UNCLASSIFIED

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0360784 4

ORNL 764
9A

PUMPING SPEED OF OIL DIFFUSION PUMPS FOR HYDROGEN AND AIR

OAK RIDGE NATIONAL LABORATORY
CENTRAL RESEARCH LIBRARY
CIRCULATION SECTION
4500N ROOM 175
LIBRARY LOAN COPY
DO NOT TRANSFER TO ANOTHER PERSON
If you wish someone else to see this report, send in name with report and the library will arrange a loan.
UCN-7969 (3 9-77)

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
CARBIDE AND CARBON CHEMICALS DIVISION
UNION CARBIDE AND CARBON CORPORATION
UCC
POST OFFICE BOX P
OAK RIDGE, TENNESSEE

UNCLASSIFIED

UNCLASSIFIED

Report Number: ORNL-764

This document consists of 17 pages.
Copy 9 of 130 Series A

Contract No. W-7405, eng 26

INSTRUMENT DEPARTMENT

PUMPING SPEED OF OIL DIFFUSION PUMPS FOR HYDROGEN AND AIR

by

Harry Reese, Jr.

Date Issued

AUG 11 1950

OAK RIDGE NATIONAL LABORATORY

operated by

CARBIDE AND CARBON CHEMICALS DIVISION
Union Carbide and Carbon Corporation
Post Office Box P
Oak Ridge, Tennessee

UNCLASSIFIED

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES

3 4456 0360784 4

Internal Distribution

1	G. T. Felbeck (C&CCD)	17	W. D. Lavers (Y-12)	32	M. T. Kelley
2-3	706-A Library	18	A. M. Weinberg	33	J. H. Gillette
4	706-B Library	19	E. J. Murphy	34	J. S. Felton
5	Biology Library	20	F. C. VonderLage	35	L. M. Reynolds
6	Metallurgy Library	21-25	C. S. Harrill	36	W. J. Ladniak
7	Health Physics Library	26	J. A. Swartout	37	H. Reese, Jr.
8-9	Training School Library	27	A. H. Snell	38	W. M. Good
10-13	Central Files	28	A. Hollaender	39	R. W. Lamphere
14	C. E. Center	29	F. L. Steahly	40	M. J. Skinner
15	C. E. Larson	30	K. Z. Morgan	41	Central Files (O.P.)
16	W. B. Humes (K-25)	31	D. W. Cardwell	42.	R. A. Bolomey

External Distribution

43-50	Argonne National Laboratory
51	Armed Forces Special Weapons Project
52-53	Atomic Energy Commission, Washington
54	Battelle Memorial Institute
55	Brush Beryllium Company
56-63	Brookhaven National Laboratory
64	Bureau of Ships
65-68	Carbide & Carbon Chemicals Division (K-25)
69-72	Carbide & Carbon Chemicals Division (Y-12)
73	Chicago Operations Office
74	Columbia University (J. R. Dunning)
75-77	General Electric, Richland
78	Idaho Operations Office
79-80	Iowa State College
81-84	Knolls Atomic Power Laboratory
85-87	Los Alamos Scientific Laboratory
88	Massachusetts Institute of Technology (A.Kaufmann)
89-91	Mound Laboratory
92-93	National Advisory Committee for Aeronautics
94-95	National Bureau of Standards
96-100	New York Operations Office
101	North American Aviation, Inc.
102	Patent Branch (Washington)
103	Sandia Laboratory
104	Santa Fe Operations Office
105-119	Technical Information Division (Oak Ridge)
120-121	USAF, NEPA
122-126	University of California Radiation Laboratory
127-130	Westinghouse Electric Company

PUMPING SPEED OF OIL DIFFUSION PUMPS FOR HYDROGEN AND AIR

By: H. Reese, Jr.

May 12, 1950

The pumping of hydrogen with an oil diffusion pump has been recognized as a problem different from that of pumping air for quite some time. Pumps in the past and most present pumps have been designed on the basis of pumping air and thus have some rated pumping speed for air which is usually published by the manufacturer. There is usually no data given for hydrogen. For accelerators employing hydrogen for the production of protons this becomes quite important because the pumping speed is a limiting factor on the maximum beam current. The pressure in the tube rising too high for operation due to admitting hydrogen at the ion source. If pumps of sufficient speed are used at the bottom of the tube, it is possible that no others will be required.

The theoretical speed of a diffusion pump is inversely proportional to the square root of the molecular weight. An ideal diffusion pump can be likened to an aperature with a perfect vacuum on one side. The molecules being pumped are lost once they go through the diffusion pump aperature. For an aperature of this type the pumping speed is inversely proportional to the square root of the molecular weight. A fundamental assumption in the kinetic theory of gases states that the translational energy of a gas molecule is only a function of temperature. If this is true then the velocity of the gas molecule must be inversely proportional to the square root of the molecular weight. Then the rate at which molecules strike the walls of a container, at pressures where we have molecular flow, would also be inversely proportional to the square root of the molecular

weight. If there is an aperature in one wall and we have molecular flow with a vacuum on the outside, the quantity of gas leaving would be inversely proportional to the square root of the molecular weight of the gas. Since the ratio of the molecular weight of air to hydrogen is approximately 14.4, we would expect a diffusion pump to pump hydrogen 3.8 times as fast as air. This, however, assumes that the gas on the fore-pressure side of the vapor jets does not diffuse back through the jet to the high vacuum side. This assumption is very difficult to realize in practice when pumping hydrogen or other light gases with a pump designed for air, since the light gases diffuse through a vapor stream much more readily than air. The problem is further complicated by the fact that if the pumping speed for air of a diffusion pump is known there is no relationship between this speed and the speed for hydrogen except that it will be in the range of 0 to 3.8 times the speed for air. As a result of this, if a diffusion pump is to be used for pumping hydrogen, its speed should be measured for hydrogen and not assumed or gotten from a ratio of hydrogen to air speed of another pump.

Having a given pump we can increase the pumping speed for light gases over the pumping speed at normal operating conditions by reducing the back diffusion of the gas through the vapor stream. There are two methods of doing this. First the oil vapor stream from the jets can be made denser by increasing the heater voltage and thus the rate of boiling of the oil. However, there is also a tendency to boil off more contaminants from the oil and increase the high vacuum pressure. For small increases the effect is to increase the speed due to the higher density of the vapor stream but if the heater voltage is increased too much the effect of the increased oil vapor pressure overrides the effect of the increased vapor jet density and the speed of the pump will decrease. If the heater voltage is raised further

the oil will "crack" and form carbon in the pump giving a very low pumping speed and necessitating cleaning of the pump. Second, we could decrease the pressure drop across the vapor stream and decrease the back diffusion. Both of these things should be heeded when pumping light gases.

