

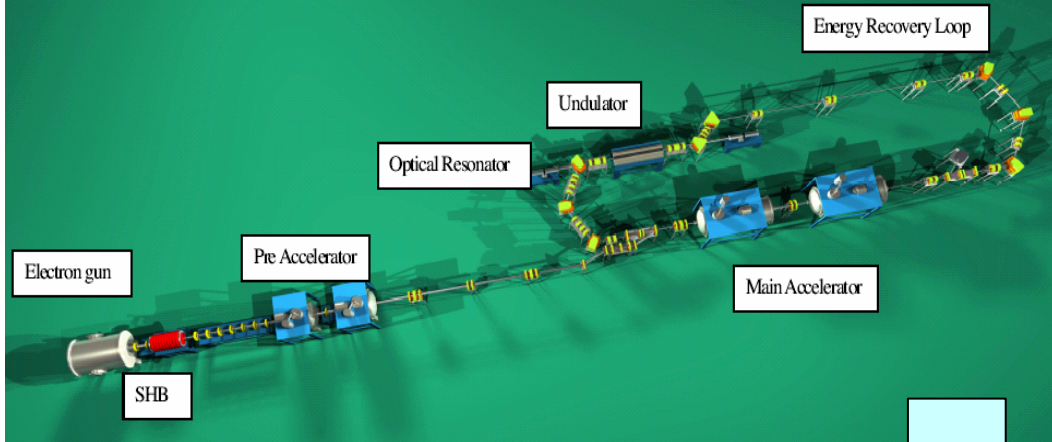
# **Cryostat Design Consideration of the ERL Light Sources and FELs**

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**About a half kilometer-long super-conducting RF linac cryostat design of mechanicals and cryogenics is briefly discussed to optimize construction, maintenance and operation costs of the low-temperature cryostat for ERL light sources as a practitioner's guide. A low temperature cryostat for the super-conducting RF linacs and other super-conducting devices should be designed and made to minimize its heat invasion through the heat bridges between the room and low temperature parts. The cryostat also should be designed and made to minimize total number of the heat cycles for the rest of its life after the initial test. We can expect that the total number of the heat bridges is roughly proportional to the number of the cryostat, and a life interval between two contiguous cryostat malfunctions inversely proportional to the number of the heat cycles. Therefore, if we can design and make a single and long cryostat to realize the operation less than a half cycle for the rest of its life, we can run our cryostat for a very longer interval than tens of years and with minimum electricity. A very powerful pulse tube refrigerator, which has been available in Japanese domestic market, will be planned to use in the cryostat for their non-stop and continuous cooling. In addition to them, we plan to summarize the JAERI ERL FEL zero-boil off cryostat design, its operational characteristics, and non-stop operation records over these 17 years and other cryostat related activities.**

JAERI Energy Recovery SC Linac-based FEL at Tokai under Construction



Future ERL-LS system  
A Half Km long Single Cryostat

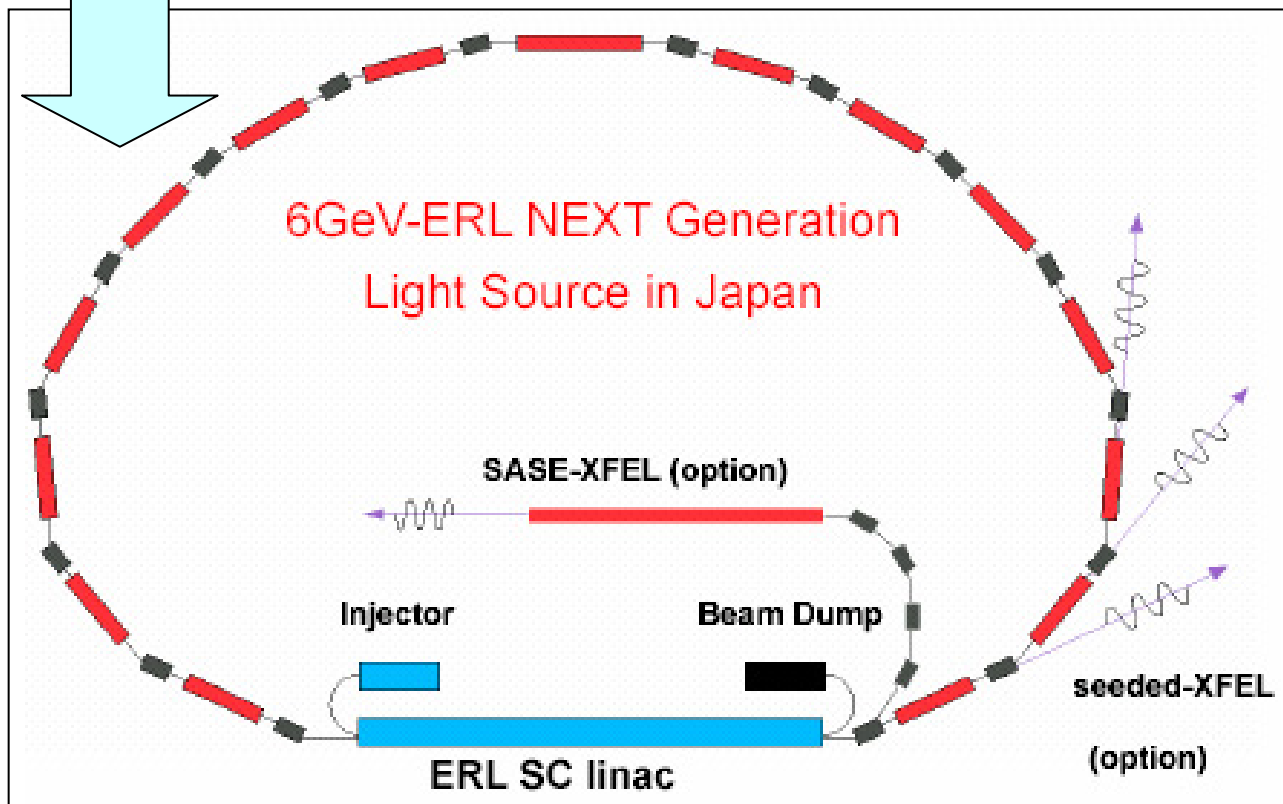
Hybrid Of Large 2K Refrigerator and  
Zero-Boil off System  
No Cold Maintenance

