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TWO-PHASE CHOKED FLOW OF SUBCOOLED OXYGEN AND NITROGEN

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16. Abstract

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SUMMARY

Liquid oxygen and liquid nitrogen data for two-phase critical flow through nozzles have been acquired with precision control. Test results from two converging-diverging nozzles and two separate test facilities are in excellent agreement. The critical flow rate and critical flow pressure ratio data conclusively demonstrate that the principle of corresponding states can be applied to two-phase choked flow through nozzles. Normalizing parameters have been developed to correlate these data, and current theories can provide an adequate means for extrapolating to other fluids.

INTRODUCTION

There is a need for good flow rate information to be incorporated in the design of storage, transfer, and handling equipment used with liquid oxygen. Among the problems are safety and two-phase choked flow. The problems (and information presently available) related to the safe handling of high-pressure oxygen are discussed in the state-of-the-art reports on oxygen technology published by NASA (refs. 1 and 2).

The general field of two-phase choked flow has been well surveyed by Hsu (ref. 3), Henry, Grolmes, and Fauske (ref. 4), and Smith (ref. 5). To the knowledge of the authors, no experiment has ever been reported on two-phase choked flow of liquid oxygen. The approach at Lewis Research Center has been to concentrate on liquid nitrogen with some exploration of other fluids. The choked flow of liquid nitrogen in converging-diverging nozzles has been extensively mapped (refs. 6 and unpublished data by R. J. Simoneau of Lewis). Simoneau also evaluates existing theories for two-phase choked flow in the subcooled region. In addition to the nozzle, other flow geometries have been examined (refs. 7 to 9). Finally, the relation between various fluids was explored (refs. 10 and 11). Hendricks and Simoneau (ref. 10), using nitrogen and methane data, demonstrated that two-phase choked flow rates could be normalized in reduced coordinates by the parameter

$$G^* \equiv \sqrt{\frac{\rho_c P_c}{Z_c}} \tag{1}$$

(Symbols are defined in the following section.)

The rationale for this normalization (ref. 10) is based on the one-dimensional, adiabatic, steady-state, energy equation

$$H_0 - H = \frac{u^2}{2}$$

In terms of the mass flow rate,

$$G^2 = (\rho u)^2 = 2\rho^2(H_0 - H)$$

It has been found (ref. 12) that enthalpy can be successfully normalized by RT_c. Thus, the normalized mass flow rate becomes

$$\frac{G^2}{(G^*)^2} = \frac{2\rho^2(H_0 - H)}{\rho_c^2(RT_c)}$$

Introducing the critical compressibility factor[1]

$$Z_c = \frac{P_c}{\rho_c R T_c}$$

yields

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[1] Other normalization parameters can be developed; e.g., one could apply the Kamerlingh-Onnes formulation of the principle of corresponding states ($P_r Z_c/\rho_r T_r = P_r/\rho_r' T_r$) rather than the van der Waals formulation (ref. 13), where ρ_r' is the ideal reduced density. Secondly, one could argue that normalizing the momentum equation directly gives $G^* = \sqrt{\rho_c P_c}$. The difference is Z_c; since Z_c is 0.294 for oxygen and 0.292 for nitrogen, the data reported herein cannot resolve questions regarding which is the proper parameter or the proper formulation.

$$\frac{G^2}{(G^*)^2} = \frac{2\rho^2(H_0 - H)}{\left(\frac{\rho_c P_c}{Z_c}\right)}$$

It is shown in reference 10 that if the flow rates, normalized by equation (1), were plotted in the reduced coordinates

$$P_r = \frac{P_0}{P_c} \tag{2}$$

$$T_r = \frac{T_0}{T_c} \tag{3}$$

the nitrogen and methane flow rate data would reduce to a single curve. The same was true for the choked flow pressure ratio data P_t/P_0. This result implies that the extensive work done with nitrogen could be extrapolated to oxygen.

The present report gives the results of a two-phase choked flow experiment with subcooled liquid oxygen and nitrogen in converging-diverging nozzles. The experiment was undertaken to demonstrate that the corresponding-states normalization, equation (1), is applicable to oxygen and to provide actual oxygen data to guide the designer. The work was performed at the NASA Lewis Research Center Plum Brook Station. It covered a range of inlet flow parameters from below to above the thermodynamic critical conditions for both oxygen and nitrogen. A special feature of this test facility and this experiment is that it was possible to obtain a high level of control on the flow parameters. Thus, the comparisons between oxygen and nitrogen in reduced coordinates can be made with considerable precision.

SYMBOLS

A	area, cm^2
d	diameter, cm
G	mass flow rate, $g/(cm^2)(sec)$
G*	mass flow rate normalizing parameter, $\sqrt{\frac{\rho_c P_c}{Z_c}}$, $g/(cm^2)(sec)$

H	enthalpy, J/g
l	length, cm
P	pressure, N/cm^2
R	gas constant, J/(g)(K)
r	radius, cm
S	entropy, J/(g)(K)
T	temperature, K
u	velocity, cm/sec
x	axial distance, cm
Z	compressibility factor, $Z = P/\rho RT$
ρ	density, g/cm^3
ρ_r'	ideal reduced density

Subscripts:

c	thermodynamic critical conditions
max	maximum or choked flow conditions
r	reduced parameters (P/P_c, etc.)
sat	saturation conditions
t	throat conditions
0	stagnation conditions
1, . . . , 9	pressure tap stations (tables I and II)

EXPERIMENTAL APPARATUS

Test Facility

Figure 1 is a schematic of the system devised for this experiment. All parts and components used were initially screened for material compatibility with the more demanding safety requirements for liquid oxygen, high-pressure gaseous oxygen, and cryogenic temperature operation. All parts, except the test sections, were cleaned for liquid oxygen service by using the standard Plum Brook procedure RDL-003 (ref. 14) and assembled under clean-room and/or continuous inert gaseous purge conditions to eliminate contamination. The test sections (nozzles) were treated separately because the authors did not wish to change the surface characteristics of these nozzles by using the nitric acid cleaning step. Also the elliptic nozzle contained some welds that were not the full-penetration welds that are standard for oxygen service. Since the test sections could not be cleaned to the normal stringent standards, a blast shield was placed around the test section to protect other components. This step and the normal oxygen operating procedure of running remotely with no personnel within 300 meters were considered adequate safety precautions for this test. All nonstandard components, except those connecting the 15.1-m^3, 35-N/cm^2 (4000-gal, 50-psig) supply dewar to the high-pressure-run tank, were pressure tested to 1.5 times the maximum anticipated operating pressure of 1040 N/cm^2 (1500 psig).

Approximately 10.2 cm (4 in.) of Foamglas insulation covered the high-pressure-run tank and test nozzle section; and 5.1 cm (2 in.) of the same material covered the flow line components. This insulation minimized heat leakage into the flowing fluid during test runs. The axial dip tube, reaching nearly to the bottom of the high-pressure-run tank, was used to bubble warm gas up through the fluid in the tank when a controlled increase in temperature was required. An antiswirl baffle at the exit port in the bottom of the tank prevented entrainment of warming or pressurizing gas during flow test runs.

The tank pressurization and vent system control valves were interlocked and slaved to a tank pressure sensor. Ten-turn trim-potentiometer-type remote controls permitted vernier positioning of these pneumatically (dry nitrogen) operated valves in selecting and holding the tank pressure to within 0.3 N/cm^2 of the chosen level.

Each of the 0.76-cm (0.3-in.) throat diameter, venturi-type flowmeters in the 1.91-cm flow line was located approximately 40 inlet diameters downstream from the nearest flow path disturbance. A cylindrical, perforated, baffle-type mixing chamber (fig. 2) fitted with a platinum resistor temperature probe was mounted in-line between the flowmeters.

The hydraulically operated inlet flow control valve was slaved to the test nozzle inlet pressure. A ramp-change-type controller allowed fine adjustment of test nozzle inlet flow rate. None of the hydraulic components were exposed to oxygen; however, since they were in the vicinity of oxygen flow lines, the hydraulic operators were placed behind the blast shield mentioned previously.

The backpressure control valve was varied as required to verify choked flow conditions at the test nozzle throat during flow tests.

These built-in provisions for accurately controlling temperature and pressure permitted rather simple test procedures: The tank was loaded with liquid oxygen and then pressurized to the approximate operating pressure. Gaseous oxygen was bubbled through the liquid oxygen to preheat it to the desired temperature while permitting a small flow through the backpressure valve. The backpressure valve was then opened. The system pressure was adjusted to maintain the desired operating conditions, and a data point was taken under stabilized conditions. The system pressure was then decreased (or increased) and a second data point taken, etc. It was also possible to maintain or adjust the desired temperature by bubbling ambient gas through the liquid oxygen at any fixed pressure while the gas was flowing. This made obtaining data points along selected isotherms quite precise. It was during this procedure that the baffle plate at the bottom of the tank prevented the gas from entraining directly into the flow stream.

Test Sections

The test sections for this experiment were two axisymmetric converging-diverging nozzles. They are shown in cross section in figures 3 and 4. The pertinent dimensions are given in table I and II. Both test sections were preceded by a plenum chamber that took the directionality out of the flow in a manner similar to that shown in figure 2. The stagnation temperature was measured in this chamber.

The test section illustrated in figure 3 had a truncated cone of nominally 7° half-angle convergence and a cone of nominally $3\frac{1}{2}^{\circ}$ half-angle divergence. The throat region had a constant-area section 3.2 diameters in length. The transition from the converging cone to the constant-area throat section was smoothed with a radius of curvature of approximately 10 times the throat radius. The transition from the constant-area throat section to the diverging cone was a sharp corner. This sharp corner was designated the throat. The test section was heavily instrumented with pressure taps near the throat. The interior surface had a 16-rms finish, and care was taken to deburr the pressure taps. Only nine pressure taps could be connected in this experiment. The pressure taps used are noted in table I. This test section was also used in unpublished experiments by R. J. Simoneau of Lewis.

The test section illustrated in figure 4 was a conventional venturi flowmeter and was designed according to the ASME long-radius flow nozzle guidelines (ref. 15). Pressure taps were subsequently installed as illustrated, and the test section was used in the experiments of references 6, 10, and 11. The converging section had a 2:1 elliptical curvature that transitioned smoothly into a constant-area section 2.1 diameters in length. The transition from the constant-area throat section to the 4.0° half-angle divergence cone was a sharp corner. This sharp corner was designated the throat. Table II gives two values for overall length. The smaller value, 6.80 cm, is the distance from the beginning of the elliptical converging section to the end of the 4.0° diverging section. The larger number is the distance from the inlet plenum to the beginning of the downstream straight section. The smaller dimension is probably more relevant, since this is really the nozzle shape under consideration. This nozzle was not as heavily instrumented in the throat region as indicated in table II. The convergence rate of the elliptical nozzle was substantially greater. Taking the beginning of the ellipse as a reference, the area ratio was 14.3 and the nozzle converged to the beginning of the constant-area throat region in 0.751 cm. For the conical nozzle, the convergence from an area ratio of 14.3 to the beginning of the throat region required a distance of 4.14 cm.

INSTRUMENTATION AND DATA ACQUISITION

Strain-gage pressure transducers were used to measure tank pressure, flow venturi differential pressure, test nozzle pressure, and barometric pressure. Normal accuracy range for this class of strain-gage pressure transducers is ±0.5 percent error. Before each days run the system was statically pressurized to the operating pressure, and all transducers were zero adjusted to eliminate deviations from the mean reading. This increased the precision between transducers to within an error of ±0.25 percent.

Platinum resistance sensors were used to measure tank, flow venturi inlet, and test nozzle plenum chamber temperatures. The four tank sensors were also used to indicate liquid level. The accuracy of these sensors was within ±0.1 percent error, and total system accuracy was within an error of ±0.2 percent. The temperature drift rate at constant pressure was about 0.001 K/sec. The pressure drift was negligible.

The analog signals were fed to a data collection system (fig. 5) where they were multiplexed, digitized, and recorded on magnetic tape. Digital data were also fed to a local computer for on-line conversion to engineering units and display on a cathode-ray-tube (CRT) screen with 1-second updating in the test control console. This on-line, real-time, updated and reduced data display helped to make the control on the experiment so precise. It was possible to monitor the CRT until the exact desired stagnation temperature condition was attained and then to record data on the high-speed data acquisition system.

All thermophysical properties used for data reduction were taken from reference 16, a versatile and accurate computer program.

RESULTS

A major result of this experiment is the acquisition of two-phase choked flow data in subcooled liquid oxygen. To the knowledge of the authors, these are the only two-phase choked flow data for liquid oxygen in existence. A second result was the acquisition of both liquid nitrogen and liquid oxygen data along the same reduced isotherms by using the same test sections in the same facility. In an earlier work (ref. 10), which established the validity of a flow-normalizing parameter, it was not possible to duplicate isotherms as accurately as in the present experiment.

The experiment covered a range in stagnation temperature isotherms from 0.61 to 1.67 times the thermodynamic critical temperature. The stagnation pressure ranged from near saturation to within twice the thermodynamic critical pressure. For oxygen this means pressures as high as 1000 N/cm^2. The data isotherms covered are summarized in table III. The data are all summarized in tables IV to VII.

Selected data isotherms from the tables for choked flow rates and pressure ratios of oxygen and nitrogen are shown in figure 6. They are all taken from the data for the conical nozzle. In general, only those data points that fall within $\pm 0.002\ T_c$ along a given isotherm were used, even though the tables may contain more points. This means that all the data shown in figure 6 agree along a given isotherm to within ±0.3 K. An examination of figure 6 shows that, in reduced coordinates, oxygen and nitrogen two-phase choked flow data fall exactly on top of each other. A careful examination of this figure shows this correspondence to be true even in the areas where there is anomalous behavior that may be due to the particular nozzle geometry, for example, in the low-pressure region of $T_r = 0.866$ (figs. 6(b) and (f)). The use of G^*, equation (1), as a normalizing parameter to relate nitrogen and oxygen choked flow data seems clearly established. The reducing parameters used herein are given in table VIII.

There are a couple of data points in figure 6 that stand out as not following the data trend. For instance, in figure 6(e) at $T_r = 0.749$ and $P_r = 1.76$, the pressure ratio is about 50 percent above the data trend. There is no evidence in the data record of anything amiss, nor is this random scatter. It is probably some metastable anomaly in the flow. It did not repeat or persist. On the other hand, the 7 percent blip in the pressure ratio data in figure 6(h) at $T_r = 1.025$ and $P_r = 0.95$ seems to be phenomologically related to nonequilibrium nozzle dynamics. It was reproduced in another reading and was also noticed on the CRT display during oxygen runs but was not recorded on data tape.

The data taken in separate test sections with oxygen are compared in figures 7(a) and (b). The choked flow rates (fig. 7(a)) in the two nozzles for the same conditions are virtually identical. The flow rates may average 1 to 2 percent higher for the elliptical nozzle than for the conical nozzle, which is consistent since the mean temperature of the elliptical nozzle data is slightly lower. However, this is all within the error level of the experiment. In the case of the pressure ratio (fig. 7(b)), however, the conical nozzle data are about 15 percent above the elliptical nozzle data. (The reader should not be misled by the scale of the figure. The difference is a pretty steady 15 percent over the entire stagnation pressure range.) This may be due to differences in the location of the "throat" pressure tap or to differences in the nozzle contours. The whole question of the sensitivity of pressure ratio measurements is explored in detail by R. J. Simoneau of Lewis (private communication). For this report it is adequate to point out that attempts to compare choked flow data with theory are destined to yield wide variations in pressure ratio results. In any case, the excellent agreement in flow rates between the two nozzles gives considerable confidence in the accuracy of the experimental measurements.

Finally in figures 8(a) and (b), the data taken with nitrogen in the conical nozzle at the Plum Brook Station are compared with unpublished data taken under the same circumstances in the Lewis Research Center facility by Simoneau. In this case fluid nitrogen data from the same nozzle were compared in two entirely separate experimental test facilities. The results are in good agreement. The present flow rate data are about 1 to 3 percent below the data of Simoneau. The pressure ratios are virtually identical. Not only does this comparison provide confidence in the test results, it also demonstrates that the anomalies observed are in no way related to the test facility or procedure.

CONCLUSIONS

An experiment has been conducted in which two-phase choked flow of liquid oxygen and liquid nitrogen was measured. The tests on both fluids were conducted in the same facility under the same reduced operating conditions and in the same test nozzles. Two converging-diverging nozzles having different contours were used. The experiment was conducted to obtain liquid oxygen data and to examine the validity of the use of corresponding-states parameters in two-phase choked flow of subcooled oxygen.

The result of the experiment is a tabulation of extensive two-phase choked flow data for oxygen and nitrogen covering a range of stagnation parameters:

$$0.61 \leq T_0/T_c \leq 1.67$$

$$P_{sat}/P_c < P_0/P_c \leq 2.0$$

where T_0 is the stagnation temperature, T_c is the thermodynamic critical temperature, P_{sat} is the saturation temperature, P_c is the thermodynamic critical pressure, and P_0 is the stagnation pressure.

From these data it can be concluded that the two-phase choked flow rates and pressure ratios of subcooled oxygen and nitrogen can be normalized in a corresponding-states manner. The flow rate data were correlated by using the normalizing parameter

$$G^* = \sqrt{\frac{\rho_c P_c}{Z_c}}$$

where ρ_c is the thermodynamic critical density and Z_c is the critical compressibility factor.

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TABLE I. - CONICAL CONVERGING-DIVERGING NOZZLE

(a) Dimensions

Overall length, cm	31.1
Throat diameter, cm	0.3555±0.0007
Throat area, cm^2	0.09926
Length of constant-area section, cm	1.135±0.020
Length-diameter ratio, l/d	3.20
Radius of curvature, cm	1.77
Pressure tap diameter, cm	0.051
Convergence half-angle, deg	6.79±0.05
Divergence half-angle, deg	3.78±0.23

(b) Tap locations (referenced to throat)

Station	Tap	Axial distance, x, cm	Radius, r, cm	Ratio of area to throat area, A/A_t
1	0	-9.12	-----	[b]∞
	[a]1	-5.062	0.645	13.18
	[a]2	-3.066	.408	5.26
	[a]3	-2.263	.312	3.08
2	4	-1.984	.279	2.46
3	5	-1.692	.244	1.88
4	6	-1.052	.178	1.00
5	7	-.536	.178	1.00
6	8	-.185	.178	1.00
7	9	.112	.185	1.08
8	10	.455	.208	1.37
	[a]11	.940	.240	1.82
	[a]12	1.933	.306	2.95
	[a]13	7.943	.703	15.61
9	14	12.939	1.033	33.73
	[a]15	17.943	1.363	58.79
	[a]B	22.0	-----	[c]∞

[a] Not connected for this experiment.

