Object: Outgassing measurements of Kapton insulated cables

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In this note we report the results obtained on Kapton insulated wires selected for possible use for VIRGO coils. The test apparatus is described in detail in the note VACPISA 025. 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 flow can be deduced from the relation:

$$Q = (P_1 - P_2) \times C \qquad (1)$$

where C is the conductance (20 l/s N_2 equivalent at 20^0C). The measurement is performed twice, with and without the sample into the sample chamber: the difference between the two flow values will represent the net sample outgassing; the difference in the RGA spectra will give the mass distribution of the sample outgassing.

1 - System performances

The chamber has been evacuated and maintained under vacuum for 15 hours:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
15	30	1.3×10^{-6}	8.9×10^{-7}	8.2×10^{-6}

The chamber has been then baked at 200°C for 144h, giving at the end:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
after	30	1.7×10^{-9}	1.2×10^{-9}	1.0×10^{-8}

The main components of outgassing were H_2, H_20, N_2/CO, CO_2.

2 - Measurement of the outgassing flow of Kapton insulated cables

We have tested 30 m of Kapton cabling (0.25 mm diameter conductor, 0.12 mm Kapton insulation thickness) produced by Raydex CDT and distributed cleaned for vacuum from Caburn MDC. The surface exposed to vacuum was 490 cm^2. The total resistance of cables was 10.6 Ω.

The temperature rise of the wires with current flowing in was measured both by a thermocouple in tight contact with the cables and with the measurement of conductor resistance (simultaneous measurement of voltage and current).

We have put the cables in the chamber and monitored the outgassing:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
14	12	6.1x10^{-5}	5.1x10^{-5}	2.0x10^{-4}
17	12	1.8x10^{-4}	1.0x10^{-4}	1.6x10^{-3}
40	12	3.7x10^{-5}	3.2x10^{-5}	1.0x10^{-4}
56	12	3.3x10^{-5}	1.9x10^{-5}	2.8x10^{-4}
58	12	3.0x10^{-5}	1.8x10^{-5}	2.4x10^{-4}
64	12	1.1x10^{-5}	7.7x10^{-7}	2.0x10^{-4}
65	12	8.9x10^{-6}	6.2x10^{-7}	1.6x10^{-4}
88	12	8.5x10^{-7}	5.7x10^{-8}	1.6x10^{-5}
91	12	7.5x10^{-7}	4.9x10^{-8}	1.4x10^{-5}
130	12	9.8x10^{-8}	3.7x10^{-9}	1.9x10^{-6}
234	12	1.9x10^{-9}	6.1x10^{-10}	2.6x10^{-8}
251	12	1.8x10^{-9}	6.1x10^{-10}	2.4x10^{-8}

After a venting of the system to replace RGA in the upper part:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
21	13	1.2x10^{-7}	7.6x10^{-9}	2.2x10^{-6}
28	13	1.7x10^{-7}	9.3x10^{-9}	3.2x10^{-6}
146	13	1.9x10^{-8}	2.2x10^{-9}	3.4x10^{-7}

After another stop to fix RGA problems we started again:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
70	12	4.4x10^{-8}	5.7x10^{-9}	7.7 x10^{-7}
72	12	4.2x10^{-8}	5.4x10^{-9}	7.3x10^{-7}

The outgassing spectrum after 72 h is reported in Fig. 1. We let 100 mA (0.1 W dissipation) flow in the cables and observed that the pressure increased to 6.7x10^{-8} mbar in 20 minutes (the final outgassing was 1.1x10^{-6} mbar l /s). We supplied 200 mA (0.4 W dissipation) to the cables starting from a base pressure of $1.7x10^{-8}$ mbar; after one night, the pressure was approaching the initial value again and we got the spectrum in Fig. 2 (pressure $1.6x10^{-7}$ mbar, outgassing $2.9x10^{-6}$ mbar l /s) with a peak at mass 69, which disappears when the current is switched off.