2K Liquefier and 80K Pulse tube  
Cooler

Current System  
4 Stand Alone-Zero Boil Off  
Cryostats

Cold Maintenance and  
Non-Stop Cold Operation  
No Warm Up

4K Recondensor and  
20K/80K Shield GM Cooler



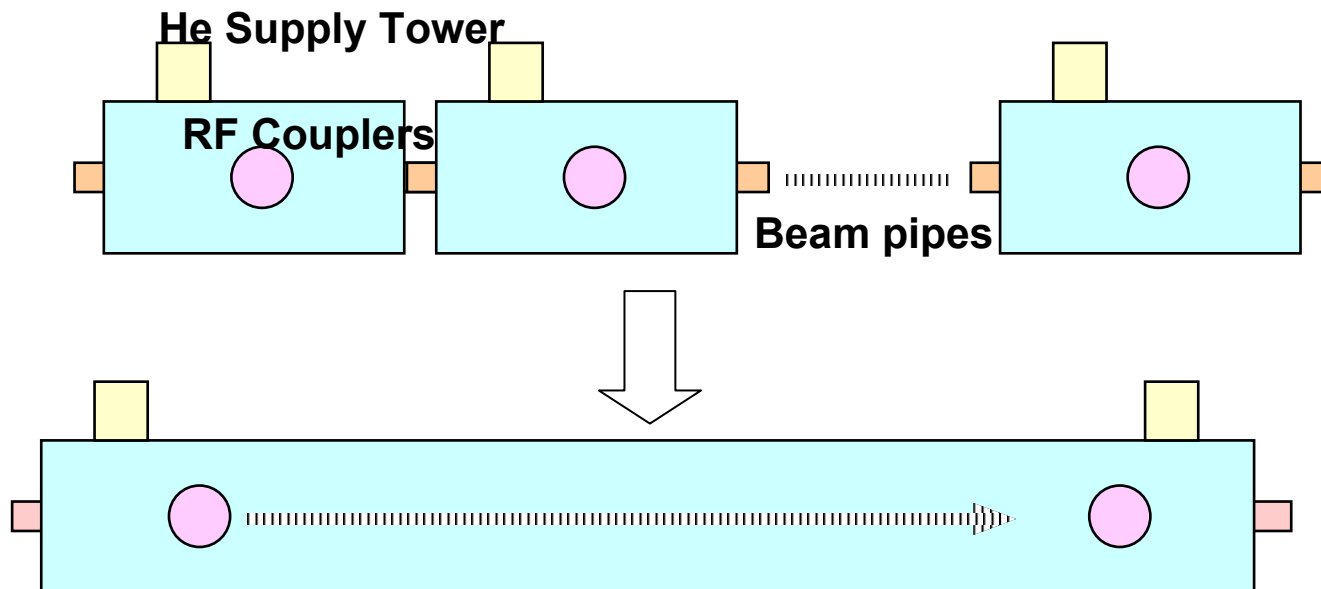
# **On the A 400m-long superconducting rf linac cryostat for an ERL light source**

- #1 Minimizing the Total Heat Invasion by Minimizing Number of Heat bridges=Single Cryostat
- #2 Easy Operation because of the Single Cryostat
- #3 Maintenance-Free or Easy-Maintenance because of the Single Cryostat
- #4 Half-Heat Cycle Operation =Little Failure
- #5 Whole Cryostat System Cold forever Over 20 Years or Longer Cold Maintenance or No Maintenance (Low Temperature < 60K )
- #6 Non-Stop and Continuous Operation of Cryogenic Refrigerator System Except for Unscheduled Emergency or Power Failure
- #7 Utilizing Vibration-Free, Long-Life and Static Pulse Tube Refrigerator System for Idling Operation
- #8 External Huge Refrigerator for Routine and High Power Operation

- #1 Minimizing Heat Invasion & Number of Heat bridges,
- #2 Easy Operation, #3 Maintenance-Free or Easy-Maintenance

