HELMET IMPACT TEST SYSTEM

OPERATION & ASSEMBLY MANUAL

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DISCLAIMER

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16. Abstract

Protective head gear is currently evaluated using several ANSI guidelines, such as ANSI 789.1. The rigid headform specified in this standard does not realistically represent the head-neck-torso complex of the potential helmet wearer; further, the impact conditions specified therein do not simulate the variety of impact conditions encountered in actual industrial accident.

The objectives of this project were to: 1) examine the literature to define the required impact characteristics, 2) identify the unavailable data then conduct tests to obtain such data, 3) develop a helmet impact test system based on acquired response data, and finally, 4) construct such a device and deliver it along with its user's manual.

These objectives were met, and the work leading to the final goal is described in this final report. The device itself is delivered separately along with all engineering drawings and the assembly and operation manual.

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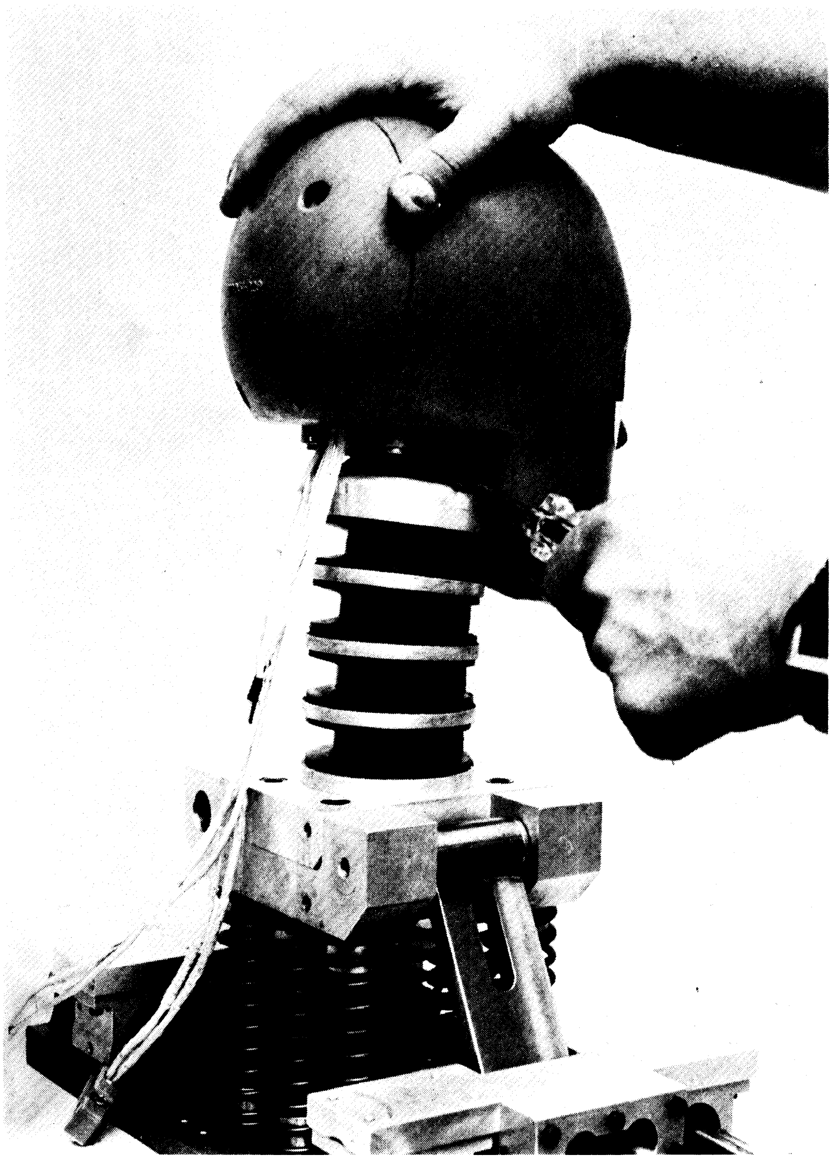
PART ONE: OPERATION INSTRUCTIONS



The Helmet Impact Test System (HITS) is designed to test the performance of industrial helmets. In order to operate the device, you need a mechanism for dropping a weight (drop tower), a test floor/platform to which the device base will be bolted, and signal conditioning and recording equipment for a minimum of six data channels.

General Description

The HITS is a mechanical system which responds to axial impacts in a human-like motion. Unlike other headforms, this device provides a plunging motion of the head along the spinal (axial) direction. The device superior-inferior (S-I) axis may be set in any direction within certain limits (described later), and the impact may be softened by adjustable friction elements.

The bending response of the head is controlled by the neck, which has been designed by General Motors Research Laboratories and validated for bending response against human volunteers responses.

The response of the device is measured with 3 trandsucers which measure the A-P, L-R and S-I accelerations at the head center of mass, and by a neck multiple transducer which measures the axial (S-I) and shear (A-P) forces at a point equivalent to the location of the occipital condyles in humans along with the moment about an L-R axis passing through the "condyles".

In order to operate the device you will need the following:

(a) the actual HITS itself;
(b) a drop tower or any impact delivery system;
(c) a test platform to which the device will be bolted;
(d) signal conditioning of six transducer signals;
(e) recording/playback equipment.

The HITS includes the mechanical device, the neck load cell and a tri-axial mount designed to fit 3 Endevco 2264 uniaxial accelerometors. The testing engineer must provide these 3 accelerometers, or a different unit to replace the triaxial mount and specified accelerometers.

Drop Tower Requirements

A 6.5-ft drop height and a 9-lb weight are the nominal parameters of the required drop tower. This provides the necessary energy to produce a response similar to that observed in humans. As more human response data becomes available, the need may arise for increased height and/or weight. However, tests on the device have indicated that a 9-ft height and an 18-lb weight would generate peak forces and accelerations which are beyond human tolerance levels.

The second requirement is the provision for a heavy platform to which the HITS base would be bolted securely and rigidly. Such platform should provide tapped holes (1/2-13) in 6 x 6-inch square patterns, so that the location of impact may be accurately controlled. Alternately, the drop tower itself could provide adjustable dropping point so that, as the angle of the S-I direction of the head changes, the location of impact is controlled.

Instrumentation

The neck transducer is a multi-channel unit designed specifically to fit the GM Hybrid III neck and head. The 3 bridges for the shear (A-P) and axial (S-I) forces and the moment (L-R) of the neck are wired out into three 5-pin connectors. The 3 accelerations (A-P, L-R, S-I) at the center of mass of the head are measured with 3 uniaxial accelerometers mounted in a triaxial cluster.

Normal laboratory procedures for calibration and signal conditioning should be employed. Because of the short duration of impact, it is recommended that the 6 conditioned signals be recorded then played back later for analysis and/or digitizing.

Filtering the signals may be done either with analog (electronic) filters or with digital filtering procedures. If analog filters are employed, they should conform to SAE J211b guidelines as follows:

Head accelerations	Channel Class 1000.
Neck loads	Channel Class 180.
Impactor force/acceleration. .	Channel Class 60.

If the signals are to be digitally filtered, then a spectral analysis should be performed on a typical sample of the various signals to determine the frequency content and to select a cutoff frequency for the 3 accelerations and another for the neck loads. The cutoff frequencies of the low-pass digital filters are recommended to be as follows:

Head accelerations	500 Hz $\pm$ 5%
Neck loads	300 Hz $\pm$ 5%
Impactor force/acceleration .	100 Hz $\pm$ 5%

Installation

After the device has been assembled, the base may be bolted to the fixed laboratory platform using four 1/2-13 machine screws. All bolts should be tightened at this time except for the 2 friction set screws and the 8 screws controlling the orientation of the device.

The next step is to "dress" the head with the helmet to be tested and make the necessary adjustments in the strap so that the seating of the helmet is as normal as possible.

Make the necessary adjustments in the drop tower to align the vertical line of the dropping weight with the desired location of impact. Adjust the orientation of the device (as described below) until the desired direction of impact is reached. After all alignments are completed, adjust the friction using a torque wrench (as described below).

Adjustment of Friction

Two friction elements are incorportated in the device for the purpose of dissipating some of the energy of impact There are two extreme settings which produce two different actions and result in different loads and acceleration readings.

One extreme setting is to loosen the two set screws completely, thereby eliminating the friction from the system. In this case, all of the impact energy is stored in the spring, then fully restored to the head resulting in a rebound action.

The other extreme setting is to lock the friction bars with over 40 in-lb torque into each of the set screws. When this is done, the springs are effectively eliminated from the system which is then reduced to the head and neck subsystem. The impact in this case is "hard" resulting in higher peaks in the S-I acceleration and load.

The maximum dissipation of energy occurs when the head/neck is allowed to plunge but not rebound. This is most similar to human response where the spine is axially displaced and does not rebound after impact.

Therefore, it is recommended that the friction be set to provide maximum dissipation of energy. This corresponds to a set screw torque of 30 $\pm$ 5 in-lb. This torque must be reset after every test.

Adjustment of Orientation

The orientation of the head S-I axis with respect to the vertical may be adjusted to allow the drop weight to impact the head virtually at any desired location above the head basic plane.

The head/neck/throax sub-assembly may be pitched, i.e., rotated about an axis paralled to the head L-R direction, and may be rolled, i.e., rotated about an axis paralled to the head A-P direction. Both pitching and rolling may be done in increments of 5 degrees (up to a maximum of 45 degrees) is either the positive or negative directions. Typical configurations are shown in the next pages, where the arm holding the spherical weight is included only for illustration. Note that pitching and rolling may be combined to cover the 4 "quadrants" of the helmet formed by A-P and L-R circumferential lines.

