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PACE
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DESIGN, DEVELOPMENT, AND DEMONSTRATION OF A WARM GAS DISTRIBUTION SYSTEM REGULATOR

FINAL REPORT

JPL CONTRACT NO.951988
PERIOD ENDING 10 AUGUST 1969

GENERAL ELECTRIC

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This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, as sponsored by the National Aeronautics and Space Administration under Contract NAS 7-100

GENERAL ELECTRIC
SPACE SYSTEMS ORGANIZATION
Valley Forge Space Center
P. O. Box 8555 • Philadelphia, Penna. 19101

ABSTRACT

The successful design, development and demonstration of a pneumatic regulator for a warm gas distribution system (WGDS) is reported. Component design, development and life test results are discussed. Performance obtained in testing of an advanced soft seat design over a range of temperatures and in a one-million cycle life test is believed to represent best performance obtained to date within current state of the art.

TABLE OF CONTENTS

Section		Page
1	INTRODUCTION	1-1
2	TECHNICAL DISCUSSION	2-1
2.1	Description of Regulator Designs	2-1
2.1.1	Soft Seat Regulator	2-1
2.1.2	Hard Seat Regulator	2-2
2.2	Material Compatibility	2-9
2.3	Regulator Acceptance Test Results	2-10
2.4	Regulator Life Tests	2-12
2.4.1	General	2-12
2.4.1.1	Exceptions to Test Plan	2-12
2.4.2	Test Results	2-14
2.4.2.1	Physical Examination	2-14
2.4.2.2	Weight	2-15
2.4.2.3	Static Leakage	2-15
2.4.2.4	Contamination Test	2-16
2.4.2.5	Flow and Regulation	2-16
2.4.2.6	Discussion of Regulator Stability	2-26
2.5	Discussion of Measurement Procedures and Equipment Accuracy	2-27
3	SUMMARY OF CONCLUSIONS	3-1
4	NEW TECHNOLOGY	4-1

APPENDIXES

A	REGULATOR SPECIFICATION	A-1
B	PROGRAM PLAN	B-1
C	WORK STATEMENT FOR REGULATOR IMPROVEMENT	C-1
D	RESULTS OF COMPATIBILITY STUDY	D-1
E	TEST PLAN FOR LIFE TEST	E-1
F	ACCEPTANCE TEST PLAN FOR REGULATOR CCC P/N 1922 001 17-1	F-1
G	STERER FUNCTIONAL TEST REPORT	G-1

LIST OF ILLUSTRATIONS

Figure		Page
1-1	Original WGDS Regulator Design	1-2
1-2	WGDS Regulator Acceptance Test Data (S/N 1)	1-4
1-3	WGDS Regulator Acceptance Test Data (S/N 2)	1-5
2-1	Initial Soft Seat Regulator Redesign	2-3
2-2	Final Design - Soft Seat Regulator	2-4
2-3	Soft Seat Regulator Dimensions	2-5
2-4	Hard Seat Regulator Design	2-7
2-5	Soft Seat Regulator Acceptance Test Data	2-11
2-6	Hard Seat Regulator Acceptance Test Data	2-11
2-7	Test Equipment Setup in Pneumatic Test Clean Room	2-29
2-8	Hard Seat Regulator in Vacuum Chamber Bell Jar	2-29
2-9	Hard Seat Regulator Outlet Pressure Adjustment	2-29
2-10	Soft Seat Regulator Mounted in Bell Jar Showing Location of Outlet Pressure Tap	2-29

LIST OF TABLES

Table		Page
2-1	Design Improvements for WGDS Regulator	2-6
2-2	Initial Hard Seat Regulator Test Results	2-8
2-3	Hard Seat Regulator Test Results with Full Range Nispan-C Spring	2-9
2-4	Regulator Pressure Setting History	2-13
2-5	Regulator Leak Test Results	2-16
2-6	Contamination Check Test Results	2-17
2-7	Performance - Flow/Regulation (Sterer Hard Seat Regulator)	2-18
2-8	Performance - Flow/Regulation (Carleton Soft Seat Regulator)	2-22

LIST OF PRIMARY CONTRIBUTORS

C.C.C. Rich	GE Program Manager
W.D.D. Boyce	GE Regulator Design Engineering
G.D.D. Edge	GE Component Test Engineering
J.A.A. Mason	GE Component Test Engineering
L.A.A. Piotti	GE Component Test Operations
E.E. Monnich	Sterer Engineering
R.R. Cummins	Carleton Controls
L.L. Gill	Carleton Controls

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SECTION 1
INTRODUCTION

The development of an improved pneumatic regulator suitable for use in a spacecraft control system is reported here. The developmental effort conducted was a follow-on to earlier work under JPL Contract 951988.* The original program covered development of a complete warm-gas distribution system; the most recent effort has been concentrated in further development of the regulator for this system, with a goal of ultimately meeting the performance requirements of Regulator Specification SVS7513, which is appended to this report as Appendix A.

The regulator must function with varying inlet pressures (50-200 psia), must be adjustable to provide a range of outlet pressures (15 to 25 psia), must operate within total regulated pressure tolerances, including lockup, of ±0.5 psi with a ±0.3 psi performance goal and must provide this performance over a -14 to +167°F temperature band.

Original development of the WGDS regulator covered testing of two units at the component level and of one of these units at the subsystem level. The original regulator design used was Carleton Controls Model No. 1992-517, shown in Figure 1-1. This regulator was a single-stage, balanced poppet design, using a bellows sensing element. The regulator was loaded with a helical, circular wire spring, and incorporated a soft seat with rounded edge sealing.

The original design concept for the regulator included sealing the bellows element and filling the sealed element with a predetermined amount of inert gas. Temperature changes, acting on the sealed volume, would cause changes in internal pressure and a displacement of the bellows element. In this manner, compensation was to be provided for temperature effects on the spring modulus and dimensions. Temperature compensation such as this was deemed necessary to approach the desired regulation goal of ±0.3 psi over a 100 to

*Design, Development and Demonstration of a Warm Gas Distribution System, General Electric Company, Report DIN 68SD4298, 2 August 1968.

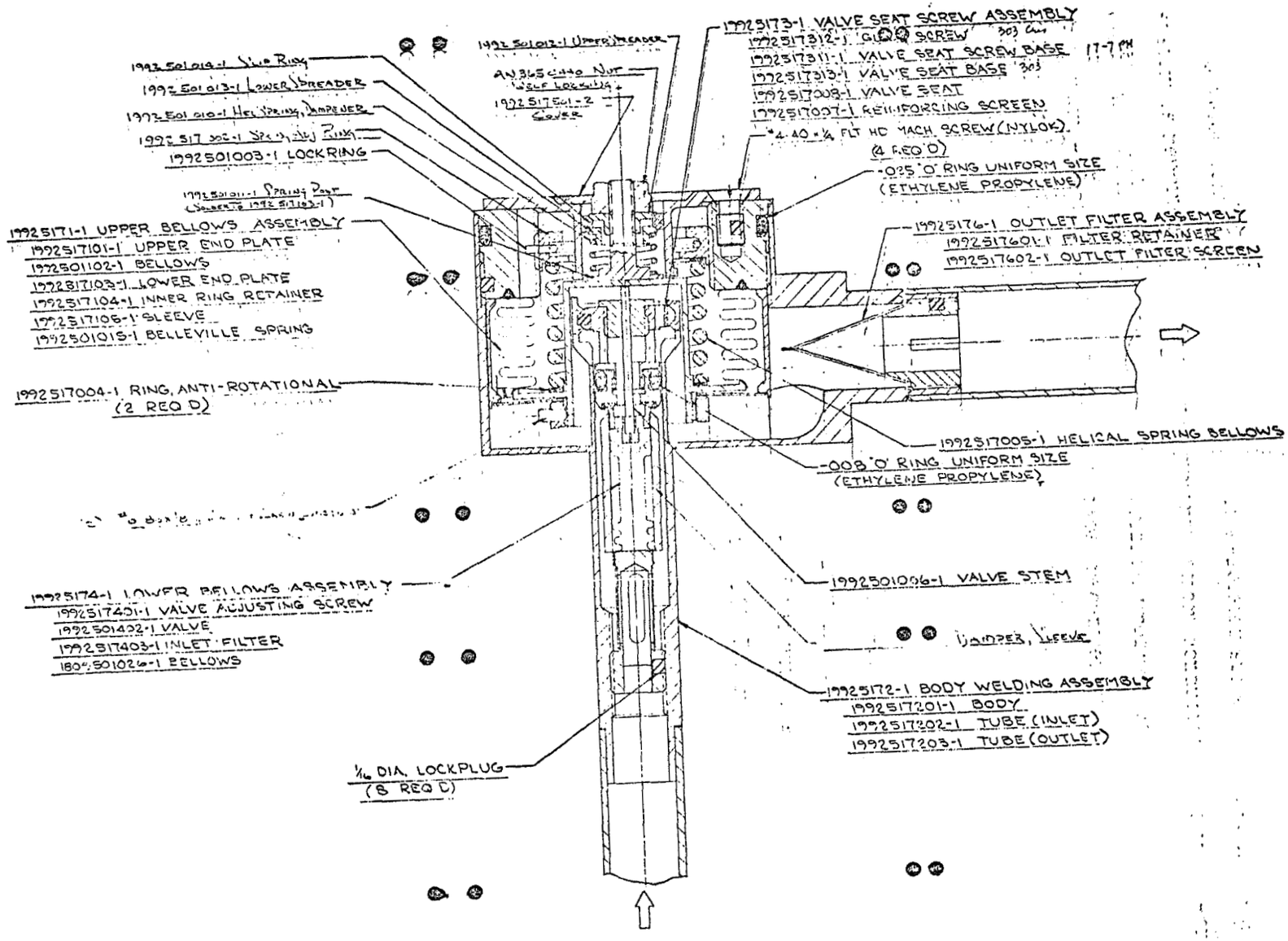


Figure 1-1. Original WGDS Regulator Design

+400°F temperature range. With the regulation tolerance redefined as required over a temperature range of -14 to +167°F, the sealed backfilled bellows compensation method was eliminated in favor of a constant modulus spring of Ni-Span C. The regulator outlet pressure could be adjusted externally. Since the spring and adjusting screw were inside the bellows (the side exposed to ambient pressure), adjustment of the spring did not introduce any contaminants into the regulator or system. During detail design of the regulator, it was found necessary to incorporate both helical and Belleville springs in order to permit adjustment over the full range of 15 to 25 psig without use of different springs.

The first regulator assembled incorporated 17-7 Cres helical and belleville springs. Initial test results showed that this unit (S/N 1) did not perform within specification limits over the full temperature range of -14 to +167°F. However, it was decided, with JPL concurrence, to expedite the system test program by using this unit in the demonstration system and to continue development activity on the backup regulator (S/N 2). Test results obtained for regulator S/N 1 are summarized in Figure 1-2. It was noted in the performance of the first regulator that a considerable "droop" existed at higher flow rates and that a considerable thermal-induced error was present. Developmental effort on the second regulator was concentrated on selection of optimum spring rates for the helical and belleville springs and on incorporation of a Nispan-C helical spring. A Nispan-C belleville was not used because of difficulty realized in fabrication. This spring carries a small (about 10 percent) percentage of the total spring load and is not so significant to regulator performance over a temperature span as is the helical spring. With the design changes incorporated, the regulator performance improved to that shown in Figure 1-3. A total regulation range of ±0.55 psi was realized with S/N 2, including all lockup and flow regulation effects, at an outlet pressure of approximately 25 psi. At a 15 psi setting, the maximum lockup pressure rise was slightly higher resulting in a ±0.7 psi band overall, although the pressure regulation during flow was ±0.5 psi at this pressure setting.

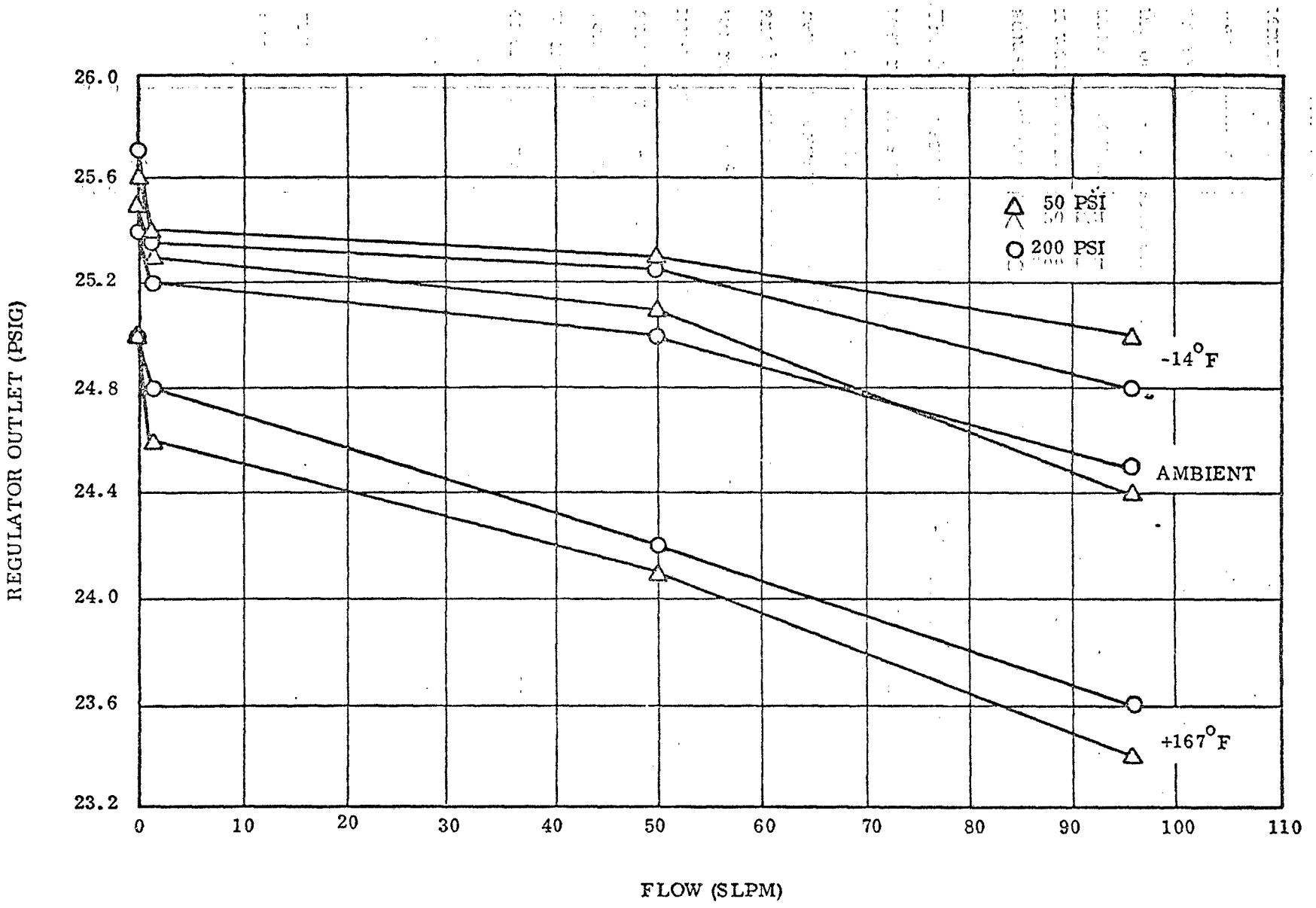


Figure 1-2. WGDS Regulator Acceptance Test Data (S/N 1)

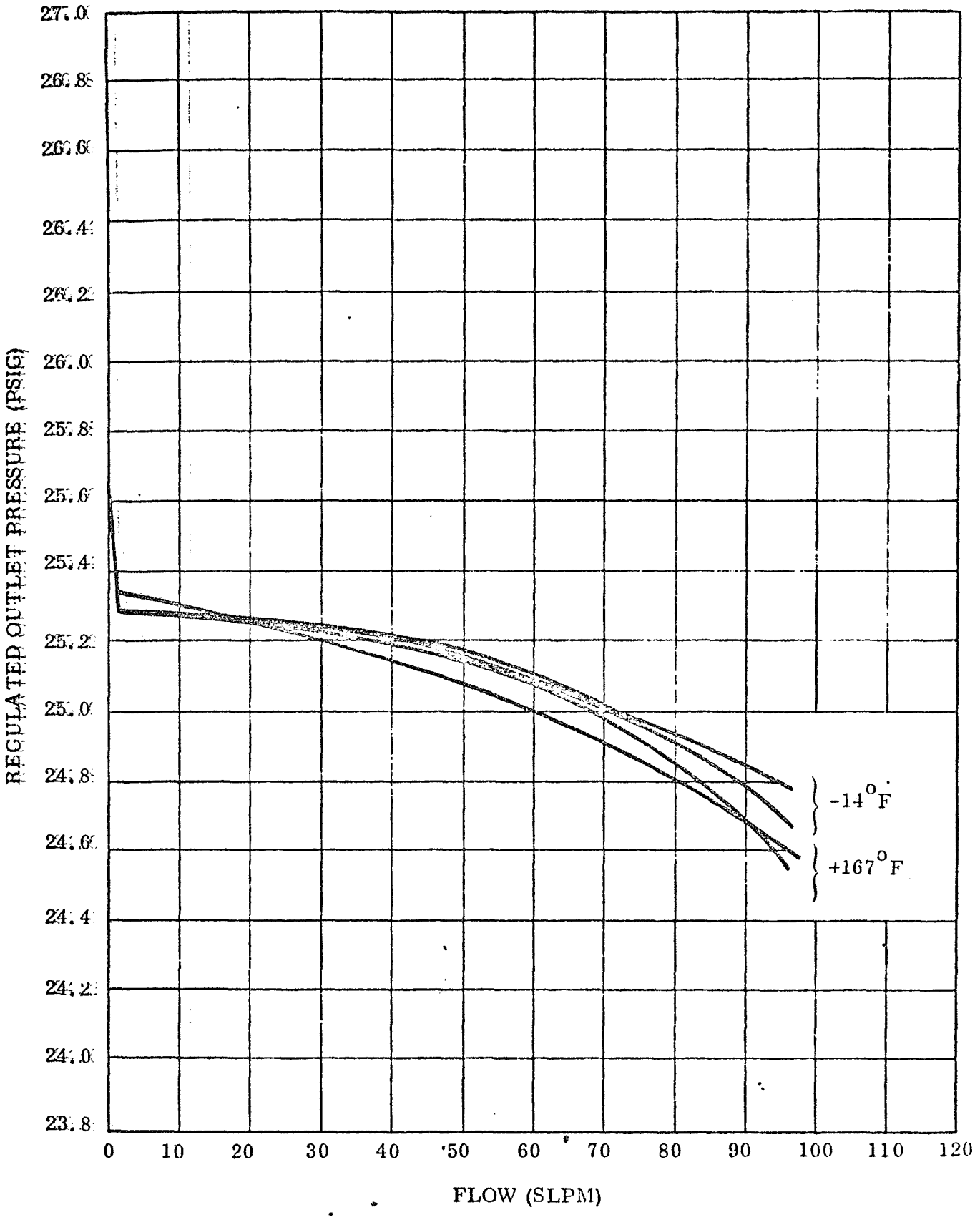


Figure 1-3. WGDS Regulator Acceptance Test Data (S/N 2)

The follow-on program was intended to fulfill the following objectives:

1. Improve regulator performance.
2. Demonstrate one-million cycle life of the soft seat design.
3. Initiate development of a backup hard seat design potentially offering better long life performance.

The Program Plan for accomplishment of these objectives is included in this report as Appendix B. The program scope permitted procurement of one unit of each design type, development and acceptance testing by each regulator supplier, and comparative functional and life testing conducted on each design by General Electric Space Systems.

SECTION 2

TECHNICAL DISCUSSION

2.1 DESCRIPTION OF REGULATOR DESIGNS

2.1.1 SOFT SEAT REGULATOR

The work statement used for initial definition of the scope of work for improvement of the performance of the soft seat regulator design manufactured by Carleton Controls is included as Appendix C. The design analysis performed included particular attention in the following areas:

1. Enlarged and smoothed flow paths downstream of seat.
2. Modifications to regulator gain to improve stability.
3. Elimination of friction dampers.
4. Reduction in number of detail parts.
5. Reduction in number of O-ring seals.
6. Simplification of adjustment provisions.
7. Reduction in use of threaded parts.
8. Elimination of sensitivity to external torques.
9. Increased clearance around helical spring.
10. Optimization of helical - Belleville spring relationships.

The initial attack was directed as shown in Table 2-1, leading to an early conceptual design shown in Figure 2-1. This design employed a tapered valve head assembly to reduce regulator gain. It was subsequently decided to continue use of the annular rounded edge poppet previously proven in earlier units but to incorporate a bimetallic element for additional temperature compensation, and to use several poppet drive pintles rather than a single central pintle. The design evolution ultimately led to the design shown in Figure 2-2. This design was felt to offer the optimum combination of improvements desired. Features

clude resistance to main helical spring cocking by means of floating spring supports, alanced poppet loading, inlet bellows support using an internal post rather than an external leeve, a bimetallic element for additional temperature compensation, simplified external djustability, and an easy-to-clean convoluted bellows design. Flow paths are enlarged to ecrease droop at maximum flows under minimum pressure conditions.

he external dimensions of the regulator are shown in Figure 2-3. The regulator weighs pproximately 0.95 pound including inlet and outlet tubes and conventional flared tube nuts sed for test connections. The actual regulator assembly weight is approximately 0.65 pound xclusive of these parts, and it is estimated that a 0.5-pound weight may be achieved by taking veight out of the main housing in subsequent units.

2.1.2 HARD SEAT REGULATOR

The hard seat regulator design selected is Sterer Part 37020. The regulator had been originally proposed by Sterer for use in the initial WGDS demonstration. The regulator is shown in Figure 2-4. This design is a modification of similar Sterer designs which employ an unbalanced poppet with a hard ball and seat in the valve head subassembly.

