

Vacuum System for KEKB (mainly LER arc design)

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Physics

June 7, 1995
KEKB Accelerator Review

Chamber style

- No use of an antechamber
- Distribute synchrotron radiation on the chamber wall

Material

- Beam duct: Copper
 - ASM C10100 for vacuum surface
(Oxygen-free electronic copper)
 - ASM C10200 for cooling channel etc.
(Oxygen-free copper)

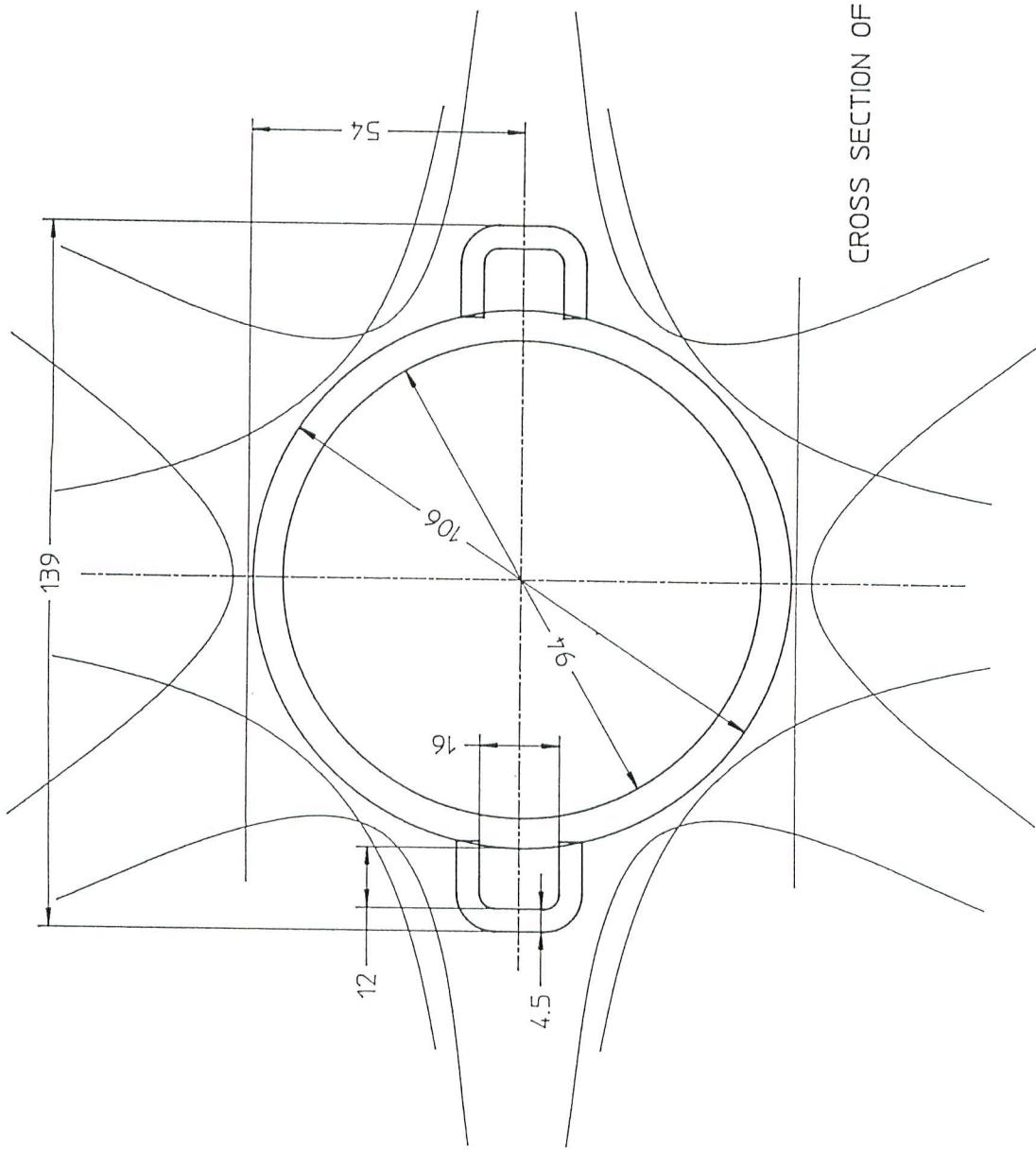
<reason>

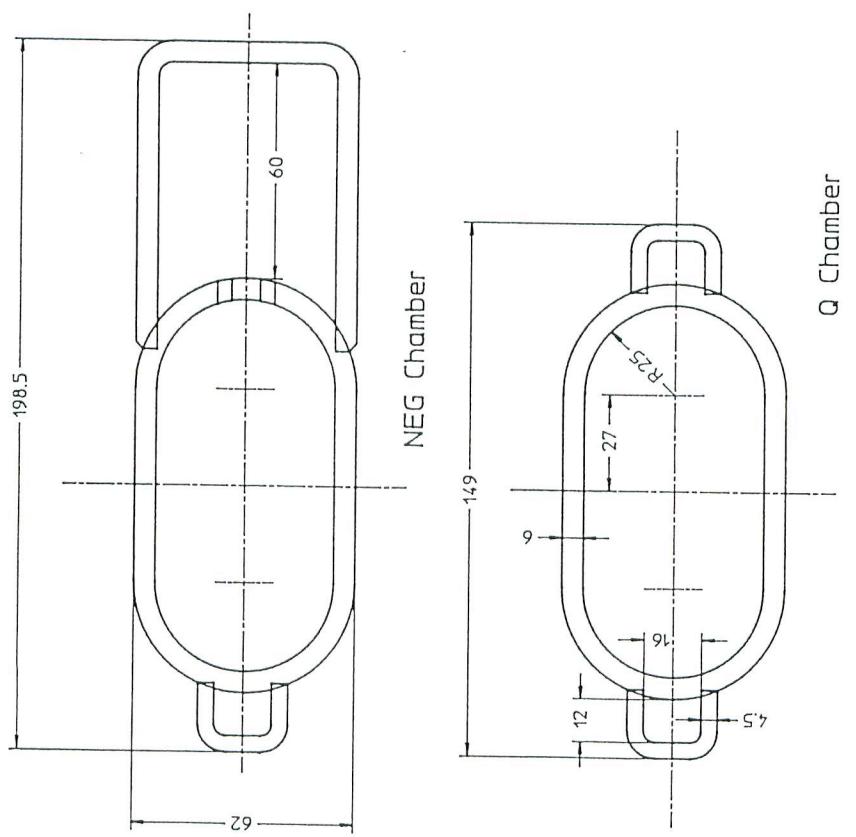
- High heat load (LER)
- Radiation shield (HER, LER)

On the top of the beam duct with a 6mm thick wall,
LER(3.5GeV, 2.6A, 7200h/y) $<10^5$ rad/y
HER(8GeV, 1.1A, 7200h/y) $<10^7$ rad/y

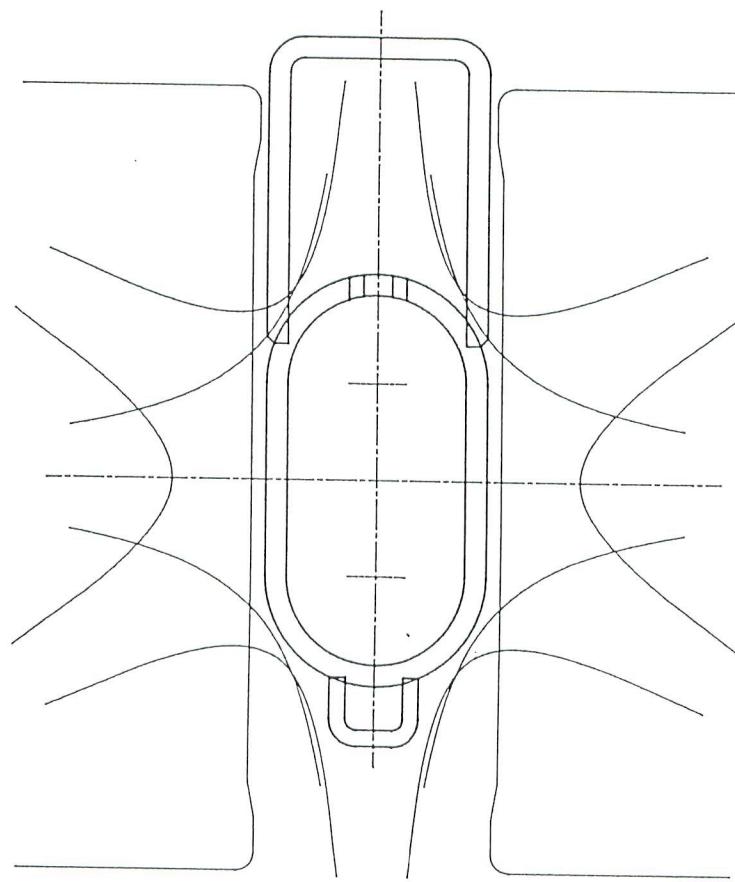
- Flange: AISI304 stainless steel
 $\mu<1.2$

