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Flexible Corrugated Cryotransferlines, Long Term Experience at JET and the Experience with Supercritical Helium Flow Conditions

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ABSTRACT

Long flexible corrugated cryotransferlines are widely used at JET for the supply of liquid nitrogen and liquid and supercritical helium. Their low thermal losses allow to use a central distribution system with individual lines to each user with line lengths of up to 90 m. The easy installation of the fully tested cryolines, their flexibility, high pressure stability and compatibilty with the remote handling requirements of JET were important design specifications. Some of the cryolines have been in operation for over 15 years and the paper reports about their excellent reliability records and the main performance data.

INTRODUCTION

For the cryosupply of JET - the world's most advanced thermonuclear fusion experiment - the concept of a central distribution system with individual cryolines to a network of load assemblies taking liquid nitrogen and liquid/supercritical helium has been adopted. This concept was chosen in order to keep all control systems (in particular valves and instrumentation) in easily accessible areas, because the loads themselves cannot be accessed in the D-T phase of the project due to the expected radiation level in the vicinity of equipment inside the torus hall. This concept required, however, long transferlines and thus the development of the JET low loss cryolines.

The use of low loss long flexible JET cryolines for liquid helium has been first reported at the ICEC12 [1]. These line were a further development of flexible lines used for CERN [2] implementing as a new element a liquid nitrogen radiation shield as an integral part of the cryoline. JET has subsequently commissioned over 30 long (>50m) flexible corrugated cryolines which represent a total length exceeding 2 km. Individual lengths of the cryoline are up to 90 m. Some of the cryolines have been in use for over 15 years and JET gained considerable experience with these lines during this period. JET installed new flexible corrugated cryolines for the 1993-94 experimental campaign for the supply of supercritical helium (in contrast to the two phase liquid helium which is supplied to all other users).

CRYOLINE SPECIFICATION

Boundary conditions

The operation of the cryogenic loads which are mainly large scale cryopumps at various places at the experiment (for details see [3]) are located in a potential radiation area with high inducted eddy currents. This requires that the cryolines:

- have low thermal losses
- have high pressure stability and small thermal mass for fast cooldown

- are radiation resistant and compatible with remote handling i.e. connection, disconnection and line exchange must be easily performed by a remote handling manipulator
- have an electrical break to separate the electrical potential of the load from that of the cryoplant
- are flexible in order to allow for the movement of cryo-loads
- can be easily rearranged to make space for new equipment
- can be used as vacuum line for pumping of vacuum spaces of the cryo-loads
- have minimum time requirement for on-site installation

Thermal losses:

The considerable length of the cryolines requires a system with low thermal losses. This_could be achieved owing to the fact that the lines have no intermediate lossy joints and are fully thermally shielded by helium boil-off and liquid nitrogen.

Thus the thermal losses of the cryolines are small in the overall thermal balance despite of their length. The specific data are listed in table 1.

Table 1 Thermal loads to JET low loss Helium-cryotransferlines

Liquid helium go-line	< 10 mW/m
Gaseous helium return line	< 100 mW/m
Liquid nitrogen shield	< 2 W/m

Pressure stability

An important specification for the cryolines is their pressure stability. The cryosupply for the JET cryo-loads operates at pressures of up to 12 bars for special transient conditions such as cooldown by using the 12 bar high pressure outlet of the cryoplant. The cryolines have also to cope with large pressure excursions of up to 10 bars from unplanned regenerations (quench) of the cryopumps. Due to the special corrugations of the pipes high pressure stability is provided for internal pressure as shown in table 2.

Table 2: Pressure stability of corrugated pipes used for JET cryolines

corrugated line diameter, wall	burst pressure	elongation 5%	buckling
14/18 mm, 0.3mm	>300 bar	>50 bar	>160 bar
39/44 mm, 0.4mm	>130 bar	>22 bar	> 80 bar
60/66 mm, 0.5mm	>130 bar	>17 bar	> 70 bar

Line flexibility

Another important issue for the use of the cryolines is their flexibility under operation conditions as they have to cope with the movement of the cryoloads during the experiment which is in some places up to +/100mm with a frequency of 2 Hz. For installation great care has to be taken to avoid torque during the movement as the line has no flexibility for torsion.

In this context it has to be noted that KEK/Japan which adopted later the JET cryolines uses them to pull their cryo-load completely out of the operation area without dismantling the cryoline.

Vacuum

One advantage of the concept of long flexible cryolines is that they can be fully tested cryogenically for thermal performance and vacuum leaks (leakrate < 10^{-9} mbar l/s) at the manufacturers and installed within a short period of time (typically 1-2 days) by a cable pulling team. The vacuum of the cryolines is also used at JET as a vacuum pumping line for interspaces of the cryoloads.

Electrical break/ Radiation resistance

The cryoplant has to be electrically insulated from the cryoloads for a potential of up to 2 kV and the cryocouplings had to be designed accordingly. The interior shrink coupling is made of a cryogenically and radiation compatible polymer, the coupling itself coated with a radiation compatible glass epoxy sleeve and the connection flanges enamelled or equipped with a polymer spacer. For all the internal spacers of the cryoline and the superinsulation, radiation resistant material had to be used.

Material

The use of austenitic stainless steels AISI 304 or 316 (equivalent DIN 17440: 1.4541, 1.4301, 1.4435, 1.4306) is a prerequisite to be compatible with the weldability for vacuum leaktighness, ductility at cryogenic temperatures, low thermal conductivity, corrosion and good emmissivity properties.

JET CRYOLINES

Over 30 long cryolines (with lengths between 45 and 90 m) are in use at JET. They originate from the central distribution area and are branched off to the various loads (see Figure 1). The inner liquid helium go lines have diameters between 10-20mm depending on the needs of the specific cryo-loads, the helium return lines have a annular gap of 3-5mm and are rated to

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