DRL NUMBER T-774
LINE ITEM 8

Final Report

JANUARY 1974

SHUTTLE PASSENGER COUCH

CR-134200

Approved by NASA

PREPARED FOR
NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION
JOHNSON SPACE CENTER
HOUSTON, TEXAS

MARTIN MARIETTA

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LINE ITEM 8

PRELIMINARY NASA APPROVAL PENDING

FINAL REPORT
FOR
SHUTTLE PASSENGER COUCH

January 1974

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FOREWORD

This report was prepared by the Martin Marietta Corporation under Contract NAS9-13010, DRL T-774, Line Item 8, "Shuttle Passenger Couch" for the Johnson Space Center of the National Aeronautics and Space Administration. The effort was administered under the technical direction of the Spacecraft Design Office with Mr. Gordon Rysavy acting as the technical manager. This report documents and summarizes the results of the entire contract work, including recommendations and conclusions based on the experience and results obtained.

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I. INTRODUCTION

This contract was initiated to design, fabricate, and test a Shuttle Passenger Couch, couch-vehicle mounting hardware, couch mounting stand, and the documentation to document each phase of the contract. The documentation also included the rationale for the selection of the couch concept, test plan and results, and drawings and specifications for the deliverable hardware. The couch was designed to provide the occupant a safe support during launch and entry modes and yet provide a comfortable personal area designed for relaxation, sleeping, eating and clerical work in zero-gravity.

The objectives of the contract were accomplished in five major tasks which included (1) Concepts and Materials, (2) Design, (3) Fabrication, (4) Test, and (5) Documentation. These tasks were somewhat inner related in that an Engineering Model was fabricated and tested early in the program to provide the required anthropometric and access dimensions in the design of the Verification Model. Also, the documentation task was performed as the phases were completed in accordance with the Program Plan, MCR72-191.

This final report describes the work performed in each major task, together with all findings, data, and conclusions.

II. SUMMARY AND RECOMMENDATIONS

A. SUMMARY

The initial step in defining the passenger couch system was to perform a complete functional analysis. This analysis established the system requirements and the hardware required to accomplish the functions that the couch must support. In addition, the functional analysis served as the basis for the performance test plan. The functional requirements that the couch was designed to satisfy were: (1) support and restraint for the passenger in the various modes of operation; (2) a personal habitat for the passenger/crewman for relaxation, sleeping, eating, and clerical work; (3) storage space for personal items and garments; (4) individual task lighting, communications; (5) entertainment provisions; (6) accommodation for different size personnel; and (7) modular installation and servicing. Concurrent with the functional analysis, an industry survey was made to take advantage of available ideas, mechanism systems, and latest material developments. The industries contacted were airlines, aircraft seat manufacturers, and manufacturing companies for hospital beds, dentist chairs, and lounge chairs. From the analyses and knowledge gained from the industry survey, conceptual designs were developed to best support the functions the couch must satisfy. These concepts were evaluated and one concept was selected with the concurrence of NASA-JSC. This concept served as the basis in the design of a full-scale passenger couch engineering model. The engineering model was fabricated and utilized to verify anthropometric dimensions, reach dimensions, ingress/egress, couch operation, storage space, restraint locations, and crew acceptability. This data was then incorporated in the design of the passenger couch verification model andincluded in the Performance Test Report, MCR 73-303.

Upon approval of the couch design by the NASA-JSC the couch verifi-

cation model was fabricated from final design drawings and tested per the Performance Test Plan, MCR73-3. The data obtained from the test helped generate the Couch Design Requirements Document, MCR73-285 and was included in the Performance Test Report, MCR73-303.

The deliverable hardware, which consisted of the passenger couch, mounting hardware, and mounting stand, was shipped to the NASA-JSC for acceptance and KC-135 test after completion of the one gravity tests.

B. RECOMMENDATIONS

As a result of the test program, several areas of the couch were found that could be improved upon and the deletion of some of the requirements. These changes, as identified in the following paragraphs, provide operational advantages and reduce costs and weight.

1.0 Articulation Control

To eliminate the large amount of free-play in the inner frame articulation, it is recommended that the actuating mechanism be attached to the sliding points on the back section and the main frame as illustrated in Figure II-1. The inherent free-play of the P. L. Porter mechanical lock is approximately 0.030 of an inch which is magnified 10 to 12 times in the present system. This is due to the geometry of the mechanical lock controlling the movement of a bell crank, with a 1.25 inch radius attached to the seat section rotation point, through a 60 degree arc. This motion allows a linear movement of 1.25 inches of the mechanical lock while moving the back section sliding point 5 inches and the leg section sliding point 8.5 inches.

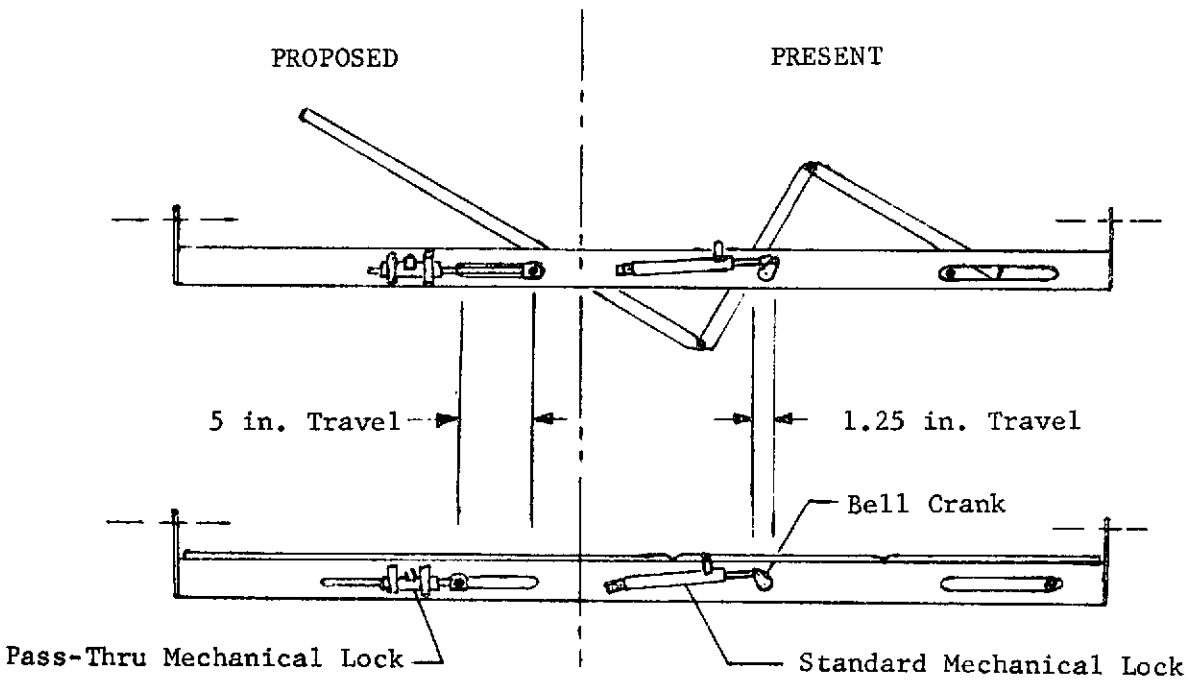

Figure II-1 Inner Frame Articulation Control

2.0 Seat Adjustment

It is recommended that the requirement for an adjustable seat depth be eliminated and only the 5th percentile male dimension of 17.5 inches be used. This would be a savings of cost and weight and is usable for the entire male percentile range.

3.0 Vent and Light Housing

Redesign of the vent and light housing lids to be identical, be held open by springs and easier closing is recommended to facilitate manufacture of the parts, provide interchangeability, and ease of operation.

4.0 Restraint Stowage

A recess in the inside of the shell for stowage of the restraint buckel would eliminate a possible annoyance item.

5.0 Couch Position Indicator

It is recommended that marks be placed on the inside of the shell to be used by the couch occupant as indicators of the couch position for critical positions such as the launch configuration.

6.0 Clerical Tray

It is recommended that the clerical tray positioning mechanism be redesigned to reduce weight but retaining the basic design.

7.0 Cushions

Since the cushions only contribute to the overall aesthetics of the couch and minimal additional comfort in one-gravity operations, they could be eliminated with a savings in cost and weight.

8.0 Sleep Restraint

As a result of the sleep test, it is recommended that the sleep restraint be larger through the shoulder area to accommodate the 95th percentile male more comfortably.

9.0 Material Change

It is recommended that the aluminum housing and control handle material be changed to stainless steel for the couch rotational control.

III. CONCEPTS AND MATERIALS

A. COUCH CONCEPTS AND SELECTION

During this phase of the program various design concepts were investigated to satisfy the passenger couch functional requirements. The evaluation of the various subsystem concepts worked down to where two basic couch design concepts looked to be feasible and required further investigation for final selection. These two couch system concepts were desinated as Fixed Hinge Couch System and Sliding Hinge Couch System. A descritpion of these concepts and the rationale for selecting the sliding hinge concept as the better system in satisfying the couch requirements is provided in the following paragraphs. Some of the more critical requirements were: capability of staying within the dimensional envelope, maintaining the couch center of gravity below the couch longitudinal axis of rotation, provide a wide body support section, compact static volume, light weight, and the lease physiological stress during launch, re-entry, and landing modes of operation.

1.0 Preliminary Design Concept

Initial design concepts were sketched to convey the ideas presented during brainstorming sessions. The sketches helped to present the ideas by pictorial means thus reducing many communication problems. To further organize the initial preliminary design concepts, a bookkeeping scheme was required that would both document couch data in a quick reference form and also indicate a relative merit of one concept over another when compared against the basic couch requirements. A concept comparison matrix chart was decided on. The concept sketches were placed on the top of the chart and applicable criteria listed at the left-hand side of the chart. The appropriate blocks

were filled in based on the apparent compatibility comparison between each design concept and selected design criteria. Results from this work effort appear in Tables III-1 thru III-11.

2.0 Basic System Concept

A basic couch system concept was derived following the evaluation and priority listing of design concepts. In reviewing the evaluation comments generated during the rating session, it was apparent that most subsystems could be separated into three major categories. These categories were likened to building blocks in reference that the primary subsystems concepts must be selected prior to adapting the secondary subsystem concepts into the overall system. The last category was peripheral subsystem concepts that could be considered as system add-ons. The subsystems were separated into categories as follows:

a. Primary Subsystem Concepts
   1) Main frame structure
   2) Couch linkage
   3) Seat adjustment capabilities
   4) Mounting fixture

b. Secondary Subsystem Concepts
   1) Body support section
   2) Arm rests
   3) Locking mechanism for selected couch positions
   4) Seat occupant restraints

c. Peripheral Subsystem Concepts
   1) Privacy curtain
   2) Ventilation
   3) Tray Provisions
   4) Lighting
   5) Communication
   6) Stowage
   7) Structure support for all items that require mounting

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TABLE III- 5

ARM RESTS AND INTERFACING LINKAGES

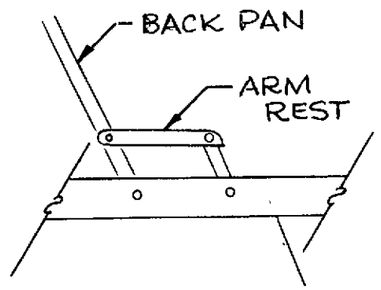
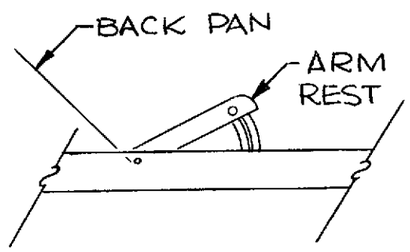
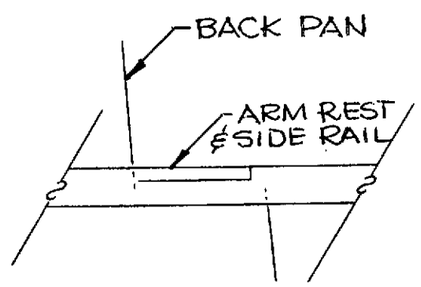
CRITERIA \ CONCEPTS	 I	 II	 III	
	Movement of Armrests in Phase with Couch Movement	Individual Manually Operated Armrests	Couch Frame Rail Used as Armrests (Non-Moveable)	
1. Adj. to comfortably accommodate a 5 to 95% man.	Limited only by nom. dim. for elbow to shoulder height (14.2").	Very comfortable, limited only by nom. dim. for elbow to shoulder height (14.2") in full deployed position.	Not a comfortable armrest, would be wide and low.	
2. Arm rest locking capacity.	Couch locking mechanism will effectively lock armrests & provide solid units.	Armrests require separate locking devices, design would be more difficult & adds two locking devices.	No locking required.	
3. Design Load Considerations: Launch/Entry - 3Gs for 30 min. System Fittings - 12Gs Crash Load - 9Gs	Will take loads easily thru linkage to couch unit.	Will require more designing to meet G loads.	Will meet all loads.	
4. Armrests capability to provide mounting bracket for clerical tray & interface for food tray.	Can meet interfacing requirement, but when tray deployed, not as adjustable as Concept II.	Very adj. when tray deployed, interfacing & mounting brackets less difficult to design.	Difficult to design for brackets or interfacing for food tray.	
Remarks:				

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TABLE III-7 PRIVACY CURTAIN DESIGN CONCEPTS

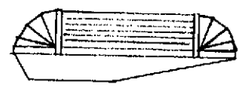
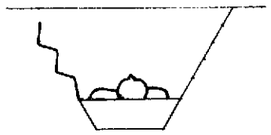
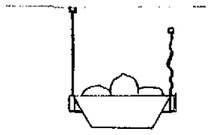
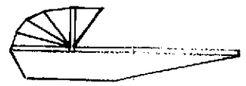
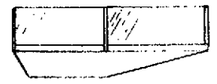
CRITERIA \ CONCEPTS	I	II	III	IV	V
					
	End Flips Up with Split Center Shade Type	Folding Sht. Metal Type on Upper Half to Wall from Couch	Side Curtains to Wall	Large Flip Up from Head End	One-Way Viewing Material
1. Couch Dimensions Width - 18" max from axis of rot. Length - 77.5" max in any direction.	Will meet dimension requirements in both width and length.	When deployed the panels extend beyond 18" width from axis of rotation dimension.	If deployed as shown in sketch it will meet dimension requirement. Side curtains can be deployed from wall to couch or visa-versa.	Will meet dimension requirements.	Will meet dimension requirements.
2. Operational in both the sitting and flat bed configuration.	Will function in either position but not with desk deployed (close distance when in sitting position).	Operational in both configurations.	Operation in both configurations.	Close head distance when in sitting position.	Will operate in both configurations with close distance in sitting position.
3. Light Shielding Capability	Very good shielding capability.	Some light can diffuse up from feet and down from open head area.	Same as concept II.	Light will filter in from feet end of couch.	See-thru panels will shield light according to amount of tint used.
4. Noise Attenuation, Potential	Provides good sound barrier.	Does not provide much of a sound barrier.	Same as concept II.	Same as concept II.	Provides a good sound barrier.
5. Capability to Withstand Design Loads in the Retracted or Stowage Position: Launch/Entry-3Gs-30 min. System Fittings-12Gs Design Load When Extended-	Units fold like auto top and latch securely in place. Will meet load requirement.	Folds up inside of couch and is securely stored and will meet load requirement.	Will meet required loads.	Will meet required loads.	Will meet required loads.
6. Located Within Easy Access of Couch Occupant	Center shade very accessible, foot cover req. deployment while out of couch.	Very accessible.	Same as concept II.	Accessible while in flat position but not in sitting position.	Leg portion accessability poor, top portion folded from wall easily.
7. Requires Inflight Maintenance	Req. several linkages and locks, could req. maintenance if bumped & bent.	Fairly sturdy but has several hinges & latches. Small maintenance required.	Reel of shade could malfunction & req. tools for maintenance.	Same as concept I.	Fairly simple should require little maintenance.
8. Provides Privacy with Device Deployed	Good privacy, but closed in feeling high because of small width dimension.	Not total privacy, only restricts field of view of occupant.	Same as Concept II.	Same as concept II.	Affords complete privacy, one-way viewing may solve closed-in feeling.
Remarks:					

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TABLE III-8 CLERICAL TRAY STOWAGE AND MOUNTING

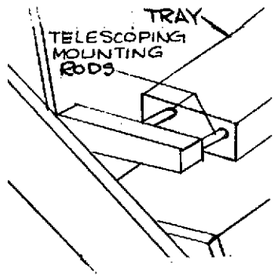
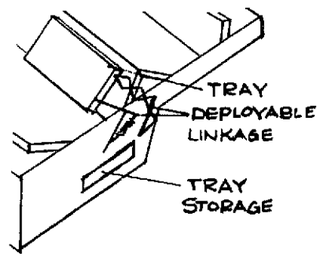
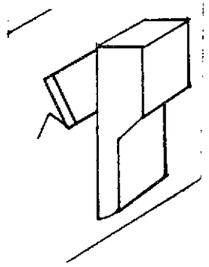
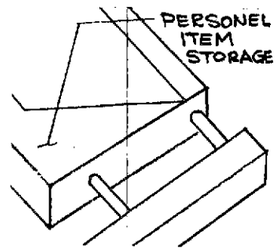
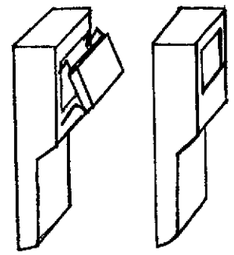
CRITERIA \ CONCEPT	I 	II 	III 	IV 	V 
	Tray not on Linkage, Mounts to Arm Rests or Frame	Tray Deployed by Linkage from Side of Couch	Tray Attached to Wall on Linkage	Tray as Personal Item Storage, Mounts to Arm Rests	Tray on Back of Adjacent Couch, on Linkage
1. Desk easily deployed from within couch.	If stowed on side of couch, OK. If stowed on back of couch, would require egress of couch.	Easily deployed.	Easily deployed - but requires that couch face the wall.	If stowed on side of couch, OK. If stowed on back of couch, would require egress of couch.	Only if back of other couch is facing the subject couch.
2. Desk provides handy surface for writing, reading and management of personal articles.	Would have to be located at proper place and angle. Should provide restraints for items on desk. Could be used with couch in any position.	Per design.	Per design.	Desk top hinges to expose compartmented storage area, or sections of top hinge open. Drawer pulls out of edge of desk, or drawers hinge or pull out of each side of edge.	Per design.
3. Able to ingress and egress couch with tray deployed.	Only if one end of tray could be detached and tray pivoted about other side.	Could be designed to permit ingress and egress.	Should be easily arranged, may require rotating couch 45 or 90 degrees for egress/ingress.	If one end of tray can be detached, and tray pivoted about other side.	Should be easily arranged, may require rotating couch 45 or 90 degrees for ingress/egress.
4. Able to be deployed with or without privacy curtain deployed.	Could be designed such.	Would be difficult to design, unless privacy curtain is attached below desk linkage attachment.	Only if privacy curtains are from the couch to the wall type.	Privacy curtain could restrict opening of drawers.	Would not be able to deploy desk with privacy curtain deployed.
5. Interface with food tray (food tray - 16 x 13 x 4.5 inches).	Tray would have to be sized, and have to provide hold downs for food tray.	Tray would have to be sized and have to provide hold downs for food tray.	Tray would have to be sized and have to provide hold downs for food tray.	Tray would have to be sized and have to provide hold downs for food tray.	Tray would have to be sized and have to provide hold downs for food tray.
6. Stay within couch dimensions, width - 18 inches max from axis, length - 77.5 inches max.	Could be designed such. May be a problem if requirement includes with tray deployed.	Could be designed such. May be a problem if requirement includes with tray deployed.	This requirement not applicable to this design.	Might be difficult with top or drawers opened.	Not applicable.
7. Design loads: Launch/Entry - 3Gs Crash Loads - 9Gs System Fittings - 12Gs					
Remarks:	This concept considers the clerical tray to have no provision for storage of personal items. Mounting to the frame requires possibly an angle adjustment on the tray mounting, and a bulkier more complex mount than if on arm rests.			Possibly have top surface transparent to display stored items. Requires bulkier (thicker) top design.	This design restricts the position of one couch, due to another passenger's desire to use his tray. The two adjacent passengers could not both use their trays simultaneously, therefore, could not eat simultaneously.

