TECHNICAL MEMORANDUM X-53729

CALIBRATIONABLE PRESSURE SWITCH (CALIPS) CHECKOUT SYSTEM LOOP ACCURACY EXPERIMENT

By

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ABSTRACT

Presented is a summary report of an experiment conducted at Marshall Space Flight Center to evaluate the accuracy capabilities of calibrationable pressure switch (CALIPS) checkout systems. It was found that if the range of the reference transducer matches that of the switch under test, if the ground A/D converter is properly aligned, and if the pneumatic ramp rate is slow enough, accuracy requirements can be met or exceeded.

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PROPULSION AND VEHICLE ENGINEERING LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

ACKNOWLEDGMENTS

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DEFINITION OF SYMBOLS

A/D	analog to digital
CALIPS	Calibrationable Pressure Switch
CEC	Consolidated Electrodynamic Corporation
DVM	digital voltmeter
GN_2	gaseous nitrogen
GSE	ground support equipment
GHe	gaseous helium
IBM	International Business Machines
KSC	Kennedy Space Center
μ	mean
OAT	overall tests
P&VE	Propulsion and Vehicle Engineering Laboratory
RCA	Radio Corporation of America
P_r	reference pressure
S-IB/SDBF	Saturn IB Systems Development Breadboard Facility
S-IB/SDBF AGCS	Saturn IB Systems Development Breadboard Facility Automatic Ground Control System
SOV	solenoid operated valve
σG	standard deviation of ground system accuracy
σv	standard deviation of pressure switch

DEFINITION OF SYMBOLS (Concluded)

P_{sw}	switch pressure
VR	voltage regulator

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SUMMARY

Presented is a summary report of an experiment conducted at Marshall Space Flight Center to evaluate the accuracy capabilities of calibrationable pressure switch (CALIPS) checkout systems. It was found that if the range of the reference transducer matches that of the switch under test, if the ground A/D converter is properly aligned, and if the pneumatic ramp rate is slow enough, accuracy requirements can be met or exceeded.

OBJECTIVE

The objective of the CALIPS checkout system loop accuracy experiment was to evaluate the capability of the existing checkout system design to meet the accuracy requirements of the CALIPS systems.

DISCUSSION

Introduction and Background

Pressure switches have long been used to control space vehicle functions such as pressurization and venting of pressure vessels. In order to verify the operation of these switches prior to launch it has been necessary to either pressurize the entire volume to which the switches were attached or disconnect the switches from their systems and actuate them through a local pneumatic source. Both of these techniques had disadvantages. Pressurization of large volumes is not always possible and offers opportunities for contamination. Disconnection of pneumatic lines increases chances for leaks, contamination and human error. To preclude these prelaunch checkout difficulties, permit remote automatic checkout of pressure switches and facilitate overall testing, the CALIPS [1] was developed by Propulsion and Vehicle Engineering Laboratory (P&VE). This switch (Figure A-1) uses two separate sensing lines, one for system operation and the other for ground checkout. Each line is pneumatically isolated from the other. Thus, during checkout, pressure is applied to the switch through the "checkout" port. The pressures at which the switch actuates and deactuates are automatically recorded.

The ground system to accomplish this checkout is schematically shown in Figure A-1. It is a checkout system such as this which was evaluated in the experiment described herein.

In mid-1964, the System Operations Branch, Vehicle Systems Division of Propulsion and Vehicle Engineering Laboratory, was asked to determine overall accuracy requirements of systems designed for remote checkout of Saturn vehicle CALIPS. With known vehicle switch tolerances and system characteristics, accuracy requirements are determined to minimize probabilities of false rejection of acceptable switches, false acceptance of bad switches, and unnecessary repeat testing. These accuracy requirements, first published in October 1964, were based on a statistical methodology developed with assistance from The Boeing Company [2].

The original accuracy requirements showed that to obtain a reasonable degree of confidence, a typical checkout system could be permitted an overall inaccuracy of only ± 0.3 percent. Since this first publication of accuracy requirements, relaxation of certain vehicle switch tolerances and other system changes has reduced the demands upon the checkout system. Accuracy goals now range as high as ± 0.95 percent (Appendix A).

The remote automatic system devised to perform vehicle pressure switch checkout at KSC consists of a pressure source, a series of valves and orifices for controlling pneumatic pressurization rates, and a high accuracy reference transducer, all operated in conjunction with an RCA 110A computer. Typically, as increasing checkout pressure is applied to the vehicle switch, the reference transducer analog signal is supplied to the computer through a filter circuit and the computer's A/D converter. When the vehicle switch actuates, a READ function is generated causing the computer to record the reading of the reference transducer at that instant.

The process is repeated during decreasing checkout pressure, and the switch deactuation point is determined. The computer then compares these values with previously stored tolerance limits and prints the measured actuation/deactuation pressures along with a go/no-go statement.

There are several possible sources of inaccuracy in a system such as described. Potentially the prime factor affecting system inaccuracy is the time rate of pressurization or ramp rate $\frac{\Delta P}{\Delta T}$. Figure 1 shows a characteristic time lag before P_{sw} reaches P_r. This time lag causes an error that varies with ramp rate. Therefore, upon increasing pressure, the measured pressure will tend to be erroneously high; upon decreasing pressure, erroneously low. In addition to the rates of pressurization, the time lag would be a function of tubing volume and pressurization medium. This inaccuracy is called pressurization lag.

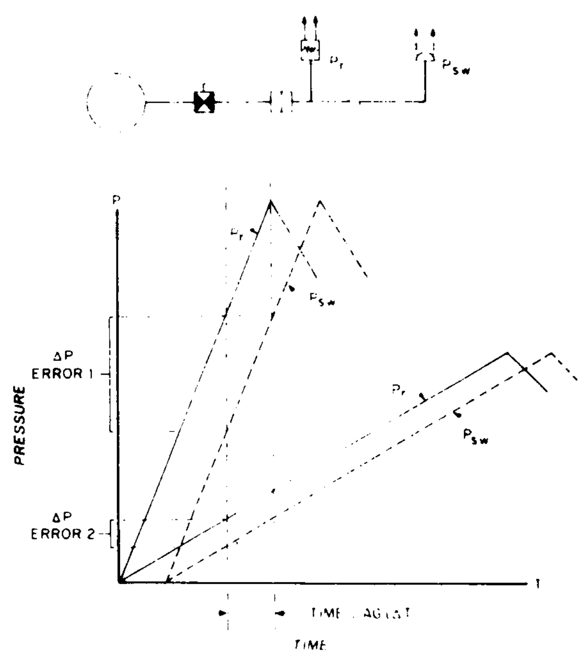

FIGURE 1. PRESSURE VERSUS TIME LAG

Errors relatively independent of pressurization rate, medium, and volume include:

1. A/D converter word length limitations.

2. Extraneous noise superimposed upon the analog signal (for which a filter has been incorporated).

3. Basic reference transducer inaccuracies.

4. Inaccuracies caused by utilization of the transducer at less than the optimum accuracy range (e.g., ± 0.05 percent declared accuracy at full scale implies ± 0.1 percent at half scale).

5. Errors due to gas gravitational head where the switch elevation is different from that of the reference transducer. However, since this error is repeatable, it can be eliminated by calibration and is not considered further herein.

The CALIPS Checkout Systems Loop Accuracy Experiment was devised and implemented to:

1. Evaluate the overall checkout system.

2. Isolate and quantify the various sources of inaccuracy.

3. Learn the relative effects of different ramp rates, gaseous media, and tubing lengths on the system.

4. Define optimum ramp rates. The optimum ramp rate is the fastest ramp consistent with accuracy goals (Appendix A).

5. Gain operating experience to implement the projected use of the proposed checkout system at KSC.

It is emphasized that the objective of the experiment was not to evaluate CALIPS but to evaluate the system with which they will be checked.

Experiment Description

The experiment hardware consisted of a pneumatic breadboard designed by the Systems Operations Branch of Vehicle Systems Division and built by the

Applied Mechanical Research Branch, Propulsion Division, Propulsion and Vehicle Engineering Laboratory. This breadboard simulates various pneumatic checkout consoles operated in conjunction with an RCA 110A computer with all necessary interfacing equipment (Fig. 2). To achieve maximum flexibility, the breadboard design (Fig. 3) incorporated features which enabled experimenters to switch easily between manual and automatic operating modes — select one of three representative tubing lengths — change transducer heads, ramp control orifices, and gaseous media. The transducer which served as a pressure standard (a Wiancko frequency modulated secondary standard) could, by valve positioning, sense pressure either at the tubing inlet (point A, where the CEC transducer under test is located) or at the tubing outlet (point B, where the CALIPS are located). Pressurization lag error was isolated from all other system errors by running identical tests with the Wiancko transducer reading at point A, and then at point B (Modes 2 and 3, Appendix B).

Tests were done under all combinations of the following conditions:

1. Three tubing lengths, 550 ft (168 m) by 0.375 in. (0.952 cm) diameter, 250 ft (76 m) by 0.25 in. (0.635 cm) diameter, and 110 ft (34 m) by 0.25 in. (0.635 cm) diameter.

2. Two pressure ranges 0-20 psig, 0-950 psig (0-137880 N/m^2, 0-6549300 N/m^2).

3. Two media (nitrogen and helium).

4. Test and reference transducers reading point A. (See Fig. 3.)

5. Test transducer at point A and reference transducer at test point B. (See Fig. 3.)

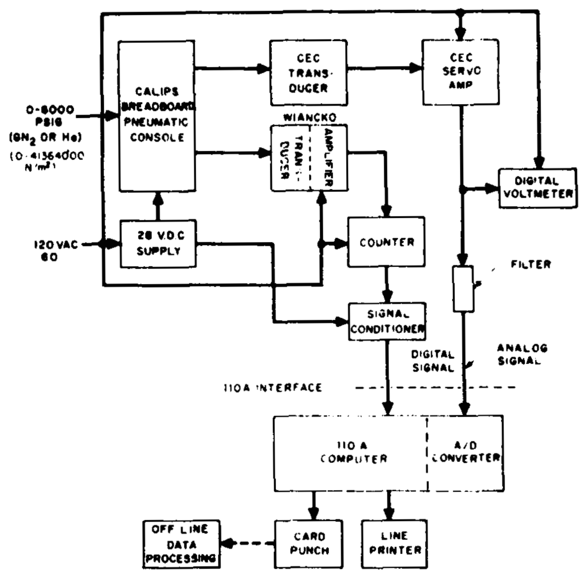

FIGURE 2. BREADBOARD SYSTEM BLOCK DIAGRAM

A conventional primary pressure input control and regulation circuit was employed to establish the different pressures required during the generation of the actual ramp rates.

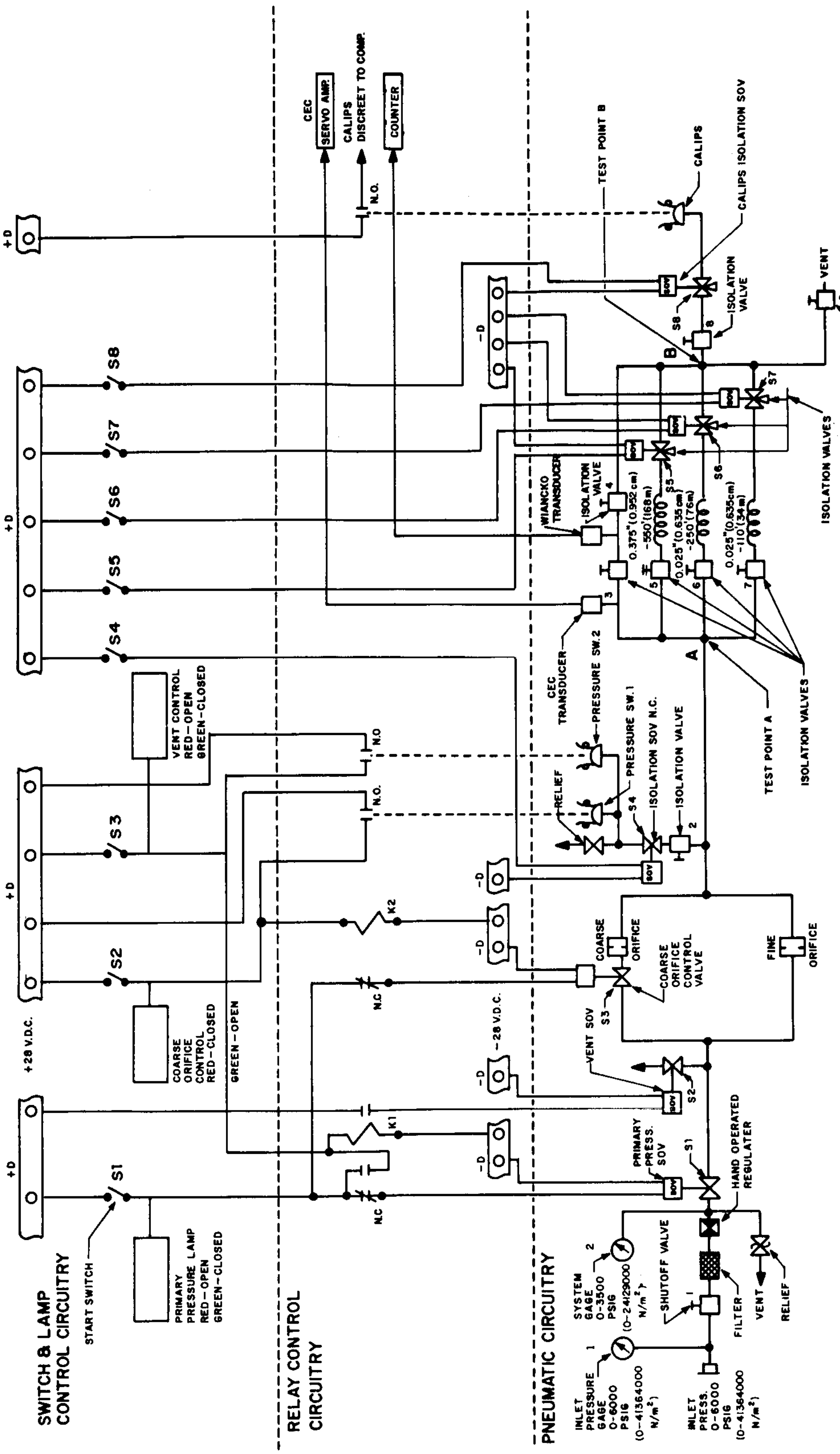

FIGURE 3. BREADBOARD SCHEMATIC

An orifice control circuit was used to generate the different ramp rates. The orifice control circuit was comprised of a fine orifice and a controlled coarse orifice. A solenoid valve (SOV S3) (see Fig. 3) controls the coarse orifice. The SOV was controlled by either manual switches located on the breadboard control panel or pressure switches located within the breadboard automatic control circuitry. Ramp rates were varied by selecting different combinations of orifice sizes, tubing lengths, and applied input pressures.

