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TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

CRASH INJURY EVALUATION

PERSONNEL RESTRAINT SYSTEMS STUDY

UH-1A AND UH-1B BELL IROQUOIS HELICOPTERS

March 1964

Contract DA 44-177-AMC-888(T)

TRECOM Technical Report 63-81

prepared by :

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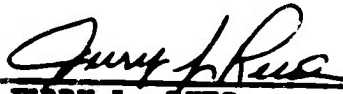
The findings and recommendations contained in this report are those of the contractor and do not necessarily reflect the views of the U. S. Army Mobility Command, the U. S. Army Materiel Command, or the Department of the Army.

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HEADQUARTERS
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Excluding fire, failure of some portion of the occupant tiedown chain is the most significant factor contributing to the injury and death of personnel involved in survivable-type aircraft accidents. In an effort to eliminate this condition, considerable research has been devoted to the study of personnel restraint system concepts and their application to specific aircraft. This report, prepared by Aviation Safety Engineering and Research (AVSER), a division of the Flight Safety Foundation, Inc., under the terms of Contract DA 44-177-AMC-888(T), contains an evaluation of the crew and passenger restraint systems installed in the UH-1A and 1B aircraft, and proposes a practical and economical method of modifying these systems to provide increased occupant protection.

While views contained in this report have not been reviewed or approved by the Department of the Army, conclusions and recommendations contained herein are concurred in by this Command. However, responsibility for the implementation of these recommendations rests with the U. S. Army Aviation and Surface Materiel Command, St. Louis, Missouri, under whose auspices this program was prosecuted.


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PERSONNEL RESTRAINT SYSTEMS STUDY
UH-1A AND UH-1B BELL IROQUOIS HELICOPTERS

Crash Injury Evaluation
AvSER 62-27

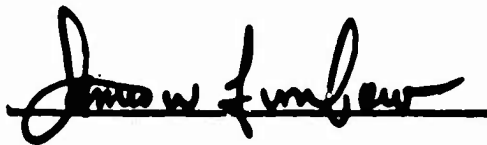
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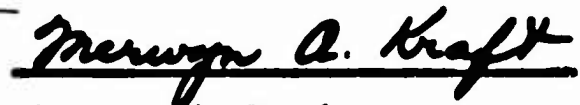
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SUMMARY

This report presents detailed recommendations for the improvement of the personnel restraint system in the U. S. Army UH-1A and UH-1B aircraft. The recommendations pertain primarily to strengthening the existing restraint system components. The modifications proposed indicate the following strength improvements: (1) Cockpit - The crew's restraint system is increased from a 10-12G value to a 20-25G value; (2) Troop Compartment - The troops' lap belt attachments are increased from a 12-15G value to a 22-25G value.

The above strength increases can be achieved with a weight increase of 7 pounds per aircraft and a cost of approximately \$70 per aircraft.

The following information is included in this report and the Supplement:

1. Engineering - Strength analysis of proposed modifications.
2. Parts Procurement - Detailed engineering drawings with a bill of materials from which retrofit kits can be procured.
3. Parts Manufacture - Drawings necessary for the manufacture of retrofit kits.
4. Retrofit Kit Installation - Sufficient drawings for installation of the retrofit kits by Army personnel.
5. Administrative - A cost and weight summary of proposed modifications.

CONCLUSIONS

An analysis of the UH-1A and UH-1B personnel restraint system reveals that:

1. The personnel restraint system is designed in accordance with, and in many instances exceeds, the requirements of the applicable military specifications; however, it is still only about one-fourth of the desired strength in accordance with crash load data and human tolerance data.
2. The shoulder straps, inertia reel, and lap belts in the cockpit are designed for a 30G loading; however, human tolerance experiments indicate that this harness allows the lower torso to "submarine" under the belt during high longitudinal decelerations. The "submarining" can cause abdominal and spinal injuries.
3. Attaching the lap belts of the crew seats to basic structure does not appear to be the most practical method for strengthening the restraint system for the pilot and copilot; however, if the cockpit crew seats and supporting structure are reinforced, and if the shoulder harness is attached to the cockpit floor as indicated in this report, the crew's restraint system is calculated to sustain a 20G longitudinal load combined with a 10G lateral load.
4. The lap belts for the troops are designed for a 25G load, but the lap belt anchorages to fuselage structure are designed for only half this amount; however, if the anchorages are reinforced as indicated in this report, a calculated load of 25G can be sustained.
5. The addition of shoulder straps for troops is not practical unless the troop seats are redesigned and modified to withstand higher crash loads.

RECOMMENDATIONS

Based on the preceding conclusions, it is recommended that:

1. The lap belt tiedown as shown in the Supplement, Drawing No. HU-1-11, be added to the pilot's and copilot's restraint harness to alleviate the "submarine" effects.
2. The cockpit crew seats and supporting structure be reinforced as indicated in the Supplement, Drawings HU-1-11 through HU-1-20.
3. The troop lap belt anchorages to the honeycomb panel be reinforced as indicated in the Supplement, Drawing HU-1-30.
4. The troop seats be redesigned and/or modified to withstand higher crash loads in accordance with known limits of human tolerance. The redesigned troop seats should also include a shoulder harness installation. This redesign work requires further study.
5. A mock-up evaluation of all proposed modifications in this report be conducted on one aircraft to insure that no operational or maintenance problems exist.

DESCRIPTION OF THE AIRCRAFT

GENERAL

The UH-1A and UH-1B Bell Iroquois helicopters are single-rotor, turbine-powered utility-type aircraft of compact design featuring low silhouettes and low vulnerability to meet combat requirements. A wide cabin permits the helicopters to be used for transport of personnel, equipment, and supplies; they may also be used for evacuation of casualties, for emergency ambulance service, and as an instrument trainer. (Loading arrangements are shown in Figure 1.) A normal operating crew may consist of a pilot alone, a pilot and a medical attendant, or a pilot and a copilot, depending upon the mission requirements.

FUSELAGE

The fuselage consists of two main sections: the forward section and the aft section or tail boom. The construction of the forward section consists primarily of two longitudinal beams with transverse bulkheads in the floor structure. The beams provide the supporting structure for the cockpit cabin section, landing gear, fuel tanks, transmission, engine, tail boom, and the anchorage for the external cargo suspension unit. The tail boom is a semimonocoque structure and is attached to the forward section with bolts to allow easy removal. The rear of the tail boom supports the tail rotor, vertical fin, and synchronized elevator. The landing gear is a skid type, attached to the fuselage at four points.

CREW AREA

The crew area of the forward section of the fuselage has accommodations for a pilot and copilot in a standard seating arrangement with dual controls. There is no bulkhead or partition between the crew area and the passenger/cargo area.

PASSENGER/CARGO AREA

UH-1A Aircraft

The passenger/cargo cabin area contains two 2-man troop seats that can be folded and stowed against the aft cabin bulkhead. When the seat is folded, the area presents an unrestricted loading space for cargo.

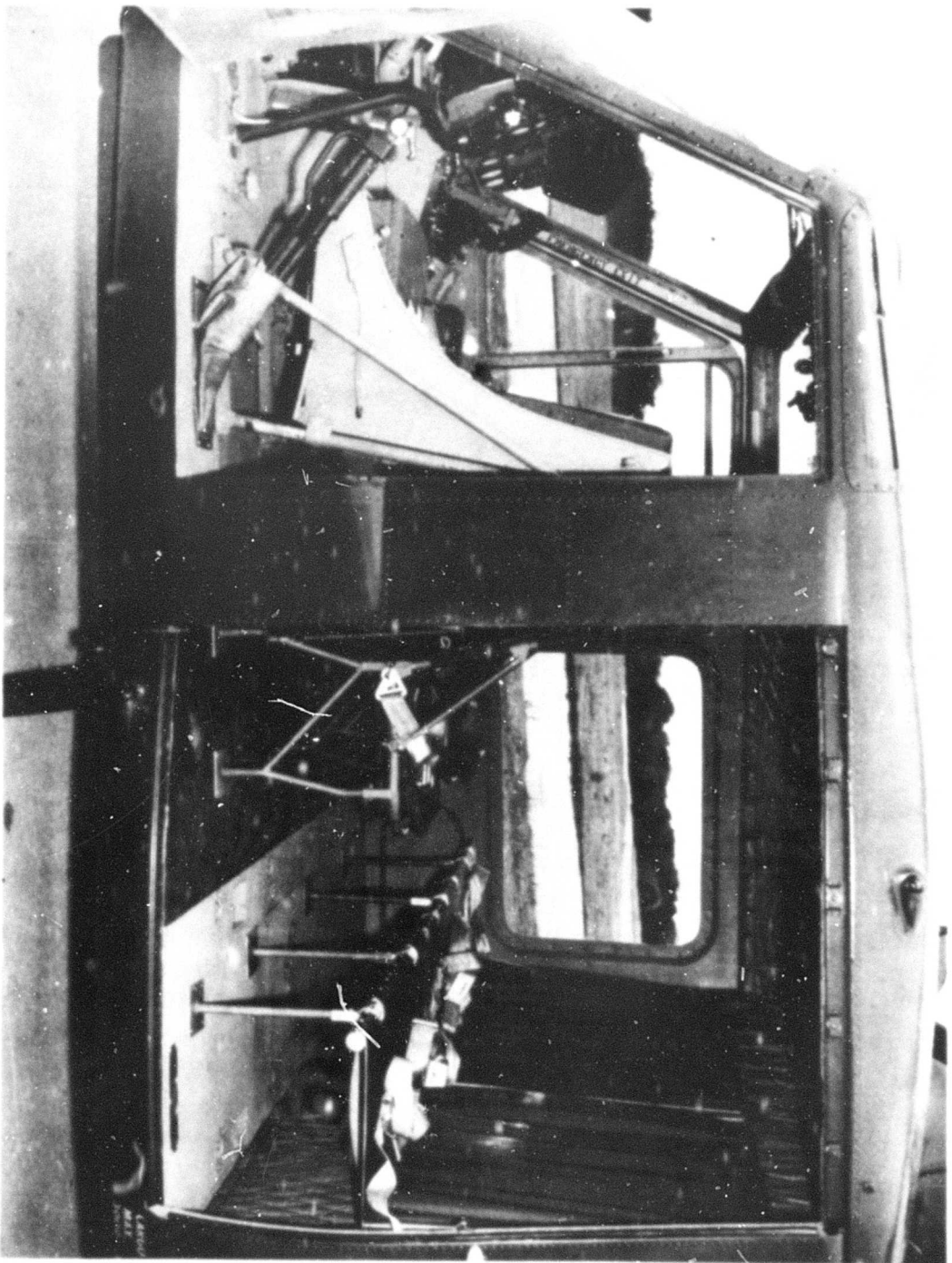


Figure 1. UH-1B Cabin Layout - Crew Seats, Medical Attendant Seats, and Troop Seats.
Note: UH-1A has only one medical attendant seat and four troop seats.

