Consideration on

He Resource Conservation for ILC SRF Cryogenics

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To be reported to ILC-TCMB, 3 December 2019

Outline

- Motivation
- Boundary conditions
- An Update suggested: 100% GHe storage, instead of 50/50(%) G-/L- He
- Technical and cost comparisons
- Summary

Motivations to:

- He resource to be 100 % recycled and conserved in the ILC, even in any emergencies and/or power outages more than 3 days.

- Important reasons:
  - No natural He resource in Japan, and
  - It may become a show-stopper for the ILC stable operation, in particular in Japan.
  - We have been experienced with major AC power outages, at least twice: Tohoku Earth Quarke (2011), and in an outstanding Typhone (2019) for more than a week.

Boundary Conditions

- LHe in the ILC SRF system will entirely evaporate within 3 days after stopping the cryogenics or AC power outage,
- He resource need to be recovered as GHe on surface, within 3 days, in any case, by using emergency recovery compressers operational by using emergency AC power generators.
- The minimum fuel (LNG or Oil) to be reserved on site for this operation. (No more LNG/oil is expected in nation-wide critical situation).

A possible solution

- 100% GHe storage
  - (instead of 50/50(%) LHe/GHe storage)

- Continuous operation of Recovery compressor (20 bar) for > 3days
  - to be supported by Diesel/emergency AC power generators.

- 12 (3x4), 20-bar GHe tank is required
  - (instead of 6 Ghe tank + 1 LHe dewar + Liquifier)

ILC Cryogenics Layout-Design Updated in 2017 -- Change Request 09 (CR-09)

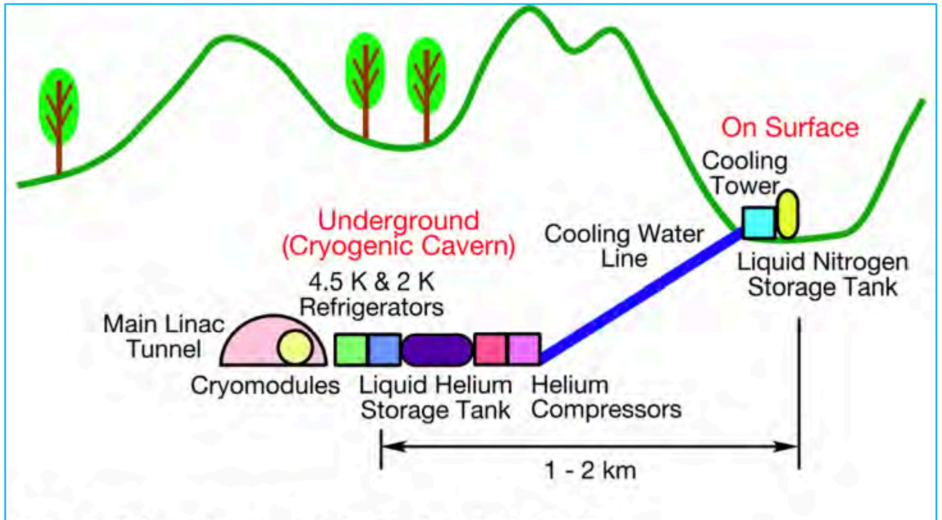

Figure 1. Schematic cryogenic layout described in TDR.

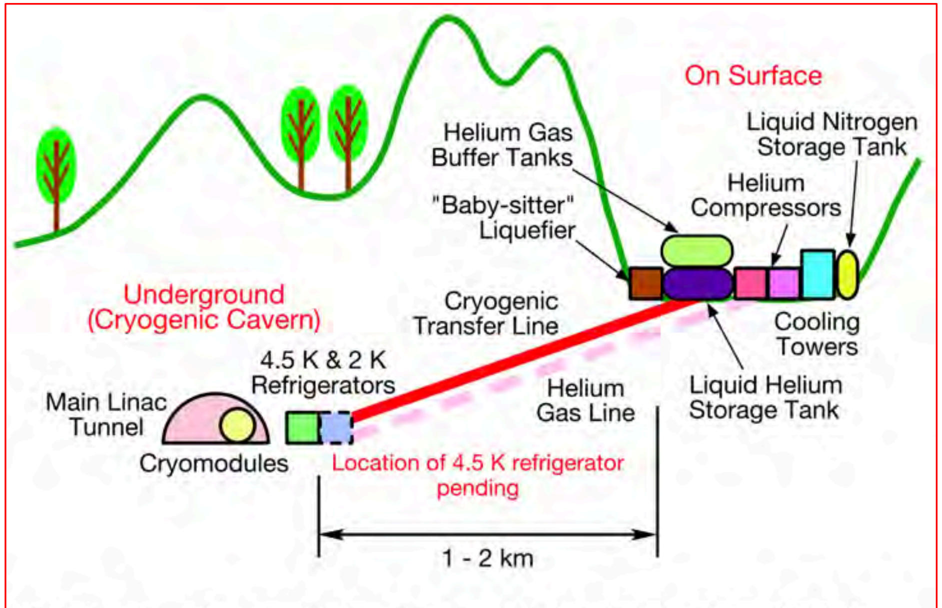

Figure 2. Schematic cryogenic layout proposed in this change request with 4.5K refrigerator location kept pending for further study.