During automatic operation in conjunction with an actual CALIPS (Mode 4, Appendix B), two conventional pressure switches were employed to control the pressurization and depressurization cycles. The low pressure switch was preset to a value well below the CALIPS actuation point. When the pressure reached that value, the low pressure switch energized to close the coarse orifice through SOV S3, thus slowing the pressurization cycle prior to CALIPS actuation. The system continued to pressurize to a predetermined pressure at which point the high pressure switch was energized initiating the depressurization cycle. Two events then occurred; source pressure SOV S1 closed (deenergized) and vent SOV S2 opened (energized). The system slowly vented, controlled by the fine orifice. During the controlled depressurization cycle, the CALIPS deactuated; thus, two accurately controlled CALIPS points were established by the control action of the high-low pressure switches. One final event occurred; the low pressure switch deenergized at its predetermined setting allowing the coarse orifice to be opened by SOV S3. The system then vented to ambient pressure.

The pneumatic console was equipped with three different pneumatic tubing lengths used to simulate the different line lengths used in the actual CALIP checkout loop. Different tubing lengths were selected by operating hand-controlled shutoff valves and solenoid valves from the breadboard control panel.

The CEC transducer and servo amplifier, vital parts of the system under evaluation, consisted of a closed-loop, self-balancing, servo system with a declared accuracy of ±0.05 percent of full-scale value under controlled conditions. The force-balance pressure transducer detected pressure differentials between a known reference pressure and the measured pressure and transmitted a proportional error signal to the servo amplifier. The servo amplifier used this error signal to develop a dc balancing current for the system and to develop an analog output voltage across the servo amplifier output. This analog voltage constituted a transducer output signal proportional to the sensed pressure. The analog voltage was carried over 150 ft (46 m) of wire through a noise elimination filter to an A/D converter and finally into the RCA 110A computer (Fig. 2).

The Wiancko pressure transducer in Figure 3 was used as a pressure standard for checking the accuracy of the overall system. The Wiancko transducer system, consisting of a pressure head, amplifier, and voltage source, has a declared accuracy of ±0.05 percent of full-scale value. According to declared accuracies, the Wiancko system appeared to be no better than the CEC transducer, which was part of the system being evaluated. The Wiancko transducer system was selected as a valid standard because of established confidence in the Wiancko transducer and because the output signal conversion was not subject to the inaccuracies of noise and A/D conversion. Also, it was expected that overall CALIPS checkout system inaccuracies would be considerably greater than that of the CEC transducer alone.

The Wiancko transducer converts pressure to a frequency readout proportional to pressure. The conversion of this readout to a digital signal was done within ±0.002 percent accuracy by feeding the frequency signal into an electronic counter operating in the "period mode." The period mode counts cycles of an internal oscillator over a period defined by one cycle of Wiancko frequency. The period mode was chosen for its higher sampling-rate-capacity (higher than the frequency mode). Because of a voltage mismatch between the output of the electronic counter and the input of the computer, a signal conditioner was used as an interface between the two. Upon receipt of the voltage input, the computer reconverted the period to frequency with no accuracy loss.

The RCA 110A computer transmitted decimal values of transducer pressure readings, time, and CALIPS actuation status to punched cards. A Fortran IV program was written for IBM 7094 computer which processed the data on the punched cards. The IBM 7094 read the card images and computed the mean, variance, and standard deviations for a series of increasing and decreasing pressure readings. (The computer programs are included in Appendix C.) The IBM 7094 transmitted the information to an SC 4020 Information Display System to produce the graphs in Figures 4 through 8. Photographs of the mechanical portion of the test setup are shown in Figures 9 through 12.

RESULTS

Tables I and II are a summary of the data which were taken. The tables include data for two ramp ranges, two media, three line lengths, and several orifice sizes. A total of 47 runs is included.

Automatic Run 9
110-ft. (34-M) Line 9-14-66
Medium He
Fine Orifice, 0.0028 in. (0.007112 CM)
CEC 0-30 psig (0-206 820 N/m^2) Head, Wiancko 0-50 psig (0-344 700 N/m^2) Head
Test Point A & B

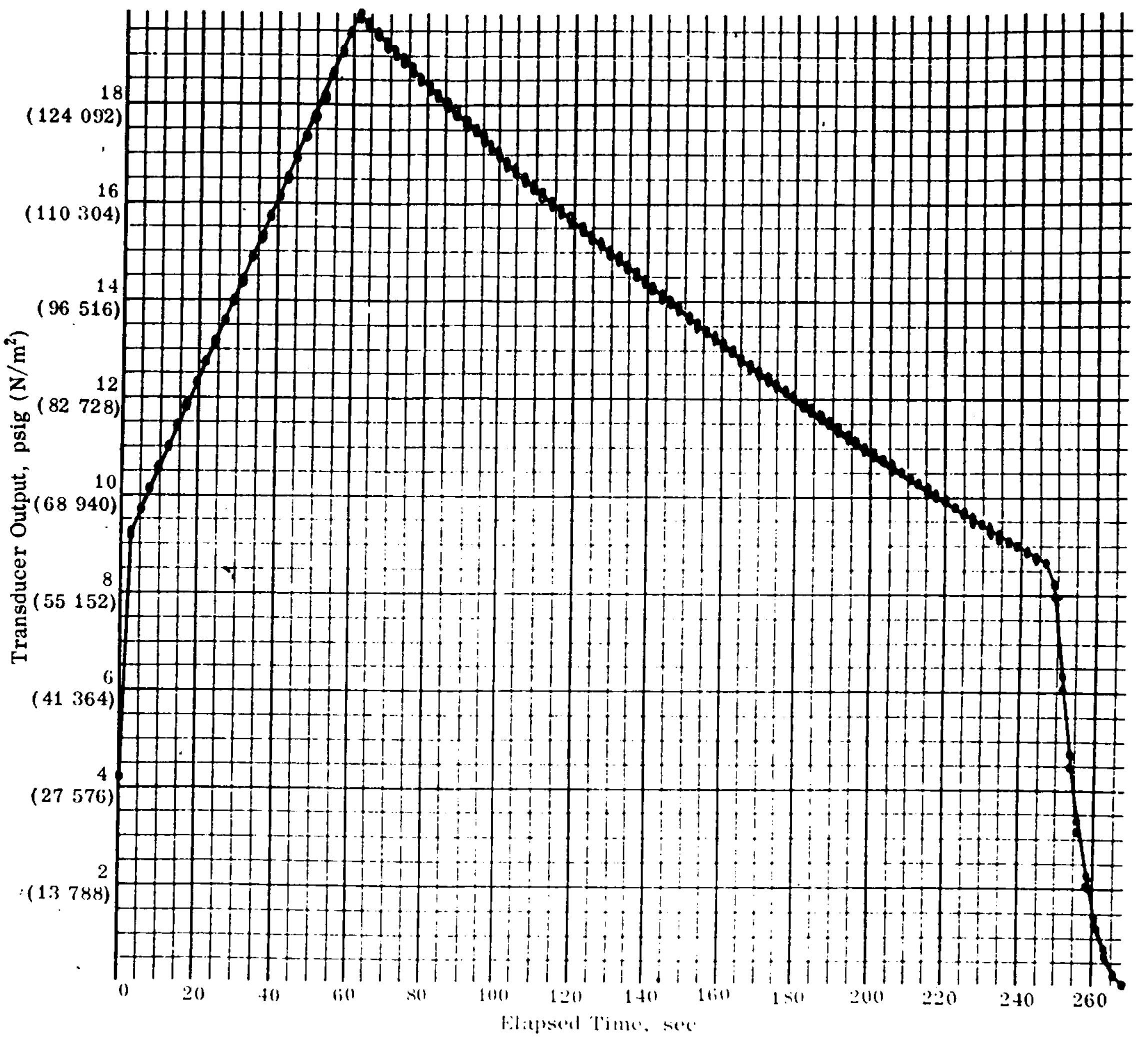

FIGURE 4. PRESSURE VERSUS TIME PROFILE

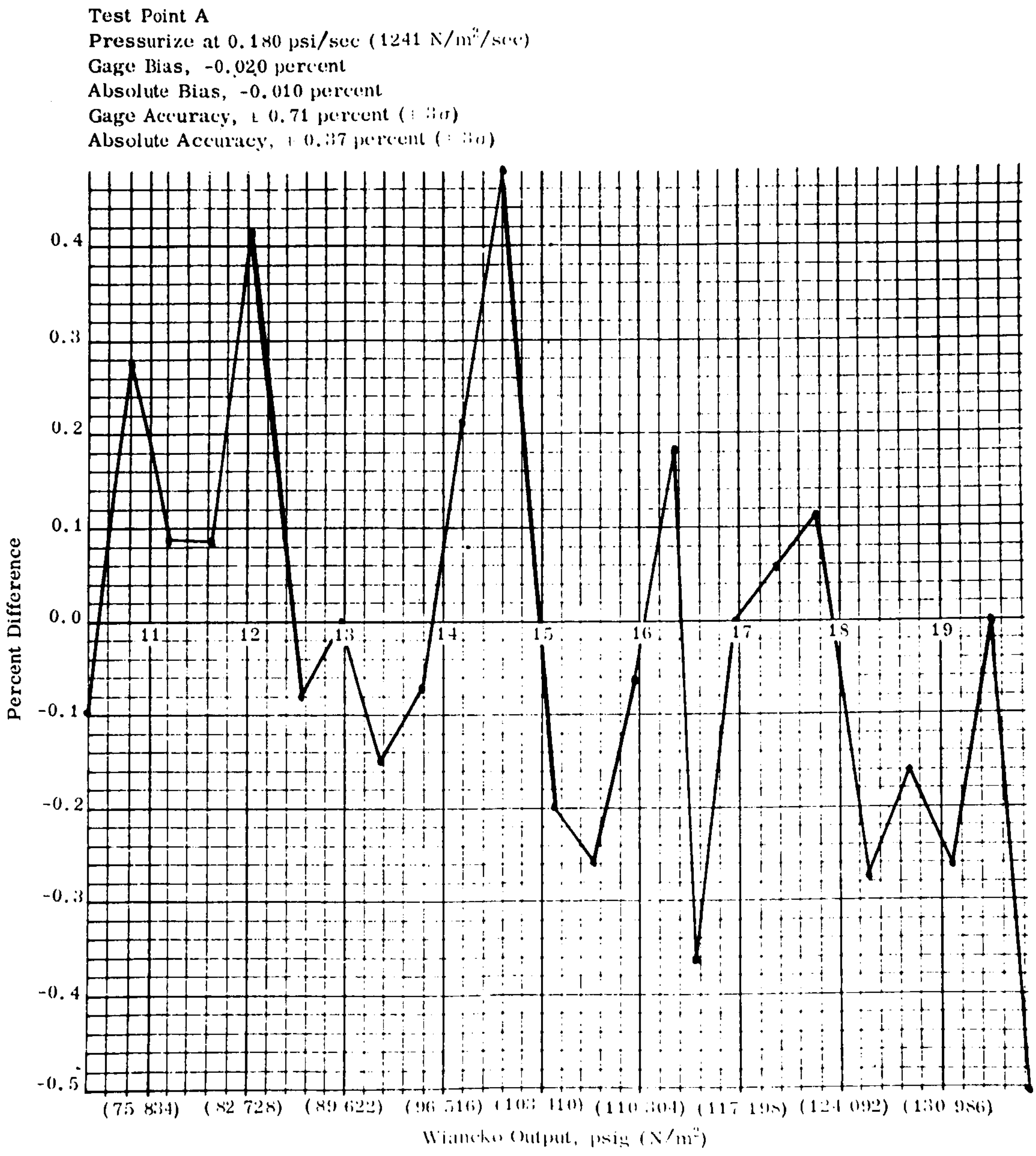

FIGURE 5. ABSOLUTE DIFFERENCE PLOT (PRESSURIZE)

Test Point A
Vent at 0.059 psi/sec (406.746 N/m^2/sec)
Gage Bias, -0.38 percent
Absolute Bias, -0.20 percent
Gage Accuracy, ± 0.42 percent (± 3σ)
Absolute Accuracy, ± 0.22 percent (± 3σ)

