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Maintenance for the TE-CRG cryogenic installations or Managing several thousand interventions with maintenance plans

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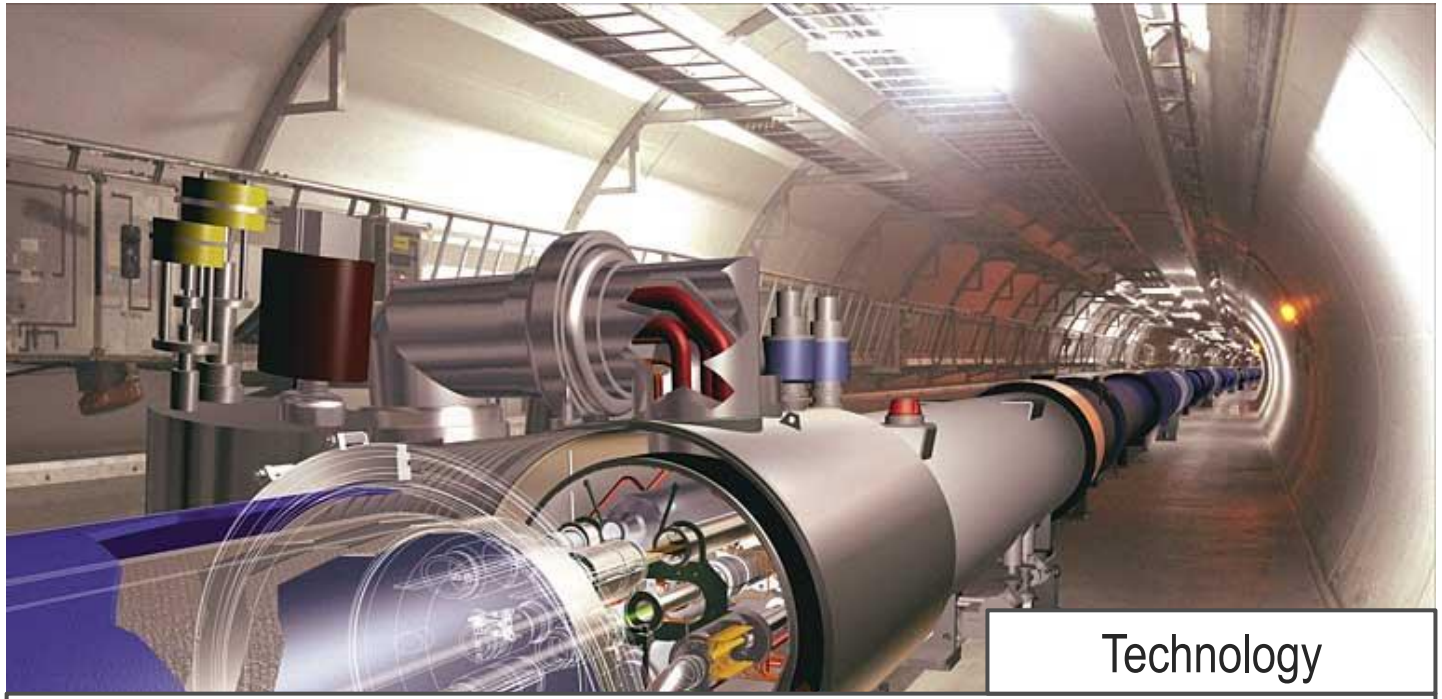
on behalf of the "Cryogenics Group" Technology Departement

Presentation Outline

- INTRODUCTION: Cryogenic Installations of LHC
- HIGHLY COMPLEX Installations
- FOCUS on Maintenance Plans Organisation
- SUMMARY
- PROSPECTS

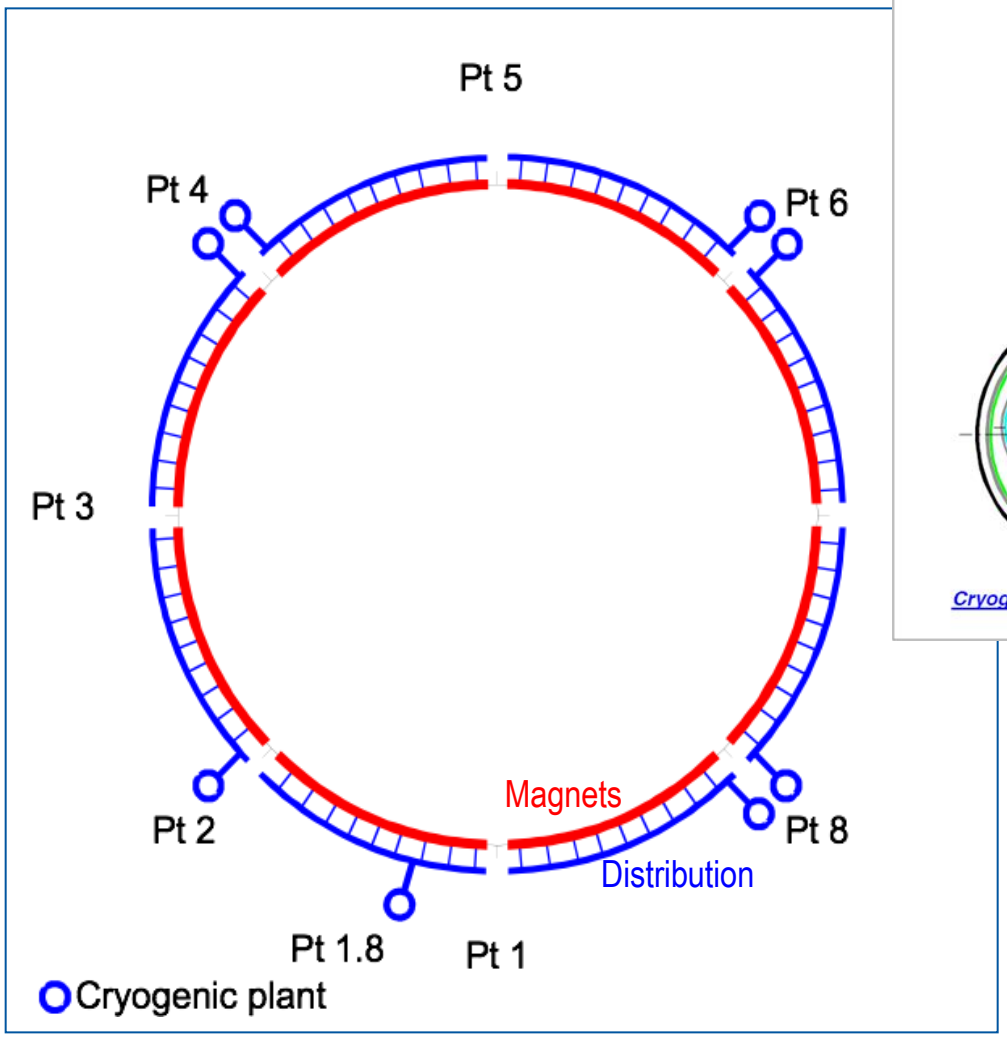
The LHC Accelerator

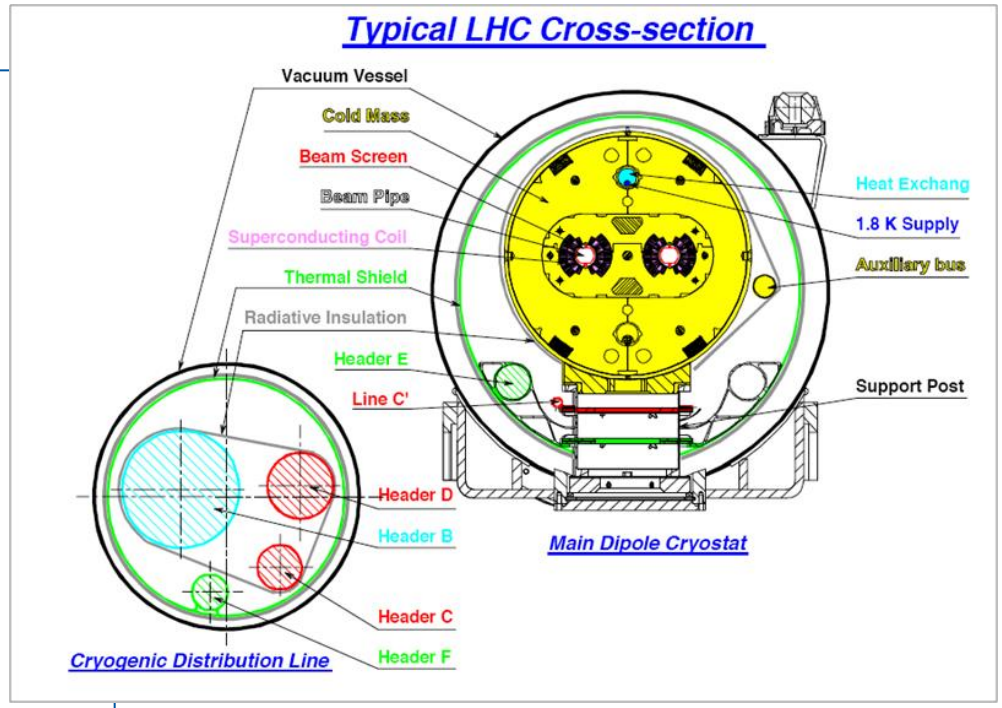


Technology

- 1800 Supraconducting Magnets
- 24 km @ 1.8 K
- 8 x 18kW @ 4.5 K
- 36 000 t @ 1.9K
- 150 t He Inventory (LHC + strategy)=7,5 MCHF

