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# The Outgassing of Magnet Laminations

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# The Outgassing of Magnet Laminations

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## Abstract

The outgassing rate of a 3" long stack of laminations taken from a typical magnet used internal to the vacuum system at the AGS has been measured. Found is that the dominant gas released from the assembly is water vapor with a very small nitrogen component being present. It was also discovered that both the quantitative outgassing rate and gas composition was not dependent on whether the laminations were tightly connected as in a stack or disconnected and lying loose in the outgassing chamber.

## I. Introduction

Internal magnets are in limited (3 or 4) use at the AGS at Brookhaven National Laboratory. Invariably, when such an internal magnet is being fabricated or replaced, questions arise as to what the initial outgassing rates are expected to be, whether a cold trap would be useful during the initial degassing period, and the effectiveness of a pre-pumped period prior to the final installation of the magnet (the installation into the AGS ring necessarily involves a brief atmospheric exposure of the magnet and laminations). The present study was undertaken to seek answers to the above questions.

## II. Experimental Considerations

The laminations (98) used in the present study consisted primarily of iron, the individual lamination having dimensions of 3-1/4" width, 3-3/4" height, being approximately 0.030" thick. The 98 were connected in a stack of length 3-1/4". The surface condition again of the individual lamination was very rusty as visually determined after the stack was disconnected. The surface condition was not considered particularly unusual since the laminations had been sitting in storage (not in vacuum) for several years before this study began. Thus, any individual outgassing rates should reflect the outgassing rates from heavily oxidized steel rather than from a clean metal surface. The 98 laminations had a geometric surface area of 5690 cm$^2$. It is noted that the assembled magnet is approximately 7' long and, hence, has approximately 28 times the number of laminations as our test sample, whereas the surface condition of the laminations in any typical magnet is not likely to be any worse than those measured in the present study.

The vessel into which the laminations were placed for the outgassing measurements was a stainless steel cylinder 6" deep with a 5-3/4" inner diameter, the top of which was fitted with a 6" diameter conflat flange allowing the placement of the lamination stack within the vessel. A schematic of the instrument is shown in Figure 1. The main components of the instrument are: the containment vessel, already described; a thermocouple-type pressure gauge, a cold trap, and a mechanical pump which provided a pumping speed at the gauge of 0.01 L/s.

The operation of the device has been described previously[1] and allows both the total outgassing rate and the $N_2$ and $H_2O$ components to be determined. The outgassing rate is evaluated by:

$$Q = P*S$$

where P is the pressure measured at the thermocouple pressure gauge and S is the pumping speed of the mechanical pump (0.01 L/s) at the pressure gauge. In all measurements, the zero of the outgassing rate is set with valve V1 closed.[2]

The outgassing rate measurement as a function of time for the vessel itself is shown in Figure 2. Seen is that the total rate falls to approximately $10^{-5}$ Torr L/s in approximately 10 to 20 minutes. This value is negligibly small with respect to the outgassing rates from the lamination stack as will be subsequently reported and hence is neglected in further discussions. Seen also in Figure 2 is that $N_2$ is a considerable part of the total outgassing until times of the order of several vacuum time constants (V/S) have been attained, at which time the water vapor component will dominate for the further history of the vacuum pumpdown (in the absence of real or virtual leaks). Displayed also in Figure 2 is $Q_{max}$ (the upper bound to the water vapor outgassing rate from Reference 3) which is seen to be an upper bound to the $H_2O$ outgassing rate, as expected.

The water vapor outgassing rate from the connected stack of 98 laminations during both the first and second pumpdown is shown in Figure 3. The second pumpdown is similar to the first pumpdown except that it followed the first pumpdown and received a three hour atmospheric exposure prior to the measurement. Comparison of Figure 3 with Figure 2 shows that the chamber outgassing rate itself is quite small with respect to the lamination outgassing rate even at t = 5 min. [Q(empty vessel) $\sim 10^{-4}$ τL/S] indicating that the plateau part of the first pumpdown curve in Figure 2 ($t < 10$ min) is due to the lamination stack being in the vessel.

