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A Human Factors Perspective on Human External Loads

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16. Abstract

Title 14 part 133 of the Federal Code of Regulations (14 CFR 133) titled, "Rotorcraft External Load Operations," describes the operation and certification rules governing helicopter external load operations. Specifically, part 133.45 addresses rotorcraft operations involving human external loads (HELs) and the design of personnel lifting devices used in HEL operations. To determine if there is a need for imposing new regulations on HEL operations, the Rotorcraft Standards Directorate of the Aircraft Certification Service requested the Civil Aeromedical Institute to review all available accident databases to determine if HEL operations are unsafe or sufficiently problematic to warrant a change in the existing regulations. This report investigates HEL accidents, categorizes commercially available equipment used in different personnel lifting operations, and provides human-factor related recommendations affecting the use of these HEL lifting devices. A review of accident data between 1973 and 1996 from several databases did not reveal any accident trends or highlight any specific safety issues related to HEL operations. A review of commercially-available HEL equipment showed the devices were designed for either short-term, rescue-type operations or long-term, work-related activities where the user is required to remain in the device for extended periods of time. Suggestions concerning the safety, comfort, and use of HEL devices are provided, as well as recommendations that standard operating procedures, training for HEL crew members, and minimal equipment specifications be added to the current regulation.

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1. INTRODUCTION

The Rotor Craft Standards Directorate responsible for overseeing FAA Rotorcraft Operations requested the Civil Aeromedical Institute to review all available aviation accident databases to determine if human external load (HEL) helicopter operations are unsafe or sufficiently problematic to warrant revising the Code of Federal Regulations **14** CFR **133.** Human external load operations involve the transportation of a passenger suspended by a cable under the helicopter. HEL operations are often found in the logging industry to access remote work sites, for transport of shore ship captains, to access electrical power lines in need of maintenance or repair, and for emergency rescue operations. The focus of this report is to investigate HEL devices used in work (non-rescue) applications. Specifically, this report describes various devices used to secure human external loads, reviews current regulations regarding HEL operations, researches the accident history associated with HEL operations, and provides recommendations for human factors based regulations concerning HEL devices.

Current regulations exist regarding the physical and structural characteristics of external load (EL) operations. However, no consideration has been given to the issue of humans as external loads. Not only are the physical characteristics of the load transport important, but the introduction of a human as a load warrants the investigation of related safety and comfort issues. Although HEL operations have been in existence for many years, no one has ever investigated the safety issues of humans as external loads. Are HEL operations problematic? Are workers frequently injured or killed as a result of HEL operations? Are there significant human factors issues associated with HEL operations? This report investigates some of the questions surrounding HEL operations. Specifically, the report: **1)** classifies and describes currently available devices for securing the HEL, 2) discusses current regulations and accident trends in rotorcraft operations (particularly HEL operations) and 3) recommends needed safety standards to be applied to human external load devices.

The report begins with the categorization and description of HEL devices so the reader can better understand the nature of the HEL task. A detailed discussion of accident data follows, summarizing all identified accidents between 1973 and 1996 according to their cause. Finally, this report concludes with a discussion of the authors' suggestions for important HEL safety regulations.

2. CATEGORIZATION OF HUMAN EXTERNAL LOAD (HEL) DEVICES

One of the objectives of this report was to survey devices currently used to secure Human External Loads. To accomplish this objective, companies and organizations involved in HEL operations were contacted. The response from most end-users was less than enthusiastic. Most end-users, particularly those who have experienced accidents or incidents, were very reluctant to discuss HEL issues with the FAA. More success was achieved through contacts with the manufacturers of HEL devices; nine such companies supplied product catalogs and videos. It was primarily from manufacturer literature and anecdotal information obtained from HEL operators involved in rescue operations that the following survey of HEL devices was developed.

There are numerous devices used to secure HELs for helicopter transport operations. Although there is overlap in the functionality of the different devices, they can be categorized according to their primary use for either long-term applications or short-term applications. The points of differentiation between such operations are the requirements of the task as well as the duration of the operation. Long-term applications include such activities as long distance transport and working from a suspended platform or basket. The important characteristic of long-term HEL devices is that the user is minimally constrained by the HEL device and is afforded some degree of mobility. It is crucial that the HEL device not subject the worker to additional strain on the body and that the device not restrict body movements essential for performing the task.

Short-term applications of HEL include rappelling, short hauling, and rescue operations. Devices used in such applications are directly attached to the user for the duration of the activity, which usually involves transporting the user to a near location. This category can be further subdivided into active users and passive users according to the level of involvement of the user in the HEL operation. In the case of the active user, the passenger must actively participate in the lifting operation, such as maintaining a grasp on a center bar or hoist rope for balance. These short-term, active-user devices can be used if the user is capable of the necessary performance. On the other hand, passive-user devices are used in rescue operations to transport injured or impaired personnel who are unable to assist in their own rescue. Examples of such devices include rescue baskets and stretchers. Typically, rescue personnel are required to assist passive users in order to position the user in the HEL device. Figure 1 is a graphic illustration of the HEL device categorization scheme.

3. DESCRIPTION OF HEL DEVICES

As previously mentioned, the survey of HEL devices was derived from voluntarily provided manufacturer information. However, among the various manufacturers, there are general categories of devices. Each type of device is described generally, including specific applications and manufacturers of the device.

3.1 Safety Harnesses

One of the more basic devices provided by HEL manufacturers is variously known as a safety harness, a rescue swimmer's harness, or a chest harness. Typically, these harnesses consist of shoulder straps attached to a waist or chest belt. The design of the straps varies. Some harnesses incorporate suspender style straps with the tether point-of-attachment at a D-ring on the front center of the chest/waist strap. Others utilize a Y-shaped design (on the front or back) for the harness, where the shoulder straps meet a strap extending vertically from the waist belt to form a three-point intersection. This design is sometimes used at the chest, at which point a D-ring is used for tether attachment. The harnesses are either designed to be fully adjustable to accommodate a variety of users or are available sized for the individual user. The harness is constructed of nylon webbing with at least a 2 in. width. Custom padding is an optional feature offered by some manufacturers. The harness is designed to support the load (i.e., body weight) by the torso and shoulders of the user. Figure 2 presents two versions of safety harnesses manufactured by Mustang Survival (1)[1]. These types of harnesses are utilized to transport or suspend people from helicopters for short durations.

3.2 Sit Harnesses

Sit harnesses comprise another category of HEL devices. Also known as pelvic harnesses, rescue harnesses,

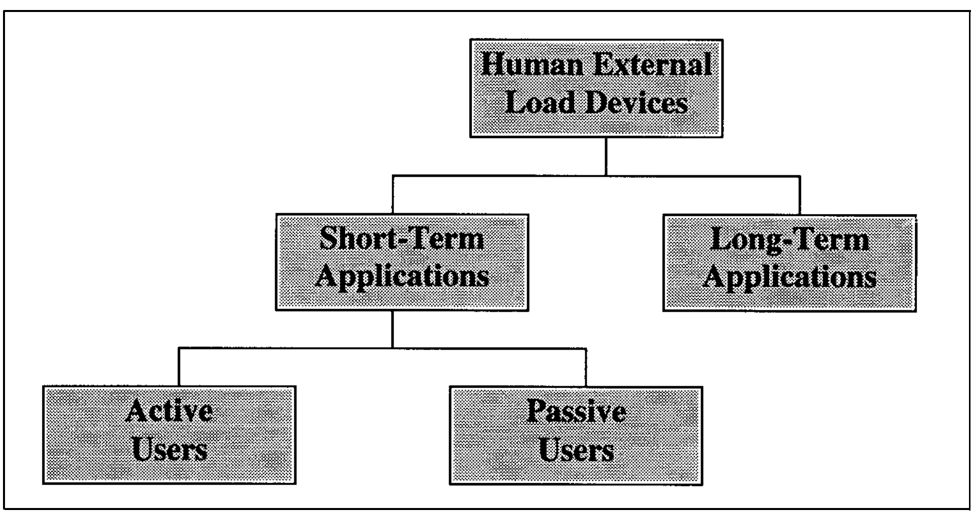

Figure 1. Categorization of Human External Load Suspension Devices.

[1] Numbers in parentheses refer to catalogs and regulations listed in the references.

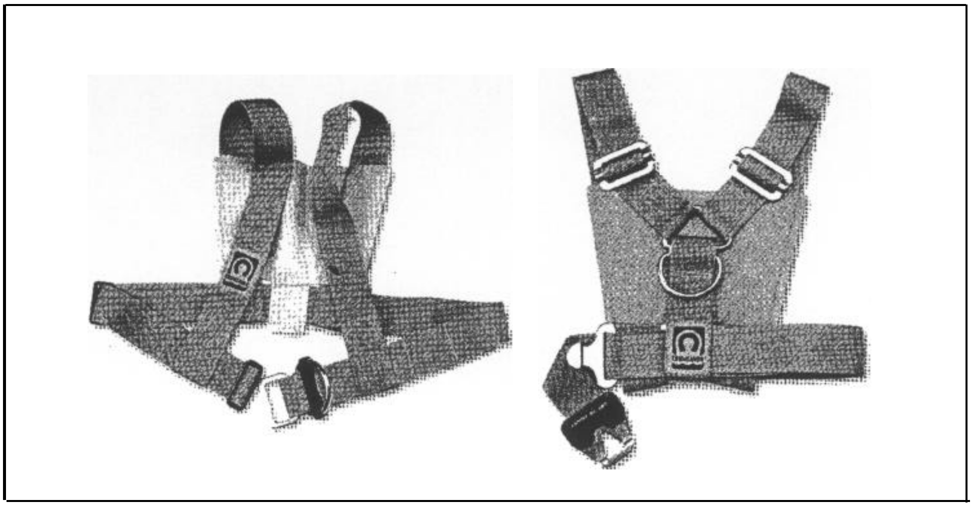

Figure 2. Safety Harnesses (Mustang Survival).

Figure 3. Pelvic Rescue Harness ("X" Design; Skedco, Inc.).

Figure 4. Pro Series Rescue Harness (CMC Rescue Equipment).

or rigger's harnesses, these devices suspend the user in a seated posture, with substantial hip flexion. The basic design of the sit harness is a waist belt (at about the level of the lumbar spine), which angles forward towards the pelvic region. The waist belt is connected to leg loops that are positioned around the top of the thighs. One design for connecting the waist and leg loops utilizes an "X" design, a crossover of the 2 loops, across the hips (refer to Figure 3). The point of the tether attachment extends about 4 in., directly in front of the upper pelvic region.

A different design attaches the waist belt to the leg loops with vertically oriented connector straps, one located in the front middle, and others located on the sides or the back (see Figure 4). The point-of-attachment is located at the intersection of the waist belt and the front vertical strap. Various other modifications exist to these basic designs. Most of these harnesses are fully adjustable at the waist and legs, with the "vertical" design allowing adjustable leg loop height. Additionally, quick and easy buckling mechanisms are provided for fast donning of the harness. A minimum of 2 in. webbing is used for the harness, although larger widths and padding are available on some models. Other variations to the sit harness include alternate locations for the D-ring attachment points and attachable chest harnesses. All sit harnesses support the user's weight at the lower back and upper thighs. Sit harnesses provide work platforms for all short-haul and longer-duration transport activities.

