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LIQUID ROCKET PLANT

PRODUCT ENGINEERING PROGRAM

MONTHLY PROGRESS REPORT

on

Coated Metallic Thrust Chambers
Expandable Nozzles
Combustion Instability Scaling Concepts
Ablative Thrust Chambers

Weapon System 107A-2
Contract AF 04(694)-212/SA3

Report 212/SA3-2.2-M-4 15 November 1963

AEROJET-GENERAL CORPORATION
SACRAMENTO, CALIFORNIA

PRODUCT ENGINEERING PROGRAM

Contract AF 04(694)-212/SA3

1 October through 31 October 1963

Prepared by

AEROJET-GENERAL CORPORATION
Liquid Rocket Plant
Sacramento 9, California

Prepared for

BALLISTIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
Norton Air Force Base, California

5610

FOREWORD

This report is the fourth in a series of monthly reports prepared in accordance with AFBM Exhibit 58-1 and submitted in partial fulfillment of Contract AF 04(694)-212, Supplemental Agreement No. 3.

Direction for contract performance is provided by C. L. D'Ooge, Program Manager, Research and Advanced Technology Division, Liquid Rocket Plant.

The contract for the continuation of the Product Engineering Program is made up of four projects:

	Project Title	Project Engineer
I.	Coated Metallic Thrust Chambers	D. G. Harrington
II.	Expandable Nozzles	D. M. Green
III.	Combustion Instability Scaling Concepts	F. H. Reardon
IV.	Ablative Thrust Chamber Feasibility	T. A. Hughes

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TABLE LIST

I. COATED METALLIC THRUST CHAMBERS

A. INTRODUCTION

1. Purpose

The objective of this project is to develop a reliable thermal barrier capable of surface temperature operation above 3300°F for use on regeneratively-cooled thrust chambers employing N_2O_4/AeroZINE 50 propellants. Thermal barrier coatings are used for improving liquid rocket engine performance through reductions in film-cooling requirements.

2. Approaches

The development of the thermal barriers will be accomplished through:

a. Full-scale testing of coated YLR91-AJ-5 thrust chambers (Titan II second stage) at fuel-film-cooling flow of 5% or less.

b. Laboratory thermal shock, thermal conductivity, erosion-corrosion, and metallographic testing.

B. PROGRESS DURING REPORT PERIOD

1. Full-Scale Testing

Although chamber 2 had been scheduled for two 12-second tests with 17.6% film cooling, no tests were conducted. The schedule slippage was caused by delays in both fabrication of the modified coating fixture and re-arrangement of the laboratory space required to install the dust collection system to the coating fixture. Details are given in Paragraph B, 3.

2. Design

The design drawings were completed. A fabrication order was prepared to modify a new 2SIN-0 injector for 5% fuel-film-cooling. The design includes each of the features outlined in last month's progress report (Report 212/SA 3-2.2-M-3).

3. Fabrication

The modifications to the full-scale coating fixture were completed and the laboratory space expanded to accommodate a dust collection system. The modifications included the dust collection system, dust covers and wiper scrapers on polished shafts, increased straightline run-out on the cam, new gear reducers for the rotation and feed drives, a higher horsepower motor, reworked remote control valves, and a spacer ring to allow air cooling and protection of seal grooves. The target date of 11 October 1963 for completion of the modifications and enlargement of the laboratory space was not met because of unforeseen difficulties in scheduling the building maintenance personnel and in obtaining the proper speed range on the feed drive of the coating fixture. On 30 October 1963 the installation was complete.

Three practice coating passes were made on a scrap chamber. When the hydraulic fluid in the system reached normal operating temperatures, it was found that the minimum speed attainable on the feed drive was 10 rpm with a 5:1 gear reducer, whereas the maximum speed attainable with a 40:1 reducer was 17 rpm. The speed range required was found to be 3 to 30 rpm from the three practice runs and from the previous experience when hand control valves were used. Since those were the only two speed reducers available in the plant, the required speed range could not be obtained. A rush order for a 15:1 reducer was placed. In the meantime, an improvised braking method to reduce the speed of the 5:1 reducer system will be employed to coat chamber 2.

