Vacuum System for BDS
[Completeness of RDR]

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- Design principle
- Basic design
- Cost estimation
- Issues to be discussed
- Summary

Design principle_1

- General remarks
  - **The vacuum system of RDR = The minimum design for cost estimation**
    - Cost per unit length
  - **No detailed design exists, that is, the layout of pumps and the diameter of pipes, for example, were determined from a general consideration.**
    - Not responding to each component
  - **Use standard UHV vacuum system**

Design principle_2

- Use standard UHV vacuum system_1
  - **Use standard materials:**
    - SS, Cu, Al-alloy, Cu-plated SS
    - Depend on SR power, impedance requirement
  - **Use standard pumps:**
    - Ion pumps, Ti-sublimation pumps, NEG (coating)
    - TMP (Turbo-molecular pump), scroll pump for rough pumping
    - Lumped pump system, basically

Design principle_3

- Use standard UHV vacuum system_2
  - **Use standard monitors:**
    - Vacuum gauge = BA gauge (Hot cathode type)
    - Mass Analyzer = Quadrupole Mass Spectrometer
  - **Use standard components:**
    - Conflat UHV flange
    - Manifolds compatible to Conflat flanges
    - Bellows chamber with RF shield inside
    - Gate valves with RF shield inside
    - Fire-retardant, radiation resistant cables
    - Etc.....

Basic design_1

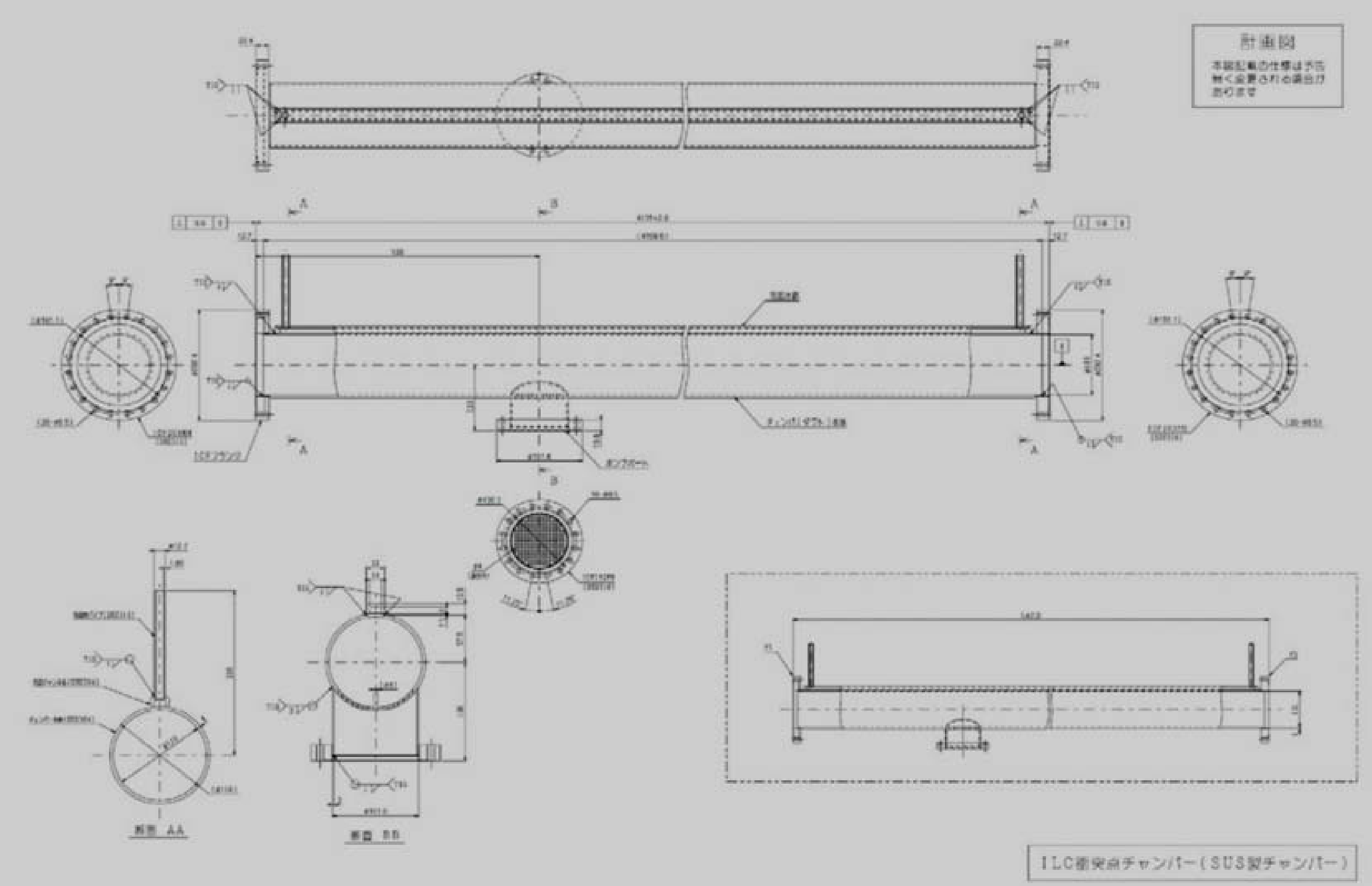
- Requirement for pressure (equivalent to N_2/CO):
  - **5×10^{-6} Pa (50 nTorr), basically.**
  - **1×10^{-7} Pa (1 nTorr) for some region at upstream side of IP**

