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CRYOGENICS FOR SUPERCONDUCTING EQUIPMENT IN LEP

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1. Introduction

The purpose of this note is to review briefly the installations needed to cool the superconducting equipment to be installed in the LEP ring to temperatures of about 4 K. In particular it is intended to indicate the buildings, excavations and facilities which these installations will require, so that they may be included in the civil engineering specifications from the outset. Refrigeration requirements at higher temperatures (e.g. liquid nitrogen or argon) are not covered here, although they may not be negligible and may, to some extent, require coordination or even integration with the helium system.

To the best of our knowledge the superconducting equipment currently proposed consists of:

(1) Low-beta quadrupoles.
(2) Detector magnets for experiments.
(3) Superconducting RF accelerating cavities.

The nominal cooling power required for a superconducting low-beta section is equivalent to about 300 W and that for the superconducting magnet for an experiment is some 600 W. These installations will probably be present at the four intersections to be equipped for experiments and are presumably intended to be in position when LEP starts operation. Refrigerators of this size are available commercially and should present few new problems.

It is currently intended to assemble superconducting accelerating structures in the form of modules some 20 m long, each containing eight multi-cell cavities. The cooling power needed for such a module is predicted to be between 500 W and 1300 W depending on the accelerating field and cavity characteristics. It has been proposed that up to twelve such modules be installed in a straight section, six either side of the intersection point. The nominal cooling power requirements for a straight section fully equipped with superconducting cavities would then be between 6 kW and 15 kW. This is several times larger than the largest refrigerator currently used at CERN and it is probable that multiple interconnected refrigerators would be used.

At present, it has not been decided if or when superconducting RF cavities will be used in LEP and a decision seems unlikely before the end of 1983. In this note we assume, for want of better information, that the installation of superconducting cavities and their associated cryogenic equipment will be progressive and will extend over a period of several years. It is assumed that this work may begin before the commissioning of LEP but would certainly continue afterwards. The first step would be to mount two pairs of modules in two diametrically opposed interaction regions. Subsequent installation would be in multiples of four modules.

If such a program is to be possible it is considered essential that the necessary provision be made from the inception for the excavations, buildings and access for pipework and transfer lines required for the refrigeration systems.

2. General Considerations

A refrigeration system will consist of a set of compressors and gas handling equipment connected by pipework to a 'cold box', where the low temperatures are produced, and vacuum insulated transfer lines in which the low temperature fluids are circulated.

Cold boxes should be located underground as close as practicable to the equipment they cool so that excessive pressure drop, heat leak and the flow instabilities associated with complex transfer lines are avoided. They must be accessible when LEP is running, however. It will probably be possible to position the cold boxes for quadrupoles and detector magnets within some 20 m of the magnets, but for the RF cavities, transfer lines of the order of 200 m may be unavoidable.

A common compressor hall should be provided at each equipped interaction region to house all the compressors serving that region. LEP Note 157 showed that the alternative technique of feeding all cold boxes from a central compressor installation via underground ring mains required very large pipes. Such a solution now appears uneconomic, particularly in view of the progressive installation of capacity assumed here.

Each refrigerator should incorporate the equipment for local automatic control in normal operation and manual override in abnormal conditions. Since the distances between the various installations will be considerable it is considered advisable to provide an autonomous central control point from which the routine operation of all refrigerators may be monitored and their controls adjusted remotely. Signals indicating the status of the refrigeration systems would be transmitted to the main LEP control room. Such a system obviously places some constraint on the selection of control equipment for the refrigerators.

The low-beta sections, detector magnets and RF cavities at a given interaction point should each have their own cold box, compressor and interconnecting pipework so that each system will normally be operated independently. Provision should also be made to allow interconnection of compressors for abnormal operation.

The refrigerator system for the RF cavities in a straight section should consist of several cold boxes connected by a common pipework system to their compressors, and by a common transfer line system to their cryostats. This choice results primarily from the assumed requirement to install the cavities progressively over a period of years. It has the added advantage of giving a size of cold box which is easier to introduce through the proposed access shafts and tunnels and, in conjunction with a degree of judicious overrating, of allowing full nominal cooling power to be maintained with one cold box failed.