TDR

CR-09

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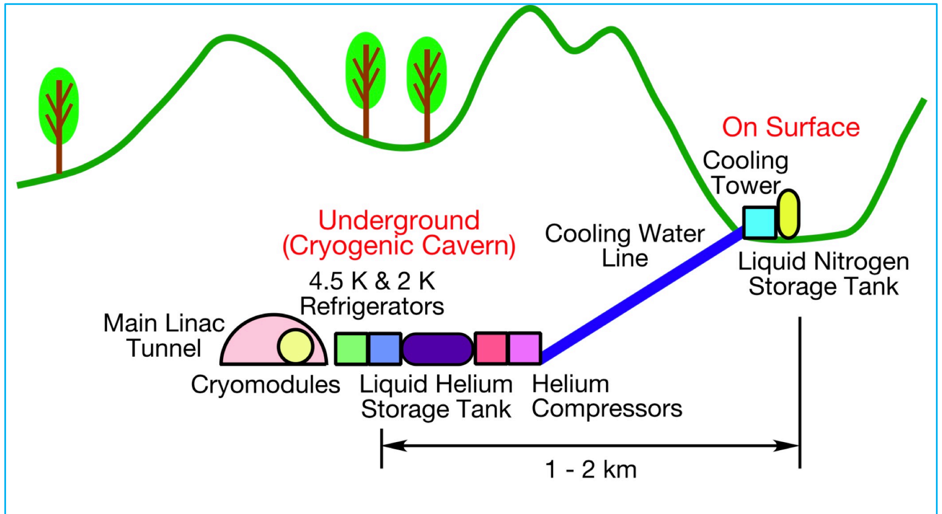

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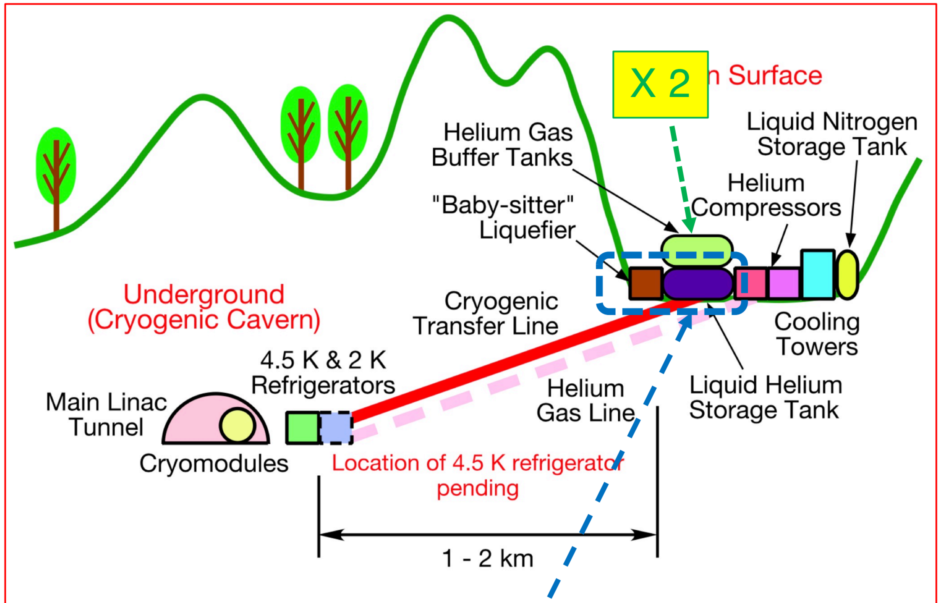
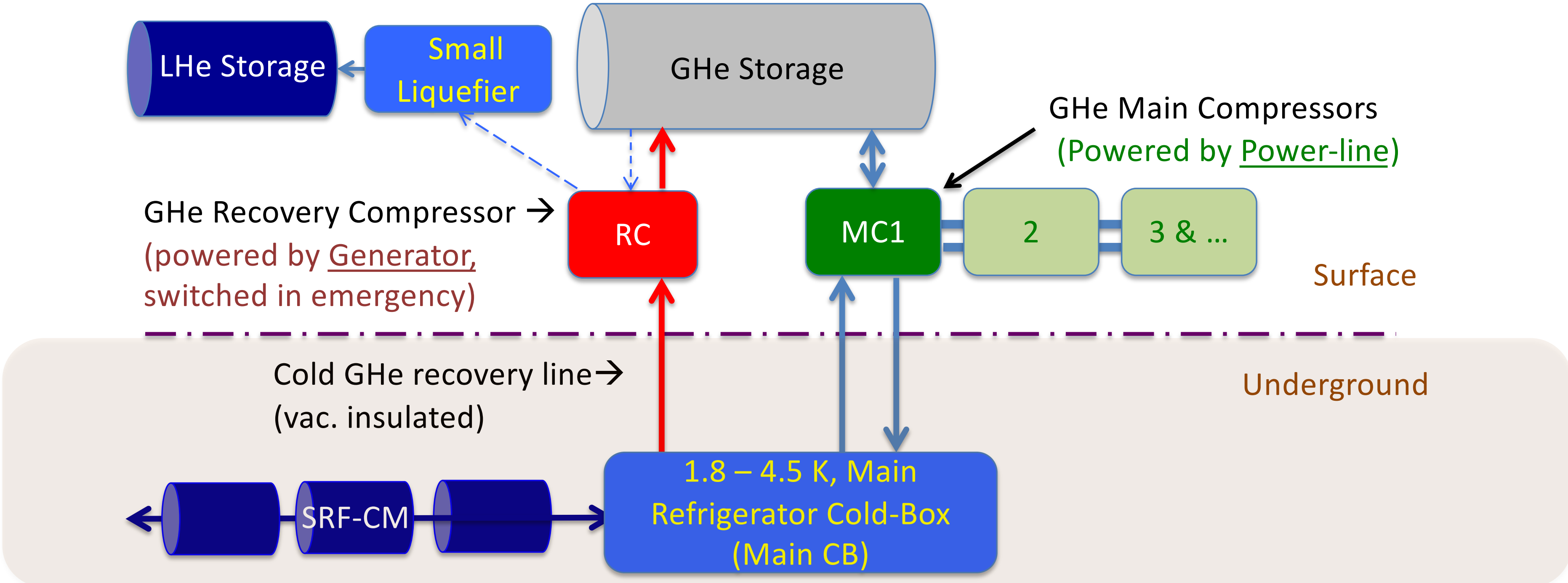


