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SACRAMENTO PLANT

REPORT NO. RP-TR-0015

TO

SPACE NUCLEAR PROPULSION OFFICE - CLEVELAND EXTENSION

COAXIAL INJECTOR DEVELOPMENT TEST

SERIES 1.2-09-NNJ

CONTRACT SNPC-35

SEPTEMBER 1967

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REPORT NO. RP-TR-0015

COAXIAL INJECTOR DEVELOPMENT TEST

SERIES 1.2-09-NNJ

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ABSTRACT

This report documents Test Series 1.2-09-NNJ, conducted during the period 11-13 July 1967 on Test Stand H-4B with Film-Cooled Nozzle Test-Assembly S/N 880002. The coaxial injector (P/N 1115321-19), controls system, valve sequencing, and the malfunction detection system were determined to be suitable for Phoebus-2 nozzle proof-testing.

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CONTENTS

	<u>Page</u>
I. Objectives	1
II. Description of Component	3
III. Test Setup and Procedures	5
IV. Test Results	17
V. Data Analysis	23
VI. Conclusions	35
List of Abbreviations	37

APPENDIX A

	<u>Page</u>
Part 1 - Basic Test Request and Supplements No. 1-6	A-1
Part 2 - Engineering Post Fire Inspection Report	A-21
Part 3 - Final Test Data at FS ₂	A-29
Part 4 - Critical Data Sheets and Test Engineer's Remarks Sheets	A-33
Part 5 - CALCOMP Plots	A-43
Plot A - NTA Milestone Parameters	A-43
Plot B - Nozzle Pressure Evaluation	A-44
Plot C - Nozzle Temperature Evaluation	A-45
Plot D - NTA Transient Evaluation	A-46

TABLES

<u>Number</u>		<u>Page</u>
1	Summary of Test Procedures for Test Series 1.2-09-NNJ	8
2	Test Results - 1.2-09-NNJ Series	18
3	Summary of High Frequency Data - Test Series 1.2-09-NNJ	30
4	Accelerometer Data Summary From Prior Testing	32

FIGURES

<u>Number</u>		<u>Page</u>
1	Test Assembly S/N 880002 Flow Schematic	4
2	Test Assembly Mounted in Test Stand H-4B	6
3	Test Assembly Instrumentation	20
4	Adapter Coolant Tubes After Testing	21
5	Nozzle Erosion After Testing	22
6	Adapter Braze Patch Locations	24
7	Adapter Braze Patch Data vs Predicted Wall Temperatures, Test No. 1.2-09-NNJ-004	25
8	Test Assembly Accelerometer Locations	28

I. OBJECTIVES

Test 1.2-15-NNN-004, the initial test of the coaxial injector, introduced some question concerning the suitability of the injector for convectively cooled nozzle testing because of suspected combustion instability. Since a flush-mounted, high-frequency chamber-pressure transducer to monitor combustion stability could not be used in the test assembly, the monitoring of combustion stability and the establishment of shutdown levels were undefined.

It was decided to conduct stability-evaluation tests with the film-cooled nozzle test assembly. The film-cooled nozzle was modified for installation of two flush-mounted, high-frequency Photocon transducers to monitor chamber pressure. Using these transducers as a reference, correlation with other instrumentation data (PfJ Kistler, PfJ EOS, PoJ EOS, and accelerometers also available on the convectively cooled nozzle test assembly) could be made.

This test series was also conducted to check-out the controls system after extensive modifications were made and additional safety features added as a result of the malfunction reported in Phoebus-2 Test Failure Report, Test No. 1.2-15-NNN-005, Report No. RP-TR-0012, April 1967.

Objectives of this test series were to:

1. Demonstrate the coaxial injector for Phoebus-2 nozzle testing.
2. Check-out the test control system.
3. Define start and shutdown valve sequence.
4. Demonstrate the safety features implemented to insure proper test conduct.

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II. DESCRIPTION OF COMPONENTS

A. FILM-COOLED NOZZLE, P/N 1134062-9, S/N 880608

The film-cooled nozzle is constructed of CRES 347 material shaped to the same gas-side contour as the Phoebus-2 nozzle, except that the exit area-ratio is 1.2:1.0. Nozzle cooling is provided by annular injection rings located at the core support-flange, the pressure-vessel flange, and upstream of the throat (see Figure 1). Through these three circuits an additional 30 percent fuel (by weight) is injected along the nozzle walls.

B. COAXIAL INJECTOR, P/N 1115321-19, S/N 884134

The coaxial injector is similar in design to the M-1 injector. It has a flat Rigimesh injector face and coaxial injector elements with oxidizer in the center tube and fuel in the outer annulus. This injector has been previously used in tests 12-15-NNN-004 through -006.

C. NOZZLE-TO-INJECTOR ADAPTER, P/N 1115486-9, S/N 880699

The nozzle-to-injector adapter joins the 21 7-inch injector interior diameter to the 59 12-inch nozzle interior diameter at a 45-degree angle. This CRES 347 adapter is regeneratively cooled by the hydrogen used for combustion and imparts sufficient heat to the fuel to preclude "cold" hydrogen combustion instability. The adapter pressure-vessel manifold joining the nozzle to the adapter is fabricated of 7039 aluminum and is designed to the configuration of the pressure-vessel flange.

Braze-alloy patches for wall-temperature indications were installed on the adapter tubes per Drawing 1117091.

D. IGNITER, P/N 1-069300-5 (.375 ALCLO)

The igniter consists of a squib and a charge of solid propellant. Four igniters, installed through the injector face near the injector/adaptor interface, are used for each test.

Figure 1 - Test Assembly S/N 880002 Flow Schematic

III. TEST SETUP AND PROCEDURES

A. TEST STAND H-4B

1. Mechanical Special Test Equipment and Facilities

Phoebus nozzle chemical tests are conducted on Test Stand H-4B at Aerojet-General Corporation's Sacramento facility. The stand has been modified for Phoebus testing by installing special test-assembly mounting and thrust take-out structures. The test assembly is mounted horizontally in the test stand with the oxidizer inlet at the top (see Figure 2).

Liquid hydrogen is supplied from a high-pressure, vacuum-jacketed, spherical run-vessel through a 12-inch diameter piping system to the nozzle for nozzle coolant and, in turn, through a 10-inch diameter piping system to the injector. Liquid oxygen is supplied to the injector through a similar system. Propellant flow rates are controlled by fast response (200 millisecond) servo-controlled, hydraulically operated valves. Pressurants are supplied from a gas farm where gaseous hydrogen and nitrogen are stored at 3500 psig and 5000 psig, respectively. Both supply systems have filters and servo-controlled, hydraulically actuated valves to regulate the gas for specific test conditions.

2. Controls System

Test control is accomplished by an analog programmer which regulates the servo-controlled valves used in Phoebus testing. Valve designations, together with design control modes, are:

TCOV (Oxidizer Thrust Chamber Valve)	Servo-controlled to maintain a steady-state chamber pressure of 685 psia.
TCFV (Fuel Thrust Chamber Valve)	Servo-controlled to maintain a steady-state mixture ratio of 5.5
OPCV (Oxidizer Tank Pressurization Valve)	Servo-controlled to maintain oxidizer-tank ullage pressure at 1600 psig.

Figure 2 - Test Assembly Mounted in Test Stand H-4B

FPCV (Fuel Tank Pressurization Valve)

Servo-controlled to maintain fuel-tank ullage pressure at 1535 psig

NCV (Nozzle Coolant Valve)

Servo-controlled to maintain a specified nozzle coolant flow-rate.

Control system design was considered in terms of the three distinct portions of a normal test firing: (1) start transient; (2) steady state; and (3) shutdown. Table 1 provides a description of valve operation during testing. A description of controls system design is contained in Engineering Report 0830:110, Status of Phoebus Convectively Cooled Nozzle Control System Design, 18 May 1967.

3. Fail-Safe Manifolds

A device to override the analog controller in the event of a control-system malfunction is provided in the fail-safe manifold system installed on the propellant control-valves. This system is placed between the servo-valve and the actuator and allows the valve to function as long as current is supplied to the fail-safe manifold. If the current is interrupted by one or more of the malfunction shutdown modes installed in the circuit, the manifold closes the valve at a predetermined rate. This system then takes control away from the analog controller and closes the propellant valves mechanically if any of the malfunctions listed in Table 1 occur.

B PHOEBUS TEST HISTORY

Prior Phoebus testing consists of: (1) five tests of the film-cooled nozzle (Series 1.2-08-NNJ) in which the test components, the test stand, and the control system were checked-out; (2) five tests of the S/N 880600 convectively cooled nozzle (Series 1.2-15-NNN) which resulted in significant changes to the controls and malfunction detection systems, and also introduced some question as to the suitability of the coaxial injector for use in convectively cooled nozzle testing; and (3) cold-flow tests to verify test-stand valves and piping operating characteristics.

TABLE 1

SUMMARY OF TEST PROCEDURES FOR TEST SERIES 1.2-09-NNJ

<u>I. SAFETY FEATURES</u>	<u>Symbol</u>	<u>Present Setting For Shutdown</u>	<u>Start</u>	<u>Steady State</u>	<u>Shut- Down</u>	<u>Comments</u>
A. MALFUNCTION FAIL-SAFE MANI- FOLD SHUTDOWN MODES						
1. Oxidizer tank overpressure	OOPS	$P_{OT} \geq 1700$ psig, Nominal $P_{OT} = 1600$ psig	X	X	X	
2. Fuel tank overpressure	FOPS	$P_{fT} \geq 1650$ psig, Nominal $P_{fT} = 1535$ psig	X	X	X	
3. Loss of 110-volt power	110 V Loss	Complete loss of 110-volt supply	X	X	X	
4. Hydraulic-fluid pump discharge pressure loss	PHD Min	$PHD \leq 2000$ psig, Nominal $PHD = 3000$ psig	X	X	X	
5. Maximum chamber pressure	P_C Max	$P_C \geq 715$ psia for test 001-002	X	X	X	
		$P_C \geq 725$ psia for test 003-004				
6. Minimum chamber pressure	P_C Min	$P_C \leq 635$ psia		X		
7. Maximum mixture ratio	MR Max	$MR \geq 6.0$ for test 001-002 $MR \geq 6.2$ for test 003-004		X		
8. Minimum mixture ratio	MR Min	$MR \leq 4.0$		X		
9. Combustion stability moni- tor - P_{C3A} high frequency flush mounted Photocon	CSM ₁	Frequency ≥ 1000 cps, Peak- to-peak amplitude ≥ 100 psi. Duration $\geq .030$ sec	X	X	X	Amplitude setting changed to ≥ 150 psi for Test 004 only.
10. Combustion stability moni- tor - P_{C3B} high frequency flush mounted Photocon	CSM ₂	Frequency ≥ 1000 cps, Peak- to-peak amplitude ≥ 100 psi. Duration $\geq .030$ sec	X	X	X	Amplitude setting changed to ≥ 150 psi for Test 004 only.

TABLE 1 (cont.)

<u>I. SAFETY FEATURE</u>	<u>Symbol</u>	<u>Present Setting for Shutdown</u>	<u>Start</u>	<u>Steady State</u>	<u>Shut- Down</u>	<u>Comments</u>
A. MALFUNCTION FAIL-SAFE MANI- FOLD SHUTDOWN MODES (cont.)						
11. Minimum chamber pressure vs time from FS ₁ . Feature causes shutdown if no ignition or delayed ignition occurs.	TCPS ₁	$P_c \leq 100$ psig at FS ₁ + 1.85 sec	X			
12. Minimum chamber pressure vs time from FS ₁ . Feature causes shutdown if no ignition or delayed ignition occurs.	TCPS ₂	$P_c \leq 15$ psig at FS ₁ + 1.60 sec	X			
13. Minimum oxidizer control valve position after fuel valve is signaled open. Feature causes shutdown if oxidizer valve position shuttles or is lost after the fuel valve is opened.	SO 22	TCOV equal to or less than position at which TCFV is signaled open.	X	X		
14. Minimum fuel valve position vs time from FS ₂ . Feature insures shutdown if oxidizer or fuel valve does not respond to closing signal.	SF 90	TCFV $\geq 90\%$ of steady state position at FS ₂ + 0.45 sec				X
15. Oxidizer tank safety valve position micro	OTSV	OTSV $\leq 80\%$ open	X	X	X	
16. Fuel tank safety valve position micro	FTSV	FTSV $\leq 80\%$ open	X	X	X	
17. Oxidizer closing command signal	CLO	CLO ≥ 3.0 volts	X	X	X	
18. Fuel closing command signal	CLF	CLF ≥ 1.5 volts	X	X	X	

TABLE 1 (cont.)

I. SAFETY FEATURES (cont.)

C. CONTROL SYSTEM AND INSTRUMENTATION CHECKOUT

1. Analog programmer model simulation	Conducted as required to check control system stability, and to predict critical pressure, flow rate, and valve behavior during normal and fail-safe shutdown conditions. Sequence changes are also checked when required.
2. COMCOR on-line simulation	Conducted 2 hours prior to test. COMCOR responds to control system by producing electrical output similar to that produced by the flow meters, pressure transducers, etc. By this method, all control valves are cycled and normal control circuits can be checked. Only one normal and one fail-safe shutdown is checked before each test due to the undesirability of cycling the valves for each mode.
3. Control instrumentation continuity checks	Conducted immediately after COMCOR simulation to insure all control system instrumentation circuits have continuity from the measuring instrument to the control system. This check also gives indication whether instrument resistance has changed from the last calibration.
4. Data instrumentation calibration	Conducted one hour prior to, and immediately after, each test to insure instrumentation accuracy.
5. Test check lists	A prepared, checked, and rehearsed test sequence is documented on check lists to insure orderly and chronological test conduct.

II. VALVE SEQUENCING

A. START SEQUENCE

TCOV

Signaled open at FS₁. Opening ramp rate 26%/sec.

TABLE 1 (cont.)

II. VALVE SEQUENCING (cont.)

A. START SEQUENCE (cont)

TCFV	Begins to open at TCOV = 30% to Test 001 and TCOV = 25% for Test 005 Opening ramp rate 70%/sec.
NCV	Begins to open at TCFV = 10%. Opening ramp rate 87%/sec for Test 001-003. Opens to 27% in 0.4 sec for Test 004.

B. STEADY STATE

NCV	Controlled to give 30 lb/sec coolant flow.
TCOV	Controlled to give $P_c = 685$ psia.
TCFV	Controlled to give MR = 5.5.

C. SHUTDOWN SEQUENCE

1. Normal

TCOV	Signaled closed at FS_2 . Closes in 1.0 sec.
TCFV	Signaled closed at TCOV = 98% of position at FS_2 Closes in 1.35 sec.
NCV	Signaled closed at TCOV = 98% of position at FS_2 . Closes in 0.6 sec.
Fuel tank safety valve	Closed at $FS_2 + 2.5$ sec in 5 - 7 sec
Oxidizer tank safety valve	Closed at FS_2 in 1.5 sec.
Fuel bleed, high and low point	Opened at $FS_2 + 2.5$ sec.
Oxidizer bleed, high and low point	Opened at $FS_2 + 2.5$ sec.

TABLE 1 (cont.)

II. VALVE SEQUENCING (cont.)

C. SHUTDOWN SEQUENCE (cont.)

2. Malfunction Shutdown - Fail-Safe Manifold

Under fail-safe manifold shutdown mode, propellant valve control is switched from the controller to the fail-safe manifold.