The water vapor outgassing rate for the stack of laminations is seen to be considerably less for the second pumpdown than for the first indicating that the three hour exposure was not sufficient to fully repopulate the $H_2O$ adsorption-desorption sites on the lamination surfaces.

The nitrogen component of the outgassing rate from the connected stack of laminations was measured 30 minutes after the start of the first pumpdown and found to be a very small part of the $H_2O$ outgassing rate again at $t \approx 30$ minutes. This result was not anticipated due to the large available volume of trapped gas ($N_2$) in the inter lamination regions with unknown but possibly poor conductance into the vacuum. A further discussion will be continued somewhat later. The conclusion of this measurement is, however, clear; namely that the $N_2$ outgassing rate from the connected stack of laminations is quite small compared to the $H_2O$ outgassing rate.

The memory of the first pumpdown which the second pumpdown of Figure 3 exhibits emphasizes the importance (for reducing the $H_2O$ outgassing) of a prior vacuum evacuation of the magnet before installation and the purging of the magnet and enclosure with dry $N_2$ before magnet transfer and installation.

In an effort to determine whether water vapor was trapped as a virtual gas or liquid in the interlamination regions, the stack of laminations was disconnected and very loosely placed in the test vessel. The results of the $H_2O$

The practical implication of the above report is that in the design of internal components to vacuum systems, one need not necessarily avoid potential sources of trapped gas provided that the designed component can be tested for trapped gas in much the same way that the present lamination stack was tested.[4]

From the above measurements, the $H_2O$ outgassing rate of a 7' laminated magnet can be estimated to be approximately $2.8*10^{-3}$ Torr liter/second after five days of pumping. Thus, with a 3000 L/s pump present (or a $LN_2$ surface of approximately 300 $cm^2$) the pressure in the magnet region should be approximately $1*10^{-6}$ Torr, which is not unlike that typically found after the initial pumpdown period following the installation of a new magnet in the AGS ring.

Due to the predominance of $H_2O$ over $N_2$ in the total outgassing rate, the $LN_2$ cold pump should provide an additional auxiliary pumping speed to reduce the system pressure during the initial phase [(0-10) days] of magnet degassing. It may be worthwhile to emphasize that the actual length of time the cold trap is necessary is a strong function of the prior vacuum degassing of the magnet and the degree to which moist air exposure during the magnet transfer into the AGS ring is minimized.

## Acknowledgements

It is a pleasure to acknowledge J.W. Glenn for the initial suggestion of this problem as well as the interesting discussions during the course of this work. I would also like to thank W. Van Zwienen for the design and fabrication of the test vessel and H. Alexandersen for making me aware of procedures used on the actual magnets prior to and during installation. Lastly, the support of the AGS Vacuum Group is appreciated.

## References

1. D. Edwards, Jr., D. Gillette, J. Vac. Sci. Technol, 18, 1023 (1981).

2. This technique introduced by Y. Straussen, Varian Technical Note VR-51, allows one to correctly compensate for the outgassing rates of the measuring instrument.

3. D. Edwards, Jr., J. Vac. Sci. Technol., 14, 606 (1977).

4. An outgassing rate test instrument is presently available from Vacuum Analysis Corporation, 503 Bailey Avenue, Greenport, NY 11944.

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Figure Captions

Figure 1 -- A schematic of the instrument used to measure the lamination outgassing rates.

Figure 2 -- The total outgassing rate (open circles) and the nitrogen component of the outgassing rate for the empty test vessel.

Figure 3 -- The $H_2O$ outgassing rate for the connected set of laminations during the first and second pumpdown.

Figure 4 -- The $H_2O$ outgassing rate of the spearated laminations (open circles) and connected laminations replotted from Figure 3 (closed circles).

Figure 5 -- The water vapor outgassing rate for the separated laminations for the first and second pumpdown plotted sequentially (in real time, t = 0 corresponding to the start of the first pumpdown).

