Long Term Experience with Cryoplant Operation for Superconducting Magnets and RF Cavities at CERN

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Abstract

Eighteen liquid-helium cryoplants are presently in use at CERN, four of them commissioned in 1992. Unit capacities (entropy equivalent) range from 0.1 to 6 kW/4.5 K. Four even larger cryoplants (12 kW/4.5 K, upgradable to 18 kW/4.5 K) are in the process of installation and commissioning. Apart from feeding laboratories for development and tests of cryogenic equipment, the cryoplants provide cooling for superconducting detector and accelerator magnets and superconducting RF cavities, where their uninterrupted availability is crucial for efficient accelerator operation. Integrated running time in 1992 was of the order of 100 000 hours. This paper summarises experience from all phases of operation, normal running, emergencies, cool-down and warm-up. Some information is given on software controls, data acquisition, and fault analysis, and on conclusions concerning corrective or preventive maintenance and advisability of investments for increased availability of cryogenics.

I. INTRODUCTION

By the end of 1991, 14 liquid-helium cryoplants were in operation at CERN, totalling a cooling capacity equivalent to 6.6 kW at 4.5 K. Nine of them were used to cool the superconducting magnets of various particle detectors [1] (including low-ß quadrupoles integrated into the LEP detectors ALEPH, DELPHI, L3 and OPAL [2]), three of them to provide liquid-helium for test facilities, mostly for the development of LEP200 superconducting cavities and superconducting magnets for LHC, and two served for the cooling of superconducting cavities in LEP and SPS [3]. The typical unit capacity of these plants was 500 W.

In the framework of the LEP200 Project [4], two much larger cryoplants of 6 kW equivalent capacity were commissioned in 1992 (and, in addition, two 400 W plants), and another four cryoplants of 12 kW capacity (upgradable to 18 kW by addition of compressors) are presently (in 1993) being installed and commissioned. The cooling capacity installed at CERN has thus nearly tripled in 1992 and will by 1994 have increased by a factor of ten with respect to 1991.

In this paper, experience with operation of the 18 cryoplants in service last year will be reported.

II. CHARACTERISATION OF THE CRYOGENIC SYSTEM

Table I summarises technical and operational data of the cryoplants. The following points should be noted:

- The cryoplants for experiments are installed close to the detectors in the experimental halls (underground halls for the LEP experiments); compressors are housed in special buildings above ground. Because of the large distances (of the order of 10 km between LEP experiments) centralisation of compressors was possible only for the complex NA35 - NA44 - NA47 - RD5 - LHC magnet test lab and for the complex OMEGA - BOC cryoplant - ex-ISR cryoplant.
- The cryoplants for experiments (with the exception of the OMEGA veteran plant) are usually operated in remote control mode from a central Cryogenic Control Room. Centralisation of cryoplant operation will also be implemented for cavity cryogenics in a later stage (Remote Cryogenics Commissioning Room); in the present LEP200 construction phase involving frequent non-routine operations, local control is often the preferred operational mode. Cryoplants of the test facilities and of the Central Liquefier are controlled locally.
- None of the plants is operated by round-the-clock shifts of operators. At night time and week-ends, operators are, however, on standby duty, and can be called in by an automatic alarm system.
- Table 1 mentions the year of commissioning of each cryoplant. Note the tremendous increase of plant efficiency (170 kW compressor power for 150 W cooling power, i.e. 1100 W/W, in 1968 versus 2500 kW for 12 kW, i.e. 210 W/W (design value) in 1993. This improvement by a factor of 5 is a very important step forward towards economy in power consumption, which accounts for a substantial part of the operation costs of a superconducting accelerator. The increase in efficiency is probably related to the requirement of utmost compactness for plants to be installed in an accelerator tunnel, where space is at a premium, since compactness requires heat exchangers of highest efficiency, which in turn increase the overall efficiency of the plant.