Full Body Harnesses

Full-body harnesses (FBHs) represent a combination of sit harnesses and chest harnesses. While there are numerous variations of the basic design of the harness, all full-body harnesses include leg loops, shoulder straps, and either a waist belt, a chest belt, or both. The design of the various components resembles that described for the sit and chest harnesses. Figure 5 is an example of the CMC Rescue Equipment (2) full-body harness. Most full-body harnesses are fully adjustable, although some are individually sized and are available with quick-release buckles for fast, easy donning. Again, some manufacturers utilize 2 in. nylon webbing while others incorporate 3 in. webbing with padding into the harness. One manufacturer, Surety Manufacturing and Testing Ltd. (3), incorporates a redundant safety system into the harness by including plastic components which ensure that the hardware is properly positioned. The design of full-body harnesses is such that it assists the user in maintaining an upright, seated posture while suspended from the helicopter.

Other modifications to the basic design of the full-body harness are worth mentioning. One modification is the addition of a mesh vest to the shoulder straps to provide additional comfort and visibility. Another manufacturer, Lifesaving Systems Corporation (4), has developed a full-body hoisting harness that is an entire torso suit. The webbing is attached to a nylon mesh suit that has a large range of adjustability. The suit helps to distribute the load across the entire torso, minimizing localized pressure points. The suit is also manufactured in orange, which dramatically improves the conspicuity of the user. The last substantial modification identified was the addition of shorts to the full-body harness, called the full-body seat harness. This fully-adjustable harness (Figure 6) combines the features of a full-body harness with a seat harness by incorporating a contoured seat in place of the leg loops and waist belt. The seat is connected to shoulder straps at the waist. The tether point-of-attachment is at the top of an inverted "Y" that connects to the seat at each hip and is connected to the shoulder straps via an additional strap. This harness provides a high degree of mobility and freedom of the hands and is perhaps the most comfortable working platform available in harnesses. The full-body seat harness is applicable to extended duration operations. A different version of this same device is the rescue

Figure 5. Pro Series Full Body Harness (CMC Rescue Equipment).

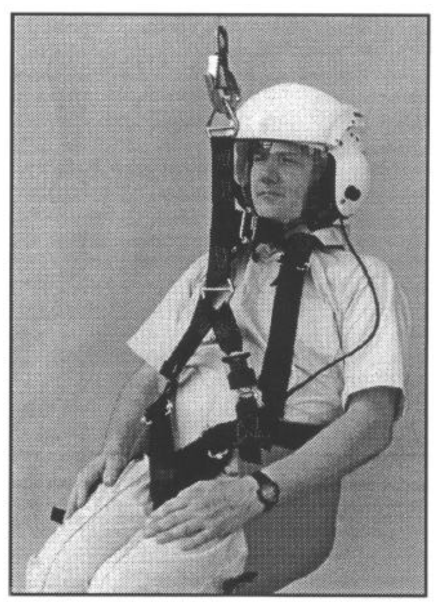

Figure 6. Full Body Seat Harness (Lifesaving Systems Corporation).

diaper, or rescue shorts, developed by Lirakis Safety Harness, Inc. (5). However, these devices are primarily for short-term, passive users in a rescue situation. These harnesses provide good support of the user, but do not appear to maintain an effective working posture.

Rescue Devices

A different HEL device, the rescue seat, is patterned after the military jungle penetrator. The rescue seat is a vertical metal bar with seats that extend from the bottom end and retention straps that are attached at the top. In the stowed position, the rescue seat is about 3 ft. long and 9 in. in diameter. The model, marketed by Life Support International, Inc. (6), and shown in Figure 7, includes 3 easily extended seats positioned at equal intervals around the center bar. Although it is intended for 1 user, 3 people can be hoisted in emergency situations. This device could be utilized for passive, short-haul operations, but this would require securing the individual's legs as well. The rescue seat marketed by Lifesaving Systems Corporation is very similar, with the exception of the seat design. This device provides only 2 folding seats positioned on opposite sides; both seats are equipped with safety straps. The primary use for these devices is short-haul transport operations. Rescue seats are not suitable as work platforms.

Rescue nets are another device developed for the transport of individuals. The series of rescue nets manufactured by Billy Pugh Co., Inc. (7) follow the basic design of a suspended cage made of a flexible cabling with one open side. The nets are designed such that gravitational forces locate the occupant to the rear of the cage. Rescue nets are available in models that fold for storage, as well as models that can be used in a chair mode or a stretcher mode. Figure 8 illustrates a rescue net in the stretcher mode. Rescue operations comprise the majority of the applications of the net, although transport of personnel is also possible. However, the user sits in the net without any additional restraints or harnesses. Also, given the nature of the flexible netting, movement within the net is somewhat cumbersome.

Rescue baskets are another form of HEL device. Precision Lift, Inc. (8) markets a newly introduced helicopter lift-basket called the Heli-basket. It is suggested that this basket is ideal for many helicopter applications, such as multiple personnel rescue

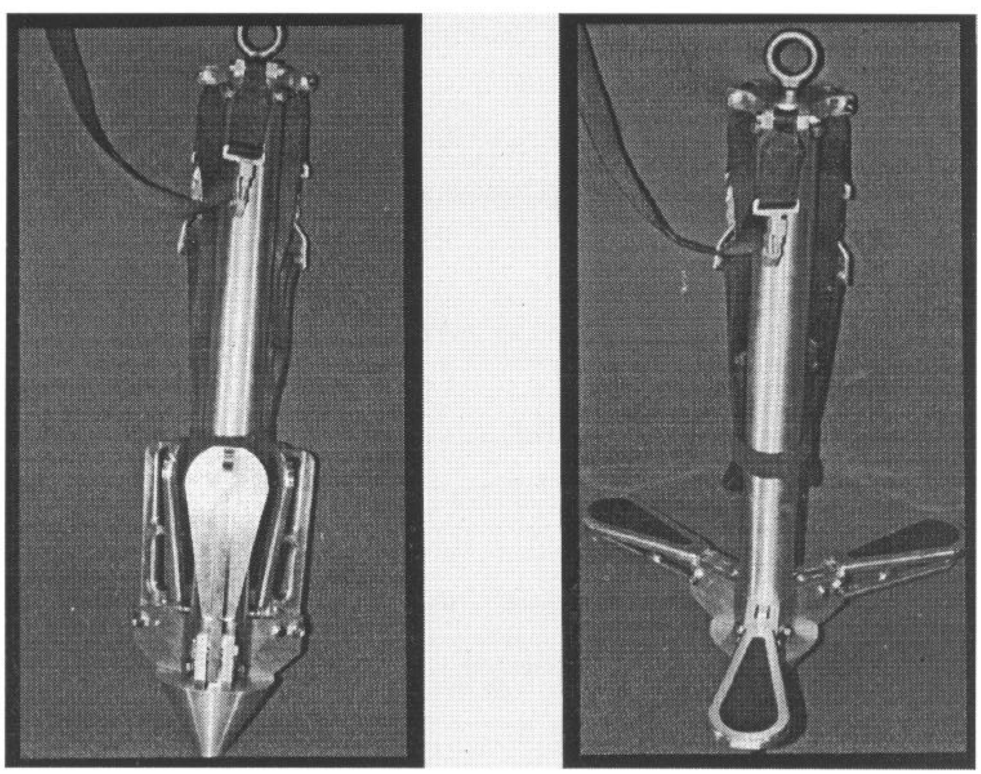

Figure 7. Forest Penetrator Rescue Seat (Life Support International, Inc.).

Figure 8. Stretcher Rescue Net (Billy Pugh Company).

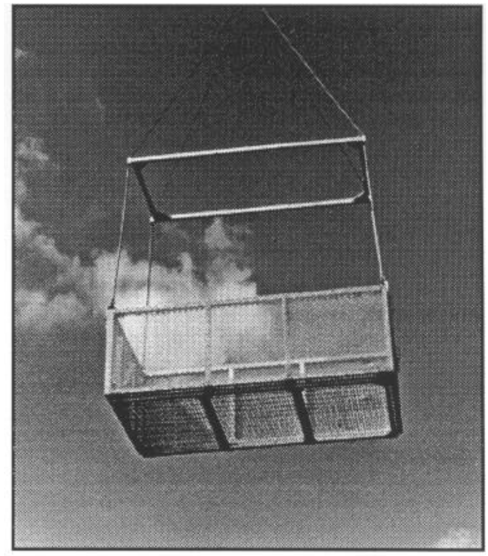

Figure 9. Heli-Basket (Precision Lift, Inc.).

andevacuation and difficult transportation needs. The basket is a rigid structure made of aluminum grating and measuring 4.5 ft. by 8.5 ft. The side rails are approximated to be 3.5 ft. high. The sides of the basket are designed to be unhinged and rotated outward to facilitate loading. The basket is attached to the tether line through an aluminum frame (approximately 8 ft. in height) with flexible movement at the joints. The capacity of the heli-basket is 4500 lb. Figure 9 depicts a suspended Heli-Basket. This basket, and others of similar design, could serve long duration HEL operations if it were modified to include a tether to secure the user.

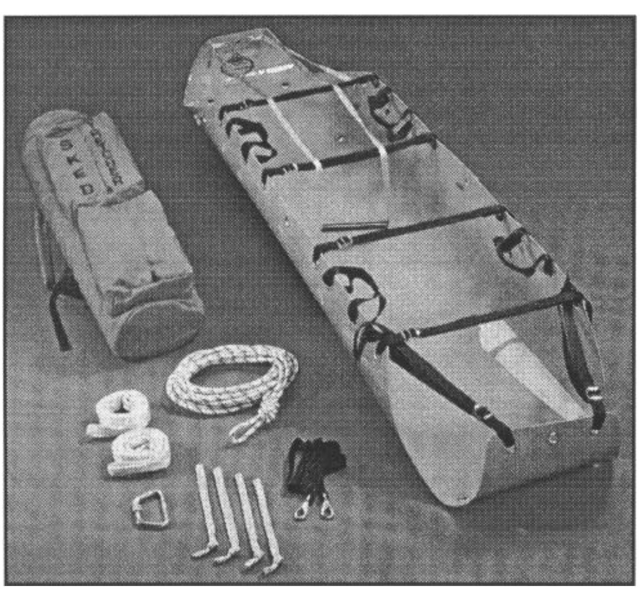

Figure 10. SKED Stretcher (Skedco, Inc.).

One of the more common devices for short-haul operations with passive users is the rescue litter. Rescue litters are available in a variety of styles, but all are adaptations of rigid or semi-rigid stretchers. The rescue litter has a variety of options, including shape, size, material, rigidity, harness attachments, use of litter shields, and the number and types of tie-down straps. Asemi-rigid rescue stretcher, made by Skedco, Inc. (9), is shown in Figure 10. Again, rescue litters are for passive users and are often accompanied by an active user attached via a harness to both the helicopter and the stretcher.

A summary of the various devices surveyed is presented in Table 1. This table is arranged according to the application groupings. Devices suitable for each application are listed accordingly.