For ambulance or mercy mission service, a litter rack and a medical attendant seat are quickly installed and two litter patients can be carried.

UH-1B Aircraft

The UH-1B series of this aircraft has the same overall fuselage dimensions as the UH-1A series. Major differences which affect this report are:

1. Provision is made to carry five passengers on one 2-man seat and one 3-man seat, either of which may be folded and stowed against the aft cabin bulkhead.
2. Provision is made for the installation of two medical attendant seats in the outboard portions of the passenger area between the crew seats and the troop seats as shown in Figure 1.

Basic characteristics of the UH-1A and UH-1B aircraft are listed in Table 1.

TABLE 1
BASIC CHARACTERISTICS OF UH-1A & UH-1B IROQUOIS

	UH-1A	UH-1B
<u>WEIGHTS</u>		
Normal take-off	5950 lb	6600 lb
Operating weight (basic)-includes pilot	--	4710 lb
Maximum fuel	125 gal	155 gal
<u>CARGO COMPARTMENT</u>		
Length - Cargo area	4.6 ft	4.6 ft
Width - Cargo area	7.7 ft	7.7 ft
Height - Cargo area	4.7 ft	4.7 ft
<u>PERSONNEL CAPACITY</u>		
Number of fully equipped troops (includes one in copilot seat)	6	8
Number of litter patients	2	2
<u>POWER PLANTS</u>		
Number/Type	one/turbine	one/turbine
Manufacturer	Lycoming	Lycoming
Model	T-53-L1	T-53-L5
Take-off power	860 hp	960 hp

SCOPE OF THIS STUDY

The contract specifies that "the contractor shall study the feasibility and practicability of improving the attachment of seat belts and shoulder harness inertia reels for crew and passengers in all Army aircraft to provide for survivability in survivable crashes". In order to fulfill the feasibility and practicability aspects of this work statement, the scope is limited to the improvement and strengthening of the existing restraint harnesses, and all related anchorages, for loads in the forward and lateral directions only.

This study has been restricted to the UH-1A and UH-1B aircraft since the necessary structural drawings of the UH-1D model were not available in time to analyze the "D" model.

It was noted in the "Basic Concepts" report (reference 1) that the majority of shoulder straps and lap belts in the U. S. Army inventory are strong enough to restrain personnel up to known limits; therefore, this study has been directed toward increasing the strength of the existing harness attachments, which realistically means increasing the strength of the entire personnel "tiedown chain". * The scope of design work and field modification work necessary to increase the strength of the existing 10G personnel restraint system to a 40G system appears impractical in this aircraft for several reasons: (1) The contract specifies that the modification work shall be accomplished by field level maintenance; (2) The cost of retrofit design components shall not be excessive. Nonetheless, it does appear practical to increase the system strength, in the horizontal plane only, to approximately a 25G level for the crew and the troops. These improvements can all be accomplished by third or fourth echelon level field maintenance. None of the modifications will require more than two days downtime with three men accomplishing the work.

Reinforcement of the crew seats or troop seats for vertical loads is not considered, since the amount of work involved is outside the scope of this study; however, the omission of work in this area does not mean that the existing seats are satisfactory. Helicopter crashes involve vertical forces primarily, rather than longitudinal forces (reference 1); therefore, all helicopter crew and passenger seats should be designed with energy absorbers to prevent the vertical forces from exceeding

* The "tiedown chain" includes the lap belt, the shoulder harness, the seat, the floor, and all related anchorages.

known human limits. The subject of energy-absorbing seats for troops is discussed more fully in reference 8. The energy-absorbing cushions which are already installed in the UH-1 models should reduce the number of spinal fractures in crashes involving high vertical forces; however, the crushing strength of these cushions should be reduced by some method in order to enhance further their energy-absorbing capacity (reference 15).

The analysis of the crew seats, as shown in the Appendix, is a check of only those components which are obvious potential failure points; therefore, a static load test should be conducted to prove that the entire restraint system is as strong as indicated.

Strengthening of the troop seats is not considered in this report because the troop lap belts are attached to the fuselage rather than to the troop seats; consequently, the lap belt attachments are analyzed independently of the troop seats. Shoulder straps are not analyzed for the troops because their addition to the existing design troop seat offers very little gain in personnel crash protection. The existing troop seats should first be replaced prior to the installation of shoulder straps (reference 8).

Strengthening of the medical attendant's seats is not covered in this report because extensive modifications are required on the seat and the floor structure to obtain a substantial strength increase; however, it is proposed that these seats be strengthened by tension cables until a more sturdy seat is installed.

ANALYSIS OF THE UH-1A AND UH-1B PERSONNEL RESTRAINT SYSTEM

The UH-1A aircraft was evaluated in regard to overall crash safety, in December of 1960, as noted in reference 14, and a discussion of the personnel restraint system was included. This analysis is a continuation of the restraint system evaluation; it includes detailed modifications which will increase the strength of the system.

Reference is made to Bell Helicopter Company drawing numbers throughout this report to identify structural parts, and reference is also made to contractor drawings; these drawings can be identified as indicated in Table 2 and are presented in the Supplement.

TABLE 2
DRAWING DESIGNATIONS FOR UH-1A & UH-1B RESTRAINT SYSTEMS

<u>Company or Organization</u>	<u>Description of Item</u>	<u>Drawing Designation</u>
Bell Helicopter Co. of Fort Worth, Texas	Equipment (Seats)	204-070-000-00
	Structural	204-030-000-00
AvSER, Div. of Flight Safety Foundation, Phoenix, Arizona	Modif. - Restraint	HU-1-00-0
	System Standard Part	AvCIR-00

The restraint systems for the cockpit and the troop compartment are analyzed separately on the following pages.

COCKPIT

General

The pilot's and copilot's (crew) seats are manufactured by a subcontractor in accordance with drawing 204-070-706. A profile view of the seats is given in Figure 1. The crew seats are identical in the UH-1A and UH-1B models up through ship no. 392, after which the seats are strengthened in accordance with drawing 204-070-099 on the remainder of UH-1B models. The lap belts and inertia reels of both these designs are attached to the seat.

Design and Strength of Existing Harness

The harness components are identified and their strengths recorded below:

Lap Belt - Type MD-2, AF Drawing 54H19650, 3-inch width by 50-inch length, 5,000-pound loop strength.

Shoulder Straps - Type G1, AF Drawing 50D3770, 1.7-inch width, 1,800-pound total strength.

Inertia Reels - Type MA-6 (rate of extension), 4,000-pound strength.

The strength of the lap belt and inertia reel is adequate, but the shoulder harness strength is inadequate as noted in reference 1. Although the 1,800-pound strength of the Type G1 harness is consistent with the 23G loading used in this study, the .04-inch webbing permits excessive elongation under high loads and also cuts into the collar bone much more than thicker webbing. Therefore, it is recommended that this harness be replaced with a continuous length of webbing as shown in Supplement drawing HU-1-16. The total weight of the new webbing and hardware is less than the weight of the existing components.

The design configuration of the existing harness is considerably improved if it is modified by the addition of a lap belt tiedown. The purpose of a lap belt tiedown is the prevention of the upward belt movement caused by shoulder harness pull during forward decelerations. This movement of the lap belt can cause injury due to impingement on soft tissue in the abdomen as well as spinal column injury caused by pelvic "submarining" under the belt. The advantages of a lap belt tiedown are discussed more fully in reference 1.

Strength of Crew Seat and Anchorages

The UH-1 crew seats (drawing 204-070-706) are designed to withstand the following loads in accordance with the company's stress analysis report:

<u>Direction of Load</u>	<u>Design Load(lb)</u>	<u>Design Factor(G)</u>
Forward: Belt	1,100	10 Total
Shoulder Straps	900	
Sideward (lateral)	2,000	10
Downward	3,000	15

The design strength of the seat in the vertical and lateral directions is considerably greater than that of previous seat designs; however, the design strength is still considerably less than the loads which have occurred in potentially survivable crashes. The seat strength is also incompatible with the lap belt and shoulder harness strength; therefore, the seat should be strengthened to more nearly approach the recommended 45G value (reference 1).

Advantage of Shoulder Strap Attachment to Basic Structure

Attaching the shoulder strap to the cockpit floor will reduce the loads in the seat structure by approximately 20 percent, which is equivalent to increasing the seat strength by 20 percent.

Disadvantage of Shoulder Strap Attachment to Basic Structure

A change of seat position in the vertical or longitudinal direction must be preceded by loosening of the shoulder straps if the inertia reel is in the manual-lock position.

Advantages of Lap Belt Attachment to Basic Structure

The attachment of the lap belts to the cockpit floor would divert a portion of the total decelerative forces to the floor. The total longitudinal decelerative force on the seat would be reduced between 40 and 60 percent, depending upon the frictional forces of the torso on the seat cushion.

Disadvantages of Lap Belt Attachment to Basic Structure

The 6-inch relative movement of the lap belt to compensate for horizontal and vertical seat adjustment would cause a problem with the adjustment buckles (located on either side of the lap belt), since in some seat positions the buckles would be below the seat pan and in other seat positions the buckles would be above the edge of the seat pan. The movement of the 4-inch-wide steel buckle is a serious installation problem, since the belts would necessarily need to be retained by some kind of loop at either side of the seat bucket and the movement of the wide buckles through this loop would probably be highly irritating to the crew member.

Any change in seat position in the forward or upward direction must be preceded by lap belt loosening. This is an inconvenience to the pilot; however, the point is of minor importance because an AvSER

questionnaire, which was mailed to more than 200 pilots, revealed that only 16 percent of helicopter pilots adjust their seats more than once per flight.

A floor-mounted belt will not hold the occupant as snugly to the seat bucket as a seat-mounted belt, especially in the lateral direction.

Proposed Modifications To Strengthen the Cockpit Restraint System

The advantages of attaching the inertia reel to the cockpit floor appear to outweigh the disadvantages, and this change is recommended. The logical location for floor attachment is the Fuselage Station 66 bulkhead. The reel is mounted flush against the web of this bulkhead beneath the floor.

The disadvantages of attaching the lap belts to the cockpit floor appear to outweigh the advantages if it is assumed that the seat structure can be strengthened significantly without removing the lap belts from the seat pan.

An examination of the crew seat and supporting floor structure indicates that the entire restraint system can be increased from its present 10-12G design strength to a 20-25G strength without the complication of attaching the lap belts to the floor. Although this strength is considerably below the 45G design strength recommended in reference 1, it appears to be the most practical approach to take for this installation in view of the extensive modifications required to anchor the belts beneath the floor.

A total 45G indicated strength can be attained by attaching both the shoulder harness and the lap belt to basic aircraft structure, without any modification to the crew seat itself. However, this solution does not add any strength to the seat and supporting structure, and this point is very important for lateral loads because a failure of the seat in the lateral direction can allow the seat occupant to impact against adjacent structure. The functional disadvantages of attaching the lap belt to floor structure have already been noted. With due consideration for all factors, it appears more practical to increase the strength of the seat by a factor of 2.0 rather than to increase strength of the harness alone by a factor of 4, with no increase in the strength of the seat.