Fabrication of chamber 3 is expected to be completed 14 November 1963. Although this is one month late, the chamber could not have been used sooner because of the schedule slippage in the coating of chamber 2. Chamber 4 will be a re-coated chamber 1, 2 or 3. Chamber 5 remains on schedule for coating on 17 March 1964.

A new 2SIN-0 injector is available to modify for 5% fuel-film-cooling. Completion is scheduled for 25 November 1963.

4. Laboratory Testing

Twelve additional thermal shock specimens were coated. The composition, thickness, and deposition parameters for these coatings are given in Table I-1. The principal variables in this series are molybdenum primers vs Nichrome primers, and topcoats of Al_2O_3, ZrO_2, 90 ZrO_2-10W,* and 50ZrO_2-50ZrB_2.

Metallographic examination was nearly completed on several of the thermal shock specimens tested last month. Preliminary results indicate that the tungsten in the 90ZrO_2-10W is of such small volume and non-uniform dispersion that its presence is believed to be of little benefit. The 75ZrO_2-25W topcoats appeared somewhat better, but still not as uniform as

* Weight percent

desired. Experiments were planned to determine if a closer spray distance would make a more uniform microstructure. The microstructure of the ThO_2-W coatings appeared more attractive than the ZrO_2-W coatings.

An overall estimate of the best coating to test on chamber 2 is a gradated Nichrome-zirconia base with a topcoat of 75ZrO_2-25W. This is a change from the 90ZrO_2-10W topcoat recommended for chamber 2 in last month's report. The reasons for the selection change are both microstructural appearance and good thermal shock resistance shown by specimens 117 and 122 which had topcoats of 75ZrO_2-25W. Also, the higher percentage of tungsten will allow more accurate evaluation of the tungsten oxidation rates to be encountered in the full-scale chambers.

5. Quality Control Studies

The current contract was completed by the Pyrco Division of Anamet Laboratories for determining the feasibility of non-destructively measuring coating thickness. A final report was completed 8 October 1963. The study included evaluation of ultrasonic, beta emission, x-ray, magnetic, eddy current, capacitance, resistance, microwave, and mechanical means for determining coating thicknesses, both as a control during spraying and after firings.

It was concluded by Pyrco that the eddy current technique is the best method available for the job. Accuracies possible were estimated to be 0.001 inches or 10% of the coating thickness, whichever is greater. The work included actual calibrations on gradated Nichrome-zirconia plasma sprayed coatings on both flat and tubular specimens. The feasibility was further proved by measurements taken on chamber 1 which had previously been coated and fired three times.

A purchase requisition is being processed for a follow-on contract which will provide Aerojet-General by 15 January 1964 with a complete package of the necessary equipment, calibration data, and instructions for measuring coating thickness by the eddy current technique.

An order was placed for 5 lb of tungsten-coated thoria. Compared to the method of mixing powders in the spray feeder, this material should provide excellent composition and microstructure control.

C. NEXT REPORT PERIOD

Chamber 2 will be coated with gradated Nichrome-zirconia with a $75ZrO_2$-25W* topcoat. Five tests of 12-second duration with 17.6% fuel film cooling will be made on chamber 2. If the coating is intact after these tests, firings with 5% film cooling will be made.

The modifications of injector 2 for 5% film cooling will be completed.

Fabrication of chamber 3 will be completed.

Additional thermal shock specimens will be coated and tested for evaluation of coatings for chamber 3.

Table I-2 is a schedule of tasks for the coated metallic thrust chamber program.