The pitch is controlled by 2 pairs of screws mounted on the two uprights of the base, while the roll is controlled by the other 2 pairs, mounted on the 2 sides of the cradle. Adjustments of the orientation is done by <u>removing</u> the bottom screw in each pair (and the opposing one) while <u>only loosening</u> the top screw in the pair (and the opposing one). The top screw serves as a hinge when the bottom screw is removed.

Each of the plates holding the 4 pairs of screws contain 5 clearance holes that are 25 degrees apart. Under each plate are 5 tapped holes that are 20 degrees apart, so that any time only two holes are aligned at one time and precisely an angle that is a multiple of 5 degrees is found.

When the hole marked (0) is aligned with a threaded hole, the angle is exactly 0 degrees. To rotate the device, first remove the bottom screws of opposing pairs and only loosen the top screws. Next rotate the device about the two top screws (now acting like a hinge) until a threaded hole appears behind the hole marked (5), indicating an rotation of 5 degrees. Rotate the device further until a threaded hole appears behind the hole marked (10) indicating that the device has been rotated 10 degrees. Further rotation will bring a threaded hole behind the other hole marked 10. This jump between the two outside holes will occur every additional 20 degrees rotation. Continue this rotation and follow the appearances of threaded holes until the desired angle is reached. Insert the bolts and tighten.

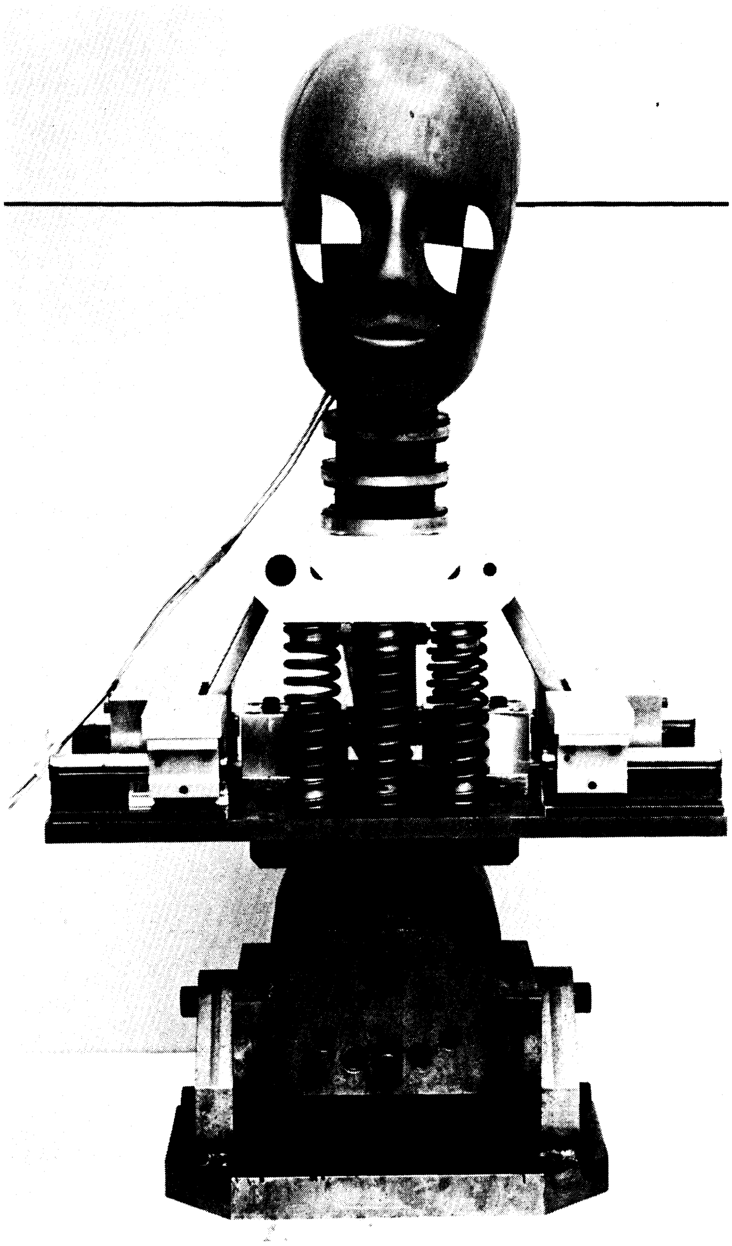
Maintenance

The device should be lubricated at the various hinges to eliminate friction and to retard rust. However, the stainless steel friction bars should be oil-free. The base should also be coated frequently with rust-retarding oil since its made out of cold rolled steel.

Every 20 or 25 tests, all the bolts should be checked and retightened if necessary. For inaccessible bolts, it may be necessary to dismantle portions of the device to check these bolts and tighten them.

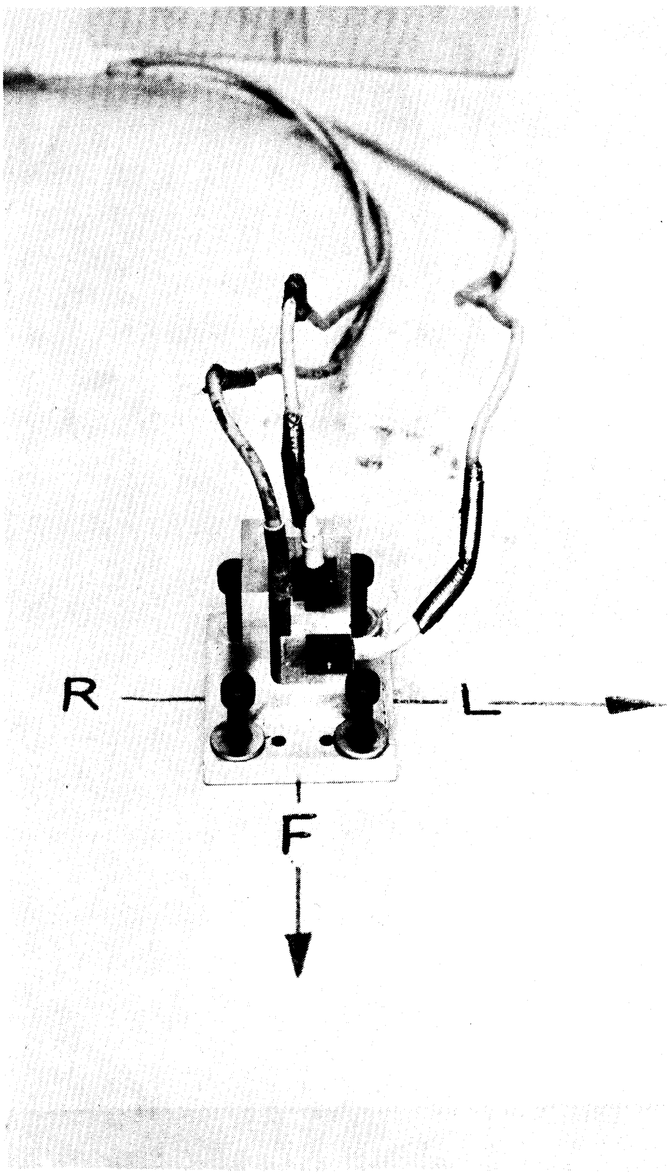
Finally, a word about the design limits of the device. Although designed to take loads of 2500 lbs impact, a longer life of the components is obtained by limiting the loads to 1000-1500 lbs.

PART TWO: ASSEMBLY INSTRUCTIONS



The Helmet Impact Test System (HITS) consists of three major sub-assemblies: the head/neck including transducers for 6 data/channels, the thorax which provides axial plunging motion for the head, and the mounting base which allows control of location and direction of impact.

