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ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD

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SOUTH NORWALK, CONNECTICUT

Nash Orifice Kit, containing complete set of standardized Nash Orifices described in this bulletin.

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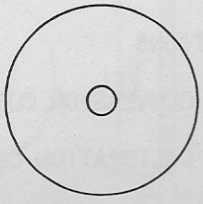

THE NASH ENGINEERING COMPANY
SOUTH NORWALK, CONNECTICUT, U. S. A.
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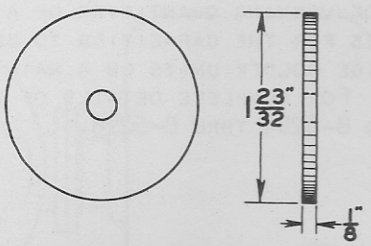
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD

CHAPTER I

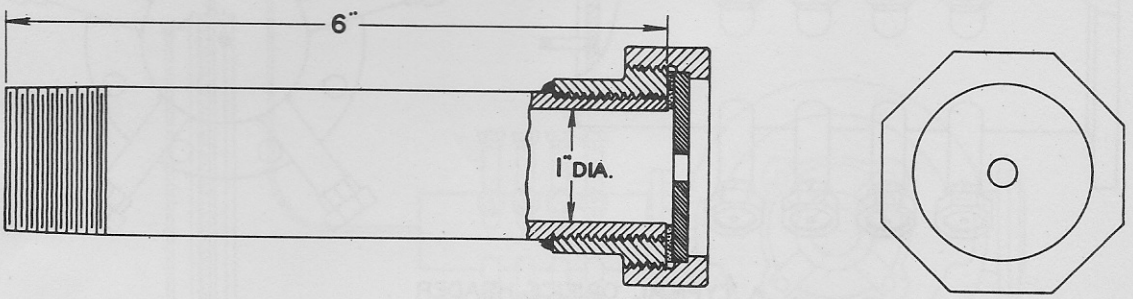
INTRODUCTION

MANY YEARS AGO THE NASH ENGINEERING COMPANY FOUND THAT A SPECIAL TYPE OF ORIFICE OFFERED THE MOST SATISFACTORY METHOD OF ACCURATELY MEASURING AIR IN THE TESTING OF NASH AIR COMPRESSORS AND VACUUM PUMPS. STANDARDIZED ORIFICE EQUIPMENT FOR THIS WORK HAS BEEN DESIGNED AND CARRIED TO A HIGH DEGREE OF PERFECTION BY EXTENSIVE INVESTIGATION AND CALIBRATION CONDUCTED IN THE ENGINEERING DEPARTMENT LABORATORIES OF THE NASH ENGINEERING COMPANY AT SOUTH NORWALK, CONN.

THIS BOOKLET GIVES A COMPLETE DESCRIPTION OF THESE ORIFICES AND THEIR USE. WHEN USED WITH THE ORIFICE EQUIPMENT SPECIFIED, THIS METHOD PROVIDES A CONVENIENT WAY TO TEST ROTARY VACUUM PUMPS AND COMPRESSORS. THE RESULTS SECURED ARE ACCURATE WITHIN 2%.



DETAIL OF STD. ORIFICE PLATE



DETAIL OF STD. ORIFICE HOLDER UNIT

CHAPTER II

DESCRIPTION OF EQUIPMENT

TYPE OF ORIFICE

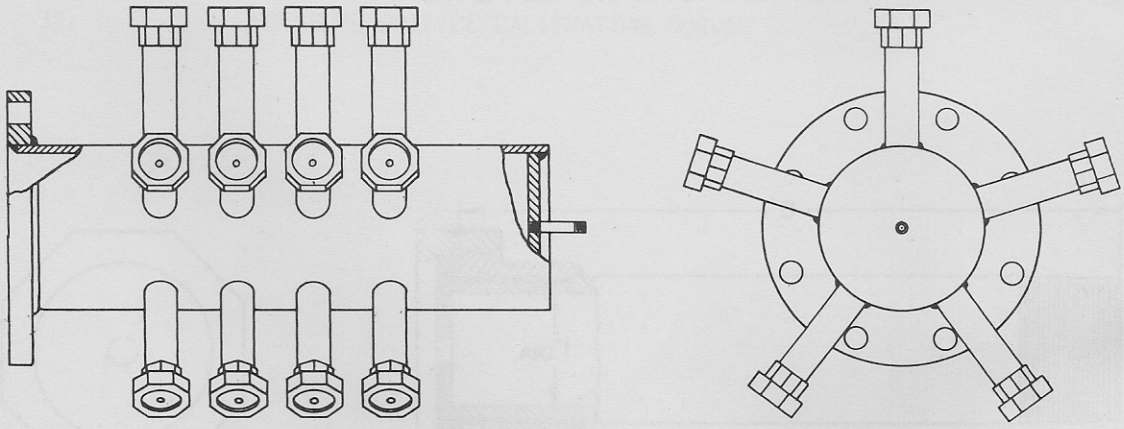
THE ORIFICES ARE MADE OF HARDENED STAINLESS STEEL PLATES OR ITS EQUIVALENT, GROUND TO A UNIFORM THICKNESS OF 1/8". THE HOLES THRU THESE ORIFICE PLATES ARE REAMED TO SIZE, EXTREME CARE BEING TAKEN TO OBTAIN A SHARP, SQUARE EDGE. IT IS ESSENTIAL THAT THE SHARPNESS OF THIS EDGE BE MAINTAINED, OTHERWISE THE ACCURACY OF THE RESULTS CAN NOT BE GUARANTEED. A TYPICAL ORIFICE IS SHOWN ON PAGE 1. FOR COMPLETE DETAILS SEE DRAWING D-8781.

ORIFICE HOLDER UNIT

A STANDARDIZED ORIFICE HOLDER UNIT CONSISTS OF A 1"x6" PIPE NIPPLE EQUIPPED WITH A SPECIAL CLAMP FOR HOLDING THE ORIFICE IN PLACE. IT IS ABSOLUTELY NECESSARY THAT THE ORIFICE PLATE BE USED ONLY IN CONNECTION WITH THIS STANDARD ORIFICE HOLDER UNIT. THE CALIBRATION DATA HEREIN IS BASED UPON THIS USE ONLY. THIS HOLDER IS ILLUSTRATED ON PAGE 1. FOR COMPLETE DETAILS SEE DRAWING D-8775.

MULTIPLE ORIFICE HEADER

FOR THE MEASUREMENT OF VARYING QUANTITIES OF AIR, ORIFICE HEADERS ARE MADE UP IN APPROPRIATE SIZES FOR THE CAPACITIES TO BE MEASURED BY INSTALLING MULTIPLES OF THE ORIFICE HOLDER UNITS ON A MAIN HEADER. A TYPICAL ORIFICE HEADER IS SHOWN BELOW. FOR COMPLETE DETAILS OF THESE HEADERS SEE DRAWINGS C-6056 THRU C-6060 AND B-5294 THRU B-5298.



A TYPICAL ORIFICE HEADER

ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD

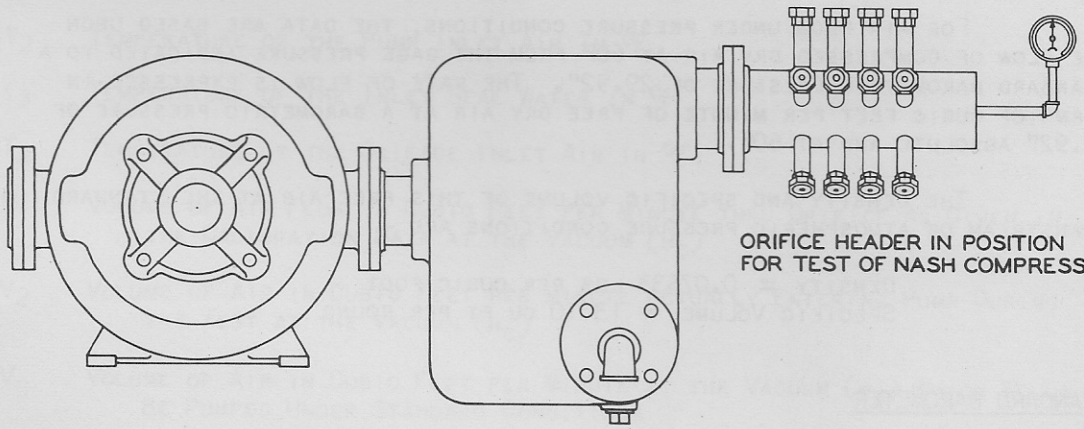
CHAPTER III

APPLICATION TO VACUUM PUMPS AND COMPRESSORS

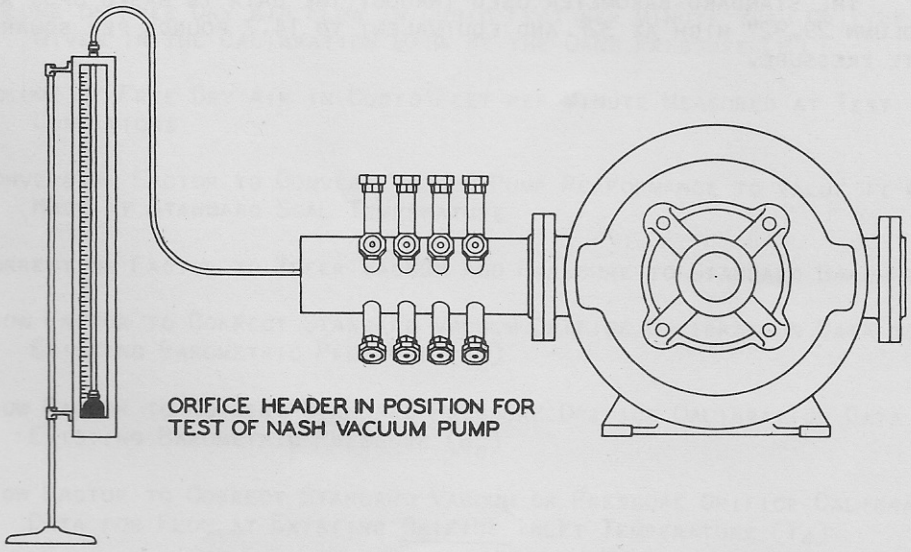
FOR THE TESTING OF A VACUUM PUMP, THE APPROPRIATE ORIFICE HEADER IS BOLTED TO THE INLET OR SUCTION CONNECTION OF THE PUMP WITH A MERCURY U TUBE MANOMETER OR MERCURY COLUMN VACUUM GAGE CONNECTED TO THE PRESSURE CONNECTION OF THE ORIFICE HEADER AS ILLUSTRATED BELOW. IN THE TESTING OF NASH COMPRESSORS, THE APPROPRIATE ORIFICE HEADER IS BOLTED TO THE DISCHARGE CONNECTION OF THE COMPRESSOR SEPARATOR WITH SUITABLE CALIBRATED PRESSURE GAGE ATTACHED TO THE PRESSURE CONNECTION OF THE ORIFICE HEADER, ALSO ILLUSTRATED BELOW.

THE VACUUM PUMP OR COMPRESSOR MAY BE TESTED OVER ITS COMPLETE VACUUM OR PRESSURE RANGE BY VARYING EITHER THE SIZE OR THE NUMBER OF ORIFICES LEFT OPEN ON THE ORIFICE HEADER. THE ORIFICE HEADER THEREFORE SERVES AS A PRESSURE CONTROLLING DEVICE WHILE AT THE SAME TIME SERVING AS A FLOW METER.

THE SUSTAINED PRESSURE OR VACUUM MAINTAINED ON THE ORIFICE HEADER WHEN REFERRED TO THE ACCOMPANYING ORIFICE CALIBRATION DATA AT THAT PARTICULAR PRESSURE OR VACUUM, INDICATES, AFTER APPLYING ANY NECESSARY CORRECTIONS, THE VOLUME OF AIR FLOWING THRU EACH ORIFICE. THE TOTAL OF THE AIR FLOW THRU ALL OPEN ORIFICES AS THUS OBTAINED, OF COURSE, INDICATES THE TOTAL AIR FLOW.



ORIFICE HEADER IN POSITION FOR TEST OF NASH COMPRESSOR



ORIFICE HEADER IN POSITION FOR TEST OF NASH VACUUM PUMP

CHAPTER IV

STANDARD CONDITIONS DEFINED

THE CALIBRATION VALUES GIVEN FOR AIR FLOW UNDER VACUUM AND PRESSURE CONDITIONS INDICATE THE FLOW OF AIR UNDER THE FOLLOWING DESIGNATED STANDARD CONDITIONS ONLY.

VACUUM

FOR FLOW INTO A VACUUM, THE DATA ARE BASED UPON THE FLOW OF FREE ATMOSPHERIC AIR AT 60F, 50% RELATIVE HUMIDITY, FROM A BAROMETRIC PRESSURE OF 29.92" TO THE VACUUM, EXPRESSED IN INCHES MERCURY. THE DENSITY AND SPECIFIC VOLUME OF THIS AIR AT THE UPSTREAM OR ATMOSPHERIC CONDITIONS ARE –

DENSITY = 0.07608 LBS PER CUBIC FOOT
SPECIFIC VOLUME = 13.144 CU FT PER POUND

THE RATE OF FLOW IS EXPRESSED IN TERMS OF CUBIC FEET PER MINUTE OF THIS AIR WHEN EXPANDED TO THE VACUUM AND AT 60F.

PRESSURE

FOR AIR FLOW UNDER PRESSURE CONDITIONS, THE DATA ARE BASED UPON THE FLOW OF COMPRESSED DRY AIR AT 60F FROM THE GAGE PRESSURE INDICATED TO A STANDARD BAROMETRIC PRESSURE OF 29.92". THE RATE OF FLOW IS EXPRESSED IN TERMS OF CUBIC FEET PER MINUTE OF FREE DRY AIR AT A BAROMETRIC PRESSURE OF 29.92" ABSOLUTE AND AT 60F.

THE DENSITY AND SPECIFIC VOLUME OF THIS FREE AIR AT THE STANDARD DOWNSTREAM OR ATMOSPHERIC PRESSURE CONDITIONS ARE –

DENSITY = 0.07633 LBS PER CUBIC FOOT
SPECIFIC VOLUME = 13.10 CU FT PER POUND

STANDARD BAROMETER

THE STANDARD BAROMETER USED THRUOUT THE DATA IS BASED UPON A MERCURY COLUMN 29.92" HIGH AT 32F AND EQUIVALENT TO 14.7 POUNDS PER SQUARE INCH ABSOLUTE PRESSURE.

NOMENCLATURE

B	Observed Barometer in Inches Mercury
B_C	Barometer Corrected to 32F in Inches Mercury
D	Orifice Diameter in Inches
H	Observed Gage Pressure in Pounds per Square Inch
H_B	Gage Pressure Referred to Standard Barometer in Pounds per Square Inch
H	Observed Vacuum in Inches Mercury
H_C	Vacuum Corrected to 32F in Inches Mercury
H_B	Vacuum Corrected to 32F and Referred to Standard Barometer in Inches Mercury
P	Partial Vapor Pressure of Water in Inches Mercury
T_1	Temperature of the Mercury in Barometer or in Differential Vacuum Gage in ^oF
T_2	Temperature of the Pump Inlet Air in ^oF
T_3	Temperature of the Inlet Seal Water in ^oF
T_4	Temperature of the Orifice Inlet Air in ^oF
V_1	Volume of Air Flow in Cubic Feet per Minute thru Orifice As Given in the Calibration Data at the Vacuum (H_C)
V_2	Volume of Air in Cubic Feet per Minute Actually Entering Pump During the Test at the Vacuum (H_C)
V_3	Volume of Air in Cubic Feet per Minute at the Vacuum (H_B) Which Would Be Pumped Under Standard Conditions
V_4	Volume of Free Dry Air Flow in Cubic Feet per Minute thru Orifice As Given in the Calibration Data at the Gage Pressure (H)
V_5	Volume of Free Dry Air in Cubic Feet per Minute Measured at Test Conditions
CF_1	Conversion Factor to Convert Vacuum Pump Performance to Value It Would Have at Standard Seal Temperature
CF_2	Correction Factor to Refer Vacuum and Pressure to Standard Barometer
FF_1	Flow Factor to Correct Standard Vacuum Orifice Calibration Data to Existing Barometric Pressure (B_C)
FF_2	Flow Factor to Correct Standard Pressure Orifice Calibration Data to Existing Barometric Pressure (B_C)
FF_3	Flow Factor to Correct Standard Vacuum or Pressure Orifice Calibration Data for Flow at Existing Orifice Inlet Temperature (T_4)
FF_4	Flow Factor to Correct Standard Vacuum or Pressure Orifice Calibration Data for Volume at Existing Pump Inlet Temperature (T_2)

CHAPTER V

ORIFICE FLOW CORRECTION FACTORS

In applying the orifice flow values as given in the calibration data, it should be kept in mind that in every instance the volume indicated is the rate of flow at the particular vacuum or pressure differential referred to. These values can be corrected to other conditions by the application of the following correction factors. The actual observed vacuum (corrected to 32F mercury column) or pressure differential across the orifice should first be referred to the calibration data for the standard volume under the same differential and then the correction factors applied to this value of volume and differential.

