

The 14th KEKB Accelerator Review Committee

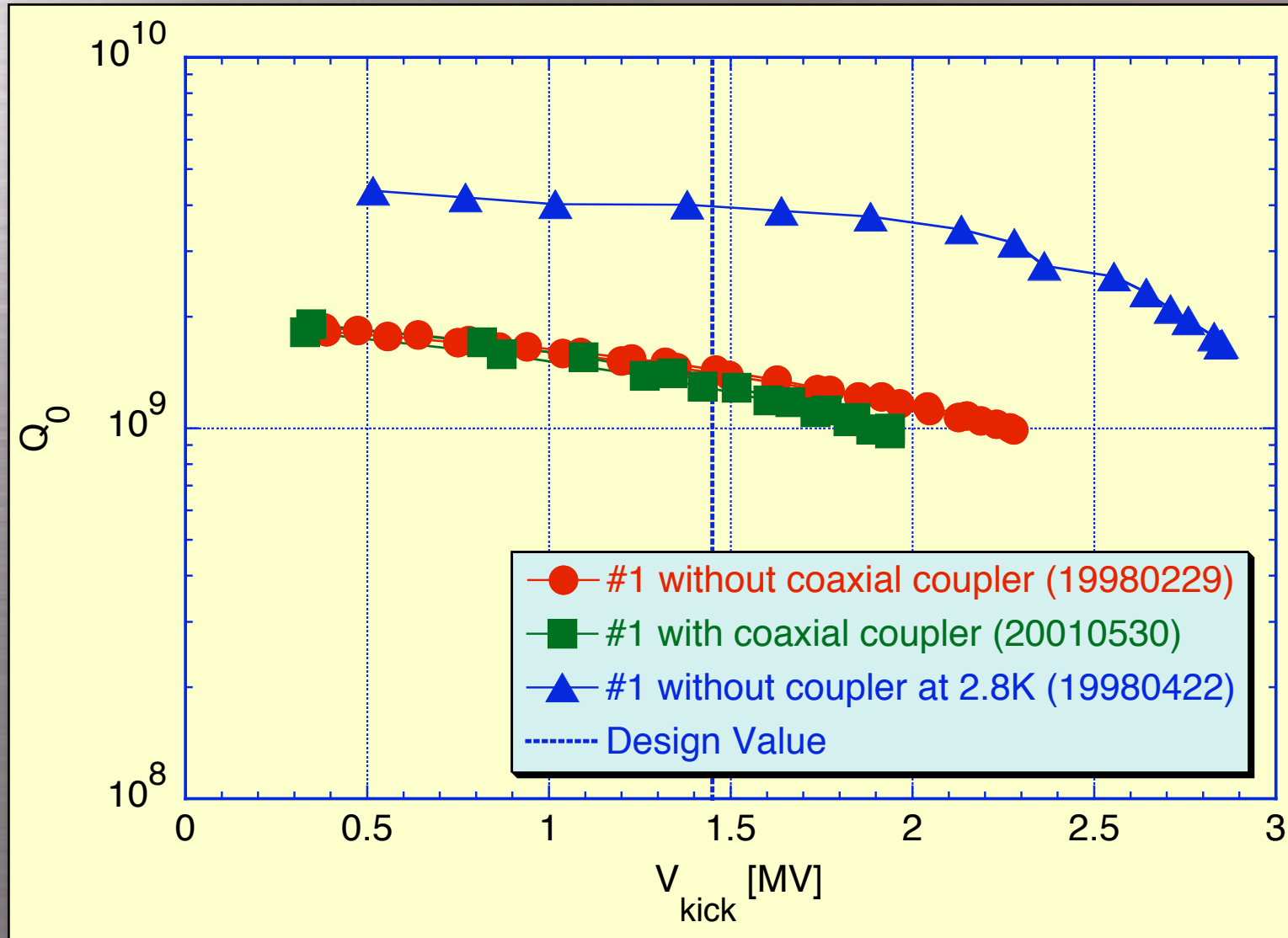
Cooling of Crab Cavities below 4K

**KEKB Crab Cavity Group
(presented by NAKAI Hirotaka)**

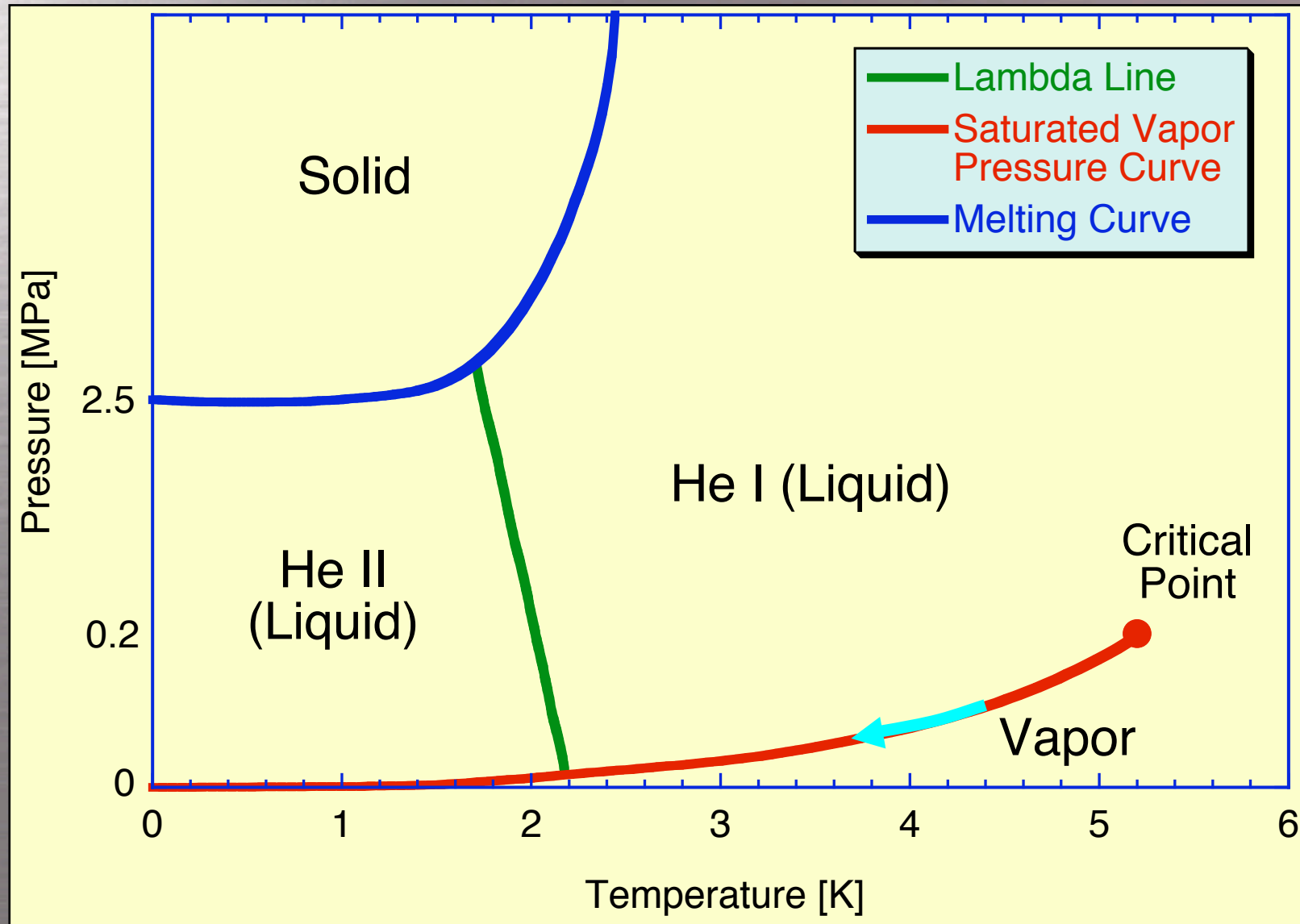
Overview

- **Past results of crab cavity performance measurements**
- **Evacuation (cooling) system**
- **1st operation of evacuation system**
- **Modification of evacuation system**
- **2nd operation of evacuation system**
- **Operation plan**

