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CRASH INJURY EVALUATION

U. S. ARMY YHU-1D

BELL IROQUOIS HELICOPTER MOCKUP

Fort Worth, Texas

7 - July 1960

19 - 20 January 1961

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AVIATION CRASH INJURY RESEARCH

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REPORT OF CRASH INJURY EVALUATION

For

United States Army
Transportation Research Command
Contract DA-44-177-TC-624

By

Jack Carroll, Chief, Training Branch

AVIATION CRASH INJURY RESEARCH
A Division of
Flight Safety Foundation, Inc.
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February 1961

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FOREWORD

In its efforts to determine the crash survival aspects of aircraft accidents, Aviation Crash Injury Research (AvCIR), a division of the Flight Safety Foundation, is guided by certain criteria which it considers fundamental for the crash protection of aircraft components. These same criteria also are used to evaluate the crash safety features of mockups and prototypes. They are:

1. Crashworthiness: The ability of basic aircraft structure to provide protection to occupants during survivable impact conditions;

2. Tie-down chain: All components of the occupant seating and restraint system including seat belt, shoulder harness, seat structure, floor, and related anchorages. Tie-down of components is also considered;

3. Occupant environment: The injury potential of all objects and structure within the occupant's striking range;

4. Transmission of crash force: The manner in which crash forces are transmitted (magnified or attenuated) to the occupant by intervening structure; and

5. Post-crash factors: Post-crash fire, emergency exits, ditching characteristics, etc.

For a more elaborate discussion of crash safety criteria, reference is made to Appendix II.

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SUMMARY

Two crash injury evaluations of the mockup of the YHU-1D were conducted by AvCIR at the request of the U. S. Army Transportation Research Command (TRECOM). The first evaluation was conducted on 7 July 1960, at which time many of the design details had not been completed. A subsequent evaluation was made on 19-20 January 1961. Both evaluations were made at the Bell Helicopter plant, Fort Worth, Texas.

The purpose of the evaluations was to:

1. Evaluate over-all crash safety of the basic aircraft structure;

2. Determine the existence, if any, of features which could lead to unnecessary exposure of crew members and passengers to serious or fatal injury in the event of an accident involving crash conditions of a survivable nature;

3. Make recommendations for remedial action in the areas where deficiencies exist in order to improve the over-all crash safety aspects of the aircraft; and

4. Point out desirable crash safety features revealed through inspection of the mockup, engineering drawings, and detailed specifications.

The above work was accomplished through a comprehensive crash injury evaluation of the entire aircraft, its components, and equipment. This was supported by discussions with members of the Bell engineering staff and reference to applicable technical manuals and military specifications.

As a result of the evaluation, which was based in part on previous accident experience with the similar HU-1A helicopter, it was concluded that: (1) The basic structure of the YHU-1D provides a strong, crashworthy platform with a reasonable degree of crash force energy absorption through a well-designed skid gear assembly; (2) the YHU-1D presents a good cockpit arrangement, with the instrument panel mounted low and out of striking range for an adequately restrained pilot or copilot; and that (3) provisions for emergency exit in both the crew and troop compartments are adequate, except as otherwise noted herein.

The evaluation also revealed a number of crash safety deficiencies existing in troop seats, litter installations, certain emergency escape provisions, potential fuel system hazards, and, in particular, the continued use of a magnesium cast transmission support case which has proven to be an inherent weak point of design in the Bell Iroquois helicopter series. In addition, the Military Specifications and crash load structural criteria governing the design and strength of various components, such as seats, litters, etc., are considered deficient in that minimum requirements specified are inadequate and incompatible with simultaneous application of crash forces in three planes, and with magnitudes and durations experienced in actual helicopter accidents.

Based on the data and analyses presented in this evaluation, several recommendations are made concerning the airframe, components, main cabin, furnishings, and related Military Specifications. These are contained in Section III.

This is the final report on the crash injury evaluation.

DESCRIPTION OF AIRCRAFT

The YHU-1D (Figure 1) is a single rotor helicopter powered by a Lycoming T53-L-9 turbine engine of 1100 horsepower. The helicopter is designed for a cruise speed of 100 knots, maximum speed 129 knots. Its gross weight varies from 6588 to 8600 pounds, depending upon the mission.

The YHU-1D is designed to serve as an instrument trainer, assist in medical evacuation, and to transport personnel, equipment, and cargo as required.

Figure 1. Bell YHU-1D U. S. Army helicopter mockup

Eleven combat troops may be transported in either of two alternate cabin seating arrangements in addition to the pilot and troop commander, who occupies the copilot seat. When employed for medical evacuation, the cabin compartment will provide for the installation of six standard Army type litters. Approximately 220 cubic feet of cargo space is available in the cabin area for equipment and cargo storage during missions of this type.

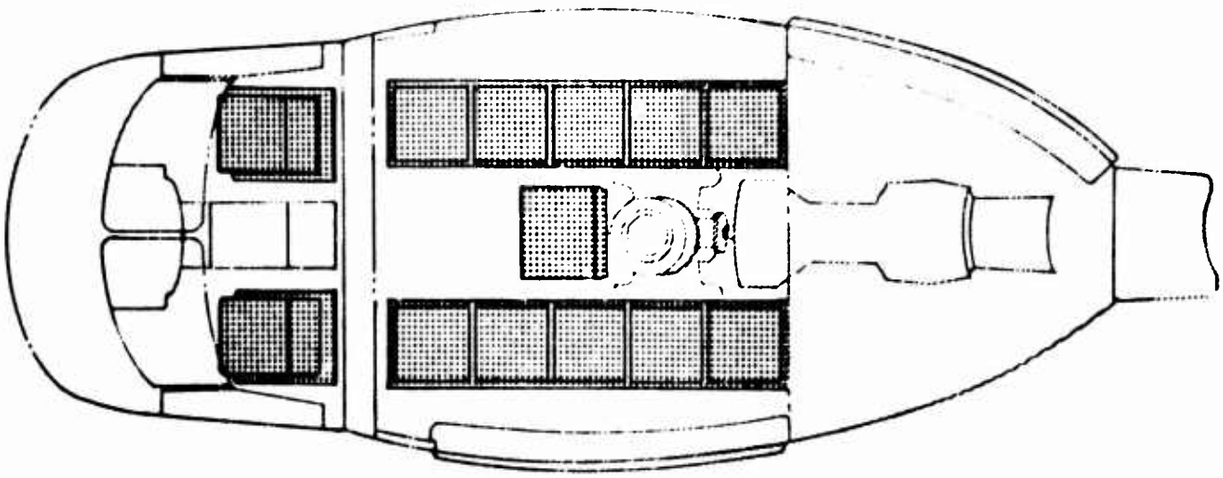

Figure 2. YHU-1D proposed seating arrangement

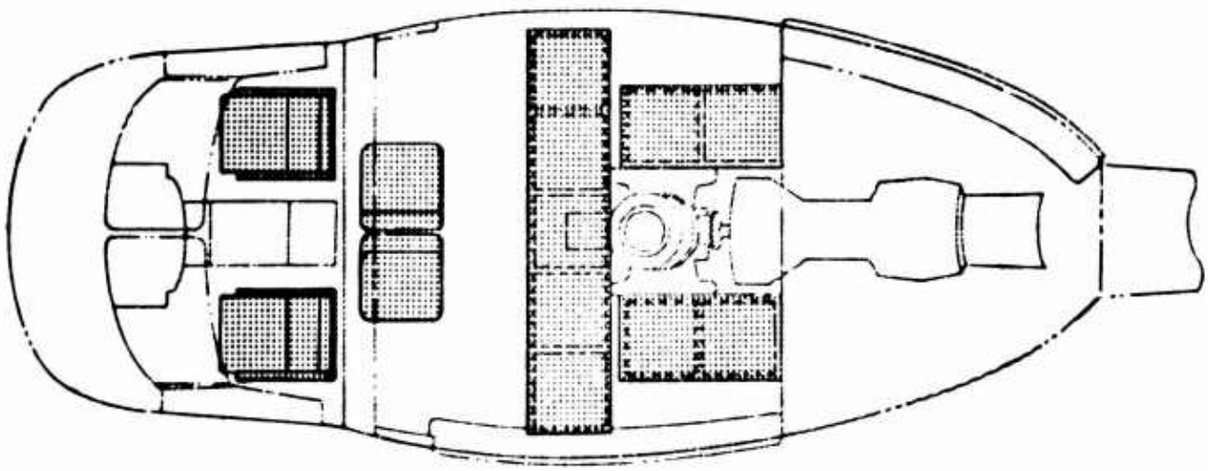

Figure 3. YHU-1D alternate seating arrangement

The YHU-1D is the largest of the Iroquois series helicopters. Figure 4 illustrates the difference in size between this model and the HU-1B. Major design features and other significant characteristics of this helicopter are discussed in subsequent sections of this report.

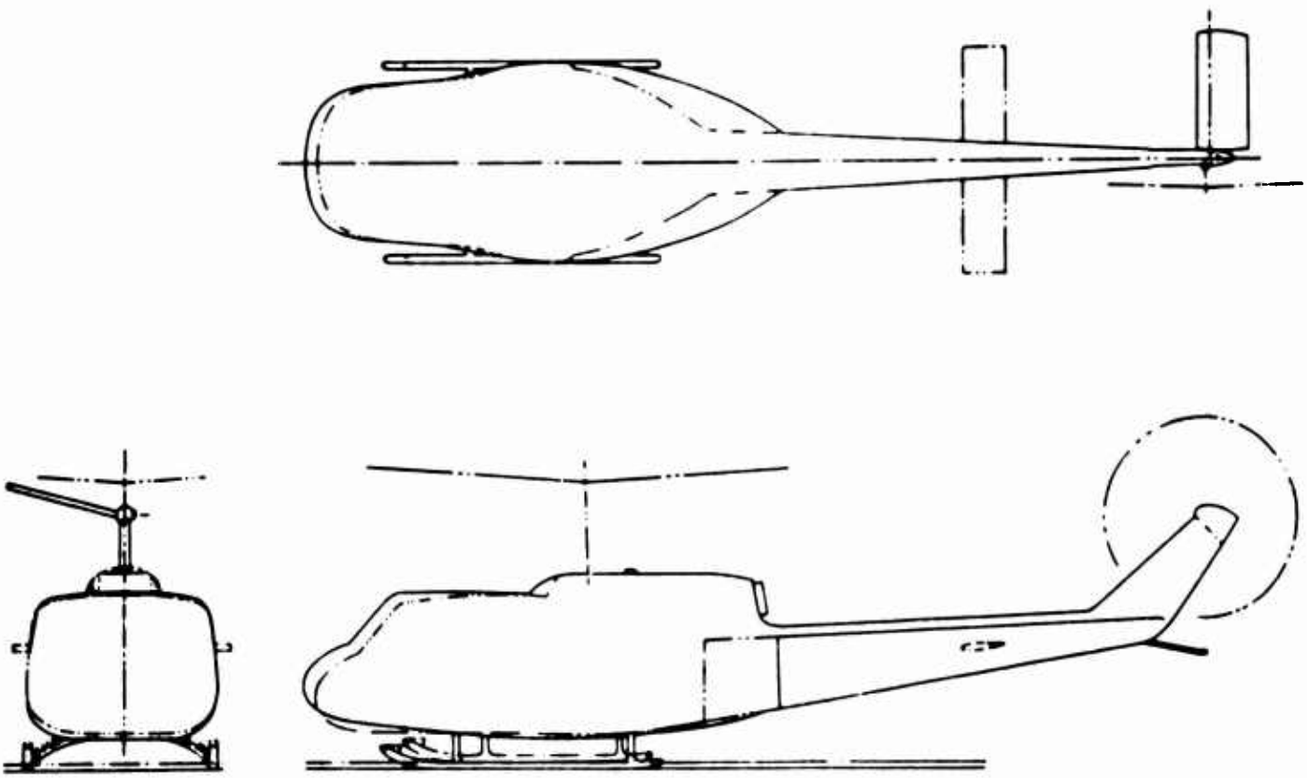

Figure 4. HU-1B and YHU-1D size comparison

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EVALUATION OF BASIC AIRFRAME

GENERAL DISCUSSION

The fuselage of the YHU-1D consists of two main sections: (a) The forward section, and (b) The aft or tail boom section. The forward section includes the landing gear, transmission, power plant, and crew and passenger locations (Figures 5 and 5A). The aft section supports the tail rotor and components and is attached to the forward section by means of four tension bolts.

BASIC STRUCTURE (FUSELAGE)

Two main parallel beams extend longitudinally fore and aft of the pylon and form the primary forward fuselage structure (Figure 6). These beams, together with adjacent structure, support an aluminum honeycomb deck, and their outer surfaces from Stations 102 to 155 provide support for the two forward fuselage fuel cells located beneath the cabin floor.

The structural integrity of this type construction has been demonstrated in several HU-1A accidents involving relatively high vertical forces. Since the main beams of the YHU-1D have been increased approximately four inches in depth, it is anticipated that crashworthiness characteristics will remain good despite the additional mass and weight being supported.

SKID GEAR ASSEMBLY

The YHU-1D skid gear assembly is essentially the same as that used on earlier Iroquois series helicopters. In HU-1A accidents, this skid gear assembly has demonstrated its ability to yield progressively, absorbing and attenuating a large portion of vertical crash force. It is anticipated that the dynamic response of this skid gear assembly will provide the same degree of crash force attenuation when crash force loading is no greater than has been experienced in accidents in the past (in the order of 9 to 13G vertical, 200 to 500G per second rate of onset).*

However, with increased load-carrying requirements of the HU-1D, it may be well to re-examine this skid gear assembly to determine its capability under such heavier loading conditions.

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* Ref.: TREC Technical Report 60-73, AvCIR 15-PR-126, "Summary Crash Injury Evaluation of U. S. Army HU-1A Bell Helicopter."

