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Organized by CERN

Collection of data related to the operation experience on the Tore Supra cryogenic system

Related to the European Fusion Development Agreement

Task TW6-TSL-004

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OUTLINE

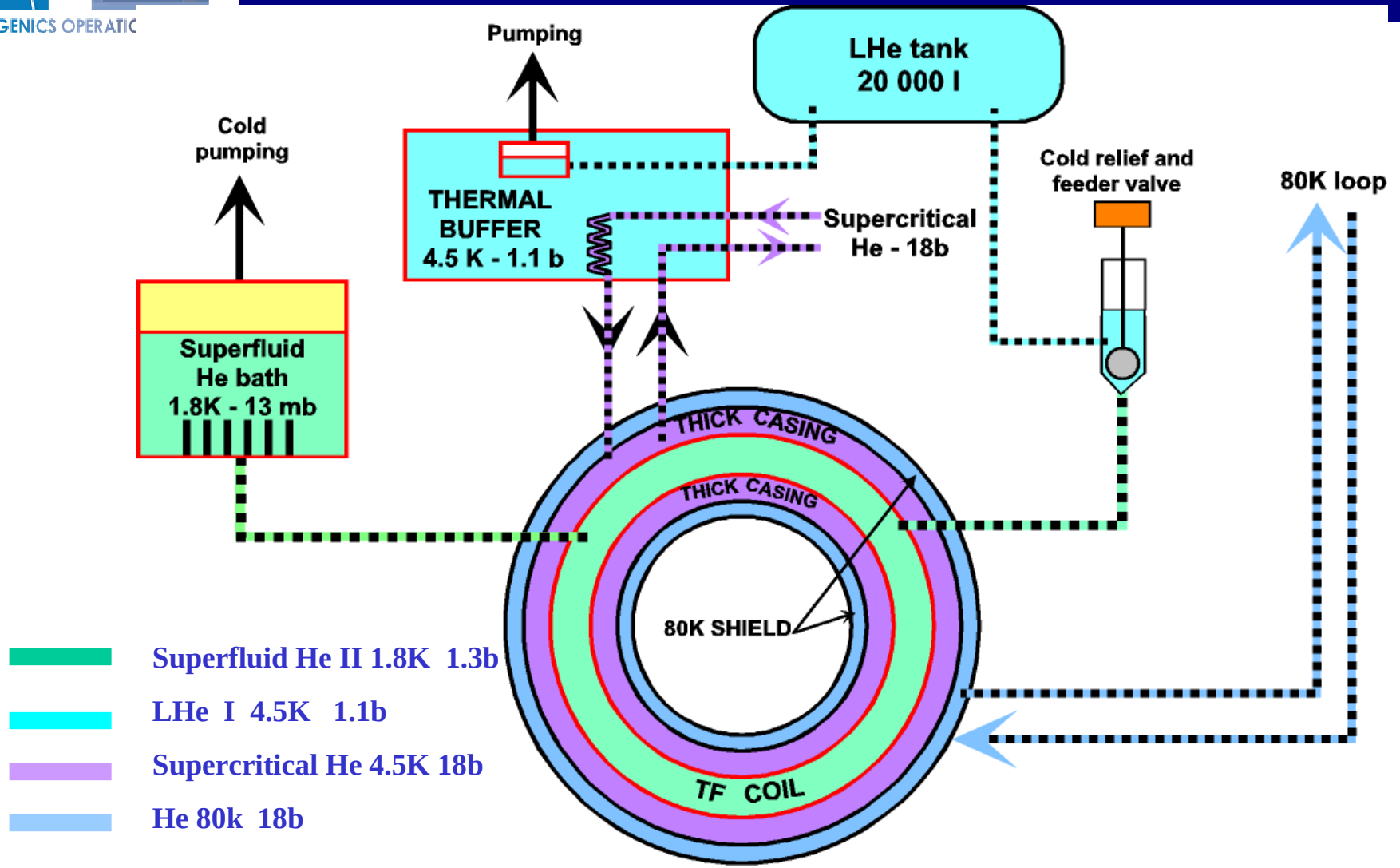
"News from Tore Supra"

- **Introduction**
- **Description of the EFDA task**
- **Recalls of the cryogenic system**
- **Data management**
- **Overall availability**
- **Remarks and conclusions**

Description of the EFDA task

- **Work related to an EFDA task,**
- **Objective: enrich a fusion specific data collection**
- **Refers to systems relevant to ITER project**
- **Deliverable 1: Water cooling system**
- **Deliverable 2: Toroïdal field magnet safety system**
- **Deliverable 3: Cryogenic system**
- **Duration : 1 year**
- **Information required per component of the system**
  - Number of failures
  - Mean time between failures
  - Resulting downtime
  - Availability of the component
  - Associated maintenance

Recalls of the cryogenic system



TF coil cooling system

Recalls of the cryogenic system

	1.8 K			4.5K				80 K
Transient load	Heat load (kJ)	ΔT (K)	Recovery time	Heat load (kJ)	ΔT - casing (K)	ΔT - bath (K)	Recovery time	Heat load
PF cycle	30	0.02	4 min	120	0.7	0.1	4 min	-
Disruptions	50	0.04	12 min	1200	3.9	0.4	25 min	-
Fast Safety Discharge	235	0.12	35 min	400	1.8	0.15	8 min	-
Cleaning Discharge	0.2 / cycle		2 s	1.5 / cycle	0.3	0.25	2 s	-
Static load (vessel at 120°C)	120 to 160 W			300 W				12kW
Static load (baking at 200°C)	-			-				20 kW
Refrigerator power	300 W			800 W + 3 g/s (C.L)				16 kW + LN_2 (total = 30kW)

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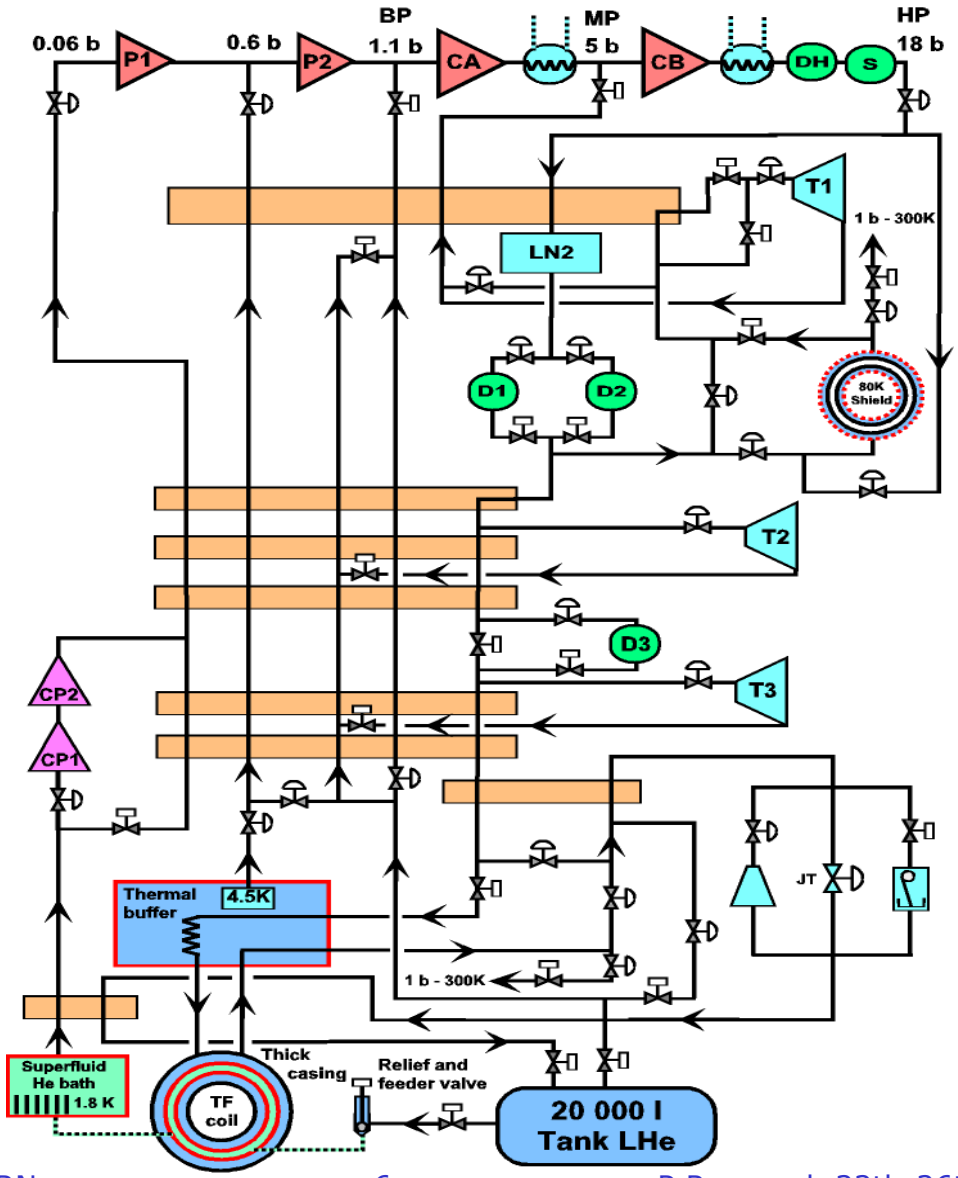
Recalls of the cryogenic system