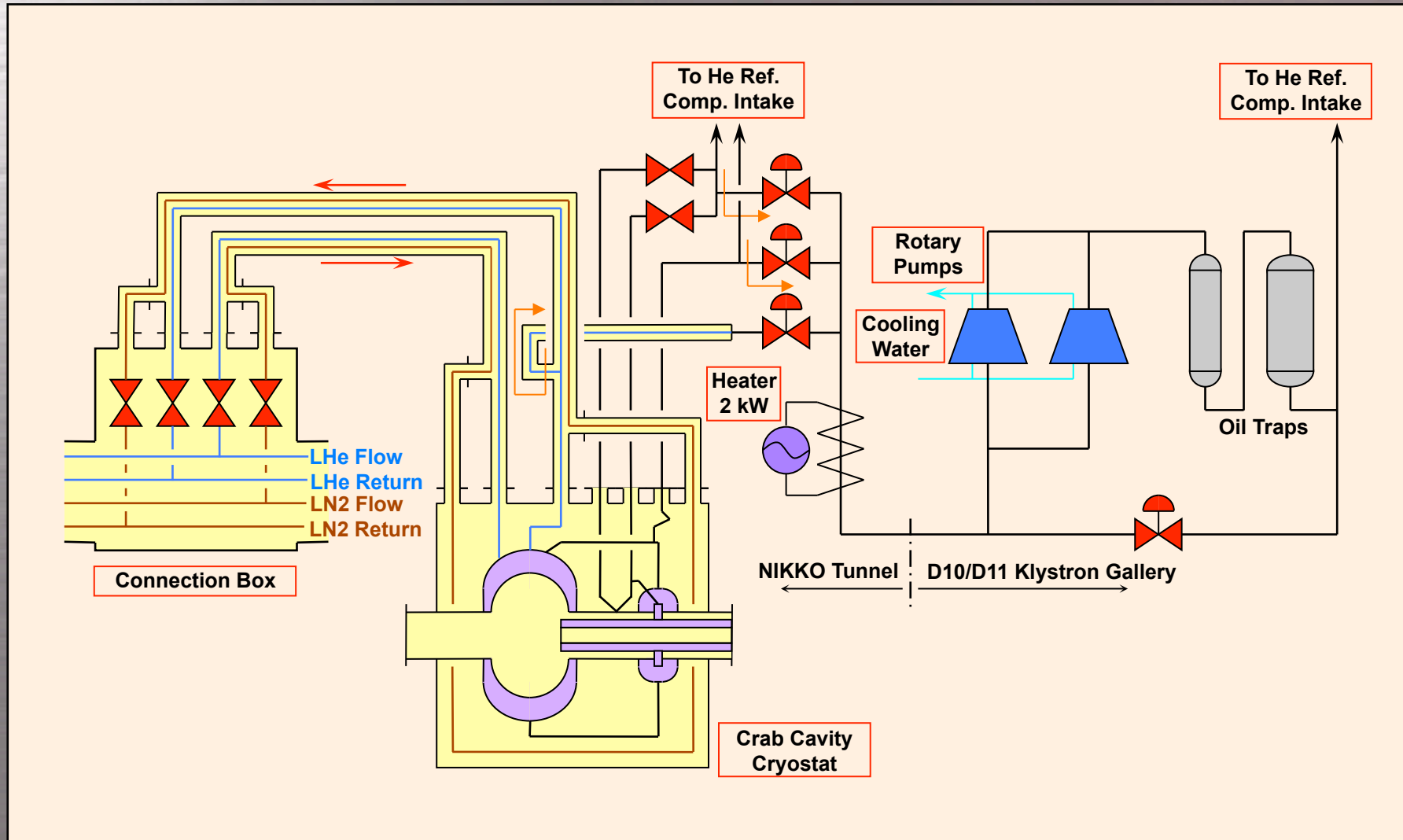
Cavity Performance Measured in R&D Phase



Phase Diagram of Helium

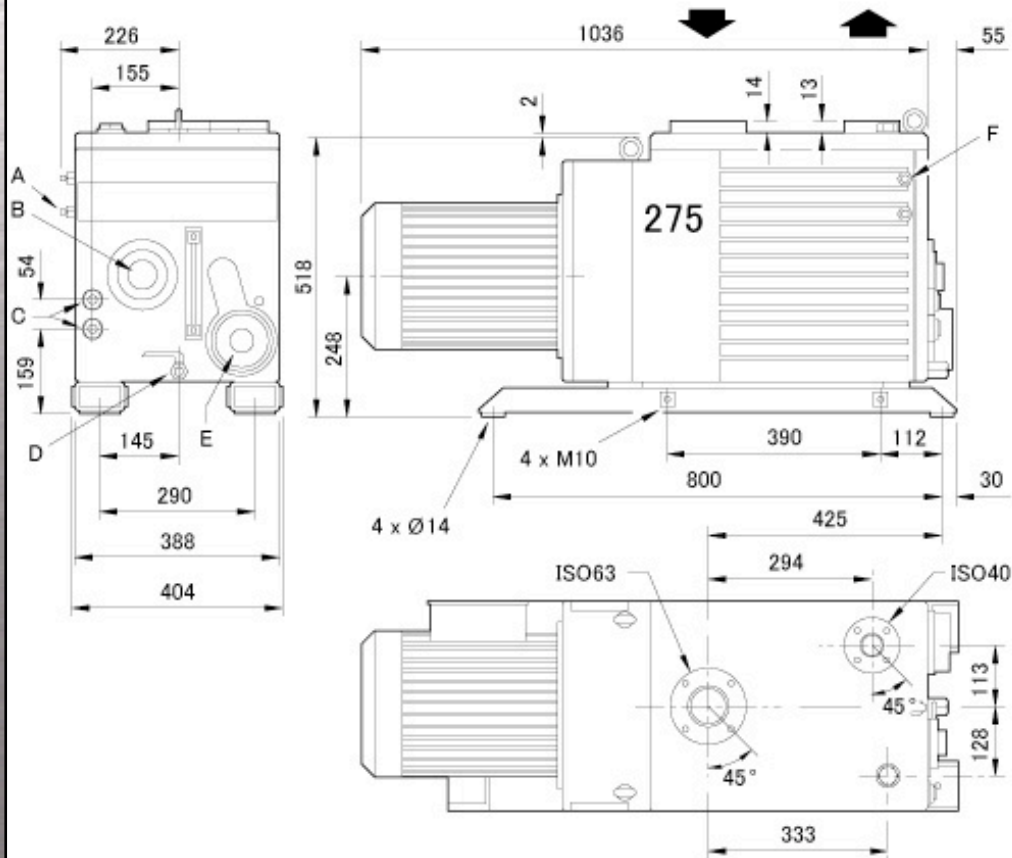


Flow Diagram of Evacuation System (1)