4. FAA Regulations Covering Rotorcraft External Load Operations

Federal Aviation Regulations applicable to rotorcraft operations, particularly those referring to human external loads, were identified. The FAA regulations are located in Title 14 of the Code of Federal Regulations (CFR) (10). The collection of FAA regulations housed in 14 CFR is often referred to as Federal Aviation Regulations (FARs) when discussed independently from the CFR. Within 14 CFR, several parts specifically reference rotorcraft operations. Part 91 is titled General Operating and Flight Rules. Within section 313 of Part 91 (1l), restricted category

Table 1. Categorization by Application of HEL Devices.

Short-Term, Active User		**Manufacturer**
	Safety Harness	Mustang Survival
	Rescue Swimmer's Harness	Life Support International, Inc. Lifesaving Systems Corp.
	Chest Harness	CMC Rescue Equipment
	Rescue Harness/Sit Harness	CMC Rescue Equipment Lirakis Safety Harness, Inc.
	Pelvic Rescue Harness	Skedco, Inc.
	Rescue Seat	Lifesaving Systems Corp.
	Forest Penetrator	Life Support International, Inc.
Short-Term, Passive User		**Manufacturer**
	Rescue Harness/Sit Harness	CMC Rescue Equipment Lirakis Safety Harness, Inc.
	Pelvic Rescue Harness	Skedco, Inc.
	Rescue Diaper/Rescue Shorts	Lirakis Safety Harness, Inc.
	Forest Penetrator	Life Support International, Inc.
	Rescue Nets	Billy Pugh Company, Inc.
	Rescue Baskets	Lifesaving Systems Corp. Precision Lift, Inc.
	Rescue Litters	CMC Rescue Equipment Ferno Junkin Safety Appliance Co. Life Support International, Inc. Lifesaving Systems Corp. Skedco, Inc.
Long-Term		**Manufacturer**
	Rescue Harness/Sit Harness	CMC Rescue Equipment
	Full Body Harness	CMC Rescue Equipment Lifesaving Systems Corp. Lirakis Safety Harness, Inc. Skedco, Inc.
	Rescue Basket	Lifesaving Systems Corp. Precision Lift, Inc.

civil aircraft are limited to certified operations directly related to work. Only crew, trainees, and essential personnel are allowed to be transported. A disclaimer is provided, waiving the regulations contained in this section for ***non-passenger*** carrying civil rotorcraft external load operations covered by Part 133, Rotorcraft External-Load Operations. Part 119, Certification: Air Carriers and Commercial Operations, defers discussion of commuter and on-demand operations to Part 135, Air Taxi Operators and Commercial Operators.

Part 133 pertains directly to rotorcraft external load operations and contains subparts that specifically address applicability, certification rules, operating rules, and related requirements. The regulations in Part 133 pertain to all rotorcraft external load operations, with specific exclusion of the external-load attachment method and flights conducted for the purpose of training. It is also stated that all essential, non-crew personnel directly involved with the external load operation may be carried only in approved Class D rotorcraft. The sections of Part 133 pertaining to certification rules detail the requirements to be included in a test of knowledge and a test of skill. Emergency operations rules and requirements are addressed in section 31 and allow for deviation from the standard rules in order to meet the emergency. However, notification must be made within 10 days to the local representative of the FAA administrator. Section 33 restricts human external load operations to Visual Flight Rule (VFR) conditions. Section 35 limits the people allowed on the rotorcraft during external load operations to crew, trainees, and other people with functions essential to or necessary for the operation. All people participating in the operation must be briefed prior to the operation. Airworthiness requirements are discussed in section 43, including the weight and center of gravity of the rotorcraft-external load combination and the necessary approvals for the external loads attachment method and the use of quick-release devices. However, the regulations provide no specific detail regarding the attachment method or quick-release devices, just references to Part 27 or Part 29. Limits of operation are discussed in section 45. This section states that all lifting devices must be FAA-approved and that the lifting devices must have emergency release capability requiring 2 distinct actions.

Parts 27 and 29 were cross-referenced, based on the reference noted in Part 133. Each of these parts of the CFR contained two sections referring to external load operations, sections 865 and 1525. The content of each section was the requirements for attachment and the applicable operations, respectively, and was identical across the different parts. The only reference to human external loads found within the FARs was in Part 133 section 33, as previously noted. This section merely restricts the use of HEL to VFR conditions and provides no guidance as to appropriate/necessary HEL safeguards and procedures. Table 2 provides a summary of the content of the regulations discussed above.

5. ROTORCRAFT ACCIDENT DATA

It has been suggested that a significant number of accidents involve the transport of human external loads using rotorcraft. More specifically, the devices used to secure the HEL were thought to be safety deficient. To document the magnitude of problems associated with human external loads, and to understand how the problems are manifested, several accident databases were queried for HEL-related incidents:

- NASA Aviation Safety Reporting System (ASRS) **(13)**
- FAA Accident Incident Data System (AIDS) (14) using two separate queries
- Records from the National Transportation Safety Board (NTSB) (15)

The data provided by these organizations were examined in detail to determine accident causality. Also, the accidents in each of the databases were cross-referenced to obtain the most complete set of data possible and to evaluate the comprehensiveness of the individual databases. In addition to these data sources, other organizations were contacted for information. These organizations included the United States Occupational Safety and Health Administration (OSHA), the Bureau of Labor Statistics (BLS), a European database from the Ministry of Transport of the Federal Republic of Germany, and the National Transportation Board of Canada. The U.S. federal organizations were approached in the hope that they maintained a record of HEL accidents and injuries. Unfortunately, no relevant information could be identified from these, and no response was obtained from the international sources.

5.1 NASA ASRS

The NASA ASRS data system was one of the U.S. databases queried for accidents/incidents involving human external loads. This data system is maintained by a NASA contractor, and all information contained within the system is submitted voluntarily. As such, it is subject to self-reporting biases, and none of the incidents have been corroborated by the FAA or the NTSB. In addition, the data are provided such that the anonymity of the reporter is maintained. However, the attractive feature of this reporting system is that in most instances, the events are described in a narrative provided by the reporter of the event. This narrative typically provides more detail as to the events surrounding the accident, but the narratives are also merely expressions of the reporters' opinions. The report provides information regarding the role of the reporter in the event, the location of the accident or incident, flight conditions, anomaly information, the

Table 2. Summary of Federal Aviation Regulations (FARs) Listed According to Location in the Code of Federal Regulations (CFR).

Part	Title	Section	Content
27/29	Airworthiness Standards	865	Requirements for external load attachment
		1525	Applicable operations
91	General Operating and Flight Rules	313	Use civil rotorcraft in certified work operations only
119	Air Carriers and Commercial Operations	25	Rotorcraft operations
133	Rotorcraft External Load Operations	31	Emergency operations rules and requirements
		33	HEL in VFR only
		35	Limits people on aircraft to crew, trainees, and essential; must be briefed
		43	Airworthiness requirements and necessary approvals
		45	Operating limitations: • all devices FAA approved • 2 action emergency release
135	Air Taxi Operators and Commercial Operators		Commuter and on-demand operations

narrative, and a synopsis of the event. No identifying information is provided with regard to names of individuals, companies, or dates of the events. Consequently, the ASRS data could not be cross-referenced with the other databases.

The ASRS data system was queried for accidents/incidents involving helicopter external cargo or loads. Between the years 1988-93,7 events were identified in the search. None of the events involved accidents with human external loads. Two of the events reported were merely situations that the reporters felt required further investigation. The first involved a fully-harnessed photographer standing on the helicopter skid to photograph the pilots. The report stated that the helicopter maintained a hover at only 4 feet for this operation, and no injuries or incidents were reported. The individual reporting this situation requested that 14 CFR 91.107 be modified to include such photography operations. The second event involved moving items to and from the roof of a multi-story apartment building. The area immediately around the external load operation had not been sufficiently cleared of residents. The reporter recommended that spot checks of the area be conducted for residential, as well as commercial operations.

The remaining 5 events reported in the ASRS did involve accidents during external load operations. In 2 cases, the load was suspended using a 100-foot-long line. The pilot was watching the line while the helicopter was descending, but the ground crew failed to alert the pilot of trees in the area. In both events, the helicopter struck the trees and caused minor damage to the load. In 2 other cases, the external load became unstable and began to swing, striking nearby objects. Again, only minor damage was suffered. The last incident reported in the ASRS involved the unintentional release of a bucket from the cargo hook. The hook had been inadvertently tripped before flight and the pilot neglected to verify its status. The bucket was dropped from 200 ft. but did not cause injury or damage to person or property. In summary, these accidents can all be attributed to either poor communication between the ground crew and the pilot or operational errors of the pilot.

5.2 FAA AIDS (Rescue Operations)

Another database query obtained from an internet search detailed non-injury accidents involving helicopters on search and rescue operations. All accidents occurred between 1978 and 1991. The FAA AIDS database was thought to be the source of information provided in this report, since each event listed the FAA Incident Form 8020-5 as its source. However, only 1 of the events could be cross-referenced with the more comprehensive FAA AIDS database search. None of these accidents was referenced by the NTSB database. This report provided information on 6 accidents occurring prior to loading passenger(s). In half of the events reported, the accident was caused by the helicopter rotors striking power lines / wires. The other accidents were attributed to **(1)** the helicopter rotor striking a hillside, (2) engine failure, and (3) striking a road sign with the tail rotor during a road landing. With the exception of the engine failure, all accidents are related to operational errors involving a miscalculation of clearance. There were no incidents listed in this report involving HEL.

The remaining 2 database sources comprise information from a multitude of rotorcraft accidents. One of the databases is maintained by the FAA and details accidents for rotorcraft flying under the FAA's jurisdiction. The second database is maintained by the NTSB and focuses on "major" rotorcraft accidents.

5.3 FAA AIDS

One of the most extensive databases reviewed was the FAAs Accident / Incident Data System. The FAA AIDS report was generated using a general request for all accidents / incidents involving helicopter aircraft. The data provided by the FAA AIDS database included several fields of information. Descriptive information was provided, including the date of the event; the aircraft make, model, and type; the city, state, and airport at which the event occurred; and the operator's name. Details specific to the accident were also included, such as the purpose or nature of the flight, phase of flight, accident / incident type, cause, supporting and contributing factors, flying and light conditions, extent of damage, and particular remarks about the accident / incident. The database also gave a count of fatalities and injuries that occurred as a result of the accident.

The FAA AIDS database was queried for rotorcraft accidents that occurred during the period from 1973 through 1995. There were 473 external load operations in which helicopters were involved in either an accident or an incident. Each report was reviewed to determine if external loads were the primary hazard in the event, and particularly, if human external loads were involved. Operations performed at the time of the accident included logging; stringing rope, power lines, and cable; other power line operations; and aerial spraying. Of the total 473 accidents listed in FAA AIDS, 282 (60%) occurred during an external load operation, but only 86 (18%) of the accidents were caused by complications with the external load. Ninety-eight percent of the directly-related external load accidents (84 out of 86 events) involved operations utilizing a sling line or sling load, while the remaining 2% (2 out of 86) involved human external loads, with HEL being the primary hazard.