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Table 1
CERN cryoplants: technical data, operation time and downtime in 1992

Function	Cryoplant commis-sioned in	Nominal cooling power at 4.5 K (entropy equivalent) W	Compressor power, kW	Running hours, 1992	Number of accidental full stops		LHe autonomy without cooling hours	Interruption of LHe delivery to users hours
					cryogenic origin	other origin		
Fixed-target experiments								
OMEGA detector	1971	800	850	6200	0	6	0	15
NA35	1976–79	400	450	2200	0	0	0	4
NA44	1979, 1991	400	450	2900	0	0	0	0
NA47	1976–79	400	450	5700	1	1	20	26
RD5	1976–79	400	450	3200	0	0	0	0
LEP collider experiments								
ALEPH (incl. low-β quadrupoles)	1988	800	600	6400	3	9	0 (low-β: 5)	18 (low-β: 10)
DELPHI (incl. low-β quadrupoles)	1988	800	600	6800	1	7	0 (low-β: 5)	10 (low-β: 0)
OPAL low-β quadrupoles	1976–79	400	450	6200	1	7	5	10
L3 low-β quadrupoles	1976–79	400	450	5950	0	6	5	12
Superconducting RF cavities in the SPS (injection of electrons/positrons into LEP)								
SPS BA4	1989	120	110	5000	0	0	0	0
SPS BA4	1992	400	450	4100	0	1	0	12
Superconducting RF cavities in LEP								
LEP Point 2	1992	6000	1350	6200	1	6	0	Operation according to accelerator requirements
LEP Point 6	(1993)	12000	2500	0				
LEP Point 8	(1993)	12000	2600	0				
Test facilities for superconducting cavities and magnets								
Hall 892: LHC magnet test lab	1976–79	400	450	5550	Intermittent operation according to test requirements			
Hall 180: BOC cryoplant	1977	335	800	4000				
Hall 180: ex-ISR cryoplant	1980, 1990	1200	600	2100				
Hall SM18: LEP200/LHC tests	1992	6000	1800	6000				
Central liquefier and Cryolab								
A.D. Little liquefier	1968	150	170	5370	Intermittent operation according to requirements			
Sulzer liquefier	1992	400	450	7400				

III. OPERATIONAL EXPERIENCE AND FAULT ANALYSIS

In the last five columns, Table 1 gives the number of running hours of the cryoplants used in regular operation with the accelerator and current experiments, the number of accidental stops of the plant and the duration of interruption of liquid-helium supply to the user. The second last column indicates a certain autonomy for some systems, being cooled from an intermediate dewar and therefore less vulnerable by short-term interruptions of power supply.

Table 1 shows that of a total of 50 interruptions, only 7 were due to malfunctioning of a component of the cryogenic system. That this number is so small is not only due to the quality of the installations, but also to the rapidity and competence of the operators on stand-by duty, who were called in 230 times by an early warning of the automatic alarm system, and who cleared the situation before aggravation led to a breakdown of the system. The total number of lost hours for accelerators and physics experiments was 117 (coincidence of cryogenic downtime with physics data taking), from which only 22 were associated with cryogenic equipment failures. Regarding the 61 000 normal running hours, the fault rate was about $1.9 \cdot 10^{-3}$ for all stops and only $3.6 \cdot 10^{-4}$ for the stops caused by cryogenic equipment failures. The high availability of the cryoplants is essentially due to the careful preventive maintenance during shutdowns (Computer Aided Maintenance is being introduced at present), and the competence of the operating team.

Reasons for the interruptions originating in the cryogenic system were the failure of a 24 V power supply (including its backup unit), process software crash, failure of a control valve and impurities in the helium cycle. The remaining 43 interruptions were mostly caused by interruption of water and electric power supplies and by perturbations in the communications network. Looking at these figures, it appears to be good policy to invest, for a reduction of cryogenic downtime, in the reliability of utilities.

It may be worthwhile to comment on this point.

It is a characteristic of cryogenic systems that immediate restart after utility failure is possible only if this failure is of very short duration. (Cryogenic buffering, e.g. by provision of an intermediate liquid-helium dewar for increased tolerance against perturbations, as mentioned, is possible in exceptional cases only, typically when the load is of a nature suitable for cooling in liquefier rather than refrigerator mode). In most cases the time required to restore thermodynamic equilibrium after severe perturbation is a multiple of the utility downtime that provoked this perturbation, in particular if a large and delicate system is concerned, e.g. if the interruption of cooling has lead to the quench of a superconducting magnet. Even if interruptions of utilities cannot be excluded, it is of prime importance to keep their duration as short as possible and to make arrangements for their fastest possible restablishment, with high priority of cryogenics versus other less critical components.

IV. REFERENCES

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