A. CORRECTION FACTORS FOR FLOW INTO A VACUUM

1. Temperature Correction to Mercury Columns

The calibration data are referred to a 29.92" barometer with mercury at 32F. It is therefore necessary to first correct the observed barometer and vacuum column readings to a 32F basis before referring to the calibration data. This correction is simplified by reference to correction curve (1), Page 11, entitled "Temperature Corrections of Barometer and Vacuum Column Readings to Standard 32F Basis".

2. Flow Correction for Barometer

For barometric pressures other than 29.92", the rate of flow and the ratio of expansion for a given vacuum differ from the values given in the calibration data. The correction factors of curves (2) and (3), Pages 12 and 13, when applied to the calibration data at the observed vacuum (corrected to 32F) will give the actual volume flow at the observed vacuum and 60F. Curves (2) and (3) are based upon the following formulas:

For vacuums above the critical value --

$$FF_1 = \frac{B_C}{29.92} \qquad \frac{(29.92 - H_C)}{(B_C - H_C)}$$

For vacuums below the critical value --

$$FF_1 = \sqrt{\frac{29.92 - H_C}{B_C - H_C}}$$

The critical vacuum is not constant for all orifices, varying from about 13 to 18 inches mercury. In this range an average correction factor is shown.

3. Flow Corrections for Change in Air Temperature and Humidity

If the air at atmosphere is at a temperature other than 60F, the rate of flow changes inversely as the square root of the absolute temperatures. By reference to curve (7), Page 17, the calibration data may be corrected to give the flow under different upstream temperature conditions. The volumes at the vacuum as corrected would be at 60F. This curve is based upon the following formula:

$$FF_3 = \sqrt{\frac{519.6}{459.6 + T_4}}$$

If the temperature at the vacuum differs from 60F at the point of measurement, a further correction should be made, the volume varying directly as the ratio of the observed absolute temperature to the standard absolute

TEMPERATURE OF 519.6F. THIS CORRECTION CAN BE MADE BY REFERENCE TO CURVE (8), PAGE 18. THIS CURVE IS BASED UPON THE FOLLOWING FORMULA:

$$FF_4 = \frac{459.6 + T_2}{519.6}$$

NOTE: WHEN APPLIED TO NASH VACUUM PUMP TESTS, THESE TEMPERATURE CORRECTIONS MAY ORDINARILY BE NEGLECTED. THE CHANGE IN VOLUME OF THE AIR DUE TO THE TEMPERATURE CHANGE, WHEN ALLOWANCE IS MADE FOR THE SLIGHT COOLING AFTER EXPANDING THRU THE ORIFICE, ABOUT OFFSETS THE CHANGE IN RATE OF FLOW THRU THE ORIFICE CAUSED BY THE TEMPERATURE CHANGE FROM STANDARD.

THE CORRECTION FOR CHANGES IN RELATIVE HUMIDITY IS SO SMALL THAT IT MAY BE NEGLECTED. AN AVERAGE HUMIDITY OF 50% IS ASSUMED FOR THE STANDARD CALIBRATION DATA.

B. CORRECTION FACTORS FOR PRESSURE FLOW TO ATMOSPHERE

1. FLOW CORRECTION FOR BAROMETER

FOR BAROMETRIC PRESSURES OTHER THAN 29.92", THE RATE OF FLOW AND THE RATIO OF EXPANSION FOR A GIVEN GAGE PRESSURE DIFFER FROM THE VALUES GIVEN IN THE CALIBRATION DATA. THE CORRECTION FACTORS OF CURVE (6), PAGE 16, WHEN APPLIED TO THE CALIBRATION DATA AT THE OBSERVED GAGE PRESSURE WILL GIVE THE ACTUAL VOLUME FLOW MEASURED AT THE OBSERVED BAROMETER AND AT 60F. CURVE (6) IS BASED UPON THE FOLLOWING FORMULAS:

FOR GAGE PRESSURES ABOVE THE CRITICAL VALUE --

$$FF_2 = \frac{29.92}{B_C} \left(\frac{B_C + \frac{H}{.4912}}{29.92 + \frac{H}{.4912}} \right)$$

FOR GAGE PRESSURES BELOW THE CRITICAL VALUE --

$$FF_2 = \sqrt{\frac{29.92}{B_C}}$$

THE CRITICAL PRESSURE IS NOT CONSTANT FOR ALL ORIFICES, VARYING FROM ABOUT 14 TO 36 POUNDS PER SQUARE INCH. IN THIS RANGE AN AVERAGE CORRECTION FACTOR IS SHOWN.

2. FLOW CORRECTIONS FOR CHANGE IN AIR TEMPERATURE AND HUMIDITY

IF THE COMPRESSED AIR FLOWING INTO THE ORIFICE IS AT A TEMPERATURE OTHER THAN 60F, THE RATE OF FLOW CHANGES INVERSELY AS THE SQUARE ROOT OF THE ABSOLUTE TEMPERATURES. BY REFERENCE TO CURVE (7), PAGE 17, THE CALIBRATION DATA MAY BE CORRECTED TO GIVE THE FLOW UNDER DIFFERENT UPSTREAM TEMPERATURE CONDITIONS. THE VOLUME AT ATMOSPHERE AS CORRECTED WOULD BE AT 60F. IF IT IS DESIRED TO REFER THIS VOLUME AT ATMOSPHERE TO ANY OTHER THAN 60F, A FURTHER CORRECTION CAN BE MADE, THE VOLUME VARYING DIRECTLY AS THE RATIO OF THE OBSERVED ABSOLUTE TEMPERATURE TO THE STANDARD ABSOLUTE TEMPERATURE OF 519.6F. THIS CORRECTION CAN BE MADE BY REFERENCE TO CURVE (8), PAGE 18.

NO CORRECTION IS ORDINARILY NECESSARY FOR VARIATIONS IN THE HUMIDITY OF THE AIR FLOWING AS THIS FACTOR IS OF NO IMPORTANCE AT HIGH PRESSURES, AND EVEN AT VERY LOW PRESSURES IT IS SUCH A LOW VALUE THAT IT MAY BE NEGLECTED.

CHAPTER VI

PERFORMANCE CONVERSION FACTORS

THE APPLICATION OF THE CORRECTION FACTORS OF CHAPTER V TO THE CALIBRATION DATA PROVIDES US WITH AN ACCURATE MEASUREMENT OF THE VOLUME OF AIR ENTERING THE VACUUM PUMP OR THE COMPRESSOR UNDER THE CONDITIONS OF THE TEST. IT IS CUSTOMARY TO EXPRESS THE PERFORMANCE OF SUCH UNITS UNDER STANDARD CONDITIONS. THE FOLLOWING FACTORS MAY BE USED TO CONVERT THE ACTUAL CAPACITY AND VACUUM OR PRESSURE DIFFERENTIAL OF THE UNIT UNDER TEST TO WHAT MAY BE EXPECTED OF IT UNDER "STANDARD CONDITIONS". THESE CORRECTIONS ARE NOT TO BE CONFUSED WITH THE CORRECTION FACTORS OF CHAPTER V WHICH DEAL EXCLUSIVELY WITH THE MEASUREMENT OF AIR BY THE ORIFICE METER.

A. VACUUM PUMP PERFORMANCE

1. Vacuum Referred to Standard Barometer

FOR A GIVEN PUMP DISPLACEMENT AND COMPRESSION RATIO, THE VACUUM THAT CAN BE PRODUCED VARIES WITH A CHANGE IN BAROMETER. FOR THIS REASON PUMP PERFORMANCE IS EXPRESSED IN TERMS OF VACUUM AT A STANDARD BAROMETER OF EITHER 29.92" OR 30.0".

THE FLOW VALUE AS OBTAINED UNDER CHAPTER V GIVES US THE ACTUAL NET CAPACITY OF THE PUMP MEASURED AT THE ABSOLUTE PRESSURE AND TEMPERATURE OF THE AIR AS IT ENTERS THE PUMP, PROVIDED, OF COURSE, THERE IS NO RESTRICTION OR FRICTION LOSS IN THE PIPING BETWEEN THE ORIFICE HEADER AND THE PUMP INLET. IF THE BAROMETER DURING THE TEST IS OTHER THAN STANDARD AND IF IT IS DESIRED TO REFER THIS PERFORMANCE TO A STANDARD BAROMETER, IT WILL BE NECESSARY TO CORRECT THE VACUUM MAINTAINED AT THIS CAPACITY BY THE RATIO OF THE STANDARD BAROMETER TO THE OBSERVED BAROMETER. IN MAKING THIS CORRECTION WARNING IS GIVEN THAT WHEN REFERRING TO A 29.92" BAROMETER BOTH THE OBSERVED VACUUM AND BAROMETER READINGS MUST FIRST BE CORRECTED TO 32F, AND WHEN REFERRING TO A 30.0" BAROMETER BOTH OBSERVED READINGS MUST BE CORRECTED TO A 58.8F BASIS.

CURVE (9), PAGE 19, MAY BE USED TO CONVERT THE OBSERVED VACUUM (CORRECTED TO 32F) TO PERFORMANCE AT A STANDARD 29.92" BAROMETER. THIS CORRECTION IS A CORRECTION OF VACUUM ONLY, THE CAPACITY REMAINING THE SAME. THIS CURVE IS BASED UPON THE FOLLOWING FORMULA:

$$CF_2 = \frac{29.92}{B_C}$$

2. Conversion to Standard Water Seal Conditions

A VARIATION IN THE TEMPERATURE OF THE SEALING WATER USED IN THE NASH VACUUM PUMP HAS A MODIFYING EFFECT UPON ITS PERFORMANCE. THIS IS BECAUSE OF THE ACCOMPANYING CHANGE IN THE PARTIAL VAPOR PRESSURE WITHIN THE DISPLACEMENT CHAMBERS OF THE PUMP, WHICH IN TURN MODIFIES THE NET PROPORTION OF AIR THAT CAN BE HANDLED AS WELL AS THE TOTAL ABSOLUTE PRESSURE THAT CAN BE OBTAINED.

ALL NASH VACUUM PUMP PERFORMANCE DATA ARE REFERRED TO A STANDARD ENTERING WATER SEAL TEMPERATURE OF 60F AND NORMAL AMOUNT OF SEAL. IF THE SEAL TEMPERATURE UNDER TEST CONDITIONS IS OTHER THAN 60F, CORRECTIONS ARE NECESSARY TO CONVERT THE OBSERVED PERFORMANCE TO WHAT WOULD BE EXPECTED UNDER THE STANDARD 60F SEAL.

CURVES (4) AND (5), PAGES 14 AND 15, ENTITLED "CONVERSION FACTORS FOR NASH VACUUM PUMP CAPACITIES TO STANDARD 60F SEAL TEMPERATURE " AND "CONVERSION FACTORS FOR NASH VACUUM PUMP CAPACITIES TO STANDARD 60F SEAL TEMPERATURE FOR EXTREME CONDITIONS", HAVE BEEN PREPARED TO APPROXIMATE THE CAPACITY THAT MIGHT BE EXPECTED, WITH STANDARD 60F WATER SEAL, BY APPLYING THESE FACTORS TO TEST CAPACITIES OBTAINED UNDER OTHER WATER SEAL TEMPERATURES. THESE CURVES ARE

BASED UPON THE FOLLOWING FORMULA:

$$CF_1 = \frac{29.92 - H_B - P \text{ (FOR WATER AT } 60 + x)}{29.92 - H_B - P \text{ (FOR WATER AT } T_3 + x)}$$

NOTE: VALUES FOR X = 4.0F FOR 0 TO 22 IN. HG. VAC.
3.7 AT 24 " " "
3.0 AT 26 " " "
2.5 AT 27 " " "
1.8 AT 28 " " "
1.0 AT 29 " " "

B. COMPRESSOR PERFORMANCE

1. PRESSURE REFERRED TO STANDARD BAROMETER

COMPRESSOR PERFORMANCE IS USUALLY EXPRESSED IN TERMS OF CUBIC FEET OF FREE DRY AIR AT A STANDARD BAROMETER OF 29.92". THE FLOW VALUE AS OBTAINED UNDER CHAPTER V GIVES US THE ACTUAL CAPACITY OR NET DISPLACEMENT OF THE COMPRESSOR UNDER THE OBSERVED BAROMETER AND MEASURED AT 60F. FOR ANY CHANGE IN BAROMETER, THE COMPRESSOR DISCHARGE PRESSURE WILL VARY DIRECTLY AS THE RATIO OF THE STANDARD BAROMETER TO THE OBSERVED BAROMETER.

CURVE (9), PAGE 19, INDICATES THE CORRECTION FACTOR TO APPLY TO THE PRESSURE OBTAINED ON TEST, TO OBTAIN A CORRECTED PRESSURE WHEN THE PUMP PERFORMANCE IS REFERRED TO A STANDARD 29.92" BAROMETER, THE CAPACITY REMAINING THE SAME. THIS CURVE IS BASED UPON THE FOLLOWING FORMULA:

$$CF_2 = \frac{29.92}{B_C}$$

2. COMPRESSOR INLET CONDITIONS

AS HAS BEEN INDICATED IN CHAPTER V, THE CORRECTED VOLUMETRIC FLOW IS MEASURED AT THE OBSERVED BAROMETER AND AT 60F. IF THE TEMPERATURE OF THE AIR ENTERING THE INLET OF THE COMPRESSOR DIFFERS FROM 60F, THE VOLUME OBTAINED UNDER CHAPTER V MUST BE CORRECTED IN ACCORDANCE WITH ANY TEMPERATURE CHANGE. FOR ORDINARY VARIATIONS IN ATMOSPHERIC TEMPERATURE, CURVE (8), PAGE 18, CAN BE USED TO CONVERT AIR VOLUMES FROM 60F TO THE VOLUME AT ANY OTHER OBSERVED TEMPERATURE. THIS CURVE IS BASED UPON THE FOLLOWING FORMULA:

$$FF_4 = \frac{459.6 + T_2}{519.6}$$

A WORD OF CAUTION IS ALSO GIVEN THAT ANY RESTRICTION IN THE PIPING AHEAD OF THE COMPRESSOR INLET SUCH AS A MUFFLER THAT REDUCES THE INLET PRESSURE BELOW THE OBSERVED ATMOSPHERIC PRESSURE, SHOULD BE TAKEN INTO ACCOUNT BY CORRECTING THE CAPACITY IN DIRECT PROPORTION TO THE RATIO OF THE OBSERVED BAROMETRIC PRESSURE TO THE ABSOLUTE PRESSURE MEASURED AT THE INLET TO THE PUMP.