5.4 NTSB

The National Transportation Safety Board (NTSB) has the authority to investigate all major transportation accidents, including highway, marine, pipeline, railroad, and aviation. The NTSB maintains a database of all accidents investigated. This database details the accident date, location, aircraft type, operation type, operator, number and severity of injuries, and narrative of the accident. In addition, the database includes a description of the sequence of events leading up to the accident.

The NTSB database was queried for accidents involving rotorcraft aircraft occurring between 1988 and 1995.[2] The 244 identified accidents were all categorized according to which CFR the aircraft was operating under, either Part 91 (General Operating and Flight Rules), Part 133 (Rotorcraft External-Load Operations), Part 135 (Air Taxi Operators and Commercial Operators), Part 137 (Agriculture Aircraft Operations), or Public Use. Various occupational applications were noted, including logging, power line operations, equipment transfer to and from rooftops, pouring concrete / water from buckets, off-shore transport of equipment and persons, and aerial spraying. The accident narratives were reviewed to determine which accidents were associated with external loads in general, and human external loads in particu-

[2] Unlike the FAA AIDS database that starts in 1973 the NTSB database only dates back to 1988.

lar. Review of the accident narratives revealed 47% (115 of 244) of the accidents occurred during external load operations, while 9% (23 of 244) were a direct result of external load operations. The use of a sling line to transport the external load was determined to be a significant factor in 18% (21 of 115) of the external load accidents. Although 4 accidents involved human external loads, only 2% (2 of 115) were directly attributable to the HEL operation.

5.5 Comprehensive Summary

To produce a comprehensive analysis of all rotorcraft accidents, the FAA AIDS and NTSB databases were combined to provide 616 accident/incident descriptions. The comprehensive database was developed, and all accidents were cross-referenced with the other database. Several accidents were common to both databases (101 of 616, or 16%). However, many were recorded in only 1 of the 2 systems. Table 3 presents a brief summary of the number of accidents found to be unique to each database and those that were common to both. Each report was categorized according to the specific events that caused or significantly contributed to the accident/incident. The categorizations of accidents listed in both databases were verified for consistency.

The comprehensive database contained 616 accidents classified into 1 of 20 categories. Potential categories were identified for each accident, based on interpretation of the accident narrative. The author identified a single causal factor that led to each accident and categorized it accordingly. The only exception to this rule was for accidents involving HEL. Any accident that involved HEL was categorized as HEL. However, if the cause of the accident was identified to be a factor other than the HEL, the accident was also listed in the other category. For example, a helicopter pilot running external loads misjudged available fuel quantity, resulting in the crash of the helicopter. This accident was attributed to fuel exhaustion. If the operation had involved human external loads, then the accident would also have been listed under the HEL category. Alternatively, if the resulting accident was the fault of the user during HEL operations, the operation was categorized only as HEL.

Accidents listed in both source databases were examined for consistency in their categorization. Frequently, I of the databases provided critical information about the accident that was unavailable in the other database. The most detailed narrative provided the basis for accident categorization. Tables 4, 5, and 6 (see Appendix) summarize the categorization of the databases (FAA AIDS, NTSB, and comprehensive, respectively) by presenting the dates of the accidents/incidents grouped under the appropriate causal headings.

Table 3. Summary of Accident Listings.

	Number
Unique to FAA AIDS	372
Unique to NTSB	143
Common to both databases	101
Total accident/incident reports	616

5.5.1 Summary of All External Load Accidents Grouped by Cause

A histogram detailing the number of external load rotorcraft accidents/incidents by cause is presented in Figure 11. Figure 12 presents the categorization as a percentage of total accidents/incidents. As shown in both figures, mechanical failure was involved in the largest number of accidents. One hundred fifty-four (25%) helicopter accidents resulted from some form of mechanical failure; mechanical failure implied failure of the airframe, a component, or system due to material fatigue. Loss of engine power was the second most common cause, contributing to 90 events, or 15% of all rotorcraft accidents. Engine power was lost either totally or partially and was typically due to specific mechanical failures and malfunctions of the engine.

A similar number of accidents was associated with improper use of the sling line/load. Eighty-five accidents (14%) occurred from tangled sling lines, insufficient load clearance, excessive load weight, etc. Obviously, these accidents occurred during external load operations. Seventy-four accidents (12%) resulted from a lack of sufficient clearance for the rotors or the skid. In these situations, it is felt that the pilot may have been focusing on external factors (such as external loads) and neglected to assure sufficient clearance for the rotorcraft. The remaining 214 events were distributed among 8 categories, including (in descending order of frequency) fuel exhaustion or contamination, miscellaneous factors (all accidents that did not fall within the defined categories), loss of

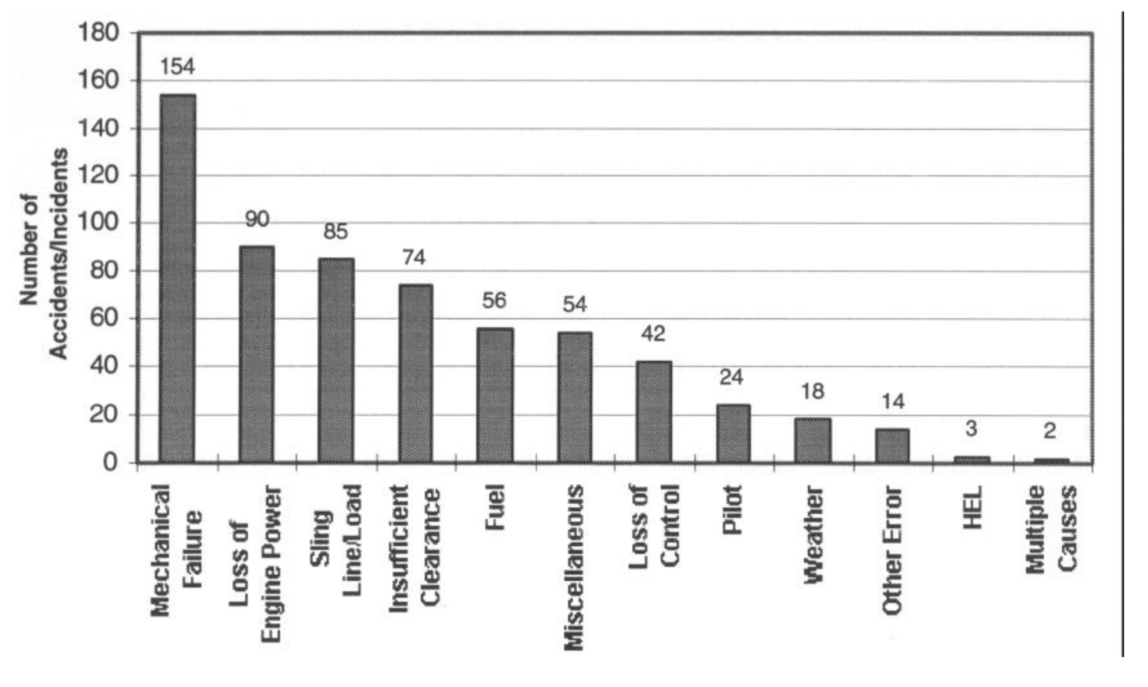

Figure 11. Number of Rotorcraft Accidents/Incidents by Cause (N=616).

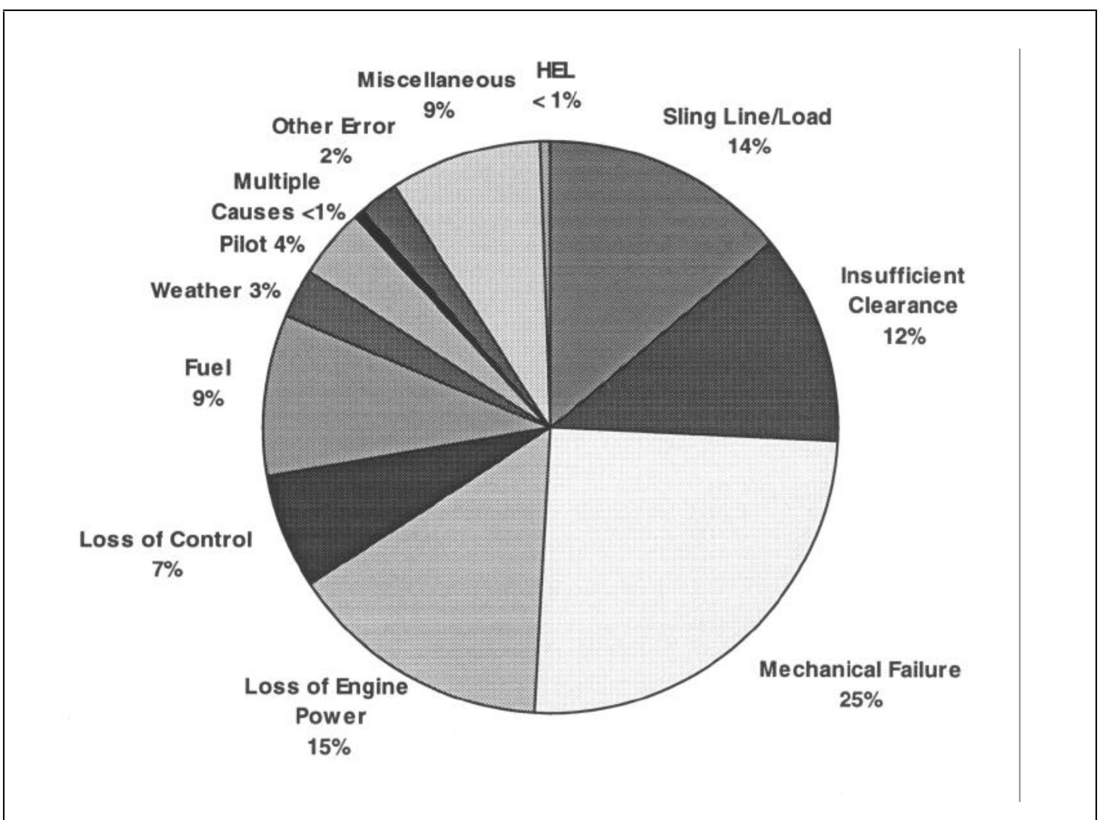

Figure 12. Categorization of Rotorcraft Accidents/Incidents by Cause (N=616).

control, pilot incapacitation or error, weather conditions, other human errors, HEL, and multiple/sequential factors.

5.5.2 Summary of Accidents That Occurred During EL Operation

A similar data presentation was made for accidents/incidents that occurred during external load operations. In 49% of all recorded helicopter accidents/incidents (301 out of 616), the helicopter was engaged in external load operations at the time of the accident. Unfortunately, it was often difficult to confirm which events were associated with external loads. Some accident descriptions indicated that the accident occurred during external load operations. Others were directly attributable to the external load, particularly those involving difficulties with the sling line or sling load. Additionally, the NTSB database included the CFR regulation number under which the rotorcraft activity was operating. However, it is felt that the identified external load operations represent a conservative estimate of the true proportion of external loads.

