

UNCLASSIFIED

AD NUMBER: AD0851136

LIMITATION CHANGES

TO:

Approved for public release; distribution is unlimited.

FROM:

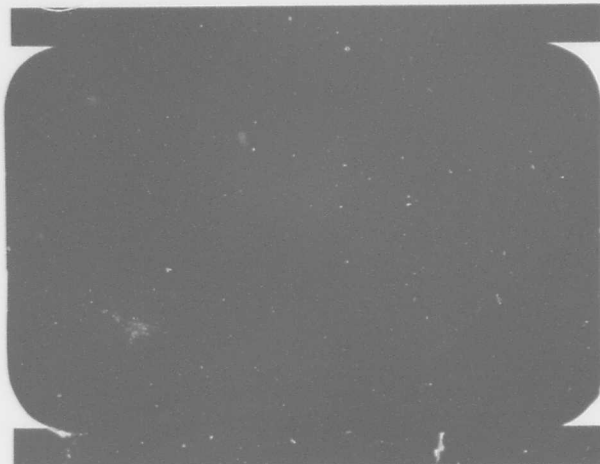
Distribution authorized to U.S. Gov't. agencies and their contractors; Export Controlled; 20 Apr 1962. Other requests shall be referred to

AUTHORITY

SAMSO ltr dtd 20 Mar 1972

~~SECRET~~
~~TOP SECRET~~
AD851136

110
1



This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of:
Hq. SAMS0, LA., Ca. 90045
Attn: SMSD



GD

**GENERAL DYNAMICS
ASTRONAUTICS**



CONVAIR | ASTRONAUTICS FORM A2136-1 (9-60) AS

DDC
MAY 1 1969
JH

AD851136

REPORT NO. AE 62-0370

GD
GENERAL DYNAMICS | AERONAUTICS

DESIGN AND ANALYSIS OF
CENTAUR INTERMEDIATE BULKHEAD
IMPROVEMENTS

GENERAL DYNAMICS
ASTRONAUTICS

MAY 1 1962

LIBRARY

PREPARED BY F. C. Rosacker

APPROVED BY J. L. Lighttown

CHECKED BY _____

APPROVED BY W. F. Radcliffe

General Dynamics | Astronautics
A Division of General Dynamics Corporation
San Diego, California

20 April 1962

MAY 1 1969

This document is subject
to special export controls and
each transmittal to foreign
governments or foreign
nationals may be made only
with prior approval of:
Hq. SAMS0, LA., Ca. 90045
Attn: SMSD

CONTENTS

List of Illustrations	iii
List of Tables	iii
Introduction	iv
Summary	vi
1. STEEL VACUUM BULKHEADS	1
1.1 Original Design	1
1.2 Firm Design Improvements	1
1.3 Improvement Development Program	5
2. NONVACUUM INSULATING BULKHEADS	9
2.1 Foam Insulated Bulkhead	9
2.2 Hydrogen Cavity Bulkhead	9
2.3 Rigid Honeycomb Bulkhead	9

ILLUSTRATIONS

1. General configuration.	v
2. Original spring ring design.	2
3. Improved spring ring for frontal bulkhead support.	4
4. Compressive stress in the meridional direction.	6
5. Compressive wrinkling in the frontal bulkhead.	7

TAELES

I. Firm improvement effectivities.	5
------------------------------------	---

INTRODUCTION

The present configuration of the Centaur propellant tank integral bulkhead is based upon the separation of oxygen and hydrogen by an intermediate double-walled bulkhead representing a minimum weight design.

The double-walled bulkhead provides a space between the two bulkheads which is filled with fiberglass insulation. In the present design, the frontal bulkhead wall facing the hydrogen is rigidly installed. The rear bulkhead wall on the oxygen side is kept elastic by means of a spring ring. The over-all arrangement is shown in Fig. 1. Upon pressurization of the oxygen tank, the rear bulkhead wall is forced against the front bulkhead wall, compressing the fiberglass insulation and supporting the frontal bulkhead against the load of the hydrogen tank.

Upon tanking liquid hydrogen all gases present in the interbulkhead space are frozen out, except traces of hydrogen and helium present in air. As a result the pressure is reduced to a value of 7 to 10 microns of mercury (μ Hg). Under these conditions the heat transfer from the oxygen into the hydrogen tank through the bulkhead is minimized.

In practice, leakage of hydrogen or helium, or both, into the interbulkhead space represents, by far, the greatest danger to the insulating quality of the bulkhead. The leakage causes the gas pressure to rise and thereby increases the thermal conductivity of the insulating material. Elimination of leakage, therefore, is the prime object of the Centaur intermediate bulkhead improvement program. However, a parallel effort is underway to design an insulation bulkhead for Centaur which will not require a vacuum for satisfactory performance.

