UNITED STATES ARMY HELICOPTER ACCIDENTS INVOLVING FIRE

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SUMMARY

This study is a statistical review of 94 major helicopter fire-accidents that occurred during the six-year period, July 1957 - June 1963. Findings of the July 1960 - June 1963 period are compared with those of the three previous years. Findings of the first three-year period were reported in an earlier USABAAR study, "Army Helicopter Accidents Involving Fire."

The number of fire accidents increased during the latter period from 42 to 52 and now account for 9.5% of the major helicopter accidents as compared to 7% reported in the initial study. Fire accidents remained at 2.9 per 100,000 hours of flying for both three-year periods.

Ninety percent of the fires erupt on, or immediately after, the initial impact during the crash sequence. Fire accidents of this type demonstrate the need of a fuel system designed to prevent fuel spillage when the helicopter comes to rest.

Seventy percent of the crashes involved forces considered within the limits of human tolerance and are classified as survivable.

Five inflight fires resulted in major accidents over the six-year period. Of these, two occurred during the recent three-year period, and only one of these resulted in a major accident.

Ruptured fuel cells and lines caused fuel spillage and subsequent fire in 80% of the accidents. Fuel served as the flammable source in 87% of the accidents.

Accidents involving collision with the ground during controlled and uncontrolled conditions have been found to produce the greatest number of fires. The greatest number of survivable fire accidents resulted from roll-overs and wire strikes. These two cause factors produced an equal number of survivable fire accidents.

Though a greater number of fire accidents have occurred during the last three-year period, the materiel costs of these accidents have decreased approximately one-half million dollars. This decrease is due to the fact that the larger, more expensive models did not show an increase in the number of fire accidents.

Sixty seven percent of the number of occupants involved were injured in fire accidents as compared to 10% injured in other types of major accidents. Forty-one percent of the occupants involved in fire accidents received thermal injuries.

The occupant survival rate in fire accidents is 62% compared to 98% for other types of major accidents Twenty-seven fatalities, ten in survivable accidents, have been attributed to thermal injuries.

Because the final position of a rotary wing aircraft involved in an accident is usually other than upright, escape provisions are essential in the reduction of thermal injury in survivable accidents

I. INTRODUCTION

Fire at impact or post-crash fire continues to remain one of the major hazards of U. S. Army helicopter operations. When fire erupts in an otherwise occupant-survivable accident, it is a grim reminder of the need to improve the crash-fire-worthiness design of these aircraft.

The fire accident experience of the current generation of Army helicopters vividly reveals crash-worthiness deficiencies. These deficiencies were pointed out in an earlier United States Army Board for Aviation Accident Research (USABAAR) study,[1] that reviewed the helicopter fire experiences of the July 1957-June 1960 period. Since the publication of that study, the Army helicopter has logged many hours in tactical units flying nap-of-the-earth. Data reflecting increased exposure to accidents of this flight profile show that previously known deficiencies are more unacceptable than ever before.

The all-time high of 25 fire accidents of FY 1963 makes it quite clear that emerging tactical concepts have out-dated the crash-fire-worthiness criteria used in the design of the generation of helicopters represented in the tables of this study. Their design borrowed heavily from the experience of fixed wing aircraft. They did not have the benefit of experience that current tactical practices offer. Experience has shown the helicopter's behavior in a crash is quite different from that of fixed wing aircraft. Fixed wing aircraft crash with a dominating forward component in contrast to the high lateral and vertical forces generated in helicopter crashes. Perhaps the difference is due to the helicopter's inherent instability, relatively low speed, low operating altitude, mass displacement, torque effects of its rotor systems, and the reaction of the airframe when rotor blades strike the terrain or other objects. Furthermore, the fact that the helicopter has no wing to protect the fuselage, to absorb energy, and to reduce the tendency to roll generates a greater variety of forces to act on its structural components following impact.

To overcome current deficiencies, the design of new generation Army helicopters must consider past Army accident experience. The fire accident experience of this study is an example. It will illustrate the vulnerability of the location of crash-susceptible metal fuel tanks of the OH-13 series. In contrast, the data will show that protectively located bladder-type fuel cells, like those of the OH-23 and UH-1 models, are far less susceptible to rupture and fuel spillage on impact.

The search for crash-fire-worthiness criteria must also look critically at the helicopter's tactical environment. This environment is portrayed in the 21 different types of accidents shown in Table 4. The impact phenomena in wire strikes, roll-overs, and rotor strikes of trees must be studied to formulate design concepts that will aid the development of features that will prevent fuel spillage and fire in potentially survivable mishaps.

This study relates the past six years of fire accident experience ending June 1963. Its purpose is to show the nature and magnitude of the helicopter fire problem, and to encourage the use of helicopter accident experience as a basis for needed design changes. Hopefully, it will also serve as a justification for the designer faced with the decision to compromise crash-fire-worthiness for other design features that may have more appeal at the moment.

The data presented are taken from USABAAR files of accident investigation reports submitted by unit investigating boards as directed by AR 385-40, "Accident Reporting and Record." All definitions used in this study such as accident classification and degree of personnel injury agree with this regulation.

For the purpose of aiding analysis and showing trends, data from the two, three-year periods are compared. The first period, July 1957-June 1960, essentially includes the same data presented in the USABAAR study, "Army Helicopter Accidents Involving Fire." The last period includes data compiled during the period July 1960 to June 1963.

TABLE 1

Trend Indication of U. S. Army Helicopter Operation
Fire and Non-Fire Major Accidents

	July 1957-June 1960	July 1960-June 1963	% Change
Major Accidents	577	547	-5.2
Aircraft (Yearly Mean)	2,400	2,500	4.2
Hours Flown	1,450,000	1,800,000	24.0
Cost – Aircraft Destroyed	$6,150,000	$5,575,000	-9.4
Fire Accidents	42	52	23.8
Post-crash Fire	46	47	2.2
Fire Impact Survivable	30	36	20.0
Occupants Involved – Fire Accidents	122	142	16.4
Occupants Injured – Fire Accidents	74	103	39.2
Fatalities – Fire Accidents	41	57	39.0

II. DISCUSSION

A. General Information

Without establishing a basis for comparison, it is difficult to clearly say whether fire accidents are increasing or decreasing. Any trend depends on whether the number or the rate of occurrences is used as a basis. Based on number alone, fire accidents have increased during the past three years (Table 1). In the early period of July 1958 - June 1960, the 42 occurrences accounted for 7% of all major helicopter accidents This percentage increased to 9.5% during the next three years when fire was present in 52 major accidents. The fire prevention problem is compounded by the increase in the number of fire accidents that took place while other types of major accidents decreased 5%. This decrease in major accidents is equivalent to ten major accidents per 100,000 hours of flying However, rate-wise per 100,000 flying hours, fire accidents during the July 1960 - June 1963 period did not increase. The rate of 2.9 fire accidents per 100,000 flying hours at the beginning of the period did not change. The significance of no increase in rate is appreciated upon noting that it was attained early in a growth phase, at the time when tactical concepts that exploit the helicopter's versatility were new to the Army's operational units.