Figures 13 and 14 display the categorized data for the number and frequency, respectively, of accidents/incidents occurring during external load operations. The charts show that the predominant cause of external load accidents (85 accidents or 28%) was problems with the sling line/load. Specifically, 28 accidents were attributed to failure to maintain sufficient clearance for the sling line or load. The typical scenario in these accidents was that the load, cargo hook, or cargo basket was dragged along the ground and became snagged on an environmental obstruction. In most cases, these were initiating events that led to the accident's direct causes, including the line rebounding into the rotor, the load falling and hitting a member of the ground crew, failed load release, or losing control of the helicopter. Twenty-four accidents involved the sling line becoming tangled in the tail or main rotor. Often, these accidents were due to turbulent winds, shifting loads, unweighted lines, inappropriate line tension, incorrect line length, failed emergency release, or other inappropriate operations. These accidents were the most critical, as evidenced by the highest frequency and severity of injuries. In 16 events, the weight of the load exceeded the maximum rated capacity of the helicopter. The remaining 17 events involving the sling line or load were distributed among excessive load swing, broken sling line, and sling line caught on the skid.

The second most common condition contributing to accidents/incidents was mechanical failure. Sixty-nine events (23%) were attributed to some form of mechanical failure of the airframe, components, or system, that occurred either during or immediately after an external load operation. This number represents almost half (45%) of all mechanical rotorcraft failures. It was anticipated that, although the external load was not the direct cause of the accident, the continual excess loading of the helicopter under external load operations would be an important factor leading to an increased occurrence of mechanical failure. This was not realized in the data as the proportion of mechanical failures during external load operations (23%) was actually less than the overall rate of mechanical failures (25%).

Loss of engine power was the third leading cause of external load accidents/incidents at a rate of 48 or 16%. Primarily, the events attributed to loss of engine power had undetermined causes, but in some instances, the loss of engine power was attributed to mechanical failures within the engine components or fuel contamination. These accidents/incidents were categorized accordingly.

Fuel exhaustion and contamination were collectively involved in 26, or 9% of the external load accidents. Eighteen events were fuel exhaustion related, and 8 were related to fuel contamination. There were 2 predominant factors that appeared when reviewing the accident narratives. Either the fuel gauge malfunctioned or the pilots tended to underestimate the needed fuel quantity when working with external loads. Insufficient clearance for the rotors or skids resulted in a total of 18 events (6%), 17 insufficient rotor clearance and 1 insufficient skid clearance. Sixteen external load events were linked to loss of control of the rotorcraft with contributing factors of weather or inappropriate pilot response. There were 14 accidents that did not qualify to be categorized under any one of the groupings. These accidents were all grouped together as miscellaneous events.

Each of the remaining categorizations included 3% or fewer of the external load accidents/incidents. Pilot error was a causal factor in 9 accidents, and pilot incapacitation was a factor in one accident. Weather played a significant role in 7 accidents. Six accidents were attributed to errors committed by personnel other than the pilot. An interaction of multiple causes was identified as the primary factor in 1 accident.

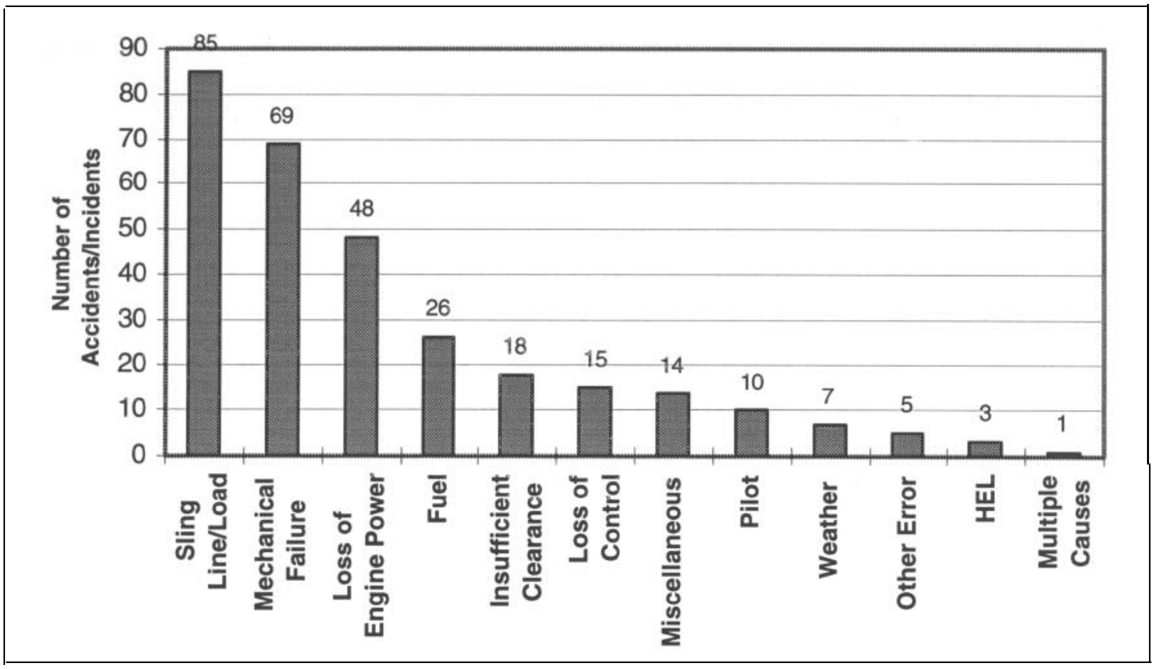

Figure 13. Accidents/Incidents During External Load Operations by Cause (N = 301).

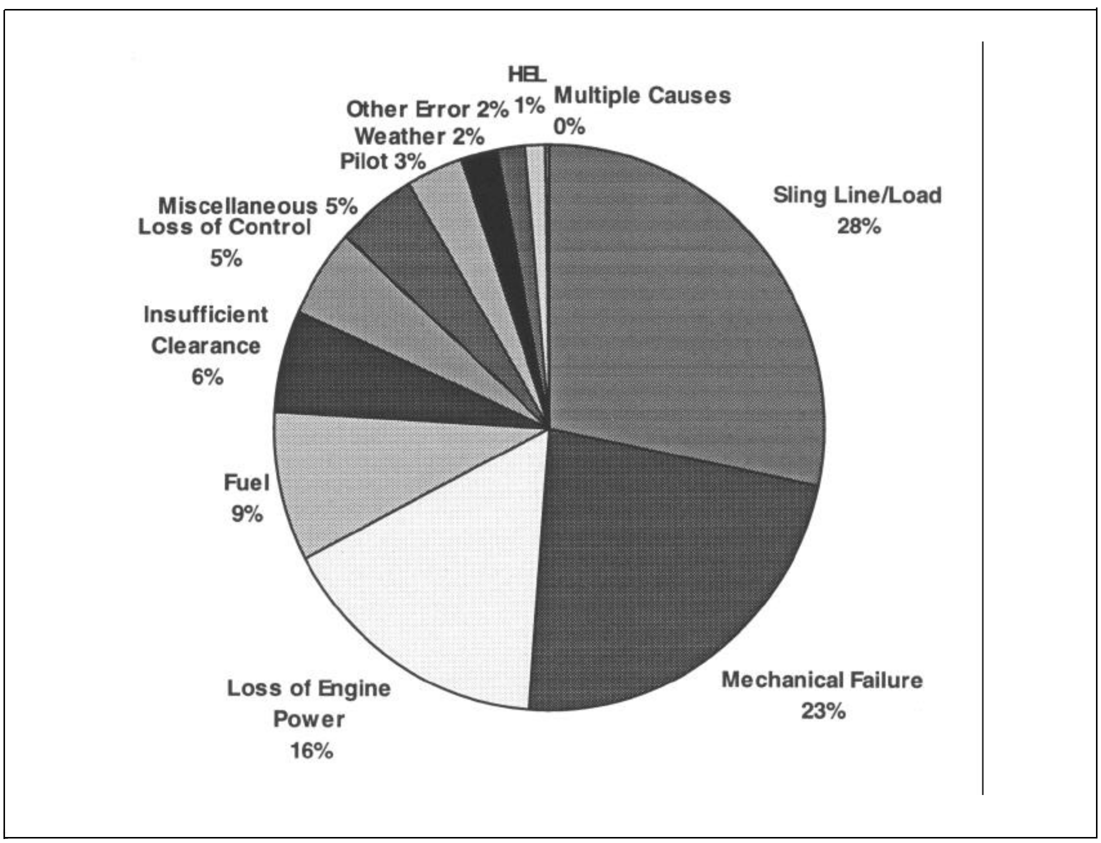

Figure 14. Categorization of Rotorcraft Accidents/Incidents During External Load Operations by Cause (N=301).

5.5.3 Summary of HEL Accidents

The use of human external loads was identified as the most significant contributing factor in only 3 accidents, although 9 total events involved HEL operations. A summary of these HEL accidents/incidents is presented in Table 7. Of the 3 HEL-related accidents, only 2 occurred during authorized work assignments. Each of the 3 HEL-related accidents resulted in the fatality of the user. The first of the authorized operations involved a barehanded live-line operation on an energized power line. As the line worker was being lowered to the work area, he raised his arm into the power line and was electrocuted. The other accident involved the retrieval of a crewmember from a ditched helicopter, floating in the ocean. The worker had been attaching marker buoys to the downed craft. As the crewmember was being raised from the craft with a nylon strap attached to a seat belt anchor point in the helicopter, he released hold of the strap and fell into the water. The report stated that the worker drowned, but the external load sling harness was cited as being inadequate. The third HEL accident identified in the data involved an unauthorized, non-work activity. An individual was performing trapeze stunts when he lost his grip on a rope sling suspended from the helicopter and fell to the ground.

Although HEL operations were involved in 6 other recorded events, they were not causal factors with respect to the accident. Each accident/incident was attributed to a non-HEL primary cause. In addition, not all of the accidents described here resulted in injuries or fatalities. The first identified accident occurred in 1975. A worker was photographing the hoisting operations when the cable separated; the worker fell and was injured. The primary cause of this accident was the broken cable. In a second accident, occurring in 1983, the pilot lost control of the helicopter while transporting 2 persons on the sling line. Both individuals were injured in the accident. Loss of control was recorded as the primary cause. Human

Table 7. Summary of Accidents/Incidents Occurring During HEL Operations.

Date	Source	Direct Cause	Result	Description
4/8/75	FAA	Cable Broke	Injury	Photo of hoisting operation. Cable separated. Photographer fell.
2/3/83	FAA	Loss of Control	2 Injuries	Lost control of helicopter while 2 crew on sling line/load.
1/12/84	FAA	HEL	Fatality	Trapeze performer lost grip on rope sling and fell.
5/10/84	FAA	Other Human Error	None	Two ground attendants fell when long line was released. Pilot was unaware of their presence.
11/28/84	FAA	Pilot Error	Fatality & Injury	Ground crew member fell from strut. Pilot misunderstood instructions.
5/23/90	FAA NTSB	Fuel Contamination	2 Injuries	Long line operations, load of equipment, passengers on load. Loss of engine power due to fuel contamination.
7/6/90	NTSB	HEL	Fatality	Barehanded live line operations. Worker raised his arm, compromised the air gap. Flashover and electrocution. Procedures/directives not followed.
3/7/91	FAA NTSB	HEL	Fatality	Crew attaching marker buoys to floating helicopter. As raised, released hold of strap and fell.
12/2/92	FAA NTSB	Insufficient Clearance - Rotor	2 Fatalities	Placing marker balls on high tension wires. Main rotor struck upper guide wire. Pilot misjudged the distance.

error was the cause of the third accident. In 1984, 2 ground attendants fell when the long line on which they were riding was accidentally released. It was stated in the record that the pilot was unaware of their presence. Since it was impossible to determine if the pilot or ground crew was negligent in their attention, this accident was attributed to "other human error". Fortunately, no injuries or fatalities were suffered in this accident.

