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JOHN F. KENNEDY SPACE CENTER
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CORRELATION OF LEAK RATES OF VARIOUS FLUIDS WITH THE LEAK RATE OF AN INERT GAS IN THE SAME CONFIGURATION

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I

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II. ABSTRACT

NASA IS INTERESTED IN FIELD TESTING FOR POSSIBLE LEAKAGE IN THEIR FUELING SYSTEMS. HOWEVER, MANY FUELS ARE HAZARDOUS TO THE EXTENT THAT PERSONNEL CANNOT BE ON HAND WHEN THE SYSTEM IS BEING MONITORED. IT IS PROPOSED THAT AN INERT MATERIAL SUCH AS HELIUM BE USED ON THE FIELD TEST, AND THAT THOSE RESULTS BE CALIBRATED TO SIMULATE THE ACTUAL PROCESS. A TECHNIQUE SUCH AS THIS WOULD ALLOW PERSONNEL TO BE ON SITE DURING THE TESTING, AND USE TECHNIQUES TO DETERMINE THE BEHAVIOR OF THE SYSTEM THAT COULD NOT BE USED OTHERWISE. THIS ENDEAVOR ATTEMPTS TO DEVELOP SUCH A CORRELATION. THE RESULTS SHOW PROMISE, BUT MORE REFINEMENT AND MORE DATA ARE NEEDED.

III. SUMMARY

IT WAS DESIRED TO PREDICT THE LEAKAGE OF VARIOUS FLUIDS WITH THE KNOWN LEAKAGE OF A KNOWN GAS FOR A FIXED CONFIGURATION. A SIMPLE MODEL WAS CONTRIVED, SOFTWARE WAS DEVELOPED, AND AN EXPERIMENT WAS RUN TO TEST THE MODEL.

CORRELATION WAS SIGNIFICANT AT THE 99% LEVEL FOR SEVENTEEN RUNS ON THREE DIFFERENT GASES. HOWEVER A LEAST SQUARES REGRESSION ON THE DATA, PRODUCED A DESIRABLE SLOPE BUT A QUESTIONABLE INTERCEPT. AT WORST, THIS WOULD INDICATE THAT THE RANGEABILITY OF THE PREDICTOR IS GOOD ONLY AT HIGHER LEAKAGE RATES, BUT THE AUTHOR BELIEVES THAT THE DISCREPANCIES THAT OCCUR AT LOWER FLOWS ARE PROBABLY DUE TO ERRORS IN FLOWMETER CALIBRATION.

IT WAS RECOMMENDED THAT A LARGER NUMBER OF TESTS OVER A WIDER VARIETY OF CONDITIONS BE RUN, AND THAT SOME SLIGHT MODIFICATIONS IN THE TESTING PROCEDURE BE MADE. THE AUTHOR BELIEVES THAT THE MODEL OR SOME MINOR VARIATION THEREOF WOULD BE AN ADEQUATE PREDICTOR FOR LEAK DETECTION.

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NOMENCLATURE

SYMBOL	DEFINITION	UNITS
A	ACOUSTIC VELOCITY	M/S
C	SPECIFIC HEAT	J/KG/K
CD	DISCHARGE COEFFICIENT	LESS
F	SCALING FACTOR	LESS
G	MASS VELOCITY	KG/M**2/S
H	SPECIFIC ENTHALPY	J/KG
K	SPECIFIC HEAT RATIO	LESS
M	MOLECULAR MASS	AMU
MDOT	MOLAR FLOW	MOL/S
P	ABSOLUTE PRESSURE	N/M**2
R	GAS CONSTANT	J/MOL/K
RHO	DENSITY	KG/M**3
S	CROSS-SECTIONAL AREA	M**2
T	ABSOLUTE TEMPERATURE	K
V	VELOCITY	M/S

SUBSCRIPT	EXPLANATION
a	UPSTREAM CONDITION
b	DOWNSTREAM CONDITION
c	CRITICAL FLOW CONDITION
gas	GAS
liq	LIQUID
o	STAGNATION CONDITION
p	CONSTANT PRESSURE CONDITION
pro	PROCESS CONDITION
ref	REFERENCE CONDITION
s	ISENTROPIC CONDITION
v	CONSTANT VOLUME CONDITION

VI BODY OF TEXT

6.1 INTRODUCTION

THE LEAKING CONFIGURATION WAS ASSUMED TO BE THAT OF A SHARP EDGED ORIFICE. THE CASES OF: 1) THE SINGLE PHASE GAS, 2) TWO-PHASE FLOW, AND 3) THE SINGLE PHASE LIQUID WERE CONSIDERED. FURTHER INVESTIGATION SHOWED THAT ONLY THE CASES OF THE IDEAL GAS UNDER A CRITICAL PRESSURE DROP, AND THE INCOMPRESSIBLE LIQUID WOULD BE CONSIDERED FOR THIS INVESTIGATION. HELIUM OR ANY OTHER GAS IS USED AS THE TEST (OR REFERENCE) GAS AND ANY SINGLE PHASE FLUID (LIQUID OR GAS) MAY BE CONSIDERED AS THE PROCESS FLUID. THE ORIFICE EQUATION FOR A SHARP EDGED ORIFICE HAVING A SMALL BETA IS APPLIED IN BOTH SITUATIONS AND THE MOLAR FLOW OF THE REFERENCE FLUID IS DYNAMICALLY SCALED TO PREDICT THE MOLAR FLOW OF THE PROCESS FLUID.

UNDER EACH CONDITION ONE HOPES THAT THE DISCHARGE COEFFICIENTS ARE THE SAME. IN REALITY THESE COEFFICIENTS HAVE A MAXIMUM RANGE OF ROUGHLY 0.61 TO 1.0. THE LOWER EXTREME IS FAVORED FOR SHARP EDGED ORIFICES AT HIGH REYNOLDS NUMBER INCOMPRESSIBLE FLOW. THE UPPER FOR CAREFULLY MACHINED VENTURI TUBES. INDUSTRIAL PRACTICE ROUTINELY ASSUMES A CONSTANT DISCHARGE COEFFICIENT IN THE SIZING OF CONTROL VALVES, SAFETY VALVES, AND RUPTURE DISCS (1).

6.2 MAIN TEXT

6.2.1 DESCRIPTIVE INFORMATION

A LABORATORY TEST WAS DESIGNED TO TEST FOR THE LEAKAGE OF VARIOUS GASES UNDER DIFFERENT CONDITIONS. THE GASES WERE FED THROUGH A PRESSURE REGULATOR TO A BALLAST TANK. ATTACHED TO THE BALLAST TANK WAS A SMALL BAR STOCK GATE VALVE THAT WAS SLIGHTLY CRACKED. A SMALL ROTAMETER WAS THEN ATTACHED TO THE OTHER END OF THAT VALVE. THE RUNS CONSISTED OF VARYING THE UPSTREAM PRESSURE, FOR THE VARIOUS GASES AND RECORDING THE PRESSURE, TEMPERATURE, AND FLOW READINGS FOR EACH INDIVIDUAL RUN. SEVENTEEN DIFFERENT CONDITIONS WERE RECORDED. THREE DIFFERENT GASES WERE USED, NAMELY HELIUM, NITROGEN, AND ARGON.