In addition to fire in major accidents, fire was also reported in four incidents and two minor accidents. During FY 1962 and FY 1963 there were four such reports. Three of these occurred in flight. Causes of these inflight fires were as follows: A shorted UH-1A generator shunt, gasoline splashing on an engine when the left cap of an OH-13H came loose, and fuel igniting in the

TABLE 2

Occurrence of Fire in Army Helicopter Accidents July 1957 – June 1963

FY Period	Maj Acdts	Fire Acdts	% Fire Acdts	Fire* Rate	Pre-Crash Fire	Post-Crash Fire	Fire External of Acft	Fire in Incidents & Minor Acdts
1963	206	25	12.1	3.8	1	22	2	3
1962	204	22	10.8	3.6	1	21	0	1
1961	134	5	3.7	.9	0	4	1	0
1960	193	14	7.3	2.6	1	11	2	2
1959	208	13	6.3	2.6	2	12	1	0
1958	179	15	8.4	3.5	0	13	0	0
Total	1124	94	8.4	2.9	5	83	6	6

$$^{*}\text{Rate} = \frac{\text{No. of accidents} \times 100{,}000}{\text{No. of hours flown}}$$

carburetor air intake filter of an OH-13D. The earlier period reported two inflight fires caused by engine malfunction and failure of an exhaust stack clamp. Both involved the UH-19D.

B. Number and Frequency of Occurrences

Post-crash fires erupting in eight of every nine fire accidents during the six year period establish a frequency that clearly indicates the need to improve the helicopter crash-fire-worthiness design (Table 2). Improvements demand priority if the helicopter is to keep pace with the planned tactical requirements. Grim evidence of fire, shown in Table 2, points out the inability of current models to cope with increasing tactical requirements. Forty-three or 52% of the reported post-crash fires occurred during the last two years. It was this period that witnessed the introduction and implementation of new tactical concepts for the helicopter in the operational units.

Inflight fire caused only one major accident during the past three years. Fire broke out in the engine compartment of a UH-19D when two cylinders failed. The relatively low inflight fire rate in contrast to the rate of post-crash fires that occur is a credit of current design practices which guard against them.

The hazard of the helicopter igniting combustible material external to itself has reduced sufficiently during the past three years to become less of a major problem. Current preventative practices that wisely include the use of fire guards, improved field refueling practices, use of ground guides, improved facilities, and, undoubtedly most important, employing direct supervision of all these factors, have been responsible for the change. The only occurrence in the past three years involved a CH-34A. Rotor blades of this aircraft struck an overhead fuel tank while taxiing into position to refuel.

Modification of the UH-1 to relocate the heater exhaust has apparently eliminated this cause as an ignition source. During the earlier period prior to modification, there were two reported occurrences of dry grass ignited on landing. One occurrence caused total loss of a UH-1. In a similar situation, engine exhaust of a UH-19 caused loss of the aircraft.

C. Fire Experience by Model of Helicopter

The fire experience of the helicopters currently in the Army's operational

TABLE 3

Fire and Non-Fire Accident Experience by Model
July 1957 - June 1963

Model	FY 1958 - FY 1960				FY 1961 - FY 1963				Change	
	Maj Acdts	Fire Acdts	Fire-Impact Survivable		Maj Acdts	Fire Acdts	Fire-Impact Survivable		All Fire	Fire Acdts Survivable
			Nr.	Rate			Nr.	Rate		
OH-23	112	7	4	1.2	101	4	2	.45	-3	-2
OH-13G,H	122	11	9	3.5	165	21	16	4.5	10	7
CH-34	68	7	5	1.8	43	8	5	1.7	1	0
CH-21	102	8	5	2.4	68	8	5	2.6	0	0
UH-19	56	4	3	1.9	45	3	2	1.1	-1	-1
UH-1	11	1*	1	9.0	63	5	3	1.8	4	2
OH-13D,E	98	2	2	1.1	45	3	3	2.4	1	1
CH-37	8	2	1	3.9	12	0	0	0.0	-2	-1
OH-13**	0	0	0	0.0	5	0	0	0.0	0	0
Total	577	42	30	2.1	547	52	36	2.0	10	6

*Grass Fire – No Impact

**Series Not Reported

inventory is shown in Table 3. To give an indication of accident exposure, the models are listed in descending order according to the total hours each has flown during the six-year period. Note that two series of the OH-13 are listed. As will be shown, the series differ significantly in fire experience and in their fuel cell installation. The D and E series have a single 29-gallon metal tank cradled above the engine immediately aft of the rotor mast (Figure 1). The later G and H series use twin metal tanks of 43 gallons total capacity cradled above the engine, one located on each side and outboard of the rotor mast (Figure 2). In this location, the cells extend beyond the protection of the airframe. They are often ruptured by ground contact, disintegrating rotor blades, and, infrequently, by linkage about the rotor mast. In wire strike accidents, the rotor mast may whip the wire across fuel system components. More important, the use of twin cells always leaves an upper tank to spill its remaining fuel on roll-over.

The number and rate at which fire erupts under survivable impact conditions is a relative indication of each model's crash-fire-worthiness (Table 3).

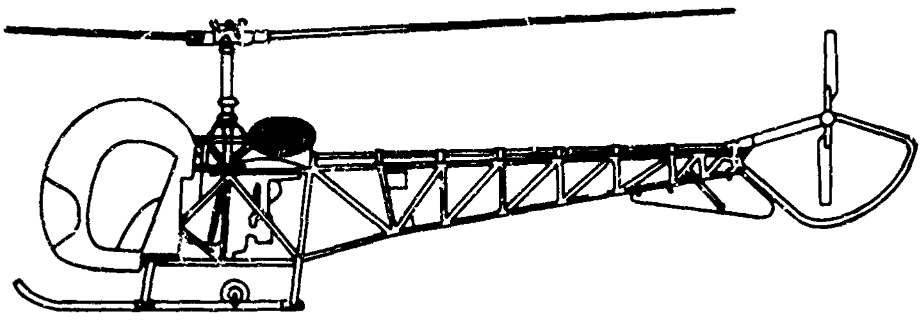

FIGURE 1

OH-13 models D and E single fuel cell

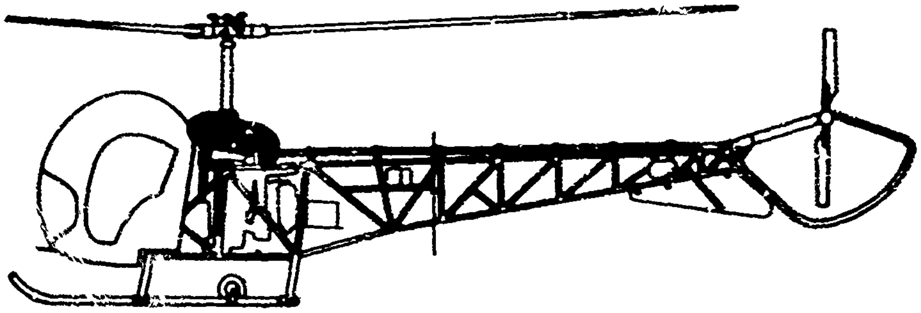

FIGURE 2

OH-13 models G and H twin fuel cells

For purposes of this study, a survivable accident is one in which the crash forces imposed on the occupant are within the limits of human tolerance and some portion of the inhabitable area of the aircraft remains reasonably intact. The definition accepts that the limits of human tolerance to crash forces in an exact sense are still essentially unestablished. Also, the difficulty of computing G forces involved in a helicopter accident is recognized. These reservations of the definition are nullified somewhat by the method used in determining the classification. Classification of accidents is determined by the flight surgeon who serves as a member of the investigating board. Professional competence, evidence found at the accident scene, and subsequent information uncovered during the investigation determine whether an accident is survivable or nonsurvivable.