The loading direction assumed for the crew seat is based on reference 13, which indicates that aircraft seat designs should sustain loads at 30 degrees to either side of the longitudinal axis; however, the 26.5-degree angle is used, for convenience, to yield an even 50-percent

lateral to longitudinal load ratio. Although reference 13 is based on fixed-wing aircraft accident statistics, the data are considered valid for helicopters until more helicopter accident statistics are collected. A sketch of the assumed loading is shown in Figure 2; this load is used for the stress analysis in the Appendix.

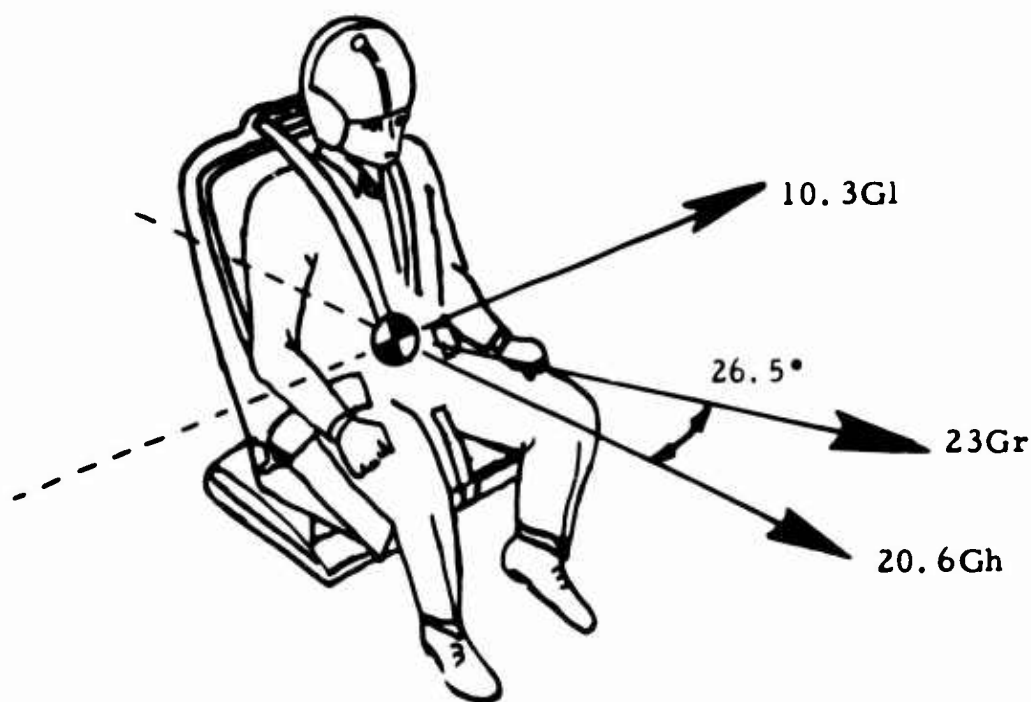


Figure 2. Crew Seat Crash Load Diagram.

Note: If a pure lateral load is applied, the seat can sustain 12-15G. If a pure longitudinal load is applied, the seat can sustain 25-30G.

The modifications proposed to increase the strength of the crew's restraint system (Supplement, Drawings HU-1-10 through 20) are simple enough to be accomplished by field personnel with retrofit kits. None of the proposed modifications should require grounding of the aircraft for more than two days with three men working if the work is planned in advance and all retrofit parts are on hand.

The proposed modifications to the crew seats and floor tracks are applicable on all UH-1A and UH-1B aircraft up to and including ship no. 391. Higher strength seats are used on higher ship numbers.

The modifications proposed for the cockpit area are described briefly in the paragraphs that follow, and a reference is given to pertinent drawings in the Supplement.

1. Lap Belt Tiedown Strap (HU-1-11). The purpose of the lap belt tiedown is the prevention of upward belt movement caused by shoulder harness pull. This function is accomplished by a single tiedown strap (AvCIR-10) attached at the forward edge of the seat pan.

The lap belt can also be tied down by the use of two side tiedown straps; the straps attach at the belt adjustment buckles at either side of the seat pan. This type of installation was shown in the CV-2 Caribou report (reference 2), Supplement drawing AC-1-16, and it can be used as a guide in making the installation on the UH-1 crew seat if this method of lap belt tiedown is preferred.

2. Modification of Aft Carriage Attachment Fitting (HU-1-12). This fitting attaches the aft tube of the seat to the floor track; it was analyzed in reference 4, and proposed modifications were detailed in the original HU-1-12 drawing. This revised drawing is an improvement of the original modification, because it adds additional restraint to the carriage channel (204-070-713).
3. Guide Rod for Shoulder Straps (HU-1-13). The existing guide rod allows excessive lateral shoulder strap movement; the modified guide rod eliminates this movement.
4. Inertia Reel Installation Beneath the Floor (HU-1-16, 3 sheets). The reel is mounted on the aft side of the bulkhead beneath the floor. This modification requires that a slot be cut through the floor for passage of the shoulder strap. A new shoulder strap is required, due to the increase in webbing length in moving from the back of the seat to the lower position.
5. Inertia Reel Control Cable Installation and Bolt Replacement on Aft Tube of Crew Seat (HU-1-17). The existing control cable must be moved from the back of the seat to the new position. The existing .25-inch-diameter bolt, which attaches the aft tube of the seat to the forward tube, must be replaced with a high-strength bolt.
6. Reinforcement of the Forward and Aft Tubes of the Crew Seat by Insertion of New Tubes (HU-1-18 & 19). The existing tubes are under-strength, and it is proposed that new tubes be inserted over the highly stressed portion of the existing tubes.

7. Reinforcement and Replacement of Rear Floor Tracks (HU-1-20, 3 sheets). The existing tracks do not overlap the carriage channel far enough for maximum load distribution; therefore, it is proposed that the tracks be lengthened and that additional fasteners be added for reinforcement.

TROOP COMPARTMENT

General

The troop seats of the UH-1A and UH-1B are anchored to the transverse bulkhead at Fuselage Station 123, and to the aircraft floor as illustrated by Figure 1. Medical attendants' seats, which may also be used for troop seats, are also shown in Figure 1; one attendant's seat is installed in the center of the UH-1A, while two are installed in the UH-1B. These seats on the first 391 aircraft are designed to withstand the following loads, based on a 200-pound occupant:

Medical Attendant Seat (Facing Aft) P/N 204-070-702-11 MIL-S-5822, Type A10

Lap Belt	1,000 lb aft	5.0G
	2,000 lb fwd	10.0G
Seat - All load directions on belt and seat with respect to ship	2,000 lb fwd	10.0G
	3,000 lb down	15.0G
	1,500 lb up	7.5G*
	100 lb fwd	0.5G**

* Belt Attachment

** Headrest

Troop Seat (Per One Man) MIL-S-5795, Para. 4.7.3

Lap Belt, 2,190 lb, (10.7G) at 45° angle upward, forward, and inboard.

Seat	Seat Bottom	2,200 lb down	11.0G
	Seat Back	600 lb aft	3.0G
	Fwd Seat Tube	225 lb side	1.1G
	Leg Load	1,000 lb up	5.0G

These strength values are too low and the seat designs are considered to be inadequate as noted in reference 8.

Strength and Applicability of Existing Harness

The troop seats are provided with lap belts only. These belts meet the strength requirements of MIL-B-6703 (4,500-pound loop strength) on early UH-1A models and MIL-B-8607 (5,000-pound strength) on all other UH-1A and UH-1B models. Although the 4,500-pound loop strength is less than the desired 5,000-pound strength, it appears probable that these belts can sustain 5,000 pounds for the very short time span of a crash pulse; however, it is recommended that the 5,000-pound-strength (MIL-B-8607) belts be substituted for the MIL-B-6703 belts when replacement is required.

The nylon belt webbing is 1.94 inches wide instead of the desired 3-inch width recommended in reference 1. Although a 3-inch-wide belt is desirable, the desirability must be considered in terms of the additional weight required to effect the change. Apparently, the lowest weight 3-inch-wide belt available is the 2.5-pound, military type MC-1. Since the existing belt weighs only 1.0 pound, a weight increase of 10.5 pounds (7 troops x 1.5 pounds) would result from the change to a 3-inch-wide belt on the UH-1B. The existing troop lap belts are considered to be acceptable in view of the weight penalty involved in changing to a standard 3-inch-wide belt, but it is recommended that a new seat belt be designed which is no less than 2.5 inches wide and no greater than 3.0 inches wide.

Preliminary calculations indicate that a newly designed lap belt can be achieved which would weigh less than 2 pounds and still fulfill the desired width and strength requirements. The modified type MC-1 lap belt, recommended for the troop commander's seat of the CH-47 "Chinook" (reference 3), is an indication of the weight that can be saved by a newly designed belt, since its weight was reduced from 2.5 pounds to 2.2 pounds by a redesign of the end fittings alone.

The troop seats and medical attendants' seats are not provided with a shoulder harness, but the addition of harnesses to these seats is not considered practical unless the seats are modified or replaced with a new design. The additional weight and cost of a shoulder strap installation must be weighed against the nebulous benefits to be gained from their use on understrength seats.

Strength of Lap Belt Anchorages

The strength of the lap belt attachments to the medical attendants' seats is greater than the strength of the seat anchorages to the floor; therefore, these attachments are not analyzed.

The strength of the lap belt attachment fittings to the Fuselage Station 123 bulkhead has already been analyzed in reference 9, and it is recommended that the new parts detailed there be incorporated. The yielding of these parts under transverse crash loads would apply a minimum amount of moment load to the honeycomb panel in comparison to the existing rigid forgings.

An ultimate analysis of the honeycomb panel in the Fuselage Station 123 bulkhead indicates that a belt load of approximately 3,200 pounds can be sustained before the phenolic block attachment fails.

Modifications Proposed To Increase the Strength of the Troop Lap Belt Support Structure

Personnel restrained by lap belts alone can sustain 25G in accordance with the known limits of human tolerance (reference 1); therefore, modifications are proposed to increase the strength of the lap belt attachments to this value. The strength verification is shown in the latter part of the Appendix and the detailed drawings (HU-1-30) of the modifications are included in the Supplement.

It is proposed that the troop lap belt attachments to the honeycomb panels of the UH-1A and UH-1B models be reinforced locally by a .100-inch-thick aluminum alloy plate on the aft side of the panels as shown in the Supplement drawing, HU-1-30. The stress analysis is shown in the latter part of the Appendix. With this localized reinforcement, the attachments are calculated to sustain a 5,000-pound loop load.

The proposed modifications to the honeycomb panels at Fuselage Station 123 are applicable to all UH-1A and UH-1B aircraft.

SUMMARY OF COST AND WEIGHT OF MODIFICATIONS,
ASSUMPTIONS USED FOR WEIGHT AND COST ESTIMATES

The cost of the modifications is based on the cost of the retrofit kits alone. The cost of man-hours required to install the kits is not computed; it is anticipated that man-hour estimates will be made by the Aviation and Surface Material Command.

