Object: An apparatus to measure the outgassing of Superattenuator components and first measurements on Stepping Motors

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The filters to be installed in the upper part of the tower will be mounted using a large number of elements such as motors, glued magnets, electrical cables, small tubes etc....... Their outgassing must be measured during the R&D phase to select the right components. Later on, during the construction time, the outgassing of each component and of the whole assembled filter must be systematically measured before the final installation on the towers.

A first apparatus has been installed in August 1995 in the Calambrone Lab. to measure the outgassing of small components. Two additional identical systems for test of small samples should be available very soon. A large vacuum chamber to measure the outgassing of the whole filter has been installed and is being characterised at this moment.

1 - Apparatus and method to measure the component outgassing

1.1 - Apparatus

The apparatus is shown in Fig. 1. It consists of a vacuum chamber made of 304L stainless-steel with a volume of 12.6 litres and an internal surface of 2500 cm^2. It is equipped with two CF200 ports to introduce the samples and four CF40 ports, two of them used for the pressure gauges: a Bayard-Alpert and an RGA. The sample chamber is separated from the pumping chamber by a diaphragm that reduces the effective pumping speed to S_e = 20 l/s N_2 equivalent at 20°C. Two CF40 ports on the pumping chamber are connected to a Penning gauge and to the rough pumping system.
The main pump used for the outgassing measurements is a triode ion pump with 250 l/s pumping speed; the rough pumping consist of a turbo 50 l/s back pumped by a scroll. A valve allows to isolate the rough pumping system and another one to vent the chamber with N_2.

1.2 - Method

The outgassing is measured using the dynamic method: measuring both pressures in the sample chamber P_1 and in the pumping chamber P_2 the total outgassing can be deduced from the relation:

$$Q = (P_1 - P_2) \times C \tag{1}$$

where C is the conductance. Obviously the measurement must be performed twice, with and without the sample into the sample chamber: the difference between the two values will represent the net sample outgassing flow.
The difference between the RGA spectra, taken in the above conditions, will give the mass distribution of the outgassing of the sample.

Both measurements are a first crude estimation because the effective pumping speed depends on the gas mass, while the measured outgassing flow and mass distribution assume a mass independent effective pumping speed.

For this reason the apparatus has been implemented for the second series of tests with a second RGA, identical to the first one, on the pumping chamber; this allows to measure the partial pressure of the more relevant components into both chambers to deduce accurate values of the outgassing flow for each one of them.

The logical steps of our measurement have been as follows:
- measure of the background rate of the sample chamber;
- measure of the outgassing of the motor with factory nominal cleaning;
- measure of the outgassing after baking of the chamber and of the motor;
- measure of the outgassing with motor working.

1.3 - Performances of the system

To know the contribution of the sample chamber to the total outgassing and its composition, in the following called "background", measurements on the sample chamber alone have been done in different conditions.
After a long staying in open air, the chamber has been evacuated and maintained under vacuum for 15 hour:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
15	34	1.5×10^{-7}	3.3×10^{-8}	2.3×10^{-6}

The chamber has been then baked at 200°C for 17 hours, giving at the end the spectrum in Fig. 2:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
after	35	1.7×10^{-8}	3.6×10^{-9}	2.7×10^{-7}

2 - Measurement of the outgassing flow of two stepping motors

Awaiting the installation of the second RGA a first component has been tested. This component is a vacuum compatible stepping motor (AML, England, B23.1 model) equipped with a sample translator. The motor has a step angle of 1.8^0. The motor is made of the following materials listed in approximate descending order of exposed surface: SS 304, 316, 440, polyimide (winding insulation), diamond-like carbon (coatings), silicon steel, Alcomax III or Samarium cobalt (magnets), PEEK (brushes), alumina ceramic, silicon nitride ceramic, silver, fluorinated ethylene polymer, copper, chromel and alumel. The motor can be baked up to 175 ^{0}C and is equipped with a K-type thermocouple to measure temperature. The sample translator is made of stainless steel.

The motor has been put inside the measurement chamber nominally cleaned from the factory. We have monitored the time evolution of the outgassing flow with the motor switched off:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
0.5	34	5.4×10^{-4}	1.1×10^{-4}	8.6×10^{-3}
16	34	1.2×10^{-5}	5.8×10^{-7}	2.3×10^{-4}
23	34	8.7×10^{-6}	4.1×10^{-7}	1.7×10^{-4}
41	39	1.7×10^{-6}	1.0×10^{-7}	3.2×10^{-5}
45	38	1.6×10^{-6}	9.4×10^{-8}	3.0×10^{-5}
89	34	2.2×10^{-7}	1.9×10^{-8}	4.0×10^{-6}
90	35	2.8×10^{-7}	2.2×10^{-8}	5.2×10^{-6}
95	37	3.0×10^{-7}	2.5×10^{-8}	5.5×10^{-6}
112	34	2.0×10^{-7}	1.8×10^{-8}	3.6×10^{-6}
136	34	1.5×10^{-7}	1.4×10^{-8}	2.7×10^{-6}
162	36	1.1×10^{-7}	1.1×10^{-8}	2.0×10^{-6}

The outgassing composition after 162h is reported in Fig. 3. We performed the baking of the chamber at 200^{0}C keeping the motor between 150 and 175 ^{0}C for 26 h. The outgassing composition during the baking is shown in Fig. 4 and the one after baking in Fig. 5.

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
during	200	2.3×10^{-5}	1.3×10^{-6}	4.3×10^{-4}
after	35	1.4×10^{-8}	2.5×10^{-9}	2.3×10^{-7}

The time evolution of the outgassing flow including the baking is shown in Fig. 6. After the cooling down of the chamber the motor has been heated up to 80^0C by self running; an increase of the outgassing flow by a factor 10 with respect to the outgassing flow at 35^0C has been observed.