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*Weight percent

TABLE I-1

SPECIMEN COMPOSITION, THICKNESS, AND DEPOSITION PARAMETERS

Applied Thickness, Mils

Composition (wt%)	Mo	NiCr	70 NiCr 30 ZrO_2	50 NiCr 50 ZrO_2	10 W 90 ZrO_2	Al_2O_3	ZrO_2	50 ZrB_2 50 ZrO_2
Specimen No.								
134		3.5	4	4	5			
135		3.5	4	4	4			
136		4	4	5		13		
137		4	4	5		12		
140(1)	7	3	4	4	6			
141	8			13				
143(1)	11			12	6			
144	11			13				
146		3	3	3	7			
147		3	3	4			4	
149		3	3	5			4	4
150		3	3	5			4	4

TABLE I-1 (cont.)

Description	Mo	NiCr	70 NiCr 30 ZrO_2	50 NiCr 50 ZrO_2	10 W 90 ZrO_2	Al_2O_3	ZrO_2	50 ZrB_2 50 ZrO_2
Powder	Metco XP1103	Metco 43C	Metco 43C (NiCr) 201B (ZrO_2)	Metco 43C (NiCr) 201B (ZrO_2)	Metco 61 (W) 201B (ZrO_2)	Metco 105	Metco 201B (2)	Norton (ZrB_2) Metco 201B (ZrO_2)
Traverse Rate (in./rev)	Specimens 140 and 141 at .075; specimens 143 and 144 at .1	.2	.15	.125	.066	.05	Specimens 149 and 150 at .075; specimens 147 at .075 and .2	.025
Surface ft/min	225	450	450	450	450	225	450	450

Test Conditions

Grit blast material: silicon carbide
Pressure, psia: 90
Deposition method: plasma arc
Arc, amps: 400
volts: 55
Argon gas flow, ft^3/hr: 100
Argon powder flow, ft^3/hr: 15
Hydrogen gas flow, ft^3/hr: 15
Feed set: 75
Deposition distance, in.: 3-3/4
Number of passes: 1

(1) Top coats not yet applied
(2) On sample 147, Norton type H zirconia substituted for Metco 201B

TABLE I-2

COATED METALLIC THRUST CHAMBER MILEPOST CHART

COATED METALLIC THRUST CHAMBERS	PRESENT SCHEDULE DAY	MO	YR	[illegible]	CY 63 J	J	A	S	O	N	D	CY 64 J	F	M	A	M	
PHASE I, ANALYSIS AND DATA EVALUATION																	
A. Heat Transfer																	
1. Initiated	1	6	63														
2. Completed	31	5	64														
B. Thermal Stress																	
1. Initiated	1	6	63														
2. Completed	31	5	64														
C. Erosion and Corrosion																	
1. Initiated	1	6	63														
2. Completed	31	5	64														
D. Data Evaluation																	
1. Initiated	1	6	63														
2. Coating Selected Chamber 2	30	10	63														
3. Coating Selected Chamber 3	30	11	63														
4. Coating Selected Chamber 4	23	12	63														
5. Coating Selected Chamber 5	17	3	64														
6. Completed	30	5	64														
E. Specification for Best Thermal Barrier																	
1. Initiated	17	3	64														
2. Completed	30	5	64														
PHASE II, LABORATORY INVESTIGATIONS																	
A. Laboratory Investigation Initiated	1	6	63														
1. Thermal Shock Tests	1	6	63														
2. Thermal Conductivity Tests	1	6	63														
3. Erosion-Corrosion Tests	1	6	63														
4. Coating Application Technique	1	6	63														
Developed																	
5. Metallography	1	6	63														
B. Laboratory Proof Tests																	
1. Initiated	15	8	63														
2. Completed	22	4	64														
C. Laboratory Investigation Completed	31	5	64														
PHASE III, QUALITY CONTROL																	
A. Studies Initiated	3	9	63														
1. Raw Material Control	3	9	63														
2. Process Control	3	9	63														
3. Destructive Sampling	3	9	63														
4. Non-Destructive Testing	3	9	63														
B. Studies Completed	22	4	64														

TABLE I-2 (cont.)

