TN-65-28
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RESULTS OF EVALUATION OF PROTOTYPE CRYOSORPTION PUMPING SYSTEMS

INTRODUCTION

This report describes tests and operational experiences with large, liquid-nitrogen-cooled molecular sieve pumps used for roughing one sector of the Stanford linear accelerator (≈ 9000 liters volume).

Roughing pumps are required to reduce the pressure in the accelerator vacuum system to below 10 microns before the main getter-ion type vacuum pumps can be started and is done on an individual sector basis.

Cryosorption pumping for rough pumpdown was originally proposed by R. B. Neal in TN-62-77, wherein the recommendation was made to use a combination of mechanical and one stage of liquid N_2 cooled cryosorption pumps. The tests made recently show that at least two stages of cryosorption pumping with mechanical prepumping are required for a reasonably fast pumpdown (approximately one hour).

OPERATIONAL TEST PROCEDURES AND RESULTS

Tests of the following roughing pump systems were conducted in Sectors 1 and 2:

(a) Three-stage cryosorption pumps; two SN-150 pumps (150 pounds of molecular sieve Linde 5A each) for stages 1 and 2, and SN-12 (12 pounds of molecular sieve Linde 5A) for stage 3.

(b) Two-stage cryosorption pumps (150 pounds each).

(c) Two 15-CFM mechanical pumps with liquid N_2 traps.

(d) A combination of the two 15-CFM mechanical pumps and two-stage 150-pound cryosorption pumps.

The test procedures and results are discussed below.

A. Cryosorption Pumps Only

Molecular sieve material in the SN-150 pumps is reactivated by means of electric "heat guns" discharging hot (380°C) air into the LN_2 reservoir space. Because the SN-12 pump sorbs relatively little gas when used for the third stage, it is reactivated by exposure to ambient temperature. Following reactivation, with the sector roughing valve closed (See Fig. 1), valves located above each pump are opened and one of the SN-150 pumps is chilled. When the pressure in the 5-inch roughing manifold reaches approximately 10 microns, the 2-inch valve above the SN-12 pump and the 6-inch valve above the uncooled SN-150 pump are closed. This operation requires approximately one hour. Sector roughing then commences by opening the sector roughing valve. During the time that stage 1 is pumping, the other two stages are chilled.

Stage 1 is valved off when the pressure reaches approximately 100 torr after some 100 minutes of pumping, at which point the second SN-150 pump is valved in.

From the curves in Figs. 2, 3, and 4, it is seen that a pressure of a few microns can be reached in about 3 hours of pumping with the use of the two-stage system.

By closing off the second stage SN-150 pump and valving in the small SN-12 pump a further reduction in pressure to 3×10^{-4} torr can be achieved in 15 minutes or so. (See Fig. 3.)

Figure 5 is included to show the effect of prechilling simultaneously all pumps for only 15 minutes. The second and third stage pumps were not prepumped by stage 1 prior to chilling. Approximately 5 hours were required to reach 1 micron.

Liquid N_2 consumption for a complete pumpdown is 350 to 400 liters. Each 150-pound pump requires about 100 liters for cooldown and 75 liters for pumpdown. The SN-12 pump consumes about 40 liters for cooldown and pumpdown.

B. Mechanical Pumps with Liquid N_2 Traps

To compare the performance of cryoscrption pumps versus mechanical pumps, a sector was evacuated by two 15-CFM mechanical pumps in parallel, each trapped with a Granville-Phillips liquid N_2 trap. Traps were chilled at about 1000 microns. Figure 7 shows a typical performance of the pumping system on one sector. A pressure of 3 microns was attained in 4-1/2 hours.

C. <u>Mechanical Pumps and Two 150-Pound Cryosorption Pumps Combination</u>

In this scheme, the sector was pumped down by two 15-CFM mechanical pumps operating in parallel (as in Sec. 1, B above) prior to cryosorption pumping. The SN-150 cryosorption pumps were processed and cooled as described in Sec. A during mechanical pumping. Both cryosorption pumps were precooled for 75 minutes.

The mechanical pumps were valved off at about 50 torr, with flow still in the viscous range, where no backstreaming of pump oil occurs.

After the mechanical pumps were valved off, one precooled SN-150 pump was opened to the system. A pressure of 14 microns was reached after only 50 minutes of total pumping. This pump was valved off and the sector pumped with the other SN-150 chilled pump. A pressure of 2×10^{-4} torr was reached after 85 minutes of total pumping. Liquid N_2 consumption was approximately 230 liters for precooling and pumpdown. This was the fastest roughdown achieved.

A pressure of 1 micron, at which point it is possible to start the getter-ion pumps, was reached in 1 hour.

