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A NEW DRY VACUUM ROUGHING PUMP

Introduction

It has been known for years that conventional oil mechanical roughing pumps are a source of hydrocarbon contamination in vacuum systems. Special foreline traps only partially reduce this contamination. As vacuum techniques became more sophisticated, "clean" vacuums were achieved by first roughing systems with cryopumps, using some form of molecular sieve,[1,2] and then using electronic capture pumps in the form of Bayard-Alpert gauges, Penning cells, or getters to achieve high vacuum.

Sorption roughing pumps (e.g., cryosorption pumps) have their limitations, however. The most significant limitation is that they will pump only a finite quantity of gas prior to becoming saturated and, as a consequence, limit the base roughing pressure of the system. To minimize the roughing gas load, particularly when pumping large volumes, preliminary bulk gas roughing of systems is sometimes accomplished through use of carbon vane pumps or gas aspirators, capable of roughing to pressures of approximately 25 - 150 torr, prior to "valving in" sorption pumps.

A metal bellows fabricating firm[3] is presently manufacturing a bulk roughing pump operating on the principle illustrated in Fig. 1: a reciprocating bellows with reed valves, and of all stainless steel construction. Outline dimensions of the particular model tested at SLAC, for possible application in the SAD high temperature furnace, are given in Fig. 2.

Test Procedures, Results, and Interpretation

The apparatus used in preliminary evaluation of the pump is illustrated in Fig. 3, which is self-explanatory. Fig. 4 gives results of several pumpdown tests using a 23 liter test volume. Calculated optimum pumpdown to be expected if using a Gasp (a commercial aspirator pump) is also shown in this figure.

Rate-of-pressure-rise tests were conducted with the bellows pump turned off in an effort to establish the leak rate of the reed valves as a function of pressure, $Q_L(P)$, to aid in finding the analytical expression for S_P, the pump speed (a constant as defined in most elementary vacuum handbooks). However, on analysis of this data in conjunction with pumpdown data (Fig. 4) it was determined that actual $Q_L(P)$ was two orders of magnitude greater than predicted by the above rate-of-rise tests.

The familiar equation[4] for pumpdown is:

$$P(t) = P_b + (P_i - P_b)\, e^{-S_p t/V} \tag{1}$$

where

$P(t)$ = pressure in torr as a function of time t in seconds.
P_i = initial pressure
P_b = base pressure of system
V = volume of system in liters
S_p = pump speed in liters per second, assumed a constant

Validity of this equation is based on the assumption that $Q_L(P)$ is also a constant, which is generally not the case.

Our objective is to be able to predict P(t) for any system on the basis of the above tests. If we arbitrarily use (1) to define $S_p(P, t)$ with P_i = 750 torr and P_b = 165 torr, and solve for $S_p(P)$ in (1) using data of Fig. 4, we find that the measured pumping speed, S_m, is a linear function of pressure, or

$$S_m = P\left(\frac{S_i - S_b}{P_i - P_b}\right) + \frac{S_b P_i - S_i P_b}{P_i - P_b} \tag{2}$$

where

S_i = initial pump speed (e.g., at atmosphere)
S_b = base pressure pump speed (e.g., speed @ ~165 torr)

If we define $S_i = S_p$ as <u>the</u> "constant" pump speed, then measured pump speed S_m may be expressed as:

$$S_m = S_i + f(P) \tag{3}$$

where

$$f(P) = (P - P_i)\left(\frac{S_i - S_b}{P_i - P_b}\right) \tag{4}$$

Through use of (1), (3), and (4) we may express, to a very close approximation, pressure as a function of time in any system for this particular type pump as:

$$P(t) \approx P_b + (P_i - P_b) \exp\left\{-\frac{S_b t}{V}\left[1 - \left(1 - \frac{S_i}{S_b}\right)e^{-S_i t/V}\right]\right\} \qquad (5)$$

Figure 5 shows actual bulk gas pumpdown data for the SAD high temperature furnace (volume ~170 liters), and the predicted pumpdown curve based on (5). The roughing pump is shown in the lower right-hand corner of Fig. 6, attached to the roughing manifold of the high temperature furnace.

From data given it is determined that speed of the all-metal reciprocating bellows pump varies as a linear function of pressure. Pump speed values at ultimate and atmospheric pressure are 0.71 ℓ/sec and 1.07 ℓ/sec respectively. Ultimate pressure, ~ 160-170 torr, is slightly greater than the Gasp pump (110 - 140 torr) and most carbon vane pumps (50 - 100 torr). Vibration proved significant, requiring that the pump be securely fastened to the floor and coupled to the vacuum system through a flexible metal hose.

