FORTY HUNDRED METERS OF FLEXIBLE CRYOGENIC HELIUM TRANSFER LINES

by

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FOUR HUNDRED METERS OF FLEXIBLE CRYOGENIC HELIUM TRANSFER LINES

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CERN is constructing in its Intersecting Storage Rings a superconducting high luminosity insertion, the main elements of which are eight superconducting quadrupole magnets, housed in liquid helium bath cryostats. Eight 50 m long cryogenic transfer lines will distribute liquid or gaseous helium from a cryogenic plant to the cryomagnets. Essential requirements are low heat inleaks as compared to those of the cryomagnets. Screened coaxial flexible lines have been manufactured by industry. Their design, construction, quality control and conditioning procedures are described, as well as the performance characteristics measured during reception tests.

INTRODUCTION

In late summer 1980, CERN will install a superconducting high luminosity insertion in its Intersecting Storage Rings (ISR).

The insertion consists essentially of eight high-gradient superconducting quadrupoles [1] housed in liquid helium bath cryostats [2]. Refrigeration power is provided by a helium liquefaction plant, located at a distance of 50 m from the insertion. This refrigeration power must be distributed from the plant to the cryomagnets by an efficient transfer system (Fig. 1).

Following the successful development of long flexible cryogenic transfer lines [3], CERN admitted rigid and flexible lines in the specification for the required transfer system.

After competitive tendering, Kabelmetal was entrusted with the execution of the contract for the supply and installation of eight 50 m long flexible transfer lines.

SPECIFICATIONS

The technical specification contains the following main requirements:

- The supply pipe must be continuously screened by the return pipe.

- The supply pipe must be sized for both the transfer of 5 g s⁻¹ gaseous helium at 350 K, with a maximum inlet pressure of 7 bar and a maximum pressure drop of 5 bar, and the transfer of 100 l h⁻¹ of liquid helium with an inlet pressure of 1.23 bar, an inlet vapour quality of 0.05 and a maximum dynamic pressure drop of 30 mbar.

- The return channel must be sized for the transfer of 5 g s⁻¹ of gaseous helium at 300 K, with an inlet pressure of 1.6 bar and a maximum pressure drop of 0.3 bar.
- The space between supply pipe and screen as well as that between screen and vacuum enclosure must be evacuated. The screen must be wrapped with reflecting multilayer insulation. The insulation space must remain below $10^{-3}$ mbar, without pumping and at room temperature for a period of three months.

- The heat inleak to the liquid supply pipe must be less than 6 W.

- The heat inleak to the screen must be less than 150 W.

- Each completed line must be pressure tested with 30 bar in the supply pipe and with 9 bar in the screen and in the vacuum spaces.

- The lines must be thermally shocked to 80 K and helium leak-tested at this temperature with pressures of 20 bar (supply) or 6 bar (screen). No leaks must be detected at a sensitivity of $10^{-10}$ mbar l s$^{-1}$.

**DESIGN, MANUFACTURE, MANUFACTURING TESTS AND VACUUM CONDITIONING**

In principle, design and manufacturing procedures correspond to those of the prototype line described in [3] and [4].

The sizes of the pipes are determined by the requirements for gaseous helium transfer and are listed in the table below.

<table>
<thead>
<tr>
<th>Tube No.</th>
<th>Inner diameter (mm)</th>
<th>Outer diameter (mm)</th>
<th>Wall thickness (mm)</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>17.5</td>
<td>0.3</td>
<td>AISI 316L</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>34</td>
<td>0.3</td>
<td>AISI 316L</td>
</tr>
<tr>
<td>3</td>
<td>51</td>
<td>58</td>
<td>0.5</td>
<td>AISI 316L</td>
</tr>
<tr>
<td>4</td>
<td>82</td>
<td>92</td>
<td>0.6</td>
<td>AISI 304</td>
</tr>
<tr>
<td>sheath</td>
<td>92</td>
<td>98</td>
<td>3</td>
<td>polyethylene</td>
</tr>
</tbody>
</table>

All manufacturing, pressure and leak tests have been performed according to [3] and to the technical specification. During the final leak tests, one single leak on the longitudinal weld of the third pipe was detected. This leak was easily located and repaired.

With respect to the line described in [3], some additional procedures were introduced in order to comply fully with the requirements for a good long-term insulation vacuum.

Firstly, the screen pipe was surrounded with a nearly continuous layer of activated charcoal adsorbant. Secondly, just before the fabrication of the fourth pipe, the entire line including adsorbant and superinsulation was baked-out at 800°C and $10^{-1}$ mbar for two days. Thirdly, the completed lines underwent another bake-out at 800°C with continuous pumping of the vacuum spaces for one week.

During one month, the pressure in the vacuum spaces rises by approximately $10^{-3}$ mbar. The corresponding outgassing rate is of the order of $10^{-7}$ mbar l s$^{-1}$ coming from 300 m² of superinsulation, 30 m² of stainless steel and 3 m² of polyethylene. The reduction of the outgassing rate with respect to the line of [3] is about 1000-fold.
For the transport of the lines from the factory to CERN, the vacuum was broken to atmospheric pressure with dry nitrogen. Repumping to $10^{-3}$ mbar took one day.

HYDRODYNAMIC AND THERMAL PERFORMANCES OF THE LINES

The hydrodynamic behaviour of one line was checked by passing gaseous helium at 1 bar and room temperature through the supply pipe and the screen. The results are shown in Figs. 3 and 4. They confirm the design calculations based on friction factors of 0.08 for the circular supply pipe and 0.10 for the annular screen channel [5].

Measurements of heat inleaks as a function of varying screen cooling conditions were performed on one line. The results are given in Figs. 5 to 7. The heat inleak to the liquid helium pipe in self-screening conditions is 4 W; this corresponds to a flow of 69 l min$^{-1}$ (NTP) of cold vapour through the screen. Under these conditions, the screen outlet temperature is 140 K and the heat inleak to the screen is 150 W.

During all tests the line was wound on its transport drum (Fig. 2). Remembering the difference between wound and unwound lines described in [3], a reduction of heat inleaks to both channels for the installed lines can be expected. Unlike the line of [3], no oscillations of the fluid column could be observed.

The lines have thermal time constants of several hours, which may explain part of the scatter in Figs. 5 to 7.

The thermal performance of the remaining seven lines was just checked at a vapour flow rate in the screen of 100 l min$^{-1}$ (NTP). Under this condition, the heat inleak into the liquid helium in the supply pipe, including both end pieces, of all transfer lines has been reproducibly measured to be $2.5 \pm 0.5$ W.

CONCLUSION

Eight 50 m long flexible cryogenic transfer lines have been manufactured according to specification and schedule. They all show excellent and reproducible transfer behaviour for gaseous and liquid helium. The lines will be incorporated in an operating machine for high energy physics, the CERN Intersecting Storage Rings. It is planned to install one 50 m line per day during September 1980.

REFERENCES

1 Billan, J. et al. 'The eight superconducting quadrupoles for the ISR high-luminosity insertion'. To be presented at the X1th Int. Conf. on High Energy Accelerators, CERN (July 1980).
2 Laeger, H., Lebrun, Ph. and Rohmig, P. 'Eight liquid helium cryostats for the superconducting magnets of the ISR low-beta insertion'. Presented at this Conference.
Fig. 2 Set-up for performance measurements

Fig. 3 Hydraulic resistance of supply pipe (helium at 1 bar, 290 K)

Fig. 4 Hydraulic resistance of return channel (helium at 1 bar, 300 K)
Fig. 5

Fig. 6

Fig. 7

Measured thermal performance