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Evaluation of the AGS Turbopumps

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Accelerator Division
Technical Note

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I. Introduction

All the roots blower roughing stations around the AGS ring and HEBTs have been replaced with the Sargent-Welch (S-W) 400 l/s horizontal turbopumps in the last 4 years. Average pressure of 1*10^-8 Torr or less is desired in the ongoing vacuum system upgrade program. Turbopumps with high pumping speeds/compression ratios, low blankoff pressure and less oil backstreaming will certainly help, both as roughing pumps and as holding pumps.

In this investigation, we have measured the blankoff pressure, the pumping speed and the oil backstreaming of these S-W roughing stations as well as the Balzer turbopumps which are considered excellent turbopumps by most vacuum practitioners. The information obtained enables us to set the scope of the necessary modifications of our roughing stations.

II. Setup and Procedure

The blankoff pressure and the oil backstreaming were measured at the inlet of the turbopump using a Bayard-Alpert ion gauge (BAG) and an UTI C100 residual gas analyzer (RGA). The test setup is shown schematically in Fig. 1(a). The BAGs were calibrated for absolute sensitivity against a standard spin rotor gauge. The RGA was used as received and the peak heights represent the relative abundance only. This UTI RGA has sensitivity down to 10^-13 Torr and is extremely useful in determining the composition of the residual gas in the vacuum system.

To measure the pumping speed and the compression ratio of the turbopumps at different pressures, a standard Fischer-Mommson dome* (Fig.1(b)) was used. This dome is mounted at the inlet of the turbopump and consists of an upper gas inlet chamber and a lower measuring chamber. These two chambers are separated by an orifice with a conductance C of 0.635 l/s for nitrogen. High purity(99.9%) nitrogen or hydrogen was fed into the upper chamber through a servo-driven

*E. Fischer and H. Mommsen, Vacuum 17, 309-315(1967).

bleed valve, which maintains the vacuum of the lower chamber at a desired level between 10^-9 Torr and 10^-3 Torr for measurement. The total gas flow Q into the lower chamber is calculated by

$$Q = C \times (P1 - P2)$$

here C is the conductance of the orifice for that gas; P1 and P2 are the pressure of the upper and the lower chambers, respectively. The pumping speed of the turbopumps is then given by

$$S = Q / P2.$$

The compression ratio K of the turbopump is given by P3/P2, here P3 is the inlet pressure of the mechanical pump. The accuracy of the measured K values is limited by the blankoff pressure of the mechanical pump and by the lack of gas analysis at the inlet of mechanical pump.

III. Measurement and Result

We have tested five different turbopumps:

a. a S-W 400 l/s after two-years' intensive use at E7 for IPM
b. a spare S-W 400 l/s in the vacuum lab.
c. a brand new Balzer 170 l/s designated for HITL
d. an used Balzer 110 l/s
e. an used Balzer 270 l/s which crashed in the middle of test

The following operation conditions were used in our blankoff measurement:

a. as removed from different systems; pump down
b. insitu bake of the turbo body and the manifold at < 100°C for 6-8 hours to remove oil contamination; vent to air for one day; pump down
c. no vent between operations; vent to air for one day; pump down

IIIA. The Ultimate Total and Partial Pressure

The pumpdown of each turbopump over several days was followed by the BAG and the RGA. Typical RGA spectra are shown in Fig. 2. The major peaks from hydrogen, water, air and oil vapor are labelled. The total pressure readings of the BAG and the peak heights of the RGA spectra as a function of pumpdown time are plotted in Fig 3(a)-3(d). All these turbopumps are capable of reaching low 10^-8 Torr in less than one day. However the partial pressure levels are significantly different from one to the other, as well as between vent and no vent of the same turbopump. For the S-W turbopumps, the oil partial pressure, as measured by peak height of mass 41 (major peak from the cracking of mechanical pump oil), is about fifty times lower if the turbopump is vented between operation as compared to no vent (curve #2 versus curve #1 in Fig 3(b)). After insitu bake at 100 C, further reduction of about ten times in the oil partial pressure was observed in the S-W turbopumps.

