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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA PROGRAM APOLLO WORKING PAPER

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SUBSYSTEM ASSESSMENT

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MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

June 1971

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COMMAND MODULE/SERVICE MODULE REACTION CONTROL SUBSYSTEM ASSESSMENT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
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SECTION 1

INTRODUCTION AND DESCRIPTION

SUMMARY

The information presented in this Working Paper is a result of a detailed assessment of the Apollo Command and Service Module Reaction Control Subsystems. The review was conducted during July and August, 1970. Detailed review of component failure histories, qualification adequacy, manufacturing flow, checkout requirements and flow, ground support equipment interfaces, subsystem interface verification, protective devices, and component design did not reveal major weaknesses in the Command Service Module (CSM) Reaction Control System (RCS). No changes to the CSM RCS were recommended. The assessment reaffirmed the adequacy of the CSM RCS for future Apollo missions.

INTRODUCTION

This paper is a review of Apollo Command and Service Module Reaction Control Subsystem assessment. The review was a part of the general Apollo Program assessment conducted during July and August, 1970. The results of the review were reported in a viewgraph presentation to NASA Headquarters. The presentation was a brief summary of the areas reviewed. Background data was not presented or discussed. Background data consisted of flight performance summaries, component failure histories, component qualification and configuration histories, component manufacturing and checkout flows, component checkout requirement histories, summaries of all Ground Support Equipment and Special Measurement Devices (SMD) interfacing with the spacecraft hardware, summaries of the subsystem protective devices, and a complete component design manual.

This Working Paper will preserve and be a reference for the data gathered for the subsystem assessment. Viewgraphs used for the visual presentation are the figures and tables in this Working Paper. The sequence of subjects follows that used for the viewgraph presentation. The subjects and component data are presented using the Service Module RCS as the baseline. The Command Module RCS information is presented as a delta to the Service Module data. Specific data on each component in the CSM RCS is listed in the table of contents.

Figure 1-1 introduces the Service Module Reaction Control Subsystem. Figure 1-2 is an illustration of the Service Module Reaction Control Subsystem (SM RCS) panel assembly (quad). Figure 1-3 is the functional flow diagram of the SM RCS.

INTRODUCTION

- SM REACTION CONTROL SUBSYSTEM (RCS) CONSISTS OF FOUR INDEPENDENT HELIUM PRESSURE FED POSITIVE PROPELLANT EXPULSION ROCKET PROPULSION SYSTEMS CALLED 'QUADS'
- SYSTEM FUNCTIONAL CRITICALITY IS II.
  - QUAD REDUNDANCY PERMITS ACCOMPLISHING MISSION REQUIREMENTS WITH THREE QUADS OPERATIONAL.
- SM RCS IS ACTIVATED ON PAD BUT NOT USED UNTIL S-IVB JETTISON. IT CONTROLS SPACECRAFT RATES, ROTATION, AND MINOR TRANSLATIONS IN ALL AXES.
- PROPELLANTS ARE EARTH STORABLE HYPERGOLICS - MONOMETHYL HYDRAZINE FUEL AND N_2O_4 OXIDIZER

Figure 1-1.- Service Module Reaction Control Subsystem.

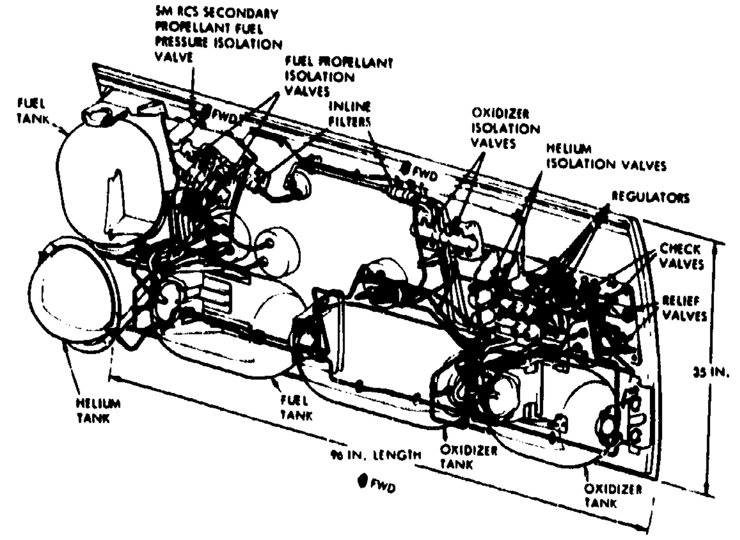

Figure 1-2.- Service Module Reaction Control Subsystem Panel Assembly.

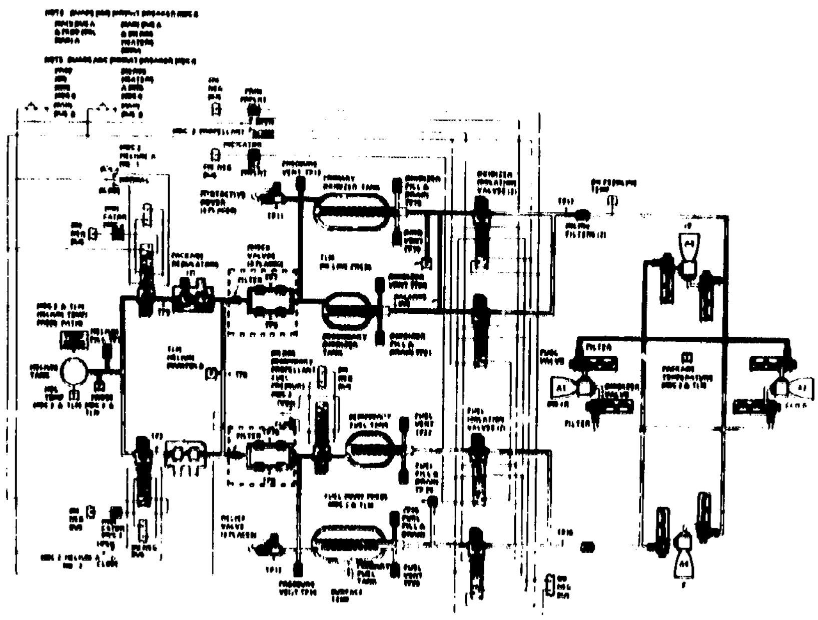

Figure 1-3.- Service Module Reaction Control Subsystem Functional Flow.

Figure 1-4 introduces the Command Module Reaction Control Subsystem (CM RCS). Figure 1-5 shows the component location on the CM RCS and figure 1-6 is a functional flow diagram of the CM RCS.

INTRODUCTION

- CM REACTION CONTROL SUBSYSTEM CONSISTS OF TWO INDEPENDENT HELIUM PRESSURE FED POSITIVE PROPELLANT EXPULSION ROCKET PROPULSION SYSTEMS
- SYSTEM FUNCTIONAL CRITICALITY IS II
  - REDUNDANT SYSTEMS - EACH CAPABLE OF ACCOMPLISHING MISSION REQUIREMENTS INDEPENDENTLY
- CM RCS IS DORMANT FOR MISSION UNTIL ONE HOUR BEFORE CM/SM SEPARATION ON ENTRY. IT CONTROLS CM RATES AND ROTATION. FOR ABORT, AUTOMATIC PROPELLANT JETTISON IS PROVIDED
- PROPELLANTS ARE EARTH STORABLE HYPERGOLICS - MONOMETHYL HYDRAZINE FUEL AND N_2O_4 OXIDIZER

Figure 1-4.- Command Module Reaction Control Subsystem.

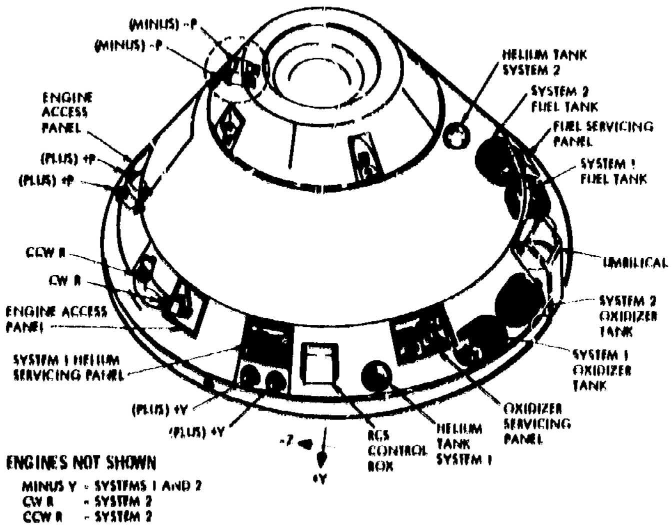

Figure 1-5.- Command Module Reaction Control Subsystem component location.

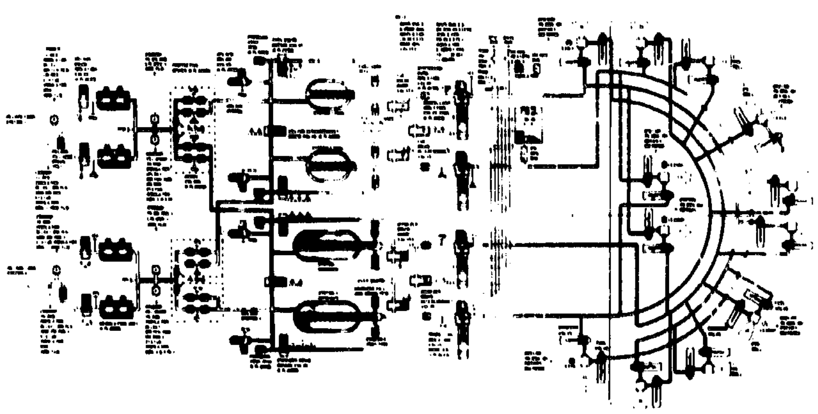

Figure 1-6.- Command Module Reaction Control Subsystem functional flow.

Figures 1-7, 1-8, and 1-9 show the installation of oxidizer, fuel, and helium systems on the Command Module.

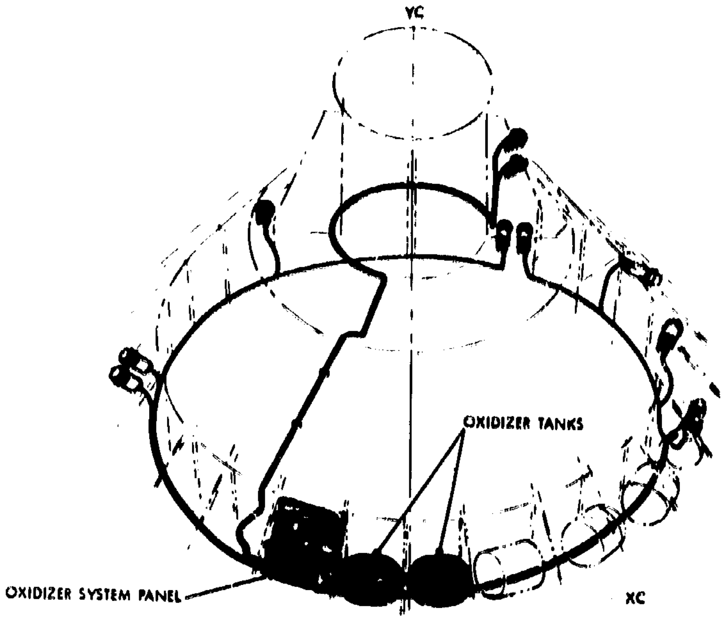

Figure 1-7.- CM RCS oxidizer installation.

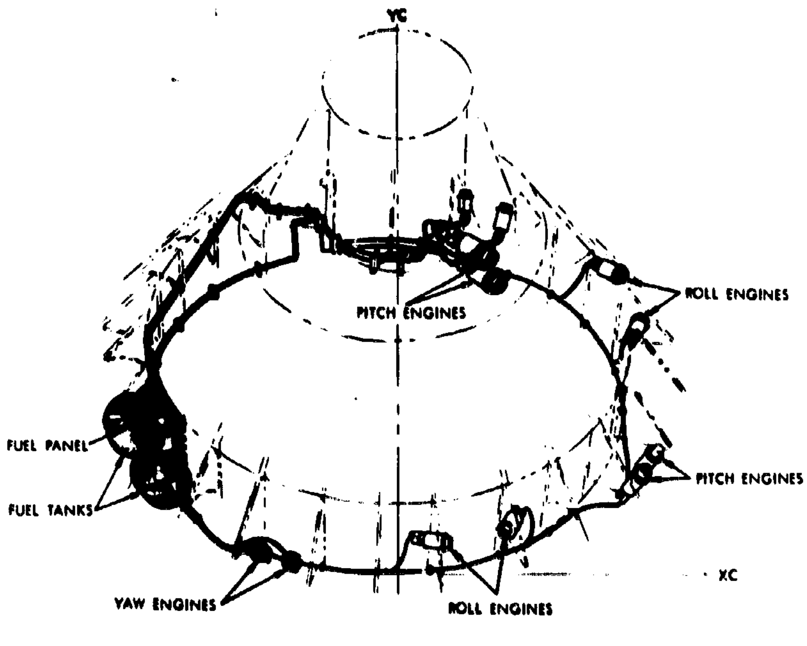

Figure 1-8.- CM RCS fuel installation.

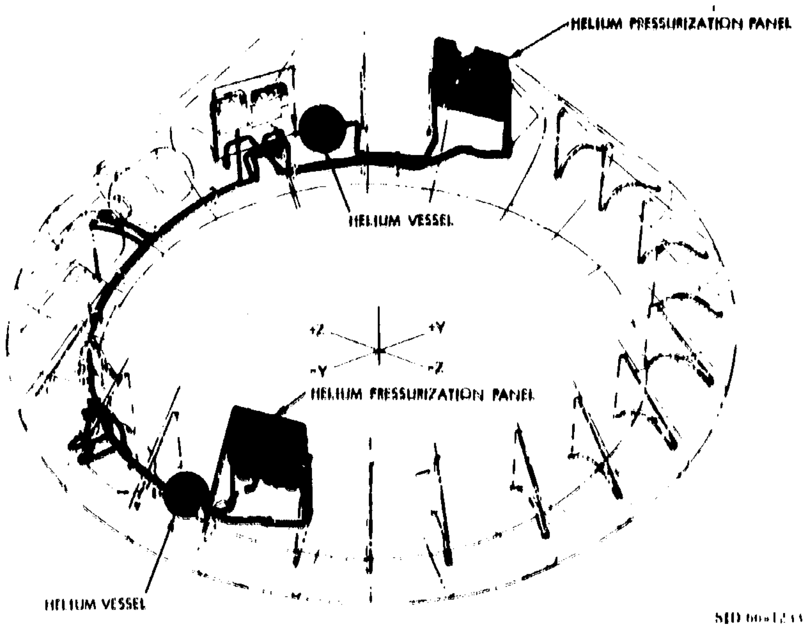

Figure 1-9.- CM RCS helium installation.

SECTION 2

PERFORMANCE HISTORY SUMMARY

HISTORY, EXPERIENCE, AND PROBLEMS

Figure 2-1 presents the performance history of the Command Module/Service Module Reaction Control Subsystem.

PERFORMANCE HISTORY

	SERVICE MODULE	COMMAND MODULE
● MISSION EXPERIENCE		
• TOTAL SYSTEM FLIGHT TIME	1,355 HOURS	1,361 HOURS
• TOTAL ENGINE OPERATION		
– FIRING TIME	15,100 SECONDS	1,325 SECONDS
– VALVE CYCLES	385,000	6,400
● DEVELOPMENT/CTR EXPERIENCE		
• TOTAL SYSTEM TEST TIME	1,440 HOURS	456 HOURS
• TOTAL ENGINE OPERATION		
– FIRING TIME	471,300 SECONDS	24,000 SECONDS
– VALVE CYCLES	1,041,090	51,290
● MISSION FAILURE EXPERIENCE		
• TOTAL HARDWARE	2	5
• TOTAL ELECTRICAL	0	5
• TOTAL INSTRUMENTATION	9	0

Figure 2-1.- Command Module/Service Module Reaction Control Subsystem.

Figure 2-2 presents the Service Module Reaction Control System flight experience details.

MISSION	ENGINE FIRINGS	BURN TIME, SEC	PROPELLANT USED, LB
201	—	—	—
202	17 000	725	260
A 4	16 000	610	220
A 6	18 000	1 015	365
A 7	60 000/8 *	2 640/1 145 *	875/425 *
A 8	46 000/8 *	1 600/1 795 *	634/666 *
A 9	57 000/8 *	2 000/1 375 *	790/510 *
A 10	43 000/8 *	1 500/1 940 *	580/720 *
A 11	44 000/8 *	1 550/1 915 *	590/710 *
A 12	60 000/8 *	2 650/1 140 *	870/400 *
A 13	23 000/3 *	810/60 *	320/22 *
TOTAL	384 000/53	15 100/9 370	5 504/3 413

* steady-state

Figure 2-2.- Service Module Reaction Control System flight experience details.

Flight experience details for the Command Module Reaction Control System are shown on figure 2-3.

MISSION	ENGINE FIRINGS	BURN TIME, SEC	PROPELLANT USED, LB
201	500	250	90
202	500	180	65
A 4	500	128	50
A 6	500	128	50
A 7	829	128	50
A 8	825/10 *	99/496 *	35/175 *
A 9	499/10 *	80/516 *	28/182 *
A 10	545/10 *	101/504 *	32/178 *
A 11	800/10 *	100/500 *	30/180 *
A 12	800/10 *	99/545 *	30/180 *
A 13	900/10 *	130/510 *	52/168 *
TOTAL	5 498/60 *	1 423/3 071	512/1 063

* steady-state

Figure 2-3.- Command Module Reaction Control System flight experience details.

Flight problems of the Command Module/Service Module Reaction Control System are shown on figure 2-4.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

FLIGHT PROBLEMS

SPACECRAFT 009	(1) -Y SERVICE MODULE RCS ENGINE INOPERATIVE (AUTO COILS)
	(2) QUAD A FAILED TO OPERATE BECAUSE OF MALFUNCTION IN OXIDIZER ISOLATION VALV`` (VALVES FROZEN CLOSED)
	(3) COMMAND MODULE REACTION CONTROL SYSTEM OXIDIZER ISOLATION VALVES FAILED TO CLOSE (FROZEN OPEN)
	(4) FUEL BYPASS VALVES INCORRECTLY WIRED
SPACECRAFT 011	(1) RUPTURED CM RCS BURST DIAPHRAMS - PNEUMATIC ACTIVATION TRANSIENT RUPTURED THE DIAPHRAMS
SPACECRAFT 017	(1) RESIDUAL PRESSURE IN CM RCS AFTER LANDING AND PURG· OPERATION - BUFFER PAD RESTRICTED GAS FLOW OUT OF THE TANKS
SPACECRAFT 020	(1) QUAD C QUAD TEMPERATURE AND QUAD C ROLL ENGINE INJECTOR TEMPERATURE MALFUNCTIONED
	(2) CM RCS OXIDIZER AND FUEL VALVES OF ALL FOUR YAW ENGINES WERE CROSS-WIRED, FUEL AND OXIDIZER LEAD WIRES REVERSED

Figure 2-4.- Command Module/Service Module Reaction Control System Flight Problems.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

FLIGHT PROBLEMS

SPACECRAFT 101	(1) QUAD B P/T GAGE FAILED
	(2) CM PROPELLANT ISOLATION VALVE DAMAGED. SYSTEM WAS ACTIVATED WHILE VALVE WAS CLOSED
SPACECRAFT 103	NONE
SPACECRAFT 104	(1) FIRST SHOCK CLOSURE OF PROPELLANT ISOLATION VALVE ON THE SM RCS
	(2) QUAD B HELIUM TANK PRESSURE TRANSDUCER ERRATIC
SPACECRAFT 106	(1) CM RCS PRIOR TO LAUNCH - a) SYSTEM 1 HELIUM LEAK (NOT FOUND) b) SYSTEM 2 RUPTURE PROPELLANT ISOLATION VALVE
	(2) QUAD D HELIUM MANIFOLD INSTRUMENTATION DRIFT
SPACECRAFT 107	(1) ISOLATION VALVES SHOCKED CLOSED
	(2) CM ENGINE FAILURE AUTO COILS (TERMINAL BOARD)

Figure 2-4.- Continued.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

FLIGHT PROBLEMS

SPACECRAFT 108 - (A12)	(1)	FOUR P/T FAILED DUE TO LIGHTING STRIKE
	(2)	HELIUM ISOLATION VALVES SHOCKED CLOSED
SPACECRAFT 109 - (A13)	(1)	CM FUEL ISOLATION VALVE WIRED INCORRECTLY
	(2)	ISOLATION VALVES SHOCKED CLOSED
	(3)	INDUCED REVERSE POLARITY CURRENT IN CM RCS PROPELLANT ISOLATION VALVES

Figure 2-4.- Concluded.

Figure 2-5 delineates the development history of the Apollo Reaction Control System. A graphic display of the periods of time during the development of the Service Module Reaction System is shown on figure 2-6. Command Module Reaction Control System is on figure 2-7. Figure 2-8 gives the dates for Apollo unmanned flight tests.

GROUND TEST HISTORY

Apollo RCS Development History
(Subsystem Level Tests)

COMMAND MODULE RCS

1. Breadboard Phase I, Block I

Start: March 1963

Complete: September 1963

Objectives - Cold-flow tests to evaluate:

1. Steady state and pulse mode single and multiengine operation
2. Bladder efficiency test
3. Mission profile

Results -

1. Redesign of regulators required due to CM RCS system design pressure increase of 100 psi over SM RCS
2. Helium tank nickel plating dislodging caused system contamination
3. CM RCS engine leakages at weld joints

Figure 2-5.- Apollo Reaction Control System Development History (ground test history at the subsystem level).

2. Breadboard Phase II, Block I

Start: September 1963

Complete: July 1964

Objectives - Initial cold flow followed by hot-fire tests

1. Duty cycle tests
2. Water hammer test
3. Steady state and pulse mode single and multiengine firing
4. Pad abort dump
5. Mission duty cycle
6. Decontamination

Results -

1. Overpressure during activation resulted in relief valve burst disc rupture
2. Accumulated system pressure profile data and performed initial evaluation of engine hot-fire system response

Figure 2-5.- Continued.

3. Breadboard Phase III, Block I

Start: September 1965

Complete: November 1966

A. CM 009 Mission Duty Cycle - S/C 009 Mission Certification

Objectives - Complete system hot-fire tests

1. Perform CM 009 simulated mission

2. Certify total system for S/C 009 mission

Results -

1. National Waterlift (NWL) propellant isolation valves closed during activation

Resolution - Apply electrical signal to valves during activation

2. Regulator over shoot allows rupture of relief valve burst disc

Resolution - Decreased regulator inlet orifice from .07 to .055 in.

B. CM 012 Pad Abort

Objectives -

1. System activation

2. Depressurize ullage pressures and dump oxidizer

Results -

1. Helium depletion time excessive
Instrumentation fitting caused obstruction

2. Oxidizer dump time exceeds requirements
Bladder folds during dump obstructing flow

Figure 2-5.- Continued.

C. CM 012 Mission Duty Cycle

Objectives –

1. Demonstrate CM 012 mission duty cycle system operation

2. Verify regulator orifice change (to 0.055 from 0.07 in.) as fix to regulator overshoot

3. Verify redesigned propellant valves

4. Verify PV check for loading

Results –

1. S/C 012 MDC successful

2. Possibility of burst disc rupture still exists with .055 orifice

3. Redesigned propellant isolation valves performed satisfactorily

4. CM RCS Flight Worthiness Demonstration Test (FWDT), Block I

Start: April 1964

Complete: September 1965

Objective – Support S/C 009 mission

1. Evaluate system operation with updated hardware

2. Evaluate system servicing techniques and checkout procedures

Results –

1. Servicing procedures developed with use of SM RCS quad

2. Checkout techniques developed

Figure 2-5.- Continued.

5. CM RCS Block II Breadboard

Start: January 1967

Complete: March 1967

Objectives -

1. Certify system operation during Block II mission simulation

2. Certify pad abort

Results -

1. System certified for Block II missions

2. Pad abort certified for Block II missions

3. Pressure recovery to 200 psi 30 seconds after initiation of purge due to antiabrasion pad acting as check valve.

   Resolved by punching holes in the pads to allow trapped gas out

4. Resolution of relief valve burst disc rupture problem - helium sensing line rerouted to the relief valves

CM RCS Miscellaneous Ground Tests

1.	Engine Boost Protective Cover Tests	February 1966
2.	CM RCS System Activation Tests	April 1966
3.	CM RCS Decontamination Tests	August 1966
4.	CM RCS Fuel Disposal Fitting Test	February 1967
5.	CM RCS Gas Flow Evaluation Test	April 1967

Figure 2-5.- Continued.

SERVICE MODULE RCS

1. Breadboard Phase I, Block I

   Start: March 1963

   Complete: June 1963

   Objectives - Cold flow tests to evaluate:

   1. Steady state and pulse mode single and multiengine firing
   2. Bladder expulsion test
   3. Simulated mission sequence

   Results -

   1. SM RCS tank bladder failed leak test
   2. SM RCS engine excessive leak

2. Breadboard Phase II, Block I

   Start: April 1964

   Complete: July 1965

   A. System hot-fire tests with PQGS

      Objectives -

      1. Functional checkout procedures
      2. System calibration
      3. Prove design concepts
      4. Propellant fill and drain technique

Figure 2-5.- Continued.

Results -

1. PQGS improper operation - temperature sensitive

2. Explosion in engine internal stand-off
   Engine redesign beefed up stand-off

B. Leak and Functional C/O after Phase II Test -

Objective -

1. Determine system status at completion of Phase II test

Results -

1. Oxidizer and fuel bladders showed excessive leakage
   Liquid-side vent change eliminated requirement for much bladder cycling

3. Breadboard Phase III

Start: November 1965

Complete: December 1966

A. SM 009 Mission Duty Cycle

Objective -

1. Support S/C 009 mission

Results -

1. Certified SM RCS for S/C 009 mission

B. SM 012 Mission Duty Cycle with PVT (Quantity Gaging System)

Objectives -

1. Certify SM RCS for S/C 012 mission

2. Evaluate backup system (PVT) to PQGS

Figure 2-5.- Continued.

Results -

1. SM RCS certified for S/C 012 mission

2. PQGS improper operation

   Resolution - PQGS eliminated in favor of PVT

4. SM RCS Block II Breadboard (S/C 101, 103)

   Start: December 1966

   Complete: March 1967

   Objectives -

   1. Certify servicing procedure

   2. Certify PVT system

   3. Perform Block II mission simulation

   Results -

   1. Burst disc rupture

      Resolution - Reroute of helium pressure sensing line

   2. P/T sensor propellant gaging accuracy low

      Resolution - Recommended nomograph for correction

   3. Certification of Block II flights satisfactory

5. SM RCS Block II Breadboard (S/C 102, 104, 106 and Subs)

   Start: January 1967

   Complete: March 1968

Figure 2-5.- Continued.

Objectives -

1. Certify modification to SM RCS to reduce gaging uncertainty (VW valve mod.)
2. Certify modification to eliminate burst disc rupture
3. Establish Cape Kennedy propellant manifold decontamination procedures

Results -

1. Certification satisfactory
2. Resolved helium ingestion "bubble growth" problem
3. Made "balance line" change to permit ullage for secondary system oxidizer tank
4. Establish switchover time available from primary to secondary system
5. Recommended decontamination procedure to Cape Kennedy

6. SM RCS Block II Breadboard (S/C 106 and subs.)

Start: October 1968

Complete: March 1969

Objectives -

1. Demonstrate SM RCS capability to sustain propellant exposure for 90 days
2. Determine minimum launch pad support during a launch hold over a 90 day period
3. Demonstrate extended mission (103 days) propellant exposure capability

Figure 2-5.- Continued.

Results –

1. System capability of successfully sustaining long periods of propellant exposure was demonstrated

2. Support procedures for use during launch delay periods on the pad were developed

3. The system operated successfully after extended mission (103 days) propellant exposure

Figure 2-5.- Continued.

SM RCS Supporting Ground Tests

1.	Fill, Drain and Decontamination Test, Phase III	July 1965
2.	Propellant Tank Exposure Test	July 1965
3.	SM RCS System Activation with Simulated Propellant	August 1965
4.	SM RCS Production Quad Acoustic Test	November 1965
5.	Propellant Quantity Gaging System Test	December 1965
6.	PQGS Back-up System Test	May 1966
7.	SM RCS Block I Propellant Quantity Determination, PVT Phase III	August 1966
8.	Acoustic Test - Unitized Housing	August 1966
9.	SM RCS Activation Tests, Phase III	September 1966
10.	S/C 008 Thermal Vacuum Tests (Block I)	October 1966
11.	SM RCS Block II Quad Acoustic Test	March 1967
12.	SM RCS Block II System Activation	June 1967
13.	SM RCS Engine Cluster Thermal Vacuum Test	July 1968
14.	Thermal Vacuum Tests (Block II), 2TV-1	September 1968

Figure 2-5.- Concluded.

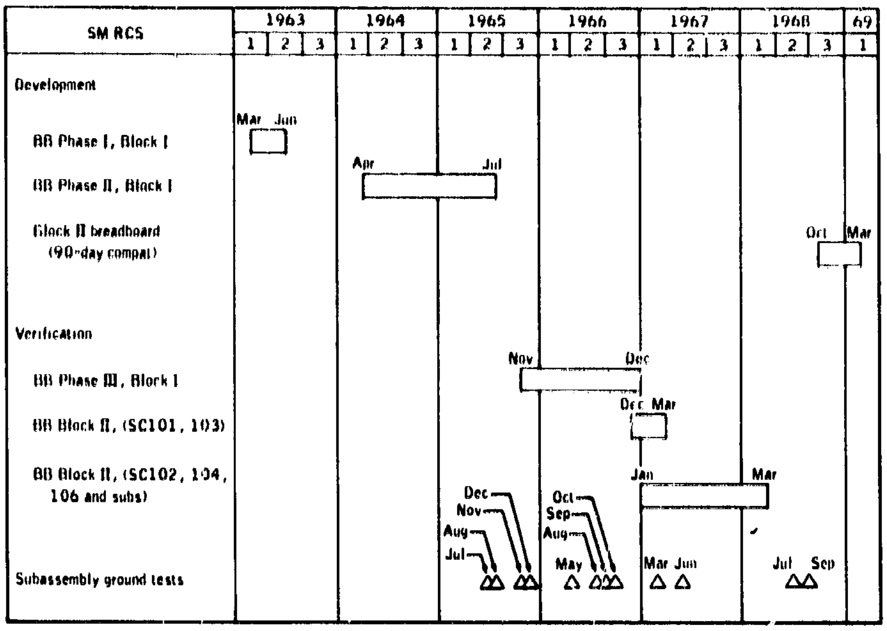

Figure 2-6.- Apollo RCS development history (SM).

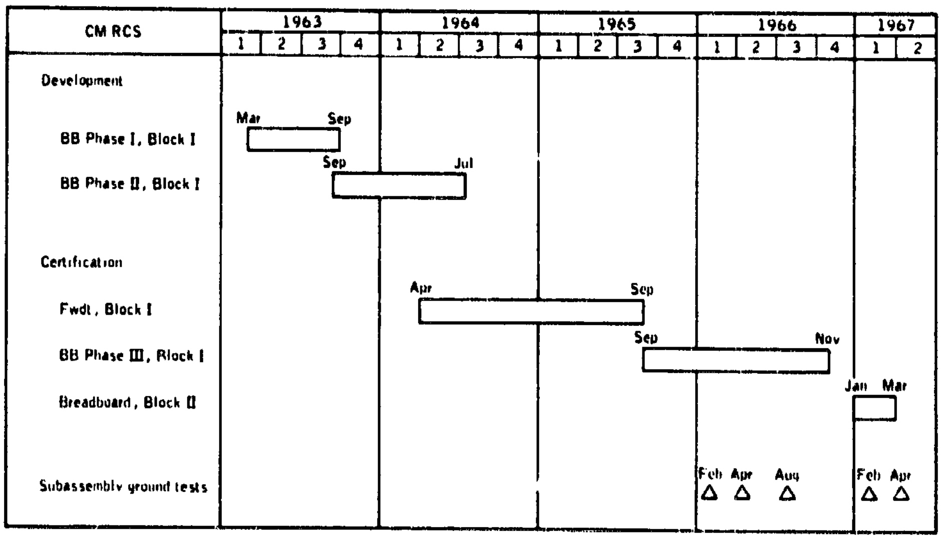

Figure 2-7.- Apollo RCS development history (CM).

CM - SM RCS Unmanned Flight Tests

1.	BP-15	Thermal-Vibration Evaluation	July 1964
2.	BP-26	Thermal Evaluation	June 1965
3.	BP-9	Thermal Evaluation	August 1965
4.	S/C 002	Vibration Evaluation	February 1966
5.	S/C 009	First System Functional Test	February 1966
6.	S/C 011	System Functional Test	September 1966
7.	S/C 017	System Functional Test	November 1967
8.	S/C 020	System Functional Test	April 1968

Figure 2-8.- Dates for the Apollo unmanned flight tests.

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FLIGHT PERFORMANCE HISTORY

This part of Section 2 summarizes by flight the performance of the Command Service Module (CSM) Reaction Control Subsystem (RCS) through the flight of Apollo 11. Information will include a performance evaluation, configuration description, anomalies within or affecting the CSM RCS, and changes in hardware which influenced subsequent hardware design.

MISSION A-004 (SPACECRAFT 002) COMMAND SERVICE MODULE RCS FLIGHT PERFORMANCE

Mission A-004 (Spacecraft 002) was launched with a Little Joe II vehicle January 20, 1966, at White Sands Missile Range (WSMR). The main objective of the mission was to subject the CM to a power-on tumbling abort.

The secondary objective was to determine vibration levels on the SM structure and SM RCS. Results of acoustic and vibration tests on the SM structure at North American Rockwell (NR) and results of the RCS flight data from BP15 caused concern. Consequently, one quad on Spacecraft 002 was instrumented with six vibration sensors; two on the forward engine, two on the counterclockwise (CCW) engine, one on the panel, and one on the oxidizer tank support. The results of the flight indicated vibration levels were nominal.

MISSION AS-201 (SPACECRAFT 009) CSM RCS FLIGHT PERFORMANCE

Mission AS-201 (Spacecraft 009) was the first flight test of a production Apollo Block I type spacecraft using the Saturn IB launch vehicle. Lift-off of the unmanned suborbital flight from launch complex 34, Cape Kennedy, Florida, occurred at 11:12 a.m. e.s.t., 16:12 G.m.t., February 26, 1966. The spacecraft CM landed safely in the primary landing area near Ascension Island approximately 37 minutes later (16:49 G.m.t.) and was recovered.

The major spacecraft mission objectives were to demonstrate the compatibility and structural integrity of the spacecraft/Saturn IB configuration and to evaluate the spacecraft heat shield during reentry.

Performance Summary

The SM RCS successfully performed the pitch maneuver before SM/CM separation and maintained proper attitude control when quad A was inoperative and one of the negative yaw (-Y) engines was either inoperative or producing partial thrust. However, as a result of the quad A and -Y engine malfunctions, the +X translation maneuvers produced somewhat less than nominal velocity change when spacecraft attitudes and rates were maintained. Performance compared favorably with predicted performance (considering the effects of the disabled engines). This indicates that nominal engine thrusts were produced by the operating engines.

The CM RCS successfully performed all required maneuvers. It maintained proper spacecraft control until electrical malfunctions disabled the B system at T + 1641 seconds and A system at T + 1649 seconds. Command Module control was maintained through the maximum q region. Both CM RCS systems performed nominally to the time of the electrical failure.

Failures during the mission were: (1) failure of the SM quad A to operate because of a malfunction in the oxidizer supply system, (2) partial, or possibly complete, loss of thrust from one of the -Y engines when the automatic coils were used (the engine involved and the cause of this failure could not be definitely determined from the available data), (3) loss of both CM RCS systems after blackout because of the transfer of the RCS control motor switches from the CM to the SM position, (4) loss of the use of CM RCS system B for the propellant depletion burn as a result of the B system logic power failure, (5) loss of the use of the A and B system helium interconnect valves, and the A system fuel tank and the B system oxidizer tank helium bypass pyrotechnic valves as a result of the B system logic power failure, and (6) failure of the CM RCS oxidizer isolation valves to close during the postflight deactivation because of incompatibility between the valves and the oxidizer.

Service Module Reaction Control Subsystem

Description.- The Block I SM RCS on Spacecraft 009 consisted of four identical RCS quads equally spaced at 90-degree intervals around the SM (fig. 2-9). Each of the four RCS quads was mounted on a hinged panel of the SM. Each quad included four 95-pound thrust radiative cooled rocket engines, an oxidizer tank, a fuel tank, a helium tank, and associated components such as valves and regulators (fig. 2-10).

High pressure helium was used to pressurize the propellants. Helium was routed from a storage tank through parallel isolation (shutoff) valves, parallel regulators, and check valves into the propellant tanks. Check valves were used to prevent contamination of the helium by propellant vapors.

The hypergolic propellants, N_2O_4 (oxidizer) and a 50/50 mixture of N_2H_4 and UDMH (fuel), were stored in positive expulsion Teflon bladders mounted inside the propellant tanks. The propellants were forced from the bladders through isolation valves to the SM RCS engines. Each engine included electrically operated fuel and oxidizer valves with an automatic coil operated by signals from the stabilization and control subsystem (SCS) and a direct coil operated by signals from automatic sequencers.

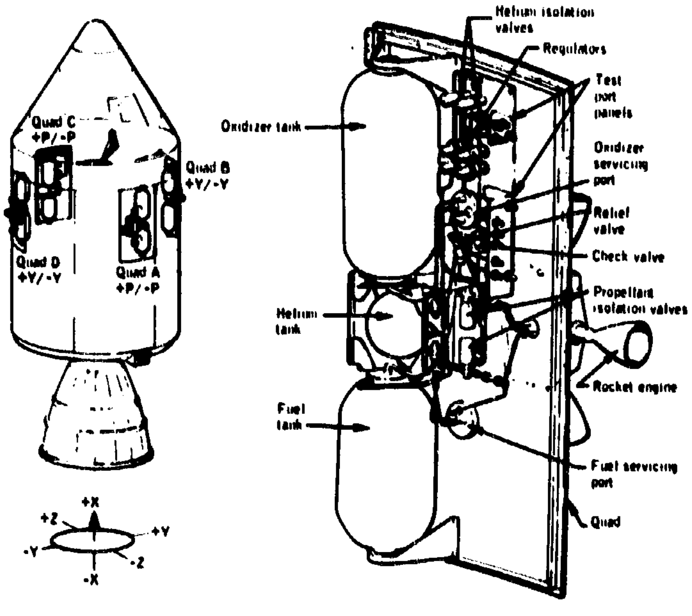


Figure 2-9.- Service Module Reaction Control Subsystem, Mission AS-201.

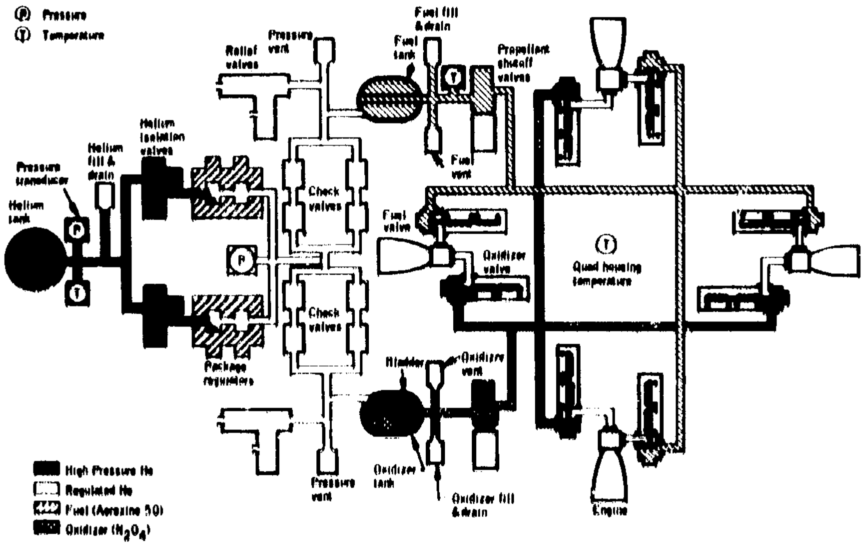


Figure 2-10.- Schematic of typical SM RCS quad, Mission AS-201.

All SM RCS components on Spacecraft 009 were certified for the short duration mission. Prior to lift-off, no components were known to be malfunctioning or failed on the SM RCS except the propellant-quantity-gaging system (which was deleted because of problems encountered during checkout) and primary stage helium check valves. All secondary stage check valves were functioning.

Performance.- Analysis of data showed no thrust was obtained from the engines on quad A and one -Y engine was inoperative. This caused the quad C positive and negative pitch (+P and -P) engines to alternately fire. The quad D positive and negative yaw (+Y and -Y) engines fired alternately to maintain correct attitudes and rates. As a result of this duty cycle, the net +X ΔV produced during the ullage maneuvers was 25 to 45 percent of the expected ΔV. With the pitch engines on quad A disabled, control authority for the CSM pitch-down maneuver was reduced. However, the maneuver was satisfactorily completed.

The only logical way to fail a complete quad is to stop the propellant flow to all four engines simultaneously by closing the propellant isolation valves. During postflight decontamination of the CM RCS, it was determined that the oxidizer isolation valves had seized in the open position after 11 days exposure to N_2O_4. The CM valves were identical to valves used on the SM. The SM RCS propellant isolation valves were exposed to propellants on the launch pad for 10 days prior to being opened. This indicated the quad A oxidizer isolation valve seized in the closed position prior to launch and disabled the system. This lack of compatibility of the valve with oxidizer was recognized and experienced during tests. Consequently, a new valve was designed, qualified, and used on Spacecraft 011, and all subsequent spacecraft.

Analysis of available data indicated the -Y/-X quad D engine was inoperative or malfunctioning. The failure mode could not be determined because of lack of information. It was deduced, however, that because bilevel indications of firing were recorded, electrical continuity existed in at least one of the automatic coils of the engine malfunctioning. Also, if both propellants were flowing but not producing thrust, as in the case of a combustion chamber failure, the overall quad pressure drop would have been approximately twice that of the normal pressure drop of the other quads. This was not true. Because no other data were available for further analysis, it could be concluded that for an unknown reason, when the SCS signaled the -Y engines to fire using the automatic coils, either the fuel or oxidizer valve of one of the -Y engines (probably the -Y/-X quad D engine) failed to respond. Thus the engine was disabled. Postflight analysis of the data led to no remedial action.

The SM RCS quad temperature increase because of boost heating was near the predicted values and verified quad temperatures established during Mission A-102. Quad temperatures caused by soakback after engine firings were near anticipated values. Temperature profiles of valves and injectors on the roll and pitch engines on quad A showed definite cooling effects after the first burn at CSM/S-IVB separation. This cooling effect is in contrast to the expected temperature increases because of soakback in other quads. Propellant tank and manifold temperatures were 70° ± 5° F throughout the mission, which was expected. Quad B valve and injector head measured temperatures were nominal for the realized duty cycles. As expected, boost heating was most pronounced in the forward firing engines. There was a maximum temperature of 200° F on the injector head.

Command Module Reaction Control Subsystem

Description.- The Block I CM RCS consisted of two identical redundant systems, A and B. Systems A and B operate simultaneously. Each system of the CM RCS consisted of six 93-pound thrust ablative cooled rocket engines, an oxidizer tank, fuel tank, helium tank, and filters, valves, and regulators (figs. 2-11, 2-12, and 2-13). The propellants used were N_2O_4 (oxidizer) and MMH (fuel). The purpose of the CM RCS was to control CM attitude after CM/SM separation.

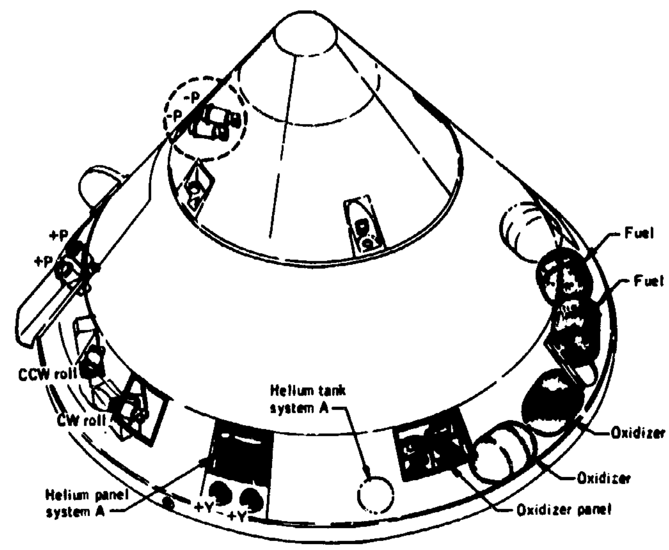


Figure 2-11.- Command module RCS component location, Mission AS-201, +Y axis.

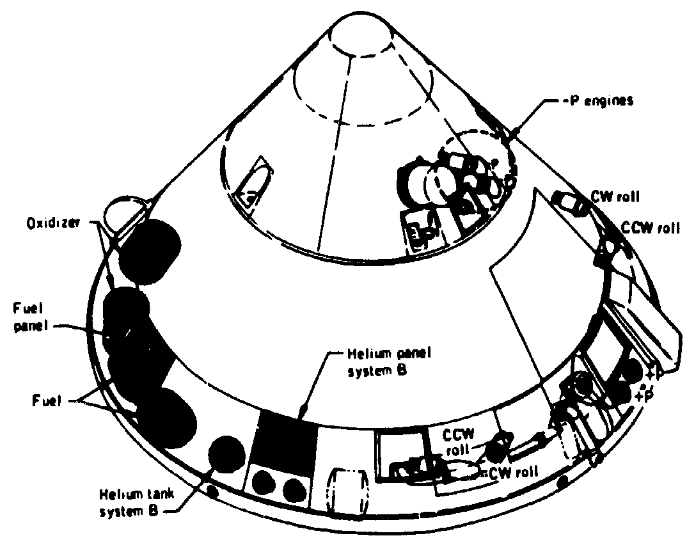


Figure 2-12.- Command module RCS component locations, Mission AS-201, -Y axis.

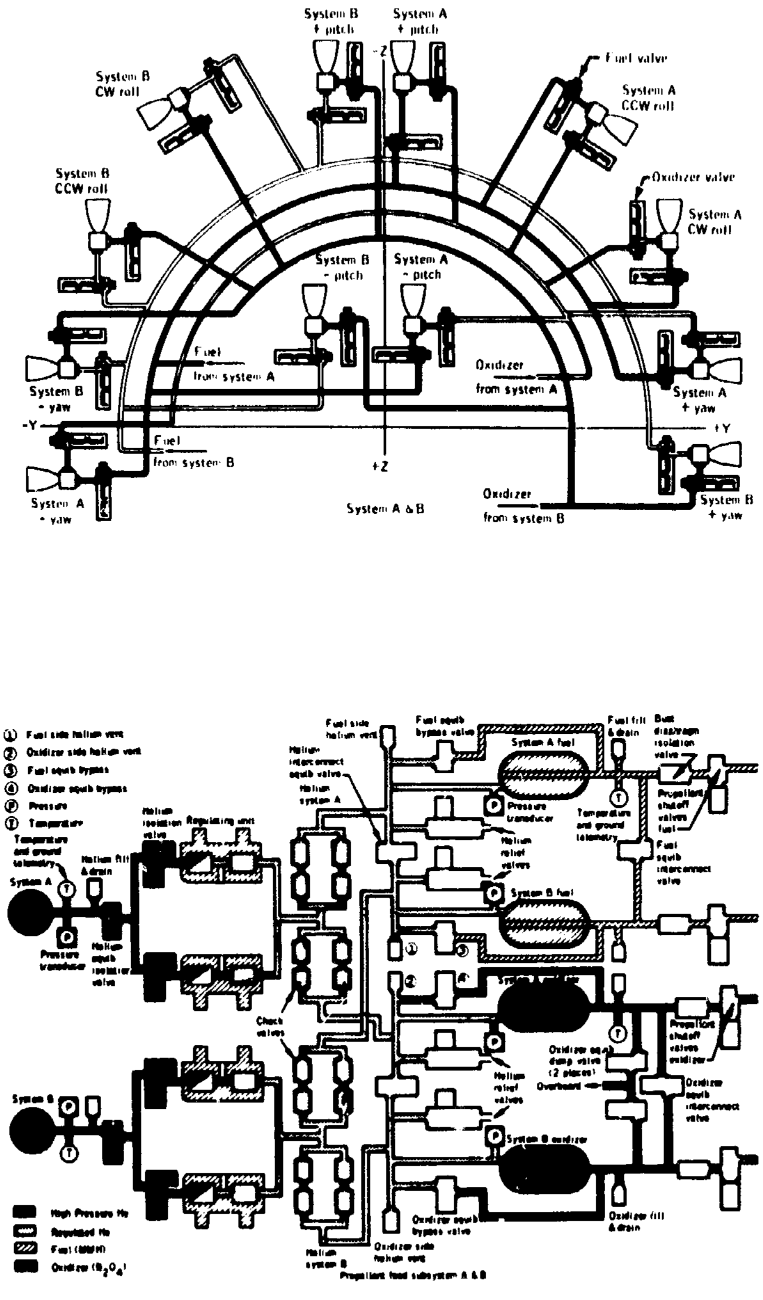


Figure 2-13.- Schematic of CM RCS, Mission AS-201.

The CM RCS components and operating principles were similar to the SM RCS except for the engines. The CM RCS engines were ablative cooled. The SM RCS engines were radiation cooled. The CM RCS engines included automatic and direct coils in the electric operated propellant valves, Automatic coils were operated by signals from the SCS. Direct coils were operated by signals from the propellant dump sequencer installed in Spacecraft 009 to control the disposal (dump) of propellants before the CM landed. During manned missions the crew dumps the propellants.

All CM RCS components were certified for the short duration mission. The only CM component known to have failed prior to lift-off was the CM B system relief valve burst diaphragm for fuel. The ruptured diaphragm was found during checkout testing. It was not replaced for the mission. (The burst diaphragm provided redundant sealing and was not required for the mission.) As in the SM, some primary helium check valves were leaking because they were out of tolerance. They were not replaced because the secondary valves were functioning normally.

Performance.- Control by the CM RCS was initiated following SM/CM separation at T + 1455 seconds. Operation was nominal until T + 1469 and T + seconds when electrical malfunctions disabled automatic operation of systems A and B, respectively.

Failure of the B system logic power caused the B system engine direct coils to be inoperative at the time of propellant depletion burn (T + 1915 to T + 2050 seconds). Therefore, both A and B system propellants were burned through the A system engines with the exception of the +P engine which was normally disabled. The burning resulted in greater than nominal charring of the A system engines, especially the roll engines. Satisfactory propellant jettison was accomplished, however, with nominal propellant residuals.

During the purge operation, data indicated that the A system fuel and B system oxidizer tank pressures did not decay. Postflight inspection of the A and B system helium interconnect squibs showed the A system fuel tank helium bypass squib and B system oxidizer tank helium bypass squib had not fired, which prevented depressurization. Also the valves were disabled by the B system logic power anomaly.

As expected, from launch to system activation, all component temperature measurements including the propellant and helium tanks, engine valves, and the engine outer wall remained constant at launch temperatures of 60° to 65° F. Within telemetry accuracies, helium and propellant tank pressures remained constant at loaded conditions from launch to system activation. There was no indication of helium leakage.

Decay in helium source pressures because of system activation was nominal and agreed with calculated pressures. Following system activation, small propellant usage resulted in no noticeable change in source pressure prior to the depletion burn at T + 1915 seconds.

Based on measured propellant residuals and nominal propellant flow rates during burnoff, propellant usage was estimated to be nominal (approximately 12 to 15 pounds). The following amounts of propellants were removed during deactivation: 5 pounds of fuel were removed from the helium side and purge lines of the CM systems A and B; 2 pounds of fuel from the propellant side of both systems; 1 pound of oxidizer from the helium side and purge lines of both systems; and 1-1/4 pounds of oxidizer from the propellant side of both systems. The propellants removed from the helium side of the systems were not unexpected, because the B system fuel and A system oxidizer tank bypass lines were opened during purging.

All measured temperatures showed nominal and in some instances less than expected effects of reentry heating and depletion burn on the CM components. The propellant tank temperatures remained constant at approximately 60° to 65° F.

During recovery of the spacecraft after landing, no problems were reported with the CM RCS or with propellants or propellant fumes. During deactivation which began 5 days later at Norfolk, Virginia, the B system +Y oxidizer valve failed to open when the direct coil was commanded. A short to ground was found on both sides of the coil. During decontamination operations, the electrical leads to the coil were inadvertently reversed on the spacecraft side of a terminal strip. Both sides of the coil were connected to ground. The automatic coil was in working order.

When the A and B system oxidizer isolation valves were cycled to the closed position during the deactivation procedures, the valve indicators showed the valves closed, but gas flow through the valves did not decrease. This indicates both valves were seized in the open position. The valves were normally open during the flight and had no inflight function. The failure had no effect on the flight. Similar problems during development and qualification of the valve indicated incompatibility between the oxidizer and the valve. The valve was replaced on Spacecraft 011 and subsequent spacecraft. There was no problem with the fuel isolation valves.

Postflight inspection revealed the fuel bypass valves on both the A and B systems to be incorrectly wired. System A valve was wired to the B pyro battery instead of the A battery. System B valve was wired to the A pyro battery instead of the B battery. As a result of this condition, the helium pressure in A and B systems was able to bleed-down during purging. In the normal configuration, high pressure helium would have been trapped in the B system.

Requested postflight testing of the CM RCS consisted of propellant bladder leak checks, electrical integrity checks of the CM B system +Y engine direct oxidizer coil, oxidizer isolation valve failure analysis, functional checks of the engine valves, char analysis of the A system CCW and -Y engines, and relief valve leakage tests.

No other problems were found during the postflight testing.

MISSION AS-202 (SPACECRAFT 011) CSM RCS FLIGHT PERFORMANCE

Mission AS-202 (Spacecraft 011) was the second flight test of a production Apollo Block I type spacecraft using the uprated Saturn I launch vehicle. This was an unmanned suborbital flight. Lift-off from launch complex 34, Cape Kennedy, Florida, was at 12:15 P.M. e.s.t. (17:15 G.m.t.) August 25, 1966. The spacecraft CM landed safely in the primary landing area in the southwest Pacific Ocean near Wake Island approximately 1 hour 33 minutes later (18:48 G.m.t.), and was recovered.

The major spacecraft mission objectives were to demonstrate the structural integrity and compatibility of the spacecraft/uprated Saturn I configuration, to verify subsystem operation, and to evaluate the spacecraft heat shield performance during a high heat load reentry.

Performance Summary

The CM and SM RCS inflight performance was nominal during the mission. All maneuvers using RCS thrusters were completed as planned and attitude rates as predicted.

Service Module Reaction Control Subsystem

Description.- The SM RCS configuration on Spacecraft 011 was identical to that on Spacecraft 009 with the following exceptions:

1. The SM RCS engine for Spacecraft 011 was of the Spacecraft 012 configuration. It produced 100 pounds of thrust rather than 95 pounds of thrust and had a fuel valve thermal standoff to increase thermal resistance between the valve and injector.

2. The propellant isolation valves were of a new design with improved performance and propellant compatibility.

3. The helium isolation valve was of the Spacecraft 012 configuration, which used an improved poppet design.

All SM RCS components on Spacecraft 011 were certified for the mission. No components were known to be malfunctioning or failed prior to lift-off. However, a quad C relief valve burst diaphragm was ruptured because of a pressure surge during activation.

Anomalies.- The only anomaly encountered during the SM RCS prelaunch countdown or mission occurred during activation of quad C on the pad approximately 4-1/2 hours prior to launch. When the helium isolation valve on quad C was opened to pressurize the propellant tanks, pressure downstream of the regulators surged to 320 psia during the activation transient and ruptured the relief valve burst diaphragm. The pressure stabilized at 220 psia following activation, indicating the overpressure ruptured the burst diaphragm and vented through the relief valve. At the first SM RCS burn, pressure downstream of the regulator dropped to nominal regulated pressure, indicating the regulator was functioning properly.

For subsequent missions, this malfunction was avoided by locking the regulators with pad pressure prior to opening the helium isolation valves.

Another possible anomaly was the master caution and warning light coming on approximately 3 seconds into the flight. Examination of the RCS quad regulated helium manifold pressures revealed that during the first 110 seconds of the mission, the regulated helium pressure transducer output on quad D indicated a considerable amount of data scatter, some data points going below 135 psia. The first time this occurred was approximately T + 3 seconds. Because other instrumentation data (propellant manifold pressures) showed the regulated pressure to be correct, it could be assumed the transducer was malfunctioning. Recognizing that a helium manifold pressure signal below 155 psia would activate the caution and warning light, this data scatter should have and apparently did activate the warning light.

The output from the quad D regulated helium pressure transducer was nominal after T + 110 seconds and remained throughout the flight. The malfunction was probably intermittent and associated with high vibration during launch. A history of problems was associated with the splice between transducers and the spacecraft wiring. During Spacecraft 011 checkout at Kennedy Space Center (KSC), high resistances and poor contact were found in several instrumentation splices. The splices were remade at KSC and verified to be satisfactory. However, it could be possible for the vibration during launch to cause momentary bad connections, which would show as voltage and pressure decreases. To preclude such problems, splicing procedures were reviewed for inadequacies, better quality control was initiated, and each splice was potted and bonded to the quad D panel to prevent flexing.

<u>Performance</u>.- Performance of the SM RCS throughout the mission was nominal. All mission objectives were met. System performance was verified as satisfactory for the AS-204 mission. Spacecraft accelerations produced by the RCS were nominal for both attitude hold and maneuvering. All measured pressures and temperatures were nominal, showing except for the quad C regulated pressure during the boost phase.

The fuel for the mission was changed from Aerozine 50 (A-50) to mono methyl hydrazine (MMH) because of engine problems associated with A-50. Two hundred and sixty pounds of SM RCS propellant were used, which compared favorably with the preflight predicted usage. During the mission, it was estimated that a total of 17 000 engine firings were made.

Command Module Reaction Control Subsystem

Description.- The command module RCS configuration on Spacecraft 011 was identical to Spacecraft 009 except:

1. The propellant isolation valves were of a new design with improved performance and propellant compatibility.

2. The CM RCS engine for Spacecraft 011 was of the Spacecraft 012 configuration having an epoxy coated throat and liner and improved valve design.

3. The oxidizer and fuel tanks were of Spacecraft 012 configuration, which used net size bladders in both tanks and 9-mil ends in the oxidizer tank bladders; both tanks had liquid side vents.

All CM RCS components on Spacecraft 011 were certified for the mission. No components were known to be malfunctioning or to have failed prior to lift-off.

Anomalies.- One CM RCS anomaly was identified. The anomaly concerned the CM system A oxidizer and the system B fuel relief valve burst diaphragms found ruptured during postflight inspection. An examination of the data at the time of CM RCS activation indicated a pressure surge occurred similar to the pressure surge for the SM RCS quad C. The ullage volumes of the CM were smaller than in the SM. Because of this, restrictive orifices were placed in the helium supply lines to limit the maximum helium flow rate. It was determined that the orifice size used was marginal. Therefore, the Block II orifice was reduced to a smaller size.

Performance.- Performance of the CM RCS from activations just prior to CM/SM separation until system purge was nominal. All mission objectives were met. Performance was certified as satisfactory for the AS-204 mission. The CM accelerations in pitch, yaw, and roll and spacecraft attitudes were nominal throughout reentry. All measured system pressures and temperatures were nominal.

Using pressure volume temperature (PVT) techniques and accumulated engine firing times, the CM RCS propellant consumption for the mission was calculated. For the PVT calculation, helium source and regulated pressure and helium source gas temperature were used as source information.

For the SM RCS, the propellant depletion derived from the engine burn times was the most accurate (approximately 1 to 2 percent). The maximum deviation of the PVT curve from the summation curve was 2.5 pounds. Overall inaccuracy for the PVT calculations was estimated to be +3 to 6 percent of full load. Sixty-four pounds of propellant were used during the reentry, 32 pounds from each system. Approximately 500 firings of the CM RCS engine were made during reentry.

APOLLO 4 (SPACECRAFT 017) CSM RCS FLIGHT PERFORMANCE

The Apollo 4 space vehicle was launched from Cape Kennedy, Florida, November 9, 1967. The spacecraft S-IVB stage combination was placed into an earth parking orbit for two revolutions. The S-IVB stage was reignited to place the spacecraft in a simulated translunar trajectory. The spacecraft was cold-soaked for 4-1/2 hours with the thickest side of the CM heat shield away from the solar vector.

At the conclusion of the 4-1/2-hour cold soak, the service propulsion system (SPS) engine was fired to increase the spacecraft inertial velocity. After the SPS burn, the CM was separated from the SM, and the CM was oriented to the entry attitude.

The SM and CM RCS inflight performance was within the nominal range throughout the mission. All maneuvers using the RCS engines were completed. Satisfactory maneuver rates, accelerations, and translation velocity changes were attained. Propellant utilization was normal for both the CM RCS and the SM RCS.

The SM RCS thermal control subsystem was flown for the first time on this mission and performance was satisfactory. The heaters on the four quads actuated satisfactorily. Quad package temperatures, as well as those of the engine injector heads which were instrumented, were within acceptable limits through CM/SM separation.

The CM RCS engines were maintained passively at acceptable temperatures from launch through subsystem activation. Maximum engine temperatures from subsystem activation through landing were within designated limits.

The SM RCS configuration, except for the addition of a modified heavy duty engine mounting structure, was practically identical to Spacecraft 011. All of the SM RCS components on Spacecraft 017 were of certified Block I configuration. Prior to lift-off, no components were known to be malfunctioning or inoperative.

The only anomaly of the SM RCS was a prelaunch pressure decay in the quad A helium source pressure. The pressure had a uniform decrease from 4150 psia at servicing to 3910 psia at launch. The leak rate was approximately 5 psi per hour or 26 standard cubic centimeters (scc) per minute. A decay rate of 17 psi per hour and a minimum pressure of as low as 3440 psia were acceptable for an unmanned spacecraft launch. Therefore, leaks caused no problems relative to the mission.

A total of 220 pounds of SM RCS propellant was used. Fuel was MMH and it is estimated that there were 16 000 engine firings.

The CM RCS configuration on Spacecraft 017 was identical to that of Spacecraft 011. All CM RCS components were of the certified Block I configuration.

Performance of the CM RCS was satisfactory from activation until subsystem purge. All mission objectives were met. Performance was verified as satisfactory for subsequent missions. Accelerations in pitch, yaw, and roll and the spacecraft attitudes were nominal. All measured subsystem pressures and temperatures were nominal.

After landing, there was several hundred psi of residual pressure in the CM RCS after the purge operation. The residual pressure was a result of the configuration of the propellant tanks and helium purge systems. To allow rapid and complete purging, both the tanks and purge systems were modified on the Block II system.

Ninety pounds of propellant were used during reentry and 500 engine firings were made. Both CM RCS systems were active during the entry. The propellant depletion burn was successful. Approximately 144 pounds of propellants were burned.

Postflight examination of the CM RCS revealed ruptured burst discs in subsystems A oxidizer and B fuel relief valves. This was expected, because it had been a characteristic in all previous missions and ground based test programs. It was caused by a pressure surge or regulator overshoot at system pressurization. The problem was eliminated on Block II systems by relocating the relief valves to provide more volume between the regulators and the relief valves.

APOLLO 6 (SPACECRAFT 020) CSM RCS FLIGHT PERFORMANCE

Lift-off was at 12:00:01 G.m.t. (7:00 a.m. e.s.t.) April 4, 1968, from launch complex 39A, Kennedy Space Center, Florida. The launch phase profile was nominal until two engines in the S-II stage shut down early. To obtain the desired velocity, the remaining three S-II stage engines and the S-IVB fired longer than planned. During the S-IVB firing, steering was required in an attempt to remove the S-II generated error in the trajectory plane. At thrust termination, the orbit was 198 by 96 nautical miles instead of the planned 100-nautical-mile circular orbit.

The vehicle remained in an earth parking orbit for 3 hours. During this period, systems were checked, operational tests such as the S-band evaluation were made, and several attitude maneuvers were made.

The second S-IVB firing was scheduled to occur during the KSC pass at the end of the second revolution. This firing could not be accomplished. Therefore, the CSM was separated from the S-IVB. A SPS engine firing sequence was initiated. This was a long duration firing of 442 seconds which provided a 12 019.5 by 18-nautical-mile free return orbit.

After SPS engine cutoff, the CSM was maneuvered to a cold-soak attitude with the minus X axis oriented toward the sun. The cold-soak attitude was maintained for approximately 6 hours.

Because the SPS was used to insert the spacecraft into the desired high apogee, insufficient propellant remained to gain the high velocity desired from the second SPS engine firing. Specifically, the total propellant remaining would allow 22 percent of the desired increase of velocity. For this reason, a decision was made to inhibit the second firing. A complete firing sequence was performed including all nominal events, except thrust was inhibited.

After the SPS cutoff signal, the CSM was maneuvered to separation attitude and SM was separated at 09:36:57. This was followed by CM entry attitude orientation and coast to 400 000 feet.

At 09:38:29, the entry interface was reached with a velocity of 32 830 feet per second and a flight path angle of -5.85 degrees. Interface conditions were less than planned. As a result, heating rates and loads during entry were lower than desired.

The parachute deployment sequence was normal. Drogue deployment was at 09:51:27. Landing occurred at approximately 09:57:20 and was about 49 nautical miles uprange of the targeted landing point of 157 degrees 11 minutes west longitude and 27 degrees 19 minutes north latitude.

Both RCS (CM and SM) performed nominally except for the thermal control of one quad. All maneuvers using the RCS were completed satisfactorily. Normal maneuver rates, accelerations, and translations velocity changes were attained. Propellant usage by both systems was normal. The thermal control system for the SM RCS maintained the engine mounting structure and injector head temperatures at satisfactory levels for quads A, B, and D. Quad C displayed anomalous temperatures during the early portion of the cold-soak phase.

Service Module Reaction Control Subsystem

The SM RCS was similar to the one used for the Apollo 4 mission; some engines were Block II configuration units with integral screens in the propellant valves. No components were known to be malfunctioning or inoperative prior to lift-off.

Engine activity.- Engine activity during the cold-soak period was greater than planned, partly because of the decreased vehicle inertia resulting from the longer-than-planned SPS engine firing. Over control caused by four engine roll control of a relatively light vehicle increased the activity. Two engine control can be selected during manned flights. Approximately 18 000 engine firings were made during the mission; 365 pounds of propellant were used.

Thermal control.- The thermal control system on Apollo 6 was identical to Apollo 4 except that the Apollo 4 heaters were bonded and mechanically clamped to the engine mounting structures. The Apollo 6 heaters were bonded to the engine mounting structures. Mechanical clamps were incorporated on Apollo 4 because of uncertainties concerning heater-mounting structure bond strengths. Verification of bond quality permitted deletion of the mechanical clamps for Apollo 6. The heaters were bonded to the mounting structures on Block II spacecraft. The primary and secondary thermal control systems were actuated at hatch closeout and remained active throughout the flight. The temperatures of the engine mounting structures of each of the four quads were monitored from launch through SM/CM separation. In addition, the temperatures of the injectors of the following engines were monitored during the same time period: negative (-) pitch engine in quad A, positive (+) yaw engine in quad B, clockwise roll engine in quad C, and counterclockwise roll engine in quad D.

The thermal control system maintained the engine mounting structures and instrumented injectors of quads A, B, and D at satisfactory temperatures during the flight. During the early portion of the cold-soak phase, the quad C engine mounting structure cooled excessively. Anomalous temperature excursions occurred in the quad C clockwise roll engine injector.

Maximum launch temperatures for the mounting structures and injectors of the four instrumented engines were comparable to or slightly higher than those encountered during the Apollo 4 mission. A comparison of trajectory parameters indicated that the launch aerodynamic heating of the quads should have been slightly higher than the Apollo 4 flight.

The RCS engines were inactive during the two revolutions prior to S-IVB separation. The performance of the thermal control system during this time cannot be fully assessed. There were periods when telecommunication network station coverage was not complete. However, available data indicate the thermal switches and heaters operated in a nominal manner to maintain the engine mounting structures and injector heads within the temperature range of 110° to 140° F.

During the approximately 5.9-hour inertial cold-soak, quads B and C were shaded and quads A and D had sun exposure at an oblique angle. During the cold-soak period, the quad A and D heaters underwent multiple cycles and maintained the engine mounting structures and the instrumented injector heads at satisfactory temperature levels.

Command Module Reaction Control Subsystem

The Apollo 6 CM RCS was identical to Apollo 4 CM and all system components were Block I. Prior to lift-off no components were known to have been malfunctioning or inoperative.

Performance.- From activation until landing, performance of the system was normal. The performance was verified as satisfactory for manned missions.

Maneuvers.- During entry, the system performed a pitch maneuver and roll maneuvers, and provided attitude-hold control. The angular acceleration produced by the engines was typically low for the first pulse or pulses of an engine. This was most apparent in the positive pitch engine which was commanded "ON" within 1 second after system activation. At first, no effect was noted on the body rates of the vehicle, then rates implied reduced engine thrust and finally nominal engine thrust level. A similar effect was noted during the Apollo 4 mission and represented normal system activation. The slow buildup was noted in the chamber pressure of the first pulse of the A system counterclockwise roll engine and the associated roll body rate.

System pressures.- When the helium pressurization systems were activated, the source pressure of each system dropped 680 psi. This decrease, 240 psi greater than during the Apollo 4 mission, was caused by the increased oxidizer tank ullage resulting from off-loading 5 pounds less oxidizer in each system. At the time the helium purge was terminated, the A and B system source pressures were 273 and 253 psia (referenced to 70°), respectively. Similar pressures occurred during the Apollo 4 mission. The purge system was modified for future command modules to permit a more rapid purging.

Control firing propellant consumption.- Propellant consumption during the mission was compared with preflight predicted consumption. The 84 pounds of propellant expended for control firings were 6 pounds less than were used for this purpose during the Apollo 4 mission.

Propellant depletion burn.- The propellant depletion burn was accomplished successfully. Approximately 152 pounds of propellant was burned. The instrumented chamber and propellant manifold pressures during the propellant depletion burn and the helium purge were normal. The oxidizer tank pressure recovered several seconds before the fuel tank pressure. This indicated usable oxidizer had been depleted before the fuel. Approximately 14.5 pounds of oxidizer remained trapped in the tank and lines of the two systems. The engine chamber pressure buildup during the helium purge indicated at least part of the trapped oxidizer was burned. During the Apollo 4 mission, the fuel was depleted first, leaving 10.5 pounds of usable oxidizer in addition to the trapped quantity. To reduce the hazard of the unburned oxidizer damaging the parachutes during the Apollo 6 mission, 5 pounds less oxidizer were loaded in each system. This oxidizer would have been excess to the required oxidizer for combustion of usable fuel.

Thermal Control

Throughout the mission, the CM RCS was passively maintained within satisfactory limits. The system withstood the effects of a high heating load entry after having been subjected to an extended cold-soak period.

The temperatures of the A and B system helium tanks and six engine oxidizer valves were monitored throughout the flight. During entry, the injector temperature and two engine outer-wall temperatures were monitored on each of four engines. To detect any leakage of hot combustion gas, the temperature of the interface seal between the ablative thrust chamber assembly and ablative nozzle extension of the two positive pitch engines was monitored during entry.

During the two revolutions prior to CSM/S-IVB separation, the temperature of the CM RCS helium tank and oxidizer valve varied only slightly from launch temperatures. Temperature data for the engine injectors, outer walls, and chamber/nozzle interface seals were recorded by the onboard flight qualification tape recorder during the launch and entry phases. However, during the first two revolutions, these temperatures should have varied only slightly from launch temperatures.

The CM RCS was subjected to cold-soak conditions for approximately 6 hours during the coast-ellipse phase. Because the system had received side sun exposure during the similar phase of the Apollo 4 mission, this flight represented the first opportunity to evaluate thermal response of the system after an extended cold-soak period. As expected, when the system was activated after the cold-soak period the temperatures were well below ambient launch temperatures. The system A and B helium tanks cooled 11° to 12° F, reaching temperatures of approximately 64° and 58° F, respectively, at SM/CM separation. These levels are considered to be normal for cold-soak operation and within design limits.

The engines were ported through and bonded to the heat shield. Substantial conductive heat losses were experienced by the engines during the cold-soak period. At SM/CM separation, the engine outer-wall temperatures had decreased to the range of -25° to -2° F, injectors to 36° to 40° F, and oxidizer valves to 44 to 54° F. These temperatures were within design limits prior to activation. However, if Apollo 6 had been a manned mission, the crew would have applied current to the engine valves prior to entry to increase the injector temperatures to above 48° F.

From system activation through landing, the helium tank temperatures decreased normally as a result of gas withdrawal. All of the engine component temperatures increased because of engine firing and aerodynamic entry thermal loads. During entry, the negative pitch engines were exposed to the airstream when the apex cover was jettisoned. The subsequent cooling effect attenuated the temperature increase of the oxidizer valves for these engines. During entry, all measurement parameters remained within design limits. No chamber/nozzle interface seal leakage was detected on either of the positive pitch engines.

Postflight Examination

The postflight examination of the CM RCS revealed ruptured burst disks in the A system oxidizer relief valve and in the B system fuel relief valve. These ruptured burst disks were characteristic of all previous missions and ground-based test programs. Ruptures were caused by a pressure surge or regulator overshoot at system pressurization.

This problem was eliminated on Block II systems by relocating the relief valves to provide more volume between the regulators and relief valves.

Another problem was the cross wiring of the oxidizer and fuel valves of all four yaw engines. Cross wiring was found during system decontamination in Hawaii. The fuel lead wires and the oxidizer lead wires were reversed. This anomaly had no effect on engine performance in flight because the oxidizer and fuel valves are wired in parallel and receive a common command signal.

APOLLO 7 (AS 205/CSM 101) CSM RCS FLIGHT PERFORMANCE

Apollo 7 was the first manned Apollo mission. Lift-off occurred at 15:02:45 G.m.t. October 11, 1968. Mission duration was approximately 260 hours. Crew members were Walter Schirra, Walter Cunningham, and Donn Eisele.

This was designated as a "C" type mission. The purpose of the mission was to demonstrate the capability of the spacecraft, crew, and Manned Spaceflight Network (MSFN) support facilities to conduct an earth orbital mission.

Several Detailed Test Objectives (DTO) were defined for the CSM RCS. These are covered in detail in the Mission Requirements Document, SPD-R-001, Revision E, August 1968. Briefly, these DTO were as follows:

1. S3.17 - SM RCS Performance. The purpose of this DTO was to demonstrate the adequacy of the SM RCS during all guidance and navigation control subsystem (GNCS), SCS, and manual control modes; to operate in both pulsing and steady state modes; and to operate using both automatic and manual valve coils.

2. P20.11 - Consumables Usage. The purpose of this DTO was to obtain data on SM RCS propellant consumption during a variety of maneuvers and control modes, and to obtain data on CM RCS usage during entry.

3. P1.13 - GNCS ΔV Control. The purpose of this DTO was to evaluate the accuracy of SM RCS ΔV maneuvers.

4. S20.17 - Propellant Slosh Damping. The purpose of this DTO was to determine SM RCS propellant usage to maintain spacecraft stability during long term main propellant slosh following SPS or RCS burns, and to develop an optimum procedure for initiating spacecraft attitude control following SPS and RCS burns.

The determination of SM RCS or CM RCS propellant utilization was also included in the following DTO:

P1.12 - GNCS Attitude Control

P1.14 - GNCS Entry

P2.2 - SCS Attitude Control

P2.10 - SCS Backup Alignment Procedure

P20.8 - Separation/Transposition/Simulated Docking

P20.13 - CSM Active Rendezvous

Summary

The SM and the CM RCS performed satisfactorily throughout the mission. All system operations were normal with the exception of the SM RCS quad B propellant quantity sensor, which failed prior to launch. All test objectives were satisfied. The SM and CM propellant loading was accomplished October 2, 1968. A total of 1341.7 pounds of propellant was loaded in the SM and 263.9 pounds was loaded in the CM. Helium servicing of both SM and CM was accomplished October 9, 1968. The SM quads were serviced to 4160 to 4300 psia helium pressure. No systems leakage was observed prior to launch. One-second static firings of the four aft-firing SM RCS engines were satisfactorily accomplished at approximately 25 minutes prior to launch. The crew heard the firings.

The SM RCS helium pressurization system maintained helium and propellant manifold pressures constant at 180 ± 4 psia. No helium or propellant leakage was observed from the SM RCS during the flight.

A total of 875 pounds of SM RCS propellants was used during the flight. With the exception of the S-IVB rendezvous, propellant consumption approximated the predicted usage. The S-IVB rendezvous required approximately 11 percent (37 pounds) more than predicted. Switchover from primary to secondary propellant tanks was accomplished at a nominal value of 43 percent propellant remaining as determined by ground calculations. At switchover the onboard gage readings were 46 to 54 percent propellant remaining. The discrepancy between ground calculations and onboard gage readings of propellant quantity remaining was caused by an end-point error in the quad propellant quantity sensor. Onboard gage readings, when corrected for end-point error and temperature, agreed with ground calculations within 1.7 percent of full scale.

Thermal control of the SM RCS was satisfactory throughout the flight. Because of boost heating, maximum quad package temperatures were 115° to 128° F. The primary heaters on all four quads were activated at orbital insertion and remained on for the remainder of the mission. The primary heater system functioned normally and it maintained the quad package temperatures between 118° and 143° F during periods of low engine firing activity. The maximum quad package temperature attained was 198° F during S-IVB rendezvous maneuvers. The primary propellant tank outlet temperatures were initially at approximately 75° F and decreased during the flight for all quads. There was a minimum temperature of 33° F on quad A after 10-1/2 days. The helium tank temperatures closely followed

temperatures variations in the primary propellant tank, but remained 5° to 20° warmer.

Prior to activation for the deorbit maneuver, no helium or propellant leakage was noted from the CM RCS. The system was activated at 259:39:02 g.e.t. The propellant isolation valves were opened shortly afterwards. Both manual and automatic controls were used during entry in combinations of dual and single system firings. The system functioned normally during entry.

A total of 50 pounds of CM RCS propellant was used (29 pounds from System 1, 21 pounds from System 2).

Prior to system activation, the CM RCS helium tank temperatures remained between 77° and 61° F. The instrumented CM RCS engine injectors remained above 46° at all times and CM valve warmup procedure was not required.

During postflight testing, an inadvertent opening of the CM RCS oxidizer isolation valves was noted. It is thought that the valves were damaged by hydraulic hammering during system activation.

A diagram of the Spacecraft 101 CM RCS is shown on figure 2-13. This system remained unchanged on subsequent spacecraft. A typical CM RCS engine propellant feed system is shown on figure 2-14. A typical CM RCS engine is shown on figure 2-15.

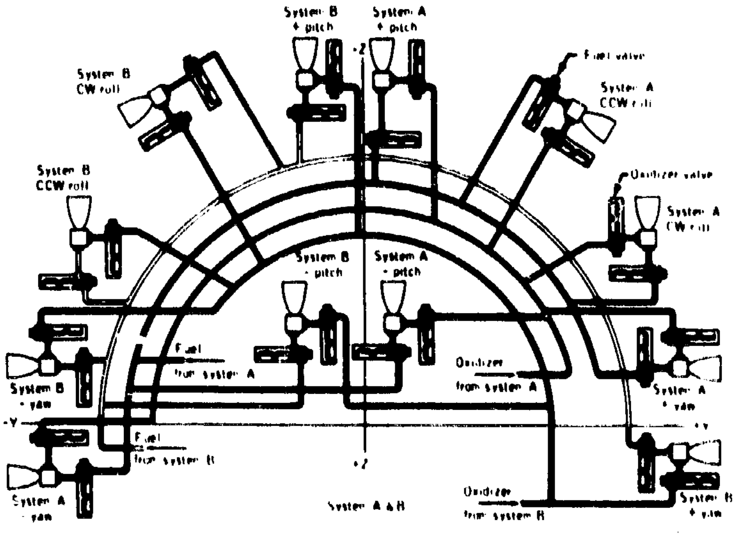


Figure 2-13.- A diagram of the Spacecraft 101 CM RCS.

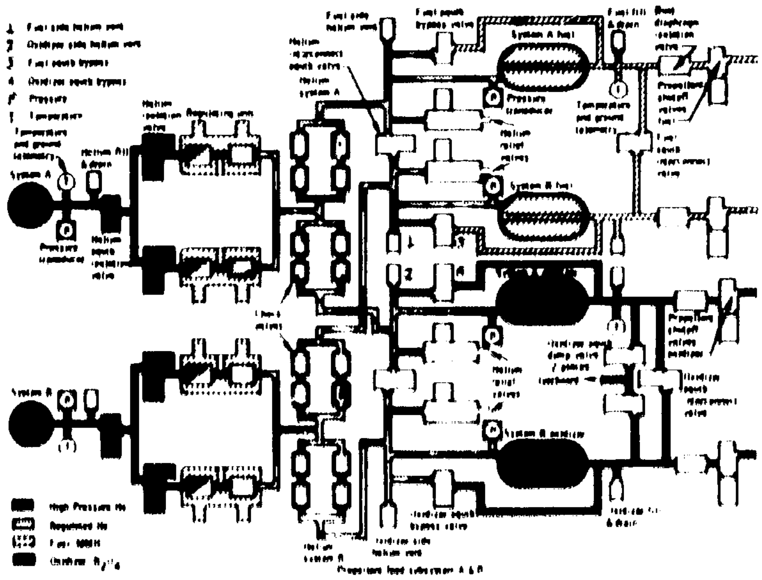


Figure 2-14.- A typical CM RCS engine propellant feed system.

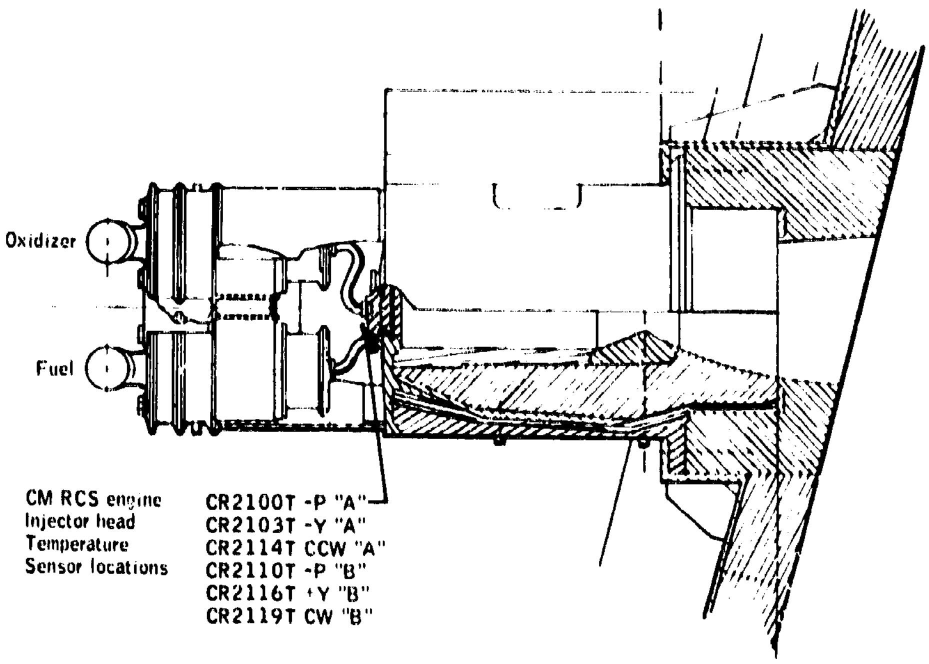


Figure 2-15.- Typical CM RCS engine.

A diagram of the SM RCS quads is shown on figure 2-16. A view of the helium pressurization and propellant system on the reverse side of the panel is shown on figure 2-17. Figure 2-17 is representative of quads B and D; quads A and C are identical to quads B and D. The relative locations of the SM and SPS components within the SM are shown on figure 2-18. The SM RCS quad housing engine is shown on figure 2-19 and the SM RCS engine on figure 2-20. This was the first Block II four propellant tank quad configuration SM RCS that was flown.

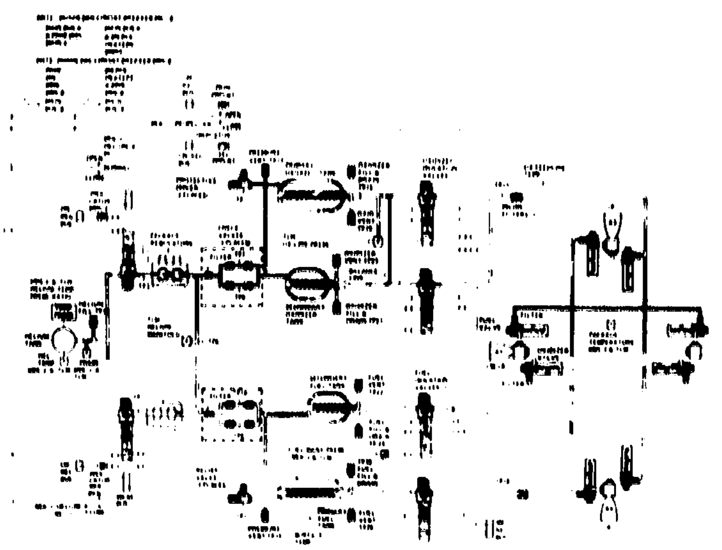


Figure 2-16.- Diagram of the SM RCS quads.

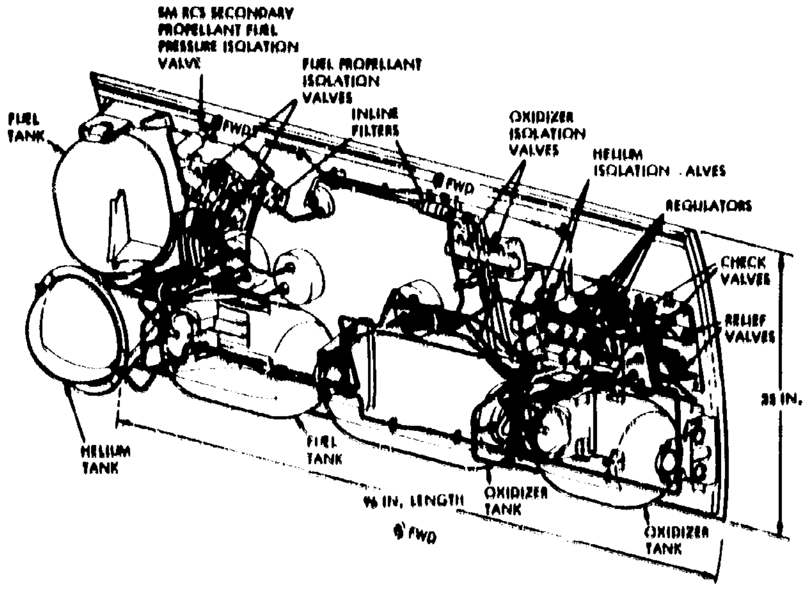


Figure 2-17.- Service module reaction control subsystem panel assembly, quads B and D.

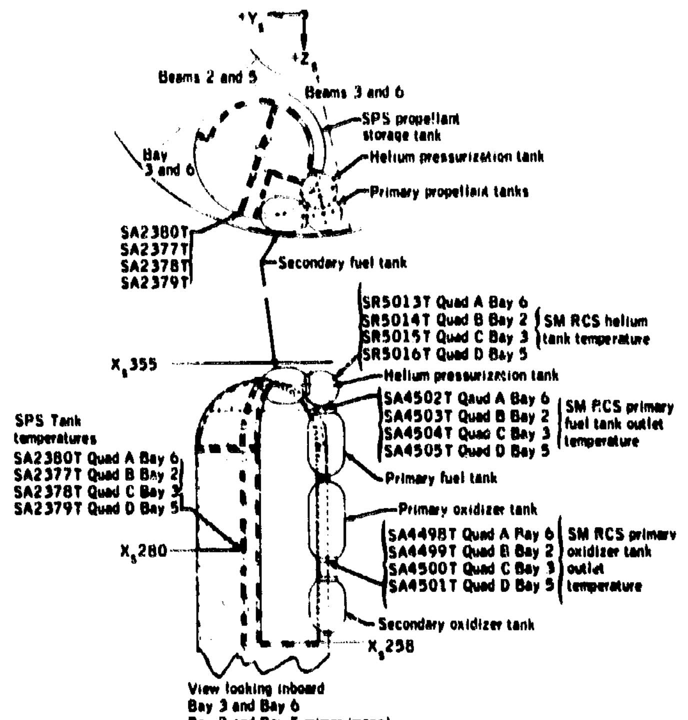


Figure 2-18.- Locations of the SM RCS and SPS components within the service module.

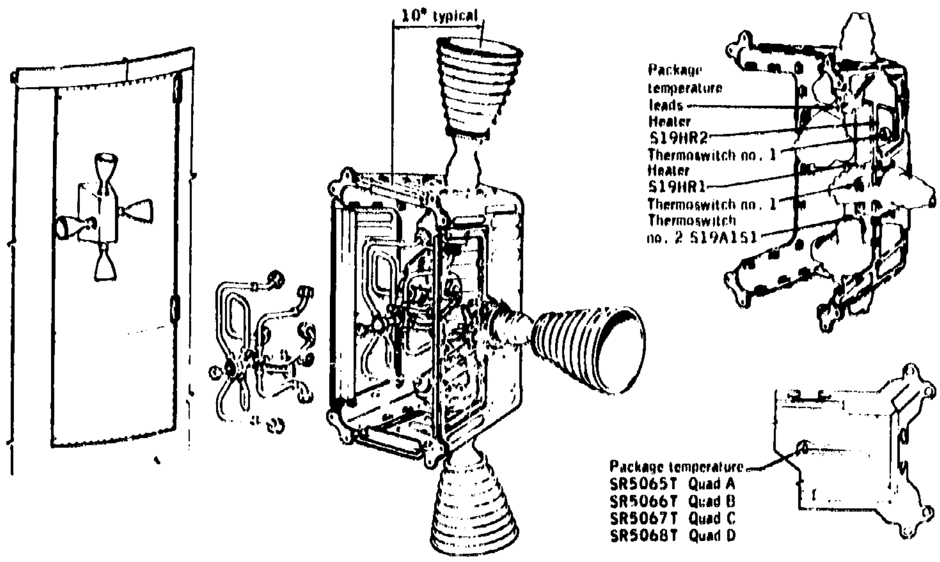


Figure 2-19.- Service module reaction control subsystem engine housing.

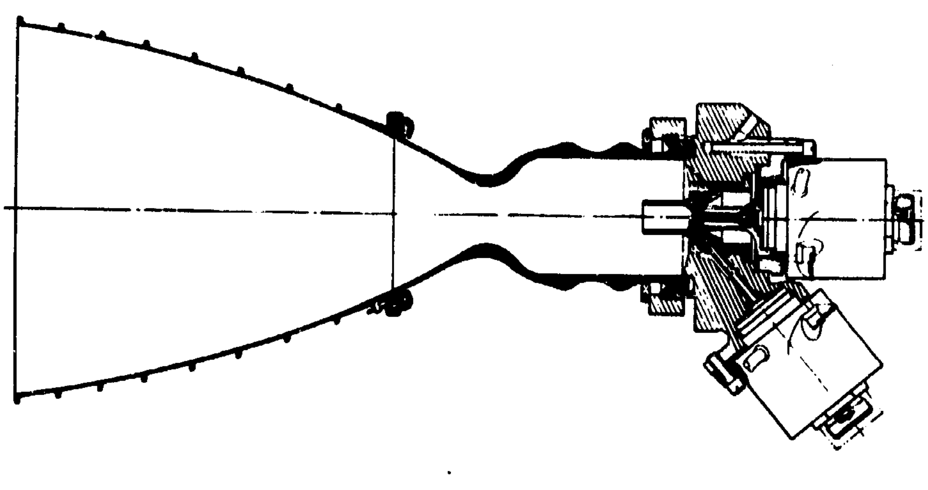


Figure 2-20.- SM RCS engine.

The Spacecraft 101 SM RCS differed from subsequent vehicles. Differences are:

1. The "Volkswagen" valve in the helium pressurization line upstream of the secondary fuel tank was not installed. This valve was included on Spacecraft 104 and subsequent vehicles.

2. Spacecraft 101 did not incorporate the ability to electrically isolate individual SM RCS engines. This capability was incorporated in Spacecraft 103 and subsequent vehicles.

3. Spacecraft 101 did not incorporate a CM cabin display of the SM RCS helium tank temperature. This capability was available for Spacecraft 103 and subsequent vehicles.

4. Primary SM RCS propellant tank outlet temperatures were measured on Spacecraft 101. These measurements were not available on subsequent vehicles.

5. The secondary SM RCS heater system thermostats on the Spacecraft 101 quads were of low range configuration (77° ± 7° F to 104° ± 14° F). On Spacecraft 106 and subsequent vehicles the switching limits were 120° ± 5° F.

6. The SM RCS panel insulation and all internal SM insulation on Spacecraft 101 was multilayer blankets of aluminized Mylar encapsulated with a surface sheet of H-film (polyamide). Effective on Spacecraft 103, all insulation was aluminized H-film.

7. Spacecraft 101 did not incorporate "look-angle" blankets, which prevent the SM RCS tankage from radiatively "seeing" cold areas internal to the SM. These "look-angle" blankets were incorporated on Spacecraft 103 and subsequent vehicles. Table I shows vehicle-to-vehicle SM RCS configuration changes.

Preflight Activities

The SM RCS quads were activated at 14:35:00 G.m.t. October 11, 1968. Approximately 25 minutes prior to launch, approximately 1-second duration static firings of the four aft firing engines were made at 14:37:00 G.m.t. Following the static firings, small amounts of N_2O_4 vapors were seen coming from the engines, and the crew heard the firings.

During the mission, all data indicated proper engine performance. Because of a lack of complete data, it was impossible to determine the exact values for total engine burn time and number of pulses. However,

TABLE I.- SERVICE MODULE RCS CONFIGURATION CHANGE SUMMARY

Parameter	AS 205 CSM 101	AS 503 CSM 103	AS 504 CSM 104	AS 505 CSM 106	AS 506 CSM 107	AS 507 CSM 108
Auxiliary helium pressurization valve upstream of secondary fuel tank	No	No	Yes	Yes	Yes	Yes
Capability to electrically isolate individual SM RCS engines	No	Yes	Yes	Yes	Yes	Yes
Cabin display of SM RCS helium tank temperature	No	Yes	Yes	Yes	Yes	Yes
Primary tank outlet temperatures measured	Yes	No	No	No	No	No
Secondary heater thermostats range (77° ± 7° to 104° ± 14° F) switch limits	Yes	Yes	Yes	No	No	No
Secondary heater thermostats range (120° ± 5° to 129° ± 5° F) switch limits	No	No	No	Yes	Yes	Yes
Panel insulation multilayer aluminized mylar encapsulated with H-film	Yes	No	No	No	No	No
Panel insulation multilayer aluminized H-film	No	Yes	Yes	Yes	Yes	Yes
Look-angle blankets installed	No	Yes	Yes	Yes	Yes	Yes

an estimate based on the total weight of propellant burned was 2640 seconds total burn time and 60 000 pulses.

The spacecraft was launched with the engine package heaters off for all four quads. The primary heater system on each quad was activated shortly after orbital insertion. The maximum quad package temperatures attained as a result of boost heating were 115° to 127.5° F. These temperatures were below the maximum temperatures (158° F) obtained during the Saturn V launches of Spacecraft 017 and 020. This resulted because the Spacecraft 101 launch trajectory was higher and Spacecraft 017 and 020 were launched with the primary heaters activated.

Heat soakback occurred after all long RCS burns (ullage maneuvers, phasing maneuvers, etc.) and following all periods of high engine firing activity. Maximum heat soakback occurred following CSM S-ICB rendezvous at approximately 30:00:00 g.e.t. At this time, maximum temperatures of 196° to 198° F were reached on quads A and C.

The SM RCS propellant quantity was determined by two methods during the flight. The PVT ground computer program utilized pressure, volume, temperature considerations, and was available only on the ground. The propellant temperature (P/T) sensor propellant values, which gave propellant quantity as a function of helium tank pressure and temperature, was displayed in the vehicle in terms of percent full scale of a 0 to 5 voltmeter, as well as being telemetered.

The PVT program was assumed to be the correct value for propellant expended. The quoted accuracy of this program was ± 6 percent because of instrumentation inaccuracies of the inputs to the program, use of nominal volumes and propellant loads, O/F ratio shift, and differential between helium tank and propellant ullage temperatures. The output of the P/T sensor was designed to read 100 percent when the helium tank pressure was 4150 psia at 70° F, and 0 percent when the pressure was 2250 psia at 70° F. The correct theoretical value of helium tank pressure at propellant depletion is 2450 psia at 65° F. A nomogram was used to correct the P/T sensor readings for this end-point error as well as for compressibility effects, system temperature variability, and propellant vapor pressure effects.

The secondary SM RCS propellant tanks contained 38 percent of the total load. Because of the inaccuracies of the gaging system, the crew was requested to switch from primary tanks to secondary tanks when the PVT program indicated 43 percent propellant remaining. Switchover was accomplished by opening the secondary propellant isolation valves and closing the primary propellant isolation valves.

Command Module Reaction Control Subsystem

Propulsion performance.- Comparison of the actual rates with the predicted rates indicated nominal CM propulsion performance. Both manual and automatic control were used during entry in combinations of dual and single system firings. Both systems were activated at approximately 259:08 g.e.t. A single system entry was planned, and system 2 was deactivated at 259:45:46 g.e.t. System 2 was subsequently reactivated at 259:58:30 g.e.t. when the crew heard a loud noise and suspected they had suffered a CM RCS engine malfunction. No malfunction occurred and the source of this noise is unknown. The remainder of the entry was made with both systems active.

Helium pressurization system.- The helium tank pressure drop at system activation was 487 psia for system 1 and 464 psia for system 2. Calculations have shown this pressure drop is equivalent to a polytropic helium expansion with an expansion exponent of 1.4. The relief valve burst discs were not ruptured at system activation.

Propellant system.- The propellant system functioned normally throughout the flight. No propellant leakage was noted. The system was activated with the propellant isolation valves closed. These valves were opened shortly after system activation. Propellant isolation valves operated normally. Postflight testing indicated that the oxidizer isolation valves were damaged, probably at system activation (discussed later).

Engines.- All data indicated proper engine performance during entry. It was estimated a total of 128 seconds of burn time and 829 pulses were accumulated by the 12 engines.

CM RCS thermal control.- During the flight prior to system activation, the CM RCS helium tank temperatures ranged between 61° and 77° F. The six CM RCS engine injector temperatures, read by the crew on the onboard meter, remained above 46° F at all times, and were above 50° F (upper limit of the meter) at the initiation of entry. Consequently the CM RCS valve heatup procedure, which was to be used if any injector fell below 34° F, was not required.

Propellant utilization.- Twenty-nine and 21 pounds of propellant were used from systems 1 and 2, respectively. Combinations of manual and automatic control and single and dual system firings were used during entry. The propellant expended figures were based on PVT calculations and were verified by engine on-time.

Spacecraft Deactivation

The Spacecraft 101 CM arrived at Pier 12, Norfolk Naval Air Station, Norfolk, Virginia, 0800 October 24, 1968, aboard the U.S.S. Essex. The CM was moved to hangar LP-2. The procedures for pyrotechnic evaluation were performed. All the pyrotechnics functioned normally. The normally unfired pyrotechnics in the RCS were verified and initiators removed from the squib valves.

Evaluation of the RCS indicated most of the propellants were onboard and system 2 had a minimum of operational use during the mission. Approximately 2.8 gallons of fuel were expelled from system 1 and 4.3 gallons from system 2. Leakage of manual valves in the ground support equipment (GSE) was noted during the fuel expulsion operation and corrections were made to eliminate the leaks. The RCS engine valve leak checks were performed to gather information for postflight analysis. These checks indicated that there was no gas leakage through the engine fuel injector valves.

An accurate volume of the oxidizer remaining in the RCS was not available because of the high boiloff rate of nitrogen tetroxide.

Anomalies

Two anomalies were noted during and after the flight.

1. The P/T quantity gage for the SM RCS quad B failed prior to launch. Cause of this failure is unknown.

2. During postflight testing of the CM RCS relief valve, a high amount of leakage was observed through the closed oxidizer propellant isolation valves. When voltage was removed, the oxidizer isolation valves opened and the position indicator switch verified the change. The valves are spring loaded closed by a bellows preload and should remain closed when voltage is removed. The oxidizer valves were removed and sent to the manufacturer for postflight tests and analysis. The analysis revealed a 0.05 to 0.06 inch compression of the poppet bellows. This permanent compression of the two poppet bellows and resultant reduction in seat load and opening voltage were, evidently, caused by a pressure surge when the CM helium system was activated with the isolation valves in the closed position. There was an an identical failure mode during the early development phase of this valve. The intended procedure was to have the valves open at system activation. The fact that the fuel valves did not fail can possibly be explained by the shorter and less dense fluid column between the isolation valve and the propellant tank. The fuel valves were not tested to determine whether degradation had occurred.

Corrective action is to open the isolation valves prior to system activation.

It is concluded that the CSM RCS performed as expected in all major respects. No flight problems for future vehicles were identified.

APOLLO 8 (SPACECRAFT 103) CSM RCS FLIGHT PERFORMANCE

Apollo 8 was the second manned Apollo mission, first manned Saturn V mission, and first manned lunar orbital mission. Lift-off occurred at 12:51:00.7 G.m.t. December 21, 1968. Mission duration was approximately 147 hours. The spacecraft landed in the mid-Pacific recovery area at 15:51:42 G.m.t. December 27, 1968. Crew consisted of Frank Borman, James Lovell, and William Anders.

This was designated as a "C-prime" type mission. The purpose of the mission was to demonstrate the capability of the spacecraft, crew, and MSFN support facilities to conduct a deep space and lunar orbital mission and to satisfy development and verification test objectives not accomplished on previous missions.

Various data test objectives (DTO) were defined for the CSM RCS. These are covered in detail in the Mission Requirements Document SPD8-R027, Revision A, dated December 13, 1968. Briefly, these DTO were:

1. P7.31 - Space Environment Thermal Control. The purpose of this DTO was to demonstrate that the passive thermal control mode of operation was adequate to maintain spacecraft systems and components, including the CSM RCS, within acceptable thermal limits.

2. P20.114 - Midcourse Correction Capability. The purpose of this DTO was to evaluate GNCS SPS/RCS guidance and control capability to make the required translunar and transearth midcourse corrections.

3. S20.116 - Exhaust Effects/CM Windows. The purpose of this DTO was to determine the effect, if any, of SM RCS engine firings on contamination of the CM windows.

4. In addition, the determination of SM RCS or CM RCS propellant utilization was included as a portion of the following DTO:

S1.32 - Midcourse Navigation/Star-Earth Landmark

P1.33 - Midcourse Navigation/Star-Lunar Horizon

P1.34 - Midcourse Navigation/Star-Earth Horizon

S20-104 - Transportation

S20-108 - CSM Consumables, Lunar Mission

P20.109 - Passive Thermal Control Modes

P20.111 - Lunar Landmark Tracking

Summary

The SM and CM RCS performance was satisfactory throughout the mission. All system parameters were within the normal range and no flight anomalies occurred. All test objectives were satisfied.

SM and CM RCS fuel was loaded November 17, 1968, and oxidizer November 18, 1968. A total of 1343.4 pounds of propellants was loaded in the SM and 245.3 pounds in the CM. The CM loading weight reflects the fact that approximately 18 pounds of oxidizer (9 pounds per CM RCS system) were off-loaded to prevent raw oxidizer from contacting the parachutes and risers during the propellant dump operation following entry. Helium servicing of the SM and CM RCS was performed December 17, 1968. The SM RCS quads were serviced to 4120 to 4230 psia helium pressure. No systems leakage was observed prior to launch. Static firing of the SM RCS engines on the pad was not performed.

The SM RCS helium pressurization system maintained helium and propellant manifold pressures constant at 181 ± 5 psia. No helium or propellant leakage was observed from the SM RCS during the flight.

Evaluation of spacecraft body rates indicated normal performance of the SM RCS throughout the flight.

A total of 634 pounds of SM RCS propellants was used during the flight. The predicted usage, adjusted for flight plan changes, was 668 pounds. Switchover from primary to secondary propellant tanks was accomplished on all four quads at 139:31:56 g.e.t. when the switchover point of 131 pounds (43 percent) of propellant remaining was reached in quads B and D. This percentage was indicated by ground calculations. The onboard propellant quantity gage readings, when corrected for end-point errors and temperature effects, agreed with ground calculations to within ± 7 percent of full scale.

It was estimated that a total of 46 000 firings of the SM RCS engines was made.

Thermal control of the SM RCS was satisfactory during the flight. Because of boost heating, maximum quad package temperatures were 124° to 142° F. The primary heaters on all four quads were activated shortly after insertion and remained on for the remainder of the mission. The primary heater system functioned normally. The quad package maintained temperatures between 118° and 142° F during periods of low engine firing activity. The maximum quad package temperature attained was approximately 185° F following the first CSM/S-IVB evasive maneuver at approximately 03:40:00 g.e.t. The quad heater duty cycles during the passive thermal control mode of operation varied between 15 and 30 percent; the average was approximately 25 percent. The SM RCS helium tank temperatures were from 59° to 88° F throughout the flight.

Prior to activation, no helium or propellant leakage was noted from the CM RCS. The systems were activated approximately an hour prior to CM/SM separation (145:32:50). Each system was briefly checked out by the crew; CM/SM separation occurred at 146:28:48.5 g.e.t.

Both manual and automatic control were used during entry. Approximately 20 seconds after CM/SM separation, CM RCS system 2 was deactivated. The remainder of the entry was performed using system 1. Evaluation of the spacecraft body rate data indicated that the system functioned normally. Following deployment of the main parachutes, the remaining CM RCS propellants were dumped at 146:57:13 g.e.t. Helium system blowdown and propellant line purge was initiated at 146:58:13 g.e.t. Approximately 20 seconds before landing, the propellant isolation valves were closed at 146:58:49 g.e.t.

A total of 34.7 pounds of CM RCS propellant was used prior to propellant dump (34.1 pounds from system 1 and 0.6 pounds from system 2). A total of 825 CM RCS engine firings was made.

The CM RCS helium tank temperatures remained between 57° and 74° F prior to system activation. The instrumented CM RCS engine injectors remained above 50° at all times. The CM valve dump warmup procedure was not required.

Slight (approximately 40 psia) pressure was found remaining in the CM RCS at deactivation. Unmeasurably small traces of fuel and oxidizer were found.

Service Module Reaction Control Subsystem

System configuration.- The Spacecraft 103 SM RCS differed from that of preceding and subsequent vehicles in the following respects:

1. The auxiliary helium pressurization valve in the helium pressurization line upstream of the secondary fuel tank was not installed on Spacecraft 101. This valve was included on Spacecraft 103 and subsequent vehicles.

2. Spacecraft 103 and subsequent vehicles incorporated the capability to electrically isolate individual SM RCS engines. This capability did not exist on Spacecraft 101.

3. Spacecraft 103 and subsequent vehicles incorporated a CM cabin display of the SM RCS helium tank temperature. This capability did not exist on Spacecraft 101.

4. Primary SM RCS propellant tank outlet temperatures measured on Spacecraft 101 were not available on Spacecraft 103 and were not available on subsequent vehicles.

5. The secondary SM RCS heater system thermostats on the Spacecraft 103 quads were of the low range configuration (77° ± 7° to 104° ± 14° F). On Spacecraft 106 and subsequent vehicles, the switching limits were 120° ± 5° to 129° ± 5° F.

6. All Spacecraft 103 quad panel insulation was multilayer blankets of aluminized H-film (polyamide) and all subsequent vehicles had identical insulation. The insulation on Spacecraft 101 was multilayer blankets or aluminized Mylar encapsulated with a surface sheet of H-film.

7. Spacecraft 103 incorporated "look angle" blankets to prevent the SM RCS tankage from radiatively "seeing" cold areas internal to the SM. These look angle blankets were installed on all subsequent vehicles but were not installed on Spacecraft 101.

A tabular summary of these vehicle-to-vehicle changes is shown in Table I.

Instrumentation.- No SM RCS instrumentation anomalies occurred during the Apollo 8 mission.

The magnitude of the pitch rates during positive (+) pitch maneuvers was consistently higher than those during the negative (-) pitch maneuvers for approximately identical vehicle mass. This is because of the fact that the CSM umbilical was located directly above the -x/-p engine on quad C. Based on theoretical calculated values, this resulted in an effective force reduction of approximately 20 percent. All other rates indicate nominal performance by all SM RCS engines throughout the mission.

Engines.- All data indicated correct engine performance during the mission. Because of a lack of complete data coverage, it was impossible to determine the exact values for total engine burn time and number of pulses. However, a rough estimate based on total weight of propellant consumed is 1600 seconds total burn time and 46 000 total pulses (exclusive of the SM RCS jettison firing following CM SM separation).

Thermal control.- The SM RCS thermal control system performed satisfactorily throughout the mission.

The spacecraft was launched with the engine package heaters "OFF" on all four quads. The primary heater system on each quad was activated at approximately 00:14:03 g.e.t., which occurred shortly after orbital insertion. The maximum quad package temperatures attained as a result of boost heating were 124° to 142° F. The Apollo 8 launch trajectory was very similar to that of Spacecraft 017. The maximum quad package temperatures during boost for Spacecraft 017, however, were 158° F. The difference in boost temperatures was because unmanned Spacecraft 017 was launched with the quad heaters "ON". Evaluation of the SM RCS thermal control system heater duty cycles during periods of passive thermal control indicated an operational duty cycle of 15 to 30 percent, depending on sun "look" angles, with most of the operation in the 20 to 25 percent duty cycle range. In general, engine temperatures and heater duty cycles during passive thermal control operation agreed with preflight NR predictions.

Heat soakback occurred following all major RCS burns (evasive maneuvers, midcourse corrections, ullages, etc.). Data were not available following all of these burns. Following the first CSM/S-IVB evasive maneuver, the maximum quad package temperature observed in the available data was 185° F on quad A at approximately 03:50:00 g.e.t.

In general, the helium tanks remained warmer during the Apollo 8 mission than during Apollo 7. This can be attributed to the effects of passive thermal control operation, differences in the SM insulation, and for Apollo 8 all the SPS tanks were full. From an RCS tankage viewpoint, the helium tank temperatures indicate passive thermal control is a satisfactory operational mode. At approximately 125 hours g.e.t. the quad A helium tank reached a temperature of 88° F, which was 2° F above the preflight predicted maximum temperature. At the present time it is uncertain whether this was caused by adjacent electronic equipment or by vehicle orientation effects. This temperature did not indicate an unacceptable thermal condition in the spacecraft, however.

Propellant utilization and quantity gaging.- Calculations from postflight data, the total propellant consumed during the mission was 634 pounds. This represented conservative usage. Propellant consumption was within 10 pounds of the predicted prior to the flight. This agreement was somewhat accidental. There was wide variance between actual and preflight predicted usage during initial phases of the mission because of deviations in the flight plan. Postflight predictions, accounting for changes in the flight plan, show favorable agreement between actual and predicted usage throughout the mission. The predictions are generally within 20 pounds of actual usage and within 34 pounds of actual usage at the end of the mission. The SM RCS propellant quantity was determined by two methods during the flight, PVT and P/T. The PVT ground computer program utilized pressure, volume, and temperature considerations at an average mission mixture ratio (MR-1) of 1.88 to 1.0. Within a quoted accuracy of ± 6 percent because of instrumentation inaccuracies, use of nominal volumes and propellant loads, O/F ratio shifts, and the differential between helium tank and propellant ullage temperatures, the PVT program was considered the best estimate for propellant expended. The pressure temperature (P/T) sensor, which gave usable propellant quantity remaining as a function of helium tank pressure and temperature, was displayed onboard in percent and telemetered. The output of the P/T sensor was designed to read 100 percent when the helium tank pressure was 4150 psia at 70° F and 0 percent when the pressure was 2250 psia at 70° F. The correct theoretical value of helium tank pressure at propellant depletion was 2450 psia at 65°. A nomogram was used to correct the P/T sensor readings for this end-point error, as well as compressibility effects, system temperature variability, and propellant vapor pressure effects. A quad-to-quad comparison of the propellant expended showed that the entire mission was flown in B and D roll, with A and C roll engines inhibited. Quads B and D propellant usage exceeded the preflight prediction, whereas A and C was slightly less. Quads B and D usage exceeded that of A and C by approximately 68 pounds. All major RCS ΔV burns and ullage maneuvers were four quad jet firings. Corrected P/T readings on quads A and D are in close agreement with PVT data during the entire mission. Quads B and C show more variance. This was because of an initial bias in each quad at launch. Quad B was initialized at 96.0 percent P/T and quad C at 98.0 percent P/T. Corrected for pressure and temperature variations, these values become 95 percent for B and 96.5 percent for C. With this initial bias, both P/T curves differ from their PVT constituent by a constant amount.

The secondary SM RCS propellant tanks contained 38 percent of the total load. Because of the inaccuracies of the gaging system, the crew was requested to switch to secondary tanks at 43 percent usable propellant remaining, as indicated by the PVT program. Switchover was accomplished at 139:31:56 g.e.t. on all four quads when the switchover limit was reached on quads B and D.

Command Module Reaction Control Subsystem

System configuration.- The CM RCS system configuration was identical to that of Spacecraft 101. On Spacecraft 104 and subsequent vehicles the fuel and oxidizer tank pressure transducers on each CM RCS system were relocated from their position downstream of the check valves to the common helium manifold between the regulators and the check valves.

Preflight activity.- The CM RCS fuel (MMH) was loaded November 17, 1968, and CM RCS oxidizer (N_2O_4) November 18, 1968. A total of 245.3 pounds of propellants was loaded into the two systems. Helium servicing of the CM RCS was accomplished December 17, 1968. To prevent raw oxidizer from contacting the parachutes and risers during the propellant dump operation following entry, approximately 9 pounds of oxidizer were off-loaded from each CM RCS system. Prior to launch, no systems leakage was observed.

Instrumentation.- No CM RCS instrumentation anomalies occurred during the Apollo 8 mission.

Propulsion performance.- The characteristic low rates during the first CM RCS firings after CM/SM separation, which were observed on previous flights and resulted from trapped gas in the propellant lines, were not seen on Spacecraft 103. This is because of the fact that the CM RCS was activated approximately an hour before CM/SM separation (at 145:32:50 g.e.t.). A series of checkout firings were performed at that time. Therefore, the propellant lines were well primed at separation. The checkout firings consisted of a positive and negative manual minimum impulse mode maneuver in each axis and a positive and negative automatic rate command maneuver in each axis. Control of the spacecraft attitude was returned to the SM RCS at approximately 145:34:45 g.e.t.

Comparison of the actual rates with predicted rates indicated nominal CM RCS propulsion performance. Both manual and automatic control were used during entry. Both systems were active at CM/SM separation; however, system 2 was deactivated approximately 20 seconds later, at 146:29:08 g.e.t. The remainder of the entry was made with system 1 only.

The CM RCS systems were activated approximately an hour before CM/SM separation at 145:32:50 g.e.t. The helium isolation squib valves operated normally at system activation. The initial helium tank pressure drop at system activation for system 1 was approximately 807 psia and for system 2 was 904 psia. After thermal stabilization, the stable pressure decrease for systems 1 and 2 was 636 and 652 psia, respectively. The relief valve burst discs were not ruptured at activation.

Propellant system.- The propellant system functioned normally throughout the flight. No propellant leakage was noted at any period. The propellant isolation valves were opened prior to systems activation. They sustained no damage because of activation. During the propellant dump operation, oxidizer was depleted approximately 5.5 seconds before fuel was depleted. This indicated the adequacy of the 9-pound oxidizer offloaded from each system. It is estimated that approximately 8.8 pounds of fuel were expelled from the systems following oxidizer depletion. Following the helium purge, the propellant isolation valves were closed approximately 20 seconds before landing at 146:58:49 g.e.t. The propellant isolation valves and talkback flags functioned normally.

Engines.- All data indicate proper engine performance during entry. Exclusive of the propellant dump, it is estimated a total of 98.8 seconds of burn time and 825 pulses were accumulated on the 12 engines.

Thermal control.- The CM RCS helium tank temperatures ranged from 57° to 74° F from launch through system activation. The six instrumented CM RCS engine injector temperatures, read by the crew on the onboard meter, remained above 50° F (upper limit of the meter) from launch through CM RCS activation. Consequently the CM RCS valve warmup procedure, which was to be used if any injector temperature went below 28° F, was not required. In general, the CM RCS was compatible thermally with passive thermal control and lunar orbital operations.

Propellant utilization.- A total of approximately 34.7 pounds of propellant was used from the CM RCS prior to the propellant dump (34.1 pounds from system 1 and 0.6 pounds from system 2).

Spacecraft Deactivation

On December 29, 1968 at 0915 the U.S.S. Yorktown docked at Ford Island. The CM was offloaded from the ship and transported to the deactivation site. At 1100 hours the Landing Safing Team (LST) began the evaluation of the CM according to the procedure in the Apollo Spacecraft Deactivation Procedures for Landing Safing Team manual. The procedures for pyrotechnic evaluation were performed. All of the pyrotechnics were found to h ve functioned normally.

Only slight traces of fuel and oxidizer as read on the GSE sight gage were detected in the spacecraft RCS system. The RCS engine valve leak checks and RCS bladder leak checks were not performed.

Slight residual pressure was found in both CM RCS systems (approximately 40 psia).

Because laboratory facilities were not available to analyze samples, purge and flush times were doubled to insure cleanliness and dryness for post mission tests at Downey. A new procedure was investigated which would effectively delete the need for laboratory analysis at the field site.

During flush operations, copious leakage of freon and isopropyl alcohol occurred around the GSE engine throat plugs. Causes for this leakage were (1) burnt throats, (2) waste matter in engine throats from drilling during removal of RCS panels on the prime recovery ship, (3) possible damage to the pitch throats because of improper removal of safety throat plugs on the prime recovery ship, (4) and improperly refurbished GSE engine throat plugs. The LST director agreed to see that the first three items were precluded from the next mission through appropriate notes in the recovery manual.

The NR RCS team director agreed to provide new GSE throat plugs instead of refurbished items on the Apollo 9 deactivation.

