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UNION CARBIDE NUCLEAR COMPANY

Division of Union Carbide Corporation

Post Office Box X

Oak Ridge, Tennessee

ORNL
CENTRAL FILES NUMBER

59-6-76

DATE:

COPY NO. 38

SUBJECT: Leybold DO-4001 - Oil Diffusion Pump

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FROM:

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LEYBOLD DO-4001

OIL DIFFUSION PUMP

C. E. Normand

This report summarizes results of tests run on a Leybold DO-4001 (14 in.) oil diffusion pump.

The test facility and instrumentation are shown schematically in Fig. 1.

Octoil-S pump fluid was used throughout the tests.

Tests were first run on the unbaffled pump, then on the pump with matching water-cooled baffle.

1. Operating power. The pump was operated at powers ranging from less than 1000 to above 4000 watts, (nominal, 3000 w). Pumping speed (for air) varies only slightly over this power range. At less than 1500 watts the ultimate pressure is lowest and pressure variations are least; but limiting fore pressure, and, therefore, gas handling capacity, is low. From 1500 to 3000 watts the ultimate pressure rises slightly, and pressure variation becomes progressively more pronounced; but limiting fore pressure rises to near its maximum value. Above 3000 watts the ultimate pressure remains essentially constant, pressure oscillations become continuous but of smaller amplitude, and limiting fore pressure rises only slightly.

There is no clearly defined optimum operating power. The 3000 watts recommended by the supplier gives near minimum pressure and near maximum limiting fore pressure; it does, however, put operation in the range of most pronounced pressure variation.

2. Pumping speed. Pumping speeds were measured over the 10^{-6} to 10^{-4} mm power range for air and hydrogen, with and without baffle, and at a number of operating powers. All speed measurements were by the metered leak method, using oil manometers. The speeds derived are speeds of pumping from the vacuum chamber.

The results are shown in the speed vs. power curves of Fig. 2

Fig.1

Fig. 2. Pumping Speed for Air at Powers Indicated.

Fig. 3. Pumping Speed for H₂ at Powers Indicated.

and 3. Since speed varies only slightly and almost linearly with pressure in all cases, comparisons may be drawn between average speeds derived from different sets of measurements. These average speeds are listed for comparison in Table I.

TABLE I
AVERAGE PUMPING SPEED AT 10^{-4} TO 10^{-6} mm PRESSURE

Date of Test	Baffle	Gas	Power (Watts)	Av. Speed (L/Sec.)	Ratio S H/S Air	Ratio $\frac{S \text{ Baf.}}{S \text{ Unbaf.}}$
1-13	No	Air	2124	2982		.45
1-13	No	Air	3052	3072		.44
1-14	No	H ₂	2124	2747	.92	.66
1-14	No	H ₂	3124	3128	1.02	.64
2-3	Yes	Air	1288	1207		
1-20*						
1-27	Yes	Air	2124	1342		
1-20*						
1-27	Yes	Air	3134	1364		
1-23	Yes	Air	3720	1316		
2-3	Yes	H ₂	1288	826	.68	
1-16*						
1-29	Yes	H ₂	2124	1825	1.36	
1-16*						
1-29	Yes	H ₂	3124	2000	1.46	
1-29	Yes	H ₂	3720	1842	1.40	

*Average of two series

Comparing the unbaffled pumping speed for air (about 3000 L/sec) with the rated speed of the pump (4000 L/sec) suggests that this latter value applies to the blanked off pump. If this is the case, the pump aperture conductance (11,180 L/sec) would reduce the speed of pumping from a chamber to a valve such that

$$\frac{1}{S} = \frac{1}{4000} + \frac{1}{11,180}$$

or

$$S = 2964 \text{ L/sec.}$$

which is in good agreement with the speed as measured.

Fig. 4. Limiting Fore Pressure vs. Power Input (Charts.1-10-59 and 1-28-59)

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Fig. 5. Base Pressure vs. Power Input.(Chart 2-5-59)

The Leybold baffle reduced the pumping speed for air by 55 per cent - about par for an optically opaque baffle. For hydrogen, the reduction is only 35 per cent due to the higher conductance of the baffle for hydrogen, ($C \propto \frac{1}{M}$).

The pumping speed for hydrogen is surprisingly low as compared with that for air. This is expected if the power input is low, but even at the highest powers applied, the speed is little different for the two gases. The whole question of hydrogen versus air pumping speed is being further investigated.