[b] Inlet plenum.

[c] Outlet plenum.

TABLE II. - ELLIPTICAL CONVERGING-DIVERGING NOZZLE

(a) Dimensions

Overall length, cm	6.80 (11.30)
Throat diameter, cm	0.2934±0.0007
Throat area, cm^2	0.06760
Length of constant-area section, cm	0.617±0.010
Length-diameter ratio, l/d	2.10
Curvature (2:1 ellipse)	
r_1	0.78
r_2	0.39
Pressure tap diameter, cm	0.080
Converging taper (half-angle), deg	10.1
Divergence half-angle, deg	4.00
Diverging taper (half-angle), deg	10.0
Diameter of straight (constant-area) section, cm	0.808

(b) Tap locations (referenced to throat)

Station (tap)	Axial distance, x, cm	Radius, r, cm	Ratio of area to throat area, A/A_t
[a]0	-4.605	-----	[b]∞
1	-2.390	0.747	25.82
2	-1.115	.274	3.47
3	-.747	.164	1.25
4	-.297	.147	1.00
5	-.150	.147	1.00
6	.373	.216	2.16
7	1.430	.290	3.89
8	3.942	.467	10.09
9	6.452	.721	24.06

[a] Not connected for this experiment.

[b] Inlet plenum.

TABLE III. - SUMMARY OF DATA ISOTHERMS

Conical-convergence nozzle				Elliptical-convergence nozzle			
Oxygen		Nitrogen		Oxygen		Nitrogen	
Reduced temperature, T_r	Table	Reduced temperature, T_r	Table	Reduced temperature, T_r	Table	Reduced temperature, T_r	Table
				0.611	VI(a)		
				.628	VI(b)		
						0.645	VII(a)
0.750	IV(a)	0.749	V(a)	.749	VI(c)		
				.810	VI(d)		
				.854	VI(e)		
.866	IV(b)	.868	V(b)				
				.885	VI(f)		
.942	IV(c)	.942	V(c)				
				.952	VI(g)		
1.026	IV(d)	1.025	V(d)				
				1.031	VI(h)	1.031	VII(b)
1.10	IV(e)	1.10	V(e)				
1.20	IV(f)						
1.30	IV(g)						
1.35	IV(h)						
				1.51	VI(i)		
				1.67	VI(j)		

TABLE IV. - CONICAL NOZZLE DATA FOR OXYGEN

(a) Reduced temperature, 0.750

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, g/(cm^2)(sec)	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
549	0.746	0.224	115.4	114	104	98	70	64	59	45	37	26	0.514	2 700	0.311	76.9	77.5
550	.746	.359	115.5	183	160	145	78	73	73	57	46	30	.400	4 270	.493	76.2	78.1
551	.749	.293	115.9	149	133	123	77	74	70	53	41	28	.469	3 500	.404	78.7	80.1
552	.749	.429	115.9	218	189	168	80	73	75	60	49	32	.345	4 900	.565	77.4	80.1
553	.750	.495	116.1	251	217	190	82	72	76	61	51	36	.303	5 450	.629	77.5	80.8
554	.752	.564	116.4	287	246	214	85	73	78	63	53	38	.273	5 950	.686	78.5	82.6
576	.751	1.46	114.8	744	618	518	101	62	68	59	51	28	.092	10 920	1.26	63.8	74.4
577	.742	1.38	114.9	701	583	489	99	63	68	59	51	51	.098	10 570	1.22	64.8	75.0
578	.744	1.24	115.2	632	527	443	96	64	70	60	52	53	.111	9 960	1.15	67.2	76.4
579	.746	1.10	115.4	561	469	396	94	65	71	61	53	52	.128	9 320	1.07	69.1	77.5
580	.747	.971	115.6	493	413	350	91	66	73	62	53	50	.147	8 650	.998	70.8	78.2
581	.747	.836	115.7	425	357	305	89	67	74	62	54	49	.173	7 930	.915	72.7	79.0
582	.749	.701	115.9	356	302	260	86	69	75	62	53	45	.209	7 140	.823	74.7	79.8
583	.750	.563	116.1	286	244	214	83	71	75	61	52	38	.263	6 230	.718	76.9	80.8
584	.751	.428	116.3	217	188	168	81	73	76	60	50	33	.348	5 170	.596	79.0	81.7
585	.752	.292	116.5	149	133	123	79	75	69	53	41	28	.467	3 820	.440	81.6	82.8
586	.754	.223	116.8	113	103	97	67	61	55	42	34	24	.485	3 190	.368	83.7	84.2
587	.736	1.76	113.9	895	743	619	106	59	65	55	48	21	.072	12 000	1.38	58.5	70.4
588	.749	.562	115.9	286	245	214	82	70	75	61	51	42	.261	6 040	.696	76.0	80.0
589	.751	.700	116.3	356	302	261	86	70	77	64	54	45	.215	6 930	.799	76.5	81.8
590	.750	.767	116.1	390	330	283	88	69	75	63	54	48	.193	7 350	.848	74.9	80.7
591	.749	.836	116.0	425	358	306	89	68	75	63	53	49	.176	7 750	.894	73.7	80.1
592	.748	.904	115.8	459	387	329	91	67	74	63	54	50	.160	8 140	.939	72.5	79.5
593	.755	.971	116.9	493	416	353	95	71	78	66	56	54	.158	8 420	.971	76.9	84.9
594	.754	1.04	116.7	527	443	376	97	70	77	66	56	54	.146	8 770	1.01	75.4	83.8
595	.753	1.11	116.6	562	471	399	99	69	76	65	56	54	.136	9 090	1.05	74.5	83.5
596	.752	1.17	116.5	596	499	422	100	69	76	65	55	55	.128	9 420	1.09	73.3	82.8
597	.752	1.24	116.5	629	527	444	101	68	76	65	↓	55	.120	9 730	1.12	72.7	82.7
598	.752	1.31	116.3	666	557	469	103	68	75	64	↓	56	.112	10 050	1.16	71.5	82.1
599	.751	1.38	116.3	700	584	491	105	67	74	64	↓	↓	.106	10 340	1.19	70.7	81.8
600	.751	1.44	116.2	733	611	514	106	67	74	64	54	↓	.100	10 640	1.23	69.9	81.4
601	.750	1.52	116.1	770	641	538	108	64	73	63	54	↓	.095	10 920	1.26	69.1	81.1
602	.750	1.58	116.1	803	669	560	109	66	73	63	54	55	.091	11 160	1.29	68.4	80.8
603	.750	1.65	116.0	837	698	583	111	↓	73	63	53	55	.087	11 450	1.32	67.7	80.6
604	.749	1.71	115.9	871	726	606	112	↓	72	62	↓	26	.083	11 710	1.35	66.8	80.1
605	.749	1.79	115.9	907	755	630	114	↓	72	62	↓	25	.079	11 960	1.38	66.2	80.0
606	.748	1.85	115.9	940	783	653	116	65	71	62	↓	23	.076	12 210	1.41	65.6	79.7

(b) Reduced temperature, 0.866

555	0.865	1.91	133.8	973	829	711	217	162	176	143	111	100	0.181	10 960	1.26	168.4	210.7
556	.864	1.79	133.8	907	774	667	214	163	177	143	110	97	.195	10 500	1.21	170.7	210.2
557	.867	1.65	134.3	838	717	621	214	169	182	146	111	95	.217	9 930	1.14	177.5	215.0
558	.867	1.51	134.1	768	659	574	211	171	182	145	110	92	.237	9 380	1.08	179.8	213.7
559	.866	1.38	134.1	700	604	528	207	172	182	143	108	86	.260	8 820	1.02	182.7	213.2
560	.866	1.24	134.0	630	547	482	205	175	183	142	106	82	.290	8 160	.941	185.5	212.4
561	.867	1.11	134.2	562	491	437	204	180	184	140	104	78	.328	7 480	.863	190.6	214.0
562	.865	.969	134.0	492	433	389	200	181	183	136	98	71	.372	6 740	.777	192.8	211.9
563	.866	.904	134.1	459	407	367	200	184	182	133	96	68	.395	6 340	.730	196.2	213.5
564	.867	.836	134.2	425	379	345	200	185	178	128	91	65	.418	5 910	.681	199.1	214.2
565	.867	.765	134.1	389	349	321	196	180	166	119	83	61	.427	5 460	.630	200.9	213.7
566	.866	.697	↓	354	320	294	183	166	148	105	73	57	.418	5 100	.588	203.4	213.2
567	.867	.698	↓	355	320	295	184	166	149	104	73	56	.419	5 110	.589	203.8	213.7
568	.866	.631	↓	321	288	264	156	140	128	91	65	55	.400	4 950	.571	205.3	212.9
569	↓	.562	↓	286	257	236	136	125	116	85	63	54	.406	4 620	.533	207.9	213.2
570	↓	.496	↓	252	228	211	125	113	104	75	58	49	.411	4 180	.482	210.0	212.9
571	↓	.426	134.0	216	200	191	136	125	114	89	76	42	.529	3 300	.380	212.5	212.7

TABLE IV. - Continued

(c) Reduced temperature, 0.942

Reading	Reduced temper-ature, T_r	Reduced pres-sure, P_r	Stagnation tempera-ture, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, $g/(cm^2)(sec)$	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation tempera-ture, T_0
607	0.940	1.77	145.6	900	790	699	308	265	275	207	142	108	0.305	9 210	1.06	279.2	353.0
608	.940	1.71	145.5	869	764	678	307	266	274	205	140	105	.315	8 970	1.03	280.5	351.2
609	.939	1.62	145.4	824	727	647	305	269	275	204	138	100	.334	8 610	.992	283.5	349.7
669	.942	1.92	145.9	975	851	750	312	263	276	211	145	113	.283	9 750	1.12	276.0	357.5
670	.941	1.85	145.7	942	822	726	309	263	276	209	144	110	.293	9 500	1.10	277.2	355.3
671	.943	1.79	146.0	908	795	704	311	268	278	209	143	106	.306	9 220	1.06	282.6	358.6
672	.941	1.72	145.7	872	765	679	308	267	277	207	141	105	.318	8 970	1.03	282.7	354.5
673	.944	1.65	146.1	838	738	657	310	274	282	207	140	100	.336	8 640	.996	290.4	360.5
674	.941	1.58	145.7	804	709	633	307	273	280	204	138	97	.348	8 390	.967	289.7	355.3
675	.942	1.51	145.8	769	680	610	308	277	281	201	135	95	.366	8 050	.928	294.3	356.7
676	.941	1.44	145.7	734	651	586	307	278	279	197	132	91	.381	7 750	.893	296.8	355.3
677	.942	1.38	145.8	700	623	564	307	280	277	192	130	87	.395	7 410	.855	300.8	355.6
678	.941	1.31	145.7	666	595	541	306	281	271	187	138	84	.407	7 080	.816	304.4	355.3
679	.942	1.24	145.9	630	566	517	304	279	259	178	156	80	.410	6 720	.774	310.4	357.1
680	.942	1.17	145.8	596	537	492	295	268	242	167	165	78	.406	6 420	.740	313.8	356.0
681	.942	1.11	145.8	563	507	466	280	252	225	167	175	75	.400	6 170	.711	318.3	356.0
682	.941	1.04	145.7	528	476	438	262	235	211	180	185	72	.399	5 920	.683	322.6	355.3
683	.941	.973	145.7	494	447	412	249	227	207	192	196	69	.420	5 670	.654	327.9	355.3
684	.942	.903	145.8	459	417	386	247	230	217	210	212	65	.474	5 260	.606	335.4	356.7
685	.942	.836	145.8	425	389	365	249	238	230	225	225	60	.541	4 760	.549	341.9	356.7
686	.942	.766	145.8	389	362	343	253	247	243	238	236	53	.623	4 180	.482	348.9	356.4
683	.944	.723	146.1	367	347	334	271	266	264	260	241	45	.718	3 500	.404	359.9	361.2

(d) Reduced temperature, 1.026

Reading	Reduced temper-ature, T_r	Reduced pres-sure, P_r	Stagnation tempera-ture, T_0	1	2	3	4	5	6	7	8	9	P_t/P_0	G_{max}	G_r	S_0	T_0
610	1.033	1.91	159.9	972	880	805	460	417	418	382	349	102	0.430	7 630	0.880	434.5	(a)
611	1.031	1.85	159.6	941	854	783	458	419	419	385	347	100	.445	7 400	.853	435.8	↓
612	1.029	1.79	159.2	908	826	760	456	420	419	388	345	97	.461	7 140	.823	437.4	↓
613	1.026	1.71	158.8	870	794	733	454	421	419	391	341	94	.482	6 840	.789	439.5	↓
614	1.025	1.65	158.6	837	766	711	454	424	420	396	336	91	.502	6 540	.754	443.0	↓
615	1.027	1.59	159.1	807	743	694	463	437	434	409	328	86	.539	6 150	.710	453.7	↓
616	1.026	1.51	158.8	770	713	669	466	443	442	415	317	81	.574	5 730	.661	459.2	↓
617	↓	1.45	158.9	735	685	648	473	453	454	422	302	76	.617	5 260	.606	467.7	↓
618	↓	1.38	158.9	700	658	626	481	465	467	419	280	70	.667	4 740	.546	477.2	↓
619	↓	1.31	158.8	668	633	607	488	475	478	380	254	63	.716	4 230	.488	486.0	↓
620	↓	1.25	↓	634	606	586	477	426	413	323	220	57	.651	3 660	.422	498.1	↓
621	↓	1.18	↓	600	576	559	419	387	368	279	189	50	.614	3 100	.357	506.4	↓
622	↓	1.12	↓	568	544	529	396	368	349	258	168	45	.615	2 570	.297	-----	↓
623	↓	1.04	158.9	529	505	488	362	336	320	234	151	39	.605	2 250	.259	430.9	↓
624	1.025	.977	158.7	497	472	455	347	325	301	217	141	35	.605	2 070	.239	383.1	↓
625	1.025	.905	158.6	460	436	418	298	280	279	211	135	32	.608	1 900	.219	327.8	↓
626	1.026	.838	158.7	426	402	386	262	241	230	192	124	30	.541	1 730	.200	276.6	↓
627	1.027	.771	159.0	392	370	355	240	220	209	167	109	28	.532	1 600	.184	230.5	↓
628	1.026	.704	158.7	358	338	324	218	201	190	137	97	25	.530	1 470	.169	196.3	↓
629	1.025	.638	158.7	324	306	293	197	182	172	123	85	23	.530	1 330	.153	160.0	↓
630	1.026	570	158.8	290	273	262	176	162	153	110	68	21	.527	1 200	.138	126.4	↓
631	1.029	.573	159.3	291	275	263	176	164	153	110	67	21	.526	1 160	.133	125.4	↓
632	1.026	.502	158.9	255	240	230	154	143	134	95	56	19	.524	1 030	.119	97.9	↓
633	1.026	.429	158.8	218	205	197	131	122	113	81	48	17	.520	910	.104	72.0	↓
634	1.027	.360	158.9	183	172	165	110	102	95	68	40	16	.517	790	.092	51.5	↓
635	1.026	.291	158.8	148	138	132	89	83	77	55	32	14	.518	680	.078	34.8	↓

(e) Reduced temperature, 1.10

Reading	Reduced temper-ature, T_r	Reduced pres-sure, P_r	Stagnation tempera-ture, T_0	1	2	3	4	5	6	7	8	9	P_t/P_0	G_{max}	G_r	S_0	T_0
706	1.10	1.40	169.8	710	672	642	461	437	436	355	229	55	0.614	3 200	0.368	452.6	(a)
707	1.09	1.31	169.1	665	629	602	427	402	399	324	208	50	.600	2 920	.337	423.5	↓
708	1.10	1.24	169.6	632	597	570	391	363	352	296	193	45	.557	2 690	.310	382.6	↓
709	↓	1.17	169.9	596	564	539	363	333	314	267	176	41	.527	2 460	.284	341.5	↓
710	↓	1.11	169.6	562	532	508	343	314	295	242	160	39	.524	2 300	.265	307.7	↓
711	↓	1.04	169.9	529	500	478	323	296	277	214	145	37	.524	2 160	.249	-----	↓
712	↓	.966	169 9	491	463	444	300	275	258	182	131	35	.526	2 000	.230	231.7	↓
713	1.09	.904	169.4	459	434	415	281	259	242	170	121	33	.526	1 890	.218	206.1	↓
714	1.10	.837	169.7	425	402	385	261	240	223	157	109	30	.526	1 750	.201	176.8	↓
715	1.09	.769	169.4	391	369	354	241	220	206	144	93	27	.527	1 580	.182	151.0	↓
716	1.10	.702	170.2	357	337	323	219	202	188	131	79	25	.526	1 420	.163	121.6	↓
717	↓	.631	169.9	321	303	290	198	181	169	119	71	23	.528	1 280	.148	99.3	↓
718	↓	.567	169.7	288	272	261	177	162	152	106	64	21	.526	1 160	.134	81.0	↓
719	↓	.496	169.9	252	237	228	155	142	132	93	55	19	.526	1 040	.120	61.8	↓
720	↓	.430	169.9	218	205	197	134	123	114	80	48	17	.524	920	.106	46.9	↓
721	↓	.360	169.7	183	172	165	112	102	96	67	40	15	.523	770	.089	34.1	↓
722	↓	.291	169.7	148	139	133	90	83	77	54	32	14	.521	660	.077	23.4	↓
723	↓	.226	169.7	115	107	103	70	64	60	42	25	12	.518	580	.066	15.4	↓

[a] Not applicable.