The following results were obtained when gas purge samples were analyzed at Downey:

Fuel side of fuel system -	9000 ppm isopropyl alcohol No MMH detected
Helium side of fuel system -	135 ppm isopropyl alcohol 10 ppm MMH
Oxidizer side of oxidizer system -	20 ppm freon 5 ppm N_2O_4
Helium side of oxidizer system -	20 ppm freon 5 ppm N_2O_4

The large percentage of isopropyl alcohol found in the fuel side of the fuel system sample was because of an improper sampling technique. After a short nitrogen purge at Downey, the sample showed 5.5 ppm isopropyl alcohol and no trace of MMH.

Postflight Investigations

Following return of the spacecraft to NR-Downey the CM RCS underwent engine inspection, leak check of the propellant isolation valves, and a reverse leakage test of the check valves.

The combustion chamber liner of the negative pitch engine of CM RCS system 2 showed evidence of a nonuniform combustion pattern. Two slight longitudinal erosion areas in the chamber liner constituted this evidence. Based upon boroscopic examination of the engine combustion chamber, throat, and nozzle extension, the engine manufacturer (Rocketdyne) considered the engine to be in satisfactory condition. Although there was evidence of a nonuniform combustion pattern, Rocketdyne felt that this condition was within the limits of variability that can exist because of manufacturing tolerances. Analysis by Rocketdyne, including sectioning and measurement of char depth of an engine from CM 011 which exhibited more severe erosion, indicated that the engine had considerable ablative life remaining. In addition, disassembly of the CM 011 injector failed to disclose the cause of the streaking.

The leak test of the CM RCS propellant isolation valves was accomplished in place, per ASHUR 103500, to verify that no functional anomaly existed. This test was prompted by the fact that the Spacecraft 101 CM RCS oxidizer isolation valves were damaged when the systems were activated with the valves in the closed position. On Spacecraft 103 the propellant isolation valves were opened prior to CM RCS activation. The test of the Spacecraft 103 valves indicated zero leakage and no damage.

The reverse leakage test of the CM RCS fuel and oxidizer check valves was accomplished in place, per ASHUR 103502, to determine the physical condition of the check valves. This test was prompted by the fact that the Spacecraft 101 CM RCS oxidizer check valves showed evidence of corrosion, thought to have been introduced during decontamination procedures. All of the Spacecraft 103 check valves showed zero leakage except the system 1 primary oxidizer check valve which had a reverse leakage of 80 scc/15 seconds (specification value of 3.6 scc/hour).

Anomalies

The oxidizer check valves in the CM RCS had valve seats made from R-88 rubber (nitroso rubber), which was selected because of its compatibility with oxidizer (N_2O_4). These check valves were subjected to an isopropyl alcohol flushing procedure at the plant of the manufacturer as a part of the cleanliness verification program of the component. It was found that an unexplained and nonrepeatable incompatibility exists between R-88 rubber and isopropyl alcohol. The result of this incompatibility was valve seat tackiness, degradation, and resultant leakage. The out-of-tolerance leakage exhibited during postflight testing by the Spacecraft 103 CM RCS system 1 oxidizer check valve was attributed to this cause. Effective on Spacecraft 104 and subsequent vehicles, only check valves which were not exposed to an isopropyl alcohol flush were used.

It was concluded that the CSM performed satisfactorily in all respects during the Apollo 8 mission, and that the adequacy of the systems for deep space and lunar orbital operations was demonstrated. No new problems requiring action on future vehicles were identified.

APOLLO 9 (SPACECRAFT 104) CSM RCS FLIGHT PERFORMANCE

Apollo 9 was the third manned Apollo mission, the second manned Saturn V mission, and the first manned LM mission. Lift-off occurred at 16:00:00.7 G.m.t. March 3, 1969, and the mission duration was approximately 241 hours. The spacecraft landed in the Atlantic Ocean at 17:00:54 G.m.t. March 13, 1969. The crew consisted of James McDivitt, David Scott, and Russell Schweickart.

This was designated as a D type mission. The primary purpose was to evaluate the LM systems performance and to perform selected CSM/LM operations.

Various DTO were defined for the CSM RCS. These are covered in detail in the Mission Requirements Document, SPD8-R-005, Revision 1, Change A, dated January 21, 1969. Briefly, these DTO are:

1. S1.26 - Orbital Navigation/Landmark Tracking. Determine SM RCS propellant consumption.

2. S7.29 - Exhaust Effects/CSM. Obtain data on the effects of the tower jettison motor, S-11 retro, and SM RCS exhaust on the CSM.

3. M17.17 - LM Environmental and Propulsion Thermal Effects. Verify performance of LM passive thermal design when exposed to natural and propulsion induced environments.

4. P20.24 - CSM Active Docking. Demonstrate CSM docking with S-IVB/SLA/LM and determine SM RCS propellant consumption.

5. P20.25 - LM Ejection from SLA. Demonstrate CSM/LM ejection from SLA using the SM RCS.

6. P20.26 - LM/CSM Undocking. Demonstrate LM/CSM undocking using SM RCS and compute CSM accelerations and SM RCS propellant consumption.

7. P20.29 - LM Jettison. Perform a pyrotechnic separation of the LM and CSM and compute CSM acceleration and SM RCS propellant consumption.

Summary

The SM and CM RCS performed satisfactorily throughout the mission. The only anomaly occurring was an inadvertent isolation valve closure during CSM/LM/S-IVB separation. The valves were later opened by the crew and remained open during the remainder of the mission. The closure was in all probability caused by the mechanical shock at CSM/S-IVB separation. All system parameters were normal during the mission and all test objectives were satisfied.

The SM and CM RCS fuel was loaded February 4, 1969. Oxidizer was loaded February 8, 1969. Approximately 18 pounds of oxidizer (9 pounds per system) were offloaded from the CM RCS. This was to prevent raw oxidizer from contacting the parachutes and risers during the propellant dump operation. Helium servicing of both SM and CM RCS was performed February 24, 1969. Prior to launch, a helium leak was detected at the high pressure helium pressure transducer in quad C. The quad door was opened without deservicing the propellant and the transducer seal replaced. No launch schedule slip was required. Static firing of the SM RCS engines on the pad was not performed.

The SM RCS helium pressurization system maintained the helium and propellant manifold pressures constant at 100 ± 6 psia. No helium or propellant leakage was detected from the SM RCS during the flight.

Evaluation of spacecraft body rates indicates normal RCS performance throughout the flight.

A total of 790 pounds of SM RCS propellant was used during the mission. The predicted usage, as corrected for flight plan changes, was 598 pounds. Most of the discrepancy between actual and predicted usage was caused by the quad C propellant isolation valves being closed during the undocked LM-active period. Secondary fuel tank helium isolation valves on all quads were opened prior to CM/SM separation. However, an empty primary tank was not indicated by a drop in the fuel manifold pressure.

An estimate for the total number of firings for the 16 SM RCS engines was 57 000.

Thermal control of the SM RCS was satisfactory throughout the flight. The maximum temperature reached because of boost heating was 145° F on quad D. The primary heaters on all quads were activated shortly after orbital insertion and remained on for the remainder of the mission. At 3:07:00 g.e.t., during the period that the quad C isolation valves were closed, the quad A package temperature reached 209° F. However, during times of low engine activity, the primary heaters maintained the package temperature between 117° and 141° F. The SM RCS helium tank temperatures ranged from 49° to 82° F.

Both manual and automatic control were used during entry. Approximately 12 seconds after CM/SM separation, system 2 was deactivated. The remainder of the entry used system 1. Evaluation of the spacecraft body rates indicates normal CM RCS performance.

A total of 27.5 pounds of CM RCS propellant was used for entry (27 pounds from system 1 and 0.5 pounds from system 2). The remaining 217.5 pounds were burned through the engines during the depletion burn following main parachute deployment. The depletion burn started at 240:56:26 g.e.t. Helium system blow-down and propellant line purge was initiated at 240:57:36 g.e.t. The propellant isolation valves were closed at 240:58:17 g.e.t.

The CM RCS helium tank temperatures remained between 54° and 74° F prior to system activation. Instrumented CM RCS injectors were approximately 50° F at all times. The CM valve warmup procedure was not required.

Service Module Reaction Control Subsystem

System configuration.- The only difference between the Spacecraft 103 and 104 RCS was the addition of an isolation valve in the helium line to the secondary fuel tanks on the SM quads. The purpose of this normally closed valve was to determine when the primary fuel tank was empty by a pressure decay in the fuel manifold pressure. When this occurred, the isolation valve (VW valve) should have been opened. This allowed the propellant remaining calculation to be updated to include the known volume of the secondary fuel tank, therefore increasing the accuracy of the measurement.

A summary of vehicle changes from Spacecraft 101 to Spacecraft 108 is presented in table I.

Preflight activity.- The SM RCS fuel (MMH) was loaded February 4, 1969, and oxidizer (N_2O_4) February 8, 1969. Prior to launch, a leak was detected from the quad C high pressure helium manifold pressure transducer. The quad door was opened without being deserviced. The seal on the transducer was replaced. Work was accomplished during a built-in hold in the countdown and did not require a launch schedule slip. The leakage did not reoccur during the mission.

The SM RCS was not static fired on the launch pad.

Instrumentation.- The quad B helium tank pressure transducer, SR-5002, was erratic for the duration of the mission. The output of this transducer would jump approximately 250 psi and then return to normal. This occurred about three times per day. No cause for the erratic readings was determined.

Caution and warning system.- The quad A package temperature CW limit of 206° F was reached during the transposition and docking period when the quad C isolation valves were closed.

Propulsion performance.- The magnitude of the pitch rates during +pitch maneuvers was consistently higher than those during the -pitch maneuvers for approximately identical vehicle mass. This was because of the fact the CSM umbilical was located directly above the -x/-p engine on quad C. This resulted in an effective force reduction of approximately 20 percent based on theoretical calculated values as well as the rate data. All other rates indicated nominal performance by all 16 SM RCS engines throughout the mission.

Propellant feed system.- With the exception of one anomaly, the SM RCS propellant feed system functioned normally throughout the mission. No indication of propellant leakage was noted. During transposition and docking with the S-IVB/LM, the primary and secondary propellant isolation valves on quad C and the secondary propellant isolation valves on quad D were found to be in the closed position. This is not believed to be a hardware problem and is discussed later. The valves were opened prior to CSM/S-IVB/LM docking and remained open for the duration of the mission. Opening of the helium isolation valves in the pressurization line to the secondary propellant tanks was intended to take place when the fuel manifold pressure decreased from 180 to 150 psia. However, this did not occur because sufficient propellant was not consumed to deplete the primary fuel tank in either of the four quads. To assure propellant would be available for the SM jettison maneuver, all four VW valves were opened approximately 3 hours prior to CM/SM separation.

Engines.- All performance data indicated correct engine performance during the mission. Because of a lack of complete data coverage, it was impossible to determine the exact values for total engine burn time and number of pulses. However, a rough estimate based on the weight of propellant consumed was 2000 seconds total burn time and 57 000 pulses. This did not include the SM jettison burn because propellant consumption data were not available after separation.

Thermal control.- The SM RCS thermal control system performed satisfactorily throughout the mission.

The spacecraft was launched with the engine package heaters "OFF" for all four quads. Shortly after orbital insertion, the primary heater system on each quad was activated at approximately 00:15:00 g.e.t. The maximum quad package temperature attained as a result of boost heating was 145° F on quad D.

During the transposition and docking period, while the quad C isolation valves were closed, the four package temperatures reached levels of 209°, 196°, 173°, and 186° F, respectively. The 209° F on quad A was sufficient to trigger the caution and warning switch; however, it was not above the 210° F redline. The high temperature on quad A resulted from the fact that left translation was being requested and quad C was unable to provide impulse because of the closed isolation valves.

A counterclockwise roll resulted which caused the control system to correct by firing clockwise roll. This means that opposing roll thrusters on quad A would fire and cause the temperature to increase.

During the remainder of the mission the thermal control system operated normally except for periods of high engine activity. The heaters cycled normally between 117° and 141° F.

Propellant utilization and quantity gaging.- During the transposition and docking maneuvers, while quad C was isolated, the actual usage of propellant exceeded the predicted by approximately 50 pounds. During the undocked LM active period, between 92 and 99 hours g.e.t., approximately 115 pounds of propellants were expended in excess of the predicted usage. At the end of the mission, the actual usage of propellant exceeded the predicted usage by approximately 140 pounds.

The maximum mismatch in propellant expended between the quads was maintained within 35 pounds by selectively varying combinations of one, two, and four jet roll maneuvers and two and four jet translation maneuvers. This was done in an attempt to keep the quads above the SCS deorbit redlines. Late in the mission quads A and C were slightly below this redline. The last three ullage burns were two jet, quads B and D, maneuvers.

The SM RCS propellant quantity was determined by two methods during the flight. The PVT ground computer program utilized pressure, volume, and temperature considerations and was available only on the ground. The P/T sensor, which gave propellant quantity as a function of helium tank pressure and temperature, was displayed in the vehicle in terms of percent full scale of a 0 to 5 voltmeter, as well as being telemetered.

The PVT program was assumed to be the correct value for propellant expended. The quoted accuracy of this program was ± 6 percent because of instrumentation inaccuracies of the inputs to the program, O/F ratio shift, and the differential between helium tank and propellant ullage temperatures. The output of the P/T sensor was designed to read 100 percent when the helium tank pressure was 4150 psia at 70° F and 0 percent when the pressure was 2250 psia at 70° F. The correct theoretical value of helium tank pressure at propellant depletion is 2450 psia at 65° F. A nomogram was used to correct the P/T sensor readings for this end-point error as well as for compressibility effects, system temperature variability, and propellant vapor pressure effects.

Command Module Reaction Control Subsystem

Systems configuration.- This system differed from the Spacecraft 101 and 103 configurations in the location of the low pressure helium manifold pressure transducer. The location was changed from downstream of the check valves in both the fuel and oxidizer manifolds to upstream of the check valves. This negated the possibility of determining which propellant was depleted first during the depletion burn because the transducer was in the common manifold between the two tanks and regulators.

Preflight activity.- The CM RCS fuel (MMH) was loaded February 4, 1969, and oxidizer (N_2O_4) February 8, 1969. A total of 245.0 pounds of propellant was loaded in the two systems. Helium servicing of the CM RCS was accomplished February 24, 1969.

To prevent raw oxidizer from contacting the parachutes and risers during the propellant depletion burn operation following entry, approximately 9 pounds of oxidizer were offloaded from each CM RCS system. No systems leakage was observed prior to launch.

Instrumentation.- No CM RCS instrumentation anomalies occurred during the Apollo 9 mission.

Propulsion performance.- Both manual and automatic control were used during entry. Both systems were active at CM/SM separation; however, system 2 was deactivated approximately 15 seconds later at 240:36:18 g.e.t. The remainder of the entry was made using system 1. Measured rate data compared favorably with theoretical rates, indicating nominal CM RCS performance.

Helium pressurization system.- The CM RCS systems were activated at 239:59:42 g.e.t., approximately 36 minutes before CM/SM separation. The helium isolation squib valves operated normally at system activation. The initial helium tank pressure drop at system activation for system 1 was approximately 845 psia and for system 2 was 800 psia. After thermal stabilization, the stable pressure decrease for systems 1 and 2 was 630 and 640 psia, respectively. The relief valve burst disks were not ruptured at activation.

Propellant system.- The propellant system functioned normally throughout the flight. No propellant leakage was noted. The propellant isolation valves were opened prior to systems activation. Because of the relocation of the low pressure helium manifold pressure transducers, it was not possible to determine which propellant was first depleted during the depletion burn. However, the onboard movies indicated a small amount of free oxidizer around the spacecraft during the depletion burn. Also, several parachute suspension lines recovered after the landing indicated they had been slightly damaged by what could have been CM RCS oxidizer. No explanation or reason for the free oxidizer was found; however, it was not considered a serious problem.

Approximately 3 minutes prior to landing, the CM RCS propellant isolation valves were closed at 240:58:17 g.e.t.

Engines.- All data indicated proper engine performance during the entry. A total of 79.42 seconds of burn time and 499 pulses were accumulated on the 12 CM RCS engines, exclusive of the steady-state propellant depletion burn which lasted approximately 70 seconds.

Thermal control.- The CM RCS helium tank temperatures ranged between 54° and 74° F from launch through system activation. The six instrumented CM RCS engine injector temperatures, read by the crew on the onboard meter, remained approximately 50° F (upper limit of the meter) from launch through CM RCS activation. Consequently the CM RCS valve warmup procedure, which was to be used if any injector fell below 28° F, was not required.

Propellant utilization.- A total of 27.5 pounds of CM RCS propellant was used prior to the propellant depletion burn (27 pounds from system 1 and 0.5 pound from system 2).

Spacecraft Deactivation

On March 16, 1969, at 0900 hours Eastern Standard Time, the U.S.S. Guadacanal docked at pier 12, Norfolk Naval Air Station. The CM was offloaded and located in hangar LP-2 at approximately 1030 hours. The CM RCS fuel deactivation lasted from 1500 March 16, 1969, to 0700 March 18, 1969. Oxidizer deactivation was accomplished between 1700 March 17, 1969, and 1900 March 18, 1969.

Although a small amount of helium pressure remained, essentially no propellants were found in the CM RCS during deactivation. After purging, the sample of the gaseous nitrogen purge fluid indicated no detectable N_2O_4 or MMH. Less than 10 parts per million of flush fluid (Freon TF) were found in the sample from the oxidizer side. The samples from the fuel side of systems 1 and 2 indicated 120 and 56 parts per million of flush fluid (isopropyl alcohol), respectively.

The postflight examination revealed that the CM RCS relief valve burst disks were not ruptured. The protective covers were still intact. All engine, helium, fuel, and oxidizer panels appeared to be in good condition with no visible anomalies.

Anomalies

Following separation from the S-IVB, the crew reported a control problem which had lasted for about 12 minutes during the transposition period. The crew first noticed a lack of capability for translation to the left. The position indicator flags for the quad C primary and secondary propellant isolation valves and the quad D secondary valves were in the "barber pole" or closed position. The valves were opened at approximately 2:51:30 g.e.t. and the system performed normally. These valves had been opened during final checks prior to launch, verified to be open during orbital insertion checks by the crew, and were verified during a cursory examination of the panel after the Commander and the Command Module Pilot exchanged seats prior to separation from the adapter.

The isolation valve magnetically latched open and was springloaded to the closed position. The valves were controlled by switches located on panel 2 which were springloaded to center-off. The four isolation valves in each quad were controlled by one switch.

Propellant usage data showed all four quad C valves were closed and quad D was performing normally before the crew reopened the propellant isolation valves. Propellant could be supplied from either the primary or secondary tanks, and only the valve position indicator for the secondary tank was in the "barber pole" position for quad D. Closure of only one of the secondary valves was sufficient to cause the indication.

It was concluded that the valve closure was caused by mechanical shock at separation of the command and service modules from the adapter. Shock tests were performed on several isolation valves and on an assembled quad. These tests were conducted to determine shock load required to close the valves and determine the effect of shock loads encountered during separation sequence. The results of individual valve tests indicate 80g with an onset rate of about 11 milliseconds up to 140g with an onset rate of about 1 millisecond could cause a normal valve to close. The shock at the valve resulting from the pyrotechnic charges used to separate the command and service modules from the adapter has been estimated to be between 180 and 260g with an onset rate between 0.2 and 3.0 milliseconds. Apollo 7 and 8, with the same configuration, did not have the problem.

Results of the investigations led to the conclusion that the shock could cause normal valves to close and, further, that valve closure was not detrimental to the valves. Since the hardware was shown not detrimentally affected, on subsequent flights the flight procedures were modified to verify isolation valve indications after exposure to shock environments.

It was concluded that the CSM RCS performed satisfactorily during the Apollo 9 mission. No new problems requiring action on subsequent vehicles were identified.

APOLLO 10 (SPACECRAFT 106) CSM RCS FLIGHT PERFORMANCE

Apollo 10 was the fourth manned Apollo mission, the third manned Saturn V mission, and the second manned LM mission. Lift-off occurred at 16:49:00.6 G.m.t. May 18, 1969, and the mission duration was approximately 192 hours. The spacecraft landed in the Pacific Ocean at 16:52:23 G.m.t. May 26, 1969. The crew consisted of Tom Stafford, John Young, and Eugene Cernan.

This was designated as an F type mission. The primary purpose was to evaluate the crew/spacecraft/mission support facilities performance during a manned CSM and LM lunar mission, and to evaluate LM performance in the lunar environment.

Various detailed test objectives (DTO) were defined for the CSM RCS. These are covered in detail in the Mission Requirements Document, SPD 9-R-037, Change B, dated February 11, 1969. Briefly, these DTO were:

1. S1.39-1 - Midcourse Navigation. Determine SM RCS propellant consumption.

2. S20.95-1 - Midcourse Corrections. Determine SM RCS performance on midcourse corrections.

3. P20.91-3 - Lunar Landmark Tracking. Determine SM RCS propellant required during docked operation.

4. P20.121-3 - Lunar Landmark Tracking. Determine SM RCS propellant consumption during undocked operations.

Summary

The SM and CM RCS performed satisfactorily during the mission. Two anomalies occurred on the CM RCS prior to launch: (1) system 1 developed a small helium leak that could not be located, and (2) system 2 had a ruptured oxidizer isolation burst disk. Neither of these anomalies affected the operation of the system during entry. Procedural changes were made to eliminate the possibility of these problems occurring on future flights. All system parameters were normal during the mission and all objectives were satisfied.

The SM and CM RCS fuel was loaded April 20, 1969, and oxidizer April 23, 1969. Approximately 18 pounds of oxidizer (9 pounds per system) were offloaded from the CM RCS. This was to prevent raw oxidizer from contacting parachutes and risers during the propellant dump

operation. Inspection of recovered parachutes indicated no damage because of RCS propellant. Helium servicing of both SM and CM RCS was performed May 13, 1969. Static firing of the SM RCS engines on the pad was not performed.

Evaluation of spacecraft body rates indicates normal SM RCS performance during the mission.

A total of 580 pounds of SM RCS propellant was used. The predicted usage of propellant was 850 pounds. The secondary fuel tank helium isolation valves on all quads were opened prior to CM/SM separation although an empty primary tank had not been indicated by a drop in the fuel manifold pressure.

An estimate for the total number of firings for the 16 SM RCS engines was 43 000.

Thermal control of the SM RCS was satisfactory throughout the flight. The maximum temperature reached because of boost heating was 150° F on quad D. The primary heaters on all quads were activated shortly after orbital insertion and remained on for the remainder of the mission. During times of low engine activity, the primary heaters maintained temperature between 120° and 142° F. The SM RCS helium tank temperatures ranged from 55° to 100° F.

Both manual and automatic control were used during entry. Approximately 9 seconds after CM/SM separation, system 2 was deactivated. The remainder of the entry performed using system 1 only. Evaluation of the spacecraft body rates indicated normal CM RCS performance.

A total of 32.5 pounds of CM RCS propellant was used for entry. The remaining 212.4 pounds were burned through the engines during the depletion burn following main parachute deployment. The depletion burn started at 191:58:50 g.e.t. and helium system blowdown and propellant line purge was initiated at 191:59:56 g.e.t. The propellant isolation valves were closed at 192.00:02 g.e.t.

The CM RCS helium tank temperatures remained between 54° and 75° F prior to system activation. The instrumentated CM RCS injectors were above 28° F at all times and the CM valve warmup procedure was not required.

Service Module Reaction Control Subsystem

System configuration.- The only difference between the Spacecraft 104 and Spacecraft 106 SM RCS was the secondary heater thermostat switching limits. The switching range was changed from 77° to 104° F to 120° to 129° F.

Preflight activity.- The SM RCS fuel (MMH) was loaded April 20, 1969, and oxidizer (N_2O_4) April 23, 1969. Helium servicing of the SM quads was accomplished May 13, 1969. No propellant or helium leakage was noted prior to launch.

The SM RCS was not static fired on the launch pad.

Instrumentation.- Prior to launch, four of the manifold pressure transducers were known to have a bias as follows: (1) helium manifold A - minus 8 psi, (2) fuel manifold - plus 11 psi, (3) oxidizer manifold B - minus 5 psi, (4) helium manifold D - plus 6 psi. With the exception of the quad D helium manifold pressure, these biases seemed to be constant for the duration of the mission. The quad D transducer began to increase approximately 3 days after launch until it reached a value 12 psi higher than the initial value. Since the fuel and oxidizer manifold pressures did not indicate a corresponding pressure increase and the difference between maximum and minimum helium manifold pressures on the remaining quads was 5 psi, it is assumed that the transducer shifted back to the correct reading.

Propulsion performance.- The magnitude of the pitch accelerations during +pitch maneuvers was consistently higher than those during the -pitch maneuvers for approximately identical vehicle masses. This was because of the fact that the CSM umbilical was located directly above the -x/-p engine on quad C. This resulted in an effective force reduction of approximately 20 percent based on theoretical calculated values as well as the rate data. All other values indicated nominal performance by all 16 SM RCS engines throughout the mission.

Engines.- All performance data indicated proper engine performance during the mission. Because of a lack of complete data coverage, it was impossible to determine the exact values for total engine burn time and total number of pulses. However, an estimate based on the weight of propellant consumed was 1500 seconds total burn time and 43 000 total pulses. This did not include the SM jettison burn because propellant consumption data were not available after separation.

Thermal control.- The SM RCS thermal control system performed satisfactorily throughout the mission.

The spacecraft was launched with the engine package heaters "OFF" on all four quads. Shortly after orbital insertion, the primary heater system on each quad was activated at approximately 00:12:40 g.e.t. The maximum quad package temperature attained as a result of boost heating was 150° F on quad B.

Propellant utilization and quality gaging.- The SM RCS propellant quantity was determined by two methods during the flight. The PVT ground computer program utilized pressure, volume, and temperature considerations and was available only on the ground. The P/T sensor, which gave propellant quantity as a function of helium tank pressure and temperature, was displayed in the vehicle in terms of percent full scale of a 0 to 5 voltmeter, as well as being telemetered.

The PVT program was assumed to be the correct value for propellant expended. The quoted accuracy of this program was ± 6 percent because of instrumentation inaccuracies of the inputs to the program, O/F ratio shift, and the differential between helium tank and propellant ullage temperatures. The output of the P/T sensor was designed to read 100 percent when the helium tank pressure was 4150 psia at 70° F and 0 percent when the pressure was 2250 psia at 70° F. The correct theoretical value of helium tank pressure at propellant depletion is 2450 psia at 65° F. To correct the P/T sensor readings for this end-point error as well as for compressibility effects, system temperature variability, and propellant vapor pressure effects, a nomogram was used.

Command Module Reaction Control Subsystem

System configuration.- This system differed from the Spacecraft 101 and 103 configurations in the location of the low pressure helium manifold pressure transducer. The location was changed from downstream of the check valves in both the fuel and oxidizer manifolds to upstream of the check valves. This negated the possibility of determining which propellant was depleted first during the depletion burn, because the transducer was in the common manifold between the two tanks and regulators.

Preflight activity.- The CM RCS fuel (MMH) was loaded April 20, 1969, and RCS oxidizer (N_2O_4) April 23, 1969. A total of 244.5 pounds of propellants was loaded in the two systems. Helium servicing of the CM RCS was accomplished May 13, 1969.

Approximately 9 pounds of oxidizer were offloaded from each CM RCS system to prevent raw oxidizer from contacting the parachutes and risers during the propellant depletion burn operation following entry.

Approximately 3.5 days prior to launch, a decrease of 0.14 psi/hr was noted in the system 1 helium manifold pressure. A check of the pressures in various portions of the system indicated 47 psia in the oxidizer tank, 33 psia in the fuel tank, and 25 psia in the helium manifold where the spacecraft transducer was located. The check valves, located between the pressure transducer and the propellant tanks, had a nominal cracking pressure of 2 psi, and therefore could account for the difference between manifold and tank pressures. This pressure distribution located the leak downstream of the check valves in the fuel leg.

The size of the propellant leak required to produce the established pressure decay, and the fact that propellant vapors could not be detected, isolated the leak in the helium system between the check valves and the fuel manifold. A mass spectrometer leak check of the entire system (both preflight and postflight) failed to locate the leak. The system was repressurized to 49 psia approximately 31 hours prior to launch. As discussed in anomalies, the leak rate decreased during the mission and had no adverse effect on the operation of the system during entry.

When the CM RCS propellant isolation valves were opened approximately 10 hours prior to launch, the system 2 helium manifold pressure dropped from 44 to 37 psia. Calculations showed that a pressure drop of this magnitude would be expected if the oxidizer burst disk was ruptured. Oxidizer would flow from the tank into the manifold when the isolation valves were opened.

It was decided to launch with the ruptured burst disk and vent the oxidizer from the lines through the engines after orbital insertion.

Propulsion performance.- The CM RCS was used in the minimum impulse mode almost entirely prior to 400 000 foot altitude during entry and the aerodynamic disturbances. The rates associated with these short firings were too small to allow reasonable angular acceleration calculations.

However, overall inspection of the vehicle dynamics during entry indicated nominal system performance.

Both manual and automatic control were used during entry. Both systems were active at CM/SM separation. However, system 2 was deactivated approximately 9 seconds later at 191:34:35 g.e.t. The remainder of the entry was made using system 1.

Helium pressurization system.- The CM RCS pressurization system functioned normally throughout the flight. The system 1 helium manifold pressure decreased from 44 to 20 psia because of a helium leak. The system 2 helium manifold pressure ranged from 35 to 37 psia because of thermal changes and indicated no system leakage.

Approximately 29 minutes before CM/SM separation, the CM RCS systems were activated at 191:04:33 g.e.t. The helium isolation squib valves operated normally at system activation. The initial helium tank pressure drop at system activation for system 1 was approximately 850 psia and system 2 was 840 psia. After thermal stabilization the stable pressure decrease for systems 1 and 2 was 700 and 720 psia, respectively. The relief valve burst disks were not ruptured at activation.

Propellant system.- The propellant system functioned normally throughout the flight. No propellant leakage was noted. The propellant isolation valves were opened prior to systems activation. Because of the location of the low pressure helium manifold pressure transducers, it was not possible to determine which propellant depleted first during the depletion burn. However, inspection of the parachutes and suspension lines showed no damage because of oxidizer contact. Also, the crew reported they did not see the red cloud generally associated with unburned oxidizer. The crew did observe the engine ablative material burning after the depletion burn. This is a normal occurrance which results from a hot ablative chamber following a long firing.

Approximately 3 minutes prior to landing, the CM RCS propellant isolation valves were closed at 192:00:02 g.e.t.

Engines.- All data indicated proper engine performance during the entry. Exclusive of the steady state propellant depletion burn lasting approximately 70 seconds, a total of 101.180 seconds of burn time and 545 pulses was accumulated by the 12 CM RCS engines.

Thermal control.- The CM RCS helium tank temperatures ranged between 54° and 75° F from launch through system activation. The CM RCS valve warmup procedure, which was to be used if any injector fell below 28° F, was not required. The system 1 negative yaw injector temperature reached 30° F at approximately 177 hours g.e.t. The remaining five instrumented injectors temperatures remained between 42° and 50° F.

Propellant utilization.- A total of 32.5 pounds of CM RCS propellant was used prior to the propellant depletion burn.

Spacecraft Deactivation

On May 31, 1969, the U.S.S. Princeton docked at Ford Island. The CM was offloaded and located in hangar 79. The CM RCS fuel and oxidizer deactivation lasted for approximately 50 hours beginning May 31 and ending June 2, 1969.

After purging, the sample of the gaseous nitrogen purge fluid indicated no detectable N_2O_2 or MMH. The samples from the oxidizer side of systems 1 and 2 indicated 43 and 28 ppm of flush fluid (freon TF), respectively. The samples from the fuel side of systems 1 and 2 indicated 1600 and 1800 ppm of flush fluid (isopropyl alcohol), respectively.

The postflight examination revealed that the CM RCS relief valve burst disks were not ruptured. The protective covers were still intact. Also, all engine, helium, fuel, and oxidizer panels appeared to be in good condition.

After the CM was returned to NR, Downey, California, the RCS was subjected to extensive leak checks in an attempt to locate the helium leak in system 1. Leak checks were conducted at 50 and 285 psia but the leak was not detected. Because the system had been subjected to deactivation procedures, it is possible that the "wetted" system or the quick disconnect actuations caused the leak to stop.

Anomalies

Command module system 1 helium leak.- After helium servicing, 3.5 days prior to launch, the system 1 helium manifold pressure in the CM RCS began to decay at 0.14 psi/hr. After approximately 2.5 days, the pressure upstream of the check valves had dropped from 45 to 35 psia. The pressure in the helium manifolds between the propellant tanks and check valves was checked. The oxidizer side was at the initial pressure of 47 psia, but the fuel side was 33 psia. Neither a helium leak or a fuel leak could be detected. The possibility that a fuel leak of this magnitude could go undetected was unreasonable. Therefore, it was concluded that the leak was in the low pressure helium manifold in the fuel leg, that it was not an indication of a serious problem, and that the rate would not increase during launch or during the mission, and could be accepted. The system was repressurized to 49 psia prior to launch.

The leak rate decreased as the mission progressed, reaching 0.04 psi/hr prior to activation. This decrease can be partially attributed to the reduced system pressure. Thus, the leak must have partially corrected itself or the properties of the leaking media changed. The helium in the propellant tanks and manifolds normally becomes diluted as propellant permeates the bladder.

At both 50 and 285 psia, postflight testing of the CM included a thorough mass spectrometer leak check on system 1. No leaks were detected. Postflight decontamination procedures, however, would tend to eliminate certain types of leaks because the quick disconnects were actuated during these procedures and the system was wet with flush fluid.

About 30 days prior to flight, for subsequent missions, a pad pressure of 100 psia was put into the system. This insured that leaks could be detected earlier in the count and repaired before launch.

Ruptured propellant burst disk.- When the propellant isolation valves in the CM RCS were opened about 10 hours prior to launch, system 2 helium manifold pressure dropped from 44 to 37 psia. A pressure drop of this magnitude would be expected if the oxidizer burst disk was ruptured and allowed oxidizer to flow from the tank into the oxidizer manifold.

The isolation valve and burst disk were redundant devices. Therefore, it was decided to proceed with the launch although the disk was ruptured. The isolation valves were closed after orbital insertion. The engine valves were opened by means of the reaction control heater circuits. Oxidizer was allowed to vent from the manifold for approximately 25 minutes. The helium manifold pressure remained at 37 psia except for changes caused by thermal effects and verified the isolation valve did not leak. When the isolation valves were opened just prior to system activation for entry, the helium manifold pressure dropped from 37 to 25 psia. This pressure drop confirmed the venting procedure had been effective and manifold was empty.

After the mission, the oxidizer and fuel burst disks were similar in physical appearance. This indicates the oxidizer burst disk had failed because of pressures in the flow direction, not because of corrosion or reverse pressure.

Appropriate caution notes were added to the prelaunch checkout procedures to establish the steps when the allowable limits on the burst disk (241 + 16 psid in the flow direction and 10 psid in the reverse direction) could be exceeded. Also, to detect a similar problem in the future, a leak check of the burst disk was added late in the launch site test flow.

It was concluded that the CSM RCS performed satisfactorily in all respects during the Apollo 10 mission. All new problems requiring action on subsequent vehicles were corrected.

APOLLO 11 (SPACECRAFT 107) CSM RCS FLIGHT PERFORMANCE

Apollo 11 was the fifth manned Apollo mission, fourth manned Saturn V mission, third manned LM mission, and first manned lunar landing mission. Lift-off occurred at 13:32:00 G.m.t. July 16, 1969. Mission duration was approximately 195 hours. The spacecraft landed in the Pacific Ocean at 16:50:35 G.m.t. July 24, 1969. The crew consisted of Neil Armstrong, Michael Collins, and Edwin Aldrin.

This was designated a G type mission. The primary purpose was to perform a manned lunar landing and return.

There were no DTO for the CSM RCS during this mission. Most of the DTO dealt with lunar surface characteristics and are presented in detail in the Mission Requirements Document, G Type Mission Lunar Landing.

Table I presents a summary of configuration changes from Spacecraft 101 to Spacecraft 108.

Summary

The SM and CM RCS performed satisfactorily throughout the mission. Two anomalies occurring were an inadvertent isolation valve closure during CSM/S-IVB/LM separation and a failure of a CM thruster to respond to automatic commands. The isolation valves were later opened by the crew and remained open during the remainder of the mission. The cause for the closure was determined to be the shock loads generated during the CSM/S-IVB separation. The CM engine malfunction was found to be caused by a faulty terminal board connector. All system parameters were normal during the mission and all mission requirements were satisfied.

The SM and CM RCS propellant loading was completed June 22, 1969, and helium July 11, 1969. Approximately 18 pounds of oxidizer (9 pounds per system) were offloaded from the CM RCS. This was to prevent raw oxidizer from contacting the parachutes and risers during the propellant dump operation. Static firing of the SM RCS engines on the pad was not performed.

Evaluation of spacecraft body rates indicated normal RCS performance throughout the flight.

A total of 560 pounds of SM RCS propellant was used during the mission. The predicted usage was 590 pounds. The secondary fuel tank helium isolation valves on all quads were opened prior to CM/SM separation; however, the fuel manifold pressure verified that the primary tanks still contained fuel.

An estimate for the total number of firings for the SM RCS engines was 40 000.

Thermal control of the SM RCS was satisfactory throughout the flight. The maximum temperature reached because of boost heating was 152° F on quad B. The primary heaters on all quads were activated shortly after orbital insertion and remained on for the remainder of the mission. During times of low engine activity, the primary heaters maintained the package temperature between 119° and 146° F. The SM RCS helium tank temperatures ranged from 52° to 97° F.

Both manual and automatic control were used during entry. Approximately 65 seconds after CM/SM separation, system 2 was deactivated. The remainder of the entry performed using system 1. Evaluation of the spacecraft body rates indicated normal CM RCS performance with the exception of the -yaw engine. This engine did not respond to automatic commands but performed normally with manual or direct coil commands. The problem was traced to a faulty terminal board connector during postflight investigation.

A total of 41 pounds of CM RCS propellant was used for entry. The remaining 205 pounds were burned through the engines during the depletion burn following main parachute deployment. The timeline of the depletion burn and purge operation is not available because of the failure of the onboard recorder used to record data during entry.

The CM RCS helium tank temperatures remained between 56° and 72° F prior to system activation. Instrumented CM RCS injectors were approximately 50° F at all times. The CM valve warmup procedure was not required.

Preflight Activity

The SM RCS fuel (MMH) was loaded June 18, 1969, and oxidizer (N_2O_4) June 22, 1969. Helium servicing of the SM quads was accomplished July 11, 1969. No helium or propellant leakage was detected prior to launch.

Although data were not available for this period, prelaunch flight data indicated that the magnitude of the pitch rates during +pitch maneuvers was consistently higher than those during the -pitch maneuvers for identical vehicle mass. This was because of the fact that the CSM umbilical was located directly above the -x/-p engine on quad C. This resulted in an effective force reduction of approximately 20 percent based on theoretical calculated values as well as the rate data. All other rates indicated nominal performance by all 16 SM RCS engines throughout the mission.

Service Module Reaction Control Subsystem

Propellant feed system.- With the exception of one anomaly, the SM RCS propellant feed system functioned normally throughout the mission. No indication of propellant leakage was noted. During CSM/S-IVB/LM separation, the primary and secondary propellant isolation valves on quad B inadvertently closed. This is discussed in the spacecraft deactivation section. The valves were opened by the crew approximately 25 seconds after separation and remained open for the duration of the mission.

Opening of the helium isolation valves in the pressurization line to the secondary propellant tanks was intended to take place when the fuel manifold pressure decreased from 180 to 150 psia. However, this did not occur. Not enough propellant was consumed to deplete the primary fuel tank in either of the four quads. All four valves were opened approximately 3 hours prior to CM/SM separation to assure that propellant would be available for the SM jettison maneuver.

Engines.- All performance data indicated proper engine performance during the mission. Because of a lack of complete data coverage, it was impossible to determine the exact values for total engine burn time and total number of pulses. However, an estimate based on the weight of propellant consumed is 1500 seconds total burn time and 40 000 total pulses. This does not include the SM jettison burn because propellant consumption data were not available after separation.

During the mission the thermal control system operated normally except for periods of high engine activity. The heaters cycled normally between 119° and 146° F.

Command Module Reaction Control Subsystem

System configuration.- This system had not been changed since Spacecraft 104 and differed from the Spacecraft 101 and 103 configurations in the location of the low pressure helium manifold pressure transducer. The location was changed from downstream of the check valves in the fuel and oxidizer manifolds to upstream of the check valves. This negated the possibility of determining which propellant was depleted first during the depletion burn, because the transducer was then in the common manifold between the two tanks and the regulators.

Preflight activity.- A total of 245.9 pounds of propellants was loaded in the two systems. Approximately 9 pounds of oxidizer were off-loaded from each CM RCS system to prevent raw oxidizer from contacting the parachutes and risers during the propellant depletion burn operation following entry. No systems leakage was observed prior to launch.

Instrumentation.- No CM RCS instrumentation anomalies occurred during the Apollo 11 mission.

Propulsion performance.- Approximately 5 minutes after deactivating system 2, the crew determined that the -yaw thruster was producing near zero thrust in response to automatic coil commands. Proper response was restored when the direct coils activated by the rotation hand controller were used. Operation in this mode provided two engine control authority, although system 2 circuit breakers were open. As discussed in the spacecraft deactivation section, the valve failure was traced to a faulty terminal board connector in the circuit for the automatic coil of the oxidizer valve. All other data indicated nominal CM RCS performance.

Both manual and automatic control were used during entry. Both systems were active at CM/SM separation. However, system 2 was deactivated approximately 65 seconds after CM/SM separation. System 1 was used for the remainder of the entry.

Helium pressurization system.- The CM RCS systems were activated at 194:16:22 g.e.t., which was approximately 33 minutes before CM/SM separation. The helium isolation squib valves operated normally at system activation. The initial helium tank pressure drop at system activation for system 1 was approximately 720 psia and system 2, 770 psia. After thermal stabilization, the stable pressure decrease for systems 1 and 2 was 580 and 610 psia, respectively. Postflight inspection verified the relief valve burst disks were not ruptured at activation.

Engines.- All data indicated proper engine performance during entry, although data were not available to determine total engine on-time and number of pulses. An estimate of 120 seconds and 750 pulses was made, based on total propellant consumption and previous exposure time. This was exclusive of the steady state propellant depletion burn which lasted approximately 60 seconds.

Thermal control.- The CM RCS helium tank temperatures ranged between 56° and 72° F from launch through system activation. The six instrumented CM RCS engine injector temperatures, read by the crew on the onboard meter, remained approximately 50° F (upper limit of the meter) from launch through CM RCS activation. The CM RCS valve warmup procedure, which was to be used if any injector temperature went below 28° F, was not required.

Spacecraft Deactivation

The spacecraft arrived at Ford Island, Hawaii, July 26, 1969, and deactivation procedures began. Although a small amount of helium pressure remained in the oxidizer system, essentially no propellants were found in the CM RCS during deactivation. The postflight examination revealed the CM RCS relief valve burst disks were not ruptured. The protective covers were still intact. Also, all engine, helium, fuel, and oxidizer panels appeared to be in good condition.

Anomalies

SM propellant isolation valve closure.- The propellant isolation valves on quad B of the SM RCS closed during CM/SM separation from the S-IVB. A similar problem was encountered on the Apollo 9 mission. Tests after Apollo 9 indicated a valve with normal magnetic latch forces would close at shock levels of 87g with an 11-millisecond duration. However, with durations in the expected range of 0.2 to 0.5 milliseconds, shock levels of 670g would not close the valves. The expected range of shock is 180 to 260g.

Two valves of nominal latching force of 7 pounds were selected for shock testing. It was found that shocks of 80g for 10 milliseconds to shocks of 100g for 1 millisecond would close the valves. The latching forces on the valves were then mechanically reduced to 5 pounds and were retested. The shock required to close the valves at this reduced latching force was 54g for 10 milliseconds and 75g for 1 millisecond. After completion of the shock testing the valves were examined and tested. No degradation was noted.

A review of the checkout procedures indicated the latching force could be degraded only when the procedures are not correctly implemented. Incorrect implementation would be the application of reverse current or ac voltage to the circuit. For Apollo 12, a special test indicated that the valve latching force was not degraded.

Because there was no valve degradation when the valve was shocked closed and the crew checklist contained precautionary information concerning these valves, no further action was necessary.

CM automatic coil failure.- The -yaw engine in CM RCS system 1 produced low and erratic thrust in response to firing commands through the automatic coils of the engine valves. Spacecraft rates verified that the engine performance was normal when fired by using the direct coils.

Electrical continuity through at least one of the parallel automatic coils in the engine was evidenced by the fact that the SCS driver signals were normal. This, along with the fact that at least some thrust was produced, indicated that one of the two valves was working normally.

During checkout at the launch site, another engine failed to respond to commands during the valve signature tests. The problem was isolated to a faulty terminal board connector. This terminal board was replaced and the systems re-tests were satisfactory. Because of this incident and the previous history of problems with the terminal boards, connectors were a prime suspect.

Postflight tests showed two pins in the terminal board were loose. The loose pins caused intermittent continuity to the automatic coils of the engine valve. This failure had been noticed on terminal boards manufactured prior to November 1967. This board was manufactured in 1966.

The intermittent contact was caused by improper clip position relative to the bus bar counterbore. This resulted in loss of some side force, which precluded proper contact pressure against the bus bar. A design change to the base gasket was made to positively insure that the bus bar was correctly positioned.

It was concluded that the CSM RCS performance was satisfactory in all respects during the Apollo 11 mission. No new problems requiring action on subsequent vehicles were identified.

CONCLUSIONS

It was apparent from the successful operation of the RCS on the Apollo flights there were no insurmountable engineering problems encountered during CSM RCS development. In retrospect, however, there were certain problems that were common to the development of many of the components. The problems were:

1. Component functional design specifications were often initially more stringent than necessary because actual requirements were not known. As requirements became better defined there was a hesitancy to relax the specification, resulting in some unnecessary, and, perhaps, unproductive effort. It was recommended that effort be expended in trying to define requirements accurately as early as possible. Additionally, when a relaxation in requirements became evident it was recommended that the specification be relaxed if cost or schedule savings could be realized.

2. Compatibility of the system/components with the propellants was a recognized problem early in the Apollo development program. A problem not evidenced until considerably later in the program involved compatibility of the system/components with the flush fluids or combinations of flush fluids and propellants. It was recommended when material compatibility of the system/components with fluids was established that it include all fluids and mixtures of fluids that might be introduced into the system. It was also recommended that particular attention be given to determining what fluids and materials could be used during "manufacturing" and "checkout" of the system. Provisions for adequate drying should be made when fluid mixing cannot be tolerated.

3. Because of the many small orifices and the close tolerances on moving parts, cleanliness control became an ever increasingly evident problem as the program progressed. At best, it was difficult to assemble a clean system. The need for component removal and replacement further aggravated the problem. To minimize the problem, filters were added to the system to protect components that had an unusually high failure rate because of contamination. It was recommended that on future programs all components be designed as insensitive to contamination as possible. Additionally, where contamination sensitive components cannot be avoided, it was recommended that the component be protected by integral filters built into the components. It was also recommended that if fluids are reverse flowed through any component during flushing or filling operations, consideration should be given to protecting both inlet and outlet ports on the component. Mainstream filters should be considered in addition to the integral component filters if large quantities of contaminates are anticipated.

4. A considerable number of unnecessary and costly situations arose during the development and qualification testing because the production of components was well underway before the testing programs were completed. This was particularly true with the system level tests. Corrective action for problems uncovered during these programs almost always involved retrofitting production units and modifying completed systems. Some problems were simply lived with because of the extensive vehicle rework required to correct the situation. Only limited changes were made to the systems as a result of these late tests, thus the test results did little to develop better, more reliable systems, but rather were only confidence builders. It was recommended that every attempt be made to integrate the test program schedules with the master production schedule so that these situations would not develop, or are at least would be minimized.

SECTION 3

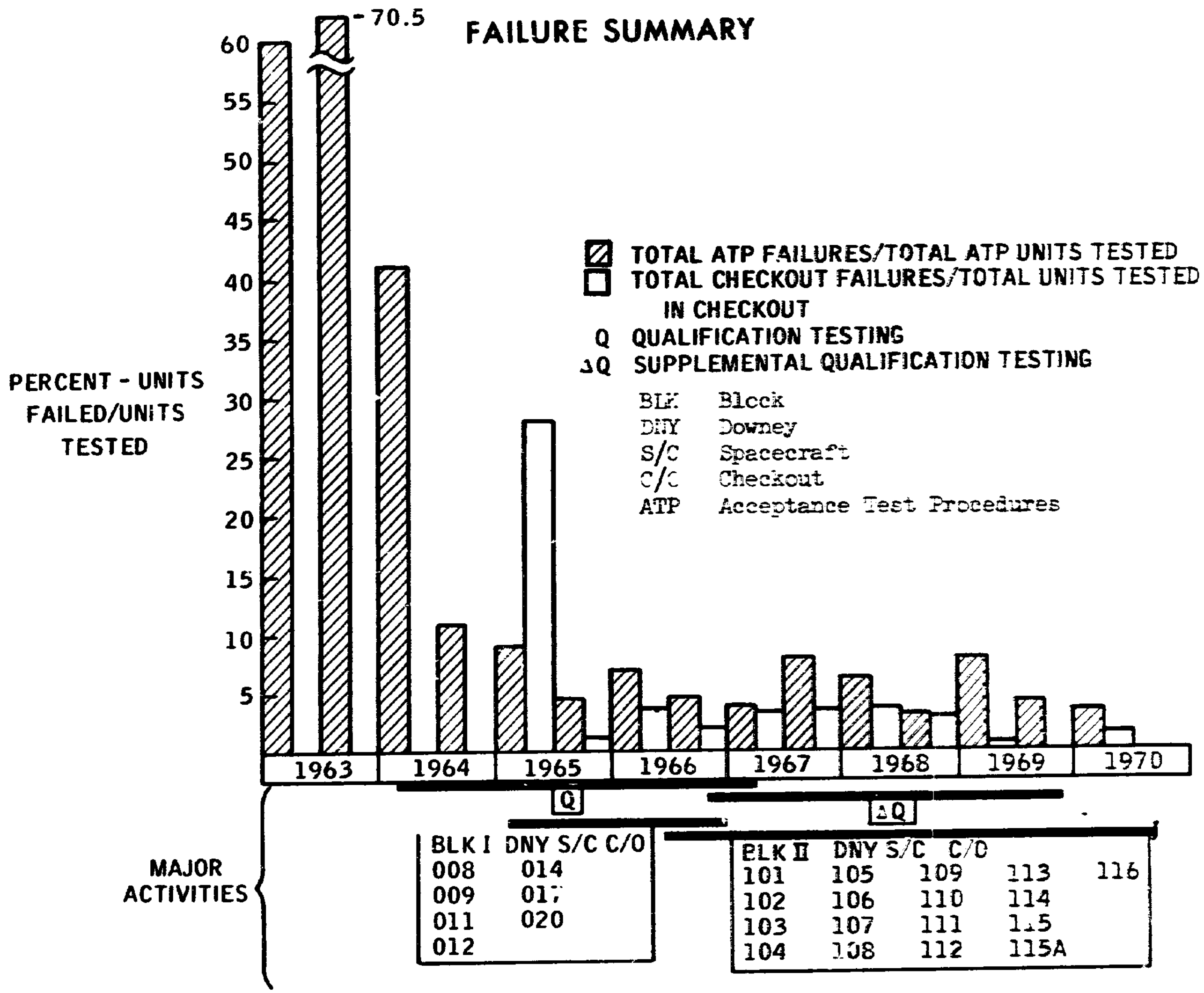
COMPONENT FAILURE HISTORY

INTRODUCTION

This section graphically presents the historical record of component failures in the Command and Service Modules Reaction Control Systems. There is no written text.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SUBSYSTEM

FAILURE SUMMARY



SERVICE MODULE REACTION CONTROL SYSTEM

FAILURE HISTORY (SYSTEM COMPONENT FAILURES/SYSTEM COMPONENT TESTS)

COMPONENT \ YEAR	1963	1964	1965	1966	1967	1968	1969	1970	*T.U.F./T.U.T.
ENGINES	85.0	42.0	16.2	3.7	7.7	3.0	3.1	1.5	6.9
CHECK VALVES	0	0	42.6	16.5	27.4	4.0	3.2	3.1	16.7
HELIUM ISOLATION VALVE	0	0	0	16.4	18.0	9.1	8.8	0	9.2
HELIUM RELIEF VALVE	0	0	3.1	10.0	25.3	6.6	1.9	0	8.1
SM/CM PROPELLANT ISOLATION VALVE	0	0	16.0	12.0	5.5	4.2	7.6	0	8.0
SM FUEL TANK	0	27.2	0	11.1	3.84	1.32	0	0	4.16
SM/CM HELIUM REGULATORS	0	0	0	6.8	0	11.8	12.1	6.5	1.19
TEST POINT COUPLINGS	0	0	0	0	2.6	2.25	0	0	0.95
SM/CM FILL VENT COUPLINGS	0	0	0	0	0	0	0	0	0
SM OXIDIZER TANK	0	0	0	0	0	0	0	0	0
SM/CM FUEL TANK	0	0	0	0	0	0	0	0	0
SM/CM HELIUM COUPLING	0	0	0	0	0	0	0	0	0
SM HEATER	0	0	0	0	0	0	0	0	0
SM/CM OXIDIZER TANK	0	0	0	0	0	0	0	0	0
SM/CM DYNATUBE	0	0	0	0	0	0	0	0	0
PROPELLANT FILTER	0	0	0	0	0	0	0	0	0
HELIUM TANK	0	0	0	0	0	0	0	0	0

NOTE: LESS THAN ONE PERCENT WAS CONSIDERED ZERO

* T.U.F. = TOTAL UNITS FAILED

* T.U.T. = TOTAL UNITS TESTED

COMMAND MODULE REACTION CONTROL SYSTEM

FAILURE HISTORY (SYSTEM COMPONENT FAILURES/SYSTEM COMPONENT TESTS)

COMPONENT \ YEAR	1963	1964	1965	1966	1967	1968	1969	1970	* T.U.F./T.U.T.
ENGINE	0	0	40.0	15.0	4.0	24.7	12.6	17.0	25.0
BURST DISC ASSEMBLY	0	0	21.8	19.2	0	1.67	0	25.0	10.5
HELIUM PRESSURE RELIEF VALVE	0	0	3.8	14.0	18.0	3.6	3.8	0	8.0
EXPLOSIVE VALVE 5/8-INCH	0	0	0	0	0	0	0	0	0
EXPLOSIVE VALVE 1/4-INCH	0	0	0	0	0	0	0	0	0
FLEX HOSE	0	0	0	0	0	0	0	0	0
DUMP HOSE ASSEMBLY	0	0	0	0	0	0	0	0	0

NOTE: LESS THAN ONE PERCENT WAS CONSIDERED ZERO

* T.U.F. = TOTAL UNITS FAILED
T.U.T. = TOTAL UNITS TESTED

EXPLANATION OF FAILURE CHART CODES

1. ATP - Acceptance of a component into deliverable status is the overall definition for ATP category items. This includes all feasibility tests, DVT tests, qualification tests, off-limit tests, inspections/tests, and any other tests that were intended to get a component into the deliverable system. The number of ATP category tests was obtained by adding the total number of component deliveries to the total number of ATP category failures. This leaves some tests during the ATP unaccounted for because there were no failures and the unit was not a deliverable item, but these are thought to be few in number.

2. C/OD - These are the tests, all categories and levels, performed on deliverable components at Downey. These tests were against components that had already passed acceptance. The tests generally were performed against components in various stages of system buildup and the complete system. The number of tests were determined from the Downey Checkout Schedules and by determining which components were under test for each checkout performed.

3. C/OK - Same as C/OD above, except that the tests were performed at KSC.

4. FLT - All failures that occurred during flight, whether discovered during flight or during CM postflight testing. No ratio of tests or flight hours was made for the flight failures.

ATP - Acceptance Test Procedure

DVT - Development Verification Test

C/OD - Checkout at Downey

C/OK - Checkout at KSC

FLT - Flight

EXPLANATION OF FAILURE CHART CODES

Within the bars on each chart there are coded letters indicating the general type or cause of failure. The word that most nearly describes the failure problem yet not confining that word to cause, mode, type, etc., of failure was selected. Within each general category a best judgment of the category into which the failure fits was made by the analyst.

a. M = Manufacturing Failures - includes bad tooling, workmanship, improper assembly, handling damage, casting porosity, improper materials, etc.

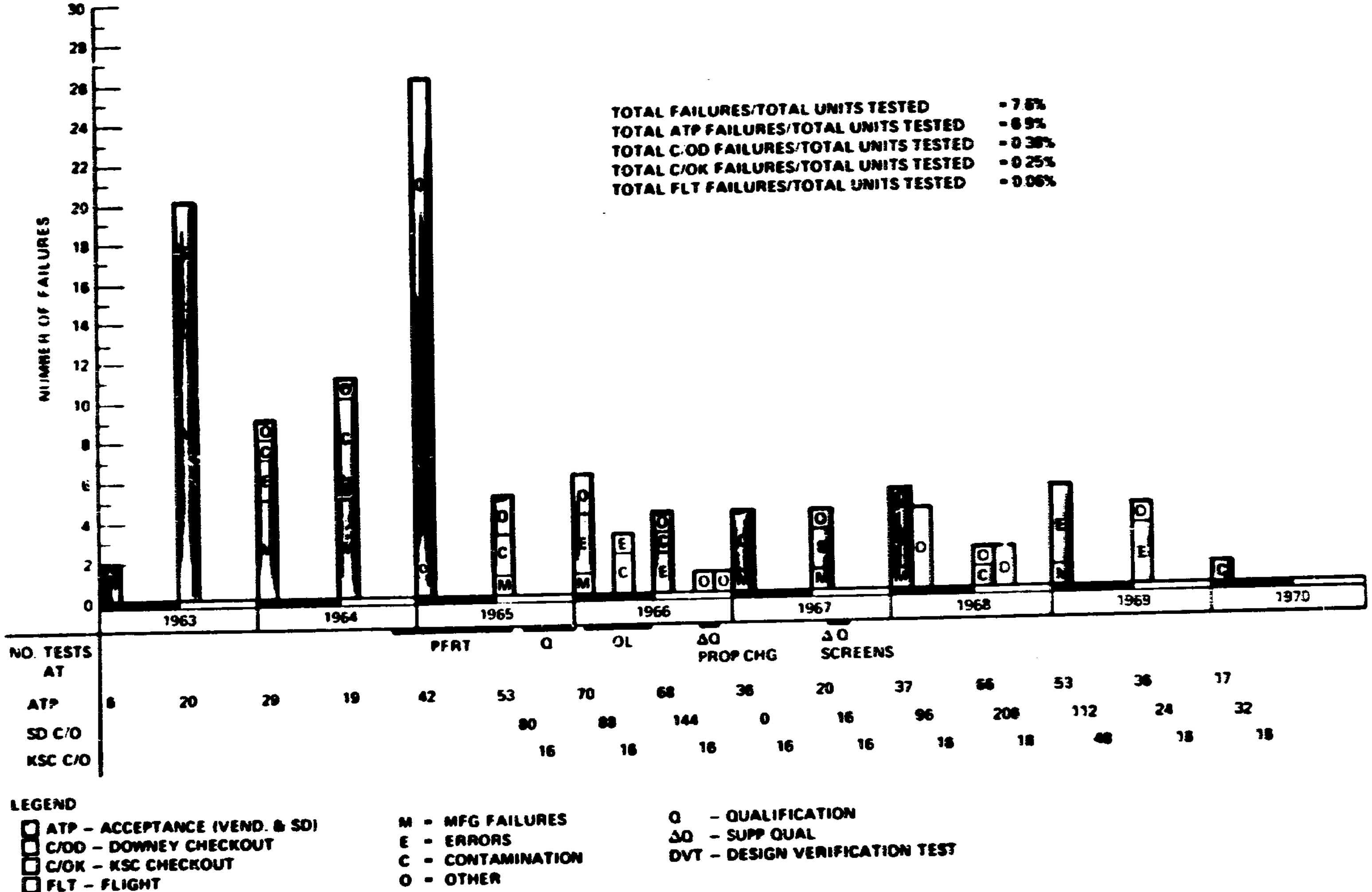
b. E = Errors - includes test errors, errors in failure reporting, and test procedure (documents) that were basic cause for failures.

c. C = Contamination - includes all failures where contamination of any kind was determined to be reason for the failure reported.

d. θ = Other - many of the failures could not reasonably be categorized into the M - E - C groups, and were of a great variety of modes and causes. These types of failures were placed into the "θ" category. These include such things as fatigue, burn, pitts, improper identification, improper operation, etc., for which causes for the failures were not determined.

e. H = Handling - for all components except test point couplings, there were so many handling failures that handling was pulled out as a separate category.

SM RCS ENGINE
ME901 0004



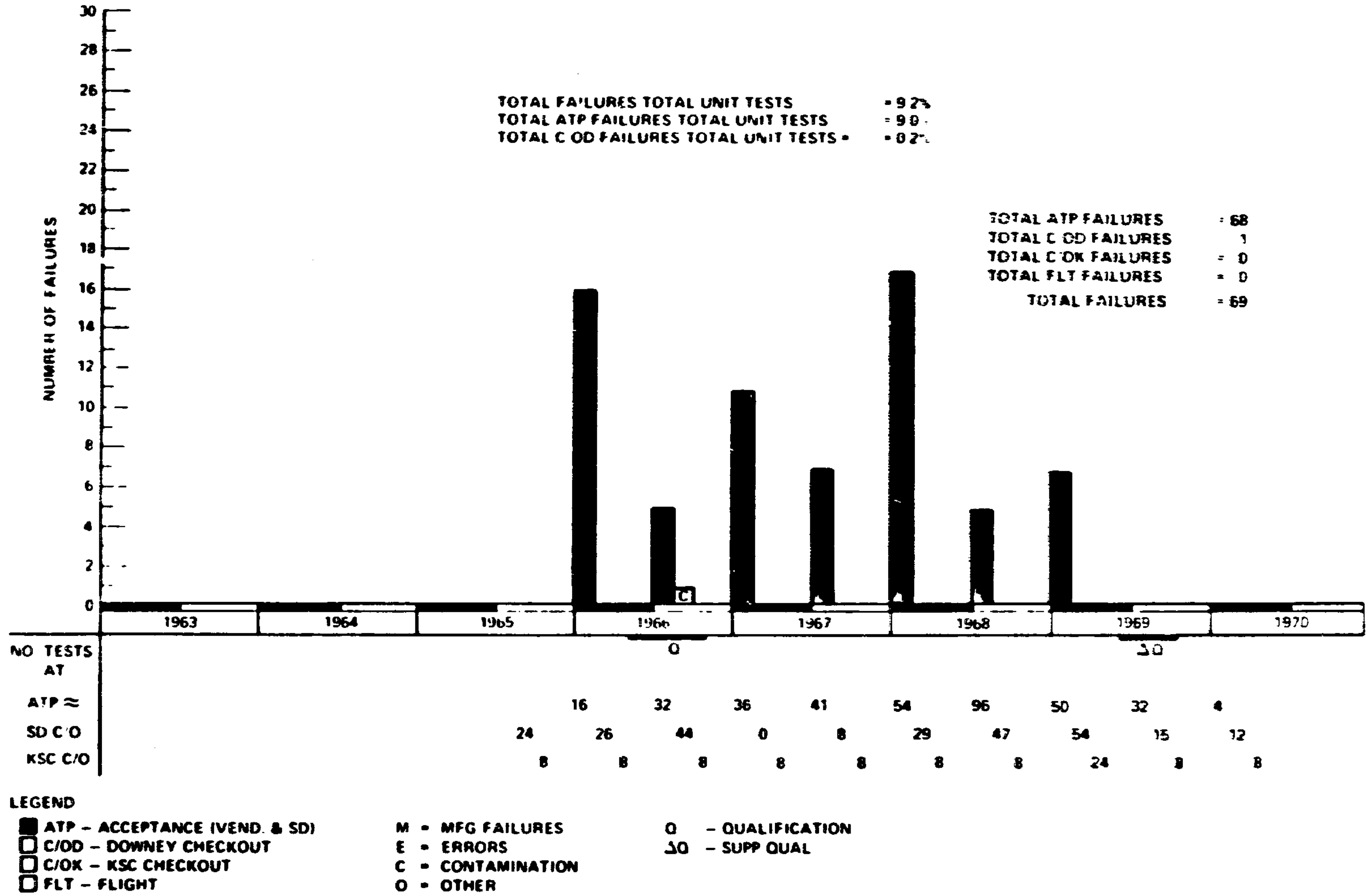
70AP107403

ENGINE FAILURE EVALUATION

SM RCS ENGINE

AREA/TIME	PROBLEM	CAUSE	CORRECTIVE ACTION
ATP FIRST HALF 1965	VARIOUS FAILURE OF ALL ATP REQUIREMENTS	INITIAL PRODUCTION OF SM RCS ENGINES (PFRT CONFIGURATION)	(1) REDEFINE ACCEPTANCE LIMITS (2) TRAIN PERSONNEL (3) RESOLVE DESIGN PROBLEMS
CHECKOUT KSC FIRST HALF 1966	CONTAMINATION FROM EXTERNAL SOURCES	(1) FAILURE TO USE PROTECTIVE COVERS ON ENGINE NOZZLES (2) FAILURE TO OBSERVE ALL NECESSARY PRECAUTIONS	(1) USE PROTECTIVE DEVICES ON ENGINES (2) REVISE GSE (3) TRAIN PERSONNEL
CHECKOUT DOWNEY FIRST HALF 1968	(1) DIRECT COIL CLOSING RESPONSE (2) DIRECT COIL OPENING RESPONSE	(1) IMPROPER TEST LIMITS (2) TEST ERROR	(1) DELETE TEST REQUIREMENT (2) TRAIN PERSONNEL
ATP 1967 TO 1968	INCREASE IN "E's"	(1) UNFAMILIARITY OF PERSONNEL WITH NEW OPERATIONS INVOLVING INSTALLATION AND TEST OF VALVE INLET STRAINER (2) NEW PERSONNEL	(1) and (2) PERSONNEL TRAINING AND EXPERIENCE

SM HELIUM ISOLATION VALVE
ME284 0281



70AP107399

SERVICE MODULE REACTION CONTROL SYSTEM

HELIUM ISOLATION VALVE ME284-0281

JAN-JUNE 1966	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	PROCEDURE FOR SARGENT-FLETCHER VALVE NOT COMPATIBLE WITH NWL
	C/A	NR/SD - REVISE PROCEDURE
JULY-DECEMBER 1966	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	VALVE SEAT DAMAGED BY CONTAMINATION. PARTICLES OVER 100 MICRON IN SIZE.
	C/A	NR/SD - ELIMINATE SOURCES OF CONTAMINATION - ELECTRO POLISH FITTINGS AND TUBE ENDS (MA0130-010)
	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	LEAKAGE CAUSED BY INCIPIENT CARBIDE PRECIPITATES ON SEALING SURFACE
	C/A	SUPPLIER - INITIATE 200 CYCLE MORTALITY TEST FOR EACH BALL AND SEAT ASSEMBLY.
JAN-JUNE 1967	PROBLEM	EXTERNAL LEAKAGE
	ANALYSIS	MALFUNCTIONING LEAK DETECTOR AT DETAIL PART CHECKOUT. PROBLEM DISCOVERED DURING ATP.
	C/A	SUPPLIER - MAINTAIN PROPER LEAK DETECTOR MAINTENANCE

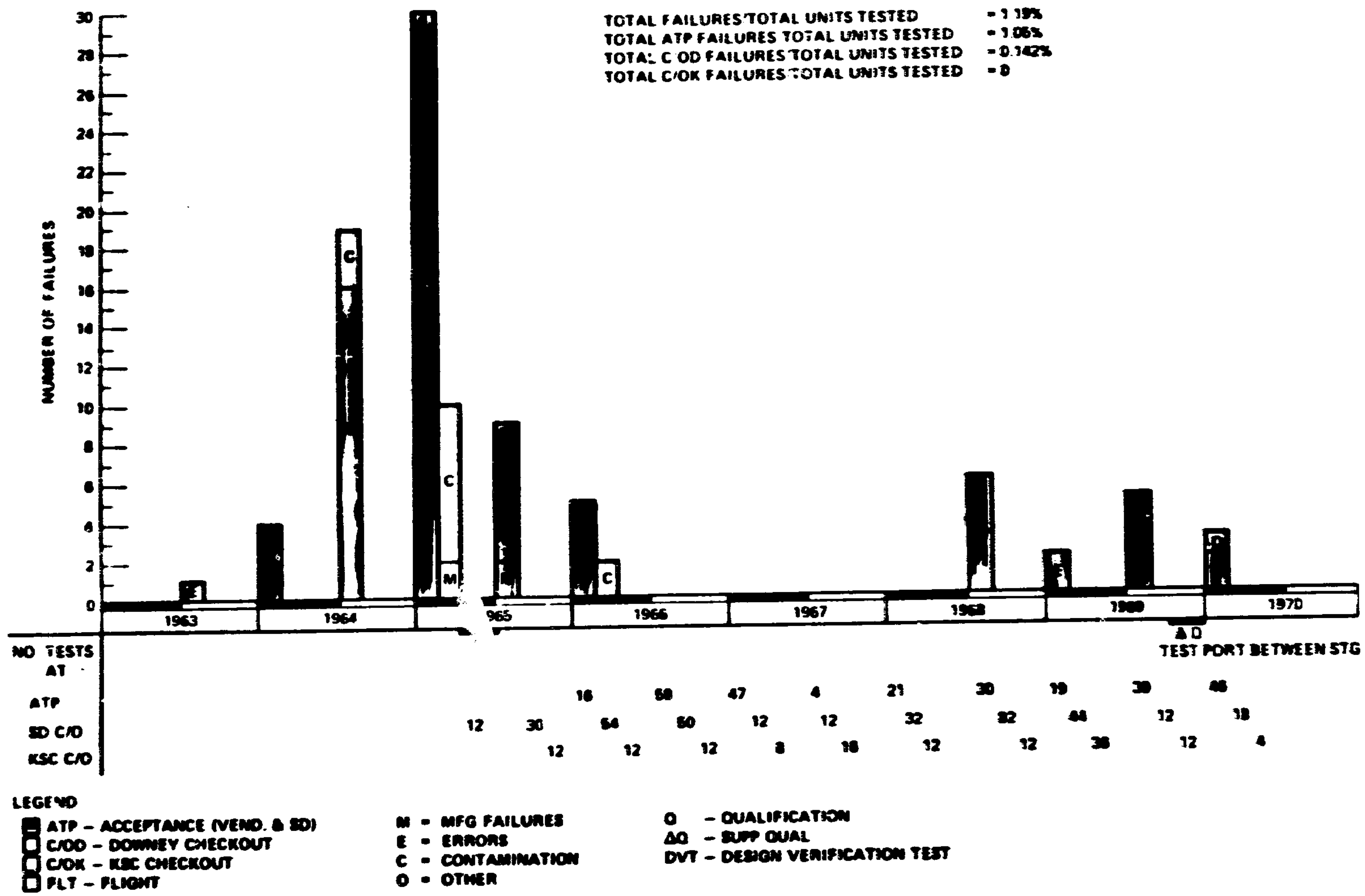
SERVICE MODULE REACTION CONTROL SYSTEM

JAN-JUNE 1967	(continued)	
	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	LEAKAGE PAST TEFLON STATIC SEAL
	C/A	SUPPLIER - REVISE ASSEMBLY TRAVELER FOR CLEANLINESS, BURRS AND SURFACE IMPERFECTIONS PRIOR TO ASSEMBLY.
JULY-DECEMBER 1967	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	CONTAMINATION CAUSED BY TRAPPED WATER IN VALVE. WATER USED BY CLEANING HOUSE WITHOUT AUTHORIZATION.
	C/A	NR/SD - RETURN ALL S/C HWD FOR REWORK SUPPLIER - DISASSEMBLE; CLEAN RETEST AND RETURN TO NR/SD
JULY-DECEMBER 1967	PROBLEM	INDICATOR SWITCH DOES NOT INDICATE PROPER POSITION
	ANALYSIS	IMPROPER SWITCH SETTING. SWITCH SCHECKED AT SUBASSEMBLY LEVEL.
	C/A	SUPPLIER - REVISE ASSEMBLY PROCEDURE TO CHECK SWITCH TRAVEL AFTER HEADER IS WELDED ON UNIT.
JAN-JUNE 1968	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	WATER CONTAMINATION
	C/A	NR/SD - RETURN ALL S/C HWD FOR REWORK SUPPLIER - REWORK AND RETURN TO NR/SD

SERVICE MODULE REACTION CONTROL SYSTEM

JAN–JUNE 1968	(continued)	
	PROBLEM	FAILED TO LATCH OPEN
	ANALYSIS	LARGE METAL BURR IN SOLENOID BORE
	C/A	SUPPLIER – C/A WAS TAKEN AFTER THAT VALVE WAS SHIPPED TO NR/SD. INSPECT BORE WITH 40X MICROSCOPE AND ADD CYCLING TEST FOR MORTALITY.
JULY–DECEMBER 1968	PROBLEM	EXTERNAL LEAKAGE
	ANALYSIS	WELD LEAKAGE AFTER PROOF PRESSURE TEST.
	C/A	SUPPLIER – CONTAMINATION OF WELD AREA – CONTROL WELDING PROCESS TO INSURE PROPER CLEANLINESS OF FLANGES PRIOR TO WELDING.
JAN–JUNE 1969	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	INCORRECT LEAKAGE RATE CALL OUT
	C/A	NR/SD – REVISE LEAKAGE CALL OUT TO 20 SCC/HR FROM 10 SCC/HR
	PROBLEM	FALSE INDICATOR INDICATION
	ANALYSIS	REACTION TO SOLENOID MAGNETIC FIELD CAUSING MOMENTARY FALSE INDICATION.
	C/A	NR/SD – PERFORM TEST PRIOR TO BRAZING INTO SYSTEM; INSTALL SHIELDING BETWEEN VALVES.

SM/CM HELIUM PRESSURE REGULATORS
ME284-0021 ME284-0022



70AP107414

CM and SM RCS He Regulators

ME 284-0021 and -0022

DATE: 1/17/70

PROBLEM: ATP, audible oscillations exceeded 15 second requirement at 4500 psi

ANALYSIS: Workmanship, problem caused from maladjustment during assembly and shimming procedure.

C/A: Normal readjustment of the spring consisting of rotating spring about its longitudinal axis, followed by retesting.

NOTE: Readjustment was allowed in ATP, this condition should not have been reported as a failure.

DATE: 11/21/69

PROBLEM: Oscillation in ATP

ANALYSIS and C/A: Readjust and retest, same as that as above.

NOTE: Should not have been reported as a failure.

DATE: 10/3/69

PROBLEM: Oscillation in ATP

ANALYSIS and C/A: Readjust and retest, same as that in number 1.

NOTE: Should not have been reported as a failure.

DATE: 8/16/69 (1)

PROBLEM: Oscillation in ATP

ANALYSIS and C/A: Readjust and retest, same as that in number 1.

NOTE: Should not have been reported as a failure

DATE: 8/16/69 (2)

PROBLEM: Oscillation in ATP

ANALYSIS and C/A: Readjust and retest, same as that in number 1.

NOTE: Should not have been reported as a failure.

DATE: 8/9/69

PROBLEM: Oscillation during ATP

ANALYSIS and C/A: Readjust and retest, same as in number 1.

NOTE: Should not have been reported as a failure.

DATE: 8/1/69

PROBLEM: Oscillation during ATP

ANALYSIS and C/A: Readjust and retest, same as that in number 1.

NOTE: Should not have been reported as a failure.

DATE: 7/18/69 (1)

PROBLEM: Oscillation during ATP

ANALYSIS and C/A: Readjust and retest, same as in number 1.

NOTE: Should not have been reported as a failure.

DATE: 7/4/69

PROBLEM: Oscillation during ATP

ANALYSIS and C/A: Readjust and retest, same as in number 1.

NOTE: This condition should not have been reported as a failure.

DATE: 7/18/69 (2)

PROBLEM: Oscillation during ATP

ANALYSIS and C/A: Readjust, retest, same as in number 1.

NOTE: This condition should not have been reported as a failure.

DATE: 12/27/68

PROBLEM: Pressure too low in ATP; the regulated outlet pressure was 177.6 psi at 4500 psi inlet pressure; the requirement is 178 psi minimum

3

ANALYSIS: Failure due to discrepant bellows heat treat; all standard bellows have been or are being removed from all regulators.

C/A: Standard Bellows no longer an approved vendor; the approved vendor is now Bell Metrics Corporation. All Standard Bellows are being replaced.

DATE: 11/8/68

PROBLEM: Oscillation during ATP

ANALYSIS and C/A: Readjust and retest, same as that in number 1.

NOTE: This condition should not have been reported as a failure.

DATE: 11/1/68

PROBLEM: Pressure too low in ATP; secondary regulated outlet pressure drops to 181.5 psi during blowdown at 300 psi inlet pressure. The minimum allowed is 182 psi.

ANALYSIS: Failure due to discrepant bellows heat treat of S.andard Bellows.

C/A: All Standard Bellows are being removed and replaced. Standard Bellows no longer approved source. Approved supplier is now Bell Metrics Corporation.

DATE: 9/27/68 (1)

PROBLEM: Oscillation during ATP

ANALYSIS and C/A: Readjust and retest, same as in number 1.

NOTE: This condition should not have been reported as a failure.

DATE: 9/27/68 (2)

PROBLEM: Oscillation during ATP

ANALYSIS and C/A: Readjust and retest, same as in number 1

NOTE: This condition should not have been reported as a failure.

DATE: 9/27/68 (3)

Same as above

4

DATE: 9/27/68 (4)

Same as above

DATE: 11/18/66

PROBLEM: Functional test leakage; regulator pressure varied from 164 psig to 199 psig during functional test of quad C RCS.

ANALYSIS: An unrealistic condition was imposed upon the regulator system by test personnel while configuring the RCS quad prior to running functional tests.

C/A: Return regulator to supplier and replace with new regulator; a deviation has been written to prevent this problem from reoccurring.

DATE: 3/6/70

PROBLEM: Pressure too low in ATP; regulation band was 176.0 to 184.2 psi after proof pressure test. requirement is 178 to 184 psig. Regulator could not be reshimmed to operate in required regulation band.

ANALYSIS: Inadequate lubrication resulted in galling of piston guide surface preventing proper piston operation.

C/A: Apply lubricant per note 6 to drawing 63-036. Requirement also placed on master route sheet.

DATE: 2/20/70

PROBLEM: Oscillation during ATP, did not stop after readjustment of spring.

ANALYSIS: Replace questionable Teflon ring in main piston, apparently end play causing oscillation.

C/A: Assembly personnel cautioned to take care to prevent Teflon ring damage during assembly.

DATE: 2/6/70

Same as above

DATE: 3/13/70

PROBLEM: Internal leakage of approximately 396 cc/hr during ATP; max allowed is 20 cc/hr.

ANALYSIS: Leakage was past defective o-ring on primary plunger; o-ring nicked during assembly.

C/A: Technicians reinstructed on procedures of o-ring inspection and assembly.

DATE: 1/17/70

PROBLEM: Oscillation of regulator second stage during ATP; adjustment of control spring ineffective to eliminate condition.

ANALYSIS: Sharp seat in guide indented pilot poppet.

C/A: Inspection to examine radius on guide seat

DATE: 8/5/66

PROBLEM: Pressure too high during KSC checkout; helium pressure regulator primary number 1 failed to lockup α 199 psig; should be 183 ± 5 psig.

ANALYSIS: None performed

C/A: None taken, no failure

DATE: 4/1/66

PROBLEM: Regulator would not lockup during C/O at Downey at pressure reading of 200 psi

ANALYSIS: Disassembly revealed residue liquid in regulator. Primary piston immovable Liquid Freon was introduced by NAA.

C/A: None required.

DATE: 2/6/70

PROBLEM: Oscillation during ATP

ANALYSIS and C/A: Readjust and retest, same as that in number 1

NOTE: This condition should not have been reported as a failure

DATE: 11/14/69

PROBLEM: Oscillation during ATP

ANALYSIS: Replaced Teflon ring in main piston; retest was satisfactory; apparently too much ring play was causing oscillation.

C/A: None other than replacement of main piston Teflon ring considered necessary.

DATE: 5/2/69

PROBLEM: Secondary regulator did not lock up; primary locked up 60 psi high due to 60 psi dome loading during ATP.

ANALYSIS: Plunger galled in guide tending to hold pilot poppet open; this caused leakage resulting in high lockup pressure of 356 psi. Max. allowed is 308 psi.

C/A: Component reworked and passed tests. Supplier cautioned to use care in polish operation of parts.

DATE: 7/4/69

PROBLEM: Pressure too low during functional test at Downey.

ANALYSIS: System pressure drop causing indicated low regulator outlet pressure. Slight shift in regulator control spring setting.

C/A: Problem will be corrected by setting regulator control spring such that regulator outlet pressure is at the nominal requirement rather than toward low side of required regulator outlet pressure.

DATE: 5/9/69

PROBLEM: Oscillation during ATP

ANALYSIS and C/A: Readjust and retest, same as that in number 1.

DATE: 9/27/68

PROBLEM: Excessive internal leakage during ATP; 44 cc/hr, max. allowed 20 cc/hr.

ANALYSIS: Leakage was caused by the primary o-ring at the plunger. O-ring had no visible defects, could have been affected by minor condition of guide finish.

C/A: 100 percent inspection of guide bore finishes. Spec. had been revised for control of o-ring production and inspection.

7

DATE: 9/27/68

PROBLEM: Secondary regulator did not lockup during ATP.

ANALYSIS: Examination indicated that the surface finish of the pilot poppet was blemished in the seat area sufficiently to cause leakage.

C/A: Manufacturing instructed to replace poppets in -900 subassembly if regulator has been subjected to high inlet pressures in the pretest phase and is subsequently disassembled for any reason.

DATE: 2/13/70

PROBLEM: Primary regulator had an oscillation band of 3.5 psi peak to peak in ATP, max. allowed is 3.0 psi.

ANALYSIS: Scratches were found in the bore of the cap, the bore is a guide for the piston.

C/A: During assembly operation inspect the bore of the cap at a 10/20 × magnification to verify polish per print.

DATE: 1/30/70

PROBLEM: In ATP, pressure oscillation was 5.5 psig P-P; max allowed is 3.0 psig.

ANALYSIS: Bellows shoulder was not fully seated on housing shoulder during welding operation causing cocked bellows.

C/A: Welders reinstructed.

DATE: 3/18/66

PROBLEM: In ATP, regulator failed to close at specified pressure of 295-305 psig. Regulator stayed open up to test pressure of 310 psig.

ANALYSIS: Failure caused by freon flushing fluid causing excessive swell of poppet seat material thus holding poppets open.

C/A: Flush fluid changed from Freon to alcohol which is compatible with poppet seat material.

DATE: 3/18/66

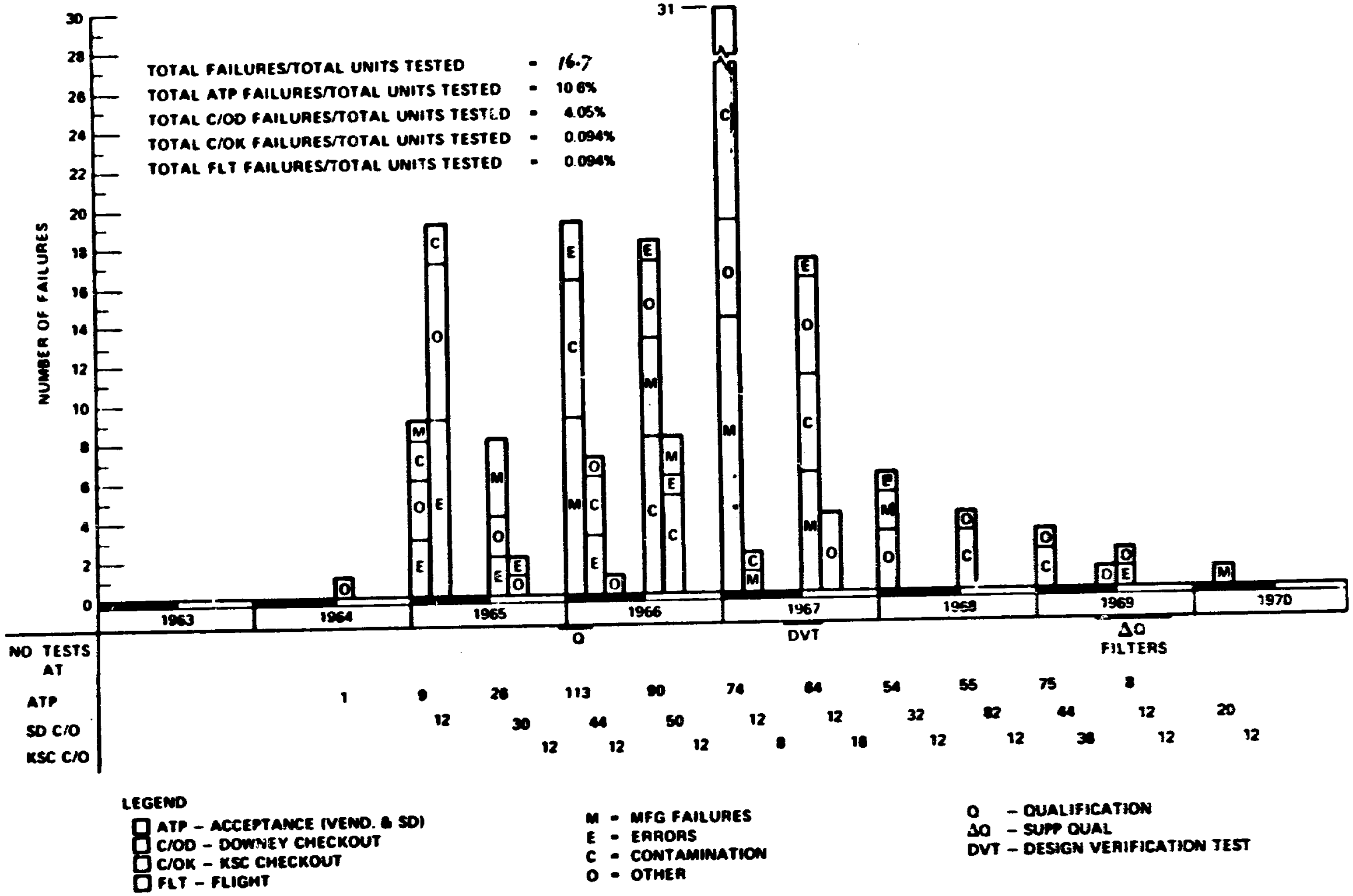
FAILURE: APT He regulator failed to close at specified pressure range of 295 to 305 psig; reg. stayed open to test pressure of 310 psig.

8

CAUSE: Contaminated; failure caused by Freon flushing fluid creating excessive swell of poppet seats which held poppets in open position.

C/A: Flushing fluid changed from Freon to alcohol which is compatible with poppet seat material.

SM/CM CHECK VALVE
ME284 0357



70AP107398

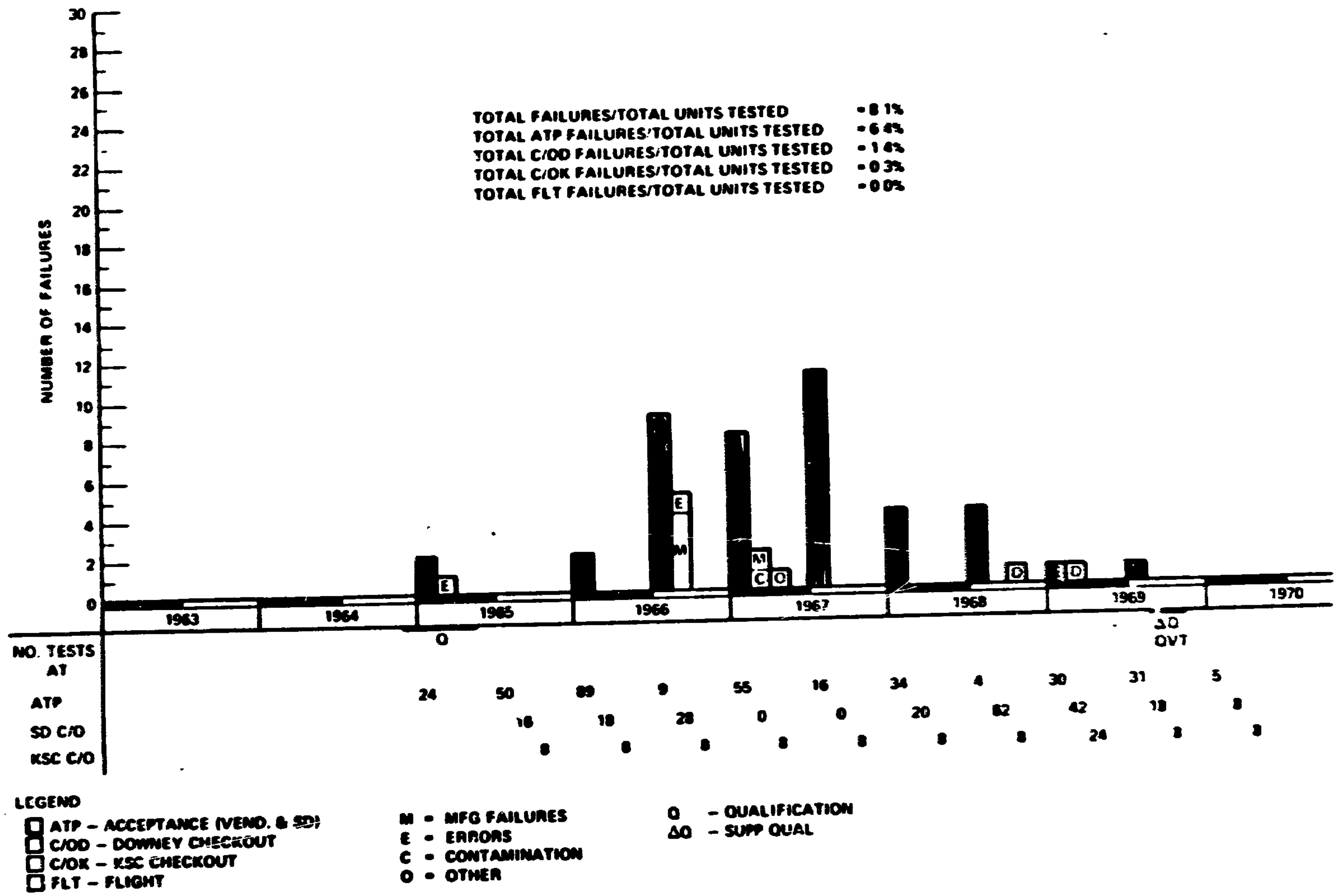
COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CHECK VALVES ME284-0357		
1st QUARTER 1969	PROBLEM	EXCESSIVE INTERNAL LEAKAGE
	ANALYSIS	CONTAMINATION
	C/A	CLOSER MONITORING OF PARTS - TO PRECLUDE REPETITION OF THIS DISCREPANCY
MID - 1968	PROBLEM	EXCESSIVE INTERNAL LEAKAGE; HIGH ΔP
	ANALYSIS	EXT. LEAK - CONTAMINATION HIGH ΔP - BURRS AND HIGH TOLERANCE SPRINGS INADVERTENTLY INSTALLED
	C/A	EXT. LEAK - INSTALLED SINK AND PRESSURIZED CLEANING SYSTEM FOR GLOVES BURRS - OPTICAL 10 POWER DEBURRING OPERATION ADDED TO SHOP TRAVELER SPRINGS - CLOSER MONITORING
1st QUARTER 1968	PROBLEM	EXCESSIVE INTERNAL LEAKAGE; SUSPECT WATER CONTAMINATION
	ANALYSIS	CONTAMINATION FROM CO_2 SYSTEM DURING WELDING WATER SPOTS NOTED IN DISASSEMBLED UNITS
	C/A	ADDED A 10 MICRON FILTER TO THE CO_2 SYSTEM WATER FROM NWL VALVES
3rd QUARTER 1967	PROBLEM	CRACKING PRESSURE HIGH ΔP
	ANALYSIS	DISASSEMBLY REVEALED NO ANOMALIES HIGH ΔP CAUSED BY CONTAMINATION
	C/A	PROCESS SPEC. MA0210-0108 REVISED TO ALLOW AN INITIAL CRACK OF 10 psi ΔP TESTS TO BE PERFORMED DURING PRE-ACCEPTANCE TESTS

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CHECK VALVES	ME284-0024		
1st QUARTER 1967		PROBLEM	HIGH Δ P LOW CRACKING PRESSURE
		ANALYSIS	EXTRACTION OR LEACHING OUT OF THE BASIC POLYMER & CURATIVE NO DISCREPANCIES DETECTED DURING DISASSEMBLY OF LOW CRACKING PRESSURE UNITS
		C/A	ELIMINATION OF SYSTEM FLUSHING; PRE-WELD AND POST-WELD CRACKING PRESSURE TESTS IMPLEMENTED TO PRECLUDE ANY MARGINAL CRACKING PRESSURE RESULTS IN FUTURE UNITS.
MID - 1966		PROBLEM	EXCESSIVE INTERNAL LEAKAGE
		ANALYSIS	HEAVY CONTAMINATION
		C/A	TEST FIXTURES EXAMINED AND RE-CLEANED; LOG SET UP FOR REGULAR SCHEDULED CLEANING OF TEST EQUIPMENT
		QUALIFIED	(WITHOUT FILTERS)
1st QUARTER 1966		PROBLEM	CRACKING PRESSURE, HIGH
		ANALYSIS	
		C/A	PROCUREMENT SPEC. CHANGED TO ALLOW AN INCREASE IN CRACKING PRESSURE
1965		PROBLEM	EXCESSIVE INTERNAL LEAKAGE
		ANALYSIS	CONTAMINATION LEAKAGE EQUIPMENT PROBLEMS
		C/A	IMPROVE CLEANING TECHNIQUES; DEVELOPED LEAKAGE TECHNIQUES - IMPROVED LEAKAGE DETECTION EQUIPMENT

SM HELIUM PRESSURE RELIEF VALVE
ME284 0026



70AP107

SERVICE MODULE REACTION CONTROL SYSTEM

HELIUM PRESSURE RELIEF VALVE ME284-0026

ATP

PROBLEM BURST DISC LEAKAGE DUE TO GALVANIC ATTACK ON THE ALUMINUM BURST DISCS

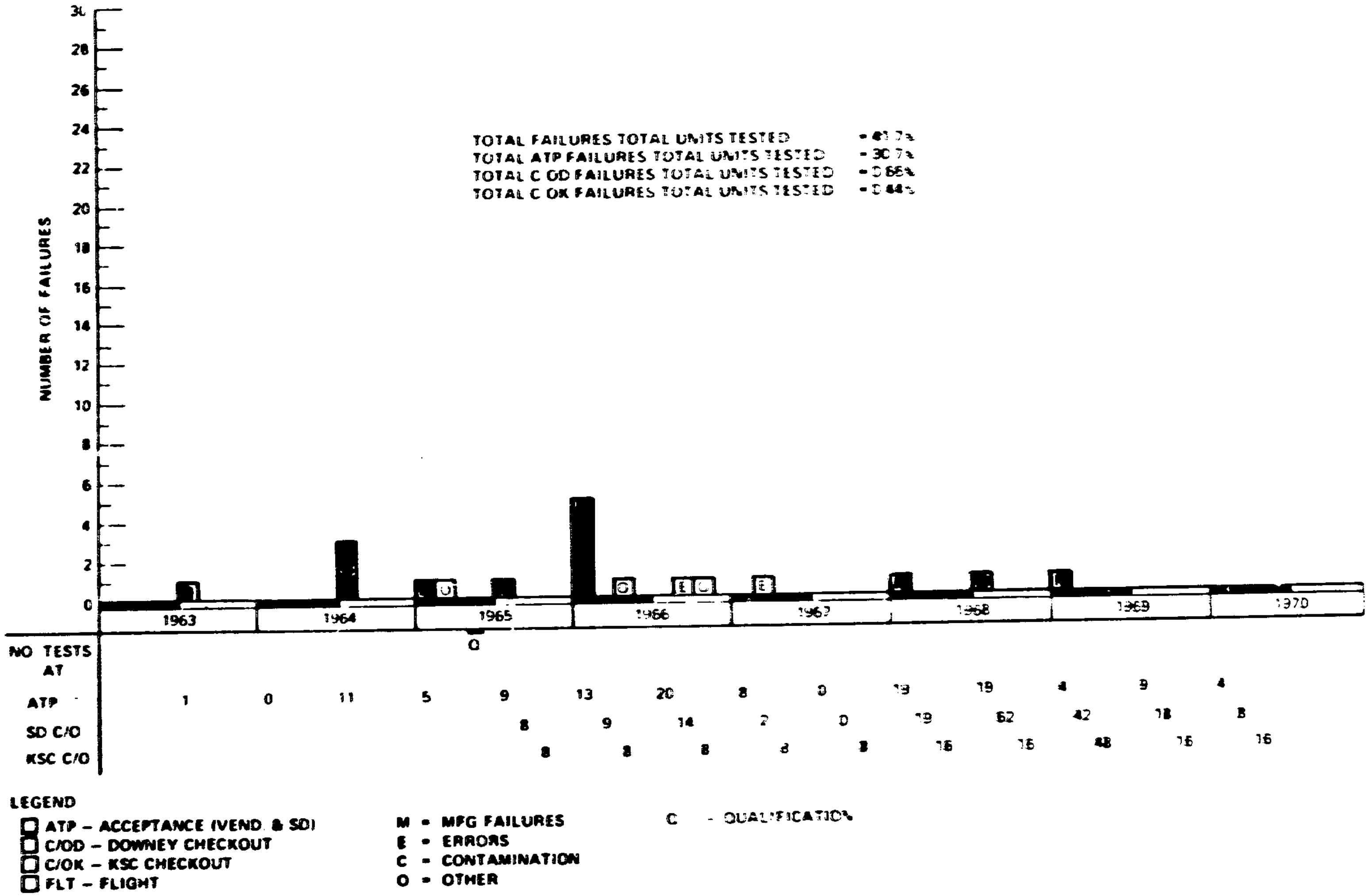
C/A IMPLEMENTED REVISED PROCEDURES TO ASSURE SYSTEM DRYNESS AND TEST CELL DRYNESS

C/OD

PROBLEM ACCIDENTAL RUPTURE OF THE BURST DISC DURING SYSTEM CHECKOUT

C/A CHECKOUT PROCEDURES AND TEST SET-UP REVISED TO PRECLUDE ACCIDENTAL APPLICATION OF ADVERSE PRESSURE TO BURST DISC DURING CHECKOUT.

SM FUEL TANK
ME282 0008



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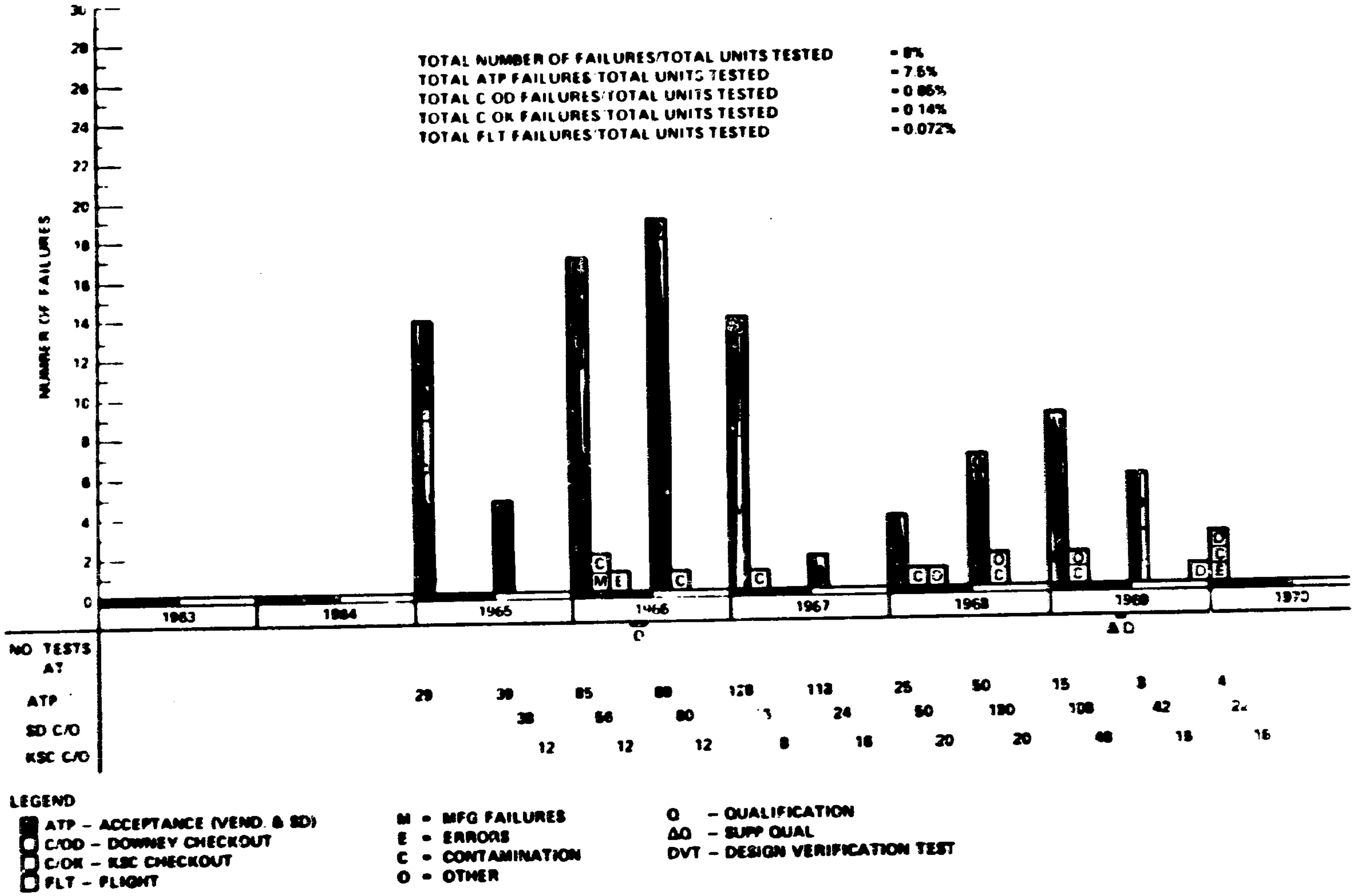
SERVICE MODULE REACTION CONTROL SYSTEM

FUEL TANK ME282-0008

PROBLEM	EXTERNAL LEAKAGE THROUGH FLANGE SEAL
C/A	REVISED PROCEDURE FOR TIGHTENING FLANGE BOLTS TO PRECLUDE ADVERSE COLD FLOW OF THE TEFLON FLANGE SEAL
PROBLEM	ACCIDENTAL IMPOSITION OF COLLAPSING PRESSURE ON TANK BLADDER DURING SYSTEM CHECKOUT.
C/A	TEST SET-UP MODIFIED TO ASSURE PRESSURE IN BLADDER INTERIOR IS ALWAYS SLIGHTLY HIGHER THAN ON BLADDER EXTERIOR.
PROBLEM	BLADDER LEAKAGE DUE TO SEVERE WRINKLING DURING BLADDER INSTALLATION
C/A	REVISED BLADDER INSTALLATION PROCEDURES TO MINIMIZE BLADDER FOLDING AND WRINKLING.

SM / CM PROP. SOLENOID VALVE
ME284-0276



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COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

PROPELLANT, ISOLATION VALVES	ME284-0276	
JAN-DEC 1966	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	CONTAMINATION
	C/A	NR/SD - CONTROL PROCESSES BETTER SUPPLIER - ASSY. PERSONNEL CAUTIONED TO FOLLOW PROCEDURES
JAN-JUNE 1966	PROBLEM	HIGH CLOSING VOLTAGE
	ANALYSIS	SHAFT MISALIGNMENT
	C/A	CAUTION ASSY. PERSONNEL - CYCLE VALVE 100 CYCLES - INFANT MORTALITY TEST
JAN-JUNE 1967	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	CONTAMINATION
	C/A	NR/SD - ELIMINATE SOURCES OF CONTAMINATION - ELECTR POLISH FITTINGS AND TUBE ENDS (MA0130-010)
	PROBLEM	HIGH POT FAILURE
	ANALYSIS	CONTAMINATION IN POTTING MATERIAL
	C/A	SUPPLIER - BETTER CONTROL POTTING MIXTURE & CLEANING OF SURFACES WHERE POTTING COMPOUNT IS APPLIED.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

JULY-DECEMBER 1968	PROBLEM	VALVE FAILED TO STAY CLOSED
	ANALYSIS	SYSTEM ACTUATED AGAINST CLOSED VALVES (S/C 101)
	C/A	NR/SD - CHANGE NO. 2171 TO CHANGE OPERATIONS HANDBOOK FOR CSM 103 & SUBS
	PROBLEM	FAILED INSULATION TEST
	ANALYSIS	IMPROPER TEST TECHNIQUE
	C/A	NR/SD - CHANGE OPERATING MANUAL C12-0000381003 TO REQUIRE PROPER TEST EQUIPMENT AND TEST METHOD
	PROBLEM	FAILED PRESSURE DROP
	ANALYSIS	IDENTIFIED IMPROPER
	C/A	SUPPLIER - CHANGE ASSEMBLY PROCEDURE TO PRECLUDE MIS-IDENTIFICATION
	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	NON-METALLIC CONTAMINANT LOCATED ON TEFLON SEAT
	C/A	NR/SD - CORRECTIVE ACTION IMPLEMENTED TO CONTROL SYSTEM CLEANLINESS BY PROCESSES CONTROL.
JAN-JUNE 1969	PROBLEM	VALVE WOULD NOT LATCH OPEN
	ANALYSIS	REVERSE VOLTAGE APPLIED TO OPENING COIL
	C/A	NR/SD -

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

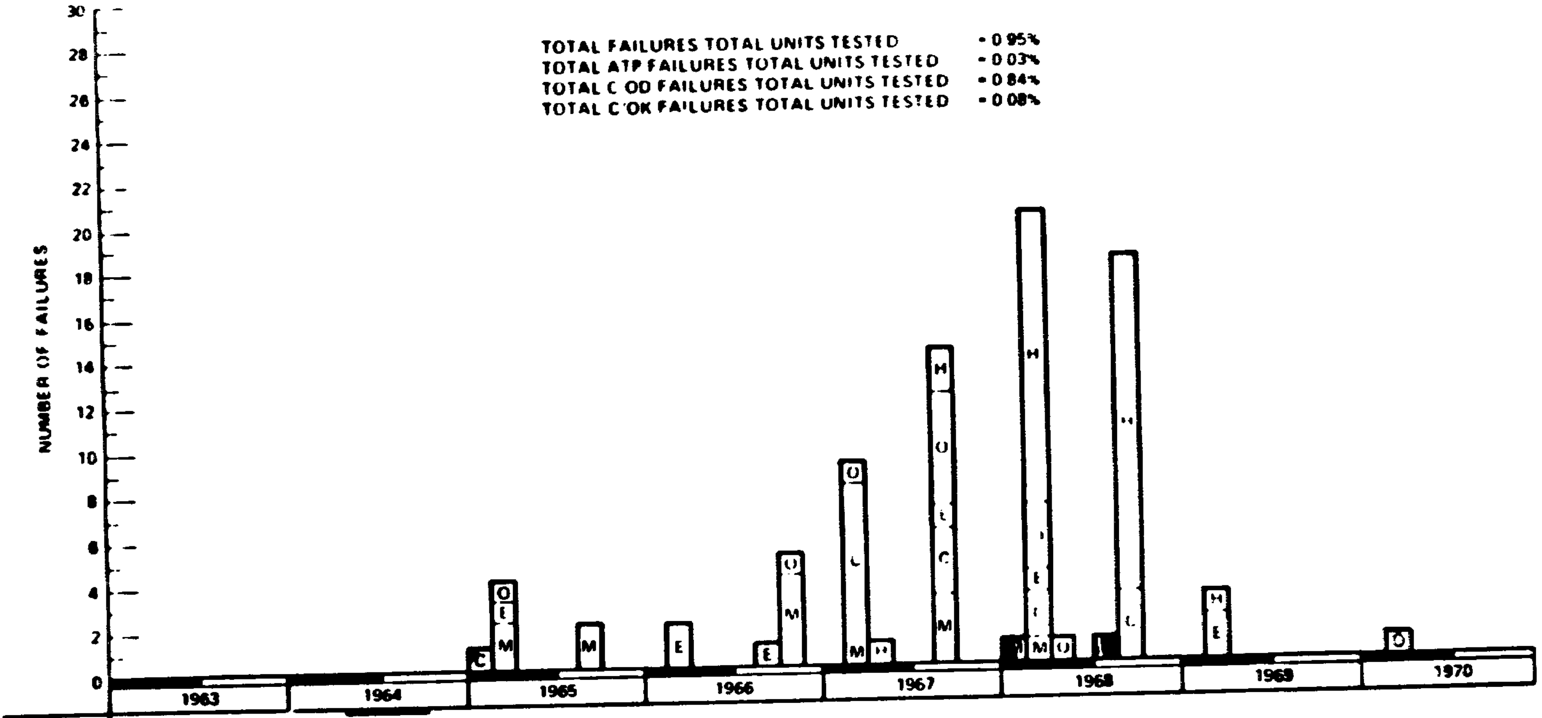
JAN-JUNE 1969	(continued)	
	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	CONTAMINATION ON SEAT
	C/A	NR/SD - NONE REQUIRED. CHECK OUT PER OCP 4182 & TCP 0052 WILL DETECT LEAKAGE PROBLEMS.
JULY-DECEMBER 1969	PROBLEM	HIGH CLOSING VOLTAGE
	ANALYSIS	CONTAMINATION BETWEEN SOLENOID BORE AND PLUNGER - LOCKTITE
	C/A	SUPPLIER - NWL TO MFG. TOOL TO PRECLUDE LOCKTITE FROM THIS AREA.
	PROBLEM	VALVE WOULD NOT LATCH OPEN
	ANALYSIS	REVERSE VOLTAGE APPLIED TO OPENING COIL
	C/A	NR/SD - RELEASE MFG CONTROL TICKET 302B TO INCLUDE CAUTION NOTE.
JAN-JUNE 1970	PROBLEM	FAILED PRESSURE DROP
	ANALYSIS	NO PROBLEM WITH VALVE ASSEMBLER ERROR IN SUBTRACTION.
	C/A	SUPPLIER - ASSEMBLER CAUTIONED TO DOUBLE CHECK ALL CALCULATIONS.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

JAN-JUNE 1967	(continued)	
	PROBLEM	HIGH OPENING VOLTAGE
	ANALYSIS	PRESSURE FORCE & FRICTION
	C/A	SUPPLIER - ASSY. PERSONNEL CAUTIONED IN STABILIZING PROCESS TO 15.5 VDC MAX.
JULY-DECEMBER 1967	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	POROUS TEFLON SEATS
	C/A	SUPPLIER - NWL PREPARED PROCUREMENT SPECIFICATION FOR TEFLON
JAN-JUNE 1968	PROBLEM	INTERNAL LEAKAGE
	ANALYSIS	METALLIC PARTICLES - GOLD
	C/A	NR/SD - RELEASE PROCESS SPEC MA0310-0039 INSTRUCTING HOW TO BRAZE & DEBRAZE COMPONENTS - TRAIN BRAZE & DEBRAZE TECHNICIANS.
	PROBLEM	INTERNAL LEAKAGE S/C 104
	ANALYSIS	INTRODUCED CONTAMINATION INTO VALVE FROM SYSTEM CAUSING CORROSION.
	C/A	NR/SD - RELEASE PRO TO MFG. TO CONTROL FLUSHING EQUIPMENT
	PROBLEM	VALVE WOULD NOT LATCH OPEN
	ANALYSIS	REVERSE VOLTAGE APPLIED TO OPENING COIL
	C/A	NR/SD - REVISE CHECKOUT PROCEDURES AND PLANNING TICKETS TO ADD CAUTION NOTES, INSTRUCT PERSONNEL TO RECHECK CONNECTIONS PRIOR TO USING EQUIPMENT AND APPLYING VOLTAGES.

SM/CM TEST POINT COUPLINGS
ME 144-0023

TOTAL FAILURES TOTAL UNITS TESTED = 0.95%
TOTAL ATP FAILURES TOTAL UNITS TESTED = 0.03%
TOTAL C OD FAILURES TOTAL UNITS TESTED = 0.84%
TOTAL C OK FAILURES TOTAL UNITS TESTED = 0.08%



NO. TESTS
AT
ATP
SD C/O
KSC C/O

O

212 727 704 402 109 307 149 50 79 370 108 130

80 288 408 474 140 120 314 1122 722 398 158

104 104 104 64 144 128 128 384 128 128

LEGEND
- ATP – ACCEPTANCE (VEND. & SD)
- C/OD – DOWNEY CHECKOUT
- C/OK – KSC CHECKOUT
- FLT – FLIGHT

M = MFG FAILURES
E = ERRORS
C = CONTAMINATION
O = OTHER

Q – QUALIFICATION
ΔQ – SUPP QUAL
DVT – DESIGN VERIFICATION TEST

70AP107400

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

TEST POINT COUPLINGS — ME144-0023

JANUARY 1967 THRU DECEMBER 1968

PROBLEM: TEST POINT COUPLINGS LEAKED EXCESSIVELY WITH DUST CAPS OFF DURING DOWNEY C/O TESTS

ANALYSIS: FAILURES WERE CAUSED BY:

(1) CUTTING AND DESTRUCTION OF AIRBORNE INTERFACE BUTT SEALS WHICH RESULTED IN PARTICLES OF BUTT SEAL MATERIAL IMPAIRING THE SEATING OF THE POPPET. THIS PROBLEM AROSE FROM THE ACCUMULATED EFFECTS OF OVERTORQUING OF THE GROUND HALF COUPLING AND/OR THE DUST CAP

(2) SHREDDING AND TEARING OF THE AIRBORNE INTERFACE LIP SEAL WHICH MAY ALSO HAVE GENERATED CONTAMINANT THAT IMPAIRED THE SEATING OF THE POPPET

(3) CONTAMINATION FROM GROUND HALF COUPLINGS, GSE, OR GSE FLUIDS.

(4) BENDING OF COUPLINGS BECAUSE OF LACK OF ADEQUATE SUPPORT OF GROUND LINES RESULTING IN THE MISALIGNMENT OF POPPET SEALS AND THEIR SEAT.

CORRECTIVE ACTION:

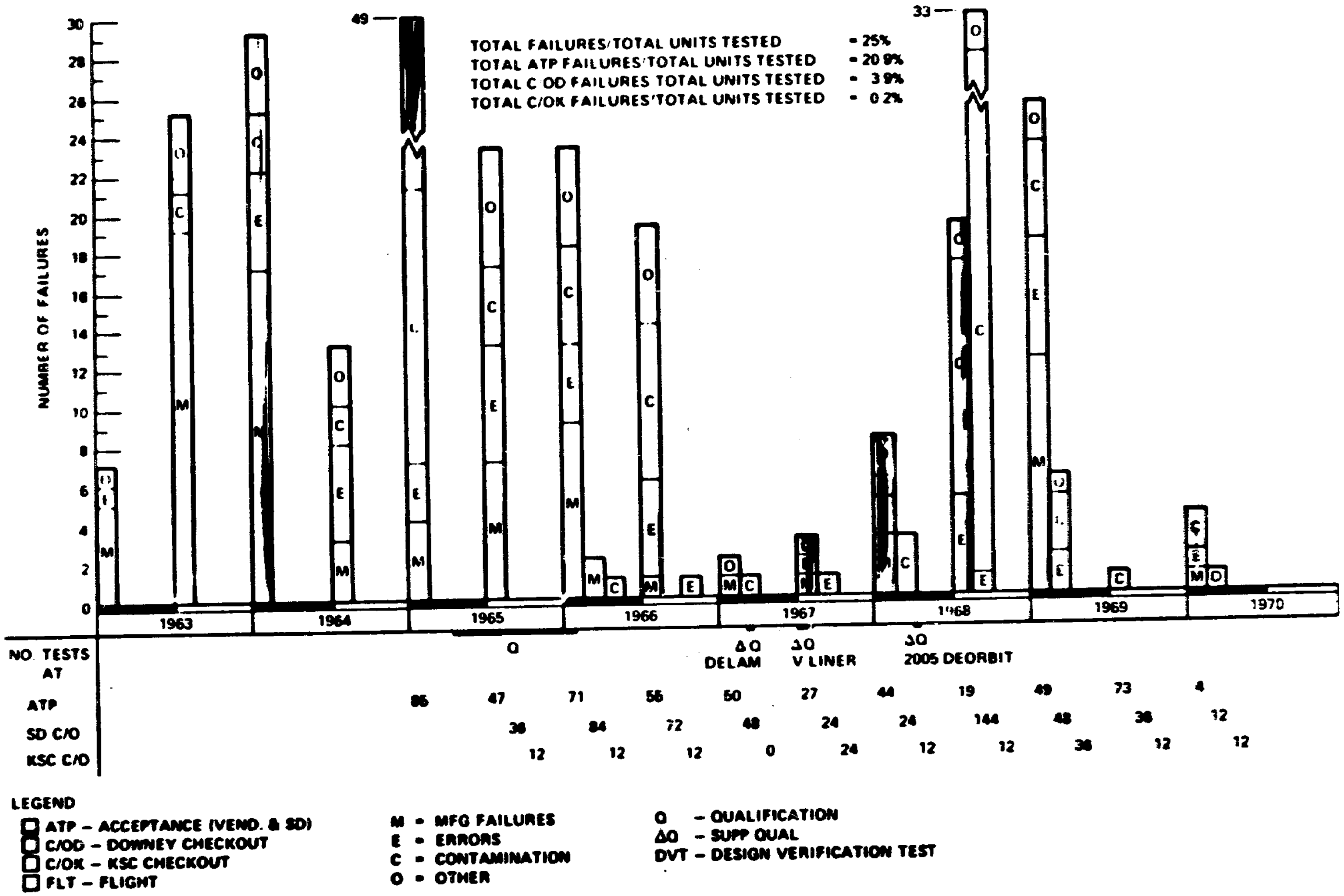
(1) C/O PROCEDURES WERE REVISED (a) TO REDUCE THE GOUND-HALF COUPLING INSTALLATION TORQUE (b) TO REDUCE THE NUMBER OF GROUND-HALF INSTALLATION CYCLES, AND (c) TO SUBSTITUTE A DUST CAP WHICH DOES NOT CONTACT THE BUTT SEAL OF INTERFACE SEALS.

