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- LIGO -
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Presentation to LIGO Group

Title

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UHV qualification of VIRGO components

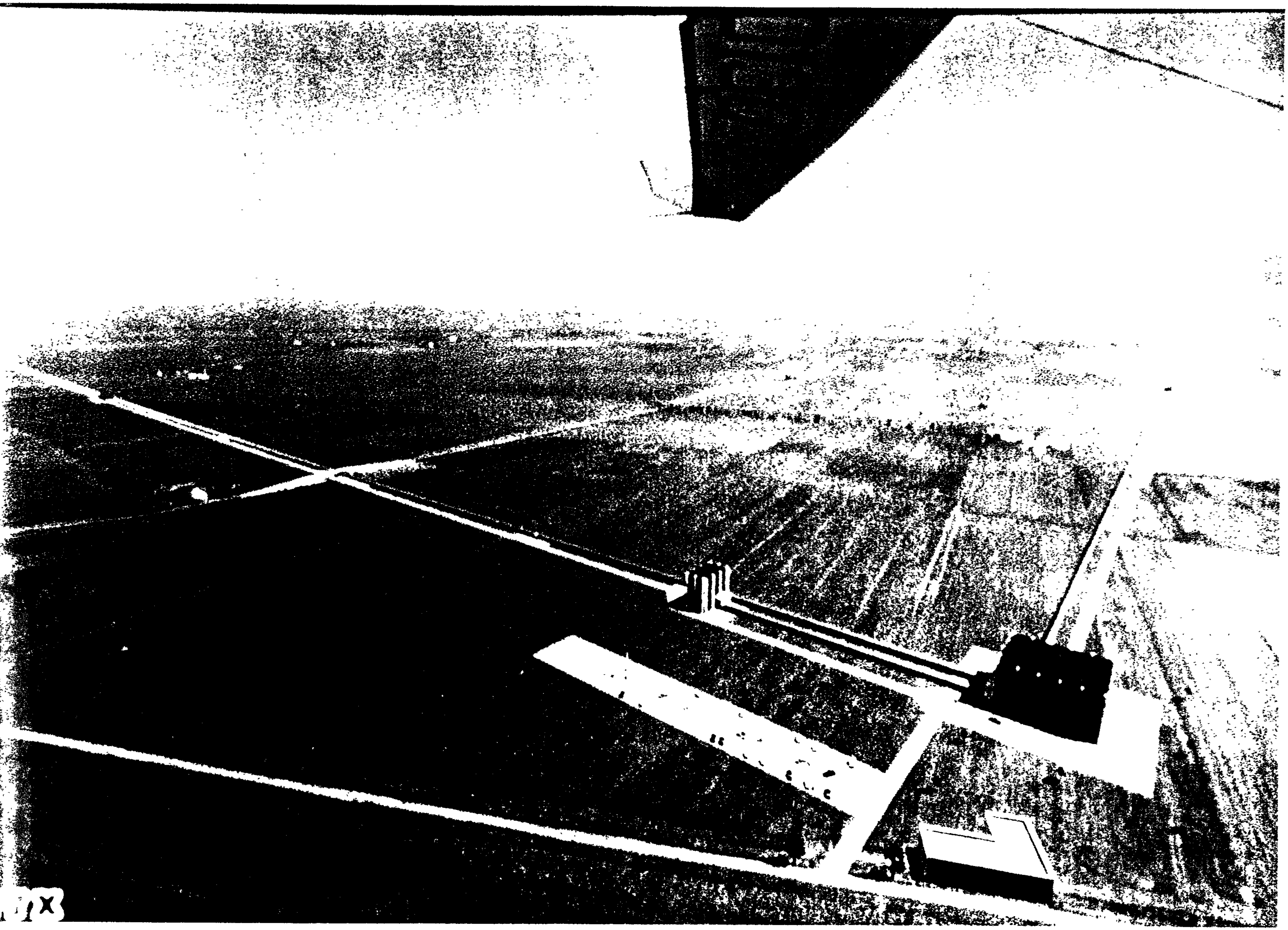
R. Poggiani
(VIRGO Pisa Vacuum Group)

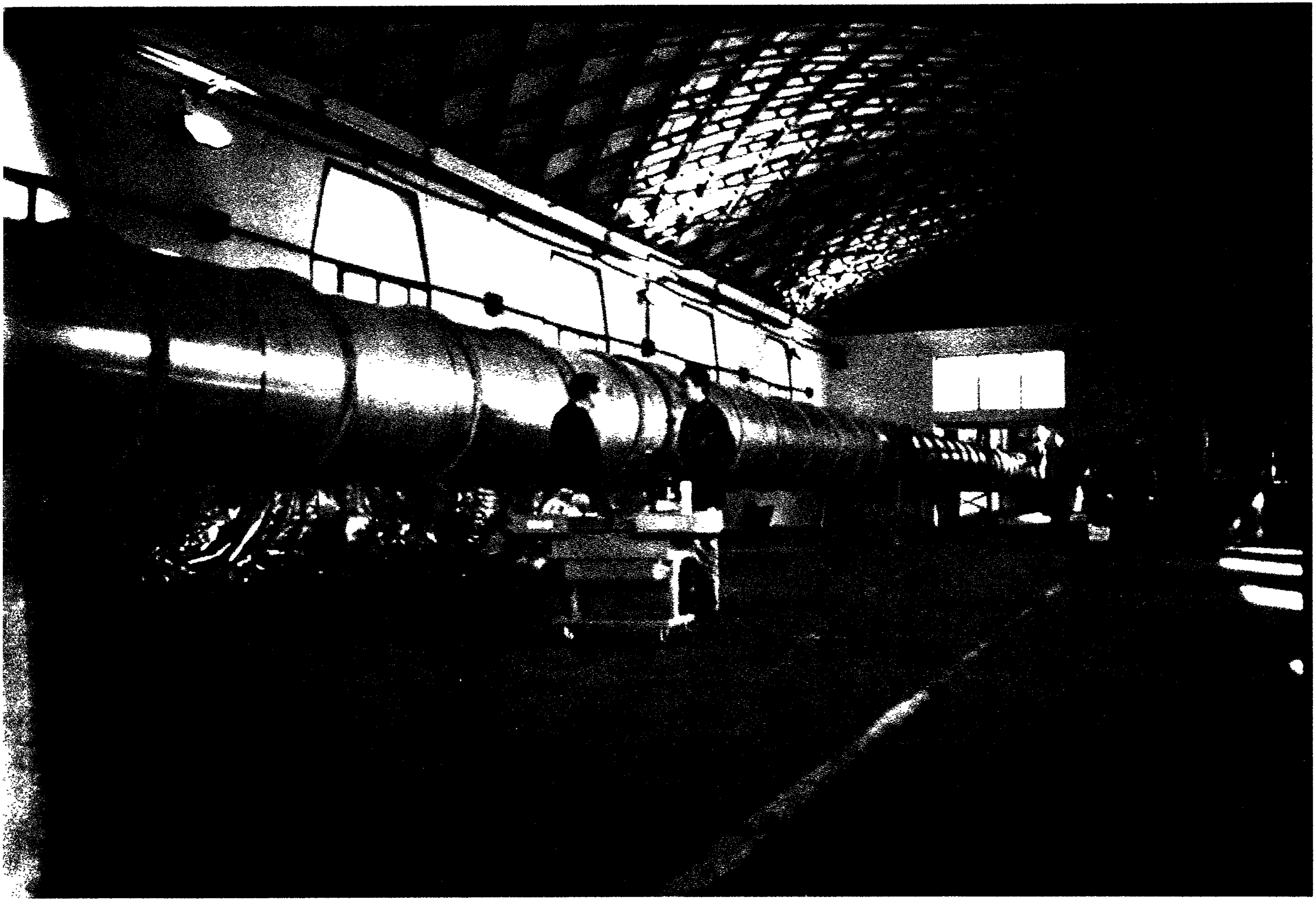
VIRGO Pisa Vacuum Group

- Physicists & Engineers : M. Bernardini, C. Bradaschia, H. B. Pan, A. Pasqualetti, R. Poggiani, Z. Zhang
- Technicians: R. Cosci, A. Ragonesi

VIRGO vacuum system

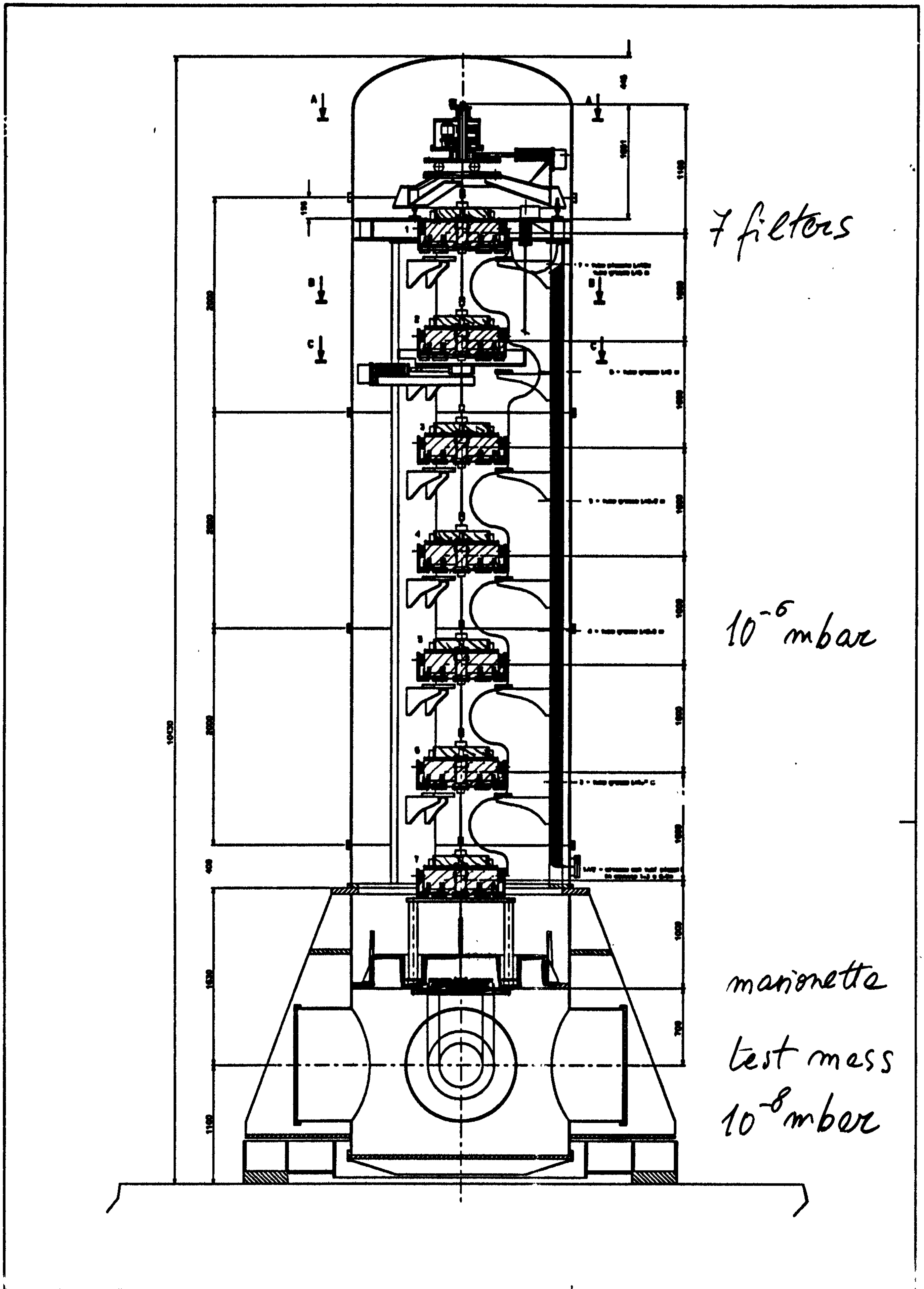
- Tube dimensions (each)
  - bore 1200 mm
  - length 3000 m
- Towers (each)
  - diameter 2000 mm
  - height 10000 mm
- Partial pressures:
  - hydrogen : $1.x10^{-7}$ mbar -> $1.x10^{-9}$ mbar
  - sum of all other gases : $1.x10^{-8}$ mbar -> $1.x10^{-10}$ mbar
  - hydrocarbons : $1.x10^{-14}$ mbar (single layer in 4 years)





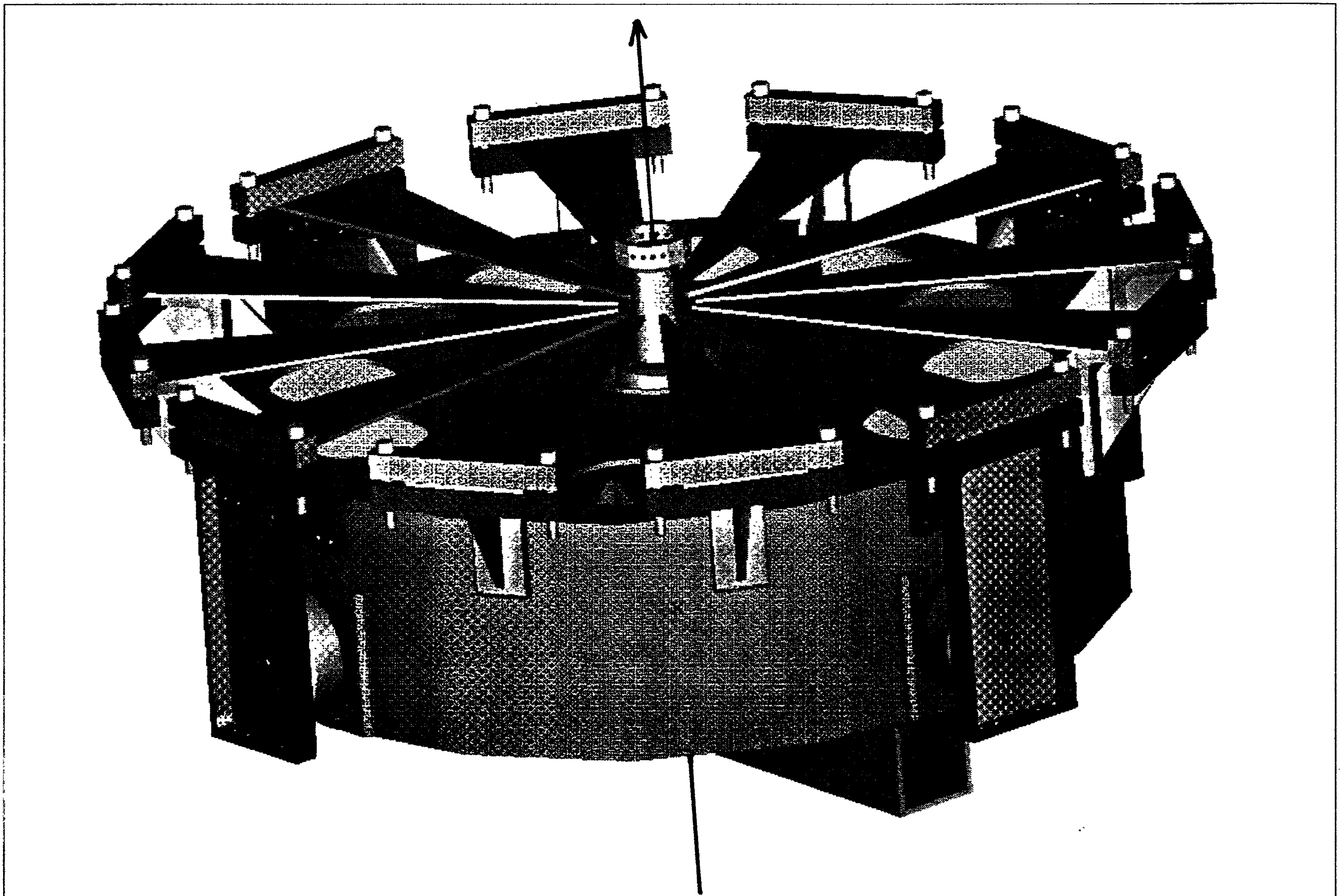
Seismic isolation: the superattenuator

- cascade of seven pendula providing attenuation of 40 dB (vertical and horizontal) each
- mirror steering system (marionetta)
- complex system involving a large number of components


7 filters
10^{-6} mbar
marionette
test mass
10^{-8} mbar

SDRC I-DEAS VI.i: Solid_Modeling 30-MAR-93 13:10:55

: new22 Units : SI
: No stored View Display : No stored Option
Assembly Bin: 5-NEW
19-BID+LAM+BELL+COL+CEN Update Level: Full



Vacuum compatibility

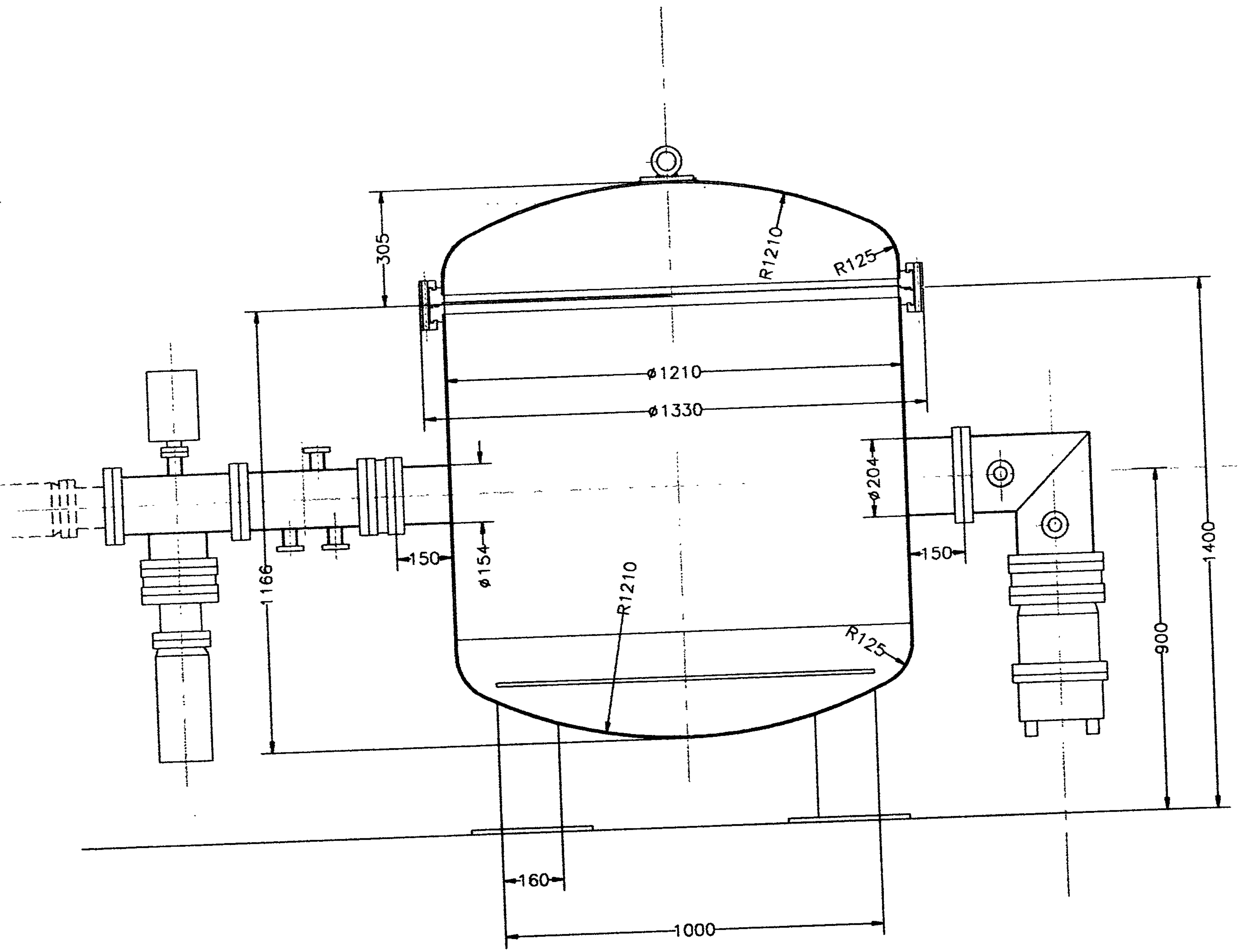
- screening methodology: measurement of the outgassing rate and composition
- necessity of a large number of tests during R&D phase for components selection
- outgassing of components before installation

Required tests

- superattenuator filters, marionetta
- signal cabling, coil wires (a few km for each tower)
  - different geometry: cables vs. ribbons
  - different insulation: Kapton, ceramic, PTFE...
- magnets: ferrite, rare-earth-magnets....
- glues: Torrseal, Vacseal....
- motors, gears and lubricants (grease and solid)
- *total number of candidate components is some tens*
- test on assembled filter and marionetta

Experimental facilities

- Large vacuum tank for superattenuator filters
- Three small systems (one in operation, two under installation)



305
R1210
R125
ø1210
ø1330
ø204
150
150
ø154
1166
R1210
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160
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26