6.2.2 MATHEMATICAL PRESENTATION

CONSIDER A CAREFULLY MACHINED CONVERGING-DIVERGING NOZZLE IN A HORIZONTAL PLANE WITH AN IDEAL GAS FLOWING ISENTROPICALLY IN STEADY STATE IN ONE DIMENSION WITH A FLAT VELOCITY PROFILE, AND STAGNATION UPSTREAM.

THEN:	$dH + V*dV = 0,$	(1)
	$P/RHO = 1000*R*T/M,$	(2)
	$dH = Cp*dT,$	(3)
	$Cp = Cv + 1000 * R/M$	(4)
	$K = Cp/Cv,$	(5)
&	$A**2 = [(partial of P)/(partial of RHO)]s$	(6)

COMBINING THE ABOVE WE GET:

	$P/RHO**K = Po/RHOo**K,$ (FOR ISENTROPIC STAGNATION)	(7)
&	$T/P**((K-1)/K) = To/Po**((K-1)/K)$	(8)
SINCE	$G = RHO*V, \& Gc = RHO*A$	(9)
AND	$A**2 = 1000*K*R*T/M$	(10)
	$Gc = RHO*sqrt(1000*K*R*T/M)$	(11)
OR	$Gc = M*P/1000/R/T*sqrt(1000*K*R*T/M)$	(12)
	$Gc = P*sqrt(K*M/1000/R/T)$	(13)

ADJUSTING FOR STAGNATION

$$Gc = Po*sqrt(K*(2/(K+1))**((K+1)/(K-1))*M/1000/R/To) \quad (14)$$

IF THE PROCESS IS NOT ISENTROPIC

$$Gc = CD*Po*sqrt(K*(2/(K+1))**((K+1)/(K-1))*M/1000/R/To) \quad (15)$$

WHERE CD IS THE DISCHARGE COEFFICIENT.

ACCORDING TO SHAPIRO (2)(CH.4,FIG.4.17)THE RANGE FOR CD IN CRITICAL FLOW VARIES BETWEEN 0.74 AND 0.85, AND DEPENDS ONLY ON THE RATIO OF DOWN-STREAM TO UPSTREAM PRESSURES.

NOW LET US CONSIDER THE ALTERNATIVE CONDITION OF AN INCOMPRESSIBLE LIQUID UNDERGOING ISOTHERMAL FLOW IN A PERFECT CONVERGING-DIVERGING NOZZLE. THE FLOW IS AGAIN ISENTROPIC WITH STAGNATION UPSTREAM. THEN THE BERNOULLI EQUATION STATES:

$$(Pb-Pa)/RHO + (Vb**2-Va**2)/2 = 0 \quad (16)$$

FOR Va = 0, LET Vb = V AND WE GET

$$(Pb-Pa)/RHO + V**2/2 = 0 \quad (17)$$

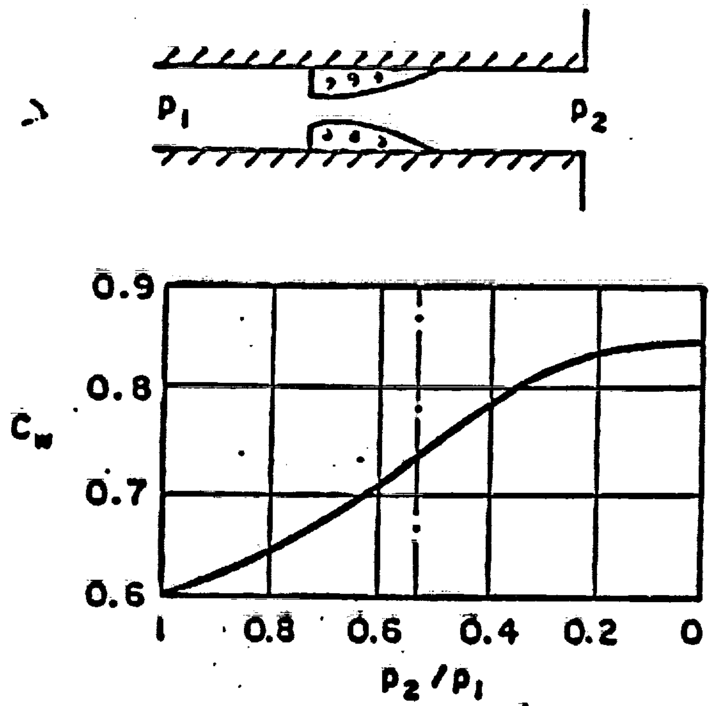

FIG. 4.17. Discharge coefficient of sharp-edged orifice meters with zero velocity of approach (after J. A. Perry).

SINCE Gliq = RHO*V (18)

(Pb-Pa)/RHO + (Gliq/RHO)**2/2 = 0 (19)

OR Gliq = sqrt(2*(Pa-Pb)*RHO) (20)

SIMILARLY FOR NON-ISENTROPIC FLOW

Gliq = CD*sqrt(2*(Pa-Pb)*RHO) (21)

WHERE CD IS THE DISCHARGE COEFFICIENT.

DISCHARGE COEFFICIENTS FOR LIQUIDS FOR ORIFICES WITH SMALL BETAS RUN ABOUT 0.61 (3)(P.5-15).THERE IS NO RECOVERY OF THE LOSS (3)(P.5-17).

THE THIRD POSSIBILITY WE WERE GOING TO CONSIDER WAS THE CASE OF TWO-PHASE CRITICAL FLOW. THE LITERATURE PROVIDES A LARGE AMOUNT OF INTERESTING APPROACHES TO THE PROBLEM, AND THE MODELING IS NOT THE OBVIOUS (4), (5), (6), (7), (8), (9). HOWEVER, THERE ARE INDICATIONS (4) THAT FOR SHARP EDGED ORIFICES WITH SATURATED LIQUID OR SATURATED VAPOR UPSTREAM THAT ONLY THE 100% LIQUID OR THE 100% VAPOR CASE NEED TO BE CONSIDERED. THEREFORE, FOR THE PURPOSES OF THIS REPORT ONLY SINGLE PHASE FLOW WAS INVESTIGATED.