(2) MORE STRINGENT INSPECTION CRITERIA WERE IMPOSED BY THE SUPPLIER ON ALL TEST POINT COUPLINGS BEFORE BEING SHIPPED TO NR/SD

(3) REQUIREMENTS FOR MORE FREQUENT CLEANLINESS VERIFICATION CHECKS OF GSE WERE IMPOSED ON TEST CELLS; TEST CELLS ARE ALSO REQUIRED TO VISUALLY INSPECT GROUND-HALF COUPLINGS BEFORE CONNECTING TO AIRBORNE COUPLINGS

(4) REQUIREMENTS FOR CONTROLLING LATERAL LOADS ON AIRBORNES HAVE BEEN IMPOSED ON TEST

CM RCS ENGINE
ME901-0067



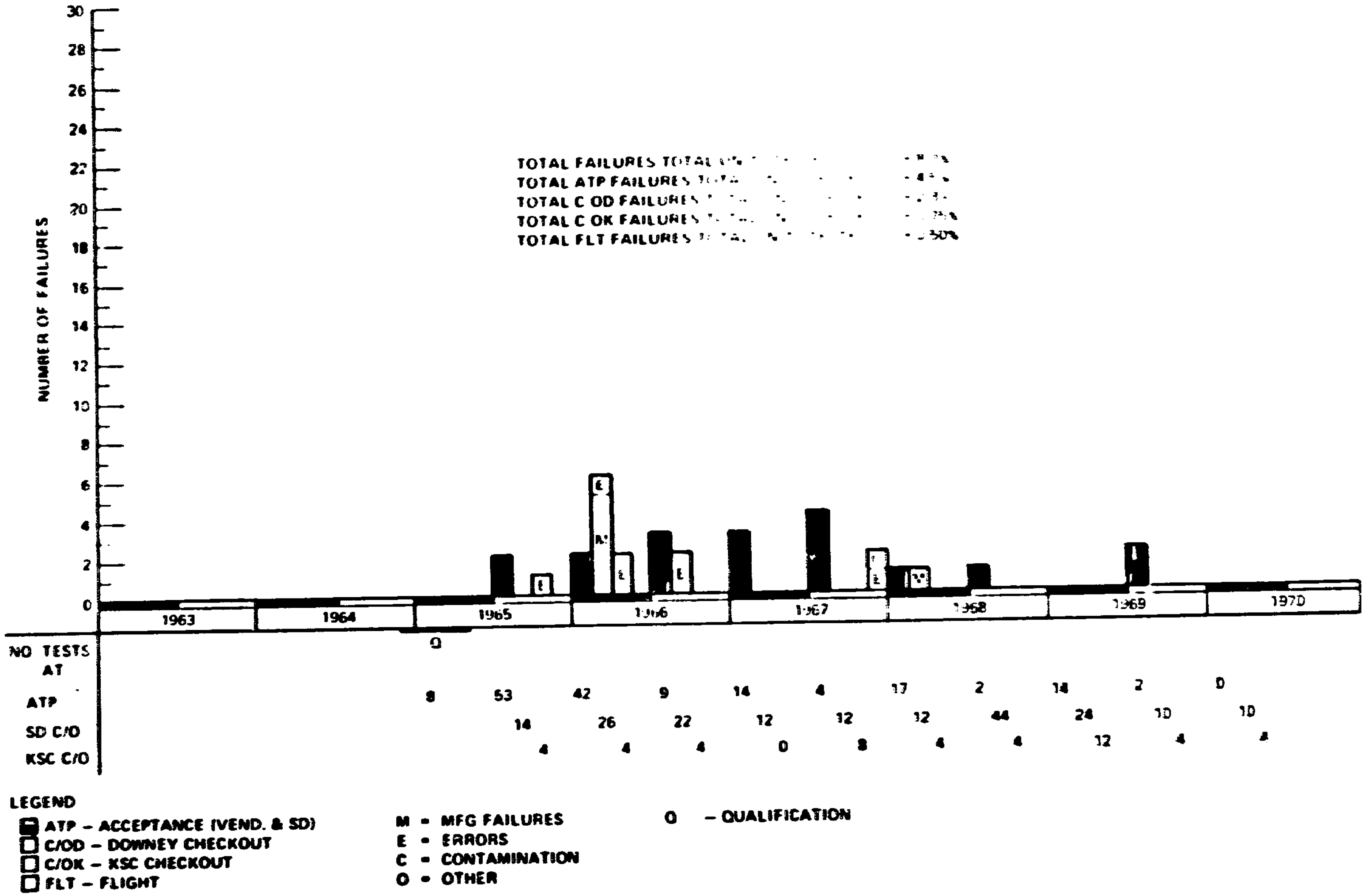
70AP107406

ENGINE FAILURE EVALUATION

CM RCS ENGINE

AREA/TIME	PROBLEM	CAUSE	CORRECTIVE ACTION
ATP SECOND HALF 1968 - - - - - - CHECKOUT DOWNEY SECOND HALF 1968	(1) VALVE RESPONSE (2) VALVE SEAT LEAK (3) VALVE WELD LEAK	(1) AND (2) RESIDUAL PROPELLANTS DUE TO INADEQUATE POST HOT-FIRE DECONTAMINATION. ALSO, PARTICULATE CONTAMINATION (3) MINUTE CRACKS IN BURN-DOWN WELD DUE TO DIFFICULTY IN WELDING DISSIMILAR MATERIALS	(1) AND (2) NEW POST HOT-FIRE DECONTAMINATION PROCEDURE, TIGHTER ACCEPTANCE TEST LIMITS, IMPROVED VALVE ASSEMBLY CONTROLS (3) OVERLAY WELD WITH IMPROVED CONTROL AND TESTING
ATP FIRST HALF 1969	(1) DECONTAMINATION (2) LOW I_{SP} (3) VALVE RESPONSE	(1) FAIL DECONTAMINATION CRITERIA (2) IMPROPER ORIENTATION OF INJECTOR INSERT (3) PARTICULATE CONTAMINATION	(1) SPECIFY RE-DECONTAMINATION (2) ADD STOP AND LOCK TO TOOLING (3) 300-CYCLE FLUSH TO INSURE PARTICULATE REMOVAL
ATP FIRST HALF 1965	VARIOUS FAILURES OF ALL ATP REQUIREMENTS	INITIAL PRODUCTION OF CM RCS ENGINE (PRE-QUAL. CONFIG.)	(1) REDEFINE ACCEPTANCE LIMITS (2) TRAIN PERSONNEL (3) RESOLVE DESIGN PROBLEMS
ATP 1968 TO 1969	AFTER LOW "E" RATE DURING LATE 1966, 1967 AND FIRST HALF OF 1968 THE "E" RATE INCREASED	(1) DRASTIC CHANGEOVER IN PERSONNEL DUE TO LAYOFFS AND BUMPING (2) NEW ASSEMBLY AND ATP REQUIREMENTS AS CORRECTIVE ACTION FOR FAILURES	(1) AND (2) TRAIN AND FAMILIARIZE PERSONNEL

CM HELIUM PRESS RELIEF VALVE
ME284 0062



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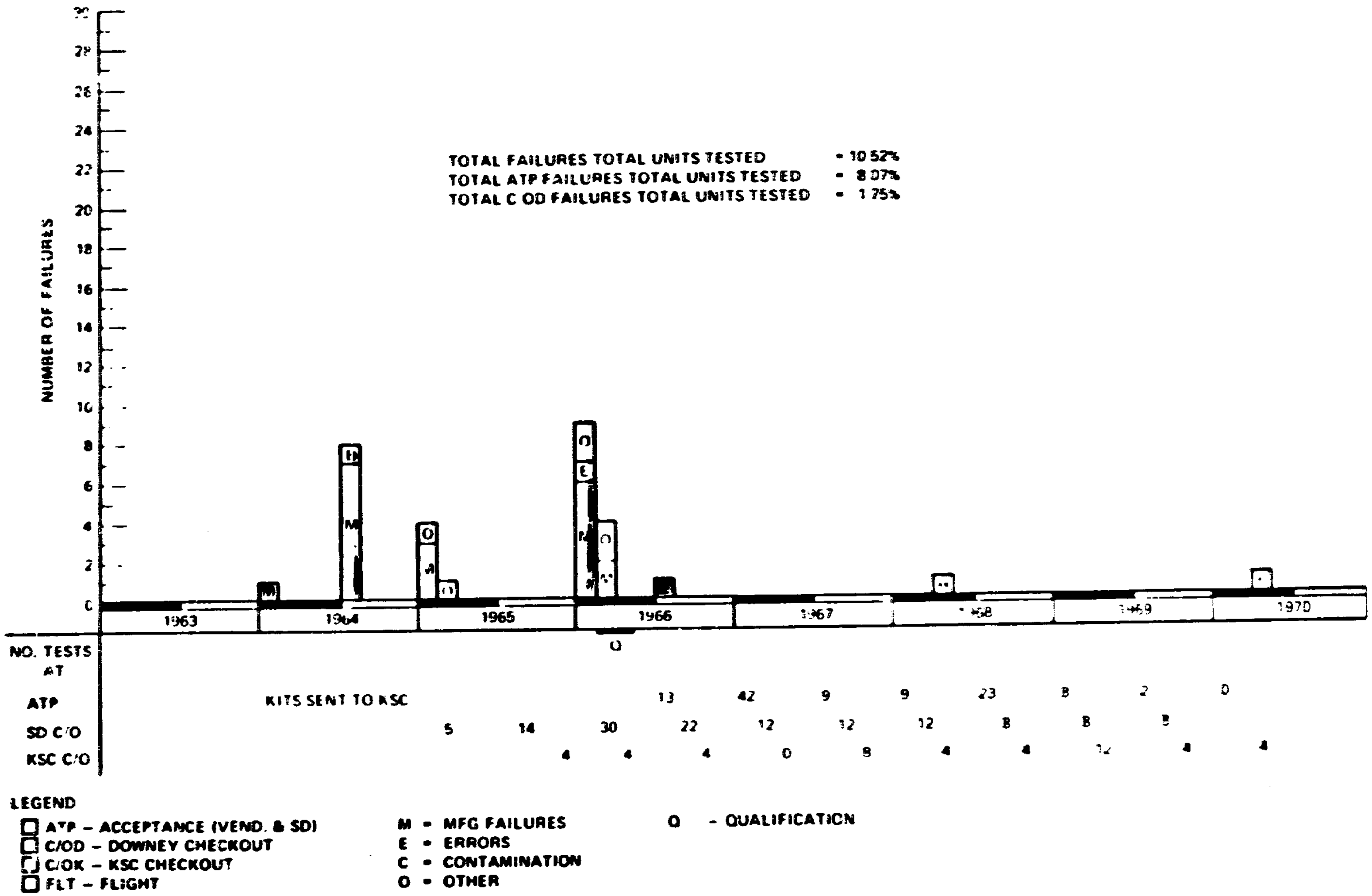
COMMAND MODULE REACTION CONTROL SYSTEM

HELIUM PRESSURE RELIEF VALVE ME284-0062

ATP	PROBLEM	BURST DISC LEAKAGE DUE TO GALVANIC ATTACK ON THE ALUMINUM BURST DISCS
	C/A	IMPLEMENTED REVISED PROCEDURES TO ASSURE SYSTEM DRYNESS AND TEST CELL DRYNESS

C/OD & C/OK		
	PROBLEM	ACCIDENTAL RUPTURE OF THE BURST DISC DURING SYSTEM CHECKOUT
	C/A	CHECKOUT PROCEDURES AND TEST SET-UP REVISED TO PRECLUDE ACCIDENTAL APPLICATION OF ADVERSE PRESSURE TO BURST DISC DURING CHECKOUT.

CM BURST DISC ASSEMBLY
ME284 0346 ME251 0005



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COMMAND MODULE REACTION CONTROL SYSTEM

BURST DIAPHRAGM ISOLATION VALVE ME251-0005

FEBRUARY 1968	PROBLEM	RESISTAZINE 88 "O" RINGS DETERI-RATED
	ANALYSIS	CAUSED BY CLEANING FLUID (ISOPROPYL ALCOHOL)
	C/A	EFFECTIVE 101 & SUBS - ME251-0005-0025 OXIDIZER BURST DISC KITS RETURNED TO SUPPLIER; CLEANING FLUID CHANGED TO FREON - PART NUMBER CHANGED TO ME251-0005-0065
	QUALIFIED	
1st QUARTER 1966 (PRIOR TO QUAL)	PROBLEM	MISC. PROBLEMS ENCOUNTERED PRIOR TO QUAL TEST PROGRAM, NAMELY, TECHNICIAN ERRORS, FAULTY EQUIPMENT, IMPROPER FLUSHING PROCEDURES, WRONG "O" MATERIAL, ETC.
	C/A	TECHNICIAN - FAMILIARIZATION OF HARDWARE TEST EQUIPMENT AND PROCEDURES - IMPLEMENTED TIGHTER CONTROLS
1st QUARTER	PROBLEM	ADDITIONAL DEV. TEST PERFORMED - INVESTIGATE VARIOUS METHODS TO IMPROVE INTERNAL LEAKAGE (METAL O RING, "V" SEALS SPRING SEAL, "K" SEAL)
	C/A	"O" RING CONCEPT IMPLEMENTED
MID 1964	PROBLEM	PROBLEMS ENCOUNTERED DURING DVT - LOW RUPTURE, EXT LEAKAGE
	C/A	VARIOUS DIMENSIONAL CHANGES IMPLEMENTED TO PRECLUDE REOCCURRENCE

SERVICE MODULE REACTION CONTROL SYSTEM

OXIDIZER TANK (ME282-0004)

- FAILURE DISTRIBUTION
  - ATP
    - MANUFACTURING (1)
    - ERROR (2)
    - OTHER (9)
  - DOWNEY CHECKOUT
    - MANUFACTURING (4)
  - TOTAL (16)

- FAILURE RESEARCHED
  - DOWNEY CHECKOUT JUNE TO DECEMBER 1965 (3)
  - PROBLEMS UNRELATED - INDIVIDUALLY CORRECTED

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

DYNATUBE FITTINGS

ME273-0046-0049

- FAILURE DISTRIBUTION
  - ATP
    - MFG (7)
  - TOTAL (7)
- FAILURE RESEARCHED
  - MFG FAILURES JUNE - DEC 64 (7)
  - PROBLEM DESCRIPTION: CIRCUMFERENTIAL FRACTURE OF SEALING SURFACE.
  - CORRECTION ACTION: CHANGE HEAT TREAT IN ATMOSPHERE FREE FROM IONIC HYDROGEN

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

FILL/VENT COUPLINGS

ME273-0011, 0019, 0021, 0024

- FAILURE DISTRIBUTION
  - ATP
    - MFG (1)
    - CONTAMINATION (2)
  - DOWNEY C/O
    - CONTAM (15)
    - OTHER (1)
    - HANDLING (2)
  - TOTAL (21)
- FAILURE RESEARCHED
  - DOWNEY C/O JUN'68 – JUN'69 (13)
    - PROBLEM DESCRIPTION : LEAKAGE CAUSED BY CONTAMINATION
    - CORRECTIVE ACTION : CLEANLINESS VERIFICATION OF GSE IMPLEMENTED

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

HELIUM FILL COUPLING (ME273-0010)

- FAILURE DISTRIBUTION
  - ATP
    - MANUFACTURING (3)
    - CONTAMINATION (2)
  - DOWNEY CHECKOUT
    - CONTAMINATION (2)
    - ERROR (4)
  - KSC CHECKOUT
    - MANUFACTURING (1)
    - OTHER (1)
  - TOTAL (13)
- FAILURE RESEARCHED
  - KSC CHECKOUT (FABRUARY 1966) (1)
    - PROBLEM DESCRIPTION: SEALS BETWEEN AIRBORNE COUPLING AND GROUND CAPS LEAKED DURING HELIUM FILL OPERATION
    - CORRECTIVE ACTION: SEALS WERE REPLACED ON THE LAUNCH PAD

SERVICE MODULE REACTION CONTROL SYSTEM

VALVE HOUSE HEATER (ME363-0014)

- FAILURE DISTRIBUTION
  - ATP
    - MANUFACTURING (3)
    - OTHER (6)
  - DOWNEY CHECKOUT
    - ERROR (2)
  - TOTAL (11)

- FAILURE RESEARCHED
  - MANUFACTURING FAILURES JANUARY TO JUNE 1966 (3)
    - PROBLEM DESCRIPTION: TEMPERATURE GRADIENT ON HEATER SURFACE EXCEEDED TEN PERCENT MAXIMUM
    - CORRECTIVE ACTION: TEST FIXTURE WAS MODIFIED TO INCREASE THE ACCURACY OF THE TEMPERATURE MEASUREMENTS (THIS TEST WAS DELETED ON 8 FEBRUARY 1968)

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

FUEL TANK (ME282-0007)

- FAILURE DISTRIBUTION
  - ATP
    - MANUFACTURING (3)
    - ERROR (2)
    - OTHER (3)
  - DOWNEY CHECKOUT
    - MANUFACTURING (6)
  - TOTAL (14)

- FAILURE RESEARCHED
  - DOWNEY CHECKOUT JUNE TO DECEMBER 1967 (3)
    - PROBLEM DESCRIPTION —
      - LOW TORQUE
      - MISSED PROCESS
      - BLADDER EMBRITTLEMENT - HI VENT
    - CORRECTIVE ACTION —
      - NONE, PROBLEMS UNRELATED

SERVICE MODULE/COMMAND MODULE REACTION CONTROL SYSTEM

OXIDIZER TANK (ME282-0006)

- FAILURE DISTRIBUTION
  - ATP
    - MANUFACTURING (2)
    - ERROR (1)
    - OTHER (3)
  - DOWNEY CHECKOUT
    - MANUFACTURING (4)
  - TOTAL (10)

- FAILURE RESEARCHED
  - DOWNEY CHECKOUT JANUARY TO JUNE 1966 (3)
    - PROBLEM DESCRIPTION –
      - CONTAMINATED CLEANING SPRAY
      - DEFECTIVE BRAZE TOOLING
      - CONTAMINATION THREADS–FALSE TORQUE
    - CORRECTIVE ACTION –
      - PROBLEMS UNRELATED, INDIVIDUALLY CORRECTED

SERVICE MODULE REACTION CONTROL SYSTEM

HELIUM TANK (ME282-0051)

- FAILURE DISTRIBUTION
  - ATP (0)
  - DOWNEY CHECKOUT
    - ERROR (1)
  - TOTAL (1)

- FAILURE RESEARCHED
  - DOWNEY CHECKOUT
    - PROBLEM DESCRIPTION — REPLACEMENT OF INLET FITTING DAMAGED TANK SEALING SURFACE
    - CORRECTIVE ACTION — NONE REQUIRED

FAILURE HISTORY OF COMPONENTS NOT PLOTTED

COMPONENT	ATP	CHECKOUT FAILURES, DOWNEY	CHECKOUT FAILURES, KSC	TOTAL
SM OX TANK	3M, 6E, 3θ	1M, 1C, 1E, 1θ	0	16
DYNATUBE FITTINGS	7M	0	0	7
FILL AND VENT COUPLINGS	1M, 2C	15C, 1θ, 2H	0	21
HELIUM COUPLING	3M, 2C	2C, 4E	1M, 1θ	13
HEATERS	3M, 6θ	2E	0	11
EXP VALVE 1/4 IN.	2M, 4θ	0	0	6
CM FUEL TANK	3M, 2E, 3θ	6M	0	14
CM OX TANK	3M, 2E, 1θ	4M	0	10
SM HELIUM TANK	0	1θ	0	1
SM FILTER	0	0	0	0
CM DUMP HOSE	0	0	0	0
CM FLEX HOSE	0	0	0	0
CM 5/8 IN.-EXP VALVE	0	0	0	0

M = MFG. FAILURES
E = ERRORS
C = CONTAMINATION
θ = OTHERS

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

WAIVERS AT DOWNEY

SPACECRAFT	SYSTEM	DISCREPANCY	COMMENTS
103	SM	QUAD B SECONDARY REGULATOR OUTPUT LOW (0.5 TO 1.0 PSI AT 3,800 PSIG INLET).	WAIVER NUMBER 0107
103	CM	PRIMARY AND SECONDARY REGULATOR CM RCS 1 AND 2 INLET PRESSURE LOW AND SECONDARY OUTPUT (1) ONE PSI LOW (STARVE TEST).	WAIVER NUMBER 0111
104	CM	CM RCS PRIMARY REGULATOR (ONE PSI LOW - STARVE TEST)	WAIVER NUMBER 0123
106	SM	QUAD C PRIMARY REGULATOR (ONE PSI LOW - STARVE TEST)	WAIVER NUMBER 0133
108	SM	SM 108 QUAD D HELIUM PRESSURE REGULATORS, PRIMARY OUTPUTS ARE LOWER THAN THE MINIMUM ALLOWABLE PER PART II C.E.I.	WAIVER NUMBER 0166
109	CM	CM RCS CM 109 SYSTEM 1, NUMBER 2 PRIMARY REGULATOR OUTPUT AND TEST FLOW RATE AND LOWER THAN THE MINIMUM ALLOWABLE PER PART II C.E.I.	WAIVER NUMBER 0187

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

WAIVERS AT KSC

SPACECRAFT	SYSTEM	DISCREPANCY	COMMENTS
109	CM RCS A	ONE + R ENGINE LEAKAGE WAS ABOVE ALLOWABLE 64 SCC/HOUR, SHOULD BE 20 SCC/HOUR.	TEST REPEATED AND LEAKAGE WAS THE SAME. WAIVER
109	CM RCS A	FUEL PANEL INSTRUMENTATION BOSS LEAK RATE EXCESSIVE.	WAIVER
109	SM RCS A	INSTRUMENTATION BOSS LEAKS 6.9×10^{-7} SCC/SECOND, SHOULD BE 1.0×10^{-7} SCC/SECOND.	WAIVER
109	CM RCS A	DELTA-P ACROSS OXIDIZER BLADDER WAS 110 PSID, SHOULD BE 40 PSID, MAXIMUM.	WAIVER
109	SM RCS A	OXIDIZER TANK BLADDER SUBJECTED TO DELTA-P OF 60 PSID.	WAIVER
109	SM RCS B	INSTRUMENTATION BOSS LEAKS 1.98×10^{-7} SCC/SECOND, SHOULD BE 1×10^{-7} SCC/SECOND.	WAIVER
109	SM RCS C	COMBINED PROPELLANT ISOLATION VALVE LEAKAGE EXCESSIVE.	WAIVER
109	SM RCS D	QUAD D COMBINED HELIUM ISOLATION VALVE LEAKAGE WAS 78 CC/45 MINUTES, SHOULD BE 60 CC/HOUR. CYCLED FIVE TIMES. NO CHANGE IN LEAKAGE RATE.	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

WAIVERS AT KSC

SPACECRAFT	SYSTEM	DISCREPANCY	COMMENTS
101	CM RCS	INJECTOR VALVE LEAKAGE SHOULD BE 20 SCC/HOUR AT 180 PSIG, READ 100 SCC/HOUR	FIVE ADDITIONAL CYCLES GOT IT DOWN TO 42 SCC/HOUR
103	SM RCS A	OXYGEN RELIEF VALVE RESEATS AT 218, MINIMUM SPECIFICATION 220	
103	SM RCS D	OXYGEN RELIEF VALVE RESEATS AT 219.2, MINIMUM SPECIFICATION 220	
103	SM RCS	ENGINE VALVE DIRECT OPENING SIGNATURES WERE 29.5 TO 32.0 MS FOR OXID (ALL ENGINES EXCEPT +P, +X, -Y +X, +R +Y) SHOULD BE 25 ± 4 MS. FOR FUEL 16.5 TO 19.0 MS (ALL ENGINES) SHOULD BE 13 ± 2 MS.	WAIVER PROCESSED SPEC. LATER CHANGED TO ALL VALVES WERE 20-32 MS
103	CM RCS A	A + YAW ENGINE VALVE INITIAL DIRECT OPENING SIGNATURE WAS 16.5 MS, SHOULD BE 9 ± 3 MS.	
103	CM RCS B	ONE OF TWO CM RCS B + YAW ENGINE VALVES HAD NORMAL OPEN SIGNATURES OF 11.8, 7.2, AND 6.6 MS FOR THE FIRST, SECOND, AND THIRD CYCLES, RESPECTIVELY, SHOULD BE 5 MS.	
106	CM RCS B	HMP DROPPED FROM 44 TO 37 PSIA WHEN SPACECRAFT PROPELLANT VALVES WERE OPENED.	CAUSED BY OXIDIZER BURST DISC BEING PREVIOUSLY RUPTURED

SECTION 4

COMPONENT QUALIFICATION ADEQUACY

Section 4 graphically delineates and summarizes the qualification adequacy of the Command Module/Service Module Reaction Control Subsystem. There is no written text.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SUBSYSTEM

COMPONENT QUALIFICATION ADEQUACY

- COMPONENT QUALIFICATION REQUIREMENTS WERE GREATER THAN
  - OPERATIONAL LIMITATIONS DEFINED IN OPERATIONAL DATA BOOK
  - ENVIRONMENTS AND TEST CONDITIONS DURING GROUND OPERATIONS EXCLUSIVE OF OFF-LIMITS TESTING
  - ENVIRONMENTS AND OPERATIONAL CONDITIONS IN FLIGHT WITH TWO EXCEPTIONS
    - DURING S-IVB/SPACECRAFT LUNAR MODULE ADAPTER (SLA) SEPARATION SM REACTION CONTROL SUBSYSTEM (RCS) PROPELLANT AND HELIUM ISOLATION VALVES SHUTTLED FROM OPEN TO CLOSED RANDOMLY BECAUSE OF PYROTECHNIC DEVICE INDUCED SHOCK
      - TESTS ESTABLISHED THAT NO VALVE DAMAGE WAS SUSTAINED. OPERATIONAL PROCEDURES ESTABLISHED OPENING VALVES SUBSEQUENT TO S-IVB/SLA SEPARATION
    - SYSTEM EXPOSURE TO PROPELLANTS
      - TESTS ESTABLISHED 103-DAY SYSTEM PROPELLANT COMPATIBILITY
- COMPONENT QUALIFICATION FULFILLS ALL MISSION REQUIREMENTS

SERVICE MODULE REACTION CONTROL SYSTEM

QUALIFICATION ADEQUACY SUMMARY

PARAMETER	GROUND TESTS	SYSTEMS OPERATIONAL DATA BOOK (SODB)	FLIGHT *ESTIMATED	REMARKS
TEMPERATURE		55°F MIN	117 - 207°F	
ENGINE PACKAGE	40 - 95°F	20 - 140°F	49 - 100°F	LOWER SODB LIMITS REFLECT ANALYTICAL EXTENSION OF SYSTEM CAPABILITY
HELIUM TANK	37 - 150°F	30 - 110°F	*49 - 100°F	
PROP BULK	40 - 85°F	30 - PRESSURE LIMITS	*49 - 100°F	
PROP TANK	39 - 93°F	20 - 175°F	*49 - 100°F	
PROP LINE	35 - 375°F	35°F MIN	105 - 170°F	
ENGINE VALVES	20°F MIN	30°F MIN	80 - NA°F	
NOZZLE NUT				
PRESSURE				
HELIUM TANK	6,000 PSIG	4,450 PSIA @ 80°F	*4,300 PSIA @ 80°F	
HELIUM MANIFOLD	177 - 193 PSIG	--	170 - 205 PSIA	INSTRUMENTATION ERROR CAUSES DIFFERENCE BETWEEN GROUND TEST AND FLIGHT TEST
FUEL MANIFOLD	167 - 198 PSIG	--	168 - 201 PSIA	
OXID MANIFOLD	167 - 198 PSIG	--	169 - 200 PSIA	
PROP TANKS	360 PSIG	248 PSID @ (99°F - 128°F)	168 - 205 PSIA	
ENGINE INLET	50 PSIA MINIMUM TESTED	75 PSIA	*168 - 201 PSIA	
COMPATIBILITY	103 DAYS	--	11 DAYS	
SINGLE ENGINE FIRING TIME	4,800 SECONDS	500 SECONDS SINGLE FIRING 1,000 SECONDS ACCUMULATIVE	*237 SECONDS	
CYCLES	26,000	10,000	*3,750	
SHOCK	1 to 20 G	--	*150 - 180 G	S-IVB/SLA SEP. SHOCK SUPPLEMENTAL TEST COMPLETED
VIBRATION	0.003 g^2/cps to 0.5 g^2/cps 5 to 2,080 cps 8.17 GRMS (S/C 105 O_x Tank Boss) 14.93 GRMS (S/C 105 Engine Input)	--		

COMMAND MODULE REACTION CONTROL SYSTEM
QUALIFICATION ADEQUACY SUMMARY

PARAMETER	GROUND TESTS	SODB	FLIGHT *ESTIMATED	REMARKS
TEMPERATURE				
HELIUM TANK	AMBIENT	20 - 140°F	0 - 70°F	LOWER SODB LIMITS REFLECT ANALYTICAL EXTENSION OF SYSTEM CAPABILITY
PROP BULK	AMBIENT - 114°F	30 - 110°F	*50 - 70°F	
PROP TANK	40 - 105°F	30 - PRESSURE LIMITS	*50 - 70°F	
PROP LINES	AMBIENT - 114°F	20 - 200°F	*50 - 70°F	
ENGINE VALVES	35 - 200°F	20 - 225°F	*20°F - 220°F	
ENGINE INJECTORS	-10°F	28 - N/A °F	23°F Min.	
PRESSURE				
HELIUM TANK	6,667 PSIG	4,700 PSIA @ 75°F	4,250 PSIA @ 75°F	
HELIUM MANIFOLD	0 - 415 PSIA	--	0 - 307 PSIA	
PROP TANKS	0 - 525 PSIG	360 PSID @ (104 to 123°F)	0 - 307 PSIA	
ENGINE INLET	0 - 415 PSIA	NO LIMIT	*0 - 307 PSIA	
COMPATIBILITY	103 DAYS	--	11 DAYS	
SINGLE ENGINE FIRING				
TIME	273 SECONDS	200 SECONDS	*87 SECONDS	
CYCLES	--	3,000	*300 CYCLES	
SHOCK	1 TO 78 G	--	* >180	
VIBRATION	0.007 g^2/cps TO 0.2 g^2/cps 5 TO 2,000 cps 3.69 GRMS (Ox TANK INPUTS S/C 105) 3.64 GRMS (FUEL TANK INPUTS S/C 105) 2.52 GRMS (HELIUM PANEL INPUTS S/C 105)	--		

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

NO FORMAL APOLLO QUALIFICATION

COMPONENT	CERTIFICATION BASIS	QUALIFICATION CONFIGURATION
THERMOSTAT ME363-003	PREVIOUS CUMULATIVE TESTING AS SEPARATE COMPONENT PER MIL-E-5272 AND MIL-T-5574 AND IN HEATER ASSEMBLY (REFERENCE, CTR 01214703)	HEATER ASSEMBLY ME363-0014 PART OF ASSEMBLY
RELIEF VALVE V37-460113 WITH OUTLET PORT COVER	DEMONSTRATED THAT BLOW OFF RESISTANCE OF STICK-ON COVER IS NEGLIGIBLE (REFERENCE, SD68-92)	RELIEF VALVE ME284-0026 ME284-0062 WITHOUT OUTLET PORT COVER
CHECK VALVE ME284-0357 WITH FILTER	SUCCESSFUL SEPARATE QUALIFICATION TESTS ON FILTER ASSEMBLIES AND THE CHECK VALVE WITHOUT (REFERENCES, CTR 13316010 AND SD67-950)	CHECK VALVE ME284-0024 WITHOUT FILTER
DUMP HOSE ME271-0050	PREVIOUS CUMULATIVE TESTING WHICH DEMONSTRATED ADEQUACY FOR APOLLO USAGE (REFERENCE, SD68-141)	SAME CONSTRUCTION EXCEPT STRAIGHT END FITTINGS AND SLIGHTLY LONGER

SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS, SODB ALLOWABLES, AND FLIGHT EXPERIENCE
COMPONENT: ROCKET ENGINE (ME901-000-)

PARAMETER	QUALIFICATION LEVELS	SUPP. TESTING	GROUND OPERATIONS *ESTIMATED	SODB LIMITATIONS	FLIGHT DATA VALUES *ESTIMATED
INLET PRESSURE	166-250 PSIA	50 PSIA	250 PSIA	75 PSIA	168-201 PSIA
TEMPERATURE (VALVE) TEMPERATURE (BELL-NUT) TEMPERATURE (PROPELLANT) TEMPERATURE (PKG. TEMP.)	35-175°F 30°F 40-100°F	35-375°F 20 MINIMUM 150°F MAXIMUM	40-110°F AMBIENT 70 ± 5°F AMBIENT-13-°F	35-N/A °F 30°F 30-110°F 55°F Min.	*108-170°F *30-N.A. *49-100°F 117-207°F
LIFE	1,000 SECONDS 10,000 CYCLES	1,800 SECONDS 26,000 CYCLES		SINGLE FIRING 500 SEC., 1,000 SEC. 10,000 CYCLES	*237 SECONDS *3700 CYCLES
VOLTAGE	21-32 VDC		*3-30 VDC	21-32 VDC	22-28 VDC
FLUID COMPATIBILITY	30 DAYS	90-103 DAY COMPATIBILITY TEST	33 DAYS AVERAGE	NOT APPLICABLE	11 DAYS
SHOCK					*150-180 G's
VIBRATION		QUAD ACOUSTIC TEST 14.93 GRMS (S/C 105)			
BOOST RANDOM	0.055 g^2/cps @ 10 cps, INCREASE @ 3 db/octave to 0.5 g^2/cps @ 90 cps, CONSTANT to 250 cps, DECREASE @ 3 db/octave to 0.06 g^2/cps @ 200 cps				
SPACE FLIGHT RANDOM	20-100 cps-LINEAR INCREASE ON A LOG-LOG SCALE FROM 0.003-0.015 g^2/cps. 100-2,000 cps CONSTANT at 0.015 g^2/cps				

COMMAND AND SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: HELIUM TANK (CSM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press.	SM/7000 psig -2 mins (burst) CM/7500 psig -2 mins (burst) SM/6000 psig (proof) CM/6667 psig -15 mins (proof)		CM/5250 ± 50 psig SM/5250 ± 50 psig	SM/4450 psia at 80°F CM/4700 psia at 75°F	4300 psia at 80°F 4250 psia at 75°F
Vibration	lin incr. from 0.04 g^2/cps at 20 cps to 0.15 g^2/cps at 80 cps; constant 0.15 g^2/cps from 80 cps to 1000 cps; lin decr. to 0.075 g^2/cps to 2000 cps. Applied 15 mins			N/A	CM 1.6 g^2/cps
Life	CM/3000 cycles 0-5000 psig SM/600 cycles 0-4500 psig		<10 <10	N/A	1
Creep	4500 psig - 720 hrs deformation 0.2 °/o offset from un-axial stress - strain curve			N/A	N/A

COMMAND AND SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: HELIUM TANK (CSM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Shock	20 g - 5 mins			N/A	CM/ < 18 g SM/ 150-180 g
Temperature	ambient		SM/20°-150°F CM/20°-150°F below 4000 psig	SM/20-140°F CM/20-140°F	SM/49-100°F CM/0-78°F

SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: HELIUM ISOLATION VALVE

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press.	6750 psig (proof) 9000 psig (burst)		5250 ± 50 at 70 ± 5°F	4450 psia at 80°F	4500 psia at 80°F
Fluid Compatibility	33 days (70-150°F)	110 days (MMH and quad test)	33 days aver.	N/A	11
Life	4000 cycles	Augmented Qual life: 1000 cycles at + 150°F and + 30°F	< 100	N/A	2
Vibration	± 5 g; lin incr. from 0.04 g^2/cps at 20 cps to 0.15 g^2/cps at 80 cps; constant to 1000 cps; lin. decrease to 0.075 g^2/cps at 2000 cps; 15 min per axis	± 5 g; lin. incr. from 0.04 g^2/cps at 20 cps to 0.15 g^2/cps at 80 cps; constant to 1000 cps; lin. decrease to 0.075 g^2/cps at 2000 cps; 15 min per axis		N/A	

SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: HELIUM ISOLATION VALVE

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Electrical Characteristics			28 ±2VDC	18 - 33 VDC	22-28 VDC
Temperature	Fluid -65 to 150°F Environmental +30 to +150°F		20 to 150°F 40 to 110°F	20-150°F	49-100°F
Shock					150-180 g

COMMAND AND SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
<u>COMPONENT:</u> HELIUM REGULATOR (CM and SM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press.	(burst) CM - inlet 9000 psig outlet 720 psig SM - inlet 9000 psig outlet 500 psig (proof) CM - inlet 6750 psig outlet - 540 psig at 5 mins SM - inlet 6750 psig outlet - 375 psig at 5 mins		5250 ± 50 400 ± 5 inlet 5250 ± 50 300 ± 5 inlet	He tank SM - 4450 psia at 80°F CM - 4700 psia at 75°F	He tank SM - 4300 psia at 80°F CM - 4250 psia at 75°F He manifold - SM - 170-205 psia CM - 30-307 psis
Shock		Augmented QVT Endurance Test internal leakage vibration endurance disassembly inspection		N/A	SM - 150-180 g CM - > 18 g

COMMAND AND SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
<u>COMPONENT:</u> HELIUM REGULATOR (CM AND SM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Vibration	linear incr. from 0.04 g^2/cps at 20 cps to 0.15 g^2/cps at 80 cps; constant 0.15 g^2/cps from 80 cps to 1000 cps; linear decr. to 0.075 g^2/cps at 2000 cps, 4500 psig inlet reg. locked up. Also do blowdown during vibration.				CM 1.6 g^2/cps
Fluid Compatibility	31 days		33 days aver.	N/A	41 days
Temperature	30°F inlet 2000 psig -65°F inlet 500 psig at vacuum		gas temp. 20-150°F	20-150°F	CM - 50-80°F SM - 50-100°F
Life	4000 cycles between temp. of 30°F to -65°F		<100 cycles ambient 40-110F	N/A	

COMMAND AND SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: CHECK VALVES (CM AND SM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press	540 psig (proof) 720 psig (burst)	Augmented Internal leak. crack press. surge press. acceleration vibration fluid compatibility endurance disassembly inspection decontamination	CM/40C ± 5 SM/30C ± 5	SM 248 psid at 49F to 128°F CM 360 psid at 104 -123°F	(He manifold) SM/170-205 psia CM/30-307 psia
Surge Press	30 cycles at 308 psig inlet; pass leakage tests				
Shock	20 g			N/A	SM/150-180 g CM/ 18 g
Vibration	see note 1			N/A	CM/1.6 g^2/cps
Cycle Life Temperature	4000 cycles at temps. ambient temp 30-150°F He temp. -65 to 80°F	103 days extended life test at WSTF	200 cycles gas temp 20-150°F ambient 40-110F	N/A CM/SM 20-150°F	SM/49-100°F (He tank) CM/0-78°F (He tank)
Propellant Compatibility	30 days - temp 80°F - 150°F		33 days aver.	N/A	11 days

SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: HELIUM RELIEF VALVE (SM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press.	375 psig (proof) 500 psig (burst)	Augmented QVT Fluid compatibility functional		ox - 248 psid at 99°F Fu, A, C, D - 248 psid at 116°F Fu B - 248 psid at 128°F	He manifold 170-205 psia
Vibration	See note	Diaph. leak humidity		N/A	g^2/cps
Shock	6 g	Vibration endurance		N/A	150-180 g
Vent life	600 cycles ambient temp 30 to 150°F helium temp -65 to 80°F	Diaph rupt endurance	Vent cycles <10	20-150°F	49-100°F (He + X)
Diaphragm Rupture	228 ± 8 psig ambient temp 30 to 150°F He temp -65 to 80°F	Vent valve			
Diaphragm life	1500 cycles ambient temp -65 to 150°F helium temp -65 to 100°F	Endurance Disassembly Inspection	< 100 cycles He at 20 to 150°F ambient 40 to 110°F	N/A	0

SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: HELIUM RELIEF VALVE (SM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Relief Valve life	4000 cycles ambient temp 30 to 150°F helium temp -65 to 80°F	103 day extended life test at WSTF	< 10 cycles He at 20 to 150°F ambient 40 to 110°F	1 cycle 215 psid 1 cycle 185 psid 1 cycle 188 psid	0
Fluid Compatibility	15 days propellants		33 day aver. Vapors		11 days

SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: PROPELLANT TANKS FU/OX (SM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press.	360 psig (proof) 460 psig (burst)		300 ± 5 psig	ox 248 psid at 99°F fu A,C,D 248 psid at 116°F fu B 248 psid at 128°F	he manifold 170 - 205 psia ox manifold 169 - 200 psia fu manifold 168 - 201 psia
Vibration	0.035 g^2/cps at 10 cps. lin incr. to 0.35 g^2/cps at 100 cps, constant to 250 cps, lin. decr. to 0.03 g^2/cps at 2000 cps		N/A	N/A	
Shock			N/A	N/A	150-180° g
Life Expulsion Tank	ox 6 cycles fu 20 cycles 3000 cycles		zero cycles < 10	N/A	1 1

SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
<u>COMPONENT:</u> PROPELLANT TANKS FU/OX (SM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Temperature	40-85°F		40-110°F	30°F min. See max. press limits for max.	50-100°F
Fluid Compatibility		ox and fuel 103 day (WSTF) SD69-459-1 fuel - 58 days in DVT ox - 30 days + (stress corrosion investigation)	33 day aver.	N/A	11 days

SERVICE DULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: PROPELLANT ISOLATION VALVES (OX/FU)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press.	540 psig (proof) 720 psig (burst)		300 ± 5 psig	248 psia at 99°F	Ox - 169-200 psia Fu - 168-201 psia
Life	4000 cycles		< 20	N/A	1
Temperature	Fluid: +40 to +100°F Env: +40 to + 105°F		40-110°F	30-105	50-80°F
Fluid Compatibility	18 days liquid 18 days vapor	103 day (MMH and N_2O_4 quad test)	33 day aver.		11 days
Shock	20 g		N/A	N/A	150-180° g
Vibration	linear incr. from 0.04 g^2/cps at 20 cps to 0.15 g^2/cps at 80 cps, constant to 1000 cps, lin decr to 0.075 g^2/cps at 2000 cps				

SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: PROPELLANT ISOLATION VALVES (OX/FU)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Electrical		Augmented Qual. 2000 flow cycle 1000 static cycle Random - same as qual level	*9-30 VDC	18-33 VDC	22-28 VDC

*magnetic latch test.

SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: PROPELLANT INLINE FILTER

PARAMETER	QUAL	SUPP. TESTING	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press.	375 psig (proof) 500 psig (burst) 248 psi ΔP (collapse)		300 ± 5 psig	N/A	Ox 169-200 psia Fu 168-201 psia
Temperature	Fluid: + 40 to + 150°F Environment: + 40 to + 105°F		40 - 110°F	20 - 175°F	50 - 100°F
Shock	6 g		N/A	N/A	150 - 180 g
Life	2000 cycles		< 10	N/A	
Fluid Compatibility	18 days liquid 18 days vapor	103 day (MMH and N_2O_4 quad test)	33 days average	N/A	11 days
Vibration					
Resonance	5-7000 cps at 2.5 g		N/A	N/A	
Random	lin. incr. from from .003 g^2/cps at 20 cps to .015 g^2/cps at 100 cps constant 0.015 g^2/cps from 100 to 2000 cps				

SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: VALVE HEATERS

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Life	2000 cycles	None	< 10	N/A	
Temperature	-65 to +250°		40-150°F	N/A	
Electrical			28 ± 3 VDC	N/A	22-28 VDC
Vibration			N/A	N/A	
Resonance	5-2000 cps at 02.5 g				
Random	lin. incr. from 0.055 g^2/cps at 10 cps to 0.5 g^2/cps at 90 cps, constant to 400 cps, lin. dec. to 0.06 g^2/cps and 2000 cps				

COMMAND AND SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: COUPLING, FILL AND VENT (CSM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPERATIONS	SODB LIMITS	FLIGHT DATA VALUES
Max press	540 psig (proof) 720 psig (burst)		CM 400 ± 5 psig SM 300 ± 5 psig	N/A	
Temperature	40 and 80° F		He temp. range, 20-100° F Environment range, 40-110° F		
Shock	30 g				SM 150-180 g CM > 18 g
Vibration	freq. 5-2000 cps incr. 0.04 g^2/cps at 20 cps to 0.15 g^2/cps at 80 cps constant 0.15 g^2/cps from 80 cps to 1000 cps decr. to 0.075 g^2/cps at 2000 cps				CM 1.6 g^2/cps
Life	400 engagement/disengagements at working press		< 100		1
Fluid Compatibility	34 days at 360 psig + 4 days vapor	103 days extended life test to WSTF	33 days aver.		41 days

COMMAND AND SERVICE MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: COUPLING TP DISCONNECT (CSM HELIUM AND PROP)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press	prop - 540 psig (proof) helium - 7500 psig (proof) prop - 720 psig (burst) helium - 9000 psig (burst)		Hi press - 5250 ± 50 CM Helium - 5250 ± 50 SM Low pressure 405 ± 5 CM Helium and prop. 310 ± 10 SM	N/A	
Temperature	40° F and 80° F		ambient 40-110°F helium 20-100°F		
Shock	30 g				SM 150-180 g CM > 18 g
Vibration	linear incr. from 0.04 g^2/cps at 20 cps to 0.15 g^2/cps at 80 cps; constant 0.15 g^2/cps from 80 cps to 1000 cps; decr. to 0.075 g^2/cps at 2000 cps.				CM 1.6 g^2/cps
Life	400 engagement/disengagements		< 100		1
Fluid Compatibility	34 days at 295 psig + 4 days vapor	103 days extended life test at WSTF	38 days aver.		41 days

COMMAND MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS, SODB ALLOWABLES, AND FLIGHT EXPERIENCE
COMPONENT: ROCKET ENGINE (ME901-0067)

PARAMETER	QUALIFICATION LEVELS	SUPP. TESTING	GROUND OPERATIONS *ESTIMATED	SODB LIMITATIONS	FLIGHT DATA VALUES *ESTIMATED
INLET PRESSURE	266-299 PSIA	0-415 PSIA	290-325	NO LIMIT	*0-307 PSIA
TEMPERATURE (VALVES) TEMPERATURE (PROPELLANT) TEMPERATURE (INJECTORS)	35-175°F 40-100°F -10°F	200°F Ambient-114°F -10°F	40-110°F 70 ± 5°F Ambient	20-225°F 30-110°F 28°F	*20-220°F *50-78°F 23°F Min.
LIFE TOTAL	230 SEC. INCL. 130 SEC. PULSING	273 SEC. INCL. 200 SEC. DEORBIT BURN		200 SEC. AT PERFORMANCE 50 SEC. AT NONPERFORMANCE 3,000 CYCLES	TOTALS: *57 SECONDS *300 CYCLES
VOLTAGE	21-32 VDC		*3-30 VDC	21-32 VDC	22-28 VDC
FLUID COMPATIBILITY	30 DAYS	103 DAYS	33 DAYS AVERAGE	NOT APPLICABLE	11 DAYS
ACCELERATION	38 G's			NOT APPLICABLE	
VIBRATION BOOST RANDOM HIGH Q ABORT RANDOM	0.015 g^2/cps @ 20 cps, INCREASE 3 db/oct. to 0.2 g^2/cps, CONSTANT to 500 cps, 3 db/oct. DECREASE TO 2,000 cps 0.156 g^2/cps @ 20 cps, INCREASE 3 db/oct. to 0.2 g^2/cps, CONSTANT to 2,000 cps	2.96 GRMS (S/C 105 CREW COMPARTMENT HEAT SHIELD)		NOT APPLICABLE	
SHOCK (IMPACT)	78 G's			NOT APPLICABLE	>18 G's

COMMAND MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: HELIUM SQUIB ISOLATION VALVE

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press.	6750 psig (proof) 9000 psig (burst)	Augmented QVT vibration same as qual level	5250 $\pm$ 50 psig	4250 psia at 70°F	4250 psia at 75°F
Life hi pres.	4500 psig		$<$ 20 cycles	N/A	1
Temperature	40-150°F	explosive atmosphere high temp.	40-110°F	20-150°F	0-78° F
Vibration	lin. incr. from 0.008 g^2/cps at 10 cps to 0.06 g^2/cps at 75 cps, constant to 2000 cps	flow rate and ΔP	N/A	N/A	1.6 g^2/cps
		post firing leakage			
		disassembly and inspec.			
Shock					$>$18 g
Electrical				5 amps min.	

COMMAND MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: HELIUM RELIEF VALVE (CM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max Press.	540 psig (proof) 720 psig (burst)	None	400 ± 5 psig to burst dia.	He manifold 15-360 psig	He manifold 30-307 psia
Vibration	linear inc. 0.0007 g^2/cps at 5 cps to 0.122 g^2/cps at 50 cps; constant 0.122 g^2/cps from 50 cps to 150 cps; linear dec. to 0.035 g^2/cps at 2000 cps		332-360 psig in relief valve cavity	N/A	1.6 g^2/cps
Shock	20 g			N/A	> 18 g
Diaphragm life	1500 cycles ambient temp 30-150°F helium temp. -65 to 100°		< 100 cycles He at 20 to 150°F. Ambient at 40-110°F	N/A 20-150°F	2 50-80°F
Rupture	340 ± 8 psig Ambient temp. 30 to 150°. He temp -65 to 80°F		N/A		
Vent life	600 cycles at 0-179 psig ambient temp 30-150°F. He temp -65 to 80°F		Vent poppet cycles < 10	N/A	2

COMMAND MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: HELIUM RELIEF VALVE (CM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Relief valve life	4000 cycles ambient temp 30 to 150°F He temp -65 to 80°F		poppet cycles < 10 He at 20-150°F. Ambient at 40-110°F	N/A	2
Fluid Compatibility	15 days		33 days average	N/A	11 days

COMMAND MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: PROPELLANT TANKS Fu/Ox (CM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press.	525 psig (proof)		400 ± 5 psig	A-ox 320 psid at 123°F B-ox 320 psid at 129°F Fu-A and B 320 psid at 141°F	He manifold 30-307 psia
	710 psig (burst)				
Vibration	Freq 5 to 2000 cps 0.008 g^2/cps at 10 cps incr. to 0.10 g^2/cps at 80 cps; constant 0.10 g^2/cps from 80 cps to 2000 cps			N/A	1.6 g^2/cps
Shock	28 g			N/A	> 18 g
Life Expulsion Tank	20 cycles at 40 and 150°F 3000 press. cycles at 310 + 10 to 360 ∓ 10 psig		None < 10 tank cycles	N/A 2 cycles at 320 psid 1 cycle at 35 psid	1 cycle 1 cycle

COMMAND MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: PROPELLANT TANKS Fu/Ox (CM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Temperature	40-105°F		ambient and He 40-110°F	30° F min., see max. press. limits for max.	50-100°F
Fluid Compatibility		Fuel and oxidizer 103 days (WSTF SD-69-459-1) Oxygen - 30 days plus during stress corr. investigation	33 days aver.	N/A	11 days

COMMAND MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: PROPELLANT SQUIB ISOLATION VALVE

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press.	540 psig (proof)		400 ± 5 psig	360 psid at 104 to 123°F	He manifold 30-307 psia
Valve	720 psig (burst)		N/A	N/A	
Pyro port	6000 psig (proof)		N/A	N/A	
Temperature	40-150°F		40-110°F	20-200°F	50-80°F
Fluid Compatibility	15 days		33 days aver.	N/A	11 days
Vibration	lin. inc. from 0.008 g^2/cps at 10 cps to 0.06 g^2/cps at 75 cps constant to 2000 cps		N/A	N/A	1.6 g^2/cps
		Augmented QVT explcs. Atmos. Flow Rate and ΔP Post-firing Disassembly Inspection			>18 g
Electrical				18-33 VDC	22-28 VDC

COMMAND MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: BURST DISK - PROPELLANT (CM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press.	540 psig		Proof press.		30-307 psia
Burst press.	720 psig		400 ± 5 psig housing only		
Rupture press.	227-255 psig temp. 40-105°F				
Life	40 cycles press 0-210 psig		No cycles		1 cycle
Vibration	freq. 5-2000 inc. from 0.008 g^2/cps at 10 cps to 0.06 g^2/cps at 75 cps; constant 0.06 g^2/cps from 75 cps to 400 cps to 0.0125 g^2/cps at 2000 cps				1.6 g^2/cps

COMMAND MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE
COMPONENT: BURST DISK - PROPELLANT (CM)

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Shock	2 g shock				18 g
Fluid Compatibility	60 day prop. compatibility	103 days prop. compatibility Internal leak burst disc rupt. ext. leak	33 day aver.		11 days
Temperature	40-105°F		40-110°F		50-80°F

COMMAND MODULE REACTION CONTROL SYSTEM
COMPARISON OF QUALIFICATION LEVELS, GROUND OPERATIONS
SODB LIMITS AND FLIGHT EXPERIENCE

COMPONENT: FLEXIBLE METAL HOSE ASSEMBLY

PARAMETER	QUAL	ADDNL VERIF	GROUND OPER	SODB LIMITS	FLIGHT DATA VALUES
Max press	2000 psig (proof)		400 ± 5 psig		30-307 psia
Vibration			N/A		1.6 g^2/cps
Resonance	5 to 2000 cps ± 2 g				
Random	linear incr. from 0.04 g^2/cps at 20 cps to 0.15 g^2/cps at 80 cps, constant to 1000 cps linear decr. to 0.075 g^2/cps at 2000 cps				
Life					
Endurance	9000 cycles		N/A		1
Pressure	30 cycles 0-200 psig		< 10		
Temperature	40-150°F		40-110°F		50-80°F
Shock	78 g		N/A		> 18 g
Fluid Compatibility	34 days-prop. at 360 psi; 4 days vapor		33 days aver.		11 days

SECTION 5

CONFIGURATION ADEQUACY

Section 5 delineates and summarizes the configuration adequacy evaluation of the Command Module/Service Module Reaction Control Subsystem. There is no written text.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SUBSYSTEM

QUALIFICATION CONFIGURATION ADEQUACY

	C/M	S/M
● NON-STANDARD COMPONENTS	16	15
• TOTAL USAGE PER SPACECRAFT	144	252
● CURRENT SPACECRAFT COMPONENT EVALUATION		
• ORIGINAL QUALIFICATION CONFIGURATION	9	9
• QUALIFICATION BY SIMILARITY		
— SERVICE MODULE		
• NON-TEST PORT REGULATORS		1
• NON-INTEGRAL THERMOSTAT HEATERS		1
• TANKS WITH REORIENTED LIQUID SIDE VENT TUBES		1
— COMMAND MODULE		
• ANTI-SURGE SOLENOID VALVE	1	
• NON-FILTER SQUIB VALVE	1	
• NON-TEST PORT REGULATORS	1	
• FAST VENT PROPELLANT TANK	1	
• QUALIFIED BY ANALYSIS/PRIOR TEST		
— SERVICE MODULE		
• THERMOSTAT		1
• RELIEF VALVE PORT PROTECTIVE COVER		1
• INTEGRAL FILTER CHECK VALVE		1
— COMMAND MODULE		
• DUMP HOSES	1	
• RELIEF VALVE PORT PROTECTIVE COVER	1	
• INTEGRAL FILTER CHECK VALVE	1	
● TOTAL	16	15

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

SM RCS ENGINE CONFIGURATION SUMMARY

ME #	Component Name	S/C / Dash #	009	011	017	020	101	103	104	106	107	108	109	110
		ME901-0004 -0110	D_1											
		-0201		S	S_1	S_1								
		-0301				D_2	D_2	D_2	D_2	D_2	D_2	D_2	D_2	D_2

S - QUAL CONFIGURATION

QUAL TEST START DATE	8-16-65	CTR 01114813
QUAL TEST COMPL. DATE	12-13-65	
OFF LIMITS START DATE	1-13-66	
OFF LIMITS COMPL. DATE	5-16-66	
S_1 - SUPPL. QUAL START DATE	8-8-66	CTR 01414701 - CHANGE PROPELLANTS TO MMH AND "GREEN" NTO, SATURATED
SUPPL. QUAL COMPL. DATE	11-8-66	

D_1 - PFRT CONFIGURATION — CTR 00914401

PFRT START DATE	11-21-64	SAME AS QUAL CONFIGURATION EXCEPT:
PFRT COMPL. DATE	6-25-65	(1) DOUBLE ANGLE GLASS FILLED TEFLON VALVE SEAT SEAL
		(2) NO FUEL VALVE THERMAL STANDOFF

D_2 - SAME AS QUAL CONFIGURATION EXCEPT ADDED VALVE INLET STRAINER SCREENS. PROPELLANTS WERE MMH AND "GREEN" NTO, SATURATED

SUPPL. QUAL START DATE	7-13-67	CTR 14316008
SUPPL. QUAL COMPL. DATE	8-22-67	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

SM RCS ENGINE Δ BETWEEN QUAL AND S/C 110

ME #	COMPONENT NAME	DASH #	QUAL CONFIG	# OF DWG CHGS (LETTER)	CSM 110 CONFIG	RATIONALE
901-0004	ROCKET ENGINE		-0201	157	-0301	-0301 ADDED VALVE INLET STRAINER DRAWING CHANGES CONSIST OF: . NON FUNCTIONAL DIMENSION CHANGES
						. DRAWING ERROR CORRECTION . SURFACE FINISH ADJUSTMENTS . DELETION OF NON-REQUIRED DIMENSIONS
						. CLARIFICATION CHANGES . ADDITION OF MORE DEFINITIVE MATERIAL SPECIFICATIONS
						. IN-PROCESS TEST REVISIONS

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
ROCKET ENGINE	ME901-0004-0201	8-16-65	12-31-65	8-8-66	11-8-66		
SM RCS	-0301			7-13-67	8-22-67		ADDED VALVE INLET STRAINER

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

TYPICAL CLASS II CHANGES SINCE QUALIFICATION

ME NUMBER	COMPONENT NAME	COMPONENT DETAIL		CLASS II CHANGE
901-0004-0201 -0301	ROCKET ENGINE - SM RCS	INJECTOR HEAD ASSEMBLY 228174	G	CHANGE - ADDED INSTRUCTIONS ALLOWING THERMAL CYCLING TO HELP ELIMINATION OF INTERFACE LEAKAGE FOLLOWING SHRINK FIT ASSEMBLY. PURPOSE WAS TO REDUCE REJECTION RATE.
			K	CHANGE - CHANGED LUBRICANT AND APPLIED TIGHTER APPLICATION CONTROLS FOR PREIGNITER TUBE ASSEMBLY INTO INJECTOR. PURPOSE WAS TO ELIMINATE A POSSIBLE SOURCE OF CONTAMINATION.
901-0004-0201 -0301	ROCKET ENGINE - SM RCS	SEAL-FACE, COMBUSTION CHAMBER 227949	D	CHANGE - ADDED INSTRUCTIONS TO RESTRAIN SEAL DURING FLATNESS CHECK BECAUSE THE SEAL IS INSUFFICIENTLY RIGID TO MAINTAIN FLATNESS DURING STORAGE.
901-0004-0201 -0301	ROCKET ENGINE - SM RCS	BODY-SOLENOID VALVE 228506	B	CHANGE - DELETED "BREAK SHARP EDGES .005 - .015". ADDED "BREAK SHARP EDGES .015 MAXIMUM". PURPOSE IS TO EASE MANUFACTURING.
			C	CHANGE - CHANGED SURFACE FINISH FROM 32 TO 125 ON NON-CRITICAL SURFACES.
			D	CHANGE - CORRECTED THREAD CALLOUT.
			G	CHANGE - CHANGED MATERIAL SPECIFICATION FROM QQ-S-763 TO MARQUARDT MMS-2211. MMS SPECIFICATION MORE DEFINITIVE AND INCLUDES REQUIREMENTS NOT INCLUDED IN QQ SPECIFICATION.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

CM RCS ENGINE CONFIGURATION SUMMARY

ME # 901-0067	Component Name	S/C Dash #	009	011	017	020	101	103	104	106	107	108	109	110	
-0005 (SE8-5)	ROCKET ENGINE	1	D 2												CTR00913103 EARQLR65-043
-0005 (SE8-9)		2	D 8												CTR00913103 EARQLR65-043
-0001		3	D 2	4	D										CTR00913103 EARQLR65-043
-0012		4		D 4	D										CTR01113314 CTA402B
-0011				4	S 12	S 12	S 12	S 8	S 8	S 8	S 4	S 7	S 5	S 8	CTR01113314 CTA402B
-0013		5							D 2	D 1					CTR013316009 CTA1234
-0014		6						D 4	D 2	D 3	D 8	D 5	D 7	D 4	CTR13316011 CTA 1300
-0015	ROCKET ENGINE	7													CTR13316011 CTA1300A
			DIFFERENCES WITH -0011					8							
1 -0005	AIR MELT CRES IN VALVE BOBBIN, 4-PIECE ORIFICE, 2.0 MR, COMBUSTION CHAMBER NOT EPOXY COATED														
2 -0005	CHAMFERED OXIDIZER INJECTOR INLET HOLES AND AS NOTED IN 1.														
3 -0001	FOUR-PIECE ORIFICE, 2.0 MR, COMBUSTION CHAMBER NOT EPOXY COATED.														
4 -0012	FOUR-PIECE ORIFICE, 2.0 MR.														
5 -0013	EXCESSIVE COMBUSTION CHAMBER LINER DELAMINATIONS. RESTRICTED TO YAW LOCATIONS, S/C 101 AND SUBS.														
6 -0014	COMBUSTION CHAMBER LINER NOT CHARRED AND IMPREGNATED.														
7 -0015	ISP ≥ 250 < 266 SECONDS, THRUST ≥ 82 POUNDS, RESTRICTED TO YAW LOCATIONS IN CM 106 THROUGH 115A														
8 -0011	UTILIZES EPOXY COATED COMBUSTION CHAMBER, A CHARRED AND EPOXY IMPREGNATED CHAMBER LINER: HAS A ONE-PIECE ORIFICE, A 2.1 MIXTURE RATIO, VALVE BOBBIN IS OF VACUUM MELT CRES AND OXIDIZER MANIFOLD														
	INJECTOR HOLES ARE NOT CHAMFERED, ISP 266 SECONDS MINIMUM, THRUST 93 ± 2 POUNDS.														

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

CM RCS ENGINE Δ BETWEEN QUAL AND S/C 110

ME #	COMPONENT NAME	DASH #	QUAL CONFIG	# OF DWG CHGS (LETTER)	CSM 110 CONFIG	RATIONALE
901-0067	ROCKET ENGINE		-0011	189	-0011	
901-0067	ROCKET ENGINE		-0011	UNIQUE PARTS 8	-0014	-0014 REPLACES PRECHARRED LINER WITH VIRGIN LINER DRAWING CHANGES CONSIST OF:
						. NON FUNCTIONAL DIMENSIONAL CHANGES . SURFACE FINISH ADJUSTMENTS . DELETION OF NON-REQUIRED DIMENSIONS
						. CLARIFICATION CHANGES . DRAWING ERROR CORRECTION . IN-PROCESS TEST REVISIONS

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
ROCKET ENGINE	ME901-0067-0011	3-65	1-21-66				
CM RCS	-0012	3-65	1-21-66				
	-0013			2-2-67	2-4-67		DELAMINATED (PRECHARRED) LINER
	-0014			6-1-67	6-30-67		VIRGIN LINER
	-0015					7-69	LOW SPECIFIC IMPULSE
	-0011 & -0014			3-68	3-68		200 SEC. DEORBIT BURN
NOZZLE EXTENSION	ME901-0189-0004	3-65	1-21-66				
	-0005	3-65	1-21-66				
	-0006	3-65	1-21-66				
	-0004			3-68	3-68		200 SEC. DEORBIT BURN
"O" RING	ME262-0002-0001	3-65	1-21-66				
	-0002	3-65	1-21-66				
	-0002			3-68	3-68		200 SEC. DEORBIT BURN
SCREW, SELF LOCKING	ME112-0004-0002	3-65	1-21-66				
	-0003	3-65	1-21-66				
SCREW, PITCH & YAW N.E.	V16-417018-3	3-65	1-21-66				
SCREW, ROLL, N.E.	V16-417018-5	3-65	1-21-66				

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

TYPICAL CLASS II CHANGES SINCE QUALIFICATION

ME NUMBER	COMPONENT NAME	COMPONENT DETAIL	CLASS II CHANGE
901-0067-0014	ROCKET ENGINE - CM RCS	ROCKET ENGINE (106026)	DELETION OF THE VALVE INLET HOUSING WELD LEAK TEST BECAUSE IT WAS ADDED TO THE POST HOT FIRE ACCEPTANCE TEST REQUIREMENTS
901-0067-0011	ROCKET ENGINE - CM RCS	ROCKET ENGINE (106012)	ADDED REFERENCE CALLOUT (VALVE INLET HOUSING FILTER) FOR ADDITIONAL INFORMATION ONLY
901-0067-0011 -0012 -0013 -0014 -0015	INJECTOR - THRUST CHAMBER CM RCS ENGINE	209440	ADDED A THIRTEEN-DEGREE BY .050 CHAMFER TO THE QUICK DISCONNECT TO PERMIT EASIER ASSEMBLY WITH THE 206906 SHELL
901-0067-0011 -0012 -0013 -0014 -0015	CORE - PROPELLANT VALVE - CM RCS ENGINE	408916	INCREASED THE LENGTH OF THE CORE TO ASSURE THAT ADEQUATE MATERIAL EXISTS FOR GRINDING OPERATIONS WHEN ADJUSTING THE LENGTH OF VALVE ARMATURE STROKE

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	Dash # \ S/C	009	011	017	020	101	103	104	106	107	108	109	110
282-0002	Helium Pressure Vessel	-0001	S	S	S	S	S	S	S	S	S	S	S	S
282-0051	Helium Pressure Vessel	-0001					S	S	S	S	S	S	S	S

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	Dash # \ S/C	009	011	017	020	101	103	104	106	107	108	109	110
ME282-0004	N_2O_4 PDS. EXP TANK SM	-0001		S	S	S	S	S	S	S	S	S	S	S
		-0005	S											
		-0006					D_1	D_1	D_1	D_1	D_1	D_1	D_1	D_1
ME282-0006	N_2O_4 PDS EXP TANK CM	-0001		S	S	S	S	S	S	S	S	S	S	S
		-0005	D_2											
		-0006							D_3		D_3	D_3	D_3	D_3
ME282-0007	MMH PDS EXP TANK CM	-0001		S	S	S	S	S	S	S	S	S	S	S
		-0005	D_2											
		-0006									D_3	D_3	D_3	D_3
ME282-0008	MMH PDS EXP TANK SM	-0001		S	S	S	S	S	S	S	S	S	S	S
		-0005	S											
		-0006					D_1	D_1	D_1	D_1	D_1	D_1	D_1	D_1

D_1 - SAME AS QUAL CONFIGURATION EXCEPT FOR VENT TUBE ORIENTATION

D_2 - SAME AS QUAL CONFIGURATION EXCEPT HAD NO LIQUID SIDE VENT

D_3 - SAME AS QUAL EXCEPT HAS FAST DEPRESSURIZATION CAPABILITY

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	Dash # \ S/C	009	011	017	020	101	103	104	106	107	108	109	110	CODE
284-0281	Helium Isolation Valve	-0001	Sargent	Sargent	S	S	S	S	S	S	S	S	S	S	S = QUALIFIED CONFIGURATION

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	S/C / Dash #	009	011	017	020	101	103	104	106	107	108	109	110	
284-0024	OX Check Valve	0002	S	S											D^1 = Tighter Leakage Requirement
284-0024	Fuel Check Valve	0012	S	S											S = Qualified Configuration
284-0024	OX Check Valve	0032	D^1	D^1											S^1 = Redesigned Qual Config.
284-0024	Fuel Check Valve	0042	D^1	D^1											D^2 = Filters Added to S^1 Design
284-0024	OX Check Valve	0022			S^1	S	C/M S	C/M S							D^3 = No test ports between stages
284-0024	Fuel Check Valve	0052			S^1	S	C/M S	C/M S							
284-0357	OX Check Valve	0001					D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	
284-0357	Fuel Check Valve	0002					D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	
284-0022	SM Regulator	0002	S	S											
284-0022	SM Regulator	0005			D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	
284-0021	CM Regulator	0002	S	S											
284-0021	CM Regulator	0005			D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	Dash # \ S/C	009	011	017	020	101	103	104	106	107	108	109	110	CODE
284-0019	HE. PRESS. EXPLOSIVE VALVE	-0002	S	S	S	S	S	S	S	S	S	S	S	S	S = QUALIFIED CONFIGURATION
284-0019	HE. INTER. EXPLOSIVE VALVE	-0004	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^2 = -0002 W/OUT INLET FILTER
284-0019	HE. BYPASS EXPLOSIVE VALVE	-0006			D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^1 = -0002 WITH L.H. THD'S
284-0130	OXID. DUMP EXPLOSIVE VALVE	-0002	S	S	S	S	S	S	S	S	S	S	S	S	D^3 = -0002 WITH L.H. THD'S
284-0130	FUEL INTER. EXPLOSIVE VALVE	-0012	S	S	S	S	S	S	S	S	S	S	S	S	
284-0130	OXID. INTER. EXPLOSIVE VALVE	-0014	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	
284-0026	SM OXID. RELIEF VALVE	-0002	S	S	S	S	S	S	S	S	S	S	S	S	
284-0026	SM FUEL RELIEF VALVE	-0012	S	S	S	S	S	S	S	S	S	S	S	S	
284-0062	CM OXID. RELIEF VALVE	-0002	S	S	S	S	S	S	S	S	S	S	S	S	
284-0062	CM FUEL RELIEF VALVE	-0012	S	S	S	S	S	S	S	S	S	S	S	S	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	S/C / Dash #	009	011	017	020	101	103	104	106	107	108	109	110	CODE
284-0276	Propellant Isolation Valve (OX)	-0001	ECKEL	ECKEL	S	S	S	S	S	S	S	S	S	S	S = QUALIFIED CONFIGURATION
284-0276	(FU)	-0002	ECKEL	ECKEL	S	S	S	S	S	S	S	S	S	S	
284-0276	(OX)	(CM RCS) -0005	ECKEL	ECKEL	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1 = ANTI-SURGE FLOW DEFLECTOR
284-0276	(FU)	(CM RCS) -0006	ECKEL	ECKEL	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1	D^1	
284-0276	(OX)	-0007	ECKEL	ECKEL	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2 = NORMALLY CLOSED VALVE
284-0276	Propellant Isolation Valve (FU)	-0008	ECKEL	ECKEL	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	S/C / Dash #	009	011	017	020	101	103	104	106	107	108	109	110	
251-0005	OX BURST DISC ASSEMBLY	0004	S	S	X	X	X	X	X	X	X	X	X	X	S = QUALIFIED CONFIGURATION
251-0005	FUEL BURST DISC ASSEMBLY	0014	S	S	X	X	X	X	X	X	X	X	X	X	D^1 = MODIFIED CLOSURE PLUG
251-0005	OX REPLACEMENT KIT	0025	S	S	S	X	X	X	X	X	X	X	X	X	UNCOATED BURST DISC-QUALIFIED BY SIMI-
251-0005	FUEL REPLACEMENT KIT	0035	S	S	S	S	S	S	S	S	S	S	S	S	LARITY TO -0004
251-0005	OX BURST DISC ASSEMBLY	0005	X	D^1	X	X	X	X	X	X	X	X	X	X	D^2= MODIFIED CLOSURE PLUG
251-0005	FUEL BURST DISC ASSEMBLY	0015	X	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	D^2	QUALIFIED BY SIMILARITY TO -0014
251-0005	OX BURST DISC ASSEMBLY	0006	X	X	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3= D^1 + D^2 AND CHG'D
251-0005	OX REPLACEMENT KIT	0065	X	X	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	D^3	FLUSHING FLUID FROM IPA TO FREON

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	S/C / Dash #	009	011	017	020	101	103	104	106	107	108	109	110	
286-0039	Filter, Propell. In Line (OX)	-0001	X	X	S	S	S	S	S	S	S	S	S	S	S = Qualified Configuration
286-0039	Filter, Propell. In Line (FU)	-0011	X	X	S	S	S	S	S	S	S	S	S	S	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	Dash # \ S/C	009	011	017	020	101	103	104	106	107	108	109	110	
ME144-0023	OX TEST POINT CPLG.	-0011	S	S	S	S	S	S	S	S	S	S	S	S	
ME144-0023	FUEL TEST POINT CPLG.	-0031	S	S	S	S	S	S	S	S	S	S	S	S	
ME144-0023	LO-PRESS TEST POINT CPLG.	-0051	S	S	S	S	S	S	S	S	S	S	S	S	
ME144-0023	HI-PRESS TEST POINT CPLG.	-0071	S	S	S	S	S	S	S	S	S	S	S	S	
ME273-0010	He FILL CPLG.	-0001	S	S	S	S	S	S	S	S	S	S	S	S	
ME273-0011	OX VENT CPLG.	-0001	S	S	S	S	S	S	S	S	S	S	S	S	
ME273-0019	OX FILL CPLG.	-0001	S	S	S	S	S	S	S	S	S	S	S	S	
ME273-0021	FUEL FILL CPLG.	-0001	S	S	S	S	S	S	S	S	S	S	S	S	
ME273-0024	FUEL VENT CPLG.	-0001	S	S	S	S	S	S	S	S	S	S	S	S	
ME363-0014	VALVE HOUSE HEATER	-0001			S	S	S	S	S						
ME363-0014	VALVE HOUSE HEATER	-0004								D	D	D	D	D	-0004 DOES NOT CONTAIN A THERMOSTAT
ME360-0003	VALVE HOUSE THERMOSTAT	-0001			S	S	S	S	S	S	S	S	S	S	
ME271-0050	OX DUMP HOSE	-0001					S	S	S	S	S	S	S	S	
ME271-0050	OX DUMP HOSE	-0003					S	S	S	S	S	S	S	S	
ME271-0050	FUEL DUMP HOSE	-0004					S	S	S	S	S	S	S	S	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	Dash # \ S/C	009	011	017	020	101	103	104	105	107	108	109	110	
ME271-0019	FLEX HOSE	-0005	X	X	X	X	S	S	S	S	S	S	S	S	Construction is identical to Qual Unit, overall length differs
		-0011	X	X	X		S	S	S	S	S	S	S	S	
		-0014	S	S	S	S	X	X	X	X	X	X	X	X	
		-0018	S	S	S	S	S	S	S	S	S	S	S	S	
		-0023	X	X	X	X	S	S	S	S	S	S	S	S	
		-0026	X	X	X	X	S	S	S	S	S	S	S	S	
		-0031	S	S	S	S	X	X	X	X	X	X	X	X	
		-0032	S	S	S	S	S	S	S	S	S	S	S	S	
		-0033	S	S	S	S	S	S	S	S	S	S	S	S	
		-0034	S	S	S	S	S	S	S	S	S	S	S	S	
		-0035	X	X	X	X	S	S	S	S	S	S	S	S	
		-0036	X	X	X	X	S	S	S	S	S	S	S	S	
		-0037	X	X	X	X	S	S	S	S	S	S	S	S	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	Dash # \ S/C	C09	011	017	020	101	103	104	105	107	108	109	110	
ME273-0046	DYNATUBE FITTING	-0003	S	S	S	S	X	X	X	X	X	X	X	X	Sealing Surface is identical to qual unit, tube length and bend angle differ.
↓	↓	-0004	S	S	S	S	X	X	X	X	X	X	X	X	↓
		-0007	S	S	S	S	S	S	S	S	S	S	S	S	
		-0008	S	S	S	S	X	X	X	X	X	X	X	X	
		-0011	S	S	S	S	X	X	X	X	X	X	X	X	
		-0017	S	S	S	S	X	X	X	X	X	X	X	X	
		-0020	S	S	S	S	X	X	X	X	X	X	X	X	
		-0023	S	S	X	X	X	X	X	X	X	X	X	X	
		-0025	S	X	X	X	X	X	X	X	X	X	X	X	
		-0027	S	S	X	X	X	X	X	X	X	X	X	X	
		-0029	S	X	X	X	X	X	X	X	X	X	X	X	
		-0033	S	S	S	S	X	X	X	X	X	X	X	X	
		-0034	S	S	S	S	X	X	X	X	X	X	X	X	
		-0035	S	S	S	S	S	S	S	S	S	S	S	S	
		-0036	S	S	S	S	S	S	S	S	S	S	S	S	
		-0037	S	S	S	S	X	X	X	X	X	X	X	X	
		-0038	S	S	S	S	X	X	X	X	X	X	X	X	
↓	↓	-0041	S	S	S	S	X	X	X	X	X	X	X	X	↓

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	Dash # \ S/C	009	011	017	020	101	103	104	106	107	108	109	110	
ME273-0046	DYNATUBE FITTING	-0043	S	S	S	S	S	S	S	S	S	S	S	S	Sealing surface is identical to qual unit, tube length, and bend angle differ
		-0044	S	S	S	S	S	S	S	S	S	S	S	S	
		-0045	X	S	X	X	X	X	X	X	X	X	X	X	
		-0047	X	X	S	S	S	S	S	S	S	S	S	S	
		-0049	X	X	S	S	S	S	S	S	S	S	S	S	
		-0050	X	X	X	X	S	S	S	S	S	S	S	S	
		-0051	X	X	S	S	S	S	S	S	S	S	S	S	
		-0052	X	X	X	X	S	S	S	S	S	S	S	S	
		-0053	X	X	X	X	S	S	S	S	S	S	S	S	
		-0054	X	X	X	X	S	S	S	S	S	S	S	S	
		-0055	X	X	X	X	S	S	S	S	S	S	S	S	
		-0056	X	X	X	X	S	S	S	S	S	S	S	S	
		-0057	X	X	X	X	S	S	S	S	S	S	S	S	
		-0058	X	X	X	X	S	S	S	S	S	S	S	S	
		-0059	X	X	X	X	S	S	S	S	S	S	S	S	
		-0060	X	X	X	X	S	S	S	S	S	S	S	S	
		-0061	X	X	X	X	S	S	S	S	S	S	S	S	
		-0062	X	X	X	X	S	S	S	S	S	S	S	S	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS
CONFIGURATION SUMMARY BY SPACECRAFT

ME #	Component Name	Dash # \ S/C	009	011	017	020	101	103	104	106	107	108	109	110	
ME273-0046	DYNATUBE FITTING	-0063	X	X	X	X	S	S	S	S	S	S	S	S	Sealing surface is identical to qual unit, tube length and bend angle differ.
ME273-0049	↓	-0001	S	S	S	S	S	S	S	S	S	S	S	S	↓
ME273-0049	↓	-0002	S	S	S	S	S	S	S	S	S	S	S	S	↓

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL. CONFIG.	# OF DRAWING CHANGES	CSM 110 CONFIG.	RATIONALE
282-0002	Helium Pressure Vessel	-0001	-0001	0	-0001	
282-0051	Helium Pressure Vessel	-0001	-0001	0	-0001	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
282-0004	N_2O_4 POS Expulsion Tank (SM)	-0001	-0001 -0005	Approx. 75 letter changes	-0001	-0001 and -0005 are identical. -0005 denoted prequal status
		-0005	-0001 -0005		---	
		-0006	-0001 -0005		-0006	-0006 is identical to -0001 except for orientation of the prop outlet tube
282-0006	N_2O_4 POS Expulsion Tanks (CM)	-0001	-0001		-0001	
		-0005	N/A			-0005 is the non-LSV design used only on S/C 009
		-0006	-0001		-0006	-0006 is identical to -0001 except has perforated internal pad for fast vent
282-0007	MMH POS Expulsion Tank (CM)	-0001	-0001	Approx. 68 letter changes	-0001	
		-0005	N/A			-0005 is the non-LSV design-used only on S/C 009
		-0006	-0001		-0006	-0006 is identical to -0001 except has perforated internal pad for fast vent.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

MS #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
282-0008	MMH POS Expulsion Tank (SM)	-0001	-0001 -0005	Approx. 75 letter changes	-0001	-0001 and -0005 are identical -0005 denoted prequal status
		-0005	-0001 -0005		----	
		-0006	-0001 -0005		-0006	-0006 is identical to -0001 except for orientation of the prop outlet tube

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COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
284-0281	Helium Isolation Valve	-0001	-0001	138	-0001	Augmented qual. was satisfactorily completed 9-26-69. Since all changes were made prior to the augmented test,
						satisfactory completion of the augmented qual. test verify that the valve meets all requirements.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
284-0024	Oxygen Check Valve	-0002	-0002	NA*		*Obsolete configuration (all parts expended)
284-0024	Fuel Check Valve	-0012	-0012	NA*		*Obsolete configuration (all parts expended)
284-0024	Oxygen Check Valve	-0032	-0002	NA*		*Obsolete configuration (all parts expended)
284-0024	Fuel Check Valve	-0042	-0012	NA*		*Obsolete configuration (all parts expended)
284-0024	Oxygen Check Valve	-0022	-0022	26		*Obsolete configuration (all parts expended)
284-0024	Fuel Check Valve	-0052	-0052	21		*Obsolete configuration (all parts expended)
284-0024	Oxygen Check Valve	-0001	-0022	1	-0001	-0001 has internal filters; qualified by similarity to ME284-0024-0022
284-0357	Fuel Check Valve	-0002	-0052	0	-0002	-0002 has internal filters; qualified by similarity to ME284-0024-0052

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL. CONFIG.	# OF DRAWING CHANGES	CSM 110 CONFIG.	RATIONALE
284-0021	CM Regulator	-0002	-0002	40	-0005	-0005 has no test ports between regulator stages; qualified by similarity to -0002
284-0021	CM Regulator	-0005	-0002	See -0002 (Same drawings)	-0005	Same as above
284-0022	SM Regulator	-0002	-0002	50	-0005	Same as above
284-0022	SM Regulator	-0005	-0002	See -0002 (Same drawings)	-0005	Same as above

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
284-0019	Helium pressure explosive valve	-0002	-0002	0	-0002	S/C 009 and subs
284-0019	Helium inter. explosive valve	-0004	-0002	0	-0004	-0004 has L.H. thd's; qualified by similarity to -0002 S/C 009 and subs
284-0019	Helium bypass explosive valve	-0006	-0002	0	-0006	-0006 has no inlet filter; qualified by similarity to -0002 S/C 017 and subs
284-0130	Oxidizer dump explosive valve	-0002	-0002	0	-0002	S/C 009 and subs
284-0130	Fuel inter. explosive valve	-0012	-0012	0	-0012	S/C 009 and subs
284-0130	Oxidizer inter. explosive valve	-0014	-0002	0	-0014	-0014 has L.H. thd's; qualified by similarity to -0002 S/C 009 and subs
284-0026	SM oxidizer relief valve	-0002	-0002	23	-0002	S/C 009 and subs
284-0026	SM fuel relief valve	-0012	-0012	see -0002 (same dwgs)	-0012	S/C 009 and subs
284-0062	CM oxidizer relief valve	-0002	-0002	23	-0002	S/C 009 and subs
284-0062	CM fuel relief valve	-0012	-0012	see -0002 (same dwgs)	-0012	S/C 009 and subs

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
284-0276	Propellant Isolation Valve (OX)	-0001	-0001	21	-0001	Augmented qual. was satisfactorily completed June 1969. Since all changes were made prior to the augmented test,
284-0276	Propellant Isolation Valve (FU)	-0002	-0002	21	-0002	satisfactory completion of the augmented qual test verify that the valve meets all requirements (normally open valves)
284-0276	Propellant Isolation Valve (OX)	(CM RCS) -0005	-0001		-0005	-0005 has anti-surge flow deflector. Qualified by similarity to -0001 and by delta vibration test
284-0276	Propellant Isolation Valve (FU)	(CM RCS) -0006	-0002		-0006	-0006 has anti-surge flow deflector. Qualified by similarity to -0002 and by delta vibration test.
284-0276	Propellant Isolation Valve (OX)	-0007	-0001		-0007	-0007 is a normally closed valve Qualified by similarity to -0001
284-0276	Propellant Isolation Valve (FU)	-0008	-0002		-0008	-0008 is a normally closed valve Qualified by similarity to -0002

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
251-0005	Burst Disc Assembly, Oxygen	-0004	-0004	*	X	*Obsolete configuration
251-0005	Burst Disc Assembly, Fuel	-0014	-0014	*	X	*Obsolete configuration
251-0005	Replacement Kit, Ox.	-0025	-0025	*	X	*Obsolete configuration
251-0005	Replacement Kit, Fuel	-0035	-0035	0	-0035	*Obsolete configuration
251-0005	Burst Disc Assembly, Oxygen	-0005	-0004	*2	X	-0005 has a modified closure plug and an uncoated burst disc; qualified by similarity to -0004.
251-0005	Burst Disc Assembly, Fuel	-0015	-0014	1	-0015	-0015 has a modified closure plug; qualified by similarity to -0014
251-0005	Burst Disc Assembly, Oxygen	-0006	-0004	1	-0006	Flushing fluid changed from IPA to freon
251-0005	Replacement Kit, Ox.	-0065	-0025	1	-0065	Flushing fluid changed from IPA to freon

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
286-0039	Filter Propellant, Inline (OX)	-0001	-0001	0	-0001	
286-0039	Filter Propellant, Inline (FU)	-0011	-0011	0	-0011	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
ME144-0023	Oxygen test point coupling	-0011	-0010 became -0011	39	-0011	-0010 and -0011 are identical; -0010 denoted prequal status, -0010 became -0011 at completion of qual
ME144-0023	Fuel test point coupling	-0031	-0030 became -0031	9 (same detailed dwg as -0011)	-0031	-0030 and -0031 are identical; -0030 denoted prequal status; -0030 became -0031 at completion of qual
ME144-0023	Low pressure He test point coupling	-0051	-0070 became -0071	9 (same detailed dwg as -0011)	-0051	-0051 is similar to -0071 except for indexing; qualified by similarity
ME144-0023	Hi pressure He test point coupling	-0071	-0070 became -0071	9 (same detailed dwg as -0011)	-0071	-0070 and -0071 are identical; -0070 denoted prequal status, -0070 became -0071 at completion of qual
ME273-0010	Helium fill coupling	-0001	-0003 became -0001	11	-0001	-0003 and -0001 are identical; -0003 denoted prequal status, -0003 became -0001 at completion of qual
ME273-0011	Oxygen Vent coupling	-0001	-0003 became -0001	22	-0001	-0003 and -0001 are identical; -0003 denoted prequal status, -0003 became -0001 at completion of qual
ME273-0019	Oxygen fill coupling	-0001	ME273-0011-0003	Same dwg as ME273-0011-0001	-0001	-0001 is similar to ME273-0011-0001 except for indexing; qualified by similarity
ME273-0021	Fuel fill coupling	-0001	ME273-0011-0003	Same dwgs as ME273-0011-0001	-0001	-0001 is similar to ME273-0011-0001 except for indexing; qualified by similarity
ME273-0024	Fuel vent coupling	-0001	ME273-0011-0003	Same dwgs as ME273-0011-0001	-0001	-0001 is similar to ME273-0011-0001 except for indexing; qualified by similarity
ME363-0014	Valve house heater	-0004	-0001	3	-0004	Qualified by similarity to -0001. -0004 does not have an internal thermostat.
ME360-0003	Valve house thermostat	-0001	see rationale	0	-0001	Thermostat was not qualified as an individual component. Qualified by similarity to thermostat installed in ME-363-0014-0001 heater which was qualified as an assembly

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
ME271-0019	Flex hose	-0005	-0021	4	-0005	Qualified by similarity to qual unit, construction is identical to qual unit, overall length differs.
ME271-0019	Flex hose	-0011	-0021	Same dwg as -0005	-0011	Qualified by similarity to qual unit, construction is identical to qual unit, overall length differs.
ME271-0019	Flex hose	-0018	-0021	Same dwg as -0005	-0018	Qualified by similarity to qual unit, construction is identical to qual unit, overall length differs.
ME271-0019	Flex hose	-0023	-0021	Same dwg as -0005	-0023	Qualified by similarity to qual unit, construction is identical to qual unit, overall length differs.
ME271-0019	Flex hose	-0026	-0021	Same dwg as -0005	-0026	Qualified by similarity to qual unit, construction is identical to qual unit, overall length differs.
ME271-0019	Flex hose	-0032	-0021	Same dwg as -0005	-0032	Qualified by similarity to qual unit, construction is identical to qual unit, overall length differs.
ME271-0019	Flex hose	-0033	-0021	Same dwg as -0005	-0033	Qualified by similarity to qual unit, construction is identical to qual unit, overall length differs.
ME271-0019	Flex hose	-0034	-0021	Same dwg as -0005	-0034	Qualified by similarity to qual unit, construction is identical to qual unit, overall length differs.
ME271-0019	Flex hose	-0035	-0021	Same dwg as -0005	-0035	Qualified by similarity to qual unit, construction is identical to qual unit, overall length differs.
ME271-0019	Flex hose	-0036	-0021	Same dwg as -0005	-0036	Qualified by similarity to qual unit, construction is identical to qual unit, overall length differs.
ME271-0019	Flex hose	-0037	-0021	Same dwg as -0005	-0037	Qualified by similarity to qual unit, construction is identical to qual unit, overall length differs.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
ME273-0046	Dynatube fitting	-0007	-0001	3	-0007	Qualified by similarity to qual units sealing surface is identical to qual unit, tube length and bend angle differ
ME273-0046	Dynatube fitting	-0035	-0001	6	-0035	Qualified by similarity to qual units sealing surface is identical to qual unit, tube length and bend angle differ
ME273-0046	Dynatube fitting	-0036	-0002	7	-0036	Qualified by similarity to qual units sealing surface is identical to qual unit, tube length and bend angle differ
ME273-0046	Dynatube fitting	-0043	-0001	6	-0043	Qualified by similarity to qual units sealing surface is identical to qual unit, tube length and bend angle differ
ME273-0046	Dynatube fitting	-0044	-0002	6	-0044	Qualified by similarity to qual units sealing surface is identical to qual unit, tube length and bend angle differ
ME273-0046	Dynatube fitting	-0047	-0001	5	-0047	Qualified by similarity to qual units sealing surface is identical to qual unit, tube length and bend angle differ
ME273-0046	Dynatube fitting	-0049	-0001	5	-0049	Qualified by similarity to qual units sealing surface is identical to qual unit, tube length and bend angle differ
ME273-0046	Dynatube fitting	-0050	-0002	3	-0050	Qualified by similarity to qual units sealing surface is identical to qual unit, tube length and bend angle differ
ME273-0046	Dynatube fitting	-0051	-0001	2	-0051	Qualified by similarity to qual units sealing surface is identical to qual unit, tube length and bend angle differ
ME273-0046	Dynatube fitting	-0052	-0002	3	-0052	Qualified by similarity to qual units sealing surface is identical to qual unit, tube length and bend angle differ
ME273-0046	Dynatube fitting	-0053	-0001	same dwg as -0050	-0053	Qualified by similarity to qual units sealing surface is identical to qual unit, tube length and bend angle differ

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM DELTA
BETWEEN QUAL AND S/C 110 CONFIGURATION

ME #	COMPONENT NAME	DASH #	QUAL CONFIGURATION	# OF DWG CHG's (LETTER)	CSM 110 CONFIGURATION	RATIONALE
ME273-0049	Dynatube fitting	-0001	ME273-0046 0001	6	-0001	Qualified by similarity to qual unit; sealing surface is identical to qual unit, tube length and bend angle differ
ME273-0049	Dynatube fitting	-0002	ME273-0046 0002	Same dwg as -0001	-0002	Qualified by similarity to qual unit; sealing surface is identical to qual unit, tube length and bend angle differ
ME271-0050	Oxygen dump hose	-0001	See Rationale	0	-0001	Dump hose was not subjected to Apollo qual tests. Certified by analysis of results of other test programs.
ME271-0050	Oxygen dump hose	-0003	See Rationale	0	-0003	Dump hose was not subjected to Apollo qual tests. Certified by analysis of results of other test programs.
ME271-0050	Fuel dump hose	-0004	See Rationale	0	-0004	Dump hose was not subjected to Apollo qual tests. Certified by analysis of results of other test programs.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Helium Pres. Vessel	ME282-0002-0001	7-22-64	10-2-64				None
Helium Pres. Vessel	ME282-0051-0001	1-3-67	2-23-67				None

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
N_2H_4 Prop Tank (SM)	ME282-0004-0001	1-66	3-66	---	---		
	-0006			---	---	---	Reorientation of propellant outlet
N_2H_4 Prop Tank (CM)	ME282-0006-0001	5-65	8-65	---	---	---	
	-0006	---	---	---	---	---	Modified internal pad to permit rapid vent
MMH Prop Tank (CM)	ME282-0007-0001	5-65	7-65	---	---	---	
	-0006	---	---	---	---	---	Modified internal pad to permit rapid vent
MMH Prop Tank (SM)	ME282-0008-0001	4-65	5-65	---	---	---	
	-0006	---	---	---	---	---	Reorientation of the propellant outlet

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Helium Isolation Valve	ME284-0281-0001	4-10-66	10-12-66	6-16-69	9-19-69		None

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Relief valve, ox	ME284-0026-0002	11-5-64	1-4-65	7-18-69	9-30-69		
Relief valve, fuel	ME284-0026-0012	11-5-64	1-4-65	7-18-69	9-30-69		
Regulator	ME284-0022-0002	3/65	6/65	X	X		
Regulator	ME284-0022-0005	X	X	9/69	11/69		No test port between stages qualified by similarity to -0002
Check Valve, ox	See CM	X	X	X	X		
Check Valve, fuel	See CM	X	X	X	X		

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Helium Pressure Explosive Valve	ME284-0019-0002	1-5-66	4-18-66	8-20-69	9-26-69		
Helium interconnect explosive valve	ME284-0019-0004	1-5-66	4-18-66	X	X		Qualified by similarity to -0002
Helium bypass explosive valve	ME284-0019-0006	1-5-66	4-18-66	X	X		Qualified by similarity to -0002
Oxidizer dump explosive valve	ME284-0130-0002	12-11-65	1-26-66	X	X		
Fuel interconnect explosive valve	ME284-0130-0012	12-11-65	1-26-66	8-20-69	9-19-69		
Oxidizer interconnect explosive valve	ME284-0130-0014	12-11-65	1-26-66	X	X		Qualified by similarity to -0002
Relief valve, ox.	ME284-0062-0002	11-5-64	1-4-65	X	X		
Relief valve, fuel	ME284-0062-0012	11-5-64	1-4-65	X	X		
Check valve, ox	ME284-0024-0022	12-17-65	2-5-66	X	X		
Check valve, fuel	ME284-0024-0052	11-15-65	1-27-66	X	X		
Check valve, ox	ME284-0357-0001	Dev. Test 5-10-67	Dev.Test 7-12-67	4/69	10/69		Qualified by similarity to -0022 - added integral filters
Check valve, fuel	ME284-0357-0002	Dev. Test 5-10-67	Dev.Test 7-12-67	4/69	10/69		Qualified by similarity to -0052 - added integral filters
Burst Disc Assembly Ox	ME251-0005-0004	2-9-66	5-12-66	X	X		
Burst Disc Assembly Fuel	ME251-0005-0014	2-9-66	5-12-66	X	X		
Replacement Kit, Ox	ME251-0005-0025	2-9-66	5-12-66	X	X		
Replacement Kit, Fuel	ME251-0005-0035	2-9-66	5-12-66	X	X		
Burst Disc Assembly Oxygen	ME251-0005-0005	X	X	X	X		Modified closure plug uncoated burst disc qualified by similarity to -0004
Burst Disc Assembly Fuel	ME251-0005-0015	X	X	X	X		Modified closure plug qualified by similarity to -0014

COMMAND MODULE/ ...VICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Burst Disc. Assembly, Oxygen	ME2 ,1-0005-0006	X	X	X	X		Changed flushing fluid from IPA to freon
Replacement Kit, Oxygen	ME251-0005-0065	X	X	X	X		Changed flushing fluid from IPA to freon
Regulator	ME284-0021-0002	3/65	6/65	*	X		*Delta qual by similarity to SM Regulator ME284-0022-0005
Regulator	ME284-0021-0005	X	X	*	X		No test port between stages qualified by similarity to -0002

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Propellant Isolation Valve (Ox)	ME284-0276-0001	4-22-66	5-6-66	6-9-69	6-16-69		None
Propellant Isolation Valve (Fu)	ME284-0276-0002	4-22-66	5-6-66	6-9-69	6-16-69		None
Propellant Isolation Valve (Ox)	ME284-0276-0005	---	---		5-5-66		Anti-surge flow deflector
Propellant Isolation Valve (Fu)	ME284-0276-0006	---	---		5-5-66		Anti-surge flow deflector
Propellant Isolation Valve (Ox)	ME284-0276-0007	---	---	---	---		Wired for normally closed position
Propellant Isolation Valve (Fu)	ME284-0276-0008	---	---	---	---		

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Rocket Engine	ME901-0004-0201	8-16-65	12-31-65	10-8-66	11-9-66		
SM RCS	ME901-0004-0301			7-13-67	8-22-67		Added valve inlet strainer

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Rocket Engine	ME901-0067-0011	3-65	1-21-66				
CM RCS	ME901-0067-0012	3-65	1-21-66				
	ME901-0067-0013			2-2-67	2-4-67		Delaminated (precharred) liner
	ME901-0067-0014			6-1-67	6-30-67		Virgin liner
	ME901-0067-0015					7-69	Low specific impulse
	-0011 and -0014			3-68	3-68		200 sec. deorbit burn
Nozzle Extension	ME901-0189-0004	3-65	1-21-66				
	ME901-0189-0005	3-65	1-21-66				
	ME901-0189-0006	3-65	1-21-66				
	ME901-0189-0004			3-68	3-68		200 sec. deorbit burn
"O" ring	ME262-0002-0001	3-65	1-21-66				
	ME262-0002-0002	3-65	1-21-66				
	ME262-0002-0002			3-68	3-68		200 sec. deorbit burn
Screw-self locking	ME112-0004-0002	3-65	1-21-66				
	ME112-0004-0003	3-65	1-21-66				
Screw-Pitch and Yaw NE	V16-417018-3	3-65	1-21-66				
Screw-Roll N.E.	V16-417018-5	3-65	1-21-66				

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Filter, Propellant Inline (Ox)	ME286-0039-0001	4-6-66	4-22-66	None	None		None
Filter, Propellant Inline (FU)	ME286-0039-0011	4-6-66	4-22-66	None	None		None

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Ox test point cplg	ME144-0023-0011	4-22-64	9-9-64	None	None		None
Fuel test point cplg	ME144-0023-0031	4-22-64	9-9-64	None	None		None
Lo press helium test point coupling	ME144-0023-0051	---	---	---	---		None
Hi press helium test point coupling	ME144-0023-0071	4-22-64	9-9-64	None	None		None
He fill cplg	ME273-0010-0001	6-30-64	10-30-64	None	None		None
Ox Vent cplg	ME273-0011-0001	6-22-64	9-8-64	None	None		None
Ox Fill cplg	ME273-0019-0001	---	---	None	None		None
Fuel Fill Cplg	ME273-0021-0001	---	---	None	None		None
Fuel Vent Cplg	ME273-0024-0001	---	---	None	None		None
Flex Hose	ME271-0019-0021	10-29-64	12-4-64	None	None		(-0021 is qual unit only; None not installed on S/C)
Flex Hose	ME271-0019-0005	10-29-64	12-4-64	None	None		None
Flex Hose	ME271-0019-0011	10-29-64	12-4-64	None	None		None
Flex Hose	ME271-0019-0018	10-29-64	12-4-64	None	None		None
Flex Hose	ME271-0019-0023	10-29-64	12-4-64	None	None		None
Flex Hose	ME271-0019-0026	10-29-64	12-4-64	None	None		None
Flex Hose	ME271-0019-0032	10-29-64	12-4-64	None	None		None
Flex Hose	ME271-0019-0033	10-29-64	12-4-64	None	None		None
Flex Hose	ME271-0019-0034	10-29-64	12-4-64	None	None		None

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Dynatube Fitting	ME273-0046-0059	---	---	None	None		None
Dynatube Fitting	ME273-0046-0060	---	---	None	None		None
Dynatube Fitting	ME273-0046-0061	---	---	None	None		None
Dynatube Fitting	ME273-0046-0062	---	---	None	None		None
Dynatube Fitting	ME273-0046-0063	---	---	None	None		None
Oxygen Dump Hose	ME271-0050-0001	certified	by analysis	---	---		None
Oxygen Dump Hose	ME271-0050-0003	certified	by analysis	---	---		None
Oxygen Dump Hose	ME271-0050-0004	certified	by analysis	---	---		None

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Ox test point cplg	ME144-0023-0011	4-22-64	9-9-64	None	None		None
Fuel Test point cplg	ME144-0023-0031	4-22-64	9-9-64	None	None		None
Lo press helium test point coupling	ME144-0023-0051	---	---	---	---		None
Hi press helium test point coupling	ME144-0023-0071	4-22-64	9-9-64	None	None		None
He Fill coupling	ME273-0010-0001	6-30-64	10-30-64	None	None		None
Ox vent coupling	ME273-0011-0001	6-22-64	9-8-64	None	None		None
Ox fill coupling	ME273-0019-0001	6-22-64	9-8-64	None	None		None
Fuel Fill coupling	ME273-0021-0001	6-22-64	9-8-64	None	None		None
Fuel Vent Coupling	ME273-0024-0001	6-22-64	9-8-64	None	None		None
Dynatube fitting	ME273-0046-0001	7-31-64	8-13-64	None	None		None (-0001 is qual unit only; not installed on S/C)
Dynatube fitting	ME273-0046-0002	7-31-64	8-13-64	None	None		None (-0002 is qual unit only; not installed on S/C)
Dynatube fitting	ME273-0046-0047	7-31-64	8-13-64	None	None		None
Dynatube fitting	ME273-0046-0049	7-31-64	8-13-64	None	None		None
Dynatube fitting	ME273-0046-0051	7-31-64	8-13-64	None	None		None
Dynatube fitting	ME273-0049-0001	7-31-64	8-13-64	None	None		None
Dynatube fitting	ME273-0049-0002	7-31-64	8-13-64	None	None		None
Valve House heater	ME363-0014-0001	4-20-66	5-14-66	None	None		None
Valve House heater	ME363-0014-0004	4-20-66	5-14-66	None	None		None

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM
CLASS I CHANGES SINCE QUAL

COMPONENT NAME	COMPONENT NUMBER	QUAL		DELTA QUAL		CLASS I CHANGES SINCE QUAL	
		START	COMPLETION	START	COMPLETION	DATE	CHANGE
Valve House Thermostat	ME360-0003-0001	*	*	None	None		None (*Qualified by similarity to thermostat in ME363-0014-0001 heater)

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CLASS II CHANGES SINCE QUAL

MS #	COMPONENT NAME	COMPONENT DETAIL	CLASS II CHANGES
282-0051	Helium Tank	---	No changes
282-0002	Helium Tank	---	No changes

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CLASS II CHANGES SINCE QUAL

ME #	COMPONENT NAME	COMPONENT DETAIL	CLASS II CHANGES
282-0004 (SM) 282-0008	N_2O_4 Prop. Tank MM Prop. Tank	Flange	. Subject weld joints to proof pressure
		Assembly	. Correct weld symbol
		Diffuser	. Revision of identification plate
		Assembly	. Remove redundant cleaning
			. Methyl alcohol deletion
282-0006 (CM)	N_2O_4 Prop Tank	Assembly	. Reduced X-ray requirements
282-0007	MMH prop. tank	Diffuser Bleed Tube	. Acceptance procedure number changed.
			. Revised to facilitate weld inspection
			. Clarification of cleaning
			. Methyl alcohol deletion

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CLASS II CHANGES SINCE QUAL

ME #	COMPONENT NAME	COMPONENT DETAIL	CLASS II CHANGES
284-0026 and 234-0062	Relief Valves	Poppet Assembly	Added ref. dim.
		Bleed Valve Poppet	Corrected drafting error
		Retainer	Added note "Thread trace allowable"
		Adjusting Pad	Added vent holes to allow drainage of cleaning fluids
284-0024 and 284-0357	Check Valves	Poppet	Changed radius on poppet from .004 ± .001 to .005 ± 002 R
		Guide	Added 16 finish to bore
		Body	Added - 4 and -5 to drawing
284-0021 and 284-0022	Regulator	End Plate	Redraw for clarity
		Bellows capsule	Added traceability note
		Bellows assembly	Added note defining free length

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CLASS II CHANGES SINCE QUAL

ME #	COMPONENT NAME	COMPONENT DETAIL	CLASS II CHANGES
284-0276	Propellant Isolation Valve	Seat	. Add $\sqrt[32]{}$ and eliminate axial marks
		Bellows capsule	. Revised note number 8 revising serial number marking requirements
			. Identify bellows prior to welding to flange.
		Magnet	. Added degreasing callout
		Actuator	. Added flatness, finish and parallelism requirement.
284-0281	Helium Isolation Valve	Solenoid Assembly	. Added dry GN_2 purge of electrical terminals just prior to potting
			. Changed routing of diode leads.
			. Added max height of welded plugs.
		Cover	. Changed identification marking
		Header Assy.	. Add two additional potting holes
			. Added tin plating on terminals

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CLASS II CHANGES SINCE QUAL

ME #	COMPONENT NAME	COMPONENT DETAIL	CLASS II CHANGES
144-0023	Test point cplg	Cap, pressure sealing	Dimensional change: 552-.564 hex across flats was .550-570
		Plug, pressure cap	Add: CRES 303 to Material Block - NAA Engineering Request
		Washer, Non-metallic	Change Note Number 1: Kynar No. 18 to Kynar Grade 400 - change inline with suppliers redesignation of Kynar.
		Coupling half, self sealing nipple, assembly of	Add: Machining Notes 13 and 14 - Specifies surface conditions after welding operation - to control mounting flange flatness and tube squareness to flange
		Tube, nipple	Replace .311/.306dia. to .3219/.3216dia., chamber with .008/.005R to reduce interference on pressure fitting to mating part (nipple bodies)
		Body Nipple	Change electrolize finish to chrome plate finish per Lsi Spec. S-196 and remove "Engine Approved Procurement Source: The Electrolizing Corporation, Cleveland Ohio" High rejection rate from electrilizing corporation necessitates a change in process from electrolize to chrome plate.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CLASS II CHANGES SINCE QUAL

ME #	COMPONENT NAME	COMPONENT DETAIL	CLASS II CHANGES
ME273-0010	Helium fill cplg	Seal Retainer	Anodize specification callout was in error (MIL-S-8625 was changed to MIL-A-8625 type II clear seal)
		Pressure cap	Corrected material callout (7075-6 Al Aly was changed to 7075-T6 Al Aly)
			Clarified electro-etch callout
ME271-0019	Flex hose	Tubular End	Changed tube O.D. to agree with SCD (.375 - .378 dia. was changed to .376-.379 dia.)

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CLASS II CHANGES SINCE QUAL

ME #	COMPONENT NAME	COMPONENT DETAIL	CLASS II CHANGES
273-0011	Propellant coupling	Coupling Assy. Class I and II	Changed reference dim. to agree with dimensions on sheet 2 which were changed on the "J" revision.
	6760	Coupling Assy. Class I and II	Identification tag added to A/B
	23090	Body-Class I Coupling	Drafting error was corrected
	23119	Outlet coupling	Etched ring was removed per M.E. Change
		Seal poppet 23132	Kynar callout moved from material block to note 2 which also added carter spec. no. 142 for Kynar
		Seal poppet 23132	Carter Spec. 142A was 142: Carter spec changed designation from Kynar 18 to Kynar 400 in line with suppliers redesignation of Kynar. No change in properties or processing was involved.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CLASS II CHANGES SINCE QUAL

ME #	COMPONENT NAME	COMPONENT DETAIL	CLASS II CHANGES
273-0046	Dynatube fitting (R44434-6)	Elbow	Dimension: Max across flats .439 was .438 (SCD rev. M)
		Elbow	Dim: Tube O.D. .378 was .379 (SCD rev. M)
		Elbow	Add info: 63 finish and note "Tolerance applys for .910 min. only" to tube O.D. 378 (SCD Rev. M)
		Elbow and Nut Assembly	Add dim. and finish info: Add radius .12 min.; add dim. .500 (distance from surface Y to point of radius .12 Min.); add finishes 32 and 63 to threads and radius (SCD rev. N)
	(R44461)	Elbow and Nut Assembly	Add dim. Tolerance change and effectivity: Dim. A 1.365 $\pm{}^{.005}_{-.015}$ was 1.365 $\pm{}^{+000}_{-010}$; add "Dimension and tolerance apply only before the acceptance proof pressure test (SCD rev. P)

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CLASS II CHANGES SINCE QUAL

MS #	COMPONENT NAME	COMPONENT DETAIL	CLASS II CHANGES
901-0004-0201 -0301	Rocket Engine - Service Module RCS	Injector Head Assembly 228174	G Change - Added instructions allowing thermal cycling to help eliminate interface Leakage following shrink fit assembly. Purpose was to reduce rejection rate. K change - Changed lubricant and applied tighter application controls for preigniter tube assembly into injector. Purpose was to eliminate a possible source of contamination.
901-0004-0201 -0301	Rocket Engine - SM RCS	Seal face combustion chamber 227949	D change - Added instructions to restrain seal during flatness check because the seal is insufficiently rigid to maintain flatness during storage.
901-0004-0201 -0301	Rocket Engine - SM RCS	Body-Solenoid Valve 228506	B change - Deleted "Break sharp edges .005 - .015". Added "Break sharp edges .015 max." Purpose is to ease manufacturing. C change - Changed surface finish from 32 to 125 on non-critical surfaces. G change - Changed material specification from QQ-5-763 to Marquardt MMS2211. MMC Specification more definitive and includes requirements not included in QQ specification. D change - Corrected thread callout.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CLASS II CHANGES SINCE QUAL

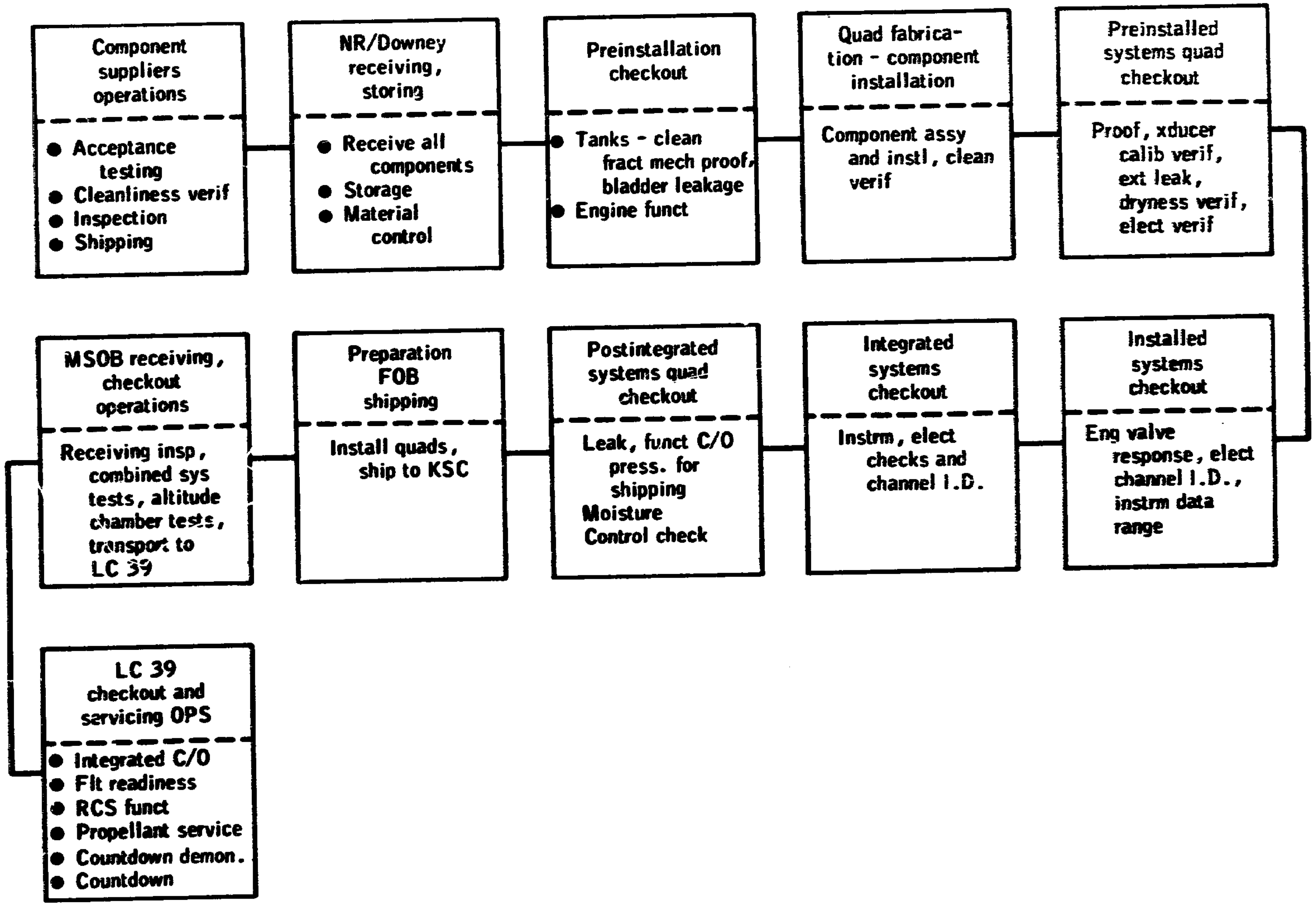
ME #	COMPONENT NAME	COMPONENT DETAIL	CLASS II CHANGES
901-0067-0014	Rocket Engine - CM RCS	Rocket Engine- (106026)	Deletion of the valve inlet housing weld leak test because it was added to the post hot fire acceptance test requirements.
901-0067-0011	Rocket Engine- CM RCS	Rocket Engine- (106012)	Added reference callout (valve inlet housing filter) for additional information only.
901-0067-0011 -0012 -0013 -0014 -0015	Injector - Thrust chamber CM RCS Engine	209440	Added a 13° x .050 chamber to the O.D. to permit easier assembly with the 206906 shell.
901-0067-0011 -0012 -0013 -0014 -0015	Core- Propellant Valve- CM RCS Engine	408916	Increased the length of the core to assure that adequate material exists for grinding operations when adjusting the length of valve armature stroke.

SECTION 6

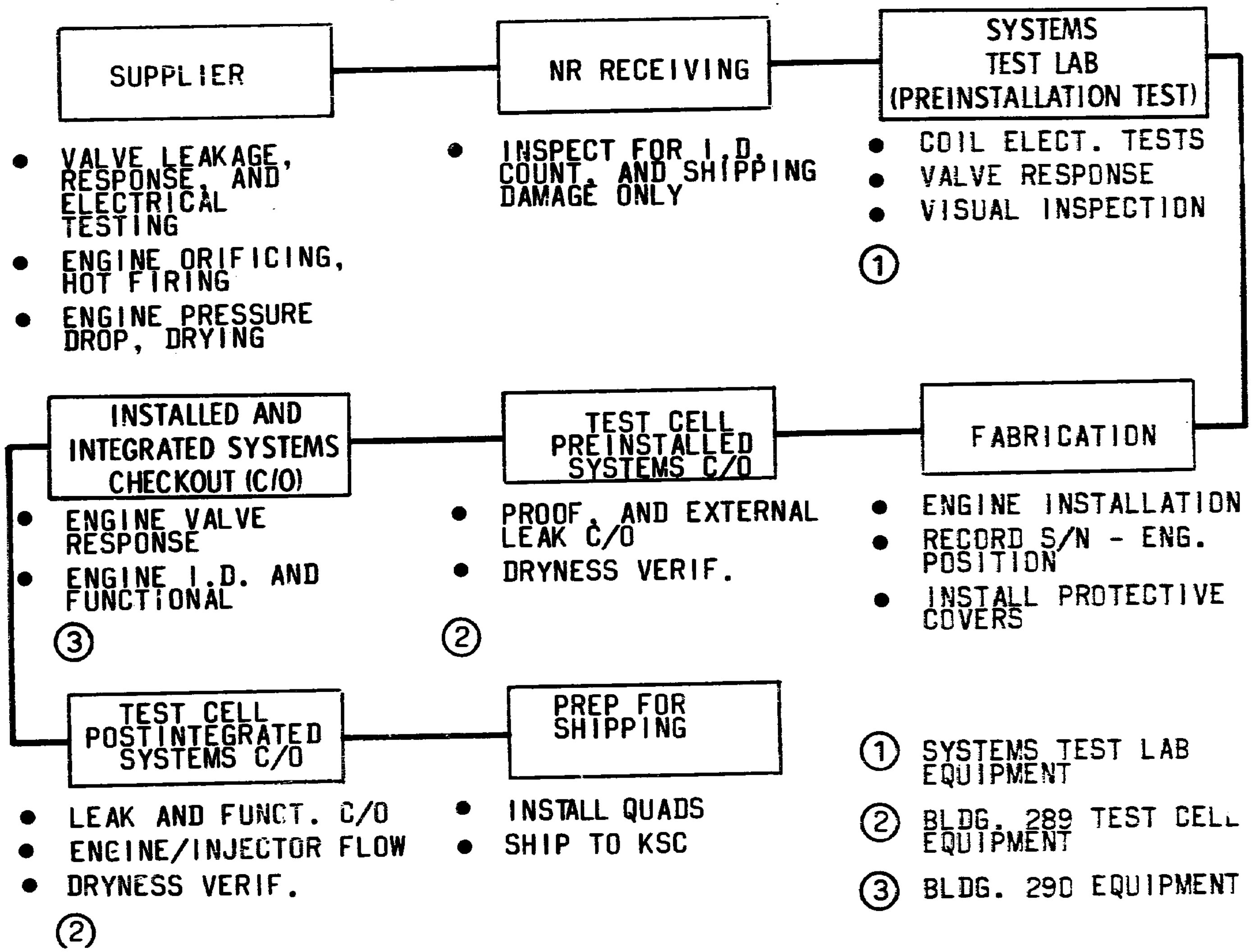
COMPONENT FLOW DIAGRAMS

Section 6 consists of flow diagrams, graphs, and tabulations for the assessment of components and the manufacturing and assembly process of the Service and Command Module Reaction Control Subsystems. There is no written text.

