normal operation in vacuum the only gas released is hydrogen.

Through successive reactivations it is possible to use the entire capacity of the getter material.

When the pumping speed no longer recovers sufficiently after reactivation, the cartridge must be replaced.
One way to determine if the getter cartridge is exhausted is when the following quantities of gas have been sorbed:

$$q(CO) + q(CO_2) + q(O_2)/5 + q(H_2O)/5 + q(N_2) = 9 \; q=\text{liter Torr/g}$$

REGENERATION OF SORB-AC® Cartridge Pumps MK5 Type

Hydrogen and hydrogen isotopes sorbed by the cartridge can be released from the getter material through a regeneration treatment.

Regeneration is necessary when:

- the pumping speed for hydrogen or hydrogen isotopes has fallen below acceptable limits because the equilibrium pressure has been approached

- equilibrium is far from being reached but the hydrogen or hydrogen isotopes quantity pumped is approaching the "embrittlement limit" of 20 liter Torr/g.

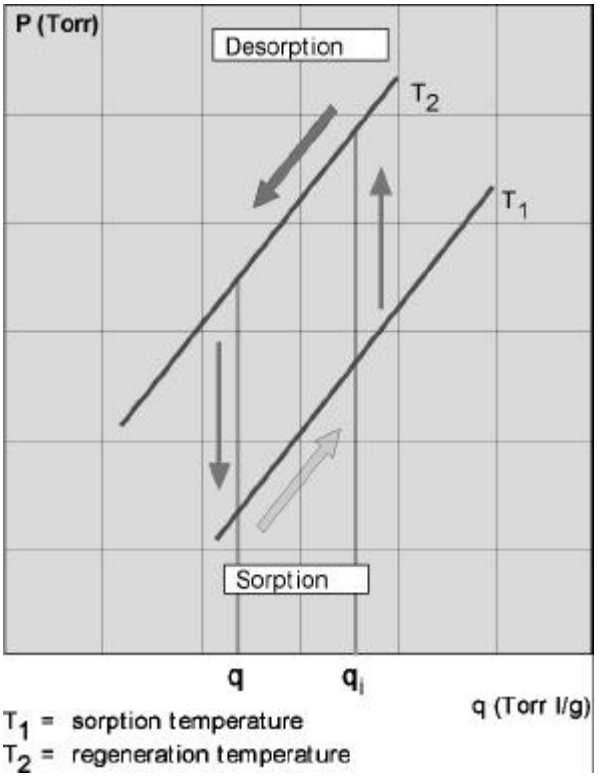


Fig. 6

Embrittlement of the material takes place when the quantity of hydrogen sorbed in the getter material is high enough to modify the mechanical characteristics of the alloy causing it to flake in small particles from the substrate.
The process of hydrogen sorption and successive desorption (regeneration), can be visualized on the Sieverts' plots of each specific alloy (see fig. 6).
The temperature increase of the getter alloy establishes a high hydrogen equilibrium pressure, allowing hydrogen removal by means of a standard backing pump. From the plot in fig. 6 one can see that the regeneration process will be more efficacious at higher temperature.

The time necessary for the regeneration of a cartridge is given by the expression:

$$t = \frac{M}{F}\left(\frac{1}{q_f} - \frac{1}{q_i}\right)10^{-\left(A - \frac{B}{T}\right)}$$

where:

t = regeneration time, in seconds
M = mass of getter material, in grams
F = pumping speed of the backing pumps, in liter/s
q_f= final H_2 concentration, in liter Torr/g
q_i= initial H_2 concentration, in liter Torr/g
A = 4.8 for St 707 alloy cartridges
B = 6116 for St 707 alloy cartridges
T = regeneration temperature, in K

Due to the exponential shape of the regeneration curve, a significant amount of time is saved when the regeneration is not programmed to be complete (100% of the sorbed hydrogen released again) but only partial (for example 90%).
Thus if a given amount of hydrogen must be sorbed in each cycle (for instance 10 Torrl/g), it is much better to operate in the q_f=2 - q_i=12 mode, than in the q_i=0 - q_f=10 one.