Recalls of the cryogenic system

Main Cold components			
Turbine T1 AL C5-500	**In/out Temperature** 110/80K	**Power** 16kW	**Flow rate** 110g/s
Turbine T2 AL C3-500	**In/out Temperature** 50/30K	**Power** 2.8kW	**Flow rate** 24g/s
Turbine T3 AL C4-500	**In/out Temperature** 19/10K	**Power** 2.2kW	**Flow rate** 50g/s
Wet reciprocating engine AL/KPS model 1400	**In/out Temperature** 6/4.5K	**In/out Pressure** 18/1.2bar	**Flow rate** 10g/s
Cold compressor PF1 AL/S2M	**Suction conditions** 10mb/4.5K	**Compression ratio** 3	**Flow rate** 14g/s
Cold compressor PF2 AL/S2M	**Suction conditions** 34mb/10K	**Compression ratio** 2.3	**Flow rate** 14g/s
Liquid storages	20000l of LHe + 2 x 50000l of LN2		

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Recalls of the cryogenic system

Main Warm components			
Compressor C1 **STAL S7**	**In/out Pressure** **1/4.5bar**	**Flow rate** **101g/s**	**Electrical power of motor** **200kW**
Compressor C2 **STAL S73**	**In/out Pressure** **1/4.5bar**	**Flow rate** **101g/s**	**Electrical power of motor** **200kW**
Compressor C3 **STAL S51**	**In/out Pressure** **4.5/18bar**	**Flow rate** **144g/s**	**Electrical power of motor** **250kW**
Compressor C4 **STAL S57**	**In/out Pressure** **4.5/18bar**	**Flow rate** **218g/s**	**Electrical power of motor** **400kW**
Oil ring pump P1 **Alstom Hydro PL 160**	**In/out Pressure** **70/600mbar**	**Flow rate** **14 g/s**	**Electrical power of motor** **315kW**
Oil ring pump P2 **Alstom Hydro PL 50**	**In/out Pressure** **0.6/1bar**	**Flow rate** **60g/s**	**Electrical power of motor** **132kW**
Recovery compressor C7 **Sulzer type C5U**	**Pressure max** **200 bar**	**Flow rate** **10g/s**	**Electrical power of motor** **90kW**
Recovery compressor C8 **Sulzer type C5U**	**Pressure max** **200bar**	**Flow rate** **10g/s**	**Electrical power of motor** **75kW**
Gas bags	**160m3 + 360m3**		
HP storage	**Pressure max** **200bars**	**Whole capacity : 1500kg**	

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Data management

PHASE 1 : Extraction of data automatically recorded

From
- **Command-control system PANORAMA**

- **To find the stable operational modes and the transitory modes during which the component was required in service and to enter time corresponding**
- **To enter the time during which the component required in service was unavailable**

PHASE 2 : Comparison with various sources of information

- **PAVANE Incident database**

From
- **Computerized logbooks**
- **Operator interviews**

- **To check and discriminate the real origin of the unavailability of the component, because some were rather induced by operating conditions**

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Data management

PHASE 3 : Treatment of data

With o **Excel conversion, VB macros**

- **To identify the real availability times of the component compared to the real-time of operation requested**

PHASE 4 : Addition of the maintenance actions and costs

From o **Computerized logbooks**

- **To finalize the report**

◊ **Task closed in August 2008**

◊ **Easiest years for data extraction and retrieval : 2004-2007**

This huge work highlights the availability of the cryogenic system

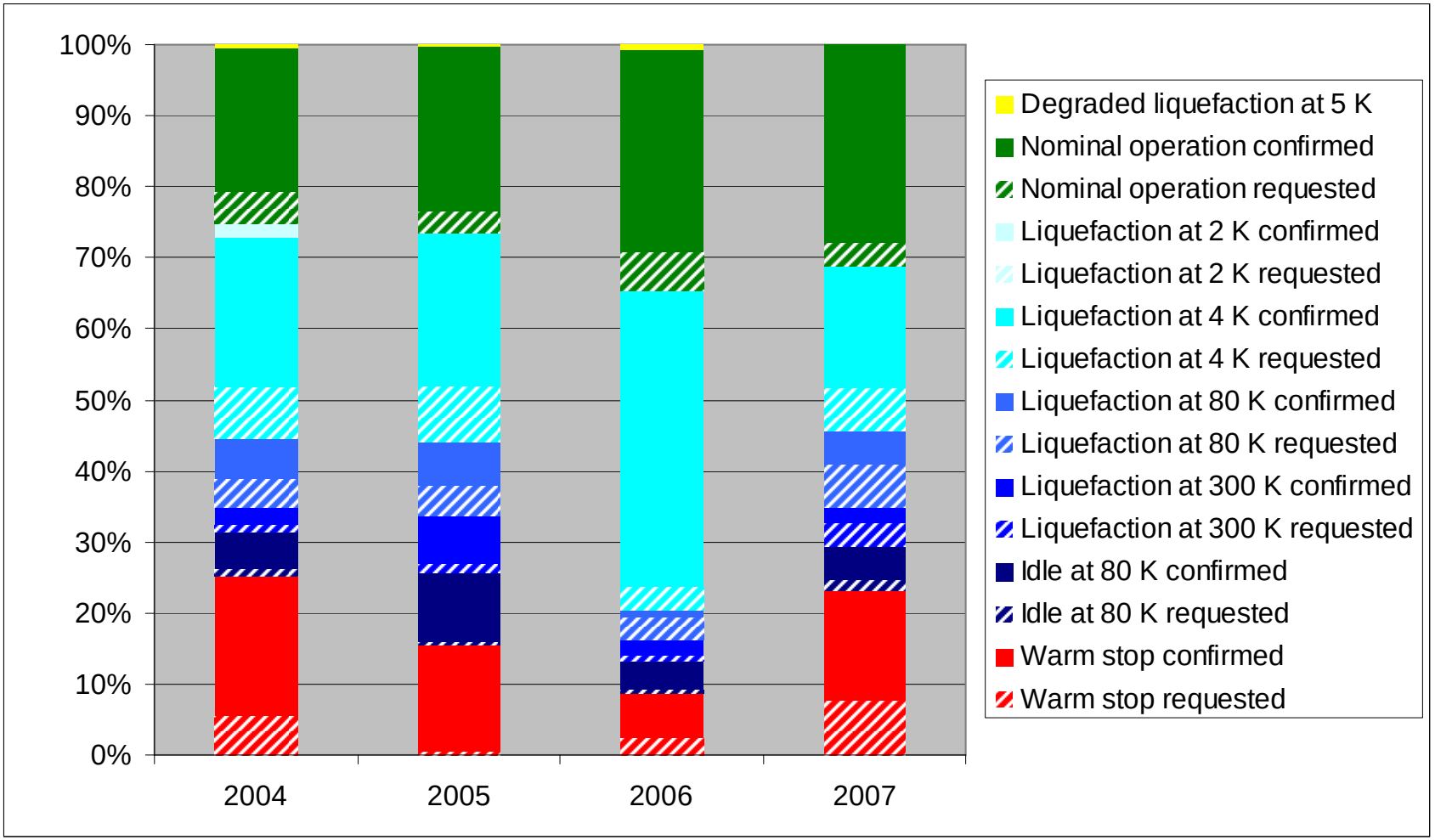
Overall availability

Time spent in the different operating modes from 2004 to 2007

	2004		2005		2006		2007	
Operating mode	**hours**	**totals**	**hours**	**totals**	**hours**	**totals**	**hours**	**totals**
Warm stop confirmed	1732 h	20 %	1311 h	15 %	543 h	6 %	1342 h	15%
Idle at 80 K confirmed	476 h	5 %	853 h	10 %	338 h	4 %	421 h	5 %
Liquefaction at 300K confirmed	222 h	3 %	577 h	7 %	192 h	2 %	192 h	2%
Liquefaction at 80 K confirmed	501 h	6 %	558 h	6 %	89 h	1 %	399 h	5 %
Liquefaction at 4 K confirmed	1841 h	21 %	1893 h	22 %	3645 h	43%	1512 h	17 %
Liquefaction at 2 K confirmed	177 h	2 %	0 h	0 %	0 h	0 %	0 h	0 %
Nominal operation confirmed	1770 h	20%	2036 h	23 %	2495 h	28 %	2445 h	28 %
Total time spent in **transitions**	2013 h	23 %	1518 h	17 %	1394 h	16 %	2440 h	28 %
TOTAL	8784 h	100 %	8760 h	100 %	8760 h	100 %	8760 h	100 %