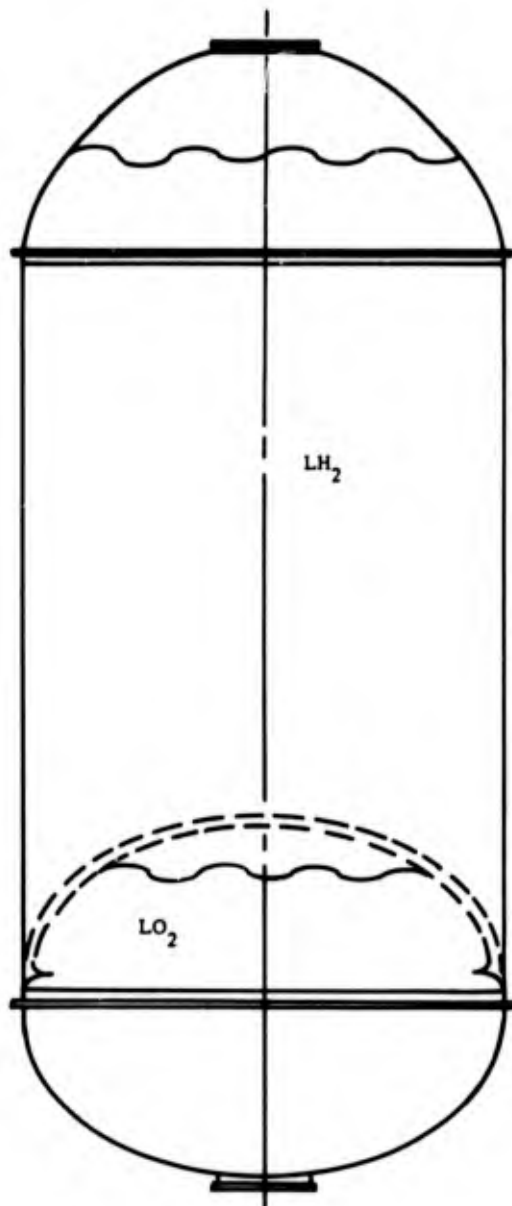


Fig. 1. General configuration.

SUMMARY

ve
This report outlines the design and analysis approach to be taken by General Dynamics/Astronautics in a program to improve the Centaur intermediate bulkhead. The total program activity includes this design plus a significant series of tests which are described in Report No. AE62-0303, Technical Plan for Centaur Alpha Bulkheads, 20 March 1962.

1 | STEEL VACUUM BULKHEADS

1.1 ORIGINAL DESIGN

The bulkhead walls are ellipsoidal and are made up of gores (orange peels) of SAE 301 1/2 hard stainless steel. These gores are fusion welded together with heli-arc butt weld joints. These joints are essentially annealed and reinforced with doubler plates which straddle the fusion weld and are resistance spot welded to the gores. This type of design is standard in all Atlas missiles, and has proven very reliable.

In Centaur three significant new conditions exist which are not present in Atlas. The first is the temperature of the liquid hydrogen, which has been shown to seriously reduce the fatigue life of spot welded joints in Type 301 steel. The second is the thin gage of the material (0.010), which taxes the welding abilities of the manufacturing department to a very high degree. The third is the elastic mounting of the bulkhead wall on the oxygen tank side. Fig. 2 shows a cross-section through the bulkheads where they join the outside cylindrical wall and illustrates this elastic "spring ring."

As discussed earlier, the spring ring will allow the oxygen tank bulkhead to move upward when this tank is pressurized, thus supporting the bulkhead in the hydrogen tank. However, the oxygen tank bulkhead will support the hoop loads, and therefore will not expand freely in a radial direction. This will result in the hydrogen tank bulkhead being not fully supported in the tangential area near the cylindrical wall. Thus, when the hydrogen tank is pressurized, the bulkhead will buckle inward in the region near the outer wall. This action, combined with the outward deflection of the outer wall under the same pressure, will place tension on the spot welds which attach the bulkhead to the outer wall.

The problems with the original design are: (1) low fatigue life of spot welds in liquid hydrogen, (2) difficulty of welding the 0.010 material, (3) buckling of the hydrogen tank bulkhead, and (4) tension loads on spot welds.

1.2 FIRM DESIGN IMPROVEMENTS

Leakage prevention, as mentioned earlier, is the prime objective of the bulkhead improvement program, and since the obvious leakage source is the welded joints, the improvements generally involve: (1) reduction or elimination of the welds, (2) increasing the fatigue life of the joints by lowering the stress level or by reducing the wrinkling and buckling, and (3) redesigning the welds so as to increase the weld