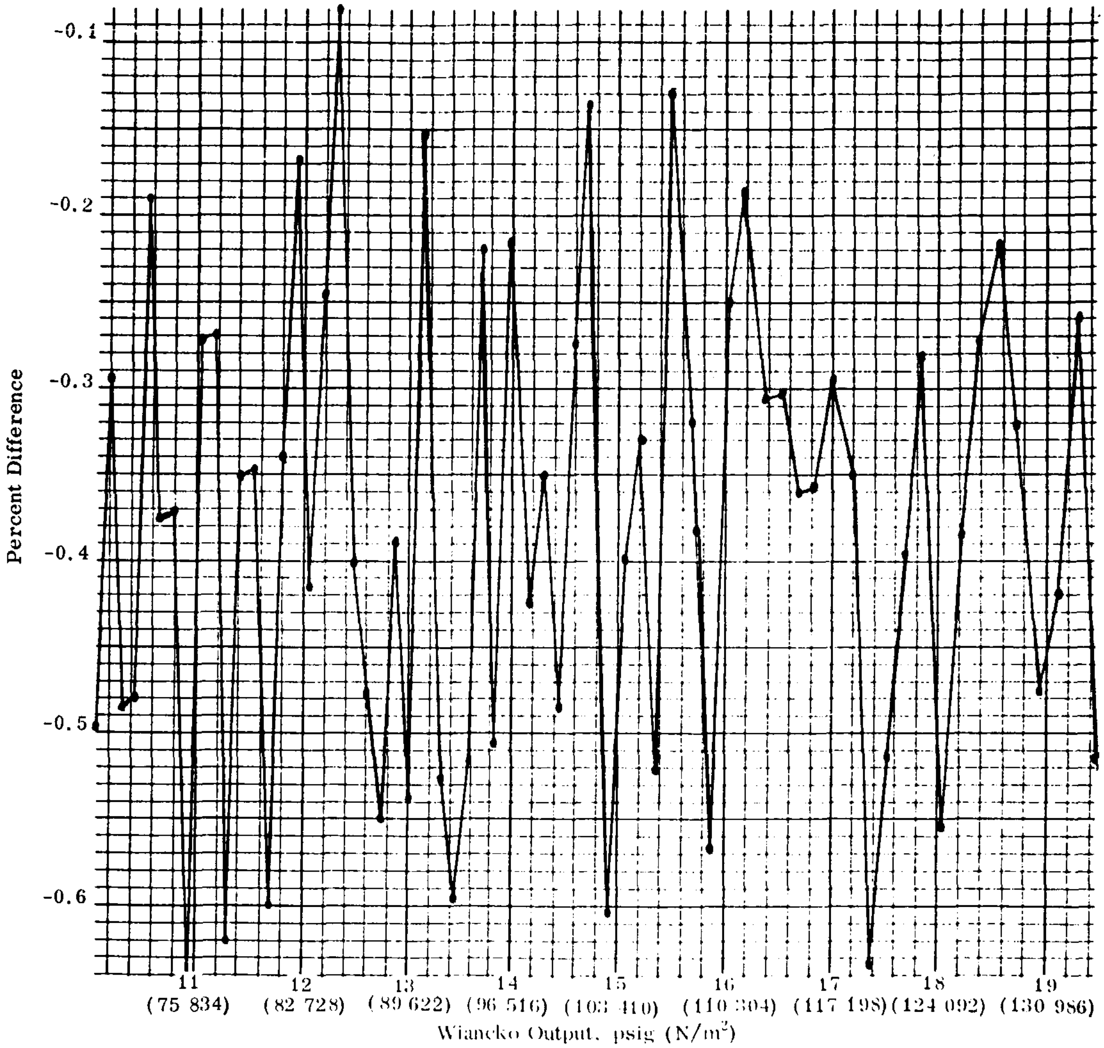

FIGURE 6. ABSOLUTE DIFFERENCE PLOT (VENT)

Test Point: A and B.
Pressurize, 0.180 psi/sec (1241 N/m^2/sec)
Gage Bias, + 0.12 percent
Absolute Bias, + 0.06 percent
Gage Accuracy, + 0.77 percent (± 3 σ)
Absolute Accuracy, ± 40 percent (± 3σ)

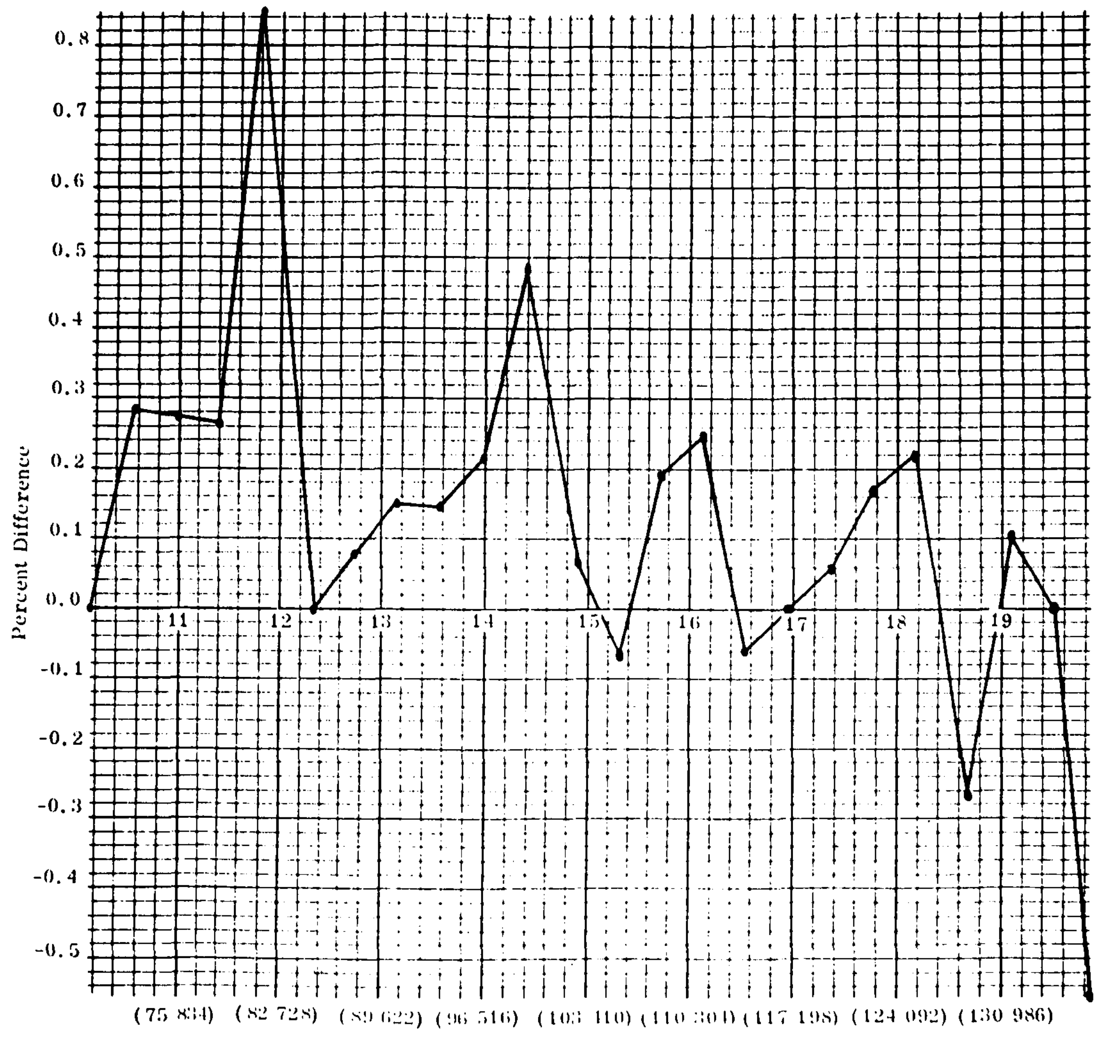

FIGURE 7. PERCENT DIFFERENCE GRAPH (PRESSURIZE)

Test Point A and B
Vent, 0.062 psi/sec (427.428 N/m²/sec)
Gage Bias, 0.45 percent
Absolute Bias, -23 percent
Gage Accuracy, + 0.44 percent (+ 3σ)
Absolute Accuracy, ± 0.23 percent (± 3σ)

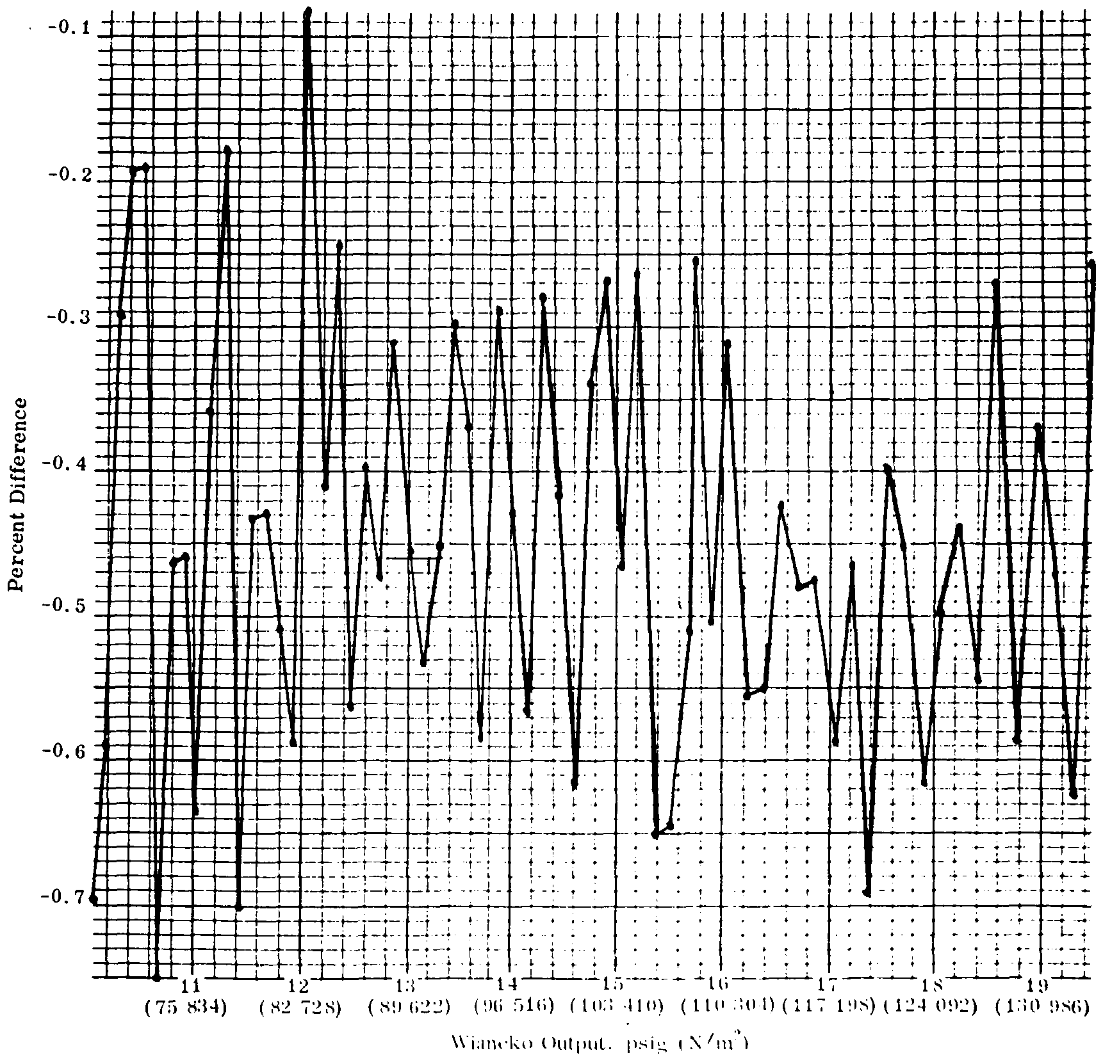

FIGURE 8. PERCENT DIFFERENCE GRAPH (VENT)