CHAPTER VII
SAMPLE CALCULATIONS

A. VACUUM TEST

1. Observed Values --

Barometer In. Hg.	(B)	29.65
Bar. Temp. °F	(T_1)	70
Merc. Gage Temp. °F	(T_1)	76
Seal Inlet Temp. °F	(T_3)	47
Orifice Dia. In.	(D)	7/32
Vacuum In. Hg.	(H)	27.76

2. Curve Values --

			Curve	Page
Bar. Corr. to 32F	(B_C)	29.54	1	11
Vac. Corr. to 32° Hg.	(H_C)	27.64	1	11
Cfm at Vac. (H_C)	(V_1)	108.5		27
Bar. Corr. Factor	(FF_1)	1.180	2	12
Seal Temp. Corr. Factor at (H_B)	(CF_1)	.872	4	14
Vac. Corr. Factor	(CF_2)	1.013	9	19

3. Performance Calculations --

			Factors Applied
(A) Actual Perf. as Tested Cfm at Vac. (H_C)	(V_2)	128	108.5 x 1.180
Vacuum	(H_C)	27.64	
(B) Perf. Referred to Std. Cond. Cfm at Vac. (H_B)	(V_3)	111.6	128 x .872
Vacuum	(H_B)	27.99	27.64 x 1.013

B. PRESSURE TEST

1. Observed Values --

Barometer In. Hg.	(B)	30.54
Bar. Temp. °F	(T_1)	79.5
Pump Inlet °F	(T_2)	84
Orifice Inlet °F	(T_4)	91
Orifice Dia. In.	(D)	7/16
Pressure Lbs/Sq In.	(H)	55.3

2. Curve Values --

			Curve	Page
Bar. Corr. to 32F	(B_C)	30.40	1	11
Cfm at Pressure (H)	(V_4)	162.0		32
Bar. Corr. Factor	(FF_2)	.988	6	16
Orif. Inlet Temp. Factor	(FF_3)	.971	7	17
Pump Inlet Temp. Factor	(FF_4)	1.046	8	18
Press. Corr. Factor	(CF_2)	.984	9	19

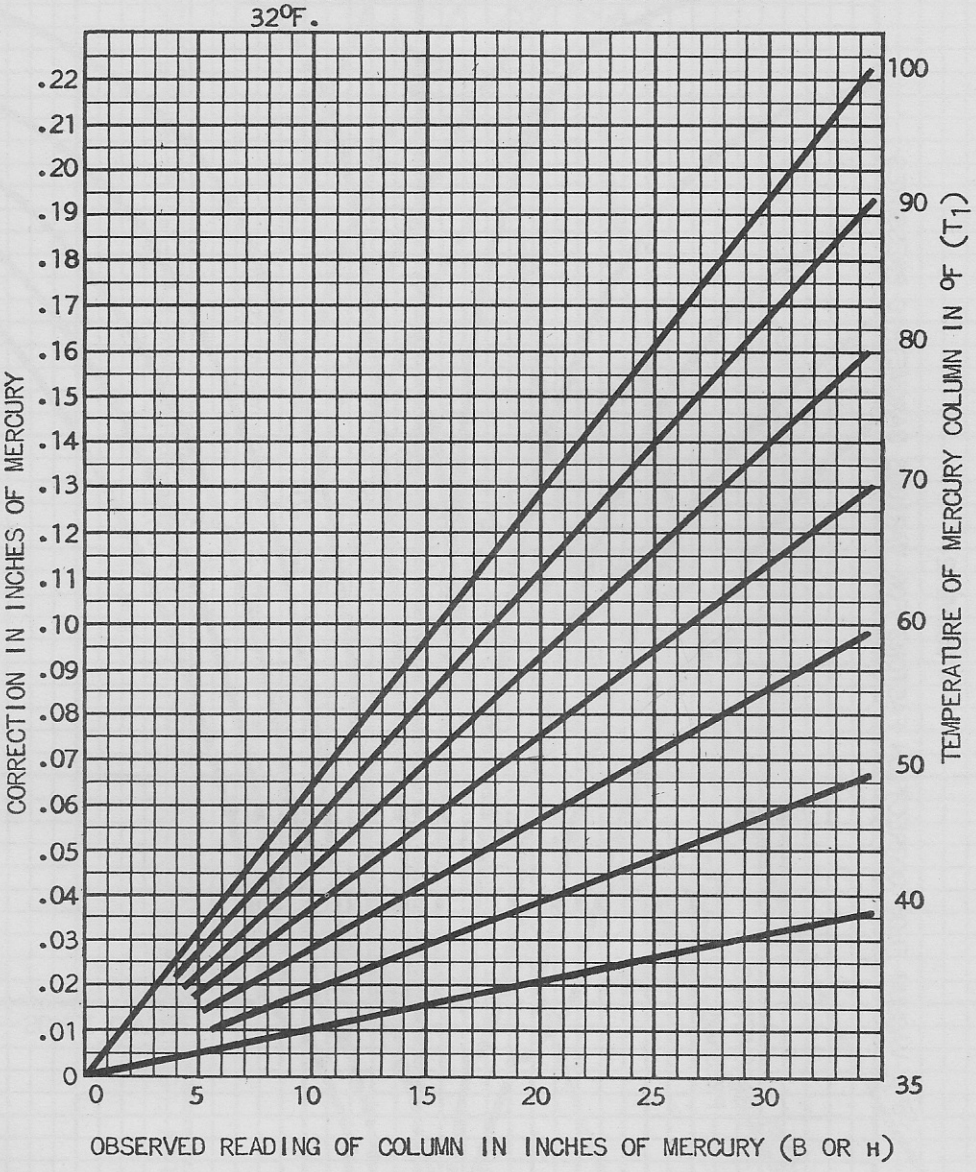
3. Performance Calculations --

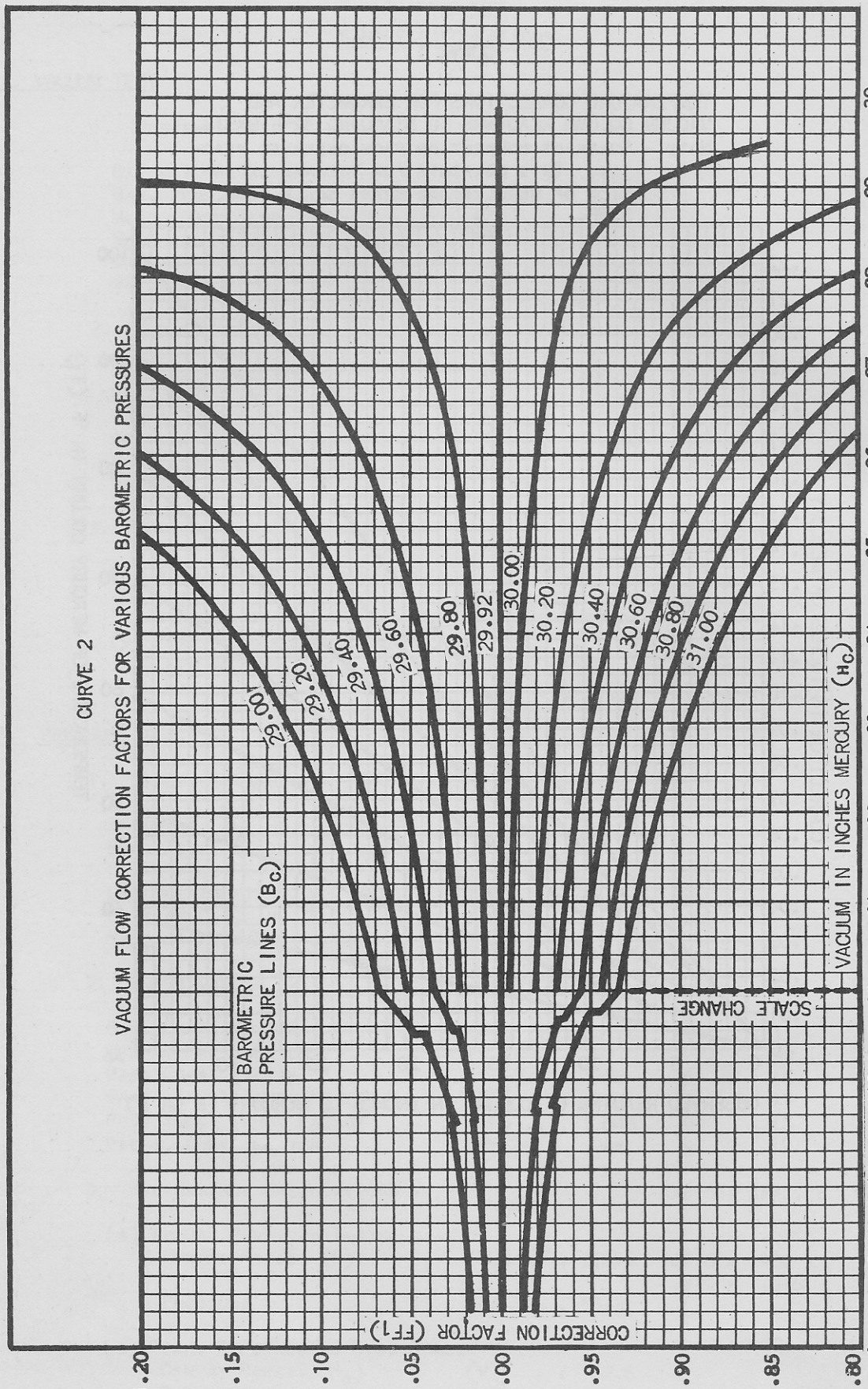
			Factors Applied
(A) Actual Perf. as Tested Cfm at Press. (H)	(V_5)	162.6	162.0 x .988 x .971 x 1.046
Pressure	(H)	55.3	
(B) Perf. Referred to Std. Cond. Cfm at Press. (H_B)	(V_5)	162.6	
Pressure	(H_B)	54.4	55.3 x .984

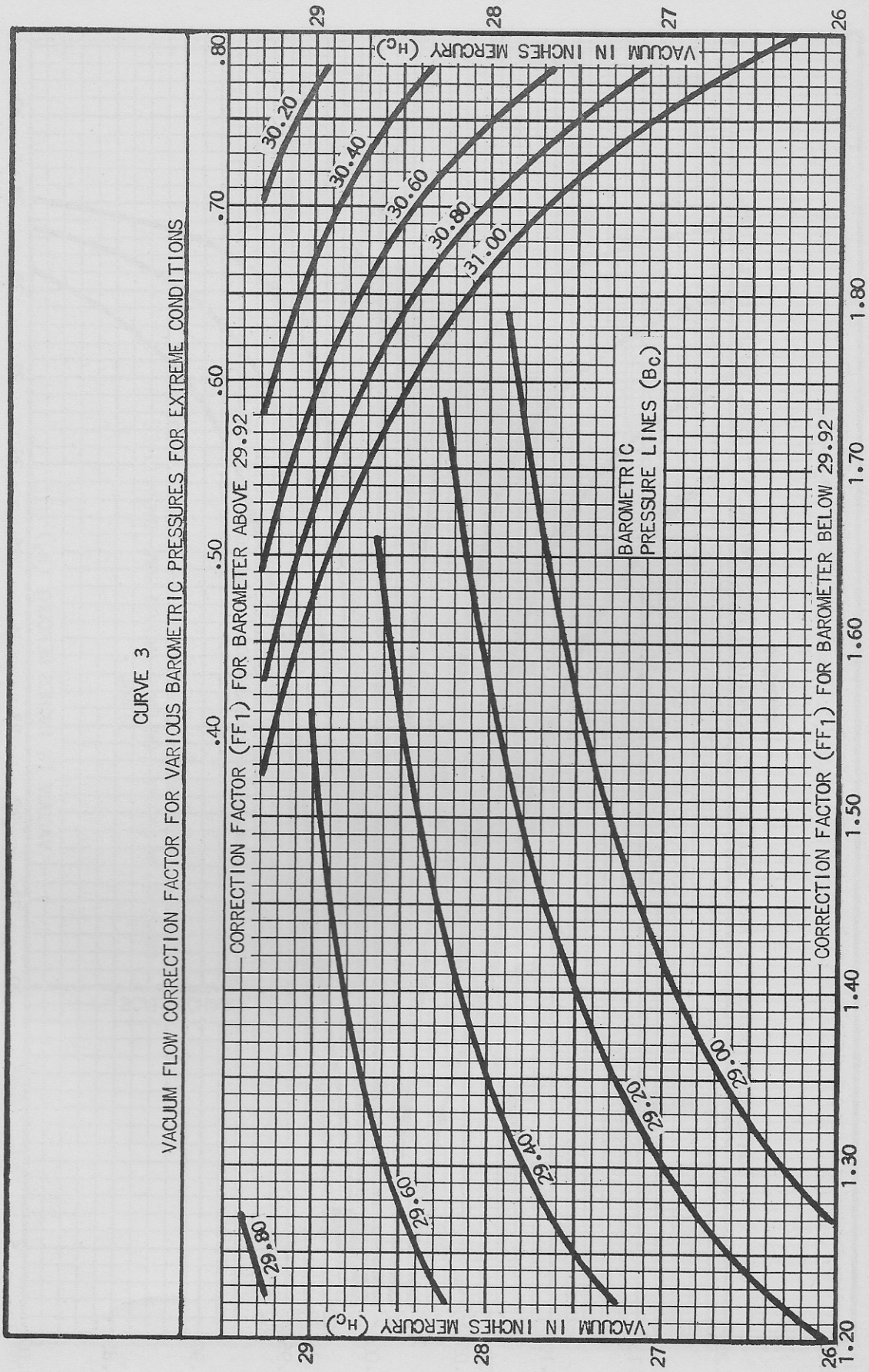
CURVE 1

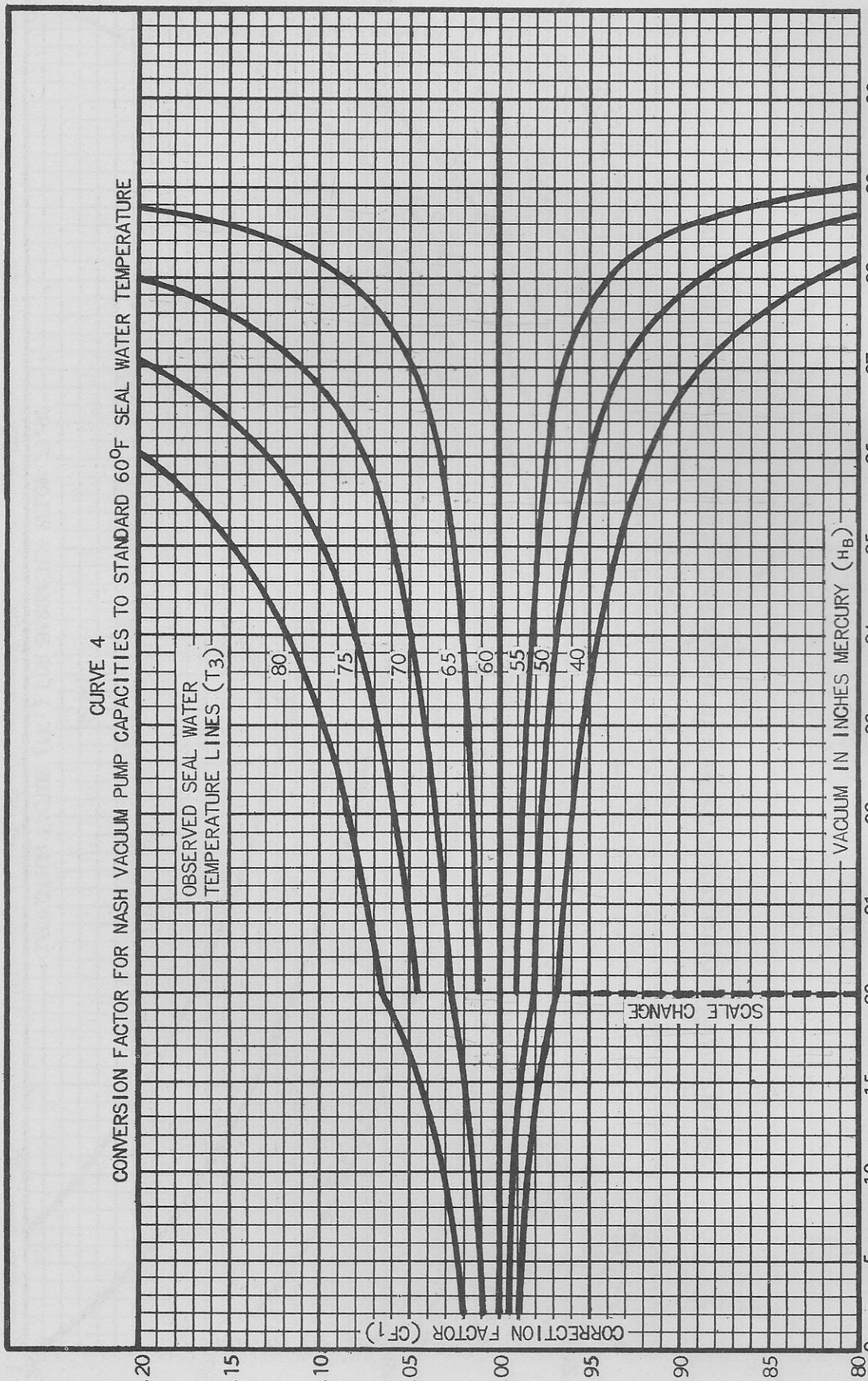
TEMPERATURE CORRECTIONS FOR BAROMETER AND VACUUM COLUMN READINGS TO STANDARD 32°F BASIS.