TABLE IV. - Concluded

(f) Reduced temperature, 1 20

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, g/(cm^2)(sec)	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
636	1.22	1.23	188.9	625	592	565	376	347	327	235	139	45	0.528	2 180	0 251	187.3	(a)
637	1.21	1.17	187.4	596	564	538	358	332	312	223	132	43	.524	2 070	.239	179.1	↓
638	1.20	1.11	185.6	563	533	509	339	313	295	212	125	40	.524	1 960	.226	170 6	
639	↓	1.06	186.3	540	511	488	325	301	283	203	120	38	.525	1 870	.215	153.0	
640		.972	185.5	494	467	446	297	275	260	185	110	35	.527	1 690	.195	131.4	
641		.841	185.9	427	403	385	258	237	225	160	95	30	.526	1 430	.165	97.0	
642		.762	185.9	387	366	350	233	215	204	145	85	28	↓	1 290	.149	79.8	
643		.696	186.2	354	334	320	213	197	186	132	78	25		1 170	.135	66.1	
644		.633	185.6	322	303	290	194	179	169	120	71	23		1 080	.124	55.9	
645		.564	186.0	287	271	259	173	159	151	107	63	21	.525	950	.110	44.2	
646		.498	185.8	253	238	228	153	140	132	94	55	19	.524	850	.098	35.2	
647		.430	186.0	218	205	197	131	121	114	81	48	17	.522	740	.085	26.7	
648		.361	185.9	184	172	166	110	102	96	68	40	15	.521	640	.073	20.0	
649		.292	185.8	149	139	134	89	82	77	55	32	14	.519	540	.062	14.2	
724	1.21	1.96	153.4	668	629	597	391	354	332	252	186	47	.496	2 880	.479	284.1	
725	1.21	1.77	152.6	604	570	542	358	325	305	228	166	42	.505	2 520	.420	257.7	
726	1.20	1.60	151.9	547	517	492	328	297	280	199	146	39	.512	2 210	.367	228.4	
727	1.21	1.40	152.4	477	451	431	289	263	247	175	121	35	.518	1 830	.305	176.5	
728	1.21	1.20	152.8	412	389	372	250	228	214	152	92	30	.520	1 530	.254	129.6	
729	1.21	1.00	152.5	343	325	310	209	191	180	128	76	25	523	1 250	.207	89.7	
730	1.20	.814	151.2	278	263	252	170	155	146	103	62	21	.524	1 000	.166	62.9	
731	1.20	.618	152.0	211	200	191	129	118	111	79	47	17	525	790	.131	35.8	
732	1.20	.429	151.8	146	138	133	89	81	76	54	33	14	.520	590	.099	18.4	

(g) Reduced temperature, 1 30

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	1	2	3	4	5	6	7	8	9	P_t/P_0	G_{max}	G_r	S_0	T_0
650	1 30	0.872	200.5	443	419	400	267	246	232	165	97	32	0.523	1 390	0.160	63.5	(a)
651	↓	.836	200.7	425	401	383	256	236	221	157	93	30	.521	1 320	.153	58.1	↓
652		.766	200.6	389	368	352	236	218	204	144	85	28	.523	1 210	.139	49.1	
653		.699	200.6	355	336	321	216	200	185	131	77	25	.521	1 100	.127	41.1	
654		.633	200.7	322	304	291	196	181	168	119	70	23	.521	950	.109	34.0	
655		.563	200.8	286	270	259	174	160	149	105	62	21	.521	830	.096	27.4	
656		.498	200.7	253	239	229	154	142	132	93	55	19	.522	730	.084	22.2	
657		.427	200.7	217	204	196	132	122	113	80	47	18	.521	610	.071	17.1	
658		.360	200.5	183	172	166	112	102	95	67	39	16	.517	510	.058	13.0	
659		.293	200.7	149	140	135	91	83	77	54	32	14	.518	400	.046	10.1	
660		.226	200.6	115	107	104	70	64	59	41	24	13	.514	290	.033	10.1	

(h) Reduced temperature, 1.35

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	1	2	3	4	5	6	7	8	9	P_t/P_0	G_{max}	G_r	S_0	T_0
536	1.41	0.698	217.6	355	336	322	217	198	185	129	77	27	0.522	990	0.114	24.8	(a)
537	1.40	.969	216.5	492	467	446	306	277	256	179	105	35	.519	1 400	.162	47.3	↓
538	1.42	1.24	220.4	630	599	573	391	354	326	227	134	45	.517	1 820	210	68.5	
539	1.45	1 38	224.6	700	666	636	435	394	358	247	147	49	512	2 000	230	74.3	
540	1.44	1 24	222.9	631	600	574	393	356	323	222	132	44	.512	1 790	.206	63.6	
541	1.43	1.10	220.6	561	534	511	350	318	288	198	117	39	.513	1 580	.182	54.0	
542	1.41	.969	218.2	492	468	448	308	279	253	173	102	34	.514	1 380	.159	44.9	
543	1.39	.835	215.5	424	402	385	265	241	218	149	88	30	.514	1 190	.137	36.6	
544	1.37	.698	212.2	355	337	323	222	202	182	124	73	25	.513	1 000	.115	29.0	
545	1.35	.564	209.6	287	272	261	180	163	147	100	59	21	.513	810	094	21.4	
546	1.34	.428	207.4	217	205	198	136	123	111	76	45	17	.512	630	.073	14.3	
547	1.33	.291	205.6	148	139	134	92	83	76	51	30	14	.511	450	.052	10.1	
548	1.32	.156	205.0	79	74	71	49	44	40	27	16	12	.504	310	.036	10.1	
661	1.35	.692	208.5	352	333	319	217	198	184	128	76	25	.522	1 000	.116	31.6	
662	↓	.633	208.4	322	305	292	201	183	167	115	68	23	.519	900	.104	27.1	
663		.560	208.5	285	269	259	177	162	147	101	60	21	.517	790	.091	21.8	
664		.497	208.5	252	238	229	158	144	130	90	53	19	.515	690	.079	17.8	
665		.428	208.4	217	205	198	136	124	112	46	46	17	.515	580	.067	13.9	
666		.358	208.3	182	171	165	114	104	93	64	38	16	.512	470	.055	9.9	
667		.292	208.3	149	139	135	93	85	76	52	31	14	.513	370	.043	10.1	
668		.226	208.4	115	107	104	71	65	59	40	24	13	.509	270	.031	10.1	
733		1.48	170.3	504	477	456	305	279	261	184	110	35	.518	1 710	.285	92.2	
734		1.22	170.5	415	393	375	252	231	216	153	91	30	.519	1 440	.239	63.0	
734		1.01	170.1	345	327	312	210	192	181	128	76	25	.523	1 200	.200	44 4	
735		.814	170.5	278	263	252	170	155	145	102	61	21	.522	1 000	.166	29.1	
737		.622	170.5	213	201	193	130	119	111	79	47	17	.523	790	.132	17.8	
738		.427	170.3	146	138	132	89	81	76	54	32	14	.521	590	.099	9.4	

[a] Not applicable.

TABLE V. - CONICAL NOZZLE DATA FOR NITROGEN

(a) *Reduced temperature, 0.749*

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, $g/(cm^2)(sec)$	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy S_0	Stagnation temperature, T_0
487	0.750	0.238	94.7	81	75	70	49	45	41	32	25	18	0.504	2 020	0.337	52.2	52.8
488	.750	.342	94.6	117	104	94	52	49	49	38	30	20	.417	2 870	.477	51.1	52.4
489	.748	.442	94.5	151	131	116	52	47	49	39	33	22	.326	3 520	.586	50.0	51.9
490	.749	.538	94.6	184	157	137	54	47	50	41	35	24	.271	4 040	.672	49.9	52.4
491	.750	.639	94.7	218	186	161	55	47	↓	42	35	28	.230	4 540	.756	49.4	52.6
492	.749	.734	94.6	251	212	182	57	46	↓	↓	36	32	.200	4 960	.825	48.7	52.5
493	↓	.834	↓	285	240	205	58	45	↓	↓	↓	32	.175	5 370	.894	47.8	52.2
494	↓	.934	↓	319	268	227	59	↓	49	↓	↓	33	.154	5 760	.958	47.4	52.3
495	↓	1.03	↓	352	295	249	60	↓	↓	↓	↓	35	.140	6 100	1.01	46.9	52.4
496	↓	1.14	↓	390	325	274	62	↓	↓	↓	↓	36	.125	6 470	1.08	46.2	52.3
497	↓	1.24	↓	425	354	297	63	↓	↓	↓	↓	↓	.115	6 790	1.13	45.9	52.5
498	↓	1.34	↓	459	381	320	64	↓	↓	↓	↓	↓	.106	7 090	1.18	45.4	52.5
499	↓	1.44	↓	493	410	343	65	↓	48	↓	↓	↓	.098	7 360	1.22	44.8	52.4
500	↓	1.55	↓	530	440	368	67	↓	49	↓	↓	↓	.092	7 680	1.28	44.2	52.3
501	.750	1.65	94.8	564	469	392	70	44	48	↓	↓	17	.085	7 950	1.32	44.2	53.0
502	.751	1.76	94.9	601	499	418	79	68	74	44	35	19	.123	8 210	1.37	44.2	53.5
503	.751	1.86	94.9	635	527	440	74	45	49	42	36	16	.078	8 470	1.41	43.6	53.4
504	.751	1.95	94.8	665	551	460	75	44	48	42	36	15	.073	8 690	1.45	43.1	53.3

(b) Reduced temperature, 0.868

505	0.862	0.636	108.8	217	196	180	108	96	87	61	44	36	0.400	3 450	0.574	131.6	137.1
506	.863	.836	109.0	286	255	231	128	119	116	84	61	44	.408	4 190	.698	128.5	138.3
507	.864	1.04	109.1	354	310	276	130	117	121	92	68	50	.340	5 000	.833	125.2	139.1
508	.865	1.24	109.2	424	366	322	132	114	120	94	70	55	.284	5 710	.950	122.2	139.9
509	.865	1.44	109.2	491	422	367	135	112	120	95	73	60	.244	6 340	1.05	119.1	140.1
510	.865	1.65	109.3	565	483	418	137	109	119	96	74	63	.211	6 950	1.16	116.1	140.7
511	.866	1.86	109.4	635	539	465	140	108	119	96	75	66	.187	7 480	1.24	113.6	141.3
512	.869	2.04	109.8	698	593	508	144	109	120	98	76	69	.171	7 890	1.31	113.8	145.1
513	.870	1.75	109.9	598	511	441	142	112	123	99	76	66	.205	7 160	1.19	114.5	145.9
514	.867	1.75	109.5	599	511	441	140	110	120	97	75	64	.201	7 220	1.20	116.2	142.8
515	.868	1.55	109.6	530	454	395	138	113	121	97	74	62	.228	6 640	1.10	120.1	143.6
516	.869	1.37	109.7	468	403	353	137	116	123	97	73	58	.263	6 100	1.02	123.9	144.4
517	.870	1.35	109.9	460	397	348	138	118	124	98	74	58	.270	6 010	1.00	125.3	145.7
518	.869	1.15	109.8	393	341	303	136	120	125	96	70	53	.318	5 370	.893	128.6	145.1
519	.870	.943	109.9	322	285	257	135	124	125	91	66	47	.387	4 570	.761	133.3	145.7
520	.871	.740	110.0	253	228	210	129	118	107	76	52	39	.422	3 720	.619	138.7	146.5
521	.870	.539	109.9	184	166	153	89	81	75	55	42	36	.408	3 140	.523	143.4	146.1

(c) Reduced temperature, 0.942

739	0.942	2.66	119.0	908	781	679	226	170	182	144	105	88	0.201	8 480	1.41	168.3	238.6
740	.942	2.44	119.0	833	718	626	221	173	184	145	104	85	.221	8 000	1.33	173.0	238.6
741	.941	2.23	118.9	763	659	577	217	174	184	144	102	83	.241	7 540	1.26	176.6	237.1
742	.945	2.04	119.3	697	606	534	217	181	189	146	102	78	.271	7 010	1.17	185.1	242.6
743	.942	1.80	119.0	614	537	477	212	182	188	142	98	72	.306	6 410	1.07	188.8	238.3
744	.940	1.62	118.7	554	487	435	208	184	187	139	95	67	.338	5 930	.987	191.5	235.0
745	.943	1.44	119.1	492	436	395	211	191	191	136	92	61	.388	5 310	.883	201.9	240.4
746	.942	1.35	119.0	460	411	373	209	192	187	131	91	58	.407	5 000	.833	204.1	238.9
747	.941	1.23	118.9	420	378	345	206	189	176	122	99	54	.419	4 630	.770	207.2	237.1
748	.940	1.13	118.7	385	347	320	195	176	157	110	107	51	.409	4 320	.718	209.7	234.0
749	.948	1.04	119.7	356	323	298	186	168	153	139	139	48	.430	3 990	.663	224.9	247.2
750	.948	.934	119.7	319	292	273	182	170	161	153	153	43	.504	3 550	.591	231.3	247.5
751	.946	.837	119.5	286	266	252	185	177	171	162	159	38	.597	3 050	.507	235.5	245.3
752	.944	.731	119.2	250	236	228	184	178	174	168	153	31	.696	2 380	.396	239.1	241.7

TABLE V. - Concluded.

(d) Reduced temperature, 1.025

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, g/(cm^2)(sec)	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
527	1.029	1.14	130.0	391	376	364	274	256	242	179	116	32	0.619	1 830	0.304	336.3	(a)
528	1.025	.930	129.6	318	302	290	213	202	202	145	92	22	.637	1 350	.224	235.4	
529	1.031	.830	130.2	284	270	258	175	160	151	125	81	20	.531	1 170	.195	181.6	
530	1.030	.740	130.1	253	240	230	156	142	134	101	69	19	.528	1 010	.169	144.3	
531	1.027	.633	129.8	216	205	197	133	122	114	80	56	16	.529	850	.141	105.3	
532	1.028	.536	129.8	183	173	167	112	103	96	68	40	15	.526	710	.119	74.5	
533	1.028	.438	129.9	150	142	136	92	84	79	56	33	14	.526	580	.096	50.6	
769	1.025	2.07	129.5	709	634	573	298	265	268	230	221	75	.379	5 900	.982	278.5	
770	1.024	1.96	129.4	669	601	546	298	269	270	239	226	72	.404	5 590	.930	282.5	
771	1.026	1.85	129.6	632	572	523	302	275	275	250	230	68	.435	5 220	.868	289.8	
772	1.025	1.75	129.5	598	544	501	303	279	278	259	230	65	.465	4 880	.812	294.2	
773	1.026	1.64	129.5	561	514	476	307	287	284	268	226	61	.507	4 490	.746	301.2	
774	1.025	1.55	129.5	530	489	457	310	293	291	276	217	57	.550	4 120	.686	306.7	
775	1.025	1.44	129.4	492	459	433	317	303	303	283	202	51	.616	3 630	.604	314.9	
776	1.025	1.34	129.5	459	433	414	326	316	318	272	179	46	.692	3 060	.509	324.0	
777	1.024	1.25	129.4	426	407	393	322	284	274	216	148	38	.644	2 510	.417	333.4	
778	1.025	1.25	129.4	426	407	393	322	284	275	216	148	39	.645	2 520	.419	333.5	
779	1.024	1.15	129.4	392	376	365	275	257	243	180	114	33	.620	1 890	.314	340.5	
780	1.025	1.05	129.5	357	341	330	245	227	215	158	102	26	.602	1 520	.254	300.1	
782	1.024	.948	129.3	324	307	295	221	211	209	145	93	23	.645	1 340	.223	248.1	
783	1.025	.848	129.4	290	274	262	181	166	159	129	83	21	.548	1 190	.197	197.3	
784		.751	129.5	257	243	233	159	144	135	106	69	19	.524	1 010	.168	153.3	
785		.607	129.5	207	196	188	128	116	109	76	52	16	.524	800	.134	97.8	
786		.386	129.4	132	124	119	81	74	69	48	28	13	.522	500	.084	40.8	
787	↓	.401	129.5	137	128	124	84	76	71	50	29	14	.521	530	.088	43.7	↓

(e) Reduced temperature, 1.10

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, g/(cm^2)(sec)	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
755	1.10	2.66	139.4	910	823	751	387	334	322	297	267	84	0.354	6 140	1.02	323.5	(a)
756		2.44	139.4	833	758	697	384	339	328	304	265	78	.394	5 550	.923	329.5	
757		2.24	139.3	764	700	649	382	343	333	310	259	72	.435	4 980	.828	334.5	
758		2.04	139.4	696	643	601	379	348	337	312	244	65	.485	4 350	.724	339.0	
759		1.82		621	580	548	371	347	340	308	222	56	.548	3 590	.597	341.1	
760		1.65		562	529	504	356	337	333	294	200	48	.593	2 980	.496	337.7	
761		1.54	↓	527	498	475	340	322	320	273	178	42	.608	2 620	.436	329.2	
762		1.44	139.3	492	465	445	315	297	294	246	159	38	.598	2 300	.383	312.0	
763		1.21	139.2	415	392	375	253	233	219	188	123	29	.529	1 820	.302	242.5	
764		1.00	139.1	343	325	311	211	193	181	128	92	25	.526	1 400	.233	169.3	
765		.839	139.4	287	271	260	176	161	151	107	71	21	.527	1 140	.190	115.5	
766		.711	139.3	243	230	221	150	137	128	91	54	18	.526	970	.161	82.1	
767		.537	139.2	184	174	167	113	103	96	68	40	15	.524	760	.126	47.9	
768	↓	.385	139.2	131	124	120	81	74	69	49	28	13	.524	590	.097	25.7	↓

[a] Not applicable.

