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A jettisonable metallic shroud is utilized on the Titan/Centaur launch vehicle as a fairing to protect the payload and the Centaur stage from aerodynamic and thermal environments during launch and ascent. A series of tests were conducted to verify the structural capabilities of the shroud and to evaluate the structural interaction of the shroud with the Centaur stage. A flight configured shroud and the interfacing structural assemblies of the associated Centaur and Titan stages were subjected to a series of tests consisting of combinations of applied axial and shear loads to design ultimate values. One set of the tests included thermal conditions to verify localized strength capabilities of the shroud and of the forward structural ties to the Centaur. Two dynamic response tests were performed to verify the analytical stiffness model. The test series demonstrated the strength capabilities of the shroud and the interfacing Centaur and Titan flight configured assemblies at ultimate (125 percent of design limit) loads. The shroud design for ultimate load without forward structural ties to the Centaur was also verified. It was further verified that the spring rate of the flight configured shroud-to-Centaur forward structural deflections of the specimen became nonlinear, as expected, above limit load values. The data provided additional verification that the stiffness properties of the shroud and associated structures were adequately defined by the previous limit load test series. This test series qualification program verified that the Titan/Centaur shroud and the Centaur and Titan interface components are qualified structurally at design ultimate loads.

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SUMMARY

by C. W. Eastwood

A jettisonable metallic shroud is utilized on the Titan/Centaur launch vehicle as a fairing to protect the payload and the Centaur stage from aerodynamic and thermal environments during launch and ascent. A series of tests were conducted to verify the structural capabilities of the shroud and to evaluate the structural interaction of the shroud with the Centaur stage. A flight configured shroud and the interfacing structural assemblies of the associated Centaur and Titan stages were subjected to a series of tests consisting of combinations of applied axial and shear loads to design ultimate values. One set of the tests included thermal conditions to verify localized strength capabilities of the shroud and of the forward structural ties to the Centaur. Two dynamic response tests were performed to verify the analytical stiffness model.

The test series demonstrated the strength capabilities of the shroud and the interfacing Centaur and Titan flight configured assemblies at ulitmate (125 percent of design limit) loads. The shroud design for ultimate load without forward structural ties to the Centaur was also verified. It was further verified that the spring rate of the flight configured shroud-to-Centaur forward structural tie system was linear to ultimate load values. Structural deflections of the specimen became nonlinear, as expected, above limit load values. The data provided additional verification that the stiffness properties of the shroud and associated structures were adequately defined by the previous limit load test series.

This test series of the shroud qualification program verified that the Titan/Centaur shroud and the Centaur and Titan interface components are qualified structurally at design ultimate loads.

INTRODUCTION

by C. W. Eastwood

All spacecraft require some form of protection from weather and a thermally controlled environment during prelaunch operations. In addition, protection is required from aerodynamic and thermal environments during launch and ascent. These requirements are usually satisfied by a shroud or fairing attached to the forward end of the launch vehicle and enclosing the spacecraft. The shroud is jettisoned after the most adverse conditions are passed in the launch and ascent phase of flight.

In addition to spacecraft protection, launch vehicle upper stages utilizing cryogenic propellants require thermal insulation during prelaunch operations to prevent excessive propellant boiloff. Insulation is also required during ascent for protection from aerodynamic heating.

The Centaur upper stage vehicle, mated with the Titan IIIE booster (modified Titan IIID) was chosen to be the launch vehicle for the Viking spacecraft which is to orbit and soft land on the planet Mars in 1976. This Centaur vehicle is called the Centaur D-1T (reference 1).

The Centaur was the United States' first upper stage vehicle to use liquid hydrogen and liquid oxygen as propellants. As the upper stage for the Atlas booster, this combination has been the launch vehicle for Surveyor, Mariner, Pioneer, OAO, and a series of communication satellites.

The D-1A Centaur upper stage vehicle, using the Atlas as the booster stage, utilizes several shroud designs for spacecraft protection dictated by spacecraft size and mission requirements. Thermal protection for the Centaur vehicle during prelaunch and ascent is provided by jettisonable insulation panels.

The Viking spacecraft includes a bioshield that is larger than the inside diameter of the D-1A shroud designs. This meant that an increased diameter shroud would be required for spacecraft enclosure. A larger diameter shroud would also be heavier than existing shrouds. This increased diameter and weight attached to the forward end of the Centaur stage would tax its strength from aerodynamic loading during ascent. One possibility to enhance structural capability would be to make the Centaur tank heavier and redesign the present insulation panels to be capable of carrying structural loading. This, however, meant increased complexities and many modifications to existing designs.

Instead, a large shroud that would cover both the spacecraft and Centaur, and act as a structural member as well as incorporating insulation for Centaur's cryogenic propellant tanks, was conceived and studied. This was the design concept chosen and Lockheed Missiles and Space Company, Inc. (LMSC) was awarded the contract to design and build the shroud. This shroud for Titan/Centaur launch vehicles has been designated the Centaur Standard Shroud (CSS).

A test program consisting of the following three major series of tests was conducted at the Lewis Research Center's Plum Brook Station to qualify the CSS for flight:

1. Cryogenic unlatch tests to qualify the CSS insulation, gas purges, and jettison systems under cryogenic conditions (references 2 and 3).

2. Static structural tests to qualify the structural capabilities of the CSS, the interstage adapter (ISA), the forward bearing reactor (FBR) system, and the flight configured assembly with the Titan forward skirt.

3. Heated jettison tests at altitude conditions to qualify the CSS jettison system operation after experiencing simulated aerodynamic heating during ascent (references 4 and 5).

This report presents the results of the ultimate load phase of the static structural test series; the limit load phase was completed in July 1973 (reference 6). The ultimate load tests were conducted in May 1974, subsequent to the heated jettison test series. They were the final tests performed in the extensive qualification program. Axial and shear loads, to ultimate load values, were applied to the CSS with and without the FBR struts installed to demonstrate the ability of the CSS, ISA, and Titan forward skirt to withstand 125 percent of design limit loads. The limit load values are shown in Figure 1. The Centaur was tanked with liquid nitrogen (LN_2) for one of the static ultimate load tests to verify the structural integrity of the FBR system at low temperature.

The tests were performed with the active participation of General Dynamics Convair Division (GDC), the Centaur contractor; Lockheed Missiles and Space Company, Inc. (LMSC), the CSS contractor; and Martin Marietta Corporation (MMC), the Titan contractor. A test report has been prepared by each of the three contractors (references 7, 8, and 9) pertaining to the performance of the test specimen hardware furnished by them.

In addition, two dynamic response tests were performed on the CSS/Centaur structural system; one with and one without the FBR struts installed. The test specimen was deflected from the vertical by application of a shear load at the forward end and abruptly released to permit it to respond freely. The resulting data were used to verify the structural stiffness of the CSS/Centaur system as determined by the static limit load tests (reference 6).

