6

Vacuum System for KEKB
(mainly LER arc design)

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and
TRISTAN Vacuum Group
KEK National Laboratory for High Energy Physics

June 7, 1995
KEKB Accelerator Review

Chamber style

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

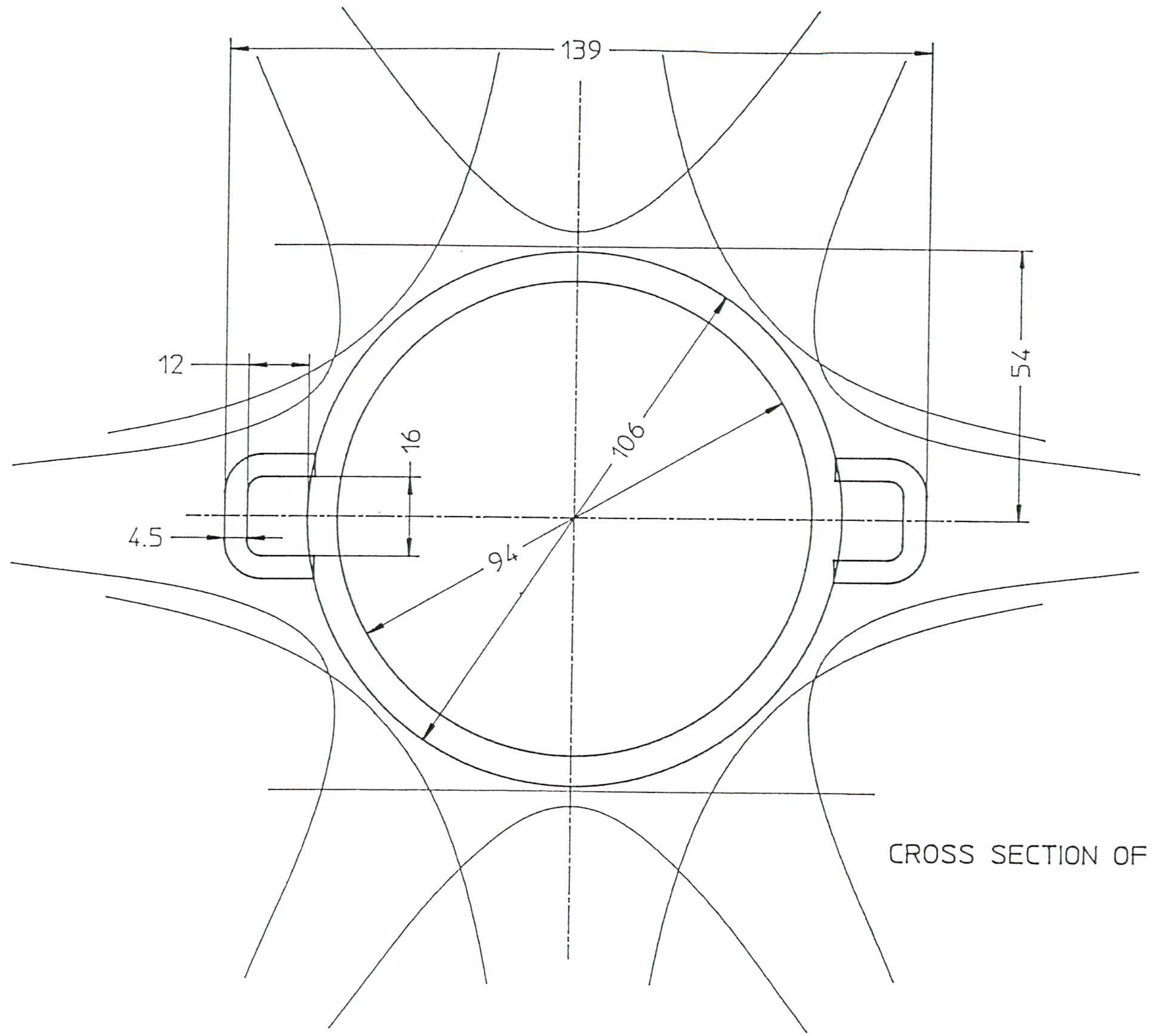
Material

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

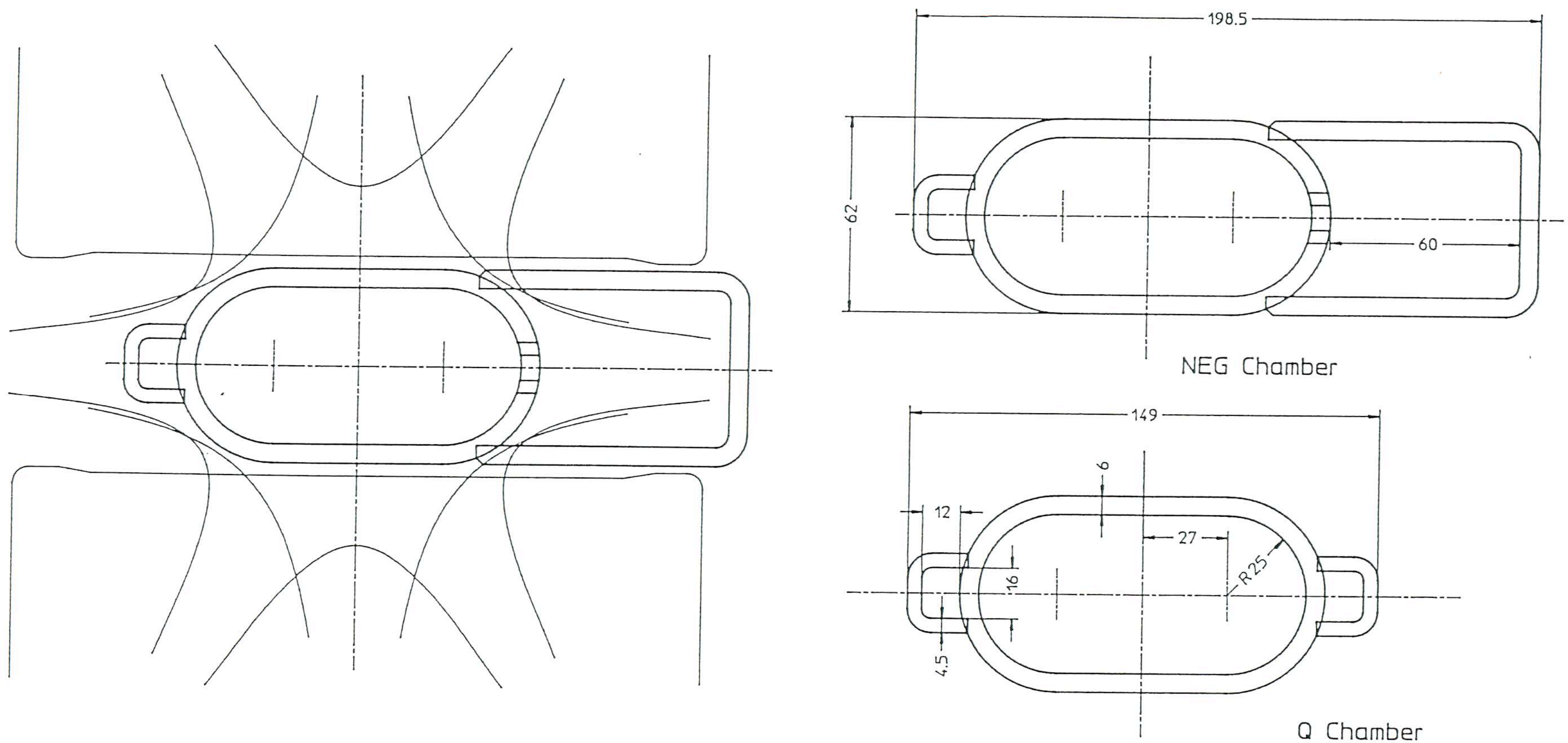
<reason>
High heat load (LER)
Radiation shield (HER, LER)

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

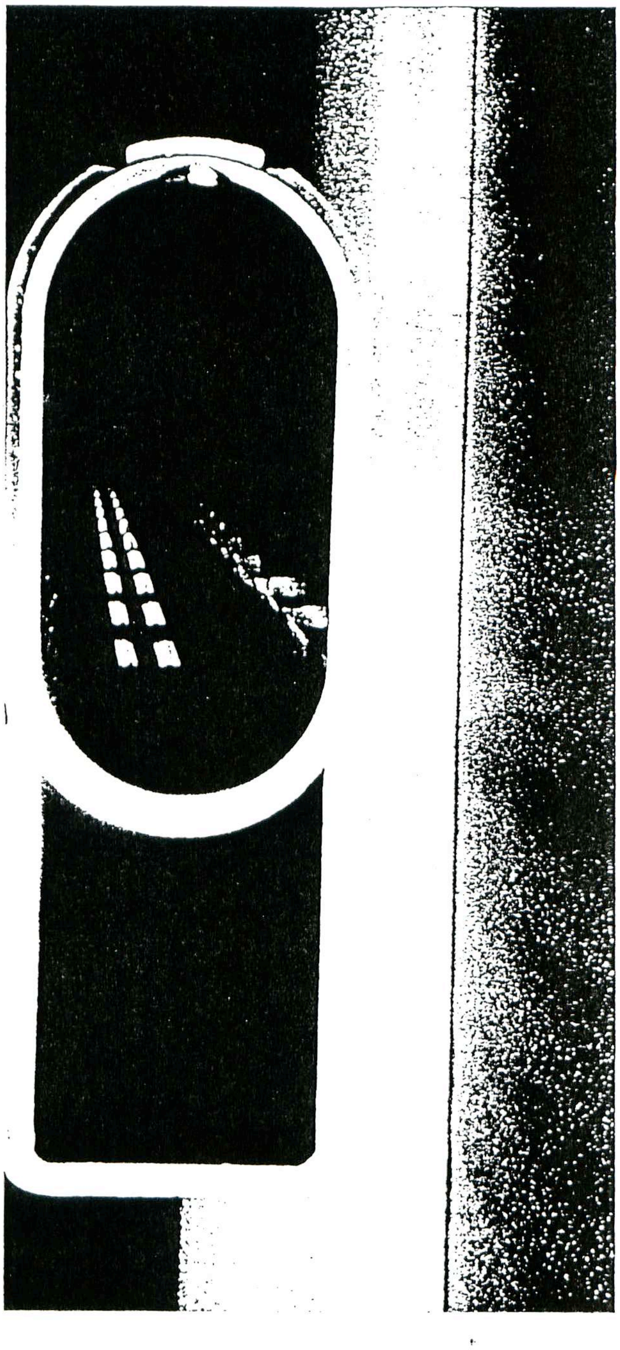
•Flange: AISI304 stainless steel
$\mu<1.2$

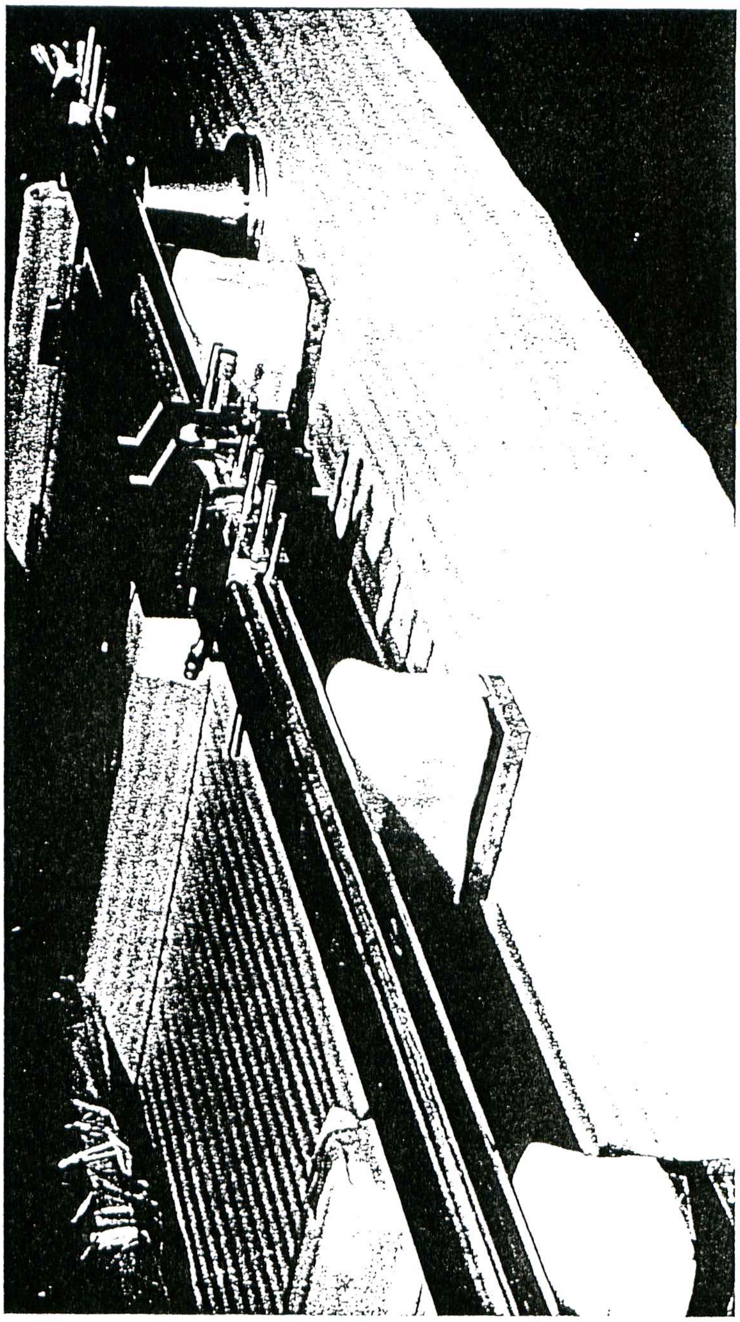


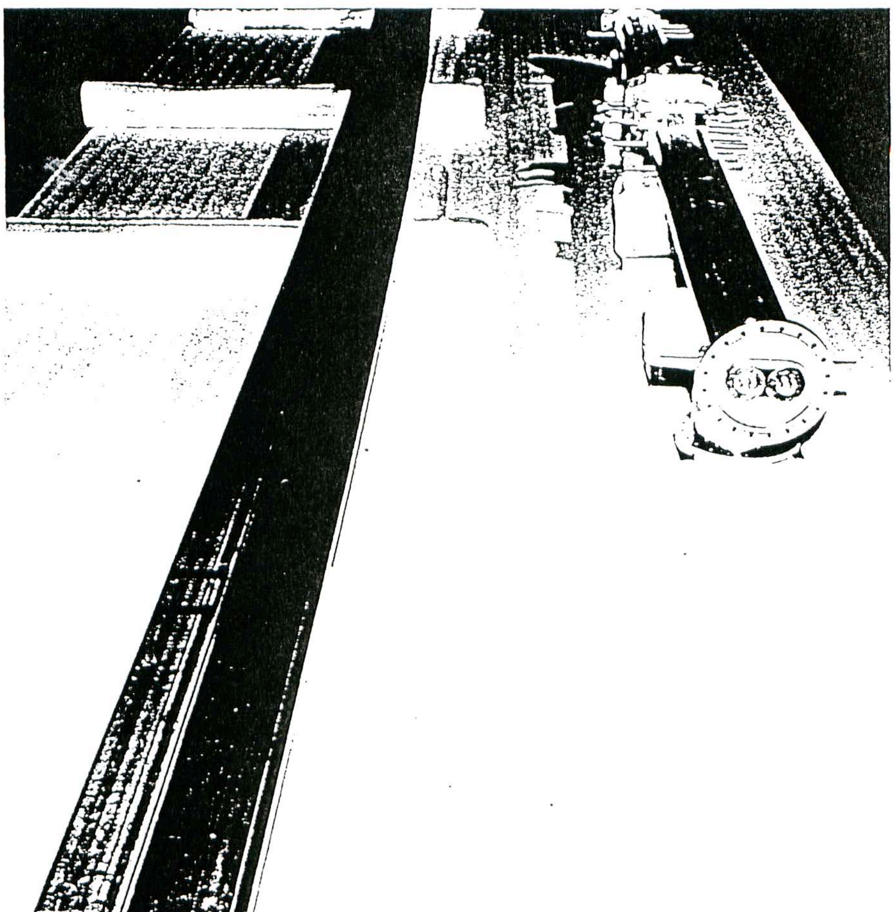
CROSS SECTION OF LER



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	線量率 (Gy/A/h)	
(cm)	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。これの rad/y への換算例を次に示す(LER 6 mmの場合)。