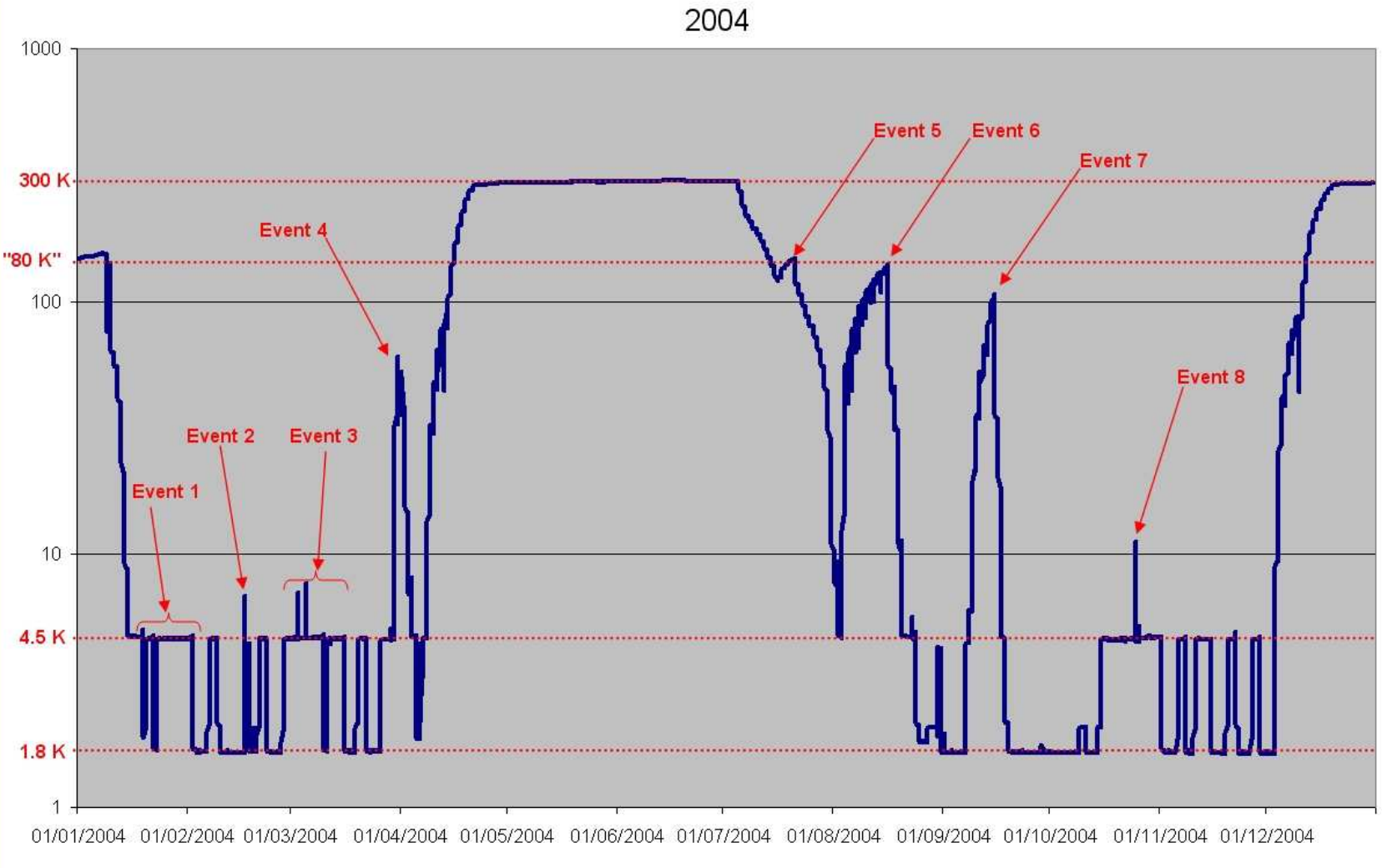
Overall availability

Relative importance of the different operating modes from 2004 to 2007



Overall availability (2004)

Toroidal magnet temperature throughout 2004



Overall availability (2004)

	Dates	What happened?	Number of days lost
Event 1	2nd half of January	Cooldown test at 2 K, toroidal magnet test at 1.8 K, then baking of the vacuum vessel at 200°C while the cryo stayed at 4.5 K until campaign start	NOT A FAILURE
Event 2	17/02/2004	Turbine replacement	1 day lost
Event 3	02/03/2004-10/03/2004	P1 pump electrical failure (motor and circuit breaker)	6.5 days lost
Event 4	30/03/2004-05/04/2004	WRE failure (bearings damaged)	4 days lost
	06/04/2004-08/04/2004	Cold pumps failure (clogging of a valve of the He/He heat exchanger circuits)	3 days lost
Event 5	3rd week of July	1st liquefaction at 80 K, then cooldown test to 4.5 K after summer warm stop	NOT A FAILURE
Event 6	1st week of August	Cadarache 1-week closure for summer holidays	NOT A FAILURE
Event 7	07/09/2004-17/09/2004	C3 compressor failure (bearings damaged)	8.5 days lost
Event 8	2nd half of October	Test of the auxiliary cold box and water leak (not on the cryogenic system)	NOT A FAILURE

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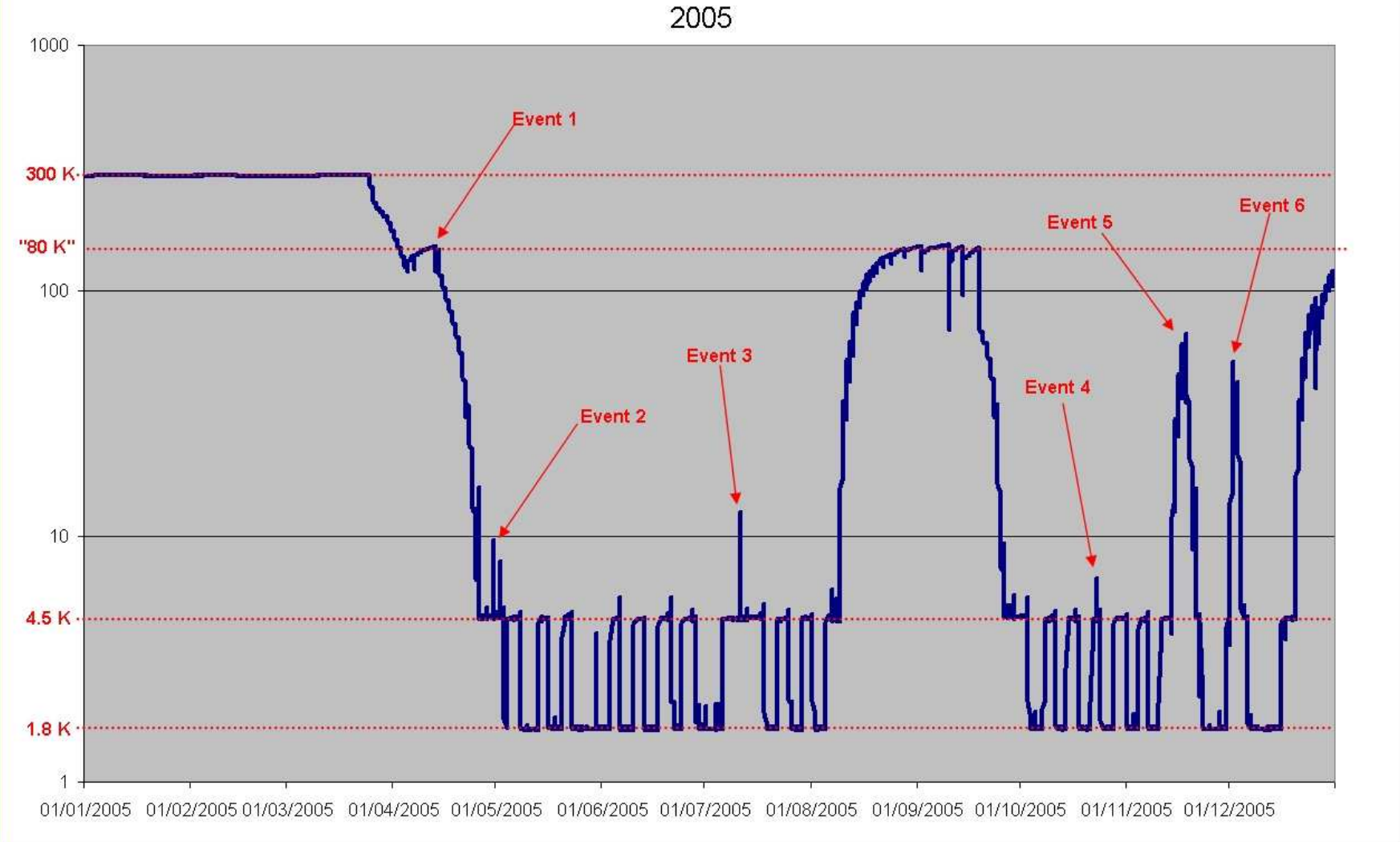
Overall availability (2005)

