# MAINTENANCE FOR CERN'S CRYOGENIC INSTALLATIONS – STRATEGIES, METHODS, CASES

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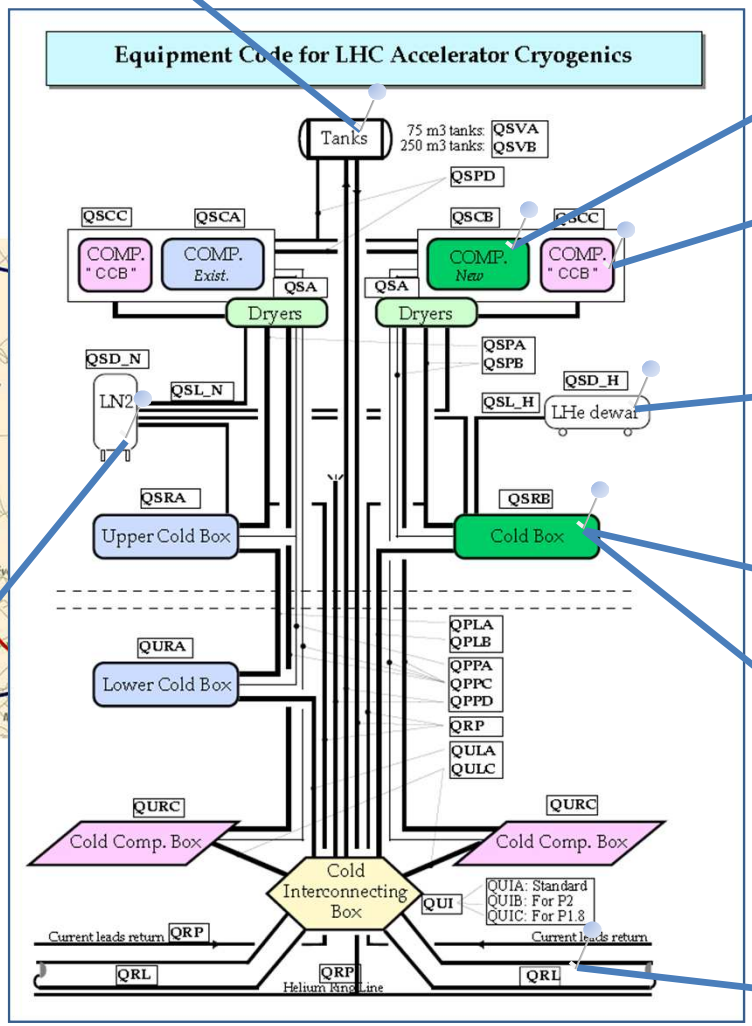
- The cryogenic installations and their specifics concerning maintenance
- Maintenance principles and elements of the maintenance process
- Maintenance organization (contract)
- Some statistics
- Some case-studies

# Components of a cryogenic installation

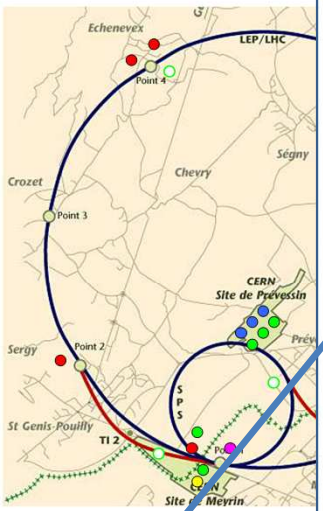
helium storage

compressor stations

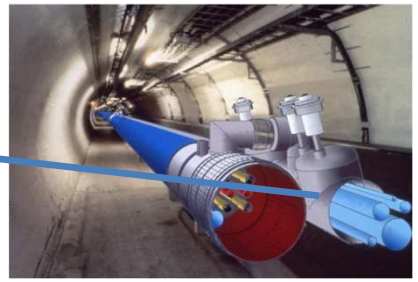
liquid helium storage




cold boxes




liquid nitrogen storage



helium transfer line

# Specifics concerning maintenance: challenges

| Number of components (example) | no./*Anz.* (approx.) |
|---|---|
| **Mechanical components** | |
| Filters | ~850 |
| Compressors | 104 |
| Oil pumps, vacuum pumps | ~350 |
| Safety valves | ~2'000 |
| Valves (manual, automatic) | ~15'000 |
| **Instrumentation** | |
| Analysers | ~100 |
| Pressure measurement | ~2'500 |
| Temperature measurement | ~2'700 |
| **Total (maintained components not including tunnel)** | **~35'000** |
| Replacement value maintained components | ~~100MCHF |
| Replacement value installed components | 300-400MCHF |
| Maintenance budget | ~~3MCHF |

**Special conditions, e.g.**

- Low temperature conditions
- High purity requirements
- High leak tightness requirements

**Possible consequences for operation**

Stop of a cryogenic installation of the accelerator
→ No LHC beams

➢ i.e. very high availability requirements

Extended stop of a cryogenic installation
→ delay of several days to r operation conditions

➢ short MTTRs

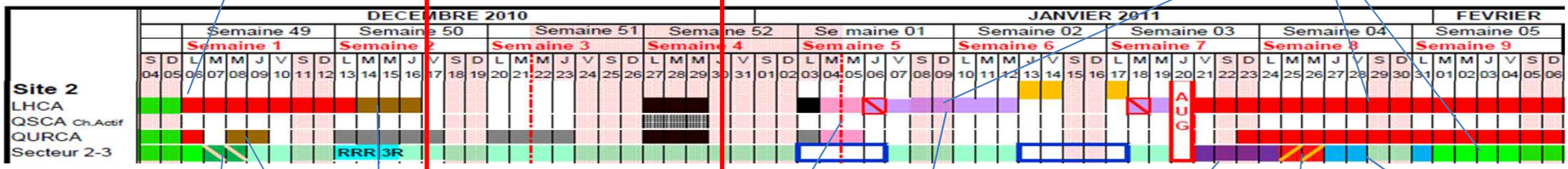
Annually there are only two weeks for the preventive maintenance and only a few days of technical stop corrective maintenance

**Reliability constraints**

- Very few redundancies exist – e.g. oil pumps and some low temperature sensors
- Some workarounds are possible – e.g. turbine power can be replaced by LN2 in some cases, the neighbouring plant can boost the process
- Many components are prototypes
- The access to underground installations is bound to spoecific conditions
- Little reliability information exists

# Specifics concerning maintenance:

## example of the shut-down planning for one refrigerator




installation fully operational
*installation in transient operation mode*

installation fully operational
*installation in transient operation mode*

cryogenic tests

**maintenance slot**

fill-up with 15 t liquid helium

warm-up of the refrigerator

cool-down to 4K

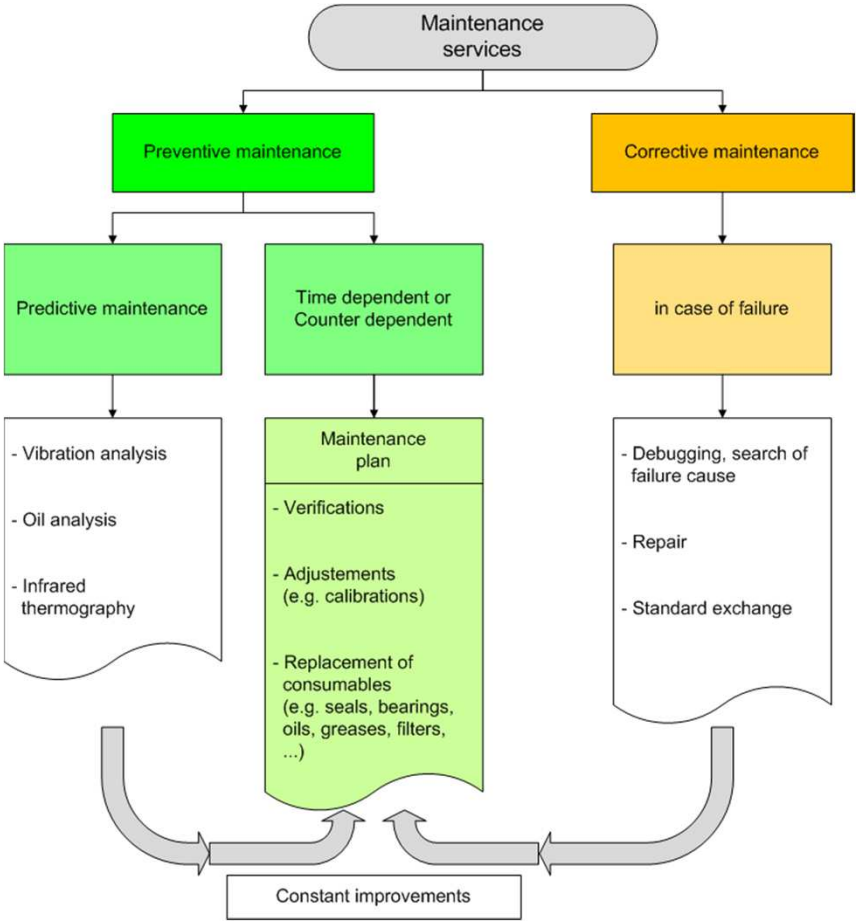
emptying of 15 t of liquid helium

cool-down and keeping between 10 and 30 K

installation conditioning after maintenance

- The cryogenic installations and their specifics concerning maintenance
- Maintenance principles and elements of the maintenance process
- Maintenance organization (contract)
- Some statistics
- Some case-studies