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

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 Advisary 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。

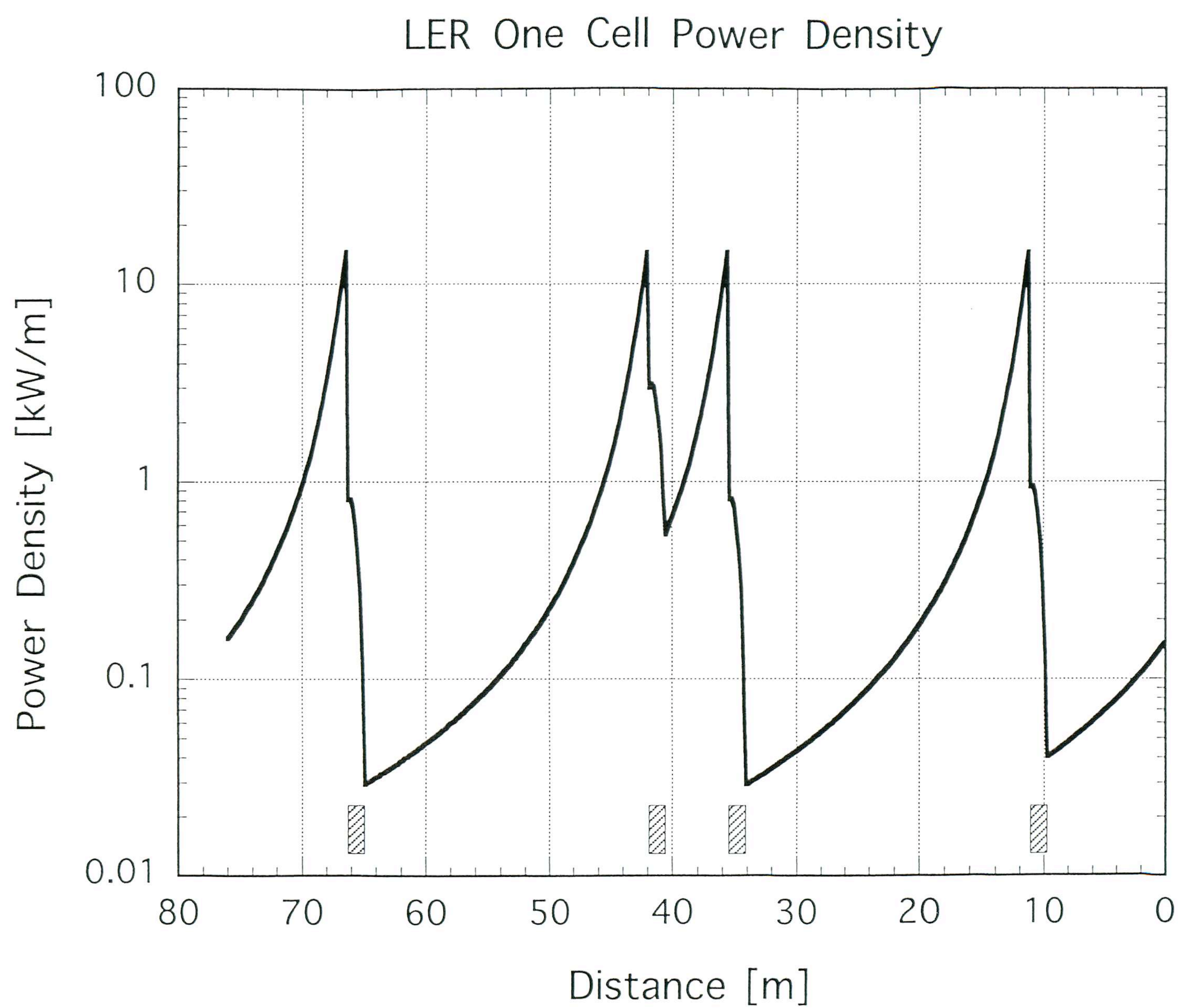
Heat load of LER

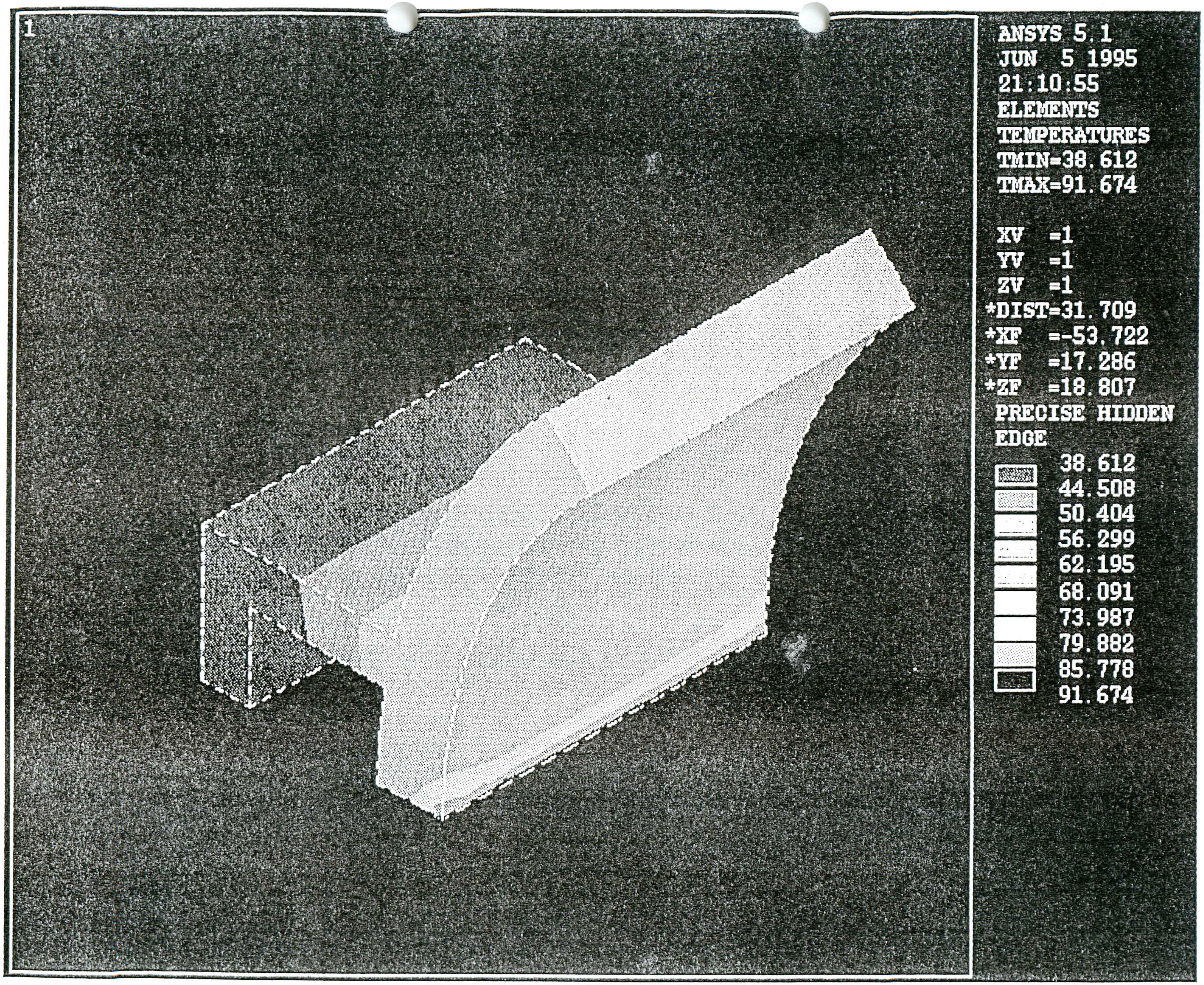
•Maximum linear power density due to synchrotron radiation is 14.8 kW/m.

This leads to, locally,
T=130°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.


LER One Cell Power Density
100
10
1
0.1
0.01
Power Density [kW/m]
80
70
60
50
40
30
20
10
0
Distance [m]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ANSYS 5.1
JUN 5 1995
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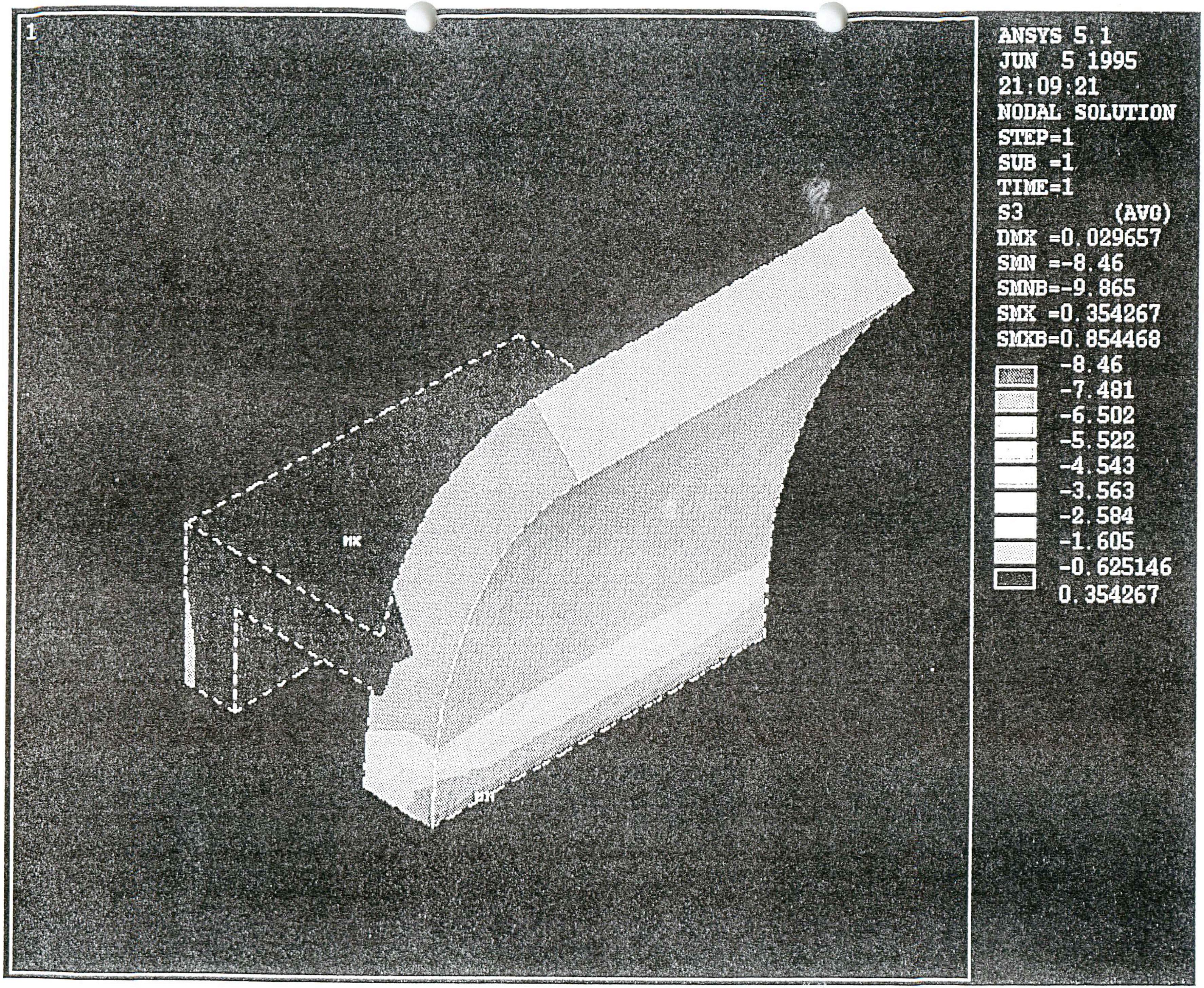
ELEMENTS
TEMPERATURES
TMIN=38.612
TMAX=91.674
XV =1
YV =1
ZV =1
*DIST=31.709
*XF =-53.722
*YF =17.286
*ZF =18.807
PRECISE HIDDEN
EDGE
38.612
44.508
50.404
56.299
62.195
68.091
73.987
79.882
85.778
91.674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JUN 5 1995
21:09:21
NODAL SOLUTION
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SUB =1
TIME=1
S3 (AVG)
DMX =0.029657
SMN =-8.46
SMNB=-9.865
SMX =0.354267
SMXB=0.854468
-8.46
-7.481
-6.502
-5.522
-4.543
-3.563
-2.584
-1.605
-0.625146
0.354267
MX

Pumping speed estimation

•Gas load comes from desorption due to synchrotron radiation.

The pressure (Torr) is given by

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

where

K is the constant ($=3.3\times10^{19}$ molecules $Torr^{-1} l^{-1}$),

N is the linear photon density ($=3.3\times10^{18}$ 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 $\eta=10^{-5}$, Sd=1000 .... unrealistic.

For $\eta=10^{-6}$, Sd=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.

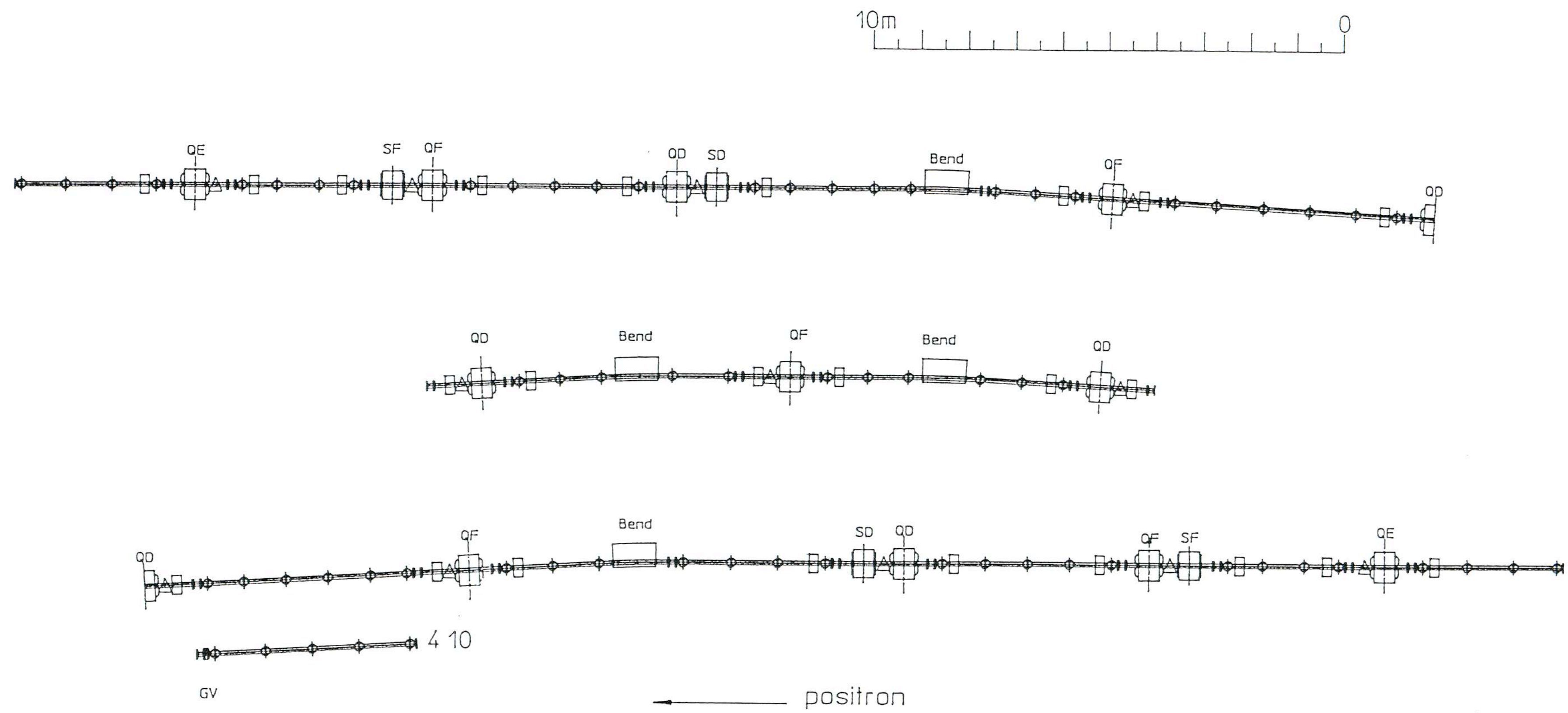
Principle of pump layout

•Roughing port
100 l/s (NET), every 40m
Roughing system is portable and removed during beam operation