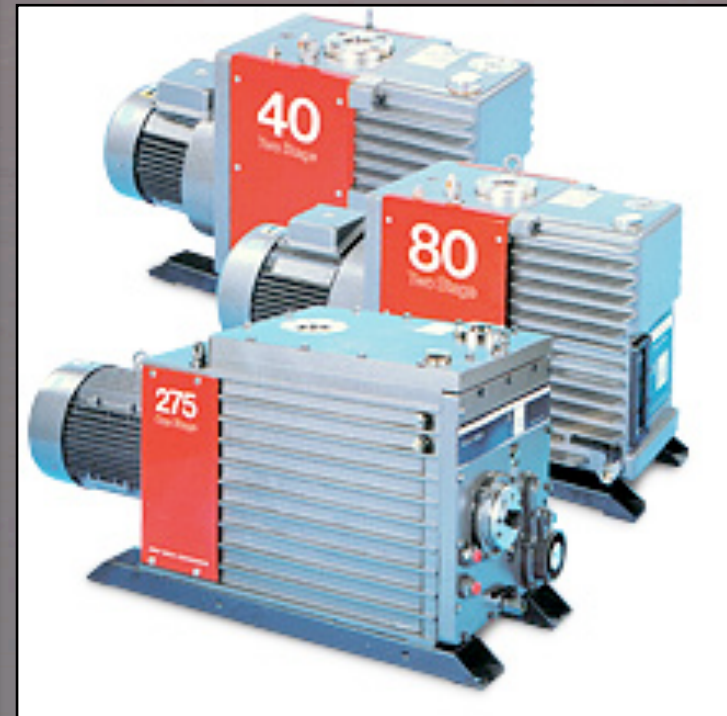


Oil Sealed Rotary Pump

E1M275/E2M275



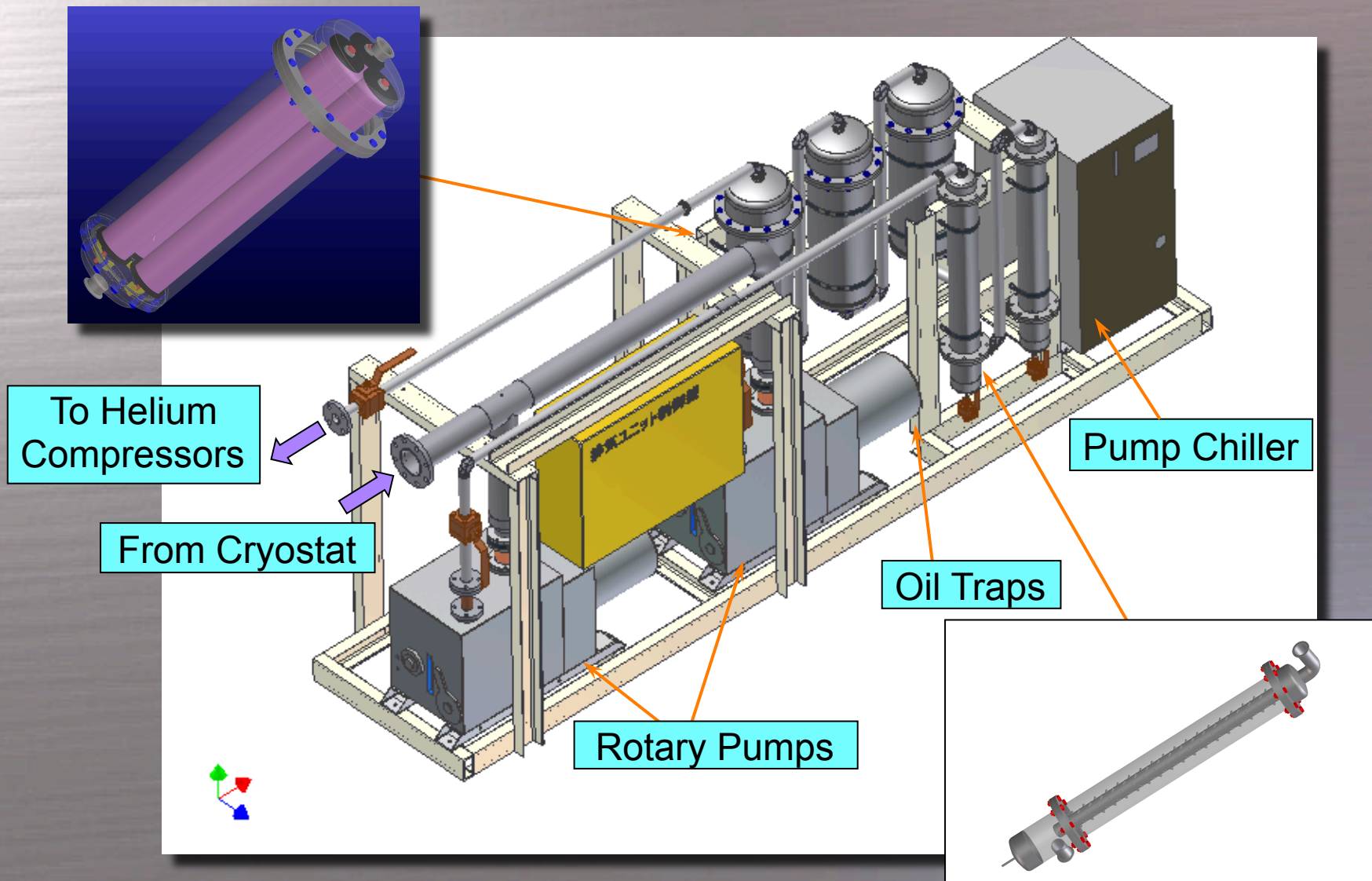
- A. オイルのリターン側接続
- B. ガスバラスト制御バルブ
- C. 冷却水接続 (3/8 BSP メス)
- D. オイルドレイン (1/2 BSP メス)
- E. 内部オイルストレーナおよび油圧ゲージ
- F. オイルの昇圧側接続



Edwards E2M275 Specifications

- **Displacement : 4867 L/min**
- **Speed : 4250 L/min**
- **Number of stages : 2**
- **Ultimate vacuum (total pressure)**
 - **Without gas ballast : 0.1 Pa**
 - **With gas ballast : 0.5 Pa**
- **Motor power : 7.5 kW**
- **Recommended oil : Ultragrade 70**
- **Standard oil capacity : 28 L**
- **Weight : 225 kg**
- **Cooling water : 120 L/h (20°C) → 2 L/min**

Evacuation Unit



Evacuation Unit (D11)



1st Trial Operations (1)