We baked the system at 120^{0}C:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
during	120	$6.8x10^{-7}$	$1.6x10^{-7}$	$1.0x10^{-5}$

The outgassing spectrum taken during the baking is shown in Fig. 3. We observed again a peak at mass 69 which disappeared when the ion pump was switched on. We let 100 mA flow in the cable again. After one night the pressure was $5.7x10^{-9}$ mbar and the outgassing $7.4x10^{-8}$ mbar l /s. The spectrum is reported in Fig. 4. After several days pumping after baking we got the spectrum in Fig. 5 and:

t(h)	T(^{0}C)	p_1(mbar)	p_2(mbar)	Q(mbar l/s)
after	21	$3.6x10^{-9}$	$1.0x10^{-9}$	$5.2x10^{-8}$

After a few days, we tested again the cables with current flowing. Currents up to 200 mA produced no sizeable effects on a scale of several minutes. On the other hand, supplying a current of 1 A (~11 W dissipation) produced a pressure rise of almost three orders of magnitude and a temperature rise of 100^{0}C in nearly 10 minutes. The increase of partial pressures of a few selected gases in shown in Fig. 6.

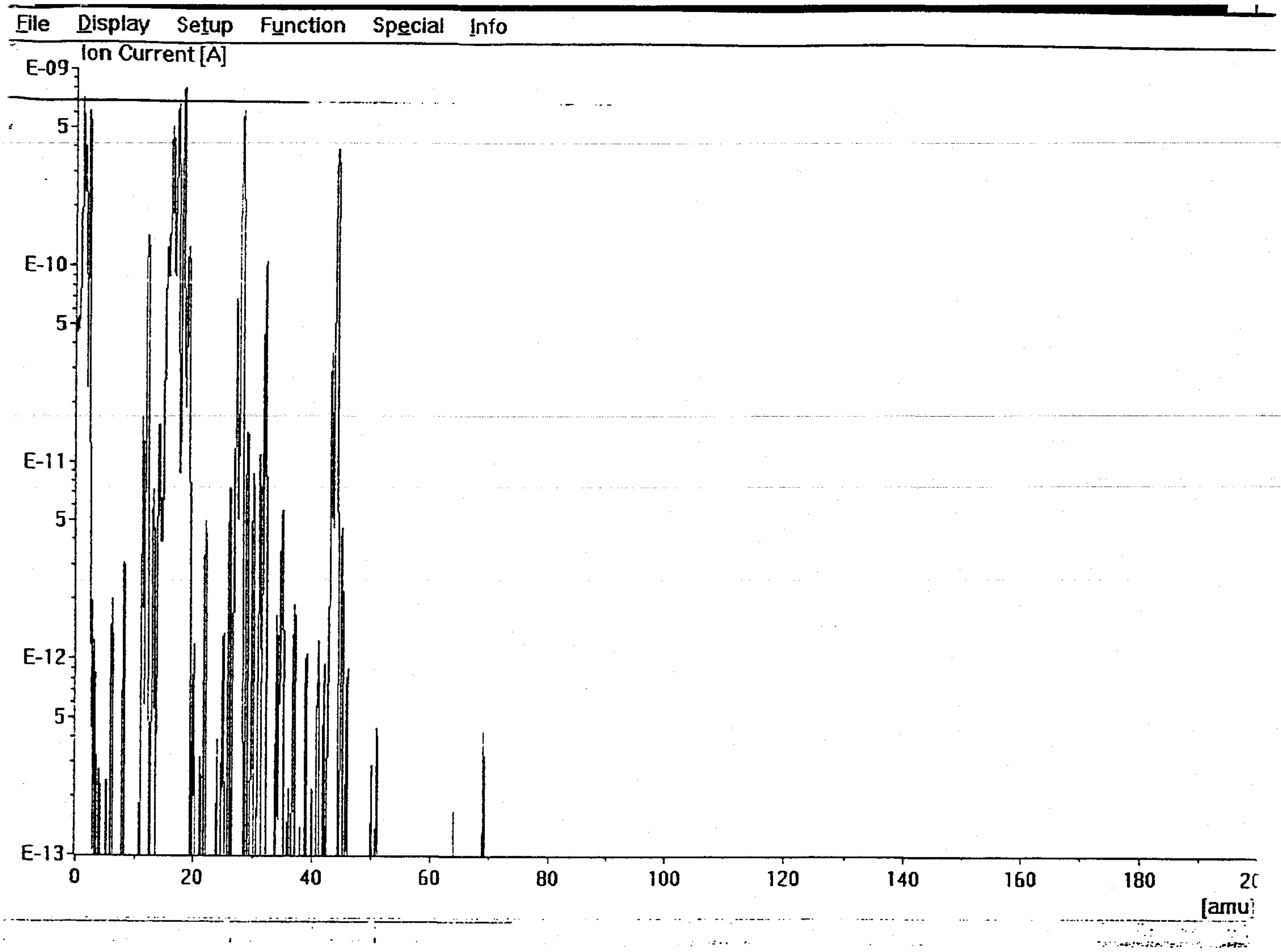
3 - Discussion