Reference 11 is used as a guide in estimating manufacturing times in producing the retrofit kits. Some of the estimates are based on inquiries at local machine shops in the Phoenix area. Some basic assumptions used in the cost estimates are listed below.

For Single Prototype Kits

1. Only standard tools and machines are used.
2. No special design jigs or fixtures are used.

For Multiple Run Kits

1. Raw materials are pre-marked.
2. More sophisticated machines such as multiple-spindle drills are used.
3. Positive stops are provided on all machines for pilot alignment.
4. Special jigs and fixtures are designed as needed.
5. A learning curve of 90 percent is used in long, repetitive runs.

A cost and weight summary is presented in Table 3.

TABLE 3
COST AND WEIGHT SUMMARY OF PROPOSED MODIFICATIONS

Dwg. No.	Title	Weight per A/C*(lb)	Cost of Parts per A/C in Dollars			
			1 A/C	50 A/C	100 A/C	300 A/C
HU-1-11	Install. - Lap Belt Strap	.55	5.25	2.34	2.25	2.20
HU-1-12 (Revision A)	Modif. - Aft Carriage Crew Seat	zero	1.00	.80	.80	.80
HU-1-13	Guide Rod Assembly	zero	12.00	6.00	5.00	4.00
HU-1-14	Doubler-Inertia Reel	.24	zero	zero	zero	zero
HU-1-15	Dust Cover-Inertia Reel	.15	26.00	15.00	10.00	5.00
HU-1-16	Sheet 1-Inertia Reel Install.	.04	69.00	25.75	15.70	15.00
	Sheet 2-Floor Modif. L. H.	.08	6.00	4.00	3.50	3.00
	Sheet 3-Floor Modif. R. H.	.08	6.00	4.00	3.50	3.00
HU-1-17	Control Cable Install. & Bolt Replacement-Seat	zero	.50	.50	.50	.50
HU-1-18	Modif. -Seat Strut (Rear Tube)	2.26	16.86	5.32	5.00	5.00
HU-1-19	Modif. -Seat Strut (Front Tube)	1.67	7.44	4.07	4.00	4.00
HU-1-20	Reinf. & Replacement-Rear Seat Tracks	.86	37.00	30.00	25.00	15.50
HU-1-30	Reinforcement, UH-1A Lap Belt	1.56	17.20	15.00	12.00	12.00
	Attachment Fitting, UH-1B F. S. 123 Bulkhead	.78	8.60	7.50	6.00	6.00
Total for complete aircraft						
	UH-1A	7.53	204.75	112.78	87.25	70.00
	UH-1B	6.75	196.15	105.28	81.25	64.00

* These weights are the entire installation weights including fasteners.

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APPENDIX
STRENGTH ANALYSIS OF UH-1A AND UH-1B AIRCRAFT PERSONNEL
RESTRAINT SYSTEMS

GENERAL CONDITIONS

Use is made of "limit analysis" concepts as outlined in references 5 and 7. Under crash conditions, large deflections and plastic strains are considered to be acceptable, provided the strains are well below the maximum elongation of the material.

Unless otherwise indicated, specific material strength data are taken from MIL-HDBK-5, dated March 1961.

Human dimensions for the purpose of locating the restraint harness loads from the occupant are obtained from Anthropometry of Flying Personnel - 1950 (reference 10). The seat occupant's center of mass under a combined longitudinal and lateral decelerative load is assumed to be displaced in the direction of the decelerative load. *

CREW SEATS

The recommended modifications to the crew seat (204-070-706) are based upon a design inertia load of 23G, because extensive modifications are required to achieve greater strength. In particular, the existing sub-floor structure is not designed to sustain seat loads in excess of 23G. The direction of decelerative load is taken as 26.5 degrees with the longitudinal axis as a statistically realistic limit to lateral deceleration (reference 13). Thus, for a 220-pound occupant and seat weight, ** the longitudinal component of inertia force is

$$P = \frac{Wa}{g} \cos 26.5^\circ = 4,540 \text{ lb}$$

* In the analysis associated with TCREC Technical Report 62-84 (reference 4), the lateral deflection was ignored; however, further study indicates that it would be more realistic to assume that the center of mass is displaced in the direction of the decelerative force.

** The full, up-seat position is critical for the components considered in this analysis, and it is considered that an occupant utilizing this position is not likely to exceed 190 pounds and that the seat weighs 30 pounds in accordance with specifications. A 200-pound man is assumed for the seat lap belt attachment strength and for the seat bucket attachment strength.



and the lateral component of inertia force is

$$L = \frac{Wa}{g} \sin 26.5^\circ = 2,260 \text{ lb.}$$

Inertia Reel Attachment to Floor

The inertia reel is attached to Fuselage Station 66 bulkhead (reference 204-030-778 and 204-030-780) below the floor level as indicated in Supplement drawing HU-1-16. The reel is mounted flush against the bulkhead web, with doublers used to distribute the load from the .19-inch-diameter mounting bolts. The inertia reel design strength of 4,000 pounds is used for this analysis. The margin of safety for the critical left side is high, since 15 (.125-inch-diameter) rivets and four .19-inch-diameter bolts distribute the load into the (.020-inch-thick) 7075-T6 web.

The cut-out in the floor for passage of the shoulder strap and the control cable is replaced by the .050-inch-thick doubler, which has the same column strength as the material removed. The area and centroid of the beam cap are not materially changed by the cut-out, since the doubler replaces more material than is removed.

Lap Belt Attachment to Seat Bucket

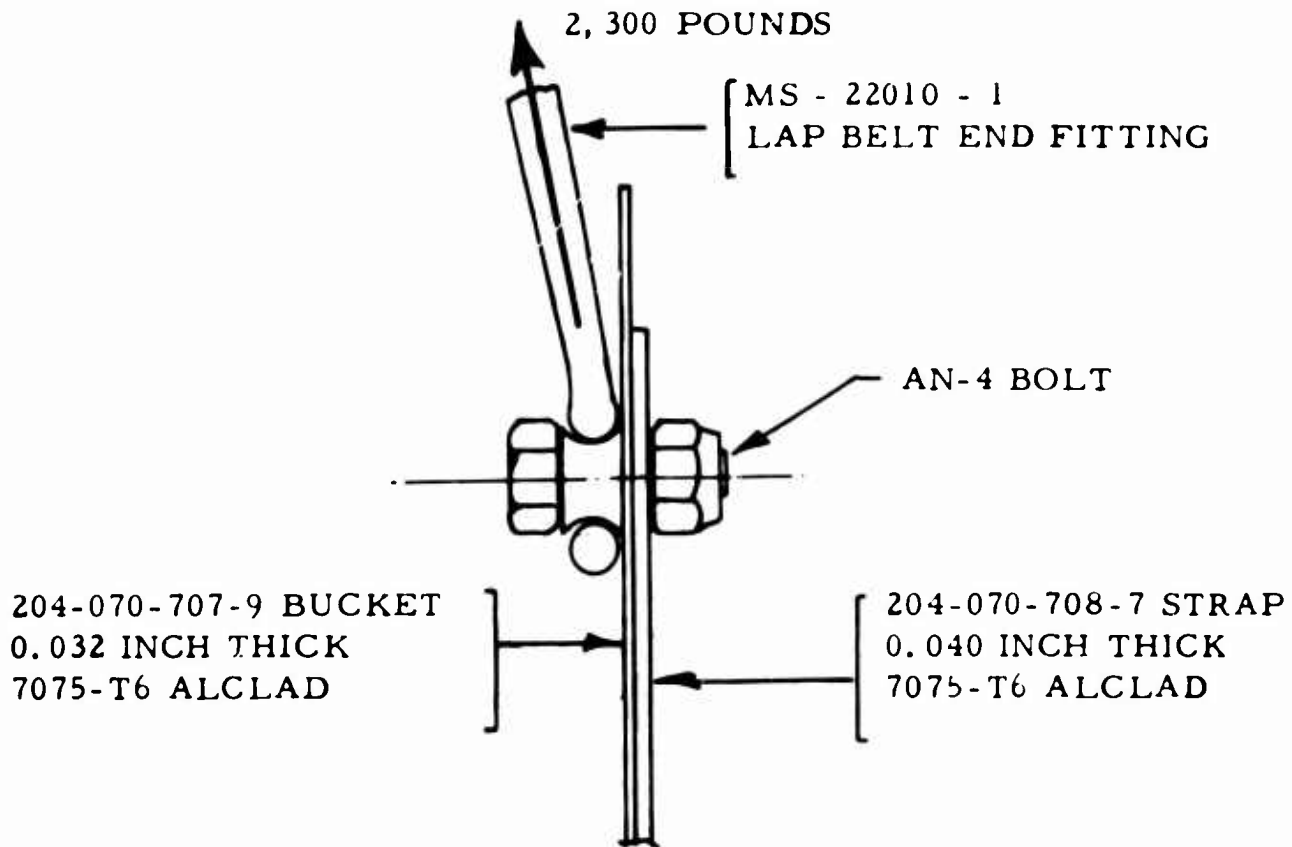
The critical load on the lap belt attachment occurs for the combined longitudinal and lateral load of 23G. Based on reference 1, the lap belt receives approximately two-thirds of the 23G loading; thus, for a 200-pound seat occupant,

$$\text{Belt load} = .67 \times 23G \times 200 \text{ lb} = 3,070 \text{ lb.}$$

Also, an uneven belt loop ratio of 75 percent to 25 percent is used in accordance with reference 9. Therefore, the higher belt-end load would be

$$.75 \times 3,070 \text{ lb} = 2,300 \text{ lb,}$$

and this load is used as the design load for the belt-end attachment.