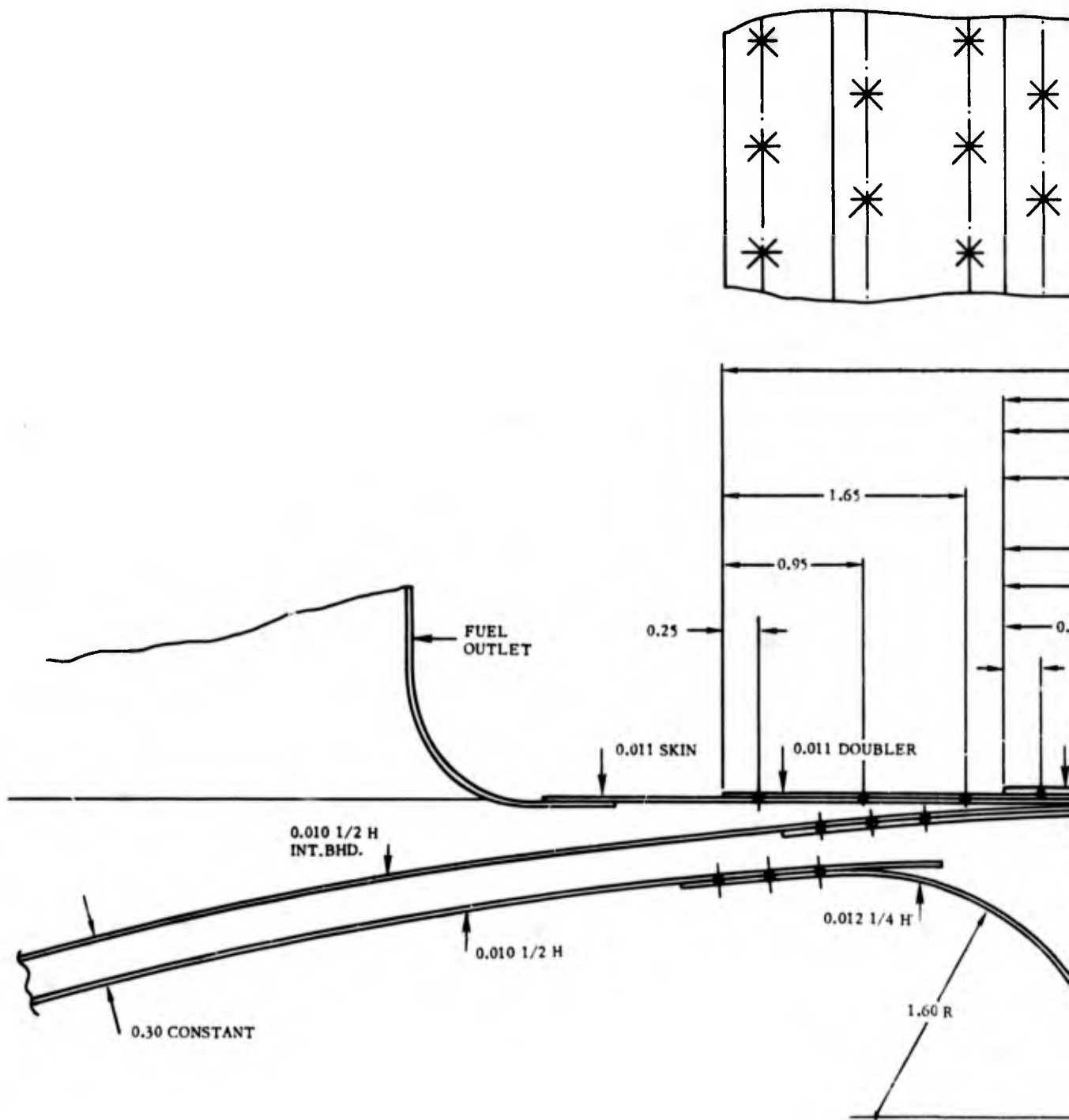
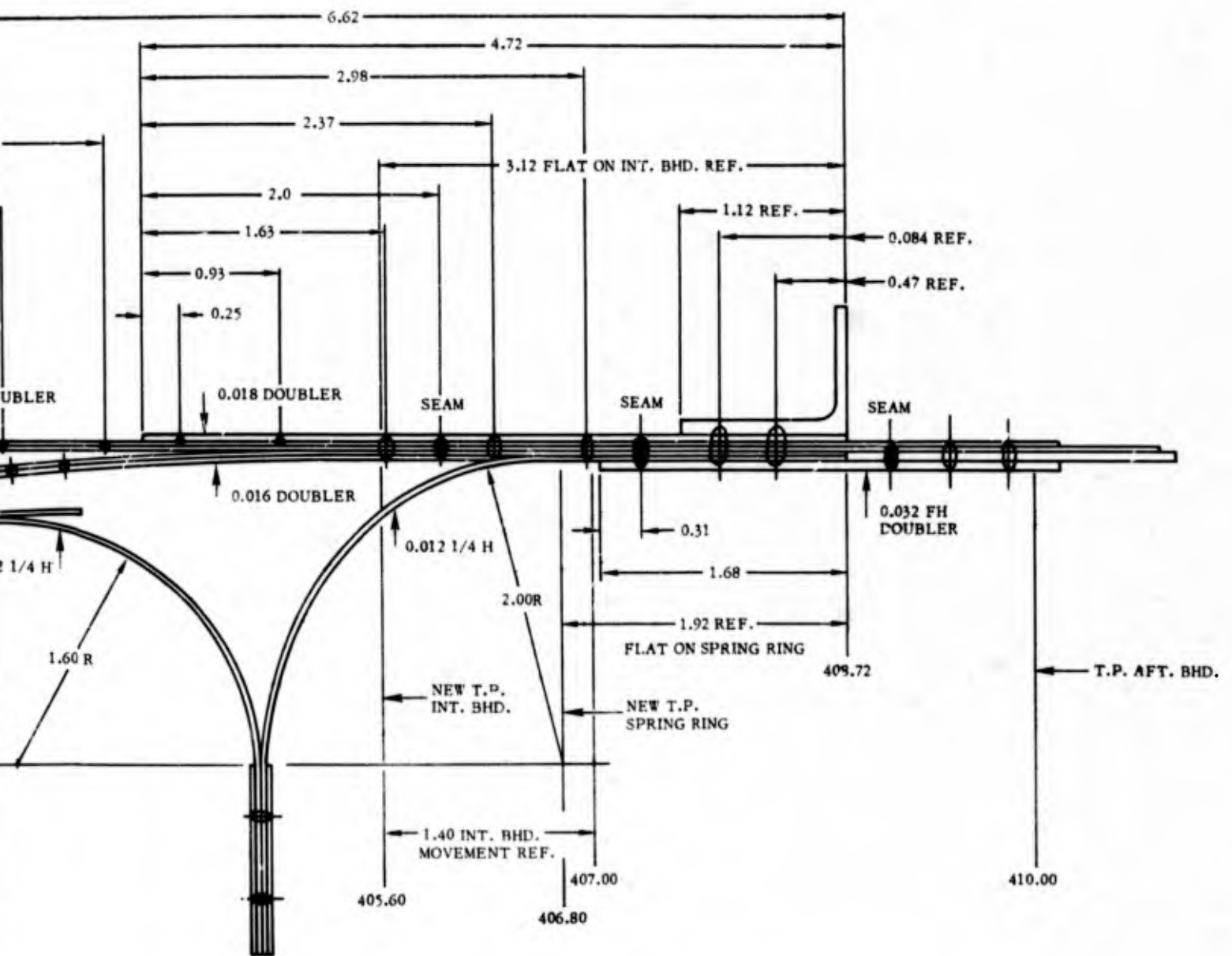
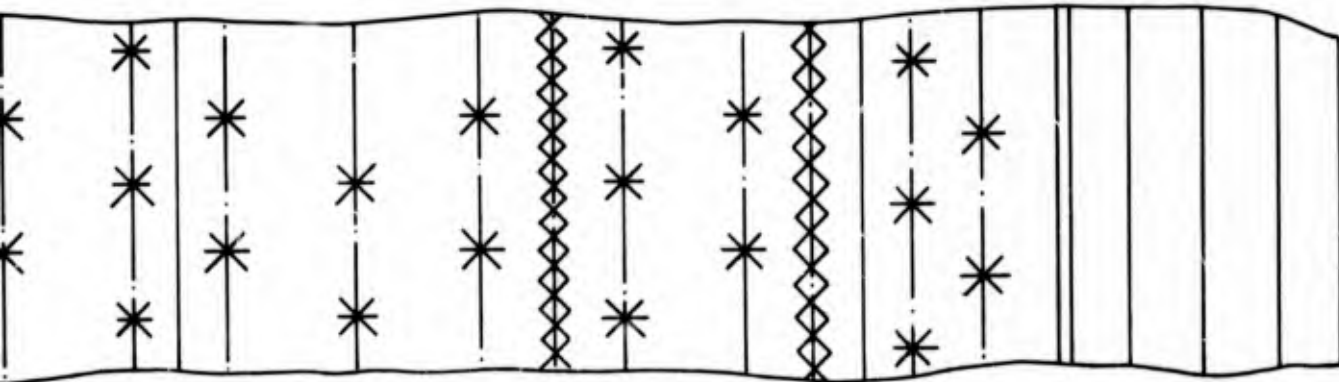