THEN FOR A GAS LEAK CONSIDER

Gc = CD*Po*sqrt(K*(2/(K+1))**((K+1)/(K-1))*M/1000/R/To) (15)

OR

$$\frac{[Gc]pro}{[Gc]ref} = \frac{[CD]pro*[Po*sqrt(K*(2/(K+1))**((K+1)/(K-1))*M/To)]pro}{[CD]\ ref\ *[Po*sqrt(K*(2/(K+1))**((K+1)/(K-1))*M/To)]ref} \quad (22)$$

OR

$$\frac{[Gc]pro}{[Gc]ref} = \frac{[CD]pro}{[CD]ref} * Fgas \quad (23)$$

WHERE

$$Fgas = \frac{[Po*sqrt(K*(2/(K+1))**((K+1)/(K-1))*M/To)]pro}{[Po*sqrt(K*(2/(K+1))**((K+1)/(K-1))*M/To)]ref} \quad (24)$$

NOTING THAT Fgas IS A DIMENSIONLESS FACTOR DEPENDING ONLY ON THE UPSTREAM PRESSURES, TEMPERATURES, AND IDENTITIES OF THE PROCESS AND REFERENCE GASES, OUR FOCUS SHIFTS TO THE RATIO OF THE DISCHARGE COEFFICIENTS - [CD]pro/[CD]ref. RE SHAPIRO (2) THE EXTREMES OF CD IN THE CRITICAL PRESSURE RATIO RANGE ARE FROM 0.74 T0 0.85 IMPLYING A MAXIMUM DIFFERENCE OF ABOUT 15% BETWEEN REFERENCE AND PROCESS CONDITIONS. HOWEVER IT IS EXPECTED THAT THE PRESSURE RATIOS WOULD BE SUFFICIENTLY

SIMILAR OVER BOTH TEST AND REFERENCE CONDITIONS SO THAT THE RATIO [CD]pro/[CD] ref COULD BE TAKEN AT UNITY, AND

$$[Gc]pro = [Gc]ref * Fgas \tag{25}$$

SIMILARLY FOR THE CASE OF THE PROCESS FLUID BEING A LIQUID WE GET:

$$Gliq = CD*sqrt(2*(Pa-Pa)*RHO) \tag{26}$$

$$\frac{[Gc]pro}{[Gc]ref} = \frac{[CD]pro}{[CD]ref} * Fliq \tag{27}$$

WHERE

$$Fliq = \frac{[sqrt(2*(Pa-Pb)*RHO)]pro}{[Po*sqrt(K*(2/(K+1))**((K+1)/(K-1))*M/1000/R/To)]ref} \tag{28}$$

IT IS NOTED THAT Fliq IS A DIMENSIONLESS FACTOR BASED ON THE DENSITY AND PRESSURE DROP OF THE PROCESS LIQUID, AND ON THE IDENTITY AND UPSTREAM CONDITIONS OF THE REFERENCE GAS. SHARP EDGED ORIFICES WITH HIGH VELOCITY LIQUID FLOWS HAVE BEEN SHOWN TO DEMONSTRATE A CD OF 0.61 QUITE RELIABLY (3)(CH.5, FIG.5-20).

HOWEVER, OTHER CONFIGURATIONS DEMONSTRATE CD'S BETWEEN 0.61 AND 1.0. CONSIDERING THE PREVIOUSLY MENTIONED GAS CD'S RANGING FROM 0.74 TO 0.85 WE MAY ESTIMATE A RATE NO MORE THAN 20% LOWER THAN AN ESTIMATE BASED ON Fliq ALONE. NEVERTHELESS THIS IS AN EXTREME CONDITION, CONFIGURATIONS OTHER THAN SHARP EDGED ORIFICES TEND TO HAVE CD'S GREATER THAN 0.61, AND UNTIL EXPERIMENTAL DATA SHOWS OTHERWISE, ESTIMATES WILL BASED ON Fliq ONLY. THAT IS, THE [CD]pro/[CD]ref RATIO WILL BE TAKEN AT UNITY.

THEREFORE FOR GASES

$$[Gc]pro = [Gc]ref * Fgas \tag{29}$$

AND FOR LIQUIDS

$$[Gliq]pro = [Gc]ref * Fliq \tag{30}$$

SINCE $MDOT = G*S/M$ (31)

WE GET $[MDOT]pro = [MDOT]ref /([Mref]/[Mpro]) * Fgas$ (32)

OR $[MDOT]pro = [MDOT]ref /([Mref]/[Mpro]) * Fliq$ (33)

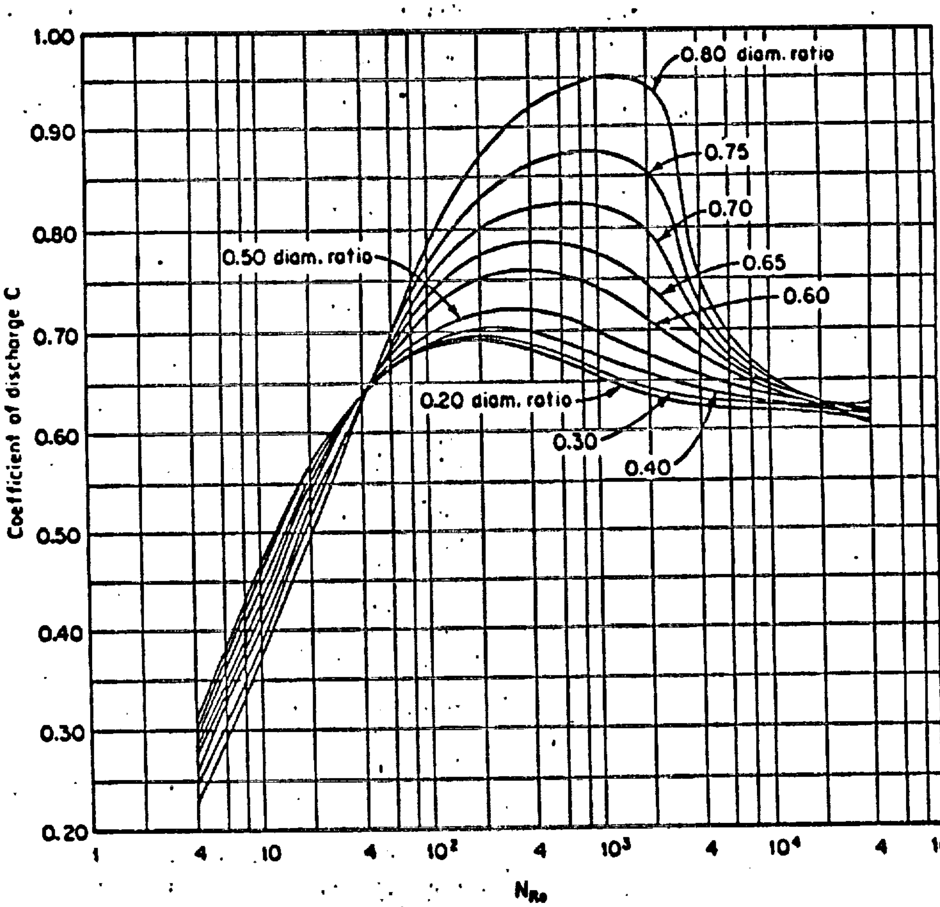

FIG. 5-20 Coefficient of discharge for square-edged circular orifices with corner taps. [*Tuve and Sprenkle, Instruments, 6, 201 (1933).*]