TEST OBJECTIVES

The static ultimate load structural tests were performed last in the CSS Qualification Test Program because of the greater risk of premature failure. The specific objectives were as follows:

1. Demonstrate the structural integrity of the CSS, the D-1T interstage adapter, the FBR system, and the Titan forward skirt at 125 percent of design limit load (ultimate load).

2. Verify the spring rate of the FBR system, which includes the effects of the adjacent structures, when subjected to ultimate load.

3. Verify the CSS ultimate load design by demonstrating the ability of the CSS without the FBR struts installed to withstand 125 percent of the design limit loads.

4. Verify the CSS/Centaur stiffness properties, as determined in the static load testing, by dynamic response on the structure.

FACILITY AND TEST EQUIPMENT

by E. J. Cieslewicz, C. W. Eastwood, R. H. Fabik,
L. C. Gentile, J. L. Harrold, F. L. Manning

B-3 Facility

The CSS static ultimate load tests were conducted in the B-3 Test Facility located at NASA/Lewis Research Center's Plum Brook Station. The B-3 Facility is a tower structure 50 feet square and 200 feet high as shown in Figure 2. It contains a test area at level 3 which is 74 feet above the ground floor. The test area is approximately 24 feet by 36 feet with a working height of 100 feet. An overall view of the test configuration is shown in Figure 3. Moveable work platforms were installed in the test area for access to the test specimen. A 65 ton bridge crane serviced the test area and the ground level rail siding adjacent to the tower. The major components of the test specimen were subassembled and prepared for the test in a building remote from B-3 tower, but serviced by a Plum Brook Station rail line.

Test Fixtures

A base and a lower distribution fixture were used to support the test specimen and to react the applied test loads. At the forward end of the test CSS another distribution fixture was mounted, together with a load application fixture, to transmit the axial loads into the CSS. A strap and whiffletree assembly was used on the CSS conic section to apply the shear loads. For the Centaur branch of the specimen, shear loads were applied through a loading fixture attached to the forward structures. This fixture, by virtue of its 14,000 pound weight, also acted as a single value axial load on the Centaur branch.

In the dynamic response phase of the test series the forward load application fixture, the axial load cables, the shear load strap, and the Centur loading fixture were not installed. A cable and attachment fitting was connected directly to the load distribution fixture at the forward end of the CSS as a means to apply the displacement load.

Load Application System

The structural load application systems allowed each test load to be applied independently to build up a combined total load in any desired order. Axial loads are defined as loads acting aft to produce compression on the test specimen structures. Shear loads are defined as loads acting laterally to produce both shear and bending moments on the test specimen structures such that maximum compression is produced at a specified azimuth and maximum tension occurs diametrically opposite. Displacement loads are those required to deflect the test specimen prior to abrupt release of the load application force in the dynamic response tests.

The CSS axial load system was used to apply and maintain a compressive load on the CSS. The basic components were the load distribution and load application fixtures, whiffletree beams, and connecting cables to the four axial hydraulic load actuators. The whiffletree beams distributed the load more uniformly into the CSS load distribution fixture. The four axial loading actuators could simultaneously apply loads at either of two manually selected load application rates. The system provided loading and unloading only while the appropriate control was activated manually. An event marker for data reduction purposes was issued to the data system each time the load or unload controls were activated. The system included feedback control. A counterforce system was used to alleviate the tare weight of the CSS axial loading system prior to load application.

The CSS shear load system was used to develop bending moments on the CSS. The system included a linkage from the load application strap and whiffletree beam to the hydraulic actuator attached to the tower. The system was oriented for application of shear loads at the 150 degree azimuth. The assembly was counterbalanced so that the loading system exerted an insignificant tare force on the CSS prior to load application. The system control was similar to the one for the axial loading except that the position of the deflected test specimen assembly was the controlling parameter instead of the load application rate. Data markers also were issued in the same manner as for the axial system.

The displacement load for the dynamic response test was applied through the CSS load distribution fixture by the attached load cable and a hydraulic actuator which was mounted on the tower structure.

The tare weight of the Centaur loading fixture, as was previously mentioned, was the only axial load applied to the Centaur tank and payload support structures. A Centaur stretch assembly, which is described later, could be used to counterbalance this axial load for a no-load condition. The shear load system consisted of a cable assembly from the Centaur loading fixture to a hydraulic actuator attached to the tower structure. The cable passed through a non-flight type hole in the CSS at 330 degrees azimuth. Except for load magnitudes and rates, this system operated in the same manner as the CSS axial loading system.

Liquid Nitrogen and Inert Gas Systems

A cryogenic system supplied liquid nitrogen (LN_2) to the test vehicle. The LN_2 was pumped via insulated lines from ground level dewars to the Centaur fuel and oxidizer sump ports for the test performed with a cryogenic environment.

Inert gas systems supplied gaseous nitrogen and helium to the test specimen. Both gases were piped from storage cylinders adjacent to the B-3 tower. The gases were used for Centaur tank pressurization, test specimen compartment purging, and facility systems operation.

Centaur Tank Protection Systems

A system of servo-operated valves and pressure relief valves was connected to each of the Centaur tanks. These systems maintained the tank pressures at the desired levels throughout the tests. A facility vent system was used instead of the flight system for the oxidizer (LO_2) tank. The LO_2 vent line and the fill line had sufficient flexibility to permit the Centaur aft bulkhead to move 2.0 inches laterally during testing. There were two vent systems on the fuel (LH_2) tank. The flight LH_2 vent system was connected to a 6-inch vent line in the facility. This vent was used during the initial tank fill operation. An 8-inch facility vent system was connected to a flange on the forward door of the LH_2 tank and was sized to accommodate a large boiloff should the CSS insulation system be damaged. The facility vent line was flexible enough to allow the Centaur forward bulkhead to move 4.0 inches laterally and 1.5 inches axially. The top of the CSS could move 20.0 inches laterally without interfering with the vent line. A facility system based on Centaur tank differential pressure was used to protect the intermediate bulkhead between the oxidizer and fuel tanks. By use of pressure transducers and an automatic control system, the necessary tank pressure differential was maintained.

Another protection system for the Centaur tank, which is not self-supporting when depressurized, was a Centaur stretch system. This system consisted of a cable sling assembly connected to an actuator that was attached to the tower structure. The sling was connected to the forward end of the Centaur loading fixture. Activation of the actuator exerted sufficient force to counterbalance the load application fixture and all hardware mounted on the forward end of the Centaur tank and, in addition, support the weight of the tank. This system was required if the tank should lose pressure or when it was purposely depressurized. Also, the system could be controlled to counterbalance the tare weight of the Centaur loading fixture only, when that load was not required in a test.

