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ACCELERATOR VACUUM PROBLEMS: IN-LINE OIL TRAPPING BETWEEN THE STANFORD LINEAR ACCELERATOR AND THE BEAM SWITCHYARD*

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Summary

The thirty accelerator sectors (each 330 feet long) of the two-mile machine will be evacuated with sputter-ion pumps to pressures low enough to limit rf breakdown and multipactor problems. After the beam leaves the accelerator it will be "switched" by pulsed magnets to one or more of the experimental areas through the 1000-foot beam switchyard.

Due to the nature of the equipment in the beam switchyard and the requirements for inexpensive, non-elastomeric, remotely operable couplings, there will be a high probability for virtual and real leaks and a consequent need for continuous high throughput pumping. Oil diffusion pumps are therefore used to evacuate the four branching beam tubes of the beam switchyard.

Some kind of in-line oil trap is needed to separate the clean, low pressure (10^{-7} torr), ion-pumped accelerator from the oil-pumped (10^{-4} torr) beam switchyard end of the machine. This trap should limit the amount of oil and organic fractions passing back through to the accelerator and should provide some of the impedance necessary to obtain the three-order-of-magnitude pressure difference between accelerator and switchyard. The pressure difference will be maintained by differentially pumping on each of two in-line vacuum impedances. One of these impedances will be a standard 10-foot section of disk-loaded waveguide and will act as an oil trap. When refrigerated, such a trap had measured transmission probabilities of 10^{-9} to 10^{-6} for heavy hydrocarbons.

Test Setup and Procedure

Figure 1 is a photograph of a standard 10-foot waveguide with longitudinal cooling tubes. Figure 2 shows a cutaway section of the disk-loaded waveguide.

Figure 3 shows the test setup. The idea was to simulate the anticipated pressure and gas throughput conditions of the differential pumping system and to measure the amount of oil or hydrocarbon fractions that traversed the waveguide when it was refrigerated and oil was purposely introduced at the diffusion pump end.

DC 705 Oil

The tests were conducted with Dow Corning 705 diffusion pump oil. Chemically, DC 705 is pentaphenyl trimethyl trisiloxane with a molecular weight of 546 and a specific gravity at 25°C of 1.095 g/cc. The vapor pressure of DC 705 follows the simple relation:

$$\log p = A - \frac{B}{T}$$

where

$$A = 12.31 \quad \text{and} \quad B = 6490$$

which gives a vapor pressure of $< 10^{-9}$ torr at 25°C and ≈ 1 torr at 250°C. The diffusion pump and both oil effusion cells were loaded with DC 705 oil.

Mass Spectrometer

A Consolidated Electrodynamics Corporation Type 21-613 residual gas analyzer was the principal tool employed to measure the partial pressures of the gases reaching the ion-pumped end of the test section. The instrument was calibrated with nitrogen and found to have a sensitivity of 4×10^{-11} torr/division for this gas. On the basis of other work showing sensitivities for most other gases not different by more than a factor of 2, we assumed a sensitivity of 4×10^{-11} torr/scale division for all gases commonly measured except hydrogen and helium.

The mass spectrometer, connecting tubes, and the chamber at the ion-pump end were all held at temperatures of 80-100°C during the tests. This ensured that any oil entering this region would be at a high enough vapor pressure to be readily detected with the mass spectrometer.

Test Sequence

Complete mass spectra patterns were recorded intermittently during all phases of the tests. Altogether over 100 patterns covering the mass range 2 to 400 were obtained during the following test sequence:

1. Ion pumping only.
2. Diffusion plus ion pumping.
3. Before and after baking system.
4. Following refrigeration of waveguide to -37°C.
5. Following heating of transverse injection oil cell to > 200°C (vapor pressure approximately 80 microns).
6. Following introduction of nitrogen through

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leak valve to simulate gas load in switchyard and flow toward ion pump end.

7. Following heating of axial injection oil cell to 250°C (vapor pressure approximately 1 torr).

8. Following admission of viscous flow pressure waves sent down waveguide by rapidly opening the nitrogen leak valve at the diffusion pump end.

9. Following cut-off of refrigeration and return of pipe to room temperature.

10. Following heating of waveguide and ion pump end in effort to drive back hydrocarbons.

11. Following re-refrigeration of waveguide to -37°C.

Results

Figure 4 shows the changes in the summed partial pressures of the heavy hydrocarbon groups (all masses > 44) as changes were made in the test conditions. It can be seen that any sudden change in pressure drove additional hydrocarbons through the trap. However, even under the most severe condition tested, the hydrocarbon pressure ratio from one end to the other of the refrigerated "trap" was of the order of 10^6, while under steady-state conditions, the ratio was 10^9 or greater.