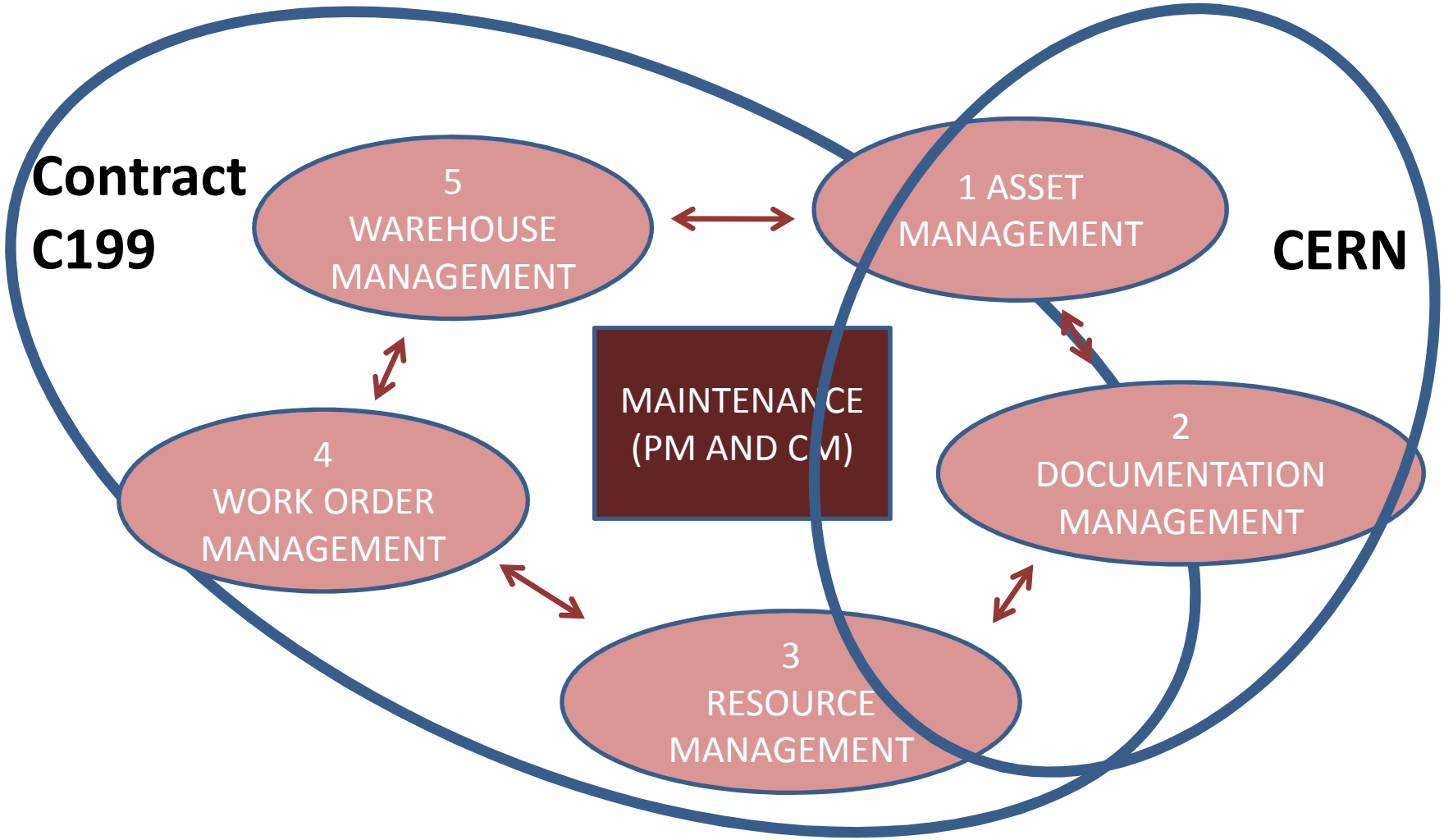
# Maintenance Principles




| | | |
|---|---|---|
| A | **Simple adjustments** foreseen by the component, equipment or installation supplier by the means of components that are accessible without disassembly and opening of the component. and/or<br>The replacement of consumables that can be accessed safely as bulbs, filters, oils, etc. | Operators |
| B | **The repair** or maintenance **by standard exchange** of elements foreseen for this type of repair<br>and/or<br>Minor operations of preventive maintenance. | Contractor |
| C | **The identification and diagnostics of the failure** which may be followed by the replacement of components.<br>and/or<br>The global adjustment and calibration of the equipment/component. | Contractor |
| D | **Complex tasks of corrective and preventive maintenance**, in particular the disassembly of a system, exchange and/or repair of components, reassembly and adjustment of the system, but it is excluding the rebuilding of components.<br>and/or<br>The replacement of an assembly of electrical components. | Contractor or CERN |
| E | **Extensive repair, renovation and rebuilding tasks.** Rebuilding means in this context the manufacturing of components on the basis of a manufacturing drawing (examples are the manufacturing of a rotor screw, the rewinding of a large motor winding and the manufacturing of a cooler). | CERN |

# Basic elements of the maintenance process

What is required to provide a merely unnoticed service?



1 ASSET MANAGEMENT

# Equipment structure in CAMMS

CMMS Service - BusinessObjects interface

Dept-Class-Category-Asset-Position

generated on : lundi, 05 septembre 2011

Rapport TURBINES LINDE par Dept, par Model

Class : Q4Q - Cryogénie
Category : QKQTU - TURBINES
Manufacturer : LINDE

**Department : QOA**

**TGL32-28R/A56**

| Parent | Asset | Description | Serial Number |
|---|---|---|---|
| 915 | QCRTU-LI097 | Turbine cryogenique pour helium LI | 9113 |
| QSRB-6-T7 | QCRTU-LI021 | Turbine cryogenique pour helium LI | 9811 |
| QSRB-8-T7 | QCRTU-LI031 | Turbine cryogenique pour helium LI | 9807 |

**TGL32-28V/A56**

| Parent | Asset | Description | Serial Number |
|---|---|---|---|
| 915 | QCRTU-LI077 | Turbine cryogenique pour helium LI | 9115 |
| QURA-4-T6 | QCRTU-LI005 | Turbine cryogenique pour helium LI | 9110 |
| QURA-6-T6 | QCRTU-LI012 | Turbine cryogenique pour helium LI | 9112 |

**TGL32-32V/A56**

| Parent | Asset | Description | Serial Number |
|---|---|---|---|
| QURCA-4-T7 | QCRTU-LI036 | Turbine cryogenique pour helium LI | 200304 |
| QURCA-8-T7 | QCRTU-LI040 | Turbine cryogenique pour helium LI | 200302 |
| QURCB-4-T7 | QCRTU-LI038 | Turbine cryogenique pour helium LI | 200303 |
| QURCB-8-T7 | QCRTU-LI042 | Turbine cryogenique pour helium LI | 9118 |

**TGL32-32Z1/A50**

| Parent | Asset | Description | Serial Number |
|---|---|---|---|
| QSRB-6-T1 | QCRTU-LI015 | Turbine cryogenique pour helium LI | 9810 |
| QSRB-8-T1 | QCRTU-LI025 | Turbine cryogenique pour helium LI | 9806 |

**TGL45-45W/A80**

| Parent | Asset | Description | Serial Number |
|---|---|---|---|
| 915 | QCRTU-LI104 | Turbine cryogenique pour helium LI ( LEP ) | 9804 |
| 915 | QCRTU-LI106 | Turbine cryogenique pour helium LI ( LEP ) | 9802 |

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CMMS Service - BusinessObjects interface

Dept-Class-Category-Asset-Position

generated on : lundi, 05 septembre 2011

Rapport TURBINES LINDE par Dept, par Model

Class : Q4Q - Cryogénie
Category : QKQTU - TURBINES
Manufacturer : LINDE

**Department : QOD**

**S 45-45W/A80**

| Parent | Asset | Description | Serial Number |
|---|---|---|---|
| QUR2H-A-TU2 | QCRTU-LI044 | Turbine cryogenique pour helium LI | 9809 |
| SH1 | QCRTU-LI076 | Turbine cryogenique pour helium LI | 200307 |

**TGL16-09N/B28**

| Parent | Asset | Description | Serial Number |
|---|---|---|---|
| 915 | QCRTU-LI103 | Turbine cryogenique pour helium LI | 7917 |
| QLR1H-O-T1 | QCRTU-LI094 | Turbine cryogenique pour helium LI | 8902 |

**TGL16-16T1/A28**

| Parent | Asset | Description | Serial Number |
|---|---|---|---|
| 915 | QCRTU-LI075 | Turbine cryogenique pour helium LI | 9103 |
| 915 | QCRTU-LI085 | Turbine cryogenique pour helium LI | 9017 |
| QSU1H-M-TU1 | QCRTU-LI066 | Turbine cryogenique pour helium LI | 9019 |

**TGL22-14P/A40**

| Parent | Asset | Description | Serial Number |
|---|---|---|---|
| QLR1H-S-TU6 | QCRTU-LI050 | Turbine cryogenique pour helium LI | 8705 |

**TGL22-14P/B32**

| Parent | Asset | Description | Serial Number |
|---|---|---|---|
| QLR1H-S-TU5 | QCRTU-LI049 | Turbine cryogenique pour helium LI | 8702 |

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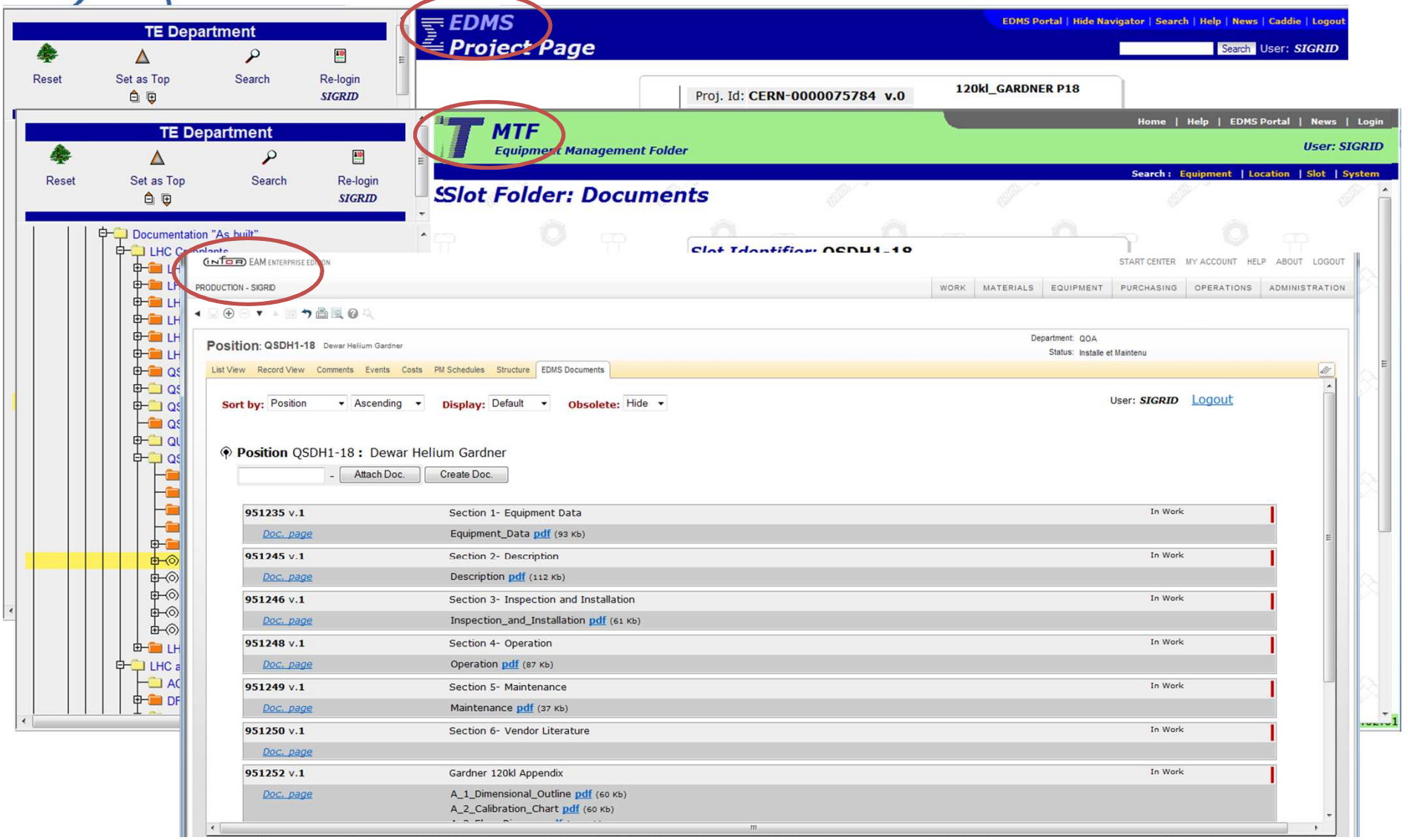
2
DOCUMENTATION
MANAGEMENT