LHC Cryogenics global cooling scheme





5+2 sites equipped with large Helium refrigerators

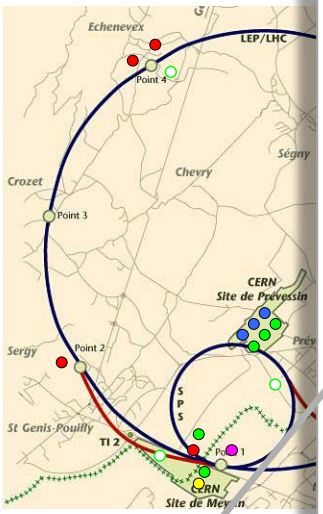
Large variety of sub-systems installed in caverns and tunnels

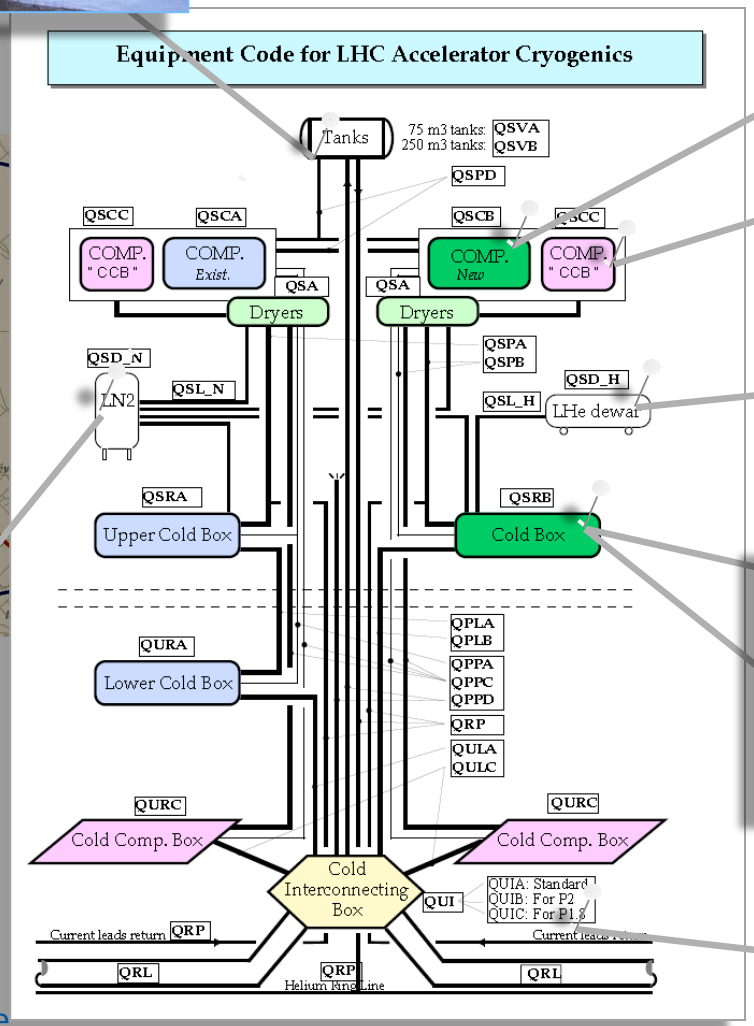
The refrigerators

helium storage

compressor stations

liquid helium storage





cold boxes

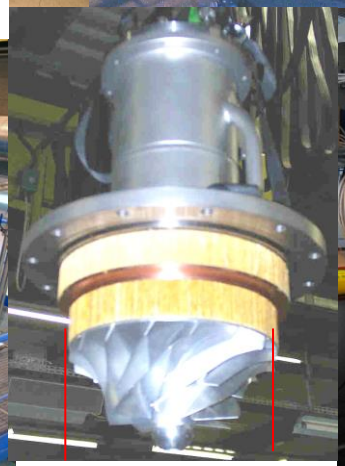
helium transfer line

liquid nitrogen storage

Some Details of LHC cryogenic hardware

33 kW @ 50 K to 75 K - 23 kW @ 4.6 K to 20 K - 41 g/s liquefaction

4.2 MW



Diam: 250mm

48 boxes

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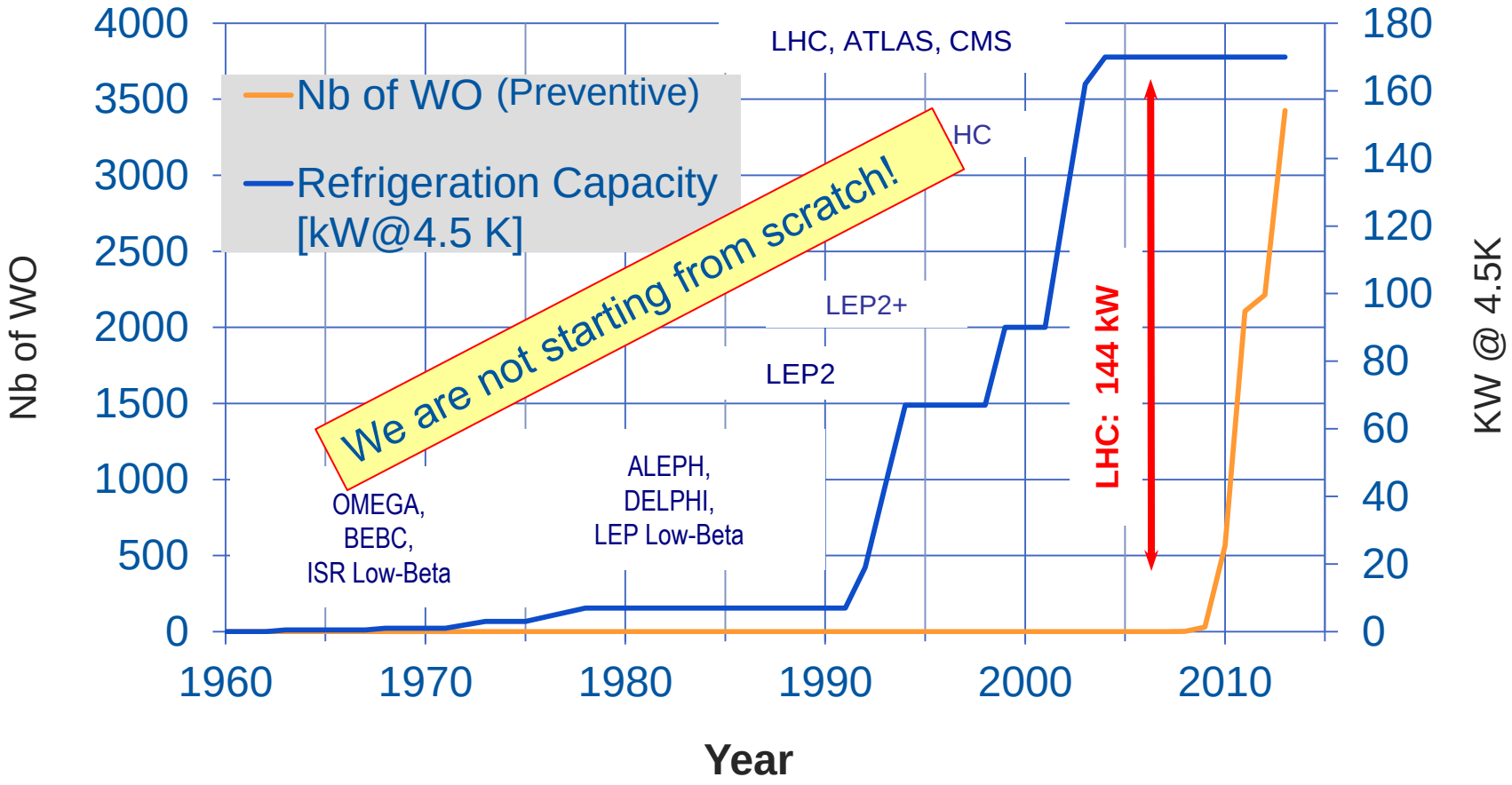
Some global comparisons