•Ion pump
100l/s (NET), every 10m

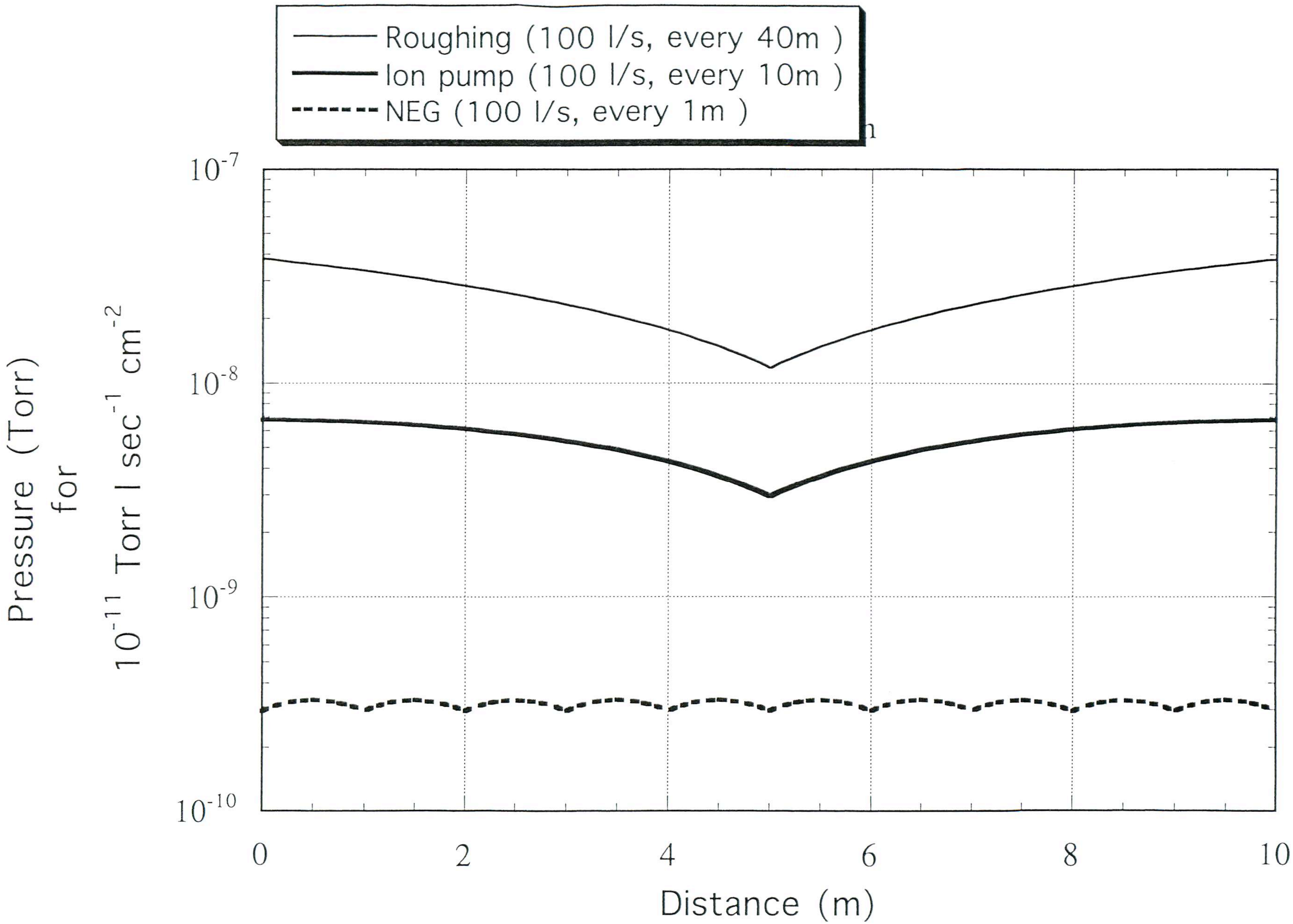
•NEG cartridge
100/s (NET), every 1m
This gives $Sd=100\ l\ s^{-1}\ m^{-1}$.

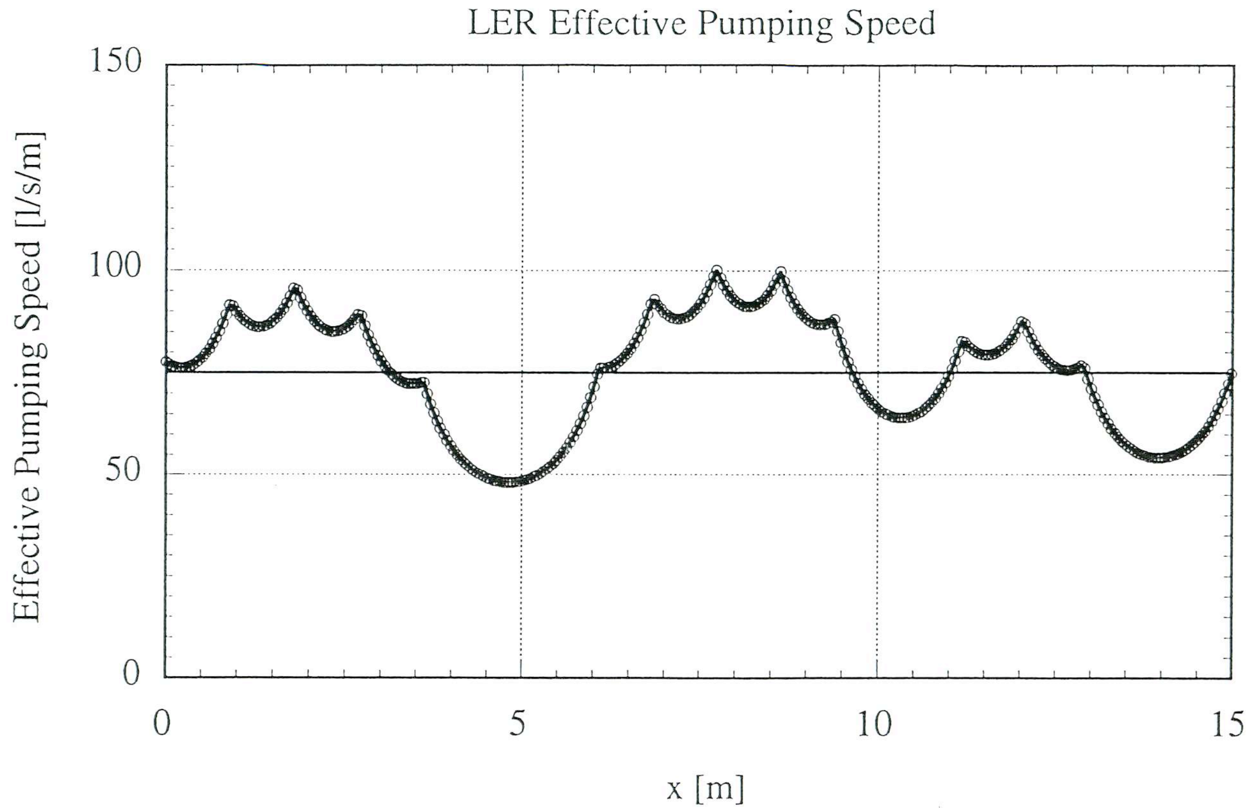
Actually, with an irregularity of pump separation, $\underline{Sd=75\ l\ s^{-1}\ m^{-1}}$.



Standard cell of LER

Figure 1


Roughing (100 l/s, every 40m)
Ion pump (100 l/s, every 10m)
NEG (100 l/s, every 1m)
Pressure (Torr)
for
10-11 Torr l sec-1 cm-2
10-7
10-8
10-9
10-10
0
2
4
6
8
10
Distance (m)



LER Effective Pumping Speed
Effective Pumping Speed [l/s/m]
150
100
50
0
0
5
10
15
x [m]

Surface treatment

<purpose>

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

<process:>

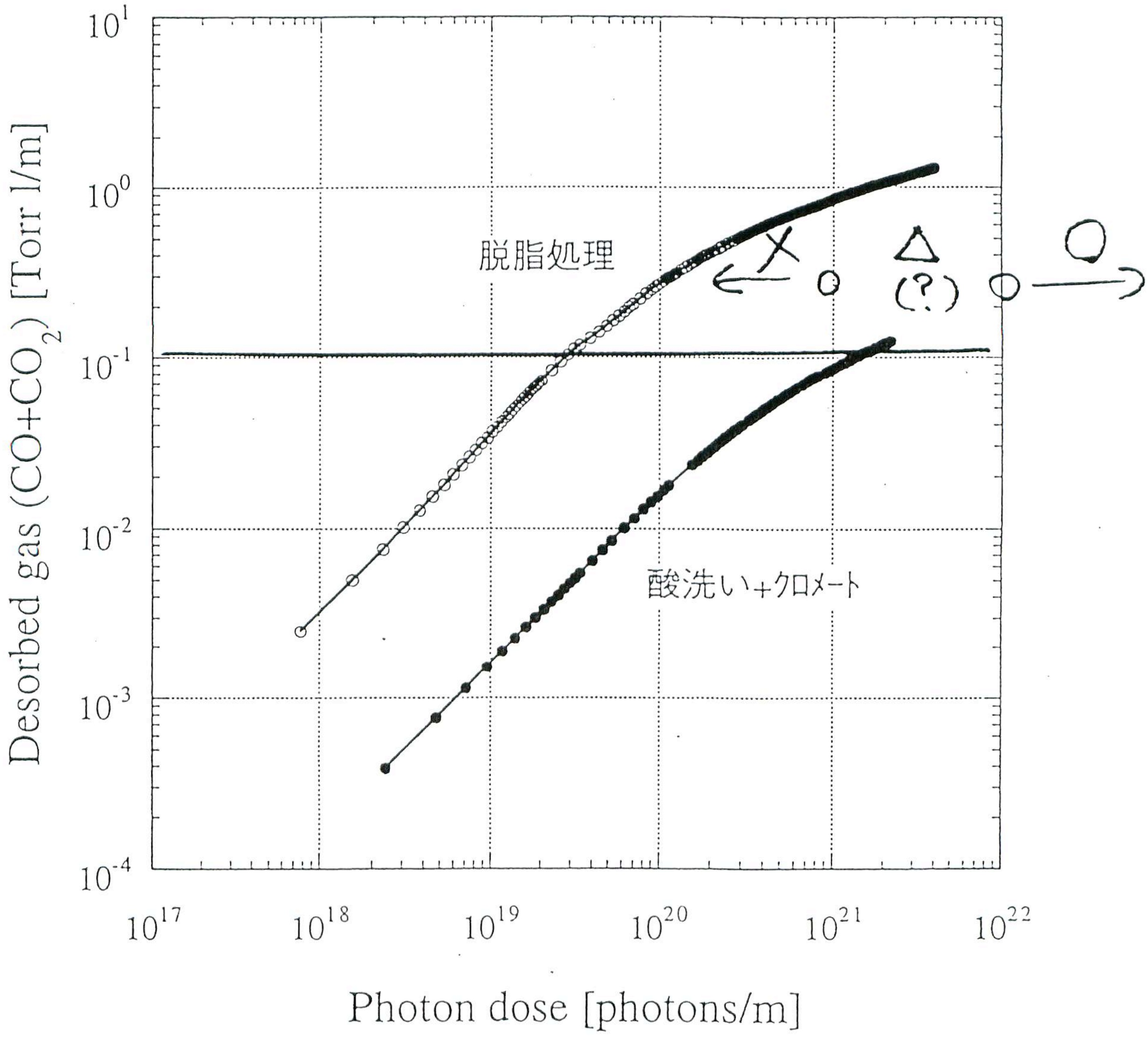
Remove a dirty surface layer after drawing (about mm) and create a new (clean) oxide layer.

(1) Acid etch

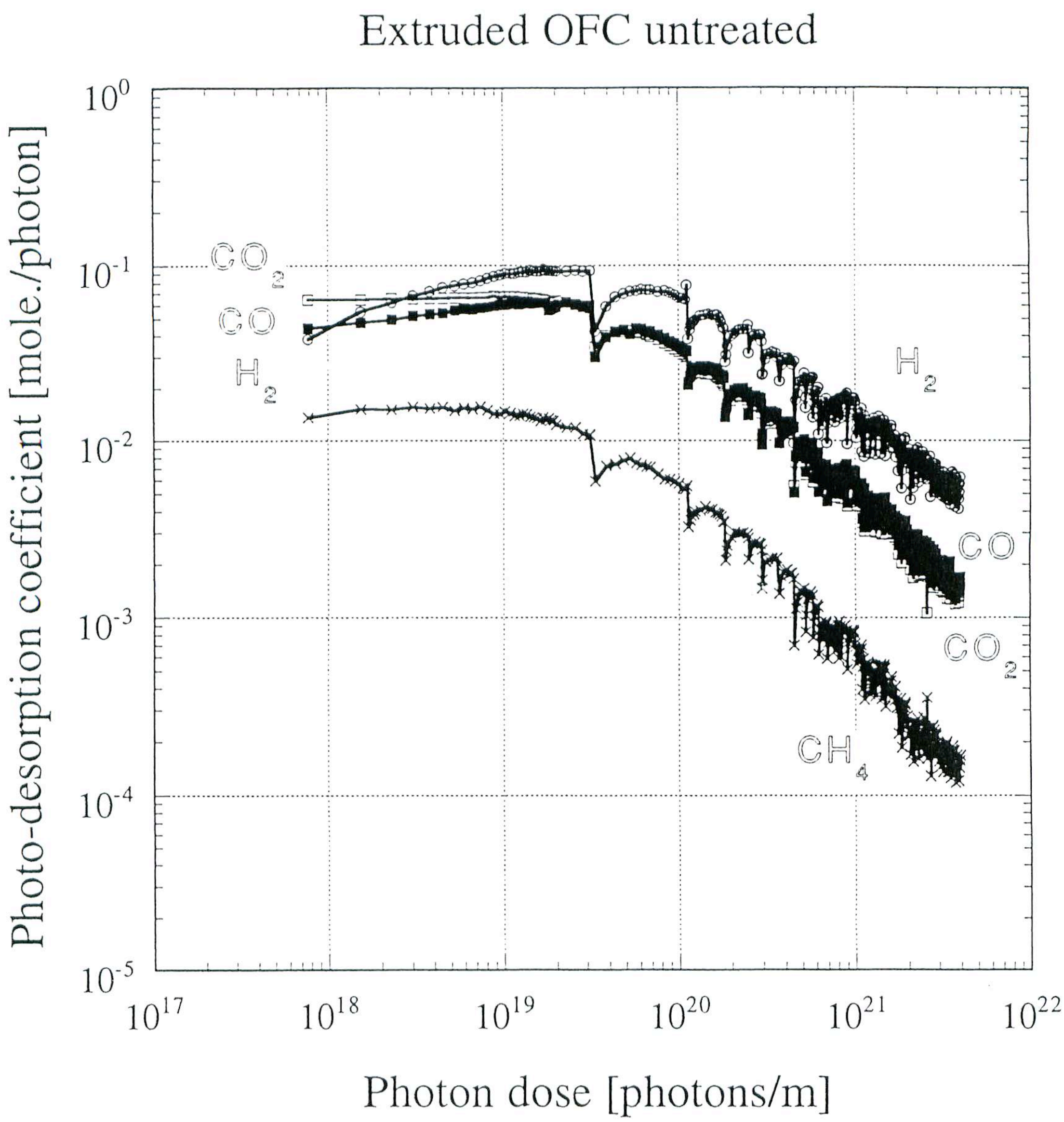
1. Alkaline soak
2. Rinse with tap water
3. Acid etch
   H_2SO_4:HNO_3:water=1:1:7~10(Vol) with bit of HCl
4. Rinse with tap water
5. Rince with demineralized water
6. Dry with boil off N_2
7. Keep in dry N_2 atmosphere