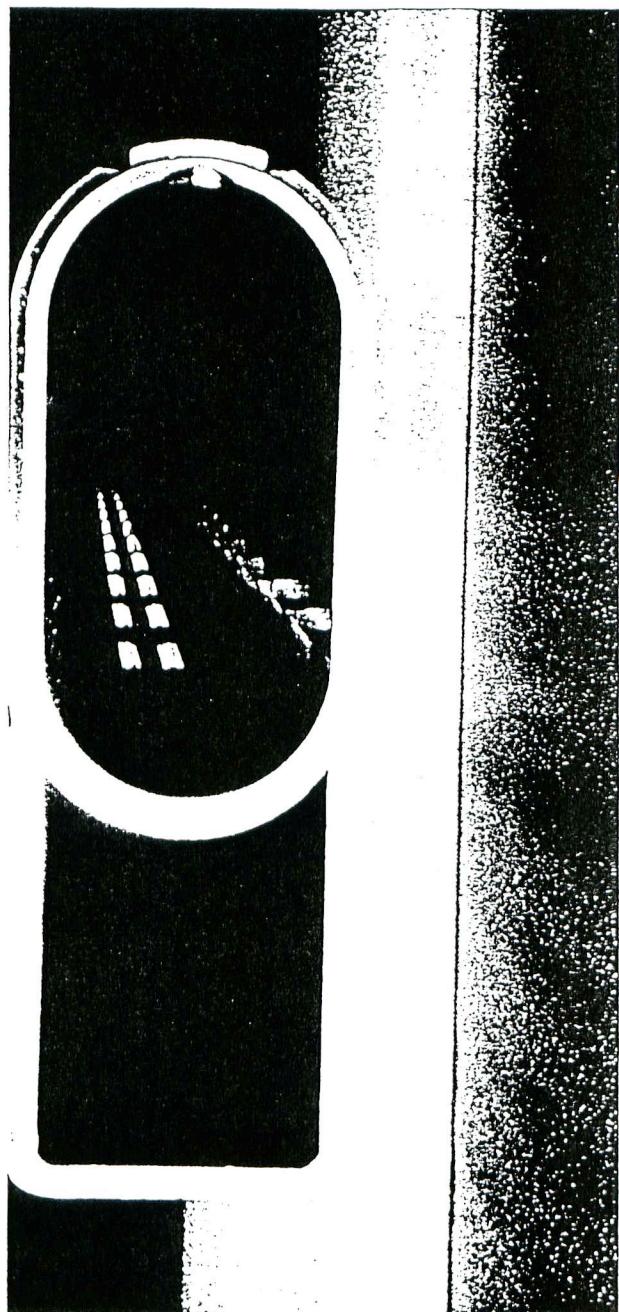
CROSS SECTION OF LER

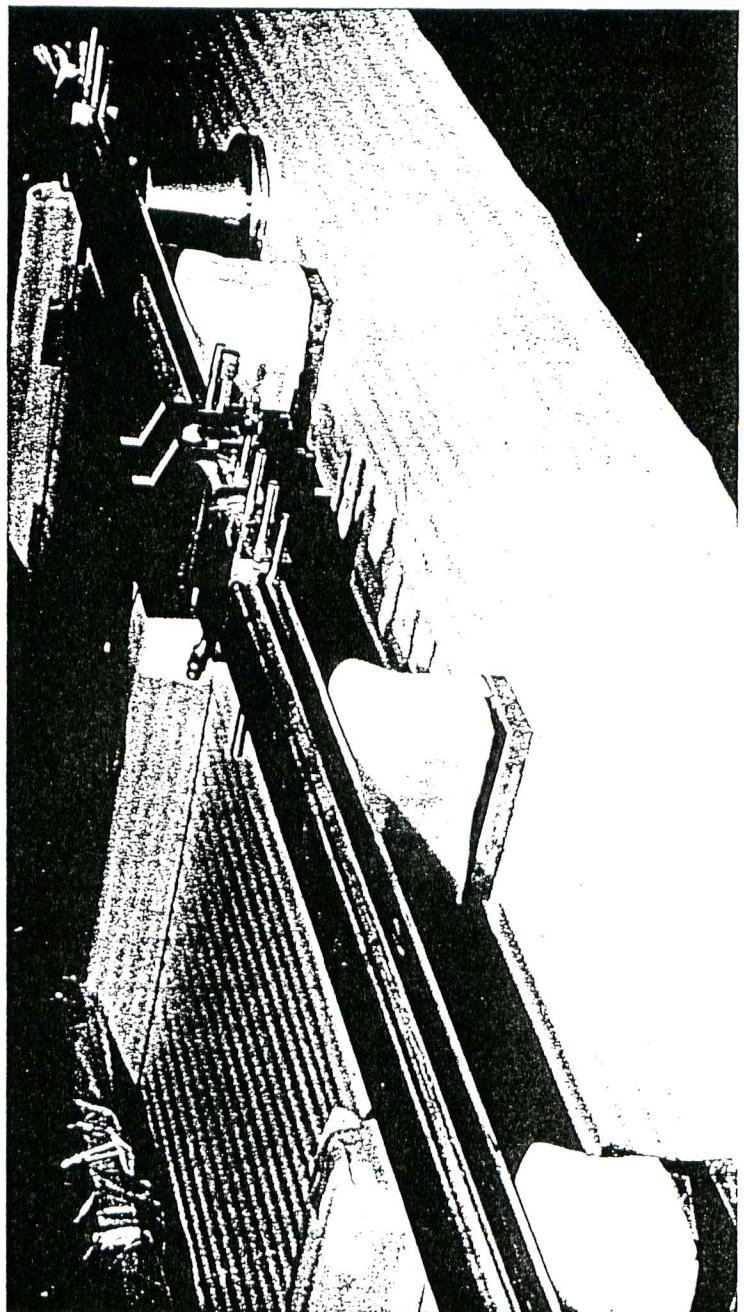


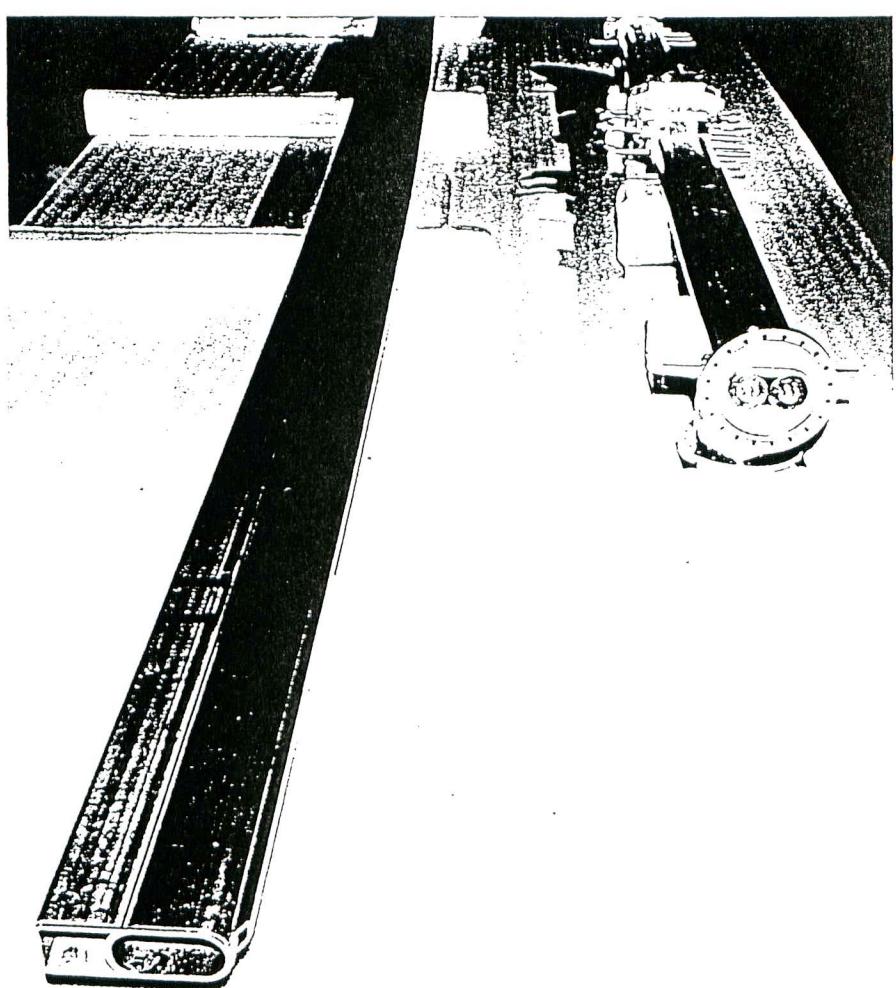


HER Vacuum chamber









KEKB ダクト外側への放射光線量

6 JUN 1995

放射線安全管理センター 波戸 芳仁

KEKBのHERとLERのダクト外側での放射光による線量をEGS4を用いて計算した¹。ユーザーコードUCSRREC5を用いた。計算に用いたパラメータを表1に示す。吸収体は「水」であり、放射

表 1: 計算条件

	HER	LER
I (A)	1.1	2.6
R (m)	104.46	16.31
θ	1.13°	1.0°

光のスコアは、放射光の反射点に正対する面(18.5 cm離れている)で行った。実際のスコア面はこれより反射点に近いので、 $1/r$ で補正する。(線線源とみなせるため)

表 2: 計算結果

ダクト厚さ (cm)	線量率 (Gy/A/h)	
	LER	HER
0.5	11.211 ± 1.5339	228.74 ± 35.424
1.0	1.6823 ± 0.49899	105.48 ± 18.921
2.0	0.19035 ± 0.47568E-1	26.156 ± 3.4873
3.0	0.47015E-1 ± 0.14332E-1	16.583 ± 3.8073
5.0	0.15550E-1 ± 0.11385E-1	5.1758 ± 2.4489
6.0	0.13306E-1 ± 0.11123E-1	1.4216 ± 0.31092
1.0	0.48316E-4 ± 0.19051E-4	0.14972 ± 0.58202E-1

計算結果を表2に示す。この rad/y への換算例を次に示す(LER 6 mm の場合)。

$$0.13306 \times 10^{-1}(\text{Gy/A/h}) \times 7200(\text{h/y}) \times 2.6(\text{A}) \times 100(\text{rad/Gy}) \times \frac{18.5(\text{cm})}{7(\text{cm})} = 6.5 \times 10^4(\text{rad/y})$$

ここで 7 cm は、LER ダクト断面図から読みとった、放射光反射点からダクト上面へのおおよその距離である。

¹末次祐介氏の依頼によって計算を行った。1995年6月のMAC(Machine Advisory Committee)用資料。LER-Cu 6 mm で 10^9 rad/y 以下になるか否かが重要な点である。

Heat load of LER

- Maximum linear power density due to synchrotron radiation is 14.8 kW/m.

This leads to, locally,
 $T=130^{\circ}\text{C}$, strain=-0.15% (horizontal).

<fatigue consideration>

- Fatigue test

With 0.15% strain,

fully annealed copper clears 10^6 cycles,
cold worked copper clears 10^8 cycles,
at room temperature.

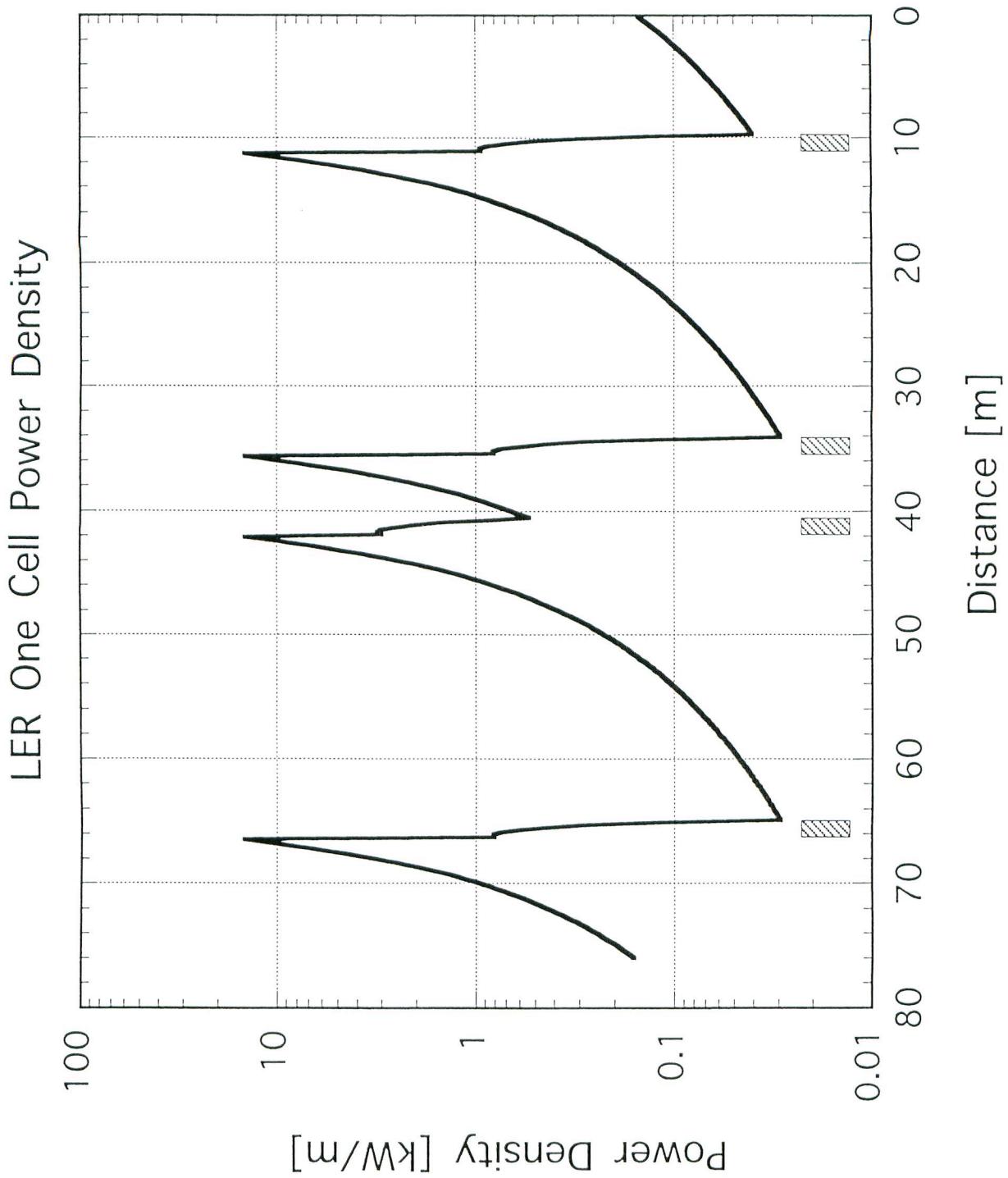
(Hitachi Works)

At 150°C , with 0.5% strain,

fully annealed copper cleared 10^4 cycles,
and will endure more cycles.

(Hitachi Cable)

- Our case is not serious but we had better avoid local annealing, i.e. we had better keep the local temperature lower than 140°C .



ANSYS 5.1

JUN 5 1995

21:10:55

ELEMENTS

TEMPERATURES

TMIN=38.612

TMAX=91.674

XV =1
YV =1
ZV =1
*DIST=31.709

*XF =-53.722

*YF =17.286

*ZF =18.807

PRECISE HIDDEN

EDGE

38.612

44.508

50.404

56.299

62.195

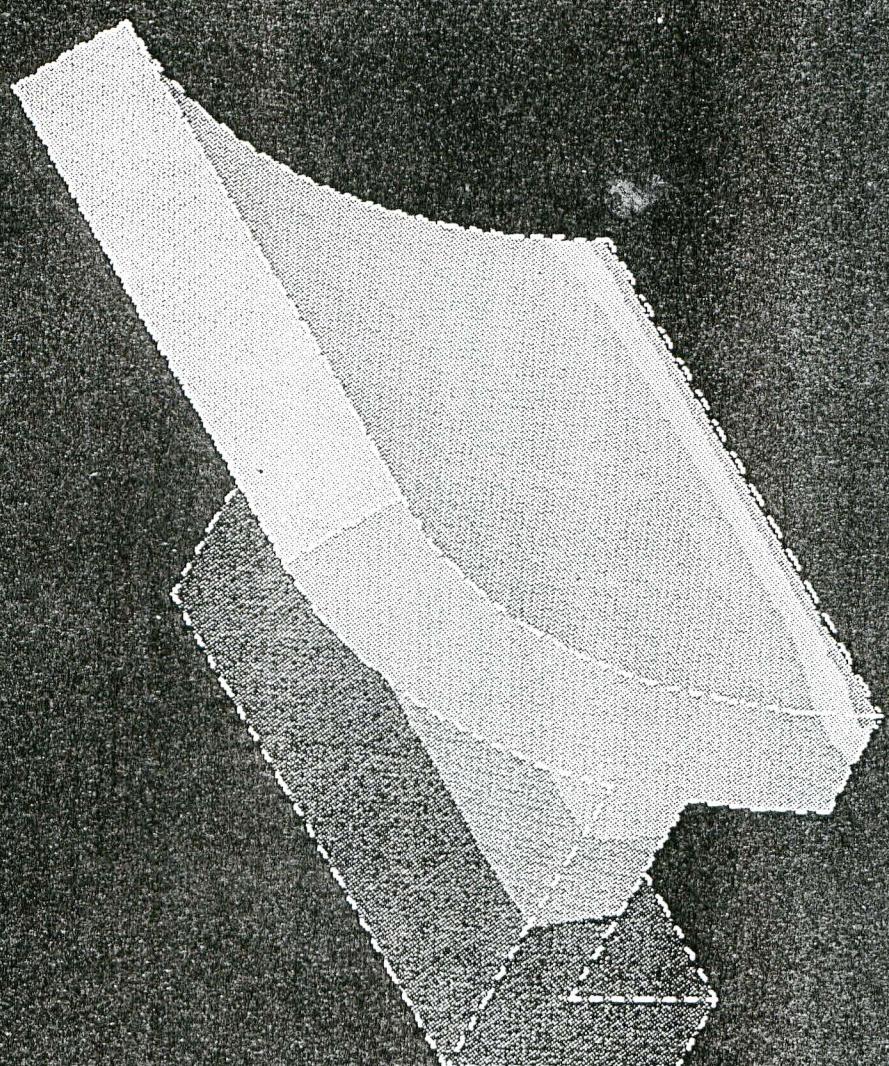
68.091

73.987

79.882

85.778

91.674



ANSYS 5.1
JUN 5 1995
21:09:21
NODAL SOLUTION

STEP=1

SUB -1

TIME=1

S3 (AVG)

