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LIGHTWEIGHT BATTERY CONTAINERS FOR EXPLORER XVII (1963 9A), THE ATMOSPHERIC STRUCTURE SATELLITE

BY
TRUMAN H. AEHLE

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NASA
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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ABSTRACT

A method is presented for the design of lightweight battery containers for satellities. The design is based on using the batteries as structural members, yet allows ease of removal for recharging.

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INTRODUCTION

Explorer XVII (S-6), a scientific satellite, is a sphere 35 inches in diameter, made of stainless steel. It is hermetically sealed to prevent the escape of gases which would contaminate the environment which it is investigating (Figure 1). It contains instruments for measuring the density, pressure, composition, and electron temperature of the upper atmosphere at altitudes of 150 to 680 miles. The detection instruments are mounted on the surface of the sphere, which is 0.025 inch thick. The electronic and telemetry components, along with the power supply, are mounted inside the sphere on a honeycomb platform located 5-7/8 inches below the equator (Figure 2).

DESIGN

A basic need for an internal chemical power source was established early in the S-6 program. This need was based on the following requirements:

(1) High voltage to operate the various experiments.
(2) A relatively long life.
(3) The preclusion of solar cells because of their outgassing characteristics.

A study was undertaken to determine what type of power source would be required. It was decided that silver-zinc type batteries would meet the requirements. They have the best energy-to-weight ratio of any chemical power source and can generate the same amount of electrical energy as other batteries; however, they are only 1/5 the volume and 1/6 the weight of other batteries. After study, it was discovered that for the power needed, a relatively large mass was required for the batteries. In most spacecraft, the power source batteries are relatively small and few in number and are recharged by solar cell activity. These, therefore, present no great problem in regard to space needed or container design. But in Explorer XVII volume and design were major problems. The power requirements indicated the batteries would be approximately 150 lb of a total payload weight of 350 lb. The batteries were of several different sizes; they consisted of silver and zinc plates; separators; and potassium hydroxide electrolyte. The case is made of Plexiglas.

In the early design stage, and in fact for the first two "spheres" manufactured, it was required that the spacecraft be able to resist an internal negative pressure differential for test purposes. At first, hermetically sealed battery containers were required to prevent any electrolyte boiloff from the cells due to less than atmospheric pressure inside the spacecraft. But is was discovered that the sphere was not able to withstand, structurally, an internal negative pressure differential, so this requirement was removed. Subsequently the requirement for sealed containers was also removed.

Because of the scientific and vehicle requirements of the various experiments, the spacecraft had to have a stable spin about the vertical axis. (This made it necessary to have a favorable moment-of-inertia ratio about this axis.) Therefore, it was mandatory that the large mass items (including the batteries) be placed as far from the spin axis of the sphere as pratical and also that they have a reasonably equal mass distribution (Figure 2). Since space and weight were at a premium, a compact, lightweight battery container had to be designed. Batteries were grouped according to power usage and in serveral cases the group of one type of battery weighed 45 lb and occupied a volume of 500 $in.^3$. The batteries could not be "potted" into the container, as in most other spacecraft, for they had to be removed for recharging during preflight tests, and just prior to flight or replaced in case of single cell failure. Most of the payload experiments were in the process of being designed and at the start of the program the power requirements were constantly changing because of circuitry and electronic changes in the experiment and housekeeping components. Therefore, the battery container design had to be flexible. Wooden mock-ups of various-sized cells were used to locate the groups of cells in close relation to the components they would serve, in order to prevent excessive line voltage drop due to long power runs. At the same time other factors had to be considered, including balance and moment of inertia of the entire spacecraft, and the physical clearance and accessibility for installation and maintenance. After the battery requirements were finalized the detailed design of the containers began.

It was decided to use the inherent rigidity of the battery case to good advantage to make a structurally homogeneous package. This eliminated the necessity of excessive structure for the container, since the batteries themselves would act as part of the structure. The individual containers were to be bolted directly to the honeycomb platform through threaded inserts in the platform.

The container basically consists of a base plate, vertical angle members, cross tie members, and a cover plate which is bolted on. The base plate is designed with holes (to lighten it) in the bottom, and the ribs are placed in a way which supports each individual battery case in the longitudinal center of its base and along the edges (Figure 4). In addition to the basic structure the container has the feature of adjustability which makes possible a rigid structure with a minimum weight. There are four adjustable bars; two on a side, at top and bottom; and two on an end, at top and bottom. These bars press against the battery cases and are adjusted in and out by means of socket head set screws. These screws are threaded through the cross members and attached to the adjustment bars in a manner which allows rotation of the screws without binding to the bars. By this method it is possible to clamp the set of batteries in two planes and transfer all inertia loads from the batteries, through the bars and screws, into the container and thus into the satellite platform.

