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G. Rommel

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A cryogenic pump of 20,000 l s⁻¹

G Rommel, GANIL, Caen, France

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This pump belongs to the vacuum system of GANIL. GANIL is a particle accelerator in construction in Caen¹, consisting principally of two separated sector cyclotrons. To pump a total surface of about 1000 m² it has been decided to install a cryogenic pump of 20,000 l s.

This system must be able to maintain a pressure of 2.10⁻⁶ Pa (2.10⁻⁸ torr) in the vacuum chamber of the SSC over a period of at least one month without regeneration by warm-up.

1. Brief description of the pump

The pump itself consists of (see Figure 1): the body of the pump, nominal diameter 800 mm; three cryogenerators from the firm CTi, model 1020; an internal structure consisting of three identical parts, each individually connected to the corresponding cryogenerator. Each of these parts is subdivided into two stages: (i) one stage (generally called the 20 K stage) consists of a circular copper plate, supporting a series of small cavities containing activated charcoal; this stage, but not the charcoal, can be seen directly via the pumping port, (ii) another stage (generally called the 80 K stage) consists of a polygonal copper structure.

A thermally insulated screen surrounds the 80 K stage.

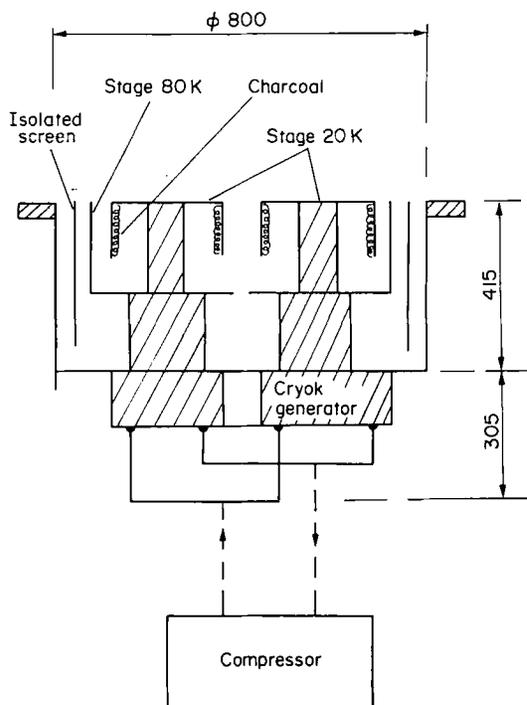


Figure 1. Scheme of the cryogenic pump (dimensions in mm).

The pump is connected to a compressor which feeds helium gas to the three cryogenerators in parallel.

Water vapour condenses on both stages, nitrogen on the 20 K panel, and hydrogen is cryosorbed by the activated charcoal which consists of grains 2-3 mm in diameter in a single layer. The grains of charcoal are stuck by araldite on a surface of 3000 to 3500 cm². The charcoal 'sees' only the 20 K panel. Figure 2 is a photographic view of the pump as seen via the pumping port.

2. Particular characteristics

This pump has the 20 K stage, the stage at the lowest temperature, in direct view of the vacuum vessel. This disposition, already successfully adopted in 1979², gives the theoretical maximum pumping speed to all gases except hydrogen. In fact this pump has a pumping speed of 20,000 l s⁻¹ for nitrogen in a circle of diameter of 560 mm.

To obtain this, one must have an adequate cooling power on the 20 K stage to obtain a temperature lower than 20 K. Typically the temperature is lower or equal to 18 K, and that of 80 K stage near



Figure 2. View of the pump via the pumping port. The three stages at 20 K can be seen.

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55 K. This is achieved by three cryogenerators type 1020 from CTi giving a sufficient cooling power without the use of liquid nitrogen.

3. Limit pressure

A stainless steel chamber of small volume (diameter 800 mm, height 300 mm) was used. After roughing by a mechanical pump with a nitrogen liquid trap, a pressure of 5.10^{-8} Pa (4.10^{-10} torr), see Figure 3, was obtained in 50 h without bakeout.

In other experiments of 10 days, the ultimate pressure was of 2.10^{-8} Pa (2.10^{-10} torr) without baking.

4. Pumping speed for nitrogen

These measurements have necessitated a large normalized test dome³, diameter 800 mm, height 2400 mm (see Figure 4). The measurements were made by two methods, calibrated conductance and external flux-meter.

The inferior part of test dome was blackened with a special paint to obtain an emissivity coefficient about 1.

At each value of pressure, the measurement lasted 30 min. The results are shown in Figure 5. The maximum pumping speed is very close to the pumping speed of $27,000 \text{ l s}^{-1}$ calculated on the assumption that all the molecules entering the polygonal 80 K panel are pumped.