Fig. 2. Original spring

A



2. Original spring ring design.

B

quality. This program consists of those changes which are based upon existing knowledge and techniques, and those which require additional time for development and evaluation. In the following section, items in the first category are discussed and then summarized with a chart showing the missiles in which each is incorporated.

1.2.1 DECREASE IN STRESS LEVEL--Increasing the thickness of the shell material is the most direct way of reducing the stress level in the welded joints. This change also has the corollary advantage of improving the weld quality since welding of thicker material is easier. Although a subsequent change decreases the shell thickness, the material at the welds remains heavy.

1.2.2 ELIMINATION OF SPOT WELDS--Increasing the joint thickness in the welds between the gores, and between the cap and gores, allows removal of the joint doublers, with a corresponding removal of over 9,000 spot welds per bulkhead.

1.2.3 UNLOADING OF SPOT WELDS--It was standard practice in the original design, as in Atlas, to use spot welded rows on each side of a seam weld to develop the strength of the joint. This joint, when in a pressure vessel, places some tension on the spot welds. An improvement is realized by rearranging the rows so as to place a seam weld on each side of the spot welded row.

1.2.4 BUTT WELDING--Machine-made fusion butt welds are generally of higher quality than other types. For this reason, this kind of weld is replacing resistance seam welds whenever possible. The gores have been butt welded since the beginning. The removal of the splice doublers has served merely to make this weld the primary structural path. Butt welding the cap and the spring ring to the shell has required the fabrication of a new fixture, which delayed the incorporation point.