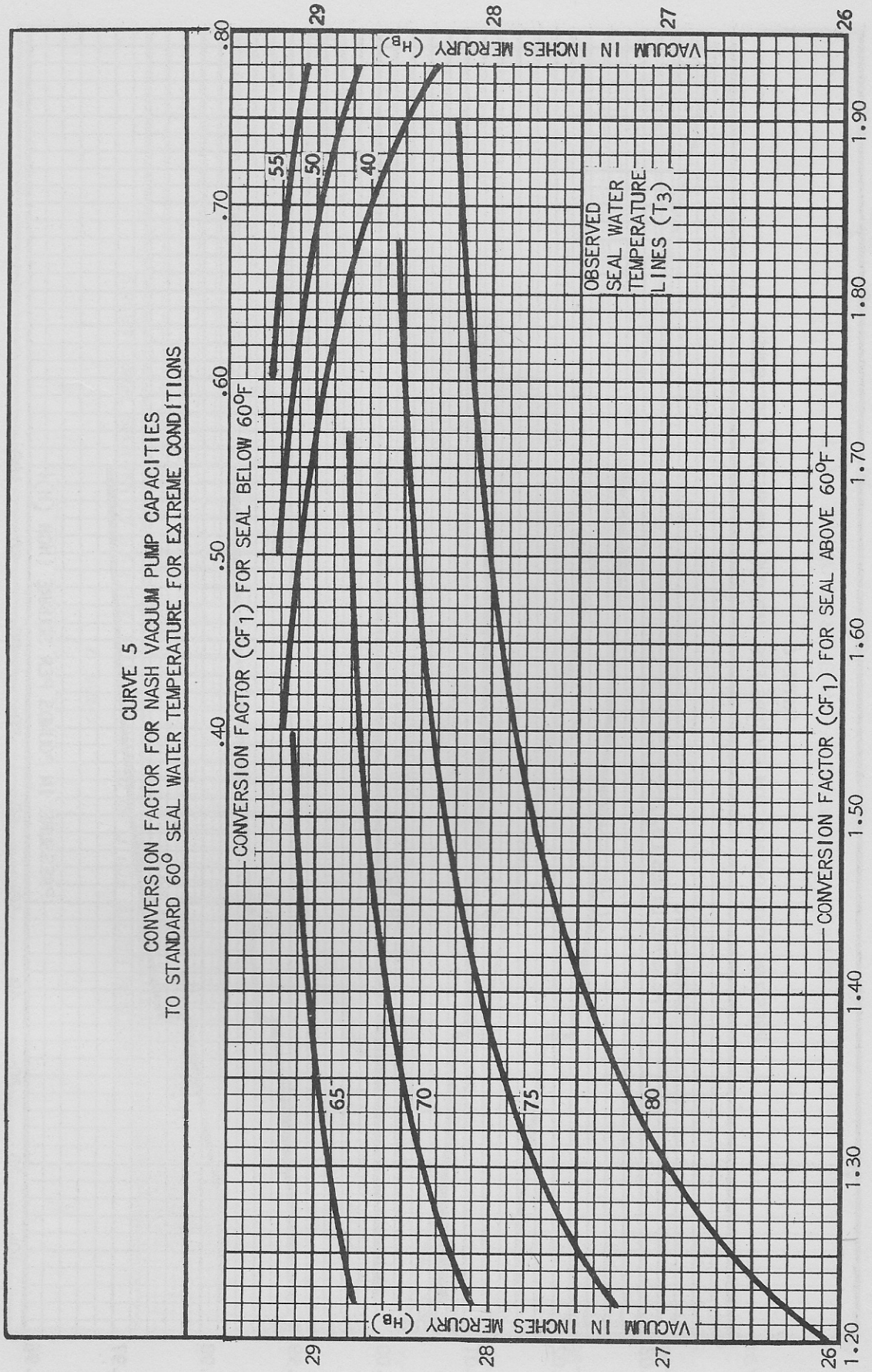
NOTE - SUBTRACT CORRECTION FROM OBSERVED READING. THIS CORRECTS FOR THERMAL EXPANSION OF MERCURY AND BRASS SCALE FROM 32°F.

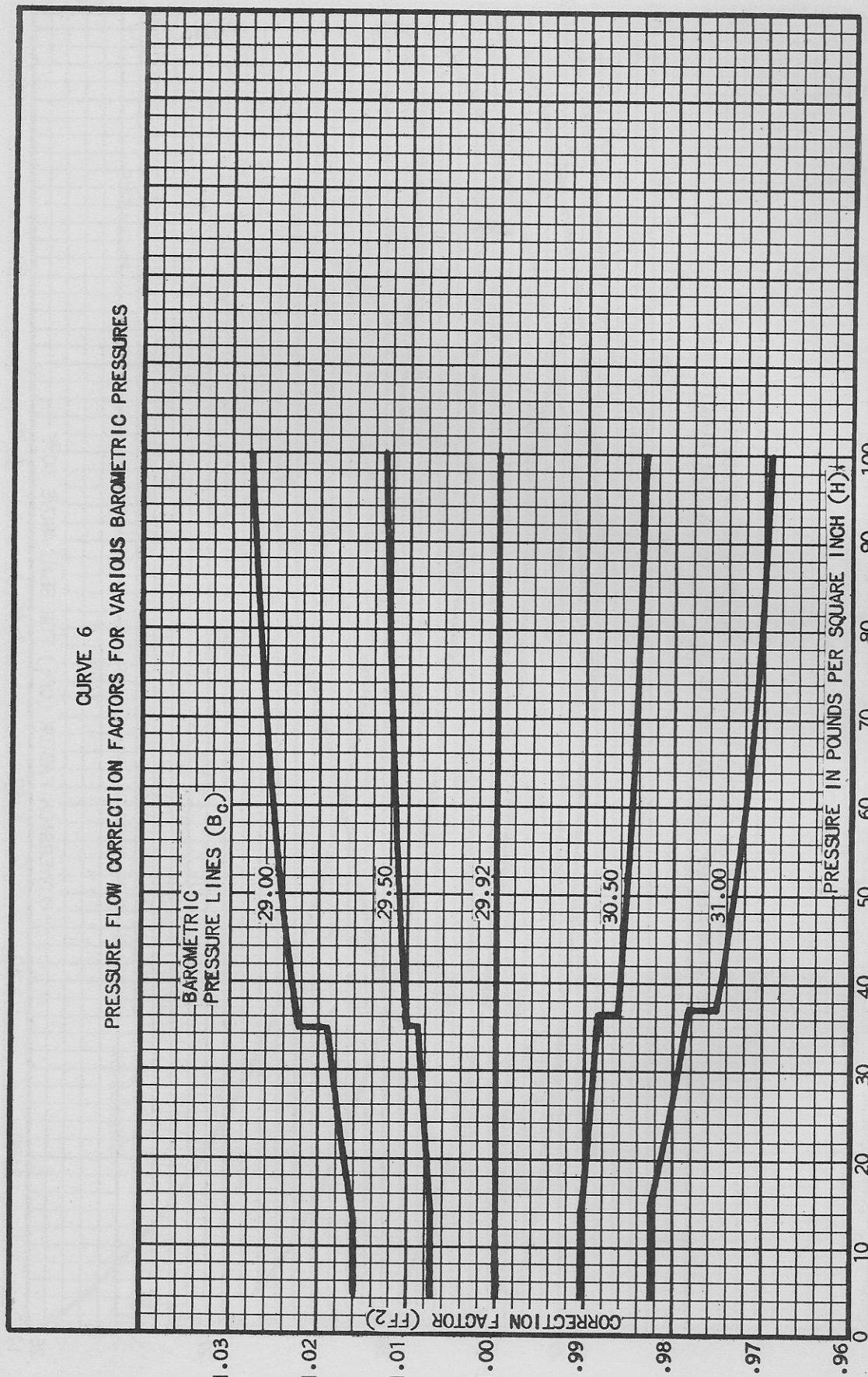


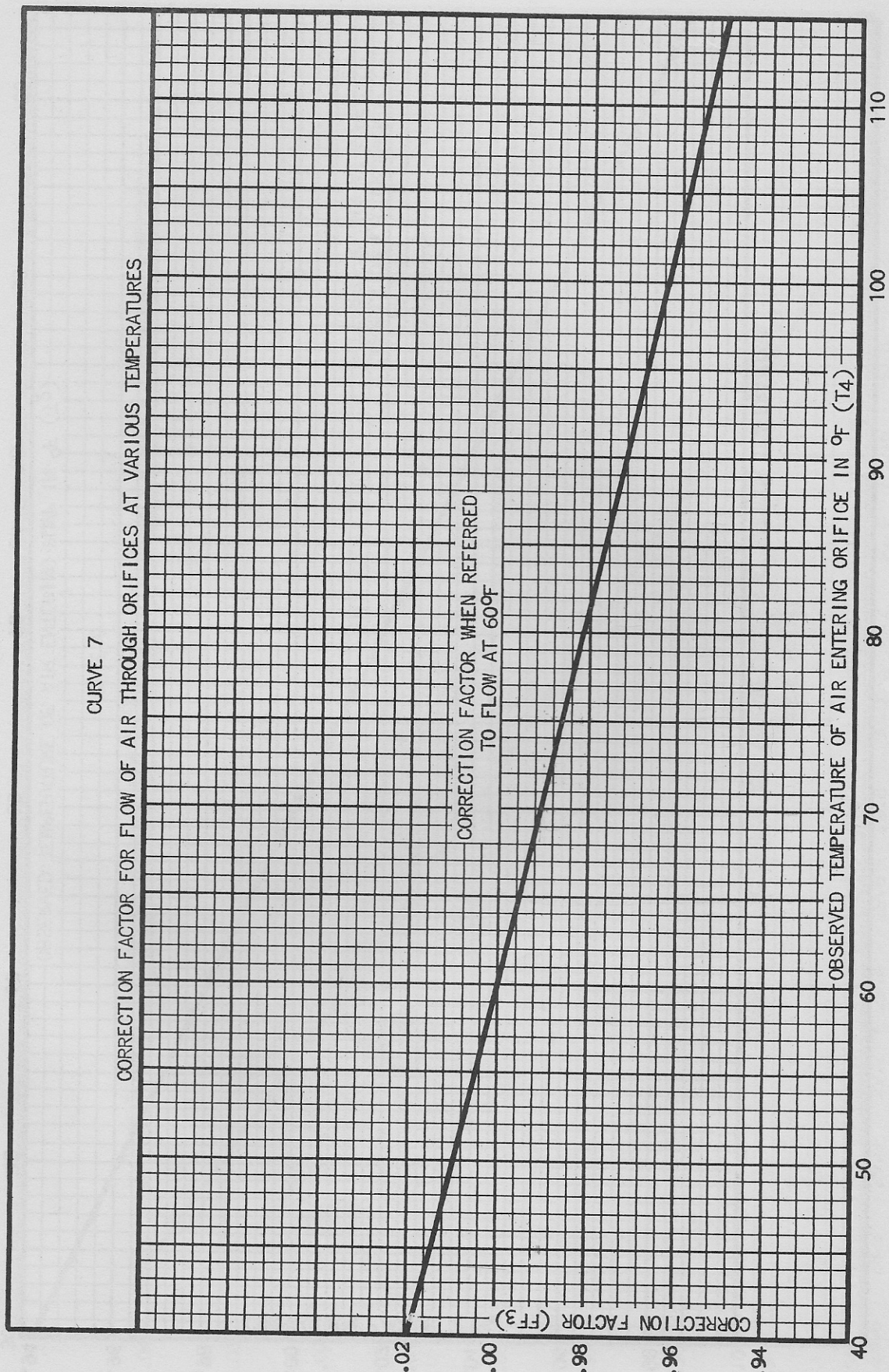

CURVE 2
VACUUM FLOW CORRECTION FACTORS FOR VARIOUS BAROMETRIC PRESSURES
BAROMETRIC PRESSURE LINES (B_C)
29.00
29.20
29.40
29.60
29.80
29.92
30.00
30.20
30.40
30.60
30.80
31.00
SCALE CHANGE
CORRECTION FACTOR (FF1)
VACUUM IN INCHES MERCURY (H_C)
1.20
1.15
1.10
1.05
1.00
.95
.90
.85
.80
0
5
10
15
20
21
22
23
24
25
26
27
28
29
30

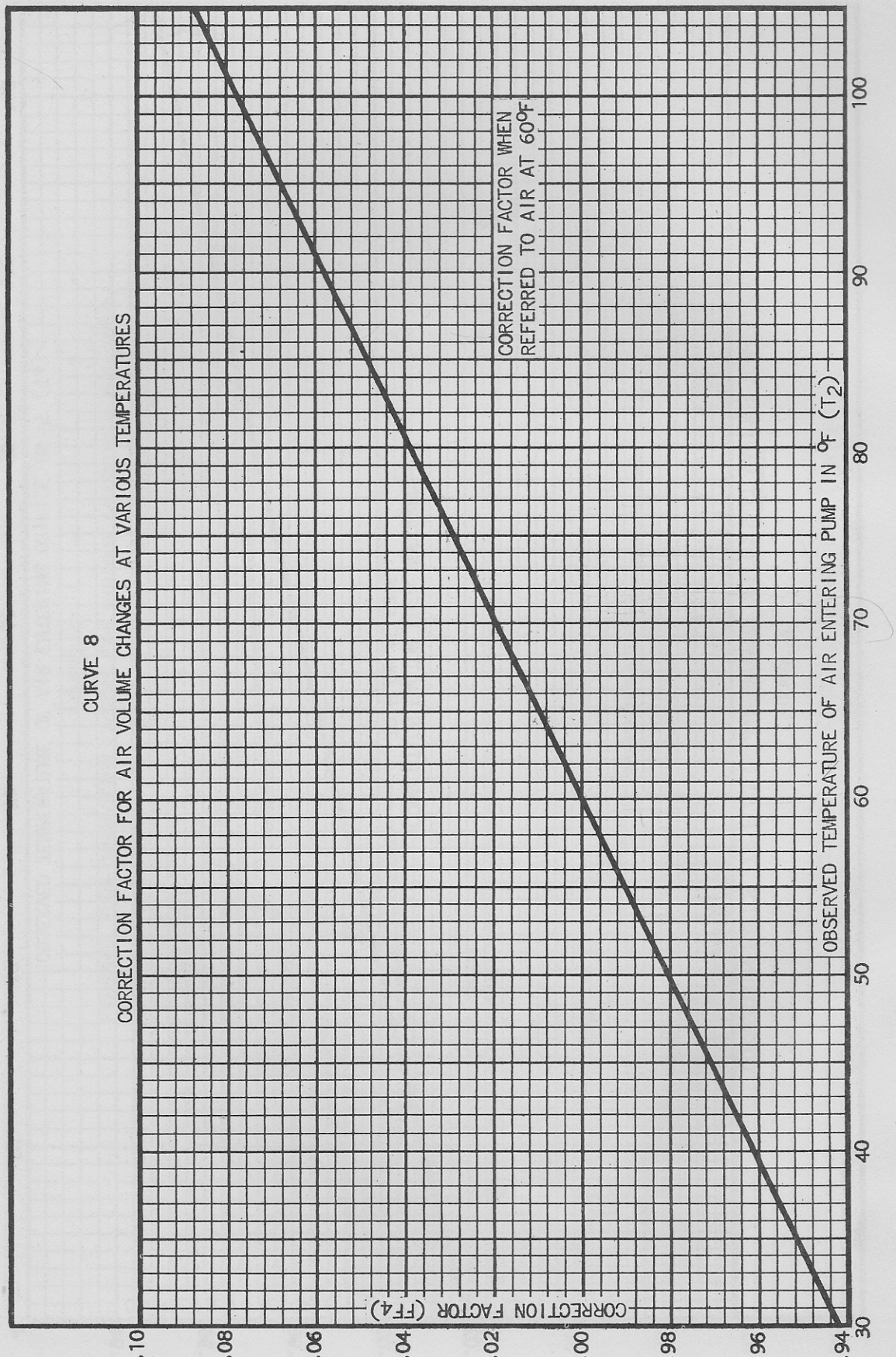

CURVE 3
VACUUM FLOW CORRECTION FACTOR FOR VARIOUS BAROMETRIC PRESSURES FOR EXTREME CONDITIONS
CORRECTION FACTOR (FF1) FOR BAROMETER ABOVE 29.92
CORRECTION FACTOR (FF1) FOR BAROMETER BELOW 29.92
VACUUM IN INCHES MERCURY (Hc)
BAROMETRIC PRESSURE LINES (Bc)
30.20
30.40
30.60
30.80
31.00
29.80
29.60
29.40
29.20
29.00
.80
.70
.60
.50
.40
1.80
1.70
1.60
1.50
1.40
1.30
1.20
29
28
27
26

