

5-year operation experience with the 1.8 K refrigeration units of the LHC cryogenic system



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CEC/ICMC 2015 Tucson



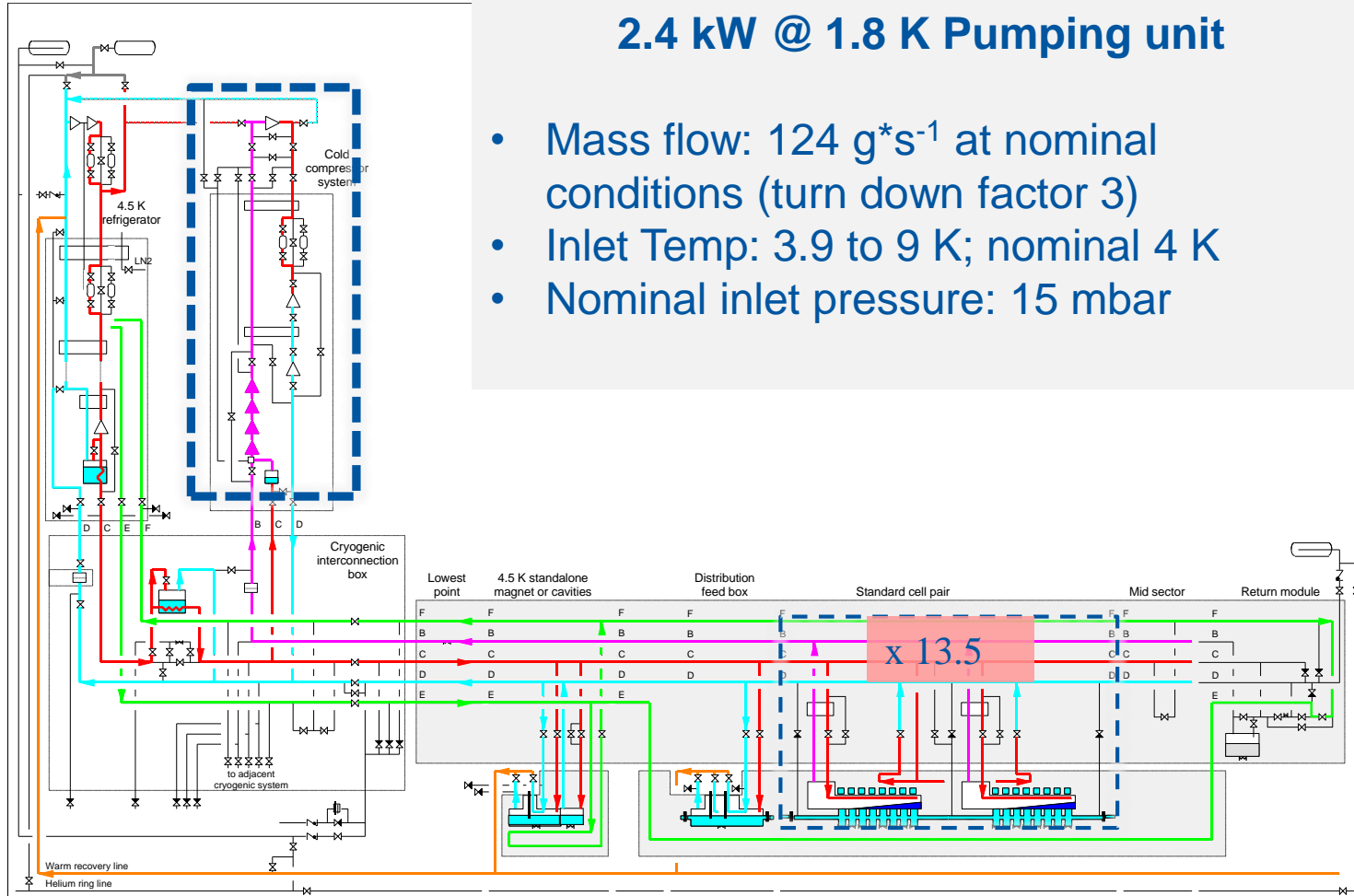