TABLE VI. - ELLIPTICAL NOZZLE DATA FOR OXYGEN

(a) Reduced temperature, 0.611

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, $g/(cm^2)(sec)$	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
63	0.633	0.427	97.9	217	206	71	26	19	17	11	9	10	0.086	6 090	0.702	20.5	21.3
64	.615	.431	92.2	219	207	68	22	15	14	10	12	15	.069	6 210	.716	16.1	16.7
65	.611	.564	94.6	287	273	86	26	15	14	9	5	5	.051	7 190	.829	15.0	15.7
66	.611	.565	94.5	287	273	87	26	15	14	↓	9	12	.051	7 180	.828	14.9	15.6
67	.608	.699	94.2	355	339	107	29	14	13	↓	5	5	.040	8 060	.929	14.2	15.1
68	.607	.834	93.9	424	404	125	31	↓	12	↓	↓	4	.033	8 820	1.02	13.6	14.7
69	.605	.969	93.7	492	470	143	37	↓	↓	↓	↓	↓	.029	9 530	1.10	13.2	14.4
70	.604	1.10	93.4	561	537	167	41	↓	↓	8	↓	↓	.025	10 200	1.18	12.7	14.1
71	.602	1.24	93.2	630	603	188	43	↓	↓	↓	↓	↓	.022	10 850	1.25	----	13.7
72	.600	1.38	92.9	700	670	208	48	↓	↓	↓	↓	↓	.020	11 480	1.32	----	13.4
73	.601	1.31	93.1	665	636	198	46	↓	↓	↓	↓	↓	.021	11 170	1.29	----	13.6
74	.603	1.17	93.4	596	569	174	42	↓	↓	↓	↓	↓	.024	10 550	1.22	12.6	14.0
75	.605	1.04	93.6	528	504	159	39	↓	↓	↓	↓	↓	.027	9 880	1.14	13.0	14.3
76	.607	.901	93.9	458	437	137	35	↓	13	9	↓	5	.031	9 190	1.06	13.6	14.8
77	.608	.767	94.2	390	371	115	32	15	13	↓	↓	5	.037	8 460	.975	14.1	15.1
78	.611	.631	94.5	321	305	97	27	↓	14	↓	↓	5	.045	7 640	.881	14.8	15.6
79	.612	.495	94.8	251	238	78	24	↓	↓	↓	6	6	.058	6 710	.774	15.3	16.0
80	.615	.358	95.2	182	173	58	21	↓	↓	↓	7	8	.083	5 660	.653	16.1	16.6
81	.616	.290	95.3	147	139	50	19	↓	↓	↓	8	9	.099	5 010	.578	16.5	16.9
82	.618	.223	95.6	113	107	40	18	↓	15	↓	9	10	.129	4 350	.502	17.0	17.3
83	.620	.156	96.0	79	74	32	18	↓	14	↓	10	11	.190	3 460	.399	17.7	17.8
84	.624	.088	96.6	45	41	24	17	↓	12	10	10	10	.338	2 260	.261	18.8	18.9

(b) Reduced temperature, 0.628

218	0.625	1.17	96.7	596	569	178	45	18	15	10	7	5	0.030	10 470	1.21	17.1	19.2
219	.624	1.31	96.5	667	638	199	52	↓	15	↓	↓	↓	.027	11 100	1.28	16.6	18.8
220	.622	1.44	96.3	733	701	216	54	↓	14	↓	↓	↓	.025	11 690	1.35	16.0	18.4
221	.620	1.58	96.0	802	768	232	59	↓	↓	↓	↓	↓	.023	12 240	1.41	----	17.9
222	.619	1.71	95.8	871	834	251	63	↓	↓	9	↓	↓	.021	12 780	1.47	----	17.6
223	.617	1.85	95.6	942	902	270	67	↓	↓	9	↓	↓	.019	13 330	1.54	----	17.2
224	.618	1.78	95.7	907	869	258	65	↓	↓	9	↓	↓	.019	13 070	1.51	----	17.4
225	.619	1.65	95.9	838	802	241	61	↓	↓	10	↓	↓	.022	12 540	1.45	----	17.7
226	.621	1.51	96.1	768	735	224	56	↓	↓	↓	8	↓	.024	11 980	1.38	15.7	18.1
227	.622	1.38	96.3	701	670	204	53	↓	↓	↓	7	↓	.026	11 460	1.32	16.2	18.5
228	.624	1.25	96.5	633	605	189	50	↓	15	↓	↓	↓	.029	10 810	1.25	16.7	18.8
229	.625	1.10	96.8	558	534	170	44	↓	15	↓	↓	↓	.032	10 180	1.17	17.3	19.3
230	.627	.972	97.0	494	471	150	41	↓	16	11	↓	↓	.037	9 540	1.10	17.9	19.6
231	.628	.835	97.3	425	404	128	38	↓	↓	↓	↓	6	.043	8 790	1.01	18.5	20.1
232	.630	.703	97.5	357	340	110	36	↓	↓	↓	↓	6	.051	8 040	.927	19.2	20.5
233	.632	.563	97.8	286	273	88	31	19	↓	↓	8	7	.065	7 160	.826	20.0	21.0
234	.634	.427	98.1	217	207	70	28	↓	17	↓	9	10	.086	6 160	.710	20.7	21.6
235	.636	.293	98.4	149	142	55	25	↓	↓	↓	11	12	.125	4 980	.575	21.7	22.2
236	.637	.257	98.6	131	125	49	25	↓	↓	↓	11	11	.146	4 640	.535	22.0	22.5
237	.637	.225	98.7	114	109	43	24	↓	↓	10	12	12	.163	4 280	.494	22.3	22.7
238	.638	.190	98.8	97	92	40	24	20	16	11	↓	12	.203	3 870	.446	22.7	23.0
239	.639	.156	98.9	79	76	35	23	20	17	11	↓	12	.248	3 410	.393	22.9	23.2
240	.641	.123	99.2	63	59	31	23	20	15	10	↓	11	.314	2 880	.332	23.6	23.8
241	.643	.090	99.5	46	43	27	22	19	13	↓	11	11	.409	2 270	.262	24.3	24.5
242	.645	.071	99.8	36	35	24	20	18	13	↓	11	11	.486	1 890	.218	25.0	25.1
243	.648	.057	100.3	29	27	21	19	16	13	↓	10	10	.554	1 540	.177	26.0	26.1
244	.649	.053	100.5	26	25	21	19	17	14	11	10	10	.615	1 230	.142	26.5	26.6

TABLE VI. - Continued.

(c) Reduced temperature, 0.749

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, g/(cm^2)(sec)	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
85	0.746	0.427	115.5	217	208	109	76	67	40	22	20	22	0.308	5 030	0.580	75.3	77.9
86	.751	.428	116.3	217	209	111	78	69	40	22	20	22	.317	5 010	.577	79.1	81.8
88	.750	.697	116.1	354	340	147	84	68	46	25	21	24	.191	7 000	.807	75.6	80.8
89	.749	.831	116.0	423	406	169	84	67	46	25	20	24	.158	7 820	.901	74.0	80.3
90	.748	.973	115.9	494	475	188	87	66	47	26	18	24	.134	8 570	.988	72.1	79.7
91	.748	1.10	115.8	561	539	206	90	65	47	│	17	22	.116	9 240	1.07	70.7	79.3
92	.747	1.24	115.6	631	607	220	92	65	48	│	16	21	.103	9 900	1.14	69.0	78.6
93	.747	1.38	115.6	700	673	244	99	64	47	│	16	19	.092	10 480	1.21	67.7	78.2
94	.746	1.44	115.5	732	704	253	100	64	│	│	15	19	.087	10 750	1.24	67.1	78.1
95	.747	1.31	115.7	666	640	232	95	65	│	│	15	20	.097	10 200	1.18	68.8	79.0
96	.748	1.17	115.9	597	573	212	94	65	↓	│	17	22	.109	9 570	1.10	70.5	79.7
97	.750	1.04	116.1	528	507	197	93	66	48	│	18	23	.126	8 910	1.03	72.5	80.7
98	.751	.902	116.2	458	440	180	87	67	47	↓	19	24	.147	8 190	.944	74.5	81.6
99	.752	.767	116.4	390	374	159	86	69	46	25	21	24	.177	7 420	.856	76.6	82.6
100	.753	.629	116.6	320	307	141	84	70	45	25	22	24	.220	6 530	.753	78.8	83.6
101	.755	.497	116.8	252	243	123	83	72	44	24	21	23	.285	5 560	.640	81.2	84.6
102	.756	.358	117.1	182	175	105	78	69	36	21	18	21	.381	4 300	.496	83.9	85.9
103	.757	.293	117.2	149	143	93	67	60	32	20	17	20	.400	3 680	.425	85.4	86.7
104	.759	.224	117.5	114	109	75	52	47	30	20	16	18	.414	3 090	.356	87.3	87.9
210	.754	1.17	116.8	596	572	216	100	68	49	27	18	23	.115	9 470	1.09	74.6	84.2
211	.756	1.31	117.1	667	641	236	98	69	49	27	18	22	.104	10 100	1.16	74.7	85.8
212	.756	1.44	117.1	734	705	258	103	│	50	27	17	21	.094	10 650	1.23	73.8	85.9
213	.757	1.58	117.1	804	773	276	112	│	50	28	│	19	.086	11 200	1.29	72.9	86.2
214	.757	1.72	117.2	872	839	294	111	↓	50	28	│	18	.079	11 720	1.35	72.2	86.7
215	.759	1.85	117.5	941	905	309	114	70	52	28	↓	16	.075	12 220	1.41	72.3	88.1
216	.765	1.92	118.4	975	938	328	123	73	54	29	18	16	.075	12 390	1.43	75.9	93.1
217	.768	1.79	118.9	908	872	309	119	76	54	29	18	20	.083	11 870	1.37	79.1	95.8
249	.743	1.17	115.0	596	572	208	86	62	45	25	17	21	.103	9 680	1.12	66.8	75.5
250	.745	1.17	115.4	596	571	210	94	64	46	25	17	22	.107	9 510	1.10	68.5	77.4
251	.745	1.31	115.3	663	637	228	96	62	45	26	16	21	.094	10 210	1.18	67.0	76.8
252	.744	1.44	115.2	734	705	250	98	│	46	│	17	19	.085	10 770	1.24	65.9	76.7
253	.744	1.58	115.1	802	771	271	100	│	│	│	16	16	.077	11 350	1.31	64.4	76.1
254	.743	1.72	114.9	872	838	286	107	│	│	↓	│	14	.071	11 900	1.37	62.8	75.3
255	.743	1.85	115.1	942	905	307	111	│	↓	25	│	13	.065	12 370	1.43	62.4	76.0
256	.743	1.92	115.1	976	938	315	106	│	47	26	│	12	.063	12 640	1.46	61.9	75.8
257	.745	1.78	115.3	906	870	300	111	↓	46	│	│	14	.069	12 090	1.39	63.6	76.8
258	.746	1.65	115.4	837	804	277	102	63	47	│	│	15	.075	11 600	1.34	65.3	77.6
259	.747	1.51	115.7	766	736	262	104	64	47	│	↓	18	.083	11 040	1.27	67.2	78.7
260	.748	1.39	115.8	705	676	243	100	64	47	│	17	20	.091	10 520	1.21	68.8	79.6
261	.750	1.24	116.0	631	606	223	91	65	48	│	18	22	.102	9 880	1.14	70.7	80.6
262	.751	1.11	116.2	563	539	206	95	66	47	↓	19	23	.117	9 240	1.06	72.7	81.4
392	.757	.899	115.6	457	438	172	86	64	45	25	20	24	.141	8 280	.954	71.6	78.5
393	.748	.768	115.7	390	374	155	84	65	45	25	22	24	.167	7 530	.868	73.4	79.1
394	.749	.632	115.9	321	308	138	81	66	43	24	23	25	.206	6 650	.766	75.3	79.8
395	.749	.562	116.0	285	275	127	81	67	43	24	23	24	.234	6 160	.710	76.3	80.2
396	.749	.496	116.0	252	242	120	79	68	41	23	22	24	.271	5 630	.649	77.0	80.3
397	.750	.425	116.1	216	208	110	79	68	39	20	21	23	.316	5 040	.581	78.2	80.8
398	.750	.359	116.1	183	176	101	77	67	36	21	20	21	.368	4 410	.509	79.0	81.1
399	.751	.290	116.3	147	142	91	68	59	31	20	18	20	.400	3 680	.424	80.5	81.7
400	.752	.225	116.4	114	111	77	57	49	29	20	17	18	.430	3 010	.347	81.5	82.6
401	.753	.170	116.6	86	83	62	48	42	28	21	16	16	.485	2 420	.279	83.6	83.6

TABLE VI. - Continued.

(d) Reduced temperature, 0.810

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, g/(cm^2)(sec)	Reduced mass flow, rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
150	0.800	0.427	123.8	217	210	131	90	80	41	25	21	26	0.368	4 530	0.522	123.6	126.8
151	.802	.565	124.2	287	277	159	116	102	49	27	23	29	.357	5 450	.628	123.7	129.4
152	.803	.696	124.4	354	341	178	123	109	56	29	24	30	.309	6 360	.733	122.6	130.5
154	.805	.967	124.6	491	473	214	130	109	63	32	25	33	.221	7 940	.915	120.1	132.4
155	.805	1.11	124.7	562	542	234	132	107	64	33	23	33	.190	8 650	.997	118.2	132.5
156	.806	1.25	124.7	637	614	259	136	106	66	34	22	32	.166	9 340	1.08	116.4	133.2
157	.806	1.38	124.8	700	674	274	137	105	66	↓	21	32	.149	9 900	1.14	115.2	133.7
158	.807	1.46	124.9	741	714	286	139	105	67	↓	21	31	.142	10 220	1.18	114.5	134.2
159	.808	1.31	125.0	667	643	265	139	107	67	↓	21	32	.160	9 600	1.11	117.4	135.3
160	.809	1.18	125.2	598	576	246	137	109	66	↓	23	33	.182	8 950	1.03	120.8	136.8
161	.810	1.04	125.4	528	508	228	135	111	65	33	24	33	.211	8 270	.953	123.7	137.7
162	.810	.908	125.4	461	444	211	134	114	63	32	25	33	.247	7 550	.870	125.9	137.9
163	.811	.769	125.5	391	377	195	132	115	60	32	24	32	.294	6 720	.774	129.0	138.6
164	.811	.629	125.6	320	309	177	127	111	53	29	23	30	.346	5 770	.665	132.0	139.2
165	.811	.494	125.6	251	243	149	102	90	45	27	22	28	.359	4 890	.564	135.0	139.5
166	.812	.422	125.7	215	208	131	91	80	43	27	21	26	.371	4 440	.512	136.5	139.9
167	.813	.357	125.8	182	175	111	72	64	38	26	22	25	.354	4 070	.469	139.4	141.2
168	.814	.292	125.9	149	143	101	75	66	41	30	19	21	.446	3 360	.387	141.7	142.0
291	.806	1.17	124.8	595	573	244	135	105	65	34	24	33	.176	8 860	1.02	118.2	133.9
292	.807	1.31	124.9	667	642	267	137	105	65	34	22	32	.157	9 510	1.10	116.8	134.6
293	.807	1.45	124.9	734	707	284	141	103	66	34	↓	31	.141	10 110	1.17	114.9	134.4
294	.807	1.58	124.9	805	775	305	143	102	67	35	↓	30	.127	10 660	1.23	113.0	134.4
295	.806	1.71	124.8	871	839	323	144	102	67	↓	↓	29	.117	11 160	1.29	110.8	133.9
296	.807	1.85	124.9	938	903	339	150	101	67	↓	↓	27	.108	11 680	1.35	109.5	134.2
297	.808	1.93	125.1	979	943	352	157	102	68	↓	↓	26	.105	11 930	1.37	109.7	135.7
298	.809	1.85	125.2	940	904	344	150	103	68	↓	21	28	.110	11 660	1.34	111.6	136.8
299	.810	1.79	125.3	908	873	329	147	105	68	↓	22	28	.115	11 410	1.32	112.9	137.5
300	.811	1.65	125.5	838	806	311	148	106	68	↓	22	30	.127	10 850	1.25	115.6	138.6
301	.811	1.52	125.6	771	742	298	148	107	68	↓	22	32	.139	10 310	1.19	118.0	139.3
302	.812	1.38	125.7	700	673	275	143	110	68	↓	23	33	.157	9 710	1.12	121.0	140.5
303	.813	1.24	125.9	632	608	259	141	111	68	↓	24	33	.175	9 130	1.05	123.7	141.4
304	.814	1.11	126.0	563	541	239	143	114	66	34	25	34	.202	8 440	.973	126.8	142.3
305	.815	.975	126.1	495	477	222	140	116	65	33	26	33	.235	7 730	.891	129.6	143.1
306	.815	.837	126.2	425	410	204	138	119	62	32	26	33	.280	6 950	.801	132.7	143.8
307	.816	.700	126.3	356	344	187	135	117	57	30	25	31	.330	6 040	.696	135.8	144.4
308	.816	.570	126.4	290	281	168	123	105	48	27	24	29	.363	5 140	.593	139.0	145.2
309	.817	.497	126.4	252	245	157	105	90	46	28	23	28	.357	4 710	.543	140.9	145.6
310	.817	.427	126.5	217	211	134	93	81	45	28	23	26	.372	4 270	.492	142.8	145.9
311	.818	.392	126.6	199	193	120	79	68	40	28	23	26	.343	4 110	.474	144.5	146.9
312	.819	.327	126.8	166	161	106	75	64	38	27	22	24	.386	3 550	.409	147.4	148.3
313	.819	.292	126.8	148	145	114	92	82	56	40	16	16	.551	2 750	.317	147.8	148.8

TABLE VI. - Continued.

(e) Reduced temperature, 0.854

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, $g/(cm^2)(sec)$	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
111	0.851	0.427	131.8	217	210	135	93	82	47	32	24	28	0.380	4 070	0.469	188.9	190.6
112	.853	.561	132.0	285	276	163	99	87	47	31	26	33	.307	5 030	.579	187.3	193.2
113	.854	.697	132.3	354	344	203	135	119	56	33	25	34	.336	5 660	.653	185.1	195.3
114	.856	.834	132.4	424	411	237	170	147	65	35	↓	36	.348	6 290	.726	182.7	197.0
115	.856	.969	132.6	492	477	256	180	158	72	36	↓	37	.320	7 070	.816	180.1	198.2
116	.857	1.11	132.7	563	545	276	184	161	77	38	↓	39	.286	7 810	.900	177.5	199.4
117	.858	1.24	132.8	632	612	295	187	160	80	39	↓	39	.253	8 490	.979	174.8	200.1
118	.858	1.38	132.8	702	680	312	189	158	82	40	↓	40	.225	9 120	1.05	172.0	200.8
119	.858	1.44	132.9	734	710	325	190	157	83	41	↓	40	.214	9 400	1.08	171.0	201.3
120	.859	1.31	↓	666	644	307	189	159	81	40	↓	40	.239	8 780	1.01	174.6	201.8
121	.859	1.17	↓	596	577	285	187	161	79	38	↓	39	.512	8 130	.938	178.0	201.8
122	.859	1.04	↓	529	512	268	184	161	76	38	↓	38	.305	7 430	.856	181.3	201.6
123	.858	.901	↓	458	444	248	178	155	69	36	↓	37	.339	6 660	.768	184.9	201.3
124	↓	.768	↓	391	379	226	158	136	59	33	↓	35	.348	5 920	.682	188.8	201.3
125	↓	.630	132.8	320	310	186	122	109	54	33	26	33	.339	5 300	.612	192.2	200.3
126	↓	.495	132.8	251	244	148	94	83	46	31	25	31	.329	4 580	.528	196.6	200.1
110	.848	.900	131.3	457	443	238	170	147	68	35	↓	36	.322	6 870	.792	170.6	186.0
411	.848	.766	131.2	389	378	221	158	136	60	33	↓	34	.349	6 060	.699	173.9	185.8
412	.847	.635	131.1	323	313	186	124	108	53	32	↓	33	.333	5 430	.626	176.2	184.4
413	.846	.563	131.0	286	278	168	110	96	50	32	26	32	.336	5 040	.581	177.8	184.0
414	.846	.496	130.9	252	244	146	90	79	44	31	26	31	.312	4 720	.544	178.6	182.8
415	.845	.458	130.8	233	226	137	87	77	42	30	26	30	.329	4 490	.517	178.8	181.9
416	.844	.427	130.7	217	211	132	89	78	45	31	25	28	.360	4 200	.484	179.0	181.3
417	.844	.387	130.7	197	191	126	91	79	46	32	24	26	.403	3 810	.439	180.3	181.3
418	.844	.363	130.7	185	180	125	94	82	50	36	23	23	.446	3 510	.405	180.4	180.6