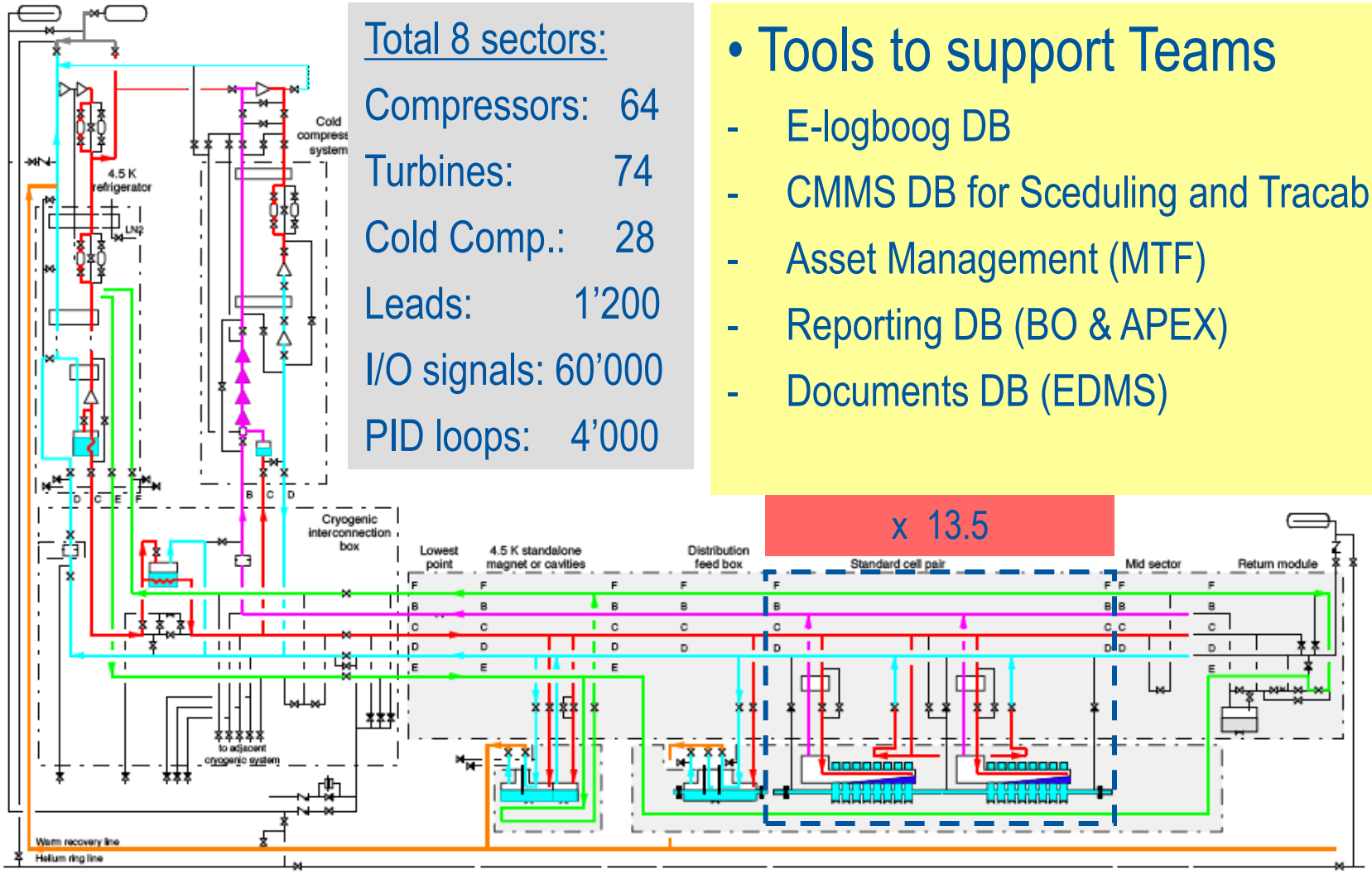
DATA Base Evolution: Paper → XL sheets → Infor

Global Reliability Challenges

There is a vast number of components

Number of components (example)	no./Anz.
Components	
Filters	1070
Compressors	110
Oil pumps, vacuum pumps	820
Safety valves	~2'600
Valves (manual, automatic)	15'110
Motors	325
Analysers	175
Heat exchangers	350
Transmitters, switches, indicators	~11400
Total (maintained components)	**~36'240**
Replacement value maintained components	**~~100MCHF**
Replacement value installed components	**300-400MCHF**
Maintenance budget	**~~3MCHF**

1/8e of LHC: production-distribution-magnets



Total 8 sectors:

