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NUCLEAR ROCKET OPERATIONS

SACRAMENTO PLANT

REPORT NO. RP-QR-0009

TO

SPACE NUCLEAR PROPULSION OFFICE - CLEVELAND EXTENSION

PHOEBUS-2 QUARTERLY REPORT (U)

FOR THE PERIOD OF

1 JUNE 1967 THROUGH 31 AUGUST 1967

SEPTEMBER 1967

CONTRACT SNPC-35

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24

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**SPECIAL REVIEW
DETERMINATION**
Class: 4
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Date: 9-1-82

REPORT NO. RP-QR-0009
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Classification cancelled (changed to)
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REPORT NO. RP-QR-0009

PHOEBUS-2 QUARTERLY REPORT (U)
FOR THE PERIOD OF
1 JUNE 1967 THROUGH 31 AUGUST 1967

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ABSTRACT

This report describes work performed on Contract SNPC-35 during the period 1 June 1967 through 31 August 1967. Activities of Task H, I, K, L, M, and N are described.

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CONTENTS

	<u>Page</u>
I. Summary	1
II. Detailed Discussion	3
A. Task H - STE and Facilities	3
B. Task I - Reports (CPFF)	4
C. Task K - Fabrication	5
D. Task L - Reliability and Quality Assurance	14
E. Task M - Testing	17
F. Task N - Reports (CPIF)	19

FIGURES

<u>Number</u>		<u>Page</u>
1	Weld Sequence and Dimensions	7
2	Coolant Tube Repair, EDM Cutouts	9
3	Coolant Tube Repair, Matching Two-Tube EDM Cutouts	10
4	Coolant Tube Repair, Center Leg Section Welding	11
5	Coolant Tube Rework Area During Rework	12
6	Coolant Tube Rework Completed	13

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I. SUMMARY

A. TASK H - STE AND FACILITIES

A six-inch thrust chamber oxidizer valve galled during cycling tests. The problem was resolved by modifying the valve design. The ten-inch main gaseous hydrogen supply valve failed to close during a liquid hydrogen pressurization test because of an actuation return spring taking a permanent compressive set. The spring was replaced and the coaxial injector film-cooled nozzle test series conducted.

Prior to convectively cooled nozzle testing, the nozzle coolant-circuit flowmeter exhibited possible secondary bearing drag. The internal rotor assembly was replaced and the convectively cooled nozzle tests were conducted.

B. TASK K - FABRICATION

Nozzle S/N 880601 fabrication was completed and buildup into Test Assembly S/N 880003 accomplished.

Nozzle S/N 880604 was ultrasonically inspected.

Nozzle S/N 880605 fabrication is approximately 80% complete.

C. TASK L - RELIABILITY AND QUALITY ASSURANCE

Reliability and Quality Assurance continued as required.

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D. TASK M - TESTING

Film-cooled nozzle test series 1.2-09-NNJ verified satisfactory operating characteristics of the coaxial injector. Convectively cooled nozzle test series 1.2-16-NNN was conducted in which Milestone No. 2 proof-test requirements and nozzle margin-performance demonstration testing were successfully accomplished.

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II. DETAILED DISCUSSION

A. TASK H - STE AND FACILITIES

1. Work Performed This Quarter

During cycling of the six-inch thrust chamber oxidizer valve (TCOV) on Test Stand H-4B 31 May, the valve remained at the 10% open position and would not close under either a normal closing signal, bias closing signal, or a fail-safe manifold closing signal. Disassembly of the valve revealed galling at the top and bottom of the horizontally oriented valve-plug and valve-sleeve. The thrust chamber fuel valve (TCFV) and the nozzle coolant valve (NCV) were then also disassembled and inspected for signs of incipient galling. Both valves revealed signs of wear although imminent seizure due to galling was not evidenced.

Repair of the TCOV, TCFV, and NCV was coordinated with the vendor, and Phoebus engineering, Phoebus materials, and test operations personnel. Sleeves and plugs of the valves were removed and returned to the vendor for modification.

With resolution of the flow control valve problem, test preparations were resumed. However, testing was further delayed when the main gaseous hydrogen supply valve failed to close during a liquid hydrogen pressurization test.

Inspection of the ten-inch inline valve revealed that the actuator return spring had taken a compressive set and required replacement.