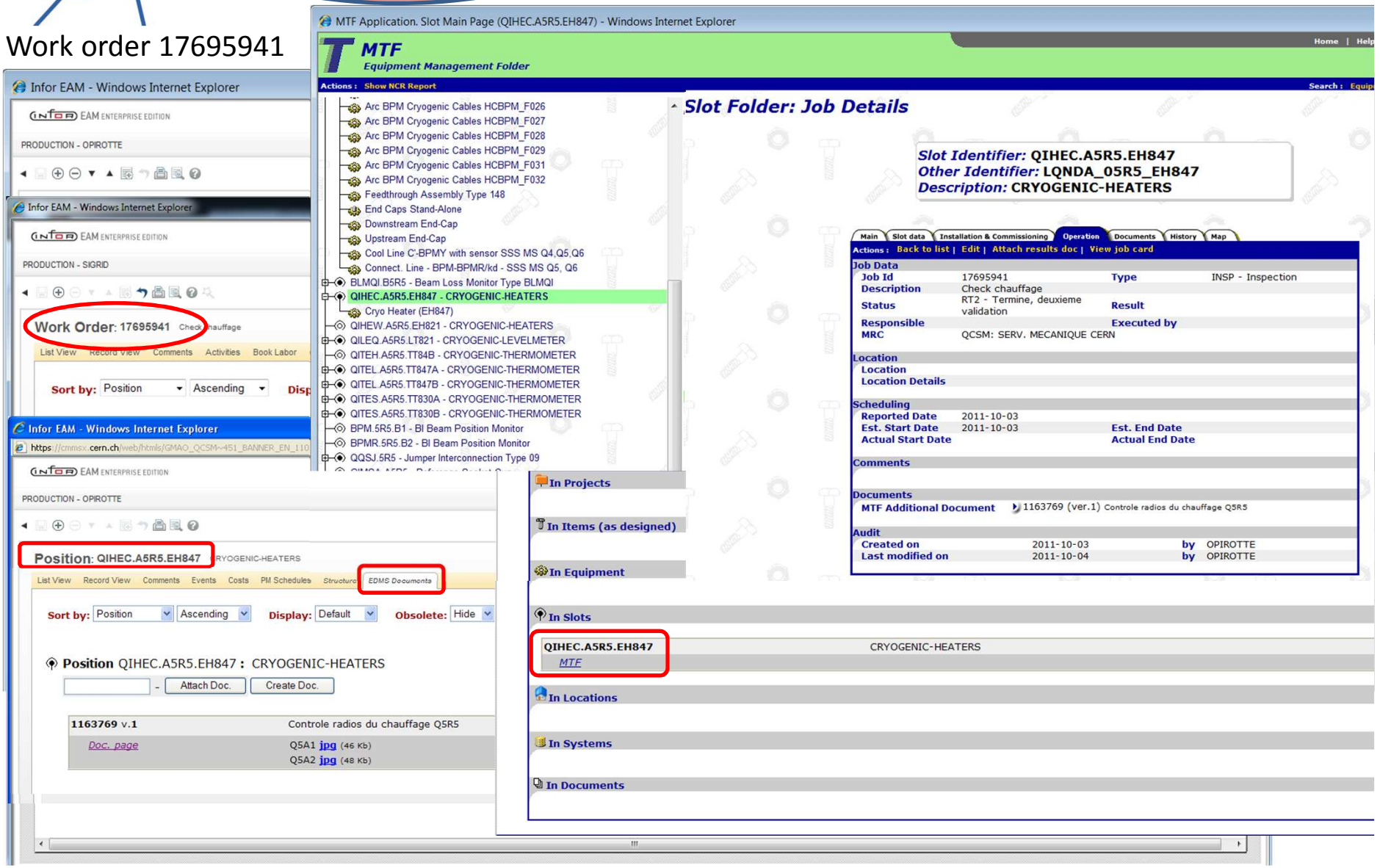
# Different ways to reach the technical documentation



2
DOCUMENTATION
MANAGEMENT

# Documents attached to work orders

Work order 17695941



3
RESOURCE
MANAGEMENT

# Planning of shutdown
# Workpackages Preventive Maintenance

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 5 | Vibrations - P4 - LHCA | 10 h | 07/11/11 | 08/11/11 |
| 6 | Vibrations - P4 - LHCCA | 10 h | 08/11/11 | 09/11/11 |

| Spécialité | Type de travaux | Departement | Site | Tache MTL - Cat. | WO | Code equipement | Equipement | Tache | Manufacturer | Date Dernière maintenance | Compt. Dernière maint. | Date relevé compteur | Compteur dernier relevé | Colonne1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| serco | | OA | P4 | MKFA | | QSCCA-4-C1-2 | Compresseur à vis | Contrôle Alignement | Mycom | 25/11/2008 | 5557 | 12/08/2010 | 12470 | |
| | | OA | P4 | MKFA | | QSCCB-4-C1-2 | Compresseur à vis | Contrôle Alignement | Mycom | 13/11/2008 | 5655 | 13/08/2010 | 14360 | |
| | | OA | P6 | MKFA | | QSCB-6-C01 | Compresseur à vis BP | Contrôle Alignement | Aerzen | 26/03/2009 | 12081 | 29/07/2010 | 21435 | |
| | | OA | P6 | MKFA | | QSCB-6-C02 | Compresseur à vis BP | Contrôle Alignement | Aerzen | 26/03/2009 | 11352 | 29/07/2010 | 20602 | |
| | | OA | P6 | MKFA | | QSCB-6-C03 | Compresseur à vis BP | Contrôle Alignement | Aerzen | 26/03/2009 | 10031 | 29/07/2010 | 18557 | |
| | | OA | P6 | MKFA | | QSCB-6-C06 | Compresseur à vis HP | Contrôle Alignement | Aerzen | 26/03/2009 | 12124 | 29/07/2010 | 21581 | |
| | | OA | P6 | MKFA | | QSCB-6-C07 | Compresseur à vis HP | Contrôle Alignement | Aerzen | 26/03/2009 | 11176 | 29/07/2010 | 20100 | |
| | | OA | P6 | MKFA | | QSCCB-6-C01 | Compresseur à vis | Contrôle Alignement | Kaeser | 25/03/2009 | 8468 | 29/07/2010 | 16695 | |
| | | | | | | | | | | | 8462 | 29/07/2010 | 16963 | |
| | | | | | | | | | | | 23355 | 27/07/2010 | 32685 | |

**Codes MTL / Quantité**

| Spécialité | Type de travaux | Site | Equipement | Sous installation | IDXI | IDSI | EHEI | EAAI | EMOI | ESLT | MVAI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| serco | | P1 | ANRS PT1 | | | | 5 | 3 | 2 | | 12 |
| | | P1 | MR PT1 | | | | 5 | 8 | 5 | | 34 |
| | | P1 | PCS PT1 | | | | 7 | 1 | | | 35 |
| | | P1 | QSC1H-A | Système de compression MR | 5 | 66 | 1 | | | 5 | |
| | | P1 | QSC2H-A | Système de compression SR | 2 | 21 | 2 | | | 2 | |
| | | P1 | QSCBN-A | Système de compression | 1 | 11 | 1 | | | 1 | |
| | | P1 | QUI2H-A | Boite à vanne DVB | | | | 1 | | | 11 |
| | | P1 | SR PT1 | | | | 8 | 6 | 5 | | 24 |
| | | P18 | LHCB-18 | | | | 12 | 12 | 13 | | 65 |
| | | P18 | LHCCB-18 | | | | 10 | 4 | 2 | | 22 |
| | | P18 | QSCB-18 | Système de compression | 5 | 64 | | | | 5 | |

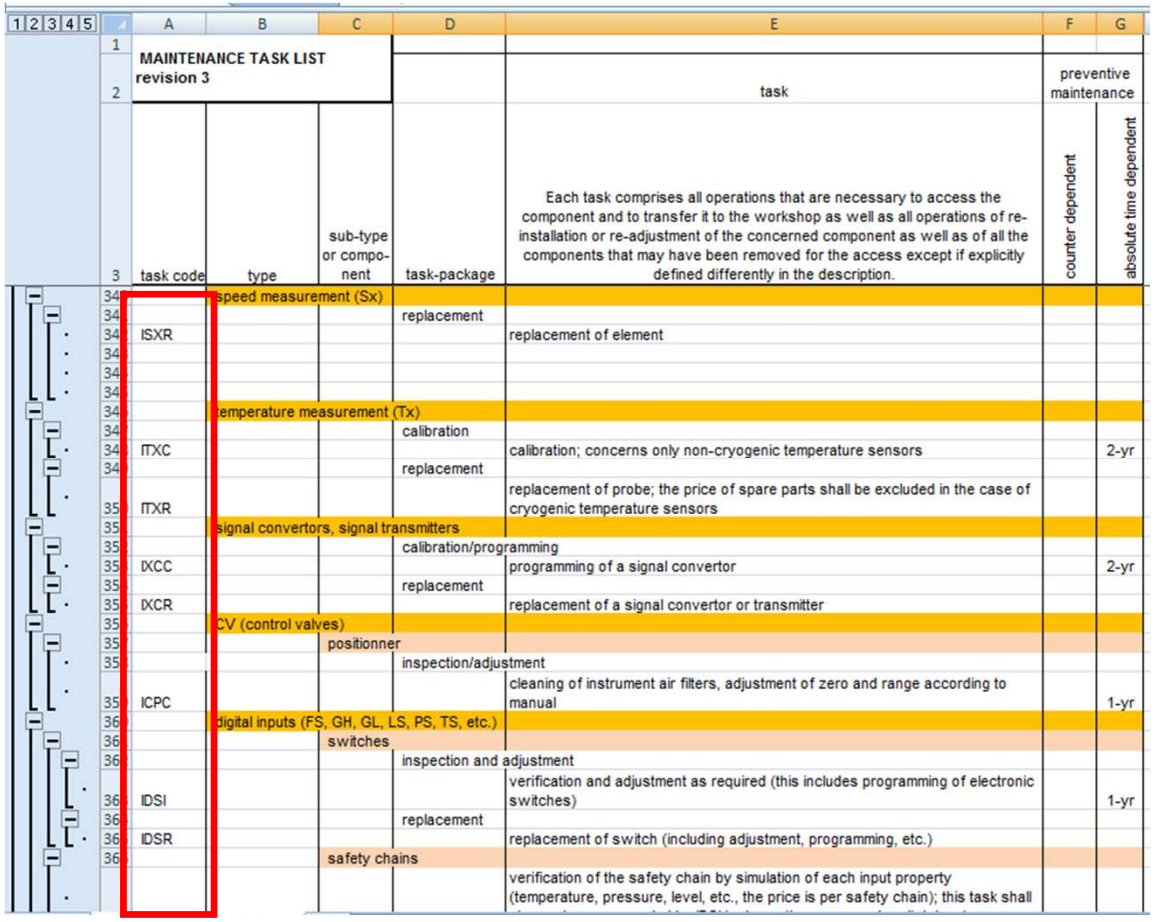
| Spécialité | Type de travaux | Departement | Site | Tache MTL - Cat. | Qté | WO | Code equipement | Equipement | Tache | Colonne1 |
|---|---|---|---|---|---|---|---|---|---|---|
| serco | | OA | P18 | IPHI | 5 | | | Penning | Nettoyage; remplacement cathode/anode | |
| | | OA | P2 | IPHI | 10 | | | Penning | Nettoyage; remplacement cathode/anode | |
| | | OA | P4 | IPHI | 10 | | | Penning | Nettoyage; remplacement cathode/anode | |
| | | OA | P6 | IPHI | 9 | | | Penning | Nettoyage; remplacement cathode/anode | |
| | | OA | P8 | IPHI | 11 | | | Penning | Nettoyage; remplacement cathode/anode | |
| | | OD | P1 | IPHI | 5 | | | Penning | Nettoyage; remplacement cathode/anode | |
| | | OD | P5 | IPHI | 2 | | | Penning | Nettoyage; remplacement cathode/anode | |
| | | | **Total** | **IPHI** | **52** | | | | | |
| | | OA | P18 | IPVI | 5 | | | Pirani | Nettoyage; réglage coffret | |
| | | OA | P2 | IPVI | 11 | | | Pirani | Nettoyage; réglage coffret | |
| | | OA | P4 | IPVI | 14 | | | Pirani | Nettoyage; réglage coffret | |
| | | OA | P6 | IPVI | 16 | | | Pirani | Nettoyage; réglage coffret | |
| | | OA | P8 | IPVI | 19 | | | Pirani | Nettoyage; réglage coffret | |
| | | OD | P1 | IPVI | 8 | | | Pirani | Nettoyage; réglage coffret | |
| | | OD | P5 | IPVI | 1 | | | Pirani | Nettoyage; réglage coffret | |