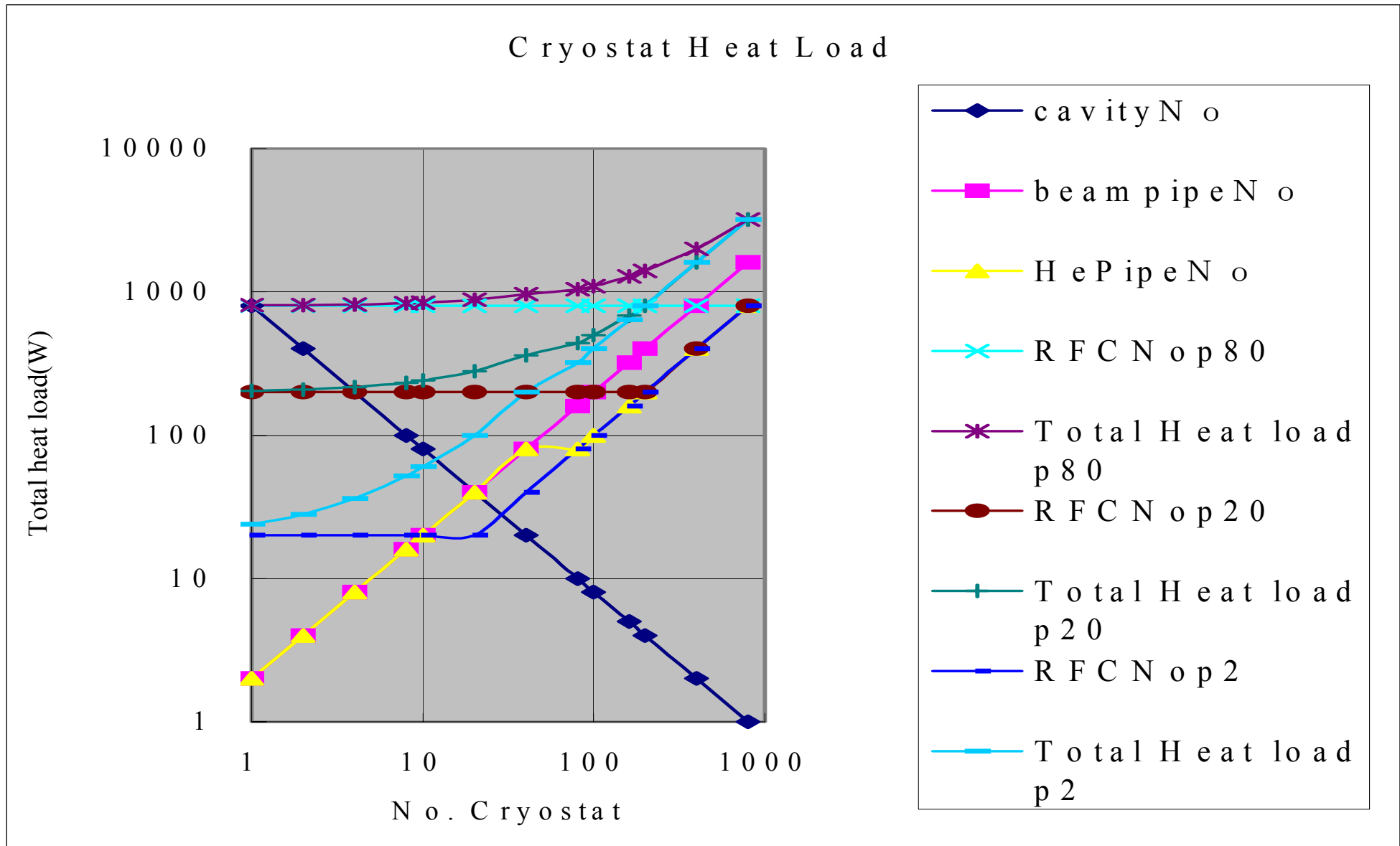
## 400m long Cryostat configuration

800 Cryostats/ 1 Cavity / 1600 Beam pipes/ 800 RF Couplers



A single Cryostat/ 800 Cavities / 2 Beam pipes/ 2 or 8 or 20 or 80 RF Couplers

# Total number of Cryostat and Total Heat Load Dependence, Accelerating Cavity Length of 400m.



#2 Easy Operation, #3 Maintenance-Free or Easy-Maintenance

## NonStopLowTempOperation or NoWarm-up Op

Possible Only for the JAERI Stand-Alone & Zero-Boil-Off ERL-SC linac ,

1) **Cold Maintenance** for Both Shield Cooler & Recondenser within a few tens minutes

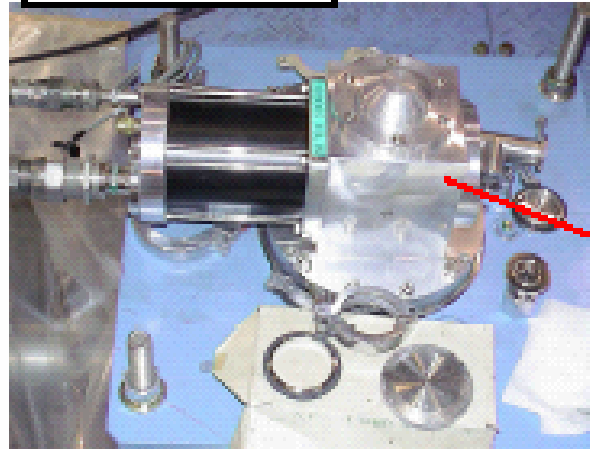
2) No Liq.He Loss, 24hours **Over 10-20years Continuous Operation. No need to reload**

3) **No Regulation** of Domestic Pressure Vessel Code required for the Cold Maintenance

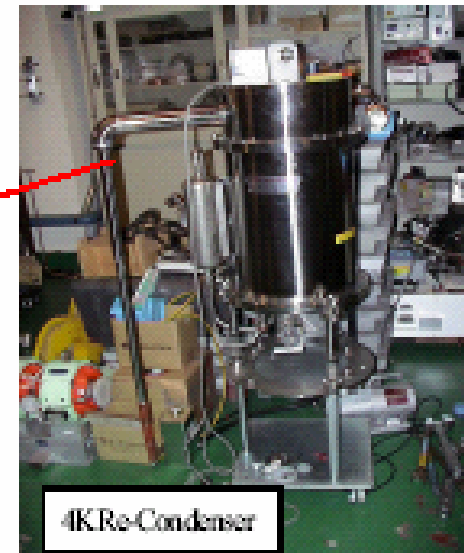
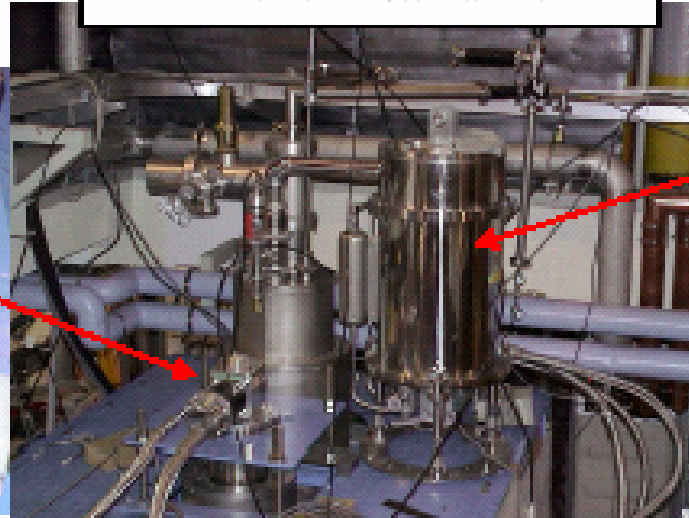
**Bonus of the No Warm-up;** (1) **No Conditioning Required** After the first, (2) **Nearly No**