All the refrigerators should have a designed cooling capacity somewhat higher than the nominal figures quoted for the installations. This is partly to allow continued operation with deteriorated performance and partly because the nominal cooling requirements of an installation do not necessarily represent the peak cooling power required of the refrigerator.

3. Compressor Buildings

Each compressor building should be located at ground level in the vicinity of the access shaft to the underground experimental area. Its exact position is somewhat arbitrary, but the piping length between compressors and cold boxes should not greatly exceed 500 m.

Compressors are sources of noise and vibrations. These can be damped out to a large degree, but problems could arise if the compressors are sited close to residential buildings.

The area required for the compressor hall for a fully equipped interaction region is about 1000 m2. An uncovered area of about the same size will be necessary for gas storage, transformers etc. The size of a compressor hall should not be less than 200 m2 and the building should be designed so that it is easily extended as additional refrigerator capacity is added.

4. Cold Boxes

The approximate position of the refrigerator cold boxes for the low-beta quadrupoles and for the detector magnets is shown by points Q and S in figure 1. The exact positions can be determined only when the layout of the experimental apparatus is known, but these are relatively small installations and no serious difficulties are expected.

Distribution of cold boxes along the klystron tunnel A-A would give the shortest transfer lines to the RF cavities, but removal of a cold box from the end of a tunnel would entail removing all the other cold boxes and dismantling most of the RF equipment in the tunnel. This would probably prove to be unacceptable. Alternatively, the cold boxes could be grouped in extensions of the stub tunnels C1 and C2 which connect the klystron tunnels to the machine ring. This solution provides easier acces for the cold boxes but requires cold transfer lines of up to 200 m length in the klystron tunnels.

The extension required to stub tunnels C1 and C2 is about 30 m per tunnel. The number of cold boxes in each stub tunnel will probably be between one and three, depending on the solutions finally adopted. In any case the cold boxes will have to be transported through tunnels B-B and this will require an unobstructed passage of at least 3 m diameter in these tunnels.

5. Piping

Piping from the compressors to the cold boxes will be routed through the access shaft and, for the cavity refrigerator, through tunnel B-B. The required pipes and sizes will be approximately as follows:

Low-beta section	:	two pipes of 100 mm and 50 mm diameter.
Detector magnet	:	two pipes of 160 mm and 80 mm diameter.
RF cavities	:	four pipes of 400 mm, 300 mm, 200 mm and 150 mm diameter.

These pipe diameters are only indicated to allow sufficient space to be reserved in the tunnels to let them pass.

6. Power and Services

The maximum electrical power requirements per fully equipped interaction region would be about 7 MW. About 10% of this would be required to be evacuated by a compressor hall ventilation system and the rest by cooling water. Most of this water could be provided by cooling towers, but it would be a considerable advantage to provide about 10% as raw water at a temperature well below 20 degrees centigrade. The colling water temperature rise should not exceed 15 degrees centigrade and its maximum outlet temperature should be less than 45 degrees centigrade.

7. Conclusions

If the cryogenic refrigeration systems described in this note are to be installed in the future it is necessary to make the following provisions from the start of the project:

(a) Reserve a suitable area for a compressor building near each interaction region to be equipped.

(b) In all interaction regions intended to be equipped with superconducting RF cavities, extend the length of stub tunnels C1 and C2 and ensure that adequate free passage is reserved in tunnel B-B.

(c) Ensure that there are no space restrictions which would hinder pipework between compressors and cold boxes.

We feel that any attempt to install and commission a complex cryogenic refrigeration and distribution system in a straight section already occupied by conventional RF cavities would lead to intolerable interference with the routine operation of the machine. If the installation of superconducting cavities in the LEP ring before commissioning of the machine is seriously considered to be a possibility, we think it essential to excavate the klystron tunnels at intersections 4 and 8 when the machine tunnel is dug.

Since it is hard to believe that, immediately after commissioning LEP, its operation would be interrupted to allow new excavation work, a decision not to excavate these klystron tunnels would imply that no superconducting cavities will be installed in LEP within the next ten years. If this is the case, further work on the associated refrigeration systems at the present time would be premature.

