CRYOGENICS OPERATIONS 2008

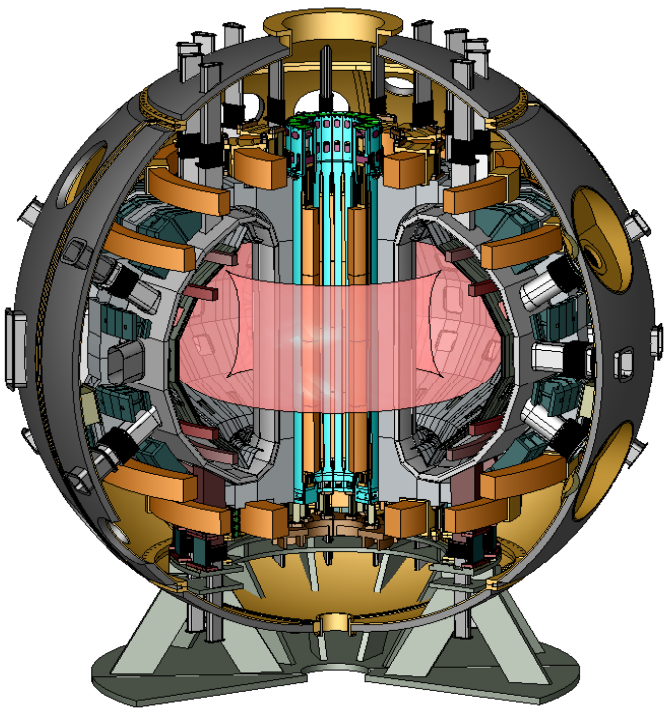
# CRYOGENICS OPERATIONS 2008

**Organized by CERN**

## Design status of the cryogenic system of JT60-SA: optimization of the refrigeration capacity for different operation modes