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TABLE III-9 LIGHTING SYSTEM

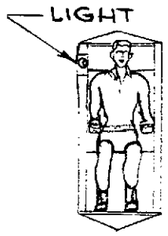
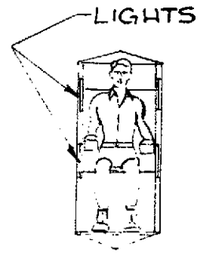
CONCEPTS / CRITERIA	I 	II 	III 	
	By Shoulders on Couch Frame	On Goose Neck By Head	Diffused Lighting Various Mtng Positions	
1. Light will be capable of being directed in both directions.	Light direction limited expecially if back pan is rotated up as in sitting position.	Capable of any direction lighting.	No direct lighting, but can be designed to provide sufficient light anywhere.	
2. The light will have controlled variable intensities.	Will meet this requirement.	Will meet this requirement.	Will meet this requirement but if fluorescent is used elec. are more complex.	
3. Power Requirement	TBD	TBD	TBD	
4. Requires inflight maintenance.	Should require little inflight maintenance.	More susceptable to damage due to more linkage & accessibility.	Shouldn't require much inflight maintenance.	
Remarks:				

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TABLE III-10 STEREO SYSTEM LOCATION

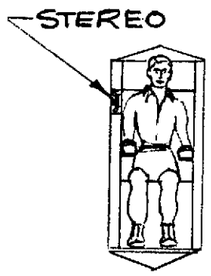
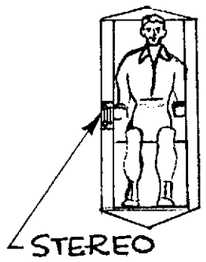
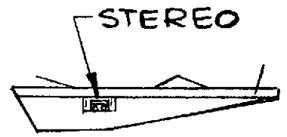
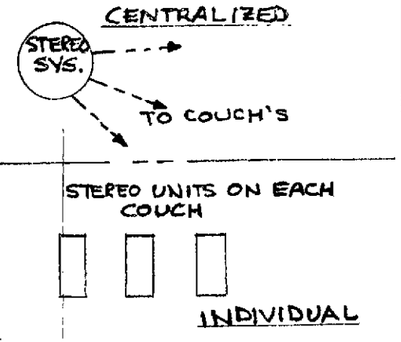
CONCEPTS / CRITERIA	I	II	III	IV
				
	Stereo Unit by Shoulders	Stereo by Couch Controls by Armrests	Stereo Unit on Side of Couch	Centralized System versus Individual Units
1. Communication Sys. shall consist of a stereo headset and controls including a four-channel selection.	Sufficient volume available.	Same as concept I.	Same as concept I.	Both systems can provide such equipment.
2. Headset will be stowed within the couch and will require a volume of approximately 8x5x4".	Sufficient volume available.	Same as concept I.	Same as concept I.	Same as concept I.
3. Design load consideration: Launch/Entry Load - 3Gs, 30 min. System Fittings - 12Gs Crash Load - 9Gs	No impact.	No impact.	No impact.	Central system will have greater interface problems & may constrain mating hardware.
4. Stowage Location for Easy Access	Hard to reach if restraints or if in sitting position.	Easy access in all modes.	Easy access but out of visible range of occupant.	Central system would be more compact, controls placed for easy access.
Remarks:				

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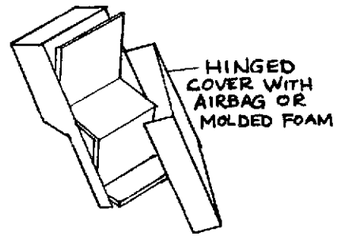
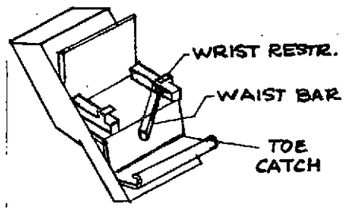
TABLE III-11 PERSONNEL RESTRAINT SYSTEMS

CRITERIA \ CONCEPT	I 	II 	III 	IV 
	Vest Restraint	Belt Restraints	Air Bag, or Molded Foam Restraint	Fixed Restraints
1. Adjustable to Comfortably Accommodate a 5 to 95 percentile man.	Could be designed so that one vest adjusts to cover the range.	Could be designed to cover the range.	By regulating pressure rather than air volume, would fit all. Molded foam, would require different pieces in order to cover 5 to 95 percentile man.	Could be designed with sufficient adjustment to cover the range.
2. Restraints shall be retractable when not in use.	Could be designed retractable.	Could be designed retractable.	Would be bulky to retract.	Could be designed retractable or not retracted.
3. Restraints shall be unobtrusive.	Could be designed to be unobtrusive.	Could be designed to be unobtrusive.	Would be obtrusive.	Could be designed to be unobtrusive.
4. Design loads considerations: Launch/Entry - 3Gs, 30 min. Sleeping - 0G Crash Load - 9Gs System Fittings - 12Gs	Per design.	Per design.	Per design.	Per design.
5. Capable of use with the seat in flat bed, normal sitting, and launch positions.	Could be used with seat in any position.	Could be designed for use with the seat in any position.	Would be difficult to design for more than one seating position.	Could be easily designed to adjust for various seating positions.
6. Complexity of Operation.	Could be designed to be simple in operation.	Could be designed to be simple in operation.	Would be complex.	Probably extremely simple operation.
7. Emergency egress capability.	Could be designed for quick egress.	Could be designed for quick egress.	Would probably be difficult to egress quickly.	Could be designed for quick egress.
8. Restrain unconscious passenger.	Would restrain unconscious passenger.	Would restrain unconscious passenger.	Would restrain unconscious passenger.	Would not restrain unconscious passenger.
Remarks:	Provides wide surface area - no high pressure points. Could be used as a sleep restraint.	Would adapt to using a set of belts for launch/reentry, and a single lap belt for zero-g use.	Reliability problems would be extremely cumbersome and complex. Would be suitable only for launch/reentry, not for zero-g.	Suitable only when the crewman is conscious, not when unconscious or sleeping. Probably not good for launch/reentry. Would be good for zero-g.

An effort was made to combine the primary subsystem concepts into one or more basic system concepts. An evaluation of the four identified primary subsystems and each concept priority rating was conducted. The only concept considered feasible for the main frame structure was one using a box-type construction with side rails and end plates. In looking at the couch linkage concepts, two were considered adequate for further study: the manual operation with fixed hinge at the hip and knee joint and the three-point hinge, one fixed a two sliding.

Combining these four primary subsystem concepts resulted in two separate basic system concepts. The nomenclature assigned to these two concepts was: Fixed Hinge Couch and Sliding Hinge Couch.

The secondary subsystem concepts were investigated to determine design impact, if any, on both the fixed hinge and sliding hinge system concepts.

The body support section of the couch could use either the frame with webbing concept or frame with a thin aluminum sheet concept. The honeycomb structure could be used if cushioning material were used on top.

The body anthropometry differences implied that only the top rated arm rest concept "individual manually adjustable" be considered in the couch system design. This arm concept has adjustment in the vertical direction and folds up in the flatbed configuration.

Evaluation of the couch occupant restraint was complex because of the various modes of operation. The restraint requirements have been separated into three mission modes: 1) launch, re-entry and landing, 2) zero-gravity sitting operation, and 3) zero-gravity sleeping.

The launch/re-entry mode requires a high stress full body restraint. The zero-gravity mission mode with low stress requires only a lap belt for the sitting configuration and a sleeping restraint for the flatbed configuration.

The double parallel shoulder harness selected for the launch/re-entry modes provides advantages of distributing the loads to two belts and prevents body torquing when side forces are applied. The lap belt portion of this concept contains the single attachment buckle. Due to the automatic gravity seeking force vector concept of the couch, the seat occupant is subjected to backward (eyeballs-in) accelerations. This results in a minimum stress on the belts.

3.0 Description of Single Fixed Hinge Couch Concept

Various flight modes require the couch contour to be re-positioned to maximize comfort and support to the crewman. The following description is of a single fixed hinge concept designed to accomplish this task. Figure III-1 is used in the clarification of the following discussion.

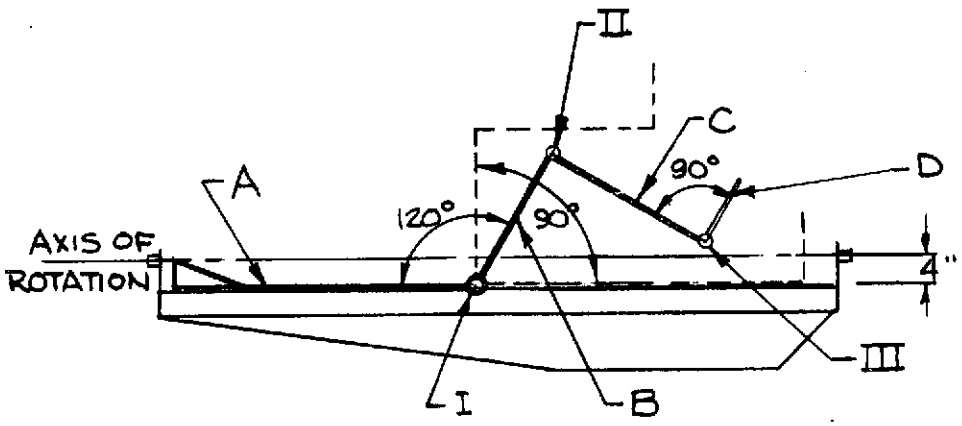


Figure III-1 Fixed Hinge Concept

The design is comprised of four sections. These are section A (the back and head pan), section B (the seat pan), section C (the leg pan), and section D (the foot pan). Section A lies parallel to and four inches below the couch longitudinal axis of rotation. Section B rotates about pivot point I and can be locked in pre-selected positions. Sections B and C are connected at hinge point II, which has a locking device at this point. Pivot point III serves as the hinge for section D (the foot pan) and contains its own locking device.

Section A remains flat at all times and contains a fixed angle headrest to accommodate a 5 to 95 percentile man. When the angle between sections A and B is 120 degrees, the couch is in the launch position.

4.0 Description of Sliding Hinge Concept

The other feasible couch concept and the one selected to develop was the sliding hinge concept. This concept as illustrated in Figure III-2 satisfies the required functions in a minimal volume. The couch as shown in Figure III-2 is in the sitting position which is used for re-entry and atmospheric flight. The seat section rotates about pivot point B as the back and leg sections rotate and slide at points A and C. Each of these points on the inner body support interfaces with the main frame through bearings to allow the required motion to change the body support to the various configurations. This particular linkage concept has several advantages: (1) the couch can be adjusted from a fully flat position to a full sitting position using a minimum envelope volume; (2) the concept holds the center of mass in nearly the same location for various couch configurations; (3) allows a volume beneath the seat and leg for storage which is uninterrupted by linkage movement.

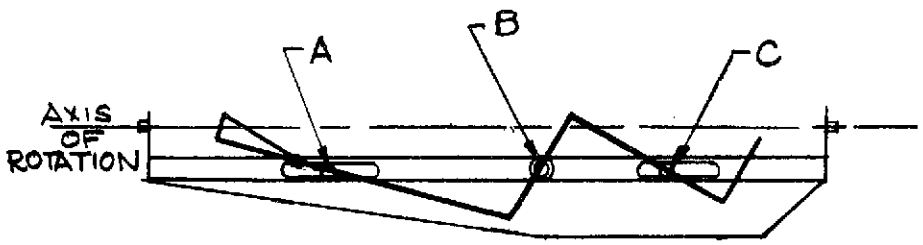


Figure III-2 Sliding Hinge Concept

The three main couch configurations are the flat bed, launch/entry and normal sitting. The flat bed configuration places the body support sections on a parallel plane four inches below the couch longitudinal axis of rotation. The launch/entry configuration positions the back section at a 20° angle from the couch longitudinal axis, the seat section at a 120° angle to the back section, and the leg section at a 120° angle to the seat section. The normal sitting configuration positions the seat occupant so that the back to seat and seat to lower leg sections are both at right angles with the back section at a 30° angle to the couch longitudinal axis of rotation.

The couch is adjustable for crew members in the 5 to 95 percentile range. Independent seat and leg sections adjustments are available because a crew member of a certain percentile height may have limb lengths of a different percentile than his height.

The back section has a fixed length of 38.8 inches, the seat section has an adjustable length of 17.5 inches to 20.5 inches, and the leg section has an adjustment length of 15.8 inches to 18.8 inches. The footrest which is part of the leg section can be rotated from a flat position to 90 degrees with respect to the leg link. A mechanical locking device is incorporated at pivot point B that provides a positive manual locking for the inner body support.

5.0 System Selection

The Sliding Hinge Couch Concept was selected for the Couch Verification Model design. This was done on the basis of the system tradeoff study. The results of the tradeoff were that the sliding hinge couch met all the design criteria. The most critical criteria affecting the rating differences were in the areas of volume and keeping the center-of-gravity below the longitudinal axis of rotation. The Fixed Hinge Couch Concept violates the dimensional envelope requirement when positioned into the normal sitting configuration, and is also considered borderline in keeping the center-of-gravity below the couch longitudinal axis of rotation with a preliminary analysis showing a distance of approximately one inch.

The next items considered were the secondary subsystem concepts; mainly the couch position locking mechanisms, body support section design and arm rests design. The couch must have the capability of being locked in various pre-selected positions for launch, atmospheric flight, zero-g flight, re-entry, and crash modes. The locking mechanism must be of a positive mechanical type rather than a friction type. In the sliding hinge concept the best locking point was initially determined to be at the fixed pivot point.

B. MATERIALS, PARTS AND PROCESSES

All materials used for components, parts and processes were investigated for compatibility with performance and environmental criteria. Manufacturing processes and associated materials used on off-the-shelf hardware were also investigated for compatibility. All materials used are identified by drawing or specification sheets as either metallic or non-metallic with material trade name, application on the equipment, part number, vendor, commercial designation, approximate weight and dimension of the material.

1.0 Metals

The principal considerations for metal are their mechanical properties and corrosion resistance properties. In addition, there are some metals and alloys that are unacceptable for usage in space vehicle systems while others are preferred.

1.1 Unacceptable Metals

The following metals and alloys have been termed unacceptable for space vehicle systems.

Beryllium	Unalloyed beryllium shall not be used within the crew compartment. Alloys containing less than 4 percent beryllium are acceptable.
Cadmium	Cadmium plated materials and alloys containing more than 30 percent cadmium are unacceptable.
Brass & Zinc	Zinc plated materials and alloys containing more than 30 percent zinc are unacceptable.
Copper	Copper shall not be used in components in contact with an aqueous media.
Magnesium	Magnesium or any magnesium alloys are unacceptable.
Mercury	Unacceptable.
Steel	Non-corrosion resistant steels (high carbon steels) are unacceptable.

1.2 Preferred Metals

The preferred metals and alloys for usage on the couch structure, parts, components, and assemblies were determined from available tables at the time of design. The preferred aluminum alloys were used for the couch structure and brackets and the preferred corrosion resistant steels for the rotating and locking components.

1.3 Dissimilar Metals

The use of dissimilar metals in contact shall be avoided unless adequately protected aginst galvanic corrosion. Metals that differ in potential by more than 0.25 volts, as determined by MSC Standard No. 63, shall not be used in direct contact when exposed to a common electrolyte such as the atmosphere.

2.0 Non-Metallics

The principal considerations for non-metals are their mechanical properties and their resistance capabilities to flammability and off-gassing. The largest usage of non-metallics in the couch system is the outer shell. The material selected for the outer shell is a fire retardant acrylic-polyvinyl chloride alloy sheet with a trade name of Kydex.

C. PRELIMINARY MASS PROPERTIES STATEMENT

The preliminary mass properties estimate of the sliding-hinge couch was made to provide an initial estimated weight for the couch, and, more primarily, to provide data to assist in making a structural config-

uration decision. Differences occur in the areas of structural members such as side rails, back support, seat support and leg support. Other items such as ventilation, lighting, stereo, and cushions were assumed to be essentially common to any configuration. Practically all structural material, with the exception of some pivot items, were assumed to be 6061 aluminum. The cushions were assumed to be material of five lb/ft^3 density. The vertical center-of-gravity of the sliding-hinge couch with passenger in a launch configuration, was located 4.5 in. below the axis of rotation and the longitudinal center-of-gravity was located 37.2 inches from the forward end plate. The detail weight statement for the sliding-hinge couch is shown below in Table III-12.

Table III-12 Initial Couch Weight Estimate

ITEM	WEIGHT-LB
Primary Couch Structure	
Side Rails	12
Subframe	8
Skin	40
End Plates	15
Arm Rests	6
Head Rest	7
Back Rest	16
Seat Rest	12
Leg Rest	10
Foot Rest	5
Mounting Provisions	14
Stowage Provisions	15
Position Control	10
Restraint System	6
Ventilation	4
Lighting	4
Privacy Curtain	10
Attach, Misc.	10
Weight Empty	204

IV. PRELIMINARY DESIGN, FABRICATION & TEST

A. DESIGN OF ENGINEERING MODEL

The preliminary design effort was directed at providing an engineering model to verify anthropometric dimensions, reach dimensions, ingress/egress, couch operation, storage space, restraint locations, and crew acceptability. The resulting design is illustrated by Figures IV-1 and IV-2 which are the top assembly drawings for the main structure and the inner body support respectively. Not shown by these drawings but included in the detail drawings were the two methods of adjustment for the inner body support. The two methods provided were a worm-and-gear and a cam and pin mechanism.

B. FABRICATION OF ENGINEERING MODEL

The passenger couch engineering model was fabricated from preliminary design drawings using the structural members as determined by the stress analysis performed earlier in the program. Since this piece of hardware was to undergo one gravity neutral buoyancy, and centrifuge testing, the electrical components were not included. Figure IV-3 depicts the Engineering Model in the sitting position with Figure IV-4 illustrating the flatbed, sleeping position. The clerical tray utilized with the Engineering Model is depicted in Figure IV-5.

C. COUCH ENGINEERING MODEL TEST PHASE

Three different types of test were conducted using the couch engineering model to verify and evaluate the various aspects of the couch. Shuttle crew compartment interface tests were conducted to establish the envelope dimensional requirements of the passenger couch. Centrifuge tests (unmanned) were employed to verify that the couch

FOLDOUT FRAME

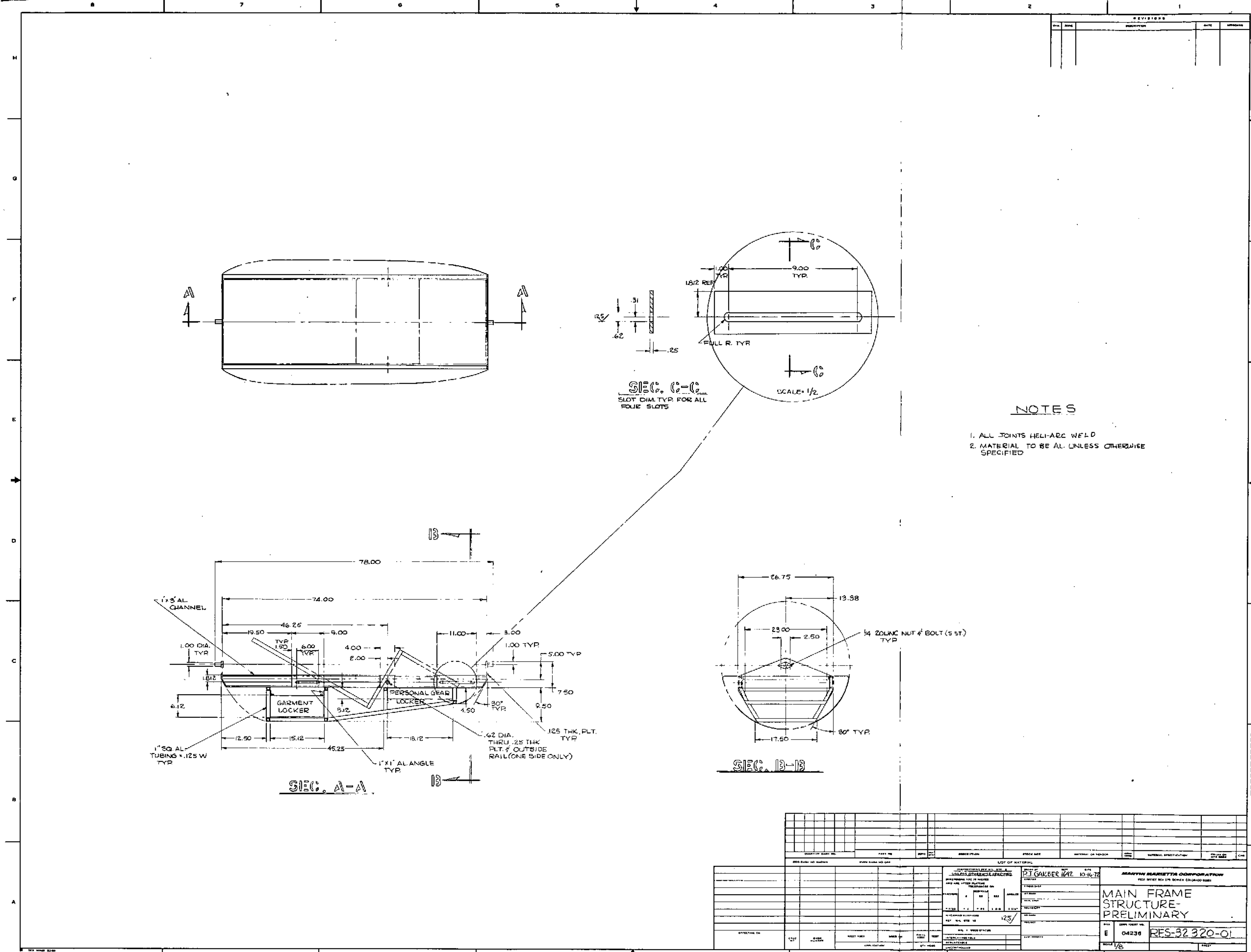
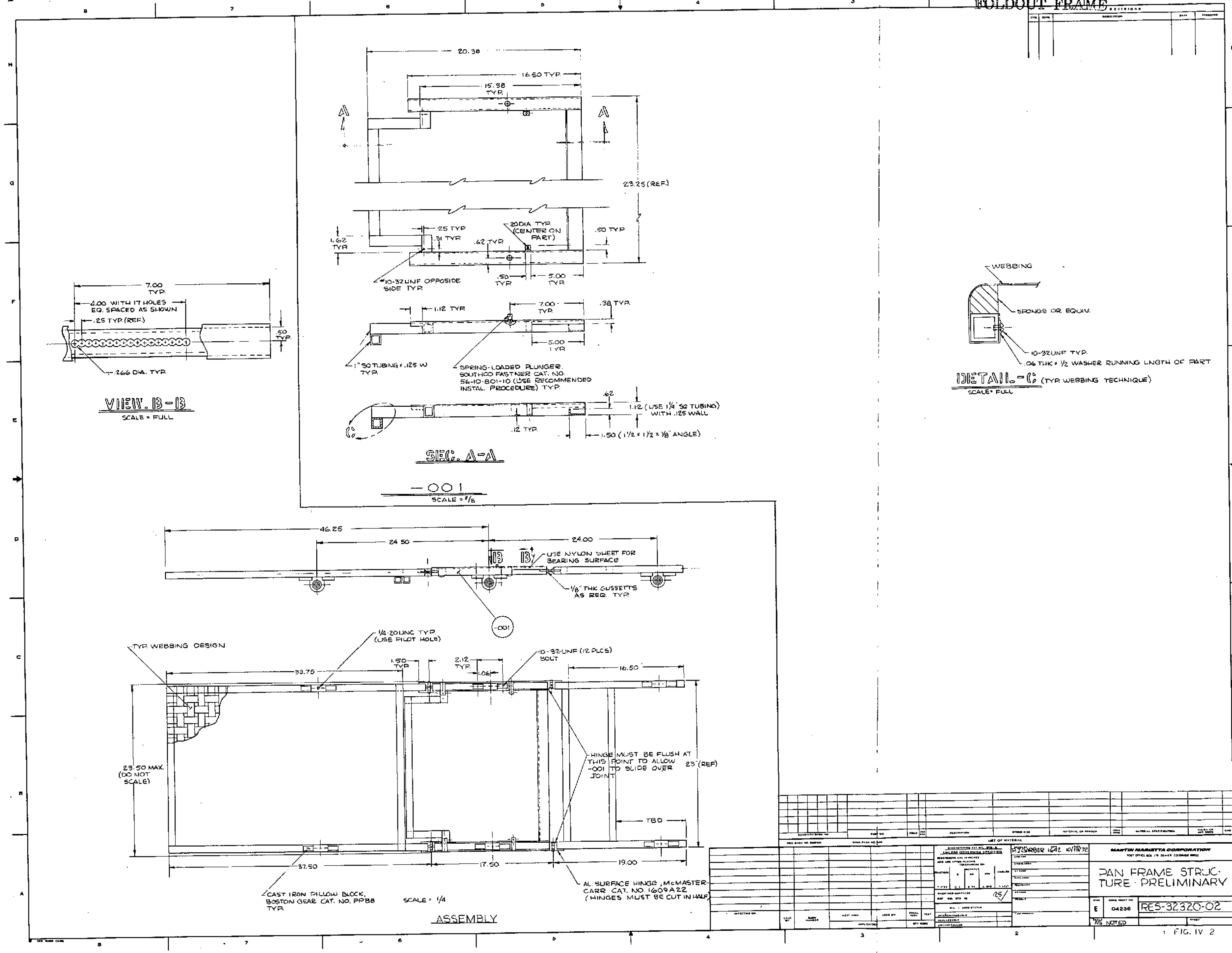