Toroidal magnet temperature throughout 2005



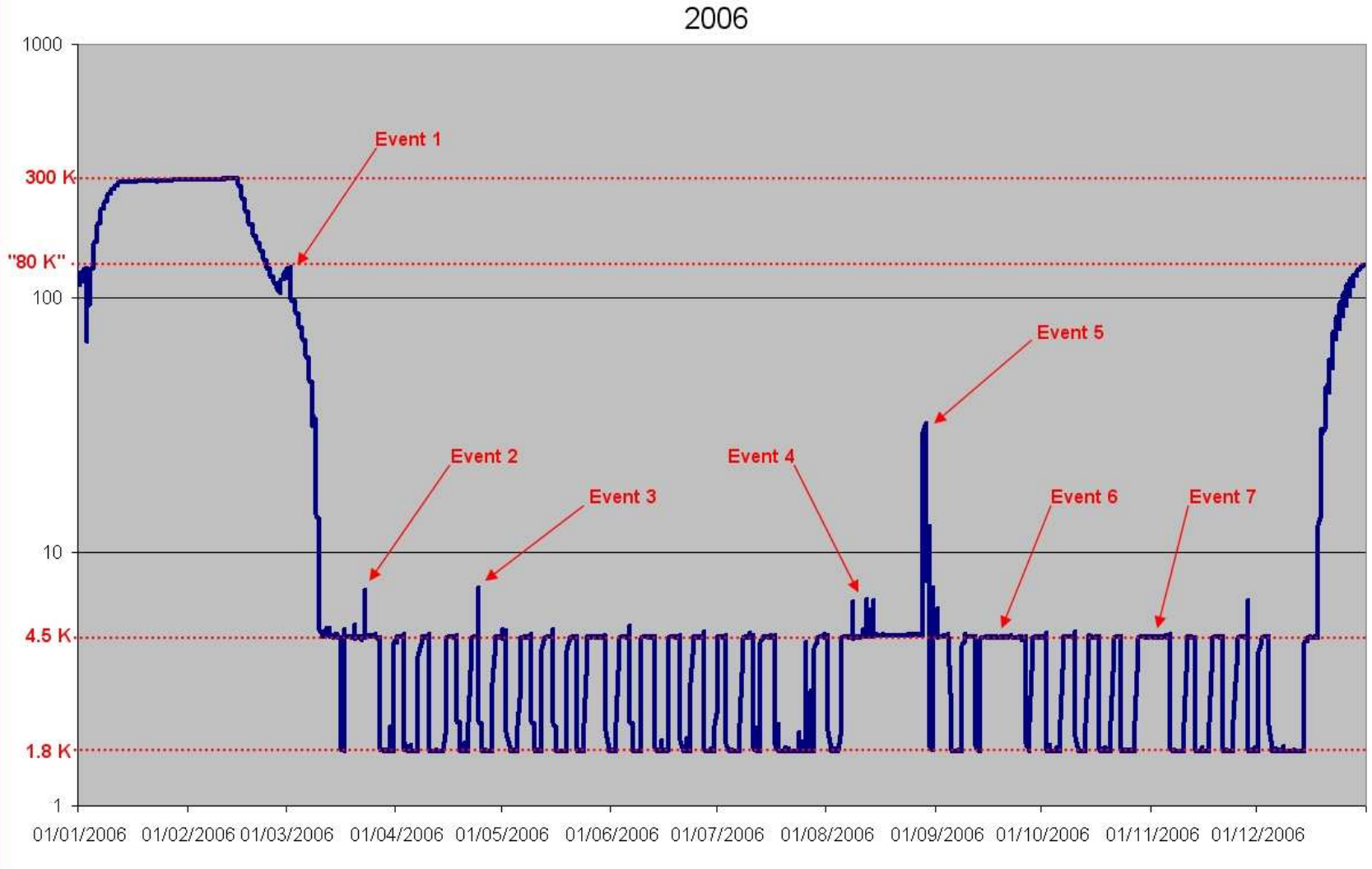
Overall availability (2005)

Notable events in 2005

	Dates (dd/mm/yyyy)	What happened?	Number of days lost
Event 1	05/04/2005-13/04/2005	1st liquefaction at 80 K	NOT A FAILURE
Event 2	30/04/2005	Electrical failure	No day lost
	1st week of May	Cooldown and toroidal field test at 1.8 K	NOT A FAILURE
Event 3	01/07/2005-19/07/2005	Test of the auxiliary cold box and removal of ICRF antennas while at 4.5 K (later reinstalled in the "unplanned" maintenance period in Sept-Oct)	NOT A FAILURE
Event 4	23/10/2005	Power supply failure due to storms	Not related to the cryogenic system
Event 5	15/11/2005-18/11/2005	Water in oil circuits and in 1st He/He heat exchanger	5 days lost to HUMAN ERROR
Event 6	01/12/2005-06/12/2005	Water in 1st He/He heat exchanger	3 days lost to HUMAN ERROR

Overall availability (2006)

Toroidal magnet temperature throughout 2006



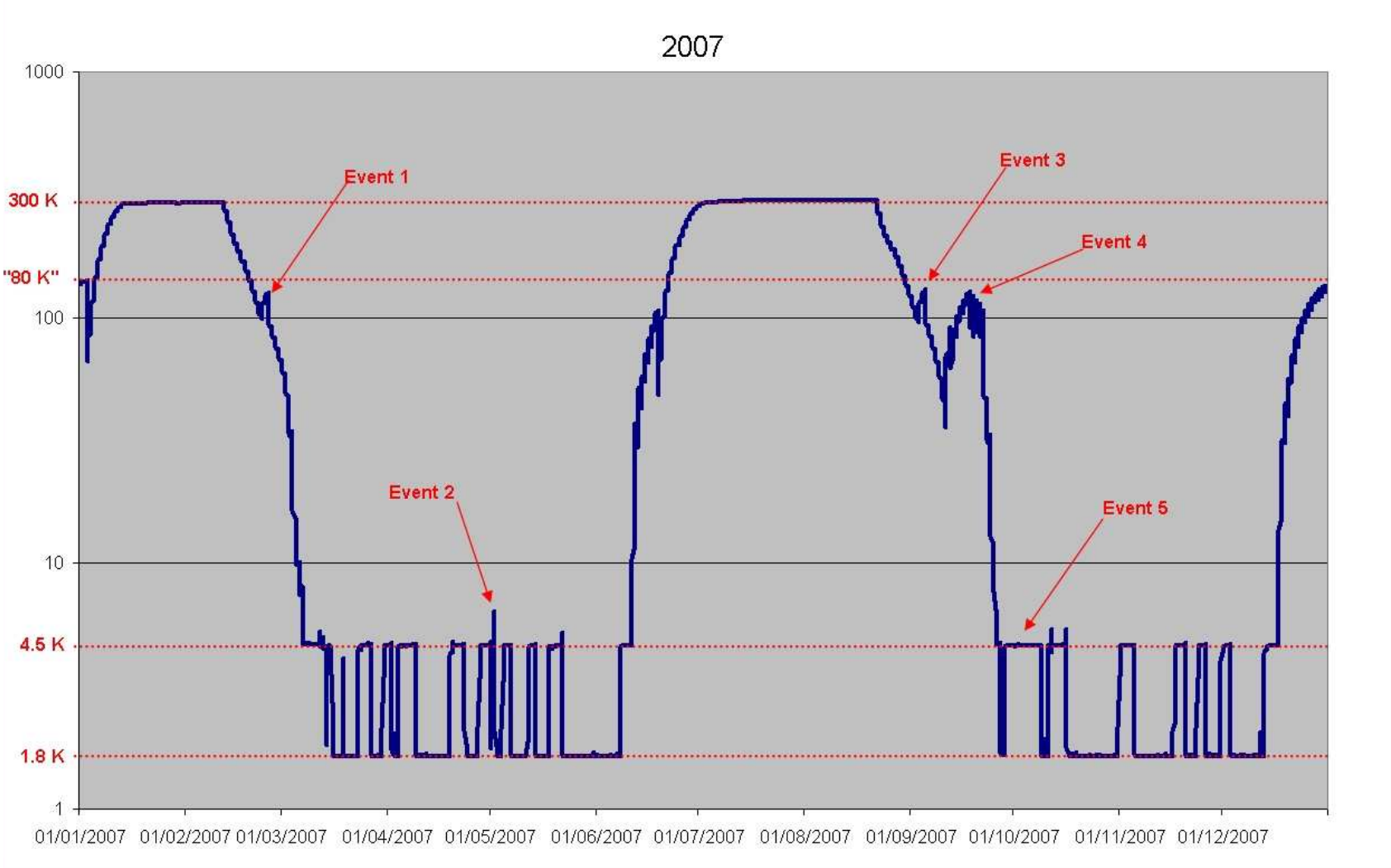
Overall availability (2006)