Camera Systems

A single frame camera was used to record the CSS and forward seal (Figure 3) deflections at discrete steps. This camera and its lighting system was activated manually for each frame. Three TV cameras were used to provide general views of the test hardware during the tests.

Instrumentation Transducers

Several types of instrumentation transducers were used to provide test data. A brief description of each type is given below. For more details of the test instrumentation, see Appendix A.

Strain Gages - Uniaxial, biaxial (Poisson), and three-element rosette types of strain gages were used in this test program. The uniaxial gages were used with temperature compensating tab mounted dummy gages, as were each of the rosette elements. Each biaxial gage was arranged in its electrical bridge circuit to be temperature compensated. Approximately 170 strain gages were used in the total test series. A maximum of 83 were used for any single test.

Deflectometers - Deflections of the test specimen were measured with rotary potentimetric transducers of various ranges. A total of 105 deflectometers were used in the test series with a maximum of 49 connected for any one test. The B-3 facility tower deflections were measured with a NASA developed system which tracked a laser light source with a two-axis photo detector.

Pressure Transducers - Most of the approximately 42 pressure measurements were made by standard eight-wire strain gage transducers. Both absolute and differential types were used. Special low temperature calibrations were employed where appropriate.

Temperature Transducers - Temperatures were measured with thermocouple and platinum resistance transducers. Platinum types were used where maximum accuracy was required. The chromal-constantan thermocouples provided low volume, low mass, and low heat transfer. Approximately seven temperature measurements were made for these tests.

Accelerometers - The vibration measurements for the dynamic response test were made with strain gage type accelerometers. A total of eight accelerometers were used.

Load Cells - Load measurements were made with standard strain gage type load cells. A total of seven measurement locations were required. However, a maximum of six locations were used for any one test configuration.

Liquid Level Probes - The three liquid level probes were capacitance type. The main LO_2 and LH_2 tank probes were standard coaxial types. The LH_2 tank ullage probe was a NASA designed double coaxial type. This design provided the additional accuracy and sensitivity required for heat transfer studies.

Signal Conditioning and Data Recording

The outputs from the various transducers were conditioned at the B-3 Facility and transmitted in digital form to the data building for further processing. All signal conditioner outputs were routed to a patchboard. This arrangement allowed interconnection flexibility from the signal conditioners to the digital data recorder, the FM recorder, the light beam oscillographs, the strip chart recorders and the panel meters. It provided also for input and output connection of amplifiers, where required. The data for these tests were recorded in digital form on magnetic tape using a 400 channel multiplexer at the B-3 tower and the central recording system at the data building. The data were recorded at a rate of 2,500 data points per second. This gave sample rates per channel of about six data points per second. High response data such as vibration were recorded on FM and light beam oscillographs. Ink type strip chart recorders were used to display certain critical parameters. Time was recorded on all recorders to provide precise time correlation.

Data Display and Reduction Systems

The data display system allowed immediate visual analysis of test data in engineering units. Data were displayed in real time in tabular and graphic forms on Cathode Ray Tube (CRT) displays. The display controller regulated three keyboard/CRT units and provided printouts on a remote digital plotter. Remote pushbutton print commands caused the program to print the associated CRT image on the remote plotter and generate, upon request, plots of selected parameters.

The magnetic tapes containing the primary data from each test were processed using a pre-programmed data retrieval program. This program was designed to retrieve preselected parameters and specific test events. The program outputs were zero-corrected (pretest zero offsets were removed from the data), averaged and smoothed. The data reduction and calibration program converted the stored signals into appropriate engineering units. These values were, in turn, printed as post-test digital data listings and data plots.

Test Control, Abort, and Alarm Systems

The test control, abort, and alarm systems consisted of a digital computer and its output relay system, an abort monitor system, a minicomputer alarm system, and a loading and positioning system which also included an analog computer ramp generating and error detection sub-system.

The digital computer allowed the test load application and positioning system to be operated manually as long as the abort limits were not violated. The minicomputer processed the multiplexed data and exhibited on television screens those channels which exceeded the alarm limits. Once an abort limit was exceeded, as determined by the abort monitor, the manual loading capability was deactivated by the digital computer and the abort sequence was performed. Essentially it activated all hydraulic load cylinder fail-safe systems. The fail-safe feature prevented the hydraulic cylinders from developing any force by closing the hydraulic pressure supply and venting the load cylinders to the hydraulic reservoir. Also, relief valves were on each cylinder and in the circuit at all times for use in case the other devices failed. Differential pressure relief valves were included in the load cylinder hydraulic circuits for redundant protection.

The ramp rate and direction command switches provided slow, medium (CSS shear only), and fast; increase and decrease; and hold. The ramp generator produced a signal which was linear with respect to time and was used as the load rate or position command. This command signal was prevented from exceeding a predetermined maximum level by the maximum command limiter, which also prevented the command signal from drifting with time. The zero command limiter prevented the command signal from going negative.

The primary purpose for the error abort system was to detect control loop failure before a maximum load abort was reached. The system was used for both the load rate controlled loops (axial load and payload shear) and the position controlled loop (CSS shear). The system used for the CSS shear also incorporated a maximum load limit detector.

The analog computer was also used to generate a marker pulse every two percent of applied load. This pulse was recorded by the digital recording system and used in the data plotting program to limit the reduced data to 100 points (50 on the increasing load ramp and 50 on the decreasing load ramp).

TEST SPECIMEN CONFIGURATION

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The test specimen for the CSS ultimate load structural tests consisted of the following major items and systems:

1. A CSS with all pertinent bolt-on hardware and the tank section insulation installed.

2. A Centaur tank with stub adapter, equipment module, truss adapter, FBR system, forward seal, aft seal, hydrogen vent disconnect system, and other hardware which interfaces with the CSS to configure the Centaur to a D-1T vehicle.

3. Centaur interstage adapter.

4. Titan forward skirt.

The overall test configuration and assembly of this specimen in the Plum Brook B-3 Facility is shown in Figure 3. Vehicle stations shown in the figure and referred to throughout this report are Centaur/CSS station designations. The interface of the Titan skirt and the ISA is Station 2127.43 and the forward terminus of the Centaur/CSS test assembly is Station 2882.25.

The test specimen was the same assembly which was previously used in the CSS cryogenic unlatch test (reference 2), limit load structural test (reference 6), and heated altitude jettison test (reference 4). As a result the specimen had been subjected to many functional operations and structural loadings prior to the ultimate load testing. Inspection of the specimen performed before the ultimate load tests did not indicate any distortion or degradation of the specimen from the earlier testing.

Structurally significant differences between the test specimen configuration and the flight hardware for the first Titan/Centaur flight (Proof Flight) are listed in Appendix B. A brief description of the CSS, Centaur structures, interstage adapter, and Titan skirt follows.