(f) Reduced temperature, 0.885

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	1	2	3	4	5	6	7	8	9	P_t/P_0	G_{max}	G_r	S_0	T_0
132	0.877	0.560	135.7	284	276	167	106	94	51	35	27	33	0.331	4 800	0.554	224.7	230.1
133	.880	.697	136.2	354	343	202	122	108	56	36	28	36	.304	5 550	.639	224.4	235.5
134	.882	.840	136.5	427	414	246	162	140	63	36	27	38	.329	6 090	.702	222.0	238.7
135	.884	.971	136.8	493	480	278	198	170	71	38	26	39	.345	6 630	.765	219.7	241.5
136	.885	1.11	137.0	563	548	299	212	186	79	39	27	40	.330	7 340	.847	216.8	243.7
137	.886	1.25	137.1	634	615	321	218	191	84	41	27	42	.301	8 040	.927	213.6	245.1
138	.887	1.38	137.3	700	680	341	222	191	90	42	27	43	.274	8 620	.994	211.2	247.1
139	↓	1.46	137.3	744	722	353	223	192	91	44	28	43	.258	9 000	1.04	209.1	247.6
140	↓	1.31	137.3	666	646	332	221	193	87	42	27	42	.290	8 320	.959	213.4	247.4
141	↓	1.18	137.3	599	581	312	217	190	83	41	27	41	.317	7 660	.884	217.1	246.8
142	.886	1.03	137.2	524	510	289	206	178	75	38	26	40	.340	6 920	.797	221.4	246.0
143	.886	.910	137.1	462	449	266	183	156	66	37	27	38	.338	6 330	.729	224.9	244.8
144	.885	.771	137.0	392	380	224	143	127	62	37	27	37	.323	5 810	.670	229.7	244.2
145	.884	.631	136.7	321	311	184	111	99	52	35	29	35	.308	5 170	.596	234.2	242.3
146	.883	.500	136.7	254	247	162	115	101	57	38	26	29	.399	4 200	.484	238.8	240.7
263	.879	1.91	136.1	971	939	404	218	170	92	44	28	41	.175	10 960	1.26	186.2	233.8
264	↓	1.78	↓	904	873	384	218	172	91	43	↓	42	.191	10 430	1.20	189.8	234.4
265	↓	1.72	↓	872	843	382	217	174	90	↓	↓	42	.199	10 200	1.18	191.2	234.1
266	↓	1.65	↓	838	810	372	217	175	89	↓	↓	42	.209	9 920	1.14	193.1	234.4
267	.880	1.86	136.2	946	915	396	219	171	91	↓	↓	41	.180	10 750	1.24	188.4	235.2
268	.884	1.58	136.9	803	776	361	221	183	89	↓	↓	43	.227	9 550	1.10	201.3	242.3
269	.886	1.51	137.1	766	742	357	222	186	89	42	29	↓	.242	9 220	1.06	206.0	245.1
270	.887	1.44	137.2	733	709	349	222	188	88	42	28	↓	.256	8 930	1.03	208.8	246.5
271	↓	1.38	137.2	700	678	334	221	189	87	42	↓	↓	.270	8 650	.977	210.8	246.5
272	↓	1.31	137.3	666	645	327	220	190	85	41	↓	↓	.285	8 320	.959	213.2	247.1
273	↓	1.24	137.2	629	609	319	219	190	84	41	↓	42	.302	8 000	.923	215.0	246.5
274	.887	1.18	↓	597	579	309	217	188	80	40	28	42	.315	7 650	.882	217.0	246.5
275	.886	1.10	↓	560	543	298	213	184	78	39	28	41	.329	7 290	.841	219.2	246.2
276	↓	1.04	↓	528	512	286	207	177	73	38	27	40	.336	6 960	.803	221.1	246.0
277	↓	.965	↓	490	476	277	195	165	70	38	27	39	.337	6 580	.759	223.6	245.7
278	↓	.902	↓	458	445	263	179	152	66	37	28	39	.332	6 300	.726	226.1	245.7
279	↓	.834	137.1	424	411	242	159	137	64	38	28	38	.322	6 070	.700	228.2	245.1
280	.885	.767	137.0	390	378	221	142	124	61	37	29	37	.318	5 810	.670	230.1	244.3
281	.885	.698	137.0	355	344	199	118	103	54	37	29	37	.292	5 550	.639	233.1	244.3
282	.885	.632	137.0	321	312	184	112	98	52	36	29	36	.306	5 180	.591	235.6	243.0
283	.884	.564	136.9	286	278	169	113	98	53	36	28	33	.343	4 730	.545	237.7	242.6
284	.884	.495	273.6	251	245	163	118	103	58	40	28	28	.412	4 110	.473	240.5	242.1
285	.880	.461	136.2	234	231	194	164	150	102	52	12	16	.640	2 700	.312	229.0	235.5

TABLE VI. - Continued.

(g) Reduced temperature, 0.952

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, $g/(cm^2)(sec)$	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
173	0.908	0.560	140.6	285	282	249	208	189	99	35	8	14	0.664	2 960	0.341	278.9	285.7
174	.927	.708	143.5	360	352	230	180	171	169	111	23	23	.476	5 140	.592	316.7	323.2
175	.932	.832	144.2	423	413	254	181	171	169	121	27	24	.404	5 800	.669	317.5	333.6
176	.936	.965	144.8	490	478	285	188	171	165	125	31	26	.348	6 390	.737	315.9	342.5
177	.939	1.10	145.4	559	545	323	212	183	158	127	32	26	.328	6 860	.790	313.8	350.5
178	.943	1.24	145.9	631	617	364	249	211	153	126	34	27	.334	7 270	.838	311.2	358.2
179	.946	1.38	146.5	701	685	395	279	239	147	127	36	28	.341	7 750	.893	309.3	366.1
180	.949	1.45	146.9	735	717	413	291	250	150	129	37	28	.341	7 970	.918	310.5	372.2
181	.948	1.32	146.8	670	654	384	267	228	164	128	35	27	.340	7 480	.862	317.3	371.1
182	.946	1.17	146.5	595	581	348	235	202	177	126	33	26	.340	6 980	.804	323.3	366.5
183	.944	1.02	146.1	520	508	312	219	200	191	121	30	25	.385	6 400	.738	329.5	361.2
184	.943	.905	146.0	460	449	294	227	215	207	110	25	23	.467	5 730	.660	338.3	359.7
185	.941	.775	145.7	394	387	278	239	231	220	88	20	20	.588	4 850	.559	345.3	354.2
186	.943	.791	146.0	402	395	286	246	237	224	88	20	20	.591	4 850	.559	349.1	359.0
187	.948	.820	146.7	417	410	305	266	257	231	83	19	18	.615	4 800	.553	358.1	369.9
188	.962	1.10	148.9	557	546	366	285	264	242	109	27	22	.475	6 060	.698	363.4	403.5
189	.983	1.39	152.2	709	695	445	337	304	262	120	31	23	.429	6 950	.801	384.7	460.1
348	.945	1.18	146.3	597	581	341	228	196	173	128	34	27	.328	6 810	.785	320.6	363.8
349	.947	1.31	146.6	664	647	377	258	219	162	129	36	28	.329	7 220	.832	316.1	368.8
350	.949	1.44	146.9	733	714	403	285	244	153	130	38	30	.333	7 740	.892	311.6	373.4
351	.951	1.58	147.2	803	781	426	300	261	145	128	40	31	.325	8 280	.955	307.2	377.6
352	.953	1.72	147.5	872	849	449	308	267	132	123	43	31	.306	8 860	1.02	302.7	381.1
353	.954	1.86	147.7	946	919	474	312	269	116	116	45	32	.284	9 420	1.09	298.4	385.0
354	.956	1.93	147.9	982	955	486	314	270	115	115	46	32	.275	9 670	1.11	297.6	388.6
355	.954	1.78	147.7	907	882	460	311	270	131	123	44	31	.298	9 080	1.05	302.5	385.4
356	.953	1.66	147.5	841	819	438	307	267	143	128	41	31	.317	8 580	.989	306.7	382.3
357	.955	1.52	147.8	772	752	423	299	257	166	133	39	28	.333	8 000	.922	318.0	387.0
358	.954	1.38	147.6	701	682	396	275	235	178	130	36	28	.335	7 440	.858	324.0	383.8
359	.955	1.24	147.8	631	615	369	256	222	202	126	34	26	.353	6 860	.790	336.2	387.0
360	.953	1.11	147.5	563	548	342	249	225	214	120	31	25	.400	6 270	.722	342.6	382.3
361	.955	1.04	147.8	528	516	338	261	242	229	112	28	24	.457	5 780	.666	352.2	386.2
362	.953	.971	147.5	493	483	328	265	248	234	105	26	23	.503	5 380	.620	354.9	382.3
363	.954	.904	147.7	459	450	327	278	266	241	92	23	21	.579	4 800	.553	364.2	384.2
364	.953	.830	147.5	422	415	321	288	278	227	78	19	19	.658	4 174	.481	369.6	381.1
365	.952	.819	147.4	416	410	320	289	279	223	75	19	19	.671	4 080	.471	370.6	380.7
366	.954	.802	147.7	408	401	326	301	293	198	66	17	18	.718	3 730	.429	377.1	384.2
367	↓	.793	147.7	403	397	327	304	296	187	63	16	17	.734	3 610	.416	379.0	384.6
368		.786	147.6	399	394	327	305	297	181	62	15	17	.745	3 530	.406	379.1	383.8
369		.774	147.6	394	388	326	306	299	172	58	15	17	.760	3 420	.394	380.3	383.5
370	.953	.762	147.5	387	383	325	307	300	162	55	14	16	.774	3 290	.380	380.3	381.9
371	.953	.753	147.5	383	379	325	308	301	155	53	13	16	.787	3 180	.367	381.2	381.5
372	.952	.747	147.4	380	375	325	307	300	147	51	13	15	.790	3 100	.358	374.7	380.7
373	.951	.743	147.3	378	373	324	303	295	143	49	12	15	.782	3 030	.349	373.0	378.4
374	.949	.734	146.9	373	369	325	291	273	121	42	11	14	.732	2 740	.316	368.5	373.4

TABLE VI. - Continued.

(h) Reduced temperature, 1.031

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, g/(cm^2)(sec)	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
196	1.031	1.38	159.7	700	693	544	488	471	223	85	21	16	0.673	4 610	0.531	487.1	(a)
197	1.038	1.45	160.7	736	728	559	491	472	238	91	22	16	.641	4 920	.567	488.5	↓
198	1.029	1.31	159.3	668	662	539	493	477	201	75	18	15	.715	4 140	.478	493.3	
199	1.026	1.18	158.9	598	594	506	390	352	151	54	13	11	.588	3 120	.360	-----	
200	1.028	1.11	159.1	563	559	469	371	336	134	47	11	7	.596	2 550	.294	-----	
201	1.030	1.07	159.5	544	540	448	357	323	126	45	10	5	.593	2 360	.272	443.3	
202	1.032	1.04	159.9	529	524	429	351	310	120	43	10	4	.586	2 260	.261	412.1	
203	1.030	.971	159.5	493	488	392	333	310	113	40	9	2	.629	2 080	.240	364.5	
204	1.030	.904	159.6	459	454	355	280	261	107	38	9	2	.568	1 930	.222	312.7	
205	1.033	.839	160.0	426	421	326	248	218	98	35	8	2	.512	1 760	.202	262.7	
206	1.032	.769	159.8	391	386	300	228	200	86	32	7	3	.512	1 580	.182	220.8	
207	1.033	.697	160.0	354	350	272	207	182	76	27	6	4	.513	1 400	.162	182.0	
208	1.028	.436	159.2	221	218	170	129	113	38	16	3	6	.512	820	.094	73.3	
209	1.033	.362	159.8	184	182	142	107	94	31	12	3	6	.509	670	.077	50.2	
322	1.014	1.18	157.0	601	595	505	402	366	173	64	17	14	.609	3 610	.416	485.2	
323	1.023	1.31	158.4	664	655	528	478	464	210	80	20	16	.699	4 300	.496	481.7	
324	1.032	1.45	159.8	734	724	550	479	460	244	76	24	18	.626	5 070	.584	479.4	
325	1.040	1.58	161.0	803	790	571	481	456	266	109	28	19	.568	5 700	.657	476.7	
326	1.047	1.71	162.1	871	857	594	483	452	282	120	31	20	.519	6 310	.727	474.2	
327	1.053	1.86	163.1	943	926	617	485	449	297	129	34	20	.476	6 850	.790	470.9	
328	1.051	1.79	162.7	909	893	606	485	451	290	124	32	20	.497	6 590	.760	473.5	
329	1.045	1.65	161.7	839	825	583	484	456	275	114	29	19	.544	5 990	.691	476.6	
330	1.038	1.51	160.7	770	758	562	484	460	256	102	26	18	.599	5 360	.618	480.6	
331	1.030	1.38	159.5	701	691	541	483	466	228	87	22	16	.665	4 650	.536	484.4	
332	1.030	1.31	159.5	668	660	540	494	478	200	75	19	15	.716	4 060	.468	494.8	
333	1.033	1.24	159.9	632	626	532	426	382	167	61	16	12	.604	3 410	.393	506.4	
334	1.030	1.18	159.5	599	593	507	404	367	145	52	13	10	.612	2 960	.341	-----	
335	1.032	1.11	159.7	564	558	468	372	335	135	48	12	7	.594	2 530	.292	468.2	
336	1.032	1.04	159.8	529	523	430	344	307	122	43	11	5	.581	2 250	.260	414.4	
337	1.029	.977	159.3	507	501	407	345	299	117	41	10	4	.591	2 140	.247	387.9	
338	1.030	.975	159.4	495	489	394	337	309	115	41	10	3	.623	2 090	.241	368.0	
339	1.034	.903	160.0	459	451	353	277	253	108	38	10	3	.552	1 960	.226	306.2	
340	1.033	.838	159.9	426	419	327	249	218	98	35	9	3	.513	1 830	.211	262.6	
341	1.030	.770	159.5	392	385	301	229	200	86	31	8	4	.511	1 690	.195	224.4	
342	1.031	.703	159.6	357	352	275	209	183	76	27	7	4	.512	1 550	.179	188.3	
343	1.030	.636	159.4	323	318	249	189	166	68	24	6	5	.512	1 430	.165	154.3	
344	1.031	.566	159.6	288	282	222	169	147	60	21	6	5	.511	1 280	.148	120.5	
345	1.031	.433	159.7	220	216	170	129	112	37	16	4	8	.508	1 010	.117	70.9	
346	1.031	.298	159.6	152	148	116	88	77	25	10	3	9	.505	770	.089	35.2	
347	1.032	.164	159.7	83	81	65	49	41	15	5	6	9	.497	610	.070	12.8	
382	1.031	1.94	159.6	984	963	585	436	390	307	139	39	24	.397	7 950	.916	429.9	
383	1.031	1.85	159.5	941	922	576	439	397	303	135	37	23	.421	7 530	.869	435.5	
384	1.031	1.72	159.6	874	857	563	447	413	291	127	34	22	.473	6 880	.794	447.5	
385	1.032	1.65	159.7	839	823	559	454	425	283	121	32	21	.506	6 470	.746	454.9	
386	1.032	1.58	159.7	803	788	554	462	436	273	114	30	20	.543	6 040	.697	462.5	
387	1.030	1.51	159.5	765	752	546	466	444	261	107	27	19	.580	5 640	.650	468.1	
388	1.031	1.45	159.7	736	725	545	475	456	248	98	25	18	.619	5 210	.601	477.1	
389	↓	1.38	159.6	703	693	542	485	468	229	87	22	17	.666	4 680	.539	485.7	
390		1.31	159.6	667	659	540	495	479	199	74	19	15	.719	4 060	.469	496.2	
391		1.24	159.5	631	624	529	428	384	171	62	16	13	.608	3 470	.400	506.3	

[a] Not applicable.

TABLE VI. - Concluded.

(i) Reduced temperature, 1.51

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, g/(cm^2)(sec)	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
36	1.57	0.429	242.7	218	215	168	125	109	35	12	14	22	0.499	560	0.065	10.1	(a)
37	1.55	.425	239.6	216	214	166	124	108	35	11	3	8	.500	580	.067	10.1	↓
38	1.50	.562	233.0	286	282	221	164	145	46	15	18	29	.507	760	.087	11.4	
39	1.50	.562	232.2	286	281	221	163	145	45	15	4	8	.507	770	.089	11.7	
40	1.49	.425	230.3	216	213	168	124	110	34	11	3	8	.507	570	.065	10.1	
41	1.48	.429	229.3	218	215	170	125	111	34	11	12	20	.508	580	.067	10.1	
42	1.50	.699	232.0	355	351	275	203	182	55	19	9	19	.511	940	.108	17.2	
43	1.50	.698	232.3	355	351	274	202	182	55	19	5	7	.512	940	.108	17.1	
44	1.51	.835	234.3	424	419	327	242	217	66	22	6	8	.512	1 120	.129	22.0	
45	1.53	.969	236.6	492	487	378	280	252	76	25	6	8	.512	1 290	.149	27.1	
46	1.54	1.11	239.1	562	555	426	320	287	85	29	7	8	.511	1 460	.168	32.2	
47	1.56	1.24	241.6	630	624	469	357	320	95	31	8	9	.508	1 600	.185	37.6	
48	1.58	1.38	244.2	700	694	562	392	351	102	33	9	9	.502	1 730	.199	43.0	
49	1.58	1.38	244.9	700	694	543	389	351	99	32	12	32	.501	1 640	.189	42.2	

(j) Reduced temperature, 1.67

51	1.72	0.428	266.9	217	213	167	123	107	35	11	2	7	0.493	530	0.061	10.1	(a)
52	1.68	.430	260.8	218	214	167	123	108	35	11	17	25	.493	550	.063	↓	↓
53	1.66	.565	257.5	287	282	219	162	143	46	15	3	7	.497	730	.084		
54	1.66	.699	256.5	355	351	273	202	177	57	19	3	7	.499	900	.104		
55	1.66	.836	257.1	425	419	326	241	212	68	23	5	7	.498	1 090	.126	13.0	
56	1.67	.971	258.3	493	487	378	280	246	80	26	6	8	.499	1 270	.146	16.3	
57	1.68	1.04	259.9	561	555	431	319	280	91	31	7	8	.499	1 450	.167	19.6	
58	1.69	1.24	261.9	631	624	484	358	315	101	34	8	9	.498	1 630	.188	22.9	
59	1.71	1.38	264.0	699	693	536	398	349	112	38	9	10	.499	1 810	.208	26.2	
60	1.67	.969	258.9	492	486	378	280	246	79	26	6	8	.499	1 270	.146	16.0	
61	1.65	.699	255.0	355	350	273	202	177	57	19	4	7	.498	910	.105	10.1	
62	1.63	.429	251.6	218	213	167	123	108	35	11	2	7	.494	550	.064	10.1	

[a] Not applicable.