G. Ferlin, CERN Technology department



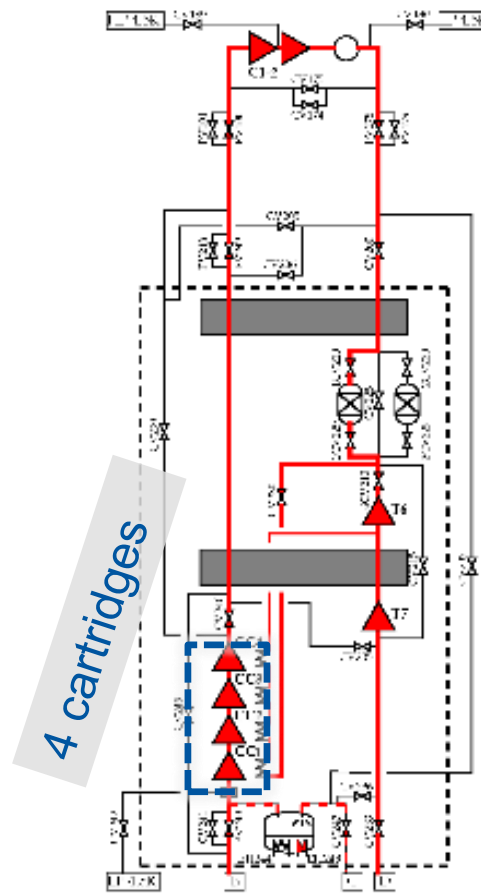
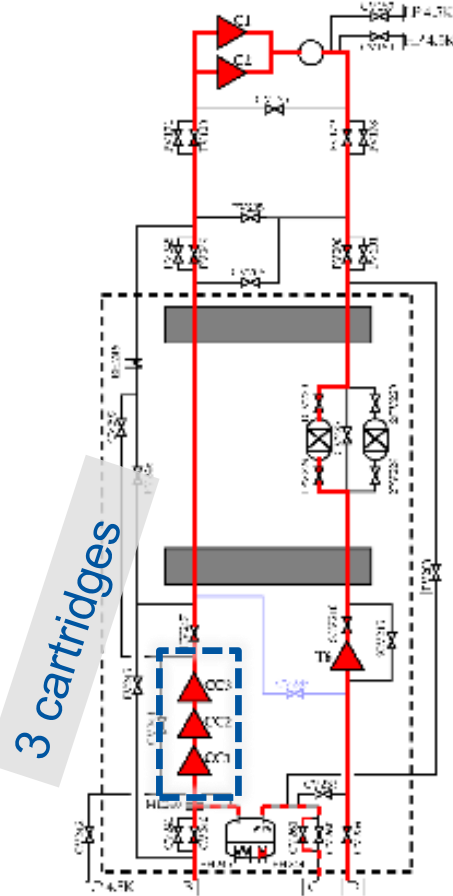
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Global arrangement for one sector