P
R
E

4
WORK ORDER MANAGEMENT

# Maintenance « Menu »

- All maintenance tasks are listed in a kind of menu: *« the maintenance task list ».*
- Each task is identified by a 4 or 5 letter code.
- In the ideal case you indicate this code when requesting a maintenance intervention.

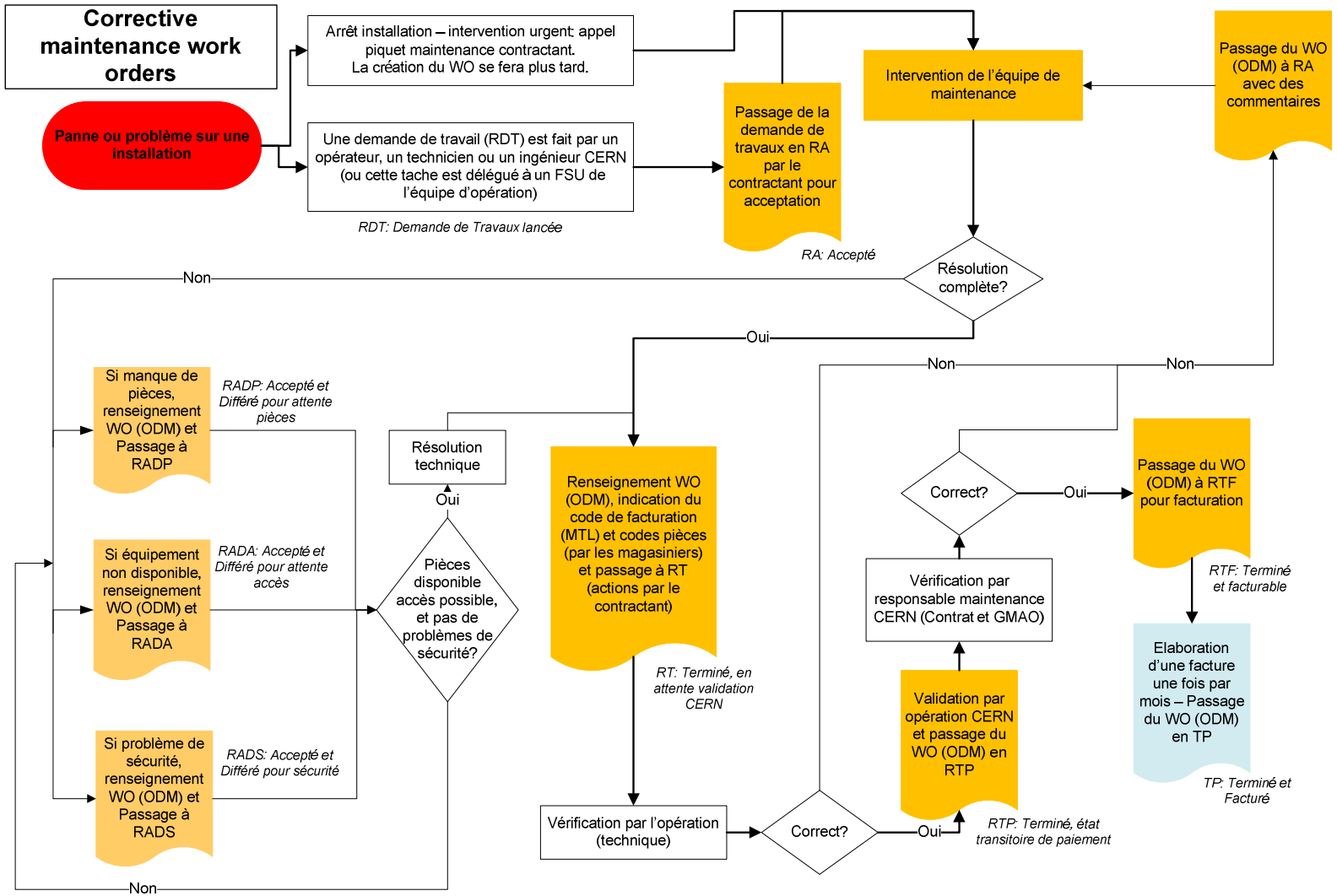


| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | MAINTENANCE TASK LIST revision 3 | | | | task | preventive maintenance | |
| 3 | task code | type | sub-type or compo-nent | task-package | Each task comprises all operations that are necessary to access the component and to transfer 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 |
| 34 | | speed measurement (Sx) | | | | | |
| 34 | | | | replacement | | | |
| 34 | ISXR | | | | replacement of element | | |
| 34 | | | | | | | |
| 34 | | | | | | | |
| 34 | | | | | | | |
| 34 | | temperature measurement (Tx) | | | | | |
| 34 | | | | calibration | | | |
| 34 | ITXC | | | | calibration; concerns only non-cryogenic temperature sensors | | 2-yr |
| 34 | | | | replacement | | | |
| 35 | ITXR | | | | replacement of probe; the price of spare parts shall be excluded in the case of cryogenic temperature sensors | | |
| 35 | | signal convertors, signal transmitters | | | | | |
| 35 | | | | calibration/programming | | | |
| 35 | IXCC | | | | programming of a signal convertor | | 2-yr |
| 35 | IXCR | | | replacement | | | |
| 35 | | | | | replacement of a signal convertor or transmitter | | |
| 35 | | CV (control valves) | | | | | |
| 35 | | | positionner | | | | |
| 35 | | | | inspection/adjustment | | | |
| 35 | ICPC | | | | cleaning of instrument air filters, adjustment of zero and range according to manual | | 1-yr |
| 36 | | digital inputs (FS, GH, GL, LS, PS, TS, etc.) | | | | | |
| 36 | | | switches | | | | |
| 36 | | | | inspection and adjustment | | | |
| 36 | IDSI | | | | verification and adjustment as required (this includes programming of electronic switches) | | 1-yr |
| 36 | | | | replacement | | | |
| 36 | IDSR | | | | replacement of switch (including adjustment, programming, etc.) | | |
| 36 | | | safety chains | | | | |
| | | | | | verification of the safety chain by simulation of each input property (temperature, pressure, level, etc., the price is per safety chain); this task shall | | |

