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INVESTIGATE METHODS OF FABRICATING AND JOINING LARGE SANDWICH SEGMENTS FOR FORMING COMMON DOMES

MONTHLY REPORT

1 OCTOBER - 31 OCTOBER 1964
DOUGLAS ~~REPORT~~ SM-48069

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
SANTA MONICA, CALIFORNIA

DOUGLAS

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PREPARED FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
GEORGE C. MARSHALL SPACE FLIGHT CENTER
CONTRACT NO. NAS 8-11648

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SEGMENTED BULKHEAD PROJECT

DOUGLAS MISSILE & SPACE SYSTEMS DIVISION

PREFACE

This is the fifth monthly progress report on the program to "Investigate Methods of Fabricating and Joining Large Sandwich Segments for Forming Common Domes." This work is being done for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama, under Contract Number NAS 8-11648, dated 11 June 1964. This report covers the period from 1 October through 31 October 1964.

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Section 1
INTRODUCTION

The objective of this program is to develop fabrication techniques and processes that will simplify or improve the manufacture of common bulkheads for Saturn upper stages. The general approach that will be followed is to exploit the latest adhesive bonding technology for the structural joint on the liquid hydrogen (LH_2) side by use of the existing welding techniques for the joint on the liquid oxygen (LO_2) side of the common bulkhead. This 15-month program will make maximum use of available Saturn S-IV tooling and manufacturing capability to build a full-scale (18-ft. -dia.) common bulkhead suitable for testing.

The program has been broken down into the following phases:

Phase I - Design and Analysis--The objective of Phase I is to analyze a variety of joints (bonded or bonded plus mechanical fasteners on the LH_2 skin and on the welded LO_2 skin) and to select the three most promising joints for further testing.

Phase II - Flat-Panel Testing--The objectives of Phase II are (1) to verify the mechanical properties (tension and compression plus limited fatigue) for the spectrum of temperature conditions to which the joints will be subjected (ambient to -423°F), and (2) to determine the effect of thermal shock on the joints. Two joints will be selected from this phase for further evaluation.

Phase III - Subscale Testing--The objectives of Phase III are (1) to obtain initial experience on manufacturing problems and techniques for application to the full-scale bulkhead, and (2) to determine the permeability of the bonded joints when they are subjected to pressure and biaxial stress. From these tests, a joint design will be selected for the full-scale bulkhead fabrication.

Phase IV - Full-Scale Fabrication--The objective of Phase IV is to design and build a full-scale (18-ft. -dia.) bulkhead suitable for testing.

The following sections of this report describe the work accomplished to date (Section 2) and the work planned for the coming month (Section 3). Within each of these sections, the discussions are arranged according to the phases and tasks outlined in the contract work statement. The accomplishments for the report period and the results obtained are discussed, and those results are analyzed and interpreted. Also included is a discussion of the problems encountered, their possible effects on the performance of the program, and proposed corrective actions.

The purpose of this report is to describe the progress that has been made on the program during the past month.