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6.2.3 RESULTS AND DISCUSSION

THE ROTAMETER DETERMINED FLOW RATES WERE CORRECTED FROM HELIUM TO THE PROCESS GAS INVOLVED (10)(FIG 8-27). THE DATA WERE THEN EVALUATED PER PROGRAM LEAX () DEVELOPED BY THE AUTHOR FOR THIS PROJECT. PICTORIAL REPRESENTATION OF THE RESULTS WERE THEN OBTAINED VIA AN ADAPTATION OF THE IN HOUSE REGIS SOFTWARE. A LINEAR REGRESSION WAS APPLIED TO THE DATA AND A LEAST SQUARES FIT INDICATED A SLOPE OF ABOUT 0.9 AND AN INTERCEPT OF ABOUT 15 SCCM WITH SIGNIFICANCE AT THE 99% LEVEL. IDEALLY ONE WOULD EXPECT A SLOPE OF 1.0 AND AN INTERCEPT OF ZERO. THE AUTHOR REGARDED THE SLOPE AS INDICATIVE OF THE RATIO OF THE CD'S WHICH WAS TAKEN AT UNITY. THOUGH THE 0.9 SLOPE IS QUITE SATISFACTORY, THE INTERCEPT OF 15 SCCM WAS CONSIDERED TO BE HIGH AT LOW LEAK RATES. IN ORDER TO DEMONSTRATE THAT THE EFFECT OF THE NONE ZERO INTERCEPT WAS NOT DUE TO THE EFFECTS OF THE CD ASSUMPTIONS THE DATA WERE AGAIN EXAMINED WITH LEAX2 WHICH CORRECTED FOR THIS DISCREPANCY AND VERY SIMILAR RESULTS WERE OBTAINED. (TABLE 1, FIGURE 1, TABLE 2, FIGURE 2)

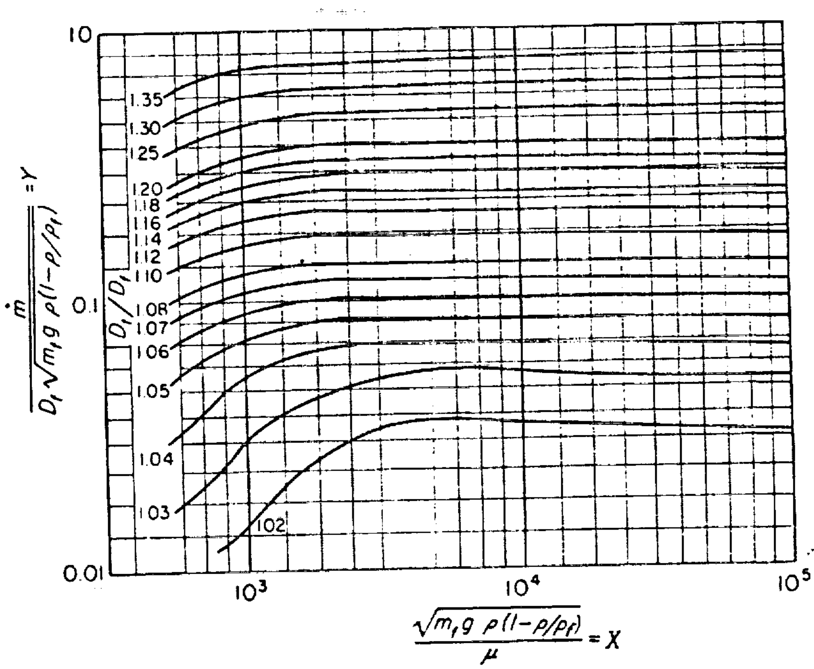

Figure 8-27 *Rotameter calibration curves.*

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TABLE 1

FILE NAME = TESTRUN
TITLE = UG. 1,1990
STATUS = NEW
DEVICE = 22

RUN	GAMMAREF	MWREF AMU	PREF PSIG	TREF DEGF	MFREF SCCM	GAMMAPRO	MWPRO AMU	PPRO PSIG	TPRO DEGF	MFPRO SCCM	MFOBS SCCM
1	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.400E+01	0.151E+02	0.797E+02	0.380E+02	0.120E+02
2	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.400E+01	0.299E+02	0.797E+02	0.568E+02	0.390E+02
3	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.400E+01	0.448E+02	0.797E+02	0.758E+02	0.600E+02
4	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.400E+01	0.601E+02	0.797E+02	0.953E+02	0.925E+02
5	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.105E+03
6	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.140E+01	0.280E+02	0.150E+02	0.757E+02	0.135E+02	0.472E+01
7	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.140E+01	0.280E+02	0.300E+02	0.789E+02	0.203E+02	0.104E+02
8	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.140E+01	0.280E+02	0.451E+02	0.797E+02	0.271E+02	0.159E+02
9	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.140E+01	0.280E+02	0.600E+02	0.805E+02	0.339E+02	0.181E+02
10	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.140E+01	0.280E+02	0.752E+02	0.813E+02	0.407E+02	0.234E+02
11	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.140E+01	0.280E+02	0.900E+02	0.813E+02	0.474E+02	0.291E+02
12	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.149E+02	0.773E+02	0.120E+02	0.475E+01
13	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.300E+02	0.797E+02	0.180E+02	0.101E+02
14	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.450E+02	0.797E+02	0.241E+02	0.139E+02
15	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.601E+02	0.797E+02	0.302E+02	0.171E+02
16	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.753E+02	0.797E+02	0.363E+02	0.221E+02
17	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.904E+02	0.797E+02	0.424E+02	0.266E+02

F(CALCULATED) = 0.336E+03 F.95 = 0.454E+01 F.99 = 0.868E+01
X(PREDICTED) = 0.153E+02 + (0.904E+00)*X(OBSERVED)
CORRELATION IS SIGNIFICANT AT THE 95% LEVEL
CORRELATION IS SIGNIFICANT AT THE 99% LEVEL

