EUROPEAN INDUSTRIES POTENTIAL CAPABILITIES ON CRYOGENICS FOR THE FUTURE ILC

P. Dauguet#, Air Liquide, BP15, 38360 Sassenage, France

Abstract

Following the construction of LHC, the European industries have demonstrated there ability to construct complete helium and nitrogen refrigeration systems both for the needs of the huge accelerator and the associated detectors. Eight 18 kW at 4.5 K and 2.4 kW at 1.8 K helium refrigeration systems have been constructed. Each refrigeration system is connected to 3.3 km of the 27 km long accelerator thanks to interconnecting valve boxes and high performances helium transfer lines. This is the biggest refrigeration system ever constructed in the world.

The demand for cryogenics for the future ILC project is comparable in terms of equipment sizes but even bigger in terms of number of units required. The present refrigeration system scenario of ILC includes ten 21 kW at 4.5 K refrigerators and twelve 3.7 kW at 2 K refrigerators. In the present paper, this scenario will be presented and compared to the realizations done by the European Cryogenic Industries for CERN.

INTRODUCTION

The ILC will be the largest cryogenic system in the world. Following the start up of the 27 km circular LHC at CERN, the new step for high energy physics experiment will be the construction of ILC in coming years, a 47 km accelerator of which 22 km is a linac composed of approximately 16000 superconducting cavities operated at 2K. For this project, the necessary helium refrigeration power is around 210 kW at 4.5K and 45 kW at 2K. The foreseen cryogenic layout is presented in Fig. 1.

ILC CRYOGENICS SCHEME

The cryogenic system will be composed, in its first version (phase 1) of : .

* Three 21 kW at 4.5 K Helium Refrigeration Systems to cool the 2 damping rings and the collision region equipments.
* Ten 3.7 kW at 2 K Helium Refrigeration Systems to cool the 22 km of superconducting RF cavities of the linac, each of them interconnected through distribution boxes and cryogenic transfer lines to 2.2 km of the linac, with interconnecting points between the transfer lines and the cavity strings every 140 m.

In phase 2, the cryogenic system is foreseen to be composed of :

* Ten 21 kW at 4.5 K Helium Refrigeration Systems to cool the 2 damping rings and the collision region equipments.
* Twelve 3.7 kW at 2 K Helium Refrigeration Systems to cool the 22 km of superconducting RF cavities of the linac.

It is comparable in term of complexity and architecture to the LHC project which includes : .

* Eight 18 kW at 4.5 K Helium Refrigerators coupled to,
* Eight 2.4 kW at 1.8 K cold compressors systems to cool the 27 km, each of them interconnected through distribution boxes and cryogenic transfer lines to 3.3 km of the LHC circular collider, with interconnecting points between the transfer lines and the cavity strings every 100 m.

Air Liquide as designed, manufactured, installed and started up half of the above refrigerators and cold compressors systems, including turbo-expanders and cold compressors developed in house, and all the interconnecting valve boxes and 27 km transfer lines, demonstrating the ability of the European industry to fulfill the needs of such huge cryogenic projects as LHC or ILC.

In the following chapters, the major components that have been constructed for LHC are described.

LHC 18 KW@ 4.5 K PLANTS

As the CERN call for tender was giving a very high importance to the electrical consumption of the plant as adjudication criteria, the choice of a very efficient cycle was mandatory [1].

The refrigerators had to fit very different operating loads. A large flexibility of operation of the machine was thus requested.

The third request to be taken into account in the design of the machine was the high availability of the cryogenic system needed by the LHC project. This is insured by the choice of reliable and technically proven components.

The cycle design presented hereafter in figure 2 is a compromise between efficiency, flexibility and reliability of operation.

The key component of the helium refrigerators and liquefiers are the turbo expanders.