Following repair of the gaseous hydrogen supply valve, the test setup for the film-cooled nozzle was completed and testing was initiated 11 July. The first three tests attempted were terminated by Remote Safety Shutdowns (RSS). The fourth test, conducted 13 July, was considered to be satisfactory and concluded testing of Nozzle Test Assembly S/N 880002.

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Subsequently, the film-cooled nozzle test assembly was removed from the test stand and Convectively Cooled Nozzle Test Assembly S/N 880003 installed. The test setup was completed and an initial test attempted 26 July. However, the test was aborted during final countdown when a RSS shutdown was experienced during bleed-in of the nozzle coolant line.

An investigation of the instrumentation and controls circuit associated with coolant flow revealed no abnormalities. However, subsequent removal and disassembly of the coolant-circuit flowmeter revealed the possibility of secondary bearing drag. The internal rotor assembly was replaced and the flowmeter reinstalled in the coolant system and flow tested.

Testing was resumed 2 August. RSS shutdowns terminated the first five tests. However, a series of eight full-duration tests were achieved concluding Phoebus-2 nozzle testing on Test Stand H-4B 14 August. Test hardware was then removed and the securing of the test stand initiated.

2. Work Planned for Next Quarter

Preparation of final report for this task will continue.

B. TASK I - REPORTS (CPFF)

1. Work Performed This Quarter

Program-highlight TWX reports were prepared and transmitted weekly to SNPO-C (RP-TWX-0114 through -0126).

Ten copies each of the Financial Management Report, NASA Form 533, were submitted to SNPO-C on 21 June, 24 July, and 23 August.

Monthly Report RP-MR-0019 (for the period 1 June through 30 June) was submitted 28 July to SNPO-C and distributed as directed by the

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SNPO-C Technical Director. This report included RP-TM-0015, Nuclear Nozzle Design Report, as an appendix. Monthly Report RP-MR-0020 (for the period 1 July through 31 July) was submitted 28 August to SNPO-C and distributed as directed by the SNPO-C Technical Director.

Quarterly Report RP-QR-0008 (for the period 1 March through 31 May) was submitted 28 June to SNPO-C and distributed as directed by the SNPO-C Technical Director.

2. Work Planned for Next Quarter

Additional reports required by the work statement and a final summary report will be prepared. Submittal of the final report will constitute completion of all reports under this task.

C. TASK K - FABRICATION

1. Work Performed This Quarter

a. Convectively Cooled Nozzle

S/N 880601 - The following operations were completed: fabrication; buildup of the nozzle test assembly (less injector); and delivery of the assembly to the test area.

S/N 880604 - The following operation was completed: ultrasonic inspection.

S/N 880605 - The following operations were completed: furnace brazing of coolant tubes to the jacket; and installation of the main and bolt coolant tori. During the final machining operation, the nozzle shear-lip diameter (67.250/67.260 inch) was machined oversize by 0.062 inch. The corrective procedure, initiated and coordinated with SNPO-C and LASL,

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involved a manual TIG-weld diameter buildup. The weld buildup of the flange was successfully accomplished and remachining of the diameter completed. During high-pressure proof and leak testing, tubes 36 and 37 ruptured at the forward end (core support-flange) at a pressure of 1290 psig. A repair procedure was initiated per IR No. 440471 and coordinated with SNPO-C. This procedure was applied to the nozzle with satisfactory results: the nozzle subsequently passed the high-pressure proof and leak test at 1450 psig. The backflush and flow operation was also initiated.

b. Welding

(1) Nozzle S/N 880605

The Phoebus-2 welding program concluded during this report period with the completion of all welding tasks on Nozzle S/N 880605.

Coolant Tube End-Cap Welding - Coolant tube end-cap welding on Nozzle S/N 880605 was completed by the vendor. The welding was accomplished under Revision 2 of Pyromet Procedure 128. This procedure has been used on the last three nozzles and has been consistently successful in the elimination of the weld-cracking encountered in the first nozzle coolant tube end-caps.

Torus Welding - Defect-free welds were completed at Aerojet-General on the bolt-coolant and fuel tori of Nozzle S/N 880605.

Pressure Vessel Flange Shear-Lip Weld Rework - The flange shear-lip diameter was over-machined 0.062 inch on Nozzle S/N 880605.