Notable events in 2006

	Dates (dd/mm/yyyy)	What happened?	Number of days lost
Event 1	3rd week of February	1st liquefaction at 80 K	NOT A FAILURE
Event 2	2nd half of March	Cooldown and toroidal field tests at 1.8 K then 1 week at 4.5 K for baking of the vacuum vessel	NOT A FAILURE
Event 3	24/04/2006	Cold pumps stop (compressed air supply failure)	Not related to the cryogenic system
Event 4	2nd week of August	Shutdown due to storms and Cadarache 1-week closure for summer holidays	Not related to the cryogenic system
Event 5	Last week of August	Test of the auxiliary cold box, then general power supply failure on Cadarache	Not related to the cryogenic system
Event 6	2nd & 3rd week of Sept.	Water leak on water cooling system	Not related to the cryogenic system
Event 7	Last week of October	Legal holidays	NOT A FAILURE

Overall availability (2007)

Toroidal magnet temperature throughout 2007



Overall availability (2007)

Notable events in 2007

	Dates (dd/mm/yyyy)	What happened?	Number of days lost
Event 1	2nd half of February	1st liquefaction at 80 K (1st campaign)	NOT A FAILURE
Event 2	20/04/2007	Replacement of compressor C2 motor	1 day
	02/05/2007	Replacement of P2 coupling	1 day
Event 3	1st week of September	1st liquefaction at 80 K (2nd campaign)	NOT A FAILURE
Event 4	Mid-September	Tests of C3 compressor on backup power supply	NOT A FAILURE
Event 5	End of September / beginning of October	Cooldown and toroidal test at 1.8 K then baking of the vacuum vessel at 4.5 K	NOT A FAILURE

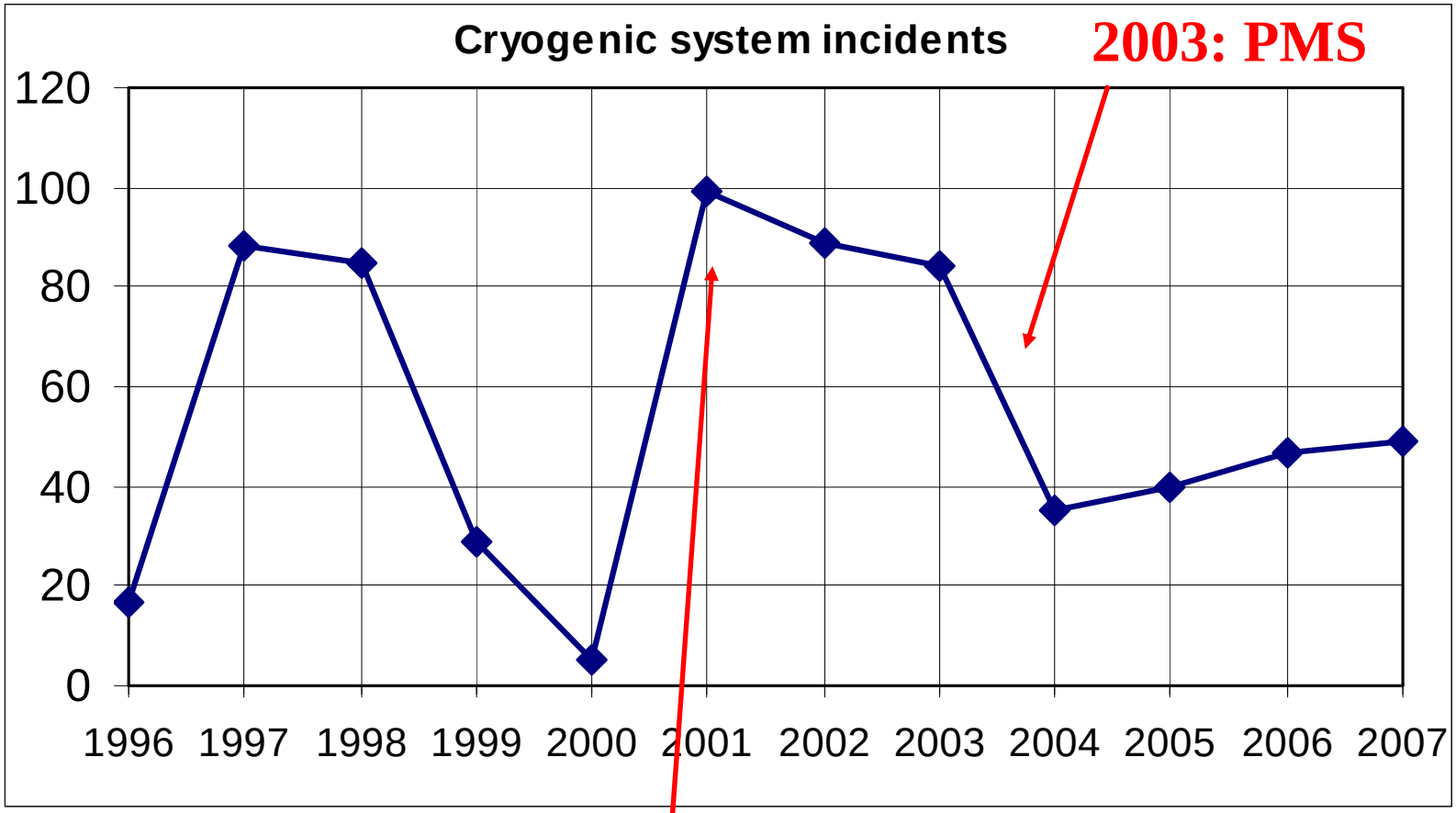
Overall availability

Availability relatively to the plasma experimental campaign

	2004		2005		2006		2007	
Operating mode	*hours*	*total*	*hours*	*total*	*hours*	*total*	*hours*	*total*
Nominal operation confirmed	1770 h	20%	2036 h	23 %	2495 h	28 %	2445 h	28 %
Availability of the cryogenic system**	76.2 % (relatively to experimental campaigns)		92.9 % (relatively to experimental campaign)		100 % (relatively to experimental campaign)		97.3 % (relatively to experimental campaigns)	
Availability of the whole Tore Supra installation	53 %		54 %		76 %		80 %	

Conclusion

Number of failures per year – CRYO-PLANT PAVANE Source only



Conclusion

More than 20 years after its commissionning, and without any large updating, the cryogenic system of Tore Supra is operated in quasi-industrial conditions with a satisfying level of performance and availability.

Keeping a human presence on the site, performing daily inspections of the critical components and a reliable and ergonomic control-command system make possible an increase of availability during the 4 last years.