(2) Chemical polishing

1. Alkaline soak
2. Rinse with tap water
3. Chemical polishing (contains H_2O_2 and H_2SO_4)
4. Rinse with tap water
5. Conditioning with H_2SO_4
6. Rinse with tap water
7. Cleaning with demineralized water jet
8. Dry with boil off N2
9. Keep in dry N_2 atmosphere

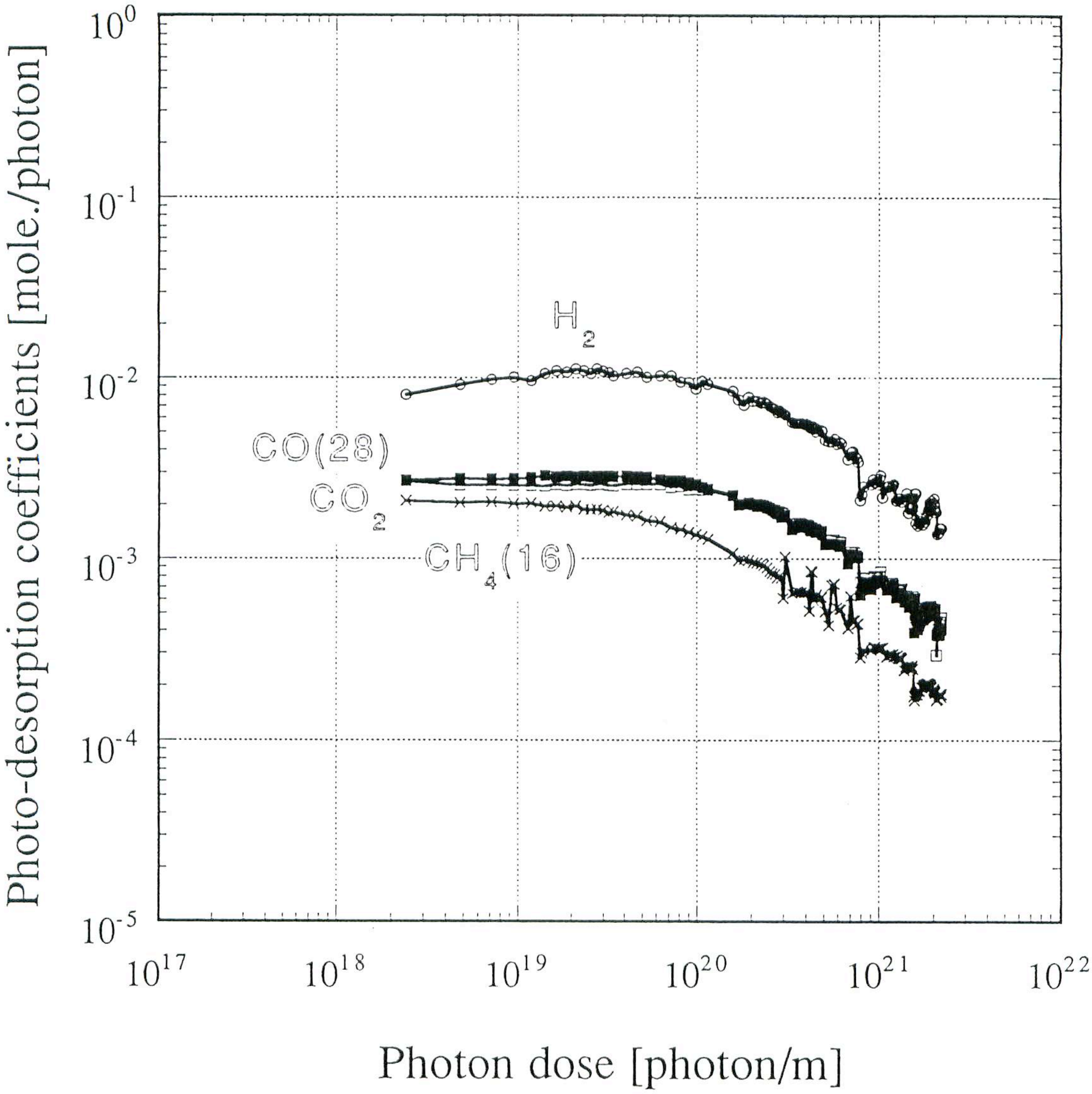


Desorbed gas (CO+CO2) [Torr l/m]
Photon dose [photons/m]
脱脂処理
酸洗い+クロメート
×
△
(?)
○
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^17
10^18
10^19
10^20
10^21
10^22

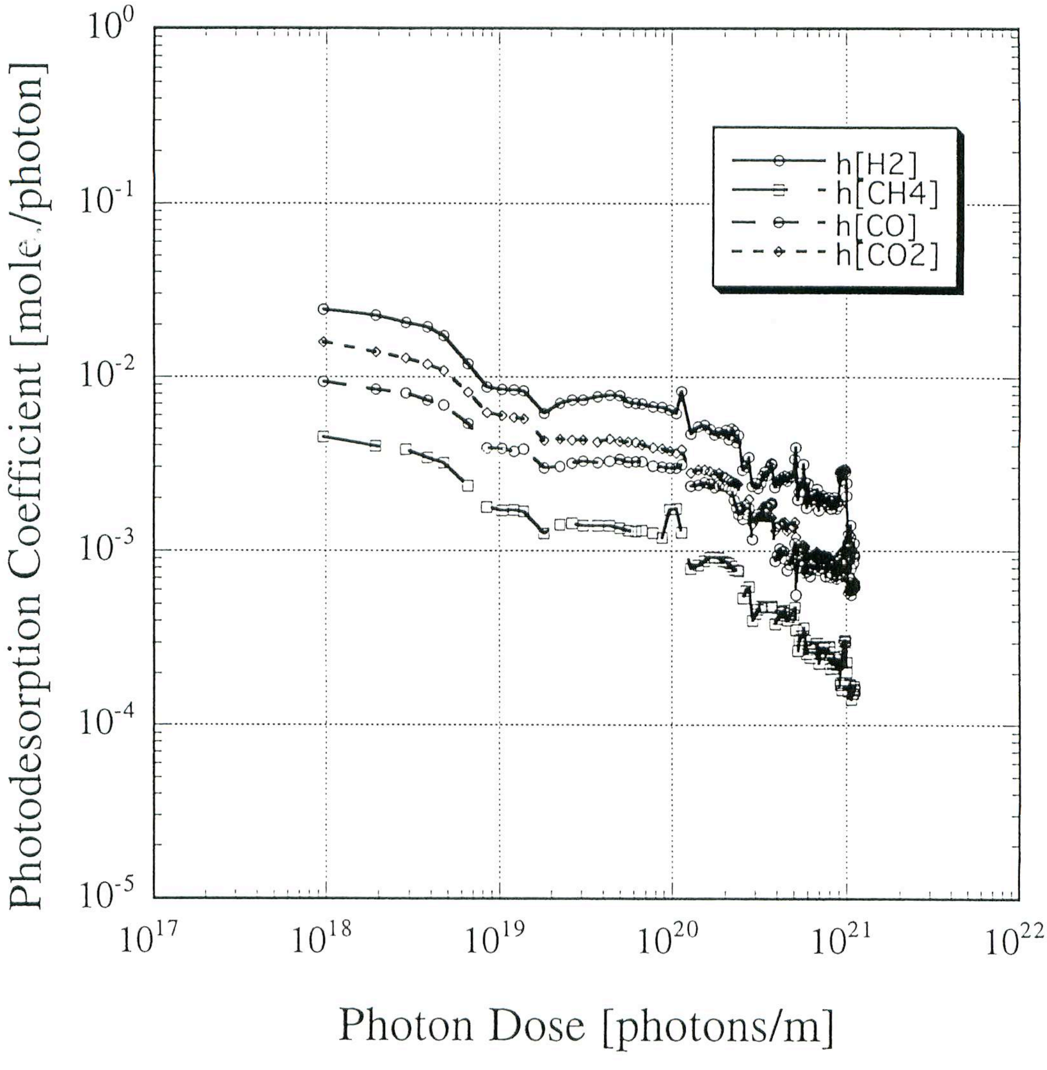


Extruded OFC untreated
Photo-desorption coefficient [mole./photon]
Photon dose [photons/m]
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^17
10^18
10^19
10^20
10^21
10^22
CO2
CO
H2
H2
CO
CO2
CH4

Acid etch + passivation by Chromic acid



Chemical Poloshing



Chambers

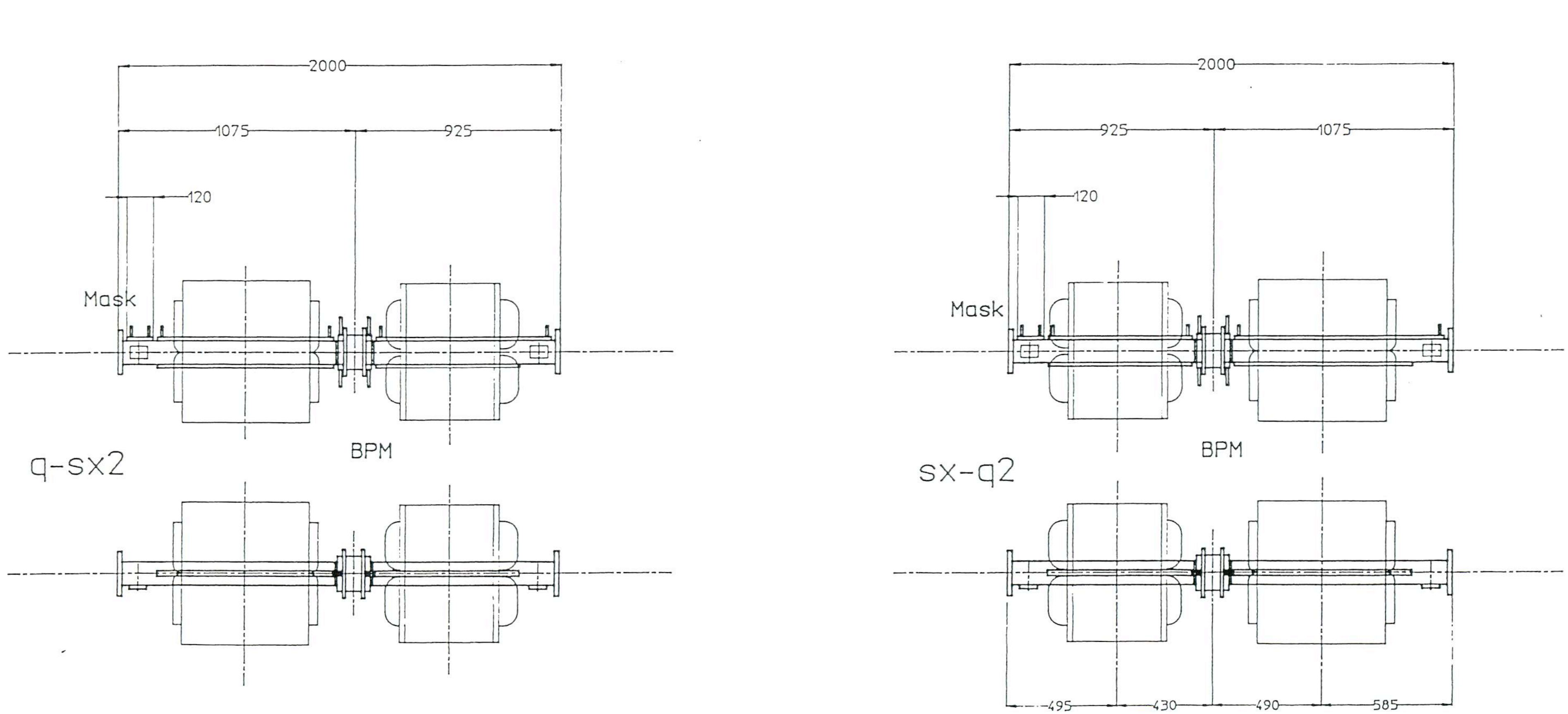
- B chamber
  For bending magnet.
  Don't anneal the wall where the heat load is maximum.
  Has pumping ports.

- Q chamber
  With BPM block
  Fixed to Q magnet
  Symmetrical cross section.

- S chamber
  Straight
  Has pumping ports.

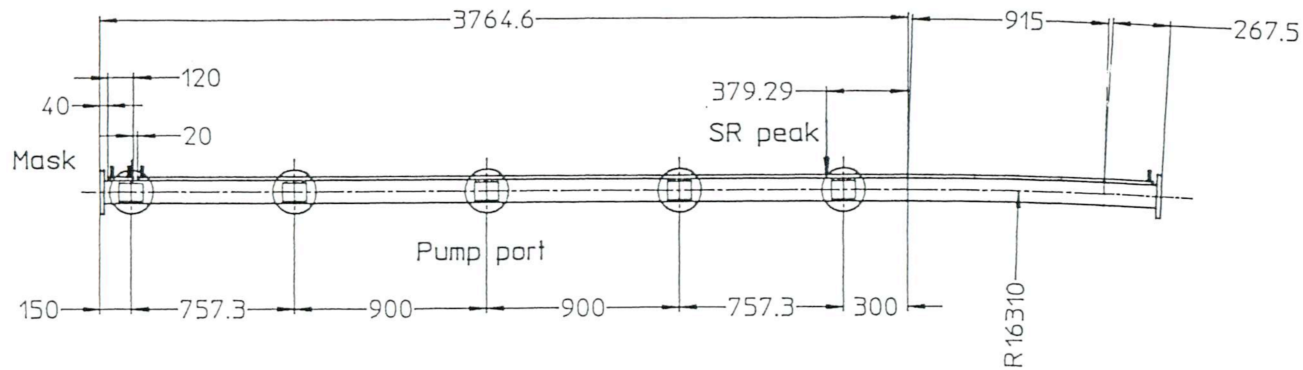
From fabrication to installtion on magnets

- 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



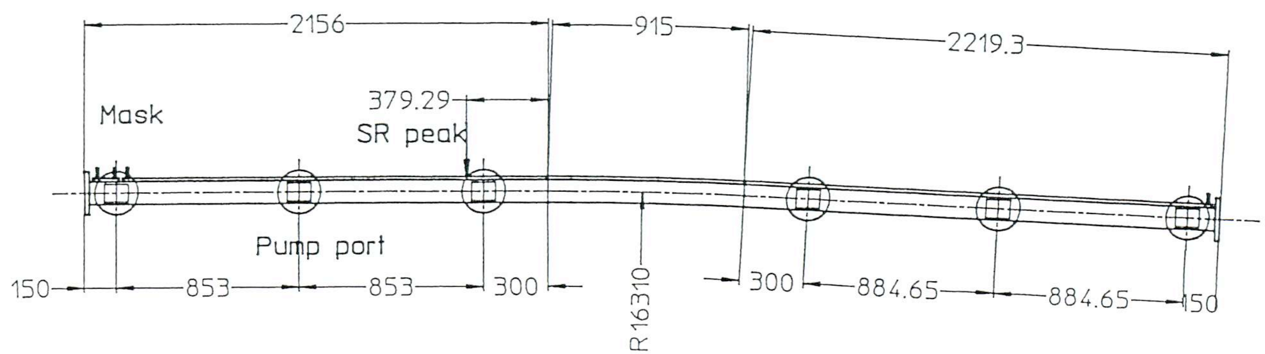
LER Q/SX chambers

Ver.3



3764.6
915
267.5
120
40
20
Mask
379.29
SR peak
Pump port
150
757.3
900
900
757.3
300
R16310