CALCULATIONS

The following calculations were made to compare the test results with the data from Varian Company and Linde Company. In our tests no attempts were made to wait long enough to measure the pressure at which each stage would base out or to measure the ultimate gas absorption capacity of each stage.

M_n = amount of gas removed by "n"th stage (torr-liters)

V = sector volume = 9×10^3 liters

P = pressure (torr)

W = weight of the absorbent = 68×10^3 grams/large SN-150 pump, 5.440×10^3 grams/small SN-12 pump

α = absorption coefficient (torr-liters/gram of absorbent)

S = pumping speed (CFM)

A. First Stage

From Fig. 3, we have:

$$M_1 = V(P_1 - P_2) = 9 \times 10^3 \times (760 - 30) = 65.7 \times 10^5 \text{ torr-liters}$$

$$\alpha = \frac{M_1}{W} = \frac{65.7}{68} \times 10^2 = 96.6 \text{ torr-liters/gram.}$$

This very closely agrees with the figure given by Linde, about 100 torr-liters/gram. Coefficient α can be written as $\alpha = \frac{V}{W} \Delta P$ or $\alpha = 0.132 \times \Delta P$. With given parameters, the maximum α that can be achieved is $\alpha = 0.132 \times 760$ or 100.3 torr-liters/gram. Varian gives a figure of about 180 torr-liters/gram.*

B. Second Stage

From Fig. 5 we have:

$$M_2 = V(P_2 - P_3) = 9 \times 10^3 \times (285 - 0.050) = 2.56 \times 10^6 \text{ torr-liters}$$

$$\alpha = \frac{M_2}{W} = \frac{2.56}{68} \times 10^3 = 37.7 \text{ torr-liters/gram.}$$

C. Third Stage

From Fig. 5 we have:

$$M_3 = V(P_3 - P_4) = 9 \times 10^3 \times (50 - 0.35) \times 10^{-3}$$

$$M_3 = 9 \times 49.65 = 446.8 \text{ torr-liters}$$

$$\alpha = \frac{M_3}{W_3} = \frac{446.8}{5.44 \times 10^3} = 0.0821 \text{ torr-liters/gram}$$

The value of the coefficient "α" obtained from calculations on 2nd and 3rd stage pumping is greatly variable, depending on the pressure when each particular stage was valved in. It is interesting to note that Linde and Varian data do not agree with each other; Varian data is higher above a pressure of 10 microns and Linde is higher below 10

*F. T. Turner and M. Feinleib "Performance Criteria for Sorption Pumps," Proceedings of the Eighth Annual Symposium of the American Vacuum Society (October 1961, p. 300). This would require ΔP to be $\Delta P = \alpha/0.132 = 180/0.132 = 1363$ torr - an obvious impossibility with given parameters.

microns. At a pressure of 10^{-5} torr, for example, Linde gives a figure of about 53 torr-liters/gram, whereas Varian gives 0.1 torr-liter/gram. Our figure for the 3rd stage is a factor of 5 lower than Varian's.

D. Pumping Speed

The pumping speed is calculated from the formula

$$S = \frac{V}{t}\ 2.3 \log \frac{P_1}{P_2}$$

For cryosorption pumps only (see Fig. 4) we obtain

First stage	5.5 CFM
Second stage	66 CFM
Overall speed	25.8 CFM

For the combination of mechanical and cryosorption/pumps (see Fig. 6) the corresponding figures are:

Mechanical pumps	28 CFM
First stage cryosorption pump	264 CFM
Second stage cryosorption pump	39 CFM
Overall speed	57 CFM

CONCLUSIONS AND RECOMMENDATIONS

From the tests run it is obvious that sector roughing with the mechanical pump—cryosorption pump combination is the most advantageous system, producing clean vacuum in the shortest time. The disadvantage of the present design is the fairly high consumption of liquid nitrogen.

However, recent discussions with Linde Company indicate that they are working on an improved design of the pump which should cut down the liquid nitrogen consumption by a factor of 2. In addition, by using a different sieve material, it is expected to increase the speed by a factor of about 1.5.

It is recommended that the combination mechanical pump—cryosorption pump be adopted for the main roughing system used on the accelerator and that proposals be invited for a system to pump from nitrogen at 760 min. to a pressure of 2×10^{-4} torr in 90 minutes or less. It is proposed that four portable systems be procured which should be adequate initially for the accelerator. It is also proposed that one 50 CFM mechanical pump be used, as shown on Fig. 1, for initial evaluation, instead of two 15 CFM pumps.