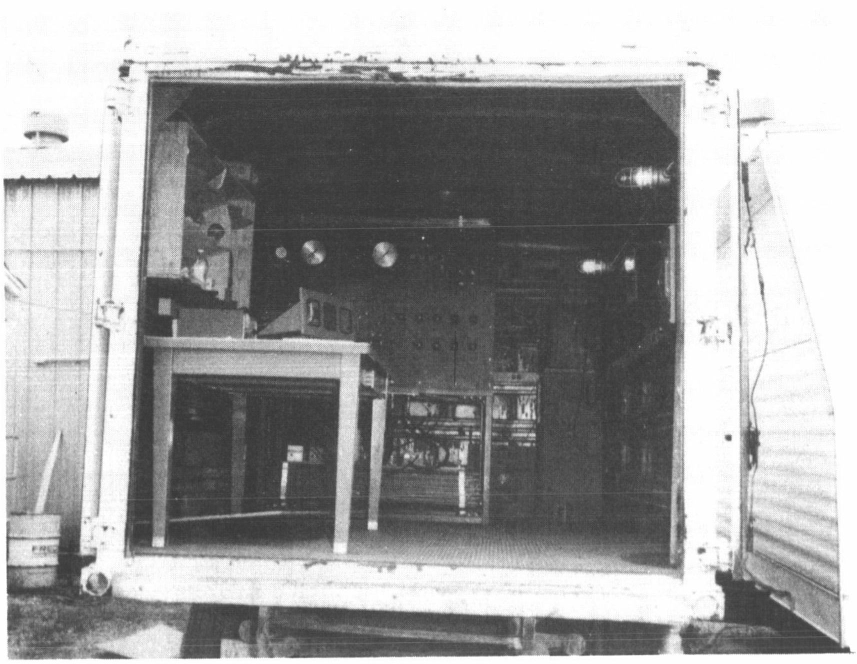

FIGURE 9. OVERALL VIEW OF BREADBOARD

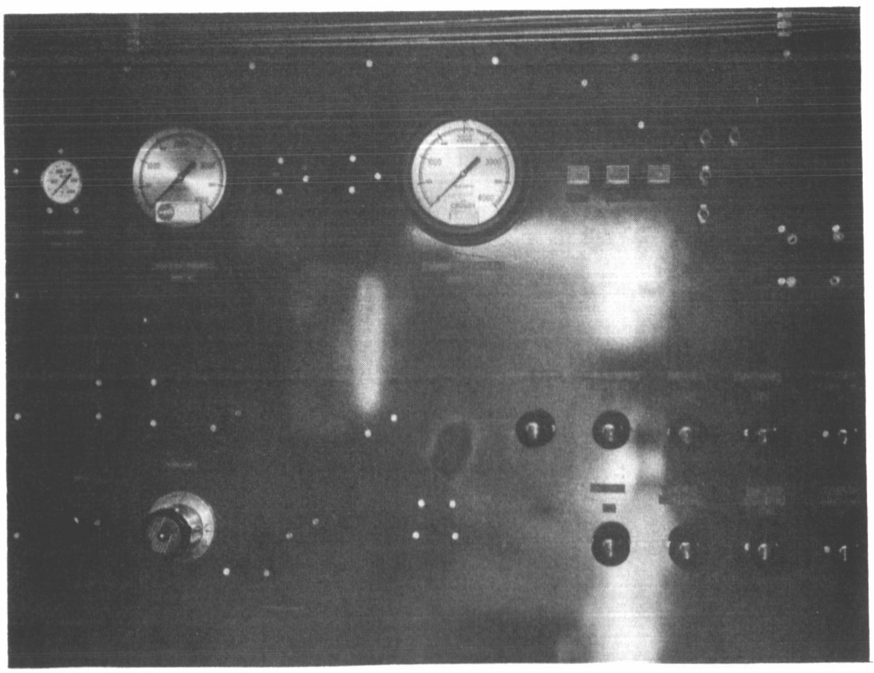

FIGURE 10. BREADBOARD CONTROL PANEL

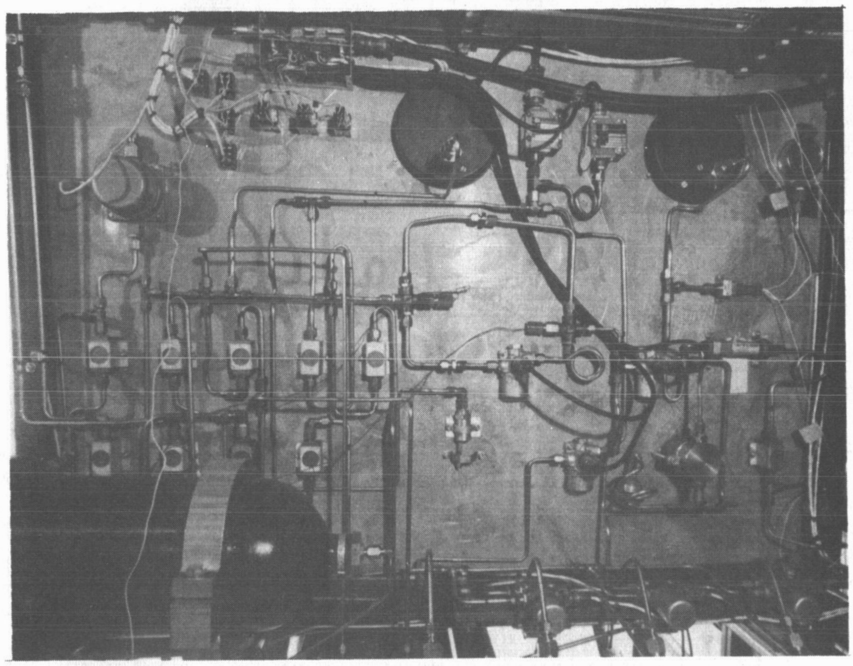

FIGURE 11. BREADBOARD PLUMBING

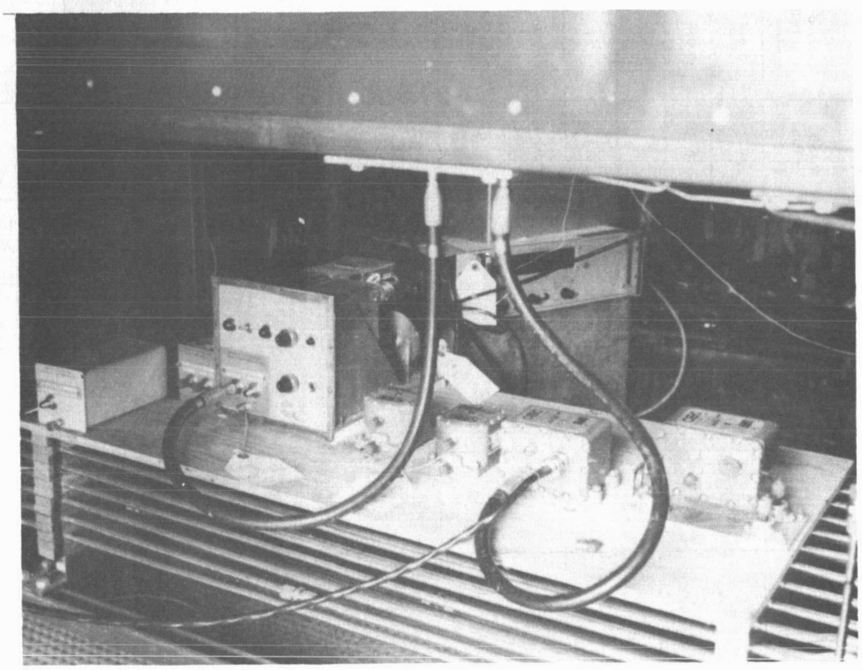

FIGURE 12. WIANCKO AND CEC TRANSDUCERS

TABLE I. RAMP RANGE: 10-20 psig (68 940-137 880 N/m^2)

Medium	Line Length	Pressurize Ramp Rate, psi/sec (N/m^2/sec)	Run No.	CEC at Point (Fig. 3)	Wiancko at Point (Fig. 3)	Observed Bias of Data, percent	3σ Absolute Accuracy about Data Mean percent	Total Accuracy percent	Maximum Pressurization Lag, percent	Maximum Electrical Error, percent	Remarks
GN_2	550 ft (168 m) 0.375 in. (0.952 cm)	0.024 (165.456)	1	A	B	-0.046	±0.241	+0.195 -0.287	Cannot be Determined	Cannot be Determined	A-B run valid only
		0.055 (379.170)	2	A	A	+0.098	±0.218	+0.316 -0.120	0.250	0.316	
			3	A	B	+0.260	±0.306	+0.566 -0.046			
		0.078 (537.732	4	A	A	+0.141	±0.288	+0.429 -0.147	0.326	0.429	
			5	A	B	+0.360	±0.395	+0.755 -0.035			
		0.161 (1109.934)	6	A	A	+0.270	±0.480	+0.750 -0.210	Cannot be Determined	0.750	A-A run only
	250 ft (76 m) 0.25 in. (0.635 cm)	0.047 (324.018)	7	A	A	-0.110	±0.210	+0.100 -0.320	0.090	0.320	
			8	A	B	-0.040	±0.230	+0.190 -0.270			
		0.081 (558.414)	9	A	A	+0.135	±0.266	+0.401 -0.131	0.243	0.401	
			10	A	B	+0.266	±0.378	+0.644 -0.112			
		0.218 (1502.414)	11	A	A	+0.276	±0.586	+0.862 -0.310	0.887	0.862	
			12	A	B	+0.719	±1.030	+1.749 -0.311			
	110 ft (34 m) 0.25 in. (0.635 cm)	0.083 (572.202)	13	A	A	-0.100	±0.210	+0.110 -0.310	0.090	0.310	
			14	A	B	-0.070	±0.270	+0.200 -0.340			
		0.145 (999.630)	15	A	A	+0.170	±0.430	+0.600 -0.260	0.080	0.600	
			16	A	B	+0.230	±0.450	+0.680 -0.220			
		0.384 (2647.296)	17	A	A	+0.560	±1.230	+1.790 -0.670	0.320	1.790	
			18	A	B	+0.750	±1.360	+2.110 -0.610			

TABLE I. (Concluded)

Medium	Line Length	Pressurize Ramp Rate, psi/sec (N/m^2/sec)	Run No.	CEC at Point (Fig. 3)	Wiancko at Point (Fig. 3)	Observed Bias of Data, percent	3σ Absolute Accuracy about Data Mean percent	Total Accuracy percent	Maximum Pressurization Lag, percent	Maximum Electrical Error, percent	Remarks
He	550 ft (168 m) 0.375 in. (0.952 cm)	0.026 (179.244)	19	A	A	-0.120	±0.200	+0.080 -0.320	0.170	0.320	
			20	A	B	-0.020	±0.270	+0.250 -0.290			
		0.045 (310.230)	21	A	A	-0.110	±0.200	+0.090 -0.310	0.230	0.310	
			22	A	B	+0.040	±0.280	+0.320 -0.240			
		0.067 (461.898)	23	A	A	+0.150	±0.250	+0.400 -0.100	0.410	0.400	
			24	A	B	+0.360	±0.450	+0.810 -0.090			
		0.176 (1213.344)	25	A	A	+0.280	±0.610	+0.890 -0.330	1.230	0.890	
			26	A	B	+0.910	±1.210	+2.120 -0.300			
	250 ft (76 m) 0.25 in. (0.635 cm)	0.100 (689.400)	27	A	A	-0.080	±0.250	+0.170 -0.330	0.330	0.330	
			28	A	B	+0.140	±0.360	+0.500 -0.220			
		0.194 (1337.436)	29	A	A	+0.310	±0.620	+0.930 -0.310	0.680	0.930	
			30	A	B	+0.730	±0.880	+1.610 -0.150			
	110 ft (34 m) 0.25 in. (0.635 cm)	0.180 (1240.920)	31	A	A	-0.101	±0.370	+0.269 -0.471	0.169	0.471	
			32	A	B	+0.054	±0.384	+0.438 -0.330			
		0.337 (2323.298)	33	A	A	+0.510	±1.200	+1.710 -0.690	0.090	1.710	
			34	A	B	+0.680	±0.940	+1.620 -0.260			

TABLE II. RAMP RANGE: 500-950 psig (3 447 000 - 6 549 300 N/m^2)

Medium	Line Length	Pressurize Ramp Rate, psi/sec (N/m^2/sec)	Run No.	CEC at Point (Fig. 3)	Wiancko at Point (Fig. 3)	Observed Bias of Data, percent	3σ Absolute Accuracy about Data Mean percent	Total Accuracy percent	Maximum Pressurization Lag, percent	Maximum Electrical Error, percent	Remarks
GN_2	550 ft (168 m) 0.375 in. (0.952 cm)	0.240 (1654.560)	35	A	A	-0.122	±0.204	+0.082 -0.326	0.054	0.326	
			36	A	B	-0.076	±0.212	+0.136 -0.288			
		0.390 (2688.660)	37	A	A	+0.050	±0.330	+0.380 -0.280		0.380	500-700 psig (3 447 000-4 825 800 N/m^2) Ramp Run A-A only
	250 ft (76 m) 0.25 in. (0.635 cm)	1.130 (7790.220)	38	A	A	+0.020	±0.354	+0.374 -0.334	0.016	0.374	
			39	A	B	+0.025	±0.365	+0.390 -0.340			
	110 ft (34 m) 0.25 in. (0.635 cm)	2.08 (1433.952)	40	A	A	+0.090	±0.410	+0.500 -0.320	0.020	0.500	
			41	A	B	+0.080	±0.440	+0.520 -0.360			
He	550 ft (168 m) 0.375 in. (0.952 cm)	0.84 (5800.96)	42	A	A	+0.083	±0.223	+0.306 -0.140	0.034	0.306	
			43	A	B	+0.120	±0.220	+0.340 -0.100			
	250 ft (76 m) 0.25 in. (0.635 cm)	2.50 (17235.00)	44	A	A	+0.160	±0.380	+0.540 -0.220	0.150	0.540	
			45	A	B	+0.180	±0.510	+0.690 -0.330			
	110 ft (34 m) 0.25 in. (0.635 cm)	5.00 (34470.00)	46	A	A	+0.210	±0.650	+0.860 -0.440	0.020	0.860	
			47	A	B	+0.220	±0.620	+0.840 -0.400			

The results of the tests indicated that the overall system loop accuracy was affected by the line volume, pressure ramp rate, (lb/in.^{2}/sec) electrical error, A/D conversion error, and the percentage of full scale on the transducer range. The data in Tables I and II included an observed bias based on the mean of the ramp up, a 3 σ accuracy and a total accuracy. The table accuracies are based on absolute pressure to agree with the accuracy requirements in Appendix A.

The data show that accuracy improves by slowing the ramp rate. For example, comparing the pressurizing or ramp up portions of two runs, the run using the smaller orifice will show the greater accuracy. Also, when the ramp up portion of a run is compared to the ramp down portion, the latter will be more accurate because it has a slower ramp rate. Tables I and II are based on the ramp up or worst case error. The improvement of accuracy on the vent side (slower ramp rate) is evidenced by comparing the absolute and percent difference graphs in Figures 9 and 11 with Figures 10 and 12. (Note: Pressurization graphs have different vertical scales than vent graphs.)

An observation of the graph in Figure 9 shows that the difference is distributed around a mean. The observed bias of data in Tables I and II represents this mean and the 3 σ accuracy is a measure of the distribution around this mean.

Tables I and II show that the pneumatic lag, as expected, was much greater for runs using the 550-ft (168-m), 0.375-in. (0.952-cm)-diameter line than for the smaller line lengths and diameters. Pressurization lag was separated from all other errors including electrical by comparing runs made with both the Wiancko and CEC transducers measuring at test point A and then with the Wiancko at test point B and the CEC at test point A (see Experiment Description).

As a result of the CALIPS checkout loop accuracy experiment, it was discovered that the vendor-recommended procedure for alignment of the A/D converter was inadequate. The Chrysler Corporation's Saturn IB Breadboard Facility operating personnel devised a new alignment procedure which greatly improved the CALIPS checkout system accuracy [3].

An example of the data is run 32 on Table I. Operational mode 4 was used to obtain the data (see Appendix B). Figure 8 is a plot of the pressure versus time showing that the system vents at a slower rate than it pressurizes. The ramp up computer data for run 32 is included in Table III.