FIG. IV 1

FOLDOUT FRAME

FOLDOUT FRAME



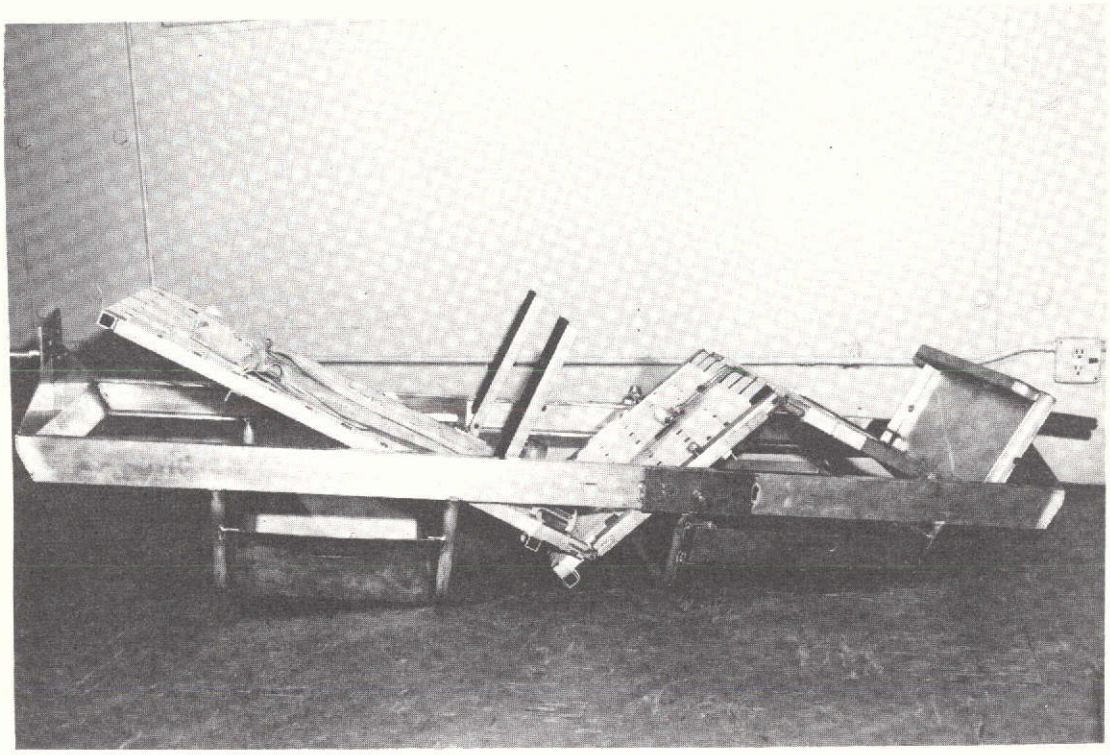


Figure IV-3 Engineer Model Sitting Position

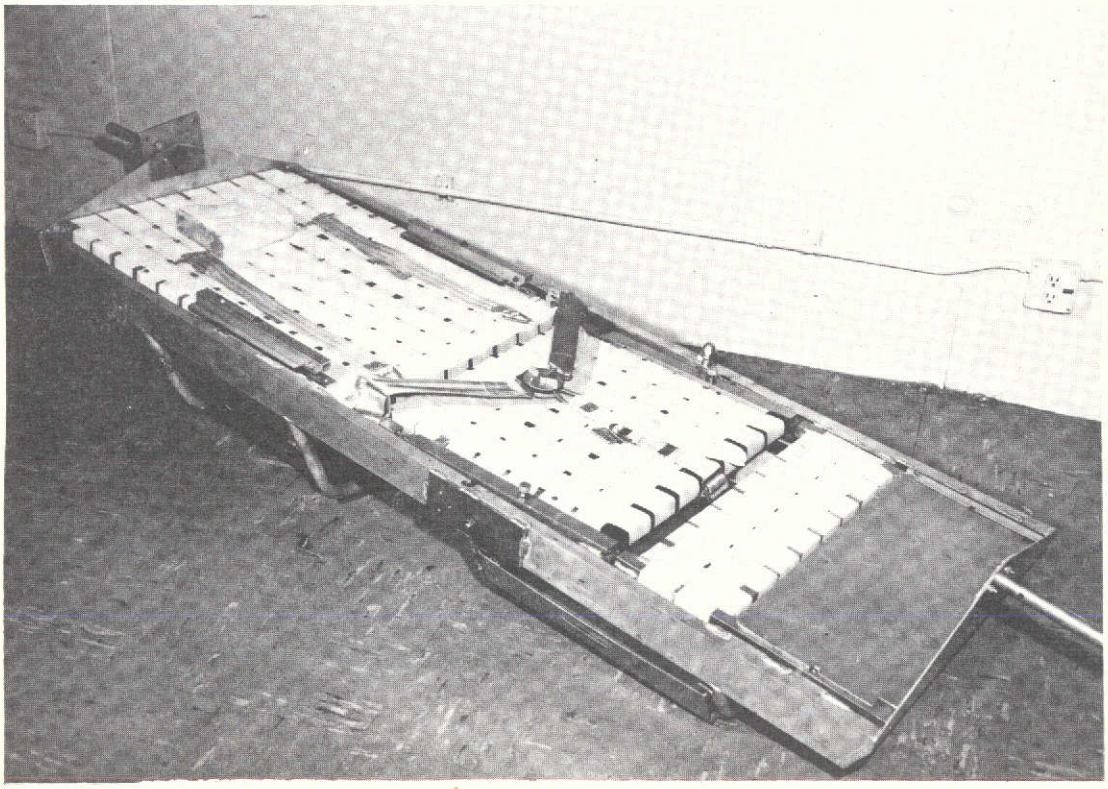


Figure IV-4 Engineering Model Flat Bed Position

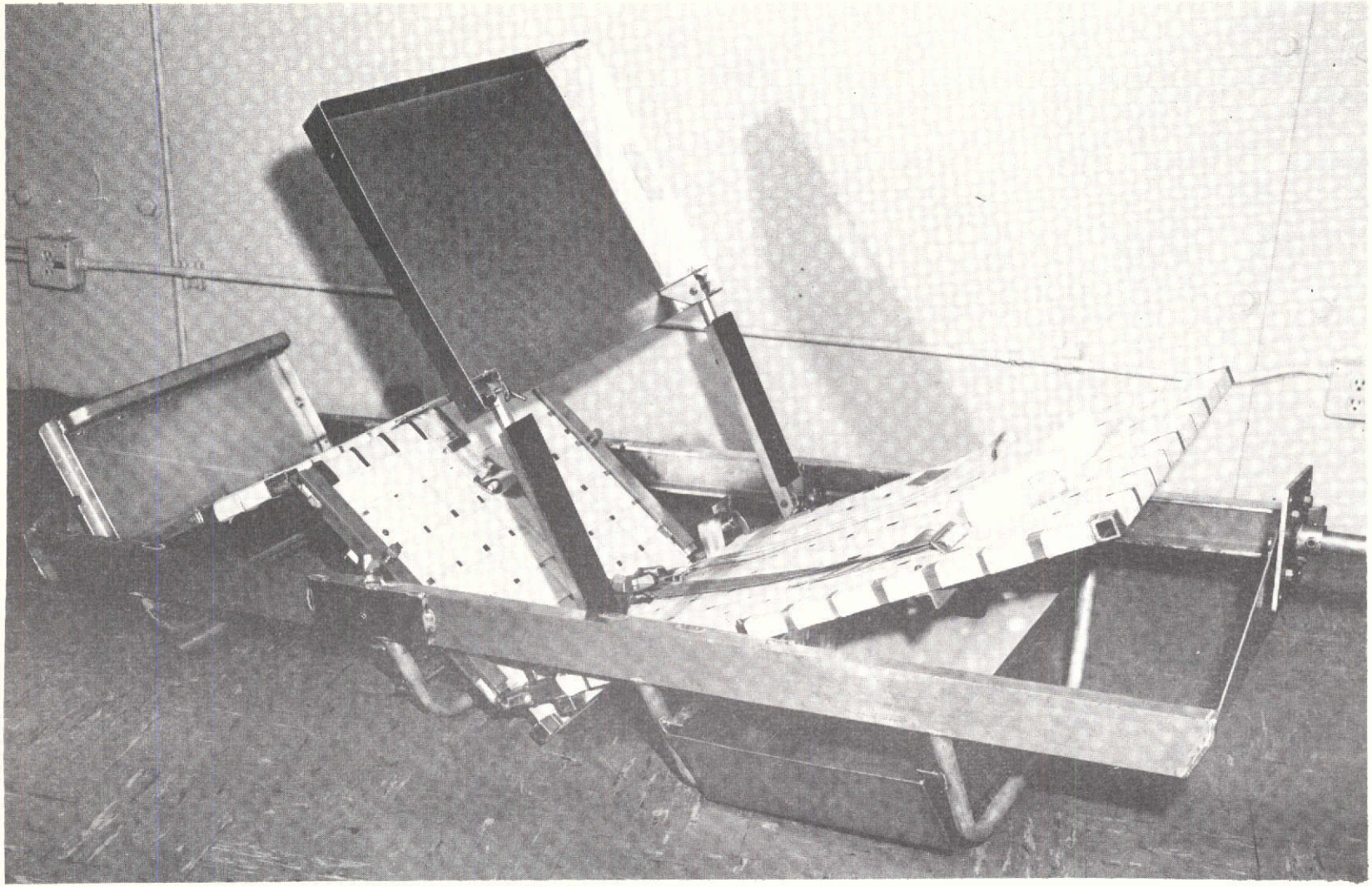


Figure IV-5 Engineering Model With Clerical Tray Deployed

structure could withstand the launch/re-entry loads of three g's for 30 minutes. Neutral buoyancy tests were utilized to simulate a zero-gravity environment for extended periods.

1.0 Crew Compartment Interface Tests

These tests were conducted to establish the envelop dimensional requirements of the passenger couch. Subjects ranging from the 5th to 95th percentile males and 50 percentile female simulated using the couch in the flatbed and fully seated positions and commented on the fit and accessibility of the various controls. These tests are illustrated in Figures IV-6, thru IV-9 where both male and female test subjects were used to evaluate the couch's functional capabilities.

The principal result of these preliminary tests was the substantiation of the increase in stature of subjects from standing to supine measurements. Table IV-1 shows the changes in stature for various subjects for different times and attitudes. Thus, a 95th percentile subject's stature increased to the point where interference occurred in the passenger couch engineering model flatbed position. Since this increase in stature can be expected in zero-g (neutral buoyancy tests have substantiated this fact), the engineering model flatbed length of 74 inches was increased to 76.25 inches for the Verification Model.

The preliminary tests also showed that the position of the body support adjustment mechanism on the couch side rail had to be moved headward to insure that 5th percentile subjects could reach it easily while in the flatbed position since the head rest was to be in a fixed position. As a result, this mechanism was designed so that the actuation levers and rotational lock on the Verification Model were 5.25 inches closer to the head of the couch. It was also determined that

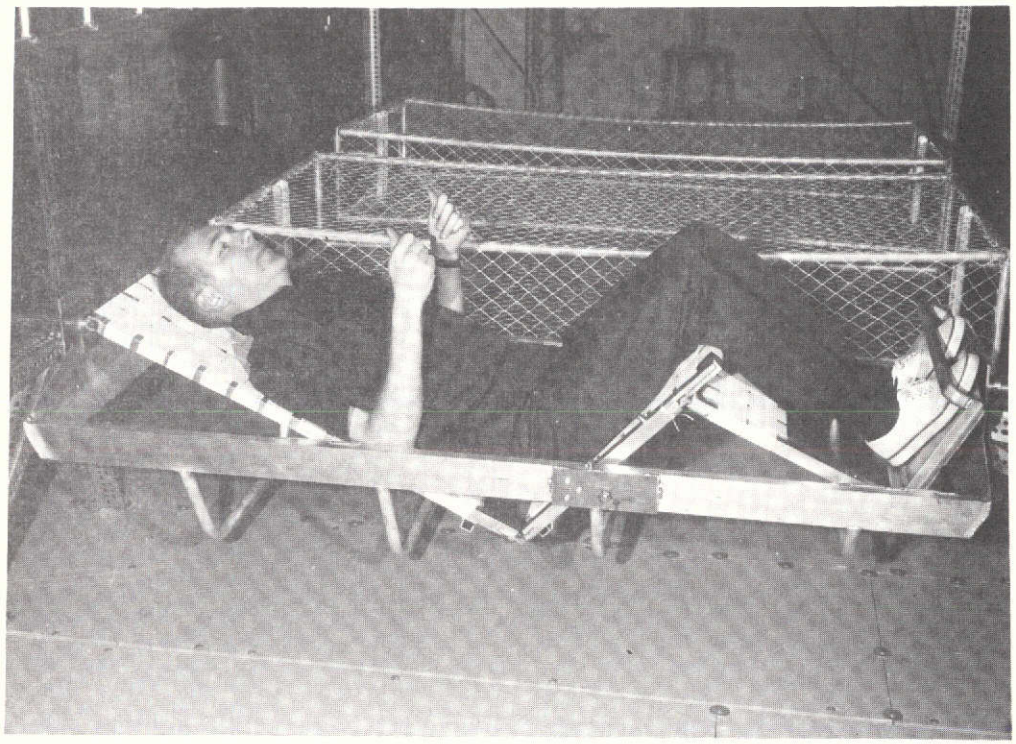


Figure IV-6 PCEM With 95 Percentile Male in Sitting Position

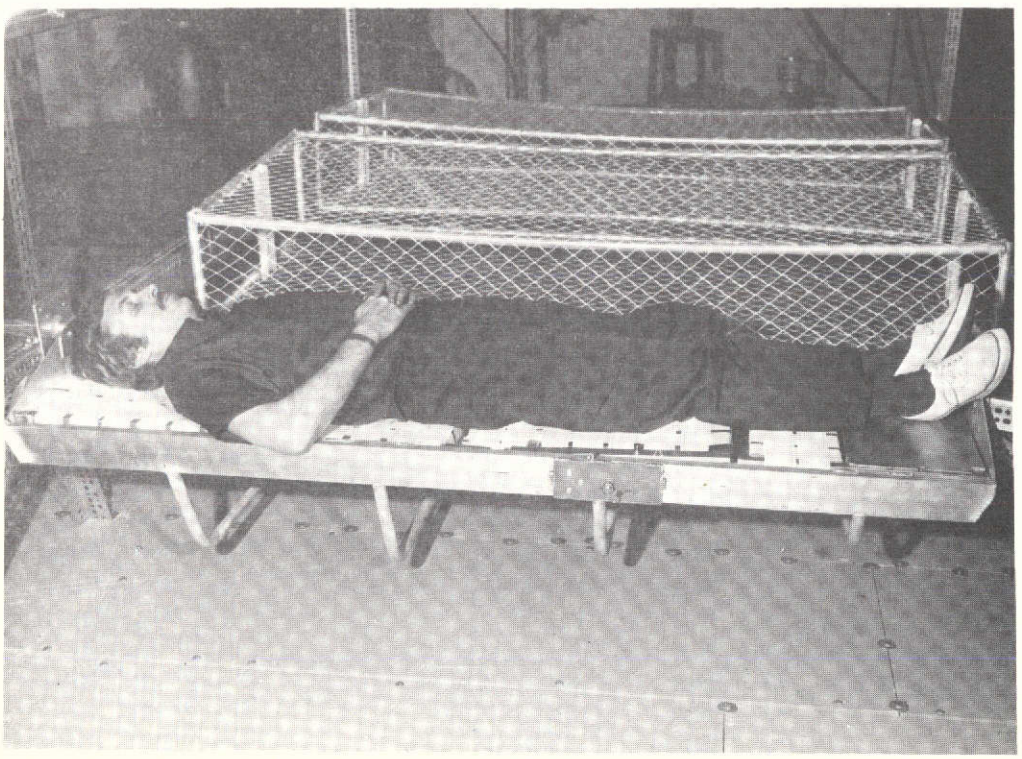


Figure IV-7 PCEM With 70 Percentile Male in Sleeping Position

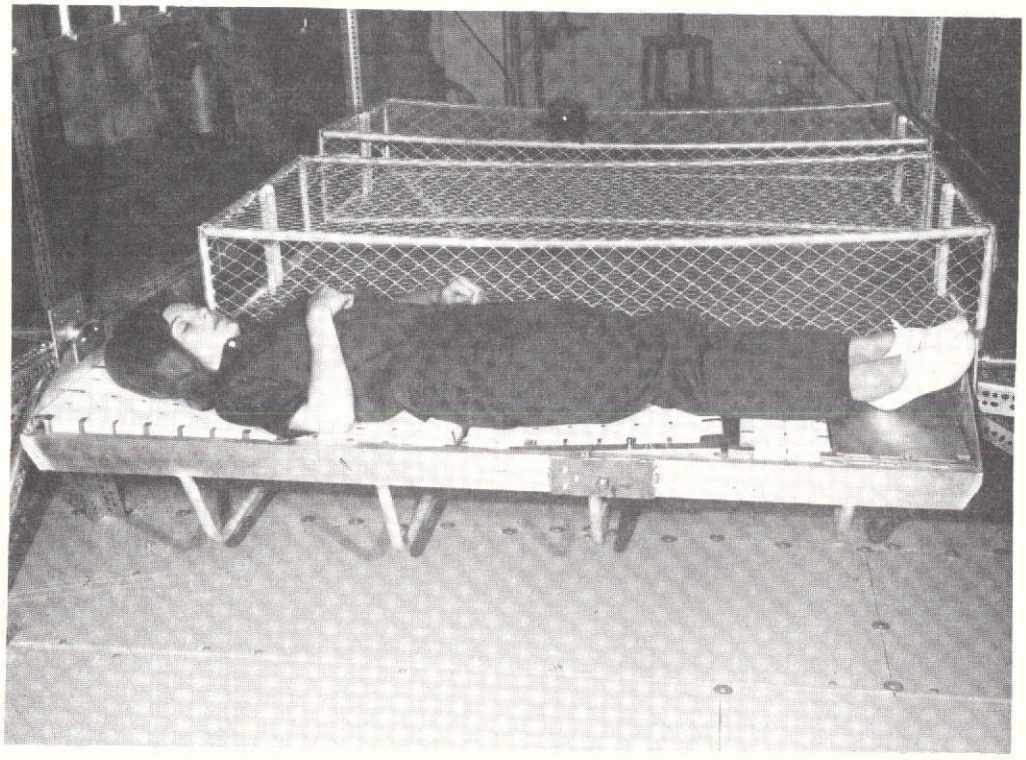


Figure IV-8 PCEM With 50 Percentile Female in Sleeping Position

Figure IV-9 PCEM With 50 Percentile Female in Sitting Position

the worm and pinon as well as the cam and detent were not satisfactory as locking devices for the body support adjustment.