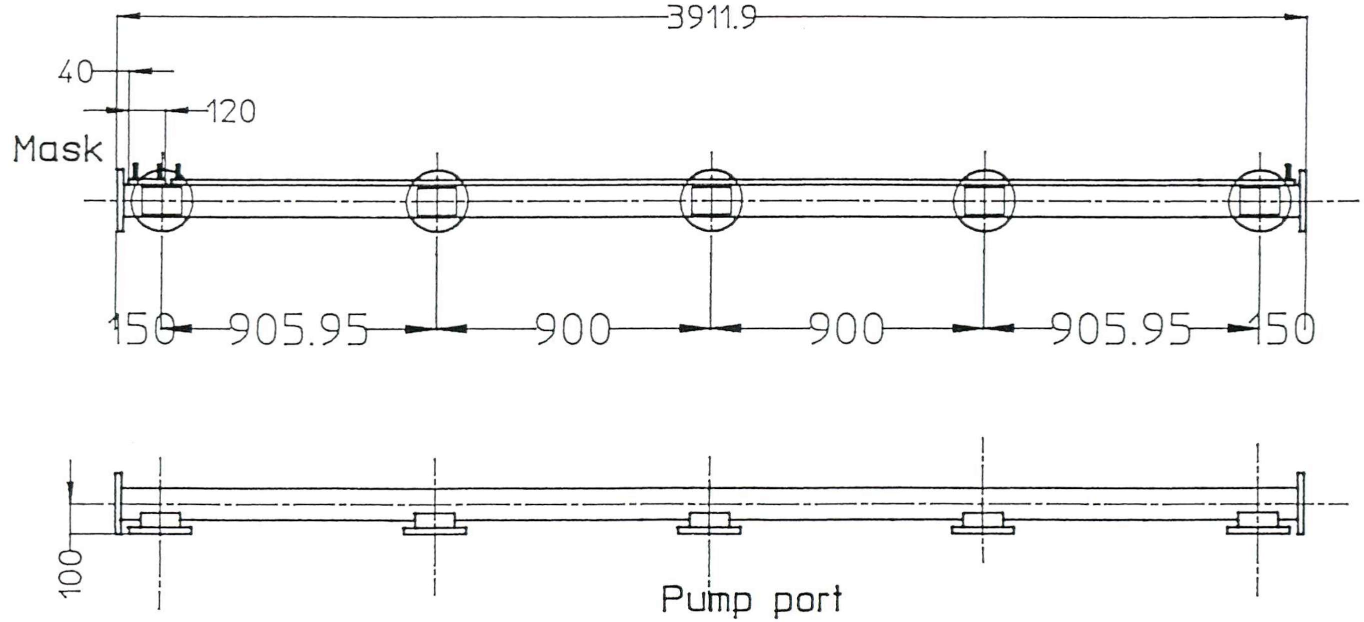
b-1



2156
915
2219.3
379.29
SR peak
Mask
Pump port
150
853
853
300
R16310
300
884.65
884.65
150

b-2

s(5)-1



Components

- BPM block

  About 100 blocks will deform due to the heat from synchrotron radiation. The deformation at the position of a pick up is10 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

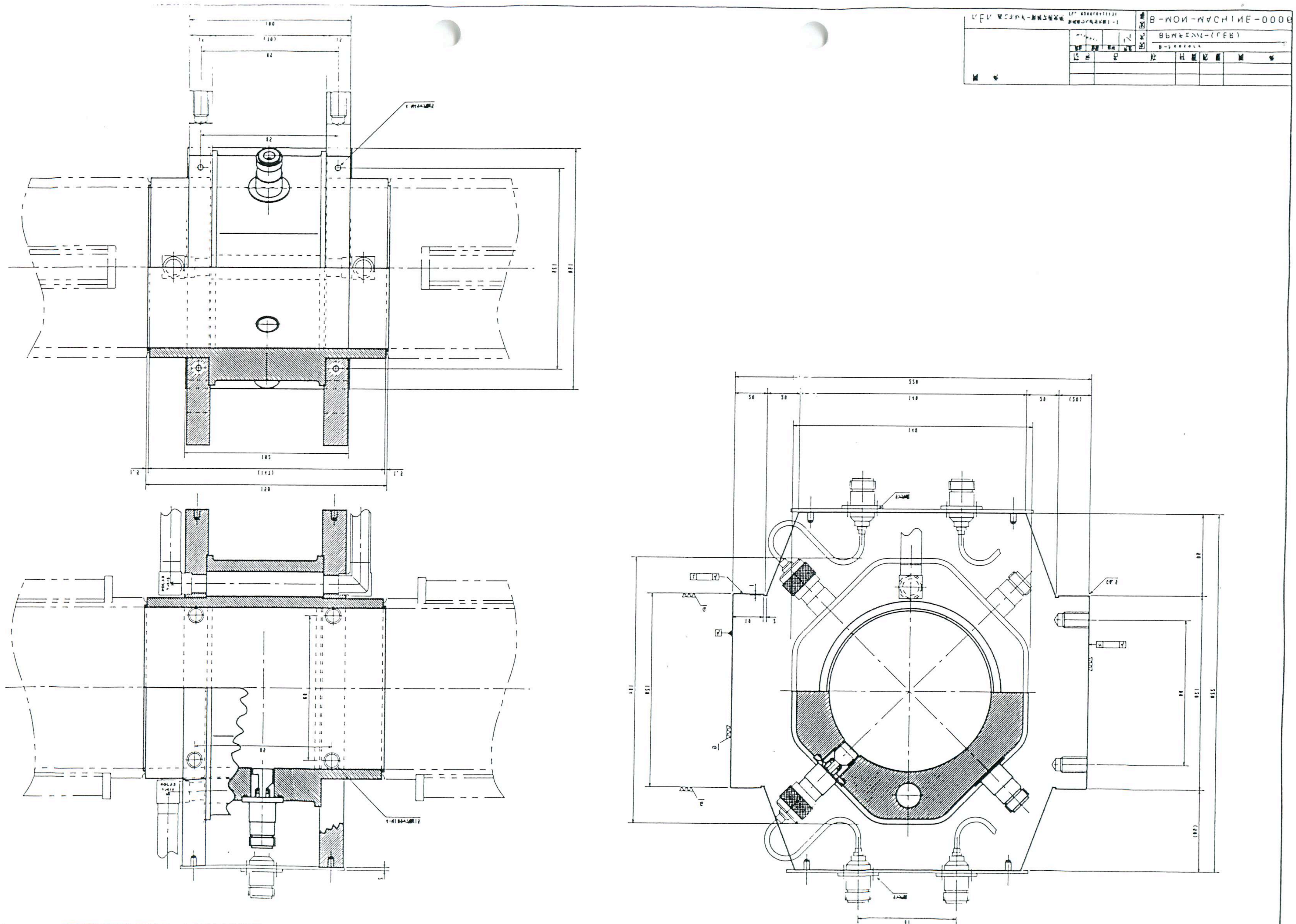
  Grid size is 4x5mm.

- NEG module, strip holder

  KEK design (Hisamatsu)

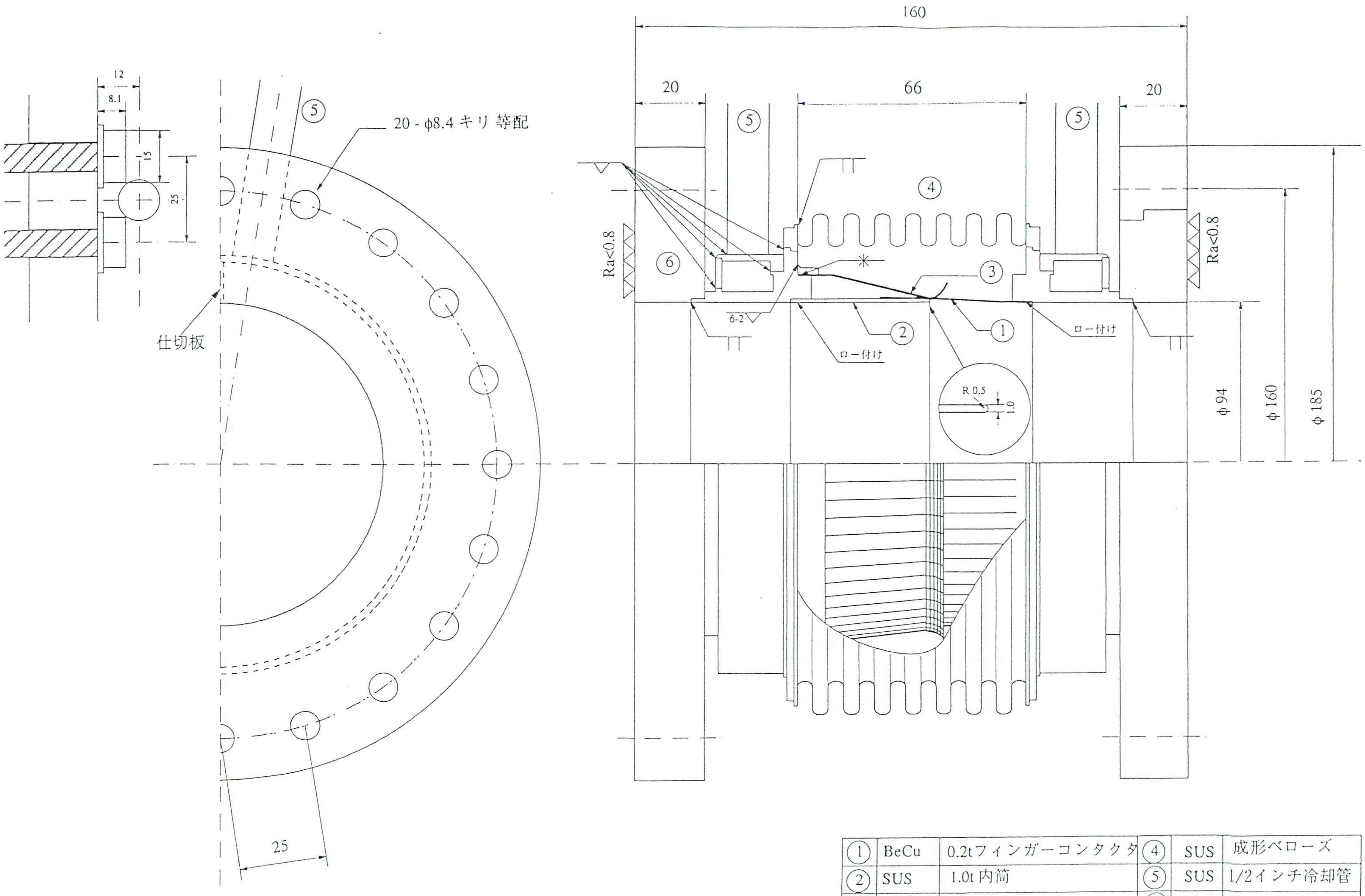
- Flanges at the end of a beam duct

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


B-MON-MACHINE-0008

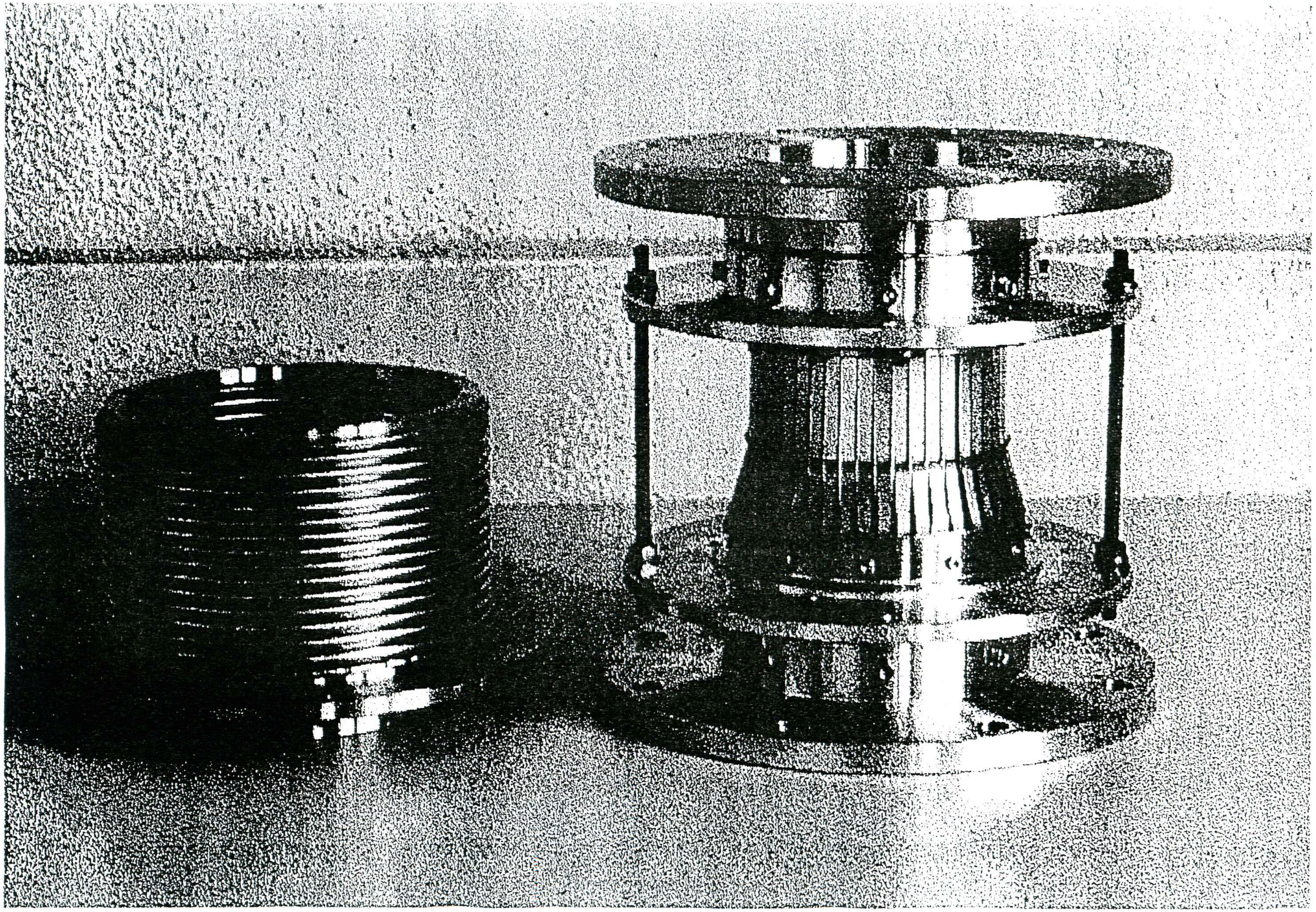
Ver 1.1

6/2

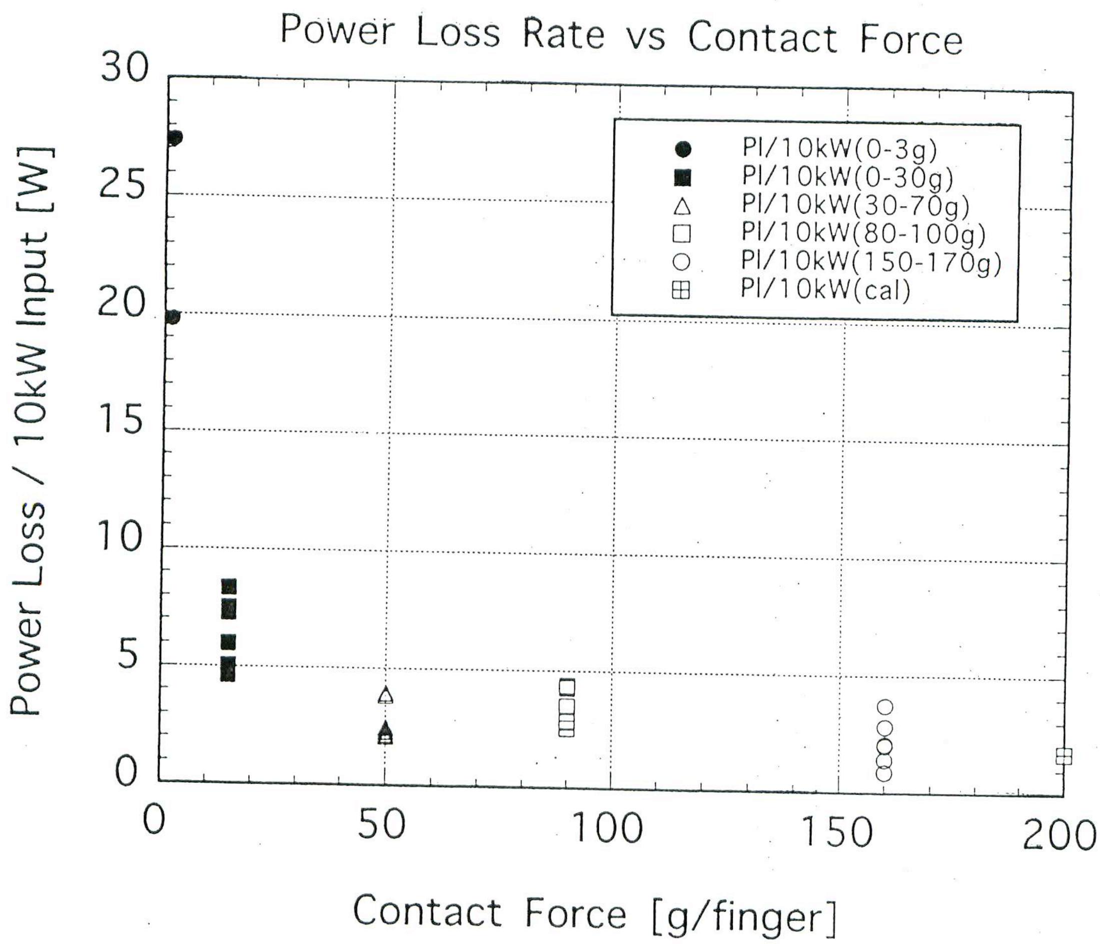


①	BeCu	0.2tフィンガーコンタクタ	④	SUS	成形ベローズ
②	SUS	1.0t 内筒	⑤	SUS	1/2インチ冷却管
③	Inconel*	0.4tフィンガースプリング	⑥	SUS	フランジ