TABLE III. RUN NUMBER 32 RAMP UP

W_g Wiancko	C_g CEC	a Abs. Diff.	b % Diff.	Absolute Wiancko	c % Diff.
10.14	10.14	0	0	24.84	0.0
10.56	10.59	03	0.284	25.26	0.119
10.98	11.01	03	0.273	25.68	0.117
11.40	11.43	03	0.263	26.10	0.115
11.81	11.91	0.1	0.847	26.51	0.377
12.33	12.33	0	0	27.03	0.0
12.74	12.75	0.01	0.078	27.44	0.036
13.15	13.17	0.02	0.152	27.85	0.072
13.57	13.59	0.02	0.147	28.27	0.071
13.98	14.01	0.03	0.215	28.68	0.105
14.39	14.46	0.07	0.486	29.09	0.241
14.90	14.91	0.01	0.067	29.60	0.034
15.31	15.30	(-) 0.01	(-) 0.065	30.01	(-) 0.033
15.72	15.75	0.03	0.191	30.42	0.099
16.13	16.17	0.04	0.248	30.83	0.130
16.54	16.53	(-) 0.01	(-) 0.060	31.24	(-) 0.032
16.95	16.95	0	0	31.65	0.0
17.36	17.37	0.01	0.058	32.06	0.031
17.76	17.79	0.03	0.169	32.46	0.092
18.17	18.21	0.04	0.220	32.87	0.122
18.68	18.63	(-) 0.05	(-) 0.268	33.38	(-) 0.150
19.09	19.11	0.02	0.105	33.79	0.059
19.50	19.50	0	0	34.20	0.0
19.85	19.74	(-) 0.11	(-) 0.554	34.55	(-) 0.318
			$\sum = 2.856$		$\sum = 1.287$

From Table III (ramp up) for run 32 the gage bias and gage accuracy were computed as follows:

a = absolute difference

b = percent gage difference

c = percent absolute difference

W_g = Wiancko transducer reading-gage

C_g = CEC transducer reading-gage

$\overline{X}$ = mean or bias

X = individual reading

S^2 = variance

n = number of readings

W_a = Wiancko transducer reading-absolute

C_a = CEC transducer reading-absolute

σ = standard deviation

i = the ith item in a series

1. $W_g - C_g = a$

2. $\dfrac{a \times 100}{W_g} = b$

3. $\dfrac{\sum_{i=1}^{n} b}{n} = \overline{X}$

4. $S^2 = \dfrac{1}{n-1} \sum_{i=1}^{n} (X - \overline{X})^2$

From Table III - Computing ramp up gage accuracy

1. $\sum_{i=1}^{n} b = 2.856$

2. $n = 24$

3. $\overline{X} = 0.119$ (gage bias)

4. $S^2 = 0.0658$

5. $S = 0.257$

6. $3\sigma = \pm 0.771$ (percent gage accuracy)

From Table III - Computing ramp up absolute accuracy

1. $\sum_{i=1}^{n} c = 1.287$

2. $n = 24$

3. $\overline{X} = 0.054$ (absolute bias)

4. $S^2 = 0.0164$

5. $S = 0.128$

6. $3\sigma = \pm 0.384$ (percent absolute accuracy)

The total accuracy (percent) in Table II was computed by adding the $\pm 3\sigma$ accuracy to the observed bias of data percent. (Example, run 32, $0.054 + 0.384 = 0.438$ and $0.054 - 0.384 = (-)\ 0.330$). The maximum pressurization lag percent was determined by subtracting the total accuracy percent from test point A-A run from the total accuracy percent test point A-B run. (Example run 32, $0.438 - 0.360 = 0.078$). Based also on the statistics which have been computed the maximum electrical error would be the $\pm 3\sigma$ value (which ever is greatest) of total accuracy for the test point A-A run.

The data in Tables I and II were taken using two gaseous media, GN_2 and GHe. No clearly defined differences were observed; however, the experiments did demonstrate that either media can be used to obtain the desired checkout accuracy.

The data indicate that loop accuracy was also improved as the pressure approached the full-scale value of the CEC transducer head.

The CALIPS breadboard was run in test mode 4 to prove the capability of the CALIPS automatic checkout system. The results of the tests in this mode proved that the system would go through the test cycle automatically and that the computer could monitor and record the results of the system test.

SUMMARY AND CONCLUSIONS

The experiment has proven that the CALIPS checkout system as designed in the mechanical ground support equipment can meet the checkout accuracy requirements as specified in the Saturn V Fluid Requirements Document.

There are, however, certain provisions which must be made to meet the requirements. They are as follows:

First, it is imperative that the transducer heads match as closely as feasible the range of the CALIPS to be tested. For example, the CEC transducers in the S-IC stage pneumatic checkout racks have a range of 0-5000 psia (0-34 470 000 N/m^2). These transducers are used to check the 1060-psia (7 307 640 N/m^2) F-1 Engine Thrust OK switches (Appendix A). The transducer accuracy of this particular system can be improved by a factor of 3.3 by using a 0-1500-psia (0-10 341 000-N/m^2) transducer head.

Second, proper alignment of the A/D converter [3] is essential for meeting the accuracy goals of Appendix A. Improper alignment can cause an offset error in the analog great enough to make it useless.

Finally, it is necessary to utilize proper ramp rates. Table IV has been extrapolated from the breadboard data; it constitutes approximate maximum ramp rates to provide the desired accuracy.

TABLE IV. APPROXIMATE MAXIMUM RAMP RATES

Medium	Range psig (N/m^2)	Typical Application	Highest Accuracy Req., percent	Line Length ft (m)	Maximum Ramp Rate, psi/sec (N/m^2/sec)
GN_2	0-20 (0-137 880)	S-IC	±0.42	550 (168)	0.04 (275.76)
				250 (76)	0.06 (413.64)
				110 (34)	0.10 (689.40)
	0-95 (0-6 549 300)	S-IC	±0.3	550 (168)	0.25 (1723.50)
		IU		250 (76)	0.60 (4136.40)
				110 (34)	0.60 (4136.40)
GHe	0-20 (0-137 880)	S-II	±0.3	550 (168)	0.03 (206.82)
		S-IVB		250 (76)	0.08 (551.52)
				110 (34)	0.16 (1103.04)
	0-950 (0-6 549 300)	S-II	±0.48	550 (168)	0.60 (4136.40)
		S-IVB		250 (76)	0.80 (5515.20)
				110 (34)	0.80 (5515.20)

APPENDIX A
ACCURACY REQUIREMENTS

Information which was documented by the Systems Operations Branch [4] reflects the deletion made by the approval of Engineering Change Proposal 034R-1 [5]. The deleted pressure switch is the lox tank translunar vent termination pressure switch on the S-IVB stage. Pressure switch actuation and deactuation settings have been updated to reflect their latest documented revisions.

Table A-I, Saturn V Pressure Switch Checkout Requirements, presents the latest requirements derived from calculations based on the assumptions listed in Note 7, page 27. This table presents the requirements, listed by fluid requirements numbers, umbilical disconnects, item numbers, and switch nomenclature.

Table A-II, CALIPS Pressurization Requirements for Overall Tests, presents the latest pressurization requirements for use of CALIPS during overall tests on the Saturn V vehicle. Time critical CALIPS are listed first, followed by the remaining CALIPS pressurized during overall tests.

Changes from Reference 3 have been noted by a single symbol, #, in the applicable column. New entries are noted by a double symbol, ##.

Figure A-1 is a schematic of the CALIPS checkout system which will be used at Kennedy Space Center. Notes relevant to this analysis are also enclosed on pages 25 through 29.

Notes

Note 1

FRF. No. are the Fluid Requirements Find Numbers.

Note 2

The finding numbers listed for the S-IC Stage are referenced to MSFC drawing 20M97001, revision F, Index of Finding Numbers for Schematic, Propulsion Control System, S-IC. S-II Stage is referenced to MSFC drawing 20M97010, revision A, Index of Finding Numbers for Schematic, Propulsion Control System, S-II. S-IVB Stage is referenced to MSFC drawing 20M97013, revision A, Index of Finding Numbers for Schematic, Propulsion Control System, S-IVB. Instrument Unit finding numbers are referenced to MSFC drawing number 20M97005, Mechanical Control System, Instrument Unit.

Note 3

The actuation and deactuation pressures and tolerances required for checkout as opposed to the actual switch tolerances.

Note 4

The minimum differential listed is the required minimum difference between the actual actuation and deactuation values (first cycle) obtained during checkout.

Note 5

This column indicates which of the following categories of testing are applicable to a particular switch. These categories are for the determination of Ground Support Equipment (GSE) requirements and do not necessarily reflect the normal checkout sequence. Some of the capabilities in the GSE will be required only for fault isolation.

Category A - Pressure switch checkout at the Vertical Assembly Building (VAB) (high bay) required the capability in the GSE for applying pressure to all CALIPS in an approximate ramp form to permit the actuation and deactuation pressures of the switches to be checked. This capability will also be required at the launch site for fault isolation purposes only. To minimize checkout time, the rate of pressure increase or decrease will be greater outside the actuation and deactuation bands.

Category B - For switches in this category, the checkout equipment at the VAB (high bay) must provide fixed pressures for "Malfunction Loop" testing (during OAT #3 or the Mechanical Systems Test) since the functions of these switches are not a part of the normal sequence. This capability is also required at the launch site for fault isolation purposes only. A summary of the switches in this category is as follows:

2, 3, 6, 9, 11, 13, 14, 15, 16, 17

Category C - To check all redundant modes of operation of switches in this category, switch output must be "blocked" electrically. A summary of the switches in this category is as follows:

7, 12, 21

Note 6

The minimum differential, between actuation and deactuation points, is based on the maximum differential required by the pressure switch to meet the vibration requirements. The minimum differential requirement is to be determined when a CALIPS is developed which will meet the vibration requirements.

Note 7

In defining ground loop accuracy requirements the following assumptions were made:

a. The true pressure at which switch actuation occurs is normally distributed with mean μ_V and standard deviation σ_V, where μ_V is the switch design actuation point. The ratio of switch tolerance (T) to σ_V is 3.

b. The difference between true pressure at the switch under test and the measured pressure is normally distributed with mean 0 and standard deviation σ_G (the dependent variable).

c. The allowable probability of falsely rejecting a good switch, and that of falsely accepting a bad switch is 0.01.

d. The allowable probability for repeating tests is 0.04 for each given manifold. This is the probability for having to take repeated readings to verify the true condition of the flight switch.

Note 8

Accuracies listed under "Ground Loop Tolerances Requirements, Percent" are $3\sigma_G$ values. These limits are valid only if the difference between true and measured pressure is less than $3\sigma_G$ 99.7 percent of the time.

Note 9

The ground loop accuracy requirements given are based on absolute pressure settings. To convert to loop accuracy requirements based on gage pressure settings the following computations must be made:

a. Take the average ratio of absolute to gage pressure setting (actuation point) for all switches on the manifold.

b. Multiply the average ratio (step a) by the loop accuracy given for the manifold.

c. The answer is the loop accuracy requirement based on gage pressures.

Note 10

Two modules per vehicle. Each must be checked separately.

Note 11

The checkout equipment at the VAB (high bay) must provide fixed pressures at the appropriate time during Overall Tests (OATS #1 and #2) and the Simulated Flight Test (SFT) such that properly sequenced switch actuation and/or deactuation will occur. The same requirements apply to the launch site equipment for the final simulated flight test.

Note 12

Although it is desirable that neither LOX nor fuel overpressurization switches be actuated during actuation of the prepressure switches, this is not absolutely mandatory. The overpressure switches can be unplugged.

Note 13

Because of the strict time requirement the thrust OK switch operation may be simulated as an alternative to pneumatic actuation. The F-1 and S-II Engine Switches must be actuated or deactuated before normal time because of the nature of the checkout line manifolding caused by staggered engine operation.

Note 14

Tolerances listed define general calibration port actuation/deactuation limits for all switches built to this specification. Because the exact relationship between checkout and system port actuation and deactuation will be unique for each switch, each vehicle may have a set of switch checkout limits which varies slightly from those given.

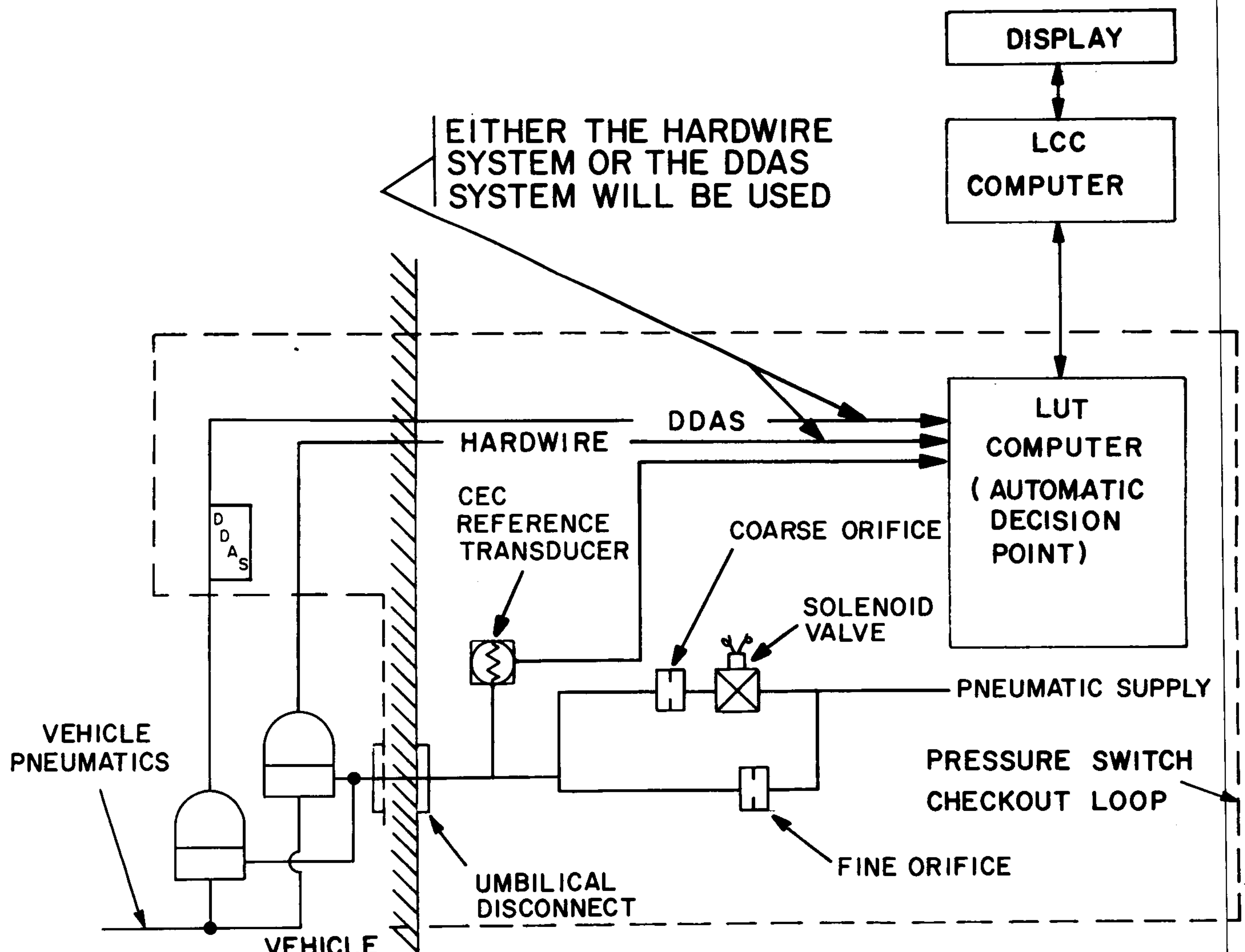

FIGURE A-1. CALIPS CHECKOUT CONFIGURATION

TABLE A-I. SATURN V PRESSURE SWITCH CHECKOUT REQUIREMENTS (KSC)