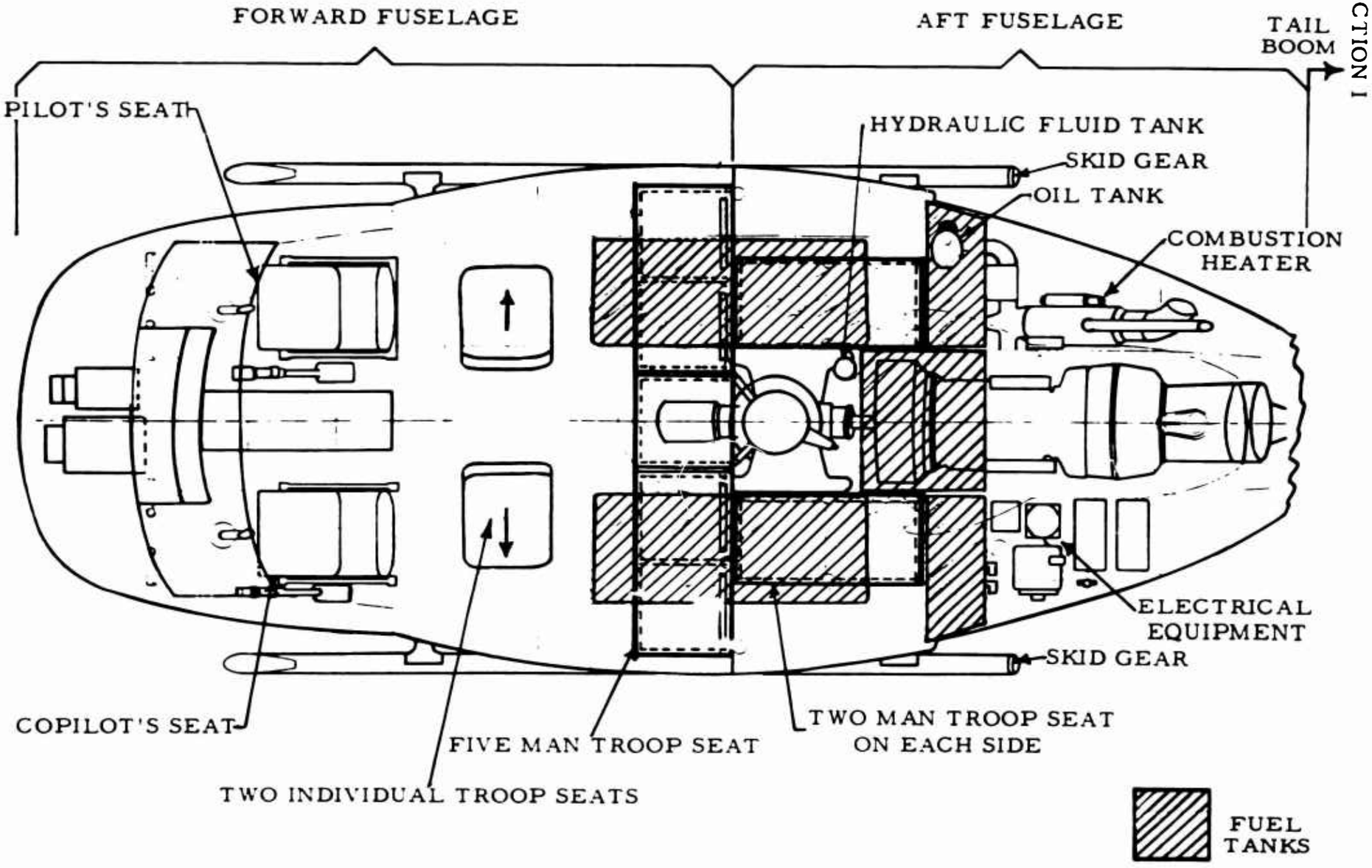

Figure 5. Top view of YHU-1D fuselage

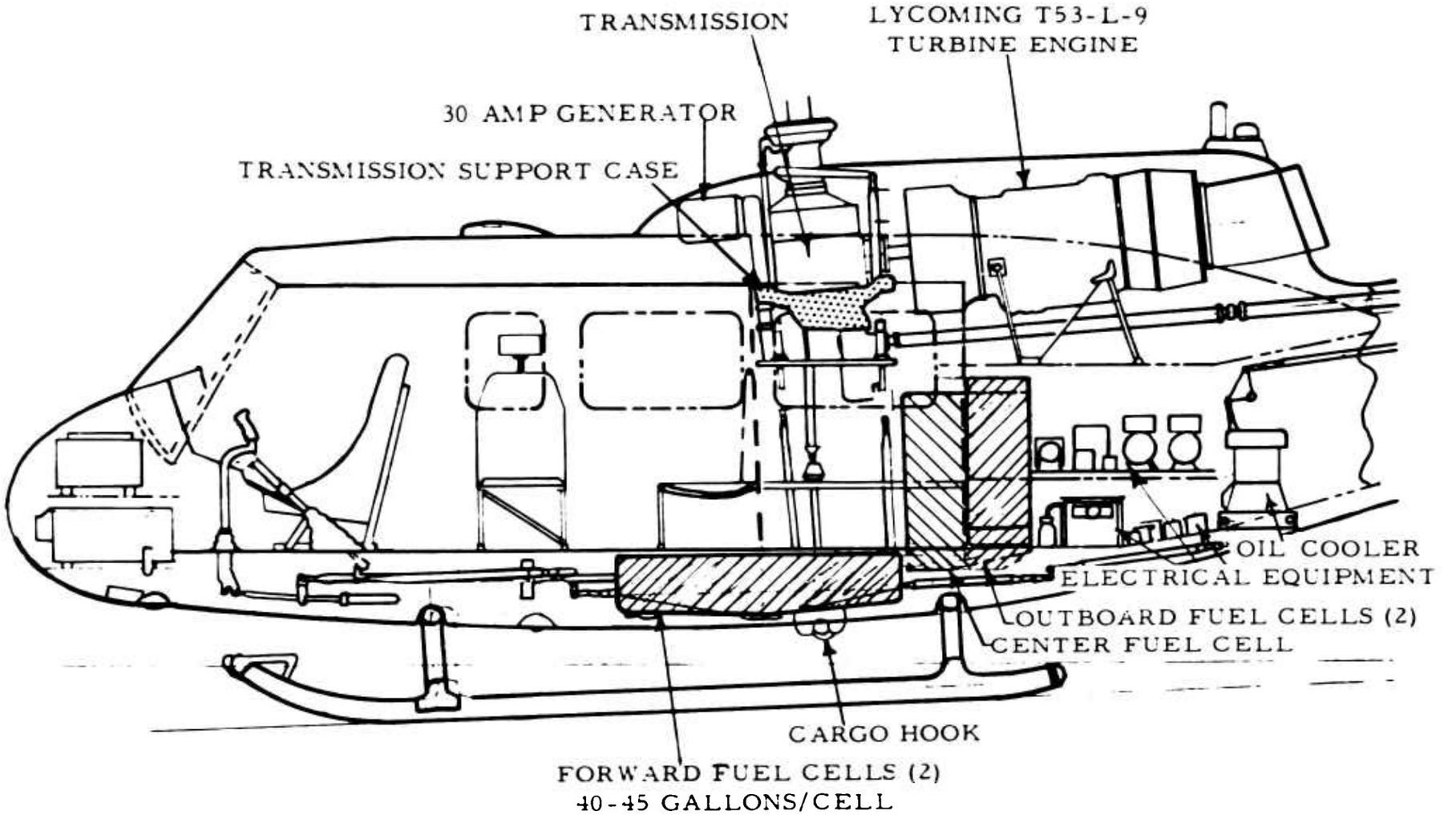

Figure 5A. Side view of YHU-1D fuselage

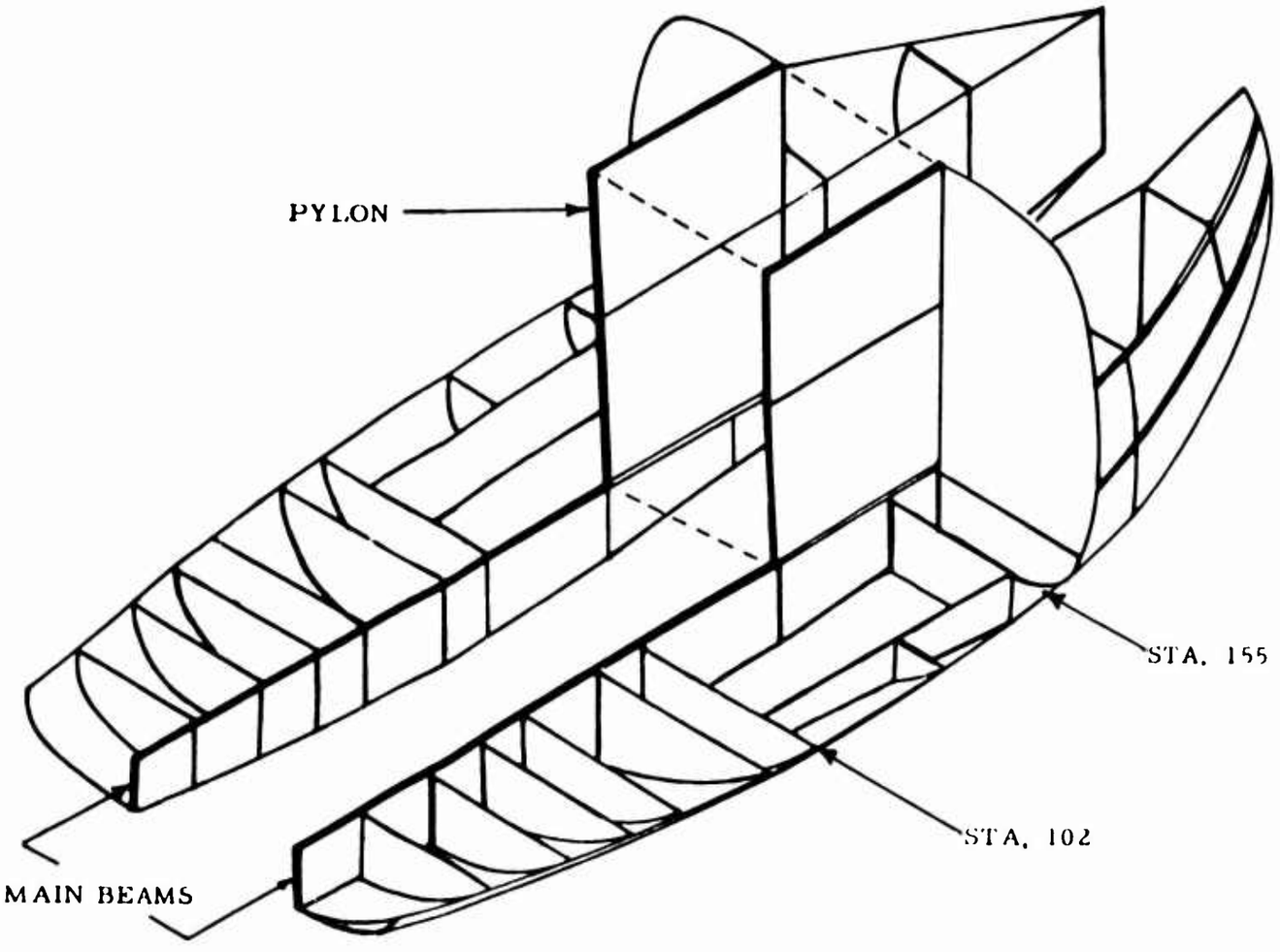

Figure 6. YHU-1D basic structure (fuselage)

ROOF

The YHU-1D roof structure varies from the earlier Iroquois series in that its thickness has been increased from approximately 2-1/4 inches to approximately 4-1/4 inches. Two aluminum honeycomb deck walkways have been provided alongside the pylon, extending from the aft edge of the forward windows to the aft end of the roof. Two additional outboard longitudinal beams have been provided inside the roof structure. The cabin roof walkway is designed for two 200-pound men located on the most critical area, providing a limit load factor of 1.5.* Considering the roof

* Bell Technical Data Report Number 205-099-001, dated August 9, 1960, "Basic Structural Design Criteria for YHU-1D Utility Helicopter."

as a single unit, the mass and weight of this unit has increased proportionately over the earlier Iroquois series and might pose a problem with respect to support when subjected to high vertical forces. This problem is discussed in the following paragraph.

ROOF SUPPORTS

The cabin roof (Figure 5A) is supported at the aft end by aluminum honeycomb firewall on either side outboard of the pylon, and by attachment to the aluminum honeycomb on the left, right, and forward walls of the pylon. At the forward end, the roof is supported between Station 63.8 and 74.3 by a left and right door post. These door posts, or vertical support members, also provide a roll-over structure (Figure 7) through the roof and are designed for the following ultimate loads* applied simultaneously:

Vertical column load on each door post = 2500 pounds

Lateral (side) load applied at roof = 2500 pounds

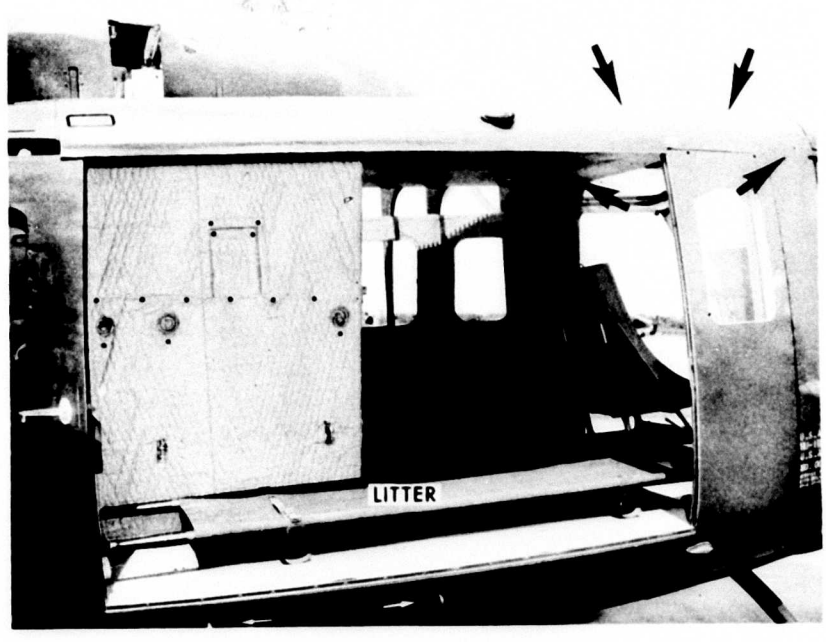

Figure 7. YHU-1D right side, main cabin. Note roll-over structure formed by vertical supports (carried through the roof structure).

* Ref.: TREC Technical Report 60-73, AvCIR 15-PR-126, "Summary Crash Injury Evaluation of U. S. Army HU-1A Bell Helicopter."

These vertical supports have been critical failure points in the HU-1A models (Figure 8) and have since been strengthened in the HU-1B. The supports for the YHU-1D are considerably larger and stronger units. By comparison with the door posts in the earlier models, which were not designed to carry any structural loading, the vertical supports in the YHU-1D are now designed not only to carry structural loading, but also extend up to the roof beams through a radius in the upper attachments to form, in effect, a complete roll-over structure.

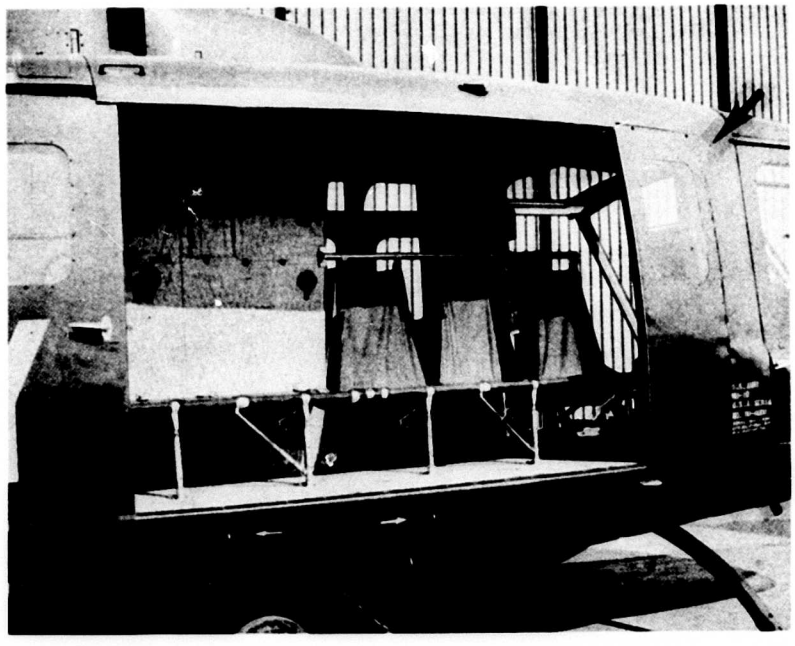

Figure 8. Vertical support, right. Arrows indicate critical failure areas in HU-1A model.