COATED METALLIC THRUST CHAMBERS	PRESENT SCHEDULE DAY	MO	YR	PRIOR	CY 63 J	J	A	S	O	N	D	CY 64 J	F	M	A	M	
PHASE IV, FULL SCALE TESTING																	
A. Thrust Chamber 1																	
1. Ready for Buildup	1	6	63														
2. Ready for Testing	7	7	63														
3. Testing Completed	6	9	63														
B. Thrust Chamber 2																	
1. Release for Fabrication	1	6	63														
2. Ready for Coating	5	9	63														
3. Ready for Buildup	12	11	63														
4. Ready for Testing	20	11	63														
5. Testing Completed	15	12	63														
C. Thrust Chamber 3																	
1. Release for Fabrication	1	6	63														
2. Ready for Coating	15	11	63														
3. Ready for Buildup	30	11	63														
4. Ready for Testing	10	12	63														
5. Testing Completed	30	12	63														
D. Thrust Chamber 4																	
1. Remove Previous Coating	1	12	63														
2. Ready for Coating	23	12	63														
3. Ready for Buildup	9	1	64														
4. Ready for Testing	13	2	64														
5. Testing Completed	29	2	64														
E. Thrust Chamber 5																	
1. Release for Fabrication	1	9	63														
2. Ready for Coating	17	3	64														
3. Ready for Buildup	2	4	64														
4. Ready for Testing	30	4	64														
5. Testing Completed	30	5	64														
F. Injector 1																	
1. Release for Modification	25	7	63														
2. Ready for TCA Buildup	3	9	63														
G. Injector 2																	
1. Release for Fabrication	30	10	63														
2. Ready for TCA Buildup	23	11	63														

◆—PRESENT SCHEDULE DATE A—ACCOMPLISHED
P—POTENTIAL CHANGE IN SCHEDULE ◇—PREVIOUS SCHEDULE DATE

II. EXPANDABLE NOZZLES

A. INTRODUCTION

1. Purpose

The purpose of this project is to develop and test high expansion ratio expandable nozzle cones for rocket propulsion systems.

2. Approach

The program objectives will be accomplished by a three-phase (design, fabrication and experimental) effort. Work will be directed to simulate the operational nozzle conditions of the Titan II second-stage engine with both metallic and non-metallic nozzle expansion cone skirt extensions. Thrust vectoring and internal gas dynamic conditions will be investigated utilizing a bi-propellant liquid rocket engine (12,000-lb thrust) mounted on a multi-axis thrust stand. A series of flight simulation tests in a wind tunnel will be conducted with scale models using various forebody shapes.

B. PROGRESS DURING REPORT PERIOD

1. Theoretical and Design Engineering

Final modifications are being made to the heat transfer computer program. This program will be ready for limited use early in November.

All test hardware and equipment has been designed and released drawings are available.

2. Fabrication

Six Lark nozzles are being fabricated of NRL material for deployment and structural evaluation.

All hardware, nozzles and throat inserts have been completed and delivered to the Azusa proving grounds for the 12K TVC test series.

Fabrication of the non-metallic AEDC Titan II second-stage expandable nozzles was initiated. Delivery of the first unit is expected to be in mid-December. The 310 stainless steel has been ordered for the metallic AEDC expandable nozzle.

For the JPL wind tunnel program, the space plane model and mount were completed. The Venus and Titan second-stage models are approximately 50% completed. The expandable nozzles for the wind tunnel test series are currently being electro-formed. All hardware will be completed in mid-November.

3. Testing

a. Lark

Five material tests were conducted on some Raybestos-Manhatten furnished nozzles, but as yet no reduced data are available.

b. 12K TVC

Repairs have been completed on the test unit that was damaged during the initial check-out series. All test nozzles and equipment have been delivered and testing will be resumed during November.

c. Titan II Second-Stage AEDC Tests

A preliminary detail test plan (Table II-1) was given to the AEDC J-4 program office for the expandable nozzle series. Before this series is begun, a short test stand shakedown series of four to six firings of the thrust chamber assembly will be conducted without expandable nozzles.

d. Wind Tunnel Tests

All preliminary preparations have been completed for the first wind tunnel tests on the space-plane type vehicle. These tests are scheduled for 21 November 1963 in the 21-inch hypersonic cell at JPL.