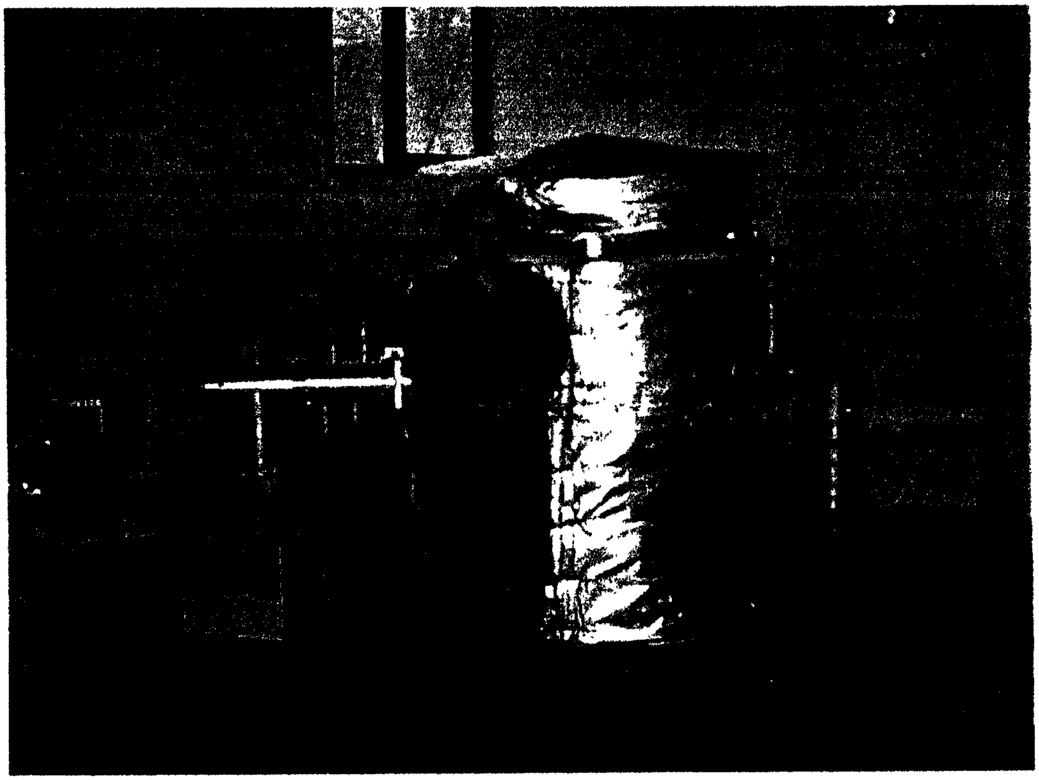
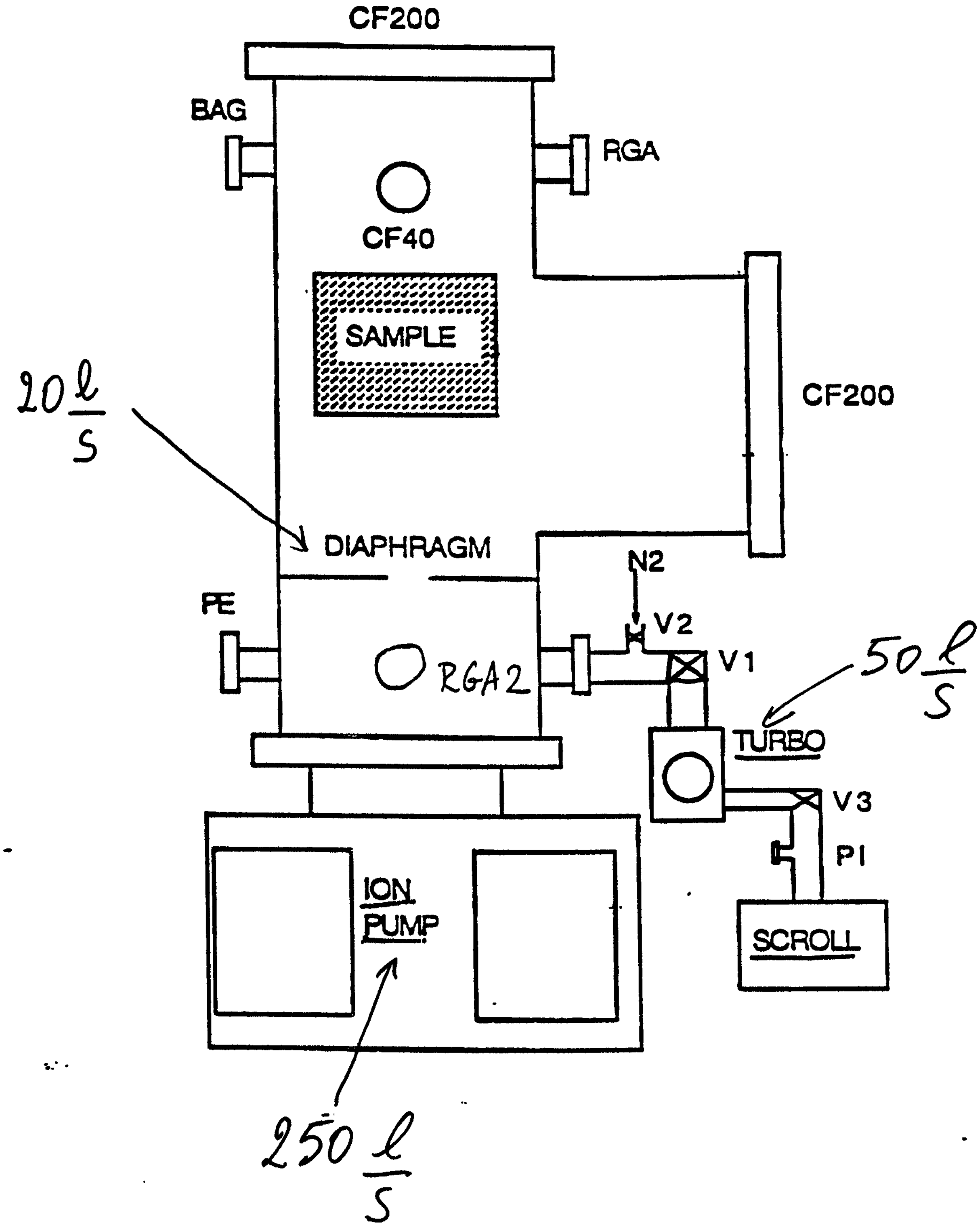
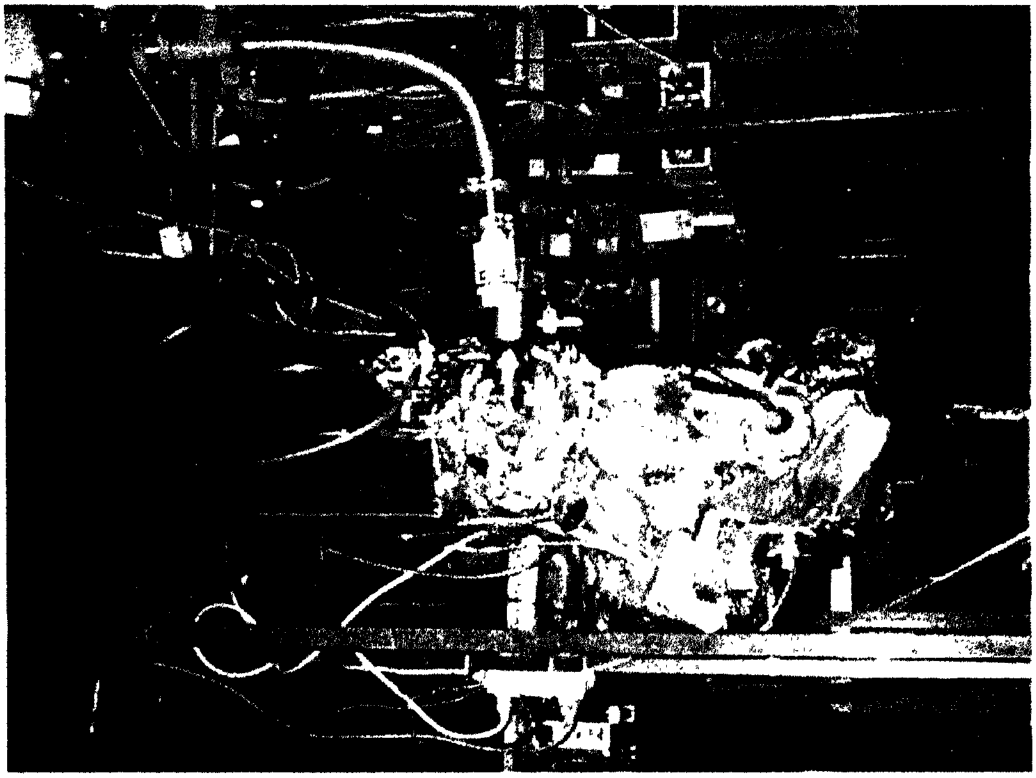


Figure 1. TEST SYSTEM





Measurement method

- outgassing flow is $Q = (P_1 - P_2)\ C$
- base pressure 1.3×10^{-6} mbar after 15h pumping, unbaked
- base pressure 1.7×10^{-9} mbar after 144h baking

Components tested to date

- Kapton insulated cables
- Alumina insulated cables
- Torrseal
- Vacseal
- Ferrite magnets
- Krytox
- AML motors

Kapton

- 30 m Kapton cabling, 0.25 mm diameter conductor diameter, 0.12 mm insulation thickness
- Manufactured by Raydex CDT, UK, distributed cleaned for vacuum by Caburn MDC, UK

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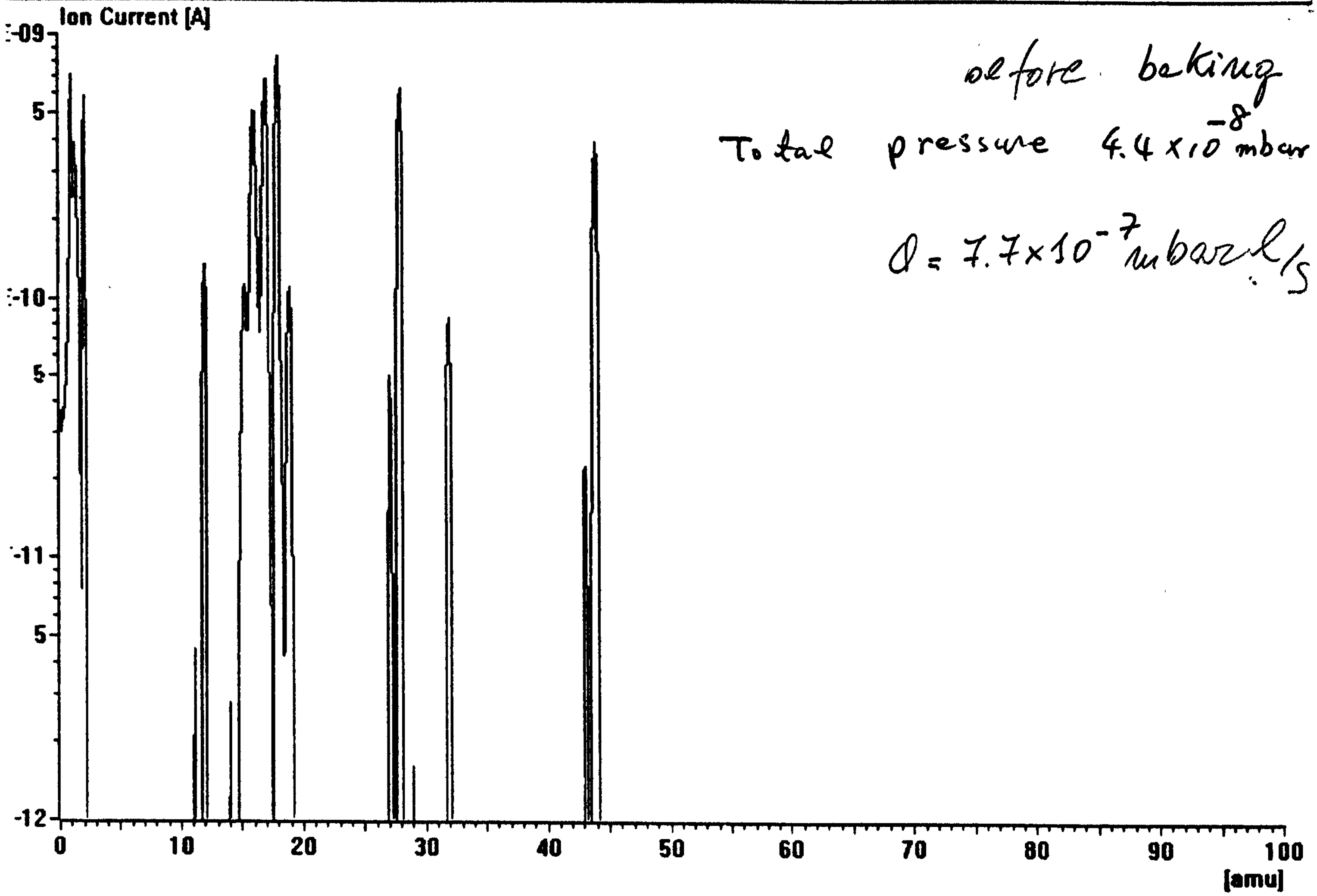