The forward edge of the roof is attached to the lower fuselage through a center windshield post and two forward door posts (Figure 5). These, however, are not intended to carry any structural load, but serve only as front windshield frames and forward door posts.

The roof supporting structures failed in all HU-1A accidents investigated to date by AvCIR*, indicating an inherent weakness in design.

* Ref.: TREC Technical Report 60-73, AvCIR 15-PR-126, "Summary Crash Injury Evaluation of U. S. Army HU-1A Bell Helicopter."

The YHU-1D roof supporting structures appear to be designed with considerable improvement; however, the dynamic response, or the structural integrity, of the larger, heavier roof and proportionately stronger supports cannot be predicted with any degree of accuracy without subjecting these units to full-scale dynamic testing. It appears desirable, therefore, to subject these structures, in their planned configuration and structural relationships, to dynamic testing under laboratory conditions.

FIREWALL

The walls of the pylon structure and aft bulkheads, including the upper firewall section of the aft cabin bulkheads, are constructed of aluminum honeycomb material (Figure 9). The aluminum honeycomb bulkheads at the aft end of the main cabin and the aft wall of the pylon provide wall surfaces for the one 67-gallon and two 33-gallon fuel tanks. The need for these bulkheads to resist tearing or puncture damage is obvious and will be discussed further in the following paragraph.

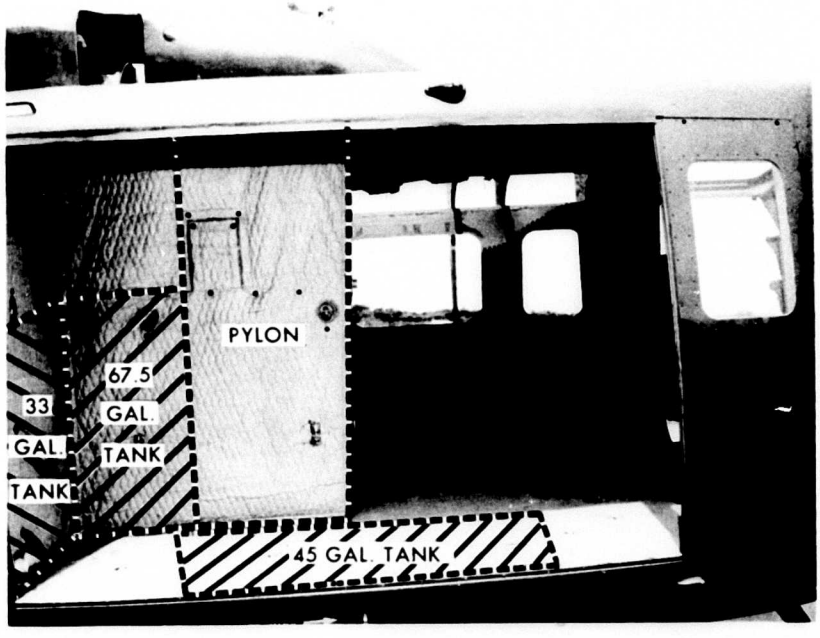

Figure 9. Relative location of fuel cells and pylon in main cabin

SECTION I

FUEL TANKS

Five individual fuel tanks (Figure 10) are provided for the YHU-1D:

One 67-gallon fuel cell aft of the pylon from Station 155 to 178.

Two 33-gallon fuel cells outboard of the above-mentioned tank from Station 166 to 178.

Two 45-gallon under-floor fuel cells outboard of the main beams from Station 102 to 155.

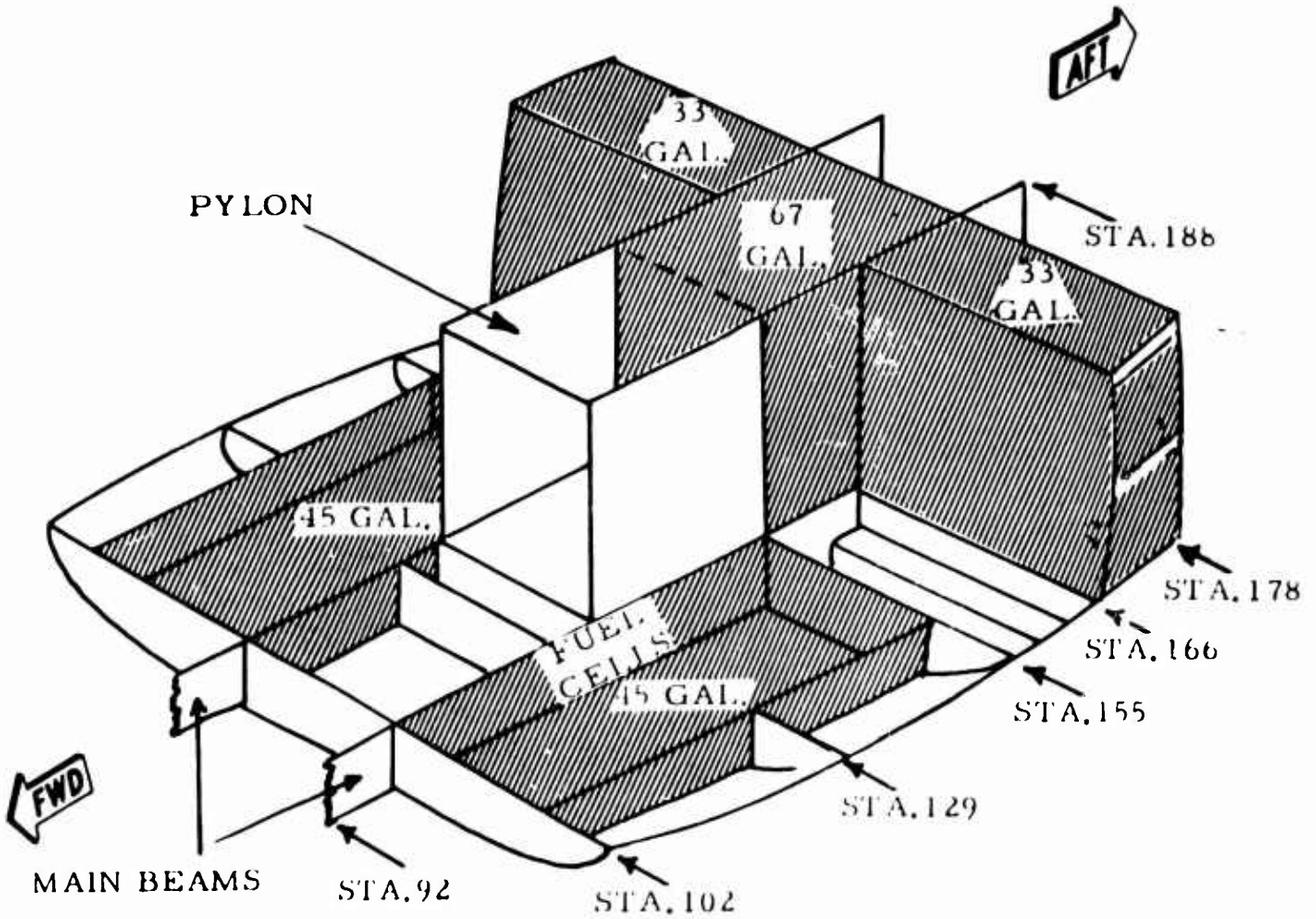

Figure 10. YHU-1D fuel cell arrangement

Due to the highly combustible nature of JP4 fuel*, it is extremely important that the possibility of crash impact fuel cell rupture be prevented. Accident experience with the HU-1A helicopter has indicated that the aluminum honeycomb construction of fuel cells provides a good degree of impact protection against rupture and massive spilling. While post-crash fuel spillage or seepage has been noted in some of the HU-1A accidents, it has not generally been of such massive dispersement that potential fire ignition sources have come in contact with flammable fuel mist. With the redistribution of fuel cell location in the HU-1D, however, it would seem wise to carefully evaluate any new fuel spillage and post-crash fire hazards which may be introduced through such relocation, particularly with reference to fuel cells in the floor.

The bottom of the under-floor tanks (Figure 5A) is designed for protection against impact rupture (or puncture by small rocks, branches, etc.) by a layer of approximately 2-1/2-inch aluminum honeycomb material. The top of the tank is approximately 1/2-inch aluminum honeycomb to which a crash-resistant fabric has been bonded. The basic structural design criteria for these outer beam tanks** calls for the following ultimate load factors acting separately:

Up and down	-	4.5
Side	-	1.5
Forward	-	8.0

Although the external surfaces of these tanks will be provided with self-sealing (anti-ballistic) bladders, these static strength requirements are not compatible with even minimal crash force conditions which can be anticipated in impact conditions otherwise considered survivable.

---

* JP4 (widely used in turbine operation) is a blend of gasoline and kerosene with the same general fire hazard characteristics as gasoline; however, due to the low vapor pressure of this fuel, the vapor/air mixture above the liquid surface in a tank will most frequently be in the flammable range under normal temperature and pressure conditions. This is opposed to kerosene which would normally be too lean, and gasoline, too rich.

** Bell Technical Data Report Number 205-099-001, dated August 9, 1960, "Basic Structural Design Criteria for YHU-1D Utility Helicopter."

The two 33-gallon outboard above-deck fuel cells are also designed to the above structural criteria requirements. The basic structure of these tanks, however, will be 1/2-inch aluminum honeycomb. The 67-gallon center fuel cell aft of the pylon is similarly constructed; however, the structural criteria requirements* indicate an increase in the side strength requirement to 8.0G.

Although aluminum honeycomb readily lends itself to applications calling for the absorption of energy at a constant rate with no rebound, failures have been experienced in aircraft accidents in the area of the bolted or riveted edges of the panels. Careful attention should be given to edge reinforcement of aluminum honeycomb wherever seams or joints are to be bonded. Aluminum honeycomb also is susceptible to puncture by objects coming into forcible contact with it under concentrated loadings. It is necessary, therefore, that the tie-down (restraint) of such items as generators, hydraulic fluid reservoirs, etc. (Figure 11) and dynamic components be sufficiently strong to resist displacement into otherwise unprotected surfaces of the honeycomb fuel cell structures.

Figure 11. Aft left fuselage - relative location of fuel cell and electrical equipment installation

* Bell Technical Data Report Number 205-099-001, dated August 9, 1960, "Basic Structural Design Criteria for YHU-1D Utility Helicopter."

No relationship exists between the crash load strength (static) requirements and the destructive (dynamic) forces which can be anticipated in the YHU-1D under otherwise survivable impact conditions*. The strength criteria/direction relationship also is not consistent with anticipated force magnitudes and directions in helicopter accidents. In the case of the floor and outboard tanks, the greatest protection required by current criteria is in the longitudinal (fore and aft) direction (8.0G). Crash forces most likely to be encountered under actual impact conditions will be primarily vertical with somewhat less side and forward components, acting simultaneously. The greatest level of protection should, therefore, be afforded in the direction parallel to the vertical axis of the aircraft, with compatible strength requirements in the sideward, forward, and aft directions. (See applicable Military Specifications, Appendix III.)

PYLON AND TRANSMISSION

The pylon, located between the two main beams of the floor from Stations 129 to 155, is essentially a rectangular aluminum honeycomb box which contains the transmission mount, support case, transmission, rotor mast, head, and rotors. Lift from the rotor system is imparted through a lift link extending up from primary structure at the service deck level about midpoint of the pylon. The lift link anchors to the main fuselage beams by means of a lift link beam running span-wise across the ship (Figure 12). The roof of the helicopter is attached to the upper forward position of the pylon and to both side areas.

The transmission support case is attached to five sprung mounts (pylon isolating mounts, Figures 12 and 13) located on a frame-type superstructure built up from basic structure at service deck height. In the case of the HU-1A and HU-1B helicopters, only four mounts are used. These mounts are provided to position and vertically support the transmission support case, and to resist torque of the rotor system. With the introduction of the fifth mount in the YHU-1D system, the strength of the other four mounts has been reduced below the strength level provided in the A and B series. The fifth mount is intended to provide additional restraint to prevent the transmission and its support case and accessories from displacing forward into the occupiable area. The transmission support case, a hollow magnesium alloy casting, is also utilized as a transmission lube oil reservoir. This support case has failed in every HU-1A accident investigated by AvCIR** (Figures 14 through 18).

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* Ref.: TREC Technical Report 60-54, "U. S. Army YHU-1B Chinook Mockup", by Jack Carroll, et al., page 66, September 1960.

** Ref.: TREC Technical Report 60-73, AvCIR 15-PR-126, "Summary Crash Injury Evaluation of U. S. Army HU-1A Bell Helicopter."

These repeated failures indicate an inherent weakness in the magnesium transmission support case.

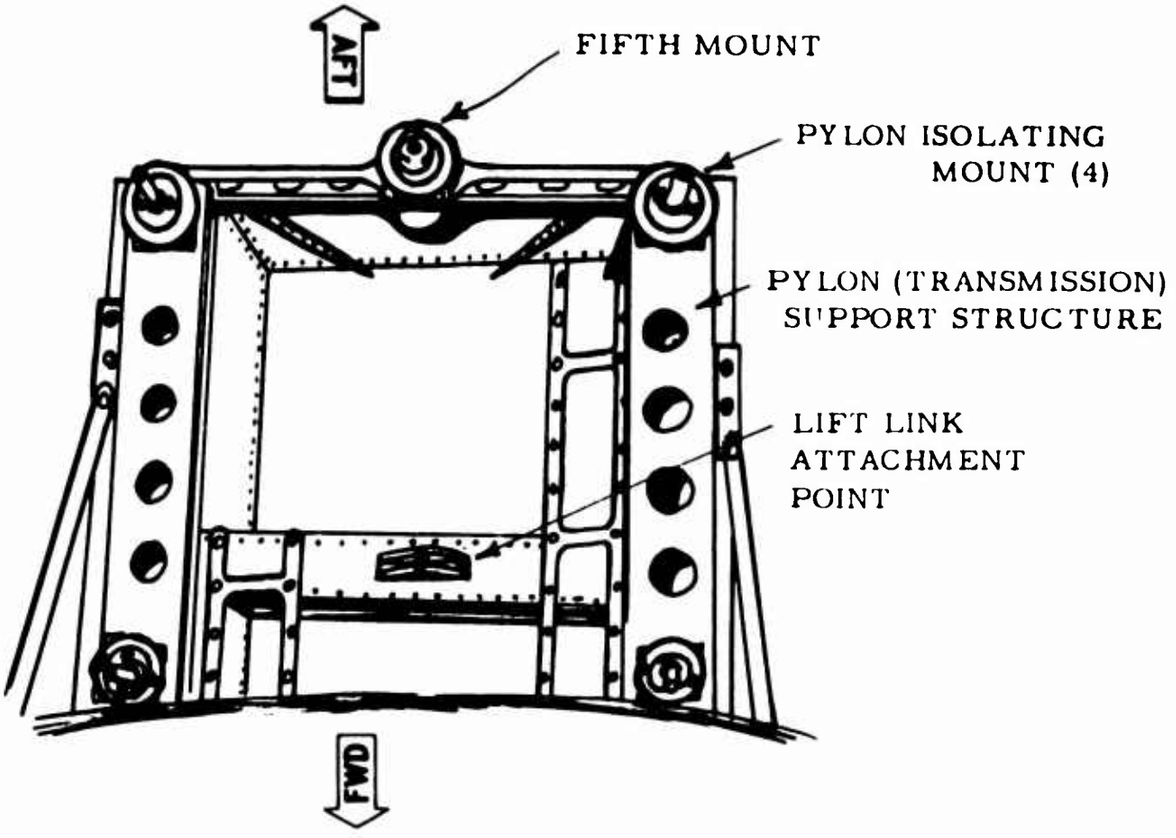

Figure 12. YHU-1D transmission support case mounts and support structure (top view)

In the YHU-1D, a greater mass must be supported by the same magnesium case because of the larger and heavier rotor system. It is questionable, therefore, whether the addition of the fifth mount will be effective in preventing failures such as experienced in the referenced HU-1A accidents. It appears that a solution to this problem would be to fabricate the transmission support case of welded ductile steel forgings, possibly stainless steel, which will yield progressively rather than shatter as in the case of the magnesium casting.