C. NEXT REPORT PERIOD

Fabrication of the Lark and Titan sized nozzles will be continued.

Lark, 12K TVC, and wind tunnel tests will be conducted.

Buildup at AEDC will be initiated.

The program plan is shown in Table II-2.

TABLE II-1

AEDC J-4 TEST SCHEDULE

Test No.	P_c (psia)	Nozzle Mat'l	Area Ratio	Minimum Altitude (ft)	Duration (sec)	Type of Test (N_2 Pressurant)
1	820	Rubber	75:1	70,000	10	Nozzle fully expanded when fired. Deployment tubes pressurized to 50 psia.
2	↓	↓	↓	↓	15	Nozzle deployment with engine firing. Tube pressure 50 to 60 psia.
3	↓	↓	↓	↓	15	Nozzle deployment with engine firing. Tube pressure 70 to 80 psia.
4	↓	↓	100:1	77,000	10	Nozzle fully expanded when fired. Tube pressure 50 psia.
5	↓	↓	↓	↓	15	Nozzle deployment with engine firing. Tube pressure 60 to 70 psia.
6	↓	↓	↓	↓	15	Nozzle deployment with engine firing. Tube pressure 40 to 50 psia.
7	↓	↓	150:1	87,000	10	Nozzle fully expanded when fired. Tube pressure 50 psia.
8	↓	↓	↓	↓	15	Nozzle deployment with engine firing. Tube pressure 50 to 60 psia.
9	↓	↓	↓	↓	45	Nozzle fully expanded when fired. Tube pressure varied during run. Start at 60 psia, drop pressure by hand 5 lb at 5 sec intervals until nozzle becomes unstable.

TABLE II-1 (cont.)

Test No.	P_c (psia)	Nozzle Mat'l	Area Ratio	Minimum Altitude (ft)	Duration (sec)	Type of Test (N_2 Pressurant)
10	500	310 S.S.	75:1	77,000	15	Nozzle deployment.
11			75:1	77,000	45	Nozzle deployment.
12			100:1	86,000	15	Nozzle deployment.
13			100:1	86,000	45	Nozzle deployment.
14	550		75:1	77,000	30	Nozzle deployment.
15	550	↓	100:1	85,000	30	Nozzle deployment.
16	-	-	-	-	-	Repeat test to be determined.

TABLE II-2

EXPANDABLE NOZZLE MILEPOST CHART

EXPANDABLE NOZZLES	PRESENT SCHEDULE DAY	MO	YR	PRIOR	CY 63 J	J	A	S	O	N	D	CY 64 J	F	M	A	M	
PHASE I, ENGINEERING DESIGN																	
A. Refinement and Correlation																	
of Design Progress																	
1. Initiated	1	6	63		A											◆	
2. Completed	31	5	64														
B. Lark Test Hardware																	
1. Initiated	1	6	63		A												
2. Completed	31	8	63				A										
C. 12K Test Hardware																	
1. Initiated	1	6	63		A												
2. Completed	31	9	63					A									
D. Titan Size Hardware																	
1. Initiated	1	7	63			A											
2. Completed	30	10	63						A	◇							
E. Wind Tunnel Flight																	
Simulation Test Hardware																	
1. Initiated	1	8	63				A										
2. Completed	30	10	64						A				◇				
PHASE II, FABRICATION																	
A. Lark Hardware																	
1. Initiated	1	7	63			A											
2. Completed	31	12	63								◆						
B. 12K Hardware																	
1. Initiated	1	7	63			A											
2. Completed	31	10	63						A		◇						
C. Titan Size Hardware																	
1. Initiated	1	9	63					A									
2. Completed	28	2	64										◆				
D. Wind Tunnel Support and Misc. Hardware																	
1. Initiated	1	9	63					A									
2. Completed	15	11	64							◆			◇				
E. Wind Tunnel Vehicle Models																	
1. Initiated	25	9	63					A	◇								
2. Completed	31	12	63								◆			◇			
PHASE III, TESTING																	
A. Lark Material Test (Azusa)																	
1. Initiated	1	9	63					A									
2. Completed	28	2	64											◆			
B. 12K TVC Test (Azusa)																	
1. Initiated	1	9	63					A									
2. Completed	28	2	64											◆			
C. Titan Size Nozzles (4 AEDC)																	
1. Initiated	1	1	64								◆						
2. Completed	31	3	64											◆			
D. Wind Tunnel Flight Simulation																	
Checkout Tests (Azusa)								DELETED									
1. Initiated																	
2. Completed																	
E. Wind Tunnel Flight Simulation																	
Model Tests (JPL)																	
1. Initiated	21	11	64							◆	◇						
2. Completed	31	3	64											◆		◇	
					J	J	A	S	O	N	D	J	F	M			