SMX =0.029657

SMN =-8.46

SMB=-9.865

SMX =0.354267

SMXB=0.854466

-8.46

-7.481

-6.502

-5.522

-4.543

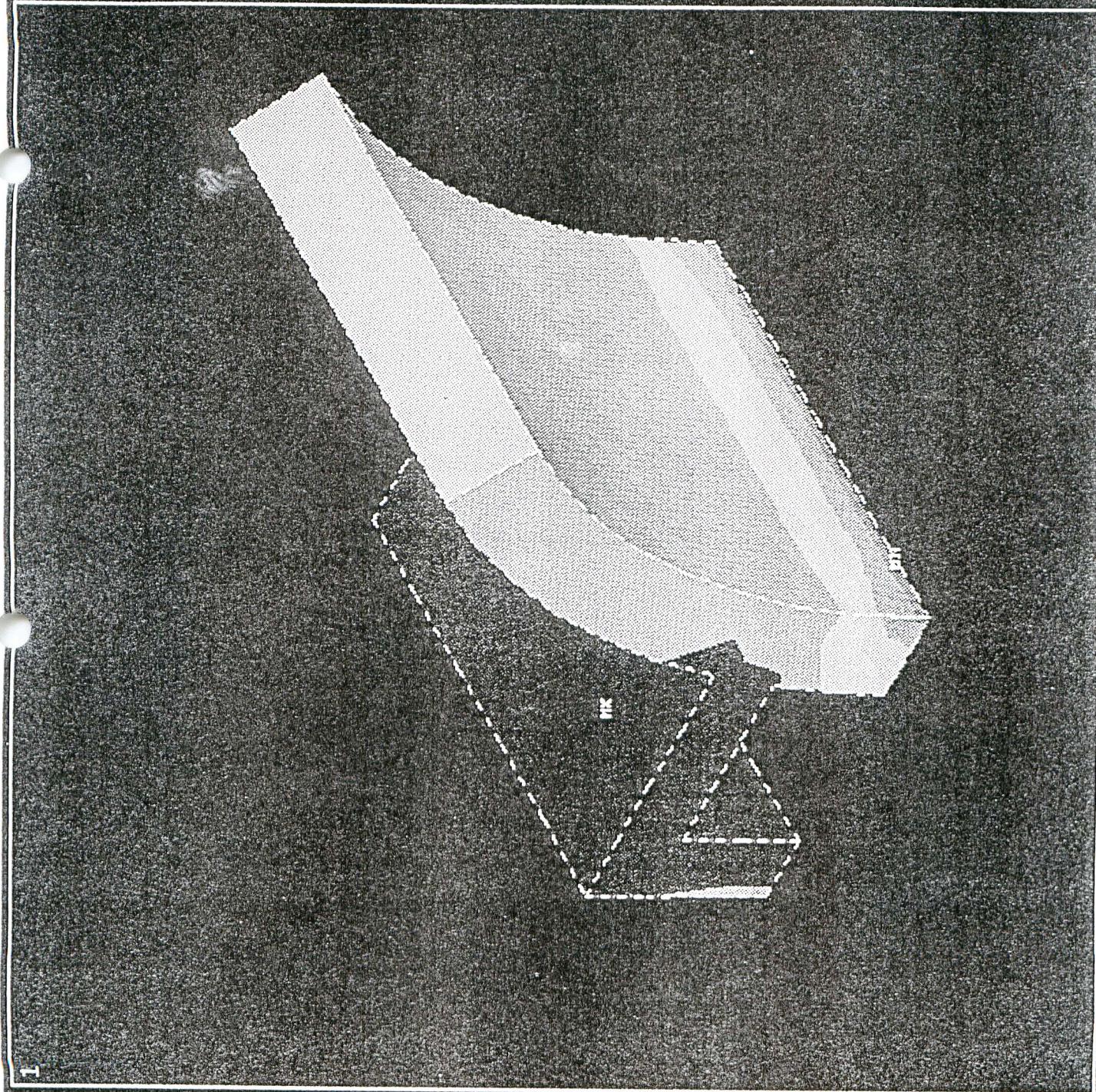
-3.563

-2.584

-1.605

-0.625146

0.354267



Pumping speed estimation

- Gas load comes from desorption due to synchrotron radiation.

The pressure (Torr) is given by

$$P = \frac{1}{K} \frac{\eta N}{S_d} = 0.1 \frac{\eta}{S_d}$$

where

K is the constant

(=3.3x10¹⁹ molecules Torr⁻¹ l⁻¹),

N is the linear photon density

(=3.3x10¹⁸ photons s⁻¹ m⁻¹ by averaging over the arc of LER),

S_d is the distributed pumping speed

(l s⁻¹ m⁻¹),

η is the photon desorption constant

(molecules photon⁻¹).

The aimed pressure with beam is 10⁻⁹ Torr.

For $\eta=10^{-5}$, $S_d=1000$ unrealistic.

For $\eta=10^{-6}$, $S_d=100$ l s⁻¹ m⁻¹.. design target

- For Cu duct η will be 10^{-6} after 1000Ah (LER)

Restriction on the vacuum design from the view of Impedance

- step <0.5mm
- Pumping slot must be a slot seen from beam but must be backed up with a grid to reduce the penetration of beam induced field which causes heating up of pump elements.
- mask(about 2000 in the arc) height < 5mm
- Bellows, Flange gap must be bridged with RF contact.

Pumping scheme

- Pumping using pumping ports (LER only).

In case for a wrong design of grid dimension, leave the possibility of adding a second grid.

Principle of pump layout

- Roughing port

100 l/s (NET), every 40m

Roughing system is portable and removed during beam operation

- Ion pump

100 l/s (NET), every 10m

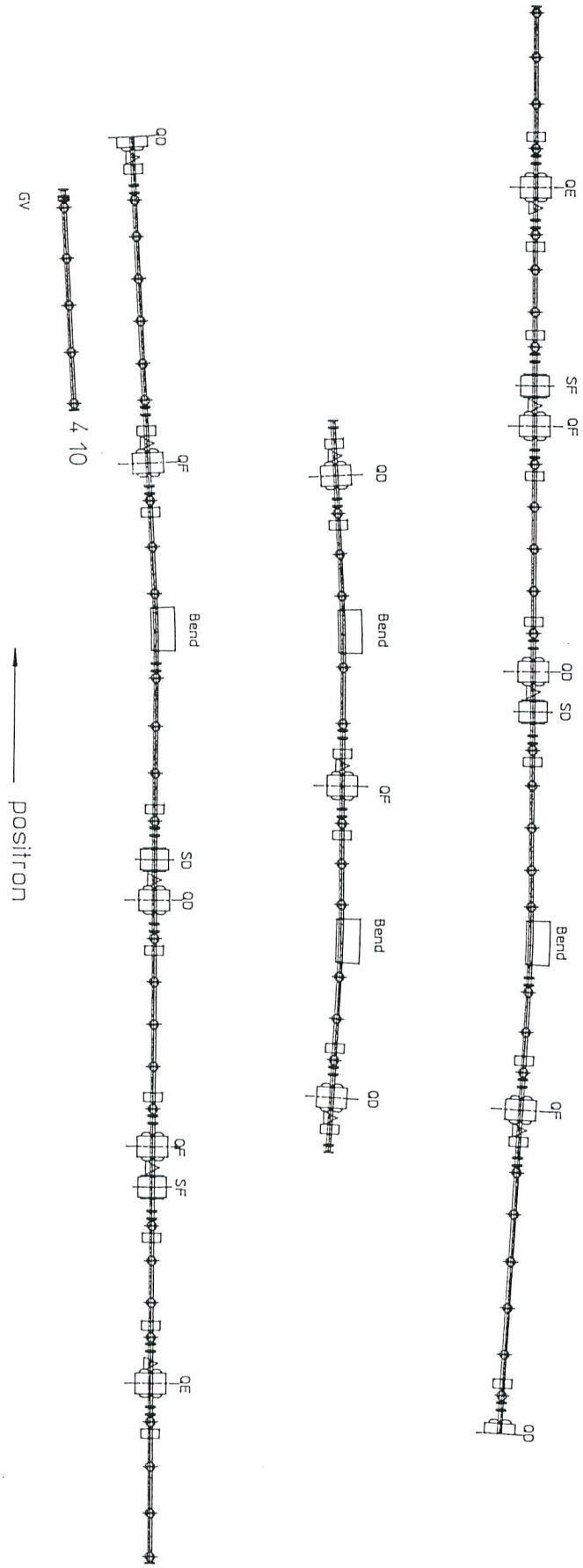
- NEG cartridge

100 l/s (NET), every 1m

This gives $S_d = 100 \text{ l s}^{-1} \text{ m}^{-1}$.

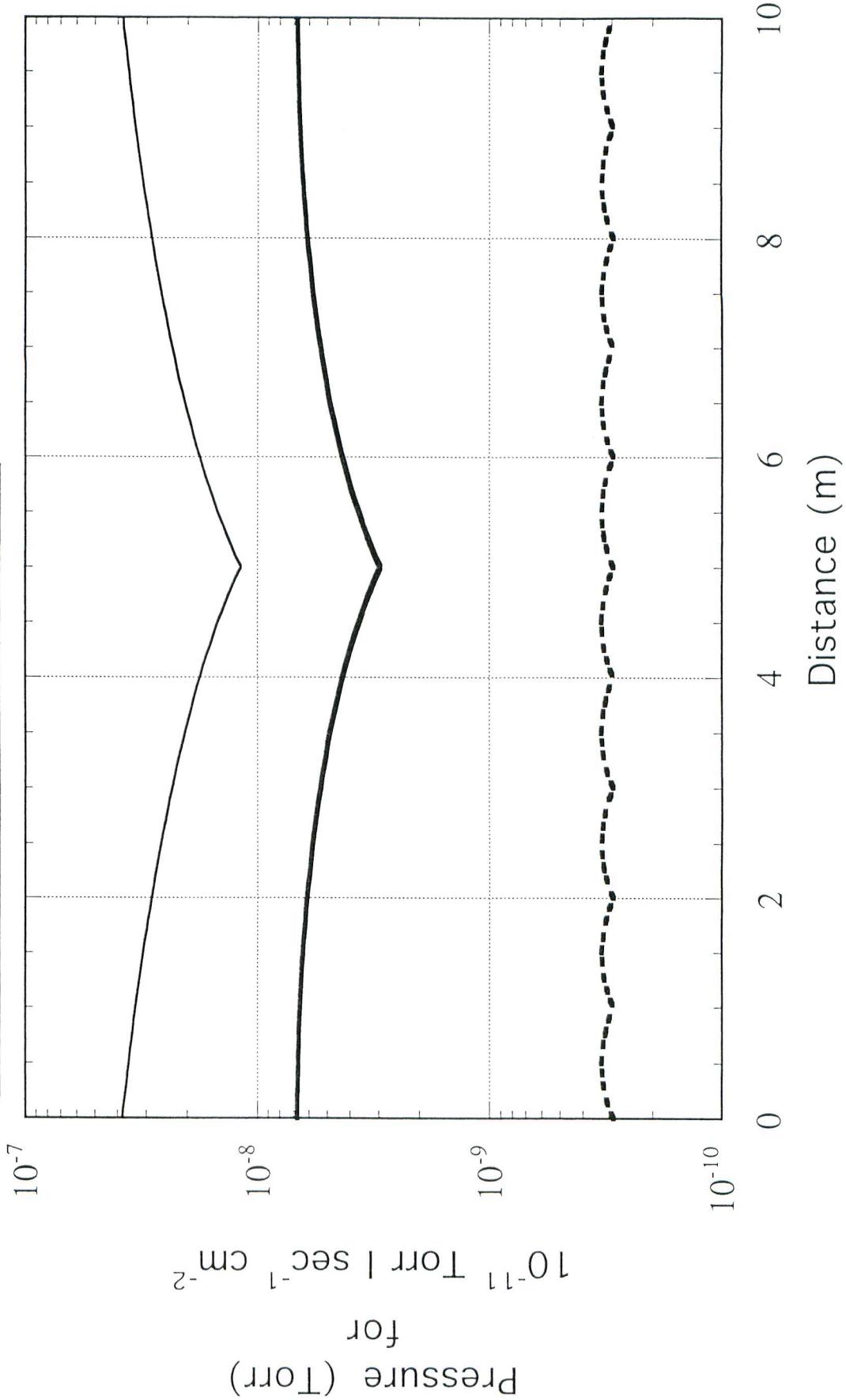
Actually, with an irregularity of pump separation, $S_d = 75 \text{ l s}^{-1} \text{ m}^{-1}$.