As explained in the next section, these results are not compatible with the factory specifications. For this reason, measurements have been performed on a second identical vacuum motor, this time without the motion translator. For this test, the system has been equipped with the second RGA quadrupole on the pumping chamber.
The chamber has been evacuated and maintained under vacuum for 8 days, then the outgassing flow and the RGA spectrum have been measured (see Fig. 7) giving:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
192	35	$6.5x10^{-8}$	$2.1x10^{-8}$	$8.8x10^{-7}$

The motor has been put inside the measurement chamber nominally cleaned from the factory. We have monitored the time evolution of the outgassing flow with the motor switched off:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
24	35	$2.0x10^{-5}$	$1.9x10^{-6}$	$3.6x10^{-4}$
27	35	$2.9x10^{-5}$	$2.3x10^{-6}$	$3.6x10^{-4}$
30	35	$2.6x10^{-5}$	$1.9x10^{-6}$	$4.8x10^{-4}$
44	35	$6.8x10^{-6}$	$4.5x10^{-7}$	$1.3x10^{-4}$
46	35	$6.2x10^{-6}$	$4.0x10^{-7}$	$1.2x10^{-4}$
48	35	$6.0x10^{-6}$	$3.9x10^{-7}$	$1.1x10^{-4}$
52	35	$6.0x10^{-6}$	$3.7x10^{-7}$	$1.2x10^{-4}$
53	35	$5.9x10^{-6}$	$3.6x10^{-7}$	$1.1x10^{-4}$
117	35	$6.3x10^{-7}$	$1.3x10^{-7}$	$1.0x10^{-5}$
118	35	$4.9x10^{-7}$	$7.0x10^{-8}$	$8.4x10^{-6}$

The outgassing composition after 52h is reported in Fig. 8. The time evolution is summarized in Fig. 9 where the slower trend as compared to the first motor is evident.
The influence of motor operation on the vacuum level is shown in Fig. 10 for three different speeds: 10 step/s, 100 step/s, 1000 step/s velocities. The total and partial pressures for a few selected substances are shown in relation to the motor speed as a function of time. It is evident that the amount of gas released from the motor is proportional to the motor speed. The increase of the partial pressures at the motor switching on is very sharp. The overall increase of temperature was 11 ^{0}C.

We have started baking to improve the vacuum performances. Due to the huge contamination step by step observed, we decided to stop when the temperature was around 100 ^{0}C (Fig. 11).

3 - Discussion

We just summarise the factory specifications here for easy comparison with the experimental results:

a) The outgassing flow from the motor should mainly come from the water vapour retention in the windings and should disappear in a few hours.
b) During the baking the only relevant products should be H_2 (90%) and CO (10%), all other peaks below 1% of H_2 peak height.
c) After baking the outgassing flow from the motor should be 1.6×10^{-8} mbar l/s and thus should not be visible in the test chamber.

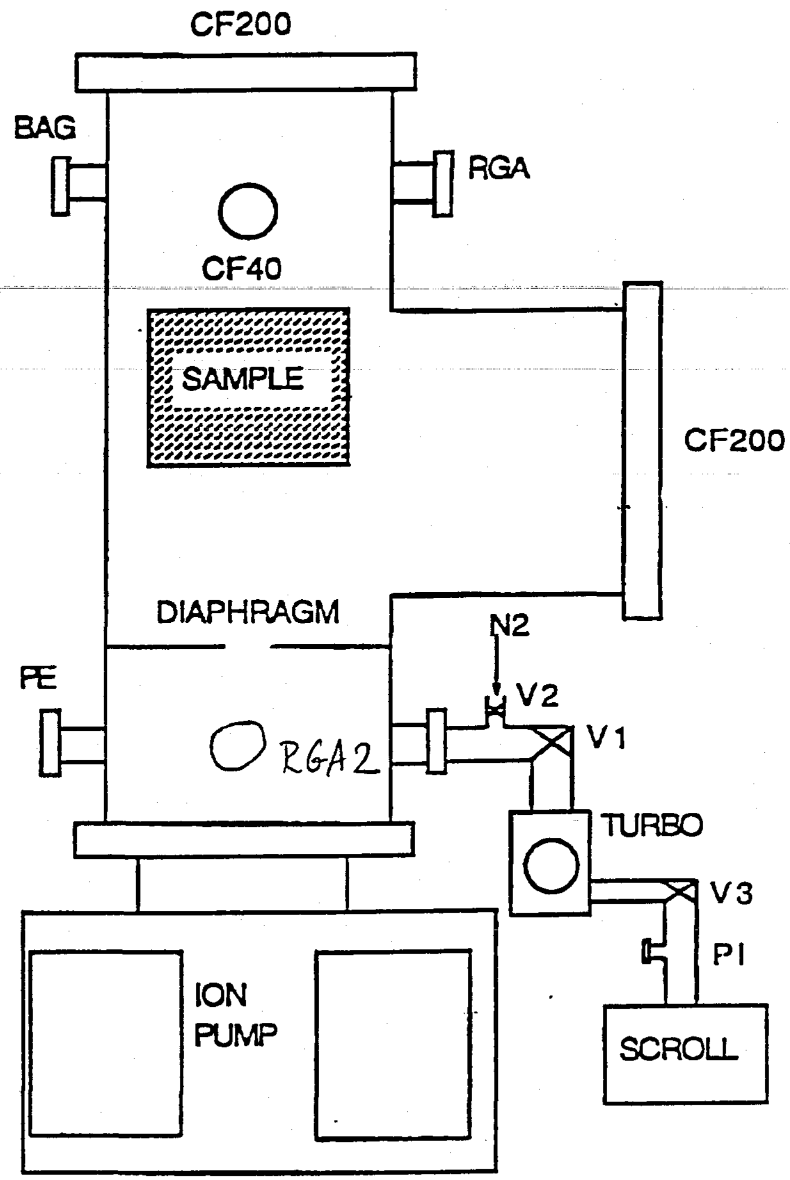
We summarize here our results about the outgassing flow for the best motor:

- before baking, 162h pumping: 2.0×10^{-6} mbar l s^{-1}
- during baking : 4.3×10^{-4} mbar l s^{-1}
- after baking : 2.3×10^{-7} mbar l s^{-1}

For both our tests, the outgassing flow of the vacuum chamber was of the order of the one quoted in the text by the factory. We have found that the vapour retention in the windings disappears in a couple of days and not in a few hours but this is still an acceptable time for us. The presence of the motor itself independently from its functioning has a sizeable effect on the achievable vacuum increasing the base pressure of the system by two orders of magnitude. Referring to the case of the first tested motor, during the baking operation there are hydrocarbons outgassed not mentioned by the producer specifications. These hydrocarbons can become a source of pollution in case baking is foreseen. After baking, the outgassing from the first motor became smaller than the one from the chamber and no hydrocarbons were no more visible. The outgassing from the second motor we tested was so large that it could not even undergo complete baking. We have observed that when motor is switched on the pressure rise is quite instantaneous.