Equipment cost ($115) is approximately one-third that of the Gasp pump. Installation costs are also significantly less, as only 110 V ac is required for operation of the metal bellows pump as opposed to a high-pressure, high-mass-flow gas source required for the Gasp pump. This pump should prove a most useful tool, particularly to those people having vacuum requirements necessitating preliminary roughing with cryosorption pumps.

Acknowledgements

I wish to thank Lou Nunes for assistance in initial tests, and Bob Silvers for assistance in installing and testing this pump on the SAD furnace.

References

1. S. Dushman, Scientific Foundations of Vacuum Technique, pp. 376 - 425, (Wiley, New York, 1962). (See for discussion of General Theory of Adsorption.)
2. F. Rosebury, Handbook of Electron Tube and Vacuum Techniques, p. 110 (Addison-Wesley, Mass., 1965). (Includes some introductory references.)
3. Metal Bellows Corp, Chatsworth, California, Pumps manufactured in Sharon, Mass.
4. A. Guthrie, R. K. Wakerling, Vacuum Equipment and Techniques, p. 51, (McGraw-Hill, New York, 1949).

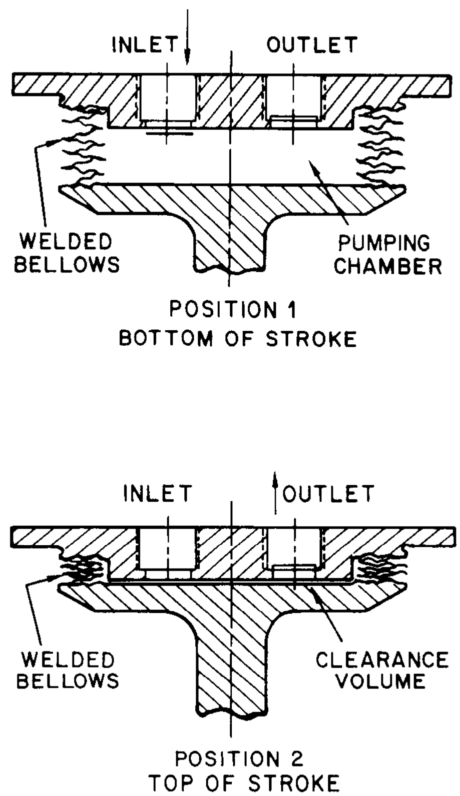

*Figure Used With Permission Of John Egbert, Contracts Administrator Metal Bellows Corporation.

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FIG. 1*--Reciprocating bellows roughing pump principle of operation.

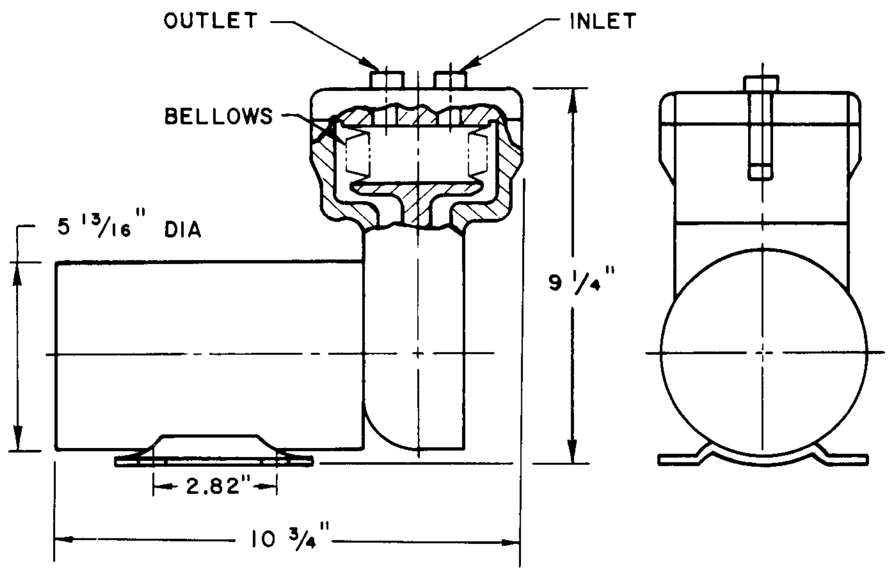

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FIG. 2*--Outline dimensions of reciprocating bellows roughing pump.