Figure 2. Schematic cryogenic layout proposed in this change request with 4.5K refrigerator location kept pending for further study.

Today, we will discuss the emergency operation: to be simplified by doubling GHe Buffer Tanks, and eliminating a small (Baby-Sitter) He Liquefier and a LHe storage tank (reservoir)

2016-8-25
Nakai, Okamura, Makida, and Yamamoto

He Flow Lines in Emergency to Recovery



Operation Sequence in emergency to resume steady state modes (under investigation):

1. GHe recovery using RC (powered by Generator for < 24 hrs, (electric capacity: < 1 MW / plant
2. Recovery of MC1 (and 2, 3, …) and Main CB, for LHe to be kept in CM after power-recovery
3. LHe to be produced in LHe storage for a period of 5 ~ 7 days, by using RC powered by power line

(Note: Balance of LHe and GHe storage capacity to be further investigated and globally discussed)

A design-update studied in 2017

ML Cryogenics

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KEK

2017/3/13

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4. Mass flow requirement during power failure
5. Buffer tank and small liquifier system
6. Discussion about inventory storage scheme
   - Cost evaluation
   - Required exclusive area
7. Summary

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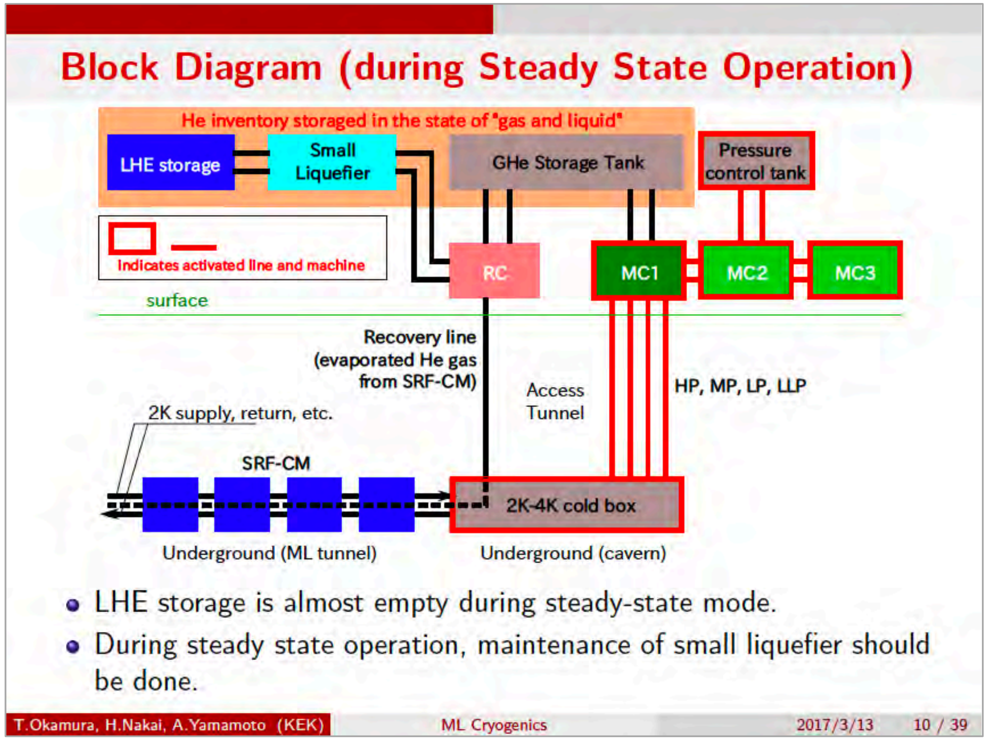
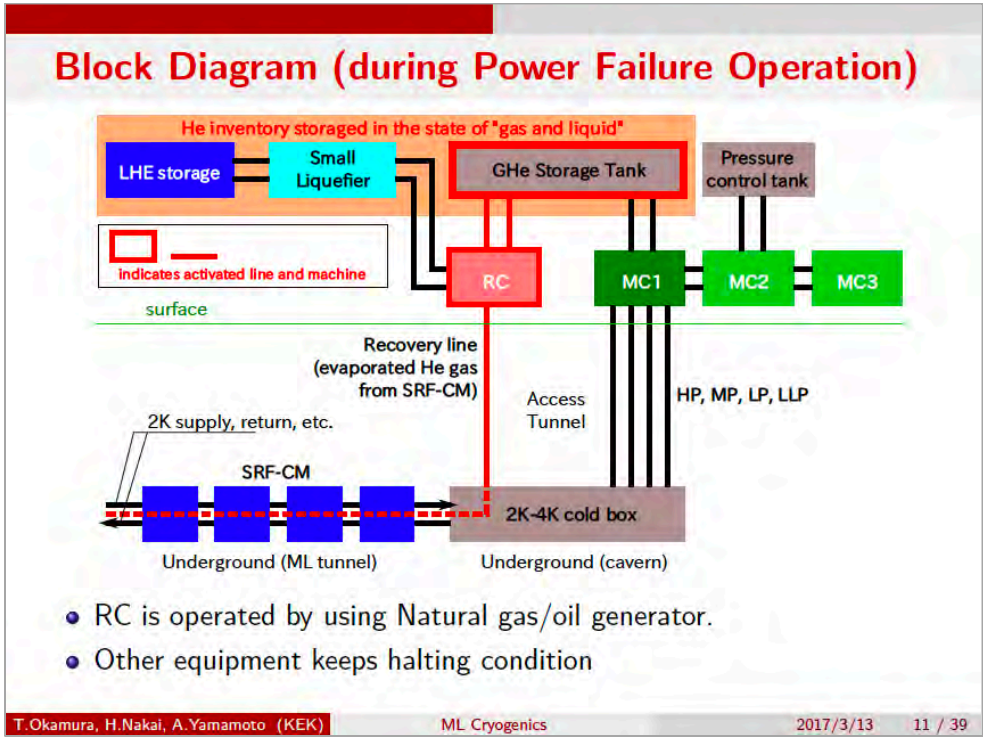
ILC SRF Cryogenics Operation Modes