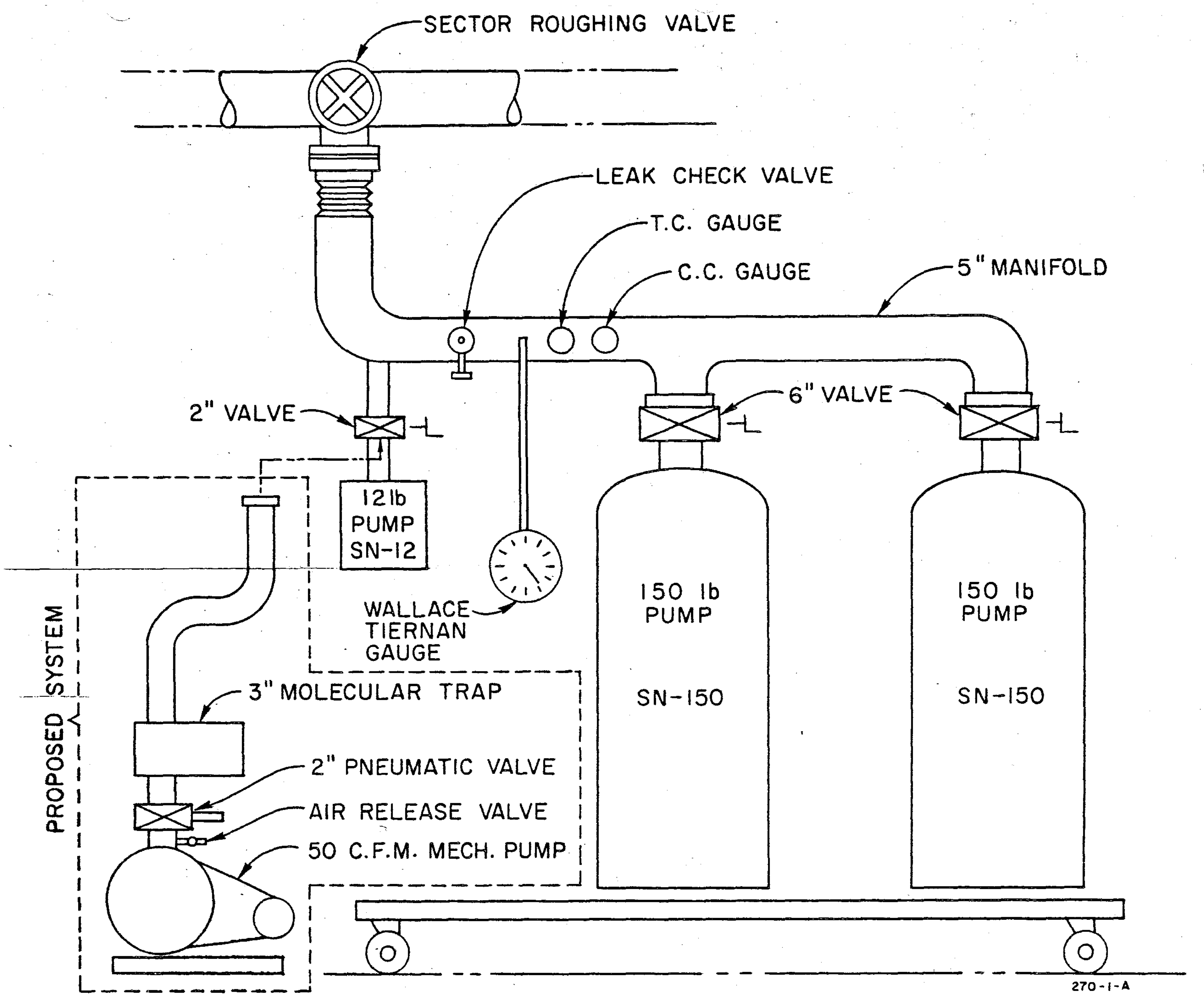

FIG. 1 - SCHEMATIC DIAGRAM CRYOSORPTION PUMPS FOR SECTOR ROUGHING.