A manual TIG-weld procedure, designed to minimize heat input and weld-bead size, was prepared. The procedure consisted of depositing four circumferential weld passes across the under-machined area as shown in Figure 1.

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Figure 1 - Weld Sequence and Dimensions

Each pass was deposited in increments three to five inches in length and placed in an alternating sequence: i.e., 0°, 180°, 90°, 270°, etc., around the circumference. Visual and penetrant inspection was accomplished at the completion of each circumferential weld pass and upon completion of remachining of the flange diameter. The weld rework was accomplished with the nozzle in a vertical position (forward-end up) at its machining stage on the vertical lathe.

Concurrent with the nozzle rework, a manual TIG-weld pass buildup was made on a Hastelloy X plate, using Hastelloy X weld wire. Build-up dimensions were approximately 1/2 inch thick, 4 inches in width, and 4 inches in length. From this "as-welded" metal deposit, two R-3 tensile specimens were machined and tested at room temperature to determine tensile ultimate, yield strength, and elongation. The results of the tests were:

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<u>F_{tu}</u> (ksi)	<u>F_{ty}</u> (ksi)	<u>e (% in</u> <u>1-in.)</u>	<u>RA</u> (%)	<u>Hardness</u> <u>R_B</u>
116.0	77.2	25	32.2	93
115.8	79.3	31	35.5	94

The room-temperature test results revealed satisfactory strength and ductility in the "as-welded" material.

Coolant Tube Repair - During hydrostatic proof testing of Nozzle S/N 880605, the common leg of two coolant tubes partially lifted from the groove. A rework procedure used successfully on Nozzle S/N 880603 was utilized to replace the damaged tubes. This consisted of removing the damaged coolant-tube section (at the forward end of the nozzle) and regrooving by the EDM process. A matching two-tube coolant section was assembled and furnace brazed at the Pyromet Company. EDM cutouts of the two-tube section in the damaged area were made as shown in Figure 2. Matching cutouts were made in the brazed replacement coolant-tube sections (see Figure 3). The center leg section of the replacement coolant tubes was placed in position in the groove and welded as shown in Figure 4. The tube crown-caps were tacked and welded in place and B-T alloy used to braze across the ends. The welds were then blended and polished to conform to the tube contour. A leak check with gaseous nitrogen at 100 psi and a proof test with water at 1450 psig were subsequently completed with no leakage noted in the reworked area. Figures 5 and 6 show the in-process and final reworked area.

Adapter S/N 880698 Repair - Extensively damaged during Test No. 1.2-15-NNN-005 by molten metal splatter on the coolant tubes, the adapter was successfully repaired during this period. Coolant-tube damage (which was most extensive within a 9 to 12-inch band extending aft from the core support-flange interface) consisted of holes and roughened areas on the surface of the tubes.

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I.R. 440471

PAGE 3 OF

△ RECORD ACTUAL DIMENSION IN TABULATION BLOCK

DIM	REF	ACTUAL
A	4.04	4.080
B	.520	.445
C	.520	.426
D	.090/.110	.100
E	.039/.041	.043

Figure 2 - Coolant Tube Repair, EDM Cutouts

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I.R. 440471

PAGE 4 OF

① MATCH ACTUAL DIM TO CORRESPONDING ACTUAL DIM RECORDED ON PAGE

② ELOX AS SHOWN PER COGNIZANT ENGINEER.

Figure 3 - Coolant Tube Repair, Matching Two-Tube EDM Cutouts

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I.R. 440471
PAGE 5 OF

- 1 INSTALL & WELD REPLACEMENT CHANNEL JOINT & CROWNS AS SHOWN PER COGNIZANT ENGINEER.

STEP II

Figure 4 - Coolant Tube Repair, Center Leg Section Welding

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Figure 5 - Coolant Tube Rework Area During Rework (u)

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Figure 6 - Coolant Tube Rework Completed

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The plasma needle arc was used for weld repairs and the oxy-hydrogen flame generator torch was used to make the necessary braze repairs. Tube "burn-through" areas 1/8-inch in diameter or less were considered to be repairable by simple plug welds. Damaged areas in excess of 1/8-inch diameter were repaired by removing the damaged tube section and welding in a flush-patch fabricated from a stock coolant-tube. Eleven flush patches and approximately 35 "burn-through" holes were welded and then blended flush with the tube surface. A leak check with helium at 100 psi and a hydrostatic proof test at 1250 psig revealed no leakage in the coolant tube assembly.