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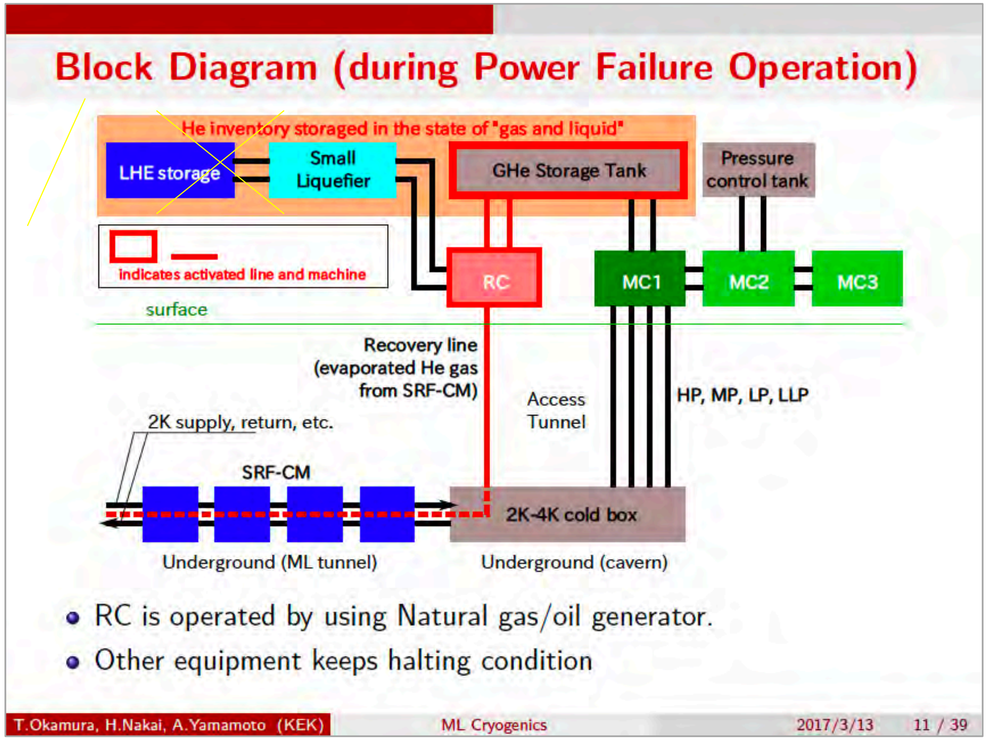