The Sieverts' law for ST 707 getter material is given by the expression :

$$\text{Log } P = 4.8 + 2 \text{ Log } Q - 6116 / T$$

where :

P = equilibrium pressure, in Torr
Q = sorbed quantity, in Torr liter/g
T = temperature, in °K

The equilibrium pressure of hydrogen for ST 707 getter material are shown in **APPENDIX C**

Air venting

Opening the vacuum chamber where SORB-AC® Cartridge Pumps MK5 Type are mounted should be performed only when the getter material is at room temperature or, at least, below 50°C.
After each air exposure, a new reactivation of the getter cartridge is required. A progressive reduction of pumping speed for hydrogen and active gases is observed after successive exposures to air.
After about 30 air exposures at room temperature followed by reactivation, St 707 cartridges at 280°C still have a pumping speed for hydrogen of about 40% of the original pumping speed.

If dry nitrogen is used instead of air, the pumping speed reduction, after the same number of exposures, appears to be smaller (residual pumping speed still about 80% of the initial value. This is because, for the first cycles, the active gas diffusion effect of the reactivation which follows a nitrogen exposure is greater than the new contamination caused by the exposure to nitrogen. Further improvement is obtained when pure argon is used as a protective gas during maintenance operations.

Vacuum failure during activation or regeneration

During activation or regeneration of SORB-AC® Cartridge Pumps MK5 Type, air must not be allowed to suddenly enter the vacuum system. Such an occurrence could cause "burning" (i.e. a quick oxidation) of the coated strip. This happens if the temperature of the cartridge at the moment of vacuum failure is above 200°C.

The burning is slow and progressive, not explosive. Should a serious vacuum failure take place when the temperature of the cartridge is high, although below the above indicated values, permanent damage of varying degrees will occur, according to temperature, but not burning. In this case, pumping characteristics of the getter material would be affected to a greater or lesser extent depending on temperature and time.

Excessive heating of the cartridge

The cartridges used in the SORB-AC® Cartridge Pumps MK5 Type uses constantan as a substrate material, and they should not be heated to temperature over 750°C to avoid possible copper or manganese evaporation from the material. At temperatures over 850°C, it is possible to have the formation of eutectic compounds between copper and zirconium which could cause melting of the cartridge.

Mechanical shocks

Due to the mechanical characteristics of the insulating elements of the heater (ceramic spacers) particular care must be observed in handling during assembly (and removal) of the pumping system. Accidental dropping and similar mechanical shock could result in breakage of the insulating elements with possible short circuits of the electrical path.