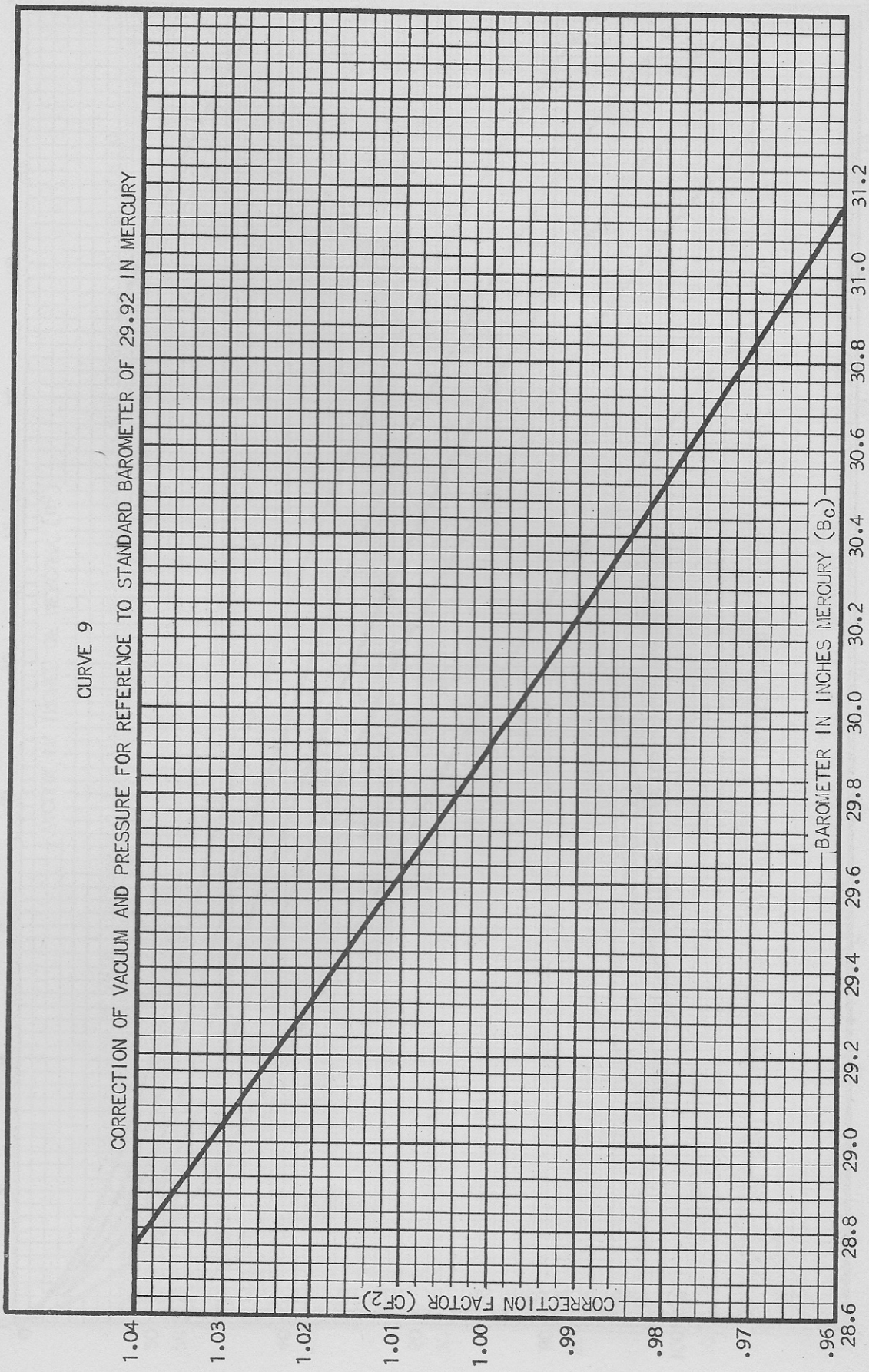

CURVE 4
CONVERSION FACTOR FOR NASH VACUUM PUMP CAPACITIES TO STANDARD 60°F SEAL WATER TEMPERATURE
OBSERVED SEAL WATER TEMPERATURE LINES (T_3)
80
75
70
65
60
55
50
40
SCALE CHANGE
CORRECTION FACTOR (CF_1)
1.20
1.15
1.10
1.05
1.00
.95
.90
.85
.80
VACUUM IN INCHES MERCURY (H_B)
0
5
10
15
20
21
22
23
24
25
26
27
28
29
30


CURVE 5
CONVERSION FACTOR FOR NASH VACUUM PUMP CAPACITIES
TO STANDARD 60° SEAL WATER TEMPERATURE FOR EXTREME CONDITIONS
CONVERSION FACTOR (CF1) FOR SEAL BELOW 60°F
CONVERSION FACTOR (CF1) FOR SEAL ABOVE 60°F
VACUUM IN INCHES MERCURY (Hg)
OBSERVED SEAL WATER TEMPERATURE LINES (T3)
55
50
40
65
70
75
80
.80
.70
.60
.50
.40
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
29
28
27
26

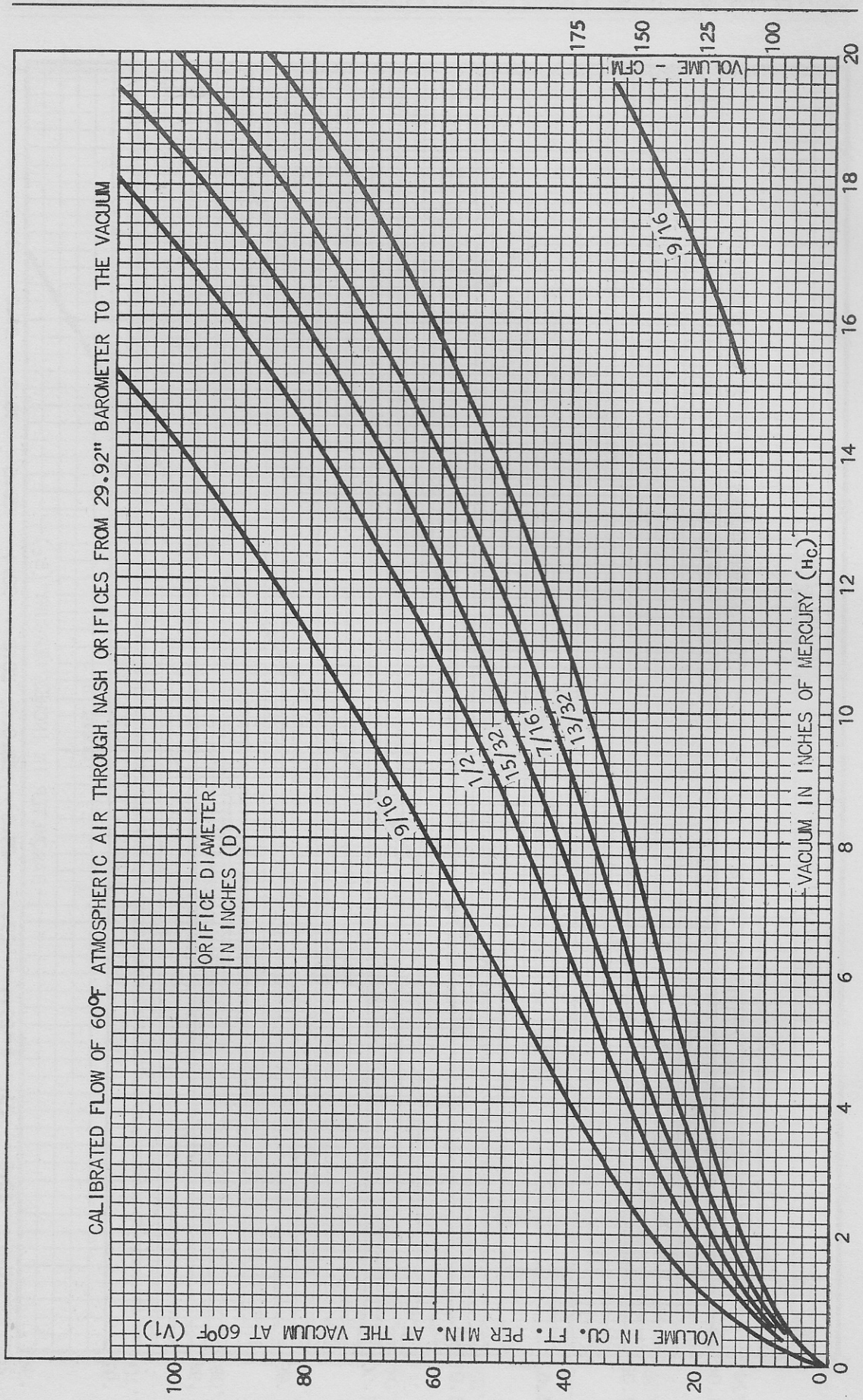

CURVE 6
PRESSURE FLOW CORRECTION FACTORS FOR VARIOUS BAROMETRIC PRESSURES
BAROMETRIC PRESSURE LINES (B_C)
29.00
29.50
29.92
30.50
31.00
CORRECTION FACTOR (FF2)
1.03
1.02
1.01
1.00
.99
.98
.97
.96
0
10
20
30
40
50
60
70
80
90
100
PRESSURE IN POUNDS PER SQUARE INCH (H)


CURVE 7
CORRECTION FACTOR FOR FLOW OF AIR THROUGH ORIFICES AT VARIOUS TEMPERATURES
CORRECTION FACTOR WHEN REFERRED TO FLOW AT 60°F
CORRECTION FACTOR (FF3)
1.02
1.00
.98
.96
.94
OBSERVED TEMPERATURE OF AIR ENTERING ORIFICE IN °F (T4)
40
50
60
70
80
90
100
110

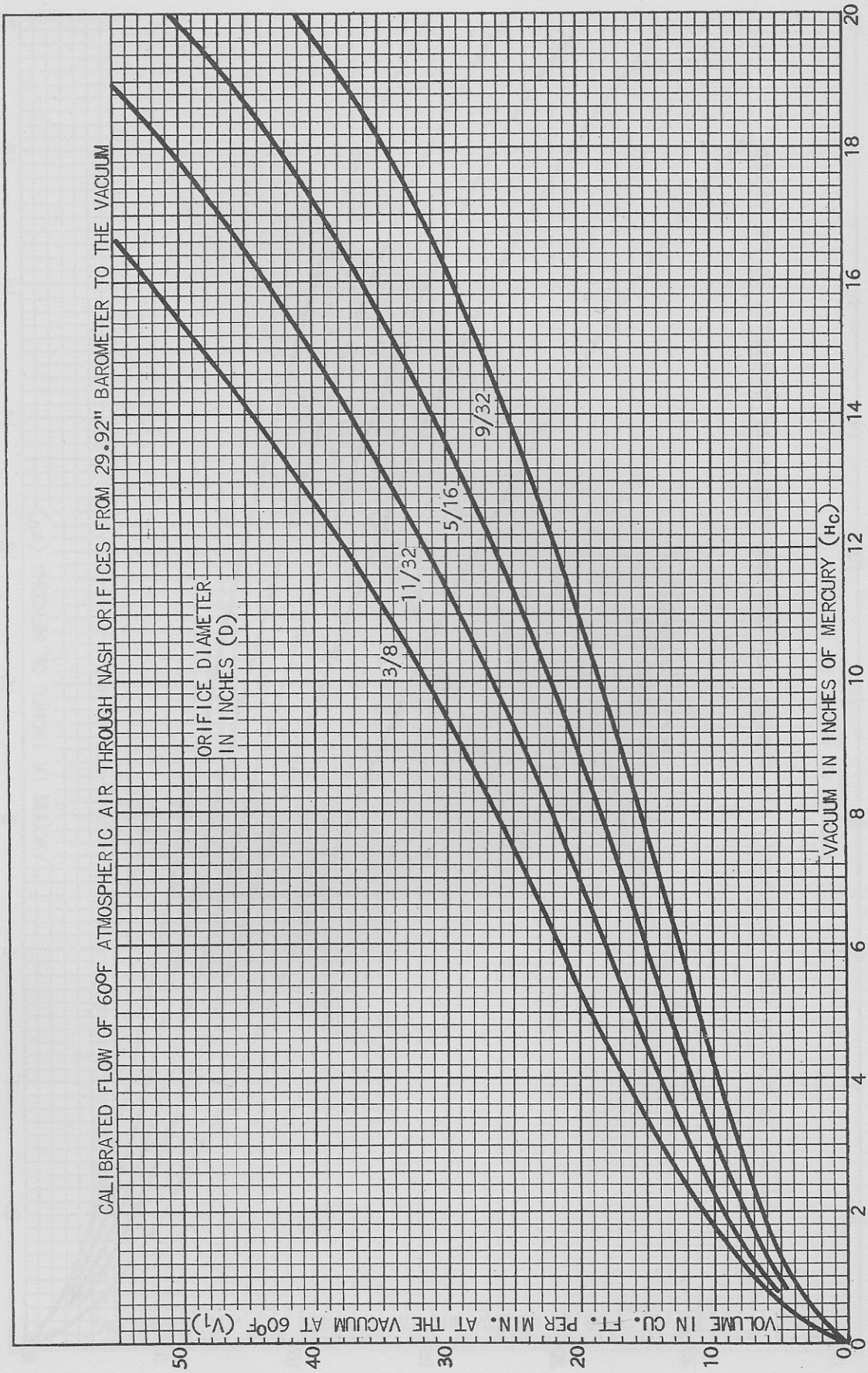

CURVE 8
CORRECTION FACTOR FOR AIR VOLUME CHANGES AT VARIOUS TEMPERATURES
CORRECTION FACTOR WHEN REFERRED TO AIR AT 60°F
CORRECTION FACTOR (FF4)
1.10
1.08
1.06
1.04
1.02
1.00
.98
.96
.94
30
40
50
60
70
80
90
100
OBSERVED TEMPERATURE OF AIR ENTERING PUMP IN °F (T2)


CURVE 9
CORRECTION OF VACUUM AND PRESSURE FOR REFERENCE TO STANDARD BAROMETER OF 29.92 IN MERCURY
CORRECTION FACTOR (CF2)
1.04
1.03
1.02
1.01
1.00
.99
.98
.97
.96
BAROMETER IN INCHES MERCURY (Bc)
28.6
28.8
29.0
29.2
29.4
29.6
29.8
30.0
30.2
30.4
30.6
30.8
31.0
31.2

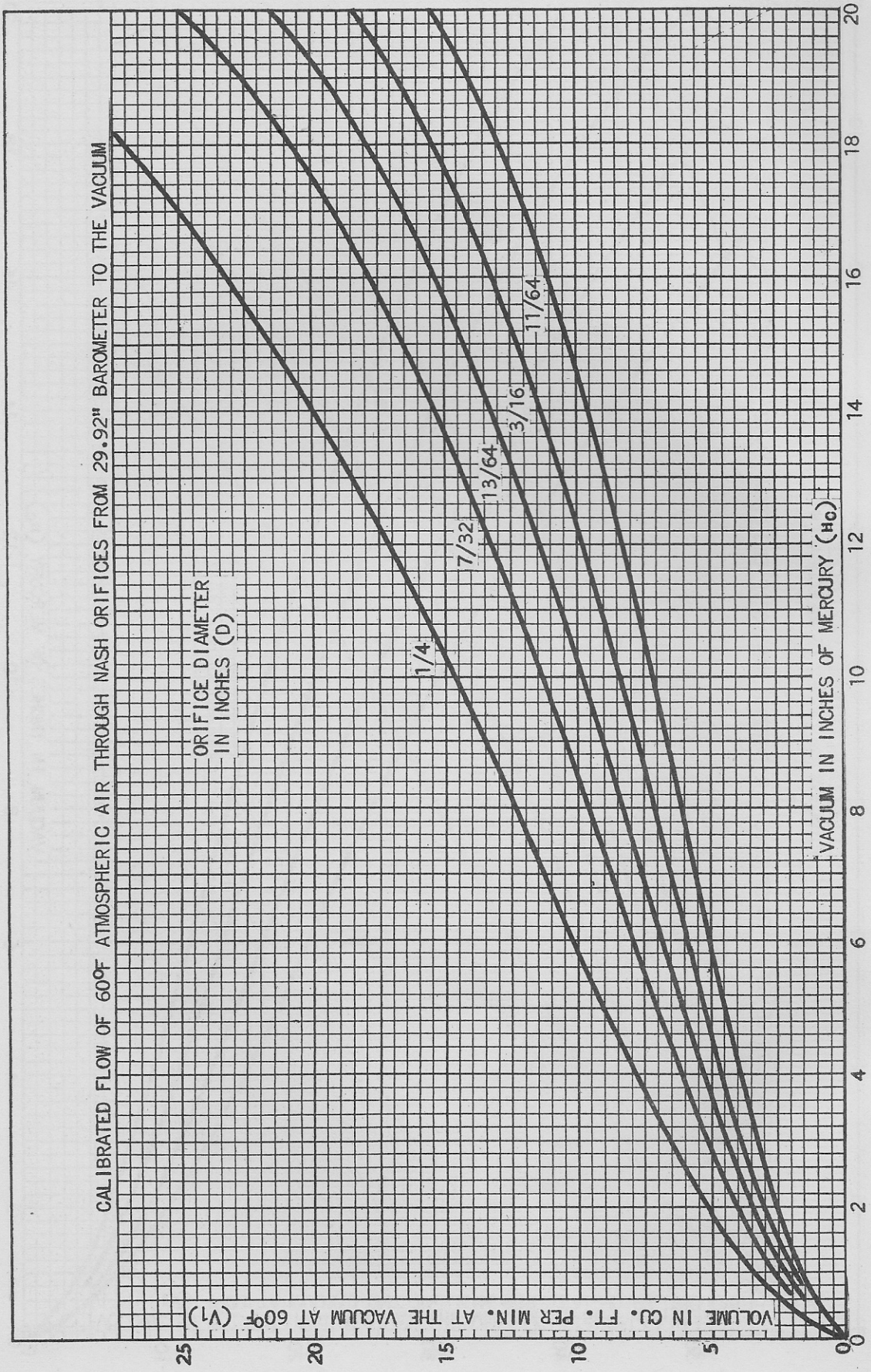
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