	10/2	10/3			
HER (D10)	1.5h \longleftrightarrow Pump #2 1h \longleftrightarrow Pump #1	4h \longleftrightarrow Pump #2			
LER (D11)	8.5h \longleftrightarrow Pump #1	1h \longleftrightarrow Pump #1			
Technical Issues and Operations	<ul style="list-style-type: none"> •Bad control of bypass valve→Adjustment of hysteresis set value •LER helium level low→About 3 % offset in data acquisition loop 				

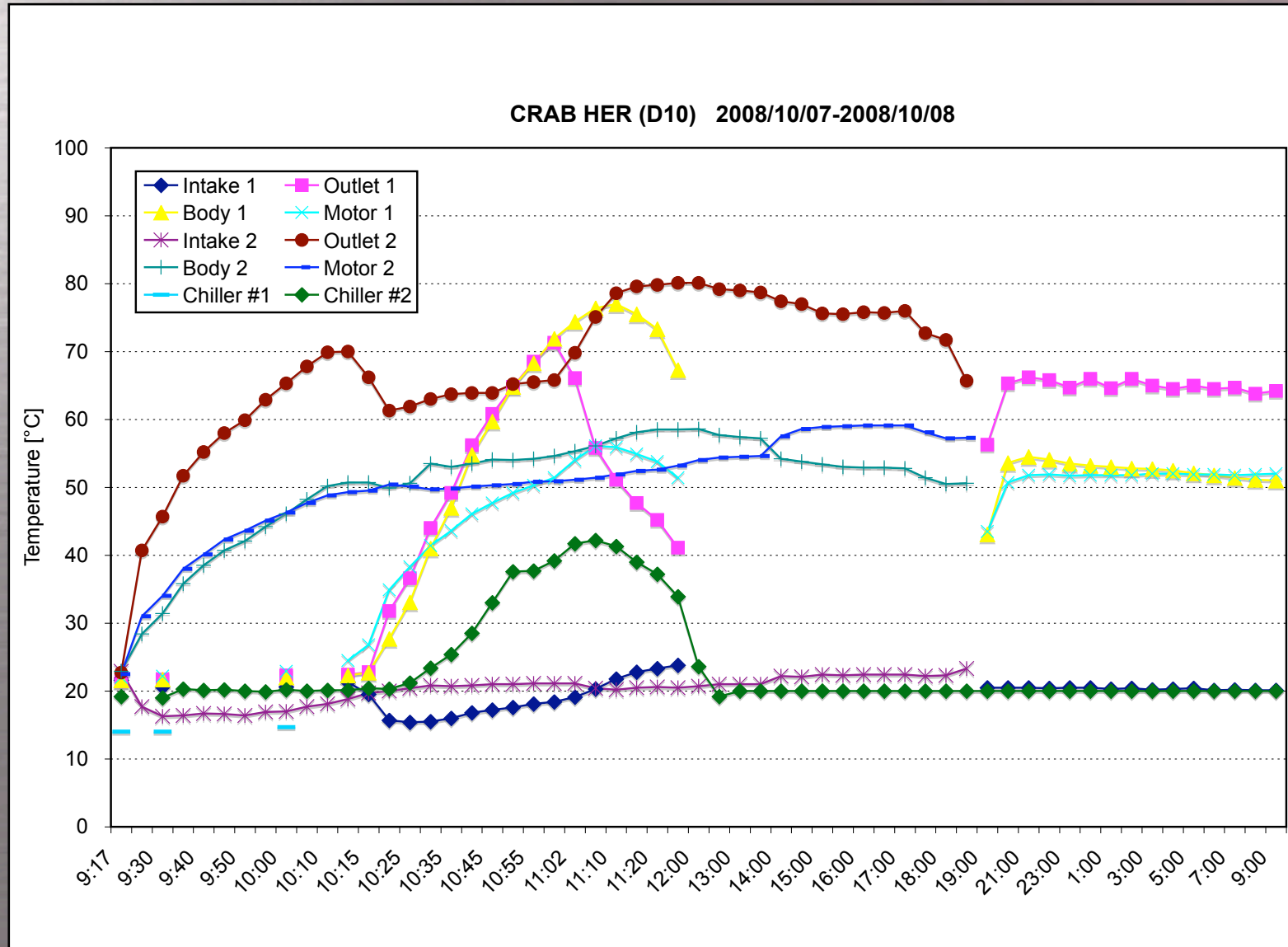
Summary of 1st Trial Operations (1)

- 1. Cooling** of two crab cavities down to 3.7 K and 2 hours continuous operation achieved.
2. High pump temperature and operation with evacuation line heaters off.
- 3. Cooling capacity of original chiller not enough and replacement by larger chillers twice.**
4. No thermal oscillation observed.
5. No problem with heat load through evacuation lines.
6. Pump oil return from oil traps to pumps necessary.

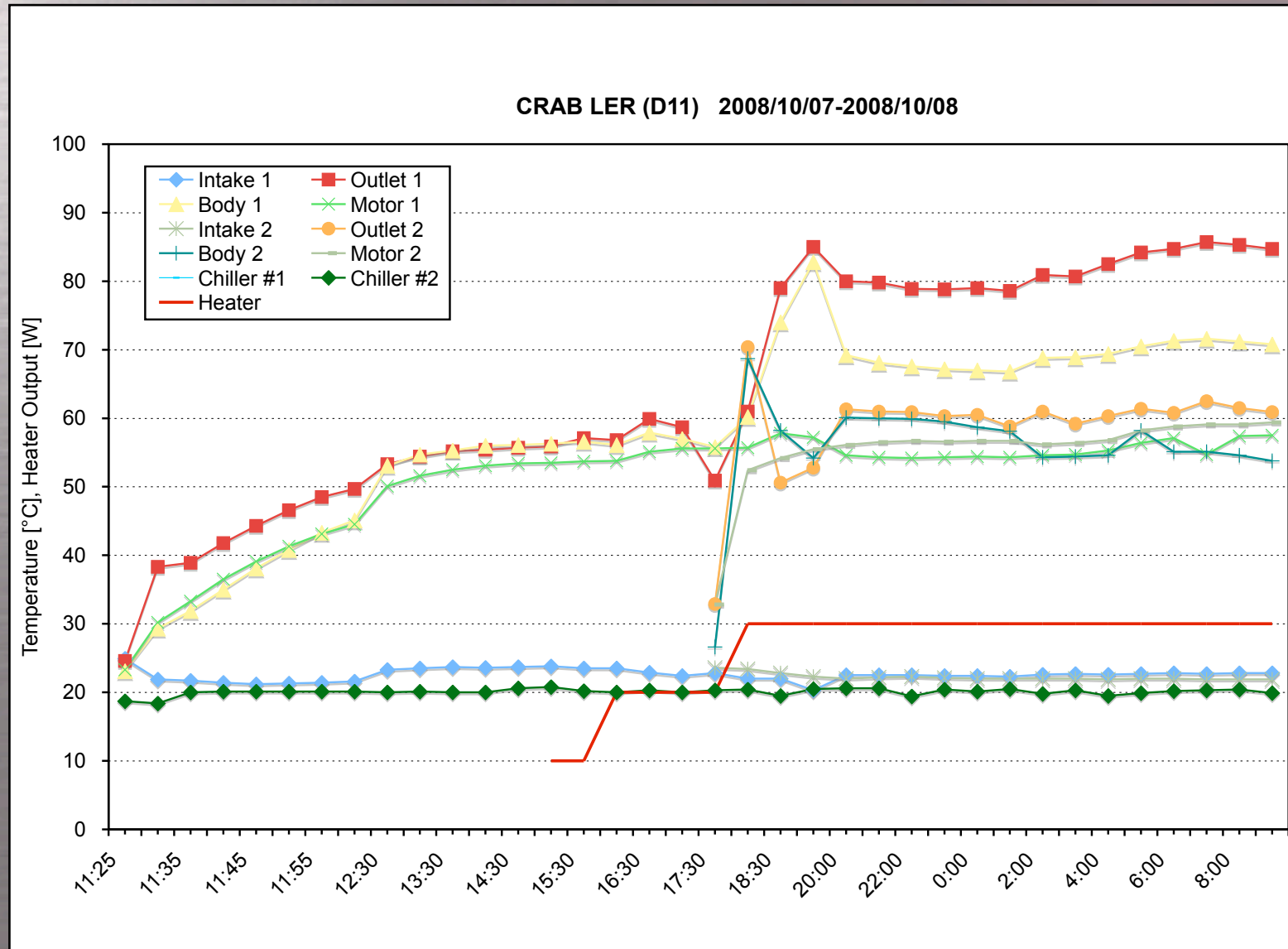
1st Trial Operations (2)