Basic design_2

- Beam duct
  - **Duct material: Stain-less steel, basically**
    Al-alloy or copper depending on SR power, and requirement from impedance
  - **No *in situ.* baking, basically**
  - **Each duct for an element is considered as a stand-alone one, that is, the flanges are at both sides of a duct.**
  - **The maximum length of a beam duct is 10 m.**
  - **The minimum length is 1 m.**
  - **One magnet has one beam duct**
  - **Circular cross section**
  - **Cooling channel at one side, if necessary**

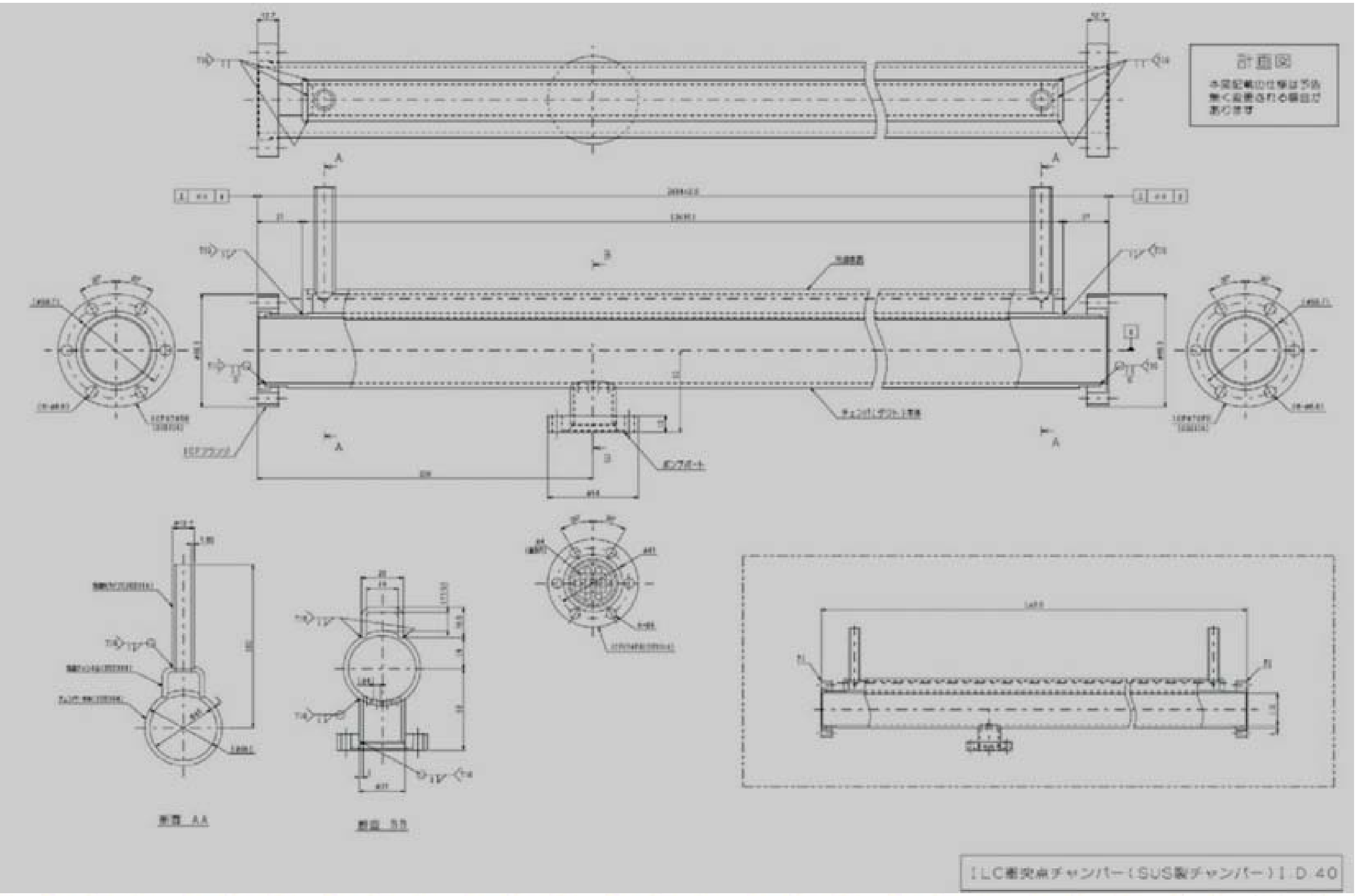
Example_1

- Ex. SS_ϕ110mm duct



Example_2

- Ex. SS_ϕ40mm duct



Basic design_3

- Aperture
  - **Basically the apertures are the same to those of elements. The thickness of duct should follow the conditions as follows.**

[D: Diameter, t: thickness]

$D < 20$ mm : $t = 1$ mm

20 mm $\leq D < 60$ mm : $t = 2$ mm

60 mm $\leq D < 100$ mm : $t = 3$ mm

100 mm $\leq D$: $t = 4$ mm

- Gap between a duct and cores of a magnet should be larger than 1 mm, to avoid interference.
- Beam pipes with a different aperture should be connected through a taper (~45°).

Basic design_4

- Connection flange
  - **Connection flange is ICF conflat type.**