We have observed that the Kapton cables exhibit a strong water vapour retention and must be pumped for quite a long time. Repeated vacuum cycling improves the vacuum perfromances (see Fig. 7 where the three different runs are compared). The peak at mass 69 which appears when cables are baked or sizeable currents are flowing has been identified as CF_3. Fluorine does not appear in the Kapton formula. We checked with Caburn that no solvent containing fluorine has been used during the cleaning process. Since the Kapton is sealed with a FEP (fluoro-ethylen-polymer) layer we think that this layer is responsible for the peak. For this reason, we have asked Raydex to remove it in the next samples.

We summarize here the outgassing rates measured in different conditions:

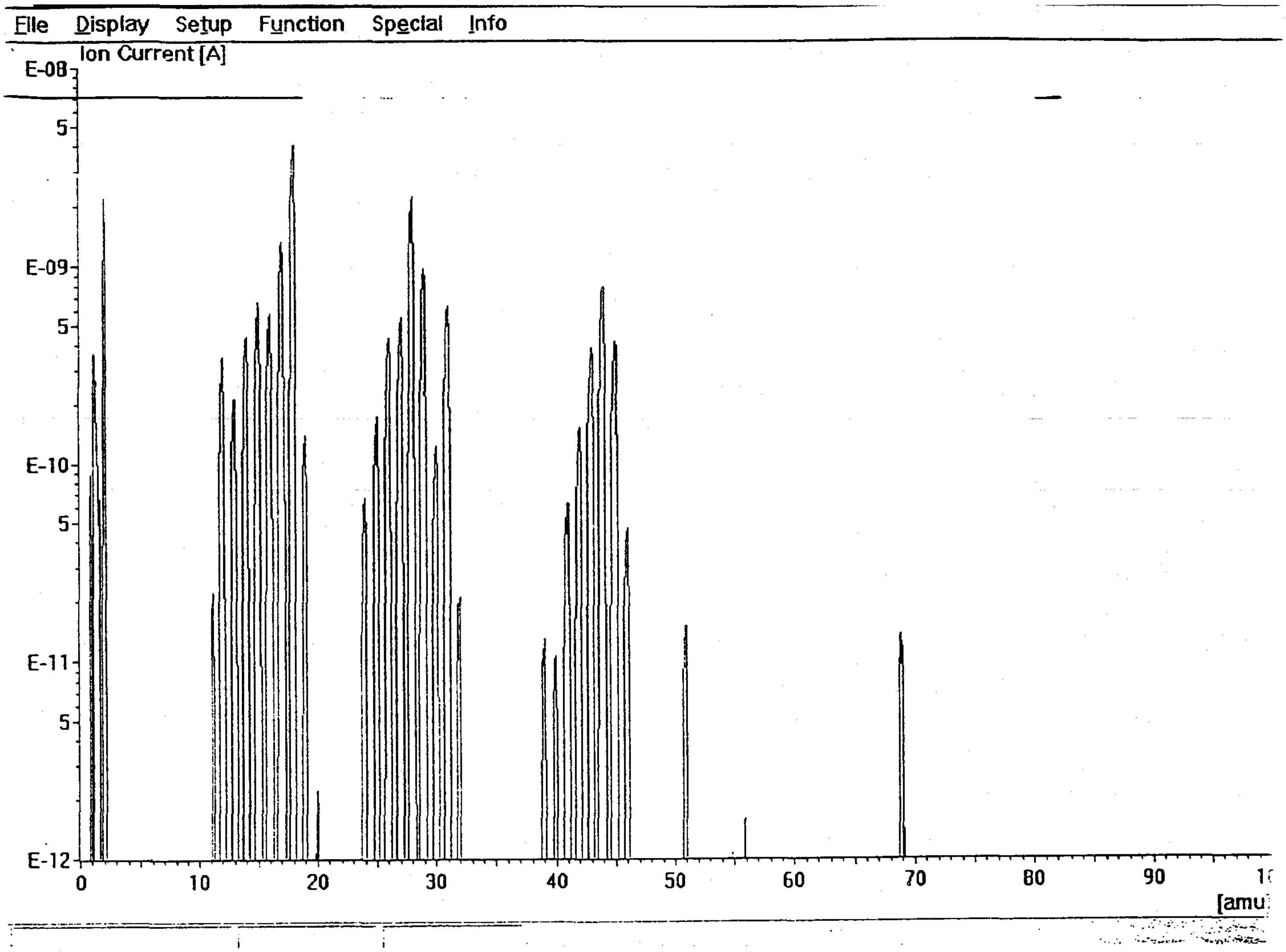
- before baking, 72h pumping, no current : 1.5×10^{-9} mbar l s^{-1} cm^{-2}
- during baking, no current flowing : 2.0×10^{-8} mbar l s^{-1} cm^{-2}
- after baking, no current flowing : 1.1×10^{-10} mbar l s^{-1} cm^{-2}
- after baking, 0.1 W dissipation for 1 night : 1.5×10^{-10} mbar l s^{-1} cm^{-2}