The bearing strength of the AN 4 bolt on the seat bucket and plate is critical, as illustrated on the previous page.

$$\text{Bearing Area} = .25 \text{ dia} \times (.04 + .032) = .018 \text{ in.}^2$$

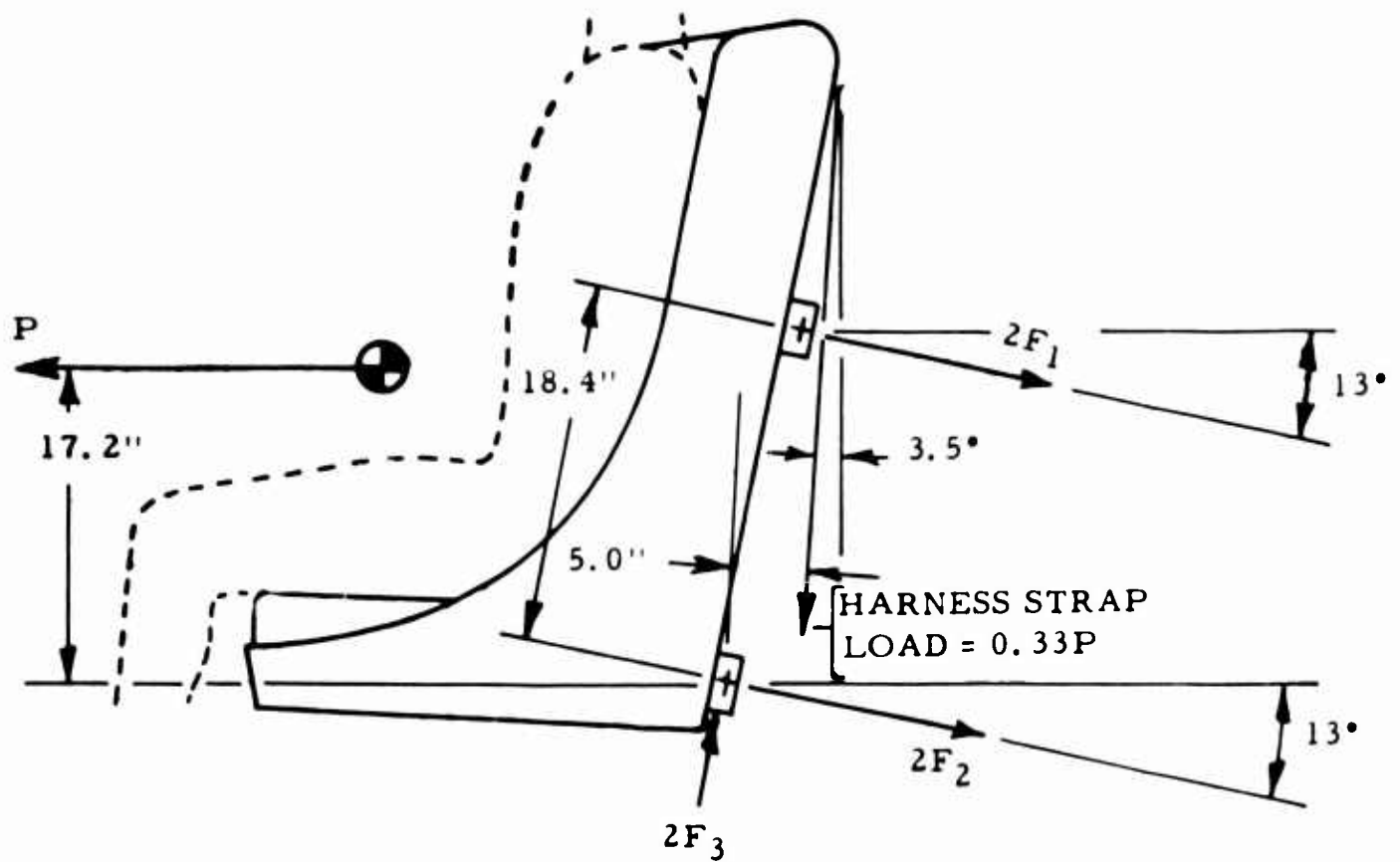
$$F_{bru} \text{ for 7075-T6 Alclad} = 140 \text{ ksi (probability value)}$$

$$\text{Bearing Capacity} = .018 \times 140,000 = 2,520 \text{ lb}$$

$$\text{M. S.} = \frac{2520}{2300} - 1 = \underline{.10}$$

Compressive Load in Forward Leg

Since the displacement of the center of mass has been assumed to be in the direction of the inertia force on the occupant, this force may be transmitted along its line of action back to the original location of the center of mass. First, consider a free-body diagram of the occupant and seat bucket only under a purely longitudinal load, P. The angle of shoulder strap load is shown with seat in the full aft position.

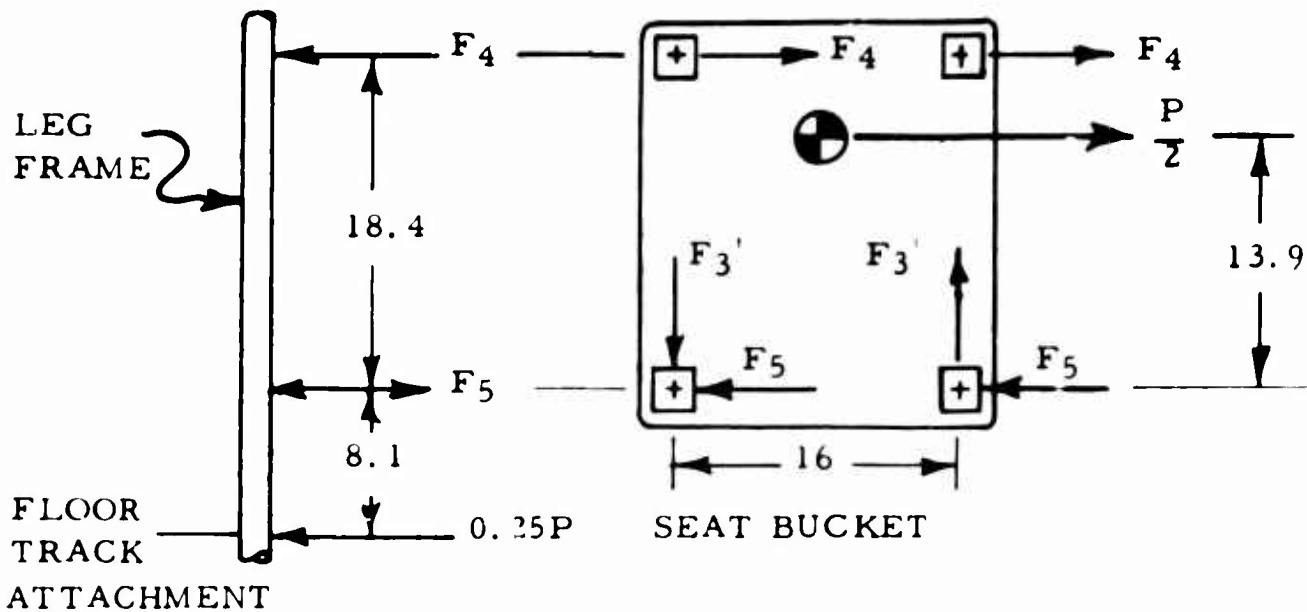


From equilibrium,

$$F_1 = .424P \quad F_2 = .036P \quad F_3 = .276P$$

Next, consider free-body diagrams of the left leg frame and of occupant plus bucket under the action of a lateral load only. *

* An indeterminacy exists in the internal seat forces resulting from the lateral component of inertia load. In the analysis accompanying an earlier report on the carriage attachment fitting modification (TCREC Technical Report 62-84, reference 4), simplifying assumptions were made to remove this indeterminacy in order to solve for the internal seat forces. Further study, however, indicates that more realistic assumptions may be made which lead to somewhat different results; hence a minor discrepancy exists between this and the earlier report in certain force magnitudes.

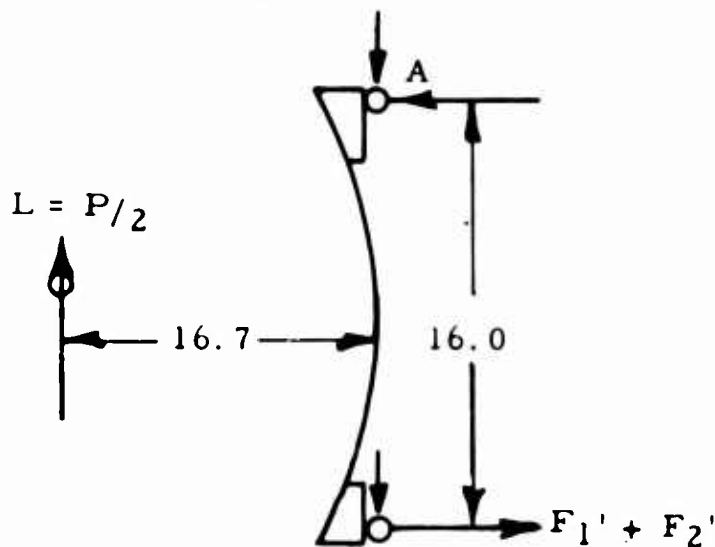


VIEW LOOKING FORWARD-PERPENDICULAR TO PLANE THROUGH
AFT SEAT LEGS (SEAT BUCKET IN FULL-UP POSITION)

From equilibrium of the leg frame in this projection, the force F_4 is found to be $.11P$ (where attachment moments are neglected). Hence, considering the equilibrium of the occupant and bucket free body,

$$F_3' = .688P.$$

Consider the plan view (looking parallel to aft legs) of seat bucket and occupant as a free-body diagram.



Summing moments about the right aft leg, A, we obtain

$$F_1' + F_2' = .522P.$$

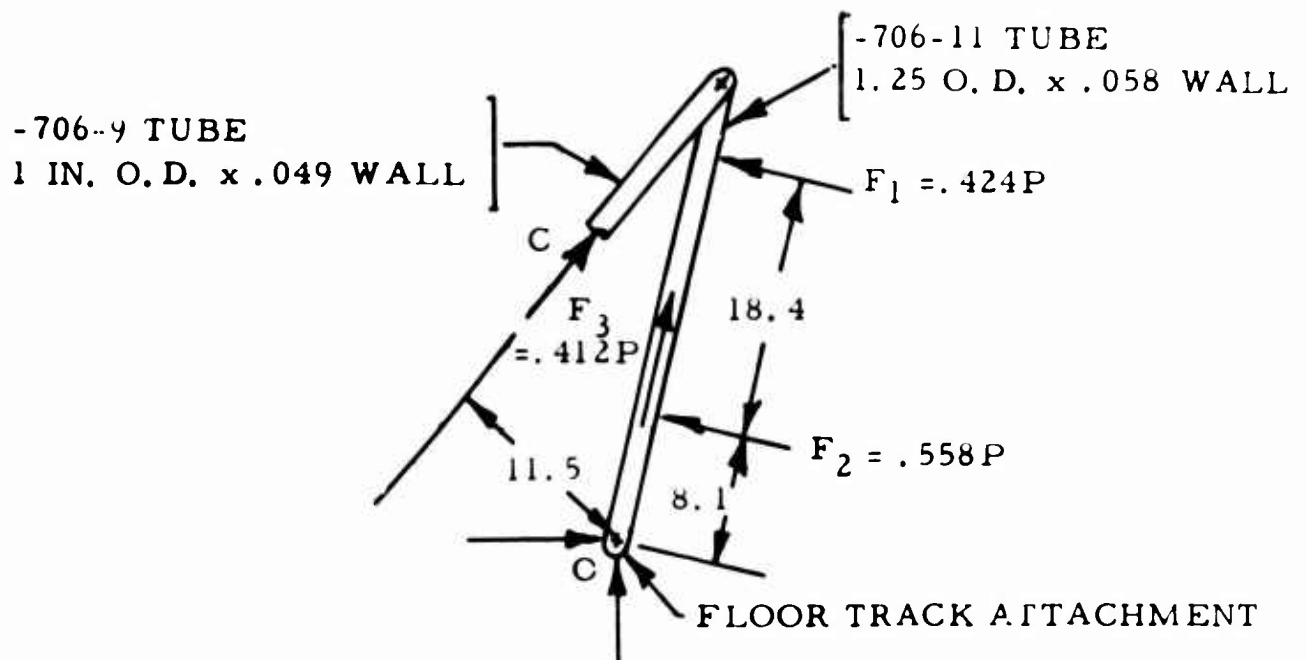
Based upon a computed low torsional rigidity of the seat bucket and the fact that the seat torque is introduced largely at the bucket bottom, a negligible force is assumed to act at the upper attachments to the aft legs. Thus

$$F_1' = 0 \quad F_2' = .522P.$$

Combining the attachment forces from the longitudinal and lateral components of inertia load, we obtain the total forces,

$$F_1 = .424P \quad F_2 = .558P \quad F_3 = .412P.$$

Consider, now, the left aft leg as a free body.