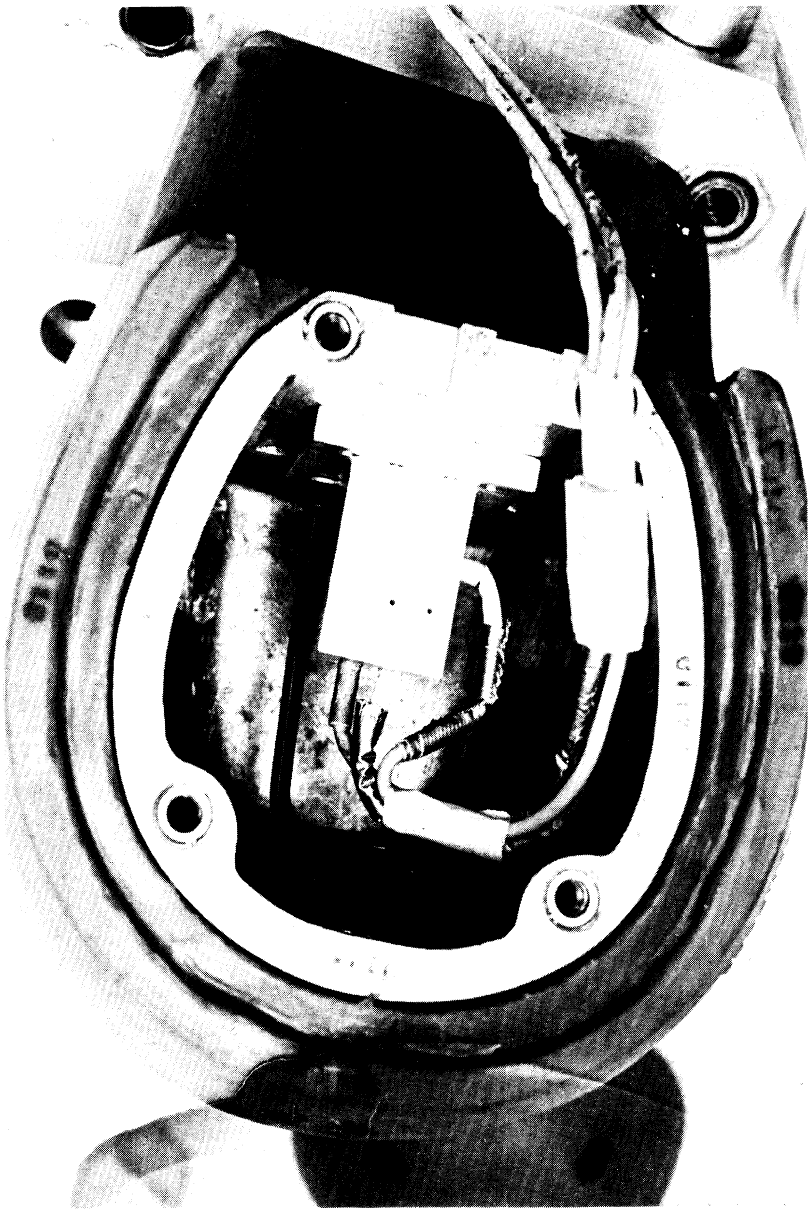
The assembly instructions given in the next pages should generally be followed in the given order. Once assembled, refer to Part One of this manual for operation.



Install 3 Endevco uniaxial accelerometers [model 2264] on triax [HITS-011] using #0-80 screws.

Note at this time the S/N of each accelerometer and whether it is mounted in the posterior-anterior (P-A), left-right (L-R) or inferior-superior (I-S) direction.

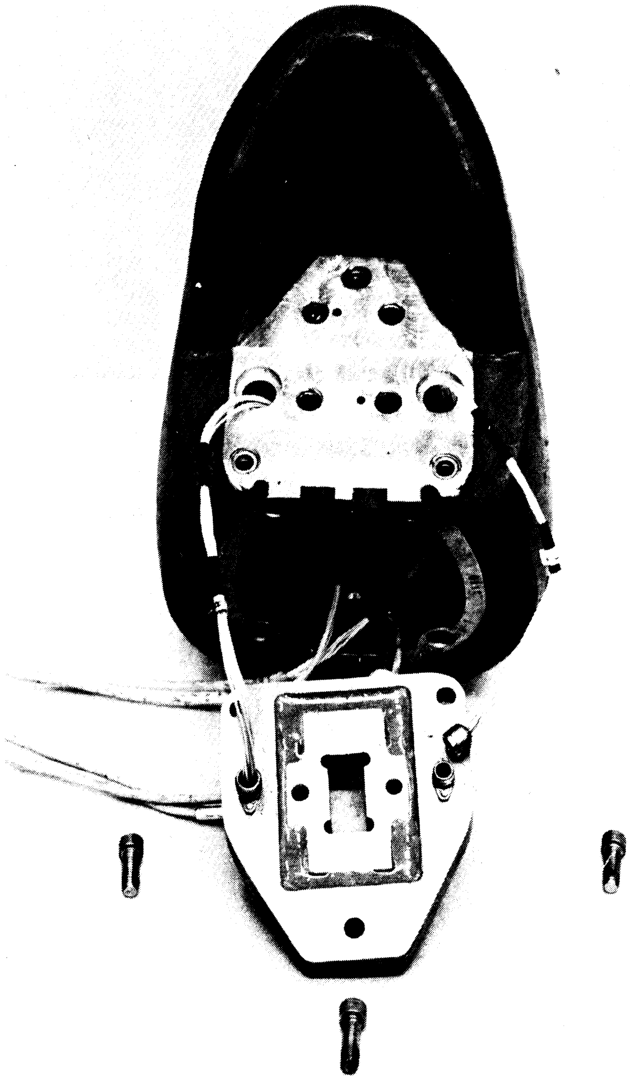
Check polarity of each accelerometer. Positive direction is defined as P-to-A, R-to-L and I-to-S. If necessary, rewire the 5-pin connectors or use a negative calibration factor.



Use 4 screws [HITS-002-70] and washers attach the triaxial accelerometer package inside the dummy head.

Place the mount with the surface stamped (B) toward the back of the head.

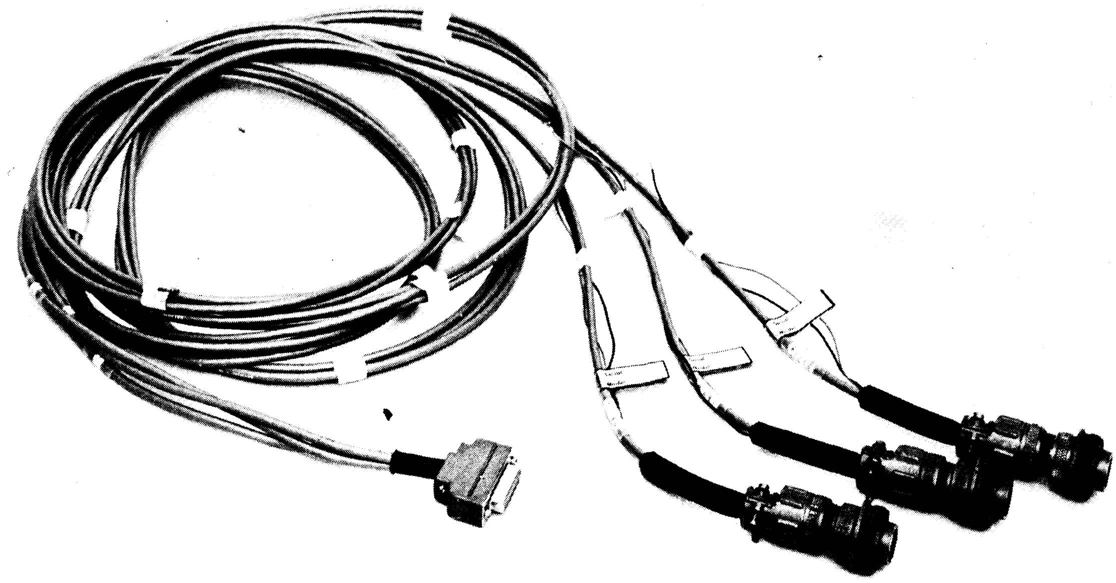
Use short allen wrench to tighten the 4 screws. To access the 2 front screws, it may be necessary to insert the whole hand inside the dummy head.



Through the two holes at the head base, pass the two 7-pin mini-connectors and cables from the inside toward the outside.

Connect the L and R mini-connectors to the neck load cell [GSE T-11449-C] at the appropriate locations stamped L and R.

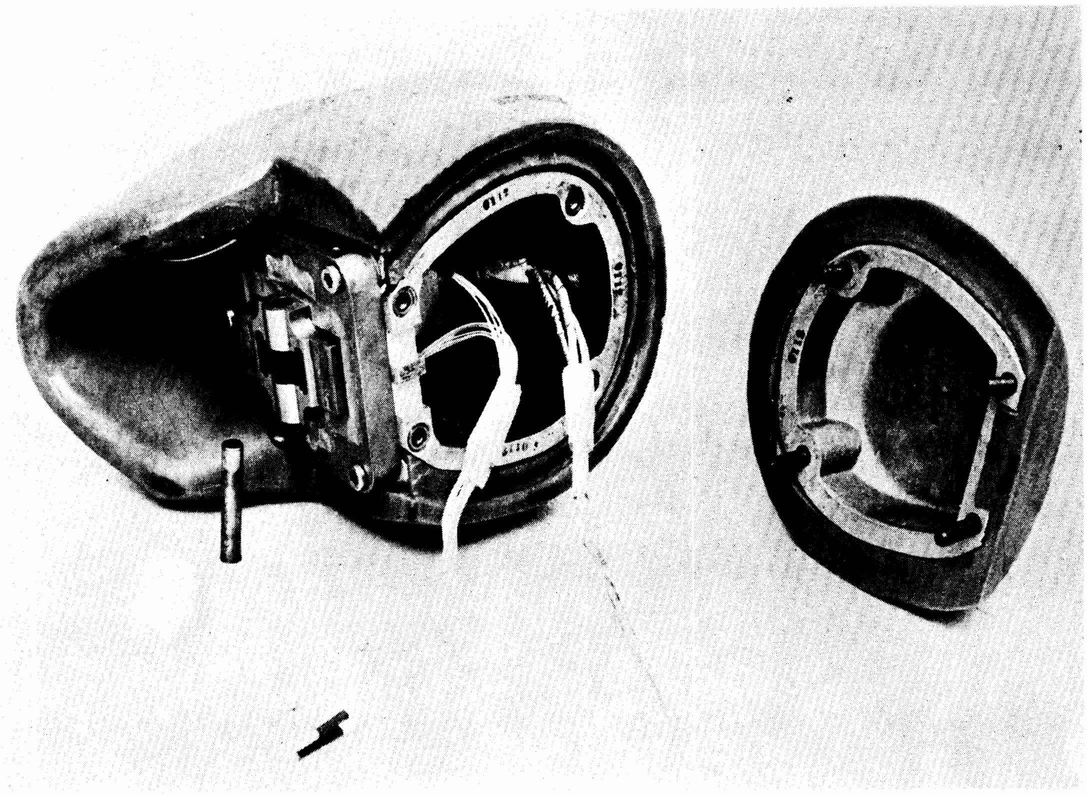
Place the load cell against bottom of head, then attach with 3 stainless screws [HITS-002-9].



