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16. Abstract

The interest of manufacturing, governmental, and safety personnel using paint schemes on propeller and rotor blades is based on improving the visual conspicuity of those blades when they are rotating. While propeller and rotor paint schemes may serve to reduce the number of fatalities and injuries due to contact with a rotating blade there is little information available regarding analyses of the circumstances surrounding such accidents.

Brief reports provided by the National Transportacion Safety Board of all "propeller-to-person" accidents from 1965 through 1979 were examined and analyzed in terms of airport lighting conditions, actions of pilots, actions of passengers and ground crew, phase of flight operation, weather conditions, and others. Analyses based on a total of 319 accidents showed a marked drop in the frequency of "propeller-to-person" accidents from 1975 through 1978. Several types of educational efforts directed toward pilots and ground crew, both prior to and during that 4-year period, were examined as possible factors contributing to the accident rate decline. Accident patterns provide a basis for assessing the probable efficacy of various recommendations (including propeller conspicuity) for further reducing "propeller-to-person" accidents.

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AN ANALYSIS OF CIVIL AVIATION PROPELLER-TO-PERSON ACCIDENTS: 1965-1979

Introduction.

The interest of manufacturing, governmental, and safety personnel in using paint schemes on aircraft propellers and helicopter rotor blades is based on improving the visual conspicuity of those blades when they are rotating. Greater conspicuity is generally considered essential to reducing the number of civil aviation accidents which involve fatal or serious injury to persons who are struck by rotating propellers and rotor blades. There are, however, no Federal Aviation Regulations (FAR's) which specify requirements regarding the conspicuity of aircraft propellers, although helicopter tail rotors are required to be marked so that the perceptual disks created by their rotation are "conspicuous under normal daylight ground conditions." Interestingly, virtually all U.S. aircraft do have propeller markings, but most of these are of factory design; others represent the choice of the owner. Although colors (particularly yellow and red) are often used, available data (5,6) suggest that black and white markings yield the best conspicuity ratings from observers.

While propeller and rotor paint schemes of one kind or another may serve to reduce the numbers of fatalities and injuries due to contact with a rotating blade, there is little information available regarding analyses of the circumstances surrounding the accidents which do occur. Thus, the present study was designed to explore the frequency, time of day, weather conditions, pilot and passenger activities, and other features possibly associated with injuries and fatalities due to persons being struck by propeller and rotor blades.

Method.

Computer retrievals of report briefs of all propeller-to-person accidents from 1965 through 1979 were made on special request to the National Transportation Safety Board (NTSB). These briefs each contain standard information regarding aviation accidents (e.g., time of day, statement of cause, nature of injuries, etc.). In addition, detailed review of the accident files for each propeller or rotor accident during the most recent 5-year period (1975 through 1979) was conducted to confirm comprehensive background information. The complete file was also reviewed for 36 accidents from 1965 through 1974 to obtain information which was not clear in t briefs. In 48 other cases, questions were raised from review of the brief

(29 questions about magneto switches, 18 about dusk-darkness conditions, and 1 about whether handcranking was involved), but access to the complete files was not possible because they had been destroyed at the NTSB Records Center (24 of these were between 1965 and 1968). Data were analyzed in terms of time of day, actions of pilots, action of passengers and ground crew, phase of flight operation, weather conditions, and others.

Results.

Tabulations over the 15-year period yielded a total of 319 accidents; 108 involved fatalities, and 211 resulted in serious injuries (see Table 1). All 319 of these accidents involved propeller deaths or injuries to single persons with the exception of 2 accidents; (i) in 1970 a U.S. helicopter delivering food in a foreign country was rushed by a crowd with three injuries resulting (two serious, one minor), and (ii) in 1972 a runaway aircraft (hand-cranked by a pilot without adequate braking safeguards) ran into two spectators, killing both. The 319 accidents thus resulted in 109 deaths, while 219 persons were seriously injured and 1 sustained a minor injury. Table 1 also shows a marked reduction in accidents during 1975 through 1978.