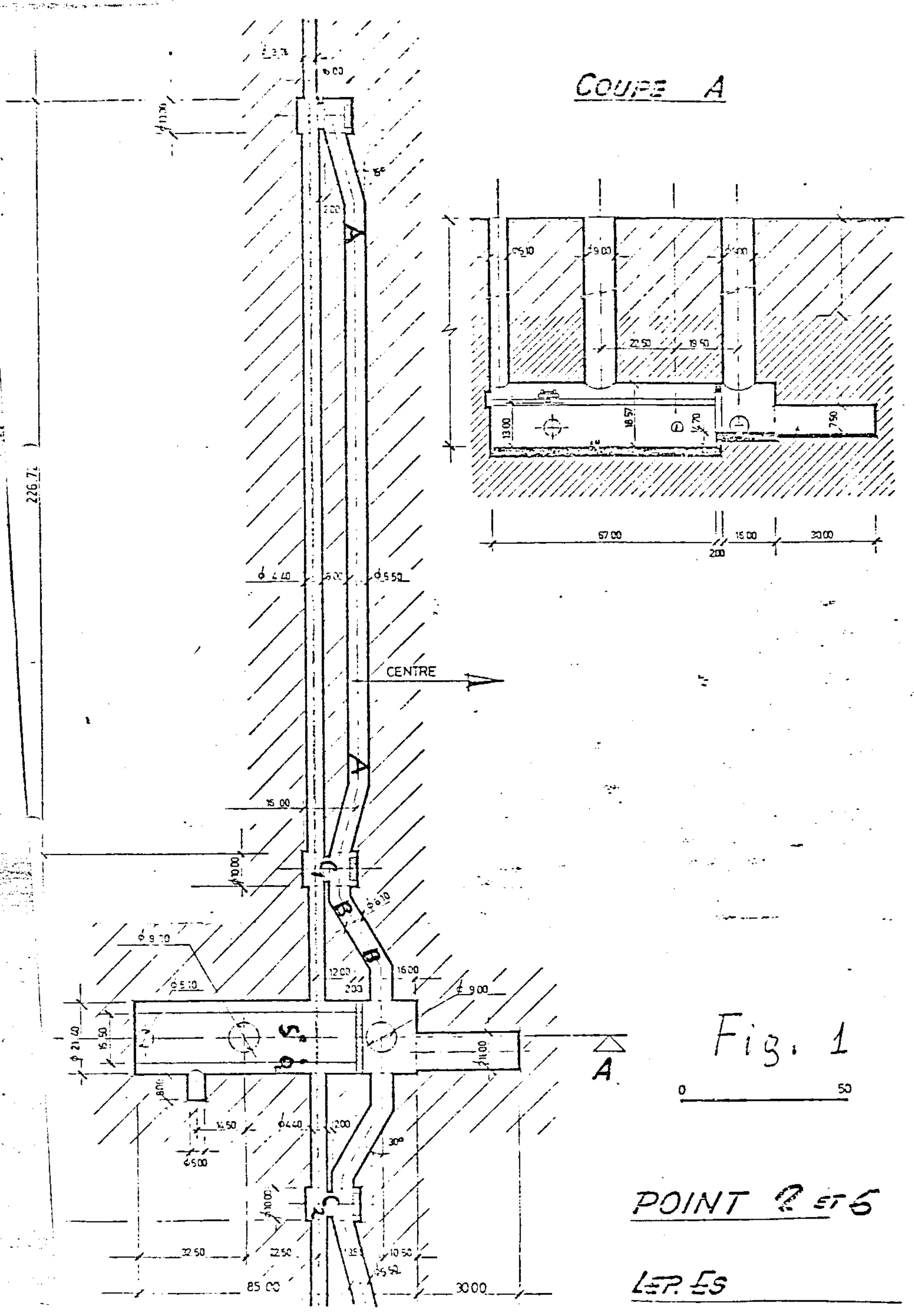

Fig. 1

POINT 2 ET 6

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