We conclude that Kapton cabling can be recommended for use in VIRGO if the FEP layer is removed. One km of 1 mm diameter cabling with 0.1 W dissipation will provide an outgassing flux of 4.7×10^{-6} mbar l s^{-1} . Since Kapton technology fulfils the VIRGO specifications we will proceed to test coaxial cables for signal transmission.



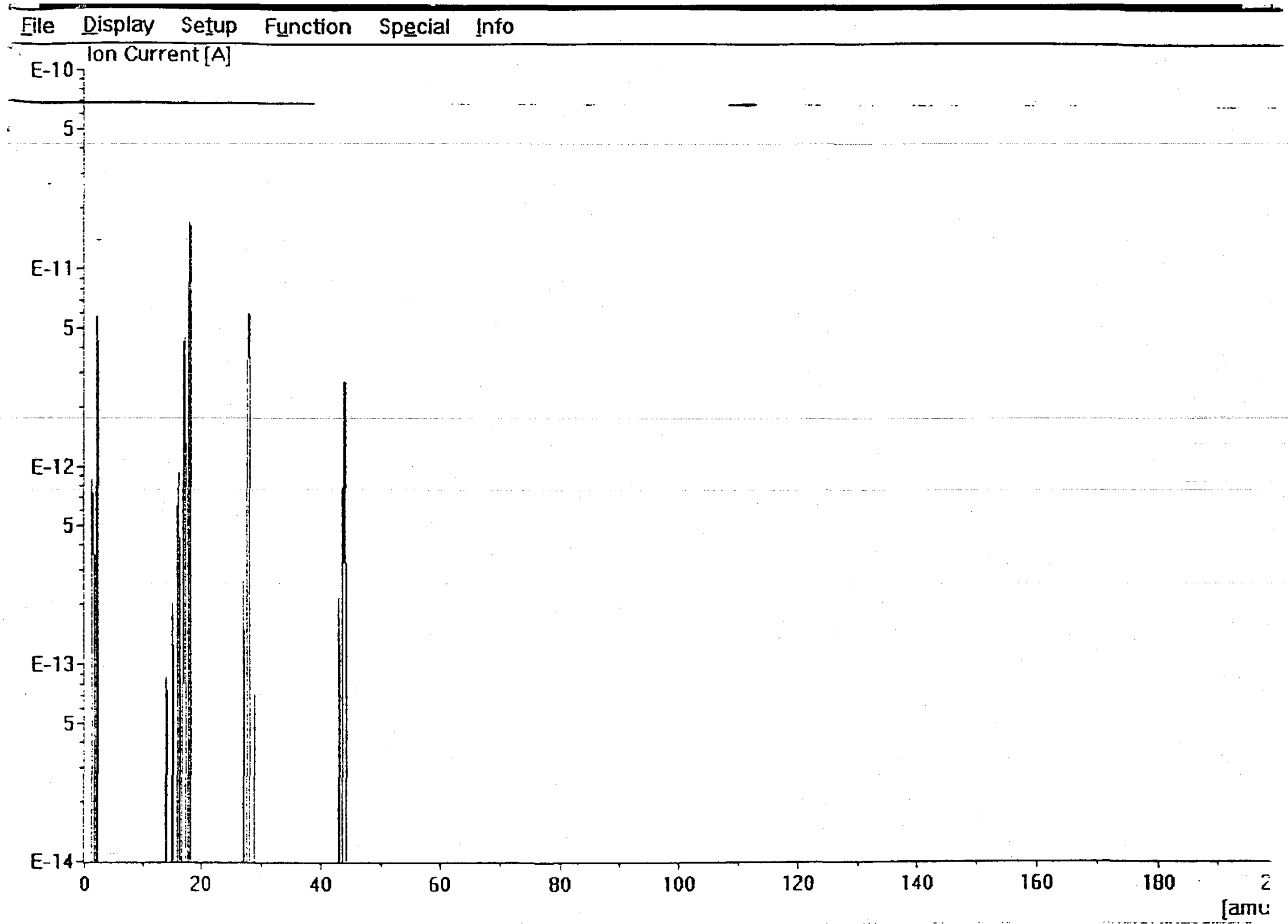