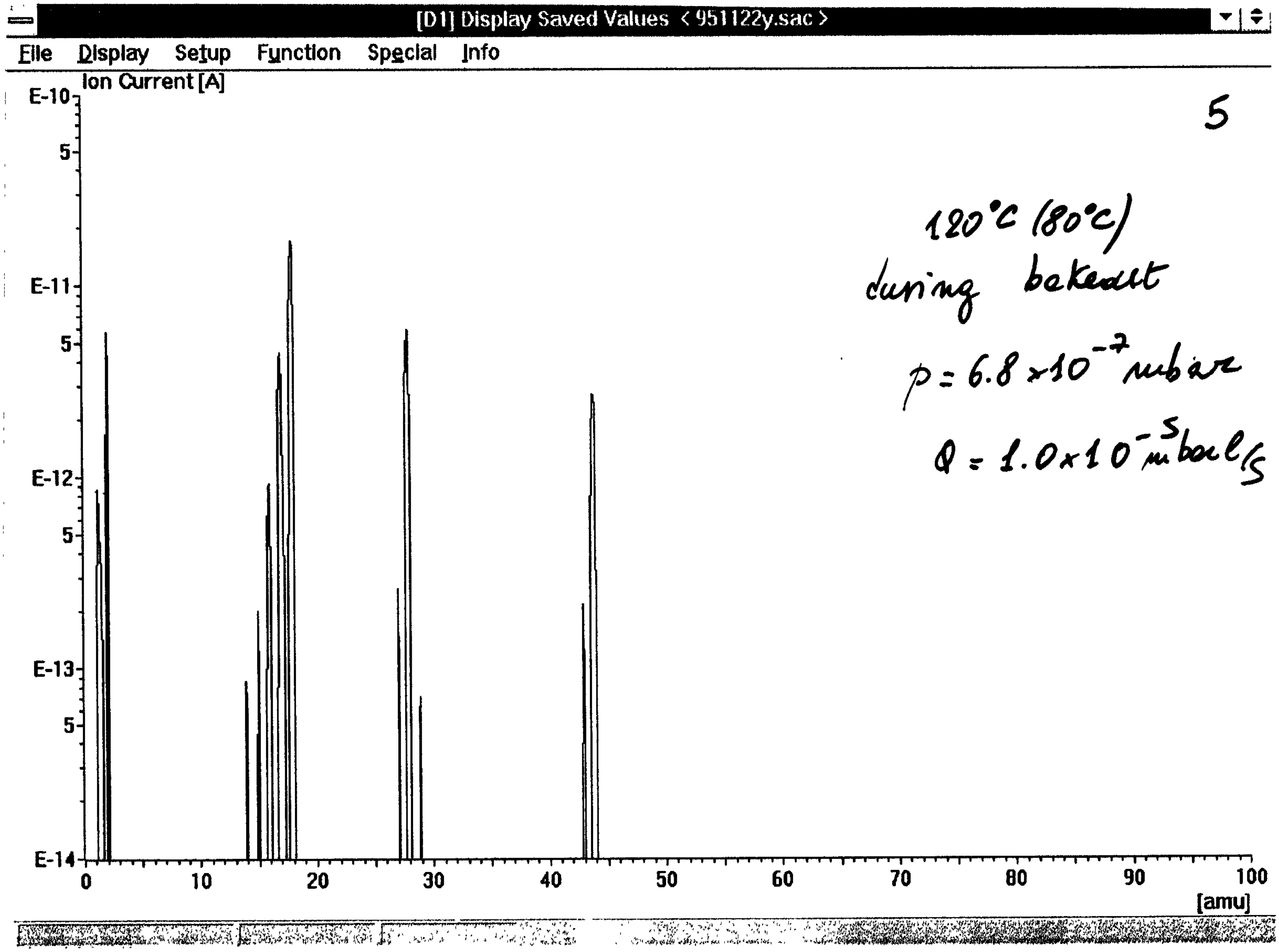
X: 64.06 Y: 5.776997E-11

before baking

Total pressure 4.4×10^{-8} mbar

$Q = 7.7 \times 10^{-7}$ mbar l/s

Kapton wires



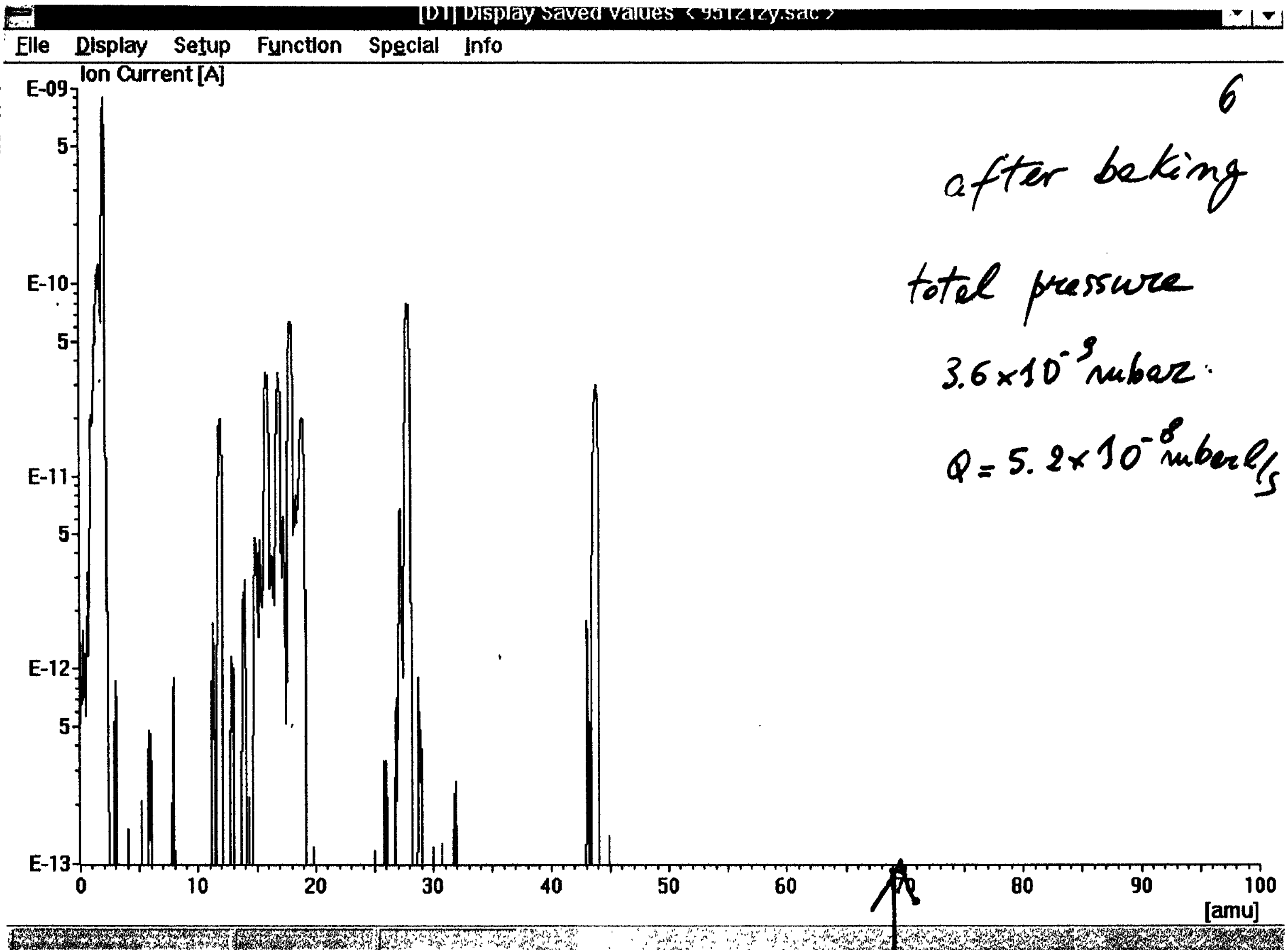
5

120°C (80°C)
during bakeout

$p = 6.8 \times 10^{-7}$ mbar

$Q = 1.0 \times 10^{-5}$ mbar l/s

Kapton wires



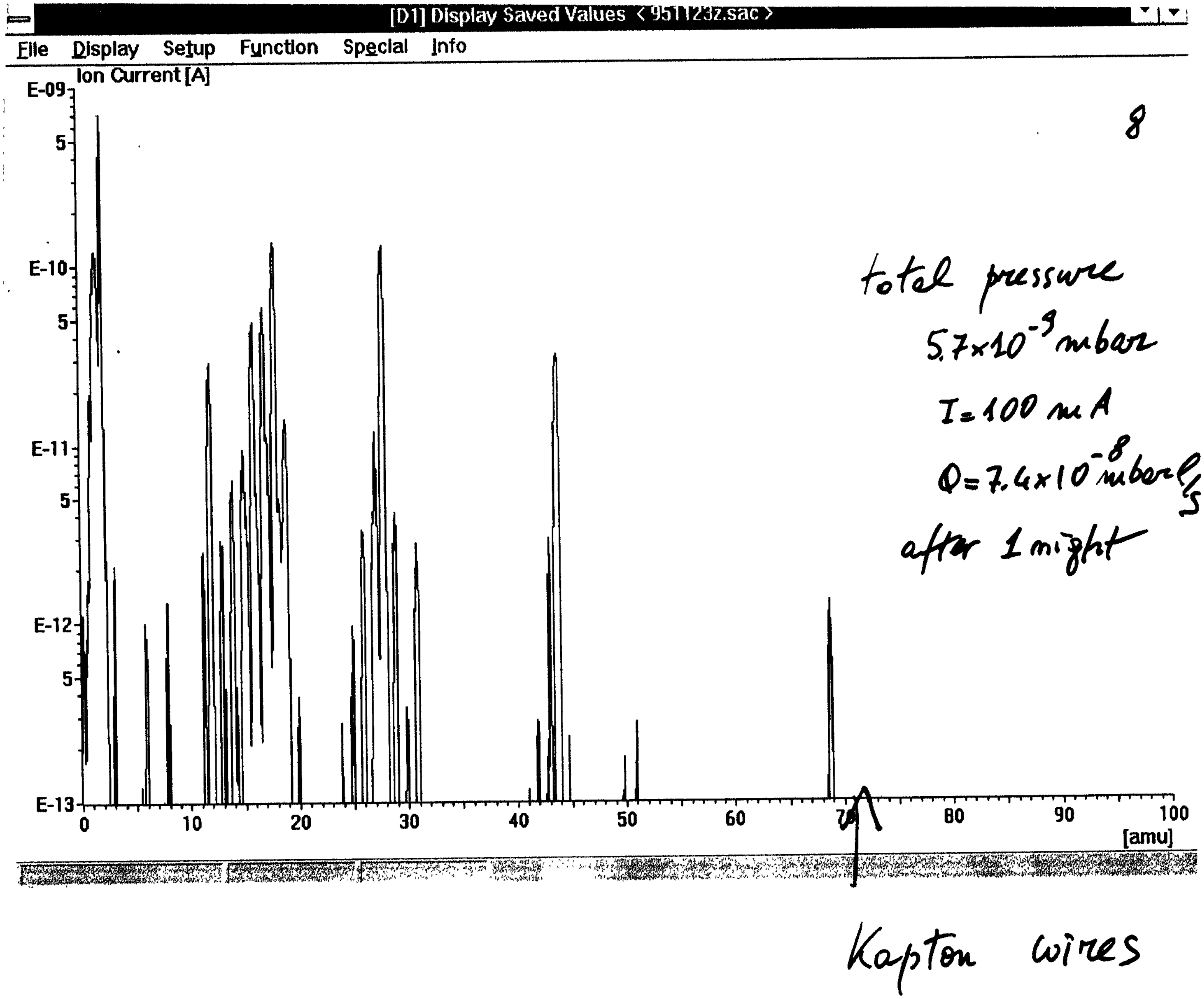
after baking

total pressure

3.6×10^{-9} mbar

$Q = 5.2 \times 10^{-8}$ mbar l/s

Kapton wires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E-11
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E-12
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E-13
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30
40
50
60
70
80
90
100
[amu]
8
total pressure
5.7×10^-9 mbar
I=100 mA
Q=7.4×10^-8 mbar l/s
after 1 night
Kapton wires

Kapton cabling

	$Q\left(\frac{mbar\ l}{s\ cm^2}\right)$
no baking, 72h pumping	1.5×10^{-3}
during baking	2.0×10^{-8}
after baking.	1.1×10^{-10}
after baking, 0.1W	1.5×10^{-10}

use Kapton without
FEP layer

Recommended

Alumina

- 50 m alumina insulation cabling, 0.5 mm diameter with 10 micron alumina thickness
- Manifactured by Dispol Chemicals, Japan

セラメッキ

（無機被覆電線シリーズ）

CERAMICS-COATED WIRE

セラメッキ電線

セラメッキ電線（セラミックス被覆電線）は、ディップソールのセラメッキ技術により電線の表面に絶縁体としてセラミックスを電解析出させた新商品です。

■ 特長

- 優れた電気絶縁性があります。
- 可とう性があるので、小口径のコイリング性にすぐれています。
- 絶縁皮膜が薄いので、スペースファクターが良好となります。
- 低温から高温までの熱変化によく耐えます。
- ガス放出が少ないため、超高真空中で使用できます。
- ガリウム、ハロゲンなどの腐食性雰囲気によく耐えます。

■ 用途

真空、放射線雰囲気、腐食性ガス、耐熱性の要求される環境下での信号線、マグネットコイルなど。

■ 特性

表1．皮膜種類と絶縁破壊電圧

皮膜種類	芯　線	標準電導率（銅線100%）	絶縁破壊電圧 2個より法（JIS）
α アルミナ セラメッキ （15μm）	アルミ	60	320 V
	銅・アルミクラッド	76	
	銅・カーボン・アルミクラッド	77	
シリケート セラメッキ （15μm）	アルミ	60	310 V
	銅・アルミクラッド	76	
	銅・カーボン・アルミクラッド	77	

芯線径は、0.5、0.8、1.0mmは常時在庫があります。
上記以外の仕様も製作に応じております。

Outgassing data

図1「セラメッキ」の超高真空特性

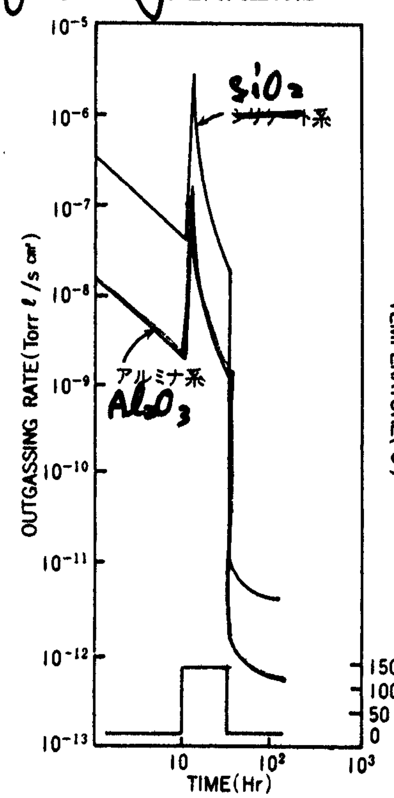


表2．銅芯電線の耐熱性

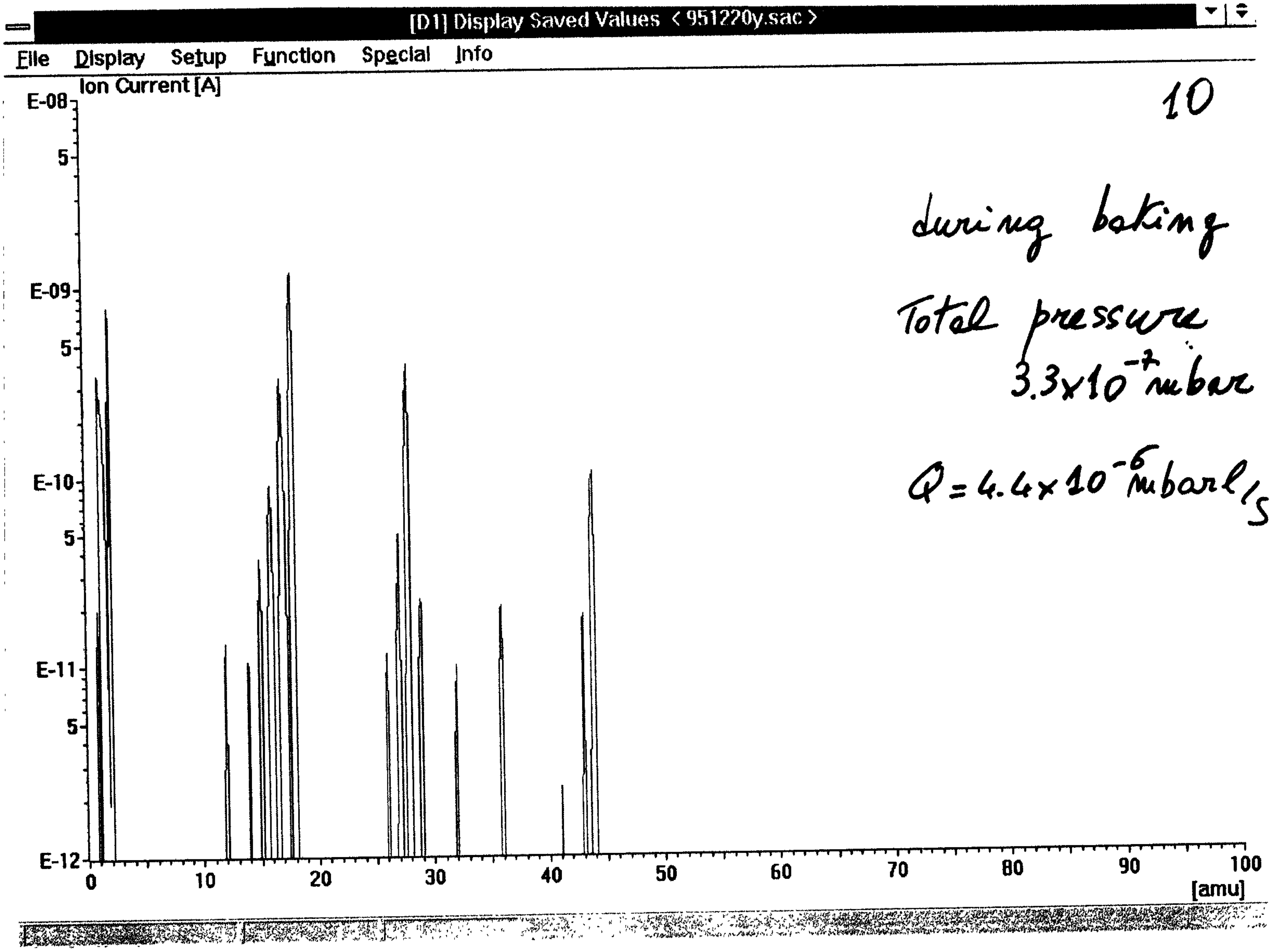
銅芯の場合、高温で使用すると次第に合金層が成長し電導率が低下してきます。下表は初期の電導率より10%低下するまでの予測期間です。

使用温度（℃）	200	250	300	400
銅芯・アルミクラッド	10年	2年	1000時間	
銅芯・カーボン・アルミ			2年	1000時間

- アルミ素材のボビンは「セラメッキ」処理で絶縁加工後セラメッキ電線を巻く方法が効果的です。
- 高真空用特殊圧着端子も取り扱っております。
- 上記各種データは保証値ではありません。

factory specs

ディップソール株式会社



10

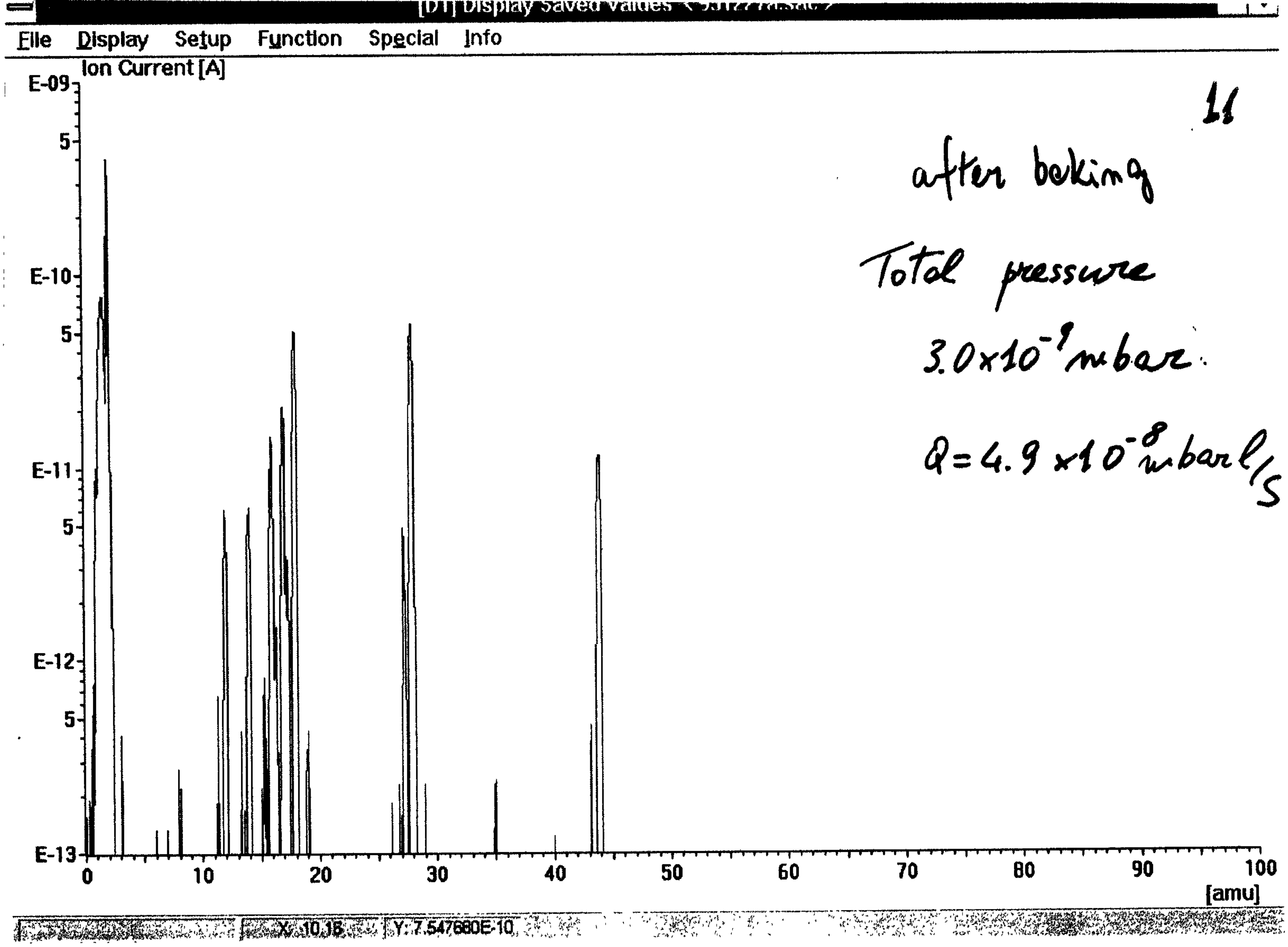
during baking

Total pressure 3.3×10^{-7} mbar

$Q = 4.4 \times 10^{-6}$ mbar l/s

Ceramic wires

11



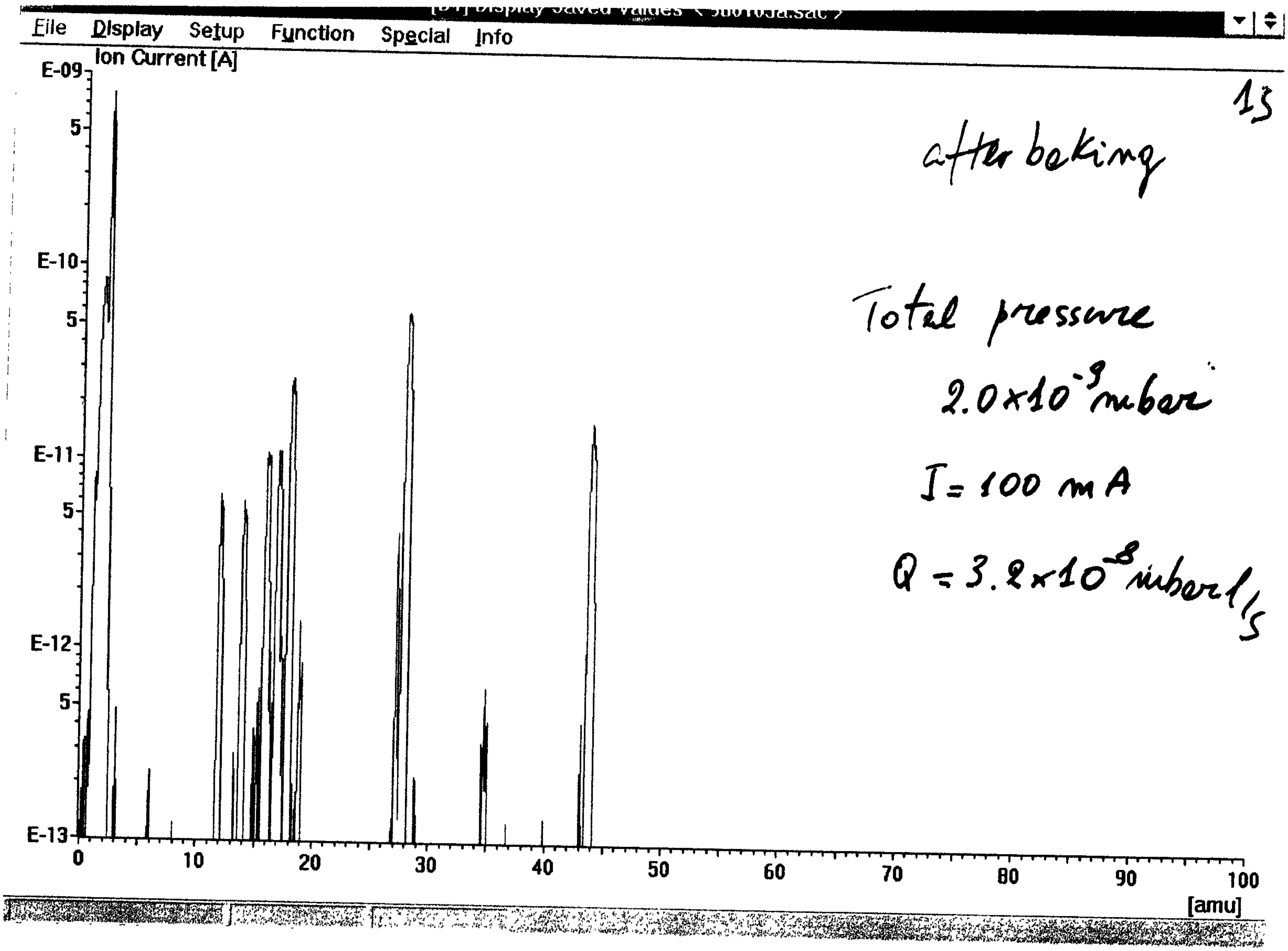
after baking

Total pressure

3.0×10^{-9} mbar

$Q = 4.9 \times 10^{-8}$ mbar l/s

Ceramic wires



13

after baking

Total pressure
2.0×10^{-9} mbar

$I = 100$ mA

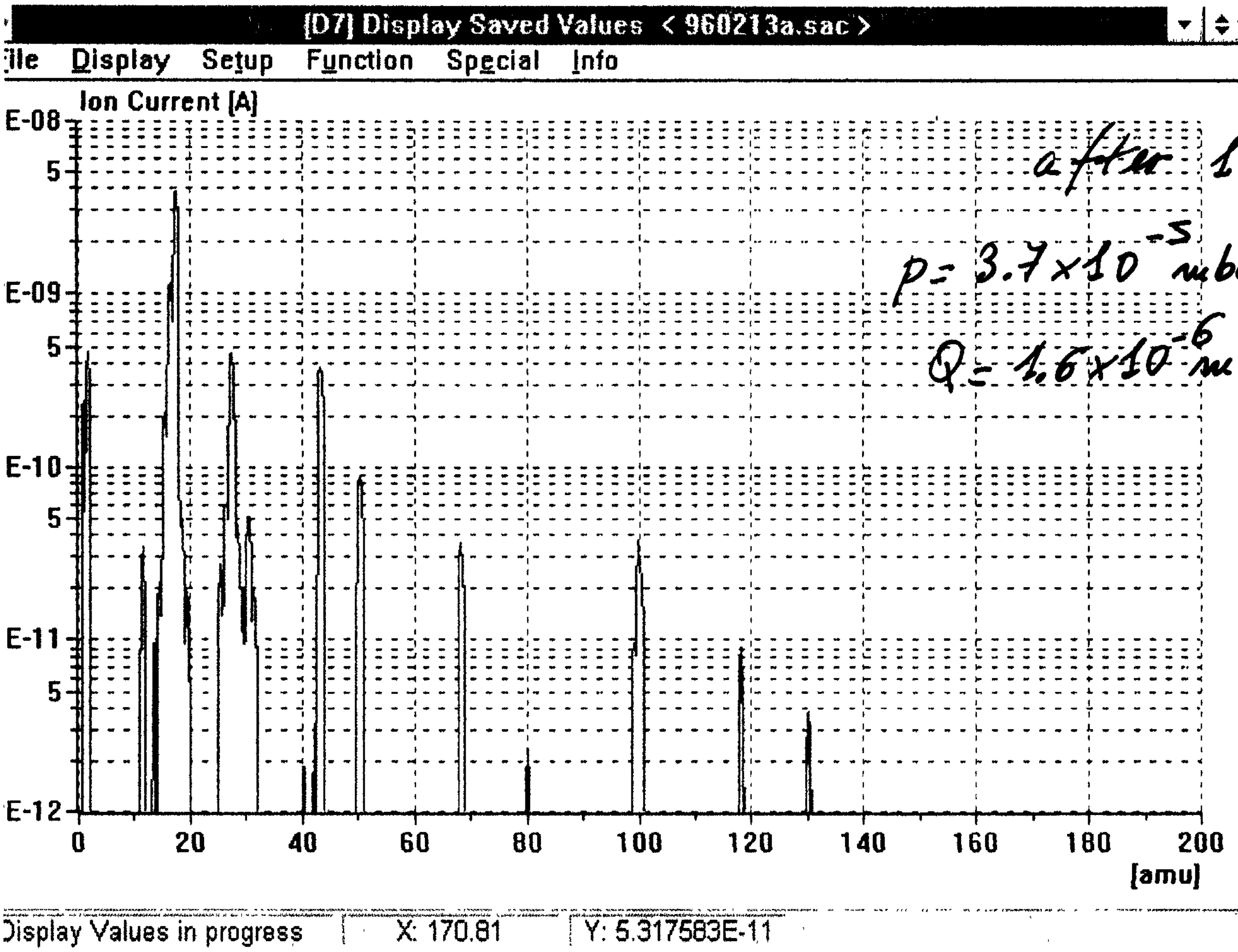
$Q = 3.2 \times 10^{-8}$ mbar l/s

Ceramic wires

Alumina cabling

	$Q\ \left(\frac{mbar\ l}{s\ cm^2}\right)$
no baking, 72h pumping	5.8×10^{-10}
during baking	5.6×10^{-9}
after baking	4.7×10^{-11}
after baking, 0.2 W	4.1×10^{-12}