	10/2	10/3	10/6	10/7	10/8
HER (D10)	<p>1.5h ↔ Pump #2</p> <p>1h ↔ Pump #1</p>	<p>4h ↔ Pump #2</p>	<p>▲ Chiller Upgrade 1kW→2.7kW</p>	<p>9h ↔ Pump #2</p> <p>15h ↔ Pump #1</p> <p>▲ Chiller Upgrade 2.7kW→11.2kW</p>	
LER (D11)	<p>8.5h ↔ Pump #1</p>	<p>1h ↔ Pump #1</p>	<p>▲ Chiller Upgrade 1kW→2.7kW</p>	<p>23h ↔ Pump #1</p> <p>16h ↔ Pump #2</p> <p>▲ Chiller Upgrade 2.7kW→11.2kW</p>	
Technical Issues and Operations	<ul style="list-style-type: none"> • Bad control of bypass valve→Adjustment of hysteresis set value • LER helium level low→About 3 % offset in data acquisition loop • Chiller water temperature rise→Introduction of 11.2 kW chillers • Pump oil flow out, cooling of pump oil and discharged helium gas 				

1st Trial Operations (HER)



1st Trial Operations (LER)



Summary of 1st Trial Operations (2)

- **Results of trial continuous operation**
 - **Pressure: 72 kPa, Temperature: 3.7 K**
 - **Effective pressure control with CV80 valve**
 - **Required cooling capacity of chillers: 11.2 kW**
 - **Required water flow rate of chillers: 3 L/min**
 - **High temperature of discharged gas (about 85°C)**
 - **Much flow out of pump oil (0.2 L/h)**
- **Further modifications**
 - **Circulation and cooling of pump oil**
 - **Cooling of discharged helium gas**
 - **Temperature monitoring at control room**
 - **Employment of safety valve in evacuation lines**

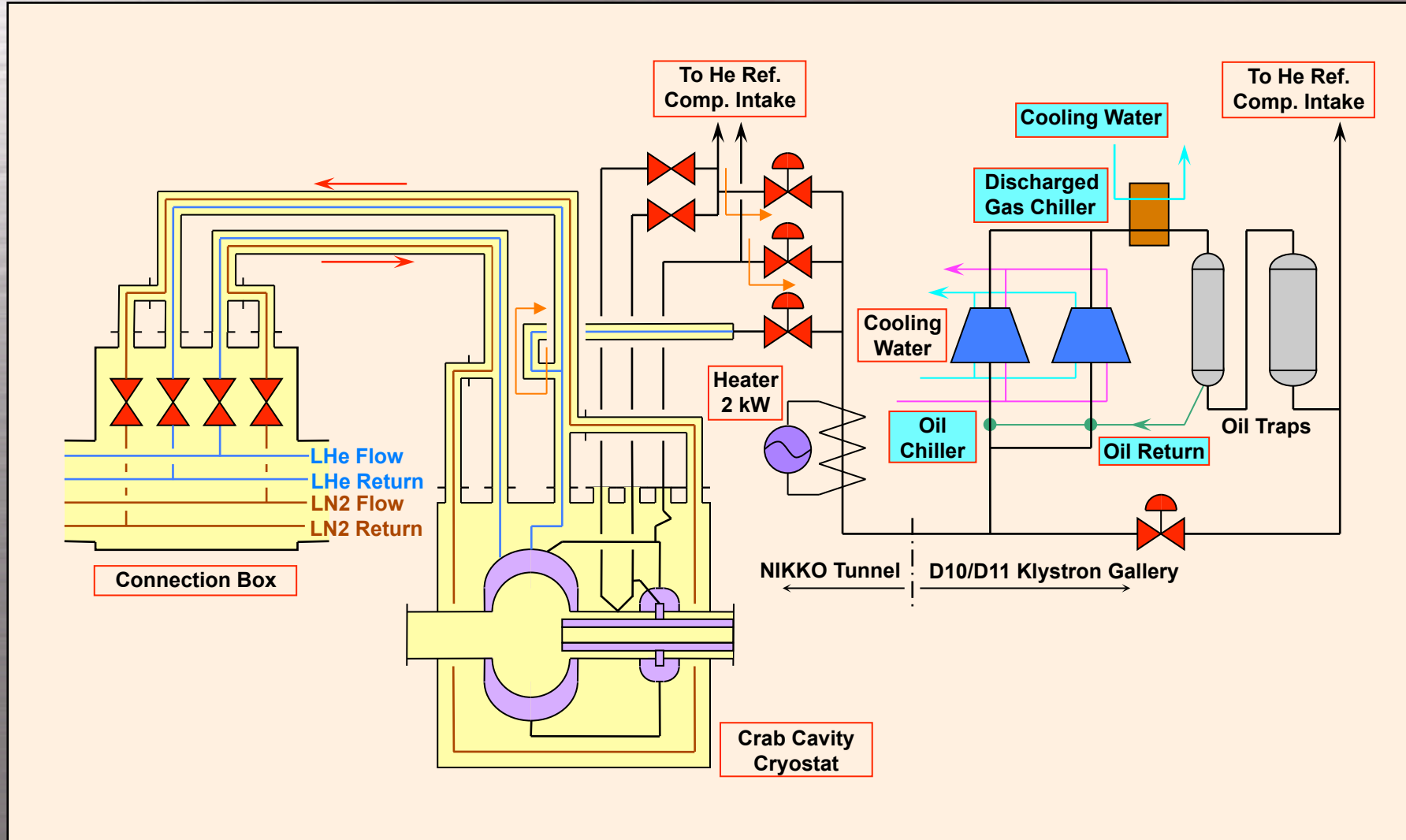
Estimated Duration of Modification

- | | |
|--|----------------|
| 1. Oil circulation | 1 week |
| 2. Pump oil cooling | 3 weeks |
| 3. Discharged gas cooling | 3 weeks |
| 4. Cooling tower | 1 month |
| 5. Plumbing of cooling water | 1 week |
| 6. Electric power lines | 1 month |
| 7. Trial operations & commissioning | 1 week |