TABLE 1. NUMBER OF PROPELLER-TO-PERSON ACCIDENTS IN GENERAL AVIATION, 1965-1979

Year	Fatal Injury	Serious Injury	Total
1979	7	15	22
1978	5	9	14
1977	5	11	16
1976	5	10	15
1975	4	8	12
1974	12	18	30
1973	8	13	21
1972	12	17	29
1971	12	15	27
1970	7	14	21
1969	5	20	25
1968	10	12	22
1967	4	23	27
1966	8	13	21
1965	4	13	17
TOTALS	108	211	319

Table 2 contains a breakdown of categories of persons injured or killed by contact with propellers or rotors. Fifty percent of the accidents involved passengers and about 20% involved the pilots, followed by ground crew, spectators, and a general category (7.5%) termed "other" (the latter includes such persons as drivers of delivery trucks, postal mail loaders, etc.).

Table 2 also presents a breakdown of the activities of the individuals which were associated with the accidents. More than 25% of the accidents

TABLE 2. NUMBER OF PROPELLER-TO-PERSON ACCIDENTS INVOLVING FATAL AND SERIOUS INJURIES (1965-1979) BY CATEGORY OF VICTIMS AND BY THE ACTIVITIES IN WHICH THEY WERE ENGAGED.

(NOTE: Two accidents involved more than one victim.)

Persons	Fatal Injury	Serious Injury	Total
Pilots	16	45	61
Passengers	57	103	160
Ground crew	15	26	41
Spectators	12	23	35*
Others	9	15	24
TOTALS	109	212	321*

*plus one spectator with minor injury

Activities	Fatal Injury	Serious Injury	Total
Handcranking	13	56	69
Jump Starting	1	5	6
Pilot Check	0	4	4
Assisting Pilot	27	40	67
Loading, Delivering	3	8	11
Walking Spectator	10	14	24
Enplaning	14	19	33
Deplaning	35	54	89
Improper Procedure	0	1	1
Runaway Aircraft	1	1	2
Other	4	9	13
TOTALS	108	211	319

occurred as a result of deplaning, approximately 20% involved handcranking the aircraft, another 20% occurred when persons were otherwise trying to assist the pilot (e.g., by helping to dock a seaplane, removing wheel chocks, etc.), about 10% occurred during enplaning, and the remainder were divided among walking visitors, delivery men and loaders, persons trying to jump start the aircraft engine, pilots checking their aircraft while the engines were running, persons hit by a runway aircraft, and a general category (4%) of "other" (including the three injuries noted above resulting from the crowd rushing a food-bearing helicopter, a pilot trying to close the canopy while the aircraft was moving, etc.). Over half of the handcranking accidents involved pilots, and 22% comprised ground crew, while the remainder were equally divided between passengers and "others."

Other than the 2 instances of a runaway aircraft (resulting from the pilot's handcranking without adequate braking), only 17 other accidents involved an aircraft in a movement pattern (e.g., taking off, in flight,

landing). Thus, the vast majority of the 319 propeller-to-person accidents occurred while the aircraft was stationary. Helicopters were involved in 46 (14%) of the accidents and seaplanes in 21 (7%). About two-thirds of the helicopter accidents involved the tail rotor and half of all rotor accidents were fatal. Moreover, about one-third (N=15) of those helicopter accidents occurred during deplaning and about 20% during enplaning (N=9), all of these during daylight hours. Of the accidents involving seaplanes, (i) 86% of the total occurred during deplaning and "assisting the pilot" activities, (ii) all of the deplaning (N=10) and enplaning (N=2) accidents were in daylight hours, and (iii) almost half (N=10) of the seaplane accidents occurred in the states of Alaska and Washington.

Several factors which might have contributed to these propeller-to-person accidents were examined. Alcohol involvement was reported only 11 times, but 8 of the 11 were fatal; of these 11 accidents, almost half (N=5) occurred during the daytime (between 0730 and 1730). Alcohol involvement may be underestimated since it is relatively unlikely that a pilot would be subjected to a blood or breath test if the passenger was fatally injured. Rain, snow, or fog was present in only 9 accidents and ground that was wet, icy, or snow covered was reported 13 times. Thus, although these factors were infrequently involved, they may well have made the difference in whether or not those particular accidents occurred. Of perhaps greater significance is the fact that at least one-fourth of the accidents occurred during the hours of dusk or darkness (the proportion is probably higher, but the NTSB brief reports do not provide sufficient data to verify "probables"). With respect to the 87 accidents in the dark, more (29) occurred with persons attempting to assist the pilot than for persons deplaning (27), enplaning (13), or for "other" reasons. Overall, these findings indicate that about 40% of accidents involving persons assisting the pilots, 39% of enplaning accidents, and 30% of deplaning accidents occurred at night when ordinary propeller conspicuity (even at a well-lighted airport) would be considerably reduced.