FIGURE 1

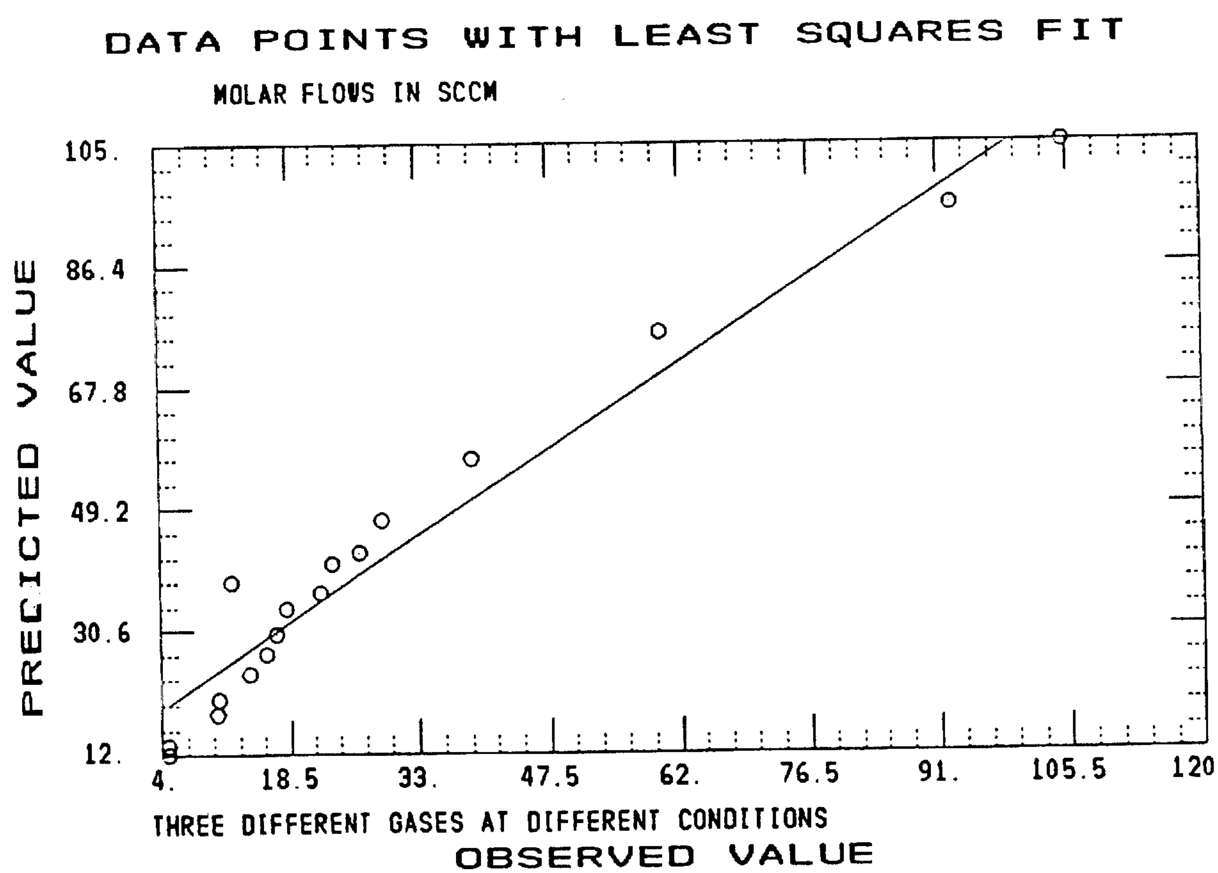

DATA POINTS WITH LEAST SQUARES FIT
MOLAR FLOWS IN SCCM
105.
86.4
67.8
49.2
30.6
12.
PREDICTED VALUE
4.
18.5
33.
47.5
62.
76.5
91.
105.5
120.
THREE DIFFERENT GASES AT DIFFERENT CONDITIONS
OBSERVED VALUE