GE had previously recommended to JPL during design activity on the original WGDS design and component selection tasks that the unbalanced poppet design might not be capable of as tight a pressure regulation accuracy band as the balanced poppet design employed in the soft seat regulator design. However, the hard seat design offered significant life advantages. Because program limitations permitted procurement of only one unit of each type for life testing at GE, advantage was taken of as much prior design data as possible, and only those changes deemed absolutely necessary to improve regulation accuracy were made. (The soft seat design was changed more radically since it is the third prototype regulator of this type and subsequent prototypes could take advantage of results obtained from the S/N 2 regulator as well as the current design.)

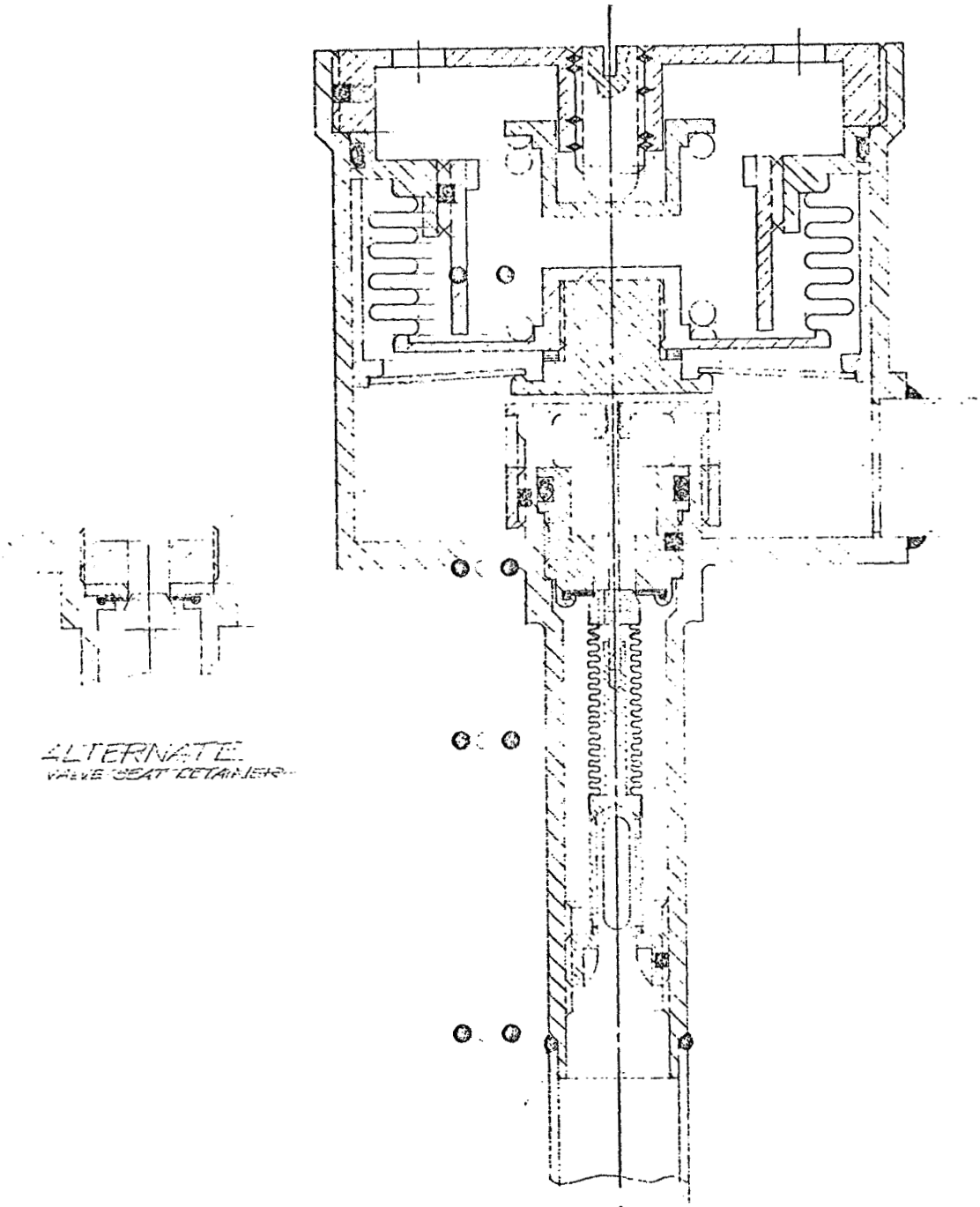


Figure 2-1. Initial Soft Seal Regulator Redesign

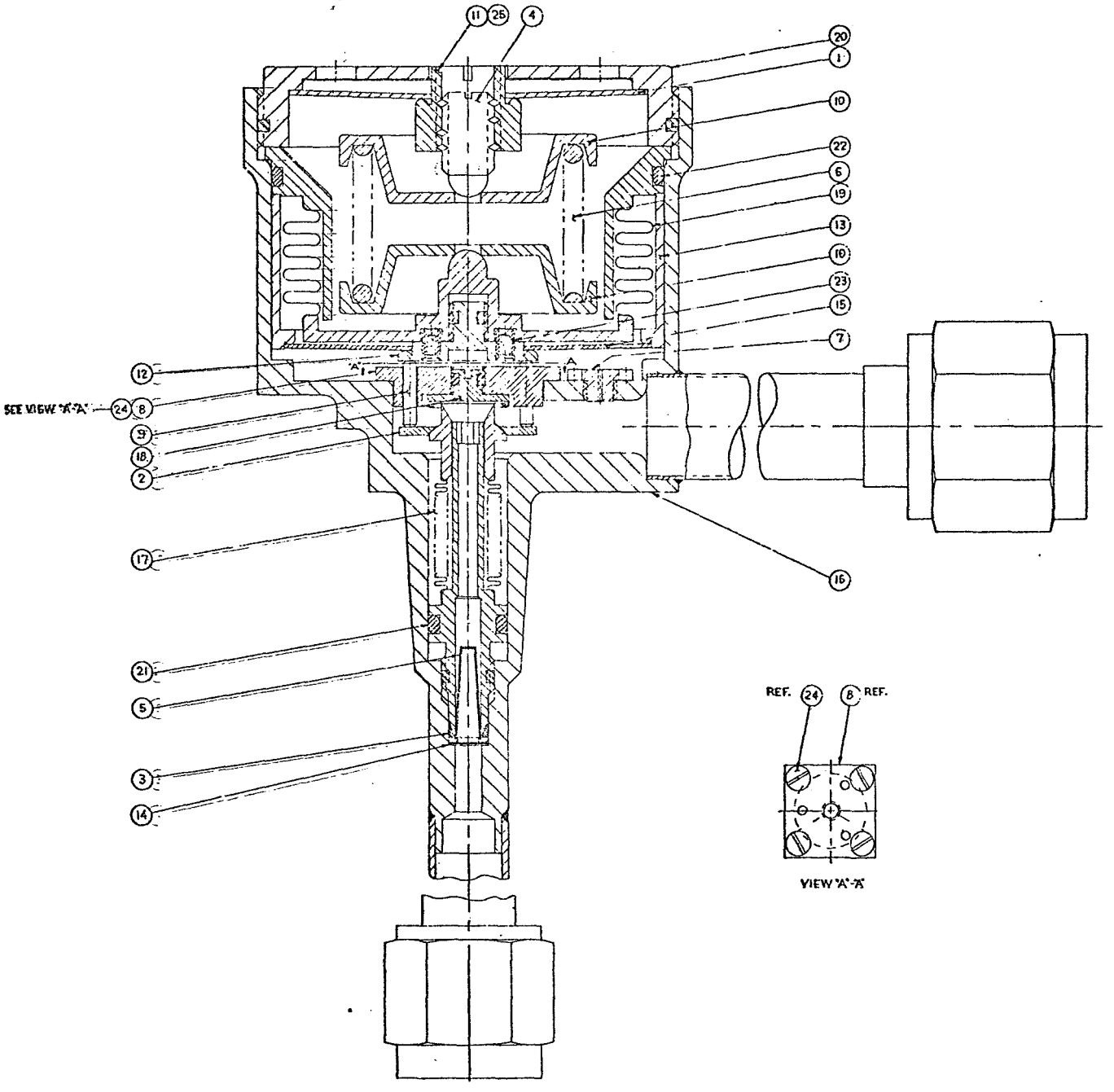
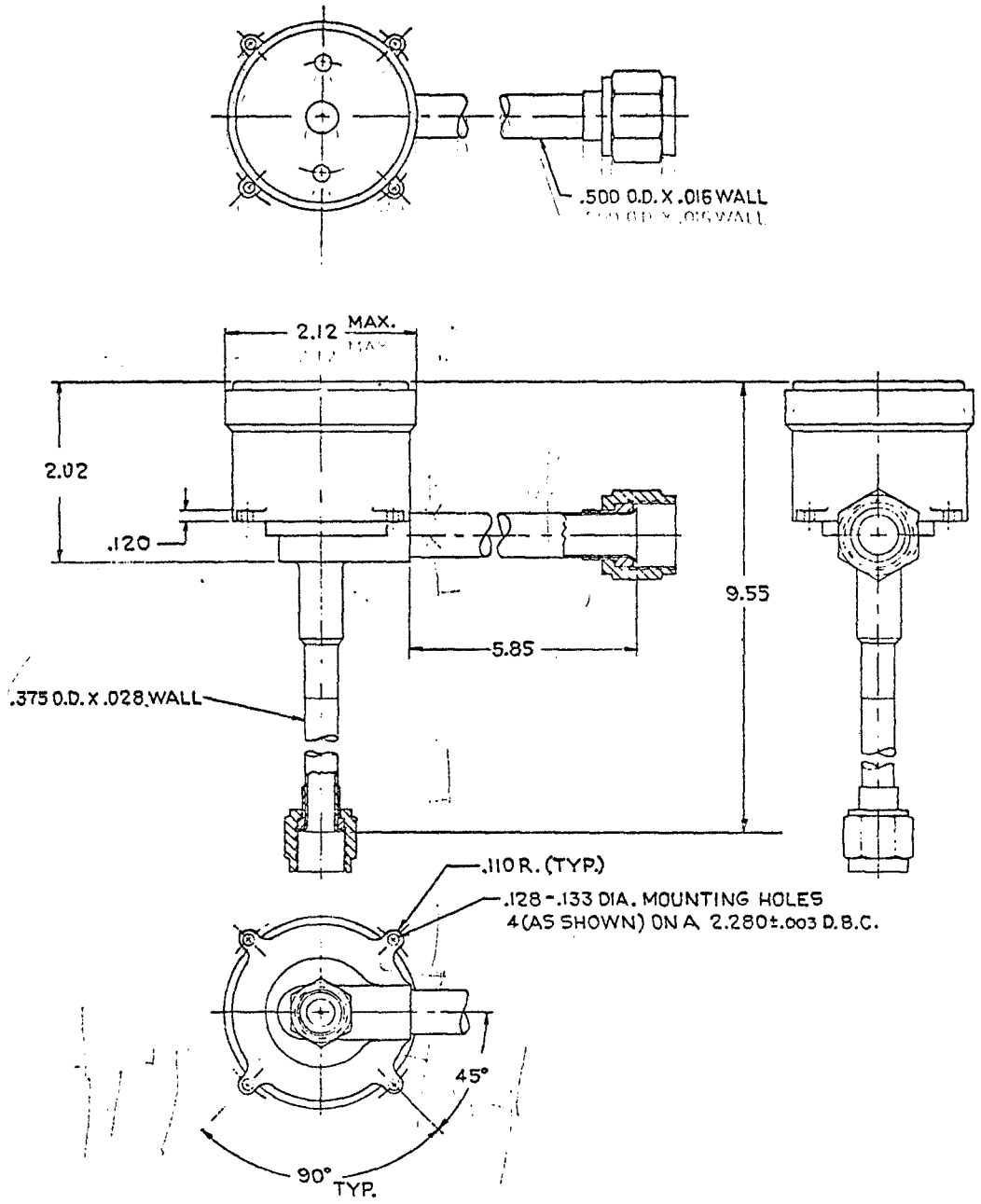


Figure 2-2. Final Design - Soft Seat Regulator

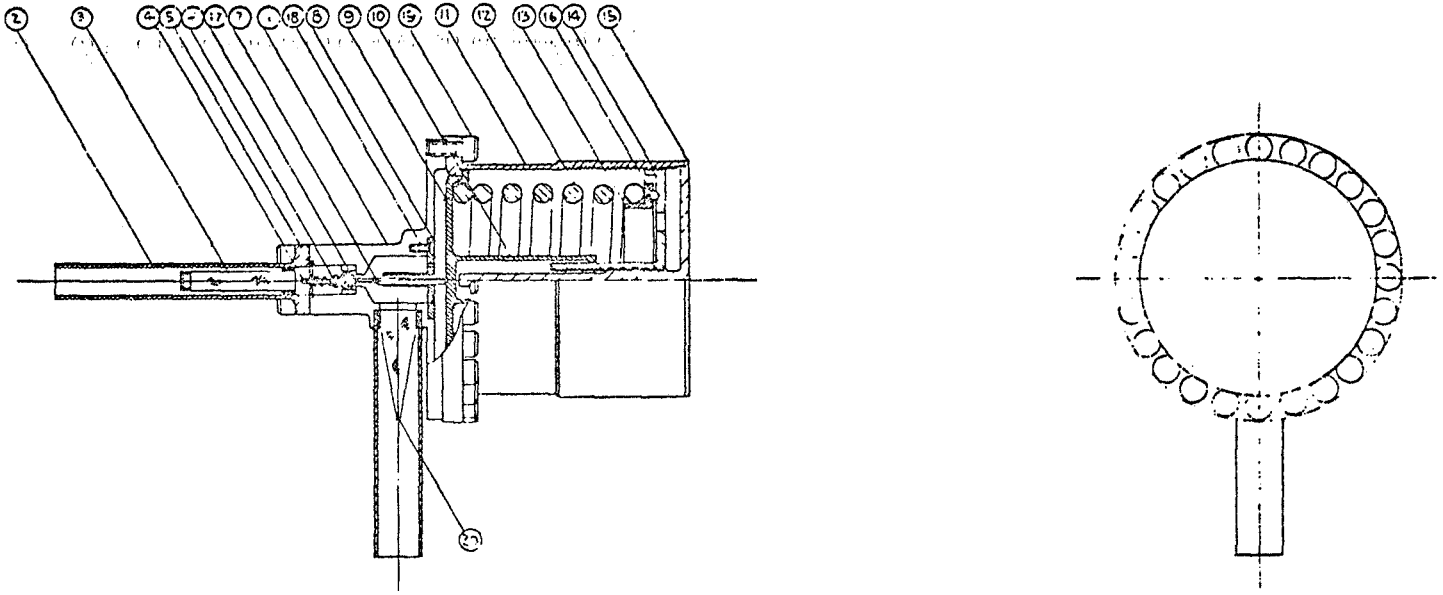


SPECIFICATIONS:
PERFORMANCE PER GE SPEC. SVS7513
INLET - 50 TO 200 PSIG.
OUTLET -15 TO 25 PSIG.
REGULATION -15 -25 ± .2 PSIG. OUTLET
PRESSURE THRU ENVIRONMENTAL
RANGE OF -14°F TO +167°F WITH 1500
TO 96,000 SCC/MIN GN_2 FLOW

Figure 2-3. Soft Seat Regulator Dimensions

Table 2-1. Design Improvements for WGDS Regulator

Objective	Design Change or Approach
Enlarged and smoothed flow paths	1. Direct flow path to exit 2. Enlarged flow area 3. Bellows bottom plate removed from flow region (stroking to full open does not restrict flow)
Modifications to regulator gain	1. Valve head change to conical head considered 2. Possible effects of change to conical head: a. Increased stability b. Increased lockup tolerance required c. Greater valve stroke required (may require new Belleville spring design) d. Seat design change required
Optimization of helical-Belleville spring relationship	1. Enlarged body (2.1 inch diameter) permits more latitude in spring design 2. Belleville spring design via computer program at Carleton; several designs tried
Elimination of friction dampers	1. Inlet bellows teflon sleeve eliminated (Internal post added for column support) 2. Adjustable damper eliminated (Possible through increased stability from decreased gain
Simplification of adjustment provisions	1. Adjusting nut made readily accessible 2. Friction damper disassembly and reassembly not required 3. Locking provisions simplified
Increase clearance around helical spring	1. Greater sensing area opens outer diametral clearance on spring 2. Shorter bellows bottom plate minimizes rubbing possibility on spring ID
Removal of sensitivity to external torques	1. Thicker body in inlet and bottom plate area
Reduction in use of threaded parts	1. Number of threaded parts reduced through simplification of seat assembly 2. Two threaded parts on friction damper eliminated
Reduction in number of O-ring seals	1. Investigated elimination of static O-ring seals in favor of Bal Seal or Omni-Seal type (spring-loaded Teflon)
Reduction in number of detail parts	1. Valve seat assembly simplified 2. Friction damper parts eliminated



INTERNAL LEAKAGE 2 SCCH MAX HELIUM - EXTERNAL 0.05 SCCH MAX HELIUM
TOTAL PRESS TOLERANCE AT LOCKUP ±0.5 PSI ABOUT THE NOMINAL OUTLET SETTING
OUTLET PRESS VARIATION ±0.4 PSI MAX @ 1500 TO 96000 SCCH N_2 FLOW @ 60-200 PSI INLET PRESS.
FLUID OPERATING TEMP RANGE 30 TO 400°F
AMBIENT OPERATING TEMP RANGE -14 TO +167°F
INLET OPERATING PRESSURE 50 TO 200 PSIG, OUTLET PRESS ADJUSTABLE FROM 15 TO 65 PSIG
OPERATING FLUID - NITROGEN, HYDRAZINE DECOMPOSITION PRODUCTS, (AMMONIA GAS)

Figure 2-4. Hard Seat Regulator Design

Initial test results of the hard seat regulator were made using a design employing three springs to cover the adjustable pressure range. GE asked Sterer to design a single spring to cover the adjustable pressure range, since the initial design concept led to a cumbersome (and possibly damaging to the regulator) adjustment process. This redesign was accomplished using a single NiSpan-C helical spring. Other redesign included modification of the end cap to accommodate the longer spring, trials with thinner diaphragm, and elimination of some internal friction. Data from initial testing with a short-range spring is presented in Table 2-2; data with a full-range spring is tabulated in Table 2-3. Data taken for the regulator with thinner diaphragm did not indicate improvement in performance and the thinner diaphragm was discarded. The data also indicated a significant droop beyond 60,000 SCCM flow at the low end of the required inlet pressure band.

Table 2-2. Initial Hard Seat Regulator Test Results

Flow (SCCM)	Inlet Pressure (psig) 200	50
Lockup	16.25	16.75
15550	16.10	16.50
22600	16.0	16.35
36800	15.95	16.25
46700	15.80	16.15
56600	15.75	16.00
67900	15.70	15.95
80600	15.70	15.80
92000	15.70	15.75
96000	15.70	15.65

Table 2-3. Hard Seat Regulator Test Results with Full Range Nispan-C Spring

Inlet Pressure (psig)	Flow (sccm)	Outlet Pressure (Two Settings) (psig)	
200	lockup	26.35	16.0
200	96000	25.0	15.0
175	96000	25.3	15.0
150	96000	25.3	15.0
125	96000	25.4	15.0
100	96000	25.15	14.9
75	96000	25.0	14.85
50	96000	24.8	14.8
50	lockup	26.8	16.55

Two alternative approaches to continuation of this portion of the program were studied. One approach was to permit delivery of the regulator with a single pressure setting (short-range spring). Anticipated regulation for this design would be similar to that acquired in the testing reported in Table 2-2, providing a tolerance of approximately $\pm$ 0.55 psi (overall including lockup) plus a small thermal sensitivity as yet undetermined by test. A second approach was continuation of the design employing a full range and fully adjustable spring. The performance of the regulator in this configuration is similar to the performance of the first prototype soft seat regulator (approximately $\pm$ 1.0 psi). It was agreed between GE and Sterer Engineers that the unbalanced poppet design could not be modified sufficiently to meet regulation goals without major redesign of all elements of the regulator. Since the objective of comparing life data for the hard and soft seat designs was a primary program objective not compromised by an out-of-tolerance pressure regulation characteristic, it was decided that acceptance of the hard seat design with full range spring for comparative life testing with the soft seat design would be the more advantageous approach.

2.2 MATERIAL COMPATIBILITY

A study to verify material compatibility with the products of combustion from a hydrazine gas generator was conducted. Results of this study are attached as Appendix D. Both the hard and soft seat regulator designs are believed to be fully compatible with the indicated

fluids. However, all testing reported here was conducted using dry nitrogen as the test fluid in accordance with program requirements.

2.3 REGULATOR ACCEPTANCE TEST RESULTS

Acceptance test data obtained by Carleton Controls for the soft seat regulator is shown in Figure 2-5 and is documented in Appendix F. This data was taken at high and at low environmental temperatures, high and low inlet pressure settings, and high and low outlet pressure settings. Overall regulation accuracy, including lockup, for the 25 psi nominal outlet setting was $\pm$0.275 psi. At the 15 psi setting, overall regulation was $\pm$0.225 psi. Performance was within regulated accuracy goals set for the program.

Acceptance test data for the hard seat regulator is presented in Figure 2-6 and Appendix G. The Sterer hard seat unit achieved a best performance of approximately $\pm$1.1 psi. Although this performance was not as good as that for the soft seat design, it was felt to be quite good for a first prototype, as contrasted to the third-generation soft seat regulator currently in test.

The original acceptance test data for each regulator was in each case the best performance measured. All subsequent functional tests of the Sterer hard seat regulator were marred by an improperly placed pressure top. One functional test of the soft seat design was also penalized by this problem before it was eliminated. In addition the life test cycles required frequent outlet pressure adjustments. A flight regulator would not be subject to as much handling, which seemed to take away some of the fine tuning of each unit.