SM RCS QUAD FLOW DIAGRAM



SERVICE MODULE REACTION CONTROL SUBSYSTEM
ENGINE FLOW AT DOWNEY



SM RCS ENGINE - DOWNEY FLOW DETAIL

SUPPLIER

- ACCEPTANCE TESTS
  - VALVE SEAT LEAKAGE
  - VALVE ELEC. RESISTANCE AND DIELECTRIC
  - VALVE RESPONSE
  - ENGINE ORIFICING
  - INJECTOR DISTRIBUTION
  - CLEANLINESS RINSE TEST (H_2O)
  - ENGINE HOT FIRE
  - ENGINE PRESSURE DROP
  - VALVE ELEC. RESISTANCE
  - VALVE RESPONSE
  - VALVE SEAT LEAKAGE
  - FINAL VACUUM OVEN DRY
- PREP. FOR SHIPMENT
  - SEAL IN NYLON BAG WITH DESICCANT AND MOISTURE INDICATOR
  - THREADED VALVE INLET CRES CAPS
  - STYRENE NOZZLE COVER WITH ABRASION PROTECTION
  - PACKAGE IN SHOCK PROTECTED CAN (POLYURETHANE PACKING)

SYSTEMS TEST LAB

- COIL RESISTANCE TEST
- COIL INSULATION RESISTANCE TEST
- VALVE RESPONSE TEST
- INSTRUMENTATION INSTALLED
- VISUAL INSPECTION

FABRICATION

- INSTALL ON MOUNT AND SUBSEQUENTLY ON QUAD. USE MB0140-005 LUBRICANT
- CONNECT ENGINE WIRING LEADS
- RECORD S/N RELATED TO POSITION
- CLEANLINESS VERIFICATION NOT REQUIRED ON ENGINE VALVE CLOSEOUT JOINTS
- ENGINE COMBUSTION CHAMBER AND NOZZLE HANDLED ONLY WITH NYLON GLOVED HANDS

SERVICE MODULE
REACTION CONTROL SUBSYSTEM
ENGINE CHECKOUT MATRIX

TEST DESCRIPTION	TEST CELL PREINSTALLED SYSTEMS CHECKOUT	INSTALLED AND INTEGRATED SYSTEMS CHECKOUT	TEST CELL POSTINTEGRATED SYSTEMS CHECKOUT
PROOF PRESSURE	(SC 011 AND SUBS)		
MECHANICAL JOINT EXT LEAKAGE	(SC 011 AND SUBS)		
ENGINE VALVE LEAKAGE	(SC 011 THRU 106)		(SC 017 AND SUBS)
ENGINE FUNCTIONAL (OPEN-CLOSE CYCLE)	(SC 011 THRU 014, 103 THRU 106)	X	(SC 017 AND SUBS)
ENGINE IDENTIFICATION (ELECT)		X	
ENGINE VALVE RESPONSE	(SC 011 THRU 014)	X	
MINIMUM IMPULSE (SM AUTOMATIC VALVE EXCITATION ON TIME)		X	
EMI SUPPRESSION		X	
ENGINE GAS FLOW			(SC 017 AND SUBS)
ENGINE INJECTOR ORIFICE FLOW	(SC 103 THRU 106)		(SC 103 AND SUBS)
DRYNESS VERIFICATION	(SC 108 AND SUBS)		(SC 103 AND SUBS)
PAD PRESSURE		X	50 PSIG FOR SHIP'G (SC 103 AND SUBS)
ENGINE ID AND DAMAGE INSPECTION	X		X
TEST EQUIPMENT INTERFACE	BLDG 1 AND BLDG 289 TEST EQUIPMENT	BLDG 290 TEST EQUIPMENT	BLDG 289 TEST EQUIPMENT

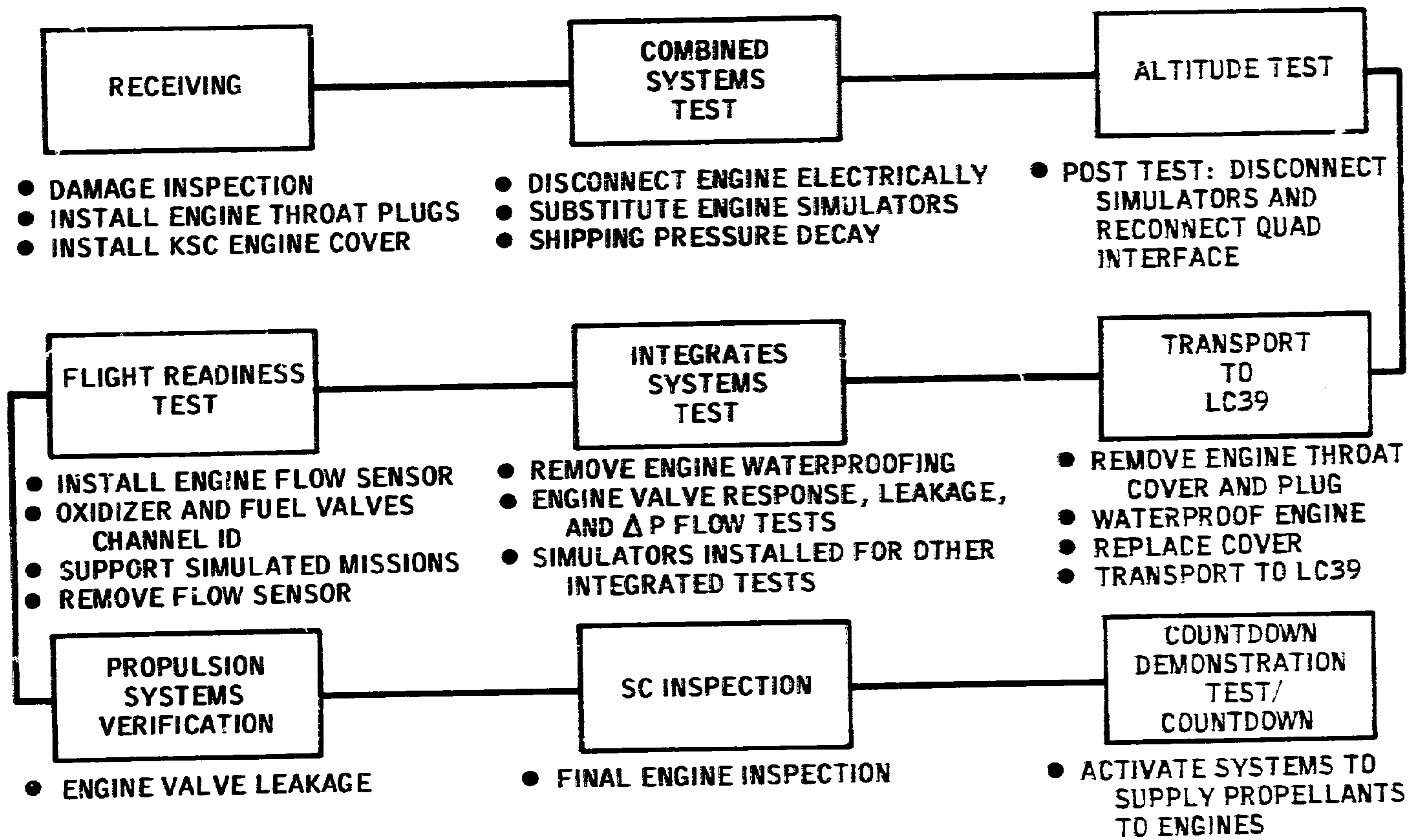
SERVICE MODULE REACTION CONTROL SUBSYSTEM

ENGINE INSTALLED AND INTEGRATED SYSTEMS CHECKOUT

TEST DESCRIPTION	TEST PARAMETERS	ACCEPTANCE CRITERIA
ENGINE FUNCTIONAL	PRESSURE 15 ± 10 PSIA INSTALLED PRESSURE 30 ± 5 PSIG INTEGRATED	ENGINE IDENTIFICATION VERIFIED BY SPACECRAFT COMMANDS VERSUS ENGINE GAS FLOW
ENGINE IDENTIFICATION (ELECTRICAL)	PRESSURE 15 ± 10 PSIG VOLTAGE 3 ± .5 VDC	SPACECRAFT COMMANDS VERSUS ENGINE VALVE RESPONSE AS RECORDED ON GSE
ENGINE VALVE RESPONSE AUTOMATIC VALVES	PRESSURE 15 ± 10 PSIG VOLTAGE 28 ± .5 VDC	FUEL VALVE OPEN - 4.5 ± 1.5 MS CLOSE - 8.5 MS MAXIMUM OXID VALVE OPEN - 6.0 ± 1.5 MS CLOSE - 8.5 MS MAXIMUM
MINIMUM IMPULSE	PRESSURE 15 ± 10 PSIG VOLTAGE 28 ± .5 VDC	EXCITATION ON TIME = 15 ± 2 MS
ENGINE VALVE RESPONSE DIRECT VALVES	PRESSURE 15 ± 10 PSIG VOLTAGE 28 ± .5 VDC	FUEL VALVE OPEN - 13 ± 3 MS CLOSE - VERIFY VALVE CLOSURE OXID VALVE OPEN - 25 ± 4 MS CLOSE - VERIFY VALVE CLOSURE
EMI SUPPRESSION	PRESSURE 15 ± 10 PSIG VOLTAGE 28 ± .5 VDC	(INSTALLED) VOLTAGE LIMIT IMMEDIATELY FOLLOWING CLOSING COMMANDS -20 + 4 VDC (INTEGRATED) NO FLIGHT SYSTEM ANOMALIES
PAD PRESSURE	- - -	13 TO 17 PSIG

SERVICE MODULE REACTION CONTROL SUBSYSTEM

ENGINE FLOW AT KSC



SM ENGINE - KSC OPERATIONS

RECEIVING INSPECTION K3084

INSPECTION
- REMOVE SHIPPING COVER
- VERIFY NOZZLE FREE OF DINGS, SCRATCHES, ABRASION OR OTHER DAMAGE
- VERIFY ENGINE CHAMBER FREE OF VISIBLE CONTAMINANTS

INSTALL THROAT PLUG
INSTALL KSC ENGINE COVER

COMBINED SYSTEMS TEST K0070

- DISCONNECT ENGINE ELECTRICALLY AT QUAD INTERFACE. CONNECT ENGINE SIMULATOR TO SUPPORT K0070, K0048, K0034
- MONITOR ENGINE MANIFOLD PRESSURES FOR EVIDENCE OF SHIPPING PRESS. DECAY

ALTITUDE TEST K0034

POST TEST
- DISCONNECT ENGINE SIMULATOR
- RECONNECT QUAD INTERFACE

SC TRANSPORTATION K3117

REMOVE ENGINE COVER AND THROAT PLUG. WEATHERPROOF ENGINE FOR MOVES AND REPLACE COVER

LC39

INTEGRATED SYSTEMS TEST K0005

- REMOVE ENGINE WEATHERPROOFING
- PRESS. ENGINE MANIFOLDS TO 10 PSI
- PERFORM ENGINE VALVE RESPONSE TESTS (NORM/DIR)
- DISCONNECT ENGINE AND CONNECT SIMULATOR FOR K0005

- POST SIM. MISSION DISCONNECT SIMULATOR AND RECONNECT ENGINE FOR FLIGHT
- PRESS. ENG. MANIFOLD TO 100 PSI
- PERFORM ENG. VALVES LEAK CHECK

- DECREASE ENGINE MANIFOLD TO 200 PSI
- PERFORM ENG. ΔP FLOW
- DECREASE MANIFOLD TO 10 PSIG
- REPLACE THROAT PLUG AND KSC COVER

FLIGHT READINESS TEST K0028

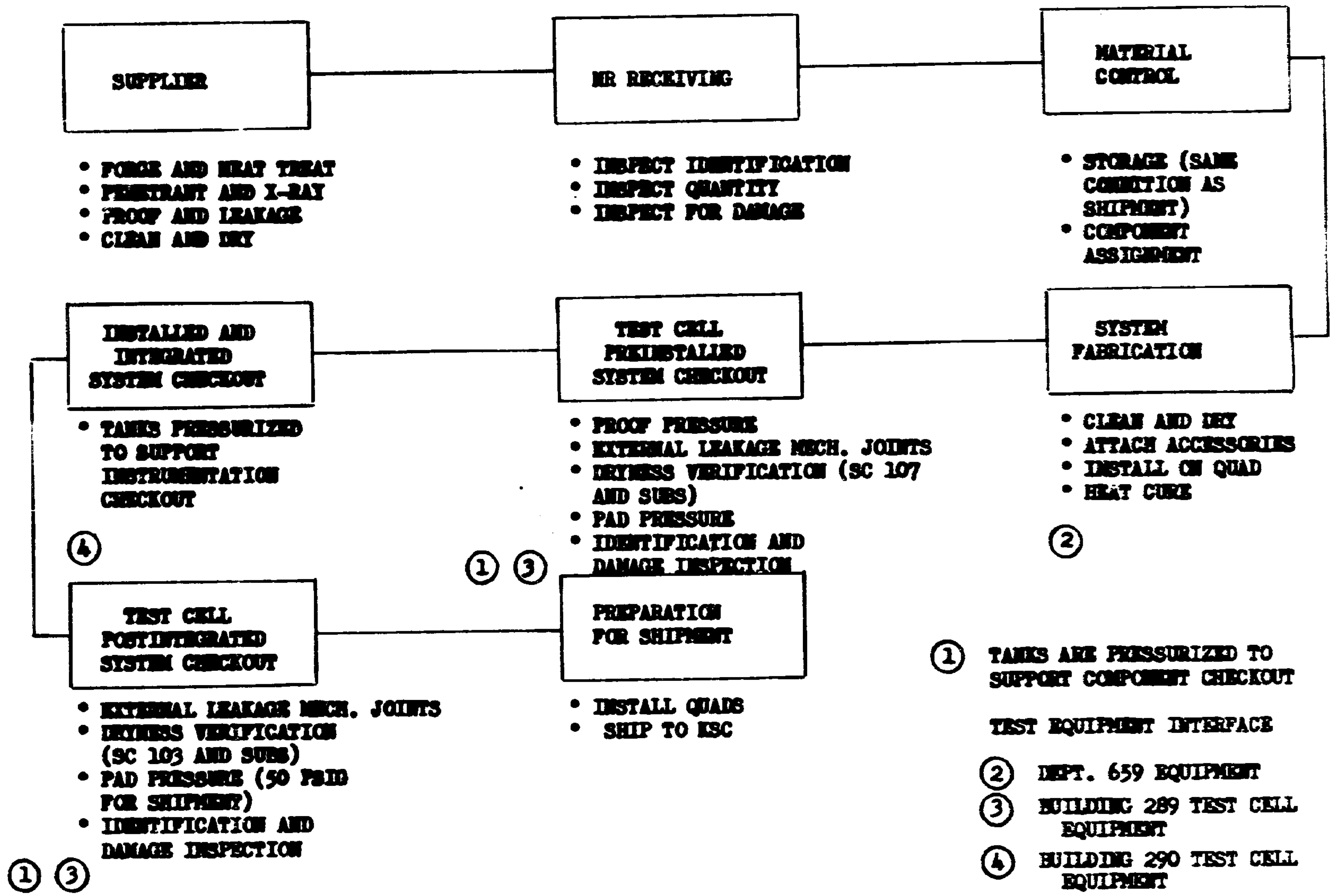
- INSTALL ENGINE FLOW SENSOR
- PRESS ENG. MANIFOLD TO 40 PSIG
- PERFORM ENG. NORMAL AND DIRECT I/D TEST (OXID & FUEL VALVES)
- SUPPORT SIM. MISSIONS

- DEPRESS MANIFOLD TO 10 PSI
- REMOVE FLOW SENSOR

SM ENGINE - KSC OPERATIONS (CONT.)

PROPULSION SYSTEMS VERIFICATION K0052	S/C INSPECTION K3211	CDDT/ COUNTDOWN K0007
. PRESS ENGINE MANIFOLD TO 100 PSI . PERFORM ENGINE LEAK CHECK . DEPRESS ENGINE MANIFOLD TO 10 PSI	. REMOVE ENGINE COVER AND THROAT PLUG . PERFORM FINAL ENGINE INSPECTION (REF. K3084) . REPLACE THROAT PLUG AND COVER	. REMOVE ENGINE COVER AND THROAT PLUG FOR FLIGHT . ACTIVATE SM PROPELLANT SYSTEMS TO SUPPLY OXID AND FUEL TO ENGINE VALVES

SM RCS HELIUM VESSEL FLOW CHART



SM RCS HELIUM VESSEL

SUPPLIER:

ACCEPTANCE TESTS

- FORGING
  - FORGING ACCEPTANCE
  - HEAT TREAT
- VESSEL
  - FLUORESCENT PENETRANT
  - RADIOGRAPHIC INSPECTION
  - PROOF AND LEAKAGE (5,985 PSIG) HYDROSTATIC
  - CLEANED (FREON TF)
  - DRIED (GN_2)
- PACKAGING FOR SHIPMENT:

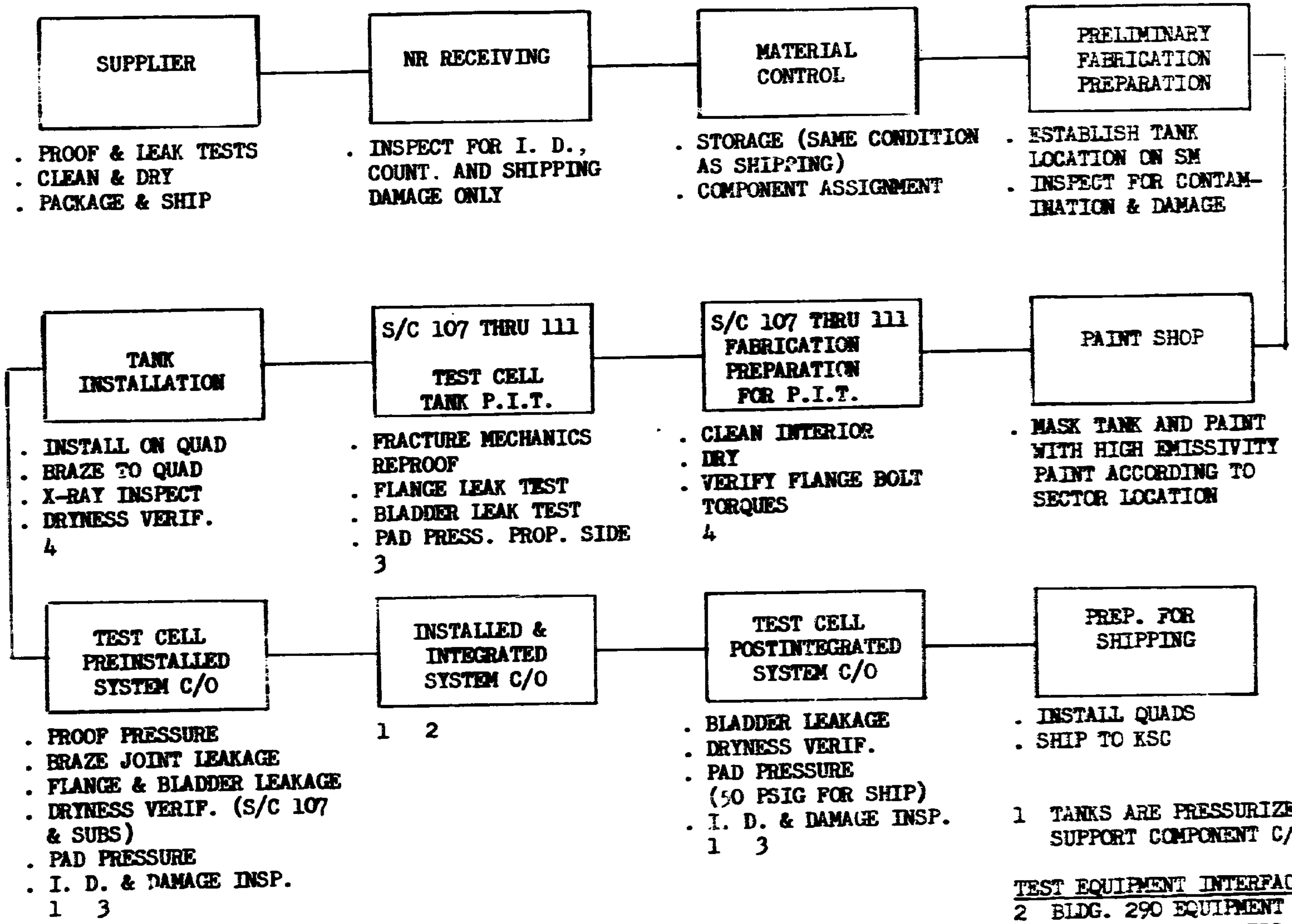
  INSTALL CAPS ON OUTLET BOSSES, DOUBLE BAG IN NYLON C BAGS, PACKAGE WITH SHOCK PROTECTION

SM RCS HELIUM VESSEL

SUBSYSTEM FABRICATION:

- VISUAL INSPECTION FOR DAMAGE
- CLEANLINESS VERIFICATION
- DRYING (GN_2 PURGE AND VACUUM OVEN
  170° TO 180°F. 25 IN HG VACUUM)
- INSTALL OUTLET FITTING
- REIDENTIFY (INK STAMP)
- INSTALL ON RCS
- INDUCTION BRAZE OUTLET FITTING (ARGON PURGE)
- CLEAN LOCAL AREA FOR BONDING
- BOND TRANSDUCER
- 200°F MAXIMUM TWO-HOUR CURE

S M R C S P R O P E L L A N T T A N K F L O W C H A R T



1 TANKS ARE PRESSURIZED TO SUPPORT COMPONENT C/O..

<u>TEST EQUIPMENT INTERFACE</u>
2 BLDG. 290 EQUIPMENT
3 BLDG. 289 TEST CELL EQUIPMENT
4 D/559 EQUIPMENT

SM RCS PROPELLANT TANK

SUPPLIER:

ACCEPTANCE TESTS

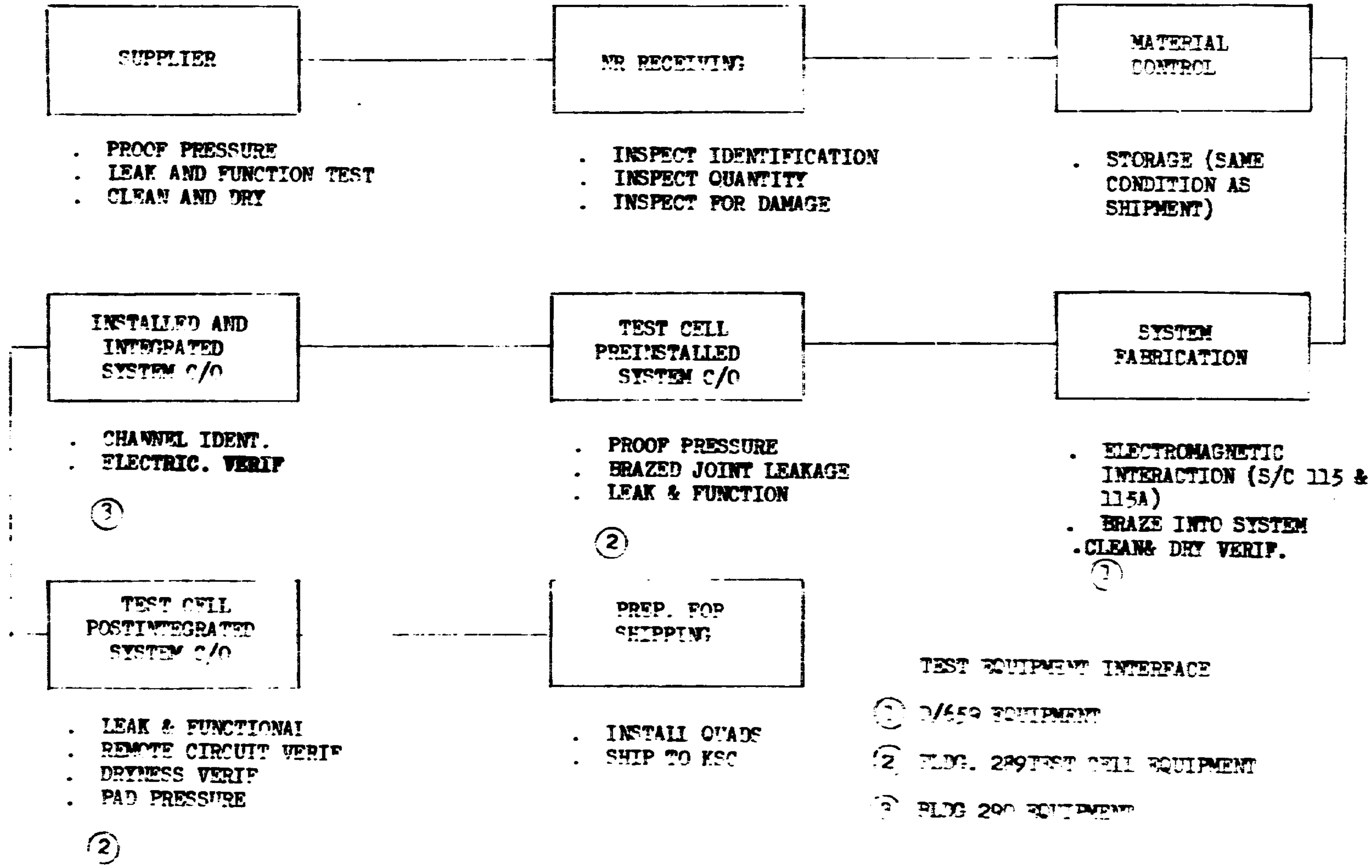
- Component test and precleaning
- Shell proof pressure (Hydrostatic)
- Bladder assembly and leak test
- Bladder installation in shell
- Internal rinse (Freon TF) on liquid side
- Internal drying (GN_2 80° to 90°F)

PREPARE FOR SHIPMENT

- Tube stems capped
- Bladder pressurized with GN_2 to 2 to 3 PSIG
- Tank double bagged with 2 mil nylon "C" bags and packaged in shock protected container.

SM RCS HELIUM ISOLATION

VALVE FLOW CHART



HELIUM ISOLATION VALVE

SUPPLIER

- ACCEPTANCE TEST
- EXAMINATION OF PRODUCT
- PROOF PRESSURE
- LEAKAGE
- ELECT. CHARACTERISTICS
- PRESSURE DROP
- FUNCTIONAL TEST
- CLEANLINESS VERIFICATION (FREON FLUSH, VACUUM OVEN DRY)
- PREPARE FOR SHIPPING
    - INNER BAG-NYLON
    - OUTER BAG-POLYETHYLENE
    - PACKAGE WITH A GN_2 BLANKET

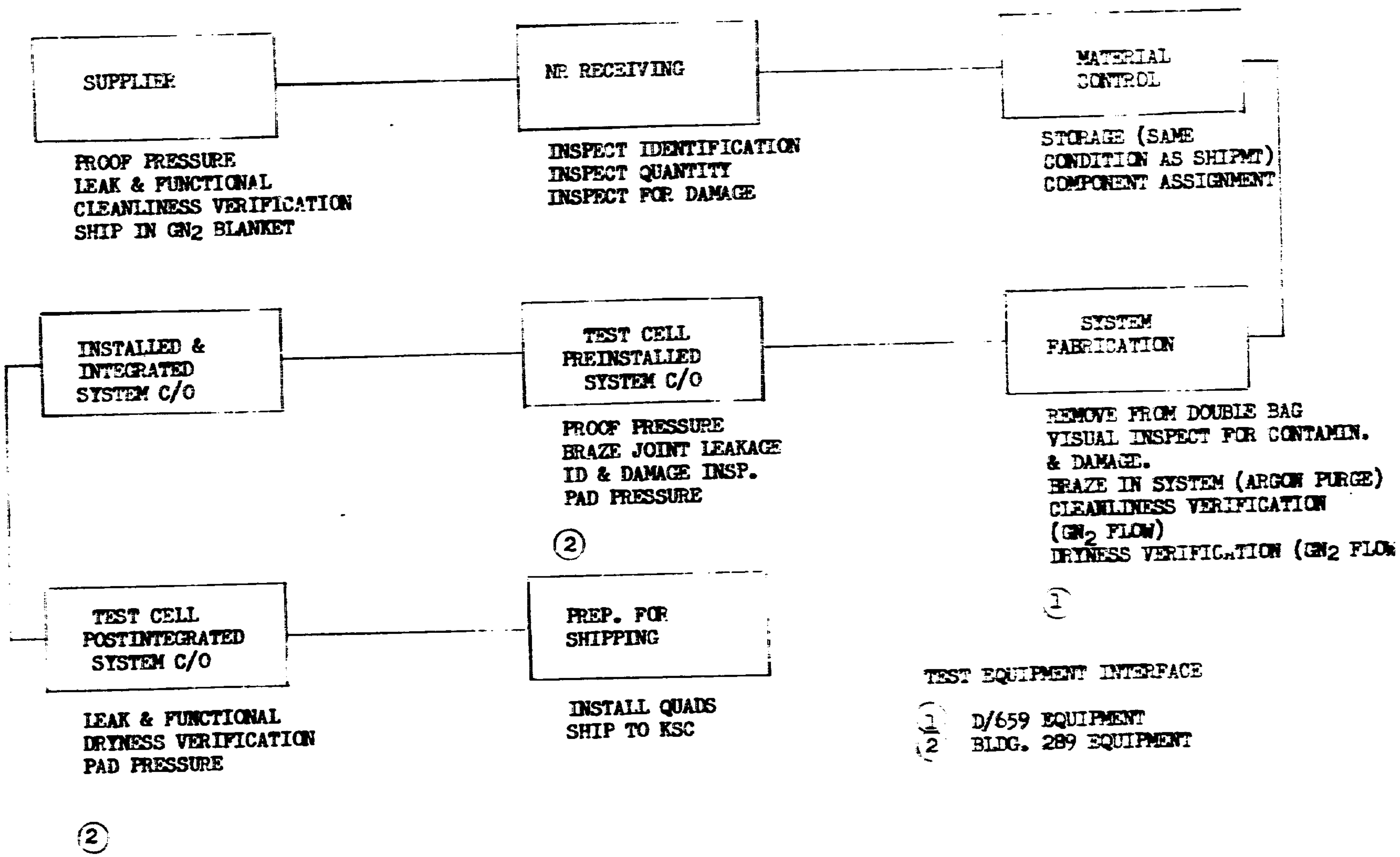
HELIUM ISOLATION VALVE
SYSTEM FABRICATION

- REMOVE FROM DOUBLE BAG
- VISUAL INSPECT FOR CONTAMINATION AND DAMAGE
- ELECTROMEGNETIC INTERACTION TEST (S/C 115 AND 115A)
- BRAZE IN SYSTEM (ARGON PURGE)
- CLEANLINESS VERIFICATION (GN_2 FLOW)
- DRYNESS VERIFICATION (GN_2 FLOW)

HELIUM ISOLATION VALVE

	HELIUM PANEL PREINSTALLED SYSTEM C/O	TEST CELL PREINSTALLED SYSTEM C/O	TEST CELL POSTINTEGRATED SYSTEM C/O
. PROOF PRESSURE	x S/C 009 only	x S/C 011 and subs	
. BRAZE JOINT LEAKAGE	x S/C 009 only	x S/C 011 and subs	
. FUNCTIONAL	x S/C 009 only	x S/C 011 and subs	x S/C 017 and subs
. SEAT LEAKAGE	x S/C 009 only	x S/C 011 thru 106	x S/C 017 and subs
. REMOTE CIRCUIT VERIFICATION		x S/C 108 and subs	x S/C 108 and subs
. DRYNESS VERIFICATION		x S/C 107 and subs	x S/C 101 and subs
. PAD PRESSURE		x S/C 011 and subs	x 50 psig for ship
. IDENTIFICATION AND DAMAGE INSPECTION	x S/C 009 only	x S/C 011 and subs	
. TEST EQUIPMENT INTERFACE	Bldg 289 Test Cell	Bldg 289 Test Cell	Bldg 289 Test Cell

SM RCS HELIUM PRESSURE REGULATOR FLOW CHART



S M R C S H E L I U M P R E S S U R E R E G U L A T O R

SUPPLIER:

- ACCEPTANCE TESTS
  - EXAMINATION OF PRODUCT
  - PROOF PRESSURE AND EXTERNAL LEAKAGE
  - INTERNAL LEAKAGE
  - FUNCTIONAL LEAKAGE
  - BLOW DOWN
  - CLEANLINESS TEST (GN_2 PURGE)

PACKAGING:

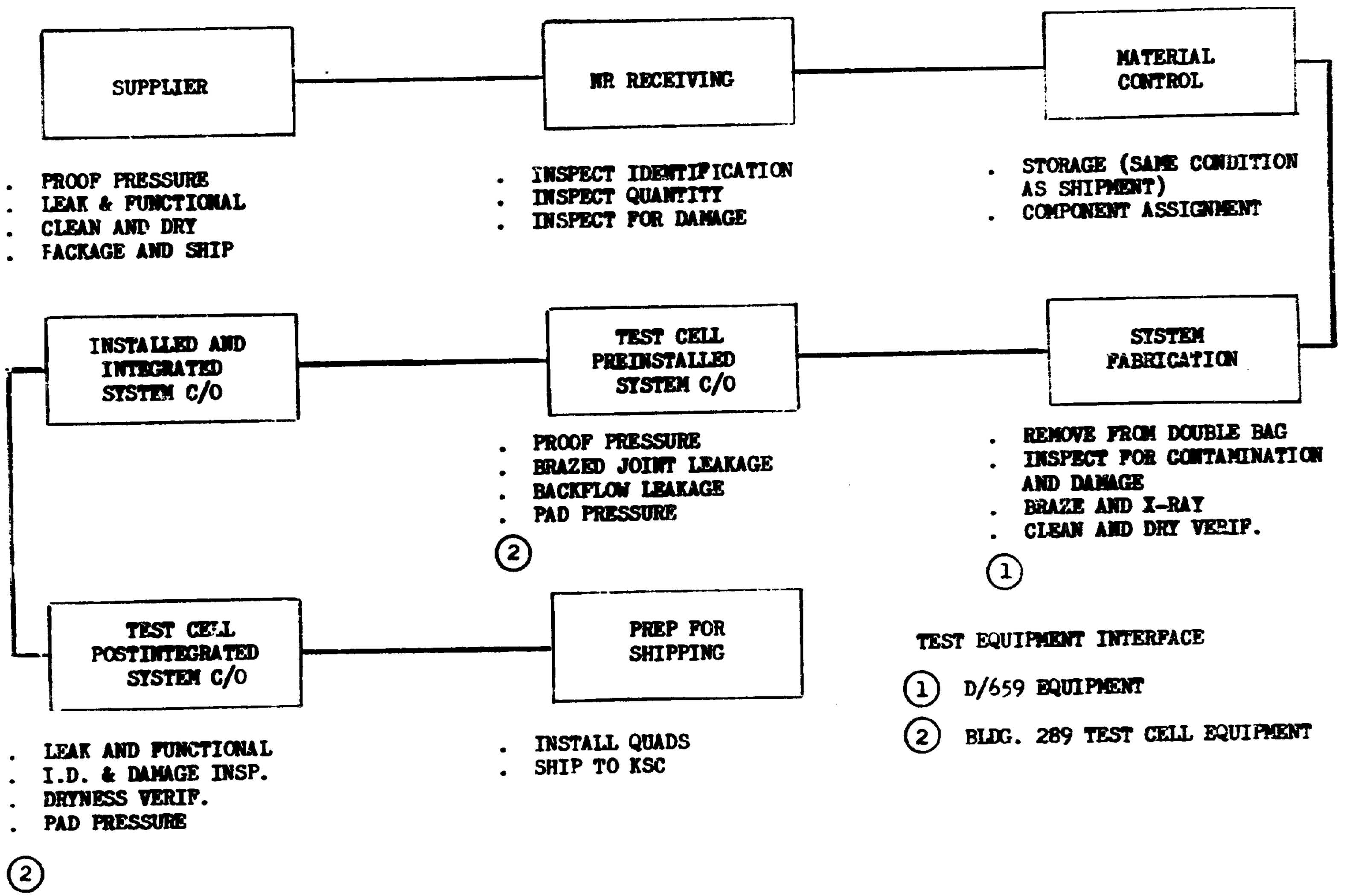
- BAG TUBE ENDS
- DOUBLE BAG
- PURGE INNER BAG WITH GN_2

SM RCS HELIUM PRESSURE REGULATOR

FUNCTIONAL C/O	PREINSTALLED SYSTEM C/O HELIUM PANEL	PREINSTALLED SYSTEM C/O	POSTINTEGRATED SYSTEM C/O
PROOF PRESSURE	S/C 009 only	X	
BRAZE JOINT EXTERNAL LEAKAGE	S/C 009 only	X	
REGULATOR FLOW AND LOCKUP	S/C 009 only	S/C 009 thru 106	S/C 017 & Subs
REGULATOR LEAKAGE	S/C 009 only	S/C 009 thru 106	S/C 017 & Subs
I.D. AND DAMAGE INSPECTION	S/C 009 only	X	X
REGULATOR RESPONSE		S/C 011 thru 106	S/C 017 & Subs
DRYNESS VERIFICATION		S/C 107 & Subs	S/C 101 & Subs
PAD PRESSURE		X	50 psig for ship.
TEST EQUIPMENT INTERFACE	Bldg. 289 Test Cell	Bldg. 289 Test Cell	Bldg. 289 Test Cell

SM RCS HELIUM SYSTEM

CHECK VALVE FLOW CHART



SM HELIUM SYSTEM CHECK VALVE

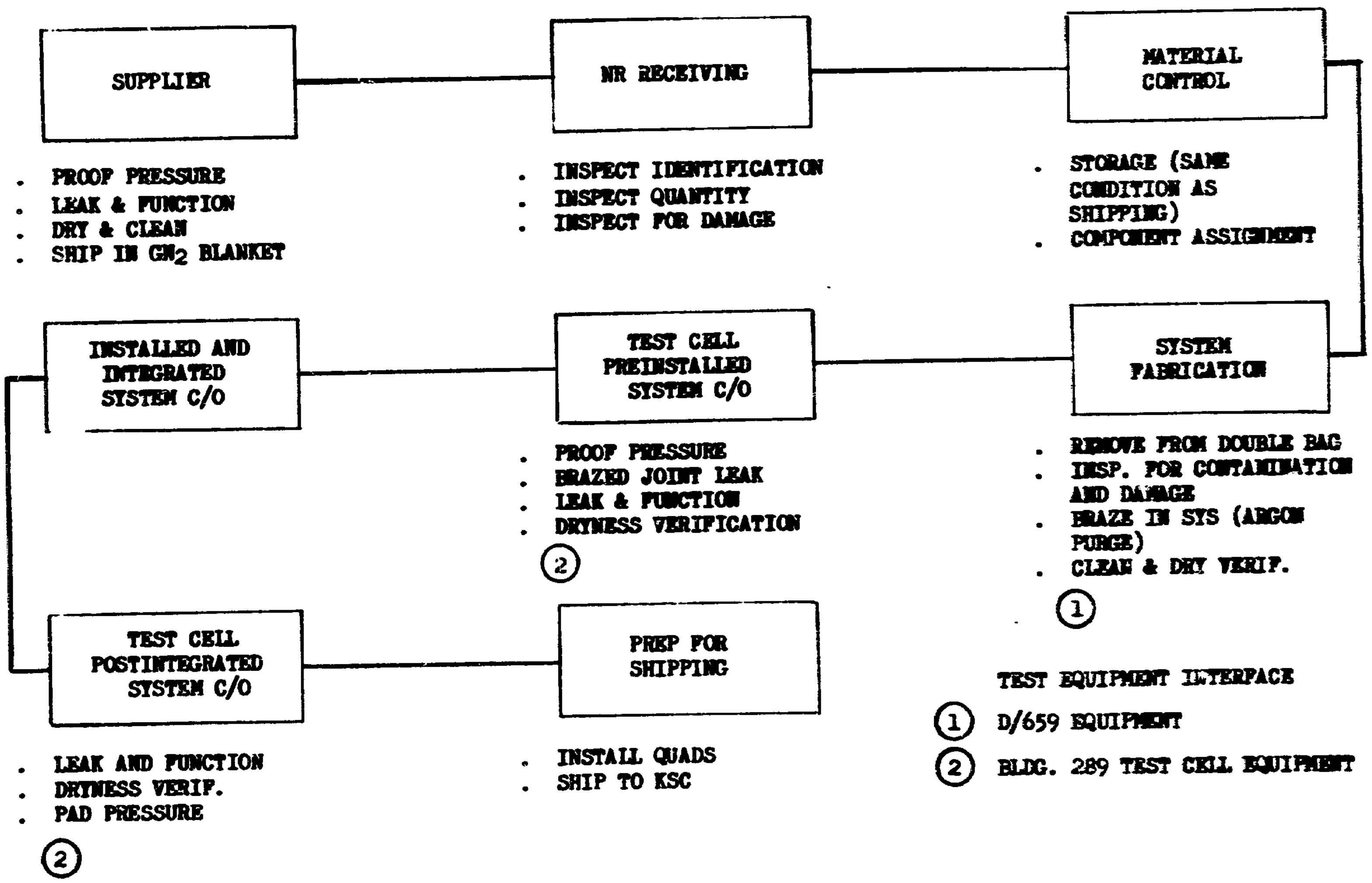
SUPPLIER

- ACCEPTANCE TEST
- EXAMINATION OF PRODUCT
- PROOF PRESSURE
- LEAKAGE
- CRACKING PRESSURE
- PRESSURE DROP
- FUNCTIONAL TEST
- CLEANLINESS (FREON FLUSH, VACUUM OVEN DRY)
- PREPARATION FOR SHIPPING
    - INNER BAG - NYLON
    - OUTER BAG - POLYETHYLENE
    - GN_2 BLANKET

SM HELIUM SYSTEM CHECK VALVE

	PREINSTALLED HELIUM PANEL CHECKOUT	TEST CELL PREINSTALLED SYSTEM C/O	TEST CELL POSTINTEGRATED SYSTEM C/O
. PROOF PRESSURE	(SC 009 ONLY)	X	
. BRAZE JOINT EXT. LEAKAGE	(SC 009 ONLY)	X	
. CHECK VALVE CRACKING PRESSURE	(SC 009 ONLY)	(SC 009 THRU 103)	(SC 101 & SUBS)
. CHECK VALVE BACKFLOW LEAKAGE	(SC 009 ONLY)	(SC 009 THRU 103)	(SC 101 & SUBS)
. I.D. & DAMAGE INSP.	(SC 009 ONLY)	X	X
. CHECK VALVE △ P FLOW		(SC 011 THRU 103)	(SC 101)
. DRYNESS VERIFICATION		(SC 107 & SUBS)	(SC 101 & SUBS)
. PAD PRESSURE		X	50 PSIG FOR SHIP
. TEST EQUIPMENT INTERFACE	B.DG. 289 TEST CELL	BLDG. 289 TEST CELL	BLDG. 289 TEST CELL

SM RCS HELIUM PRESSURE RELIEF VALVE FLOW CHART



SM RCS HELIUM PRESSURE RELIEF VALVE

SUPPLIER

- ACCEPTANCE TEST
- EXAMINATION OF PRODUCT
- PROOF PRESSURE
- LEAKAGE
- FUNCTIONAL TEST
- CLEANLINESS (FREON FLUSH AND VACUUM OVEN DRY)
- PREPARATION FOR SHIPPING

    INNER BAG - NYLON

    OUTER BAG - POLYETHYLENE

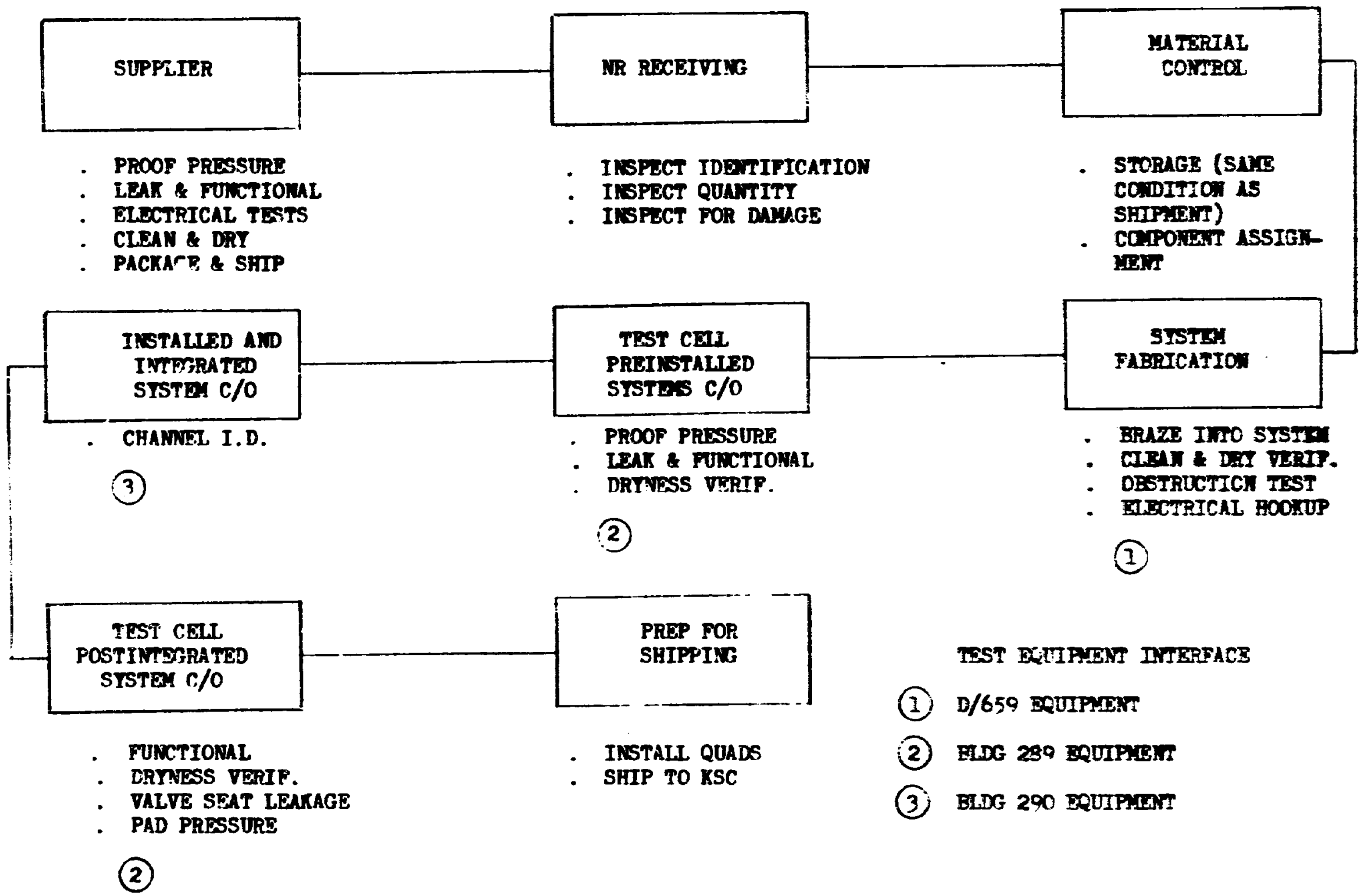
    PACKAGE IN A GN_2 BLANKET

SM RCS HELIUM PRESSURE RELIEF VALVE

	TEST CELL PREINSTALLED HELIUM PANEL C/O	TEST CELL PREINSTALLED SYSTEM C/O	TEST CELL POSTINTEGRATED SYSTEM C/O
• PROOF PRESSURE	SC 009 ONLY	X	
• BRAZE JOINT EXT. LEAKAGE	SC 009 ONLY	X	
• CRACK & RESEAT PRESSURE OF RELIEF POPPET	SC 009 ONLY	X	X
• LEAKAGE OF RELIEF & VENT POPPETS	SC 009 ONLY	X	X
• BURST DIAPHRAGM LEAKAGE	SC 009 ONLY	X	X
• LOW PRESS. VENT POPPET FUNCTION & LEAKAGE		SC 101 & SUBS	X
• DRYNESS VERIFICATION		SC 107 & SUBS	SC 101 & SUBS
• VENT PORT COVER (NOT REUSED)		REMOVE, TEST, REPLACE 101 & SUBS	REMOVE, TEST, REPLACE 101 & SUBS
• PAD PRESSURE		X	50 PSIG FOR SHIP
• I.D. AND DAMAGE INSP.	SC 009 ONLY	X	X
• TEST EQUIPMENT INTERFACE	BLDG. 289 TEST CELL	BLDG. 289 TEST CELL	BLDG. 289 TEST CELL

SM RCS PROPELLANT ISOLATION

VALVE FLOW CHART



S M R C S P R O P E L L A N T I S O L A T I O N V A L V E S

SUPPLIER

- ACCEPTANCE TEST
  - EXAMINATION OF PRODUCT
  - PROOF PRESSURE & EXTERNAL LEAKAGE
  - INTERNAL LEAKAGE
  - ELECTRICAL CHARACTERISTICS
  - FUNCTIONAL TEST
  - PRESSURE DROP
  - CLEANLINESS (FREON FLUSH,VACUUM OVEN DRY)
  - PREPARE FOR SHIPMENT

    INNER BAG-NYLON

    OUTER BAG-POLYETHYLENE

    PURGE WITH DRY N_2

    SQUEEZE OUT N_2 AND SEAL BAGS

S M R C S P R O P E L L A N T I S O L A T I O N V A L V E S

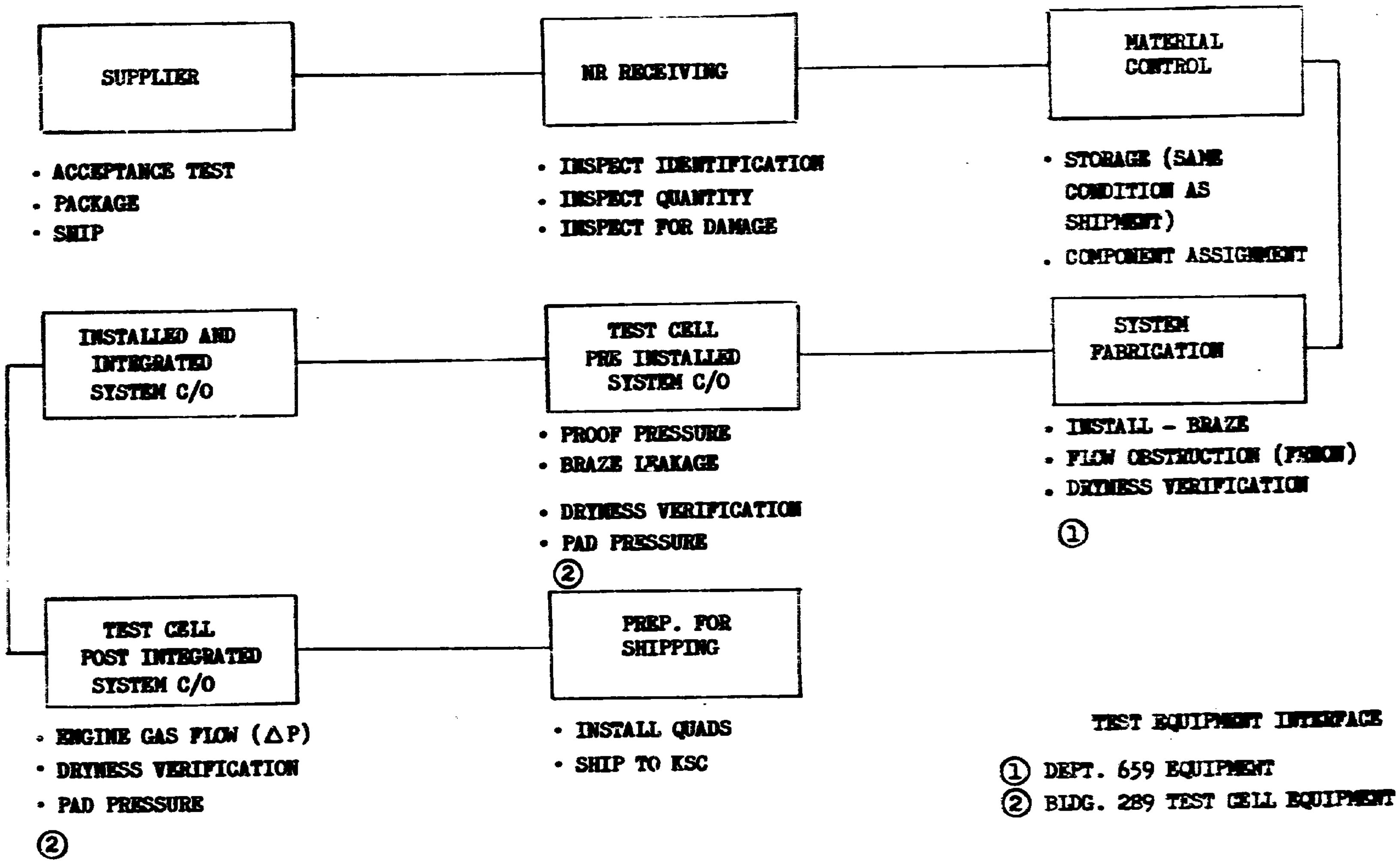
S Y S T E M F A B R I C A T I O N

- REMOVED FROM DOUBLE BAG
- VISUAL INSPECT FOR CONTAMINATION AND DAMAGE
- BRAZE TO SYSTEM (ARGON PURGE) AND X-RAY
- PERFORM SYSTEM CLEANLINESS VERIFICATION (FREON TF)
- PERFORM OBSTRUCTION TEST (FREON TF)
- PERFORM DRYNESS VERIFICATION TEST (NG_2 AND He)
- CLOSING VOLTAGE TEST
- CONNECT ELECTRICAL LEADS TO TERMINAL BOARD

SM RCS PROPELLANT ISOLATION VALVES

	TEST CELL PREINSTALLED SYSTEM C/O	TEST CELL POSTINTEGRATED SYSTEM C/O
. PROOF PRESSURE	X	
. BRAZE JOINT (EXT. LEAKAGE)	X	
. FUNCTIONAL: OPEN, CLOSE CYCLE	X	(S/C 101 & SUBS)
. VALVE SEAT LEAKAGE	(S/C 006 THRU 106)	(S/C 101 & SUBS)
. DRYNESS VERIFICATION	(S/C 107 & SUBS)	(S/C 101 & SUBS)
. PAD PRESSURE	X	50% PSIG FOR SHIP
. I. D. AND DAMAGE INSPECTION	X	X
. TEST EQUIPMENT INTERFACE	BLDG 289 TEST CELL EQUIPMENT	BLDG 289 TEST CELL

S M R C S P R O P E L L A N T F I L T E R F L O W C H A R T



FILTER INSTALLED SM QUADS S/C 012 & SUBS

SM RCS PROPELLANT FILTER

SUPPLIER:

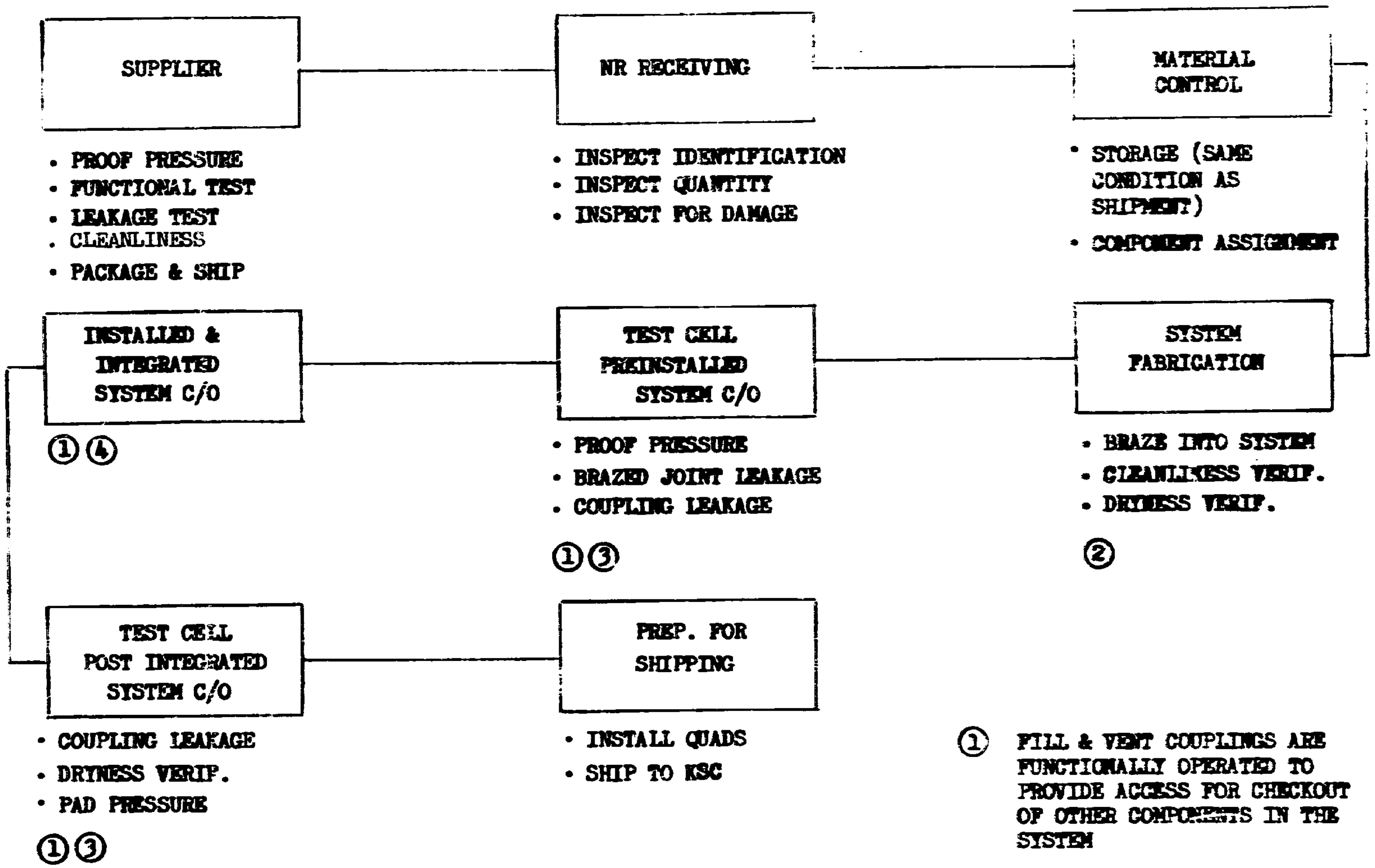
- ACCEPTANCE TEST
  - PROOF PRESSURE
  - EXTERNAL LEAKAGE
  - BUBBLE POINT
  - PRESSURE DROP
  - CLEANLINESS VERIFICATION
    - FREON FLUSH
  - VACUUM OVEN DRY
- PACKAGING
  - DOUBLE BAGGED
    - INNER, NYLON
    - OUTER, POLYETHYLENE
    - PURGE WITH DRY N_2, EVACUATE N_2 AND SEAL BAG
  - CUSHIONED CONTAINER

SM RCS PROPELLANT FILTER

	PREINSTALLED SYSTEM C/O	POST INTEGRATED SYSTEM C/O
PROOF PRESSURE	012 & SUBS	———
BRAZED JOINT LEAKAGE	012 & SUBS	———
ENGINE GAS FLOW	012 THRU 106	101 & SUBS
DRYNESS VERIFICATION	107 & SUBS	101 & SUBS
PAD PRESSURE	012 & SUBS	012 & SUBS
I. D. AND DAMAGE INSPECT	012 & SUBS	012 & SUBS
TEST EQUIP. INTERFACE	BLDG. 289 TEST CELL	BLDG. 289 TEST CELL

FILTER INSTALLED SM QUADS S/C 012 & SUBS

SM RCS FILL AND VENT COUPLING FLOW CHART



① FILL & VENT COUPLINGS ARE FUNCTIONALLY OPERATED TO PROVIDE ACCESS FOR CHECKOUT OF OTHER COMPONENTS IN THE SYSTEM

TEST EQUIPMENT INTERFACE

② D/659 EQUIPMENT
③ BLDG 289 TEST CELL EQUIPMENT
④ BLDG 290 EQUIPMENT

SM RCS FILL AND VENT COUPLINGS

SUPPLIER:

ACCEPTANCE TEST

- EXAMINATION OF PRODUCT
- PROOF PRESSURE
- FUNCTIONAL (ENGAGE/DISENGAGE)
- LEAKAGE
- CLEANLINESS
- PACKAGE
- SHIP

SYSTEM FABRICATION

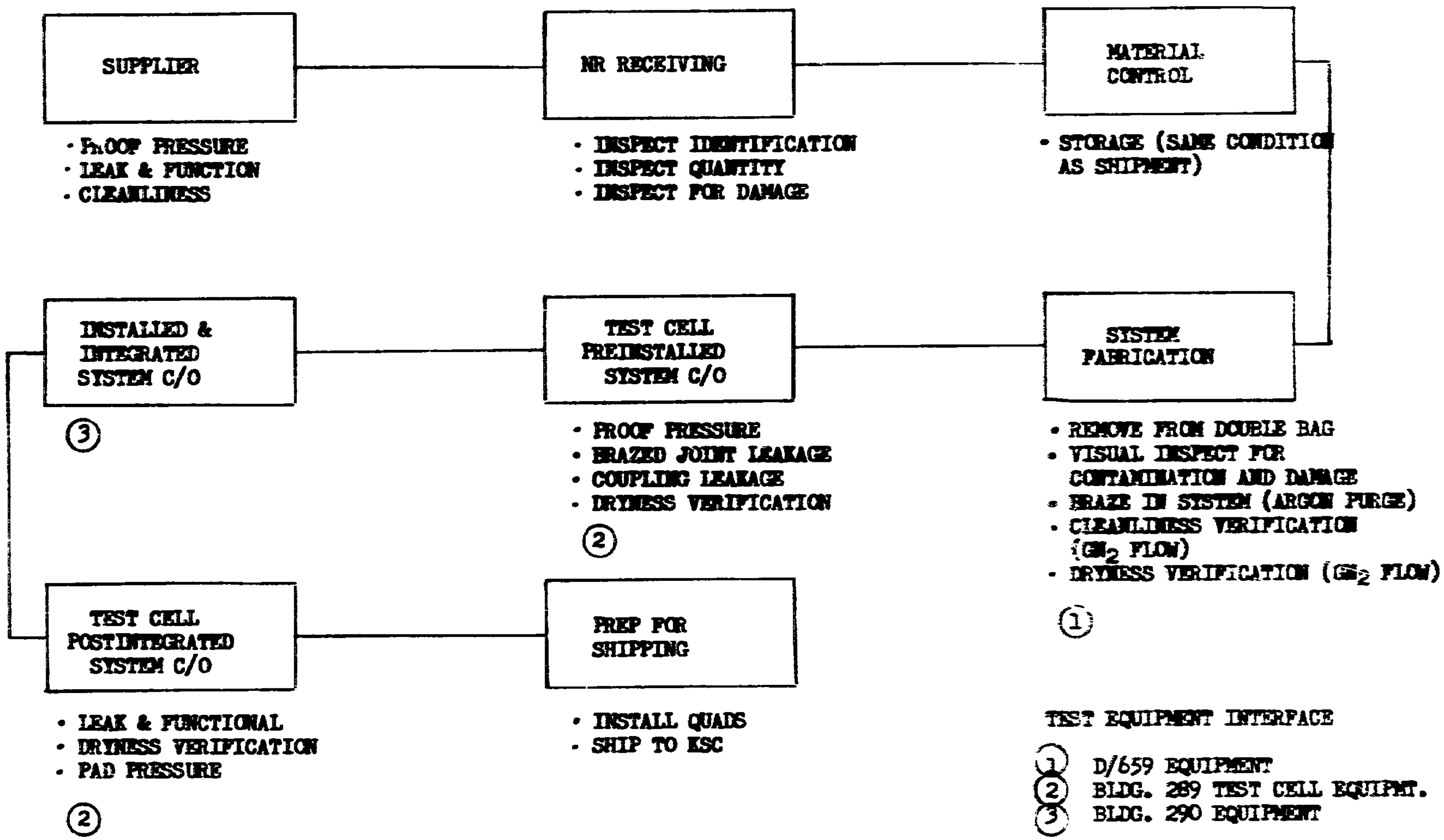
- REMOVE FROM DOUBLE BAG
- VISUAL INSPECT FOR CONTAMINATION AND DAMAGE
- BRAZE IN SYSTEM (ARGON PURGE)
- CLEANLINESS VERIFICATION (GN_2 FLOW)
- DRYNESS VERIFICATION

SM RCS FILL AND VENT COUPLINGS

	TEST CELL PREINSTALLED C/O	POST INTEGRATED C/O
• PROOF PRESSURE	X	
• BRAZED JOINT EXTERNAL LEAKAGE	X	
• INTERNAL LEAKAGE (DUST CAPS "OFF")	X	X S/C 014 & SUBS
• EXTERNAL LEAKAGE (DUST CAPS "ON")	X	X S/C 014 & SUBS
• FILL AND VENT COUPLING FUNCTIONAL	X *	X *
• DRYNESS VERIFICATION	X S/C 107 & SUBS	S/C 101 & SUBS
• PAD PRESSURE	X	X 50 PSIG FOR SHIP
• I. D. AND DAMAGE INSPECTION	X	X
• TEST EQUIPMENT INTERFACE	BLDG. 289 TEST CELL	BLDG. 289 TEST CELL

* NOTE: THE FILL AND VENT COUPLINGS ARE FUNCTIONALLY OPERATED TO PROVIDE ACCESS FOR CHECKOUT OF THE OTHER COMPONENTS IN THE SYSTEM.

SM RCS TEST COUPLING FLOW CHART



SM RCS TEST POINT COUPLING

FUNCTIONAL C/O	TEST CELL PREINSTALLED SYSTEM C/O HELIUM PANEL	PREINSTALLED SYSTEM C/O	POSTINTEGRATED SYSTEM C/O
PROOF PRESSURE	S/C 009 only	S/C 011 & Subs	
BRAZED JOINT EXTERNAL LEAKAGE	S/C 009 only	S/C 011 & Subs	
INTERNAL LEAKAGE (DUST CAPS OFF)	S/C 009 only	S/C 011 & Subs	S/C 014 & Subs
EXTERNAL LEAKAGE (DUST CAPS ON)	X	S/C 011 & Subs	S/C 014 & Subs
TEST PORT FUNCTIONAL	*	*	*
IDENTIFICATION & DAMAGE	X	X	X
PAD PRESSURE		X	50 psig for ship.
DRYNESS VERIFICATION		S/C 107 & Subs	S/C 101 & Subs
TEST INTEGRATION REQUIREMENTS	Bldg. 289 Test Cell		Bldg. 289 Test Cell

*THE TEST PORTS ARE FUNCTIONALLY OPERATED AND PROVIDE ACCESS FOR CHECKOUT OF OTHER COMPONENTS IN THE SYSTEM.

S M R - S TEST POINT COUPLING

SUPPLIER:

ACCEPTANCE TEST

EXAMINE COUPLING

PROOF PRESSURE

FUNCTIONAL (ENGAGE/DISENGAGE)

PRESSURE DROP

LEAKAGE

CLEANLINESS

SEAL INSPECTION

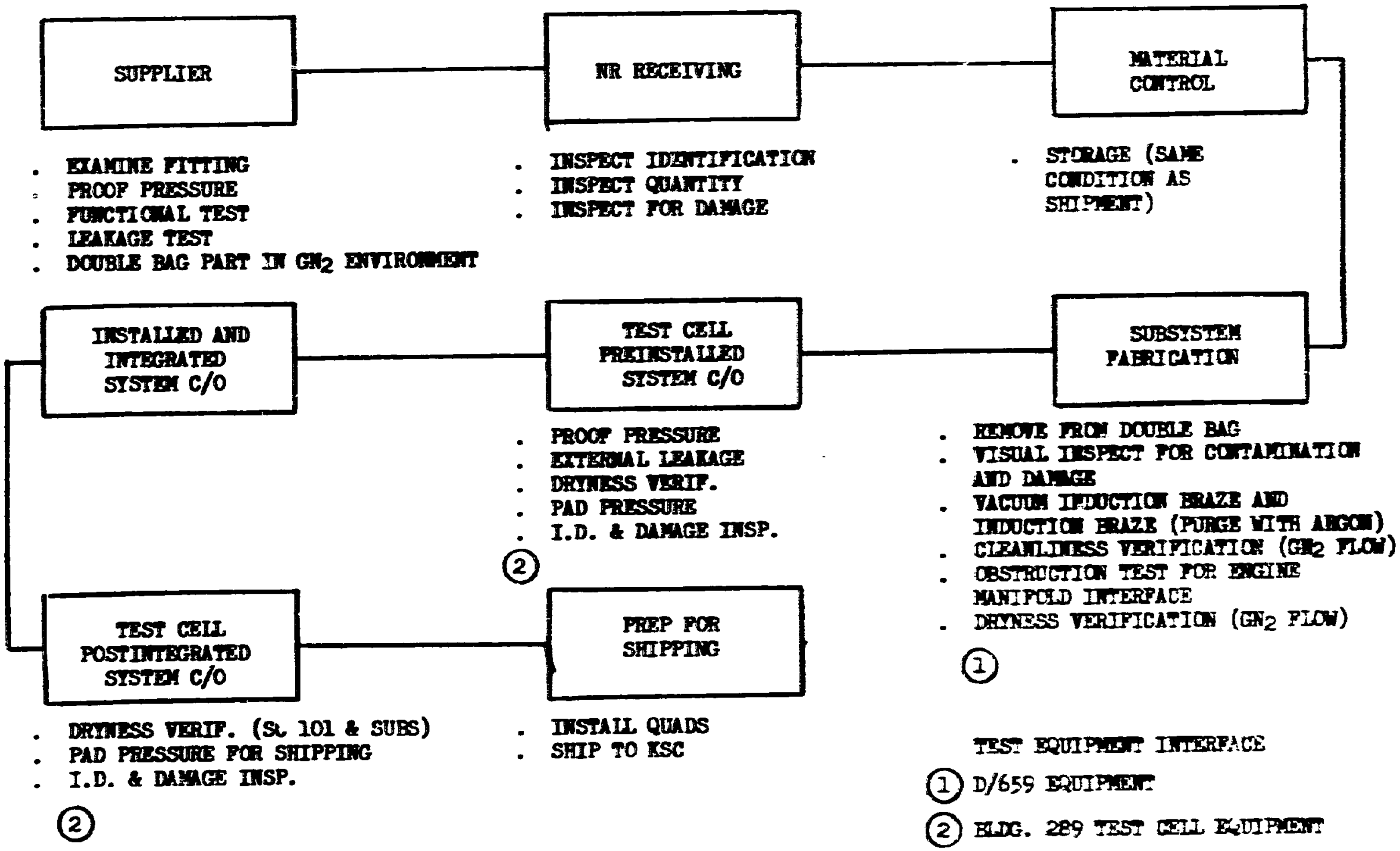
PACKAGE

DOUBLE BAG

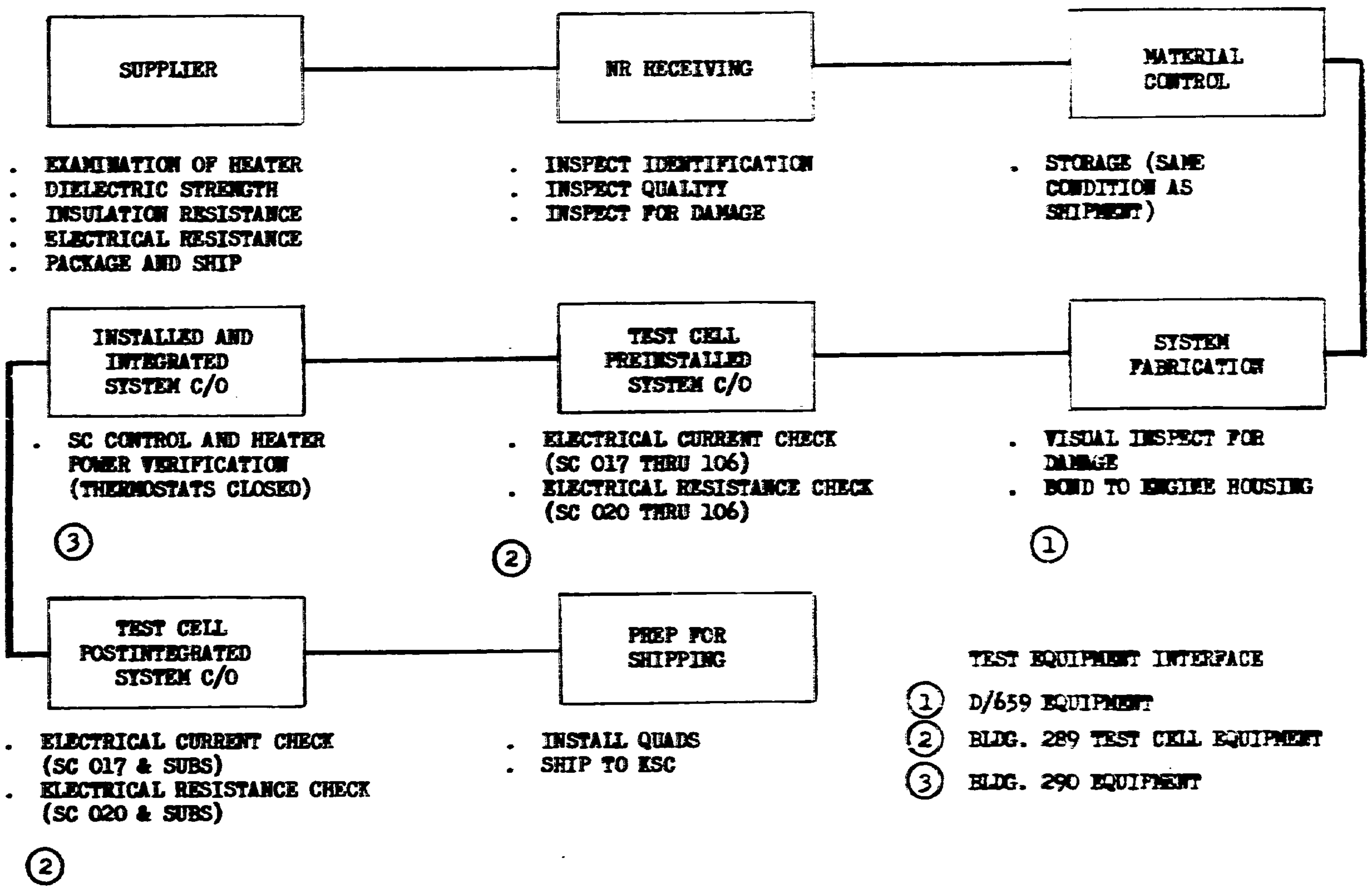
PURGE BAG WITH GN_2

ENVE 'P PART IN GN_2 ENVIRONMENT

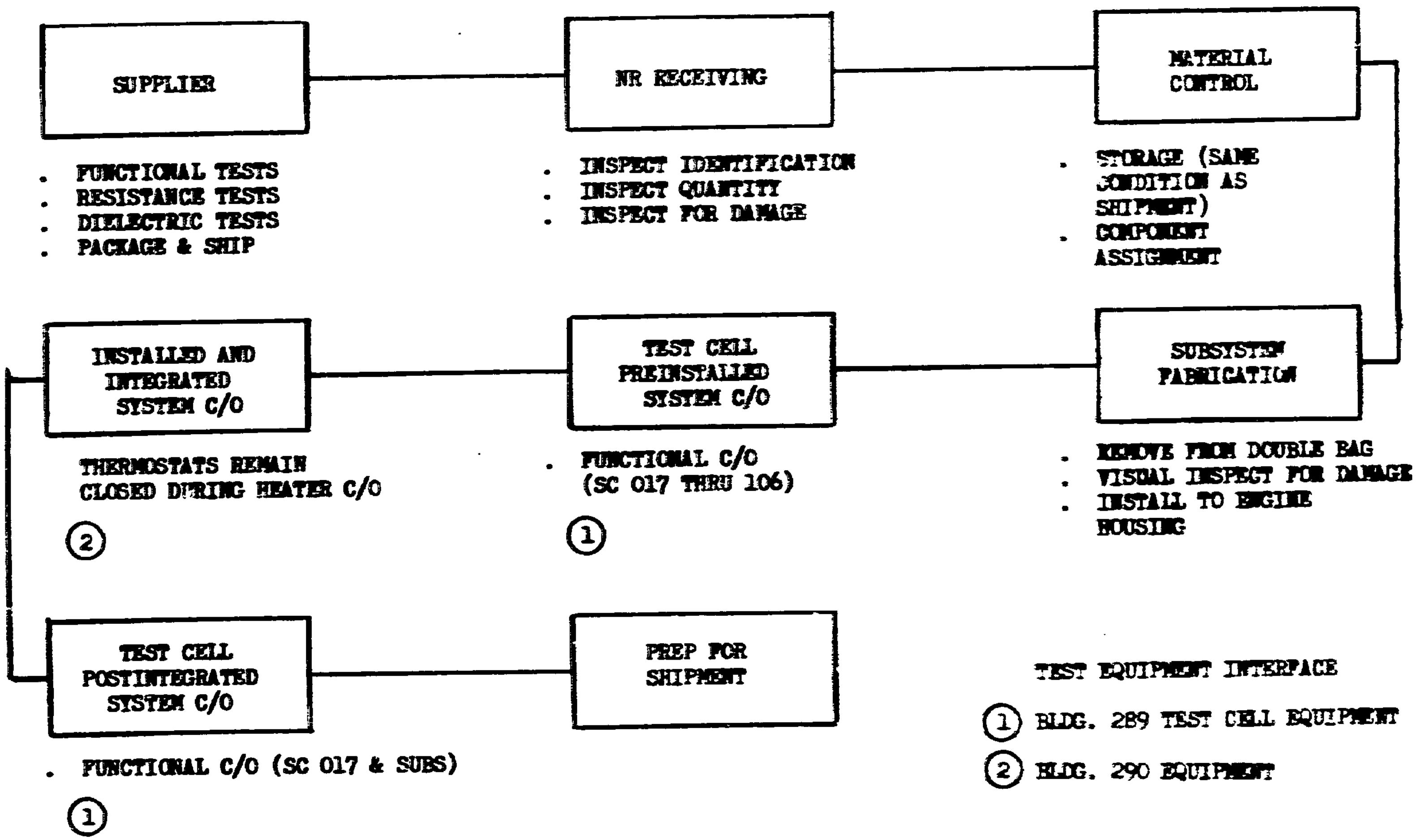
SM RCS DYNATUBE FITTING FLOW CHART



SM RCS VALVE HOUSING HEATER FLOW CHART



SM RCS VALVE HOUSING THERMOSTAT FLOW CHART

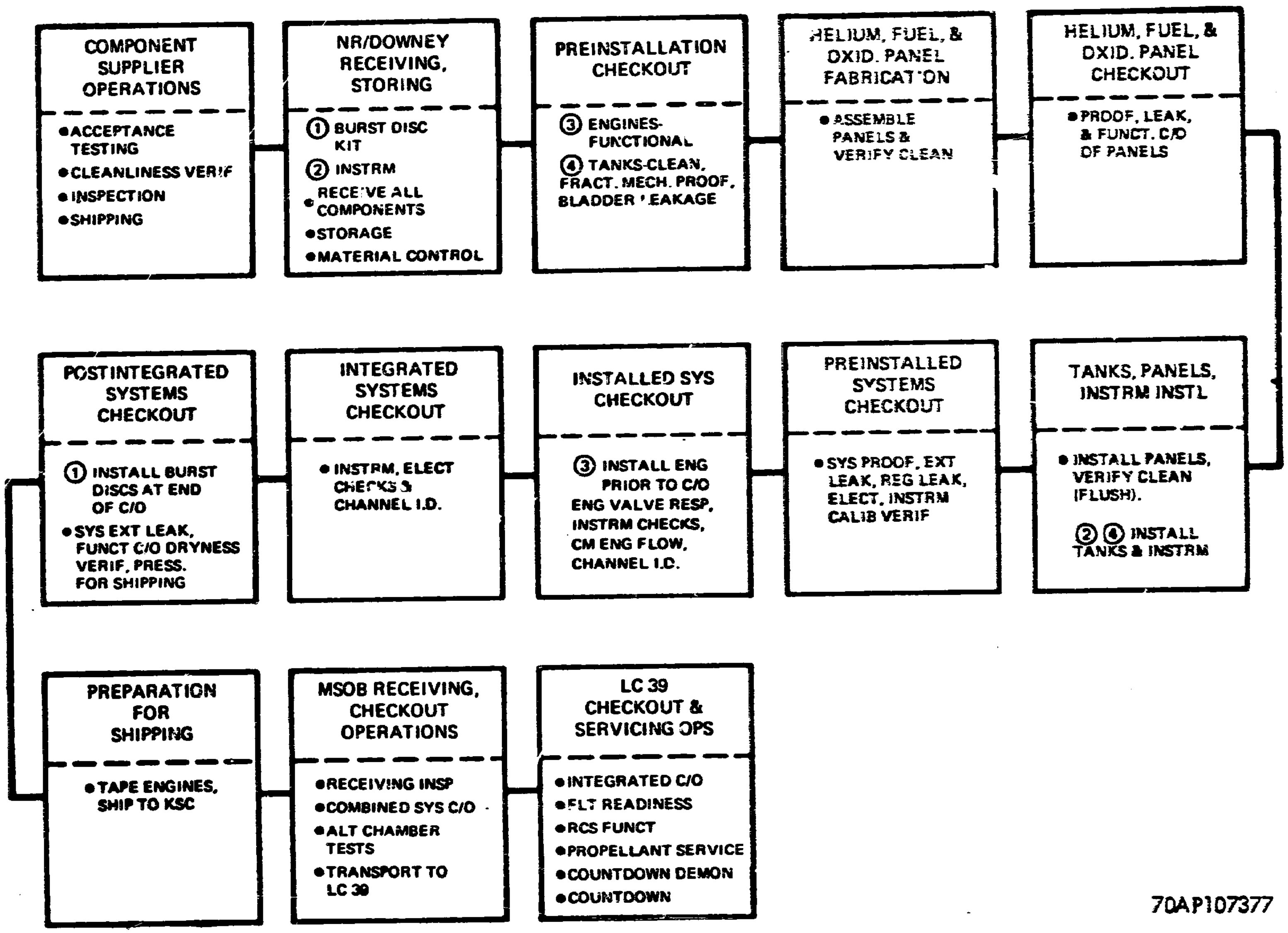


SM RCS VALVE HOUSING THERMOSTAT

SUPPLIER:

- ACCEPTANCE TEST
  - EXAMINATION OF THERMOSTAT
  - HERMETIC SEAL
  - CLOSING TEMPERATURE
  - OPENING TEMPERATURE
  - INSULATION RESISTANCE
  - DIELECTRIC TEST
  - CONTACT RESISTANCE
  - PACKAGE
  - SHIP

CM RCS COMPONENT FLOW DIAGRAM



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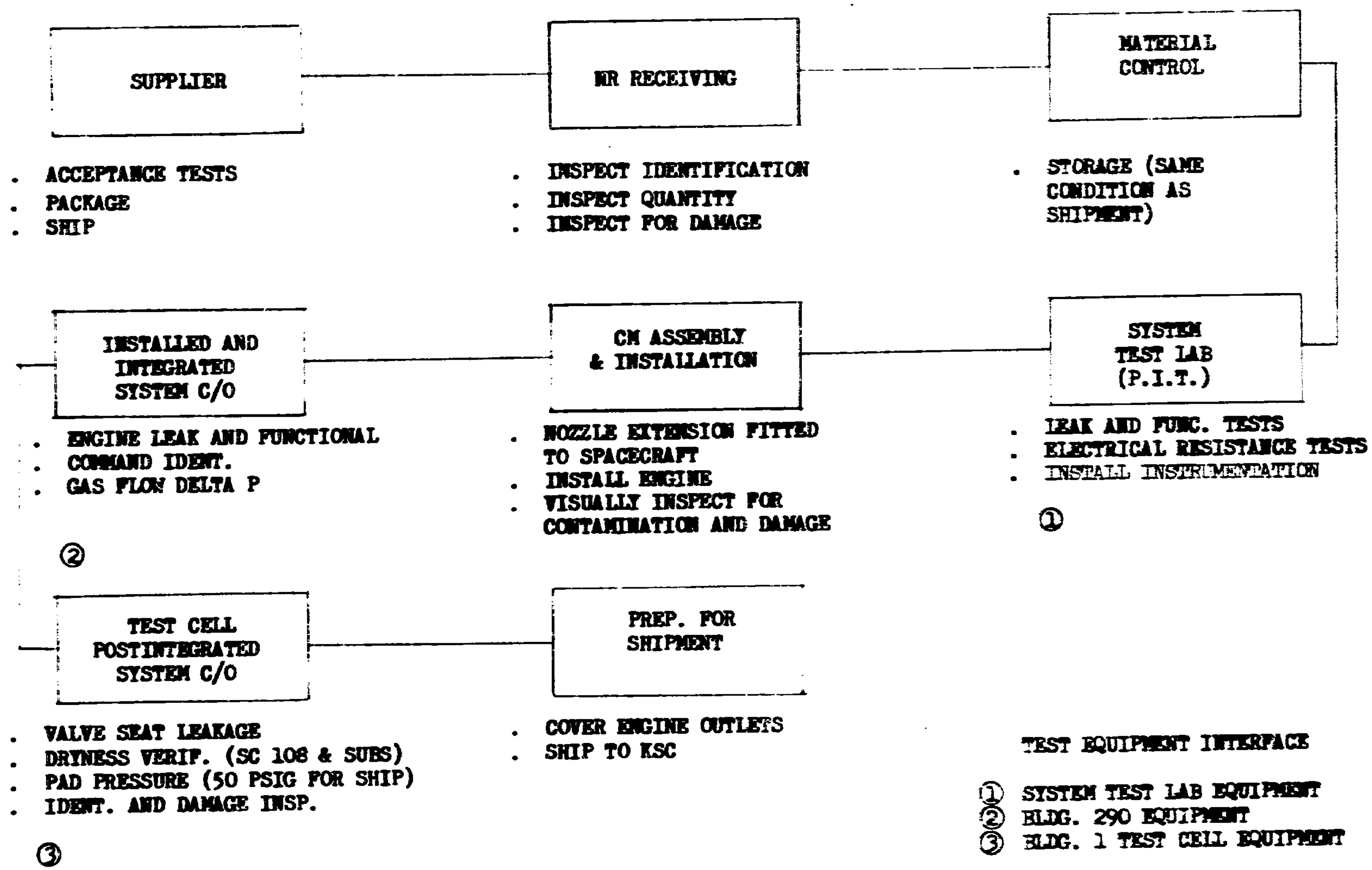
CM RCS ENGINE FLOW CHART



CM RCS ENGINE

SUPPLIER:

- ACCEPTANCE TESTS
  - CLEANLINESS MAINTAINED BY INFLUENT CONTROLS
  - VALVES
    - SEAT LEAKAGE
    - INSULATION AND COIL RESISTANCE
    - RESPONSE
    - PROOF PRESSURE
  - INJECTOR PROOF PRESSURE
  - THRUST CHAMBER PROOF PRESSURE
  - HOT FIRE
  - COAT CHAMBER
  - DECONTAMINATION-VACUUM OVEN DRY
  - VALVES
    - DIELECTRIC STRENGTH
    - INSULATION AND COIL RESISTANCE
    - SEAT LEAKAGE
    - RESPONSE
    - PROOF PRESSURE

- ACCEPTANCE TESTS (CONTINUED)
  - INJECTOR PROOF PRESSURE
  - THRUST CHAMBER PROOF PRESSURE
  - THRUST CHAMBER EXTERNAL LEAKAGE
  - THRUST CHAMBER X-RAY
  - VALVE SEAT LEAKAGE
  - VACUUM OVEN DRY

C M R C S E N G I N E

SUPPLIER

- PACKAGING
  - CRES STEEL THREADED VALVE CLOSURES
  - THRUST CHAMBER PLACTIC CLOSURE WITH DESICCANT
  - THRUST CHAMBER PROTECTIVE WRAP
  - POLYETHYLENE BAGGED
  - PLASTIC RUDL-PAK WITH POLYURETHANE PACKING
  - RUDL-PAK SEALED
  - CARTONED AND SEALED

CM RCS ENGINE

SYSTEM TEST LAB

- PREINSTALLATION TEST
  - SEAT LEAKAGE
  - INLET HOUSING WELD LEAKAGE
  - INSULATION AND COIL RESISTANCE
  - RESPONSE
  - SEAT LEAKAGE
  - INSTRUMENTATE AS REQUIRED
  - 200°F MAX. 2-HOUR CURE
  - VISUAL INSPECTION
  - REPACKAGE
    - AS IN SUPPLIER PACKAGING EXCEPT FOR RUDL-PAK SEAL AND CARTON

C M R C S E N G I N E

INSTALLED AND INTEGRATED SYSTEM CHECKOUT

INSTALLED

- INLET FITTING LEAKAGE
- INLET HOUSING WELD LEAKAGE
- VALVE SEAT LEAKAGE
- INDIVIDUAL FUEL & OXIDIZER VALVE RESPONSE
- SYSTEM VALVE RESPONSE
- ENGINE COMMAND IDENT
- EMI SUPPRESSION
- MINIMUM IMPULSE RESPONSE
- VALVE COIL-HEATER UTILIZATION
- SEAT LEAKAGE
- ENGINE GAS FLOW - ΔP

INTEGRATED

- HEATER FUNCTION
- ENGINE COMMAND IDENT

COMMAND MODULE REACTION CONTROL SYSTEM

INSTALLED AND INTEGRATED SYSTEM CHECKOUT

<table>
<tr><th>TEST DESCRIPTION (LISTED IN TEST SEQ.)</th><th>TEST PARAMETERS</th><th>ACCEPTANCE CRITERIA</th></tr>
<tr><td>Engine inlet weld leakage and inlet fitting leakage</td><td>Pressure 300 ±15 psig</td><td>Leakage less than 1 x 10-7 scc/sec (indicated)</td></tr>
<tr><td>Engine Valve Seat Leakage</td><td>Pressure 300 ±15 psig</td><td>Leakage less than 20 scc/sec (actual)</td></tr>
<tr><td>Engine, Individual, Valve Response
Fuel Direct
Fuel Auto
Oxidiser Direct
Oxidiser Auto</td><td>Pressure 35 ±5 psig
Voltage 28 ±.5 vdc
Valve excitation time - 28 ms auto valve, undefined direct valve.
engine test shall be completed within 16 hrs
EMI suppression networks shall not be connected</td><td>
<table>
<tr><th>Step</th><th>For Valve Response:</th><th>Proceed as Follows:</th></tr>
<tr><td>1.
a.</td><td>Direct Coils Only
Open: 6.5 to 10.5 ms
Close: 4.0 to 8.0 ms</td><td>Verify conformance with Step 2.</td></tr>
<tr><td>b.</td><td>Open: < 25.0 ms
Close: < 15.0 ms</td><td>Verify conformance with Step 3.</td></tr>
<tr><td>2.</td><td>Auto Coils Only
Open: 3.0 to 6.0 ms
Close: 4.5 to 8.5 ms</td><td>Valve response acceptable.</td></tr>
<tr><td>3.</td><td>Auto Coils Only
Open: 3.0 to 6.0 ms
Close: 4.5 to 8.5 ms</td><td>Perform 5 direct responses and 2 auto responses - evaluate to Step 4 criteria.</td></tr>
<tr><td>4.</td><td>Direct Coils
Open: 6.5 to 10.5 ms
Close: 4.0 to 8.0 ms

Auto Coils
Open: 3.0 to 6.0 ms
Close: 4.5 to 8.5 ms</td><td>Valve response acceptable</td></tr>
</table>
</td></tr>
<tr><td>Engine Function ID and Individual fuel/oxidiser valve to S/C wiring verif.</td><td>Pressure 35 ±5 psig
Voltage 20 ±2 vdc
Valve Excitation time not less than 5 sec.</td><td>Verify gas flow and engine position</td></tr>
</table>

COMMAND MODULE REACTION CONTROL SYSTEM

INSTALLED AND INTEGRATED SYSTEM CHECKOUT

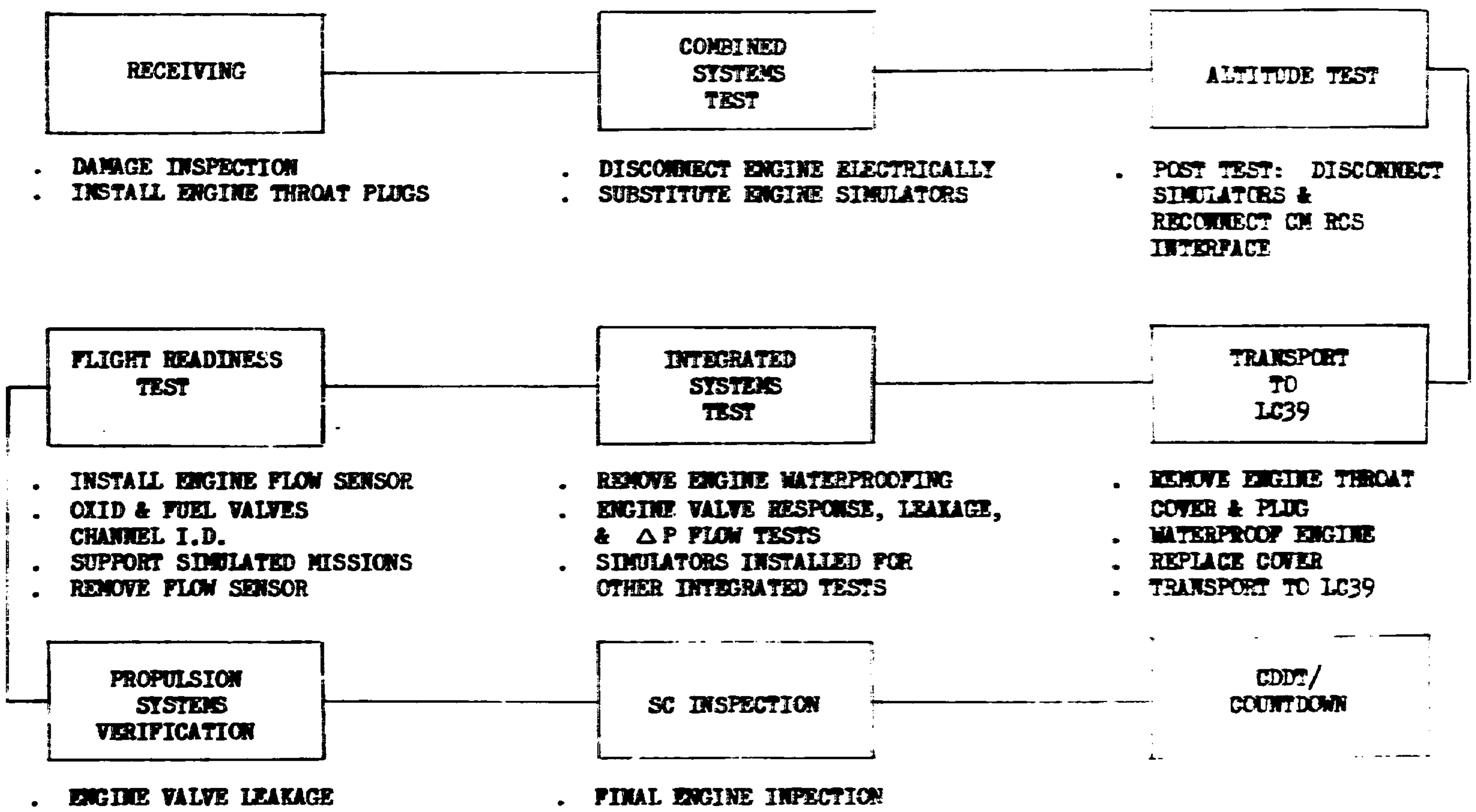
TEST DESCRIPTION LISTED IN TEST SEQ.	TEST PARAMETERS	ACCEPTANCE CRITERIA		
		Valve	Opening Time (Milliseconds)	Closing Time (Milliseconds)
Engine Valve Response Fuel & Oxid Automatic Fuel & Oxid Direct	Pressure 35 ±5 psig Voltage 28 ±.5 vdc Valve Excitation time 15 ±2 ms for automatic coils	CM Auto Response		
		First Response	No opening time requirement	No Requirement
		Second Response	Less than 13	
		All additional responses	4.5 ±1.5	
		CM Direct Response	8.2 ±2	No Requirement
Engine ID	Voltage 28 ±.5 vdc	Engine position versus CM control position is verified by measuring electrical stimulus.		
EMI Suppression	Pressure 35 ±5 psig Voltage 28 ±.5 vdc	Voltage following the direct valve closing command shall be -19 ±3 vdc		
Engine Injector Valve min. Impulse Response	Pressure 35 ±5 psig Voltage 28 ±.5 vdc Valve excitation time 15 ±2 ms	Engine excitation time shall be 15 ±2 ms		
Engine Heaters	Pressure 35 ±5 psig Voltage 28.5 ±.5 vdc	Verify CM heater switch controls all 12 heaters by measuring power applied at each heater.		

COMMAND MODULE REACTION CONTROL SYSTEM

INSTALLED AND INTEGRATED SYSTEM CHECKOUT

TEST DESCRIPTION LISTED IN TEST SEQ.	TEST PARAMETERS	ACCEPTANCE CRITERIA
Engine Valve Seat Leakage	Pressure 300 ±15 psig Leakage test to be performed after valve response tests.	Leakage less than 20 scc/sec.
Engine △ P (Engine Valve Obstruction)	Gas flow orifice .0292 ±.0002 inch Test Gas N_2 Oxidizer Inlet Pressure 160 ±.25 psig Fuel Inlet Pressure 108 ±.25 psig	Oxidizer downstream shall be 15.5 ±3.5 psig and the deviation from the average of all engines shall be less than 2.2 psi. Fuel downstream pressure shall be 16 ±3 psig and the deviation from the average of all engines shall be less than 2.2 psi.

CM RCS ENGINE - KSC OPERATIONS



CM ENGINE - KSC OPERATIONS

MSOB

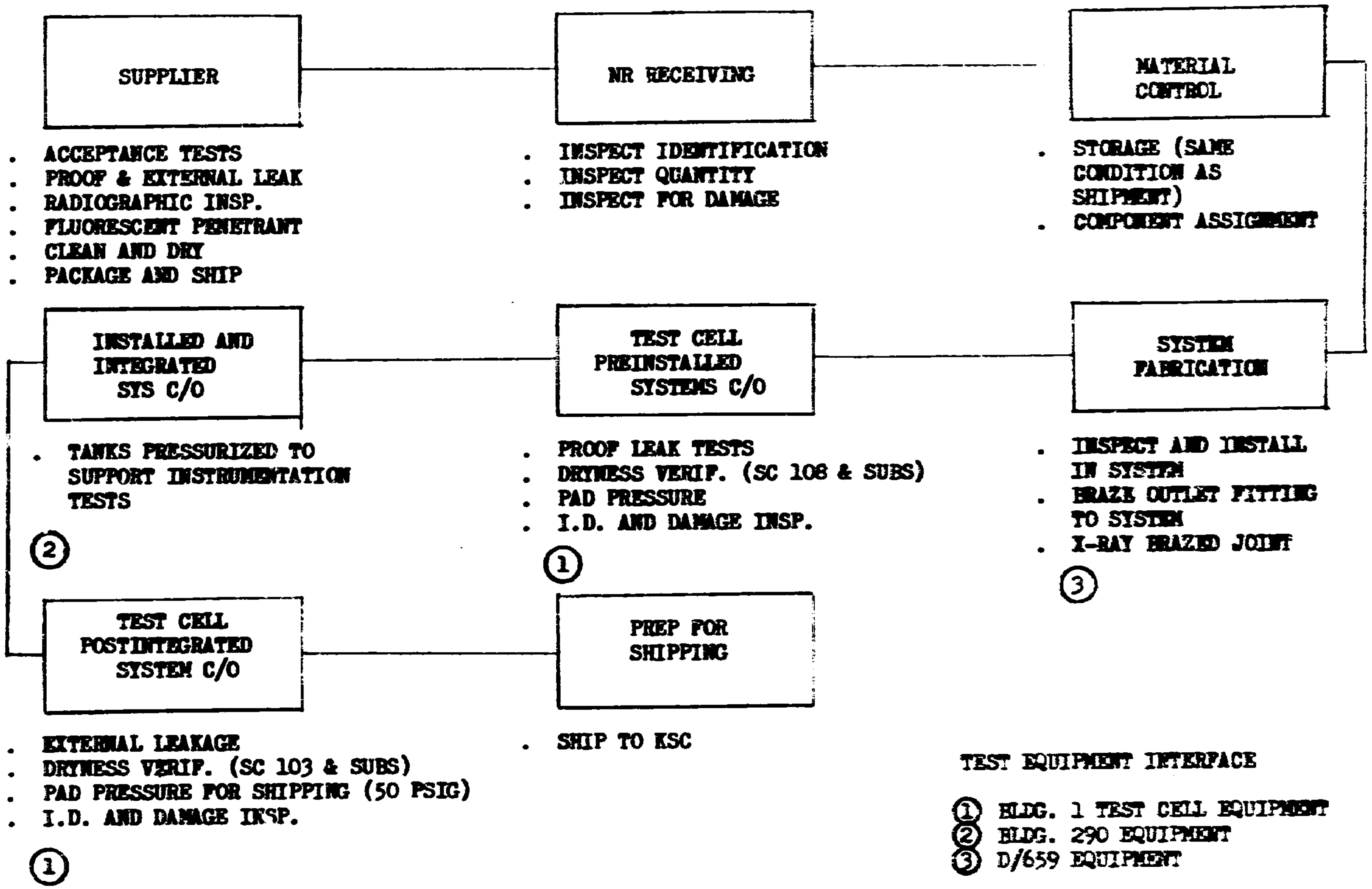
RECEIVING INSPECTION K3084	COMBINED SYSTEMS TEST K0070	ALTITUDE TESTS	S/C TRANSPORTATION K3117
INSPECTION . REMOVE SHIPPING COVER . VERIFY TAPE ON ENGINE NOZZLE	. DISCONNECT ENGINE ELECTRICALLY . CONNECT ENGINE SIMULATOR TO SUPPORT K0070, K0048, K0034	K0048 . REMOVE ENGINE NOZZLE SHIPPING COVERS K0034 POST TEST . DISCONNECT ENGINE SIMULATOR . RECONNECT ENGINE ELECTRICALLY	. REINSTALL ENGINE NOZZLE SHIPPING COVERS

CM ENGINE - KSC OPERATIONS

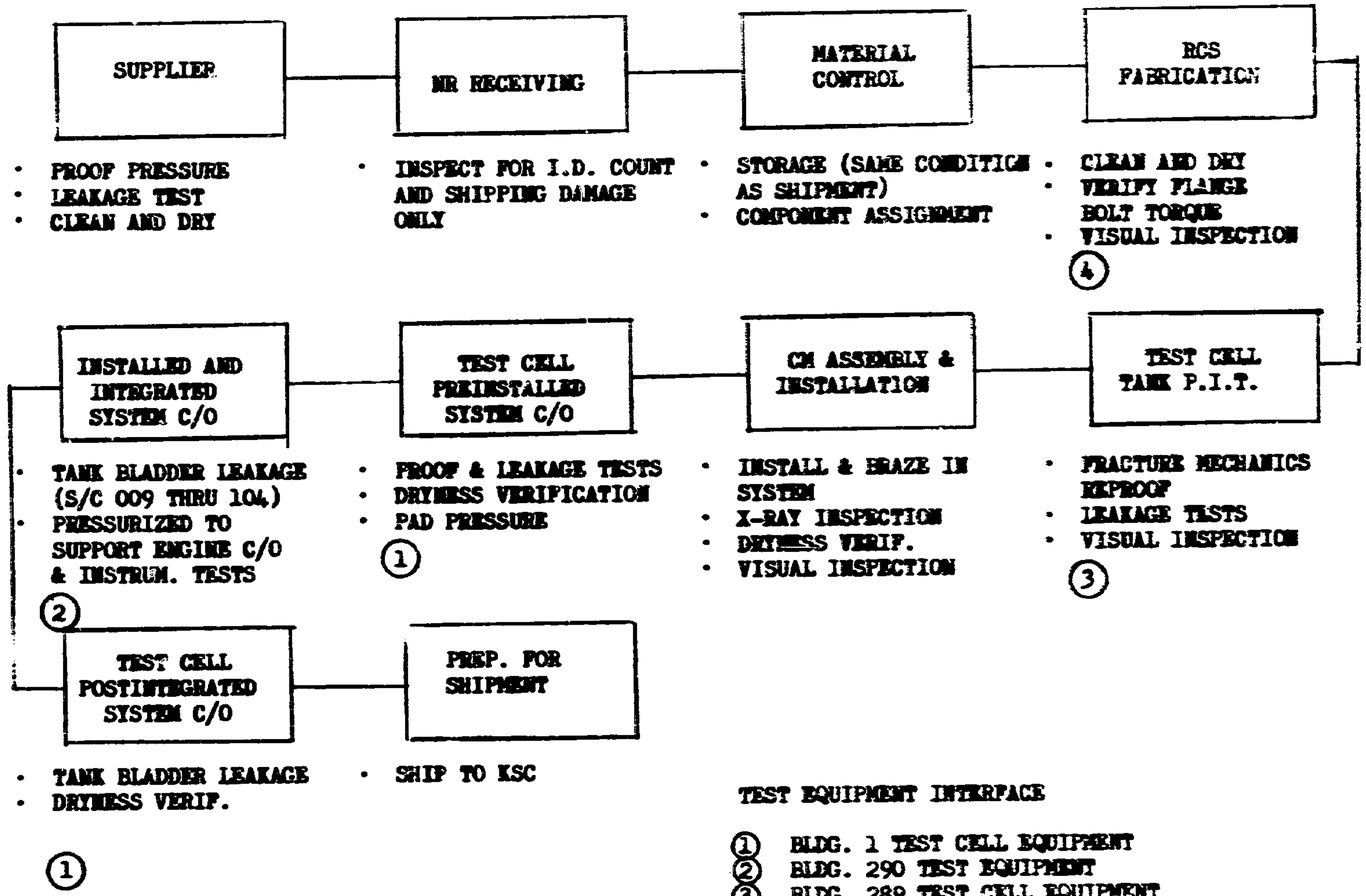
LC39

INTEGRATED SYSTEMS TEST K0005	FLIGHT READINESS TEST K0028	PROPULSION SYSTEMS VERIFICATION K0052	S/C INSPECTION K3211	CDDT/ COUNTDOWN K0007
. REMOVE ENGINE NOZZLE SHIPPING COVER . PRESS ENGINE MANIFOLD TO 10 PSIG . PERFORM ENGINE VALVE RESPONSE TESTING . DISCONNECT ENGINE ELECTRICALLY & CONNECT ENGINE SIMULATOR FOR K0005 . POST SIM. MISSION DISCONNECT SIMULATOR & RECONNECT ENGINE FOR FLIGHT . PRESS ENGINE MANIFOLD TO 200 PSIG . PERFORM ENGINE P FLOW . INSTALL THROAT PLUGS . PRESS ENGINE MANIFOLD TO 300 PSIG . PERFORM ENGINE VALVES LEAK CHECK . DECREASE MANIFOLD TO 50 PSIG	. INSTALL ENGINE FLOW SENSOR . PRESS ENG. MANIFOLD TO 40 PSIG . PERFORM ENG. NORMAL & DIRECT I/D TEST (OXID & FUEL VALVES . SUPPORT SIM. MISSIONS . CLOSEOUT MANIFOLD WITH 40 PSIG . REMOVE FLOW SENSOR	. PRESS. ENGINE MANIFOLD TO 300 PSIG . PERFORM ENGINE LEAK CHECK . DEPRESS MANIFOLD TO 40 PSIG . REMOVE ENGINE THROAT PLUG . TAPE ENGINE NOZZLE OUTLET . INSTALL NOZZLE SHIPPING COVER	. VISUALLY INSPECT AND PHOTOGRAPH ENGINES	. REMOVE ENGINE NOZZLE OUTLET TAPE

CM RCS HELIUM PRESSURE VESSEL FLOW CHART



CM RCS PROPELLANT TANK FLOW CHART



TEST EQUIPMENT INTERFACE

1. BLDG. 1 TEST CELL EQUIPMENT
2. BLDG. 290 TEST EQUIPMENT
3. BLDG. 289 TEST CELL EQUIPMENT
4. D/659 EQUIPMENT

CM RCS PROPELLANT TANK C/O

SUPPLIER:

ACCEPTANCE TESTS

- COMPONENT TEST & PRECLEANING
- SHELL PROOF PRESSURE (HYDROSTATIC)
- BLADDER ASSY. & LEAK TEST
- BLADDER INSTALLATION ON SHELL
- TANK ASSY. PROOF & LEAK TEST (360 PSIG HELIUM)
- INTERNAL RINSE (FREON TF) ON LIQUID SIDE
- INTERNAL DRYING (GN_2 80° TO 90°F)
- PREPARE FOR SHIPMENT

RCS FABRICATION

- PREPARE FOR TEST
- INTERIOR CLEANING (FREON TF)
- DRY WITH GN_2 (80° TO 90°F) TO LESS THAN 220 PPM FREON CONCENTRATION
- VERIFY TORQUE ON FLANGE BOLTS
- VISUAL INSPECT FOR CONTAMINATION & DAMAGE

TEST CELL - TANK P.I.T.