TCOV	Closed at a constant rate of 52%/sec.
NCV	Closed at a constant rate of 55%/sec.
TCFV	Closed at a constant rate of 26%/sec.
Fuel tank safety valve	Same as normal shutdown.
Oxidizer tank safety valve	Same as normal shutdown.
Fuel bleed	Same as normal shutdown.
Oxidizer bleed	Same as normal shutdown.

3. Emergency Shutdown (ESS)

ESS is used only after a catastrophic failure has occurred in order to bring the stand to a "no-fire" condition as rapidly as possible. In this shutdown mode, each operation conducted in the normal or malfunction shutdown sequence is signaled simultaneously.

D. VALVE LIMITS

The propellant control valves are mechanically clamped.

TCOV	55% maximum allowable
TOFV	70% open position
NCV	85% open position Test 001 30% open position Test 002-004

III. CLEANING, DEHYDRATION AND PURGING PROCEDURES

A. CLEANING

1. All test components are cleaned to the level required by the propellant used.
2. The injector oxidizer manifold is flushed with methylene chloride after installation into the test stand.

B. DEHYDRATION

1. Prior to testing, the humidity level is maintained below 10% relative humidity.

C. PURGING

1. A positive purge is maintained on the propellant circuits at all times.
2. A GN_2 purge is initiated in the oxidizer manifold immediately before and after the test to remove propellants from the chamber.
3. GN_2 and helium purges are conducted on the fuel injector circuit immediately prior to test.
4. A GN_2 purge is initiated in the fuel injector and nozzle coolant circuits after the test to remove excess hydrogen.
5. A helium purge is initiated in the fuel propellant line (coolant and fuel) after the test to inert H_2 system.
6. A GH_e purge is maintained on the P_{c2} and P_{c5} instruments during a test.
7. A GN_2 purge of the adapter support cavity is maintained during a test.

IV. LEAK DETECTION SYSTEMS

1. TV cameras allow visual monitoring of the test stand. Known trouble areas (e.g., the fuel safety valve actuator at the bottom of the LH_2 run tank) are especially watched.
2. Automatic H_2 and infrared sensors monitor strategic locations where propellant leakage is most probable.

C. TEST PROCEDURES

The documents authorizing Test Series 1.2-15-NNN are the Test Specification, Report RP-DR-0002, and the Test Request and Supplements (see Appendix A). These documents are approved by projects, test operations, and reliability and quality assurance, and are reviewed by SNPO personnel before they are issued. A summary of the test procedures used for this test series is listed in Table 1.

A modes-of-failure analysis and a preliminary special-test-equipment system failure analysis* were prepared and reviewed prior to test.

*Phoebus-2 Nozzle Chemical Testing Modes-of-Failure Analysis,
Report No. 0822N004, Revision A, 24 May 1967.

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IV. TEST RESULTS

Descriptions of the tests, test hardware, and test results are shown in Table 2. Corrective action taken after each test is also noted in this table.

Control-system valve sequencing and the malfunction detection system were determined to be satisfactory.

Data for each test are shown in Appendix A. Figure 3 shows test assembly instrumentation locations. The following information is provided:

1. Basic Test Request and Supplements No 1 through 6
2. Engineering Post Fire Inspection Report
3. Final-data sheet for test parameters at FS₂
4. Critical-data sheet for hardware identification.
5. Test Engineer's Remarks Sheet.
6. CALCOMP plots, taken from millisecond recordings, as follows:

Plot A = NTA milestone parameters, Plot B = nozzle-pressure evaluation; Plot C = nozzle-temperature evaluation; and Plot D = NTA transient evaluation.

TABLE 2

TEST RESULTS - 1.2-09-NNJ SERIES

<u>Test No.</u>	<u>Date</u>	<u>Time</u>	<u>Duration, Sec</u>	<u>FS₂ Data</u>	<u>Test Description</u>	<u>Hardware Description</u>	<u>Comments</u>
001	11 July 67	2236	1.700	P _C = 205 psia MR = 31.2 W _C = 50 lb/sec	Combustion started smoothly, nozzle coolant flow overshoots to 70 lb/sec causing a closing demand on NCV exceeding the CLC kill setting of 2.5 volts. $\Delta P_C \Delta$ kill signalled after shutdown apparently caused by P _C oscillation being greater than 30 psi.	<u>Nozzle & Injector</u> No damage. <u>Adapter</u> - Coolant tubes heat marked in a band 5 to 15 inches from the core support flange and along the entire length of the tubes under the four igniter ports, see Figure 4.	Response of coolant valve too fast; therefore, gain was decreased to slow response. P _C feed-back to $\Delta P_C \Delta$ filtered to smooth oscillations.
002	12 July 67	1827	2.152	P _C = 700 psia MR = 4.9 W _C = 10.1 lb/sec	Combustion started smoothly, nozzle coolant valve responds too slowly resulting in inadequate coolant flow causing a W _C MIN shutdown.	<u>Adapter</u> - No change. <u>Injector</u> - Rigimesh face heat spotted. <u>Nozzle</u> - Throat eroded 0.050 inch maximum in 9-inch band from the nozzle exit (360°). Pressure vessel and core support coolant rings are heat marked (360°), see Figure 5.	Gain of coolant valve increased.
003	13 July 67	1509	1.806	P _C = 402 psia MR = 8.7 W _C = 53 lb/sec	Combustion system normal. W _C overshoot to 50 lb/sec caused NCV to close to a position lower than the NCV Min kill setting of 5%.	<u>Adapter & Nozzle</u> - No change <u>Injector</u> - Additional 1-inch diameter heat spot at 1 o'clock outboard of the ring baffle.	Coolant-flow demand changed from flow rate to a valve position.

TABLE 2 (cont.)

<u>Test No.</u>	<u>Date</u>	<u>Time</u>	<u>Duration, Sec</u>	<u>FS₂ Data</u>	<u>Test Description</u>	<u>Hardware Description</u>	<u>Comments</u>
004	13 July 67	2120	2.443	P _C = 695 psia MR = 5.0 W _C = 46.8 lb/sec	Combustion system normal. ΔP _C Δ shutdown occurred although measured value of the two P _C readings did not exceed the 30 psi differential kill setting. Apparently oscillations in P _C were of an amplitude that when out of phase would cause the differential between them to exceed 30 psi.	<u>Nozzle & Adapter</u> No change. <u>Injector</u> - Baffle under igniter ports slightly eroded.	Sufficient steady-state duration obtained to meet test objectives.

Figure 4 - Adapter Coolant Tubes After Testing

Figure 5 - Nozzle Erosion After Testing

V. DATA ANALYSIS

A. ADAPTER BRAZE PATCH DATA ANALYSIS

The test series was conducted with Adapter Assembly P/N 1115486-9, S/N 880699, which had braze alloy patches placed on the adapter tubes. The tests were stable and no hardware damage was apparent. The braze patches were inspected after each test, but no significant changes after the first test were noted.

Data used in this analysis are from the last test, No. 1.2-09-NNJ-004, and are as follows: $P_c = 695$ psia; $MR = 5.01$; $\dot{W}_T = 620.2$ lb/sec; $\dot{W}_f = 103.1$ lb/sec; $T_{fI} = 51^\circ R$; $P_{fI} = 1166$ psia. A heat-transfer analysis (computer program 8047) was made using the above test conditions with the gas-side heat-transfer coefficients derived from previous braze-patch data of the smaller NERVA technology adapter.

Selection of temperature ranges and braze patch locations was based on the wall-temperature predictions: these are shown in Figure 6. Three circumferential and seven axial locations are shown with six braze patches at each axial location. The braze patch temperatures ranged from 990 to 1670°F.

1. Discussion of Results

Braze-patch data are shown in Figure 7 with the predicted temperatures. The predictions agree reasonably well with the braze-patch data under the igniter, but the wall temperatures between the igniters were cooler: two of the three circumferential braze-patch locations were under the igniter holes. The braze-patch data show that the majority of the adapter tubes were probably at the lower temperatures because there were four igniters 90-degrees apart.

PATCH NO.	SOLIDUS TEMP. °F	LIQUIDUS TEMP. °F
4	990	-
5	1125	1145
6	1235	1310
7	1365	1450
8	1430	1500
9	1500	1575
10	1575	1600
11	1670	1697

Figure 6 - Adapter Braze Patch Locations

Figure 7 - Adapter Braze Patch Data vs Predicted Wall Temperatures, Test No. 1.2-09-NNJ-004

There were two areas under the igniter where the data and predictions were apart. The first was at the forward end adjacent to the injector where the braze patch "read" lower than predicted (1125 versus 1280°F): the lower temperature, however, can be attributed to film cooling. The second point is at an axial distance of about 13 inches where the patches "read" higher than predicted (≥ 1500 versus 1340°F). It is interesting to note that of the data taken, there seems to be two maximum temperature points at an axial distance of 4.0 and 13.0 inches.

The predicted coolant bulk-temperature rise and coolant tube pressure-drop were 57.2°R and 61 psi, respectively. Considerable test data scatter were noted for the coolant-outlet temperature and pressures. For example, outlet-manifold pressures (P_{f0}) ranged from 1025 to 1064 psia and temperatures (T_{fJ}) from 108 to 139°R: the respective averages are 1051 psia and 119°R. Based on these averages, the coolant temperature-rise and pressure-drop of the test would be 68°R and 110 psi. A direct comparison of the predicted and test data pressure-drop cannot be made at this time until a more detailed hydraulic analysis is conducted to insure that the comparisons are proper.

B. DYNAMIC DATA ANALYSIS

An analysis of the high-frequency data of tests 1.2-09-NNJ-001 through -004 was made: (1) to determine the combustion-stability characteristics of the coaxial injector; and (2) to establish stability-shutdown criteria for the convectively cooled nozzle when mated with the same injector.

On Tests 1.2-09-NNJ-002 and -004 there were indications of some unstable burning but no hardware damage.

The following instrumentation was installed to obtain high-frequency data:

1. Accelerometers

Since the nozzle configurations of the film-cooled and the convectively cooled nozzles are different, it was considered desirable to install a tri-axial accelerometer mount on the injector ring which would be identical for both nozzle test assemblies and would constitute a direct reference with this injector on both nozzles. Tri-axial accelerometers were mounted at three locations: (1) the injector ring; (2) the adapter support outer flange near the test-stand mounting ring; and (3) the nozzle jacket at a position midway down the convergence section, (see Figure 8).

2. Chamber Pressure

Two flush-mounted Photocon Model 352A water-cooled transducers, at the same axial distance from the injector but with 120° rotation from each other, were mounted in the nozzle convergent section. Transducer designations were Pc3A and Pc3B. The frequency response was flat to a minimum of 10,000 Hz.

3. Fuel Manifold

One Kistler transducer was flush-mounted with the internal manifold cavity and designated PfJ-1C. Frequency response was flat to 10,000 Hz. One EOS transducer (Electro Optical Systems Model 101003-0134) was instrumented but because of the hardware configuration was not flush-mounted. The tube passage from the transducer diaphragm to the fuel manifold was 2.7 inches long with a diameter of 0.180 in. The natural frequency of this tube configuration was between 2,000 and 3,000 Hz. Although the transducer has a very-high natural frequency, the system (tube and transducer) is limited by the tube connection.

Figure 8 - Test Assembly Accelerometer Locations

4. Oxidizer Manifold

One EOS transducer (Model 101003-134) was mounted in the oxidizer torus. Although the transducer has a very-high natural frequency (100,000 Hz), the limitation would be that imposed by the 1/2-inch long passage connection. The cavity resonance would be in the 6-7,000 Hz range.

5. Discussion of Results

A detailed review of the data indicates a discrete change in hardware stability on two of four tests. Tests 1.2-09-NNJ-002 and -004 show a locked-in oscillation frequency at 5,200 Hz with higher overall acceleration levels than those experienced on Tests 001 and 003 and on the previous series of tests with this injector. One difference noted is that Tests 002 and 004 reached a higher Pc level than any of the other tests. The tabulated maximum Pc levels are:

<u>Test No.</u>	<u>Test Duration (sec)</u>	<u>Max Pc Level (psia)</u>	<u>Injector Type</u>
1.2-09-NNJ-001	1.70	310	Coaxial
1.2-09-NNJ-002	2.15	700	Coaxial
1.2-09-NNJ-003	1.6	460	Coaxial
1.2-09-NNJ-004	2.4	710	Coaxial

It should also be noted that rough burning began on Test 002 with increasing chamber pressure at 670 psig and continued until a level of 550 psig was reached on the shutdown transient. This period was approximately 0.4 second. On Test 004, rough burning began with increasing chamber pressure at 700 psig and continued until a level of 500 psig was reached on shutdown transient. This period was approximately 0.6 second. There was no apparent increase of roughness once this higher chamber-pressure region was reached. Table 3 lists a tabulated comparison of frequency and oscillation level.

TABLE 3

SUMMARY OF HIGH FREQUENCY DATA - TEST SERIES 1.2-09-NNJ

TEST NO.	Predominant Frequency Maximum Level at Listed Frequency Maximum Overall Value Above 1000 Hz			Predominant Frequency Maximum Level at Listed Frequency Maximum Overall Value Above 1000 Hz			Predominant Frequency Maximum Level at Listed Frequency Maximum Overall Value Above 1000 Hz		
	Hz	PSI(RMS)	PSI(PP)	Hz	PSI(RMS)	PSI(PP)	Hz	PSI(RMS)	PSI(PP)
1.2-09-NNJ									
	<u>Pc 3A</u>			<u>Pc 3B</u>			<u>PfJ-1C</u>		
001	not analyzed low levels								
002	5200	3	33	5200	17	90	1000	10	
	10400	8		10400	6		5200	5	
003	7200	1	10	7200	3	20	1000	5	
004	5200	11	35	5200	27	90	1000	9	
	10400	3		10400	7		5200	6	
	<u>GJ-1X</u>			<u>GJ-1Y</u>			<u>GJ-1Z</u>		
	Hz	G's(RMS)	G's(RMS)	Hz	G's(RMS)	G's(RMS)	Hz	G's(RMS)	G's(RMS)
001	not analyzed low levels								
002	5000	80*	80*	5200	39*	60*	5200	35*	60*
	10000	61*		10400	28*		10400	42*	
003	4800	33	60	4800	51	60	4800	24	40
	9800	12					9800	20	
004	5200	113	140	5200	130	150	5200	66	90
	10400	83		10400	69		10400	51	
	<u>GA-1X</u>			<u>GA-1Y</u>			<u>GA-1Z</u>		
	Hz	G's(RMS)	G's(RMS)	Hz	G's(RMS)	G's(RMS)	Hz	G's(RMS)	G's(RMS)
001	not analyzed low levels								
002	5200	28*	50*	5200	38*	45*	5200	53	75
	10400	19*		10800	12*		10400	8	
003	7200	4	35	4200	3	35	7200	12	40
004	5200	25*	70*	5200	145	150	5200	103	150
	10400	42*		10400	39		10400	48	
	<u>GN-1X</u>			<u>GN-1Y</u>			<u>GN-1Z</u>		
	Hz	G's(RMS)	G's(RMS)	Hz	G's(RMS)	G's(RMS)	Hz	G's(RMS)	G's(RMS)
001	not analyzed low levels								
002	5000	131	150	5000	38	90	5000	61	95
	7200	25		2800	32		10400	24	
003	7200	34	50	2800	13	40	7200	15	40
	7800	18		7200	4		7800	17	
004	5200	96	130	5200	47	90	5200	71	95
	10400	26		2800	31		10400	38	

At this point it is interesting to compare data from the previously conducted convectively cooled nozzle series (1.2-15-NNN-001 through 005). The maximum chamber-pressure levels and injector type are:

<u>Test No.</u>	<u>Test Duration (sec)</u>	<u>Pc Level (psig)</u>	<u>Injector Type</u>
1.2-15-NNN-001	2.64	675	Multiorifice
1.2-15-NNN-002	2.9	710	Multiorifice
1.2-15-NNN-003	16.0	670	Multiorifice
1.2-15-NNN-004	1.9	550	Coaxial
1.2-15-NNN-005	1.8	490	Coaxial

On all of the above runs, no unusual condition was noted concerning stability (see Table 4). Acceleration levels were low on all tests: however, the last two tests did not attain full chamber-pressure level. If these data are compared with the later data gathered from film-cooled nozzle testing, it might be concluded that the coaxial injector is "stability-sensitive" with chamber pressure since only on those tests with chamber-pressure levels more than 550 psig was an increased acceleration level experienced. In the case of the film-cooled series, chamber-pressure was instrumented with high-frequency transducers and increased oscillation levels were noted in chamber pressure at the 5200 Hz frequency.