Compressors: 64

Turbines: 74

Cold Comp.: 28

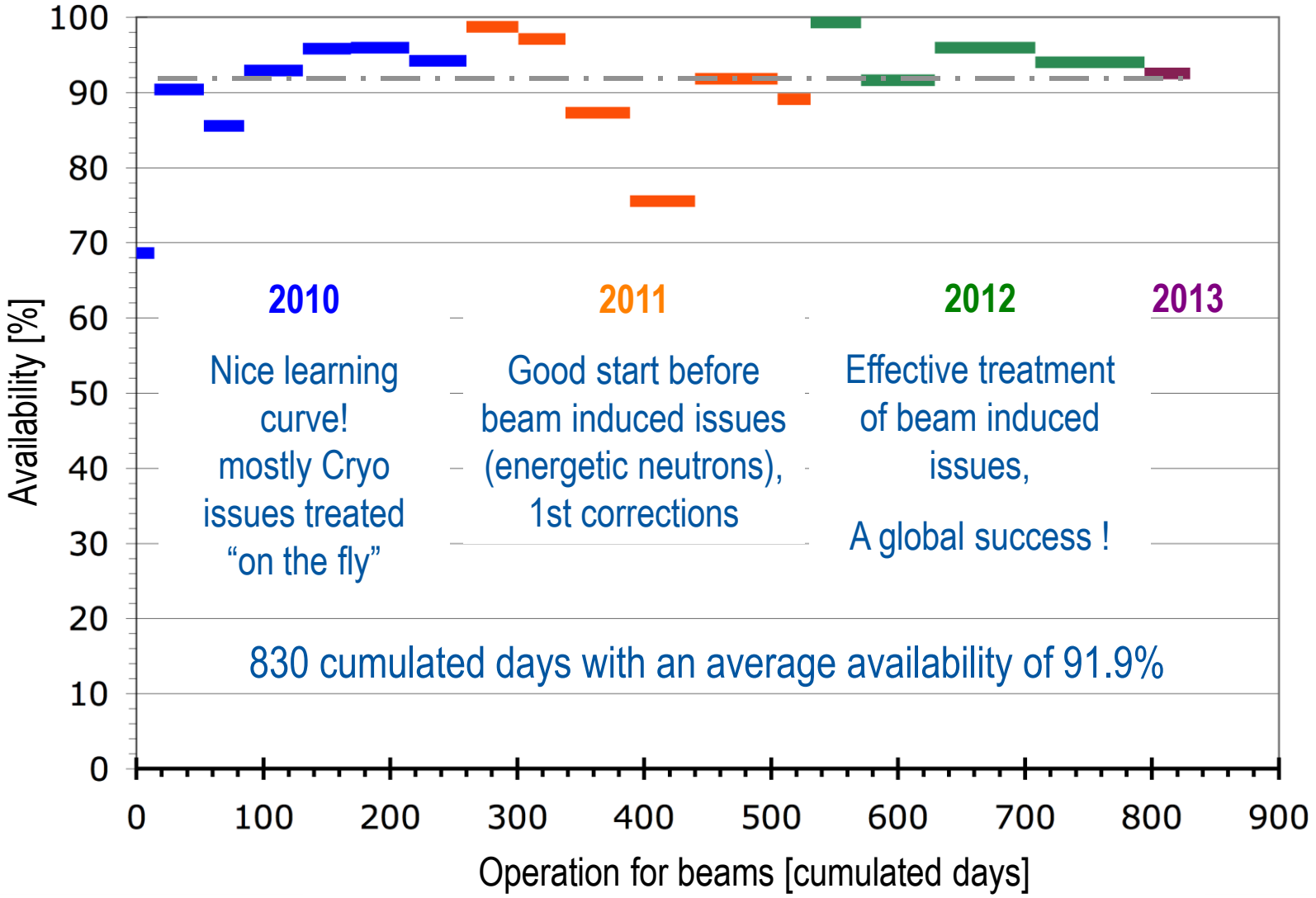
Leads: 1'200

I/O signals: 60'000

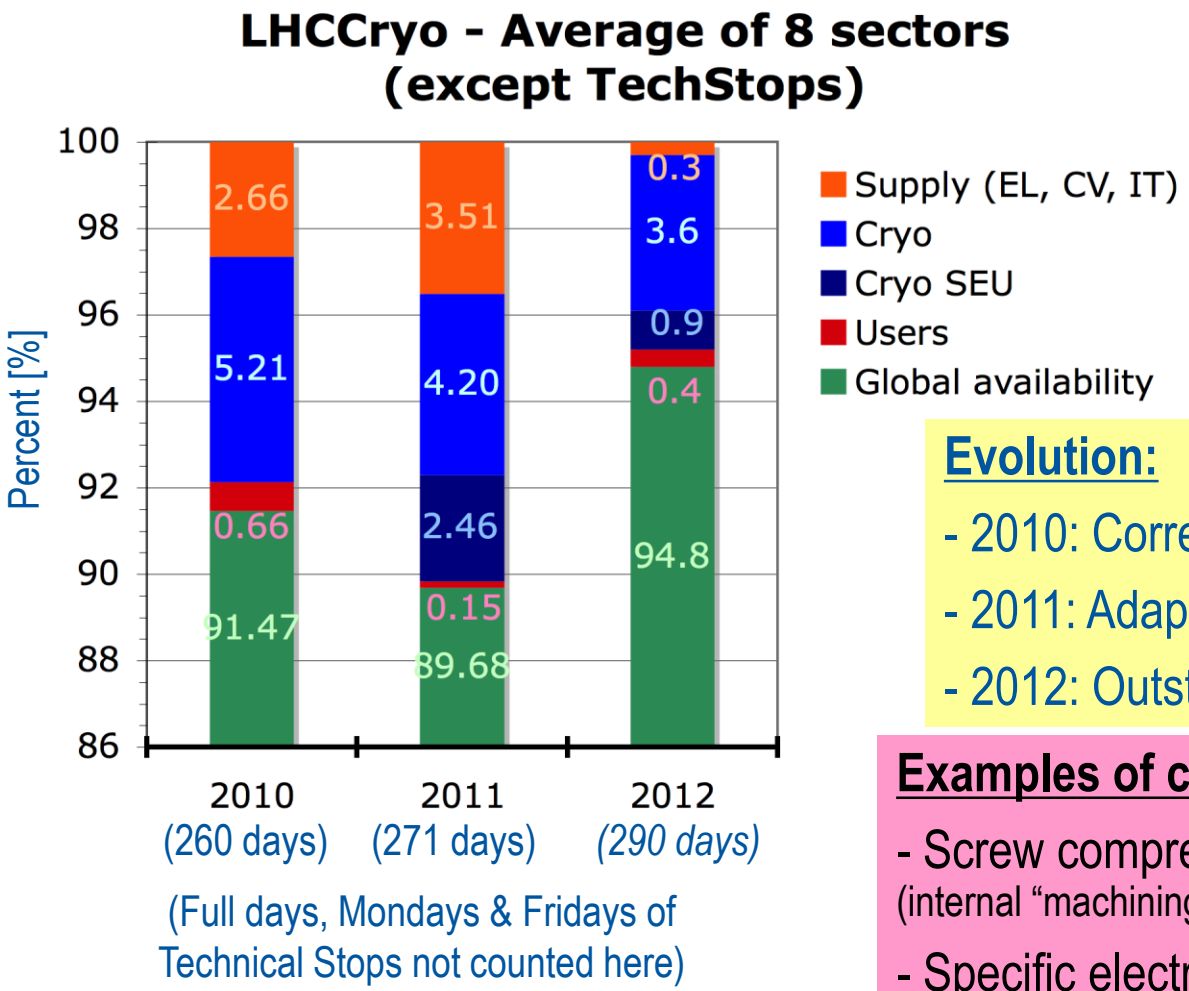
PID loops: 4'000

- Tools to support Teams
  - E-logboog DB
  - CMMS DB for Sceduling and Tracability
  - Asset Management (MTF)
  - Reporting DB (BO & APEX)
  - Documents DB (EDMS)

LHC Cryo global availability



Performance and origin of downtine



(Full days, Mondays & Fridays of Technical Stops not counted here)

Global availability
as seen by LHC during beam operation periods

Others
according to relative ratio of their average for the 8 sectors

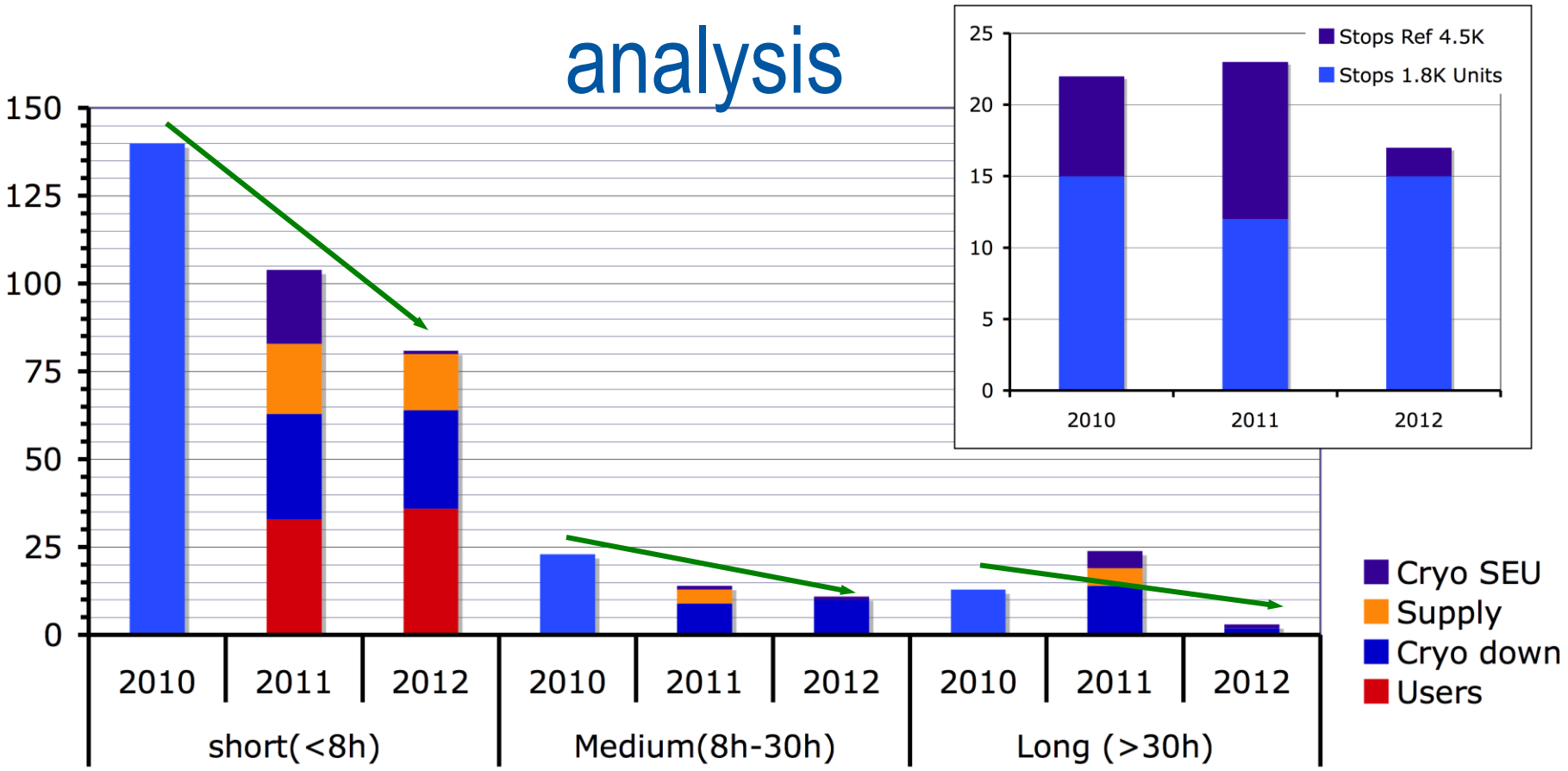
Evolution:

- 2010: Correcting early Cryo bugs
- 2011: Adapting to SEU (corrected @Xmas)
- 2012: Outstanding performance !