Global arrangement for one sector



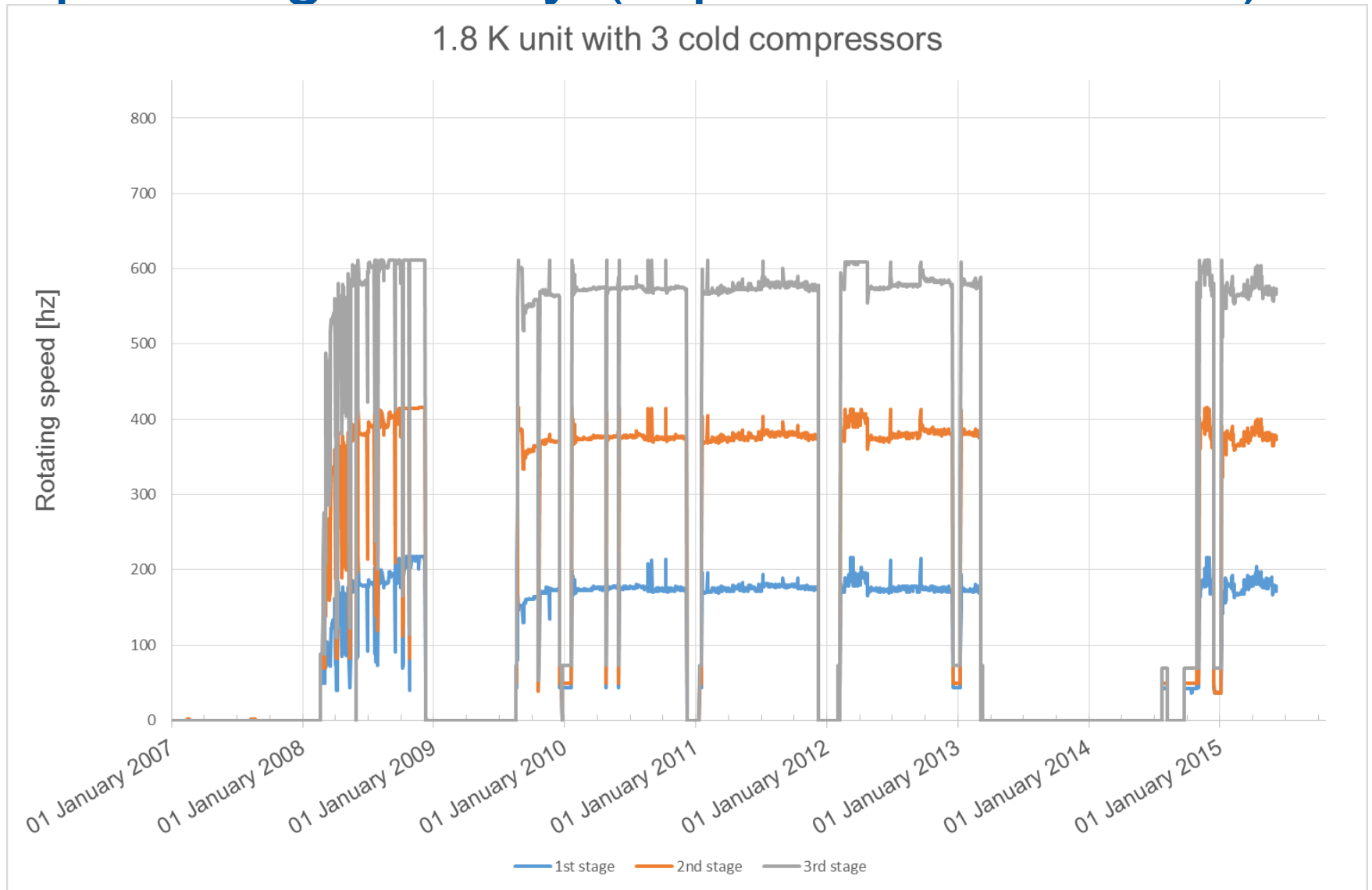
Two arrangements possible, combined with warm volumetric screw compressors using sub-atmospheric suction allowing a turn down ratio of 3

Active Magnetic Bearing system and Variable-Frequency Drive are used for Cold Compressor cartridges