From the test results we can make some estimate of how much oil and/or organic fractions might get through the "trap" under the worst anticipated conditions. For this analysis, let us assume a steady-state transmission rate for heavy organics, corresponding to a partial pressure, during the tests, of 10^{-10} torr.

$$\text{Transmission rate} = \text{pumping speed} \times \text{partial pressure}$$

Speed for mass 58 measured at the spectrometer was 20 liters/sec. Therefore,

$$\text{transmission rate} = 20 \frac{\text{liters}}{\text{sec}} \times 10^{-10} \text{ torr}$$

$$= 2 \times 10^{-9} \frac{\text{torr-liter}}{\text{sec}}$$

Converting to molecules, we get

$$2 \times 10^{-9} \frac{\text{torr-liter}}{\text{sec}} \times 3.3 \times 10^{19} \frac{\text{molecules}}{\text{torr-liter}} =$$

$$6.6 \times 10^{10} \frac{\text{molecules}}{\text{sec}}$$

From this transmission rate, we can estimate how long it might take to cover the internal parts of the accelerator with a monolayer of organic molecules.

$$\text{time to form monolayer} = \frac{\text{number of sites}}{\text{rate of arrival} \times \text{sticking fraction}}$$

From electron diffraction work we can assume monolayer coverage requires 2×10^{14} molecules/cm^2 for molecules of average mass 100.

For this argument, we assume that the sticking probability for heavy organics is 1.0. Therefore the minimum time required to get a monolayer on 1 cm^2 would be:

$$\frac{2 \times 10^{14}}{6.6 \times 10^{10}} \approx 3000 \text{ seconds}$$

The internal area of the last ten-foot section of the accelerator with related waveguide and vacuum plumbing is approximately 10^5 cm^2. Therefore, monolayer coverage of this part would take 3×10^8 seconds or nearly 10 years.

Conclusions

It has been demonstrated that a refrigerated disk-loaded waveguide section can act as an effective barrier and reduce to low values ($< 10^{11}$ molecules/sec) the number of heavy hydrocarbon molecules reaching the accelerator from the beam switchyard and the end stations where oil pumps will be used. For noncondensable gases in the molecular-flow regime, pressure ratios of 100 to 300 can easily be maintained across the disk-loaded waveguide. The waveguide will be maintained sufficiently out of tune to prevent significant absorption of rf power from the beam.

Heating the "trap" in order to drive back the accumulated oil and oil fractions did not appear promising. Therefore, great care will be taken to ensure that the trap remains cold, or valved-off when permitted to warm up.