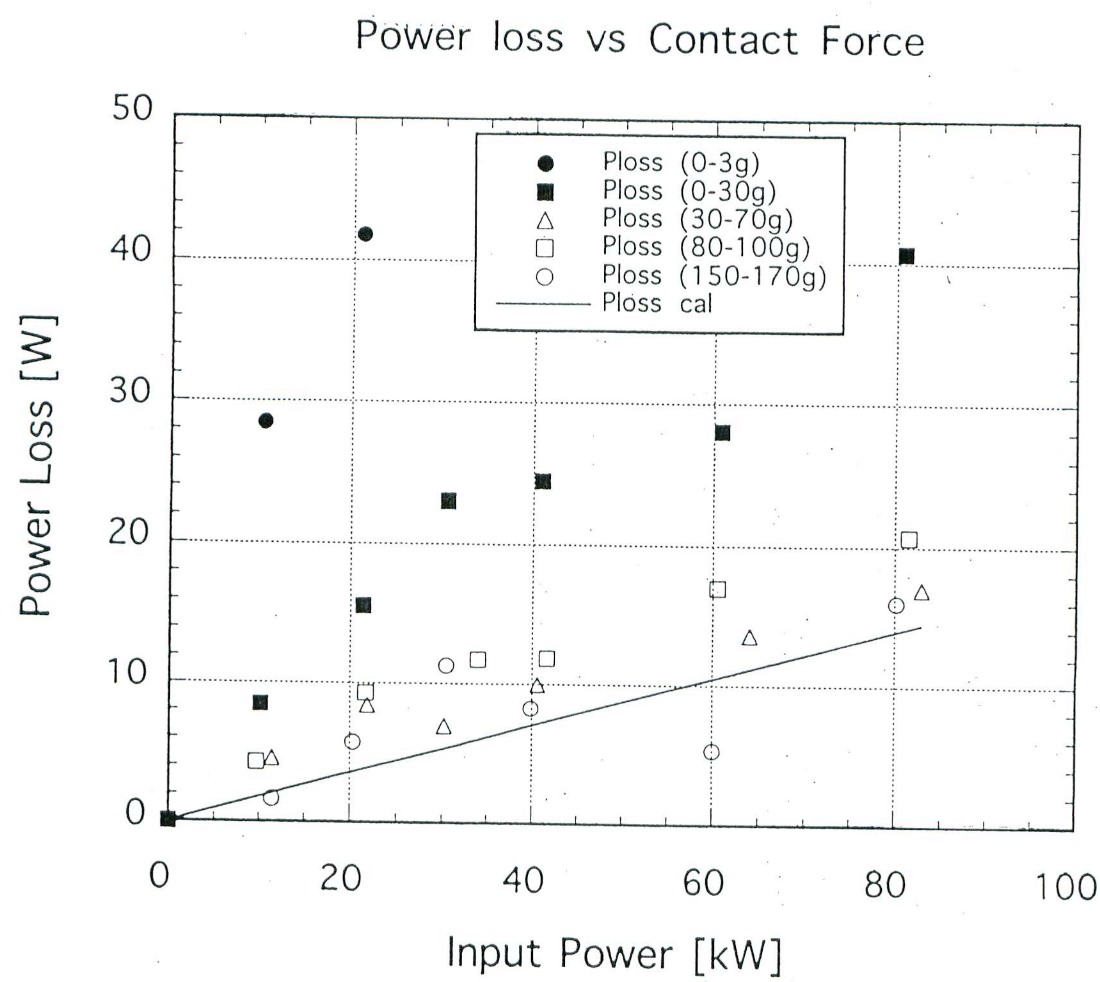
・参考



bello-finger.photo

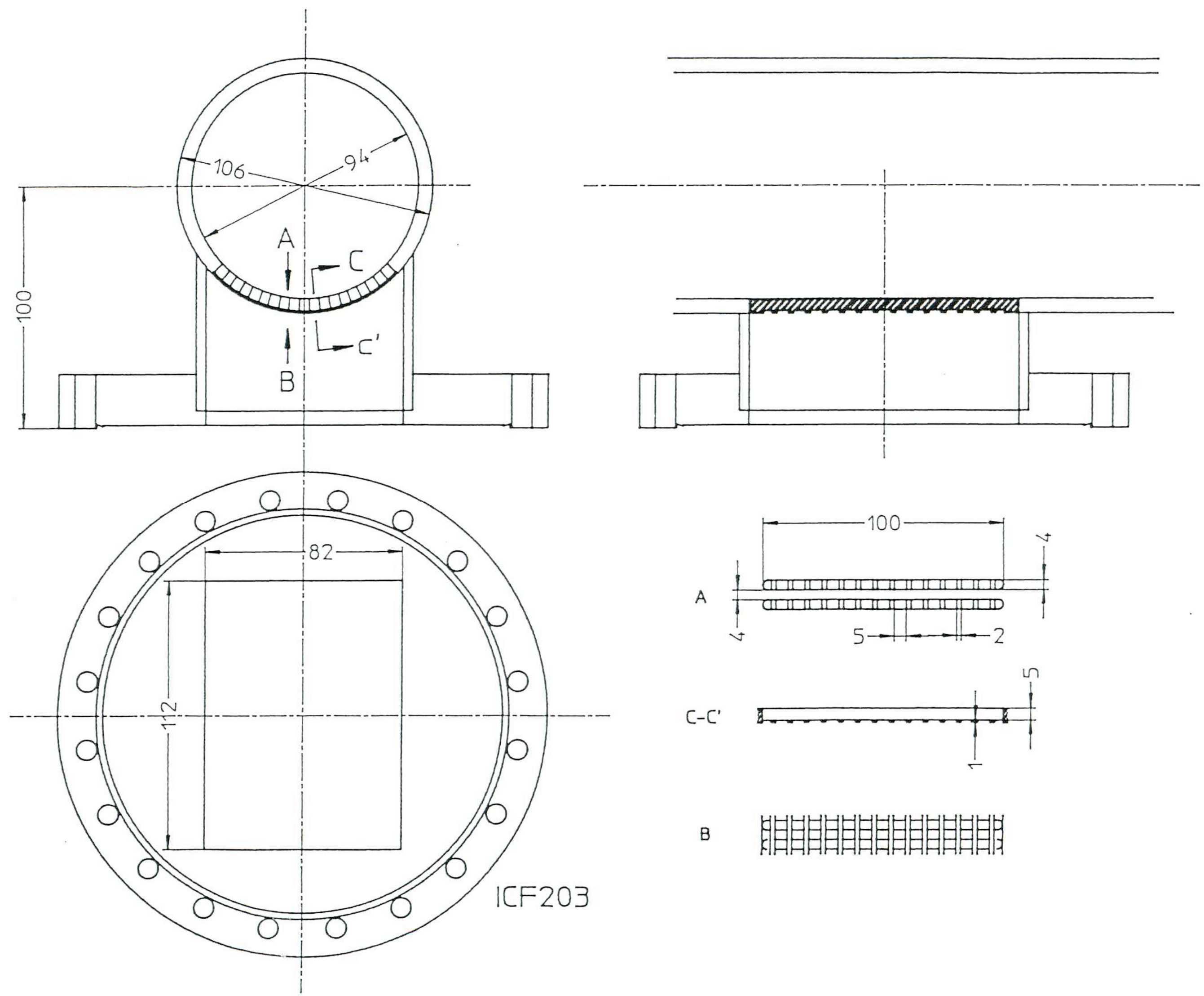


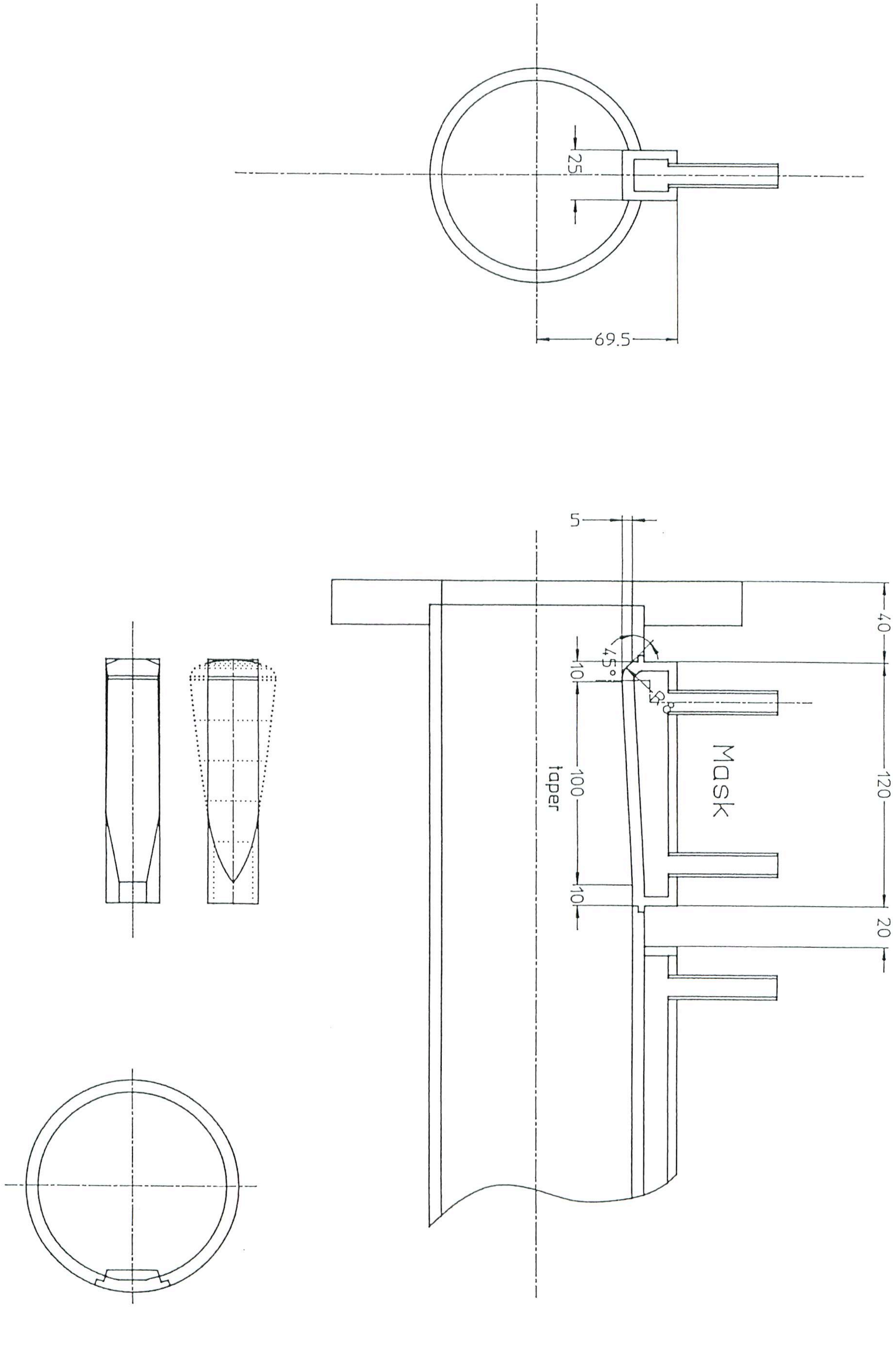
ploss rate.plot



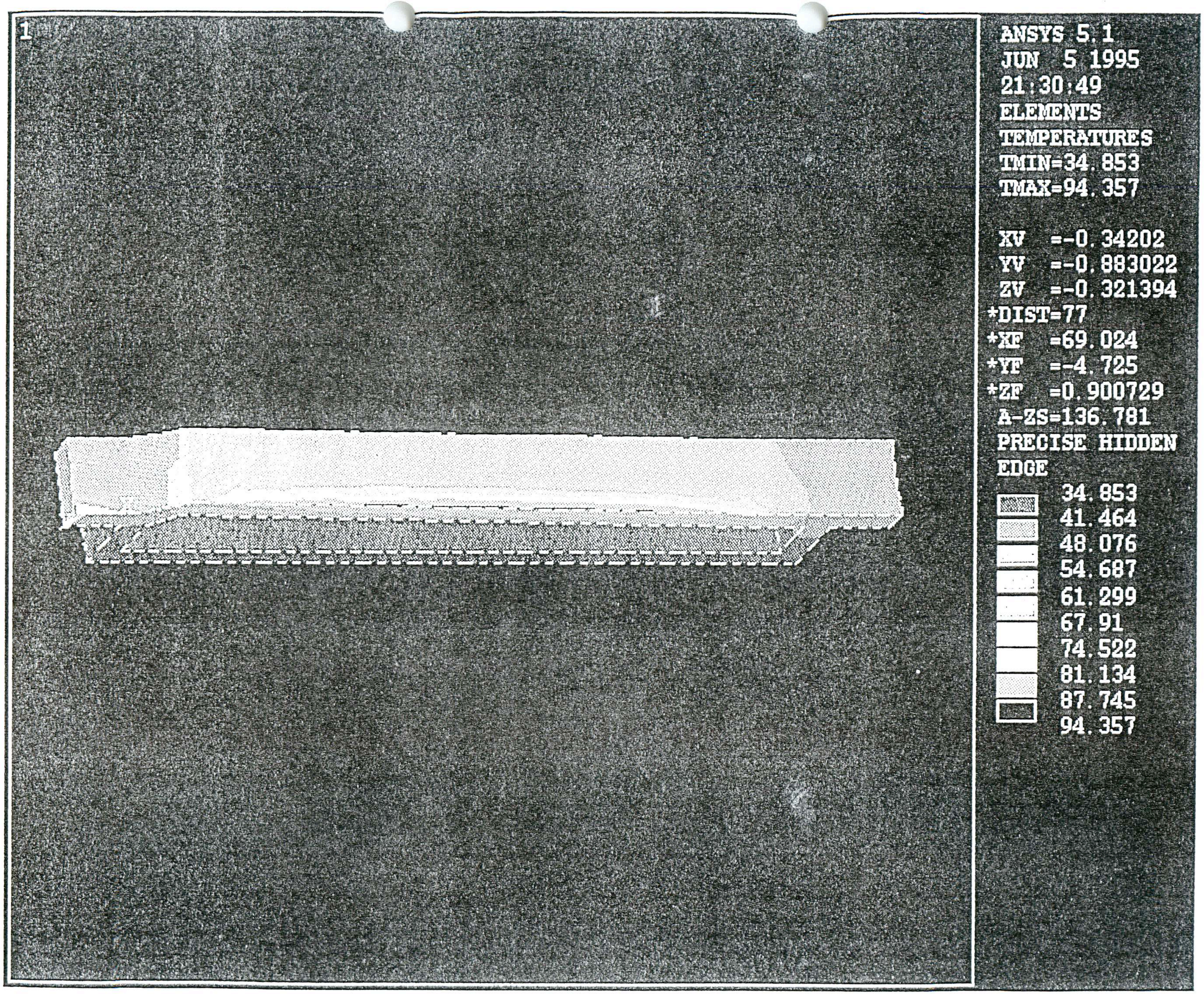
Power loss vs Contact Force
Ploss (0-3g)
Ploss (0-30g)
Ploss (30-70g)
Ploss (80-100g)
Ploss (150-170g)
Ploss cal
Power Loss [W]
Input Power [kW]
0
10
20
30
40
50
0
20
40
60
80
100