**Deterioration** of all the Cryogenic Components and Conditions, (3) **Always Ready** to fire,

20K/80K Shield Cooler



Pre-Accelerator's Shield Cooler & Recondenser



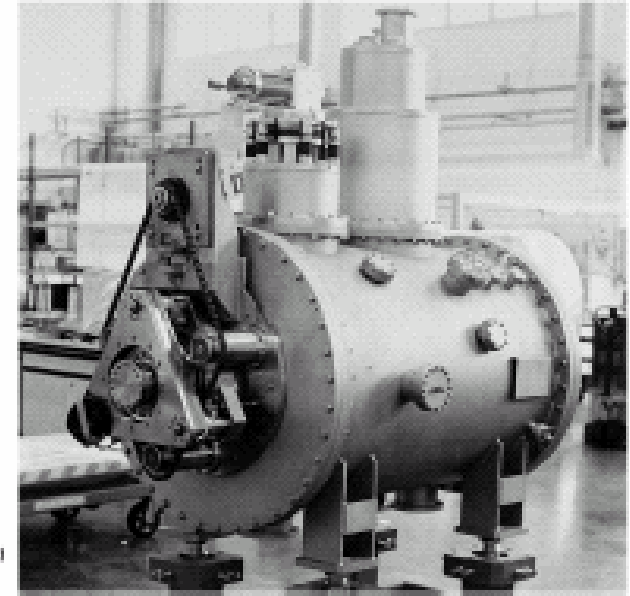
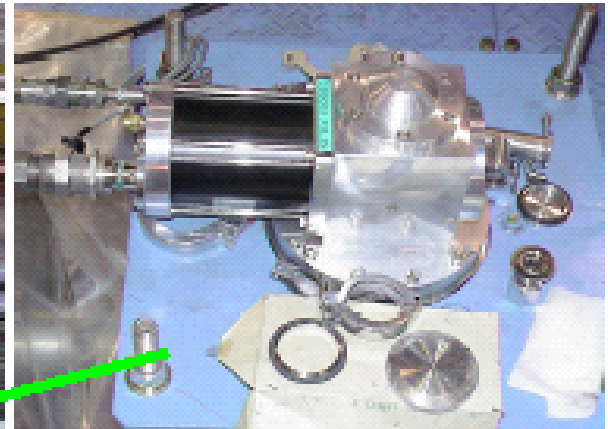
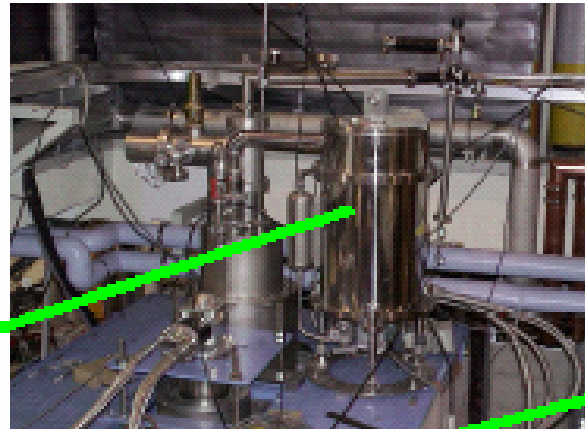
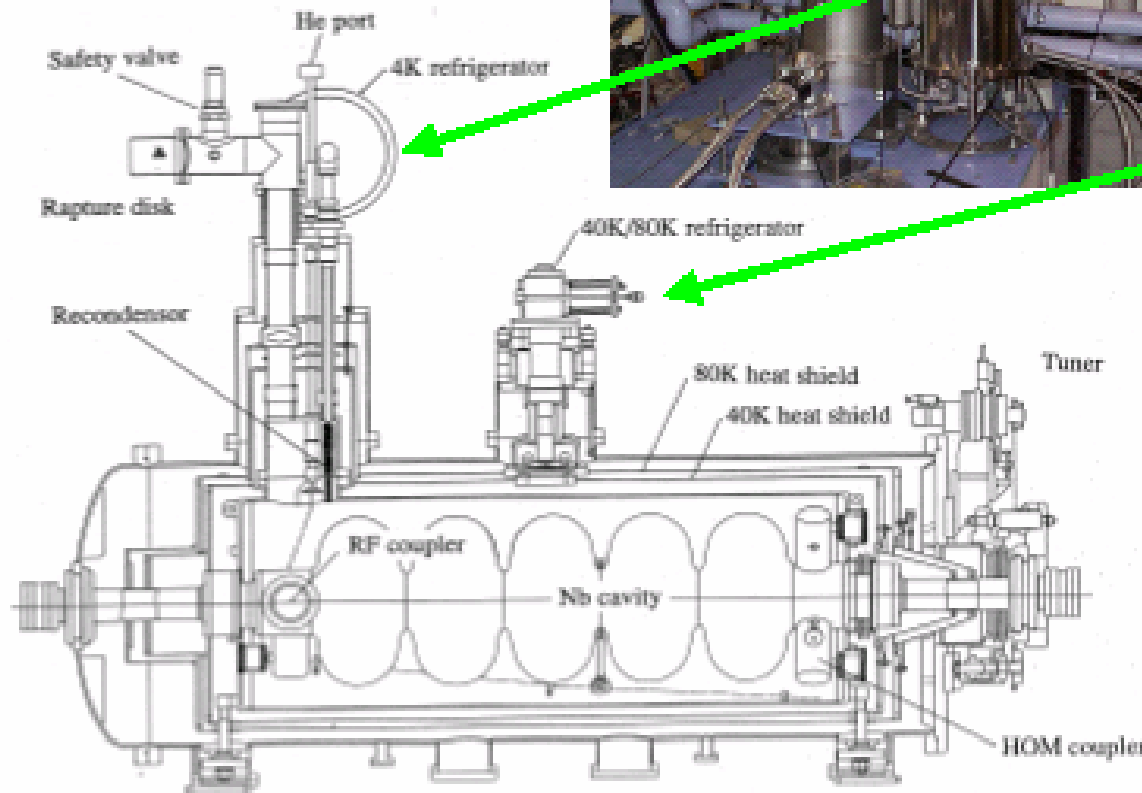
4K Re-Condenser