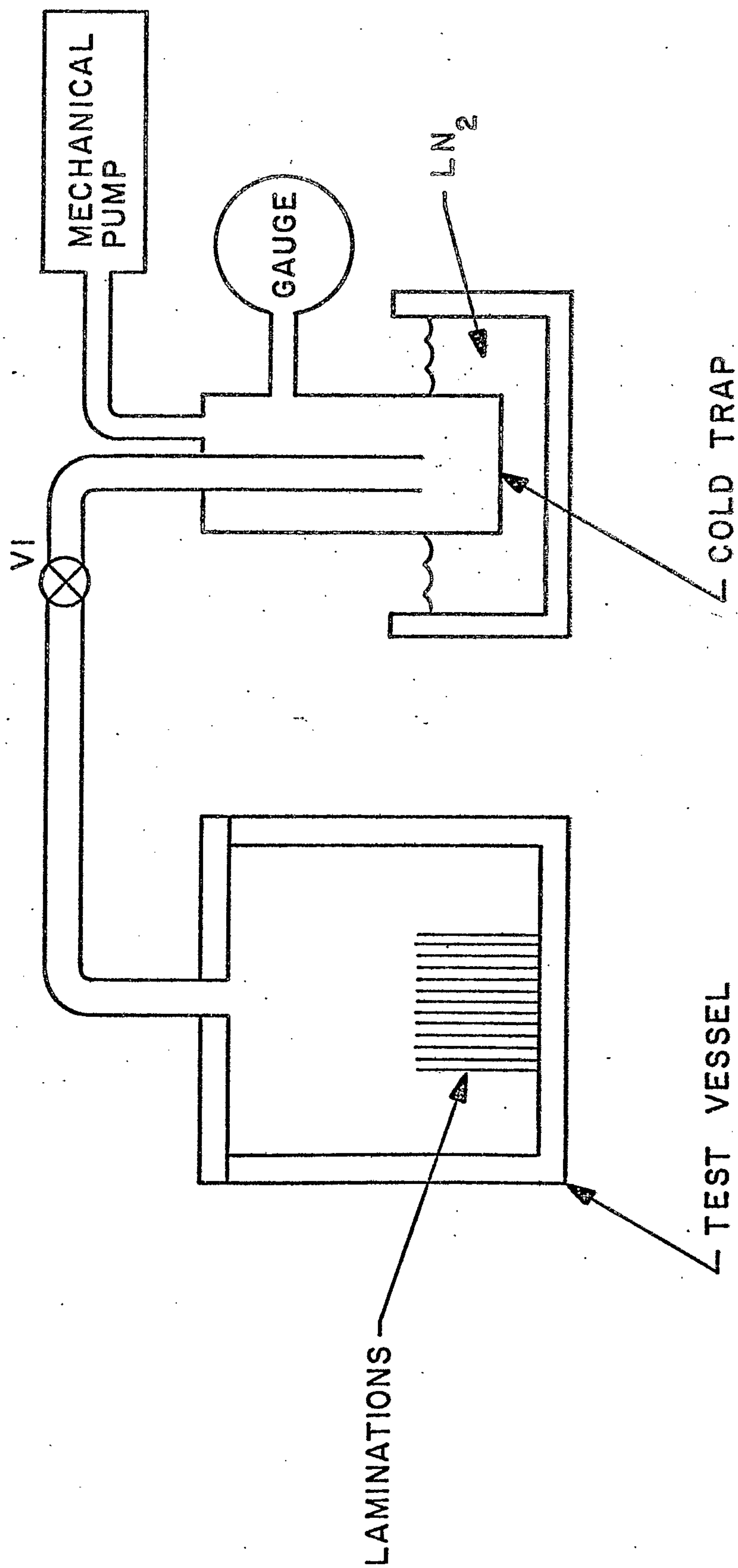

MECHANICAL
PUMP
GAUGE
$LN_2$
COLD TRAP
VI
TEST VESSEL
LAMINATIONS

Figure 1

