Operation of the Cryogenic System for Superconducting Cavities in LEP

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At CERN the upgrade of the e^- LEP e^+ collider towards higher beam energies
under way by installing superconducting cavities in the rin
superconducting cavity modules have been operated together wit
temperature copper accelerating cavities allowing for a first
increase. We report on the experience with the operation of the
system. Particular attention is given to stability, automatic cont
Failure analysis and redundancy programs are presented which sho
increase the availability of the cryogenic system in the environ
high energy particle collider.

INTRODUCTION

The upgrade of the e^- LEP e^+ collider from 45 GeV to 96 GeV per beam is under w
gradually up to 272 superconducting cavities on both sides of the four inte
352 MHz cavities are assembled in 4-cavity modules and cooled by four la
equivalent capacity at 4.5 K. In 1995 a total of 16 modules have been op
addition to the ambient temperature copper accelerating cavities allowi
increase from 45 to 70 GeV. After the LEP winter shut-down 1995/96 all fou
will be in operation with 35 out of the final 68 cavity modules, the total
1998.

THE LEP2 CRYOGENIC SYSTEM

The cryogenic system at each of the four interaction points of LEP, d
publications, consists of a cryoplant [2,3,4] with an equivalent cooling c
associated liquid helium distribution system, a pair of about 200 m-long
to feed the 8 or 9 superconducting (sc) acceleration cavity modules on
experience with the 12 kW plants was reported in [5,6]. A description of
circuits inside the 11 m long 4-cavity modules, which are treated as in
cooling and controls, is given in [7]. In addition to the sc cavities the
points are also being cooled by the 12 kW plants. As an example of the la
LEP point 2 is shown in Figure 1.

CONTROLS AND AUTOMATIC OPERATION

The industrial process control system [8], purchased by CERN apart from t
equipment at 4 points evenly-spaced around the 27 km long LEP ring, with a
office building of the operation team. At each point a local control room
control units are distributed on the surface and under ground. 1800 input/
the process of each cryoplant and the associated modules.
The control system is programmed for fully automatic operation including c

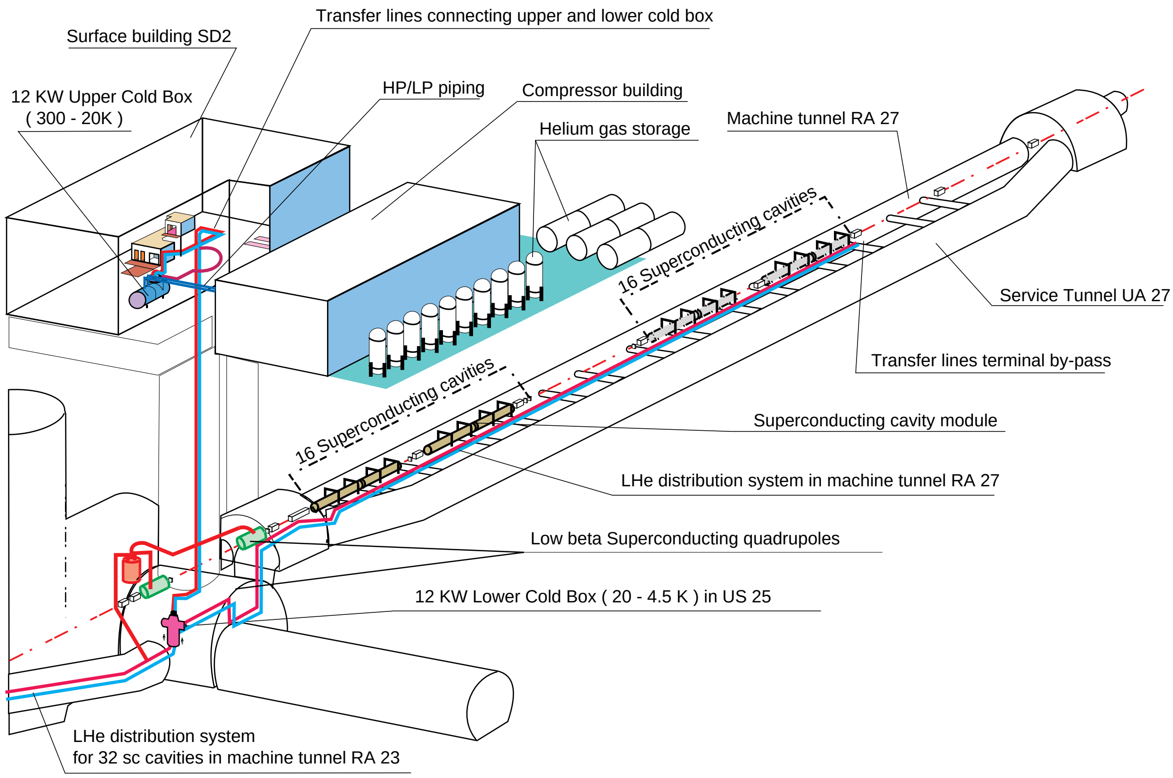


Figure 1

after utility failure and adaptation of the plant capacity to reduced l
supervised from the central control room by a small operator team, on dut
hours or on automatic call in case of failure or alarm on sensitive parame

OPERATING CONDITIONS FOR CAVITY MODULES

The inlet and outlet valves of each module are controlling the level and t
bath. In addition a compensation of the induced dynamic radio frequency (
means of electrical heaters. An algorithm is calculating the necessary com
RF field strength signal and the pre-set cavity quality factor.