Examples of corrective actions:

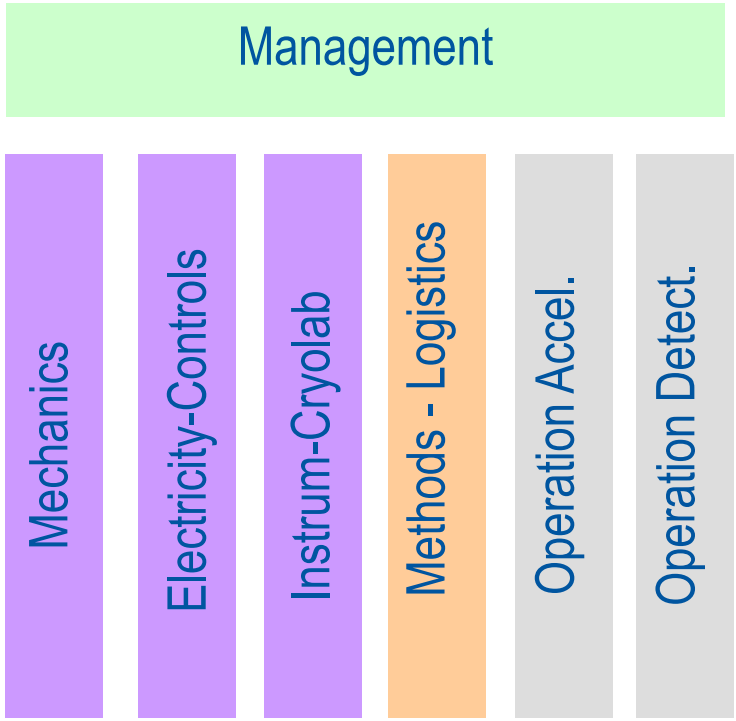
- Screw compressor
(internal "machining"due to damaged balancing piston)
- Specific electronic controler failure: Mecos …
- Instrumentation: valve actuator, sensor, …

Origin of downtime, systematic analysis



From the books:		
Immediate effect of (good!) practice	Annoying if frequent, to be kept low with moderate efforts	Serious cases requiring specific monitoring and significant efforts

A structure adapted to the complexity



- Management: 2 pers.
- Electrical support: 11 pers.
- Mechanical support 12 pers.
- Instrumentation support +Cryolab: 10 pers.
- Methods & logistics: 7 pers.

- Operation LHC: 20 pers.
- Operation Detectors: 12 pers.

Maintenance level 1 & diagnostics process

Other maintenance levels & methods

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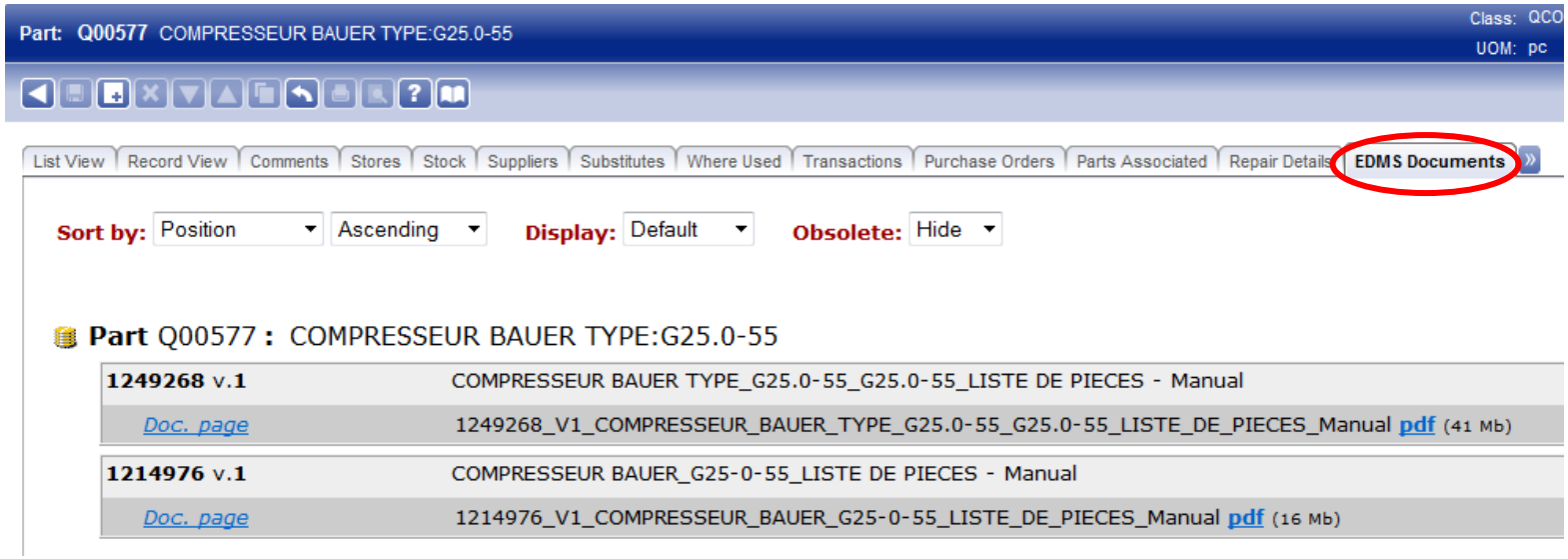
How it works with compressors

- Class
- Categories
- Association Position /Asset
- Association Asset/Part
- Models

Class	Category	Position	Asset	Description	Part
Begins w	Begins with	Begins with	Begins with	Begins with	Begins with
			Q	compresseur	
Q4CC	QKCCPHP	QSX1H-M-K1	QCCP-BUR001	Compresseur à pistons VHP	Q00105
Q4CC	QKCCPHP	QSX1H-M-K3	QCCP-BAU001	Compresseur à pistons VHP	Q00577
Q4CC	QKCCPHP	QSC1H-N-K1	QCCP-BUR006	Compresseur à pistons VHP	Q00123
Q4CC	QKCCPHP	QSC1H-N-K2	QCCP-BUR007	Compresseur à pistons VHP	Q00123
Q4CC	QKCCPHP	QLG1H-S-CPR1	QCCP-BUR003	Compresseur à pistons VHP	Q00108
Q4CC	QKCCPHP	QLG1H-S-CPR2	QCCP-BUR004	Compresseur à pistons VHP	Q00123
Q4CC	QKCCPHP	QLG1H-S-CPR3	QCCP-BUR005	Compresseur à pistons VHP	Q00123
Q4CC	QKCCPHP	QSX1H-M-K2	QCCP-BAU003	Compresseur à pistons VHP	Q00577
Q4CC	QKCCV	QLCWS-S-CP1	QCCV-KAE012	Compresseur à vis	Q00827
Q4CC	QKCCV	QLCWS-S-CP3	QCCV-KAE014	Compresseur à vis	Q00827
Q4CC	QKCCV	QSCCB-4-C1-2	QCCV-MYC002	Compresseur à vis	Q03407
Q4CC	QKCCV	QSCCB-8-C1-2	QCCV-MYC004	Compresseur à vis	Q03407
Q4CC	QKCCV	QLCWS-S-CP2	QCCV-KAE013	Compresseur à vis	Q00827
Q4CC	QKCCV	QSCCA-6-C01	QCCV-KAE005	Compresseur à vis	Q07160
Q4CC	QKCCV	QSCCA-6-C02	QCCV-KAE006	Compresseur à vis	Q07160
Q4CC	QKCCV	QSR1H-M-CP165	QCCV-KAE010	Compresseur à vis	Q00827
Q4CC	QKCCV	QSC2H-A-2C1120	QCCV-HOW004	Compresseur à vis	Q00575
Q4CC	QKCCV	QSCBN-A-C01	QCCV-KAE011	Compresseur à vis	Q00827
Q4CC	QKCCV	QSC2H-N-CP7	QCCV-SUL001	Compresseur à vis	Q01144
Q4CC	QKCCV	QSU1H-M-CP163	QCCV-KAE016	Compresseur à vis	Q00827
Q4CC	QKCCV	QSC1H-S4-C1	QCCV-KAE018	Compresseur à vis	Q01467
Q4CC	QKCCV	QSC1H-A-CP6	QCCV-HOW007	Compresseur à vis	Q01588
Q4CC	QKCCV	QSC1H-8C-C01	QCCV-AERB13	Compresseur à vis BP	Q00130
Q4CC	QKCCV	QLC2H-ZO	QCCV-STAB27	Compresseur à vis BP	Q03053
Q4CC	QKCCV	QSCA-4-CP1	QCCV-STAB07	Compresseur à vis BP	Q00580
Q4CC	QKCCV	QSCA-4-CP3	QCCV-STAB09	Compresseur à vis BP	Q00580
Q4CC	QKCCV	QSCA-4-CP4	QCCV-STAB10	Compresseur à vis BP	Q01147
Q4CC	QKCCV	QSCA-6-CP1	QCCV-STAB11	Compresseur à vis BP	Q00580

How it works with compressors

- The next step is to associate the documentation in order to extract the critical spare parts, plans and manufacturer's recommendations



How it works with compressors

Documentation

Bill of Materials | Manufacturer's recommendations | Layout

Materials Lists

Part: Q00577 COMPRESSEUR BAUER TYPE:G25.0-55

List View | Record View | Comments | Stores | Stock | Suppliers | Substitutes | Where Used