TABLE VII. - ELLIPTICAL NOZZLE DATA FOR NITROGEN

(a) Reduced temperature, 0.645

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, g/(cm^2)(sec)	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
425	0.651	0.439	82.2	150	142	.50	21	14	12	9	8	9	0.097	4 250	0.708	16.5	17.2
426	.648	.640	81.8	219	208	68	24	↓	12	9	6	7	.066	5 230	.870	15.5	16.6
427	.645	.832	81.5	284	271	86	27	↓	12	9	↓	5	.049	6 020	1.00	14.8	16.1
428	.643	1.04	81.2	355	338	107	31	↓	11	8	↓	4	.039	6 760	1.12	14.0	15.5
429	.641	1.25	80.9	426	405	127	34	↓	↓	↓	↓	↓	.033	7 430	1.24	13.3	15.1
430	.638	1.44	80.6	492	470	145	37	13	↓	↓	↓	↓	.027	8 020	1.33	12.7	14.6
431	.636	1.64	80.4	560	535	161	41	↓	↓	↓	5	↓	.024	8 590	1.43	12.1	14.2
432	.634	1.85	80.1	631	603	179	44	↓	10	↓	↓	↓	.021	9 140	1.52	----	13.8
433	.632	2.06	79.8	704	672	199	49	↓	↓	7	↓	↓	.019	9 680	1.61	----	13.4
434	.633	1.94	80.0	664	634	188	47	↓	↓	7	↓	↓	.020	9 400	1.56	----	13.6
435	.636	1.75	80.3	599	571	171	43	↓	↓	8	6	↓	.022	8 900	1.48	----	14.2
436	.638	1.55	80.6	529	504	153	39	14	11	↓	↓	↓	.026	8 320	1.38	12.5	14.5
437	.640	1.34	80.9	459	437	136	36	↓	11	↓	↓	↓	.030	7 740	1.29	13.1	15.0
438	.643	1.15	81.2	392	373	117	33	↓	12	↓	↓	↓	.036	7 120	1.18	13.8	15.5
439	.645	.944	81.5	323	307	98	29	↓	↓	↓	↓	↓	.045	6 420	1.07	14.5	16.0
440	.648	.746	81.8	255	243	78	26	↓	↓	9	↓	5	.055	5 680	.946	15.4	16.6
441	.649	.645	81.9	220	209	69	24	12	↓	↓	↓	6	.066	5 250	.873	15.8	16.8
442	.651	.546	82.2	187	177	59	23	14	↓	↓	7	8	.078	4 800	.798	16.3	17.2
443	.654	.338	82.6	115	110	42	20	15	13	↓	10	10	.130	3 680	.612	17.4	18.0
444	.656	.285	82.8	97	92	37	19	15	13	↓	↓	↓	.154	3 320	.552	17.9	18.4
445	.657	.233	83.0	80	76	33	↓	16	13	↓	↓	↓	.195	2 940	.489	18.4	18.8
446	.659	.185	83.2	64	60	28	↓	16	12	↓	↓	↓	.254	2 500	.416	18.8	19.2
447	.663	.133	83.7	46	43	24	↓	16	11	10	↓	↓	.352	1 960	.327	20.0	20.1
448	.667	.083	84.3	28	27	20	17	14	10	9	↓	↓	.509	1 270	.211	21.2	21.3

(b) Reduced temperature, 1.031

Reading	Reduced temperature, T_r	Reduced pressure, P_r	Stagnation temperature, T_0	Pressure at station -									Ratio of throat pressure to stagnation pressure, P_t/P_0	Maximum mass flow rate, G_{max}, g/(cm^2)(sec)	Reduced mass flow rate, G_r	Saturation pressure, P_{sat}, at -	
				1	2	3	4	5	6	7	8	9				Stagnation entropy, S_0	Stagnation temperature, T_0
453	1.030	2.13	130.1	728	709	408	289	254	206	97	28	18	.349	6 070	1.01	281.3	(a)
454	1.030	2.05	130.1	700	682	401	290	257	206	95	28	18	.367	5 850	.973	284.9	↓
455	1.032	1.95	130.3	666	650	396	294	264	207	94	26	17	.397	5 510	.917	-----	↓
456	1.032	1.84	130.3	630	615	388	297	270	203	90	25	17	.429	5 150	.857	296.9	↓
457	1.032	1.75	130.3	598	584	382	300	277	198	86	23	16	.464	4 840	.805	301.5	↓
458	1.031	1.65	130.2	562	550	374	304	285	190	81	21	15	.507	4 470	.743	307.4	↓
459	↓	1.55	↓	528	518	370	311	296	180	74	19	14	.561	4 030	.670	314.5	↓
460	↓	1.45	↓	495	486	366	319	307	167	66	17	13	.621	3 560	.593	321.4	↓
461	↓	1.35	↓	462	455	364	329	320	146	54	14	12	.692	3 030	.504	329.5	↓
462	1.030	1.24	130.1	425	419	355	289	262	115	42	11	11	.618	2 390	.397	339.0	↓
463	1.030	1.15	130.1	392	388	328	260	236	96	33	9	8	.602	1 830	.305	335.9	↓
464	1.031	1.05	130.3	358	354	292	232	209	83	29	9	6	.583	1 540	.256	288.7	↓
465	1.033	.950	130.4	325	320	254	211	198	77	27	8	4	.610	1 370	.228	235.5	↓
466	1.030	.846	130.1	289	284	222	169	150	68	24	7	5	.521	1 190	.197	190.1	↓
467	↓	.745	↓	254	250	195	147	129	55	20	6	6	.506	990	.165	145.8	↓
468	↓	.642	↓	219	215	168	127	111	45	17	5	6	.505	810	.134	106.3	↓
469	↓	.536	↓	183	179	140	106	92	35	13	4	7	.503	620	.104	73.3	↓
470	1.032	.437	130.3	149	147	115	86	74	25	10	4	8	.498	490	.082	49.5	↓
471	1.031	.336	130.2	115	112	88	66	57	19	8	6	8	.500	370	.062	30.4	↓
472	1.029	.233	130.0	80	70	61	46	40	13	5	7	10	.500	200	.034	16.0	↓

[a] Not applicable.

TABLE VIII. - CRITICAL CONSTANTS USED IN REDUCING PARAMETERS

Fluid	Critical pressure, P_c, N/cm^2	Critical temperature, T_c, K	Critical density, ρ_c, g/cm^3	Compressibility factor, Z_c	Mass flow rate normalizing parameter, G^*, g/(cm^2)(sec)
Oxygen	508.3	154.78	0.4325	0.2922	8673.9
Nitrogen	341.7	126.3	.3105	.2937	6010.4

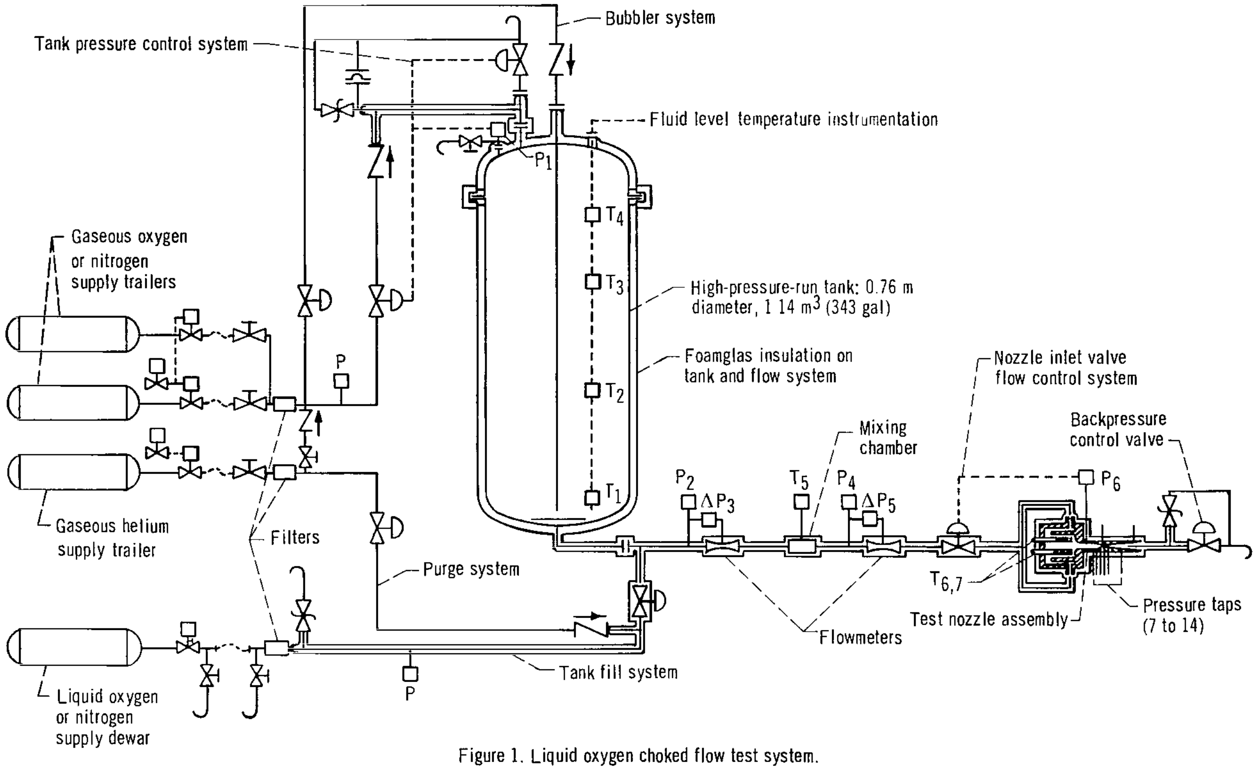

Figure 1. Liquid oxygen choked flow test system.

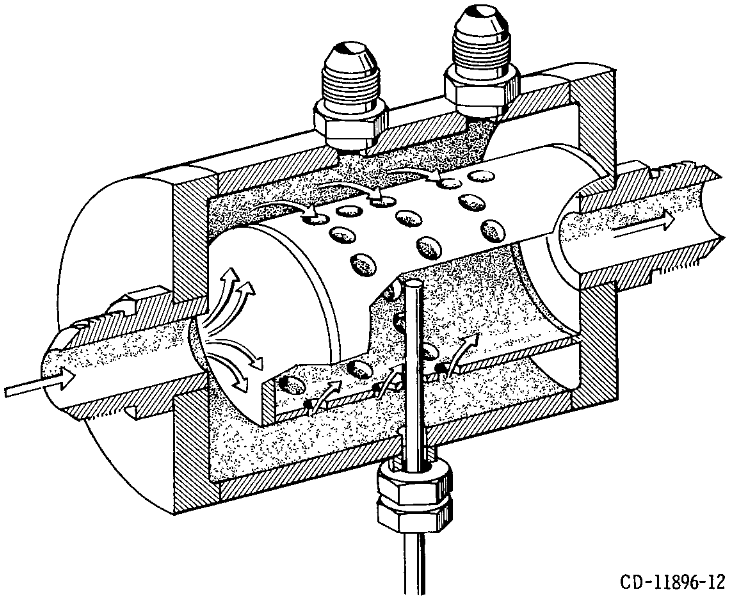

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Figure 2. - Cylindrical, perforated, baffle-type mixing chamber.

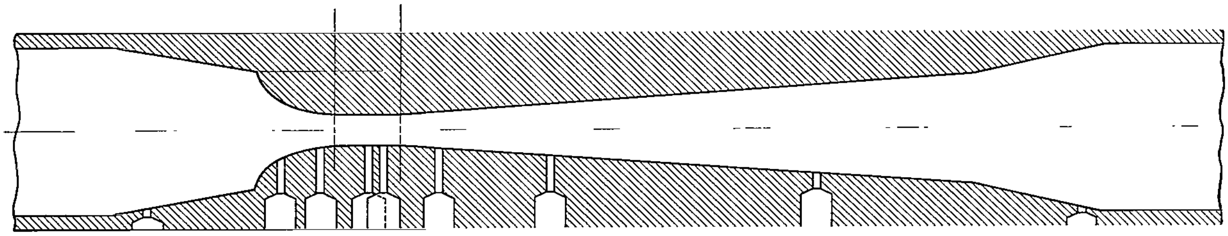


Figure 4. - Elliptical-convergence test section.

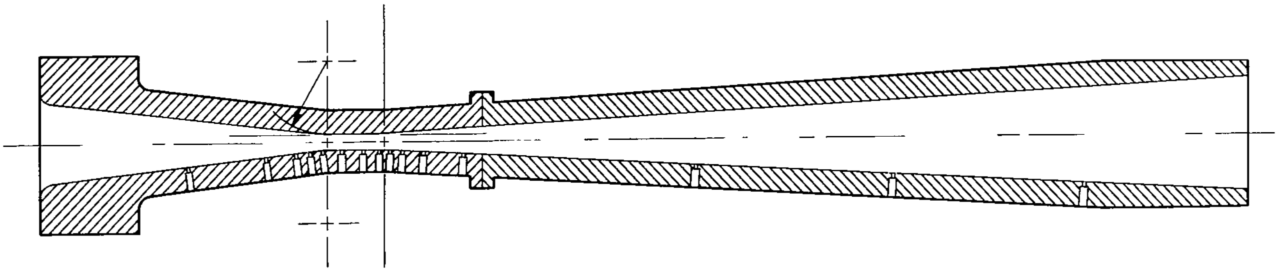


Figure 3. - Conical-convergence test section.

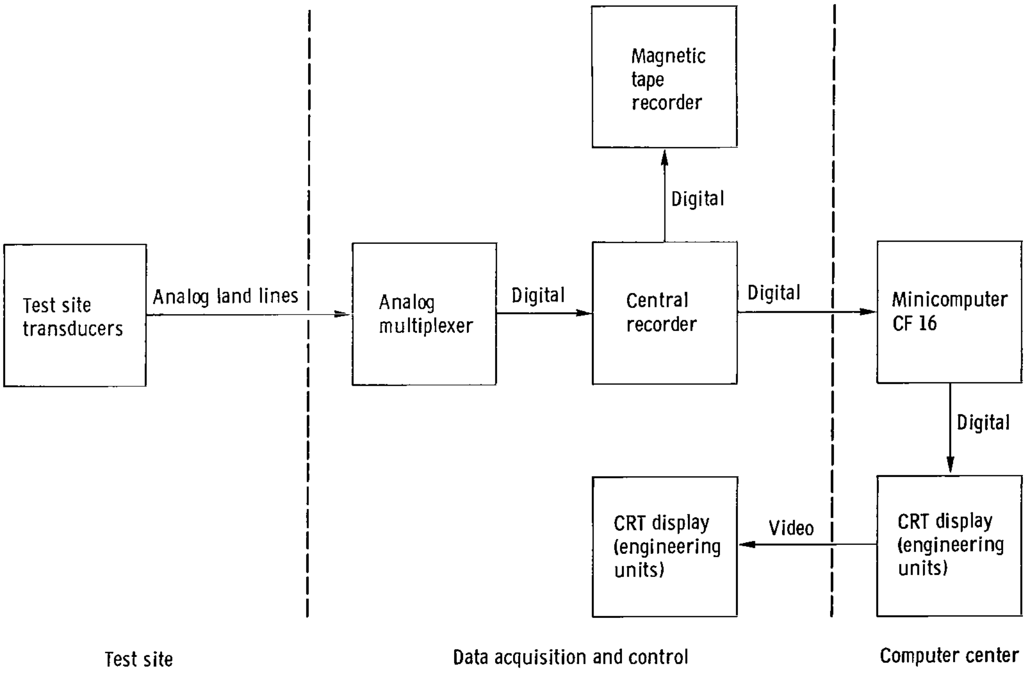
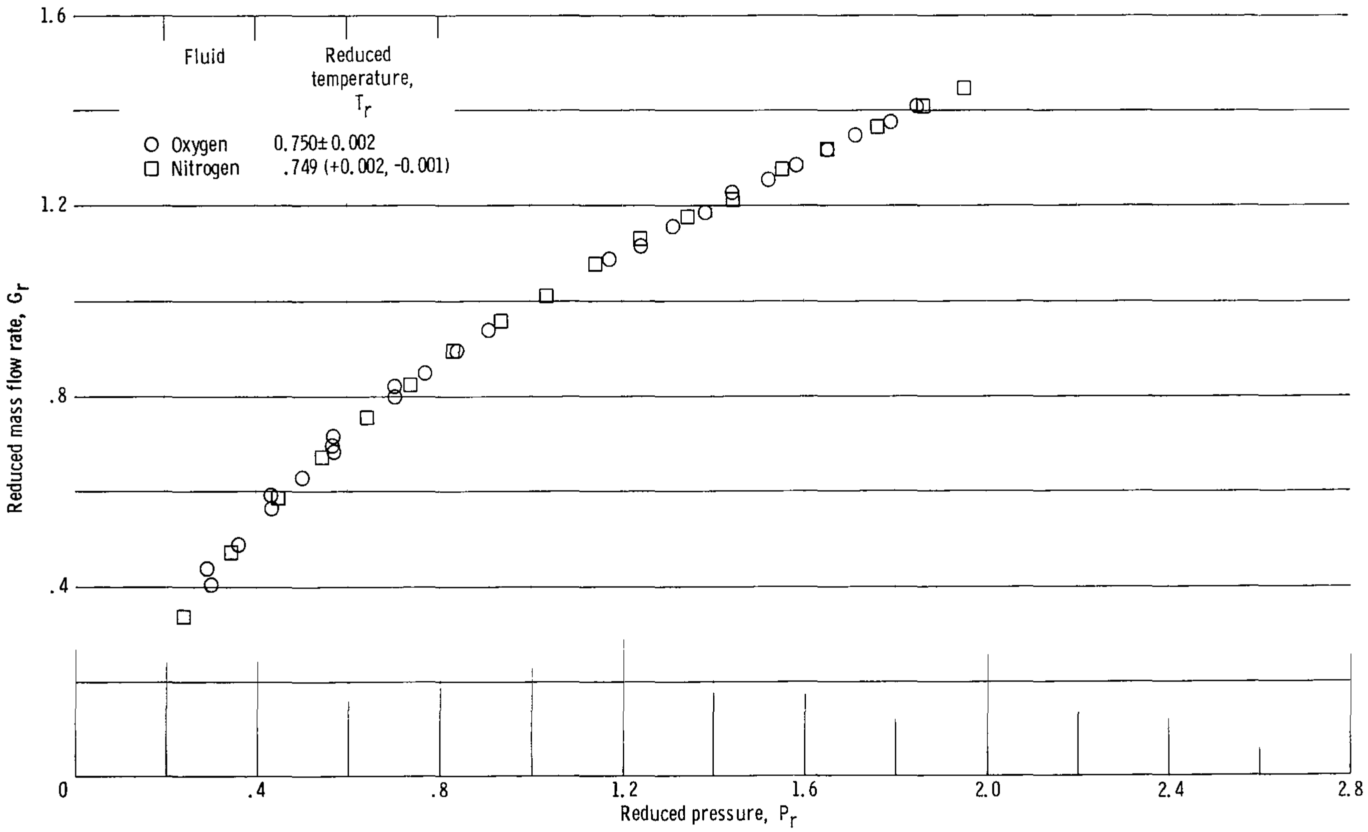
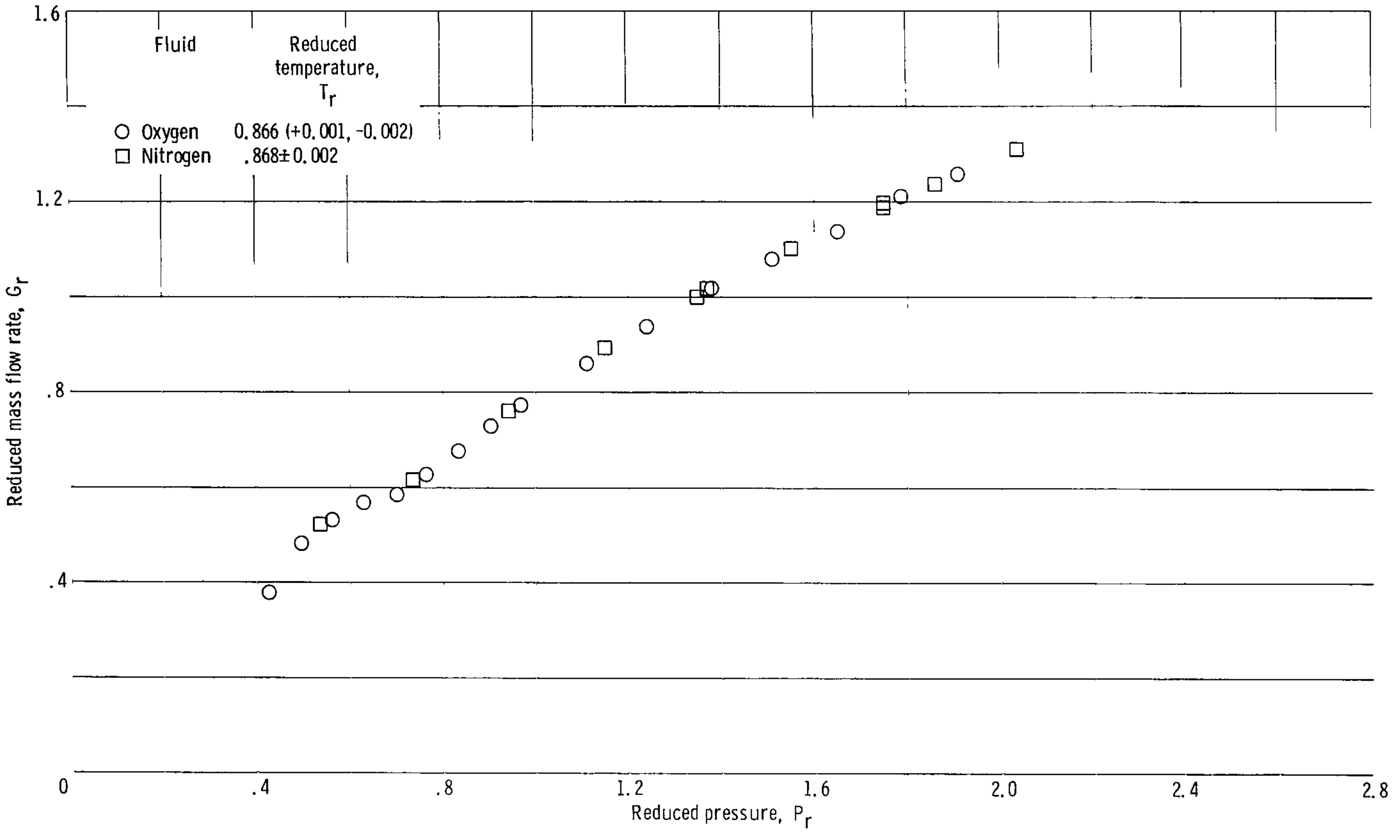