The GSE load cell is a 3-channel transducer to measure the shear force (FX) in the P-A direction, the axial force (FY) in the I-S direction, and the neck moment (MZ) about an axis in the R-L direction.

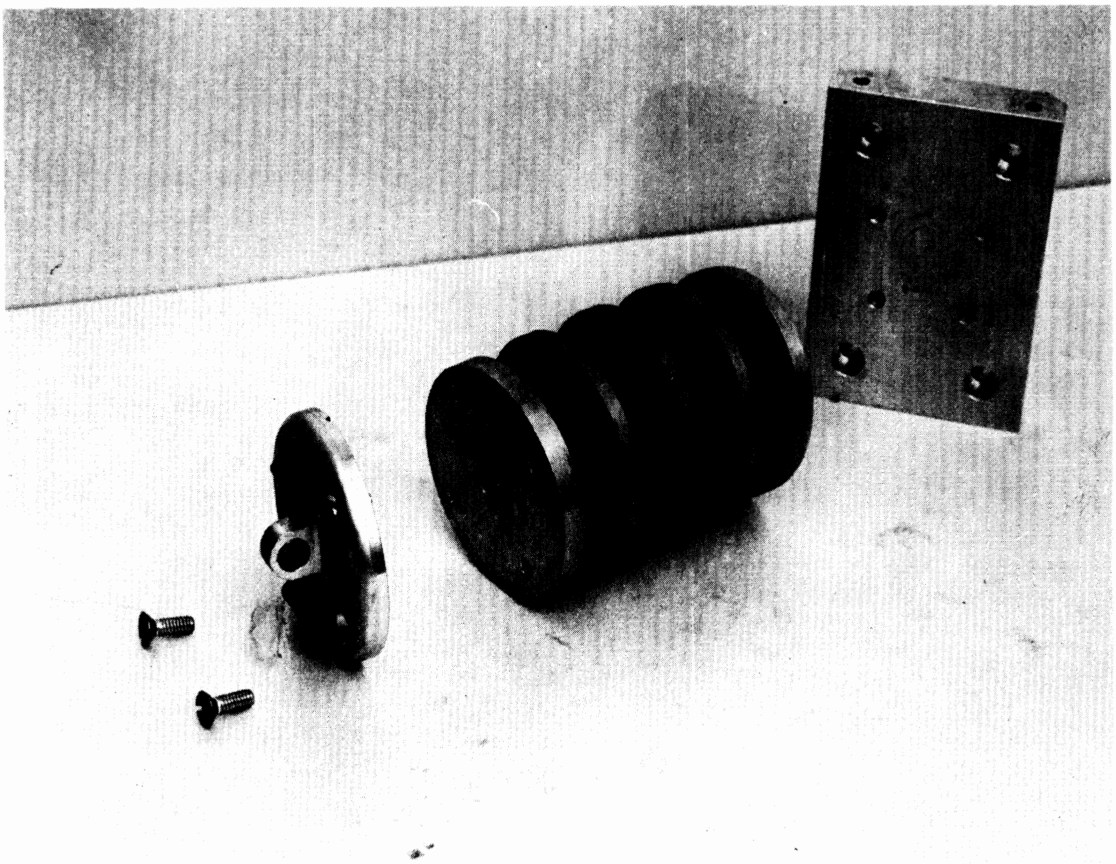
Because of the design of the transducer, wires from the 3 bridges are brought out in two bunches. To simplify the signal conditioning, the two bunches are joined into a single 14-pin connector, from which 3 cables emerge.

The ends of the FX, FY, and MZ cables are terminated with 5-pin connectors. The shunt calibration resistors (provided by GSE) are wired inside the connectors and pair of leads are left exposed for shorting during calibration.



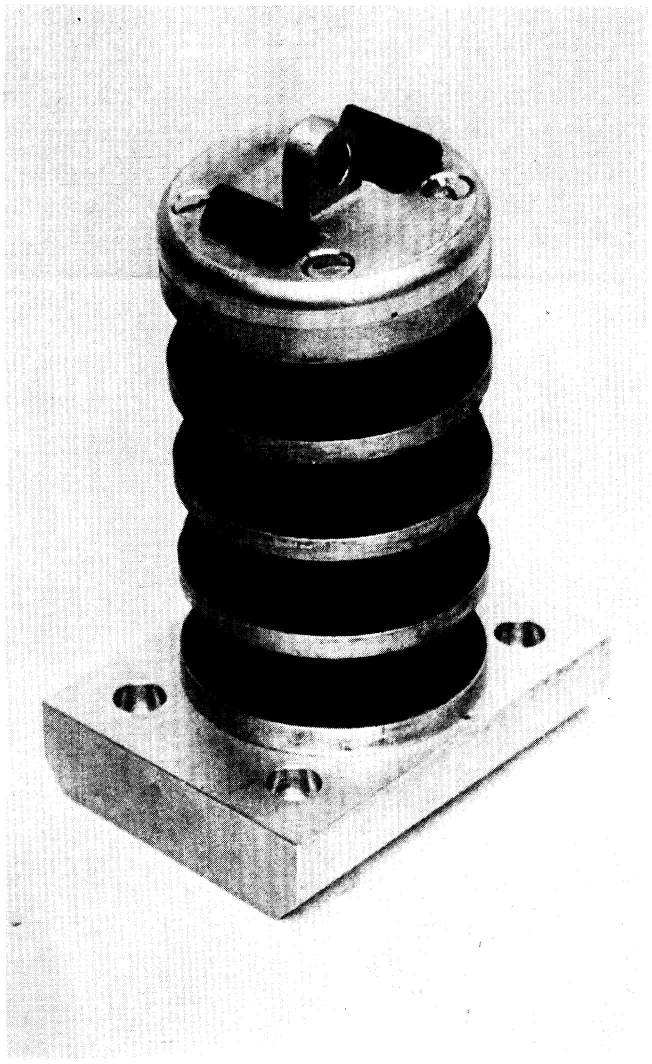
Using drafting tape, arrange cables inside the head and tape the 3 accelerometer cables into one bunch and the two load cell cables into another bunch. Place the 2 bunched cables into the two slots in the back of the head.

Attach head cap to the head using 4 screws provided with the head.



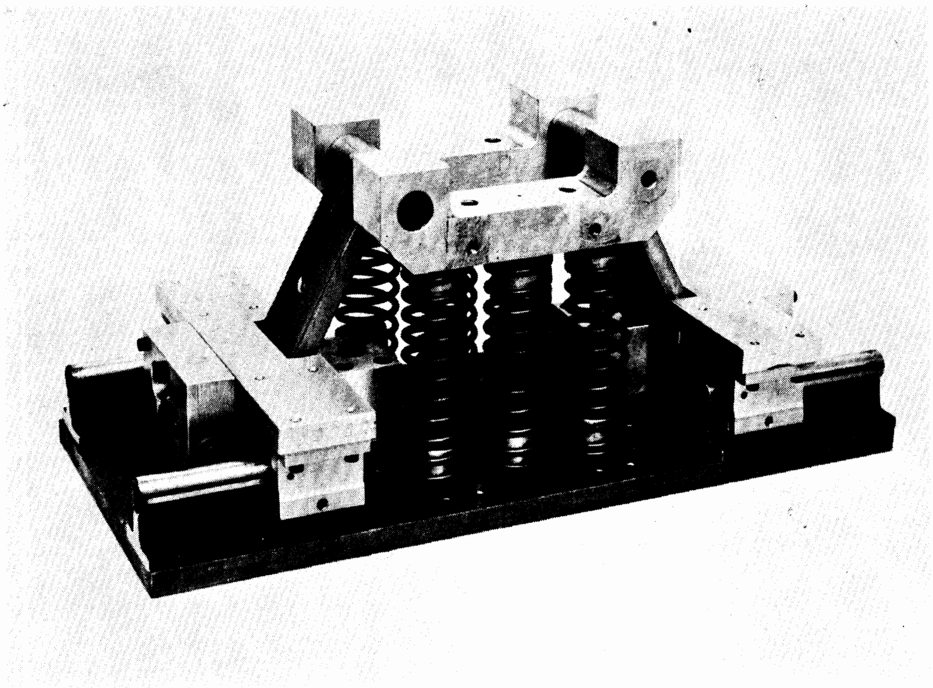
Attach the neck mounting base [HITS-111] to the bottom of the neck.
Use 4 screws [HITS-002-70].

The bottom side of the neck is the face with 4 holes in non-symmetic pattern, while the top side is the face with 4 holes in a symmetric pattern.