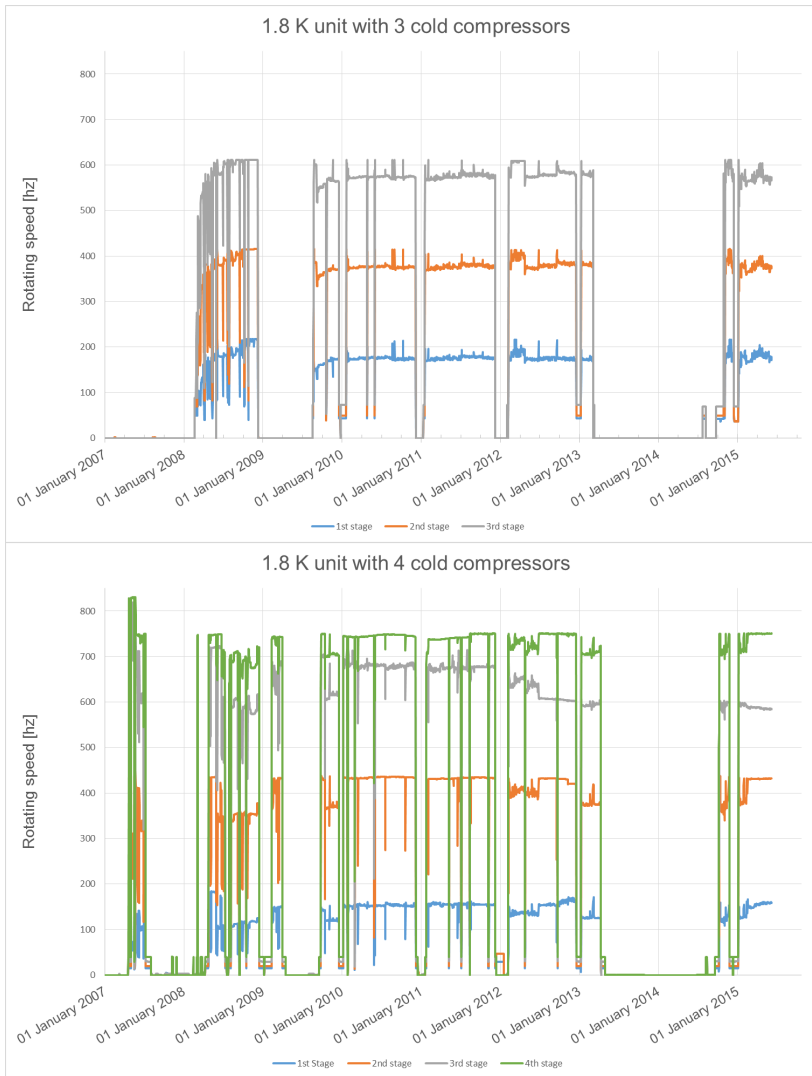
Each set of cold compressor is driven by a dedicated PLC with complex software used to drive individually each compressor

In total 8 sectors including 4 of each design

Operating History (representative unit)



Operation numbers



Each 1.8 K unit has been operated about 40000 hours.
With around 28 cold compressors cartridges, the cumulative operation duration is 1.1 million hours.

Availability must be understood as seen by the final user during expected period of beam (~ 230 days in 2012) and including all cryogenic issues

Downtime for the reference year 2012:

18 stops of the 1.8 K units of which 2 are related to a global stop of the 4.5 K refrigerator.