Recommended

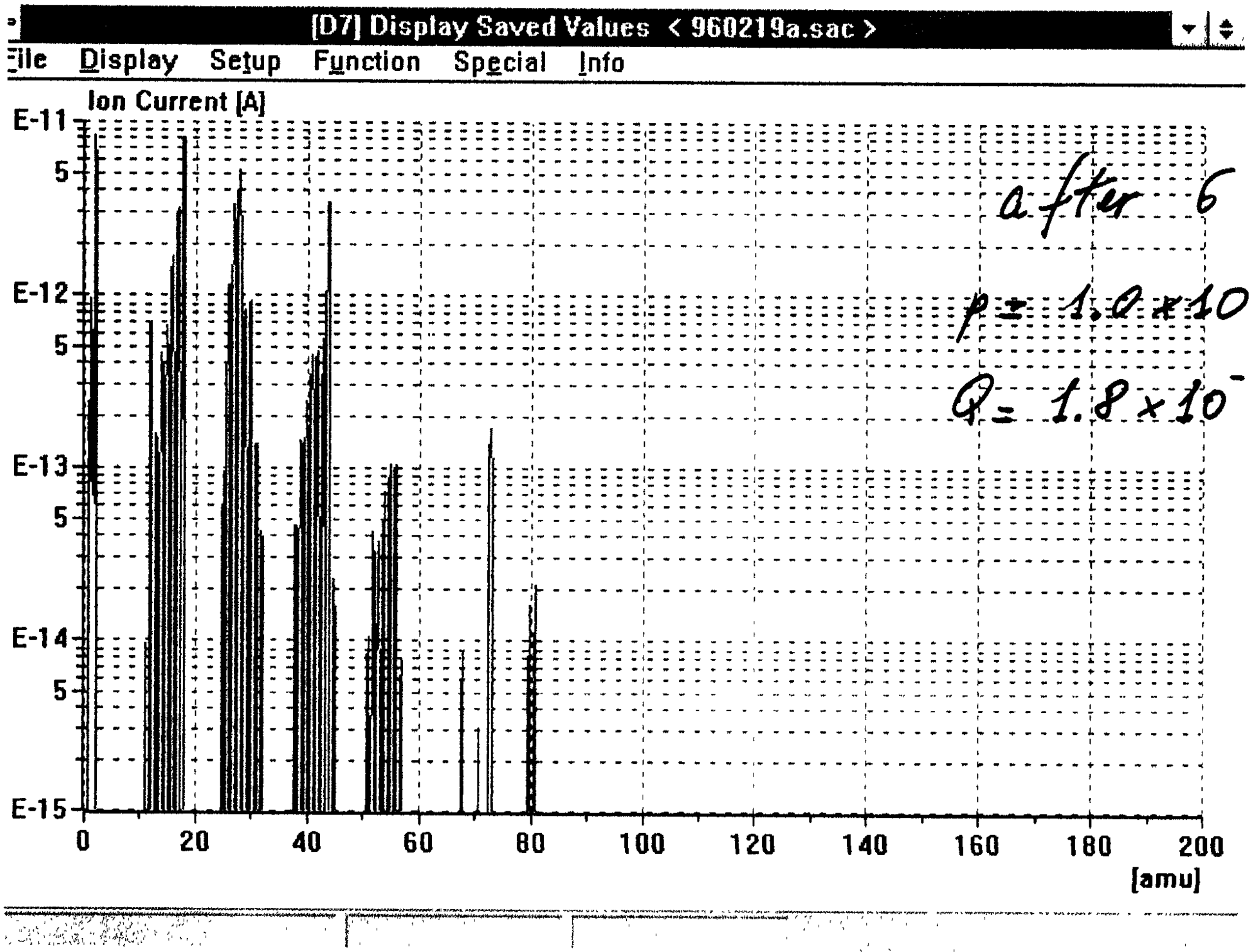


after 1 h

$p = 3.7 \times 10^{-5}$ mbar

$Q = 1.6 \times 10^{-6}$ mbar l/s cm^2

Torrseal



after 6 days

$p = 1.0 \times 10^{-6}$ mbar

$Q = 1.8 \times 10^{-7}$ mbar l/s cm^2

Torrseal

Torrseal

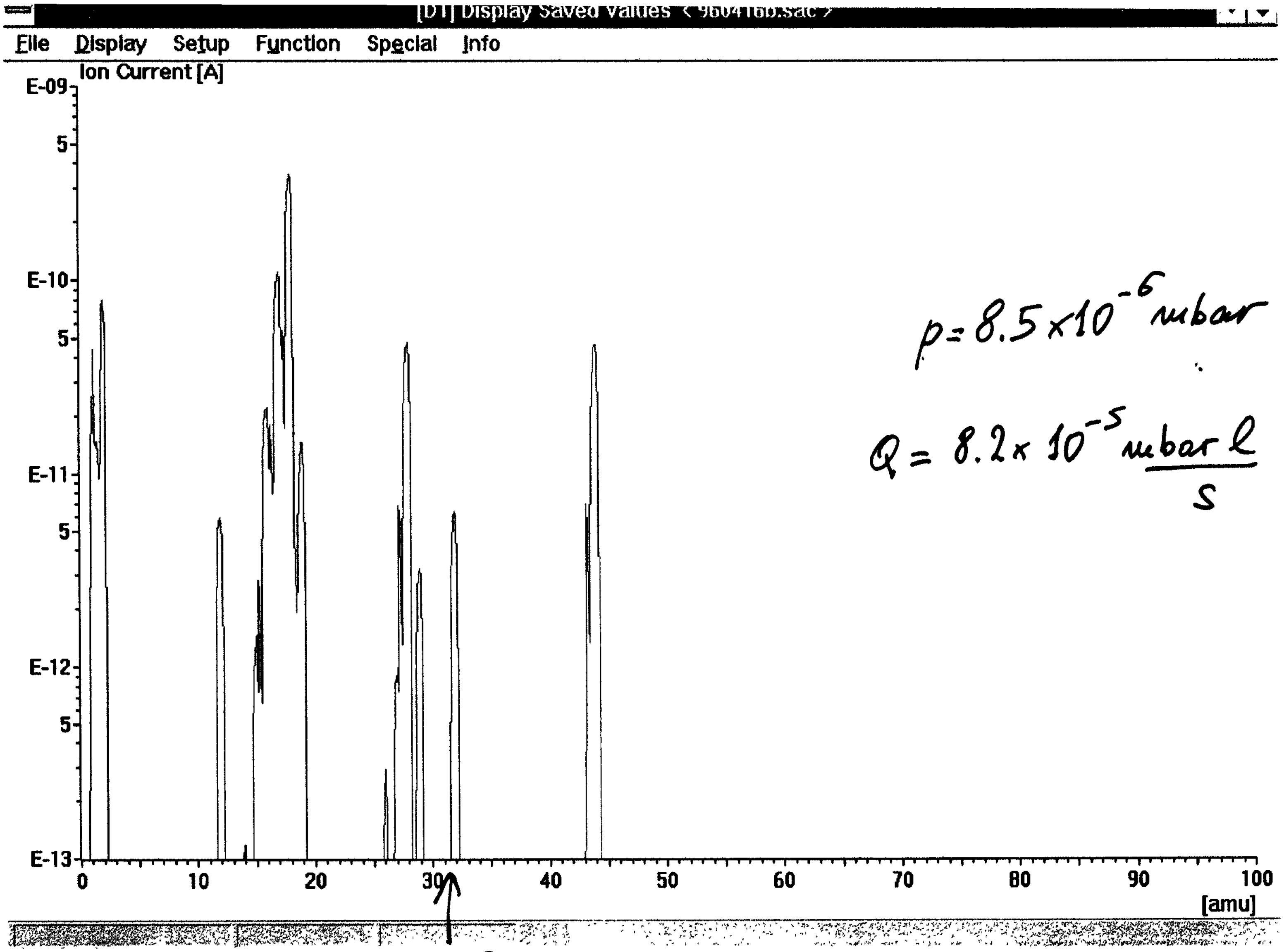
room temperature curing

$Q\left(\frac{mbar\ l}{s\ cm^2}\right)$

after 1^h	1.6×10^{-6}
after 145^h	1.8×10^{-7}

evidence of organic contamination

not recommended



$p = 8.5 \times 10^{-6}$ mbar

$Q = 8.2 \times 10^{-5} \frac{\text{mbar } \ell}{\text{s}}$

32

Vacseal

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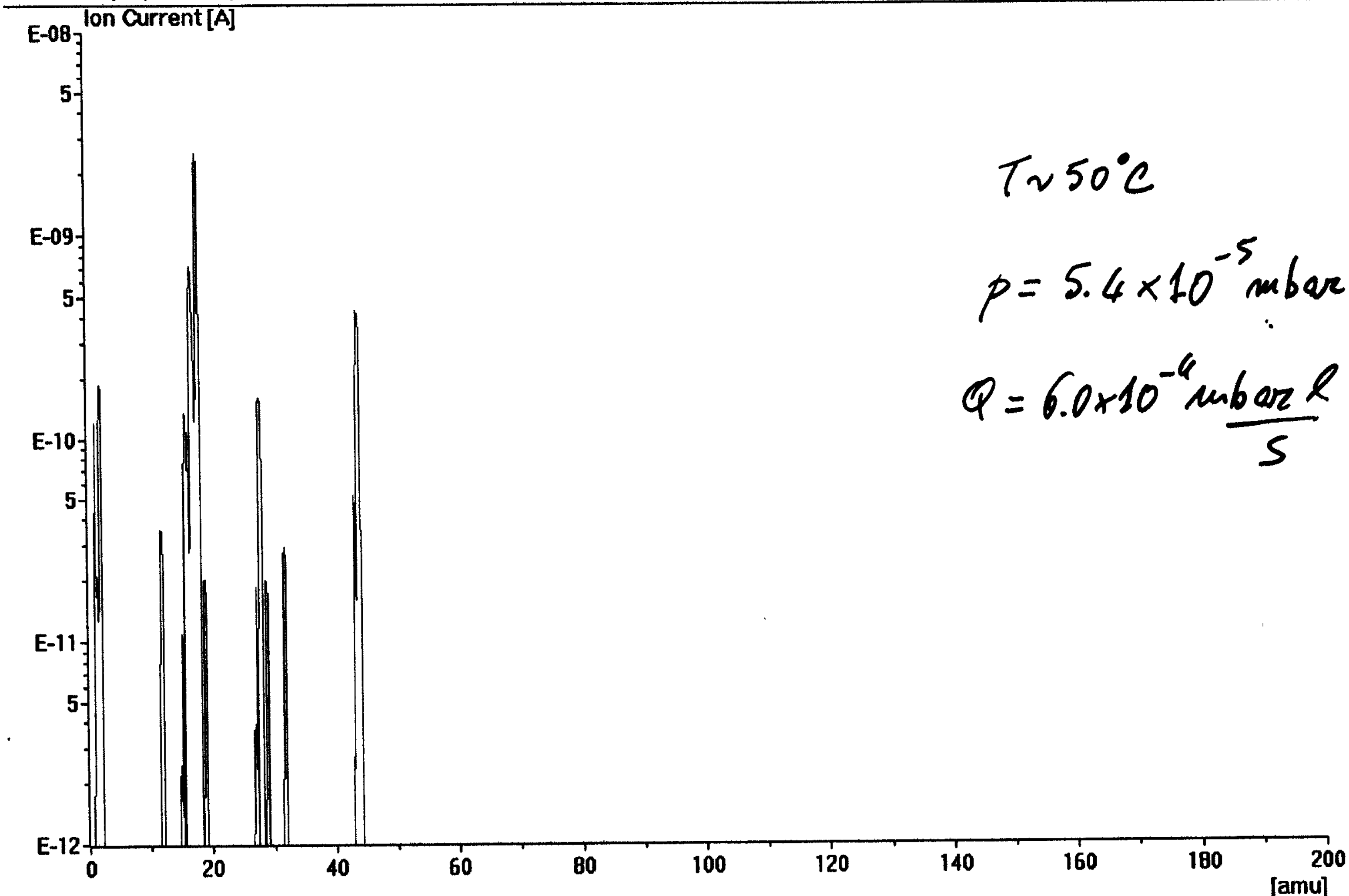
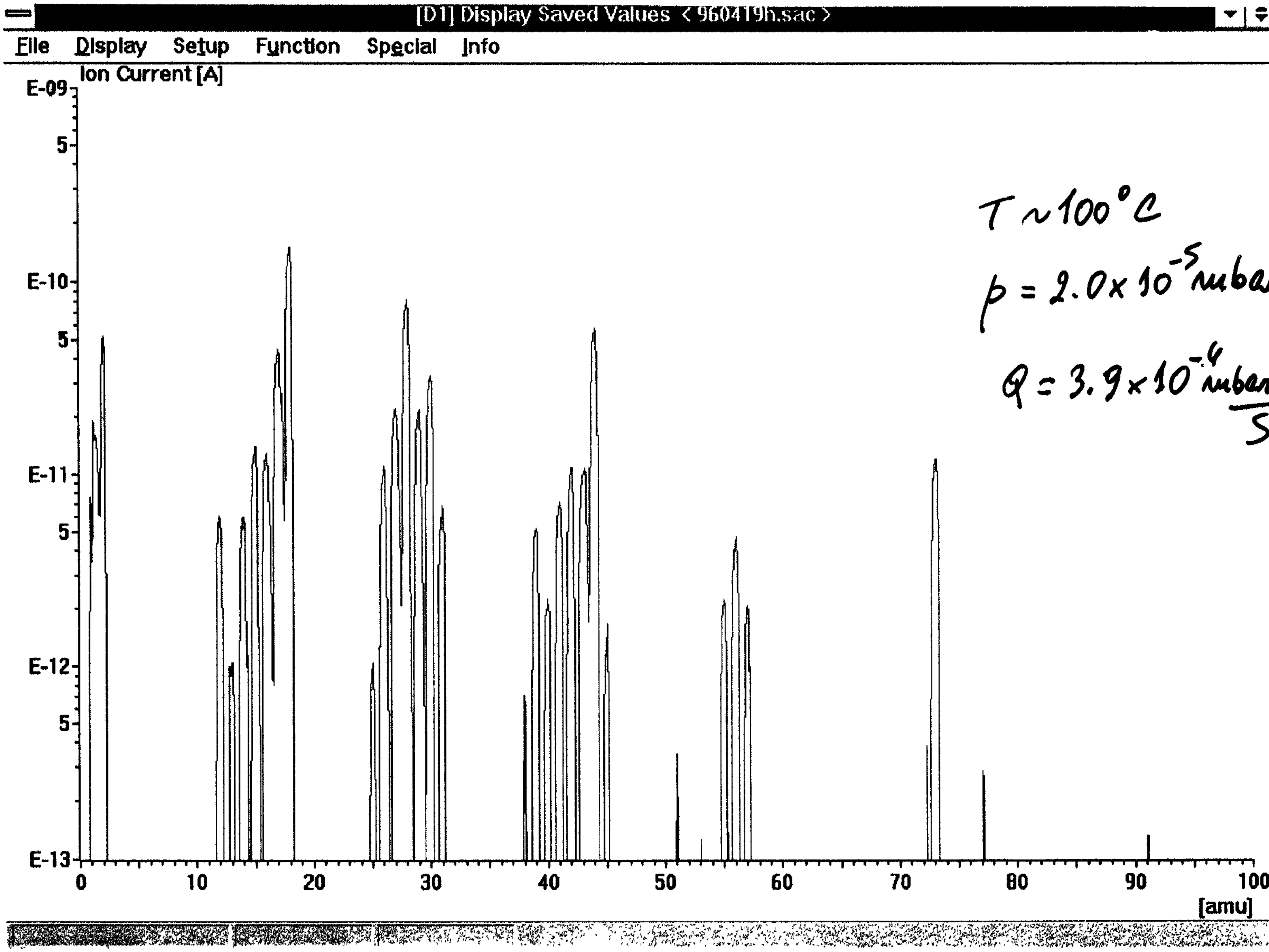


T ~ 50°C

$p = 5.4 \times 10^{-5}$ mbar

$Q = 6.0 \times 10^{-4}$ $\frac{\text{mbar l}}{\text{s}}$

Vacseal

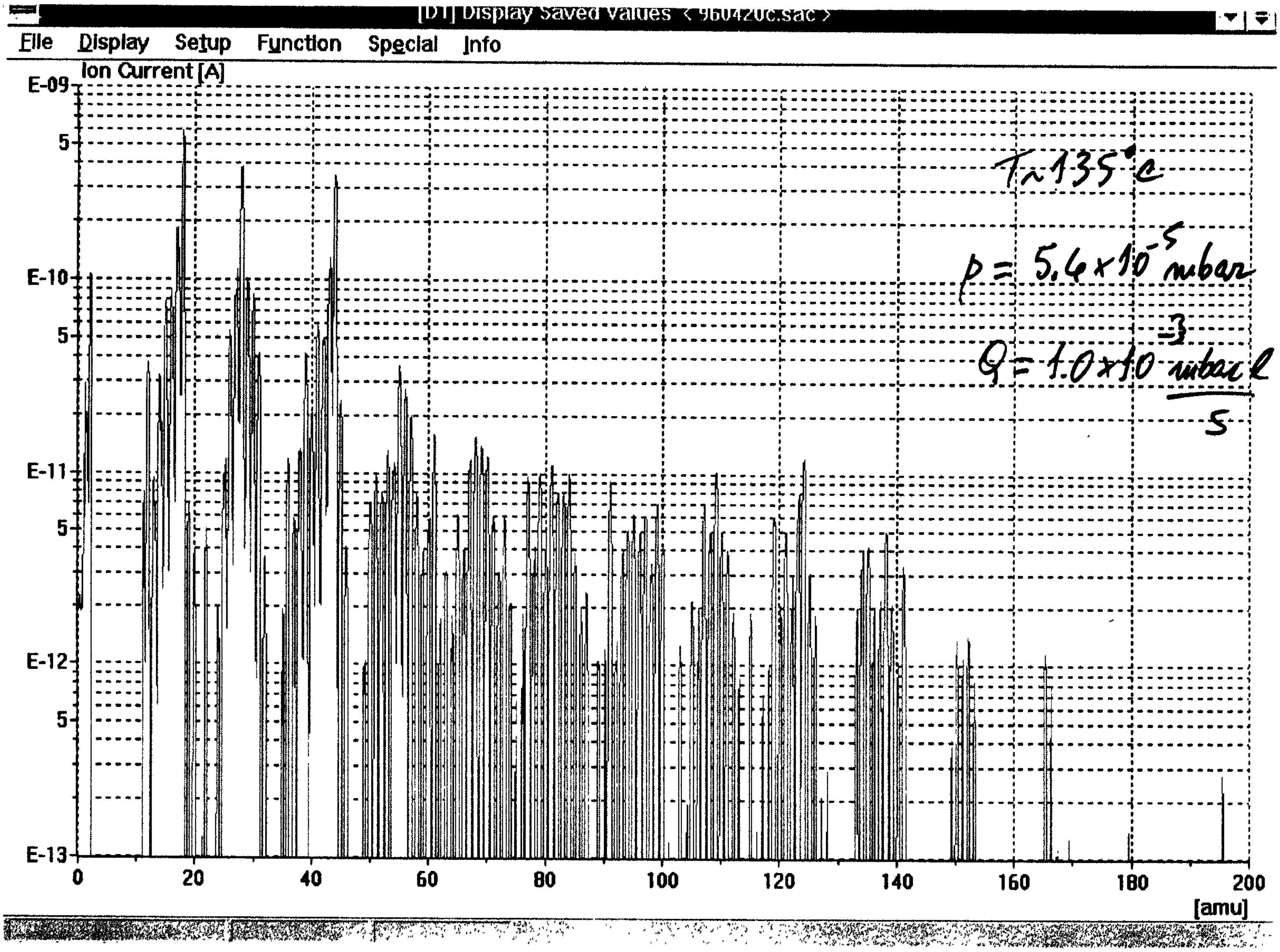


T ~ 100 °C

$p = 2.0 \times 10^{-5}$ mbar

$Q = 3.9 \times 10^{-4} \frac{\text{mbar l}}{\text{s}}$

Vacseal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E-10
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E-11
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E-12
5
E-13
0 20 40 60 80 100 120 140 160 180 200
[amu]
T~135°C
p = 5.6×10⁻⁵ mbar
Q = 1.0×10⁻³ mbar l / s