4

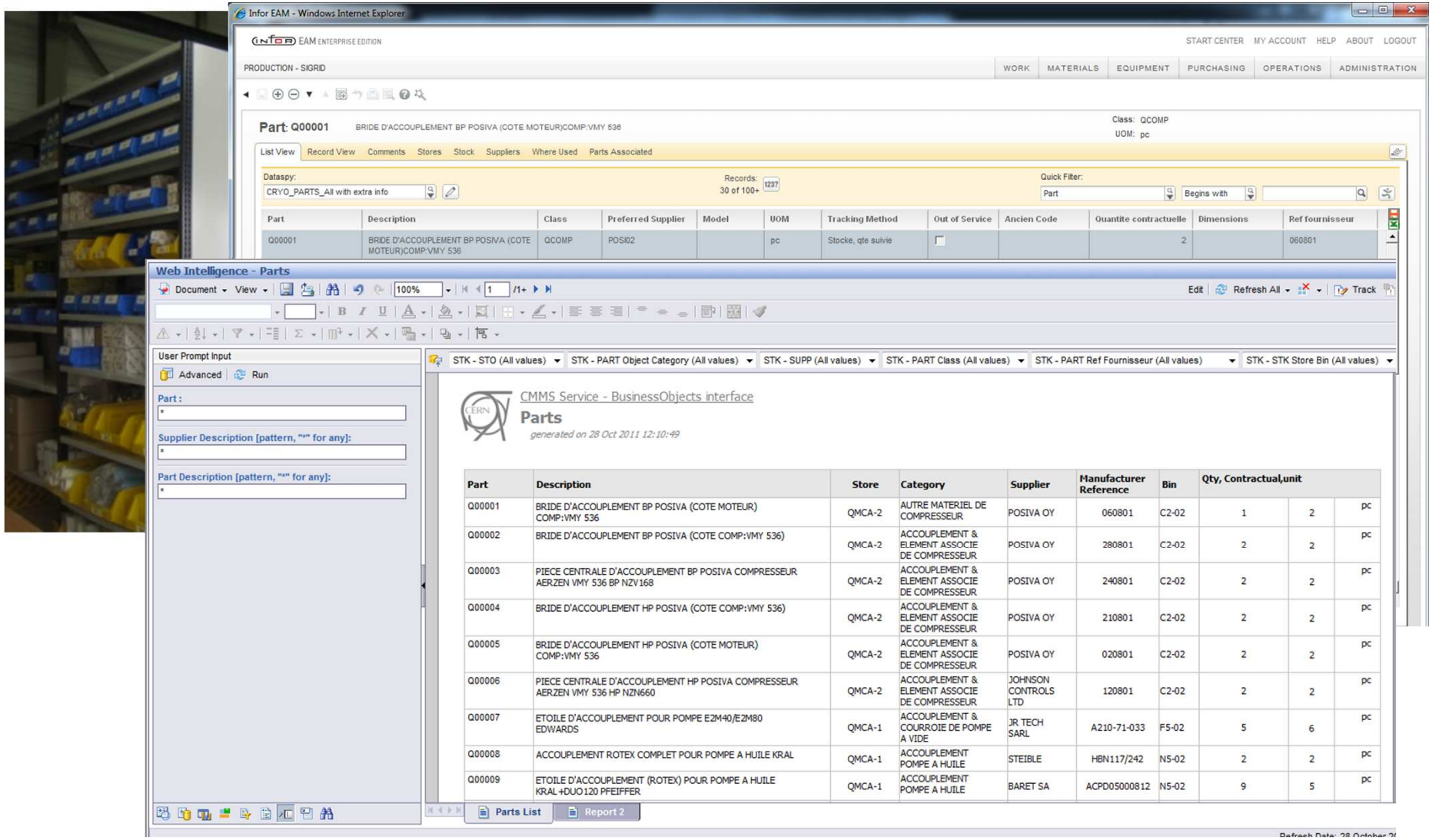
# WORK ORDER MANAGEMENT

## Work order flow



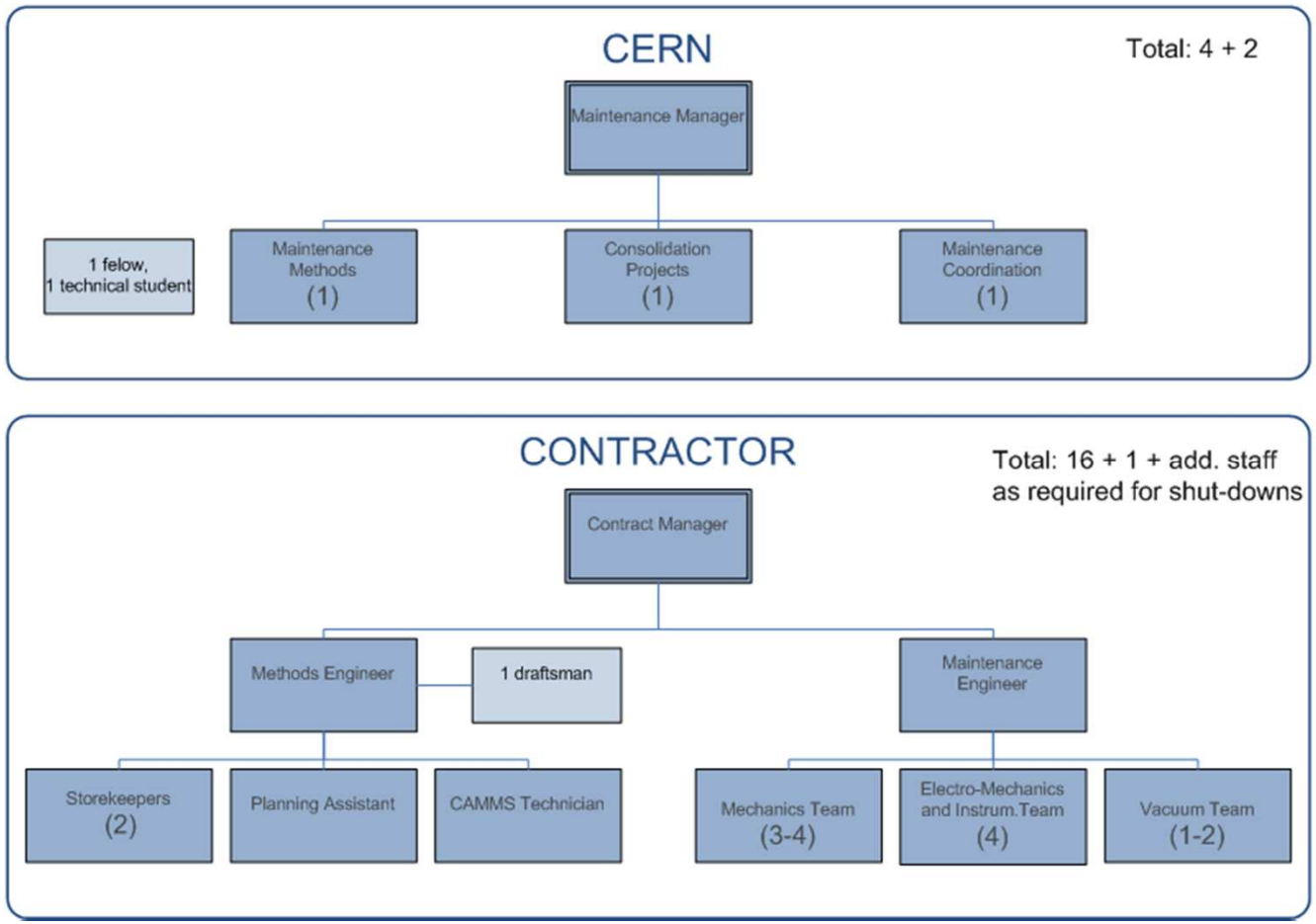
5
WAREHOUSE
MANAGEMENT

# The warehouse managed by the cryogenics group



- The cryogenic installations and their specifics concerning maintenance
- Maintenance principles and elements of the maintenance process
- Maintenance organization (contract)
- Some statistics
- Some case-studies

# Maintenance organisation



- The cryogenic installations and their specifics concerning maintenance
- Maintenance principles and elements of the maintenance process
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# Maintenance statistics
# PM, PDM and CM (1 yr period)

| | Trade | Preventive maintenance (during yearly shut-down) | Predictive and corrective maintenance |
|---|---|---|---|
| Total number of work orders | | 1102 | 768 |
| Break down of work order numbers by trade | Mechanics | 380 | 325 |
| | Instrumentation | 487 | 354 |
| | Vacuum | 235 | 89 |
| Total number of hours | | 2303 | 4564 |
| Break down of intervention hours by trade | Mechanics | 1001 | 2567 |
| | Instrumentation | 714 | 1243 |
| | Vacuum | 588 | 754 |

- 1870 interventions with a mean intervention time of 3.7 hours

- An important part of the predictive and corrective maintenance is done during the technical stops

# Maintenance statistics
# most frequent tasks (PM + PDM + CR; 1 yr period)

| Top 10 maintenance tasks | Numbers |
|---|---|
| Digital inputs – switches – inspection and adjustment | 1,526 |
| Heaters – heaters elements – inspection: | 233 |
| Safety valves – standard revision | 192 |
| Valves – inspection of functioning of automatic valves | 191 |
| Vibration measurement – motor-compressor set | 190 |
| Motors – inspection | 161 |
| Instrumentation – debugging of instrumentation | 140 |
| Control cubicles – replace (without debugging) any extra low voltage component | 128 |
| Couplings – adjustment of flexible couplings, verification, correction of alignment | 91 |
| Power supplies – lockout-tagout (includes locking and tagging and unlocking) | 90 |

- Most frequent are typical PM tasks
- Second rank interventions on instrumentation

# Maintenance statistics
# equipment with most interventions (1 yr period)

| | Preventive maintenance (top 3) | | Predictive and corrective maintenance (top 3) | |
|---|---|---|---|---|
| **Trade** | **Equipment category** | **Number of work orders** | **Equipment category** | **Number of work orders** |
| Mechanics | Screw compressors | 101 | Compressor station | 110 |
| | Compressor station | 97 | Screw compressor | 38 |
| | Recovery compressor | 26 | Oil pumps (screw type) | 24 |
| Instrumentation | Compressor station | 104 | Compressor station | 63 |
| | Refrigeration system | 101 | Control valves | 34 |
| | Electrical cubicles | 80 | Cold box | 30 |
| Vacuum | Cold box | 71 | Cryogenic installation | 12 |
| | Rotary vane pumps | 57 | Diffusion pump | 12 |
| | Diffusion pumps | 36 | Pressure transmitter | 9 |

- Any sub-component can be concerned (valve: plug, bellow, seal, actuator,…)
- For some equipments the breakdown structure was not available for the whole period (therefore e.g. “refrigeration system”)
- Rotary machinery ranks (obviously) high


# Maintenance statistics
# first estimation of MTBF (observation 2 ¼ yr period)

| Description | Subject to PM | Number of spare parts used | Observed component population | system operation time | estimated MTBF |
|---|---|---|---|---|---|
| **Mechanical components** | | | | | |
| Valve cone seals cryogenic valves | | 41 | ~1'100 | ~18'000h | ~0.5 Mh |
| Valve sealing issue warm valves | | 182 | ~13'000 | ~18'000h | ~1.3 Mh |
| Safety valves and parts thereof | X | 95 | ~3'100 | ~18'000h | ~0.6 Mh |
| Compressor shaft seal – all compressors | X | 11 | 83 | <18'000h | ~0.12 Mh |
| Compressor shaft seal – worst type | X | 8 | 20 | ~18'000h | ~0.045Mh |
| Oil pump shaft seal – worst type | X | 13 | 12 | ~12'000h | ~0.011Mh |
| **Instrumentation components** | | | | | |
| Pressure transmitters – all types | | 30 | ~3'100 | ~19'700h | ~2 Mh |
| End switches | | 31 | ~4'000 | ~19'700h | ~2.5 Mh |
| Electro-valve | | 77 | ~1'500 | ~19'700h | ~0.38 Mh |
| Electro-pneumatic positioner | X | 12 | ~1'400 | ~19'700h | 2.3 Mh |

- A few selected values only for large populations with significant failure rates, i.e. components with few failures have not been considered
- Break down to individual types and manufacturers will continue

# Maintenance statistics: Christmas break

- Task review
  - 967 tasks of preventive maintenance carried out
  - 288 tasks of corrective maintenance carried out
  - hereafter only tasks with special observations or open problems are mentioned

- Planning review
  - A reliable planning is extremely valuable!
  - A large majority of the tasks has been completed according to planning
  - In the future more manpower shall be foreseen towards the end of the shut-down to solve start-up problems

CMMS Service - BusinessObjects interface

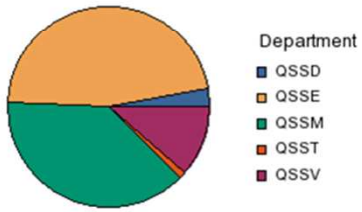
**Preventive maintenance**

*generated on 31 Jan 2011 17:55:47*

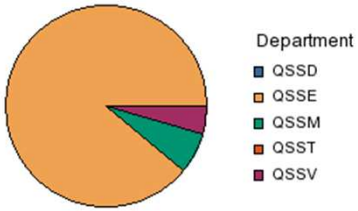
**Completed between 01/12/2010 and 01/02/2011**

| MRC | Corrective | Corrective % | Preventive | Preventive % |
|---|---|---|---|---|
| QSSD | 8 | 2.78% | | |
| QSSE | 134 | 46.53% | 859 | 88.83% |
| QSSM | 110 | 38.19% | 65 | 6.72% |
| QSST | 3 | 1.04% | | |
| QSSV | 33 | 11.46% | 43 | 4.45% |
| Sum: | 288 | 100.00% | 967 | 100.00% |

| MRC | Corrective | Percentage |
|---|---|---|
| QSSD | 8 | 2.78% |
| QSSE | 134 | 46.53% |
| QSSM | 110 | 38.19% |
| QSST | 3 | 1.04% |
| QSSV | 33 | 11.46% |
| Sum: | 288 | 100.00% |




| MRC | Preventive | Percentage |
|---|---|---|
| QSSD | | |
| QSSE | 859 | 88.83% |
| QSSM | 65 | 6.72% |
| QSST | | |
| QSSV | 43 | 4.45% |
| Sum: | 967 | 100.00% |



- The cryogenic installations and their specifics concerning maintenance
- Maintenance principles and elements of the maintenance process
- Maintenance organization (contract)
- Some statistics
- Some case-studies