The two tests with increased acceleration levels (002 and 004) experienced a locked-in frequency of 5,200 Hz on both flush-mounted chamber-pressure transducers and all accelerometers. Although the 5,200 Hz was present on the flush-mounted PfJ-1C, the level was very low, indicating a combustion mode of unstable burning. No oscillation at this frequency (5,200 Hz) was detected in the oxidizer manifold. The two Photocons in the nozzle (spaced at 120° orientation) were not in-phase but, rather, nearly 180° out-of-phase. Additionally, one Photocon read approximately three times the oscillation amplitude of the other. These facts rule out a pure radial or longitudinal mode-of-instability and point rather to a type of transverse mode or a transverse combination mode.

ACCELEROMETER DATA SUMMARY FROM PRIOR TESTING

32

All dynamic transducers worked satisfactorily with the exception of some of the accelerometers which overscaled or saturated the operational amplifier. This is especially notable on Test 002 where the acceleration level exceeded the range level of some of the accelerometers. All accelerometers were re-ranged to higher levels after Test 002.

To determine a combustion stability monitor (CSM) trip-level for the three injector accelerometers, the analog tapes from 003 and 004 were played back through the CSM and the data trip-level noted. The data levels as seen by the CSM unit were:

<u>Function</u>	<u>003</u>	<u>004</u>
GJ-1X	69 g RMS	131 g RMS
GJ-1Y	59 g RMS	118 g RMS
GJ-1Z	62 g RMS	165 g RMS
GN-1X	126 g RMS	168 g RMS
GN-1Y	67 g RMS	112 g RMS
GN-1Z	67 g RMS	135 g RMS

From the above data, it can be seen that a level setting of 131 or less on the CSM GJ-1X for Test 004 would have resulted in a trip of the unit and a shutdown of the test. This, then, can become the basis of establishing a CSM trip-level for the next series of tests (1.2-16-NNN).

The backup CSM could be set to trip from a Kistler pressure transducer which is flush mounted in the fuel-injector manifold. This would give assurance of safety from severe oscillations starting in the propellant-feed system or progressing back to the fuel manifold from the combustion-chamber zone. The trip level recommended would be: pressure oscillations ≥ 100 psi peak-to-peak; frequency ≥ 1000 Hz; duration ≥ 0.030 second.

A pressure transducer flush-mounted in the combustion chamber remains the best device for monitoring combustion instability. With the change to convectively cooled nozzle testing, this will no longer be possible. Although accelerometers are not a good device for analyzing combustion modes, they are nevertheless satisfactory for monitoring the stability index of previously tested hardware.

6. Results and Conclusions

a. The coaxial injector exhibits a locked-in high-frequency instability at 5,200 Hz at amplitudes as high as 168 g RMS (as measured by accelerometers). Although these levels are greater than that previously experienced in Phoebus testing, the coaxial injector appears to be suitable for use in Phoebus nozzle proof-testing.

b. The primary CSM for convectively cooled nozzle testing should be accelerometer GJ-1X. CSM setting should be: amplitude >131 g RMS; frequency >1000 Hz; duration >0.030 second.

c. The backup CSM should be a PfJ-1C Kistler set at: amplitude >100 psi peak-to-peak; frequency >1,000 Hz; duration >0.030 second.

VI. CONCLUSIONS

A. The test controls system, valve phasing, and the malfunction detection system were proven to be suitable for subsequent testing.

B. The coaxial injector (P/N 1115321-19) was determined to be suitable for use in Phoebus-2 nozzle proof-testing.

C. The primary CSM should be installed on injector radial-mode accelerometer GJ-1X. The "kill" setting should be: amplitude ≥ 131 g RMS; frequency $\geq 1,000$ Hz; duration ≥ 0.030 second.

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LIST OF ABBREVIATIONS

CSM	Combustion Stability Monitor
FBV	Fuel Bleed Valve
FFC	Fuel Film Coolant
FIMP	Fuel Injector Manifold Purge
FMf	Flowmeter Fuel
FMo	Flowmeter Oxidizer
FS ₁	Fire Switch (At Ignition)
FS ₂	Fire Switch (At Shutdown)
GH ₂	Gaseous Hydrogen
GN ₂	Gaseous Nitrogen
LH ₂	Liquid Hydrogen
LIMP	LOX Injector Manifold Purge
LN ₂	Liquid Nitrogen
LNCV	Nozzle Coolant Valve Trace
LO ₂	Liquid Oxygen
LTCFV	Thrust Chamber Fuel Valve Trace
LTCOV	Thrust Chamber Oxidizer Valve Trace
MTCPS	Thrust Chamber Pressure Switch Monitor
NCBV	Nozzle Coolant Bleed Valve
NCMP	Nozzle Coolant Manifold Purge
NCPV	Nozzle Coolant Purge Valve
NCVS	Nozzle Coolant Valve Microswitch
NTA	Nozzle Test Assembly
PaNCV	Nozzle Coolant Valve Actuation Pressure
PaTCfV	Fuel Valve Actuation Pressure
PaTCoV	Oxidizer Valve Actuation Pressure
Pc	Chamber Pressure
PcNCVi	Nozzle Coolant Valve Pressure Inlet
PcO	Nozzle Coolant Outlet Pressure - Adapter Plenum
PcCL	FFC Nozzle Film Coolant Line - Venturi Pressure

LIST OF ABBREVIATIONS (cont.)

PffcM	FFC Nozzle Throat Manifold Pressure
PfI	Adapter Fuel Inlet Pressure
PfJ	Injector Fuel Pressure
PfO	Adapter Fuel Outlet Pressure
PfT	Fuel Tank Pressure
PfTCVi	Thrust Chamber Fuel Valve Pressure Inlet
PoI	Injector Oxidizer Inlet Pressure
PoJ	Injector Oxidizer Pressure
PoT	Oxidizer Tank Pressure
PoTCVi	Thrust Chamber Oxidizer Valve Pressure Inlet
RTT	Resistance Temperature Transmitter
TC	Thermocouple
TCFV	Thrust Chamber Fuel Valve
TCFVPV	Thrust Chamber Fuel Valve Pilot Valve
TcO	Nozzle Coolant Outlet Temperature
TCFVS	Thrust Chamber Fuel Valve Microswitch
TCOPV	Thrust Chamber Oxidizer Purge Valve
TCOV	Thrust Chamber Oxidizer Valve
TCOVPV	Thrust Chamber Oxidizer Valve Pilot Valve
TCOVS	Thrust Chamber Oxidizer Valve Microswitch
TCPS	Thrust Chamber Pressure Switch
TCV	Thrust Chamber Valve
TfJ	Injector Fuel Temperature
TfFM	Flowmeter Fuel Temperature
TfTCV	Thrust Chamber Fuel Valve Temperature
TNCV	Nozzle Coolant Valve Temperature
TNFM	Nozzle Flowmeter Temperature
ToFM	Flowmeter Oxidizer Temperature
ToJ	Injector Oxidizer Temperature
ToTCV	Thrust Chamber Valve Oxidizer Temperature

LIST OF ABBREVIATIONS (cont.)

Wf	Fuel Flow Rate by Weight
Wc	Total Fuel Film Coolant $Wc = WcNT + WcCS + WcPV$
WcNT	Fuel Film Coolant Flow Rate by Weight into Nozzle Manifold and Injected above Nozzle Throat
WcCS	Fuel Film Coolant Flow Rate by Weight Injected at Nozzle Core Support Flange
Wo	Oxidizer Flow Rate by Weight
W_T	Total Propellant Flow Rate $W_T = Wo + Wf$
WcPV	Fuel Film Coolant Flow Rate by Weight Injected at Nozzle Pressure Vessel Flange

APPENDIX A

PART 1, BASIC TEST REQUESTS AND
SUPPLEMENTS NO. 1-6

TEST REQUEST

ASC 2-112

Logged 5/16/67 10:44

☒ BASIC TEST REQUEST		SECURITY CLASSIFICATION			
		☒ UNCLASSIFIED ☐ CONFIDENTIAL ☐ SECRET ☐ OTHER (EXPLAIN)			
☐ SUPPLEMENT NO.	S T NUMBER 3537	TEST SERIES NO. 1.2-09-NNJ	WORK CHARGE NO. 0960-64-210	GWA REFERENCE TP. 193708	
TO: D. M. Tenenbaum			BLDG. 3308	DEPT. 0800	
REQUESTED BY: G. M. Kawashige <i>G. M. Kawashige</i>			BLDG. 2019A1	DEPT. 7750	EXT. 7655
ACTION APPROVAL: <i>[Signature]</i>			DATE	ESTIMATED COMPLETION DATE	
MANHOURS		INSPECTION REQUIREMENTS			

DESCRIBE BELOW: OBJECT OF TEST, INFORMATION DESIRED, MATERIAL FURNISHED, SUGGESTED TEST PROCEDURE, SUGGESTED TEST SETUP, GENERAL REMARKS:

1. **OBJECT OF TEST:** To determine acceptability of Coaxial Injector, P/N 1115321-19, for use on Phoebus-2 Nozzle proof tests.
2. **INFORMATION DESIRED:** Obtain data required per test specification, Phoebus-2 Nozzle, Nuclear Simulation, RP-DR-0002, Revision 1, dated 20 January 1967, except as noted under Item 8.
3. **MATERIAL FURNISHED:**
 - a. Test Assembly, Film Cooled Nozzle, P/N 1134247
 Nozzle Assembly, P/N 1115858-19, S/N 880002
 (1) Nozzle, P/N 1134062-9, S/N 880608
 (2) Injector, Coaxial, P/N 1115321-19, S/N 884134
 (3) Adapter, Nozzle-to-Injector, P/N 1115486-9, S/N 880699
 - b. Igniter Assembly, Gas Generator, .375 ALCL0, P/N 1-069300-5
 - c. TCA Cart, T-1015220
 - d. Lift Beam, TCA, T-1015219
 - e. Helium Leak Fixture, E-1015267.
4. **SUGGESTED TEST SETUP:** Per Drawing No. 1134247 After the first firing, retorque center 7/8-in bolt RN CS 10-44-44 in the coaxial injector to 340 - 360 ft/lbs. Recheck torque after each test until it is determined that it does not loosen during tests.
5. **BUDGET:** GWA 193708.
6. **REMARKS:** A minimum of one hour notice shall be given to Phoebus Project personnel prior to each test:
 C. M. Kawashige, 5-7655/363-3045
 R. L. Murray, 5-8017/YO 7-3167

DISTRIBUTION

COPY	1 ORIGINATOR	2 MASTER	3 ZONE ENGINEER	4 INST. OPERATIONS	5 DATA SERVICES	6 FACILITY DESIGN
COORDINATION APPROVAL			<i>[Signature]</i>			
DATE						

7. SUGGESTED TEST PROCEDURE: Conduct test per Test Specification, Phoebus-2 Nozzle, Nuclear Simulation, RP-DR-0002, Revision 1, dated 20 January 1967, except as noted under Item 8. and the following test plan:

TEST PLAN D

COAXIAL INJECTOR DEVELOPMENT TEST PLAN - FILM COOLED NOZZLE

Test No.	Dur. Sec.	MR	P _{c2} Psia	% Noz FFC	$\dot{W}_o^*$ #/sec	$\dot{W}_f^*$ #/sec	$\dot{W}_c^*$ #/sec	$\dot{W}_{cCS} + \dot{W}_{cPV}^*$ #/sec	$\dot{W}_{cNT}^*$ #/sec
001	2.4	5.5	685	30.3	545	99	30	14	16
002	5.0	5.5	685	30.3	545	99	30	14	16
003**	8.0	5.5	685	30.3	545	99	30	14	16

8. Modifications to Test Specification, Phoebus-2 Nozzle, Nuclear Simulation, RP-DR-0002, Revision 1, dated 20 January 1967.

a. Paragraph 2.0 - LIST OF ABBREVIATIONS

(1) Delete: W_{ffc1} , W_{ffc2} , W_{ffc3} , and P_{ffcL}

(2) Add:

P_{cCL}	FFC Nozzle Film Coolant Line - Venturi Upstream Pressure
ΔP_{cCL}	FFC Nozzle Film Coolant Line - Venturi Pressure Drop
$\dot{W}_{cCL-1}$ & $\dot{W}_{cCL-2}$	Nozzle Film Coolant Flow Rate into Adapter Plenum Through Coolant Lines 1 and 2, respectively
$\dot{W}_{cCS}$	Nozzle Film Coolant Flow Rate Through Core Support Flange Injection Ring. $\dot{W}_{cCS} = 1/2 (\dot{W}_{cCL-1} + \dot{W}_{cCL-2})$
$\dot{W}_{cPV}$	Nozzle Film Coolant Flow Rate Through Pressure Vessel Flange Injection Ring. $\dot{W}_{cPV} = 1/2 (\dot{W}_{cCL-1} + \dot{W}_{cCL-2})$
$\dot{W}_{cNT}$	Nozzle Film Coolant Flow Rate Through Nozzle Throat Injection Ring. $\dot{W}_{cNT} = \dot{W}_c - (\dot{W}_{cCL-1} + \dot{W}_{cCL-2})$

b. Paragraph 5.4.5 - Additional Purge Procedure (Revision):

5.4.5.1 A flow of ambient temperature GN₂ shall be maintained on the fuel line purge boss (FIMP) to maintain a pressure of .75-in. of water minimum, and in the oxidizer line purge boss (LIMP) to maintain a pressure of 1.5-in. of water minimum from the start of

*See Figure 1.

** To be conducted at project engineering discretion.

manifold degrease to FS₁. A flow of ambient temperature GN₂ will be maintained on the coolant line purge boss (CMP) to maintain a pressure of .75-in. of water, minimum, when the coolant line valve is open.

5.4.5.2 Pre FS₁ Purge

5.4.5.2.1 Ambient nitrogen purges of 750 ± 25 psig shall be conducted at the oxidizer inlet manifold immediately prior to FS₁ to remove all hydrogen which may have accumulated in the combustion chamber. Purge shall be terminated at FS₁.