Centaur Standard Shroud (CSS)

The Centaur Standard Shroud (CSS) encloses both the Centaur and the spacecraft, and provides environmental protection for both while on the ground and in flight. The CSS general configuration is shown in Figure 4. The cylindrical portion of the CSS is 14 feet in diameter. Total CSS length is 58 feet.

The payload section (forward of Station 2514.00) is a biconic/cylindrical configuration approximately 31 feet long. The nose dome is made from stainless steel, but was not installed for the structural tests. The two conical sections forward of Station 2680.66 are of magnesium semimonocoque construction reinforced by internal rings. The cylindrical section between the Stations 2514.00 and 2680.66 is of aluminum semimonocoque construction with corrugated outer skin and smooth inner skin weld-bonded together and riveted to internal rings. Attached to the internal rings in the biconic and cylindrical sections are fiberglass insulation blankets (these fiberglass blankets were not installed for these tests).

The equipment section, from Station 2459.14 to Station 2514.00 allows access to hardware on the Centaur equipment module through doors in the CSS structure. This section is of the same construction as the cylindrical portion of the payload section.

The forward bearing reaction system between the CSS and the Centaur at Station 2459.14 reduces CSS/Centaur relative deflections through load sharing during launch and ascent. This reaction path is released in flight after maximum aerodynamic loading by a pyrotechnic system that severs the FBR struts which retract to stowed positions on the Centaur and the CSS.

The tank section of the CSS from Station 2241.78 to 2459.14 encloses the Centaur LH_2 tank. It is also of aluminum semimonocoque, corrugated construction with reinforcing internal rings. The annular space between the CSS and the Centaur is isolated from the other compartments of the CSS by the aft and forward seals at Stations 2241.78 and 2459.14. This annular volume is purged with gaseous helium during prelaunch operations to prevent the formation of frozen air. Fiberglass insulation attached to internal rings in this section of the CSS provides insulation for the Centaur LH_2 tank.

The boattail section of the CSS is from Station 2180.48 to 2241.78. It contains the aft circumferential separation joint, jettison hinges, and the interface to the Centaur interstage adapter. The section forward of Station 2209.00 is of the same construction as the tank section of the CSS. The section aft of Station 2209.00 is of riveted aluminum ring-skin-stringer construction.

The two halves of the CSS are joined along a longitudinal separation joint. Each half also is joined to the fixed aft part of the shroud along the circumferential separation joint at Station 2211.80.

At jettison, all separation joints are severed by a noncontaminating pyrotechnic system. Eight main springs (four per half) mounted longitudinally at the aft end of the cylindrical section of the CSS force the two halves to rotate about hinges and jettison. Four smaller springs (two at the nose dome and two at the equipment section) mounted laterally between the halves assist in the initial separation. Two hinges for each half are mounted at the aft circumferential separation plane. The conical section of the boattail is bolted to the Centaur interstage adapter which is jettisoned with the Titan Stage. The separation and jettison systems were not actuated during this test series.

Centaur Structures

The Centaur test specimen structures consisted of the basic propellant tank assembly, stub adapter, equipment module, and truss adapter. Other Centaur D-1T systems not necessary for the conduct of the tests, such as propulsion, pneumatic, and propellant feed systems, were not installed.

Centaur Tank - The Centaur tank assembly used was a flight-weight tank of the "D" series configuration. The basic tank configuration and dimensions are shown in Figure 5. The tank assembly is made of type -301 stainless steel and is a completely monocoque structure requiring internal pressure for structural strength. A double-walled bulkhead separates the forward liquid hydrogen tank from the aft liquid oxygen tank.

The Centaur tank assembly was not tested to ultimate conditions in this program. It was included in the specimen stack-up primarily as a support for the forward structures and as a container for the liquid nitrogen (LN_2) during the thermal phase of the test series.

Stub Adapter - The stub adapter shown in Figure 3 is a cylindrical structure 25 inches in height and 120 inches in diameter and is mounted on the forward end of the Centaur tank. The adapter as used on the Titan/Centaur vehicle consists of titanium skin and stringers reinforced by aluminum rings.

Equipment Module - The Centaur equipment module (Figure 3) is a truncated conical aluminum structure 30 inches in height. The diameter of the base, which is attached to the stub adapter, is 120 inches; the diameter of the forward end is 60 inches. The construction of the equipment module is skin/stringer with reinforcing rings.

Truss Adapter - The Centaur truss adapter (Figure 3) is 120 inches in diameter and 49 inches in height. It consists of 24 aluminum tubular struts equally spaced around the circumference. The struts were attached to 12 fittings located on the aft end of the Centaur loading fixture and to 12 fittings located on the forward end of the stub adapter. The wall thickness of the struts used in the test assembly were slightly below the design minimum value. However, the assembly was not a qualification item in the test program and was not subjected to full load. It was primarily acting as a spacer to support the Centaur loading fixture.

CSS/Centaur Bolt-ons

Forward Bearing Reaction System - The CSS/Centaur FBR system provides load sharing and limits the relative deflection between the CSS and the Centaur vehicle during flight until the vehicle has passed through the period of significant aerodynamic loading (approximately 100 seconds after lift-off). The system is located at Station 2459.14 and consists of six spring loaded double action struts. The major structural components of the struts are aluminum. Figures 6 and 7 illustrate the FBR system and details of the strut installation. The spring rate of the system (19,000 lbs/in) is compatible with the relative stiffnesses of the CSS and the Centaur in order to prevent overloading the Centaur and yet maintain payload-to-CSS clearances at acceptable levels. Conical steel washers are utilized to produce the required spring rate in tension and compression (Figure 8).

Separation of the FBR struts is accomplished by redundant explosive bolts. Following bolt separation, the strut halves are retracted against the CSS by a spring loaded retractor and against the Centaur stub adapter by a tension spring. Non-explosive bolts were used in this test series since the separation system was not actuated.

Forward Seal and Release System - The forward seal, illustrated in Figure 9, is located at Station 2454 between the CSS and Centaur stub adapter. The seal consists of a silicone rubberized dacron fabric attached to the stub adapter by bolts and retained on the CSS forward bulkhead by a cable and retaining mechanism. A 5/16-inch diameter segmented teflon bead on the outboard edge of the seal holds the seal under the cable. A bolt with redundant explosive cartridges is employed to release the seal. This is the same bolt design used for the FBR separation. Two bolts, one at each split line, are attached to the seal retaining cable. When the bolts separate, the cable tension is relaxed and the seal releases. For this test series the release system was not activated and non-explosive bolts were employed.