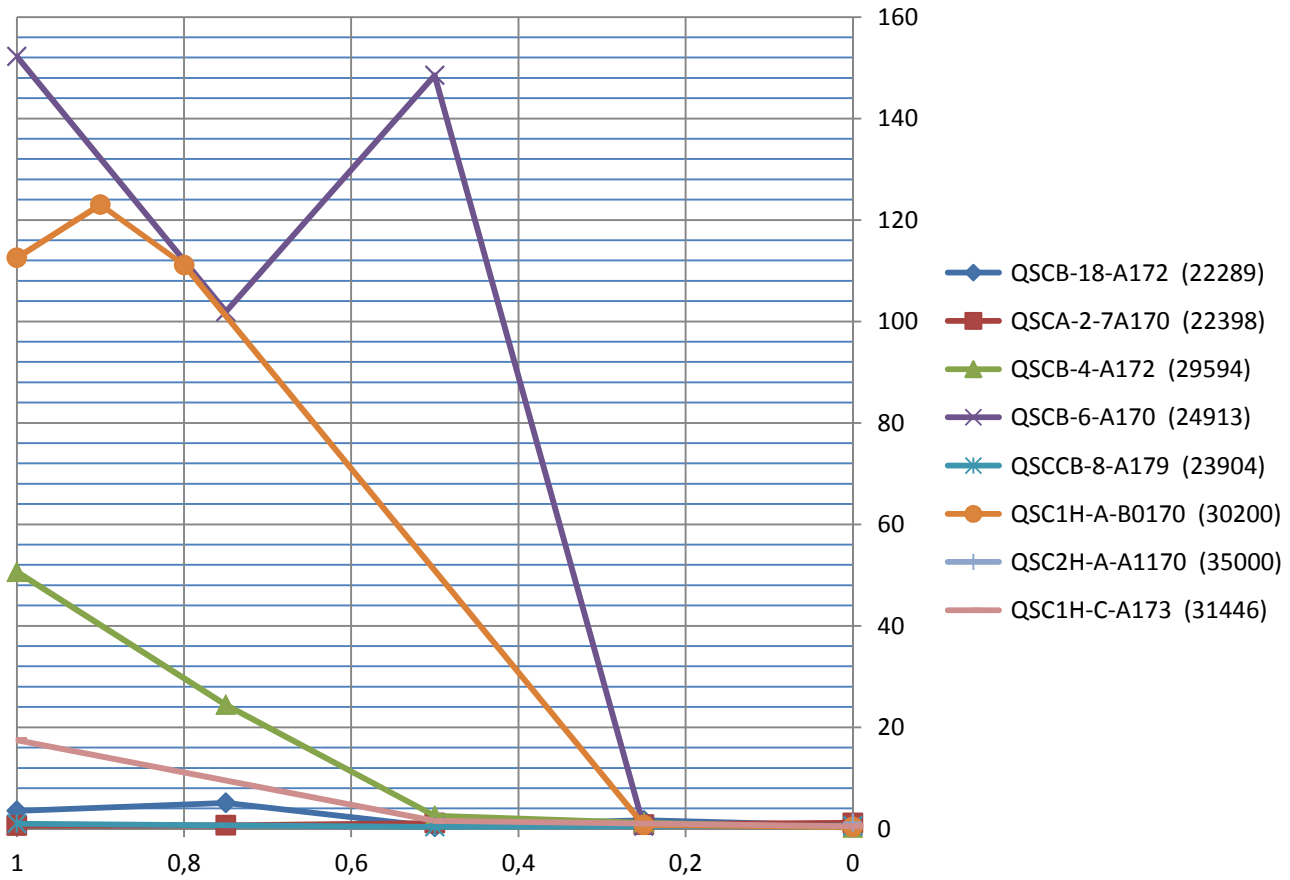
# Maintenance – OA installations

- Xmas break - activated charcoal replacement – analysis results

- inlet values from
< 1 g/kg to 150 g/kg !

- all values above 50%
are OK (< 1,66 g/kg)

The installations with
values > 100 g/kg
must be followed!



# Maintenance – OA installations

- Analysis breakdown inlet QSCB-6-A170

**Probe 11-019928-16 (1:10 Verdünnung):**

| Retentionszeit | Verbindung | CAS-Nr. | Konzentration |
|---|---|---|---|
| min | | | mg/kg |
| 13,23 | 1-(2-Propenyloxy)-2-propanol | 21460-36-6 | 9000 |
| 14,84 | 1-Butoxy-2-propanol | 5131-66-8 | 220 |
| 15,16 | 1,2-Propandiol-2-acetat | 6214-01-3 | 1200 |
| 15,44 | Dithiokohlensäuredimethylester | 19708-81-7 | 600 |
| 19,04 | Nicht identifiziert, wahrscheinlich weiterer Thiokohlensäureester | | 1200 |
| 18,6 / 18,7<br>19,7 - 19,8 (3 Peaks)<br>22,6 – 22,9 (5 Peaks)<br>23,7 – 23,8 (3 Peaks)<br>27,2 – 27,6 (5 Peaks)<br>28,8 – 29,3 (4 Peaks) | 6 Peakgruppen mit jeweils identischen Spektren. Eine genaue Einzelidentifizierung war nicht möglich. Es handelt sich wahrscheinlich um Polyethylen- bzw. Polypropylenglycolderivate unterschiedlicher Kettenlänge. | | 140000 |

cracking products

Breox

# OA – Installations 1

- QSCA4 – CV135

  The valve recuperated from P6 has been installed.
  A new cone has been ordered to repair the removed valve and to install it in P6.

# Maintenance – OA installations

- Analysis of the motor bearing oil
  - All 4 analysed samples are OK as far as the oil properties are concerned, i.e. the oil is not degraded, but the cleanliness is outside the permissive limits!
  - A campaign to change the slide bearing oil on all installations is under way.

- **Recommended control values for the lubricating oil (ABB documentation)**

The lubricating oil should be verified regarding the following aspects:
- Check the oil visually with respect to color, turbidity and deposits in a test bottle. The oil should be clear or negligibly turbid. The turbidity may not be caused by water
- The water content must not exceed 0.2 %
- The original viscosity must be maintained within a tolerance of ±15%
- The oil should be free from debris, and its cleanliness according to ISO 4406 class 18/15, or NAS 1638 class 9
- The quantity of metal impurities should be less than 100 PPM. An increasing trend of the value means that the bearing is wearing
- The total acid number (TAN) should not exceed 1 mg KOH per gram of oil. Please note that the TAN value is not the same as the TBN (total base number) value
- Smell the oil. Strong acid or burnt smell is not acceptable.

An oil check should be performed a few days after the first test run of the machine, just before the first oil change, and subsequently as required. If the oil is changed just after the commissioning, it can be used again after removing wear particles by filtering or centrifuging. In doubtful cases, an oil sample may be sent to the laboratory to determine viscosity, acid number, foaming tendency, etc.

**Diagnose**

De grosses particules de contamination sont clairement visibles. L'indice PQ indique une teneur accrue en particules ferreuses magnétiques. Augmentation sensible de la teneur en cuivre en raison de la corrosion ou de l'usure des composants contenant du cuivre (également du bronze ou du laiton). La classe de propreté de l'huile est nettement insuffisante par rapport aux recommandations des fabricants des composants. Conseil : si vous ne l'avez pas déjà fait, changez l'huile principalement en raison de la forte teneur en particules d'usure.

**Dipl.-Ing. Hendrik Karl**

**Evaluation totale**

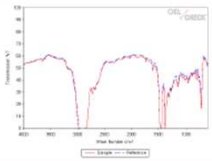
**Action**

| RÉSULTATS DE LAB | | | Échantillon | Échantillons précédents | | |
|---|---|---|---|---|---|---|
| NUMÉRO D'ÉCHANTILLON | | | 1421917 | | | |
| EVALUATION TOTALE | | | ! | | | |
| Date d'analyse | | | 13.04.2011 | | | |
| Date du prélèvement | | | 29.03.2011 | | | |
| Date de la dernière vidange | | | - | | | |
| Litres dernière vidange | | | - | | | |
| Durée de marche de l'huile | | | - | | | |
| Temps de fonctionnement | | | - | | | |
| Vidange | | | - | | | |
| PARTICULES D'USURE | | | | | | |
| Fer | Fe | mg/kg | 0 | | | |
| Chrome | Cr | mg/kg | 0 | | | |
| Étain | Sn | mg/kg | 0 | | | |
| Aluminium | Al | mg/kg | 0 | | | |
| Nickel | Ni | mg/kg | 0 | | | |
| Cuivre | Cu | mg/kg | 71 | | | |
| Plomb | Pb | mg/kg | 0 | | | |
| Molybdène | Mo | mg/kg | 0 | | | |
| Indice PQ | - | | 95 | | | |
| CONTAMINATION | | | | | | |
| Silicium | Si | mg/kg | 0 | | | |
| Potassium | K | mg/kg | 0 | | | |
| Sodium | Na | mg/kg | 2 | | | |
| Eau K. F. | ppm | | 32 | | | |
| ÉTAT DE L'HUILE | | | | | | |
| Viscosité à 40°C | mm²/s | | 30.80 | | | |
| Viscosité à 100°C | mm²/s | | 5.38 | | | |
| Indice de viscosité | - | | 108 | | | |
| Oxydation | A/cm | | 1 | | | |
| Couleur | couleur ASTM | | 1.5 | | | |
| ADDITIFS | | | | | | |
| Calcium | Ca | mg/kg | 14 | | | |
| Magnésium | Mg | mg/kg | 27 | | | |
| Bore | B | mg/kg | 0 | | | |
| Zinc | Zn | mg/kg | 292 | | | |
| Phosphore | P | mg/kg | 245 | | | |
| Baryum | Ba | mg/kg | 0 | | | |
| Soufre | S | mg/kg | 9583 | | | |

| RÉSULTATS DE LAB | | | Échantillon | Échantillons précédents | | |
|---|---|---|---|---|---|---|
| NUMÉRO D'ÉCHANTILLON | | | 1421917 | | | |
| EVALUATION TOTALE | | | ! | | | |
| Date d'analyse | | | 13.04.2011 | | | |
| Date du prélèvement | | | 29.03.2011 | | | |
| Date de la dernière vidange | | | - | | | |
| Litres dernière vidange | | | - | | | |
| Durée de marche de l'huile | | | - | | | |
| Temps de fonctionnement | | | - | | | |
| Vidange | | | - | | | |
| TESTS SUPPLÉMENTAIRES | | | | | | |
| Classe de propreté | ISO 4406 (1999) | | 23/22/17 | | | |
| A: >4µm = ISO >4µm | particules/100 ml | | 6895540 | | | |
| B: >6µm = ISO >6µm | particules/100 ml | | 3689270 | | | |
| C: >14µm = ISO >14µm | particules/100 ml | | 112250 | | | |
| D: >21µm | particules/100 ml | | 47510 | | | |
| E: >38µm | particules/100 ml | | 70 | | | |
| F: >70µm | particules/100 ml | | 10 | | | |
| Classe de propreté | SAE AS 4059 | | > 12A | | | |

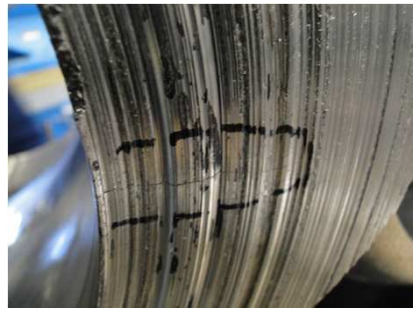
Échantillon et oburateur

Spectre infrarouge



# Review of m. on OA installations

- Point 4 – QSCB compressor Cp6
  - Situation
    - Sudden rapid increase of the oil filter pressure drop
    - Abnormal noise and high vibration signal
  - Analysis
    - The main axial bearing was completely destroyed
    - Compressor has suffered severe damages
    - Aerzener report expected today
  - Actions
    - Decision to be taken once we receive the repair/replacement offer
    - The vibration measurement approach is under consideration. Visit by expert on 16.02.



