



ML Cryogenics - Preliminary Study of Baby-Sitter System -

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Confidential



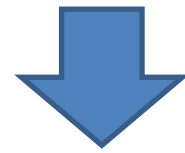
Concept of Baby-Sitter System (BSS)

- Helium inventory is liquefied and stored in Liquid Storage Dewar (LSD)
LSD capacity : 65,000L/cryo plant
- Unexpected power failure shall be considered
- BSS and LSD are located on surface
- LN2 is available for cold box

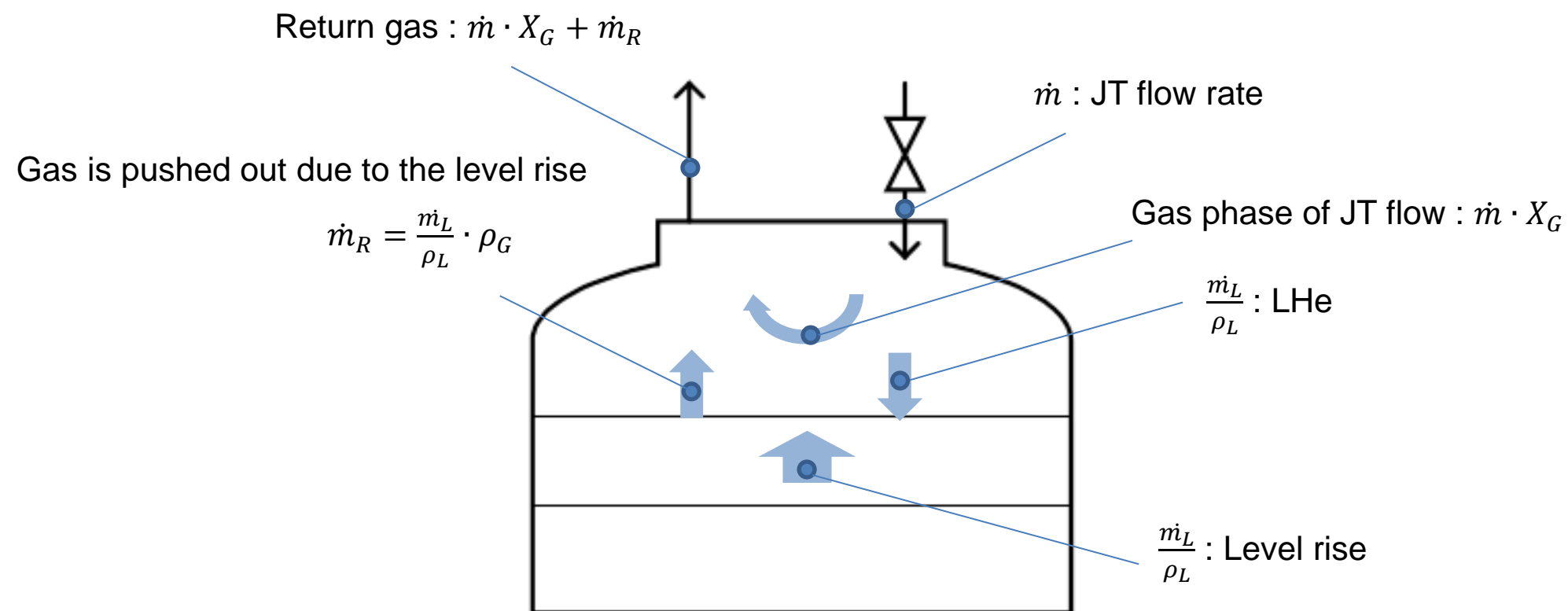
Study items

- Estimate of necessary liquefaction capacity
- Recovery line for boil-off gas
- Compressor for BSS
- Cost of BSS

Boil-off mass flow rate : 50g/s



Liquefaction capacity : 1,820L/h (at 125kPaA, rising level)



\dot{m} : JT flow rate

\dot{m}_L : Liquid phase of JT flow rate

\dot{m}_G : Raw gas supply flow rate

X_G : Gas ratio

ρ_L : Liquid density

ρ_G : Gas density

$$\dot{m}_G = \dot{m}_L - \dot{m}_L \frac{\rho_G}{\rho_L} = \dot{m}_L \left(1 - \frac{\rho_G}{\rho_L}\right)$$

- Boil-off gas is recovered and liquefied by BSS.
- If the power failure occurs, 2K line is isolated and return the boil-off gas through dedicated recovery line.
- Since the recovery line is at room temperature at first, the cooldown of pipe shall be necessary.