LH_2 Vent Fin Disconnect - The LH_2 vent disconnect is an extendable duct connection between the fixed vent nozzle on the Centaur tank vent duct and the vent fin duct on the CSS. The function of the vent disconnect is to accommodate the differential motion between the tank and the CSS during prelaunch and boost flight phase. It also provides a release mechanism to disconnect the vent fin duct from the fixed vent nozzles at CSS jettison. The LH_2 vent system configuration is illustrated in Figure 10. The design is a telescoping tube section with the inboard end attached to the vent nozzle and the outboard end attached to the CSS mounted vent fin duct fitting by means of spherical ball joints. The disconnect mechanism is engaged by extension of the telescoping tubes to the full free length of travel as limited by internal stops. Release of the disconnect can be accomplished in one of two modes during CSS jettison. In the primary mode a continued pull on the disconnect in the bottomed-out condition shears two pins in the assembly. Shearing the pins permits release of the latching lugs and disconnection of the assembly from the vent nozzle. The secondary mode is used if the pins fail to shear. In this mode the continued outward pull on the vent disconnect forceably pulls the telescoping duct assembly off the vent nozzle by bending the latching lugs. The latching lugs are designed to bend in this manner at a load slightly above that required to shear the pins. The vent disconnect detailed design is shown in Figure 11.

Interstage Adapter

The Centaur interstage adapter is the structure that provides the interface between the Centaur tank, CSS, and Titan forward skirt. The D-1T ISA is a 113-inch long structural spacer between the forward end of the Titan skirt and the aft end of the Centaur vehicle. It also supports the CSS through an external ring flange at Station 2180.48. It is an all-aluminum sheet and stringer structure with 10 circular rings. At the aft end there are 72 external hat section stringers. Thirty-six internal fittings are included in the aft bay of the ISA to match up with the Titan skirt 36 internal longerons. Each longeron has two bolts, for a total of 72 interface bolts. A bearing pad fits between the rings at each longeron connection to ensure controlled load distribution on the Titan skirt ring.

Titan Forward Skirt

The Titan forward skirt (Figure 3) is the most forward section of the Titan booster vehicle. It is a 10-foot diameter, 76-inch long aluminum structure of ring reinforced skin and stringer construction. The face of the forward ring flange (Station 2127.43) is the interface plane between the Titan booster vehicle and the face of the aft flange of the ISA section of the Centaur upper stage vehicle. A Titan guidance equipment truss is mounted in the forward end of the Titan forward skirt.

TESTS PERFORMED

by C. W. Eastwood

Because of the nature of the tests (ultimate loading) and the danger of structural failure of the test specimen under such conditions, only a select few tests were planned. All were conducted satisfactorily and consisted of three groups, not including preliminary runs at low level loads to exercise and settle the test hardware assemblies. The numerical designations (except those of the dynamic response series) were based on the similarity of the test conditions to those of the limit load tests in reference 6. The chronological order of the tests was not associated with the numerical designation but was arranged for structural strength considerations and priority of objectives. A summary of the tests as performed is presented in Table I.

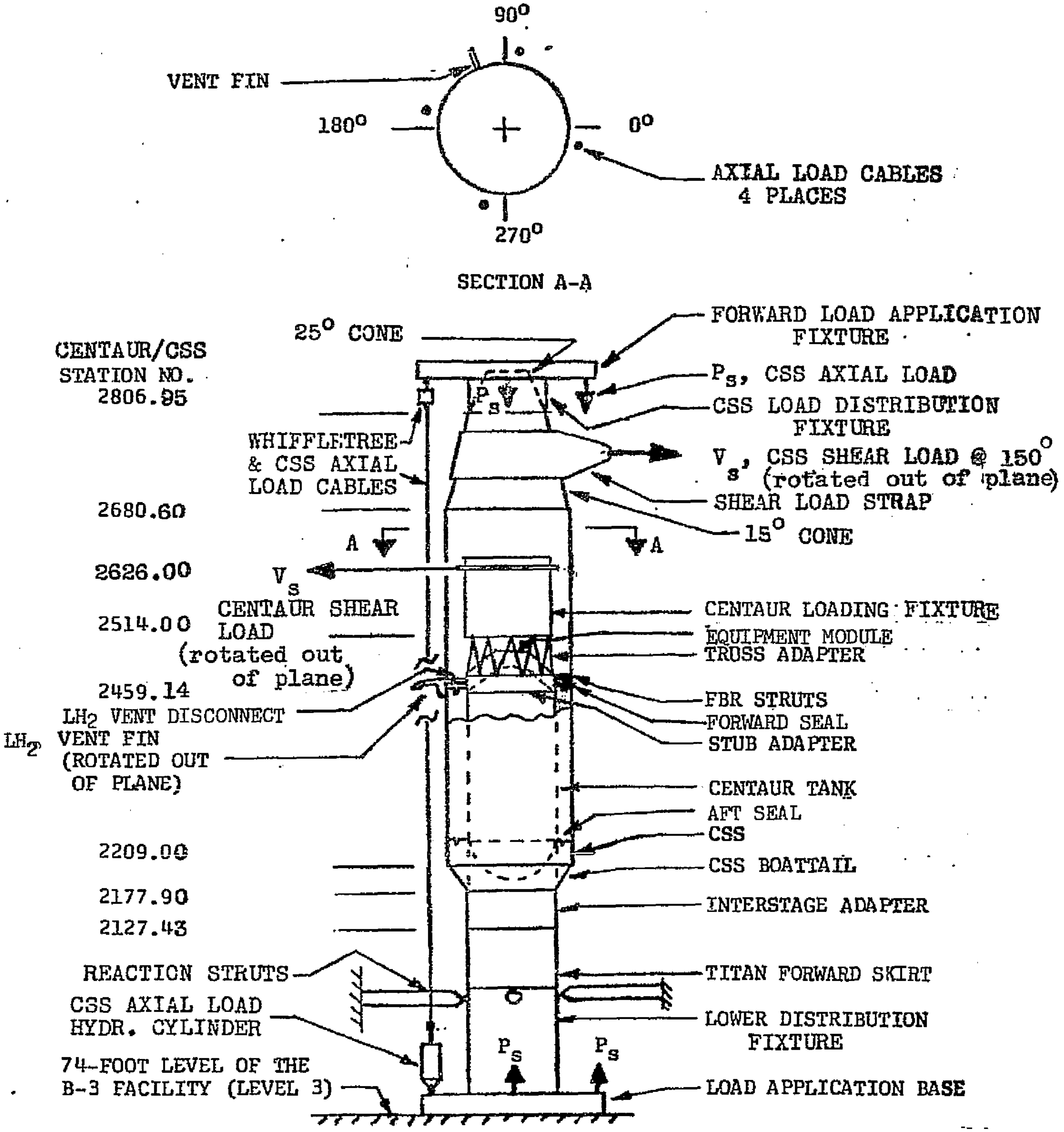

FIGURE 3. TYPICAL TEST CONFIGURATION FOR CSS ULTIMATE LOAD TESTS.