ploss.plot


106
94
100
A
B
C
C'
82
112
ICF203
100
4
A
4
5
2
C-C'
5
1
B



25
69.5
5
40
120
20
45°
R8
10
100
10
taper
Mask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JUN 5 1995
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ELEMENTS
TEMPERATURES
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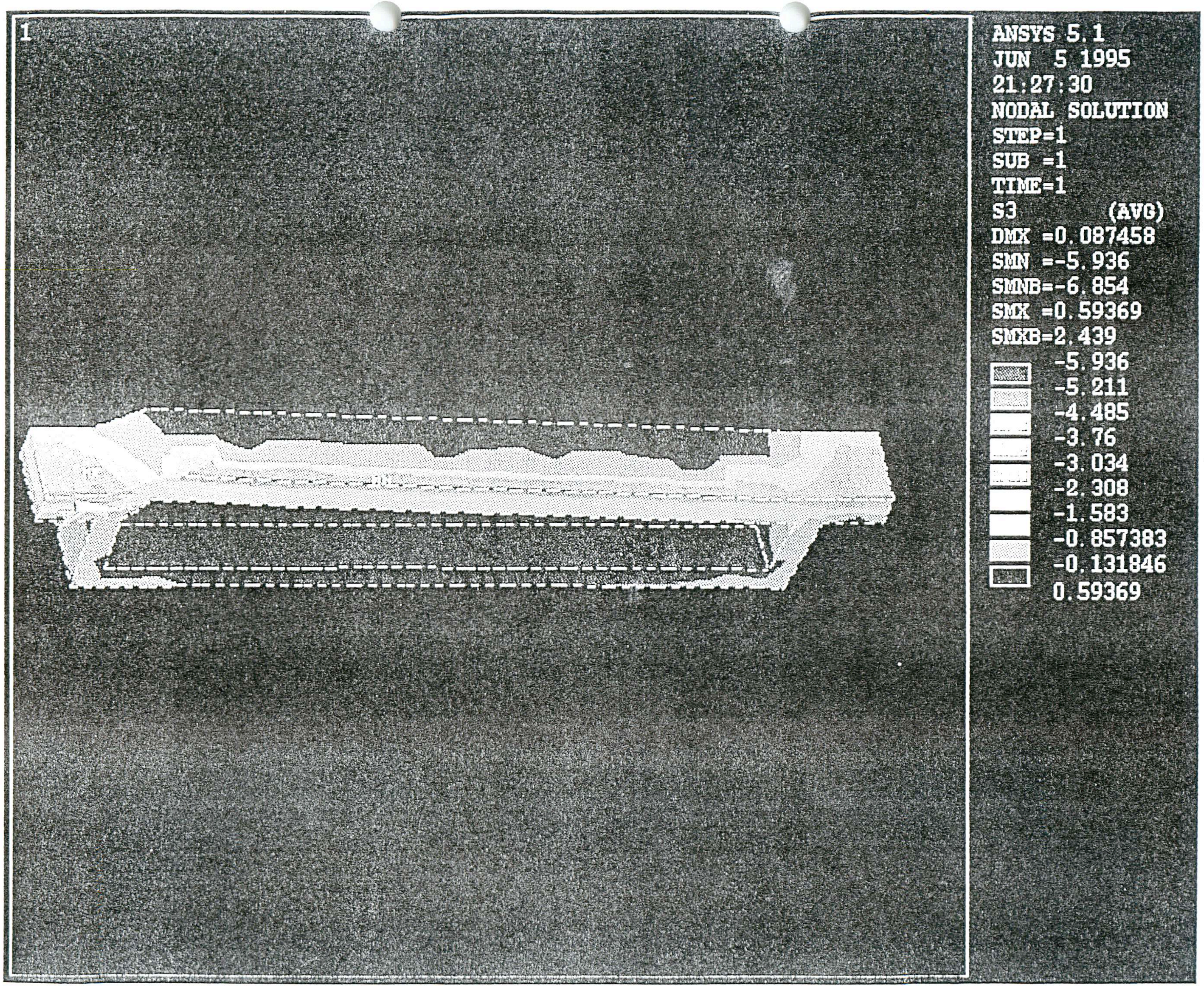
TMAX=94.357
XV =-0.34202
YV =-0.883022
ZV =-0.321394
*DIST=77
*XF =69.024
*YF =-4.725
*ZF =0.900729
A-ZS=136.781
PRECISE HIDDEN
EDGE
34.853
41.464
48.076
54.687
61.299
67.91
74.522
81.134
87.745
94.357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JUN 5 1995
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NODAL SOLUTION
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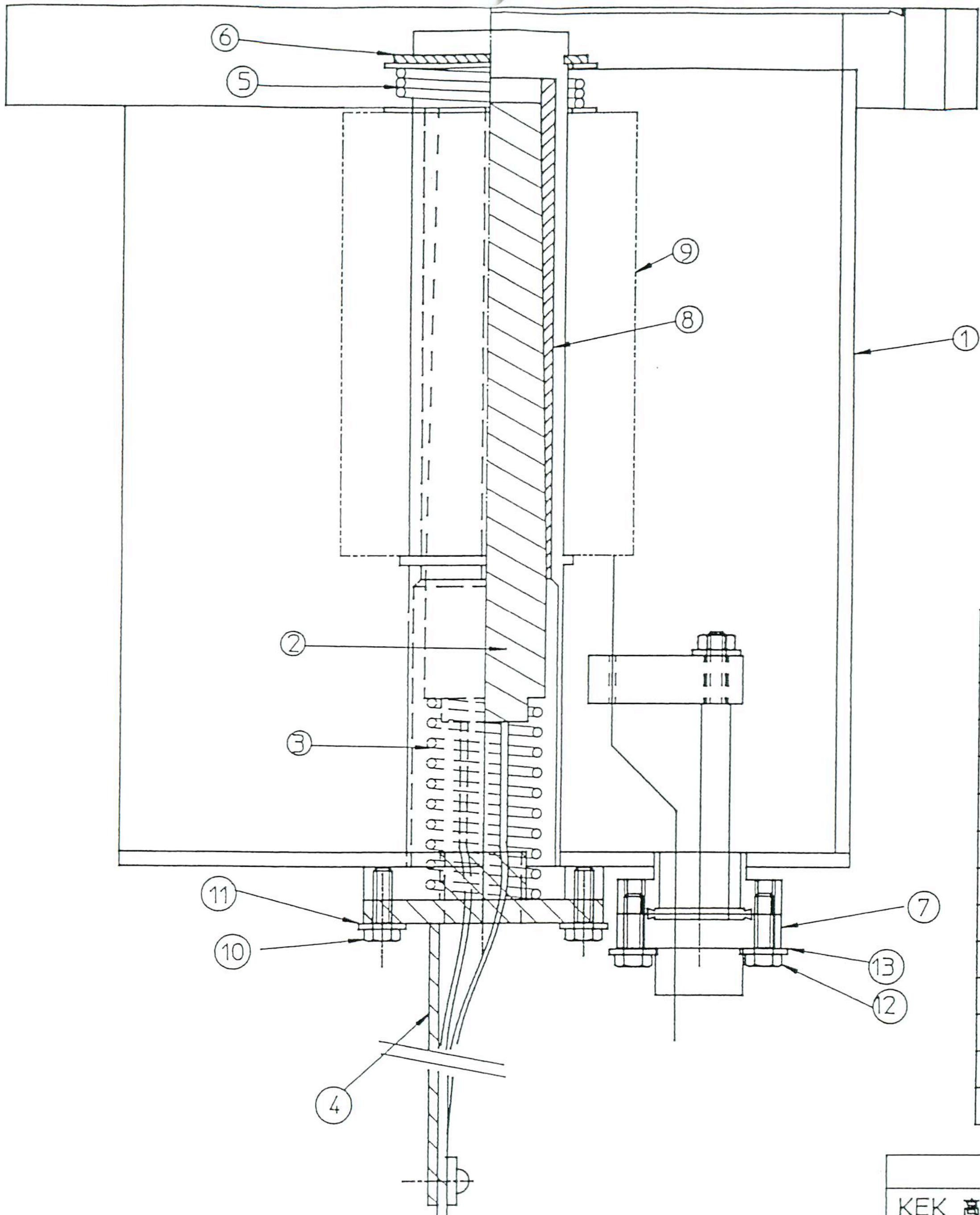
SUB =1
TIME=1
S3 (AVG)
DMX =0.087458
SMN =-5.936
SMNB=-6.854
SMX =0.59369
SMXB=2.439
-5.936
-5.211
-4.485
-3.76
-3.034
-2.308
-1.583
-0.857383
-0.131846
0.59369

LER 10KW/m

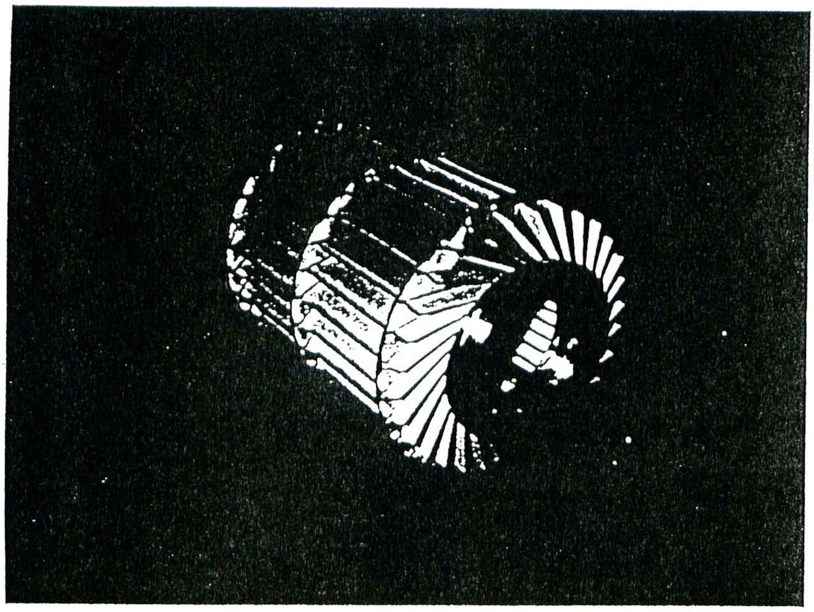
	Cu	Al	
ρ	8.9×10^{-3}	2.7×10^{-3}	g/mm³
C	0.38	0.90	J/g/°C
k	0.387	0.20	W/°C/mm
E	1.34×10^{4}	7×10^{3}	kg/mm²
ν	0.3	0.3	
α	1.7×10^{-5}	2.4×10^{-5}	1/°C
水温	30°C		
熱伝達率	0.01		W/°C/mm²
入熱	20		W/mm²
入熱幅	0.5		mm

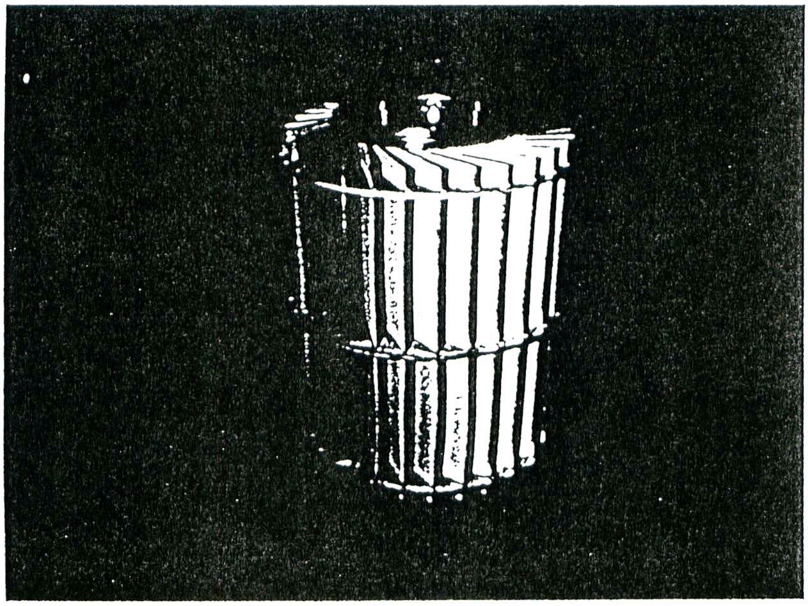
	Cu	Al	
Max 温度	97	135	°C
Max ストレス	−9.1	−12.4	kg/mm²

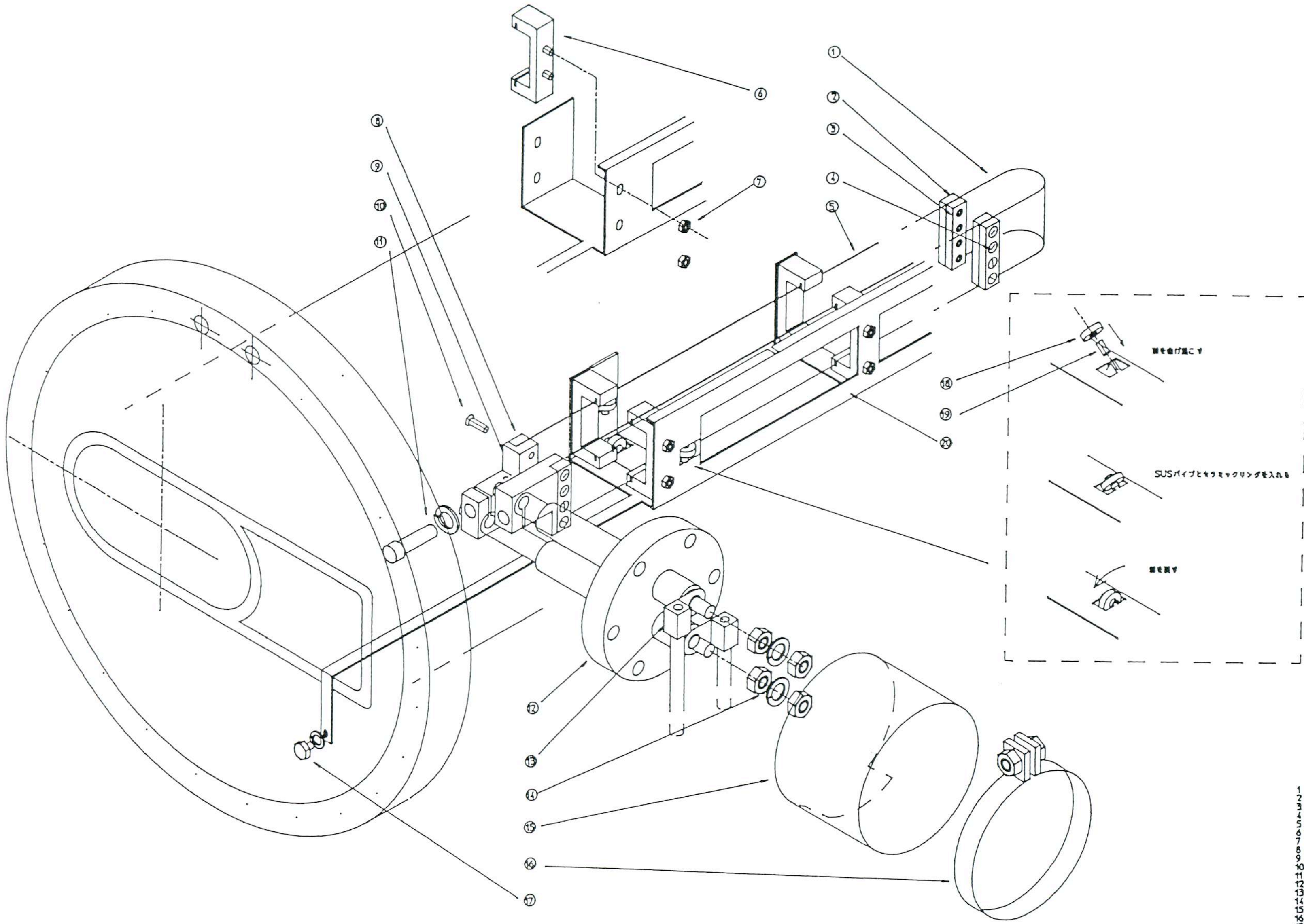


番号	品名	図番	数量
13	M4 WASHER	SUS	6
12	M4 L15	SUS	6
11	M4 SPRINGWASHER	SUS	4
10	M4 L12	SUS	4
9	CNEG		
8	SLEEVE	CNEG-P8	1
7	Pt THERMO	CNEG-P7	1 or 0
6	STOP RING	径32 SUS	1
5	SUPPORT RING	CNEG-P5	1
4	HEATER FLANGE	CNEG-P4	1
3	SPRING	CNEG-P3	1
2	HEATER	CNEG-P2	支給
1	CNEG CHAMBER	CNEG-P1	A or B