## #4 Half-Heat Cycle Operation = Little Failure



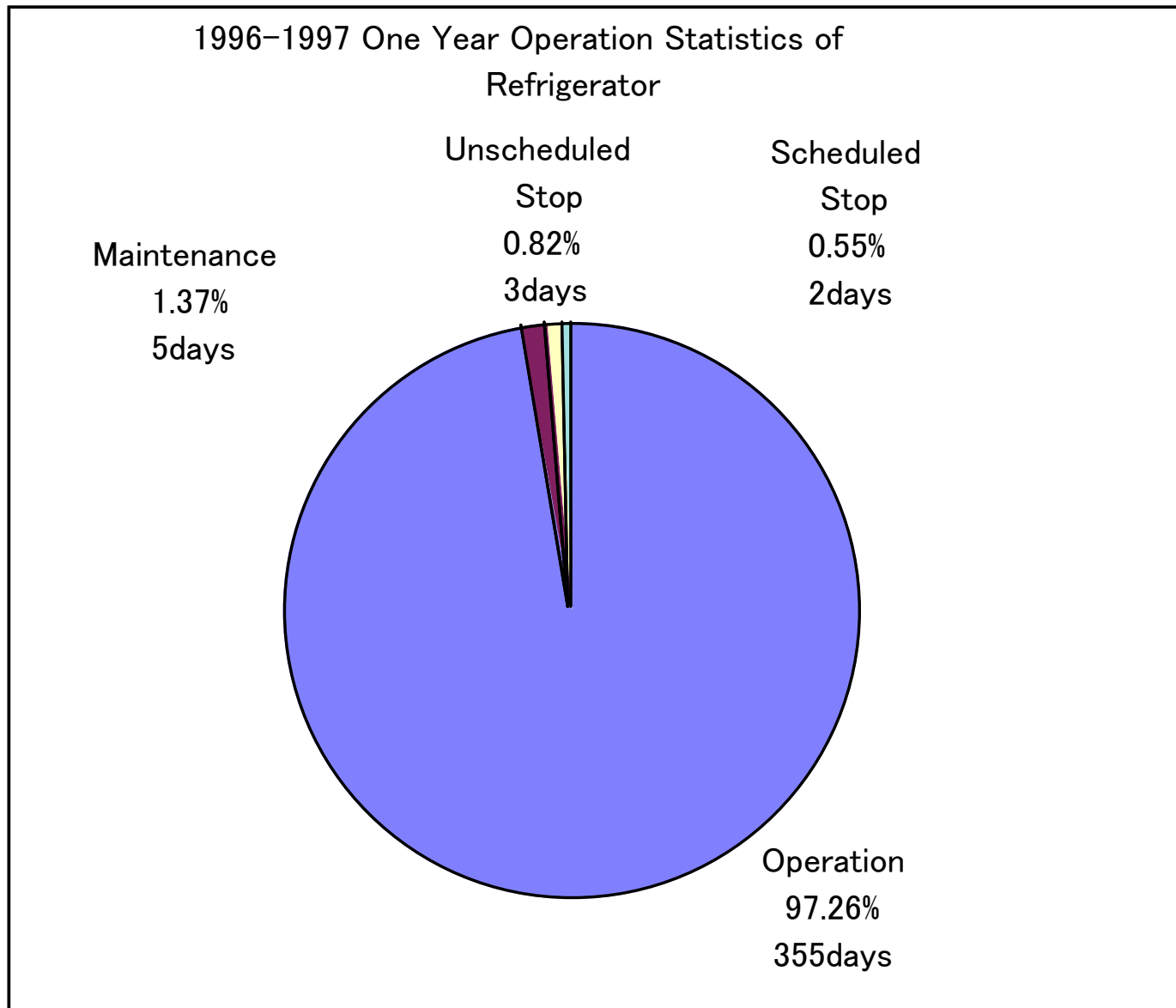
## A Stand-alone & Zero-boil-off Cryogenics

=Big Dewar with Refs



The JAERI stand-alone, and zero-boil off cryostat has duplex heat shields, and the shield-cooler and He-recondenser refrigerators integrated into the cryostat vacuum vessel.

# #5 Whole Cryostat System Cold Over Twenty Years/Cold Maintenance



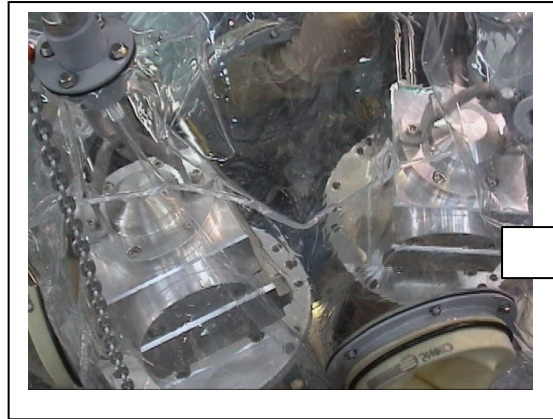
Statistics of the cryogenic system operation in 1997 Japanese fiscal year