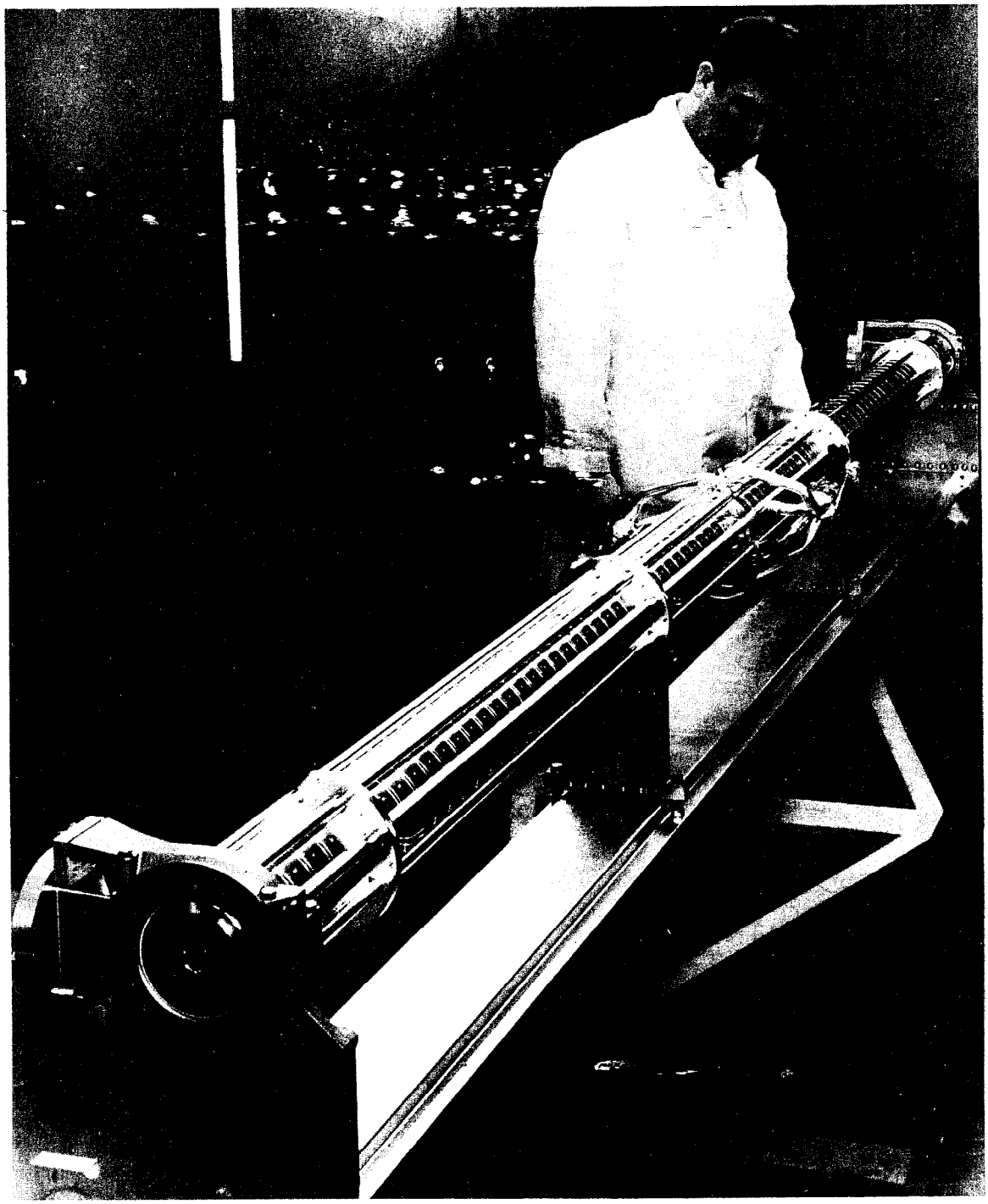

FIG. 1--Standard 10-foot accelerator section (disk-loaded waveguide).