The ultimate goal of design for crash-fire-worthiness is to prevent the occurrence of fire in all accidents regarded as survivable. Seventy percent of the fire accidents are potentially survivable. The tragedy of thermal injury, the cost of material loss, and subsequent decrease in mission capability point to the urgency of incorporating design features that will prevent fire in these otherwise survivable accidents. It is apparent from the OH-13 data of Table 3 that the D and E series which use a single metal fuel tank offer considerably more fire protection. The chance of fire in the G and H series which use twin metal tanks is three times as great. It can be determined from the data that the D and E models experience fire in 3.4% of their major accidents as compared to 11% in the G and H series. A comparison of rates in these accidents shows a similar difference.

During FY 1958 - FY 1960, the OH-13D's and E's made up 15% of the Army's helicopter inventory and flew 12% of the hours and attained the lowest fire-impact survivable accident rate of all models listed (Table 3). During the next three years, an increase of one accident and a 30% reduction in flying hours caused the rate to more than double that of the previous three years, reaching 2.4/100,000 hours. In addition to showing a change in trend, this change illustrates the variability of rates and emphasizes the need for caution in their use.

The OH-23, during the six-year period, achieved the best overall fire accident record of all models. In 213 major accidents during this period, fire was reported in only six survivable accidents. This gave it the remarkable rate of less than one fire-survivable accident for each 100,000 hours of flying (Table 3)

The record of the OH-23 suggests that the protective location of bladders.

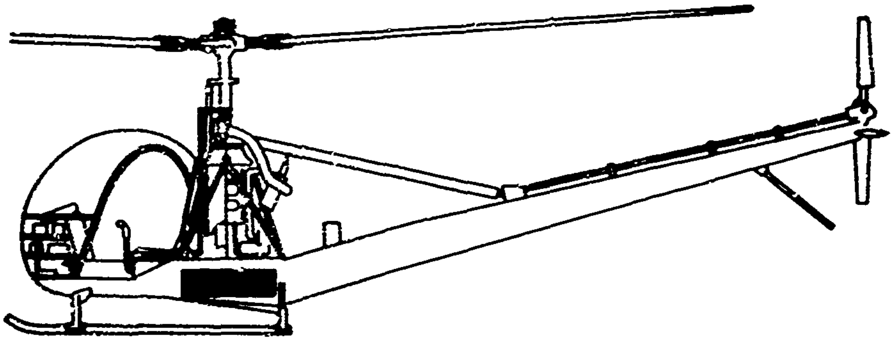

FIGURE 3

OH-23 single bladder-type fuel cell

type fuel cells, shielded by the cockpit floor and outer skin, is near ideal (Figure 3). The type of flying done by the OH-23 and the type of accidents it is involved in indicates that the OH-23 fuel cell installation has proven to be highly crash resistant (Table 5).

The OH-23 accumulates more than half of its flying hours as a student trainer (60% during FY 1963) at the Army's Primary Helicopter School at Fort Wolters, Texas. When comparing it with other models, one must recognize that controlled conditions during student training leave it relatively free of many hazards that are encountered by field units during tactical operations. Seldom do the OH-23 accident reports from Fort Wolters show the underside damaged sufficiently to rupture the fuel cells. Obviously, the many available landing areas, relatively clear of stumps, boulders, and other penetrating objects, attribute much to the OH-23 record. For these reasons, the OH-23 fuel cell installation for aircraft committed to extensive field operations should not be adopted without thorough evaluation of all factors involved.

The UH-1 bladder-type cells located aft and outboard of the cockpit with most of the cells above the cockpit floor provide added protection (Figure 4). The lower portion of the cells are extra strength self-sealing, while a layer of energy-absorbing honeycomb surrounds the lower portion of cells adjacent to the skin. As a result, statements taken from a UH-1D, FY 1964, accident report read: "Sharp object (tree trunk) penetrated the fuselage bottom under the left forward fuel cell and crushed the protective honeycomb layer without affecting fuel cell integrity."[2]

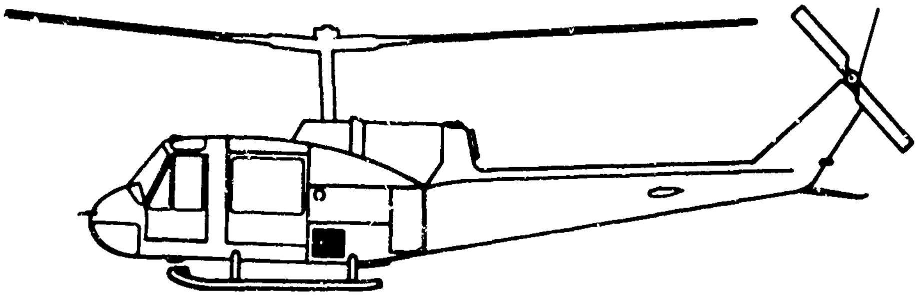

FIGURE 4

UH-1 bladder-type fuel cells aft and outboard of the cockpit

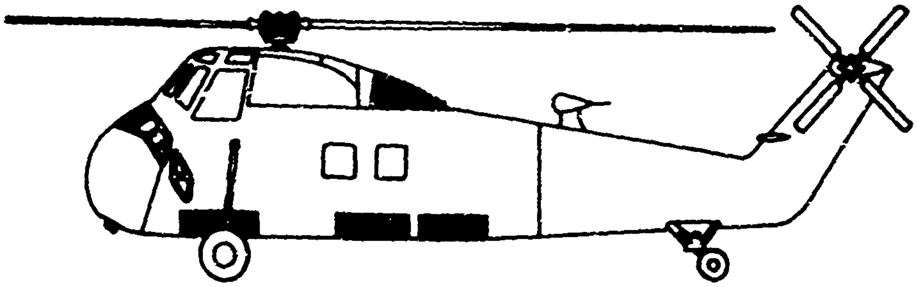

FIGURE 5

CH-34 with three fuel cells in the belly of the helicopter

In contrast, a CH-34 (Figure 5) accident report of the study period reads: "Tree trunk penetrated the belly of helicopter, rupturing the fuel tanks. Explosion and fire ensued."[3]

The UH-1 fire accident record in Tables 3 and 4 is an indication of the Army's success in developing a helicopter to meet its requirements. All other models were adopted by the Army after having been developed and produced for other services.

With due consideration of its excellent operational record and general acceptance, the design of the UH-1 does not completely achieve the ultimate in crash-fire-worthiness. Eight percent of the major accidents it was involved in terminated in fire. Four of these accidents were deemed survivable. One of these, during FY 1960, was caused by the heater exhaust igniting tall dry grass. Impact played no part in fire production. Ruptured fuel lines and fuel cells (Table 4) were the cause of the fire in the two survivable accidents. The addition of fuel cells below the cabin floor bears watching as more D's become operational.