Summing moments about point O, we obtain the compressive force in the forward seat leg,

$$C = 1.37P;$$

or, for

$$P = 4,540 \text{ lb,}$$

$$C = 6,210 \text{ lb.}$$

For a column length of 33.5 inches and a radius of gyration of .337 inch, the allowable stress is found to be 28.5 ksi; hence, for a cross-sectional area of .146 square inch,

$$C = (28,500) (.146) = 4,160 \text{ lb,}$$

which corresponds to an inertia load of 16G.

The recommended modification as shown in HU-1-18 employs a .875-inch O. D., normalized 4130 steel tube of .049 inch wall thickness inserted into the center portion of the existing tube. For variable cross-section columns, an approximation to critical load is given by the expression

$$P_{cr} = \alpha \frac{E I_o}{L^2}$$

where the coefficient α is found to be approximately 9.5 for the given geometry. Adding the moments of inertia for the leg tube and insert tube, $I_o = .0275 \text{ in.}^4$. Hence,

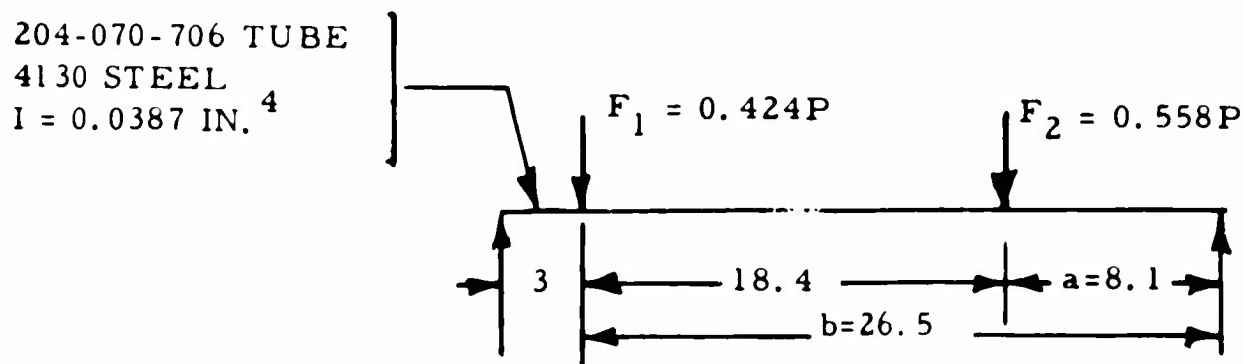
$$P_{cr} = 9.5 \frac{(29) 10^6 (.0275)}{(33.5)^2} = 6,750 \text{ lb,}$$

and therefore, for $C = 6,210 \text{ lb,}$

$$\text{M. S.} = \frac{6750}{6210} - 1 = \underline{.09.}$$

Bending in Aft Legs

Treating the aft seat leg as a simple beam, we have



The maximum bending moment is given by

$$M = \frac{a}{L} F_1 (L-b) + F_2 (L-a);$$

or, substituting numeric values,

$$M = 16,460 \text{ in. -lb.}$$

For a steel tube of 150-180 ksi heat treat and a diameter-to-thickness ratio of 21.5, the modulus of rupture in bending is given as $F_B = 205$ ksi probability value.

The allowable bending moment is then

$$\begin{aligned} M &= \frac{I}{y} F_B = .0619 (205,000) \\ &= 12,700 \text{ in. -lb.} \end{aligned}$$

Therefore, it is proposed that the tube be reinforced by insertion of a 1.125-inch O.D. x .028-inch wall thickness tube which is heat treated to 160-190 ksi, in the section of maximum bending moment (20.7 in. long), as shown in Supplement drawing HU-1-19. The moment of inertia is increased to .053 in.⁴, and the allowable bending moment is

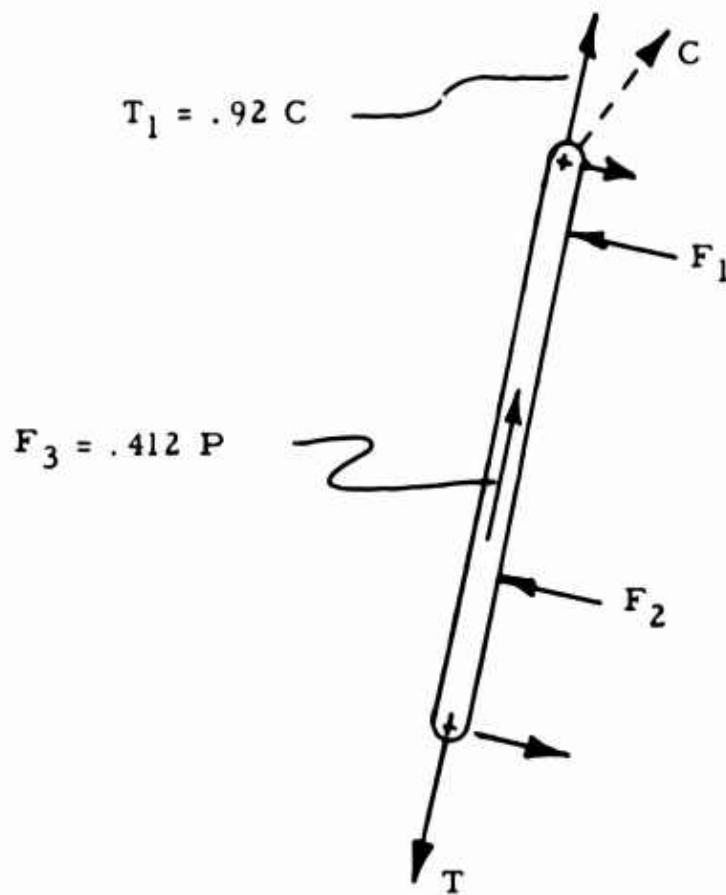
$$M = \frac{I}{y} F_B = \frac{.053}{.625} (205,000) = 17,400 \text{ in. -lb}$$

and

$$M. S. = \frac{17,400}{16,460} - 1 = \underline{.06.}$$

Connection at Top of Aft Seat Leg

Resolving the compressive force, C, in the forward seat leg into components along and perpendicular to the aft seat leg, we have the free-body diagram of the aft leg.



The force T_1 must be transmitted through an AN-4 tension bolt at the top of the aft leg. We have

$$T_1 = .92C = .92 (6210) = 5,710 \text{ lb,}$$

a load which is in excess of the existing bolt capacity.

Substituting an MS-20004 (160 ksi) bolt (6,190 pounds capacity), the modified strength is

$$\text{M. S.} = \frac{6190}{5710} - 1 = \underline{.08.}$$

Aft Carriage Attachment Fitting

Referring to the free-body diagram of the aft leg shown in the preceding section, the tensile force T at the base of the leg is given by

$$T = T_1 + F_3 = 5,710 + .412P.$$

For $P = 4,540$ pounds, we have

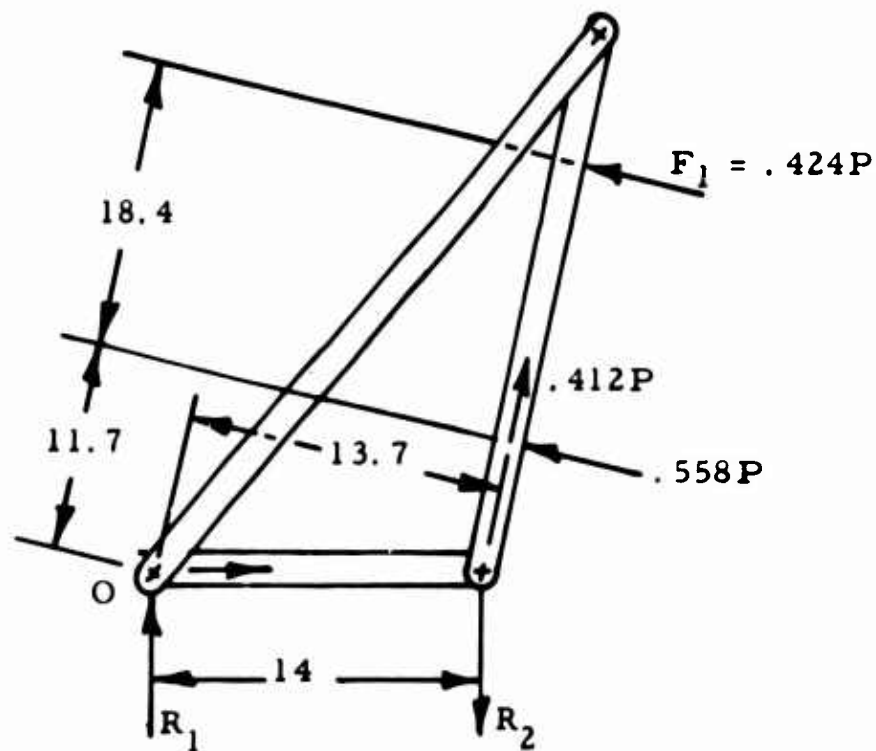
$$T = 7,580 \text{ lb.}$$

The aft fitting as modified in accordance with Supplement drawing HU-1-12 has a tested tensile capacity of 7,580 pounds, as developed on page 11 of reference 4. Thus, with the modified fitting installed,