From the graphs attached it can be seen that the pumping speed for hydrogen is quite critical with regard to heater voltage, more critical than for air. The pumping speed for the Distillation Products Inc. type VMF-260 was plotted in figure 5 for a given voltage with two different forepressures for hydrogen at 130 volts on the heater. This difference in forepressure has little effect on the pumping speed for air but, as can be seen, has a very large effect on the pumping speed for hydrogen. This would be expected because the back diffusion for air is small at even the higher forepressure whereas the back diffusion for hydrogen is quite large at the higher forepressure and can still probably be lowered further than that at the lower forepressure to advantage.

As a result the pumps should be operated with minimum possible forepressure when maximum pumping speed for hydrogen is required but the heater voltage should not necessarily be as high as possible. There is usually some optimum value which should be found experimentally. A brief description of each pump tested follows, and graphical data is enclosed at the end of the report.

D.P.I. TYPE VMF-260

This is a water cooled, metal, three stage fractionating oil diffusion pump. The normal heater voltage is 110 to 120 volts (314 to 372 watts) and the normal cooling water flow is about 1500 cc/min. The attached graphs for the VMF-260 show a peak pumping speed of about 100 liters per second at 5×10^{-4} MM for hydrogen and 88 liters per second at 2.3×10^{-4} MM for air with a forepressure of 15 microns. The heater voltage

in both cases is 130 volts (438 watts). This was the maximum safe voltage to use with this heater but higher pumping speeds can be obtained with a higher wattage heater. 130 volts on the heater should not be used continuously when Octoil-S is used as a pump fluid because it was found to decompose with time and lower the pumping speed. This is probably caused by local superheating of the oil and resultant "cracking" of the oil. Octoil and Anoil would probably be better in this respect because they are more resistant to cracking and would not affect the pumping speed to any great extent.

When the VMF-260 was used with only a Welch #1405 forepump so that forepressure was about 50 microns, the pumping speed at 5×10^{-4} MM was about 10 liters per second for hydrogen as can be seen in figure 5.

The lowest ultimate pressure obtained with this pump was about 1.5×10^{-6} MM and does not change much with heater voltages. There is a small baffle integral with the pump so that no baffle is necessary to obtain the ultimate.

D.P.I. TYPE MCF-300

This unit was designed for pumping hydrogen and is a water cooled, metal, three stage, fractionating oil diffusion pump. It has a four inch high vacuum lead and is one of the best oil diffusion pumps for air and hydrogen. As can be seen in figures 8 and 9, it has a pumping speed greater than 300 liters per seconf for hydrogen and about 150 liters per second for air with 110 volts (412 watts) on the heater. It does not have a built in baffle so that the ultimate vacuum is quite poor (about 10-5). However when a conical baffle similar to the D.P.I. type WB-8 is used at room temperature the ultimate vacuum is about 1.5×10^{-6} MM. The ultimate vacuum decreases with heater voltage for this pump and the lowest was obtained with about 85 volts (246 watts) on the heater. The pumping speed

of the baffle and pump combination remains about the same, indicating that the decreased conductance of the system was offset by the reduced oil vapor pressure.

It is necessary for this pump to be backed up by a high capacity forepump of about 5 liters per second or else used with a booster pump and a lower capacity forepump. The reason of course being that the forepressure must be maintained below 100 microns and lower if possible when pumping hydrogen at 300 liters per second. A satisfactory arrangement is to use a D.P.I. type VKB-8 booster pump and a Welch #1405 forepump. The booster pump is capable of holding the forepressure on the diffusion pump to about 20 microns when the pressure at the forepump is about 600 microns.

D.P.I. TYPE VMF-20A

This is a metal, air cooled, two stage fractionating oil diffusion pump. It is a very good for small static vacuum systems. The ultimate vacuum is about 10^{-6} MM and the pumping speed at 10^{-4} for air is about 15 liters per second with 105 volts (150 watts) on the heater. The maximum pumping speed for hydrogen is about 34 liters per second with 115 volts (175 watts) on the heater. The ratio of two for the pumping speed of hydrogen to air indicates that the vapor stream is fairly dense. No booster pump was used with this diffusion pump, only a Welch #1400 forepump.

D.P.I. TYPE VKB-8

This is a water cooled, metal, oil ejector booster pump. Its rated pumping speed is seven liters per second at 100 microns. Since an ejector type pump inherently has a dense vapor stream, one would expect it to pump light gases faster than air. Very little quantitative data were obtained for the VKB-8, but it was determined that the ultimate vacuum is about 2 microns and the pumping speed for hydrogen is about twice the rated speed for air or about 14 liters per second at 100 microns. Cooling water required is about 2 liters per minute.

It is recommended by the manufacturer that the heater voltage should be adjusted until the sight glass is three fourths full with oil. It was found, however, that this does not give maximum pumping speed or highest ultimate vacuum. These were obtained with a heater voltage of about 80 volts (430 watts) which does not permit any oil to build up in the sight glass.

D.P.I. TYPE MC-275

This is a metal, water cooled, three stage, fractionating oil diffusion pump. Quantitative data were not obtained for this pump but when used on an accelerator tube it was determined that it was slightly better than the VMF-260 but did not have nearly as much pumping speed as the MCF-300.