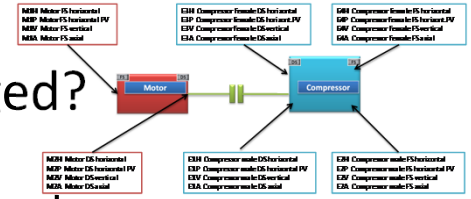
# Lessons Learned and Improvements

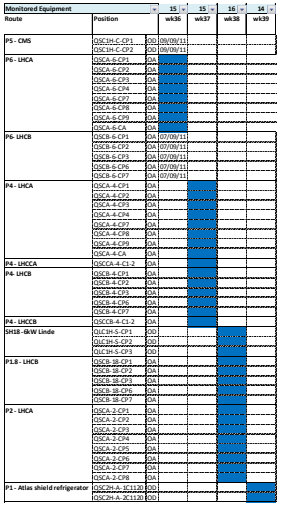
- What have we learned from the analysis?
  - For compressors ISO 10816 gives only limited information as the vibrations are linked to
    - load
    - compressi…

However, we had already a powerful tool

…tect… only …ures!

- What has been changed?
  - The data taking method has been validated by a CERN expert
  - The measurement database has been re-configured for a larger bandwidth and bearing data has been implemented
  - Vibration data is now regularly analyzed by a vibration expert
  - A data taking planning s… by CERN



Point 1

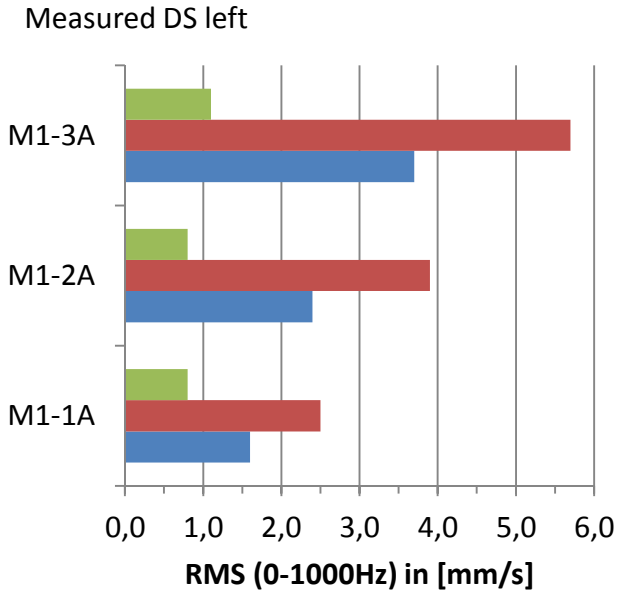
2011

| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | | 0.00 | | 0.55 | | 0.00 | | | | | |

Key for Equipment condition: normal / unproblematic ✓; to pay attention !; critical / acions recommended ✗

| ID | Equipment | | Monitoring Schedule | Prov. monitoring Schedule | January | February | March | April | May | June | July | August | September | October | November | December | Fault Description | Recommended Actions | Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Atlas shield refrigerator** | | | | | | | | | | | | | | | | | | | |
| QSC2H-A-1C | Compressor | QSC2H-A-1C1120 | 30 | | | | | | | | | | | | | | | | |
| QSC2H-A-2C | Compressor | QSC2H-A-2C1120 | 30 | | | | | | | | | ✓ | | | | | | | |
| **Atlas main refrigerator** | | | | | | | | | | | | | | | | | | | |
| QSC1H-A-CP1 | Compressor | QSC1H-A-CP1 | 30 | | | | | | | | | ! | | | | | Untypical sidebands from the female rotor | Do another measurement | ✗ |
| QSC1H-A-CP2 | Compressor | QSC1H-A-CP2 | 30 | | | | | | | | | ✗ | | | | | Motor & Compressor Resonanz / internal play bearing motor | Further measurements --> bump test, vibration shape mode | ✗ |

# Predictive maintenance – vibration measurements (1)




Comparing motor vibration shape
in axial direction
for the three LHCB-6 booster compressors

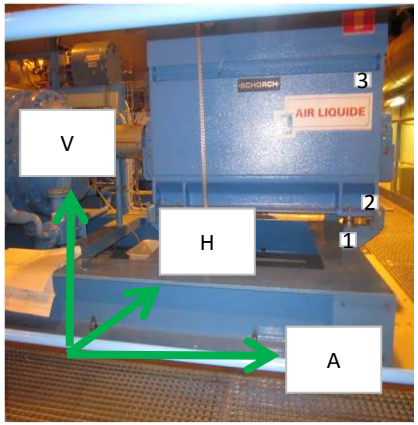
QSCB-6-MO3 -DS_left

QSCB-6-MO2 -DS_left

QSCB-6-MO1 -DS_left

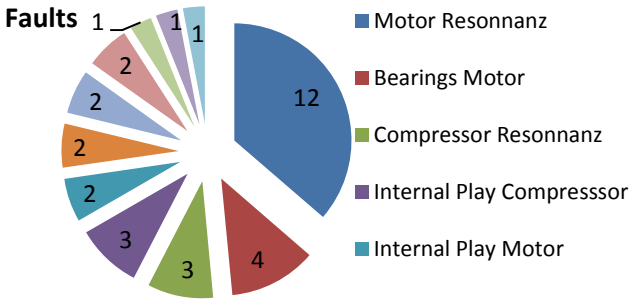

QSCB-M03
M=2.5t
P=408kW

QSCB-M01 & M02
M=2.5t
P=543kW

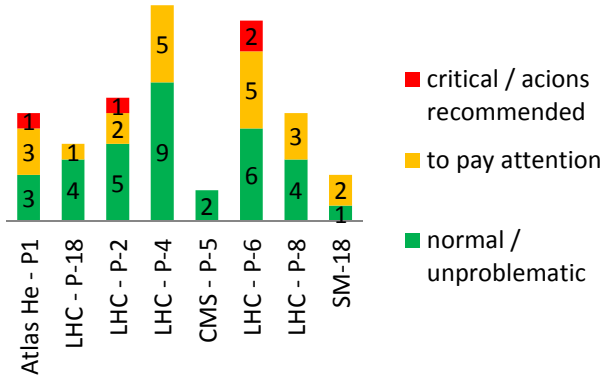


# Intermediate Conclusions

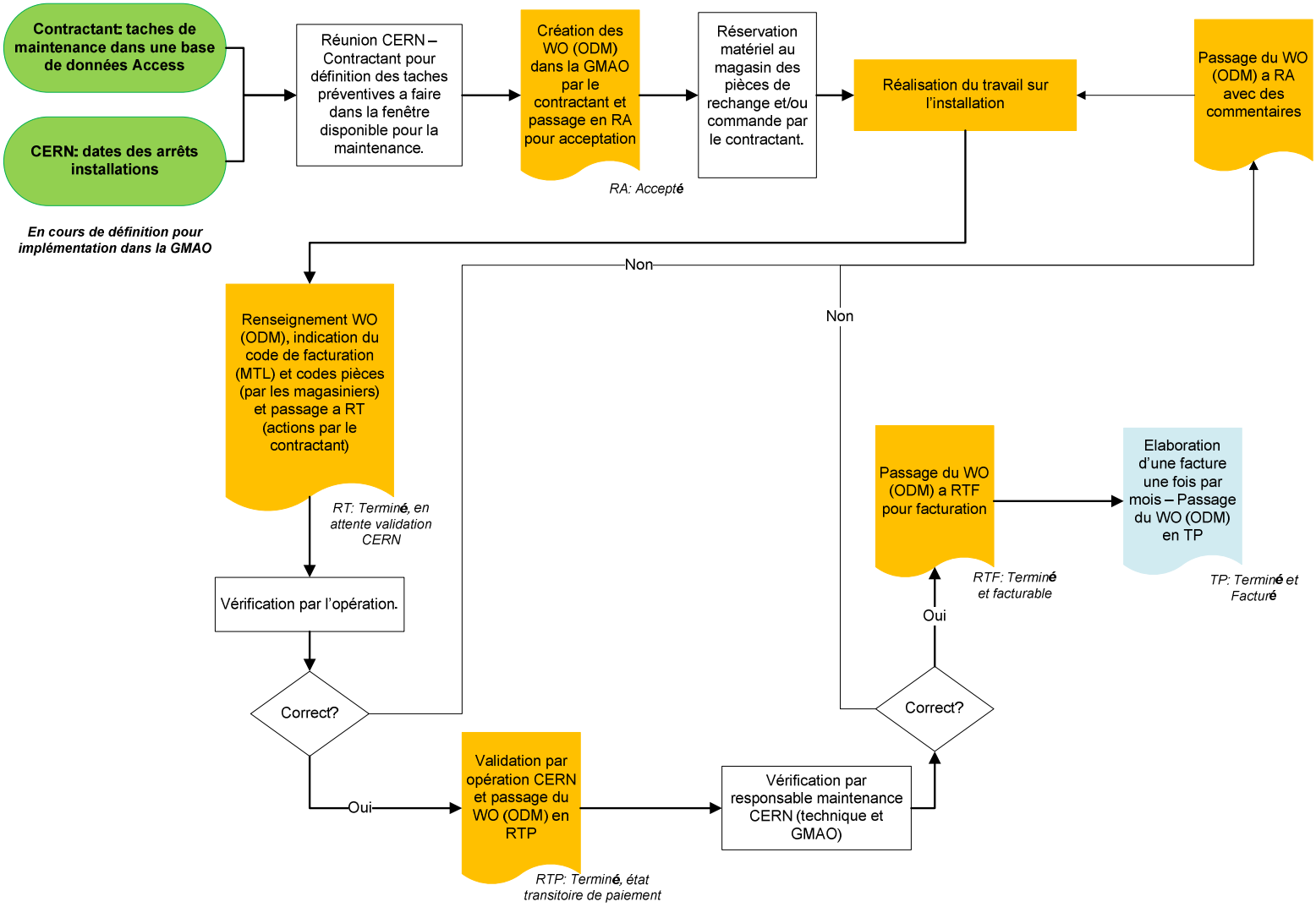
- The visibility of the compressor and motor condition has been considerably improved
- A clear and simple classification from normal to critical has been established
- A number of improvement starting points have been identified
  - Check and consolidation of motor fixation
    - comprising bolts, mounting shims and skid surface quality, planar errors of motor feet
  - Carry out additional vibration measurements
    - bump tests and vibration shape
  - Check and consolidation of foundation
    - comprising anti-vibration pads, additional grouting, skid modifications and reinforcements
- A correlation of wear and damages found during revisions with the vibration measurements will allow even better understanding of the criticality