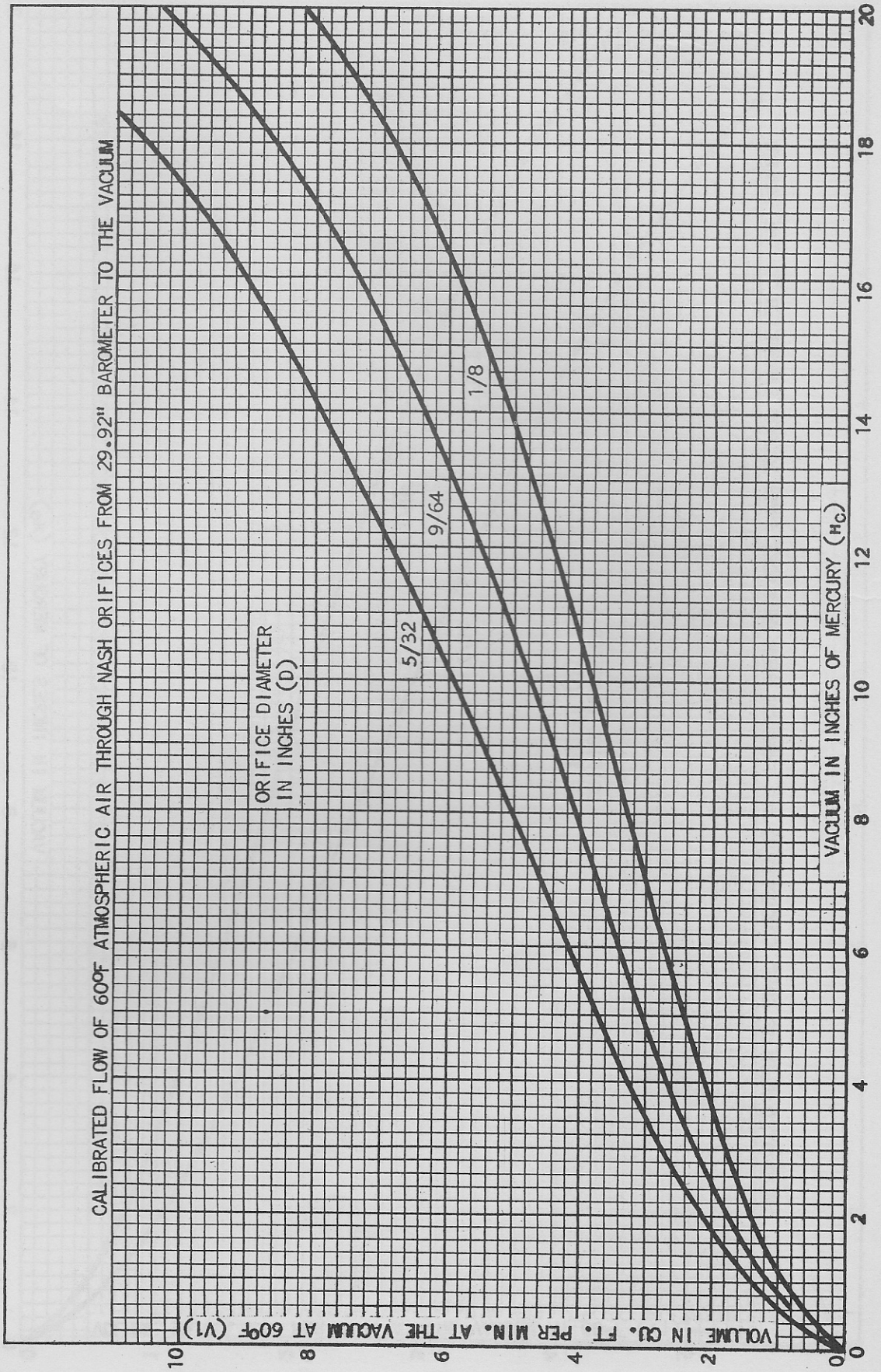
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



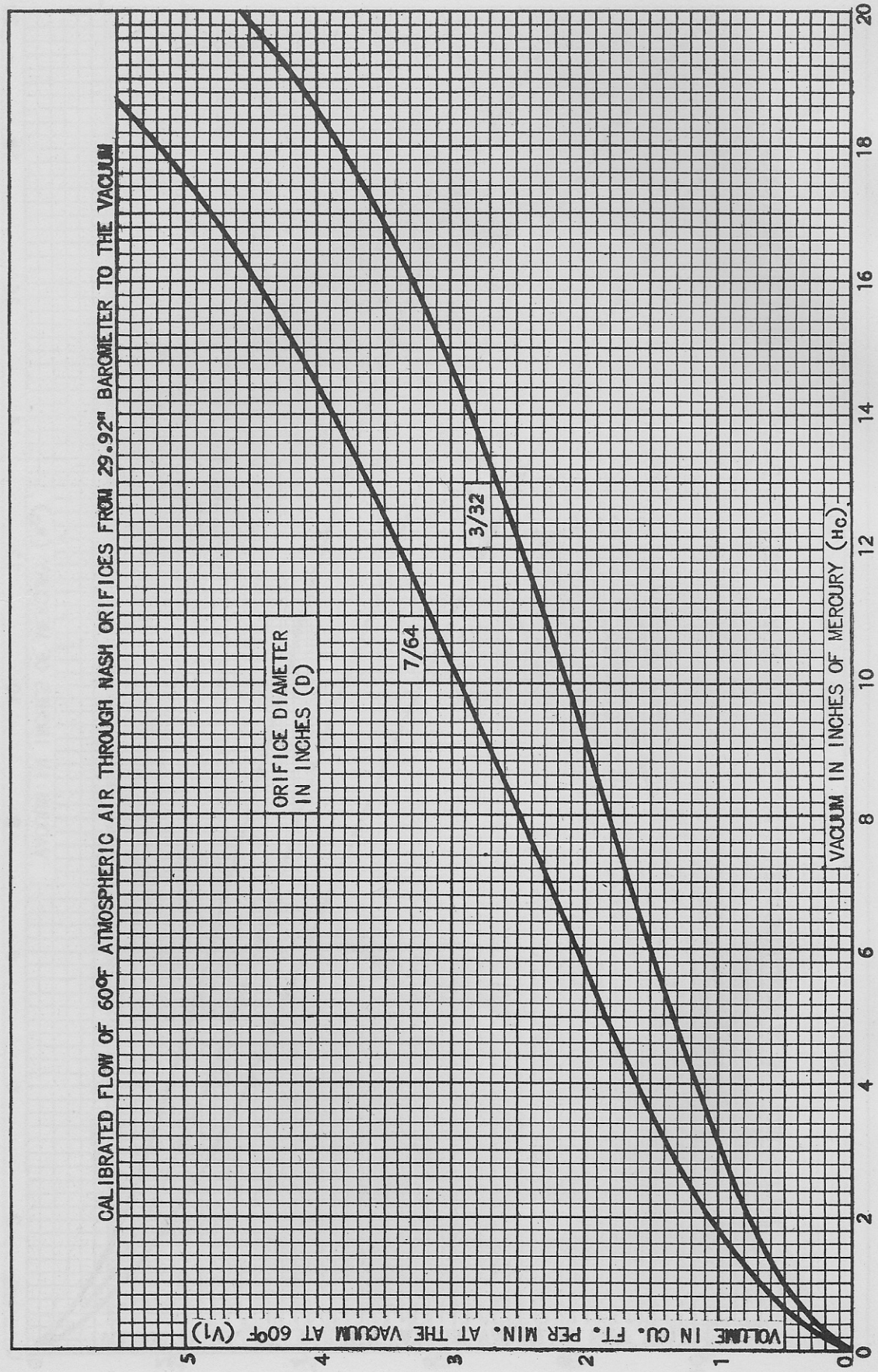
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



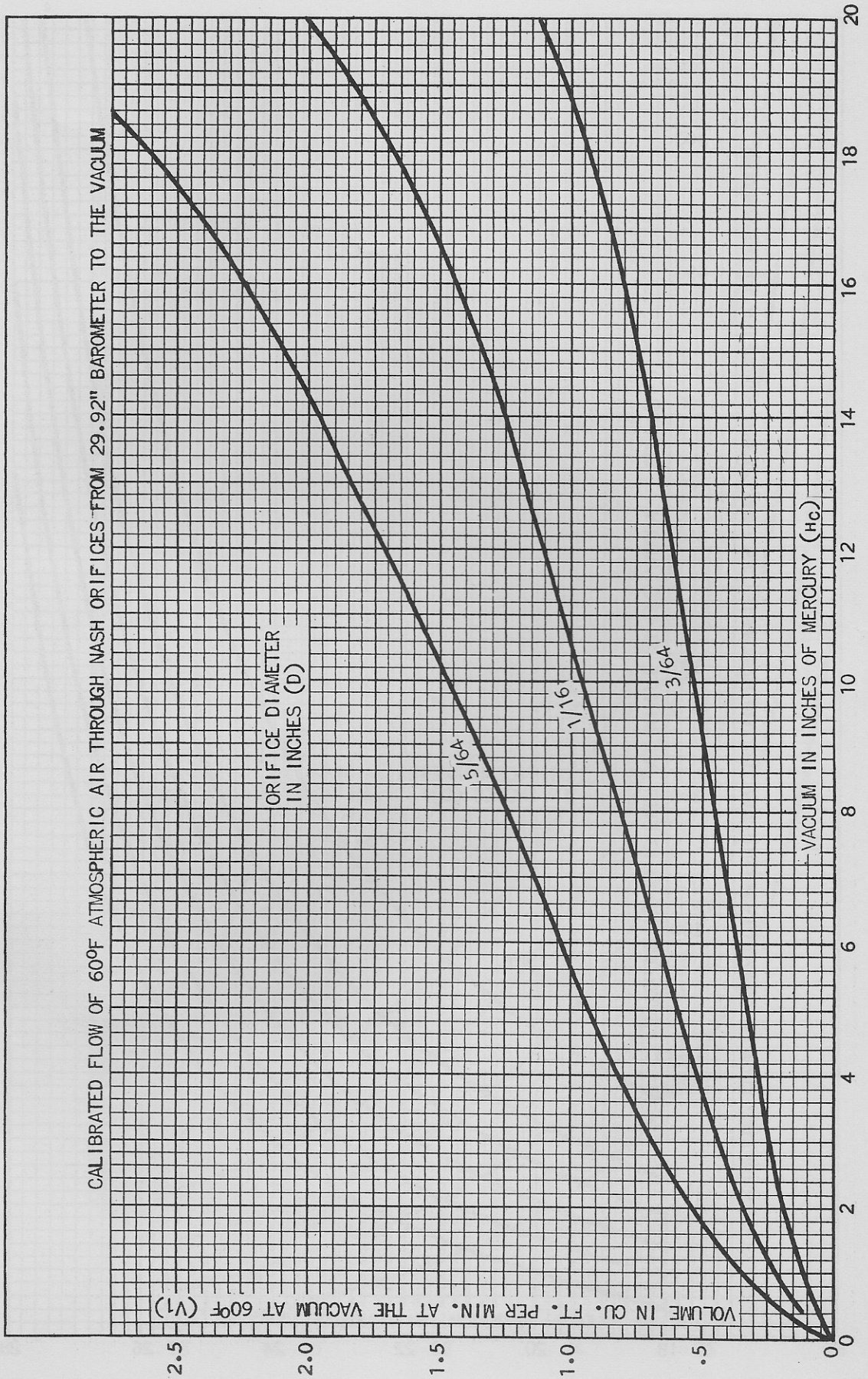
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



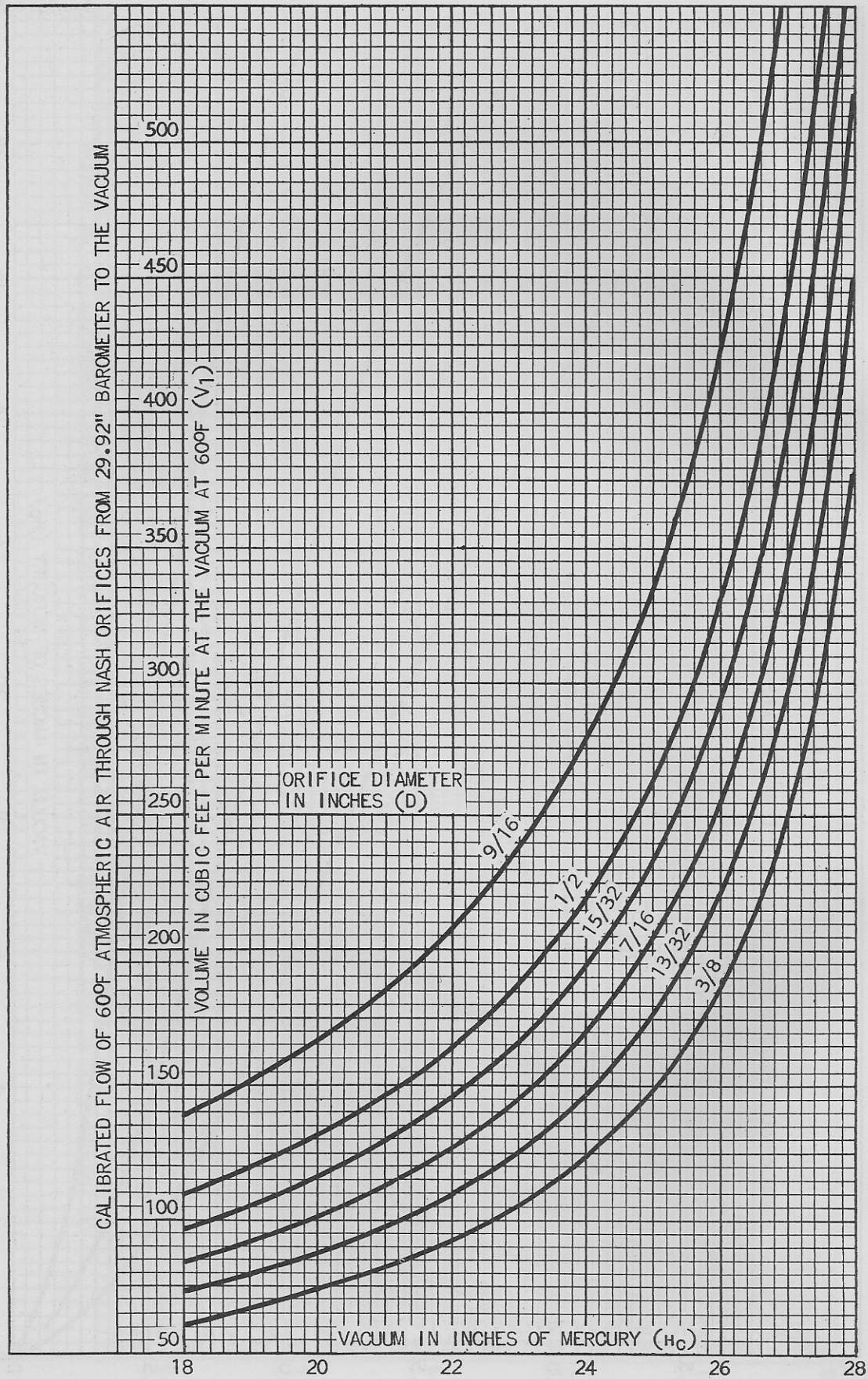
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