Figure 5. - Data path for liquid-oxygen choked flow test runs.



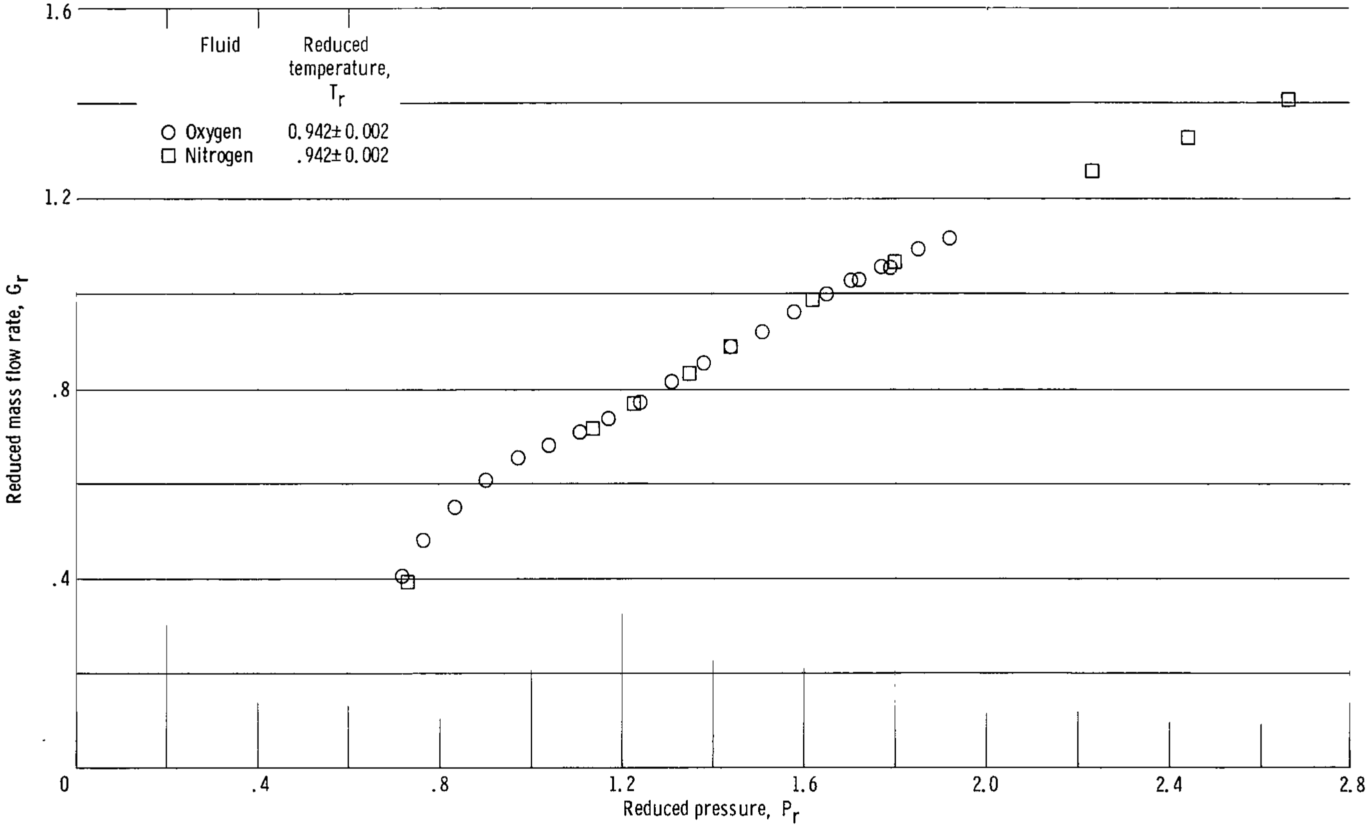
(a) Choked flow rate for reduced temperature of ~0.750.

Figure 6. - Choked flow rate and pressure ratio as function of reduced pressure and temperature - conical nozzle.



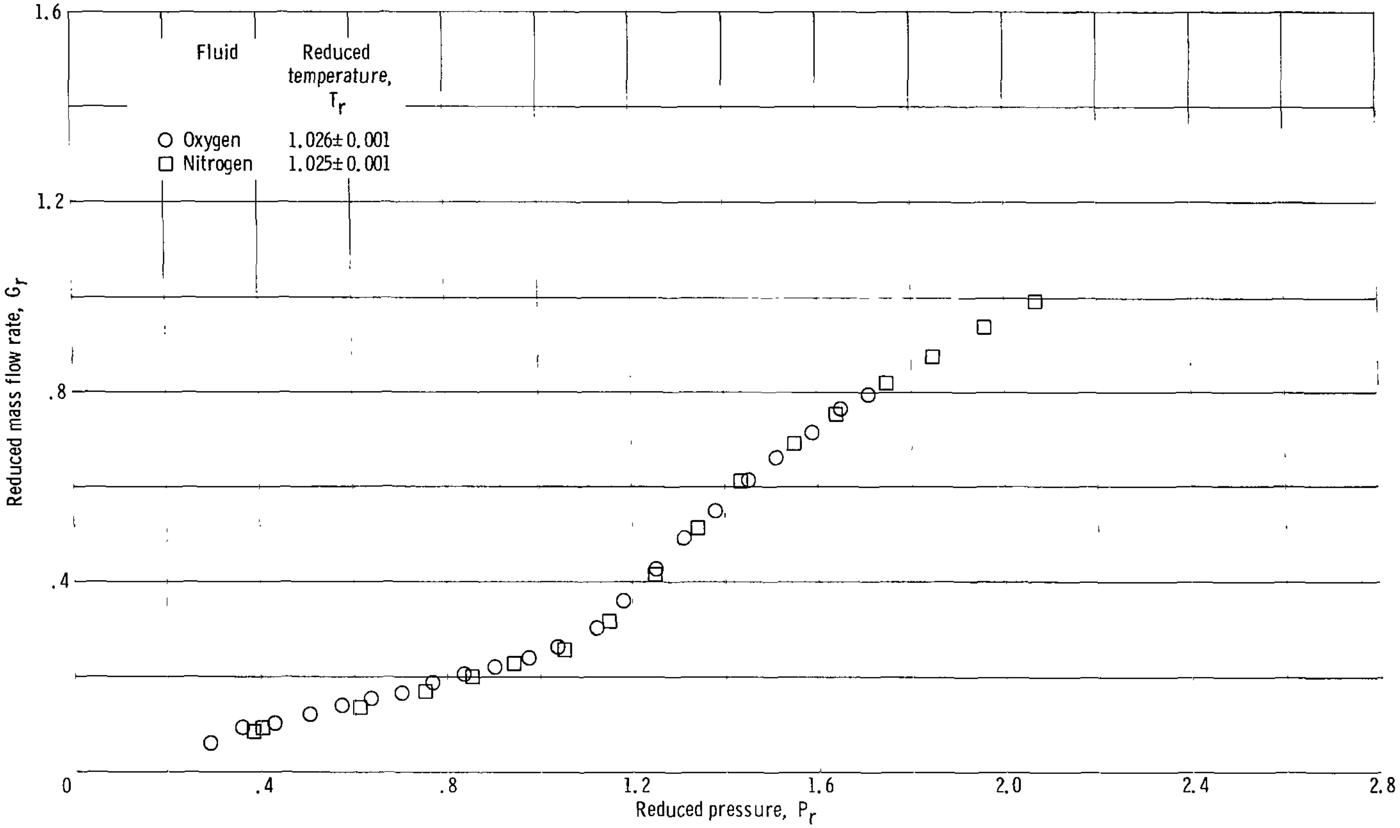
(b) Choked flow rate for reduced temperature of ~0.866.

Figure 6. - Continued.



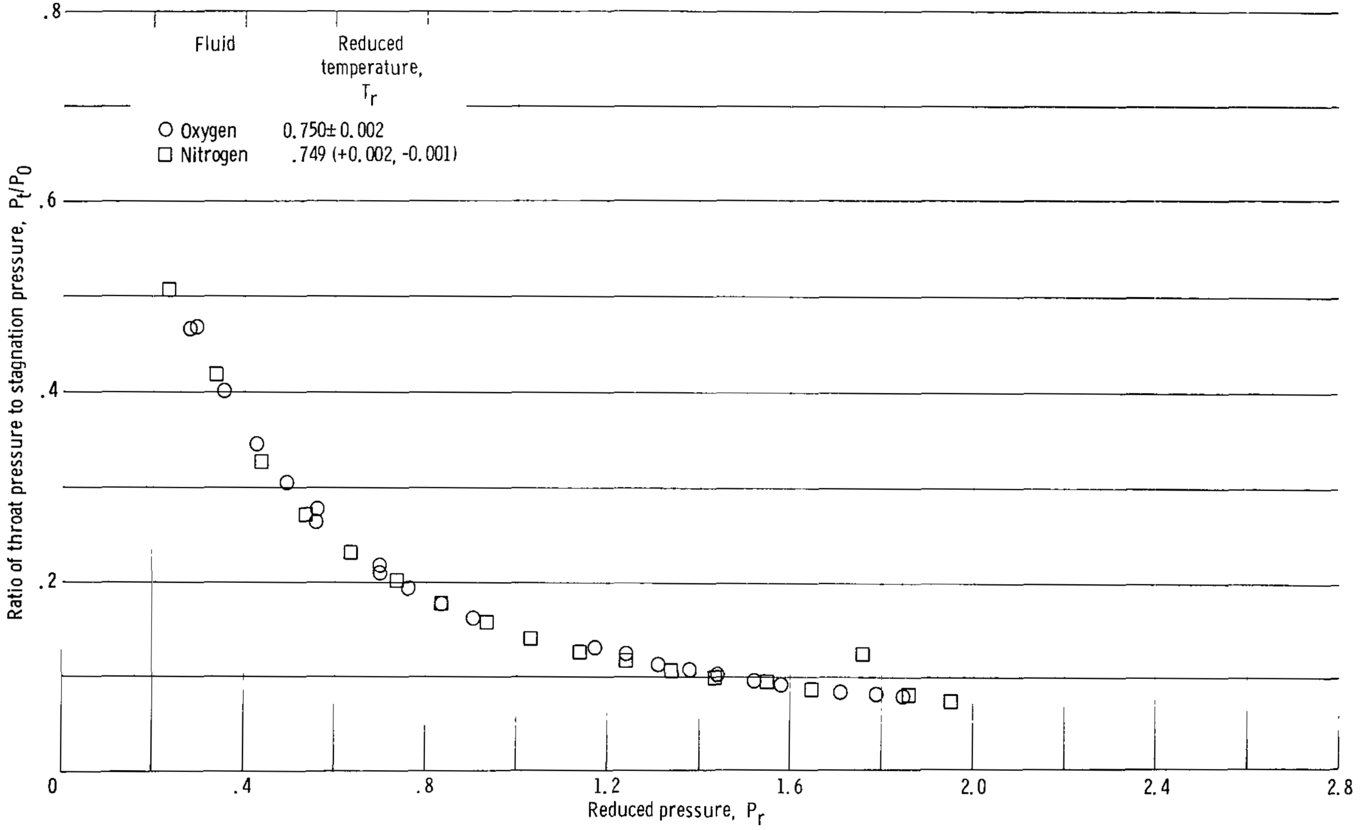
(c) Choked flow rate for reduced temperature of ~0.942.

Figure 6. - Continued.



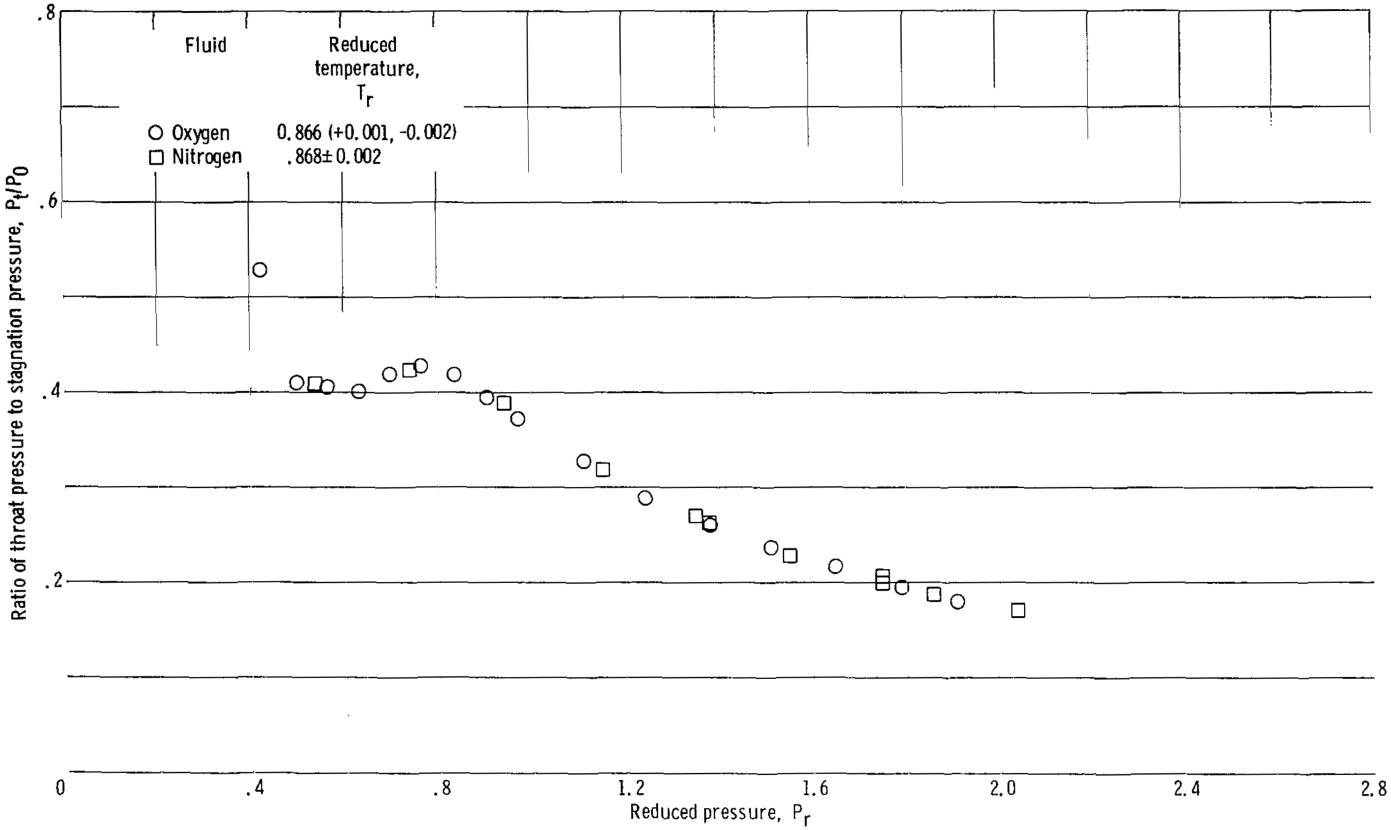
(d) Choked flow rate for reduced temperature of ~1.025.