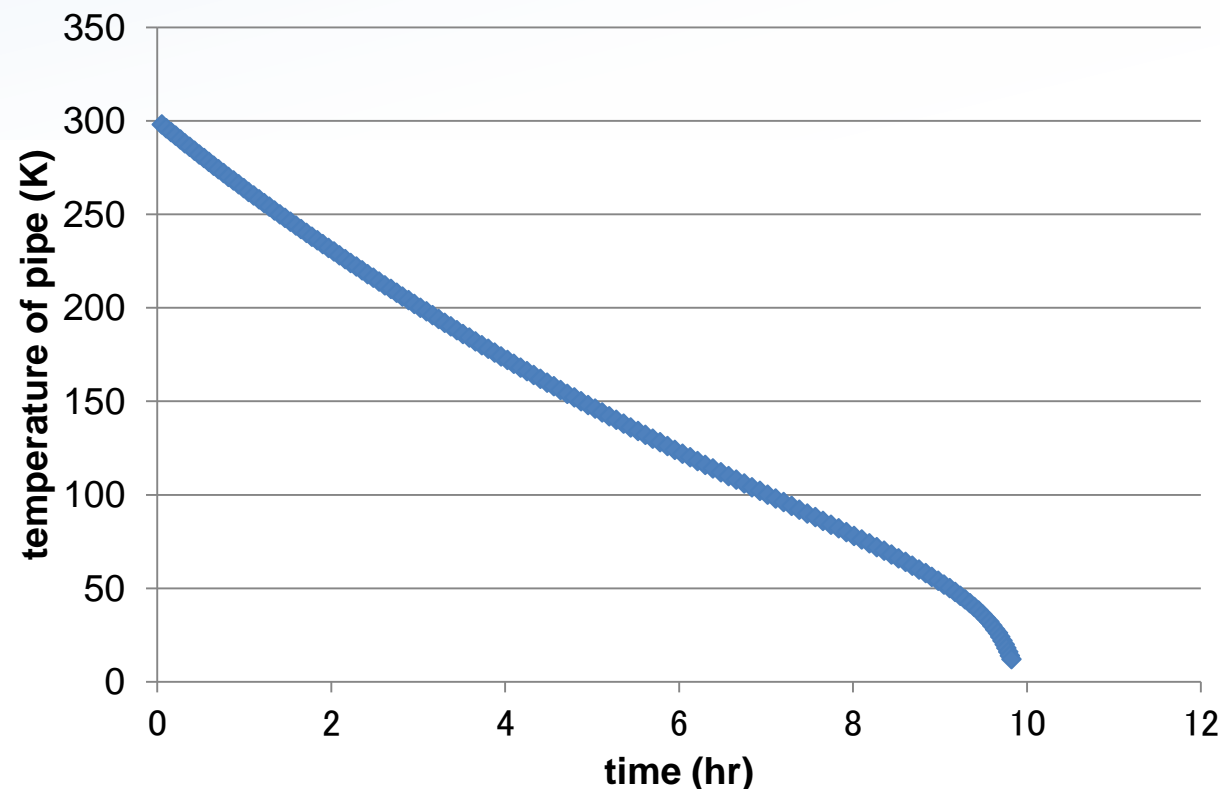
Dedicated recovery line

Design pressure of 2K line : 200kPa

- Pipe size : $\phi 114.3\text{mm} \times t2.1\text{mm}$

Allowable pressure drop of 20kPa with 300K return gas is considered.

- Pipe length : 2km (Mass : 11.6ton)



Cool down time : approx. 10hrs

LHe recovery time is 40hrs

Which is better ?

- Single TRT
- Non-insulated pipe



Two cases was studied for liquefaction of boil-off gas

- Liquefaction by BSS
- Liquefaction by MCB (Turn-down)

If the power failure occurs, 2K line is isolated and the boil-off gas is returned through LLP line.

LLP (sub-atmospheric line)

- Pipe size : $\phi 165.2\text{mm} \times t2.8\text{mm}$
- Pipe length : 2km
- Outlet temperature : 15K

Flow rate of 50g/s, heat inleak of 1W/m (w/o shield cooling) is considered.