Addition of restraining cables attached to, or encircling, the transmission case and anchored to primary aft fuselage structure, also should be considered as a possible means of preventing the transmission group assembly from penetrating into the occupiable area when subjected to impact.

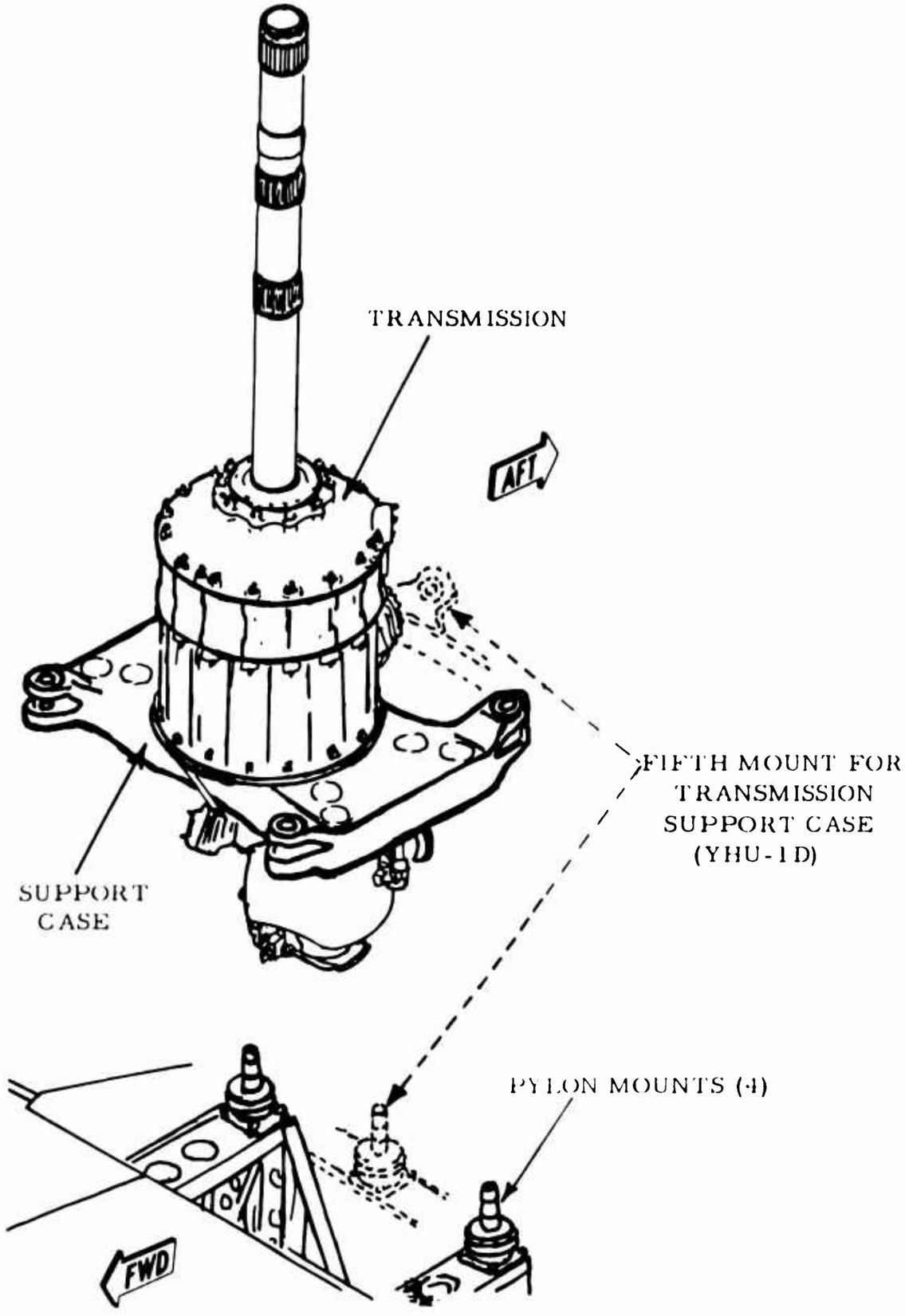

Figure 13. HU-1A mast, transmission support case, and pylon isolating (sprung) mounts

In order to prove the restraint capability of the transmission group and support assemblies early enough in the development of the YHU-1D, it would be advisable to subject the entire arrangement to dynamic testing under impact conditions consistent with magnitudes, directions, time, and rate of onset associated with the upper limits of survivable crash force conditions. *

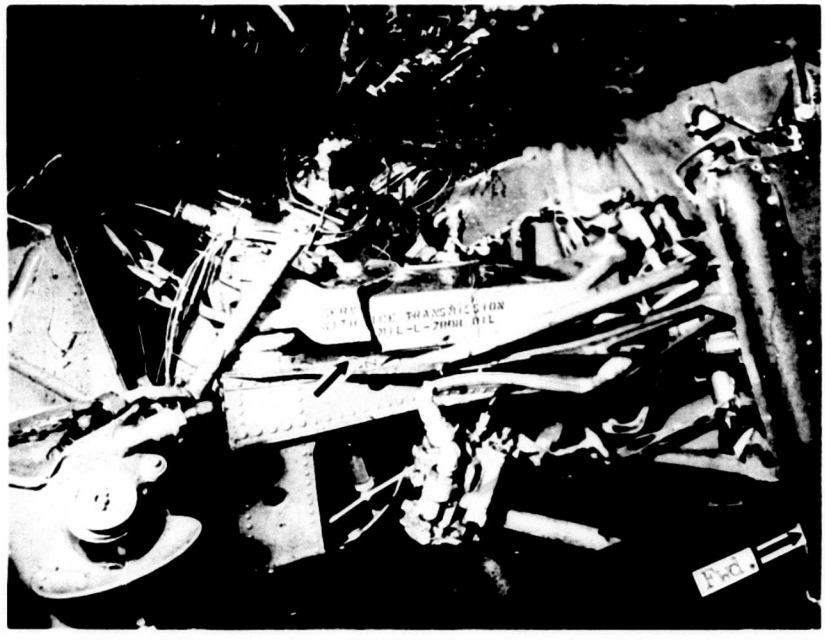

Figure 14. Transmission support case failure, HU-1A accident, East St. Louis, Illinois, 21 October 1959

* Ref.: TREC Technical Report 60-54, "U. S. Army YHC-1B Chinook Mockup", by Jack Carroll, et al., page 66, September 1960

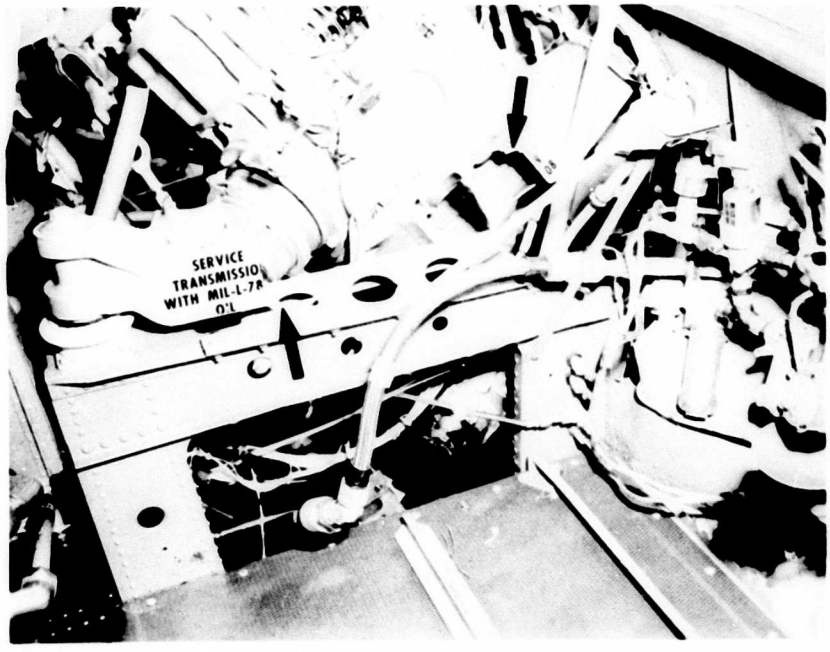

Figure 15. Transmission support case failure, HU-1A accident, Fort Carson, Colorado, 9 June 1960

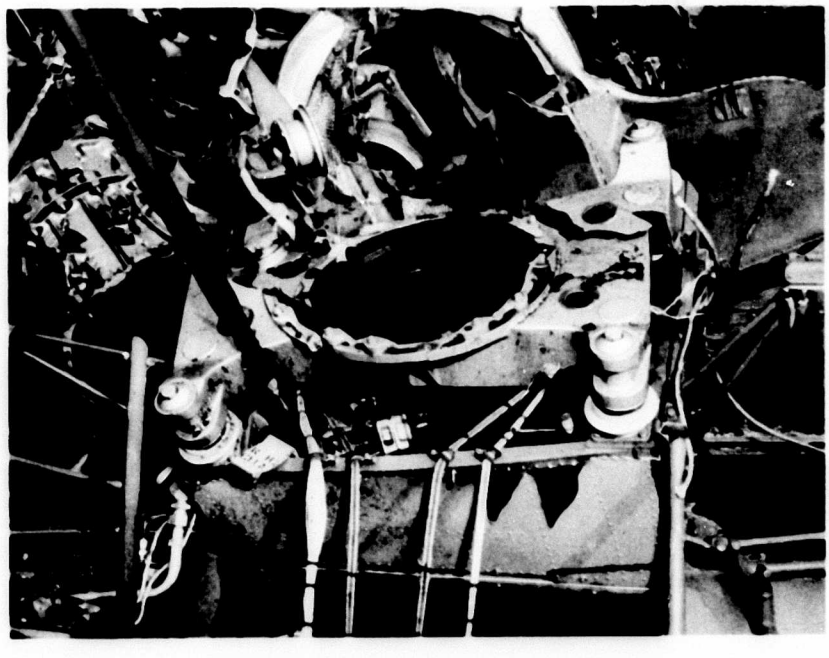

Figure 16. Transmission support case failure, HU-1A accident, Fort Bragg, North Carolina, 20 August 1960

Figure 17. Transmission and support case failure, HU-1A accident, Fort Rucker, Alabama, 4 March 1960

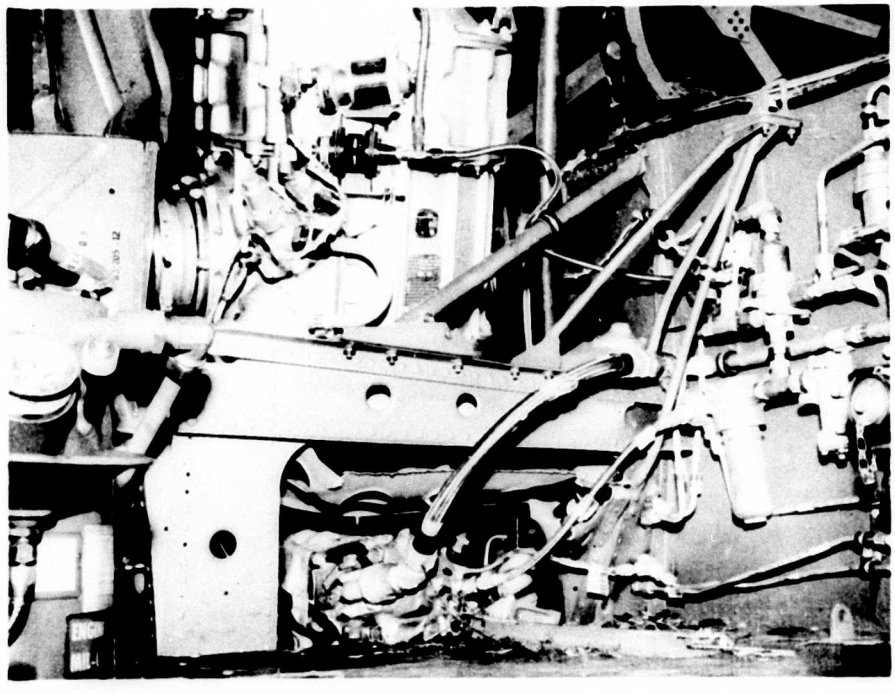

Figure 18. Transmission support case failure, HU-1A accident, Fort Rucker, Alabama, 26 August 1960

ENGINE

The T53-L-9 engine is supported on the service deck of the aft fuselage at approximately Stations 166 to 215, between the fore and aft engine compartment firewalls (Figures 5, 5A, 19 and 20). The center 67-gallon fuel cell and the two 33-gallon outboard fuel cells are located beneath the service deck upon which the engine is mounted (Figure 10).