EXPERIMENTAL PROCEDURE

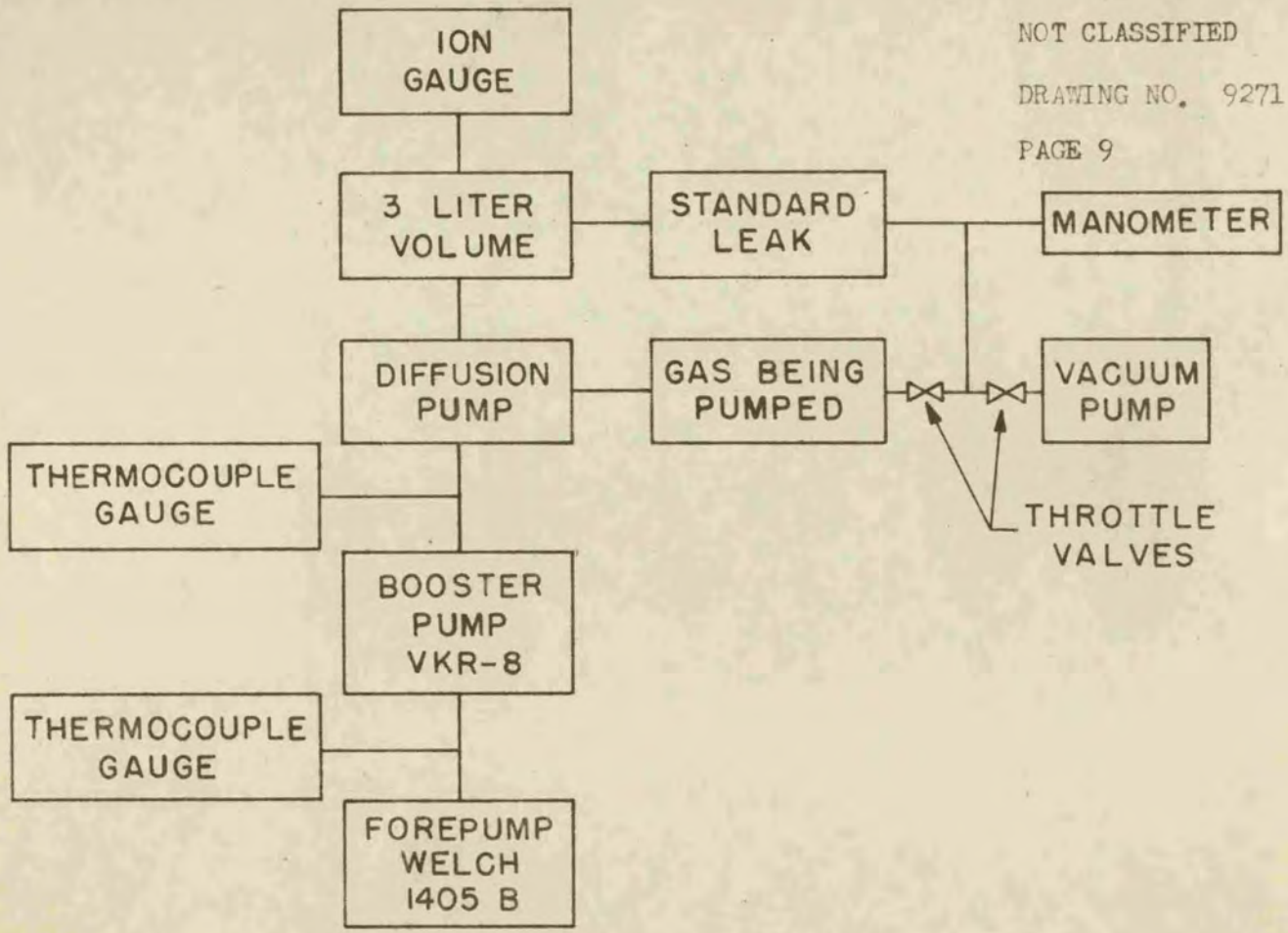
A block diagram of the equipment used is shown in Figure 1. The conductance of the connection between the pump and the ionization gauge has been neglected since it is approximately 2000 liters per second. This would tend to make the actual pumping speed slightly higher than that shown on the graph. There are no baffles or cold traps used in the system other than those that are a part of the pumps. It was thought that a more accurate picture of the particular pump would be obtained in this manner since the pumping speed would be that of the pump and not that of a cold trap with a pump. Oil diffusion pumps are frequently used without cold traps.

The high vacuum readings were taken with a VG-1A ionization gauge corrected for hydrogen. Octoil-S pump oil was used in all of the diffusion pumps and Myvane-10 oil was used in the VKB-8 booster. The forepressures were taken with a type 701 National Research thermocouple gauge. A calibration curve for hydrogen for this gauge is shown in Fig. 2. This was obtained by comparing the gauge reading with a McLeod gauge for dry hydrogen.