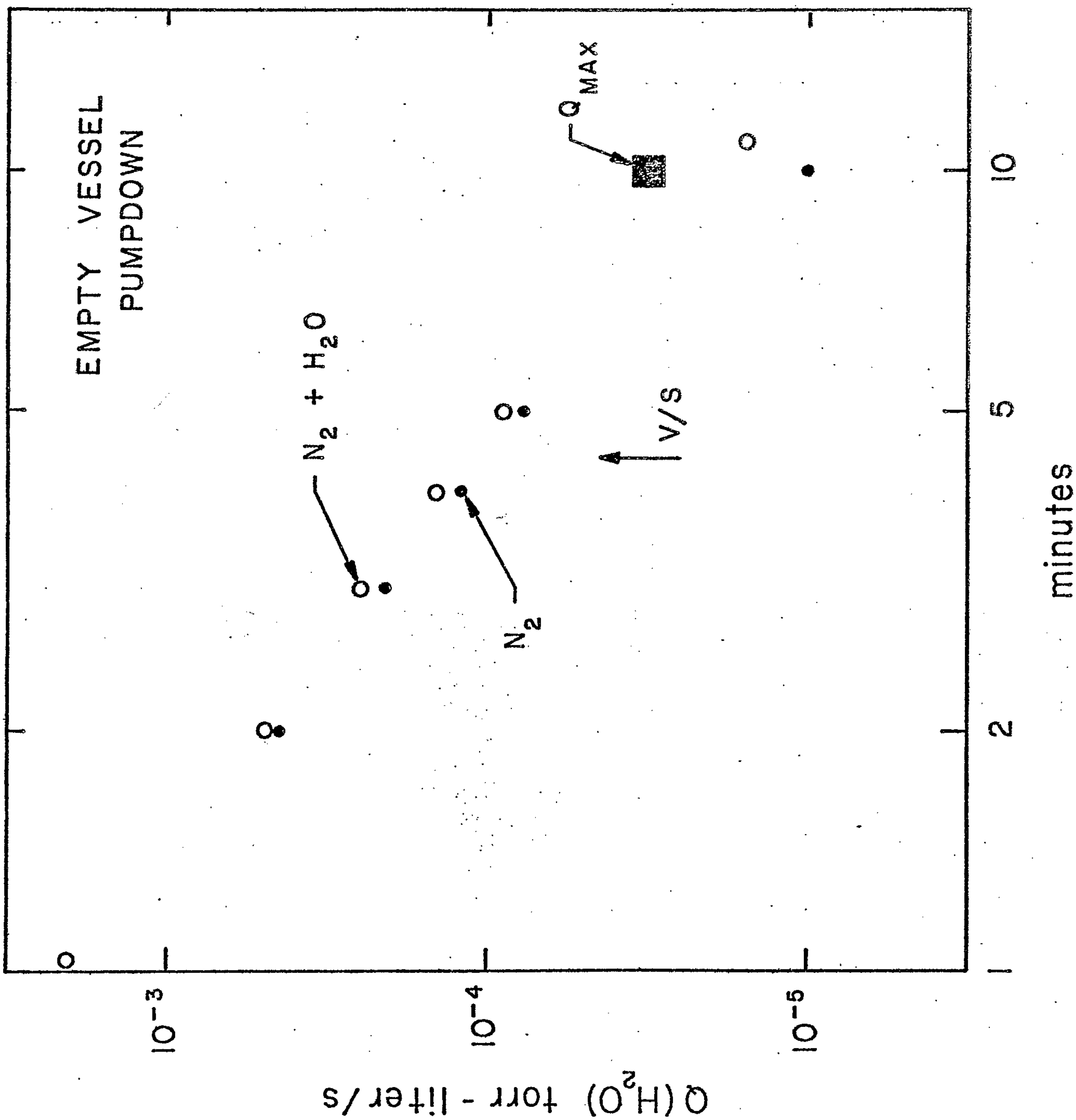

EMPTY VESSEL
PUMPDOWN
N2 + H2O
N2
V/S
QMAX
Q (H2O) torr - liter/s
10^-3
10^-4
10^-5
minutes
2
5
10