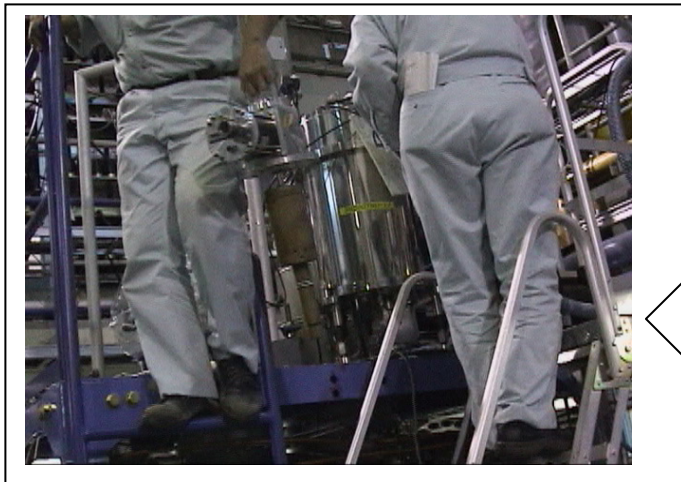
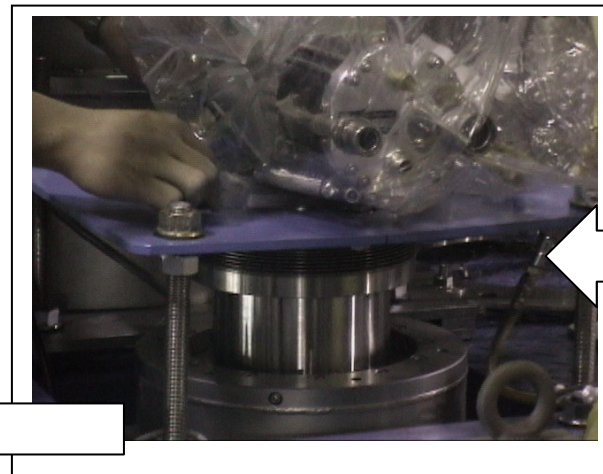
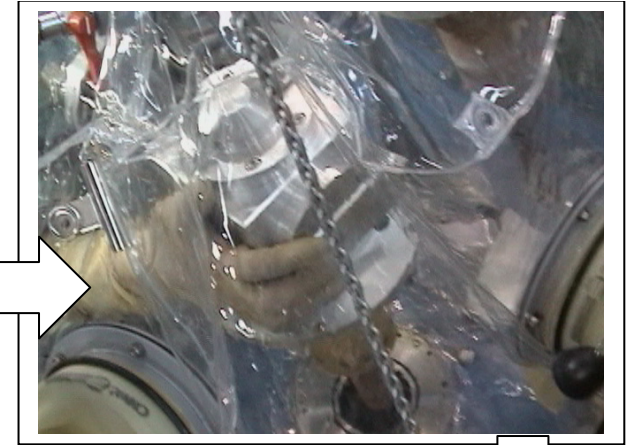
# COLD GM Refrigerator Maintenance Pictures



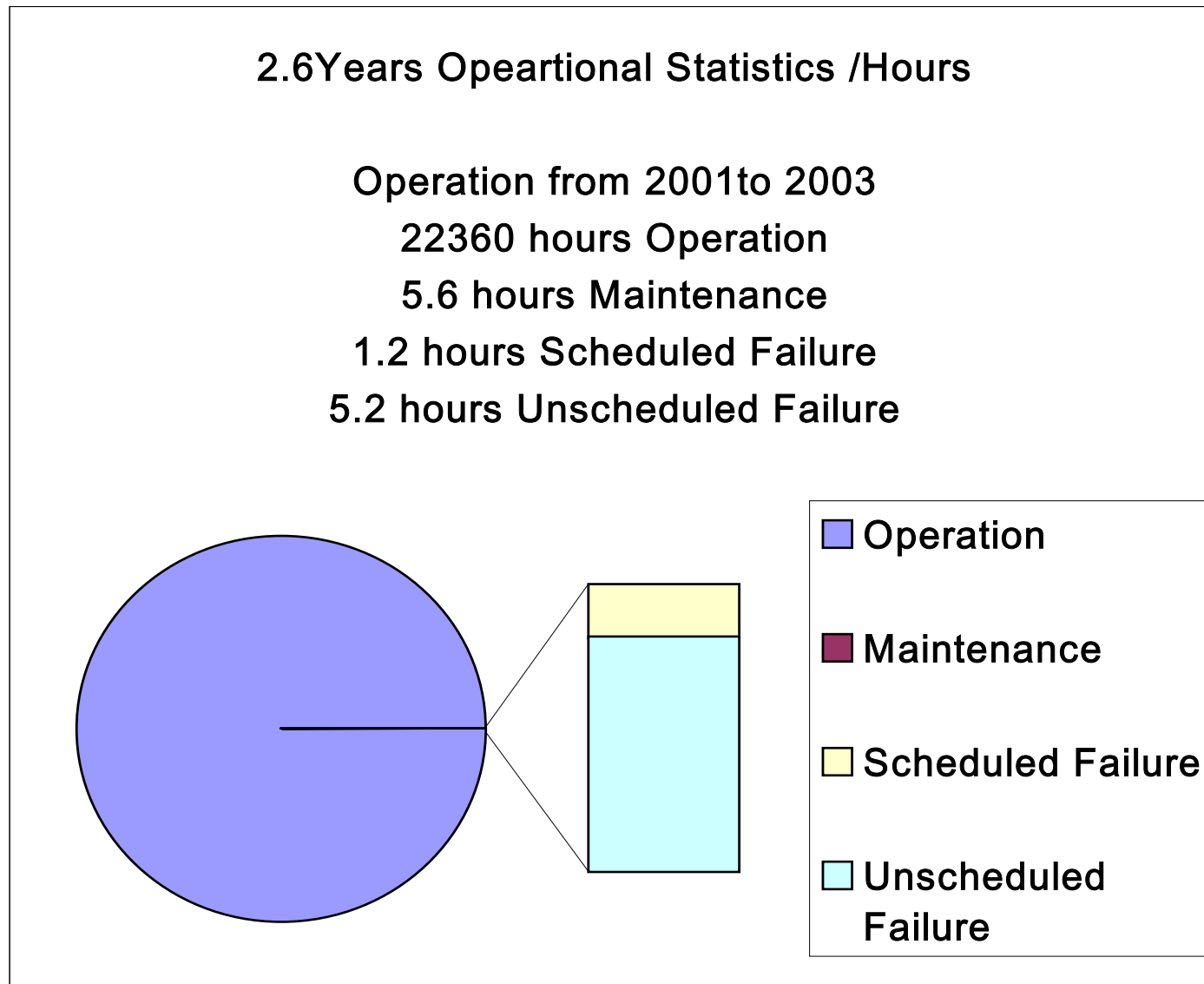
GM Refrigerator Engine in the Cryostat



Lift the GM Engine inside Plastic Bag



# #6 Non-Stop and Continuous Operation of Cryogenic Refrigerator System Except for Unscheduled Emergency or Power Failure



Statistics of the cryogenic system operation in 2001-2003 Japanese fiscal year.