10m

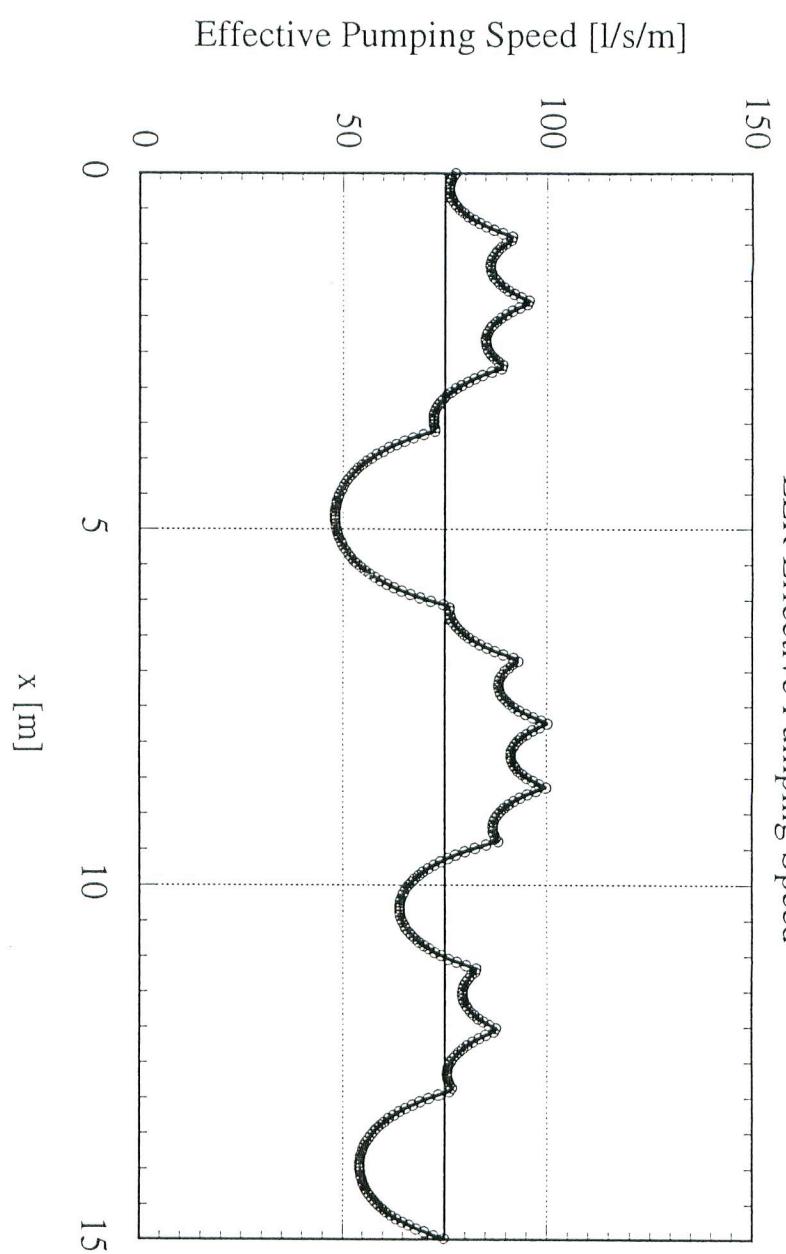


Standard cell of LER

— Roughing (100 l/s, every 40m)
— Ion pump (100 l/s, every 10m)
- - - NEG (100 l/s, every 1m)



LER Effective Pumping Speed



Surface treatment

<purpose>

Reduce the desorption and avoid frequent conditioning of NEG during commissioning.

<process:>

Remove a dirty surface layer after drawing (about mm) and create a new (clean) oxide layer.

(1) Acid etch

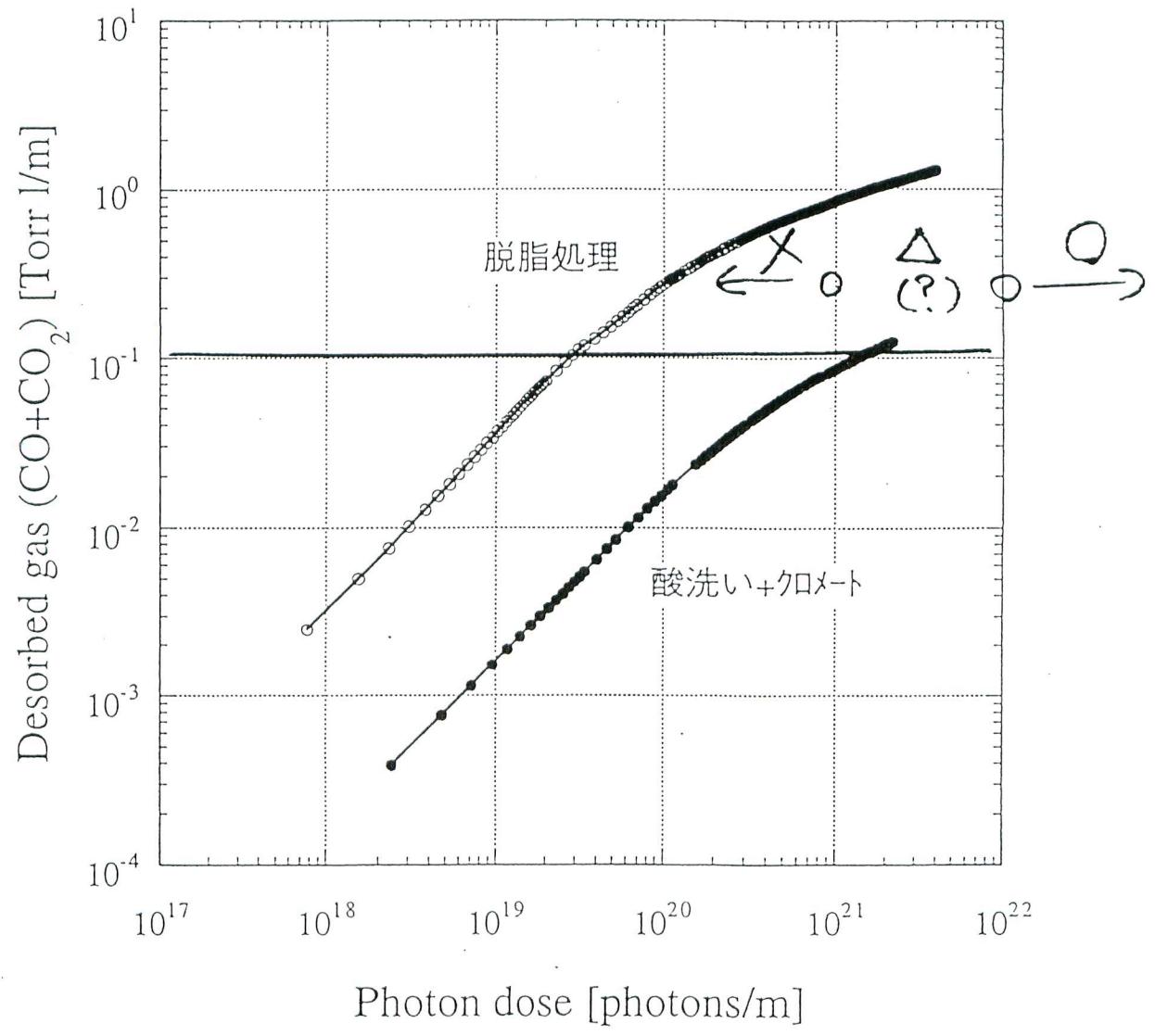
- 1.Alkaline soak
- 2.Rinse with tap water
- 3.Acid etch

$H_2SO_4:HNO_3:water=1:1:7\sim10$ (Vol)
with bit of HCl

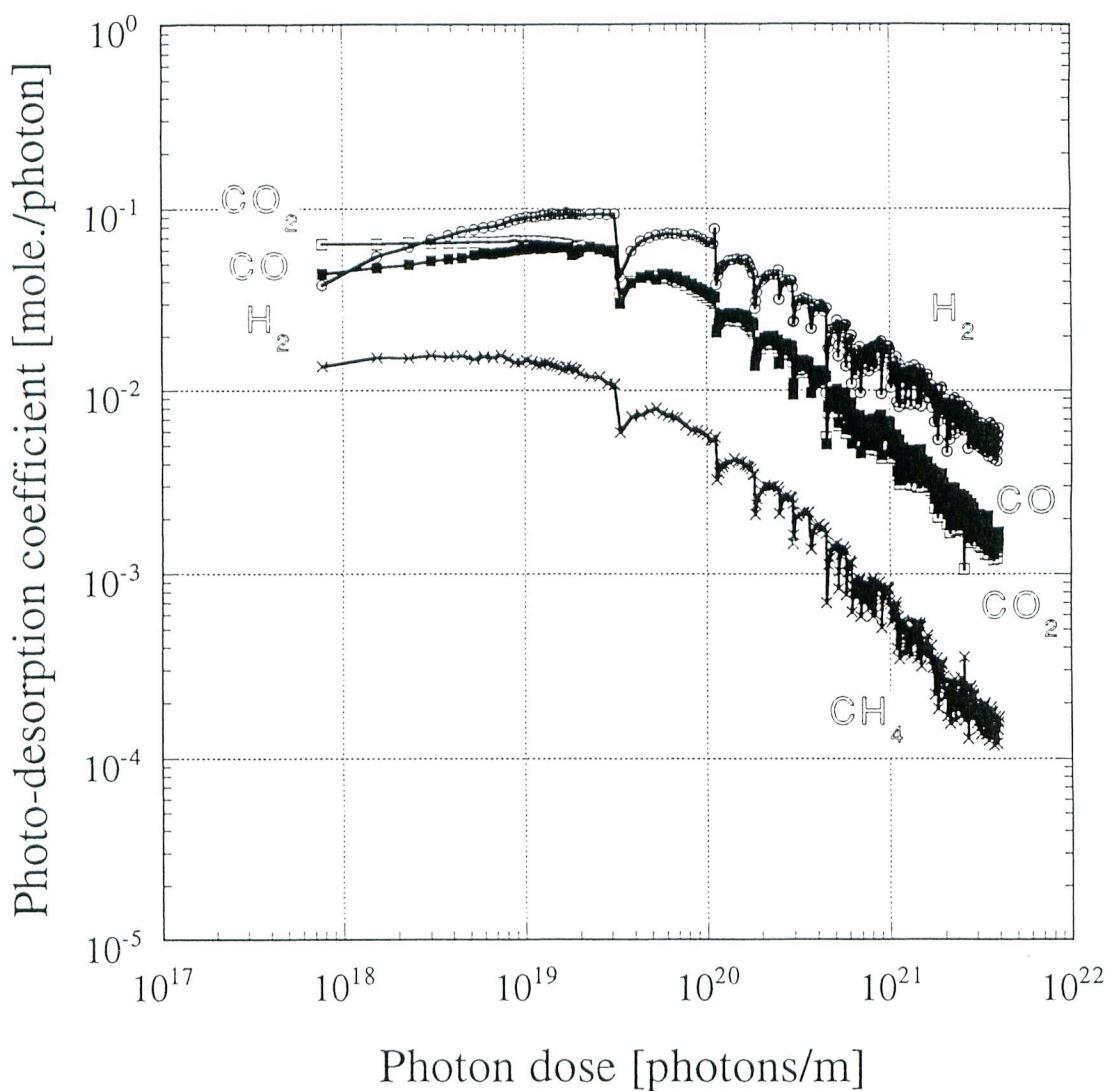
- 4.Rinse with tap water
- 5.Rinse with demineralized water
- 6.Dry with boil off N₂
- 7.Keep in dry N₂ atmosphere