A foamed plastic spacer is placed between the cover and the top of the battery cases. The spacer is cut to fit over the battery terminals and press against the top of the battery case. It protrudes 1/16 inch above the container so that when the cover is bolted down, the foam is compressed between the cover and the battery case. A test program was conducted to determine the required density of the foam in order to provide the correct pressure necessary to carry the vertical loads. The spacer also provides insulation between battery terminals since a metal object cannot then fall into the space between the cover and the terminals.

The cover is bolted in several places in the proximity of the vertical members to increase the rigidity of the assembly. The adjusting feature is used only after the cover bolts have been installed. The cover acts in tension to prevent bending of the cross members due to the reaction to tightening of the adjusting screws (Figure 3).

The electrical connectors are mounted in the cross member and allow ready access for disconnect.

FABRICATION

The battery containers are constructed of 6061-T6 aluminum alloy and consist of sheet metal and machined parts welded together and then heat treated to return the material to the T6 condition. They are machined after welding to "true up" the various mounting surfaces. Stainless steel self-locking Helicoil inserts are installed in all threaded places to prevent wear on aluminum parts due to repeated adjustments, disassembly, and so forth.

The entire structure is coated with "Tygon" paint to prevent corrosion due to potassium hydroxide electrolyte spillage from the battery cases.

The bolt-down holes in the lugs of the base are drilled from a master jig which is also used to drill the holes in the honeycomb platform and to precisely position the threaded inserts. This prevents any misalignment due to tolerance build up in the parts.

The foamed spacers are molded in a custom mold designed for the individual container size and have a density of 12 lb per ft^3 which maintains proper tension when the spacer is compressed against the top of the battery cases. They are hand fitted to the particular container by being cut to fit the individual cable runs to the various terminals.

TESTING AND EVALUATION

Several vibration tests were run to determine the structural integrity of the battery container and also to determine any effects upon the honeycomb platform (Figure 5).

To simulate the worst condition on both the container and the platform, the tests were made on the tallest and heaviest container. The tests were run at prototype levels and revealed flaws in the original design. As a result, the number of cover retaining bolts was increased and the floating plate nuts on the vertical angles were changed to solid blocks welded to the angles. Helicoil inserts were installed. After these minor changes no troubles developed and all vibration tests were passed successfully.

Several tests of various coatings were made to determine a suitable coating to be applied to the container to prevent corrosion from the electrolyte. The proprietary paint "Tygon" was chosen. This paint gave adequate protection against potassium hydroxide and other alkaline corrosives.