Figure 2

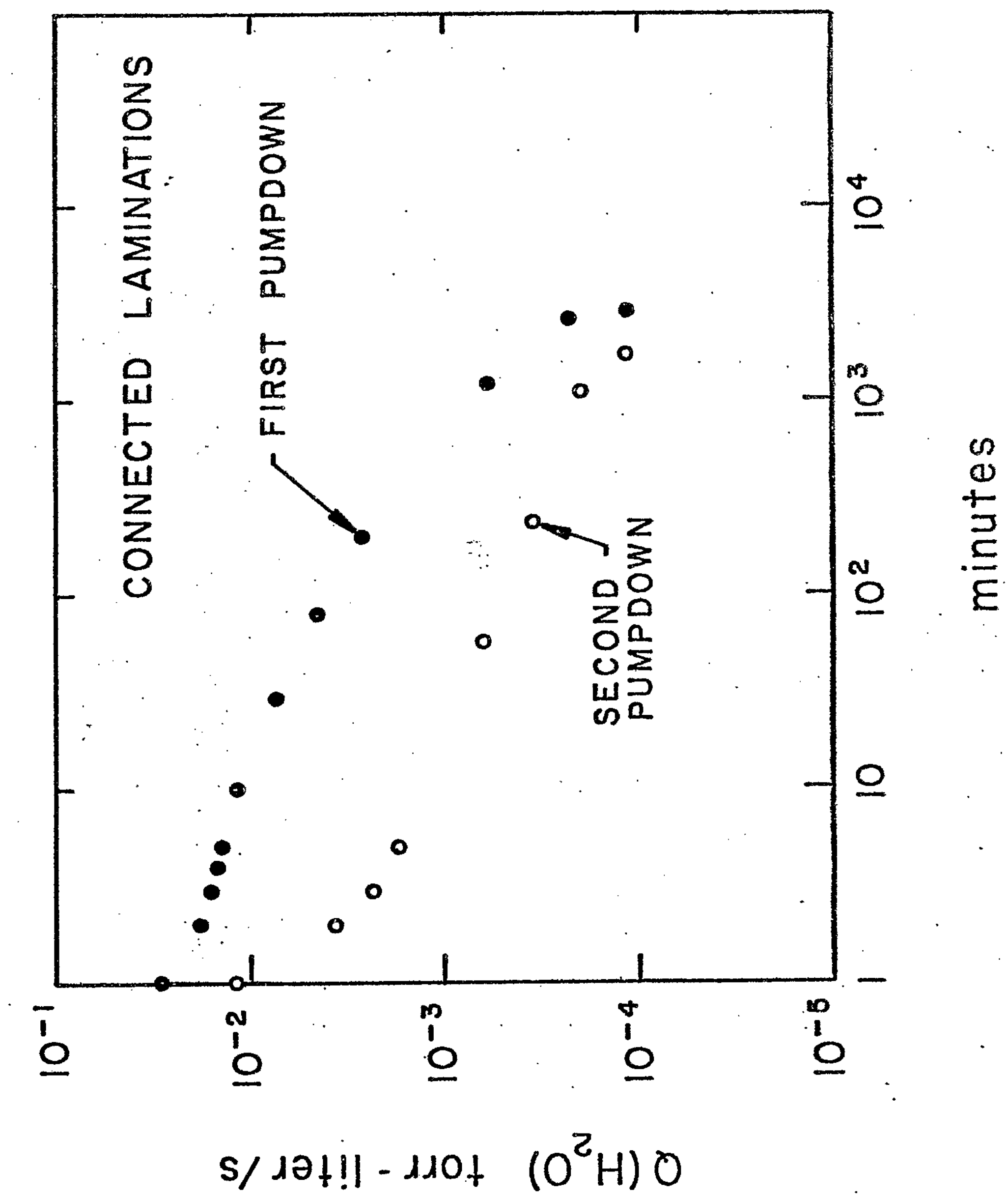