2. Work Planned for Next Quarter

a. Convectively Cooled Nozzle

S/N 880605 - Fabrication will be completed and the unit delivered to NRDS.

D. TASK L - RELIABILITY AND QUALITY ASSURANCE

1. Work Performed This Quarter

a. Design

The following drawings were reviewed and approved:

P/N 1116478	Test Assembly, Convectively Cooled
P/N 1115486	Adapter, Injector to Nozzle
P/N 1116062	Adapter, Injector to Nozzle
P/N 1118300-29J	Nozzle, Nuclear Rocket Engine

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Final design reviews, in compliance with the reliability program plan, were published on Development Nozzle P/N 1114830, Deliverable Nozzle P/N 1118300, and Convectively Cooled Nozzle Test Assembly P/N 1115034.

b. Fabrication

The following integrated manufacturing and inspection planning was reviewed and approved for AGC fabrication:

P/N 1118706-1	Stud, Mounting Detector
P/N 1118797-1	Cover, Protective Mounting Stud
P/N 1114830-29	Nozzle, Nuclear Rocket Engine, Cleaning for, S/N 880601
P/N 1115858-9	Nozzle Assembly, Test, Film-Cooled
P/N 1115468-9	Adapter Assembly
P/N 1115493-9	Leg Adapter
P/N 1115311-9	Injector Assembly
P/N 1115858-19	Nozzle Assembly, Test, Film-Cooled
P/N 1115886-1	Support-Adapter Assembly
P/N 1115034-19	Nozzle Test Assembly, Convectively Cooled
P/N 1118300-9	Nozzle, Nuclear Rocket Engine, S/N 880604, Ultrasonic Inspection
P/N 1118300-29	Nozzle, Nuclear Rocket Engine, S/N 880605, Machining
P/N 1118300-29	Nozzle, Nuclear Rocket Engine, S/N 880605, Ultrasonic Inspection
P/N 1118300-29	Nozzle, Nuclear Rocket Engine, S/N 880605, Hydrotest
P/N SF4-2665-1PAJ	Seal, Packaging
P/N 1115319-1	Ring Baffle, Coaxial Injector
P/N 1114844	Round R-3 Tensile Specimen
P/N 1115321	Injector Assembly, Coaxial
P/N 1118300-29	S.O.S. No. 2, Nozzle, Nuclear Rocket Engine

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P/N 1118300-9	Nozzle, Nuclear Rocket Engine, S/N 880604, Dehydration and Packaging
P/N 1116088-1	Boss, Clamp
P/N 1118300-29/J	Nozzle, Nuclear Rocket Engine, for Tube Rupture Rework
P/N 1114830-49	Nozzle, Nuclear Rocket Engine, S/N 880601 (Ref. TCA S/N 880003) for Tube Crack Metallurgical Evaluation.

c. Nondestructive Testing

Nozzle S/N 880601 was X-rayed to assure tube and torus cleanliness between the throat and the aft end.

Neutron radiography experiments on a nozzle wall-section were successful in demonstrating that small items can be detected inside coolant tubes.

2. Work Planned For Next Quarter

Fabrication and inspection planning of work to be performed at Aerojet-General will be reviewed. Further experiments for detection of tube blockage will continue. Tube samples containing low-density material will be radiographed while the tubes are filled with a high-density noncorrosive aqueous solution. This "negative-radiographic" technique is expected to show low-density materials as voids in the higher-density fluid. Drawing review, approval, and release for implementation of quality requirements will continue.

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E. TASK M - TESTING

1. Work Performed This Quarter

The final critical experiment review for film-cooled nozzle test series 1.2-09-NNJ was held with representatives of SNPO, Phoebus engineering, NRO reliability and quality assurance, and test operations. Supplement No. 1 to the test request and the film-cooled nozzle test assembly addendum to the modes-of-failure analysis were presented. The review board accepted the test procedures as presented.

Tests 1.2-09-NNJ-001 through -004 of the coaxial-injector test series were conducted. Operating characteristics of the injector were verified as being satisfactory for convectively cooled nozzle testing.