(2) Chemical polishing

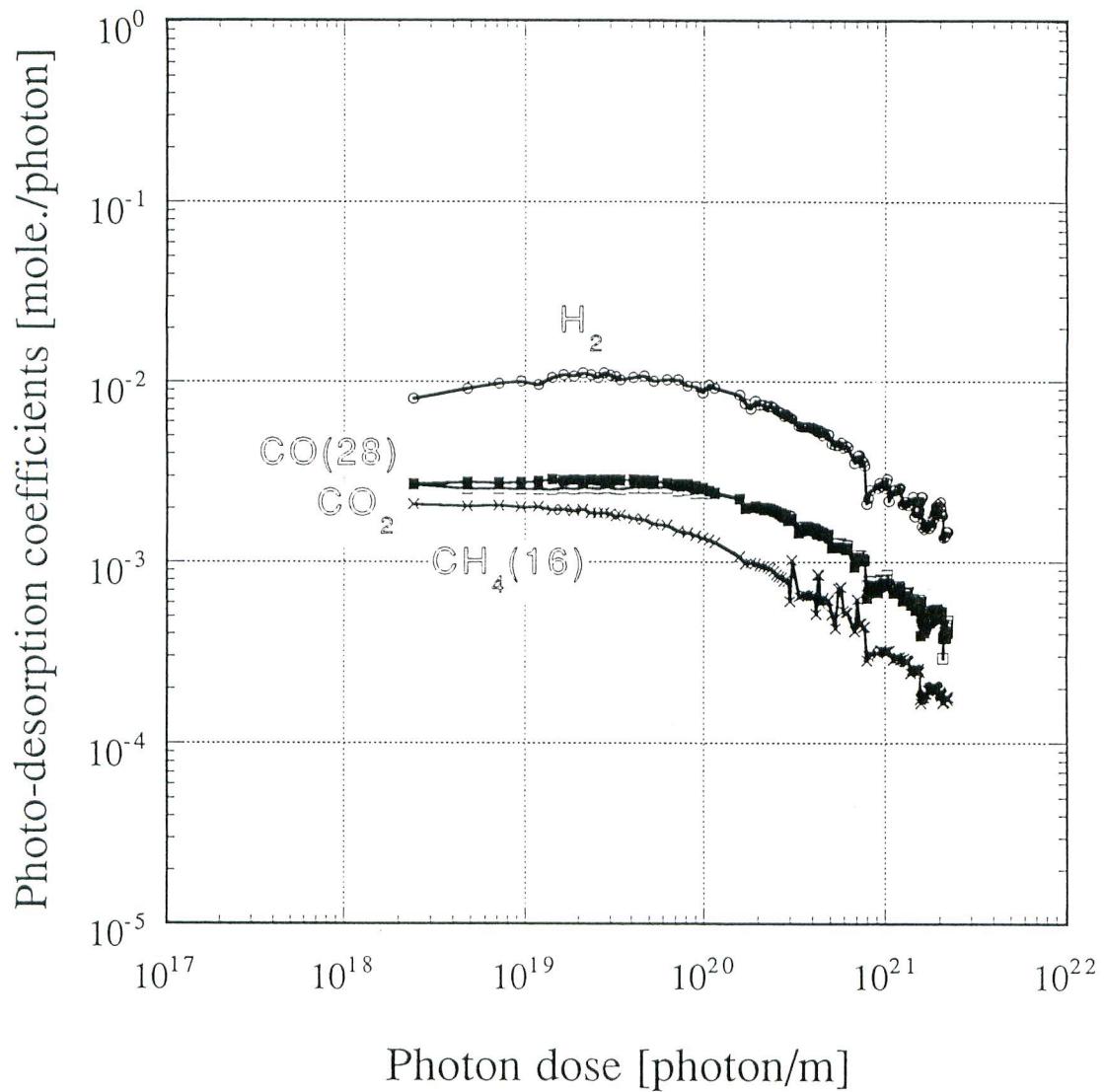
- 1.Alkaline soak
- 2.Rinse with tap water
- 3.Chemical polishing (contains H₂O₂ and H₂SO₄)
- 4.Rinse with tap water
- 5.Conditioning with H₂SO₄
- 6.Rinse with tap water
- 7.Cleaning with demineralized water jet
- 8.Dry with boil off N₂
- 9.Keep in dry N₂ atmosphere



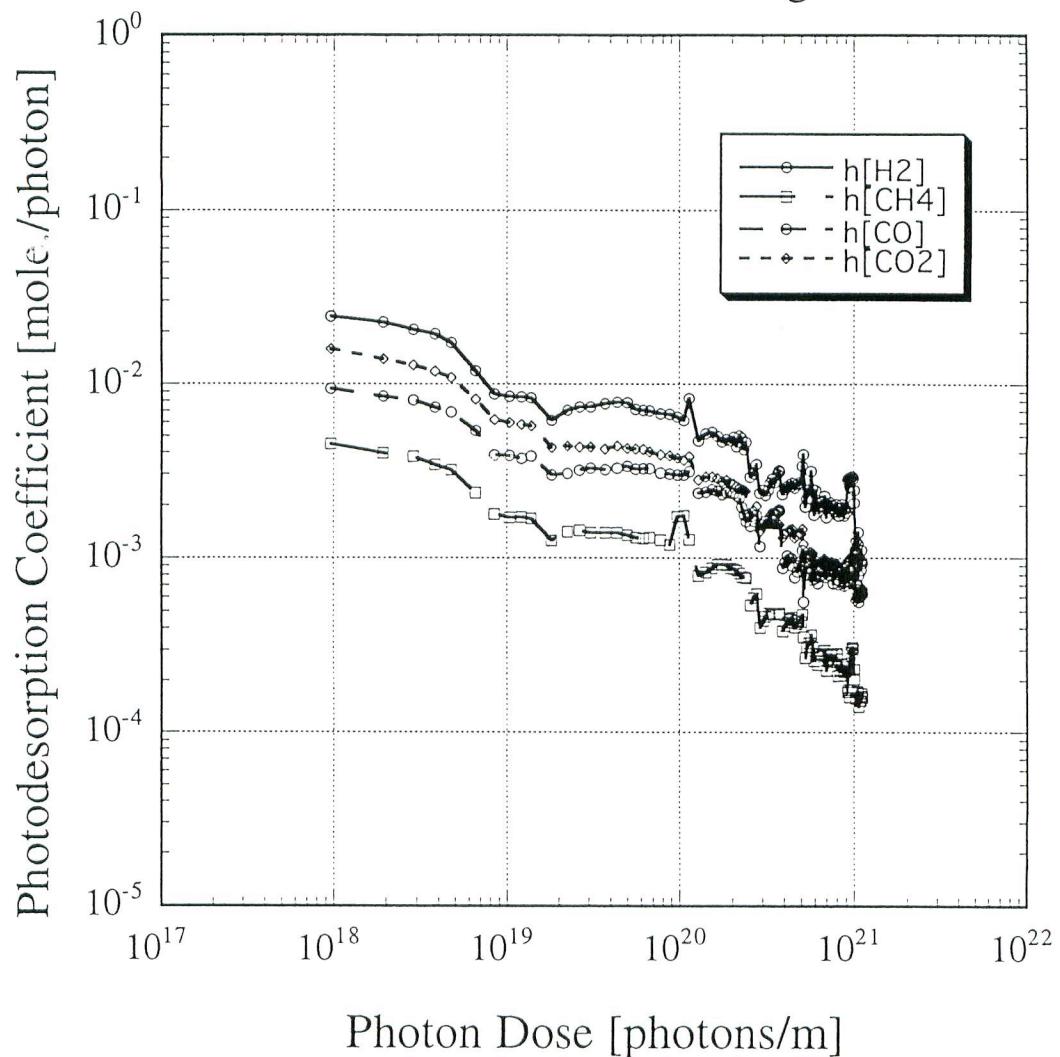
Extruded OFC untreated



Acid etch + passivation by Chromic acid



Chemical Poloshing



Chambers

- **B chamber**

- For bending magnet.

- Don't anneal the wall where the heat load is maximum.

- Has pumping ports.

- **Q chamber**

- With BPM block

- Fixed to Q magnet

- Symmetrical cross section.

- **S chamber**

- Straight

- Has pumping ports.

From fabrication to installation on magnets

- At factory

- 1. fabrication

- 2. leak test

- At KEK

- 3. Bake out with full set up

- 4. Dry N₂ purge and close with flange

- 5. Stored till installation

- 6. Installation

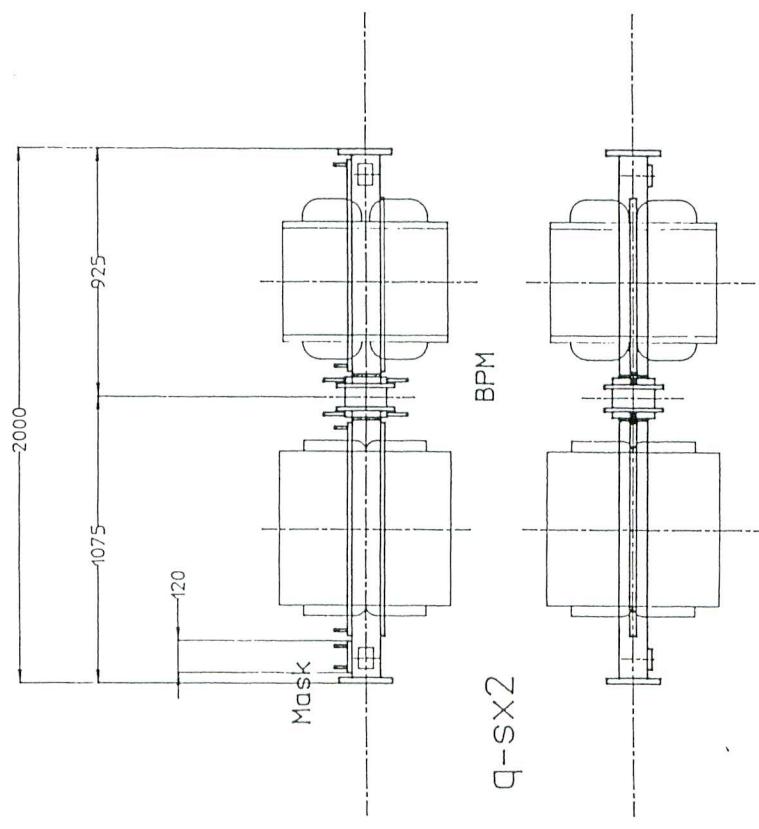
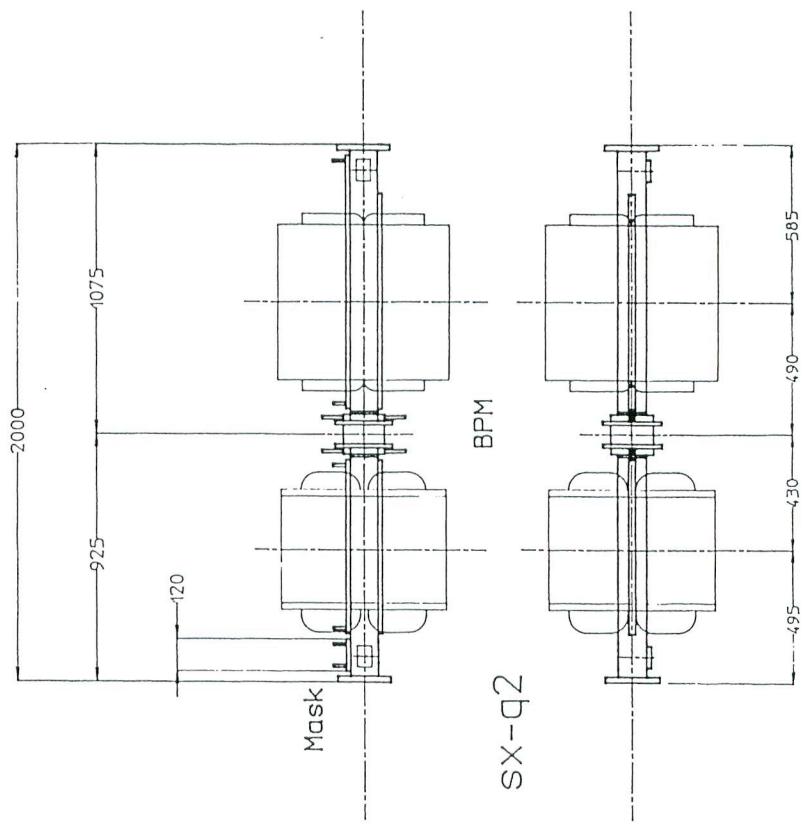
- 7. Connection of chambers with bellows