In view of the results obtained for both motors and the lack of reproducibility, we cannot recommend them for use in VIRGO. The factory claims that contamination could be caused by imperfect cleaning processes since the peaks in the outgassing spectrum seem to correspond to lubricants. They have been invited to perform a test on a motor of their choice in our apparatus (end of February 1996).

Figure 1. TEST SYSTEM



$p = 1.7 \times 10^{-8}$ mbar

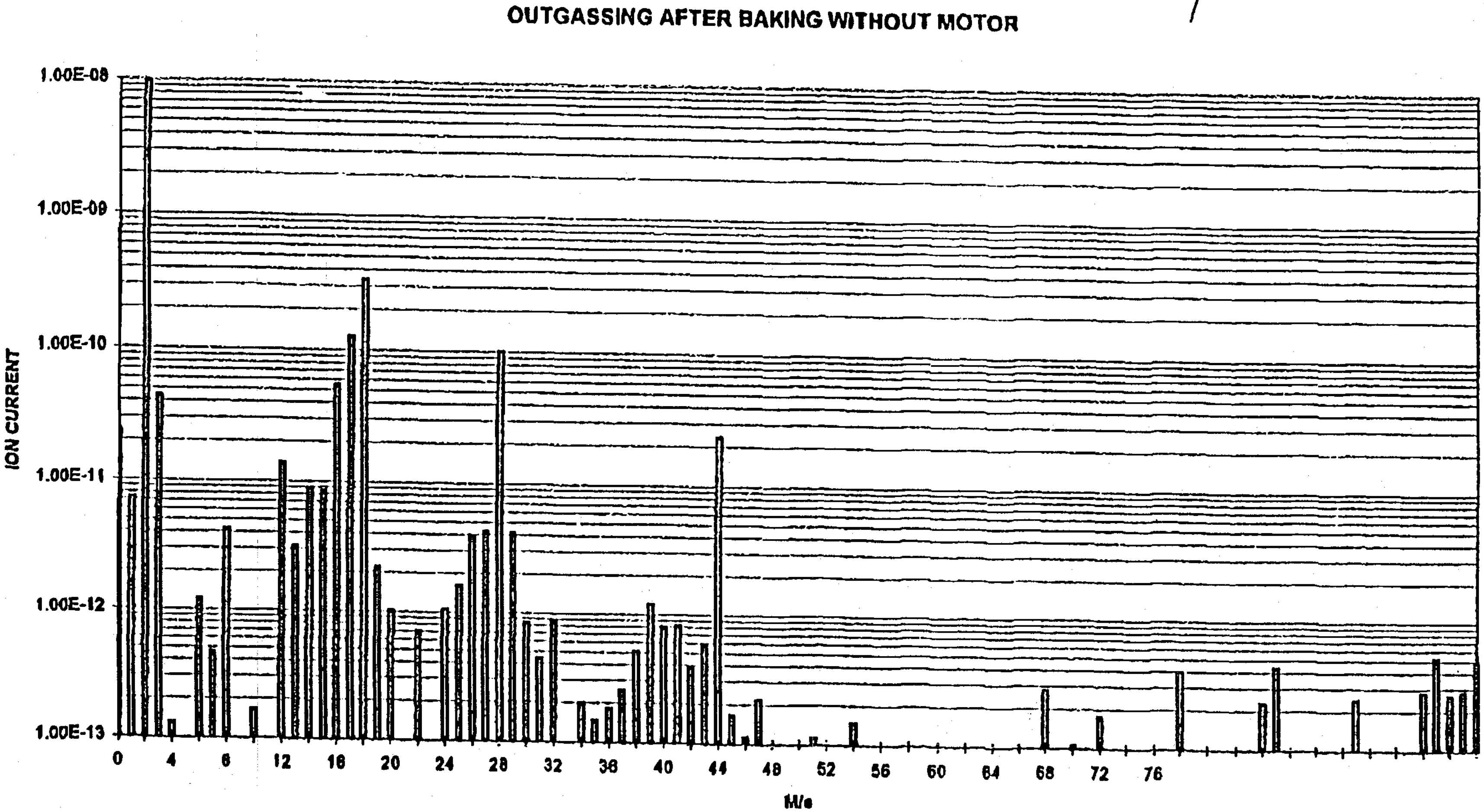


Fig. 2

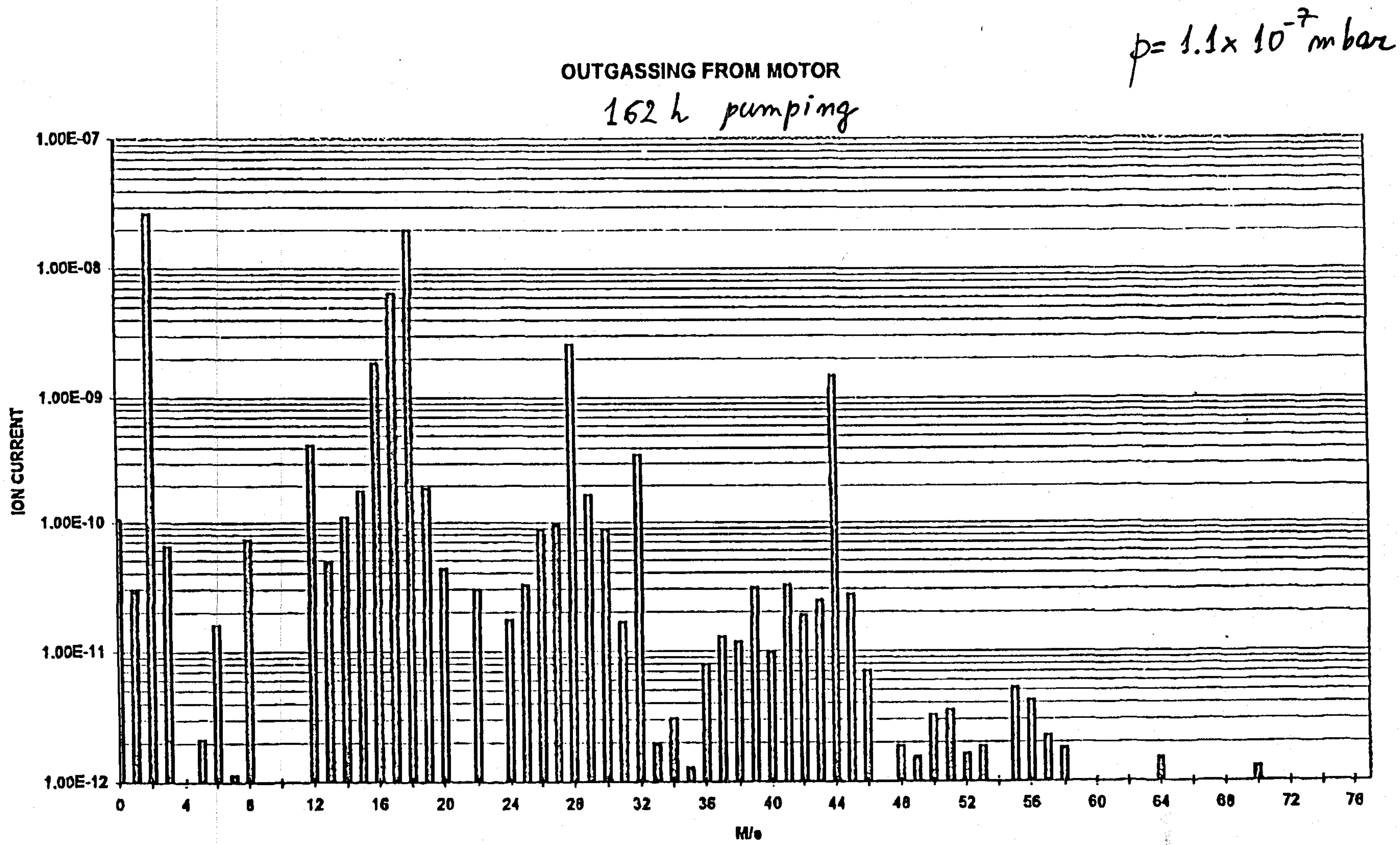

p= 1.1x 10^-7 mbar
OUTGASSING FROM MOTOR
162 h pumping
1.00E-07
1.00E-08
1.00E-09
1.00E-10
1.00E-11
1.00E-12
ION CURRENT
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
M/e