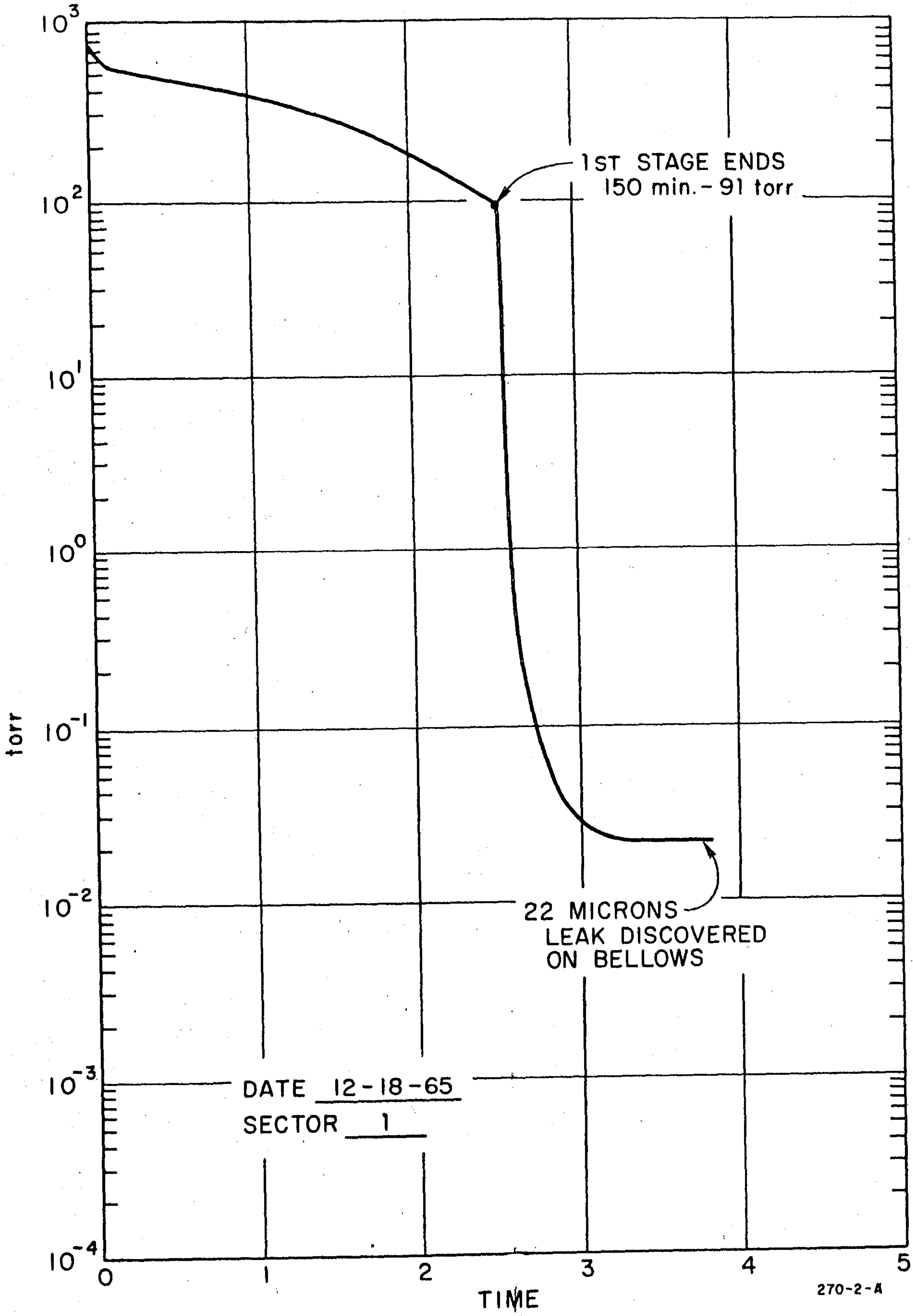

FIG. 2 - MANIFOLD VOLUME 9000 LITERS GN_2. PUMPS PRE-COOLED 60 MINUTES. ST ST'L + Cu.