- FRACTURE MECHANICS REPROOF (525 PSIG)
- LEAK TEST OF FLANGE SEAL (355 PSIG)
- BLADDER LEAK TEST
- CAP TUBE STEMS W/4 - 5 PSIG GN_2 ON PROPELLANT SIDE OF BLADDER
- VISUAL INSPECTION

CM RCS PROPELLANT TANKS

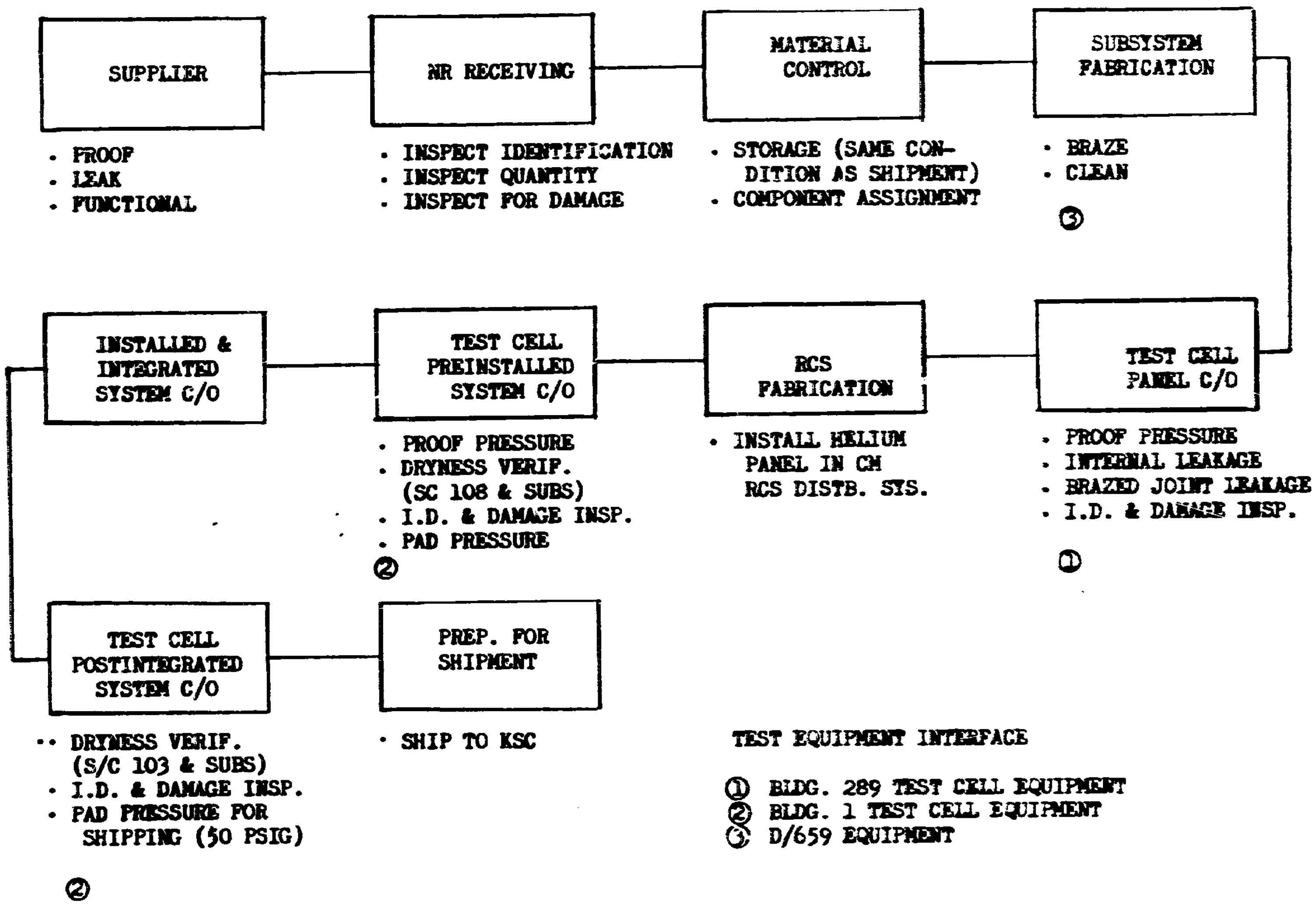
	* PREINSTALLED SYSTEM C/O	** INSTALLED SYSTEM C/O	* POST-INTEGRATED SYSTEM C/O
• PROOF PRESSURE	X		
• EXTERNAL LEAKAGE OF BRAZE JOINTS	X		
• EXTERNAL LEAKAGE OF TANK FLANGE	X S/C 101 & SUBS		
• TANK BLADDER LEAKAGE	X	X S/C 009 THRU 104	X S/C 101 & SUBS
• DRYNESS VERIFICATION	X S/C 108 & SUBS		X S/C 103 & SUBS
• PAD PRESSURE	X	X	X 50 PSIG FOR SHIP
• I.D. AND DAMAGE INSPECTION	X		X
• TEST EQUIPMENT INTERFACE	BLDG. 1 TEST CELL	BLDG. 290	BLDG. 1 TEST CELL

* NOTE: TANKS PRESSURIZED TO SUPPORT COMPONENT CHECKOUT

** NOTE: TANKS PRESSURIZED TO SUPPORT ENGINE CHECKOUT AND INSTRUMENT TESTS DURING MA0710-4223, MA0710-4225, MA0710-4224 AND MA0710-0131

CM RCS HELIUM ISOLATION VALVE (EXPLOSIVE ACTUATED)

FLOW CHART



TEST EQUIPMENT INTERFACE

① BLDG. 289 TEST CELL EQUIPMENT
② BLDG. 1 TEST CELL EQUIPMENT
③ D/659 EQUIPMENT

HELIUM ISOLATION VALVE (EXPLOSIVE ACTUATED)

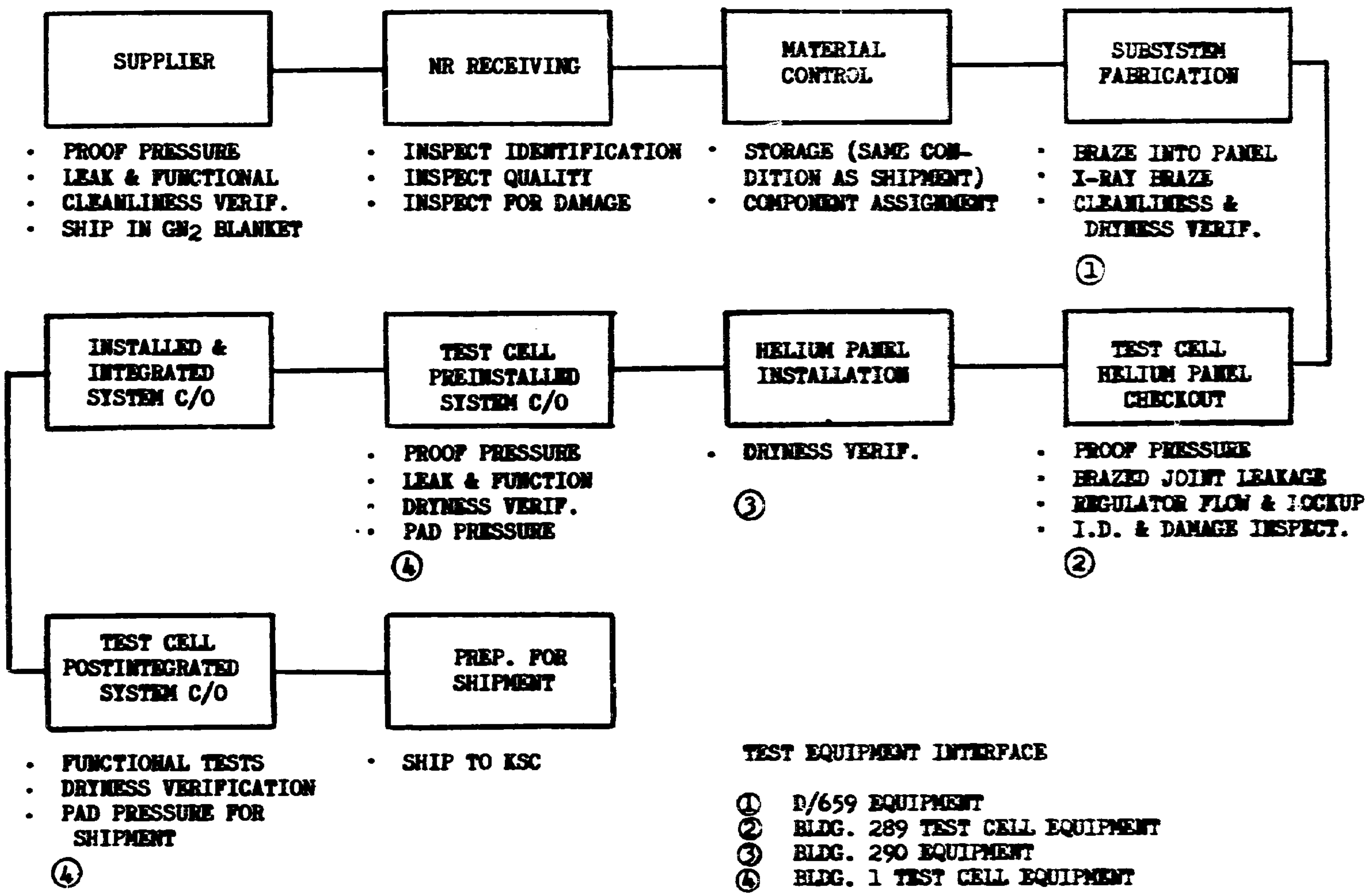
SUPPLIER:

- ACCEPTANCE TESTS:
  - EXAMINATION OF PRODUCT
  - PROOF PRESSURE AND LEAKAGE TESTS
  - LOT ACCEPTANCE
  - CLEANLINESS (FLUSH WITH FREON, VACUUM OVEN DRY)
- PREPARATION FOR SHIPPING:
  - INNER BAG - NYLON
  - OUTER BAG - POLYETHYLENE
  - PURGE WITH DRY N_2 & SQUEEZE OUT N_2. SEAL BAGS

SUBSYSTEM FABRICATION:

- REMOVE FROM DOUBLE BAG
- VISUAL INSPECT FOR CONTAMINATION & DAMAGE
- PERFORM GAS FLOW (GN_2)
- PERFORM CLEANLINESS VERIFICATION (CHECK FOR PARTICULATE)
- BRAZE INTO SYSTEM (ARGON)
- X-RAY INSPECT BRAZED JOINT
- BAG ASSEMBLED PANEL

CM RCS HELIUM PRESSURE REGULATOR FLOW CHART



C M R C S H E L I U M P R E S S U R E R E G U L A T O R

SUPPLIER:

- ACCEPTANCE TESTS:
  - EXAMINATION OF PRODUCT
  - PROOF PRESSURE AND EXTERNAL LEAK
  - INTERNAL LEAK
  - FUNCTIONAL LEAK
  - BLOW DOWN
  - CLEANLINESS TEST (GN_2 PURGE)
- PACKAGING
  - BAG TUBE ENDS
  - DOUBLE BAG
  - PURGE INNER BAG WITH GN_2

CM RCS HELIUM PRESSURE REGULATOR

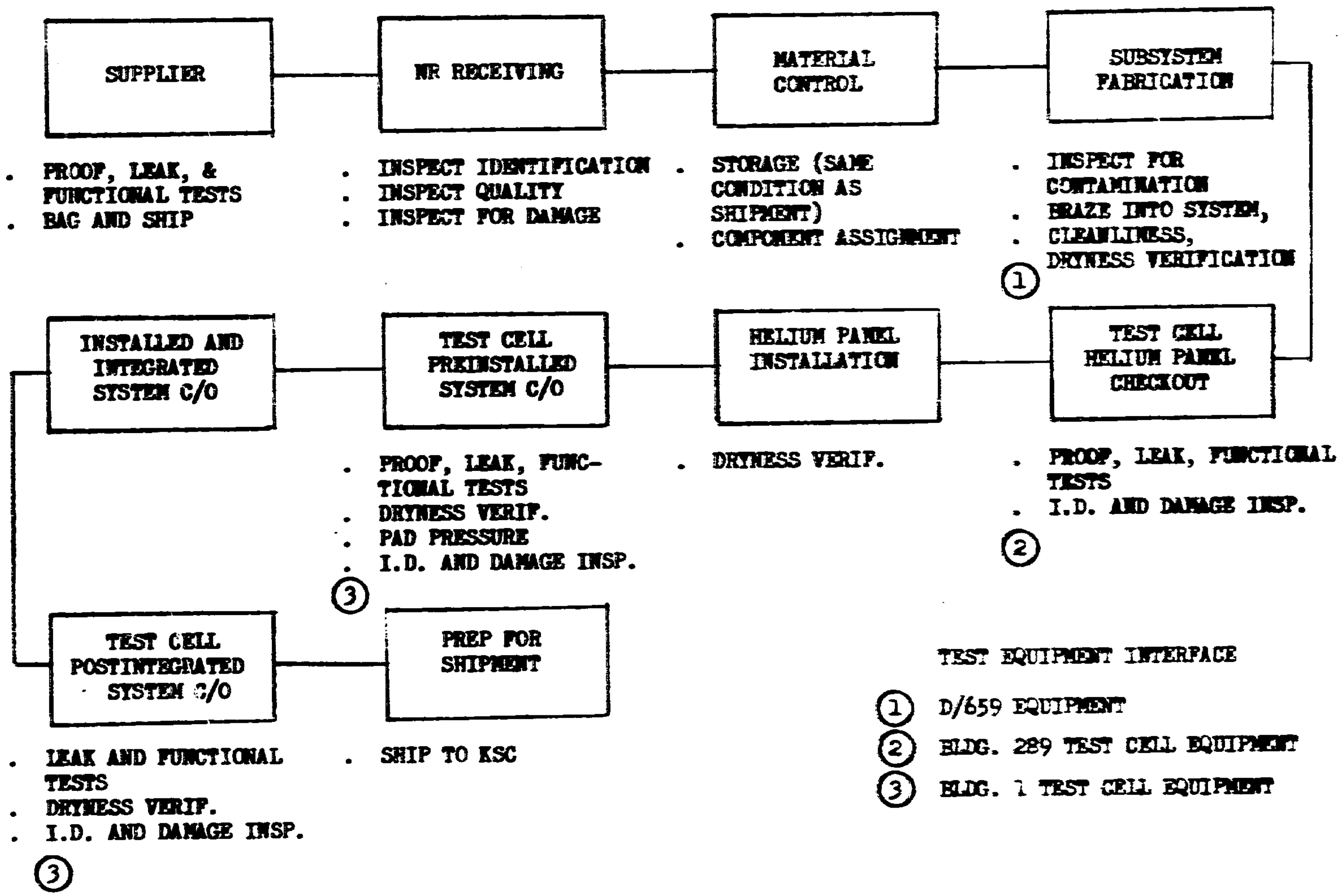
SUBSYSTEM FABRICATION:

- REMOVE REGULATOR FROM DOUBLE BAG
- VISUAL INSPECT FOR CONTAMINATION AND DAMAGE
- BRAZE INTO SUBSYSTEM (ARGON)
- X-RAY BRAZED JOINTS
- PERFORM SYSTEM CLEANLINESS VERIFICATION
- PERFORM DRYNESS VERIFICATION TEST
- BAG TUBE ENDS
- PACKAGE FOR TRANSFER TO TEST CELL

CM RCS HELIUM PRESSURE REGULATOR

FUNCTIONAL C/O	TEST CELL PREINSTALLED SYSTEM C/O	TEST CELL POSTINTEGRATED SYSTEM C/O
• PROOF PRESSURE	X	
• REGULATOR FLOW & LOCKUP	S/C 009 THRU 110	S/C 101 & SUBS
• REGULATOR LEAKAGE	X	
• REGULATOR RESPONSE	S/C 011 THRU 110	S/C 101 & SUBS
• DRYNESS VERIFICATION	S/C 108 & SUBS	S/C 103 & SUBS
• PAD PRESSURE	X	50 PSIG FOR SHIP
• IDENTIFICATION & DAMAGE INSP.	X	X
• TEST EQUIPMENT INTERFACE	BLDG. 289 TEST CELL	BLDG. 289 TEST CELL

CM RCS HELIUM SYSTEM CHECK VALVE FLOW CHART



C M R C S H E L I U M P R E S S U R E C H E C K V A L V E

SUPPLIER

- ACCEPTANCE TESTS
  - EXAMINATION OF PRODUCT
  - PROOF PRESSURE AND EXTERNAL LEAK TEST
  - CRACKING PRESSURE
  - PRESSURE PROP
  - FUNCTIONAL TEST
  - CLEANLINESS - (FLUSH WITH FREON - VACUUM OVEN DRY)
  - PREPARATION FOR SHIPPING

    INNER BAG - NYLON

    OUTER BAG - POLYETHYLENE

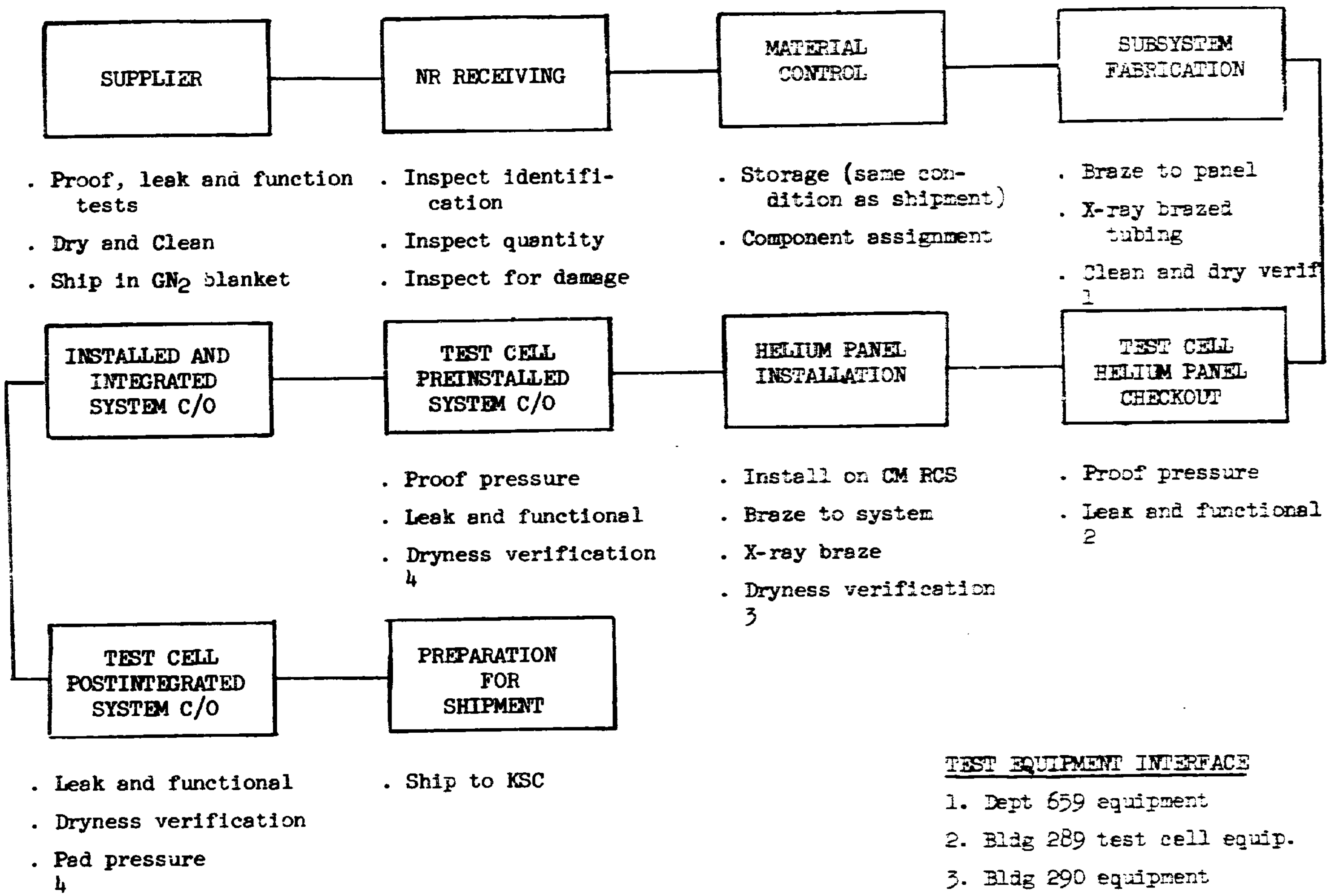
SUBSYSTEM FABRICATION

- REMOVE FROM DOUBLE BAG
- VISUAL INSPECT FOR CONTAMINATION
- BRAZE IN SYSTEM (ARGON PURGE)
- CLEANLINESS VERIFICATION (GN_2 FLOW)
- DRYNESS VERIFICATION (GN_2 FLOW)
- PACKAGE FOR TRANSFER

CM RCS CHECK VALVES

	PANEL C/O	PRE-INSTALLED C/O	POST-INTEGRATED C/O
• PROOF PRESSURE	X	X	
• CHECK VALVE CRACKING PRESSURE	X	X SC 108 THRU 110	X SC 111 & SUBS
• CHECK VALVE BACKFLOW LEAKAGE	X	X SC 009 THRU 110	X SC 101 & SUBS
• EXTERNAL LEAKAGE OF BRAZED JOINTS	X		
• CHECK VALVE DELTA P FLOW TEST		X SC 012 THRU 103	X SC 101 THRU 103
• DRYNESS VERIFICATION		X SC 108 & SUBS	X SC 103 & SUBS
• PAD PRESSURE		X	X 50 PSIG FOR SHIPPING
• I.D. AND DAMAGE INSP.	X	X	X
• TEST EQUIPMENT INTERFACE	B/239 TEST CELL	B/1 TEST CELL	B/1 TEST CELL

CM RCS HELIUM PRESSURE RELIEF VALVE FLOW CHART



<u>TEST EQUIPMENT INTERFACE</u>

1. Dept 659 equipment
2. Bldg 289 test cell equip.
3. Bldg 290 equipment
4. Bldg 1 test cell equipment

HELIUM PRESSURE RELIEF VALVE

Supplier:

Acceptance Tests

- Examination of product
- Proof pressure and external leak test
- Functional
- Internal leakage
- Cleanliness - (freon TF) flush - (vacuum dry)
- Packaging - bag tube ends - double bag - inner bag filled with dry GN_2

Subsystem Fabrication:

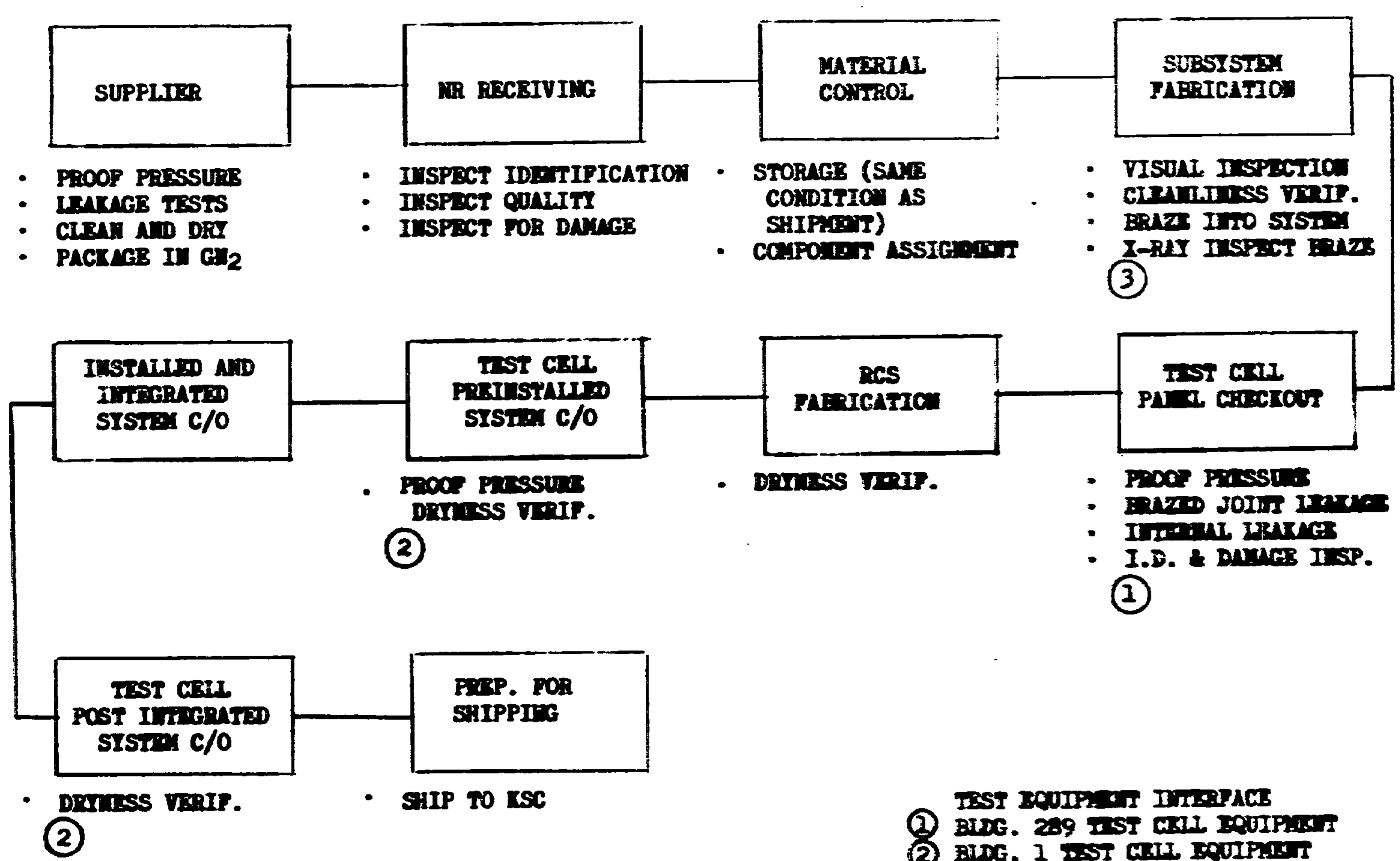
- Remove from double bag
- Visual inspect for contamination and damage
- Braze into subsystem (argon)
- X-ray brazed tubing
- Cleanliness verification
- Dryness verification
- Install aluminum foil cover over exhaust port of relief valve
- Bag tube ends and package for transfer

CM RCS RELIEF VALVE

Functional C/O	Panel Checkout	Preinstalled System C/O	Postintegrated System C/O
. Proof pressure	X	X	
. Brazed joint leakage	X	X	
. Diaphram leakage	X	009 thru 110	012 and subs
. Low pressure vent poppet function and leakage	X	101 thru 110	101 and subs
. Relief and vent poppet leakage	X	009 thru 110	101 and subs
. Relief poppet cracking and reseat	X	009 thru 110	101 and subs
. Dryness verification		108 and subs	103 and subs
. Vent port cover (not reused)		remove, test, replace	remove,test, replace
. Pad pressure		X	X 50 psig for ship
. Test equipment interface	Test Cell 289 Test Equipment	Bldg. 1 Test Cell Test Equipment	Bldg. 1 Test Cell Test Equipment

X = ~009 and subs

CM RCS SYSTEM INTERCONNECT VALVES (EXPLOSIVE ACTUATED) FLOW CHART



CM RCS SYSTEM INTERCONNECT VALVES (EXPLOSIVE ACTUATED)

SUPPLIER:

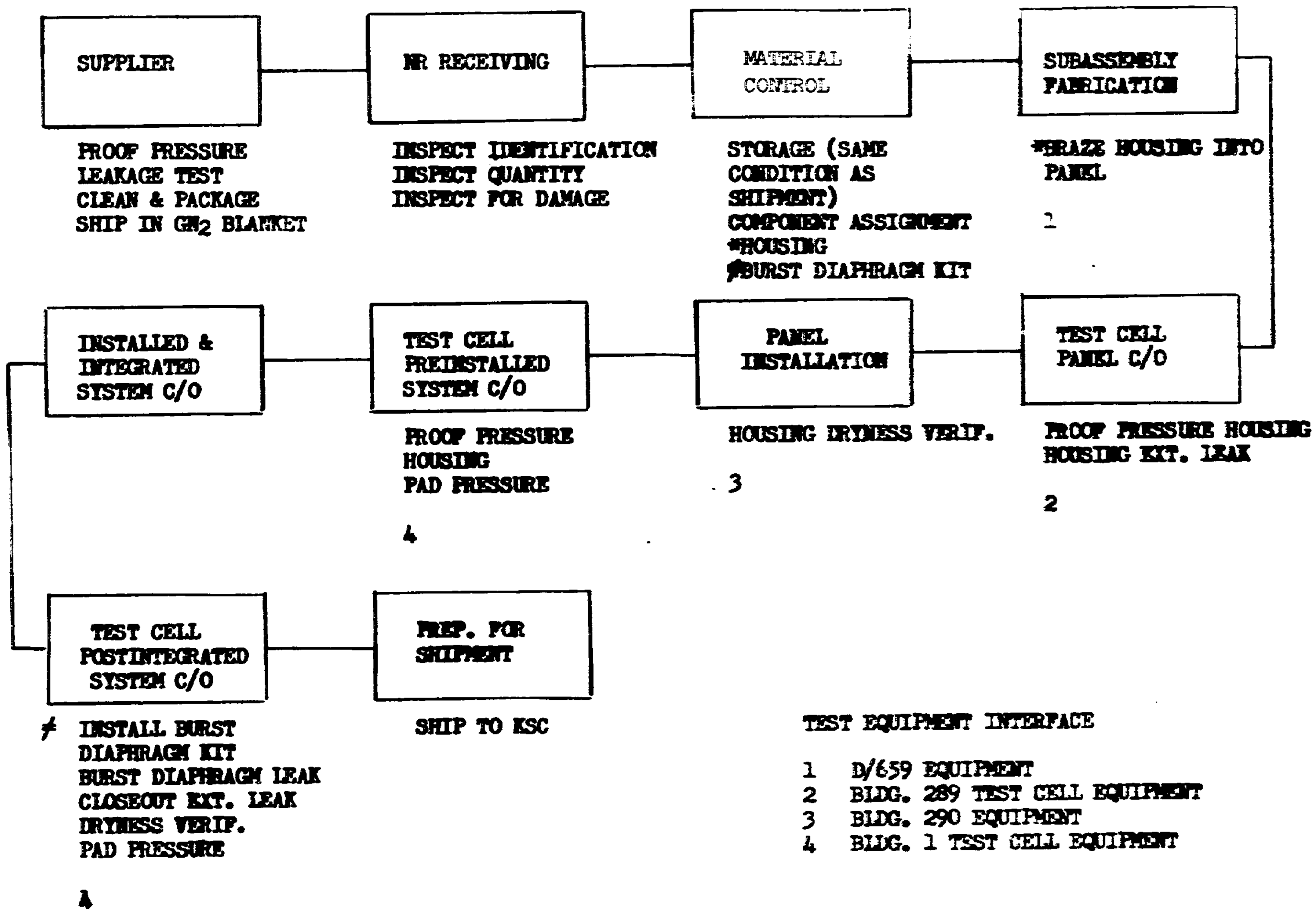
ACCEPTANCE TESTS

- EXAMINATION OF PRODUCT
- PROOF PRESSURE AND LEAKAGE TESTS
- LOT ACCEPTANCE
- CLEANLINESS (FLUSH WITH FREON - VACUUM OVEN DRY)
- PREPARATION FOR SHIPPING - 1. (INNER BAG = NYLON) 2. (OUTER BAG = POLYETHYLENE)
- PACKAGE WITH GN_2 BLANKET AND SEAL BAGS

SUBSYSTEM FABRICATION:

- REMOVE FROM DOUBLE BAG
- VISUAL INSPECT FOR CONTAMINATION AND DAMAGE
- PERFORM CLEANLINESS VERIFICATION - CHECK FOR PARTICULATE
- BRAZE INTO SYSTEM (ARGON)
- X-RAY INSPECT BRAZED JOINT
- BAG PANEL

CM RCS PROPELLANT BURST DIAPHRAGM HOUSING AND KIT FLOW DIAGRAM



CM RCS PROPELLANT BURST DIAPHRAGM

SUPPLIER:

- HOUSING
  - ACCEPTANCE TESTS
    - EXAMINATION OF PRODUCT
    - PROOF PRESSURE
    - CLEANLINESS TEST (FLUSHED WITH FREON - OVEN DRYED)
    - PACKAGING (FILLED WITH DRY GN_2 INNER BAG)

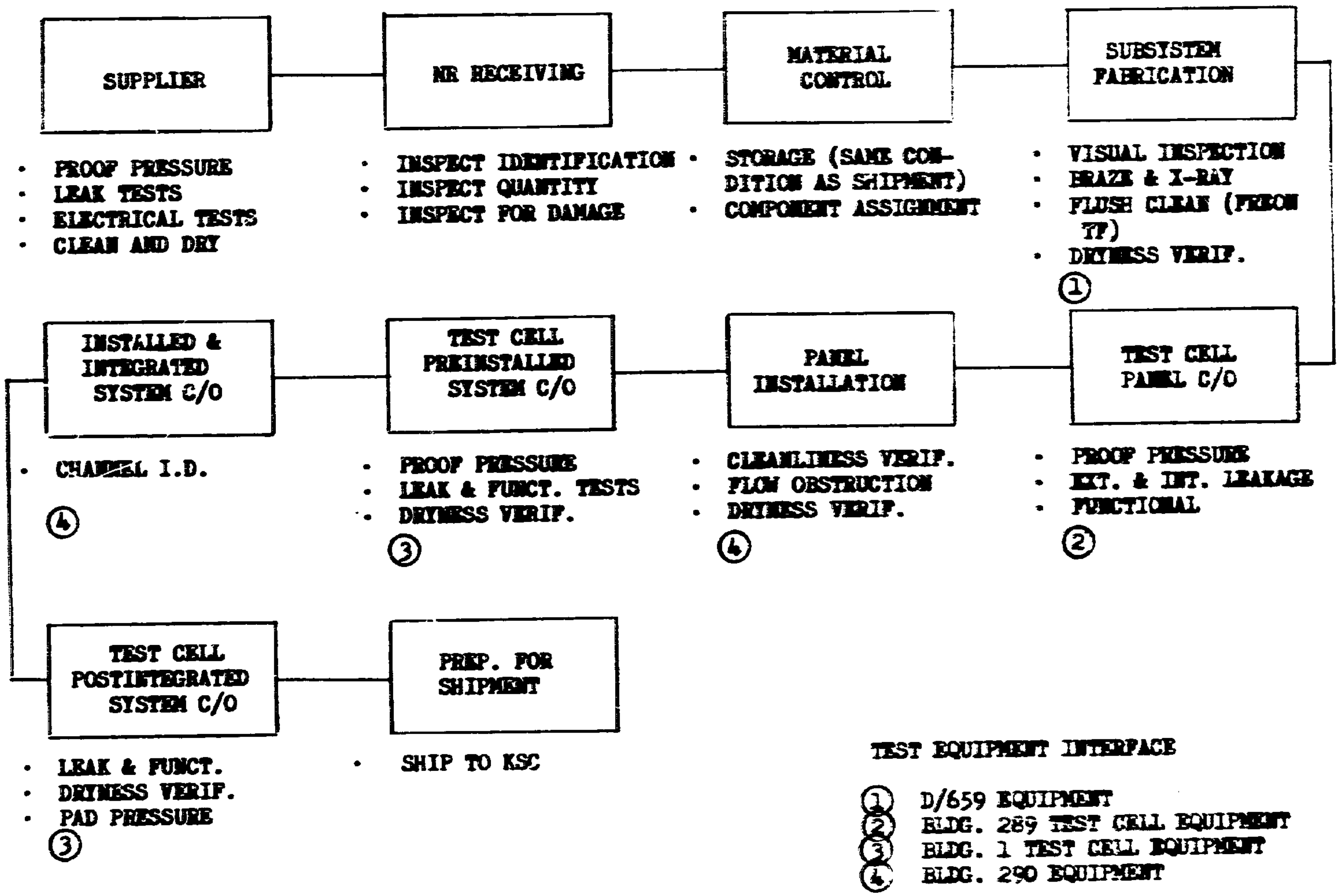
- REPLACEMENT KIT
  - ACCEPTANCE TESTS
    - EXAMINATION OF PRODUCT
    - FILTER PERFORMANCE
    - BURST DIAPHRAGM DEFLECTION
    - INTERNAL LEAKAGE
    - BURST DIAPHRAGM RUPTURE PRESSURE
    - PRESSURE DROP
    - CLEANLINESS TEST (FLUSH WITH FREON - OVEN DRIED)
    - PACKAGING (FILLED WITH DRY GN_2 - INNER BAG)

CM RCS PROPELLANT BURST DIAPHRAGMS

FUNCTIONAL C/O	PANEL CHECKOUT	PREINSTALLED SYSTEM C/O	POST INTEGRATED SYSTEM C/O
PROOF PRESSURE HOUSING	X	X	
EXTERNAL LEAKAGE OF BRAZED AND MECHANICAL JOINTS	X		
INSTALL BURST DIAPHRAGM KIT			S/C 009, 011, S/C 104 & Subs
BURST DIAPHRAGM LEAKAGE	X	X	X
CLOSEOUT - EXTERNAL LEAKAGE		SC 009, 011	SC 104 & Subs
DRYNESS VERIFICATION		SC 108 & Subs	SC 103 & Subs
PAD PRESSURE		X	50 PSIG FOR SHIPPING
ID AND DAMAGE INSPECTION	X	X	X
TEST EQUIPMENT INTERFACE	Bldg. 289 Test Cell	Bldg. 1 Test Cell	Bldg. 1 Test Cell

NOTE: BURST DIAPHRAGM INSTALLED AT KSC S/C 012 THRU 103.

CM RCS PROPELLANT ISOLATION VALVE FLOW CHART



C M R C S P R O P E L L A N T I S O L A T I O N V A L V E

SUPPLIER:

- ACCEPTANCE TEST
  - EXAMINATION OF PRODUCT
  - PROOF PRESSURE AND EXTERNAL LEAK
  - INTERNAL LEAKAGE
  - ELECTRICAL CHARACTERISTICS
  - PRESSURE DROP
  - CLEANLINESS AND DRYNESS VERIFICATION (FREON TF & VACUUM OVEN DRY)

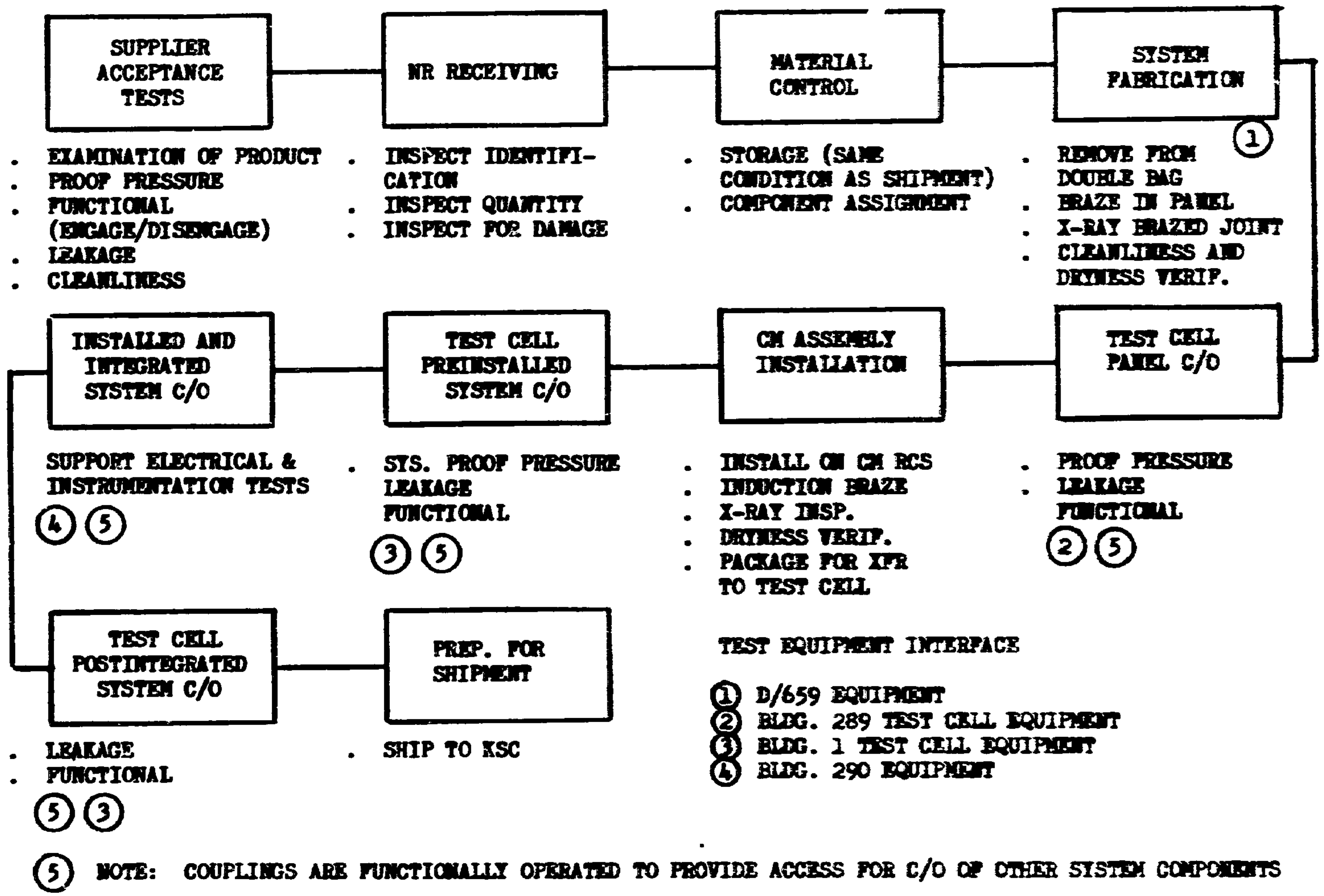
  PREPARE FOR SHIPMENT

  - PACKAGE IN DOUBLE BAG WITH GN_2 ENVIRONMENT

CM RCS PROPELLANT ISOLATION VALVE

FUNCTIONAL C/O	PANEL CHECKOUT	PREINSTALLED SYSTEM C/O	POST INTEGRATED SYSTEM C/O
• PROOF PRESSURE	X	X	
• EXTERNAL LEAKAGE OF BRAZED JOINTS	X		
• VALVE FUNCTIONAL	X	X	X
• VALVE LEAKAGE	X	X	X
• I.D. AND DAMAGE INSPECTION	X	X	X
• DRYNESS VERIFICATION		X	X
• PAD PRESSURE		X	X 50 PSIG FOR SHIP
• TEST EQUIPMENT INTERFACE	BLDG. 289 TEST CELL	BLDG. 1 TEST CELL	BLDG. 1 TEST CELL

C M   R C S   F I L L   A N D   V E N T   C O U P L I N G   F L O W   C H A R T

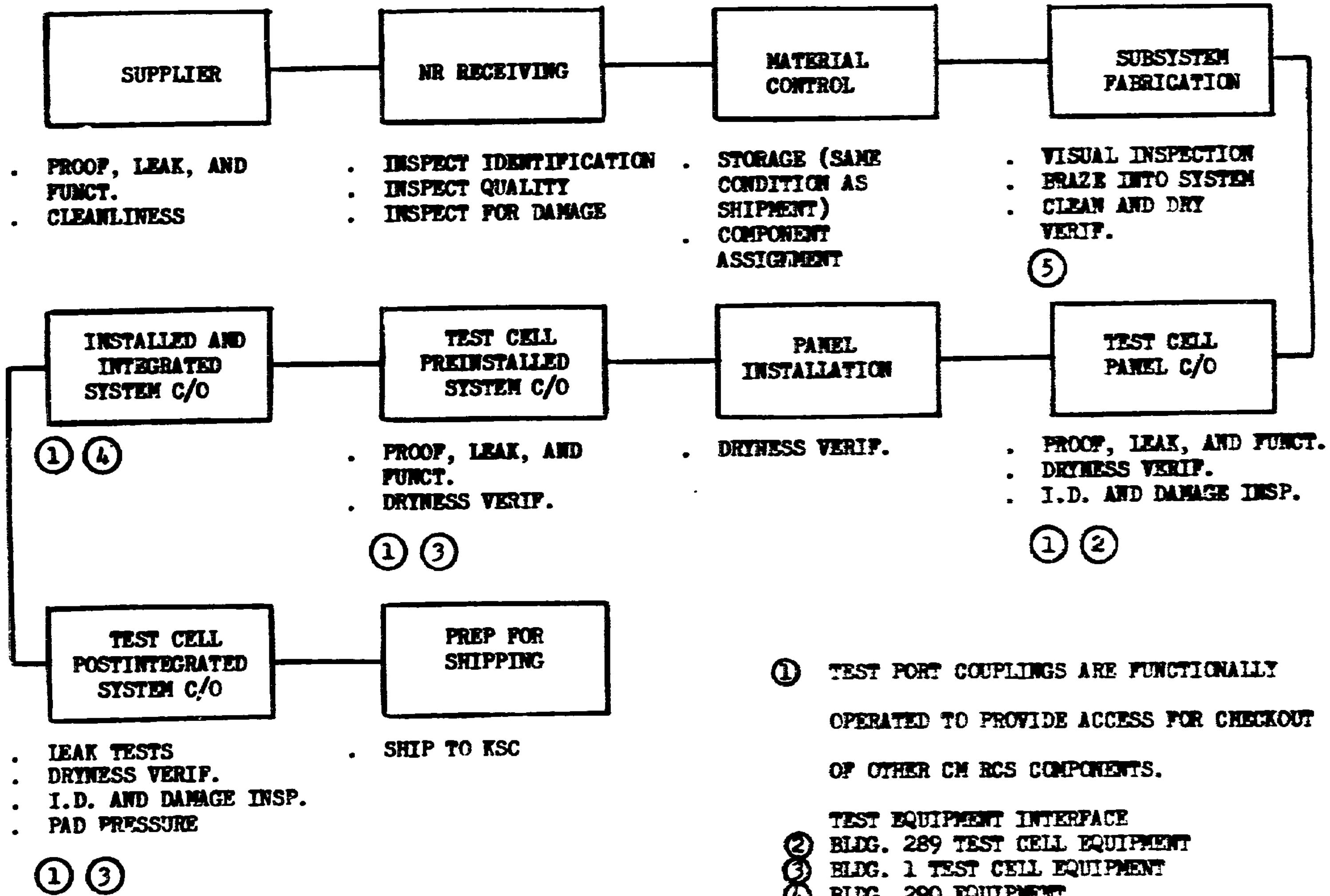


CM RCS FILL AND VENT COUPLINGS

	PANEL C/O	PRE-INSTALLED C/O	POST-INTEGRATED C/O
. PROOF PRESSURE	X	X	
. INTERNAL LEAKAGE (DUST CAPS "OFF")	X	X	X SC 014 & SUBS
. EXTERNAL LEAKAGE (DUST CAPS "ON")	X	X	X SC 014 & SUBS
. COUPLING FUNCTIONAL	X	X	X
. DRYNESS VERIFICATION		X SC 108 & SUBS	X SC 103 & SUBS
. BRAZED JOINT EXTERNAL LEAKAGE	X		
. PAD PRESSURE		X	X 50 PSIG FOR SHIP'G.
. I.D. DAMAGE INSP.	X	X	X
. TEST EQUIPMENT INTERFACE	B/289 TEST CELL	B/1 TEST CELL	B/1 TEST CELL

NOTE: COUPLINGS ARE FUNCTIONALLY OPERATED TO PROVIDE ACCESS FOR C/O OF OTHER CM RCS COMPONENTS

CM RCS PROPULSION SYSTEM
TEST POINT COUPLING FLOW CHART



(1) TEST PORT COUPLINGS ARE FUNCTIONALLY OPERATED TO PROVIDE ACCESS FOR CHECKOUT OF OTHER CM RCS COMPONENTS.

TEST EQUIPMENT INTERFACE
(2) BLDG. 289 TEST CELL EQUIPMENT
(3) BLDG. 1 TEST CELL EQUIPMENT
(4) BLDG. 290 EQUIPMENT
(5) D/659 EQUIPMENT

C/O PROPULSION SYSTEM TEST POINT COUPLINGS

SUPPLIER:

- ACCEPTANCE TESTS
- EXAMINATION OF PRODUCT
- PROOF PRESSURE
- FUNCTIONAL (ENGAGE/DISENGAGE)
- PRESSURE DROP
- LEAKAGE
- CLEANLINESS
- SEAL INSPECTION
- PACKAGE AND SHIP

SUBSYSTEM FABRICATION

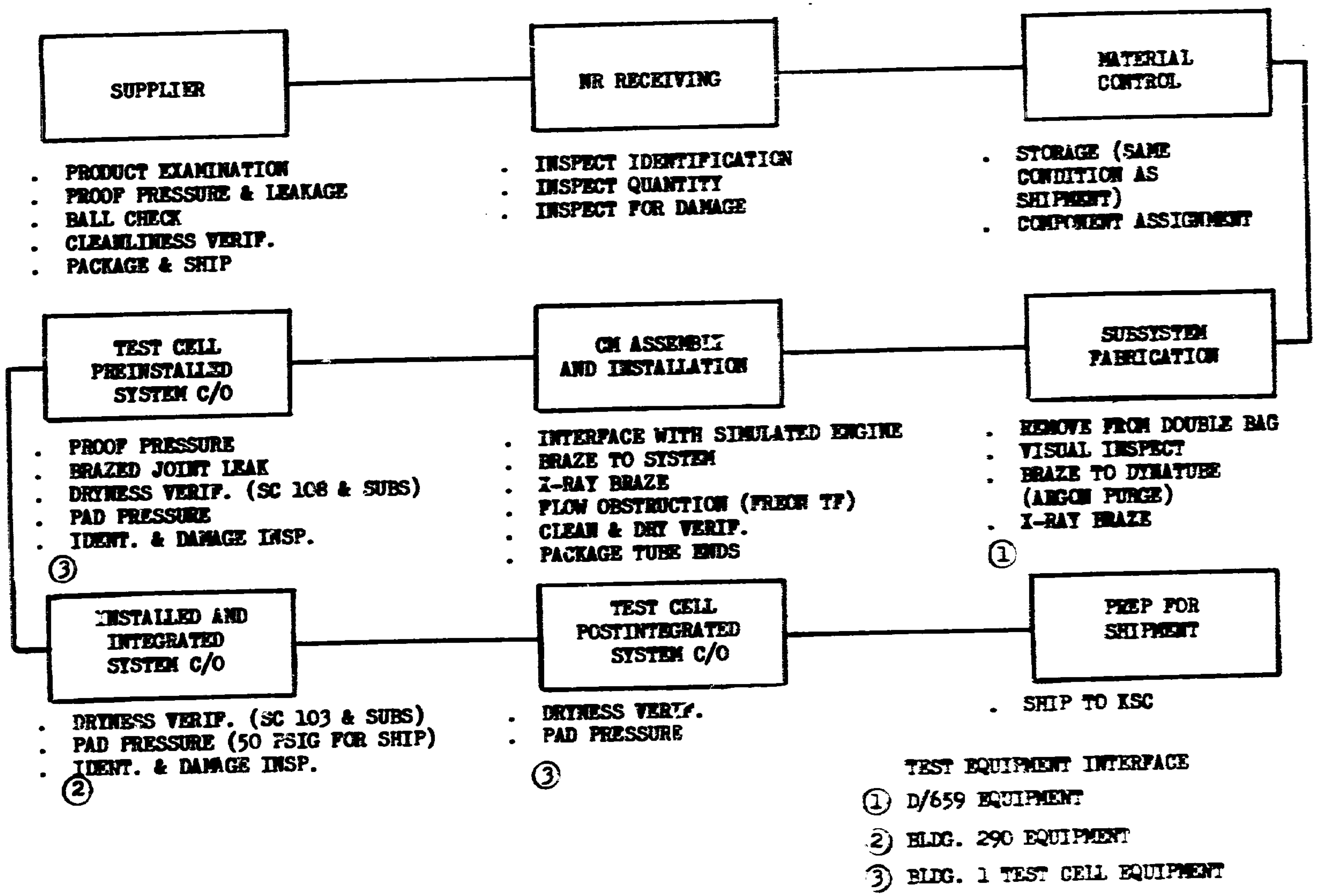
- REMOVE FROM DOUBLE BAG
- VISUAL INSPECT FOR CONTAMINATION AND DAMAGE
- BRAZE IN SYSTEM (ARGON PURGE)
- CLEANLINESS VERIFICATION (GN_2 FLOW)
- DRYNESS VERIFICATION (GN_2 FLOW)
- PACKAGE FOR TRANSFER

CM RCS TEST PORT COUPLINGS

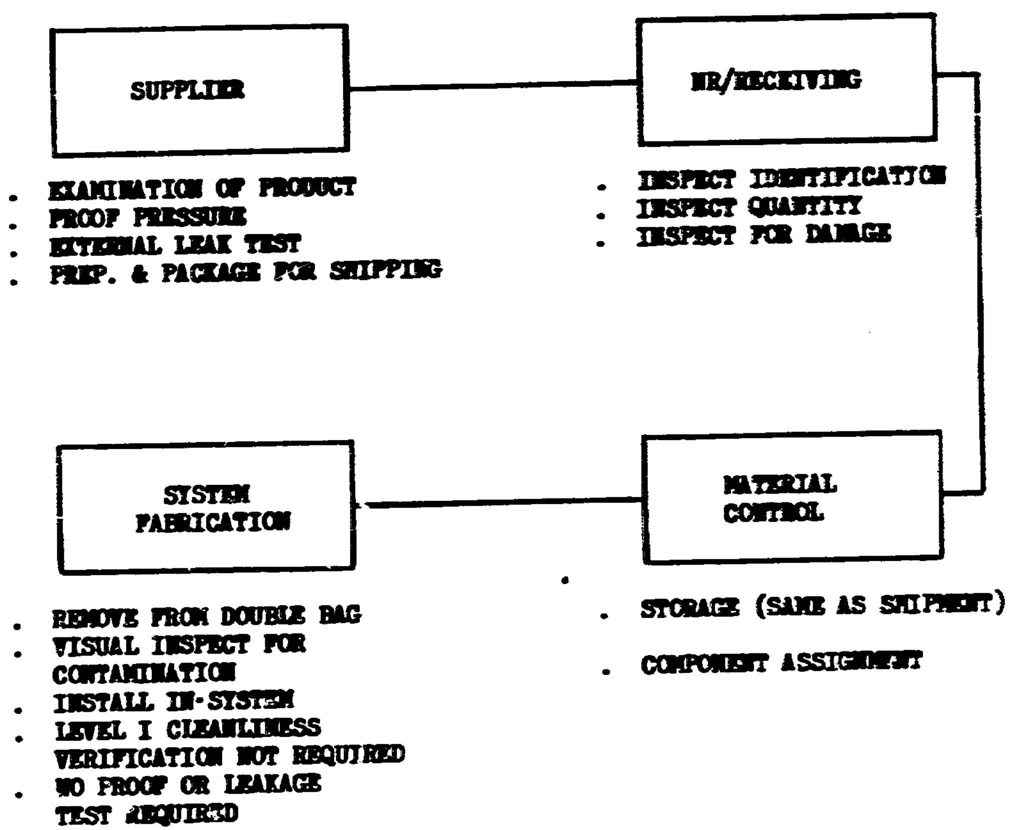
	PANEL C/O	PRE INSTALLED C/O	POST INTEGRATED C/O
• PROOF PRESSURE	X	X	
• INTERNAL LEAKGE (DUST CAPS OFF)	X	X	X S/C 014 & SUBS
• EXTERNAL LEAKAGE (DUST CAPS ON)	X	X	X S/C 014 & SUBS
• BRAZED JOINT EXTERNAL LEAKAGE	X		
• DRYNESS VERIFICATION		X S/C 108 & SUBS	X S/C 103 & SUBS
• IDENTIFICATION AND DAMAGE INSPECTION	X	X	X
• PAD PRESSURE		X	X 50 PSIG FOR SHIPPING
• TEST EQUIPMENT INTERFACE	BLDG. 289 TEST CELL	BLDG. 1 TEST CELL	BLDG. 1 TEST CELL

NOTE: TEST PORT COUPLINGS ARE FUNCTIONALLY OPERATED TO PROVIDE ACCESS FOR CHECKOUT OF OTHER RCS COMPONENTS.

CM RCS FLEX HOSE FLOW CHART

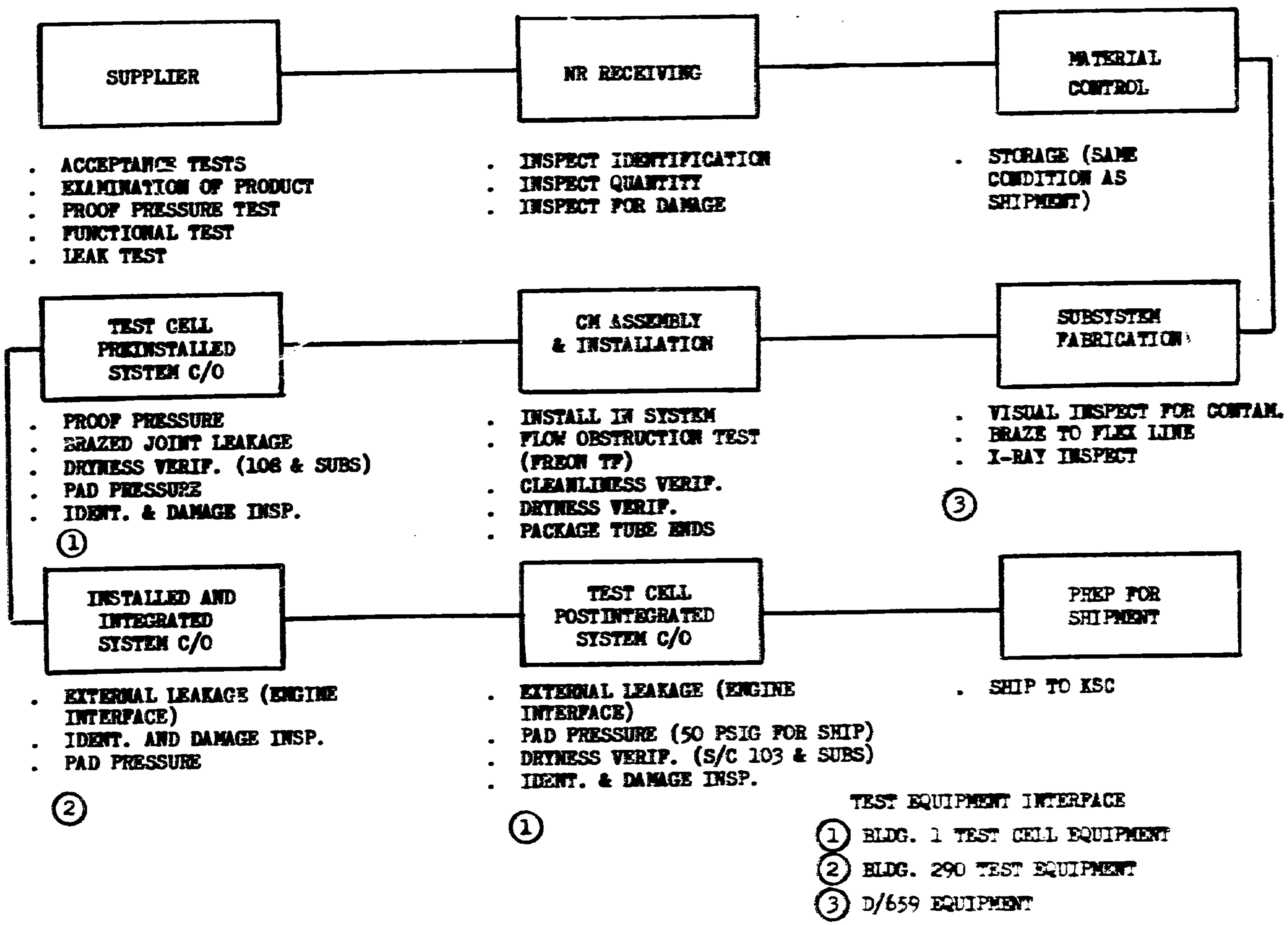


C M RCS DUMP HOSE FLOW CHART



NO TEST EQUIPMENT NECESSARY

CM RCS DYNATUBE FITTING FLOW CHART



KSC - RCS OPERATIONS
CM & SM

	BLOCK I					BLOCK II							
	009	011	012	017	020	101	103	104	106	107	108	109	110
MSOB	CSM-I	CSM-I CM-LF SM-LF	CSM-I CM-LF SM-LF	SM-LF	SM-LF	SM-LF CM-LF CSM-I	SM-LF CSM-I	CSM-I →	→	→	→	→	CSM-I
HYPER	CM-LF SM-LF												
LC 34	CSM-I CSM-S					CSM-I CSM-S							
VAB				CM-LF CSM-I	CM-LF CSM-I		CM-LF CSM-I	CSM-I → CSM-LF₁ →	→	→	CSM-I CSM-LF₁		
LC 39				CSM-S	CSM-I CSM-S		CSM-I CSM-S	CSM-I → CSM-LF₁ → CSM-S →	→	→	→	CSM-LF₁	CSM-I CSM-LF CSM-S

CM / SM (solid lines) LF = DETAILED COMPONENT LEAK & FUNCTIONAL - PRIME & REDUNDANT FUNCTIONS

CM / SM (dashed lines) LF_1 = LIMITED LEAK & FUNCTIONAL - PRIME FUNCTIONS ONLY - LIMITED DUE TO DETAILED CHECKOUT PRIOR TO SHIPMENT, SHORT KSC FLOW AND ESTABLISHED COMPONENT RELIABILITY - EFFECTIVE S/C 104 THROUGH 109 ONLY.

I = INTEGRATED TESTS - RCS PARTICIPATION & SUPPORT

S = PROPELLANT/GAS SERVICING FOR LAUNCH

70AP107379

KSC RECEIVING (MSOB)

PURPOSE
- TO PERFORM A VISUAL AND PHYSICAL RECEIVING INSPECTION

DOCUMENT
- TCP K 3084

OPERATION
- INSPECTION OF QUADS, CM RCS
  - WIRING
  - CONNECTORS
  - TERMINAL BOARDS
  - PRESSURE VESSELS
  - ENGINES
  - PROTECTIVE COVERS
  - COMPONENTS
  - IDENTIFICATIONS
  - LINES
  - BRACKETS/CLAMPS
  - WIRE LOCKING
- REMOVAL OF SM ENGINE SHIPPING COVERS
- INSTALLATION OF A14-146 SM ENGINE THROAT
- PLUGS AND Z00-091 SM ENGINE COVERS

HYPERGOLIC FACILITY CHECKOUT

S/C 009 ONLY

- CM LEAK AND FUNCTIONAL TEST
- CM ENGINE FLOW TEST
- SM LEAK AND FUNCTIONAL TEST
- SM ENGINE FLOW TEST

MSOB CHECKOUT OPERATIONS

COMBINED SYSTEMS TEST K-0070	SIM. ALTITUDE TEST K-0048	ALTITUDE TEST K-0034	S/C TRANSPORT K-3117
• Disconnects Quads electrically for AI4-275 RCS Engine Simulator Installation - Simulators Support K0070 Through K0034 • Monitor CSM System Pressures For Decay Subsequent to Shipment Preps	Prep system for altitude runs Perform: • SM Heater functional (no limit cycling) • CM Heater functional • CSM isolation valve functional	Perform at altitude: • SM Heater functional (inc. limit cycling) • CM Heater functional • CSM isolation valve functional Post Test • Remove A14-275 RCS Engine Simulators and Reconnect quads	• Prep engines (weatherproof) for transport to VAB/PAD

FLOW SHOWN IS FOR S/C 104 AND SUBS.

MSOB CHECKOUT OPERATIONS

(PRE S/C 104)

S/C 011 THROUGH 103	SM RCS LEAK AND FUNCTIONAL TESTS
S/C 011 ONLY	SM RCS ENGINE FLOW TEST
S/C 011, 012 AND 101	CM RCS LEAK AND FUNCTIONAL
S/C 101 AND 103	CSM - ALTITUDE TESTS

VAB CHECKOUT OPERATIONS

S/C 109 and subs	. No power on tests . No RCS operations
S/C 017 and 020	. CM RCS leak and functional test . CSM Engine valve response tests
S/C 103	. CSM Engine valve response tests
S/C 104 thru 108	. CSM Limited leak and functional tests (Lo pressure) . CSM Engine valve response tests

LAUNCH PAD CHECKING AND SERVICING OPERATIONS (LC39)

INTEGRATED TEST K-0005	FLIGHT READINESS TEST K-0028	PROPULSION SYSTEMS VERIFICATION K-0052	PROPELLANT SERVICING K-0038	CDDT COUNTDOWN K-0007
PERFORM:	PERFORM:	PERFORM:	PERFORM:	PERFORM:
. CSM Isolation Valve Functional	. CM Engine temp TDCR upper limit check	. CSM Final Engine leak test	. CSM Propellant Servicing for flight.	. Final CSM Systems decay check
. CSM Engine Valve Response	. Engine I/D	. CSM Helium Servicing and Vent		. CM Propellant Systems press. for flight
. CSM Caution and Warning	. SM Engine Heater functional			. CSM helium servicing for flight
. CRT/Panel/Gage Correlation				. Activate SM system for flight
. CSM Relief Valve Checkout				
. CSM Regulator Checkout				
. CSM Isolation Valve leak check				
. CSM Engine leak checks and flows				
. CM Propellant burst disc leak check				
. CSM moisture checks				
. CSM check valves checkout				
. CSM Bladder permeation				
. Close out quads for flight				

FLOW SHOWN IS FOR S/C 110 AND SUBS.

LAUNCH PAD CHECKOUT AND SERVICING OPERATIONS

PRE S/C 110

LC 39

S/C 104 through 108	. CSM RCS limited leak and functional tests (high pressure)
	. CSM engine valve response
S/C 109	. CSM RCS limited leak and functional tests (high and low pressure)
	. CSM Engine valve response
S/C 103	. CSM preservicing leak test
S/C 103 through 109	. CSM gas and propellant servicing

LC 34

S/C 009, 011, 012, 101	. CSM engine valve response
S/C 009, 011, 101	. CSM preservicing leak test
	. CSM gas and propellant servicing

RCS CHECKOUT DEFINITION

KSC

TCP 0070	Monitor for system decay No significant decay in shipping pressures • CM helium 100 ± 5 psig • CM helium manifold 50 ± 5 psig • SM helium 50 ± 5 psig • SM helium and propellant manifolds 50 ± 5 psig
TCP 0048	SM heater functional Verify package temperature increase in both pri and sec modes (min. 10 deg. F) CM heater wiring functional Verify simulated engine response following CM heater switch actuation
TCP 0034	SM heater functional Verify cycle limits in pri and sec modes at altitude Cutoff 141.5 ± 17.5°F Cuton 120. ± 15°F Monitor CRT and panel 2 CM heater wiring functional (reference 0048) Isolation valve functional Cycle each isolation valve switch open-close. Verify correct enunciator/GSE displays.
TCP 0005	Isolation valve functional (Reference 0034) Engine valve response Pressure 10 ± 5 psig

SM normal - ACE subroutine

SM direct - ROT controller

CM direct - ROT controller

CM normal - ACE subroutine

Caution and Warning

Quad fuel man. and engine package temp limits

Correlation CRT versus panel 2 displays

SM quantity

SM helium tank pressure

Fuel manifold pressure

Engine package temperature

SM relief valve test

Bypass poppet functional

Relief poppet cracking (236.5 ± 11.5 psig)

Relief poppet reseat (220 psi min.)

Primary/bypass poppets leak check at 196 ± 4 psig (20 cc max/hr)

SM regulator test

Individual regulator flow and lockup (pri flow
181 ± 4 psig
L/U 188 psig max

sec flow 183 ± 6 psig
L/U 192 psig max)

Primary leakage check - helium manifold increase 8.7 psi/hr.

SM propellant valve leakage
205 ± 5 psig ⊁ 100 cc/hr

SM engine flow test

200 ± 5 psig - verify delta P
Correlation between engines

SM engine valve leak test

100 ± 5 psig $\ngtr$ 30 cc/hr

SM helium isolation valves leak test

1000 ± 25 psig $\ngtr$ 60 cc/hr

SM moisture check

TP 13, 14, 15, and 16 $\ngtr$ 90 ppm

SM check valve tests

Individual cracking α 9 ± 1 psig

Leak check secondaries $\ngtr$ 3.6 cc/hr

Leak check primaries $\ngtr$ 3.6 cc/hr

SM bladder permeability

10 ± 1 psig oxid $\ngtr$ 240 cc/15 min
fuel $\ngtr$ 210 cc/15 min

CM relief valve test

Bypass poppet functional

Relief poppet cracking (346 ± 14 psig)

Relief poppet reseat (327 min)

Pri/bypass poppets leak check (20 cc ^{max}/hr)
at 305 ± 5 psig

CM regulator test

Individual regulator flow and lock up
(pri flow 291 ± 6 psig
L/U 302 psig max
sec flow 285-302 psig
L/U 308 psig max)

Primary leakage check - helium manifold
increase $\ngtr$ 7.8 psi/hr

CM propellant isolation valve leak check
302 ± 5 psig $\ngtr$ 100 cc/hr

CM engine flow test
200 ± 5 psig - verify delta P correlation
between engines

6-100

CM engine leak check

$300 \pm {}^{0}_{5}$ psig 20 cc/hr

CM propellant burst disc LK-CK

170 ± 5 psig ≯ 3.6 cc/hr

CM moisture check

TP 14, 15, 64, 65 ≯ 90 PPM

CM check-valve leak checks

individual cracking α 9 ± 1 psig

leak check secondaries ≯ 3.6 cc/hr

leak check primaries ≯ 3.6 cc/hr

CM bladder permeability

10 ± 1 psig oxid ≯ 130 cc/15 min

fuel ≯ 120 cc/15 min

K0028 SM heater functional

Verify package temperature increase in pri mode

CM heater functional

Verify engine fire and temp transducers upper limit

CSM engine identifications

Verify individual oxid and fuel flows from each engine fired in normal and direct modes.

K0052 CSM engine leak check

CM 300 ± 5 ≯ 20 cc/hr

SM 100 ± 5 ≯ 100 cc/hr

CSM helium pressurization

4350 ± 100 psia

5

PT sensor functional

Transducer correlation

Vent to 50 psia

K0038 Fuel servicing (loads per ODB Vol. III)

CMA, B load (soft-fill, weigh scale)

CMA,B PV load verification

SM A,B,C,D pri load (hard fill)

SM A,B,C,D aux. load (soft-fill, weigh scale)

SM A,B,C,D pri ullage withdrawal

SM A,B,C,D total ullage pv check

Oxidizer servicing (loads per ODB Vol III)

CM a,b, load (soft-fill, weigh scale)

CM A,B PV load verification

SMA, B,C,D pri and aux load (hard fill)

SMA,B,C,D pri and aux ullage withdrawal
SMA,B,C,D total ullage PV check

K0007 Closeout pressures for CM 100 ± 5 psia helium manifolds

CSM helium pressurization for flight
pressure SM He to 500 psig
pressure SM prop to reg lockup
pressure CSM He to 4150 ± 50 psia at 70 deg. F (normal)

Monitor all parameters for final system integrity prior to flight. SM RCS propellant system activation.

DRAWING/ SPECIFICATION	NAME	REMARKS
V37-460105	QUAD HELIUM PANEL	S/N 14 REQUIRES PROTECTIVE COVER ON RELIEF VALVE OUTLET PORT BUT SPECIFIES NO PART NUMBER. S/N 3 REQUIRES MAINTENANCE OF CLEANLINESS PER MA0610-017. NOT A MAINTENANCE SPECIFICATION, A METHODS AND REQUIREMENTS DOCUMENT. NEITHER PROBLEM IS CONSIDERED MAJOR. THE FIRST ONLY OCCURS IN THE CLEAN ROOM WHERE ALL PERSONNEL ARE CERTIFIED REGARDING PROPER TECHNIQUES FOR CONTAMINATION PROTECTION OF SPACECRAFT HARDWARE. THE SECOND IS BEING CHANGED TO MA0610-018 AND IS INTERPRETED AS STATING THE REQUIREMENTS FOR CLEANLINESS CONTROL.
V37-460107	SUPPORT	
V17-460123-3	TEE	
V17-460124	ELBOW	
V17-460130-3, -5	TEE	
V17-460135-3, -9	ELBOW	
V17-460160-5	CROSS	
V37-460105	QUAD HELIUM PANEL	
V37-460852	LINES	
MA0101-005 REV. "F"	INSTALLATION OF THREADED AND COLLARED FASTENERS	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

MANUFACTURING AND ASSEMBLY PROCESS ASSESSMENT

DRAWING/ SPECIFICATION	NAME	REMARKS
MA0101-008	INSTALLATION OF LD127-0048 SADDLE-TYPE LINE SUPPORTS	
MA0102-001	FABRICATION AND INSTALLATION OF RIGID AND FLEXIBLE TUBE ASSEMBLIES	
MA0103-005 REV. "C"	TOLERANCES ON MACHINED PARTS	TWO AMENDMENTS, NO E.O.'s
MA0103-010	ELECTROLYTIC POLISHING	
MA0104-003	APPLICATION OF ETCHED MARKINGS	
MA0210-0108	CHECK VALVE ASSEMBLY, APOLLO RCS, LEAKAGE AND FUNCTIONAL CHECKOUT	
MA0310-0021	THE PREPARATION AND CONDITIONING OF CRES DETAILS FOR BRAZING APOLLO PROPULSION SYSTEMS	
MA0310-0034	PROCEDURE FOR CONNECTING, DISCONNECTING, AND MAINTAINING THE CLEANLINESS OF APOLLO CSM RCS FLUID SYSTEMS DISCONNECT COUPLINGS	
MA0607-024	INDUCTION BRAZING OF CRES STEEL TUBE FITTINGS TO CRES AND INCONEL X FOR APOLLO CSM	
MA0610-017	PRECISION CLEANING METHODS AND CLEANING REQUIREMENTS FOR PARTS AND ASSEMBLIES OF APOLLO CSM FLUID SYSTEMS	
MB0295-006 REV. "C"	PRECISION CLEAN PACKAGING TRANSPARENT FILM	

COMMAND/SERVICE MODULE REACTION CONTROL SYSTEM

MANUFACTURING DOCUMENTATION REVIEW

BRAZE TUBING PER MA0607-024		
MACHINE FITTINGS PER MA0103-005	A	(REVISION LTR)
ELECTROLYTIC POLISH PER MA0103-010 TYPE I	B	
MARK PER MA0104-003 CLASS 2	B	
CLEAN PER MA0610-017 LEVEL 1	B	
PREPARE FOR BRAZE PER MA0310-0021	C	
FABRICATE AND BOND 3D RADII PER MA0102-001	B	
MARK WARNING PER MA175-5023-1517	D	
PACKAGE PER MB0295-006 LEVEL 1	E	
MARK PER MP175-0002-0001	E	

COMMAND/SERVICE MODULE REACTION CONTROL SYSTEM

MANUFACTURING AND ASSEMBLY ASSESSMENT

- CONTROL DOCUMENTATION REVIEWED
  - MACHINING
  - FORMING
  - MARKINGS
  - FINISHING
  - BRAZING
  - CLEANING
  - DRYING
  - PACKAGING

- NO PROBLEM AREAS FOUND
- SYSTEM FABRICATION TECHNIQUES ARE ADEQUATE

SECTION 7

CHECKOUT REQUIREMENTS FOR SM AND CM

REACTION CONTROL SYSTEM

Section 7 presents in tabular form the requirements for checkout of the Service Module and Command Module Reaction Control Subsystems and instrumentation. There is no written text.

SERVICE MODULE REACTION CONTROL SYSTEM - QUAD CHECKOUT SUMMARY

COMPONENT	DOWNEY						KSC		
	Supplier	Fabri-cation	Sub-System	COMPLETE SYSTEM			MSOB	VAB	Launch Pad
				Pre-Integrated	Installed-Integrated	Post-Integrated			
Helium Tank	P L			P L	S	L	L		F
P/T Sensor	P F			P L F	F	L F	L		F.
Fill Couplings	P L F	S		P L	S	L	L		F
Pressure Transducer	P F			P L F	F	L F	L		F
Helium Isolation Valve	P L F			P L F	F	L F	F		F L
Regulators	P L F			P		L F			F L
Check Valves	P L F			P		L F			F L
Test Ports	P L F	S		P L	S	L	L		F
Lines and Joints	P	C & D		P L	S		L		
Relief Valves	P L F			P L F		L F			F L
Propellant Tanks	P L F			P L F	S	L			F L
Temperature Sensors	F			F	F	F	F		
Propellant Isolation Valves	P L F	F		P F	F	L F	F		F L
Filters	P L F			P					
Heaters	F			F	F	F	F		
Engines	P L F	L F		P	F	L F			F L
Systems Complete		D		D	I	D			D

LEGEND:
- D - Dryness Verification
- P - Proof Pressure
- L - Leakage
- F - Functional
- S - Supporting
- C&D - Cleanliness and Dryness Verification
- I - Interface Verification

SM ENGINES

ME901-0004 (MARQUARDT)

TEST	SUPPLIER	SYSTEM MA0210-0208	SYSTEM MA0710-4182 MA0210-0148	SYSTEM MA0710-4224 MA0210-0190	PART II	TSCD	KSC
Resistance							
Voltage	500 ±50 vdc	100 vdc					
Resistance	20 megohms max	20 megohms max					
Injector Orifice Gas Flow							
Pressure (a)			Results reduced from data supplied by GFP-C-647 and DVM		(a) 125 ±15 psig at TP18 and 10 ±5 psig at TP17		
Pressure (b)					(b) 125 ±15 psig at TP17 and 20 ±5 psig at TP18		
Flow					Under condition (a) and (b) there shall be a gas flow from each engine injector orifice.		
Injector Valve Gas Flow							
Pressure (Fuel Valve)			21 ±5 psig**		21 ±5 psig		
Max △ P			0.88 psi		0.88 psi		
Pressure (Oxid Valve)			11 ±3 psig		11 ±3 psig		
Max △ P			0.60 psi		0.60 psi		
Coil Resistance							
Direct Coil - Fuel		*14.55 ±.55 ohms			*14.55 ±.55 ohms		
Direct Coil - Oxid		*14.15 ±.55 ohms			*14.15 ±.55 ohms		
Auto Coil - Fuel		*12.55 ±.55 ohms			*12.55 ±.55 ohms		
Auto Coil - Oxid		*17.35 ±.55 ohms			*17.35 ±.55 ohms		
Dielectric Strength							
Voltage	600 ±60 vdc						
Leakage	0.5 milliamps						

*Resistance measured corrected to 68°F. **Specification - MA0210-0158.

SM ENGINES

ME901-0004 (MARQUARDT)

(continued)

TEST	SUPPLIER	SYSTEM MA0210-0208	SYSTEM MAC710-4182 / MA0210-0158	SYSTEM MAC710-4224 / MA0210-0190	PART II	TSDD	KSC
VALVE SEAT LEAKAGE							
PRESSURE	100 - 105 psig		95 - 100 psig		100 ± 5 psig	100 ± 5 psig	200 ± 5 psig
LEAKAGE	10 scc/hour maximum		30 cc/hour		30 cc/hour	30 cc/hour	30 cc/hour
PURGE PRESSURE	60 ± 5 psig GN_2						
WATER FLOW CALIBRATION							
PRESSURE	181 ± 4 psig						
OXIDIZER	700 ± 3% pph						
FUEL	440 ± 3% pph						
AUTOMATIC COIL							
PRESSURE	181 psig	AMBIENT		15 ± 10 psig	15 ± 10 psig	15 ± 10 psig	15 ± 10 psig
VOLTAGE	27 ± 0.2	28 ± 0.5 VDC		28 ± 0.5 VDC	28 ± 0.5 VDC	28 ± 0.5 VDC	28 ± 0.5 VDC
PULSE WIDTH	10 ± 0.5 ms			15 ± 2 ms	15 ± 2 ms	15 ± 2 ms	15 ± 2 ms
OPEN							
FUEL	5.7-7.4 ms	4.5 ± 1.5 ms		4.5 ± 1.5 ms	4.5 ± 1.5 ms	4.5 ± 1.5 ms	4.5 ± 1.5 ms
OXIDIZER	7.8-9.5 ms	6.0 ± 1.5 ms		6.0 ± 1.5 ms	6.0 ± 1.5 ms	6.0 ± 1.5 ms	6.0 ± 1.5 ms
CLOSE							
FUEL	4.0-7.5 ms	≤ 8.5 ms		8.5 ms max.	8.5 ms max	8.5 ms max	8.5 ms max
OXIDIZER	4.5-8.0 ms	≤ 8.5 ms		8.5 ms max.	8.5 ms max	8.5 ms max	8.5 ms max

SM ENGINES

ME901-0004 (MARQUARDT)

(continued)

TEST	SUPPLIER	SYSTEM MA0210-0208	SYSTEM MA0710-4182 / MA0210-0158	SYSTEM MA0710-4224 / MA0210-0190	PART II	TSCD	KSC
AUTOMATIC COIL (continued)							
ON TO FULL CLOSE							
FUEL	13.0-18.0 ms						
OXIDIZER	11.5-20.0 ms						
AMPS, DROPOUT							
PRESSURE	250 ± 4 psig						
FUEL AND OXIDIZER	0.05-0.20 amps						
DIRECT COIL							
PULL-IN (OPEN)							
FUEL	0.35-0.53 amps			13 ± 3 ms	13 ± 3 ms	20 ms max	20 ms max
OXIDIZER	0.35-0.56 amps			25 ± 4 ms	25 ± 4 ms	32 ms max	32 ms max
DROP-OUT (CLOSE)							
FUEL	0.02-0.15 amps			VERIFY VALVE CLOSURE			
OXIDIZER	0.02-0.15 amps			VERIFY VALVE CLOSURE			
MINIMUM IMPULSE				15 ± 2 ms	15 ± 2 ms		
EMI SUPPRESSION				-20 ± 4 VDC	-20 ± 4 VDC		

HELIUM ISOLATION VALVE (S/M)
ME284-0251 (NWL)

TEST	SUPPLIER	SYSTEM			PAT II	KSC	TSCD
		MA0210-0158	*MA0710-4181	MA0710-4182			
Proof Pressure	6750	5250 ±50	5200-5300		5250 ±50		
External Leak Pressure	250 & 4500						
External Leak	5 x 10^{-6}						
Internal Leak Pressure	0 - 4500	3300 ±50 25 ±6 (LV9) (VW Valve)	25 ±6	3750-3850 25 ±6	3800 ±50	1000 ±25	400 - 3500
Internal Leak	20 cc/hr	60 cc/hr	60 cc/hr	60 cc/hr	60 cc/hr	60 cc/hr	60 cc/hr

Pressures in PSIG

Leak Rates in Std cc/sec.

*Use MA0710-0005 for SC 110 Only.

REGULATOR (S/M)
ME284-0022 (FAIRCHILD)

TEST	SUPPLIER	SYSTEM MC0210-0153	SYSTEM **MC0710-4281	SYSTEM MC0710-4282	PART II	KSC	TSCD
Proof Press							
Inlet	6750	5250 ±50	5200-5300				
Outlet	375	300 ±5 (SC110 & 111) 310 ±10 (SC112 & Subs)	295-305				
Ext Leak	5×10^{-6} at 6750						
Ref Port Press		30 ±10	30-35				
Pressure (Inlet)							
High	4500-2000	3800 ±50		3750-3850	3800 ±50	4150 ±50	3500 max.
Low	300	400 ±5		400 ±5	400 ±5		400 min.
Regulated Pressure							
Primary						181 ±4 (comb)	181 ±4 (comb)
Hi Press-Low Flow	181 ±3	181 ±4		177-185	177-185		
Low Press-Hi Flow	181 ±3	175-185		177-185	175-185		
Secondary						185 ±4 (comb)	183 ±6 (comb)
Hi Press-Low Flow	185 ±3	177-189		177-189	177-189		
Low Press-Hi Flow	185 ±3	175-189		175-189	175-189		
Flow							
High	.2	.16 ±.02		.14 - .18	.16 ±.02	.16 ±.01	.16 ±.02
Low	.036	.06 ±.02		.04 - .08	.06 ±.02		
Lockup Pressure	178-188				188 max.	183 ±5	188 max.
Primary							
Hi Press-Low Flow		177-188		177-188			
Lo Press-Hi Flow		188 max.		188 max.			
Secondary	182-192				192 max.	183 ±5	192 max.
Hi Press-Low Flow		177-192		177-192			
Low Press-Hi Flow		192 max.		192 max.			

REGULATOR (S/M)
ME284-0022 (FAIRCHILD)

TEST	SUPPLIER	SYSTEM			PART II	KSC	TSDD
		MA0210-0158	**MA0710-1181	MA0710-1182			
Internal Leak		45 cc/hr (comb)		45 cc/hr (comb)	45 cc/hr (comb)	*22.5 cc/hr (each)	45 cc/hr (comb) (3 psi max./30 min. or 3.7 psi max/hr.)
Primary	20 cc/hr	5.5 psi per 15 min.		5.5 psi/min			
Secondary	20 cc/hr	10.5 psi per 15 min.		10.5 psi per min.			

Pressures in PSIG
Leak Rates in Std cc/sec.
Flow Rates in #/min.

*Modified - Any Leak Combination not to exceed 45 scc/hr.
**Use MA0710-0005 for SC 110 Only.

CHECK VALVES (SM)
ME284-0357-0001 Oxidizer (APCO)
ME284-0357-0002 Fuel

TEST	SUPPLIER	SYSTEM MA0210-0158	SYSTEM **MA0710-4181	SYSTEM MA0710-4182	PART II	KSC	TSCD
Proof Press	540		305-310		300 +0 -5		
Ext Leak	5×10^{-6}						
Crack Press							
Primary	0.2 - 4	4 max* > 0		4 max* > 0	P 4* > 0	9 ±1	
Secondary	1 - 5	5 max* > 0		5 max* > 0	P 5* > 0	9 ±1	
Pressure Drop							
Pressure	180						
Flow	.045						
Primary	3.5						
Secondary	5.0						
Reverse Leakage							
Leak Press	.05, 2, 308, 360	0.5 ±0.1		0.5 ±0.1	0.5 ±0.1	0.5 ±0.1	0.5 ±0.1
Leak Rate	5×10^{-5}	1×10^{-3}		3.6cc/hr	1×10^{-3}	3.6cc/hr	1×10^{-3}

Pressures in psig
Flow Rates in #/min.
Leak Rates in Std cc/sec.
*Maybe 10 on initial run
**Use MA0710-0015 for SC 110 Only.

RELIEF VALVE (S/M)
ME284-0026 (CALMEC)

TEST	SUPPLIER	SYSTEM			PART II	KSC	MSCD
		MC0215-0158	*MC0710-0181	MC0710-0182			
Proof Press	500	300 ±5	300 ±5		300 ±5		
Ext Leak	< 5 x 10^{-6}						
Burst Diaphragm							
Leak Press	215	**185 ±5		**195 ±5	195 ±5		250 ±6
Leak Rate	< 5 x 10^{-6}	5 x 10^{-6}		5 x 10^{-6}	5 x 10^{-6}	5 x 10^{-6}	5 x 10^{-6}
Rupture Press	228 ±8						
Poppet							
Leak Press	220	150 ±5 196 ±4		145-155 195-200	150 ±5 196 ±4	196 ±4	195 ±5
Leak Rate	< 20 cc/hr	20 cc/hr		20 cc/hr	20 cc/hr	20 cc/hr	20 cc/hr
Crack Press	P>225	225-248		225-248	236.5 ±11.5	236.5 ±11.5	236.5 ±11.5
Reseat Press	P>220	220 min		220 min	220 min	220 min	220 min
Flow Press	P< 248						
Line Downstream of Burst Disc							
Proof Press		225-248	225-248		236.5 ±11.5		

Pressures in psig.
Leak Rates in Std cc/sec.
*Use MC0710-0005 for S/C 110 Only.
**△ P C/C Sys. maintains 195 ±5 during C/O with 205 in Prop Side minus 10 psi △ = 195 on burst disc.

TANKS (SM)

HELIUM TANK ME282-0051 (AIRITE)

TEST	SUPPLIER	SYSTEM			PART II	KSC	TSCD
		MA0210-0158	*MA0710-4181	MA0710-4182			
Proof Press	6000	5250 ±50	5200-5300		5250 ±50		3500 $^{+0}_{-100}$
Leak Press	4500	4150 ±50	4150 ±50	3750 ±50	3800 ±50		
Leakage (Tank)	5 x 10-6						
Leakage (Mech. Joints)		1 x 10-7 Ind	5 x 10-6		5 x 10-6		1 x 10-7 Ind.

PROPELLANT TANKS ME282-0004 PRI OXIDIZER, ME282-0006 SEC OXIDIZER, ME282-0007 SEC FUEL, ME282-0008 PRI FUEL (BAC)

TEST	SUPPLIER	MA0210-0158	*MA0710-4181	MA0710-4182	PART II	KSC	TSCD
Proof Press							
Pri-Ox & Fuel	331	300 ±5	300 ±5		300 ±5		
Sec-Ox & Fuel	480	300 ±5	300 ±5		300 ±5		
Leak Press							
Pri-Ox & Fuel	331	243 ±5	243 ±5		243 ±5		
Sec-Ox & Fuel	480	243 ±5	243 ±5		243 ±5		
Leakage (Tank Flange)	1.5 x 10-3	3 x 10-3	3 x 10-3		3 x 10-3	No Leak (Test Liquid)	
Bladder Leak							
Press	9 ±1	10 ±1	9-11	9-11	10 ±2	10 ±1	10 ±1
Oxid Pri	80cc/15 min	130cc/15 min (comb)	130cc/15 min (comb)	130cc/15 min (comb)	160cc/15 min	240cc/15 min (comb)	160cc/15 min 240cc/15 min (comb)
Sec	65cc/15 min				130cc/15 min		130cc/15 min 240cc/15 min (comb)
Fuel Pri	70cc/15 min	120cc/15 min (comb)	120cc/15 min (comb)	120cc/15 min (comb)	140cc/15 min	210cc/15 min (comb)	140cc/15 min 210cc/15 min (comb)
Sec	60cc/15 min				120cc/15 min		120cc/15 min 210cc/15 min (comb)

Pressures in PSIG
Leak Rates in Std cc/sec.

*Use MA0710-0005 for SC 110 Only.

PROPELLANT ISOLATION VALVE (SM)

ME284-0276 (NWL)

TEST	SUPPLIER	SYSTEM			PART II	KSC	TSCD
		MA0210-0158	*MA0710-4181	MA0710-4182			
Proof Press	540	300 ±5	300 ±5		300 ±5		
Leak Press	360	205 ±5		200-210	205 ±5	205 ±5	205 ±5
Internal Leak Rate	20	100		100	100	100	100

Pressures in PSIG.
Leak Rates in Std cc/hr.
*Use MA0710-0005 for SC 110 Only.

FILTER, PROPELLANT (S/M)

ME286-0039 (WINTEC)

TEST	SUPPLIER	SYSTEM			PART II	KSC	TSCD
		MA0210-0158	*MA0710-4181	MA0710-4182			
Proof & Leak Press	375	300 ±5	300 ±5		300 ±5		
Leakage Rate	$<5 \times 10^{-6}$						
Δ P Fuel	0.5 @ .24						
Δ P Oxidizer	0.5 @ .48						

Pressures in PSIG.
Leak Rate in Std cc/sec
Δ P in psi/lb/sec

*Use MA0710-0005 for SC 110 Only.

TEST PORT COUPLINGS (S/M)

ME144-0023-0011	Oxidizer	TP: 7, 8, 11, 17	LEAR-SIEGLER
ME144-0023-0031	Fuel	TP: 9, 10, 12, 18	LEAR-SIEGLER
ME144-0023-0051	He Lo Press	TP: 6	LEAR-SIEGLER
ME144-0023-0071	He Hi Press	TP: 2, 3	LEAR-SIEGLER
ME273-0011-0001	Oxid Vent	TP: 13, 19, 21	J. C. CARTER
ME273-0019-0001	Oxid Fill	TP: 15, 23	J. C. CARTER
ME273-0021-0001	Fuel Fill	TP: 20, 24	J. C. CARTER
ME273-0024-0001	Fuel Vent	TP: 14, 16, 22	J. C. CARTER
ME273-0010-0001	He. Fill	TP: 1	PUROLATOR

TEST	SUPPLIER	SYSTEM MA0210-0158	SYSTEM *MA0710-4181	SYSTEM MA0710-4182	PART II	KSC	TSCD
PROOF PRESSURE							
TP: 1	7500	5250 ±50	5200-5300		5250 ±50		
TP: 2, 3	6750	5250 ±50	5200-5300		5250 ±50		
TP: 6, 7, 8, 9, 10	540	300 ±5	300 ±5		300 ±5		
TP: 11, 12, 13, 14	540	225-248	225-248		237 +11/-12		
TP: 15 thru 24	540	300 ±5	300 ±5		300 ±5		
LEAK PRESSURE							
TP: 1	375, 2000 5000 & 75000	3800 ±50	3750-3850		3750-3850		3500 +0/-100
TP: 2, 3	4500	3800 ±50	3750-3850		3750-3850		3500 +0/-100
TP: 6	360	185 ±5			195 ±5		200 ±5
TP: 11, 12	360	140 ±5	197-207		195 ±5		200 ±5
TP: 13, 14	360	185 ±5	205-215		195 ±5		200 ±5
TP: 15, 16, 19 thru 24	360	205 ±5	215-225		205 ±5		205 ±5
LEAKAGE							
CAPS "OFF"							
TP: 2, 3, 6 thru 12, 17, 18	5×10^{-6}	75cc/hr.	75cc/hr.		75cc/hr.		75cc/hr.
TP: 1, 13 thru 16, 19 thru 24	5×10^{-6}	20cc/hr.	20cc/hr.		20cc/hr.		20cc/hr.
CAPS "ON"							
TP: ALL	5×10^{-6}	1×10^{-7} Ind.	1×10^{-7} Ind.		5×10^{-6}		1×10^{-7} Ind.

*Use MA0710-0005 for S/C 110 Only.
Pressure in PSIG
Leak Rates in Std cc/sec.

ENGINE HEATER (SM)

ME363-0014 (Thermal Systems)

TEST	SUPPLIER	SYSTEM				PART II	TSCD	KSC
		MA0210-0158	MA0710-4182	MA0210-0190	MA0710-4225			
High Temp.	250°F 3 hrs							
Low Temp. & Vacuum	-65°F 1×10^{-6} mm Hg 3 hrs							
High Potential	1060 volts RMS AC							
Insulation Resistance	500 VDC							
Electrical Resistance	$17.36 \ {}^{+1.93}_{-1.58}$ ohms (component)	$8.68 \ {}^{+0.97}_{-0.79}$ ohms (system)	$8.68 \ {}^{+0.97}_{-0.79}$ ohms (system)					
Operation Voltage		30.5 ±0.5 VDC	30-31 VDC	Bus Voltage	Bus Voltage	Bus Voltage	Conti-nuity	Bus A & B Verify Temp. Increase
Current Individual				1.2-2.2 amps Individual	1.2-2.2 amps Individual	1.2-2.2 amps Individual		
Current System		3.5 ±0.6 amps		Sum of Individual ±.5 amp	Sum of Individual ±.5 amp	Sum of Individual ±.5 amp		
Sw Actuation Opens		124-159°F	124-159°F			141.5°F ±17.5°F	OFF	
Closes		120 ±15°F	105-135°F			120° ±15°F	ON	

COMMAND MODULE REACTION CONTROL SYSTEM - CHECKOUT SUMMARY

COMPONENT	DOWNEY						KSC		
	Supplier	Fabrication	Sub System	COMPLETE SYSTEM			MSCB	VAB	Launch Pad
				Pre-Integrated	Installed-Integrated	Post-Integrated			
Helium Tanks	P L			P L	S	L	L		F
Temperature Sensors	F			F	F	F			F
Fill Couplings	P L F	S	P L	P L	S	L	L		F
Pressure Transducers	P F			P L F	F	L F	L		F
Squib Valves	P L		P L	P L		L			
Regulators	P L F		P L F	P L F		L F			L F
Check Valves	P L F		P L F	P		L F			L F
Test Ports	P L F	S	P L	P L	S	L	L		F
Lines and Joints	P	C&D	P L	P L	S		L		
Relief Valves	P L F		P L F	P		L F			L F
Propellant Tanks	P L F			P L	S	L			L F
Propellant Isolation Burst Diaphragm and Filter	P L					L			L
Propellant Isolation Valve	P L F	F	P L F	P L F	F	L F	F		L F
Engines	P L F	L F			F	L F			L F
Heaters	F				F		F		
System Complete		D		D	I	D			D

LEGEND:

- D - Dryness Verification
- P - Proof Pressure
- L - Leakage
- F - Functional
- S - Supporting
- C&D - Cleanliness and Dryness Verification
- I - Interface Verification

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	PRE INSTALLATION MA0210-0207	SYSTEM MA0210-0190	SYSTEM MA0710-4224	CEI PART II	KSC	TSCD
Engines							
Valve Seat Leakage		S/C 108 & Subs			3.1.1.7.5.6		
Test Pressure PSIG	300 ±10	300 ±5	300 ±15	300 ±5	300 ±15	300 (+0,-5)	300 ±5
Leak Rate	5.0 scch	20 scch	20 scch	20 scch	20 scch	20 scch	20 scch
Automatic Coil							
Test Pressure PSIG	0	35 ±5	35 ±5	35 ±5			
Test Voltage VDC	27 ±.3	28 ±.5	28 ±0.5	28 ±0.5			
Pulse Width		25 ms	15 ±2 ms	15 ±2 ms			
Time to Open (Auto Coil)							
Fuel	4.2 ±0.8 ms	5 ±2 ms*	4.5 ±1.5 ms	4.5 ±1.5 ms	4.5 ±1.5 ms	5 ±2 ms	5 ±2 ms
Oxidizer	4.2 ±0.8 ms	5 ±2 ms*	4.5 ±1.5 ms	4.5 ±1.5 ms	4.5 ±1.5 ms	5 ±2 ms	5 ±2 ms
Time to Close (Auto Coil)							
Fuel	6.7 ±2 ms	7 ±2 ms	6.5 ±2 ms	6.5 ±2 ms**	6.5 ±2 ms		
Oxidizer	6.7 ±2 ms	7 ±2 ms	6.5 ±2 ms	6.5 ±2 ms**	6.5 ±2 ms		
Eng. Inj. Valve Min. Impulse							
Voltage vdc			28 ±0.5	28 ±0.5	28 ±0.5		
Time			15 ±2 ms	15 ±2 ms	15 ±2 ms		
Eng. Closeout Joint Leakage							
Test Pressure PSIG			300 ±15	300 ±15	300 ±15		
Leak Rate			1 x 10^{-7} sccs ind	1 x 10^{-7} scc ind	1 x 10^{-7} sccs ind		
Valve Coil Resistance							
Automatic Coils	15 (+1,-0)	15.5 ±.5 ohms			15 (+1,-0)		
Direct Coils	30 (+2,-0)	31 ±1			30 (+2,-0)		

*The greater tolerance was performed on engines before the tolerance was tightened. The closer tolerances were observed on subsequent tests of those engines.

**MA0710-4223 Presystem C/O.

COMMAND MODULE REACTION CONTROL SYSTEM
DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	PRE INSTALLATION MA0210-0207	SYSTEM MA0210-0190	SYSTEM MA0710-4224	CEI PART II	KSC	TSCD
Direct Coil							
Pull-In (open)							
Fuel	7.5 ±1.5 ms	6 +3.5 -0 ms	8.5 ±2 ms	8.5 ±2 ms	8.5 ±2 ms	9 ±3 ms	9 ±3 ms
Oxidizer	7.5 ±1.5 ms	6 +3.5 -0 ms	8.5 ±2 ms	8.5 ±2 ms	8.5 ±2 ms	9 ±3 ms	9 ±3 ms
Drop-Out (Close)							
Fuel	8.2 ±2.4 ms	7 ±3 ms	6 ±2 ms	6 ±2 ms**			
Oxidizer	8.2 ±2.4 ms	7 ±3 ms	6 ±2 ms	6 ±2 ms**			
Dielectric Strength							
Test Voltage	6 ±24 vrms						
Leakage	0.001 amp						
Injector Gas Flow	DNA						
Injector Valve Gas Flow	DNA						
Test Pressure -Fuel	DNA						
Fuel Pressure-Drop	DNA						
Test Pressure-Oxid	DNA						
Oxid Pressure Drop	DNA						
Proof Pressure Test (He)							
Injector & Valves	640 ±15 psig						
Leak Check							
Injector & Valves							
Test Pressure (He)	300 ±10 psig						
Leak Rate	5 x 10^{-6} sccs						

**MA0710-4223 Presystem C/O.

COMMAND MODULE REACTION CONTROL SYSTEM
DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	PRE INSTALLATION MA0210-0207	SYSTEM		CEI PART II	KSC	TSCD
			MA0210-0190	MA0710-4224			
Thrust Chamber Test Press (GN_2)	300 $^{+10}_{-0}$ psig						
Leak Rate	300 scch						
Hot Fire Thrust (Calc.) Mixture Ratio Chamber Pressure Specific Impulse (Calc.)	 93 ±2 lbs 2.1 ±.050 141 ±4 psia 266 sec.						
Inj. Valve. Sol. Insul. Resist. Test Voltage	20 Meg 500 ±20 vdc	20 Meg 100 vdc					
Injector Valve Obstruc. Orifice (Fuel & Oxid) Oxid Inlet Press (N_2) Downstream Pressure Deviation from Avg.			 .0292 ±.0002" 160 ±.25 psig 15.5 ±3.5 psig 2.2 psi	 .0292 ±.0002" 160 ±.25 psig 15.5 ±3.5 psig 2.2 psi	 .0292 ±.0002" 160 ±.25 psig 15.5 ±3.5 psig 2.2 psi		
Fuel Inlet Press Downstream Press. Deviation from Avg.			108 ±.25 psig 16.0 ±3 psig 2.2 psi	108 ±.25 psig 16.0 ±3 psig 2.2 psi	108 ±.25 psig 16.0 ±3 psig 2.2 psi		
EMI Suppression			-19 ±3 vdc	-19 ±3 vdc	-19 ±3 vdc		
Engine Heaters			Verify heater on. CM swith ON. Verify heater current and voltage.	Verify heater current. Heater voltage measured 26 ±10 vdc.	Verify heater on. CM switch ON.		

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040, -0055, -0061	SYSTEM MA0210-0142	SYSTEM MA0710-4170 MA0710-4171	CEI PART II	KSC	TSCD
Helium Tank							
Proof Pressure	$6700 ^{+100}_{-0}$ psig		5250 ±50	5200-5300	5250 ±50		
Leak Test Pressure	$5000 ^{+100}_{-0}$ psig		4150 ±50	4200-4300	4150 ±50	100 psd	$3750 ^{+0}_{-100}$
Leakage	5×10^{-6} sccs		1×10^{-7}	5×10^{-6}	5×10^{-6}	No decay	1×10^{-7} (ind)

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040, -0055, -0061	SYSTEM MA0210-0142	SYSTEM MA0710-4170 MA0710-4171	CEI PART II	KSC	TSCD
Couplings & Test Ports							
Proof Press.-High -Low	He.Fill 6750, 7500 540	6750 ±50 540 ±5	5250 ±50 400 ±5	5200-5300 395-405	5250 ±50 400 ±5		
Leak Test High Pressure	He.Fill 4500, 5000	4150 ±50	4150 ±50 (TP1, 51) 3800 ±50 (TP3,4,53,54)	3750-3850	3750 ±50	50 psd	3750^{+0}_{-100}
TP Leak (w/o caps) (w/caps)	5×10^{-6} sccs 5×10^{-6} sccs	25 scch 5×10^{-6}	75 scch 1×10^{-7}	75 scch 1×10^{-7}	75 scch, 5×10^{-6}	No decay	75 scch 1×10^{-7} (ind)
Fill/Vent (w/o caps) (w/caps)	5×10^{-6} sccs 5×10^{-6} sccs	10 scch 5×10^{-6}	20 scch 1×10^{-7}	20 scch 1×10^{-7}	20 scch 5×10^{-6}	No decay	20 scch 1×10^{-7} (ind)
Low Pressure	360 psig	310 ±5	302 ±5	305-315	300 ±5		290 ±5
TP Leak (w/o caps) (w/caps)	5×10^{-6} sccs 5×10^{-6} sccs	25 scch 5×10^{-6}	75 scch 1×10^{-7}	75 scch 1×10^{-7}	75 scch 5×10^{-6}	No decay	75 scch 1×10^{-7} (ind)
Fill/Vent (w/o caps) (w/caps)	5×10^{-6} sccs 5×10^{-6} sccs	10 scch 5×10^{-6}	20 scch 1×10^{-7}	20 scch 1×10^{-7}	20 scch 5×10^{-6}	No decay	20 scch 1×10^{-7} (ind)

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040, -0055, -0061	SYSTEM MA0210-0142	SYSTEM MA0710-4170 MA0710-4171	CEI PART II	KSC	TSCD
Helium **Regulators**							
Proof Press-Inlet	6750 psig	6750	5250 ±50	5200-5300	5250 ±50		
-Outlet	540 psig	540 ±5	400 ±5	395-405	400 ±5		
External Leakage							
Test Pressure	Same as proof						
Leak Rate	5 x 10^{-6} sccs						
Reference Port Press	Ambient	30 ±10	30 ±10	20-40 psig		10 ±2	10 ±2
Normal Flow Pressures							
Primary							
Inlet Pressure	4500-400	4150 ±50	4150 ±50	4150 ±50	4150 ±50	1000 ±100	500-3750
Flow	.058 to .3#/min	.16 ±.02	.06 ±.01 .16 ±.01	.06 ±.02#/min	.06 ±.02#/min	.16 ±.02#/min	.16 ±.02#/min
Regulated Pressure	287-295	285-297	285-297	285-297	285-297		291 ±6
Lockup Pressure	302 max		302 max	302 max	285-302	302 max	302 max
Secondary							
Inlet Pressure	4500-400	4150 ±50	4150 ±50	4150 ±50	4150 ±50	1000 ±100	500-3750
Flow	.058 to .3#/min	.16 ±.02	.06 ±.01#/min	.06 ±.02#/min	.06 ±.01#/min	.16 ±.02#/min	.16 ±.02#/min
Regulated Pressure	287-302	287-302	285-302	285-302	285-302		285-302
Lockup Pressure	308 max	285-308	308 max	308 max	285-308	308 max	308 max
Starved Flow Pressures							
Primary							
Inlet Pressure	400	500 ±5	500 (+50,-0)	500 ±50	500 (+50,-0)		
Flow	.058 to .3#/min	.16 ±.02#/min	.16 ±.02	.16 ±.02	.16 ±.02#/min		
Regulated Press	287-295	283-297		283-297	283-297		
Lockup Pressure	302 max	302 max	302 max	302 max	302 max		

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040, -0055,-0061	SYSTEM MA0210-0142	SYSTEM MA0710-4170 MA0710-4171	CEI PART II	KSC	TSCD
Starved Flow Pressures							
Secondary							
Inlet Pressure	400	500 ±5	500 (+50,-0)	500 ±50	500 (+50,-0)		
Flow	.058 to .3#/min	.16 ±.02	.16 ±.02	.16 ±.02	.16 ±.02#/min		
Regulated Pressure	287-302	285-297		283-302	283-302		
Lockup Pressure	308 max	308 max	308 max	308 max	308 max		
Internal Leakage	20 scch						
Combined Primaries							
Inlet Pressure		4150 ±50	4150 ±50	4100-4200	4150 ±50	1000 ±100	500-3750
Leakage		45 scch	45 scch	45 scch	45 scch	7.8 psi/hr	7.8 psi/hr
Combined Secondaries							
Inlet Pressure		4150 ±50	4150 ±50	4150	4150 ±50	1000 ±100	500-3750
Leakage		45 scch	45 scch	45 scch	45 scch	7.8 psi/hr	7.8 psi/hr

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040 -0055,-0061	SYSTEM MA0210-0142	SYSTEM MA0710-4170 MA0710-4171	CEI PART II	KSC	TSCD
Check Valve, Helium							
Proof Pressure	540	540 ±5	400 ±5	395-405	400 ±5		
External Leakage	5 x 10^{-6} sccs						
Cracking Pressure							
Upstream Element	.2 to 4	>0, NMT 4 psi	>0, NMT 4 psi	NMT 4.0	>0,NMT4 psi	9 ±1	10 max
Downstream Element	1 to 5	>0, NMT 5 psi	>0, NMT 5 psi	NMT 5.0	>0,NMT5 psi	9 ±1	10 max
Pressure Drop Test	3.5 prim 5.0 sec						
Pressure	181						
Flow							
Primary	0.3 #/min						
Secondary	0.3 #/min						
Reverse Flow Leakage							
Test Pressure	.05 to 360	0.5 ±0.1 psig	0.5 ±0.1 psig	.5 ±.1	0.5 ±0.1 psig	0.5 ±0.1	0.5 ±0.1
Leak Rate/Element	5 x 10^{-5} sccs	1 x 10^{-3} sccs	1 x 10^{-3} sccs	1 x 10^{-3} sccs	1 x 10^{-3} sccs	1 x 10^{-3} sccs	1 x 10^{-3} sccs

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040, -0055,-0061	SYSTEM MA0210-0142	SYSTEM MA0710-4170 MA0710-4171	CEI PART II	KSC	TSCD
Propellant Tanks							
Proof Pressure	525		400 ±5 psig	395-405	400 ±5		
Leak Pressure	360		355 ± 5	355 ± 5	355 ±5		
Leak Rate (Tank Flange)	1.5 x 10^{-3} sccs		3 x 10^{-3} sccs	3 x 10^{-3} sccs	3 x 10^{-3} sccs		
Bladder Leakage							
Test Pressure	9 ±1 psi		10 ±2 psig	8-12 psi	10 ±2 psig	10 ±1	10 ±2
Leak Rate							
Oxidizer Tank	65cc/15min		130 scc/15 min	130 scc/15 min	130 scc/15 min	130 scc/15 min	130scc/15
Fuel Tank	60cc/15min		120 scc/15 min	120 scc/15 min	120 scc/15 min	120 scc/15 min	120scc/[illegible]
Prop. Distri. Lines/ Proof Press.		540 ±5	400 ±5 psig	395-405	400 ±5 psig		

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040 -0055,-0061	SYSTEM MA0210-0142	SYSTEM MA0710-4170 MA0710-4171	CEI PART II	KSC	TSCD
Relief Valves, Helium							
Proof Pressure	540 psig	540 ±5	400 ±5	395-405	400 ±5		
External Leakage	5×10^{-6} sccs						
Burst Diaphragm							
Test Pressure	327	290 ±15 psig	290 ±15 psig	290 ± 15 psig	290 ±15 psig	50 psd	290 ±15
Leak Rate	5×10^{-6} sccs	5×10^{-6} sccs	5×10^{-6} sccs	5×10^{-6}	5×10^{-6} sccs	No decay	5×10^{-6} sccs
Rupture Pressure	340 ±8						
Poppet							
Leak Test Pressure							
High	327	300 $^{+10}_{-0}$ psig	305 ±5 psig	305-310	305 ±5	305 ±5	305 ±5
Low		150 ±5 psig	150 ±5 psig	150-155	150 ±5		
Leak Rate	20 scch	20 scch	20 scch	20 scch	20 scch	20 scch	20 scch
Cracking Pressure	346 ±14	346 ±14 psig	346 ±14 psig	332-360	346 ±14 psig	346 ±14	346 ±14
Reseat Pressure	327	327 psig min	327 min	[illegible] 327	327 min	327 min	327 min
Flow Pressure	360						
Line Downstream							
Burst Disk							
Proof Pressure			346 ±14	332-360	346 ±14		

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040, -0055,-0061	SYSTEM MA0210-0142	SYSTEM MA0710-4170 MA0710-4171	CEI PART II	KSC	TSCD
Squib Valves							
Helium Isolation							
Proof Pressure	6750	6750 ±50	5250 ±50	5250 ±50	5250 ±50		
Test Pressure	6750	4150 ±50			4150 ±50		
Leak Rate (2 vlvs)	5×10^{-6} sccs	5×10^{-6}			1×10^{-5}		
Helium Interconnect							
Proof Pressure	6750	540 ±5	400 ± 5	400 ± 5	400 ± 5		
Test Pressure	6750	302 ±5			302 ±15		
Leak Rate	5×10^{-6} sccs	5×10^{-6}			5×10^{-6}		
Propellant Interconnect							
Proof Pressure	540	540 ±5	400 ±5	400 ±5	400 ± 5		
Test Pressure	540	302 ±5	302 ±5	315-325	302 ±15		
Leak Rate	5×10^{-6} sccs	5×10^{-6}	5×10^{-6}	5×10^{-6}	5×10^{-6}		

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040 -0055, -0061	SYSTEM MA0210-0142	SYSTEM MA0710-4170 MA0710-4171	CEI PART II	KSC	TSCD
Propellant Isolation Burst							
Diaphragm & Filter							
Test Pressure	5, 120, 200		170 ±5 psig	165-175	170 ±5 psig	170 ±5	175 ±5
Leak Rate Internal	5×10^{-4} sccs		4 scc/15 min	16 scch	4 scc/15 min	3.6 scch	1×10^{-3} sccs
External	5×10^{-6} sccs		1×10^{-7} sccs ind.	1×10^{-7} ind			

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY	SYSTEM		CEI PART II	KSC	TSCD
			MA0210-0190	MA0710-4225			
SCS Interface					3.1.1.7.5.8		
Command/Engine Response							
SCS Command			CM Engine	CM Engine *	CM Engine		
+Pitch			13 & 23	13 & 23	13-23		
-Pitch			14 & 24	14 & 24	14-24		
+Yaw			15 & 25	15 & 25	15-25		
-Yaw			16 & 26	16 & 26	16-26		
+Roll			11 & 21	11 & 21	11-21		
-Roll			12 & 22	12 & 22	12-22		

*MA0710-4224

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040, -0055, -0061	SYSTEM MA0210-0142	SYSTEM MA0710-4170 MA0710-4171	CEI PART II	KSC	TSCD
Propellant Isolation Valves							
Proof Pressure	540 psig	540	400 ±5	400 ±5			
Test Pressure	360 psig	302 ±5	310 (+10,-0)	315-325	302 ±15 psig	302 ±5	302 ±5
Leak Rate - Internal	20 scch	100 scch (ea)	100 scch (ea valve)	100 scch	100 scch (ea valve)	100 scch (ea valve)	100 scch (ea valve)

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY	SYSTEM MA0210-0190	SYSTEM MA0710-4225	CEI PART II	KSC	TSCD
Instrumentation & Measurement System					3.1.1.7.5.9		
Pressure Sensor							
Helium Tank							
Pressure psig			500 ±50	500 ±50	500 ±50		
CM Meter Ind.			Stim ±250	Stim ±250	Stim ±250		
ACE Display			Stim ±150	Stim ±150	Stim ±150		
Helium Manifold							
Pressure			40 ±10	40 ±10	40 ±10		
CM Meter Ind.			Stim ±20	Stim ±20	Stim ±20		
ACE Display			Stim ±15	Stim ±15	Stim ±15		
Temperature Sensor							
Helium Tank							
Applied Temp.			Ambient/ID	Ambient/ID	Ambient		
CM Meter Ind.			Amb. ±20/ΔT	Amb. ±20/ΔT	Amb. ±20		
ACE Display			Amb. ±15/ΔT	Amb. ±15/ΔT	Amb. ±15		
Engine Injector							
Applied Temp			ID	ID	Ambient		
CM Meter Ind.			ΔT	ΔT	Amb. ±20		
ACE Display					Amb. ±15		
Prop. Isol. Valve. Event. Ind.							
Switch Up (ON)			Gray flag	Gray flag	Gray flag		
Switch Down (OFF)			Barberpole	Barberpole	Barberpole flag		

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY	SYSTEM MA0210-0190	SYSTEM MA0710-4225	CEI PART II	KSC	TSCD
Instrumentation & Measurement System					3.1.1.7.5.9		
Caution & Warning Display							
Helium Manifold Press							
Excitation Voltage			3.22-3.28	3.22-3.28	3.22-3.28		
CM Panel Ind. (PSIA)			240-280	240-280	240-280		
C&W Light Response			Off to On	Off to On	Off to On		
Excitation Voltage			3.84-3.90	3.84-3.90	3.84-3.90		
CM Panel Ind. (PSIA)			290-330	290-330	290-330		
C&W Light Response			Off to On	Off to On	Off to On		

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY	SYSTEM MA0210-0142	SYSTEM MA0710-4170	CEI PART II	KSC	TSCD
Transducer Verification							
Manifold Xducer Test Pressure			100 ±4 psia 200 ±4 psia 300 ±4 psia 400 ±4 psia	81-89 psig 181-189 psig 281-289 psig 381-389 psig			
Acceptance Criteria				3 psi Differential between Facility Test Gage & SC Xducer.			
Helium Tank Xducer Test Pressure			1250 ±50 psig 2500 ±50 psig 3750 ±50 psig 4950 ±50 psig	1200-1300 psig 2450-2550 psig 3700-3800 psig 4900-5000 psig			
Acceptance Criteria				100 psi	Differential between Facility Test Gage and Spacecraft Xducer		

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040	SYSTEM MA0210-0142	SYSTEM MA0710-4170	CEI PART II	KSC	TSCD
Proof Pressure							
Helium System							
High Pressure			5250 ±50	5250 ±50	5250 ±50		
Low Pressure			400 ±5	400 ±5	400 ±5		
Fuel Distrib. System			400 ±5	400 ±5	400 ±5		
Oxidiser Distrib. System			400 ±5	400 ±5	400 ±5		
External Leakage							
Helium Tank Boss							
Test Pressure			4150 ±50	4150 ±50	4150 ±50		
Leak Rate			1×10^{-7} sccs	5×10^{-6} scc per sec	*5×10^{-6} sccs		
Helium High-Press. Xducer Boss							
Test Pressure			4150 ±50	4150 ±50	4150 ±50		
Leak Rate			1×10^{-7} sccs	5×10^{-6} scc per sec	*5×10^{-6} sccs		
Brazed Joints Upstream of Regs.							
Test Pressure			3800 ±50	3800 ±50	3750 ±50		
Leak Rate			1×10^{-7} sccs	5×10^{-6} scc per sec	*5×10^{-6} sccs		
Propellant Tank Flange							
Test Pressure			355 ±5	355-360 psig	355 ±5		
Leak Rate			3×10^{-3} scc per sec	3×10^{-3} cc per sec	3×10^{-3} sccs		

*110, 111, 112 & Sub = 1×10^{-7}.

COMMAND MODULE REACTION CONTROL SYSTEM

DETAILED COMPONENT CHECKOUT REQUIREMENTS

EVENT	SUPPLIER	SUBASSEMBLY MA0210-0040	SYSTEM MA0210-0142	SYSTEM MA0710-4170	CEI PART II	KSC	TSCD
Brazed & Mech. Joints, Xducer Bosses Downstream of Regs. Test Pressure Leak Rate			302 ± 5 1×10^{-7}sccs	302 ± 5 5×10^{-6}	300 ± 5 *5×10^{-6} sccs		

*110, 111, 112 & Sub = 1×10^{-7}

PRESSURE/TEMPERATURE SENSOR

(HELIUM MASS SENSOR)

TEST	SUPPLIER	SYSTEM				PART II
		MA0210-0158	MA0710-4182	MA0210-0190	MA0710-4225	
INSULATION RESISTANCE	>100 MEGOHMS @ 50 VOLTS DC					
INPUT TO OUTPUT ISOLATION RESISTANCE	>100 MEGOHMS @ 100 VDC					
NOISE FEEDBACK	< 10 MV PEAK-TO-PEAK TO 20 KC					
OUTPUT REGULATION VOLTAGE RANGE 24-32 VDC	<3 MV					
INPUT CURRENT	$\leq 50x10^{-3}$ AMPS DC					
OUTPUT NOISE	< 10 MV PEAK-TO-PEAK TO 10 KC					
VIBRATION	CHANGE IN OUTPUT ≤ 10 MV @ 2,250 PSIA					
OUTPUT VOLTAGE	IDEAL P/T OUTPUT ±200 MV					
CALIBRATION VERIFICATION						
TEST PRESSURE		3000±50 and 3800±50 PSIG	3000±50 and 3800±50 PSIG			3000±150 PSIG

PRESSURE/TEMPERATURE SENSOR

(HELIUM MASS SENSOR)

(continued)

TEST	SUPPLIER	SYSTEM MA0210-0158	SYSTEM MA0710-4182	SYSTEM MA0210-0190	SYSTEM MA0710-4225	PART II
TEMPERATURE +10°F or TEST CELL AMBIENT		OUTPUT WITHIN 0-200 VDC OF THE CALCULATED VALUE	OUTPUT WITHIN 0-200 VDC OF THE CALCULATED VALUE	OUTPUT WITHIN 0-200 VDC OF THE CALCULATED VALUE	OUTPUT WITHIN 0-200 VDC OF THE CALCULATED VALUE	OUTPUT WITHIN 0-200 VDC OF THE CALCULATED VALUE
SYSTEM CHECK SIMULATE P/T SENSOR VOLTAGE. VERIFY VOLTAGE ON CM DISPLAY						
TEST VOLTAGE				DISPLAY	DISPLAY	DISPLAY
.25 VDC ± 10 MV				5 ± 2.5%	5 ± 2.5%	5 ± 2.5%
2.5 VDC ± 10 MV				50 ± 2.5%	50 ± 2.5%	50 ± 2.5%
4.75 VDC ± 10 MV				95 ± 2.5%	95 ± 2.5%	95 ± 2.5%

PRESSURE TRANSDUCERS

ME431-0069 (WHITTAKER)

TEST	SUPPLIER	SYSTEM			PART II	TCSD	KSC
		MA0210-0158	MA0710-4181	MA0710-4182			
INSULATION RESISTANCE							
VOLTAGE	50 VDC						
RESISTANCE	100 MEGOHMS						
INPUT TO OUTPUT ISOLATION RESISTANCE							
VOLTAGE	50 VDC						
RESISTANCE	100 MEGOHMS						
NOISE FEEDBACK							
INPUT VOLTAGE	28 ± 1 VDC						
OUTPUT VOLTAGE	10 MVDC PEAK-TO-PEAK TO 20 KC						
OUTPUT REGULATION							
PRESSURE	50% FULL RATED						
INPUT VOLTAGE	24 MINIMUM, 32 MAXIMUM VDC						
OUTPUT DIFFERENCE	10 MVDC MAX.						
INPUT CURRENT							
VOLTAGE	28 ± 1 VDC						
CURRENT	56 MA MAXIMUM						

PRESSURE TRANSDUCERS

ME431-0069 (WHITTAKER)

(continued)

TEST	SUPPLIER	SYSTEM MA0210-0158	SYSTEM MA0710-4181	SYSTEM MA0710-4182	PART II	TCSD	KSC
OUTPUT NOISE							
INPUT VOLTAGE	28 ± 1 VDC						
OUTPUT VOLTAGE	10 MVDC PEAK-TO-PEAK TO 10 KC						
ENDPOINT AND TEMPERATURE							
INPUT VOLTAGE	28 ± 1 VDC						
TEMPERATURE	-65 ± 5°F and 200 ± 5°F						
OUTPUT VOLTAGE							
@ 0% FS PRESSURE	.000-.400 VDC						
@ 100% FS PRESSURE	4.600-5.000 VDC						
VIBRATION							
INPUT VOLTAGE	28 ± 1 VDC						
OUTPUT VOLTAGE CHANGE	10 MVDC MAX.						
PROOF							
MANF TRANSDUCER		300 ±5 psig (SC110-111) 310 ±10 psig (SC 112 and subs)	295-305 psig (SC110-111) 300-305 psig (SC 112 and subs)				
HELIUM TANK TRANSDUCER		5,250 ± 50 psig	5,200-5,300 psig				

PRESSURE TRANSDUCERS

ME431-0069 (WHITTAKER)

(continued)

TEST	SUPPLIER	SYSTEM			PART II	TCSD	KSC
		MA0210-0158	MA0710-4181	MA0710-4182			
CALIBRATION							
INPUT VOLTAGE	28 ± 1 VDC						
HYSTERESIS	10 MV						
REPEATABILITY	10 MV						
ZERO ENDPOINT	.000-.225 VDC						
FS ENDPOINT	4.775-5.000 VDC						
TRANSDUCER VERIFICATION							
MANIFOLD TRANSDUCER TEST PRESSURE		ZERO 100 ± 25 psig 200 ± 25 psig 300 ± 25 psig	AMBIENT 81- 89 psig 181-189 psig 280-290 psig	AMBIENT 181-189 psig			
ACCEPT. CRITERIA		±2% FULL SCALE	±2% FULL SCALE	±2% FULL SCALE			
HE TANK TRANSDUCER TANK PRESSURE		ZERO 1,250±50 psia 2,500±50 psia 3,750±50 psia 5,000±50 psia	AMBIENT 1,200-1,300 psig 2,450-2,550 psig 3,750-3,850 psig 4,900-5,000 psig	AMBIENT 3,750-3,850 psig			
ACCEPT. CRITERIA		±2% FULL SCALE	±2% FULL SCALE	±2% FULL SCALE			

PRESSURE TRANSDUCERS

ME431-0069 (WHITTAKER)

(continued)

TEST	SUPPLIER	SYSTEM			PART II	TSCD	KSC
		MA0210-0158	MA0210-0190	MA0710-4225			
SYSTEM END-TO-END CHECK			PRESSURE STIMULUS APPLIED TO EACH PRESSURE SENSOR. DELTA-P VERIFIED ON EACH CAN GAGE WITHIN ±5% OF SYSTEM RANGE. DELTA-P VERIFIED ON ACE WITHIN 3% OF SYSTEM RANGE	PRESSURE STIMULUS APPLIED TO EACH PRESSURE SENSOR. DELTA-P VERIFIED ON EACH CAN GAGE WITHIN ±5% OF SYSTEM RANGE. DELTA-P VERIFIED ON ACE WITHIN 3% OF SYSTEM RANGE	PRESSURE STIMULUS APPLIED TO EACH PRESSURE SENSOR. DELTA-P VERIFIED ON EACH CAN GAGE WITHIN ±5% OF SYSTEM RANGE. DELTA-P VERIFIED ON ACE WITHIN 3% OF SYSTEM RANGE	AMBIENT CHECK ±5% FS	AMBIENT AND CHAMBER I.D.