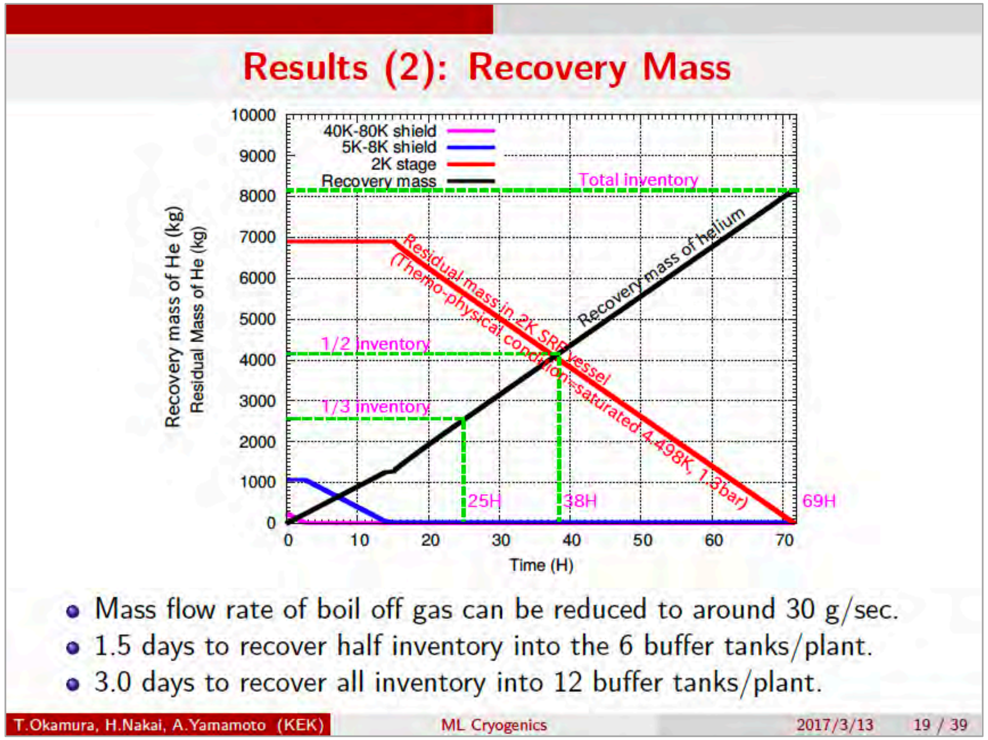

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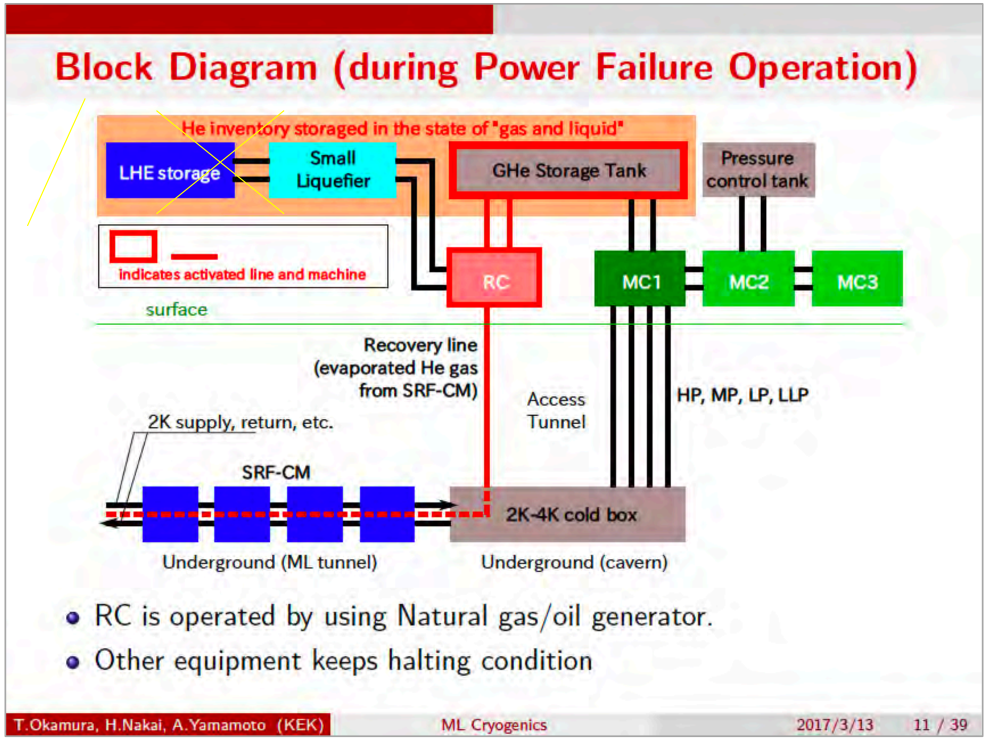
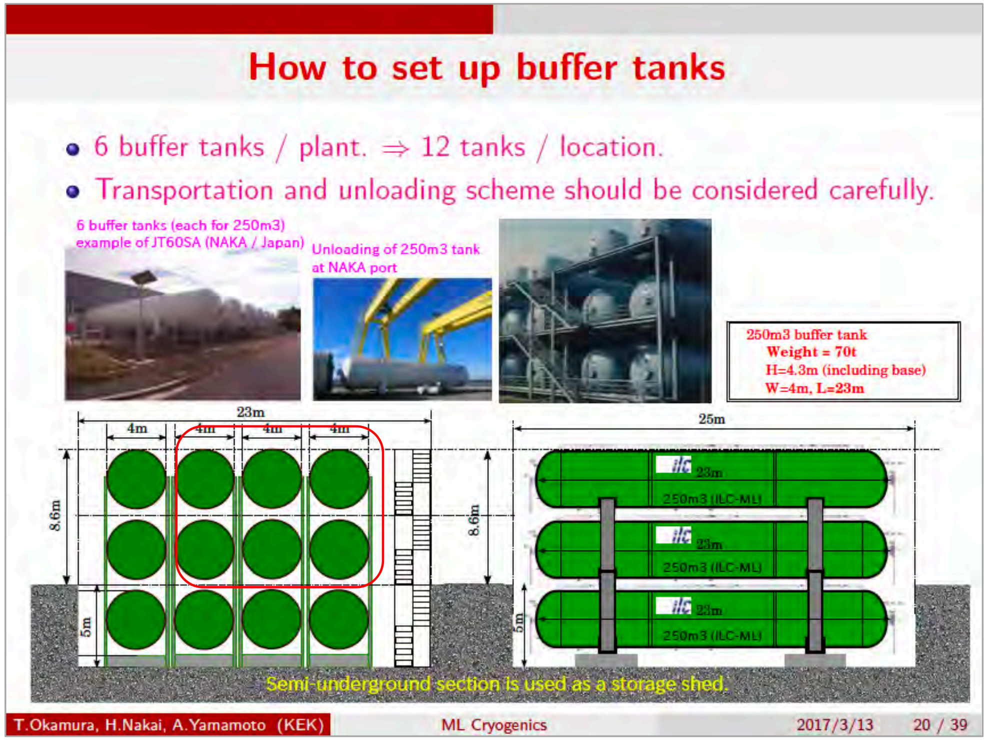