5.4.5.2.2 LIMP shall be maintained on the oxidizer circuit until SO 22 (TCOV = 30%).

5.4.5.2.3 A low pressure GH_e purge shall be conducted on the injector fuel circuit prior to FS₁ and terminated at SO 22 (TCOV = 30%).

5.4.5.2.4 A 150 psig GH_e purge shall be conducted on the nozzle coolant inlet manifold prior to FS₁ and terminated at SO 22 (TCOV = 30%).

5.4.5.3 Test Purge

5.4.5.3.1 A GH_e purge shall be maintained on all P_c2 and P_c5 instruments during the conduct of a test.

5.4.5.3.2 An ambient GN₂ purge of the adapter support cavity shall be conducted during testing. See Figures 1 and 2 of Test Specification RP-DR-0002, Revision 1.

5.4.5.4 Posttest Purge

5.4.5.4.1 An ambient gaseous nitrogen purge at 750 psig ± 25 shall be initiated at FS₂ at the two-inch boss on the oxidizer inlet manifold.

5.4.5.4.2 A shutdown fire control GN₂ purge is permissible on the fuel and coolant circuit, provided it is actuated no earlier than FS₂ + 2.5 sec.

5.4.5.4.3 Propellant lines downstream of the tank safeties must be purged with GN₂ to remove water vapor any time they have been opened to atmosphere. The purge must be continued until the water vapor has been displaced by GN₂ to a relative humidity of 10% maximum.

5.4.5.4.4 A 150 psig GN₂ purge shall be conducted on the nozzle coolant inlet manifold at FS₂.

c. Paragraph 5.5 - INSTRUMENTATION

5.5.1 Instrumentation Drawing 1134232 shall be used. See Figure 2 of Test Request for accelerometer locations.

5.5.2 Reference Table 5, Instrumentation

Table 5, Part b

32.	P_{OJ-2G}^b	Monitor with high frequency EOS transducer
34.	P_{fJ-1B}^b	Monitor with high frequency EOS transducer

Table 5, Part c

58.	$P_{ffC}M-B$	Delete

Table 5, Part d

60.	$P_{ffC}L-1$	Change to P_{CCL-1}
61.	$P_{ffC}L-2$	Change to P_{CCL-2}
62.	$P_{C}MO$	Delete
64.	$\Delta P_{ffC}L-1$	Delete
69.	$\Delta P_{C}MO$	Delete

Table 5, Part e

95.	T_{cO-H}	Monitor with C/A Thermocouple
Range 0 - 400°F
99.	T_{fJ-D}	Delete

Additions to Table 5

<u>PARAMETER</u>	<u>TRANSDUCER TYPE</u>	<u>RANGE</u>	<u>DCS</u>	<u>OSCIL</u>	<u>TAPE</u>	<u>DESCRIPTION</u>
P_{fJ-1C}	Hi Freq. Press. (Kistler)	0-1500 psi			X	Fuel Inj. Manifold Press. Measured Through T_{fJ-D} Boss
P_{C-3A}	Hi Freq. Press. Photocon	0-1000 psi			X	Chamber Pressure, CSM_1
P_{C-3B}	Hi Freq. Press. Photocon	0-1000 psi			X	Chamber Pressure, CSM_2

Additions to Table 5 (continued)

<u>PARAMETER</u>	<u>TRANSDUCER TYPE</u>	<u>RANGE</u>	<u>DCS</u>	<u>OSCIL</u>	<u>TAPE</u>	<u>DESCRIPTION</u>
ΔP_{cCL-1}	Pressure	0-50 psi	M			Venturi - Coolant Line No. 1
ΔP_{cCL-2}	Pressure	0-50 psi	M			Venturi - Coolant Line No. 2
GJ-1X	Accelerometer	0-50 g			X	Injector
GJ-1Y	Accelerometer	0-50 g			X	Injector
GJ-1Z	Accelerometer	0-50 g			X	Injector

d. 5.6.2 - Digital Plot Requirement (Note: Include NTA, Injector, and Nozzle Part Number and Serial Number)

5.6.2.1 Preliminary Data

TITLE: Phoebus-2 NTA Preliminary Data

X Axis: 0.2 sec/in. from FS_1 to $FS_1 + 4.0$
1.0 sec/in. from $FS_1 + 4.0$ to $FS_2 - 0.5$
0.2 sec/in. from $FS_2 - 0.5$ to $FS_2 + 5.0$

Y Axis: 0 - 1600 units

Functions: P_{oI} , P_{fI-A1} , P_{fJ-1A} , $\Delta P_{cOA-Pc2C}$,
 P_{c-2C} , P_{cO-A} , P_{ffcM-A} , $\dot{W}_o$, $\dot{W}_f$,
 $\dot{W}_c$, $\dot{W}_{cCL-1}$, $\dot{W}_{cCL-2}$, $\dot{W}_{cNT}$, MR, LNCVX10,
LTCOVX10, LTCFVX10.

5.6.2.2 Final

Plot A: Title: Phoebus-2 NTA Milepost Parameters

X Axis: 1 sec/in. from FS_1 to $P_c = 0$ psig

Y Axis: 0 - 800 units

Functions: P_{c-2C} , P_{c-2D} , P_{c-5A} , P_{c-5B} , $\dot{W}_o$, $\dot{W}_f$, $\dot{W}_c$,
and MR

Plot B: Title: Phoebus-2 Nozzle Pressure Parameters

X Axis: 1 sec/in. from FS_1 to $P_c = 0$ psig

Y Axis: 0 - 1600 units (factor flow rate by 10)

Functions: P_{cO-A} , P_{cO-B} , P_{cO-C} , P_{cO-D} , P_{c-2C} ,
 P_{c-5A} , P_{ffCM-A} , P_{ffCM-C} , $\Delta P_{cOA-P_{c2C}}$,
 $\dot{W}_c$, $\dot{W}_{cCL-1}$, $\dot{W}_{cCL-2}$, $\dot{W}_{cNT}$, $\dot{W}_{fFC-3}$, and
LNCV

Plot C: Title: Phoebus-2 Nozzle Temperature Parameters

X Axis: 1 sec/in. from FS_1 to $P_c = 0$ psig

Y Axis: 0 - 800 units (factor flow rate by 10)

Functions: T_{cO-A} , T_{cO-C} , T_{cO-E} , T_{cO-G} , P_{c2-C} ,
 T_{cNCVi} , $\dot{W}_c$, $\dot{W}_{cCL-1}$, $\dot{W}_{cCL-2}$, $\dot{W}_{cNT}$

Plot D: Title: Phoebus-2 NTA Transients

X Axis: a) 0.2 sec/in. from FS_1 to $FS_1 + 4$ sec.
b) 0.2 sec/in. from $FS_2 - 0.5$ to $FS_2 + 3.5$ sec.

Y Axis: 0 - 1600 units (factor flow rate by 10 and
MR by 100)

Functions: P_{cO-A} , P_{c2C} , P_{c-5A} , P_{fJ-1A} , P_{oI} ,
 $\Delta P_{cOA-P_{c2C}}$, $\dot{W}_o$, $\dot{W}_f$, $\dot{W}_c$, $\dot{W}_{cCL-1}$, $\dot{W}_{cCL-2}$,
 $\dot{W}_{cNT}$, MR, LTCFV, LTCOV, and LNCV

NOTE: Plot pressure in psia, temperature in $^{\circ}R$, and
flow rate in lb/sec.

e. Paragraph 5.10 - Emergency Shutdown (Revision)

5.10.1 Instability shutdown monitors (CSM)

The CSM trip levels shall be set as follows:

Amplitude of pressure oscillation ≥ 100 psi peak-to-peak

Frequency of pressure oscillation ≥ 1000 cps

Duration of instability $\geq .030$ sec.

If CSM trip occurs after FS_1 , a malfunction shutdown shall be initiated. The signal for CSM_1 and CSM_2 shall be taken from P_{c3A} and P_{c3B} , respectively, as measured by flush mounted Photocon transducers.

5.10.2 Chamber pressure monitor (TCPS)

5.10.2.1 A malfunction shutdown shall be signaled by $TCPS_1$ if P_{c-2} is not at least 100 psig at $FS_1 + 1.75$ sec.

5.10.2.2 A malfunction shutdown shall be signaled by $TCPS_2$ if P_{c-2} is not at least 15 psig at $FS_1 + 1.50$ sec.

5.10.3 Minimum nozzle coolant valve position (NCV MIN)

A malfunction shutdown shall be signaled by NCV MIN if NCV is not at least 10% open by $FS_1 + 1.50$ sec.

5.10.4 Minimum and maximum mixture ratio (MR MIN and MR MAX)

A malfunction shutdown shall be signaled any time from controller switchover to P_c/MR mode to FS_2 by MR MIN if $MR \leq 4.0$ or by MR MAX if $MR \geq 6.0$.

5.10.5 Minimum and maximum chamber pressure (P_c MIN and P_c MAX)

5.10.5.1 A malfunction shutdown shall be signaled by P_c MIN any time between controller switchover to P_c/MR mode to FS_2 if P_{c-2} is less than 635 psia.

5.10.5.2 A malfunction shutdown shall be signaled by P_c MAX any time $P_c \geq 715$ psia.

5.10.6 Oxidizer and fuel tank overpressure
(OOPS and FOPS)

A malfunction shutdown shall be signaled by OOPS if $P_{OT} \geq 1700$ psig or by FOPS if $P_{FT} \geq 1650$ psig.

5.10.7 Loss of 110 Volt Power (110V Loss)

A malfunction shutdown shall be signaled if the 110V power supply to the analog programmer is lost.

5.10.8 Hydraulic fluid pump discharge pressure loss
(PHD MIN)

A malfunction shutdown shall be signaled by PHD MIN if $PHD \leq 2000$ psig.

5.10.9 Minimum oxidizer valve position (SO 22)

A malfunction shutdown shall be signaled by SO 22 if $TCOV \leq 30\%$ after TCFV is signaled to open.

5.10.10 Maximum fuel valve position (SF 90)

A malfunction shutdown shall be signaled by SF 90 if $TCFV \geq 90\%$ of steady state value at $FS_2 + .45$ sec.

5.10.11 Oxidizer and fuel tank safety valve position
micro (OTSV and FTSV)

A malfunction shutdown shall be signaled by OTSV and FTSV if the oxidizer or fuel safety valves close to 80% open position before FS_2 .

5.10.12 Oxidizer, fuel, and coolant command signals
(CLO, CLF, and CLC)

A malfunction shutdown shall be signed by CLO, CLF, or CLC if the closing command to TCOV, TCFV, or NCV exceeds 3.0 volts.

5.10.13 Chamber pressure measurement error ($\Delta P_c \Delta$)

A malfunction shutdown shall be signaled by $\Delta P_c \Delta$ if the difference between the controller chamber pressures, P_{c-2A} and P_{c-2B} , is greater than 30 psi. A bias of 1.0 volt shall be placed on P_{c-2A} and P_{c-2B} . A reading of zero voltage on either parameter shall cause a malfunction shutdown.

f. Paragraph 5.11 - Propellants

5.11.1 The fuel and coolant for these tests shall be hydrogen per Marshall Space Flight Center Document 356.

g. Paragraph 6.0 - FIRING SEQUENCE

6.1 Valve Sequencing

Valve sequencing and opening and closing rates shall be as listed below. The critical requirements are identified by *.

<u>START</u> <u>TRANSIENT</u>	<u>OPENING SIGNAL</u>	<u>INITIAL OPENING</u>	<u>OPENING RATE</u>
TCOV	FS ₁ + 0.0*	FS ₁ + 0.110 sec	26%/sec*
TCFV	TCOV = 26% open	TCOV = 30% open*	70%/sec*
NCV	TCFV = 3% open	TCFV = 10% open*	87%/sec
<u>STEADY</u> <u>STATE</u>	<u>CLOSED LOOP</u> <u>CONTROL SWITCHOVER</u>	<u>CONTROL POINT</u>	<u>NOMINAL OPERATING</u> <u>POSITION</u>
TCOV	Pc2 = 675 psia*	Pc2 = 685 psia*	46%
TCFV	Pc2 = 675 psia*	MR = 5.5*	51%
NCV	TCFV = 10% open*	Wc = 30 lb/sec*	26%
<u>SHUTDOWN</u> <u>NORMAL</u>	<u>CLOSING SIGNAL</u>	<u>INITIAL CLOSING</u>	<u>CLOSING RATE</u>
TCOV	FS ₂ + 0.0*	FS ₂ + .110 sec	Fully closed by FS ₂ + 1.0 sec*
TCFV	At SO 98*, i.e., TCOV = 98% of FS ₂ position	SO 98 + .110 sec	Fully closed by FS ₂ + 1.35 sec*
NCV	At SO 98*	SO 98 + .110 sec	Fully closed by FS ₂ + 1.30 sec*
<u>SHUTDOWN</u> <u>FAIL-SAFE</u>	<u>CLOSING SIGNAL</u>	<u>INITIAL CLOSING</u>	<u>CLOSING RATE</u>
TCOV	Any malfunction mode	.110 sec after closing signal	59%/sec*
TCFV	Any malfunction mode	.110 sec after closing signal	20%/sec*
NCV	Any malfunction mode	.110 sec after closing signal	56%/sec*

VALVE LIMITS

The maximum allowable open position of the propellant control valves shall be physically limited:

TCOV	55 % Maximum
TCFV	60 % Maximum
NCV	85 % Maximum

PHOEBUS-2 FILM COOLED TEST ASSEMBLY

FLOW SCHEMATIC

FIGURE 1

SN 880002 TEST ASS'Y

Accelerometer Locations

FIGURE 2

TEST REQUEST

AGC 2-1112

☐ BASIC TEST REQUEST		SECURITY CLASSIFICATION			
		☒ UNCLASSIFIED ☐ CONFIDENTIAL ☐ SECRET ☐ OTHER (EXPLAIN)			
☒ SUPPLEMENT NO. 1		ST NUMBER	TEST SERIES NO	WORK CHARGE NO.	GWA REFERENCE TP.
			1.2-09-NNJ	0960-64-210	193708
TO:				BLDG.	DEPT.
D. M. Tenenbaum				3308	0800
REQUESTED BY:		BLDG.	DEPT	EXT.	DATE
C. M. Kawashige <i>CmKawashige</i>		2019A1	7750	7655	7 June 1967
ACTION APPROVAL <i>[Signature]</i>		DATE	ESTIMATED COMPLETION DATE		
			Prior to Test -001		
MANHOURS	INSPECTION REQUIREMENTS				

DESCRIBE BELOW: OBJECT OF TEST, INFORMATION DESIRED, MATERIAL FURNISHED, SUGGESTED TEST PROCEDURE, SUGGESTED TEST SETUP, GENERAL REMARKS.

1. Revisions and additions to Test Specification, Phoebus-2 Nozzle, Nuclear Simulation, RP-DR-0002, Revision 1, dated 20 January 1967, and Basic Test Request:

a. Paragraph 4.0 - Applicable Documents (Revision to Test Specification)

4.1 Aerojet-General Corporation Documents - Unless otherwise specified, the following documents, of the latest issue in effect, shall form a part of the specification to the extent specified herein:

Specifications - AGC-44020-A, 22 January 1965 - Material Specification; Solvents, Safety Type.

Aerojet-Test Procedures - Test Division Operations (ATP-TDO) H-PH-8001, Rev. Q, dated 8 May 1967.

