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FROM:

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LEYBOLD DO-501
A NOMINAL 6" OIL DIFFUSION PUMP
Frank A. Knox

This report summarizes results of tests run on a Leybold DO-501 diffusion pump with some comparisons with two other nominal 6" diffusion pumps.

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

Convoil 20 and Narcoil 40 were the two diffusion pump oils used in the test of this pump.

1. Operating Power - The pump was operated at powers from 300 to 1600 watts with both oils. Figure 2 shows typical base pressures derived in such a traverse and indicates differences in the behavior of the two oils as found in the first month of operation. The rated power for the pump is 800 watts but with neither oil was this found to be a good power for operation. With Convoil 20 the steadiest pressure and the lowest pressure was found in the range of 1000-1200 watts. With Narcoil 40 pumping was steady from 1100 to 1500 watts, and from 400 to 600 watts. At intermediate powers the pressure was unsteady during the first months operation. For pumping hydrogen and for most uses 1100 watts power would be recommended with Narcoil 40 and the 400 to 600 watt region being reserved for pumping very tight systems without hydrogen. At 1100 watts the pumping speed to power ratio of this pump is less than for MCF700 and the PMC144D.

2. Pumping Speed - The DO-501 is rated at 600 liters per second at 10^{-5} mm Hg. The entrance losses into the pump should drop this to about 460 liters per second and a speed of 420 liters per second was actually measured at 10^{-5} mm Hg. With a baffle in place the average air speeds at various powers from 10^{-6} to 10^{-4} varied from 210 to 250 liters per second (Figure 3). The average hydrogen speeds through the baffle at powers above 1100 watts ran from 410 to 430 liters per second. Below 1100 watts the pumping speed for hydrogen diminishes with power. Both Narcoil 40 and Convoil 20 were similar in their speed characteristics with both air and hydrogen. The pumping speed to aperture ratio of the Leybold pump is less than that of the PMC144D and MCF700.

3. Limiting Forepressure - The rated forepressure tolerance of the Leybold pump is given as 200 microns. However, at its rated power of 800 watts the fore pressure tolerance is only 15 to 30 microns and at 1100 watts where the pump might best be operated, it is only 90 microns (Figure 4). This is much less than the 400 microns forevac tolerance of the PMCl44D but is somewhat better than the MCF700 which usually needs booster pumps to hold the forevac pressure down.

4. Ultimate Pressure - The ultimate pressure of the Leybold D0-501 is rated by NRC with their oils to give 1×10^{-7} or with Deffelen oil to give 5×10^{-7} mm Hg. With Narcoil 40 and Convoil 20 a pressure of 4×10^{-7} was reached in the time of these tests. However, with Narcoil 40 this low pressure was reached only at a power of 400 watts which is out of the useful range of the pump for most applications. With Convoil 20 a more general range of low pressures was obtained around 1100 watts, the power most likely to be used (Figure 2).

5. Pressure Variations - Figures 5 and 6 give examples of the pressure record of the two oils Narcoil 40 and Convoil 20 at various power levels in the Leybold D0-501. It should be noted that the record for Convoil 20 is on the 10^{-7} scale and that for Narcoil 40 is on the 10^{-6} scale. Thus the record for Convoil 20 is generally better than that of Narcoil 40 although it is certainly not free of power sensitive pressure variations. The record for Narcoil 40 was taken on the 10^{-6} scale to get it all in one range although the size of the irregularities seen are reduced to 1/10. The base pressures have been plotted on Figure 2 to give a better idea of the relationship of the two oils.

Generally two types of boiling occurs in the oils of these diffusion pumps. The normal or quiet boiling takes place quietly and with a relatively steady evolution of vapor producing a smooth pumping action. Eruptive or noisy boiling produces bursts of vapor which in some way interfere with normal pumping. High pressures result, either in temporary high pressure peaks or in generally higher pressures. In figure 6 with Narcoil 40 the pressure record at 1100 watts and higher, although fairly smooth is probably increased because of the continuous noisy boiling which is occurring during this time. The type of boiling occurring from 400 to 600 watts is quiet and is characterized by low pressures. In the intermediate region from 700 to 1000 watts the boiling alternates from noisy to quiet with the resultant cyclic pressure

record shown. The change from noisy boiling to quiet boiling and the reverse occurs instantaneously. Noisy boiling suddenly starts and suddenly stops, producing the cyclic record. The percentage of noisy boiling increases with power until at 1100 watts it is continuous and the large pressure variations no longer occur, but the pressure increases with power. This particular action has been observed only with Narcoil 40 in this pump.

The boiling action and the resulting steadiness or unsteadiness of the pressure produced by an oil diffusion pump is a characteristic usually dependent upon how the heat reaches the oil and how the vaporization of the oil occurs. Pumps can be designed which minimize these unsteady effects. The PMC144D, through better design, uses higher power and has steadier pumping than the Leybold DO-501. The Leybold DO-501 may, under certain conditions, pump more smoothly than the MCF700.