**Christine Hoa, Frédéric Michel**
**SBT, CEA Grenoble**

# Outline

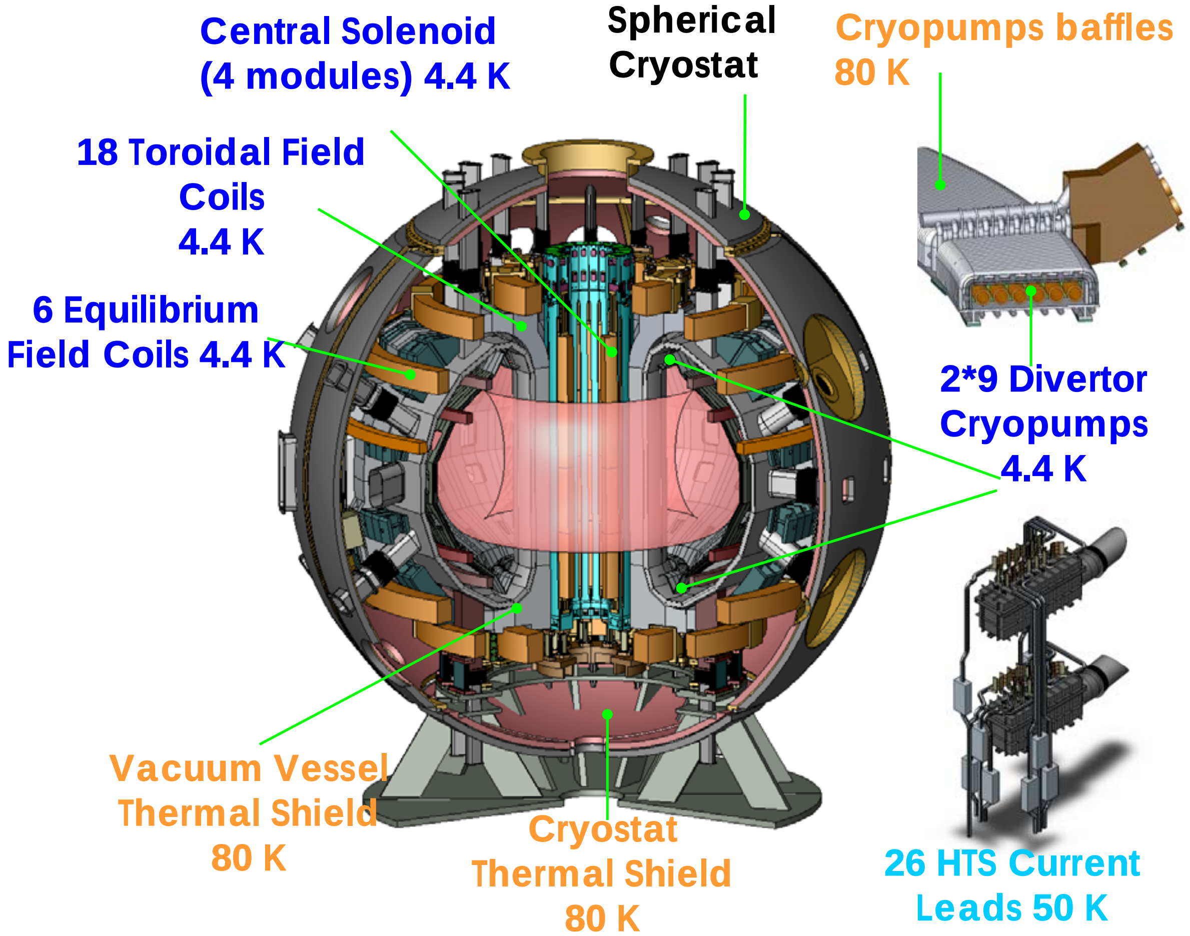


- **Cryogenic system for the tokamak JT-60SA**
- **Operation modes and heat loads**
- **Optimization of the refrigeration capacity**
  - » Thermal buffer operation during day
  - » Liquid storage during night
- **Perspectives and conclusions**

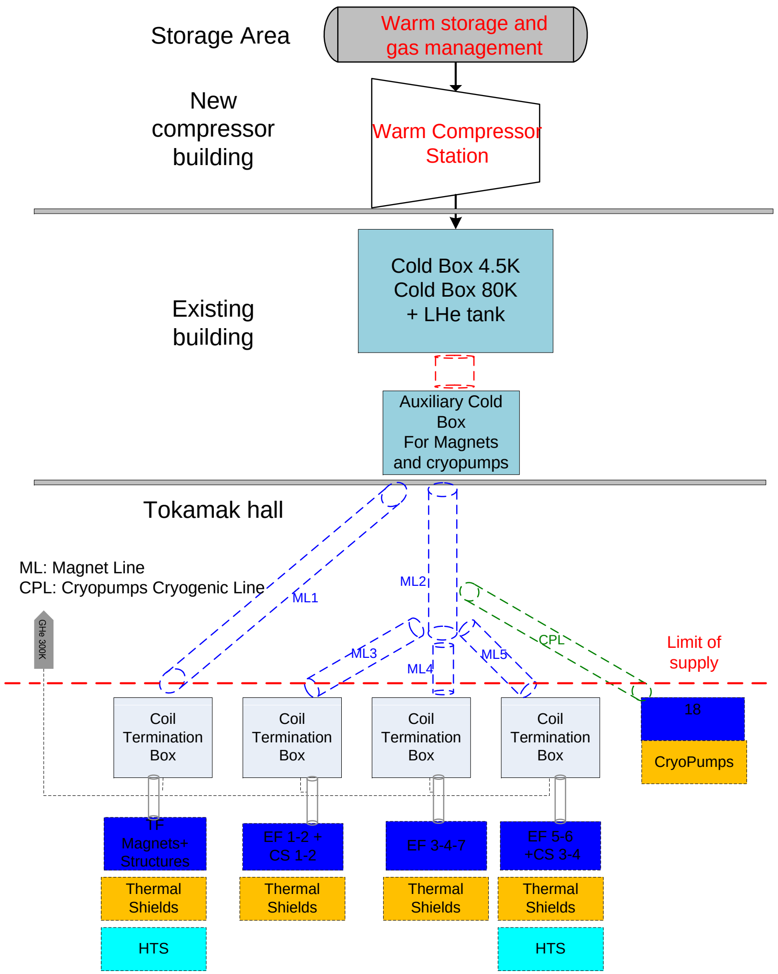
# Cryogenic system for the tokamak JT-60SA

- **Presentation of the tokamak JT-60SA**
  - » Superconductive tokamak in Naka, Japan
  - » ITER Broader approach, joint project between Japan and Europe
  - » CEA in charge of the cryogenic system procurement
  - » D-D Plasma physics planned for 2015
  - » 2008: Concept design phase