From an inventory and utilization point of view, the record of UH-1's did not really begin until FY 1961. At the close of FY 1960, only a small number of these aircraft were on hand and they had barely accumulated 10,000 hours of flying. During the next three years, the number grew until the UH-1 now ranks third to the OH-23 and CH-34, respectively, in hours flown. During this recent period, only the OH-23 has a better fire record. The UH-1 record speaks well of the Army's initial development effort. It gives hope for the next generation of helicopters to be introduced by the light observation model. If an equal step can be taken, the ultimate in crash-fire-worthiness may be within reach of that generation.

D. Fire Causation

Data presented thus far has already indicted the helicopter's fuel and fuel system. Fuel was the flammable source in 82 of the 94 fire accidents during the six-year period. In eight of the remaining 12 fire accidents, fuel was strongly suspected even though oil and another flammable fluid was present when fire occurred. In each instance, fire broke out in the engine compartment after the

TABLE 4

Fire Causation by Model
Major Survivable and Nonsurvivable Accidents
July 1957 - June 1963

Model	Fuel Cells/ Lines		Loose Fuel Lines		Fuel Tank Cap		Vent Lines		Engine Malfunction		Exhaust Heater/ Engine		A/C Strike External Source		Clutch/ Engine Drive Failure	
	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S
OH-23	2	6	0	0	0	0	0	0	2	0	0	0	0	0	1	0
OH-13G,H	22	6	0	0	2	0	2	0	0	0	0	0	1	0	0	0
CH-34	5	4	1	0	0	0	1	0	1	0	1	0	1	0	0	0
CH-21	7	7	0	0	0	0	0	0	3	0	0	0	0	0	0	0
UH-19	4	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0
UH-1	2	2	0	0	0	0	0	0	0	0	1	0	0	0	1	0
OH-13D,E	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH-37	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	48	28	1	0	2	0	3	0	8	0	2	0	2	0	2	0
Percent	79%		1%		2%		3%		8%		2%		2%		2%	

S = Survivable Accidents N/S = Nonsurvivable Accidents

engine failed (Table 6). Only in one instance was hydraulic fluid thought to be the flammable agent. This accident involved an OH-13.

Design inadequacy of each model's fuel system to prevent spillage during and following impact is evident in the data of Table 4. It may be determined that the fuel system failed to contain the fuel in 75% of the survivable accidents. Failure of this magnitude strongly suggests the need to design fuel systems that are crash resistant. The vent system and other fuel system plumbing not only need to remain intact, particularly in the survivable accidents, but must also prevent fuel spillage when the helicopter finally comes to rest in some unusual attitude. In a majority of accidents, the helicopter's final position is not upright but lying on its side. For some reason, not yet investigated, the right side is the most frequent final position.

The following quotation taken from a post-crash fire accident report illustrates the need for total system design and why design considerations must include provisions for fire prevention after the helicopter has come to rest: "Fuel spillage in this accident was the result of the attitude of the aircraft, not the rather severe impact conditions. In this instance, the post-crash fire can be considered coincidental. If the aircraft had rolled on its right side, a fire would probably not have occurred because of the location of the fuel vent terminal."[4] We may note that fire would not have occurred had the fuel vent lines been installed according to HIAD* which states that the vent lines should traverse the three dimensions of a tank.

To illustrate another design requirement and the coincidence of post-crash fire, the statements of two accidents are given:

". . .engine stopped immediately and the helicopter completed impact on its right side. The passenger got out first and discovered gasoline leaking down

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**Handbook of Instructions for Aircraft Designers, AFSC Manual 80-1, Air Force Systems Command, Andrews Air Force Base, Washington, D. C* onto the hot exhaust pipe. The aircraft started to burn immediately. . ."[5]

". . .landed the helicopter on a slope, which was later measured as 6.5 degrees laterally from right to left skid and 1.2 degrees downhill from rear to front. The engine was not shut down. Approximately two minutes had now elapsed. In this time, fuel level from the right (uphill) tank was flowing through the connecting line into the left (downhill) tank, filling it. At this time, the passenger glanced over his left shoulder and saw fuel spraying out from around the fuel cap. The aircraft burst into flames. . ."[6]

The susceptibility of fuel cells to rupture when located in a position similar to those of the OH-13G and H series is reflected in this statement: "The main rotor blades struck the ground six times and stopped revolving. The impact of the main rotor blades caused the aircraft to roll to its left and strike the ground with the left gasoline tank, then bounce and come to rest on its right side. As it came to rest, the fuel tank and lines were ruptured allowing fuel to contact the hot engine. . ."[7]

The ignition of spilled fuel is difficult to determine and seldom pinpointed by the accident investigators. The many ignition sources which the helicopter's engine provides are cited most often. Because of the extent of fire damage in most accidents, it is often impossible for the investigating board to probe and, if necessary, conduct additional tests. In one instance, however, the path of spilled fuel to the ignition source was determined. In this case, with the helicopter (OH-13) engine running, it was demonstrated that a liquid sprayed on the bubble behind the pilot's head would run down the firewall, be picked up by the cooling fan, atomized, and forced back through the cooling baffles of the engine as far aft as the rear of the radio compartment on the tail boom. This is farther back than the engine exhaust stacks.[6]

Based on the investigators' reports of the 94 major accidents included in this study, the helicopter's electrical system has played only a minor contributory role in the fire accidents to date. Only three cases could be found citing that the electrical system had a part. In two separate but near identical OH-23 accidents, spilled fuel was ignited by an electrical short that occurred when the instrument console in each of these aircraft broke loose on impact. In the other, also involving an OH-23, an extremely hard landing in a level attitude at a high angle of descent is believed to have ruptured the tank on roll-over. Spilled fuel from the ruptured tank is believed to have been ignited by an electrical source.

Fire erupting due to the landing gear penetrating the fuselage and puncturing the fuel cells is not an unusual experience for the CH-21 and UH-19. Figures 6 and 7, respectively, show the relative location of the fuel cells and landing gear in these aircraft.