Section 2

WORK ACCOMPLISHED DURING REPORT PERIOD

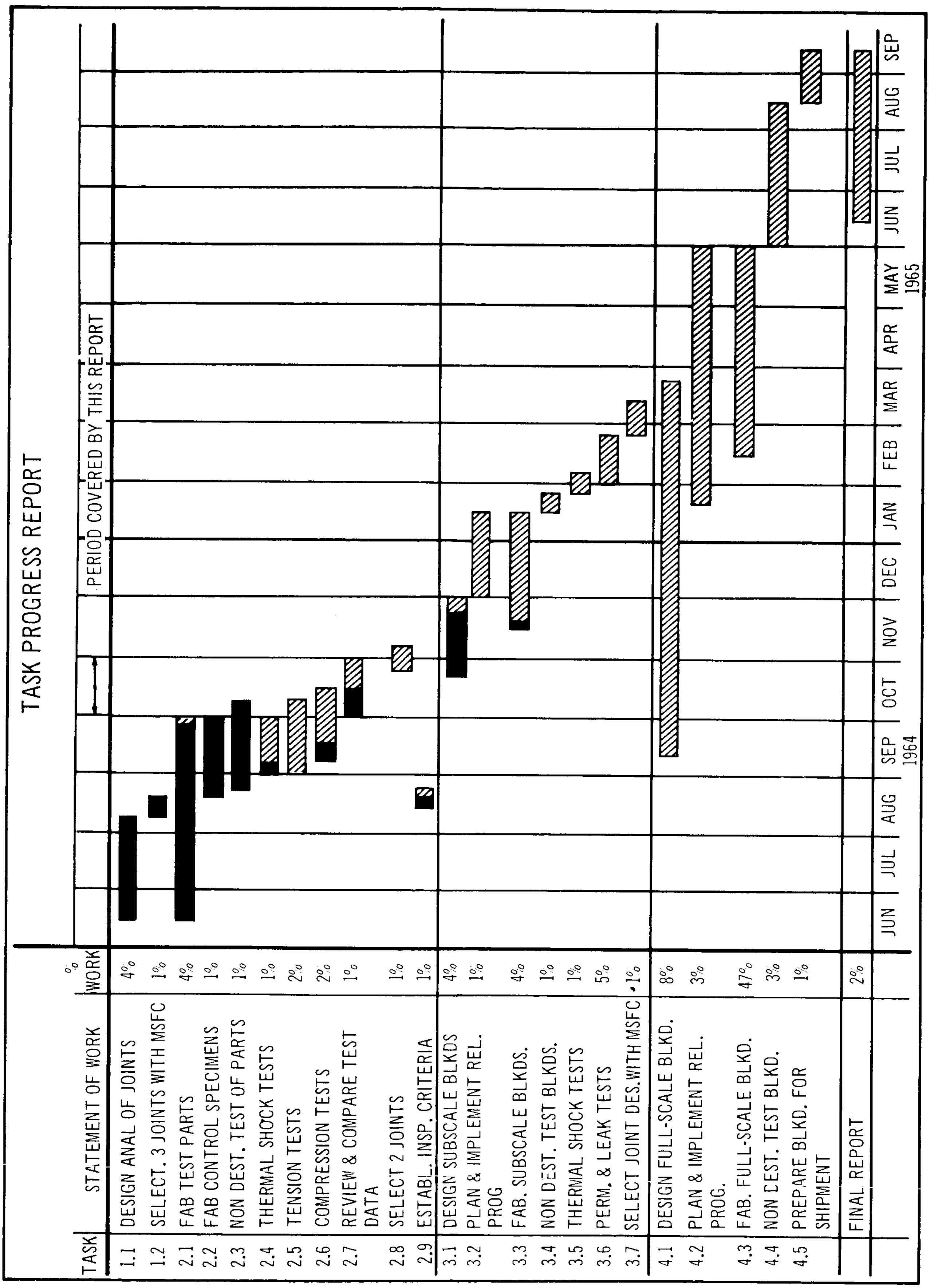
The schedule for the entire program is shown in Figure 1. The solid black bars represent the progress on each task to date. Only Task 2.1, Fabrication of the Test Parts; Task 2.3, Nondestructive Test of Parts; Task 2.4, Thermal Shock Tests; Task 2.5, Tension Tests; Task 2.6, Compression Tests; Task 2.7, Review and Comparison of Test Data; Task 2.8, Selection of Two Joints; Task 3.1, Design of Subscale Bulkheads; and Task 4.1, Design of Full-Scale Bulkhead, were scheduled to be under way at this time. As of 1 November, as shown in Figure 1, Task 2.3 was complete; Task 3.1 was three weeks ahead of schedule; and upon completion of Tasks 2.1 and 2.4, Tasks 2.5, 2.6, and 2.9 will be carried to completion.

The progress to date is discussed in more detail in the following paragraphs, which are arranged according to the task numbers shown in Figure 1.

Task 2.1--Fabrication of the Test Parts

The objectives of this task are to prepare suitable tension and compression test specimens for verification of the candidate joint design concepts and to modify existing test fixtures where needed (or to fabricate test equipment as required) to test flat-panel specimens.