  - **The diameter of the flange, D_f [mm], are:**

[D_f : Flange diameter, D : duct diameter]

$D < 20$ mm : $D_f = 34$ mm (ICF 034)

$20 \leq D < 40$ mm : $D_f = 70$ mm (ICF 070)

$40 \leq D < 60$ mm : $D_f = 114$ mm (IFC 114)

Etc.....

  - **Stainless-steel**
  - **Copper gasket**
  - **RF bridge between flange, if necessary.**

Basic design_5

- Surface treatment
  - Basically, the inner surface of the duct should be cleaned by a detergent.
  - The acid cleaning should etch the surface by about 1 micron to remove contaminated layer.
  - Following the cleaning by pure water, the duct should be dried by dry nitrogen.
  - Individual ducts will be baked, and leak checked as part of the vacuum system quality control.

Basic design_6

- Accuracy of manufacturing
  - Total length = ±2 mm for 10 m.
  - Tilt between the end flanges is 0.5 degree.
  - Displacement of the duct against the axis in the horizontal and vertical plane is ±2 mm.
  - Slant of the end flanges against the axis of the duct is 1 degree.
  - Displacement of the center of end flanges against the axis of the duct is less than ±0.5 mm.
  - Width of a gap inside should be less than 0.5 mm.
  - Inside step should be less than 0.5 mm.