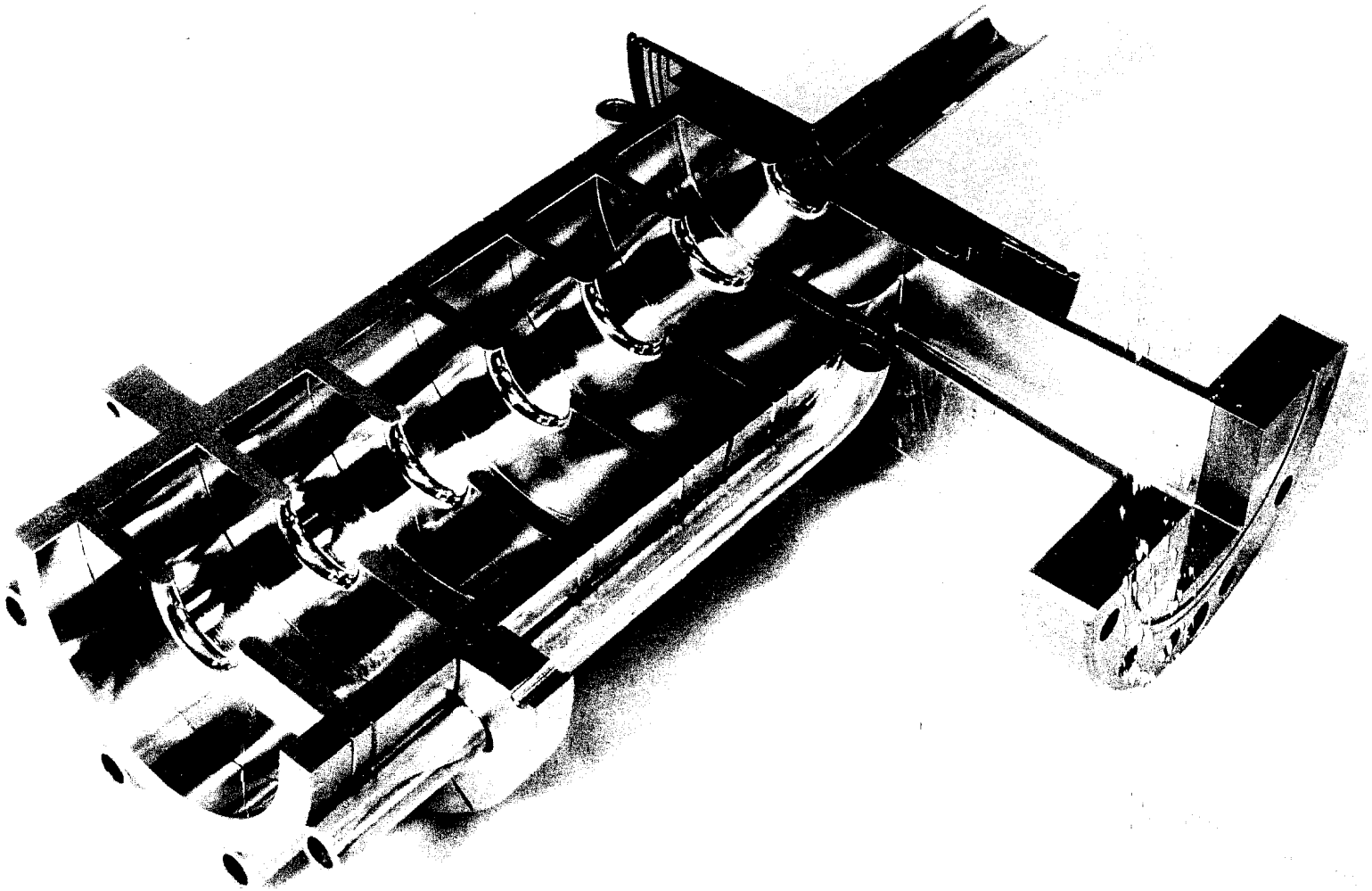

FIG. 2--Cutaway section of disk-loaded waveguide.