Table IV-1 Male Height Changes for Attitude & Time

Subject Percentile Height	One-G Height, Inches					
	Morning (AM)			Afternoon (PM)		
	Standing	Supine	Delta	Standing	Supine	Delta
10	65 1/2	66 7/8	1 3/8	65 1/4	66 3/4	1 1/2
60	69 1/2	70 3/4	1 1/4	69	70 1/2	1 1/2
65	70 5/8	71 1/2	7/8	70 1/8	71 9/16	1 7/16
65	70 3/4	71 1/2	3/4	70 1/4	71 9/16	1 5/16
92	73 7/16	75	1 9/16	73 1/8	75	1 7/8
94	73 9/16	74 7/16	7/8	73 3/16	74 1/16	7/8
95	74	75	1	73 1/2	74 5/8	1 1/8
95	74	75	1	73 5/8	74 7/8	1 1/4

The utilization of the foot pan indicated that the adjustment for length should be located on the inner frame close to the leg calf position rather than in the foot pan itself to facilitate adjustment for all subjects.

2.0 Centrifuge Test

Since the flight unit of the Shuttle Passenger Couch must withstand specific launch/re-entry loads, the couch verification model was designed to accept those loads and keep its occupant safe and comfortable. To insure that the couch verification model would meet the load criteria, the engineering model (structure identical to the proposed couch verification model design) was subjected to centrifuge tests on Martin Marietta's Rucker Centrifuge.

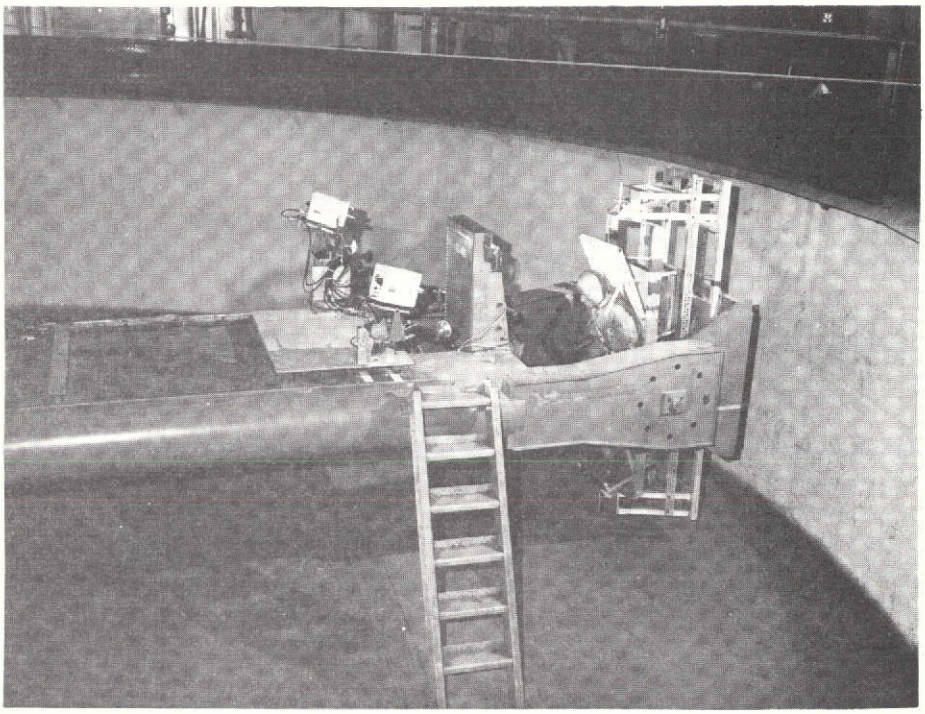


Figure IV-10 Couch Engineering Model Mounted on Centrifuge Arm

Figure IV-11 Man Model (200 lb, 95th Percentile) in SPCEM-Centrifuge Test

The couch engineering model was mounted on the centrifuge arm in the launch position with a 200-lb, 95th percentile man model restrained in the seat as shown in Figures IV-10 and IV-11. Weights were added to the couch frame to simulate the anticipated total weight of the verification model. Six strain gages (type FAB-25-12513) were attached to the couch frame and end plate to record the stresses experienced at critical points during peak loading.

Since there was no requirement to test the couch to its failure point, the test was conducted only to demonstrate that the frame as designed could withstand a load of 3.0 g's for 30 minutes. When this test was successfully completed and the actual stresses proved to be close to those estimated by analysis, an additional test at 4.5 g's was conducted until the data recording movie camera mount malfunctioned and the test was terminated. Table IV-2 shows the actual stress at points A and B (side rail) versus the stress calculated by analysis for loads of 3.0 and 4.5 g's. Point A was at the center pivot point and Pivot B was at the head sliding point. Values of stress at the end plate are not included because of the complex stress distribution and the questionable nature of the strain gage readings.

Table IV-2 Couch Stress Levels

STRESS	LOAD LEVEL (g's)			
	3.0		4.5	
	Pt.A	Pt.B	Pt.A	Pt.B
Analysis (Est.) - psi	4900	5500	7350	8250
Actual (Avg) - psi	4815	4100	8320	7570

Pt.A - Pivot Point; Pt.B - Sliding Point

Inspection of all welds after completion of the tests revealed no visible degradation or failure; the couch assembly demonstrated that it could withstand loads of up to 4.5 g's for extended periods. In addition, the stress analysis for higher load levels was verified

to the extent that the actual stresses at 3.0 and 4.5 g's were very close to those predicted; therefore, expected stresses at a crash-load of 9.0 g's should approximate the values estimated by analysis, which are below the limit for the structure.

3.0 Neutral Buoyancy Tests

Operational performance characteristics of the couch as related to crew tasks in zero-gravity were determined by neutral buoyancy testing of the couch engineering model. Male and female subjects were utilized to define motion requirements and access capability during such crew tasks as couch ingress/egress, couch adjustment, clerical tray utilization, deployment/release of the restraint belts and the use of controls, tape player and stowage areas while restrained.

Figures IV-12, thru IV-15 show some of the activities accomplished in the neutral buoyancy tests. There was no appreciable performance difference between male and female subjects during any of the couch area tasks; each subject could adequately perform the required activities. The principal results of the neutral buoyancy testing are summarized as follows:

- o Subjects entered the couch by approaching from the side, grasping some part of the couch framework, then pivoting the body so that the posterior contacts the seat pan first. Simultaneously the legs are lowered and extended so that the feet can be placed beneath the toe rail on the foot pan while the subject steadies himself in the couch with one or both hands grasping the couch side. The belt restraint is then attached as required.
- o All couch belt restraints could be operated in zero-g; however, the lap belt in conjunction with the foot rail was all that was necessary to provide complete body stabilization and control.

o The couch itself provided adequate mobility aids. The subsequent couch shell should retain this capability by employing a curved lip around the top surface or sides.

o Couch controls are accessible while restrained in all modes of operation.

o Subjects exited the couch by releasing the restraint system, grasping one side of the couch frame with one hand, pivoting about that point away from the couch to the proper orientation, then pushing off with hands and/or feet as desired.

o Access to storage areas in the couch sides while the subject is restrained in the couch is adequate but awkward. Limited volumes anticipated in the shuttle orbiter crew compartment indicated that storage locations should be incorporated into the couch back, with access available by exiting the couch and rotating it 180^{o} about its longitudinal axis.

o The clerical tray attached to the armrests was convenient to use and provided a stable working surface for the couch occupant.

o Simulated activities such as sleeping, eating or writing were performed satisfactorily by all subjects.

o Couch ingress/egress with the clerical tray in place was relatively easy although use of both hands was necessary to position the body properly. Ingress/egress while carrying an object in one hand was also tested; greater care had to be exercised by the subjects but the task was not difficult.

Neutral buoyancy tests demonstrated the concept of the overall couch design and pointed out areas which would impact the verification model design.

Figure IV-12 Test Subject Restraint in Reentry Position

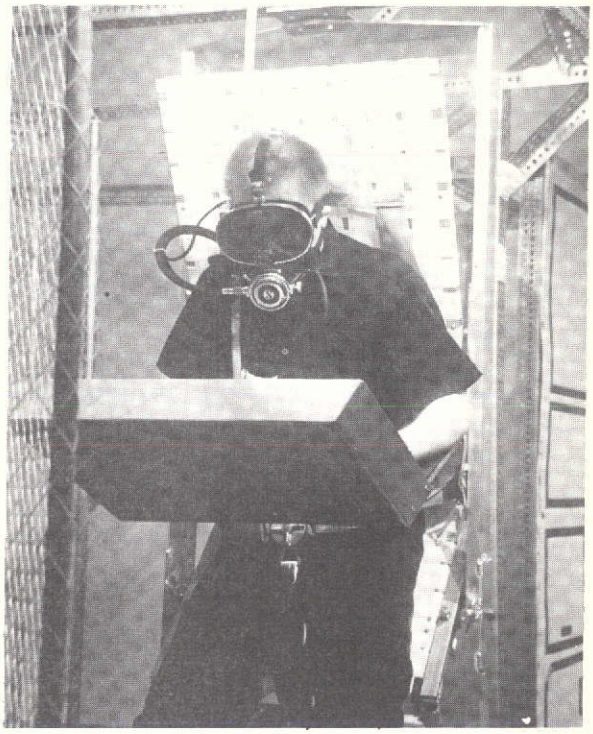


Figure IV-13 Clerical Tray Attached to Couch

Figure IV-14 Ingress to Couch With Clerical Tray Attached

Figure IV-15 Ingress Carrying Food Tray

V. COUCH VERIFICATION MODEL

A. DESIGN REQUIREMENTS AND FABRICATION

The design requirements for the couch verification model are broken down into the system and subsystem requirements. These requirements are based upon the functional requirements and performance characteristics that the couch must possess to satisfy the requirements

1.0 Requirements

1.1 System Design Requirements

The Shuttle passenger couch requirements are primarily established from the functions that the couch must satisfy while maintaining the degree of safety necessary for a manned mission. Another contributing factor is the vehicle interface requirements such as volume, ingress/egress, comfort, privacy, etc.

From the projected 1980 anthropometric dimensions of man, the minimum internal length of 75.5 inches and the minimum internal width of 21 inches are required to accept the 95th percentile male when laying on his back. In addition a minimum of 5 inches on the length and 3 inches on the width must be added to provide structural integrity and vehicle interface provisions. The depth of the occupied couch envelope is determined by placing the center-of-gravity of the occupied couch below the couch longitudinal axis of rotation when the couch occupant is sitting in the launch position. The basic functional couch envelop is depiected in Fig. V-1.

The gravity loads that the couch system must be designed to withstand are as follows: three g's for 30 minutes to satisfy launch and entry loads; crash load of nine g's for the couch and 12 g's for the couch mounting hardware. These loads shall include a 95th percentile occupant, approximately 205 pounds in addition to the couch weight.

The basic design consists of a main framework, which allows rotational

positioning relative to the vehicle and serves as the attachment interface to the vehicle. Within the main framework an inner frame is used to provide support and position the occupant during the various modes of operation.

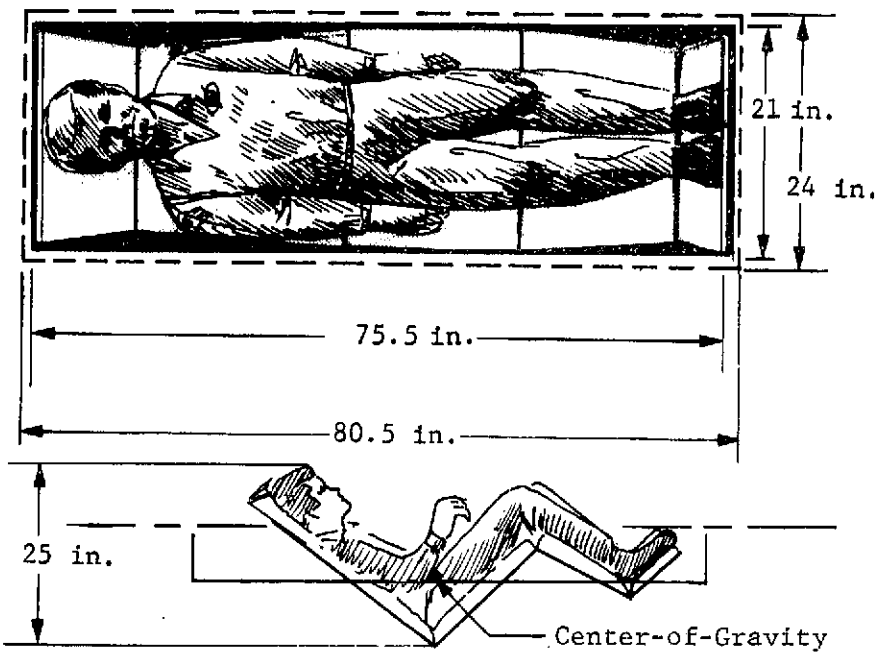


Figure V-1 Basic Passenger Couch Envelope

This design is incorporated in the couch verification model which consists of five major assemblies plus the ancilliary subsystems for environmental control, stowage provisions, privacy, sleep restraint, and personal entertainment. The major assemblies are the main frame, the lower framework, inner frame, shell, and the vehicle mounting hardware. These assemblies and subsystems are identified in the exploded view of the couch in Fig. V-2.

1.1.1 System Requirements

1.1.2 Functional Requirements

The functions that the couch must satisfy are to provide the occupant: (1) a safe support during launch, entry and landing; and (2) a personal habitat for the orbital mode where the astronaut can relax, sleep, eat, perform clerical duties, and have personal privacy with his own private lighting, ventilation, tape player and personal stowage area. To satisfy these functions the couch must: (1) contain a restraint system that can be used for launch, entry, and during orbital operations; (2) conserve volume by providing rotational

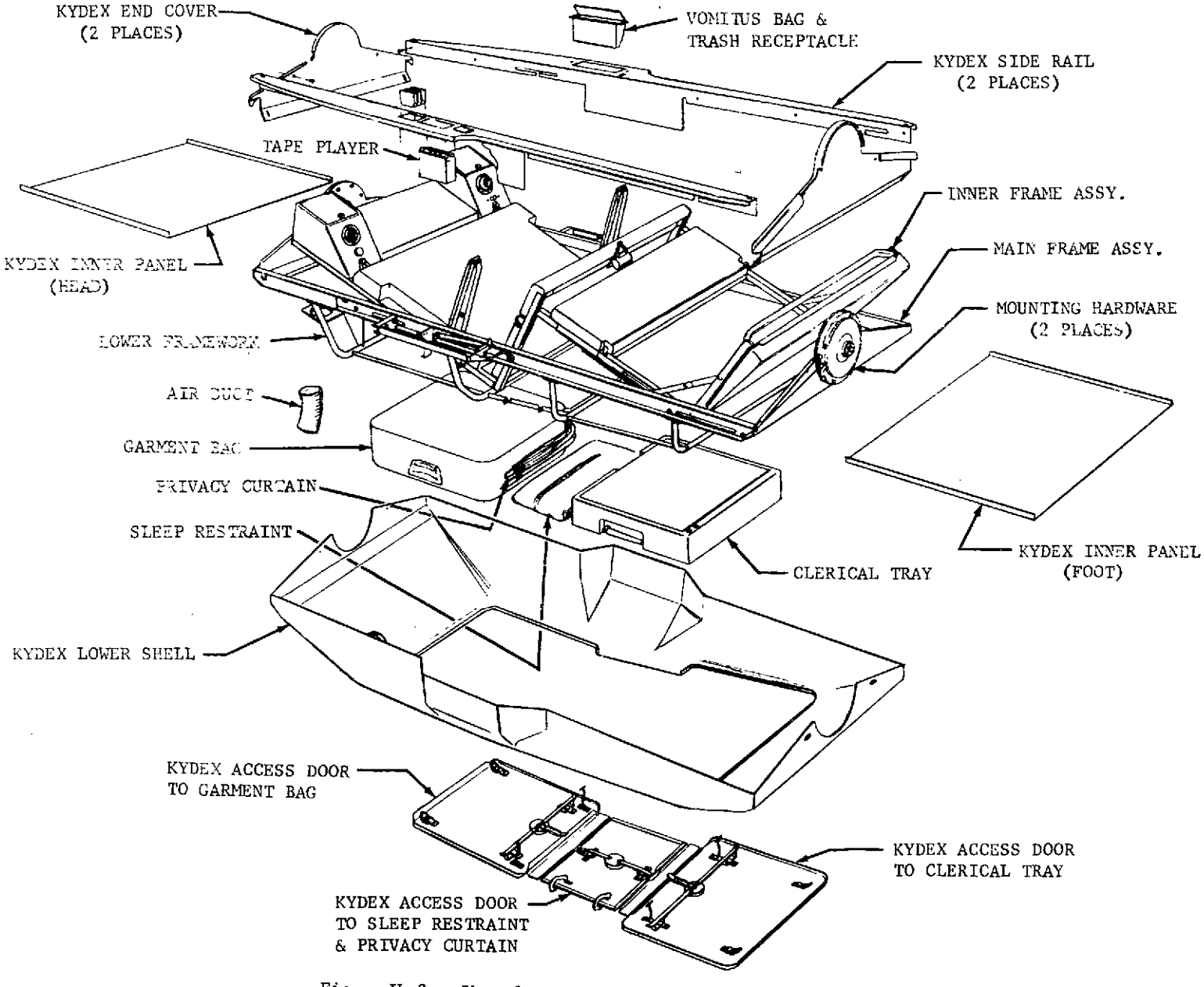


Figure V-2 Shuttle Passenger Couch

capability to gain access to stowage areas and keep the couch perpendicular to the gravity vector during launch and entry, to assure physiological safety to the occupant; (3) position the occupant from an erect sitting position to a prone, flatbed, position while in the couch; and (4) provide lighting, air ventilation, entertainment by tape player, and a privacy curtain.

1.1.3 Performance Characteristics

The operation of the system must be considered for the launch, entry, and orbital modes and any compromise in performance shall not endanger the safety of the occupant. Therefore, the structural members are designed for the greatest loads that may be placed on the couch during the life of the couch system in any of the operating modes. The restraint system must perform in two vastly different conditions. One is to provide restraint during launch and entry when loads are one gravity and greater. The other requirement is to provide restraint in a zero-gravity environment where minimal restraint is required but ease of operation is desirable. The remaining subsystems are primarily personal habitability items and the main concern is in locating them in a manner that complements the couch system and are easily accessible to the couch occupant.

To satisfy the requirements of the above paragraphs the Passenger Couch Verification Model was designed and built as illustrated in Figure V-3.

2.0 Subsystem Design Requirements

2.1 Main Frame

As shown by Figure V-2 the main frame is the foundation of the entire couch system. This frame must provide the required structural strength to satisfy the design loads, attachment structure for the various subsystems, attachment for the vehicle mounting hardware, and provide mounting provisions for the couch shell. Because of the many

Physical Specifications

Couch Dimensions (envelop) 18 x 34 x 80.5 inches

Couch Weight Breakdown (pounds)

		Ancillary Items Breakdown (pounds)	
Main Frame	32.6	Tape Player	4.4
Inner-Frame Body Support	52.9	Trash Stowage	2.2
Cushions	10.2	Personal Stowage	16.3
Shell	39.5	Privacy Curtains	4.3
Mounting Hardware	16.1	Sleep Restraint	2.2
Ancillary Items	33.1	Power Supply	3.7
Couch Total Weight	184.4 lb.	Total	33.1 lb.

Figure V-3 Passenger Couch Verification Model

functions the main frame must satisfy, a channel was selected for the frame sides and sheet stock for the end pieces. The channel flanges were turned to the outside to provide a smooth interior and a shorter distance for the cantilevered inner frame supports. The outside channel also provides a space for the mechanism to adjust the inner frame and the routing of the rotational device operating cables. The main frame is fabricated by welding the preformed end pieces to the machined side rails.

2.1.1 Lower Framework

The lower framework, as identified in Figure V-2, provides the structure to hold the clerical tray, garment bags, and support for the access doors. The framework consists mainly of welded tubing and angles bolted to the main frame.

2.1.2 Couch Mounting Hardware

The couch mounting hardware must perform the functions of transmitting the loads of the couch and occupant to the vehicle, allow rotation of the couch around its longitudinal axis for 345 degrees in either direction freely or in 15 degree increments, and provide access for electrical connections between the vehicle and the couch. To satisfy these functions, two parts of hardware are required. One part is permanently attached to the vehicle and will mate with the part attached to the couch. The female part attached to the vehicle accepts the couch male part and orients the couch relative to the vehicle. The male part attached to the couch end plates consists of the rotation control mechanism and electrical interface with the vehicle. The rotation control mechanism consists basically of a gear, two sets of pawls, and two

operating levers within a housing. The gear has 24 teeth to allow the 15 degree incremental adjustment and two sets of pawls are utilized to allow rotation in either direction with a positive lock and minimal backlash. The operating levers bear against the spring loaded pawls and extend out of the housing in a manner that allows a cable yoke to activate the levers simultaneously. The cable yoke on each end of the couch is attached to a cable that runs to a single control on the side of the couch within easy reach of the couch occupant. The mounting hardware details are shown in Figures V-4 and V-5.