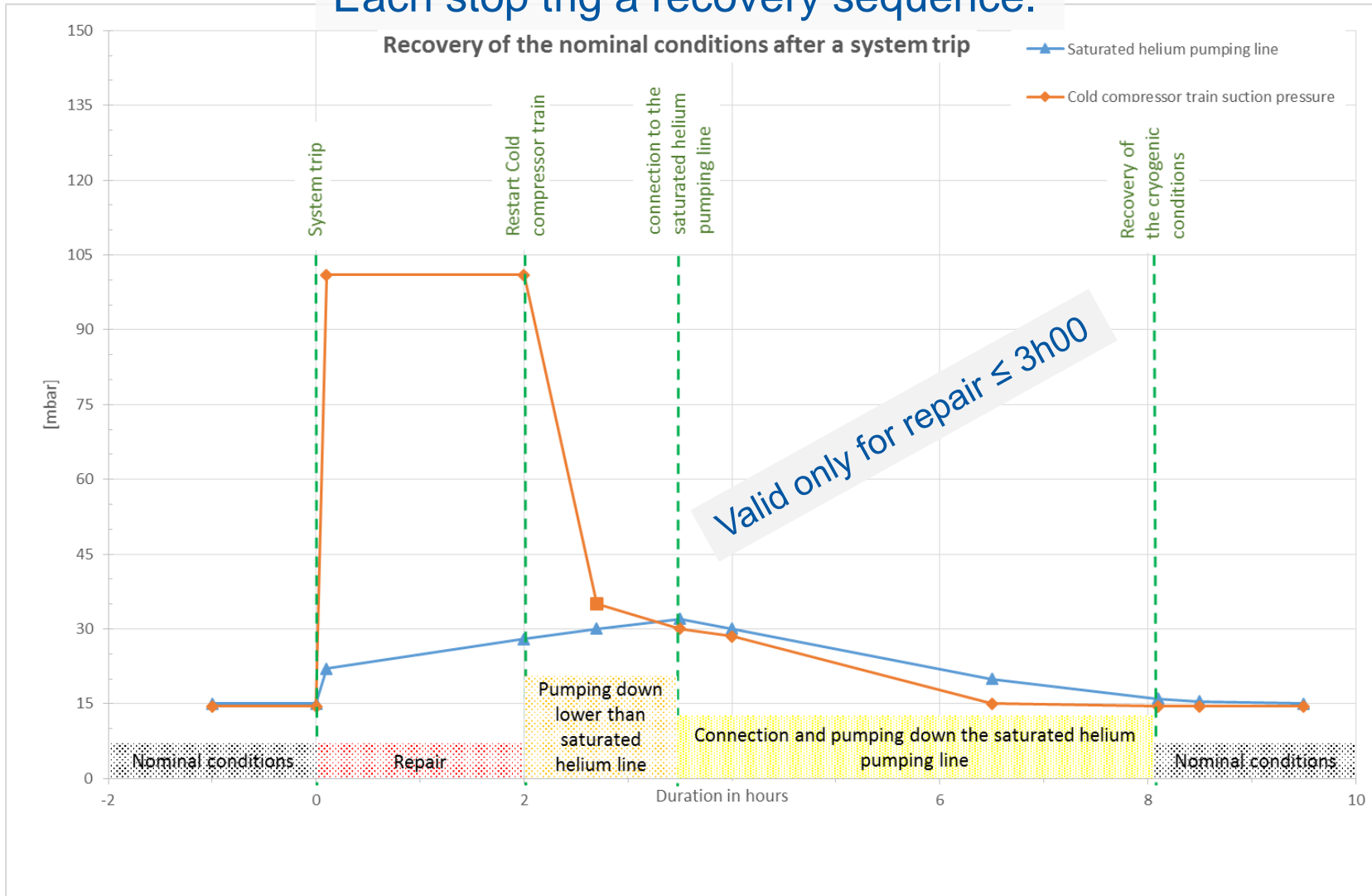
Availability of the 1.8 K units

In 2012 the global availability of the cryogenic system for LHC has been 94.8 %. The total failure duration has been mainly linked to 1.8 K units (64 % of the failure duration) with 18 stops.

The global availability has been **higher than 99%** in average per **1.8 K unit**. If necessary, maintenance is done during scheduled Technical Stop (3 * 5 days / year) or during “end of the year” foreseen stop, without impact on global availability.

Recovery sequence

Each stop trig a recovery sequence.



Recovery sequence duration

For a short repair duration (< 3h00)

Configuration of the cold compressors units	Repair	Average duration [hours], repair not included		
		pumping down lower than saturated line	Connection and pumping down the saturated helium pumping line	Total duration to restore stable presurised temperature below 2.1 K
All units	from 20 min to 3:00 h	1.25 h	4.75 h	6 h
configuration with 3 cold compressors	from 20 min to 3:00 h	0.75 h	3.25 h	4 h
configuration with 4 cold compressors	from 20 min to 3:00 h	2 h	7 h	9 h

Static pressure 100 mbar

Static pressure 250 mbar

Driving control more complex (4 compressors vs 3)

For an extended repair duration up to 24h00, the recovery duration could go up to 24h00.

Mean Time Between Maintenance (MTBM)

13 cartridges (on 28 + 7 spares) has been sent back to supplier for maintenance (including 1 damaged during tests done by CERN on a spare cartridge).

Major maintenance items:

- Emergency Touch-Down Bearings (ETDB)
- Restore electrical insulation
- Mechanical damage on shaft rotor

MTBM is 100000 hours for one vendor and 90000 for the other one (Cold compressor cartridges only)

Consolidations

Improve the process stability

Improve the utilities availability

Move electrical cabinet to a beam noise free area

Improve the inspection of all components (adding remote communication) to detect a potential failure asap.

Improve driving software

Upgrades

VFD electronic unit exchange

AMB electronic unit exchange

65 % done; Expected to be finished end of 2016



Conclusion

From hardware point of view, the MTBM of the cold compressor cartridges is very good.

But the electronic components must be kept under control.

Global availability per 1.8 K unit is higher than 99% after 24 months of operation.

But no reliable data for unit working permanently at 100 % of the installed capacity

The impact on the availability of the 1.8 K Refrigeration units is in the range 50 to 60 % of the total downtime of the cryogenic system.



Thank you