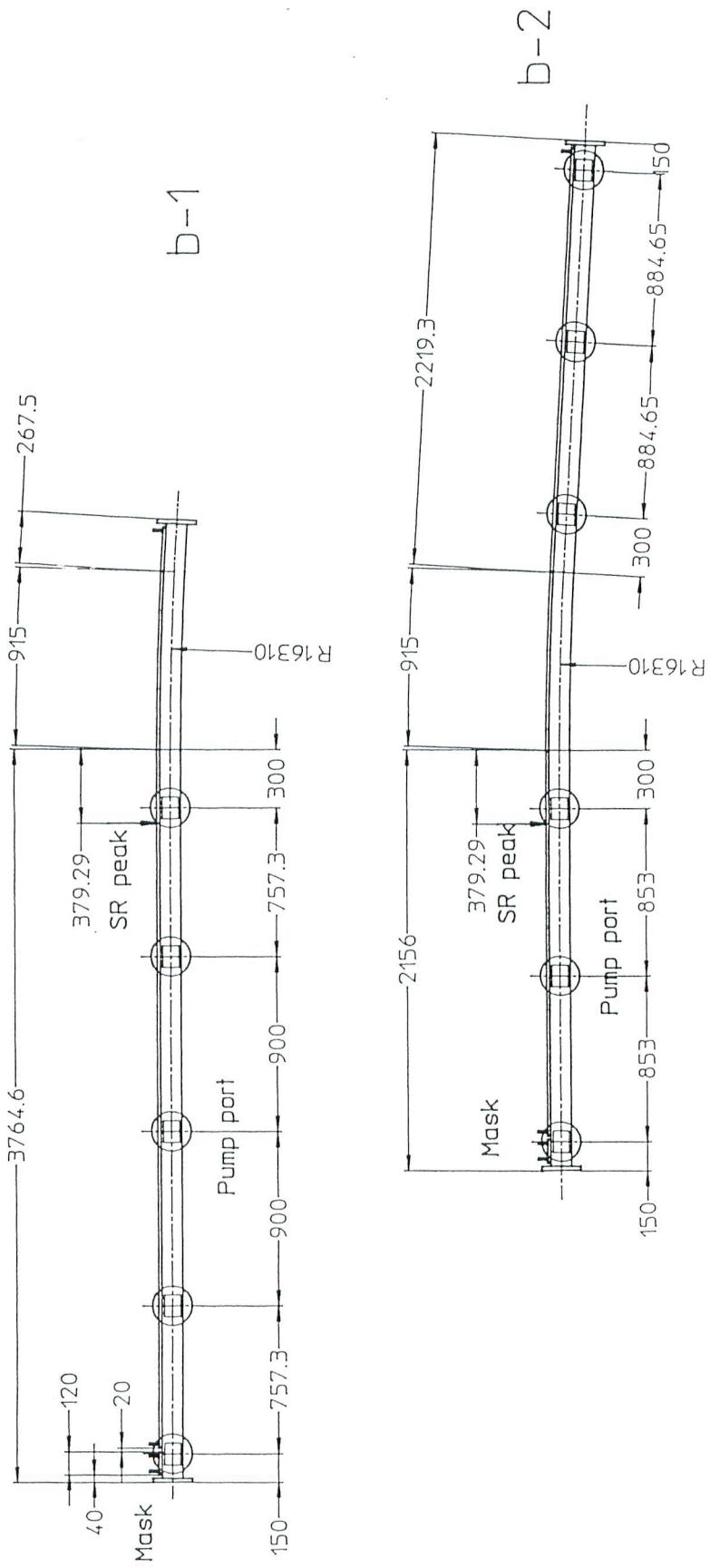
- 8. under 'dry tent'.

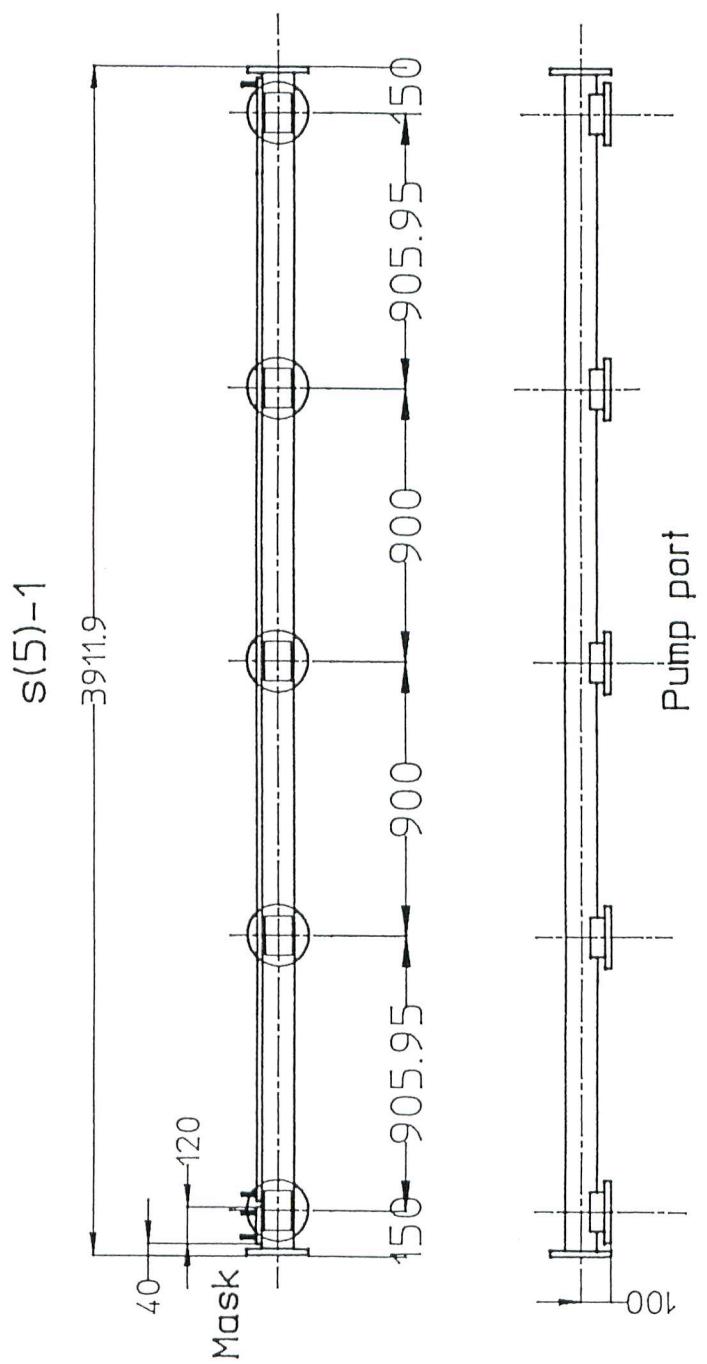
- 9. Pumping down without baking

LER Q/SX chambers

Ver.3







Components

- BPM block

About 100 blocks will deform due to the heat from synchrotron radiation. The deformation at the position of a pick up is 10 to 20 μm .

- Bellows

Finger contacts with pressing force less than 30g are abnormally heated in the RF test with 508 MHz continuous wave up to 80 kW (AC power by beam is about 10 kW)

- Slot

Grid size is 4x5mm.

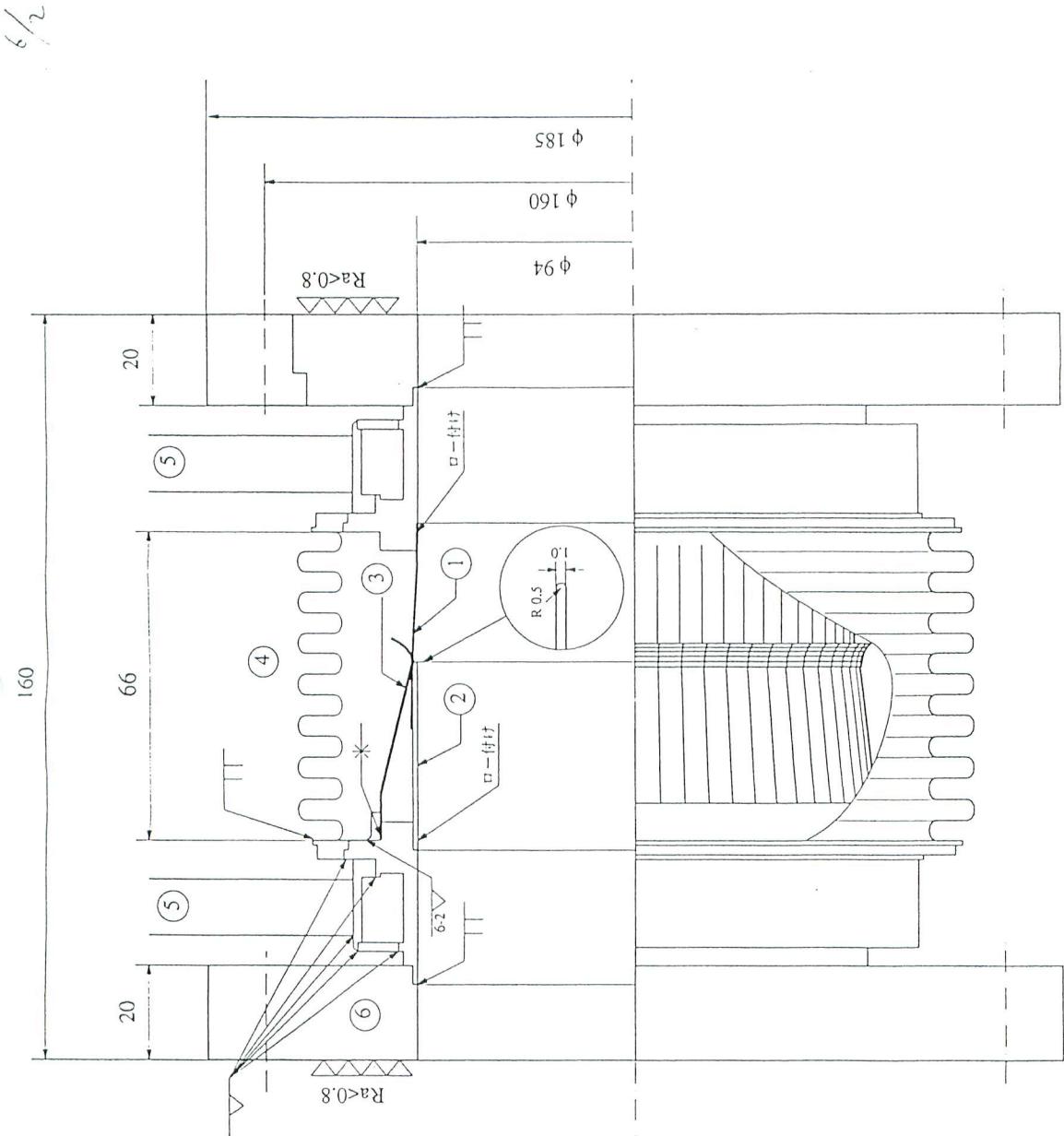
- NEG module, strip holder

KEK design (Hisamatsu)

- Flanges at the end of a beam duct

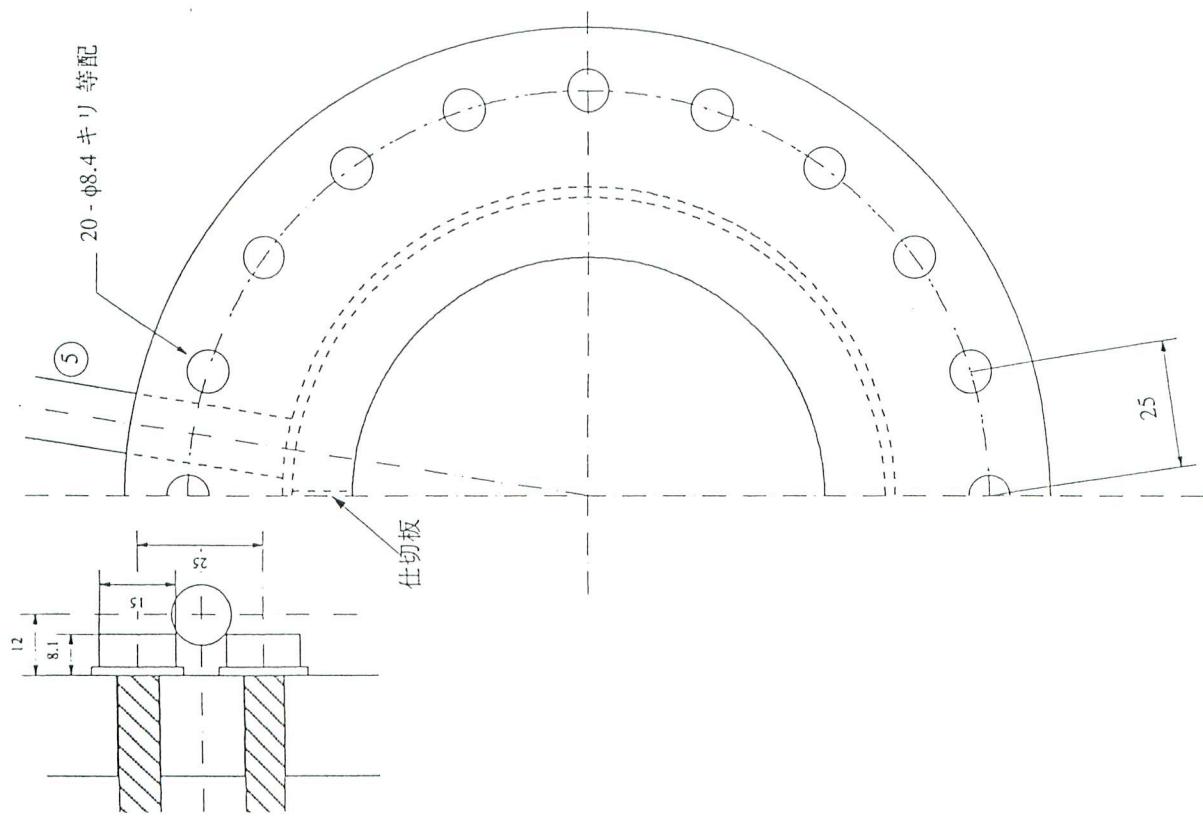
Al spacer for RF bridge. Helicoflex delta for vacuum seal.