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Extra slide

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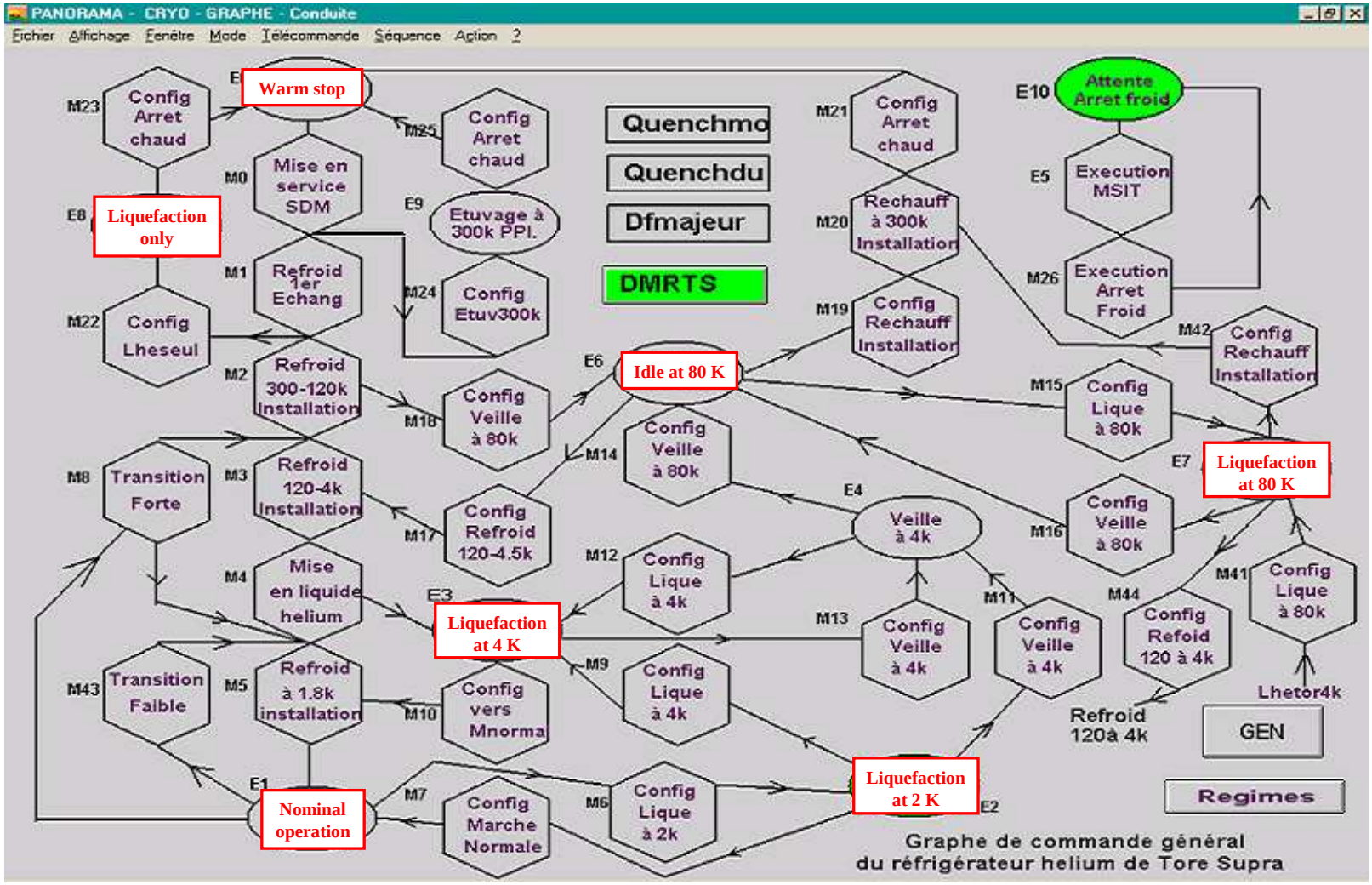
Extra slide



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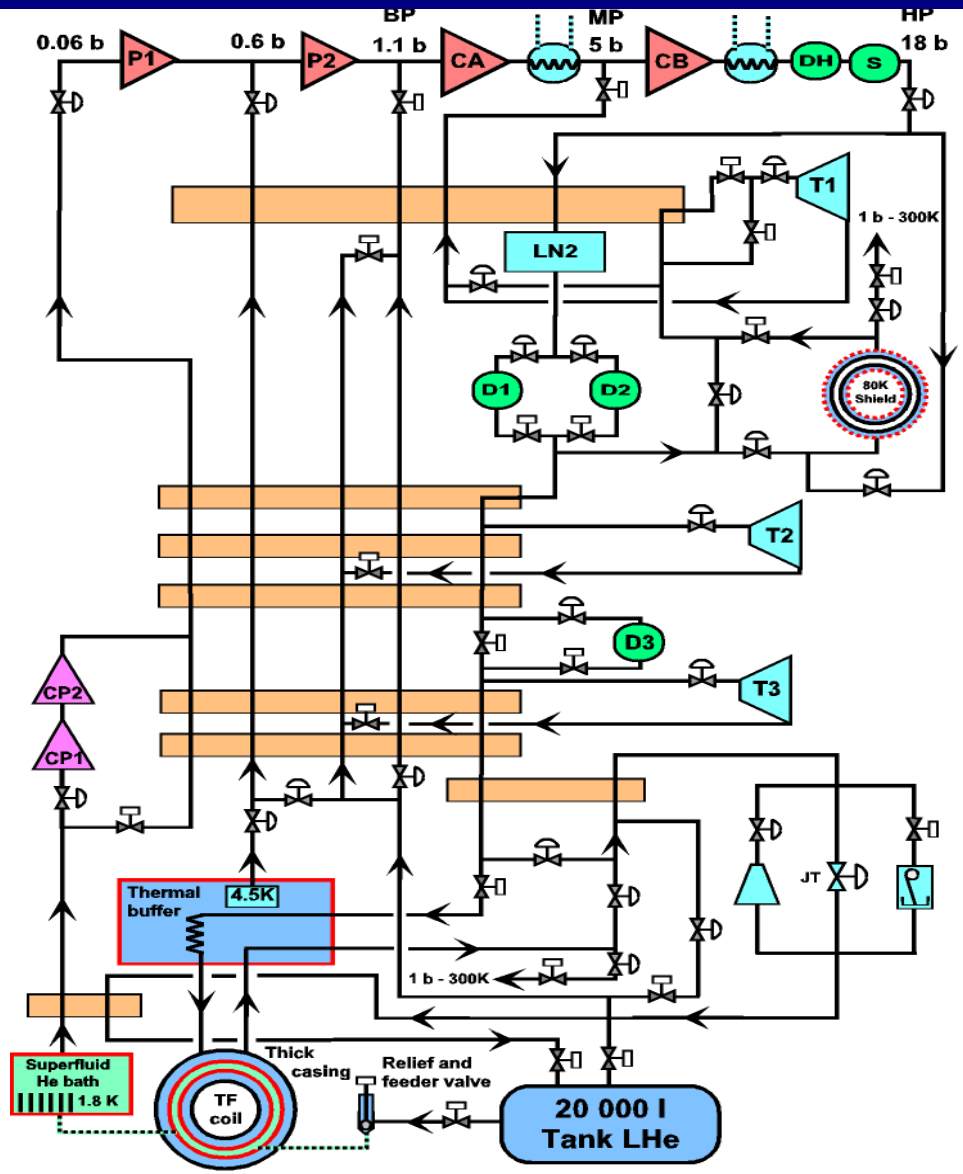
Nominal operation