Figure 6. - Continued.



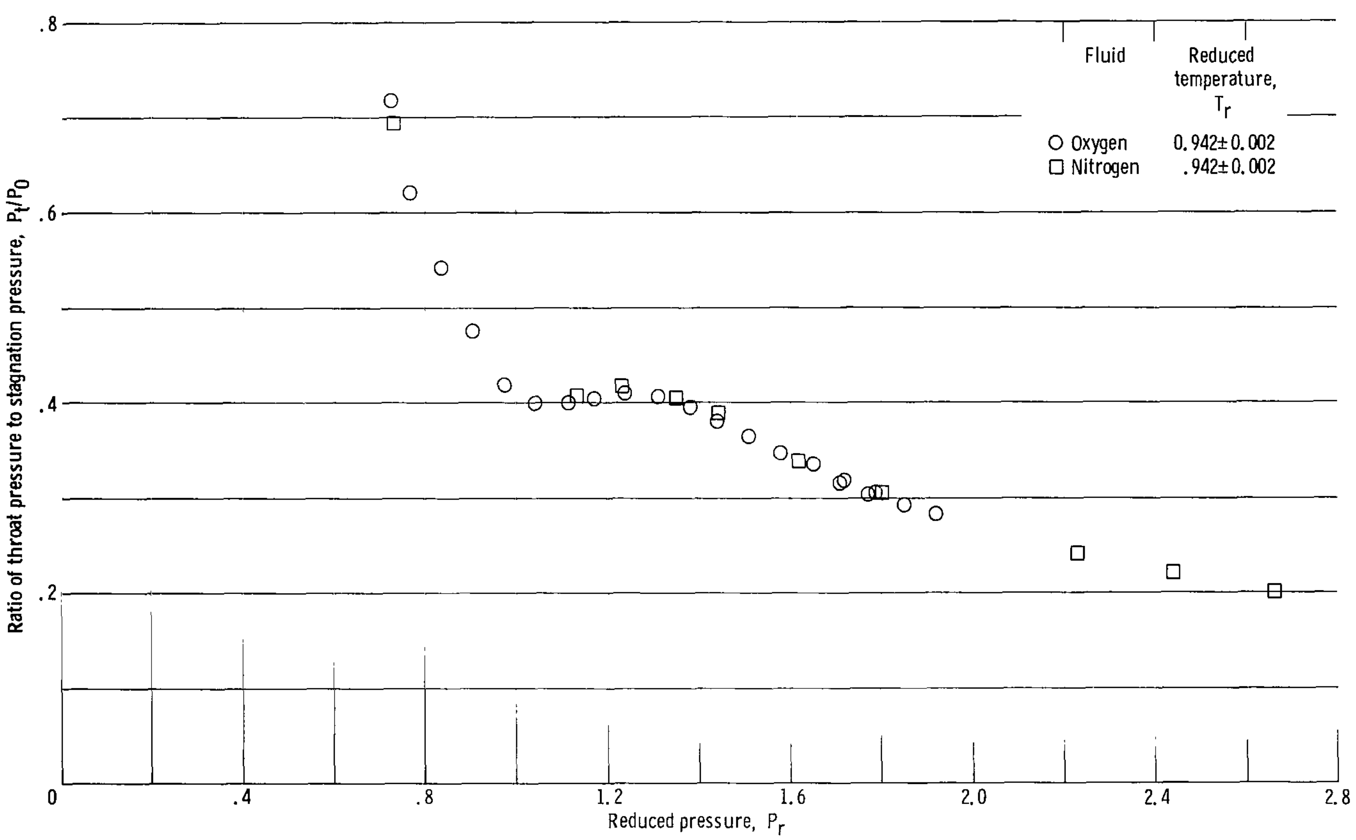
(e) Pressure ratio for reduced temperature of ~0.750.

Figure 6. - Continued.



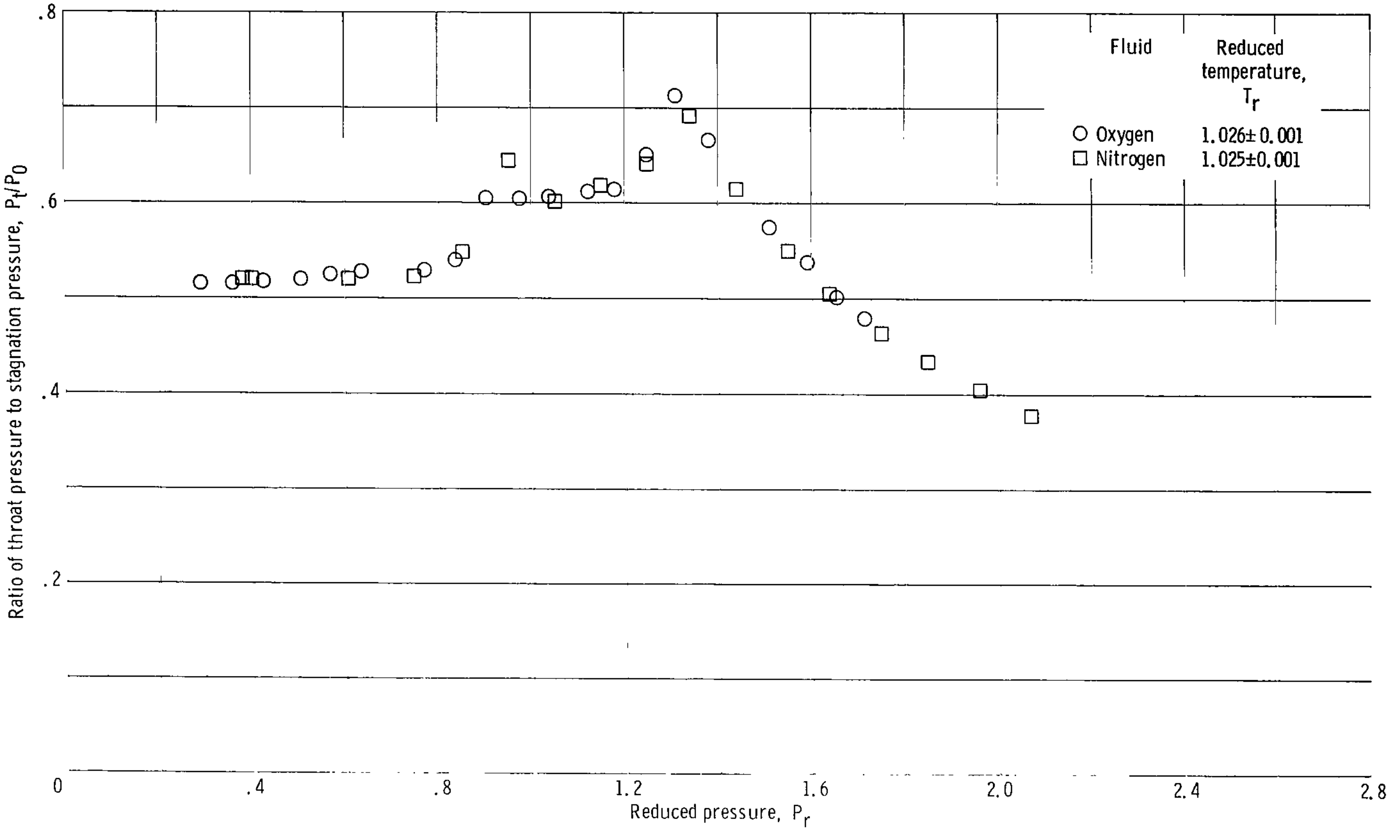
(f) Pressure ratio for reduced temperature of ~0.866.

Figure 6. - Continued.



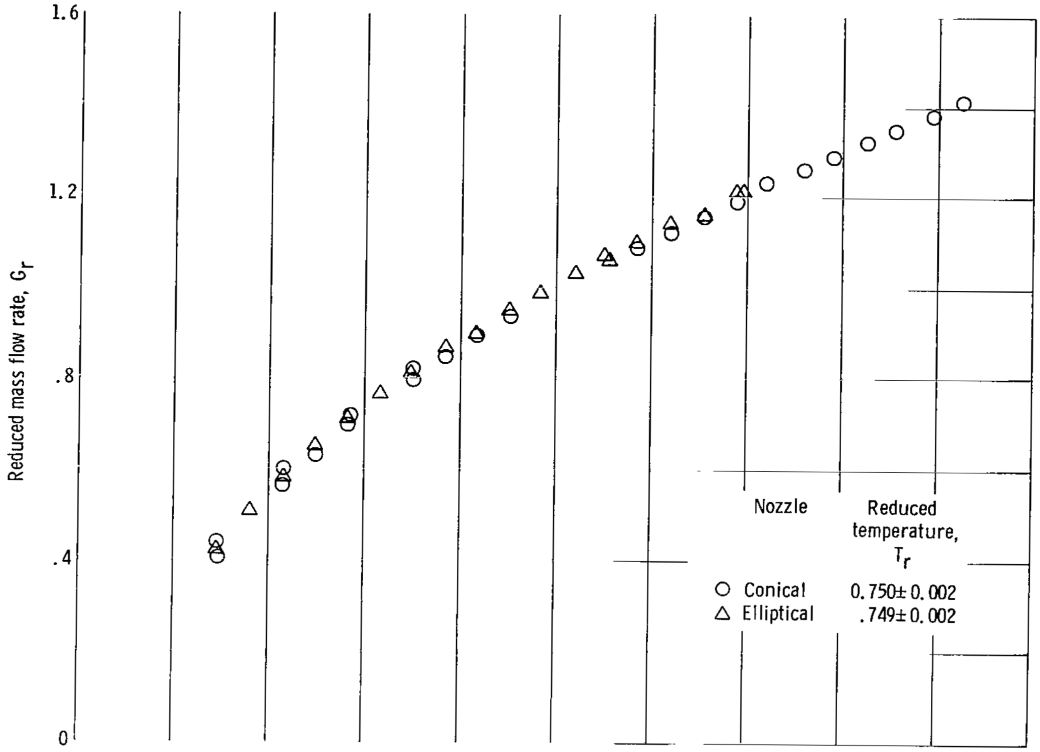
(g) Pressure ratio for reduced temperature of ~0.942.

Figure 6. - Continued.

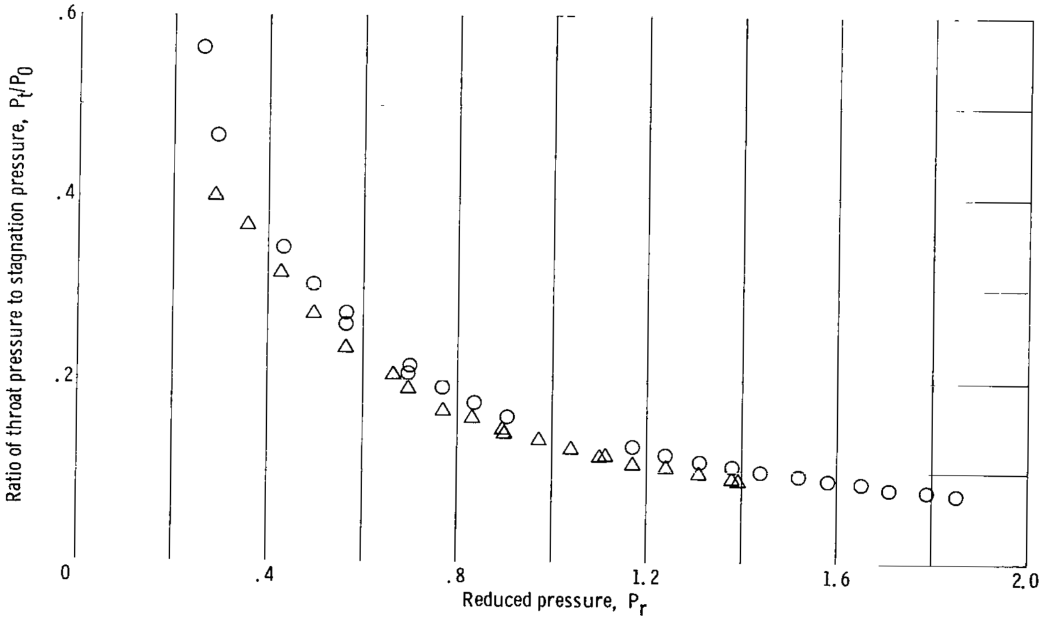


(h) Pressure ratio for reduced temperature of ~1.025.

Figure 6. - Concluded.

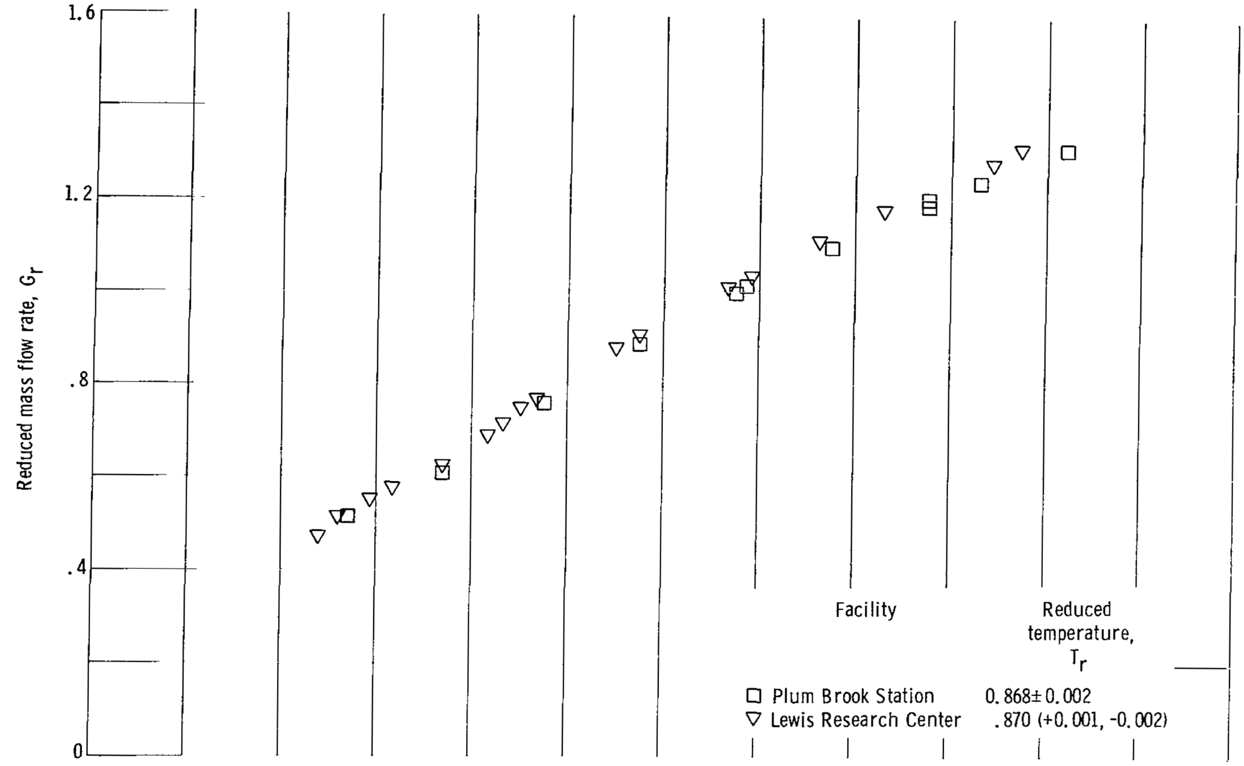


(a) Choked flow rate.

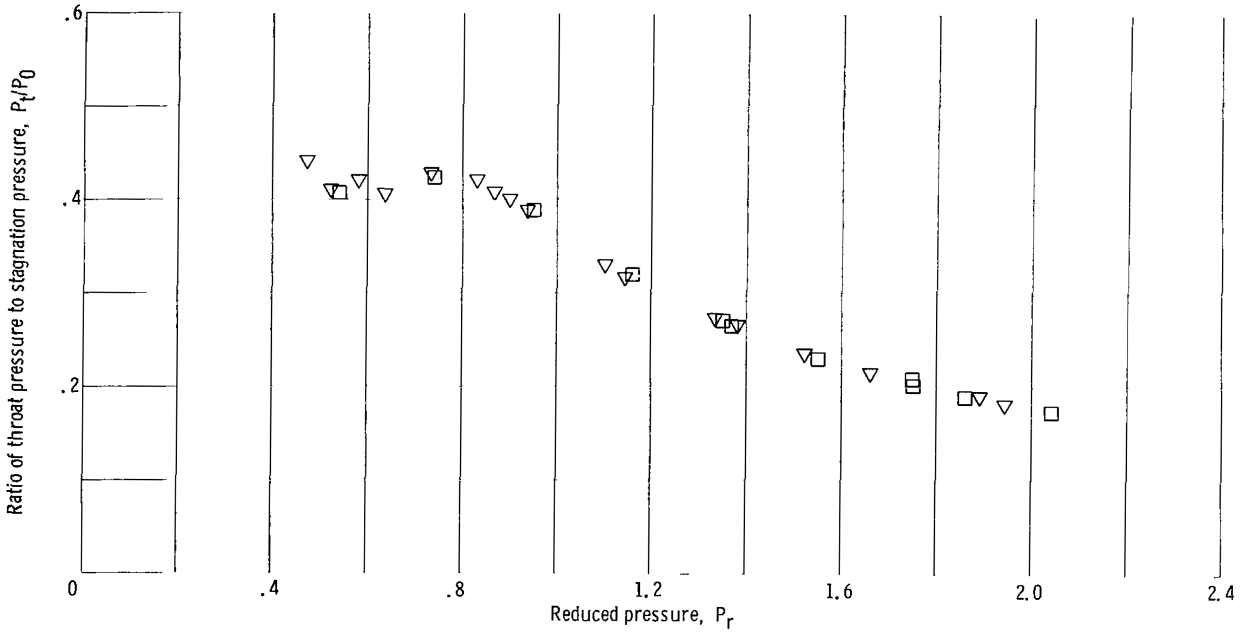


(b) Pressure ratio.

Figure 7. - Choked flow rate and pressure ratio as function of reduced pressure for oxygen in both conical and elliptical nozzles.



(a) Choked flow rate.



(b) Pressure ratio.

Figure 8. - Choked flow rate and pressure ratio as function of reduced pressure for nitrogen in two test facilities - conical nozzle.

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