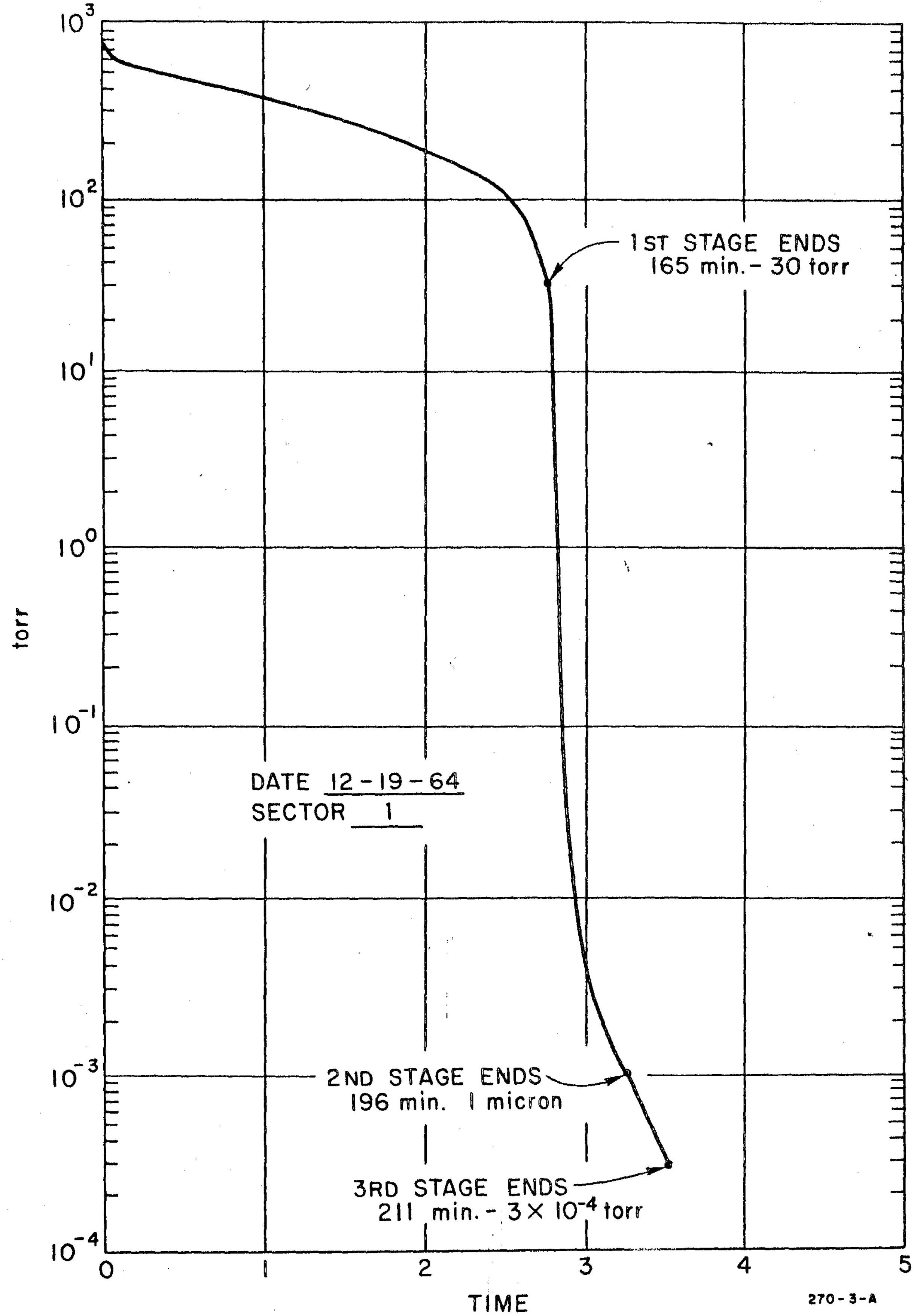

FIG. 3- MANIFOLD VOLUME 9000 LITERS GN_2. PUMPS PRE-COOLED 75 MINUTES. ST ST'L + Cu.