Vacseal

Vacseal

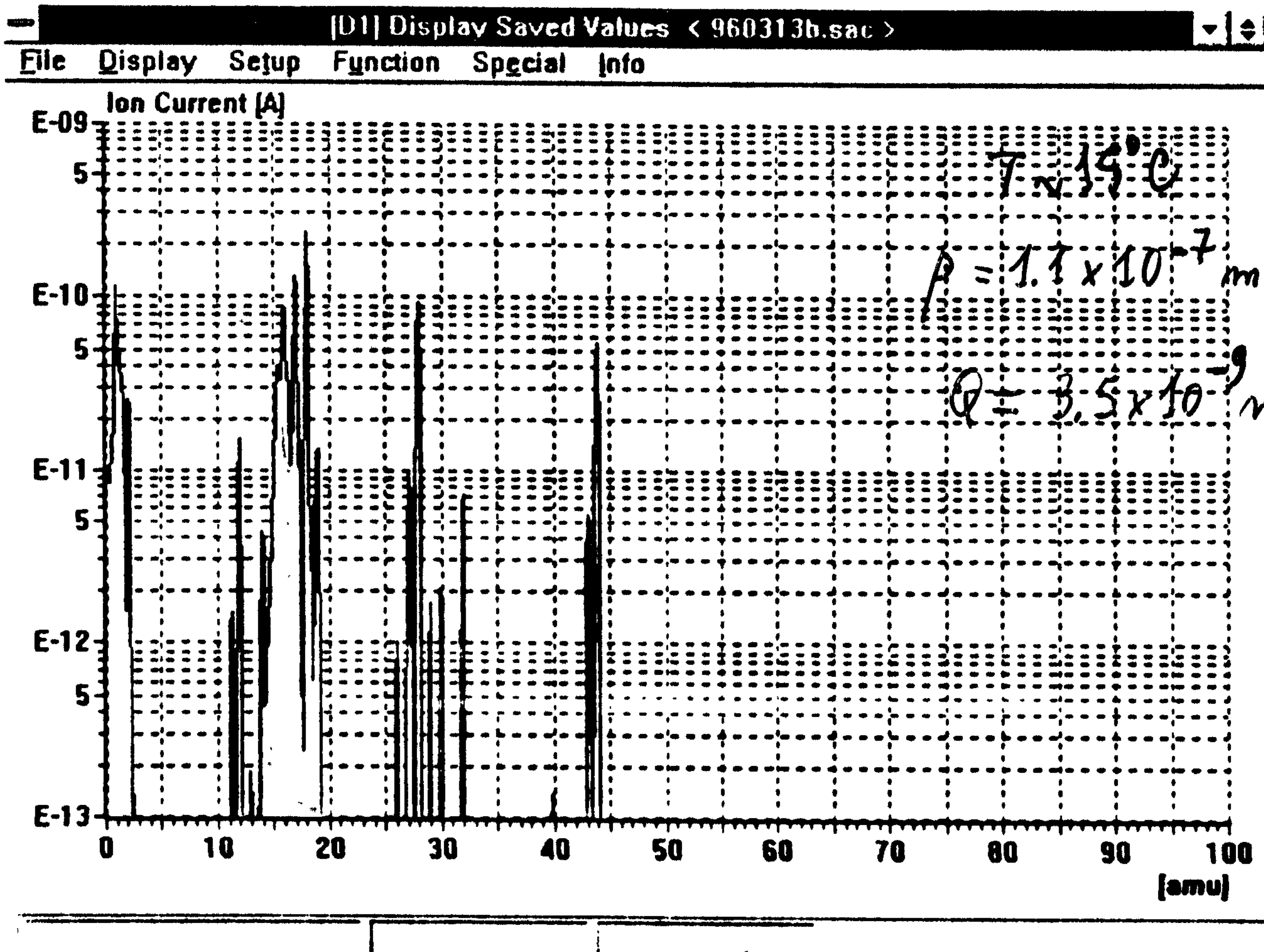
	$Q \left(\frac{mbar\ l}{s\ cm^2} \right)$
100°C	9.8×10^{-6}
135°C	2.5×10^{-5}
after baking	5.2×10^{-10}

to be used at moderate temperature

recommended

Ferrite magnets

- Phillips Ferroxdure 330 (strontium ferrite)
- two different cleanings methods
  - alkaline soap cleaning + baking at 150 ^{0}C in air
  - baking at 150 ^{0}C in air