Technical Memorandum No. 125, Revision D, 30 October 1962, Revised Estimate of Instrumentation Accuracy for Performance Calculations.

4.2 Government Documents - Unless otherwise specified below, the following documents of the issue in effect on date of invitation for bids, shall form a part of this specification to the extent specified herein:

Specifications - MIL-P-25508-D, 16 March 1962, W/supplement sheet, 15 July 1964, Propellant, Oxygen.

Marshall Space Flight Center Document 356, 27 January 1965 - Propellant, Hydrogen.

MIL-P-27401-B, 19 September 1962 - Propellant Pressurizing Agent, Nitrogen.

MIL-L-25567-A, Amend. 1, 7 January 1959 - Leak Test Compound, Oxygen Systems.

DISTRIBUTION

COPY	1 ORIGINATOR	2 MASTER	3 ZONE ENGINEER	4 INST OPERATIONS	5 DATA SERVICES	6 FACILITY DESIGN
COORDINATION APPROVAL						
DATE						

b. Paragraph 5.6.2 - Digital Plot Requirements (Changes to Test Request)

5.6.2.1 Change $\Delta P_{cOA}-P_{c2C}$ to $\Delta P_{cOA}-P_{c2A}$
Change P_{cO-A} to P_{cO-B}

5.6.2.2 Plot B

Delete P_{cO-A}
Delete $\dot{W}_{FC-3}$
Change $\Delta P_{cOA}-P_{c2C}$ to $\Delta P_{cOA}-P_{c2A}$

Plot D

Change P_{cO-A} to P_{cO-B}
Change $\Delta P_{cOA}-P_{c2C}$ to $\Delta P_{cOA}-P_{c2A}$

c. Paragraph 5.10 - Emergency Shutdown (Change to Test Request)

5.10.3 Minimum Nozzle Coolant Valve Position (NCV MIN)

A malfunction shutdown shall be signaled by NCV MIN if NCV is not at least 10% open by $FS_1 + 1.60 \text{ sec}$ (was 1.50 sec).

5.10.12 Oxidizer, Fuel and Coolant Command Signals (CLO, CLF, and CLC)

A malfunction shutdown shall be signaled by CLO if the closing command to TCOV exceeds 3.0 volts.

A malfunction shutdown shall be signaled by CLF if the closing command to TCFV exceeds 1.5 volts (was 3.0 volts).

A malfunction shutdown shall be signaled by CLC if the closing command to NCV exceeds 2.0 volts (was 3.0 volts).

d. Paragraph 5.10 - Emergency Shutdown (Addition to Test Request)5.10.14 Minimum Nozzle Coolant Flow Rate ($\dot{W}_c$ MIN)

A malfunction shutdown shall be signaled by $\dot{W}_c$ MIN if $\dot{W}_c$ is less than 20 lb/sec from control switchover to P_c /MR mode to FS_2 .

e. Valve Sequencing (Change to Test Request)

Normal shutdown closing rate. The NCV will be fully closed by $FS_2 + 0.6 \text{ sec}$ (was 1.30 sec).

Fail-safe shutdown closing rate. The TCFV closing rate shall be 24%/sec (was 20%/sec).

2. Film Coolant Line K_w

$$K_w = 7.83$$

where

$$\dot{W} = K_w \sqrt{\Delta P \text{ S.G.}}$$

TEST REQUEST
AGC 2-1112

Logged 7/3 w.H.

☐ BASIC TEST REQUEST		SECURITY CLASSIFICATION ☒ UNCLASSIFIED ☐ CONFIDENTIAL ☐ SECRET ☐ OTHER (EXPLAIN)			
☒ SUPPLEMENT NO. 2		ST NUMBER 3537	TEST SERIES NO. 1.2-09-NNJ	WORK CHARGE NO. 0960-64-210	GWA REFERENCE TP. 193708
TO: D. M. Tenenbaum				BLDG. 3308	DEPT. 0800
REQUESTED BY: C. M. Kawashige <i>C. M. Kawashige</i>			BLDG. 2019A1	DEPT. 7750	EXT. 7655
ACTION APPROVAL <i>C. M. Kawashige</i>			DATE	ESTIMATED COMPLETION DATE Prior to Test -001	
MANHOURS		INSPECTION REQUIREMENTS			

DESCRIBE BELOW: OBJECT OF TEST, INFORMATION DESIRED, MATERIAL FURNISHED, SUGGESTED TEST PROCEDURE, SUGGESTED TEST SETUP, GENERAL REMARKS:

Revision to Test Specification, Phoebus-2 Nozzle, Nuclear Simulation, RP-DR-0002, Revision 1, dated 20 January 1967, and Basic Test Request.

1. Paragraph 5.10.3 - Minimum Nozzle Coolant Valve Position (NCV MIN)

A malfunction shutdown shall be signaled by NCV MIN if NCV is not at least 10% open by FS₁ + 1.70 sec. Was FS₁ + 1.60 sec.

2. Paragraph 5.10.12 - Oxidizer, Fuel, and Coolant Command Signals (CLO, CLF, and CLC)

A malfunction shutdown shall be signaled by CLC if the closing command to NCV exceeds 2.5 volts. Was 2.0 volts.

3. Paragraph 6.0 - FIRING SEQUENCE (change to Test Request)

Shutdown Fail-Safe

Closing Rate

TCOV	50.5%/sec	<u>Was</u> 59%/sec
TCFV	26.0%/sec	<u>Was</u> 24%/sec
NCV	52.3%/sec	<u>Was</u> 56%/sec

Valve Limits

The maximum allowable open position of the propellant control valves shall be physically limited.

TCFV	70% Maximum	<u>Was</u> 60%
------	-------------	----------------

4. Test duration for Test -001. Test duration from FS₁ to FS₂ shall be such that FS₂ occurs 0.5 sec after P_c/MR switchover. Was 2.4 sec total duration.

DISTRIBUTION

COPY	1 ORIGINATOR	2 MASTER	3 ZONE ENGINEER	4 INST. OPERATIONS	5 DATA SERVICES	6 FACILITY DESIGN
COORDINATION APPROVAL			<i>[Signature]</i>			
DATE						

AEROJET-GENERAL CORPORATION

TEST REQUEST SUPPLEMENT

CONTROL NO.: 3537

SUPPLEMENT NO.: 3

TEST SERIES NO.: 1,2-09-NNJ

WORK AUTHORIZATION NO.: 0960-64-210

TO: DM Tenenbaum AT:

DATE: 11 July 1967

REQUESTED BY: AM Kawashige ON Kawashige AUTHORIZED BY: R. L. Murray CM Kawashige

1. PURPOSE OF SUPPLEMENT: To request changes in TCPS₁ & TCPS₂, malfunction shutdown mode settings

2. EXTENT OF SUPPLEMENT: All 1,2-09-NNJ tests

3. ADDITIONAL INFORMATION DESIRED: NONE

4. SUGGESTED TEST MODIFICATIONS: TCPS₁ timer shall be set at FS₁ + 1.65 sec
was FS₁ + 1.75 sec. TCPS₂ timer shall be set at
FS₁ + 1.60 sec. was FS₁ + 1.50 sec.

5. ADDITIONAL MATERIAL FURNISHED: NONE

6. REMARKS: TCOV closing bias increased to insure no leakage.
This change delays TCOV initial opening by 0.10 sec
necessitating TCPS₁ & TCPS₂ timer increase.

FOR TEST DIVISION USE ONLY

DISTRIBUTION

APPROVED BY

DATE

TEST REQUEST
AGC 2-1112

Logg'd 7/18 W.H.

☐ BASIC TEST REQUEST		SECURITY CLASSIFICATION ☒ UNCLASSIFIED ☐ CONFIDENTIAL ☐ SECRET ☐ OTHER (EXPLAIN)			
☒ SUPPLEMENT NO. 4		ST NUMBER 3537	TEST SERIES NO. 1.2-09-11.1J	WORK CHARGE NO. 0960-64-210	GWA REFERENCE TP 193708
REQUESTED BY: D. H. Tenenbaum				BLDG. 3308	DEPT. 0800
REQUESTED BY: G. H. Kawashige <i>G.H. Kawashige</i>				BLDG. 2019-1	DEPT. 7750
ACTION APPROVAL: R. L. Murray <i>R.L. Murray</i>				EXT. 7655	DATE 7-12-67
MANHOUS				DATE	ESTIMATED COMPLETION DATE Prior to Test -002
INSPECTION REQUIREMENTS					

DESCRIBE BELOW: OBJECT OF TEST, INFORMATION DESIRED, MATERIAL FURNISHED, SUGGESTED TEST PROCEDURE, SUGGESTED TEST SETUP, GENERAL REMARKS:

Revision to Test Specification, Phoebus-2 Nozzle, Nuclear Simulation,
RP-DR-0002, Revision 1, dated 20 January 1967, and Basic Test Request.

1. Duration of Test -002 will be 5.0 sec. ($FS_1 + FS_2$)
2. Delete CLC malfunction shutdown mode.
3. Change NCV mechanical clamp to 30% open maximum was 85% open maximum.
4. Failsafe shutdown closing rates.

TCOV	52%/sec	<u>was</u>	50.5%/sec
TCFV	26%/Sec	<u>was</u>	26%/sec
NCV	55%/Sec	<u>was</u>	52.3%/sec
5. Change NCV Min malfunction shutdown setting to 5% open at $FS_1 + 1.70$ sec.
was 10%.
6. Change We Min malfunction shutdown setting to 10 lb/sec from P_0/MR
switchover to FS_2 . was 20 lb/sec.

DISTRIBUTION

	1 ORIGINATOR	2 MASTER	3 ZONE ENGINEER	4 INST. OPERATIONS	5 DATA SERVICES	6 FACILITY DESIGN
COORDINATION APPROVAL			<i>[Signature]</i>			
DATE						

TEST REQUEST
ASC 2-1112

Logged 7/8 WHL

☐ BASIC TEST REQUEST		SECURITY CLASSIFICATION ☒ UNCLASSIFIED ☐ CONFIDENTIAL ☐ SECRET ☐ OTHER (EXPLAIN)			
☒ SUPPLEMENT NO. 5		ST NUMBER 3537	TEST SERIES NO. 1.2-09-NNJ	WORK CHARGE NO. 0960-64-210	GWA REFERENCE TP- 193708
D. M. Tenenbaum				BLDG. 3308	DEPT. 0800
REQUESTED BY: C. M. Kawashige		DATE 2019A1	DEPT. 7750	EXT. 7655	DATE 7-13-67
ACTION APPROVAL R. L. Murray		DATE 7-13-67	ESTIMATED COMPLETION DATE Prior to Test -003		
MANHOUS		INSPECTION REQUIREMENTS			

DESCRIBE BELOW: OBJECT OF TEST, INFORMATION DESIRED, MATERIAL FURNISHED, SUGGESTED TEST PROCEDURE, SUGGESTED TEST SETUP, GENERAL REMARKS:

Revision to Test Specification, Phoebus-2 Nozzle, Nuclear Simulation, RP-DR-0002, Revision 1, dated 20 January 1967, and Basic Test Request.

1. Duration of Test -003 will be 5.0 sec (FS₁ - FS₂).
2. Change P_c maximum malfunction shutdown setting to 725 psia.
Was 715 psia.
3. Change M.R. maximum malfunction shutdown setting to 6.2.
Was 6.0.

DISTRIBUTION

COORDINATION APPROVAL DATE 7/13/67	1 ORIGINATOR	2 MASTER	3 ZONE ENGINEER	4 INST. OPERATIONS	5 DATA SERVICES	6 FACILITY DESIGN

TEST REQUEST
ACCS-1

Logg & H's 2nd

☐ BASIC TEST REQUEST		SECURITY CLASSIFICATION			
		☒ UNCLASSIFIED	☐ CONFIDENTIAL	☐ SECRET	☐ OTHER (EXPLAIN)
☒ SUPPLEMENT NO. 6	ST NUMBER 3537	TEST SERIES NO. 1.2-09-1111	WORK CHARGE NO. 0960-64-210	GWA REFERENCE TP-193708	
TO: <i>J. H. Zonenbaum</i>			BLDG. 3308	DEPT. 0300	
REQUESTED BY: C. H. Kawashige <i>C. H. Kawashige</i>		BLDG. 2019A1	DEPT. 7750	EXT. 7655	DATE 7-13-67
ACTION APPROVAL R. L. Murray <i>R. L. Murray</i>		DATE 7-13-67	ESTIMATED COMPLETION DATE Prior to Test -004		
MANHOURS	INSPECTION REQUIREMENTS				

DESCRIBE BELOW: OBJECT OF TEST, INFORMATION DESIRED, MATERIAL FURNISHED, SUGGESTED TEST PROCEDURE, SUGGESTED TEST SETUP, GENERAL REMARKS:

revision to test specification, rhobas-2 No. 11c, Nuclear simulation, DR-DR-0002, revision 1, dated 20 January 1967, and Basic test request.

1. Duration of Test -004 will be 4.0 sec ($FS_1 - FS_2$)
2. Change NOV opening sequence. Open NOV to 27. in 0.4 sec. NOV initial opening signal at TGV = 3.5.
3. Change CM_1 and CM_2 amplitude level to 150 psi peak to peak.
was 100 psi

DISTRIBUTION

COPY	1 ORIGINATOR	2 MASTER	3 ZONE ENGINEER	4 INST. OPERATIONS	5 DATA SERVICES	6 FACILITY DESIGN
COORDINATION APPROVAL			<i>[Signature]</i>			
DATE						

APPENDIX A

PART 2, ENGINEERING POST FIRE INSPECTION REPORT

PHOEBUS-2

ENGINEERING POST FIRE INSPECTION REPORT

REPORT DATE: 12 July 1967

Page 1 of 2

PRE FIRE NOTES

TEST OBJECTIVE Verify start transient and controls system for Coaxial Injector Acceptance Test SeriesTEST NO: 1.2-09-NNJ-001 DATE: 11 July 67 TIME OF TEST: 2236 DURATION: 1.700

COMPONENT:	PART NO.	SERIAL NO.	REMARKS (Use continuation sheet)
TEST ASSEMBLY	1115858-19	880002	
Film Cooled Nozzle			
NOZZLE	1134062-9	880608	No damage
Film Cooled			
INJECTOR	1115321-19	884134	No damage
Coaxial w/Baffle			
ADAPTER	1115486-9	880699	Coolant tubes heat marked in a band 5 to 15 inches from the core support flange and also along the entire length under the 4 igniter ports. Braze alloy results are shown on Page 2.
LEG			
SUPPORT			
LINES			
FUEL INLET			
OXID INLET			
COOLANT INLET			
COOLANT DUMP			

TEST RESULTS CLC malfunction shutdown occurred causing premature test termination. W overshoot to 70 lb/sec created a NCV closing voltage exceeding the 2.5 volt kill setting. ΔP Δ malfunction also signalled after CLC malfunction shutdown. FS₂ P_c was 200 psia, FS₂ MR was 31.2. Maximum P_c was 310 psia.

*All locations on Nozzle, Adapter, and Injector are located clockwise from oxidizer inlet (Oxid inlet = 0 & 360° or 12 o'clock.) looking forward toward injector face.

REPORTED BY C. M. Kawashige

C. M. Kawashige

ADAPTER BRAZE ALLOY RESULTS

REF: 1117091

POSTTEST 1.2-09-NNJ-001

x Indicates braze patch melt

PHOEBUS-2

ENGINEERING POST FIRE INSPECTION REPORT

REPORT DATE: 17 July 67

Page 1 of 2

PRE FIRE NOTES

TEST OBJECTIVE Conduct 5 second acceptance test of the coaxial injector.