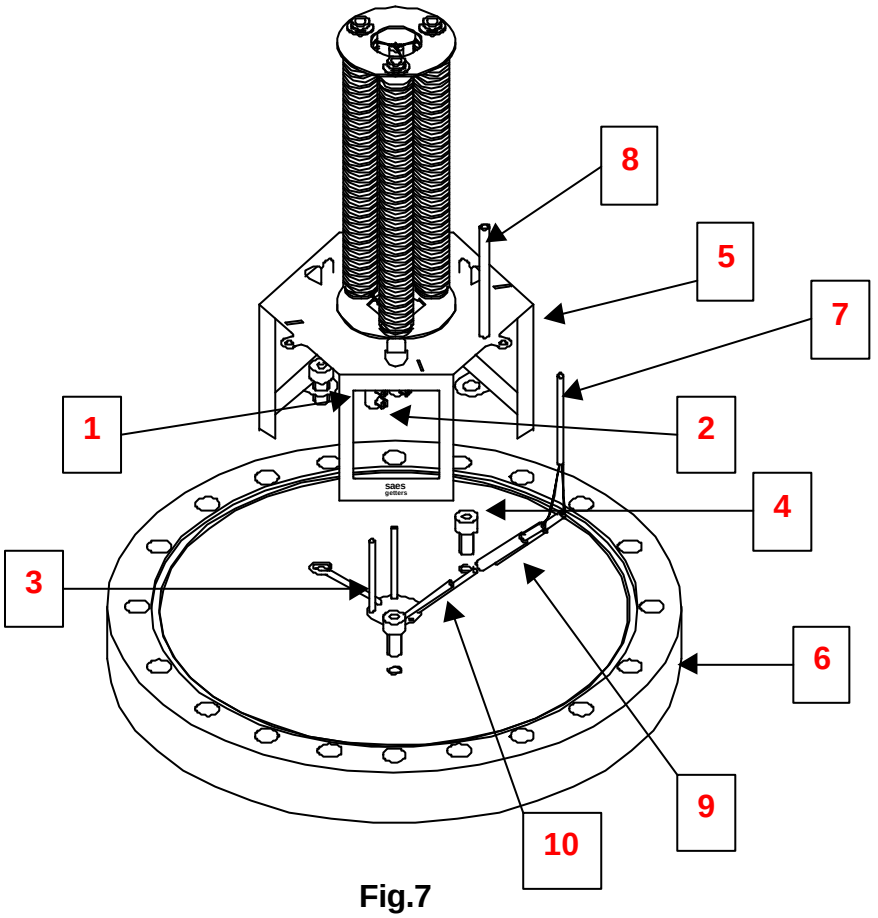


Fig.7

MAINTENANCE OPERATION

Thermocouple replacement

When the thermocouple needs to be replaced, proceed according to the following instructions and refer to Fig. 7.

Loosen the screws (2) of the two terminals (1) connecting the heater filament with the connector current conductors (3). Unscrew and remove the 3 socket head screws (4) which fix the base (5) to the bottom of the flange (6). Lift and separate the base (5) from the flange (6)allowing the thermocouple (7) slide out the tube (8). Remove the two thermocouple plugs (9) from the connector thermocouple conductors (10). Insert the two plugs (9) of the new thermocouple in the conductors (10) paying attention to the right polarity.

NOTE: use a magnet to check the polarity; the magnetic plug goes in the magnetic conductors.

Place the base (5) back on the flange (6), insert the new thermocouple inside the tube (8) while doing it. Place the 3 socket head screws (4) back on the base (5) and fix the base (5) to the bottom of the flange (6). Connect the heater filament with the connector current conductors (3) tightening the screws (2) of the two terminals (1).

Heater replacement

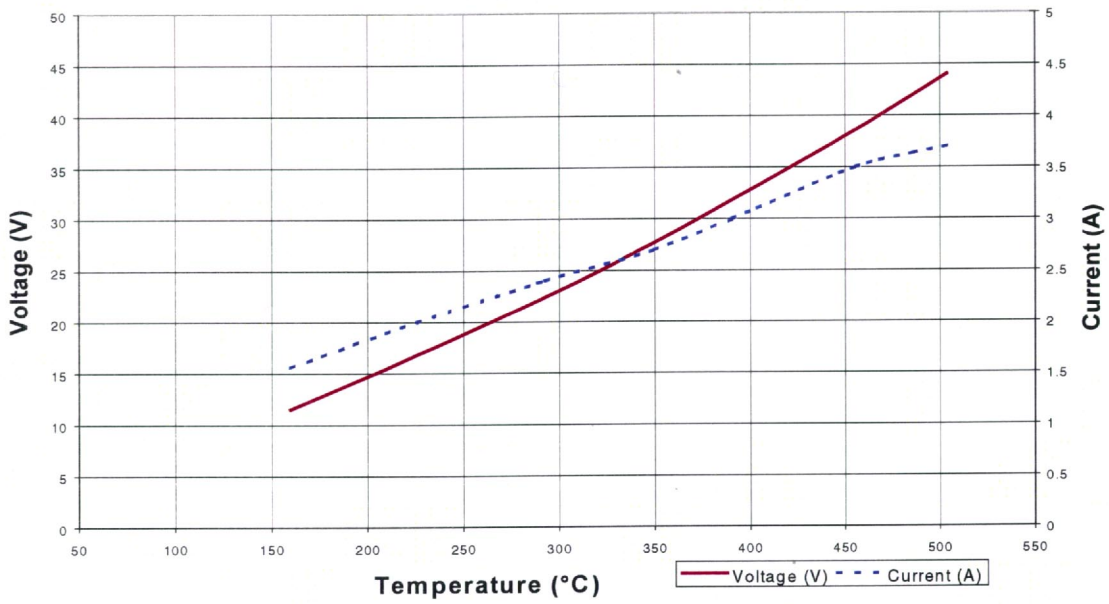
When the heater needs to be replaced, proceed according to the following instructions and refer to Fig. 7.

Loosen the screws (2) of the two terminals (1) connecting the heater filament with the connector current conductors (3). Unscrew and remove the 3 socket head screws (4) which fix the base (5) to the bottom of the flange (6). Lift and separate the base (5) from the flange (6)allowing the thermocouple (7) slide out the tube (8). Place the base of the new heater (5) back on the flange (6), insert the thermocouple inside the tube (8) while doing it. Place the 3 socket head screws (4) back on the base (5) and fix the base (5) to the bottom of the flange (6). Connect the heater filament with the connector current conductors (3) tightening the screws (2) of the two terminals (1).