TEMPERATURE TRANSDUCERS

ME431-0068 (WHITTAKER)

TEST	SUPPLIER	SYSTEM MA0210-0190	SYSTEM MA0710-4225	SYSTEM MA0210-0158	PART II	TSCD	KSC
INSULATION RESISTANCE							
VOLTAGE	50 VDC						
RESISTANCE	≥ 100 MEGOHMS						
INPUT TO OUTPUT ISOLATION RESISTANCE							
VOLTAGE	50 VDC						
RESISTANCE	100 MEGOHMS MINIMUM						
INPUT CURRENT							
VOLTAGE	28 ± 1 VDC						
CURRENT	56 MA MAX.						
OUTPUT NOISE							
INPUT VOLTAGE	28 ± 1 VDC						
OUTPUT VOLTAGE	10 MV PEAK-TO-PEAK TO 10 KCPS						
ENDPOINT							
INPUT VOLTAGE	28 ± VDC						
OUTPUT VOLTAGE @ 0% FS TEMP @100% FS TEMP	0-200 MVDC 4800-5000 MVDC						

TEMPERATURE TRANSDUCERS

ME431-0068 (WHITTAKER)

(continued)

TEST	SUPPLIER	SYSTEM			PART II	TCSD	KSC
		MA0210-0190	MA0710-4225	MA0210-0158			
TEMPERATURE (SIGNAL CONDITIONER ONLY)							
TEMPERATURE	-65 ± 5°F and +200 ± 5°F						
INPUT VOLTAGE	28 ±1 VDC						
MAXIMUM ERROR @ ZERO POINT	±2.5% FS						
VIBRATION INPUT VOLTAGE	28 ± 1 VDC						
OUTPUT VOLTAGE SHIFT	± 0.15% MAX. OF FS						
CALIBRATION VOLTAGE	28 ± 1 VDC						
END POINTS @ 0% FS TEMP	0-200 MVDC						
@ 100% FS TEMP	4800-5000 MVDC						
LINEARITY							
NON-LINEARITY	±3% FS MAX (± 150 MV)						
REPEATIBILITY	± 10 MVDC (0.2% FS)						

TEMPERATURE TRANSDUCERS

ME431-0068 (WHITTAKER)

(continued)

TEST	SUPPLIER	SYSTEM			PART II	TCSD	KSC
		MA0210-0190	MA0710-4225	MA0210-0158			
AMBIENT DATA CHECK		TEST AREA AMBIENT ±5% ON CM DISPLAY, ±3% ACE DISPLAY	TEST AREA AMBIENT ±5% ON CM DISPLAY, ±3% ACE DISPLAY		TEST AREA AMBIENT ±5% ON CM DISPLAY, ±3% ACE DISPLAY	TEST AREA AMBIENT VERIFICATION ±5% ON CM DISPLAY	TEST AREA AMBIENT VERIFICATION ±5% ON CM DISPLAY
SYSTEM END-TO-END CHECK		TEMPERATURE APPLIED TO EACH TEMPERATURE SENSOR. DELTA-T VERIFIED ON EACH CORRESPONDING DISPLAY (CM AND ACE)	TEMPERATURE APPLIED TO EACH TEMPERATURE SENSOR. DELTA-T VERIFIED ON EACH CORRESPONDING DISPLAY (CM AND ACE)		TEMPERATURE APPLIED TO EACH TEMPERATURE SENSOR. DELTA-T VERIFIED ON EACH CORRESPONDING DISPLAY (CM AND ACE)		

TEMPERATURE TRANSDUCER

ME 431-0068 (Whittaker)

TEST	SUPPLIER	SYSTEM MA0210-0190	SYSTEM MA0710-4225	PART II	TSCD	KSC
Insulation Resistance						
Voltage	50 VDC					
Resistance	100 megohms					
Input to Output Isolation Resistance						
Voltage	50 VDC					
Resistance	100 megohms min					
Input Current						
Voltage	28 ± 1 VDC					
Current	56 MA max					
Output Noise						
Input Voltage	28 ± 1 VDC					
Output Voltage	10 MV Peak to Peak to 10 KCPs					
Endpoint						
Input Voltage	28 ± VDC					
Output Voltage						
α 0 o/o FS temp	0-200 MVDC					
α 100% FS temp	4800-5000 MVDC					

TEMPERATURE TRANSDUCER

ME 431-0068 (Whittaker)
(continued)

TEST	SUPPLIER	SYSTEM MA0210-0190	SYSTEM MA0710-4225	PART II	TSCD	KSC
Temperature (Sig conditioner only)						
Temp	-65 ± 5°F and +200 ± 5°F					
Input Voltage	28 ± 1 VDC					
Max Error						
α Zero point	± 2.5 °/o FS					
Vibration						
Input Voltage	28 ± 1 VDC					
Output Voltage Shift	± 0.15 °/o max of FS					
Calibration						
Voltage	28 ± 1 VDC					
End points						
α 0 °/o FS temp	0-200 MVDC					
α 100 °/o FS temp	4800-5000 MVDC					
Linearity						
Nonlinearity	± 3 °/o FS max (± 150 MV)					
Repeatability	± 10 MVDC (0.2 °/o FS)					
Ambient Data Check		Test area Ambient ± 5 °/o on CM display ± 3 °/o ACE display	Test area ambient ± 5 °/o on CM display ± 3 °/o ACE display	Test area ambient ± 5 °/o on CM display ± 3 °/o ACE display	Test area ambient verification ± 5 °/o CM display	Test area ambient verification ± 5 °/o CM display

TEMPERATURE TRANSDUCER

ME 431-0068 (Whittaker)
(continued)

TEST	SUPPLIER	SYSTEM MA0210-0190	SYSTEM MA0710-4225	PART II	TSCD	KSC
System End to End Check		Temperature Stimulus applied to each temperature sensor. ΔT verified on each corresponding display.	Temperature Stimulus Applied to each temperature sensor ΔT verified on each corresponding display	Temperature Stimulus applied to each temperature sensor ΔT verified on each corresponding display.	----	---

SECTION 8

GROUND SUPPORT EQUIPMENT AND SPECIAL MEASUREMENT DEVICES

Section 8 graphically presents and summarizes the Ground Support Equipment (GSE)/Special Measurement Devices (SMD) used at Downey, California and Kennedy Space Center, Florida for interfacing with spacecraft. There is no written text.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

BUILDING 6 (DEPARTMENT 659) SMD INTERFACING WITH SPACECRAFT

UNIT	DESCRIPTION	POTENTIAL DAMAGE
9FC-5225	DATA ACQUISITION SYS HI-SPEED RECORD	OVERVOLTAGE AND IMPROPER CONNECTION
9FS-0013	VACUUM DRYING CART	CONTAMINATION
9FS-5313	PORT FLUSH AND COOL CART	CONTAMINATION
9FS-5918	PNEUMATIC TEST CONSOLE	OVERPRESSURIZATION AND CONTAMINATION
11FC-6001	HYDCARB RECORD AND EQUIP RACK	CONTAMINATION

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

BUILDING 288 TEST CELL SMD INTERFACING WITH SPACECRAFT

UNIT	DESCRIPTION	POTENTIAL DAMAGE
9FS-4307	PNEUMATIC TEST CONSOLE	OVERVOLTAGE, IMPROPER CONNECTION, OVERPRESSURIZATION, AND CONTAMINATION
9FS-5911	MASS SPECTR LEAK TEST	CONTAMINATION
11FC-0016	INSTRUMENTATION CONSOLE	OVERVOLTAGE AND IMPROPER CONNECTION
11FC-0050	VOL LEAK RATE IND UNIT	CONTAMINATION
11FC-0051	MOIST AND HYDROCARB DETECTOR	CONTAMINATION

DOWNEY BUILDING 288 TEST CELL NUMBER 3, PNEUMATIC SYSTEM, PROTECTION AGAINST OVERPRESSURIZATION

THE SYSTEM IS COMPOSED OF FOUR PRESSURE SYSTEMS, ONE HIGH PRESSURE SYSTEM, ONE LOW PRESSURE SYSTEM, AND TWO MEDIUM PRESSURE SYSTEMS. ASSUMING MULTIPLE FAILURES, THE HIGH PRESSURE SYSTEM COULD BE CONNECTED TO THE LOW PRESSURE SYSTEM AND DESTROY THE REGULATORS, TO THE MEDIUM PRESSURE SYSTEM AND DESTROY THE CHECK VALVES, AND THE RELIEF VALVES. THE RECEIVER IS RATED AT 10,000 PSIG AND CONSTANT MONITORING OF PRESSURE IS MAINTAINED DURING COMPRESSOR OPERATION. FACILITY REGULATOR IS PRE-SET AT 8,000 PSIG AND DOWNSTREAM RELIEF VALVE IS SET AT 7,500 PSIG. THIS PRESSURE IS REGISTERED ON A ZERO TO 10,000 PSIG GAGE AND CONTROLLED BY A ZERO TO 8,000 REGULATOR AND MONITORED BY A ZERO TO 10,000 PSIG GAGE. DOWNSTREAM IS A 4,600 PSIG RELIEF VALVE WITH A 6,900 PSIG RELIEF VALVE BACKUP. THE OTHER THREE PRESSURE SYSTEMS ARE CONTROLLED BY A ZERO TO 4,000 PSIG REGULATOR, MONITORED BY A ZERO TO 3,000 PSIG GAGE BEFORE SPLITTING INTO SEPARATE SYSTEMS. THE LOW PRESSURE SYSTEM IS CONTROLLED BY A ZERO TO 100 PSIG REGULATOR, MONITORED ON A ZERO TO 60 PSIG GAGE, BACKED BY A ZERO TO 60 PSIG RELIEF VALVE. THE REMAINING TWO PRESSURE SYSTEMS ARE CONTROLLED BY A ZERO TO 500 PSIG REGULATOR, ONE IS MONITORED BY A ZERO TO 600 PSIG GAGE; THE OTHER IS MONITORED BY A ZERO TO 1,000 PSIG GAGE: BOTH ARE BACKED BY THREE RELIEF VALVES, ONE SET AT 280 PSIG, ONE AT 400 PSIG, AND ONE AT 600 PSIG. EACH REGULATOR IS DESIGNED TO FAIL CLOSED AND HAS AN AUTOMATIC OVERPRESSURE RELIEF VALVE SET AT A MAXIMUM OF 15 PSI ABOVE THE DIALED PRESSURE. EACH PRESSURE GAGE HAS BLOWOUT PROVISIONS AT 25 PERCENT ABOVE THE MAXIMUM GAGE PRESSURE. THEREFORE, DAMAGE TO ANY RCS PANEL IS DOUBTFUL.

DOWNEY BUILDING 288 TEST CELL NUMBER 3, PNEUMATIC SYSTEM, PROTECTION AGAINST CONTAMINATION

EACH LINE UNDER NORMAL CONNECTION HAS FOUR (4), FIVE TO FIFTEEN MICRON, FILTERS IN SERIES. EACH LINE MUST PASS A BLOW DOWN BEFORE BEING CONNECTED. ALL FLUIDS ARE CERTIFIED TO SPECIFIED CONDITIONS BEFORE USE. EACH INTERFACE FILTER AND GROUND-HALF DISCONNECT IS CLEANED BEFORE BEING CONNECTED TO THE TEST ARTICLE. CONTAMINATION OF THE RCS IS DOUBTFUL.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

BUILDING 289 TEST CELL SMD INTERFACING WITH SPACECRAFT

UNIT	DESCRIPTION	POTENTIAL DAMAGE
9FC-5225	DATA ACQUISITION UNIT	OVERVOLTAGE AND IMPROPER CONNECTION
9FS-4307	PNEUMATIC TEST CONSOLE	OVERPRESSURIZATION, CONTAMINATION, OVERVOLTAGE, AND IMPROPER CONNECTION
11FC-0051	MOISTURE AND HYDROCARB DETECT	CONTAMINATION
11FC-0079	DIFFERENTIAL PRESSURE CONSOLE	OVERPRESSURIZATION AND CONTAMINATION
11FS-0030	HELIUM HEAT EXCHANGE UNIT	CONTAMINATION
9FS-5911	MASS SPECTR - LEAK TEST	CONTAMINATION
11FC-0050	VOL LEAK RATE IND UNIT	CONTAMINATION

DOWNEY - BLDG. 289 - TEST CELLS 5A AND 5B, PNEUMATIC SYSTEM, PROTECTION AGAINST OVERPRESSURIZATION

THE K BOTTLES ARE PURCHASED AT 2,250 PSIG, PRESSURE IS REGISTERED ON A ZERO TO 3,000 PSIG GAGE, CONTROLLED BY A ZERO TO 600 DOME LOADED REGULATOR. PROTECTED BY A RELIEF VALVE, COMPRESSOR PRESSURE IS REGISTERED ON A ZERO TO 20,000 PSIG GAGE. THE RECEIVER IS RATED AT 10,000 PSIG AND RECEIVER PRESSURE IS MONITORED BY A ZERO TO 20,000 PSIG GAGE. OUTPUT PRESSURE IS DIALED ON A ZERO TO 10,000 DOME LOADED REGULATOR AND MONITORED BY A ZERO TO 20,000 PSIG GAGE. THIS SPLITS INTO TWO SYSTEMS. THE HIGH PRESSURE SYSTEM IS REGISTERED ON A ZERO TO 10,000 PSIG GAGE, DIALED BY A ZERO TO 8,000 PSIG REGULATOR MONITORED BY A ZERO TO 10,000 PSIG REGULATOR, AND PROTECTED BY A 5075 PSIG RELIEF VALVE. THE LOW PRESSURE SYSTEM HAD A ZERO TO 10,000 PSIG DOME LOADED REGULATOR CONTROLLED WITH A ZERO TO 10,000 REGULATOR, MONOTIRED ON A ZERO TO 2,000 PSI GAGE AND PROTECTED BY A 1,850 PSIG RELIEF VALVE. THIS SPLITS INTO THREE MAIN PRESSURE SYSTEMS AND THREE AUXILIARY RCS SYSTEMS. ONE OF THE AUXILIARY SYSTEMS IS CONTROLLED BY A ZERO TO 2,000 PSIG REGULATOR AND MONITORED BY A ZERO TO 1,000 PSIG GAGE AND PROTECTED BY A ZERO TO 1,000 PSIG ADJUSTABLE RELIEF VALVE. THE OTHER TWO AUXILIARY SYSTEMS FEED GAS INTO THE DELTA PRESSURE SYSTEM WHERE ONE IS FED INTO A MOISTURE MONITOR TO MONITOR THE DRYNESS OF THE SUPPLIED FLUID. THE OTHER AUXILIARY SYSTEM FEEDS FLUID TO THE DELTA PRESSURE SYSTEM WHERE IT IS USED TO MAINTAIN A DELTA PRESSURE ACROSS THE BLADDERS AND THE RELIEF VALVE BURST DISC. THIS SYSTEM IS PROTECTED BY A 320 PSIG RELIEF VALVE FOR THE TWO PRESSURE LEVELS ACROSS THE TANK AND A 285 PSIG RELIEF VALVE DOWNSTREAM OF THE SPACECRAFT RELIEF VALVE. OF THE THREE MAIN SYSTEMS, TWO ARE ALIKE IN THAT BOTH ARE CONTROLLED BY A ZERO TO 2,000 PSIG REGULATOR, MONITORED BY A ZERO

DOWNEY - BLDG. 289 - TEST CELLS 5A AND 5B, PNEUMATIC SYSTEM, PROTECTION AGAINST OVERPRESSURIZATION

(continued)

TO 1,000 PSIG GAGE AND PROTECTED BY AN ADJUSTABLE ZERO TO 1,000 RELIEF VALVE. THE REMAINING SYSTEM IS CONTROLLED BY A ZERO TO 2,000 PSIG REGULATOR, MONITORED BY A ZERO TO 60 PSIG GAGE, AND PROTECTED BY AN ADJUSTABLE ZERO TO 100 PSIG RELIEF VALVE. ALL EXCEPT THE DOME LOADED REGULATORS HAVE A FAIL CLOSE DESIGN AND A BUILT-IN RELIEF VALVE THAT RELIEVES AT PRESSURES OF 0 TO 15 PSI OVER THE SET PRESSURES. EACH GAGE HAS A 25-PERCENT OVERPRESSURE BLOWOUT PLUG SO DAMAGE TO THE RCS FROM THE SYSTEM IS DOUBTFUL.

DOWNEY - BLDG. 289 - TEST CELLS 5A AND 5B, PNEUMATIC SYSTEM, PROTECTION AGAINST CONTAMINATION

EACH LINE HAS A BLOW DOWN BEFORE CONNECTION, HAS TO PASS FOUR FILTERS BEFORE BEING FED INTO THE SYSTEM. THE FIRST FILTER HAS A PRESSURE READOUT AND A HYDROCARBON INDICATOR ATTACHED AND THE INTERFACE FILTER IS CLEANED BEFORE EACH USE. THE FLUID IS VERIFIED TO BE WITHIN REQUIREMENTS BEFORE USE AND IS CONSTANTLY MONITORED FOR MOISTURE DURING USE. CONTAMINATION OF THE RCS IS DOUBTFUL.

TEST CELLS - ELECTRICAL SYSTEM
BLDG. 288 - 289

OVERVOLTAGE: POWER SUPPLIES ARE NOW RESTRICTED TO 32 VDC, DUE TO THE LENGTH OF WIRE AND DESIGN OF SPACECRAFT VALVES. IT IS DOUBTFUL ANY DAMAGE COULD OCCUR TO THE RCS VALVES. POWER SUPPLIES ARE CAPABLE OF BEING DIALED TO 36 VDC BUT DAMAGE TO VALVE IS PROBLEMATICAL.

IMPROPER CONNECTION: BIGGEST SOURCE IS THE PATCH PANEL. COULD REVERSE POLARITY ON THE SPACECRAFT VALVES TO THEIR DETRIMENT. TEST POINTS EXIST AT NUMEROUS AREAS AND 110 VAC CAN AND HAVE BEEN IMPRESSED ON THE SPACECRAFT VALVES, DESTROYING THEM. THE SYSTEMS ARE ALL FUSED TO PREVENT OVER CURRENT DAMAGE.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

BUILDING 1 TEST CELL SMD INTERFACING WITH SPACECRAFT

UNIT	DESCRIPTION	POTENTIAL DAMAGE
9FS-4307	PNEUMATIC TEST UNIT	OVERPRESSURIZATION AND CONTAMINATION
11FC-0016	INSTRUMENTATION CONSOLE	OVERVOLTAGE AND IMPROPER CONNECTION
11FC-0050	VOL LEAK RATE IND UNIT	CONTAMINATION
11FC-0051	MOISTURE AND HYDROCARB DETECT	CONTAMINATION
11FC-0076	CONTROLLED PRESSURE UNIT	OVERPRESSURIZATION AND CONTAMINATION
9FS-5911	MASS SPECTR LK TST	CONTAMINATION
11FS-0030	HELIUM HEAT EXCH UNIT	CONTAMINATION

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

BUILDING 290 GSE INTERFACING WITH SPACECRAFT

UNIT	DESCRIPTION	POTENTIAL DAMAGE
C14-075	PROPULSION SYSTEM FLUID CONTROL	OVERPRESSURIZATION
S14-082 or S14-014	FLUID DISTRIBUTION SYSTEM	OVERPRESSURIZATION
C14-650/ C34-664	RCS VALVE RESPONSE MOBILE DATA RECORDER	OVERVOLTAGE

SERVICE MODULE
REACTION CONTROL SUBSYSTEM

BUILDING 290 GROUND SUPPORT EQUIPMENT INTERFACING WITH SPACECRAFT SM REACTION CONTROL SUBSYSTEM ENGINES

UNIT	OVERPRESSURIZATION	CONTAMINATION	COMMENTS
C14-075 PROPELLANT SYSTEM CHECKOUT UNIT S14-082 OR S14-014 FLUID DISTRIBUTION SYSTEM	RELIEF VALVES, PRESSURE REGULATORS, SELF-RELIEVING REGULATORS, PRESSURE CONTROL SYSTEM IN VALVE BOX (SPACECRAFT SYSTEM DELTA-P CONTROL)	REDUNDANT 5-15 MICRON FILTERS	IN LINE 5-15 MICRON FILTERS AT INTERFACE BEFORE QUICK DISCONNECTS AND AT VALVE BOX
UNIT	**OVERVOLTAGE**	**EXCESS CYCLES OR ON TIME**	**COMMENTS**
RECORDER INTERFACE CONTROL CONSOLE C14-650	INTERNAL POWER SUPPLY LIMITED TO 60 VDC PRE-CHECKOUT AT THREE VOLTS IS ACCOMPLISHED BEFORE TEST VOLTAGE	MANUAL PUSH BUTTON SPRING LOADED OPEN	INTERNAL SELF CHECK AND CALIBRATION CAPABILITY. CONTINUOUS MONITORING OF TEST VOLTAGES (METER)

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

BUILDING 290 SMD INTERFACING WITH SPACECRAFT

UNIT	DESCRIPTION	POTENTIAL DAMAGE
9FS-0008	PURGE PUMP AND FILTER CART	CONTAMINATION
9FS-0013	VACUUM DRYING CART	CONTAMINATION
9FS-5313	PORTABLE FLUSH AND COOL CART	CONTAMINATION
9FS-5911	MASS SPECTR LEAK TEST	CONTAMINATION
11FC-0050	VOL LEAK RATE IND UNIT	CONTAMINATION
11FC-6001	HYDCARB HYDRO PRESS SAMP UNIT	CONTAMINATION
11FC-0034	RCS VALVE RESPONSE TEST SET	OVERVOLTAGE

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

DOWNEY TEST FACILITY EVALUATION

LOCATION	OVERPRESSURIZATION	CONTAMINATION	OVERVOLTAGE
SMD EQUIPMENT LOCATED IN BUILDING 1 TEST CELLS, BUILDING 288 TEST CELL 3, BUILDING 289 TEST CELLS 5A AND 5B, DEPARTMENT 659, AND BUILDING 290.	EACH PRESSURE LINE HAS PRESSURE RELIEF VALVES SET AT 10 PERCENT ABOVE MAXIMUM OPERATING PRESSURE. EACH RELIEF VALVE IS CHECKED FOR CRACKING PRESSURE AND RESEAT BEFORE EACH USE. EACH GAGE HAS BLOWOUT PROVISIONS 25 PERCENT ABOVE MAXIMUM GAGE DIAL PRESSURE. EACH HAND LOADING PRESSURE REGULATOR HAS A BUILT-IN RELIEF VALVE 0-15 PSIG ABOVE THE DIALED PRESSURE AND ARE DESIGNED TO FAIL CLOSED.	EACH LINE IS CLEANED BEFORE INSTALLATION, BLOWN DOWN BEFORE USE, AND THE INTERFACE FILTER AND GROUND-HALF COUPLING ARE CLEANED AND DRIED BEFORE EACH USE. EACH LINE HAS FILTERS IN SERIES TO PROTECT TEST ARTICLE. EACH FLUID IS VERIFIED TO BE WITHIN SPECIFICATION BEFORE USE.	THE 28 VDC POWER SUPPLY CANNOT BE DIALED TO A VOLTAGE IN EXCESS OF 36 VDC.

SUMMARY OF MAJOR SMD/GSE PROBLEMS AND HARDWARE MODIFICATIONS

11FC-0027

C11-002700 A bypass cable was made to interconnect two patch panels (C11-002300). This eliminated the hazard caused by patching errors and patching changes on the installation patch boards.

11FC-0016

C11-001600 When this model was redesigned the amp patch board was replaced with switching circuits to eliminate patching errors. These patching errors could result in damage to spacecraft instrumentation.

Most of the incidents which resulted in damage to the spacecraft were procedure errors and not STE design problems. For this reason it is recommended that patching and manual operations be replaced by switching circuits.

Date: 11-13-68 B/288 TC #3
C11-007002 Electrical cable. J3 and J6 wires and connector pins were twisted and bare wires exposed.

Recommendation to prevent future problems of this type: All connectors should have cable clamps.

B/288 TC #3

9FS-4307

SMDA-4992 Valve Control Panel. DC power supply sense leads were rewired and resistors added to prevent the power supply from applying maximum output voltage to spacecraft solenoid valves. This situation occurs when the power supply sense leads are open.

11FC-0016

C11-001600 Calibration panel. Damage to spacecraft transducers could occur from incorrect jumpering on the calibration panel. This patching section could be replaced with pushbutton controls to eliminate this hazard.

11FC-0068 RCS helium panel interface kit
Entire kit was redesigned after several panels were damaged during tests. Excessive side loads were imposed on airborne couplings by technicians. The redesigned kit supported the ground half couplings against side loads.

2

Tube stem adaptors for CM RCS helium panel tests

Improper cleaning caused etching of the tube stem adaptor material. When the undersized parts were assembled and installed on spacecraft tube stems, they would not properly grip the tube stem. During application of high pressure in the tube, the tube and adaptor acted as a piston and cylinder and the resulting movement caused the spacecraft tubing to be bent. Action was taken to replace undersized parts.

11FC-0050 Leak detection unit

Several devices which used the displacement of water for determining leak rates have been used in the various test cells. It was found that water vapor could migrate from the leak measurement device into the spacecraft component under test. When moisture was found in a spacecraft component, it was necessary to purge it until it met dryness requirements. The STE Model 11FC-0050 replaced water displacement devices. It uses a calibrated piston to measure gas volumes. This unit has reduced the amount of drying required.

Gas compressor failure and resulting oil contamination.

Required addition of:

1. Oil detector
2. Mechanical and chemical separation system
3. Blowdown requirements
4. Defined maximum allowable oil content of gas delivered to STE by the facility.

Not met by facilities in reoccurrence

11FC-0079 Differential pressure console

During testing of RCS fuel and oxidizer tanks, there is a requirment to maintain a positive differential pressure across the bladders. The original method used a system of check valves that would open at pre-selected pressures to maintain the proper differential. The check valves failed frequently and would not maintain the proper pressures.

The STE Model 11FC-0079 was designed to replace the previously used method. The 11FC-0079 contains two (3) differential pressure regulators that automatically sense and adjust the differential pressure to selected valves.

Operational Improvement

9FS - 4307

In test cells 3, 5A, and 5B, a variety of spacecraft components are tested. Each of the various components requires different maximum pressure during testing. To insure that a relief valve is providing protection against overpressurizing the spacecraft component, a manually adjustable valve has been provided in each system. A validation procedure, which is run prior to the hookup of spacecraft components to the test cell, verifies the proper setting and operation of each of these relief valves.

All flex hoses

Many flexible hoses are used in the various test cells. During high pressure testing, the separation of the hose from the end fitting would allow the hose to whip and possibly cause damage to other STE, personnel, and the spacecraft.

All STE drawings have been updated to add restraints to the ends of flexible hoses. In case of failure, the hose will be prevented from whipping.

11FC-0009 Leak Detector

During a test, a valve was left in the open position when it was required to be closed. A volume micrometer rated at 1,000 psig failed when it was exposed to 3,200 psi. The resulting explosion endangered 2 technicians and the CM RCS panel. Several pieces of STE were damaged. No relief valve had been installed due to the possibility of leakage and the resulting errors in the leakage measurement.

A burst disc rated at 1125 psi has been added in each console of this type. The disc will prevent a similar accident if the test procedure is not followed.

Tools, R-57613, R-972485, T-7118667, T-7118670, T-7118671

Subject tools were investigated through the planning department. There is no record of any of these tools ever having a failure.

The tools were investigated through the planning department. There is no record of any of these tools ever having a failure.

The tools were also investigated through the using department. Personnel involved in the use of these tools, stated they had never had a failure on any of these tools. They have had clearance problems, etc., nothing more serious, but these tools are now in Class I shape.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

KSC GSE INTERFACING WITH SPACECRAFT

MODEL NUMBER	DESCRIPTION	POTENTIAL DAMAGE
A14-146	SM ENGINE THROAT PLUGS	NONE
Z00-091	SM ENGINE COVERS	NONE
A14-179	CM ENGINE THROAT PLUGS	NONE
A14-026	CM ENGINE COVERS	NONE
C34-398	CSM CHECKOUT SET	CONTAMINATION
C14-075	FLUID CHECKOUT UNIT	OVERPRESSURIZATION AND CONTAMINATION
S14-132	FLUID DISTRIBUTION SYSTEM	OVERPRESSURIZATION AND CONTAMINATION
S14-009	HELIUM SERVICING UNIT	OVERPRESSURIZATION AND CONTAMINATION
S14-057	OXIDIZER SERVICING UNIT	OVERPRESSURIZATION AND CONTAMINATION
S14-064	FUEL SERVICING UNIT	OVERPRESSURIZATION AND CONTAMINATION
S14-122	OXIDIZER BLEED UNIT	OVERPRESSURIZATION AND CONTAMINATION
S14-124	FUEL BLEED UNIT	OVERPRESSURIZATION AND CONTAMINATION
S34-141	SCUPPER SET	NONE
C34-664	RECORDER AND VALVE DRIVER	OVERVOLTAGE

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

KSC SPACECRAFT - GSE INTERFACE

UNIT	POTENTIAL DAMAGE	COMMENTS
C34-650 RECORDER INTERFACE CONTROL UNIT HARRISON POWER SUPPLY (MODEL 6271A)	DAMAGE TO ENGINE VALVE COIL AND/OR SPACECRAFT WIRING DUE TO OVERVOLTAGE OR OVERHEATING	VALVE WILL MEET REQUIREMENTS OF SPECIFICATION WHEN OPERATED AT 27 $\pm$ 3 VOLTS. POWER SUPPLY IS SET TO 28 $\pm$ 1 VDC (CAPABLE OF 60 VOLTS AT 3 AMPS MAXIMUM CURRENT LIMITED). SPRING LOADED PUSH BUTTON IS USED TO ACTUATE ENGINE ON TIME APPROXIMATELY 30 SECS. PROTECTION COMES FROM PROCEDURE CONTROL. UNIT USED IN CSM ENGINE FLOW TEST AND AS RECORDER IN VALVE SIGNATURES.
C34-664 RECORDER AND VALVE DRIVER HARRISON POWER SUPPLY (MODEL 6271A)	DAMAGE TO ENGINE VALVE COIL AND/OR SPACECRAFT WIRING DUE TO OVERVOLTAGE OR OVERHEATING	VALVE WILL MEET REQUIREMENTS OF SPECIFICATION WHEN OPERATED AT 27 $\pm$ 3 VOLTS. POWER SUPPLY IS SET TO 28 $\pm$ 1 VDC (CAPABLE OF 60 VOLTS AT 3 AMPS MAXIMUM CURRENT LIMITED). SPRING LOADED PUSH BUTTON IS USED TO ACTUATE ENGINE ON TIME APPROXIMATELY 30 SECONDS. PROTECTION COMES FROM PROCEDURE CONTROL. UNIT USED IN CSM ENGINE FLOW TEST AND AS RECORDER IN VALVE SIGNATURES.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

KSC SPACECRAFT-GSE INTERFACE PROTECTIVE DEVICES

UNIT	OVERPRESSURIZATION	CONTAMINATION	COMMENTS
S14-009 S14-132 (ASSOCIATED FDS)	PRESET REGULATOR IN UNIT (4,500 ± 100) BACKED UP BY BACK PRESSURE VALVE (4,650 ± 100) AND RELIEF VALVE (4,900 +50 -200). ALSO, RELIEF VALVE IN VALVE BOX (4,500 ± 50) ORIFICE IN LINE (V/B) RESTRICTS FLOW (20-25 cfm) PRESSURE CAN BE READILY VENTED BY OPENING APPROPRIATE FILL VALVE AND VENT VALVE IN VALVE BOX. DIRECT CONTROL OF VENT AND UNIT SHUTDOWN FROM LCC IF ACE CONTROL IS LOST.	FILTERS AT EACH INLET TO SPACECRAFT (5 μ)	SPACECRAFT TANK TEMPERATURE ARE MONITORED CONTINUOUSLY DURING PRESSURIZATION TO ENSURE COMPLIANCE WITH TANK LIMITATIONS
C14-075	REGULATOR UPSTREAM OF CONTROL REGULATOR IS USED AS LIMITING DEVICE RELIEF VALVES ARE SET AT PRESSURES WHICH WOULD PREVENT TANK FAILURES BUT NOT SPACECRAFT BURST DISCS. THEREFORE, UNIT REGULATION IS CLOSELY CONTROLLED.	5 μ FILTER AT INLET OF UNIT AND AT SPACECRAFT INTERFACE	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

KSC SPACECRAFT-GSE INTERFACE PROTECTIVE DEVICES

UNIT	OVERPRESSURIZATION	CONTAMINATION	COMMENTS
S14-057 S14-064 S14-132 (ASSOCIATED FDS)	RELIEF VALVE (75 PSIG) TO PROTECT AGAINST OVERPRESSURIZATION OF TANK IN UNIT BY-PASS VALVE (62 PRI) IN UNIT, PRI IN VALVE BOX AND MANUAL VALVING CONTROL FLOW RATES TO SPACECRAFT INTERFACE PRESSURE ON INSIDE OF SPACECRAFT TANKS CONTROLLED BY BPR1 IN CONJUNCTION WITH PRI PR2 CONTROLS BACK SIDE OF BLADDER. RV3 PROTECTS INLET PRESSURE TO PR2. RV2 PROTECTS DOWNSTREAM PRESSURE OF PR2.	FILTERS (5 μ) IN UNIT AND VALVE BOX. IN ADDITION, WINTEC FILTERS AT SPACECRAFT INTERFACE	BPR1 FAILURE CAN RESULT IN DELTA-P CYCLE OF BLADDER
BLEED UNITS (S14-122) (S14-124)	RELIEF VALVE PR3 TO PROTECT AGAINST TANK OVERPRESSURIZATION	REFERENCE S14-057 AND S14-064	
C34-398 (CSM CHECKOUT SET)	NOT APPLICABLE	WATER CAN BE INTRODUCED INTO SYSTEM BY INADVERTENTLY PUTTING VACUUM INTO SPACECRAFT LINES. PROTECTED BY JUDICIOUS CONTROL OF PROCEDURES AND TECHNICIANS.	

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SUBSYSTEMS

G.S.E./SPECIAL MEASUREMENT DEVICES SUMMARY AND RECOMMENDATIONS

UNIT	POTENTIAL HAZARD	RECOMMENDATION
C14-650 RECORDER INTERFACE CONTROL CONSOLE (DOWNEY) C34-664 RECORDER AND VALVE DRIVER (KSC)	POSSIBILITY OF APPLYING MAXIMUM OF 60V AT 3 AMPS TO ENGINE DIRECT COILS	PROVIDE AUTOMATIC VOLTAGE LIMITER SET AT 30 VOLTS
C34-398 CSM CHECKOUT SET (VOLUMETRIC LEAK DETECTOR AT KSC)	POSSIBILITY OF INTRODUCING MOISTURE INTO THE SYSTEM	USE WATERLESS LEAK DETECTION TECHNIQUES OR PROVIDE DEVICES TO PROTECT THE SYSTEM FROM WATER

SECTION 9

COMMAND/SERVICE MODULE

PROTECTION DEVICES

Section 9 presents and summarizes in tabular form the Command/ Service Module protection devices. There is no written text.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

SUMMARY OF DEVICES THAT PROVIDE AUTOMATIC PROTECTIVE FUNCTIONS

ITEM	INTENT	LIMITATIONS	REMARKS
RELIEF VALVES	COUNTERACT ABNORMAL TEMP INCREASE BY LIMITING SYSTEM PRESSURE. HANDLE REGULATOR LEAKAGE.	CANNOT HANDLE DUAL SERIES REGULATOR OPEN FAILURE	REGULATOR DUAL FAILURE PROBABILITY LOW
CAUTION AND WARNING	ALERT CREW TO ABNORMAL OPERATING CONDITIONS	MASKING OF SUBSEQUENT EVENT	NO AUTOMATIC PROTECTION ALERTS CREW ONLY
FILTERS	PARTICULATE CONTAMINATION PROTECTION	DIRT HOLDING CAPACITY	
CIRCUIT BREAKERS AND FUSES	OVERVOLTAGE PROTECTION	ENGINE PIGTAILS HAVE 20-GAUGE WIRE, SHOULD BE 16-GAUGE HELIUM ISOLATION VALVES HAVE 24-GAUGE WIRE, SHOULD BE 22-GAUGE	SPECIAL OFF-LIMITS TESTING ESTABLISHED WIRE TEMPS BELOW 600°F SPECIFICATION LIMIT

SERVICE MODULE REACTION CONTROL SYSTEM

OVERPRESSURIZATION PROTECTION

ITEM	INTENT	LIMITATIONS	REMARKS
HELIUM REGULATOR	CONTROL HELIUM PRESSURE TO 181 $\pm$ 3 PSIG; FOUR FULL-SIZE STAGES IN SERIES-PARALLEL CONFIG.	NO FLOW LIMITER IN THE EVENT OF A DUAL SERIES OPEN FAILURE	PROBABILITY OF DUAL SERIES OPEN FAILURE LOW
RELIEF VALVES	LIMIT PROPELLANT SYSTEM PRESSURE TO A MAXIMUM OF 248 PSIG. PRIMARILY INTENDED FOR THERMAL EXCURSIONS.	CANNOT RELIEVE AT A SUFFICIENT RATE TO HANDLE DUAL SERIES OPEN REGULATOR FAILURE	PROBABILITY OF DUAL SERIES OPEN FAILURE LOW

SERVICE MODULE REACTION CONTROL SYSTEM

PROPELLANT EXPOSURE PROTECTION

ITEM	INTENT	LIMITATIONS	REMARKS
CHECK VALVES	PREVENT OXYGEN/FUEL VAPOR OR LIQUID MIXING IN PRESSURIZATION SYSTEM	FAILED CLOSED CONDITION WILL RESTRICT HELIUM FLOW	SERIES/PARALLEL CONFIGURATION
RELIEF VALVE BURST DISC	PREVENTS PROPELLANT VAPOR/LIQUID CONTACT WITH RELIEF VALVE	CAN BE RUPTURED WITHOUT UNSEATING RELIEF VALVE	RELIEF VALVE REMAINS OPERATIONAL

SERVICE MODULE REACTION CONTROL SYSTEM

PARTICULATE PROTECTION

ITEM	INTENT	LIMITATIONS	REMARKS
HELIUM FILL COUPLING	FILTRATION OF HELIUM ENTERING SYSTEM	40 NOM. 75 ABS.	
PROPELLANT FILL + DRAIN COUPLING	FILTRATION OF PROPELLANT ENTERING SYSTEM	40 NOM. 75 ABS.	
IN-LINE PROPELLANT FILTER	PROTECTION OF ENGINES	5 NOM. 15 ABS.	
HELIUM REGULATOR	PROTECTION OF REGULATOR POPPETS	25 NOM. 40 ABS.	
CHECK VALVES			
• INLET	PROTECTION OF VALVE SEATS	40 NOM. 74 ABS.	
• TEST PORT	FILTRATION OF INCOMING GASES	40 NOM. 74 ABS.	
ENGINES	PROTECTION OF ENGINES	100 NOM. 250 ABS.	
TEST POINT COUPLINGS	FILTRATION OF INCOMING GASES	55 ABS.	
RELIEF VALVE	RETENTION OF BURST DISC PIECES	10 NOM. 25 ABS.	

SERVICE MODULE REACTION CONTROL SYSTEM

CAUTION/WARNING SYSTEM

ITEM	INTENT	LIMITATIONS	REMARKS
HIGH PACKAGE TEMPERATURE	INDICATES ABNORMAL $>$ 205°F (NOM.) QUAD TEMPERATURE ILLUMINATES $<$ 75°F $>$ 205°F		
LOW PACKAGE TEMPERATURE	$<$ 75°F (NOM.)		
LOW FUEL MANIFOLD PRESSURE	INDICATES ABNORMAL $<$ 145 PSIA (NOM.) PRESSURE ILLUMINATES $<$ 145 $>$ 215 PSIA		

COMMAND MODULE REACTION CONTROL SYSTEM

OVERPRESSURIZATION PROTECTION

ITEM	INTENT	LIMITATIONS	REMARKS
HELIUM REGULATOR	CONTROL HELIUM PRESSURE, FOUR FULL-SIZE STAGES IN SERIES-PARALLEL CONFIG.	NO FLOW LIMITER IN THE EVENT OF A DUAL SERIES OPEN FAILURE	PROBABILITY OF DUAL SERIES OPEN FAILURE LOW
RELIEF VALVES	LIMIT PROPELLANT SYSTEM PRESSURE TO A MAXIMUM OF 360 PSIG. PRIMARY INTENDED FOR THERMAL EXCURSIONS.	CANNOT RELIEVE AT A SUFFICIENT RATE TO HANDLE DUAL SERIES OPEN REGULATOR FAILURE	PROBABILITY OF DUAL SERIES OPEN FAILURE LOW

COMMAND MODULE REACTION CONTROL SYSTEM

PROPELLANT EXPOSURE PROTECTION

ITEM	INTENT	LIMITATIONS	REMARKS
CHECK VALVES	PREVENT OXYGEN/FUEL VAPOR OR LIQUID MIXING IN PRESSURIZATION SYSTEM	FAILED CLOSED CONDITION WILL RESTRICT HELIUM FLOW	SERIES/PARALLEL CONFIGURATION REDUNDANT SYSTEM
RELIEF VALVE BURST DISC	PREVENTS PROPELLANT VAPOR/ LIQUID CONTACT WITH RELIEF VALVE	CAN BE RUPTURED WITHOUT UNSEATING RELIEF VALVE, I.E., TEMPERATURE CAUSED PRESSURE INCREASE	RELIEF VALVE REMAINS OPERATIONAL

COMMAND MODULE REACTION CONTROL SYSTEM

PARTICULATE PROTECTION

ITEM	INTENT	LIMITATIONS	REMARKS
HELIUM FILL COUPLING	FILTRATION OF HELIUM ENTERING SYSTEM	40 NOM. 75 ABS.	
PROPELLANT FILL + DRAIN COUPLING	FILTRATION OF PROPELLANT ENTERING SYSTEM	40 NOM. 75 ABS.	
ISOLATION VALVE	RETENTION OF BURST DISC PIECES	75 NOM. 100 ABS.	
HELIUM REGULATOR	PROTECTION OF REGULATOR POPPETS	25 NOM. 40 ABS.	
CHECK VALVES			
. INLET	PROTECTION OF VALVE SEATS	40 NOM. 74 ABS.	
. TEST PORT	FILTRATION OF INCOMING GASES	40 NOM. 74 ABS.	
ENGINES	PROTECTION OF ENGINES	5 NOM. 15 ABS.	
TEST POINT COUPLINGS	FILTRATION OF INCOMING FLUIDS	55 ABS.	
RELIEF VALVE	RETENTION OF BURST DISC PIECES	10 NOM. 25 ABS.	
HELIUM SQUIB VALVE	PROTECTION OF REGULATORS	40 NOM. 74 ABS.	

COMMAND MODULE REACTION CONTROL SYSTEM

CAUTION/WARNING SYSTEM

ITEM	INTENT	LIMITATIONS	REMARKS
HIGH HELIUM MANIFOLD PRESSURE	INDICATES ABNORMAL >330 PSIA (NOM.) REGULATED PRESSURE ILLUMINATED AT <260 PSIA >330 PSIA		
LOW HELIUM MANIFOLD PRESSURE	<260 PSIA (NOM.)		

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CIRCUIT BREAKERS

CIRCUIT BREAKER	FUNCTION	OPERATION	C/B LOSS	COMMENTS
B - MNA	QUAD B HEATERS PRIMARY AND SECONDARY	QUAD B PACKAGE HEATERS	QUAD B LOSS	OTHER QUADS UNAFFECTED
	TALKBACKS: QUAD B AND D: PRIMARY AND SECONDARY PROP ISO VALVES HELIUM 1 AND 2 ISO VALVES CM RCS 1: PROP ISOL VALVES	MDC DISPLAY	LOSS OF VALVE POSITION INTELLIGENCE	QUAD A AND C UNAFFECTED SYS 2 UNAFFECTED
	CM RCS SYS 1 PROP ISO VALVES AUTO CLOSED	VALVE CLOSURE ON ABORT TO T+42 SEC.	SYS 1 GALLERY LINES WETTED ON ABORT	SYS 2 UNAFFECTED
MNA - D	QUAD D HEATERS PRIMARY AND SECONDARY	QUAD D PACKAGE HEATERS	QUAD D LOSS	OTHER QUADS UNAFFECTED
MNA	QUAD B AND D HELIUM ISO VALVES 1 AND 2 PRIMARY AND SECONDARY OX AND FU ISO VALVES SEC FU PRESS VALVE	PROPELLANT ISOLATION	HELIUM AND PROP ISO CLOSURE AND SEC FU PRESSURE VALVE OPENING CAPABILITY	QUADS A AND C UNAFFECTED
	CM RCS SYS 1 PROP ISO VALVES	PROPELLANT ISOLATION	VALVE POSITION CHANGE	SYS 2 UNAFFECTED

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CIRCUIT BREAKERS

CIRCUIT BREAKER	FUNCTION	OPERATION	C/B LOSS	COMMENTS
1 - MNA	CM VALVE HEATING	CM RCS SYS 1 DIRECTS COILS	SYS 1 VALVE HEATING	SYS 2 VALVE HEATING UNAFFECTED
2 - MNB	CM VALVE HEATING	CM RCS SYS 2 DIRECTS COILS	SYS 2 VALVE HEATING	SYS 1 VALVE HEATING UNAFFECTED
A - MNB	QUAD A HEATERS PRIMARY AND SECONDARY	QUAD A PACKAGE HEATERS	QUAD A LOSS	OTHER QUADS UNAFFECTED
	TALKBACKS: QUAD A AND C: PRIMARY AND SECONDARY ISO VALVES HELIUM 1 AND 2 ISO VALVES CM RCS 2: PROP ISO VALVES	MDC DISPLAY	LOSS OF VALVE POSITION INTELLIGENCE	QUAD B AND D UNAFFECTED SYS 1 UNAFFECTED
	CM RCS SYS 2 PROP ISO VALVES AUTO CLOSED	VALVE CLOSURE ON ABORT TO T+42 SEC.	SYS 2 GALLERY LINES WETTED ON ABORT	SYS 1 UNAFFECTED
MNB - C	QUAD C HEATERS PRIMARY AND SECONDARY	QUAD C PACKAGE HEATERS	QUAD C LOSS	OTHER QUADS UNAFFECTED

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEM

CIRCUIT BREAKERS

CIRCUIT BREAKER	FUNCTION	OPERATION	C/B LOSS	COMMENTS
MNB	QUAD A AND C HELIUM ISO VALVES 1 AND 2 PRIMARY AND SECONDARY OX AND FU ISO VALVES SEC FU PRESS VALVE	PROPELLANT ISOLATION	HE AND PROP ISO VALVE CLOSURE AND SEC FU PRESS VALVE OPENING CAPABILITY	QUAD B AND D UNAFFECTED
	CM RCS SYS 2 PROP ISO VALVE	PROPELLANT ISOLATION	VALVE POSITION CHANGE	SYS 1 UNAFFECTED
MNA	RCS LOGIC	RCS TRANSFER MOTOR 1 CONTROL OF CM SYS 1 HEATER CIRCUIT	MOTOR TRANSFER SYS 1 VALVE HEATING	MNB CIRCUIT BREAKER FUNCTIONS UNAFFECTED
		PROP JETTISON CIRCUIT A	SYS PROP JETTISON	
		AUTO RCS ULLAGE ON SPS ABORT	AUTO ULLAGE ON ABORT	MNB CIRCUIT BREAKER WILL POWER ULLAGE
MNB	RCS LOGIC	RCS TRANSFER MOTOR 2 CONTROL OF CM SYS 2 HEATER CIRCUIT	MOTOR TRANSFER SYS 2 VALVE HEATING	MNA CIRCUIT BREAKER FUNCTIONS UNAFFECTED
		PROP JETTISON CIRCUIT B	SYS PROP JETTISON	
		AUTO RCS ULLAGE ON SPS ABORT	AUTO ULLAGE ON ABORT	MNA CIRCUIT BREAKER WILL POWER ULLAGE

COMMAND/SERVICE MODULE REACTION CONTROL SYSTEM - ELECTRICAL HARNESS PROTECTION

CB NUMBER (PANEL 8)	FUNCTION	RATING, AMPS	MINIMUM AVERAGE		REMARKS
			CRITERIA	ACTUAL	
72, 73	DIRECT ULLAGE	5	24	22	
13, 71	DIRECT CONTROL	10	22	22	
14, 70	DIRECT CONTROL	5	24	22	
15, 16	A/C ROLL	15	20	20	
17, 18	B/D ROLL	15	20	20	
19, 20	PITCH	15	20	20	
21, 22	YAW	15	20	20	
66, 67	CM HEATERS	20	16	20	ENGINE PIGTAILS
37, 38, 39, 40	SM HEATERS	7.5	22	22	
41, 42	PROP ISOL	10	22	24	HELIUM VALVE PIGTAILS
43, 44	RCS LOGIC	15	20	20	
C19A1F1-F20	RCS PYRO CKTS	5 (FUSE)	24	24	

SECTION 10

POTENTIAL HAZARDS FOR THE COMMAND/SERVICE MODULE REACTION CONTROL SUBSYSTEMS

Section 10 presents in tabular form the potential hazards for the Command/Service Module Reaction Control Subsystems. There is no written text.

SERVICE MODULE REACTION CONTROL SUBSYSTEM
POTENTIAL HAZARDS

HAZARD	PROBLEM	CAUSE	CONTROLLED BY	TESTING
ENGINE DAMAGE	LOW ENGINE INLET PRESSURE	FIRING OF ENGINES WITH: a) HELIUM ISOLATION VALVES CLOSED b) PROPELLANT ISOLATION VALVES CLOSED c) SECONDARY PROPELLANT HELIUM VALVE CLOSED AFTER PRIMARY DEPLETION	PERIODIC STATUS CHECKS OF VALVE POSITIONING, MONITORING OF ALL MANIFOLD PRESSURES (CSM AND TELEMETRY), CAUTION/WARNING SYSTEM - LOW FUEL MANIFOLD PRESSURE, CONSTANT GROUND EVALUATION OF PROPELLANT REMAINING	OFF-LIMIT ENGINE TESTING
	LOW PACKAGE TEMPERATURE	a) INADVERTENT HEATER DEACTIVATION b) SEVERE CSM ORIENTATION	MONITORING OF ALL PACKAGE TEMP. (CSM AND TELEMETRY), CAUTION/WARNING SYSTEM - LOW PACKAGE TEMP., CSM ORIENTATION RESTRICTIONS	
PROPELLANT FREEZING	LOW PACKAGE TEMPERATURE	SAME AS ABOVE	SAME AS ABOVE	SAME AS ABOVE
STRUCTURE DAMAGE	PLUME DAMAGE TO SM OUTER SKIN	EXCESSIVE STEADY-STATE FIRING OF ENGINES	PROTECTIVE CORK COVERING FOR ALL ENGINE PLUMES, PROCEDURAL LIMITATIONS, RESTRICTING LENGTH OF STEADY-STATE BURNS	CORK COVERING SIZED TO PROTECT SM OUTER SKIN FOR A 750-SEC. ENGINE BURN

COMMAND MODULE
REACTION CONTROL SUBSYSTEM
POTENTIAL HAZARDS

HAZARD	PROBLEM	CAUSE	CONTROLLED BY	TESTING
REDUCED ENGINE THRUST	LOW ENGINE INLET PRESSURE	FIRING OF ENGINE WITH PROPELLANT ISOLATION VALVES CLOSED	PROCEDURAL RESTRICTIONS	OFF-LIMIT ENGINE TESTING
	LOW TEMPERATURE ENGINES	FAILURE TO PREHEAT PRIOR TO SYSTEM ACTIVATION	PROCEDURAL RESTRICTIONS	OFF-LIMIT ENGINE TESTING
	OVERHEATING ENGINES	UNDETECTED INADVERTENT ACTIVATION OF HEATING SWITCH	PROCEDURAL RESTRICTIONS	OFF-LIMIT ENGINE TESTING
PROPELLANT ISOLATION DAMAGE	SYSTEM ACTIVATION	SYSTEM ACTIVATION WITH VALVES CLOSED	PROCEDURAL RESTRICTIONS	CM BLOCK II BREADBOARD TEST
PROPELLANT FREEZING	PREMATURE FILLING OF GALLERY LINES	PREMATURE SYSTEM ACTIVATION	PROCEDURAL RESTRICTIONS, LINES CAN BE EMPTIED BY CLOSING ISOLATION VALVES AND OPENING ENGINE VALVES	OFF-LIMIT TESTING

SECTION 11

COMMAND/SERVICE MODULE REACTION CONTROL SUBSYSTEMS

INTERFACE VERIFICATION AND PROBLEM SUMMARY

Section 11 presents the verification of the Command/Service Module RCS interfaces and summarizes the interface problems. There is no written text.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

INTERFACE VERIFICATION

SPACECRAFT INTERFACE	VERIFICATION
° CSM - RCS ENGINE/SCS	1. IDENTIFICATION - CM MANUAL CONTROL VERSUS RCS ENGINE OPERATION. 2. PERFORMANCE - SCS ENGINE CONTROL COMMANDS VERIFIED FOR ON-TIME AND SIGNAL LEVEL BY MONITORING ENGINE RESPONSE AND ON-TIME.
° CM RCS ENGINE/ SM RCS ENGINE TRANSFER	1. IDENTIFICATION - VERIFICATION OF SWITCH POSITIONS BY ENGINE OPERATION. 2. PERFORMANCE - VERIFICATION BY ENGINE VALVE RESPONSE.
° CM RCS ENGINE/ HEATER CONTROL	1. IDENTIFICATION AND PERFORMANCE - VERIFICATION OF CURRENT FLOW AND APPLIED VOLTAGE AT EACH HEATER COIL.
° CSM HELIUM AND PROPELLANT ISOLATION VALVES/ CM CONTROL AND POSITION INDICATORS	1. IDENTIFICATION - VERIFICATION OF CONTROL SIGNALS AND POSITION DISPLAYS ARE IDENTIFIED TO CORRESPOND TO ASSOCIATED VALVES.
° SM HELIUM AND SECONDARY PROPELLANT ISOLATION VALVES/ GSE CONTROL	1. IDENTIFICATION - VERIFICATION OF SIGNAL PATH.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SYSTEMS

INTERFACE VERIFICATION

SPACECRAFT INTERFACE	VERIFICATION
° CSM RCS ANALOG INSTRUMENTATION READOUT	1. IDENTIFICATION OF CAUTION AND WARNING AND PROPELLANT GAGING - SIMULATED STIMULUS APPLIED TO EACH RCS INSTRUMENTATION POINT ASSOCIATED WITH CAUTION AND WARNING GAGING. 2. IDENTIFICATION - EACH RCS SENSOR IS STIMULATED INDIVIDUALLY AND CORRESPONDING READOUT VERIFIED. 3. PERFORMANCE - A ONE-POINT STIMULUS (PRESSURE OR TEMPERATURE) DISPLAY VERIFIED FOR ACCURACY.
° SM RCS HEATERS/ CM CONTROL	1. IDENTIFICATION AND PERFORMANCE - VERIFICATION OF CURRENT FLOW AND HEATER POWER AT EACH HEATER.

COMMAND AND SERVICE MODULE REACTION CONTROL SYSTEM

INTERFACE PROBLEMS

PROBLEM	COMPONENT/INTERFACE	CAUSE	NO. OF FAILURES	CORRECTIVE ACTION
IMPROPERLY CONNECTED CONNECTIONS	ENGINES/EPS ISO VALVES/EPS	MISWIRED TERMINAL BLOCKS	25-TEST 1-FLIGHT	IMPROVE INSTALLATION INSPECTION AND REUSE CHECKOUT SPECIFICATION, EFFECTIVE 110
INTERMITTENT CONNECTIONS	ENGINE/EPS	TERMINAL BLOCK DESIGN FAILURE	20-TEST 1-FLIGHT	REDESIGN TERMINAL BOARD, EFFECTIVE AAP, X-RAY EFFECTIVE 108, REVISE CHECKOUT SPECIFICATION, EFFECTIVE 108
EXCESSIVE ON TIME OR CYCLES	ENGINES/SCS ISO VALVES/GSE	ERROR	36	REVISE PLACARDS AND LIMITATIONS, EFFECTIVE 112, IMPROVE MONITORING, EFFECTIVE 108
IMPROPER CONTROL SIGNAL	ENGINE/SCS	MANUAL CONTROLLER (MULTIPLE PULSES) SCS PULSE GENERATOR (SHORT DURATION PULSE)	24 *	REDESIGN MANUAL SWITCH, EFFECTIVE SPACECRAFT 103 PROCEDURE CORRECTION, EFFECTIVE SPACECRAFT 110
SHORT LIFE	ENGINES/EPS	DUMP AND HEATER RELAY	**	ADDED ARC SUPPRESSION DIODES, EFFECTIVE SPACECRAFT 108
	P/T SENSOR	P/T SENSOR DESIGN FAILURE	10	SUPPLIER PROCESS CONTROL IMPROVEMENT, EFFECTIVE 108

* FLIGHT DATA REDUCTION INFORMATION ONLY

** SHORT LIFE EXPECTENCY, NO FAILURE DURING RCS TESTING

SECTION 12

COMMAND/SERVICE MODULE REACTION CONTROL

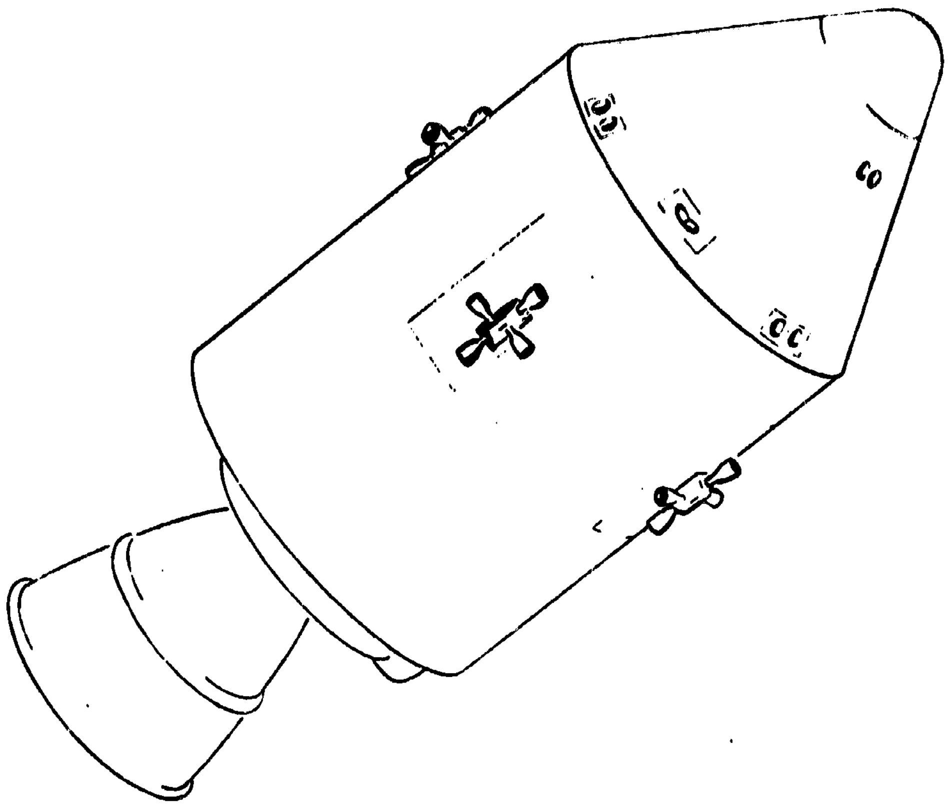
SUBSYSTEM COMPONENT MANUAL

Section 12 is the component manual for the CSM Reaction Control Subsystems, published by the North American Rockwell Corporation. It contains detailed design and qualification information and a component schematic for all of the command and service module Reaction Control Subsystem Components.

COMPONENT MANUAL

REACTION CONTROL SYSTEM

project apollo



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CONTENTS

1. Test Point Disconnect Coupling

The test point disconnect coupling (Figure 1-1) is composed of an airborne half and a ground half.

The airborne half (Figure 1-2) consists of a stainless steel body, a stainless steel outlet tube, an outlet filter assembly, a poppet system, and a coupling-engagement seal system. The stainless steel body is tubular in shape with a 3/8-24 UNF-3A external thread at the forward end and three integral mounting ears located at the aft end. An internal flange in the center of the body separates the coupling-engagement seal chamber from the poppet system chamber. The aft surface of the flange is a conical machined surface which serves as the seat for two of the four poppet seals.

The poppet system is installed in the aft chamber of the body and consists of a poppet assembly and a stainless steel compression spring. The poppet assembly consists of a stainless steel poppet, four kynar washer-shaped seals, a stainless steel spacer and a stainless steel nut. The poppet is a closed end tube with a long cylindrical solid nose at its closed end. The four seals, with the spacer separating the front two from the back two, are installed over the nose of the poppet. They are held against the outer face of the closed end of the poppet by the nut which is threaded on the nose. The seals are located in the approximate center of the poppet. The poppet assembly is installed nose first in the aft chamber of the body. The inner wall of the tubular body serves as the guide for the poppet as it slides back and forth during the coupling engagement-disengagement cycle. The seat for the aft two seals of the poppet assembly is the machined conical surface of the internal flange. The seat for the forward two seals is the wall of the hole drilled through the internal flange. The compression spring is installed in the tubular aft section of the poppet and holds the poppet seals against their seats. The aft end of the spring is restrained by the flange of the filter assembly. The filter assembly is composed of a cylindrical Rigimesh sintered woven wire filter welded to a stainless steel flange; the filter assembly is installed against a shoulder of the body and is held in place by a flange of the stainless steel outlet tube which is welded to the body.

The coupling-engagement seal system consists of a stainless steel washer, a thick kynar washer-shaped seal, a tubular stainless steel seal retainer, four thin kynar washer-shaped seals, and a tubular stainless steel sleeve installed in that order in the forward cavity of the body. The washer bears against the forward face of the internal flange of the body and the sleeve is welded to the forward face of the body.

The ground half of the test point disconnect coupling (Figure 1-3) consists of a rulon sleeve bearing, a poppet system, and a stainless steel coupling nut installed in a stainless steel housing. The housing has a hexagonal outer surface and contains two cylindrical chambers separated by an internal flange. The rulon sleeve bearing is pressed into the aft chamber of the housing. The poppet system is positioned in the center and aft portion of the housing with the body of the poppet system free to rotate inside the sleeve bearing. The coupling nut is a cylindrical nut with a 3/8-24 UNF-3B internal thread; the nut is pressed into the forward section of the housing in front of the poppet system body and is held in place by a stainless steel washer which is welded to the housing. When the housing (and coupling nut) is rotated in relation to the poppet system body during coupling engagement, the forward face of the internal flange of the housing bears against the aft face of the flange of the poppet system body and pushes the poppet system forward. The rulon washer-shaped bearing is sandwiched between the internal flange of the housing and the flange of the poppet system body. When the ground half is disengaged from the airborne half, the aft end of the coupling nut bears against the forward face of the flange of the poppet system body and pulls the poppet system away. A second rulon washer-shaped bearing is installed between the coupling nut and the flange.

The poppet system consists of a stainless steel forward body section, a poppet assembly, a poppet compression spring and a stainless steel aft body section. The forward body section is a large diameter closed-end tube with a smaller diameter tubular probe at its forward closed end. A hole the size of the ID of the probe is drilled through the closed end. The inner surface of the closed end is a machined conical surface that serves as the seat for two of the four poppet seals. The poppet assembly is identical to the poppet assembly in the airborne half and consists of a stainless steel poppet, four kynar washer-shaped seals, a stainless steel spacer and a stainless steel nut. The poppet is a closed end tube with a long cylindrical solid nose at its closed end. The four seals, with the spacer separating the front two from the back two, are installed over the nose of the poppet. They are held against the outer face of the closed end of the poppet by the nut which is threaded on the nose. The seals are located in the approximate center of the poppet. The poppet assembly is installed nose first in the large diameter portion of the forward body system; the long nose of the poppet assembly is positioned along the center line of the tubular probe of the forward body section. The seat for the aft two seals of the poppet assembly is the machined conical surface at the inner face of the closed end of the forward body section. The seat for the forward two seals is the wall of a counterbore just forward of the conical surface. The aft body section is a thick walled tube with a 7/16-20 UNF-3A external thread at its upstream end for connection to ground servicing lines. The tubular forward portion of the aft body section is installed over the poppet but inside the tubular aft portion of the forward body section. The inner wall of the tubular aft body section serves as the guide for the poppet as it slides back and forth during the coupling engagement-disengagement cycle. The compression spring is installed in the tubular portion of the poppet. The forward end of the spring pushes against the poppet and holds the poppet seals against their seats; the aft end of the spring is restrained by a shoulder in the aft body section. The aft body section is welded to the forward body section. (A kynar washer-shaped seal is installed between the forward face of the aft section and the mating surface of the forward section before they are joined by welding.)

During periods when the airborne half and the ground half are not engaged, the airborne half is protected by a pressure cap assembly and the ground half is protected by a pressure plug.

The airborne pressure cap assembly consists of a stainless steel nut, a kynar washer, a stainless steel probe and a stainless steel probe retainer. The nut has a hexagonal outer surface and contains a 3/8-24 UNF-3B internal thread. The probe is a closed end tube with a large flange at the closed end. The probe is positioned inside the nut along the nut center line with its flange and the kynar washer installed in a groove. The forward side of the groove is the aft face of the nut; the aft side of the groove is the forward face of a shoulder of the retainer. The probe is free to rotate in the groove. The retainer is welded to the nut. When the pressure cap assembly is threaded on the airborne half, the probe is pushed into the airborne coupling-engagement seal system. The inner surfaces of the kynar washer-shaped seals bear against the outer surface of the probe and seal the coupling half.

The ground half pressure plug consists of a stainless steel plug with a kynar disk seal pressed into its forward face. The plug has a 3/8-24 UNF-3A external thread. The plug is threaded into the forward end of the ground half coupling nut until the kynar seal presses against the end of the poppet system probe sealing the coupling half.

Engagement of the ground half and the airborne half follows the following sequence:

1. The pressure cap is removed from the airborne half by turning the cap counterclockwise.
2. The pressure plug is removed from the ground half by turning the cap counterclockwise.
3. The internal threads of the ground half housing are engaged with the external threads of the airborne half body.
4. As the coupling nut is turned clockwise the probe of the ground half body is pushed into the airborne coupling-engagement seal system. The inner surface of the kynar washer-shaped seals bear against the outer surface of the probe and seal the engagement.
5. After the ground half housing has been turned eight to ten turns clockwise, the tip of the nose of the ground half poppet makes contact with the forward end of the nose of the airborne poppet.

6. Additional clockwise turns of the ground half housing cause one of the poppets to unseat and travel until the spring force acting on the poppet becomes of sufficient magnitude to overcome the spring force acting on the other poppet; the other poppet will then open. This will occur only if the pressure is equal in the systems to which the two coupling halves are assembled. If one system is at a higher pressure than the other system, the poppet in the low pressure system will unseat and travel to its maximum position first; the poppet in the high pressure system will then unseat and travel to a position just short of its maximum position. When the airborne half and the ground half are fully engaged, one of the poppets may be bottomed and the other not bottomed (as described above) but generally neither poppet is bottomed.
7. A torque of 20 inch pounds is sufficient to engage the coupling halves.

Disengagement of the ground half and the airborne half follows the following sequence:

1. The ground half housing is turned counterclockwise. After 3 to 5 turns, one of the poppets will seat. After 5 to 6 turns the other poppet will seat. Should the poppets fail to close, or a major seal failure occur, an audible continuous hissing sound or propellant leakage will warn the operator of this condition.

2. After the poppets have closed, the ground half housing is turned a few additional turns counterclockwise until the internal threads of the ground half coupling are disengaged from the external threads of the airborne half.
3. The pressure cap is installed on the airborne half coupling in accordance with the procedures of MA0310-0034.
4. The dust cap is installed in the ground half coupling by turning the cap clockwise until the kynar seal is pressed against the forward face of the poppet system probe.

The important performance characteristics of the test point disconnect coupling and general information concerning the component are listed below.

Working pressure	
Low pressure helium, fuel, and oxidizer couplings	0 - 360 psig
High pressure helium coupling	0 - 4500 psig
Proof pressure	
Low pressure helium, fuel, and oxidizer couplings	540 psig
High pressure helium coupling	6750 psig
Burst pressure	
Low pressure helium, fuel, and oxidizer couplings	720 psig
High pressure helium coupling	9000 psig

Maximum leakage (Helium)	
Half-couplings engaged	8×10^{-6} scc/sec
Ground half without cap, and with cap (and poppet open)	8×10^{-6} scc/sec
Airborne half without cap, and with cap (and poppet open)	5×10^{-6} scc/sec
Numerical reliability (maximum probability of failure)	
Airborne half	1×10^{-6} for 336 hours
Half-couplings engaged	1000×10^{-6} for 100 cycles
Minimum total operating life	400 cycles
Specification number	MC144-0023
SCD number (NR part number)	
Qualified airborne half	
Oxidizer coupling	ME144-0023-0011
Fuel coupling	ME144-0023-0031
Low pressure helium coupling	ME144-0023-0051
High pressure helium coupling	ME144-0023-0071
Qualified ground half	
Oxidizer coupling	ME144-0023-0021
Fuel coupling	ME144-0023-0041
Low pressure helium coupling	ME144-0023-0061
High pressure helium coupling	ME144-0023-0081

Pre-qualified airborne half	
Oxidizer coupling	ME 144-0023-0010
Fuel coupling	ME 144-0023-0030
Low pressure helium coupling	ME 144-0023-0050
High pressure helium coupling	ME 144-0023-0070
Pre-qualified ground half	
Oxidizer coupling	ME 144-0023-0020
Fuel coupling	ME 144-0023-0040
Low pressure helium coupling	ME 144-0023-0060
High pressure helium coupling	ME 144-0023-0080
Supplier	Lear Siegler, Inc. Elyria, Ohio
Supplier's part number per SCD	
dash number -0011	264004-3500
-0031	264004-3700
-0051	264004-4100
-0071	264004-3900
-0021	264004-3600
-0041	264004-3800
-0061	264004-4200
-0081	264004-4000
-0010	264004-3500P
-0030	264004-3700P
-0050	264004-4100P
-0070	264004-3900P
-0020	264004-3600P
-0040	264004-3800P
-0060	264004-4200P
-0080	264004-4000P

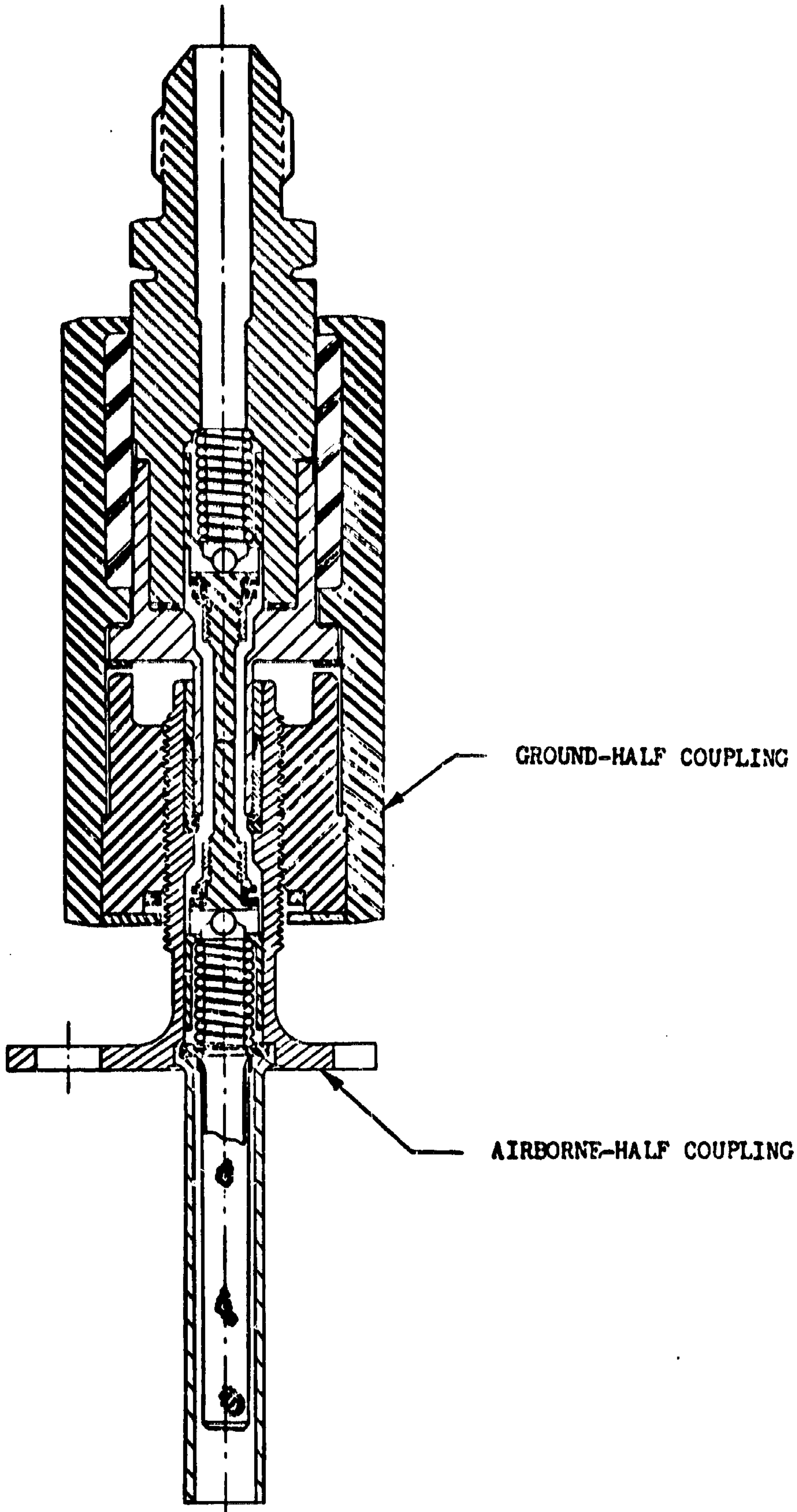
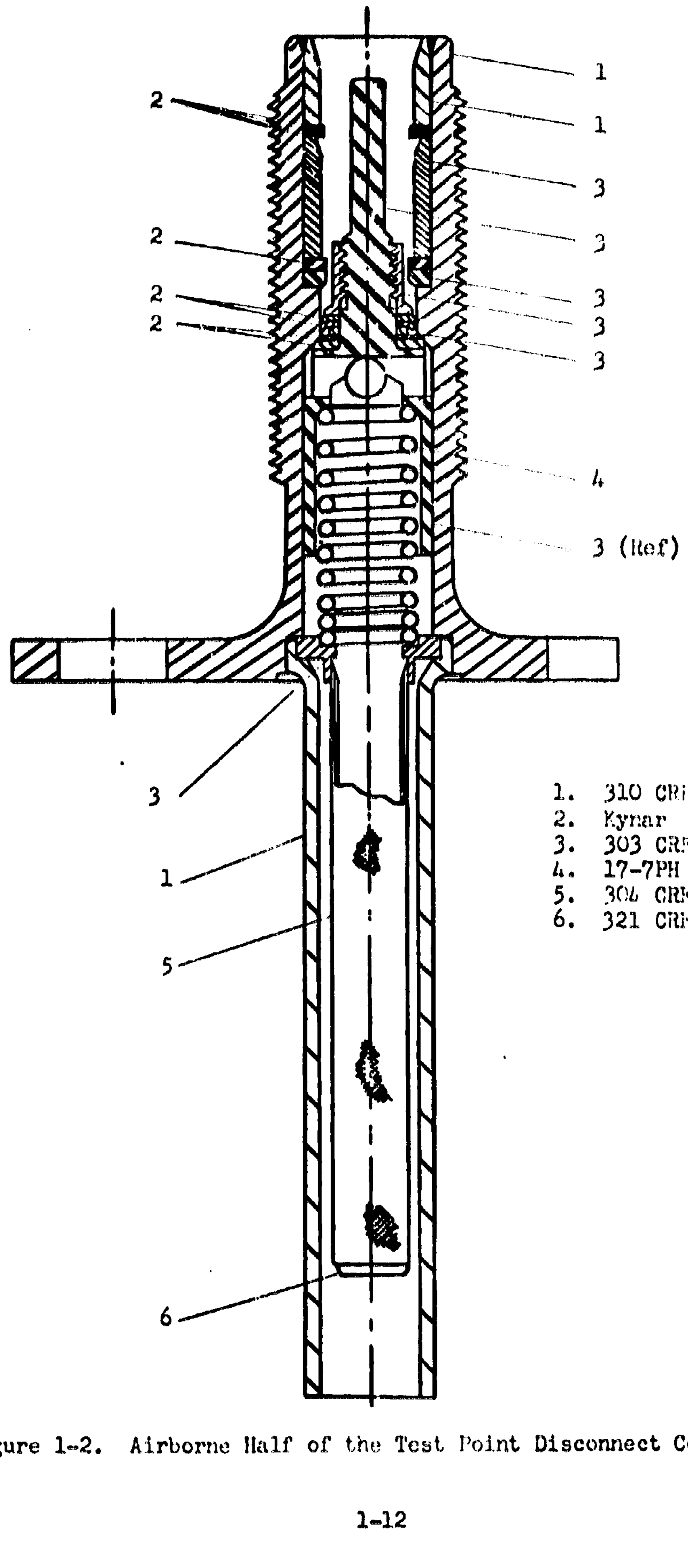


Figure 1-1. Test Point Disconnect Coupling



1. 310 CRES
2. Kynar
3. 303 CRES
4. 17-7PH CRES
5. 304 CRES Screens
6. 321 CRES

Figure 1-2. Airborne Half of the Test Point Disconnect Coupling.

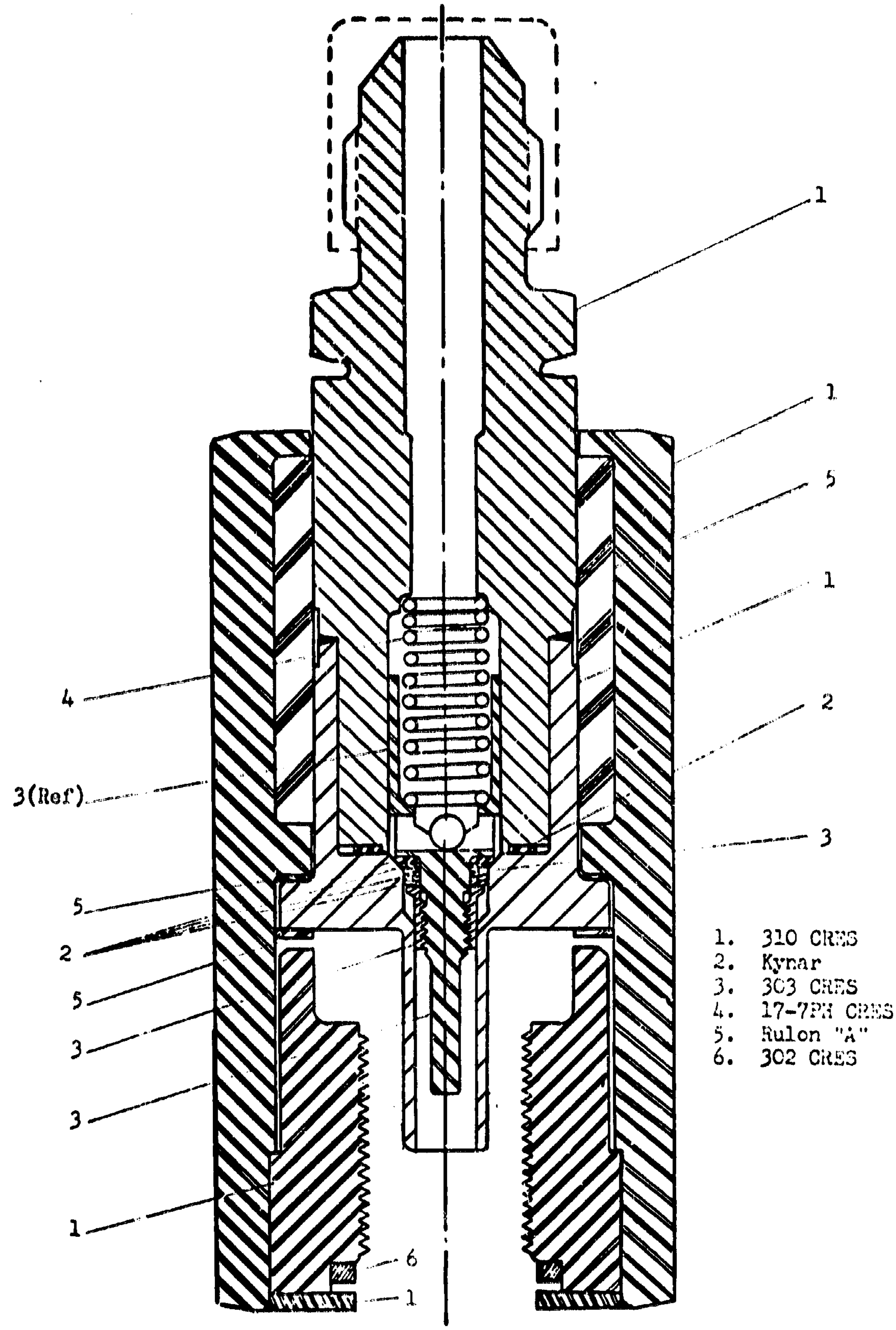


Figure 1-3. Ground Half of the Test Point Disconnect Coupling.

PART NUMBER	ME144-0023-0011 Ox TP coupling ME144-0023-0031 Fuel TP coupling ME144-0023-0051 Lo Press He. TP coupling ME144-0023-0071 Hi Press He. TP coupling
DVT TEST COMPLETION DATE	February 1964
NUMBER TEST UNITS	8
QUAL TEST COMPLETION DATE	August 1964
QUAL TESTS	Proof pressure (540 psig, 6750 psig), functional (3 engagement cycles), leakage (5×10^{-6} scc/sec helium, caps on and off), pressure drop (NMT across 0.094 orifice), vibration (16 grms), endurance cycling (400 cycles), propellant exposure (DVT: 38 days).
ACCEPTANCE TESTS	Examination of Product Proof pressure (540 or 6750 psig) Functional (3 engagement cycles) Pressure drop (NMT across 0.094 orifice) Leakage (5×10^{-6} scc/sec. Helium, caps on and off) Cleanliness (per MA0610-004)
DIFFERENCE BETWEEN QUAL AND SC UNITS	None
NOTES:	Leakage requirements at NR: Caps off - 75 scc/hr. He. Caps on - 5×10^{-6} scc/sec He. Dust Cap Torque: C/O Operations - per MA0310-0034 Just before launch - 27 to 30 inch pounds Allowable Δ P: Same as across 0.094 orifice (0.772 psid @150 psig and 0.050 #/min) Seal material: kynar Filter: 55 micron absolute Weight: 0.09 pound

2. Burst Diaphragm Isolation Valve

The burst diaphragm isolation valve (Figure 2-1) consists primarily of a stainless steel main body casting, five-eighths inch OD stainless steel inlet and outlet tubes, an aluminum alloy burst diaphragm, a fragment screen assembly, and a stainless steel close-out plug. The inlet and outlet tubes are positioned in line and are heli-arc welded to the main body casting. The fragment screen assembly consists of a conical stainless steel 150 mesh plain weave screen and two stainless steel end rings; the rings are attached to the ends of the screen by continuous overlap spotwelds. The burst diaphragm is a closed end thick-walled tube with a large hole drilled perpendicular to the center line of the tube and a horseshoe shaped "V" groove machined in the outside surface of the closed end. The groove is machined so that a material thickness of approximately 0.003 inch remains between the bottom of the "V" groove and the inner surface of the closed end. The burst diaphragm for the fuel burst diaphragm isolation valve is teflon coated.

The burst diaphragm isolation valve is constructed so that the burst diaphragm can be removed after rupture and replaced with a new unit. The fragment screen assembly is installed inside the burst diaphragm and the combination is installed in a hole in the main body casting which is machined at a forty-five degree angle to the direction of flow. A teflon anti-friction disc is installed on top of the burst diaphragm. The closeout plug is threaded into the same hole and serves to hold the screen assembly and burst diaphragm in place. A rubber O-ring installed in a groove in the closed end of the burst diaphragm seals the surface between the burst diaphragm and the main body. The closeout plug is sealed by two rubber O-rings installed in grooves in the plug. An external safety wire locks the closeout plug in place. Two stainless steel rivets pressed into the burst diaphragm act as a key to position the burst diaphragm in the main body.

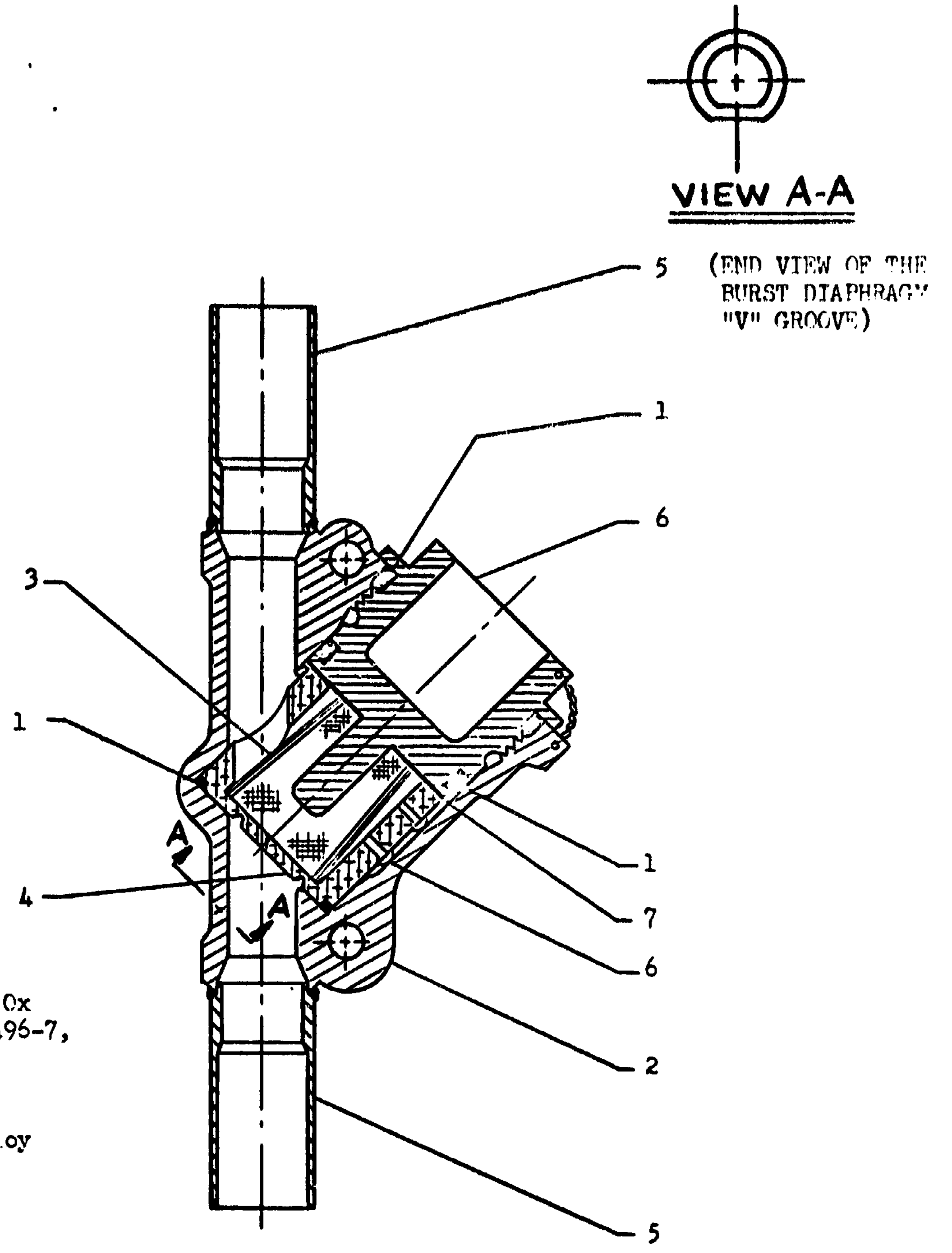
The propellant is stored upstream of the burst diaphragm until system activation. When the propellant reaches a pressure of 241 $\pm$14 psid during system activation, the resulting force acting on the burst diaphragm shears the material between the bottom of the V-groove and the inner surface of the closed end. The material at the heel of the horseshoe-shaped groove does not shear but the force acting on the diaphragm causes it to bend out of the flow path. Any fragments resulting from the shearing action are prevented from flowing downstream by the screen assembly. Upon passing through the screen, the propellant flows through the perpendicular hole in the burst diaphragm cylinder and thence through the outlet tube to the downstream distribution system.

The important performance characteristics of the burst diaphragm isolation valve and general information concerning the component are listed below:

Operating pressure	Vacuum of 28" Hg. to 291 psig

Supplier's part number per SCD

Dash number	-0006	4440-16
	-0015	4440-17
	-0004	4440-20
	-0014	4440-30
	-0065	4470-65
	-0055	4497



1. Resistazine 88, Ox Valve; Parker B496-7, Fuel Valve
2. 17-4 Cres
3. 304 Cres
4. 6061-T651 Al Alloy
5. 304L Cres
6. 303 Cres
7. Teflon

Figure 2-1. Burst Diaphragm Isolation Valve

TITLE	Burst Disc Assembly - CM (Pyrodyne)
PART NUMBER	**Ox** **Fuel**
	ME251-0005-0006 and -0015 (assy) ME284-0346-0004 and -0014 (body) ME251-0005-0055 and -0065 (kit)
QUAL TEST COMPLETED	May, 1966
NUMBER UNITS TESTED	8 Qualification 4 Supplemental Qualification 2 Off-Limits
QUALIFICATION TESTS	Vibration, endurance cycles (40), leakage (internal and external, helium and propellant), rupture pressure (227-255), pressure drop (2 psi), burst pressure (720 psig min.). Propellant exposure (30 days).
ACCEPTANCE TESTS	Examination of product, burst diaphragm deflection (BD), internal leakage (5×10^{-4} scc/sec), rupture pressure test (BD), pressure drop (BD - 2.0 psid), external leakage (body - 5×10^{-4} scc/sec.) and bubble point (filter -2.4 inches of water).
DIFFERENCES BETWEEN QUAL AND SC-020 UNITS	Burst disc stop, conical screen, compatible seals, zero-gap closeout.

3. Flexible Metal Hose Assembly

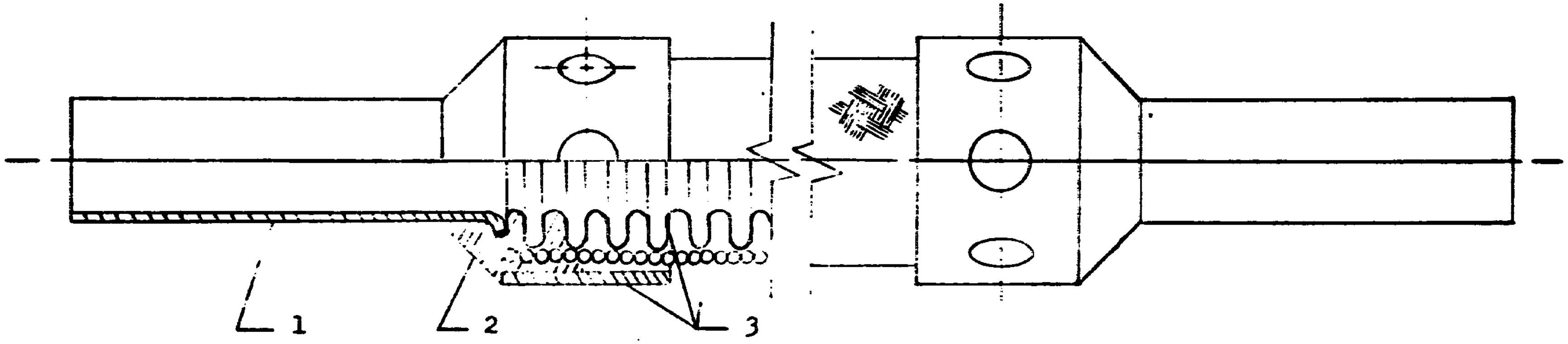
The flexible metal hose assembly (Figure 3-1) consists of a stainless steel one ply, seamless convoluted innercore which is welded at both ends to stainless steel end tubes and protected by a stainless steel braid. A stainless steel braid retaining ring is located over each weld joint; it is attached to the braid, the innercore and the end tube by silver braze consisting of 60 percent silver, 30 percent copper and 10 percent tin.

The stainless steel braid contains a copper coated stainless steel strand in two adjacent weaves for identification purposes.

The important performance characteristics of the flexible metal hose assembly and general information concerning the component are listed below.

Working pressure	360 psig
Proof pressure	2000 psig
Burst pressure	3000 psig
Pressure surge	360 to 750 to 360 psig within 2 milliseconds for minimum of 9000 cycles
Maximum external leakage	
up to 360 psig	5.0×10^{-6} std. cc/sec.
360 to 2000 psig	1.0×10^{-4} std. cc/sec.
Minimum bend radius	4.0 inches from ℄
Numerical reliability (maximum probability of failure)	1×10^{-6} for 336 hours
Minimum total operating life	9000 pressure surge cycles
Specification number	MC271-0019

SCD number (NR part number)	
Qualified hoses	ME271-0019-0001 thru -0041
Pre-qualified hoses	ME271-0019-1001 thru -1034
Pre-DVT hoses	ME271-0019-2001 thru -2041
Supplier	Titeflex, a division of Atlas Corporation Springfield, Massachusetts
Supplier's part number per SCD	
dash number -0001 thru -0041	94972-0001 thru 94972-0041
-1001 thru -1015	94972-1001P thru 94972-1015P
-2038 thru -2041	94972-2038 thru 94972-2041



1. 304L Cres
2. Braze Alloy AMS 4773
   60% Ag; 30% Cu; 10% Sn
3. 321 Cres

Figure 3-1. Flexible Metal Hose Assembly

TITLE	Flex Hose Assembly (Titeflex)
PART NUMBER	ME271-0019-00xx (9 dash numbers)
DVT TEST COMPLETION DATE	September, 1964
QUAL TEST COMPLETION DATE	December, 1964
NO. TEST UNITS	6
QUAL TESTS:	Pressure cycling (30 cycles 0 to 2000 psig), vibration (16 grms), shock (78g for 11 millisec), endurance cycling (9000 cycles 360 to 750 psig), temperature and vacuum (DVT: 40°F to 150°F and 7.5×10^{-10} mm Hg), propellant exposure (DVT: 38 days).
ACCEPTANCE TESTS	Proof pressure (2000 psig) Leakage (5×10^{-6} scc/sec at 360 psig) Ball check (.28 dia. ball). Cleanliness (per MA0610-004)
DIFFERENCE BETWEEN QUAL AND SC UNITS	Qual units: all 20 inches in length S/C units : 9 different lengths
CONSTRUCTION	Innercore 321 stainless (convoluted) Reinforcement 321 stainless wire braid End fittings 304L Braid retainers 321 or 347
NOTES:	
Weight:	0.2 to 0.3 pounds

TITLE	Flex Hose Assembly (Titeflex)
PART NUMBER	ME271-0019-0041 (Qual) ME271-0019-2041 (Qual Config. (E))
DESCRIPTION	5/8 Nom.; Ends, tubular for brazing: (1) end str (1) end rt. angle
QUAL TEST COMPLETION DATE	6 mo. from AGA (DVT - N.A.)
NO. TEST UNITS	4
VERIFICATION (QUAL) TESTS	Flexure cycling (500 cycles from neutral to flexed position) Leakage (30 min. He at 248 $^{+10}_{-0}$ psig and ambient temp. Max. allowable leak. rate 5 x 10^{-6} scc/sec). Vibration (2½ minutes at boost intensity; 12½ minutes at flight intensity). Endurance pressure cycling (10,000 cycles, 15 to 450 and 15 psig within 70 m sec). Burst (1800 psig for 5 minutes w/o visible leakage). Off-limits burst (Increase in 100 psig increments - record failure pressure, describe failure mode). Propellant exposure (167 days each with N_2O_4 and MMH including 144 days at 248 $^{+10}_{-0}$ psig and 175F). Proof pressure (900 psig He, ambient temp., for 5 minutes each flexed and unflexed without damage, permanent deformation or leakage rate above 1 x 10^{-4} scc/sec of He)
ACCEPTANCE TESTS	Proof pressure (as above). Leakage (as above). Ball Check. Cleanliness (per MA0610-004).
CONSTRUCTION	Innercore: 0.010 thick 321 CRES - 7½-8½ convolutions/inch Min. I.D. 0.593. Braided Protective Cover: 321 CRES. End Fittings: 304L CRES; 0.629 O.D. x 0.579 I.D. tips finished for brazing 0.025 ±.002 wall x ½ lg. Braid retainers, brazed in assy; 321 or 347 CRES. Max. diam. over protective ferrules: 1.025.
WEIGHT	1.34 pounds

4. Dump Hose Assembly

The dump hose assembly (Figure 4-1) consists of two stainless steel end fittings and a non-metallic, flexible innercore which is protected by a stainless steel wire braid.

The innercore consists of convoluted TFE Teflon laminated to convoluted woven fiberglass cloth. Each end fitting consists of a stainless steel welded insert subassembly, a stainless steel nut and a stainless steel collar. The nut is installed at the mating end of the insert and the collar is attached to the other end. The innercore and braid are sandwiched between the insert and the collar by a progressive-swaging technique.

The dump hose assembly is supplied in three models. One model (-0004) is a -16 hose (1 inch nominal) and is used for dumping fuel. The other two models (-0001 and -0003) are -12 hoses (3/4 inch nominal) and are used for dumping oxidizer. The fuel dump hose and one of the oxidizer dump hoses (-0001) have a 45° fitting at one end and a straight fitting at the other end. The other oxidizer dump hose (-0003) is equipped with a 90° fitting and a straight fitting.

The important performance characterisitics of the dump hose assembly and general information concerning the component are listed below.

Operating pressure	360 psig
Proof pressure	1000 psig

Burst pressure	2000 psig
Maximum external leakage (Helium at 0 to 15 psig)	
-0001 and -0003	30 scc/ft/hr
-0004	60 scc/ft/hr
Minimum bend radius (from center line)	
-0001 and -0003	3.75 inches
-0004	5.00 inches
Specification number	ME271-0050
SCD number (NR part number)	
Oxidizer dump hose (45° & 0°)	ME271-0050-0001
Oxidizer dump hose (90° & 0°)	ME271-0050-0003
Fuel dump hose (45 & 0°)	ME271-0050-0004
Supplier	Titeflex, a division of Atlas Corporation Springfield, Mass.
Supplier's part number per SCD	
Dash number -0001	95704-1
-0003	95704-3
-0004	95704-4

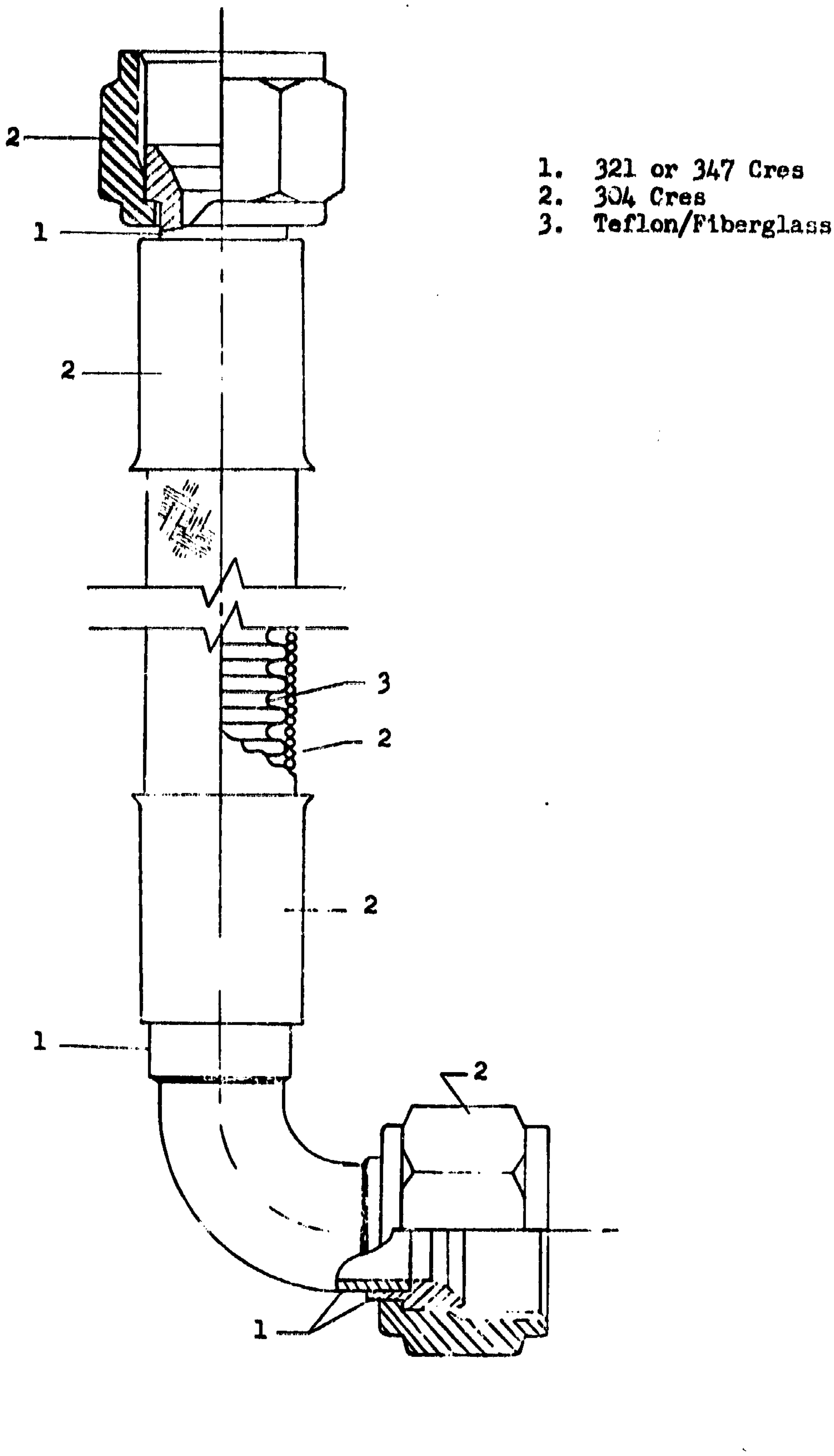


Figure 4-1. Dump Hose Assembly

TITLE	Dump Hoses (Titeflex)
PART NUMBER	ME271-0050-0001 (Ox Dump) ME271-0050-0003 (Ox Dump) ME271-0050-0004 (Fuel Dump)
DVT COMPLETION DATE	No DVT or qual.
QUAL TEST COMPLETION DATE	A commercial part controlled by SCD
ACCEPTANCE TESTS	Examination of Product Proof Pressure (1000 psig) Leakage (30 scc/ft/hr at 15 psig for -0001) (" " " " -0003) (60 scc/ft/hr at 15 psig for -0004)
DIFFERENCE BETWEEN QUAL AND SC UNITS	None
CONSTRUCTION	Innercore: Convaluted teflon Reinforcement: 304 stainless wire braid End Fittings: 304 & 321 or 347

NOTES

Dash #	Length	Angles	Hose Size	Min. Bend R
-0001	10.78	0° & 45°	-12	3.75
-0003	14.10	0° & 90°	-12	3.75
-0004	21.50	0° & 45°	-16	5.00

5. Helium Fill Disconnect Coupling

The helium fill disconnect coupling (Figure 5-1) is composed of an airborne half and a ground half.

The airborne half (Figure 5-2) consists of a stainless steel body, a stainless steel outlet tube, a poppet system, and a coupling-engagement seal system. The stainless steel body is tubular in shape with a 1"-10 standard Acme external thread at the forward end and three equally spaced integral mounting ears located at the aft end. An internal flange in the center of the body separates the coupling-engagement seal chamber from the poppet system chamber. The aft surface of the flange is a conical machined surface which serves as the seat for the poppet seal.

The poppet system is installed in the aft chamber of the body and consists of a poppet assembly, a stainless steel compression spring, and a filter assembly. The poppet assembly is composed of a stainless steel poppet, a kynar seal, and a stainless steel insert nose. The poppet is a closed end tube. The kynar seal is a truncated cone with a hole through its center and is installed in a groove in the forward face (the closed end) of the poppet. The seal is held in place by a flange of the insert nose which is threaded into the face of the poppet. The poppet assembly is installed nose first in the aft chamber of the body. The inner wall of the tubular body serves as the guide for the poppet as it slides back and forth during the coupling engagement-disengagement cycle. The compression spring is installed in the tubular aft section of the poppet. The forward end of the spring pushes against the poppet and holds the poppet seal against the seat; the aft end of the spring is restrained by the support ring of the filter assembly which is installed behind the spring. The ring is held in place by a flange of the outlet tube; the flange is welded to the body. The filter assembly is composed of a stainless steel 10 x 10 wire mesh screen and a stainless steel 200 x 200 wire mesh screen welded back to back to a stainless steel support ring.

The coupling-engagement seal system consists of two stainless steel spring washers and two teflon V-seals installed in the forward chamber of the tubular body and held in place by an aluminum alloy retainer which is threaded into the body. An aluminum alloy spacer is installed between the lips of each V-seal. The outer lip of each V-seal bears against the inner wall of the tubular body and the inner lip bears against the outer surface of the tubular probe of the ground half coupling or against the tubular probe of the pressure cap assembly whichever is fastened to the airborne coupling.

The ground half of the helium fill disconnect coupling (Figure 5-3) consists of a stainless steel body, a stainless steel coupling nut, a stainless steel end fitting, and a poppet system. The body is a large diameter closed-end tube with a smaller diameter tubular probe at its closed end. A hole the size of the ID of the probe is drilled through the closed end. The inner surface of the closed end is a machined conical surface that serves as the seat for the poppet seal. The poppet system of the ground half is similar in configuration to the poppet system of the airborne half. The poppet system is installed in the stainless steel body and consists of a poppet assembly and a stainless steel compression spring. The poppet assembly is composed of a stainless steel poppet, a kynar seal, and a stainless steel insert nose. The poppet is a closed end tube. The kynar seal is a truncated cone with a hole through its center and is installed in a groove in the forward face (the closed end) of the poppet. The seal is held in place by a flange of the insert nose which is threaded into the face of the poppet. The poppet assembly is installed nose first in the large diameter aft section of the body; the long nose of the poppet assembly is positioned along the center line of the forward tubular probe of the body. The inner wall of the aft section of the body serves as the guide for the poppet as it slides back and forth during the coupling engagement-disengagement cycle. The compression spring is installed in the tubular aft section of the poppet. The forward end of the spring pushes against the poppet and holds the poppet seal against the seat; the aft end of the spring is restrained by the stainless steel end fitting which is threaded into the aft end of the body. A teflon ring gasket installed between the end fitting and a shoulder of the body seals the attachment. The aft end of the end fitting is equipped with an MS24385-4 external thread for connection to ground servicing lines.

The coupling nut is a closed end thick-walled tube with a large hole in the closed end and a 1"-10 standard Acme internal thread at the open end. The coupling nut is installed open end first over the aft end of the body-end fitting combination and is held in position by a ring of stainless steel balls which are free to rotate in an annular groove; half of the groove is machined in the end fitting and the other half is machined in the wall of the hole in the closed end of the coupling nut. The inner face of the closed end of the coupling nut forms a shoulder which bears against a teflon (FEP) bearing installed between the coupling nut and a flange of the end fitting. The Acme internal thread at the open end of the coupling nut engages the Acme external thread on the airborne half body.

During the periods when the airborne half and the ground half are not engaged, the airborne half is protected by a pressure cap assembly and the ground half is protected by a dust cap.

The airborne pressure cap assembly consists of an aluminum alloy pressure cap, an aluminum alloy internal probe and a stainless steel snap ring. The pressure cap is a closed-end thick walled tube with a 1"-10 standard Acme internal thread. The probe is a small diameter closed-end tube. The closed end of the probe is installed in a tubular boss located in the center of the inner surface of the closed end of the pressure cap. The snap ring is installed in a groove in the probe and holds the probe in place. When the pressure cap assembly is threaded on the airborne half, the probe is pushed into the airborne coupling-engagement seal system. The inner lip of each of the V-seals bears against the outer surface of the probe and seals the coupling half. A secondary seal is formed when a ring ridge on the inner surface of the closed end of the pressure cap bears against a kynar ring gasket installed in a groove in the forward end of the airborne half. Full engagement of the pressure cap and airborne body is required to produce the secondary seal.

The ground half dust cap is an aluminum alloy closed-end, thick walled tube with a 1"-10 standard Acme external thread. The dust cap is threaded into the forward end of the ground half coupling nut. A teflon sleeve seal and a silicone rubber "O"-ring are installed in a groove in the cap behind the threads and form a seal with the forward inner surface of the coupling nut.

Engagement of the ground half and the airborne half follows the following sequence:

1. The pressure cap is removed from the airborne half by turning the cap counterclockwise.
2. The dust cap is removed from the ground half by turning the cap counterclockwise.

3. The internal Acme threads of the ground half coupling nut are engaged with the external Acme threads of the airborne half body.
4. As the coupling nut is turned clockwise, the probe of the ground half body is pushed into the airborne coupling-engagement seal system. The inner lip of each of the V-seals of the airborne coupling-engagement seal system bears against the outer surface of the probe and seals the engagement.
5. After the coupling nut has been turned three to five turns clockwise, the tip of the nose of the ground half poppet makes contact with the forward end of the nose of the airborne poppet.
6. Additional clockwise turns of the coupling nut cause one of the poppets to unseat and travel until the spring force acting on the poppet becomes of sufficient magnitude to overcome the spring force acting on the other poppet; this will occur only if the pressure is equal in the systems to which the two halves are assembled. If one system is at a higher pressure than the other system, the poppet in the low pressure system will unseat and travel to its maximum position first; the poppet in the high pressure system will then unseat and travel to a position just short of its maximum position. When the airborne half and the ground

half are fully engaged, one of the poppets may be bottomed and the other not bottomed (as described above) but generally neither poppet is bottomed.

7. A torque of 150 inch pounds is required to engage the coupling halves when a high pressure acts on the airborne half.

Disengagement of the ground half and the airborne half follows the following sequence:

1. The coupling nut of the ground half is turned counterclockwise. After 3 to 5 turns, one of the poppets will seat. After 5 to 6 turns, the other poppet will seat. When the airborne poppet seats a momentary hisst sound is produced. Should the poppets fail to close, or a major seal failure occur, an audible continuous hissing sound will warn the operator of this condition.
2. After the poppets have closed, the coupling nut is turned a few additional turns counterclockwise until the internal Acme threads of the ground half coupling are disengaged from the external Acme threads of the airborne coupling.
3. The pressure cap is installed on the airborne half coupling by turning the cap clockwise and applying 5 to 6 foot pounds of torque.
4. The dust cap is installed in the ground half coupling by turning the cap clockwise until the flange of the cap touches the face of the coupling nut.

The important performance characteristics of the helium fill disconnect coupling and general information concerning the component are listed below.

Working pressure	5000 psig
Proof pressure	7500 psig
Burst pressure	10,000 psig
Maximum leakage (Helium)	
Half-couplings engaged	10 std. cc/min.
Ground half with cap	10 std. cc/min.
Airborne half without cap, and with cap (and poppet open)	5×10^{-6} std. cc/sec.
Numerical reliability (maximum probability of failure	
Airborne half with cap	1×10^{-6} for 336 hours
Half-couplings engaged	1000×10^{-6} for 100 cycles
Minimum total operating life	400 cycles
Specification number	MC273-0010
SCD number (NR part number)	
Qaulified airborne half	ME273-0010-0001
Qualified ground half	ME273-0010-0002
Pre-qualified airborne half	ME273-0010-0003
Pre-qualified ground half	ME273-0010-0004
Supplier	Puralator Products, Inc. Newbury Park, Calif.
Supplier part number per SCD	
dash number -0001	1238004-02
-0002	1238004-01
-0003	1238004-02P
-0004	1238004-01P

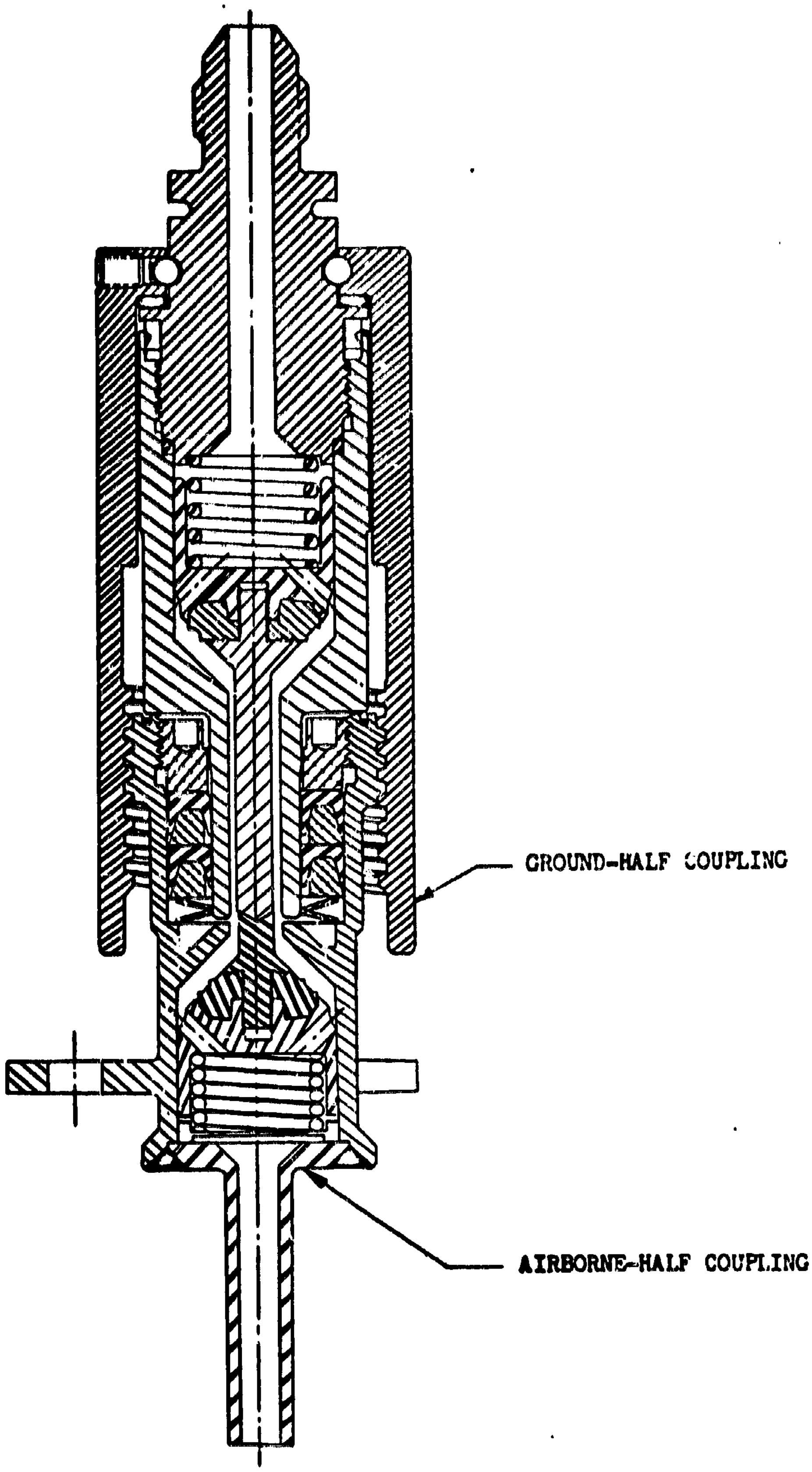


Figure 5-1. Helium Fill Disconnect Coupling.