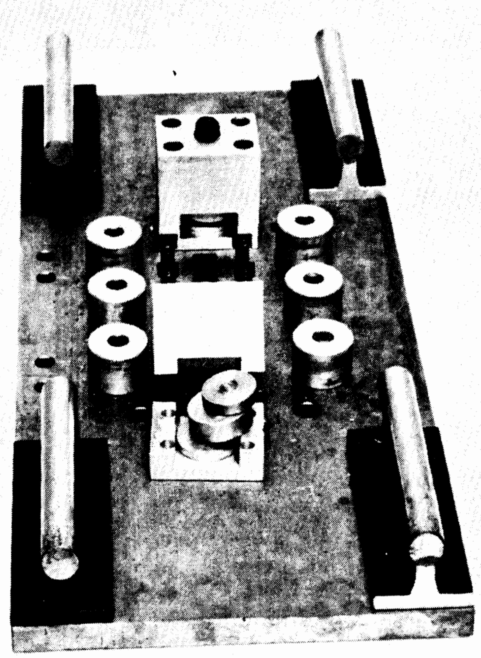
Attach the neck adaptor to the top of the neck as shown. Use 4 flat head screws [HITS-002-20].

The direction in which the head will face is determined by the direction of the bushing in the neck adaptor. The lateral direction (L-R) of the head is always along the axis of the neck adaptor bushing.



This major sub-assembly may be referred to as the thorax, since it allows the axial plunging of the head/neck.

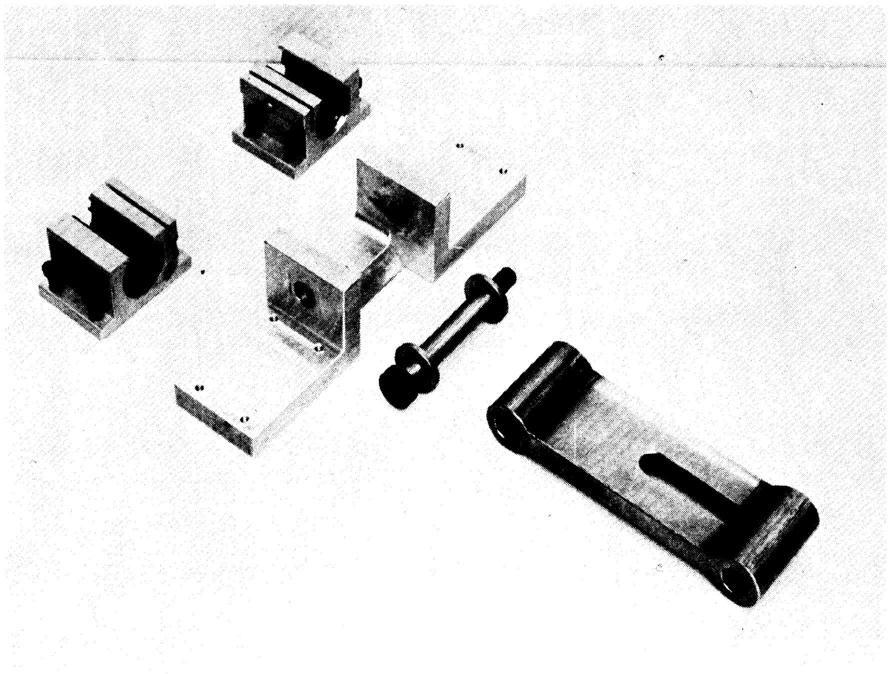
The thorax may be assembled in smaller sub-assemblies which are then put together. The order of the procedures outlined here may be slightly modified; however, it is recommended to proceed in the order given here.



Install 4 guide rod assemblies [HITS-153] at the corners of the thorax lower plate [HITS-161] using 16 screws [HITS-002-13].

Install 6 spring inserts [HITS-004] on the plate. Use 6 screws [HITS-002-15].

Do not install friction blocks at this point.

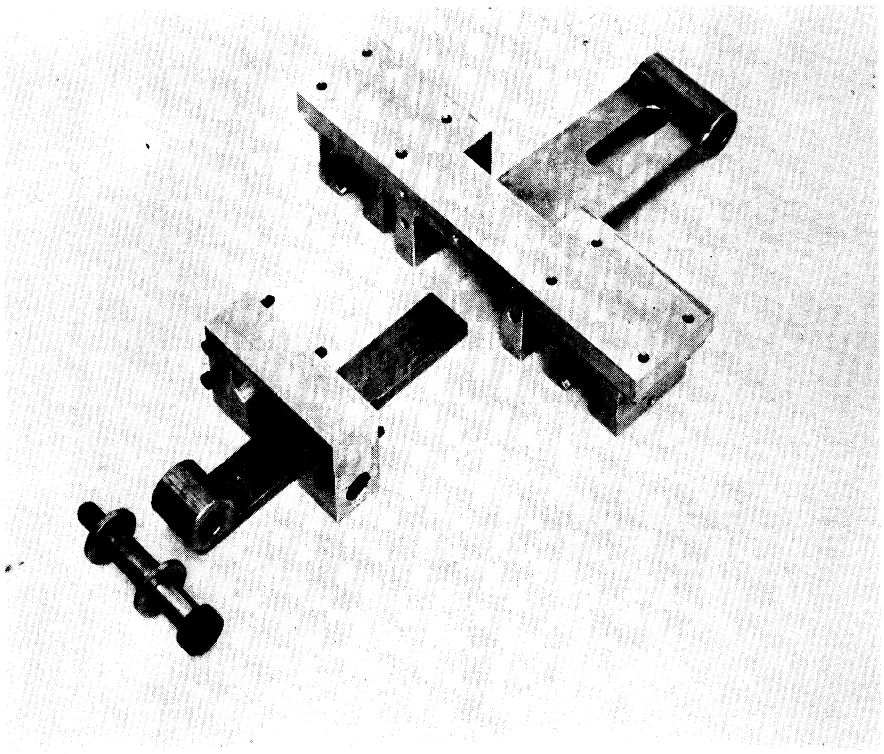


Using 1 shoulder bolt [HITS-002-31] and 2 brass spacers [HITS-003], attach the pivoting arm [HITS-121] to the sliding platform [HITS-151]. The slot should be on the far side of the platform as shown.

Note that this is the last time this shoulder bolt will be accessible. Therefore, use some anti-slip thread compound (e.g. Locktite) then tighten the screw, but, not as to stop the pivoting of the arm.

Next, install 2 linear motion ball bushings using 8 screws [HITS-002-7]. Check the alignment of the two bushings against the two guide rods installed in step 9. Adjust as necessary then tighten.

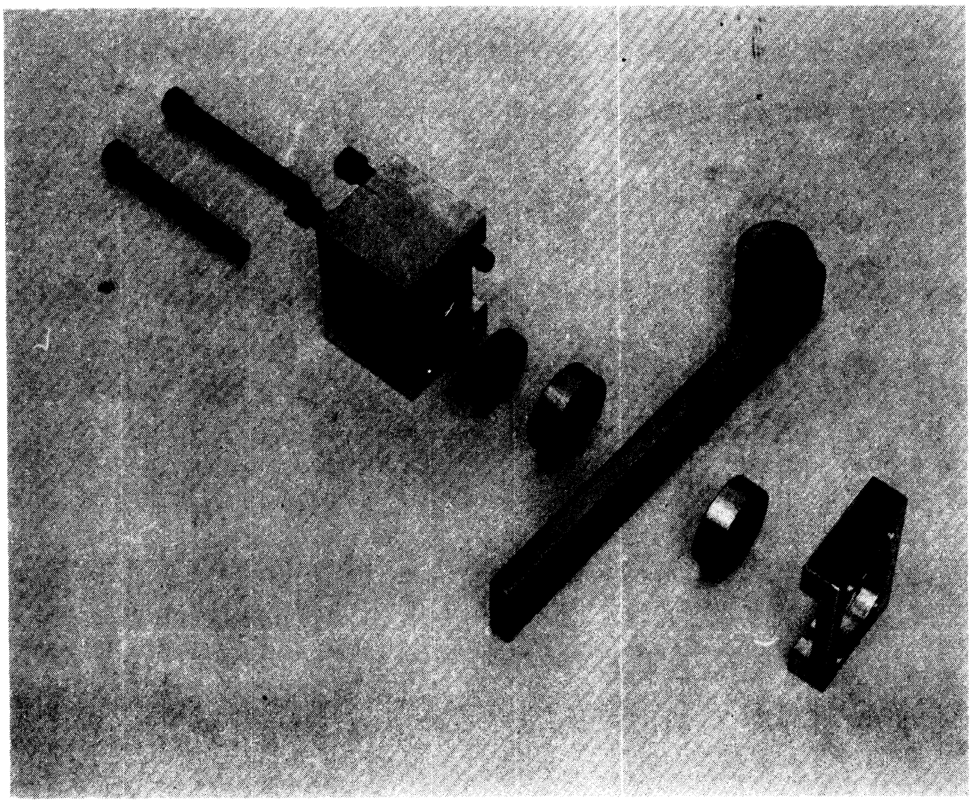
Repeat the above procedure for the second sliding platform subassembly.



Using 1 shoulder bolt [HITS-002-30] and 2 brass spacers [HITS-003], attach the friction bar [HITS-142] to the friction bar pivot [HITS-141].

Attach the friction bar pivot to the back of the sliding platform using 5 screws [HITS-002-6].

Repeat the above procedure for the second friction bar and hinge.