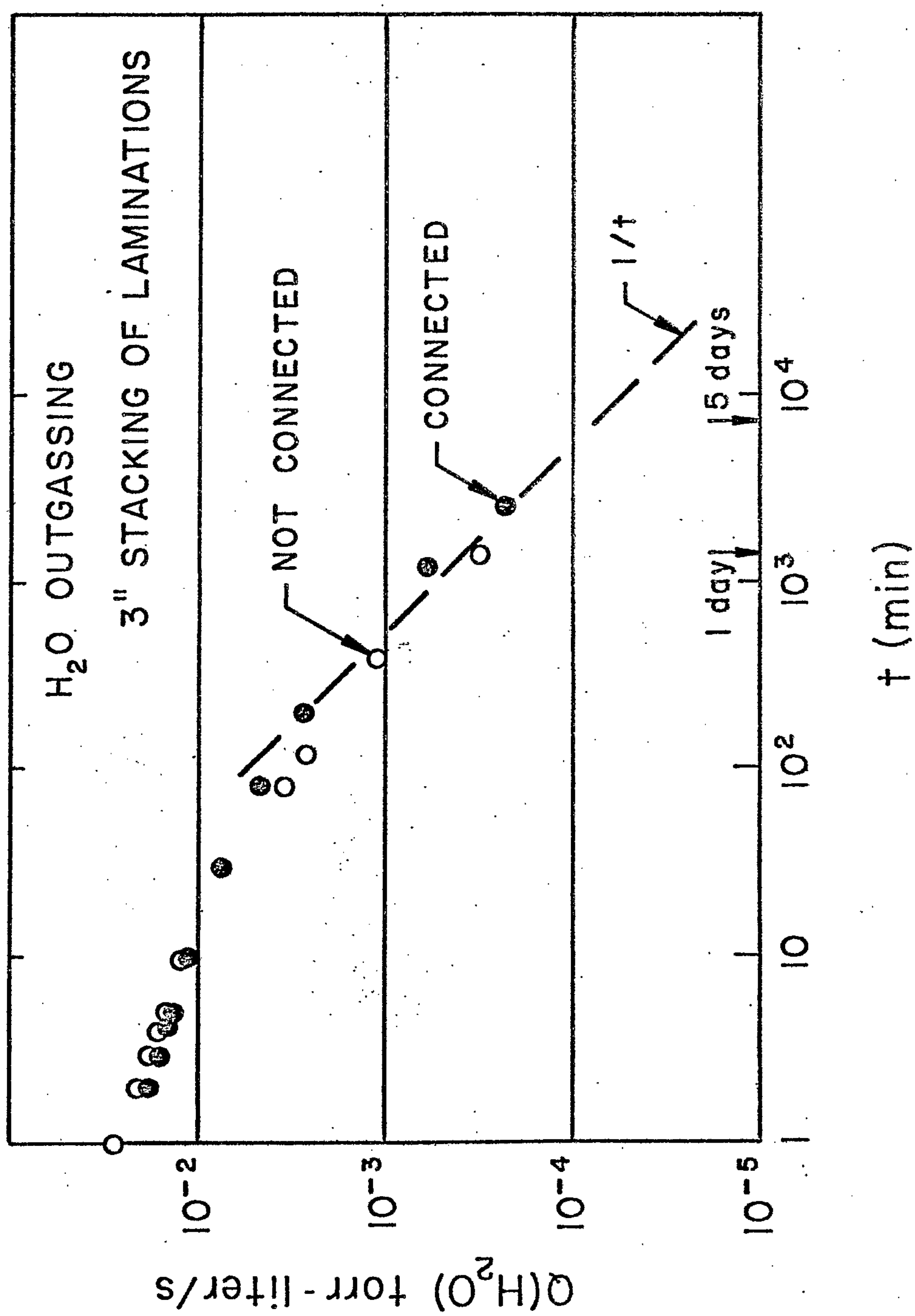