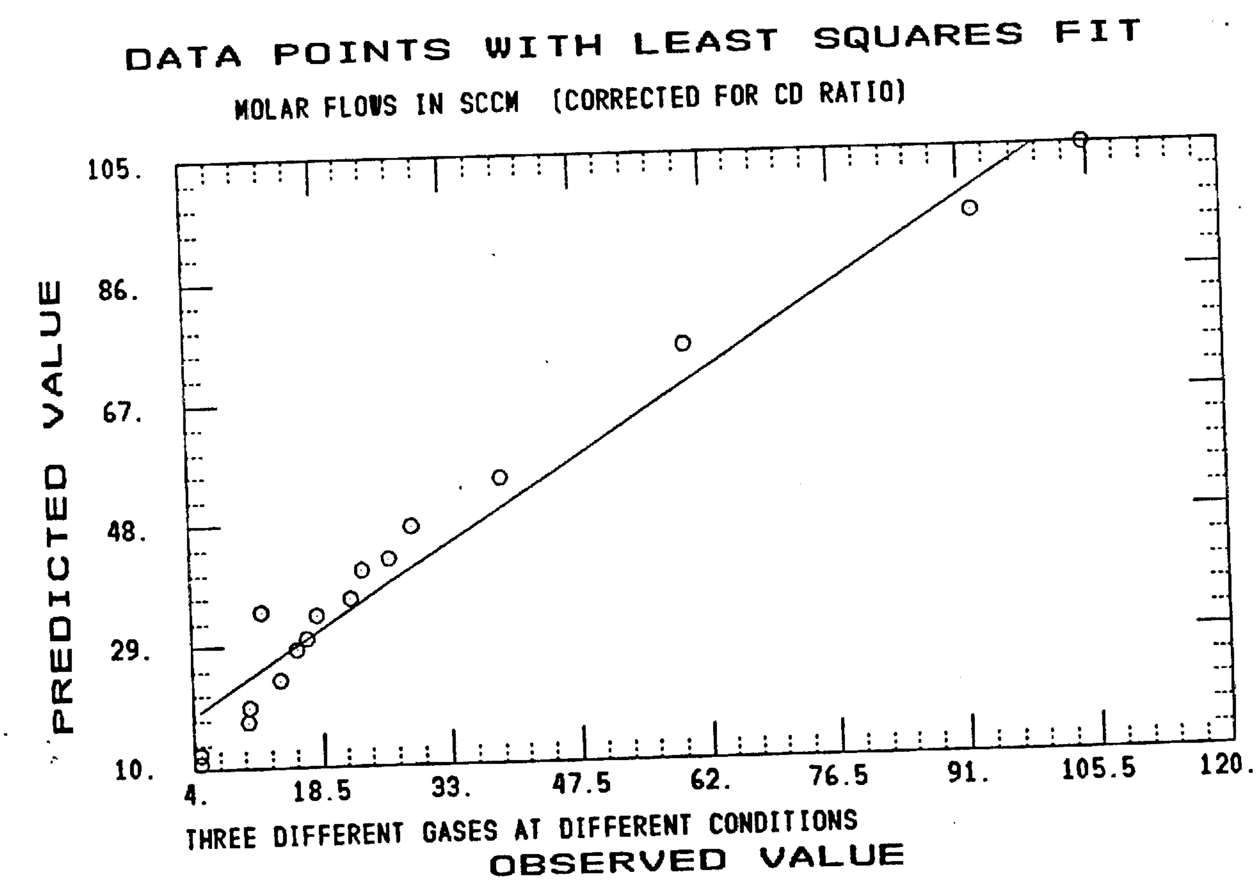
TABLE 2

FILE NAME = TEST2
TITLE = AGAIN AUG 6.1990
STATUS = NEW
DEVICE = 22

RUN	GAMMAREF	NUREF AMU	PREF PSIG	TREF DEGF	MFREF SCCM	GAMMAPRO	NUPRO AMU	PPRO PSIG	TPRO DEGF	MFPRO SCCM	MFOBS SCCM
1	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.400E+01	0.151E+02	0.797E+02	0.349E+02	0.120E+02
2	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.400E+01	0.299E+02	0.797E+02	0.549E+02	0.390E+02
3	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.400E+01	0.448E+02	0.797E+02	0.749E+02	0.600E+02
4	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.400E+01	0.601E+02	0.797E+02	0.950E+02	0.925E+02
5	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.105E+03
6	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.140E+01	0.280E+02	0.150E+02	0.757E+02	0.123E+02	0.472E+01
7	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.140E+01	0.280E+02	0.300E+02	0.789E+02	0.196E+02	0.104E+02
8	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.280E+02	0.451E+02	0.797E+02	0.284E+02	0.157E+02
9	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.140E+01	0.280E+02	0.600E+02	0.805E+02	0.338E+02	0.181E+02
10	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.140E+01	0.280E+02	0.752E+02	0.813E+02	0.405E+02	0.234E+02
11	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.140E+01	0.280E+02	0.900E+02	0.813E+02	0.477E+02	0.291E+02
12	0.157E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.149E+02	0.773E+02	0.108E+02	0.475E+01
13	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.300E+02	0.797E+02	0.174E+02	0.101E+02
14	0.-67E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.450E+02	0.797E+02	0.238E+02	0.139E+02
15	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.601E+02	0.797E+02	0.301E+02	0.171E+02
16	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.753E+02	0.797E+02	0.364E+02	0.221E+02
17	0.167E+01	0.400E+01	0.677E+02	0.797E+02	0.105E+03	0.167E+01	0.399E+02	0.904E+02	0.797E+02	0.426E+02	0.266E+02

F(CALCULATED) = 0.379E+03 F.95 = 0.494E+01 F.99 = 0.868E+01
X(PREDICTED) = 0.147E+02 + (0.989E+00)*X(OBSERVED)
CORRELATION IS SIGNIFICANT AT THE 95% LEVEL
CORRELATION IS SIGNIFICANT AT THE 99% LEVEL

FIGURE 2



DATA POINTS WITH LEAST SQUARES FIT
MOLAR FLOWS IN SCCM (CORRECTED FOR CD RATIO)
105.
86.
67.
48.
29.
10.
PREDICTED VALUE
4.
18.5
33.
47.5
62.
76.5
91.
105.5
120.
THREE DIFFERENT GASES AT DIFFERENT CONDITIONS
OBSERVED VALUE

VII CONCLUDING SECTION

7.1 CONCLUDING REMARKS

X (PREDICTED) = 0.9 * X (OBSERVED) + B WAS SIGNIFICANT AT A LEVEL OF 99%, X REFERRING TO THE MOLAR FLOW RATE. OF COURSE ONE WOULD IDEALLY EXPECT THAT X (PREDICTED) = X (OBSERVED). HOWEVER DUE TO THE ROUGH NATURE OF THE PREDICTOR 0.9 SEEMS TO BE ACCEPTABLE AS THE SLOPE AND IS INDICATIVE OF THE ASSUMPTION THAT THE RATIO OF THE DISCHARGE COEFFICIENTS BE UNITY. THE INTERCEPT B WOULD EXERT LITTLE INFLUENCE AT THE HIGHER FLOWS BUT WOULD BE SIGNIFICANT AT LOWER FLOW RATES.

THE DATA WERE AGAIN PROCESSED USING AN ALGORITHM THAT ACCOUNTED FOR THE RATIO OF THE DISCHARGE COEFFICIENTS. VERY SIMILAR RESULTS WERE ACHIEVED, INDICATING THAT THE RESIDUAL INTERCEPT MAY HAVE ARISEN FROM FLOWMETER CALIBRATION. IT IS RECOMMENDED, THAT THE DATA BE RETAKEN ON A "TIME-WEIGH" BASIS TO DETERMINE WHETHER OR NOT THE FLOW MEASUREMENT GAVE RISE TO THE SOMETIMES UNDESIRABLE INTERCEPT.

VIII APPENDIX

LABORATORY DOCUMENTATION

COMMENTS TO ELAINE WHITE REPORT

Add Title to report. "SPECIAL LEAK RATES TEST".

ABBREVIATIONS/ACCRONYMS

PSIG	Pounds Per Square Inches
oF	Degrees Farenheit
SCCM	Standard Cubic Centimer
KC	Kennedy Space Center fittings
GN2	Gaseous Nitrogen
GHe	Gaseous Helium
Ar	Gaseous Argon

George
4526

INTRODUCTION

A need to know small leak rates for different gases at ambient temperatures was the test objective. The Prototype Lab (DM-MED-2) was used to contruct the test tool to perform (See fig. HH). The tool made of 6061 Aluminum pipe measuring 12 inch by 8 inch had both end capped with an 6061 Aluminum plate. Ports were drilled and tapped at one end for installing the pressure, temperature and flowrate instrumentation.

PRELIMINARY MEETING

A preliminary meeting was held on July 26, 1990 to discuss the test project requirements. Personnel attending the meeting were: John Puppert, Ernie Walters, and Ron Fox with DM-MED-2, and Andy Rodriguez, Elaine White with DM-MED-4.

DISCUSSION

Figure HH shows a pictorial of the test setup. The instrumentation used is also shown on this figure. The test result is shown on Table H. Flow rates were measured at each pressure increment of 15 PSIG.

CONCLUSION

There were no anomalies during the fabrication/test phase and all the test objectives were accomplished.

INTRODUCTION

ON 26 JULY 1990 @ 0930 HRS., JOHN POPPERT, ERNIE WALTERS, RON FOX (DM-MED-2), ANDY RODRIGUEZ, AND ELAINE WHITE (DM-MED-4) MET IN THE PROTOTYPE SHOP BUILDING TO DISCUSS FABRICATION OF A TEST SET-UP TO RECORD LEAK RATES OF VARIOUS GASEOUS MEDIUMS IN A VESSEL WITH A KNOWN AMBIENT TEMPERATURE AND PRESSURE. WITH A CONTROLLED LEAK, THE FLOWRATE WOULD BE MEASURED AND CONVERTED TO SCCM.