1.2.5 SPRING RING CONFIGURATION--The original spring ring in Fig. 2 was attached to the bulkhead shell at a point several inches forward of the tangential intersection of the frontal bulkhead and the outside cylindrical tank wall. As a result the frontal bulkhead receives poor, if any, support in these several inches from the aft tank pressure. Wrinkling of the frontal bulkhead under the front tank pressure is therefore experienced. To combat this condition the spring ring configuration has been altered to reduce the length of unsupported frontal bulkhead. (See Fig. 3.)

1.2.6 CHEMMILLING--Chem milling of bulkhead gores and tank skins was incorporated in all areas where weight could be saved without compromising the structural integrity. In particular, this process allows parts to be thickened or reinforced where required without the use of spot welded doublers, that is, any doublers can be integral with the basic sheet.

1.2.7 RELOCATION OF INSTRUMENTATION TAPS--In the original design, the bulkhead cavity pressure was measured by tapping into the cavity on the inside surface of the spring ring. The tubing which was connected to this tap was routed

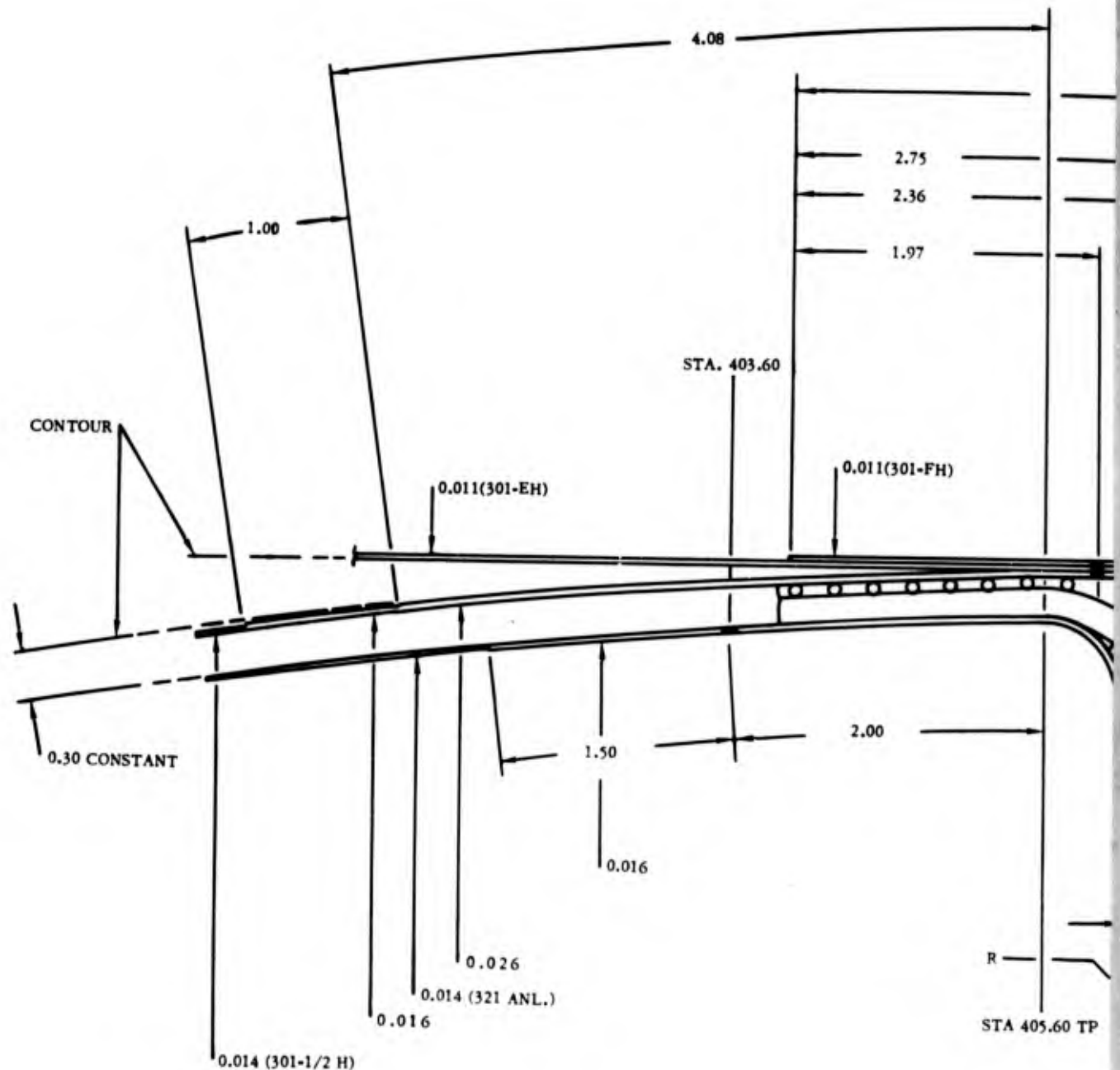
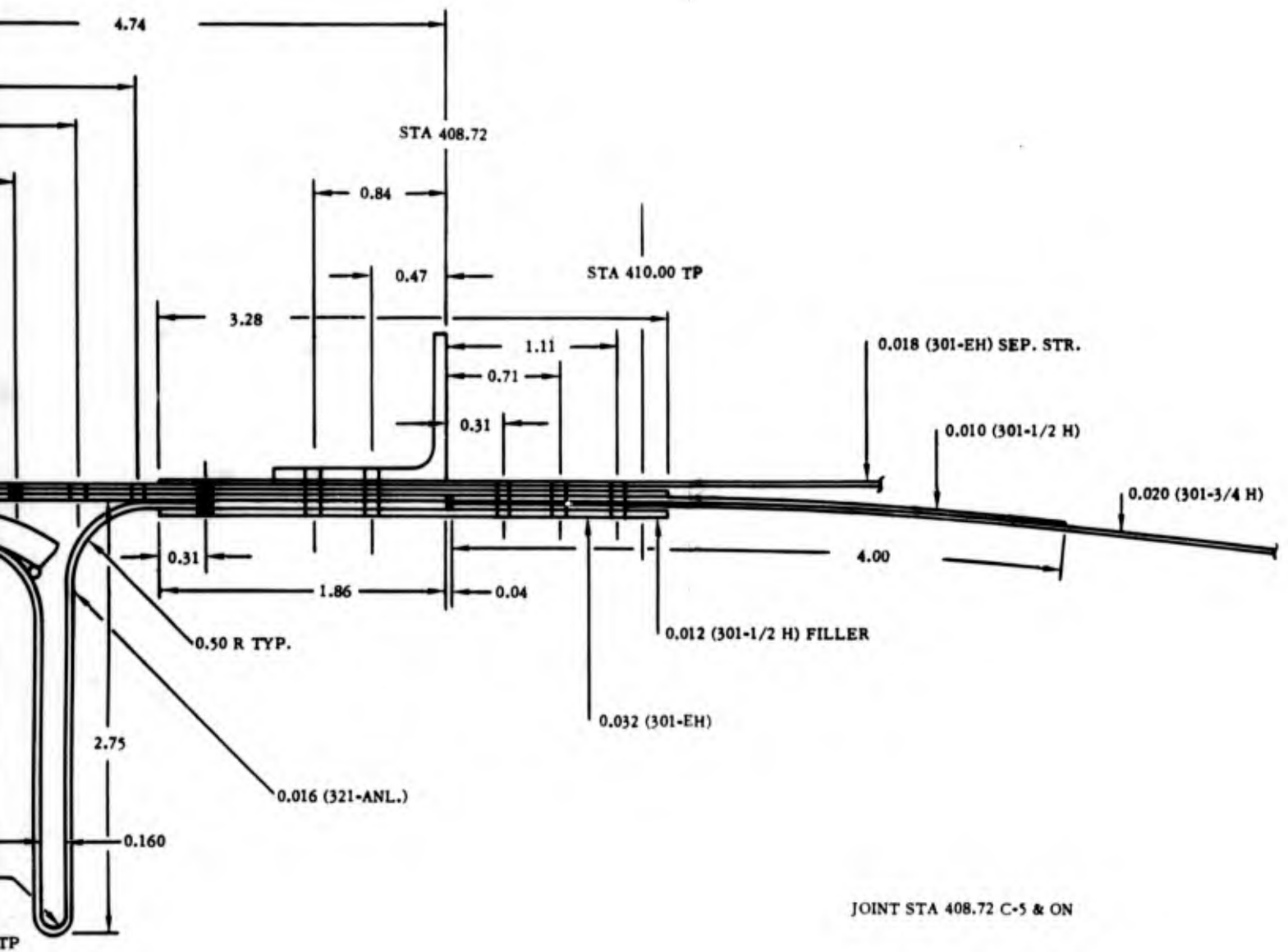


Fig. 3. Improved sprin

A



ring ring for frontal bulkhead support.

B

through the liquid oxygen tank to a boss on the rearmost bulkhead of the tank. In this line, and its connections, a number of joints provided potential leaks. This entire installation has now been replaced with a connection into the cavity directly through the outside cylindrical skin.

1.2.8 BLEEDER MAT--Tests with samples of the original design have shown that poor flow of gases through the glass mat insulation can be expected when it is compressed by the pressure in the liquid oxygen tank. This condition inhibits purging of the bulkhead cavity, should it be required, and the detection of leaks. To overcome this, a "bleeder mat" has been inserted in the cavity on the surface of the insulation. This material is capable of providing flow passageways even when compressed.

1.2.9 FIRM IMPROVEMENTS EFFECTIVITIES--All of the changes so far discussed have been firmly committed for the missile effectivities shown in Table I below. The first two Centaurs are the only missiles using the original design.

1.3 IMPROVEMENT DEVELOPMENT PROGRAM

The following items are those which require additional time for development and evaluation. Each, if successful, will provide additional confidence in the integrity of the Centaur intermediate bulkhead. Generally, each is an effort to improve the fatigue life of the bulkhead or to improve the quality by further reduction of welds.