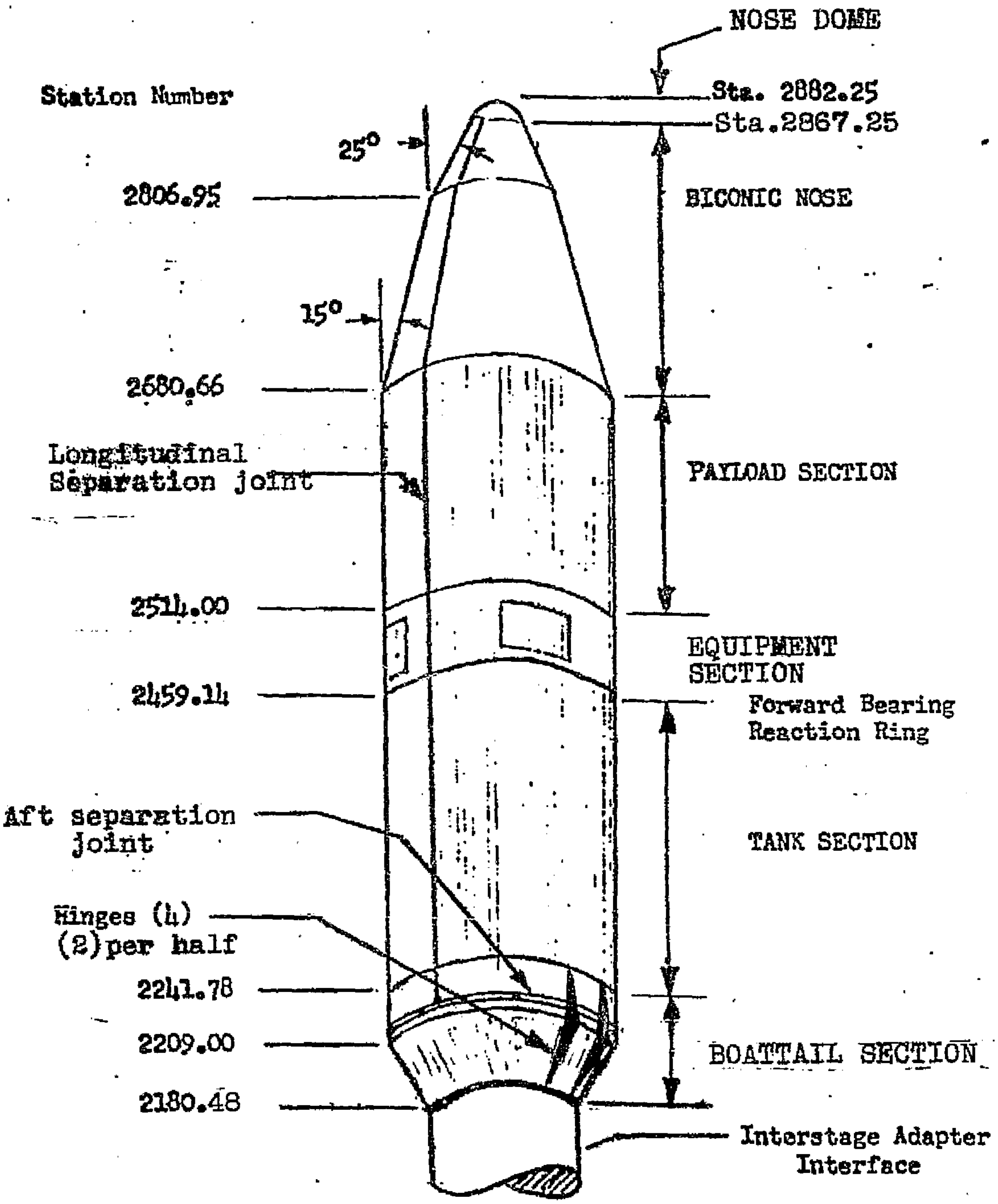

FIGURE 4. CENTAUR STANDARD SHROUD (CSS) GENERAL CONFIGURATION

STAINLESS STEEL WELDED CONSTRUCTION; SKIN THICKNESS, 0.013 TO 0.026; PRESSURE STABILIZED STRUCTURE; MODIFIED FORWARD BULKHEAD