TEST NO: 1.2-09-NNJ-002 DATE: 12 July 1967 TIME OF TEST: 1827 DURATION: 2.152

COMPONENT:	PART NO.	SERIAL NO.	REMARKS (Use continuation sheet)
TEST ASSEMBLY	1115858-19	880002	
Film Cooled Nozzle			
NOZZLE	1134062-9	880608	Nozzle throat eroded .050 inches max. in a 9 inch wide band from the nozzle exit (360 degrees). Pressure vessel and core support coolant injector rings heat marked (360 degrees). Injector has heat spots scattered over regimesh face.
Film Cooled			
INJECTOR	1115321-19	884134	
Coaxial w/Baffle			
ADAPTER	1115486-9	880699	No change. See Page 2 for braze alloy results.
LEG			
SUPPORT			
LINES			
FUEL INLET			
OXID INLET			
COOLANT INLET			
COOLANT DUMP			

TEST RESULTS W MIN malfunction shutdown terminated test. W MIN level of 10 lb/sec after control switchover to P /MR mode was not met. MR MAX malfunction also signalled after W MIN malfunction shutdown. FS₂ P_c was 690 psia, FS₂ MR was 5.0. Maximum P_c was 700 psia.

* All locations on Nozzle, Adapter, and Injector are located clockwise from oxidizer inlet (Oxid inlet = 0 & 360° or 12 o'clock.) looking forward toward injector face.

REPORTED BY

C. M. Kawashige
C. M. Kawashige

ADAPTER BRAZE ALLOY RESULTS

REF: 1117091

POSTTEST 1.2-09-NNJ-002

x Indicates braze patch melt

PHOEBUS-2

ENGINEERING POST FIRE INSPECTION REPORT

REPORT DATE: 17 July 1967

Page 1 of 1

PRE FIRE NOTES

TEST OBJECTIVE Conduct 5 second acceptance test of the coaxial injector.

TEST NO: 1.2-09-NNJ-003 DATE: 13 July 1967 TIME OF TEST: 1509 DURATION: 1.806

COMPONENT:	PART NO.	SERIAL NO.	REMARKS (Use continuation sheet)
TEST ASSEMBLY	1115858-19	880002	
Film Cooled Nozzle			
NOZZLE	1134062-9	880608	No change
Film Cooled			
INJECTOR	1115321-19	884134	Heat spot on regimesh face approximately 1 in. Dia. at 1 o'clock position outboard of injector baffle.
Coaxial w/Baffle			
ADAPTER	1115486-9	880699	No change
LEG			
SUPPORT			
LINES			
FUEL INLET			
OXID INLET			
COOLANT INLET			
COOLANT DUMP			

TEST RESULTS NCV Min. shutdown terminated test. w. overshoot to 50 lb/sec caused NCV to close to a position lower than the NCV MIN = 5% kill position. PS_2 P_e was 400 psia, PS_2 MR was 8.5. Maximum P_e was 460 psia.

All locations on Nozzle, Adapter, and Injector are located clockwise from oxidizer inlet (Oxid inlet = 0 & 360° or 12 o'clock.) looking forward toward injector face.

REPORTED BY

C. M. Kawashige

PHOEBUS-2

ENGINEERING POST FIRE INSPECTION REPORT

REPORT DATE: 17 July 1967
Page 1 of 2

PRE FIRE NOTES

TEST OBJECTIVE Conduct 5 second acceptance test of the coaxial injector.

TEST NO: 1.2-09-NNJ-004 DATE: 13 July 1967 TIME OF TEST: 2120 DURATION: 2.443

COMPONENT:	PART NO.	SERIAL NO.	REMARKS (Use continuation sheet)
TEST ASSEMBLY	1115858-19	880002	
Film Cooled Nozzle			
NOZZLE	1134062-9	880608	No Change
Film Cooled			
INJECTOR	1115321-19	884134	Baffle tip slightly eroded under igniter ports.
Coaxial w/Baffle			
ADAPTER	1115486-9	880699	No change. See Page 2 for braze alloy results.
LEG			
SUPPORT			
LINES			
FUEL INLET			
OXID INLET			
COOLANT INLET			
COOLANT DUMP			

TEST RESULTS ΔP malfunction shutdown terminated test. Mean value of the two P readings used in the controls system did not exceed the 30 psi kill setting, but the oscillations in P had an amplitude high enough to cause the shutdown. FS₂ P was 690 psia, FS₂ was 5.0. Approximately 0.3 to 0.4 steady state duration was obtained.

*All locations on Nozzle, Adapter, and Injector are located clockwise from oxidizer inlet (Oxid inlet = 0 & 360° or 12 o'clock.) looking forward toward injector face.

REPORTED BY

Om Kawasige

ADAPTER BRAZE ALLOY RESULTS

REF: 1117091

POSTTEST 1.2-09-NNJ-004

x Indicates braze patch melt

APPENDIX A

PART 3, FINAL TEST DATA AT FS₂

PHOEBUS TEST DATA

DATA TIME 1.700 SEC PRELIMINARY ☐ FINAL ☒

PAGE 1 OF 1
1.2-09-NNJ-001B
TEST NO. _____
TEST DATE 7-11-67

	P/N	S/N	ORIFICE	SIZE	THROAT AREA
T.C.A.	1115858-19	880002	FUEL INLET	N/A	IN. PRE 238.002 IN ²
NOZZLE	1134062-9	880608	COOL. INLET	N/A	IN. POST 238.002 IN ²
INJECTOR	1115321-19	884134	DUMP FLOW	N/A	IN. _____ IN ²
ADAPTER	1115486-9	880699	DUMP LOAD	N/A	IN. _____ IN ²
FUNCTION	DATA	UNIT	FUNCTION	DATA	UNIT
POT-13	1575.8	PSIA	PCO-E	2.553	PSIA
POFM	1458.0		-F	N/A	
POTCVI	1438.1		-G	N/A	
POI	326.0		-H	N/A	
POJ-2A	N/A		PcE-1A	N/A	
-2B	N/A		PCE-2	N/A	
-2C	N/A		PcBC	N/A	
-2D	N/A		ΔPcBC	N/A	
-2E	N/A		PC-2A	205.6	
-2F	N/A		-2B	N/A	
-2G	N/A		-2C	205.6	
PFT-12	1537.8		-2D	205.6	
PFFM	1538.0		-2E	N/A	
PFTCVI	1535.5		-2F	N/A	
PFI-A1	199.0		-5A	204.5	
PFI-A2	196.0		-5B	170.1	PSIA
PFO-A	198.0		TOFM	179.2	OR
-3	190.0		TOTCVI	178.01	
-C	258.0		TOI	189.25	
-D	199.0		TOJ	N/A	
PfJ-1A	207.0		TTFM	N/A	
-1B	N/A		TFTCVI	53.9	
-2A	N/A		T-I-A	110.0	
-2B	N/A		TfJ-A	526.7	
-2C	N/A		-B	479.82	
-2D	N/A		-C	473.81	
-2E	N/A		-D	N/A	
-2F	N/A		TCFM	N/A	
PCFM	1538.3		TCMO	N/A	
PCMO	N/A		TCNCVI	53.99	
ΔPCMO	N/A		TCT-1	N/A	
PCNCVI	1539.3		-A	N/A	
PFFCL-1	N/A		-B	N/A	
ΔPFFCL-1	N/A		-C	N/A	
PfTCV-A	714.6		-D	N/A	
-B	N/A		-E	N/A	
-C	675.4		-F	N/A	
PCI-1	N/A		TCO-A	524.20	
-2A	N/A		-B	N/A	
-2B	N/A		-C	524.0	
-2C	N/A		-D	N/A	
-2D	N/A		-E	524.0	
-2E	N/A		-F	N/A	
-2F	N/A		-G	512.9	
PCO-A	221.5		-H	596.09	OR
-B	223.9				
-C	221.8				
-D	236.6				

SPECIFIC GRAVITY
OXID 1.1176
FUEL .0738
COOL. .0730

CALCULATED DATA
Wo 424.9617 LB/EC
Wf 13.6280 LB/EC
MR 31.183
Wc 50.0492 LB/EC
V.CNT 50.0492*
WcPV 0*
WCCS 0* LB/EC
C² (CALC) 2935.9 FT/EC
C² bT-ECR %

CONTROL TIMES
FSI-FS2 1.700 SEC
FSI-LTCOV .025
FSI-LTCFV 1.42
FSI-LFDV N/A
FSI-POJ PISE N/A
FSI-PFJ PISE 1.415
FSI-PC PISE 1.416
FSI-PC b C² N/A SEC

REMARKS
* FILM COOLANT FLOW
DATA IS QUESTIONABLE
DUE TO TRANSIENT
CONDITIONS

PVB 5/27/6

PHOEBUS TEST DATA

DATA TIME 2.152

PRELIMINARY ☐
FINAL ☒

PAGE 1 OF 1
1.2-09-NNV-002
TEST NO.
TEST DATE 7/12/67

	P/N	S/N	ORIFICE SIZE	THROAT AREA				
T.C.A.	1115858-19	880002	FUEL INLET	N/A IN. PRE 238.002 IN ²				
NOZZLE	1134062-9	880608	COOL. INLET	N/A IN. POST				
INJECTOR	1115321-19	884134	DUMP FLOW	N/A IN.				
ADAPTER	1115486-9	880699	DUMP LOAD	N/A IN.				
FUNCTION	DATA	UNIT	FUNCTION	DATA	UNIT	SPECIFIC GRAVITY		
POT-13	1550.4	PSIA	PCO-E	785.1	PSIA	OXID 1.1139		
POFM	1415.1		-F	N/A		FUEL .0759		
POTCVI	1389.3		-G			COOL. .0746		
POI	895.2		-H	N/A		CALCULATED DATA		
POJ-2A	N/A		PCE-1A	672.3		Wo	538.8330	LB/SEC
-2B			PCE-2	N/A		Wf	109.2094	LB/SEC
-2C			PCBC			M R	4.934	
-2D			ΔPCBC	N/A		Wc	10.1196	LB/SEC
-2E			PC-2A	702.4		WCNT	0 *	
-2F			-2B	N/A		WCPV	8.2911 *	
-2G	N/A		-2C	698.1		WCCS	8.2911 *	LB/SEC
PfT-12	1522.6		-2D	706.6		C ² (CALC)		FT/SEC
PffM	1542.3		-2E			C ² b THEOR		%
PfTCVI	1529.0		-2F			CONTROL TIMES		
PfI-A1	1275.3		-5A	699.3	PSIA	FSI-FS2	2.152	SEC
PfI-A2	1286.6		-5B	694.6	OR	FSI-LTCOV	.2417	
PfO-A	1145.2		ToFM	180.33		FSI-LTCFV	1.3737	
-B	1156.6		TOTCVI	179.34		FSI-LFDV	N/A	
-C			TOI	187.36		FSI-POJ RISE	N/A	
-D	1157.4		TOJ	N/A		FSI-PFJ RISE	1.3399	
PfJ-1A	1054.2		TfFM	699.1		FSI-PC RISE	1.391	
-1B	N/A		TfTCVI	48.99		FSI-PC INJECT		SEC
-2A			TfI-A	56.23		REMARKS		
-2B			TfJ-A	176.04		* FILM COOLANT DATA		
-2C			-B	137.02		: QUESTIONABLE		
-2D			-C	131.50		DUE TO TRANSITION		
-2E			-D	N/A		COOL. FLOW		
-2F	N/A		TCFM					
PCFM	1542.2		TCMO	N/A				
PCMO	N/A		TCNCVI	56.23				
ΔPCMO	N/A		TCI-1	N/A				
PCNCVI	1543.3		-A					
PffCL-1	N/A		-B					
ΔPffCL-1	N/A		-C					
PfICM-A	722.7		-D					
-B	N/A		-E					
-C	702.3		-F					
PCI-1	N/A		TCO-A	N/A				
-2A	702.4		-B					
-2B	N/A		-C					
-2C			-D					
-2D			-E					
-2E			-F	N/A				
-2F			-G	540.0				
PCO-A	N/A		-H	625.7	OR			
-B	698.1							
-C	698.6							
-D	702.6	PSIA						

P.V.B. 5/27/65

PHOEBUS TEST DATA						PAGE 1 OF 1	
DATA TIME 1.806		PRELIMINARY ☐		1.2-09 - NNJ-003		TEST NO.	
		FINAL ☒				TEST DATE 2/13/67	
	P/N	S/N	ORIFICE	SIZE	THROAT AREA		
T.C.A.	1115858-19	880002	FUEL INLET	N/A	IN. PRE	IN ²	
NOZZLE	1134062-9	880608	COOL. INLET	N/A	IN. POST	IN ²	
INJECTOR	1115321-19	884134	DUMP FLOW	N/A	IN.	IN ²	
ADAPTER	1115486-9	880699	DUMP LOAD	N/A	IN.	IN ²	
FUNCTION	DATA	UNIT	FUNCTION	DATA	UNIT	SPECIFIC GRAVITY	
P ₀ T-13	1563.7	PSIA	P _{CO} -E	428.3	PSIA	OXID	1.1076
P _{OF} M	1432.3		-F	N/A		FUEL	.0748
P _{OT} CVI	1406.8		-G	N/A		COOL.	.0739
P _{OI}	542.9		-H	N/A		CALCULATED DATA	
P _{OJ} -2A	N/A		P _{CE} -1A	386.4		W _o	463.9509 LB/SEC
-2B			P _{CE} -2	N/A		W _f	53.2750 LB/SEC
-2C			P _{CBC}	N/A		M _R	8.709
-2D			ΔP _{CBC}	N/A		W _c	53.0426 LB/SEC
-2E			P _C -2A	401.7		W _{CNT}	53.0426 * ↑
-2F			-2B	N/A		W _{CPV}	0 * ↓
-2G	N/A		-2C	401.4		W _{CSS}	0 * LB/SEC
P _{FT} -12	1526.2		-2D	401.9		C* (CALC)	5393.5 FT/SEC
P _{FF} M	1538.1		-2E	N/A		C*%TH-50R	%
P _{FT} CVI	1526.3		-2F	N/A		CONTROL TIMES	
P _{FI} -A1	546.7		-5A	404.3	PSIA	FSI-FS2	1.806 SEC
P _{FI} -A2	567.8		-5B	393.0	PSIA	FSI-LTCOV	.2362
P _{FO} -A	546.9		T _{OF} M	182.84	°R	FSI-LTCFV	1.3682
-B	526.0		T _{OT} CVI	181.29		FSI-LFDV	N/A
-C	510.5		T _{OI} -A	193.07		FSI-POJ RISE	
-D	549.0		T _{OJ}	N/A		FSI-PEJ RISE	
P _{4J} -1A	540.5		T _{FM}	N/A		FSI-P _C RISE	1.3604
-1B	N/A		T _F CVI	51.55		FSI-P _{CL} C.F.*	N/A SEC
-2A			T _I -A	110.0		REMARKS	
-2B			T _J -A	396.02		* FILM COOLANT FLOW DATA IS QUESTIONABLE DUE TO TRANSIENT CONDITIONS	
-2C			-B	405.71			
-2D			-C	393.63			
-2E			-D	N/A			
-2I	N/A		T _{CF} M	N/A			
P _{CF} M	1538.9		T _{CM} O	N/A			
P _{CM} J	N/A		T _{CNC} VI	52.08			
ΔP _{CM} O	N/A		T _C I-1	N/A			
-CNCVI	1535.1		-A				
P _{CL} -1	N/A		-B				
ΔP _{CL} -1	N/A		-C				
P _{TC} M-A	412.4		-D				
-B	N/A		-E				
-C	384.0		-F	N/A			
P _{CI} -1	N/A		T _{CO} -A	401.78			
-2A			-B	N/A			
-2B			-C	N/A			
-2C			-D	N/A			
-2D			-E	490.0			
-2E			-F	N/A			
-2F			-G	346.0			
P _{CO} -A	N/A		-H	497.31	°R		
-B	391.3						
-C	391.0						
-D	396.9	PSIA					

PVB 5/27/60

PHOEBUS TEST DATA

PAGE 1 OF 1

1.2-09-NW-004

DATA TIME 2.443 sec PRELIMINARY ☐ FINAL ☒

TEST NO.