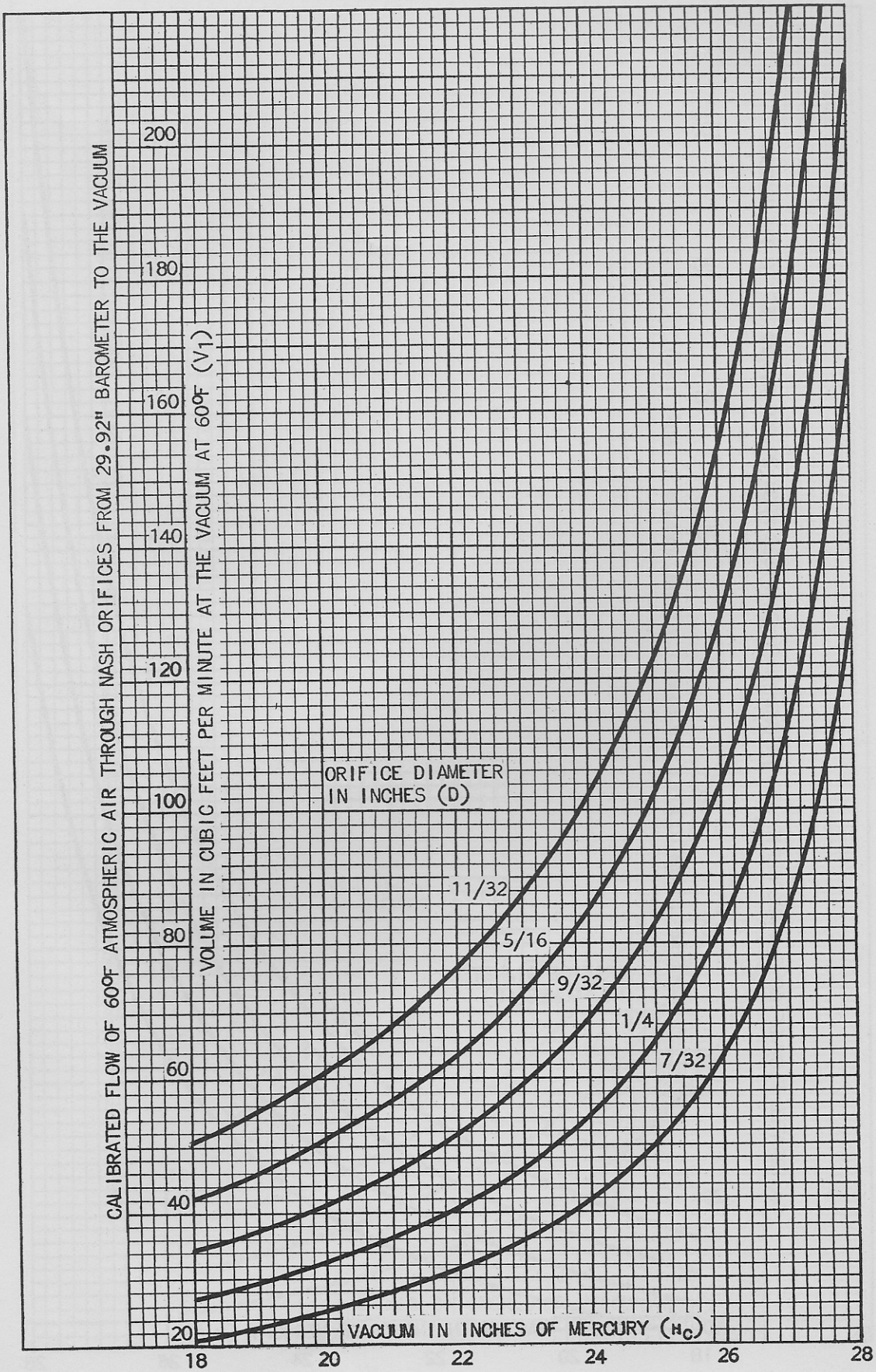
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



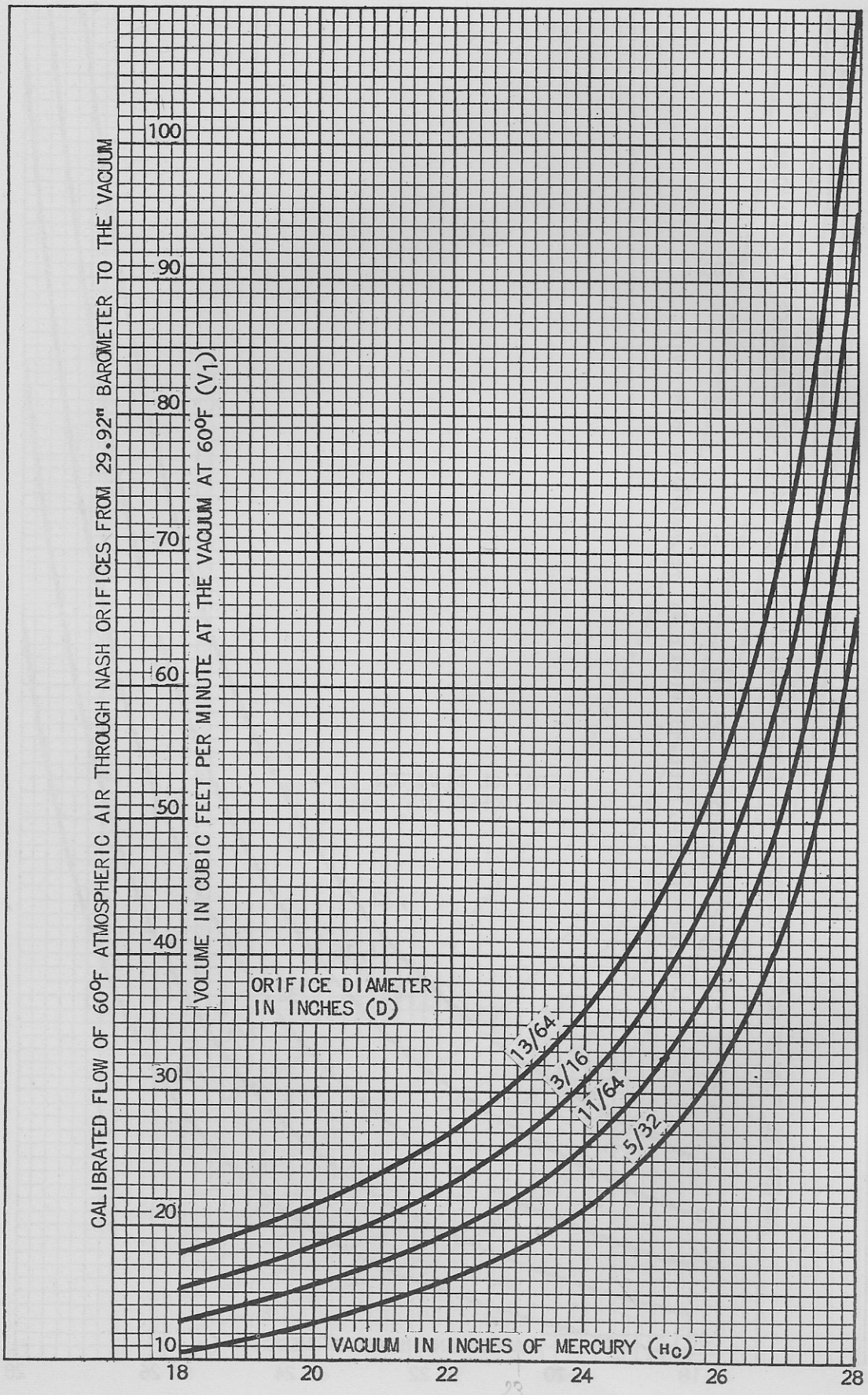
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



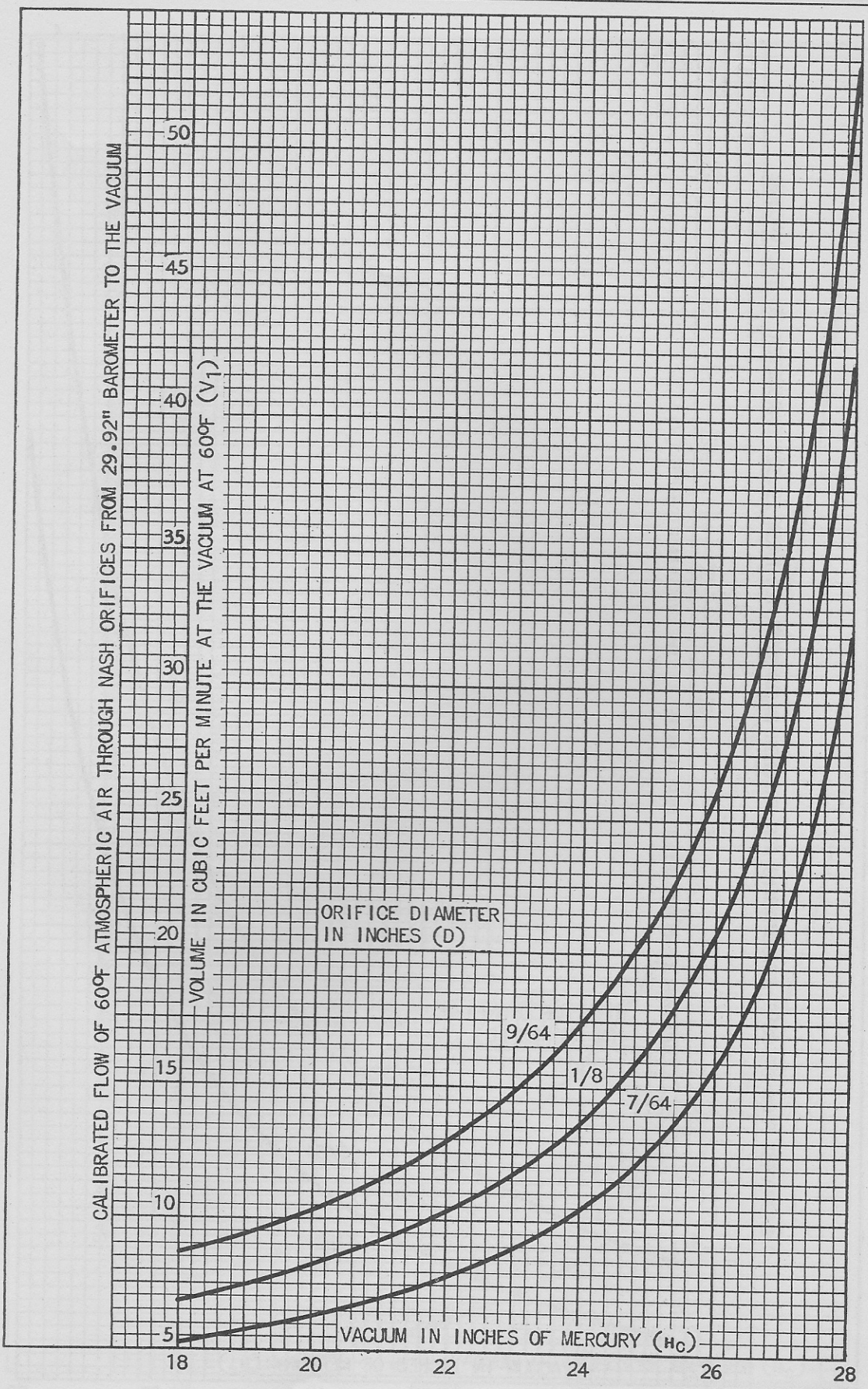
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



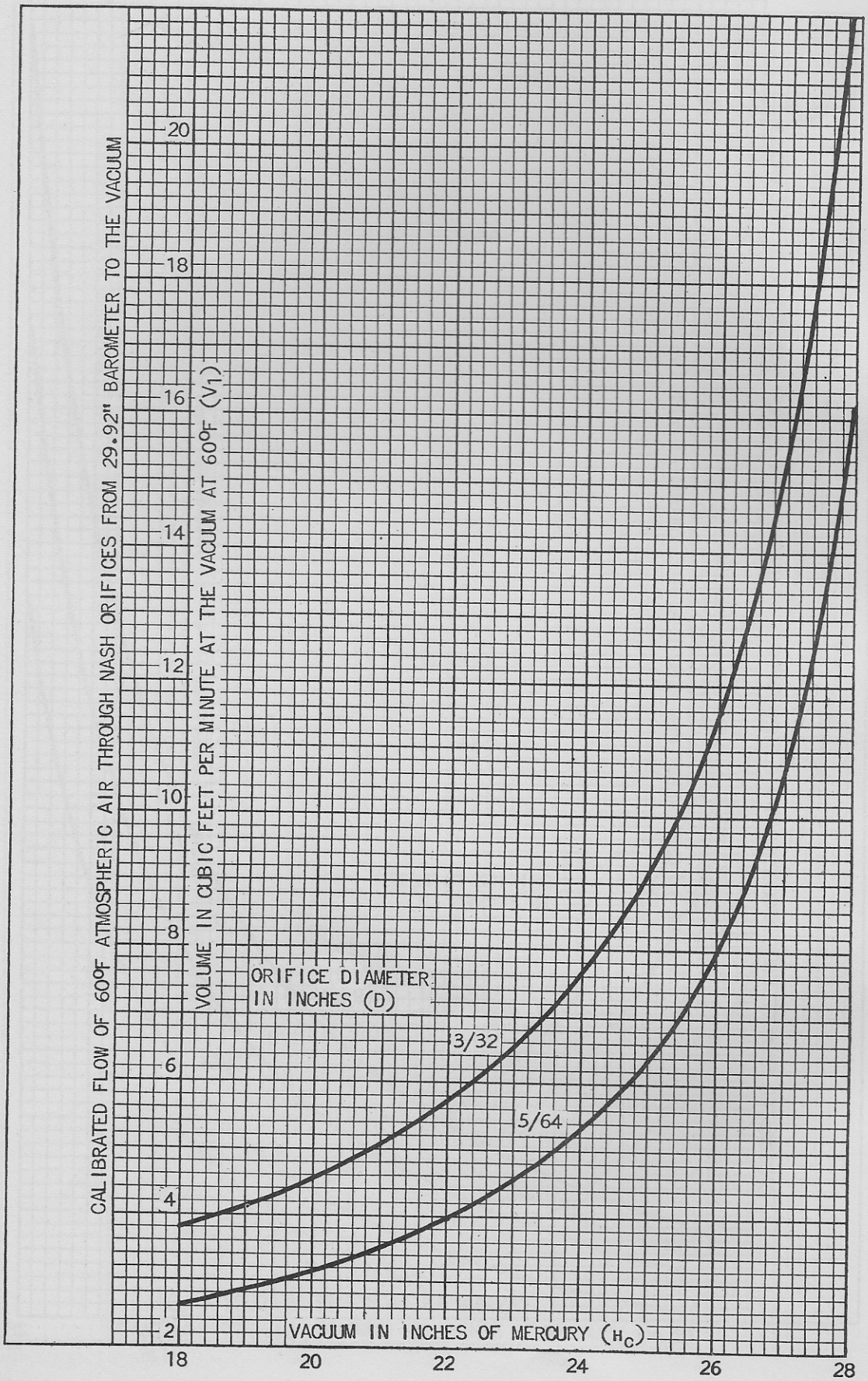
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



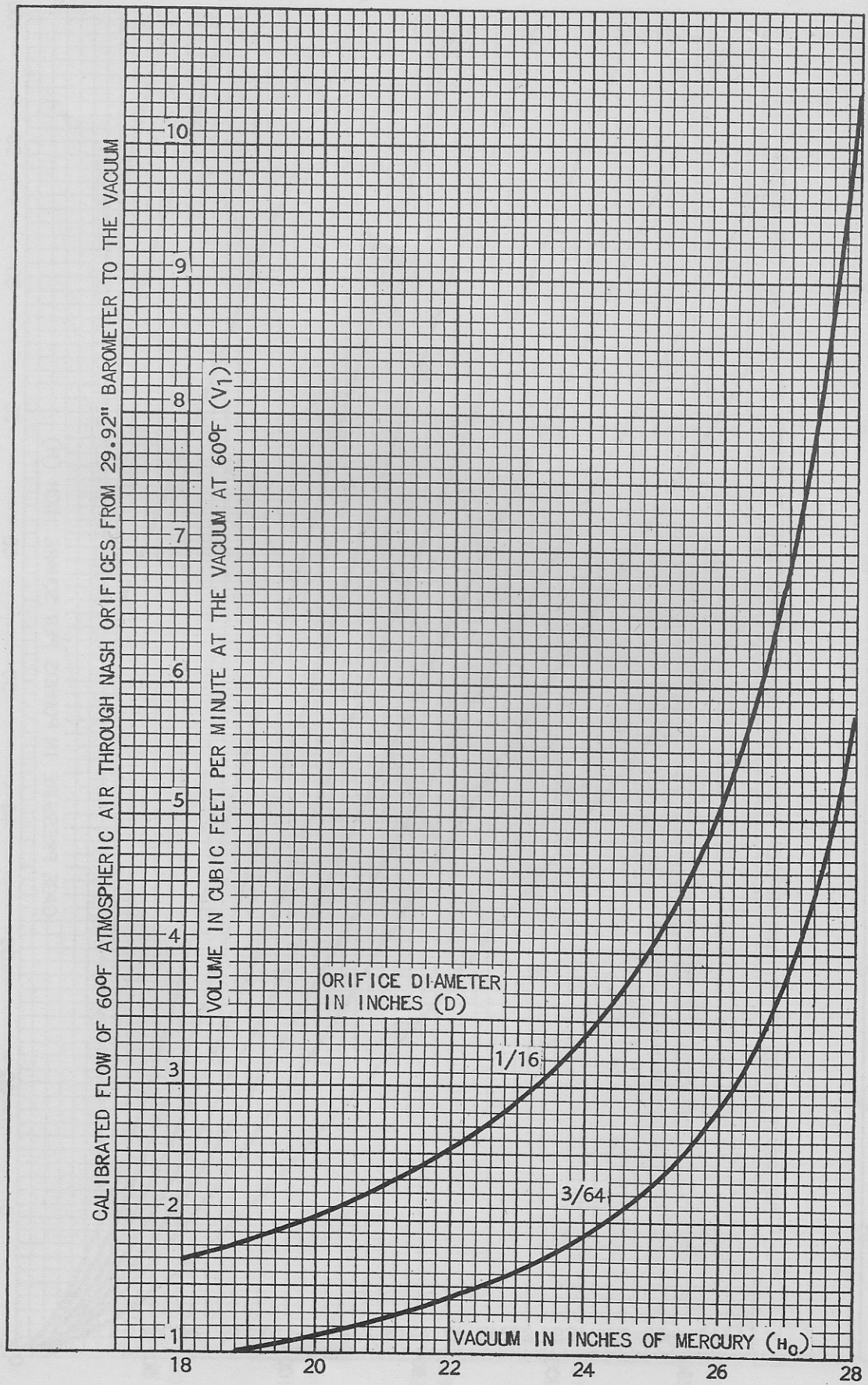
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