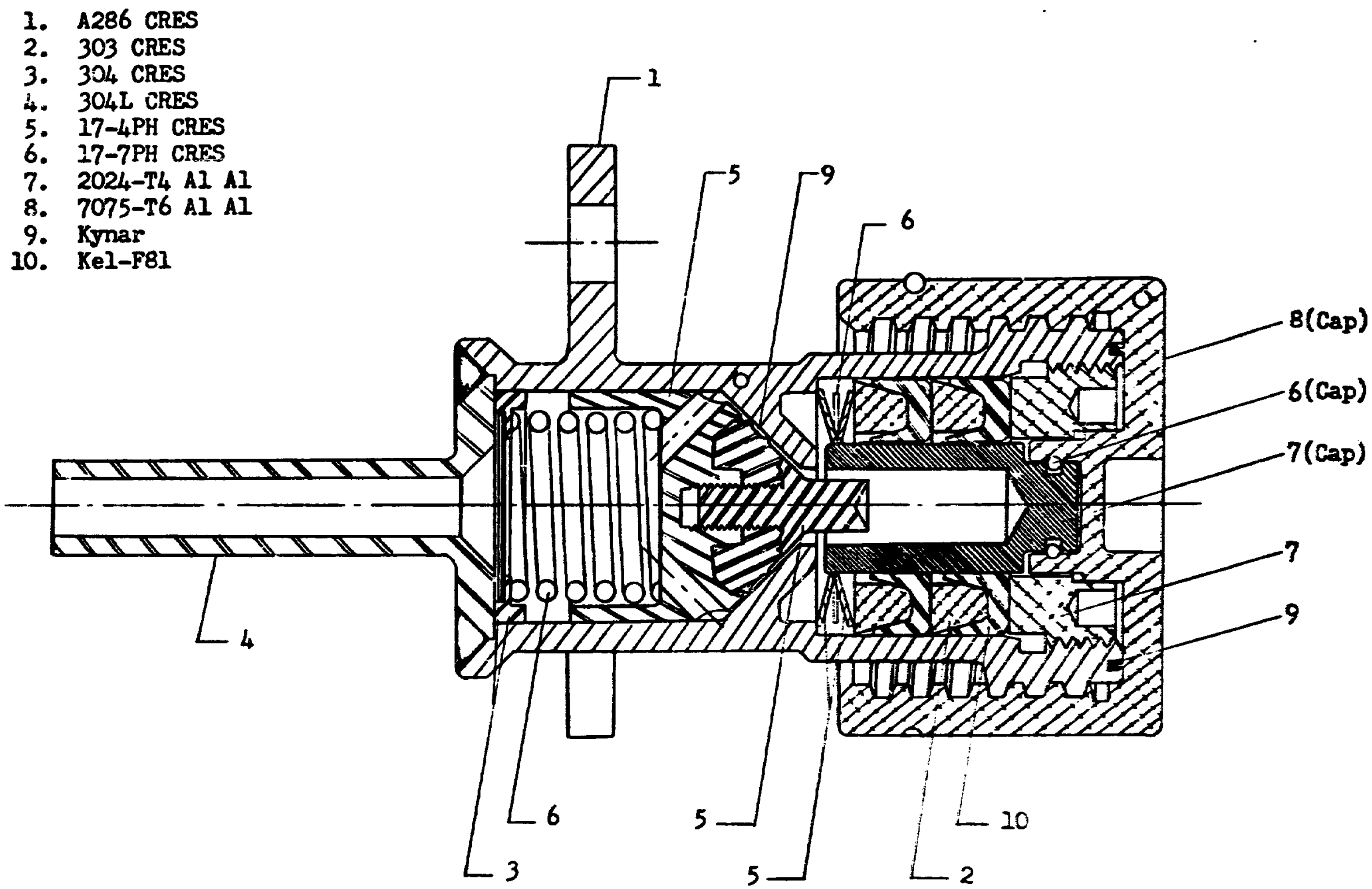
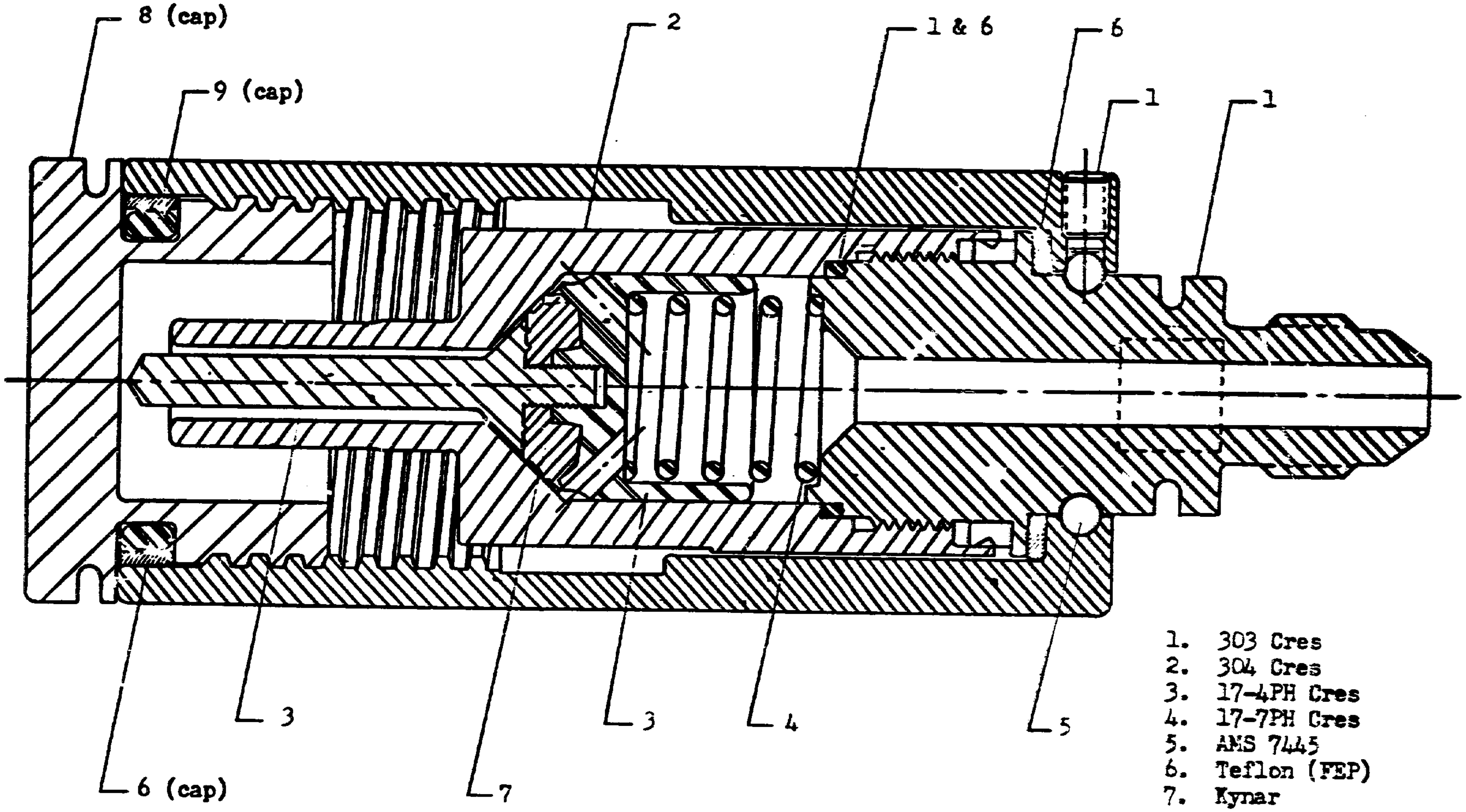


Figure 5-2. Airborne Half of the Helium Fill Disconnect Coupling



1. 303 Cres
2. 304 Cres
3. 17-4PH Cres
4. 17-7PH Cres
5. AMS 7445
6. Teflon (FEP)
7. Kynar
8. 2024-T4 Al Al
9. Silicone Rubber

Figure 5-3. Ground Half of the Helium Fill Disconnect Coupling

TITLE	Helium Fill Coupling (Purolator - On-Mark)
PART NUMBER	ME273-0010-0001
DVT TEST COMPLETION DATE	June, 1964
QUAL TEST COMPLETION DATE	October, 1964
NUMBER TEST UNITS	4
QUAL TESTS	Proof pressure (7500 psig), functional (12 engagement cycles), leakage (5×10^{-6} scc/sec helium, caps on and off), pressure drop (NMT across 0.133 orifice), vibration (16 grms), endurance cycling (400 cycles).
ACCEPTANCE TESTS	Proof pressure (7500 psig) Functional (12 engagement cycles) Leakage (5×10^{-6} scc/sec helium at 375, 2K, 5K and 7500 psig*) Cleanliness (per MA0610-004)
DIFFERENCE BETWEEN QUAL AND SC UNITS	None
NOTES:	Leakage requirements at NR:

Caps off - 20 scc/hr helium
Caps on - 5×10^{-6} scc/sec helium

Minimum acceptable loading temperature: -225°F

Seal material: kynar

Filter: 24 x 24 wire mesh + 200 x 200 wire mesh
(specification requirement: 40-75)

Weight: (A/B): 0.21 pound

* Leakage is determined with cap off and poppet closed and with cap on and poppet open

6. Propellant Disconnect Coupling

The propellant disconnect coupling (Figure 6-1) is composed of an airborne half and a ground half.

The airborne half (Figure 6-2) consists of a stainless steel body, a poppet system, a poppet guide assembly, a filter assembly and a stainless steel outlet tube. The stainless steel body is a thin-walled tube with a cup-shaped indexed flange at the forward end and three integral mounting ears located at the aft end. The internal surface of the indexed flange is a conical machined surface which serves as the seat for the poppet seal.

The poppet system consists of a poppet assembly, a stainless steel inner poppet spring, and a stainless steel outer poppet spring. The poppet assembly is composed of a stainless steel flanged shaft, a bowl-shaped kynar primary seal, a stainless steel seal retainer, two stainless steel Omniseal springs, and a stainless steel self-locking nut. The flange of the flanged shaft is a thin truncated cone; the conical surface of the flange bears against the conical poppet seat of the body when the poppet is closed. The flat-bottomed section of the bowl-shaped primary seal (which has a hole in the center) is installed over the poppet shaft and is sandwiched between the inner surface of the poppet flange and the seal retainer. The seal retainer is a thick truncated cone with a hole in the center and is installed over the poppet shaft behind the primary seal. The self-locking nut is threaded on the shaft behind the seal retainer and serves to hold the retainer and seal in place. The two Omniseal springs are installed on the conical surface of the seal retainer under the inboard surface of the "side" of the bowl-shaped primary seal. The outboard surface of the "side" of the seal contains two ridges. The two Omniseal springs act against the sides of the seal to ensure proper seating of the seal ridges on the conical poppet seat of the body. The inner and outer poppet springs are installed concentric with the poppet shaft. The forward end of each spring pushes against the seal retainer and holds the poppet and poppet seal against the seat. The aft end of each poppet spring is restrained by the poppet guide assembly.

The poppet guide assembly consists of a stainless steel guide and a kynar flanged tubular bearing. The guide is wheel-shaped with a wide hub. The kynar bearing is installed in the hub of the guide. The guide assembly is installed over the end of the poppet shaft; the rim of the guide is positioned against a shoulder of the coupling half body. The poppet shaft slides back and forth in the kynar bearing during the coupling engagement-disengagement cycle.

The filter assembly forward ring is installed behind the poppet guide assembly rim. The ring and guide are held against the shoulder of the body by the reverse-cap flange of the outlet tube which is welded to the aft end of the coupling body. The filter assembly consists of a stainless steel conical "Microweave" wire mesh screen welded to a stainless steel end ring and four stainless steel rectangular "teepee-pole" supports.

The ground half of the propellant disconnect coupling (Figure 6-3) consists of a stainless steel body, a collar assembly, a coupling-engagement seal system, a poppet system, a poppet actuating system, and a collar actuating system. The body is an intricate machined investment casting which is basically cylindrical in shape. The body contains an integral guide tube in the center of a large poppet chamber, a counterbored hole perpendicular to the flow path for the poppet actuating shaft, and an external UNF thread at the aft end for connection to ground servicing equipment.

The coupling-engagement seal system is installed in the forward mating face of the body and consists of a teflon seal, two stainless steel Omniseal springs, and a stainless steel seal retainer. The washer-shaped teflon seal is installed in a groove of the body mating face with the two Omniseal springs installed between the seal and the bottom of the groove. The seal retainer is a ring which bears against the outer edge of the seal and holds the seal in place; the retainer is bolted to the body. The forward face of the washer-shaped seal contains two concentric ridges which are pressed against the mating face of the airborne half body during engagement of the coupling halves.

The poppet system is installed along the flow path center line in the poppet chamber which is located in the forward end of the ground half body. The poppet chamber is bottle shaped with the neck positioned at the forward face. The poppet seal bears against the cylindrical wall of the neck and seals the coupling half. The poppet system is composed of a stainless steel flanged shaft, a kynar poppet seal, a stainless steel Omniseal spring, and a stainless steel retainer. The kynar seal is a ring which is L-shaped in cross section. The seal is installed over the poppet shaft and the long leg of the L is sandwiched between the inner surface of the poppet flange and the seal retainer. The Omniseal spring is installed in a groove in the outer edge of the seal retainer under the short leg of the seal. The short leg of the seal contains a ridge on its outer surface which is pressed against the wall of the neck of the poppet chamber when the poppet is in the closed position. The spring exerts a force on the seal and ensures that all parts of the ridge make contact with the neck wall. The seal retainer is held in place by the forward end of a stainless steel shaft extension which is threaded on the end of the poppet shaft. The shaft extension is installed in the guide tube located in the center of the poppet chamber and slides back and forth in the guide during the engagement-disengagement cycle. The actuator arm of the poppet actuating system is pinned to the aft end of the shaft extension.

The poppet actuating system is installed aft of the poppet system and consists of the stainless steel actuator arm, a stainless steel lower body shaft, a stainless steel upper body shaft, two stainless steel drive pins and a stainless steel handle. The lower body shaft and the upper body shaft are installed in separate sections of a bore which is perpendicular to the flow path. The short lower body shaft is installed in the section of the bore which is below the flow path; this section of the bore is equipped with a kynar sleeve bearing. The stepped upper body shaft is installed in the section of the bore which is above the flow path. Two Omniseals are installed around the upper body shaft just above the flow path. The Omniseals are held against a shoulder of the shaft by a kynar bearing and a stainless steel thin washer-shaped seal retainer. Because the flow path separates the upper body shaft from the lower body shaft, the two shafts are connected by the two drive pins which are pressed into the facing ends of the shafts. The pins are installed eccentric to the center line of the shafts. The flat actuator arm is positioned along the flow path center line. The aft end of the actuator arm is installed between the lower body shaft and the upper body shaft. One of the drive pins passes through a hole in the actuator arm and serves as a pivot for the actuator arm. The other pin serves as a stop for the arm. Stainless steel balls are installed in an annular groove in the upper body shaft outboard of the Omniseals to facilitate rotation of the shaft; half of the groove is machined in the shaft and the other half is machined in the wall of the bore. The handle of the poppet actuating system is bolted to the outboard end of the upper body shaft and is prevented from rotating independent of the shaft by a pin installed parallel to the bolt.

The collar actuating system consists of a stainless steel collar, a stainless steel handle, a detent pin mechanism, and two collar lock mechanisms. The collar is a machined investment casting, tubular in shape, with a thick-walled forward section which engages the indexed flange of the airborne half during the engagement operation. The collar is installed over the ground half body and is held in position by a ring of stainless steel balls which are free to rotate in an annular groove. Half of the groove is machined in the outer surface of the coupling-engagement seal retainer which is bolted to the mating face of the ground half body; the outer half of the groove is machined in the thick-walled forward section of the collar. The collar handle is bolted to the aft end of the collar. The detent pin mechanism is installed in a bore in the ground half body. The bore is located between the upper body shaft and the forward mating face of the coupling half. The mechanism is composed of a stainless steel compression spring installed inside a closed end tubular pin. The outboard end of the spring pushes against the inner surface of the closed end of the pin; the inboard end of the spring is restrained by the bottom of the bore. The outboard end of the pin bears against the inner wall of the collar until a hole in the collar is positioned over the pin. The pin then snaps into the hole but is prevented from completely passing through the hole by a shoulder of the pin which is larger in diameter than the hole. A slot in the collar and a socket head bolt in the body prevent the collar from being rotated more than 45°; the head of the bolt serves as a stop for the end of the slot.

When the ground half coupling is not connected to the airborne half, the poppet cannot be opened because the collar prevents the poppet actuating system shaft from being rotated; the collar is positioned so that a cutout on the collar is out of phase with the shaft and the aft end of the collar is located against a flat spot on the shaft. The collar is locked in this position by the two collar lock mechanisms. The two collar lock mechanisms are installed in the forward section of the ground half body and each consists of a stainless steel collar lock disc, a stainless steel collar lock pin, and a stainless steel spring. The lock pin has a large diameter center section and smaller diameter forward and aft sections. The large diameter center section and the smaller diameter forward part of the pin are installed in a stepped bore which is machined in the coupling-engagement seal retainer. The large diameter section of the stepped bore is machined in the aft face of the retainer; the smaller diameter bore is machined through the forward face of the retainer. The small diameter forward part of the pin protrudes forward of the mating face of the retainer. The collar lock disc is installed over the small diameter aft part of the pin against the end of the large diameter section. The forward end of the spring is also installed over the aft part of the pin. The spring pushes against the lock disc and holds it in the lock position. The aft end of the spring is installed in a hole in the forward face of the body behind the retainer. The aft end of the spring is restrained by the bottom of the hole. In the locked position, the lock disc is held in a cutout in the collar. The cutout is a sector of a circle which is slightly larger than the corresponding sector of the disc. When the lock pin is depressed (pushed aft), the lock disc is pushed out of the cutout into a large ring groove in the collar and the collar is free to rotate.

During periods when the airborne half and the ground half are not engaged, the halves are protected by dust caps.

The airborne dust cap assembly consists of a stainless steel body, a kynar seal, two stainless steel Omniseal springs, and a stainless steel seal retainer. The body is an intricate cup-shaped machined investment casting which engages the indexed flange of the airborne half. The kynar seal has a disc-shaped aft part and a washer-shaped forward part separated by an air space but joined at the outer edge of each. The forward face of the washer-shaped part of the seal contains two concentric ridges which are pressed against the flat sealing surface of the airborne half body during engagement of the airborne half and the dust cap. The two Omniseal springs are installed concentrically in the space between the washer-shaped part of the seal and the disc-shaped back of the seal. The springs exert a force on the seal and ensure that all parts of each ridge make contact with the sealing surface of the airborne half. The spring retainer is a ring which is installed inside the washer-shaped part of the seal against the back of the seal. The outer edge of the retainer bears against the inner edge of the inboard spring. The seal is installed back first against the inner surface of the closed end of the body and is held in place by three self-locking nuts. The nuts are threaded on three bolts which are installed through the closed end of the dust cap body. A small sector of each nut bears against a part of a flange of the seal. The flange is an extension of the disc-shaped back of the seal.

The ground dust cap assembly consists of a stainless steel plug and a stainless steel grip plate. The plug is an intricate machined detail which is similar in shape to the indexed flange part of the airborne half. The sealing surface of the dust cap plug, however, protrudes a greater distance from the mating face than does the sealing surface of the airborne half. For this reason, the ground dust cap does not depress the collar lock pins when the sealing surface of the dust cap makes contact with the coupling-engagement seal system of the ground half. The flat grip plate is a disc with a scalloped edge; the plate is bolted to the back of the plug and serves as the handle for the dust cap.

The propellant disconnect coupling is supplied in four models. Each model has all the design features described above but each model is used for a distinct and independent purpose. A different model of the coupling is used as each of the following: an oxidizer fill coupling, an oxidizer vent coupling, a fuel fill coupling, and a fuel vent coupling. To ensure that each of the four models is used only for its intended purpose and to prevent the interconnection of the halves of the models, the couplings are indexed in three areas:

1. The location of the mounting holes on the airborne half is different for each model to ensure the installation of the correct model airborne half on a specific spacecraft panel.
2. The location of the indexing bolt head in the ground half and the corresponding cutout in the airborne half is different for each model to prevent the engagement of one model ground half with another model airborne half.
3. The external threads on the aft end of the ground half of the oxidizer models are 9/16-18 UNF-3A and the external threads on the aft end of the ground half of the fuel

models are 7/16-20 UNF-3A. As a result, an oxidizer ground servicing line cannot be connected to a fuel ground half coupling and vice-versa. In addition, the aft end of the ground half of the fill coupling models is designed to mate with a flared tube and the aft end of the ground half of the vent coupling models is designed to mate with a flareless tube. Because of this additional indexing feature, a propellant fill ground servicing line cannot be connected to a helium vent ground half coupling and vice-versa.

Engagement of the ground half and the airborne half follows the following sequence:

1. The airborne dust cap is turned 45° counterclockwise and the cap is pulled away from the airborne half coupling.
2. The ground half dust cap is turned 45° counterclockwise and the cap is pulled away from the ground half coupling.
3. The handle of the ground half coupling (which is positioned along the center line of the ground half when it is disengaged from the airborne half) is lined up with the square slot in the indexed flange of the airborne half. This action will line up the lugs and the protruding bolt heads of the ground half with the cutouts on the airborne half.

4. With the ground half handle lined up with the square slot of the airborne half, the ground half is advanced on to the airborne half until the mating surfaces make contact. This operation depresses the two collar lock pins in the ground half permitting the ground half collar to be turned.

5. The ground half collar is turned 5° clockwise until the detent pin of the ground half snaps into the hole in the collar. If a slight clockwise torque is applied to the ground half collar during the operation described in step 4 above, the collar will automatically rotate 5° clockwise when the mating faces make contact, and the detent pin will lock into position.

6. The detent pin is depressed and the ground half collar is turned an additional 30° clockwise for a total rotation of 35°. In this position, the ground half coupling is fully engaged with the airborne half and the cutout in the aft edge of the ground half collar is positioned in line with the ground half poppet actuating shaft. With the cutout in this position the poppet actuating shaft is free to be rotated.

7. The ground half handle is turned 200° counterclockwise. As the handle is turned, the ground half poppet is pushed forward to its open position by the shaft-actuating arm. The ground half poppet in turn pushes against the airborne

poppet, overcomes the spring force, and pushes the poppet off its seat to the full open position. (In the full open position, the seal of the ground half poppet is located well forward of the sealing surface of the neck of the ground half poppet chamber.) When the handle has been rotated only a few degrees, the full diameter of the poppet actuating shaft is rotated into the cutout in the collar and the flat spot on the shaft is turned out of parallel with the edge of the collar. When the full diameter enters the cutout, the collar cannot be turned; the collar is effectively locked in position and the coupling cannot be uncoupled.

NOTE: The poppets are open when the flat spot on the shaft is located on the side of the shaft away from the airborne half.

8. A nominal torque of 25 inch pounds is required to turn the ground half handle to the open-poppet position when a pressure of 360 psig acts on the airborne half.

Disengagement of the ground half and the airborne half follows the following sequence:

1. The ground half handle is turned 200° clockwise. As the handle is turned, the ground half poppet seal is pulled back to its closed position by the shaft-actuating arm mechanism and the airborne poppet is returned to its closed

position by the poppet spring. The full diameter of the poppet actuating shaft remains in the collar cutout until the poppets have closed. When the handle has been turned the full 200° clockwise the flat spot on the shaft is positioned parallel and slightly aft of the edge of the collar. With the flat spot in this position, the collar can be turned.

NOTE: The poppets are closed when the flat spot on the ground half poppet actuating shaft is located on the side of the shaft facing the airborne half.

2. The ground half collar is turned 30° counterclockwise until the detent pin automatically locks in the hole in the collar. This is a safety check point. Any evidence of leakage in the intercoupling area indicates that poppet leakage exists. When this condition occurs, the coupling halves must be fully engaged by depressing the detent pin and turning the ground half collar 30° clockwise. The system must then be drained and the cause of the leakage ascertained.
3. If there is no evidence of leakage, the detent pin is depressed and the ground half collar is turned an additional 5° counterclockwise.
4. The ground half is pulled away from the airborne half.

5. The airborne dust cap is installed on the airborne half coupling by lining up the lugs of the dust cap with the cutouts on the airborne indexed flange, pushing the dust cap forward until the sealing surfaces mate, and turning the dust cap 45° clockwise.

6. The ground half dust cap is installed against the mating face of the ground half coupling by lining up the cutouts in the dust cap with the lugs on the ground half collar, pushing the dust cap forward until the sealing surfaces mate, and turning the dust cap 45° clockwise.

The important performance characteristics of the propellant disconnect coupling and general information concerning the component are listed below.

Working pressure	0-360 psig
Proof pressure	540 psig
Burst pressure	720 psig
Maximum leakage (helium)	
Half-couplings engaged	5×10^{-4} scc/sec
Airborne half without cap	5×10^{-6} scc/sec
Airborne half with cap and poppet open	5×10^{-5} scc/sec
Ground half without cap and with cap (and poppet open)	1×10^{-4} scc/sec

Numerical reliability (maximum probability of failure)	
Airborne half with cap	1×10^{-6} for 336 hours
Half-couplings engaged	1000×10^{-6} for 100 cycles
Minimum total operating life	400 cycles
Specification number	MC 273-0011
SCD number (MR part number)	
Qualified airborne half	
Oxidizer vent coupling	ME 273-0011-0001
Oxidizer fill coupling	ME 273-0019-0001
Fuel fill coupling	ME 273-0021-0001
Fuel vent coupling	ME 273-0024-0001
Qualified ground half	
Oxidizer vent coupling	ME 273-0011-0002
Oxidizer fill coupling	ME 273-0019-0002
Fuel fill coupling	ME 273-0021-0002
Fuel vent coupling	ME 273-0024-0002
Pre-qualified airborne half	
Oxidizer vent coupling	ME 273-0011-0003
Oxidizer fill coupling	ME 273-0019-0003
Fuel fill coupling	ME 273-0021-0003
Fuel vent coupling	ME 273-0024-0003
Pre-qualified ground half	
Oxidizer vent coupling	ME 273-0011-0004
Oxidizer fill coupling	ME 273-0019-0004
Fuel fill coupling	ME 273-0021-0004
Fuel vent coupling	ME 273-0024-0004

Supplier	The J.C. Carter Co. Costa Mesa, Calif.
Supplier part number per SCD	
dash number -0011-0001	6760-1
-0019-0001	6760-3
-0021-0001	6760-5
-0024-0001	6760-7
-0011-0002	6760-2
-0019-0002	6760-4
-0021-0002	6760-6
-0024-0002	6760-8
-0011-0003	6760-1P
-0019-0003	6760-3P
-0021-0003	6760-5P
-0024-0003	6760-7P
-0011-0004	6760-2P
-0019-0004	6760-4P
-0021-0004	6760-6P
-0024-0004	6760-8P

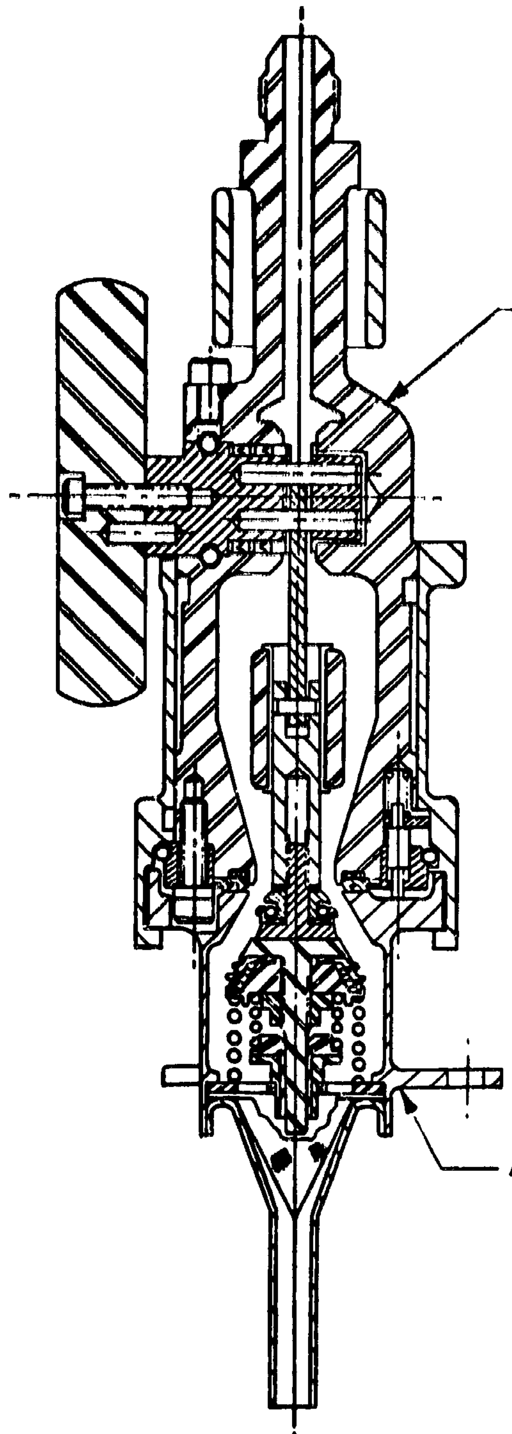


Figure 6-1. Propellant Disconnect Coupling.

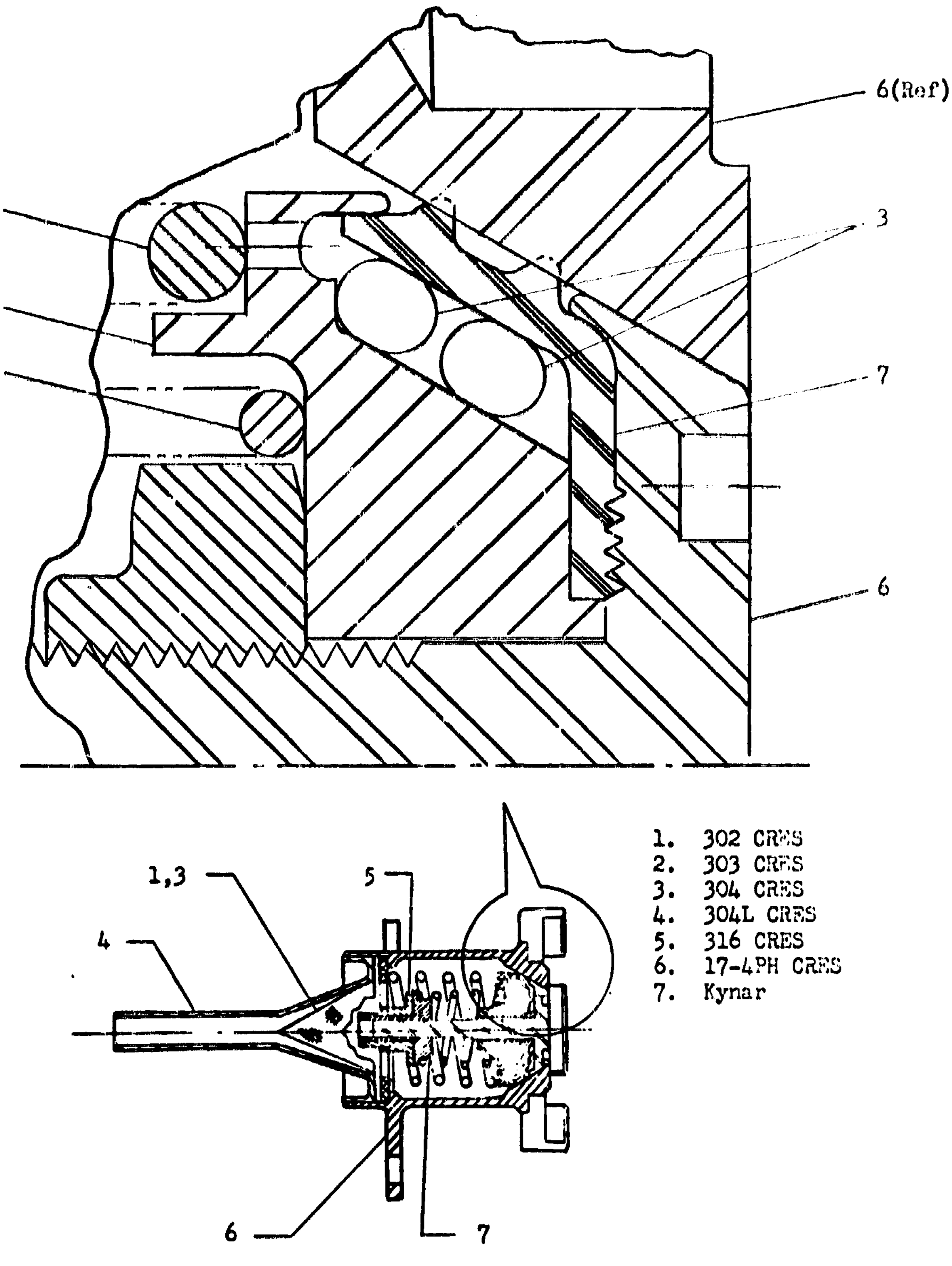


Figure 6-2. Airborne Half of the Propellant Disconnect Coupling

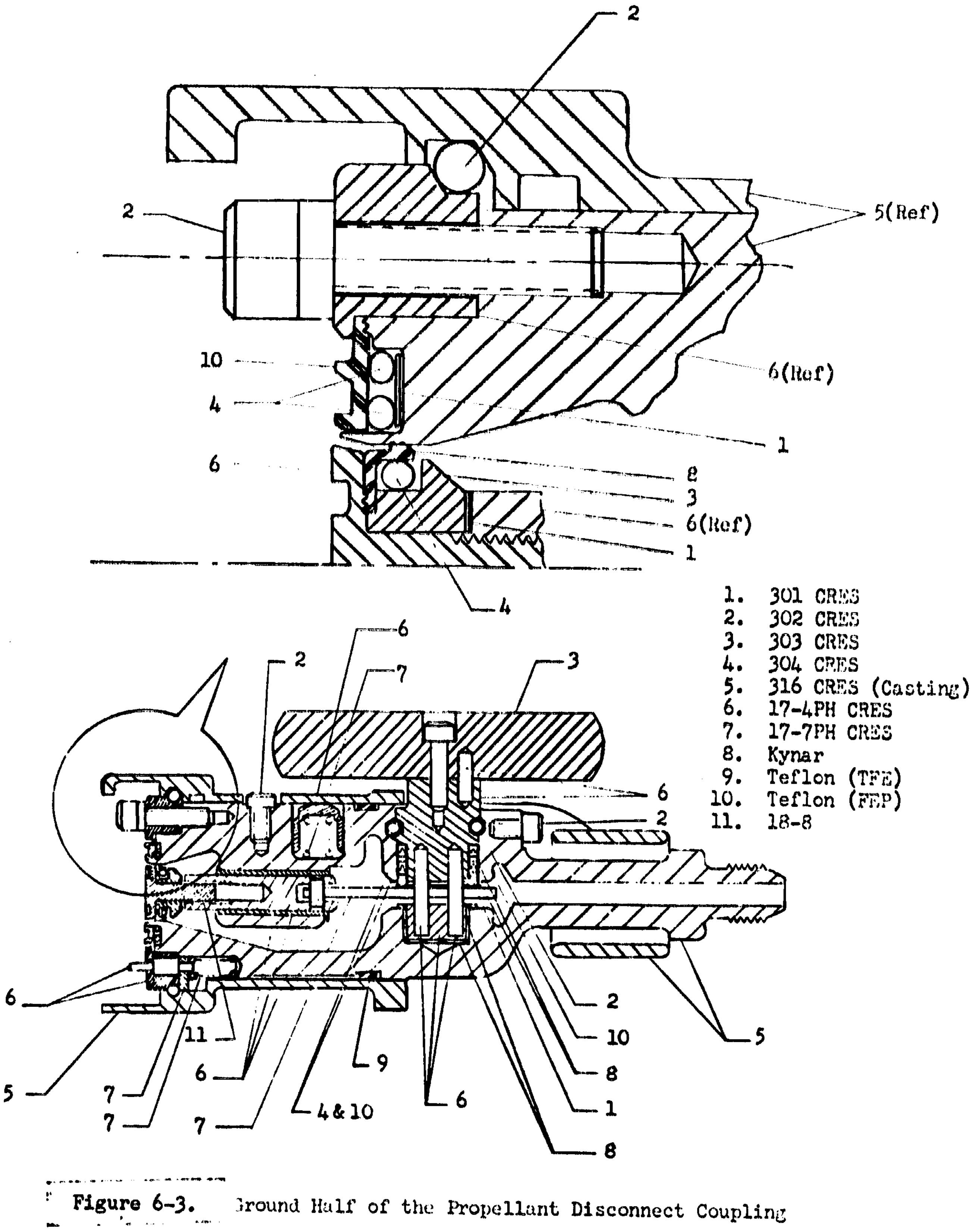


Figure 6-3. Ground Half of the Propellant Disconnect Coupling

TITLE	Propellant Fill and Drain Couplings (J. C. Carter)
PART NUMBER	ME273-0011-0001 Ox Vent coupling ME273-0019-0001 Ox Fill coupling ME273-0021-0001 Fuel Fill coupling ME273-0024-0001 Fuel Vent coupling
DVT TEST COMPLETION DATE	May, 1964
QUAL TEST COMPLETION DATE	September, 1964
NUMBER TEST UNITS	6
QUAL TESTS:	Proof pressure (540 psig), functional (10 engagement cycles), leakage (5×10^{-6} scc/sec Helium, caps on and off), pressure drop (NMT 0.5 psid N_2 or 12 psid prop.), vibration (16 grms), endurance cycling (400 cycles), propellant exposure (DVT: 38 days).
ACCEPTANCE TESTS	Proof pressure (540 psig) Functional (10 engagement cycles) Leakage (5×10^{-6} scc/sec helium at 360 psig, caps on and off). Cleanliness (per MA0610-004)
DIFFERENCE BETWEEN QUAL AND SC UNITS	None
NOTES:	Leakage requirements at NR:

Caps off - 20 scc/hr helium
Caps on - 5×10^{-6} scc/sec helium

Seal material: kynar

Filter: 75 micron absolute

Weight (A/B): 0.32 pound

Ground-half design improvement:

G/Hs made after 9/65 have modified crank drive pins and omniseal retainers to prevent binding of the operating crank.

P/N	S/N Effectivity	
	Bearing Chg	Pin Chg
-0011-0002	175 & Subs	191 & Subs
-0019-0002	146 & Subs	158 & Subs
-0021-0002	145 & Subs	174 & Subs
-0024-0002	146 & Subs	168 & Subs

7. Dynatube Fitting

The dynatube fitting (Figure 7-1) consists of a stainless steel nut and a stainless steel shoulder/tube. The face of the shoulder/tube is an integral washer-shaped sealing surface which is cantilevered from its OD. By deflecting the cantilevered surface against a mating solid member, a high unit load is created in the sealing band resulting in a very effective metal to metal seal.

The important performance characteristics of the dynatube fitting and general information concerning the component are listed below.

Working pressure	360 psig
Proof pressure	2000 psig
Burst pressure	3000 psig
Pressure surge	0 to 750 to 0 psig within 4 milliseconds for min. of 18,000 cycles
Maximum external leakage (He) 0 to 750 psig	5×10^{-6} std. cc/sec
Numerical reliability (maximum probability of failure)	1×10^{-6} for 336 hours
Minimum total operating life	400 engagement-disengagement cycles
Specification number	MC273-0046
SCD number (NR part number) Qualified fittings	ME273-0046-0001 thru -0044 -0045 -0047 -0049 -0050 thru -0063 ME273-0049-0001 -0002

Pre-qualified fittings	ME273-0046-0101 thru -0144 ME273-0049-0101 -0102
Pre-DVT fittings	ME273-0046-0201 thru -0244 ME273-0049-0201 -0202
Supplier	Resistoflex Corp. Roseland, New Jersey
Supplier's part number per SCD dash number -	See ASL

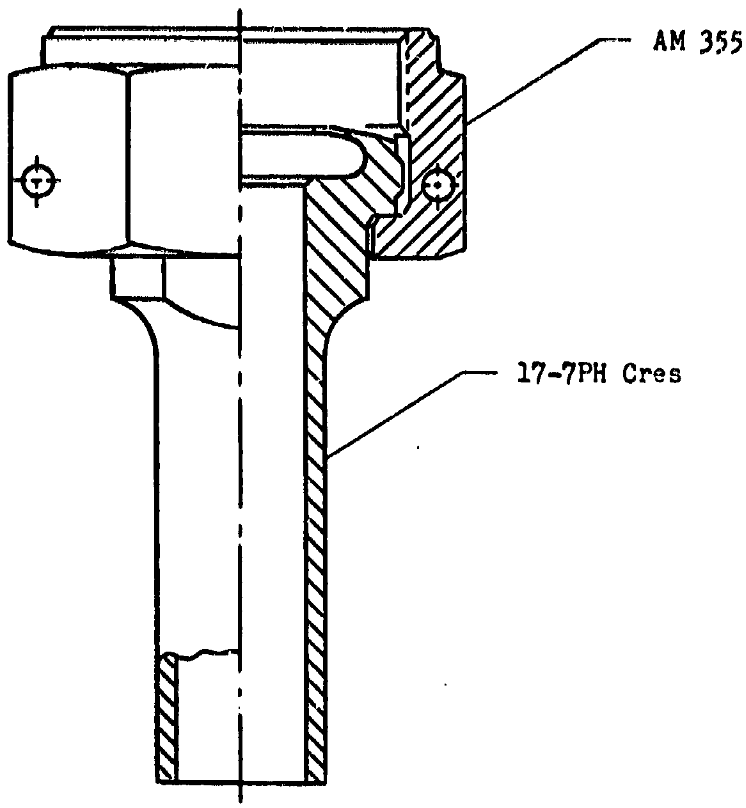


Figure 7-1. Dynatube Fitting

TITLE	Dynatube Fitting (Resistoflex)
PART NUMBER	ME273-0046-00xx (16 dash numbers) ME273-0049-00xx (2 dash numbers)
DVT COMPLETION DATE	July, 1964
QUAL TEST COMPLETION DATE	August, 1964
NUMBER TEST UNITS	7
QUAL TESTS:	Proof pressure (2000 psig), functional (4 assembly cycles), leakage (5 x 10-6 scc/sec helium), shock (78g's for 11 millisec), vibration (16 grms), endurance cycling (100 cycles), propellant exposure (DVT: 38 days)
ACCEPTANCE TESTS	Examination of Product *Proof pressure (2000 psig) *Functional (4 assembly cycles) *Leakage (5 x 10-6 scc/sec at 750 psig) *Deleted for S/C 112 and Subs
DIFFERENCE BETWEEN QUAL AND SC UNITS:	Qual Units: -101 and -102 tested Bend and length only S/C UNITS: Eighteen different configurations (-101 and -102 are not used).
CONSTRUCTION	Shoulder and Tube - 17-7PH (TH1050) Nut - AM355

TITLE	Dynatube Fitting (Resistoflex)
PART NO.	ST2730001ME0001 (Str. Shank) ST2730001ME0007 (85° Elbow)
DVT TEST	N.A.
QUAL. TEST COMPLETION DATE	February 19, 1970
NO. TEST UNITS	2
VERIFICATION (QUAL) TESTS	(1 each of -0001 and -0007 configuration). Proof Pressure: (2000 psig with deionized water for 3 minutes without visible leakage, permanent deformation, or damage. Shall then pass leakage test, below). Leakage (360 psig deionized water 15 min. at +40F. Repeat for 15 min. at + 175F. No visible leakage tolerated. Recheck at ambient temp. with 360 psig He. Max. all. leak. 5 x 10^{-6} scc/sec). Vibration (2½ min. at boost intensity; 12½ min. at flight intensity). Functional (2 assemblies at min. torque, (25 ft.lbs.); followed by 2 assemblies at max. torque (80 ft.lbs.); Leak check each assembly with helium as above; each assy. followed by complete disassembly) Endurance (50 complete assys. at max. torque and 50 complete assys. at min. torque alternating max. to min. every 5 cycles, followed by proof pressure test. Leak check with He as above after 5, 10, 25, 30, 45, 50, 75 and 80 assemblies). Burst (5 minutes at 3000 psig deionized water at ambient temperature w/o visible leakage or structural deformation). Off-limits burst (Increase at ±100 psi/min. to failure. Record failure pressure; describe failure mode).
ACCEPTANCE TESTS	Examination of product.
CONSTRUCTION	Union type coupling with highly finished (8 RMS) cantilever loaded mating faces. Redundant O-ring outer seal. Tube end finished to NR 5/8 tube brazing detail ($0.631^{+.000}_{-.004}$ O.D. with 0.025 ±.002 wall x ½ lg). Min. allowable I.D. - 0.570. Material - 17-7PH Cres, AMS 5644.

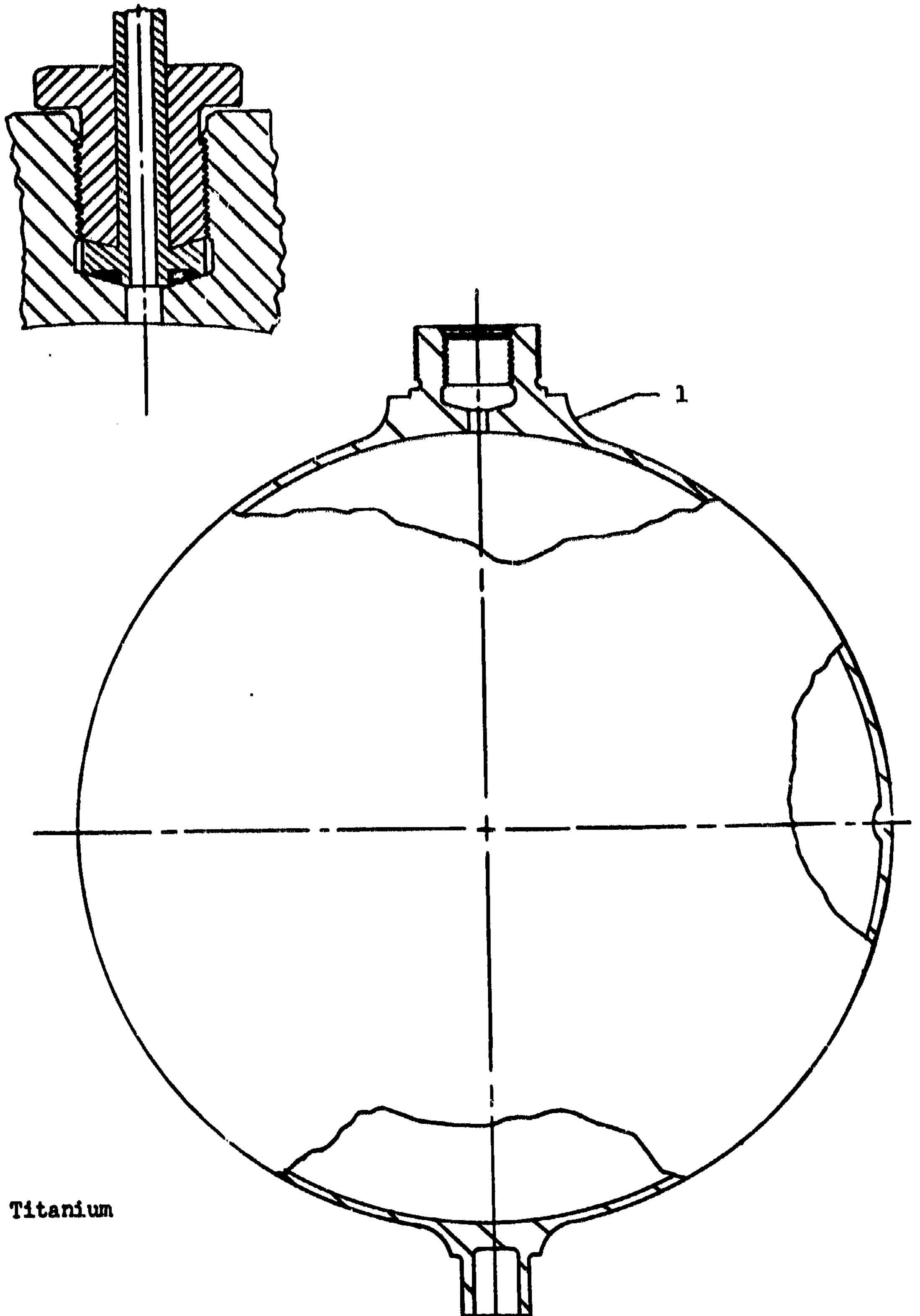
8. Helium Pressure Vessel (356 cu. in.)

The helium pressure vessel (Figure 8-1) is fabricated from two hemispherical titanium forged sections joined by fusion welding at the tank "equator". The pressure vessel has a minimum wall thickness of 0.102 inch after machining. A mounting provision is located at the "pole" of each hemisphere. When the pressure vessel is installed, one side is fixed and the other side is free to move along the mount axis only, allowing for tank expansion and contraction. The combination inlet and outlet port is located on the mount centerline at the fixed end. The inlet-outlet port is a machined boss containing a 1-3/8 - 18 NEF - 3A external thread and a tapped hole with a 3/4 - 16 UNF - 3B internal thread. A 0.209 inch diameter hole is drilled through the vessel skin between the bottom of the tapped hole and the inner surface of the pressure vessel.

When the pressure vessel is assembled in the reaction control system, a stainless steel adapter and a stainless steel nut are installed in the tapped hole. The adapter is a thick-walled tube with a flange at one end. A rubber "O" ring and a teflon-coated stainless steel "V" seal are installed in a groove in the face of the adapter flange. The tubular section of the adapter is installed in the hollow center of the nut with one end of the nut bearing against the inboard surface of the flange. The combination is threaded into the boss until the seals in the face of the flange seal against the conical shaped bottom of the tapped hole. The external thread on the boss is used to hold the pressure vessel mounting nut.

The helium pressure vessel carries 356 ± 5 cubic inches of helium gas, initially stored at 4150 psig and 70 ± 10F. The important performance characteristics of the helium pressure vessel and general information concerning the component are listed below:

Operating pressure	4500 psig
Proof pressure	6667 psig
Burst pressure	7500 psig
Maximum external leakage	5×10^{-6} std. cc/sec.
Numerical reliability (maximum probability of failure)	60×10^{-6} for 336 hrs.
Minimum total operating life	3000 cycles
Specification number	MC 282-0002
SCD number (NAA part number)	
Qualified vessel	ME 282-0002-0001
Pre-qualified vessel	ME 282-0002-0002
Pre-DVT vessel	ME 383-0003-0003
Supplier	Menasco Mfg. Co. Burbank, Calif.
Supplier's part number per SCD	
dash number -0001	891000-501
-0002	891000-501P
-0003	891000-501X



1. Titanium

Figure 8-1. Helium Pressure Vessel (356 cu. in.)

TITLE	Pressure Vessel, Helium (Menasco)
PART NUMBER	ME282-0002-0001
DVT TCD	July 17, 1964
QUAL TCD	October 2, 1964
NO. QUAL UNITS TESTED	4
QUAL TESTS	Random vibration - 0.04g^2/cps @ 20 cps; linear increase to 0.15g^2/cps @ 80 cps; constant to 1000 cps; linear decrease to 0.075g^2/cps. Proof pressure and external leakage - 5 x 10^{-6} std cc/sec. @ 6,667 psig. Acceleration -20g for 30 minutes. Creep - 4500 psig for 720 hours Pressure Cycling - 3000 cycles 0 to 5000 to 0 psig. Burst - 7500 psig (Actual - 8600, 8800 and 8900)
ACCEPTANCE TESTS	Examination of Product Proof Pressure - 6667 psig External Leakage - 5 x 10^{-6} std cc/hr Cleanliness
DIFFERENCE BETWEEN QUAL AND SC UNITS	None
CONSTRUCTION	Pressure welded Titanium Alloy (6Al-4V)
SHELL THICKNESS	0.102" min.
WEIGHT	5.25#
USAGE	CM All Block I and II SC SM Block I and 2TV-1

9. Propellant Tank, Fuel and Oxidizer

The propellant tank (Figure 9-1) consists of a shell assembly, a diffuser assembly, and a teflon bladder. The shell assembly is composed of a titanium cylindrical center section and titanium hemispherically domed ends joined by fusion welding. The diffuser assembly consists of a stainless steel inlet tube, an aluminum alloy cover plate, an aluminum alloy flange, an aluminum alloy diffuser tube, a stainless steel liquid side vent (LSV) tube, and an aluminum alloy retainer. The stainless steel inlet tube is brazed to the aluminum alloy cover plate and the cover plate is welded to the flange. The forward end of the diffuser tube is welded to the cover plate and the aft end of the diffuser tube is welded to the retainer. The LSV tube is installed inside the diffuser tube through a hole located in the bend at the forward section of the diffuser tube; the LSV tube is welded to the diffuser tube at this point. The aft end of the LSV tube is installed in a tubular boss in the center of the retainer. A teflon bushing is installed between the LSV tube and the inner wall of the boss. (The pre-DVT tanks are not equipped with an LSV tube.)

The teflon bladder is the shape of the shell assembly and is of single ply construction of 6 mil teflon except for the ME282-0006 tank which has hemispherical ends of single ply, 9 mil teflon. The teflon bladder has a small hole at the aft end and a large flanged opening at the forward end. The threaded stud of the diffuser retainer is installed through the small hole of the bladder. The section of the bladder around the small hole is sandwiched between the large diameter flat end of the retainer and an aluminum washer. The aluminum washer is installed over the threaded stud and is held in place by a stainless steel nut threaded on the stud. The forward end of the bladder with the flanged opening is attached to the forward end of the diffuser assembly. The flange of the bladder is sandwiched between the diffuser assembly flange and an aluminum ring. The ring is attached to the diffuser assembly flange by stainless steel bolts.

The shell assembly is equipped with a large machined boss at the forward end and a small closed-end tubular boss at the aft end. The large boss at the forward end contains a large access hole, ten tapped bolt holes, and a tapped helium inlet hole drilled perpendicular to the center line of the tank. The diffuser assembly with the bladder attached is installed in the shell assembly through the access hole in the large boss. The aft end of the diffuser assembly is inserted first and is carefully pressed into the small closed-end tubular boss at the aft end of the shell. A teflon gasket ring installed in a groove in the aluminum washer bears against the I.D. of the tubular boss and ensures a snug fit. The flange at the forward end of the diffuser assembly is attached to the large boss at the forward end of the shell assembly by stainless steel bolts; a teflon ring gasket installed against a shoulder in the boss seals the attachment. A stainless steel inlet fitting is installed in the helium inlet hole.

The fitting is a threaded insert with an integral one-quarter inch OD tubular aft end; the fitting is sealed by two teflon gaskets installed in grooves in the fitting.

The propellant is contained within the bladder. When helium flows through the inlet fitting into the tank, it surrounds the outside of the bladder and exerts an equal force on all sections of the bladder causing the propellant to be forced through the many small holes in the wall of the diffuser tube into the diffuser tube itself and thence out of the tank into the system feed lines.

Performance and physical characteristics of the propellant tank include the following:

1. With the tank oriented in any position and the propellant at any temperature from 40°F to 105°F, the expulsion device expels approximately 98 percent of the propellant capacity.
2. It is a specification requirement that the expulsion device and port design are such that neither 40 psig in the propellant compartment with zero psig at the helium inlet, nor 250 psig helium pressure with zero psig at the propellant outlet will cause expulsion device failure or damage.
3. Complete actuation of the expulsion device for expulsion or filling of propellant requires a pressure differential across the device of not more than 1 psi.
4. There is no propellant leakage from the tank at any pressure from zero psig to maximum operating pressure.

Additional performance characteristics of the propellant tank and general information concerning the component are listed below.

CM Oxidizer Tank

Working pressure	2 inch of Hg to 360 psig
Proof pressure	525 psig
Burst pressure	710 psig
Helium Leakage	
Internal	65 cc/15 min. at a 10 psi differential
External	1.5×10^{-3} scc/sec at MEOP or less
Pressure drop	2 psid from He inlet to Ox outlet at flow rate of 0.66 #/sec. of N_2O_4
Numerical reliability (maximum probability of failure)	100×10^{-6} for 1 cycle
Minimum total operating life	20 cycles
Specification number	MC 282-0006
SCD number (NAA part number)	
Qualified tank (with LSV)	ME282-0006-0001, -0006 and -0007
Pre-qualified tank (cancelled)	ME282-0006-0002
Pre-DVT tank:	
Al. Diffuser, 3 ply, no LSV	ME282-0006-0003
Cres Diffuser, 3 ply, no LSV	ME282-0006-0004
Al. Diffuser, 1 ply, no LSV	ME282-0006-0005
Supplier	Bell Aerosystems Co. Buffalo, New York

Supplier's part number per SCD	
dash number -0001	8271-471154-1
-0002	8271-471104-5P
-0003	8271-471104-1X
-0004	8271-471004-1X
-0005	8271-471104-5X
-0006	8271-471154-3
-0007	8271-471154-5

CM Fuel Tank

Working pressure	2 inch of Hg to 360 psig
Proof pressure	525 psig
Burst pressure	710 psig
Helium leakage	
Internal	60 cc/15 min. at a 10 psi differential
External	1.5×10^{-3} scc/sec at MEOP or less
Pressure drop	2 psid from He inlet to fuel outlet at flow rate of 0.33 #/sec. of MMH
Numerical reliability (maximum probability of failure)	100×10^{-6} for 1 cycle
Minimum total operating life	20 cycles
Specification number	MC282-0007
SCD number (NR part number)	
Qualified tank (with LSV)	ME282-0007-0001, -0006, -0007
Pre-qualified tank (cancelled)	ME282-0007-0002
Pre-DVT tank:	
Al Diffuser, 3 ply, no LSV	ME282-0007-0003
Cres Diffuser, 3 ply, no LSV	ME282-0007-0004
Al. Diffuser, 1 ply, no LSV	ME282-0007-0005

Supplier	Bell Aerosystems Co. Buffalo, New York
Supplier's part number per SCD	
dash number -0001	8271-471153-1
-0002	8271-471103-5P
-0003	8271-471103-1X
-0004	8271-471003-1X
-0005	8271-471103-5X
-0006	8271-471153-5
-0007	8271-471153-7

<u>SM Oxidizer Tank</u>

Working pressure	2 inch of Hg to 248 psig
Proof pressure	360 psig
Burst pressure	460 psig
Helium leakage	
Internal	95 scc/15 min. at a 10 psi differential
External	1.5 x 10^{-3} scc/sec at MEOP or less
Pressure drop	2 psid from He inlet to Ox outlet at flow rate of 0.44 #/sec. of N_2O_4
Numerical reliability (maximum probability of failure)	100 x 10^{-6} for 1 cycle
Minimum total operating life	6 cycles
Specification number	MC282-0004
SCD number (NR part number)	
Qualified tank (with LSV)	ME282-0004-0001, -0006, -0007 and -0008
Pre-qualified tank (cancelled)	ME282-0004-0002

Pre-DVT tank:

Al. Diffuser, 3 ply, no LSV	ME282-0004-0003
Cres Diffuser, 3 ply, no LSV	ME282-0004-0004
Al. Diffuser, 1 ply, with LSV	ME282-0004-0005
Supplier	Bell Aerosystems Co. Buffalo, New York
Supplier's part number per SCD	
dash number -0001	8271-471152-1
-0002	8271-471152-1P
-0003	8271-471102-1X
-0004	8271-471002-1X
-0005	8271-471152-1X
-0006	8271-471152-5
-0007	8271-471152-11
-0008	8271-471152-13

<u>SM Fuel Tank</u>

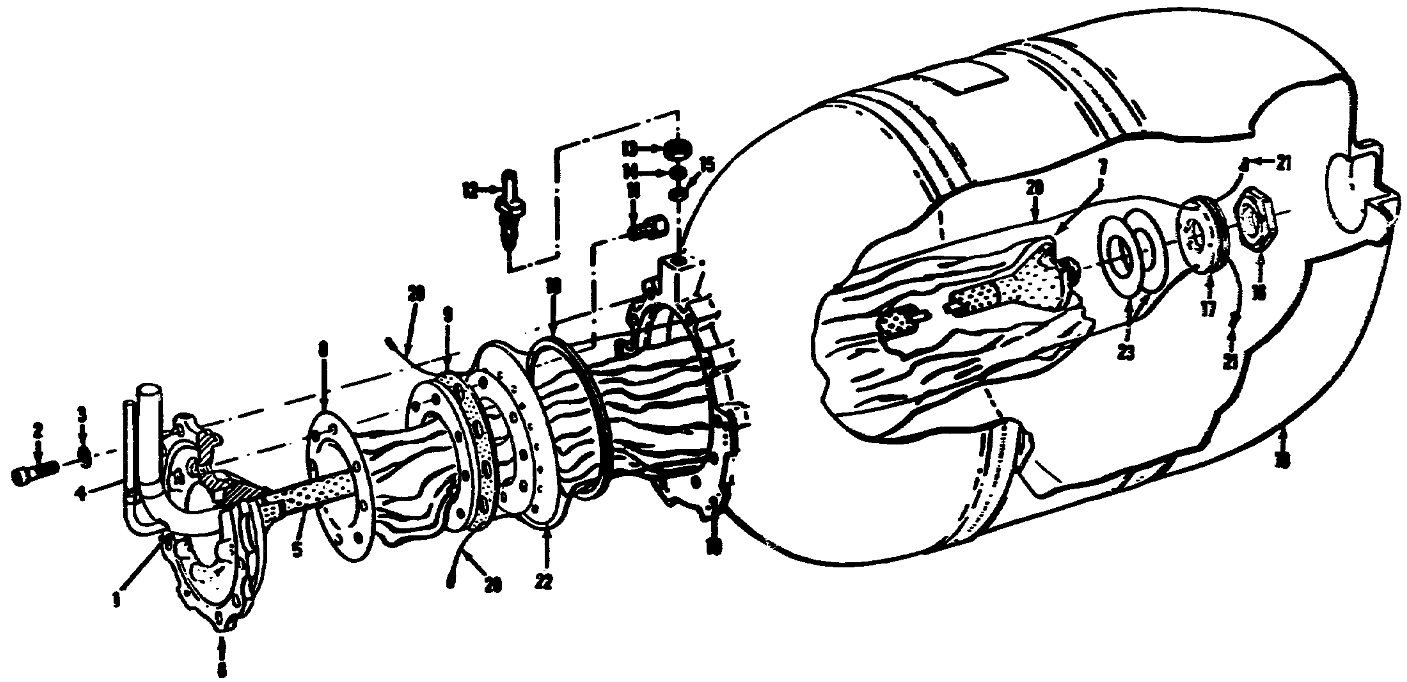
Working pressure	2 inch of Hg to 248 psig
Proof pressure	360 psig
Burst pressure	460 psig
Helium leakage	
Internal	80 scc/15 min. at a 10 psi differential
External	1.5 x 10^{-3} scc/sec at MEOP or less
Pressure drop	2 psid from He inlet to fuel outlet at flow rate of 0.22 #/sec. of 50-50 blend of UDMH and N_2H_4 or MMH
Numerical reliability (maximum probability of failure)	100 x 10^{-6} for 1 cycle
Minimum total operating life	20 cycles
Specification number	MC282-0008

SCD number (NR part number)	
Qualified tank (with LSV)	ME282-0008-0001, -0006, -0007 and -0008
Pre-qualified tank (cancelled)	ME282-0008-0002
Pre-DVT tank:	
Al. Diffuser, 3 ply, no LSV	ME282-0008-0003
Cres Diffuser, 3 ply, no LSV	ME282-0008-0004
Al. Diffuser, 1 ply, with LSV	ME282-0008-0005
Supplier	Bell Aerosystems Co. Buffalo, New York
Supplier's part number per SCD	
dash number -0001	8271-471151-1
-0002	8271-471151-1P
-0003	8271-471101-1X
-0004	8271-471001-1X
-0005	8271-471151-1X
-0006	8271-471151-5
-0007	8271-471151-11
-0008	8271-471151-13

<u>PSM Oxidizer and Fuel</u>

Working pressure	2 inch of Hg to 248 psig
Proof pressure	375 psig
Burst pressure	500 psig
Helium leakage	
Internal	143 scc/15 min. at a 10 psi differential
External	2×10^{-6} #/hr at MEOP or less
Pressure drop	2.5 psid from He inlet to propellant outlet at a flow rate of 0.44 #/sec MMH or 0.88 #/sec N_2O_4

Numerical reliability	5×10^{-4} for 1 cycle
Minimum total operating life	20 cycles
Specification number	ST2820001ME
Qualified tank (with LSV) (Qualified by similarity to Bell P/N 8339-471102-7)	ST2820001ME0001
Supplier	Bell Aerosystems Co. Buffalo, New York
Supplier's part number per SCD	
dash number -0001	8580-471001-1



1.	Outlet Tube	(347 CRES)	9. Ring	(6061 Al)	17.	Washer	(6061-T6 Al)
2.	Bolt	(Titanium)	10. Gasket	(Teflon TFE)	18.	Shell	(Titanium)
3.	Washer	(347 CRES)	11. Bolt	(347 CRES)	19.	Nut Plate	(A286 CRES)
4.	LSV Tube	(347 CRES)	12. Fitting	(304L CRES)	20.	Vent Cord	(Teflon TFE)
5.	Diffuser Tube	(6061 Al)	13. Nut	(347 CRES)	21.	Flanged Eyelet	(304 CRES)
6.	Flange	(6061 Al)	14. Gasket	(Teflon TFE)	22.	Pad	(Teflon TFE/FEP)
7.	Retainer	(6061-T6 Al)	15. Gasket	(Teflon TFE)	23.	Pad	(Teflon TFE)
8.	Bladder	(Teflon TFE/FEP)	16. Nut	(347 CRES)			

Figure 9-1. Propellant Tank.

TITLE	CSM Positive Expulsion Tanks (BAC)

PART NUMBERS (SC-020)

SMO	ME282-0004-0001	8271-471152-1
CMO	ME282-0006-0001	8271-471154-1
CMF	ME282-0007-0001	8271-471153-1
SMF	ME282-0008-0001	8271-471151-1

QUALIFICATION (2 units each tested)

Difference between qual and SC-020 units = None

TESTS COMPLETED

SMO 3-1-66
CMO 8-15-65
CMF 7-1-65
SMF 5-1-65

TESTS

Acceptance, expulsion cycling:

CMO, CMF and SMF (20), SMO (6), Slosh, vibration - SMO & SMF (2 axes, 30 minutes @ 14.8 grms) CMO and CMF (2 axes, 30 minutes @ 14 grms), Tank shell cycling (3000), Burst Pressure:

	DES	ACTUAL
SMO	460	567, 604
CMO	710	885
CMF	710	1045, 1040, 1074
SMF	460	603, 638

ACCEPTANCE TESTS

Examination of product, proof pressure - SMO and SMF (331 psig) CMO and CMF (480 psig), External leakage (He.) 1.5×10^{-3} scc/sec,

Bladder Leakage (N_2) and (He.) cc/15 min.

	N_2	He.
SMO	5.0	80.0
CMO	4.0	65.0
CMF	3.5	60.0
SMF	4.5	70.0

PROBLEMS RESOLVED

Tank shell compatibility
Flange Bolts retorqued
Contamination Tolerance Tests

CONSTRUCTION

Tank Shell 6 al 4V Titanium
TIG welded (no rod)
Thickness - .022 hemisphere, .027 cyl.

NOTES

Tank Volumes

	Max	Nom	Min
SMO	2856.6	2848.1	2838.1
CMO	1794.3	1786.6	1782.2
CMF	1478.6	1473.0	1459.8
SMF	2265.3	2257.8	2240.8

Deliverable

SMO - 132.5#
SMF - 68.0
CMO - 83.5
CMF - 42.1
LEMO - 190.4
LEMF - 98.8

TITLE:	Tank Propellant, Positive Expulsion (BAC)
PART NUMBER:	ST282000lME0001, BAC 8580-471001-1
QUALIFICATION:	Similarity to LM Oxidizer 8339-471102-5 and Fuel 8339-471101-5 Propellant Tanks (2 each qualified)
TESTS COMPLETED	November 1966
TESTS:	<u>Acceptance Test</u>

Temp. Extremes:	-20°F 12 hrs/160°F 12 hrs Tank unpressurized and empty	
Acceleration:	8.5g 5 min.	
Slosh:	500 cycles, 3.2 cps 0.19 inch DA. Tank 1/3 full pressurized to 250 psig.	
Vibration:	<u>Launch and Boost</u>:	
	10-23 cps	12 db/oct rise to
	23-80 cps	.025 g^2/cps
	80-100 cps	12 db/oct rise to
	100-1000 cps	.06 g^2/cps
	1000-1200 cps	12 db/oct roll off to
	1200-2000 cps	.025 g^2/cps
	9.2 grms	5 min/axis
	<u>Flight</u>:	
	10-20 cps	12 db/oct rise to
	20-100 cps	.034 g^2/cps
	100-120 cps	12 db/oct roll off to
	120-2000 cps	.017 g^2/cps
	5.9 grms	12.5 min/axis
Expulsion:	16 cycles ambient temp. 2 cycles high temp. 105°F 2 cycles low temp. 40°F	
Shock:	15 g max. sawtooth wave 11±1 ms Tank 3/4 full, 250 psig, 3 shocks each direction, 3 axes	
Pressure Cycling:	0 to 181 to 0 psig 270 cycles 0 to 250 to 0 psig 30 cycles	Repeated 10 times
Burst:	500 psig (design) 767 and 775 psig (actual)	

ACCEPTANCE TESTS:	Examination of Product, Proof Pressure (375 psig min) External Helium Leakage (2×10^{-6} lb/hr, zero to 250 psig) Internal Helium Leakage (143 cc/15 min, P 9 $^{+1}_{-0}$ psi)		
CONSTRUCTION:	Tank Shell 6AL4V Titanium TIG Welded (Burn down flange) Thickness .023 Hemisphere, .030 cyl. Bladder - 6 mil TFE/FEP O.D. Undersize by 2% in cylindrical section.		
	Length	38.819 inches	
	Diameter	12.645 O.D.	
	Volume	4115 cu. in.	
	Weight	12.2 lb.	
	Ports	Propellant outlet	.750
		Helium inlet	.250
		Liquid side vent	.188

10. Helium Pressure Vessel (910 cu. in.)

The helium pressure vessel (Figure 10-1) is fabricated from two hemispherical titanium forged sections joined by TIG welding at the tank "equator". The pressure vessel has a minimum wall thickness of 0.132 inch after machining. A mounting provision is located at the "pole" of each hemisphere. When the pressure vessel is installed, one side is fixed and the other side is free to move along the mount axis only, allowing for tank expansion and contraction. The combination inlet and outlet port is located on the mount centerline at the fixed end. The inlet-outlet port is a machined boss containing a 7/8-14 UNF-3A external thread and a standard AND 10050-4 internal port. The machined mounting boss at the free end also contains a standard AND 10050-4 internal port.

When the pressure vessel is assembled in the reaction control system, a pressure transducer is installed in the port at the free end and a stainless steel adapter is installed in the inlet/outlet port. The adapter is a thick-walled tube with a flange and an AND 10056-4 male end. A teflon-coated stainless steel "V" seal is installed in a groove in the face of the adapter flange and a teflon omni-seal is installed at the ID of the flange. The adapter is threaded into the boss until the seals seal against the boss flange and the AND 10050-4 sealing surface. The external thread on the boss is used to hold the pressure vessel mounting nut.

The helium pressure vessel carries 910 ± 5 cubic inches of helium gas, initially stored at 4150 psig and 70 ± 10F. The important performance characteristics of the helium pressure vessel and general information concerning the component are listed below:

Operating pressure	4500 psig
Proof pressure	6000 psig
Burst pressure	7000 psig
Maximum external leakage	5×10^{-6} std. cc/sec.
Numerical reliability (maximum probability of failure)	60×10^{-6} for 336 hrs.
Minimum total operating life	3000 cycles
Specification number	MC 282-0051
SCD number (NR part number)	
Qualified vessel	ME 282-0051-0001
Supplier	Airite Division Sargent Industries El Segundo, Calif.
Supplier's part number per SCD dash number -0001	6499-7

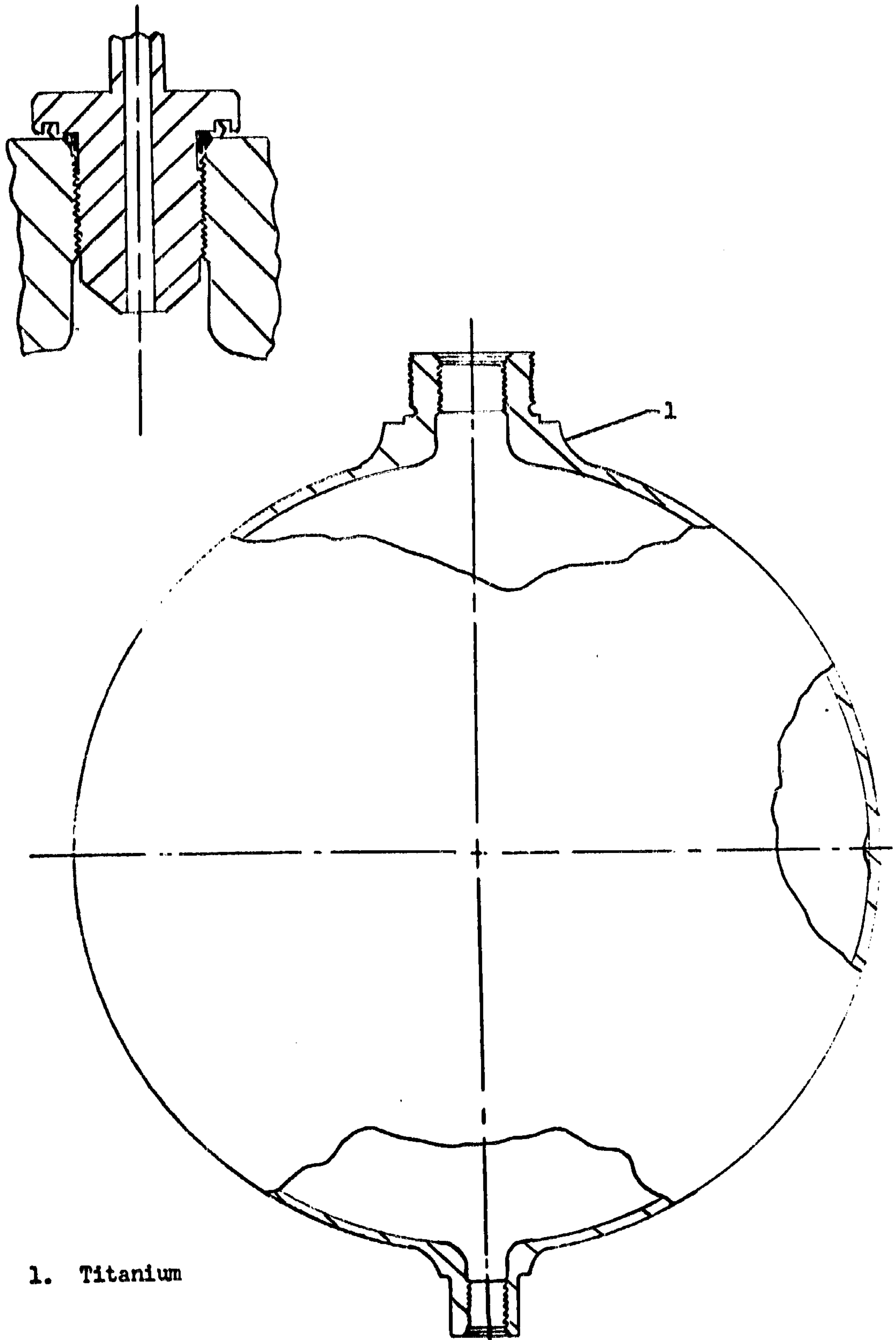


Figure 10-1. Helium Pressure Vessel (910 cu. in.)

TITLE Pressure Vessel, Helium (Airite)

PART NUMBER ME282-0051-0001

QUAL TCD 2/23/67

NO. QUAL UNITS TESTED 2

QUAL TESTS: Random Vibration -

$0.04g^2$/cps @ 20 cps; linear increase to $0.15g^2$/cps @ 80 cps; constant to 1000 cps; linear decrease to $0.075g^2$/cps @ 2000 cps.

External Leakage -

5×10^{-6} std cc/sec @ 4500 psig

Creep -

Pressurize to 4500 psig for 720 hours

Pressure Cycling -

600 cycles 0 to 4500 to 0 psig

Burst - 7000 psig (Actual - 7800 and 8000)

ACCEPTANCE TESTS:

Examination of Product
Proof Pressure —— 6000 psig
External Leakage —— 5×10^{-6} std cc/sec @ 4500 psig
Cleanliness

DIFFERENCE BETWEEN QUAL & S/C UNITS -- None

CONSTRUCTION TIG welded Titanium Alloy (6Al-4V)

SHELL THICKNESS 0.132" to 0.137"

WEIGHT 11.5#

USAGE S/M only SC101 and Subs

11. Helium Explosive Valve

The squib operated helium isolation valve (Figure 11-1) consists of a machined vacuum melt stainless steel body, a stainless steel cutter, a stainless steel piston, inlet and outlet fitting assemblies, and a cartridge (the explosive device). The inlet fitting assembly is composed of a one-quarter inch stainless steel tube brazed to a threaded stainless steel fitting which is closed on the inboard end. The outlet fitting assembly consists of a one-quarter inch stainless steel tube brazed to a filter assembly which in turn is brazed to a threaded stainless steel fitting which is also closed on the inboard end. The inlet and outlet fitting assemblies are threaded into the valve body and sealed by brazing. When installed in the valve body, the closed ends of the fittings are positioned beneath the cutter. The cutter and piston are installed in the body perpendicular to the direction of flow, with the piston acting on the cutter. A viton O-ring and two viton backup rings are installed in a groove in the piston to seal the pyrotechnic gas from the helium flow path. The cartridge is threaded over the body behind the piston and is sealed by a viton O-ring installed against an external shoulder of the body.

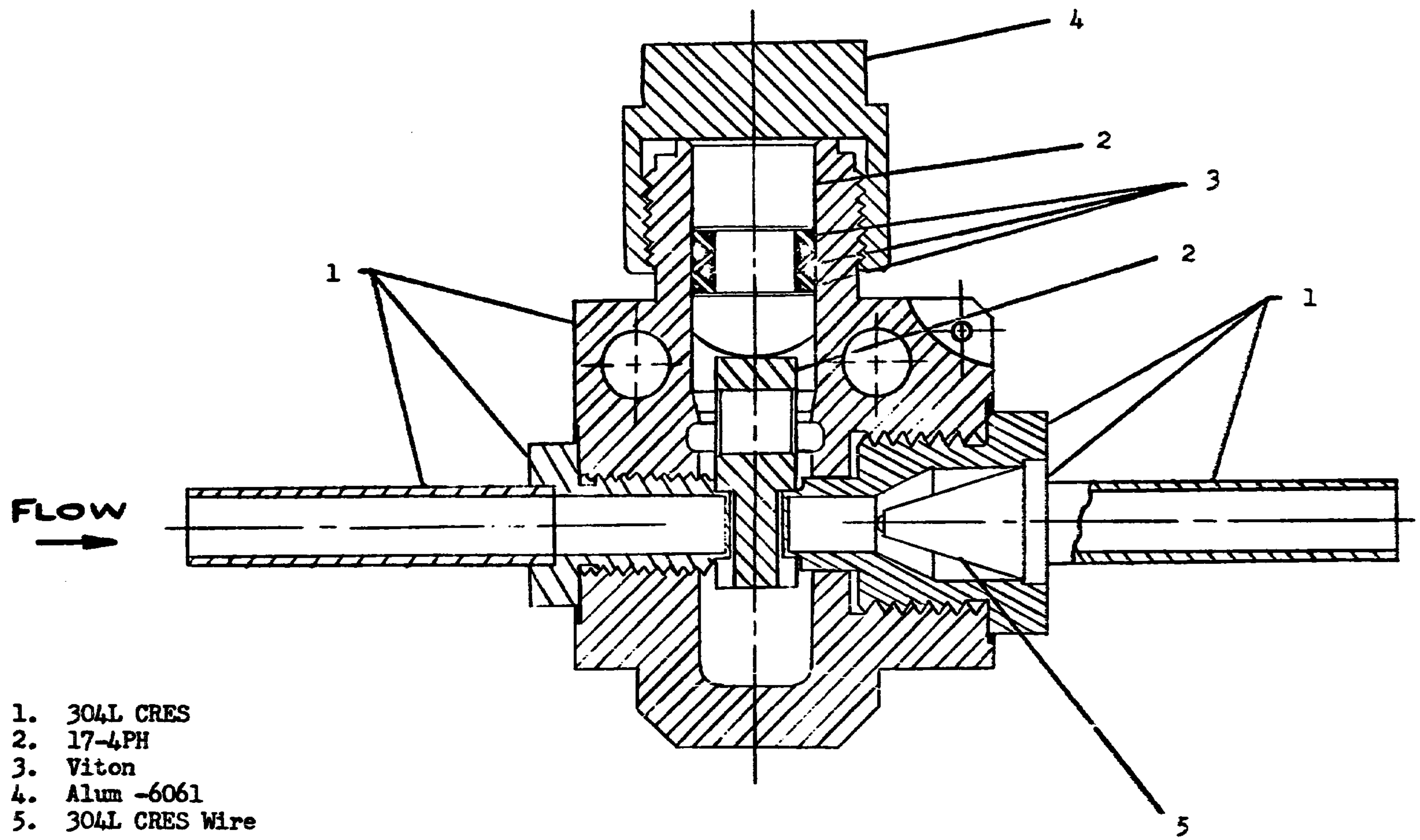
When the valve is actuated, the gases generated by the explosive device act against the piston driving the cutter to the bottom of the valve, severing the ends of the inlet and outlet fittings. When the cutter reaches the bottom of the valve, a hole drilled through the cutter is positioned in line with the holes in the inlet and outlet fittings providing an unrestricted flow path through the valve. The cutter is held in the down position by the piston which is driven into a deformable metal seat in the body; a permanent metal to metal seal results.

The filter assembly in the outlet fitting consists of a conical stainless steel wire mesh cloth supported by (but not attached to) a stainless steel conical support. Any debris resulting from the valve actuation is prevented from flowing downstream by the filter. The filter removes 98 percent of all particles whose smallest dimensions are greater than 40 microns, and 100 percent of all particles whose two smallest dimensions are greater than 74 microns.

The helium squib valve operates at a working pressure up to 4500 psig in the helium pressurization system and will open within 10 milliseconds after being subjected to a firing current of 5.0 amperes. Other important performance characteristics of the helium squib valve and general information concerning the component are listed below.

Proof pressure	6750 psig
Burst pressure	9000 psig
Pressure drop	3 psid at a He flow rate of 0.3 pounds per minute & an inlet pressure of 400 psig

Maximum external leakage	5×10^{-6} std. cc/sec.
Maximum internal leakage	5×10^{-6} std. cc/sec.
Numerical reliability (maximum probability of failure)	100×10^{-6} for 1 cycle
Minimum total operating life	1 cycle and 1 hour
Specification number	MC 284-0019
SCD number (NR part number)	
Qualified valve (isolation)	ME 284-0019-0002
Qualified valve (interconnect)	ME 284-0019-0004
Qualified valve (By-pass w/o Filter)	ME284-0019-0006
Pre-qualified valve	ME 284-0019-0001
Pre-DVT valve	ME 284-0019-0003
Supplier	Pelmec Division of Quantic Industries San Carlos, Calif.
Supplier's part number per SCD	
dash number -0002	1128-02
-0004	1128B-02
-0001	1128-02P
-0003	1128-02X
-0006	1128F-02



1. 304L CRES
2. 17-4PH
3. Viton
4. Alum -6061
5. 304L CRES Wire

Figure 11-1. Helium Explosive Valve.

TITLE	1/4" Explosive Valve (Pelmec)
PART NUMBER	ME284-0019-0002 Filter (He. Press. and by-pass) ME284-0019-0004 (He. Inter.) ME284-0019-0005 (He. Dump) ME284-0019-0006 Same except no filters ME284-0019-0008 Not on S/C 017
QUAL COMPLETED	April 1966
DVT COMPLETED	December 1963 (**)
NUMBER UNITS TESTED	4
QUAL TESTS(*)	Δ P at low temp. 3 at 0.3 #/min at -65°F Δ P at high temp. 3 at 0.3 #/min at +150°F Explosive atmosphere at low temp/MIL-STD-810 32-52% Hydrogen gas at 40°F Vibration .06 G^2/cps at 75 cps Disassembly and Inspection
ACCEPTANCE TESTS	Examination of product, proof pressure and leakage: Flow ports 5 x 10^{-6} std cc/sec at 6750 psig Pyro chamber proof pressure: 13,000 psig Lot Acceptance Cleanliness
DIFFERENCE BETWEEN QUAL AND SC UNITS	None
PROBLEMS RESOLVED	Wt. Valve .8# spec., .4 #/actual High Pressure Helium ME284-0019-0002; Cartridge ME453-0005-0121 Helium By-pass ME284-0019-0002 and -0006; Cartridge ME453-0005-0121 Helium Interconnect ME284-0019-0004; Cartridge ME453-0005-0122 Helium Dump ME284-0019-0005; Cartridge ME453-0005-0141
EFFECTIVITY	ME284-0019-0005 S/C 020 only ME284-0019-0002, -0004, -0006 - S/C 020 and Subs Respective Differences: -0002 11/16 RHTD, -0006 11/16 RHTHD without filter, -0004 11/16 LHTHD, -0005 3/4 RHTHD

* Prop. Exp. based on similarity to ME284-0130.

** 37 units (43 firings) used in supplemental devel. tests prior to qual. program to determine overkill margin and affects of combined environment.

1. Firing in vacuum environ. at 150°F
2. Firing during vibration Δ P at -65°F during vibration.

12. Helium Pressure Regulator Unit

The helium pressure regulator unit (Figure 12-1) consists of two independent regulators. The upstream regulator is designated the primary regulator; the downstream regulator is designated the secondary regulator. The primary and secondary regulators are designed to regulate the outlet pressure within an allowable pressure band. The primary regulator will do the regulating at all times unless there is a malfunction in its operation. The secondary regulator operates only upon failure of the primary regulator. Both the primary and secondary regulators are of the same design except for a small difference in the outlet pressure settings.

Each regulator consists of a stainless steel base housing, an aluminum spring housing, a main poppet system, a pilot poppet system, a bellows assembly system, an aluminum actuating piston, and stainless steel tubing. The base housing is a complex machined part which is composed of a conical base and an upper tubular shell. The shell is equipped with a flange at its upper end.

The main poppet system consists of a kynar poppet, an aluminum alloy poppet retainer, a stainless steel poppet spring, and a stainless steel poppet guide. The guide is installed in a bored hole in the base and is a cylinder with a tubular nose. The kynar poppet is installed in the flanged end of the tubular poppet retainer which is slipped into the tubular nose of the guide. The poppet spring is installed over the tubular nose of the guide; one end of the spring pushes against the flange of the poppet retainer and holds the poppet against the seat; the other end of the spring is restrained by the inboard end of the cylindrical section of the guide. A stainless steel insert is pressed into the nose of the poppet. The main poppet seat is a machined conical surface which is an integral part of the stainless steel base.

The kynar pilot poppet has a large diameter head with a conical sealing surface and a smaller diameter stem. The stem is slipped into the tubular main poppet retainer. The pilot poppet spring is installed over the stem; one end of the spring pushes against the pilot poppet head and holds the poppet against the seat; the other end of the spring is restrained by the end of the main poppet retainer. The pilot poppet seat is a machined conical surface which is an integral part of the stainless steel guide.

In addition to the seat for the pilot poppet, the guide contains a number of drilled holes that create two distinct chambers: a main poppet chamber and a pilot poppet chamber. The main poppet chamber is sealed from the pilot poppet chamber by a rubber "O" Ring and a teflon backup ring which are installed in a center groove in the guide and press against the walls of the bored hole in the base. Similarly, the pilot poppet chamber is sealed from the bellows assembly chamber above the guide by a rubber "O" Ring and a teflon backup ring installed in a groove provided near the end of the guide.

The guide is prevented from being pushed out of the base, when pressure is applied, by a stainless steel pressure compensator which is threaded into the base above the guide and locked by a set screw.

The bellows assembly system is installed above the guide and consists of a stainless steel plunger, a bimetal temperature compensator disc, a bellows assembly, a spring, and an aluminum alloy bellows stop. The bellows assembly is composed of an AM350 steel bellows welded at one end to a stainless steel terminal ring and at the other end to a stainless steel piston. The temperature compensator disc is bolted to the upper end of the plunger which is slipped into a hole in the poppet guide; the hole is in line with, and just above the pilot poppet seat. The nose of the plunger makes contact with the pilot poppet. The bellows assembly piston is installed in the tubular shell section of the base housing assembly and bears against the temperature compensator disc. The terminal ring of the bellows assembly is welded to the upper flange of the base housing assembly. The lower end of the bellows system spring is installed against the bellows assembly piston; the spring force is transmitted to the nose of the plunger which pushes the pilot poppet off its seat. When pressure is applied to the underside of the bellows piston, the resulting force on the piston overcomes the force of the bellows system spring and the pilot poppet is seated by the force of the pilot poppet spring.

The upper end of the bellows system spring is restrained by the aluminum spring housing which is bolted to the base housing upper flange. The stem of the bellows stop is installed in the center of the spring with the flange of the stop sandwiched between the upper end of the spring and the spring housing. The end of the stem is positioned a fraction of an inch above the bellows piston and limits the travel of the piston when pressure is applied to its underside.

A teflon piston ring and a stainless steel ring expander are installed in a groove in the bellows piston. The piston ring separates the chambers above and below the piston and ensures that the chambers will be sealed from each other during piston movement. The aluminum spring housing is equipped with an AND 10050-2 port in its crown. This port will be open during Apollo flights; the center chamber of the bellows will, therefore, be open to the environment of space. During some ground tests, however, the port will be outfitted with a fitting and the center chamber of the bellows will be evacuated. The mating surface between the bellows terminal ring and the aluminum upper housing is, therefore, sealed with a rubber "O" Ring which is installed in a groove in the spring housing.

The aluminum actuating piston is installed below the main poppet. An integral inboard pin in the center of the piston bears against the insert in the main poppet. A stainless steel end cap is threaded into the base housing behind the piston and is welded to the base. The cap seals the chamber below the piston and a hole in the cap provides a guide for an outboard pin in the piston. A teflon piston ring and a stainless steel ring expander are installed in a groove in the actuating piston. The piston rign separates the chambers above and below the piston and ensures that the chambers will be sealed from each other during piston movement.

An in-line stainless steel filter is installed in the inlet to the primary regulator. One-quarter inch stainless steel tubing is used for the primary regulator inlet line, the secondary regulator outlet line, the line connecting the primary regulator outlet to the secondary inlet, and the secondary regulator inlet test port line. Both regulators use one-eighth inch stainless steel tubing to connect the pilot poppet chamber to the chamber below the actuating piston. The sensing lines of both regulators are made of one-sixteenth inch stainless steel tubing. All the stainless steel tubes are assembled to the base housing by gold alloy brazing.

When pressure is applied to the regulator, helium flows through the filter into the poppet chamber, through the open pilot poppet, and into the cylinder below the actuating piston. As the pressure builds up in the cylinder, the piston moves to open the main poppet. Gas now flows through the main poppet to the inlet of the second regulator, where the operation is repeated. The output of the second regulator flows into the distribution manifold and the pressure sensing lines of both regulators. As the pressure builds up in the system, it is transmitted through the sensing lines to the bellows assemblies, compressing them. When the pressure reaches the preset operating level, the bellows will have been compressed sufficiently to allow the pilot poppet to close. The pressure on the actuating piston is bled off through the drilled passage, equalizing the pressure on both sides of the piston. This allows the spring to reseat the main poppet, which stops the flow of gas through the regulators. As propellants are consumed, the pressure in the manifold decreases, allowing the bellows to expand, unseat the pilot poppet, and start another operating cycle.

The regulator unit is supplied in two models. One model is employed in the Command Module Reaction Control System (CM RCS) and the second model is employed in the Service Module Reaction Control System (SM RCS).

The following table lists the regulator outlet pressures for the two models for the various operating modes:

	CM RCS Regulator	SM RCS Regulator
Inlet pressure	400 - 4500 psig	300 - 4500 psig
Normal outlet pressure	291 ±4 psig	181 ±3 psig
Outlet pressure with primary regulator failed open	287 - 302 psig	182 - 188 psig
Outlet pressure with secondary regulator failed open	287 - 295 psig	178 - 184 psig
Normal lockup pressure	287 - 302 psig	178 - 188 psig

	CM RCS Regulator	SM RCS Regulator
Lockup pressure with primary regulator failed open	287 - 308 psig	182 - 192 psig
Lockup pressure with secondary regulator failed open	287 - 302 psig	178 - 188 psig

From a lockup condition: The CM RCS regulator outlet pressure will not drop below 285 psig or rise above 297 psig, and will stabilize to 291 ± 4 psig in 2 seconds; the SM RCS regulator outlet pressure will not drop below 177 psig or rise above 187 psig, and will stabilize to 181 ± 3 psig in 2 seconds.

Additional performance characteristics of the two regulator models and general information concerning the components are listed in the table below:

	CM RCS Regulator	SM RCS Regulator
Proof pressure		
Primary regulator	6750 psig	6750 psig
Secondary regulator	540 psig	375 psig
Burst pressure		
Primary regulator	9000 psig	9000 psig
Secondary regulator	720 psig	500 psig
Flow Rate (Helium)(#/Min.)	0.058 to 0.3	0.036 to 0.2
Maximum external leakage (scc/sec)	5×10^{-6}	5×10^{-6}
Maximum internal leakage	20 scc/hr	20 scc/hr
Numerical reliability (maximum probability of failure)	780×10^{-6} for 1 hr	2000×10^{-6} for 336 hours

	CM RCS Regulator	SM RCS Regulator
Minimum total operating life	8000 cycles	8000 cycles
Specification number	MC 284-0021	MC 284-0022
SCD number (NR part number)		
Qualified regulator		
(w/o test port tube stem)	ME 284-0021-0005	ME 284-0022-0005
(with test port tube stem)	ME 284-0021-0002	ME 284-0022-0002
Pre-qualified regulator (Not compatible)	ME 284-0021-0001	ME 284-0022-0001
Pre-DVT regulator (Not compatible)	ME 284-0021-0003	ME 284-0022-0003
Pre-qualified regulator (Compatible)	ME 284-0021-0004	ME 284-0022-0004
Supplier's part number per SCD		
Dash number -0005	63-036-09	63-036-08
-0002	63-036-04	63-036-03
-0001	63-036-02P	63-036-01P
-0003	63-036-02X	63-036-01X
-0004	63-036-04X	63-036-03X
Supplier	Fairchild Stratos Corp., Stratos Division Western Branch Manhattan Beach, Calif.	

1. 17-4PH CRES
2. Kynar
3. 304L
4. Teflon TFE
5. 7075-T6 Al
6. 17-7PH CRES
7. 440C CRES
8. "O" Ring SR634-70
9. AM350 CRES
10. 347 CRES
11. 2024-T4 Al
12. SAE 9254
13. 6061-T6 Al
14. 302 CRES
15. Bimetal

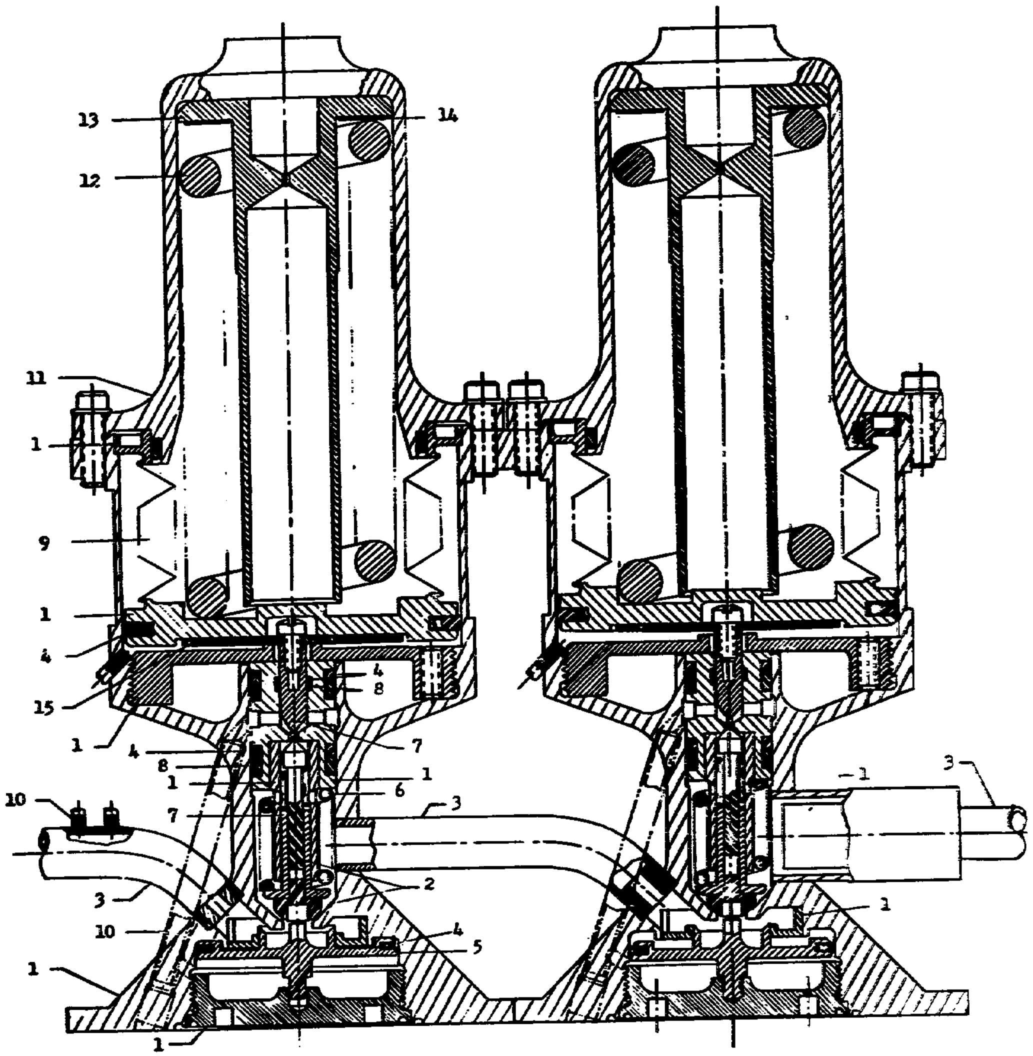


Figure 12-1. Helium Pressure Regulator Unit

TITLE C/M Regulator Unit - Pressure, Helium RCS (Fairchild)

PART NUMBER ME284-0021-0002 and -0005

DVT COMPLETED March 23, 1964

QUAL TEST June 15, 1965

NO. QUAL UNITS TESTED 4

QUAL TESTS Random vibration - $0.04g^2$/cps @ 20 cps; linear increase to $0.15g^2$/cps @ 80 cps; constant to 1000 cps; linear decrease to $0.075g^2$/cps @ 2000 cps.
High-low temp. and vacuum-150°F to 30°F @ 1 x 10^{-6} mm Hg.
Life Cycling-4,000
Salt Fog-5% for 50 hours
Fluid Compatibility (by similarity to ME284-0022)

ACCEPTANCE TESTS

Examination of product
Proof pressure and external leakage-6750 inlet, 540 outlet; 5 x 10^{-6} std cc/sec.
Internal leakage-20 std cc/hr.
Functional Tests-(Flow -P 291 ±4 S294.5 ±7.5
(L.U -P 287 to 302 S 287 to 308
Blow-down tests
Cleanliness

DIFFERENCES BETWEEN QUAL & SC UNITS -0005 units have no test ports between regular stages

CONSTRUCTION Welded body

WEIGHT 3#

INLET FILTER 25-40μ

USAGE CM-017 and Subs -0005

TITLE	SM Regulator Unit - Pressure, Helium RCS (Fairchild)
PART NUMBER	ME284-0022-0002 and -0005
DVT COMPLETED	March 30, 1964
QUAL TEST COMPLETED	June 15, 1965
NO. QUAL UNITS TESTED	6
QUAL TESTS	Random Vibration - $0.04g^2$/cps @ 20 cps; linear increase to $0.15g^2$/cps @ 80 cps; constant to 1000 cps; linear decrease to $0.075g^2$/cps @ 2000 cps. High-low temp. and vacuum - 150°F to 30°F @ 1×10^{-6} mm Hg Life Cycling - 4,000 Fluid Compatibility - 31 days Salt Fog (by similarity to ME284-0021)
ACCEPTANCE TESTS	Examination of product Proof pressure and external leakage - 6750 inlet, 375 outlet; 5×10^{-6} std cc/sec. Internal leakage - 20 std cc/hr Functional tests (Flow - P 181 ±3 S 185 ±3 (L.U. - P 178 to 188 S 182 to 192 Blow-down test Cleanliness
DIFFERENCE BETWEEN QUAL & SC UNITS	-0005 units have no test ports between regulator stages
CONSTRUCTIONS	Welded body
USAGE	SM-017 and Subs -0005
WEIGHT	3#
INLET FILTER	25 - 40 μ

13. <u>Helium Pressure Relief Valve</u>

The helium pressure relief valve assembly (Figure 13-1) consists of a forged stainless steel body, a burst diaphragm system, an automatic bleed device system, a relief valve system, and stainless steel inlet, outlet, and test port fittings. The burst diaphragm system consists of an aluminum alloy burst disc held in position against a stainless steel belleville spring by a disc support, a backup ring, and a backup ring pad all made of stainless steel. A stainless steel retainer, threaded into the body, bears against the outer edge of the burst disc and seals it against a body shoulder. The retainer is held in place by the inlet fitting which is threaded behind the retainer and heli-arc welded to the body. A stainless steel punch and a filter are installed immediately downstream of the burst disc-belleville spring combination. The relief valve system is located downstream of the filter and consists of a stainless steel poppet seat, a poppet assembly, a stainless steel poppet housing, a spring, and a stainless steel poppet guide. The poppet seat is installed against a shoulder of the body and is held in place by the poppet housing which is threaded into the body. The poppet assembly is installed in a tubular guide in the forward end of the housing and consists of a teflon insert installed between a stainless steel retainer and a stainless steel stem. The aft end of the stem is guided by the stainless steel guide which is threaded into the aft end of the housing. The guide also restrains the aft end of the poppet spring. The forward end of the spring acts against a stainless steel spring support which in turn pushes against the poppet and holds the teflon poppet insert against the conical seat.

The automatic bleed system is located perpendicular to the direction of flow between the burst disc and the relief valve system. The automatic bleed system consists of a stainless steel poppet, a teflon seat, a stainless steel guide, a stainless steel retainer, a poppet spring, and a stainless steel spring retainer. The poppet is installed in the poppet guide. The guide and poppet are installed behind the teflon seat. The retainer is threaded into the body behind the buide and holds the guide and teflon seat against a shoulder of the body. The spring is installed in the center of the cup-shaped poppet and holds the poppet against a shoulder of the guide. The outboard end of the spring is restrained by the spring retainer which is welded to the body.

The outlet fitting and the test port fitting are heli-arc welded to the body. The outlet fitting is equipped with an MS24385-6 external thread which is used for mounting purposes.

During system operation at normal pressures, the burst disc of the relief valve assembly serves as a near-perfect seal and prevents any helium from escaping through the relief valve. If the pressure in the helium system becomes above normal, the resulting force acting on the burst disc and belleville spring will snap the belleville spring and drive the burst disc against the punch, shearing the disc. The filter will prevent the sheared disc from reaching the relief valve system. When the pressure acting on the relief valve poppet overcomes the spring force, the poppet will unseat. Helium will be dumped overboard until the system pressure decreases below the spring force. At this pressure the spring force will overcome the force acting on the poppet retainer and the poppet will reseat.

The normally-open automatic bleed system will prevent a pressure buildup in the chamber between the burst disc and the relief valve system by permitting any trapped gases to be bled overboard. At low pressures, the bleed assembly spring pushes the stainless steel poppet away from the teflon seat. When the pressure in the chamber reaches approximately 30 psig following the rupture of the burst disc, the force acting on the poppet will overcome the spring force and the poppet will seat.

The relief valve is supplied in two models. One model is employed in the Command Module Reaction Control System (CM RCS) and the second model is employed in the Service Module Reaction Control System (SM RCS). The following table lists the pressures for the two models:

	CM RCS Relief Valve	SM RCS Relief Valve
Working pressure	0-327	0-215
Diaphragm rupture pressure	340 ±8 psig	228 ±8 psig
Cracking and Full Flow Pressure	346 ±14 psig	236.5 ±11.5 psig
Minimum reseat pressure	327 psig	220 psig
Proof pressure	540 psig	375 psig
Burst pressure	720 psig	500 psig

	CM RCS Relief Valve	SM RCS Relief Valve
Flow rate	0.3 pounds/min. of He; inlet press. 360 psig	0.3 pounds/min. of He; inlet press. 248 psig
Maximum external leakage	5×10^{-6} std. cc/sec	5×10^{-6} std. cc/sec
Maximum internal leakage		
Burst diaphragm	5×10^{-6} std. cc/sec	5×10^{-6} std. cc/sec
Relief and Bleed valve	20 std cc/hr	20 std cc/hr
Numerical reliability (maximum probability of failure)		
Burst diaphragm	1×10^{-6} for 336 hrs	1×10^{-6} for 336 hrs
Relief poppet	150×10^{-6} for 336 hrs	150×10^{-6} for 336 hrs
Minimum total operating life		
Burst diaphragm	3000 cycles	3000 cycles
Relief poppet	8000 cycles	8000 cycles
Specification number	MC284-0062	MC284-0026
SCD number (NR part number)		
Qualified oxidizer-side valve	ME284-0062-0002	ME284-0026-0002
Qualified fuel-side valve	ME284-0062-0012	ME284-0026-0012
Pre-qualified oxidizer-side valve	ME284-0062-0004	ME284-0026-0004
Pre-qualified fuel-side valve	ME284-0062-0014	ME284-0026-0014
Pre-qualified oxidizer-side valve	ME284-0062-0001	ME284-0026-0001
Pre-qualified fuel-side valve	ME284-0062-0011	ME284-0026-0011
Pre-DVT oxidizer-side valve	ME284-0062-0003	ME284-0026-0003
Pre-DVT fuel-side valve	ME284-0062-0013	ME284-0026-0013
Supplier	Calmec Mfg. Corp. Los Angeles, Calif.	

	CM RCS Relief Valve	SM RCS Relief Valve
Supplier's part number per SCD		
dash number -0002	488-503	487-503
-0012	488-505	487-505
-0004	488-503P	487-503P
-0014	488-505P	487-505P
-0001	488P	487P
-0011	488-501P	487-501P
-0003	488X	487X
-0013	488-501X	487-501X

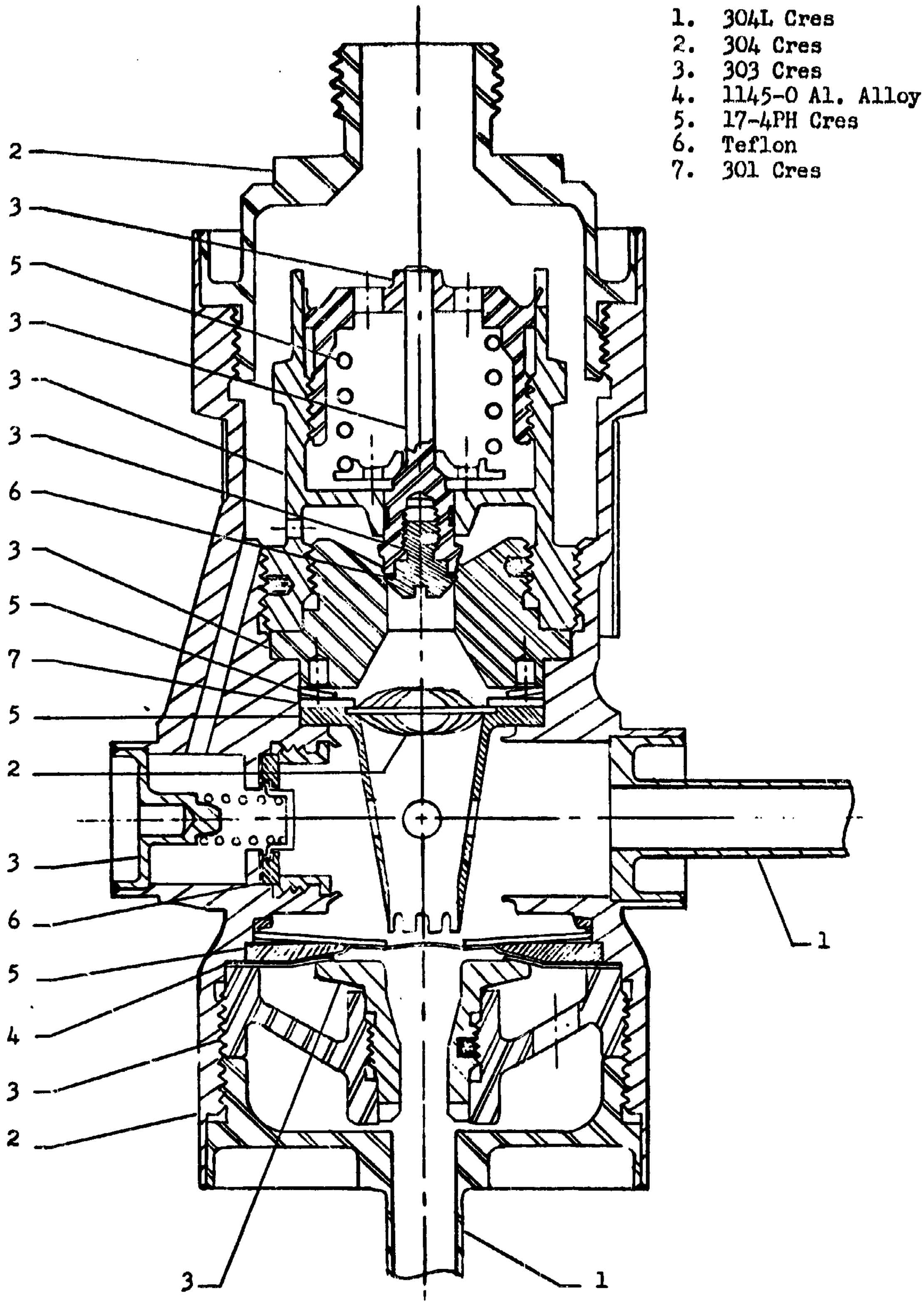


Figure 13-1(a) CM RCS Helium Pressure Relief Valve

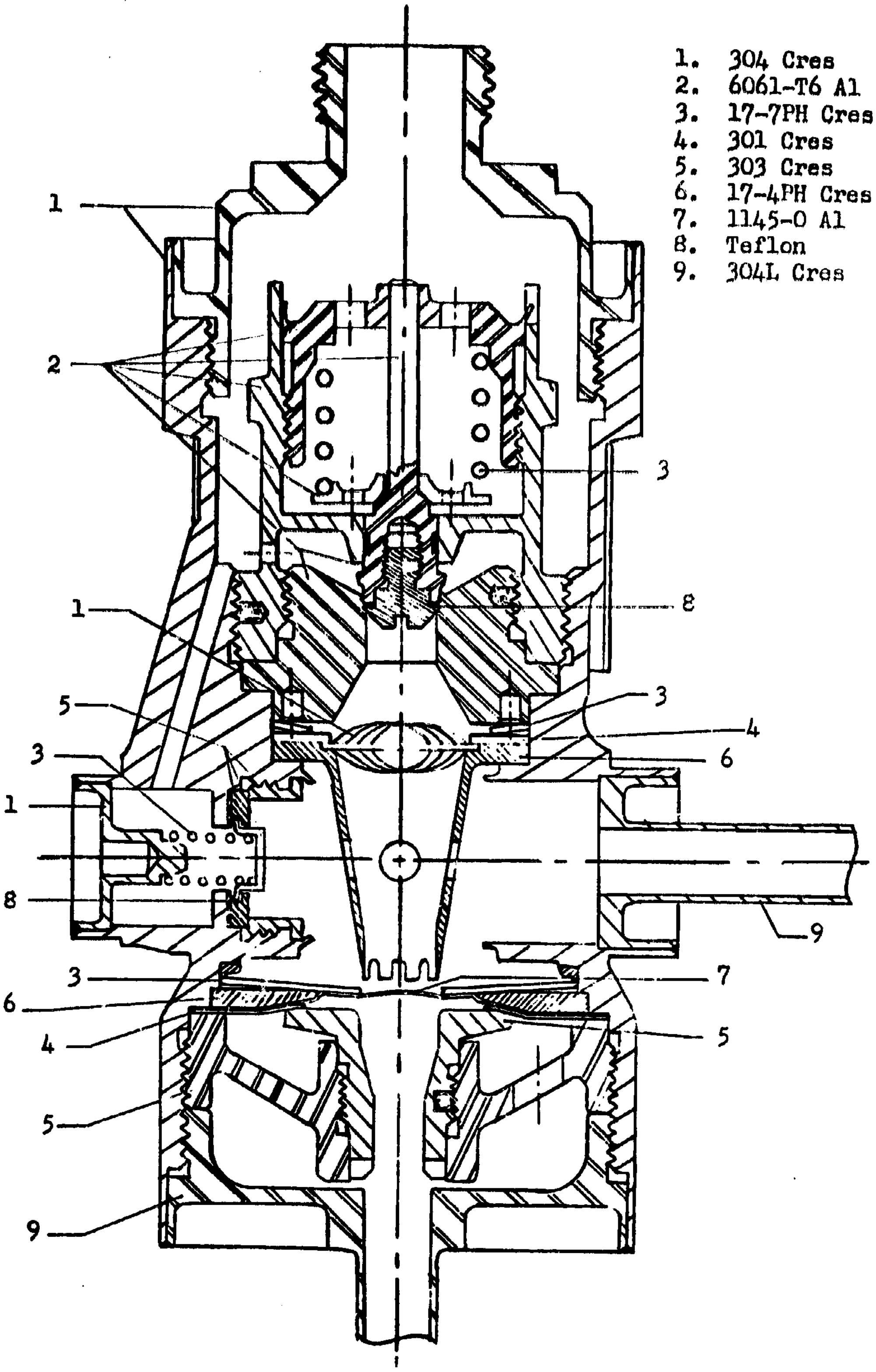


Figure 13-1(b). SM RCS Helium Pressure Relief Valve

TITLE Relief Valve Pressure Helium CM (Calmec)

PART NUMBER ME284-0062-0002 and -0012

QUAL TEST COMPLETION DATE January, 1965

NO. TEST UNITS 4

QUAL TESTS: Vibration, vent endurance - 600 pressure cycles (zero to 179 psig), relief endurance - 4000 pressure cycles leakage shall not exceed 20 scc/hr @ 327 psig acceleration - 20g, diaphragm endurance - 1500 pressure cycles, diaphragm leakage - less than 5×10^{-6} scc/sec @ 327 psig, relief leakage - less than 20 scc/hr @ 327 psig, diaphragm rupture - rupture pressure 340 $\pm$8 psig, burst pressure - no rupture @ 720 psig, fluid - monomethyl hydrazine vapor for 15 days, functional - cracking pressure - greater than 332 psig full flow pressure - less than 360 psig - reseat pressure greater than 327 psig. Flow .3#/sec.

ACCEPT. TESTS

Diaphragm leakage - less than 5×10^{-6} scc/sec @ 327 psig
Relief leakage - less than 20 scc/hr @ 327 psig
Functional - see qual requirements above
External leakage - less than 5×10^{-6} scc/sec @ 540 psig

DIFFERENCE BETWEEN QUAL & SC UNITS

None

SPECIAL CHARACTERISTICS

Bleed Valve Characteristics: Spring loaded in open position closes before increasing pressure reaches 150 psig - opens before decreasing pressure reaches 20 psig. Bleed valve is capable of venting $1\frac{1}{4}$ scfm at 10 psi and 2 scfm at 20 psi.

Burst Diaphragm: The burst diaphragm is capable of withstanding a maximum back pressure of 10 psi. Back pressures greater than 35 psi will result in an increase in the diaphragm rupture pressure that would exceed design requirements.

TITLE Relief Valve - Pressure Helium SM (Calmec)

PART NUMBER ME284-0026-0002 and -0012

QUAL TEST COMPLETION DATE February, 1965

NO. TEST UNITS 4

QUAL TESTS: Vibration, vent endurance - 600 pressure cycles (zero psig to 181 psig) Relief endurance - 4000 pressure cycles (leakage shall not exceed 20 scc/hr @ 220 psig), acceleration 6g, diaphragm endurance - 500 (179-215), 500 (181 - 215), 500 (0-215) pressure cycles, diaphragm leakage less than 5×10^{-6} scc/sec @ 215 psig, relief leakage less than 20 scc/hr @ 220 psig diaphragm rupture - rupture pressure 228 ± 8 psig, burst pressure - no rupture @ 500 psig, fluid compatibility nitrogen tetroxide vapor for 15 days, functional - cracking pressure greater than 225 psig - full flow pressure less than 248 psig - reseat pressure greater than 220 psig.

ACCEPTANCE TESTS

Diaphragm leakage - less than 5×10^{-6} scc/sec @ 215 psig, relief leakage - less than 20 scc/hr @ 220 psig, functional see qual test requirements above external leakage less than 5×10^{-6} scc/sec.

DIFFERENCE BETWEEN
QUAL AND SC UNITS None

SPECIAL CHARACTERISTICS

Bleed Valve Characteristics: Spring loaded in open position - closes before increasing pressure reaches 150 psig - opens before decreasing pressure reaches 20 psig. Bleed valve is capable of venting $1\frac{1}{4}$ scfm at 10 psi and 2 scfm as 20 psi.

Burst Diaphragm: The burst diaphragm is capable of withstanding a maximum back pressure of 10 psi. Back pressures greater than 35 psi will result in an increase in the diaphragm rupture pressure that would exceed design requirements.

14. Propellant Explosive Valve

The explosive operated propellant isolation valve (Figure 14-1) consists of a machined vacuum melt stainless steel body, a stainless steel cutter and piston, inlet and outlet fitting assemblies, and a cartridge (the explosive device). The inlet fitting assembly is composed of a five-eighths inch stainless steel tube brazed to a threaded stainless steel fitting which is closed on the inboard end. The outlet fitting assembly consists of a five-eighths inch stainless steel tube brazed to a threaded stainless steel fitting which is also closed on the inboard end. The inlet and outlet fitting assemblies are threaded into the valve body and sealed by brazing. When installed in the valve body, the closed ends of the fittings are positioned beneath the cutter/piston. The cutter/piston is installed in the body perpendicular to the direction of flow. A viton O-ring and two viton backup rings are installed in a groove in the cutter/piston to seal the pyrotechnic gas from the propellant flow path. The cartridge is threaded into the body behind the piston and is sealed by a viton O-ring installed against an external shoulder of the body.

When the valve is actuated, the gases generated by the explosive device act against the cutter/piston driving it to the bottom of the valve, severing the ends of the inlet and outlet fittings. When the cutter/piston reaches the bottom of the valve, a hole drilled through the cutter/piston is positioned in line with the holes in the inlet and outlet fittings providing an unrestricted flow path through the valve. The cutter/piston is held in the down position by a deformable metal seat in the body; a permanent metal to metal seal results.

The propellant explosive valve operates at a working pressure up to 360 psig in the propellant pressurization system and will open within 10 milliseconds after being subjected to a firing current of 5.0 amperes. Other important performance characteristics of the propellant explosive valve and general information concerning the component are listed below.

Proof pressure	540 psig
Burst pressure	720 psig
Pressure drop	5 psig at an N_2O_4 flow rate of 9.5 pounds per second and an MMH flow rate of 6.5 pounds per second and an inlet pressure of 144 psig
Maximum external leakage	5×10^{-6} std. cc/sec.
Maximum internal leakage	5×10^{-6} std. cc/sec.
Numerical reliability (maximum probability of failure)	100×10^{-6} for 1 cycle
Minimum total operating life	1 cycle and 1 hour
Specification number	MC284-0130
SCD number (NR part number)	
Qualified valve	
Ox. overboard dump	ME284-0130-0002
Ox. interconnect	ME284-0130-0014
Fuel interconnect & overboard dump	ME284-0130-0016

Pre-qualified valve	
Ox.	ME284-0130-0001
Fuel	ME284-0130-0011
Pre-DVT valve	
Ox.	ME284-0130-0003
Fuel	ME284-0130-0013
Supplier	Pelmec Division of Quantic Industries San Carlos, Calif.
Supplier's part number per SCD	
Dash number -0002	1167A-02
-0014	1167C-02
-0012	1167B-02
-0001	1167A-02P
-0011	1167B-02P
-0003	1167A-02X
-0013	1167B-02X

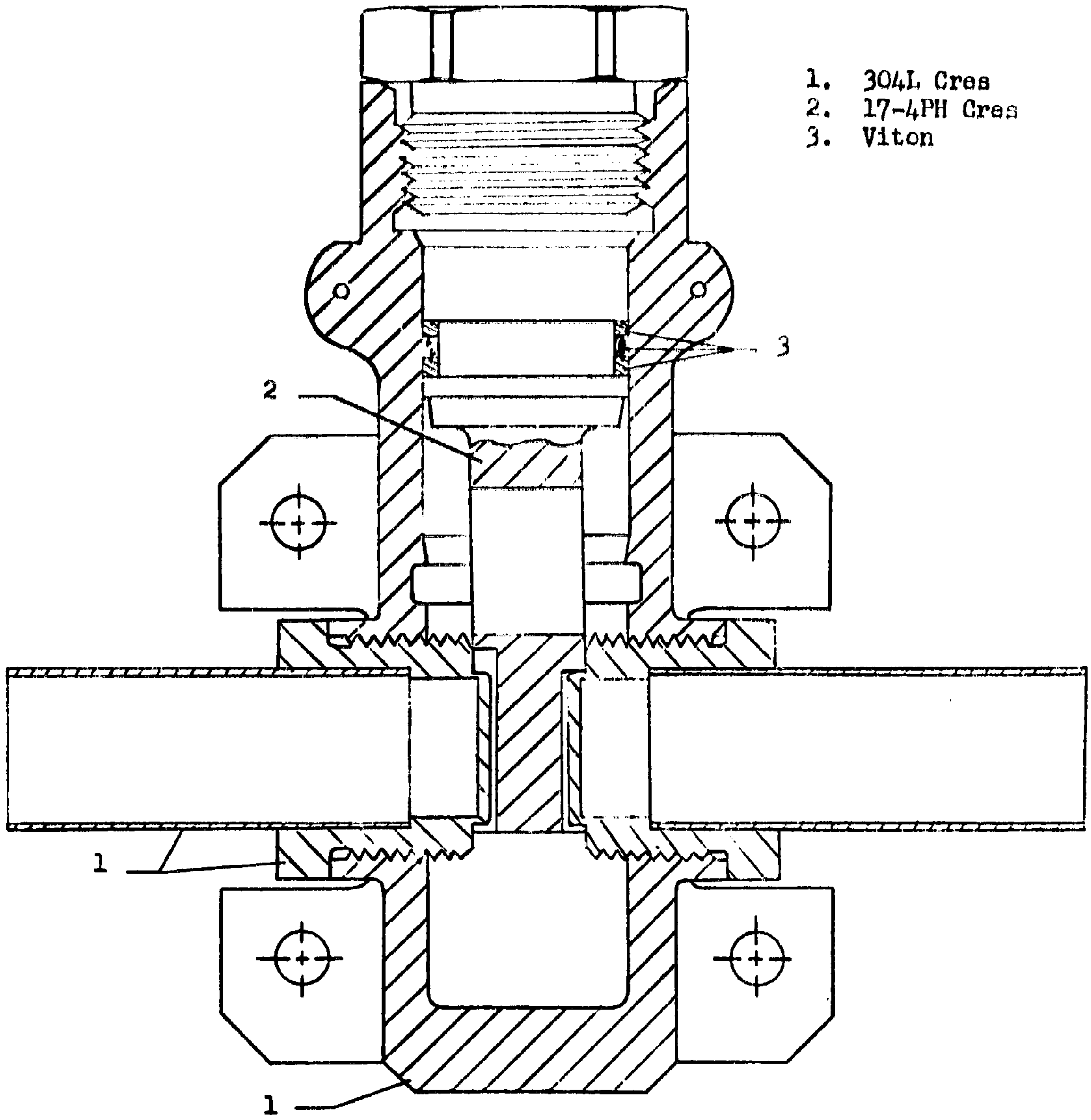


Figure 14-1. Propellant Explosive Valve

TITLE 5/8" Explosive Valve (Pelmec)

PART NO. ME284-0130-0002 (Oxid. dump)
ME284-0130-0012 (Fuel inter. & dump)
ME284-0130-0014 (Oxid. inter.)