Table I. Firm improvement effectivities.

DESIGN IMPROVEMENT	FLIGHT NUMBER									
	1	2	3	4	5	6	7	8	9	10
1. DECREASE STRESS LEVEL			X	X	X	X	X	X	X	X
2. REDUCE NUMBER OF SPOT WELDS			X	X	X	X	X	X	X	X
3. UNLOAD SPOT WELDS			X	X	X	X	X	X	X	X
4. BUTT WELDING										
a. GORES			X	X	X	X	X	X	X	X
b. CAP					X	X	X	X	X	X
c. SPRING RING					X	X	X	X	X	X
5. SPRING RING CONFIGURATION CHANGE					X	X	X	X	X	X
6. CHEMMILLING					X	X	X	X	X	X
7. RELOCATE INSTRUMENTATION TAPS					X	X	X	X	X	X
8. BLEEDER MAT					X	X	X	X	X	X

This portion of the bulkhead improvement program relies heavily upon a testing program which is described in Report No. AE62-0303. The following discussion, therefore, is confined to design and evaluation considerations.

1.3.1 WRINKLE ELIMINATION--Fig. 4 and 5 are illustrations of the kind of wrinkling that prevails in the present intermediate bulkhead. Fig. 4 shows the "gathering" effect which occurs because the material is subjected to a compressive stress in the meridional direction. Stiffening of the material in this direction with beads will be attempted.

Fig. 5 shows the compressive wrinkling which occurs in the frontal bulkhead because of insufficient support from the rear bulkhead. It is anticipated that the presence of the beads in the rear bulkhead will alleviate this condition. It is not known at this time what this bead must look like to perform this double function while under pressure and at cryogenic temperatures. A comprehensive design and test program is now underway to develop the needed know-how.

1.3.2 ELECTROFORMED NICKEL EVALUATION--A technique which offers the possibility of realizing a weld free bulkhead shell is the electroforming process. In this instance, nickel can be deposited upon a mandrel of the proper form, and can provide peculiarities, such as the spring ring, as an integral part of the form.

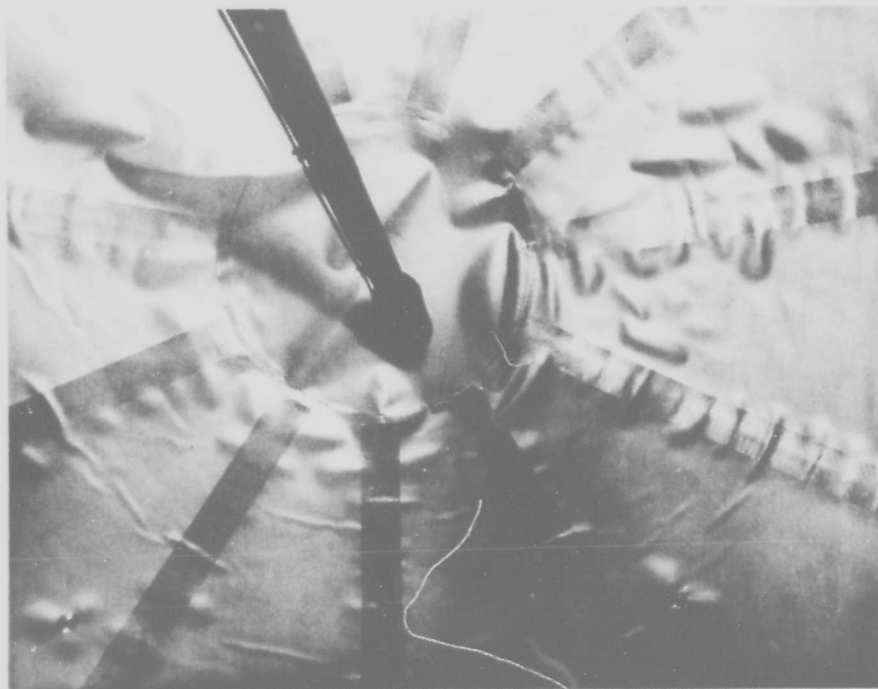


Fig. 4. Compressive stress in the meridional direction.