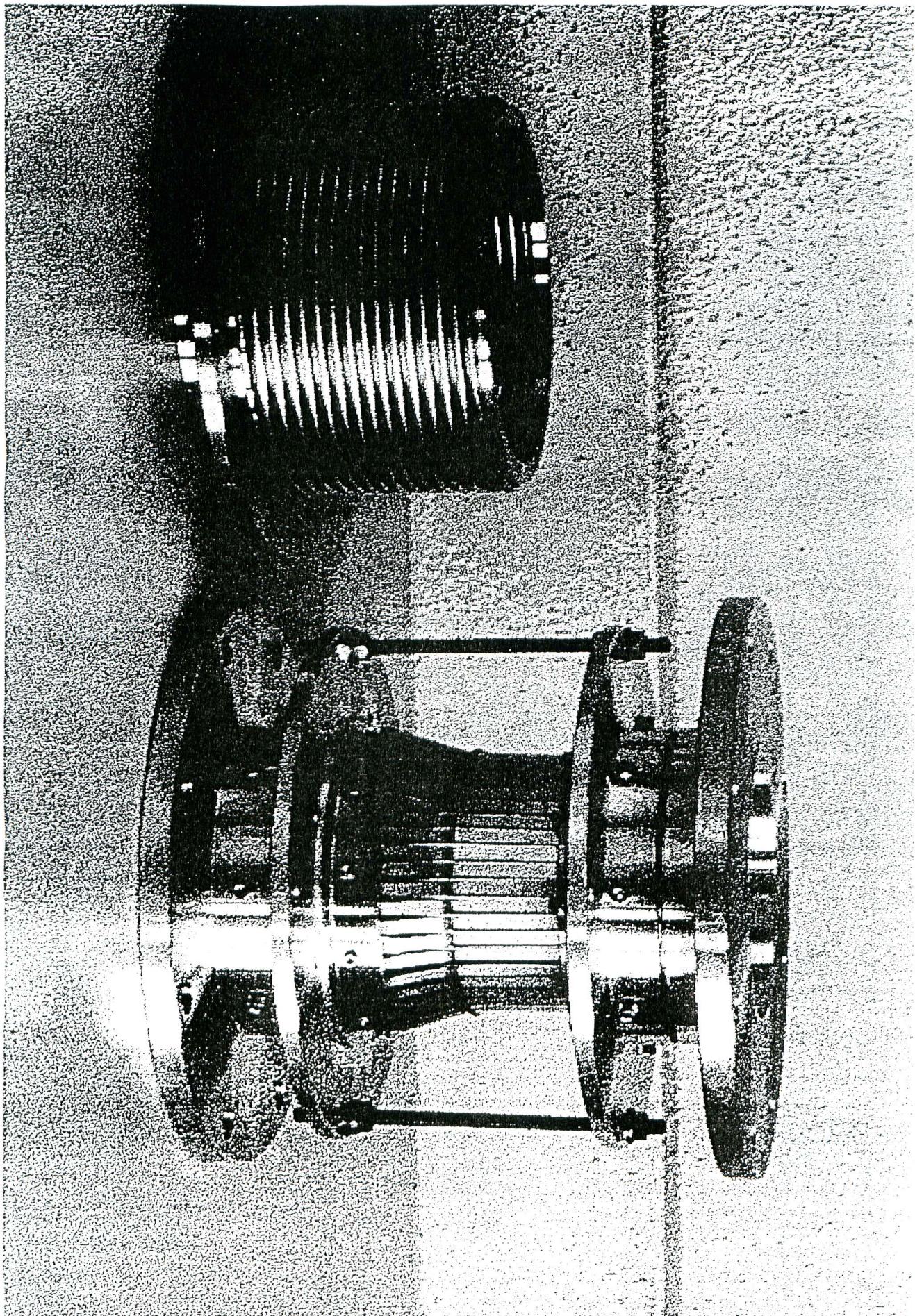
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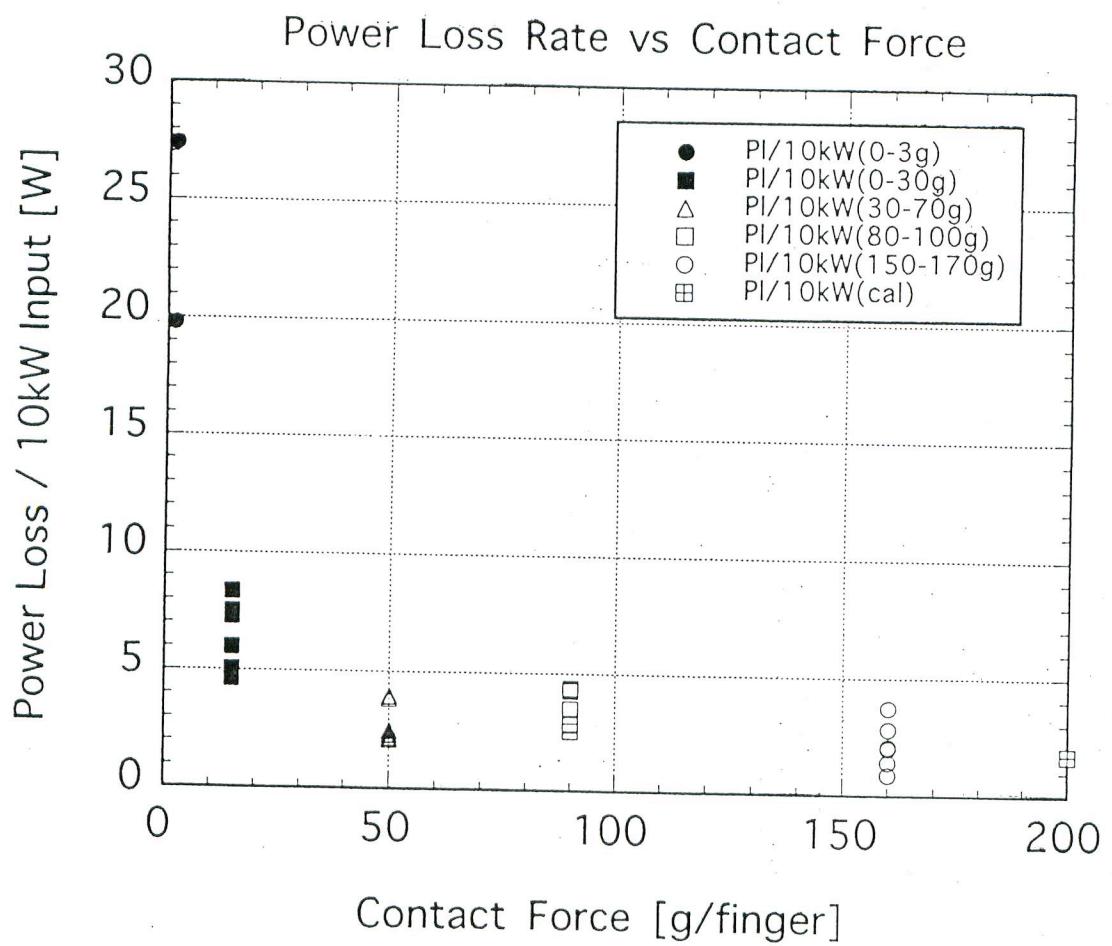


(1)	BeCu	0.2t フィンガーコンタクタ	(4)	SUS	成形ペローズ
(2)	SUS	1.0t 内筒	(5)	SUS	1/2インチ冷却管
(3)	Inconel	0.4t フィンガースプリング	(6)	SUS	フランジ