Film-Cooled Nozzle Test Assembly S/N 880002 was removed from Test Stand H-4B. The coaxial injector was removed and installed on Convectively Cooled Nozzle Test Assembly S/N 880003, and the assembly and lines installed on test stand H-4B. A test request for convectively cooled nozzle test series was released.

Tests 1.2-16-NNN-001 of the convectively cooled nozzle proof-test series was conducted 2 August on Test Assembly S/N 880003. Combustion stability monitor shutdown (CSM₂) occurred at FS₁ + 1.865 seconds. Visual examination of the nozzle revealed no damage. High-frequency data were reviewed and the CSM trip level was revised.

A summary of tests -002 through -013 follows:

Test 1.2-16-NNN-002: conducted 4 August; duration 1.9 seconds; RSS due to $\Delta PCO - P_c$ in excess of 400 psid; no hardware damage.

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Test 1.2-16-NNN-003: conducted 5 August; approximate duration 2.0 seconds; RSS shutdown due to nozzle coolant-flow dropping below minimum allowable during start transient; no hardware damage.

Test 1.2-16-NNN-004: conducted 7 August; approximate duration 3.9 seconds; RSS shutdown due to CSM₂ in excess of 200 g; no hardware damage.

Test 1.2-16-NNN-005: conducted 8 August; approximate duration 5.6 seconds; RSS shutdown due to CSM₁ peak-to-peak amplitude in fuel-injector pressure in excess of 100 psi; no hardware damage.

Test 1.2-16-NNN-006: conducted 9 August; approximate duration 15.4 seconds; normal shutdown (at 20% liquid hydrogen tank level); all test objectives achieved.

Test 1.2-16-NNN-007: conducted 11 August; approximate duration 15.1 seconds; normal shutdown; all test objectives achieved.

Test 1.2-16-NNN-008: conducted 11 August; approximate duration 15.8 seconds; normal shutdown; all test objectives achieved.

Test 1.2-16-NNN-009: conducted 12 August; approximate duration 14.7 seconds; normal shutdown; all test objectives achieved.

Test 1.2-16-NNN-010: conducted 12 August; approximate duration 14.6 seconds; normal shutdown; all test objectives achieved.

Test 1.2-16-NNN-011: conducted 13 August; approximate duration 15.6 seconds; normal shutdown; all test objectives achieved.

Test 1.2-16-NNN-012: conducted 14 August; approximate duration 15.0 seconds; normal shutdown; all test objectives achieved, completing more than 75 seconds of steady-state duration at specified operating conditions.

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Test 1.2-16-NNN-013: conducted 14 August; approximate duration 16.6 seconds; successful margin demonstration test with a coolant flow-rate of 219.9 lb/sec; post-test inspection revealed a small, transverse crack on the crown of tube 128 approximately 3 inches upstream of nozzle throat.

The nozzle test assembly was removed from the test stand and returned to the assembly shop.

2. Work Planned for Next Quarter

Test reports will be written and published to complete all work under this task.

F. TASK N - REPORTS (CPIF)

1. Work Performed This Quarter

Program-highlight TWX reports were prepared and transmitted weekly to SNPO-C (RP-TWX-0114 through -0126).

Ten copies each of the Financial Management Report, NASA Form 533, were submitted to SNPO-C on 21 June, 24 July, and 24 August.

Monthly Report RP-MR-0019 (for the period 1 June through 30 June) was submitted 28 July to SNPO-C and distributed as directed by the SNPO-C Technical Director. This report included RP-TM-0015, Nuclear Nozzle Design Report, as an appendix. Monthly Report RP-MR-0020 (for the period 1 July through 31 July) was submitted 28 August to SNPO-C and distributed as directed by the SNPO-C Technical Director.

Quarterly Report RP-QR-0008 (for the period 1 March through 31 May) was submitted 28 June to SNPO-C and distributed as directed by the SNPO-C Technical Director.

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Bi-weekly PERT Reports were submitted 2, 16, and 30 June, 7 and 28 July; and 9 and 25 August (RP-PR-0050 through 0056).

2. Work Planned for Next Quarter

Additional reports required by the work statement and a final summary report will be prepared. Submittal of the final report will constitute completion of all reports under this task.