Comparison item		12 buffer tanks scheme	6 buffer tanks and LHE Dewar scheme
Cryo components for recovery system	buffer tanks	12	6
	recovery compressor	400kW	400kW
	small liquefier	-	280L/h
	LHE dewar	-	42000L
	cryogenic pipe	-	4 cryo pipes (3-5m)
	cryo control system	-	necessary
Piping through access tunnel	HP	318.5mm	318.5mm
	MP	508mm	508mm
	LP	406mm	406mm
	LLP	406mm	406mm
	Recovery line	165.2mm	165.2mm
exclusive area on surface(m2)		1265	1265
necessity for building		-	necessary
Cost	buffer tanks	6.72	3.36
	recovery compressor	0.7	0.7
	Cold box	-	4.4
	LHE dewar	-	1
	Transportation	1.8	0.9
	unloading crane	0.4	0.4
	Site construction	1.2	0.6
	SUM	10.82	11.36

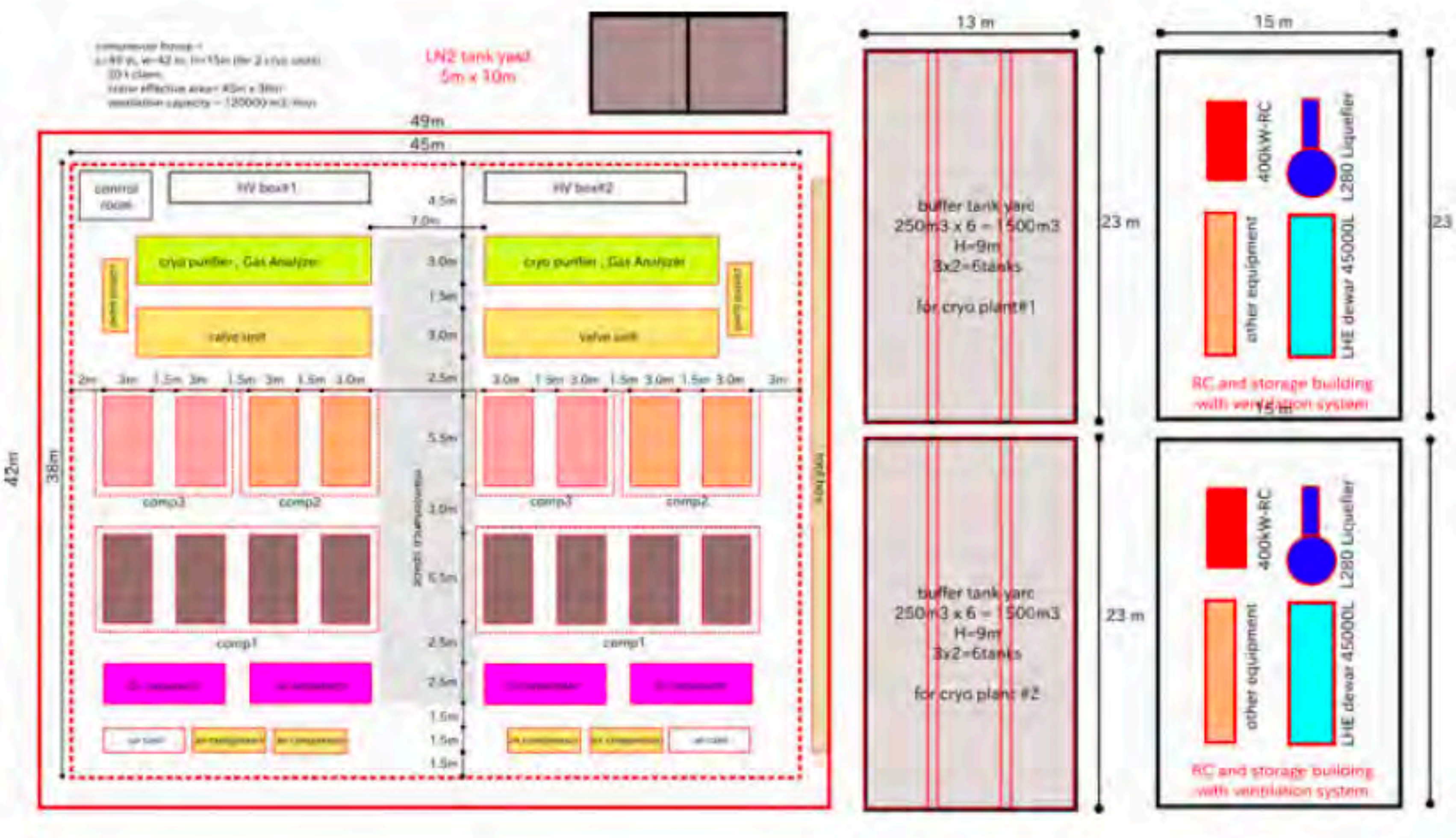
Comparison Item		12 buffer tanks scheme	6 buffer tanks and LHE Dewar scheme
	buffer tanks	12	6
	SUM	10.82	11.36