・参考

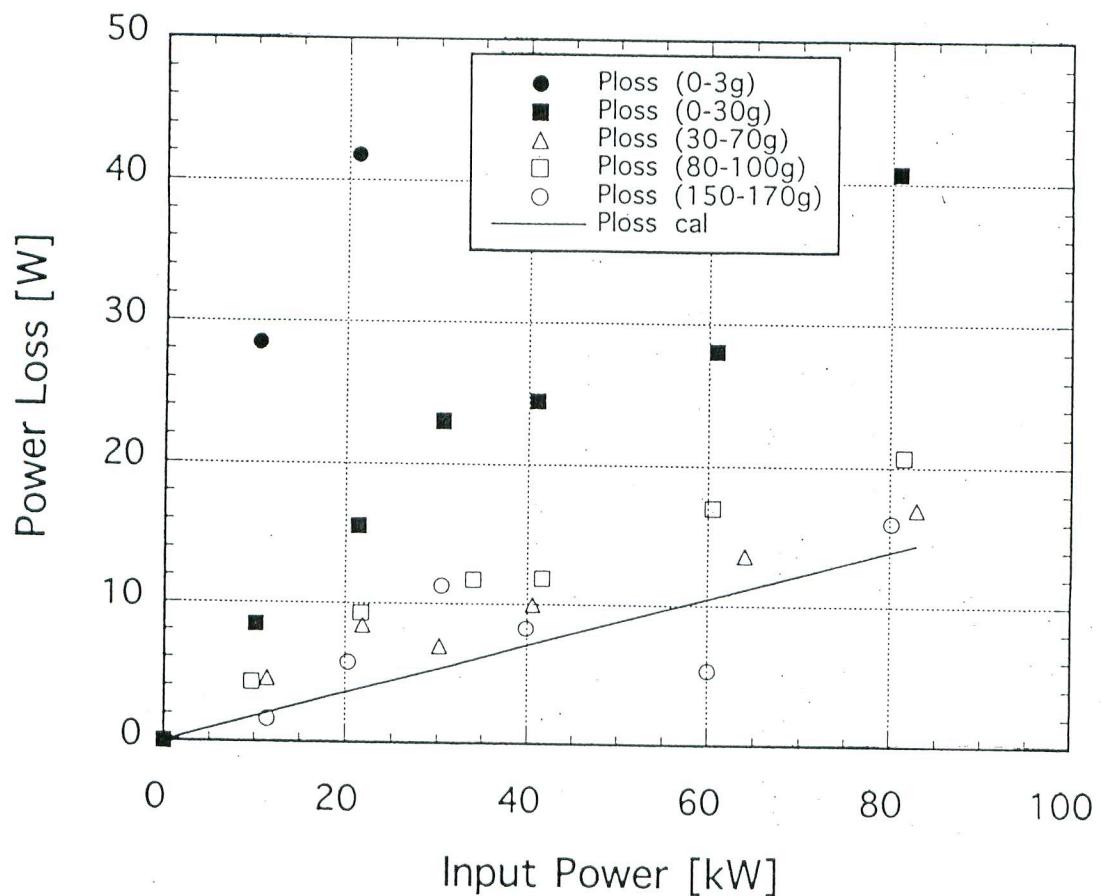




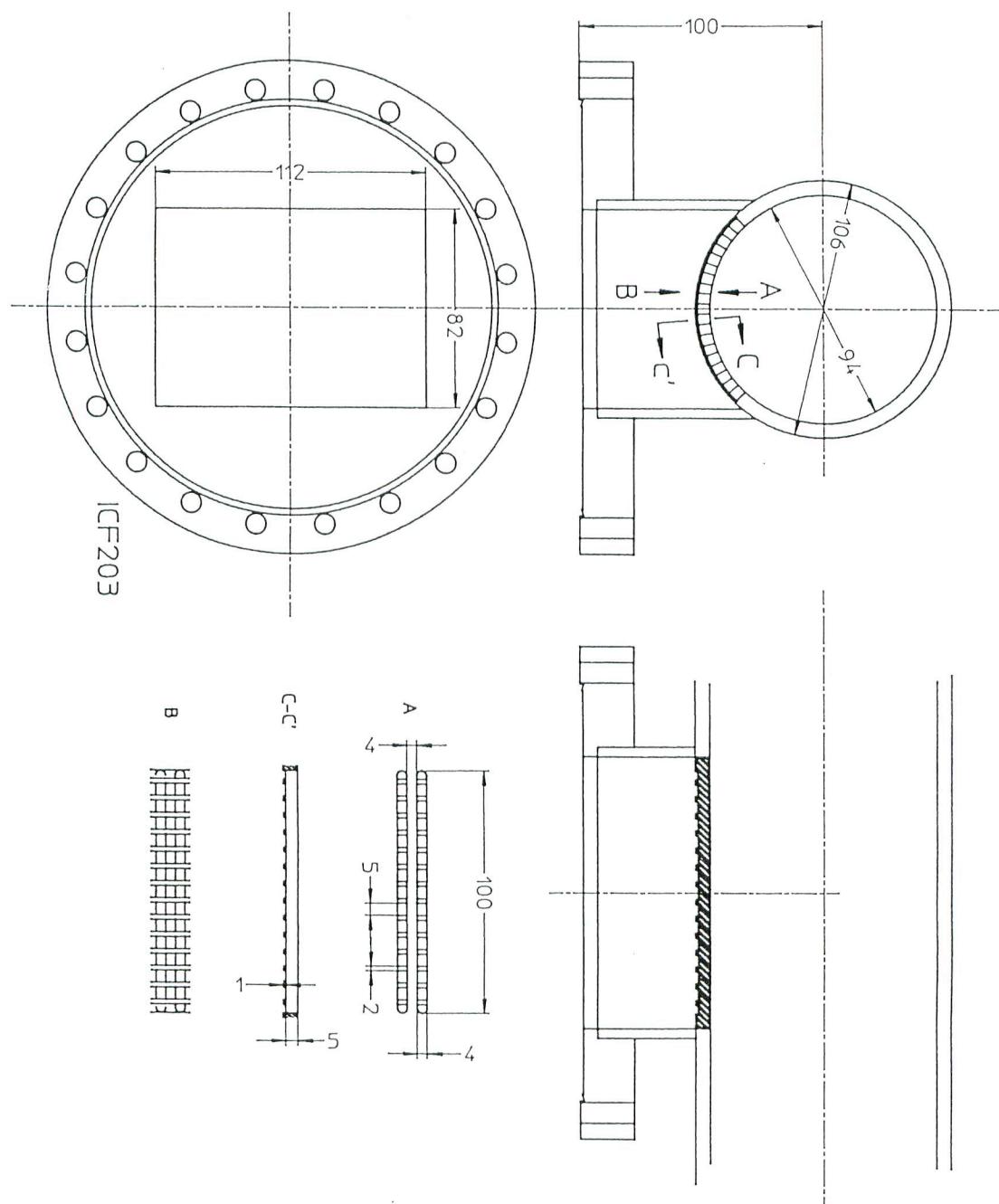


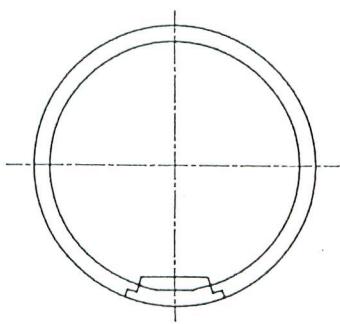
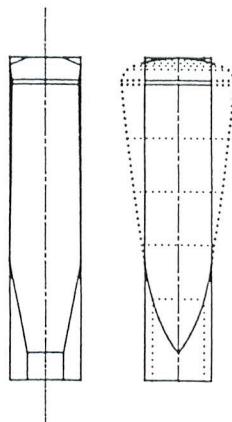
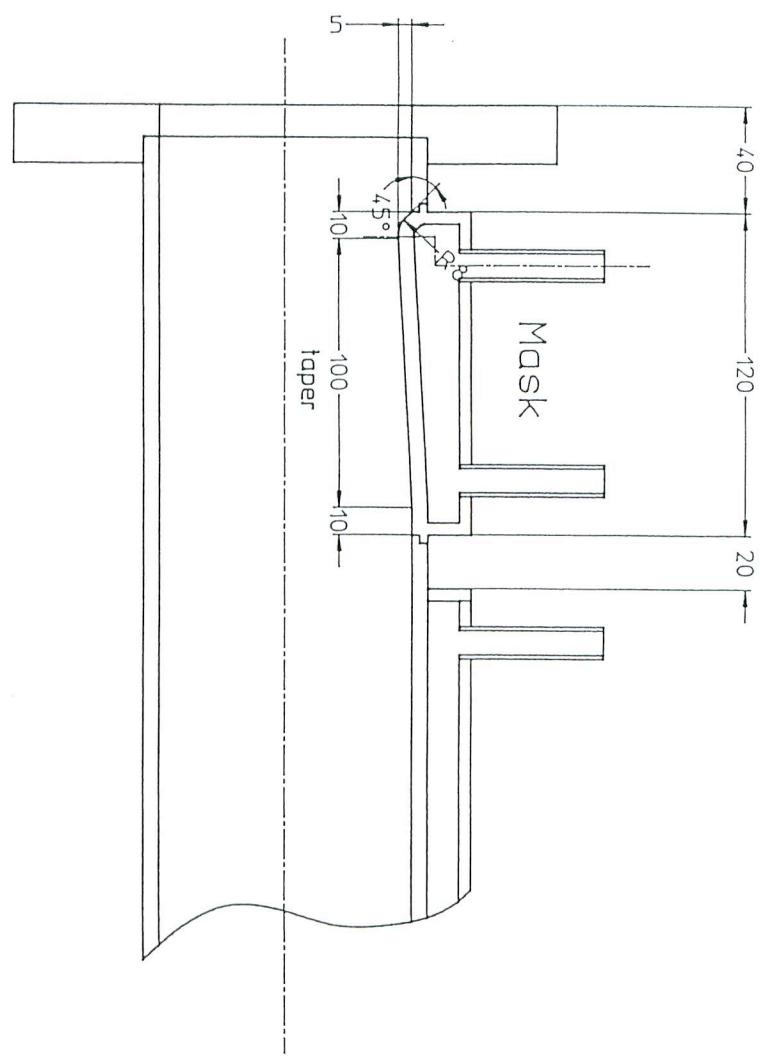
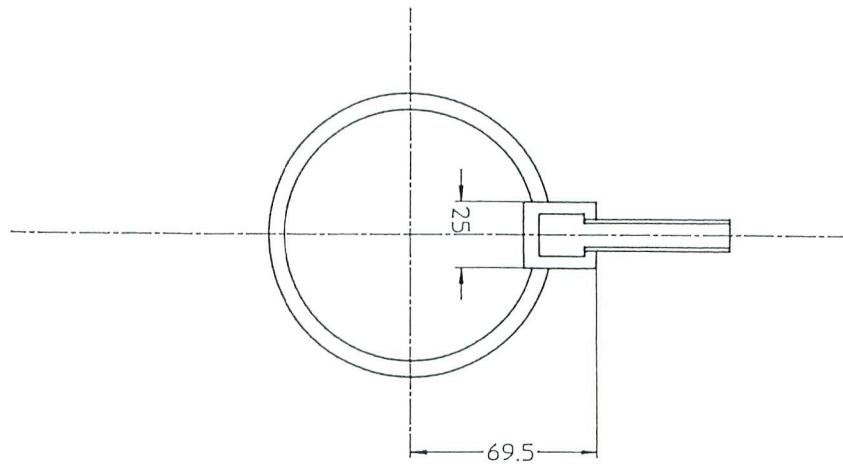
ploss rate.plot

Power loss vs Contact Force



ploss.plot





ANSYS 5.1
JUN 5 1995
21:30:49

ELEMENTS

TEMPERATURES

TMIN=34.853

TMAX=94.357

XV =-0.34202
YV =-0.883022
ZV =-0.321394

*DIST=77

*XF =69.024
*YT =-4.725

*ZF =0.900729
A-ZS=136.781

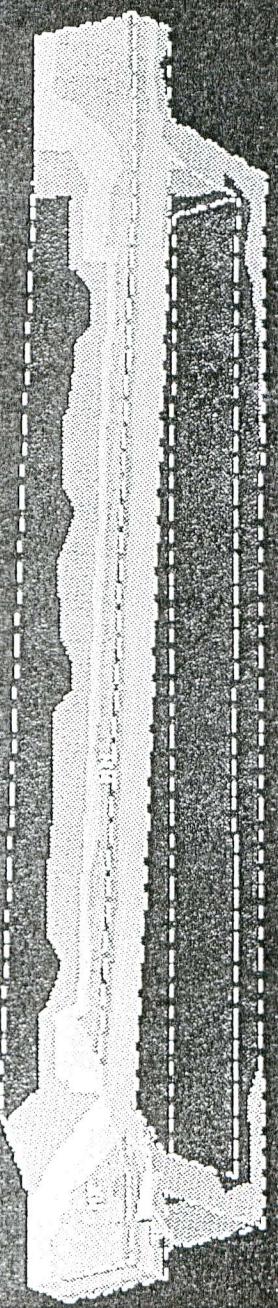
PRECISE HIDDEN
EDGE

34.853
41.464
48.076
54.687
61.299
67.91
74.522
81.134
87.745
94.357

ANSYS 5.1
JUN 5 1995
21:27:30
NODAL SOLUTION
STEP=1
SUB =1
TIME=1

S3 (AVG)

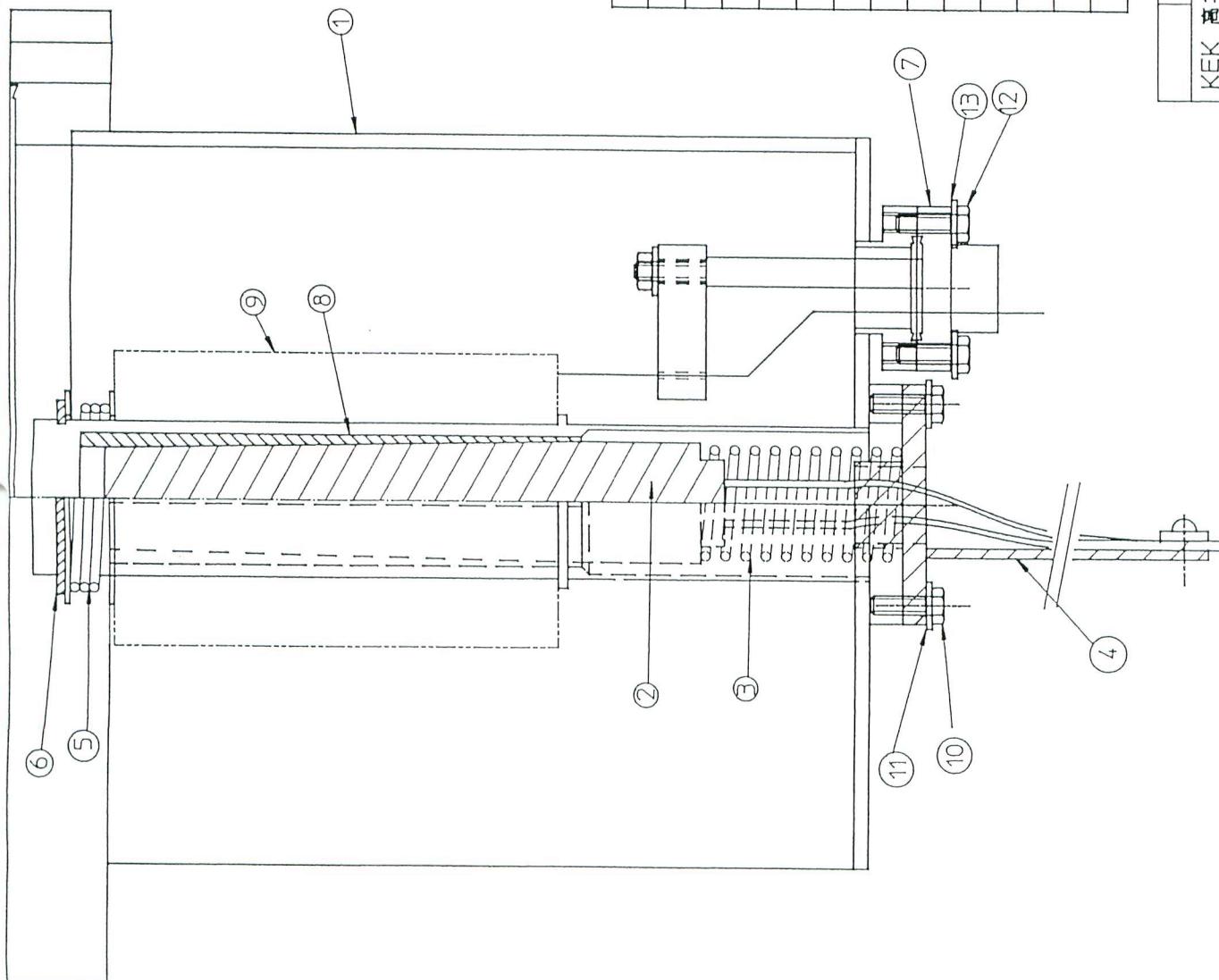
DMX	=0.087458
SMX	=-5.936
SMXB	=-6.854
SMZ	=0.59369
SMXB	=2.439
SMZ	=-5.936
DMX	=-5.211
SMX	=-4.485
SMXB	=-3.76
SMZ	=-3.034
SMXB	=-2.308
SMZ	=-1.583
DMX	=-0.857383
SMX	=-0.131846
SMXB	=0.59369
SMZ	=0



LER		<u>10 kN/m</u>
Cu	Al	
ρ	2.7×10^{-3}	g/mm^3
C	0.90	$\text{J/g/}^\circ\text{C}$
k	0.20	$\text{W/}^\circ\text{C/mm}$
E	7×10^3	kg/mm^2
ν	0.3	
λ	2.4×10^{-5}	$^\circ\text{C}$
水 ρ	30 $^\circ\text{C}$	
熱伝導率	0.01	$\text{W/}^\circ\text{C/mm}^2$
入熱	20	W/mm^2
入熱幅	0.5	mm

Max 溫度 99 135 $^\circ\text{C}$

Max ZHV -9.1 -12.4 kg/mm^2



番号	品名	回数	数量
13	M4 WASHER	SUS	6
12	M4 L15	SUS	6
11	M4 SPRINGWASHER	SUS	4
10	M4 L12	SUS	4
9	CNEG		
8	SLEEVE	CNEG-P8	1
7	Pt THERMO	CNEG-P7	1 or 0
6	STOP RING	32 SUS	1
5	SUPPORT RING	CNEG-PS	1
4	HEATER FLANGE	CNEG-P4	1
3	SPRING	CNEG-P3	1
2	HEATER	CNEG-P2	支給
1	CNEG CHAMBER	CNEG-P1	A or B

KEK 高エネルギー物理学研究所	回数	ヒータアンブリ
TEL 0298 (64)-1171	回数	CNEG-ASS