NOT CLASSIFIED

DRAWING NO. 9271

PAGE 9



BLOCK DIAGRAM OF EQUIPMENT USED IN MEASURING PUMPING SPEEDS OF DIFFUSION PUMPS

FIG. 1

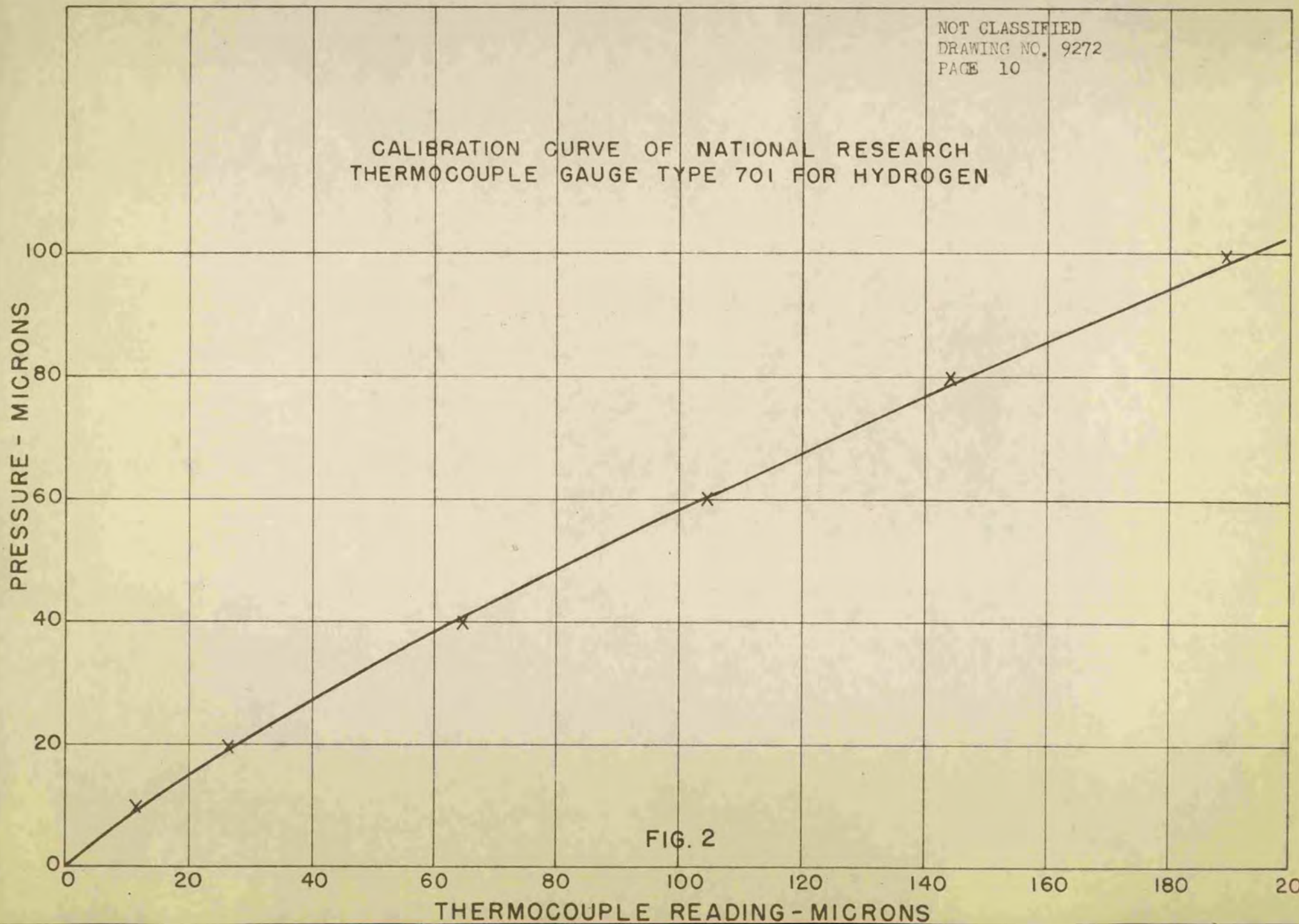

CALIBRATION CURVE OF NATIONAL RESEARCH
THERMOCOUPLE GAUGE TYPE 701 FOR HYDROGEN
PRESSURE - MICRONS
0
20
40
60
80
100
THERMOCOUPLE READING - MICRONS
0
20
40
60
80
100
120
140
160
180
200

FIG. 2

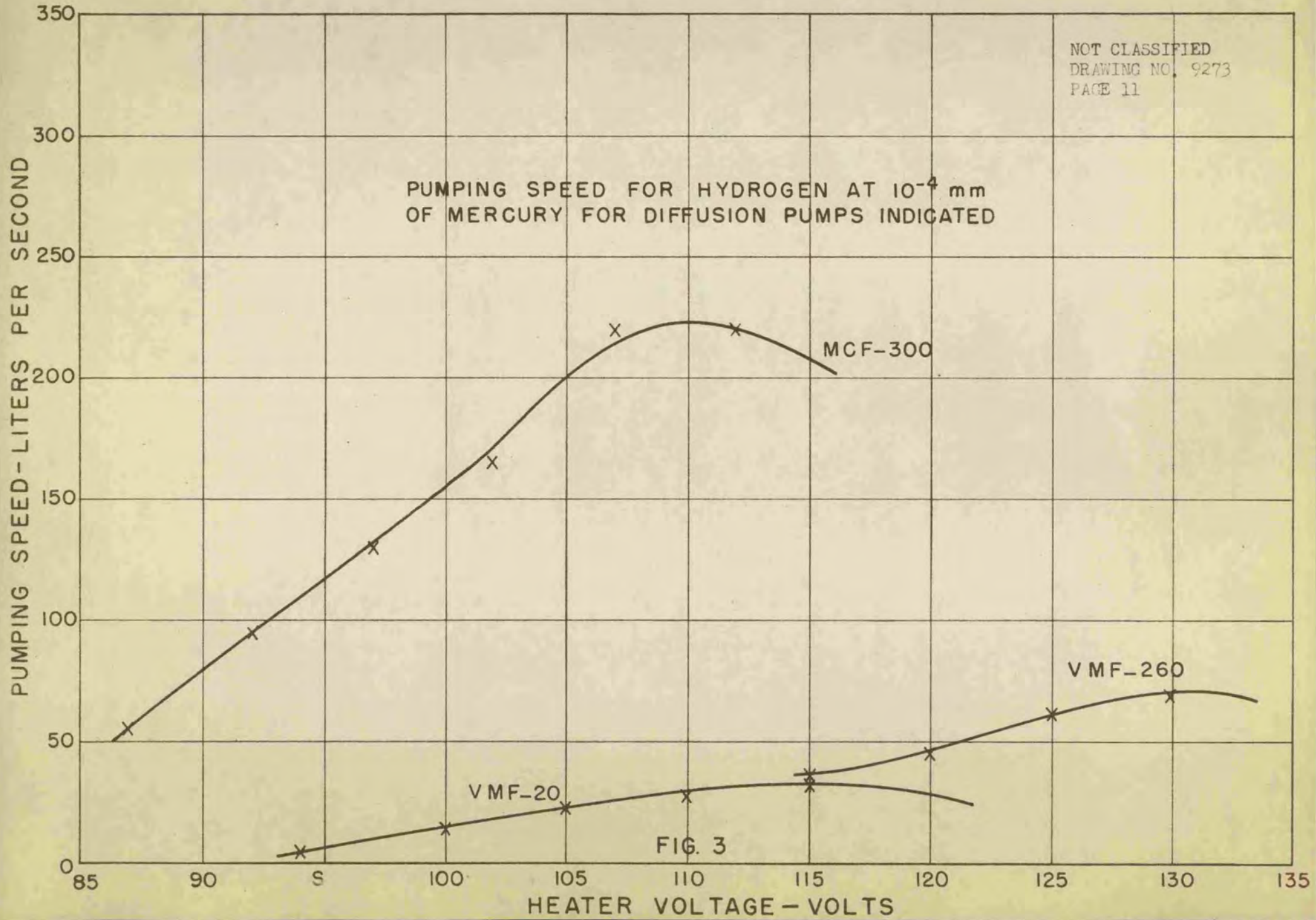

NOT CLASSIFIED
DRAWING NO. 9273
PAGE 11
PUMPING SPEED FOR HYDROGEN AT 10^{-4} mm
OF MERCURY FOR DIFFUSION PUMPS INDICATED
MCF-300
VMF-260
VMF-20
PUMPING SPEED-LITERS PER SECOND
HEATER VOLTAGE-VOLTS
0
50
100
150
200
250
300
350
85
90
S
100
105
110
115
120
125
130
135