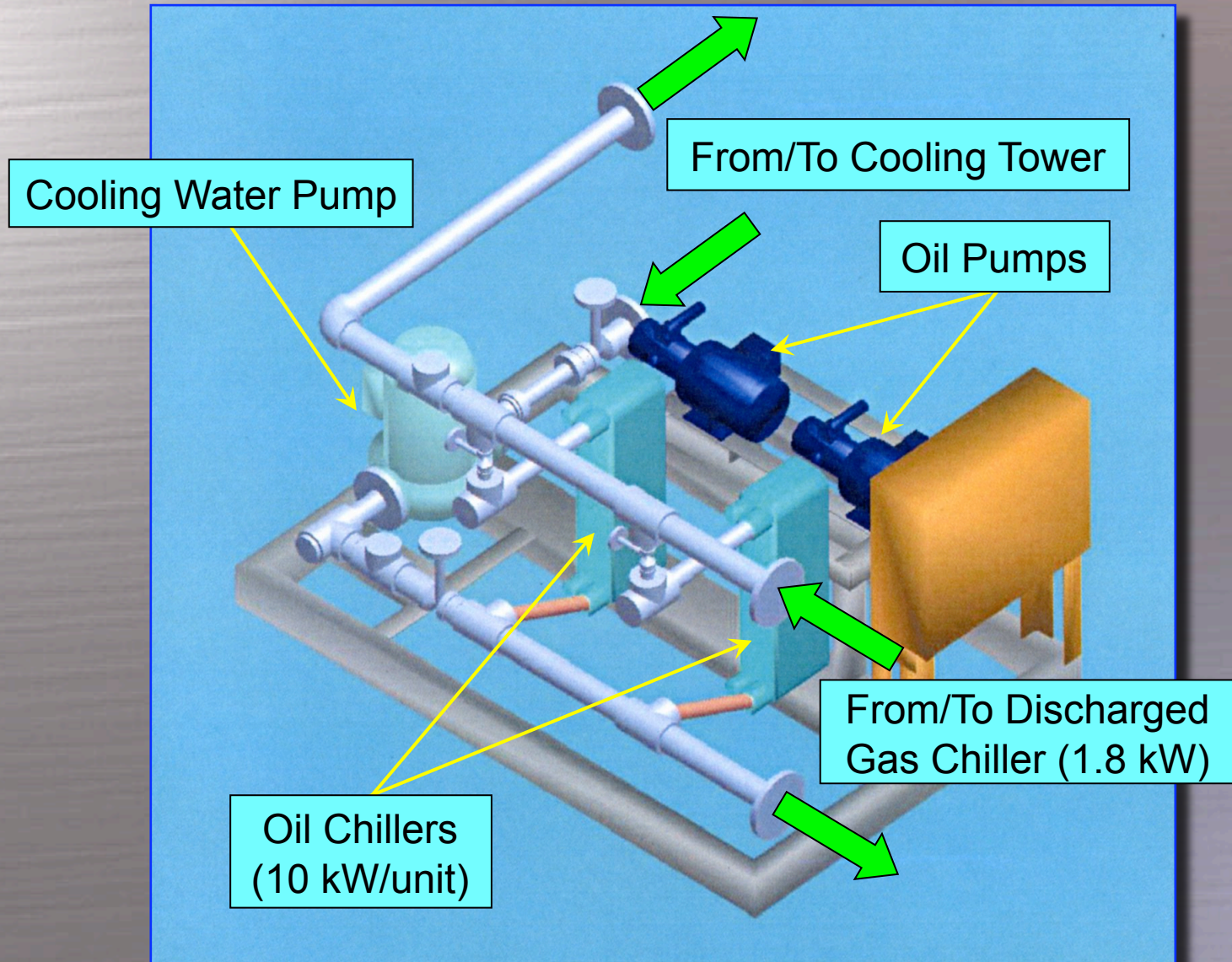
Discussions on Technical Issues

- **Technical discussion with the pump company**
 - **Temperature rise is not abnormal**
 - **Oil refill during operation**
- **Discussions on modifications of the system**
 - **Cooling of pump oil and discharged helium gas**
 - **Required cooling power of cooling tower**
 - **Electric power and water supplies**
 - **Locations of equipment**

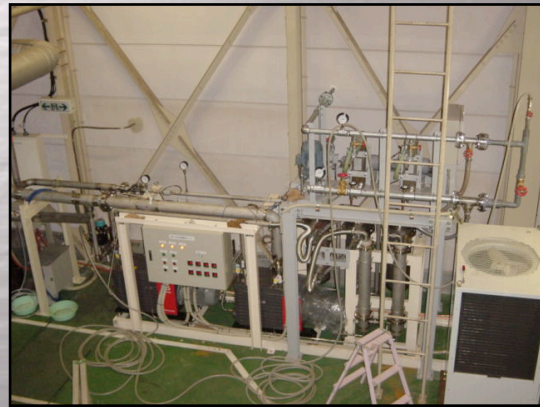
Flow Diagram of Evacuation System (2)