The difference between the S-W's and the Balzer's is small if both are baked and vented. The Balzer ones clearly can achieve lower ultimate pressure (in the low 10^-9 Torr range) than the S-W ones. This is due to the all-metal construction and the all-metal seals used in the Balzer pump, which have much lower hydrogen and water outgassing. The tight tolerance between the Balzer turbo blades gives higher compression ratio which also helps to achieve better ultimate vacuum. The presence of more hydrogen and water is not desirable but is not detrimental since these S-W turbopumps are mainly used as roughing pumps.

IIIB. Pumping Speed and Compression Ratio

Most turbopumps should have a constant pumping speed at the molecular flow region which is < 10^-4 Torr in the present geometry. The measured pumping speeds at different pressures are plotted in Fig 4. The nitrogen pumping speed of the Balzer turbopump is fairly constant over a wide pressure range, while that of the S-W turbopump drops off at both ends. The hydrogen pumping speed of both turbopumps drops off rapidly at the high and the low pressure ends, and is mainly due to non-molecular flow and backstreaming.

The compression ratio is a function of geometry, the turbo rpm and the molecular mass. The blankoff pressure of the mechanical pump is typically around 1*10^-2 Torr which limits the accuracy of the measured compression ratio. Nevertheless, nominal values are obtained as following:

COMPRESSION RATIO K (10^-6 to 10^-4 Torr)

	S-W 400 l/s	Balzer 110 l/s	Balzer 270 l/s
Nitrogen	200 ± 100	800 ± 200	1000 ± 200
Hydrogen	100 ± 50	300 ± 100	300 ± 100

The measured K values for nitrogen of both types of turbopumps are much lower than the manufacturer's stated values of ~10^5 and might be due to changes in gas composition at the inlet of the mechanical pump.

IV. Summary and the Proposed Upgrade

The high vacuum compatibility and the operation procedures of our present roughing station, the S-W 400 l/s horizontal turbopump, were questioned by several participants of the AGS Vacuum Workshop held in October, 1985, which gave the initial motivation of the present investigation. The information obtained can be summarized as following:

1. The ultimate (blankoff) pressure of the S-W turbopumps is at low 10^-8 Torr while that of the Balzer turbopumps is at low 10^-9 Torr.

2. In the S-W turbopumps, the level of oil contamination can be reduced by a factor of 500, if the turbopump and the manifold are baked periodically and vented between operation. The level of oil contamination of the Balzer turbopumps is slightly better than that of the S-W ones if both are baked and vented.

3. The pumping speeds for nitrogen of the S-W ones and the Balzer ones are about 300 l/s and 100 l/s, respectively in 10^-7 to 10^-4 Torr range. The compression ratios of the Balzer turbopumps are higher than those of the S-W ones and are due to higher rpm and tighter tolerance, which resulted in better ultimate pressure. However the more rugged construction of the S-W turbopump will enable it to survive under severe operational conditions such as human error or major leaks.

Based on the above information, the following modifications on the existing roughing stations are planned/proposed:

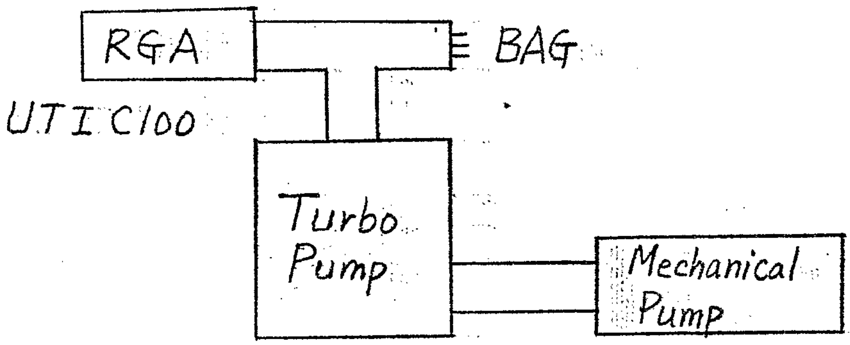
1. The cost (about half million dollars) of replacing these 30 roughing stations with the Balzer ones or equivalent can't be justified solely on the better ultimate pressure, since they are used mainly during pump down and conditioning ion pumps. Balzer turbopumps or equavalent should certainly be used as holding pumps.