The friction block assembly [HITS-143] consists of several elements which are shown above. These are (from lower right to upper left corners):

* a lower housing which mounts directly against the thorax lower plate and houses the lower shoe;

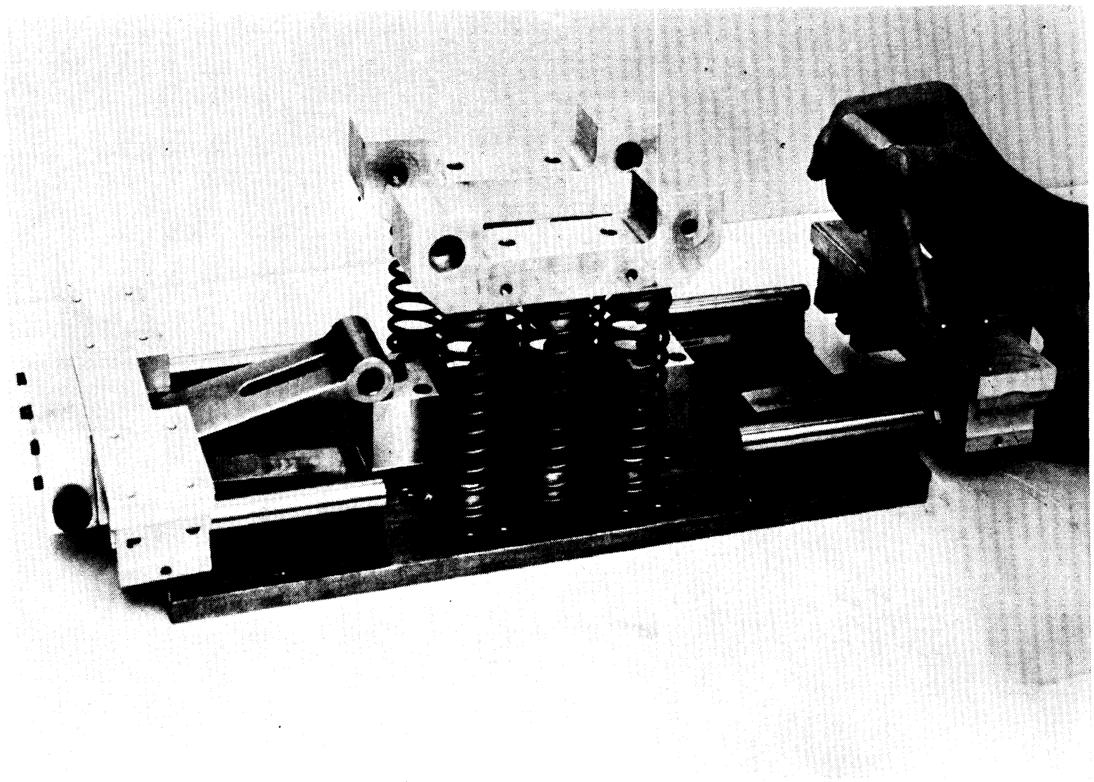
* a lower brass friction shoe [HITS-144],

* the friction bar itself [HITS-142] which should by now be attached to the sliding platform assembly,

* an upper brass friction shoe [HITS-144],

* a thick steel disk to distribute screw load,

* an upper housing for the top shoe and pressure disk.



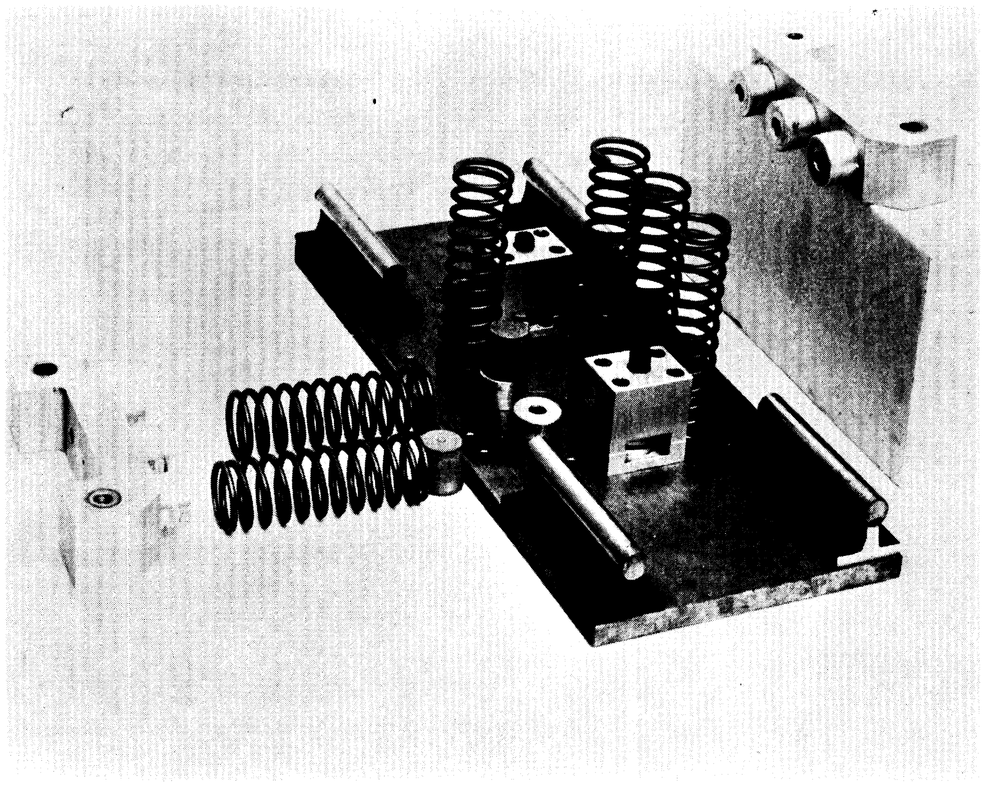
Do not install springs and cradles (shown here) at this time.

Place 1 lower housing and 1 brass shoe over the thorax plate at the appropriate location. Hold this housing with a couple of temporary pins or small screws.

Insert the platform assembly into the two guide rods as shown. Note in the above picture the correct placement of the cutout in the platform.

Slide platform until the friction bar passes over the lower brass shoe. Replace the temporary pins by the upper brass shoe, steel disk and upper housing. Secure the whole assembly with 4 long screws [HITS-002-5]. Lock the sliding motion with the set screw [HITS-002-40].

Repeat this procedure for the other sliding platform and friction block.

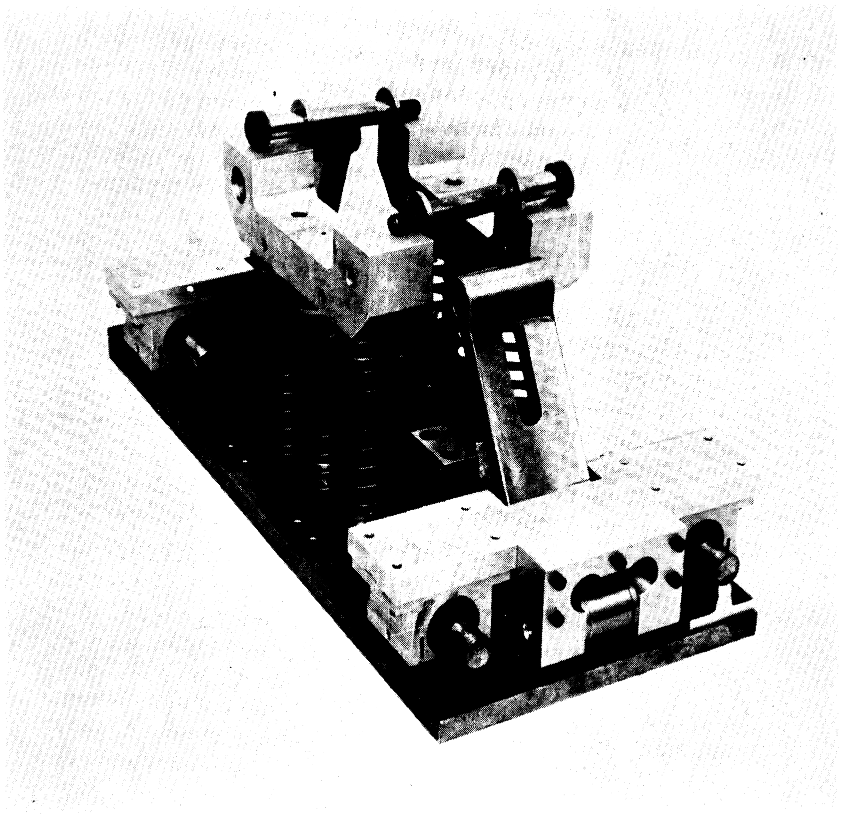


The sliding platform and friction block should now be installed, even though not shown in this picture.

Attach 3 spring inserts [HITS-131] in one neck base cradle [HITS-112], and the remaining 3 inserts in the second cradle. Note the two tapped holes in side of one of the cradles.

Place 1 snubber [HITS-132] on each of the 6 spring inserts (already attached to the thorax lower plate. Secure with double-sided tape or rubber cement. Slip the 6 large compression springs over the 6 snubber and inserts until they sit on the plate.