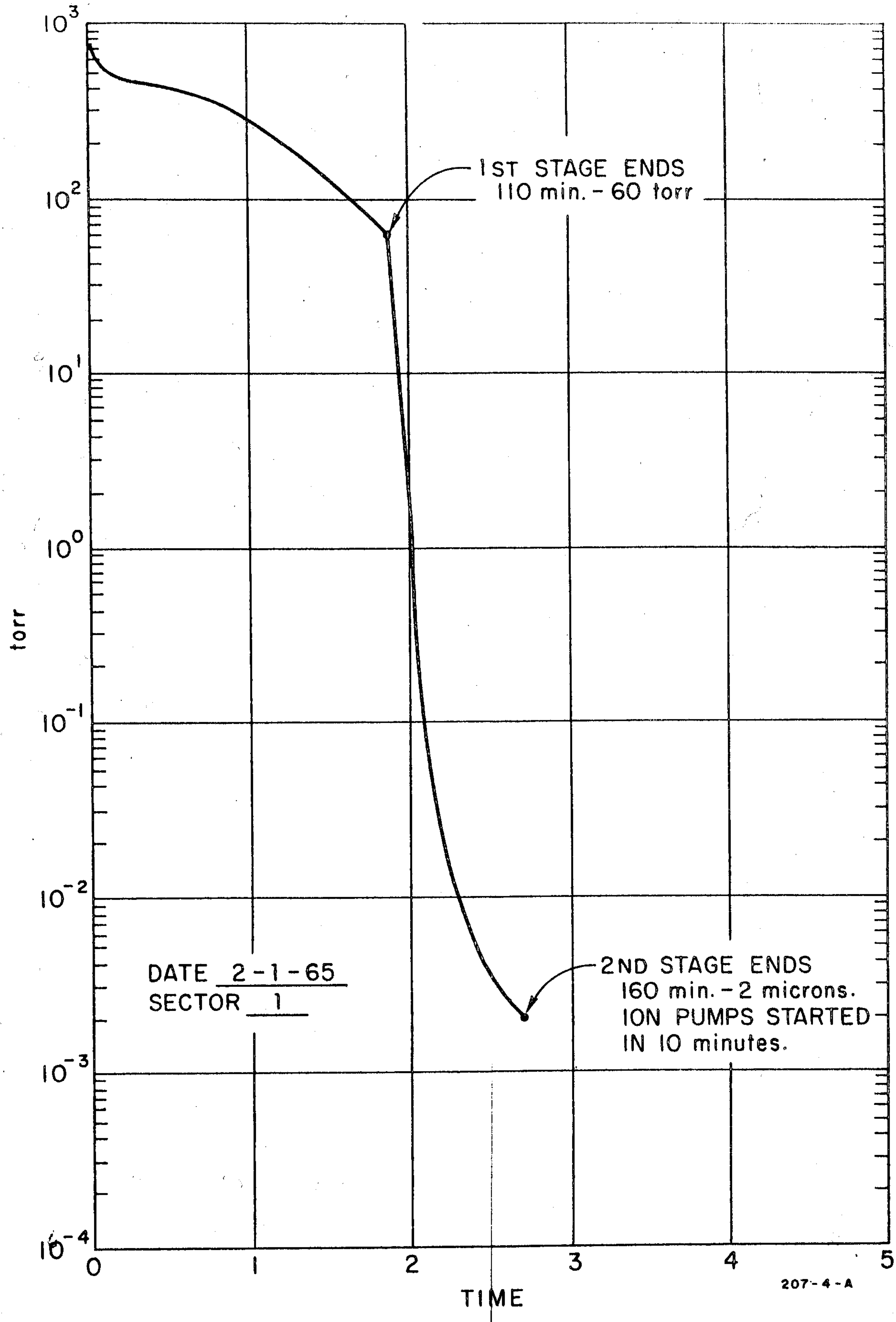

FIG. 4 - MANIFOLD VOLUME 9000 LITERS GN_2. PUMPS PRE-COOLED 60 MINUTES. ST ST'L + Cu.