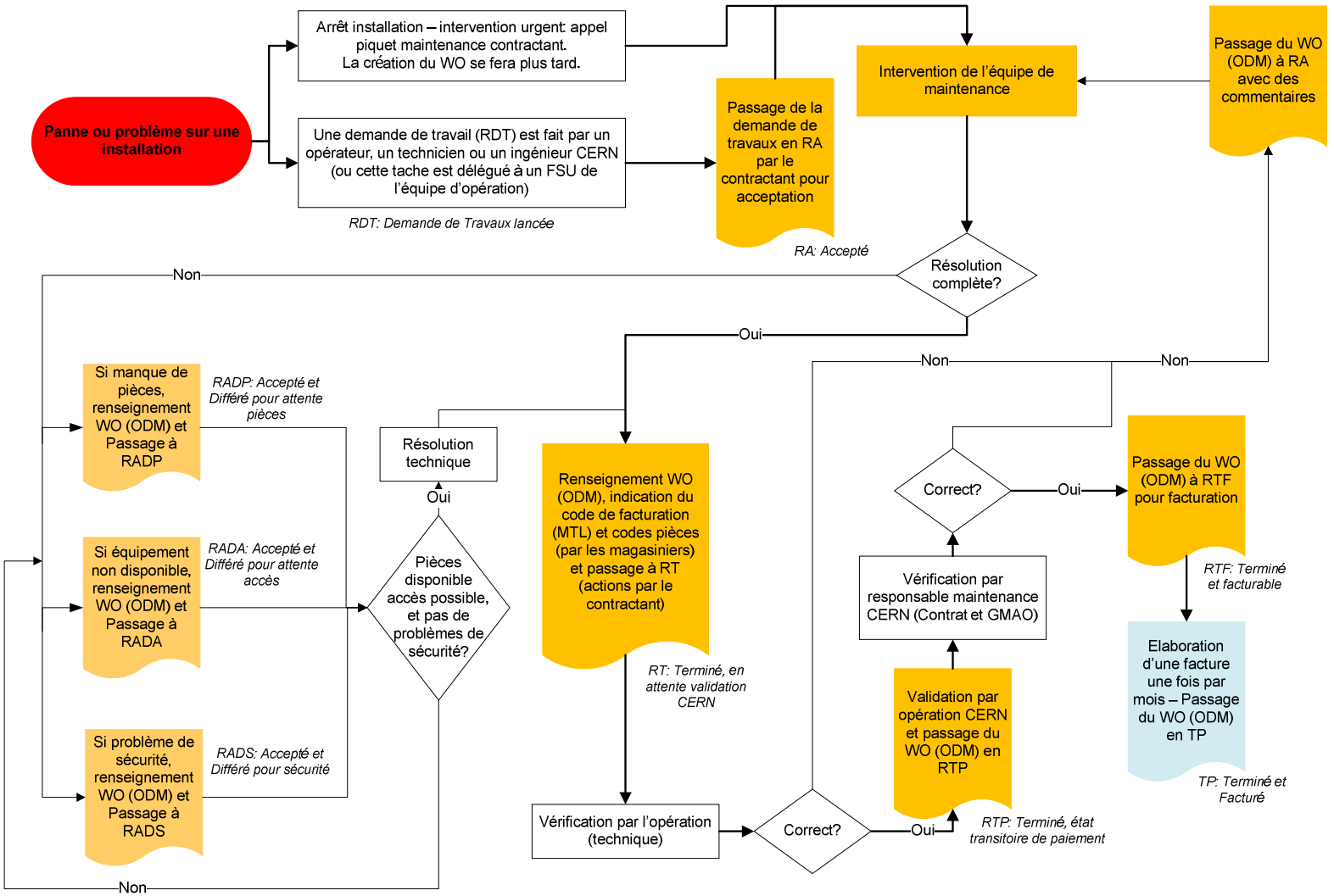

**Classification of equipment condition**

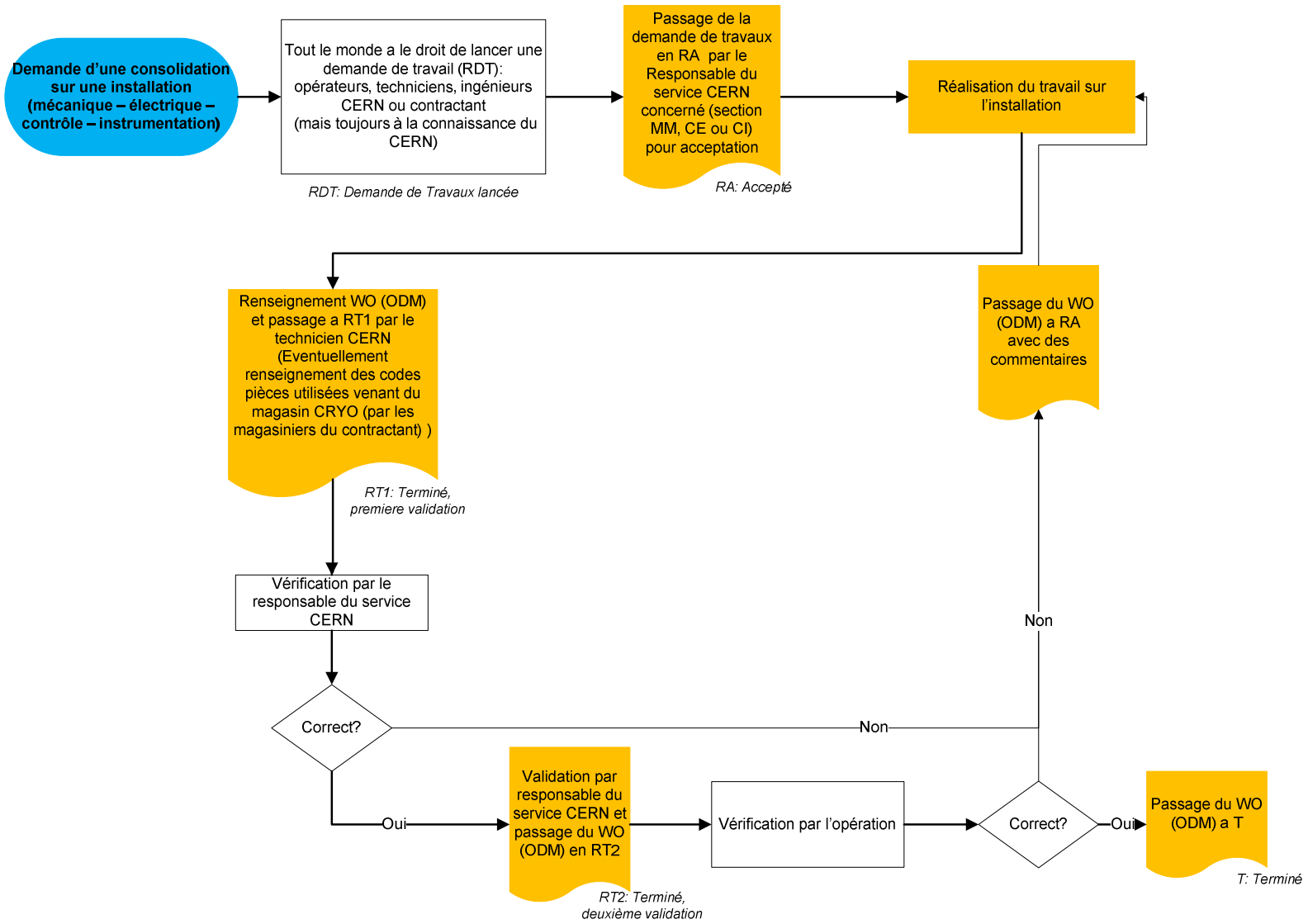


# PM work flow


Contractant: taches de maintenance dans une base de données Access
CERN: dates des arrêts installations
En cours de définition pour implémentation dans la GMAO
Réunion CERN – Contractant pour définition des taches préventives a faire dans la fenêtre disponible pour la maintenance.
Création des WO (ODM) dans la GMAO par le contractant et passage en RA pour acceptation
RA: Accepté
Réservation matériel au magasin des pièces de rechange et/ou commande par le contractant.
Réalisation du travail sur l'installation
Passage du WO (ODM) a RA avec des commentaires
Renseignement WO (ODM), indication du code de facturation (MTL) et codes pièces (par les magasiniers) et passage a RT (actions par le contractant)
RT: Terminé, en attente validation CERN
Vérification par l'opération.
Correct?
Non
Oui
Validation par opération CERN et passage du WO (ODM) en RTP
RTP: Terminé, état transitoire de paiement
Vérification par responsable maintenance CERN (technique et GMAO)
Correct?
Non
Oui
Passage du WO (ODM) a RTF pour facturation
RTF: Terminé et facturable
Elaboration d'une facture une fois par mois – Passage du WO (ODM) en TP
TP: Terminé et Facturé

# CM work flow


Panne ou problème sur une installation
Arrêt installation – intervention urgent: appel piquet maintenance contractant. La création du WO se fera plus tard.
Une demande de travail (RDT) est fait par un opérateur, un technicien ou un ingénieur CERN (ou cette tache est délégué à un FSU de l'équipe d'opération)
RDT: Demande de Travaux lancée
Passage de la demande de travaux en RA par le contractant pour acceptation
RA: Accepté
Intervention de l'équipe de maintenance
Passage du WO (ODM) à RA avec des commentaires
Résolution complète?
Non
Oui
Si manque de pièces, renseignement WO (ODM) et Passage à RADP
RADP: Accepté et Différé pour attente pièces
Si équipement non disponible, renseignement WO (ODM) et Passage à RADA
RADA: Accepté et Différé pour attente accès
Si problème de sécurité, renseignement WO (ODM) et Passage à RADS
RADS: Accepté et Différé pour sécurité
Résolution technique
Oui
Pièces disponible accès possible, et pas de problèmes de sécurité?
Non
Renseignement WO (ODM), indication du code de facturation (MTL) et codes pièces (par les magasiniers) et passage à RT (actions par le contractant)
RT: Terminé, en attente validation CERN
Vérification par l'opération (technique)
Correct?
Non
Oui
Validation par opération CERN et passage du WO (ODM) en RTP
RTP: Terminé, état transitoire de paiement
Vérification par responsable maintenance CERN (Contrat et GMAO)
Correct?
Non
Oui
Passage du WO (ODM) à RTF pour facturation
RTF: Terminé et facturable
Elaboration d'une facture une fois par mois – Passage du WO (ODM) en TP
TP: Terminé et Facturé


Demande d'une consolidation sur une installation (mécanique – électrique – contrôle – instrumentation)
Tout le monde a le droit de lancer une demande de travail (RDT): opérateurs, techniciens, ingénieurs CERN ou contractant (mais toujours à la connaissance du CERN)
RDT: Demande de Travaux lancée
Passage de la demande de travaux en RA par le Responsable du service CERN concerné (section MM, CE ou CI) pour acceptation
RA: Accepté
Réalisation du travail sur l'installation
Renseignement WO (ODM) et passage a RT1 par le technicien CERN (Eventuellement renseignement des codes pièces utilisées venant du magasin CRYO (par les magasiniers du contractant) )
RT1: Terminé, premiere validation
Passage du WO (ODM) a RA avec des commentaires
Vérification par le responsable du service CERN
Correct?
Non
Non
Oui
Validation par responsable du service CERN et passage du WO (ODM) en RT2
RT2: Terminé, deuxième validation
Vérification par l'opération
Correct?
Oui
Passage du WO (ODM) a T
T: Terminé