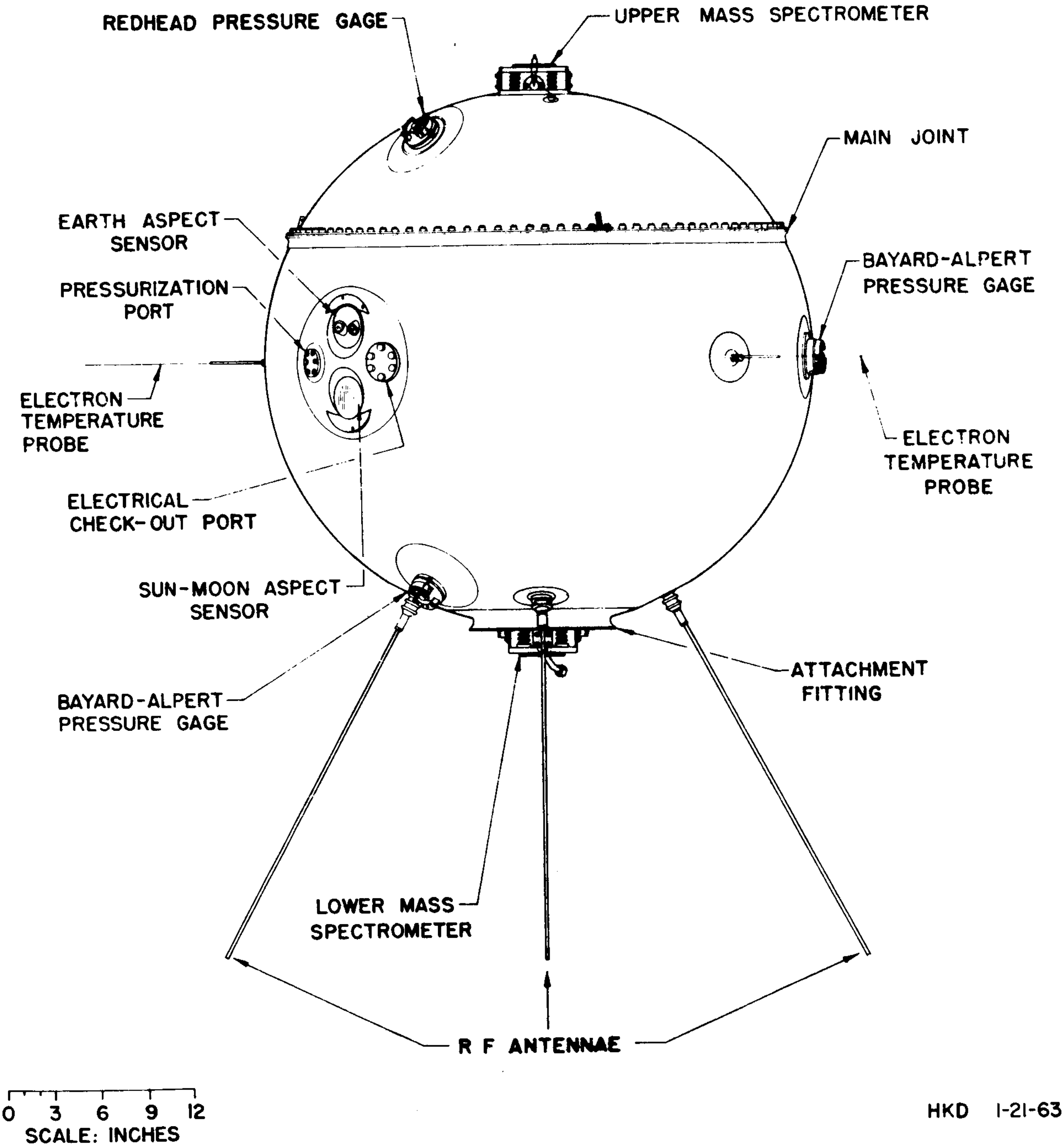
CONCLUSION

The battery containers performed in a satisfactory manner throughout all experimental, prototype, and flight tests. The adjustment feature was used many times when the batteries were removed for recharging of replacement during these tests.

From the results of tests and the apparent success of operation during the actual orbital life, it can be assumed that battery containers can be designed that are light in relation to the batteries by considering the batteries an integral part of the container structure and thereby utilizing the rigidity of the batteries to supplement the lightweight structure of the container. This will be especially true in the case of the relatively larger cells.

The adjustment feature allowed removal of the batteries from the spacecraft without costly and troublesome removal of the containers, which would have required removal of many other items in the sphere.

The battery-to-container weight ratio was approximately 10 to 1 whereas in many other battery container designs the container is heavier than the batteries. The container design was such that subsequent experiments were mounted on the structure and the containers were even used to stiffen the satellite shell and prevent excessive transmission of vibrations.