All Parts Associated — Edit

Part	Description	Quantity	UOM
Q00780	DOUILLE DE PISTON 4EME ETAGE CP BAUER (POS.60)	1	pc
Q00871	JOINT O-RING VITON 70SH Dim: 10.78X2.62	1	pc
Q00872	JOINT O-RING VITON 70SH DN80 Dim: 100.97X5.33	1	pc
Q00948	JOINT PLAT CUIVRE	1	pc
Q01085	JOINT O-RING VITON 70SH Dim: 20.29X2.62	1	pc
Q01213	CYLINDRE DE PISTON 1ER/2EME ETAGE CP BAUER (POS.5)	1	pc
Q01214	CYLINDRE DE PISTON 3EME ETAGE CP BAUER (POS.30)	1	pc
Q01637	HUILE MOBIL RARUS 829 COMPRESSEUR DE RECUP. FUT 200L	40	l
Q04184	JOINT O-RING VITON 70SH Dim: 120.24X3.53	1	pc
Q04203	JOINT O-RING VITON 70SH Dim: 15.54X2.62	1	pc
Q04212	JOINT O-RING VITON 70SH Dim: 17.12X2.62	1	pc
Q04215	JOINT O-RING VITON 70SH Dim: 171.04X3.53	1	pc
Q04217	JOINT PLAT CUIVRE	2	pc
Q04218	JOINT O-RING VITON 70SH Dim: 18.77X1.78	2	pc
Q04236	JOINT O-RING VITON 70SH Dim: 234.54X3.53	1	pc

Procedures

serco

- Remplacement du tamis moléculaire du pot de récupération

a. Inspection Visuelle

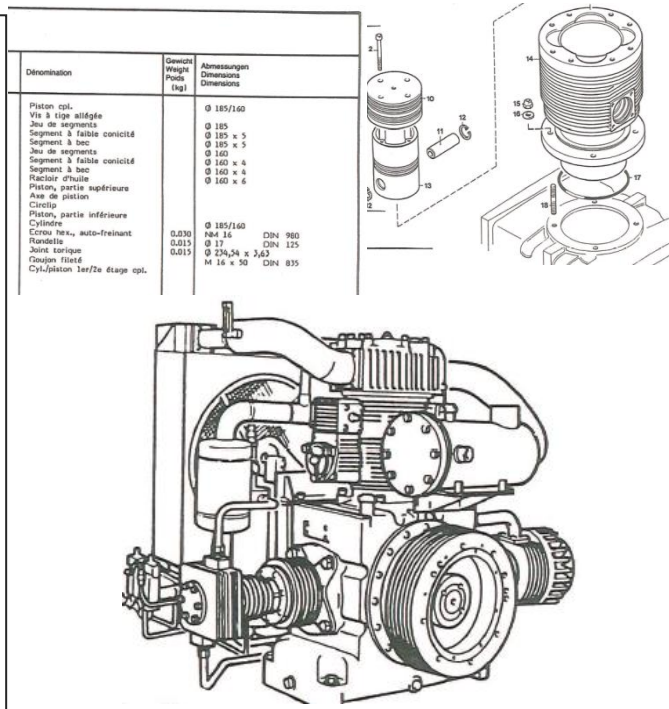
- Vérifier l'intégrité des supports de tuyauteries, instruments et vannes : traces d'usures causées par les vibrations, état des fixations, …
- Vérifier visuellement tous les raccords, eau, hélium et huile.
- Contrôler l'état des flexibles d'eau en partie supérieure du compresseur (usures, détérioration).
- Contrôler l'état des couvercles de cylindre.
- Contrôler l'état de la boulonnerie (vérification de l'absence éventuelle d'un boulon).
- Vérifier l'absence de fuite d'huile ou d'eau au niveau des raccords et brides.
- Contrôler les fixations du compresseur et l'état des fondations (fissures, détériorations).
- Contrôler l'état des calorifuges des tuyauteries de refoulement.
- Contrôler la fixation et l'intégrité de la protection d'accouplement.
- Noter la valeur de fuite de garniture : l'information est disponible auprès de l'équipe d'opération du site.

b. Remplacement du tamis moléculaire

Le remplacement du tamis moléculaire est réalisé sur la base d'une périodicité de 6000 heures.

- Contrôler l'absence de pression.
- Déposer la bride supérieure et la couche de laine de roche.
- Déposer la couche de ouate supérieure.
- Aspirer la totalité du tamis moléculaire à l'aide d'un aspirateur.
- Remplacer la couche de ouate inférieure.
- Remplir le pot avec du tamis moléculaire neuf (≈ 13 kg).
- Remplacer la couche de ouate supérieure et la laine de roche.
- Reposer la bride après avoir remplacer le joint.
- Faire procéder à la pressurisation du pot par l'opération dès que les conditions le permettent afin de valider l'étanchéité.

Plans, Sketches...



Preventive Maintenance Task MCPS

How it works: MaintenanceTask List

- The contractor works on the basis of fixed price per task
- The MTL contains 362 codes for standard maintenance tasks
- The maintenance plans are based on defined counter dependent or absolute time dependent

Revue MAINTENANCE TASK LIST revision NB 12_10_24 YEAR 3 -				task	preventive maintenance	
task code	type	sub-type or compo-nent	task-package	Each task comprises all operations that are necessary to access the component and to transfer it to the workshop as well as all operations of re-installation or re-adjustment of the concerned component as well as of all the components that may have been removed for the access except if explicitly defined differently in the description.	counter dependent	absolute time dependent
		rotary vane vacuum pumps (cat1 PS<17m3, cat2 17m3<PS<40m3, cat3 40m3<PS<100m3, cat4 100m3<PS<=250m3, cat 5 250m3<PS<630m3, cat6		(cat1 PS<=17m3, cat2 17m3<PS<=40m3, cat3 40m3<PS<=100m3, cat4 100m3<PS<=250m3, cat 5 250m3<PS<=630m3, cat6 630m3<PS<=1600m3) PS = pumping speed for N2 gas according to DIN28400		
			standard inspection			
				oil change	8000	3-yr
				oil filter change	8000	3-yr
				exhaust filter change	8000	3-yr
MPPI				clean inlet strainer	8000	3-yr
				check inlet valve	8000	3-yr
				check float valve	8000	3-yr
				clean strainer	8000	3-yr
			standard revision			
				replace bearings	16000	
MPPS				replace vanes	16000	
				replace shaft seals	16000	
		roots vacuum pumps		(cat1 PS<=250m3, cat 2 250m3<PS<=630m3, cat3 630m3<PS<=1600m3, cat4 1600m3<PS<=4000m3, cat5 4000m3<PS<=10000m3, cat6 10000m3<PS<=16000m3)		
			standard inspection			
				oil change gearboxes	6000	
				oil change shaft-seal compartment	6000	
MPRI				clean ventilator and air ducts	6000	
				clean inlet strainer/filter	6000	
				(line deleted and transferred to MPRS)		
				clean by-pass valve	6000	
			standard revision			
				replace shaft-seals	40000	
				replace bushing	40000	
MPRS				replace bearings	40000	
				replace oil filter as applicable	40000	
				clean view glasses	40000	
				inspect compression chamber, clean as	40000	

How it works with compressors

- The meter is read regularly by technicians during the monthly inspections

- It triggers the maintenance plans in fonction of the Meter Interval

- We can also read the Meter Due

Asset: QCCP-BAU003 Compresseur à pistons VHP

List View | Record View | Comments | Events | Costs | PM Schedules | Structure | **Meters** | EDMS

All Meters — Edit

UOM	Description	Total Usage	Usage Since Install
HUR	Hour	1,411	1,411

Asset: QCCP-BAU003 Compresseur à pistons VHP

List View | Record View | Comments | Events | Costs | **PM Schedules** | Structure | Meters | EDMS Documents | Inspections & Read

PM	Description	Department	Meter Interval	Meter UOM	Meter Due	Location
QMCPE2-1	Révision étendue (roulements / pompe à huile)(cat1 V<160m3/h)	QSSM	24,000	HUR	24,000	253
QMCPO	Vidange Huile Piston Compressors HP : 40l<Vol.<=100l	QSSM				253
QMCPR2-1	Remplacements des clapets :(cat1 diam. <= 100mm)	QSSM	6,000	HUR	7,411	253
QMCPS2-1	Piston compressor: standard revision (cat1 V<160m3/h)	QSSM	12,000	HUR	12,000	253
QMCQE-1	Révision etendue CP à pistons HP :(cat1 V<160m3/h)	QSSM	24,000	HUR	24,000	253
QMCQI-1	Piston compressor: service high pressure compressor (cat1 V<160m3/h)	QSSM	6,000	HUR	7,411	253