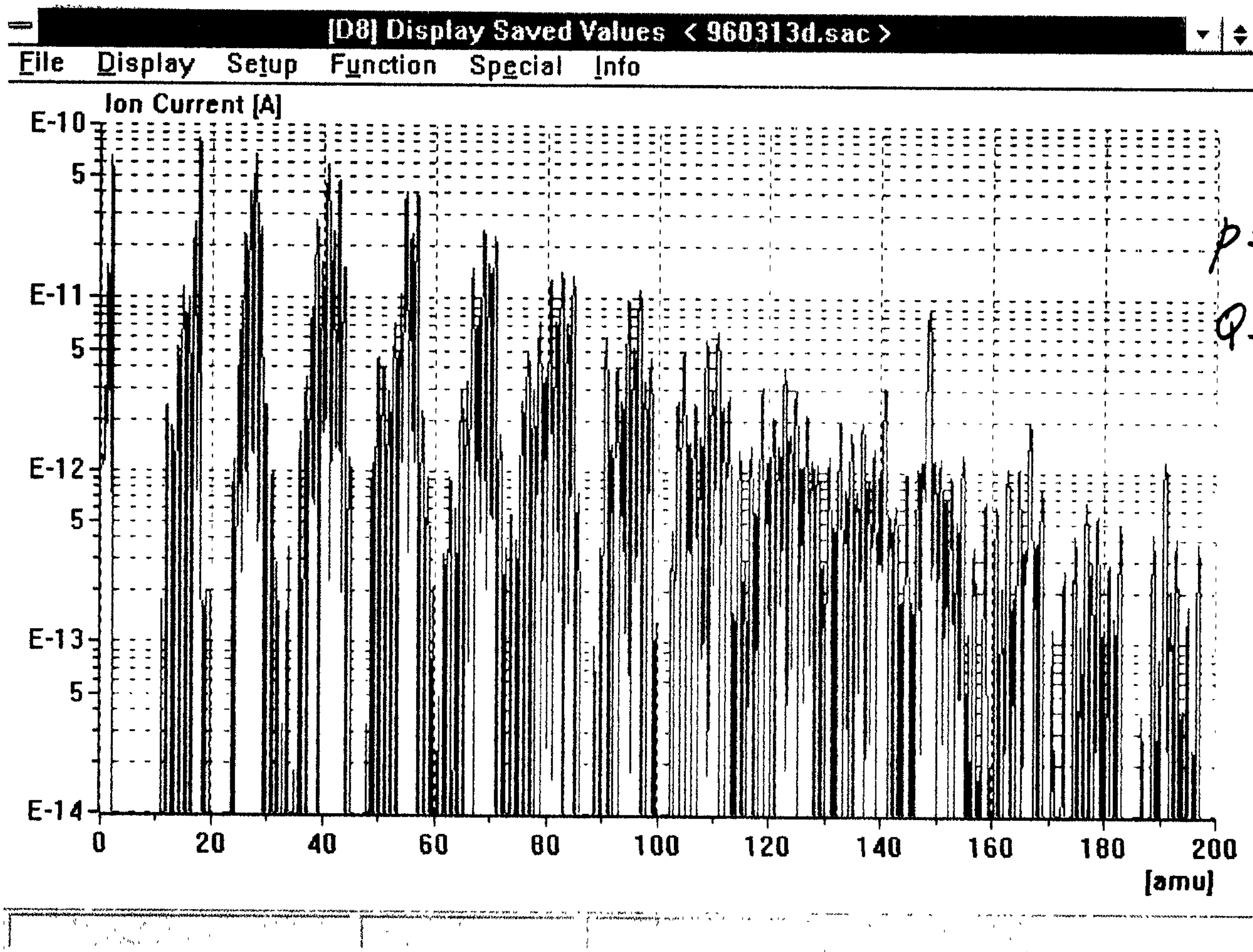


$T \approx 15°C$

$p = 1.1 \times 10^{-7}$ mbar

$Q = 3.5 \times 10^{-9}$ mbar l/s cm^2

magnets A

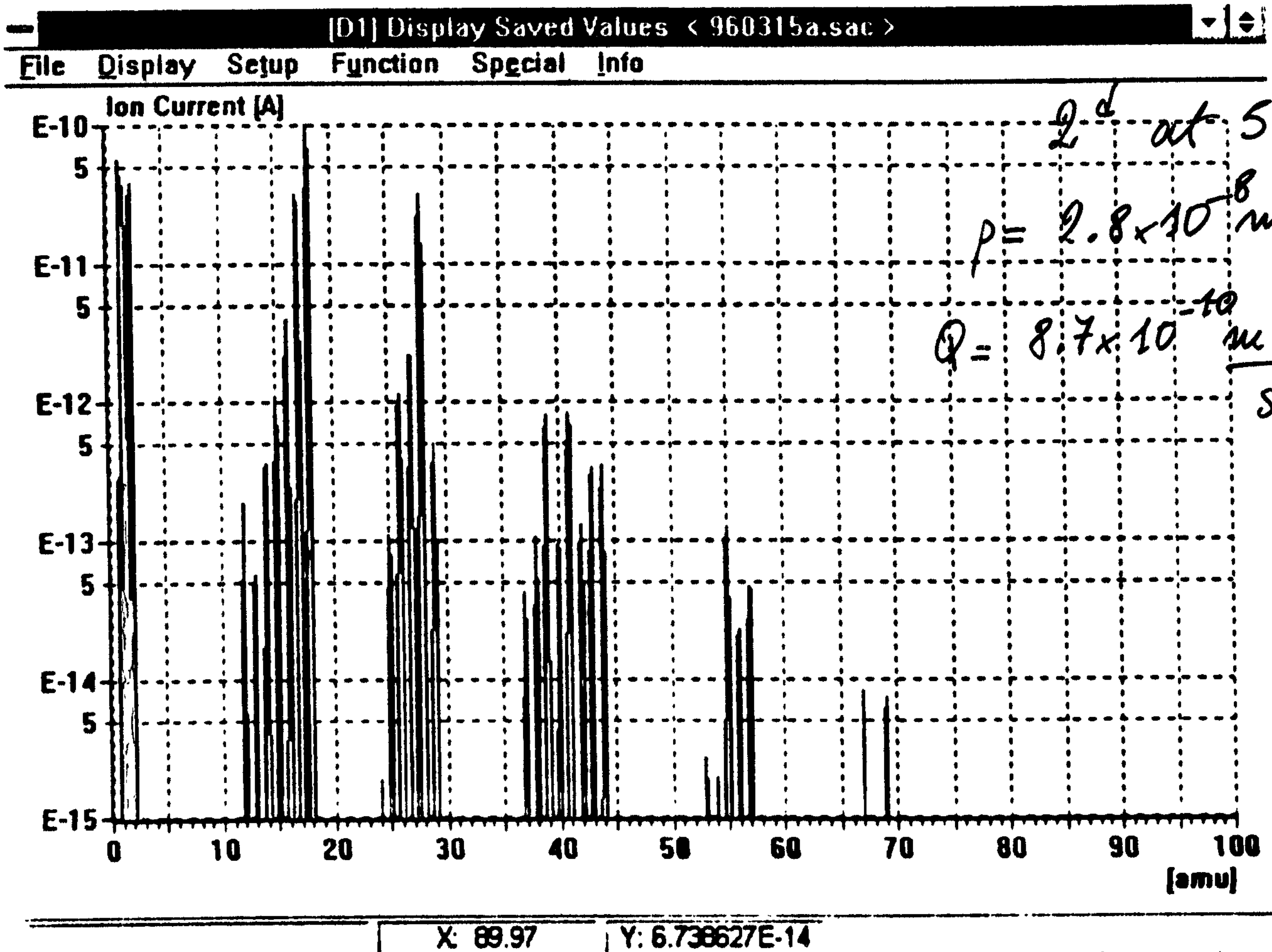


$p = 2.2 \times 10^{-5}$ mbar

$Q = 7.2 \times 10^{-7} \frac{\text{mbar l}}{\text{s cm}^2}$

$T \sim 100\,^\circ C$

magnets A

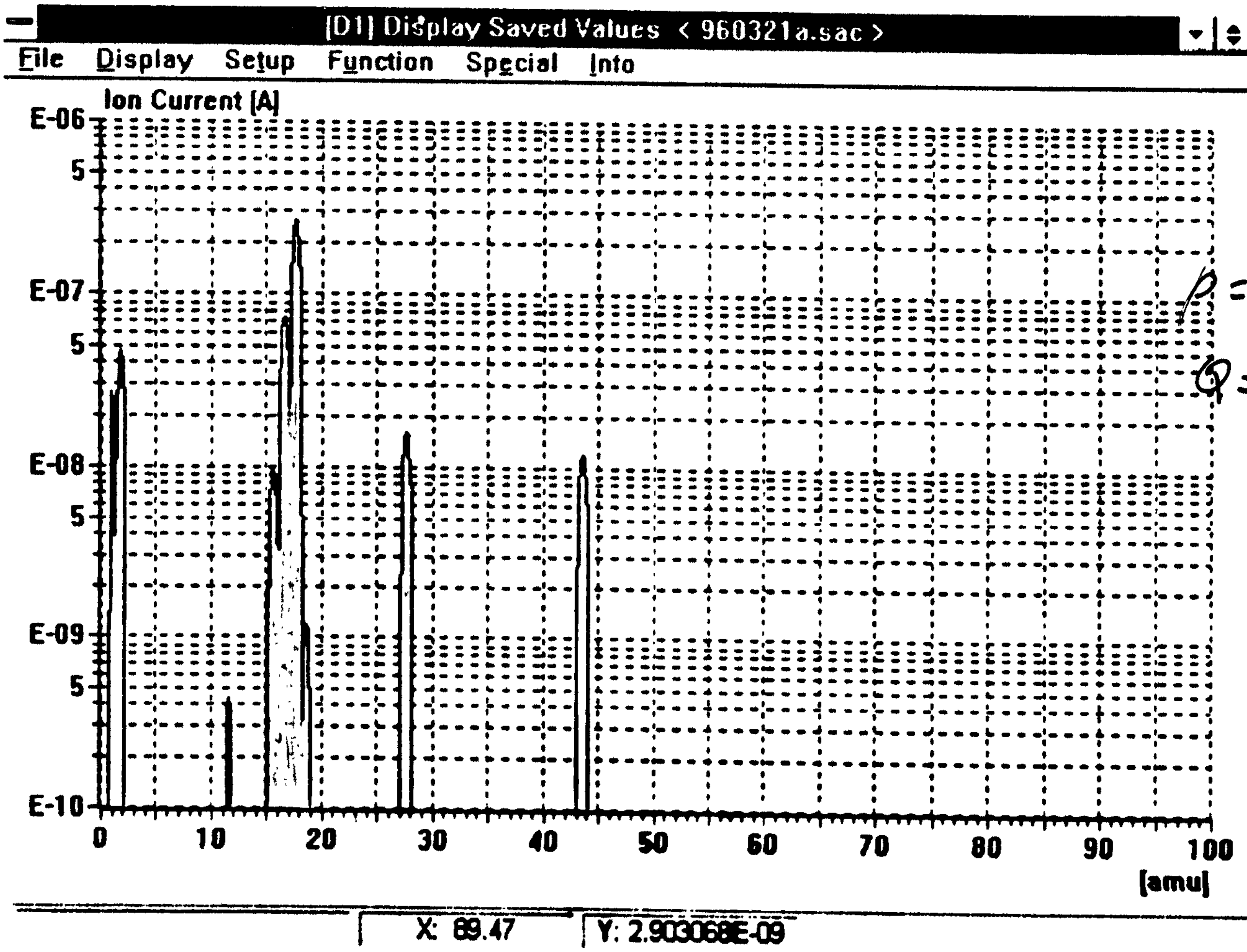


2d at 50°C

$p = 2.8 \times 10^{-8}$ mbar

$Q = 8.7 \times 10^{-10} \frac{\text{mbar l}}{\text{s cm}^2}$

magnets A



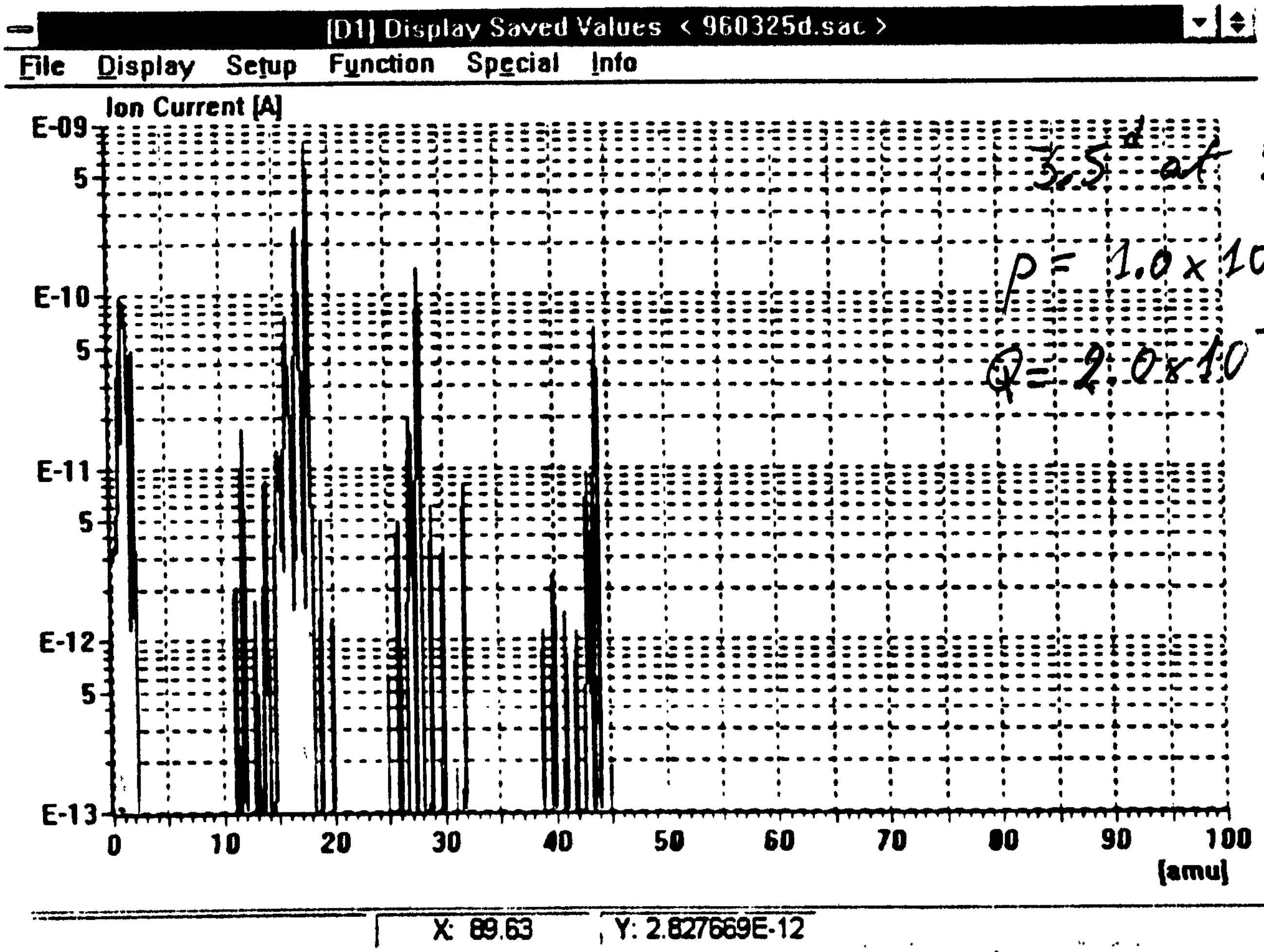
$T \sim 15°C$

$p = 2.5 \times 10^{-6}$ mbar

$Q = 5.6 \times 10^{-8} \frac{mbar}{s\,cm^2}$

magnets B

11



3.5 d at 50 °C

$p = 1.0 \times 10^{-7}$ mbar

$Q = 2.0 \times 10^{-9} \frac{\text{mbar l}}{\text{s cm}^2}$

magnets B

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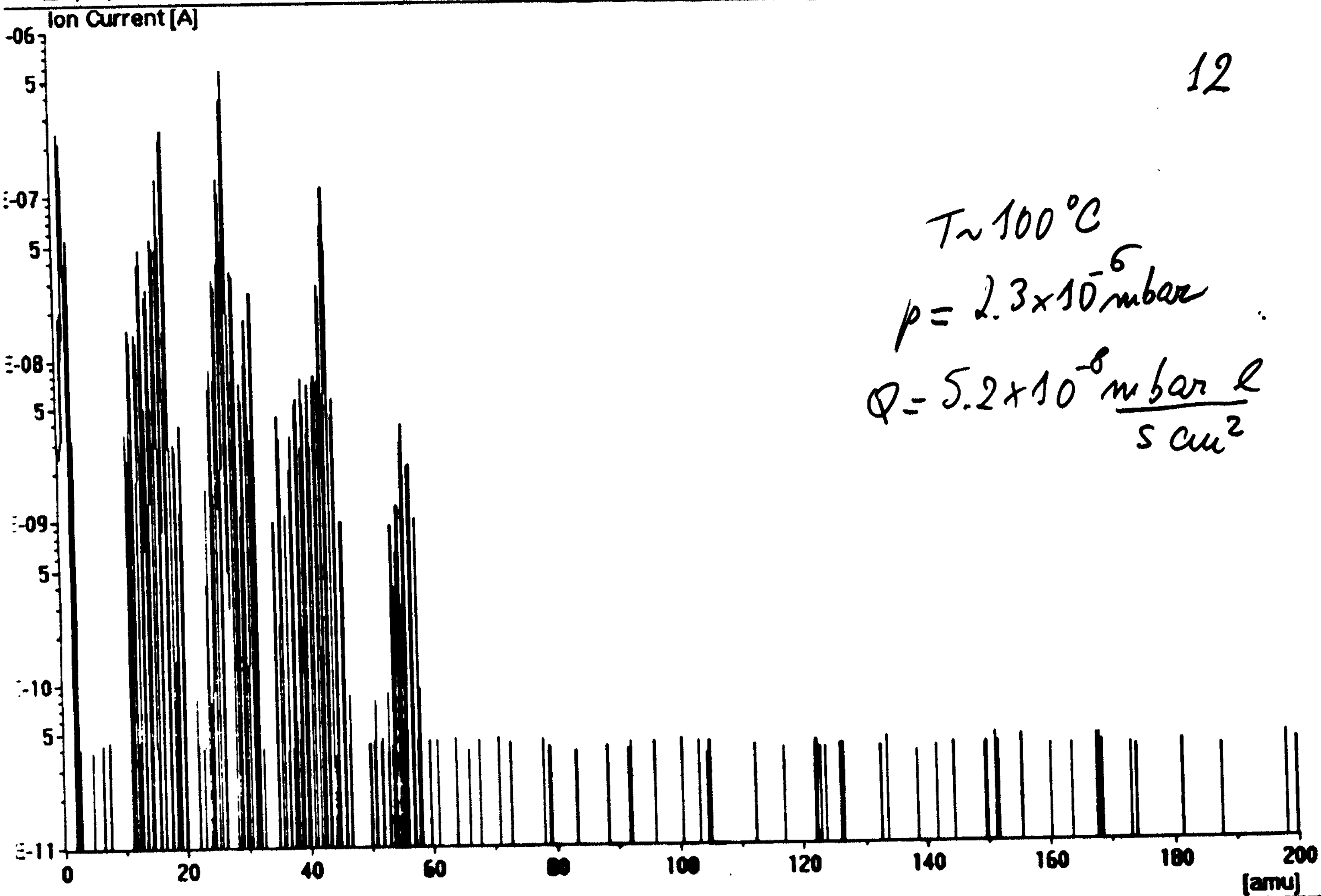


12

$T \sim 100\,°C$

$p = 2.3 \times 10^{-6}$ mbar

$Q = 5.2 \times 10^{-8} \frac{mbar\ l}{s\ cm^2}$

Magnets B

Ferrite magnets

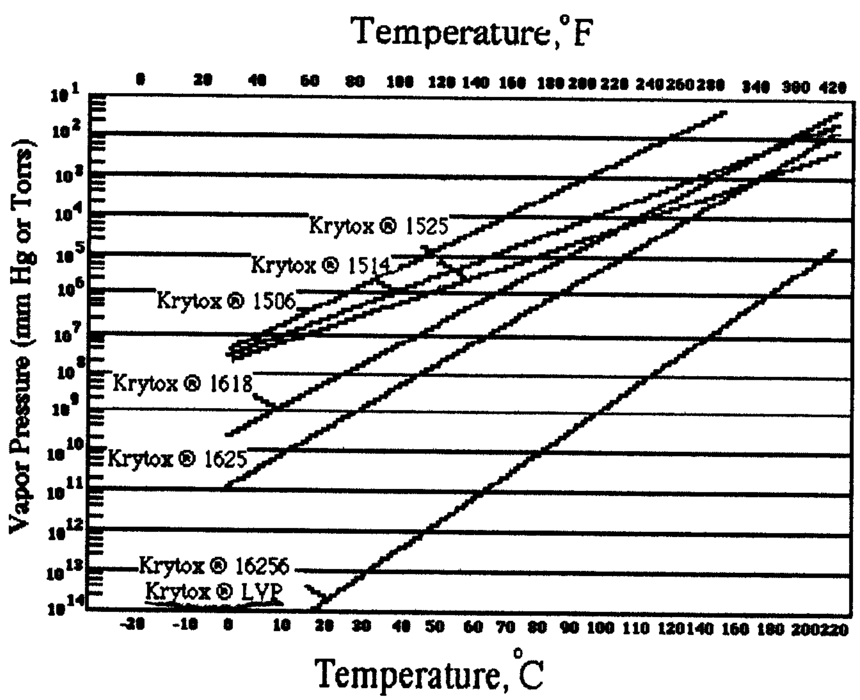
	$Q\left(\frac{mbar\ \ell}{s\ cm^2}\right)$
before baking, 72^h pumping	4.4×10^{-8}
after baking at 100°C	7.6×10^{-14}

- cleaning procedures have a strong impact on vacuum properties
- to be used at room temperature only
- contamination from powder to be studied

recommended with precaution

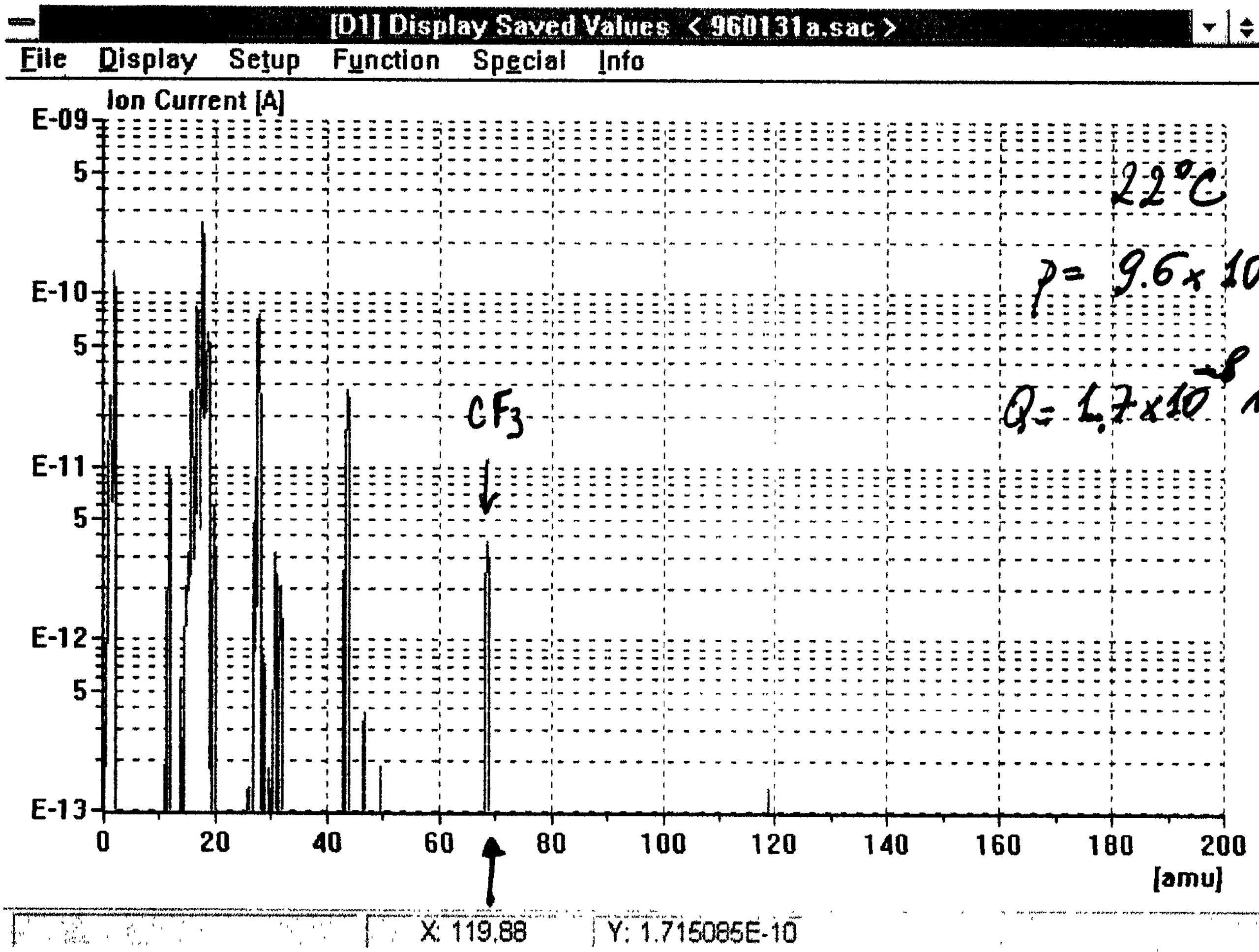
Technical Information

Typical Vapor Pressure-Temperature Characteristics



HOME INDEX BACK NEXT

LUBEINFO@JLCL01.DNET.DUPONT.COM



22°C

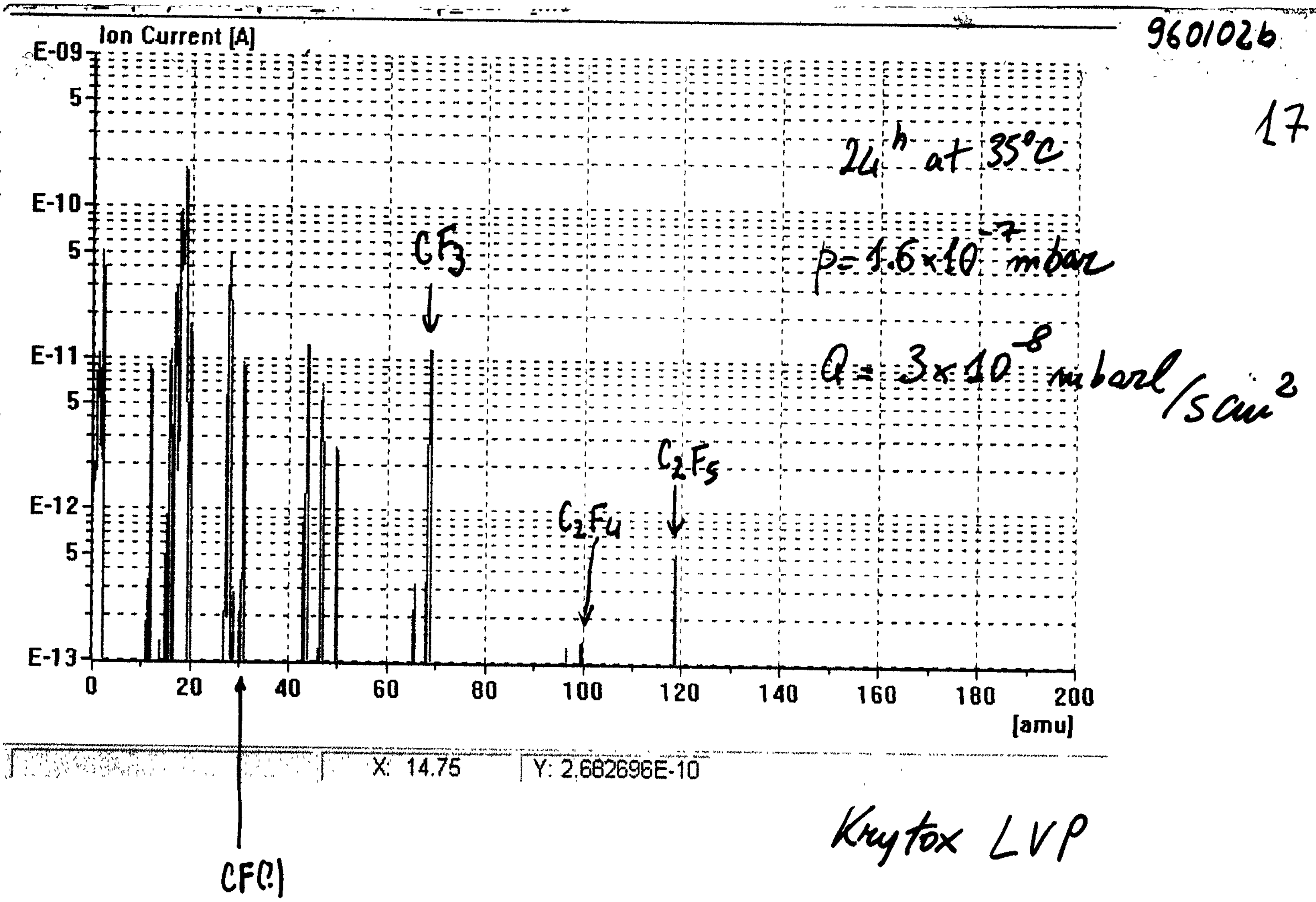
$p = 9.6 \times 10^{-8}$ mbar

$Q = 1.7 \times 10^{-8}$ mbar l/s cm^2

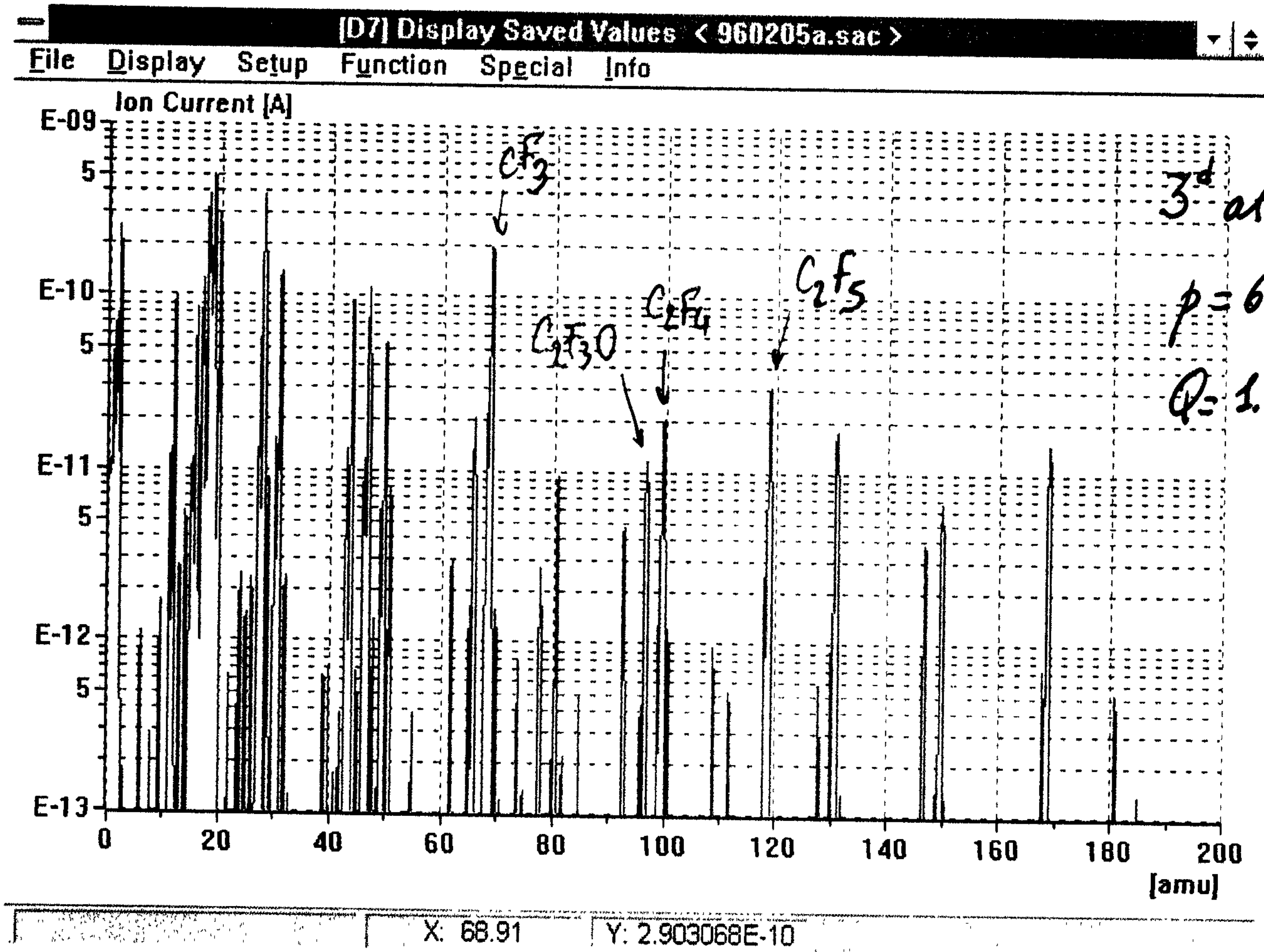
Krytox LVP

9601026

17



Krytox LVP



3^d at 49°C

$p = 6.0 \times 10^{-8}$ mbar

$Q = 1.1 \times 10^{-8} \frac{\text{mbar}\,l}{5\,\text{cm}^2}$

Krytox LVP

Krytox LVP

	$Q\left(\frac{mbar\ l}{s\ cm^2}\right)$
30h pumping, 22°C	1.6×10^{-8}
46 h pumping, 35°C	1.5×10^{-8}
73 h pumping, 49°C	1.1×10^{-8}

evidence of fluorine compounds in outgassing spectra

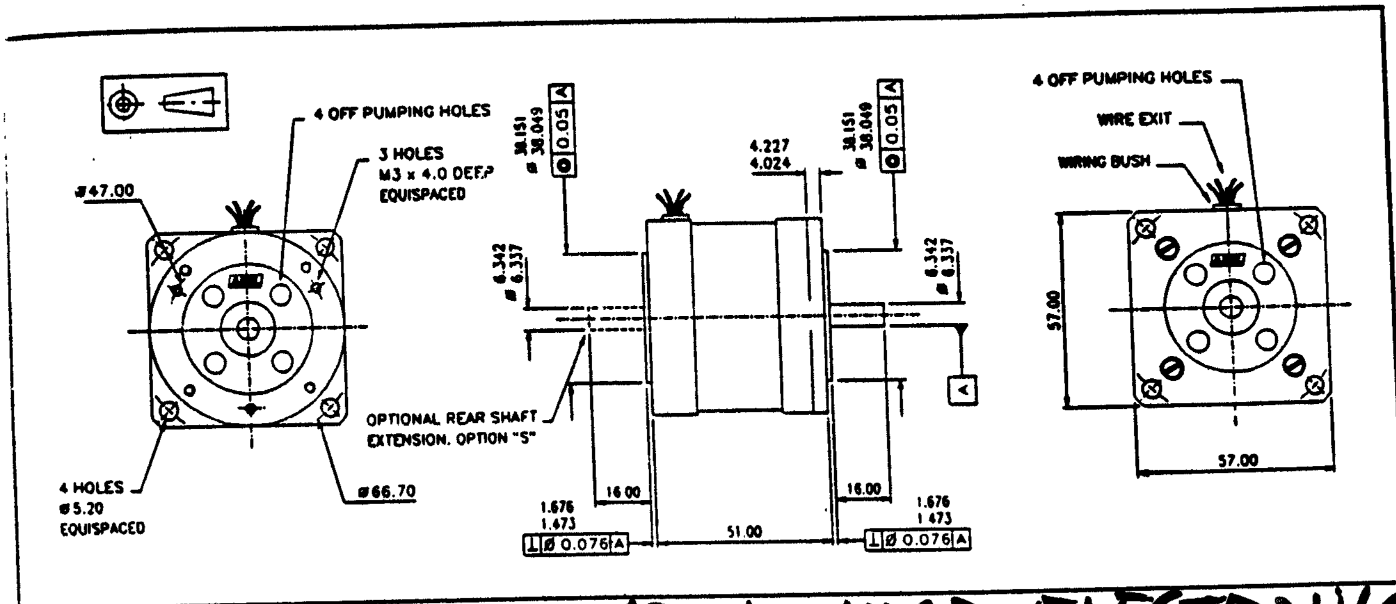
not recommended
(the same holds for Fomblin)

AML motors

- UHV compatible stepper motors produced by AML, UK
- Step angle 1.8^0
- Bakeable up to 175 ^{0}C

IMPROVED UHV STEPPER MOTOR MODEL B23.1

AML's improved UHV-compatible stepper motor has a significantly-reduced thermal resistance between the windings and the case and generally improved materials. In conjunction with the SMD2 drive this enables continuous running with reasonable torque and low outgassing to be achieved in UHV.