There was, however, no indication of performance degradation of either unit due to wear over the million operational cycles of life testing.

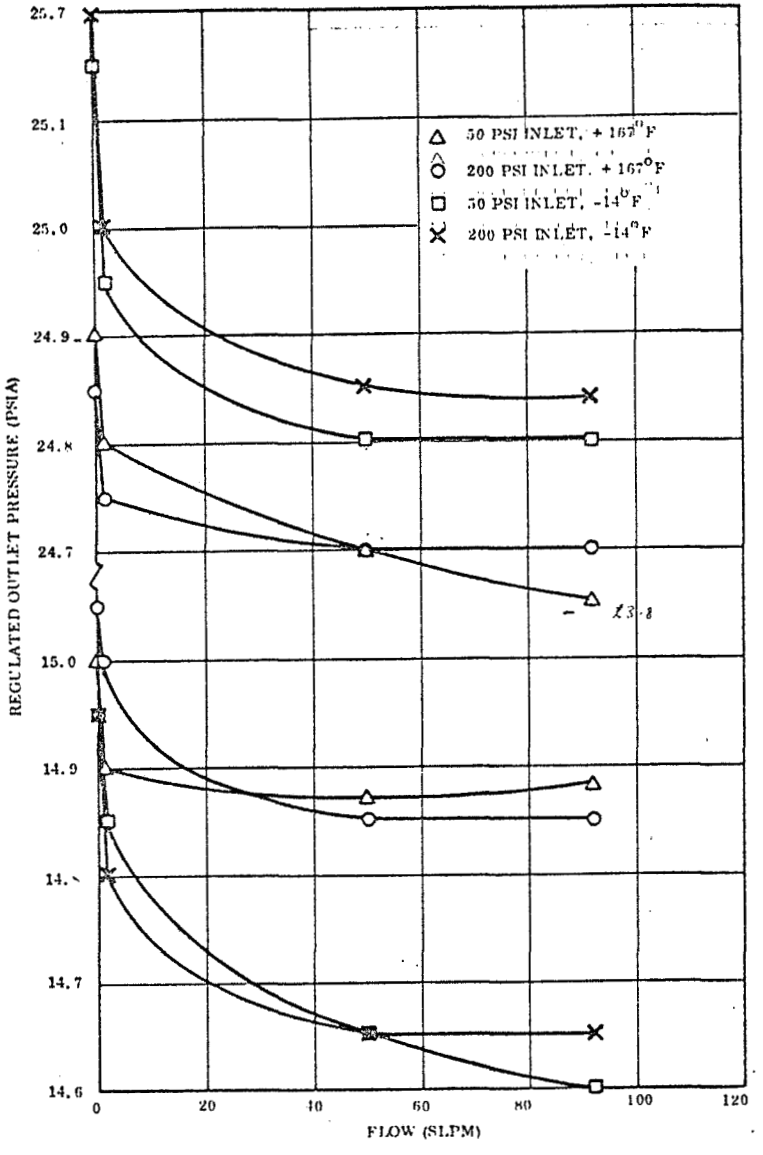


Figure 2-5. Soft Seat Regulator Acceptance Test Data

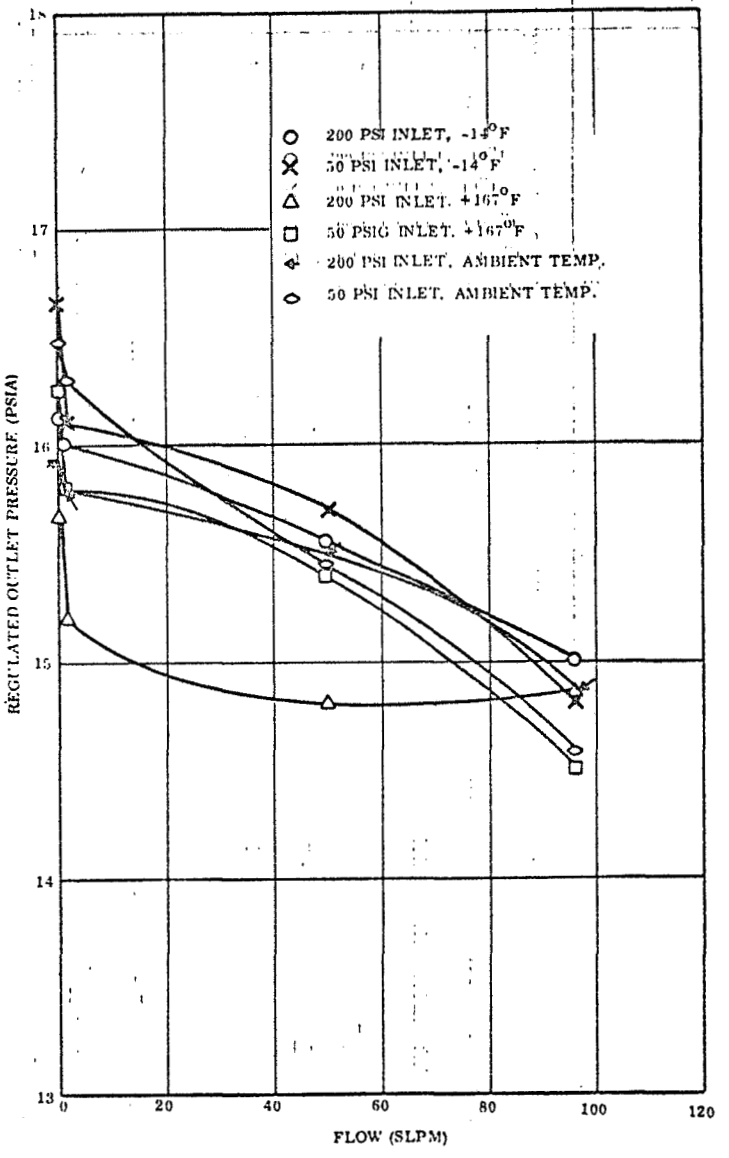


Figure 2-6. Hard Seat Regulator Acceptance Test Data

4. REGULATOR LIFE TESTS

4.1 GENERAL

his section contains the results of the one-million-cycle life tests, conducted in ccordance with the requirements of ETP 1K49-011, "Test Plan for WGDS Regulator," ppendix Five) with the exceptions noted herein.

4.1.1 Exceptions to Test Plan

4.1.1.1 Regulator Life Testing Pressure Set Point

deviation to the original test plan was made to change the requirement to adjust the egulator outlet pressure to a new set point after 500,000 cycles to reduce the number of ljustments of outlet pressure set points. This change in procedure was introduced to educe the possibility of adjustment thread galling in the sterer regulator. For comparison urposes, the same change in procedure was maintained during life testing of the Carleton egulator.

he revised procedure is as follows:

ach regulator was received with a regulator outlet pressure setting of 15 psig. Functional ests were conducted initially at 15 psig, and then the outlet pressure was reset to 25 psig nd functional tests repeated. Both regulators were life-cycled at the 25-psig outlet pressure etting for the first 100,000. Functional tests were then conducted at 25 psig, the regulator utlet pressure was reset to 15 psig, functional tests were conducted, and life cycling was esumed.

abulation of regulator set points and life cycle history is as shown in Table 2-4.

Table 2-4. Regulator Pressure Setting History

Function	Set Point	Life Cycle Accumulation	
		15 psig	25 psig
Initial Functional Test	15 psig	-	-
Regulator Readjusted	25 psig	-	-
Initial Functional Test	25 psig	-	-
100,000 Life Cycles	25 psig	-	100,000
Functional Test	25 psig	-	-
Regulator Readjusted	15 psig	-	-
Functional Test	15 psig	-	-
200,000 Life Cycles	15 psig	200,000	100,000
Functional Test	15 psig	-	-
Regulator Readjusted	25 psig	-	-
Functional Test	25 psig	-	-
200,000 Life Cycles	25 psig	200,000	300,000
Functional Test	25 psig	-	-
Regulator Readjusted	15 psig	-	-
Functional Test	15 psig	-	-
300,000 Life Cycles	15 psig	500,000	300,000
Functional Test	15 psig	-	-
Regulator Readjusted	25 psig	-	-
Functional Test	25 psig	-	-
200,000 Life Cycles	25 psig	500,000	500,000
Functional Test	25 psig	-	-
Regulator Readjusted	15 psig	-	-
Functional Test	15 psig	-	-
Total Life Cycles	15 psig	500,000	
Total Life Cycles	25 psig		500,000

2.5.1.1.2 Pressure Tap Location

Flow tests were conducted on the Sterer Regulator in accordance with the test set-up as described on Figure 3 of Appendix E. The gauge (Item 6) used to monitor regulator outlet pressure is shown with the pressure pickup point down stream external to the leak box assembly (Item 4). The increased pressure drop caused by tubing and additional fittings required to direct the downstream flow out of the leak test box contributed to lower regulator outlet pressure measurements equal to 0.6 psi, with a regulator inlet pressure of 50 psig, an outlet pressure of 15 psig, and a flow demand of 96 SLPM. This discrepancy was noted during the initial functional test on the Carleton Regulator prior to the first life cycle phase.

A deviation to the flow test setup was made to improve the regulation/flow performance measurements, by installing a special piezo-type pressure pickup point in the AN reducing union fitting directly on the outlet tube stub provided as part of the Carleton Regulator.

The flow and regulation tests conducted at the completion of each cyclic life test phase show the results of regulator performance utilizing the piezo-type pressure pickup as described herein.

2.4.2 TEST RESULTS

2.4.2.1 Physical Examination

Each regulator was inspected for conformance to the applicable drawing and for any defects, such as cracks, body distortion, lock wire breaks, and thread damage, upon receipt of component and at the completion of each intermediate phase of cycle life testing.

Both regulators conformed to their respective drawings and, during each subsequent functional test and at the completion of 1,000,000 cycles, showed no visual evidence of distortion, degradation, or damage due to life cycle testing.

During the initial adjustment of the Sterer Regulator, evidence of an accumulation of an oily substance was found in the thread adjustment area of the regulator. Infrared spectroscopy disclosed the substance to be that of the ester of a long chain fatty acid. Contact with Sterer disclosed that a thread lubricant was used to prevent galling of the thread adjustment area.

Since a strong possibility of galling existed in adjustment of the Sterer unit, a change in test scope was introduced, as discussed in the preceding section.

2.4.2.2 Weight

The weight of each regulator was determined, as follows.

Soft Seat Regulator: 0.992 pounds, including "B" nuts and sleeves

0.642 pounds minus "B" nuts and sleeves

Hard Seat Regulator: 1.95 pounds

2.4.2.3 Static Leakage

Static leakage was conducted with the regulator pressurized with 200 psig (he). Regulator outlet pressures were at the pressure settings of that phase of cyclic testing. External leakage was monitored with a CEC helium leak detector, with the regulator assembly in a vacuum environment of 1×10^{-3} MM Hg or less at standard temperature conditions. Internal (seal leakage) was monitored with the regulator in a lockup condition, measuring pressure increase in a known volume versus time. Monitoring time was for a minimum of 2 hours. Results are shown in Table 2-5. Both regulators exhibited excellent internal and external leakage levels over the entire life test.

Table 2-5. Leak Test Results

Functional	Outlet Press (psia)	Hard Seat		Soft Seat	
		Internal (scc/hr(He)	External (scc/hr(He)	Internal (scc/hr(He)	External (scc/he(He)
al	15.0	0.61	0.011	0.054	0.073
t 100,000 Cycles	25.0	1.15	0.007	0.000	0.070
t 300,000 Cycles	15.0	1.05	0.009	0.000	0.060
t 500,000 Cycles	25.0	1.40	0.004	0.000	0.060
t 800,000 Cycles	15.0	1.30	0.007	0.000	0.0549
t 1,000,000 Cycles	25.0	0.24	0.006	0.000	0.0786

4.2.4 Contamination Test

ntamination tests were conducted during the initial functional and during each subsequent ctional test. The regulator had 200 psig of pre-filtered dry nitrogen applied to the inlet h the outlet flow adjusted to 96 slpm. The regulator outlet pressure was consistent with e current phase of the life test. Ten (10) cubic feet of dry nitrogen was sampled with a llipore 0.45 μ filter attached to the outlet of the regulator. Results obtained are shown Table 2-6. Although a few particles larger than 24μ were found, there was at no time y performance problem due to contamination. Neither regulator exhibited substantial ounts of self-contamination.

4.2.5 Flow and Regulation

ch regulator was tested in a test setup as shown in Figure 3 of Appendix E and in accordance th Paragraph 5.4 of Appendix E. The inlet nitrogen supply to the regulator was protected om contamination by two 0.45 μ Millipore filters, installed in series. Prior to installation the test specimen, the test set was purged and cleaned. Millipore sample checks were ade of the test setup with a limited requirement of zero particlaes greater than 25 microns. he regulator remained undisturbed in this setup during the complete series of tests performed,

Table 2-6. Contamination Check Test Results

Functional	Outlet (psig)	Size (Microns)	Sterer S/N 1 Particulate		Carleton S/N 1 Particulate	
			Metallic	Nonmetallic	Metallic	Nonmetallic
Inital	15	0-25	0	11	3	18
		26-50	0	0	0	0
		51-100	0	0	0	0
		>100	0	0	0	0
Post 100,000 Cycles	25	0-25	6	18	Deleted to expedite continuation of cycling test	
		26-50	0	2		
		51-100	0	0		
		>100				
Post 300,000 Cycles	15	0-25	3	0	1	4
		26-50	0	1	0	2
		51-100	0	0	0	0
		>100	0	0	0	0
Post 500,000 Cycles	25	0-25	3	8	0	2
		26-50	2	4	0	0
		51-100	0	0	0	0
		> 100	0	0	0	0
Post 800.00 Cycles	15	0-25	2	1	2	4
		26-50	0	0	0	2
		51-100	0	0	0	1
		> 100	0	0	0	0
Post 1,000,000 Cycles	25	0-25	2	5	2	3
		26-50	1	3	0	0
		51-100	0	0	0	0
		>100	0	0	0	0

including functionals, leakage, and contamination tests. To improve the accuracy of monitoring regulator pressure/flow performance, pressure readings were recorded with increasing flow and then repeated with decreasing flow at each specific inlet pressure and flow rate. The average of each of these readings was then used to determine the regulation band, under dynamic flow conditions. The average of the lockup pressure readings was used to determine the norminal outlet pressure lockup. To determine the full regulation band,

Table 2-7. Performance - Flow/Regulation (Sterer Hard Seat Regulator) (Sheet 1 of 4)

Test Date / Functional at 15 psig Set Point		6/19/69 Initial Functional			6/23/69 Post 100,000 Cycle Functional			6/24/69 Post 300,000 Cycle Functional		
Inlet (psig)	Flow (slpm)	Outlet (psig) Up	Outlet (psig) Down	Average	Outlet (psig) Up	Outlet (psig) Down	Average	Outlet (psig) Up	Outlet (psig) Down	Average
50	1.5	16.00	15.95	15.975	15.85	15.85	15.85	16.52	16.60	16.56
50	40.0	15.00	15.00	15.00	15.25	15.10	15.175	15.63	15.60	15.62
50	96.0	12.75	13.00	12.775	13.95	13.80	13.90	12.90	12.85	12.875
100	96.0	13.00	13.15	13.07	13.60	13.75	13.70	13.25	13.20	13.225
100	40.0	15.25	15.20	15.225	15.00	15.00	15.00	15.62	15.64	15.63
100	1.5	15.75	15.60	15.70	16.00	16.00	16.00	16.47	16.52	16.49
200	1.5	15.50	15.50	15.50	15.80	15.50	15.65	16.07	15.90	15.97
200	40.0	15.00	15.10	15.05	14.75	14.75	14.75	15.35	15.54	15.345
200	96.0	13.25	13.25	13.25	13.25	13.00	13.125	13.34	13.35	13.345
Lockup at	50		16.25			16.00			16.70	
Lockup at	200		16.20	16.20		16.25	16.125		16.16	16.55
Lockup at	50		16.10			16.00			16.79	
Dynamic regulation band (psig)			±1.60*			±1.437*			±1.837*	
Regulation band/lockup (psig)			±1.712*			±1.50*			±1.842*	

*Improper pressure tap location caused additional pressure droop of approximately 0.6 psi at maximum flow, leading to a ±0.3 psi increase in the regulation/lockup band.

Table 2-7. Performance - Flow/Regulation (Sterer Hard Seat Regulator)
(Sheet 2 of 4)

Test Date Functional @ 15 psig Set Point		6/19/69 Initial Functional Outlet (psig)			6/23/69 Post 100,000 Cycle Functional Outlet (psig)			6/24/69 Post 300,000 Cycle Functional Outlet (psig)		
Inlet (psig)	Flow (slpm)	Up	Down	Average	Up	Down	Average	Up	Down	Average
50	1.5	16.55	16.65	16.60	16.36	16.44	16.40	16.89	16.94	16.915
50	40.0	15.70	15.84	15.77	15.56	15.75	15.65	16.04	16.04	16.04
50	96.0	13.55	13.46	13.50	13.74	15.40	13.57	13.99	13.83	13.91
100	96.0	13.80	13.86	13.83	13.90	13.70	13.80	14.16	14.14	14.15
100	40.0	15.70	15.62	15.66	15.64	15.70	15.67	16.00	15.97	15.985
100	1.5	16.43	16.30	16.36	16.38	16.80	16.34	16.80	16.78	16.79
200	1.5	16.05	16.25	16.15	16.10	15.94	16.02	16.38	16.34	16.36
200	40.0	15.50	15.50	15.50	15.38	15.46	15.42	15.65	15.69	15.67
200	96.0	13.90	13.85	13.875	13.80	13.80	13.80	14.10	14.11	14.105
Lockup @	50		16.78			16.75			17.00	
Lockup @	200		16.22	16.61		16.64	16.78		16.44	16.85
Lockup @	50		16.85			16.97			17.12	
Dynamic Regulation Band (psig)			±1.55*			±1.425*			±1.502*	
Regulation Band/Lockup (psig)			±1.555*			±1.605*			±1.502*	

*Improper pressure tap location caused additonal pressure droop of approximately 0.6 psi at maximum flow, leading to a ±0.3 psi increase in the regulation/lockup band.

Table 2-7. Performance - Flow/Regulation (Sterer Hard Seat Regulator)
(Sheet 3 of 4)

Test Date Functional @ 25 psig Set Point		6/19/69 Initial Functional Outlet (psig)			6/23/69 Post 100,000 Cycle Functional Outlet (psig)			6/24/69 Post 300,000 Cycle Functional Outlet (psig)		
Inlet (psig)	Flow (slpm)	Up	Down	Average	Up	Down	Average	Up	Down	Average
50	1.5	24.75	24.75	24.75	24.75	25.00	24.875	25.35	25.11	25.23
50	40.0	24.00	24.00	24.00	24.00	24.00	24.00	24.44	24.42	24.43
50	96.0	21.50	21.28	21.39	21.50	21.25	21.375	21.74	21.66	21.70
100	96.0	21.80	21.75	21.775	21.90	21.75	21.825	22.20	22.10	22.15
100	40.0	24.00	23.90	23.95	24.00	24.00	24.00	24.44	24.40	24.42
100	1.5	24.50	24.50	24.50	24.25	24.60	24.725	25.20	25.18	25.19
200	1.5	24.40	24.25	24.325	24.75	24.50	24.625	24.76	25.00	24.88
200	40.0	23.75	23.75	23.75	23.75	23.75	23.75	24.20	24.12	24.16
200	96.0	21.75	21.75	21.75	21.75	21.75	21.75	22.16	22.23	22.195
Lockup @	50		25.00			25.00			24.47	
Lockup @	200		24.90	24.77		24.75	24.91		25.00	24.98
Lockup @	50		25.00			25.00			25.57	
Dynamic Regulation Band (psig)			±1.68*			±1.747*			±1.765*	
Regulation Band/Lockup (psig)			±1.69*			±1.767*			±1.765*	

*Improper pressure tap location caused additional pressure droop of approximately 0.6 psi at maximum flow, leading to a ±0.3 psi increase in the regulation/lockup band.