How it works with compressors

- WO are generated in Work Packages

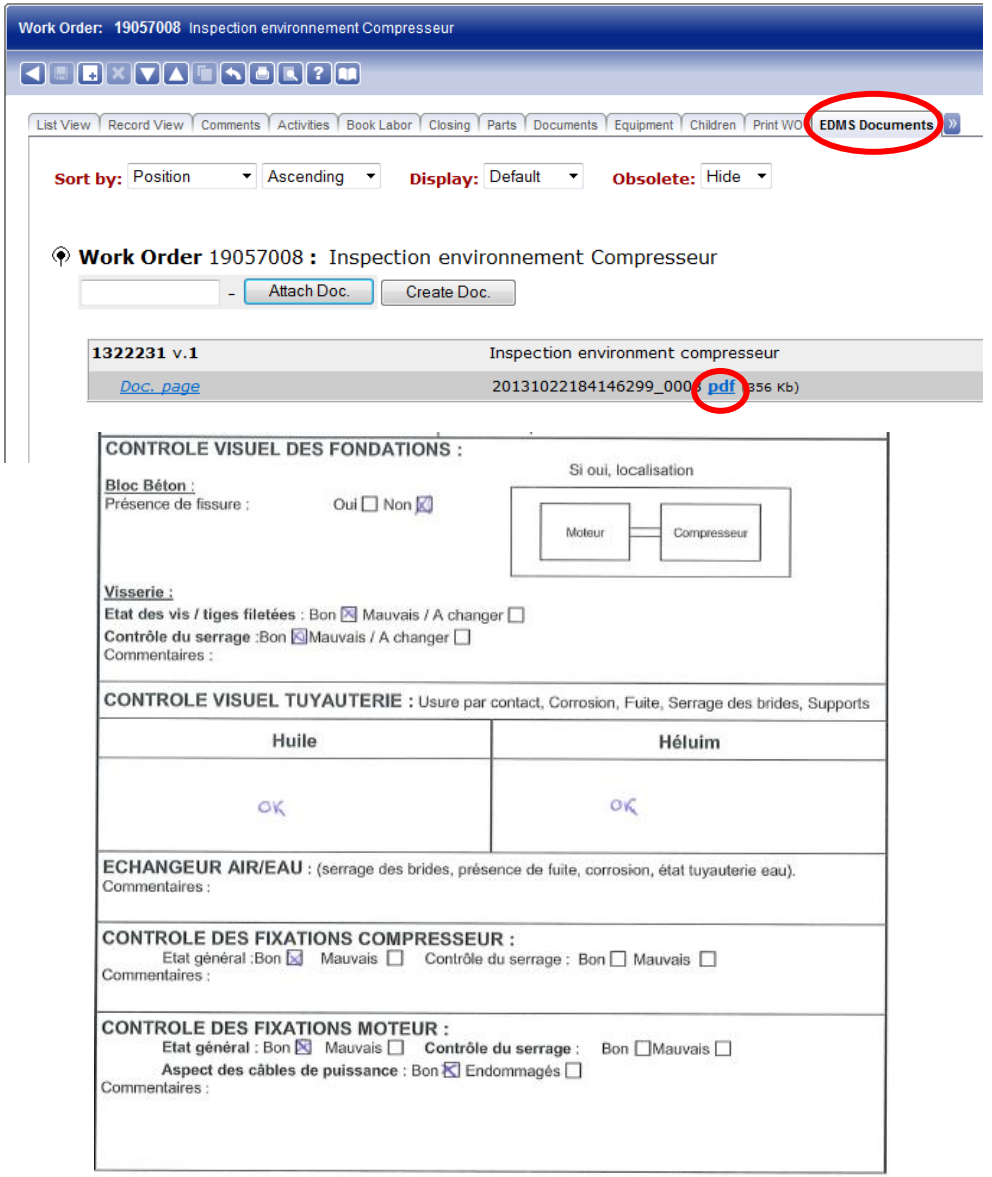
Work Order	Description	Status	Equipment	Type
Begins with	Contains	Begins with	Begins with	Begins with
	compresseur			pm
				maintenance
19056820	Inspection environnement Compresseur	RA - Accepte	QSCCB-18-C01	PM - Preventive maintenance
19056809	Inspection environnement Compresseur	RA - Accepte	QSCB-18-CO7	PM - Preventive maintenance
19056798	Inspection environnement Compresseur	RA - Accepte	QSCB-18-CO6	PM - Preventive maintenance
19056787	Inspection environnement Compresseur	RA - Accepte	QSCB-18-CO3	PM - Preventive maintenance
19056776	Inspection environnement Compresseur	RA - Accepte	QSCB-18-CO2	PM - Preventive maintenance
19056765	Inspection environnement Compresseur	RA - Accepte	QSCB-18-CO1	PM - Preventive maintenance
19056754	Inspection environnement Compresseur	RA - Accepte	QSCCA-2-C02	PM - Preventive maintenance
19056743	Inspection environnement Compresseur	RA - Accepte	QSCCA-2-C01	PM - Preventive maintenance
19056732	Inspection environnement Compresseur	RA - Accepte	QSCA-2-C08	PM - Preventive maintenance
19056723	Inspection environnement Compresseur	RA - Accepte	QSCA-2-C07	PM - Preventive maintenance

- WO are treated and closed

Work Order	Description	Status	Equipment	Type
Begins with	Contains	Begins with	Begins with	Begins with
	compresseur	t		pm
19080206	Inspection environnement Compresseur	TP - Termine et paye	QSACP-8I-CP410	PM - Preventive maintenance
19057024	Inspection environnement Compresseur	TP - Termine et paye	QSCCA-6-C02	PM - Preventive maintenance
19057015	Inspection environnement Compresseur	TP - Termine et paye	QSCCA-6-C01	PM - Preventive maintenance
19057008	Inspection environnement Compresseur	TT - Termine,attente validation CERN	QSCA-6-CPA	PM - Preventive maintenance
19056999	Inspection environnement Compresseur	TT - Termine,attente validation CERN	QSCA-6-CP9	PM - Preventive maintenance
19056990	Inspection environnement Compresseur	TT - Termine,attente validation CERN	QSCA-6-CP8	PM - Preventive maintenance
	Inspection environnement Compresseur	TT - Termine,attente validation CERN	QSCA-6-CP7	PM - Preventive maintenance
19056970	Inspection environnement Compresseur	TT - Termine,attente validation CERN	QSCA-6-CP4	PM - Preventive maintenance
19056961	Inspection environnement Compresseur	TT - Termine,attente validation CERN	QSCA-6-CP3	PM - Preventive maintenance
19056951	Inspection environnement Compresseur	TT - Termine,attente validation CERN	QSCA-6-CP2	PM - Preventive maintenance
19056941	Inspection environnement Compresseur	TT - Termine,attente validation CERN	QSCA-6-CP1	PM - Preventive maintenance
18947056	Inspection environnement Compresseur	TP - Termine et paye	QSU1H-M-CP163	PM - Preventive maintenance
18947055	Inspection environnement Compresseur	TP - Termine et paye	QSR1H-M-CP165	PM - Preventive maintenance

How it works with compressors

- Finally a complete report is done by the technician for each task
- We have forms that we currently fill out manually
- We are working on an online solution



Work Order: 19057008 Inspection environnement Compresseur

List View | Record View | Comments | Activities | Book Labor | Closing | Parts | Documents | Equipment | Children | Print WO | EDMS Documents

Sort by: Position | Ascending | Display: Default | Obsolete: Hide

Work Order 19057008 : Inspection environnement Compresseur

Attach Doc. | Create Doc.

1322231 v.1	Inspection environment compresseur
Doc. page	20131022184146299_0003 pdf (356 Kb)

CONTROLE VISUEL DES FONDATIONS :

Si oui, localisation

Bloc Béton :
Présence de fissure : Oui ☐ Non ☒

Visserie :
Etat des vis / tiges filetées : Bon ☒ Mauvais / A changer ☐
Contrôle du serrage :Bon ☒ Mauvais / A changer ☐
Commentaires :

CONTROLE VISUEL TUYAUTERIE : Usure par contact, Corrosion, Fuite, Serrage des brides, Supports