ITEM	Stage Umbilical Disconnect F.R.F. No.*	Pressure Switch Identification (Note 2)	Pressure Switch Function and Interlocks	Checkout Port Actuation (Note 3, 11, 12) Checkout Port Deactuation (Note 3, 11, 12)	Differential (Note 4)	Checkout Requirements (Note 5)	Ground Loop Tolerances Requirements, percent (Notes 7, 8, 9)	Remarks
1	S-IC [6] Fwd. A7759 1.32	Lox Tank Pressurization (B210)	Maintains lox tank ullage pressure by controlling grd. prepress. Valve A9942. actuation interlocked into S-IC fwd. umb. arm disconnect and ignition.	27.0 psia (186 165 N/m^2) max 23.7 psia (163 412 N/m^2) min	0.3 psi (2068.2 N/m^2) min to 2.3 psi (15 858 N/m^2) max	A	± 0.42	Systems port 26.5 psia (182 718 N/m^2) Diff. 5 psia (3448 N/m^2) 24.2 psia (166 859 N/m^2)
2	S-IC [6] Fwd. A7759 1.32	Lox Tank Pressurization Relief (B211)	Control vent and relief valve B207 from prepress. until T + 75 sec. Acts as backup to switch B210 during prepress.	30.6 psia (210 987 N/m^2) max 27.4 psia (188 923 N/m^2) min	0.3 psi (2068.2 N/m^2) min to 2.0 psi (13 790 N/m^2) max	A, B		Actuation is 30.0 psi (206 850) max, deactuation is 28.0 (193 060) min and max. Diff. is 0.5 psia (3448 N/m^2) for SA-500F, SA-503 and subs.
3	S-IC [6] Fwd. A7759 1.32	Lox Tank Relief Gage Pressure (B213)	Controls vent and relief valve B207 after T + 25 sec.	25.5 psig (3 175 823 N/m^2) max 21.5 psig (148 243 N/m^2) min	0.3 psi (2068.2 N/m^2) min to 3.0 psi (20 685 N/m^2) max	A, B		Actuation is 25.0 psi (172 375) max, deactuation is 22.0 (151 690) min and max. Diff. is 0.5 psig (3448 N/m^2) for SA-503 and subs.
4	S-IC [6] Aft #2 A7942* 1.33	Fuel Tank Pressurization (B119)	Regulates fuel tank ullage pressure during flight by controlling fuel pressurization valve B107-5.	26.5 psia (182 718 N/m^2) max 23.7 psia (163 412 N/m^2) min	0.3 psi (2068.2 N/m^2) min to 1.8 psi (12 411 N/m^2) max	A	± 0.48	

TABLE A-I. (Cont'd)

ITEM	Stage / Umbilical / Disconnect / F.R.F. No.*	Pressure Switch Identification (Note 2)	Pressure Switch Function and Interlocks	Checkout Port Actuation (Note 3, 11, 12) / Checkout Port Deactuation (Note 3, 11, 12)	Differential (Note 4)	Checkout Requirements (Note 5)	Ground Loop Tolerances Requirements, percent (Notes 7, 8, 9)	Remarks
5	S-IC [6] Aft #2 A7942 1.33	Fuel Tank Pressurization (B118)	Maintains fuel tank ullage pressure by controlling primary prepress. Valve A10111 to start off ignition sequence and secondary prepress. Valve A10110 until lift-off. Interlocked into S-IC fwd. umb. arm disconnect and ignition.	29.6 psia (204 062.4 N/m^2) max 26.9 (185 476 N/m^2) min	0.3 psi (2068.2 N/m^2) min to 1.8 psi (12 409.2 N/m^2) max	A	±0.48	29.0 psia max (199 955 N/m^2) 27.5 psia min. (189 613 N/m^2) 0.5 psi min. (3448 N/m^2)
6	S-IC [6] Aft # 2 A7942 1.33	Fuel Tank Vent and Relief (B124)	Controls fuel tank vent valve B129 during prepress. and flight	32.1 psia (221 297.4 N/m^2) max 29.1 psia (200 615.4 N/m^2) min	0.3 psi (2068.2 N/m^2) min to 1.8 psi (12 409.2 N/m^2) max	A, B		
7	S-IC [6] Aft # 3 A7966 1.64	F-1 Engine Thrust OK (B59, B60, B61)	Senses fuel injection pressure. Actuation of 2 interlocked into launch commit. Deactuation of 2 will cause engine cutoff in flight.	1060^{+35}_{-65} psig (7 307 640 +241 290 −448 110 N/m^2) Actuation less 75 ±25 psi (517 050 ±172 350 N/m^2)	50 psi (344 700 N/m^2)	A, C	± 0.30	
8	S-II [7] Intermed. A7744 2.11	Lox Tank Pressure (C213)	Maintains lox tank ullage pressure by controlling lox tank prepress valve C221. Actuation interlocked into S-IC fwd. umb. arm disconnect and ignition.	39.0 psia (268 866 N/m^2) max 37.0 psia (255 078 N/m^2) min	(Note 6)	A	± 0.30	2 required

TABLE A-I. (Cont'd)

ITEM	Stage / Umbilical / Disconnect / F.R.F.No.*	Pressure Switch Identification (Note 2)	Pressure Switch Function and Interlocks	Checkout Port Actuation (Note 3,11,12) / Checkout Port Deactuation (Note 3, 11, 12)	Differential (Note 4)	Checkout Requirements (Note 5)	Ground Loop Tolerances Requirements, percent (Notes 7, 8, 9)	Remarks
9	S-II [7] Intermed. A7744 2.11	Lox Tank Fill Overpressure (C215)	Monitors lox tank pressure during checkout for personnel safety	23.0 psia (158 562 N/m^2) max 21.0 psia (144 774 N/m^2) min	(Note 6)	A, B		
10	S-II [7] Fwd. A7661 2.13	LH_2 Tank Pressure (C117)	Maintains fuel tank ullage pressure by controlling LH_2 tank prepress. valve C113. Actuation interlocked into S-IC fwd. umb. arm disconnect and ignition.	36.0 psia (248 220 N/m^2) max 34.0 psia (234 430 N/m^2) min	(Note 6)	A	±0.30	2 required
11	S-II [7] Fwd. A7661 2.13	LH_2 Tank Fill Overpressure (C119)	Monitors LH_2 tank pressure during checkout for personnel safety.	23.0 psia (158 562 N/m^2) max 21.0 psia (144 774 N/m^2) min	(Note 6)	A, B		
12	S-II [7] Intermed. A7803 2.58	J-2 Engine Mainstage OK (C40)	Actuation of either switch required for engine mainstage operation. Deactuation of both will cause engine shutdown.	515 ± 30 psia (3 550 925 ± 206 850 N/m^2) (Note 13) 20 - 105 psia (137 880 -723 870 N/m^2) below actuation	20 psi (137 880 N/m^2) min	A, C	± 0.48	2 per engine 10 per stage, one umbilical disconnect.

TABLE A-I. (Cont'd)

ITEM	Stage / Umbilical / Disconnect / F.R.F.No.*	Pressure Switch Identification (Note 2)	Pressure Switch Function and Interlocks	Checkout Port Actuation (Note 3, 11, 12) / Checkout Port Deactuation (Note 3, 11, 12)	Differential (Note 4)	Checkout Requirements (Note 5)	Ground Loop Tolerances Requirements, percent (Notes 7, 8, 9)	Remarks
13	S-IVB [8] Aft A7694 3.42	Cold GH_e Regulator Backup, Lox Pressurization (D216)	Monitors plenum chamber D209 pressure during flight and controls GH_e supply shutoff valves (D208 & D257) in the event regulator D207 fails.	467.5 ± 23.5 psia (3 223 299 ± 162 027 N/m^2) 362 ± 33.5 psia (2 495 990 ± 230 983 N/m^2)	48 psi (723 870 N/m^2) min	A, B	±0.95 for SA-501 and SA-502 ± 0.71 for SA-503 and subs #	
14 ##	S-IVB [8] Aft A7694 3.42	Cold GH_e Regulator Backup, Lox Repressurization * ##	Monitors plenum chamber D* pressure during repress. and controls lox tank repress. control valves D* and D* in the event regulator D207 fails.	467 ± 23.5 psia (3 223 299 ± 162 027 N/m^2) 362 ± 33.5 psia (2 495 990 ± 230 983 N/m^2)	48 psi (723 870 N/m^2) min	A, B		Effectivity: SA-503 and subs. * Find numbers not available at this time.
15 ##	S-IVB [8] Aft A7694 3.42	Cold GH_e Regulator Backup, LH_2 Repressurization * ##	Monitors plenum chamber D* pressure during repress. and controls LH_2 tank repress. control valves D* and D* in the event regulator D207 fails.	467.5 ± 23.5 psia (3 223 299 ± 162 027 N/m^2) 362.5 ± 33.5 psia (2 499 438 ± 230 983 N/m^2)	48 psi (723 870 N/m^2) min	A, B		Effectivity: SA-503 and subs. * Find numbers are not available at this time.

TABLE A-I. (Cont'd)

ITEM	Stage / Umbilical / Disconnect / F.R.F. No*	Pressure Switch Identification (Note 2)	Pressure Switch Function and Interlocks	Checkout Port Actuation (Note 3, 11, 12) / Checkout Port Deactuation (Note 3, 11, 12)	Differential (Note 4)	Checkout Requirements (Note 5)	Ground Loop Tolerances Requirements, percent (Notes 7, 8, 9)	Remarks
16 #	S-IVB [8] Aft A7694 3.42	Engine Purge and Valve Control Regulator Backup (D308)	Maintains plenum chamber D307 pressure by controlling solenoid valve D306 in the event regulator D305 fails. Normal condition interlocked into automatic sequence, S-IC fwd. umb. arm disconnect and ignition commands.	600 ± 21 psia ($4\ 136\ 400 \pm 144\ 774$ N/m^2) 490 ± 31 psia ($3\ 378\ 060 \pm 213\ 714$ N/m^2)	58 psi (399 852 N/m^2) min	A, B	± 0.95 for SA-503 and subs.	
17 #	S-IVB [8] Aft A7694 3.42	J-2 Engine Purge Control (D319)	Maintains purge pressure by controlling engine purge control valve D317.	136 psia (937 584 N/m^2) max 99 psia (682 506 N/m^2) min	3 psi (20 685 N/m^2) min	A, B		
18 #	S-IVB [8] Aft A7692 # 3.77 #	Lox Recirculation Pump Purge Control (D318)	Maintains purge pressure by controlling the lox recirculation pump purge control valve (D316)	41.5 psia (286 101 N/m^2) max 37.5 psia (258 525 N/m^2) min	0.3 psi (2069 N/m^2)	A, B	± 0.42 #	
19 #	S-IVB [8] Aft A7692	Lox Tank Pre-pressurization Ground Fill, Flight Fill, Flight Control Repress. and M. L. O. #D262)	Maintains tank pressure by providing signal for ground fill and controlling valves D257 and D208 during prepress. valve B210 during flight and valve D238 during repress. Tank pressurized indication interlocked into S-IC fwd. umb. arm disconnect and ignition commands.	41 psia (282 654 N/m^2) max 37.5 psia (258 563 N/m^2)	0.5 psi (3447 N/m^2) min	A		

TABLE A-I. (Concluded)

ITEM	Stage / Umbilical / Disconnect / F.R.F. No.*	Pressure Switch Identification (Note 2)	Pressure Switch Function and Interlocks	Checkout Port Actuation (Note 3, 11, 12) / Checkout Port Deactuation (Note 3, 11, 12)	Differential (Note 4)	Checkout Requirements (Note 5)	Ground Loop Tolerances Requirements, percent (Notes 7, 8, 9)	Remarks
20 #	S-IVB [8] Aft A7691 3.78	LH_2 Tank Ground Fill Prepress., Repress., and Second Burn Flight Control (D150)	Maintains tank pressure by controlling valve A3911 during ground fill, valve A11967 during prepress., valve D331 during repress., and valve D113 during second burn. Tank pressurized indication is interlocked into S-IC fwd. umb. arm disconnect and ignition commands.	34 psia (234 396 N/m^2) max 30.8 psia (212 335.2 N/m^2) min	0.5 psi (3447 N/m^2) min	A	± 0.61	
21 #	S-IVB [8] Aft A7693 3.73	J-2 Engine Mainstage OK (D40)	Actuation of either switch required for main stage operation. Deactuation of both will cause engine shutdown.	515 ± 30 psia # (3 550 925 ± 206 850 N/m^2) (Note 13) Pickup 75 psi $^{+61}_{-36}$ (517 125 $^{+420\ 595}_{-248\ 220}$ N/m^2)		A, C	± 0.89	2 required