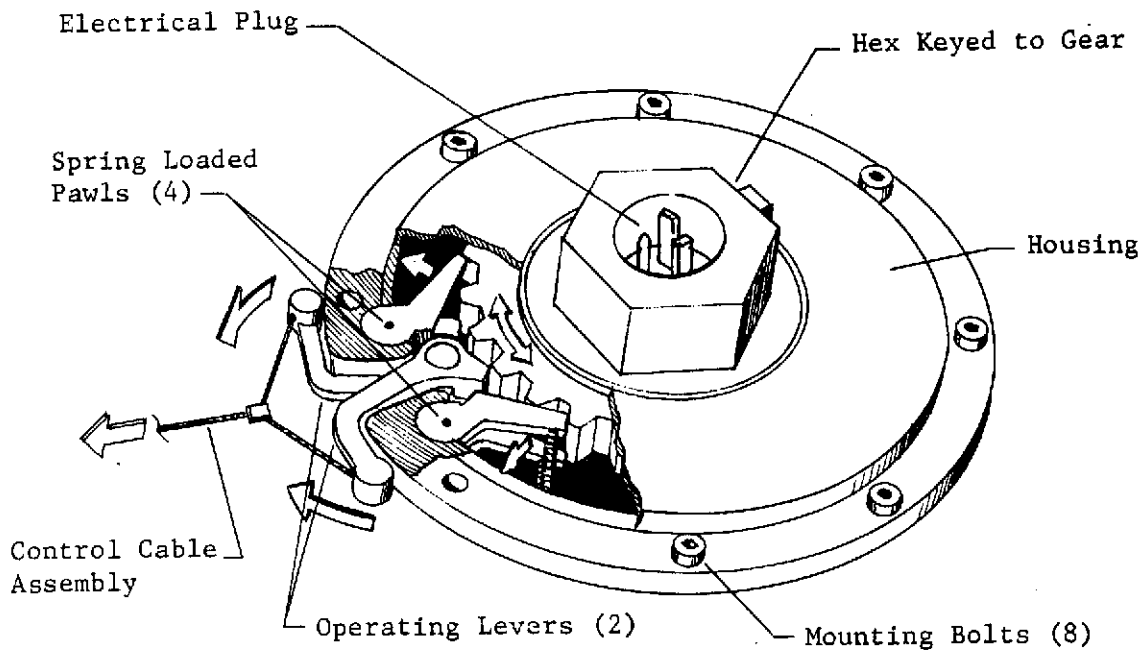


Figure V-4 Couch End Fitting Mechanism

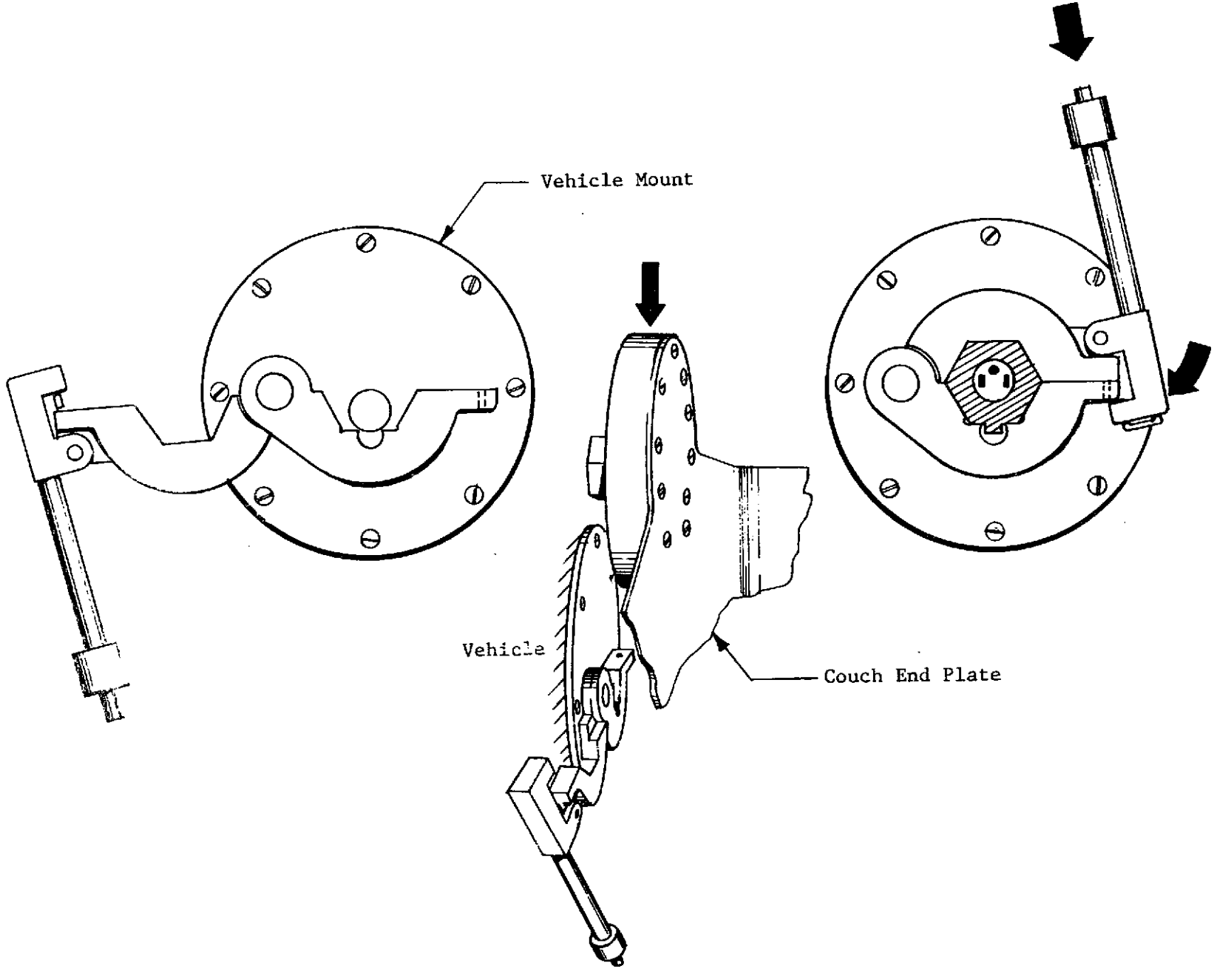


Figure V-5 Passenger Couch Mounting Hardware

2.2 Inner Frame - Body Support

The design of the inner frame as depicted by Figure V-6 allows the positioning of the body in the various positions for the Shuttle modes of operation. To change the body from an erect sitting position (90 degrees) to a flatbed configuration within a minimum volume, the inner frame is segmented into three sections. These three sections are identified as the back body support section, seat section, and legs section. The sections are connected by hinges that allows the required movement to obtain the various body positions. The occupant's weight is transmitted to the vehicle via the main frame through a combination of a rigid rotating point on each side of the seat section and a primarily sliding point on each side of the back and leg sections. The back and leg section attachment points are defined as sliding points, but they do rotate approximately 30 degrees during the length of the linear travel of the point between the flatbed and 90 degree configuration. Figure V-7 depicts the articulation of the inner frame and the three attach points. In the following paragraphs the details of individual sections are defined.

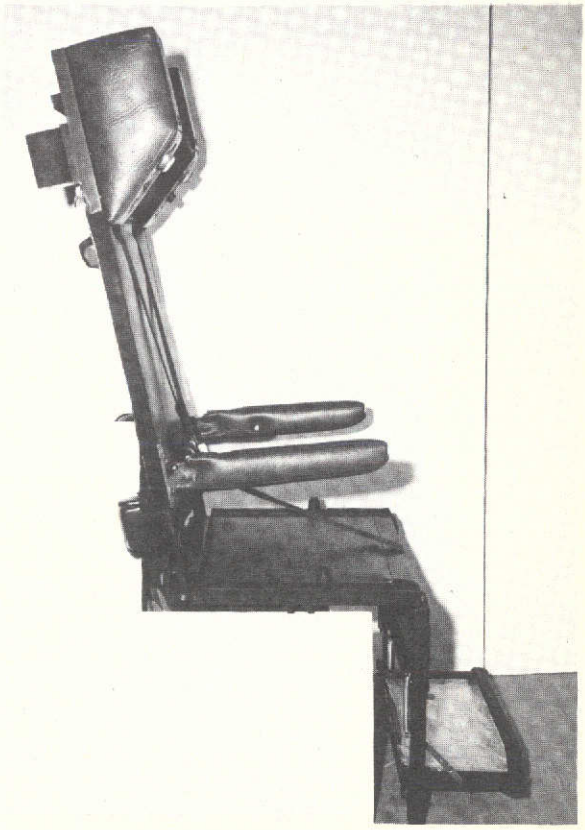


Figure V-6 Passenger Couch Inner Frame Assembly

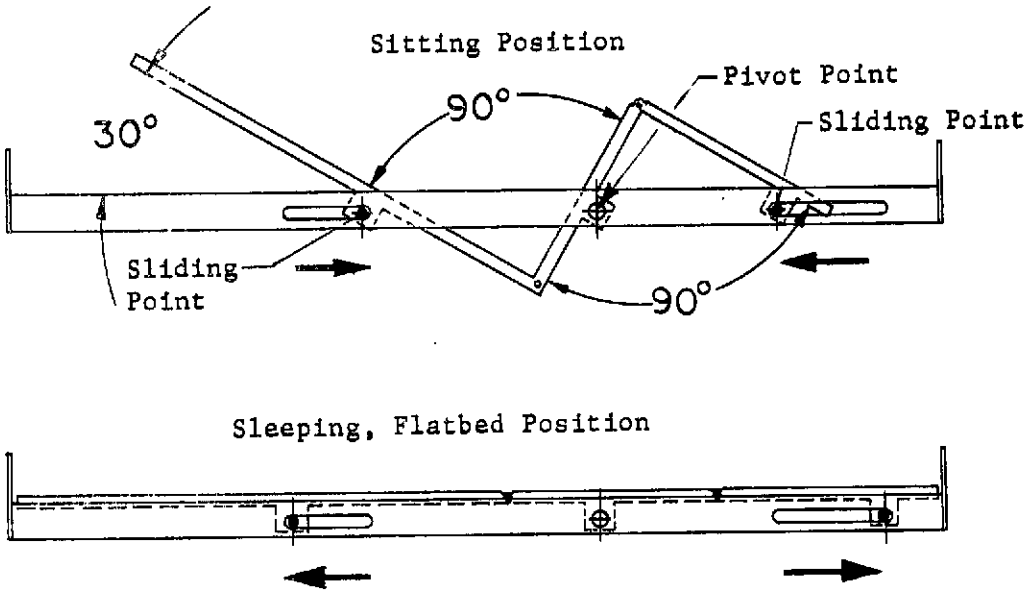
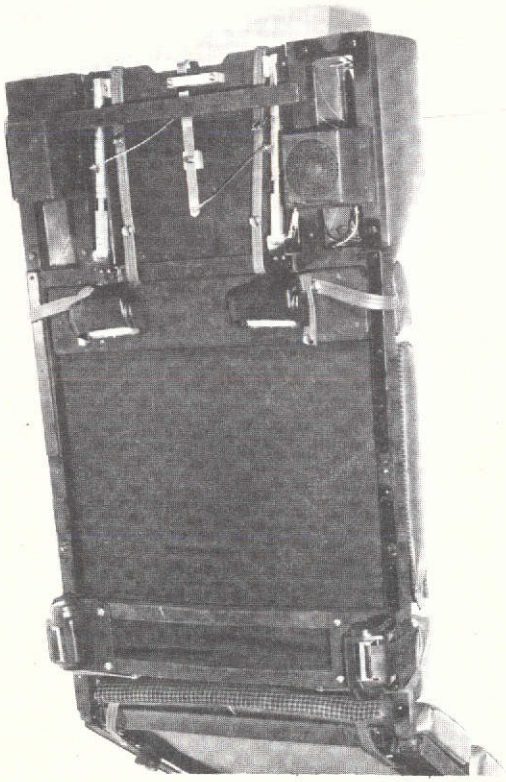


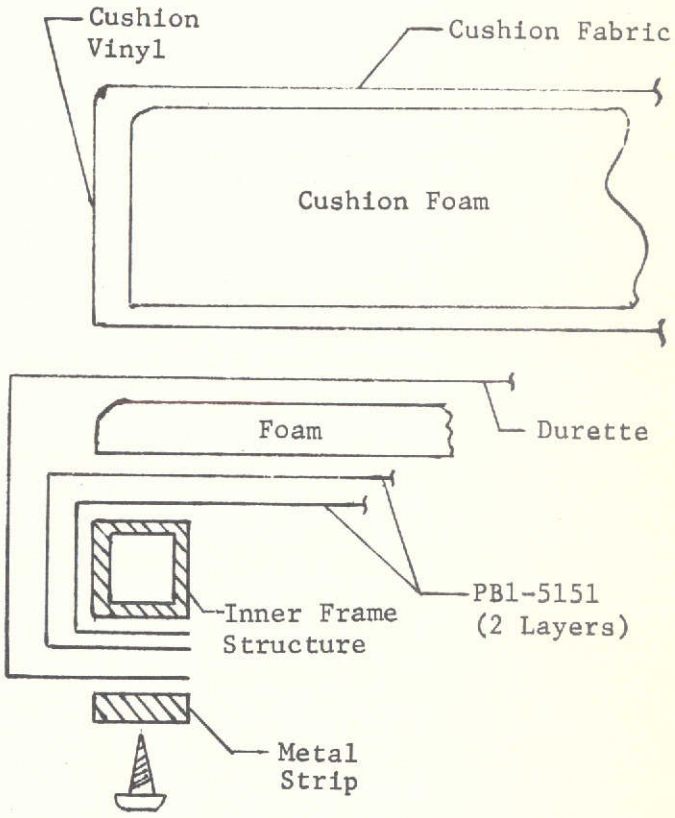
Figure V-7 Inner Frame Articulation

2.2.1 Back Section

The back section of the inner frame is designed to support the majority of the body including the torso, arms, and head during the various modes of operation. The back section is constructed of a welded framework of one inch square aluminum tubing. Fabric is attached to the framework to support the occupant. A cushion of fire retardant polyurethane foam with a density of 4 pounds per cubic foot is an optional item that is placed over the fabric support sections. The fabric support must withstand a 100 pound evenly distributed load at the 9 g's level with a deflection not to exceed one and one-half inch. The fabric consists of two layers of PBI-S151 and one layer of Durette RL4770 with Fluorel backing as the top surface. Between the PBI-S151 and the Durette is a layer of one-fourth inch of fire retardant foam. The fabric is fastened to the inside or bottom of the tube frame with a restraining metal

strip and screws. This allows the fabric to go around a minimum of two 90 degree corners which enhance fabric retention. The cushions are retained by snaps to facilitate easy application and removal of the cushions as desired. The back section also provides the mounting provisions for the environmental subsystems, which are defined in a separate section, adjustable head rest, adjustable arm rests, and four-fifths of the restraint system. The rear of the back section is shown in Figure V-8.





Cross Section of Inner Frame

Figure V-8 Back Section of Inner Frame

The head rest is attached to the back section and is infinitely adjustable from being parallel to 45 degrees up from the back section through the use of P. L. Porter mechanical locks with a two inch piston travel. The control lever is centerally located at the head end and is operated by moving the control to the side with either hand. The mechanical lock mechanism provides positive locked positions throughout the operating range and yet is simple, has minimum volume, and lightweight. A two inch thick cushion comprised of fire retardant foam, with a density of 2 pounds per cubic foot and a fabric and vinyl covering covers the entire head rest area and is intended to be used at all times. The cushion can be removed by unsnapping for maintenance to either the cushion or the headrest structure.

The arm rests upper surface is nominally located approximately nine inches above the seat cushion when the armrest is parallel with the seat section. Provisions are provided to adjust the armrests either up or down one inch by removing the arm rest mounting plate from the back section to permit access to the arm rest positioning screws. In the mounted position the armrests are capable of being independently adjusted thru a 100 degree range from flat against the back section to 10 degrees down from a position parallel with the seat section. This adjustment is made by depressing the button control located on the inside of each armrest and physically moving the armrest to the desired position. The mechanism that provides the infinite locked positions within the stated range consists of an internally mounted P. L. Porter mechanical lock with a four inch piston travel. To obtain this large range of travel with a simple piston type mechanical lock, the pivot point of the armrest is located below and in front of the mechanical lock pivot point at the base of the armrest, as shown in Figure V-9.

The portion of the restraint system that is attached to the back section consists of the two retracting inertia reels for the shoulders restraint and two retracting reels with positive locks for the waist restraint. The restraint reels are positioned as shown in Figure V-10. To prevent the shoulder straps from being retracted completely into the reel, a button stud is provided on the light and ventilation housings to hook the end piece onto. The left waist restraint has the 5-position rotary buckel permantely attached to it. The right strap is retained from retracting completely by a stop on the belt and a holder for the end piece.

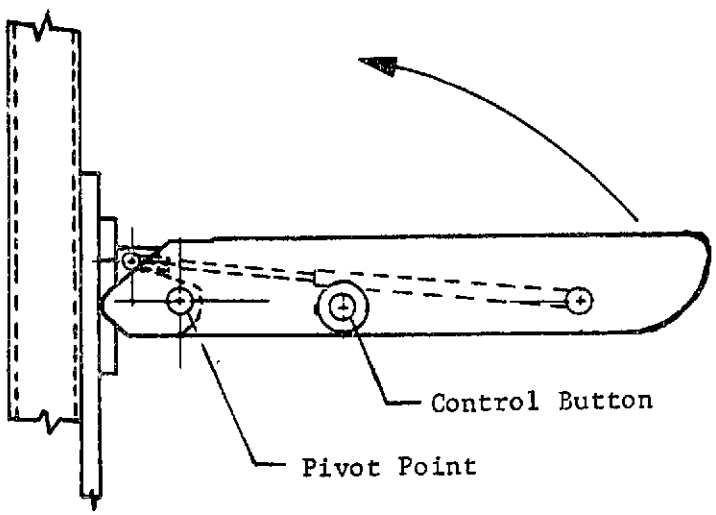


Figure V-9 Couch Armrest

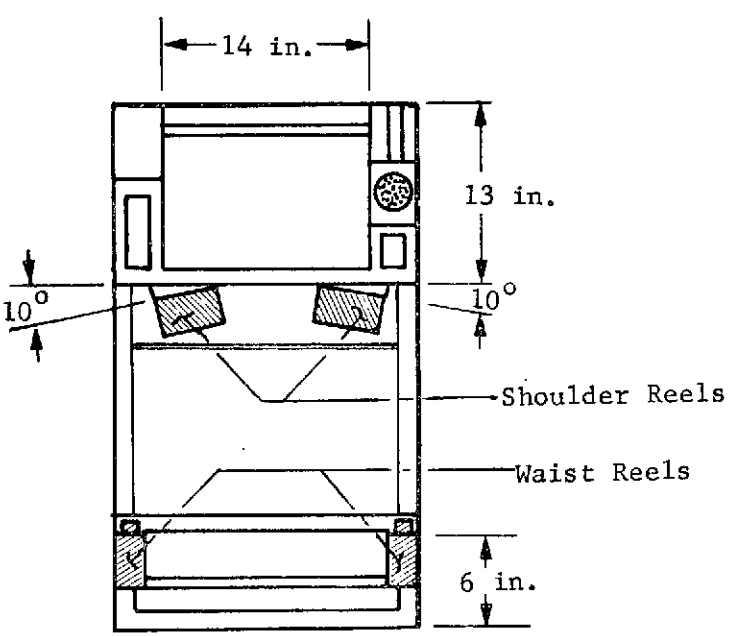


Figure V-10 Restraints Installation

2.2.2 Seat Section

The seat section is comprised of two major parts which are: (1) one inch square aluminum tube rails that attach to the back and leg sections and to the seat positioning tube and (2) the portion the occupant sits on which can slide on the rails to accommodate the 5th thru 95th percentile males. Positive adjustment is accomplished through the use of a spring loaded tapered pin on the sliding part engaging in a series of holes in the frame rails. Smoothness is provided by the Teflon strips bonded on the top and sides of the rail. The seat section is depicted by Figure V-11.

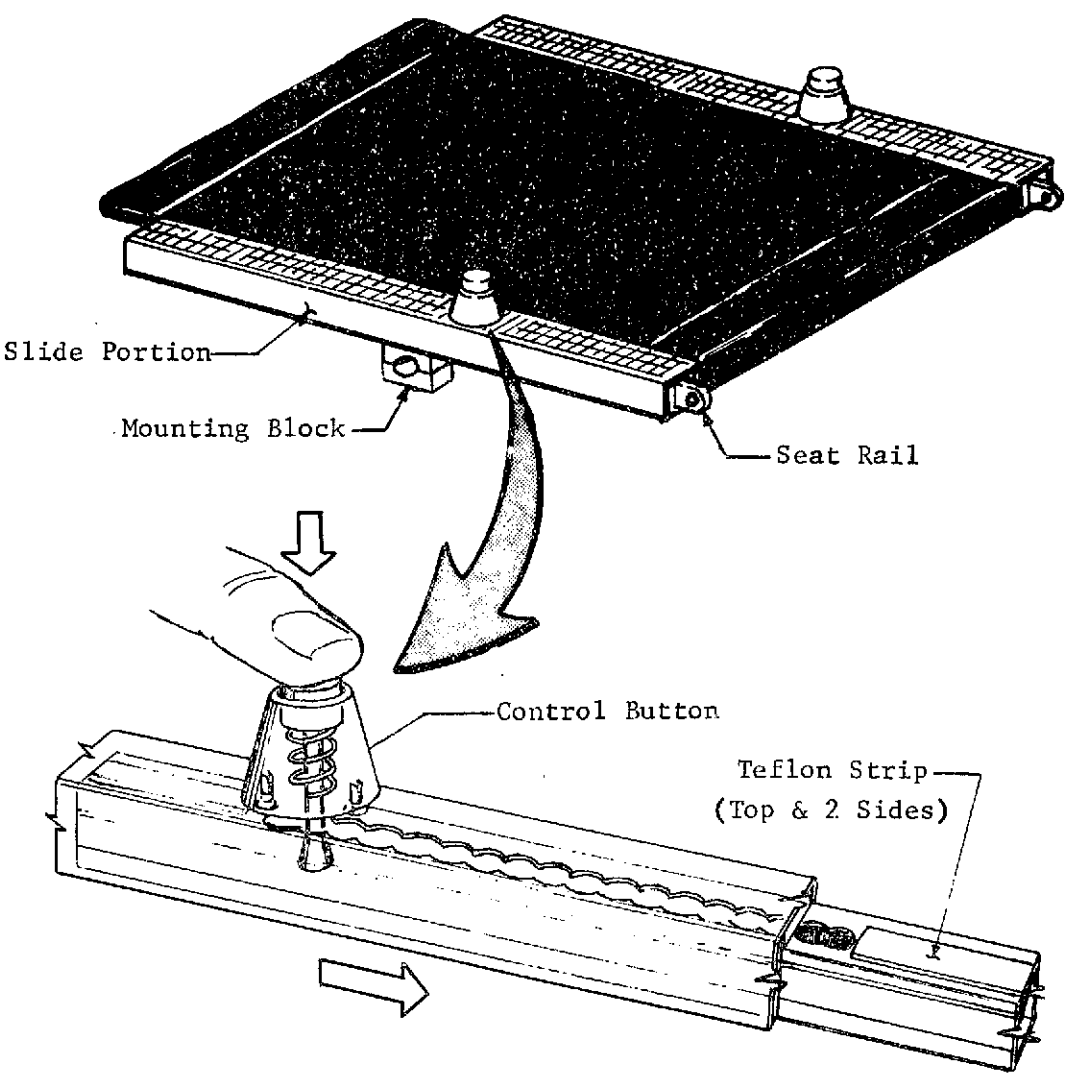


Figure V-11 Inner Frame Seat Section

2.2.3 Leg Section

The leg section provides the popliteal height for the couch occupant, mounting structure for the foot restraint, and serves as the third point in the inner frame articulation. The foot pan/restraint satisfies the requirement of a place to restrain the lower legs and feet during launch, entry, and the need of a simple restraint in the zero-gravity environment. The distance between the seat section and the foot pan is infinitely adjustable to accommodate the 5th thru 95th percentile male. The adjustment is accomplished with P. L. Porter mechanical locks mounted in the outside channels and the piston end attached to the foot pan spring loaded mounting block. The leg section and operation is depicted by Figure V-12.