The crash load factor criteria for the engine support system is as follows:

Up and Down - 8

Sideward - 1.5

Forward - 8

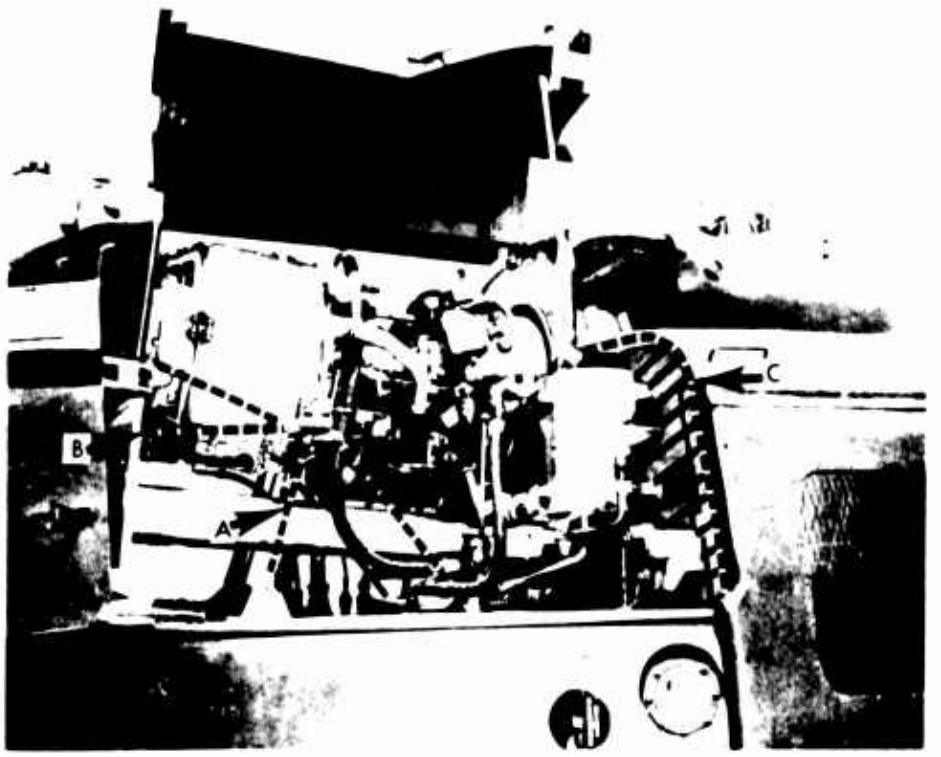

Figure 19. YHU-1D engine, mounts (arrows A and B), and firewall (arrow C) - right side

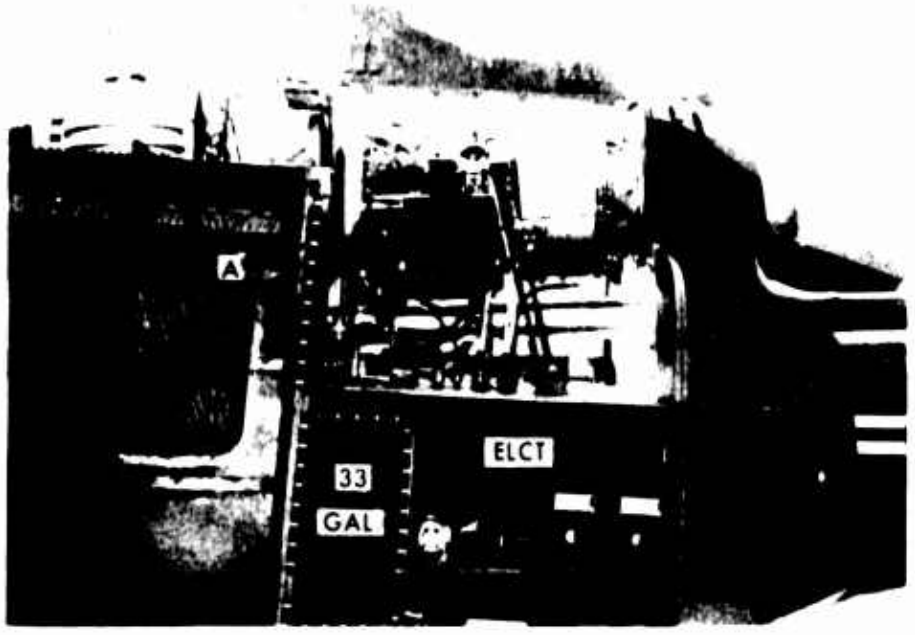

Figure 20. YHU-1D engine, mounts, firewall (A), electrical equipment, and fuel cell proximity - left side

Although some engine mount failures occurred in the HU-1A accidents investigated, the failures were not significant from a crash injury point of view. In the YHU-1D, however, failures will be more significant because of the fuel cells located directly beneath the engine compartment.

Vertical impact loading by the engine support system should be distributed over large areas where the supports are attached to the honeycomb deck structure above the fuselage fuel cells. Concentrated penetrating forces transmitted to the honeycomb structure can be reduced in p. s. i. loading by the use of large flat plate area mounting plates to reduce concentrated loading (Figures 19, 20, and 21).

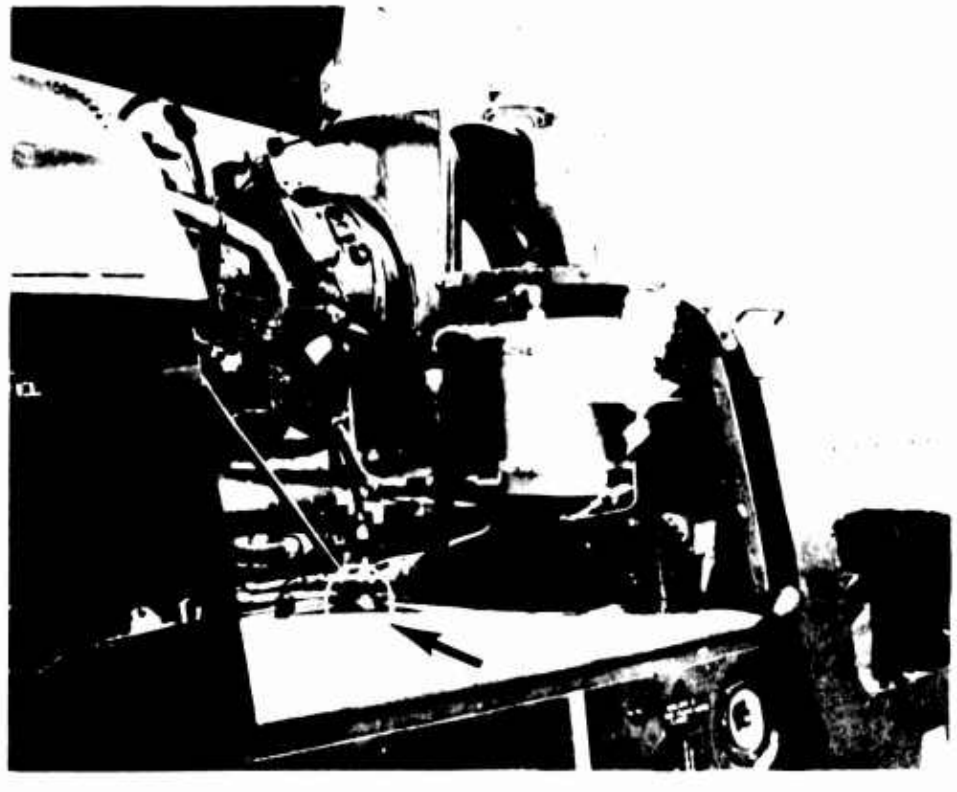

Figure 21. YHU-1D engine mounts, right forward (arrow)

AFT FUSELAGE

The proximity of the 100,000 BTU/HR combustion heater to the right outboard 33-gallon fuel cell (Figures 5 and 22) may constitute a fire hazard in the event of a crash. Although the heater exhaust is deflected up and away from the tank area, flammable fuel mists coming in contact with hot exhaust surfaces could present a dangerous post-crash fire ignition source. Likewise, "hot" electrical components on the left side, being in close proximity to the left outboard 33-gallon fuel cell, (Figures 11 and 20) may present similar potential hazards.

The Bell Structural Design Criteria for items of equipment and useful load not otherwise covered, failure of which would be apt to cause injury to occupants of the helicopter, provide the following ultimate load factors acting separately:

Down	-	8.0
Up	-	4.0
Side	-	8.0
Forward	-	8.0

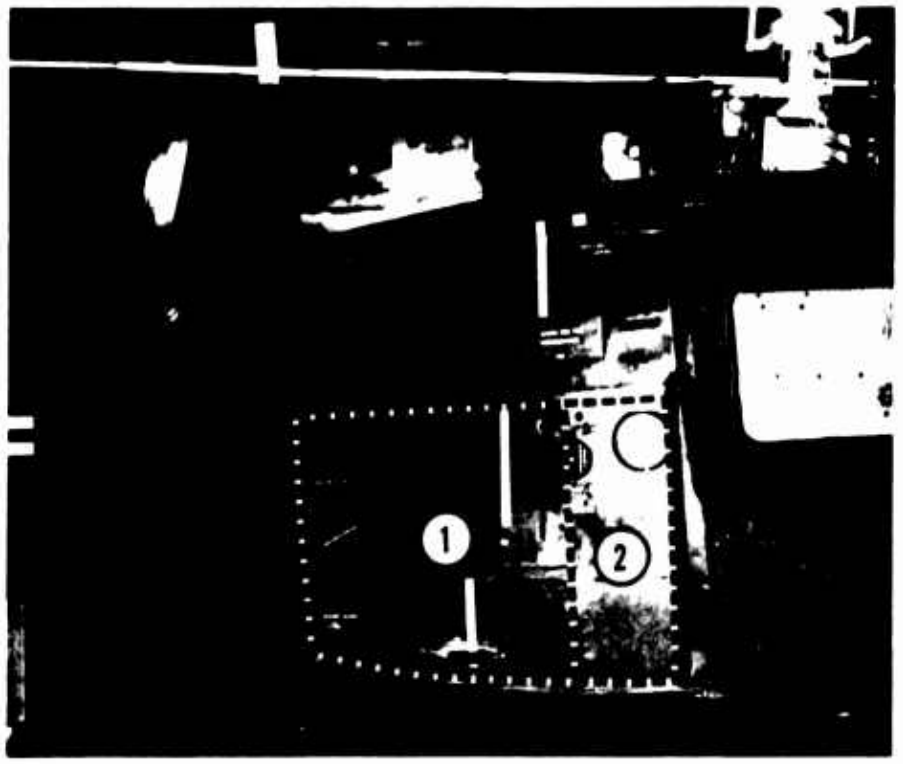

Figure 22. YHU-1D right side aft fuselage - heater compartment (1), and outboard 33-gallon fuel cell (2)

Although the combustion heater, electrical equipment, etc., are not considered in this category by Bell (failure of which would be apt to cause injury to occupants), they are potentially capable of inflicting injury or death in a less direct manner. These items, therefore, should be secured to withstand failure and possible fuel tank penetration resulting in post-crash fire under anticipated crash load conditions.

TAIL BOOM

The tail boom, considered as a unit, is essentially the same as in previous Iroquois series helicopters with the exception that the left and right fixed horizontal stabilizers of the A and B models have been replaced by a fixed stabilizer located on the upper aft right portion of the tail rotor pylon. Failure and separation of the tail boom structure as a unit has been experienced in a number of HU-1A accidents and is considered a desirable crash safety feature in that it removes a considerable mass from the main fuselage, the kinetic energy of which otherwise might be imparted to, or absorbed by, the main fuselage during a crash deceleration.

CONCLUSIONS

Based on the evaluation of the basic airframe of the YHU-1D, it is concluded that:

1. The impact condition/damage relationships anticipated with the YHU-1D should remain similar in nature to accident experience with HU-1A aircraft.

2. The skid gear assembly may be expected to absorb a reasonable degree of impact energy. However, since the gear will be subjected to greater loads than those experienced with the HU-1A, it may be well to re-examine the capabilities of this assembly.

3. The ability of the roof structure to resist dynamic displacement into the occupiable area appears to have been improved over the HU-1A through addition of an integral roll-over structure and incorporation of load-carrying capabilities to the vertical support members. However, the increased strength is questionable, considering the additional weight of the roof. Its value can only be determined through dynamic testing or evaluation of accident experience.

4. The strength requirements and criteria governing the design and construction of fuel cells are not compatible with crash force loads sustained in survivable type aircraft accidents.

5. The ability of such items as heater, electrical components, and hydraulic fluid reservoirs to resist failure and subsequent fuel cell penetration under impact conditions is questionable.

6. The transmission support case can be expected to fail under impact loads due to the nature of its construction, i.e., casting.

7. Dynamic testing of the transmission group and support assemblies under impact conditions consistent with magnitudes, directions, time, and rate of onset associated with the upper limits of survivable crash force conditions would provide a realistic indication of the manner in which these assemblies withstand crash impacts.

8. The concentrated loading of the engine support system may subject fuel cells to penetration under heavy vertical

impact loading.

9. The proximity of the combustion heater and "hot" electrical components to the fuel cells is hazardous should rupture, spillage, or leakage occur from adjacent fuel tanks in the event of a crash.

10. The requirement that crash load factors be considered as acting separately and tested under static conditions (Military Specifications and other structural criteria) is neither adequate nor realistic when considering that magnitude, time, rate of onset, and direction of dynamic forces act simultaneously on structures and components under actual impact conditions.

RECOMMENDATIONS

Based upon the foregoing conclusions, it is recommended that:

1. Full-scale dynamic crash tests of the YHU-1D be conducted under rigidly controlled conditions to determine:

   a. The capability of the skid gear assembly to provide crash energy absorption in proportion to known performance of the HU-1A gear.

   b. The dynamic response, structural integrity, and ability of the larger, heavier roof to resist failure or deformation into the occupiable area of the aircraft.

   c. The ability of fuel cells, installed as presently planned, to resist puncture or spillage under crash force conditions, thereby creating potential post-crash fire ignition sources.

   d. The restraint capability of the transmission group and support assemblies.

   e. The restraint capability of such items as generators, other electrical components, dynamic components, and hydraulic fluid reservoirs to resist failure or displacement into otherwise unprotected surfaces of honeycomb fuel cell structures.

2. Consideration be given to replacement of the cast magnesium transmission support case with a newly designed type which would yield progressively rather than shatter. Consideration should be given to the use of materials such as ductile steel forgings, possibly stainless steel.

3. Consideration be given to the use of restraining cables attached to or encircling the transmission case and anchored to primary aft fuselage structure to prevent the transmission group assembly from penetrating into the occupiable area when subjected to impact.

4. Consideration be given to the use of large flat plate area mounting plates at the base of the engine mounts to reduce concentrated vertical loads transmitted by the engine through its mounts to the honeycomb structure over the fuel cells.

5. Military Specifications and structural design criteria governing crash landing loads for engines, pylon assemblies, fuel tanks, occupiable structure, etc., failure of which, directly or indirectly, would be apt to cause injury to occupants of the aircraft, be revised and increased to levels of protection consistent with the simultaneous dynamic application of forces likely to be encountered under otherwise survivable impact conditions.

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EVALUATION OF CABIN

GENERAL DISCUSSION

The YHU-1D crew compartment is essentially the same as that of the HU-1A and HU-1B, with maximum visibility a basic design feature. Crew entrance is accomplished through two hinged doors located in the forward cabin area next to the pilot's and copilot's stations (Figures 1, 5, and 5A). Entrance to the passenger/cargo area is through large single-unit sliding doors located one on each side of the aft cabin area (Figures 1, 5, and 5A).

The passenger/cargo cabin area (Figures 23 through 28) will accommodate either: (1) seating accommodations for eleven combat-equipped troops; (2) six litters and a medical attendant; or (3) loading space for up to 3500 pounds of cargo.