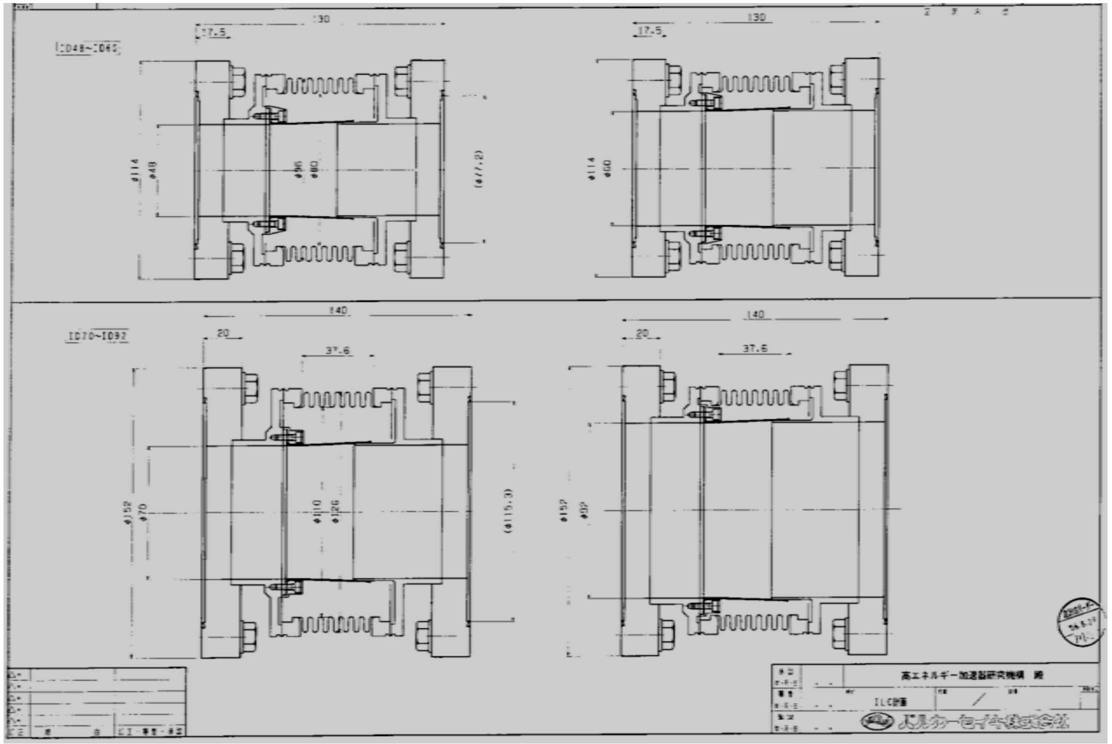
Basic design_7

- Thermal gas desorption rate
  - Assumed to be 5×10^{-8} Pa $m^3 s^{-1} m^{-2}$ ~ 5×10^{-11} Torr l $s^{-1} cm^{-2}$
  - Assumed thermal gas desorption rate was relatively large, because no baking *in situ.* was basically assumed.
- Photo-desorption Rate
  - Assumed to be 1×10^{-5} molecules $photon^{-1}$. Some extent of vacuum scrubbing is expected.
  - Photon density was assumed to be

    1×10^{17} photons $s^{-1} m^{-1}$ for the copper region, and 1×10^{15} photons $s^{-1} m^{-1}$ for other regions.

Basic design_8

- Bellows chamber
  - **With the same radius to adjacent beam pipes**
  - **With finger-type RF-shield**



Basic design_9

- Pumps
  - **Pumps: Sputter ion pumps**
  - **Lumped pump scheme.**
  - **Effective pumping speed, S [m^3s^{-1}], are:**

    [D: Diameter, S: Pumping speed]

    $D < 20$ mm : $S = 0.02$ m^3s^{-1}

    20 mm $\leq D < 40$ mm : $S = 0.04$ m^3s^{-1}

    40 mm $\leq D < 60$ mm : $S = 0.06$ m^3s^{-1}

    Etc……
  - **Pumping speed includes the conductance of pumping slot. The actual pumping speed is the twice of the effective pumping speed.**

Basic design_10

- Rough pumping unit
  - Oil-free system
  - A rough pumping unit consists of:
    - A turbo-molecular pump (S ~ 0.3 m^3s^{-1})
    - A scroll pump (S ~ 0.3 m3 min^{-1})
    - A manifold (cross tube, for example),
    - A Pirani-gauge, a cold cathode gauge,
    - A leak valve, an electrical valve.
    - Controllers of pumps and gauges.
  - Number of the rough pumping system is 20.
  - Removed during beam operation.