Fig.3

$p = 2.3 \times 10^{-5}$ mbar

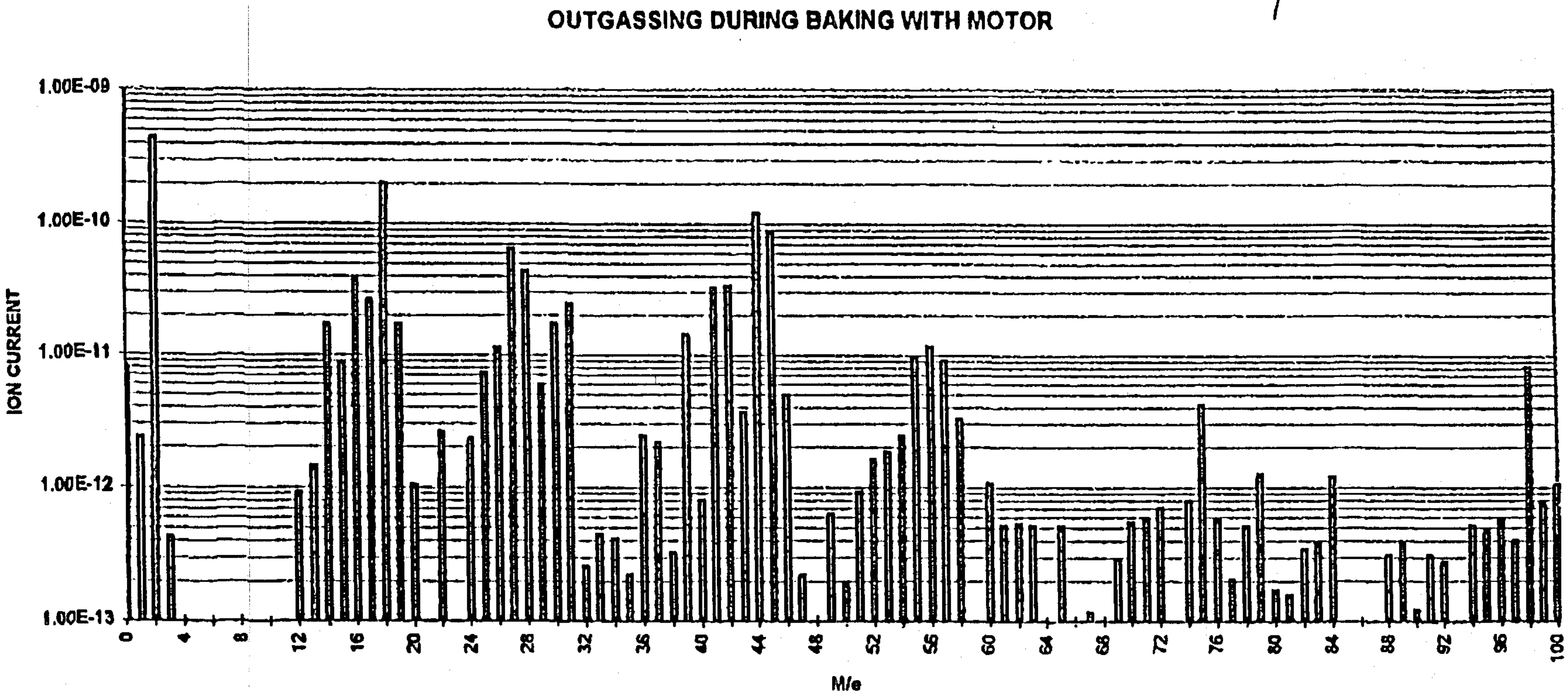


Fig. 4

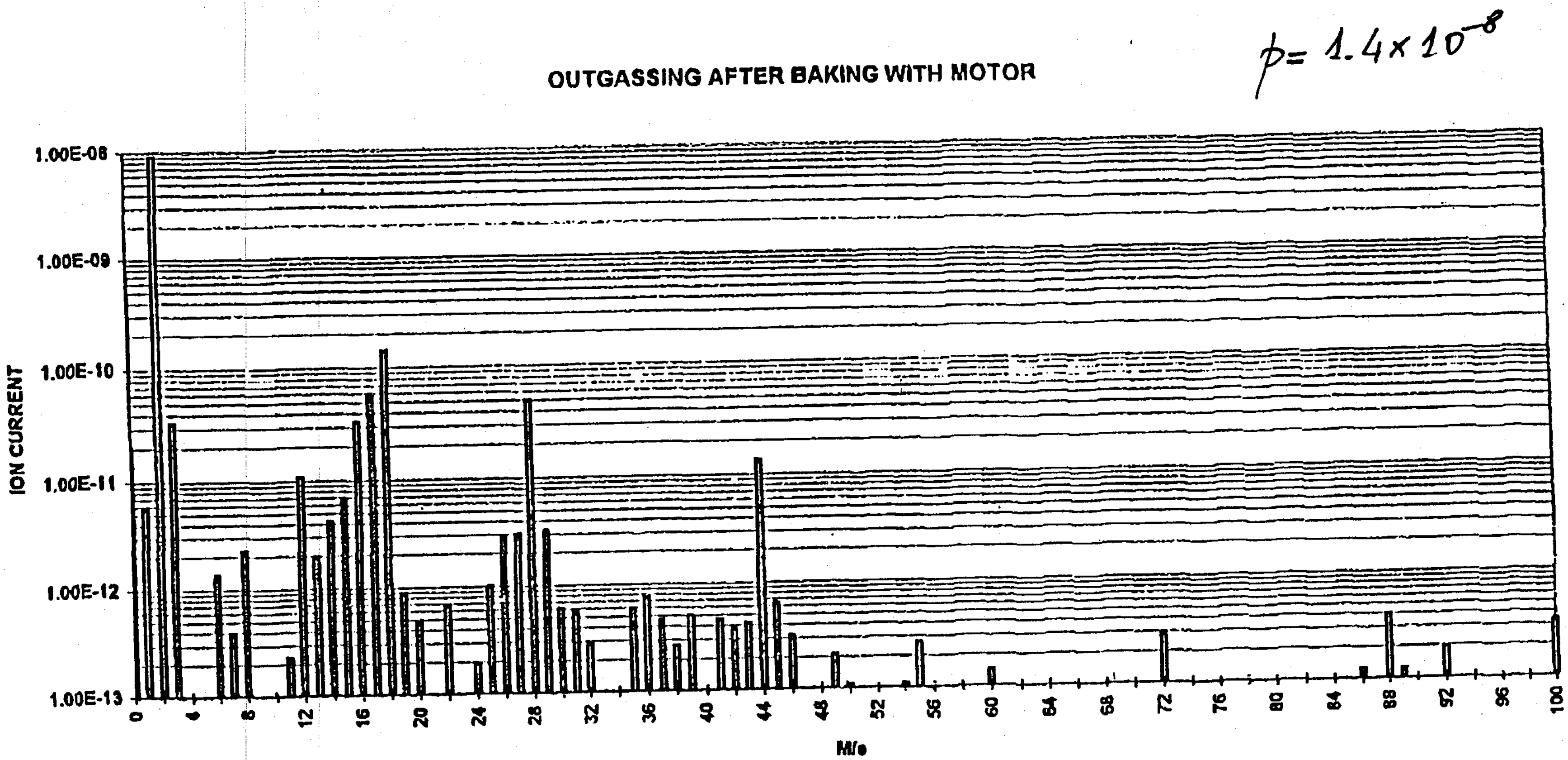
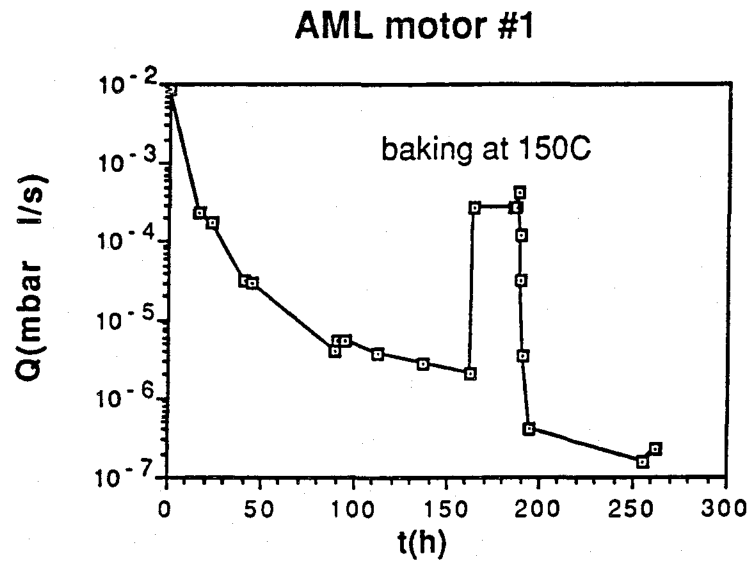

p= 1.4×10^-8
OUTGASSING AFTER BAKING WITH MOTOR
ION CURRENT
1.00E-08
1.00E-09
1.00E-10
1.00E-11
1.00E-12
1.00E-13
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80 84 88 92 96 100
M/e

Fig. 5



AML motor #1
baking at 150C
Q(mbar l/s)
t(h)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0
50
100
150
200
250
300