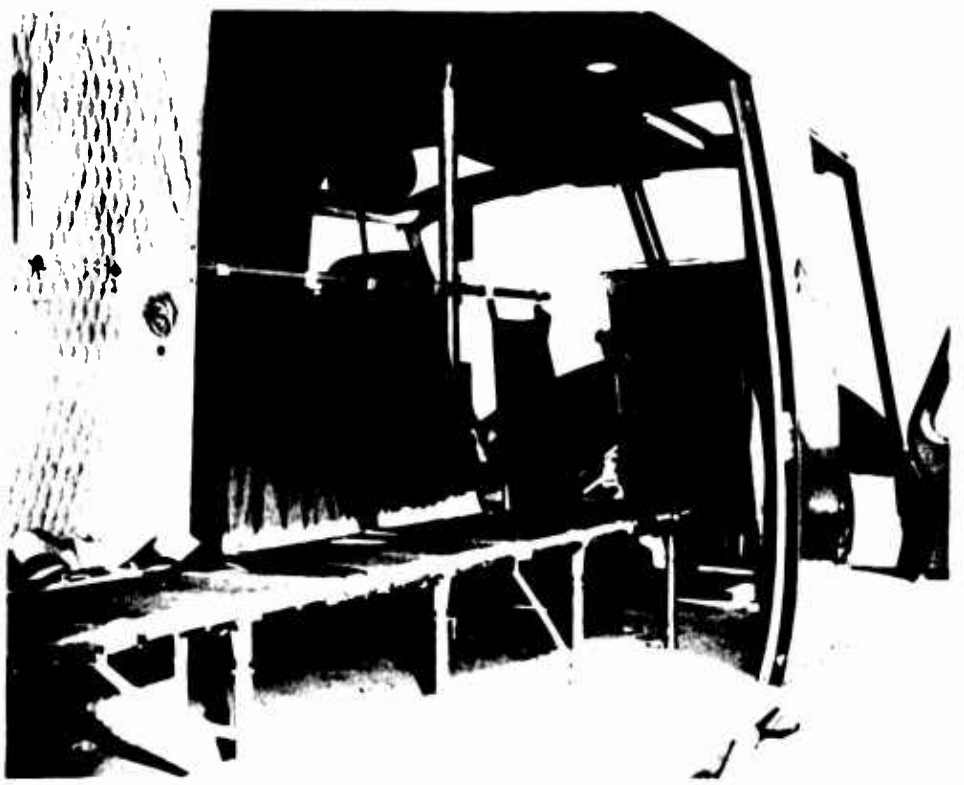

Figure 23. YHU-1D troop compartment and main cabin door (open)

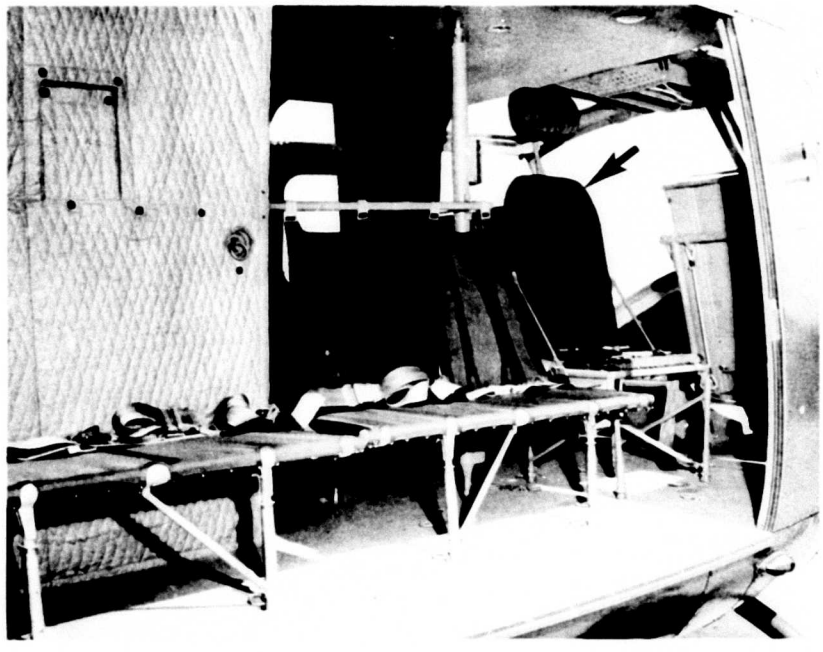

Figure 24. YHU-1D proposed troop seating configuration. Single seat (arrow) is essentially the same as the medical attendant's seat which is installed either forward or aft-facing in the center of the fuselage.

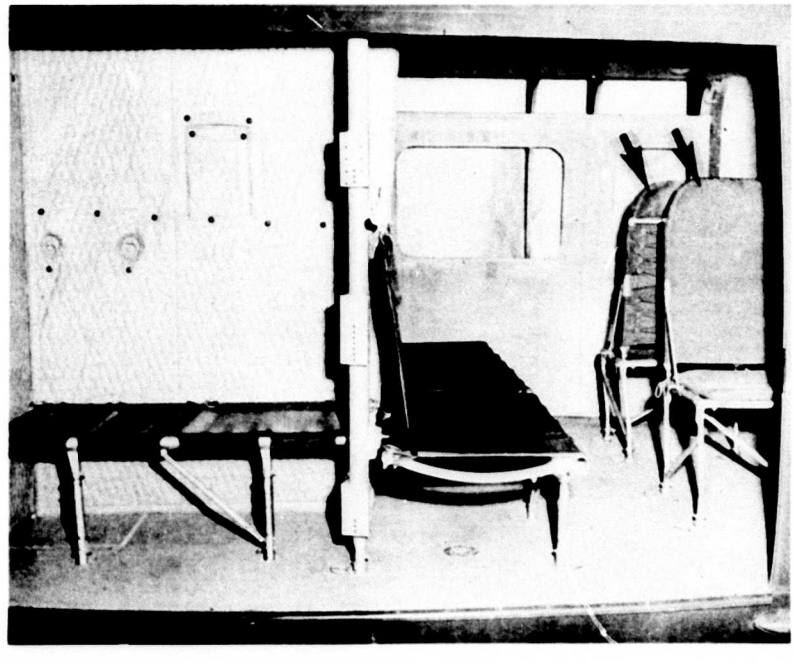

Figure 25. YHU-1D alternate troop seating configuration. Single troop seats (arrows) face outboard in this configuration.

Figure 26. YHU-1D, eleven men seated in cabin (same configuration as illustrated in Figure 25)

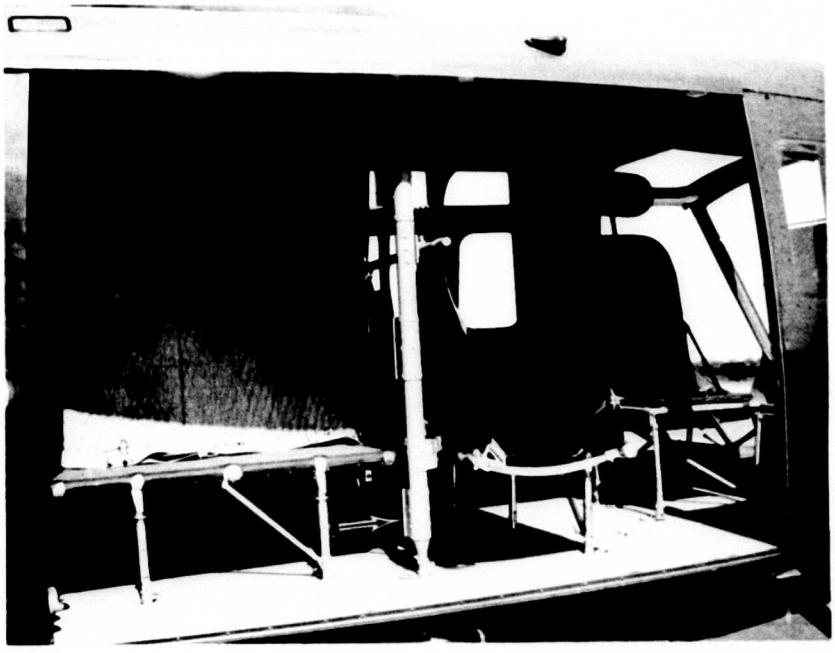

Figure 27. YHU-1D alternate troop seating configuration. Note seat support pole (arrow) which is also to be utilized as a litter pole.

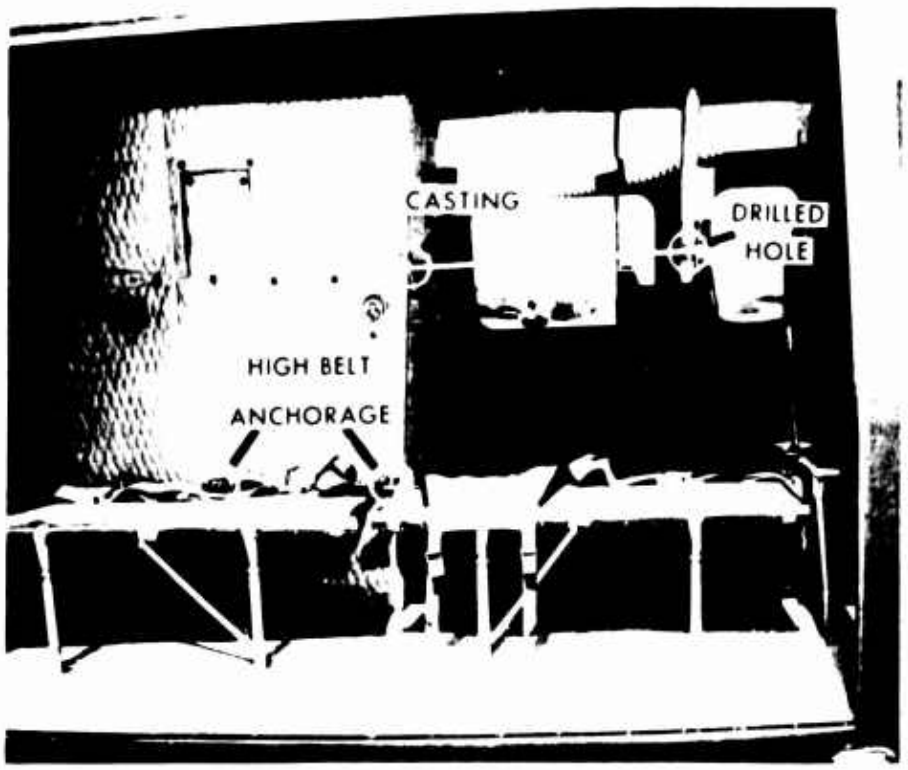

Figure 28. YHU-1D proposed troop seating configuration (note different seat support pole location from alternate configuration, Figure 27); belt anchorage above seat pan level

PILOT AND COPILOT SEATS

Pilot and copilot seats are intended to be identical and interchangeable; however, actual seat selection has not been made as of this writing. Indications are that a newly-designed seat incorporating a nylon fabric mesh netting is being considered. This seat is quite similar to the pilot and copilot seats provided in the U. S. Army YHC-1B "Chinook" helicopter* and its design is the result of development work conducted by the U. S. Air Force for Project Manhigh 2.**

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* TREC Technical Report 60-54, "U. S. Army YHC-1B Chinook Mockup" Crash Injury Evaluation, AvCIR, Jack Carroll, September 1960.

** AFMDC TR-59-28 Air Force Missile Development Center Technical Report "Manhigh 2", Simmons, June 1959.

Present seat load structural criteria indicate design strength for these seats to be in the order of 15G forward, side, and down; 5G aft; and 7.5G up. These structural criteria are a definite improvement over those specified for crew seats in the HU-1A and HU-1B. However, care should be taken to insure that strengthening of the seat structure and tie-down system has not compromised their ability to absorb energy through constant-rate progressive collapse. Further, this design strength should be verified dynamically rather than through static testing. The structural criteria indicate that all loads are considered to act separately. It would be desirable in this case to subject these seats to simultaneous combinations of crash force compatible with magnitudes, directions, durations, and rates of onset experienced under actual crash conditions.

MEDICAL ATTENDANT'S SEAT

The medical attendant's seat in the YHU-1D (Figure 24) is a single seat located in the center of the cabin fuselage just aft of the flight crew station. Its floor mounts, unlike those in the HU-1A and HU-1B, are not rectangular but square, and may be anchored to the floor attachments in either a side, forward, or aft-facing position. This tubular metal seat provides a head-rest extending out from the seat-back on a single tubular support (Figure 24).

Following is the crash load factor criteria for this seat, acting relative to the seat position:

Forward, aft, side	-	10
Down	-	15
Up (through belt)	-	7.5
Lap-belt	-	13 (40° up)

The restraint system with these seats consists solely of a seat belt. Because of their proximity to surrounding structure, occupants are exposed to injury of extremities, upper torso, and head in the event of crash impact accelerations. Thus, provision for additional occupant restraint in the form of chest straps or shoulder harness should be considered.

TROOP SEATS

Two seating configurations have been considered for accommodation of the eleven occupants in the YHU-1D cabin.

SECTION II

Proposed seating arrangement:

> Two individual troop seats, similar in construction to the medical attendant's seat, face outboard in the vincinity of the medical attendant's seat station (Figures 24 and 28). Eight (four double seats) tubular/nylon troop seats, side-facing, four on each side of the pylon. One tubular/nylon troop seat, forward facing, on the front end of the pylon.

Alternate seating arrangement:

> Two individual troop seats, similar in construction to the medical attendant's seat, face outboard in the vicinity of the medical attendant's seat station (Figures 25 and 26). Five tubular/nylon troop seats, forward facing, forward of the pylon (a single center seat and two outboard double seats). Four tubular/nylon troop seats, side facing, two on each side of the pylon.

With the exception of the two single tubular metal seats in the vicinity of the medical attendant station, the remaining troop seats will be "junior" versions of the standard troop seats commonly used in the past by the military. In order to accommodate the high density seating configurations of the YHU-1D, it was necessary to employ smaller seats than those specified in MIL-S-5705 (Appendix III).

Seats and their supporting structures will be designed to the following ultimate load factors, acting separately and in directions relative to seat position:

Forward (through belts)	- 8.0
Aft (seat back)	- 8.0
Side	- 1.1
Down (seat bottom)	- 10
Up (through belt)	- 6.8
Lap belt	- 11.3*

* 2500 pounds belt load applied 45° up, forward-facing seats, and 45° up and forward for side-facing seats (1760/.707 = 2500 pounds). Load factors are based on 220-pound fully equipped combat troops.

Although this seat exceeds, in some cases, the minimum requirements set forth in MIL-S-5705, it presents a number of critical problems from a crash safety point of view. When seats of this type fail, numerous injuries are experienced as a result of broken, exposed ends of tubing coming into contact with occupants or by occupants being thrown free and coming into contact with other occupants and/or various parts of the aircraft. *

The Military Specifications governing the design, strength, and testing of troop seats are considered deficient in that:

1. The magnitude and direction of required load strength criteria are inadequate;

2. The requirement that these strength levels be tested statically is incongruous in that crash forces are actually sustained dynamically; and

3. To consider such loads to be acting separately is unrealistic since crash forces always act simultaneously.

The 1.1G side strength requirement is grossly inadequate and cannot realistically be related to even minimal accelerations associated with crash landing.