◆ – PRESENT SCHEDULE DATE
A – ACCOMPLISHED
P – POTENTIAL CHANGE IN SCHEDULE
◇ – PREVIOUS SCHEDULE DATE

III. COMBUSTION INSTABILITY SCALING CONCEPTS

A. INTRODUCTION

1. Purpose

The combustion instability project is directed toward establishing the applicability of subscale longitudinal mode stability testing to the prediction of the stability of all modes in large liquid rocket engines. The experimental technique under investigation has been demonstrated previously on a laboratory scale in limited testing. The primary tool is a variable length thrust chamber assembly. Both the theoretical approach and the experimental apparatus have been described in detail in previous monthly progress reports.

B. PROGRESS DURING THE REPORT PERIOD

1. Design

The final design of nearly all parts has been completed. The only exceptions are the exhaust nozzle, rear injector support, and the Kistler small-passage transducer assembly. All design work on the nozzle and injector support has been completed; only the final working drawings remain to be made. The transducer design has been delayed pending receipt of the passage configuration dimensions from Princeton University. This information is expected in the very near future. No program slippage is expected.

2. Fabrication

Fabrication of all designed components has been initiated and is proceeding according to schedule.

3. Theoretical Calculations

Calculation of preliminary theoretical instability zones has been delayed due to some uncertainties in the values of the nozzle admittance coefficient calculated by a new digital computer program. The nozzle admittance coefficient describes mathematically the effect of the exhaust nozzle on oscillations in the combustion chamber. The difficulties have been resolved and the calculations of theoretical instability zones are continuing. Because the axial distribution of combustion enters the calculation in a very significant fashion, final instability zones, used for deducing values of the combustion parameters n and τ, cannot be determined until the initial combustion distribution tests have been made.

C. NEXT REPORT PERIOD

Fabrication of thrust chamber components will continue. Procedures for determining theoretical instability zones from combustion distribution test data will be developed. Calculation of preliminary instability zones will be completed.

The milepost chart for this project is shown in Table III-1.

TABLE III-1

COMBUSTION INSTABILITY SCALING CONCEPTS MILEPOST CHART

COMBUSTION INSTABILITY SCALING CONCEPTS	PRESENT SCHEDULE			PRIOR	CY 63							CY 64				
	DAY	MO	YR		J	J	A	S	O	N	D	J	F	M	A	M
PHASE I, ENGINEERING DESIGN																
A. Concept Completed				A												
B. Predesign																
1. Initiated	1	7	63			A										
2. Completed	31	8	63				A									
C. Final Design Initiated	1	9	63					A								
1. Mount Completed	12	8	63				A	◇								
2. Thrust Chamber Completed	7	11	63					◇	◇	▲						
3. Injector Completed	4	10	63						A							
4. Actuation System Completed	12	8	63				A									
5. "Aerofoil"	11	10	63						◇A							
PHASE II, FABRICATION INITIATED	26	8	63				A									
1. Mount Completed	4	11	63							▲						
2. Thrust Chamber Completed	6	12	63								▲					
3. Injector Completed	6	12	63							P	▲					
4. Actuation System Completed	16	12	63								▲					
5. Calibration Completed	24	12	63								▲					
PHASE III, TESTING INITIATED	16	12	63								▲					
1. Test Stand Build-up Completed	6	1	64									▲				
2. Calibration Firings Completed	13	1	64									▲				
3. Test Program Completed	31	1	64									▲				
PHASE IV, ANALYSIS INITIATED	1	7	63			A										
1. Calculation of Theoretical																
Instability Zones Completed	13	1	63								◇	▲				
2. Completion of Comparison Between																
Theoretical Zones and Test Results	22	4	64												▲	