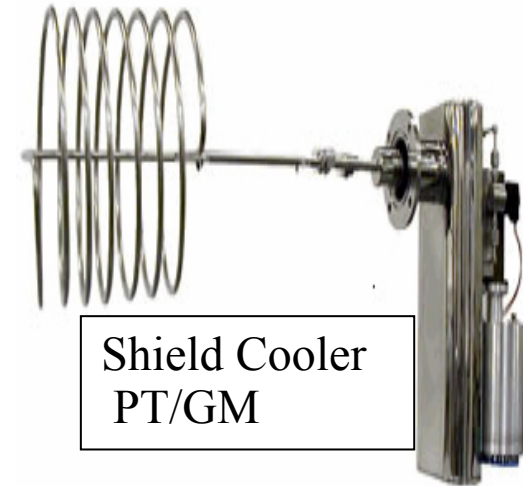
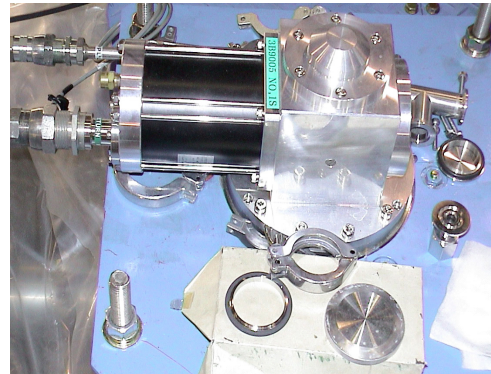
# #7 Long-Life and Static Pulse Tube /GM Refrigerator System for Idling Stand-Alone, Zero-Boil Off Superconducting rf Linac FEL Driver

## Large-Scale Liquefier Cases

## JAERI Design

☒ 3

Large N<sub>2</sub> Liquefier & Circulating Loop



Shield Cooler  
PT/GM

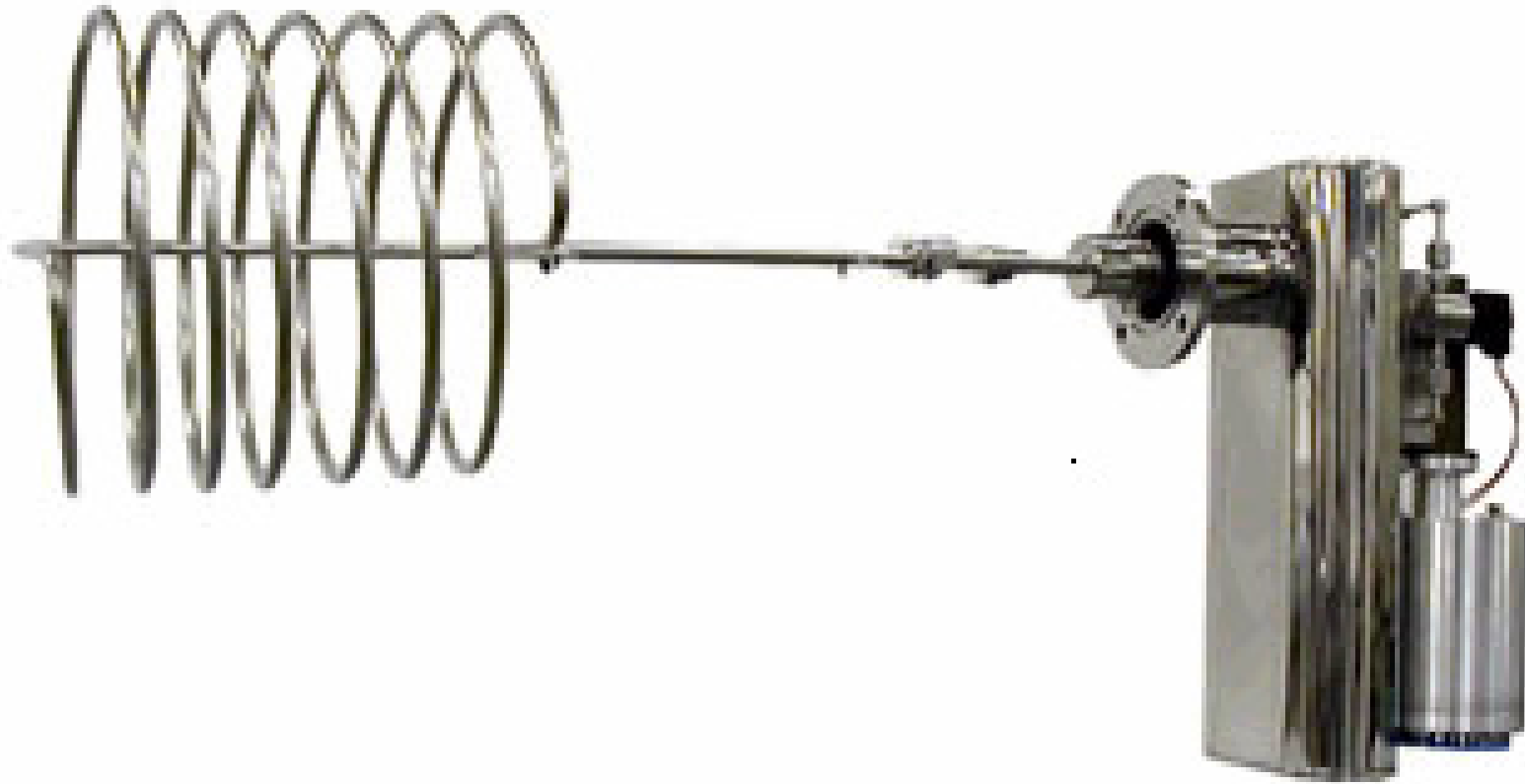
24hrs/ 3months Continuous  
Operation x 3 Maintenances Over-  
Night Operation 10-20 operators