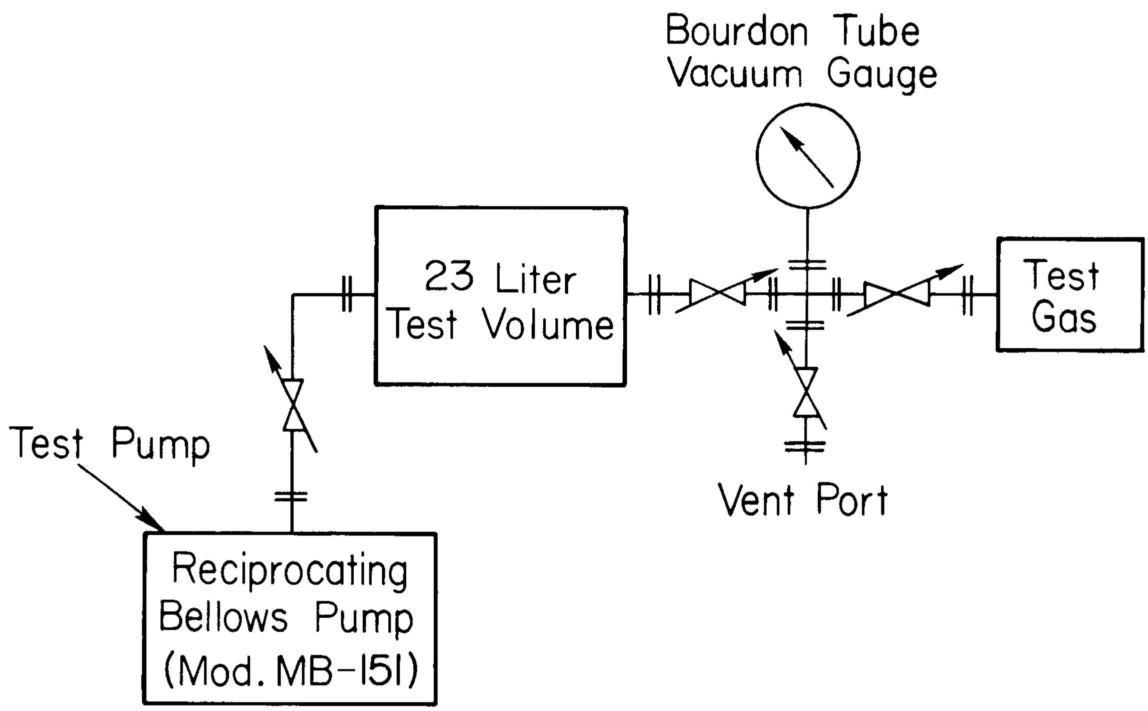


FIG. 3--Schematic representation of apparatus used in preliminary evaluation of reciprocating bellows pump.