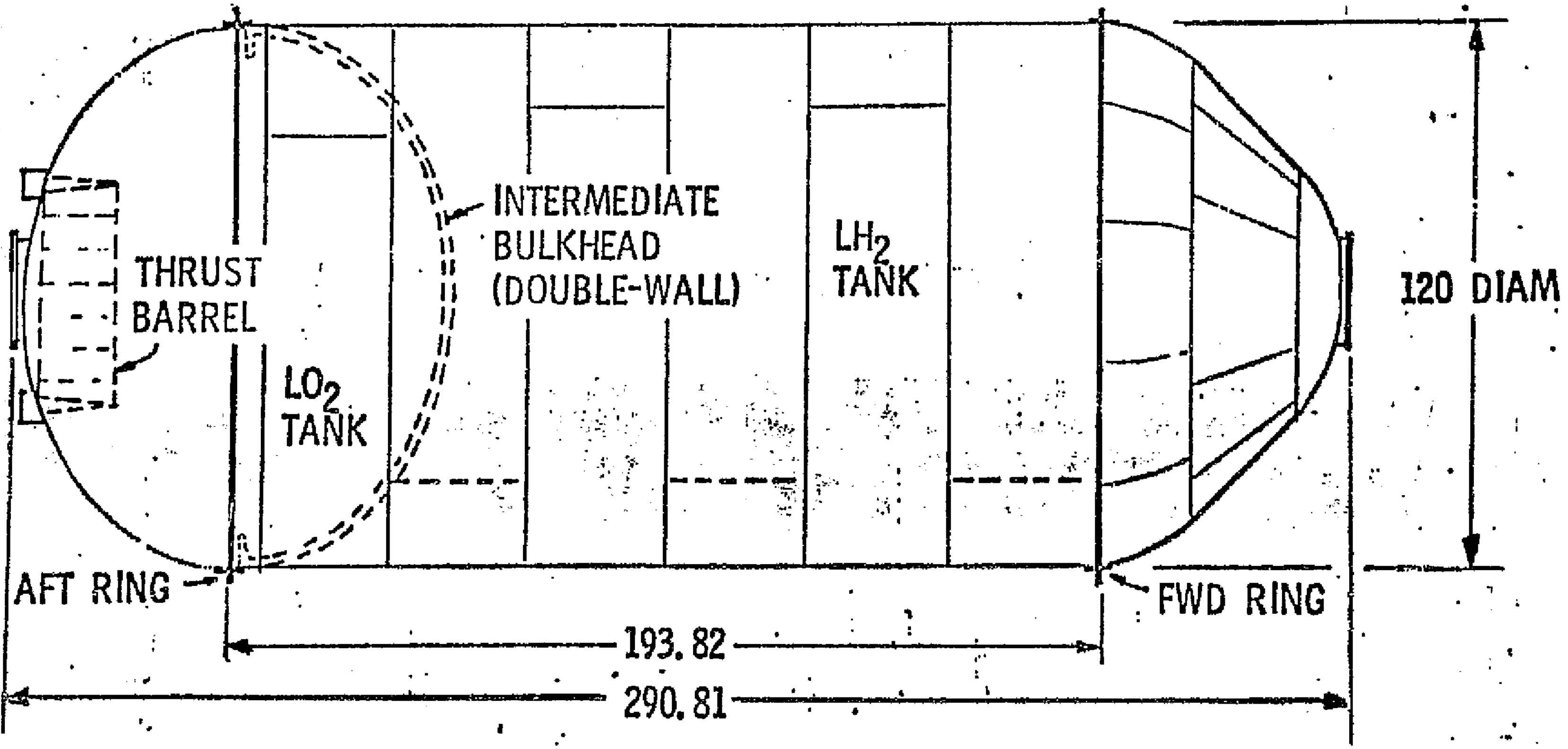

FIGURE 5. CENTAUR PROPELLANT TANK CONFIGURATION

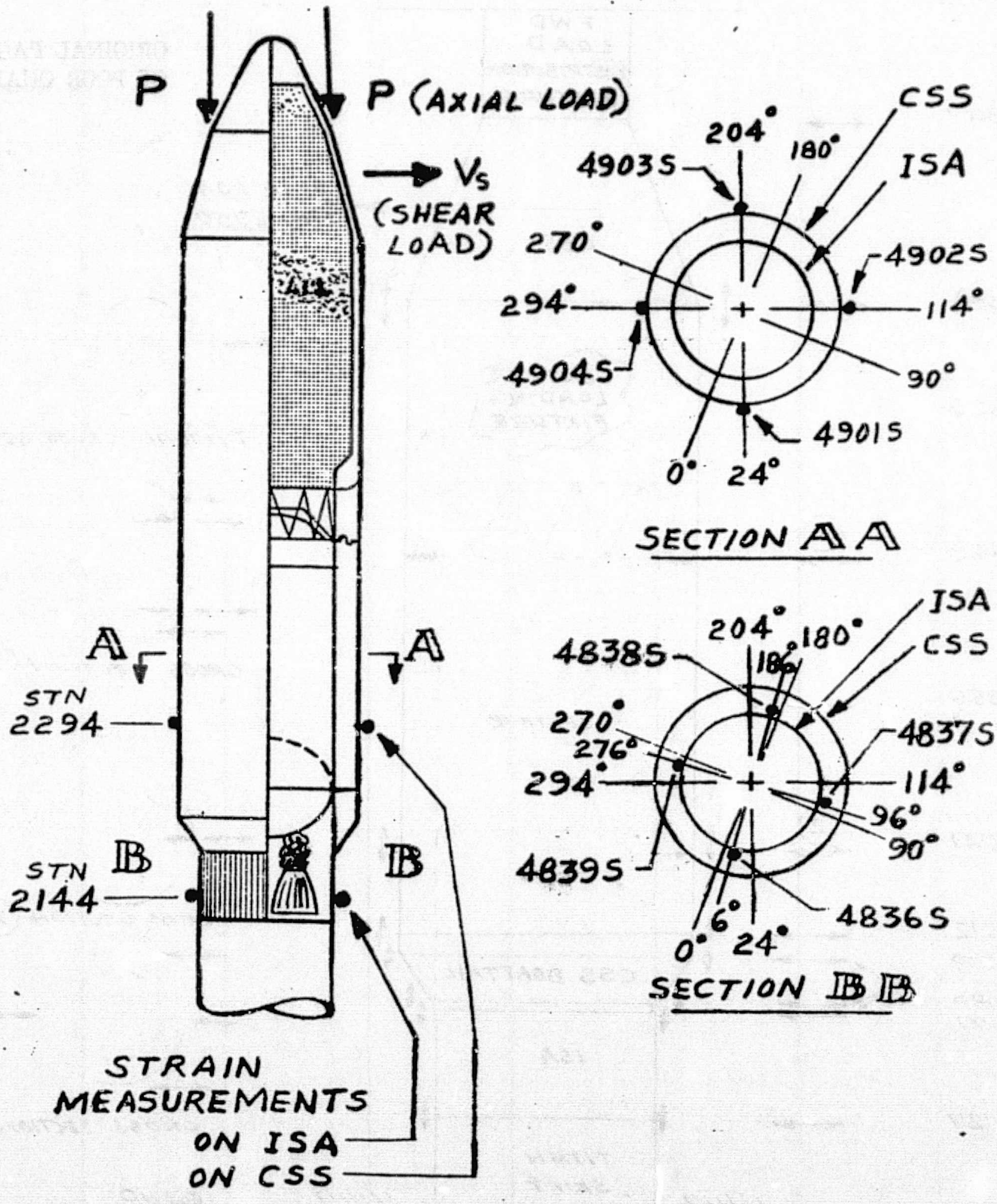

FIGURE 15. FLIGHT SIMULATED STRUCTURAL STRAIN MEASUREMENT LOCATIONS ON CSS AND ISA.