REDHEAD PRESSURE GAGE
UPPER MASS SPECTROMETER
MAIN JOINT
EARTH ASPECT SENSOR
PRESSURIZATION PORT
BAYARD-ALPERT PRESSURE GAGE
ELECTRON TEMPERATURE PROBE
ELECTRON TEMPERATURE PROBE
ELECTRICAL CHECK-OUT PORT
SUN-MOON ASPECT SENSOR
ATTACHMENT FITTING
BAYARD-ALPERT PRESSURE GAGE
LOWER MASS SPECTROMETER
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SCALE: INCHES
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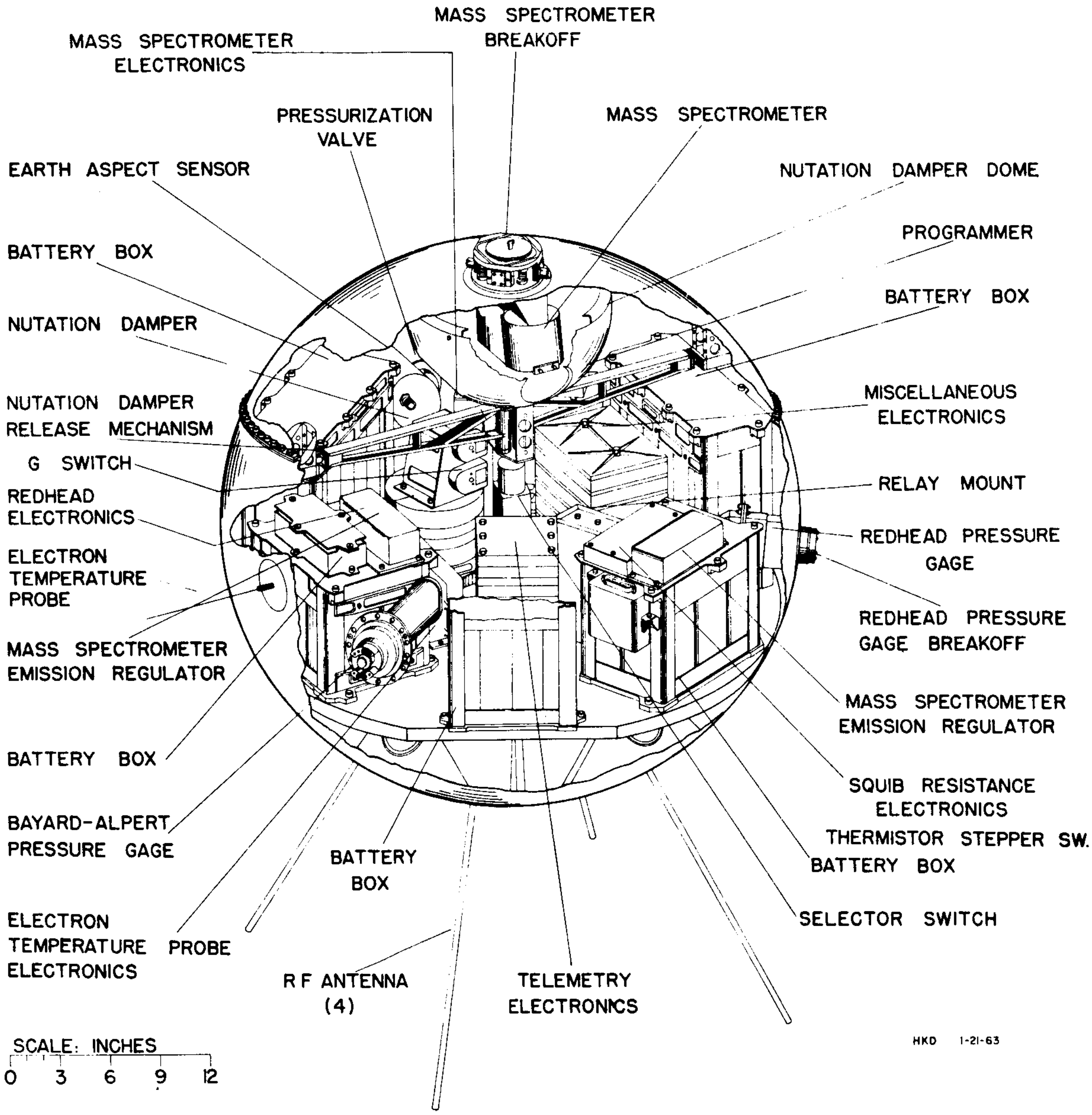
Figure 1


MASS SPECTROMETER BREAKOFF
MASS SPECTROMETER ELECTRONICS
PRESSURIZATION VALVE
MASS SPECTROMETER
EARTH ASPECT SENSOR
NUTATION DAMPER DOME
PROGRAMMER
BATTERY BOX
BATTERY BOX
NUTATION DAMPER
NUTATION DAMPER RELEASE MECHANISM
MISCELLANEOUS ELECTRONICS
G SWITCH
REDHEAD ELECTRONICS
RELAY MOUNT
REDHEAD PRESSURE GAGE
ELECTRON TEMPERATURE PROBE
REDHEAD PRESSURE GAGE BREAKOFF
MASS SPECTROMETER EMISSION REGULATOR
MASS SPECTROMETER EMISSION REGULATOR
BATTERY BOX
SQUIB RESISTANCE ELECTRONICS
BAYARD-ALPERT PRESSURE GAGE
THERMISTOR STEPPER SW.
BATTERY BOX
BATTERY BOX
SELECTOR SWITCH
ELECTRON TEMPERATURE PROBE ELECTRONICS
R F ANTENNA (4)
TELEMETRY ELECTRONICS
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SCALE: INCHES
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Figure 2