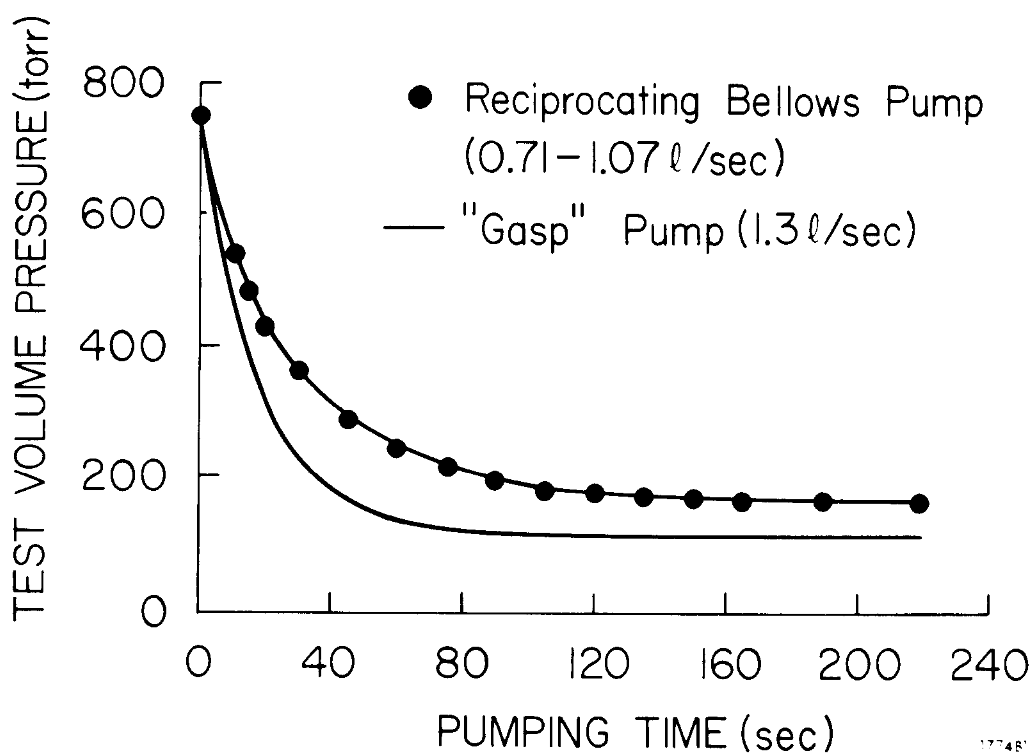
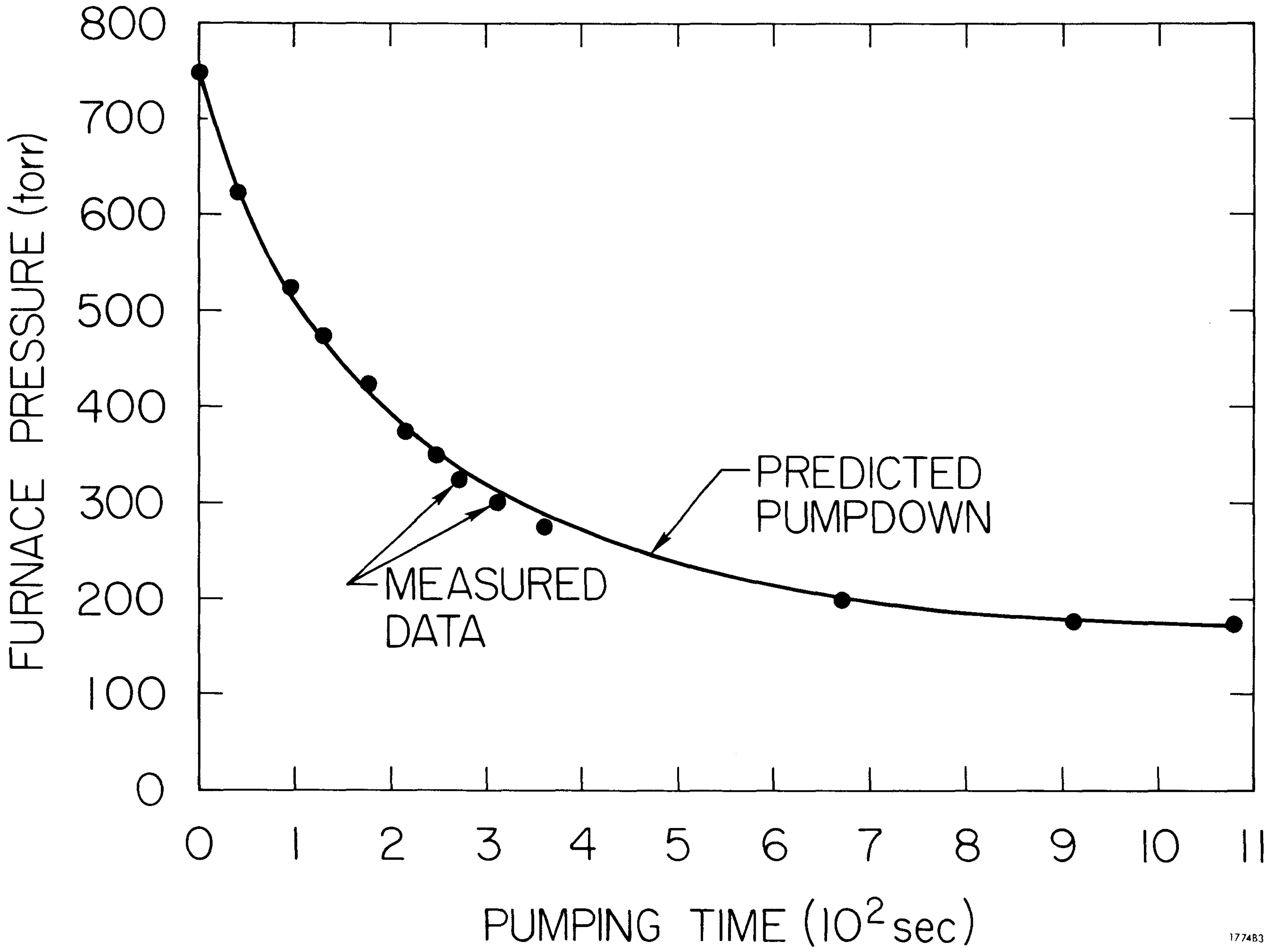


FIG. 4--Reciprocating bellows pump and gasp pumpdown characteristics using a 23 liter test volume.