5. Pumping of hydrogen

This pump must run without regeneration 1 month at pressure about 2.10^{-6} Pa . At this pressure the quantity of adsorbed hydrogen is small. Therefore about 300 g of charcoal on a surface of $3000\text{--}3500 \text{ cm}^2$ is used.

5.1. Pumping speed. The measurement of pumping speed for hydrogen was made with the same test dome. We use almost pure hydrogen (purity $> 99.9995\%$), because in industrial hydrogen the quantity of helium present is too high. The stabilization time was

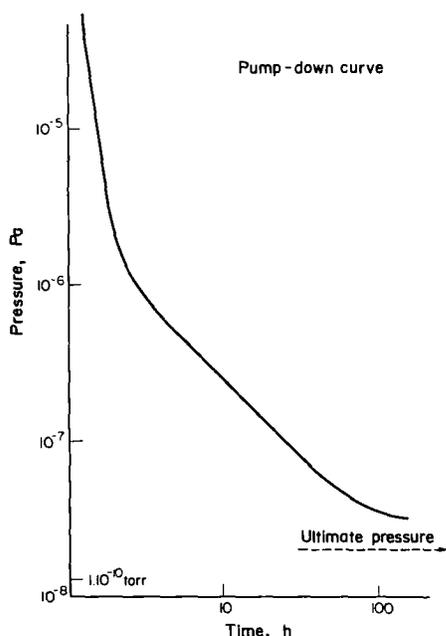


Figure 3. Pump-down curve inside a small dome.

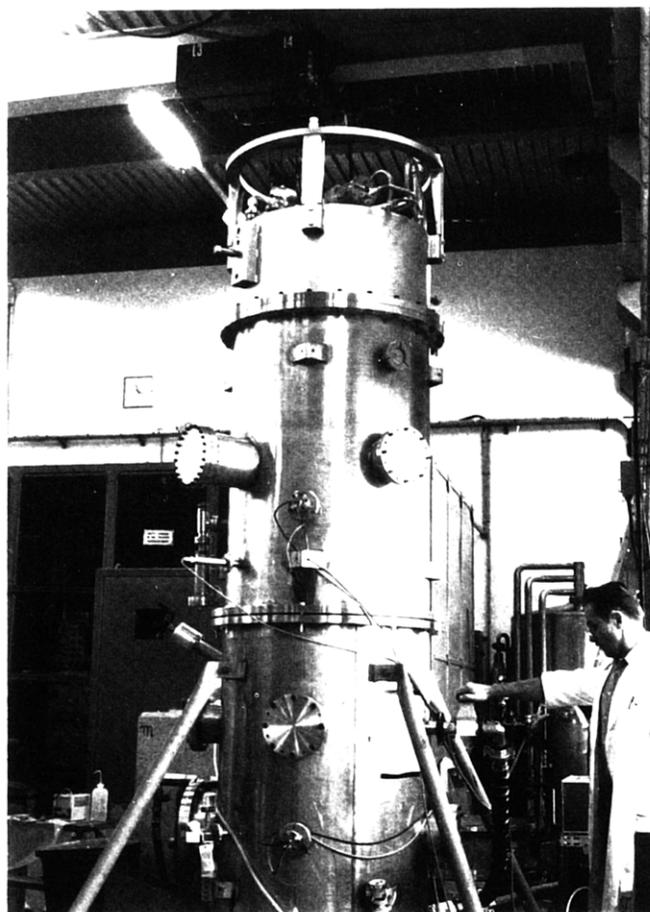


Figure 4. Test dome for pumping speed measurement. The pump is on the top.

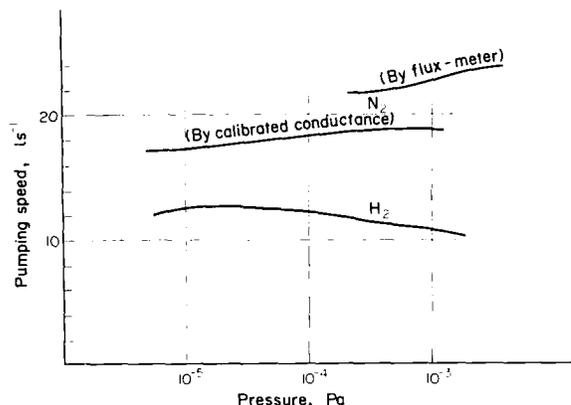


Figure 5. Curves of N_2 and H_2 pumping speed.

50 min for all points below 10^{-5} Pa , 20 min for those between 10^{-5} and 10^{-4} Pa , and 15 min above 10^{-4} Pa . The measured pumping speed varied between $12,000\text{--}10,000 \text{ l s}^{-1}$ for a theoretically estimated pumping speed between $6000\text{--}12,000 \text{ l s}^{-1}$. This seems to indicate that all the H_2 molecules falling on the activated charcoal were crysorbed.