$$\text{M. S.} = \frac{7580}{7580} - 1 = \underline{.00.}$$

Channel - Track Connection

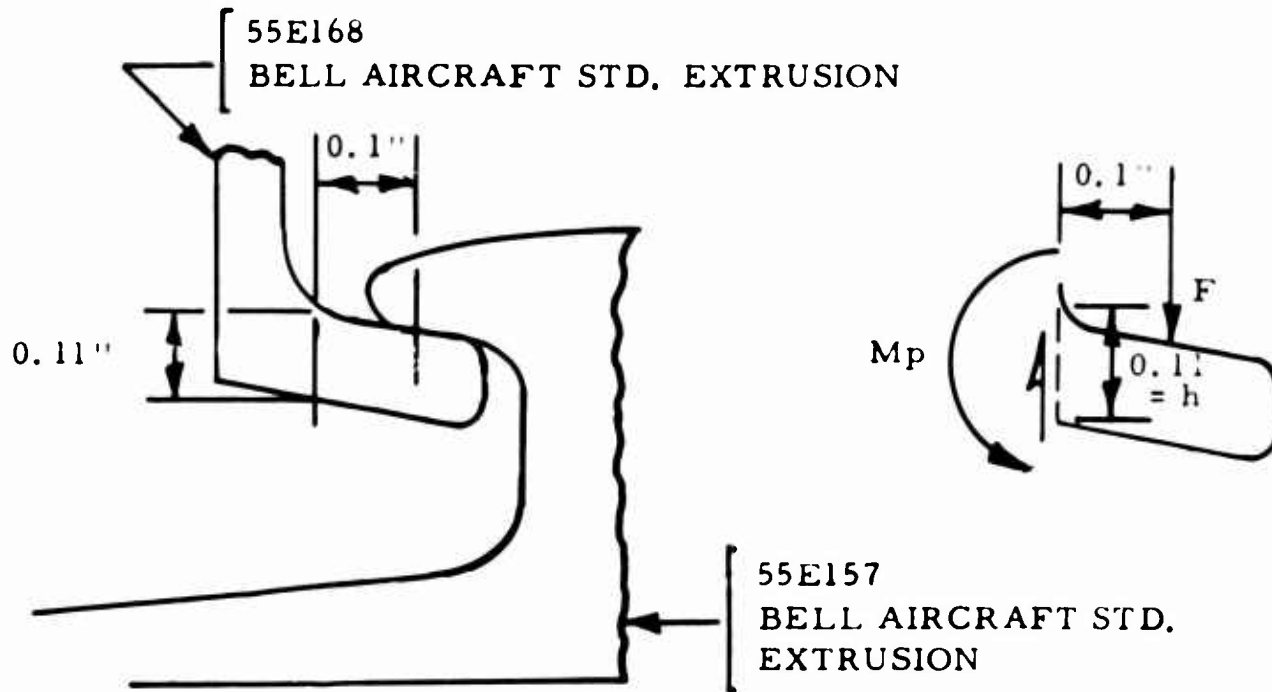
To evaluate the load transmitted from the carriage channel to the floor track, the left leg frame is depicted as a free-body diagram with the seat shown in the full-up position.



Summing moments about point O, we obtain

$$R_2 = 1.78P = 8,080 \text{ lb.}$$

To obtain the load-carrying capacity of the channel-track connection, consider a section through the channel and track. The line of contact between the channel and track is 0.1 inch from the critical section in the channel, as shown in the sketch below.



Let F be the force per unit length acting on one flange of the channel. The plastic hinge moment per inch of length is given by

$$M_p = \frac{F_{ty} h^2}{4} = 45,000 (.11)^2 = 135 \text{ in. -lb per in.}$$

where F_{ty} (equivalent) = 45 ksi,

and, consequently,

$$F = \frac{M_p}{.1} = 1,350 \text{ lb per in.}$$

For the seat in the full forward position on the UH-1A and early model UH-1B aircraft, the track-channel overlap is 1.88 inches. Thus, in this position the ultimate reaction, R_2 , is

$$R_2 = (2) (1.88) (F) = 5,070 \text{ lb (this value is understrength).}$$

It is recommended that a new track section (Bell Aircraft Standard Extrusion Number 40-033) be substituted for the existing track. This would effectively reduce the lever arm from the line load F to the critical bending section to .07 inch.

$$F = \frac{M_p}{.07} = 1,930 \text{ lb per in.}$$

Also, the aft track is to be increased in length by .81 inch; hence, the overlap at full forward seat position is then 2.69 inches. Thus,

$$R_2 = (2 \text{ flanges}) (2.69 \text{ in.}) (1,930) = 10,400 \text{ lb}$$

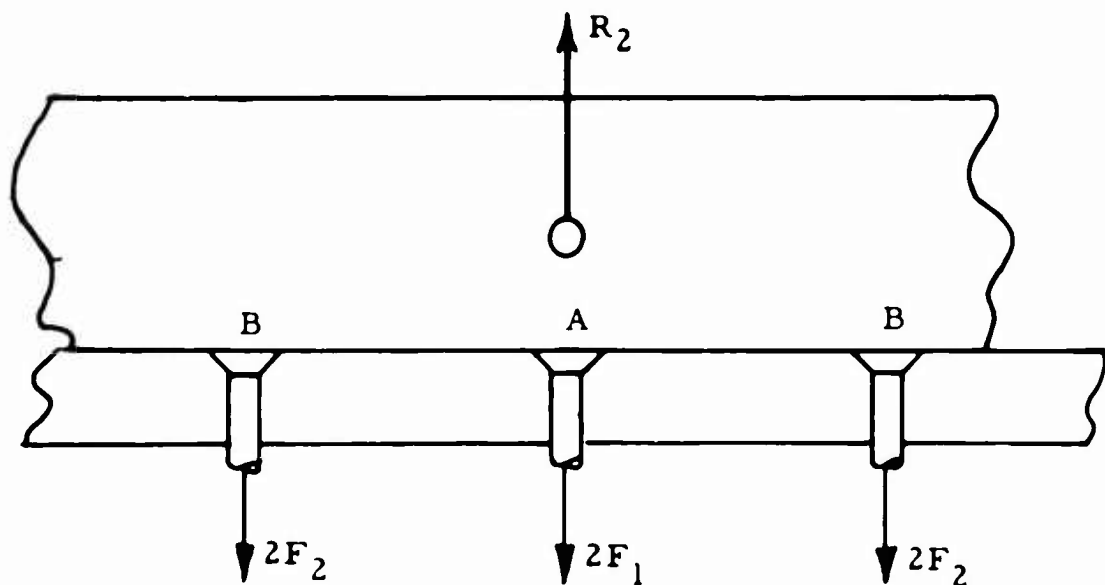
and

$$\text{M. S.} = \frac{10,400}{8,080} - 1 = \underline{.29.}$$

For the latest UH-1B aircraft, the track is continuous from the aft to the forward attachments. Consequently, effective track-channel contact length is assumed to be 3 inches, a length which is greater than the 2.69-inch overlap used in the above calculations, and no analysis is made.

Track Tiedown

As a critical position for the aft seat reaction, R_2 , consider it to act directly above one pair of tiedown bolts.



Associated with a local plastic bending compliance at the channel flange and track flange, the effective length of contact force between track and channel is assumed to be 3 inches as previously noted. This would have the effect of distributing the load over three pairs of tiedown

bolts, provided they are spaced sufficiently close to each other. The existing spacing on the newest UH-1B models is such that any 3-inch length will span three pairs of bolts. On UH-1A models and early UH-1B models, the existing spacing between pairs is 1.75 inches, which (in the absence of significant bolt elongation prior to failure) is too wide a spacing to depend upon assistance from bolts "B" (in above figure) in carrying the load R_2 . Thus, R_2 must be assumed to be limited by

$$R_2 = 2F_1$$

where F_1 is the ultimate tensile load for an AN-3 bolt, 2,210 pounds. Hence, $R_2 = 4,420$ pounds, which corresponds to an inertia load of 12G. As indicated in Supplement drawing HU-1-20, it is recommended that bolts be added to reduce the spacing to .88 inch between pairs. With both this modified spacing and the existing spacing on the newest UH-1B models with the continuous track, for the load R_2 directly above a pair of bolts (A), the adjacent bolts (B) may conservatively be assumed to sustain half the load of bolts A.

Thus,

$$R_2 = 4F_1 = 8,840 \text{ lb}$$

or

$$\text{M. S.} = \frac{8840}{8080} - 1 = \underline{.09.}$$

Sub-Floor Structure

The seat tracks are supported under the floor by four beams running longitudinally at Butt line's 30L, 14L, 14R, and 30R. These beams were analyzed for the critical load (R_2) of 8,080 pounds applied over a track length of 2.69 inches. The analysis indicates a positive margin of safety for all four beams, but the lengthy analysis is not included in this appendix since no reinforcement is recommended. If the analysis is desired, the calculations are available in rough form.

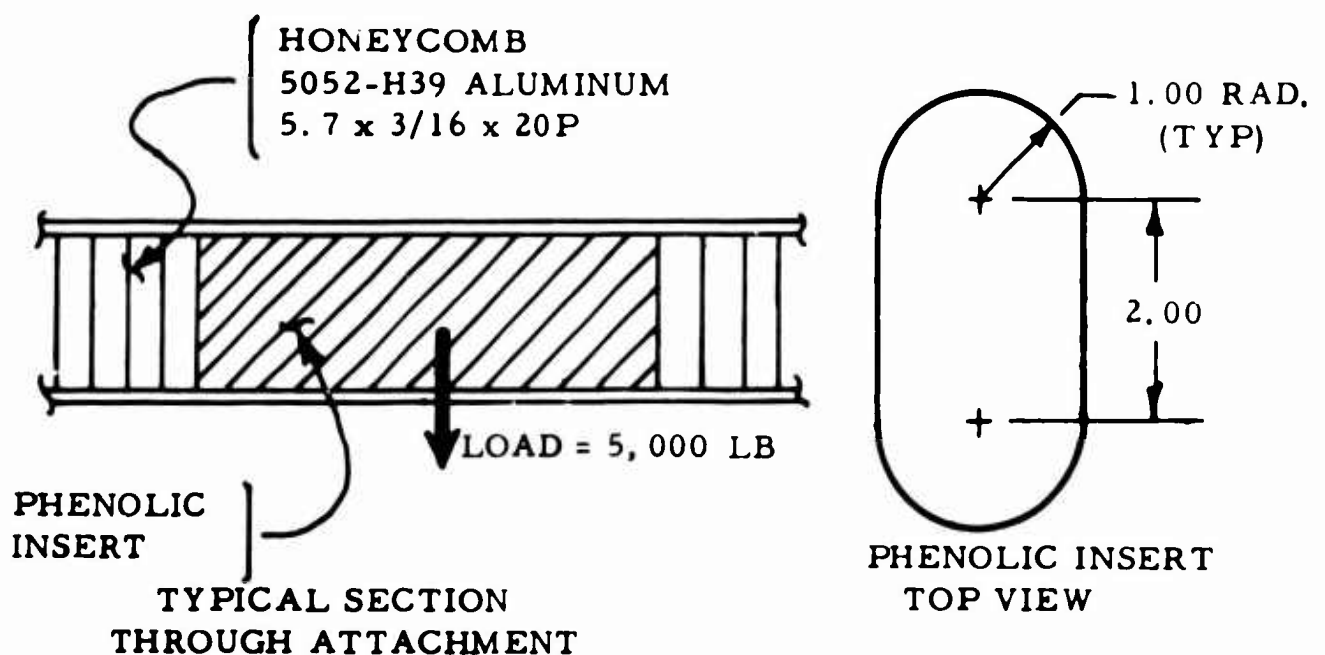
TROOP SEATS

Lap Belt Attachments - Fuselage Station 123 Bulkhead

In both the UH-1A and the UH-1B, the troop lap belts are attached to the Fuselage Station 123 bulkhead by means of forged aluminum fittings which are bolted to phenolic inserts in the honeycomb panels. The location and the number of fittings vary between the two models, but the details of attachments are essentially the same (reference Bell Helicopter Company Drawings 204-031-178, 204-031-277, 204-030-177, and 204-030-178).