2.2.4 Couch Shell

The couch shell consists of seven parts with the major single part covering the complete lower part of the couch. The other 6 parts consist of 2 side rails, 2 end covers, and 2 panels to cover the lower frame from a top view. These items are identified in Figure V-2. The shell is vacuum formed from an acrylic-polyvinyl chloride sheet with a trade name of Kydex. The formulation used for the couch shell is fire retardant Kydex 100 per the Rohm and Haas Company Bulletin PL-674c. The Kydex 100 sheet thickness was 0.156 inches before the forming process began with a resulting thickness after forming of between 0.90 inches and 0.125 inches. The shell is attached to the couch structure with quarter-turn fasteners and screws. Two sliding and one swing-out door are provided in the bottom of the shell for access to the garment bag, clerical tray, privacy curtain, and sleep restraint, as shown in Figure V-13.

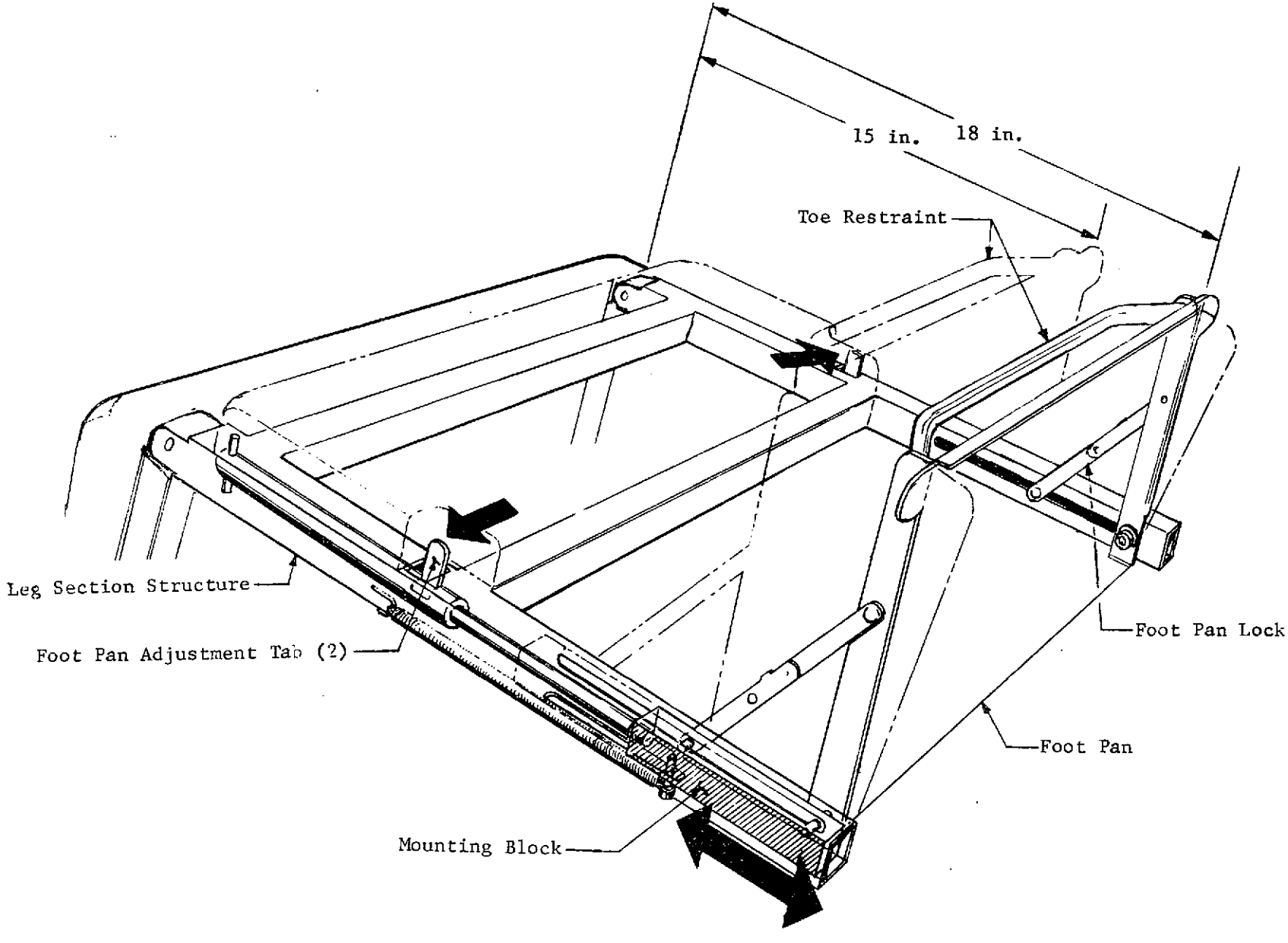


Figure V-12 Inner Frame Leg Section

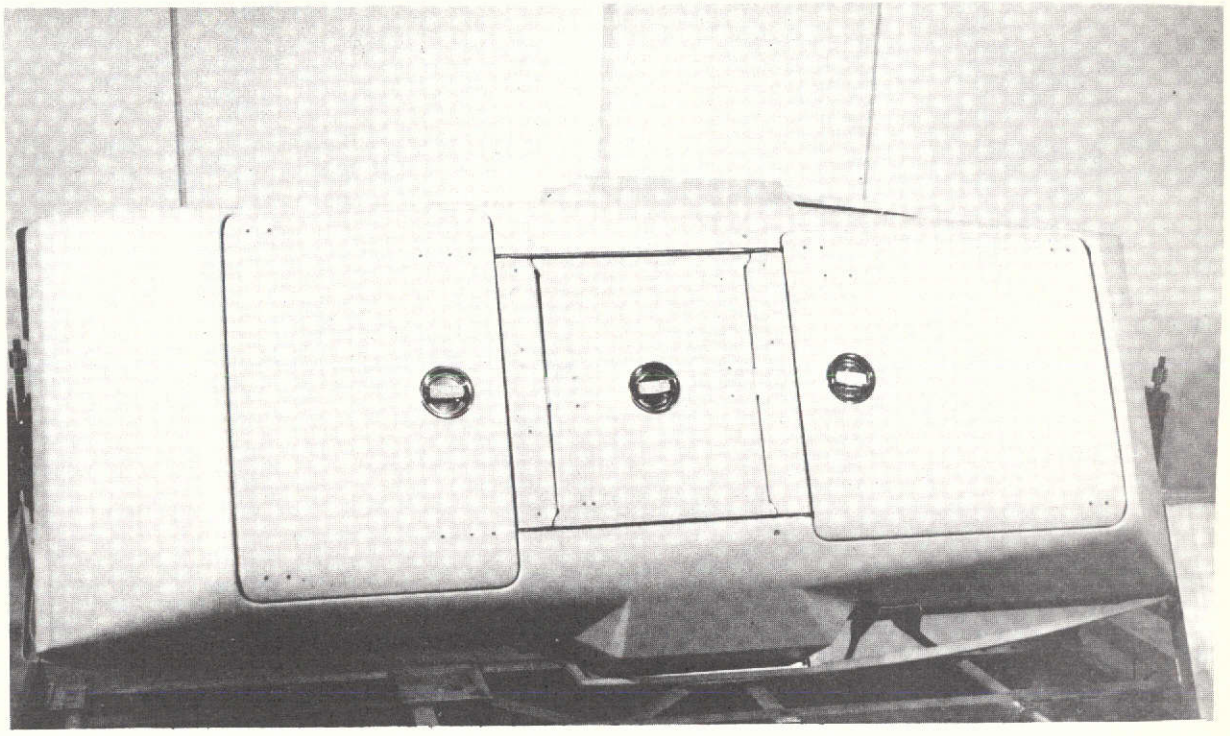


Figure V-13 Access to Bottom of Couch

2.3 Environmental Requirements

2.3.1 Lighting

The light for the occupant's personal use is mounted in the housing that stores the headset on the upper left hand corner of the back section as shown in Figure V-14. The light direction is adjustable within a 30 degree cone with a separate control to adjust the intensity to four levels. The maximum intensity of the light is 25 foot candles with a 20 inch diameter spot at 18 inches.

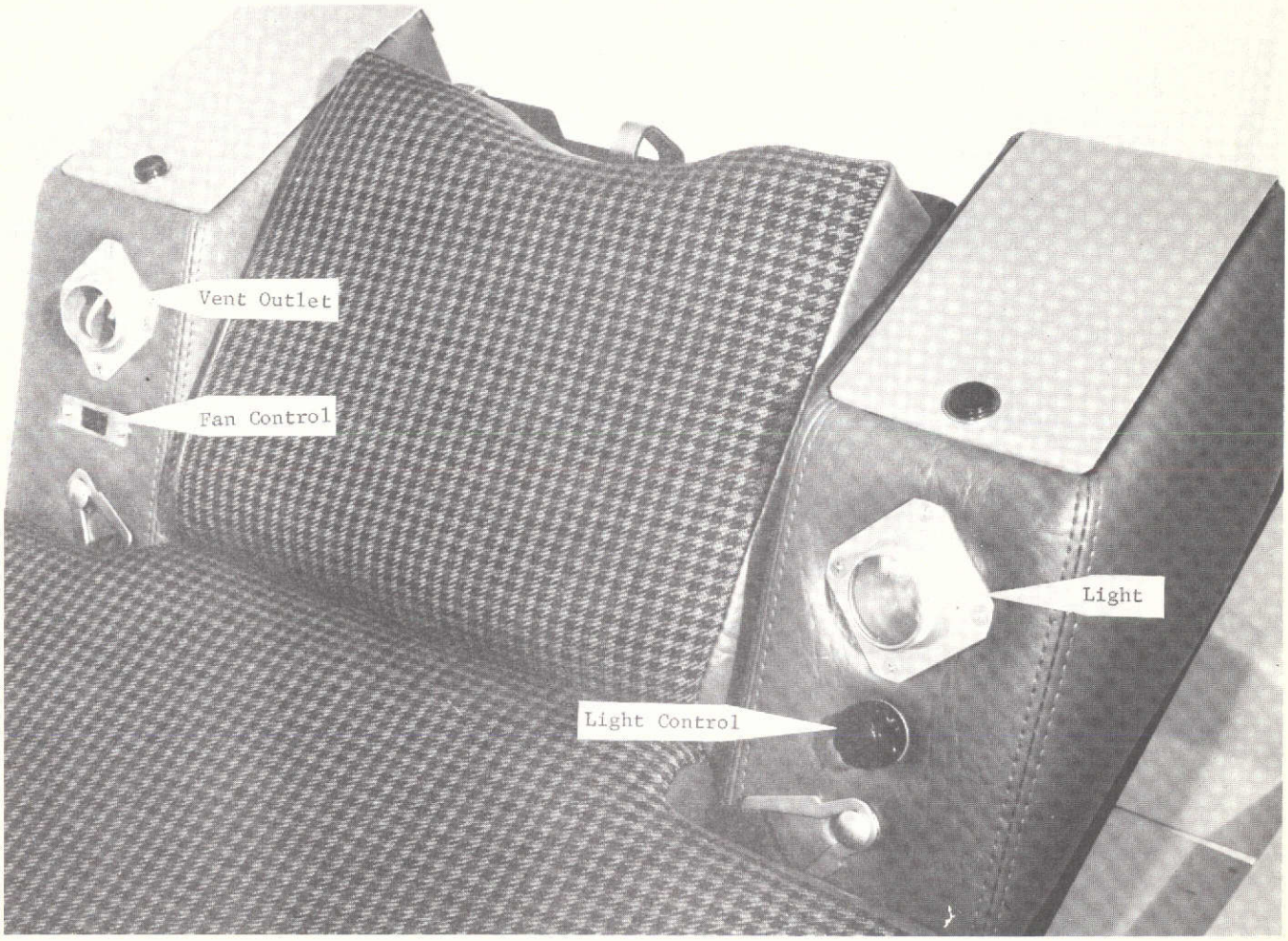


Figure V-14 Light and Ventilation Details

2.3.2 Ventilation

The ventilation for the couch to prevent CO_2 buildup when the privacy curtains are deployed is supplied by a vaneaxial fan mounted to the underside of the back section with ducting to an adjustable outlet. The adjustable outlet and switch are mounted in a housing on the upper right hand side of the back section that also contains the tissues dispenser as depicted in Figure V-14. When the back section is in the flat bed configuration, fresh cabin air is taken in from the rear of the couch through a grille and ducting to the fan. In the sitting position, the cabin air is taken in directly through the bottom of the fan housing. The flow rate of the fan is adjustable from 0 to 20 cubic feet per minute at a velocity of up to 50 feet per minute. The adjustable outlet can be directed within a 30 degree cone.

2.4 Stowage Provisions

2.4.1 Garment Locker

Within the basic couch envelope, a storage volume of 1.5 cubic feet for garments, (clean and soiled) and shoes is provided. The garment locker is partioned such that the clean and soiled clothes and shoes are separated by a vapor barrier. Access to this stowage locker is from the rear of the couch through a sliding door in the couch shell. The locker is retained in the lower frame work of the couch with wing-nut fasteners.

2.4.2 Clerical Tray

The clerical tray serves as a surface for writing, holding papers, food tray holder, and as a storage locker for personal gear, The volume provided for the personal gear is approximately 0.8 cubic feet. The design shall afford easy utilization of the tray while seated in the couch and the arm rests in the deployed position. The tray is infinitely adjustable when attached to the arm rests from a position parallel to the couch seat, with the couch in the seating configuration, through a 90 degree arc to a position parallel with the couch back section. Figure V-15 depicts the mechanism used to obtain the required clerical tray movement and rigidity.

2.4.3 Trash Receptacle

Within the basic couch envelope, and within easy reach of the couch occupant, storage provisions of approximately 0.1 cubic feet is provided to receive assorted trash items. The design of the receptacle retains the trash in all operational environments and is convenient to dispose of and/or remove all trash either in flight or during ground maintenance.

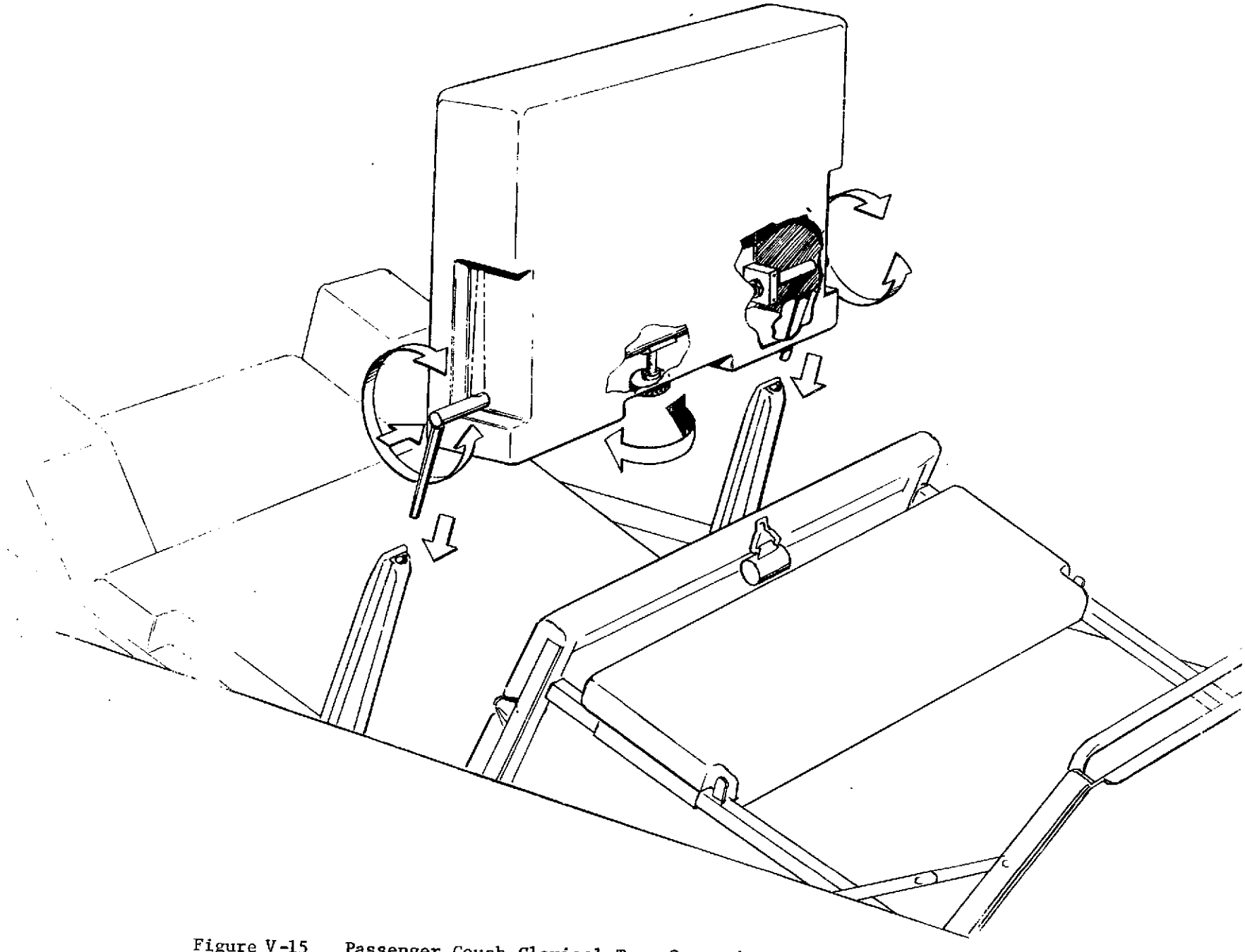


Figure V-15 Passenger Couch Clerical Tray Operation

2.4.4 Vomitus Bag Receptacle

A vomitus bag receptacle is provided within the trash receptacle and within easy reach of the couch occupant. The volume of the receptacle is sufficient to store a minimum of six vomitus bags. The package size of the vomitus bag is 6 inches by 7 inches by 0.2 inches thick but being flexible it can be folded into different configurations.

2.4.5 Tissue Dispenser

The tissue dispenser is located within easy reach of the couch occupant and contained within the ventilation housing. The envelop of the dispenser accepts a tissue box with dimensions of 4.25 x 4.50 x 5.50 inches.

2.5 Ancillary Components

2.5.1 Tape Player

The tape player is contained within the couch basic envelope, and located within easy reach and view of the couch occupant when in the seated position. The envelope of the tape player is 2.75 x 6 x 6.5 inches and weighs 4.4 pounds. The unit operates from a 12 volt DC source and is protected by a 3 amp fuse. The unit accepts and plays a standard 8 track stereo cartridge with a 4-channel tape. The tape player controls consist of volume, balance, tone control and channel selection and indication. An ear phone jack receptacle is on the face of the unit allowing private listening with a headset which is stowed in the light housing.

2.5.2 Privacy Curtain

A privacy curtain is provided and attached to the couch without

the aid of tools. The curtain is designed to form an enclosure in front of the couch and also be capable of forming a privacy screen on each side of the couch as illustrated in Figure V-16. The curtain is of a fire retardant cloth material with the supports of metal. The curtain is capable of being stored in the lower couch shell through the center door.