TEST DATE 7/13/67

	P/N	S/N	ORIFICE	SIZE	THROAT AREA
T.C.A.	1115858-19	880002	FUEL INLET	N/A	IN. PRE
NOZZLE	1134062-9	880608	COOL. INLET	N/A	IN. POST
INJECTOR	1115321-19	884134	DUMP FLOW	N/A	IN.
ADAPTER	1115486-9	880699	DUMP LOAD	N/A	IN.
FUNCTION	DATA	UNIT	FUNCTION	DATA	UNIT
POT-13	1554.7	PSIA	PCO-E	844.1	PSIA
POFM	1434.6		-F	N/A	
POTCVI	1407.4		-G	N/A	
POI	888.3		-H	N/A	
POJ-2A	N/A		PCE-1A	687.5	
-2B			PCE-2	N/A	
-2C			PcBC		
-2D			Δ PcBC		
-2E			PC-2A		
-2F			-2B	N/A	
-2G	N/A		-2C	694.6	
PFT-12	1539.7		-2D	700.9	
Pffm	1536.9		-2E	N/A	
PFTCVI	1531.9		-2F	N/A	
PFI-A1	1160.3		-5A	694.8	
PFI-A2	1172.9		-5B	693.3	PSIA
PFO-A	1054.0		TOFM	179.55	°R
-B	1061.0		TOTCVI	179.01	
-C	1024.8		TOI-A	183.63	
-D	1063.8		TOJ	N/A	
PfJ-1A	980.4		TfFM	N/A	
-1B	N/A		TfCVI	50.83	
-2A			TfI-A	56.49	
-2B			TfJ-A	138.92	
-2C			-B	111.28	
-2D			-C	108.10	
-2E			-D	N/A	
-2F	N/A		TCFM	N/A	
PCFM	1537.5		TCMO	N/A	
PCMO	N/A		TCNCVI	52.52	
Δ PCMO	N/A		TCI-1	N/A	
PCNCVI	1542.7		-A		
PffCI-1	N/A		-B		
Δ PffCI-1	N/A		-C		
PffCM-A	881.7		-D		
-B	N/A		-E		
-C	880.6		-F	N/A	
PCI-1	N/A		TCO-A	313.96	
-2A			-B	N/A	
-2B			-C	N/A	
-2C			-D	N/A	
-2D			-E	365.56	
-2E			-F	N/A	
-2F			-G	200.22	
PCO-A	N/A		-H	395.74	°R
-B	863.1				
-C	862.9				
-D	864.0	PSIA			

SPECIFIC GRAVITY

OXID 1.1163

FUEL .0749

COOL. .0737

CALCULATED DATA

Wo 517.0676 LB/SEC

Wf 103.1460 LB/SEC

MR 5.0173

Wc 46.7684 LB/SEC

WcNT 33.5276

WcPV 6.6204

WCCS 6.6204 LB/SEC

C* (CALC) 8011.7 FT/SEC

C* (THEOR) N/A %

CONTROL TIMES

FSI-FS2 2.443 SEC

FSI-LTCOV .2459

FSI-LTCFV 1.3522

FSI-LFDV

FSI-PCJ RISE

FSI-PfJ RISE

FSI-PC RISE 1.370

FSI-PcI 0.111 SEC

REMARKS

PVB 5/22/67

APPENDIX A

PART 4, CRITICAL DATA SHEETS AND
TEST ENGINEER'S REMARKS SHEETS

ROCKET GENERAL CORPORATION
LIQUID ROCKET PLANT SACRAMENTO, CALIFORNIA

PHOEBUS-2

NOZZLE TEST ASSEMBLY
CRITICAL DATA SHEET

TEST NO.	1.2-09-NNJ-001B	TEST DATE	11 JULY 1967
TEST STAND	H-4B	TEST TIME	2240 HRS
AMB PRESS	14.54 PSIA	AMB TEMP.	540 DEG F
		DURATION	1.700 SEC
		WORK ORDER	0960-64-210

HARDWARE	P/N	S/N	PRE RICS
NTA	1115858-19	880002	1 17.409 IN.
NOZZLE	1134062-9	880608	2 17.408
INJECTION	1115321-19	884134	3 17.408
ADAPTER	1115486-9	880669	4 17.404
IGNITERS	1-069300-5	375 ALCLO	5 17.408
5" OXID INLET LINE	1115645-9	N/A	6 17.410
6" FUEL INLET LINE	1115454-9	N/A	PRE AT 238.002 IN. ²
8" NOZZLE COOLANT INLET LINE	1115456-9	N/A	
8" NOZZLE COOLANT DUMP LINE	1115453-9	N/A	POST RICS
FILM COOLANT INLET LINE 1	N/A	N/A	8 SAME AS PRE
FILM COOLANT INLET LINE 2	N/A	N/A	2 (SEE PAGE 16 OF
FILM COOLANT INLET LINE ADAPTER	N/A	N/A	3 RPT. DR-0002
THROAT FILM COOLANT LINE	N/A	N/A	4 - 5.6.1.4.)
TCV CHANNEL ORAL FCV-FLASH FLOW	N/A	N/A	5
TCV CHANNEL ORAL FCV-FLASH FLOW	N/A	N/A	6
NCV CHANNEL ORAL FCV-FLASH FLOW	N/A	N/A	POST AT

FLOW MEASUREMENT SYSTEM

ORIFICE TYPE:	FILM COOLANT SUPPLY ORIFICE	DIAM.	N/A	"K" N/A	"P" N/A
VENTURI TYPE:	S/N 884097 FILM COOLANT SUPPLY ORIFICE-1	DIAM.	2"	"K" 7.83	"P" N/A
VENTURI TYPE:	S/N 884099 THROAT FILM COOLANT SUPPLY ORIFICE-2	DIAM.	2"	"K" 7.83	"P" N/A
TURBINE TYPE:	FAF AJS-7-45	DIAM.	7"	"K" 0.43930	"P" N/A
TURBINE TYPE:	FAF AJS-9-4	DIAM.	9"	"K" 0.16656	"P" N/A
TURBINE TYPE:	FAF AJS-12-4	DIAM.	12"	"K" 0.079963	"P" N/A

SYSTEM LOAD ORIFICE (DIAMETER)

NOZZLE DUMP	5.07"	ORIFICE DUMP LINE	N/A
FILM COOLANT SUPPLY LINE	N/A	THROAT FILM COOLANT SUPPLY LINE	N/A

AEROJET-GENERAL CORPORATION
SACRAMENTO CALIFORNIA

TEST ENGINEER'S REMARKS
ST1168 REV 1/64

PAGE 1 OF 2

ITEM TESTED	DATE	WORK ORDER	TEST NUMBER
FILM COOLED PHOEBUS NTA	11 JULY 1967	0960-64-210	1.2-09-NNJ-001B
NOTE: LIST REMARKS IN SEQUENCE OF PRE-TEST, TEST CONDITIONS, POST TEST			TEST STAND

PRE-TEST: (A) ASSEMBLY WAS RECEIVED IN THE TEST AREA 8 MAY 1967 AND INSTALLED IN TEST STAND H-4B. (B) THE ASSEMBLY WAS INSTRUMENTED IN ACCORDANCE WITH BASIC TEST REQUEST ST NUMBER 3537, GWA REF. TP 193708. (C) PRELIMINARY LEAK CHECK OF THE TEST ASSY REVEALED "FUZZ" LEAKAGE AT THE 2-PHOTO-CON HOSES, WHICH WAS REPAIRED ON JOB BY ASSY SHOP PERSONNEL. (D) ELEC./MECH. SEQUENCING OF THE FGV'S RESULTED IN ERRATIC OPERATION OF TCOV, REMOVAL OF TCOV, TCFV & NCV FOR INSPECTION DISCLOSED GALLING OF THE TCOV & NCV PLUGS & SLEEVES, THE TCOV, TCFV & NCV PLUGS & SLEEVES WERE FORWARDED TO THE MANUFACTURER FOR REWORK. (E) MECHANICAL STOPS WERE INSTALLED ON TCOV, TCFV & NCV TO LIMIT OPENING TRAVEL. INITIAL STOP ADJUSTMENT WAS TCOV FULL OPEN 55%, TCFV FULL OPEN 60%, & NCV FULL OPEN 85%. (F) SATISFACTORY HOT GAS & LO₂/LH₂ FEED SYSTEM LEAK CHECKS WERE ACCOMPLISHED. (G) SATISFACTORY ELEC./MECH. FUNCTIONALS AND PRE-TEST CHECKS WERE MADE IN ACCORDANCE WITH EXISTING TEST DIVISION TDO'S. (H) COMPLETED MILLI-PORE FILTERING OF FGV HYDRAULIC SYSTEM WITH 7 & 1 MICRON FILTERS.

COMMENTS: PRIOR TO TEST 1.2-09-NNJ-001B, 2-ATTEMPTS WERE MADE TO START THE NTA. (A) ATTEMPT #1 ON 7/8/67 RESULTED IN A FSM SHUTDOWN DUE TO GLC TRIP DURING COUNTDOWN BLEED OF COOLANT SYSTEM. (H) COOLANT FLOW FEEDBACK FROM FMC HOWEVER NOTHING WAS COMMANDED, THEREFORE PSS INITIATED PRIOR TO FS-1. (B) ATTEMPT #2, ALSO ON 7-8-67, GLC WAS ENERGIZED AFTER FS-1 ON COUNTDOWN TO AVOID PREVIOUS ATTEMPT RESULTS.

TEST ENGINEER	DATE	APPROVED BY	DATE
F. H. LYONS	8-17-67	FE Oststadt	8/25/67

TEST ENGINEER'S REMARKS

ST1168 REV 1/64

PAGE 2 OF 2

ITEM TESTED	DATE	WORK ORDER	TEST NUMBER
FILM COOLED PHOEBUS NTA	11 JULY 1967	0960-6420	1.2-09-NNTJ-0013
NOTE: LIST REMARKS IN SEQUENCE OF PRE-TEST, TEST CONDITIONS, POST TEST			TEST STAND

TCOV FAILED TO OPEN AT FS-1, NO PC, ETC,
SHUTDOWN WAS DUE TO MPC-2 @ 1.5 SEC. TOI
INDICATED LO_2 FLOW, $FMO \approx 30\%/SEC$. NOMINAL.
POSTFIRE INSPECTION REVEALED A 28V. FSM
SOLENOID INSTALLED INSTEAD OF 12V.

TEST: DURATION WAS 1.65 SEC, TEST WAS
TERMINATED BY CLC MALF. SHUTDOWN CAUSED BY
LNCV OVER SHOOT OF CONTROL POSITION, RESULTING
IN EXCESSIVE W_c VERSUS VALVE POSITION. AT FS-2
 $W_c \approx 50\%/SEC$ AND $LNCV \approx 30\%$, COMING CLOSED
FROM A PEAK OF 36%. $K_p=10$, $K_i=4$, $K_f=2$

POSTFIRE: POSTFIRE INSPECTION REVEALED NO
APPARENT DAMAGE OR ABNORMALITIES. SATIS-
FACTORY H.G. & 500 PSI LEAK CHECKS OF LH_2/KO_2
FEED SYSTEMS WAS ACCOMPLISHED. COMPLETED
POSTFIRE CHECK LISTS.

TEST ENGINEER

F. H. LYONS

DATE

8-17-67

APPROVED BY

[Signature]

DATE

AEROJET GENERAL CORPORATION
LIQUID ROCKET PLANT SACRAMENTO, CALIFORNIA

PHOEBUS-2
NOZZLE TEST ASSEMBLY
CRITICAL DATA SHEET

TEST NO.	1.2-09-NNJ-002	TEST DATE	12 JULY 1967
TEST STAND	H-4B	TEST TIME	1830 HRS.
AMB PRESS	14.54 PSIA	AMB TEMP.	540 DEG F
		DURATION	2.152 SEC
		WORK ORDER	0960-64-210

HARDWARE	P/N	S/N	PRE HICS
N/A	1115858-19	880002	1 17.409 IN.
NOZZLE	1134062-9	880608	2 17.408
INJECTOR	1115321-19	884134	3 17.408
ADAPTER	1115486-9	880669	4 17.404
IGNITER	1-069300-5	.375 ALCLO	5 17.408
6" OXID INLET LINE	1115645-9	N/A	6 17.410
6" FUEL INLET LINE	1115454-9	N/A	PRE AT 238.002 IN. ²
8" NOZZLE COOLANT INLET LINE	1115456-9	N/A	
8" NOZZLE COOLANT DUMP LINE	1115453-9	N/A	POST HICS
FILM COOLANT INLET LINE 1	N/A	N/A	1 SAME AS PRE
FILM COOLANT INLET LINE 2	N/A	N/A	2 (SEE PAGE 16 OF
FILM COOLANT INLET LINE ADAPTER	N/A	N/A	3 RPT. DR-0002
THROAT FILM COOLANT LINE	N/A	N/A	4 5.6.1.4)
TCV (HAMMEL OHL FCV)-FLASH FLOW	N/A	N/A	5
TCV (HAMMEL OHL FCV)-FLASH FLOW	N/A	N/A	6
NCV (HAMMEL OHL FCV)-FLASH FLOW	N/A	N/A	POST AT

FLOW MEASUREMENT SYSTEM

ORIFICE TYPE:	FILM COOLANT SUPPLY (WFS)	DIAM.	N/A	"K"	N/A	"B"	N/A
VENTURI TYPE:	S/N 884097 FILM COOLANT SUPPLY (WFS-1)	DIAM.	2"	"K"	7.83	"B"	N/A
VENTURI TYPE:	S/N 884099 THROAT FILM COOLANT SUPPLY (WFS-2)	DIAM.	2"	"K"	7.83	"B"	N/A
TURBINE TYPE:	FMS AJS-7-45	DIAM.	7"	"K"	0.43930	"B"	N/A
TURBINE TYPE:	FMS AJS-9-4	DIAM.	9"	"K"	0.16656	"B"	N/A
TURBINE TYPE:	FMS AJS-12-4	DIAM.	12"	"K"	0.079963	"B"	N/A

SYSTEM LOAD ORIFICE (DIAMETER)

NOZZLE DUMP	5.07"	NOZZLE POND DUMP LINE	N/A
FILM COOLANT SUPPLY LINE	N/A	THROAT FILM COOLANT SUPPLY LINE	N/A

AEROJET-GENERAL CORPORATION
SACRAMENTO CALIFORNIA

TEST ENGINEER'S REMARKS
ST1168 REV 1/64

PAGE 1 OF 1

ITEM TESTED	DATE	WORK ORDER	TEST NUMBER
FILM COOLED, PHOEBUS NTA	7/12/67	0960-64-210	1.2-09-NNJ-002
NOTE: LIST REMARKS IN SEQUENCE OF PRE-TEST, TEST CONDITIONS, POST TEST			TEST STAND

PRE-TEST:

1. REPLACED PC-0-A-E, PC-2A-E, PC-2B-E & PC-5A TRANSDUCERS, FOR UP-DATING. TIGHTENED PC-2BE APPROX. 1/4 TURN. REPLACED A PCCL-2 TRANSDUCER DUE TO A SIGNAL. 2. ADJUSTED NEW MECHANICAL STOP FOR 30% FILL OPEN. 3. COMPLETED SATISFACTORY HIGH PRESSURE LEAK CHECK OF THE LH2 & FEED SYSTEMS. 4. INSTALLED NEW IGNITERS AND COMPLETED SATISFACTORY H.G. LEAK CHECK. 5. CONDUCTED COMBUSTION & BLEED FIRE (HE-15 LISTS REQ. ACCEPTED TEST DIVISION TDC'S) 6) DECREASED LP OF NGV PRIOR TO TEST 7) RESET F31-ES 2 TIMER TO 5 SEC.