- Recovery time can be reduced from 1 week to 3 days in the case of GHe storage scheme.
- Manufacturing cost without small liquefaction system is a little bit cheaper than half and half mixing storage scheme.
- Required surface area is almost same each other. (if config. shown P19 is applied)

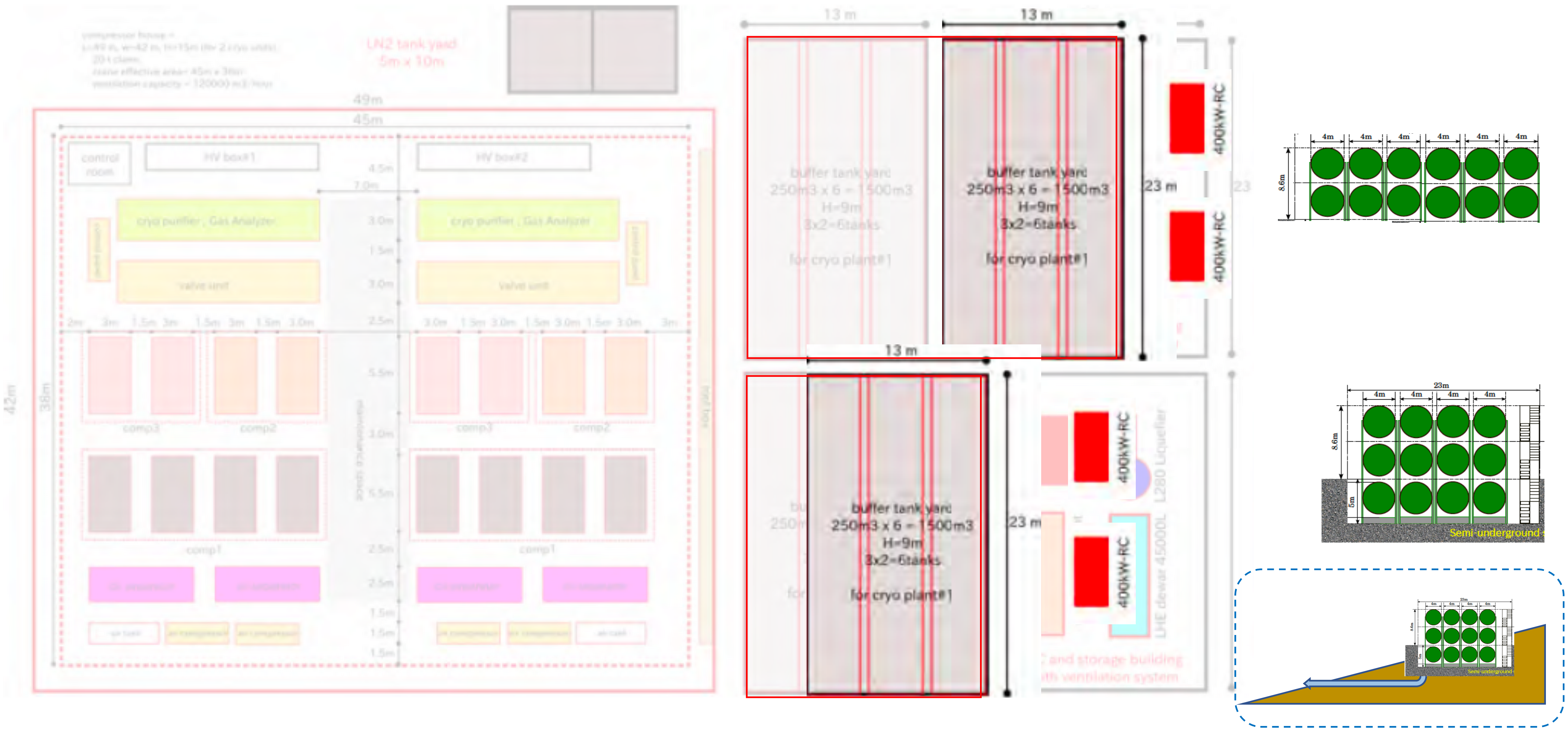
Storage Scheme unit : (**)		buffer tank	Small liquefaction system	Other, Transport etc.	Total Cost
12 buffer tanks	w/o small liquefier	6.72	0	4.1	10.82
6 buffer tanks	w/ small liquefier	3.36	5.4	2.6	11.36