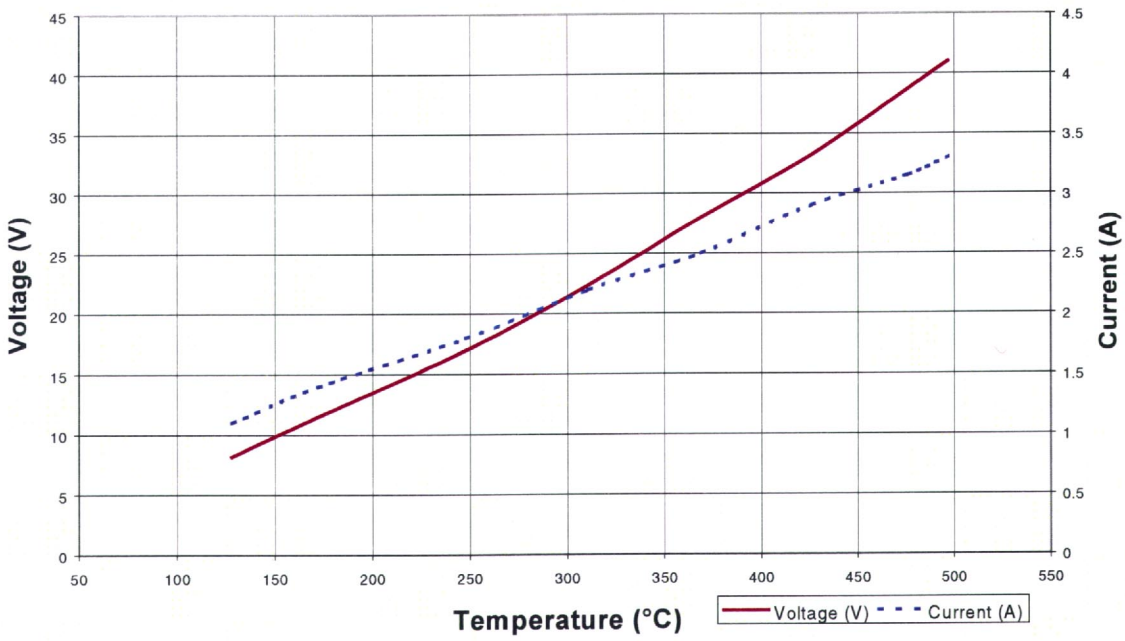
APPENDIX A/1

GP 100 MK5
Heating curve

NUDE PUMP



PUMP BODY

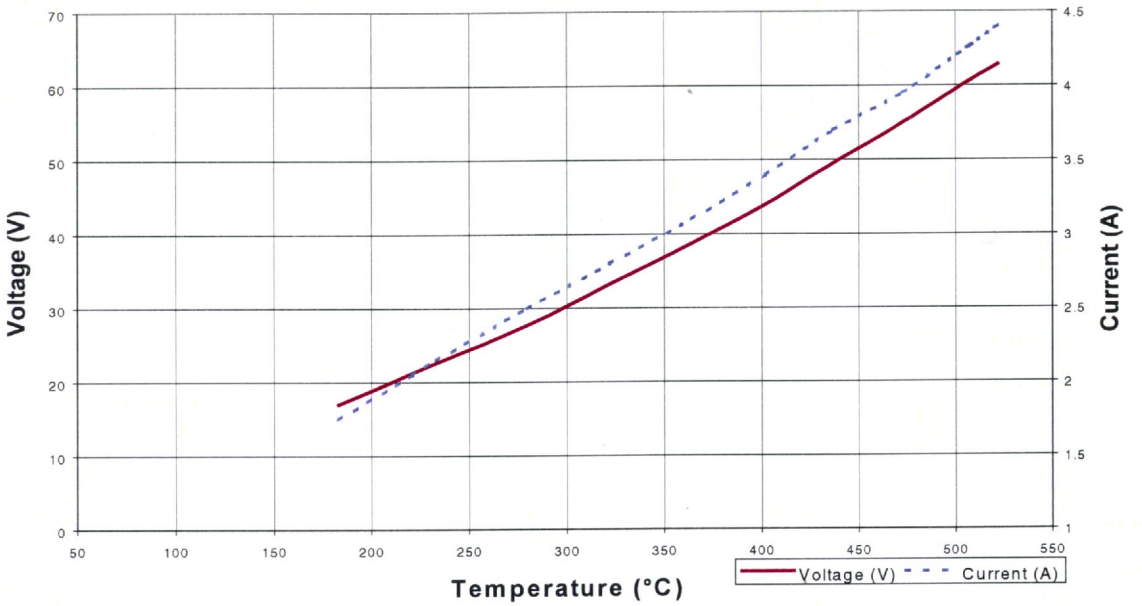


APPENDIX A/2