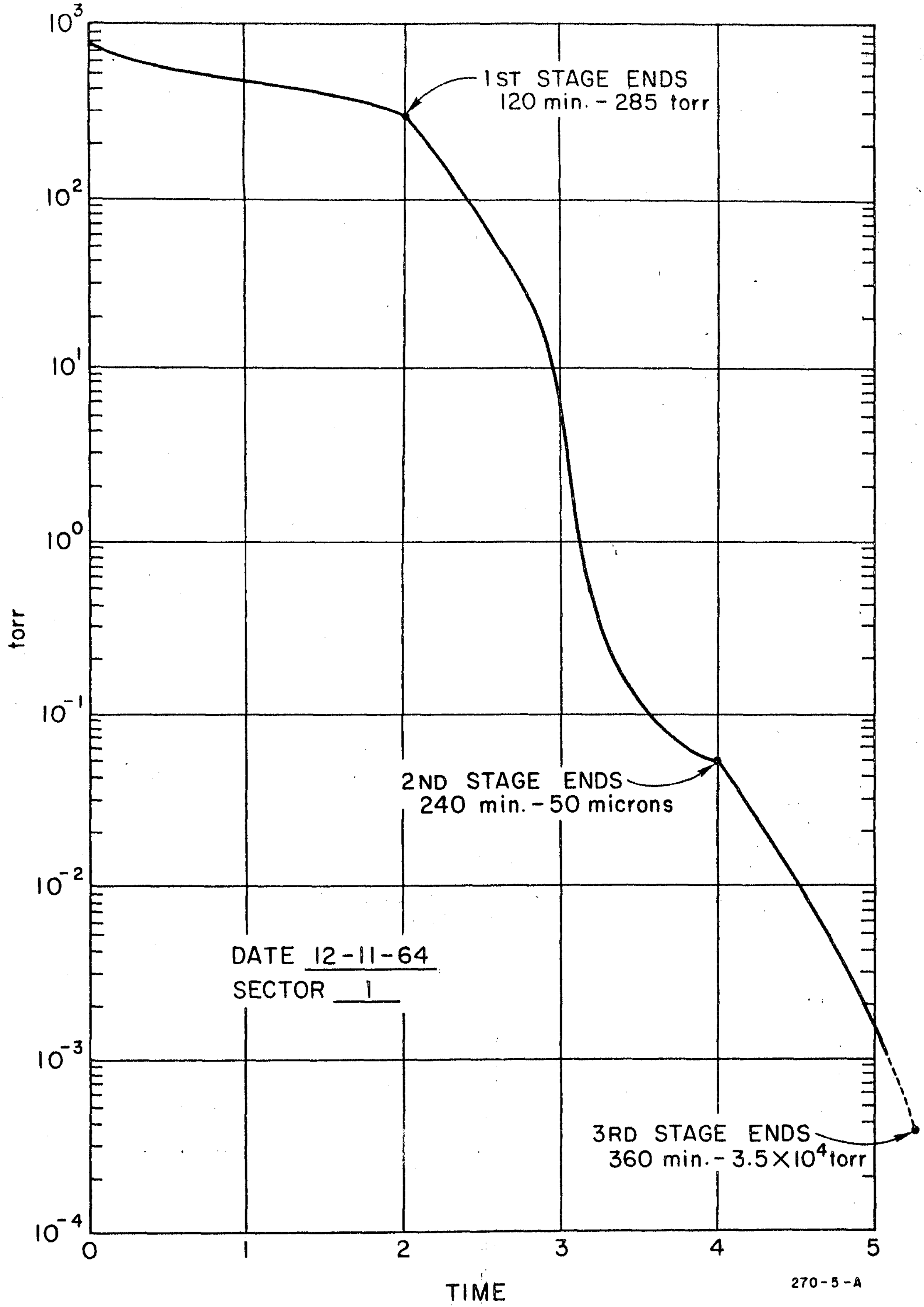

FIG. 5 - MANIFOLD VOLUME 9000 LITERS GN_2. PUMPS PRE-COOLED 15 MINUTES. ST ST'L + Cu.

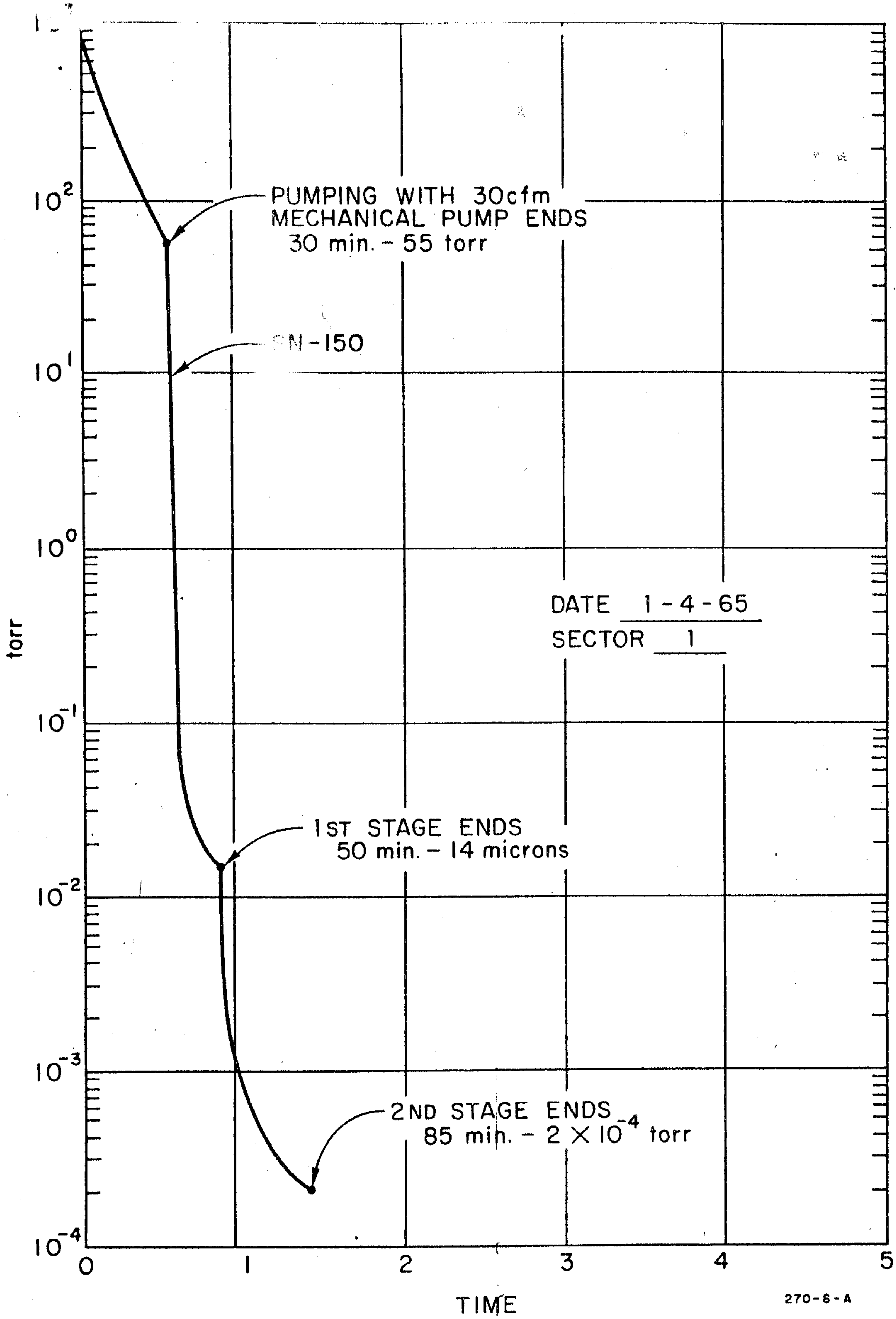

FIG. 6 - MANIFOLD VOLUME - 9000 LITERS GN_2. WHOLE SYSTEM PRE-PUMPED WITH TWO 15cfm MECHANICAL PUMP ROUGHING CARTS. SN-150 PUMPS PRE-COOLED 75 MINUTES. ST ST'L + Cu.