The compression specimens and controls are complete. The tension specimens are complete except for drilling the hole patterns for the end-plate attachment. Before the mechanically fastened splice specimens are completed, some sample blind bolts (Figure 2) were tried to establish normal installation processes and to experience repair procedures. On the actual flat-panel specimens, a seal technique was also developed. The quality of this seal will not be known until Phase III testing is complete.


TASK PROGRESS REPORT
PERIOD COVERED BY THIS REPORT
TASK
STATEMENT OF WORK
% WORK
1.1 DESIGN ANAL OF JOINTS 4%
1.2 SELECT. 3 JOINTS WITH MSFC 1%
2.1 FAB TEST PARTS 4%
2.2 FAB CONTROL SPECIMENS 1%
2.3 NON DEST. TEST OF PARTS 1%
2.4 THERMAL SHOCK TESTS 1%
2.5 TENSION TESTS 2%
2.6 COMPRESSION TESTS 2%
2.7 REVIEW & COMPARE TEST DATA 1%
2.8 SELECT 2 JOINTS 1%
2.9 ESTABL. INSP. CRITERIA 1%
3.1 DESIGN SUBSCALE BLKDS 4%
3.2 PLAN & IMPLEMENT REL. PROG 1%
3.3 FAB. SUBSCALE BLKDS. 4%
3.4 NON DEST. TEST BLKDS. 1%
3.5 THERMAL SHOCK TESTS 1%
3.6 PERM. & LEAK TESTS 5%
3.7 SELECT JOINT DES. WITH MSFC 1%
4.1 DESIGN FULL-SCALE BLKD. 8%
4.2 PLAN & IMPLEMENT REL. PROG. 3%
4.3 FAB. FULL-SCALE BLKD. 47%
4.4 NON DEST. TEST BLKD. 3%
4.5 PREPARE BLKD. FOR SHIPMENT 1%
FINAL REPORT 2%
JUN
JUL
AUG
SEP
1964
OCT
NOV
DEC
JAN
FEB
MAR
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1965
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FIGURE 1

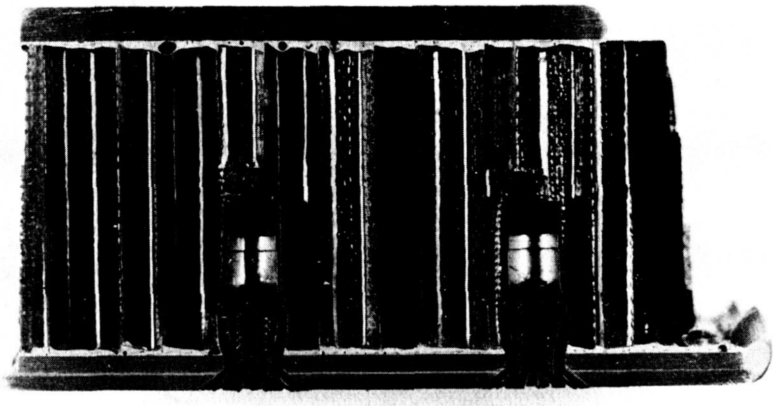


Figure 2 Section of Mechanically Fastened Splice Samples

The modifications to the compression test fixture are complete. The cryostat for the tension test has been completed; however, it did not pass the LN_2 leak check and is being reworked. This rework consists of (1) replacing the existing angle with a heavier one and using more and heavier screws to fasten it to the cryostat, (2) using a backup plate on the door, and (3) sealing the lower load fixture to the base of the cryostat.

Task 2.3--Nondestructive Testing of the Parts

The weldments on the LO_2 skin have been X-rayed. The core-to-skin bond and the bonded and mechanically fastened plus bond joints have been ultrasonically tested; C-scan recordings were made at several db intensities. These will later be correlated with physical test results. Some unbonded or bubble areas have been detected adjacent to the splice centerline. It is felt that this could be caused by air in the honeycomb core adjacent to the splice centerline attempting to escape through the glue when the splice was bagged and cured. This can be avoided on subsequent joints of this type by sealing the gaps between skin segments with a high-viscosity room-temperature curing adhesive (highly viscous version of EC 2216). This process will be helpful in keeping etchant and water out of the core during the etching process.