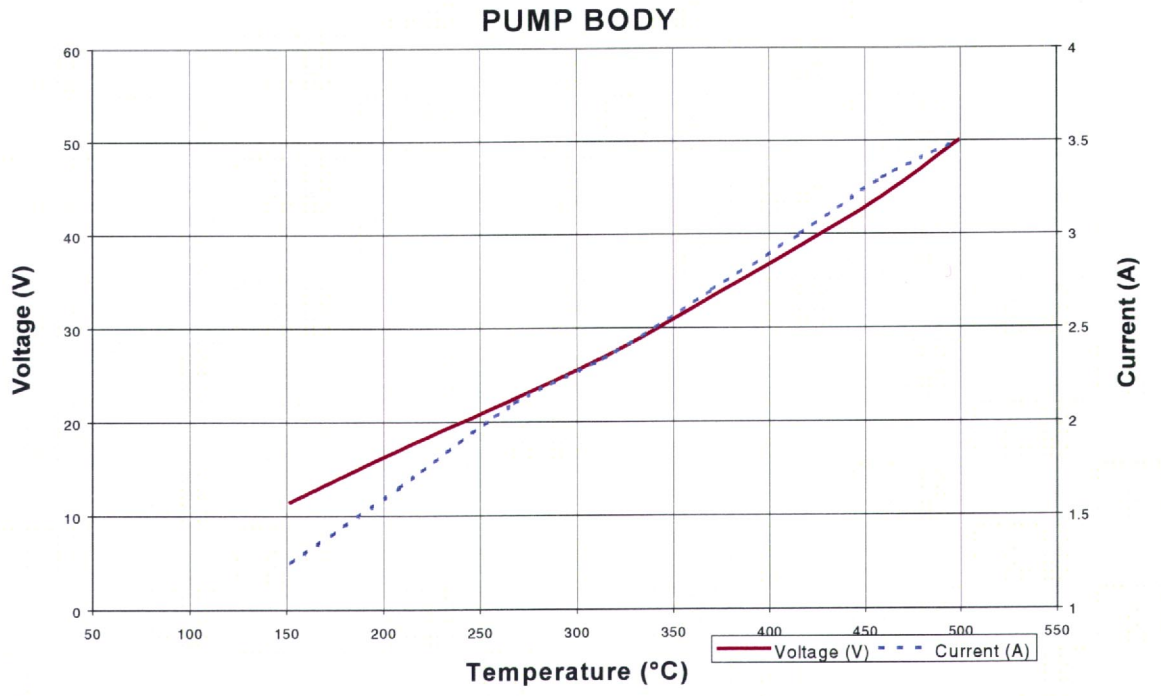
GP 200 MK5

Heating curve

NUDE PUMP



PUMP BODY

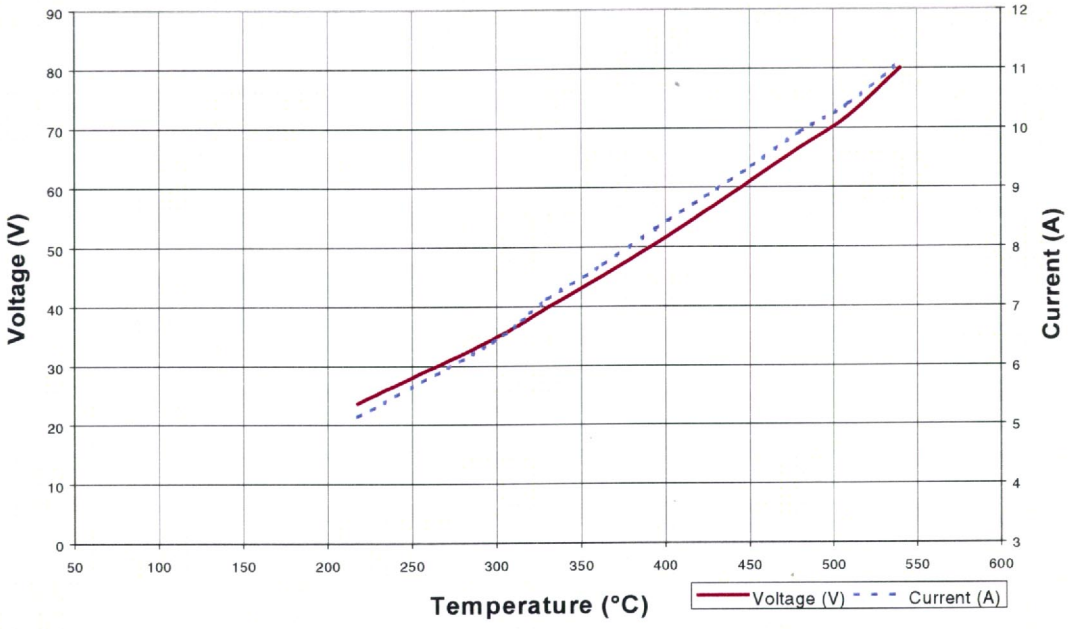


APPENDIX A/3

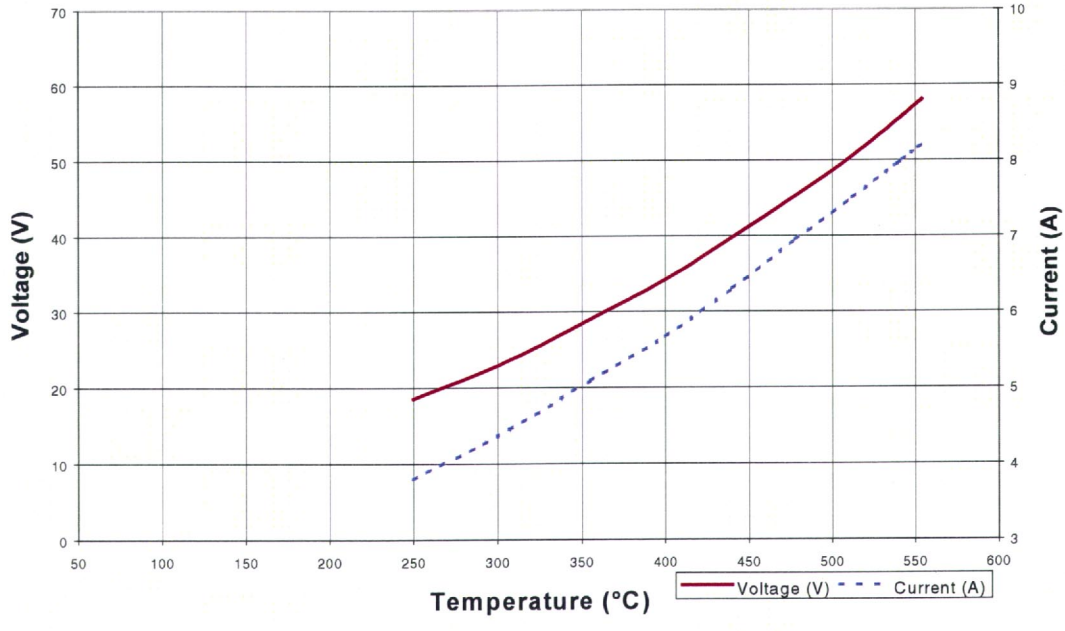