Discussion.

The data show clearly that individuals most at risk for a propeller-to-person accident are passengers who are either deplaning or attempting to assist the pilot. That the accident frequency is high for these groups is perhaps surprising since, in some respects at least, pilots would have reasonable, direct, and timely opportunities to control, caution, or counsel passengers regarding safe procedures in deplaining or in providing assistance with the aircraft. Two features of this finding seem clear: (i) pilots have a major responsibility for actively seeking to prevent propeller-to-person accidents to their passengers, and (ii) the means by which such accidents could be reduced or virtually eliminated require no esoteric equipment and are relatively simple (careful instruction of passengers prior to their deplaning; either not using passengers as assistants or instructing them more carefully regarding hazards; and having engines shut down prior to loading or unloading passengers).

Another feature of significance in the data is the number of accidents which occurred at dusk or in darkness. While there is a significant reduction

in general aviation activity during these hours, over 27% of the propeller-to-person accidents occurred during periods of reduced natural lighting (specified in the accident report). This percentage is probably an underestimation since time-of-day data on the NTSB brief reports (taking into account the month of the year and the location of the accident) suggest the possibility of additional dusk or nighttime accidents which were unverifiable because the complete file for a number of these accidents had already been destroyed. The ratio of accidents which occurred to persons assisting the pilot virtually doubled at night as compared with daytime (33.3% vs. 16.8%); *moreover, passengers were involved in proportionately more accidents* at night than in the daytime--the pilots proportionately less--and the ratio of enplaning accidents was also considerably higher in reduced illumination (15% vs. 9% in daylight). The increased nighttime accident rate for enplaning passengers suggests that propeller markings, which would be visible during the daytime but not in reduced illumination may have been effective signaling devices to passengers approaching the aircraft in daylight. It is also worth noting that the absolute number of nighttime deplaning accidents has remained relatively constant over the years (9 during 1965-69; 10 during 1970-74; 9 during 1975-79) despite reductions in daytime deplaning totals and in the overall number of propeller-to-person accidents.

Major Accidents Categories: Perhaps surprisingly, more than twice as many accidents occurred during the handcranking of an aircraft than occurred during passenger enplaning. Pilots were most often victims of handcranking accidents (56% of such cases) followed in frequency by ground crew members (22%). Of the 69 accidents of this type, the magneto switches were confirmed as "on" in 30 cases, but "off" (and therefore probably defective) in 10 cases, and could not be assessed in the other 29 cases due to the unavailability of the full accident report. Moreover, more than 80% of the handcranking accidents occurred with "nose wheel" (tricycle gear) aircraft as compared with "tail wheel" (conventional gear) configurations. And the proportion of *handcranking accidents involving these closer-to-the-ground propellers* has increased from 68% (1965-69) to 75% (1970-74) to 94% (1975-79).

Among all propeller-to-person accidents involving pilots, most occurred during handcranking (64%), followed in frequency by deplaning (18%) activity. As noted above, passengers were involved most often in deplaning accidents (49%), followed by accidents which occurred while they were attempting to assist the pilot (22%), and while enplaning (20%). Almost all propeller-to-person accidents involving ground crew occurred while they were assisting the pilot (61%) or attempting to handcrank the propeller (37%). The majority of accidents to spectators (63%) occurred while they were walking around aircraft.

Changes in the Accident Rate: The annual tabulations show a marked drop in the number of propeller-to-person accidents during 1975-1978 when they averaged 14 per year. During the two prior 4-year periods (1971 through 1974; 1967 through 1970) they averaged, on an annual basis, approximately 27 and 24 accidents, respectively. However, in 1979, the number rose to 22 accidents, closely approximating those earlier, higher levels.