# Cryogenic system for the tokamak JT-60SA



# Cryogenic system for the tokamak JT-60SA



CRYOGENICS OPERATIONS 2008

# Operation modes

- **Yearly schedule**

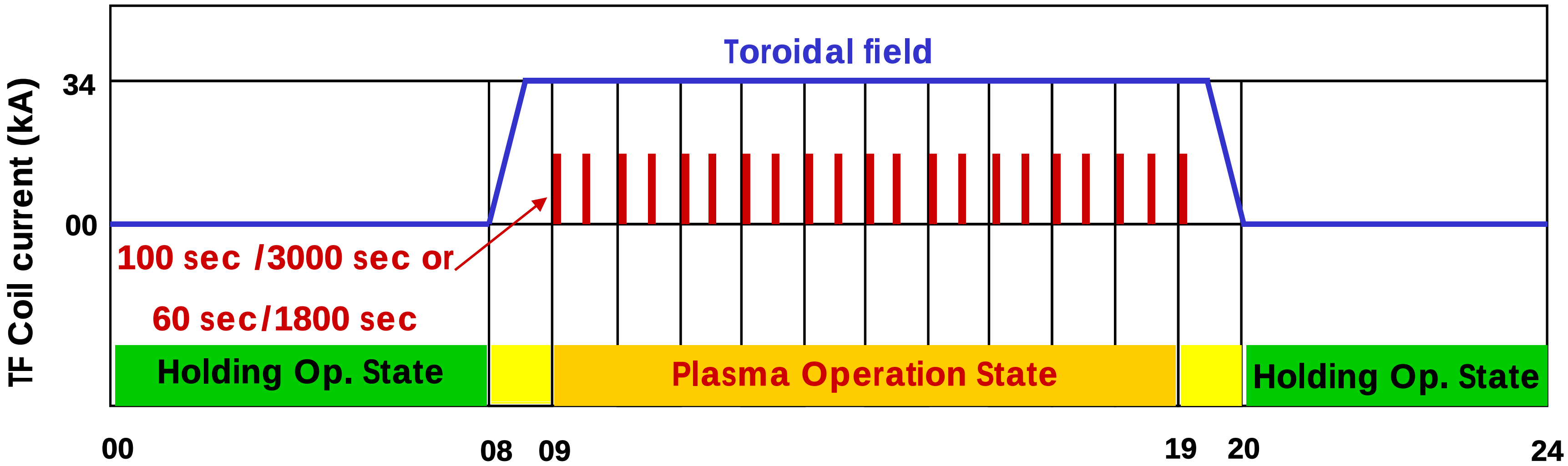
| JT-60SA Operation States | | Long Term Maintenance (LTM) | Baking Operation State (BOS) | Holding Operation State (HOS) | Plasma Operation State (POS) |
|---|---|---|---|---|---|
| Duration | | >30 days | ~ 7 days | Night (12 h) or WE | Day (10 h) |
| Magnets | Temperature (K) | 300 | 20 | 4.6 | 4.4 |
| | TF current | OFF | OFF | OFF/ON | ON |
| | EF and CS current | OFF | OFF | OFF/ON | ON |
| Vacuum Vessel & Cryostat Thermal Shield Temperature (K) | | 300 | 80/120 | 80/100 | 80/100 |
| Vacuum Vessel | Temp (K) | 300 | 470 | 313 | 313 |
| Divertor Cryopumps Temperature (K) | | 300 | 470 | 20-30 K regeneration | 4.4 |