Table 2-7. Performance - Flow/Regulation (Sterer Hard Seat Regulator)
(Sheet 4 of 4)

Test Date Functional @ 25 psig Set Point		6/25/69 Post 500,000 Cycle Functional Outlet (psig)			6/26/69 Post 800,000 Cycle Functional Outlet (psig)			6/30/69 Post 1,000,000 Cycle Functional Outlet (psig)		
Inlet (psig)	Flow (slpm)	Up	Down	Average	Up	Down	Average	Up	Down	Average
50	1.5	25.95	25.30	25.625	25.30	25.04	25.17	25.22	25.61	25.41
50	40.0	22.50	24.37	23.435	24.57	24.45	24.51	24.09	24.50	24.29
50	96.0	22.45	22.17	22.31	22.56	22.30	22.43	22.45	22.20	22.32
100	96.0	22.90	22.80	22.85	21.85	22.53	22.19	22.95	22.67	22.80
100	40.0	24.75	24.22	24.47	24.57	24.50	24.535	23.93	24.83	23.88
100	1.5	24.96	25.53	25.245	25.30	25.32	25.31	25.21	25.60	25.40
200	1.5	24.90	25.36	25.13	24.76	25.15	24.94	25.11	25.52	25.31
200	40.0	24.20	24.25	24.255	24.53	24.20	24.36	24.41	24.41	24.41
200	96.0	22.68	22.73	22.705	22.57	22.55	22.56	22.34	22.40	22.37
Lockup @	50		25.97			25.73			26.10	
Lockup @	200		25.35	25.73		25.17	25.55		25.22	25.79
Lockup @	50		25.87			25.75			26.07	
Dynamic Regulation Band (psig)			±1.657			±1.49			±1.54	
Regulation Band/Lockup (psig)			±1.720			±1.68			±1.735	

Table 2-8. Performance - Flow/Regulation (Carleton Shut Down Regulator)
(Sheet 1 of 4)

Test Date Functional @ 15 psig Set Point		7/30/69 Initial Functional Outlet (psig)			7/31/69 Post 100,000 Cycle Functional Outlet (psig)			8/4/69 Post 300,000 Cycle Functional Outlet (psig)		
Inlet (psig)	Flow (SLPM)	Up	Down	Average	Up	Down	Average	Up	Down	Average
50	1.5	15.05	15.10	15.07	15.02	15.04	15.03	15.15	15.20	15.175
50	40.0	14.75	14.80	14.77	14.82	14.85	14.84	14.95	15.05	15.00
50	96.0	13.40	13.35	13.37	14.24	14.20	14.22	14.35	14.45	14.40
100	96.0	13.45	13.30	13.37	14.30	14.21	14.26	14.50	14.40	14.45
100	40.0	14.75	14.70	14.72	14.83	14.83	14.83	15.00	15.00	15.00
100	1.5	15.10	15.00	15.05	15.00	14.95	14.97	15.20	15.15	15.175
200	1.5	15.20	15.10	15.15	14.99	15.00	14.99	15.20	15.15	15.175
200	40.0	14.75	14.75	14.75	14.85	14.84	14.845	15.00	15.05	15.025
200	96.0	13.40	13.40	13.40	14.32	14.31	14.315	14.45	14.45	14.45
Lockup @	50		15.15			15.05			15.20	
Lockup @	200		15.25	15.20		15.04	15.06		15.25	15.24
Lockup @	50		15.20			15.08			15.25	
Dynamic Regulation Band (psig)			±0.890*			±0.205**			±0.387**	
Regulation Band/Lockup (psig)			±0.915*			±0.420**			±0.420**	

*Initial functional test conducted with regulator outlet pressure pickup downstream leak test box. Reference Section 2.4.1.1.1.

**Regulator outlet pressure pickup locate in outlet AN fitting of regulator tube stub for all post cycling functional tests from tests from 100,000 cycles through 1,000,000 cycles.

Table 2-8. Performance - Flow/Regulation (Carleton Soft Seat Regulator)
(Sheet 2 of 4)

Test Date Functional @ 15 psig Set Point		8/7/69 Post 500,000 Cycle Functional Outlet (psig)			8/9/69 Post 800,000 Cycle Functional Outlet (psig)			8/12/69 Post 1,000,000 Cycle Functional Outlet (psig)		
Inlet (psig)	Flow (SLPM)	Up	Down	Average	Up	Down	Average	Up	Down	Average
50	1.5	15.00	15.00	15.00	14.95	14.95	14.95	14.95	15.00	14.97
50	40.0	14.80	14.80	14.80	14.75	14.70	14.725	14.80	14.80	14.80
50	96.0	14.30	14.20	14.25	14.25	14.30	14.27	14.20	14.15	14.17
100	96.0	14.30	14.30	14.30	14.15	14.20	14.17	14.30	14.30	14.30
100	40.0	14.80	14.80	14.80	14.65	14.75	14.70	14.85	14.85	14.85
100	1.5	15.00	14.90	14.95	14.95	14.95	14.95	15.00	14.95	14.97
200	1.5	15.00	15.00	15.00	14.95	14.95	14.95	15.00	15.00	15.00
200	40.0	14.80	14.90	14.85	14.75	14.80	14.77	14.85	14.85	14.85
200	96.0	14.40	14.40	14.40	14.30	14.25	14.27	14.35	14.35	14.35
Lockup @	50		15.10			15.05			15.00	
Lockup @	200		15.10	15.10		14.95	15.00		15.05	15.03
Lockup @	50		15.10			15.05			15.05	
Dynamic Regulation Band (psig)			±0.125			±0.340			±0.415	
Regulation Band/Lockup (psig)			±0.425			±0.460			±0.430	

Table 2-8. Performance - Flow/Regulation (Carleton Soft Seat Regulator)
(Sheet 3 of 4)

Test Date Functional @ 25 psig Set Point		7/30/69 Initial Functional Outlet (psig)			7/31/69 Post 100,000 Cycle Functional Outlet (psig)			8/4/69 Post 300,000 Cycle Functional Outlet (psig)		
Inlet (psig)	Flow (SLPM)	Up	Down	Average	Up	Down	Average	Up	Down	Average
50	1.5	25.10	25.20	25.15	25.08	25.15	25.12	25.10	25.10	25.10
50	40.0	24.90	24.85	24.87	24.99	24.98	24.985	24.95	24.90	24.92
50	96.0	23.85	23.75	23.80	24.42	24.45	24.435	-	-	-
100	96.0	23.95	23.85	23.90	24.60	24.52	24.56	24.50	24.45	24.47
100	40.0	24.85	24.80	24.82	25.02	24.98	25.00	24.90	24.90	24.90
100	1.5	25.15	25.10	25.125	25.15	25.05	25.10	25.05	25.00	25.025
200	1.5	25.15	25.15	25.14	25.14	25.14	25.14	25.10	25.05	25.07
200	40.0	24.95	24.85	24.90	25.01	25.03	25.02	24.90	25.0	24.95
200	96.0	23.85	23.85	23.85	24.62	24.59	24.61	24.50	24.50	24.50
Lockup @	50		25.20			25.08			25.10	
Lockup @	200		25.235			25.23	25.17		25.20	25.167
Lockup @	50		25.25			25.21			25.20	
Dynamic Regulation Band (psig)			±0.662*			±0.342**			±0.30**	
Regulation Band/Lockup (psig)			±0.717*			±0.410**			±0.333**	

*Initial Functional Test conducted with regulator outlet pressure pickup downstream leak test box. Reference Section 2.4.1.1.1.

**Regulator outlet pressure pickup locate in outlet AN fitting of regulator tube stub for all post cycling functional tests from 100,000 cycles through 1,000,000 cycles.

Table 2-8. Performance - Flow/Regulation (Carleton Soft Seat Regulator)
(Sheet 4 of 4)

Test Date Functional @ 25 psig Set Point		8/7/69 Post 500,000 Cycle Functional Outlet (psig)			8/9/69 Post 800,000 Cycle Functional Outlet (psig)			8/12/69 Post 1,000,000 Cycle Functional Outlet (psig)		
Inlet (psig)	Flow (SLPM)	Up	Down	Average	Up	Down	Average	Up	Down	Average
50	1.5	24.90	25.00	24.45	25.05	25.05	25.05	25.10	25.10	25.10
50	40.0	24.80	24.80	24.80	24.85	24.95	24.90	24.95	24.95	24.95
50	96.0	24.10	24.30	24.20	24.10	24.15	24.12	24.40	23.80	24.10
100	96.0	24.40	24.40	24.40	24.50	24.50	24.50	24.60	24.50	24.55
100	40.0	24.80	24.80	24.80	24.95	24.90	24.92	24.95	24.95	24.95
100	1.5	24.90	24.90	24.90	25.02	24.50	24.16	23.10	25.00	25.05
200	1.5	24.90	24.90	24.90	25.05	25.03	25.04	25.20	25.10	25.15
200	40.0	24.80	24.80	24.80	24.95	24.95	24.95	25.00	25.00	25.00
200	96.0	24.40	24.40	24.40	24.55	24.55	24.55	24.60	24.60	24.60
Lockup @	50		24.90			25.15			25.10	
Lockup @	200		25.1	25.03		25.15	25.15		25.30	25.20
Lockup @	50		25.1			25.15			25.20	
Dynamic Regulation Band (psig)			±0.35			±0.465			±0.500	
Regulation Band/Lockup (psig)			±0.415			±0.515			±0.550	

ie differences between the nominal (average) static lockup pressure and the minimum
verage) outlet pressure under all inlet and flow conditions were utilized.

he results of flow and regulation tests are reported in Tables 2-7 and 2-8. Test results
r the hard seat regulator are consistent with those obtained in acceptance testing through-
ut the life test if a correction is made for the improperly placed pressure tap used. A
alculated droop of about 0.6 psi and a subsequent $\pm$0.3 psi decrease in regulation band
esulting from the pressure tap are included in the test data.

est data for the first functional test of the soft seat regulator is similarly penalized.
ubsequent test data after incorporation of an improved tap indicates performance varying
rom $\pm$0.334 psi to $\pm$0.550 psi. Performance did not degrade significantly over the life
dst. However, it is believed that the data reflects a loss of regulator "fine tuning" through
he many adjustments to the outlet pressure required by the test plan.

2.4.2.6 Discussion of Regulator Stability

Both the Sterer and the Carleton regulators demonstrated some slight instability during flow/regulation testing. The instability occurred during the process of slowly increasing the outlet flow demand manually from a lock-up condition to flow rates of slightly less than 1.5 slpm (N_2). During this period, the Sterer regulator oscillated 1.25 psi (peak-to-peak) at a frequency of 950 cps. No measurements were taken during the Carleton regulator tests, since the oscillation was of very small signficance, as indicated on the regulator outlet pressure monitoring gauge. In both cases, instability could be eliminated by a change in the rate of increase in flow demand consistent with the anticipated spacecraft use for such a regulator.

During solenoid actuated flow demands, drastic reductions in the downstream volume between the regulator outlet and the solenoid valve, from the specified 40 cubic inches, would also cause instability in the Sterer regulator. This test was conducted with a downstream volume of 11.5 cubic inches.

Neither the Sterer nor the Carleton regulators exhibited any instability during the actual life-cycle phase of testing, with a fixed downstream volume of 40 cubic inches, a flow demand of 96 slpm, inlet pressures of 50 to 200 psig, and with regulator outlet pressures set at 15 psig or 25 psig.

Both regulators are designed to be compatible with a downstream volume of 40 cubic inches and to function with abrupt flow demands, such as solenoid valve actuation. Changes in operating regimes may require modification of regulator damping or gain.

2.2.5 DISCUSSION OF MEASUREMENT PROCEDURES AND EQUIPMENT ACCURACY

As previously noted regulator pressure and flow measurements were taken with increasing flow, and then repeated with decreasing flow rates. The average of each of these readings were used to determine a nominal value.

The flow meters used during GE tests were N_2-calibrated Fisher and Porter rotometers (variable orifice) with 600-mm scales, and an accuracy of 1 percent of indicated reading.

The pressure gauge used to measure regulator outlet pressure was a 12-in.-diameter Heise gauge, with an accuracy of ± 0.1 percent full scale (150 psig). The gauge scale has minor subdivision reading capability of 0.1 psig.

Carleton Controls used the following equipment during acceptance testing of the soft seat regulator under GE Engineering cognizance.

1. Rotometers

   a. Brooks 118 slpm full scale

      Scale: 25 slpm subdivisions

      Accuracy: $\pm$ 0.1 liter (calibrated with air)

bb. Brooks Flowrator, 3800 cubic centimeters maximum capacity

Scale: 100 cubic centimeters/subdivision

Accuracy: ±2 percent full scale (calibrated with air)

2. Outlet Pressure Gauge

aa. United states Gauge 30 psig full scale, 8-inch dial

Scale: 0.1 psig subdivisions

Accuracy: ±0.05 psig full scale

Sterer Engineering Corporation used the following equipment during acceptance testing of the hard seat regulator under GE Engineering cognizance.

1. Flowmeters

aa. Fisher and Porter percentage flowmeters calibrated for N_2

2. Outlet Pressure Gauge

aa. (Manufacturer unknown) 0 to 60 psig full scale, 8-inch dial

Scale: Data not available

Accuracy: 0.25 percent full scale

Flow and regulation monitoring test equipment used by Sterer, Carleton and GE were visual-indicating instruments subject to tolerance errors and human inaccuracies. However, the differences in accuracy of gauge readings is slight. GE used a 12-inch dial gauge with a full-scale range of 150 psig instead of the 30 psig full-scale gauge used by Carleton Controls. The measurements taken with the Carleton gauge would involve less difficulty in reading pressure.

As previously discussed, discrepancies in measuring the regulator outlet pressure can exist, dependent on the location and type of pressure pickup point used. Pressure drops can be

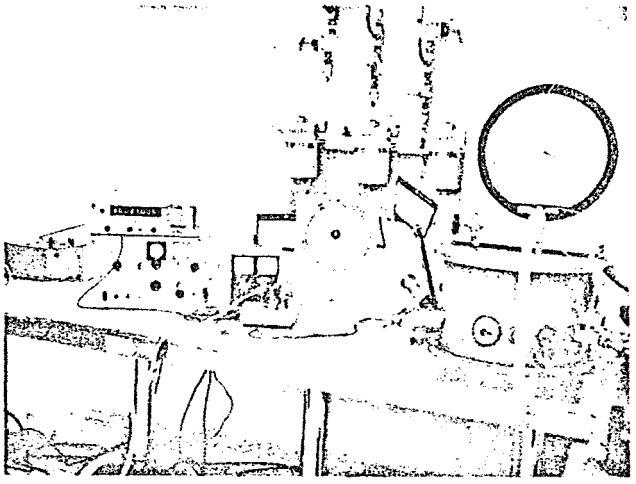


Figure 2-7. Test Equipment Setup in Pneumatic Test Clean Room

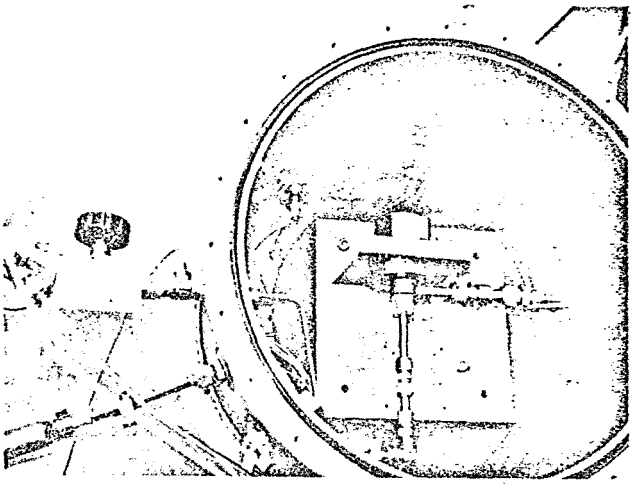


Figure 2-8. Hard Seat Regulator in Vacuum Chamber Bell Jar

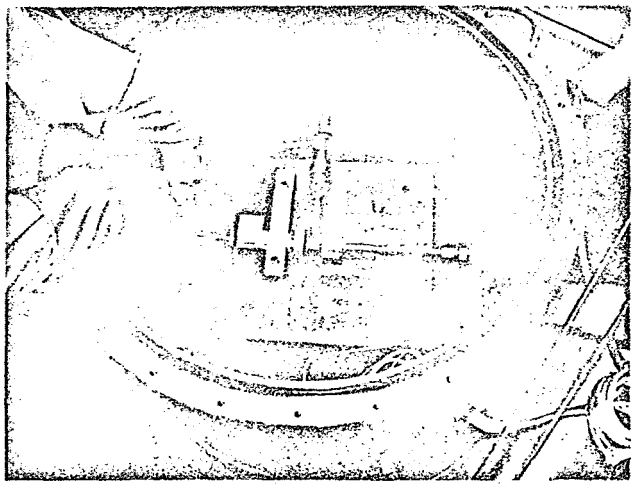


Figure 2-9. Hard Seat Regulator Outlet Pressure Adjustment

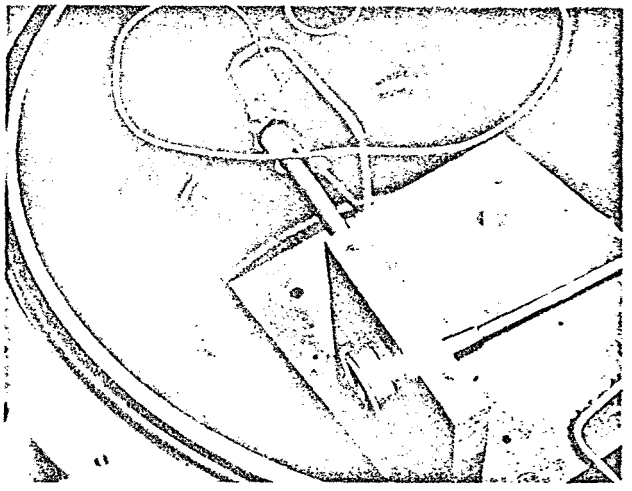


Figure 2-10. Soft Seat Regulator Mounted in Bell Jar Showing Location of Outlet Pressure Tap

created by additional tube lengths and fittings. The use of a standard AN938 "T" can cause reduced pressure readings under dynamic (flow) conditions.

GE used a pressure pickup (shown in Figure 2-10) consisting of a standard AN919 tube reducer, with a 0.125-inch OD tube inserted in the reducer hexagon. The end of the inserted tube was machined flush with the reducer inside diameter. The 0.125-inch tube was silver-soldered leak-tight, and the assembly ultrasonically cleaned. This pickup was used only on the Carleton regulator.

Carleton used a standard AN938 "T", with the pressure pickup area filled with epoxy to reduce the chamber volume, and a small pressure-sensing hole provided.

Sterer used a standard AN938 "T" with no modifications. This "T" was attached to a tube union on the outlet port tube stub.

GE tested the Sterer regulator as described on Figure 3 of Appendix E, with a standard AN938 "T" located outside the Bell Jar, with tubing and fittings introducing additional pressure drop. This discrepancy was noted after the Sterer regulator tests were completed, and the unit delivered to JPL.

SECTION 3

SUMMARY AND CONCLUSIONS

The reported program has demonstrated the compatibility of a properly designed soft seat regulator with the functional requirements of a long-life spacecraft mission.

Where very tight regulation performance over a band of environmental extremes and functional regimes is required, the use of a balanced poppet design appears to offer the greatest probability of success.

Although no inherent life limiting characteristic was found in the hard or soft seat designs, further testing to include dynamic environments, particularly vibration, is recommended.

The soft seat regulator offers the tightest regulation accuracy known to GE under current state of the art over the range of performance and environmental regimes tested. In order to take greater advantage of this performance, in applications other than with a gas generator, the regulator may be used in conjunction with an upstream "rough" regulator to provide a closely regulated output with a widely varying inlet pressure range.

SECTION 4

NEW TECHNOLOGY

No reportable items of new technology have been identified during this report period.

APPENDIX A

General Electric Company
Missile & Space Division
Valley Forge Space Technology Center
P.O. Box 8555
Philadelphia, Pennsylvania 19101

Specification SVS 7513

Issued: 11/1/67

Regulator, Pneumatic

Pressure

Warm Gas Distribution System

Prepared by: R F Sedlacek Date: 7-31-67
M. F. Sedlacek, System Engineer
Reaction & Actuation Equipment Engineering

Approved by: W D Boyce /ccd Date: 7-31-67
W. D. Boyce, Project Engineer
Reaction & Actuation Equipment Engineering

Approved by: C C Rich Date: 7-31-67
C. C. Rich, Manager
Reaction & Actuation Equipment Engineering

ISSUED BY: Print Control & Reproduction DATE: November 1, 1967

1100 Scope

1111 Scope

This specification covers one type of pneumatic pressure regulator hereinafter referred to as the regulator. The regulator is intended for use as part of a warm gas distribution system to regulate the flow of hydrazine decomposition products including dissociated and undissociated ammonia.

2200 Applicable Documents

2211 Government Documents

The following documents of the exact issue shown, form a part of this specification to the extent specified herein:

Specifications

Military

MIL-D-70327 27 March 1962	Drawings, Engineering and Associated Lists
MIL-P-5518 10 May 1956	Pneumatic System, Design, Installation and Tests in Aircraft
MIL-S-7742A 21 June 1963	Screw Threads, Standard, Aeronautical

Standards

Military

MIL-STD-130B 24 April 1962	Identification, Marking of U. S. Military Property
MIL-STD-143A 14 May 1963	Specifications and Standards, Use of
MIL-STD-447 28 May 1959	Definition of Interchangeable, Substitute and Replacement Items
MS-20995	Wire, Lock
MS-33546	Safety Wiring, General Practices for
MS-33586A	Metals, Definition of Dissimilar
ANA Bulletin 438B	Age Controls for Age-Sensitive Elastomeric Materials
Federal Standard No. 209	Clean Room and Work Station Requirements for Controlled Environment

2212 Non-Government Documents

The following documents form a part of this specification to the extent specified herein:

Standards:

General Electric Company

118A1600 Finishes and Coatings

Drawings:

General Electric Company

47D212117 Regulator, Pneumatic Pressure

(Copies of Specifications, Standards Drawings and Publications required by Contractors in connection with specific procurement functions dhouls be obtained from, or as directed by, the Purchasing Department of GE/MSD.)

2233 Order of Precedence

In the event of conflict between this specification and the documents referenced herein, this specification shall govern.

330 Requirements

331 Design and Construction

The regulator shall be of the design and construction specified on the General Electric Drawing and this specification.

3311 Interchangeability

All parts having the same part number shall be interchangeable as defined in paragraph 3.1 of MIL-STD-447.

3312 Workmanship

Fabrication and finishing shall be in a thoroughly workmanlike manner. There shall be no cracks, breaks, chips, bends, loose attachments, illegible markings, or other defects that could adversely affect the suitability, use, or life of the component parts. The parts shall be free from burrs and sharp edges.

3313 Identification

Components, assemblies and parts shall be marked for identification in accordance with MIL-STD-130. Where the component drawing requires a nameplate, it shall be permanently and legibly marked with the following information:

a. Nomenclature
b. Customer part number
c. Serial number
d. Contract number
e. Manufacturers drawing number
f. GE drawing number
g. Manufacturers name or trademark
h. Date of manufacture

3.1.1.4 Tube Stubs

The regulator design shall incorporate inlet and outlet tube stubs for welding into a system. The material, size, and length of these stubs shall be as shown on General Electric Drawing SVS 47D212117.