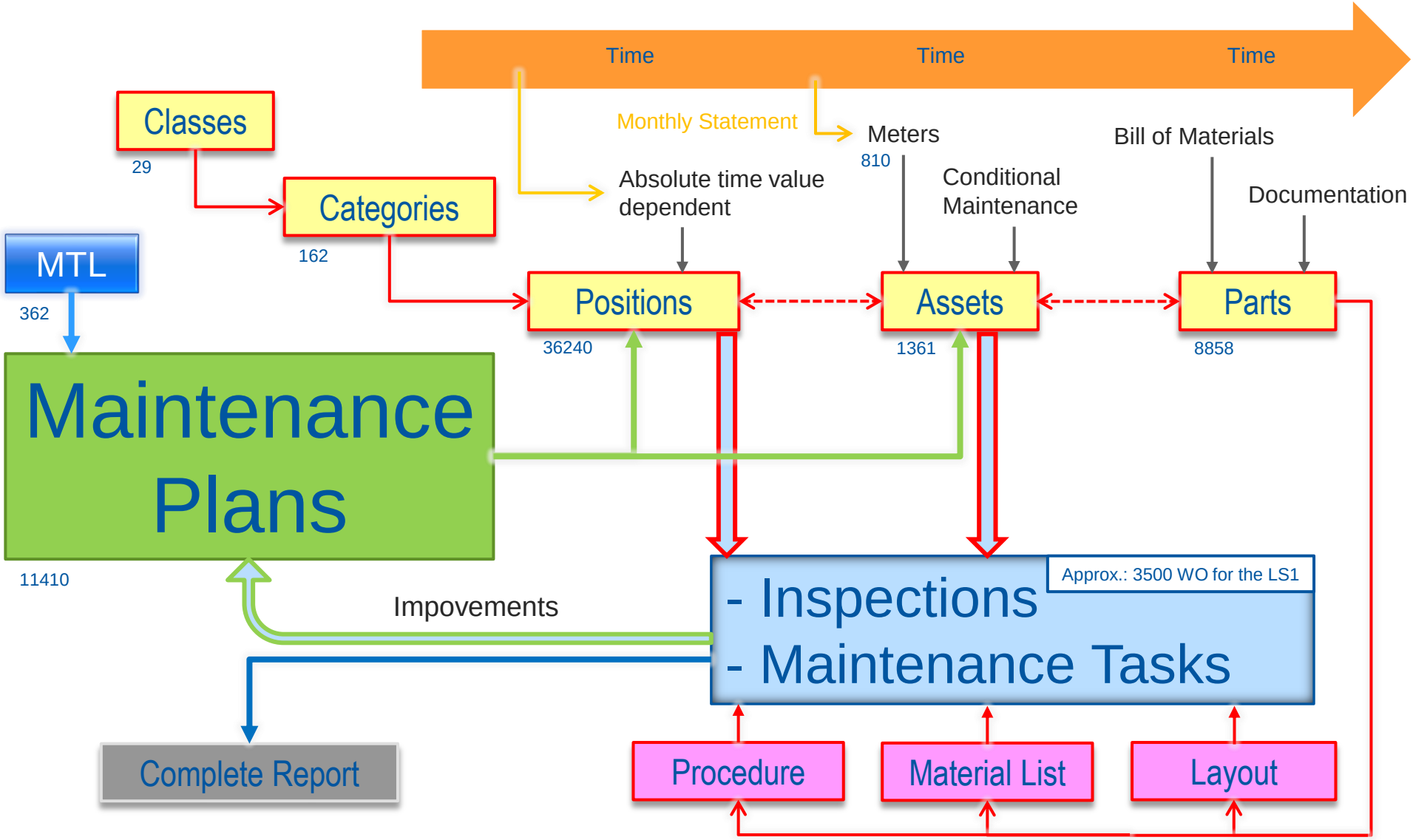
Huile	Héluim
OK	OK

ECHANGEUR AIR/EAU : (serrage des brides, présence de fuite, corrosion, état tuyauterie eau).
Commentaires :

CONTROLE DES FIXATIONS COMPRESSEUR :
Etat général :Bon ☒ Mauvais ☐ Contrôle du serrage : Bon ☐ Mauvais ☐
Commentaires :

CONTROLE DES FIXATIONS MOTEUR :
Etat général : Bon ☒ Mauvais ☐ **Contrôle du serrage** : Bon ☐ Mauvais ☐
Aspect des câbles de puissance : Bon ☒ Endommagés ☐
Commentaires :

How it works: Structure to summarize



Presentation Outline

- INTRODUCTION: Cryogenic Installations of LHC
- HIGHLY COMPLEX Installations
- FOCUS on Maintenance Plans Organisation
- SUMMARY
- PROSPECTS

SUMMARY

- Maintain CERN cryogenics installations is a challenge!!
- We have a lot of experience but a lot of work has to be done as well
- The long shut down 1 is the great opportunity to verify the efficiency of our methods
- The optimization is on the way…….

Presentation Outline

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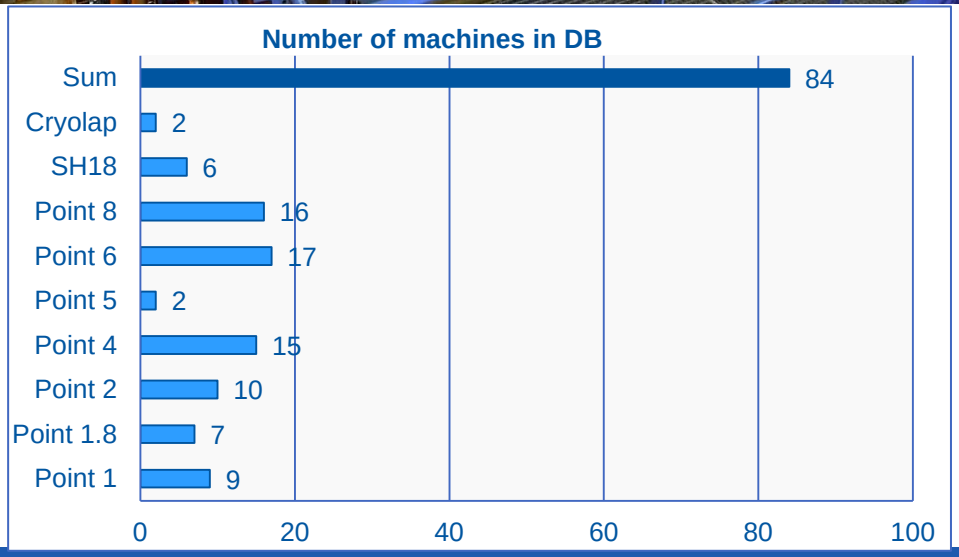
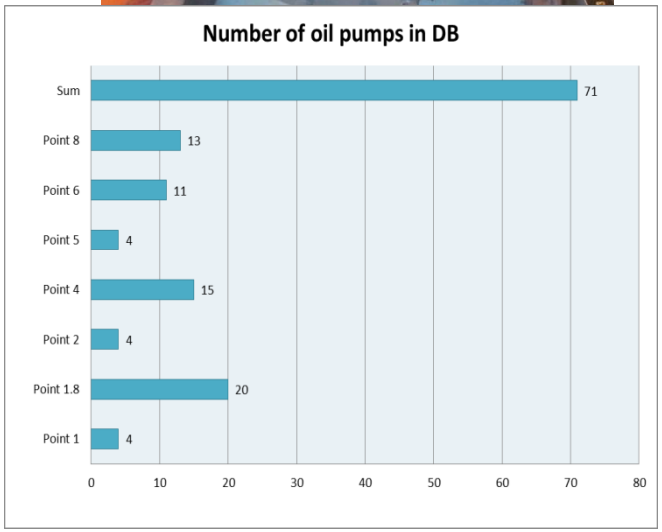
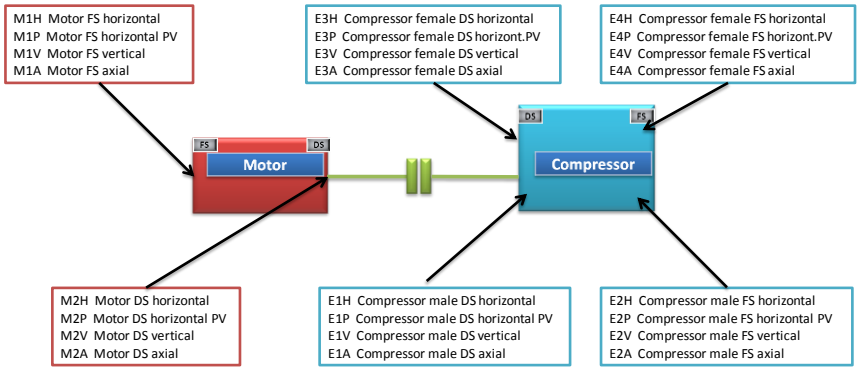
Rotary machines



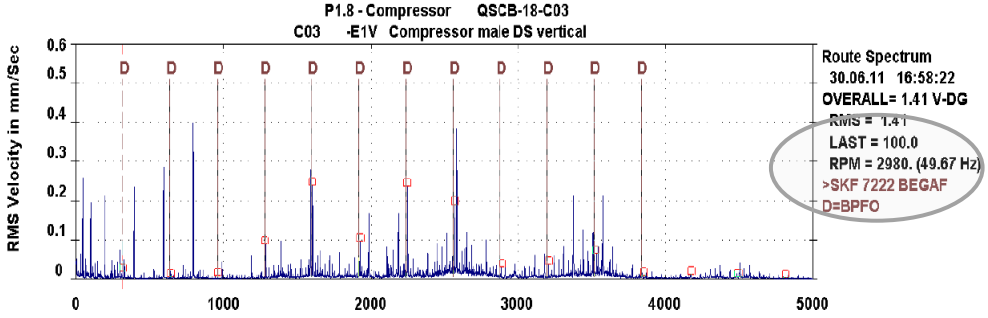


Vibration measurements as part of condition based maintenance

Measuring points



Tri-Axe Sensor



Bearing data stored in analyses settings

Measured frequency range as a function of machine conditions

Machinery Health Analyser

Many thanks for your attention


CERN