Task 2.4--Thermal Shock Tests

Before mechanical testing, the program requires that those specimens slated for testing at cryogenic temperatures must first be exposed to LH_2 three times. Five pairs of specimens have been thermal-shocked once. A good deal of difficulty has been encountered and these tests are progressing very slowly. The silicone sealing material sealing the edges of the parts has proven to be inadequate and the specimens have been reworked with NARMCO 7343 as a sealant (Figure 3).

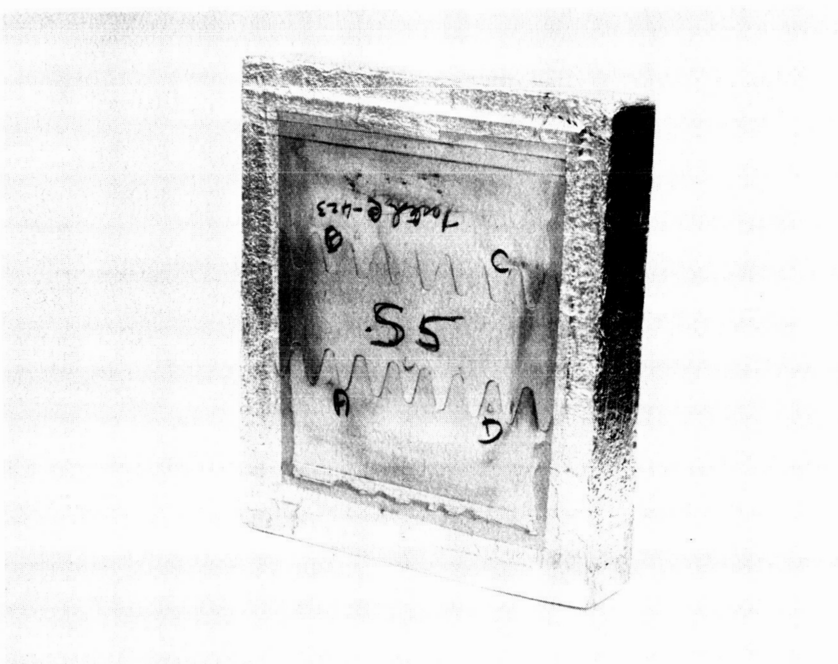


Figure 3 Two Specimens Sealed for Thermal Shock

The first attempted thermal shock test revealed some shortcomings in the test procedure and equipment. As a result, some revisions were made and a second attempt to thermal-shock the specimens resulted in some success, although the liquid-level sensor failed to function properly and it is not known whether the specimen was completely submerged in LH_2. The test took more than 3 hours and the 100-liter cryostat was not full at the end of the work shift, so the test was terminated. The third test also proved somewhat successful. The procedure was changed to precool the lower half of the cryostat with LN_2 while suspending the specimen in the upper half. The LN_2 was then blown off and the LH_2 was filled to the proper level. Then the specimen was plunged into the LH_2. The level sensor operated routinely during LN_2 precool; however, it again malfunctioned when the LN_2 was blown off and the LH_2 added. The test proceeded as usual (with the exception that the level indicator was malfunctioning) until it was noticed that LH_2 was overflowing the top of the cryostat. The fill was then stopped; when the vent line was turned on, no blow-off occurred, indicating that the aspirator valve was frozen or the vent line clogged. After considerable delay, blow off occurred using an alternate vent line. It was subsequently found that the bottom half of the cryostat and the vent line contained frozen nitrogen, indicating that all the LN_2 had not been blown off during the precool procedure. This may also explain the malfunction of the liquid-level sensor.