FIG. 3

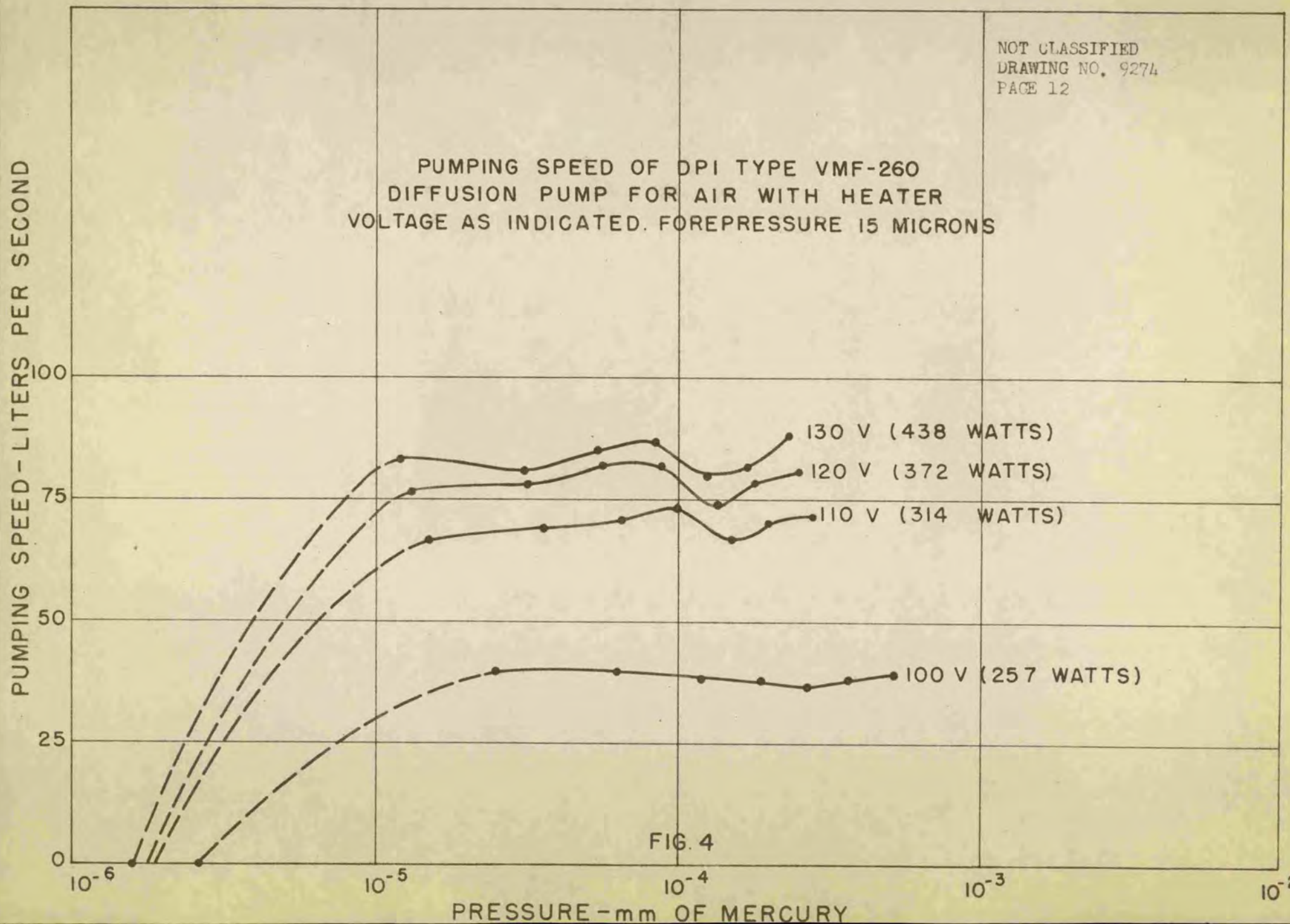

NOT CLASSIFIED
DRAWING NO. 9274
PAGE 12
PUMPING SPEED OF DPI TYPE VMF-260
DIFFUSION PUMP FOR AIR WITH HEATER
VOLTAGE AS INDICATED. FOREPRESSURE 15 MICRONS
PUMPING SPEED-LITERS PER SECOND
100
75
50
25
0
130 V (438 WATTS)
120 V (372 WATTS)
110 V (314 WATTS)
100 V (257 WATTS)
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
PRESSURE-mm OF MERCURY