3.1.1.5 Filter

An integral inlet and outlet filter shall be provided to protect the regulator from contamination; the filter shall be a woven stainless steel wire type, capable of removing 98% of all solid particulate contaminants in excess of 10 microns and 100% in excess of 25 microns. The filter flow area shall be a minimum of 10 times the flow area of the valve seat restriction and shall be optimized to provide low pressure drop and adequate resistance to clogging.

3.1.1.6 Elastomer Stabilization

All regulator seats and seals shall be stabilized to reduce variation in settings and operating characteristics under all environments, by subjecting the valve seats to a maximum working pressure at a temperature equal to or in excess of 400°F. The time duration shall be determined by the materials used and the application in the particular valve design. The vendor shall submit documentation outlining his material and procedures.

3.1.1.7 Adjustment Provisions

The regulated outlet pressure shall be adjustable within the range of 15 to 25 psig. A mechanical adjustment feature shall be incorporated into the regulator design to accomplish this adjustment. In the event that more than one spring is required to provide adjustability over the full range, any special tools and procedures for spring changing and adjustment shall be provided with the regulator.

3.1.1.8 Weight

The regulator weight shall not exceed 0.5 pounds.

3.2 Materials and Finishes

3.2.1 Materials

Unless otherwise specified herein, the regulator shall be constructed of materials selected in accordance with MIL-STD-143.

3.2.1.1 Metals - Metal parts shall be inherently corrosion resistent or shall be protected against corrosion by means of chemical or electrolytic finishes and treatments, or a combination thereof.

3.2.1.2 Dissimilar Metals - Contact between dissimilar metals as defined by Military Standard MS 33586 shall be avoided. Where it is necessary that dissimilar metals be assembled in intimate contact with each other, an interposing insulating or mutually compatible material shall be used.

3.2.1.3 Fungus Resistance - Materials shall be treated by an approved method to resist fungus growth insofar as practical.

3.2.2 Finishes

All finishes shall conform to the requirements of Specification 118A160C.

3.2.3 Lubricants

Unless otherwise authorized by the customer, no lubricating oils or greases shall be used in the regulator.

3.2.4 Threads

All threads shall be in accordance with MIL-S-7742.

3.2.5 Screw Thread Locking Devices

All threaded parts shall be positively locked by safety wire or other approved methods. Safety wire shall conform to standard MS 20995 and be installed in accordance with standard MS 33540.

3.2.6 Age-Sensitive Elastomeric Materials

The provisions and requirements of ANA Bulletin 438B shall apply for all elastomeric materials used in the construction and assembly of the system. A record shall be maintained of cure dates and assembly dates of each assembly or subassembly which shall be part of the completed system and contain(s) elastomeric materials.

3.2.7 Inserts

Threads in soft metals, such as aluminum alloys, for bolts and screws, having a thread diameter of less than 0.75 inch and subject to removal for routine maintenance, testing, or mounting purposes, shall be provided with corrosion resistant steel inserts. Inserts shall not project above the mating surfaces. Wire wound inserts shall not be inserted more than 1.75 turns below the mating surface. All other types shall not be inserted more than one turn below the mating surface.

3.2.8 Mountings

Provisions for mountings shall be in accordance with General Electric Drawing SVS 47D212117.

3.2.9 Compatibility

All materials and finished used in the construction of the regulator shall be compatible for long term exposure to the following test media and cleaning fluids:

a. argon
b. nitrogen
c. helium
d. hydrogen
e. ammonia
f. hydrazine

g. water
h. ethylene oxide (external surfaces only)
i. methyl alcohol
j. acetone
k. methyl ethyl ketone

3.3 Performance

The regulator shall be capable of the following performance before and after exposure to the conditions specified in paragraph 3.4.2 and while exposed to the conditions specified in paragraph 3.4.1.

3.3.1 Operating Fluid

The operating fluid shall be hydrazine decomposition products including dissociated and undissociated ammonia gas.

3.3.1.1 Operating Fluid Temperature - The temperature of the operating fluid may vary between +30 and +400°F.

3.3.1.2 Test Fluids - The test fluid used during component and system testing shall be gaseous nitrogen.

3.3.1.3 Fluid Purity - When using nitrogen as a test fluid, the fluid shall be dried to a dew point of -100°F or lower. No oil or hydro carbon contents shall be allowed in the test fluid. The fluid shall be filtered through a 0.45 micron absolute filter prior to entering the regulator.

3.3.2 Pressure

3.3.2.1 Inlet Pressure - Inlet pressure to the regulator will vary from 50 to 200 psig.

3.3.2.2 Outlet Pressure - The design of the regulator shall be such that the outlet pressure setting can be readily adjusted in the range of from 15 to 25 psig by either the vendor or the customer.

3.3.2.3 Pressure Regulation - The regulator must operate over an environmental temperature range of -14 to +167°F and gas temperature range of +30 to +400°F. For any outlet pressure setting between 15 and 25 psig, no more than ± .4 psi variation in output pressure shall occur over an inlet pressure range of 50 to 200 psig, and flowrates from 1500 to 96,000 scc/min GN_2. As a design goal, the output pressure variation shall be no more than ± .2 psi for these operating conditions. Regulation tolerance outside the temperature range of -14°F to +167°F may be greater than ± .4 psi.

3.3.2.4 Lockup Pressure - For any output pressure setting, not more than ± .1 psi additional downstream pressure uncertainty shall accrue when the flow is stopped and the regulator locked up. Total pressure tolerance at lockup is ± .5 psi about the nominal setting.

3.3.2.5 Design Pressure - The regulator shall be designed for maximum inlet and outlet operating pressures of 200 psig and 60 psig respectively.

3.3.2.6 Proof Pressure - The regulator shall be capable of withstanding a proof pressure 1.5 times the design pressure without sustaining any damage or degradation of performance in accordance with MIL-P-5518. The proof pressure capability is applicable for all individual tests or any combination of tests tabulated below:

3.3.2.6.1 Proof pressure of 300 psig applied at inlet fitting with outlet fitting capped.

3.3.2.6.2 Proof pressure of 90 psig applied to the outlet fitting.

3.3.2.7 Burst Pressure - The regulator shall be designed to withstand a pressure 2.2 times the design pressure without rupture of internal or external parts in accordance with MIL-P-5518.

3.3.3 Flow Rate

The regulator shall be capable of handling flow rates within the range of 1500 to 96,000 scc/min of the test fluid.

3.3.4 Response Time

With the regulator in the lockup condition, it shall take no more than 1 second to establish flow and regulate pressure within specified limits from the time a quick operating valve downstream of the outlet port is is fully opened. It shall take no more than 100 milliseconds to change from flow to lockup pressure within specified limits from the time the quick operating valve is fully closed.

3.3.5 Leakage

External leakage shall not exceed .05 scc/hr helium at any operating inlet pressure. Internal leakage shall not exceed 2 scc/hr helium.

3.4 Service Conditions

The regulator shall be capable of satisfactory operation under any of the conditions specified in 3.4.1 after exposure to any of the conditions specified in 3.4.2.

3.4.1 Operating

The regulator shall be capable of satisfactory operation and performance while exposed to any of the following conditions or any natural combination of these conditions.

3.4.1.1 Temperature - The regulator shall perform within specification performance at temperatures between -14 & +167°F. The regulator must withstand temperatures between -100 & +400°F but need not operate within specification limits over the wider temperature band.

3.4.1.2 Altitude - A reduced air pressure range of from 10^{-12} to 10^{-16} mm Hg.

3.4.2. Non-Operating

The regulator shall be capable of satisfactory operation after exposure to any of the following conditions or any natural combination of these conditions.

3.4.2.1 Vibration

3.4.2.1.1 Low Frequency (Sinusoidal) - $\pm$ 1.5 inches displacement from 1.0 to 4.4 cps, and 2.1 g rms from 4.4 to 15 cps in each of three orthogonal axes. The sweep from 10 to 15 cps shall require 1.5 minutes and shall be repeated twice. Resonances shall not be dwelt upon.

3.4.2.1.2 Complex Wave - This test shall be performed in each of three orthogonal axes.

3.4.2.1.2.1 Noise

0.2 g^2/cps from 300 to 1000 cps with a 6 db per octave roll-off from 300 to 20 cps, and a 24 db per octave roll-off below 30 and above 2000 cps for three minutes.

3.4.2.1.2.2 White Gaussian Noise

5.0 g rms, band limited between 15 and 2000 cps, plus:

a. A 2.0 g rms sinusoid superimposed on the noise between 15 and 40 cps.

b. A 9.0 g rms sinusoid superimposed on the noise between 40 and 250 cps.

c. A 4.5 g rms sinusoid superimposed on the noise between 250 and 2000 cps.

The frequency of the sinusoid shall be swept from 15 to 2000 cps and back to 15 cps in a total time of 10 minutes, at a rate increasing directly with frequency.

3.4.2.2 Shock - The regulator shall be designed to withstand five, 200g, 0.7 $\pm$ 0.2 ms, terminal peak sawtooth shocks in each of three orthogonal axes.

3.5 Design Life

Over a 600-day period and in the environment specified herein, the regulator shall meet all requirements during and after 2×10^6 cycles. A cycle is defined as a three-step sequence. With inlet pressure being maintained

within specified limits, the outlet pressure set for one particular value within the range specified, the regulator is first in the lockup (no flow) condition as a result of a downstream valve being shut. Second, the downstream quick operating valve opens requiring the regulator to regulate pressure while flowing. The third and final step in the cycle returns the regulator to the lockup condition as the quick operating downstream valve shuts.

3.6 Cleanliness

In order to meet the stringent leakage, life, and environment requirements of the regulator application, it is necessary that the utmost care be taken to assure that the assembly is free from actual or incipient contamination. Operations in paragraphs 3.6.1 through 3.6.5 and 3.6.7 through 3.6.9 shall be accomplished in an area equivalent to a clean room. The procedures, methods, and operations listed below shall serve as a guide in achieving the cleanliness requirements delineated in Paragraph 3.6.4.

3.6.1 Part Degreasing

After all fabrication and test processes (except final assembly) have been completed, the parts which comprise the final assembly shall be thoroughly degreased. The parts shall be inspected under an ultra violet lamp, 2500 to 3700 angstroms wave length, to verify that this condition has been attained. Thereafter, the parts shall be stored in plastic bags, or other containers, which are equally clean, until ready for assembly.

3.6.2 Temporary Parts

Temporary parts such as port closures, shipping bags, etc., shall be cleaned to the same level and by the same procedures as the parts used in the assembly itself.

3.6.3 Inspection

Prior to assembly and after fabrication processes have been completed, all parts which comprise the final assembly shall be critically examined to assure freedom from burrs, feather edges, attached slivers, or any other similar type particles, which could subsequently become dislodged. The examination shall also include a careful check of platings, coatings, or other finishes to assure that a satisfactory bond exists and that there is no danger of flaking, peeling, or other contamination hazard.

3.6.4 Assembly Cleaning

Immediately prior to the assembly operation, all parts which constitute the final assembly (including shipping covers, port closures, shipping bags, etc.) shall be thouroughly cleaned using procedures and equipment which will provide an assembly which is clean to the level specified herein. The gases and liquids used in this process shall have been passed, finally, through a .45 micron absolute filter. The cleaning equipment shall be so arranged that contamination cannot get into the immediate area of the parts being cleaned. Assembly or other tools which will come in contact with the parts being assembled shall be cleaned to the same level as the parts. The parts shall be cleaned until the final rinse solution contains no more than the number of particles

shown below per 100 ML of solution filtered through a standard HA millipore filter.

Particle Size, Microns	Maximum Number Particles Metallic	Non-Metallic (max. dia.)
0-25	No Requirement	
25	None Allowable	

There shall be no visible reflectivity of hydrocarbons per black light inspection.

3.6.5 Assembly

Assembly techniques which minimize generation of particles shall be used. Where the assembly is composed, or can be composed, of one or more sub-assemblies, these sub-assemblies shall be cleaned in accordance with Paragraph 3.6.4. Precautions shall be taken to assure that the parts and sub-assemblies contain no residual cleaner, either as a liquid or as a solid residue. Handling of parts shall be accomplished only through the use of clean rubber gloves and tweezers, or other assembly tools, cleaned in accordance with 3.6.4 above.

3.6.6 Testing

The cleanliness level of the assembly shall be protected at all times during the testing operation. The inlet of the assembly shall be protected by external filters having a 10 micron or lower absolute rating, cleaned in accordance with 3.6.4. If filters cannot be directly attached to the assembly, the intermediate fittings used shall be cleaned to the same cleanliness level as the assembly parts. The filters shall be applied to the assembly in an area equivalent to a Class 100 clean room area, and shall not be removed until testing has been completed. Removal shall also take place under the same conditions.

During testing, any other precautions necessary to assure that the assembly will remain clean, shall be incorporated into the test procedure.

3.6.7 Exterior Cleaning

At the completion of testing, but prior to the removal of external filters, the assembly shall be cleaned externally using the methods and measurements of 3.6.4.

3.6.8 Final Cleaning

At the time the protective filters are removed from the assembly, final flushing and packaging shall be performed. Flushing shall be accomplished by flowing through the assembly with a liquid solvent or gaseous fluid which is compatible with the assembly materials and a flushing rate which shall be approved. The flushing time shall be sufficient to assure that all surfaces have been adequately exposed to the cleaning action. The flush fluid, before entering the assembly shall be filtered to a .45 micron absolute level. Flushing will contine until the particle count does not exceed that specified in 3.6.4.

3.6.6.9 Packaging

Precautions shall be taken to assure that the assembly contains no residual cleaner, either as a solid, liquid, residue film, or gas. At the same time that the regulator is receiving its final cleaning, the packaging equipment shall be cleaned to the same or better cleanliness level.

The port closures shall be covered with plastic wrap, secured with nylon cord or tape. If tape is used, it shall not come in contact with the port threads. Plastic and metallic caps are specifically prohibited.

The regulator assembly shall be placed in dual sealed cleaned plastic bags (or equivalent) cleaned to the requirements of paragraph 3.6.4. The bags shall be suitably wrapped with protective material to prevent puncturing, and placed in its shipping box. More than one regulator may be placed in one shipping container, provided adequate precautions are taken to protect against damage to the assemblies and to the sealed plastic bags.

3.7 Documentation

The vendor shall have on file the following documentation:

3.7.1 Cleanliness Plan

The implementation of a plan to maintain satisfactory contamination levels in accordance with paragraph 3.6 including cleaning of detail parts, sub-assemblies, and assemblies, and appropriate tests to verify acceptable cleanliness of the delivered component.

3.7.2 In-Process Quality Plan

The vendor shall have an In-Process Quality Plan prior to the start of fabrication of prime hardware. This plan shall consist of the procedures utilized in receiving inspection (including sampling plans), a fabrication block diagram including in-process inspection test points and overall configuration control requirements.

3.7.3 Drawings

A complete set of all assembly and detail parts drawings for the component in accordance with the requirements of MIL-D-70327, Class 2 Drawings.

3.7.4 Test Procedures

The vendor test plan for acceptance testing, including test procedures, equipment, data to be obtained, data sheets, etc., shall be prepared and submitted in accordance with paragraph 4.6.

3.7.5 Log Book

A component log book in accordance with paragraph 4.5

3.7.6 Failures

The customer shall be notified of all regulator test failures, and the test discontinued pending customer direction.

4.0 Quality Assurance Provisions

To insure satisfactory quality and compliance with the requirements of Section 3 of this specification, each regulator shall be subjected to the tests defined herein.

4.1 Classification of Tests

The inspection and testing of the regulator shall be classified as follows:

4.1.1 Acceptance Tests

Each regulator shall be subjected to the acceptance tests described under paragraph 4.4.1 of this specification. These tests shall be witnessed by GE-SD personnel unless otherwise specified.

4.2 Procedure In Case of Failure

If a failure, malfunction, or out-of-tolerance performance occurs, testing shall immediately cease, pending analysis to determine the reason for the failure. If the corrective action affects the validity of previous test results, such tests shall be repeated.

4.3 Test Conditions

4.3.1 Ambient Conditions

Unless otherwise specified, the test shall be performed under the following conditions:

a. Temperature: $70^{\circ}F \pm 15^{\circ}F$
b. Relative Humidity: 90% or less
c. Barometric Pressure: 28 to 32 inches Hg
d. Altitude: 28 to 32 inches Hg

4.3.2 Measurements and Tolerances

All measurements shall be made with instruments which are periodically calibrated with standards traceable to the National Bureau of Standards.

4.4 Test Methods

4.4.1 Acceptance Tests

Acceptance testing shall be performed on the regulator at the completion of regulator assembly in the order specified.

4.4.1.1 Visual and Mechanical Inspection - Each regulator shall be carefully examined to determine conformance with applicable drawings. Component serial numbers shall be checked to ascertain whether labelled functions are correct. Component flow arrows shall be checked against system schematic. Each fitting shall be checked for correct torque installation. All exterior outlets shall be capped at all times except when used for test. Any auxiliary fittings or plugs used during testing shall be red tagged and removed at the completion of test and in preparation for shipment.

4.4.4.1.2 Cleanliness Check - The regulator cleanliness level shall be checked using the methods and measurements of paragraph 3.6.4 to determine that the particle count does not exceed that specified in paragraph 3.6.4.

4.4.4.1.3 Proof Pressure Test - The regulators, both upstream and downstream ports, shall be pressurized to that required by paragraph 3.3.2.6 using the test fluid as specified in paragraph 3.3.1.1. The pressure shall be maintained for ten (10) minutes. There shall be no degradation of component performance as a result of the proof pressure test.

4.4.4.1.4 External Leak Test - The regulator shall be subjected to a static leak test to insure compliance with paragraph 3.3.5. A helium mass spectrometer shall be used for this test.

4.4.4.1.4.1 Internal Leak Test - The regulator shall be subjected to an internal leak test to assure compliance with paragraph 3.3.5.

4.4.4.1.5 Gas Flow Test - With the regulator inlet pressurized and the regulator adjusted to the values found in Table I, flow checks of 30 seconds duration shall be conducted to insure operation in accordance with paragraph 3.3.2.3 (Test sequence need not be as indicated in Table I).

4.4.4.1.6 Lockup Pressure - With the regulator inlet pressurized to 200 psig and outlet adjusted to 25 psig, a check for variation in outlet pressure level at a no-flow condition shall be made. The test shall be repeated with the regulator outlet adjusted to 15 psig.

4.4.4.1.7 Cycling Test - The regulator shall be subjected to a series of 10,000 cycle tests. These shall be conducted with a shutoff valve installed downstream of the regulator. Regulator inlet and outlet pressures shall be as per paragraph 3.3.2.1 and 3.3.2.2. There shall be a minimum duration of two seconds between each cycle.

4.4.4.1.8 The tests specified in paragraphs 4.4.1.4, 4.4.1.4.1, and 4.4.1.2 shall be repeated.

4.5 Records and Reports

A record shall be maintained for each serialized component part showing inspections and rejections, parts replaced, and all rework performed on any component part. This record shall include a history of malfunctions, rejections, and quality control problems encountered in any piece part or component part. In addition, the results of all performance tests shall be noted for each component part.

4.6 Test Plans

A detailed test plan shall be prepared and submitted to the GE-SD Project Engineer in a minimum of thirty (30) days prior to the initiation of Acceptance tests. This plan shall include a test set-up schematic, a list of equipment to be used with specified accuracy, a step-by-step test procedure, and the d data sheets to be used. Written approval of the test plan is required from the GE-SD Project Engineer prior to start of testing. Subsequent changes to these test procedures or data sheet(s) shall also require approval by the GE-SD Project Engineer prior to implementation.

Table I

Test Nos.	Reg. Inlet Pressure Psig	Reg. Gas Inlet Temperature °F	Reg. Ambient Temp. °F	Reg. Outlet Pressure Psig	Flow Rate scc/min
1	+0 50 -2	+70±15	-14° ± 5°	25	1500, 50,000 & 96,000
	50	+70±15	+167° ± 5°	25	"
2	+2 200 -0	70±15	-14° ± 5°	25	"
	200	70±15	+167° ± 5°	25	"
3	+0 50 -2	70±15	-14° ± 5°	15	"
	50	70±15	+167° ± 5°	15	"
4	+2 200 -0	70±15	-14° ± 5°	15	"
	50	70±15	+167° ± 5°	15	"

5.0 Preparation for Delivery

5.1 The requirements of 3.6 of this specification shall be complied with prior to delivery.

6.0 Notes

6.1 Definitions

a. Customer - General Electric Company, Missile and Space Division.

APPENDIX B

PROGRAM PLAN

WARM GAS DISTRIBUTION SYSTEM PNEUMATIC REGULATOR DEVELOPMENT

(JPL Contract 951988 - Modification One)

19 August 1968

Approved By: W. D. Boyce Date: 8/19/68
W. D. Boyce, GE
Project Engineer

Approved By: G. M. Courville Date: 10/9/68
G. M. Courville, JPL
Technical Representative

Approved By: F. G. Moseley Date: 10/10/68
F. G. Moseley ~~XXXXXXXXXX~~ JPL
Senior Contract Negotiator

1.0 INTRODUCTION AND GENERAL SCOPE OF WORK

The effort described herein represents the agreed scope of work for performance by General Electric under Modification Number One to JPL Contract Number 951988. The activity is oriented to the further development of a pneumatic regulator intended for use as part of a warm gas distribution system previously developed and demonstrated under the initial contract scope.

The general scope of work includes analysis of the existing WGDS regulator design and delineation of potentially effective design changes for the purpose of improving regulated pressure accuracy. Procurement of two different regulators, each incorporating design features identified in design analysis, will precede functional, limited environmental, and life testing to evaluate regulator performance.

2.0 SCOPE OF CONTRACT

The following tasks comprise the requirements for total completion of JPL Contract 951988, Modification One.