AFTER CONSTRUCTION OF THE VESSEL ON 27 JULY 1990, IT WAS CHECKED FOR LEAKS BY A DU PONT INSTRUMENTS 120 SSA LEAK DETECTOR. THE TESTS WERE CONDUCTED ON 01 AUG 1990 AFTER A TWO DAY DELAY BECAUSE OF OTHER HIGHER PRIORITY PROJECTS AT THE PROTOTYPE LAB. THE TEST CONDUCTOR WAS ELAINE WHITE (DM-MED-4) AND THE TECHNICIAN WAS RON FOX (DM-MED-2).

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TEST SET-UP

A HEISE DIGITAL PRESS. INDICATOR
RANGE 0-100 PSI, ACCURACY 0.1 %
CALIBRATION CAL/CERT # M06071
DATE 11 JAN 90

B FLOWMETER
MATHESON # 610A RANGE 0-100
MAX PRESS. 250 PSI
KC-116 FITTING WITH TEFLON TAPE
CALIBRATION CAL/CERT # M05881
DATE 05 DEC 89

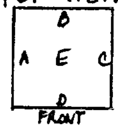
C [SEE NEXT SHEET]

D ASTRO-MED, INC. STRIP CHART
MT-9500
PRESSURE READING 0-100 PSI
TEMPERATURE READING 0-100 % ≅ 23° -104°F

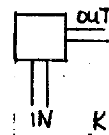
[C] VESSEL

PIPING AND PLATES BOTH ALUMINUM

TOP VIEW



A SHUTOFF VALVE
TESCOM CORP.
KEL-F-81 SEATS
6000 PSI MAX
SERIAL # L46004



KC112-C4
KC171-C4
(3) PACKINGS
(1) SEAL RING KC103-4

B PRESSURE TRANSDUCER
TELEDYNE TABER
MODEL # 2403
RANGE 0-100 PSI, ACCURACY 1% FULL SCALE
SERIAL # 848388
SPLC # 79K 034-38-S3N1Z REV G
CALIBRATION CAL/CERT Z80276
DATE 29 NOV 89

C METERING VALVE
PARKER HANNIFIN CORP.
CPV-84-1-11
(2) KC 116-C4-2
(1) KC 103-4

D TANK BLEED VALVE
TESCOM CORP.
KEL-F-81 SEATS
6000 PSI MAX
SERIAL # L46023

E TEMPERATURE TRANSDUCER
SCIENTIFIC INSTR. INC.
MODEL # 49WT-02-13
RANGE -5C to +40° C, ACCURACY ± 1%
SPLC # 79K03449-02-13S
CALIBRATION CAL/CERT Z 06160
DATE 1 APR 90

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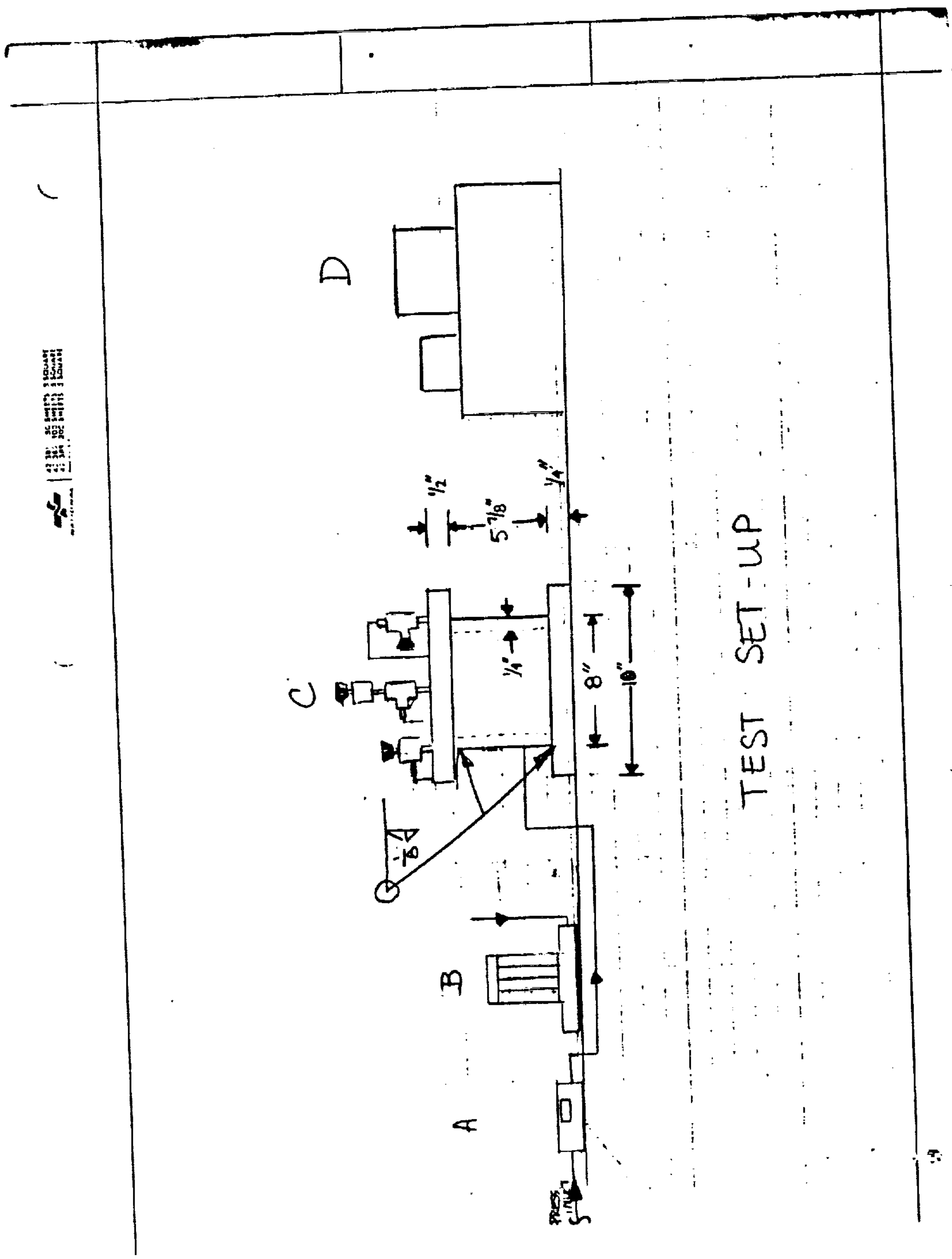