**CRYOP08- 25/09, 15:30 Baking scenarios studies, V.Lamaison**

**JT-60SA will be operated 6 or 7 months / year**

# Operation modes

- **Daily schedule**



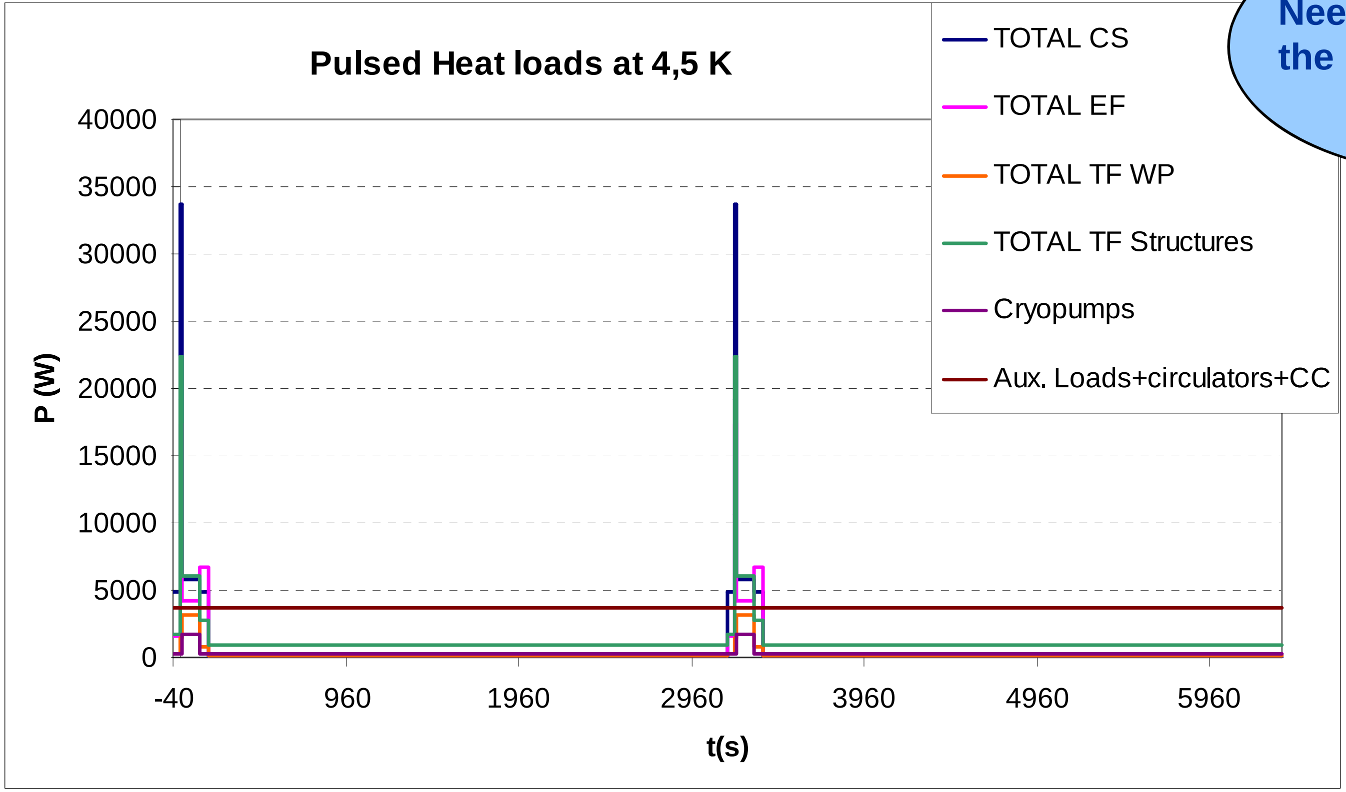
# Heat loads

- **Refrigerator Capacity of ~10 kW @4.5 K**

| Temperature levels | Cryogenic subsystems | units | POS 100/3000 sec scenario | HOS | BOS |
|---|---|---|---|---|---|
| 4,5 K | total CS coils | W | 475 | 0 | 0 |
| | total EF coils | W | 635 | 312,5 | 612,5 |
| | total TF coils | W | 1444 | 1032,61 | 1837,5 |
| | aux. Loads | W | 730 | 730 | 650 |
| | cryopump panel | W | 248 | 0 | 0 |
| | cold circulators | W | 2201 | 1576,5 | 1 |
| | cold compressor | W | 734 | 390 | 0 |
| | TOTAL 4,5 K | W | 6467 | 4042 | 3101 |
| | | | | | |
| 50K | HTS Current leads flow@(50 K-300 K) | g/s | 23,8 | 23,03 | 0 |
| | | | | | |
| 80 K | Thermal shields 80 K | W | 31962 | 31890 | 118500 |
| | | | | | |
| 4,5 K | Equivalent refrigeration power | kW | 8,1 | 5,8 | 8,2 |