Basic design_11

- Gate valves
  - **All metal valves**
  - **Each region (EFF1 and so on) has at least one gate valve.**
  - **Valves are located every 250 m at minimum**
  - **Apertures of gate valves are :**

[*D*: Diameter, *A*: Aperture size]

$D < 60$ mm : A = ICF114

60 mm $\leq D < 100$ mm : A = ICF152

100 mm $\leq$ D < 150 mm : A = ICF203

Etc.....

Basic design_12

- Gauge
  - Vacuum gauge: BA (hot cathode), QMA
  - The interval of gauge is 200 m.
- L-Angle Valve
  - All-metal L-angle valve is located every 50 m.
  - Rough pumping system is connected to the valve when the duct is evacuated from atmosphere.

Cost estimation_1

- General remarks
  - **Basically, obtained from major vacuum manufactures.**
  - **Discussed among TS leaders to find reasonable numbers in all regions.**
  - **Based on TS leaders' experience so far.**
    - For example, in Asia, KEK B-factory (~1996).
  - **The present cost estimation, however, is not yet well optimized.**
    - Diameter, lengths, etc.

Cost estimation_2

- Included terms
  - Beam ducts
  - Bellows chambers (with finger-type RF-shielding)
  - Pumps (and controllers, Rough pumping unit)
  - Vacuum gauges (and controllers)
  - Gate valves (and controllers, with RF-shielding)
  - Manifolds (6 ports for rough pumping unit and gauges)
  - Gaskets, bolts, Supports (in average number)
  - Control cables between components and controllers
  - Interlock box per one gate valve
  - Baking heaters and thermal insulators: Option
  - Preparation before installation, such as assembling, pre-baking of beam pipe, testing, etc.

Cost estimation_3

- Not included terms
  - **All R&D**
  - **Spares**
  - **Man power for Installation, such as transportation, setting, connection, alignment, leak-checking, (baking)**
    - 4 km per year by 7 persons (1 specialist)
  - **Power supply for baking: Option**
  - **Others (facilities)**
    - Electric power, Cooling water system, Storage area of vacuum components before installation, and so on

Cost estimation_4

- Ambiguity in the present cost estimation
  - **Overall specifications and requirements are clear. But, the detailed specification are not yet given.**
    - Required pressure
    - Accuracy of manufacturing
    - Surface treatment
    - Gap between magnets, etc. ..
  - **Design is not yet fixed. The manufacturer counted a risk factor.**
    - Beam pipe radius, lengths
    - the structure of RF shielding at pumping port , etc. ..

Issues to be discussed_1

- Required pressure should be updated, at first.
- Detailed design responding to each component and region
  - **Aperture, lengths, etc. ..**
- Simplification of structure
  - **bellows chambers and gate valves**
- R&D
  - **Way to reduce gas desorption rate without baking**
    - Passivation, for example
  - **Quick connection flange**
- Optimization

Issues to be discussed_2

- Optimization_ Ex. Choice of duct material
  - **SS (stainless-steel), Al, or Cu.**
  - **In general, SS is cheaper and (may be) has higher reliability (for baking).**
  - **For ducts with a small radius the extrusion of Al pipe has an advantage in manufacturing.**
  - **SS pipe with Cu coating inside is also difficult to control the quality of the coating (and expensive).**
  - **Gas desorption rate of Al is comparative, if the surface is treated appropriately.**

Issues to be discussed_3

- Optimization_ Ex. Baking (in situ.) or not
  - **Baking in situ. can much reduce the gas desorption rate, and can reduce the number of pumps.**
  - **Baking (up to 200 degrees), furthermore, make it possible to consider the NEG (Non Evaporable Getter) coating, which could improve the vacuum, especially for pipes with mall radius.**
  - **Uniform baking along the beam pipe is difficult due to the firm fixing of the cavity BPM at present. The tuning of BPM will be required after baking.**

Summary

- The design principle and the basic design of the vacuum system for BDS in RDR phase were summarized.

- The design is sufficient for the rough cost estimation, but primitive for the actual system.

- Detailed design and elaborative discussion should be required for ED phase.
  - **Design responding each component and region**
  - **Simplification of structures**
  - **Optimization of system**