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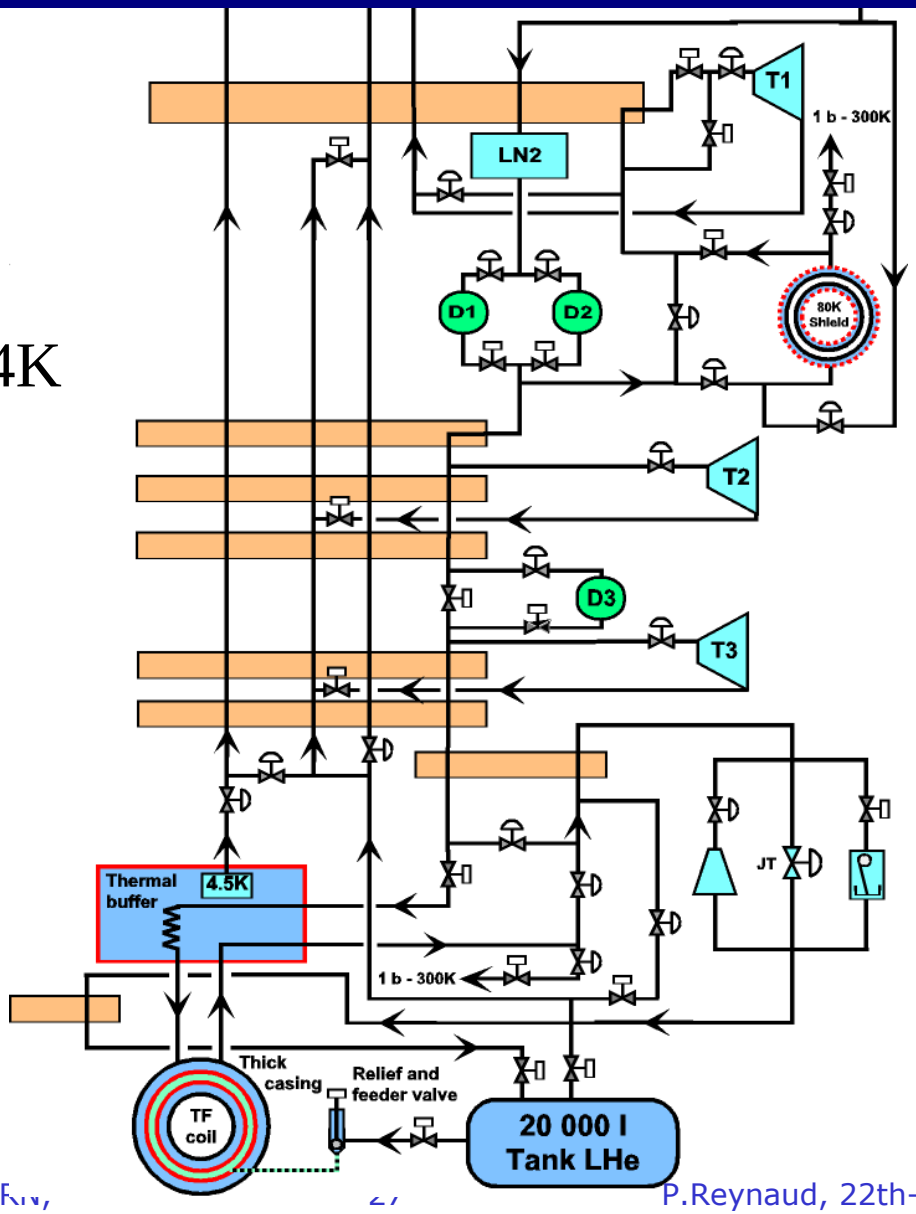
Liquefaction at 4K



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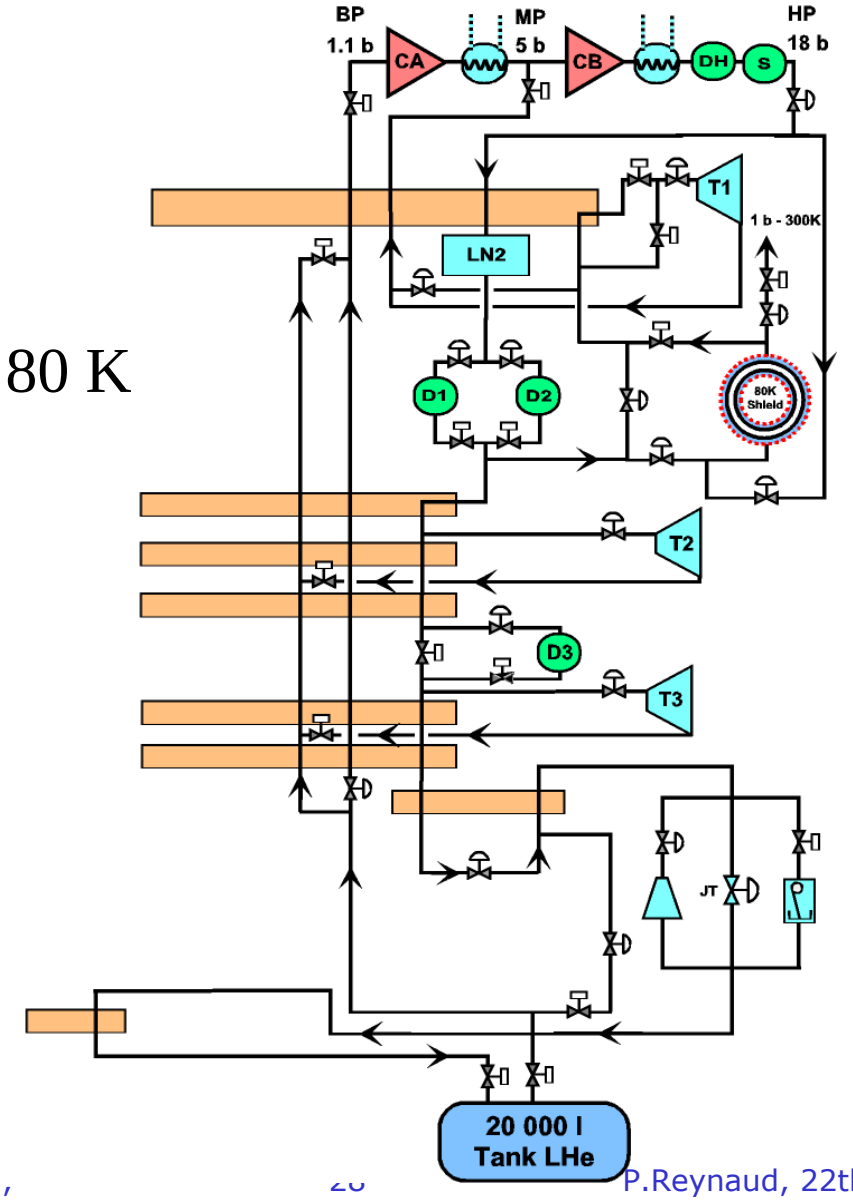
Liquefaction at 80 K



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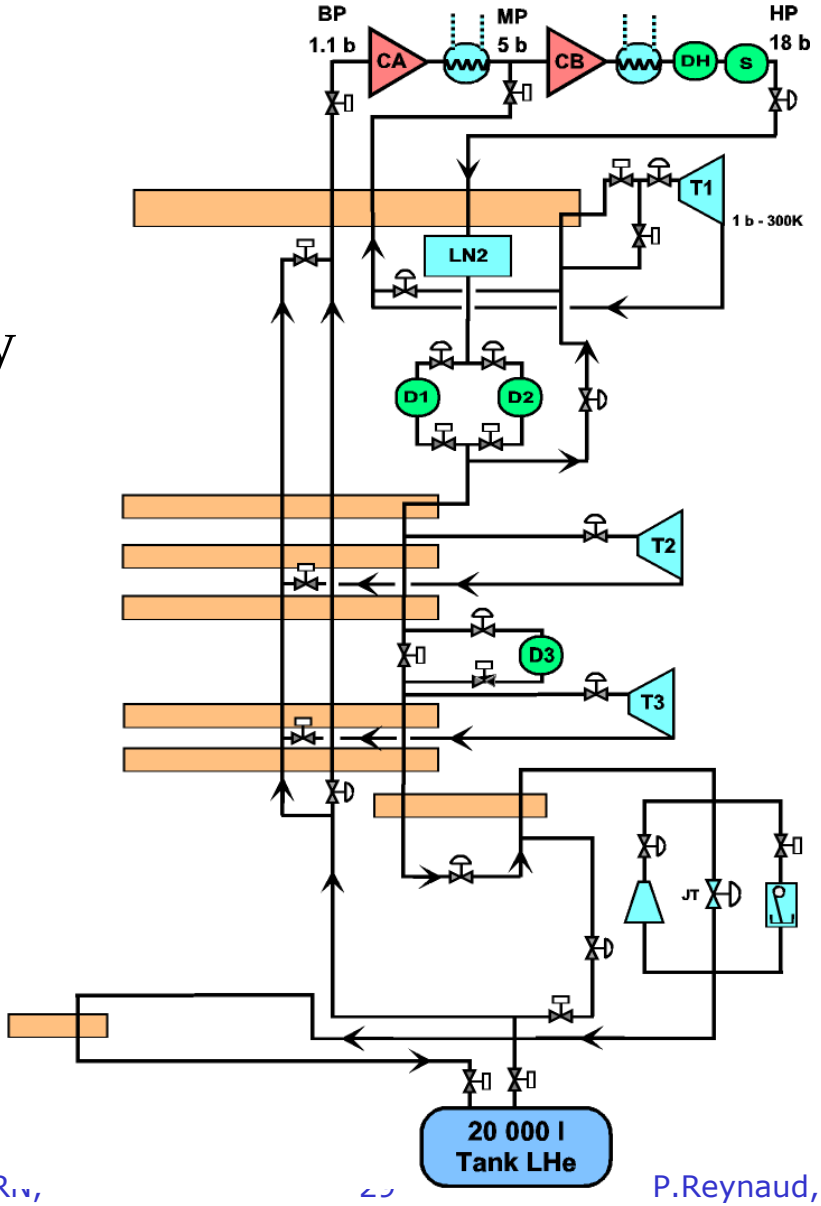
Liquefaction only