2.1 Regulator Design Analysis

GE/SSO shall perform a study of the existing WGDS regulator for the purpose of identifying design techniques which, if incorporated into the regulator, may improve pressure regulation accuracy. The performance accuracy goal shall be regulation within a $\pm$ .2 PSI accuracy band over an adjustable outlet pressure band from 15 to 25 PSIA flowrates to 96,000 SCCM, inlet pressure range from 50 to 200 PSIG, and an environmental temperature range from -14°F to +167°F. Degraded performance will be permitted over extended environmental limits of -100°F to +300°F. The design analysis shall include, but not necessarily be limited to, consideration of the following design techniques.

1) Enlarged and smoothed flow paths.
2) Modifications to regulator "gain".
3) Elimination of dampers.
4) Reduction in number of detail parts.
5) Reduction of number of O-ring seals.
6) Simplifications to adjustment provisions.
7) Reduction of use of threaded parts.
8) Removal of sensitivity to external torques.
9) Increase clearance around helical spring.
10) Optimization of helical-belleville spring relationship.

2.2 Regulator Procurement

GE/SSO shall procure two regulators of the type identified as optimum in the design analysis effort. One unit shall be obtained through modification of the existing WGDS spare regulator. The other unit shall be of the "hard seat" design type in order to compare performance of this type against the current soft seat design.

2.2.1 Evaluation of Design

Evaluation of candidate regulator designs shall be by means of a point rating system similar to that attached as Appendix A. A design review shall be conducted for JPL prior to release of hardware designs for fabrication.

2.3 Regulator Testing

Testing shall be performed on the two regulator designs including vendor development tests (as required and identified by the vendor for each regulator), vendor acceptance tests, and GE life tests. Vendor acceptance tests shall be in accordance with Paragraph 4.4 of the component specification, SVS 7513, attached hereto as Appendix B. GE life testing of each regulator shall be conducted in accordance with the provisions of the following paragraph.

2.3.1 Regulator Life Testing

Regulator life testing shall be performed by GE/SSO after completion of vendor acceptance tests and delivery of the two regulators to GE. Functional tests consisting of flow regulation, leakage, and contamination checks shall be run prior to initiation of life tests, and after 100,000, 300,000, 500,000, 800,000 and 1,000,000 cycles. Total duration of the life test shall be 1,000,000 cycles or to component failure, whichever shall occur first. The regulator outlet pressure shall be adjusted to a new set point after 500,000 cycles.

2.3.1.1 Functional Tests During Life Testing

Functional tests will be performed as follows at the intervals required.

2.3.1.1.1 Leakage - The regulator will be mounted in a leakage box as shown in Figure One. External leakage will be monitored by a mass spectrometer sensing gas in the box. Internal leakage will be measured by pressure rise in a known volume. Temperature of the downstream tubing will be monitored. At least a two hour period will be allocated for internal leakage surveillance.

2.3.1.1.2 Flow and Regulation - The regulator will be pressurized to 50 and 200 PSIG at the inlet port as shown in Figure Two. The flow will be adjusted to 96,000 scc/min, 40,000 scc/min, and 1,500 scc/min at each inlet pressure. Regulation accuracy, including lockup effect, will be tested.

2.3.1.1.3 Contamination Check - The regulator will be adjusted to 96,000 scc/min flow with an inlet pressure of 200 PSIG and 10 cubic feet of dry filtered nitrogen gas passed through the regulator and through a .45 micron millipore filter. The filter will be examined for evidence of particles larger than 25 microns.

2.3.1.2 Life Test

The regulator will be set up as previously shown in Figure Two, except that a solenoid valve will replace the downstream hand valve (item 7 in Figure Two). The solenoid valve will be linked to an automatic cycling circuit providing pulses to operate the solenoid valves. In this manner the regulator will be

required to alternately flow and lockup. Cycling will be more rapid than normally associated with a spacecraft mission in order to reduce program cost and schedule.

2.4 Required Deliveries

GE/SSO shall deliver to JPL the following documentation and hardware.

2.4.1 Prototype Regulators

Both test regulators will be delivered to JPL at the conclusion of testing.

2.4.2 Drawings

Five copies of vendor supplied envelope and cross section drawings for each regulator will be supplied to JPL.

2.4.3 Reports

2.4.3.1 Cost Reports

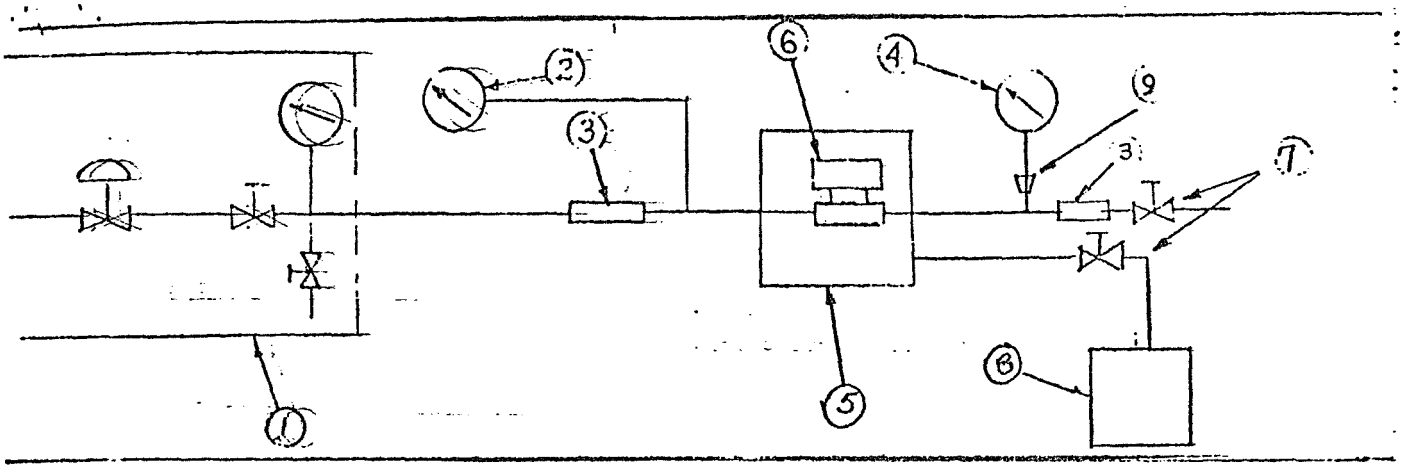
GE/SSO shall provide monthly cost reports of a format and to a schedule mutually agreed between the GE and JPL Contract Negotiators.

2.4.3.2 Technical Reports

GE shall provide bimonthly technical letter reports and a final report of all work performed following completion of testing.

2.5 Program Schedule

The schedule for completion of all effort under JPL Contract 951988 is shown in Figure Three.

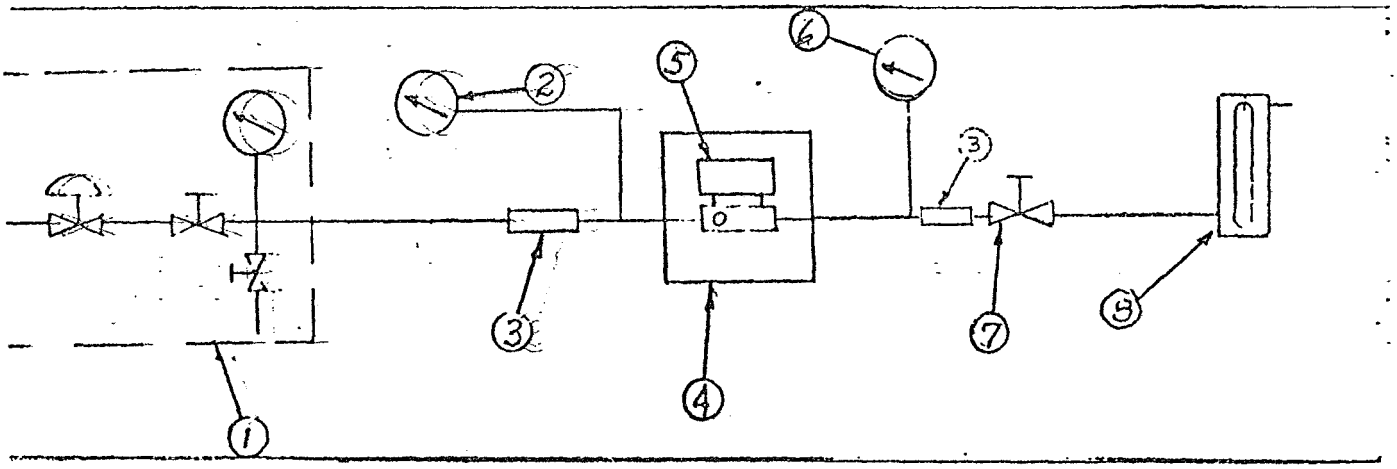


Legend:

1. Helium Pressure Source
2. Pressure Gauge 0-300 psi, Heise, or equal.
3. 5 u filter or better.
4. Pressure Gauge, 0-50 psi, Heise, or equivalent.
5. Leak Box Assembly #243R136
6. Test Specimen
7. Hand Valve
8. Mass Spectrometer CEC #24-120 or equivalent.
9. Temperature Sensor

FIGURE ONE

Static Leakage Schematic - Regulator



Legend

1. Nitrogen pressure source
2. Pressure gauge 0-300 psi, Heise or equivalent.
3. Filter - 5 Micron absolute or better
4. Leak Box Assembly - 243R136 or equivalent.
5. Test specimen
6. Pressure gauge - 0-30 psi, Heise or equivalent
7. Hand valve
8. Flowmeter - Fisher & Porter - 1.4 to 7.2 scfm or equiv.

FIGURE TWO

Regulation Pressure and Flow Schematic - Regulator

MILESTONE SCHEDULE

WGDS REGULATOR — ENGINEERING ~~PROPOSAL~~/PROGRAM

(NAME)

FORM 1-9511 REV. (2-61)

"B" LEVEL OPER. NO.	OPER. NAME	PREPARED BY	DATE	APPROVED BY	DATE	ISSUE NO.
1JM0	Guidance and Control	C. C. Rich	7/9/68		7/9/68	

TASK NO.	SUB-TASK NO.	DESCRIPTION OF DETAIL MILESTONES
	PROGRAM PLAN REF. PARA. -	Program Plan Available for Review
-	-	Approved Program Plan Available
	2.1	Regulator Design Analysis, Review
	2.2	Vendor Negotiations
	2.2	Vendor Manufacturing
	2.3	Vendor Acceptance Testing
	2.2	Delivery to GE
	2.3.1	GE Life Testing
	2.4	Delivery to JPL
		Technical Reports
		Final Report

ELAPSED TIME SCHEDULE

(INDICATE YEARS) 1968

(SPECIFY CATEGORY) MONTHS/ WEEK

JULY | AUGUST | SEPT. | OCT. | NOV. | DEC. | JAN.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

△ START ▽ COMPLETE ▭ TIME PERIOD OF WORK

⇩ MAJOR ITEM EVENT (REPORT, HARDWARE DELIVERY, FLIGHT TEST, ETC.) – INDICATE ITEM NAME NEXT TO ARROW.

*4 Weeks after Completion of testing

APPENDIX A

PNEUMATIC REGULATOR TRADEOFF

VENDOR: _____

FEATURE	WEIGHTING FACTOR	POINTS (1-10)	TOTAL
1. Complexity	5		
2. Sliding Fits	8		
3. Dynamic Seals	8		
4. Seat Configuration	10		
5. Contamination Susceptibility	5		
6. Cleanability	3		
7. Filter Size and Design	8		
8. Weight	2		
9. Size	2		
10. Body Strength and Rigidity	10		
11. Sensing Element Seal	5		
12. Static Seals	5		
13. Relief Valve Design	10		
14. Material Selection	5		
15. Absence of Plating	3		
16. Proven Design	10		

APPENDIX C

Work Statement 1JM3-053
Date: 6 August 68

Work Statement

for

Development and Procurement of a Warm Gas

Distribution System Regulator

Prepared by: W. D. Boyce 8/7/68
W. D. Boyce, Supervising Engineer, Pneumatic Equipment
Reaction and Actuation Equipment Engineering

Approved by: C. C. Rich 8-7-68
C. C. Rich, Manager
Reaction and Actuation Equipment Engineering

1. General Scope

This Work Statement defines the tasks required to improve performance of Carleton Controls Pneumatic Regulator P/N 1992001-17, two units of which were previously delivered to GE/MSD for use on the Warm Gas Distribution System. The objective of the current effort is to bring the regulator into compliance with GE Specification SVS 7513. If feasible, a previously delivered regulator will be returned to Carleton Controls by GE/MSD for modification in accordance with a design previously approved by Carleton Controls and GE Cognizant Engineers. If modification is not possible, manufacture and acceptance test of one additional unit will be required.

The vendor is asked to propose an improved design based on the objectives of incorporating improvements that will enhance stability, regulation tolerance, adjustability, and decrease temperature sensitivity. Proposed design changes must be approved by GE prior to finalization of design and fabrication of hardware.

2. Design

The improved design shall be prepared by the vendor with consideration given to potential improvement areas in light of experience with previously delivered units. The design analysis shall include, but not necessarily be limited to, consideration of the following design techniques:

a. Enlarged and smoothed flow paths downstream of seat.

b. Modifications to regulator gain to improve stability.

c. Elimination of friction dampers.

d. Reduction in number of detail parts.

e. Reduction in number of O-ring seals.

f. Simplification of adjustment provisions.

g. Reduction in use of threaded parts.

h. Elimination of sensitivity to external torques.

ii. Increased clearance around helical spring.

jj. Optimization of helical - Belleville spring relationships.

221 Design Review

The vendor shall prepare a cross section drawing of the proposed design, and any alternate configurations for approval of the cognizant GE/MSD Design Engineer prior to finalization of design and fabrication of hardware. The vendor shall provide design engineers to meet with the GE/MSD Cognizant Engineer as required by the program. The vendor shall keep on file a complete set of up-to-date drawings for review by GE/MSD as required.

3. Fabrication and Development

After approval of the design by GE, the vendor shall immediately begin fabrication of a deliverable unit. If any changes to the approved configuration are required to accomodate fabrication, the GE representative shall be notified immediately for approval.

31 Development Testing

The vendor shall be responsible for the scope and performance of development testing to demonstrate that the unit will meet the requirements of GE Specification CVS 7513. It is a mandatory requirement, however, that satisfactory regulation, lockup, and leakage characteristics be demonstrated at environmental temperatures of -100°F and +300°F. If any changes to the approved configuration are required as a result of development testing, the GE representative shall be notified immediately for approval.

4. Acceptance Tests

Acceptance tests shall be conducted by the vendor in accordance with GE Specification CVS 7513, Para. 4.4.1.

5. Delivery

Delivery of one unit is required. Schedule for delivery and key militone events are given in the attached Milestone Schedule.

C-4

MILESTONE SCHEDULE

WGDS Regulator

ENGINEERING PROPOSAL/PROGRAM

(NAME)

FORM [illegible] REV. (2-61)

Work Statement 1JM3-05

PAGE [illegible] OF [illegible]

"E" LEVEL OPER. NO.	OPER. NAME	PREPARED BY	DATE	APPROVED BY	DATE	ISSUE NO.
1JM0	Guidance & Control	W. D. Boyce	8/6/68			

TASK NO.	SUB-TASK NO.	DESCRIPTION OF DETAIL MILESTONES	ELAPSED TIME SCHEDULE
			(INDICATE YEARS)
			(SPECIFY CATEGORY) [illegible]/WEEK
			1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
		Design Analysis	△ ▽
		Design Review	▽
		Fabrication & Dev. Test	△ ▽
		Acceptance Tests	△ ▽
		Delivery	⇩

△ START ▽ COMPLETE [illegible] TIME PERIOD OF WORK

⇩ MAJOR ITEM EVENT (REPORT, HARDWARE DELIVERY, FLIGHT TEST, ETC.) - INDICATE ITEM NAME NEXT TO ARROW.

APPENDIX D

GENERAL ELECTRIC
MISSILE AND SPACE DIVISION
PHILADELPHIA

PROGRAM INFORMATION REQUEST / RELEASE

PIR NO.	*CLASS. LTR.	OPERATION	PROGRAM	SEQUENCE NO.	REV. LTR.
	U	— 1K63 —	PJR —	164	

*USE "C" FOR CLASSIFIED AND "U" FOR UNCLASSIFIED

FROM	TO
Peter J. Ring, Metallurgist Materials Development & Applications VFSTC-Rm. M-2101	W. D. Boyce Room U4426

DATE SENT	DATE INFO. REQUIRED	PROJECT AND REQ. NO.	REFERENCE DIR. NO.
12-26-68			

SUBJECT:

COMPATIBILITY OF MATERIALS WITH HYDRAZINE AND HYDRAZINE DECOMPOSITION PRODUCTS

INFORMATION REQUESTED/RELEASED

Materials selected for application in assembly regulating valves have been assessed for compatibility with Hydrazine and Hydrazine decomposition products.

Note: Several other factors can result in valve failure or malfunction, for example; the 300 Series Stainless Steels are subject to catastrophic failure by stress cracking if chlorides (even very small traces) are present. Sulphides rapidly attack nickel bearing alloys and cryogenic temperatures considerably decrease the impact resistance of martensitic steels (440C, 17-7PH, 17-4PH). For the purpose of this report, it is assumed that factors, such as these, have been considered and only the effects of hydrazine, ammonia, hydrogen and nitrogen have been evaluated here.

SUMMARY

Table 1, in this report, lists the materials involved in the valve construction. Of the materials under consideration, the following can be used in this application without ill effect. (It should be noted that in this application, fuel decomposition effects can be ignored.)

302 Stainless Steel, 304 and 304L Stainless Steel, Nickel Plate, Teflon and Ethylene Propylene Rubber.

The following materials can, in the opinion of the writer, also be used but references in respect to these alloys are contradictory.

17-7PH Stainless Steel, 17-4PH Stainless Steel, 2024 Aluminum and 7075 Aluminum.

PAGE NO.	RETENTION REQUIREMENTS	
	COPIES FOR	MASTERS FOR
1 OF 6	☐ 1 MO.	☐ 3 MOS.
	☐ 3 MOS.	☐ 6 MOS.
	☐ 6 MOS.	☐ 12 MOS.
	☐ MOS.	☐ MOS.
	☐	☐ DO NOT DESTROY

FORM 1020 (REV. 6-65)

440C Stainless Steel and Nylon should not be used. 440C Stainless Steel is susceptible to hydrogen embrittlement and Nylon tends to degrade in hydrazine.

ALUMINUM ALLOYS

As can be seen from Table (1) several references do not recommend Aluminum in contact with Hydrazine. There is, however, considerable contradiction among the various references, for instance; all Aluminum Alloys are considered compatible with MMH and a particular Alloy (2024) although, Class 1 at 68°F in liquid hydrazine is Class 4 at 80°F in liquid hydrazine, and yet, Class 1 at 75° in UDMH (Ref.9). Reference 7 and Reference 8 state unequivocally that all Aluminum Alloys are compatible with respect to corrosion and decomposition. Mr. Boyd of the Battelle Institute and author of the DMIC Memo #201 gave two reasons for avoiding Aluminum Alloys:

1. 2024 - This alloy contains 4.5% Cu, the formation of Al-Cu compounds can render the alloy susceptible to intergranular attack by hydrazine and its decomposition products.
2. 7075 T6 - This Alloy is considered (by Mr. Boyd) to be susceptible to stress corrosion. A heat treatment resulting in a lower stress level should resolve the problem, if the lower strength can be tolerated.

STEELS

302 and 304 Steels are considered acceptable from all standpoints (i.e., corrosion, decomposition and hydrogen embrittlement). 303 Stainless Steel is not recommended however, due to its tendency towards pitting corrosion. A lower sulphur steel, for example; 302 or 304 should be used.

17-7 and 17-4PH were both advised against by Mr. Boyd (Battelle) on the grounds of H_2 embrittlement. In the opinion of the writer, this danger is non-existent since 17-7 and 17-4 Steels are not subject to hydrogen embrittlement, Ref. 10, 11.

440C Stainless Steel is, however, most definitely subject to embrittlement and should be avoided.

Nickel Plating

Nickel Plating is given a Grade 4 classification in DMIC Memo 201. This classification is, however, based upon the catalytic effect of plated nickel, not on its resistance to corrosion and can therefore be disregarded in this application.

Non Metals

Teflon may be used without any serious degradation. E.P.R. There are many formulations of Ethylene Propylene Rubber, however, E.P.R. formulations which have been tested gave excellent results in hydrazine, formulation No. 2, Ref. 5.

NYLON

Nylon does not appear to be very satisfactory for hydrazine applications, Ref. 6.

TABLE 1

COMPATIBILITY OF MATERIALS WITH HYDRAZINE

(Information Taken Mainly From DMIC Memo 201)

	Gas				Liquid				Ref.	H_2	NH_3
	1	2	3	4	1	2	3	4			
302					80	140			1, 2	OK	OK
303						75			3,	OK	OK
304	140				140				3, 1,	OK	OK
304C									---	OK	OK
17-7					75				1	OK	OK
17-4	140				140			160	1	OK	OK
440C					80			75	3	— Not Recommended	OK
2024-T4					68			80	3,1,2	OK	OK
7075-T6							160	75	3,1	OK	OK
Electro Ni								68	1	OK	OK

KEY TABLE 1. COMPATIBILITY CLASSIFICATIONS FOR METALS (a)

Class	Corrosion Resistance: Rating	Penetration Rate, mils/year	Decomposition of Propellant	Shock Sensitivity
1	Excellent	1	No	No
2	Good	5	No	No
3	Fair	5 to 50	Some	No
4	Poor	50	Extensive	Yes

(a) The classification of a material is based on the lowest rating of any one of the three properties.

The numbers in the columns refer to the temperature at which the material was evaluated (°F).