# Heat loads

- **Direct Pulsed Heat loads**



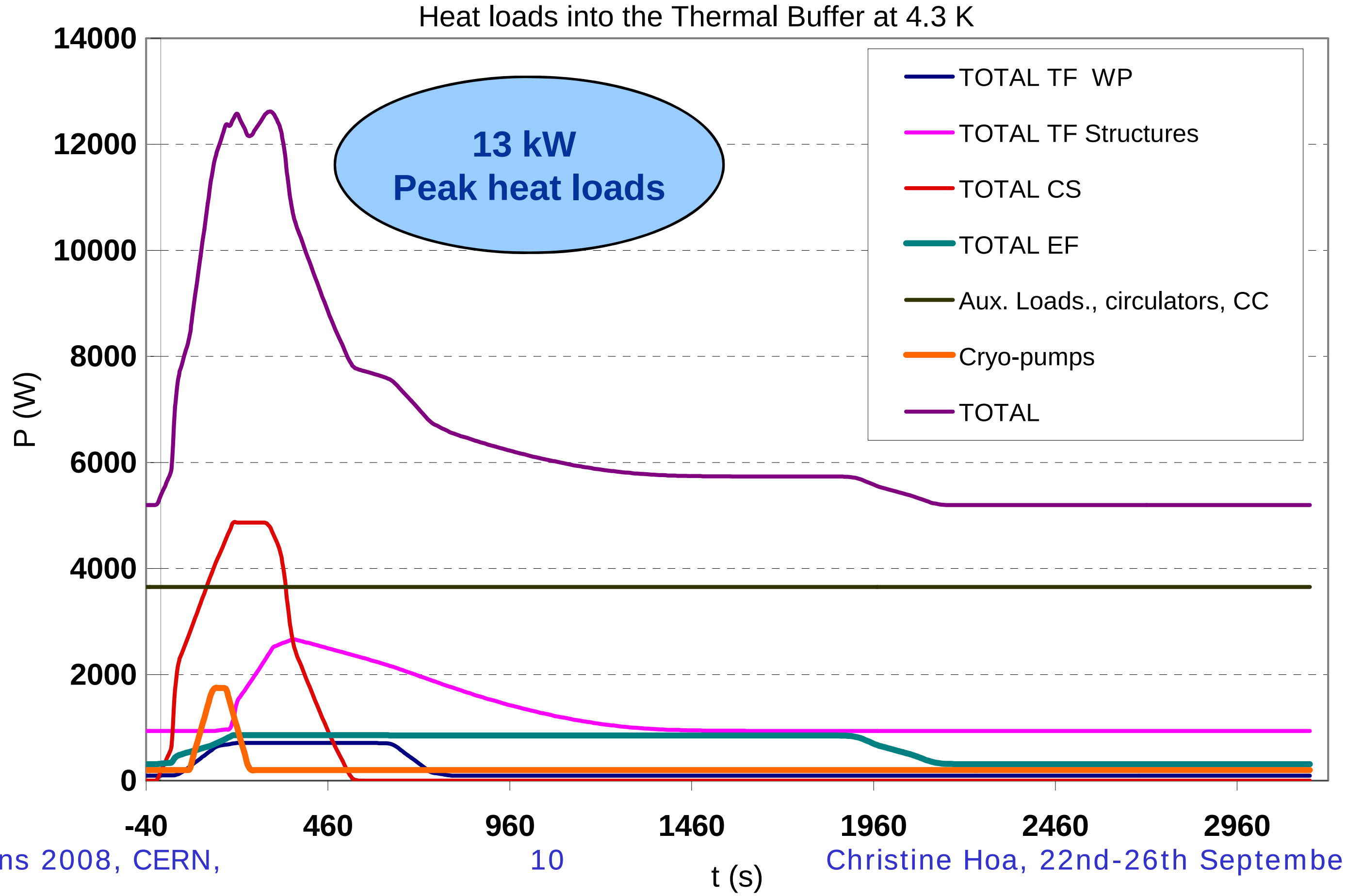

**Needs of smoothing the pulsed heat loads**

Averaged heat loads at 4.5 K: 6.5 kW

# Heat loads

- **Pulsed heat loads: (POS: 100s plasma/3000 s)**

**A first smoothing in the CICC and in the cooling channels**



# Heat loads

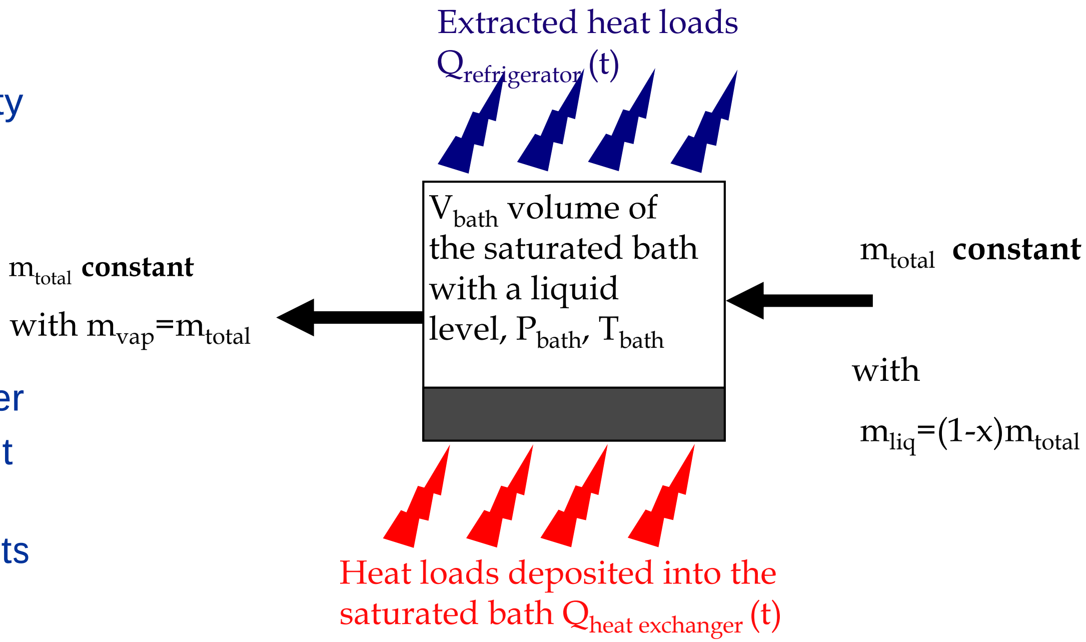
- **Pulsed heat loads: Comparison with other tokamaks**

| Tokamaks | Equivalent Refrigeration Power at 4.5 K | Averaged power At 4.5 K | Peak heat loads at 4.5 K | Ratio Peak/Averaged Power | Thermal buffer size |
|---|---|---|---|---|---|
| **ITER [1]** | **2*30 kW** | **37 kW** (magnets) | **43 kW** | **1.2** | **4*2 $m^3$** |
| **JT60-SA** | **10 kW (TBC)** | **6.5 kW** (magnets+ cryo-pumps) | **13 kW** | **2.2** | **6 $m^3$** |
| **K-STAR [2]** | **9 kW** | **4.7 kW** | **6.2 KW** | **1.3** | **6 $m^3$** |
| **TORE SUPRA [3]** | **800 W** **Thick casing only** | **100 W** **Thick casing only** | **17 kW** **Thick casing only** | **170** | **3*1.5 $m^3$** |

**References**
**[1] Review of conceptual design of ITER cryoplant system, Sanmarti M., Kalinin V., Lässer R., Michel F, Murdoch D., Poncet J.-M., Roussel P., Serio L.**
**[2] KSTAR Tokamak helium refrigeration System design and manufacturing, Pascal Dauguet, Air Liquid.**
**[3] Thermal buffer made of He I at constant volume, JAGER B. ; MARDION G. B. ; CLAUDET G. ; DESMARIS M. ; Cryogenics 1985, vol. 25, no10, pp. 578-582 .**