$p = 4.2 \times 10^{-8}$ mbar

Fig. 1



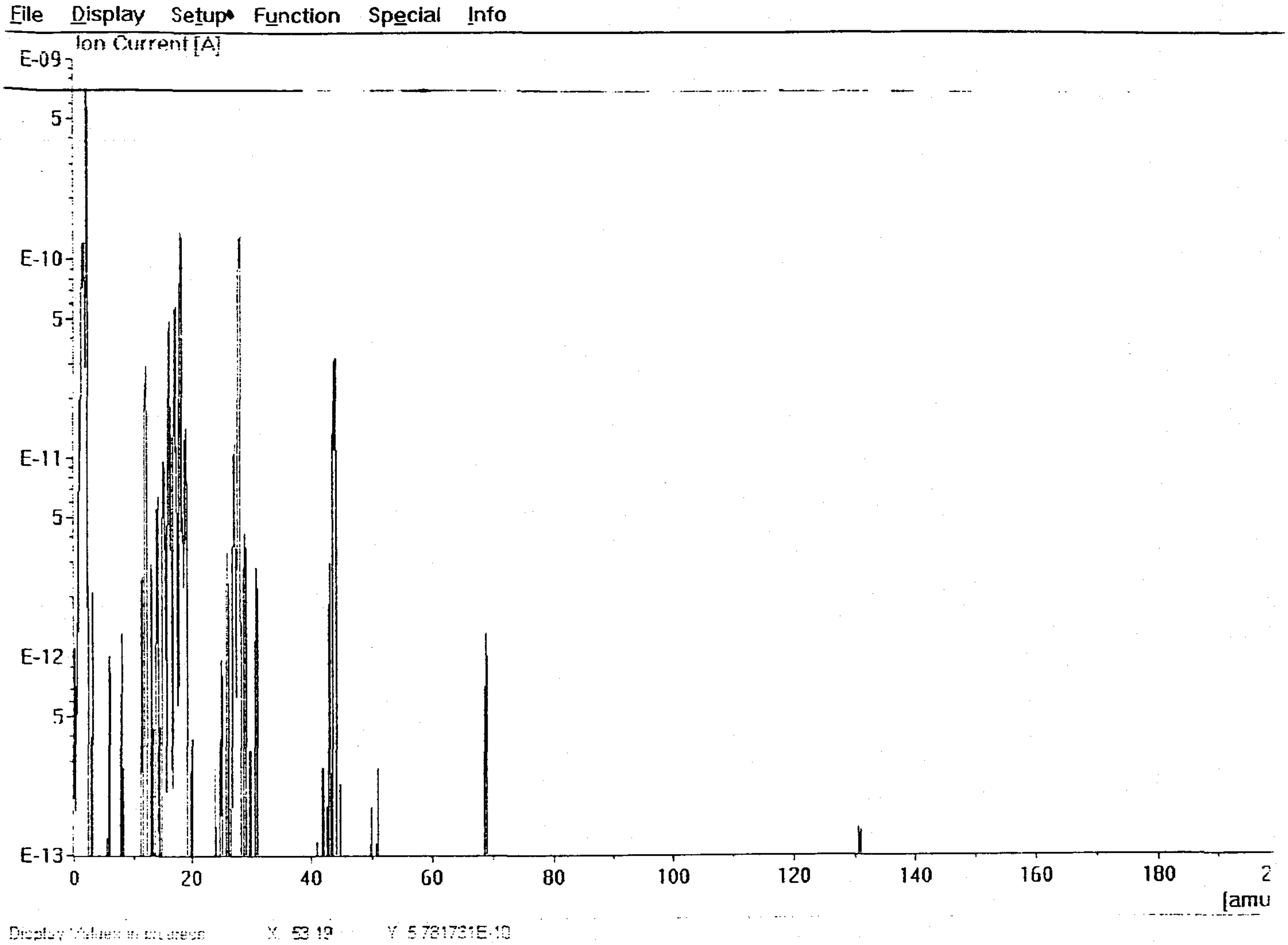
$p = 1.6 \times 10^{-7}$ mbar

Fig. 2



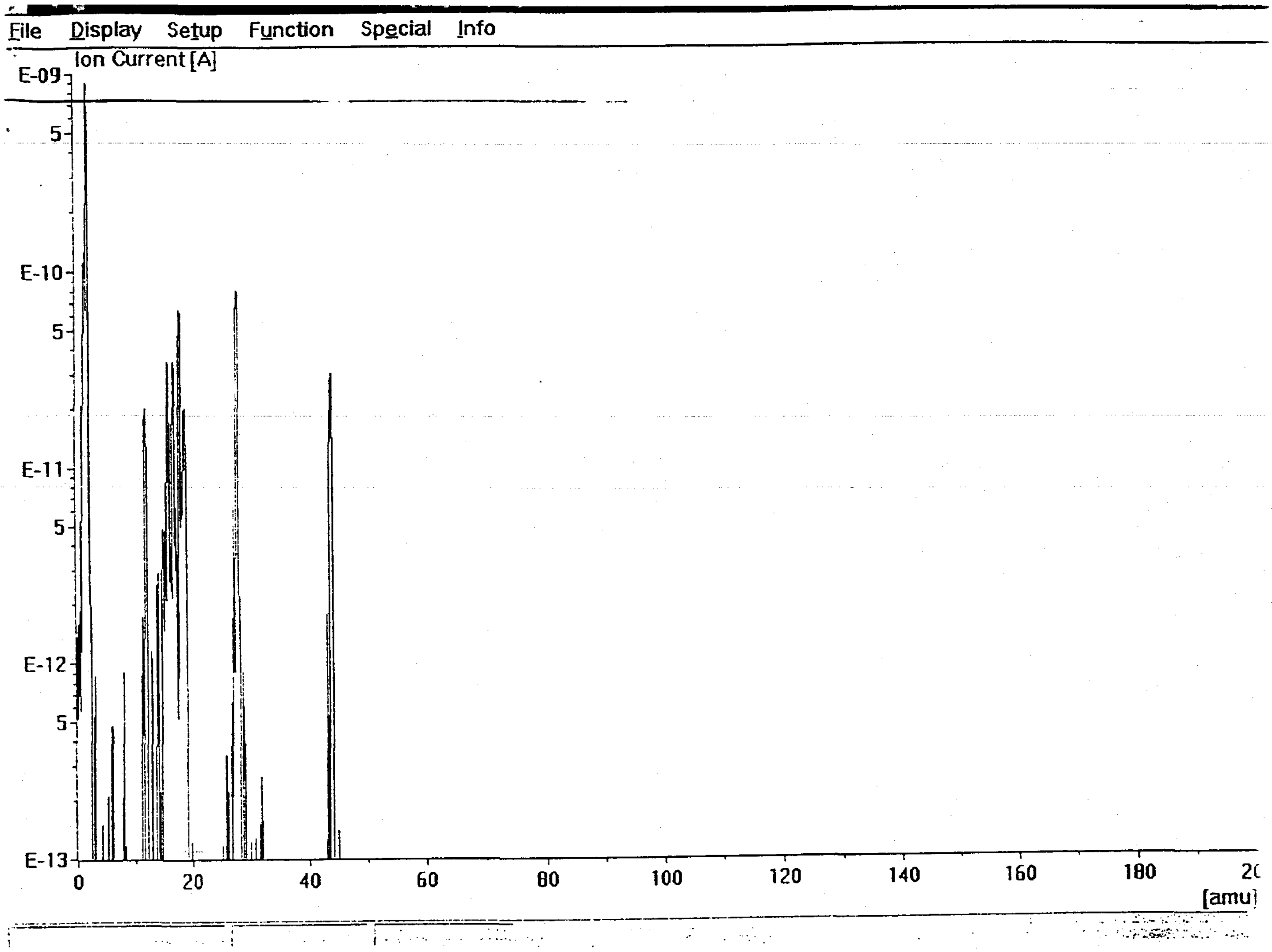