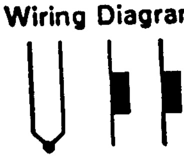


ARUN MICROELECTRONICS

- ◆ Proven technology, similar AML motors have been in constant use since 1986.
- ◆◆ All insulating materials are self-coloured polyimide or PEEK, with exceptional outgassing and insulating performance. Typically < 3 x 10^{-8} mBar l sec^{-1} after 2 hours running at torque of 100 mNm. Only hydrogen (90%) and CO can be resolved in the spectrum.
- ◆◆ Improved hybrid ceramic bearings for longer life and reduced friction after multiple bakeouts.
- ◆ Electrical connections reduced to only 6 durable polyimide film-coated wires. Simplified connection with MLF12 bakeable lead and feedthrough kit.
- ◆◆ Further reduced thermal resistance between windings and case. Continuous running in vacuum at 0.7A is now possible.
- ◆◆ All stainless-steel surfaces are etched and sputter-coated with a hard matt black diamond-like film for increased heat-loss by radiation and reduced outgassing.
- ◆ Particularly suited to continuous substrate rotation for deposition uniformity for load inertias up to 1 x 10^{6} g cm^2. Use reduction gearing or B23.2 for larger loads.
- ◆ Suitable for use below 1 x 10^{-10} mb
- ◆ Bakeable to 200°C, operable at 77°K.
- ◆ Radiation-hard version available.
- ◆ Rear shaft and rear wire entry options.
- ◆ Full range of drives, accessories and mechanisms are available.
- ◆ Very low particulate generation.

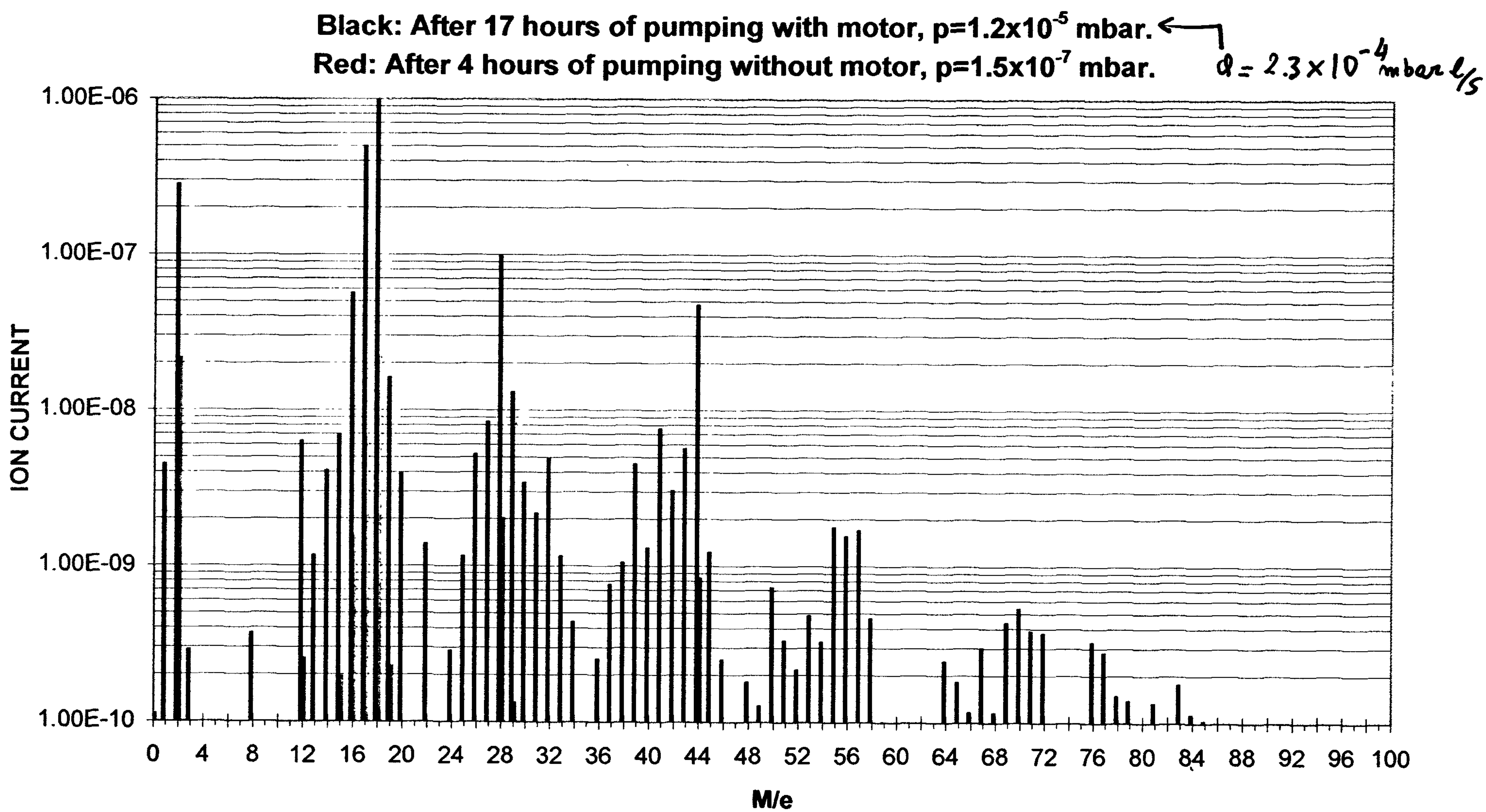
Step angle	1.8°	Bakeout Temperature	200°C
Step angle tolerance (unloaded)	5%	Operating Temperature	< -196 to 175°C
		Weight	750g
Resistance per phase	10 ohms		
Inductance per phase	25 mH	Power leads (Polyimide)	0.6mm
		K-type T/C leads (Polyimide)	0.2mm
Holding torque (2 phases, 1 A)	0.4 Nm	Lead length	0.75m
Detent torque	0.03 Nm	Bearings are silicon nitride balls running in	

Wiring Diagram



Identify phases with a resistance meter. Reverse one phase to reverse rotation. The

MOTOR #1 TEST



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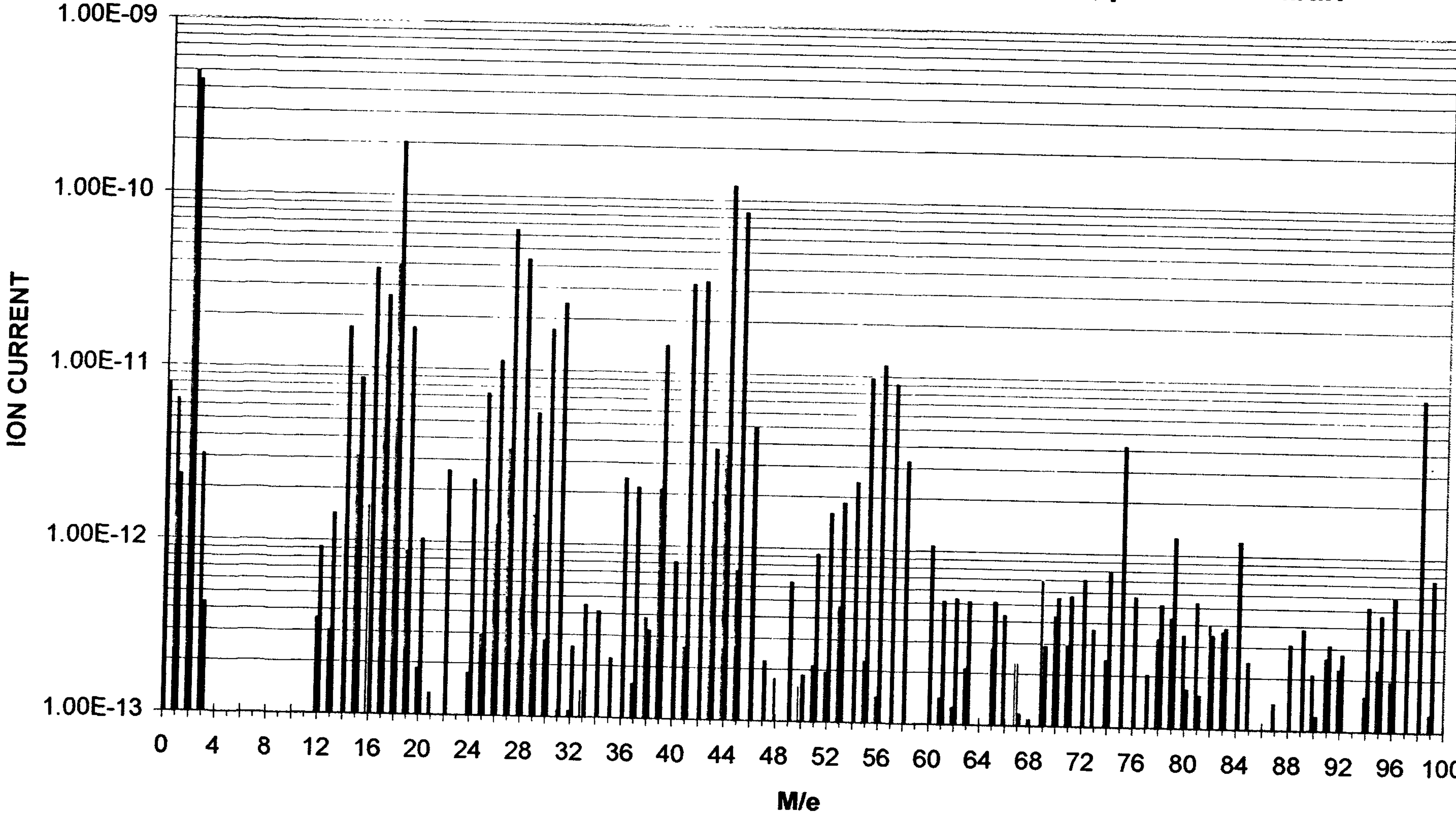
MOTOR #1 TEST

Black: Measurement at baking of 200°C at 28 hours with motor, p=2.3x10^{-5} mbar; $Q = 4.3\times10^{-4}$ mbar l
Red: Measurement at baking of 200°C at 17 hours without motor, p=2.3x10^{-6} mbar.



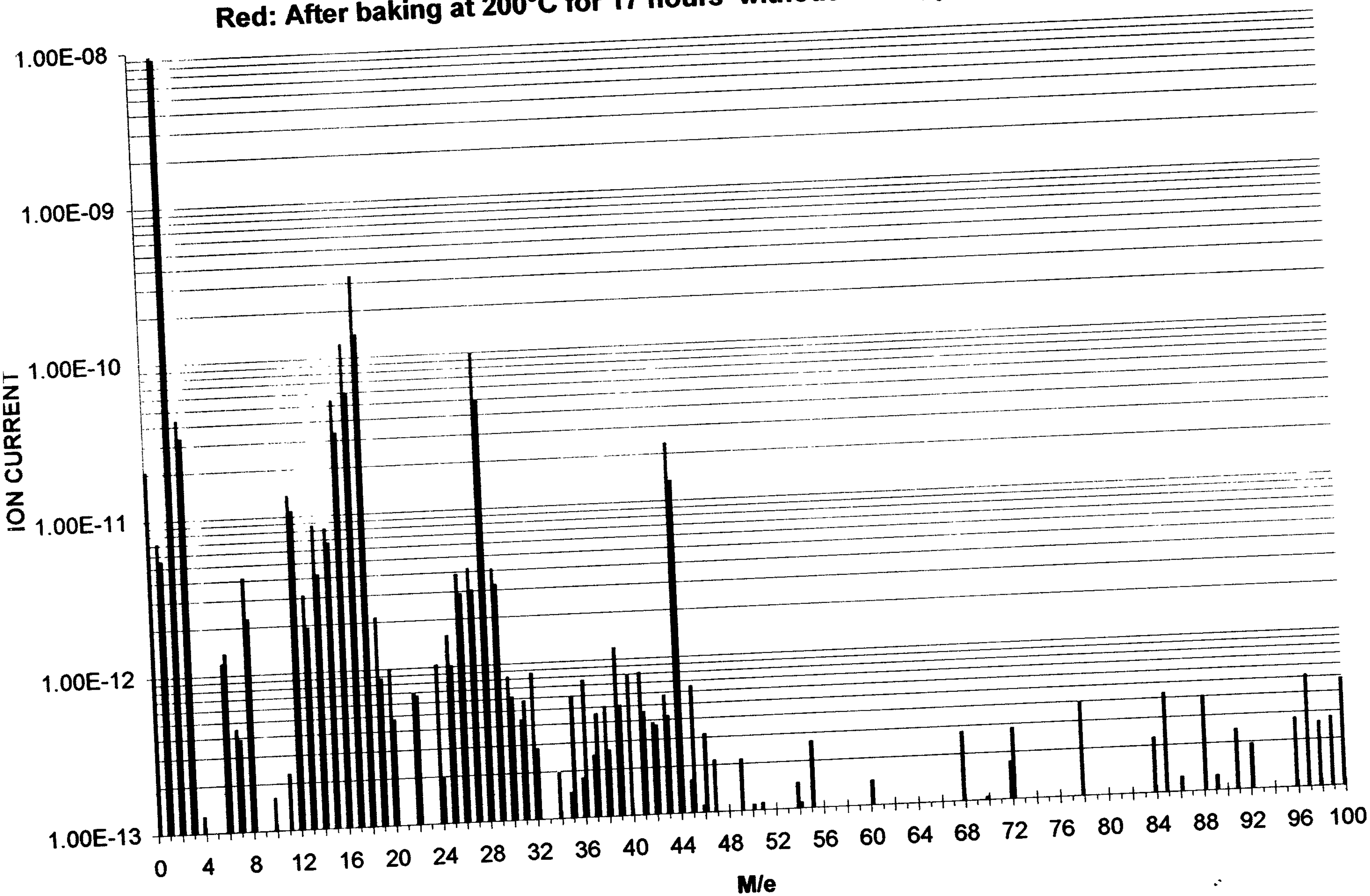
MOTOR #1 TEST

$Q = 2.3 \times 10^{-7}$ mbar l/s

$Q = 1.6 \times 10^{-7}$ mbar l/s

Black: After baking at 200°C for 30 h with motor, p=1.0x0^{-8} mbar;

Red: After baking at 200°C for 17 hours without motor, p=1.7x10^{-8} mbar.



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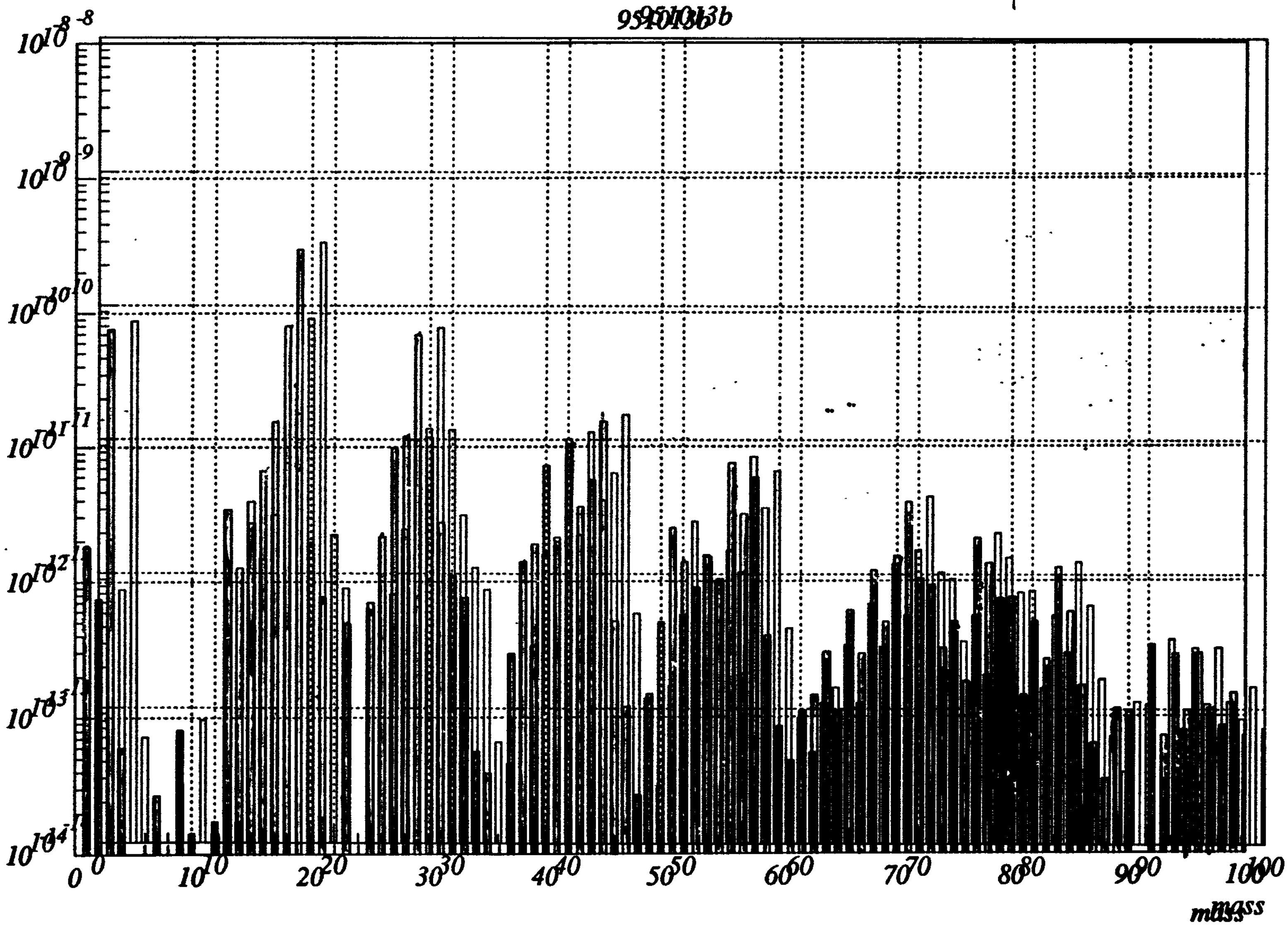
MOTOR #2 TEST