Pump Oil Chiller Unit



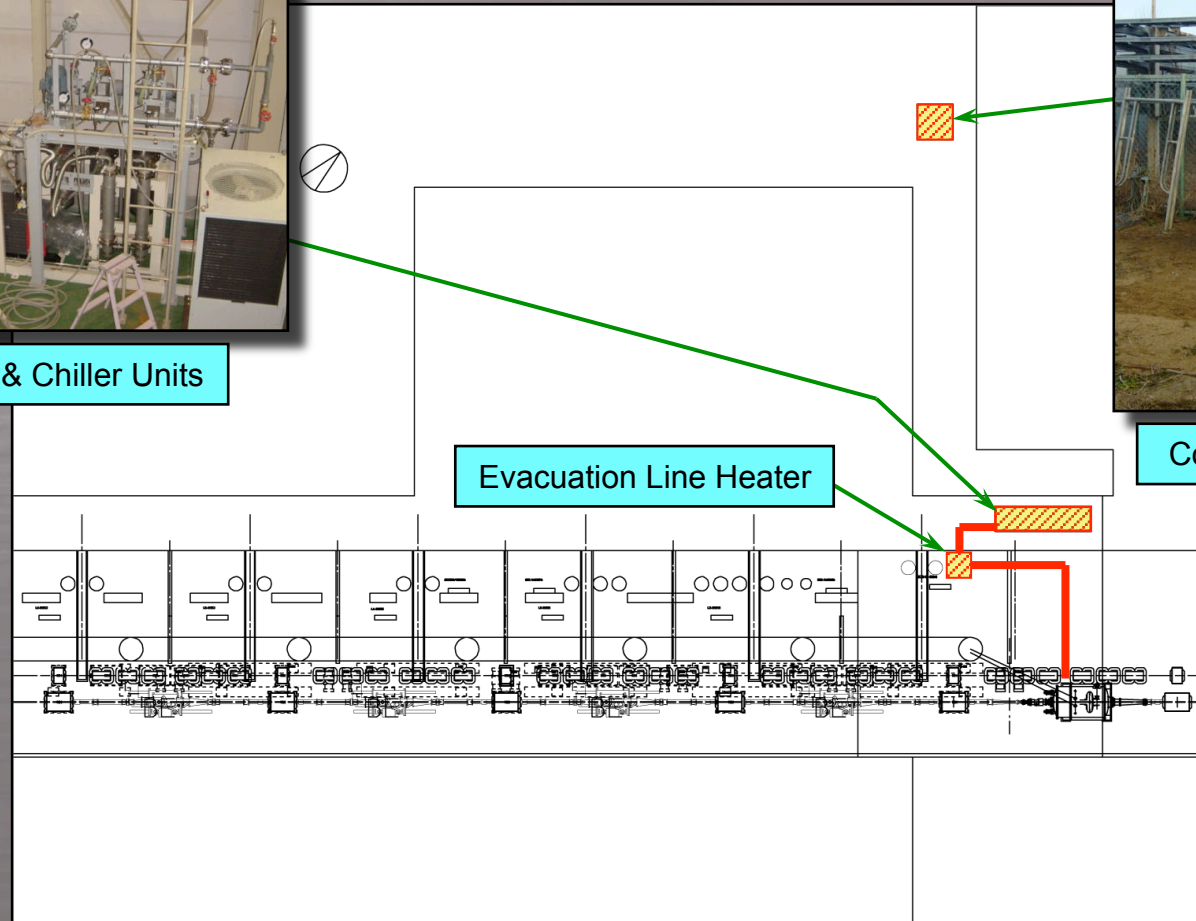
Equipment Locations at D10



Evacuation & Chiller Units



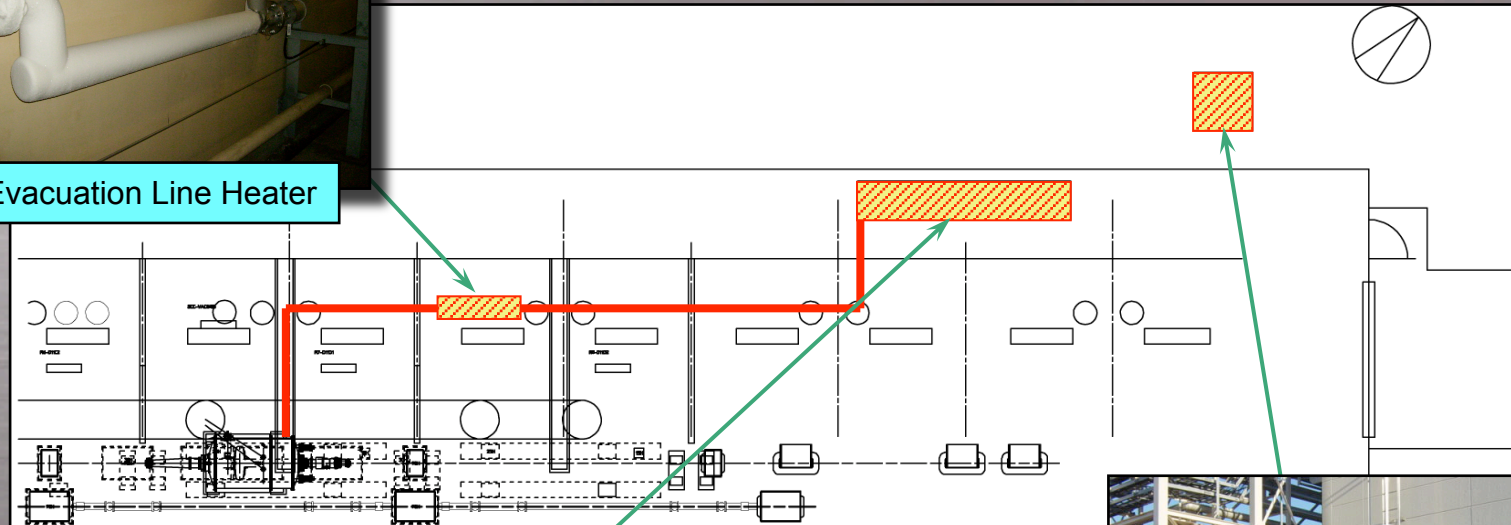
Cooling Tower 68 kW



Equipment Locations at D11



Evacuation Line Heater



Evacuation & Chiller Units

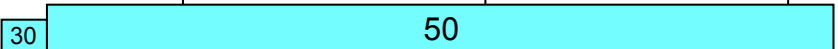
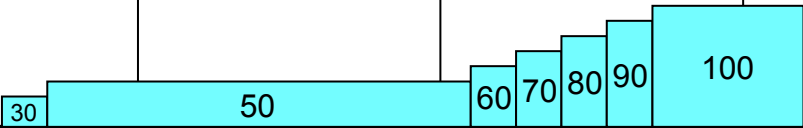