Pilot error was the clear cause of the next 1984 HEL-related accident. During the retrieval of ground crew from a stalled boat, a worker fell from the strut. One person was killed and another injured, although the specific individuals affected were not clarified in the report. This accident was attributed to the pilot's misunderstanding of the instructions. In 1990, fuel contamination contributed to a loss of engine power during long line operations. Two passengers were seated on the load of equipment and fell when the rotorcraft lost power, although the report recorded 3 individuals as receiving injuries. Again, the HEL was unauthorized. However, this accident was recorded as fuel contamination. The last accident with indirect HEL involvement occurred in 1992. During a procedure to place marker balls on high tension wires, the main rotor blade struck the wires and caused the helicopter to crash, resulting in two fatalities. Insufficient clearance for the rotor blades was the primary cause of this accident.

Three primary issues seem to appear in the HEL accident data: malfunction, communication, and error. Although not all HEL accidents were associated with one of these causes, there were multiple instances of each association. In 3 accidents (1975, 1983, and 1990), various malfunctions were the primary cause of the accident. Two accidents (both in 1984) can be related to problems with communication between the pilot and the ground crew. Either accident might have been avoided had there been better communication. Human error (of the crew and the pilot) was a significant factor in 2 accidents (1990 and 1992). Additionally, the 1990 accident could also be linked to poor communication in the form of training regarding the procedures and directives for power line work. Seven of the 9 HEL-related accidents can be attributed to 1 of these 3 causes. Of the remaining 2 accidents, 1 involved a trapeze performer engaged in au unauthorized activity, and is, therefore, not a focus of this discussion. The last accident involving the placement of marker buoys on a floating helicopter provides perhaps the most insight into the critical issues associated with HEL's: the HEL sling harness. As a result of releasing his grasp on the sling line, the worker fell. Although very little evidence was found to suggest that a serious problem exists with the device used for securing human external loads, this final accident directs attention towards possible needed improvements for the sling harness.

6. RECOMMENDATIONS FOR HEL DEVICE SAFETY REGULATIONS

The overall objective of this report was to examine HEL accidents/incidents and determine where there may be a need for imposing new regulations. The review of the data did not demonstrate that a serious safety issue exists with HEL operations; across 24 years of data (1973 - 1996), only 9 accidents were documented involving HELs. More significantly, only 2 of those 9 accidents were directly caused by authorized HEL operations. In relation to the overall frequency of rotorcraft accidents/ incidents, it is felt that HEL operations are a minor issue, compared to mechanical and structural properties of rotorcraft. However, there are still important issues that can be addressed to improve the safety and comfort of the individual acting as the human external load.

A brief summary of the issues most relevant to HEL operations is presented in Table 8. The table categorizes HEL issues into safety, comfort, communication, and regulations. These issues were identified from the data analysis, as well as from input obtained from HEL operators involved primarily in rescue operations.

The first category, safety, is critical in spite of the minimal accident history. One of the first recommendations to improve the safety of HEL operations is that a passive HEL device be used. A passive device retains the user without the user's assistance. The need for this recommendation is most clearly demonstrated by the HEL accident where the worker fell after releasing his hold of the retrieval strap. Had the device been designed for passive user involvement (and been properly donned), the release of the strap would have been inconsequential. In addition, a passive device allows the worker to have free use of the hands to perform any necessary work tasks.

The next 2 recommendations relate to posture and security. The HEL device must maintain the worker in an upright posture. In addition, the device must fully secure the individual. Although maintaining upright posture may seem unnecessary, given a fully secure device, the upright posture helps the worker remain oriented with respect to the ground and allows the work task to be more easily executed. Even if the

Table 8. Considerations for FAR Modification.

Safety	
	Passive Device
	Maintains Upright Posture
	Individual Fully Secured
	Locking, Easily Released Attachments to Tether
	Safety Orange Vest
	Warning/Instruction Labels on Equipment
Comfort	
	Ease of Donning
	Ease of Walking
	Minimize Localized Stress
Communication	
	"Spotter" to Visually Monitor HEL
	Continual Training on Basic and Emergency Operations
Regulations	
	Add Information Relevant to HEL
	Minimum Competency Standards for HEL Crew Members
	Definition of FAA Approved Equipment

device adequately maintains the worker's posture, there are exceptional situations where the HEL is subjected to excessive turbulence and may be tossed, or even swung, around. In these instances, it is critical that the device fully secure the individual, regardless of body orientation.

The remaining recommendations are just as critical to the safety of the HEL operation. All HEL devices should have the ability to be quickly released from the tether cable. Typically, the HEL device is attached to the tether with a carabiner. Only locking carabiners should be used, such that inadvertent release does not occur during the HEL operation. However, the locking mechanism should be simple enough to allow for fairly rapid release once the HEL operation is complete. Another recommendation regards the visibility of the HEL operator. All individuals working externally suspended should wear an orange safety vest. If the HEL device is a chest or full-body harness, then the vest should be incorporated into the harness. An orange safety vest would greatly enhance the visibility of the operator to anyone monitoring the operation. The final safety recommendation is for the incorporation of warning and instruction labels on the HEL device. Harnesses should have appropriately designed labels to fit on the straps or vests, and baskets should be labeled with warnings and instructions. Although the use of warnings in no way ensures compliance, they should be provided for users who are seeking additional information about the device and to stimulate awareness of the hazardous nature of the operation.

Although worker safety is the primary concern during HEL operations, worker comfort is an important concern as well. Typically, if products are designed to be comfortable and unobtrusive, users will be more receptive to the correct and proper use of the product. It is felt that this same phenomenon applies to HEL devices. Comfort, ease of donning the device, ease of walking, and minimization of local stresses on the body are all important considerations. If the device does not interfere with normal operation, then the user is more likely to use the device correctly and safely. For long-term applications (i.e., long-distance transport or long-duration work), the minimization of localized stresses is important. For example, in harness design, there is wide variability among the manufacturers in the webbing design. The better designs utilize larger width webbing covered with additional padding. Perhaps an even better design is the harness that incorporates a cloth seat for body support. Not only will the user be more receptive to using the harness if it is comfortable, but the minimization of localized stresses on the body will reduce any short-term (i.e., numbness, pain) or long-term (i.e., permanent loss of circulation) effects of use.

Another issue that warrants consideration is HEL crew communication. First, it is suggested that, during all HEL operations, an additional crew member be designated as a "spotter." This crew member should have no other duties than to visually monitor the HEL operation. For localized HEL operations, this individual could be located on the ground but should have continual, uninterrupted communication with the pilot. For HEL operations over extended areas, the spotter should be aboard the helicopter and should have some method of visually monitoring the HEL. The addition of a spotter might have helped prevent the 1984 accident caused by the pilot's lack of awareness of the HEL. Another critical factor related to communication is the training of the HEL crew. All HEL crew members should be initially trained and continually updated on basic and emergency HEL procedures. One HEL accident in particular (1990 - worker compromised air gap and was electrocuted) might have been prevented with improved crew training. In addition, continual training with regard to emergency procedures is critical for HEL safety. One accident was recounted on video by an HEL worker who described himself as swinging violently towards trees. The HEL pilot over-anticipated the contact of the worker with the tree and released him seconds too early, before the worker could grab the tree. As a result, the worker fell and suffered serious injuries. The worker commented that this was a "rookie" pilot who perhaps did not fully understand emergency procedures. Again, this scenario might have been prevented with improved HEL training.

These final recommendations regarding HEL operations may be of relevance when new regulations are developed. HEL needs to be addressed specifically in the FARs. The only mention of HEL found in the regulations was in reference to VFR flight. Upon talking with several HEL operators (rescue organizations), the need for clarifying the regulations became apparent, particularly, the issues of competency standards and FAA-"approved" equipment. The current regulations do not address minimal competency standards for HEL crew members. Currently, there is little standardization of operations among companies and among rescue organizations performing HEL operations. In addition, the standards discussing training for rescue operations are vague, and according to one interviewee, are open for alternate interpretation. It is recommended that, as part of this effort, attention also be directed towards the introduction of competency standards and training requirements for HEL operations. The definition of FAA-"approved" equipment is one that has also troubled users. For example, the regulations refer to an "FAA approved attachment point", but do not describe how to accomplish and obtain that approval. This discussion should be clarified and expanded to incorporate other necessary equipment (i.e., ropes, carabiners, harnesses) requiring FAA approval.

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APPENDIX A

Table 4. Categorization of FAA Accident/Incident Database.

SLING LINE/LOAD: tangled in rotor:	SLING LINE/LOAD: insufficient clear:	SLING LINE/LOAD: load swing:	SLING LINE/LOAD: load > max:	SLING LINE/LOAD: caught on skid:	SLING LINE/LOAD: cable broke:
5/3/73	10/19/74	2/25/74	7/11/75	11/29/74	**4/8/75**
6/9/73	4/3/75	2/17/80	9/5/75	2/15/80	2/28/79
7/20/73	1/6/77	11/29/84	3/9/76	7/17/80	7/10/79
7/24/73	5/25/77	5/17/89	3/11/77	10/20/83	11/10/80
10/2/73	6/13/78	3/26/90	3/21/80	12/13/83	11/13/84
8/13/75	10/8/79		7/20/84	7/10/84	6/25/85
6/17/76	11/7/79		1/3/85		
1/31/77	1/16/81		3/7/86		
5/24/77	6/26/81		9/11/90		
5/30/77	5/20/82		5/21/91		
12/7/77	4/1/83		8/31/91		
2/24/78	7/8/83		2/19/93		
4/9/80	7/26/83		5/2/93		
7/12/80	6/2/84		5/12/93		
9/26/80	11/13/86		6/19/73		
12/4/81	7/13/88				
4/23/82	11/15/89				
7/20/82	11/17/89				
5/8/85	11/28/89				
5/13/87	5/21/90				
4/12/88	8/30/90				
2/2/89	10/21/90				
11/26/90	11/8/90				
2/23/92	11/10/92				
	2/3/94				
	2/28/94				
	11/19/94				
	3/18/96				