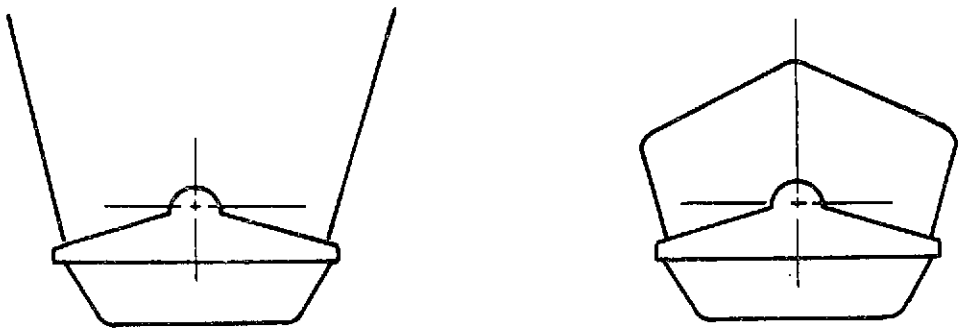


Figure V-16 Couch Privacy Curtain Installation

2.5.3 Sleep Restraint

A sleep restraint is provided to accommodate the 5th to 95th percentile male. The sleep restraint is made of a fire retardant cloth and designed to be firmly attached to the couch cushions or the couch inner frame. The restraint incorporates a single zipper opening that is operable from either inside or outside. The restraint also employs a minimum of three two-inch elastic bands sewn into the

material. The elastic bands are located across the upper torso area, the waist area, and thigh area. The sleep restraint is depicted by Figure V-17.

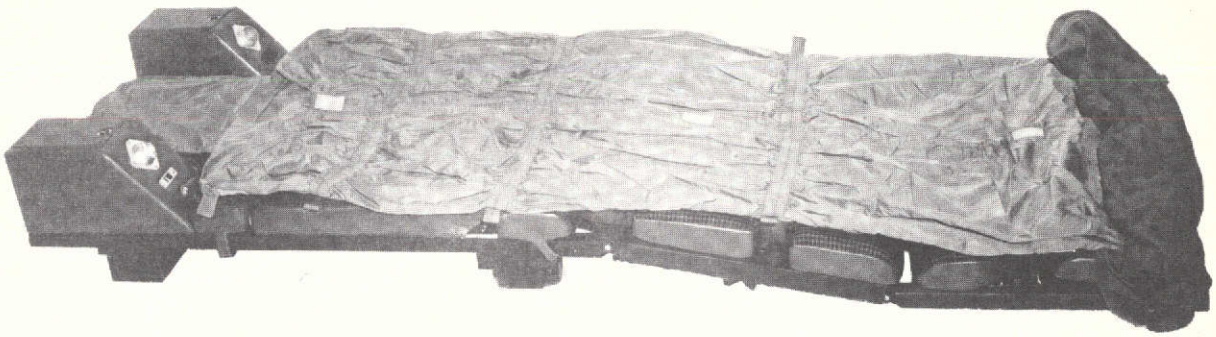


Figure V-17 Shuttle Passenger Couch Sleep Restraint

3.0 Passenger Couch Support Stand

The remaining piece of deliverable hardware is the couch support stand. The support stand is used to hold the couch in both the horizontal and vertical mounting positions to simulate the vehicle interface. The support stand was utilized in all test phases to hold the couch to simulate the actual Shuttle vehicle. In Figure V-18 the support stand is shown holding the basic couch framework in the vertical position.

B. COUCH VERIFICATION MODEL TEST PHASE

The most comprehensive series of tests of the couch assembly were those conducted in an ambient, one-g environment. All aspects of the couch system were evaluated by several subjects ranging in size from the 5th to 95th percentile. Electrical power was supplied to the couch so that the light, fan and stereo unit could be utilized.

Data obtained from the one-g tests was of a qualitative nature; crew/couch interfaces and performance characteristics were evaluated in the following areas: ingress/egress capability, comfort and convenience of system design, couch adjustability, accessibility to controls and stowage items, suitability of restraints, clerical tray, lighting, fan and stereo, mounting hardware provisions, and eight-hour sleep test acceptability.

1.0 Functional Tests

Subjective evaluations of the couch showed that controls were accessible and fairly easy to operate. Either end could be used to adjust the headrest or armrests, to operate the light or fan, or to reach the storage compartments in the head area as shown in Figure V-19. The five-belt restraint system operated very smoothly; the single-turn release mechanism and the retractable belts were convenient. Adjustment of the body support position, seat pan or foot pan was easily completed while restrained with the lap belt. When a new subject attempted to adjust the couch from the full seated to the flatbed position, the initial attempt was sometimes awkward until the subject learned where to apply pressure with his body to achieve the desired support position. After one or two attempts, however, adjustments were easily and quickly accomplished. Several subjects found it convenient to grasp the sides of the couch shell top surface, and used this means to stabilize the body and apply pressure.

The electrical system of the verification model (fan, light, tape player and 12-VDC power supply) operated perfectly and the controls were accessible in any body support position. Figure V-20 depicts the test subject fully restrained and listening to the tape player through earphones. The noise level of the fan was very low and was indistinguishable from normal background noises. The stereo unit was simple to operate and readily accessible.

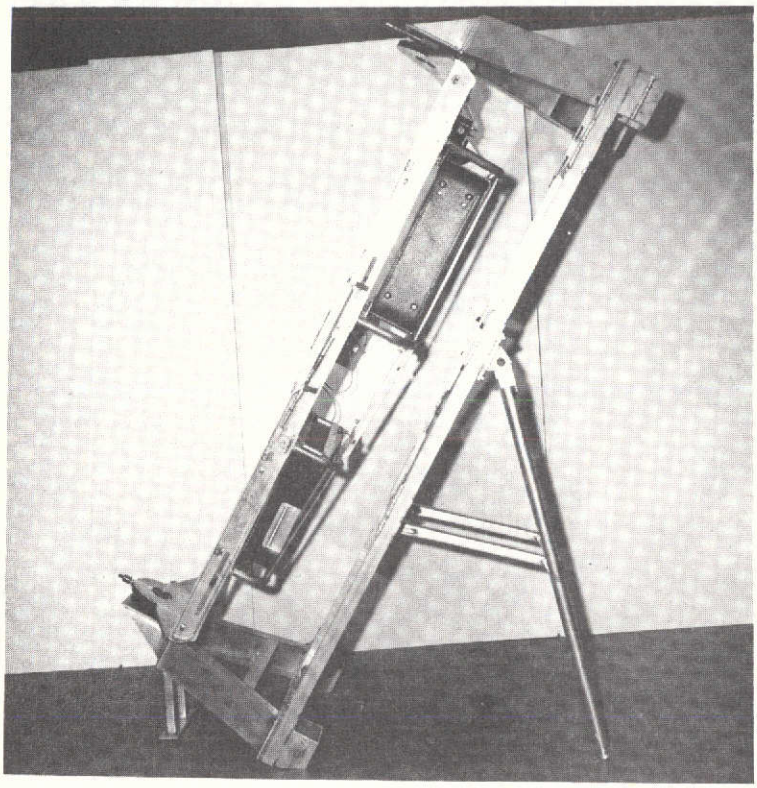


Figure V-18 Couch Mounting Stand-Vertical Position

Figure V-19 Access to Tissue Dispenser

The armrests provided a very stable platform for attachment of the clerical tray, which was easy to adjust to the desired angle and did not interfere with the subject's knees as illustrated in Figure V-21.

The interface between the couch and its mounting stand was trouble free and the couch could be removed from the stand by two men (one each end).

2.0 Sleep Test

In order to evaluate the overall comfort of the verification model over extended periods and the sleep restraint during actual use, an eight-hour sleep test was conducted. A summary of that test follows:

Test Configuration: The couch was set in the flatbed position with all cushions in place. The sleep restraint was placed on the cushions and loosely secured to the couch framework by means of bungee cords (two each side).

Test Period: The subject was in place in the restraint from approximately 11:30 PM until 7:00 AM the next morning. Almost seven hours of this time were actually utilized for sleep.

Subject Comments: In general, the couch provided a very comfortable sleep station and was comparable in many respects to a standard bed. The sleep restraint was acceptable in all details except for tightness around the shoulders (subject approximately 95th percentile in height) which was noticeable in all body positions. Couch length and width were sufficient to accommodate the subject in all positions (on each side, stomach and back). At no time during the test period did the subject strike his head on the end plate, headrest control or headrest storage areas; the knees never struck the couch side frame or any other

Figure V-20 Restrained While Listening to Tape Player

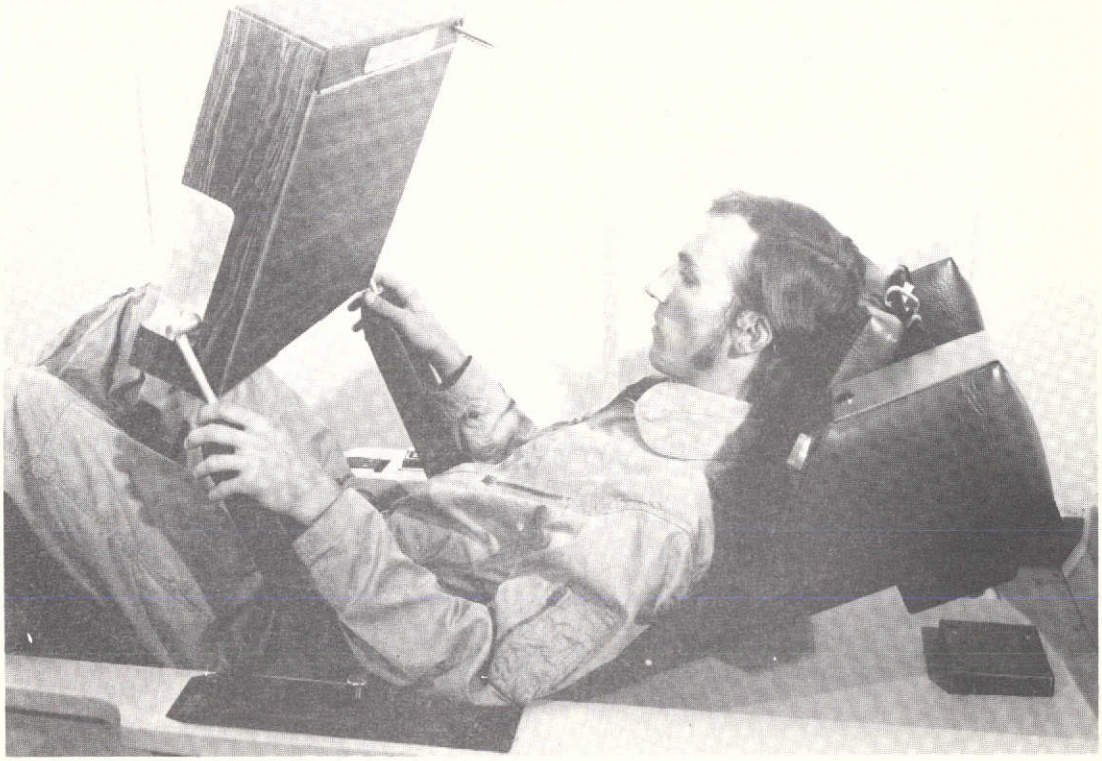


Figure V-21 Clerical Tray Attached to Arm Rests

protuberances. In a supine position the subject was aware that his feet occasionally touched the couch end plate but the effect was very negligible. No pressure points on the body were evident at any time. Although the subject was aware of the proximity of the storage spaces on each side of the headrest, they did not interfere with comfort.

Initially the sleep restraint was fully zipped up and the subject's arms were placed through the arm slits. Within a few minutes a heat buildup was noticeable around the feet and the restraint was partially unzipped; the heat quickly dissipated and did not build up again later during the night when the zipper was readjusted upward.

Although it was possible to turn and assume any position within the restraint, the tightness around the shoulders was sufficient in most positions that the subject elected to slip the restraint off the shoulders for the majority of the test period. The transverse elastic straps within the restraint provided an agreeable amount of tension in most positions and added to the feeling of security. The bungee cords held the restraint in position on the body support sections and there was little inclination for the subject to become entangled in the restraint even while changing positions. Near the end of the sleep period the subject utilized the outer blanket for greater warmth while leaving the upper body free of the restraint itself.

At the start of the test period the subject listened to the stereo unit for approximately ten minutes and was able to operate the necessary controls very easily while totally enclosed within the restraint. The time required to fall asleep initially was approximately fifteen (15) minutes. The subject awakened on three occasions during the night, probably due to extraneous noises within the test area, but was able to fall asleep again very quickly. The test was terminated when renewed

activity in the test area made continued sleep impossible even though the subject was still very comfortable and would have preferred a longer sleep period.

In summary, the subject was satisfied with the couch and restraint arrangement, and felt he received a restful sleep period in all respects.

3.0 KC-135 Tests

The couch Verification Model was utilized for zero-g testing aboard the KC-135 aircraft to compare its operational capabilities in that environment to its performance in neutral buoyancy and one-g environments. In addition, a check on the structural integrity of the SPCVM was achieved and the ability of the couch to properly seek the gravity vector during aircraft pullout (couch rotational lock disengaged) was evaluated. The SPCVM was installed in the athwartship position on the KC-135 and was tested through a total of 258 parabolas; approximately 55 parabolas were utilized for active testing with male and female subjects. During the remaining parabolas the couch was left in place on board the aircraft and experienced the ± 2.5 g's associated with the parabolic flight path.

Data acquisition included an eight-minute 16mm movie, still photographs and an extensive debriefing of the test subjects subsequent to the flights. Table V-1 presents a summary of the tests and the evaluation of the tests and test subjects comments (male and female) on each of the couch systems.

The couch was tested both with and without the cushions in place and subjects found both configurations to be very comfortable. Since the cushions are several inches thick, the position of the body with respect to the couch shell is slightly lower when the cushions are not

used. Some subjects felt elbow pressure but did not identify this as a major problem. Without the cushions in place, the subject could not feel any pressure point on his back, due to the couch structure during the 2.5 "G" pullout.

4.0 KC-135 Test Summary

In summary, the couch successfully completed the KC-135 zero-g flights even though several areas proved to be troublesome. The couch did demonstrate that the overall design and mounting technique were feasible designs for a Shuttle Orbiter passenger couch which must perform under varied conditions. The athwardship mounting and rotational capability proved that the couch would seek the proper gravity vector to prevent physiological damage to the couch occupant. The problem areas were partly due to test subjects being unfamiliar with the couch system, failure to comply with test procedures, the malfunction of some controls, and the lack of a qualified test conductor during the test. The areas that are recommended to be reworked and/or re-designed to overcome the deficiencies and problems experienced during the test are outlined in paragraph 5.0.

Table V-1 SPCVM KC-135 Evaluations

Area Tested	Merits	Deficiencies	Remarks
Ingress/Egress	Formed lip along each side provided a good hand hold to position the body relative to the couch. Regardless of the couch configuration there were adequate hand holds such as couch sides, vent and light housings, arm rest, foot restraint, etc.	Formed lip required the user to grasp the side with the palms up or down, depending on the users position relative to the couch. Thus at times the user could not grasp the side lip in a manner that would permit a torquing action.	Comments from the test subjects suggested hand rails along the entire length of the couch side so they could be grasped in any manner desired by the user. Reference Figures V-22 thru V-24.
Restraint System General	Five belt system provided adequate restraint for all operations. The single release of all belts operated very smoothly.	Crotch belt seemed unnecessary since all loading was through the rear of the couch.	All restraints were located to provide adequate restraint. Reference Figure V-25.
Shoulder Belts	Inertia reels allowed the necessary movement to perform the couch functions.	It was difficult to use the belt storage pins with the couch back cushion in place.	It was determined the inertia reels locking activating force should be reduced from the 1.5 to 3 g's to .75 to 1.5 g's.

Table V-1 (Cont'd)

Area Tested	Merits	Deficiencies	Remarks
Lap Belt	Retractable belt met the requirement for a convenient storable belt system.	No Place to store either the buckle or hook end. Lack of a stop on the belt to prevent complete retraction below the seat.	Some test subjects would have preferred a manually adjustable belt to allow different tensions in zero gravity.
Crotch Belt	Easily accessible and operated very smoothly.	When attached it hinders the couch occupant from changing positions on the inner body support.	An inertia locking reel in the .75 to 1.5 g's range should be investigated as a replacement.
Couch Adjustments			
Body Support Position	With both hands occupied holding the release tabs open, there is no chance to pinch the hands in the structural members. The body could be positioned from a supine to an erect sitting position.	The release tabs were small and with both hands in a fixed position the occupant had to use "body english" to change positions. The initial design allowed too much free play and eventual failure of the system.	To fully incorporate the modification of the addition of attaching the "pass thru" P.L. Porter mechanical locks to the back section, the control of these locks require some redesign. This eliminates almost all free play in the system. Some subjects felt some type of mechanical assist would

Table V-1 (Cont'd)

Area Tested	Merits	Deficiencies	Remarks
Body Support Position (Cont'd)			be useful to change body positions and a one handed operation would be preferred.
Seat Adjustment	Not tested.		One-g tests determined this feature is not required.
Foot Pan	The adjustment range was adequate for all personnel and the operation was very smooth. Redundancy was built-in with a lock on each side. Spring return worked very well.	The control tabs were small and required both hands to operate. Occupant had to bend over to reach the control tabs. Foot restraint would not accept flight boots. Reference Figure V-26.	Since the flight boots would not fit under the foot restraint, this item was not used to assist in entry. When it was used while sitting it forced the calf of the occupant's leg into the structural member of the leg section, causing a pressure point. Some subjects recommended that this adjustment be a one-handed operation.

Table V-1 (Cont'd)

Area Tested	Merits	Deficiencies	Remarks
Arm Rests	Operated very smoothly and provided some security to the couch occupant.	The inherent free play made the couch test subjects feel as though the arm rests were not strong enough.	The arm rests operated satisfactorily for what they were intended.
Head Rest	Operated smoothly and provided adequate support for the head.	With seat and back cushions in place the head could come in contact with the control handle during the 2.5 "G" pull-out.	The almost full-up position was used by most test subjects. It was suggested that the head set elevation be by means other than a hinge in order to get support for the full head.
Accessibility	The couch occupant could reach all positioning controls, tape player, headset stowage, tissue dispenser, and trash receptacle while in any position in the couch.	Access to the stowage compartments are only accessible from the rear of the couch. The lids on the light/vent housings required too much effort to close. The controls along the top of the couch shell sides could be tilted toward the occupant to facili-	During the flights the rear sliding compartment doors popped loose several times. the design did retain the doors in a loose condition. It would take major modification to improve visibility of controls.

Table V-1 (Cont'd)

Area Tested	Merits	Deficiencies	Remarks
Accessibility (Cont'd)		tate visual acquisition and improve access. Attachment of the shoulder belts on the storage pins was difficult with the cushions in place.	
Rotational Capabilities	With the rotational lock released, the couch moved very easily about its longitudinal axis and sought the gravity vector as the aircraft completed its parabolic flight path.	The release control would flex and therefore would not completely release the locking pawls every time. The lock actuating cable would tend to hang up. The pawl actuating levers should be spring loaded. There was no dampening of the movement.	The bracketry supporting the rotational control lever requires some structural strengthening to provide a solid base. The control lever material should be changed from aluminum to steel. Rework of the locking pawl actuating system is required to provide a smooth operation.