TEST:

1) THE TEST WAS CONDUCTED WITH A FILL OF 2.1 SEC. 2) THE TEST WAS TERMINATED BY A MAJOR SIGNAL AT 2.1 SEC. BY UNCV MINIMUM, DUE TO SLOW NGV RESPONSE. $WC \approx 10\%/SEC$ $KP=2$, $KI=4$, $KF=2$.

POST TEST:

1) POSTFIRE INSPECTION REVEALED NO APPARENT TEST HARDWARE DAMAGE OR ABNORMALITIES 2) COMPLETED SATISFACTORY POSTFIRE PROCEEDING & LEAK CHECKS, PREPARATORY TO REPEAT TEST

TEST ENGINEER	DATE	APPROVED BY	DATE
F. H. LYONS	8/1/67	E. Orstad	8/25/67

GENERAL CORPORATION
 GOLD RACKET PLANT SACRAMENTO, CALIFORNIA

PHOEBUS-2

 NOZZLE TEST ASSEMBLY
 CRITICAL DATA SHEET

TEST NO.	1.2-09-NNJ-003	TEST DATE	13 JULY, 1967
TEST STAND	H-4B	TEST TIME	1510 HRS.
AMB. PRESS.	14.57 PSIA	AMB. TEMP.	557 DEG F
		DURATION	1.806 SEC
		WORK ORDER	0960-64-210

HARDWARE	P/N	S/N	PRE MICS
NTA	1115858-19	880002	1 17.409 IN.
NOZZLE	1134062-9	880608	2 17.408 "
INJECTOR	1115321-19	884134	3 17.408 "
ADAPTER	1115486-9	880669	4 17.404 "
IGNITERS	1-069300-5	.375 ALCL0	5 17.408 "
6" OXID INLET LINE	1115645-9	N/A	6 17.410 "
6" FUEL INLET LINE	1115454-9	N/A	PRE AT 238.002 IN. ²
8" NOZZLE COOLANT INLET LINE	1115456-9	N/A	
8" NOZZLE COOLANT DUMP LINE	1115453-9	N/A	
FILM COOLANT INLET LINE 1	N/A	N/A	1 SAME AS PRE
FILM COOLANT INLET LINE 2	N/A	N/A	2 (SEE PAGE 16 OF
FILM COOLANT INLET LINE ADAPTER	N/A	N/A	3 RPT. DR-0002
THROAT FILM COOLANT LINE	N/A	N/A	4 5.6.1.4)
1 CV (HAMMILL ORAL FCV) FLASH FLOW	N/A	N/A	5
1 FV (HAMMILL ORAL FCV) FLASH FLOW	N/A	N/A	6
NO HAMMILL ORAL FCV FLASH FLOW	N/A	N/A	POST AT

FLOW MEASUREMENT SYSTEM

ORIFICE TYPE	FILM COOLANT SUPPLY INFE	DIAM.	N/A	"K"	N/A	"B"	N/A
ORIFICE TYPE	S/N 884097	DIAM.	2"	"K"	7.83	"B"	N/A
ORIFICE TYPE	FILM COOLANT SUPPLY (OFF.)	DIAM.	2"	"K"	7.83	"B"	N/A
ORIFICE TYPE	S/N 884099	DIAM.	2"	"K"	7.83	"B"	N/A
ORIFICE TYPE	THROAT FILM COOLANT SUPPLY (OFF. -2)	DIAM.	2"	"K"	7.83	"B"	N/A
ORIFICE TYPE	1.00 AJS-7-45	DIAM.	7"	"K"	0.43930	"B"	N/A
ORIFICE TYPE	1.00 AJS-9-4	DIAM.	9"	"K"	0.16656	"B"	N/A
ORIFICE TYPE	1.00 AJS-12-4	DIAM.	12"	"K"	0.079963	"B"	N/A

SYSTEM LOAD ORIFICE (DIAMETER)

NOZZLE DUMP	N/A 5.07"	BURN POND DUMP LINE	N/A
FILM COOLANT SUPPLY LINE	N/A	THROAT FILM COOLANT SUPPLY LINE	N/A

TEST ENGINEER'S REMARKS

ST1168 REV 1/64

PAGE 2 OF 2

ITEM TESTED	DATE	WORK ORDER	TEST NUMBER
FILM COOLED PHOEBUS NTA	7-13-67	0960-64-210	1.2-09-NNJ-003
NOTE: LIST REMARKS IN SEQUENCE OF PRE-TEST, TEST CONDITIONS, POST TEST			TEST STAND

PRE-TEST

1. CHECKED TORQUE ON CENTER BOLT @ BACK OF INJECTOR 350 FT LB.
2. CONTROLS CHANGED GAIN ON MCV TO $K_P = 9.5$ $K_I = 8$ $K_F = 2$ MNCV @ 570
3. INSTALLED NEW IGNITERS AND CONDUCTED SATISFACTORY HOT GAS LEAK CHECK
4. TOPPED OFF LO_2 & LH_2 RUN VESSELS
5. COMPLETED PRE-FIRE CHECKLISTS
6. COMPLETED COM COR SIMULATIONS

TEST

THE TEST WAS CONDUCTED FOR A DURATION OF 1.9 SEC. DUE TO LNCV MIN TRIP. PLC SWITCH WAS NOT REQUESTED FOR THIS TEST. NO LEAKS OR OTHER ABNORMALITIES WERE NOTED.

POST TEST

POST FIRE INSPECTION SHOWED NO DAMAGE TO TEST HARDWARE COMPLETED MINIMUM POST FIRE CHECKS FOR RAPID REPEAT HARDWARE REMAINED IN TEST POSITION FOR REPEAT TEST. REVIEW OF RECORD INDICATED HIGH COOLANT FLOW, VALVE COMMANDED CLOSED TO LOWER IN AND LNCV MINIMUM TRIPPED MCV MECHANICAL CLAMP WAS SET @ 30%

TEST ENGINEER	DATE	APPROVED BY	DATE
H.E. SHEPLER	7-20-67	PE Ostlund	7-21-67

NOZZLE TEST ASSEMBLY
JULY ROCKET PLANT
SACRAMENTO CALIFORNIA

PHOEBUS 2
NOZZLE TEST ASSEMBLY
CRITICAL DATA SHEET

TEST NO.	12-09-NNJ-004	TEST DATE	13 JULY, 1967
TEST STAND	H-4B	TEST TIME	2120 HRS.
AMB PRESS	14.56 PSIA	AMB TEMP.	541 DEG F
		DURATION	2.443 SEC
		WORK ORDER	0960-64-210

DESCRIPTION	P/N	S/N	PRE MICS
N/A	1115858-19	880002	1 17.409 IN
NOZZLE	1134062-9	880608	2 17.408 "
INJECTOR	1115321-19	884134	3 17.408 "
ADAPTER	1115486-9	880629	4 17.404 "
IGNITERS	1-069300-5	.375 ALCL0	5 17.408 "
6" OXID INLET LINE	1115645-9	N/A	6 17.410 "
6" FUEL INLET LINE	1115454-9	N/A	PRE AT 238.002 IN. ²
6" NOZZLE COOLANT INLET LINE	1115454-9	N/A	
6" NOZZLE COOLANT DUMP LINE	1115454-9	N/A	
FILM COOLANT INLET LINE	N/A	N/A	POST MICS
FILM COOLANT INLET LINE 2	N/A	N/A	1 SAME AS PRE
FILM COOLANT INLET LINE ADAPTER	N/A	N/A	(SEE PAGE 16 OF
ADAPT FILM COOLANT LINE	N/A	N/A	3 RPT. DR 0002
COY. FRAME ORAL FCV FLASH FLOW	N/A	N/A	4 561.4)
1. FV (HAMMEL ORAL FCV) FLASH FLOW	N/A	N/A	5
1. FV (HAMMEL ORAL FCV) FLASH FLOW	N/A	N/A	6
1. FV (HAMMEL ORAL FCV) FLASH FLOW	N/A	N/A	POST AT

FLOW MEASUREMENT SYSTEM

ORIFICE TYPE	FILM COOLANT SUPPLY (MFC)	DIAM.	N/A	"K" N/A	"B" N/A
ORIFICE TYPE	S/N 884097 FILM COOLANT SUPPLY (MFC, 1)	DIAM.	2"	"K" 7.83	"B" N/A
ORIFICE TYPE	S/N 884099 THROAT FILM COOLANT SUPPLY (MFC -2)	DIAM.	2"	"K" 7.83	"B" N/A
ORIFICE TYPE	FMC ADS 7-45	DIAM.	7"	"K" 0.43930	"B" N/A
ORIFICE TYPE	FMC ADS-9-4	DIAM.	9"	"K" 0.16656	"B" N/A
ORIFICE TYPE	FMC ADS 12-4	DIAM.	12"	"K" 0.079963	"B" N/A

SYSTEM LOAD ORIFICE (DIAMETER)

NOZZLE DUMP	N/A	DUMP POND DUMP LINE	N/A
FILM COOLANT SUPPLY LINE	N/A	THROAT FILM COOLANT SUPPLY LINE	N/A

TEST ENGINEER'S REMARKS

ST1168 REV 1/64

PAGE 2 OF 2

ITEM TESTED	DATE	WORK ORDER	TEST NUMBER
FILM COOLED PHOEBUS NTA	7-13-67	0960-64-210	1.2-09-NNJ-004
NOTE: LIST REMARKS IN SEQUENCE OF PRE-TEST, TEST CONDITIONS, POST TEST			TEST STAND

PRE-TEST

1. BACKED OFF MECHANICAL STOP ON NCV FOR CONTROLS TO STROKE VALVE 100%
2. RESET NCV MECHANICAL STOP TO 32% & ELECT. @ 27%
3. NCV SET TO RAMP ON POSITION CONTROL
4. INSTALLED IGNITERS AND CONDUCTED SATISFACTORY HOT GAS LEAK CHECK
5. COMPLETED PRE FIRE CHECKLISTS

TEST

THE TEST WAS CONDUCTED FOR A DURATION OF 2.5 SEC. SHUTDOWN DUE TO APA. NO LEAKS OR OTHER ABNORMALITIES WERE NOTED DURING TEST. ACHIEVED 0.300 SECS OF STEADY STATE OPERATION.

POST TEST

POST FIRE INSPECTION SHOWED NO DAMAGE TO HARDWARE COMPLETED POST FIRE CHECKLISTS

REVIEW OF RECORDS INDICATED PC TRANSDUCERS OSCILLATING 40 PSI PEAK TO PEAK AND APA TRIP WAS SET @ 230 PSI RECEIVED WORD FROM PROJECTS @ 1100 HRS 7-14-67 TO REMOVE NTA. REMOVED NTD FROM TEST POSITION AND PLACED ON SHIPPING CART. REMOVE INJECTOR PN 115321-19 5/8" 88-134 FROM FILM COOLED NTA AND INSTALLED ON CONVECTIVE/Y COOLED NTA.

SHIPPED FILM COOLED NTA WITH LEAK CHECK FIXTURE AND TRAVEL BOOK @ 0845 HRS. 7-20-67 TO BLDG. 2002.

TEST ENGINEER	DATE	APPROVED BY	DATE
H.L. SHEPHER	7-20-67	J.E. Orlowski	7/20/67

APPENDIX A
PART 5, CALCOMP PLOTS

FINAL DATA

1	PC-2C	PSIA	C	WE	LB/SEC
2	PC-2D	PSIA	*	MB	TEA
3	PC-5A	PSIA			
4	PC-5B	PSIA			
A	WO X.1	LB/SEC			
B	WE	LB/SEC			

PHOEBUS-2 NTA MILEPOST PARAMETERS
 TEST NO. 1.2-09-NNJ-0018 PLOT A
 TEST STAND H-48 NTA S/N 880002 P/N 1115858-19
 TEST DATE 11 JULY 1967 NG2 S/N 880608 P/N 1134062-9
 TEST DUA. 1.700 SEC. INJ S/N 884134 P/N 1115321-19
 WORK ORDER 0960-64-210
 CHECKED BY
 PLOT APPROVED BY DATE

FINAL DATA

FINAL DATA

FINAL DATA

FINAL DATA

FINAL DATA

FINAL DATA

FINAL DATA

PHOEBUS-2 NTA TRANSIENTS
 TEST NO. 1.2-09-NNJ-0018 PLOT 0
 TEST STAND H-48 NTA S/N 880002 P/N 1115858-19
 TEST DATE 11 JULY 1967 NTA S/N 880808 P/N 1134062-9
 TEST DUA. 1,700 SEC. INJ S/N 884134 P/N 1115321-19
 WORK ORDER 0560-59-210
 CHECKED BY
 PLOT APPROVED BY DATE

FINAL DATA

FINAL DATA

FINAL DATA

FINAL DATA

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FINAL DATA

FINAL DATA

FINAL DATA

FINAL DATA

FINAL DATA

0	PA1	PSIA	6	MC	LB/SEC	A	MA IN	
1	PC1-B	PSIA	7	MCL-1	LB/SEC	F	LTCV	PERCENT
2	PC-2C	PSIA	8	MCL-2	LB/SEC	G	LTCV	PERCENT
3	PC-SR	PSIA	9	VENT	LB/SEC	C	LNCV	PERCENT
4	PTJ-10	PSIA	8	M1 X-1	LB/SEC			
5	1 PCMB-PC2B	PSI	8	MC	LB/SEC			

PHOEBUS-2 NTA TRANSIENTS
TEST NO. 1.2-09-NNJ-003 PLUT D
TEST STAND H-48 NTA S/N 680002 P/N 1115858-19
TEST DATE 13 JULY 1967 MC2 S/N 880608 P/N 1134062-8
TEST DUA. 1.806 SEC. INJ S/N 684154 P/N 1115321-19
MARK ORDER 09C0-64-210
CHECKED BY
PLUT APPROVED BY DATE

FINAL DATA

FINAL DATA

FINAL DATA

FINAL DATA

FINAL DATA

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FINAL DATA