DVT COMPLETED November, 1964

NOTE: 26 units (31 firings) used in supplemental development tests prior to qual program to determine overkill margin and affects of combined environment:

1. Firing in vacuum environ. @ 130°F

2. Firing during vibration: Δ P @ 130 and 40°F during vibration with propellants.

NO. UNITS TESTED 4

QUAL. TESTS Vibration $0.06G^2$/cps @ 75 cps

Δ P @ low temp. 5 @ 9.5#/sec. @ 40 to 150°F 144 psig N_2O_4

Δ P @ high temp. 5 @ 6.5#/sec. @ 40 to 150°F 144 psig MMH

Explosive Atmosphere @ low temp/MIL-STD-810 32-52% hydrogen gas @ 40°F.
Explosive Atmosphere @ high temp./MIL-STD-810 32-52% hydrogen gas @ 130°F.
Disassembly and Inspection
Prop. Exp. 15 days (N_2O_4 & MMH) (DVT)

ACCEPTANCE TESTS Examination of Product
Proof pressure and leakage;
Flow ports 5×10^{-6} std cc/sec. @ 540 psig
6,000 psig pyro. chamber proof pressure
Lot Acceptance
Cleanliness

DIFFERENCE BETWEEN
QUAL & SC UNITS None

Ox Dump ME284-0130-0002; cartridge ME453-0005-0034
Ox interconnect ME284-0130-0014; cartridge ME453-0005-1034
Fuel " ME284-0130-0012; cartridge ME453-0005-0034
Fuel Dump ME284-0130-0012; cartridge ME453-0005-0034

EFFECTIVITY:

Fuel Dump S/C 101 and Subs
Ox Dump, Ox Interconnect, and fuel interconnect S/C 020 and subs

RESPECTIVE DIFFERENCES:

-0002 15/16 RH THD
-0012 15/16 RH THD
0014 15/16 LHTHD

15. Propellant Latching Solenoid Valve

The propellant latching solenoid valve (Figure 15-1) is a two-port, solenoid operated, latching, normally open, emergency shutoff valve. The valve consists of a valve base assembly, a solenoid assembly, and an electrical switch mechanism. The valve base assembly is composed of a teflon seat, a stainless steel seat retainer, and a bellows assembly installed in a vacuum melt stainless steel forged housing. The inlet and outlet port tubes are an integral part of the housing. The teflon seat is held against a shoulder of the housing by the retainer which is welded to the housing. The bellows assembly consists of a shaft bellows subassembly attached to a poppet bellows subassembly by threading the shaft into the poppet. The shaft bellows subassembly is composed of an AM 350 steel bellows welded to a flange of a stainless steel shaft and to a stainless steel terminal ring. The poppet bellows subassembly consists of an AM 350 steel bellows welded to an AM 355 poppet and to a stainless steel terminal ring. The stem of the poppet is installed in a tubular guide of the terminal ring before welding the bellows to the poppet. A teflon sleeve installed over the poppet stem provides a low-friction bearing surface for the movable stem. The sleeve is held in place against a shoulder of the stem by an aluminum alloy retainer which is restrained by a cotter pin installed in the stem. The terminal rings of the two bellows are welded to the housing. The bellows have two important functions.

They provide a net spring force which holds the poppet against the seat; they also seal the movable shaft and poppet so that propellant is completely contained within the valve base assembly. No propellant is permitted to reach the solenoid assembly or the electrical switch mechanism.

The solenoid assembly consists of a coil assembly, an Armco ingot iron plunger, and an Alnico tubular magnet. The magnet is installed around the outside of the coil assembly and is held in place against a shoulder of the coil assembly pole by an Armco ingot iron nut. The plunger is attached to the shaft of the shaft bellows subassembly and moves in the center of the coil assembly. The coil assembly consists of two concentric coils wound around a bobbin assembly which is composed of an Armco ingot iron pole and an Armco ingot iron flange separated by a stainless steel spacer; the three pieces are joined by furnace brazing. The coils are wound one on top of the other. The inner coil, or latching coil, contains 1001 turns of #29 AWG single ML coil wire having a resistance of 16.5 ± 0.5 ohms at 70°F. The outer coil, or unlatching coil, contains 516 turns of #32 AWG single ML coil wire having a resistance of 22.0 ± 0.7 ohms at 70°F. The solenoid assembly is threaded on to the valve base assembly and locked by safety wire.

The electrical switch mechanism consists of an actuator assembly, a bracket and switch assembly, and an aluminum alloy spacer. The spacer is bolted to the coil assembly and the bracket and switch assembly is bolted to the spacer. The actuator assembly is composed of a magnetic stainless steel plate bonded to an aluminum alloy actuator. A boss on the actuator contains a horseshoe shaped recess with an internal lip. The boss is installed over a small disc flange at the end of a shaft which is part of the coil assembly plunger. When the plunger moves toward the actuator, the top of the disc flange will contact the bottom of the recess and push the actuator in the same direction; when the plunger moves away from the actuator, the underside of the disc flange will contact the lip and pull the actuator in the same direction as the plunger. The bracket and switch assembly consists of a pair of magnets bonded to an aluminum alloy bracket, and a subminiature switch bolted to the bracket. When the valve is in the closed position with the poppet held against the seat, the actuator plate has been pushed against the switch button, by the plunger, closing the indicator light circuit. The actuator is held in this position by the magnets. When the plunger pushes the poppet to the open position, the actuator will be held against the switch button by the magnets until the plunger has moved 90% of its full travel. At this point, the plunger disc flange will contact the actuator recess lip and pull the actuator away from the switch button, opening the indicator light circuit. Because of the depth of the recess, the plunger is also required to move 85% of its full travel in the closed-poppet position before the disc flange will contact the bottom of the recess.

A stainless steel tubular cover is installed over the solenoid assembly and the electrical switch mechanism. One end of the cover is welded to the base assembly housing; the other end is welded to a header assembly which consists of five gold plated electrical contacts installed in a stainless steel plate and insulated from the plate by glass insulation. The electrical leads from the coils and the switch are connected to the inboard end of the contacts. Back to back zener diodes are connected in parallel with the coil leads. The wires in the valve cable assembly are connected to the outboard ends of the contacts. The cable is tied to the valve by a stainless steel clamp which is bolted to the header assembly. All electrical connections are encapsulated with a silicone rubber potting compound.

The plunger is actuated with a maximum pull-in voltage of 18 volts dc. RCS current will not exceed 2 amperes at 30 volts d.c. In the closed position, the poppet is held against the seat by the net spring force of the two oppositely loaded bellows. In the open position, the poppet is held away from the seat by the magnetic force acting on the plunger. Normal operation is as follows:

1. Closed to open operation: (a) the latching coil is energized; (b) the poppet is unseated by movement of the plunger and push rod (the flux from the latching coil aids the flux from the permanent magnet and the combined effects overcome the net spring force of the bellows); (c) the valve position indicator switch is mechanically actuated to the open position; (d) the

latching solenoid is de-energized (the plunger will be held in the closed gap position by the force of the permanent magent).

2. Opened to closed operation: (a) the unlatching coil is energized; (b) the poppet reseats (the flux of the unlatching coil momentarily partially cancels the flux of the permanent magnet and the plunger is acted upon by the net spring force of the bellows); (c) the valve position indicator switch is mechanically actuated to the closed position; (d) the unlatching solenoid is de-energized (the plunger will be held in the open gap position by the net spring force of the bellows).

The important performance characteristics of the propellant latching solenoid valve and general information concerning the component are listed below.

Operating pressure	360 psig
Proof pressure	540 psig
Burst pressure	720 psig
Pressure drop	
Oxidizer valve	4 psid for Type I, 7 psid for Type III at an N_2O_4 flow rate of 0.66 #/sec. and an inlet pressure of 360 psig
Fuel valve	3 psid for Type II, 6 psid for Type IV at an MMH flow rate of 0.33 #/sec. and an inlet pressure of 360 psig
Maximum external leakage	5×10^{-6} std. cc/sec.
Maximum internal leakage	20 std. cc/hour

Switch rating	2.5 watts
Maximum switch contact resistance	50 milliohms
Maximum continuous duty application of electrical power	2 minutes (with 10 minutes between operations)
Numerical reliability (maximum probability of failure)	11×10^{-6} for 336 hours
Minimum total operating life	8000 cycles
Specification number	MC284-0276
SCD Number (NR part number)	
Qualified oxidizer valve	
Type I w/o thermal AT N/O	ME284-0276-0001
Type I with thermal AT N/O	ME284-0276-0011
Type I w/o thermal AT N/C	ME284-0276-0007
Type I with thermal AT N/C	ME284-0276-0017
Type III w/o thermal AT N/O	ME284-0276-0005
Type III with thermal AT N/O	ME284-0276-0015
Qualified fuel valve	
Type II w/o thermal AT N/O	ME284-0276-0002
Type II with thermal AT N/O	ME284-0276-0012
Type II w/o thermal AT N/C	ME284-0276-0008
Type II with thermal AT N/C	ME284-0276-0018
Type IV w/o thermal AT N/O	ME284-0276-0006
Type IV with thermal AT N/O	ME284-0276-0016
Pre-qualified oxidizer valve	ME284-0276-0003
Pre-qualified fuel valve	ME284-0276-0004
Supplier	National Water Lift Co. A Division of Pneumo Dynamics Corp. Kalamazoo, Michigan

Supplier's part number per SCD

dash number -0001	34900
-0002	349001
-0003	294002
-0004	349003
-0005	349006
-0006	349007
-0007	349010
-0008	349011
-0011	3490015
-0012	3490016
-0015	3490017
-0016	3490018
-0017	3490019
-0018	3490020

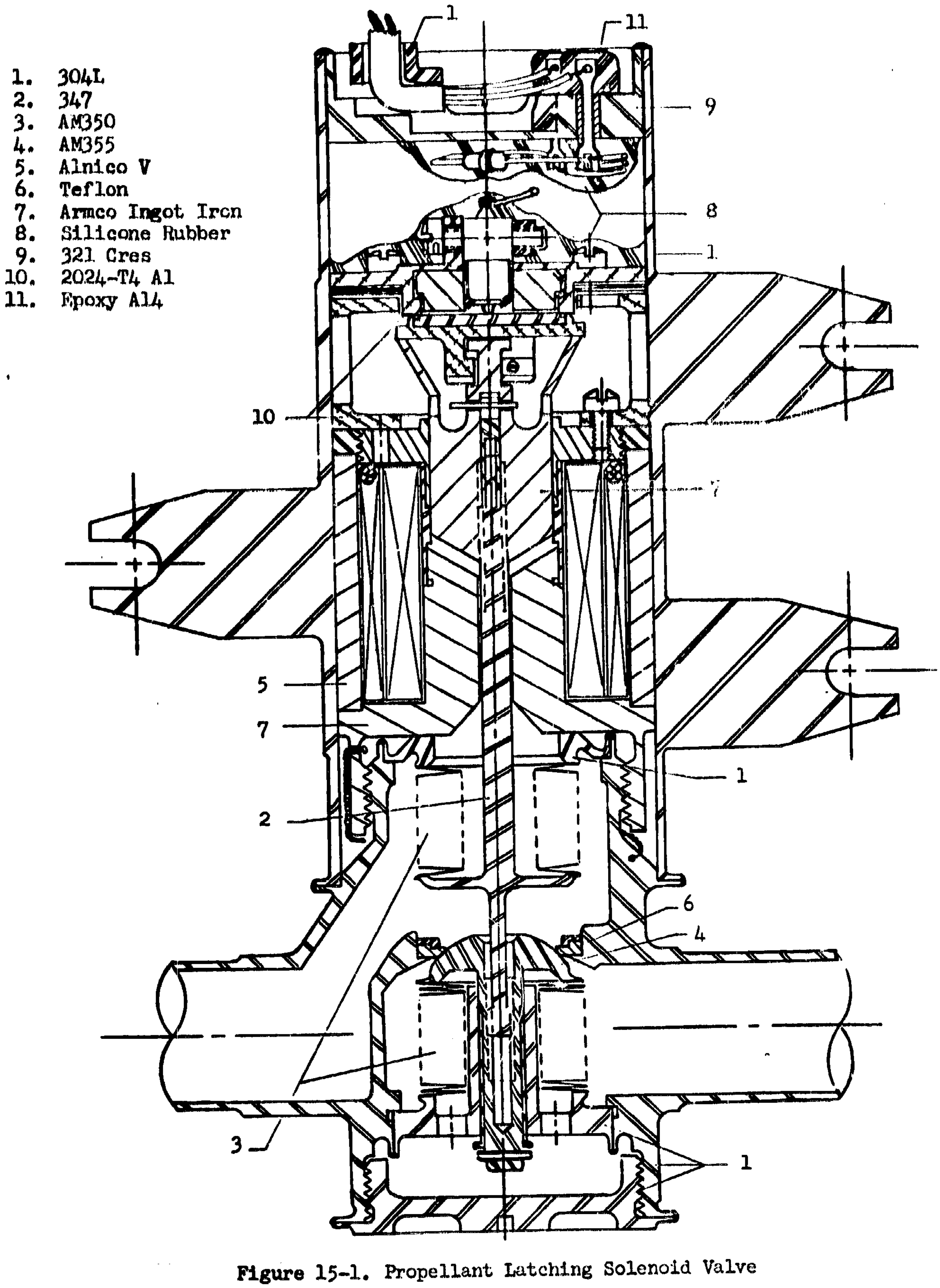


Figure 15-1. Propellant Latching Solenoid Valve

TITLE Valve, Solenoid, Latching (NWL) (Propellant)

PART NUMBER ME284-0276-0001 and -0002 (CM Block I; SM Block I and II)

ME284-0276-0005 and -0006 (CM Block II Anti-surge)

ME284-0276-0007 and -0008 (SM Block II Secondary Fuel and Ox. Valves; switch closes with valve in open position.)

DVT COMPLETED November 23, 1965

QUAL TEST COMPLETED December 20, 1965

May, 1966 (-0001 and -0002, -0005 and -0006; -0007 and -0008 Qual by similarity to -0001 and -0002)

NO. QUAL UNITS TESTED 5

QUAL TEST
Fluid compatibility-36 days
Electromagnetic Interference
Explosive Atmosphor
Salt Fog-5% 48 hours
Acceleration - 20 g for 60 minutes
Life Cycling - 4,000 cycles
Random Vibration - $0.04g^2$/cps @ 20 cps; linear increase to $0.15g^2$/cps @ 80 cps; constant to 1000 cps; linear decrease from 1000 cps to 0.075 g^2/cps @ 2000 cps.
Heat Rise - time required to reach within 50°F of propellant flash point or coil short out. (Approx. 2.5°F/min to 280°F)

ACCEPTANCE TESTS

Examination of product
Proof pressure and external leakage-540 psig @ 5 x 10^{-6} std cc/sec.
Internal leakage-20 std cc/hr
Electrical Characteristics - High pot. 560V RMS; Insulation Res. 500 VDC for 1 min., minimum 100 megohms
Functional - min. voltage - 18 vdc
Check Inductive Transient-50 vdc maximum
Pressure Drop - 4 psia @ .66#/sec. @ 360 psi
Cleanliness

DIFFERENCE BETWEEN QUAL AND SC UNITS None

CONSTRUCTION Welded (Opening coil resistance 16.5 ±.5 Ω @ 70°F -
(Closing coil resistance 22.0 ±.7 Ω @ 70°F
Nominal Oper. Time, Opening-15 to 50 ms, Closing-5 to 15 ms

WEIGHT 1.6#

MAGNETIC LATCH

USAGE
EOPR change point was -011 and subs
C/M -011 and subs has NWL
S/M -008, -011 and subs has NWL

NOTE: -009 SM had one Eckel replaced with NWL

Anti-surge valve change point (-0005 and -0006) is SC-101 and subs

16. Helium Latching Solenoid Valve

The helium latching solenoid valve (Figure 16-1) is a two-port, solenoid operated, latching, normally open, emergency shutoff valve. The valve consists of a valve base assembly, a solenoid assembly, and an electrical switch mechanism. The valve base assembly is composed of a teflon seal and a seat system installed in a vacuum melt stainless steel housing. The inlet and outlet port tubes are brazed to the housing.

The seat system consists of a stainless steel seat, a stainless steel spacer, a stainless steel spherical washer, and a stainless steel retainer. The plug-shaped seat, which has a flow path in its center, is installed in a bored hole in the housing which intersects the inlet-outlet tube passages. A teflon seal is installed in a recess in the housing hole and provides a seal between the hole and the OD of the seat body. A flange on the seat bears against the shoulder of the hole. The spacer, which is equipped with flow passages and a large-radius spherical base, is installed behind the seat and bears against it. The spherical base of the spacer bears against the spherical face of the washer which is installed in a recess of the retainer. The retainer is threaded into the housing and holds the seal system in position. A circumferential ring on the retainer is welded to a concentric ring on the housing to provide an external seal for the installation.

The solenoid assembly consists of a coil assembly, an Armco ingot iron plunger, and an Alnico tubular magnet. The magnet is installed around the outside of the coil assembly and is held in place against a shoulder of the coil assembly pole by a stainless steel ring. The plunger is attached to a shaft subassembly that moves in the center of the coil assembly. The shaft subassembly consists of a shaft, a sleeve which captures the kennametal ball used as a poppet, and a small magnet which is used for actuating the indicator switch. The sleeve and magnet are at opposite ends of the shaft.

The coil assembly consists of two concentric coils wound around a bobbin assembly which is composed of a stainless steel iron core and a stainless steel iron flange separated by a stainless steel spacer; the three pieces are joined by furnace brazing. The coils are wound one on top of the other. The inner coil, or latching coil, contains 1100 turns of #26 AWG single ML coil wire having a resistance of 15.25 ±0.5 ohms at 70°F. The outer coil, or unlatching coil, contains 375 turns of #30 AWG single ML coil wire having a resistance of 14.6 ±0.5 ohms at 70°F. The solenoid assembly is threaded on to the valve base assembly and locked by welding the two assemblies together.

The electrical magnetic reed switch module consists of a bracket and switch assembly. The switch module is mounted to a boss on top of the coil assembly by a set screw.

The boss is installed over a small magnet at the end of the shaft which is part of the coil assembly plunger. When the plunger moves toward the switch, the top of the shaft will move toward the top of the boss and attract the magnetic reed opening the switch contact; when the plunger moves away from the switch, the top of the shaft will move away from the top of the boss and switch and the spring force in the magnetic reed will overcome the remaining magnetic force of the magnet and close the switch contacts.

A stainless steel tubular cover is installed over the solenoid assembly and the electrical switch assembly. One end of the cover is welded to the base assembly housing; the other end is welded to a header assembly which consists of five gold plated electrical contacts installed in a stainless steel plate and insulated from the plate by glass insulation. The electrical leads from the coils and the switch are connected to the inboard end of the contacts. Zener diodes, used for arc suppression, are connected in parallel with the coil leads. The wires in the valve cable assembly are connected to the outboard ends of the contacts. The cable is tied to the valve by a teflon grommet which is placed thru the header assembly. All electrical connections are encapsulated with a silicone rubber potting compound.

The plunger is actuated with a maximum pull-in voltage of 18 volts dc. RCS current will not exceed 25 amperes at 30 volts d.c. In the closed position, the poppet is held against the seat by the net spring force of two loaded springs. In the open position, the poppet is held away from the seat by the magnetic force acting on the plunger. Normal operation is as follows:

1. Closed to open operation: (a) the latching coil is energized; (b) the poppet is unseated by movement of the plunger and shaft (the flux from the latching coil aids the flux from the permanent magnet and the combined effects overcome the net force of the springs); (c) the valve position indicator switch is magnetically

1. (cont)

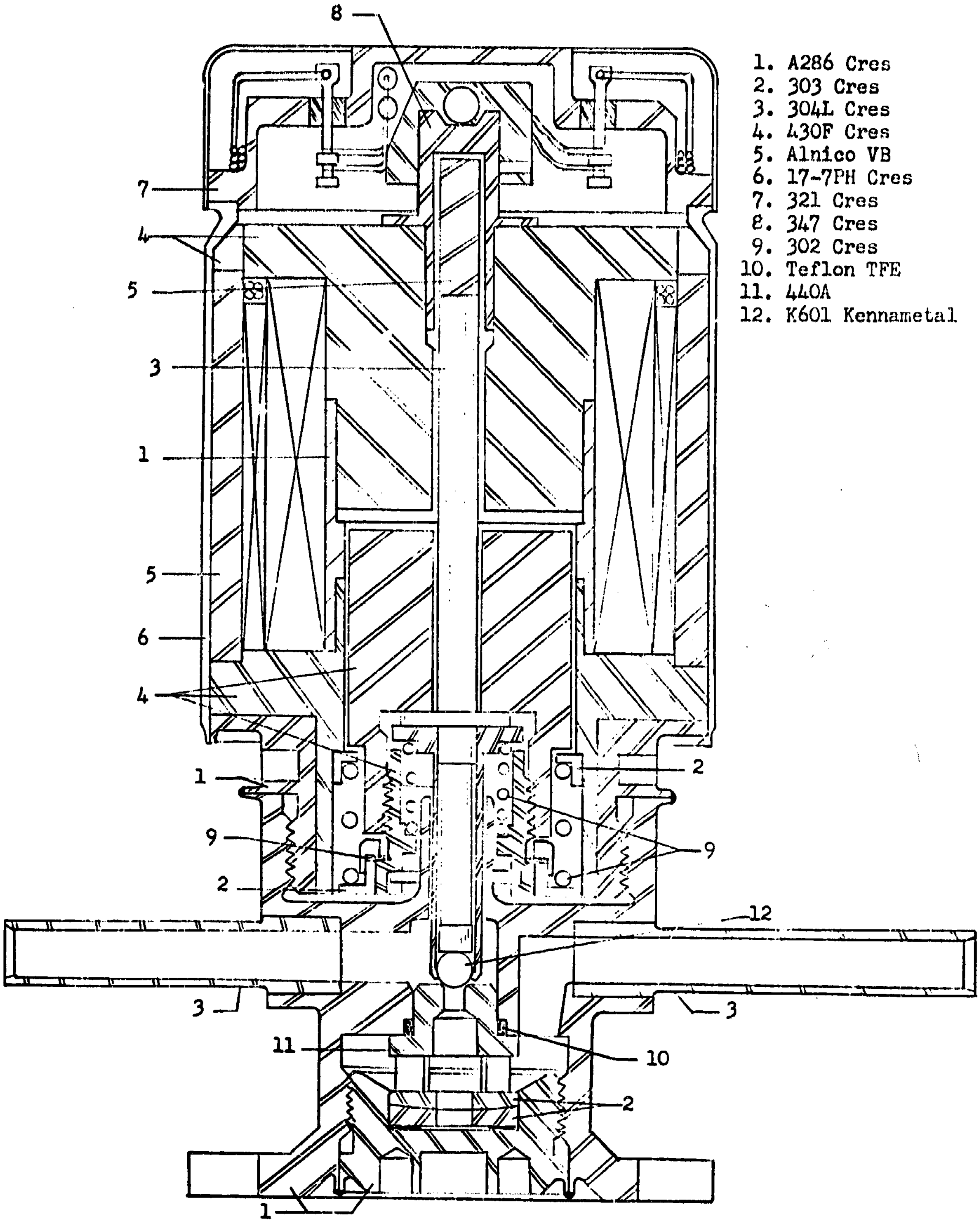
actuated to the open position; (d) the latching solenoid is de-energized (the plunger will be held in the closed gap position by the force of the permanent magnet).

2. Opened to closed operation: (a) the unlatching coil is energized; (b) the poppet reseats (the flux of the unlatching coil momentarily partially cancels the flux of the permanent magnet and the plunger is acted upon by the net force of the springs; (c) the valve position indicator switch is actuated to the closed position by breaking the magnetic field; (d) the unlatching solenoid is de-energized (the plunger will be held in the open gap position by the net force of the springs).

The important performance characteristics of the helium latching solenoid valve and general information concerning the component are listed below.

Operating pressure	4500 psig
Proof pressure	6750 psig
Burst pressure	9000 psig
Pressure drop	25 psid at a helium flow rate of 0.25 #/min. at an inlet pressure of 250 psig
Maximum external leakage	5×10^{-6} std. cc/sec. helium
Maximum internal leakage	20 std. cc/hour helium

Maximum switch contact resistance	500 milliohms
Maximum continuous duty application of electrical power	2 minutes (with 10 minutes between operations)
Numerical reliability (maximum probability of failure)	11×10^{-6} for 336 hours
Minimum total operating life	8000 cycles
Specification number	MC284-0281
SCD number (NR part number)	
Qualified valve	ME284-0281-0001
Supplier	National Water Lift Co. A Division of Pneumo-Dynamics Corp. Kalamazoo, Michigan
Supplier's part number per SCD	
dash number -0001	6699-0



1. A286 Cres
2. 303 Cres
3. 304L Cres
4. 430F Cres
5. Alnico VB
6. 17-7PH Cres
7. 321 Cres
8. 347 Cres
9. 302 Cres
10. Teflon TFE
11. 440A
12. K601 Kennametal

Figure 16-1. Helium Solenoid Latching Valve

TITLE	Valve, Solenoid, Latching (Helium) - National Water Lift
PART NUMBER	ME284-0281-0001
DVT COMPLETED	August, 1966
NO. QUAL UNITS TESTED	4
QUAL TESTS	Fluid Compatibility 33 days 70 to 150°F Life Cycling (high and low temperature) 4000 cycles Vibration - $0.04g^2$/cps; linear increase to $0.15g^2$/cps @ 80 cps; constant to 1000 cps; linear decrease from 1000 cps to 0.075 g^2/cps @ 2000 cps. Burst Pressure - 9000 psig (1 minute) Detail Inspection
ACCEPTANCE TESTS	Examination of Product Proof Pressure - 6750 psig External Leakage 5×10^{-6} std cc/sec @ 250 and 4500 psig Electrical Characteristics - High potential - 810vrms Insulation resistance 100 meghoms minimum @ 500 vdc for 1 minute Pressure Drop - 25 psi maximum @ 0.3#/min. @ 250 psig Functional tests - minimum volts 2-18vdc check ind. transient 50 vdc max. Cleanliness
DIFFERENCE BETWEEN QUAL AND SC UNITS	None

CONSTRUCTION WELDED

Closing coil resistance $14.6 \pm .5\ \Omega$ @ 70°F
Opening coil resistance $15.25 \pm .5\ \Omega$ @ 70°F

Magnetic latch

WEIGHT	2.15#
USAGE	EOPR change point was SC 017 and Subs

SM 014	6 NWL
SM 017	6 NWL
SM 020	6 NWL

NOTE: All spares are NWL.

17. Check Valve

The check valve assembly (Figure 17-1) consists primarily of a stainless steel forged body, four check valve elements, an inlet port assembly, an outlet port assembly, and two test port assemblies. Each inlet and test port assembly consists of a one-quarter inch stainless steel tube welded to a filter assembly which in turn is welded to the valve body.

The four check valve elements are contained within the valve body in a parallel arrangement of two in a series. Each check valve element consists of a poppet assembly, a stainless steel poppet guide, a poppet spring, and a stainless steel spring retainer. The poppet assembly is composed of a stainless steel poppet, and a rubber seal. The rubber seal (EPR) is molded and machined in place in a groove in the poppet for the fuel check valves. The oxidizer check valves employ a rubber washer (Resistazine 88) held in place on each poppet with a retaining ring and kynar nut.

The poppet assembly stem is installed in the poppet guide which is brazed to a shoulder in the valve body forging. The poppet seat is a machined conical surface which is an integral part of the valve body. The poppet assembly has a conical shaped top, rounded at the apex, which is acted upon by the poppet spring retainer which is also conical in shape with a rounded apex. The forward end of the poppet spring pushes against the retainer and holds the poppet against the seat. The aft end of each of the upstream poppet springs is restrained by a stamped ring on the underside of a thin walled cup which is welded to the body. The aft end of each of the downstream poppet springs is restrained by a machined boss which is a part of the outlet port assembly cap. The outlet port assembly consists of a one-quarter inch O.D. stainless steel tube welded to the stainless steel cap. The cap is welded to the body.

The four check valve elements are identical in design; however, the poppet springs of the upstream elements are cylindrical and the poppet springs of the downstream elements are conical. The check valve elements are installed at angles to each other to preclude the possibility of two elements having the same resonant frequency when subjected to vibration.

When equal pressure exists at the inlet and outlet ports, and the pressure is slowly increased at the inlet port, one of the parallel upstream poppets will open when the product of the inlet pressure increase and the poppet seat area exceeds the spring force against the poppet. The second parallel upstream poppet will open almost simultaneously (only the normal tolerance variations in the seat area and spring force will cause differences). As the inlet pressure is increased, the remaining two poppets will open almost simultaneously. When the inlet pressure exceeds the outlet pressure by a maximum of 5 psig, all four poppets will be open and flow through each flow path will be approximately equal. Decreasing the inlet pressure below the differential pressure required to overcome the spring force will first allow the spring force on each of the downstream poppets to drive the poppet toward its closed position until reseat occurs and then allow the upstream poppets to reseat.

When there is greater pressure at the outlet port than at the inlet port, all the poppets tend to seat with a force which increases directly as the increase in the differential pressure.

The important performance characteristics of the check valve and general information concerning the component are listed below.

Working pressure	180 - 302 psig
Cracking pressure	
Upstream poppets	0.2 to 4 psid
Downstream poppets	1.0 to 5.0 psid
Pressure drop	
Normal	5.0 psi at a He flow rate of 0.09 pounds per minute and an inlet pressure of 180 psig
One path closed	6 psi at a He flow rate of 0.09 pounds per minute and an inlet pressure of 180 psig
Proof pressure	540 psig
Burst pressure	720 psig
Maximum external leakage	5×10^{-6} std. cc/sec.
Maximum internal leakage	
Single poppet element	$5. \times 10^{-5}$ std. cc/sec.
Two poppet elements in parallel	1×10^{-4} std. cc/sec.
Numerical reliability (maximum probability of failure)	1×10^{-6} per 1 hour
Minimum total operating life	8000 cycles
Specification number	MC284-0024
SCD number (NR part number)	
Qualified oxidizer-side valve	ME284-0357-0001

Qualified fuel-side valve	ME284-0357-0002
Pre-qualified oxidizer-side valve	ME284-0024-0001
Pre-qualified fuel-side valve	ME284-0024-0011
Pre-DVT oxidizer-side valve	ME284-0024-0003
Pre-DVT fuel-side valve	ME284-0024-0013

Supplier — Accessory Products Co.
Division of Textron, Inc.
Whittier, Calif.

Supplier's part number per SCD

dash number 0357-0001	219000
0357-0002	219100
0024-0001	214000P
0024-0011	214100P
0024-0003	214000X
0024-0013	214100X

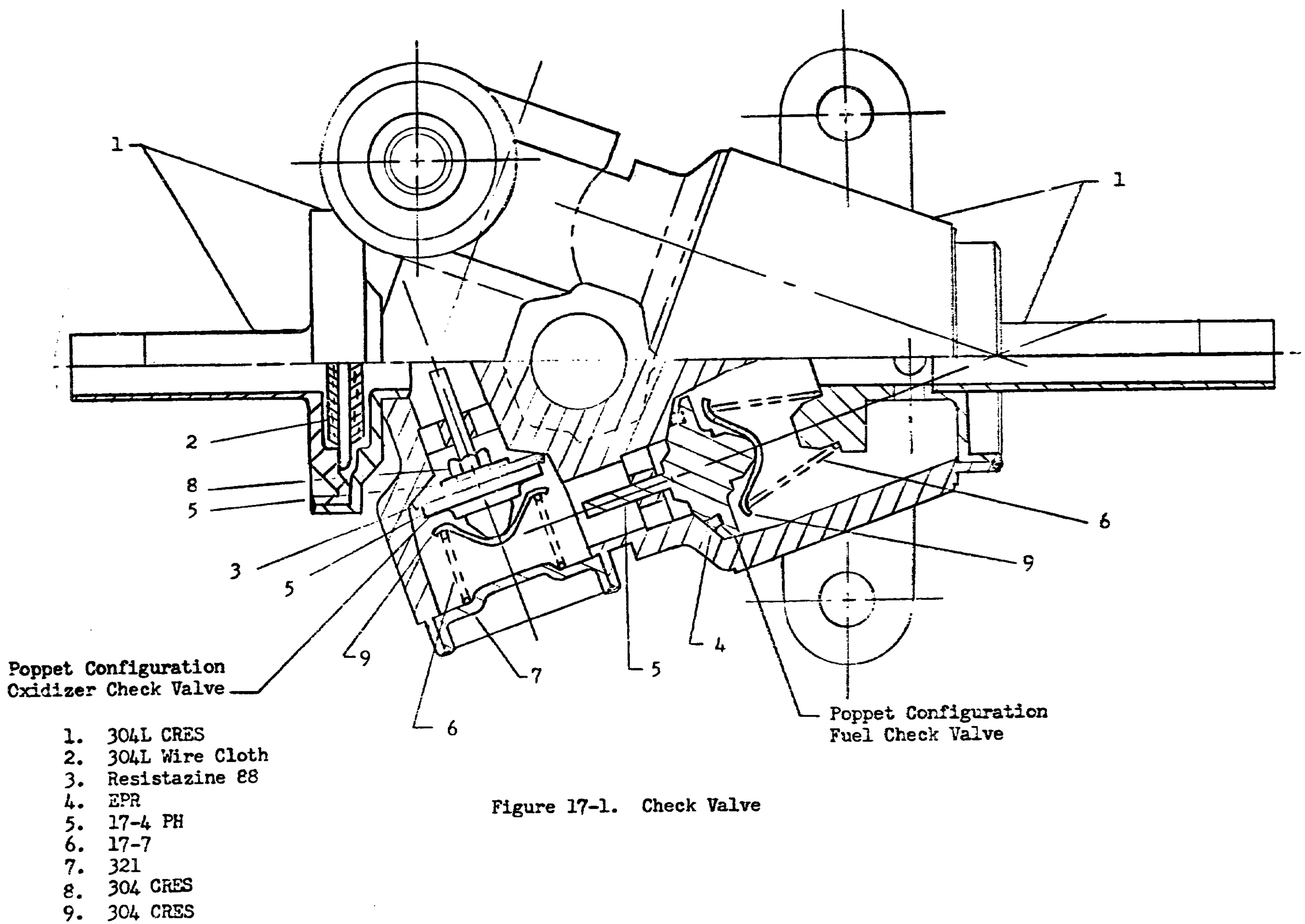


Figure 17-1. Check Valve

TITLE	Series Parallel Check Valve (APCO)
PART NUMBER	ME284-0024-0022 (oxid) ME284-0024-0052 (fuel) ME284-0357-0001 (ox) w/filters ME284-0357-0002 (fuel) w/filters
DVT COMPLETED	No DVT
QUAL COMPLETED	January 1966 (ME284-0024 ONLY)
DEVELOPMENT TEST COMPLETED	May 1967 (ME284-0357 ONLY)
NUMBER UNITS TESTED	4 (ME284-0024 ONLY)

QUAL TESTS

(ME284-0024 ONLY)

Surge pressure	308 psig in 10 ms
Acceleration	20g's
Vibration	.15 g^2/cps at 80 cps
Endurance	4000 cycles - 65°F to +150°F

Fluid Compatibility 30 day exposure ambient to 150°F N_2O_4 and UDMH/N_2H_4 vapor
Contamination - Deterioration
Disassembly

DEVELOPMENT TESTS

(ME284-0357 ONLY)

Inlet Filter - (40-74μ)

Surge pressure - clean element: 500 psig in 10 ms
Particle Retaining Capacity - Delta P shall not be greater than 2 psi with the introduction of 0.2 grams A.C. fine dust.
Surge Pressure - Contaminated Element: 5C0 psig in 10 ms with 0.2 grams of A.C. fine dust in filter.
Strength Demonstration: Filter must withstand 200 Delta P

Test Port Filter (40-74μ)

Surge pressure - clean element: 500 psig in 10 ms
Particle retaining capacity: Similar to inlet filter test - no requirements

ACCEPTANCE TESTS	(ME284-0024 ONLY) Examination of product Proof pressure (540 psig) and external Leakage (5 x 10^{-6} std cc/sec) Cracking pressure: Upstream poppets - 0.2 to 4.0 psi Downstream poppets 1.0 to 5.0 psi Internal Leakage 1 x 10^{-4} std cc/sec helium Pressure drop 4 at .12 #/min of helium (inlet press) 5 at .24 #/min of helium 181 psig Cleanliness Verification (ME284-0357 ONLY) Examination of filter element Bubble Point Test - Filter: Inlet - 3 to 4.5 in. H_2O Test Port - 3 to 9.0 in. H_2O Examination of Product Proof pressure (540 psig) and External Leakage (5 x 10^{-6} std cc/sec) Cracking pressure: Upstream poppets 0.2 to 4.0 psi Downstream poppets 1.0 to 5.0 psi Internal Leakage - 1 x 10^{-4} std cc/sec Helium Pressure Drop: Prim. Poppets - 3.5 psi at 0.045 #/min of helium - 180 inlet pressure Sec. Poppets 5.0 psi at 0.045 #/min of Helium 180 inlet press. Cleanliness Verification
DIFFERENCE BETWEEN QUAL AND SC 020 UNITS	A portion of the SC 020 units have been flushed with IPA. Qual units were flushed with Freon TF.
UNDESIRABLE CHARACTERISTICS	None
AREAS OF APPREHENSION	Two of the six oxidizer check valves installed on SC 020 were flushed with IPA. IPA was determined to be incompatible with Resistazine 88 (the poppet seal material in the oxidizer check valve). IPA flush has been abandoned.
WEIGHT	.8 specification .4 actual (ME284-0024 only) .5 actual (ME284-0357 only)
EFFECTIVITY	ME284-0024-0022, 0052 SM (SC 020); CM (101, 103) ME284-0357-0001, 0002 SM (SC 101 and Subs); CM (SC 104 and Subs)

18. Propellant Filter

The propellant in-line filter (Figure 18-1) is a straight flow-through type unit. The filter consists of a case assembly and the filter element assembly.

Case Assembly. The case assembly is composed of a case, inlet fitting and a test fitting. The case is a cylindrical tube with an 0.25 inch wall section. The test port fitting is brazed to the inlet fitting to form a "T", and in turn the inlet port fitting is welded to the case to form the case assembly.

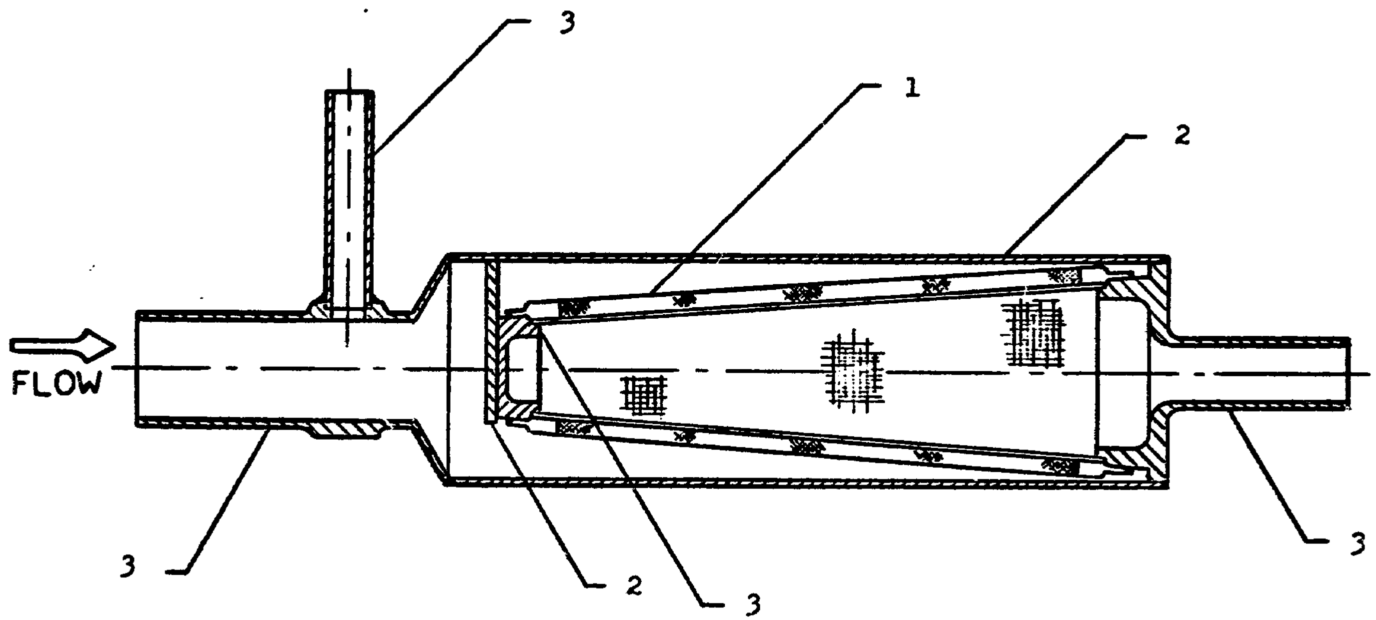
Filter Element Assembly. The filter element assembly consists of a filter support, a filter screen, an end-cap and a filter outlet fitting. The filter support is fabricated from an 0.035 304L sheet stock with 3/32 diameter holes spaced 5/32 apart in a staggered pattern and it is formed to a conical shape and seam welded. (In the breadborad unit a coarse filter screen was utilized for the filter support). The filter screen is constructed from a single layer of 200 x 1400 Dutch Twilled Weave of 304L wire cloth with 5 microns nominal and 15 microns absolute filtration rating. The filter screen is pleated to 0.1 inch high; there are approximately 80 pleats around the circumference. Each end of the filter screen is resistance welded to a closeout support. The filter screen is then placed over the filter support. The smaller diameter of the conical shape filter screen with the support is closed with an end-cap and welded together. The end-cap includes a three prong member which provides support for the filter in the case. The outlet fitting is welded to the larger diameter of the filter screen to complete the filter element assembly.

Upon the completion of the subassemblies the filter element assembly is placed inside of the case assembly and welded together to form a leak proof joint.

The major performance characteristics and general information concerning the propellant filter are listed below.

Operating pressure	181 psig
Proof pressure	375 psig
Burst pressure	500 psig
Collapse pressure (filter element) in the direction of flow	248 psig for a period of 0.5 second flow
Maximum external leakage	5×10^{-6} std cc/sec of He
Pressure drop (clean filter)	
Oxidizer filter (N_2O_4)	0.5 psid at 0.48 #/sec flow rate
Fuel filter (MMH)	0.5 psid at 0.24 #/sec flow rate
Filtration rating	5 microns nominal, 15 microns absolute
Pressure cycling	20,000 pressure cycles, each cycle 40 ms duration with 20 ms propellant flow during the cycle

Inlet port, oxidizer and fuel	$0.631\ ^{+.000}_{-.003}$ O.D.
Outlet port, oxidizer	$0.504\ ^{+.000}_{-.003}$ O.D.
Outlet port, fuel	$0.379\ ^{+.000}_{-.003}$ O.D.
Test port, oxidizer & fuel	$0.253\ ^{+.000}_{-.003}$ O.D.
Length, oxidizer & fuel	6.75
Case diameter	$1.200\ ^{+.004}_{-.000}$ O.D.
Specification number	MC286-0039
SCD number (NR part number)	
Qualified Filter	
Type I - Oxidizer	ME286-0039-0001
Type II - Fuel	ME286=0039-0011
Breadboard Test Filter	
Type I - Oxidizer	ME286-0039-0002
Type II - Fuel	ME286-0039-0012
Supplier	Wintec Corporation Inglewood, California
Supplier part number per SCD	
ME286-0039-0001	15241-525
ME286-0039-0011	15241-526
ME286-0039-0002	15241-533
ME286-0039-0012	15241-534



1. 304L CRES Wire
2. 321 CRES
3. 304L CRES

Figure 18-1. Propellant Filter

TITLE Filter, Propellant, In Line (Wintec)

PART NUMBER ME286-0039-0001 Ox Filter
ME286-0039-0011 Fuel Filter

QUAL TEST COMPLETION DATE April, 1966

NO. OF QUAL TEST UNITS 4

QUAL TESTS Vibration $0.01g^2$/cps @ 10 cps, linear increase to $0.8g^2$/cps @ 100 cps, constant to 400 cps, linear decrease from 400 cps to $0.16g^2$/cps @ 2000 cps.

Leakage - Less than 5×10^{-6} scc/sec @ 375 psig
Acceleration - 6g
Pressure drop - less than .5 psi @ .48#/sec oxidizer & .24#/sec fuel
Dirt capacity - 1 gram AC fine dust with less than 3 psi pressure drop
Pressure cycling - 2000 cycles of rated flow for 40 millisec per cycle
Collapse pressure - greater than 248 psi
Burst pressure - greater than 500 psig
Assembly bubble point - No less than 15.9 inches of water when tested in IPA (15 micron absolute)
Disassembly

ACCEPTANCE TESTS

Pressure drop - oxid. .5 psi @ .48 lb/sec
fuel .5 psi @ .24 lb/sec
Visual examination
Element bubble point - No less than 15.9" H_2O in IPA
Leakage and Proof pressure - less than 5×10^{-6} scc/sec. @ 375 psig
Cleanliness

DIFFERENCE BETWEEN QUAL & SC UNITS None

CONSTRUCTION The filter housing is machined from AISI-321 material. Both inlet and outlet ports are machined from AISI-304L material and welded to the housing.
The filter is 250x1400 dutch twill weave, non-sintered, non-calendared, non-patched or repaired 304L SS wire cloth pleated.
Area of filter cloth is 52.5 sq. inches.
Filter rating is 5 micron nominal 15 micron absolute

WEIGHT 0.4#

USAGE SM -012 and Subs

19. Thermostat

The thermostat (Figure 19-1) is a hermitically sealed, SPST, snap-action thermal switch.

It consists of a cold rolled steel drawn cup, a temperature sensitive bimetallic disc, a ceramic transfer pin, a movable contact arm assembly, a ceramic insulating liner and a cap assembly. The movable contact arm assembly consists of a perma-nickel movable contact arm with a fine-silver plated contact installed on one end. The cap assembly consists of two Haynes 52 alloy terminals installed in a cold rolled steel cap and insulated from the cap by glass insulation. The cap is heli-arc welded to the top edge of the drawn cup. The thermostat is vacuum-baked, back-filled with 90 percent dry nitrogen and 10 percent dry helium and welded in an atmosphere of the same composition.

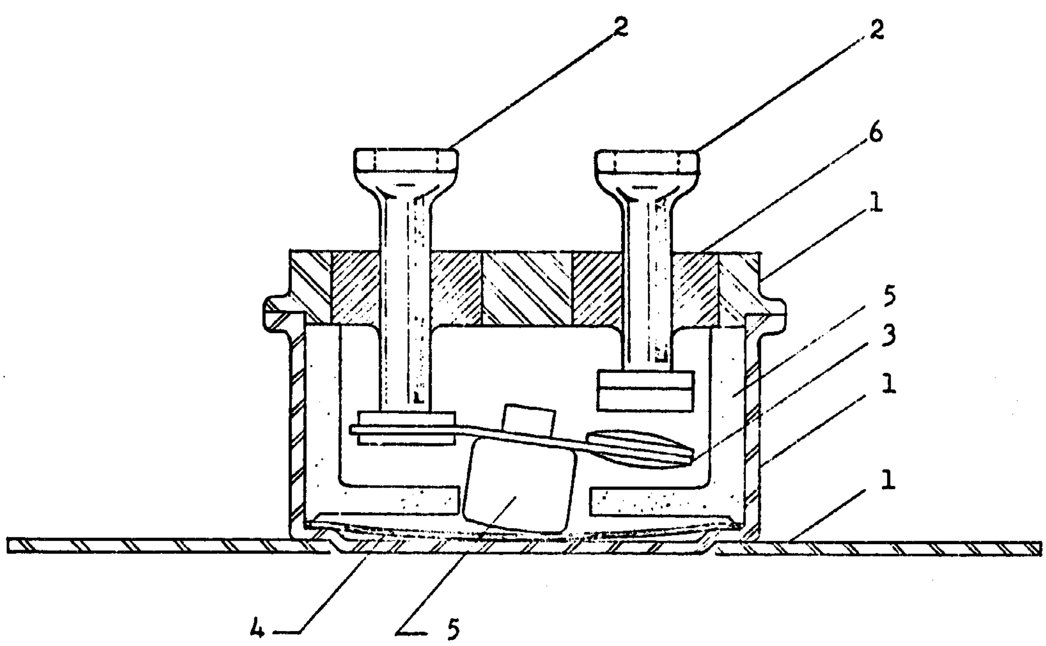
The bimetallic disc is positioned in the bottom of the cup and its OD is held in place by the ceramic insulating liner which fits snugly inside the cup. The rounded bottom of the transfer pin rides on the center of the disc. The top of the transfer pin bears against the center of the movable contact arm. One end of the contact arm is attached to the internal end of one of the terminals; the other end of the contact arm contains the electrical contact and is positioned just below the internal end of the second terminal which also contains an electrical contact.

A rise in temperature causes the bimetallic disc to snap away from the cup bottom. As the disc snaps, it pushes against the transfer pin which in turn pushes against the contact arm causing the contact at the end of the arm to make positive contact with the contact at the end of the second terminal. This action completes an electrical circuit within the switch.

A drop in temperature causes the bimetallic disc to snap toward the cup bottom. As the disc snaps, it relieves the force acting on the transfer pin. The spring force in the movable contact arm pulls the contact on the arm away from the contact on the terminal. This action breaks the internal electrical circuit.

The important performance characteristics of the thermostat and general information concerning the component are listed below.

Closing temperature	120 ±5°F
Opening temperature	129 ±5°F
Minimum dead band	9°F
Maximum contact resistance	0.015 ohm
Maximum external leakage (He)	1 x 10^{-8} scc/sec
Numerical Reliability (maximum probability of failure)	350 x 10^{-6} for 336 hours
Reliable operating life	4,000 cycles
Specification number	ME360-0003
SCD number (NR part number)	
Qualified thermostat	ME360-0003-0001
Supplier	Metals and Controls Inc., a Division of Texas Instruments Attleboro, Massachusetts
Supplier's part number per SCD	
dash number -0001	11041-50-129



1. Cold rolled steel copper nickel plated
2. Haynes 52 alloy
3. Perma-nickel
4. Bimetal
5. Ceramic
6. Glass

Figure 19-1. Thermostat

TITLE	Thermostat (Texas Instruments)
PART NUMBER	ME360-0003-0001
DVT COMPLETION DATE QUAL COMPLETION DATE	No DVT or Qual.** A commercial part controlled by SCD
ACCEPTANCE TESTS	Examination of Product. Hermetic seal (1×10^{-8} scc/sec) Closing Temperature (120 ±5°F) Opening Temperature (129 ∓5°F) (9° min. band) Insulation resistance (500 vdc) High potential (1500 volts RMS AC) Contact resistance (0.015 ohm max.)
DIFFERENCE BETWEEN QUAL AND SC UNITS	None

**The thermostat has been qualified by the supplier to the requirements of MIL-E-5272C and MIL-T-5574A, (Vibration, salt spray, humidity, sand and dust, high temperature, low temperature, temperature shock, acceleration, strength of terminals, shock). These requirements satisfy all Apollo requirements except for Acoustic and Vibration; however, the thermostat was a part of a heater during the Acoustic Test Panel test and during the heater qual tests.

NOTES:

Weight: 5.9 grams

20. Valve House Heater

The valve house heater (Figure 20-1) is a flat, rectangular, two element, metal encased heater.

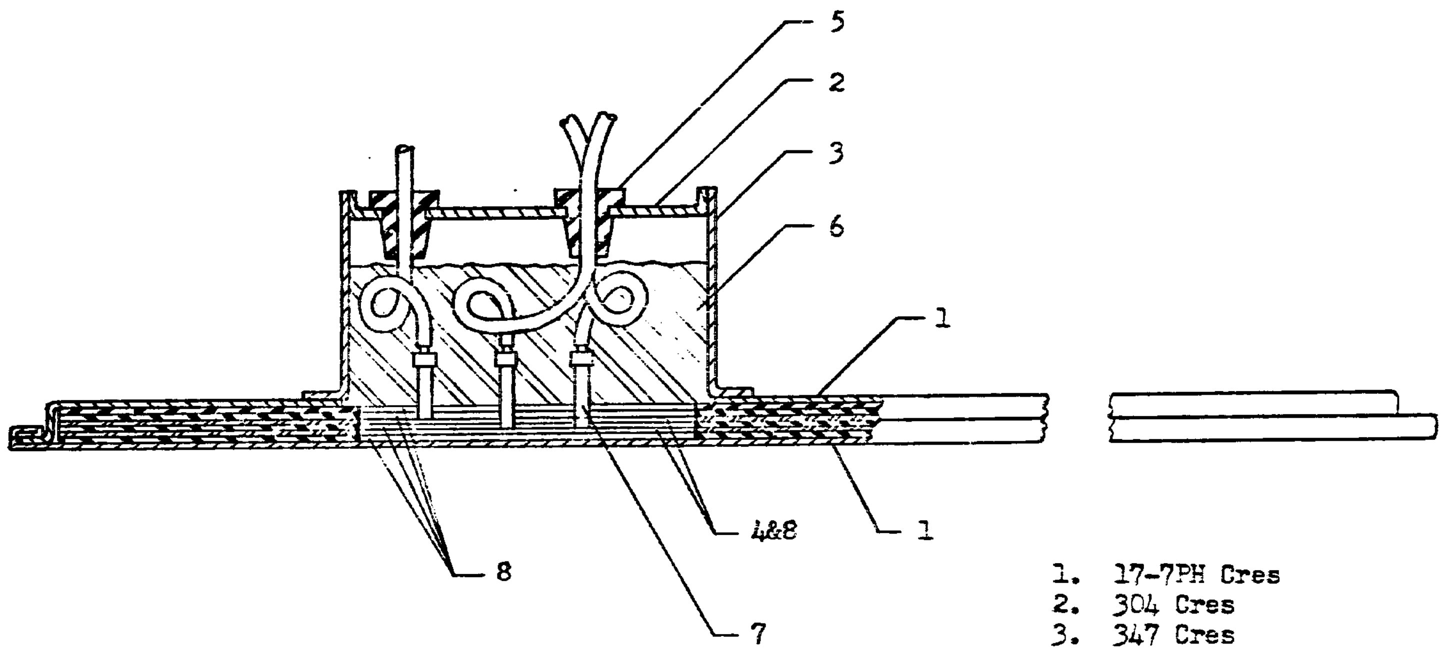
The elements are positioned one on top of the other and are electrically independent. Each element is chemically milled from inconel resistance foil which has been attached to silicone rubber impregnated glass cloth during a curing cycle. The elements are insulated from each other and from the stainless steel envelope by several layers of silicone rubber impregnated glass cloth.

The upper and lower stainless steel sheets, which comprise the envelope, are attached to the insulation during the curing cycles and are attached to each other at the perimeter of the rectangle by folding the edges in a dutch fold. The heater assembly is sealed against moisture by filling the folds with a silicone compound sealant.

The electrical leads are 20 AWG teflon-insulated, silver-plated wire and are attached to the heater elements by a special proprietary welding technique which employs an interconnecting gold ribbon. The welded joints are encapsulated and protected by an epoxy potting. The leads are looped within a stainless steel cylindrical housing which is spot welded to the upper envelope sheet. The loops are encapsulated in epoxy potting. Teflon glens protect the leads where they are fed through the stainless steel lid of the housing.

The important performance characteristics of the valve house heater and general information concerning the component are listed below.

Power dissipation	36 watts at 25 vdc
Element resistance	15.78 to 19.29 ohms
Numerical reliability (maximum probability of failure)	255×10^{-6} for 336 hours
Minimum total operating life	4000 cycles
Specification number	MC363-0014
SCD number (NR part number)	
Qualified heater	
with integral thermostat	ME363-0014-0001
without integral thermostat	ME363-0014-0004
Supplier	Thermal Systems, Inc. Los Angeles, Calif.
Supplier's part number per SCD	
dash number -0001	45-1646-1
-0004	45-1646-21



1. 17-7PH Cres
2. 304 Cres
3. 347 Cres
4. Inconel 600
5. Teflon
6. Apoxy potting
7. Gold ribbon
8. Silicone rubber impregnated glass cloth

Figure 20-1. Valve House Heater

TITLE	Valve House Heater (Thermal Systems)
PART NUMBER	ME363-0014-0004
DVT COMPLETION DATE	DVT was cancelled
QUAL TEST COMPLETION DATE	May 15, 1966
NUMBER TEST UNITS	4
QUAL TESTS	High temperature (250°F for 3 hrs), vibration (24 grms), life cycle (2000 cycles), low temperature - vacuum (-65°F and 1 x 10^{-6} mm Hg for 3 hours)
ACCEPTANCE TESTS	Examination of Product High potential (1060 volts RMS AC) Insulation resistance (500 vdc) Electrical resistance (17.36 plus 1.93 minus 1.58)
DIFFERENCE BETWEEN QUAL AND SC UNITS	Qual units were ME363-0014-0001 which are equipped with an internal thermostat
NOTES	The ME363-0014-0004 heater does not have an internal thermostat. Effectivity - 106 and Subs Weight - 0.13 pound

TITLE	Valve House Heater (Thermal Systems)
PART NUMBER	ME363-0014-0001
DVT COMPLETION DATE	DVT was cancelled
QUAL TEST COMPLETION DATE	May 15, 1966
NUMBER TEST UNITS	4
QUAL TESTS	High temperature (250°F for 3 hrs), vibration (24 grms), life cycle (2000 cycles), low temperature - vacuum (-65°F and 1 x 10^{-6} mm Hg for 3 hours)
ACCEPTANCE TESTS	Examination of Product High potential (1060 volts RMS AC) Insulation resistance (500 vdc) Thermal switch operation (10 cycles) Power dissipation (temp. distribution and total input power)
DIFFERENCE BETWEEN QUAL AND SC UNITS	None

CONSTRUCTION:

Integral thermostat - closing temperature 77^{+10}_{-7}

opening temperature 104 ± 14

20° minimum spread

Elements - Inconel (etched)

Covers - 17-7PH (.0015)

Insulation - fiber glass coated with silicone rubber

NOTES:

INSTALLATION:	SC 017	Bond + clamp
	SC 020, Quad A	Bond + clamp
	SC 020, Quads B, C, D	Bond only

WEIGHT 0.12 pound

21. <u>Service Module Rocket Engine</u>

The service module rocket engine (Figure 21-1) consists of an oxidizer valve assembly, a fuel valve assembly, an injector assembly and a thrust chamber and bell assembly.

The oxidizer valve assembly consists of a spool assembly, an Inconel X armature spring, a stainless steel armature, and a seat assembly. The spool assembly is composed of a stainless steel body, with a non-magnetic weld midway between the end flanges, a stainless steel plug, a stainless steel cover and two coils, the direct coil and the automatic coil. The body weld forms a non-magnetic gap and prevents a magnetic short circuit through the body material. The inlet end of the body is threaded externally with 0.7188-20NS-3A threads designed to mate with a Resistoflex Dynatube fitting. The plug, which mates into the body via an interference fit, is cylindrical in shape, with a hole drilled axially through its entire length. The downstream end is counter-bored to serve as a retainer for one end of the spring.

The coil assembly consists of two coils, the direct coil and the automatic coil, wound coaxially around the valve body. The automatic coil contains 685 turns of #30 AWG copper wire having a resistance of 17.2 ±0.4 ohms at 68F. The direct coil is wound around the automatic coil and is insulated from it with electrical tape. The direct coil contains 1020 turns of #26 AWG copper wire having a resistance of 14.3 ±0.4 ohms at 68F. The cover is tubular in shape with three equally spaced mounting ears at one end. A slot, to provide an exit for the electrical leads, is located at the end of the cover that contains the mounting ears. An interference fit secures the cover to the body. The four electrical leads from the two coils are soldered to four #20 AWG stranded teflon coated copper conductors. The four teflon insulated wires are twisted together and sheathed in a transparent extruded teflon jacket. The cable assembly is then fed through the slot in the cover and secured by means of a grommet installed in the slot. The hole is sealed off from the atmosphere by means of a potting compound. The armature is cylindrical in shape with the downstream end terminating in a conical shaped stellite tip (valve poppet) which provides the contact area for the valve seat. The oxidizer flow path is through an axially drilled hole terminating in four equally-spaced slanted holes drilled through the wall of the cylinder to serve as flow ports. The upstream end of the armature is counter-bored to serve as a retainer for one end of the spring. The spring is sandwiched between the plug and the armature and is retained by the respective counterbores described above. The spring and armature are retained by the seat assembly which screws into the valve body. The seat assembly consists of a stainless steel seat, a teflon seal and a stainless steel insert. The teflon seal is pressed into the seat to form the poppet seating surface. The seal is retained in the seat by the insert. A stainless steel pressure drop trim orifice and a sediment strainer with a spherical particle rating of 165 microns are installed against a shoulder in the inlet end of the valve body and are held in place by a snap ring which is installed in a groove in the body.

With the valve coils de-energized, the valve poppet is held against the teflon seat by the force of the armature spring and the force exerted by the propellant supply pressure acting on the armature thus preventing oxidizer from flowing downstream of the oxidizer valve seat. When either of the coils is energized, the force set up in the armature by the electromagnetic field will overcome the force holding the poppet against the seat and the poppet will be pulled away from the seat. The oxidizer will flow into the valve body, through the orifice, through the sediment strainer, through the spring and the four slanted holes in the armature, around the poppet, through the center of the seat assembly and finally to the injector head assembly.

The fuel valve assembly is identical in construction and operation to the oxidizer valve assembly except for the size of the pressure drop trim orifice and the number of turns in the valve coils. The fuel automatic coil contains 505 turns of #30 AWG copper wire having a resistance of 12.4 ±0.3 ohms at 68F. The fuel direct coil contains 1080 turns of #26 AWG copper wire having a resistance of 14.4 ±0.4 ohms at 68F. In order to minimize main chamber ignition spikes, the fuel valve is designed to open two milliseconds before the oxidizer valve.

The injector head assembly is composed of an aluminum housing assembly, an aluminum and stainless steel pre-igniter insert assembly, two phenolic insulators and stainless steel fuel and oxidizer pre-igniter tubes. The fuel valve, which is oriented 50 degrees from the axis of the engine, is attached to the injector assembly by means of titanium screws through the three ears on the valve cover. The pre-ignitor insert assembly is located in the center of the housing assembly and is coaxial with it. The insulators are part of the thermal isolation of the valves from the injector assembly. The oxidizer valve is attached to the injector assembly by three stainless steel screws. The downstream end of the pre-igniter insert assembly is tubular in shape and projects beyond the face of the injector into the combustion chamber area. The projecting end of the pre-igniter insert assembly is the pre-igniter chamber.

The oxidizer igniter tube orifice is installed in the pre-igniter insert downstream of the oxidizer valve. The fuel igniter tube orifice is installed in the housing assembly downstream of the fuel valve. When assembled, the component parts of the injector head assembly form chambers, passages and manifolds to distribute the propellants where required for optimum ignition characteristics, combustion stability, and temperature distribution on the inner wall of the combustion chamber and the outer wall of the pre-igniter chamber.

Oxidizer leaving the oxidizer valve assembly flows through the oxidizer igniter tube into the pre-igniter chamber through an 0.043 inch diameter hole. Simultaneously, oxidizer flows out through four equally spaced radial holes in the upstream end of the igniter tube. After leaving the oxidizer igniter tube orifice holes, oxidizer flows into a circular manifold chamber and thence into the combustion chamber through eight 0.035 inch diameter holes located equidistant from the engine axis in a circular pattern. The holes are slant drilled so that the oxidizer flows outboard. The time lag between the oxidizer entering the pre-igniter chamber and the oxidizer entering the combustion chamber is approximately five milliseconds.

The fuel enters the pre-igniter chamber and the combustion chamber in a manner similar to that of the oxidizer. The fuel hole in the pre-igniter chamber has a diameter of 0.025 inch. The fuel enters the combustion chamber through 24 holes consisting of three sets of eight holes each. The sets of holes are concentric about the axis of the engine at different diameters from the center. The holes in each set are equidistant from each other. On the same radial lines as the oxidizer holes and slightly outboard are the 0.025 inch diameter fuel holes used for main combustion. These holes are slant drilled and aligned so that fuel flows inboard and impinges on the outboard flowing oxidizer, forming doublets. The streams from the other two sets of fuel injector holes serve as coolants for the pre-igniter chamber and the combustion chamber wall. The seven 0.010 inch and one 0.020 inch diameter holes which are used for cooling the pre-igniter chamber are the same diameter from the centerline as the main combustion fuel holes but offset from them by 22-1/2 degrees. The 0.019 inch diameter holes that are used for cooling the combustion chamber wall are on the same radial lines as the doublets, but farther outboard. As with the oxidizer, fuel enters the pre-igniter chamber approximately five milliseconds before fuel enters the main combustion chamber.

The thrust chamber assembly consists of a cobalt base steel thrust chamber bell attached to a disilicide-coated molybdenum thrust chamber with a waspalloy attach nut. The engine throat is an integral part of the thrust chamber. The thrust chamber assembly is attached to the injector assembly with Rene 41 split-ring assembly, a Rene 41 attach ring, a cobalt base steel combustion chamber seal and six Rene 41 bolts that thread into inserts in the injector head assembly.

Upon mixing in the combustion and pre-igniter chambers, the propellants react hypergolically. The products of this reaction are high temperature gases which create a high pressure in the combustion chamber before escaping through the engine throat. The gases are accelerated to supersonic velocity in the divergent section of the thrust chamber and produce a resulting thrust as the gas molecules leave the thrust chamber bell.

The important performance characteristics of the rocket engine assembly and general information concerning the components are listed below:

Propellant inlet pressure	
Static, operational range	177 to 190 psia
Dynamic, operational range	166 to 179 psia
Dynamic, specification performance	170 $\pm$2.5 psia
Proof pressure, specification requirements	
Valves	465 psig
Injector head	465 psig

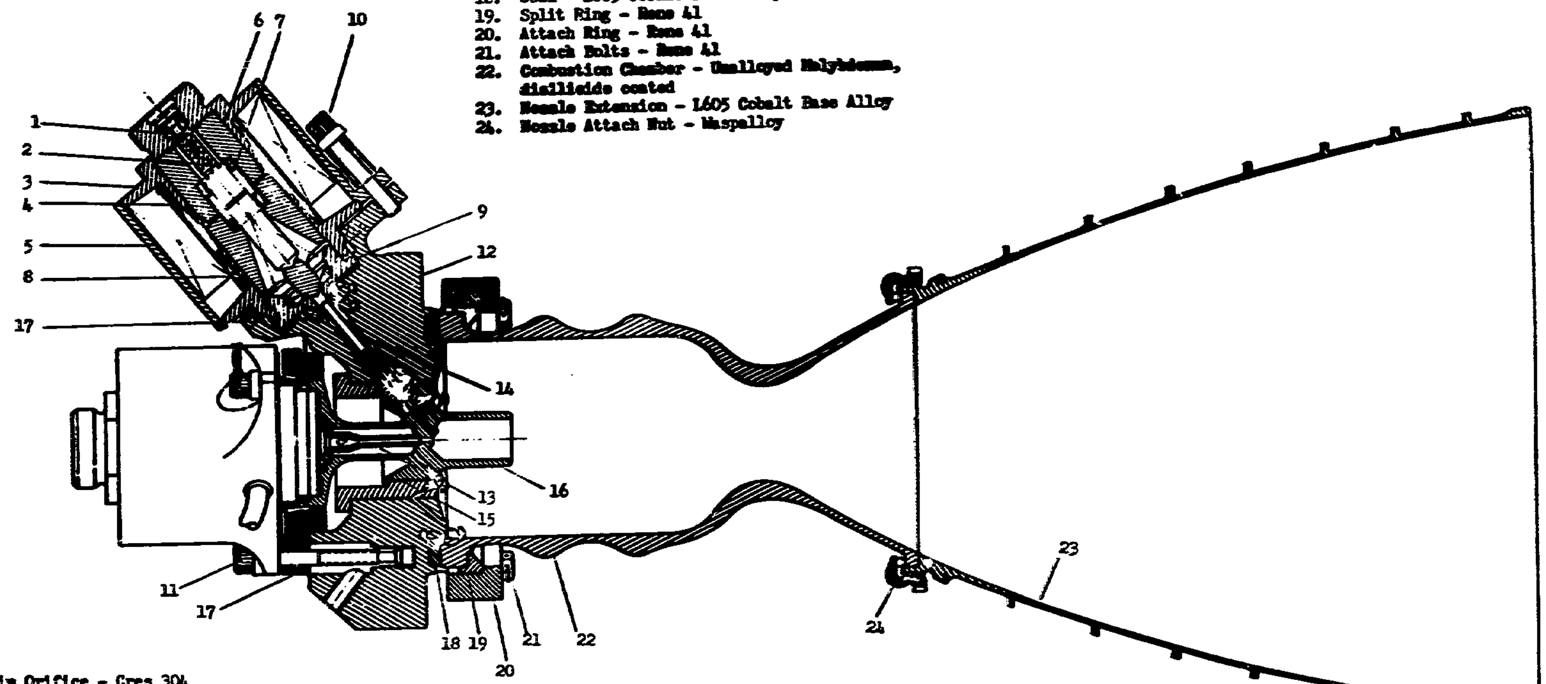
Burst pressure, specification requirements	
Valves	700 psig
Injector head	700 psig
Maximum external propellant leakage	none allowed
Maximum internal (seat) leakage, specification requirement	1.5 cc/6 min GN_2 at 100 psig
Maximum internal (seat) leakage, acceptance test	1.0 cc/6 min GN_2 at 100 psig
Reverse seat leakage, specification requirement	3 cc/6 min GN_2 at 20 psig
Voltage, specification perf.	24-30 VDC
Voltage, operational range	21-32 VDC
Maximum current	
Automatic coils	4.0 amps total at 27 VDC
Direct coils	1.0 amps total at 27 VDC
Maximum operating temperatures	
Propellant valves, continuous	200°F
Propellant valves, 300 pulses	275°F
Combustion chamber, steady state	2450°F
Propellant temperature range	
Specification performance	40 to 100°F
Operational range	40 to 150°F
Oxidizer to fuel ratio	2 to 1
Vacuum thrust	100 ±5 lbs
Minimum total operating life	
Specification requirement	1000 seconds
Demonstrated (qual. and off limits)	4600 seconds
Specification number	MC901-0004
SCD number (NR part number)	
Qualified with integral filter screen (Alt.)	ME901-0004-0301
Qualified with integral filter screen (S.L.)	ME901-0004-0303

SCD number (cont)

Qualified (Altitude)	ME901-0004-0201
Qualified (Sea level)	ME901-0004-0203
Prototype (Altitude) (Tested at AEDC)	ME901-0004-0101
Prototype (Sea level)(B/B Phase I)	ME901-0004-0103
Prototype (Non-fireable)	ME901-0004-0104
Prototype (Altitude)	ME901-0004-0105
Prototype (Sea level)(B/B Phase II)	ME901-0004-0106
Simulated (Thermo)	ME901-0004-0107
Simulated	ME901-0004-0109
Preflight Rating Test Type (Altitude) (B/B Phase III)	ME901-0004-0110
Preflight Rating Test Type (Non-fireable)	ME901-0004-0111
Preflight Rating Test Type (Sea level)	ME901-0004-0112

Supplier — The Marquardt Company, Van Nuys, California

13. Oxidizer Pre-igniter Tube - Cres A286
14. Fuel Pre-igniter Tube - Cres A286
15. Pre-igniter Insert - Cres A286
16. Pre-igniter Chamber
17. Thermal Insulator - Plastic Laminate
18. Seal - L605 Cobalt Base Alloy
19. Split Ring - Rene 41
20. Attach Ring - Rene 41
21. Attach Bolts - Rene 41
22. Combustion Chamber - Unalloyed Molybdenum, disilicide coated
23. Nozzle Extension - L605 Cobalt Base Alloy
24. Nozzle Attach Nut - Waspalloy



1. Trim Orifice - Cres 304
2. Strainer - Cres 316, 321, 347
3. Valve Body - Cres 446/MIL-E-21562 Type MIL- RN6A Weld Rod
4. Auto Coil
5. Direct Coil
6. Plug - Cres 446
7. Spring - Inconel X
8. Armature - Cres 446 with stellite tip
9. Valve Seat Assy - AM 355 w/TFE teflon seal
10. Fuel Valve Attach Bolts - 6AL-4V Titanium
11. Oxidizer Valve Attach Bolts - Cres A286
12. Injector Housing - 6061T6 Aluminum

Figure 21-1. Rocket Engine

TITLE	SM RCS ENGINE
PN	ME901-0004-0301
QUAL TCD	December 31, 1965
QUAL TESTS	Shock, vibration, humidity, salt-fog, static load, performance calibration, mission simulation, pulse survey, orbit retrograde, direct coil operation, elect. & structural integrity, pre-fire heating, pre-fire cooling.
COMBUSTION CHAMBER PROOF TESTS	.Altitude pressure - $\leq$.001 psia .Engine Attitude - vertical up, horizontal, down .Engine Bell attach nut temps: - Vertical Up - 50, 40, 30, 20 °F Horizontal - 50, 40, 30, 20 °F (failed combustor at 10°F) Down - 30°F (only temp. tested) .Firing sequence - 12 ms. pulse width with various off times-oxidizer lead on last pulse of each pulse series .Total number pulses at 30°F - Vertical up - 1,041 Horizontal - 615 Down - 604
TCD	August 25, 1966
SUPPLEMENTAL QUAL, MMH	Performance calibration, cold mission simulation (vertical up and horizontal), ambient and hot mission simulation (down), pulse survey, orbit retrograde, direct coil operation, electrical and structural integrity.
TCD	November 8, 1966
SUPPLEMENTAL QUAL, VALVE INLET STRAINER	Performance calibration W/O strainers, performance calibration W/strainers, pulse survey, bench cycling, propellant exposure, final examination.
TCD	August 22, 1967
OFF LIMIT TESTS	Life tests (2 engines), vibration (3X), high temperature (150 F prop., 200°F valve seats)
ACCEPTANCE TESTS	Visual inspection, dielectric strength, proof pressure, water flow calibration, continuity & resistance, valve response, valve seat leakage, injector flow distribution, insulation resistance, steady state performance.

TITLE	SM RCS ENGINE
PROBLEM AREAS	
Current	None
MMH Supp. Qual	MMH, helium saturated propellants, direct coil arc suppression, inhibited N_2O_4
Qualification	Combustion chamber shattered during cold MDC failure caused by ignition spike induced by oxidizer lead caused by oxidizer valve leak. Oxidizer valve leak caused by ZOT induced by inadequate space simulation.
Development	Valve seat leakage - single angle, pure teflon seat
	Valve bobbin leakage - improved inspection technique
	Low thrust - enlarged oxidizer P.I. windows
	Chamber shattering - pre-ignitor, fuel lead, ribbed chamber, 12 on 12 injector; 2 piece chamber
	High chamber temp. - Oxid. standoff, fuel film cooling, grit blasted combustor
	Pre-Ignitor Melting- Fuel film cooling, enlarged 1 cooling hole
	Low Performance - Accepted as is.
	Oxidizer Standoff Buckling - Increased standoff strength
	Thrust oscillations - Accepted as is. (saturated propellants)
Acceptance Test	.Valve Inlet Strainers - quality 165-233 μ
	.Oxidizer Valve attach screw head recess - quality
SM ENGINE QUAL "ZOT" FAILURE	."B" Engine S/N 0009
	.OX Injector Manifold Explosion - Caused by fuel migration into ox manifold
	.All tests rerun on new engine
	.Failure caused by Facility (too hi amb press) .06 psia
	.Tests rerun successfully (lower amb. press) .02 psia

22. Command Module Rocket Engine Assembly

The command module rocket engine assembly (Figure 22-1) consists of an oxidizer valve assembly, a fuel valve assembly, and a thrust chamber assembly.

The oxidizer valve assembly consists of a 430F steel (solenoid quality steel) core, an armature spring, an armature assembly, a seat assembly, and a coil assembly. The coil assembly is composed of a stainless steel bobbin weldment and two coils, the direct coil and the automatic coil. The bobbin weldment consists of a solenoid-quality steel large-flanged forward tube, a stainless steel tubular spacer, a solenoid-quality large-flanged aft tube, and a stainless steel aft small-flanged tubular projection; the four pieces are joined by heli-arc welding. The direct coil is wound around the bobbin tubular center section at the upstream end of the bobbin. The direct coil contains 1870 turns of #28 AWG single ML magnet wire having a resistance of 30 +1.88, -0.00 ohms at 70°F. The automatic coil is wound around the bobbin tubular center section at the downstream end of the bobbin and contains 935 turns of #28 SWG single ML magnet wire having a resistance of 15 +0.88, -0.00 ohms at 70°F.

The core is a thick-walled tube with a small flange and is installed in the upstream half of the coil assembly bobbin under the direct coil. A stainless steel inlet housing is threaded into the bobbin behind the core and serves to hold the core flange against a bobbin shoulder. The armature assembly and the seat assembly are installed in the downstream section of the coil assembly bobbin with the armature positioned under the automatic coil and the seat assembly threaded into the small-flanged tubular projection downstream of the armature. A flange of the seat assembly housing is welded to the flange of the projection. The armature spring is installed in a recess in the armature assembly; one end of the spring bears against the bottom of the recess in the armature and the other end of the spring is restrained by the downstream end of the core.

The armature assembly consists of a solenoid-quality steel armature and a stellite ball; the ball is installed in a hemispherical seat in the downstream end of the armature and a lip of the armature is crimped loosely over the ball. The seat assembly is composed of a teflon seat installed in a stainless steel housing and held in place by a stainless steel retainer; the retainer is pressed into the housing behind the teflon seat and a lip of the housing is spun over the retainer.

The inlet housing contains a 5 micron nominal, 15 micron absolute filter and is equipped with an external thread at the inlet. The filter is held in place by a trim orifice which is installed against a shoulder in the inlet housing and is held in place by a snap ring.

A tubular stainless steel jacket weldment is installed over the coil assembly and welded to the large diameter flanges of the bobbin. The jacket is equipped with a short, large diameter access tube which is welded perpendicular to the jacket center line. The header plate of the leadwire housing assembly is welded to the outboard edge of the access tube. The leadwire assembly consists of a stainless steel header plate, a micarta bushing, a stainless steel collar, a stainless steel nut, the oxidizer valve lead wires, and a stainless steel housing. The electrical leads from the coils are connected to the four contacts installed in the header plate; the contacts are insulated from the plate by glass insulation. The end of the oxidizer valve lead wires are fed through the holes in the bushing and connected to the outboard ends of the contacts. The connections are encapsulated with a silicone rubber potting compound. The bushing is wedged between oppositely sloped conical surfaces of the housing and the collar. The collar is held against the bushing by the stainless steel nut which is threaded onto the housing. The housing is welded to the header plate.

Before either the direct coil or the automatic coil is energized, the stellite ball is held against the teflon seat by the force of the armature spring plus the force of propellant inlet pressure acting on the armature, thus preventing oxidizer from flowing downstream of the oxidizer valve assembly. When either of the coils is energized, the force set up in the armature by the electromagnetic field will overcome the force holding the armature against the seat and the ball will be pulled away from the seat. The oxidizer entering the oxidizer valve assembly will flow into the inlet housing, through the orifice, and then through the filter. The filter will remove any particulate contamination. The oxidizer will then flow through the centers of the core, the armature spring and the armature, around the ball, through the center of the seat assembly, and finally to the tube leading to the injector assembly.

The fuel valve assembly is identical in construction and operation to the oxidizer valve assembly except for the size of the thread on the inlet housing assembly and the size of the orifice.

The thrust chamber assembly consists of an injector assembly, a body assembly, and a stainless steel shell. The injector assembly, fabricated of stainless steel, is composed of a central oxidizer manifold and a peripheral fuel manifold. The body assembly consists of a silica fabric reinforced phenolic combustion chamber sleeve, a nozzle throat insert made of a graphite zirconium diboride silicon composite, a nozzle body made of a high silica laminated ablative material, and a covering of asbestos phenolic. The downstream face of the throat insert is installed against a shoulder of the nozzle body; the shoulder is located just downstream of the body center. The combustion chamber sleeve is installed in the nozzle body upstream of the throat insert. All the parts are bonded together. The asbestos phenolic is bonded to the outside of the nozzle body. Ears of the injector assembly are bonded to a conical surface at the upstream end of the body assembly, with a high temperature rubber O-ring installed between the assemblies before bonding. Glass fabric is then wrapped around and bonded to the outer surface of the injector assembly ears and the outer surface of the liner assembly. The assembled injector assembly and liner assembly are encased in the stainless steel shell which is welded to the injector assembly and bonded to the liner assembly. A layer of alumina silica insulation is installed between the body assembly and the shell around the circumference of the body upstream of the throat. The downstream end of the shell is located just downstream of the throat and has a flange with sixteen holes for mounting purposes.

The oxidizer valve assembly and the fuel valve assembly are welded to brackets which are welded to the thrust chamber assembly. Three-eighths OD stainless steel tubes provide propellant passage from the valve assemblies to the injector manifolds. The tubes are attached by welding at both ends.

Oxidizer leaving the oxidizer valve assembly flows through the three-eighths inch tube to the circular oxidizer manifold in the injector assembly. From the manifold, the oxidizer flows through sixteen equally spaced 0.026 inch diameter holes to the combustion chamber. The sixteen holes are drilled at a slight angle away from the center line of the engine. Similarly, the fuel leaving the fuel valve assembly flows through the three-eighths inch tube to the circular fuel manifold in the injector assembly. From the manifold, the fuel flows through sixteen equally spaced 0.021 inch diameter holes to the combustion chamber. The sixteen holes are drilled outboard of the oxidizer injector holes at a slight angle toward the center line of the engine. The fuel injector holes and the oxidizer injector holes are on the same radial lines. Because of the angles of the drilled holes, the flow of oxidizer intersects the flow of fuel almost immediately after they leave the injector assembly. The upstream conical surface of an internal shoulder is located at the intersection point; this surface serves as a "splash" plate. The intersecting flow paths and the splash plate ensure that the oxidizer and fuel mix and react as required to produce the optimum in ignition characteristics, combustion stability, and temperature distribution on the inner wall of the combustion chamber.

Upon mixing, the propellants react hypergolically. The products of this reaction are high temperature gases which create a high pressure in the combustion chamber before escaping through the engine nozzle throat. The gases are accelerated to supersonic velocity in the divergent section of the nozzle and produce a resulting thrust as the gas molecules leave the nozzle exit.

Nozzle extensions are provided to duct the engine exhaust gases through the spacecraft heat shield. These nozzle extensions are provided in three basic configurations dimensioned to fit the specific spacecraft installation requirements for pitch, roll and yaw positions. Each nozzle extension is scarfed after installation to match the precise contour of the spacecraft heat shield. The nozzle extensions are fabricated from zero degrees oriented high silica fabric reinforced laminated phenolic. Redundant sealing for exhaust gas leakage between the engine and nozzle extension is provided by a Viton rubber O-ring and a plastic (nylonate phenolate ablative) gasket.

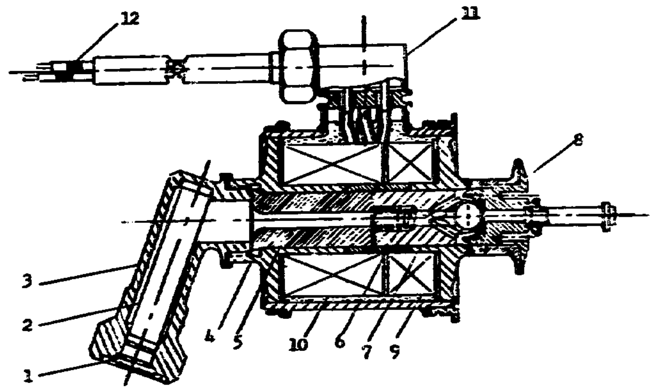
The important performance characteristics of the rocket engine assembly are listed below.

Propellant inlet pressure	
Static, operational range	291 +11 -4 psia
Dynamic, operational range	280 +11 -4 psia
Dynamic, specification performance	280 ±4 psia
Chamber pressure, nominal	140 psig
Proof pressure, specification requirement	
Valves	540 psig
Burst pressure, specification requirement	
Valves	720 psig
Maximum external propellant leakage	None allowed
Maximum internal (seat) leakage	5 cc/hour Helium at 300 psig
Voltage, specification performance	24 - 30 VDC
Voltage, operational range	21 - 32 VDC
Maximum current	
Automatic coils	4 amps at 27 VDC
Direct coils	2 amps at 27 VDC
Maximum operating temperatures	
Propellant valves	200°F
External wall	850°F

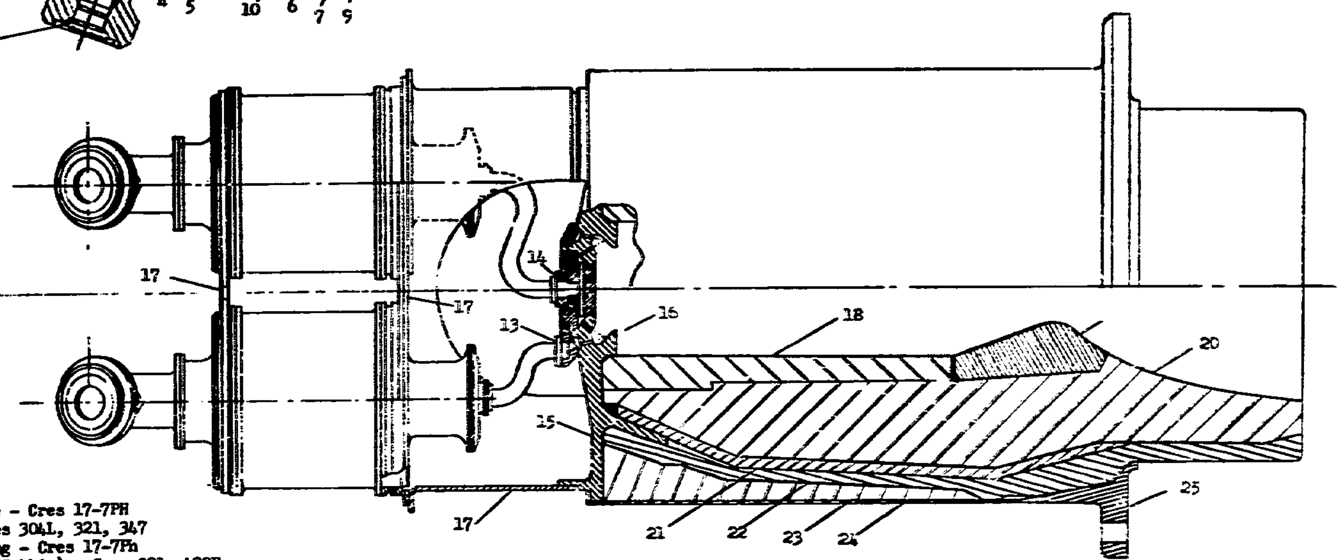
Propellant Temperature Range	40° to 100°F
Oxidizer-to-fuel ratio	2.1 to 1
Vacuum thrust, specification requirement	88.3 lbs. minimum
Minimum total operating life, specification performance	130 seconds (pulsing)
Operational range	273 seconds (including 200 sec steady state) 3000 cycles
Specification number	MC901-0067
SCD number (NR part number)	
Qualified engine (Pre-charred liner)	ME901-0067-0011
Qualified engine (O/F = 2.0)	ME901-0067-0012
Qualified engine (Delaminated liner)	ME901-0067-0013
Qualified engine (Virgin liner)	ME901-0067-0014
Qualified engine (Low Isp)	ME901-0067-0015
Prototype engine	ME901-0067-0001
Prototype engine	ME901-0067-0005
Pre-qualified engine	ME901-0067-0006
Prototype engine	ME901-0067-0010
Pre-qualified engine (B/B Phase II)	ME901-0067-0008
Development engine (tested at AEDC)	ME901-0067-0003
Pre-qualified engine (tested at AEDC)	ME901-0067-0007
Development engine (Non-fireable) (B/B Phase I)	ME901-0067-0002
Development engine (Non-fireable) (B/P 14)	ME901-0067-0004
Qualified Nozzle Extension (Pitch)	ME901-0189-0004
Qualified Nozzle Extension (Yaw)	ME901-0189-0005
Qualified Nozzle Extension (Roll)	ME901-0189-0006
Prototype nozzle extension (Pitch)	ME901-0189-0001
Prototype nozzle extension (Yaw)	ME901-0189-0002
Prototype nozzle extension (Roll)	ME901-0189-0003

Development nozzle extension (+P)	ME901-0189-0101
Development nozzle extension (-P)	ME901-0189-0102
Development nozzle extension (+Y, -Y)	ME901-0189-0103
Development nozzle extension (CW-B)	ME901-0189-0104
Development nozzle extension (CCW-A)	ME901-0189-0105
Development nozzle extension (CCW-B)	ME901-0189-0106
Development nozzle extension (CW-A)	ME901-0189-0107

Supplier	Rocketdyne, a Division of NR Canoga Park, Calif.



11. Leadwire Housing - Cres 347
12. Leadwires - AWG 20, MIL-W-16878 Type EE 19 Strand Nickel Coated
13. Fuel Manifold
14. Oxidizer Manifold
15. Injector Assembly - Cres 321
16. Splash Plate
17. Valve Mounting Bracket - Cres 321
18. Thrust Chamber Sleeve - 6° oriented high silica fabric reinforced laminated phenolic
19. Thrust Insert - Refractory Graphite, Zirconium Diboride, Silicon Composite
20. Nozzle Body - 45° Oriented high silica fabric reinforced laminated phenolic
21. Asbestos Wrap - Asbestos phenolic
22. Glass Wrap - Uncured Phenolic Resin Impregnated Glass Roving
23. Insulation - Alumina Silica Fiber
24. Thrust Chamber Shell - Cres 321
25. Mounting Flange



1. Trim Orifice - Cres 17-7PH
2. Filter - Cres 304L, 321, 347
3. Inlet Housing - Cres 17-7Ph
4. Valve Body (Bobbin) - Cres 321, 430F
5. Core - Cres 430F
6. Spring - Cres 17-7PH
7. Armature - Cres 430F w/stellite ball
8. Valve Seat Assembly - Cres 321, 17-7PH w/FEP Teflon Seal
9. Automatic Coil
10. Direct Coil

Figure 22-1. Rocket Engine Assembly

TITLE	CM RCS ENGINE
PN	ME901-0067-0011 (O/F = 2.1) -0013 (delaminated liner) -0012 (O/F = 2.0) -0014 (virgin liner)
QUAL TCD	December 31, 1965
QUAL TESTS	Performance calibration, shock, vibration, humidity, salt fog, acceleration, electrical & structural integrity, vacuum temp. cycling, pre-fire heating, pre-fire cooling, direct coil operation, mission simulation, hot fire proof pressure, final examination.
SUPPLEMENTAL QUAL - DELAMINATED LINER	(Limited to Yaw position only) ME901-0067-0013 Performance calibration, electrical and mechanical, mission simulation (ambient), final examination.
TCD	February 10, 1967
SUPPLEMENTAL QUAL - VIRGIN LINER	ME901-0067-0014 Performance calibration, electrical and mechanical, mission simulation (ambient and hot), hot fire proof pressure, final examination.
TCD	July 28, 1967
OFF LIMIT TESTS	High and low temperature, high and low O/F, high and low inlet pressure, valve mismatch, life, high humidity, vibration (failed at 2.5 x abort levels).
ACCEPTANCE TESTS	Visual and X-ray inspection, valve seat leakage, proof pressure, dielectric strength, valve response, liquid flow calibration, steady state performance, insulation resistance.
PROBLEM AREAS	
Current	None
Qualification	.Throat spalling - epoxy coating, failure of epoxy coated throat was facility induced. .Valve seat leakage - epoxy coating. subsequent to boost .Nozzle ext. to engine - viton O-ring as secondary seal seal leakage .Excessive skin temp. - installed heat sink in SC. .O/F shift - one piece orifice, inspection of two piece orifice. .Performance shift - induced by facility feed sys.

TITLE	CM RCS ENGINE	
PROBLEM AREAS (Cont.)		
Qualification (Cont.)	.Vent hole leakage - increased acceptable limits.	
	.Engine to noz. ext. mounting bolt excessive torque	- reworked noz. ext. to remove epoxy from threads, revised process to prevent epoxy from entering threads.
SUPPLEMENTAL QUAL - VIRGIN LINER	.Excessive thrust chamber outer wall temperature - attributed to plugged vent hole	
	.Short roll nozzle extension cracking - crack on O.D. only, no crack on any Spacecraft.	
DEVELOPMENT	.Thrust chamber body delaminations	- 45° one piece body
	.Combustion chamber liner Delam. & glassing	- 6° pre-charred ablative liner
	.Valve poppet opening during boost	- strengthened valve mounting brackets
	.Valve insulation resistance decrease after humidity exposure	- elastic valve header grommet.
	.Throat cracking - JTA throat, TR69 backing.	
	.Low performance - removed chamfer from oxidizer orifices.	
	.Valve bobbin leakage	- improved inspection and welding techniques.
	.Valve seat leakage - soft seat valve.	
	.Injector manifold explosions - strengthened injector.	
ACCEPTANCE	.Combustion chamber liner delaminations - virgin liner.	
	.Low I_{sp} - revised injector welding process to eliminate distortion.	
	.Valve response: Test circuit masks fast opening valve - revise procedures.	
	.Valve response: Slow - propellant decontamination, cleanliness procedures.	
	.Valve seat leakage - Valve deburring, cleanliness control.	

TITLE	CM RCS ENGINE
OFF LIMITS	Long Roll nozzle extension - failures were determined to have been induced by special test mount.
ENGINE MOUNTING BOLT FAILURE	Random Failure
8 ENGINES USED IN OFF LIMITS TEST	1 engine from Qual Prog. 7 Production rejects - (1 "worst" case engine had excessive ablative leakage; subjected to steady-state to destruction 1152 sec.!)
TYPES OF TESTS	Humidity (epoxy coat) Valve mismatch 100 ms both ways Off-limits vibration 2.5 x max. spec. Multiple MDC 2 x SS to Failure 1152 sec. vs 70 + MDC (100 sec) Demonstrated + Margin in every case No "Unexpected" Failures
NOTES	Inlet Filters - 5-15μ

23. <u>Valve, Solenoid, Low Delta P, Latching</u>

The Low Delta P Latching Solenoid Valve (Figure 23-1) is a two port (with integral filter), solenoid operated, latching, normally open or normally closed, shutoff valve. The valve consists of the following major assemblies: valve assembly, filter assembly, solenoid assembly, latching mechanism, position indicator switch assembly, electrical circuit, solenoid cover and mounting brackets.

<u>Valve Assembly</u>. The valve assembly is composed of a valve housing, a valve seat and support, a valve poppet assembly, a coil spring and cap, and inlet and outlet port stubs. The valve housing is machined from a 304L vacuum melt cres bar stock. The teflon seat is mounted against the shoulder of the seat support and held in position by a retainer ring welded to the support under a predetermined force to provide a seal around the seat. The seat assembly is welded to the housing. The poppet assembly is divided into two subassemblies: the shaft-bellows subassembly and the poppet-bellows subassembly. The shaft-bellows subassembly is composed of an AM350 steel bellows and a stainless steel shaft. One end of the bellows is welded to the flange of the shaft, the other end is welded to a terminal ring. The poppet-bellows subassembly consists of an AM350 steel bellows welded to an AM355 poppet and to a terminal ring. The stem of the poppet is installed in a tubular guide of the terminal ring before welding the bellows to the poppet.

A teflon sleeve installed over the poppet stem provides a low-friction bearing surface for the movable stem. The shaft-bellows subassembly is attached to the poppet-bellows subassembly by threading the shaft into the poppet. The terminal rings of the bellows are welded to the housing. The bellows have three important functions: they provide a part of the net spring force which holds the poppet against the seat; they seal the movable shaft and poppet so that propellant is contained within the valve assembly; they provide pressure balance for the poppet-seat area in order to achieve a constant seating force regardless of variation in the fluid pressure. On the end of the poppet stem, a spring retainer with a low spring rate coil spring is installed. The spring retainer is locked to the stem by a cotter pin. The primary purpose of the coil spring is to provide an adjustable poppet seat load in addition to the bellows spring force. Spring load adjustment is obtained through the close-out end cap. Upon the final adjustment, the end cap is welded to the valve housing. The inlet and outlet port stubs are attached to the valve housing (after filter installation) by threads and welded to the housing to provide a leak proof joint.

Filter Assembly. The filter assemblies are installed at the inlet and outlet ports and they are an integral part of the valve. The purpose of the filters is to prevent entrance of contamination of the size considered detrimental to the satisfactory operation of the valve. Each filter assembly consists of the filter element and the structural components. The filter element is constructed from a single layer of Twilled Dutch Weave 304L wire cloth with 100 microns absolute filteration rating. The filter element is fusion welded to the two end supports to form a conical shape. The allowable pressure drop of the filter is 1.0 psid maximum at 1.32 #/sec N_2O_4 and 0.66 #/sec MMH at 248 psig inlet pressure. The filter assembly is retained in the inlet (and the outlet) side of the valve housing by the flange of the larger end-support of the filter. The retaining force is provided by the threaded port stubs.

<u>Solenoid Assembly</u>. The solenoid assembly consists of a coil assembly, an Armco ingot iron plunger, and an Alnico tubular permanent magnet. The magnet is installed around the outside of the coil assembly and is held in place against a shoulder of the coil assembly pole by an Armco ingot iron nut. The plunger is attached to the shaft of the shaft bellows subassembly and moves in the center of the coil assembly. The coil assembly consists of two concentric coils wound around a bobbin assembly which is composed of an Armco ingot iron pole and an Armco ingot iron flange separated by a stainless steel spacer; the three pieces are joined by furnace brazing. The coils are wound one on top of the other. The inner coil, or valve opening coil, contains 1150 turns of #26 AWG single ML coil wire having a resistance of 12.5 $\pm$0.1 ohms at 70°F. The outer coil, or valve closing coil, contains 294 turns of #31 AWG single ML coil wire having a resistance of 13.4 $\pm$0.1 ohms at 70°F. The solenoid assembly is

threaded onto the valve base assembly and locked by safety wire. The solenoid is actuated with a maximum pull-in voltage of 18 volts dc. The current will not exceed 2.5 amperes at 30 volts dc.

Latching Mechanism. With the solenoid de-energized and the valve poppet in either the fully closed or fully open position, the valve poppet is latched in this position. Latching the valve poppet in the open position is achieved by the permanent magnet of the solenoid assembly, which supplies enough force across the plunger gap to maintain the valve poppet in the open position without voltage on the solenoid coil when the plunger gap is zero. The valve poppet is maintained in the closed position without voltage on the solenoid coil by the pre-load of the balanced bellows assembly. The pre-load force is the combination of the bellows spring force and the adjustable coil spring force.

Position Indicator Switch Assembly. The indicator switch consists of an actuator assembly, a switch and bracket, and an aluminum spacer. The actuator assembly is composed of an Armco Iron Disc bonded to the aluminum actuator. The actuator assembly is attached to the extension of the solenoid coil plunger and is mechanically locked in place by a cotter pin to provide a positive indication of the poppet travel. The extension of the solenoid coil plunger is designed to allow at least 60 percent of free travel (in each direction) of the poppet before it contacts the switch actuator assembly. The bracket and switch assembly consists of a pair of permanent magnets bonded to an aluminum alloy bracket and a positive snap-action type switch bolted to the bracket. The switch is a single pole, double throw type provided with three wires so that it may be used to indicate either a normally closed or a normally open valve function. The switch contacts and terminals are gold to reduce contact resistance to a minimum value. The switch rating is 2.5 watts and the maximum allowable contact resistance is 50 milliohms. Operation: When the poppet moves toward the "closed" position, no actuation occurs in the switch actuating mechanism until a minimum of 60 percent of the stroke is completed. The extension of the solenoid plunger, which is positively connected to the poppet, contacts the switch actuating assembly and it is moved toward the switch plunger. When it comes near the permanent magnet, it attracts the Armco Iron plate which actuates the switch. The switch is held actuated by the magnetic attraction between the actuator assembly and the magnet. The switch now indicates that the valve is in the "closed" position. To move the switch to the de-actuated (normal) position, the poppet is free to travel until 60 percent of its travel is completed. The plunger now contracts the actuating assembly and pulls it free from the permanent magnet. The restoring force in the switch returns the contacts to their normal position and the switch indicates that the poppet is "open".

<u>Electrical Circuit</u>. The electrical leads from the coils and the switch are connected to the junction terminals of the printed circuit board. To preclude the possibility of degaussing the permanent magnet which provides latching force in the valve-open position, diodes in the common solenoid leads are utilized to prevent current flow in the event that voltage with incorrect polarity is applied across the solenoid. Redundant Zener diodes in series are wired into the circuit parallel to the solenoid coils and mounted on the printed circuit board. The circuit board is mounted on the switch spacer and locked in position. Six electrical leads from the circuit board are connected to the inboard terminals of the header assembly. The header assembly is a stainless steel plate with terminals insulated from the plate by glass insulation. The wires in the valve cable assembly are connected to the outboard terminals of the header. The cable assembly is tied to the valve by a stainless steel clamp which is bolted to the header assembly.

<u>Solenoid Cover</u>. A tubular cover with flanges on both ends is installed over the solenoid, the actuator switch assembly and the electrical circuit. One end of the cover is welded to the valve housing, the other end is welded to the header assembly. Through a hole in the cover, silastic potting is injected into the wiring cavity to completely encapsulate all wiring and solder connections. Air pockets are avoided by bleeding through a hole in the cover opposite to the fill hole. After the potting is

cured, the holes in the cover are plugged and the plugs are welded into place. The outboard side of the header is potted with silastic to cover the terminals. The potting is protected by covering it with a thin film of epoxy.

Mounting Brackets. Mounting of the valve is provided by three pre-formed strap-around mounting brackets. Between each bracket and the valve body is a split teflon liner to absorb some of the vibration energy and provide a soft mounting. One mounting bracket is located on the solenoid cover, the other two are mounted on the filter housings.

Normal valve operation is as follows:

1. Closed to open position: (a) Voltage is applied to the pull-in coil; (b) the magnetic flux generated by the pull-in coil, aided by the permanent magnet flux, overpowers the net seating force of the bellows and coil spring, moves the plunger to the closed (zero) gap position and in turn moves the poppet in the "open" position; (c) the position indicator switch is actuated to the valve-open position; (d) the pull-in coil is de-energized. The valve-open position (plunger closed gap) is maintained by the force of the permanent magnet.
2. Open to closed position: (a) Voltage is applied to the drop-out coil; (b) the magentic flux generated by the drop-out coil partially cancels the permanent magent force, the net seating force (bellows and coil spring) acts on the plunger, moves the plunger to the open gap position and in turn moves the poppet in the "closed" position; (c) the position indicator switch is

2. (cont)

actuated to the valve-closed position; (d) drop-out coil is de-energized. The valve-closed position (plunger open gap) is maintained by the net seating force (bellows and coil spring force).

The major performance characteristics and general information concerning the Low Delta P Latching Solenoid Valve are listed below:

Operating pressure	0 to 248 psig
Pressure surge	555 psig with 10 to 15 millisecond rise time
Proof pressure	496 psig
Burst pressure	992 psig
Pressure drop - including filters Oxidizer valve (N_2O_4)	7.4 psid at 1.32 #/sec flow at 60°F
Fuel valve (MMH)	4.4 psid at 0.66 #/sec flow at 60°F
Maximum external leakage	5×10^{-6} std. cc/sec of He
Maximum internal leakage from inlet to outlet or from outlet to inlet	20 std cc/hr
Solenoid current	2.5 ampers at 30 vdc
Maximum pull-in and closing voltage	18 vdc at ambient temp.
Indicator switch rating	2.5 watts with a max. contact resistance of 50 milliohms

Maximum continuous duty application of electrical power	2 minutes (with 10 minutes between operation)
Valve response	Open-to-close or close-to-open: 200 ms or less
Service life	4000 cycles without maintenance and 135 days of propellant exposure time
Inlet and outlet ports	$0.631 \begin{smallmatrix}+.000 \\ -.003\end{smallmatrix}$ O.D.
Length - inlet to outlet port	8.500 $\pm$.020
Height	6.4 in.
Max. body diameter	2.10 in.
Specification number	ST284MC0021
SCD number (NR part number)	
Oxidizer valve	ST2840021ME0001
Fuel valve	ST2840021ME0002
Supplier	National Water Lift Co. El Segundo, California
Supplier's part number per SCD	
ST2840021ME0001 (Ox)	3780000-1
ST2840021ME0002 (Fu)	3780000-2

1. 304L CRES
2. 302 CRES
3. AM350 CRES
4. AM355 CRES
5. Armco Ingot Iron
6. Alnico Magnet
7. Aluminum Alloy
8. Epoxy
9. Silastic Potting
10. Teflon

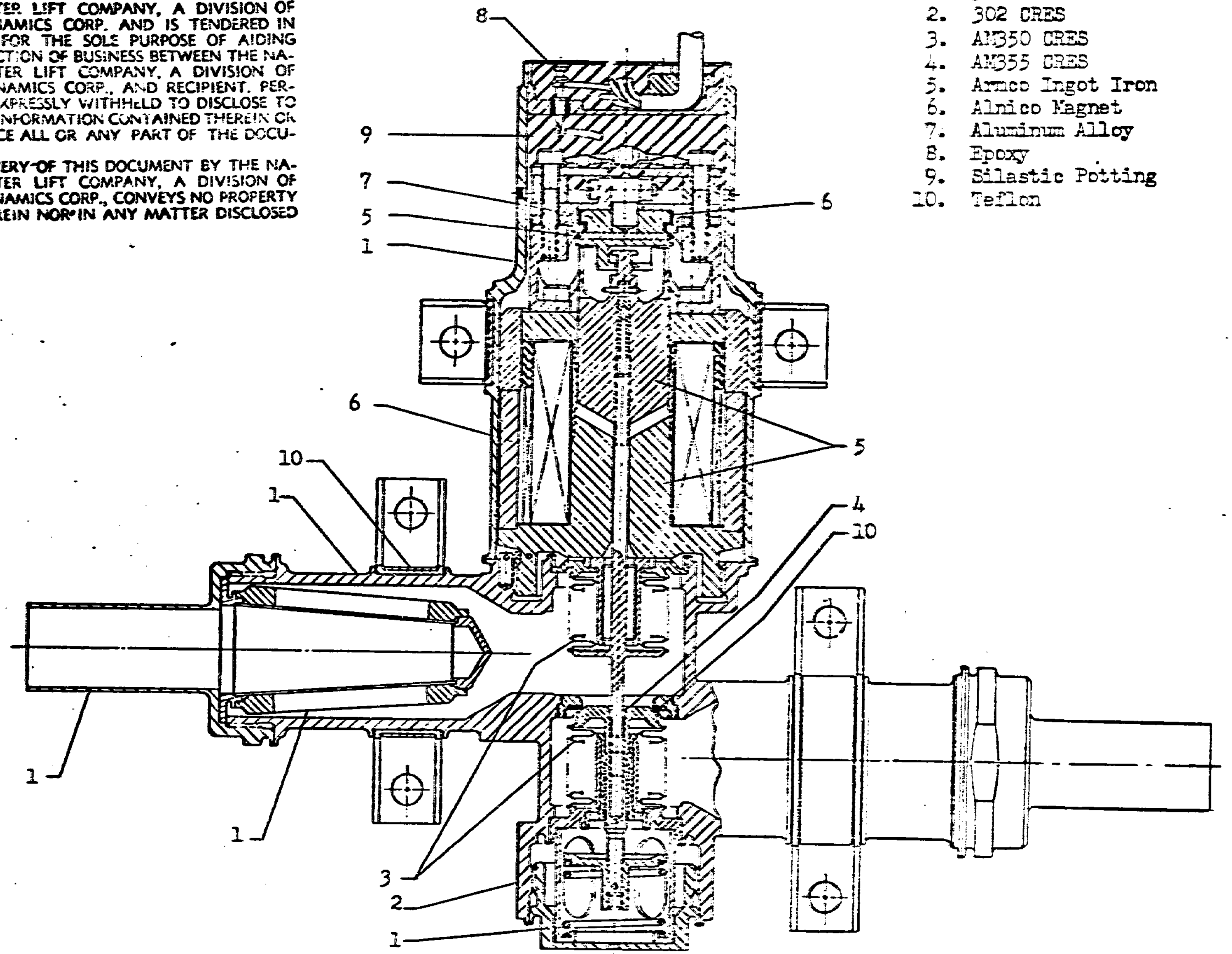


Figure 23-1. Low Delta P Latching Solenoid Valve

24. Hydropneumatic Accumulator

The Accumulator (Figure 24-1) consists primarily of a stainless steel cylindrical housing, five-eighths inch O.D. stainless steel inlet and outlet tubes, a stainless steel welded bellows, an inboard bellows retainer, and a closeout plug assembly. The closeout plug assembly consists of a stainless steel outboard bellows retainer, a stainless steel pressure charge tube, and a position indicator device assembly. The position indicator device assembly consists of two electrodes, two 3 foot #24 gauge wires, epoxy compound, and a stainless steel cap. One electrode is mounted in a glass compression seal (isolated from the closeout plug assembly) and the other electrode is mounted to the closeout plug assembly. The inboard bellows retainer contains a leaf spring which contacts the isolated electrode when a pressure of 265 psig or greater is applied to the inlet or outlet ports of the accumulator. The leaf spring and the isolated electrode are used to confirm (continuity check) that no loss of pressure in the gas compartment has occurred.

The gas side (inside the bellows) of the accumulator is pre-charged with GN_2 through the pressure charge tube and sealed during acceptance tests. The welded bellows is in the relaxed position (bottom out on the propellant side) until a pressure is applied to the inlet or outlet port. The bellows will compress to the mid-position at system operating pressure (181 psig), and will not bottom out on the gas side or contact the position indicator device until a minimum pressure of 265 psig is applied to the inlet or outlet ports of the accumulator.

The accumulator will dampen pressure transients caused by the simultaneous firing of four engines (one per quad) for a single 30 ms pulse. The accumulator is capable of expelling a minimum propellant volume of 2.0 in^3.

The important performance characteristics of the accumulator and general information concerning the component are listed below:

Operating pressure	181 psig
Differential pressure	
Gas to propellant compartment	100 psig
Propellant to gas compartment	250 psig
Bellows stroke	.625 in.
Pressure drop	1.5 psi at an N_2O_4 flow rate of 0.5 #/sec and an MMH flow rate of 0.25 #/sec and an inlet pressure of 97 to 181 psia at 60°F.
Proof pressure	500 psig
Burst pressure	1000 psig
Maximum external leakage	5×10^{-7} std cc/sec He 1×10^{-7} std cc/sec GN_2
Maximum internal leakage	5×10^{-7} std cc/sec He 1×10^{-7} std cc/sec GN_2
Minimum total operating life	50,000 cycles
Specification number	ST282MC0003

SCD number (NR/SD part number)	
Qualified oxidizer-side valve	ST2820003ME-0001
Qualified fuel-side valve	ST2820003ME-0002
Supplier	Accessory Products Co. Division of Textron, Inc. Whittier, Calif.
Supplier's part number per SCD	
Dash number -0001	803600-0001
-0002	803600-0002

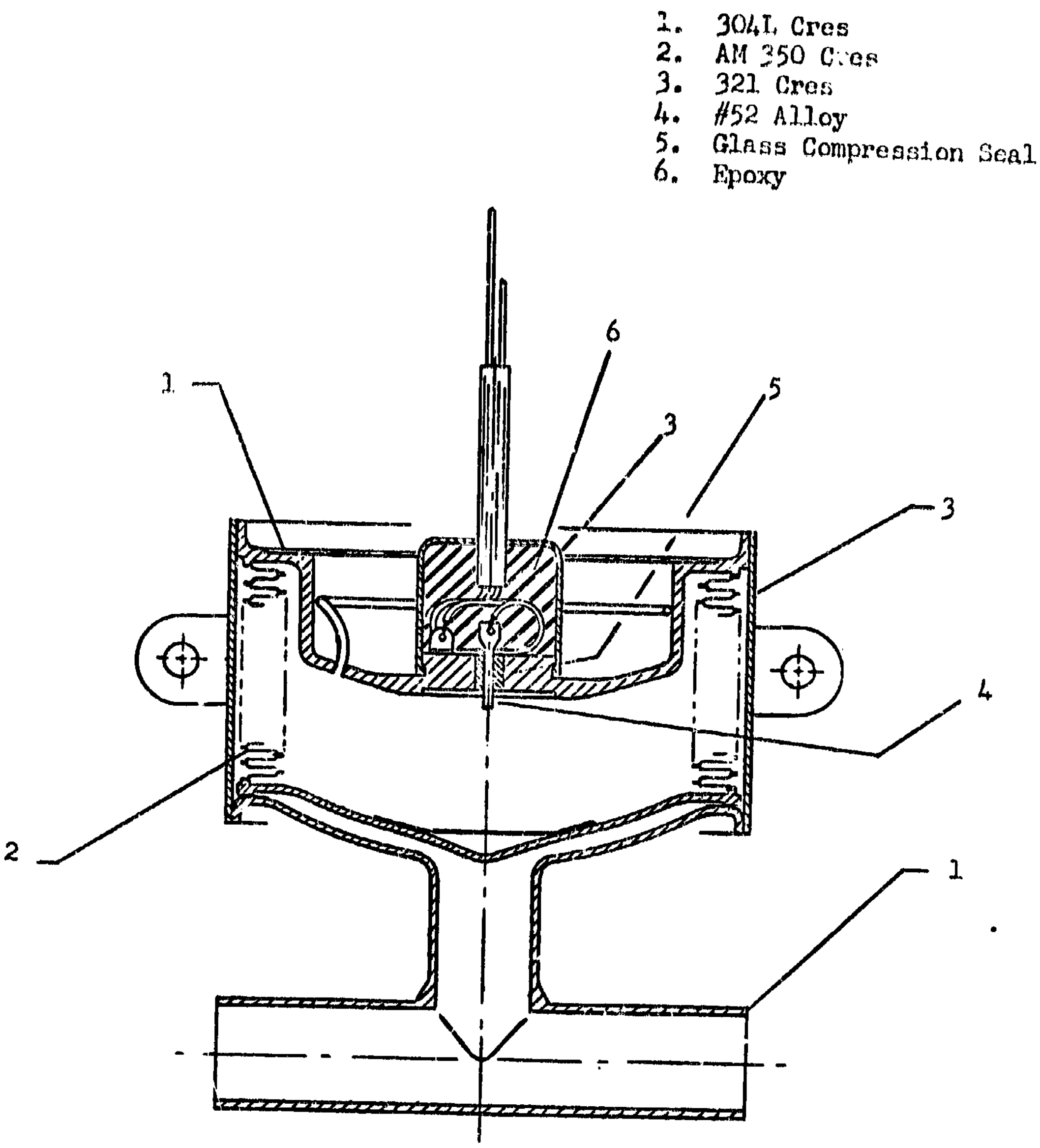


Figure 24-1. Hydropneumatic Accumulator

SECTION 13

SUMMARY

Section 13 summarizes the Command Module/Service Module Reaction Control Subsystem assessment review. There is no written text.

COMMAND MODULE/SERVICE MODULE REACTION CONTROL SUBSYSTEM

SUMMARY

- CONCLUSIONS
  - NO MAJOR WEAKNESS REVEALED IN CSM RCS
    - AREAS OF ASSESSMENT
      - COMPONENT QUAL ADEQUACY
      - CONFIGURATION ADEQUACY
      - MANUFACTURING FLOW
      - CHECKOUT REQUIREMENTS AND FLOW
      - SPECIAL MEASUREMENT DEVICES (SMD)/HARDWARE INTERFACES
      - INTERFACE PROBLEMS
      - PROTECTIVE DEVICES
      - SYSTEM QUAL ADEQUACY
      - FAILURE HISTORY
      - MANUFACTURING CHECKOUT
      - GROUND SUPPORT EQUIPMENT (GSE)/HARDWARE INTERFACES
      - INTERFACE VERIFICATION
      - COMPONENT DESIGN
  - FLIGHT EXPERIENCE HAS CERTIFIED THE ADEQUACY OF CSM REACTION CONTROL SUBSYSTEM (RCS)
  - SPECIFIED AREAS OF CONCERN REVIEWED WERE PREVIOUSLY RECOGNIZED
  - RATIONALE FOR ACCEPTING THEM STILL VALID
- RECOMMENDATION
  - NO CHANGES TO THE CSM RCS ARE REQUIRED
    - REASSESSMENT HAS REAFFIRMED THE SYSTEM ADEQUACY

NASA — MSC — Coml., Houston, Texas