NON METALS

		Reference
TEFLON	Class 1 in liquid hydrazine at 140°F	3, 4, 1
NYLON	Class 3 in liquid hydrazine at 75°F	3
E.P.R. 132 (i)	Twenty (20) percent volume swell after 15 weeks at 140°F in Hydrazine UDMH mixture. This is considered a very good performance	12
(E.P.R. (ii) FORMULATION NO. 2)*	3.8% fuel leakage through an O Ring Seal in 17 months considered a very good performance. Temp. 73°F	5

** E.P.R. Formulation #2 contains:

E.P.R. 404-	100 parts
Statex R	50
Zinc Oxide	1
Sulphur	0.45
Varox	8

Cure time 40 minutes at 330°F

TABLE 1 COMPATIBILITY CLASSIFICATIONS FOR NONMETALS

	Class 1	2	3	4
Volume Change Percent	0 to +25	-10 to +25	-10 to +25	-10 or +25
Durometer Reading Change	±3	±10	±10	-10 or +10
Effect on Propellant	None	Slight Change	Moderate Change	Severe
Visual Examination	No Change	Slight Change	Moderate Change	Severely blistered, or cracked, dissolved
General Usage	Satisfactory General Use	Satisfactory for Repeated Short Term Use	Satisfactory for Short Time Use	Unsatisfactory

REFERENCES

Reference		Second Source
1.	Liberto, R.R., "Research and Development on the Basic Design of Storable High-Energy Propellant Systems and Components" , Final Report TR 60-61 under Air Force Contract AF 33(616)-6689, Bell Aerosystems Company, Division of Bell Aerospace Corporation, Buffalo, New York (May 19, 1961).	DMIC Memo 201
2.	Ordin, P.M., Miller, R.O., and Diehl, J.M., "Preliminary Investigation of Hydrazine as a Rocket Fuel", NACA Report No. E7H21, National Advisory Committee for Aeronautics, Washington, D.C. (May 24, 1948).	DMIC Memo 201
3.	Agricola, K. R., "The Usefulness of Materials Used in Booster Structures", paper presented at the Symposium, The Application and Properties of Materials Used in Aerospace Vehicle Design, sponsored by The Martin Company, Denver, Colorado, May 4-6, 1960.	DMIC Memo 201
4.	"6000 Pound Thrust Jet Propulsion Unit; Part II, Materials Corrosion Data", Report SPD 121 under Air Force Contract AF W33(038)-ac-13916, M. W. Kellogg Company (March, 1948).	DMIC Memo 201
5.	Evaluation of Elastomers as O Ring Seals for Liquid Rocket Fuels and Oxidizer Systems Wright Patterson Air Base Project 7381 Task 738103 ASD-TDR-03-496	AD607240
6.	TITAN II Storable Propellant Hand Book Ralph R. Liberto , Bell Aerosystems Company Buffalo, New York, 1963.	AD400748
7.	American Society of Metals, Metals Hand Book, 8th Edition, Vol. 1.	———
8.	Aluminum with Food & Chemicals, Feb., 1967, The Aluminum Association, New York, N. Y.	———
9.	Compatibility of Materials with Rocket Propellants and Oxidizers, DMIC Memo 201 Jan. 1965.	———
10.	Armco Steel Co. Publication S-14.	———
11.	Aerospace Structural Metals Hand Book, Vol., Ferrous Alloys, Syracuse University Press.	———
12.	Positive Expulsion Bladders for Storable Propellants Thioxol Chemical Corp. Report RMD 5052-Q2.	AD457619

APPENDIX E

TEST PLAN

FOR

WGDS REGULATOR

Prepared by: Charles W Gurney Date: 23 April 69

C. W. Gurney, System Engineer
Lunar & Planetary Systems Engineering
Advanced Manned Systems Engineering

Approved by: C C Rich Date: 4-24-69

C. C. Rich, Manager
Reaction and Actuation
Equipment Engineering

22

1.0 SCOPE

This test plan describes the tests to which the WGDS Pneumatic Pressure Regulator will be subjected to verify its functional performance and acceptability for use in the Warm Gas Distribution System. These tests will consist of life, leakage, flow, regulations, and contamination level tests, in accordance with the requirements herein.

2.0 APPLICABLE DOCUMENTS

GE SVS 7513	Component specification for a Regulator, Pneumatic Pressure - Warm Gas Distribution System
GE Standard 171A4412	Nitrogen Gas, High Purity
GE Standard 171A4413	Helium Gas, High Purity
Stearer Engineering & Manufacturing Co. 37020B	Regulator - Pressure, Pneumatic
Carleton Controls Corp. 1992517B	Assembly, Regulating Valve

3.0 TEST FLUIDS

3.1 The operating fluid shall be nitrogen gas conforming to the requirements of GE Standard 171A4412.

3.2 For leak testing, the test fluid shall be helium gas conforming to the requirements of GE Standard 171A4413.

4.0 TEST EQUIPMENT, FACILITIES AND CONDITIONS

4.1 Test Equipment

4.1.1 Test Equipment Requirements

All measurements shall be made with instruments of which accuracy has been verified and which are calibrated at least every six (6) months. Calibrations shall be traceable to the National Bureau of Standards. The maximum allowable tolerance on measuring instruments shall be as follows:

a. Temperature	$\pm 3°F$
b. Pressure	$\pm 0.10\%$
c. Flow	$\pm 1\%$

4.1.2 Test Equipment

Test equipment requirements are listed on the schematic diagrams (Figures 1 through 4) applicable for each test.

4.2 Test Facilities

All tests shall be conducted in the Spacecraft Pneumatics Laboratory Clean Room, U-4209 VFSTC, under Class 100 clean bench conditions.

4.3 Test Conditions

4.3.1 Environment

Unless otherwise specified, these tests shall be conducted under the following conditions:

Temperature:	25°C ± 10°C
Relative Humidity:	60% or less
Barometric Pressure:	28" to 32" Hg

4.3.2 Cleanliness

In order to meet the stringent leakage and life cycle requirements, it is necessary that the utmost care be taken to assure that the regulator is tested free from all induced contamination. In achieving this, the following procedure shall be adhered to when assembling test setups. Immediately prior to assembly of a setup, all parts such as tubing and fittings shall be thoroughly degreased and ultrasonically cleaned and flushed with a non-residue type cleaning fluid, and purged with clean, prefiltered dry nitrogen.

After assembly of the setup, but prior to installation of the regulator, the plumbing shall be purged with prefiltered dry nitrogen until the following particle count is achieved:

Contaminant Dimensions, Microns	Max. Number Particles
0-25	no requirement
greater than 25	none allowable

4.4 Setup Approval

After completion of the test setups and contamination checks, the setup and particle counts shall be reviewed and approved by the WGDS Project Engineer prior to proceeding with any tests.

4.5 Failure Reporting

In the event any component failure is detected the test shall be delayed pending notification of the responsible engineer.

5.0 TEST DESCRIPTION

Testing shall be performed on the regulators supplied by Sterer Engineering and Manufacturing Co. and by Carleton Controls Corp. including physical examination (para. 5.1), life tests (para. 5.2), static leakage (para. 5.3), flow and regulation (para. 5.4), and contamination checks (para. 5.5).

5.1 Physical Examination

The regulator shall be examined for conformance to the applicable vendor drawing for any defects such as cracks, body distortion, torque stripe disturbance, lockwire breaks, thread damage, etc. Any defects shall be noted on the data sheet.

5.2 Regulator Life Testing

Total duration of the life test shall be 1,000,000 cycles or to component failure, whichever shall occur first. The regulator outlet pressure shall be adjusted to a new set point after 500,000 cycles. Functional tests consisting of flow regulation, leakage, and contamination checks shall be run prior to initiation of life tests, and after 100,000, 300,000, 500,000, 800,000 and 1,000,000 cycles. The regulators will be set up as shown in Figure 1. The solenoid valve will be linked to an automatic cycling circuit providing pulses to operate the solenoid valves. In this manner the regulator will be required to alternately flow and lockup. Cycling will be more rapid than normally associated with a spacecraft mission in order to reduce program cost and schedule and shall not exceed 4 cycles per second.

5.3 Static Leakage

Mount the regulator in a leak box assembly as shown in Figure 2. With the regulator in a locked up condition, pressurize the inlet to 200 psig (He) and monitor seat leakage. Seat leakage shall be measured by observing the pressure increase in a known volume for a minimum of two (2) hours.

Seat leakage shall not exceed 2.0 scc/hr helium. Body (external) leakage shall be monitored with a mass spectrometer and shall not exceed 0.05 scc/hr helium.

The volume of the tubing downstream of the regulator shall be measured by pressurizing this tubing with one atmosphere of helium, and bleeding of the gas into a cubic centimeter graduate immersed in alcohol until one atmosphere has been bled off. Temperature of the downstream tubing shall be monitored.

The internal leakage shall be calculated using the following formula:

$$Q = \frac{2154\ V}{t} \quad \left(\frac{P_2}{T_2} - \frac{P_1}{T_1}\right)$$

where

Q = scc/hr
t = elapsed time, min.
V = volume, cc
P_1 = initial pressure, psia
P_2 = final pressure, psia
T_1 = initial temperature, °R
T_2 = final temperatue, °R

5.4 Flow and Regulation

Install the regulator in the test setup shown in Figure 3. The volume of the lines and fittings between the regulator and solenoid valve shall be 40 cubic inches. Pressurize the regulator inlet with clean dry nitrogen at 50 psig. Using the hand valve, adjust flow rate to 1500 scc/min. Remove the flowmeter from the test setup. By opening and closing the solenoid valve, obtain lockup and regulated pressure cycles at inlet pressure of 50 and 200 psig (pressure increasing). Change inlet pressures with the solenoid valve closed. Repeat the above sequence with decreasing inlet pressures of 200 and 50 psig. Record regulated pressure gage reading at each flow and lockup condition. Repeat the above test series at flow rates of 40,000 scc/min and 96,000 scc/min.

Using the manufacturer's procedure provided with the unit, adjust the regulator to its alternate setting (15 or 25 psig). Repeat the above flow and regulation tests at the new setting.

5.5 Contamination Control

With an inlet pressure of 200 psig applied to the regulator and flow adjusted to 96,000 scc/min, flow 10 cubic feet of dry filtered nitrogen gas through the regulator and through a downstream .45 micron millipore filter. Perform a particle count on the filter element to determine contamination level of the regulator effluent. The test setup is shown in Figure 4.

6.0 LOG BOOK

A data log book shall be initiated for each component and all test data recorded therein. All significant events, observations, and any calculations shall also be recorded, along with the data and time of test, and name of technician.

7.0 NOTES:

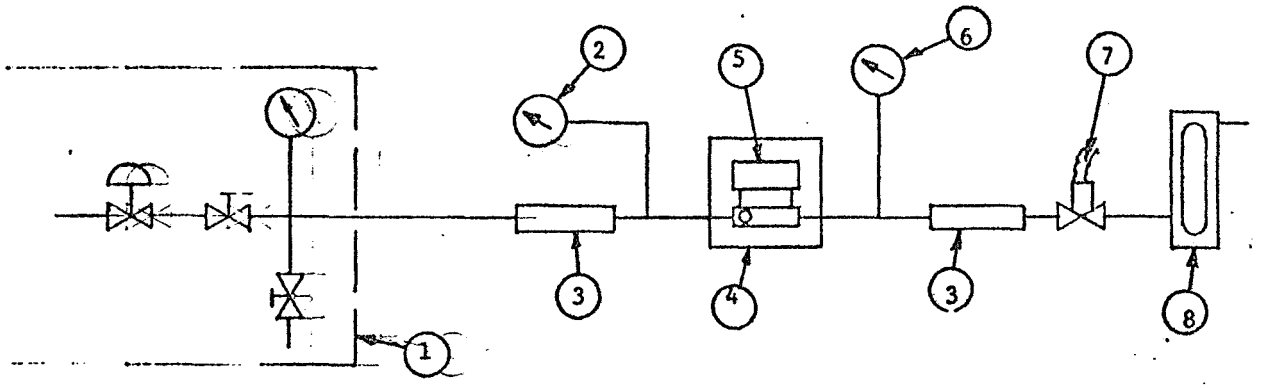
7.1 Test Interfaces

The inlet supplied with each regulator shall be 3/8 x .028 inch tubing, ultrasonically drawn, electropolished, and a minimum of six (6) inches long. It shall be type 304L stainless steel.

The outlet supplied with each regulator shall be 1/2 x .016 inch tubing, ultrasonically drawn, electropolished, and a minimum of six (6) inches long. It shall be type 304L stainless steel.

7.2 Test Set-up

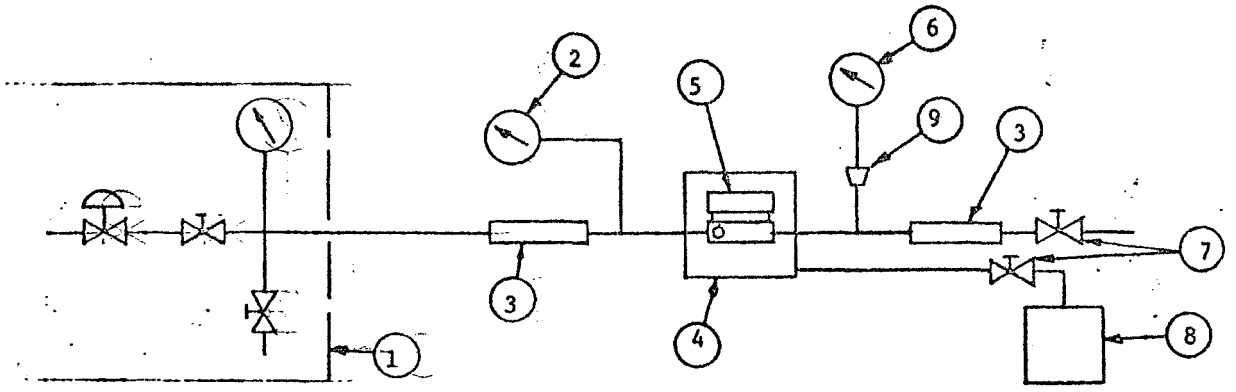
The four schematics are shown only to depict minimum test equipment requirements. They do not prohibit one overall test set-up to accomplish all tests.



Legend

1. Nitrogen pressure source
2. Pressure gauge 0-300 psi, Heise or equivalent
3. Filter -- 5 micron absolute or better
4. Leak Box Assembly - 243R136 or equivalent
5. Test specimen
6. Pressure gauge 0-30 psi, Heise or equivalent
7. Solenoid valve controlled by automatic cycling circuit
8. Flowmeter -- Fisher & Porter - 1.4 to 7.2 scfm or equivalent

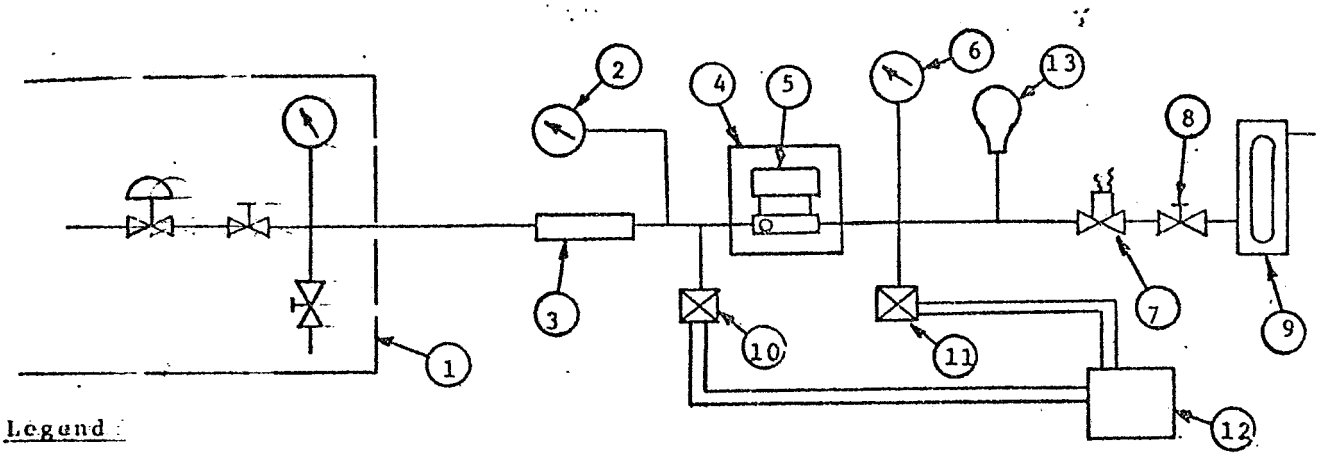
FIGURE 1: LIFE CYCLE SCHEMATIC



Legend

1. Helium pressure source
2. Pressure gauge 0-300 psi, Heise or equivalent
3. Filter -- 5 micron absolute or better
4. Leak Box Assembly - 243R136 or equivalent
5. Test specimen
6. Pressure gauge 0-50 psi, Heise or equivalent
7. Hand valve
8. Mass spectrometer CEC #24-120 or equivalent
9. Temperature sensor

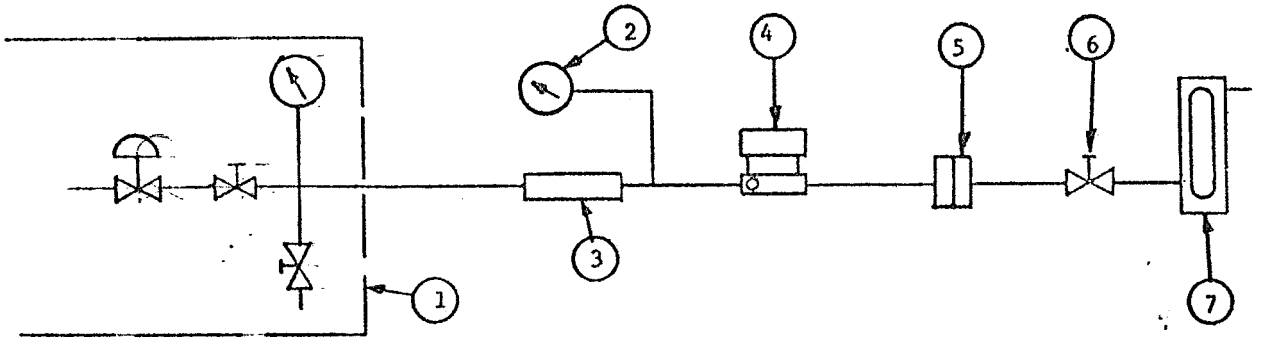
FIGURE 2: STATIC LEAKAGE SCHEMATIC



Legend :

1. Nitrogen pressure source
2. Pressure gauge 0-300 psi, Heise or equivalent
3. Filter - 5 micron absolute or better
4. Leak Box Assembly - 243R136 or equivalent
5. Test specimen
6. Pressure gauge 0-30 psi, Heise or equivalent
7. Solenoid valve
8. Hand valve
9. Flow meter - Fisher & Porter - 1.4 to 7.2 scfm or equivalent
10. Pressure transducer 0-300 psig
11. Pressure transducer 0-50 psig
12. Oscillograph
13. Volume - to total 40 in^3 downstream of regulator to solenoid valve

FIGURE 3: FLOW AND REGULATION SCHEMATIC



Legend :

1. Nitrogen pressure source
2. Pressure gauge 0-300 psi, Heise or equivalent
3. Filter, 5 micron absolute or better
4. Test specimen
5. Filter, 0.45 micron millipore
6. Hand Valve
7. Flowmeter - Fisher & Porter - 1.4 to 7.2 scfm or equivalent

FIGURE 4: CONTAMINATION CHECK

APPENDIX F

PREPARED BY		NUMBER
L. Gill	Code Ident No. 04577 CARLETON CONTROLS CORPORATION EAST AURORA, NEW YORK	CFT 426
APPROVALS		TYPE Acceptance Test Plan
ENG. L. Gill		DATE July 17, 1969
Q.C. L. Bracci		SUPERSEDES SPEC. DATED
CUSTOMER	SPECIFICATION	REV. LTR. / PAGE 1 OF 11
TITLE		

ACCEPTANCE TEST PLAN

FOR

REGULATOR

CCC P/N 1992 001 17-1

SECTIONS

1.0 Scope

2.0 Applicable Documents

3.0 Procedure

4.0 Data Sheets

92

1.0 Scope

This test plan establishes the conditions and procedures for the Acceptance Tests of the CCC 1992 001 17-1 Regulator.

2.0 Applicable Documents

2.1 CCC Drawing 1992 001 17-1

2.2 General Electric Purchase Order #028-G43280

3.0 Procedure

Note: All test data and approval signatures are to be recorded on data sheets in section 4.0 of this specification.

The filtered pressure fittings are not to be removed outside the clean room.

3.1 Visual Examination Visually inspect the unit for any defects in workmanship and conformance to drawing 1992 001 17-1. Mark acceptance on data sheet.

3.2 Cleanliness Check The unit cleanliness level shall be checked by flushing N_2 gas thru the unit and checking the particle as follows:

Particle Size (Microns)	Max. Count
0-25	No Requirement
25 or greater	None Allowable

There shall be no visible reflectivity of hydrocarbons per black light inspection.

3.3 Proof Pressure

3.3.1 Inlet Proof Pressure

Set up the Regulator as in Figure 1. Apply 300 ± 10 PSIG to the inlet of the Regulator with the outlet shut off and hold for ten (10) minutes.

NOTE

Monitor the outlet pressure gage. In the event of a leak, (thru the regulator) terminate test before outlet pressure reaches 30 PSIG.

3.3.2 Outlet Proof Pressure

Set up the Regulator as in Figure 2. Apply 90 ± 3 PSIG to the outlet of the regulator with the inlet valve shut off and hold for ten (10) minutes.

3.4 Leakage

3.4.1 External Leakage

Set up the regulator as in Figure 3. Apply 200 ± 7 PSIG pressure with helium gas to the inlet of the regulator. Leakage shall not exceed .05 scc/hr helium.