Storage Scheme unit : (m2)		buffer tank	Small liquefaction system	Other, Transport etc.	Total Area
12 buffer tanks	w/o small liquefier	46m x 25m	8m x 14m (RC)		1263
6 buffer tanks	w/ small liquefier	23m x 25m	30m x 23m (RC, Liquefier, LHe dewar)		1265

Surface Layout for 2 plants



Surface Layout for 2 plants



Summary (1)

Power Failure

- Instead of Storage Scheme introduced in TDR, not only LHE dewar but also GHE buffer tanks are employed for preventing loss of He inventory during power failure.
- Recovery compressor (RC) should be located on surface but its capacity should be enough small to be operated using LNG generator during the failure. Several hundreds kW can be acceptable. (MW order can not be acceptable.)
- To perform this, recovery mass flow rate during the failure should be reduced. Enthalpy recovery operation seems effective way to reduce the mass flow rate.
- According to the simulation based on toy model, mass flow rate can be reduced to around 30 g/sec. In this case, if 6 tanks with 250 m3 are located on surface, resting state of MCS and MCB for 1.5 days can be acceptable.

The design change already authorized by TCMB

Comparisons of CR-09 and the Update proposed

	CR-09	Update proposed
# GHe Buffer Tank	6 (3 x 2 layers)	12 (4 x 3 layers)
Small He Liquefier	Needed	Not needed
LHe Storage Tank (Reservor)	Needed	Not needed
Surface area required Lowered base than GL	Baseline Not needed	Equivalent or smaller Needed (~ 3 m)
Emergency Operation:		
He recovery time: --> emergency AC power required	7 days (2 x 3 + alpha)	3 days
Periodic operation during shut-down	Requird for baby-sitting	Not required
Redundancy for emergency. required	RCs and He liquefier	RCs only
Cost	Baseline	Equivalent or lower

A Design-Update Proposal:

- Simplify the He recovery system:
  - Doubling numbers of GHe storage tank (6 --> 12)
  - Eliminating {small He Liquifier + LHe storage/reservoir}
    - Except for specific location such as a main plant at each e- and e+ linac site for overall backup He reserve: 20 ~25 % for the whole He resource amount, for long term stability and risk management.
  - It may be wise to reinforce the redundancy for the Recovery Compressors (RCs) with an additional backup RC.

- The above design-update may realized much simpler emergency operation with well predicted and limited emergency AC power source.

- No cost-increase is expected, and a minor cost-saving may be expected.

Reserved

Summary (2)

Maintenance and other operation

- When all inventory is recovered for maintenance season, small liquefier is needed. RC can also be applied to small liquefaction system.
- Fraction between Liquid and Gas can be optimized by considering site environmental condition.
  - Recently, we considered 1/2 in Gas and 1/2 in LHE.
  - to be discussed further with Tohoku group.
- Recovery time for the total inventory is within 1 week by using small liquefaction system. To perform this, MCS and MCB have to be operated continuously during recovery mode.
- Tentative stop of the Small liquefaction system such as planned outage can be acceptable. To ensure it, allowable pressure should be 10 bar or so and less heat load into the dewar such as 0.2-0.5 %/day should be used.

Do not need to be concerned, In case of doubling GHe tanks

Evaporated mass vs Buffer tank volume

Recovery Time and Buffer tank volume are shown at around 30 g/sec.

HE Inventory		evaporated mass flow	recovery time		Number of 250m3 Buffer tank	
(kg / plant)		(kg/sec)	(H)	(Days)	required	contingency
40K shield	246	0.03	2	0.1		
5K shield	1068	0.03	10	0.4		
2K SRF	6901	0.03353	57	2.4		
1/3 inventory	2738	0.03	25	1.1	4	2
1/2 inventory	4108	0.03	38	1.6	6	2
Total inventory	8215	0.03291	69	2.9	11	2

Time to fill up at 30 g/sec.

- 4+2=6 tanks (1/3 inventory) ⇒ 25H
- 6+2=8 tanks (1/2 inventory) ⇒ 38H
- 11 tanks (total inventory)⇒ 69H

Further detailed dynamic simulation will be performed continuously instead of using TOY model.