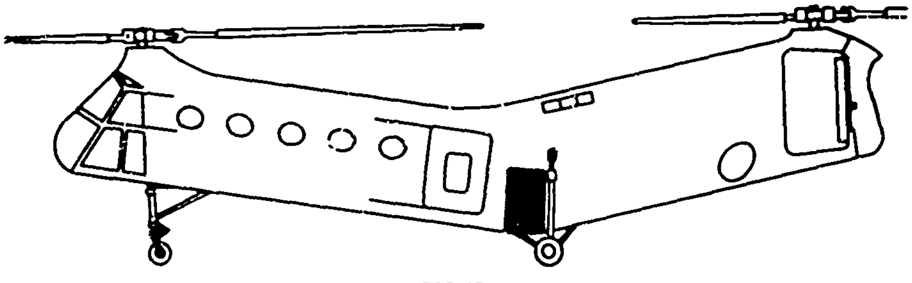

FIGURE 6

CH-21 fuel cell location in relation to landing gear

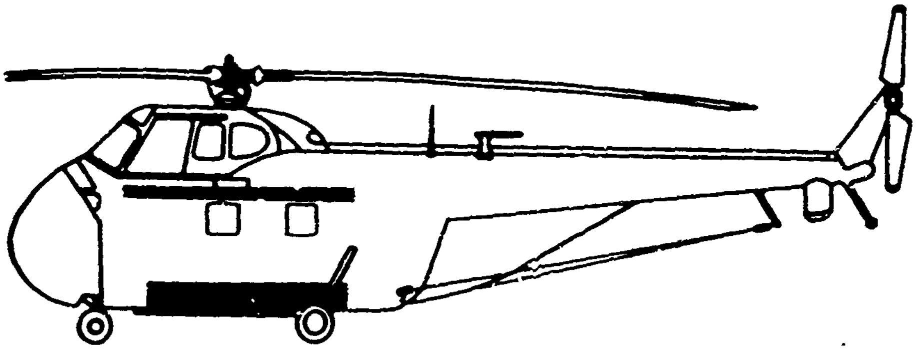

FIGURE 7

UH-19 fuel cell location in relation to landing gear

The fire hazard in this type of installation is evident in the following statement: "The aircraft (CH-21) contacted the ground with an excessive rate of descent resulting in a hard touchdown which caused both main gear struts to detach at the upper end and the fuel cells to rupture. The aircraft immediately burst into flames."[8] Fire in the two CH-21 roll-over type accidents listed in Table 5 are also the result of gear punctured fuel cells.

The UH-19 and CH-34 experience, as the following statement from a UH-19 report illustrates, are quite similar. In addition, the fire origin is pinpointed—a fact seldom determined. "The left main gear was forced upward by the impact and punctured the left side of the aft tank. Subsequent pitching motion caused fuel from the punctured tank to splash forward making contact with either the engine exhaust or the engine itself, causing the fire."[9]

E. Fire Occurrence by Type of Accident and Cost

Twenty-one different types of accidents produced the fire accidents shown in this study. The experience of each model in these accidents is shown in Table 5. For the reader, the classification of accidents into types listed is a function of USABAAR's coding process preparatory to machine data processing. For example, to classify whether a collision-with-terrain accident is controlled or uncontrolled, the coder is guided by the statement, "An aircraft is in uncontrolled flight when the aircraft is not responding adequately to the manipulation of its control system or when the pilot is unable to operate the control system."[14]

Eight of the 21 different types of accidents exceeded the expected frequency, assuming the distribution was equal among them. Controlled and uncontrolled collision-with-terrain accidents each occurred 14 times and accounted for approximately 30% of the fire accidents. Three helicopter models are involved in a majority of the collision type accidents. The CH-21 is included among these.

The incidence of fire in 10 wire-strike accidents is sufficient cause for concern that fire adds to the hazard in the operation of the low-flying OH-13 and OH-23 observation aircraft. The 91 major wire-strike accidents which occurred during the six-year period establish that the chance of fire in these accidents is approximately one in ten for all models listed in Table 5. The OH-23 and OH-13 account for 74 (82%) of the major wire-strike accidents.

Among the observation models, the accident experience of the OH-23 re-

TABLE 5

Fire Occurrence by Type of Major Accident and Model
July 1957 - June 1963

	Models																	
	OH-23		OH-13G,H		CH-34		CH-21		UH-19		UH-1		OH-13D,E		CH-37		Total	
Types of Accidents	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S
Roll Over	1	0	5	0	0	0	2	0	0	0	0	0	0	0	0	0	8	0
Collision with terrain-Controlled	0	1	3	1	1	1	3	2	1	1	0	0	0	0	0	0	8	6
Collision with terrain-Uncontrolled	0	1	2	0	3	0	1	4	0	0	1	0	1	0	1	0	9	5
Collision in air-trees, etc.	0	0	2	1	2	1	0	0	0	0	0	1	1	0	0	0	5	3
Collision in air-aircraft	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Collision on terrain-bldgs, ditches	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Collision on terrain-other	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	2
Fire-before accident occurred	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	3	0
Fire-during ground operations	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	3	0
Wire strike	2	1	2	2	0	0	0	0	1	0	1	0	2	0	0	0	8	3
Tail rotor striking landing area	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Main rotor hits part of aircraft	0	0	4	0	0	0	0	0	0	0	0	0	1	0	0	0	5	0
Rotor blades hit part of aircraft	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Spin/stall-landing or takeoff	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	1
Spin/stall-inverted	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Spin/stall-clean configuration	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Spin/stall-settling with power	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Hard landing	1	0	0	0	1	0	2	0	0	0	1	0	0	0	0	0	5	0
Under shoot runway	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0
Under shoot other landing area	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
Airframe failure inflight/on ground	0	1	0	0	0	0	1	0	0	1	0	1	0	0	0	0	1	3
Other	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Dollar Cost of Helicopters Destroyed	227,607	247,646	1,017,300	280,683	1,496,040	990,100	2,402,565	1,503,140	642,412	281,875	834,923	591,508	166,380		640,330	640,330	7,427,557	4,535,282

flects the highest probability of fire in wire strikes. Fire occurred in three out of 16 wire strike accidents as compared to two out of 21 for the OH-13D and E and four out of 37 for the OH-13G and H.

Note the fire experience among the various models in the roll-over type of accident (Table 5). This rather characteristic type of helicopter accident which, as a rule, is survivable, appears most frequently in the experience of the observation models. During the study period, the three models listed were involved in 72 such accidents. The OH-13G and H, involved in 33 of these accidents, resulted in fire to five, while the OH-13D and E had no instance of fire in 29 occurrences. In ten roll-overs, one OH-23 caught fire. In this case, the fuel cell ruptured because of an extremely hard landing.

The earlier USABAAR study reported that the dollar damage of fire accidents was $6,150,000. Quoting current prices for these models, $11,962,839 is now the total cost for the six-year period, Table 5. The new total reflects a decrease of less than a half million dollars for the recent three-year period, even though seven more fire accidents occurred during this time. The cost reduction, as analysis of Table 3 indicates, is due to a decrease or no change in the number of fire accidents involving expensive cargo and utility models. The CH-37 that costs $606,000, for example, was not involved in any fire accidents during the latter period.

When making a cost analysis, one must consider that it is almost impossible for the investigators to determine the damage caused by fire alone. It is also significant to recall that in 90% of the accidents, fire followed initial impact and caused most of the damage. And, that in a majority of the accidents, the impact forces were relatively light and considered occupant survivable. Because of these facts, the cost of survivable accidents is slightly less than twice that of non-survivable accidents. It must be remembered, too, that fire in survivable accidents prevented the retrieval of reparable components and assemblies. The loss of instruments, electronic gear, engine and accessories in addition to other high value items not only requires additional dollars for their replacement but compounds the logistical problems of supply and maintenance

F. Where Fire Accidents Occur

Data of Table 6 points out the fundamental difficulty of having fire fighting and rescue equipment immediately at hand when a fire accident occurs. The difficulty is that so few of them occur on airfields. Seventy-five of the 94 accidents were in locations remote from station equipment. Too often in these instances, the accident location is inaccessible to the equipment at hand, or the distance is too great to be reached in time for the equipment to be effective.