2. Through the existing manifold and the cold trap, the available pumping speed of these roughing stations is less than 20 l/s. A new manifold with higher conductance and without the cold trap is needed to increase the available pumping speed. Components for baking and venting are also required.

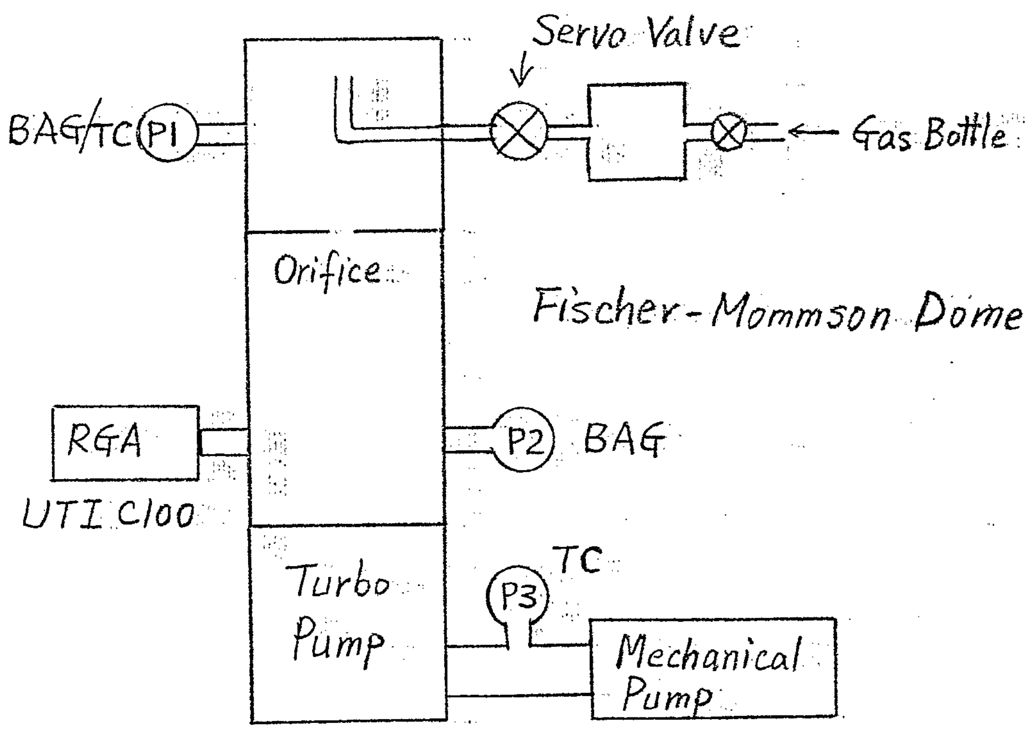
3. To minimize oil backstreaming, each roughing station (both turbo and manifold) should be baked to 100°C periodically (i.e., every 2-3 months). A 6-8 hour bake is needed to heat up the rotor blades through radiation.

4. The interlock of turbo operation with vacuum gauges and the automatically delayed vent after turbo off have been implemented in the vacuum instrumentation upgrade, which will help prevent the human error amd minimize the oil backstreaming.