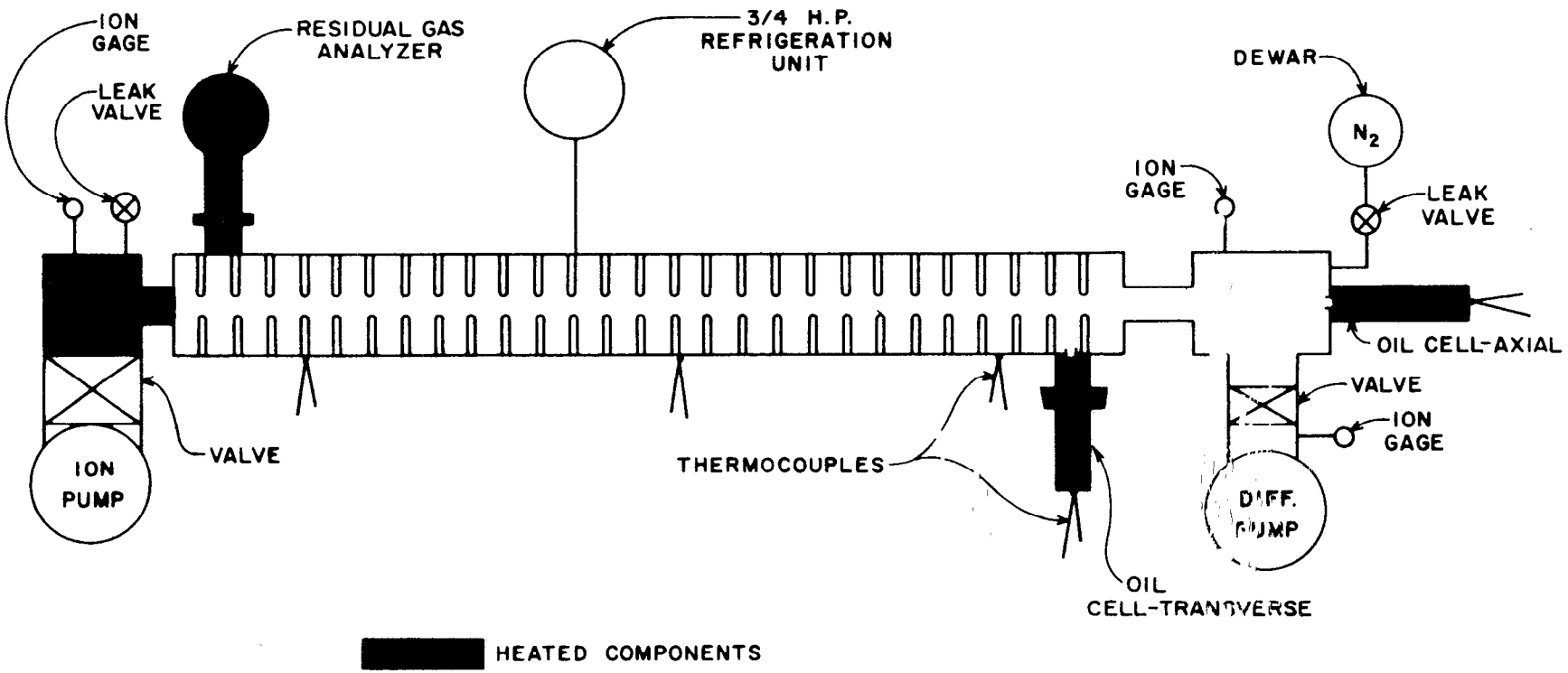

FIG. 3 – TEST SETUP USING 10 FT. ACCELERATOR SECTION AS AN OIL BARRIER

130-1-A

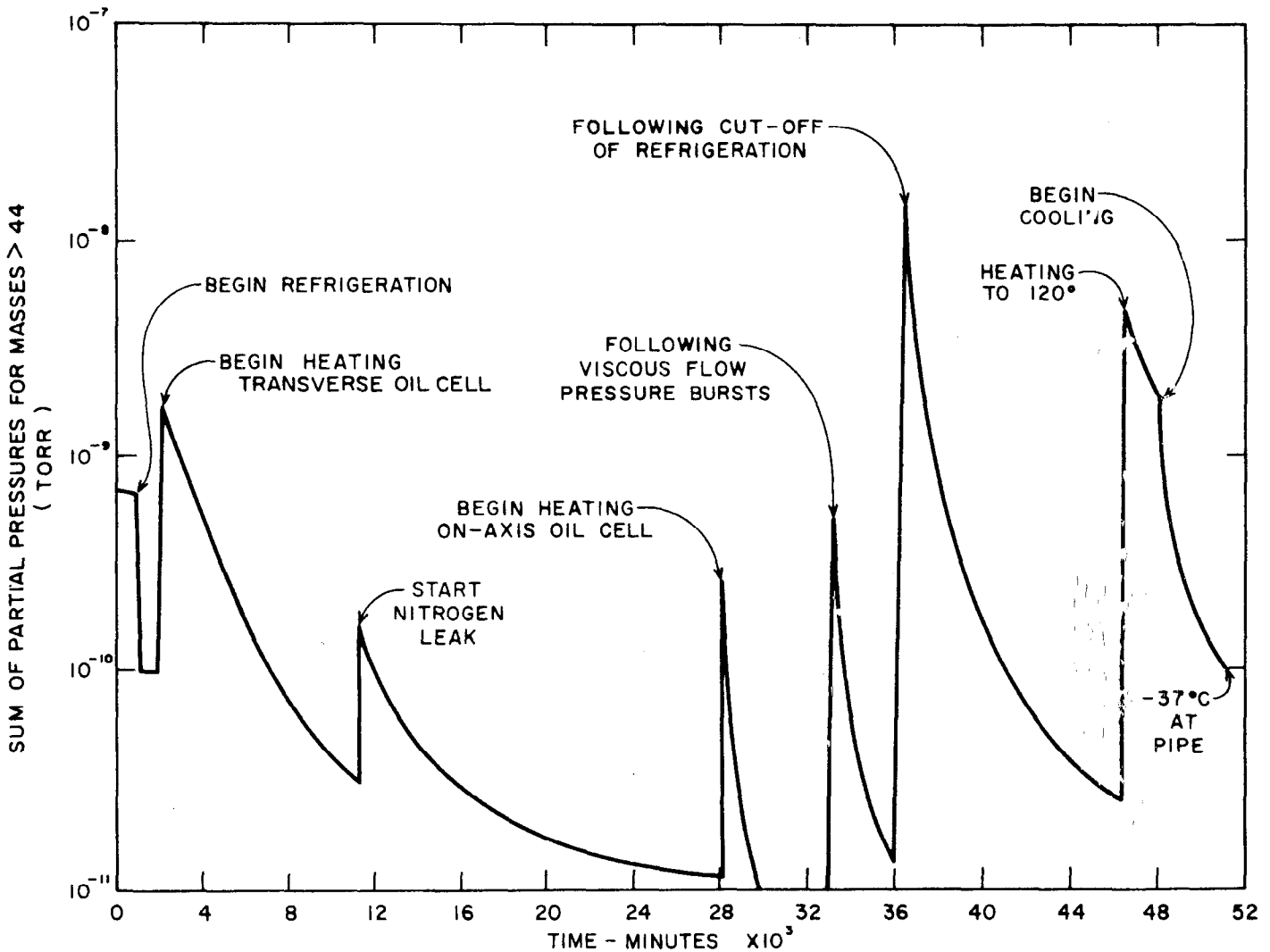

FIG.4 - PARTIAL PRESSURE OF HEAVY HYDROCARBONS MEASURED AT MASS SPECTROMETER DURING OIL TRAPPING TESTS

130-2-A