It is not unusual in these instances for the accident report to read: ". . .the pilot attempted to extinguish the fire with a hand extinguisher until the fire went out of control. . ."

"The fire department arrived and extinguished the fire, but the helicopter was a total loss. . ."

". . .Area of the fire was inaccessible to crash fire equipment. . ."[11] In the following statement, the investigators give an indication of time (29 minutes in this case) in which fire fighting equipment must arrive if it is to be effective: "The aircraft was witnessed at about 0631 hours as it descended and struck the ground . .on impact, the engine section was engulfed in flames The airfield and post fire engines extinguished the fire at approximately 0650 hours. . ."[12]

The rapidity with which fire spreads varies as do the types of accidents It is a function of a number of factors made evident throughout this study

Predominant is the availability of spilled fuel and the rate at which leaking fuel is fed to the flame. As has been shown, the number and size of the fuel cells, their location, and the vulnerability of interconnecting plumbing to damage, all influence the amount of fuel spilled during an accident sequence.

The limited opportunity airfield stationed equipment has to serve fire accidents suggests the advisability of recruiting the assistance of civil units. Experience shows that, both within and outside the United States, more than half of the fire accidents occurred off-post. The number of off-post accidents is increasing (Table 6). During FY 1963, 88% of the fire accidents occurred off-post. This trend, if it continues, not only supports the wisdom of employing the services of civil components, but the need to improve the program that exists today.

The remote inaccessible location in which many of these accidents occur limits the type of equipment that can effectively rescue personnel and fight fire. Only 19 of the 94 accidents took place on an airfield where truck type equipment could be assured access to the scene. The number of off-base accidents that automotive type equipment reached, or could have reached, in sufficient time could not be determined from available data.

Analysis shows that because of the rapidity with which fuel fed fires consume aluminum and magnesium, the most that can be achieved is the rescue and evacuation of occupants. The chance of saving the helicopter is remote. Of course, the need to confine the fire to the crash site is essential and necessary.

This experience points to the necessity of using a vehicle such as the helicopter for this purpose. It has both speed and the capability to reach accidents in inaccessible locations. In addition, after unloading rescue personnel, the helicopter can take to the air and use its rotor-wash in an effort to establish an escape avenue for occupants and to aid fire rescue personnel in gaining access to the aircraft.

The need for fire fighting and rescue equipment plus the capability of using it effectively is an Army-wide requirement. During each of the past three years, the number of fire accidents overseas has paralleled the experience within the United States (Table 6). In FY 1963, the overseas units operated 48% of the helicopter fleet and flew 42% of the total hours.

It is not difficult to determine why 61% of the injured are occupants of accidents that occur off the military base and off an airfield. It is not entirely a matter of the degree of safety each location provides, even though it is accepted that the off-base and particularly the off-airfield environment offers many more projections and depressions to increase the hazards of a crash landing.

TABLE 6

Location of Helicopter Fire Accidents
July 1957 - June 1963

FY Period	Within USA	Outside USA	On Post		Off Post	
			On Airfield	Off Airfield	On Airfield	Off Airfield
1963	13	12	2	6	1	16
1962	10	12	8	4	1	9
1961	2	3	0	2	0	3
1960	10	4	3	6	0	5
1959	11	2	1	5	0	7
1958	10	5	3	5	0	7
Total	56	38	17	28	2	47
Annual Mean	9.3	6.3	2.8	4.7	3	7.8
Percent	60	40	18	30	2	50

TABLE 7

Helicopter Fire Accidents
Occupant Injury Experience by Location
July 1957 - June 1963

No. of Personnel	Total	Within USA	Outside USA	On Post		Off Post	
				On Airfield	Off Airfield	On Airfield	Off Airfield
Involved	264	150	114	32	68	15	149
Injured	177	101	76	17	52	0	108
Fatal	98	68	30	3	32	0	63
Thermal Injury	107	66	41	8	32	0	67
Fatalities Due to Burns	27	15	12	0	13	0	14

The injured percentage found is a function of accident frequency. It has already been shown that 80% of the fire accidents occur off base and off an airfield. However, there appears to be a distinct difference in the severity of the accidents of the two locations if number of fatalities is accepted as an indication. It can be determined from data of Table 7 that 97% of the fatalities which includes all of the fatalities (27) due to burns occurred in off-base, off-airfield accidents.

The occupants' injury experience shown in Table 7 more than justifies the need for prompt rescue and medical evacuation. More than 65% of the occupants suffer injuries ranging from minor to fatal. In fire accidents, the time period during which no injuries, major injuries, and deaths due to fire occur is only a matter of a few seconds. The degree of burns that two-thirds of the injured received is shown in Table 11. This experience points out that allowable time between crash rescue and evacuation is critical.

The importance of evacuation is indicated in a flight surgeon's statement concerning an accident that occurred in the remote jungle area of Colombia, South America: ". . .Rescue was accomplished by an accompanying helicopter, and the injured man was in a hospital within 20 minutes. Had the rescue helicopter not been present, the only access to the accident site would have required a two day trip by mule. A man with 25% body burns undoubtedly would not have survived a two day trip. . ."[19]

G. Comparison of Occupant Injury Experience

The data of this study has dwelled primarily on the materiel and operational aspects of the fire problem. Emphasis in these areas is necessary because it is clear that the solution of the fire problem can only be achieved by eliminating known design deficiencies. However, accepted solutions must be tempered by their suitability to meet current and projected operational requirements.

If these requirements are not met, no decided change toward improvement in the occupant injury experience can be expected. Though occupant experience holds no key to the post-crash fire problem, it does illustrate in terms of personnel loss the effect on mission capability. The following facts clearly show the loss. Fire accidents that account for only 8% of the major accidents are responsible for 42% of the injured occupants and 62% of the fatalities in all major helicopter accidents. Of the 467 injured occupants, 22% suffered burns. Of the 107 thermally injured occupants, 25% received fatal burns. Fire accidents account for 18% of the 150 fatalities experienced in helicopter accidents shown in this study. Tragically, from the occupant's point of view, 10 of the fatalities were due to thermal injuries received in accidents classed as survivable.

TABLE 8

Major Helicopter Accidents
Occupant Injury Experience Excluding Fire
July 1957 - June 1963

No. of Occupants	Total	FY 1957-1960	FY 1961-1963	Change	
				No.	Percent
No. of Accidents	1053	538	515	-23	4
Involved	2792	1429	1363	-66	5
Injured	290	107	183	76	71
Fatally Injured	52	23	29	6	26
Percent Injured	10	7	13		
Percent Survived	98	98	98		

To place a dollar value on personnel loss due to injury and fatality is an almost impossible task. Quotable Army figures for the study's purpose could not be readily located and the cost figures of other services were used. For example, one service states that each of their aviators, equivalent to the Army's rank of major, represents a replacement investment cost of one to one and a quarter million dollars. Using these same cost figures, the death of the 12 Army aviators due solely to thermal injuries would be placed between 12 and 18 million dollars. This amount, greater than that shown for materiel loss in Table 5, includes only those aviators who at the time of the accident were at the controls. It does not include aviators flying as passengers. For example, in a CH-21 accident[15] two of the thermal fatalities were aviators.