GP 500 MK5

Heating curve

NUDE PUMP



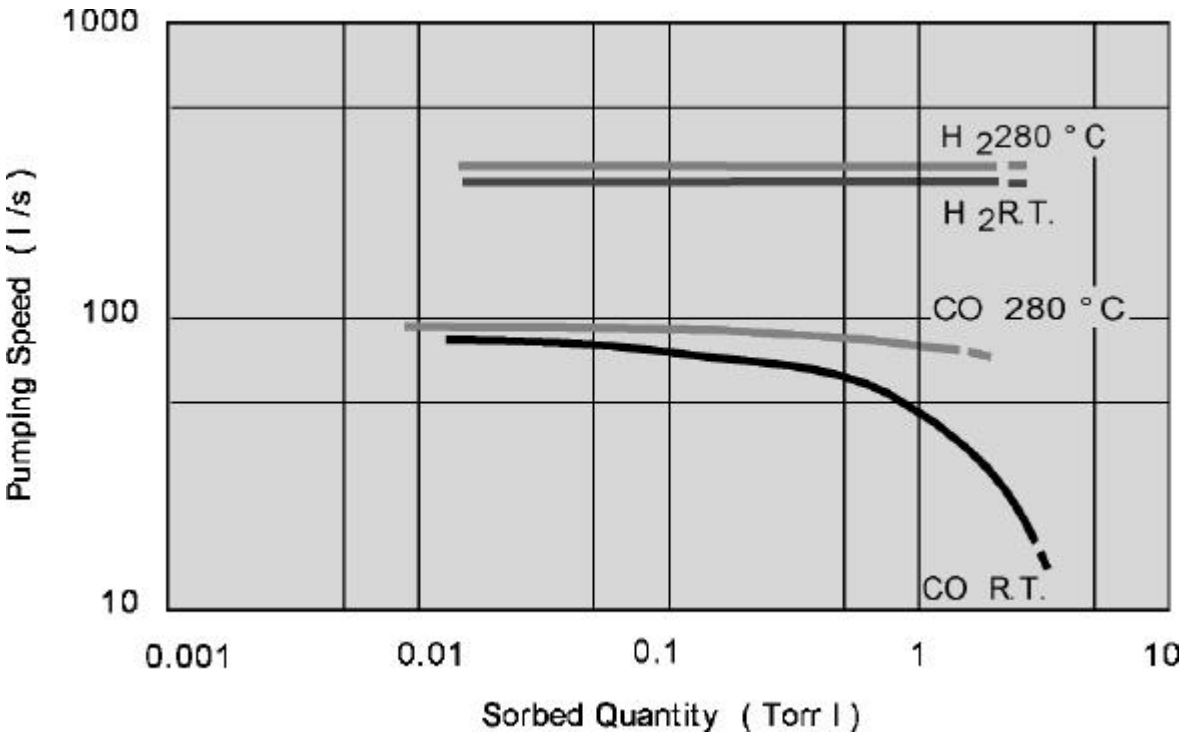
PUMP BODY



APPENDIX B/1

Typical Sorption Curve
ST 707 Cartridge