FIG. 4

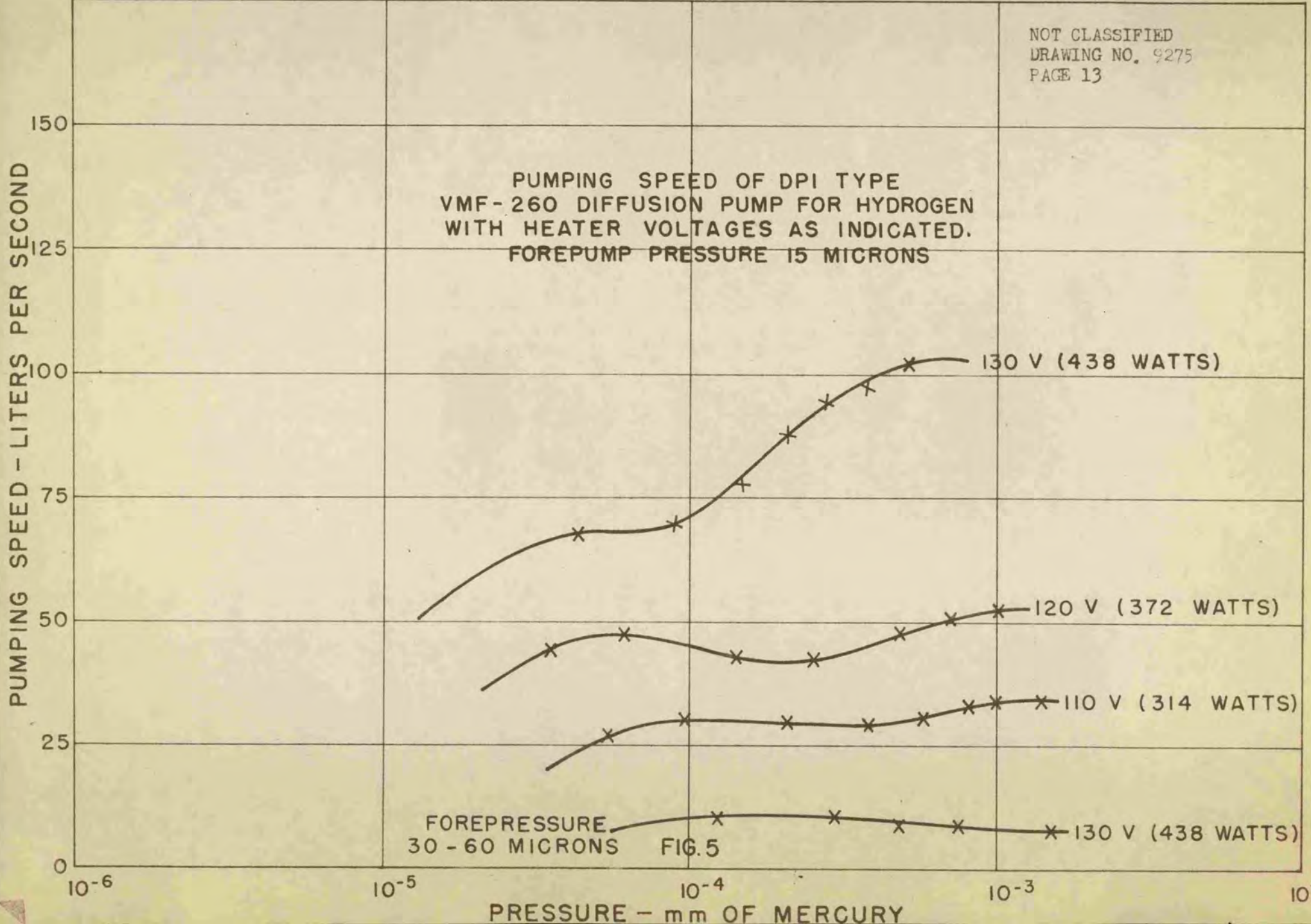

PUMPING SPEED OF DPI TYPE
VMF-260 DIFFUSION PUMP FOR HYDROGEN
WITH HEATER VOLTAGES AS INDICATED.
FOREPUMP PRESSURE 15 MICRONS
130 V (438 WATTS)
120 V (372 WATTS)
110 V (314 WATTS)
130 V (438 WATTS)
FOREPRESSURE
30 - 60 MICRONS
PUMPING SPEED - LITERS PER SECOND
150
125
100
75
50
25
0
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
PRESSURE - mm OF MERCURY

FIG. 5

PUMPING SPEED OF DPI TYPE VMF-20 DIFFUSION PUMP FOR AIR. FOREPRESSURE 20 TO 50 MICRONS. PUMP BACKED BY WELCH 1400 B FOREPUMP. HEATER VOLTAGES AS INDICATED