5.2. Saturation of the superficial layer of charcoal. After these measurements of H_2 pumping speed we have observed a phenomenon of superficial saturation. Figure 6 describes the phenomenon. After 8 h of measurement, the system did not

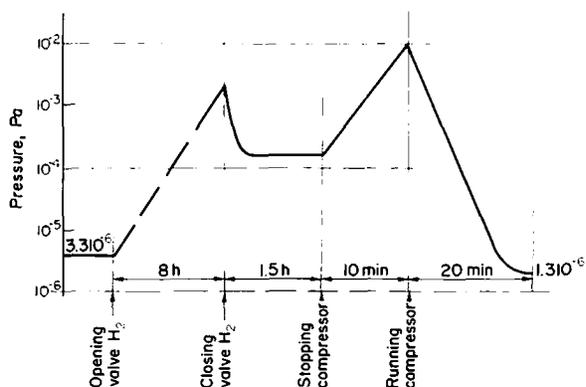


Figure 6. Variation of pressure during and after the measurement of H₂ pumping speed.

recover the initial pressure on closing the valve. The compressor was stopped for 10 min during which time the pressure increased. On re-starting the compressor a pressure of 1.6.10⁻⁶ Pa was obtained after 20 min without additional pumping.

Since a lower pressure was obtained with the same quantity of the H₂ present we think that this is due to a rearrangement of the H₂ molecules inside the activated charcoal.

5.3. Variation of pumping speed for H₂. The cryosorption capacity of charcoal for H₂ is limited. The adsorption isotherm gives the relation between the adsorbed quantity and the equilibrium pressure at a given temperature. Pure H₂ was introduced at constant pressure and the variation of pumping speed was followed during many hours (see Figure 7).

One may note that, at 1.6.10⁻² Pa H₂, the speed falls rapidly. After 1 h the pumping speed has decreased from 10,600 l s⁻¹ to 7100 l s⁻¹ and after 3.5 h has reached 4900 l s⁻¹. By contrast at 1.6.10⁻⁴ Pa H₂ the pumping speed decreases slowly and remains constant at 8200 l s⁻¹ during many hours.

One can compare the pumped quantity of H₂ with that given by adsorption isotherm (curve from 'L'AIR LIQUIDE').

Injection Pressure	1.65.10 ⁻² Pa (1.25.10 ⁻⁴ torr)	1.65.10 ⁻⁴ Pa (1.25.10 ⁻⁶ torr)
Pumped quantity (torr litre)	9.5.10 ³	0.3.10 ³
Quantity given by isotherm (torr litre)	3.3.10 ⁴	2.10 ⁴

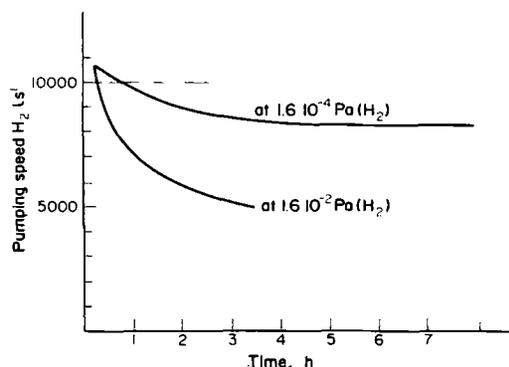


Figure 7. Variation of pumping speed of H₂ at two values of constant pressure.

The difference between the calculated saturation and injected quantity is greater at the lowest injection pressure of 1.65.10⁻⁴ Pa. It is consequently normal that the pumping speed remained more constant at this lower pressure.

6. Influence of ambient temperature

Typically the ambient temperature is between 19–23°C. So we have heated the blackened dome to a temperature of 29°C and measured the effect on the pumping speed of N₂.

At 29°C, the temperature of the 20 K stage is 20, 21 and 23 K respectively on each of the three cryogenerator panels. The pumping speed was measured as 18,200 l s⁻¹ at 6.6.10⁻⁴ Pa N₂.

We conclude that this pump can operate without modification in the ambient-temperature range of 25°C, for example during the summer.

Conclusion

In conclusion the tests have proved the suitability of this pump. At this moment we are mounting these pumps on the first separated sector cyclotron of GANIL.

Acknowledgement

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- ² G Flesch, C Henriot and G Rommel, Performances d'une pompe cryogénique à 20 K, *Le Vide*, **179**, September (1975).
- ³ Frenche norme AFNOR NF X 10-507 et NF X 10-519 and ISO norme 3556.