▲ – PRESENT SCHEDULE DATE   A – ACCOMPLISHED
P – POTENTIAL CHANGE IN SCHEDULE   ◇ – PREVIOUS SCHEDULE DATE

IV. ABLATIVE THRUST CHAMBERS

A. INTRODUCTION

1. Purpose

The purpose of this project is to demonstrate the feasibility of large ablatively-cooled thrust chambers for high performance liquid rocket engines operating at chamber pressures up to 300 psia for extended durations. The ablative chambers will employ the compression-molded building block concept.

2. Approaches

Six thrust chambers fabricated under Contract AF 04(647)-652/SA 33 will be used with injectors developed under the Apollo Service Module Engine Program (Contract NAS 9-150). A water-cooled transition will be used to adapt the injector to the ablative chambers, which have a Titan II second-stage configuration. The thrust chambers are described in detail in Volume I of the final report for Contract AF 04(647)-652/SA 33[1], and are briefly described in Report 212/SA 3-2.2-M-1 of the current series of monthly progress reports.

B. PROGRESS DURING THE REPORT PERIOD

1. Transition Section

Fabrication was approximately 75% completed during the report period. A one to two-week delay is anticipated in meeting the originally scheduled completion date because of a delay in delivery of material and a heavy demand on brazing furnace time. This delay will not significantly affect the overall schedule.

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(1) BSD-TDR-63-118, "Ablative Thrust Chamber Feasibility," 28 June 1963.

2. Injector

Final selection of the injector to be used in the firing tests has not yet been made. Two stainless steel injectors (S/N AT-6, AT-3) used in the early Apollo service module engine tests will be shipped from Azusa to Sacramento in order that their physical condition may be assessed. The amount of reconditioning required (if any) will determine the firing dates, and will have an influence on selection of a specific injector.

3. Ablative Chambers

Five chambers are complete and ready for firing tests. Fabrication of the sixth and last chamber has been temporarily delayed as the steel shell distorted in stress-relieving after welding. The flanges have been cut from this shell and will be welded to a new center body after it is rolled and welded.

4. Injector Heat Transfer and Stress Analysis

The analysis of the modified stainless steel Apollo injectors is underway. The results are too incomplete for incorporation in the current report.

C. NEXT REPORT PERIOD

Fabrication of the sixth chamber will be completed. The injectors will be inspected and the selection made. The thermal and stress analysis of the injector will be completed and evaluated along with the physical condition of the injectors. Upon approval of the proposed firing parameters by the

Rocket Propulsion Laboratory, the preliminary test request to the test area will be superseded by a specific test request.

The program schedule is presented in Table IV-1.