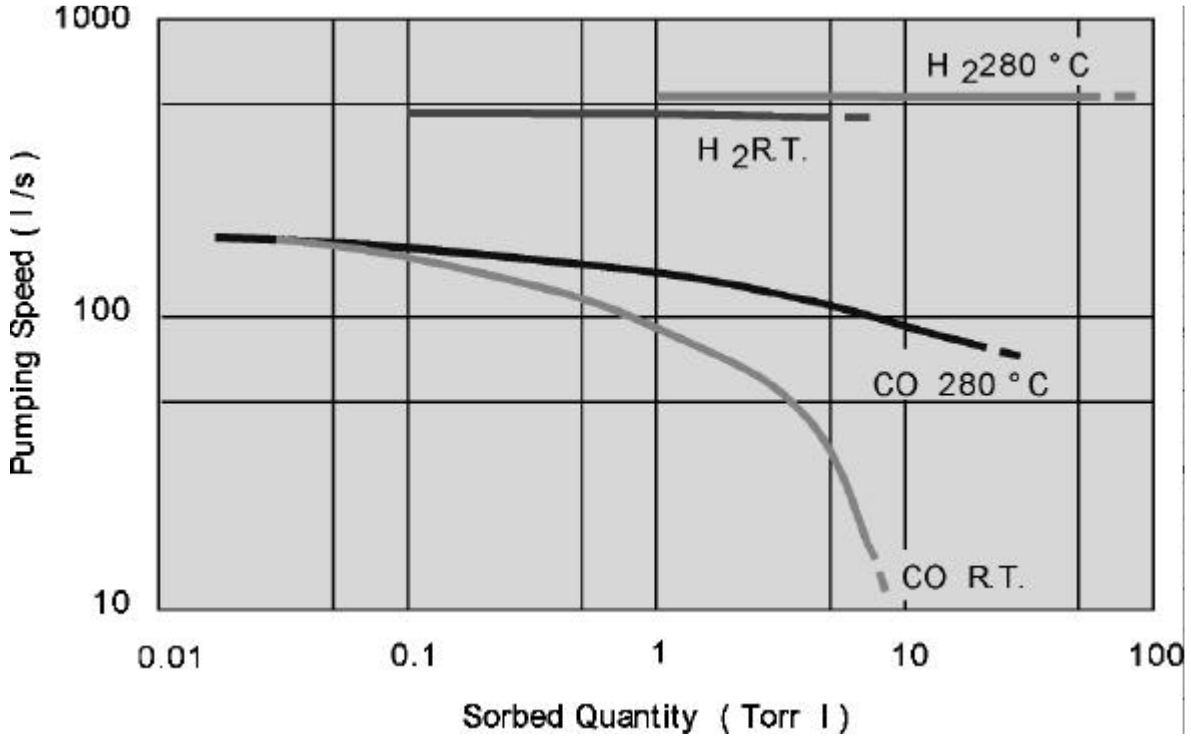
GP 100 MK5 PUMP BODY



APPENDIX B/2

Typical Sorption Curve
ST 707 Cartridge

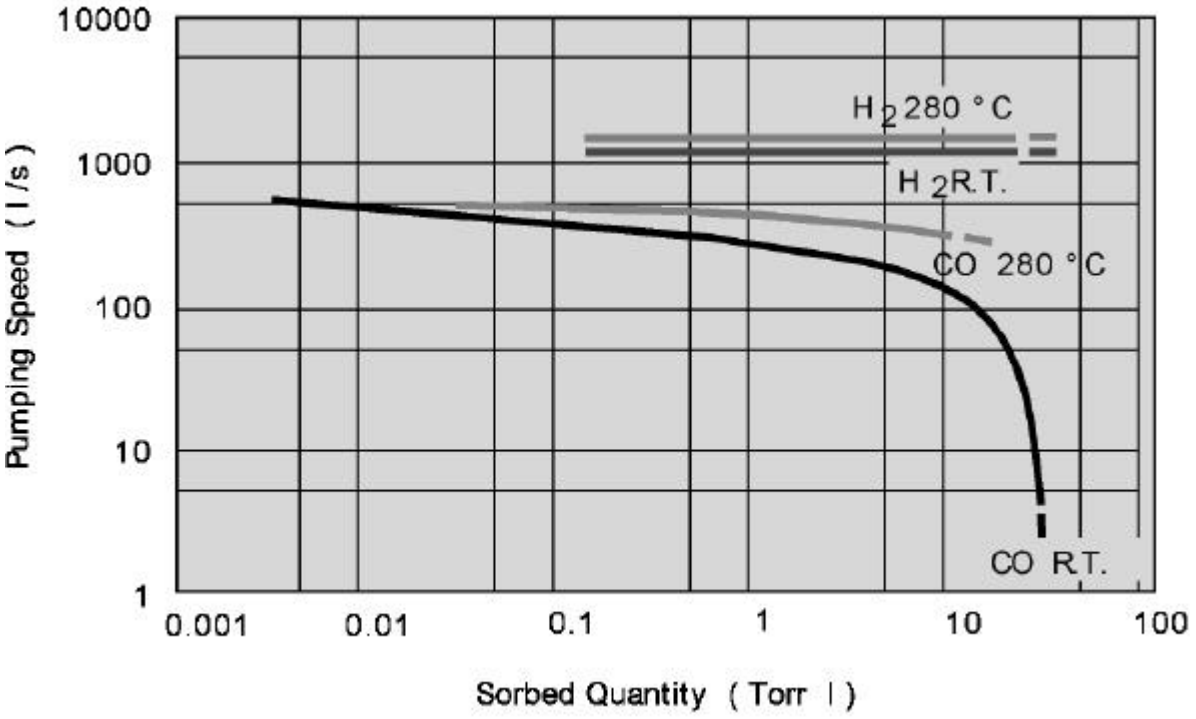
GP 200 MK5 PUMP BODY



APPENDIX B/3

Typical Sorption Curve
ST 707 Cartridge

GP 500 MK5 PUMP BODY



APPENDIX C

Equilibrium pressure of Hydrogen for 707 getter material