Pascale.dauguet@airliquide.com

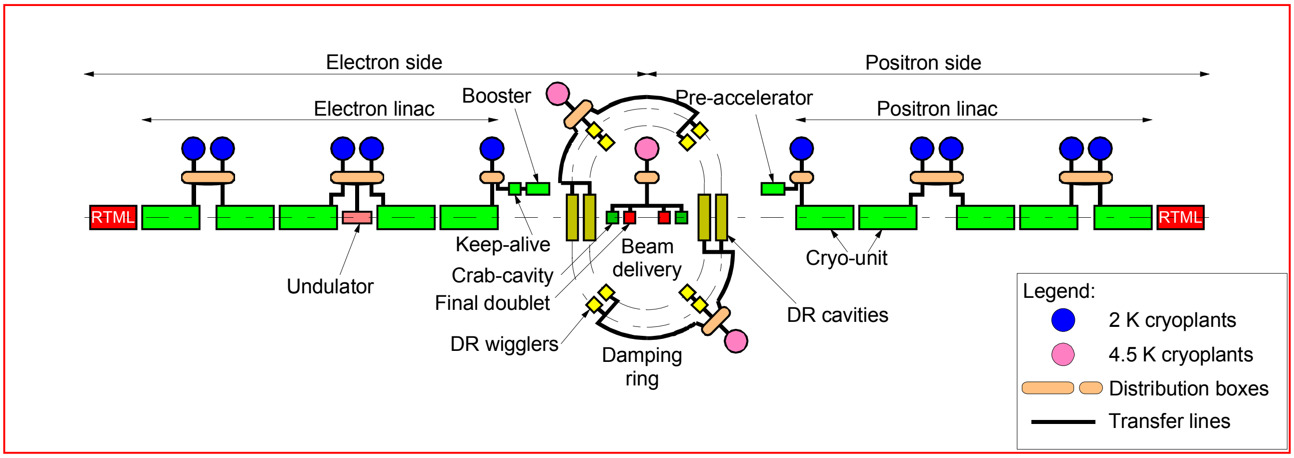

Figure 1: ILC phase 1 cryogenic architecture

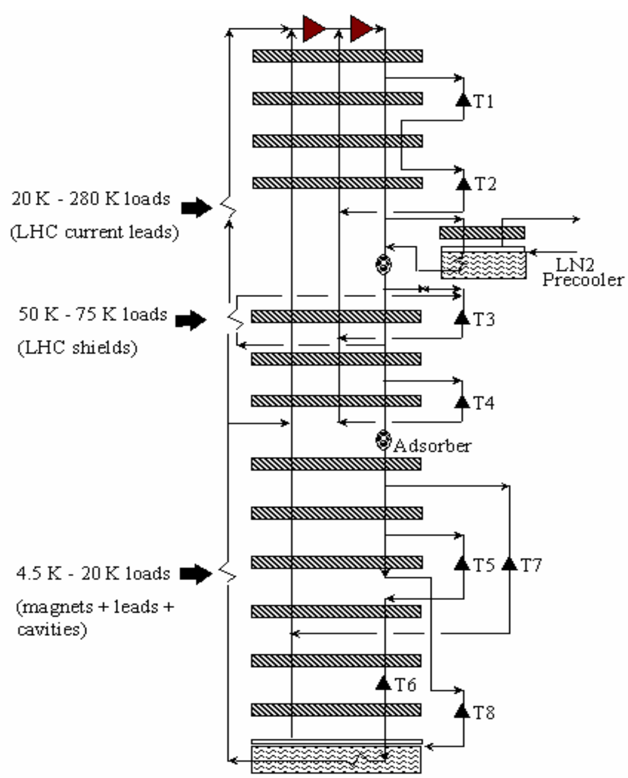

Figure 2: Process Flow Diagram of a LHC 18 kW plants

Air Liquide have developed for more than 40 years high reliability gas bearing turbo-expanders for cryogenic applications. Today, more than 400 turbo-expanders, with extracted power ranging from 500 W to 200 kW are operated in Helium plants and also Hydrogen and Carbon Monoxyde plants. The isentropic efficiency of such machines ranges from 65% (for the smaller ones) to 85% for the bigger ones.