# Optimization of the refrigeration capacity

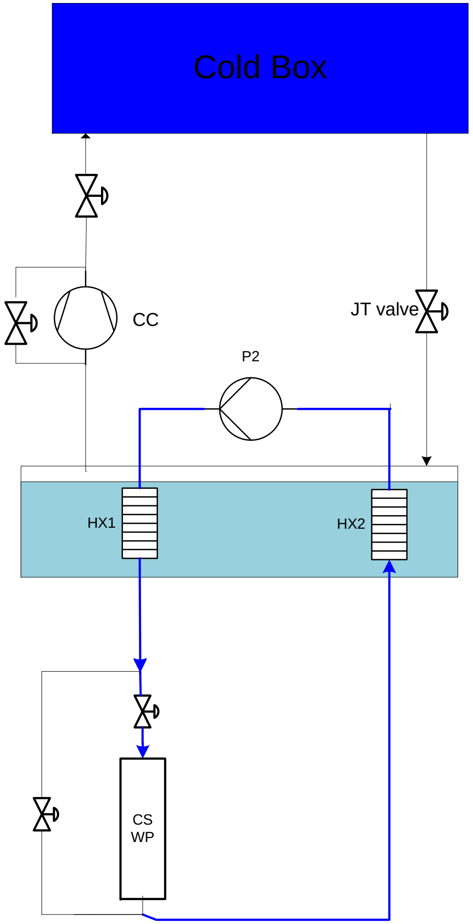
- **Smoothing the heat loads with a thermal buffer**
  - » Optimization of the refrigeration capacity for an **averaged power over a plasma scenario (6.5 kW)**
  - » Stable interface with the refrigerator: **constant mass flow rate**
  - » Drawbacks
    - Large volume for the thermal buffer
    - T variations in the buffer constraint on the magnets
    - P variations in the buffer constraints on the cold compressor



# Heat loads

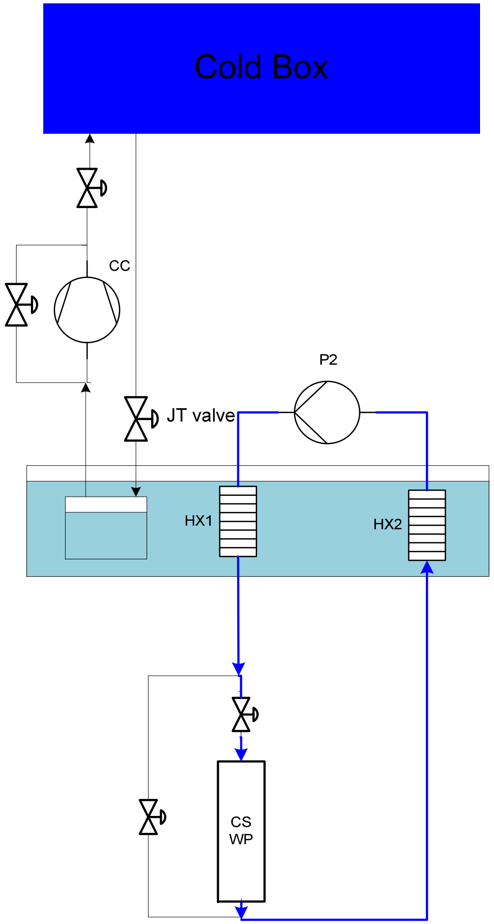
- **How to smooth the pulsed heat loads?**
  - » Practical solution, but not economical: regulation with a heater immersed into the saturated bath.
    - Installed power for the cryoplant: peak heat loads
    - JT60-SA: 13 kW at 4.5 K
  - » Optimized solutions with a thermal buffer
    - Installed power for the cryoplant: averaged heat loads
    - JT60-SA: 6.5 kW at 4.5 K
    - Technical challenges and compromises
      - **Cryodistribution: to ensure a stable operation of the refrigeration**
      - Cryoplant: new developments for adapted refrigerator that can cope with mass flow rate variation?

# Optimization of the refrigeration capacity




- **Baseline solution for a thermal buffer operation**
- **T, P variations in the thermal buffer**
  - » 4.3 to 5.0 K
  - » 1.09 to 1.96 bars
- **Regulation on the mass flow rate:**
  - » Cold compressor speed,
  - » Control valve
  - » By-pass valve...