It is important to note that the outlet valve of the module throttles
influence of pressure variations from one module to its neighbours, as wel
by the compressors suction pressure. Table 1 presents the operating cond
state operation and when a RF field step with typically 400W load change i

Table 1 Cavity module operation conditions and stability

	Nominal conditions	Steady state variations	Variations by RF steps
Pressure	1250 mbar	+/- 2 mbar	+/- 10 mbar
Level	800 mm	+/- 5 mm	+/- 10mm

RELIABILITY AND AVAILABILITY

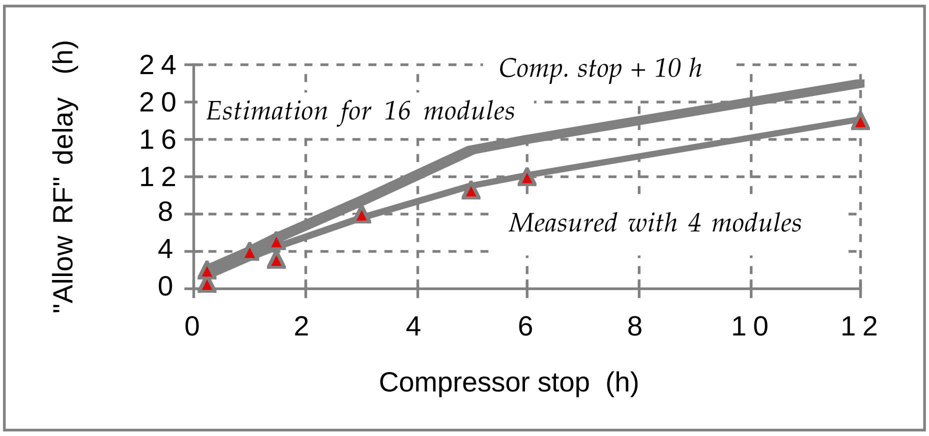
The four 12 kW plants have now accumulated a total of 34000 hours of opera
complete cryosystem operation (including control system) during last year
Table 2. This includes the final 12 kW plants, as well as the now replace
interruptions of operation were mostly related to utility failures (electr
specific cryogenic problems. As a consequence of the failures in 1995,
cryosystem for RF operation of the cavities was 32 h, including normal re
0.4 % of the total LEP running time.

Table 2 Cryosystem fault statistics

Year	Number of installed modules	LEP point	Cryoplant type & operation time during LEP run		Cryoplant stops: Cryo faults-total f
1992	2	2	6 kW	6200 h	1-7
1993	3	2	6 kW	3800 h	2-8
	1	6	12 kW	1400 h	0-2
1994	4	2	6 kW	4600 h	3-14
	3	6	12 kW	1500 h	1-3
1995	4	2	12 kW	3900 h	0-3
	8	6	12 kW	3900 h	0-4
	4	8	12 kW	840 h	0-0

After plant stops the cryogenic system will introduce unavoidable delays establishing of steady state conditions. Table 3 shows the recovery time years with a small number of modules (4 to 6) and the extrapolation for plant. It also indicates the characteristic times of the cryosystem for the

Table 3 Characteristic times for the cryosystem



Action	time
Cryoplant cool down	30 h
Cryoplant warm-up	48 h
Module cool down	5 h
Module filling	1 h
Module warm-up	4 h
Module emptying	1 h
(only static losses)	5 h

CONSOLIDATION TASKS

Large storage tanks

In addition to the present 10 helium gas storage tanks (each 75 m^3, 20 ba four LEP points, 3 large tanks (each 250 m^3, 20 bar, horizontal axis) will be installe complete refill of the modules in case of accidental loss of helium.

Redundancy and maintenance

For cost reasons the plants where originally specified and built without r ensure minimum downtime most spares are now on stock. In view of the rathe compressor repairs and future needs of increased flowrates for plant upg project LHC, fully equipped redundancy compressors, one for each of the plant, are being procured from industry. It is also planned to install re the cooling water system, similar to those already in place for the compres Most crucial for the reliability of components is the future preparation o the thoroughly executed preventive maintenance during the winter shut-down

Helium management

An operating 12 kW plant is filled with 2500 Nm3 of helium. During insta testing about 4 times this amount has been used for each plant. The to

cryosystem at one point with 18 modules (550 Nm3 each) will be 15000 Nm3,
lost last year during maintenance or module installation, 15% for leaks
helium recovery. Efforts must be spent on reducing these losses during nex

Optimisation of operation modes
Further work is planned to optimise the operation modes, in particular t
reduce restarting delays of the increasing number of modules. A close foll
losses in the modules will be implemented to minimise unnecessary lo
compensation heaters.

Organisation of operation
CERN has established a contract with an experienced company to ensure ope
all cryogenic installations at CERN. The intention is that this company
period will take over the operation and maintenance responsibilities with
outsourcing policy, which is now also applied to operation tasks on comple
promising results after the first 9 months of the contract, much further
transfer of specific experience will still be necessary in the coming year

CONCLUSIONS AND OUTLOOK

Operating experience with the LEP2 cryogenic system, which is at preser
efficient helium system world-wide, is very encouraging. After replacement
in the upper coldbox of one plant, roughly the same cooling capacities h
points. Reliability of the cryoplant components and of the control syster
good. Some further work on automatic procedures, redundancies and preven
allow to face successfully the future demands for full capacity and high
system as part of the upgraded LEP collider.

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