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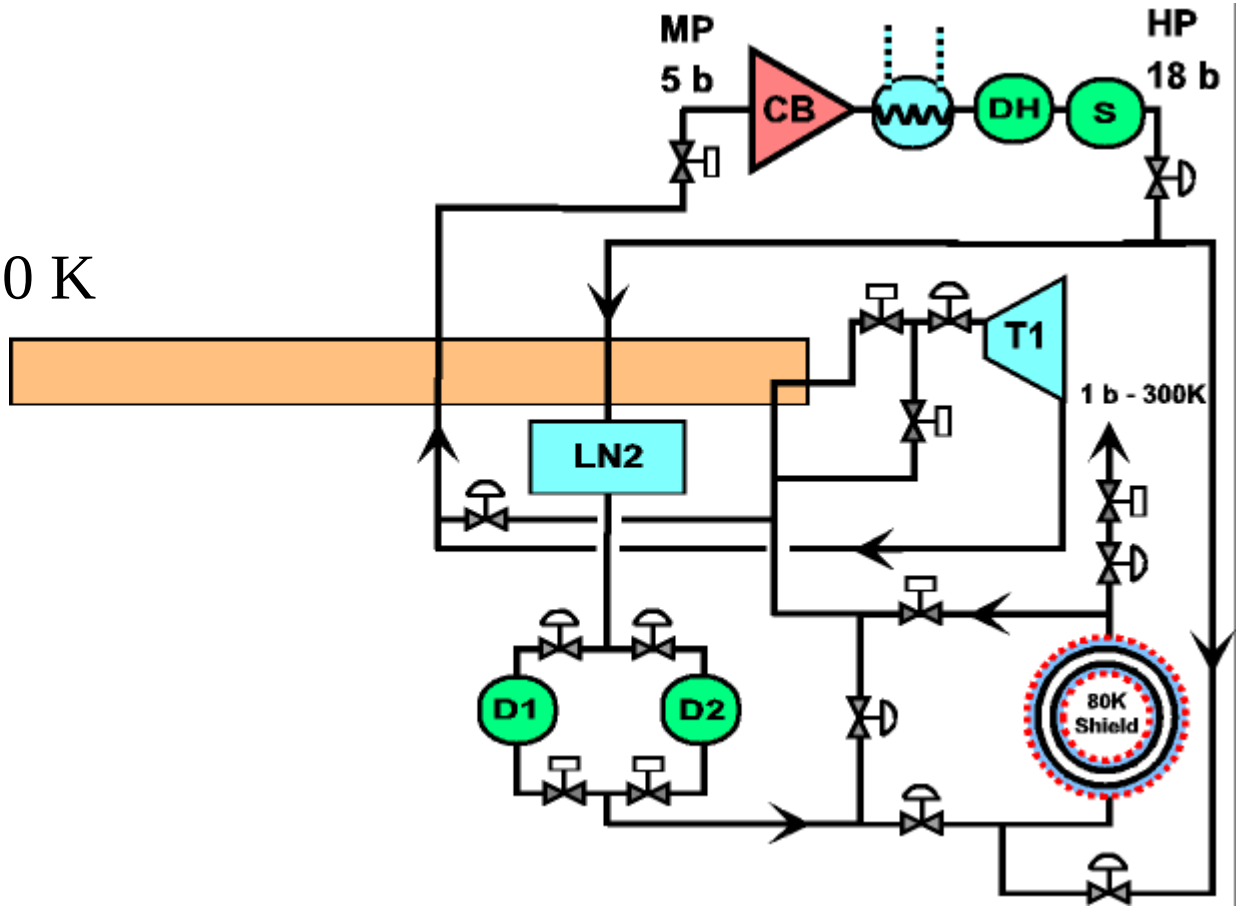
Stand-by at 80 K



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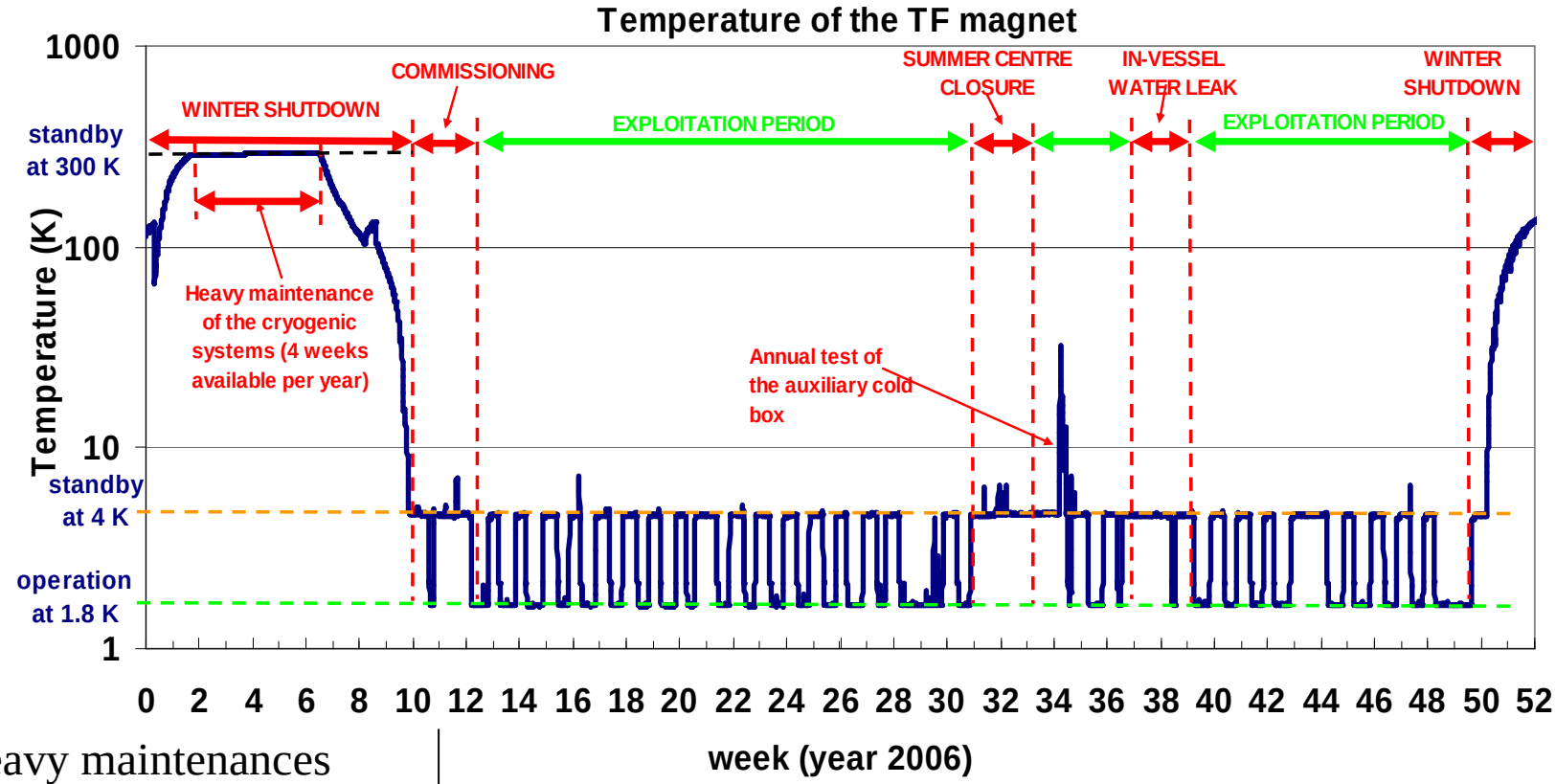

Heavy maintenances
~ 3 months per year
Regulatory controls for
Cryogenic system , CWS
Power Supplies
Tore Supra Configuration

Plasma Operation rhythm ~ 40 hours a week
4 days a week : TF magnet at 1.8K
3 days at 4.2K w.e. and maintenance day (Monday)

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Extra slide

- **PAVANE database: from 1996 up to now**
  - » Data related to tests and plasma discharges
  - » Data related to failures
  - » A few continuous data but mainly reports from different systems operators

Extra slide

- **PEGASE database: from mid-2003 up to now**
  - » Operating parameters automatically collected from systems Command-Control
  - » Continuously collected data, stocked with a 3s interval, but only retrieved from the database 5000 points at a time, for any given length of time:
    - 5000 points/year > ca. 1h45 interval
    - 5000 points/month > ca. 9min interval

Extra slide

- **Log books from the start of Tore Supra (1989) up to now**
  - » Data related to tests and plasma discharges
  - » Data related to failures
- **Incidents reports**
- **Maintenance reports**
- **Operators interviews**

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Extra slide