TEST SET-UP

TEST RUN DATA - TEST DATE 01 AUG 1990

	PRESS (PSI)	LEAKRATE (SCCM)	TEMP (°F)
NITROGEN	15.0	12.5	75.7°
	30.0	27.5	78.9°
	45.1	42	79.7°
	60.0	48	80.5°
	75.2	62	81.3°
	90.0	77	81.3°
HELIUM	15.1	12	79.7°
	29.9	39	79.7°
	44.8	60	79.7°
	60.1	92.5	79.7°
	67.7	105	79.7°
ARGON	14.9	15	79.3°
	30.0	32	79.7°
	45.0	44	79.7°
	60.1	54	79.7°
	75.3	70	79.7°
	90.4	84	79.7°
			79.7°

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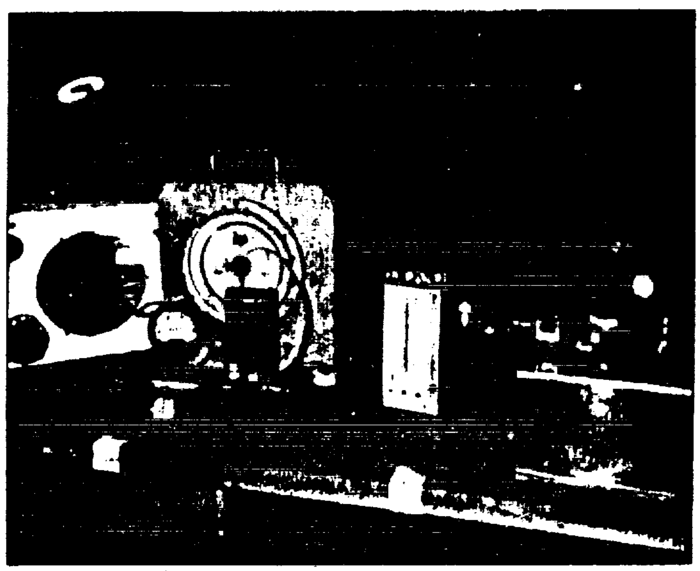
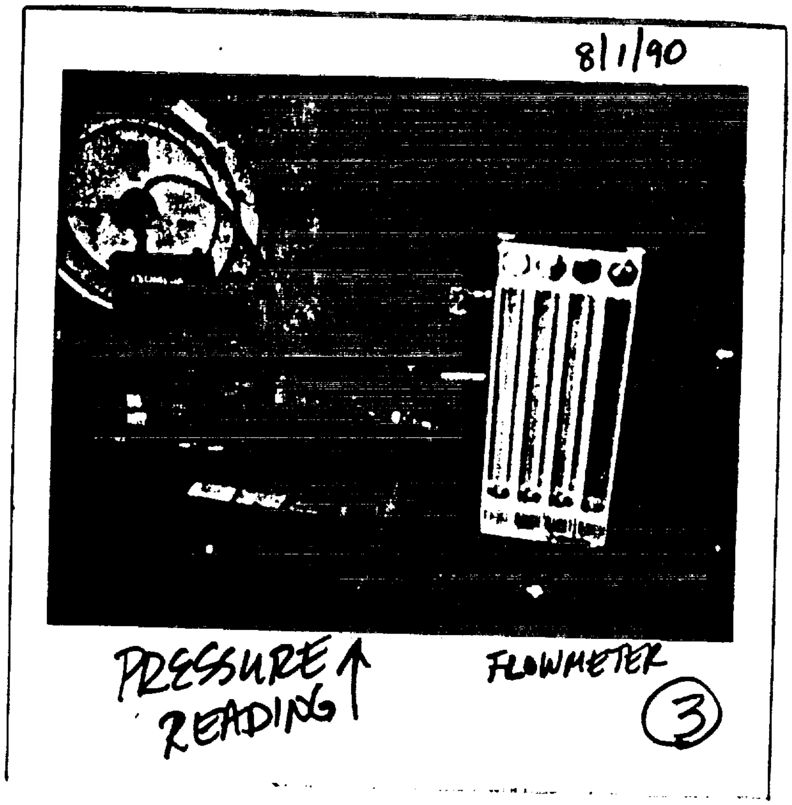


Test setup stripchart →

(1)



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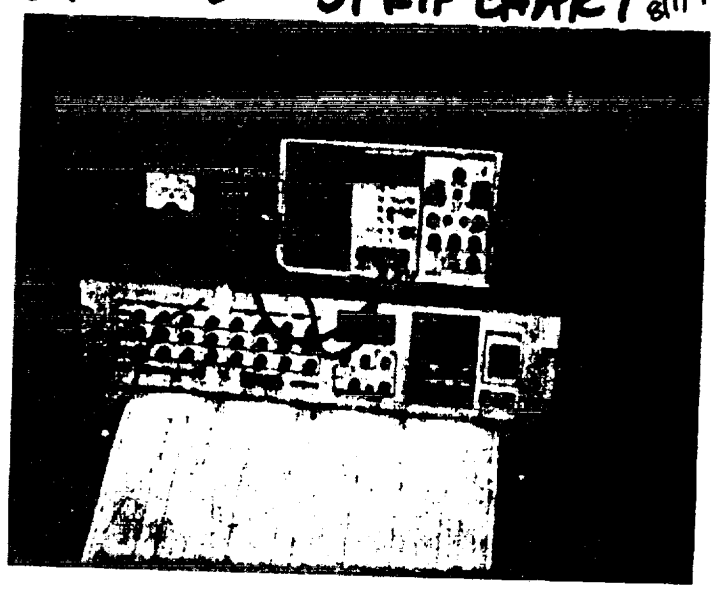
ASTRO-MED STRIP CHART 8/1/90



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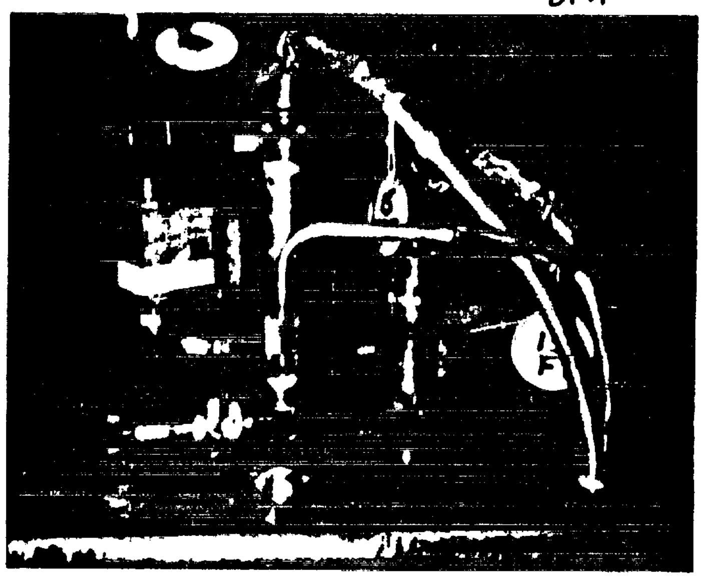
8/1/90



MTR VLV SIDE (5)

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