The degree of injury reflected by the occupants in the tables that follow are of four classifications:

Minor: *Injury from which recovery is expected and which is considered (for reporting and coding) an injury less than major.*

Major: *Injury less than critical, recovery expected, requiring more than five (5) days hospitalization and/or quarters.*

Critical: *Injuries which threaten to result in death, either from injuries sustained in the accident, or from complications.*

Fatal: *Any injury which results in death prior to submission of Flight Surgeons Technical Report of Aircraft Accident.*

The experience of the 177 injured fire-accident occupants reveals a distribution injured severity of 21% minor, 23% major, 4% critical, and 52% fatal.

Omitting the fire accident fatalities, the percentage of occupants surviving a major non-fire helicopter crash is remarkably high and well above normal expectation. Only 2% of 2,792 occupants in 1,053 major accidents are fatally injured (Table 8).

The 98% survival indicates a degree of safety which occupants of Army helicopters can expect when post-crash fires become as infrequent as inflight fires. This expectation must, of course, discount the 29 non-survivable post-crash fire accidents in which the injuries produced by fire are of secondary importance.

To achieve this degree of occupant safety would establish Army helicopter experience well above the level of three other forms of aviation. The Aviation Safety Engineering and Research Division of the Flight Safety Foundation in a recently completed study[13] reported fatality percentages of (a) aerial application (crop dusting) 14.6%, (b) general aviation not involving aerial application 10.3%, and (c) scheduled domestic air carrier operations 8.8%.

TABLE 9

Helicopter Fire Accidents
Occupant Injury Experience
July 1957 - June 1963

No. of Occupants	Total	FY 1957-1960	FY 1961-1963	Change	
				No.	Percent
Involved	264	122	142	20	16
Injured	177	74	103	29	39
Fatally Injured	98	41	57	16	39
Injured-Thermal	107	51	56	5	10
Fatal-Thermal	27	12	15	3	25
Percent Injured	67	61	73		
Percent Survived	63	66.4	60		
Percent with Burns	41	42	39		

Adding the experience of the 255 fire-accident occupants of Table 9 increases the Army's helicopter experience by 3% to an overall figure of 5%. Though the increase is significant, the survival percentage remains at a respectable level when compared to other forms of aviation.

To place whatever conclusions that may be drawn from the comparison in proper perspective, the variability of the factors that determines the degree of exposure of each form to accidents must be considered. This is necessary because of the distinct differences that exist among the various forms of aviation. The differences are due to type of operation, number of landings, mission length, crew selection and training, and others which need not be discussed here. They are well known to those familiar with aviation safety.

From an injury production standpoint, it is significant to note that in 90% of the non-fire accidents, occupants escape even minor injury (Table 8). The addition of fire experience decreases the injury-free survival picture by 5% to 85%. The fact that 15% of the occupants are injured is sufficient justification to consider improving the crash-fire-worthiness of the helicopters selected to remain in operation.

The need is not necessarily protection from thermal injury alone, but other types of injuries as well. This point is made by the 58% increase in the number of occupants injured during FY 1961-1963 when the number of accidents and occupants involved decreased 5% (Tables 8 and 9). Fire accidents alone during this period were responsible for increasing the number of occupants injured by 29. Of these, fire caused a thermal injury increase of only five. Additional study, exploratory in nature, failed to reveal an acceptable explanation, other than the added UH-1 experience shown in Table 10, as to why the other types of injuries are increasing. The rate of this upward trend warrants additional study, particularly if the responsible models continue to pace the acceleration of nap-of-the-earth operation.

H. Occupant Experience by Model of Helicopter

The degree of occupant safety each model provides in survivable and non-survivable fire accidents is evident in Table 10. However, caution must be exercised when comparing models. Erroneous conclusions may be drawn unless one keeps clearly in mind that injury production is largely a function of impact severity. And in fire accidents, thermal injury depends upon the occupant's

TABLE 10

Occupant Injury Experience in Fire Accidents
By Model of Helicopter
July 1957 - June 1963

	No. of Acdts		Number of Occupants													
			Involved		Injured		Fatalities		Percent Injured		Percent Survived		Injured Thermal		Thermal Fatalities	
Model	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S	S	N/S
OH-23	6	5	9	8	8	8	3	8	89	100	67	0	2	7	2	0
OH-13G,H	25	7	37	11	22	11	3	9	59	100	92	18	17	10	3	1
CH-34	10	5	34	14	18	14	2	14	53	100	94	0	7	12	2	9
CH-21	10	6	37	38	15	35	1	33	41	92	97	13	1	22	0	4
UH-19	5	2	21	6	5	6	1	6	24	100	95	0	3	6	1	0
UH-1	4	2	20	7	12	7	5	7	60	100	75	0	6	7	2	0
OH-13D,E	5	0	8	0	6	0	1	0	75	0	88		2	0	0	0
CH-37	1	1	9	5	5	5	0	5	56	100	100	0	1	4	0	3
% Survivable	70		66		51		16						36		37	

location relative to the main bulk of the fire. The experience of the observation models is a good example. Data of Table 10 effectively shows the OH-13's to have a much higher degree of occupant safety. However, this study has shown that higher impact forces are required to cause fuel to spill and ignite in the OH-23 than in the OH-13's. The location of the OH-13 fuel cells relative to the cockpit usually places the occupants very near the main fire. This statement from a flight surgeon's report is descriptive of what often happens: "When the aircraft fell over, the bubble broke and the right tank ruptured releasing fuel which ignited on the hot manifold. It then spilled into the cockpit seating area. The spray of burning fuel on the pilot's face, hands, and clothes continued to burn as he exited through the shattered plexiglas. . ."[16]

The survival of seven occupants in non-survivable accidents of the OH-13G, H, and CH-21 is an example of the ineptness of the definition of accident survivability to meet the variety of conditions accidents present. The CH-21 was involved in two accidents of this type. In each case the sequence of impact was quite similar. The crew compartment impacted first and sustained sufficient damage to cause the accident to be classified as non-survivable. The collapsing structure of the crew compartment reduced the forces transmitted to the cargo compartment, thus permitting this area to be survivable. In one accident,[15] a passenger thrown clear of the wreckage into the snow escaped with only minor injuries. He was able to rescue a more seriously injured passenger from the fire that caused the death of four others.

The respective records of the UH-19, CH-21, and CH-34 show that these three models reflect the highest degree of occupant safety of all models in the survivable fire-accident experience shown in Table 10. The UH-19 record shows that in these accidents where fire, in addition to impact, increases the exposure to injury, 76% of its occupants are free of injury. The combined experience of the three models shows that 59% of the occupants are not injured. With the exception of the CH-37 which was involved in only one survivable fire accident, these models reflect a high degree of occupant survival.

Also among these models, the record of the CH-21 in survivable accidents stands out, particularly in regard to thermal injury. Only one of its occupants suffered thermal injury even though its fire-accident experience was equal or greater, and involved more occupants than other models. Undoubtedly much of its record is due to the availability of escape exits. Its cargo compartment, unlike the UH-19 and CH-34, has convenient openings on both sides including the large cargo door on the right. Frequently, the location of the exits relative to the location of the fire does not require the occupants to pass through a wall of fire to escape.