$p = 6.8 \times 10^{-7}$ mbar

Fig. 3



$p = 5.7 \times 10^{-9}$ mbar

Fig. 4



$p = 3.6 \times 10^{-8}$ mbar

Fig. 5

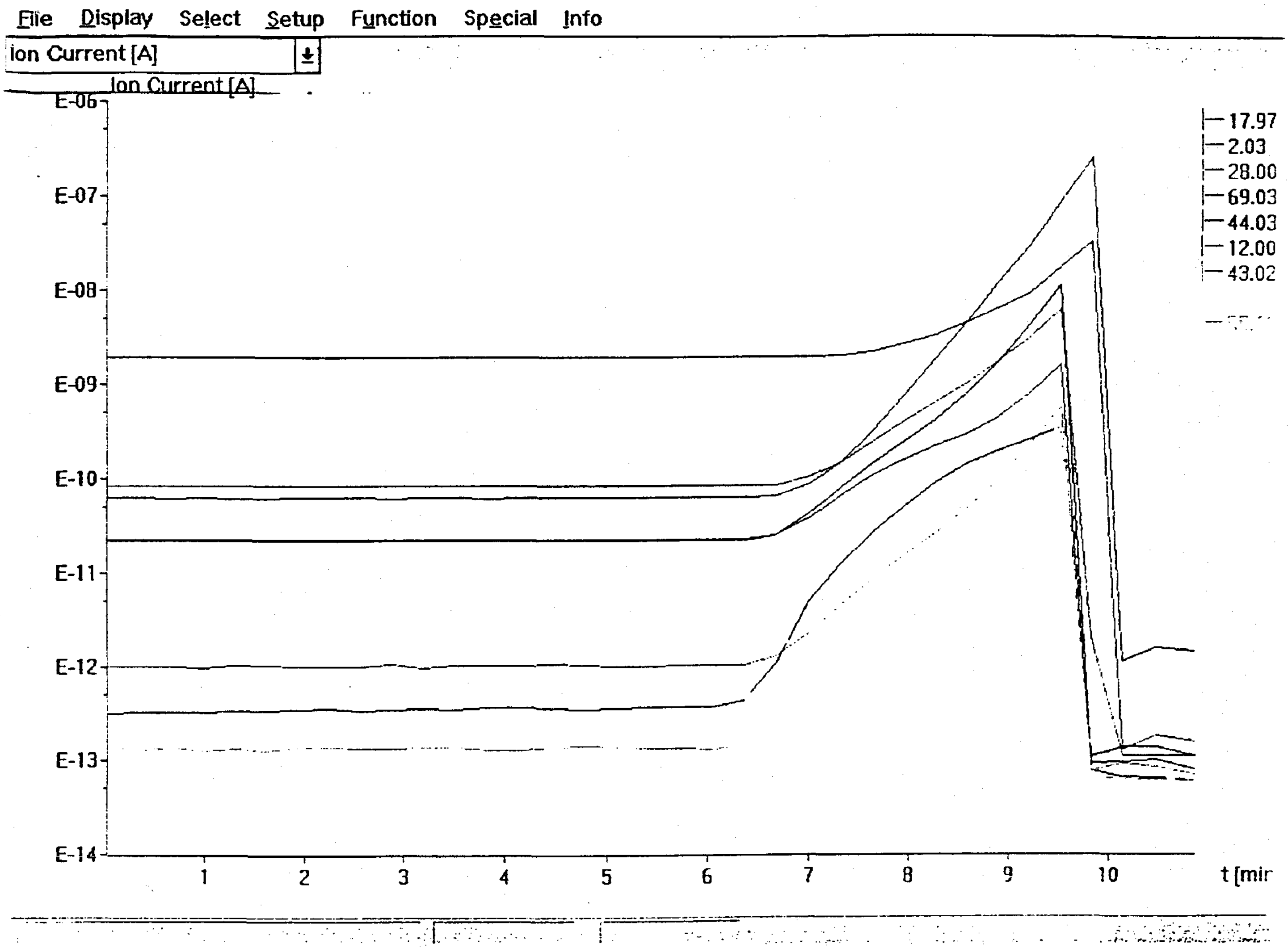