# Optimization of the refrigeration capacity



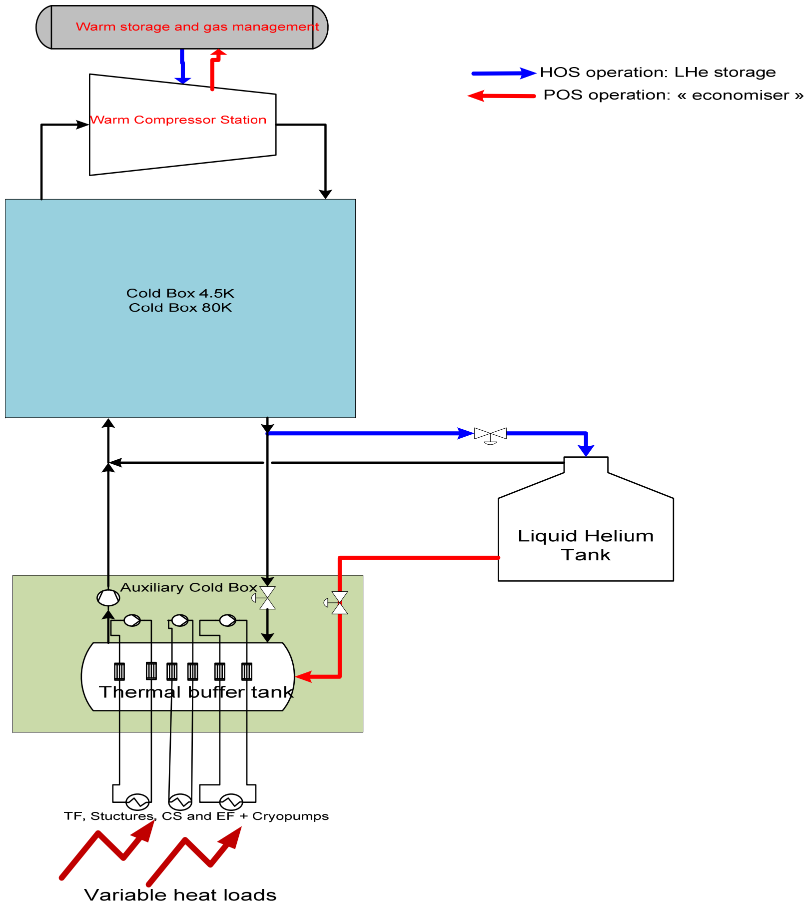

- **Other solution for a thermal buffer operation: a refrigeration box immersed into the thermal buffer**

- **Advantages**
  - » Decoupling of the refrigerator interface and the thermal buffer
    - Thermal buffer at constant volume
    - Regulation on a constant pressure in the refrigeration box
  - » Easier operation

- **Drawbacks**
  - » Refrigeration box: a supplementary component to design and connect

# Optimization of the refrigeration capacity

- **Day/night operation**
  - » Heat loads at 4.5 K during HOS and POS are significantly different
    - 6.5 kW at **P**lasma **O**peration **S**cenario
    - 4.0 kW at **H**olding **O**peration **S**cenario
  - » HOS: to store Liquid Helium into a tank using a **liquefaction mode** for the cryoplant
  - » POS: to supply supplementary Liquid Helium from the storage to cope with higher loads, using an **"economiser" mode** for the cryoplant.



# Optimization of the refrigeration capacity

- **Day/night operation**
  - » Hypothesis
    - Heat loads: 6.5 kW at POS, 4.0 kW at HOS
    - The expected efficiency for the cryoplant to produce LHe:

      120 W needs to produce 1g/s.
    - The expected efficiency for the cryoplant to convert LHe into refrigeration power: 1g/s could give 80 W.
    - All the liquid stored during HOS is used during POS.
  - » Results
    - Installed power at 4.5 K ~ **5.5 kW**
    - The active liquid helium volume : **4.3 m$^3$**

# Perspectives and Conclusions

- **Operation under pulsed heat loads**
  - » New challenges for the cryogenic system (cryoplant and cryodistribution)
  - » Different concepts for smoothing the heat loads with a thermal buffer
  - » Optimization of the refrigerator capacity:
    - **P**lasma **O**peration **S**cenario
    - **H**olding **O**peration **S**cenario

- **Investigations**
  - » Process modeling (Vincenta, HYSYS,...)
  - » Experimental mock up
  - » Analysis of the available cryogenic components under pulsed heat loads
  - » Feedbacks from other tokamaks operations ( TORA SUPRA, KSTAR...)
  - » Other abnormal operation modes: disruption, fast discharge...

CRYOGENICS OPERATIONS 2008

# Thank you for your attention!