Although passenger restraint is afforded primarily through the lap belt, the seat itself must be considered as the prime support. If seat failure is induced through the weakest link in the tie-down chain, injuries can be expected as a result of overshoot accelerations (bottoming out) and contact with surrounding structures.

EMERGENCY EXITS

While the two front crew doors (Figure 1) are non-jettisonable, classic failure of the forward hinges in HU-1A accidents allows these doors to be thrown clear during moderate accelerations. Although roof and door frame distortions in the HU-1A accidents may have contributed toward "popping out" these doors, they do not seem to present any serious hazards with regard to emergency escape. Should the helicopter roll onto its side during an accident, it may be desirable to have kick-out provisions in the overhead windows.

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* Ref.: TREC Technical Report 60-54, "U. S. Army YHC-1B Chinook Mockup", AvCIR 13-PV-118, September 1960, by J. Carroll, et al., pages 62-65.

The main cabin door openings (Figures 9 and 27) provide a large area for emergency escape. The smaller sliding cabin doors on the HU-1A have generally "jumped" their tracks in accidents, being thrown free from the aircraft. This action provided large areas for escape. It is not likely, however, that the large sliding doors on the YHU-1D will be thrown out of their tracks because they are mounted in deeper channels and have a greater number of attachment points. Although mockup photographs do not so indicate, it is intended that at least one of the two windows in the large side doors will be of a standard jettisonable emergency exit type. Bell engineers have further indicated that the plexiglass windows in these doors can easily be kicked out in emergencies to provide reasonable areas of escape.

While emergency exit provisions in the basic aircraft appear to be adequate in size, number, and location, a serious problem is presented for the center seat occupant (forward of the pylon) if the seating configuration illustrated in Figures 2 and 23 is utilized. Evacuation would be even more critical should the aircraft come to rest on its side after an impact, in which case the troop seat occupants on the "low side" would also be in a very difficult position from which to emerge. For these reasons, the alternate configuration (Figures 3 and 25) is recommended.

OTHER EQUIPMENT

Crash landing load structural criteria for the intended litter installations requires 8G static strength in all directions (up, down, side, fore, and aft) applied separately. Two stacks of three litters each, located on each side of the pylon, are expected to be supported by litter poles inboard and litter straps and fittings outboard. Since the litter support system has not yet been devised, it is difficult to evaluate the entire installation in terms of crash safety.

Currently utilized litters are considered "field exchange" items in the military service. Of necessity, then, they must be of strong, durable construction, adaptable to use under field and combat conditions. Also, they must be suitable for use not only in aircraft but in ambulances, field hospitals, etc., as well. Unlike components designed specifically for use in air vehicles, the litter is extremely heavy and bulky and presents many injurious structures when utilized in the manner required for mass evacuation of injured. Litter installation requirements (MIL-S-5705 USAF-Appendix III) provide that supports and attachment fittings for the litters shall be designed so that they will carry to the primary structure a 250-pound litter load, multiplied by the following ultimate load factors:

Forward - 8

Side - plus or minus 1.5

Vertical - 4.5 down; 2.0 up

These factors are considered inadequate and although the Bell Structural Criteria calls for a load factor of 8, up, down, side, and forward, acting separately, even these higher values are questionable.

Consideration should be given to re-evaluation of current minimum strength requirements as presented in Bell's Structural Criteria for the YHU-1D and in MIL-S-5705 (USAF) and these requirements should be increased to a point where they are compatible with anticipated crash load conditions.

As an interim measure, the proposed litter configuration and installation in the YHU-1D should be subjected to dynamic testing with full-scale anthropomorphic dummies under force magnitude, direction, and time history conditions associated with survivable crash loading conditions in helicopters and the results of these tests should be utilized for the development of a more suitable specification. *

The proposed litter pole stowage (Figure 29) in the ceiling of the YHU-1D presents a potentially injurious environmental factor, although such storage is not normally associated with troop or litter patient transportation. Positive restraint for stowed litter poles should be provided to a point that will insure positive retention (from flailing forward into occupiable area) under crash impact accelerations.

CONCLUSIONS

Based on the evaluation of the YHU-1D cabin, it is concluded that:

1. Evaluation of the pilot and copilot seats is not possible at this time. (Seat design has not been selected).

2. The occupant restraint system for the medical attendant's seat is inadequate to preclude bodily contact with injurious environmental structures and components.

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* Ref.: TREC Technical Report 60-54, "U. S. Army YHC-1B Vertol Chinook Mockup", September 1960, by J. Carroll, et al., page 66.

3. The specifications and crash load strength criteria governing the design of crew seats, medical attendant's seats, and troop seats are inadequate and incompatible with experienced and anticipated crash force conditions.

4. The size, type, number, and location of emergency exits appear to be adequate, provided the large plexiglass panels in the main doors are either jettisonable or "kick-out" type. However, both troop seating configurations present potential post-crash emergency escape hazards in the event the helicopter comes to rest on its side.

5. The litter installation, designed in accordance with MIL-S-5705, will be subject to gross failure even under minimal crash force loading conditions.

RECOMMENDATIONS

Based upon the foregoing conclusions, it is recommended that:

1. Pilot and copilot seats be subjected to a separate evaluation after their selection has been made.

2. Consideration be given to provision for additional occupant restraint in the form of chest straps or shoulder harness for the medical attendant's seat.

3. The Military Specifications and crash load strength criteria governing the design of troop seats, medical attendant's seats, crew seats, litters, and all items of equipment and useful load in the occupiable area, failure of which, directly or indirectly, would be apt to cause injury to occupants of the helicopter to be reviewed, revised, and increased to more realistic levels of protection consistent with the simultaneous dynamic application of forces experienced under survivable impact conditions.

4. The seating configuration shown in Figure 3 be utilized in preference to the proposed seating arrangement illustrated in Figure 2.

5. Crew seats, medical attendant seats, troop seats, and litter installations be dynamically tested to provide data which can be used as a basis for recommending changes to existing Military Specifications and structural design criteria.

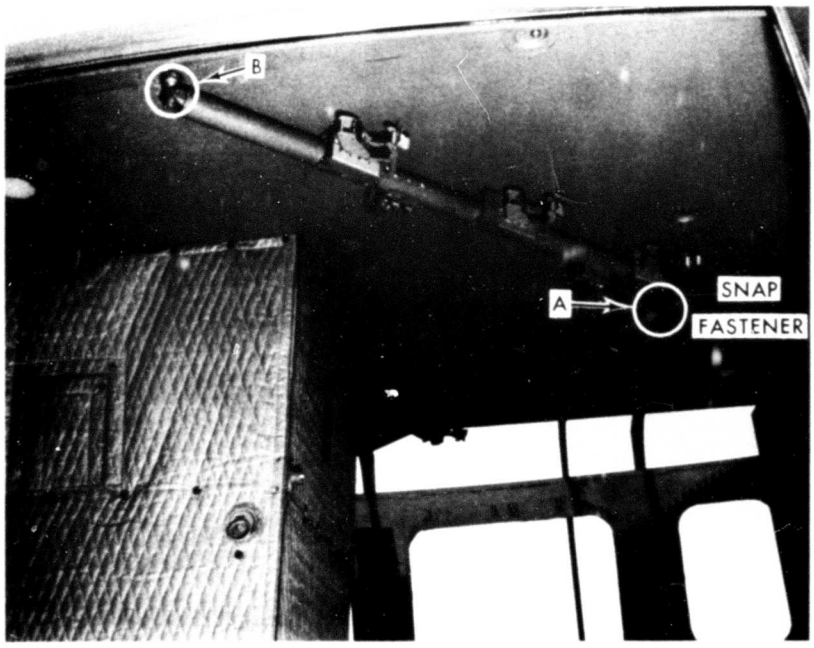

Figure 29. YHU-1D litter/seat support poles in overhead stowage. Arrow "A" shows snap fastener, arrow "B" shows pivoted anchorage.

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SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Airframe

Based on the evaluation of the basic airframe of the YHU-1D, it is concluded that:

1. The impact condition/damage relationships anticipated with the YHU-1D should remain similar in nature to accident experience with HU-1A aircraft.

2. The skid gear assembly may be expected to absorb a reasonable degree of impact energy. However, since the gear will be subjected to greater loads than those experienced with the HU-1A, it may be well to re-examine the capabilities of this assembly.

3. The ability of the roof structure to resist dynamic displacement into the occupiable area appears to have been improved over the HU-1A through addition of an integral roll-over structure and incorporation of load-carrying capabilities to the vertical support members. However, the increased strength is questionable, considering the additional weight of the roof. Its value can only be determined through dynamic testing or evaluation of accident experience.

4. The strength requirements and criteria governing the design and construction of fuel cells are not compatible with crash force loads sustained in survivable type aircraft accidents.

5. The ability of such items as heater, electrical components, and hydraulic fluid reservoirs to resist failure and subsequent fuel cell penetration under impact conditions is questionable.

6. The transmission support case can be expected to fail under impact loads due to the nature of its construction, i.e., casting.

7. Dynamic testing of the transmission group and support assemblies under impact conditions consistent with magnitudes, directions, time, and rate of onset associated with the upper limits of survivable crash force conditions would provide a realistic indication of the manner in which these assemblies withstand crash impacts.

8. The concentrated loading of the engine support system may subject fuel cells to penetration under heavy vertical impact loading.

9. The proximity of the combustion heater and "hot" electrical components to the fuel cells is hazardous should rupture, spillage, or leakage occur from adjacent fuel tanks in the event of a crash.

10. The requirement that crash load factors be considered as acting separately and tested under static conditions (Military Specifications and other structural criteria) is neither adequate nor realistic when considering that magnitude, time, rate of onset, and direction of dynamic forces act simultaneously on structures and components under actual impact conditions.

Cabin

Based on the evaluation of the YHU-1D cabin, it is concluded that:

1. Evaluation of the pilot and copilot seats is not possible at this time. (Seat design has not been selected).

2. The occupant restraint system for the medical attendant's seat is inadequate to preclude bodily contact with injurious environmental structures and components.

3. The specifications and crash load strength criteria governing the design of crew seats, medical attendant's seats, and troop seats are inadequate and incompatible with experienced and anticipated crash force conditions.

4. The size, type, number, and location of emergency exits appear to be adequate, provided the large plexiglass panels in the main doors are either jettisonable or "kick-out" type. However, both troop seating configurations present potential post-crash emergency escape hazards in the event the helicopter comes to rest on its side.

5. The litter installation, designed in accordance with MIL-S-5705, will be subject to gross failure even under minimal crash force loading conditions.

RECOMMENDATIONS

Airframe

Based upon the foregoing conclusions, it is recommended that:

1. Full-scale dynamic crash tests of the YHU-1D be conducted under rigidly controlled conditions to determine:

    a. The capability of the skid gear assembly to provide crash energy absorption in proportion to known performance of the HU-1A gear.

    b. The dynamic response, structural integrity, and ability of the larger, heavier roof to resist failure or deformation into the occupiable area of the aircraft.

    c. The ability of fuel cells, installed as presently planned, to resist puncture or spillage under crash force conditions, thereby creating potential post-crash fire ignition sources.

    d. The restraint capability of the transmission group and support assemblies.

    e. The restraint capability of such items as generators, other electrical components, dynamic components, and hydraulic fluid reservoirs to resist failure or displacement into otherwise unprotected surfaces of honeycomb fuel cell structures.

2. Consideration be given to replacement of the cast magnesium transmission support case with a newly designed type which would yield progressively rather than shatter. Consideration should be given to the use of materials such as ductile steel forgings, possibly stainless steel.

3. Consideration be given to the use of restraining cables attached to or encircling the transmission case and anchored to primary aft fuselage structure to prevent the transmission group assembly from penetrating into the occupiable area when subjected to impact.

4. Consideration be given to the use of large flat plate area mounting plates at the base of the engine mounts to reduce

concentrated vertical loads transmitted by the engine through its mounts to the honeycomb structure over the fuel cells.

5. Military Specifications and structural design criteria governing crash landing loads for engines, pylon assemblies, fuel tanks, occupiable structure, etc., failure of which, directly or indirectly, would be apt to cause injury to occupants of the aircraft, be revised and increased to levels of protection consistent with the simultaneous dynamic application of forces likely to be encountered under otherwise survivable impact conditions.

Cabin

Based upon the foregoing conclusions, it is recommended that:

1. Pilot and copilot seats be subjected to a separate evaluation after their selection has been made.

2. Consideration be given to provision for additional occupant restraint in the form of chest straps or shoulder harness for the medical attendant's seat.

3. The Military Specifications and crash load strength criteria governing the design of troop seats, medical attendant's seats, crew seats, litters, and all items of equipment and useful load in the occupiable area, failure of which, directly or indirectly, would be apt to cause injury to occupants of the helicopter to be reviewed, revised, and increased to more realistic levels of protection consistent with the simultaneous dynamic application of forces experienced under survivable impact conditions.

4. The seating configuration shown in Figure 3 be utilized in preference to the proposed seating arrangement illustrated in Figure 2.

5. Crew seats, medical attendant seats, troop seats, and litter installations be dynamically tested to provide data which can be used as a basis for recommending changes to existing Military Specifications and structural design criteria.