Fig. 6

chamber outgassing

$p = 6.5 \times 10^{-8}$ mbar

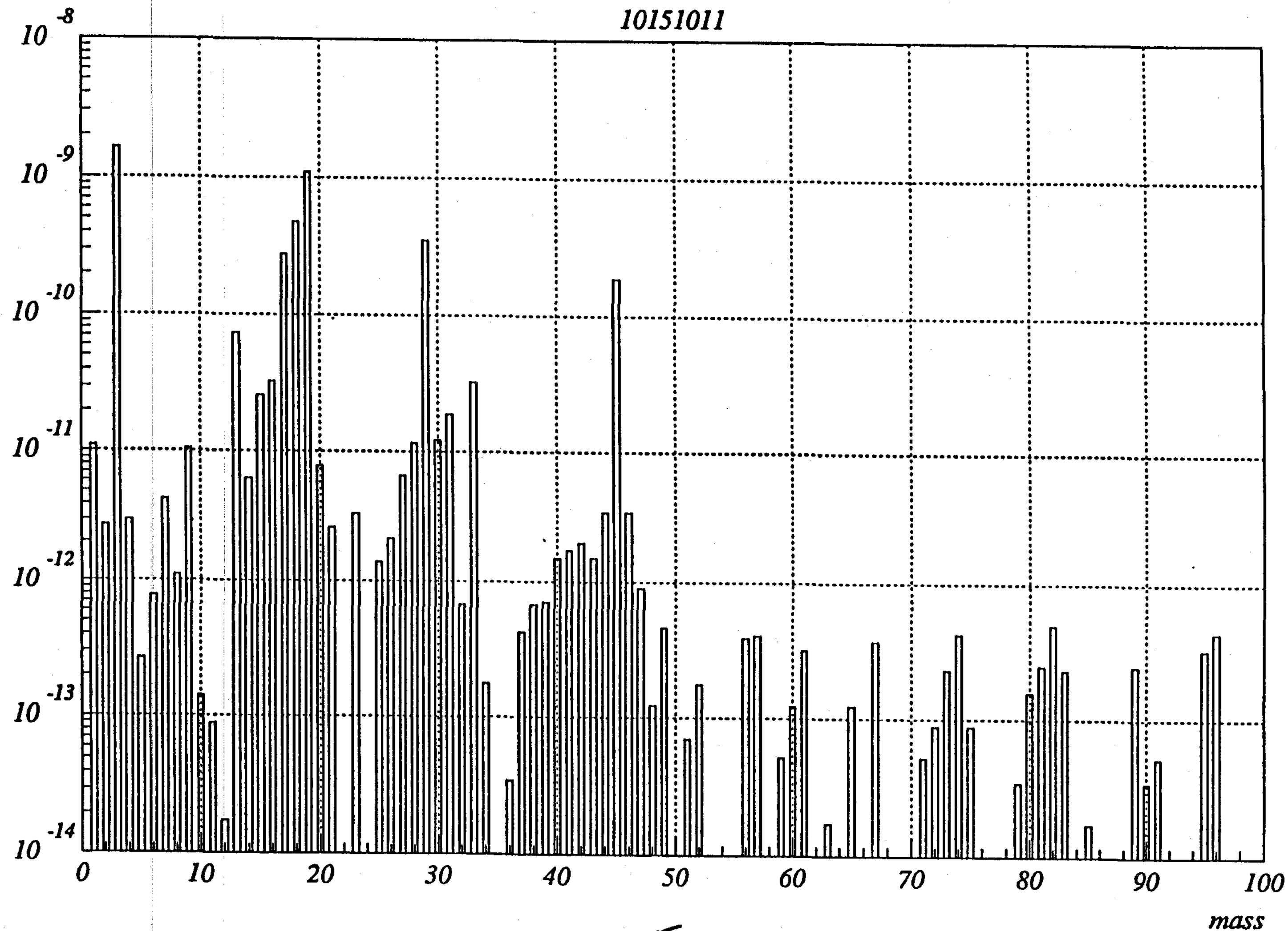
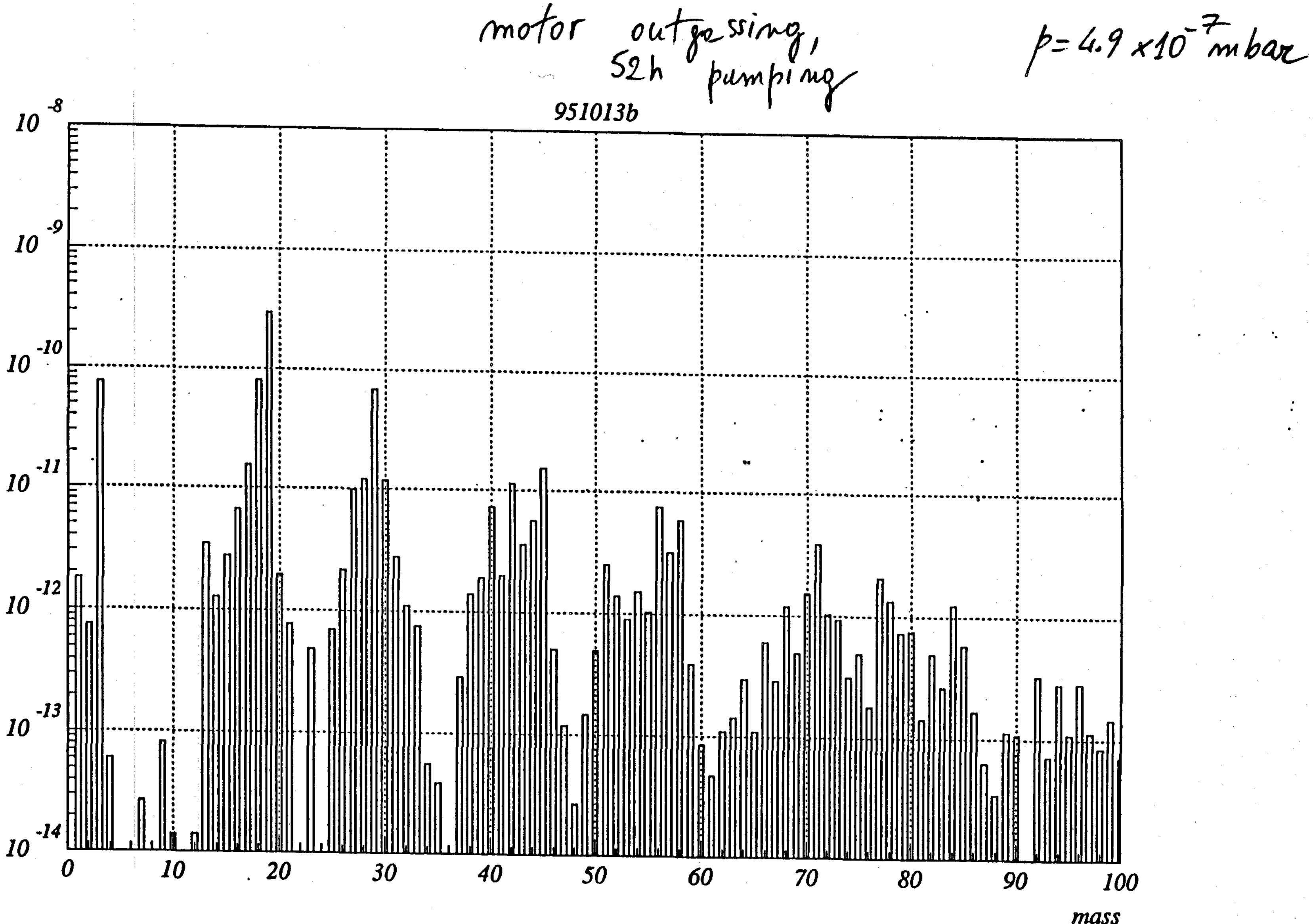