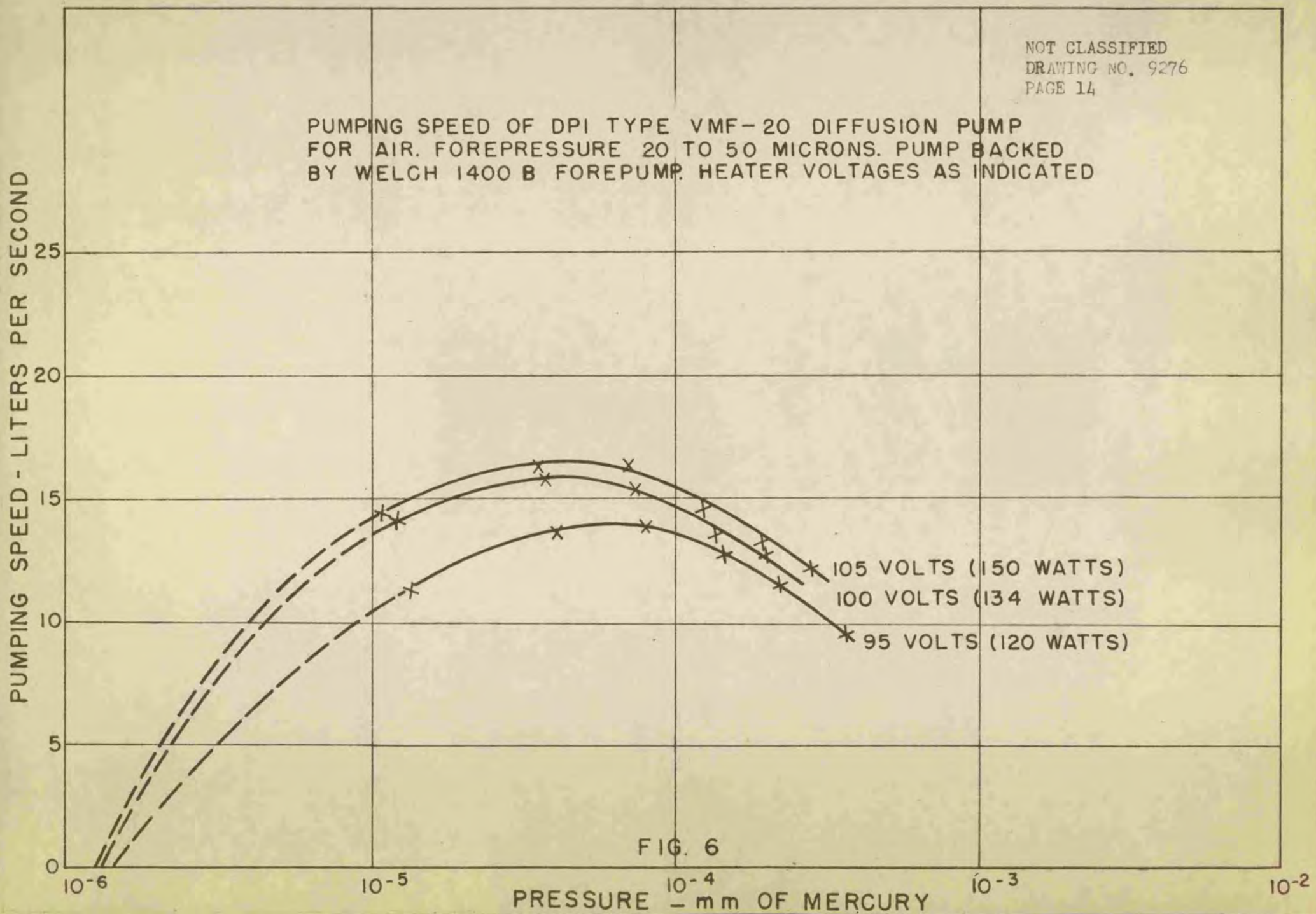


FIG. 6

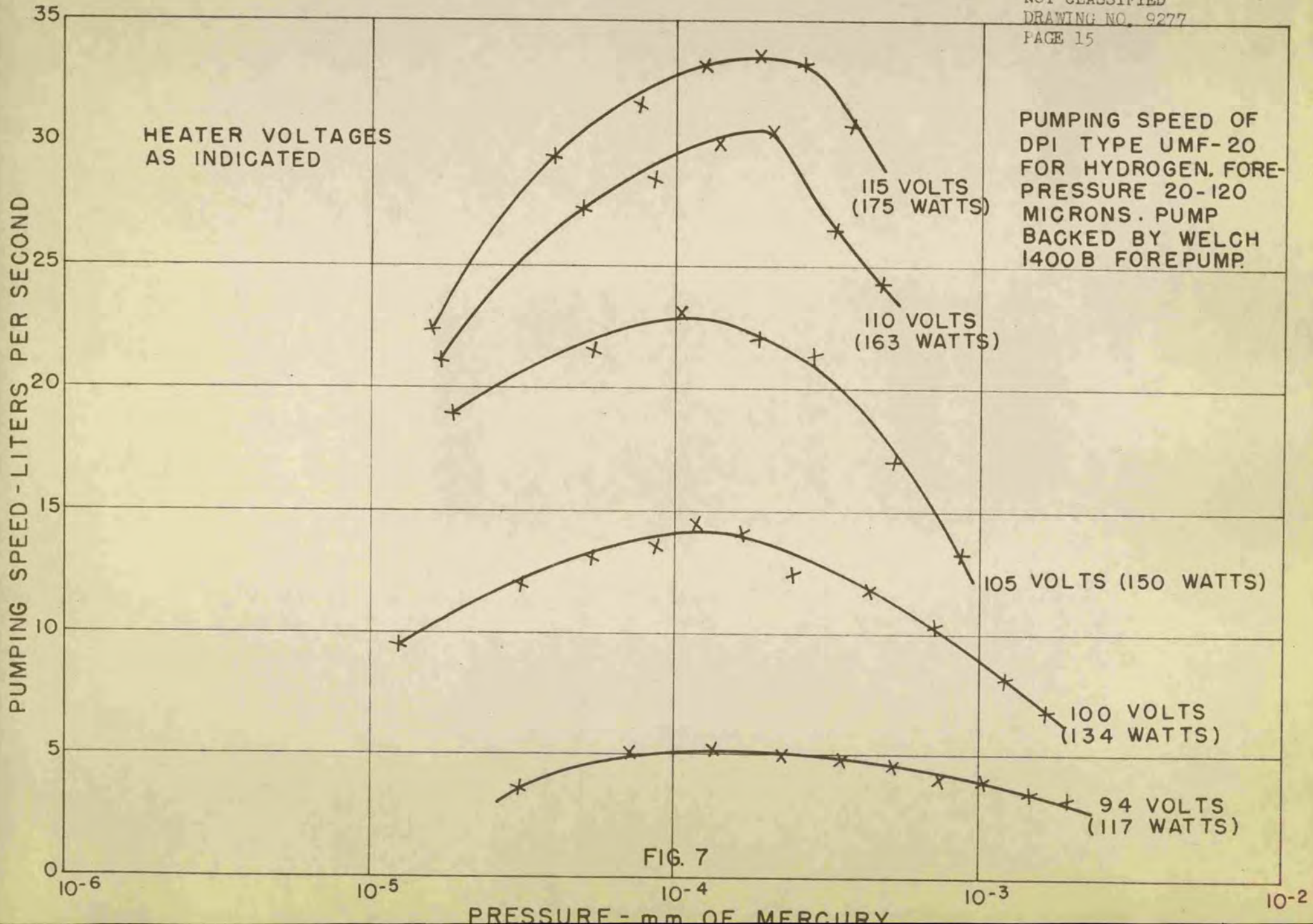

HEATER VOLTAGES
AS INDICATED
PUMPING SPEED OF DPI TYPE UMF-20 FOR HYDROGEN. FORE-PRESSURE 20-120 MICRONS. PUMP BACKED BY WELCH 1400 B FOREPUMP.
115 VOLTS (175 WATTS)
110 VOLTS (163 WATTS)
105 VOLTS (150 WATTS)
100 VOLTS (134 WATTS)
94 VOLTS (117 WATTS)
PUMPING SPEED - LITERS PER SECOND
0
5
10
15
20
25
30
35
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
PRESSURE - mm OF MERCURY