Cooling Tower 68 kW

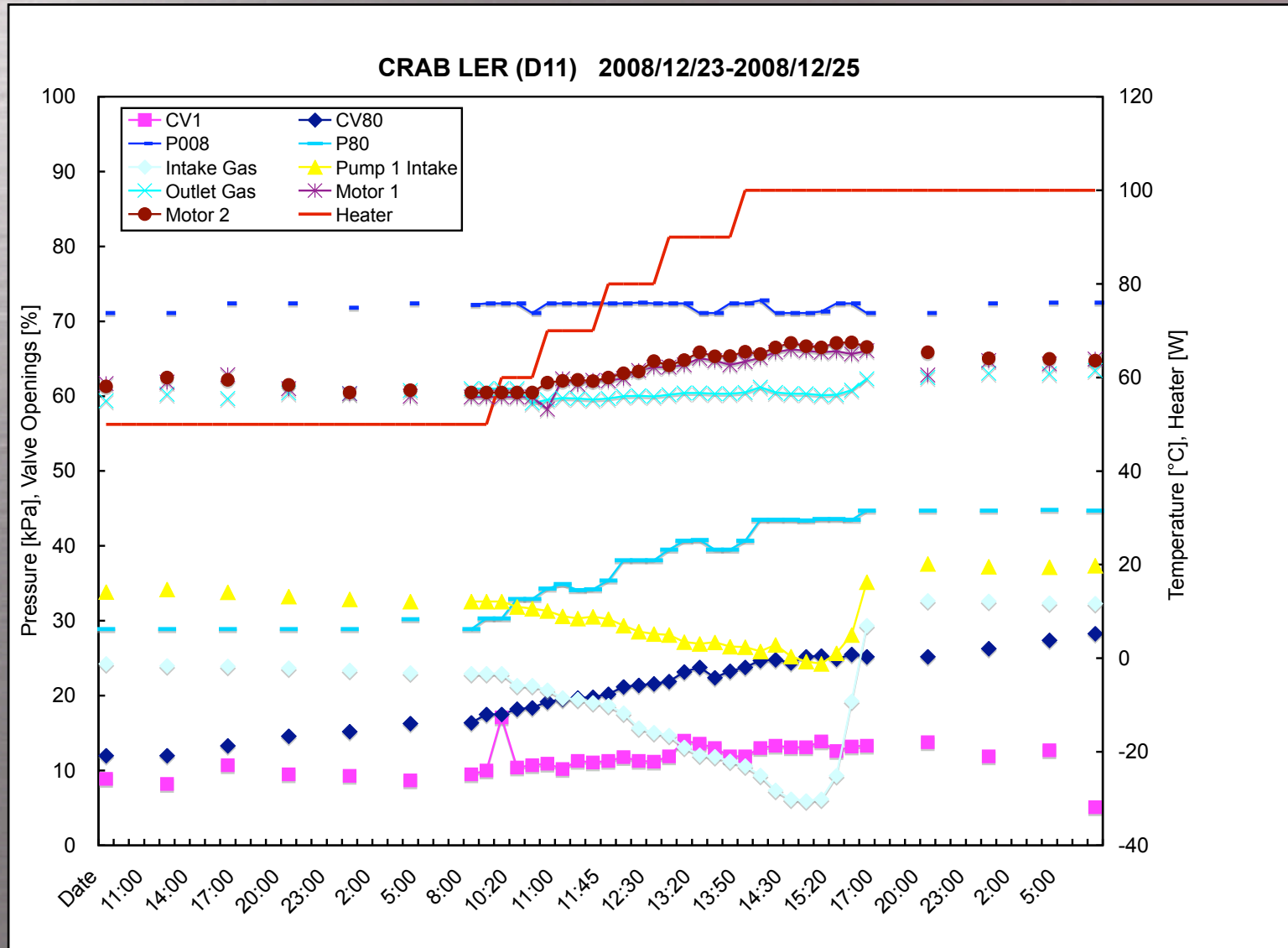
Temperature Monitoring



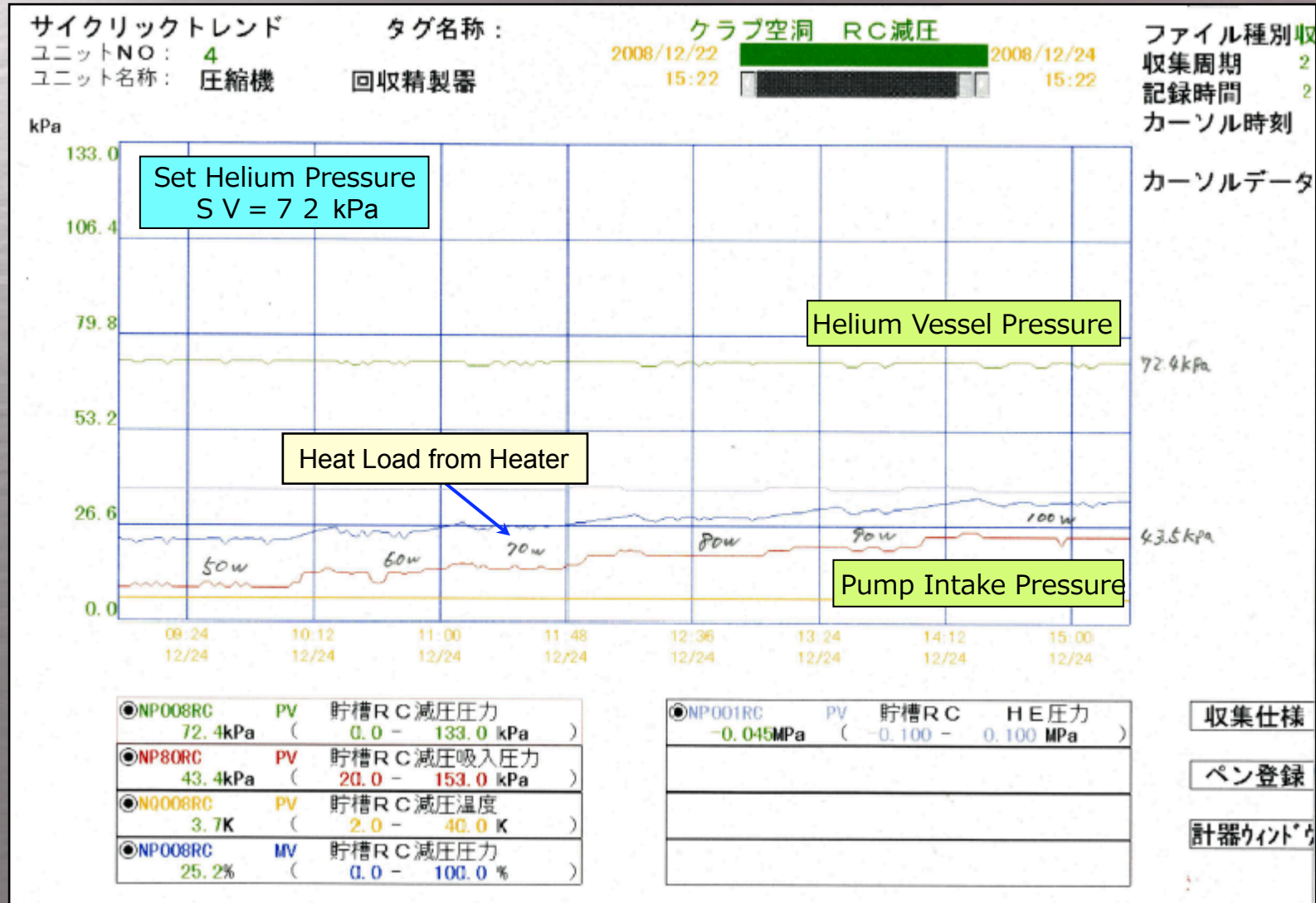
2nd Trial Operations

		12/22	12/23	12/24	12/25
HER (D10)	Operation	13:45 ← Pump #1 ON Pump #2 ON	Pressure: 72 kPa, Temperature: 3.7 K		→ 8:30 Pump #1 OFF Pump #2 OFF
	Heat Load (W)				
LER (D11)	Operation	14:30 ← Pump #1 ON Pump #2 ON	Pressure: 72 kPa, Temperature: 3.7 K		→ 9:00 Pump #1 OFF Pump #2 OFF
	Heat Load (W)				
Technical Issues and Operations		<p>▲ : LER oil pump #1 over current → Reset thermal protection</p> <p>▲ : Refill of pump oil (5 L)</p> <p>▲ : Low intake gas temp. → Evac. line heater ON</p>			

2nd Trial Operations (LER)



Pressure Control under Heat Load



Summary of 2nd Trial Operations

- **HER (D10): continuous operation for 67 hours under 50 W heat load.**
- **LER (D11): continuous operations for 43 hours under 50 W heat load and for 17 hours under 100 W.**
- **Helium pressure can be stably controlled at 72 kPa.**
- **Heat load to refrigeration system is not so large, since the opening of LHe supply valve is not large even under 100 W heat load to LER crab cavity.**
- **Though oil exhaust can not be suppressed, operation can be continued with refill of oil every 2 hours.**
- **Electric currents of equipment are larger than those specified.**

Operation Plan

- Trial operations with rf power to crab cavities are scheduled for late March or for early April.