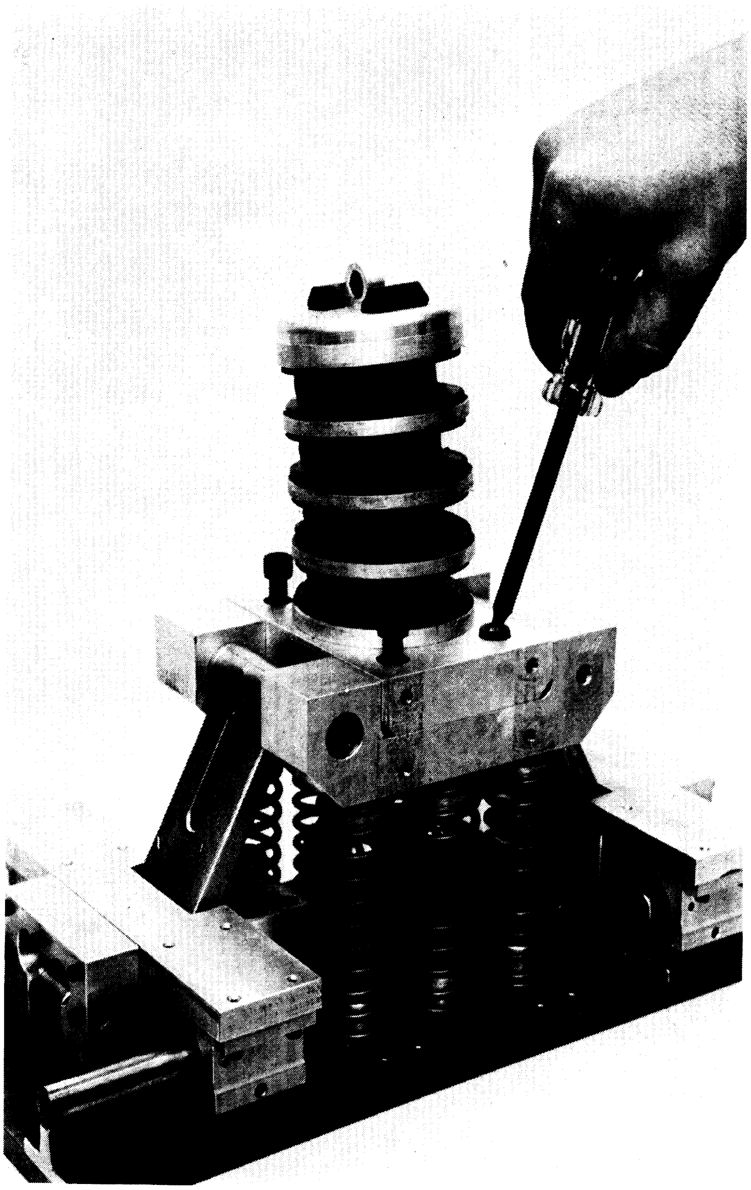
Note the 2 pairs of clearance holes on one side of the plate, and slip the cradle with 2 tapped holes over the row of springs near these 4 holes, with the 2 tapped holes facing the outside. Slip the second cradle over the other row of springs.



Unlock the set screw of the friction block and slide platform until bushing of pivoting arm is lined up with the cradle holes.

Using 1 shoulder screw [HITS-002-32] and 2 brass spacers [HITS-003] attach loosely the pivoting arm to one side of the pair of cradles.

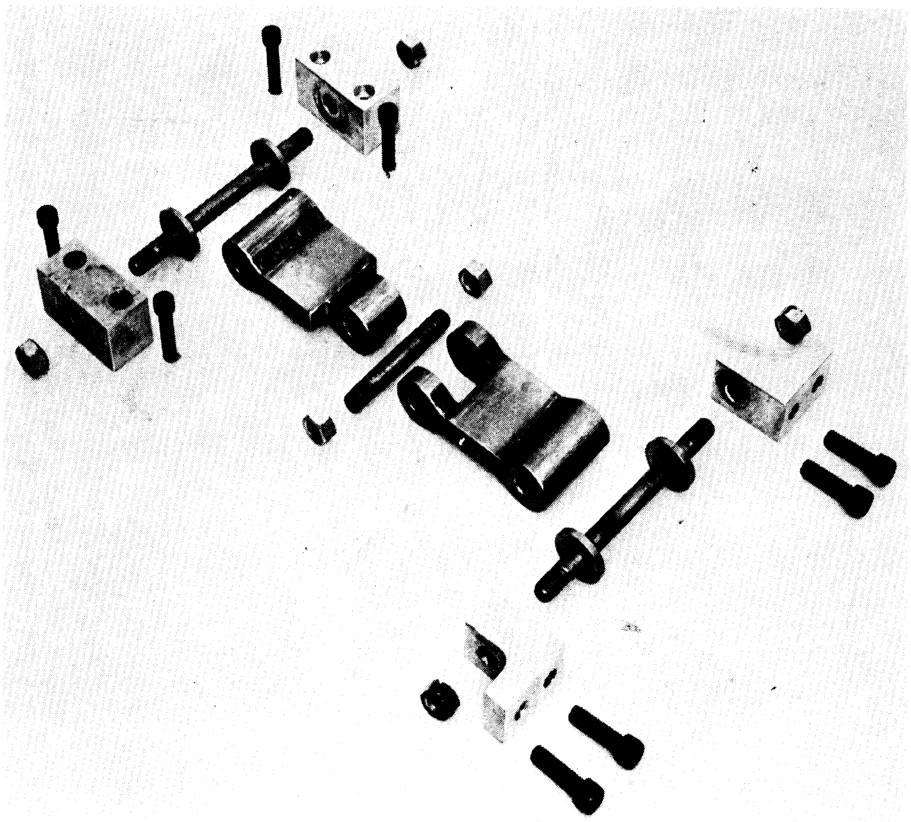
Repeat the above procedure for the other side of the cradle-pair and pivoting arm.



Using 4 screws [HITS-002-4], attach the neck sub-assembly (described in step 7) to the pair of cradles as shown.

Note the correct placement of the 4 tapped holes on the combined cradle/base face and the two pairs of holes on the lower plate.

Tighten the 4 screws simultaneously with the two shoulder bolts in the cradle.

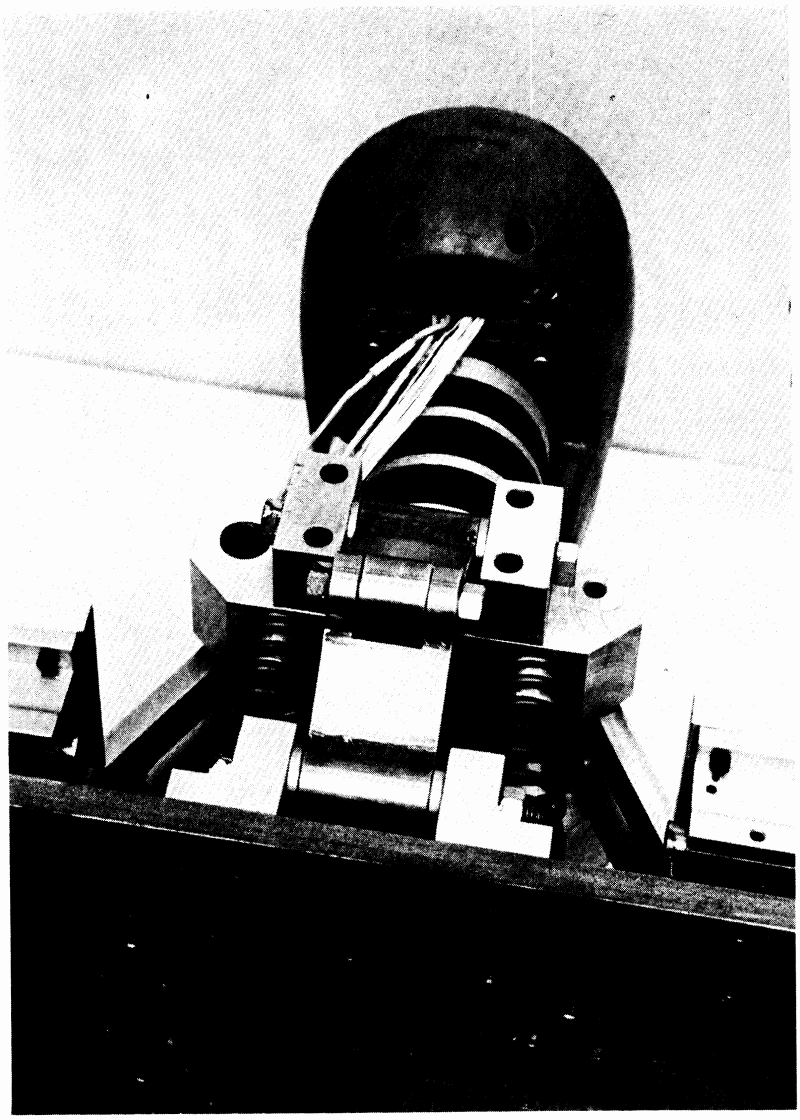


The next sub-assembly is used for control of sway of the device during its axial plunging.

Assemble the upper and lower sway control links [HITS-122] and [HITS-124] using a short stud [HITS-002-51] and two nuts.