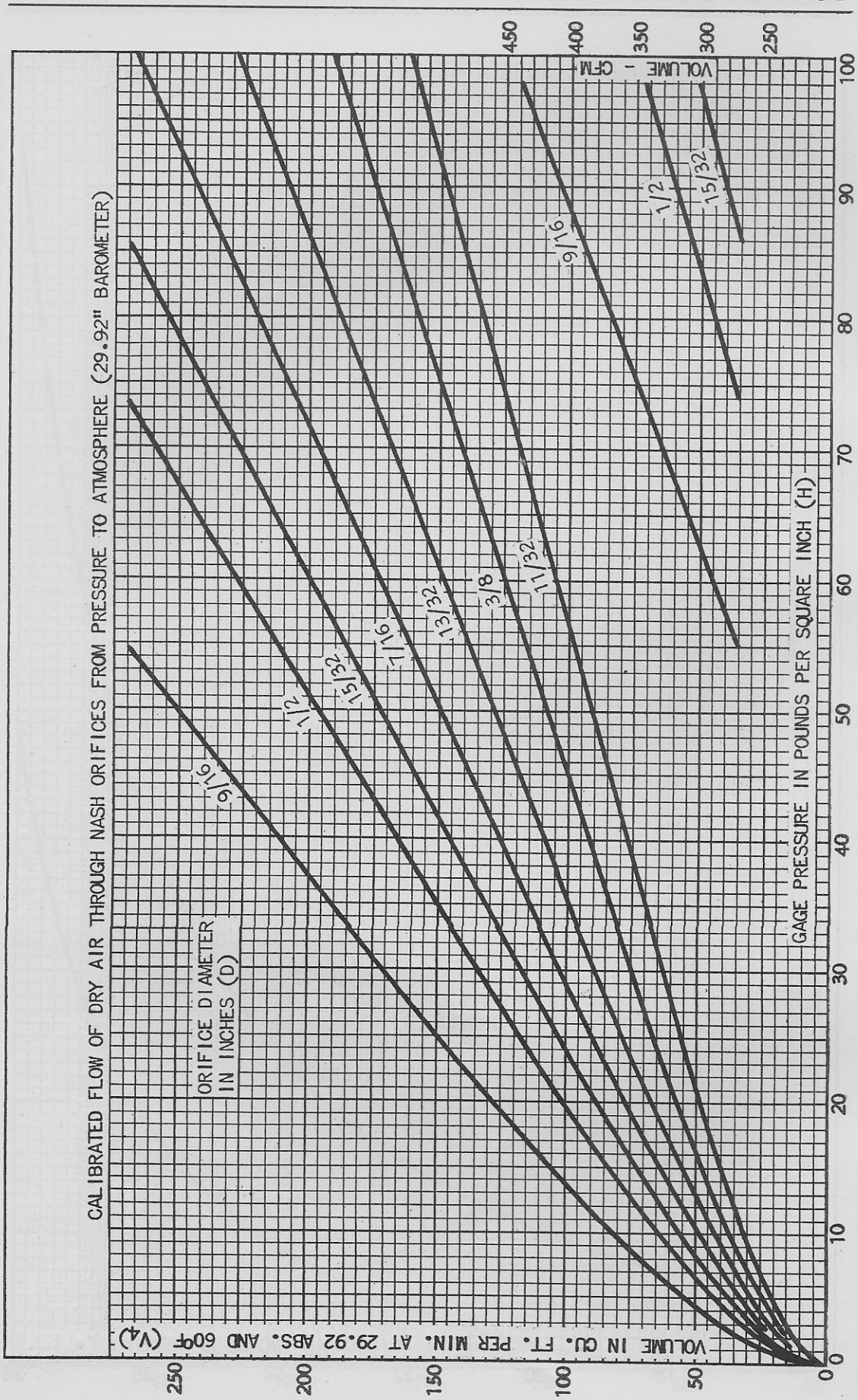
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



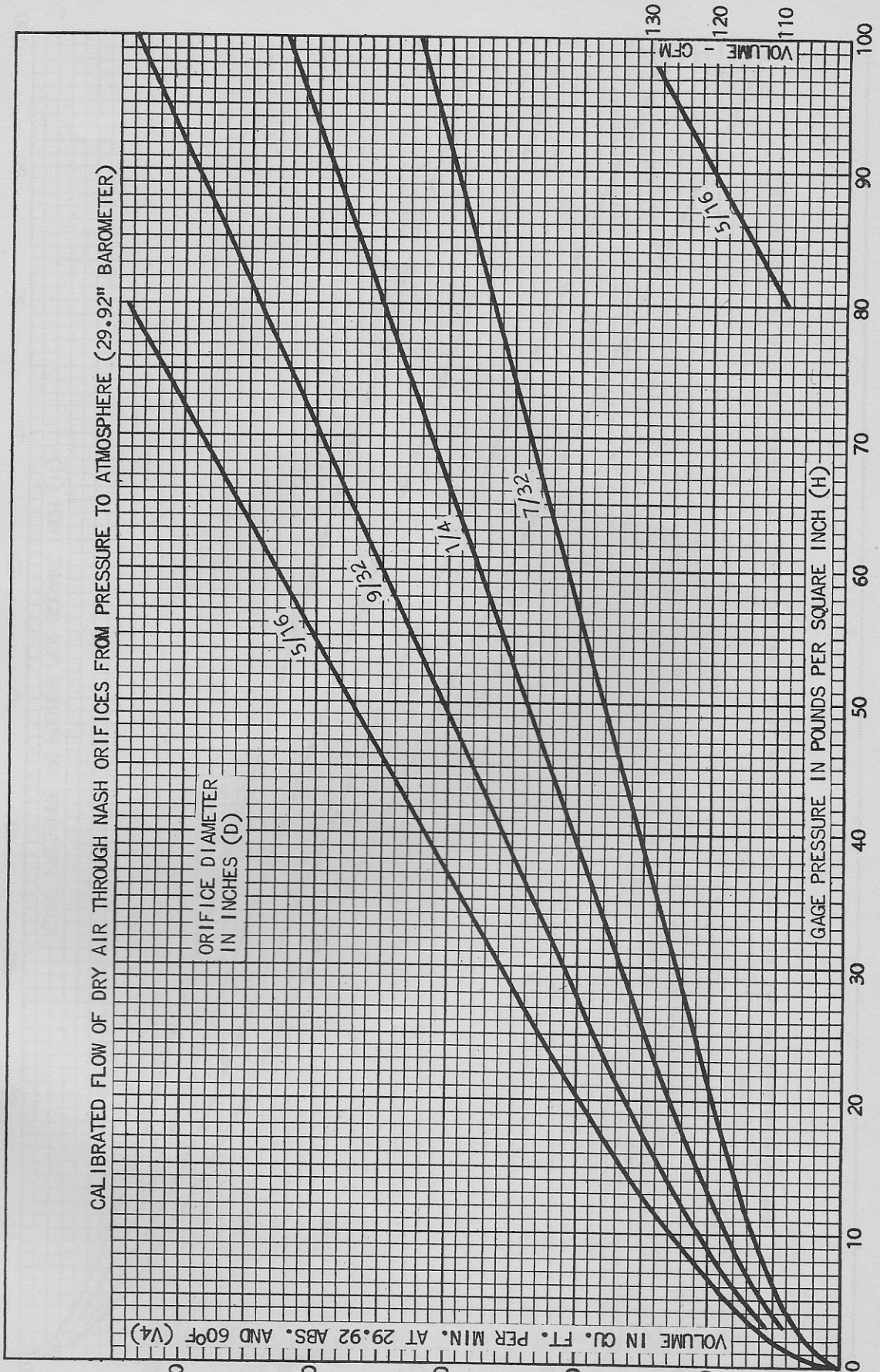
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



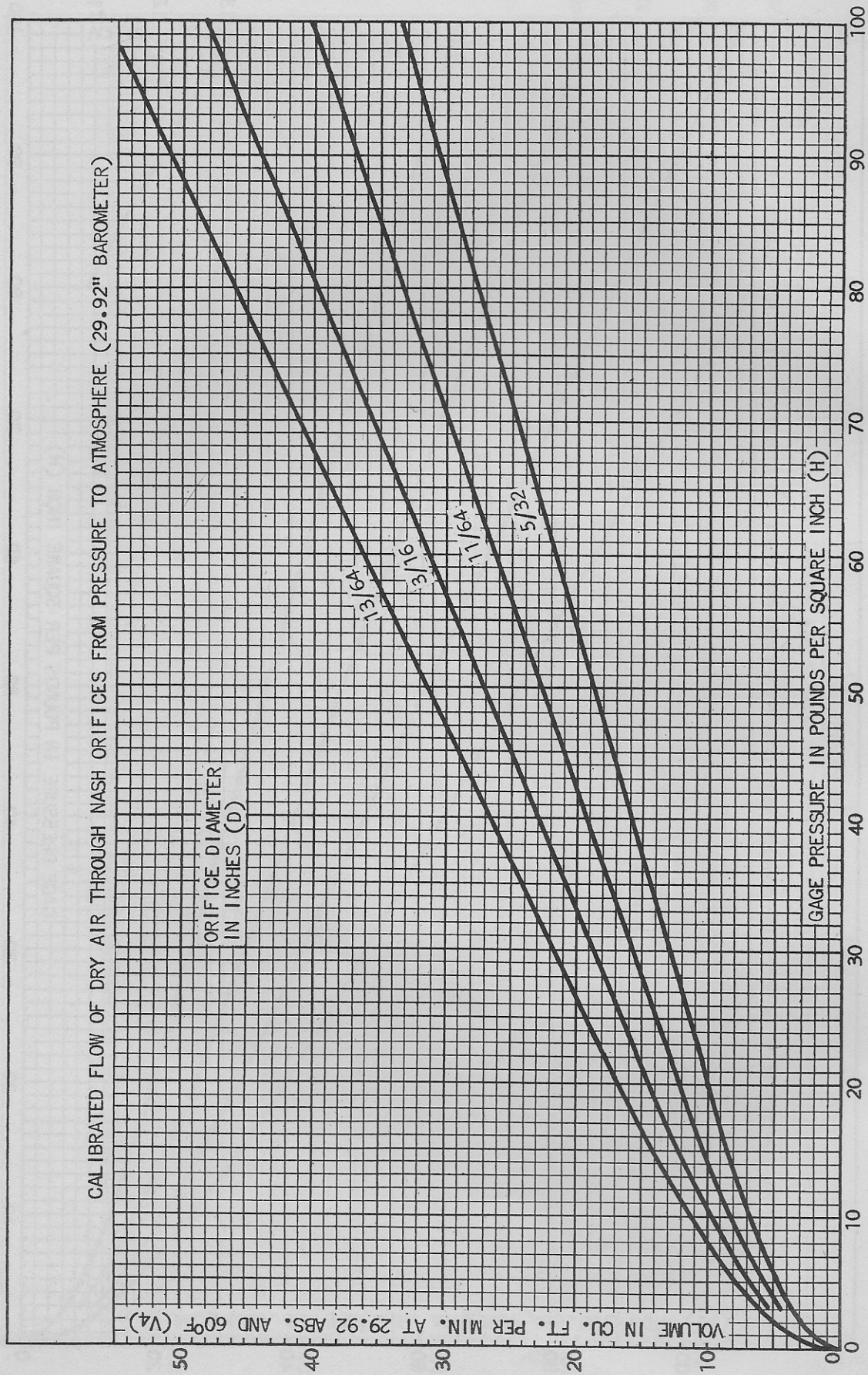
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



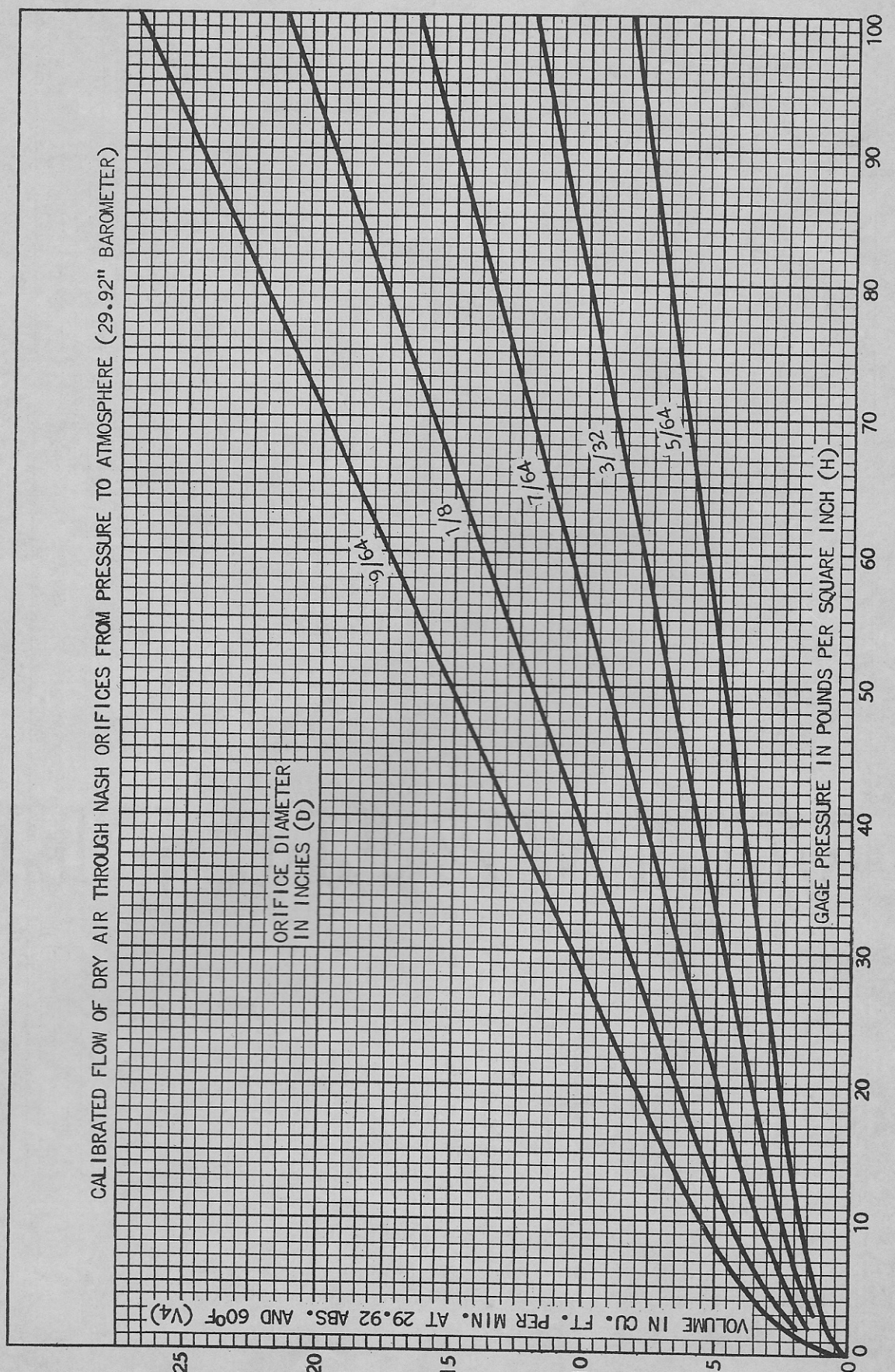
ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD



ACCURATE AIR MEASUREMENT BY NASH ORIFICE METHOD