TABLE A-II. CALIPS PRESSURIZATION REQUIREMENTS FOR OVERALL TESTS

ITEM	Stage Umbilical F.R.F. No.*	Pressure Switch Identification (Note 2)	Pressurization Requirements	Remarks
1	S-IC Fwd. 1.32	Lox Tank Prepressurization (B210)	**Pressure is applied to CALIPS port at T-72 secs and must reach 27.0 psia (186 138 N/m^2) prior to T-20 sec.**	Time critical. Pressure must reach 27.0 psia (186 138 N/m^2) for SA-500F, SA-503 and subs.
5	S-IC Aft. #2 1.33	Fuel Tank Prepressurization (B118)	Pressure is applied to CALIPS port at T-97 secs and must reach 29.6 psia (204 062.4 N/m^2) prior to T-20 sec.	Time critical
8	S-IC Aft # 3 1.64	F-1 Engine Thrust OK (B59, B60, B61)	Pressure is applied to CALIPS port port at T-8.8 secs and must reach 1095 psia (754.8930 N/m^2) prior to T-0.1 sec. (Note 16)	Time critical
9	S-II Intermed. 2.11	Lox Tank Pressure (C213)	Pressure is applied to CALIPS port at T-187 secs and must reach 39.0 psia (268 866 N/m^2) prior to T-20 sec.	Time critical
11	S-II Fwd. 2.13	LH_2 Tank Pressure (C117)	Pressure is applied to CALIPS port at T-97 secs and must reach 36.0 psia (222 184 N/m^2) prior to T-20 sec.	Time critical
13	S-II Intermed. 2.58	J-2 Engine Mainstage OK (C40)	Pressure is applied to CALIP port as S-II Engine Start and must reach 525 psia (3 619 350 N/m^2) within 2.9 sec. (Note 16)	Time critical
18	S-IVB Aft. 3.77	Lox Tank Prepress., Grd. Fill, Flight Control Repress. and M.L.O. (D262)	Pressure is applied to CALIP port at T-168 secs and must reach 41.0 psia (282 654 N/m^2) prior to T-20 sec.	Time critical

TABLE A-II. (Concluded)

ITEM	Stage / Umbilical / F.R.F. No.*	Pressure Switch Identification (Note 2)	Pressurization Requirements (Note 14)	Remarks
20	S-IVB / Aft. / 3.78	LH_2 Tank Grd. Fill, Pre-press., Re-press. and Second Burn (D150)	Pressure is applied to CALIP port at T-97 secs and must reach 34.0 psia (234 369 N/m^2) prior to T-20 sec.	Time critical
22	S-IVB / Aft / 3.73	J-2 Engine Mainstage OK (D40)	Pressure is applied to CALIP port at S-IVB Engine Start and must reach 525 psia (3 619 350 N/m^2) within 3.0 sec. (Note 16)	Time critical
4	S-IC / Aft # 2 / 1.33	Fuel Tank Pressurization (B119)	Pressure applied to CALIP port must reach 26.5 psia (182 691 N/m^2) prior to T-0.0 sec and is maintained to T + 2 min 27.3 sec.	Not considered time critical
21	S-IVB / Aft / 3.78	LH_2 Tank First Burn Flight Control (D120)	Pressure applied to CALIP port must reach 31.5 psia (217 161 N m^2) prior to T + 8 min 36 sec and is maintained to T + 11 min 32.3 sec.	Not considered time critical
23	IU / Fwd. / 4.10	Gas Bearing Sphere Low Pressure OK (E703)	Pressure applied to CALIP port must reach 1300 psia (8 962 200 N/m^2) prior to 187 sec. and is maintained to end of flight.	Not considered time critical

APPENDIX B
STANDARD OPERATING PROCEDURES

General Instructions

The following instructions should be observed to maintain maximum protection for personnel and equipment:

1. Verify that all equipment is properly grounded.

2. Verify that all high-pressure lines external to the breadboard are properly connected and secured.

3. Verify that all power cables external to the breadboard are connected properly and are of adequate size to carry the load required by the breadboard.

4. Establish two-way telephone communications between the breadboard and computer control console.

Equipment List

1. Four CEC Force Balance Pressure Transducers of the following types:

   a. Type 4-335-0102, 0-5000 psid (0-34 470 000 N/m^2)

   b. Type 4-335-0001, 0-1000 psid (0-6 894 000 N/m^2)

   c. Type 4-333-0001, 0-100 psid (0-689 400 N/m^2)

   d. Type 4-333-0001, 0-30 psid (0-206 820 N/m^2)

2. One CEC Servo Amplifier, Type 1-156.

3. One Hewlett Packard Model 3440A Digital Volt Meter (DVM).

4. Wiancko Secondary Standard, Type Q-3403.

5. Wiancko Plug-in Pressure Transducer Heads of the following types:

   a. Type M1165, 0-50 psid (0-344 700 N/m^2)

   b. Type M1155, 0-100 psid (0-689 400 N/m^2)

   c. Type M1155, 0-1000 psid (0-6 894 000 N/m^2)

   d. Type M1155, 0-5000 psid (0-34 470 000 N/m^2)

6. One Hewlett Packard Model 5245L Electronic Counter.

7. One Custom Built Signal Conditioner.

8. One Sorenson Model E28-30 Nabotron (Voltage Regulated 28 Vdc Power Supply).

Preliminary to Verification of CEC Transducer Accuracy

1. Verify that all equipment is within its respective calibration period.

2. Verify that equipment is connected as shown in Figure 2, Breadboard System Block Diagram.

NOTE

Before start of test, the Wiancko Secondary Standard and CEC amplifiers and associated transducer heads should be turned on and allowed to stabilize for a period of 24 hours.

CAUTION

Before performing a step, read the step thoroughly.

Damage to the transducer heads is caused by overpressurization. The CEC head may not achieve more than 150 percent of full pressure range without permanent damage.

3. Before running CEC verification test, perform the following steps:

a. Check calibration of DVM by depressing CAL-CHECK button and verify that the DVM reads 8000. Make adjustment if necessary.

b. CEC Transducer Zero Adjustment is accomplished by inserting a small screwdriver bit in the Zero Adjust slot on the transducer head and rotating the control in either direction until the DVM indicates ± 0000 voltage.

CAUTION

Never turn the Zero Adjust control on the transducer more than 10 turns from its original position. Over-adjusting the Zero Adjust control may cause permanent damage and require factory realignment.

Do not disconnect the electrical connector from the transducer without first removing power from the CEC amplifier. (Position the ON-OFF switch to the OFF position). If the connector is disconnected with power ON, fuse F3 on the chopper amplifier will be blown. To replace fuse F3, necessitates removal of amplifier housing and PC board.

c. To accomplish Wiancko secondary standard zero adjustment, connect a coax cable between the X4 connector on the Wiancko and the Hewlett Packard counter input. Position the counter controls to display a frequency count of 000.000.

d. To accomplish Wiancko zero adjust, depress the Range Check pushbutton on the front panel and observe the output frequency. This reading should coincide with the reading recorded on the surface of the name plate of the transducer. If the readings do not agree, loosen the knurled lock behind the Range Set control and rotate the range control until the desired reading is obtained. Release the pushbutton. The counter should display a Zero count of 40 000. If the reading does not agree, adjust the Zero Set control until a reading of 40 000 is obtained. Repeat the above procedure as many times as necessary to obtain the correct zero set.

NOTE

All zero adjustments are made at ambient pressure.

WARNING

The preceding steps are mandatory before proceeding into the actual CALIP loop accuracy verification test.

Operational Modes

See Breadboard Schematic, Figure 3, for position of valves and transducers, and Table B-I for summary of the operational modes.

1. Mode I — Stabilization Verification. This mode of operation serves to produce data which verify that the CEC transducer is stable. The pressure readings of the CEC are checked against the Wiancko transducer readings at various pressures. The system is manually controlled by switching the solenoids. The pressure in the system is raised and lowered in steps.

a. Install desired CEC and Wiancko transducer heads.

b. Position the hand valves as follows:

(1) Isolation valves 2 and 8 to the closed position.

(2) Isolation valve 3 to the open position.

(3) Isolation valve 4 to the closed position.

(4) Isolation valves 5 and 7 to the closed position.

(5) Isolation valve 6 to the open position. (Left open so that system can be vented through vent valve 9 at the end of valve testing).

(6) Vent valve 9 to the closed position.

TABLE B-I. SUMMARY OF OPERATIONAL MODES

Mode	Monitoring Test Point		System Control	Data Recording	Additional Systems	Objectives
	CEC	WIANCKO				
1	A	A	Manual Steps	Manual	None	Determine differences in transducer readings under static conditions.
2	A	A	Manual Ramping	Computer	None	Determine differences in transducer readings under dynamic conditions.
3	A	B	Manual Ramping	Computer	None	Determine system accuracies.
4	A	B	Pressure Switch Ramping	Computer	CALIPS	Check complete operational system.
5	A	B	Manual Ramping	Computer	None	Determine optimum orifice size.
5	A	A	Manual Ramping	Computer	None	Determine optimum orifice size.

c. Position the solenoid valves (SOV's) as follows:

(1) SOV S1 to OFF Indicator (GREEN).

(2) SOV S2 to OFF Indicator (GREEN).

(3) SOV S3 to OFF Indicator (GREEN).

(4) SOV S4 to VENT (no indication toggle switch).

(5) SOV S5 to VENT (no indication toggle switch).

(6) SOV S6 to OPEN (no indication toggle switch).

(7) SOV S7 to VENT (no indication toggle switch).

(8) SOV S8 to VENT (no indication toggle switch).

d. Open facility shutoff valve (not shown on Fig. 3) and verify approximately 3000 psig (20 682 000 N/m^2) as read on gage 1.

e. Open shutoff valve 1.

f. Set hand-operated regulator to the desired pressure as read on gage 2.

g. Position the start switch to ON. The indicator illuminates red indicating SOV S1 is open.

NOTE

Position the start switch to ON and then to OFF allowing the system to stabilize at 20 percent intervals up to the transducer full-scale reading. Record the CEC and Wiancko reading at each stabilized interval.

h. Position vent switch S2 to ON and then to OFF. Allow the system to stabilize at 20 percent intervals down to zero. Record CEC and Wiancko readings at each stabilized interval, including the zero reading.

NOTE

Open vent valve 9 to assure the system is at ambient pressure.

The preceding Steps 7 through 8 are performed to minimize the hysteresis of each transducer.

The readings obtained during the stabilization run from both transducers should agree substantially. If substantial agreement is not obtained, repeat steps 7 through 8 until substantial agreement is obtained.

2. Mode 2 — Determination of Loop Accuracy. This mode evaluates all of the system inaccuracies with the exception of pressurization lag. The system is operated by manual control of solenoids. The computer monitors the system operation. Pressure is ramped up and down using the coarse and fine orifices. The transducers are connected to the same end of the line.

Before performing the loop accuracy test, the following conditions should be accomplished.

a. Prepare test setup as follows:

(1) Select desired tubing length (see Breadboard Schematic, Fig. 3).

(2) Install desired CEC and Wiancko transducer heads.

(3) Position the hand valves as follows: [Example using 550 ft (167.8 m) of 0.375 in. (0.9 cm) tubing].

(a) Isolation valves 2 and 8 to the closed position.

(b) Isolation valve 3 to the open position.

(c) Isolation valve 4 to the closed position.

(d) Isolation valves 6 and 7 to the closed position.

(e) Isolation valve 5 to the open position.

(f) Vent valve 9 to the closed position.

b. Position the solenoid valves (SOV's) as follows:

(1) SOV S1 to OFF Indicator (GREEN).

(2) SOV S2 to OFF Indicator (GREEN).

(3) SOV S3 to ON Indicator (RED).

c. Verify loop accuracy test point A.

(1) Adjust the hand regulator to desired pressure (refer to step a. 2).

(2) Notify the computer operator to start the computer.

(3) Position the start switch to ON (RED indication). Pressurize the system to approximately 80 percent of full-scale (maximum value of transducer). Position switch S3 (coarse orifice control) to OFF (GREEN indication). The system will continue to pressurize through the fine orifice. When full-scale pressure is attained, position switch S2 (vent valve) to ON (RED indication). Allow the system to vent to approximately 80 percent on full-scale. Position switch S3 (coarse orifice control) to ON. The system will continue to vent through the combined fine and coarse orifices until ambient pressure is indicated.

(4) Notify the computer operator to stop the computer.

(5) Position vent valve 9 to OPEN. Allow the system to stabilize to ambient pressure.

CAUTION

Care should be taken during manual pressurization not to over-pressurize the system beyond full-scale readings as this will result in permanent damage to the transducers.

(6) Repeat steps a through c for the remaining tubing lengths. (See Fig. 3 for correct valve setting.)

NOTE

During ramping, the computer will receive and process data at approximately 2-second intervals.

3. Mode 3 — Determination of Loop Accuracy (Manual Controlled Test Points A and B). The system is controlled by manual operation of the solenoid valves. The transducers are at each end of the tubing line. The pressure is ramped up and down with the computer recording the readings from both transducers. This mode will allow the overall accuracy to be evaluated including the effect of pressurization lag.

a. Prepare test setup as follows:

(1) Select desired tubing length (see Breadboard Schematic, Fig. 3).

(2) Install desired CEC and Wiancko transducer heads.

(3) Position the hand valves as follows: [Example using 550 ft (167.8 m) of 0.375 in. (0.9 cm) tubing].

(a) Close isolation valve 3.

(b) Open isolation valve 4.

(c) Close isolation valves 2 and 8.

(d) Close isolation valves 6 and 7.

(e) Open isolation valve 5 (this valve opens the desired tubing length).

(f) Vent valve 9 to the closed position.

b. Position the solenoid valves (SOV's) as follows:

(1) SOV S1 to OFF Indicator (GREEN).

(2) SOV S2 to OFF Indicator (GREEN).

(3) SOV S3 to ON Indicator (RED).

(4) SOV S5 to ON Indicator (RED).

(5) SOV S6 to OFF Indicator (GREEN).

(6) SOV S7 to OFF Indicator (GREEN).

c. Verify zero settings for the Wiancko and CEC transducer heads. If the zero settings have drifted, readjust as necessary (reference to zero set procedure).

d. Verify loop accuracy test points A and B:

(1) Set hand-operated regulators to desired pressure (gage 2).

(2) Notify the computer operator to start computer.