3.4.2 Internal Leakage

Set up the regulator as in Figure 4. Adjust the regulator outlet to 15 PSIG and apply 200 ± 7 PSIG helium pressure to the inlet of the regulator. Allow the outlet pressure to stabilize for 10 minutes. Then, note the change in outlet pressure over a 1/2 hour period.

Calculate the leakage per the formula on the data sheet. Leakage shall not exceed 2.0 scc He per hour.

3.5 Gas Flow & Lock-up Pressure Test

Set up the regulator as in Figure 5. Apply the conditions of Table I to the regulator. A minimum of one hour soak with the regulator at the indicated temperature is required before data is taken. Flow checks shall be a minimum of 30 seconds duration. Outlet pressure shall not vary more than ± .4 PSI about the nominal setting when the conditions for flow of Table I are applied and no more ± .1 PSI additional variation when the regulator is locked up. Total pressure tolerance at lock-up is ± .5 PSI about the nominal setting.

3.6 Cycling Test

Set up the regulator as in Figure 6. Apply 125 ± 10 PSIG to the inlet and set the regulator outlet pressure for 20 ± 1 PSIG nominal. Cycle the regulator for 10,000 cycles between zero and 90 ± 6 SLPM with a minimum two seconds between each cycle.

3.7 Repeat the test of 3.4 Leakage.

3.8 Repeat the test of 3.2 Cleanliness Check.

4.0 DATA SHEET

CCC P/N 1992 17-1

Tested by E. V. Karlinski

S/N 1

Date 7/16/69 - 7/24/69

Quality Control (CA 4)

4.1 Visual Examination test of paragraph 3.1

Acceptability? ok

4.2 Cleanliness Check of paragraph 3.2

Acceptability? ok

4.3 Proof Pressure test of paragraph 3.3

4.3.1 Inlet: Completed? ok

4.3.2 Outlet: Completed? ok

4.4 Leakage test of paragraph 3.4

4.4.1 External Actual Leakage 0

4.4.2 Internal Actual Leakage 0

Leakage = L = .136 $\triangle$ P · V.

$\triangle$ P = change in pressure gage reading over a 1/2 hour period.

V. = Internal downstream volume of regulator and test set up.

CARLETON CONTROLS CORPORATION

SPEC. NUMBER	REVISION LETTER	
CET 426		PAGE 7

4.5 GAS FLOW & LOCKUP PRESSURE TEST OF PARAGRAPH 3.5

Nominal Outlet Pressure Setting (PSIG)	Regulator Temperature °F	Inlet Pressure PSIG	Required Flow SLPM	Actual Outlet Pressure PSIG
15	+167°	50	0.0	15.05
			1.5	15.00
			50.0	14.85
			960	14.45
		200	0.0	15.00
			1.5	14.9
			50.0	14.87
			96.0	14.9
	-14°	50	0.0	14.95
			1.5	14.85
			50.0	14.65
			96.0	14.6
		200	0.0	14.95
			1.5	14.8
			50.0	14.65
			96.0	14.65
25	-14°	50	0.0	25.2
			1.5	25.0
			50.0	24.85
			96.0	24.8
		200	0.0	26.15
			1.5	24.95
			50.0	24.8
			96.0	24.8
	+167	50	0.0	24.9
			1.5	24.8
			50.0	24.7
			96.0	24.65
		200	0.0	24.85
			1.5	24.75
			50.0	24.7
			96.0	24.7

4.6 Cycling Test of paragraph 3.6

4.6.1 Before Cycling –

Flow	Outlet Pressure
0	19.9
90	19.7

4.6.2 Number of cycles completed 10,115

4.6.3 After Cycling –

Flow	Outlet Pressure
0	19.95
90	19.75

4.7 Leakage Test of paragraph 3.7

4.7.1 External Actual Leakage 0

4.7.2 Internal Actual Leakage 0

4.8 Cleanliness check of 3.8

Acceptability ok.

(1)

7/22/69

1992 17-1 Regulating Valve supporting data

W.O. 1992-14

R.V.K.

Due to vibration during cycling test, orifice inductance changed to 20 drill size. No vibration encountered so cycling test resumed.

Data prior to continuing cycling test.

Inlet press.	Outlet press.	0 Flow	96 LPM.
50.	15	15.0	14.8
200.	15	14.9	14.9
50.	25	24.9	24.66
200.	25	24.8	24.75

Unit reset to 19.9 PSI outlet pressure & cycling resumed

After completion of cycling test.

Inlet	Outlet	0 Flow	92
50.	20	19.95	19.75
200.	20	19.95	19.8.

3)

7/22/69

R.V.K.

Additional performance tests were conducted due to change of orifice. Unit reset to 15 PSI Outlet Press.

Room temp.

Inlet Press	Outlet Press Setting	Flow 0	96 LPM.
50	15	15.05	14.95
200	15	15.0	14.95

Cold temp -14°F

50	15	15.0	14.85
200	15	14.95	14.85

Hot temp +167°F

50	15	15.15	15.0
200	15	15.1	15.05

July 23, 1969

General Electric Company
Valley Forge Space Technology Center
Goddard Boulevard
King of Prussia, Pennsylvania

Reference: PO# 028-G43280
1 Each 1992-001-17-1 Regulator S/N 1
Carleton Invoice # 4613

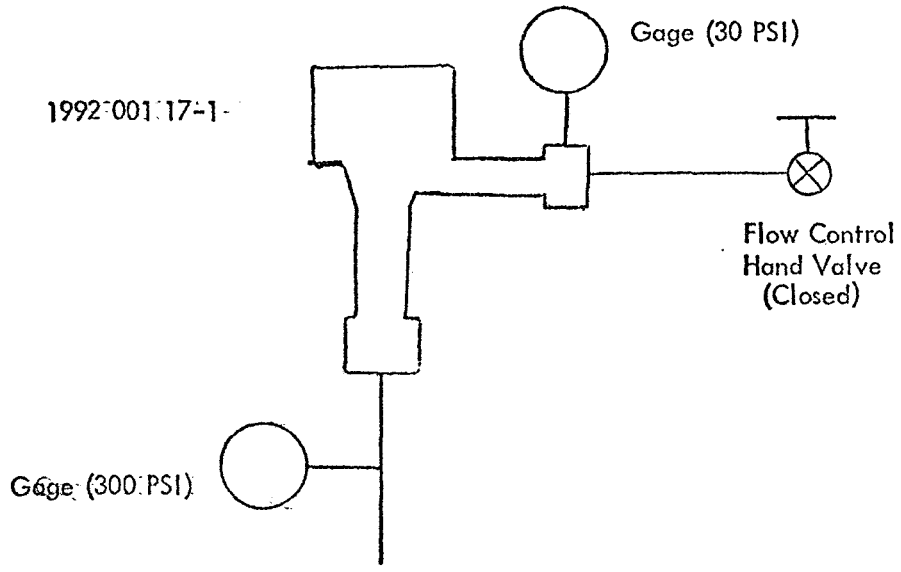
C E R T I F I C A T I O N

The Carleton Controls Corporation certifies that material shipped on General Electric purchase order #028-G43280 on Carleton Invoice # 4613 on July 23, 1969 conforms to all purchase order drawing and specification requirements. Manufacturers certification of materials used are available for review.

CARLETON CONTROLS CORPORATION

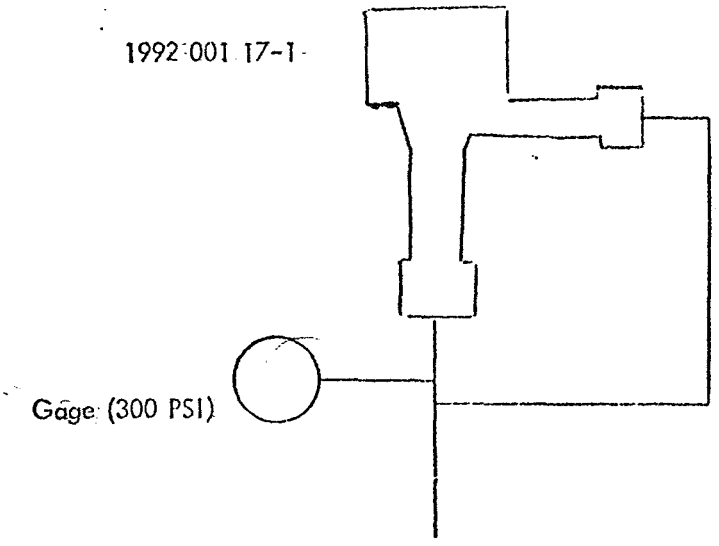
A. Bracci
Quality Control Manager

st:



300 ± 10 PSIG

FIGURE 1



90 ± 3 PSIG

FIGURE 2

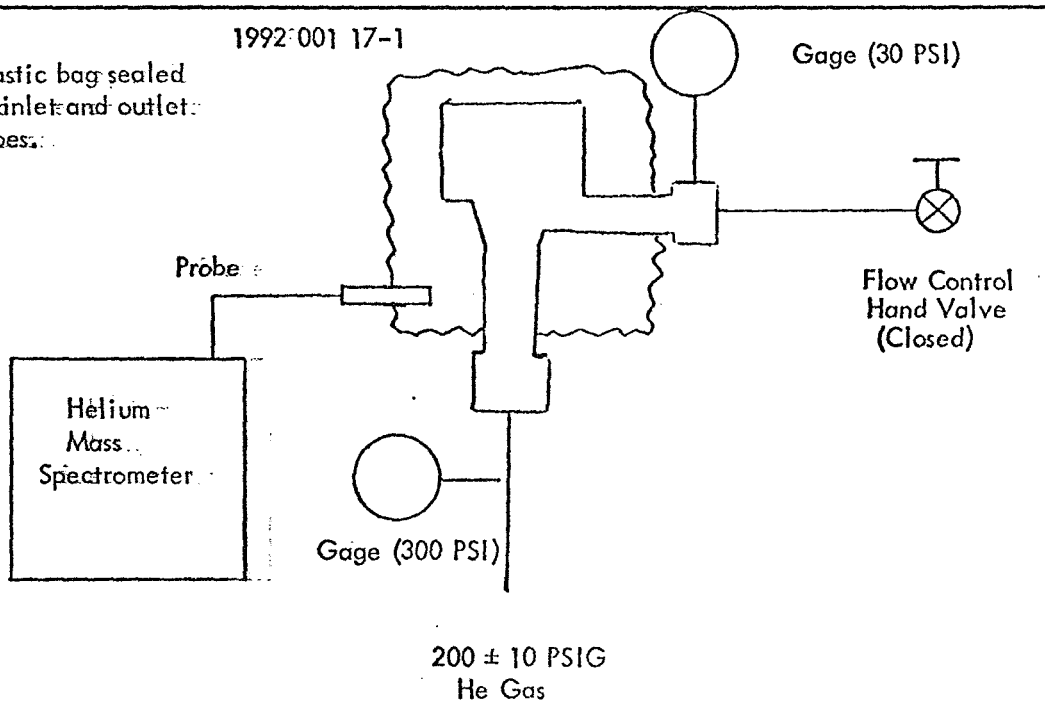


FIGURE 3

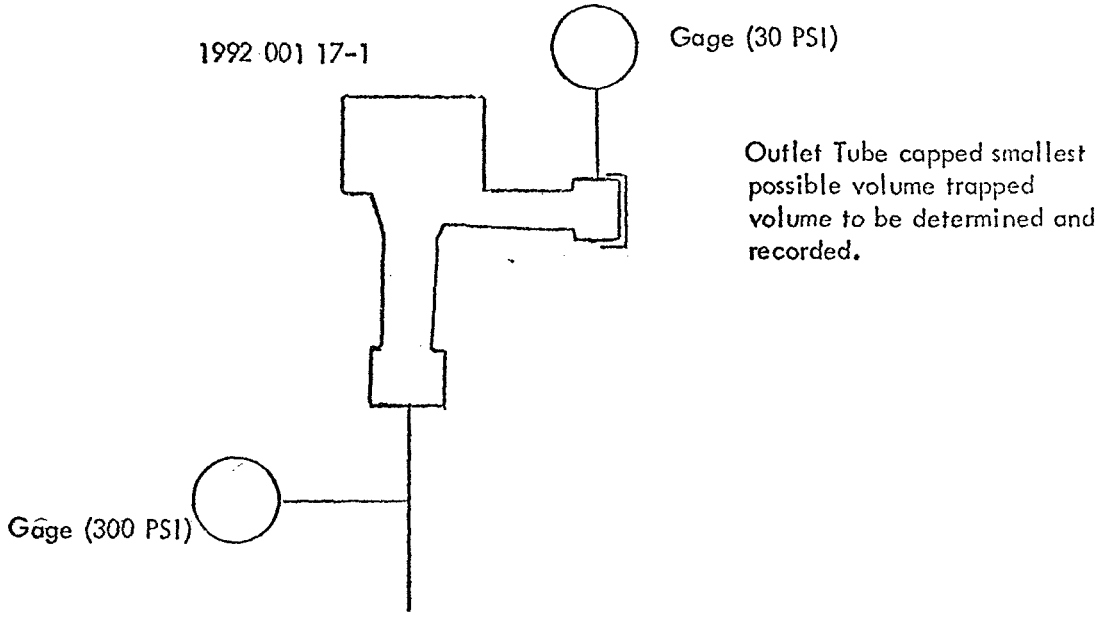


FIGURE 4

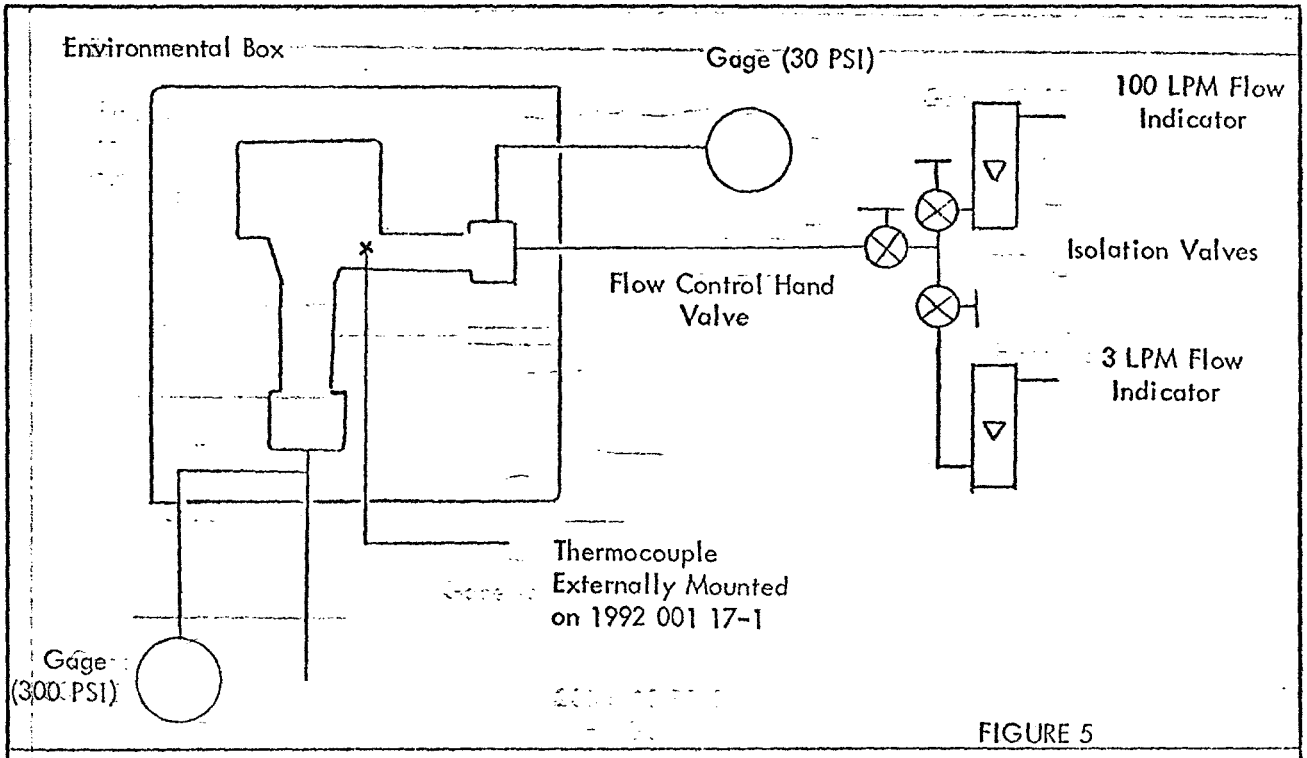


FIGURE 5

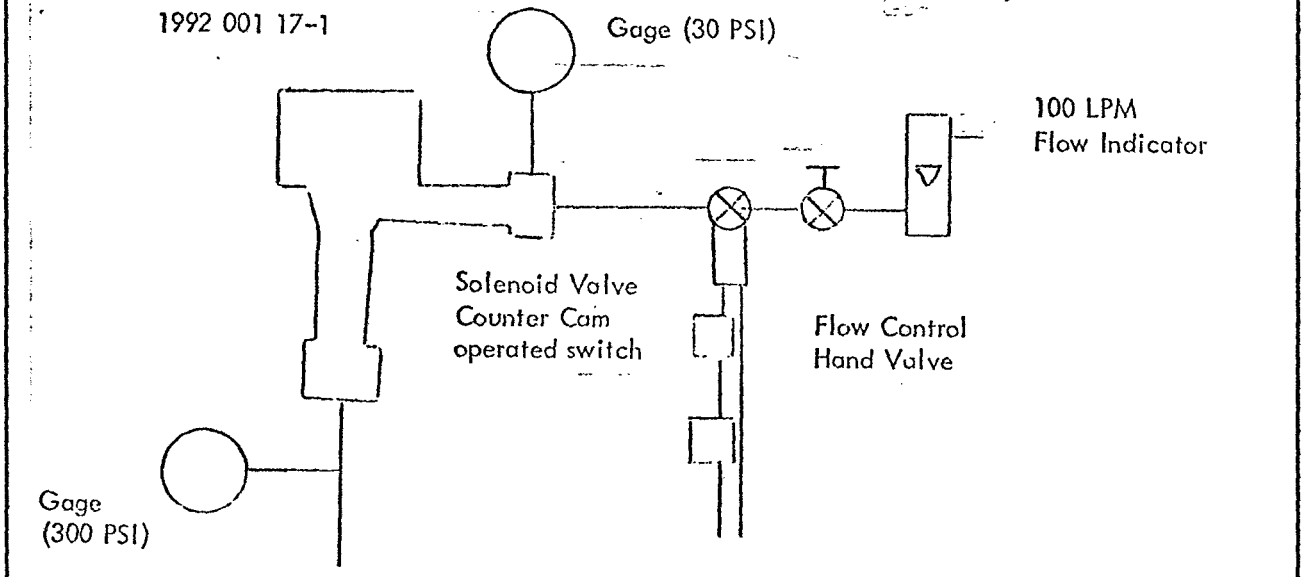


FIGURE 6

APPENDIX G

STEARER ENGINEERING & MANUFACTURING CO.

4690 COLORADO BOULEVARD • LOS ANGELES, CALIFORNIA 90039

COMPLETED UNIT NOTIFICATION

NEW VALVES [X] CUSTOMER SERVICE [ ]

C.S.O. NO. _____

PART NO. 37020 QTY. 1 DATE 6-18-69

SERIAL NOS. 1

PREPARED BY _____

SHIPMENTS

(To be determined by Contracts Dept.)

Qty	Serial Nos. From	Thru	Customer	Purchase Order No.	Via / Prepaid or Collect	Date	Shipper No.
1	1		G.I.	P-24-6-43371	UPS	6/26/69	53118

SE227

STIERER ENGINEERING AND MANUFACTURING CO.

4690 COLORADO BOULEVARD • LOS ANGELES, CALIFORNIA 90039

FUNCTIONAL TEST REPORT

PART No. 37020 QUANTITY 1

PART NAME Regulator, Pneumatic DATE 6-10-69

CUSTOMER G.E. P.O. No.

SHIPPER No. SERIAL No. #1

VALVE NO.	SERIAL NO.		INLET	OUTLET			
Proof	Press.	O.K.	300 PSI	90 PSI			
Regulation:		PER ATTACHED.					
Leakage:		INTERNAL - @ 60 PSI inlet			- .3 cc/HR		
		@ 200 PSI "			- -0-		
Unit cycled 10,000 with 200 PSI inlet & Flow 96,000 sccm.							
AT 1 cps							
Leakage	AFTER 10,000			@ 60 PSI inlet	- 1.5 cc/HR		
"	"	"	"	@ 200 " "	- -0-		
External	Leakage		INLET 200 Helium	OUTLET 12 PSI MAX.	= -0-		

CURE DATE ASSEMBLY DATE

IN PROCESS INSPECTION	FUNCTIONAL TESTS	FINAL INSPECTION
Approved	Approved	Approved

G-2

SE 706-A

−14°F.

	Inlet	Outlet	Lock-up
1500 SCCM Flow	200 Psi	16.0	16.15
"	50 "	16.6	16.65
60,000 SCCM Flow	200 "	15.55	16.15
	50 "	15.70	16.70
96,000 " "	200 "	15.00	16.00
	50 "	14.80	16.70

+167°F.

1500 SCCM Flow	200	15.2	15.55
"	50	15.8	16.25
50,000 " "	200	14.8	15.65 ⇔ VARIABLE outlet
"	50	15.4	16.4
96,000 " "	200	14.85	15.8
"	50	14.60	16.35

ROOM TEMP. (AFTER cold + HOT Regulation)

1500 " "	200	15.8	15.95
" "	50	16.3	16.45
60,000 " "	200	15.5	15.95
	50	15.45	16.50
96,000 " "	200	14.85	15.80 ⟷ VARIABLE
" "	50	14.55	16.50

GENERAL ELECTRIC

SPACE DIVISION

SPACE SYSTEMS ORGANIZATION