1 (a) Setup for Blankoff Test



1 (b) Setup for Pumping Speed Measurement



BAG: Bayard-Alpert Ion Gauge
TC: Thermocouple Gauge
RGA: Residual Gas Analyzer

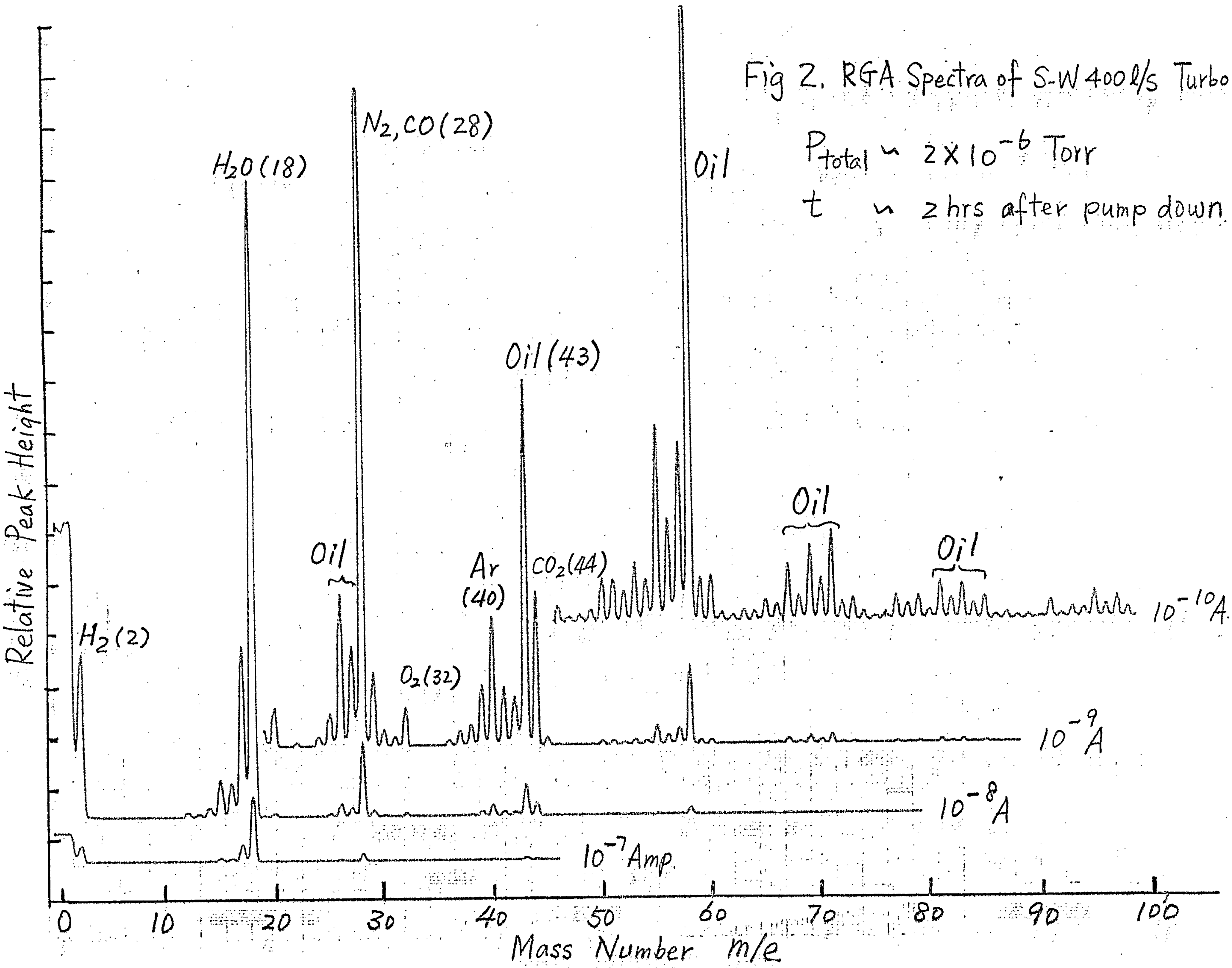
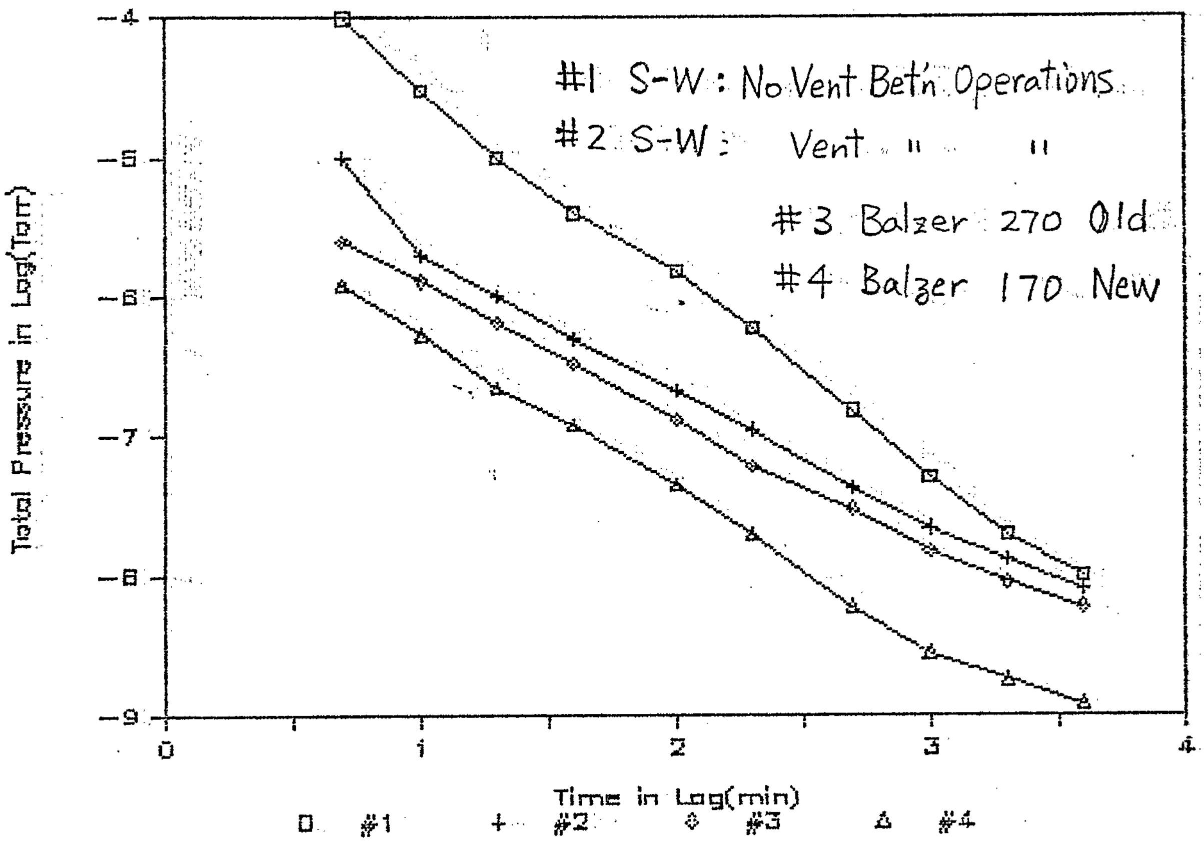
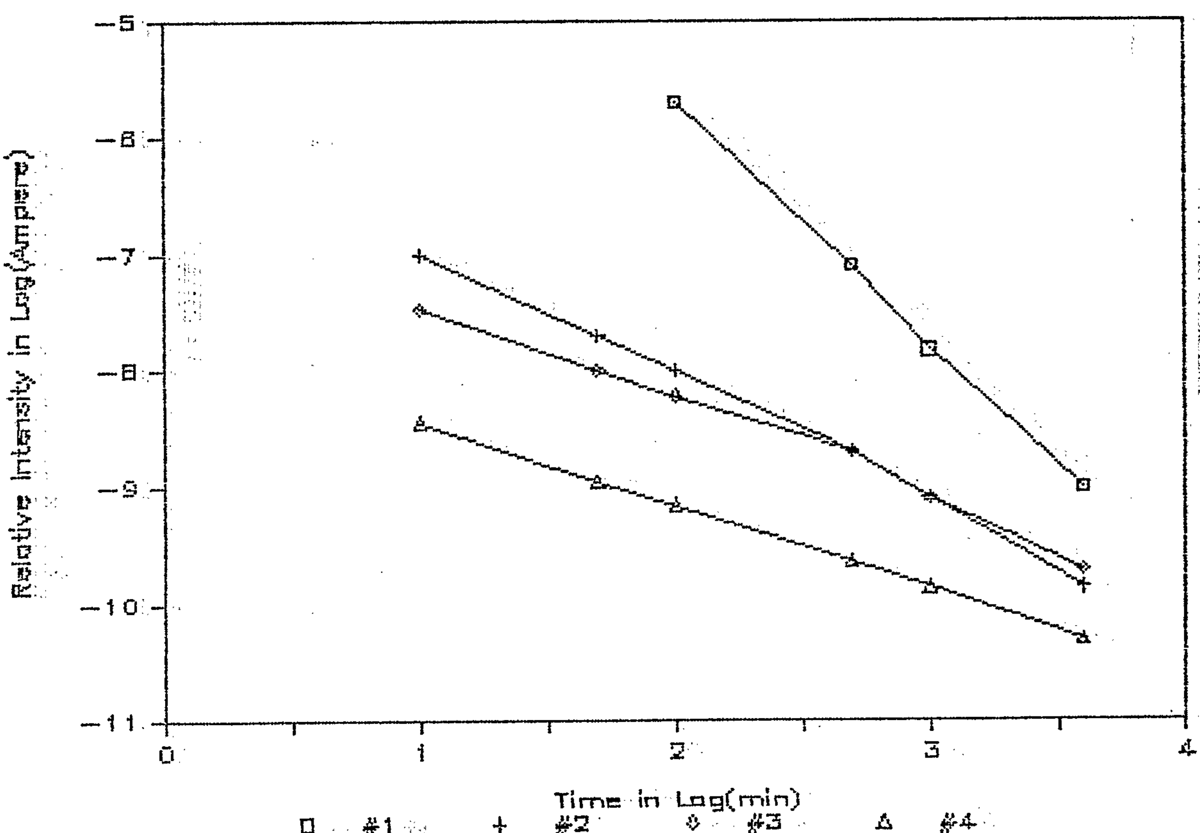