Under crash loading, the honeycomb panels of the UH-1A are more critically loaded than the panels of the UH-1B due to the number of fittings and their location on the panel. Analysis of the UH-1A bulkhead panels, using the method of limit analysis, indicates that the panels and the fasteners which attach the panels to the surrounding structure are adequate to sustain 5,000 pounds at each fitting (total load of 10,000 pounds) acting perpendicular to the panel. This load corresponds to an acceleration of 25G along the longitudinal axis of the aircraft, for a 200-pound occupant. (An acceleration of 25G acting on a 200-pound occupant would produce a 2,500-pound load at each attaching point of the lap belt. There are two lap belts attached to the panel at each fitting. Thus, the total load on each fitting would be 5,000 pounds.)

The favorable analysis of the honeycomb panel is based upon the assumption that no local failure occurs; therefore, it is necessary to determine the local strength of the attachments in order to verify this assumption.



1. Shearout of Phenolic Insert:

The conservative assumption is made that no benefit is derived from the titanium facing material in resisting the localized shear around the periphery of the insert.

The minimum strength of the attachment of the phenolic insert to the honeycomb will occur when the long axis of the phenolic insert is parallel to the ribbon direction of the honeycomb and will depend upon the shear strength of the honeycomb. For this case, there will be a minimum of 88 thicknesses of foil available in shear. Thus, the minimum shear area will be

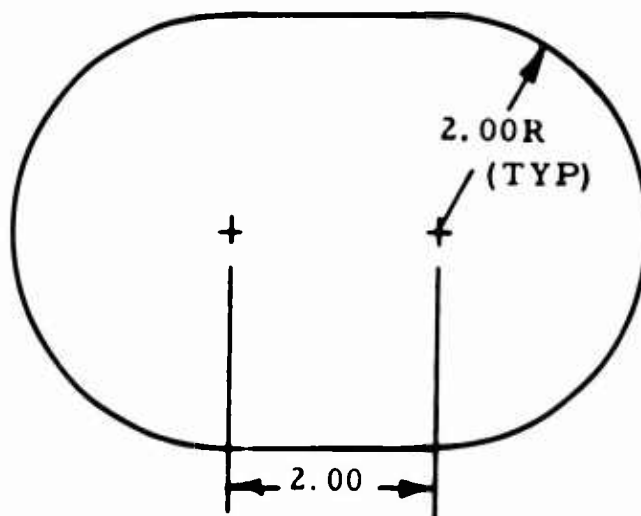
$$(88) (0.75 \text{ in.}) (0.002 \text{ in.}) = 0.132 \text{ in.}^2$$

The ultimate shear strength of the honeycomb is 24,000 psi. Thus, the maximum shear load is

$$(0.132 \text{ in.}^2) (24,000 \text{ psi}) = 3,168 \text{ lb.}$$

The honeycomb core cannot carry the 5,000 pound-load in shear; therefore, reinforcement is necessary to insure the structural integrity of the attachment.

2. Consider a reinforcing plate with the following dimensions placed on the aft side of the panel and located centrally over the existing insert.



In tests of the UH-1A static test ship, the lap belt attachments have been loaded to 2,190 pounds without failure. As a compromise between assuming that the existing panel carries

the 5,000-pound load and assuming that the reinforcing plate carries all the 5,000 pounds, let the existing phenolic insert carry 2,000 pounds, which has been verified by test, and let the reinforcing plate carry the remaining 3,000 pounds.

This 3,000 pounds will be carried as a uniformly distributed compressive load over the portion of the honeycomb panel covered by the reinforcing plate. Thus, the area in compression would be

$$[(2)(4) + \pi 4] - [(2)(2) + \pi] = 13.43 \text{ in.}^2,$$

and the resulting pressure would be

$$\frac{3,000 \text{ lb}}{13.43 \text{ in.}^2} = 224 \text{ psi.}$$

For each square inch of panel surface, there is 0.0193 square inch of aluminum available in the honeycomb to resist compression. The compressive yield strength of the aluminum is 30,000 psi; therefore, the allowable panel compression load is

$$(0.0193 \text{ in.}^2/\text{in.}^2) (30,000 \text{ lb/in.}^2) = 577 \text{ psi.}$$

This yields a margin of safety in compression of

$$\left(\frac{577}{224} \right) - 1 = +1.57,$$

which indicates that the honeycomb panel can easily carry the 3,000 pounds in compression.

The circumference of the reinforcing plate is 16.58 inches, whereas the circumference of the phenolic insert is 10.28 inches. Thus, the ability of the honeycomb to withstand a normal shear load is increased from 3,168 pounds to

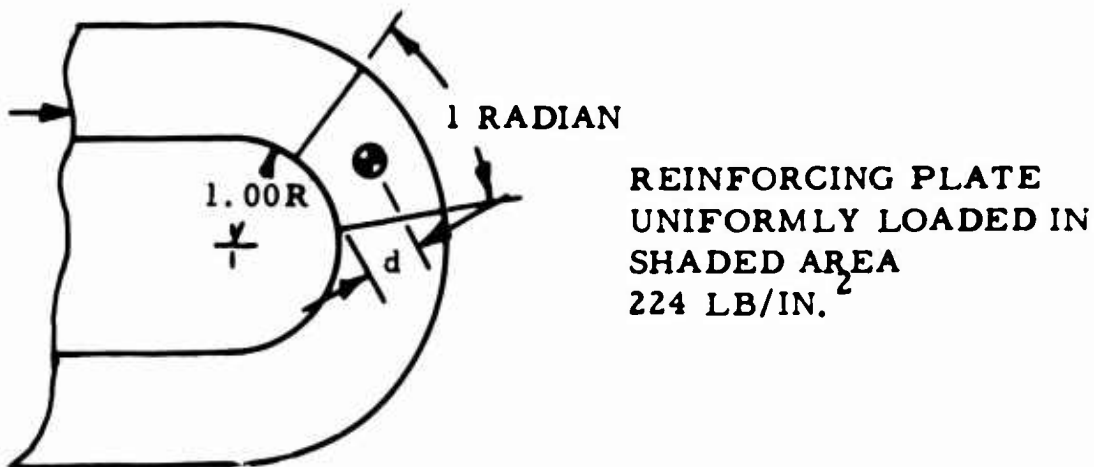
$$\left(\frac{16.58 \text{ in.}}{10.28 \text{ in.}} \right) \times 3,168 \text{ lb} = 5,120 \text{ lb,}$$

which is sufficient, yielding a margin of safety in normal shear of

$$\left(\frac{5,120}{5,000} \right) - 1 = +0.04.$$

3. Determination of Thickness of Reinforcing Plate

By inspection, the maximum bending moment in the reinforcing plate would occur on a segment at the end of the plate as shown.



The moment to be resisted by the plate at the edge of the phenolic insert would be

$$\text{(Moment/inch)}_{\text{Max}} = (224 \text{ psi}) (A) (d)$$

where A = Total area under pressure of 224 psi

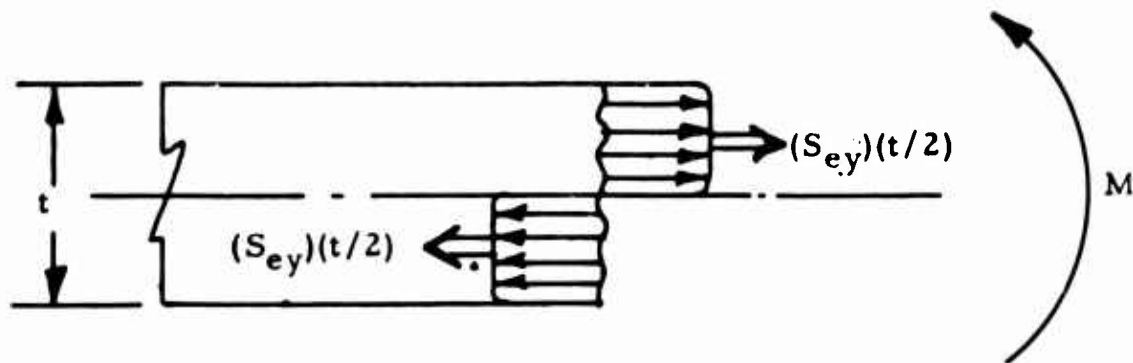
d = Distance of centroid of area from the resisting section.

$$A = \pi (r_2^2 - r_1^2) \left(\frac{1 \text{ rad}}{2\pi \text{ rad}} \right) = \pi [(2)^2 - (1)^2] \left[\frac{1}{2\pi} \right] = 1.5 \text{ in.}^2$$

$$d = 0.558 \text{ in.}$$

$$\begin{aligned} \text{Therefore, } (M/\text{in.})_{\text{Max}} &= (224 \text{ psi})(1.5 \text{ in.}^2)(0.558 \text{ in.}) \\ &= 187 \text{ in.-lb} \end{aligned}$$

Using the plastic hinge concept, this bending moment would be resisted in the reinforcing plate as shown.



For a unit length of plate, the resisting moment in the plate is

$$M_r = \left(\frac{S_{ey}}{4} \right) (t)^2.$$

If the reinforcing plate is made of 0.100-inch-thick 7075-T6 aluminum and the equivalent yield stress is 75,000 lb/in.², the resisting moment is

$$M_r = \frac{(75,000)(0.100)^2}{4} = 187.5 \text{ in. - lb,}$$

which yields a margin of safety in bending of

$$\frac{187.5}{187.0} - 1 = +0.002.$$

(Note: For 7075-T6 aluminum plate, the probable ultimate tensile strength is 79,000 lb/in.² and the minimum guaranteed ultimate tensile strength is 77,000 lb/in.²)

Therefore, it is recommended that the attachment points for the troop lap belts be reinforced with 0.100-inch-thick 7075-T6 reinforcing plates as shown in Supplement drawing HU-1-30, to increase the ability of these attachments to withstand crash loads.

SUPPLEMENT

RESTRAINT SYSTEM MODIFICATION DRAWINGS, UH-1A AND UH-1B AIRCRAFT (Published under separate cover)

The restraint system modification drawings included in the supplement to this report are listed as follows:

- HU-1A-10 - This is a master drawing which locates and identifies the modifications.

- HU-1-11 thru
HU-1-20 - These drawings cover crew seat modifications.

- HU-1-30 - This drawing covers the modification of the troop lap belt attachment fittings.

- HU-1B-50 - This is a master drawing which locates and identifies the modifications.

- AvCIR-10 and
AvCIR-15 - These drawings describe the single tiedown strap which is applicable to all Army aircraft.

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