Fig. 7



motor outgassing,
52h pumping
p= 4.9 x10^-7 mbar
951013b
10^-8
10^-9
10^-10
10^-11
10^-12
10^-13
10^-14
0
10
20
30
40
50
60
70
80
90
100
mass

Fig. 8

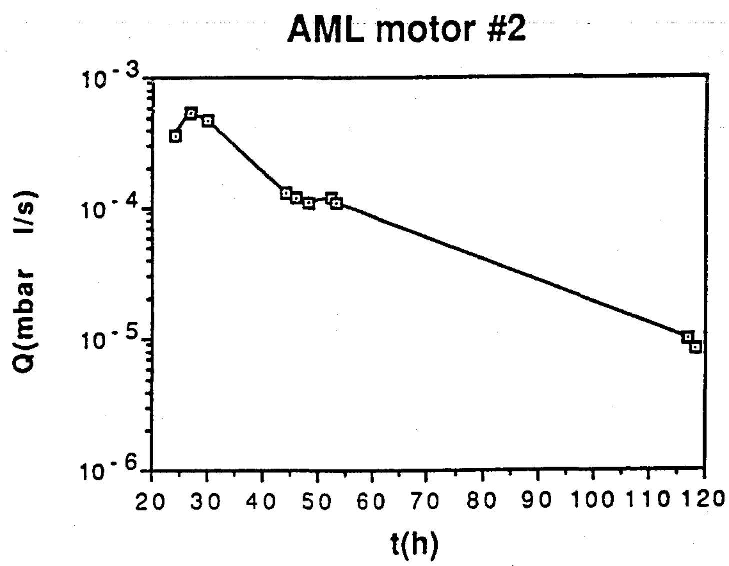
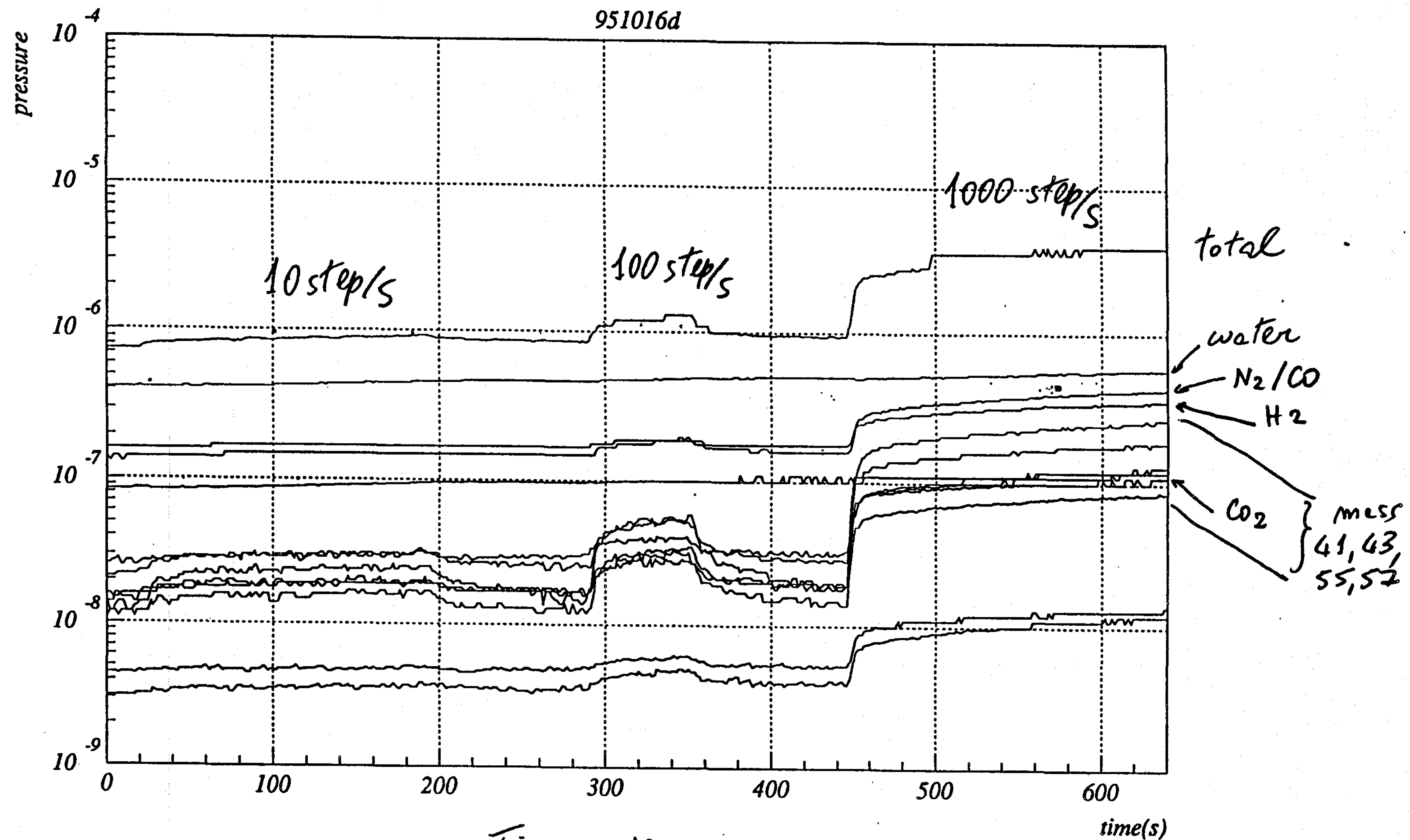
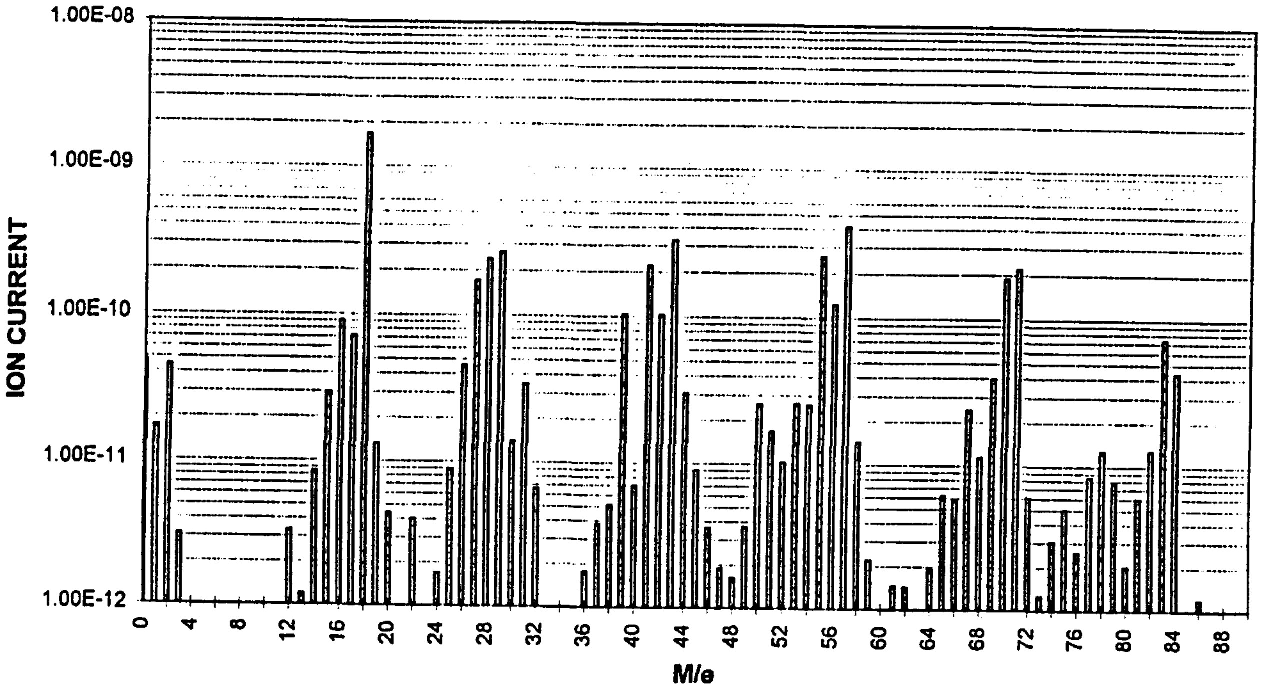