(3) Position the start switch to ON (RED Indication). Pressurize the system to approximately 80 percent of full-scale (maximum value of transducer). Position switch S3 (coarse orifice control) to OFF (GREEN Indication). The system will continue to pressurize through the fine orifice. When full-scale pressure is attained, position switch S2 (vent valve) to ON (RED Indication). Allow the system to vent to approximately 80 percent on full-scale. Position switch S3 (coarse orifice control) to ON. The system will continue to vent through the combined fine and coarse orifices until ambient pressure is indicated.

e. Reset system for remaining tubing lengths (Steps a.3.e, b.4, b.5, b.6, above), and repeat steps c and d above.

NOTE

Observe all notes and cautions under Mode 2.

The tests conducted under modes 2 and 3 are performed using the transducer pressure ranges in Table B-II with each tubing length.

TABLE B-II. TRANSDUCER PRESSURE HEADS

CEC	WIANCKO
30 psid (206 820 N/m^2) 100 psid (689 400 N/m^2) 1000 psid (6 894 000 N/m^2) 5000 psid (34 470 000 N/m^2)	50 psid (344 700 N/m^2) 100 psid (689 400 N/m^2) 1000 psid (6 894 000 N/m^2) 5000 psid (34 470 000 N/m^2)

4. Mode 4 — Determination of Loop Accuracy Using CALIPS (Automatically Controlled). The system is completely automatically controlled. The transducers are at each end of the tubing line and the up and down ramp and high and low ramp rates are pressure switch controlled. The test is designed to give actual CALIPS actuation and deactuation points on the pressurization and depressurization cycle.

NOTE

The digital voltmeter should be observed during the automatic pressurization cycle. If the high pressure switch should fail, the transducers and CALIPS would be damaged.

a. Prepare test setup as follows:

(1) Select desired tubing length (see Breadboard Schematic, Fig. 3).

(2) Install desired fine orifice size.

(3) Open CALIPS isolation valve 8.

(4) Open pressure switch isolation valve 2.

(5) Position pressure switch solenoid valve S4 to ON.

b. Verify zero settings for Wiancko and CEC transducer heads. If either zero settings have drifted, readjust as necessary (reference to zero set procedure).

c. Position transducer isolation valve 4 to the closed position and valve 3 to open position (test point A).

NOTE

Test is repeated with valve 3 closed and valve 4 open (test point A and B).

d. Verify all other valves are in the OFF position (see pneumatic schematic).

e. Set hand-operated regulator to desired pressure (gage 2).

f. Before initiating the test start, verify that the zero settings of the transducers have stabilized. Refine setting if necessary.

g. Notify the computer operator to start computer.

h. Position the start switch to ON.

NOTE

After the start switch has been initiated, the sequence of operations is automatically controlled by the console high low-pressure switches.

i. When the system indicates zero pressure, as monitored by the CEC DVM, notify the computer operator to stop the computer.

j. Position start switch to OFF.

k. Position vent valve 9 to open.

l. Close vent valve 9.

m. Repeat steps c through l for the remaining tubing lengths.

n. Substitute fine orifices and repeat the above test, steps c through k.

o. Position transducer isolation valve 4 to the open position and valve 3 to the closed position (test point A and B). (See note above.)

p. Repeat steps d through n above.

5. Mode 5 — Establishment of Optimum Ramp Rates. This mode of operation is used to determine the optimum ramp rates and hence to establish an optimum orifice size for each pressure range. Gaseous nitrogen (GN_2) and helium (He) shall be used in determining ramp ranges. The system is manually operated. Both transducers are monitoring test point A and then the system is changed so that the CEC is at test point A and the Wiancko at test point B.

a. Prepare test setup as follows:

(1) Select desired tubing length (see Breadboard Schematic, Fig. 3).

(2) Install desired CEC and Wiancko transducer heads.

(3) Position the hand valves as follows: [Example using 550 ft (167.8 m) of 0.375 in. (0.9 cm) tubing].

(a) Isolation valves 2 and 8 to the closed position.

(b) Isolation valve 3 to the open position.

(c) Isolation valve 4 to the closed position.

(d) Isolation valves 6 and 7 to the closed position.

(e) Isolation valve 5 to the open position.

(f) Vent valve 9 to the closed position.

(4) Select desired fine orifice size and install.

(5) Select desired media (GN_2 or He).

b. Position the solenoid valves (SOV's) as follows:

(1) SOV S1 to OFF Indicator (GREEN).

(2) SOV S2 to OFF Indicator (GREEN).

(3) SOV S3 to ON Indicator (RED).

c. Verify loop accuracy test point A.

(1) Adjust the hand regulator to desired pressure (refer to step a. 2 above).

(2) Notify the computer operator to start the computer.

(3) Position the start switch to ON (RED indication). Pressurize the system to approximately 80 percent of full-scale (maximum value of transducer). Position switch S3 (coarse orifice control) to OFF (GREEN indication). The system will continue to pressurize through the fine orifice. When full-scale pressure is attained, position switch S2 (vent valve) to ON (RED indication). Allow the system to vent to approximately 80 percent on full-scale. Position switch S3 (coarse orifice control) to ON. The system will continue to vent through the combined fine and coarse orifices until ambient pressure is indicated.

(4) Notify the computer operator to stop the computer.

(5) Position vent valve 9 to OPEN. Allow the system to stabilize to ambient pressure.

CAUTION

Care should be taken during manual pressurization not to over-pressurize the system beyond full-scale readings as this will result in permanent damage to the transducers.

(6) Repeat steps a through c for the remaining tubing lengths. (See Fig. 3 for correct valve setting.)

NOTE

During ramping, the computer will receive and process data at approximately 2-second intervals.

(7) Change orifice size and repeat steps a through c for each tubing length.

d. Change gaseous media and perform a through c for each orifice size and tubing length.

e. Prepare test setup as follows:

(1) Select desired tubing length (see Breadboard Schematic, Fig. 3).

(2) Install desired CEC and Wiancko transducer heads.

(3) Position the hand valves as follows: [Example using 550 ft (167.8 m) of 0.375 in. (0.9 cm) tubing].

(a) Close isolation valve 3.

(b) Open isolation valve 4.

(c) Close isolation valves 2 and 8.

(d) Close isolation valves 6 and 7.

(e) Open isolation valve 5 (this valve opens the desired tubing length).

(f) Vent valve 9 to the closed position.

f. Position the solenoid valves (SOV's) as follows:

(1) SOV S1 to OFF Indicator (GREEN).

(2) SOV S2 to OFF Indicator (GREEN).

(3) SOV S3 to ON Indicator (RED).

(4) SOV S5 to ON Indicator (RED).

(5) SOV S6 to OFF Indicator (GREEN).

(6) SOV S7 to OFF Indicator (GREEN).

g. Verify zero settings for the Wiancko and CEC transducer heads. If the zero settings have drifted, readjust as necessary (reference to zero set procedure).

h. Verify loop accuracy test points A and B:

(1) Set hand-operated regulators to desired pressure (gage 2).

(2) Notify the computer operator to start computer.

(3) Position the start switch to ON (RED Indication). Pressurize the system to approximately 80 percent of full-scale (maximum value of transducer). Position switch S3 (coarse orifice control) to OFF (GREEN Indication). The pressure is attained, position switch S2 (vent valve) to ON (RED Indication). Allow the system to vent to approximately 80 percent on full-scale. Position switch S3 (coarse orifice control) to ON. The system will continue to vent through the combined fine and coarse orifices until ambient pressure is indicated.

i. Reset system for remaining tubing lengths (Steps e.3.e., f.4, f.5, f.6, above), and repeat steps g and h above.

NOTE

Observe all notes and cautions under operational Mode 2.

The test conducted under Mode 5 is performed using the transducer pressure ranges in Table B-II with each tubing length.

j. Change orifice size and repeat steps e through i for each tubing length.

k. Change gaseous media and perform e through j for each orifice size and tubing length.

APPENDIX C
COMPUTER PROGRAMS

```
$JOB            NASA-NELSON, BIN 3 ,450890,01,12,120CEP

$EXECUTE        IBJOB

$IBJOB

$IBFTC CDTOGF   LIST,DD,DECK

      DIMENSION XA(150),YA(150),YA1(150),XB(150),YB(150),XC(150),

     1 YC(150),ABAX(12),ABAY(12),ABBX(12),ABBY(12),ABCY(12),

     2 XD(150),YD(150)

      DIMENSION SYCC(11)

      DIMENSION C(10),SYC(150),AB6(12),ABAZ(12)

      READ (5,50)(ABAX(K),K=1,12),(ABAY(K),K=1,12),(ABBX(K),K=1,12),

     1 (ABBY(K),K=1,12),(ABCY(K),K=1,12),(AB6(K),K=1,12)
     2 ,(ABAZ(K),K=1,12)
   50 FORMAT (12A6)
    9 READ (5,579) M,CUTOFF,THROUT
  579 FORMAT (I2,2F10.0)
      NPA=0
      NP=0
      JUMP=0
   10 READ (5,100) P1,P2,ICON,JH,JM,JS,JDS,NSW
  100 FORMAT (F8.0,4X,F8.0,18X,I2,14X,4I2,6X,I2)
      IF (ICON.EQ.1) GO TO 30
      IF (ICON.GE.2) JUMP=0
      IF (ICON.GE.2) GO TO 420
      IF (P1.EQ.0.0)GO TO 10
      IF (P1.LT.AP1.AND.AP1.GT.AAP1.AND.AAP1.GT.0.0) ICON=1
      AAP1=AP1
      AP1=P1
      IF (JUMP.GE.1)GO TO 333
      IH=JH
      IM=JM
      IS=JS
      IDS=JDS
      JUMP=1
  333 CONTINUE
C        I=INITIAL
C         J=PRESENT
      IF (JH.GE.IH) GO TO 339
      JH=JH+24
  339 NH=JH-IH
  340 IF (JM.GE.IM) GO TO 341
      JM=JM+60
      NH=NH-1
  341 NM=JM-IM
  342 IF (JS.GE.IS) GO TO 343
      JS=JS+60
      NM=NM-1
  343 NS=JS-IS
  344 IF (JDS.GE.IDS) GO TO 345
      JDS=JDS+10
```

```
      NS=NS-1
  345 NDS=JDS-IDS
      TTT=NH*36000+NM*600+NS*10+NDS
      T=TTT/10.0
      NPA=NPA+1
      XB(NPA)=T
      XC(NPA)=P1
      XD(NPA)=P2
      IF (NPA.LT.150) GO TO 431
      CALL CAMRAV(9)
  420 CALL QUIK3V (-1,B,ABAX,ABAY,-NPA,XB,XC)
      CALL QUIK3V (0,B,ABAX,ABAY,NPA,XB,XD)
      DO 430 NPA=1,150
      XB(NPA)=0.0
      XC(NPA)=0.0
      XD(NPA)=0.0
  430 CONTINUE
      NPA=0
      IF (ICON.GE.2) GO TO 30
  431 IF (P1.LT.CUTOFF) GO TO 10
      IF (ICON.GE.1) GO TO 30
      NP=NP+1
      SW=NSW
      YD(NP)=CUTOFF*1.01+CUTOFF*0.05*SW
      XA(NP)=T
      YA1(NP)=P2
      YA(NP)=P1
      YB(NP)=P2-P1
      YC(NP)=(P2-P1)*100.0/P1
      IF (NP.LT.150) GO TO 10
   30 CONTINUE
      IF (NP.LT.M+1) GO TO 599
      CALL STAT (YC,NP)
      CALL QUIK3V (-1,B,ABAX,ABAZ,-NP,XA,YA)
      CALL QUIK3V(0,A,ABAX,ABAZ,NP,XA,YA1)
      CALL QUIK3V (0,B,ABAX,ABAZ,-NP,XA,YD)
      CALL QUIK3V (-1,B,ABBX,ABCY,-NP,YA,YC)
      CALL QUIK3V (-1,B,ABBX,AB6,-NP,YA,YB)
      CALL QUIK3V (-1,B,ABBX,ABBY,-NP,YA,YA1)
      CALL QUIK3V (-1,B,ABBX,ABCY,NP,YA,YC)
      CALL SMOOTH (YA,YC,NP,M,C)
      MP1=M+1
      DO 200 I=1,NP
      SYC(I)=0.0
      DO 205 J=1,MP1
  205 SYCC(J)=0.0
      DO 210 J=1,MP1
      L=J+1
      K=J-1
  210 SYCC(L)=SYCC(J)+C(J)*YA(I)**K
  200 SYC(I)=SYCC(L)
      CALL QUIK3V (0,B,ABBX,ABCY,-NP,YA,SYC)
  599 DO 600 NP=1,150
      XA(NP)=0.0
      YA1(NP)=0.0
      YA(NP)=0.0
      YB(NP)=0.0
      YC(NP)=0.0
      YD(NP)=0.0
```

```
      SYC(NP)=0.0
  600 CONTINUE
      NP=0
      AP1=0.0
      AAP1=0.0
      IF (ICON-3) 10,9,31
   31 CALL CLEAN
      STOP
      END
$DATA
ELAPSED TIME IN SECONDS
TRANSDUCER OUTPUT -PSIG-
WIANCKO OUTPUT PSIG
CEC OUTPUT PSIG
PERCENT DIFFERENCE
ABSOLUTE DIFFERENCE
TRANSDUCER OUTPUT -PSIG-  AND SWITCH ACTUATION
 5  10.0
$IBFTC STATIS  LIST,DD,DECK
      SUBROUTINE STAT (Y,NP)
      DIMENSION Y(150)
      SAVE =0.0
      DO 10 I=1,NP
   10 SAVE=SAVE+Y(I)
      XBAR=SAVE/FLOAT(NP)
      DIFS=0.0
      DO 20 J=1,NP
   20 DIFS=DIFS+(Y(J)-XBAR)**2
      VAR=DIFS/FLOAT(NP-1)
      STDIV=SQRT(ABS(VAR))
      WRITE (6,6) XBAR,VAR,STDIV,NP
    6 FORMAT (/6H MEAN=,F10.6,10H VARIENCE=,F10.6,8H ST DEV=,
     1 F10.6,5X,I3,9H READINGS/)
      RETURN
      END
```

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July 17, 1968

APPROVAL

NASA TM X-53729

CALIBRATIONABLE PRESSURE SWITCH (CALIPS) CHECKOUT SYSTEM LOOP ACCURACY EXPERIMENT

By

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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