Conditions for each case



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	MCB underground with no-insulated pipe	MCB underground with TRT	MCB on surface with LHe recovery by BSS	MCB on surface with LHe recovery by MCB
Liquefier	BSS	BSS	BSS	MCB
Recovery line	Additional Size: 100A Length: 2km Allowable DP>20kPa	Additional Size: 100A/150A Length: 2km Allowable DP>20kPa	LLP line (Multi TRT)	LLP line (Multi TRT)
Boil off gas temperature at inlet of cold box	300K	approx. 300K-15K Cooling capacity of gas is available	approx. 15K shield cooling is not considered Cooling capacity of gas is available	approx. 15K shield cooling is not considered Cooling capacity of gas is available
Liquefaction capacity	1,820L/h	1,820L/h (design) 400L/h (off-design)※	1,820L/h	1,820L/h(off-design)

※ During the cooldown of pipe, the liquefaction capacity is decreased because the cooling capacity of recovery gas is not available and the surplus recovery gas is stored in Buffer tanks temporary.



WCS is available for BSS.

Case	Total Power Consumption
MCB underground with non-insulated pipe	1,728 kW
MCB underground with TRT	1,389.5 kW
MCB on surface with BSS liquefaction	1,390.5 kW
MCB on surface with MCB liquefaction	1,846.5 kW



Large emergency power is necessary.

Manufacturing cost

Case	Item
① MCB underground with non-insulated pipe	BSS+LSD+non-insulated pipe
② MCB underground with TRT	BSS+LSD+TRT
③ MCB on surface with BSS liquefaction	BSS+LSD
④ MCB on surface with MCB liquefaction	LSD

BSS include ;

- ✓ Cold box
- ✓ TRT between cold box and LSD
- ✓ TRT for nitrogen
- ✓ JHPGSL
- ✓ Packing & transport
- ✓ Installation
- ✓ Commissioning

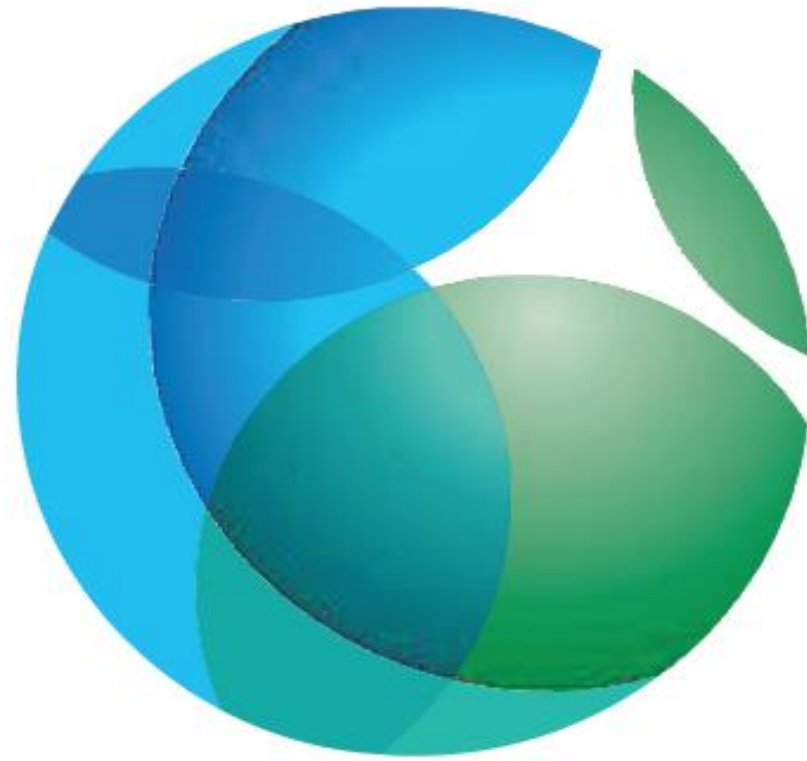
Cost : ② >> ① > ③ >> ④



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Liquefier	BSS	BSS	BSS	MCB
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Liquefaction capacity	1,820L/h	1,820L/h (design) 400L/h (off-design)✕	1,820L/h	1,820L/h(off-design)
Compressor (Input Power)	WCS (1,728kW)	WCS (1,389.5kW)	WCS (1,390.5kW)	WCS (1,846.5kW)
Cost	more expensive	most expensive	cheaper	cheapest



- Liquefaction capacity more than 1,820L/h is necessary for boil-off gas recovery.
- LLP line is available for recovery line in **MCB on surface**.
- Dedicated recovery line shall be necessary in **MCB underground**.
- WCS are available for BSS.
- MCB is available for LHe recovery in **MCB on surface**.
- The cost in **MCB on surface** with LHe recovery by MCB is the cheapest.
- BSS cost in **MCB underground** with TRT recovery line is the most expensive because of the big impact of TRT with 2km.



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Thank you for your attention.