6. Oil Backstreaming - The rate of oil backstreaming from this pump is given as less than $0.05 \text{ mg/cm}^2/\text{min.}$ which is about 0.6 cc per hour. As measured at 1100 watts the backstreaming rate was found to be 0.17 cc per hour. This is still about four times the rate of the PMC144D which was measured at approximately 0.043 cc/hr. Figure 7 shows the oil backstreaming rate at various power levels. The record of the oil collected from the cone may be more reliable than that from the walls due to the length of time necessary to get equilibrium of drainage from the walls.

7. Summary - The Leybold DO-501 pump should normally be operated at 1100 watts instead of its rated 800 watts in order to have an adequate forepressure tolerance, to pump hydrogen and to handle a reasonable gas load. Convoil 20 has proved to be a better pumping fluid in this pump than Narcoil 40 since it has a low base pressure over a much wider range and is less prone to eruptive or noisy boiling. The higher forepressure tolerance, better speed to aperture ratio, and reduction in high vacuum pressure fluctuation make the PMC144D a better pump by most standards. The Leybold DO-501 is not as good as the MCF700 in speed to aperture ratio, although it is better in forevac pressure tolerance. However, since the MCF700 is usually run with booster pumps this advantage may be reduced to one of convenience and size. A summary of some of the characteristics of these three nominal 6" pumps is found in Table I.

TABLE I

	DO-501		6" MCF 700			PMCl44D	(Units)
	Oil		Oil			Oil	
	Convoil 20	Narcoil 40	Convoil 20	Octoil S	Apiezon C	Convoil 20	
Aperture Area	27.5 in. ²	27.5 in. ²	28.2 in. ²	28.2 in. ²	28.2 in. ²	41.1 in. ²	
Air Speed Baffled	225-250	225-250	345-365	318-340	360	---	lit/sec.
Air Speed without Baffle	-	385-450	-	650	-	920	"
H ₂ Speed Baffled	410-430	410-430	-	-	-	-	"
H ₂ Speed without Baffle	-	500-600	-	-	-	-	"
Oil Backstreaming	-	0.17	-	-	-	0.043	cc/hr.
Limiting Forepressure	90	90	*	*	*	400	microns
Ratio with Baffle Speed to Aperture	9.1	9.1	12.9	12.0	12.7	-	
Ratio w/o Baf. Spd to Aperture	-	16.3	-	23.0	-	22.3	
Ratio Speed to Power	-	.408	-	.810	-	.511	
Observed (*) Base Pressure	4 x 10 ⁻⁷	4 x 10 ⁻⁷	5 x 10 ⁻⁷	5 x 10 ⁻⁷	5 x 10 ⁻⁷	5 x 10 ⁻⁷	mm Hg
Recommended Power (Manufacturer)	800	800	800	800	800	1800	watts
Best Opr. Power (This Lab)							
1. Air	11-1200	1100 or 600	*)	800	800	1800	watts
2. H ₂	11-1200	1100	*)	-	-	-	watts

*The MCF 700 does not behave normally in this regard, the pressure beginning to increase the minute the forevac valve is closed, and thus may be from 10 to 100 microns over the range of operating powers.

(*)The base pressure observed may not be near the ultimate base pressure possible with the pump and oil combination.

*)It appears that the most power put into this pump (950 watts) was still less than the amount required for its best performance.

10-5

6" LEYBOLD DO-501

Laboratory Testing Assembly

Figure #1

Pressure

mm. Hg

10⁻⁶

6* LEYBOLD DO-501

Ultimate Pressure Characteristics

Shape of Pressure vs. power curve for two
cells after approximately one month's operation.
Actual ultimate may be different than shown.
See Figures #5 & 6 for nature of pressure
irregularities.

Figure #2

10-7

Speed
Liters/Second

6" LEYBOLD DO-501

Average Speeds at Various Power Levels, 20" x 20" chamber with Baffle.

Hydrogen and Air

Narcoil 40 and Conveil 20

Narcoil 40-△

Conveil 20-○

600

500

400

300

200

100

0

Average Hydrogen Speeds

Average Air Speeds

Figure #3

500

600

700

800

900

1000

1100

1200

1300

1400

Power, Watts

10-8

Pressure
Microns

6" LEYBOLD DO-501

Forevac Tolerance Tests

Narcoil 40 and Convoil 20

Narcoil 40 - x

Convoil 20 - o

300

200

100

0

Figure #4

Power, Watts

6-01

LEYBOLD DO-501
 Convoil 20
 Characteristic Pressure Variations
 Figure #5

Taken on 10^{-7} mm. Hg Pressure Scale.

91-01

LEYBOLD DO-501

Taken on 10⁻⁶ mm.Hg Pressure Scale

Narcoil 40
Characteristic Pressure Variations
Figure #6

11-01

Rate
cc./hr.