Task 2.5--Tension Tests

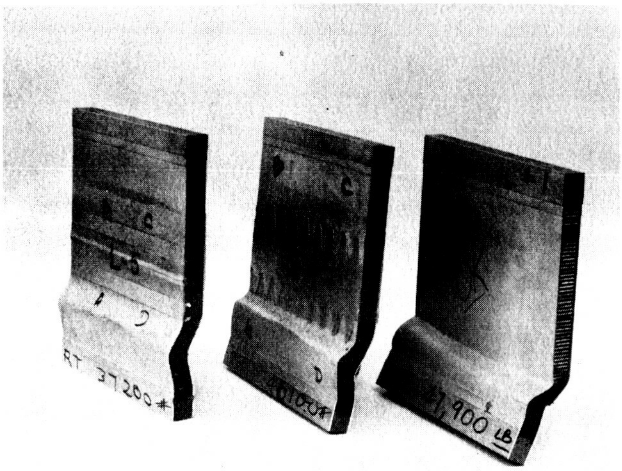
The specimens are not quite complete and the cryostat is being reworked, so these tests have not been started.

Task 2.6--Compression Tests

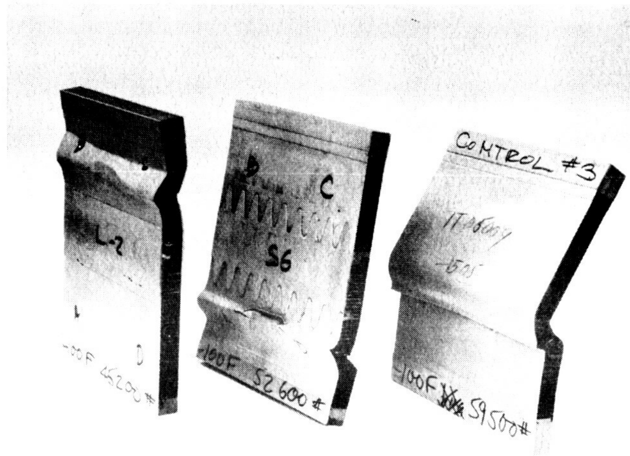
Four compression specimens have been tested at room temperature and four at -100°F. In addition, two compression control specimens each have been tested at room temperature, -100°F, and LN_2 temperature (Figure 4). The test site surrounding the sand-bagged test facility is being cleared to conduct the cryogenic compression tests safely.

Task 2.7--Review and Comparison of Test Data

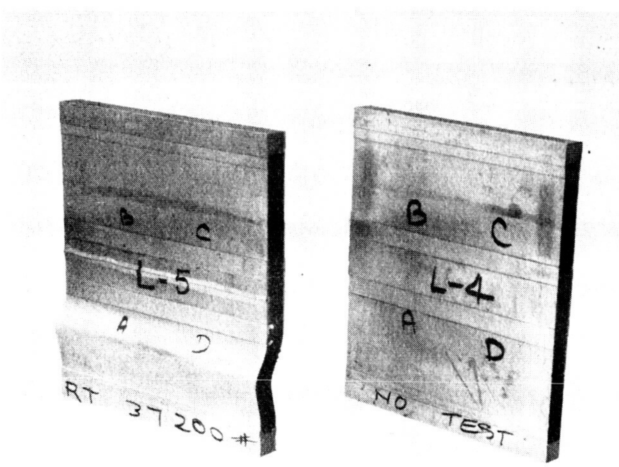
The objective of this task is to compute (1) the loads to be applied to individual tension or compression specimens at all temperature points, and (2) fatigue loads for those specimens requiring fatigue testing, and to compare the actual