AML motor #2
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Q(mbar l/s)
20
30
40
50
60
70
80
90
100
110
120
t(h)

Fig. 9



951016d
pressure
10 -4
10 -5
10 -6
10 -7
10 -8
10 -9
0
100
200
300
400
500
600
time(s)
10 step/s
100 step/s
1000 step/s
total
water
N2/CO
H2
CO2
mass 41, 43, 55, 57

Fig. 10


1.00E-08
1.00E-09
1.00E-10
1.00E-11
1.00E-12
ION CURRENT
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80 84 88
M/e

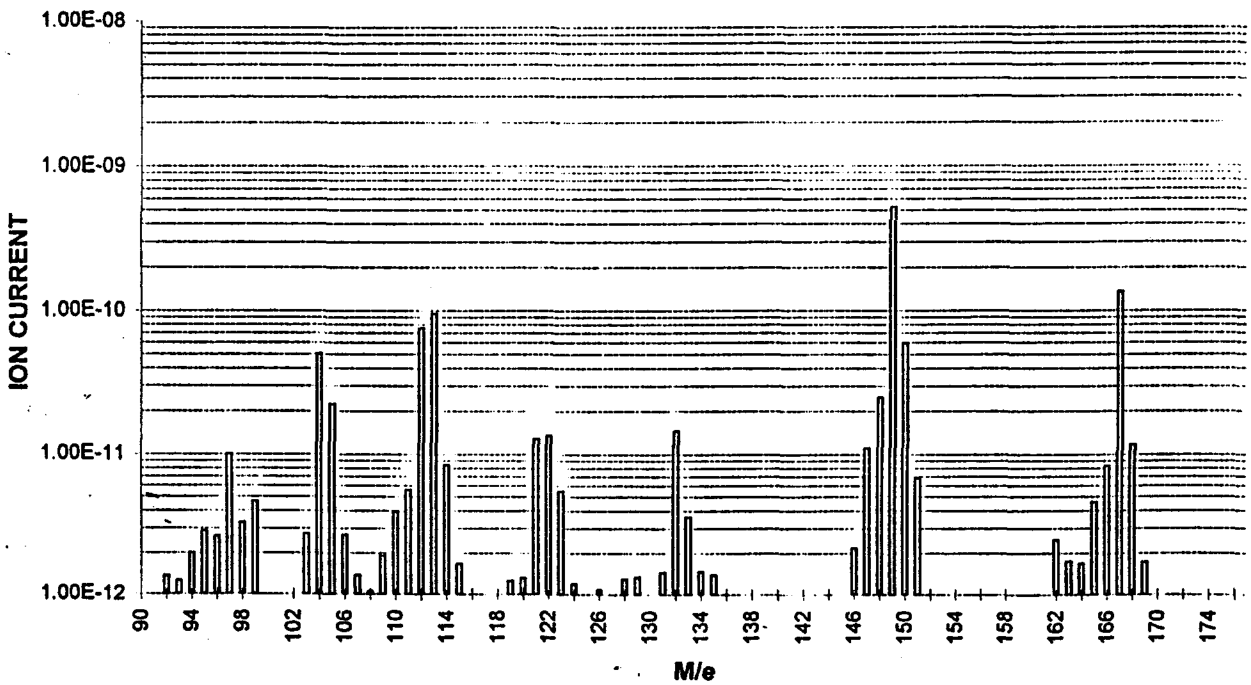

1.00E-08
1.00E-09
1.00E-10
1.00E-11
1.00E-12
ION CURRENT
90 94 98 102 106 110 114 118 122 126 130 134 138 142 146 150 154 158 162 166 170 174
M/e

Fig 11