INSUF CLEARANCE: rotor:	INSUF CLEARANCE: skid:	MECH FAILURE	LOSS OF ENGINE POWER	LOSS OF CONTROL
11/4/74	9/16/79	6/25/73	9/7/76	7/22/75
10/24/75	5/27/80	11/1/73	9/11/78	2/6/78
7/28/76	6/11/81	12/28/73	1/22/79	10/23/79
11/19/76	6/15/82	3/3/74	3/5/79	2/19/80
12/1/76	3/3/89	3/30/74	8/1/79	7/5/80
5/16/78	4/26/96	4/21/74	8/18/79	8/5/80
7/30/78		7/21/74	9/6/79	1/22/81
9/10/78		12/16/74	9/20/79	4/20/81
4/2/79		3/23/76	2/21/80	4/21/81
6/21/80		4/4/76	3/2/80	7/30/81
6/22/80		5/9/76	3/26/80	8/30/81
7/10/80		12/13/76	7/28/80	2/14/82
12/17/80		3/31/77	7/28/80	6/25/82
1/5/81		6/2/77	8/2/80	**2/3/83**
2/11/81		7/30/77	8/31/80	9/12/83
4/1/81		10/16/77	9/22/80	10/29/84
5/4/81		12/22/77	10/1/80	5/31/86
3/8/82		1/4/78	10/20/80	6/28/86
5/28/82		2/6/78	11/19/80	5/13/88
7/28/82		2/10/78	11/22/80	4/11/89
9/25/84		2/10/78	12/24/80	7/4/93
11/11/84		3/6/78	7/21/81	9/15/93
11/11/84		5/8/78	7/22/81	12/29/93
7/5/88		6/30/78	8/8/81	7/17/94
5/17/89		7/7/78	11/14/81	
5/26/90		8/8/78	12/24/81	
4/9/92		8/14/78	1/22/82	
8/12/92		8/17/78	2/3/82	
12/2/92		9/25/78	3/7/82	
11/26/93		9/28/78	4/6/82	
10/31/94		2/11/79	4/20/82	
4/11/95		4/28/79	6/3/82	
6/1/95		4/29/79	6/11/82	
11/29/95		10/23/79	6/26/82	
		10/29/79	7/28/82	
		11/29/79	8/9/82	
		1/17/80	9/5/82	
		3/17/80	9/6/82	
		3/21/80	9/15/82	
		5/1/80	8/5/83	
		6/11/80	9/13/83	
		6/15/80	9/18/83	
		9/2/80	9/25/83	
		10/12/80	3/12/84	
		12/15/80	12/2/84	
		12/19/80	12/5/84	
		2/12/81	4/15/85	
		3/9/81	6/11/85	
		5/6/81	8/8/85	
		6/2/81	10/16/85	
		6/10/81	10/19/85	
		8/18/81	3/10/87	
		10/1/81	4/3/87	
		1/27/82	12/11/87	
		2/22/82	7/5/88	
		3/14/82	7/10/88	
		5/15/82	1/3/89	
		8/11/82	10/22/89	
		8/27/82	5/10/90	
		10/14/82	5/24/90	
		1/12/83	7/16/90	
		6/6/83	8/7/90	
		7/14/83	9/9/90	
		8/20/83	5/22/91	
		10/20/83	4/13/92	
		4/27/84	8/25/92	
		6/12/84	12/11/92	

FUEL: exhaustion:	FUEL: contamination:	WEATHER	PILOT: incapacitation:	PILOT: error:	MULT CAUSES	OTHER HUMAN ERROR	MISC	HEL
6/25/76	4/27/79	5/7/74	4/28/90	10/19/73		7/11/74	8/4/74	**4/8/75**
6/3/77	5/5/80	7/5/74		8/10/76		5/24/77	7/2/75	**2/3/83**
6/8/78	8/15/80	6/24/79		10/12/76		10/3/78	8/11/75	1/12/84
4/28/79	12/3/81	6/27/79		3/9/80		1/25/80	12/11/75	**5/10/84**
10/31/79	8/12/82	10/22/79		5/4/80		6/15/81	8/24/76	**11/28/84**
2/5/80	11/4/86	4/20/80		11/19/80		8/25/81	8/13/77	**5/23/90**
2/27/80	9/6/89	12/15/81		1/7/81		**5/10/84**	11/7/77	**3/7/91**
5/17/80	**5/23/90**	5/14/82		8/15/81		1/16/86	2/8/78	**12/2/92**
6/7/80	8/7/90	2/25/83		6/16/82		3/3/86	4/12/78	
7/13/80	11/12/93	5/18/86		7/26/83		6/27/91	7/8/78	
7/23/80	12/22/93	4/11/87		**11/28/84**		10/1/93	7/29/78	
9/12/80	10/28/94	6/9/87		10/10/87			9/7/78	
11/21/80	7/1/95	7/19/87		4/17/88			9/29/78	
2/1/82		9/8/87		11/4/88			1/8/79	
5/19/82		5/26/89		8/24/90			1/26/79	
8/31/83				11/27/92			2/3/79	
10/20/83				2/23/94			6/21/79	
6/7/84				6/6/94			8/8/79	
7/28/84							1/9/80	
1/22/85							2/3/80	
2/15/85							4/2/80	
11/13/87							4/3/80	
1/28/88							5/15/80	
7/13/88							5/26/80	
12/12/88							6/16/80	
4/14/89							6/23/80	
3/9/90							7/15/80	
12/8/90							8/15/80	
9/11/91							9/27/80	
7/14/92							8/7/81	
12/7/93							8/15/81	
1/28/94							10/18/81	
4/1/94							11/5/81	
3/3/96							9/15/82	
5/15/96							11/5/85	
							7/29/87	
							9/9/88	
							11/5/89	
							9/4/92	
							11/27/95	

Notes
1. Shaded cells are accidents which were cross-referenced with the NTSB database.
2. Bold-type entries are accidents which are dually listed.
They are indirect HEL and counted under the alternate categorization.
3/7/91 counted as HEL.

Table 4. Categorization of FAA Accident/Incident Database.

SLING LINE/LOAD						INSUF CLEARANCE		MECH	LOSS OF	LOSS OF	FUEL		WEATHER	PILOT		MULT	OTHER	MISC	HEL	
tangled in rotor:	insufficient clear:	load swing:	load > max:	caught on skid:	cable broke:	rotor:	skid:	FAILURE	ENGINE POWER	CONTROL	exhaustion:	contamination:		incapacitation:	error:	CAUSES	HUMAN ERROR			
								7/26/84	9/12/93											
								9/17/84	12/1/93											
								11/16/84	11/9/95											
								12/10/84												
								2/18/85												
								4/1/85												
								6/19/85												
								8/1/85												
								9/14/85												
								10/10/85												
								1/16/86												
								2/21/86												
								10/4/86												
								2/10/87												
								7/12/88												
								8/3/88												
								8/4/88												
								9/16/88												
								10/25/88												
								11/4/88												
								2/8/89												
								4/17/89												
								6/14/89												
								7/20/89												
								9/15/89												
								10/27/89												
								11/29/89												
								11/29/89												
								12/20/89												
								4/20/90												
								5/21/90												
								6/24/90												
								2/12/91												
								3/7/91												
								7/22/91												
								1/1/92												
								3/6/92												
								7/28/92												
								9/23/93												
								10/18/93												
								11/9/93												
								11/12/93												
								2/23/94												
								7/19/94												
								8/31/94												
								11/21/94												
								2/13/95												
								4/22/95												
								6/17/95												
								6/19/95												
								8/26/95												
								9/18/95												
								12/20/95												
								4/25/96												
24	28	5	15	6	6	34	6	120	70	24	35	13	15	1	18	0	11	40	2	473

Table 5. Categorization of NTSB Accident/Incident Database.

SLING LINE/LOAD						INSUF CLEARANCE		MECH	LOSS OF	LOSS OF	FUEL		WEATHER	PILOT		MULT	OTHER	MISC	HEL
tangled in rotor:	insufficient clear:	load swing:	load > max:	caught on skid:	cable broke:	rotor:	skid:	FAILURE	ENGINE POWER	CONTROL	exhaustion:	contamination:		incapacitation:	error:	CAUSES	HUMAN ERROR		
4/12/88	7/13/88	5/17/89	5/28/88			7/5/88	7/8/88	2/18/88	7/5/88	5/13/88	1/28/88	9/6/89	1/20/88	4/28/90	3/10/88	4/14/89	1/24/88	9/9/88	5/23/90
11/26/90	11/15/89		5/21/91			8/10/88	3/3/89	4/9/88	7/10/88	8/11/88	5/18/88	5/23/90	4/5/89	4/9/92	5/24/88	9/1/94	6/30/90	7/13/90	7/6/90
2/23/92	11/17/89		8/31/91			5/17/89	9/16/89	7/12/88	8/6/88	4/11/89	6/24/88	8/7/90	2/11/92		8/24/90		6/27/91	10/4/90	3/7/91
	11/28/89		2/19/93			5/25/89	6/23/90	8/4/88	1/3/89	7/8/89	7/13/88	11/12/93			5/1/92		10/1/93	12/9/90	12/2/92
	5/21/90		5/2/93			7/18/89	6/23/90	9/29/88	5/30/89	8/10/89	12/12/88	12/22/93			11/27/92		11/20/94	6/30/91	
	8/30/90		5/12/93			9/3/89	7/18/90	11/4/88	8/6/89	12/27/89	4/14/89	2/21/94			2/23/94			2/10/92	
	11/8/90					9/8/89	5/29/91	11/4/88	10/22/89	2/10/90	3/9/90	4/18/94			6/6/94			8/3/92	
	11/10/92					5/3/90	8/28/91	2/8/89	11/9/89	8/13/90	12/8/90	10/28/94			8/30/94			8/27/92	
	2/3/94					7/21/90	11/20/91	4/17/89	5/10/90	8/13/90	6/26/91							9/4/92	
	2/28/94					4/5/91	4/28/92	4/26/89	5/24/90	1/19/91	7/14/91							3/10/94	
	11/19/94					7/26/91	8/9/92	5/6/89	6/1/90	3/31/91	9/11/91							5/5/94	
						4/9/92	1/3/93	6/14/89	7/16/90	7/1/91	7/14/92							9/3/94	
						5/29/92	1/12/93	7/24/89	8/7/90	8/8/91	7/24/92							9/22/94	
						6/10/92	2/8/93	8/9/89	9/9/90	11/8/91	12/7/93							12/1/94	
						8/12/92	8/27/93	8/21/89	3/11/91	4/20/92	1/28/94							5/31/95	
						12/2/92	6/9/94	8/27/89	4/20/91	7/4/93	4/1/94							9/18/95	
						1/24/93	7/19/94	9/15/89	5/22/91	9/15/93	10/30/94								
						6/11/93	4/25/95	10/27/89	10/11/91	12/29/93									
						6/17/93	7/20/95	11/29/89	10/14/91	4/1/94									
						11/26/93		11/29/89	4/13/92	6/25/94									
						4/12/94		4/20/90	8/25/92	7/17/94									
						7/9/94		4/21/90	12/7/92	8/2/94									
						10/31/94		5/21/90	12/11/92	2/1/95									
						2/7/95		7/14/90	1/27/93	8/28/95									
						6/1/95		7/27/90	9/12/93										
								8/17/90	12/1/93										
								8/19/90	4/3/94										
								12/3/90	4/9/94										
								12/9/90	4/10/94										
								3/7/91	12/4/94										
								4/3/91	4/23/95										
								4/23/91	5/2/95										
								5/28/91	7/18/95										
								6/20/91											
								7/21/91											
								10/11/91											
								3/6/92											
								6/19/92											
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								9/11/92											
								9/25/92											
								9/30/92											
								11/16/92											
								4/1/93											
								5/8/93											
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								6/14/94											
								7/7/94											
								7/19/94											
								8/31/94											
								2/13/95											
								4/22/95											
								8/26/95											
								9/18/95											
3	11	1	6	0	0	25	19	59	33	24	17	8	3	2	8	2	5	16	2

Notes
1. Shaded cells are accidents which were cross-referenced with FAA database.
2. Bold-type entries are accidents which are dually listed.
   They are indirect HEL and counted under the alternate categorization.
   3/7/91 counted as HEL.