APPENDIX I

YHU-1D MISSION ANALYSIS, WEIGHT, AND SIZE SUMMARY

MISSION ANALYSIS, WEIGHT, AND SIZE SUMMARY

YHU-1D

MISSION ANALYSIS

Spec. Wt. Empty	4411
Misc. U.L. Items *	157
Pilot	200
Basic Operating Weight	4768

Take-Off Gross Weight = Basic Operating Weight + Fuel + Payload

PERSONNEL CARRIER

2 hrs (100 N.Mi. Rad.) + 10% Reserve	
Basic Weight	4768
Fuel (Internal)	1020
4 Passengers @ 200	800
T.O. Gross Wt.	6588

SQUAD CARRIER

2 hrs (100 N.Mi. Rad.) + 1/2 hr Reserve	
Basic Weight	4768
Fuel (Internal)	1158
7 Troops @ 220	1540
T.O. Gross Wt.	7466

MAX. TROOP CARRIER

2 hrs (100 N.Mi. Rad.) + 1/2 hr Reserve	
Basic Weight	4768
Fuel (Internal)	1158
11 Troop @ 220	2420
T.O. Gross Wt.	8346

3500 LBS. CARGO

1/2 hr (25 N.Mi. Rad.) + 1/4 hr Reserve	
Basic Weight	4768
Less Misc. U.L. Items	103
Fuel (Internal)	435
Cargo	3500
T.O. Gross Wt.	8600

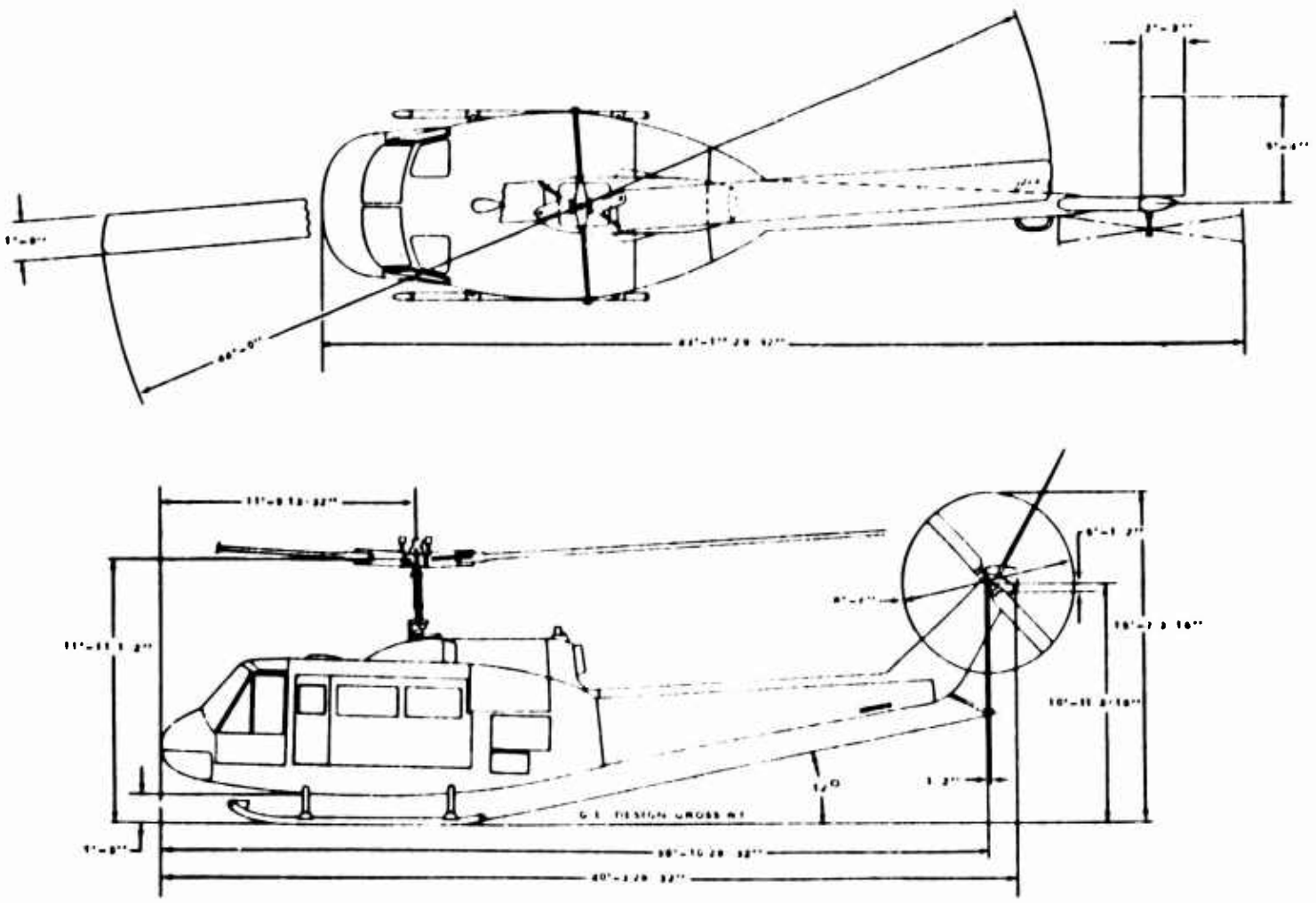
*Useful load items consist of seats, lubricants, trapped fluids, etc.

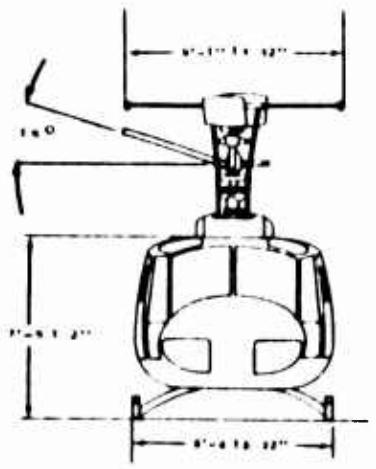
WEIGHT SUMMARY

GROUP	PROPOSED SPEC.	GROUP	PROPOSED SPEC.
Rotor Group	777 lbs.	Instruments	72 lbs.
Tail Group	112 lbs.	Flight Controls	311 lbs.
Body Group	1015 lbs.	Hydraulic System	32 lbs.
Alighting Gear	91 lbs.	Electrical Group	324 lbs.
Engine Section	100 lbs.	Electronics	222 lbs.
Power Plant Group	1256 lbs.	Furnishings	190 lbs.

Total 4411 lbs.
EMPTY WEIGHT

APPENDIX I





YHU-1D general arrangement and size

APPENDIX II

CRASH SAFETY CRITERIA

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CRASHWORTHINESS

Crashworthiness may be defined as the ability of basic aircraft structure to provide protection to occupants during survivable impact conditions. Impact conditions are considered survivable in that part of the cockpit/cabin area where the crash forces are within the limits of human tolerance (with minimal or no injury)* and where surrounding structure remains reasonably intact.

Lack of crashworthiness, generally, indicates that the basic aircraft structure, seen as a protective container, is subject to extensive inward collapse thereby affecting the "inhabitability" of this area. Typical in this respect are (1) the rearward movement of the engine in single engine aircraft; (2) the downward displacement of transmissions and other heavy components in helicopters; (3) the upward collapse of lower structures into the cockpit/cabin area. This deformation or collapse of the occupiable area may result in crushing type injuries or trapping of the occupants.

When evaluating the crashworthiness of basic aircraft structure, stress is placed upon the expected behavior of this structure during a survivable type impact. Attention is also given to anticipated dynamic response under the most probable conditions of impact angle and aircraft attitude, based upon accumulated past experience. This facilitates an appraisal of the possibility of displacement of certain heavy components into the occupiable area as a result of inertia forces.

TIE-DOWN CHAIN

Although a crashworthy structure provides primary protection during a crash deceleration, injuries may still occur when occupants are allowed to come into forceful contact with their environment or to be struck by loose objects thrown through the occupiable area. The restraint system used to prevent occupants, cargo and components from being thrown loose within the aircraft is commonly referred to as the tie-down chain. The occupant's tie-down chain consists of: seat belt, seat belt anchorage, shoulder harness and anchorage, seat structure, seat anchorages and floor. Failure of any link in this chain results in a higher degree of exposure to injury.

Accident statistics indicate that the site of most serious and frequent injury in general aviation accidents is the head. In most cases, this is due to lack of restraint, allowing the head to gain momentum during impact and to strike objects in its path with a force exceeding that of the overall crash deceleration. This is especially true in the case of cockpit occupants who face the instrument panel, control wheel and many other injurious environmental structures. Considering these factors, it is practically impossible to avoid contact injuries during crash deceleration when such occupants are not restrained by a properly installed and properly used shoulder harness of adequate strength in combination with a seat belt.

Although seat structure and anchorages meet static strength tie-down requirements, failures frequently occur as a result of dynamic loads imposed by the occupants on seat belts and shoulder harness when these are anchored to the seats instead of primary structure. This type of crash force amplification should be taken into consideration when evaluating the dynamic strength of the occupant tie-down chain. Inadequately or improperly secured aircraft equipment and components in the occupiable area also have an injury potential during crash decelerations. Therefore, the tie-down and stowage of such items as luggage, cargo, radio equipment, fire extinguishers and tool boxes requires careful consideration.

OCCUPANTS' ENVIRONMENT

Accident experience has shown that under many impact conditions occupants who are reasonably restrained within a crashworthy structure may still receive injuries through forceful contact with injurious environmental structures, components, etc. (This is particularly true when shoulder harness is not used.) The freedom of movement of the occupant's body during a crash deceleration is governed by the type of restraint system installed and the manner in which it is used. Generally, it can be stated, however, that injuries resulting from the flailing action of the occupant's body show a peripheral trend; that is, the areas farthest away from the seat belt receive most of the injuries (head and lower extremities)

To preclude the probability of injury through striking injurious environment, the limitations of the restraint system should be used as a guide for the extent to which the occupant's environment should be made harmless. The injury potential of all objects and structure within striking range, omni-directionally, can be reduced to a minimum by such measures as elimination of sharp surfaces, safety-type control wheels, breakaway features in instrument panels, use of ductile or energy-absorbing material wherever possible.

TRANSMISSION OF CRASH FORCE

Another independent injury-producing factor presents itself in the fact that crash forces may be transmitted or even magnified through rigid aircraft structures. This is usually associated with "bottoming out" on structures incapable of absorbing or reducing crash force. Although crash force in most accidents is applied in a direction oblique to the occupant's spine, it is customary to resolve vertical and horizontal components of the crash force resultant and relate these to the human G-force tolerance levels, either parallel or transverse to the spine. A normally seated

*Approximately 40G transverse to the spine, 25G parallel to the spine (positive G), 15G parallel to the spine (negative G) with due consideration for peak magnitude, duration, rate of onset, and method of body restraint. J.P. Stapp, Human Exposure to Linear Deceleration, Part 2. The Forward-Facing Position and the Development of a Crash Harness. WADC, Wright-Patterson AFB, Ohio, Dec. 1951. A.F.Technical Report No. 5915, Part 2.

APPENDIX II

person, when effectively restrained by a seat belt and shoulder harness, can tolerate (with minimal or no injury) approximately 40 G transverse to the spine, 25 G parallel to the spine in the foot-to-head direction (positive G), 15 G parallel to the spine in the head-to-foot direction (negative G).

Injuries attributed solely to transverse G will seldom be encountered in aircraft accidents, because collapse of structure and/or failure of the restraint system will most likely occur before the limit of transverse G tolerance (40 G) is reached. This is an undesirable situation. Although operational and economic considerations impose limits on the overall fuselage strength, the occupant tie-down chain should be more compatible in strength with tolerance levels of the body.

Accident experience has shown that injuries directly attributed to the transmission or magnification of crash force are usually associated with predominantly vertical impacts. Vertebral injuries are most often associated with vertical crash force application.

The seat, as the occupant's supporting structure, and the underlying floor structure are the media through which vertical forces are usually transmitted to the occupant. The dynamic response of these media during an impact determines the manner in which the forces acting on the aircraft structure can be modified before reaching the occupant. An extremely rigid structure, which normally is not found in aircraft, would transmit the forces without modification. An elastic structure, which has energy-storing properties, may modify the magnitude and other characteristics of decelerative force to the extent that amplification takes place. For example, a foam rubber cushion (which does not offer an appreciable resistance to compression) allows an occupant to "bottom out" against rigid seat and seat pan structures during a vertical impact. A more desirable situation would be that in which the structure between the occupant and the point of impact had high energy-absorbing characteristics. This may be achieved by the use of structure which collapses progressively without failing suddenly. This ideal form of crash energy absorption results in attenuation of the crash forces transmitted to the occupant. It is one of the basic methods for the incorporation of occupant protection in aircraft design.

POST-CRASH FACTORS

Although a distinction could be made between the prevention of injuries sustained in the dynamic phase of the impact and those sustained in the post-crash events, it is felt that the overall crash survival concept does not allow this distinction. Past experience has shown that accidents involving only very minor impact forces can become catastrophies as a result of post-crash factors.

One of the greatest hazards in an otherwise survivable accident is the possibility of a post-crash fire. These fires, normally, are of a sudden nature and may severely restrict the time available for evacuation. According to a NACA study (Technical Note 2996), not more than 50 seconds may be available for escape in all but the most severe fires, although in some cases passengers must move away from areas of burned-through fuselage in as few as 7-1/2 seconds. This time element becomes even more critical when occupants are handicapped by such factors as disabling injuries, stunned condition, unfamiliarity with the seat belt release or the operation of the emergency exits, being trapped, and panic.

Control of post-crash fires, to some extent, is governed by design (location of fuel cells and fuel lines in relation to electrical and mechanical ignition sources; resistance of fuel system components against rupture under conditions of moderate crash forces or distortion). Other preventive measures include location of fire extinguishers at strategic points and automatic emergency or impact-operated fire extinguishing systems.

In the event of a post-crash fire or a ditching, the ability of all occupants to timely evacuate the aircraft probably becomes the most important survival factor. The evacuation time is a function of the number, location and adequacy of the normal and emergency exits.* The location and emergency operation of normal and emergency exits should be obvious even to the non-experienced passenger. Hand or impact-operated emergency lights can be of vital importance during evacuation in conditions of darkness or subdued light.

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*MIAD (the military Handbook of Instructions for Aircraft Designers) requires "a sufficient number of doors, hatches, and emergency exits to permit complete abandonment of the aircraft in the air, on the ground, or in ditching, in 90 seconds by trained personnel representing the crew and all passengers."

APPENDIX III

APPLICABLE MILITARY SPECIFICATIONS

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APPLICABLE MILITARY SPECIFICATIONS

MILITARY SPECIFICATION: MIL-S-8698 (ASG)

3.4.7 Crash Landing - Sufficient strength shall be provided in the seat installation and attachments of engines, transmissions, equipment, and useful load items (including fuel tanks one-half full) and their carry-through structure to prevent failure of such ultimate inertia-load factors shall be those specified by the procuring activity.

MILITARY SPECIFICATION: MIL-S-5705 (USAF)

4.7.2 Passenger Seats - Passenger seats shall be designed to the load requirements of Specification MIL-S-5797 (USAF). All attachments and supports shall have sufficient strength to withstand the seat design loads.

MILITARY SPECIFICATION: MIL-S-5705 (USAF)

4.7.3 Troop Seats - Troop seats and supporting structures shall be designed to the load requirements of Specification MIL-S-5804 (USAF). Troop seat lap belts and their attachments to the airplane structure shall be capable of carrying an ultimate load of 2,190 pounds acting at an angle of 45° upward, forward, and inward. Troop seat shoulder harnesses and their attachments to the airplane structure shall be capable of carrying an ultimate load of 1,260 pounds acting horizontally at an angle of 45° forward and inward.

MILITARY SPECIFICATION: MIL-S-5705 (USAF)

4.7.4 Airplane Litter Installation - Supports and attachment fittings for litters shall be designed so that they will carry to the primary structure a 250-pound litter load, multiplied by the ultimate load factors specified below, acting separately.

Forward	8G	Vertical	4.5G (down)
Side	1.5G		2.0G (up)

APPENDIX III

MILITARY SPECIFICATION: MIL-S-8698 (ASG)

3.1.1 Strength - The entire helicopter structure, including beaching units and hoisting sling, where applicable, shall be capable of supporting without failure the ultimate loads resulting from the loading conditions and ultimate factor of safety specified in Section III, and shall be capable of withstanding without failure the repeated load and endurance tests of Specification MIL-T-8679. Allowable stress values to be used in the stress analyses shall be those taken from approved Government publications, such as Bulletin ANC-5, or various NACA or Bureau of Standards reports, whenever possible.

MILITARY SPECIFICATION. MIL-T-8679

3. REQUIREMENTS

3.1.2 Addition of Tests - If the tests required by the contract, to be performed by the contractor, are inadequate to prove that the helicopter meets the specified design requirements, the contractor or the procuring activity shall propose amendments to the contract to include tests which will prove adequately that the structure incorporates specified strength and rigidity.

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