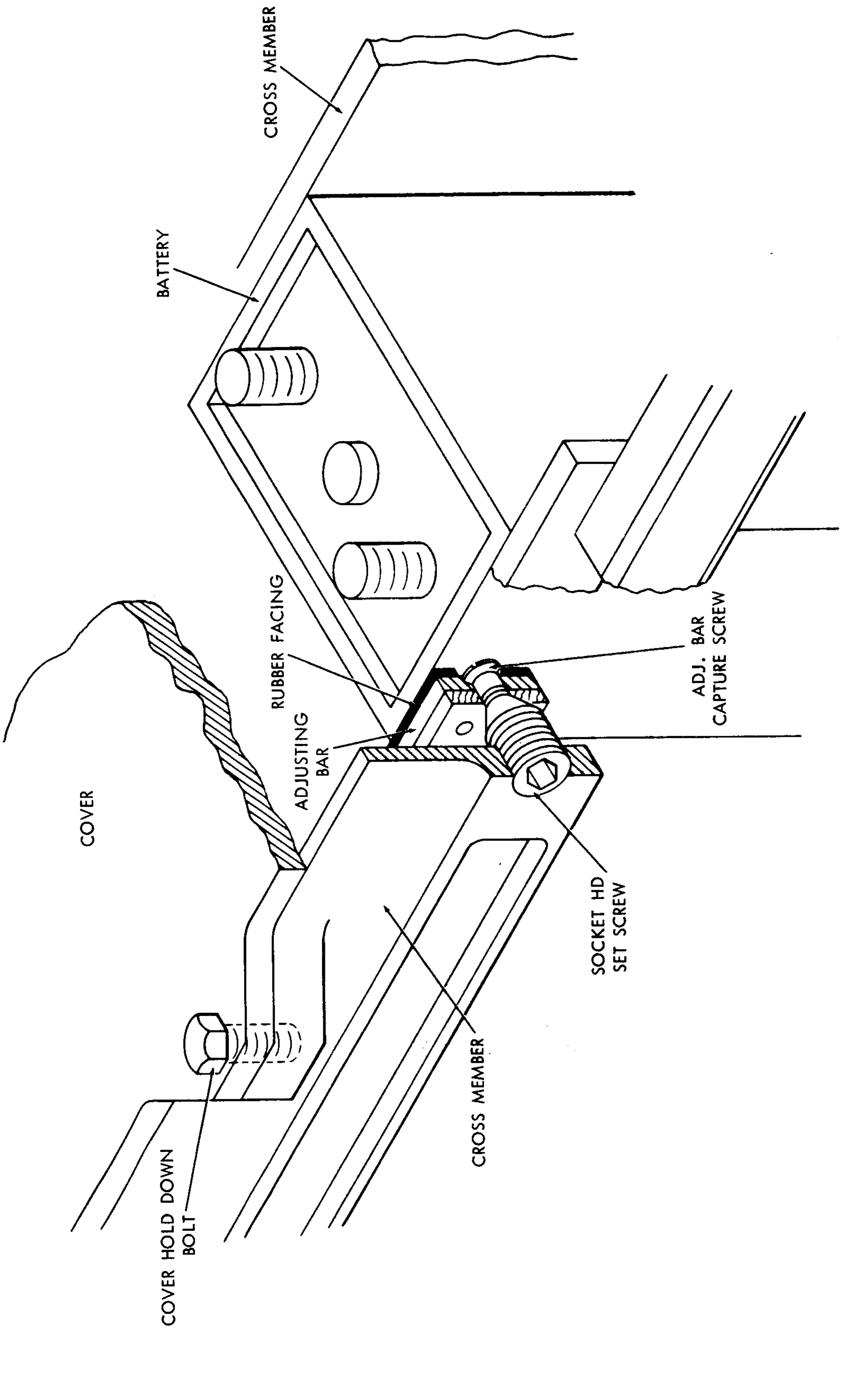
CROSS MEMBER
BATTERY
COVER
RUBBER FACING
ADJUSTING BAR
ADJ. BAR CAPTURE SCREW
SOCKET HD SET SCREW
CROSS MEMBER
COVER HOLD DOWN BOLT

Figure 3