Fig 2. RGA Spectra of S-W 400l/s Turbo
P total ~ 2×10^-6 Torr
t ~ 2 hrs after pump down
Relative Peak Height
H2(2)
H2O(18)
N2,CO(28)
Oil
O2(32)
Ar (40)
Oil(43)
CO2(44)
Oil
Oil
Oil
10^-10 A
10^-9 A
10^-8 A
10^-7 Amp.
0
10
20
30
40
50
60
70
80
90
100
Mass Number m/e

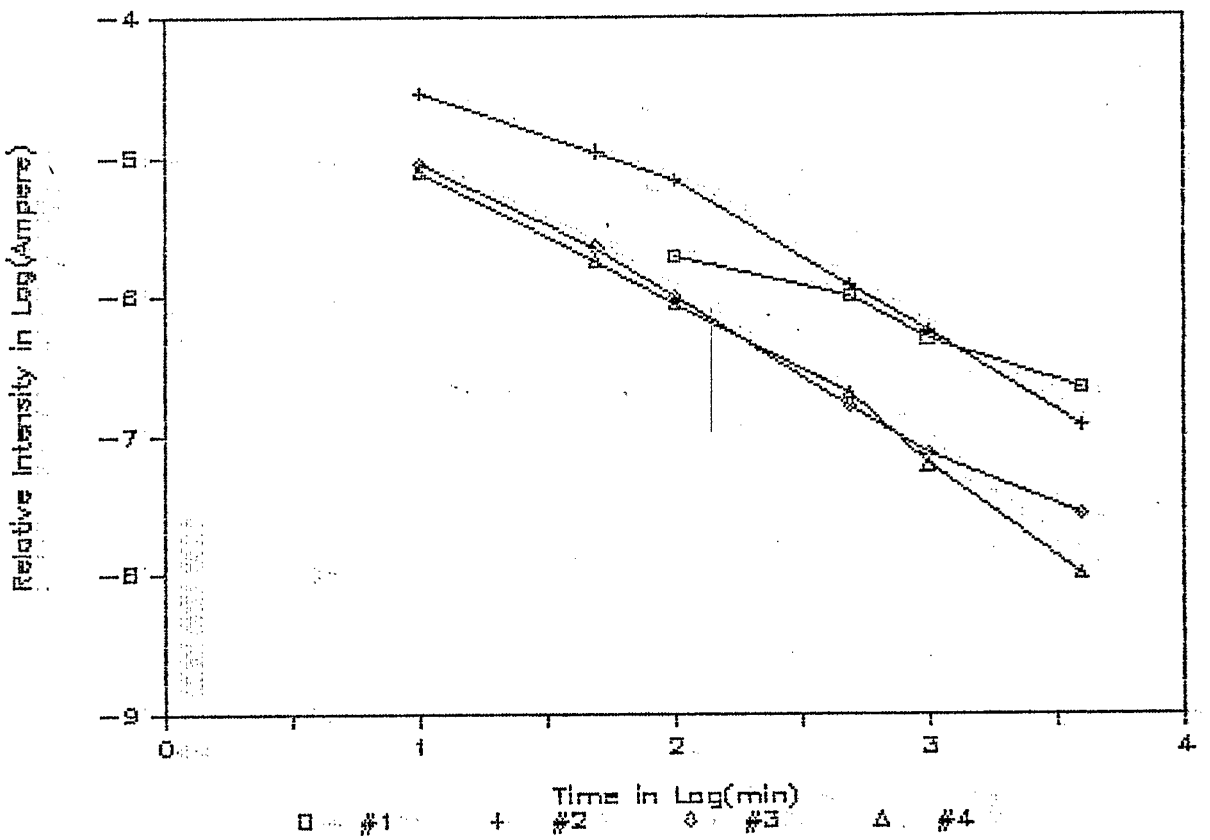
3(a) Total Pressure Curve



3(b) Oil Partial Pressure m/e=41



3(c) Water Partial Pressure m/e=18



3(d) Hydrogen Partial Pressure m/e=2

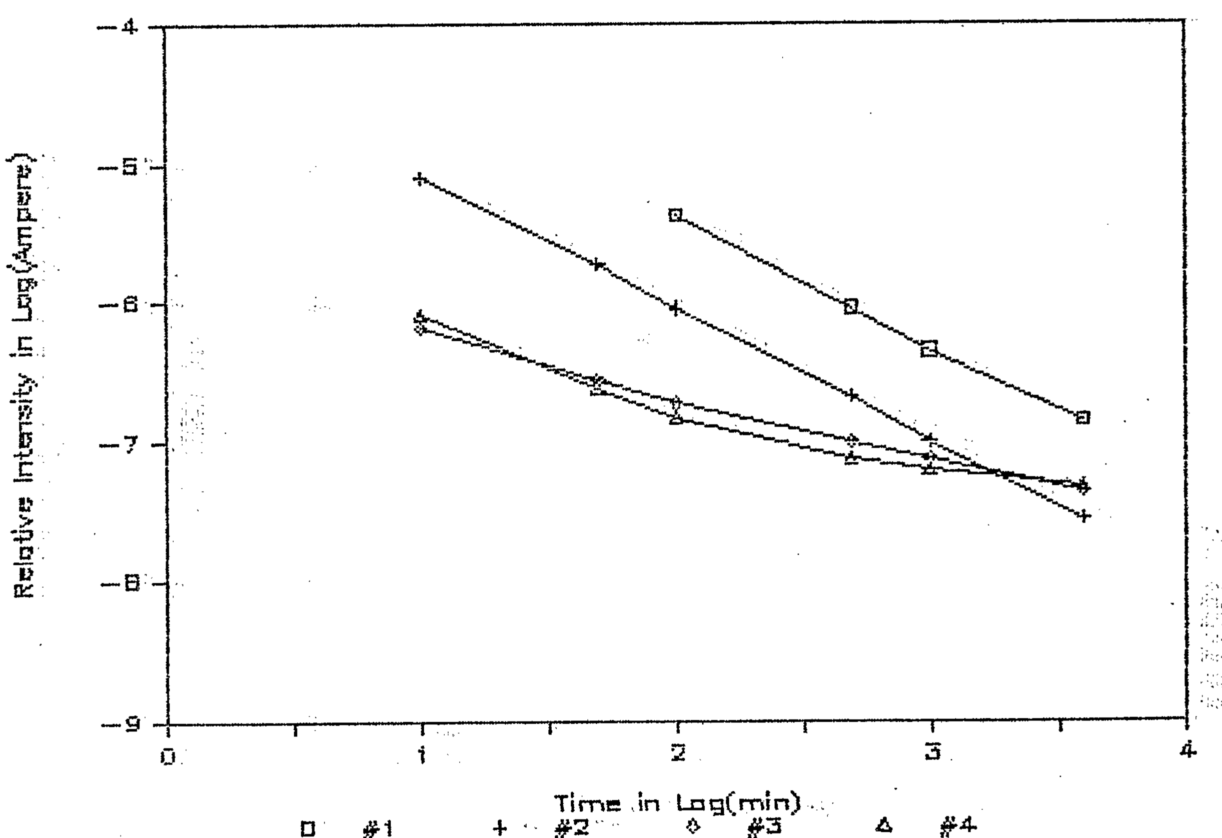


Fig 4. Pumping Speed of Turbopumps