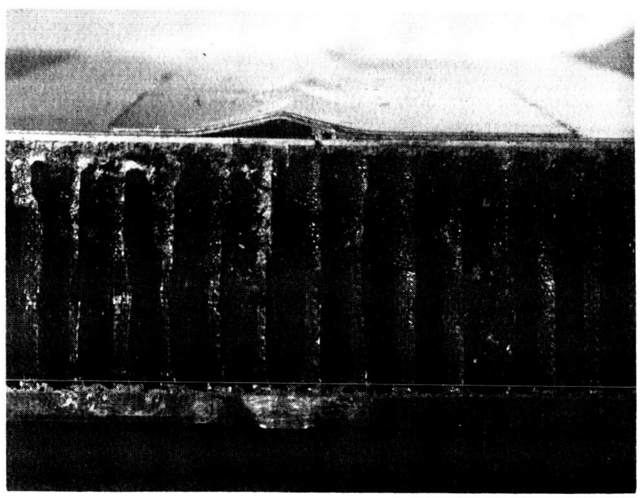
A. COMPRESSION SPECIMENS TESTED AT ROOM TEMPERATURE



B. COMPRESSION SPECIMENS TESTED AT -100°F



C. LAMINATED DOUBLERS – COMPRESSION SPECIMENS BEFORE AND AFTER TEST



D. SPECIMEN L-5 SHOWING BUCKLING FAILURE IN DOUBLER

Figure 4 Compression Specimens

ultimate fatigue loads and applied fatigue loads to the predicted or required values. This comparison is to serve as a basis for evaluation.

In the previous progress report (SM-48034, "Investigate Methods of Fabricating and Joining Large Sandwich Segments for Forming Common Domes," Monthly Report dated 1 September - 30 September 1964), Task 2.7, the predicted or computed loads were given for the tension specimens. Because of an error during manufacturing in rough sawing the specimens before finish machining, the test specimen width had to be reduced from 6-7/8 in. to 6-5/8 in.; therefore, the expected and applied loads had to be revised for the tension specimens only. These new loads are as follows: ultimate, 18,830 lb. at room temperature; 32,360 lb. at -320°F; and 34,380 lb. at -423°F. Fatigue loads to be applied to tension specimens for cryogenic testing are 13,950 lb. at -320°F and 25,450 lb. at -423°F.

As mentioned in Task 2.6, SM-48034, some compression testing has been accomplished at ambient and -100°F. The results of these tests are shown in Table I. The table shows that a wide variation exists between the failure loads of Specimens No. S4 and No. S3. The premature failure of No. S3 was caused by contamination of the bond line near the butt end of the facing skins; a substrength bond was made, causing consequent doubler buckling at the skin joints. An additional panel of this type will be tested at ambient temperature in an attempt to verify the failure load of No. S4. It can also be seen that the laminated doubler, Configuration 3C, scores consistently lower than the scalloped doubler.

Specimens No. L6 and No. L5, tested at ambient temperature, both failed to meet the basic strength requirement of 40,500 lb. Testing has not been done on mechanically fastened joints and, consequently, a comparison between bonded and mechanically fastened joints cannot be made at this time.

Task 2.9--Establishment of Inspection Criteria

The objective of this task is to establish the inspection criteria to be used on the fabrication of the subscale and full-scale bulkhead. Since these criteria are dependent on the joints selected and the fabrication techniques used,

Table I

FLAT-PANEL COMPRESSION TEST RESULTS

Joint Type	Ambient			$-100^{\circ}F$			LN_2			LH_2		
	Spec. No.	Ultimate Load	LH_2 Skin Stress	Spec. No.	Ultimate Load	LH_2 Skin Stress	Spec. No.	Ultimate Load	LH_2 Skin Stress	Spec. No.	Ultimate Load	LH_2 Skin Stress
Scalloped Doubler (Conf. No. 4)	S4 S3 Avg.	46,100 38,500 42,600		S2 S6 Avg.	47,500 52,600 50,050							
Laminated Doubler (Conf. No. 3C)	L6 L5 Avg.	38,900 37,200 38,050		L3 L2 Avg.	46,200 45,200 45,700							
Mechanical Fastener Doubler (Conf. No. 8A)												
Control No Splice in Either Skin	No. 1 No. 2 Avg.	47,900 41,500 45,700		No. 3 No. 4 Avg.	59,500 56,600 58,050		No. 5 No. 6 Avg.	65,200 67,500 66,350				

meaningful criteria can best be determined during and after the fabrication of the flat-panel specimens.

Since the fabrication of test parts was scheduled for completion in early October, but has been delayed because of difficulty in the cryostat for the tension cryogenic testing, these inspection criteria will be determined during the coming month, at which time the cryostat will have been reworked and sufficient experience gained from fabrication of the test parts.