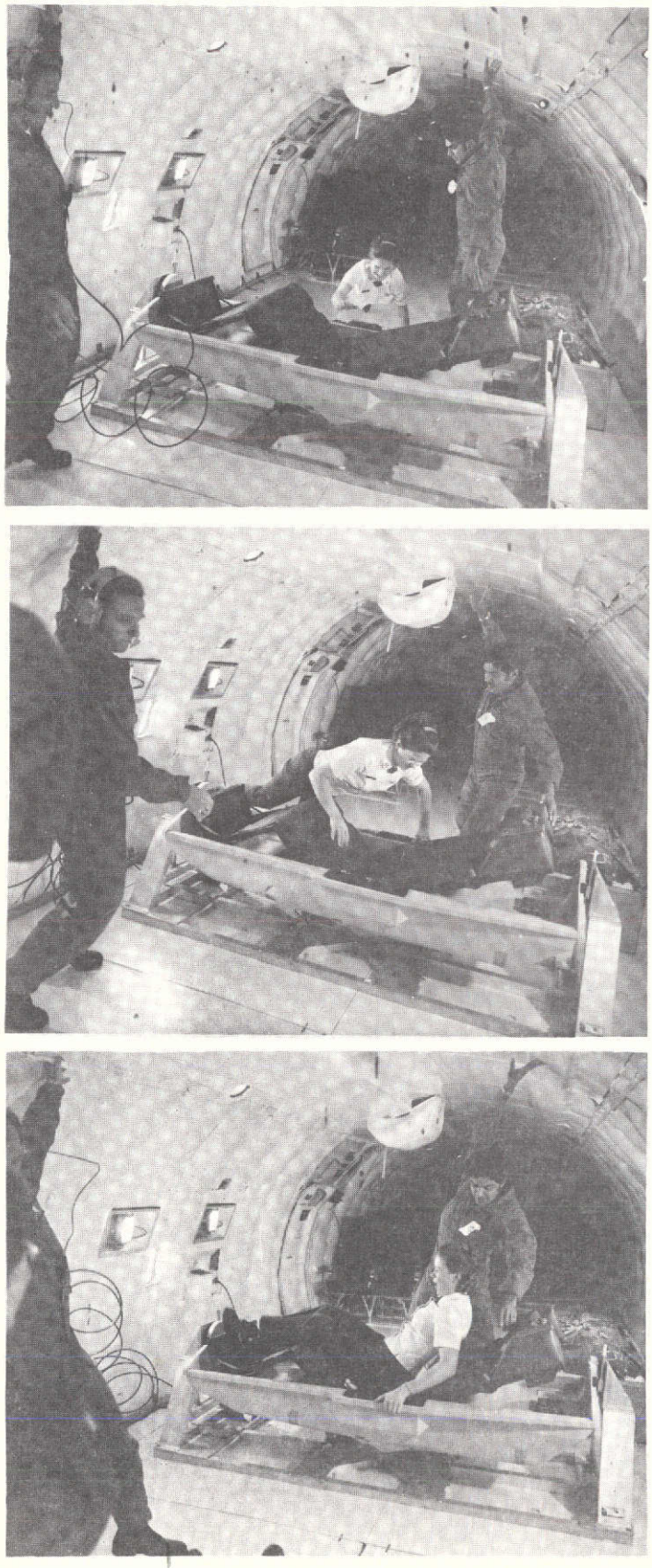


Figure V-22 - V-24 Couch Ingress by Female Subject

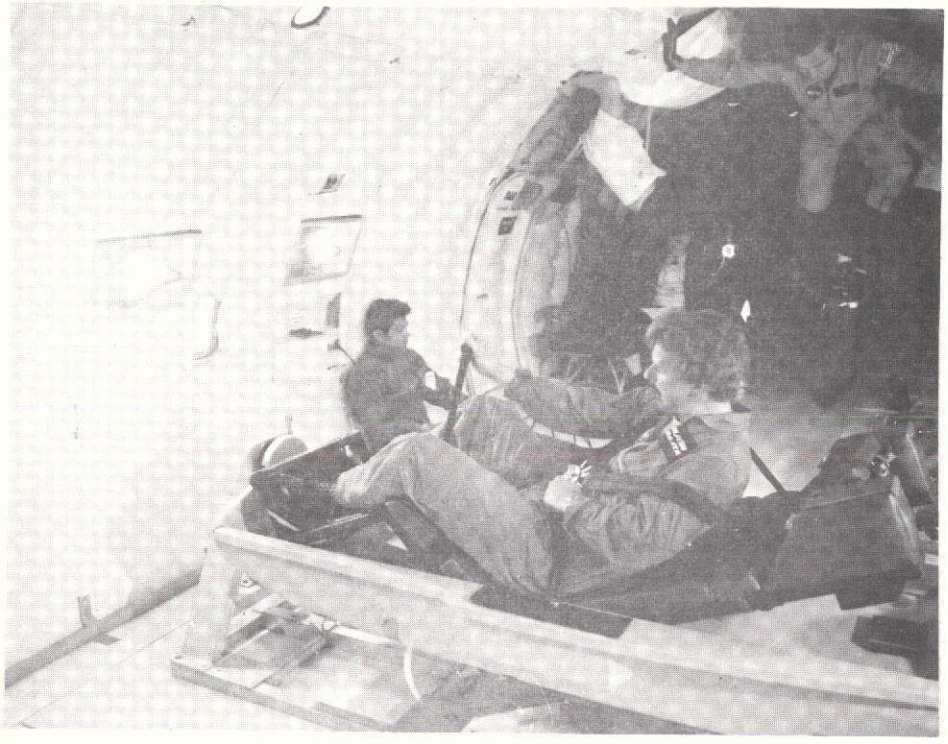


Figure V-25 Subject Attaching Restraints

Figure V-26 Subject Adjusting Foot Pan

5.0 Recommended Modifications

5.1 Rework of Existing Design

In order to put the couch in a pretest condition including improvements in areas that do not affect the design, the following rework is recommended:

a. The body support actuating mechanism and control require rework to incorporate two "pass through" P.L. Porter mechanical locks attached to the back section. The controls to operate these locks should be made larger and a more positive actuation method for release and lock should be used.

b. The lids on the vent and light housing should incorporate a better locking device and spring to hold the lid in the open position.

c. Eliminate the interference between the leg section of the body support and the Kydex foot inner panel by replacing the lower structural cross member which was added during the one-g test to prevent twisting of the leg section side members, with a more compact member.

d. Structurally strengthen and reduce free play in the arm rests to provide a more rigid arm rest.

e. Structurally strengthen and change material in the couch rotational control lever to eliminate continual adjustment of the release mechanism. The control supporting bracketry also needs to be strengthened to provide a solid attach point.

f. Rework couch rotational mechanism to provide a more positive release and lock. This must involve the pawls, actuating levers, gear, and housing. This is in addition to pinning the pawls to retain the relative position between the gear and pawls. The actuating cables also require some rerouting and support changes to provide a smoother operating mechanism.

g. Replace shoulder belt restraints to incorporate the lower .75 to 1.5 g's locking actuating force inertia reels to more closely meet the requirements of the Shuttle Orbiter. Modify to permit easier retraction and stowage on the retaining pins.

h. Provide a storage space in the Kydex inner panel for the lap belt buckle and a storage stud on the other side for the other end in conjunction with a positive stop on the belt to prevent the belt from retracting completely into the reel below the seat.

i. Trim Kydex shell as required to eliminate all sharp edges and provide a pleasing appearance.

5.2 Modifications and Rework

Test subjects comments indicated that the following work would be desirable to improve the couch system. Those changes should be investigated in addition to the improvements stated in subparagraph 5.1:

a. Redesign the body support control actuating mechanism and controls to provide single hand actuation and provide larger control knobs.

b. On the leg section of the body support investigate the foot pan adjustment control frame two handed operation to be replaced with one hand operation.

c. Redesign the belt restraint system to an inertia reel crotch belt and manual adjustable lap belt that can be stored within the couch shell.

d. Incorporate a dampening device in the couch rotational mechanism to prevent over-reactions in the couch movement due to momentum or direct forces imposed on the couch.

e. Incorporate a mechanical assist on the body support section to help change body positions in a zero-gravity environment.

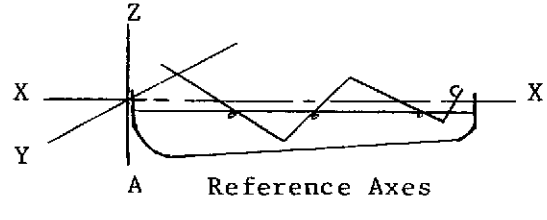
C. VERIFICATION MODEL MASS PROPERTIES STATEMENT

The final mass properties was performed for the shuttle passenger couch using the design fabrication of the couch verification model. Throughout the program the mass properties was updated on a monthly basis as more of the calculated and actual weights became known. The weights were presented as either estimated, calculated, or actual with a computer readout summarized into percentages for the monthly reports. Estimated is defined as the weight determined from schematics; calculated as the weight calculations from engineering drawings; and actual is defined as the physical measurement. As indicated by Table V-2, the final weight increased for manufactured items but decreased significantly for purchased items from the initial weight estimation.

Table V-2 Mass Properties Statement

SHUTTLE PASSENGER COUCH ASSEMBLY INSTALLATION PRONE POSITION

DESCRIPTION	DWG NO.	WEIGHT (POUNDS)		CENTER OF GRAVITY			RADIUS OF GYRATION		
		INITIAL	FINAL	X	Y	Z	KX	KY	KZ
					(IN)			(IN)	
Adapter, Latch	110-019	1.5	2.313	1.3	0.	0.	2.8	2.1	2.1
End Fitting	110-009	4.5	5.738	1.3	0.	0.	2.8	2.1	2.1
Adapter, Latch	110-019	1.5	2.313	79.7	0.	0.	2.8	2.1	2.1
End Fitting	110-009	4.5	5.738	79.7	0.	0.	2.8	2.1	2.1
Couch Mounting	100	12.0	16.102	40.5	0.	0.	2.8	39.3	39.3
Body Supt Frame	220-009	72.0	63.103	35.8	-.0	2.6	8.7	23.2	24.9
Lock, Seat Position	211	10.0	2.579	45.5	0.	4.7	10.7	9.3	14.1
Main Supt Frame	230-009	35.0	30.052	38.0	0.	5.9	10.6	24.5	26.3
Couch Shell	260	40.0	39.500	40.4	0.	8.0	10.7	23.4	25.2
Couch Struc +Shell	200	157.0	135.234	37.6	-.0	4.7	10.0	23.6	25.2
Lockers + Trays	340	12.0	16.310	40.0	0.	10.3	5.7	19.2	19.2
GFP, Vomitus, Trash	330	1.5	2.000	38.3	-4.3	5.5	13.4	1.3	13.5
Stereo Unit	320	7.5	4.405	39.5	14.0	5.5	3.0	2.0	3.0
Controls	310	1.0	.500	44.5	13.6	4.5	1.0	1.0	1.0
Couch Stowage Items	300	21.0	23.215	39.8	3.8	8.8	9.2	15.4	17.2
Privacy Curtain	410	7.0	4.208	39.5	-14.0	8.0	1.0	5.0	5.0
Sleep Restraint	440	1.5	1.982	20.0	0.	12.5	4.7	6.6	7.7
Power Supply	530-	5.5	3.678	8.0	0.	5.0	2.0	2.0	2.0
Couch Subsystems	400	14.0	9.868	27.1	-11.3	5.2	6.9	14.7	15.8
Total Couch		204.0	184.419	37.6	3.8	5.5	10.0	24.6	26.3
Passenger		212.300	212.300	32.7	0.	.8	4.8	17.5	18.0
Personal Gear		15.000	15.000	62.1	-0.	-0.	0.	0.	0.
Pass. + Pers. Gear		227.300	227.300	34.7	0.	.7	4.6	18.4	18.8



Reference Axes

VI. QUALITY ASSURANCE, RELIABILITY, AND SAFETY SUMMARY

A. QUALITY ASSURANCE

During the performance of this program, quality requirements were assured by the participation of the Quality Assurance Department of MMC. Their function was to sign-off all purchase requisitions for parts and materials, inspect and sign-off all incoming parts and materials, review test procedures and inspect test set-up, and the inspection and sign-off of the items immediately prior to shipment.

B. RELIABILITY

The reliability requirements of the program were satisfied by the identification of failures during the testing phase and the performances of an FMEA of the components in the couch. The FMEA is presented as Table VI-1. There were no structural failures of the main frame and support. On the inner frame the leg section required an additional brace across the lower end to support the high torque loads that could be imposed from standing on the foot pan. During final assembly the pillow blocks which support the center shaft at the body support pivot point allowed the shaft to rotate excessively, thus damaging one of the P.L. Porter locks. This was corrected by placing set screws in the pillow blocks to hold the shaft. Other problems/failures which occurred during end item testing, and the corrective actions, are summarized in section V.B. of this report. The design of the couch Verification Model precludes the use of limited life components which would degrade either in operation within the duration of anticipated use or in storage.

FOLDOUT FRAME 1

TABLE VI-1 FAILURE MODES AND EFFECTS ANALYSIS

FOLDOUT FRAME 2

IDENT. NO.	ITEM	FUNCTION	FAILURE MODE AND CAUSE	FAILURE EFFECT ON SYSTEM	CREW/PASSENGER ACTION REQUIRED	CRITICALITY
1	Ventilation Fan	Circulates Air Thru Diffuser for CO_2 Control and Thermal Comfort	Fails to Start (Fails Off)	Bleed Air From Cabin Atmosphere Cannot Circulate. CO_2 Buildup in Immediate Vicinity	Privacy Curtain Should Not Be Used.	III
2	Fan Switch	Activates Ventilation Fan	Fails to Shut Off Fan (For Failure to Start Fan, See Ident. No. 1)	Continuous Fan Operation, Power Drain on Vehicle Systems	To Deactivate Blower, Disconnect Power Supply to Couch at Electrical Connector, disconnect Blower Switch from 115 VAC Source, Reconnect Electrical Power Supply to Couch.	III
3	Diffuser	Directs Air Over Passenger in Couch	a) Fails Closed or Direction Capability Lost	Same as Ident. No. 1	Same as Ident. No. 1	III
			b) Fails Full Open	Continuous Full Flow Over Passenger When Fan is On.		III
4	Ventilation Ducting (Fan to Diffuser)	Carries Airflow For CO_2 Control and Thermal Comfort.	Clogs	Same as Ident. No. 1	Same as Ident. No. 1	III
5	Light Assy	Provides Illumination for Tasks in Couch	Fails Off	Illumination for Various Tasks Must Come From Vehicle General Lighting System.	Perform Procedures to Isolate Failure	III
6	Light Switch	Activates Light Assy	a) Fails to Turn Light On	Same as Ident. No. 5	Perform Procedures to Isolate Failure	III
			b) Fails to Turn Light Off	Continuous Light Operation, Power Drain On Vehicle Systems	To Deactivate Light, Disconnect Couch Power Supply, Disconnect Wire at Terminal (1) of Rheostat, Reconnect Power Supply to Couch.	III
			c) Rheostat Fails	Illumination Range Limited	None Necessary	III
7	Head Rest Position Locks	Adjust Headrest Position in Couch	a) Locks Fail to Release-Lever Failed or Cable to Lock Broken	Head Rest Position Cannot be Changed From Couch; Manual Adjustment Still Possible	To Readjust Head Rest, Exit Couch and, if cable is broken, Manually Release Locks. If Lock Itself has Failed, Follow Maintenance Procedure Applicable.	III
			b) Lock on Either Side of Head Rest Fails	Operational Lock can Maintain Head Rest Position, Withstand Anticipated Loads, and Allow Adjustment	None Necessary; if Desired Follow Applicable Maintenance Procedures for Porter Lock.	III
8	Arm Rest Locks	Adjust Arm Rests Individually and Lock in Position.	a) Lock Fails to Actuate (one or Both Arm Rests)	Arm Rest(s) Cannot be Locked in Position, Must Remain Flat in Stored Position.	None Necessary; if Desired Follow Maintenance Procedure for Porter Locks.	III
			b) Lock Cannot be Released - Lever Failed	Arm Rest Position Cannot be Changed	None Necessary; if Desired Follow Maintenance Procedure for Porter Locks.	III
9	Seat Pan Locks	Lock Seat Pan in Position After Adjustment for Passenger Size and Comfort.	a) Lock Fails to Actuate (One Side) - Tapered Pin Broken	Operational Lock can be Utilized to Fix Seat Pan Position.	None Necessary	III
			b) Lock Cannot be Released - Spring Failure	Seat Pan Cannot be Adjusted; if Failure Occurs in Other Than Forward Position, Seat Pan Must be Manually Adjusted to Achieve Flat Bed Position	To Release Seat Pan, Exit Couch, Remove Seat Pan Cushion and Follow Applicable Maintenance Procedure.	III

FOLDOUT FRAME 1

FOLDOUT FRAME 3

TABLE VI-1 FAILURE MODES AND EFFECTS ANALYSIS (Cont)

IDENT NO.	ITEM	FUNCTION	FAILURE MODE AND CAUSE	FAILURE EFFECT ON SYSTEM	CREW/PASSENGER ACTION REQUIRED	CRITICALITY
10	Foot Pan Locks	Lock Foot Pan in Position after Adjustment for Passenger Size and Comfort.	a) Lock fails to Actuate (One Side)	Operational Lock can be Utilized to Fix Foot Pan Position	None Necessary	III
			b) Lock Cannot be Released -Lever Failed	Foot Pan Cannot be Adjusted; if Failure Occurs in other than fully Extended Position, Foot Pan must be Manually Adjusted to Achieve Flat Bed Position.	Follow Applicable Maintenance Procedures	III
			c) Spring Failure	Foot Pan Must be Adjusted Manually	None Necessary	III
11	Foot Pan Braces	Lock Foot Pan in Sitting Position (90^{o} to Seat Pan)	Failure of Brace (One Side)	Operational Brace can Lock and Support Foot Pan in 90^{o} Position.	None Necessary	III
12	Body Support Locks	Adjust Positions of Body Pans from Flat Bed (180^{o}) to Fully Seated (90^{o})	a) Lock Fails to Actuate (One Side)	Operational Lock can Adjust Body Pans and Withstand Loads Applied	None Necessary	III
			b) Lock Cannot be Released-Lever Failed or Material Degradation	Body Support Position Cannot be Changed From Couch, Manual Adjustment Necessary to Achieve Proper Position for Re-entry/ Landing.	Perform Maintenance Procedure for Body Support Locks	III
			c) Cable between activation lever and pass-through lock breaks or detaches (either side)	Foot Pan Cannot be Adjusted; if Failure Occurs in other than fully Extended Position, Foot Pan must be Manually Adjusted to Achieve Flat Bed Position.	Perform applicable maintenance procedure	
			d) Pass-through lock fails to actuate (either side)	Some free-play may develop in the inner frame articulation; remaining locks can control adjustment and withstand all loads.	None necessary	
			e) Pass-through lock cannot be released (either side)	Foot Pan Cannot be Adjusted; if Failure Occurs in other than fully Extended Position, Foot Pan must be Manually Adjusted to Achieve Flat Bed Position.	Perform applicable maintenance procedure.	
13	Couch Rotational Lock	Fixes Couch Position with Respect to its Longitudinal Axis	a) Locks Fails to Actuate -Spring Failure	Couch Free to Rotate About Longitudinal Axis, Ingress/Egress Must be Accomplished with Greater Care	None Necessary	III
			b) Lock Cannot be Released -Lever, Cable or Pawl Failure	Couch Fixed in Given Position, Zero-G Access May be Limited, Lock Must be Manually Released Prior to Re-entry/Landing	Perform Maintenance Procedure for Couch Rotational Lock.	III
14	Restraint Harness Lock	Provides Central Locking Mechanism for Shoulder, Lap and Crotch Belts	a) Fails Open	Harness Inoperative	Replace Harness Lock	III
			b) Fails Closed	Passenger Restrainted, Emergency Egress Hampered, but Passenger can Still Disengage Body From Harness	Perform Maintenance Procedure for Couch Rotational Lock	III
15	Belt Inertia Reel or Self Adjusting Reel	Retract belts for Storage	Fails Stored or Fails Open (Any One Reel)	Belt Becomes Unusable, Other Belts can Still be Utilized for Restraint	Replace Reel	III
16	12-Volt Power Supply	Converts 115 VAC to 12-Volt DC for Use by Light Assy and Stereo	Fails to Provide Output	Light Assy and Stereo Inoperative	If Blower is Operative, Failure is in Circuit Breaker, Connector, Plug or Vehicle Power Supply. Perform Fault Isolation Procedures.	III

TABLE VI-1 FAILURE MODES AND EFFECTS ANALYSIS (Cont)

IDENT. NO.	ITEM	FUNCTION	FAILURE MODE AND CAUSE	FAILURE EFFECT ON SYSTEM	CREW/PASSENGER ACTION REQUIRED	CRITICALITY
17	Circuit Breaker	Provides Circuit Protection	a) Fails Closed	No Circuit Protection for Stereo, Blower, Light or 12 VDC Power Supply	Perform Fault Isolation Procedures Replace Circuit Breaker	III
			b) Fails Open	Stereo, Blower, Light & 12 VDC Power Supply Inoperative	Perform Fault Isolation Procedures Replace Circuit Breaker	III
18	Stereo and Headset	Provides Entertainment for Passenger	a) Fails Off, or Headset Failure	Entertainment Unavailable	None Necessary	III
			b) Fails On	Continuous Operation, Power Drain on Vehicle Systems	Isolate Stereo from Power Supply to Prevent Power Drain	III
19	Sleep Restraint	Restrains Passenger During Sleeping	a) Zipper Fails Shut	Ingress/Egress More Difficult	None Necessary	III
			b) Zipper Fails Open	Restraint Only Partially Effective, Harness Belts can be Used to Supplement Sleep Restraint	None Necessary	III
20	Clerical Tray Rotation Lock	Allows Tray to be Rotated to any Desired Angle, then Locked in Position	a) Fails Locked	Clerical Tray Angle Cannot be Changed, May Limit Some Activities	None Possible	III
			b) Fails Unlocked	Tray Free to Rotate, Cannot be Utilized	None Possible	III

C. SAFETY

The safety requirements of the program were assured by the performance of a stress analysis of the basic structure and the selection of materials to meet the stress and environmental requirements. Other safety precautions observed were the review and sign-off by the MMC Safety Department of all test plans and the personal observance of all tests conducted.

VII. PROGRAM DOCUMENTATION

The documentation for the program consisted of this final report in addition to the following reports:

A. PROGRAM PLAN, MCR 72-191

This document outlined Martin Marietta Corporation's approach, milestones, anticipated results, and workload allocation to provide a Shuttle passenger couch verification model and the associated documentation of the functions required to achieve the contract objectives.

B. MONTHLY PROGRESS REPORTS, MCR 72-206

These reports were submitted monthly and describe all effort expended during each month of contract performance.

C. CONCEPTS AND MATERIALS REPORT, MCR 72-250

This report defined the various couch concepts and materials considered and the rationale for the selected concepts and materials.

D. PERFORMANCE TEST PLAN, MCR 73-3

This test plan fully defined the functional and performance tests that were performed on the couch system including the test objectives, rationale, setup, implementation and control techniques, with the data recording required.

E. PERFORMANCE TEST REPORT, MCR 73-303

This report described the individual tests including objectives, procedures, results, and pertinent events and/or observations as defined in the Performance Test Plan.

F. DESIGN REQUIREMENT DOCUMENT, MCR 73-285

This document defines the basic design criteria and requirements for the Shuttle passenger couch verification model. The data contained in the document were obtained from the design, fabrication, and testing of the couch verification and engineering models.

G. UTILIZATION MANUAL, MCR 73-285

This manual forms a part of the Design Requirement Document and defines the operating instructions for the Couch Verification Model.

H. CONTRACT SUMMARY REPORT, MCR 74-41

The contract summary report summarizes the results of the contract in a brief, precise manner.

I. MASS PROPERTIES STATEMENT

This statement has been included in the monthly progress reports and in this final report to provide the weight, center of gravity, and moments of inertia for the equipment and the complete couch system.

J. NEW TECHNOLOGY REPORT

This report is to disclose the technical details of new technology to

government agencies.

K. SUMMARY OF NEW TECHNOLOGY REVIEW ACTIVITIES REPORT

This report is to reflect the contractor's activities regarding compliance with the reporting requirements of the New Technology Clause.