Picture 1: A LHC 18 kW cold box

LHC 2.4 KW@ 1.8K UNITS

The Large Hadron Collider (LHC) makes intensive use of superconducting magnets operated below 2.0 K. It thus requires high-capacity auxiliary refrigeration systems - the so–called "Cold Compressor System (CCS)" - for operations below 2.0 K. These systems, making use of cryogenic centrifugal-compressors in a series arrangement with room-temperature screw compressors, are each coupled to one of the refrigerator [2] providing 18-kW equivalent at 4.5 K. They are able to absorb a cryogenic power of 2.4 kW at 1.8 K in nominal conditions.

The key components of such units are the cold compressors, able to compress the cold gas evaporated below 2K in the magnets. This technology have been first developed for the Tore Supra Project (experimental fusion reactor) in the 80's and them improved for CEBAF (inlet conditions : 240 g/s at 30 mbar).

For LHC, the cold compressors trains (3 compressors in series) compress each 120 g/s of Helium from 15 mbar to around 400 mbar.

The isentropic efficiency of cold compressors achieves now 75% with most recent technologies. The evolution of the performances of cold compressors from the 80's is presented in figure 3.

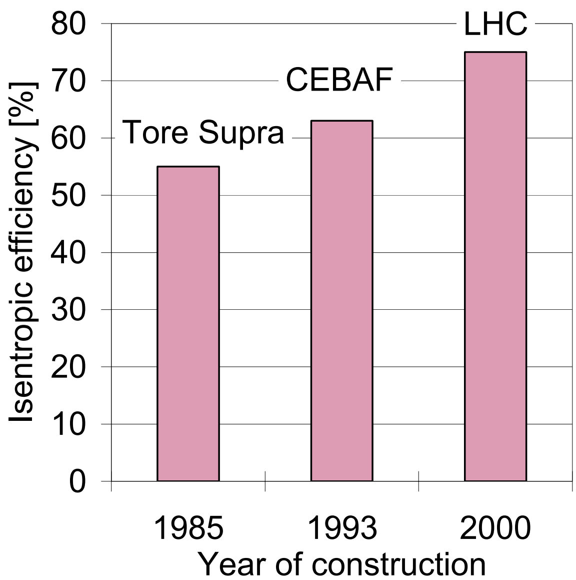

Figure 3: Improvement of Cold Compressors performances (isentropic efficiency) from very first large 2K systems to nowdays.

LHC DISTRIBUTION SYSTEM

LHC is the largest integrated cryogenic system in the world, not only considering the total cryogenic power requested, but also due to the size of the accelerator. The refrigerating helium of the magnets and cavities have to be distributed over the 27 km of the accelerator, in the LHC tunnel, 100 m below ground level. Due to the size of the experiment, ultra high performance cryogenic lines have been specially designed for the LHC project.

The achieved performance of the line is : around 0.05 W/m on each of the 4.5 K tubes of the transfer line, a performance around 10 times better than usually achieved for such transfer lines.

CONCLUSION

LHC is today the largest integrated cryogenic system in the world. The cryogenic components of LHC are very similar to the ones necessary for the ILC project construction. Trough LHC, the European Industry has demonstrated its ability to fill the cryogenic needs of the future ILC project.

Picture 2: A LHC cold compressor (Air Liquide design)

Picture 3: LHC 27 km Liquid He transfer lines

REFERENCES

[1] S. Claudet , P. Gayet and U. Wagner, Specification of four new large 4.5 K refrigerators for the LHC, Advances in Cryogenic Engineering 45 (1999), p. 1269-1276

[2] P. Dauguet , P. Briend, E. Monneret, Air Liquide large 18 kW (equivalent power at 4.5 K) Helium Refrigerators for CERN LHC Project, Advances in Cryogenic Engineering 49 (2003), p. 147-153

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