Table 6. Categorization of Comprehensive Accident/Incident Database.

SLING LINE/LOAD: tangled in rotor:	insufficient clear:	load swing:	load > max:	caught on skid:	cable broke:
x 5/3/73	x 10/19/74	x 2/25/74	x 6/19/73	x 11/29/74	x **4/8/75**
x 6/9/73	x 4/3/75	x 2/17/80	x 9/5/75	x 2/15/80	x 2/28/79
x 7/20/73	x 1/6/77	x 11/29/84	x 7/11/75	x 7/17/80	x 7/10/79
x 7/24/73	x 5/25/77	x 5/17/89	x 3/9/76	x 10/20/83	x 11/10/80
x 10/2/73	x 6/13/78	x 3/26/90	x 3/11/77	x 12/13/83	x 11/13/84
x 8/13/75	x 10/8/79		x 3/21/80	x 7/10/84	x 6/25/85
x 6/17/76	x 11/7/79		x 7/20/84		
x 1/31/77	x 1/16/81		x 1/3/85		
x 5/24/77	x 6/26/81		x 3/7/86		
x 5/30/77	x 5/20/82		x 5/28/88		
x 12/7/77	x 4/1/83		x 9/11/90		
x 2/24/78	x 7/8/83		x 5/21/91		
x 4/9/80	x 7/26/83		x 8/31/91		
x 7/12/80	x 6/2/84		x 2/19/93		
x 9/26/80	x 11/13/86		x 5/2/93		
x 12/4/81	x 7/13/88		x 5/12/93		
x 4/23/82	x 11/15/89				
x 7/20/82	x 11/17/89				
x 5/8/85	x 11/28/89				
x 5/13/87	x 5/21/90				
x 4/12/88	x 8/30/90				
x 2/2/89	x 10/21/90				
x 11/26/90	x 11/8/90				
x 2/23/92	x 11/10/92				
	x 2/3/94				
	x 2/28/94				
	x 11/19/94				
	x 3/18/96				

INSUF CLEARANCE: rotor:	skid:	MECH FAILURE	LOSS OF ENGINE POWER
x 11/4/74	9/16/79	x 6/25/73	
10/24/75	5/27/80	11/1/73	9/7/76
x 7/28/76	6/11/81	12/28/73	9/11/78
x 11/19/76	6/15/82	3/3/74	x 1/22/79
x 12/1/76	7/8/88	x 3/30/74	x 3/5/79
	x 3/3/89	4/21/74	x 8/1/79
5/16/78	9/16/89	7/21/74	8/18/79
7/30/78	6/23/90	12/16/74	x 9/6/79
9/10/78	7/18/90	3/23/76	x 9/20/79
4/2/79	5/29/91	x 4/4/76	x 2/21/80
x 6/21/80	8/28/91	5/9/76	3/2/80
6/22/80	11/20/91	12/13/76	3/26/80
7/10/80	4/28/92	x 3/31/77	x 7/28/80
12/17/80	8/9/92	6/2/77	7/28/80
1/5/81	1/3/93	x 7/30/77	8/2/80
2/11/81	1/12/93	10/16/77	8/31/80
4/1/81	2/8/93	x 12/22/77	9/22/80
5/4/81	8/27/93	1/4/78	10/1/80
x 3/8/82	6/9/94	2/6/78	x 10/20/80
5/28/82	7/19/94	x 2/10/78	11/19/80
7/28/82	4/25/95	2/10/78	x 11/22/80
9/25/84	7/20/95	x 3/6/78	12/24/80
11/11/84	4/26/96	5/8/78	x 7/21/81
11/11/84		6/30/78	7/22/81
x 7/5/88		7/7/78	8/8/81
8/10/88		8/8/78	x 11/14/81
x 5/17/89		x 8/14/78	12/24/81
5/25/89		8/17/78	x 1/22/82
7/18/89		x 9/25/78	2/3/82
9/3/89		9/28/78	x 3/7/82
9/8/89		2/11/79	x 4/6/82
5/3/90		4/28/79	4/20/82
x 5/26/90		4/29/79	x 6/3/82
7/21/90		x 10/23/79	x 6/11/82
4/5/91		x 10/29/79	x 6/26/82
x 7/26/91		11/29/79	7/28/82
x 4/9/92		1/17/80	x 8/9/82
5/29/92		3/17/80	9/5/82
6/10/92		x 3/21/80	x 9/6/82
x 8/12/92		x 5/1/80	9/15/82
x **12/2/92**		6/11/80	x 8/5/83
1/24/93		6/15/80	x 9/13/83
6/11/93		9/2/80	x 9/18/83
6/17/93		10/12/80	x 9/25/83
x 11/26/93		x 12/15/80	x 3/12/84
4/12/94		12/19/80	12/2/84
7/9/94		2/12/81	12/5/84
x 10/31/94		x 3/9/81	x 4/15/85
2/7/95		5/6/81	6/11/85
x 4/11/95		6/2/81	8/8/85
x 6/1/95		6/10/81	10/16/85
11/29/95		8/18/81	x 10/19/85
		x 10/1/81	x 3/10/87
		x 1/27/82	x 4/3/87
		x 2/22/82	x 12/11/87
		x 3/14/82	x 7/5/88
		x 5/15/82	x 7/10/88
		x 8/11/82	8/6/88
		8/27/82	x 1/3/89
		x 10/14/82	5/30/89
		x 1/12/83	8/6/89
		x 6/6/83	x 10/22/89
		7/14/83	11/9/89
		x 8/20/83	x 5/10/90
		x 10/20/83	x 5/24/90
		4/27/84	6/1/90
		6/12/84	x 7/16/90
		7/26/84	x 8/7/90
		x 9/17/84	x 9/9/90
		x 11/16/84	9/9/90
		x 12/10/84	3/11/91
		2/18/85	4/20/91
		x 4/1/85	x 5/22/91
		6/19/85	10/11/91
		8/1/85	10/14/91
		x 9/14/85	x 4/13/92
		10/10/85	x 8/25/92

LOSS OF CONTROL	FUEL: exhaustion:	FUEL: contamination:	WEATHER
x 7/22/75	x 6/25/76	4/27/79	5/7/74
x 2/6/78	x 6/3/77	x 5/5/80	x 7/5/74
10/23/79	6/8/78	8/15/80	6/24/79
2/19/80	4/28/79	12/3/81	6/27/79
x 7/5/80	10/31/79	8/12/82	10/22/79
8/5/80	2/5/80	x 11/4/86	4/20/80
1/22/81	x 2/27/80	x 9/6/89	12/15/81
4/20/81	5/17/80	x **5/23/90**	x 5/14/82
x 4/21/81	6/7/80	x 8/7/90	x 2/25/83
7/30/81	7/13/80	x 11/12/93	x 5/18/86
8/30/81	7/23/80	x 12/22/93	x 4/11/87
x 2/14/82	9/12/80	2/21/94	x 6/9/87
6/25/82	11/21/80	4/18/94	7/19/87
2/3/83	2/1/82	x 10/28/94	9/8/87
x 9/12/83	5/19/82	7/1/95	1/20/88
x 10/29/84	x 8/31/83		4/5/89
5/31/86	10/20/83		x 5/26/89
6/28/86	6/7/84		2/11/92
x 5/13/88	7/28/84		
8/11/88	1/22/85		
x 4/11/89	2/15/85		
x 7/8/89	x 11/13/87		
8/10/89	x 1/28/88		
12/27/89	5/18/88		
2/10/90	6/24/88		
x 8/13/90	x 7/13/88		
8/13/90	x 12/12/88		
1/19/91	x 4/14/89		
3/31/91	x 3/9/90		
7/1/91	x 12/8/90		
8/8/91	6/26/91		
11/8/91	7/14/91		
4/20/92	x 9/11/91		
x 7/4/93	x 7/14/92		
x 9/15/93	x 7/24/92		
x 12/29/93	x 12/7/93		
4/1/94	x 1/28/94		
6/25/94	x 4/1/94		
x 7/17/94	x 10/30/94		
8/2/94	3/3/96		
2/1/95	5/15/96		
8/28/95			

PILOT: incapacitation:	PILOT: error:	MULT CAUSES	OTHER HUMAN ERROR	MISC	HEL
x 4/28/90	10/19/73	4/14/89	7/11/74	8/4/74	x **4/8/75**
4/9/92	8/10/76	x 9/1/94	x 5/24/77	x 7/2/75	x **2/3/83**
	x 10/12/76		10/3/78	8/11/75	x 1/12/84
	3/9/80		1/25/80	12/11/75	x **5/10/84**
	5/4/80		6/15/81	x 8/24/76	x **11/28/84**
	x 11/19/80		x 8/25/81	x 8/13/77	x **5/23/90**
	1/7/81		x **5/10/84**	x 11/7/77	x 7/6/90
	8/15/81		1/16/86	2/8/78	xx **3/7/91**
	x 6/16/82		3/3/86	4/12/78	x **12/2/92**
	7/26/83		1/24/88	7/8/78	
	x **11/28/84**		6/30/90	7/29/78	
	10/10/87		x 6/27/91	9/7/78	
	3/10/88		x 10/1/93	9/29/78	
	4/17/88		11/20/94	1/8/79	
	5/24/88			1/26/79	
	x 11/4/88			2/3/79	
	x 8/24/90			6/21/79	
	5/1/92			8/8/79	
	x 11/27/92			1/9/80	
	x 2/23/94			2/3/80	
	x 6/6/94			4/2/80	
	8/30/94			4/3/80	
				x 5/15/80	
				5/26/80	
				6/16/80	
				6/23/80	
				7/15/80	
				8/15/80	
				x 9/27/80	
				x 8/7/81	
				x 8/15/81	
				10/18/81	
				11/5/81	
				9/15/82	
				11/5/85	
				x 7/29/87	
				x 9/9/88	
				x 11/5/89	
				7/13/90	
				10/4/90	
				12/9/90	
				6/30/91	
				2/10/92	
				8/3/92	
				8/27/92	
				x 9/4/92	
				x 3/10/94	
				5/5/94	
				9/3/94	
				9/22/94	
				12/1/94	
				5/31/95	
				9/18/95	
				x 11/27/95	

Notes
1. Shaded cells are accidents which were cross-referenced.
x indicates EL.
xx indicates EL and counted as HEL instead of the other category.
2. Bold-type entries are accidents which are dually listed.
They are indirect HEL and counted under the alternate categorization.
3/7/91 counted as HEL.