The factors responsible for the 1975-1978 decrease in accidents are not readily isolated. Careful examination of the categorized data revealed that the decrease was not due to a drop in any specific conditions or activities surrounding the accidents, but to an overall drop in the number of accidents across the various defined categories. (The only notable changes were a drop in the percentage of accidents involving rotor blades and an increase in the percentage of accidents involving seaplanes.) A search of the aviation literature yielded no information that might have influenced general aviation pilots regarding the safety hazards of propellers. However, a number of contacts with FAA personnel involved with standards and accident prevention during that period led to the piecing together of several activities and events that appear to comprise the best assessment of factors which influenced the 4-year decline in the number of propeller-to-person accidents.

In March 1968, the FAA began a 2-year test program to promote safety by educating general aviation pilots on accident prevention through clinics, seminars, and lectures. This Accident Prevention Program (APP) was tested in the Central and Southwest FAA regions until March 1970, when it was judged as successful in reducing aircraft accidents by improving the attitudes and behavior of pilots through increased knowledge and proficiency. Based on this favorable assessment, the APP concept was officially expanded to nationwide status during 1971, but was not in full operation until the latter part of 1972 or, perhaps, early 1973.

The FAA was obviously actively aware of the problem of propeller accidents, initiating a defined effort by the APP in the early 1970's to reduce the number of such accidents. The APP specialists were provided with various types of educational material relating to the hazards of propellers. The most dramatic educational tool was a fortuitously recorded film of an actual handpropping accident that occurred in California in 1967. The pilot involved handpropped his engine with an inexperienced passenger at the controls, without having the wheels chocked or the plane tied down. The film shows the pilot hanging on to the plane as it spins in a circle on one wheel until the centrifugal force throws him on the ground where he is struck by the plane. As the pilot lies on the ground, seriously injured and covered with blood, the runaway plane is finally stopped after running into several parked aircraft. The film is a very powerful demonstration of one hazard of handpropping, although the accident depicted is obviously not the most familiar sequence of events for propeller-to-person injuries. This film was available in 1969 but did not get wide national exposure until after the APP program went nationwide in 1971. It was then shown frequently by the APP specialists in the safety clinics (one estimate is that the film was being shown at least two times a week by 85 APP specialists across the country). The handprop film was mentioned by almost every FAA person we contacted, and was especially emphasized by former APP specialists who had been in the field during that time, as a definite factor contributing to the decline in the propeller accidents. This contribution seems likely if one allows for a time lag of about 18 months before a new program begins to show an effect.

In addition to the film, several posters and handouts relating to the dangers of propellers were distributed during the safety clinics from 1971-1974. One of the handouts released in 1974 was a special bulletin (Beware of Propeller Accidents) that listed several hazardous practices for pilots to avoid in order to prevent propeller accidents. Accident prevention specialists also discussed actual propeller accidents during the clinics, emphasizing the measures that could have been taken to prevent the accidents.

Besides emphasizing the importance of reducing propeller accidents through the APP, the FAA issued an advisory circular (2) on propeller-to-person accidents "Hazards of Rotating Propeller" in June of 1975; revised versions of the circular were published in 1976 (3) and 1979 (4). The original circular discussed the frequency of propeller accidents, emphasizing the fact that all such accidents could be prevented with proper education and discipline. The circular warned of the power of the rotating propeller and the likelihood that a propeller accident would result in serious or fatal injury. Special warnings and preventive measures were listed for nonflight crew personnel, aircraft service personnel, flight personnel and flight instructors which, if followed, would probably be effective in reducing propeller-to-person accidents. The procedure referred to training of non-flight crew, the provision of safety barriers and markings on ramps and landing areas, the development of specific safety habits by aircraft service personnel, education of student pilots by flight instructors, and checklist tests and close supervision of passengers and others by pilots.

The 1976 version of the circular (3) was titled "Hazards of Rotating Propeller and Helicopter Rotor Blades" and, as the title implies, added specific suggestions regarding rotor blades (e.g., "tail rotor danger areas should be clearly marked on ramp areas."), proper use of wheel chocks, maintenance of propeller markings to insure conspicuity, and tests for faulty ignition switches. The 1979 version (4) presented, for the first time, a nine-item breakdown of events leading to propeller-to-person accidents.