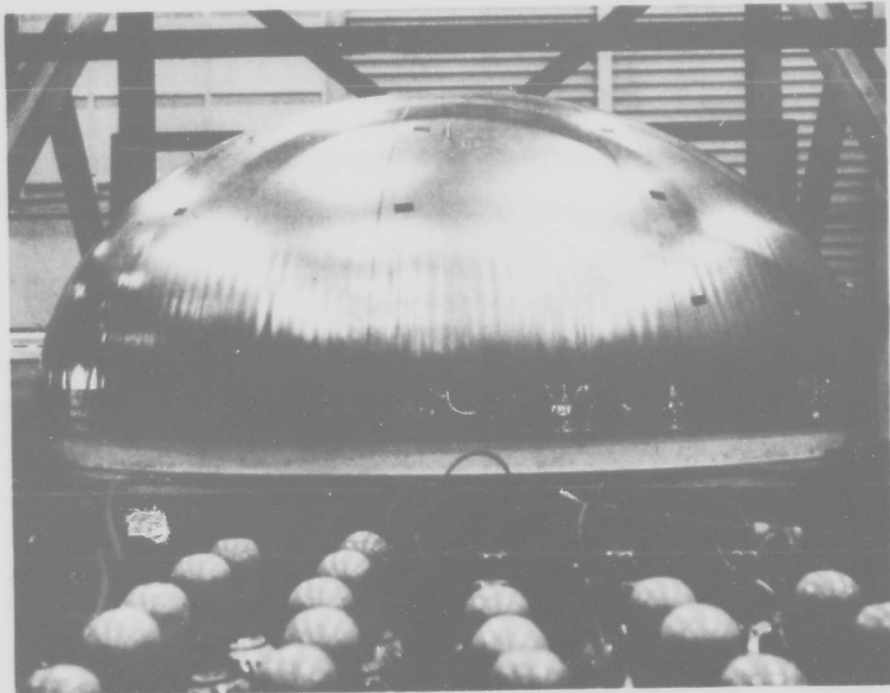


Fig. 5. Compressive wrinkling in the frontal bulkhead.

The nickel is used, in this case, because it has reasonably good strength and is weldable to the Type 301 stainless steel tank. Parts can be produced rapidly and at low cost.

The attractive features of this technique, however, are dimmed somewhat by several problem areas which will be resolved before committing to this method. For instance, design allowables are not adequate, manufacturing processes are not trouble free, and procurement specifications have not been established. A program to obtain this knowledge is vigorously underway with the intent of ultimately obtaining and testing full-size bulkheads of this material.

1.3.3 EXPLOSIVELY FORMED ONE-PIECE BULKHEADS--Another technique which offers the possibility of realizing a weld-free bulkhead shell is the explosive forming process. This technique has been successfully used to form shells in sizes considerably smaller than the 10-ft. diameter required for Centaur. Size, however, appears to be important only in regard to the size of the flat sheet stock which is available.

For a one-piece Centaur bulkhead, a flat sheet 12 ft. \times 12 ft. is required. Stainless sheet stock is available in only Type 321 annealed, which is usable for the rear bulkhead. The frontal bulkhead requires 1/2 hard temper, which is unavailable.

General Dynamics/Astronautics has evaluated this process, and has tentatively concluded that bulkheads formed this way would be far more costly than those formed by the electroformed nickel process. This, coupled with the lack of material suitable for forming the 1/2 hard bulkhead, is the reason why the nickel bulkhead appears most attractive.

2 | NONVACUUM INSULATING BULKHEADS

Originally, the allowable heat transfer across the intermediate bulkhead was so low that the vacuum cavity approach was mandatory from the standpoint of minimum missile weight. Subsequently, the missions for Centaurs No. 7 and on have been revised, and as a result, the heat transfer requirement across the bulkhead is less stringent. This makes other methods of insulating more competitive, and a program for evaluating other concepts is actively underway.

Several nonvacuum type of designs have been suggested and are broadly described below. Each of these is being evaluated with the intent of designing, fabricating, and testing a full-size version if feasibility is indicated. This portion of the bulkhead improvement program will also rely heavily upon the test program described in Report No. AE62-0303.

2.1 FOAM INSULATED BULKHEAD

In theory, foam insulation is entirely feasible. However, practical application will present a number of problems. For instance, the foams and adhesives available today are not compatible with liquid oxygen, which will force them to be used on the hydrogen tank side of the bulkhead. However, foams suitable for this environment are also an unknown. Before satisfactory design can be expected, knowledge must be obtained relative to design allowables, manufacturing processing, and procurement specifications. These areas are now being investigated.

2.2 HYDROGEN CAVITY BULKHEAD

An attractive concept for the Centaur application uses gaseous hydrogen as the insulating medium. To achieve this, it is necessary to devise a method of trapping a gaseous hydrogen layer on to the top of the intermediate bulkhead (in this case the bulkhead is a single pressure supported membrane).

Various methods for trapping the gas were suggested and each is being investigated. As far as is known, this concept has never been used and many unknown side effects are anticipated. For instance, the performance of such an insulation with g loads, and 0 - g, are areas requiring much study and testing.

2.3 RIGID HONEYCOMB BULKHEAD

A rigid-sandwich hemispherical bulkhead was proposed and described in Report No. AE62-0057-2, Intermediate Bulkhead Study, Part II, Rigid Type Vacuum Bulkhead.

The concepts presented in this report are being considered for a nonvacuum application. It is anticipated that the principal difference would be that a thicker, vented core would be used.

A more attractive and rigid bulkhead is one which is flat instead of dome shaped. This shape is attractive principally because the manufacturing problems of making flat parts fit together are negligible.

Both the flat and dome shaped sandwich require the use of core and adhesives in environments which are new. Here, also, design allowables, manufacturing processes and procurement specifications must be developed. The development program now underway is aimed at providing this knowledge.