FURNACE PRESSURE (torr)
800
700
600
500
400
300
200
100
0
PREDICTED
PUMPDOWN
MEASURED
DATA
0
1
2
3
4
5
6
7
8
9
10
11
PUMPING TIME (10² sec)
177483

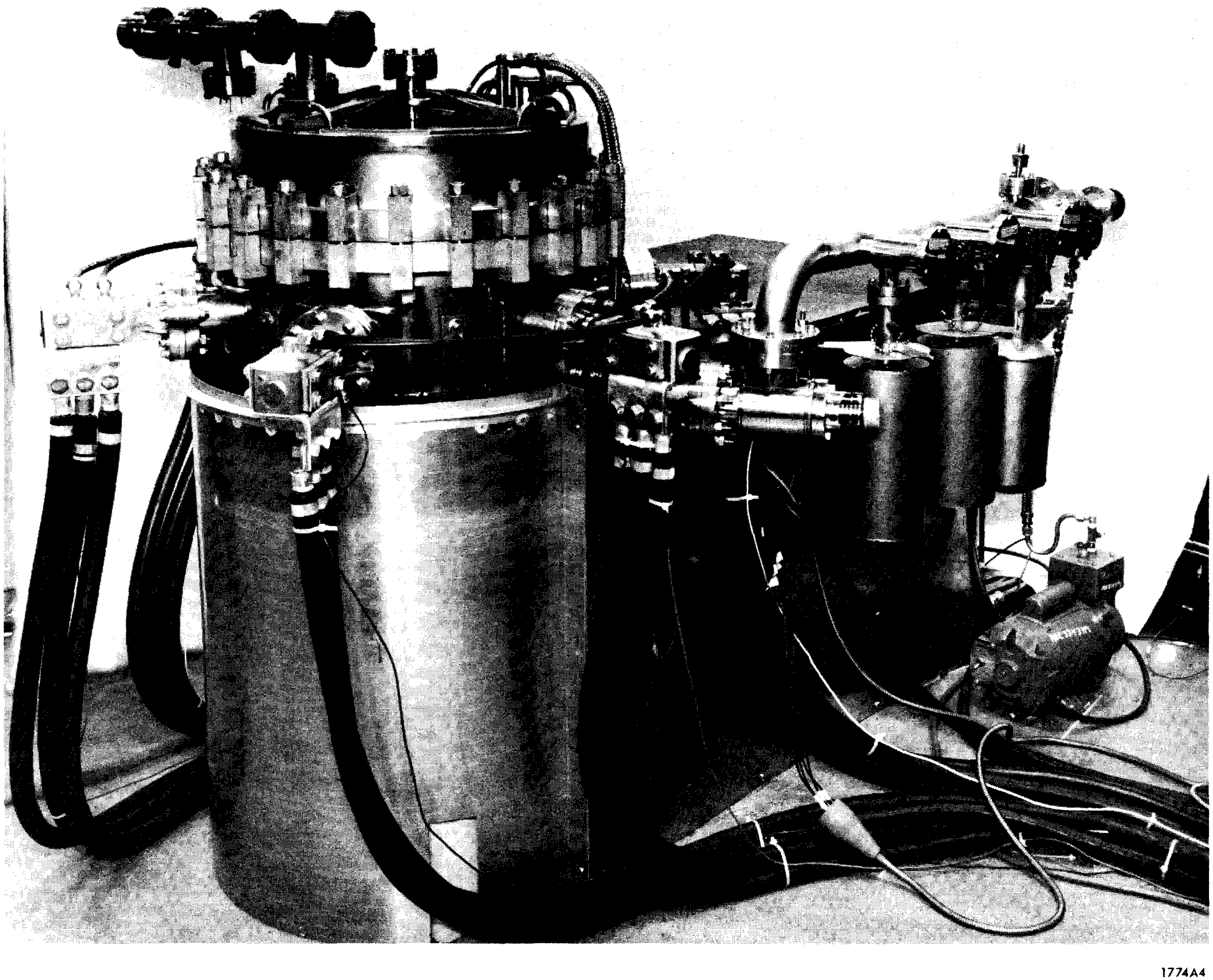


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FIG. 8 SAP high