TABLE IV-1

ABLATIVE THRUST CHAMBERS FEASIBILITY MILEPOST CHART

ABLATIVE THRUST CHAMBER FEASIBILITY	PRESENT SCHEDULE DAY	MO	YR	PRIOR	Calendar Year 1963 J	J	A	S	O	N	D	Calendar Year 1964 J	F	M	A	M	
Phase I, TEST PREPARATION																	
A. Design of Ablative Chamber				▲													
B. Fabrication of Ablative Chamber																	
1. Chamber 284528-9				▲													
2. Chamber 278120-149	31	8	63				▲										
3. Chamber 278120-259	21	8	63				▲										
4. Chamber 278120-189	31	8	63				▲										
5. Chamber 284528-29	15	10	63				◇		◆								
6. Chamber 278120-219	20	11	63				◇	◇		◆							
C. Design of Metal Shell				▲													
D. Fabrication of Metal Shells (2)	10	11	63				◇	◇		◆							
E. Design of Transition Section	10	8	63				▲	◇									
1. Heat Transfer Analysis	10	7	63			▲	◇										
F. Fabrication of Transition Section	15	11	63						◇	◆							
G. Selection of Injectors	31	10	63				◇		◆	P							
H. Injector Fabrication (if required)	30	12	63					◇			◆						
I. Uncooled Chamber Acquisition	15	6	63		▲												
J. Selection of Instrumentation	15	11	63					◇		◆							
K. Selection of Firing Parameters	15	9	63					▲		◇							
L. Ablative Chamber Assembly	31	12	63						P		◆						
M. Installation of Instrumentation	30	11	63							◆							
PHASE II, FIRING TESTS																	
A. Injector Checkout	30	11	63							◆							
B. Ablative Chamber Test	31	1	64									◆					
PHASE III, DATA EVALUATION																	
A. Data Reduction	21	2	64										◆				
B. Chamber Evaluation																	
1. Performance	16	3	64											◆			
2. Materials Evaluation	16	3	64											◆			
3. Comparison with Subscale Tests	15	4	64												◆		

◆—PRESENT SCHEDULE DATE ▲—ACCOMPLISHED
P—POTENTIAL CHANGE IN SCHEDULE ◇—PREVIOUS SCHEDULE DATE

V. PROGRAM REPORTING

Listed in Table V-1 is the schedule for contract reports.

TABLE V-1

PROGRAM REPORTING MILEPOST CHART

PROGRAM REPORTING	PRESENT SCHEDULE DAY	MO	YR		CY 63 J	J	A	S	O	N	D	CY 64 J	F	M	A	M	J
1. FINANCIAL STATUS REPORT																	
1st Quarter	25	9	63					A									
2nd Quarter	25	12	63								▲						
3rd Quarter	25	3	64											▲			
4th Quarter	25	6	64														▲
2. FUNDING STATUS REPORT																	
June 1963	10	7	63			A											
July 1963	10	8	63				A										
August 1963	10	9	63					A									
September 1963	10	10	63						A								
October 1963	10	11	63							▲							
November 1963	10	12	63								▲						
December 1963	10	1	63									▲					
January 1964	10	2	64										▲				
February 1964	10	3	64											▲			
March 1964	10	4	64												▲		
April 1964	10	5	64													▲	
May 1964	10	6	64														▲
3. MANPOWER STATUS REPORT																	
June 1963	10	7	63			A											
July 1963	10	8	63				A										
August 1963	10	9	63					A									
September 1963	10	10	63						A								
October 1963	10	11	63							▲							
November 1963	10	12	63								▲						
December 1963	10	1	64									▲					
January 1964	10	2	64										▲				
February 1964	10	3	64											▲			
March 1964	10	4	64												▲		
April 1964	10	5	64													▲	
May 1964	10	6	64														▲
4. PROGRAM PROGRESS REPORT (MONTHLY)																	
June 1963	20	7	63			A											
July 1963	20	8	63				A										
September 1963	20	10	63					A									
October 1963	20	11	63						▲								
December 1963	20	1	64							▲							
January 1964	20	2	64								▲						
March 1964	20	4	64									▲					
April 1964	20	5	64										▲				
5. PROGRAM PROGRESS REPORT (QUARTERLY)																	
August 1963	17	9	63					A									
November 1963	20	12	63								▲						
February 1964	20	3	63											▲			
6. FINAL PROGRAM REPORT	15	7	64														▲
7. DOCUMENTARY FILM	15	7	64														▲

▲—PRESENT SCHEDULE DATE A — ACCOMPLISHED
P—POTENTIAL CHANGE IN SCHEDULE ◊ — PREVIOUS SCHEDULE DATE

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