CONNECTED LAMINATIONS
FIRST PUMPDOWN
SECOND PUMPDOWN
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
10
$10^2$
$10^3$
$10^4$
minutes
Q ($H_2O$) torr - liter /s

Figure 3



$H_2O$ OUTGASSING
3" STACKING OF LAMINATIONS
NOT CONNECTED
CONNECTED
1/t
1 day
15 days
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$Q(H_2O)$ torr - liter/s
1
10
$10^2$
$10^3$
$10^4$
t (min)


Figure 4

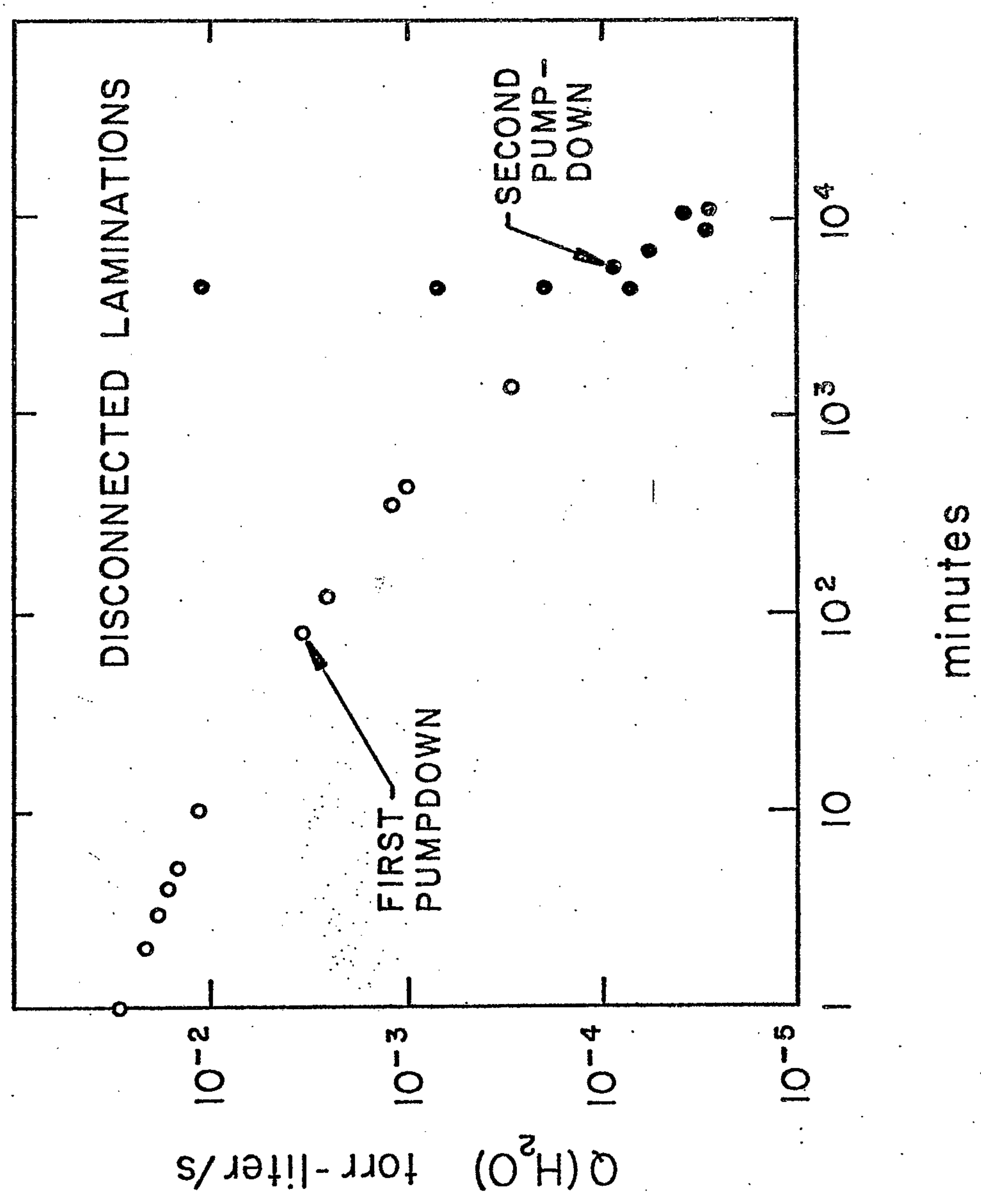

DISCONNECTED LAMINATIONS
FIRST PUMPDOWN
SECOND PUMP-DOWN
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$Q(H_2O)$ torr-liter/s
10
$10^2$
$10^3$
$10^4$
minutes

Figure 5