KEK 高エネルギー物理学研究所 茨城県つくば市大穂1-1 〒305 TEL 0298 (64)-1171	図名	ヒータアセンブリ
	図番	CNEG-ASS





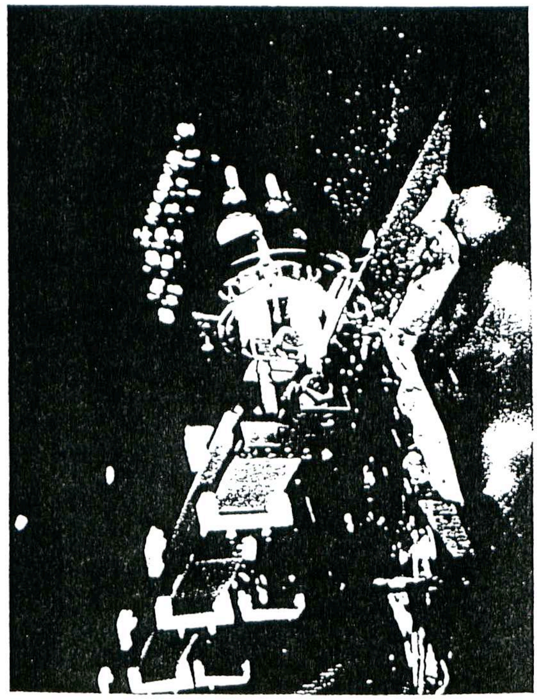


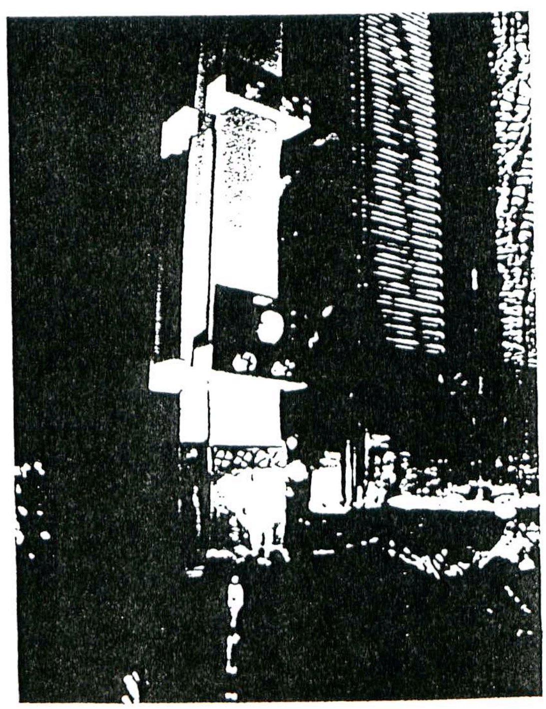
1 [illegible]
2 電極止め板（オス）
3 電極止め板（メス）
4 M3皿ビス
5 ストリップ型NEG
6 セラミックNEGホルダー
7 M3ナット
8 電極止め板（オス） (2)と同じ
9 NEG-電流導入端子結合板
10 M3皿ビス (4)と同じ
11 M6六角穴付きボルト
12 50A-5kV NEG用電流導入端子
13 [illegible]
14 M6ナット
15 端子カバー
16 クランプ
17 ベース固定ビス
18 セラミックリング
19 SUSパイプ
20 ベース

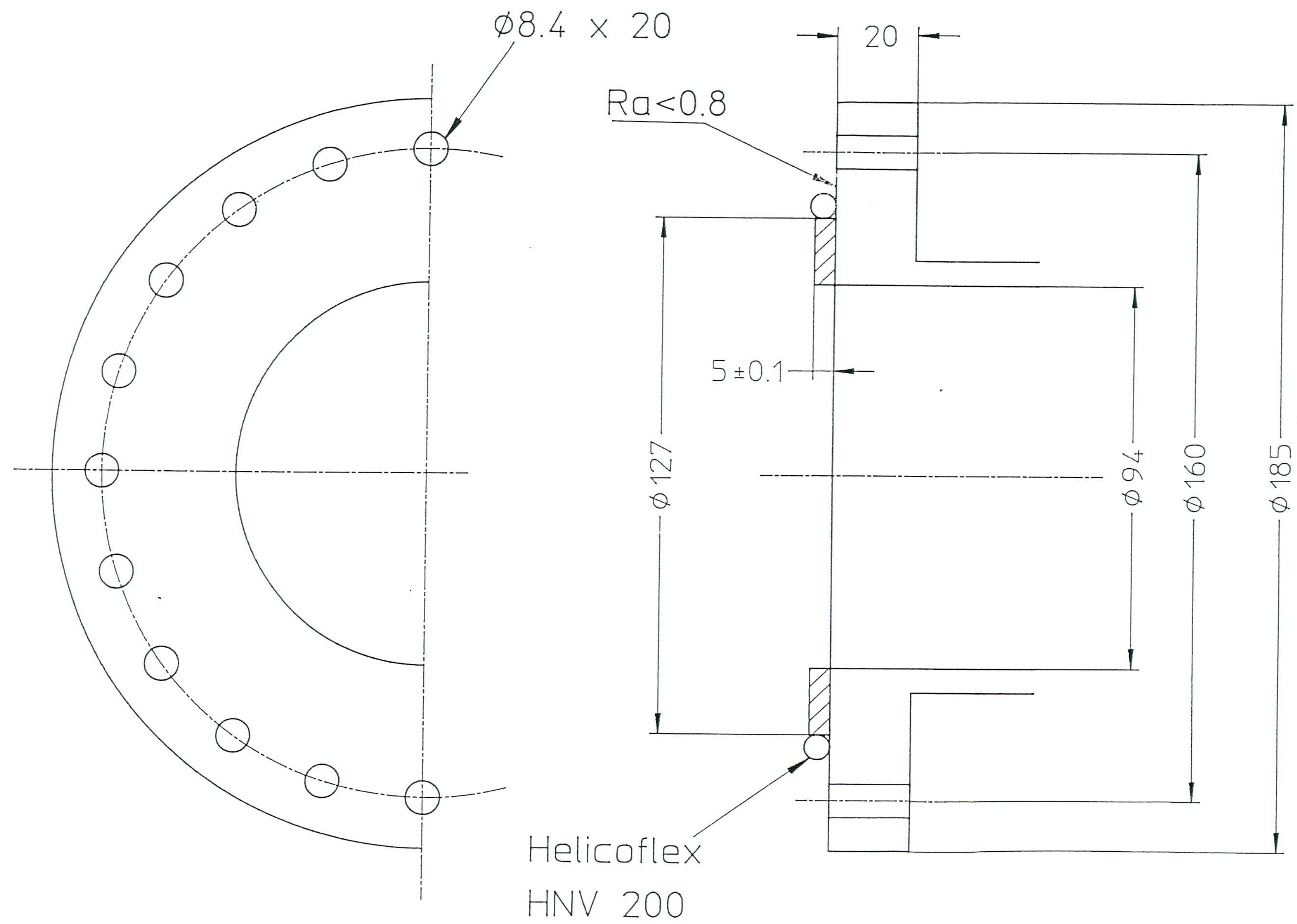
KEK 高エネルギー物理学研究所

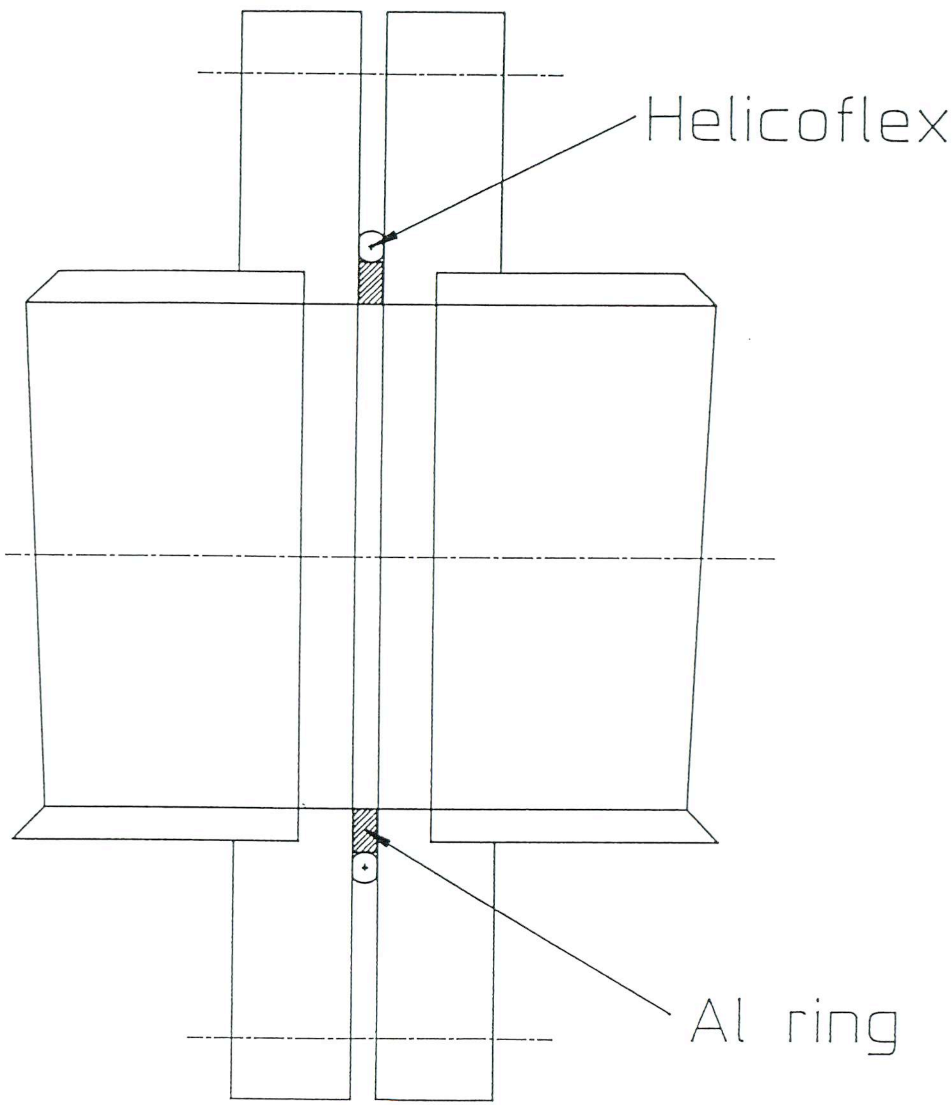
図名

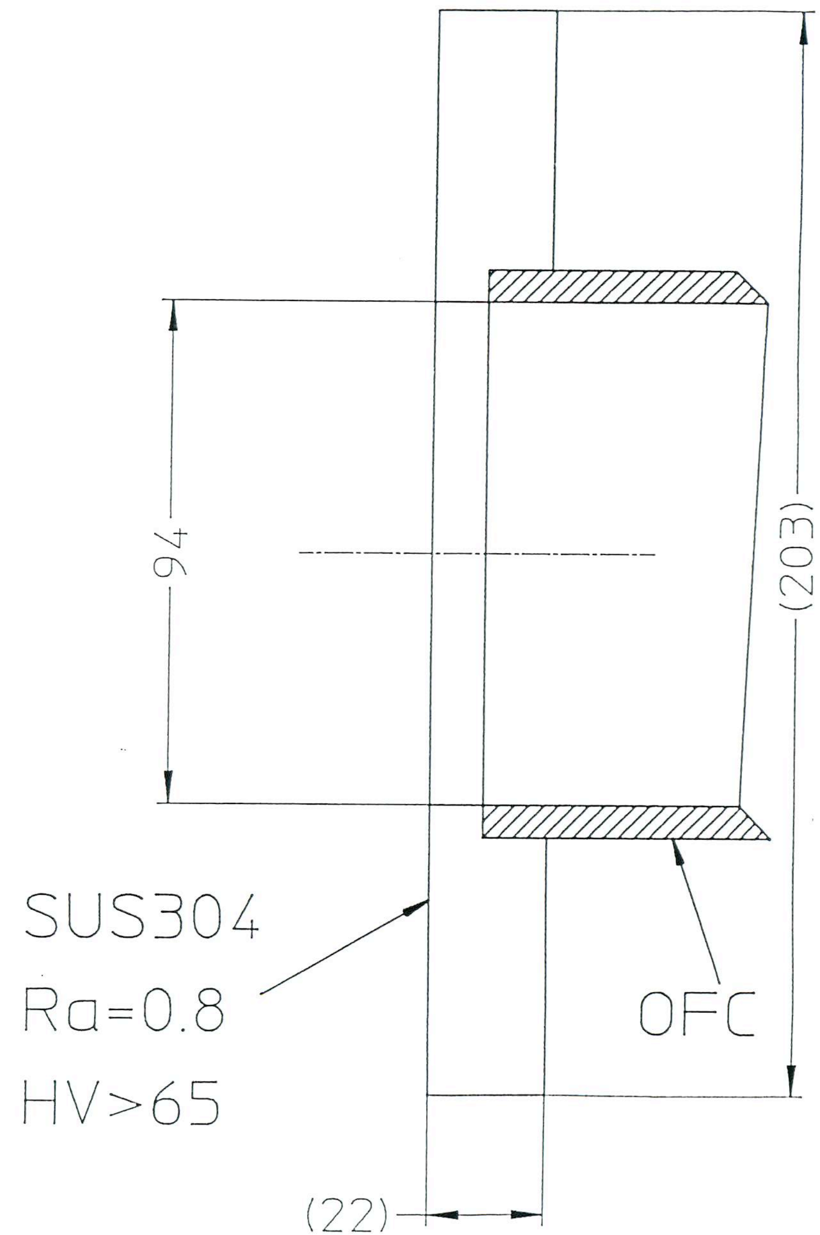
図番






Ø8.4 x 20
20
Ra<0.8
5 ±0.1
ϕ127
ϕ94
ϕ160
ϕ185
Helicoflex
HNV 200


Helicoflex
Al ring


94
(203)
SUS304
Ra=0.8
HV>65
OFC
(22)