FIG. 7

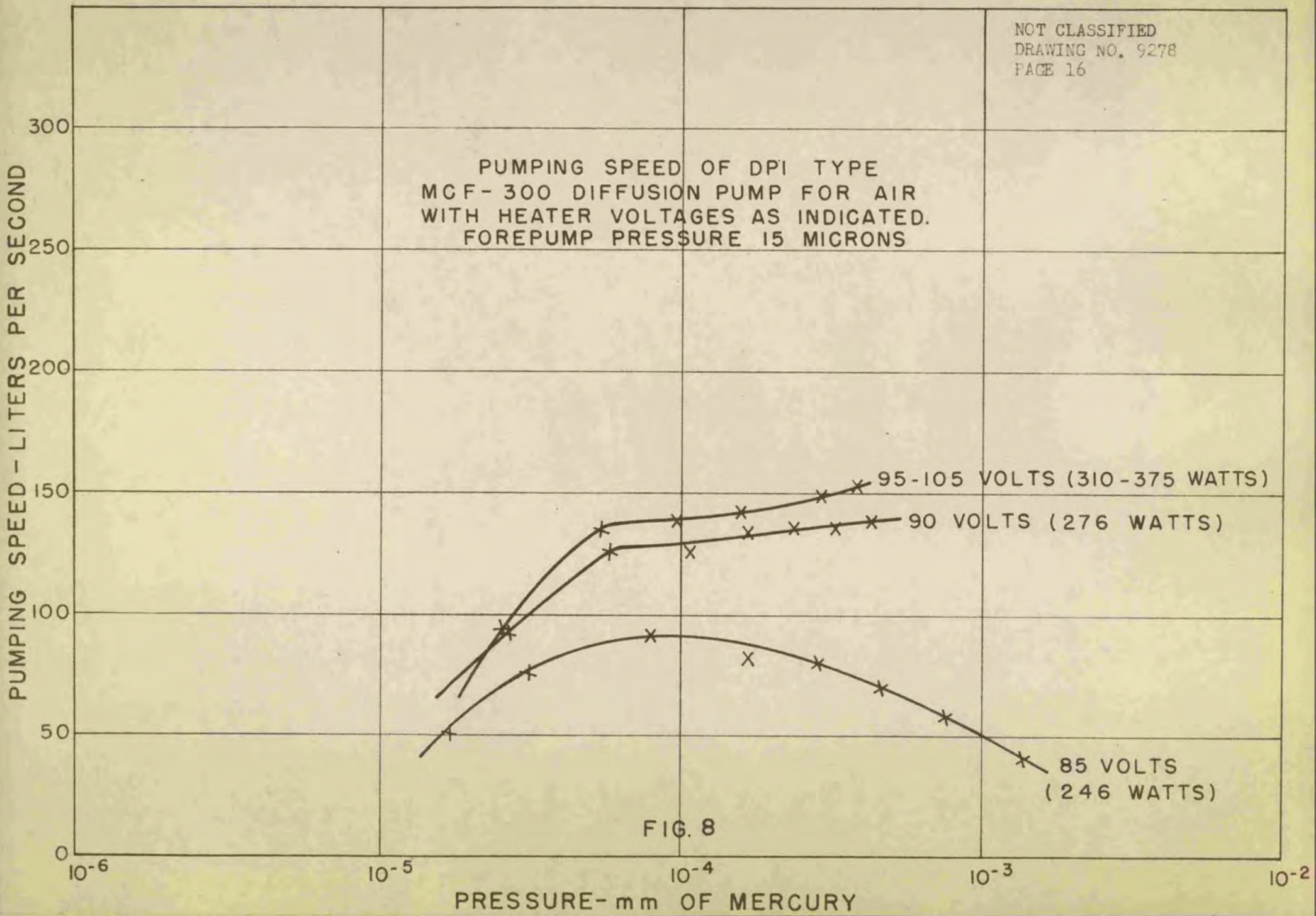

NOT CLASSIFIED
DRAWING NO. 9278
PAGE 16
PUMPING SPEED OF DPI TYPE
MCF-300 DIFFUSION PUMP FOR AIR
WITH HEATER VOLTAGES AS INDICATED.
FOREPUMP PRESSURE 15 MICRONS
95-105 VOLTS (310-375 WATTS)
90 VOLTS (276 WATTS)
85 VOLTS
(246 WATTS)
PUMPING SPEED - LITERS PER SECOND
300
250
200
150
100
50
0
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
PRESSURE - mm OF MERCURY

FIG. 8

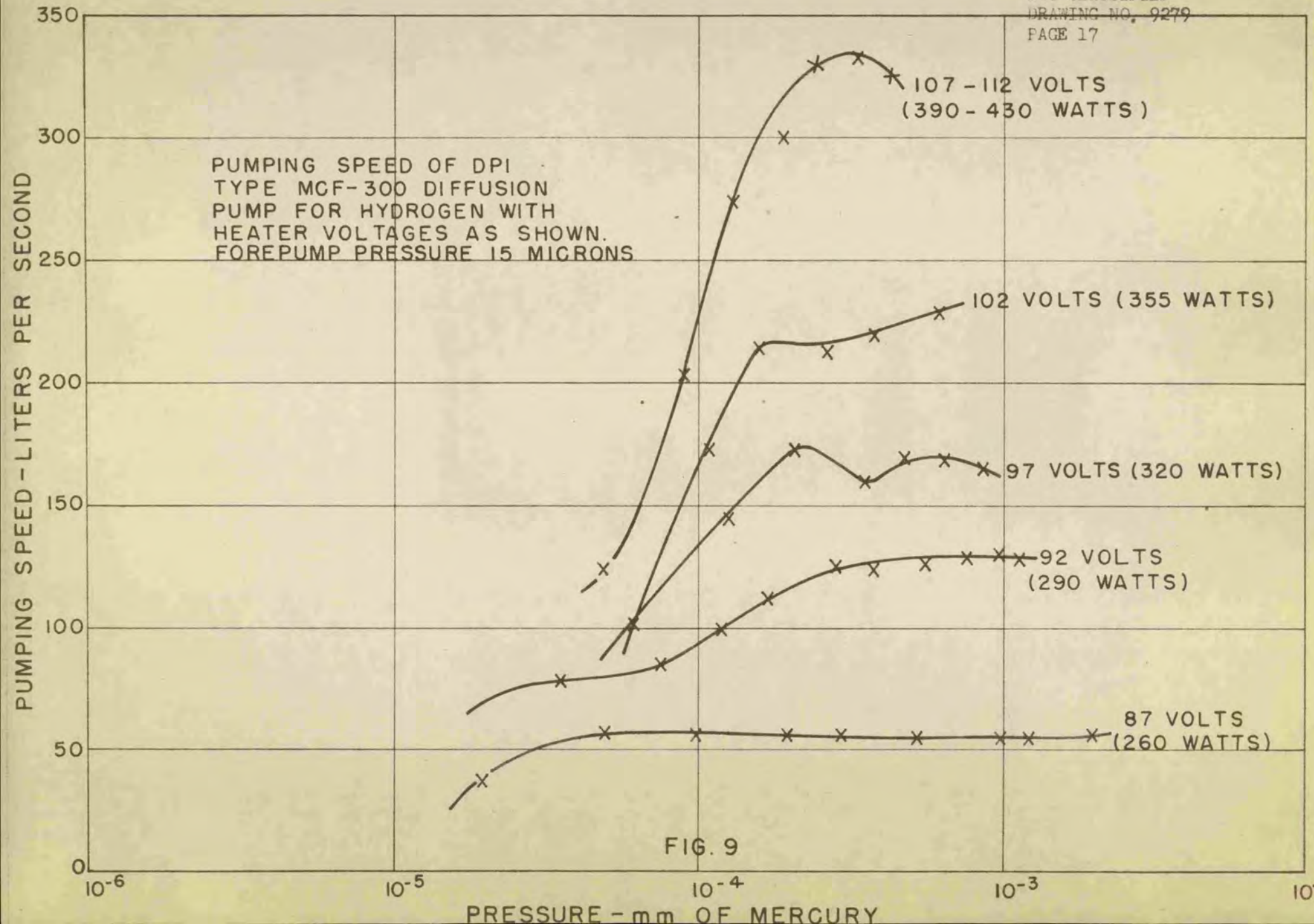

PUMPING SPEED OF DPI
TYPE MCF-300 DIFFUSION
PUMP FOR HYDROGEN WITH
HEATER VOLTAGES AS SHOWN.
FOREPUMP PRESSURE 15 MICRONS
107 - 112 VOLTS
(390 - 430 WATTS)
102 VOLTS (355 WATTS)
97 VOLTS (320 WATTS)
92 VOLTS
(290 WATTS)
87 VOLTS
(260 WATTS)
PUMPING SPEED - LITERS PER SECOND
0
50
100
150
200
250
300
350
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
PRESSURE - mm OF MERCURY

FIG. 9