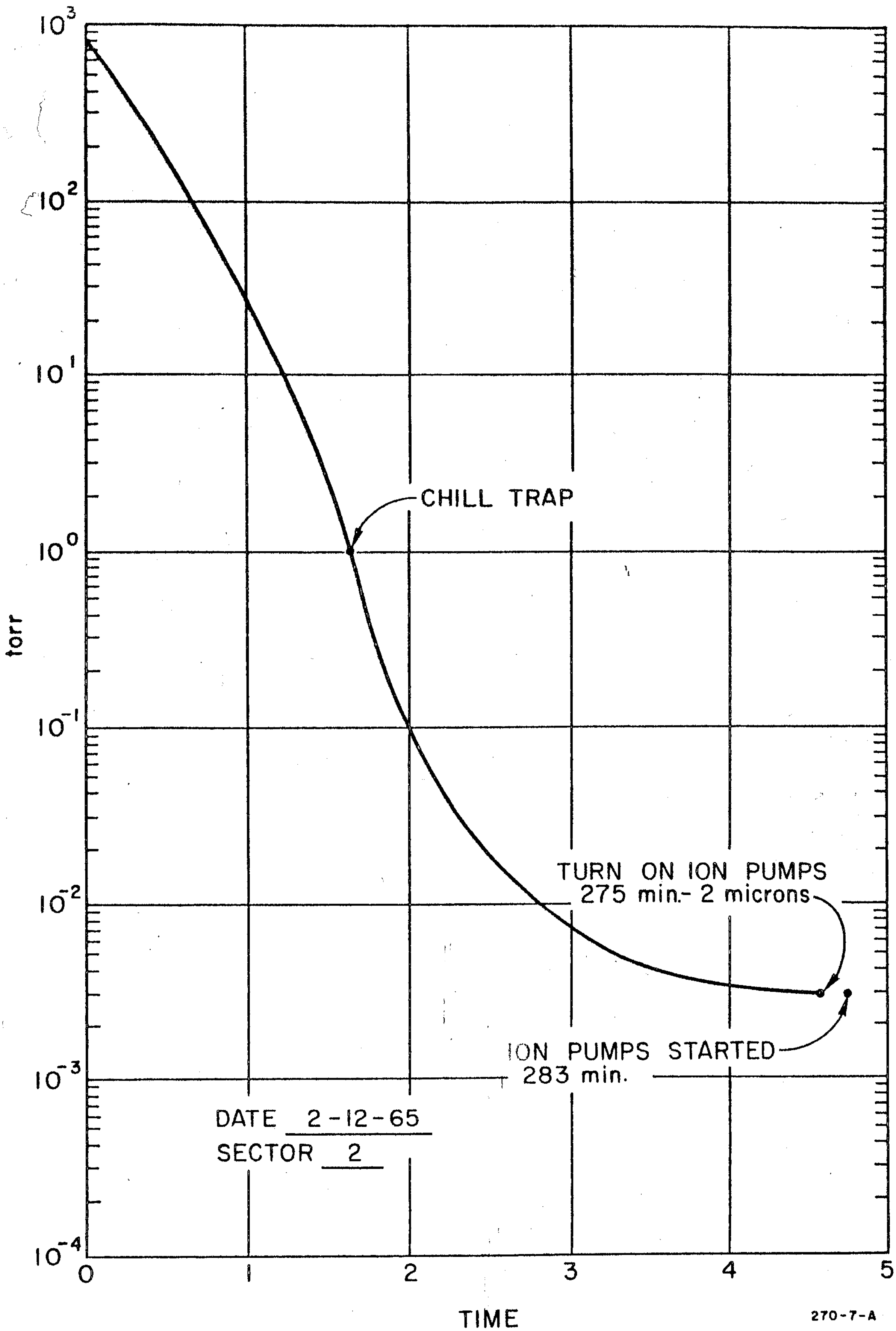

FIG. 7 - MANIFOLD VOLUME - 9000 LITERS PUMPDOWN FROM GN_2 WITH TWO 15cfm MECHANICAL PUMP ROUGHING CARTS.