The injury experience of the observation models contrasts the findings mentioned for the three larger models. The degree of occupant safety in the observation models is much lower. In survivable fire accidents only 33% of observation-model occupants escape injury. The 87% occupant-survival rate indicates that the degree of injury incurred is much more severe in the smaller models. The fatality experience of the two types is evidence of this fact.

A portion of this difference may be explained upon noting that the smaller models experienced 11 more survivable fire accidents than did the larger models (Table 8). Though the additional accidents increase the exposure and chance of injury, a more logical explanation is the difference in structural configuration, increased occupant protection, particularly the structure surrounding the cockpit area, and the location of the fuel cells relative to the position of the occupants. The observation models have a plexiglas "bubble" enclosing much of the cockpit. This enclosure breaks away in most accidents to provide an excellent escape exit; however, when it breaks away, it offers no resistance to the path of fire in these post-crash fires. In addition, the shattered plexiglas is a source of injury. Plexiglas fragments often act as flying missiles and the jagged remaining pieces cause laceration during exit. Fortunately, most of these injuries are not of a major consequence.

The relative location of fuel cells to the occupants in the larger models is a significant factor in the reduction of thermal injury. The thermal-injury experience of the OH-13G and H is an example. This model is responsible for 44% of the thermally injured occupants in survivable accidents. The chance of thermal injury in this model is highest of all models. From Table 10, it may be determined that 46% of the occupants involved received thermal injuries. Fortunately, the number of fatalities is much less.

However, all factors that contribute to occupant safety are not necessarily inherent in the design nor in the operation of the larger models. Data of Table 10, to consider both the survivable and non-survivable accident experience, supports this observation. The accidents involving the larger models are much more severe; the impact forces are greater. Proportionally, these models experience three times as many non-survivable accidents as do the smaller observation models. Their accidents account for 75% of the fatalities. However, the occupancy factor in the larger models is almost three times as great as in the smaller observation models which accounts for the difference in number of fatalities.

I. Thermal Injury

Of the various injuries that can be experienced by occupants of helicopter fire accidents, skin injuries are reported most frequently. Whether other types, like those to the respiratory system and those due to toxic gases, do not occur as frequently or are not reported could not be established. It may be, and

TABLE 11

Occupant Thermal Injury by Body Area and Degree
July 1957 - June 1963

Body Area	Survivable Accidents			Non-Survivable Accidents		
	Percent of Injuries	Degree of Injury		Percent of Injuries	Degree of Injury	
		Percent 1° & 2°	Percent 3° & up		Percent 1° & 2°	Percent 3° & up
Head	6	40	60	0	0	0
Face	17	92	8	0	0	0
Neck	9	57	43	0	0	0
Upper Extremities	24	81	19	10	29	71
Chest	1	0	100	4	50	50
Abdomen	0	0	0	0	0	0
Pelvis	0	0	0	0	0	0
Back	1	33	66	4	0	100
Legs	13	50	50	10	0	100
General	29	23	77	86	0	100

No. of Occupants = 39 No. of Occupants = 66

particularly among survivors, that the significance of reporting other types of injuries is overlooked in the presence of extensive skin injuries. Among the deceased, an autopsy is not performed in all cases and often the findings, though required, are not included in the investigation report.

In reported cases of respiratory system injuries, the occupant's escape was hindered in some manner. In one case a crewchief panicked at the sight of flames. He forgot about the quick release of his shoulder harness and lap belt. He struggled until he managed finally to slip beneath the belt. In another, a pilot fought the release of his lap belt (he had learned at the preflight inspection that it was improperly installed in the aircraft and would require the reverse of the normal procedure to release it). Others were not so fortunate. In two cases, occupants suffered blows to their heads and, in an unconscious state, inhaled superheated air of the flash fire that swept through the cockpit. One of them wore a helmet, but a blow on the forehead was thought to have caused loss of consciousness. The other did not use his helmet; he placed it in the seat next to him because the flight was to be "just a short hop."

Data of Table 11 shows the pattern of skin injury by body area and the degree of thermal injury to that area. The injury pattern and degree are given in percentages. For example, the experience of 39 thermally injured occupants of survivable accidents shows that 6% of their injuries were confined to the area of the head, and 60% of the burns were third degree or more severe.

Thermal injury to the head could have been prevented in many cases and reduced in severity in others had the helmet been available, remained on the occupant's head during the crash, and had the occupant not removed it prior to exit.

Prior to the fall of 1959, before the APH-5 was available, and for a period after initial distribution, helmet availability was a problem. It is not a serious problem today for pilots. There were only six reported cases involving fire accidents in which helmets were not available for pilots during FY 1963. However, helmet availability remains a problem for crewchiefs, other crew members, and passengers.

Helmet dislodgement is a problem and will probably remain so until wearer comfort is sufficient to promote the need to keep the chin strap fastened and the nape strap in adjustment. Of the 100 occupants who wore helmets in this study, 24 lost their helmet sometime during the accident sequence. This group accounts for much of the head injuries shown in Table 11.

Removing the helmet prior to exit is a pilot reaction that is not understood. Why it occurs is not known. One pilot questioned on the point said: "I released my seat belt and for some reason thinking that the helmet would keep me in the helicopter. I removed it also."[17]

Another who had the presence of mind to hold his breath while exiting removed his helmet. The only burn injuries he suffered were to his head and neck.

The issuance of chemically treated fire resistant flight suits would have reduced the injuries of many survivors. Only 21, less than 10% of the aviators involved, wore flight suits. The number of suits properly treated to resist fire is not known.

The circumstances involving gloves and the prevention of hand injuries is somewhat similar. The problem is not, however, the availability of gloves! Instead it is that the issued gloves are unsatisfactory for the requirements of most pilots. Consequently, in these accidents only 22 aviators wore gloves of some type. One pilot suffered second degree burns to both hands. He had removed his gloves only ten minutes prior to the crash because his hands were too warm.

Gloves would have helped others in escaping. The experience of five passengers trapped in a CH-34 is explained by one of them who said: ". . . everytime I reached for something, my hands would burn."[18] They were trying to reach the exit which was located five feet overhead because of the aircraft's final position.

The relationship of impact severity and the production of thermal injury is evident in the data shown by Table 11 when comparing the two accident categories. As expected, the thermal injury occupants of survivable accidents sustain is less severe. A review of the survivable fire accidents provides these reasons: Rarely are the impact forces sufficient to incapacitate the occupants to hinder escape; escape provisions of the OH-13, OH-23, and CH-21, responsible for 70% of the survivable accidents, have proven to be excellent and of great importance as fire in 90% of these accidents followed impact and allowed time for escape. Only in a few accidents did fire completely engulf the aircraft before it came to rest and prevented those capable of escaping from exiting in sufficient time.

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17. Aircraft Accident, File Nr. 5322, 26 October 1962, OH-13H, U. S. Army Board for Aviation Accident Research, Fort Rucker, Alabama.
18. Aircraft Accident, File Nr. 3992, 26 October 1961, CH-34A, U. S. Army Board for Aviation Accident Research, Fort Rucker, Alabama.
19. Aircraft Accident, File Nr. 04504, 6 April 1962, OH-13H, U. S. Army Board for Aviation Accident Research, Fort Rucker, Alabama.