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Fig. 6

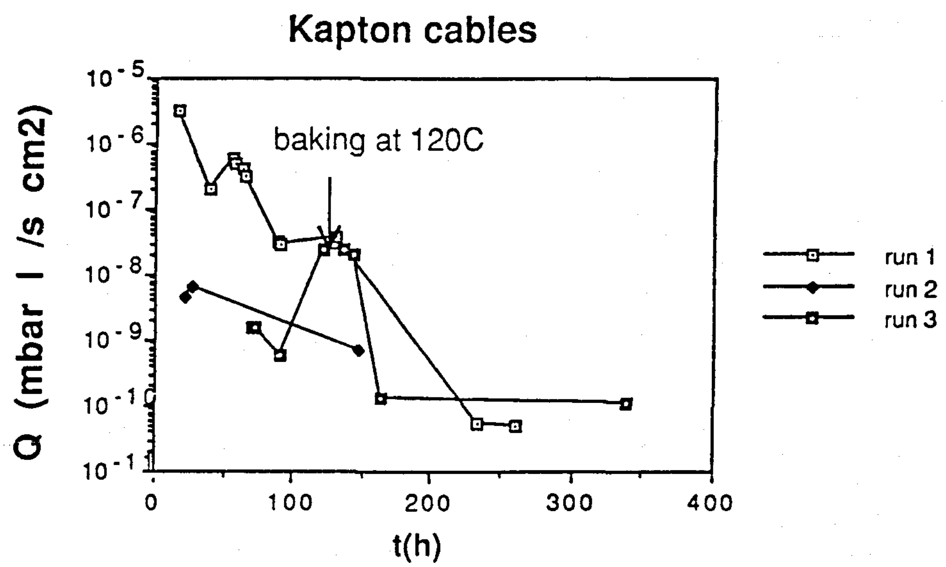
Kapton cables
Q (mbar l /s cm2)
t(h)
baking at 120C
run 1
run 2
run 3
0
100
200
300
400

Fig. 7