Task 3.1--Design of the Subscale Bulkhead

The objectives of this task are (1) to gather some initial experience in the manufacturing problems and techniques for the full-scale bulkhead, and (2) to determine the permeability of the bonded joints. The design has been completed on the entire bulkhead (LH_2 skin splices and doublers) for all three types of joints now being tested in Phase II of this program. However, only the LO_2 skins (honeycomb core, ring spacers, and leak-detector fittings) have been released to manufacturing. As soon as flat-panel testing is complete and the joint selection for Phase III has been accomplished, the LH_2 skins and splices can be modified, if necessary, to improve or further continue the joint, and the drawings can be released immediately to manufacturing departments for fabrication of the remaining parts (LH_2 skins and splice details).

The drawings for the subscale bulkheads will be submitted to Marshall Space Flight Center following the Phase III joint selection.

Task 3.3--Fabrication of the Subscale Bulkheads

Initial drawings for the fabrication of the subscale bulkhead were released early in October so as to allow planning and fabrication of the unchanged parts to be initiated early in the program.

Task 4.1--Design of the Full-Scale Bulkhead

The objective of this task is to design and issue drawings suitable for fabricating and testing an S-IV-size common bulkhead, incorporating the joint or joints selected from Phase III.

The design commenced with layout and determination of basic geometry compatible with existing tooling, or requiring the smallest amount of modification to that tooling, but still adaptable to bonded or mechanically attached joints between dome skins and lower attach rings. Several different joint configurations have been nominated; however, the design has not been carried far enough to determine the most feasible type of joint for the forward (LH_2) skin. It has become apparent that if an all-bonded joint were selected for this bulkhead, it would be desirable to have a new extruded "T" for the forward attach ring that would allow more overlaps for bond strength. However, a new extruded "T" would necessitate new stretch dies to form the ring segments and new indexing points in the bonding fixture for holding the ring during bonding to the forward dome skin.

Section 3

WORK TO BE ACCOMPLISHED DURING COMING MONTH

Task 2.1--Fabrication of the Test Parts

During the early part of November, fabrication of the test parts will be completed.

Task 2.4--Thermal Shock Tests

Thermal shock tests of all the compression specimens to be tested in liquid nitrogen and liquid oxygen will be completed early in November.

Task 2.5--Tension Tests

During the next month, tension testing will be initiated as soon as the bolt holes for attaching the tension specimens to the test fixtures are drilled. This effort is scheduled to begin the first week of November.

Task 2.6--Compression Tests

Compression testing will continue during the next month on the laminated-doubler configuration and the scalloped-doubler configuration; all tests will be conducted on the mechanical fastener configuration. As noted previously, available test results are indicated in Table I.

Task 2.7--Review and Comparison of Test Data

During the next report period, it is anticipated that nearly all testing will be completed. At the completion of this testing, comparison can be made among the three types of joints, including those at the cryogenic temperatures, and the effect of fatigue loading on the ultimate strength of the joint will be determined.

During the next month, another panel will be tested and its ultimate failure load will be compared to No. S3 and No. S4 for more reliable failure loads for this type of joint.

Task 2.9--Establishment of Inspection Criteria

During the coming month, inspection criteria will be determined following the fabrication of all test parts.

Task 3.1--Design of the Subscale Bulkheads

During the coming month, design of the subscale bulkhead will cease until the Phase II flat-panel tests are completed and the two joint configurations to be used in the subscale bulkheads are selected.

Task 3.3--Fabrication of the Subscale Bulkheads

Work will continue on the planning and fabrication of the unchanged parts to be initiated early in the program. This work is expected to get under way the second week of November.

Task 4.1--Design of the Full-Scale Bulkhead

The design of the full-scale bulkhead will continue on a part-time basis, since most attention will be paid to analysis of the results of the flat-panel testing and preparation of evaluation data for joint selection. The work that will be done on this design is concentrated on the LO_2 skin and its joints, as it will be the pacing item for full-scale bulkhead fabrication.