$Q = 1.1 \times 10^{-4}$ mbar l/s

MOTOR INSIDE

$p = 6 \times 10^{-6}$ mbar



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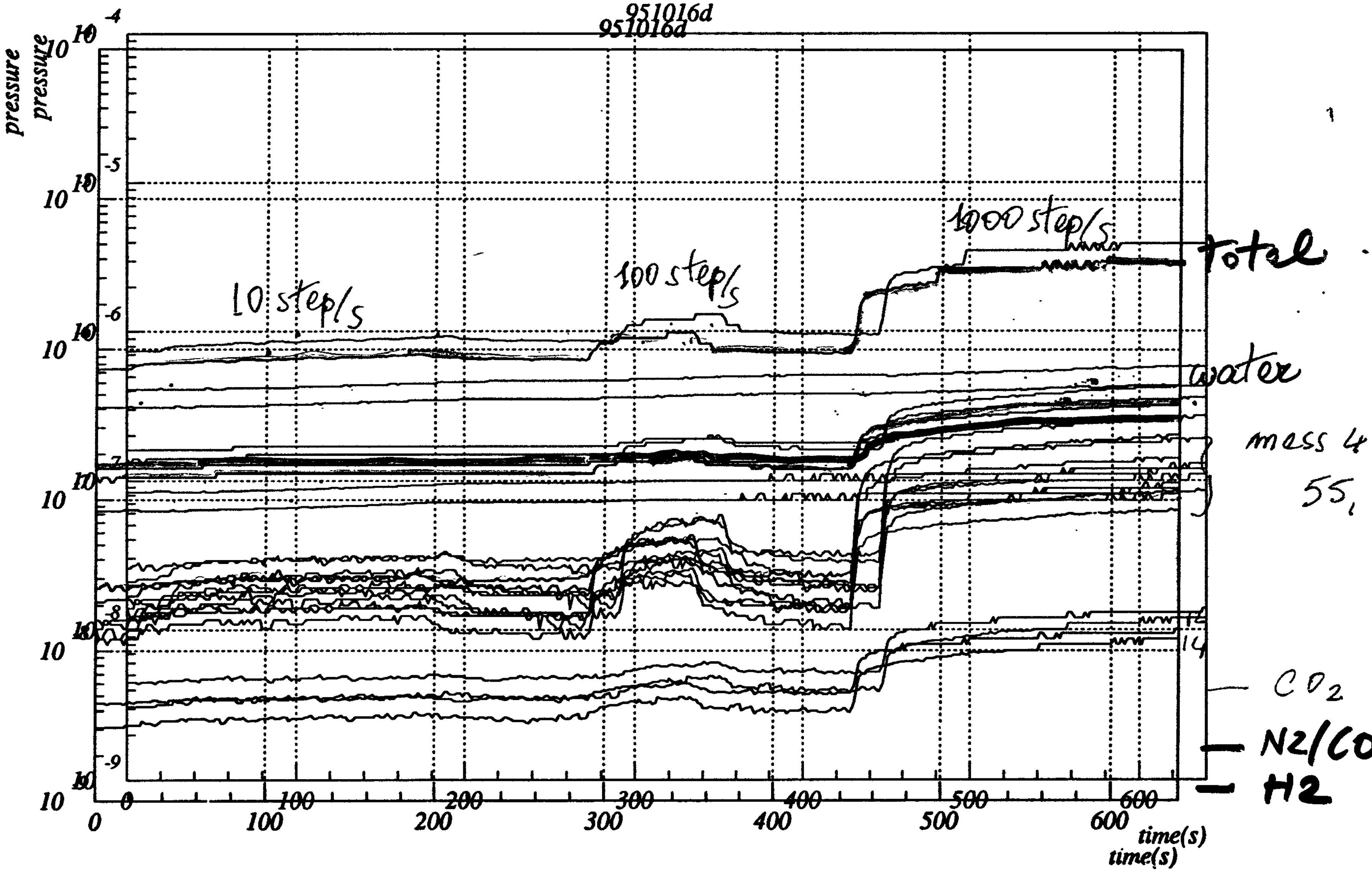
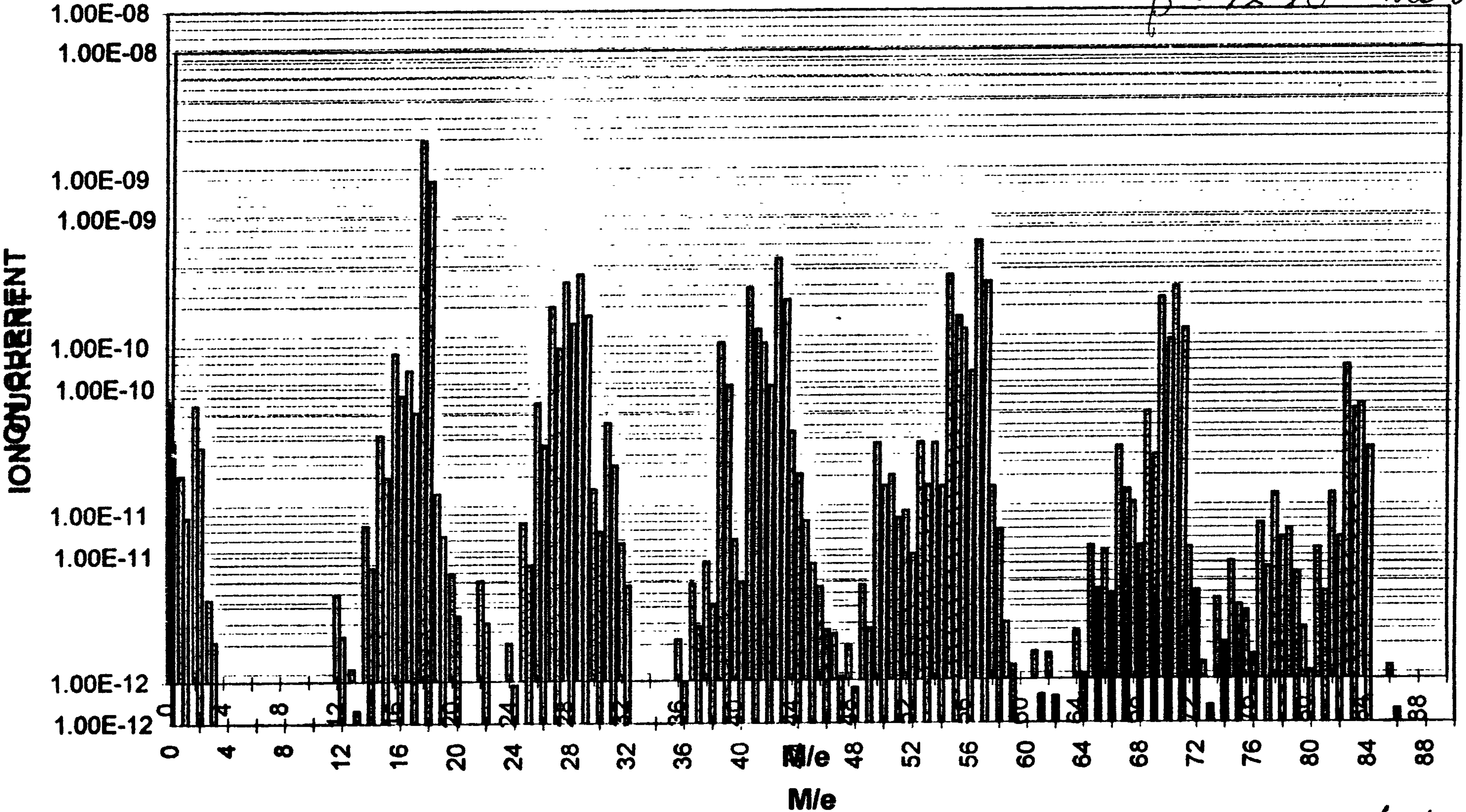
MOTOR OPERATING



MOTOR #2 TEST

T= 91°C ON MOTOR, T= 100°C ON CHAMBER

p = 9x10^{-5} mbar

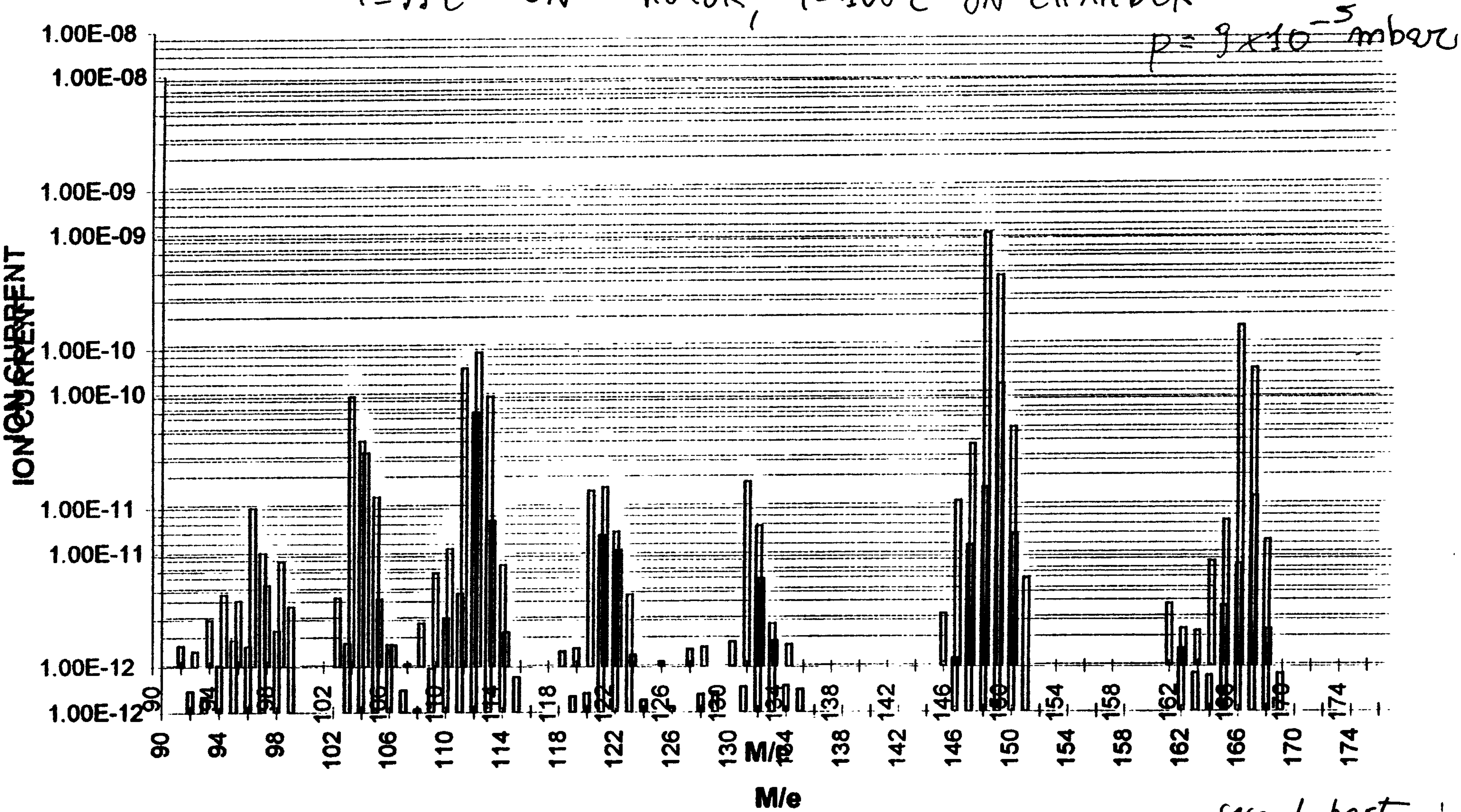


first part

MOTOR #2 TEST

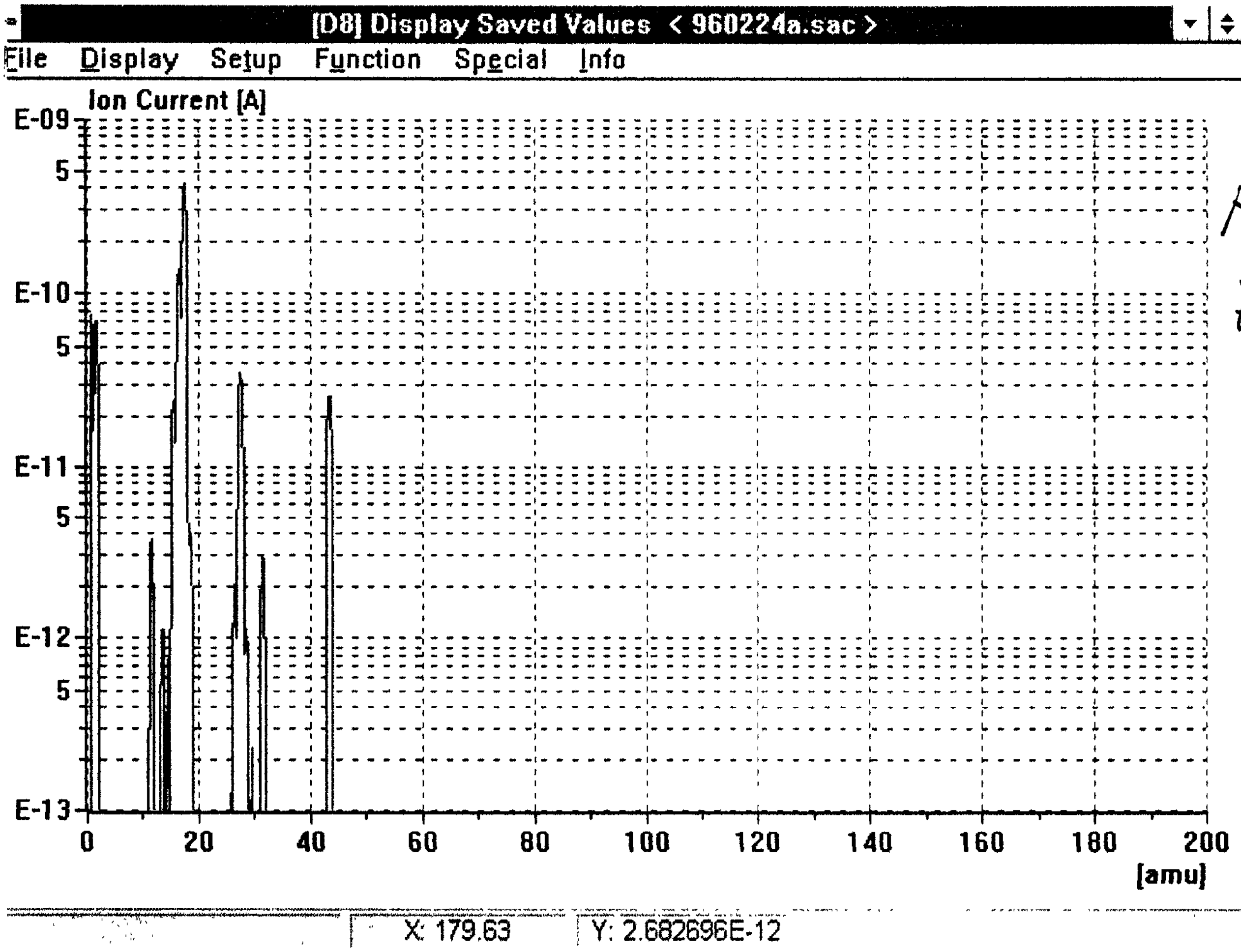
Q = 1.8x10^{-3} mbar l/s

T=91°C ON MOTOR, T=100°C ON CHAMBER



second part

MOTOR #2 TEST



after 16 h

$p = 4.3 \times 10^{-6}$ mbar

7.9×10^{-5} mbar l / s

motor

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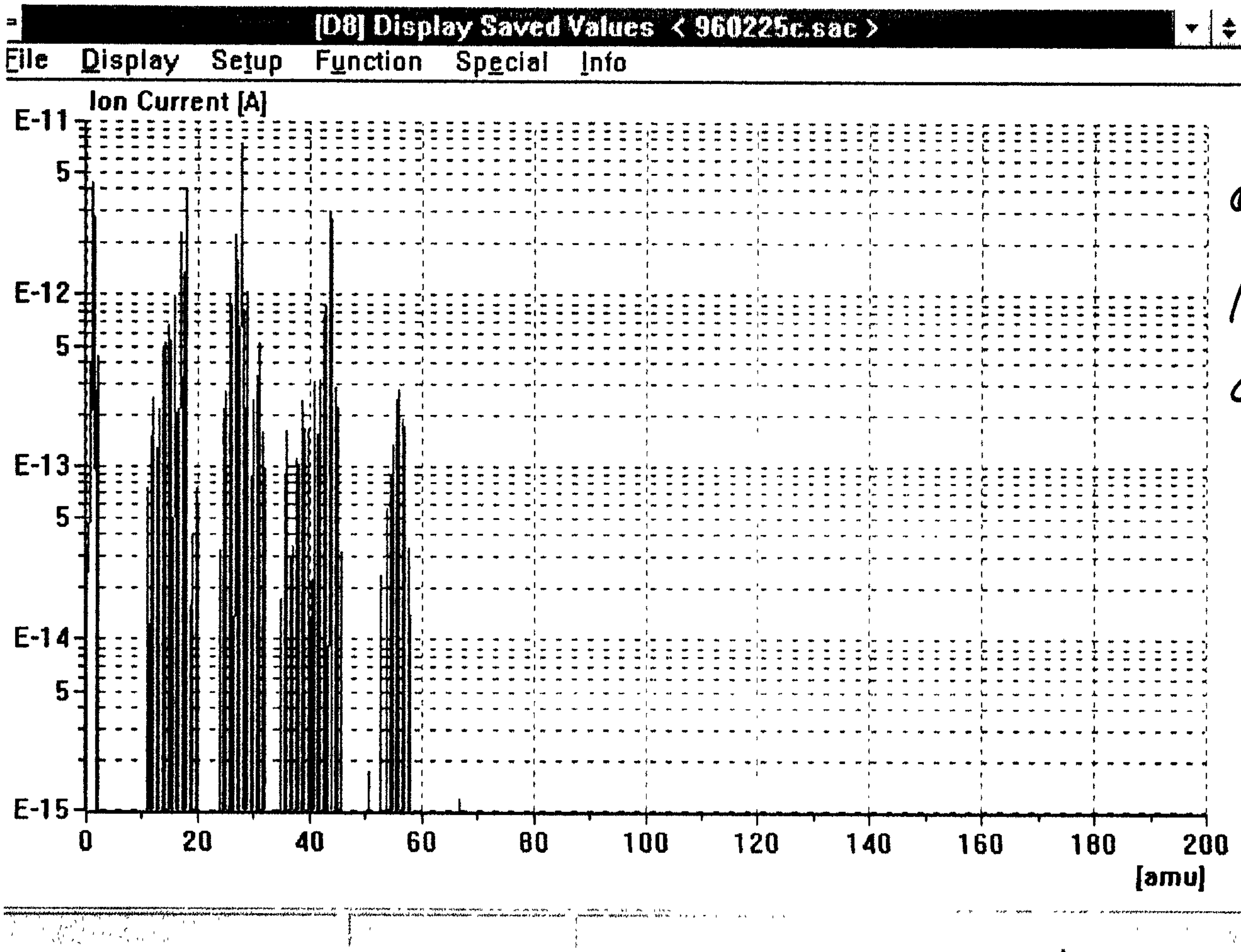

during baking

$p = 1.8 \times 10^{-6}$ mbar

$4 \times 10^{-6} \frac{\text{mbar l}}{\text{s}}$

$T \sim 116°C$

motor #3

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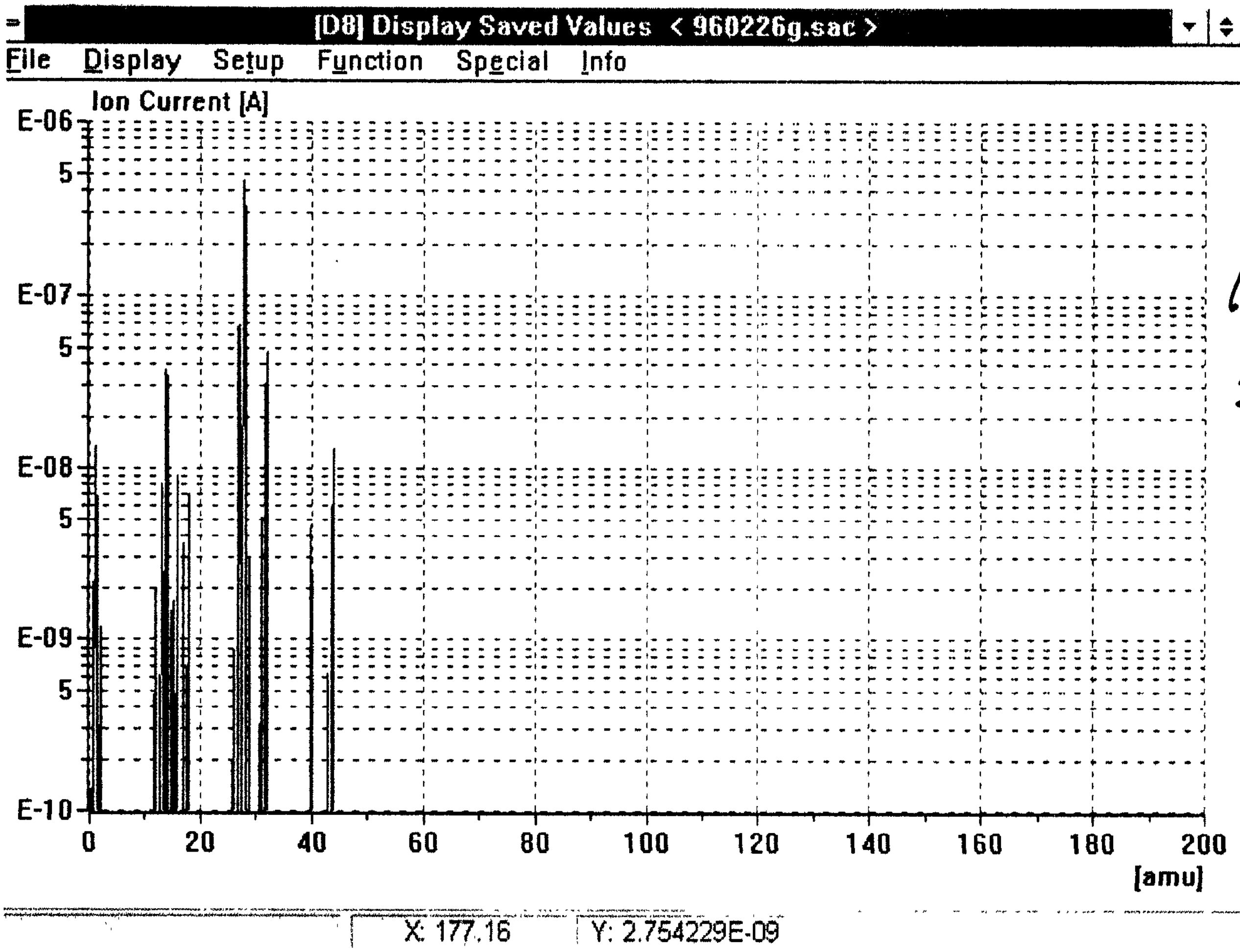

after baking

$p = 1.6 \times 10^{-2}$ mbar

1.3×10^{-6} mbar l / s

T ~ 30°C

motor #3

AML motors

Φ ($\frac{mbar\,l}{s}$)

#1, after baking — 2.3×10^{-7}

cleaned with ethyl-lactate

hydrocarbon emission during baking

#2, not clean

#3, after baking — 1.3×10^{-6}

cleaned with 141b dichloro-fluoro-ethane

hydrocarbon + fluorine compounds emitted during baking

lack of repeatibility

not recommended

Conclusions

- total outgassing flow from seismic attenuation cascade as deduced from the tests is of the order of 10^{-4} mbar l/s (one order of magnitude within requests)
- filters : 3.0×10^{-5} mbar l/s
- blades : 1.7×10^{-5} mbar l/s
- magnets : 4.3×10^{-5} mbar l/s
- cabling : 1.0×10^{-5} mbar l/s
- others : $< 2.0 \times 10^{-6}$ mbar l/s

Future options

- Perform optical surface contamination test
- Collaboration and data sharing with LIGO very welcome