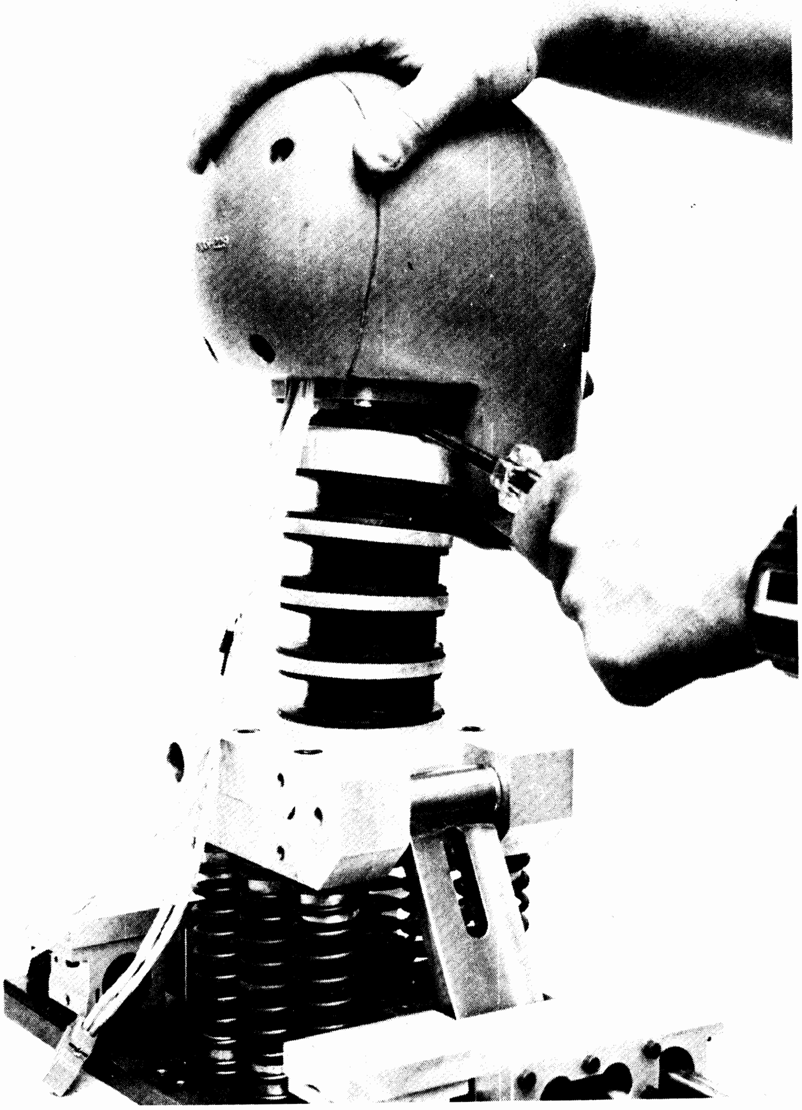
Attach 2 upper sway control pivots [HITS-123] to the upper link using 1 long stud [HITS-002-50] and 2 brass spacers with 3/8-inch holes, and two nuts.

Attach 2 lower pivots [HITS-125] using the remaining stud, spacers and nuts.



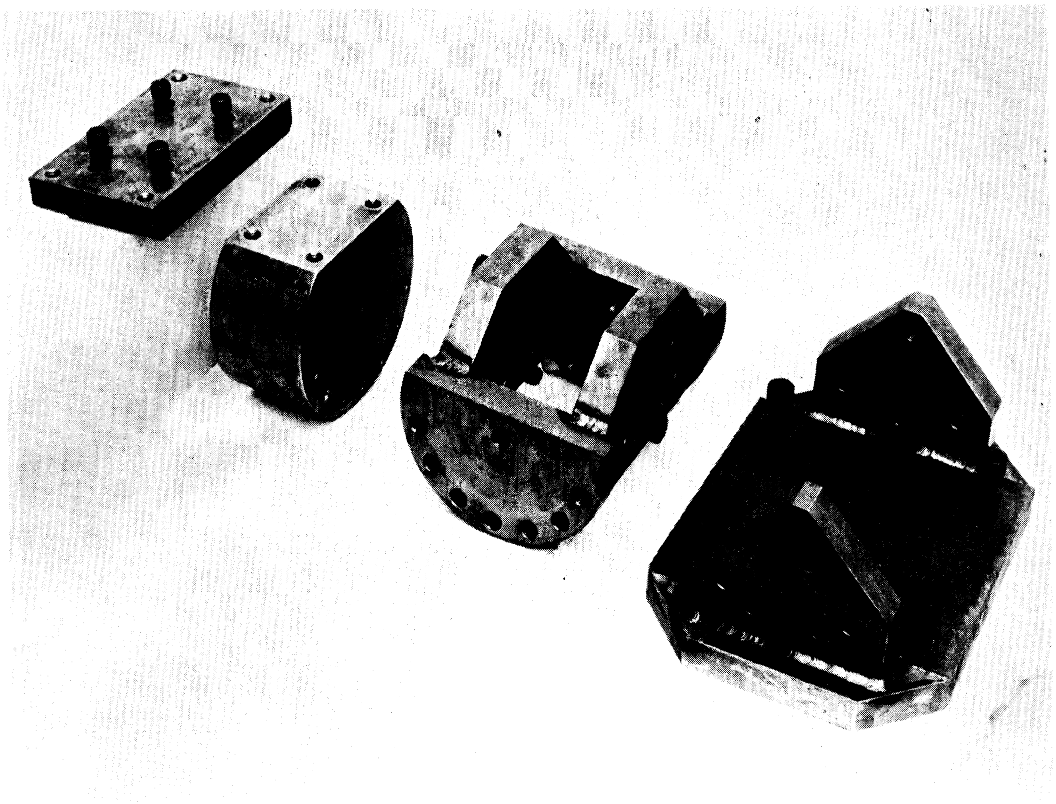
Attach the two upper pivots of the sway control assembly to the cradle face using 4 screws [HITS-002-3].

Attach the two lower pivots to the thorax plate, using 4 screws [HITS-002-2], as shown in the above photo.



Finally, place the head assembly on the neck assembly by slipping the yoke of the neck load cell over the bushing of the neck adaptor plate.

Push the head down against the two rubber elements of the neck adaptor until the 3 holes of the yoke and bushing are aligned, then insert the shear pin to complete the assembly of the device. Use a screwdriver or a rod to push the shear pin in place.

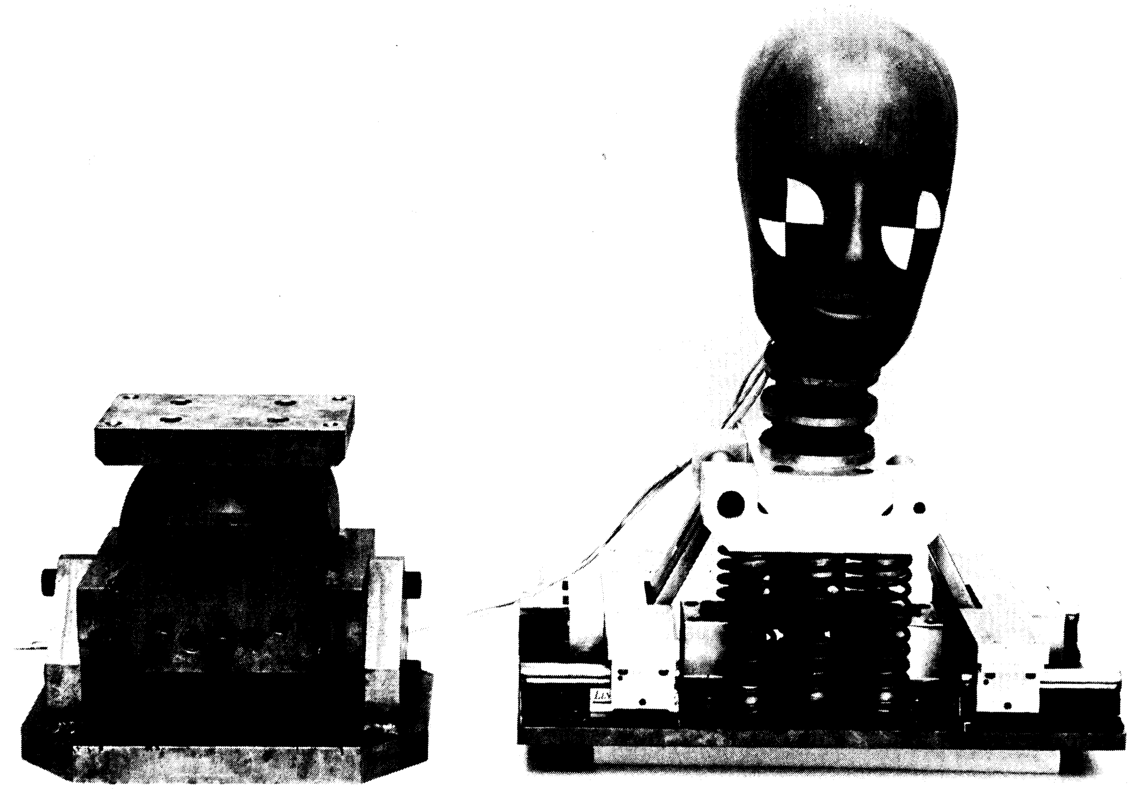


The massive mounting base consists of a welded base assembly (HITS-220] with two uprights, a welded cradle assembly [HITS-210] with two semi-circular sides, a rotating cylinder [HITS-202] with a flattened top, and an upper platform [HITS-201].

To assembly, first place welded cradle between the two uprights of the base and secure with 4 screws [HITS-002-12].

Next insert rotating cylinder into cradle then secure with 4 screws [HITS-002-11].

Attach upper platform to flat top of rotating cylinder, and secure with 4 screws [HITS-002-10].



When the mounting base is properly bolted to the laboratory test fixture using 4 bolts [HITS-002-1] and the drop tower (or similar device) is aligned with the device, the head/neck/thorax assembly (shown on the right) may be attached to the fixed mounting base using 4 screws (HITS-002-9].

The mounting base weigh's approximately 70 lbs, and the HITS another 30 lbs for a total of about 100 lbs. It is recommended that the two sub-assemblies be moved separately, when necessary.