The variation of pumping speed with power input is insignificant in the case of air, except at the lowest power (1288 w) where a real decrease of some 10 per cent appears to occur. In the case of hydrogen the speed variation is somewhat greater, but still rather unimportant, at the higher powers (2100-3700 w). At 1288 watts, however, the speed drops by more than 50 per cent.

3. Limiting Fore Pressure. Limiting static forepressure is plotted as a function of power input in Fig. 4. (Two series taken with different fore-vacuum lines and different locations of the thermocouple gage).

Three significant facts are indicated:

- a. The limiting fore pressure is never greater than 110μ .
 - b. Increasing the power above 3000 w results in little improvement in limiting fore pressure.
 - c. Reducing the power below 3000 w results in a sharp decrease in limiting fore pressure.
4. Ultimate Pressure. Throughout the test period, base pressures of 3 to 4×10^{-7} mm were consistently obtained in the test chamber. The chamber is of stainless steel, has copper gaskets, and is unbaked and untrapped. The system was first run without baffle, and was not cleaned of oil which diffused into the chamber during this period.

The variation of base pressure with power input is shown in Fig. 5. The approximate range of pressure variation at each power is also indicated.

As compared with other pumps tested, the effect of power on ultimate pressure is very small.

5. Pressure Variations. As with other pumps tested, the base pressure under constant operating conditions is never quite constant; but varies according to a number of patterns characteristic of different operating powers. Representative pressure traces at different power inputs are shown in Fig. 6.

It will be noted that at very low powers the pressure is relatively unvarying; at very high powers, the pressure varies rapidly and continuously through a fairly narrow range; at intermediate powers pressure variations are intermittent, but of considerable amplitude.

It is quite apparent that some---and possibly all---of these pressure variations result from particular modes of boiling. At low power, boiling is quiet - no audible indication. At high power, a continual "frying" sound is produced in the pump boiler. At intermediate power, each large pressure burst can be identified with a sound of "explosive" boiling.

6. Oil backstreaming. During the initial week of operation the pump was run without baffle. Power was varied during this period, but most of the time operation was in the 2100 to 3100 watt range. During the final 64 hours, oil was draining from the "drip cone" at an essentially constant rate of 0.54 cc/hr. During this same period, no drainage from the chamber wall was observed.

This measured value of backstreaming rate (.054 cc/hr.) is probably on the low side since the pump was not operated continuously at its rated power; also, it is possible that true equilibrium between backstreaming and drainage had not been reached.

Since the Leybold baffle was installed (about a month) no measurable drainage of oil has occurred. It can be safely said that backstreaming through the baffle is less than a few tenths of a cc per month.

7. Summary. Operating characteristics of the Leybold DO-4001 pump are summarized in Table II, column 1. Characteristics of three other pumps are also tabulated for comparison.

On the basis of these comparisons, the Leybold pump rates well, except for its rather low limiting fore pressure. This feature suggests that in applications demanding large gas handling capacity, this pump should be followed by a booster pump or by a blower---Kinney type combination of backing pumps.

FIGURE 6. TYPICAL PRESSURE TRACES AT DIFFERENT POWER INPUTS

TABLE II
SUMMARY OF PUMP CHARACTERISTICS

	Leybold ⁽¹⁾ DO-4001	W-house DPI ⁽²⁾ 20"-8"	Consoli- dated (3) MCF-1400	Consoli- dated (4) PMC-144D
Speed - unbaffled at 10^{-5} mm(L/sec.)	3050	6300	1350	920
Limiting fore pressure (μ)	110	300 (With Booster)	140	400
Obs. Base* Pres. (mmHg)	3.5×10^{-7}	-	8×10^{-7}	5×10^{-7}
Norm. Oper. Power (Watts)	3000	4000 Prim. 2200 Boost.	2400	1300
Oil Back Str. Rate (cc/Hr.)	> .054	-	> .077	.043
Ratio : Speed To Aperture	19.8	20.1	17.1	22.3
Ratio : Speed to Power	1017	1016	466	511

*Observed base pressures are not strictly comparable since they do not necessarily represent true ultimate pressures.

As desirable features of design and construction one might list:

- a. Small over-all dimensions.
- b. Ruggedness without excessive weight.
- c. Precision of fit, spacings, and alignments.
- d. Floating flanges.
- e. Cast aluminum base on jet assembly.
- f. Heat-up and cool-down times are short for a pump of this size.

Whether the cooling water jacket is superior to the more commonly used cool-coils is not apparent.