Unmanned Semi-Infinite Continuous Operation

Large He Liquefier & Circulating Loop



Liq. He  
Recondensor

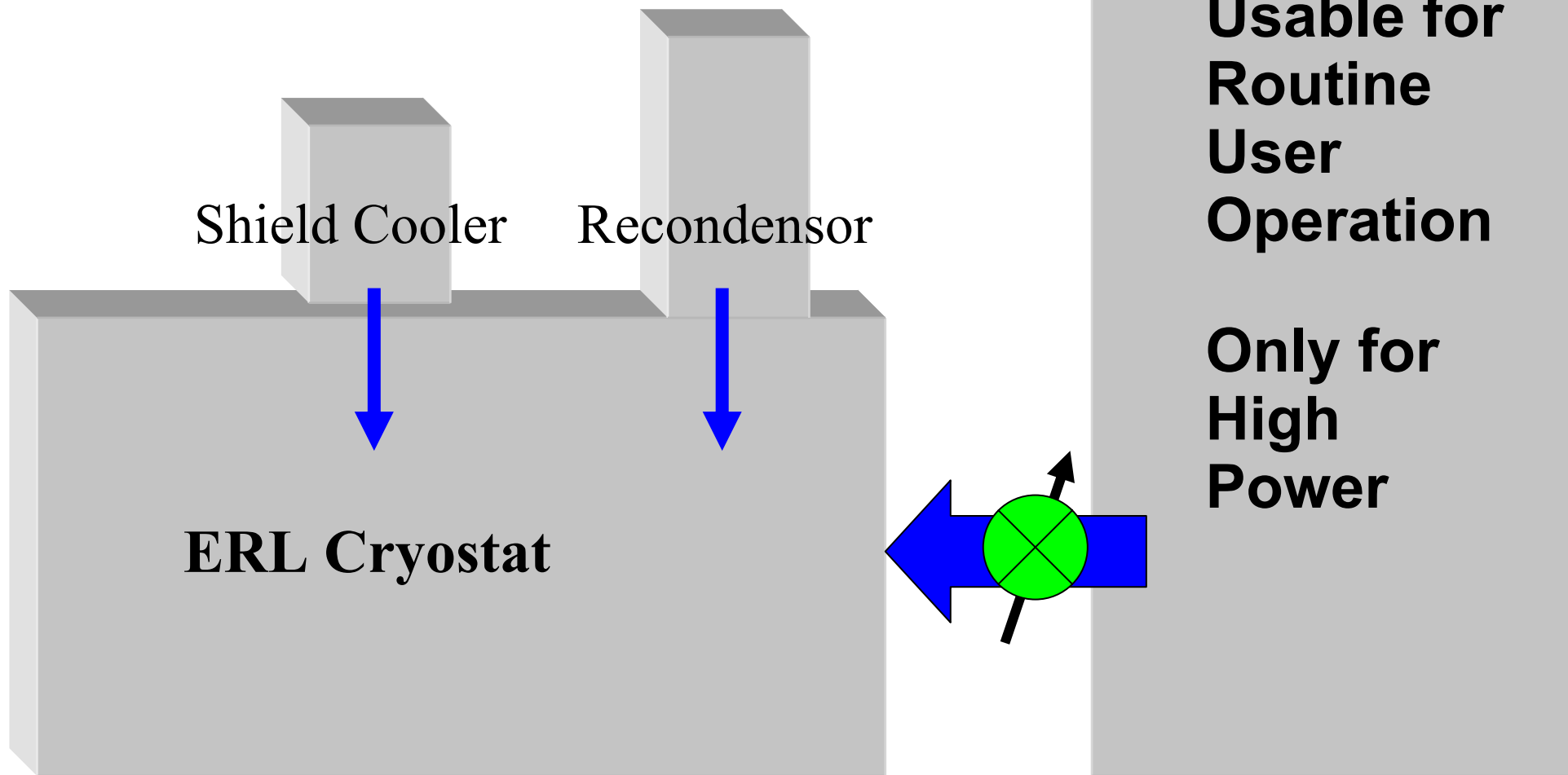


Future Shield Cooler : 500W at 80K Pulse Tube Refrigerator  
(AirWatwer Co.Ltd.) 2-3kW at 80K available in Japanese Domestic  
Market.

**No Vibration and Infinite life** in the cooling head Because of No  
moving parts= Maintenance Free Except for Warm Parts(Compressor)  
2-3K pulse tube refrigerator is under development in the world, Japan,  
US.

# #8 External Huge Refrigerator for Routine and High Power Operation

ZBO Refrigerator System for Idling & Routine Always Running



**External  
Huge  
Refrigerat  
Usable for  
Routine  
User  
Operation**

**Only for  
High  
Power**

## **SUMMARY**

**Here, we discussed about the new consideration of a 400m-long super-conducting rf linac cryostat for an ERL light source in the following issues.**

- #1 Minimizing the Total Heat Invasion by Minimizing No.of Heat bridges**
- #2, #3, Easy Operation and Easy-Maintenance because of the Single Cryostat**
- #4 Half-Heat Cycle Operation =Little Failure**
- #5 Whole Cryostat System Cryogenically Cold Over 20 Years / Cold Maintenance**
- #6 Non-Stop and Continuous Operation of Cryogenic Refrigerator System.**
- #7 Cryogenic Cooling By Long-Life and Static Pulse Tube /GM Refrigerator System for Idling Operation Between the user Operations**
- #8Cryogenic Cooling by External Huge Refrigerator for Routine and High Power User Operations.**

**We plan to develop the single cryostat system and non-stop cooling for future ERL light sources like the JAERI FEL.**