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OF POOR QUALITY

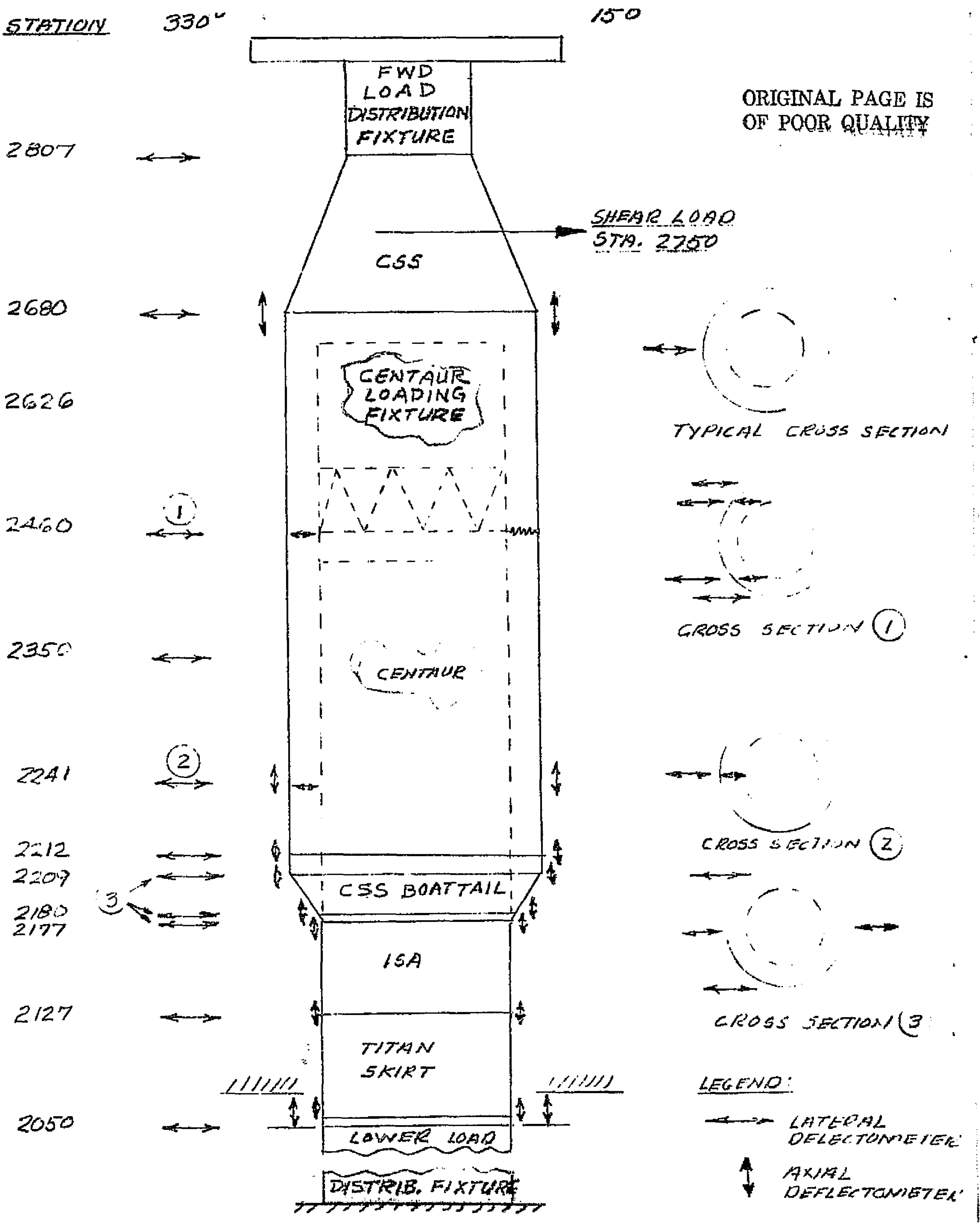

FIGURE 16. DEFLECTION INSTRUMENTATION PLAN.

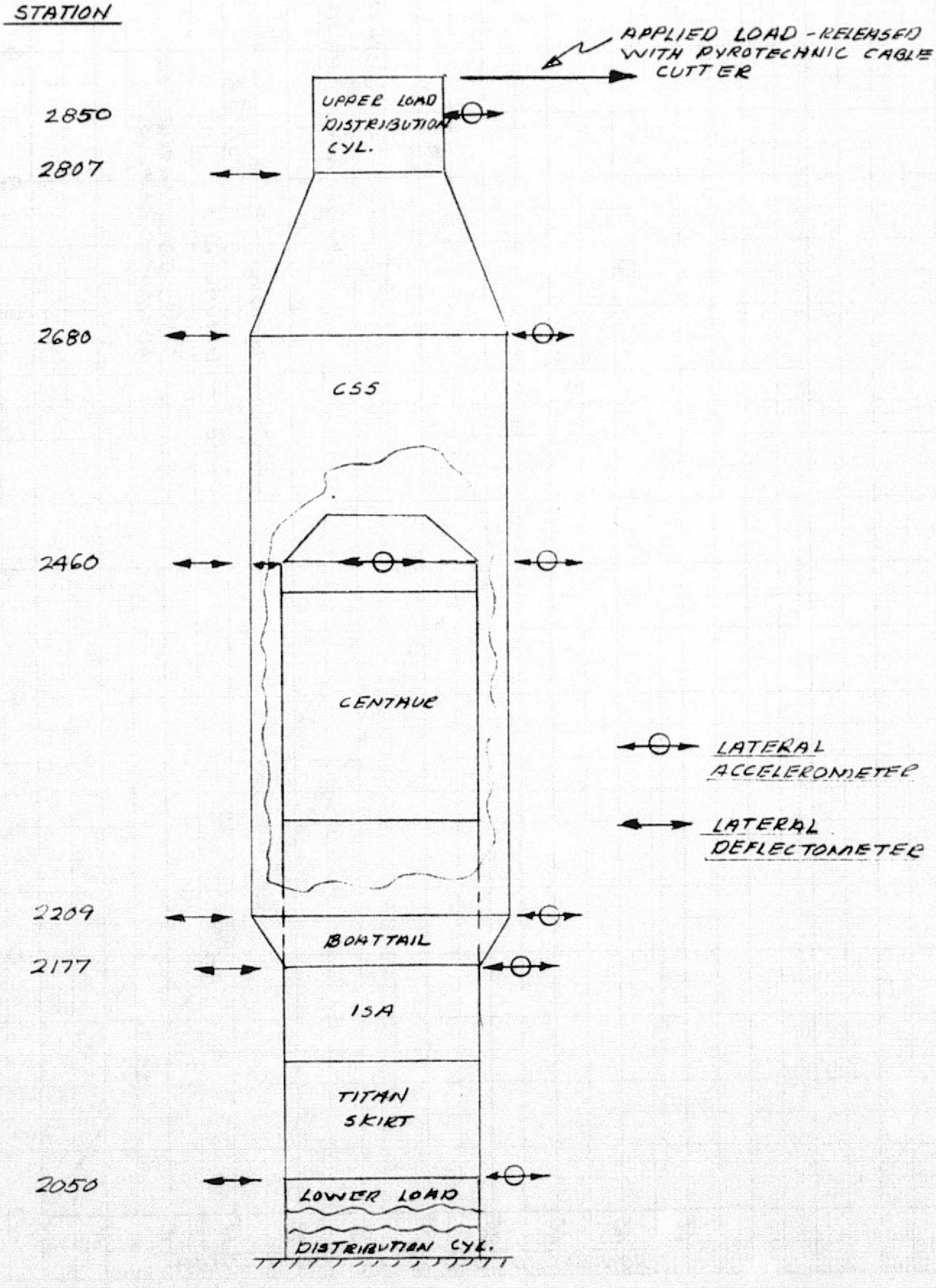

FIGURE 24. DYNAMIC RESPONSE TEST CONFIGURATION AND INSTRUMENTATION