Copies of the 1975 circular were distributed at safety clinics and meetings across the country. Although the number of propeller accidents had already shown evidence of decline during the first half of 1975, the release of the 1975 circular and its subsequent revisions in conjunction with the aforementioned films, handouts, and lectures probably worked together to effect a reduced propeller-to-person accident rate through 1978.

While it seems unlikely that the maintenance over a 4-year period (1975-1978) of a substantial decrease in the absolute number of propeller-to-person accidents would be due to chance factors, the 1979 data show a sharp increase in such accidents. It is possible that this 1-year increase is an artifactual variation; if it is not, it suggests that the various factors that were operating to keep the number of accidents at a lower level have either declined in their effectiveness or are no longer being used. If our assessment is correct that concerted educational attention to the dangers of propeller accidents has been effective in reducing propeller-to-person accidents, then these educational methods should again be vigorously pursued.

Methods of Further Reducing Propeller-To-Person Accidents: The findings of this study suggest that propeller conspicuity probably reduces accidents (based on the higher nighttime rate of enplaning accidents). There are data available (4,5) which indicate the type of markings that most readily catch the eye and those data should be used by manufacturers to mark propellers. An FAR specifying such requirements would probably be needed to stimulate the use of the most appropriate conspicuity scheme.

The Flight Instructor's Handbook (1) could explicitly present the need for appropriate instruction regarding procedures for handcranking and cautions in "pulling the propeller through two revolutions" in cold weather (this handbook makes no mention of either activity). The problems associated with these two similar activities could be tersely and effectively stated for educational purposes. Similarly, this handbook could also provide a brief discussion of the responsibility of the pilot for the safety of his passengers and the need to safeguard their entry and departure from the aircraft. The dangers associated with having untutored passengers assisting in starting or tying down an aircraft could be succinctly and effectively noted. We recommend such additions to the handbook. Also, questions on written tests for all pilot applicants should require responses based on an understanding of the responsibilities of the pilot for the safety of passengers, enplaning, deplaning, or assisting with the aircraft.

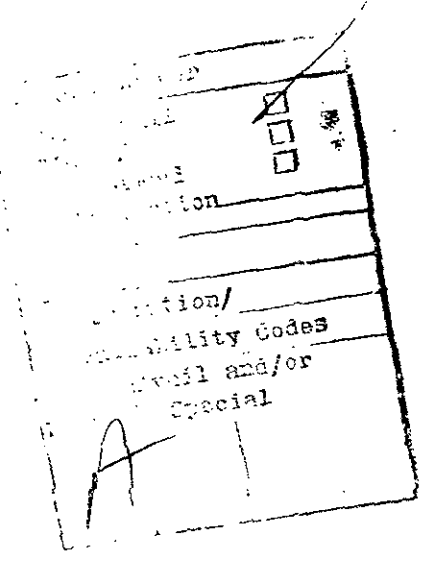
In addition to the methods noted above, attention needs to be directed toward the education of ground crew and aircraft employees and to "refresher" education of pilots. Warning signs might be effective if placed (i) in waiting areas where passengers could read them and (ii) on the inside of aircraft doors.

Requiring that pilots turn on the rotating beacon to indicate engine operation (a practice already followed by some pilots and encouraged by some airport operators) might also be helpful.

On the more technical side, the development of auditory or visual warning signals might be explored to indicate that aircraft doors are open while engines are running. Another technical approach that might be effective would be the development of additional lighting of the propeller blades (e.g., by a wing light aimed at the blades, switch-operated by the pilot) to increase conspicuity at dusk, in darkness, or in otherwise reduced illumination condition. Other possible developments include: (i) propeller markings on the side of the blades facing the pilot with patterns such that the markings would be visible to the pilot only at low (idling) propeller speed, but not at taxi, takeoff, or cruising speeds; (ii) markings on propeller spinners which are forward of the pilot, similar to those on the propeller blades, to increase conspicuity; and (iii) back-lighting (switch-operated by the pilot) of the propeller spinner, modified by translucent patterns, to create a conspicuous configuration particularly in reduced lighting.

Summary.

In response to the number of fatal and serious propeller-to-person accidents, the FAA took several actions in the early 1970's, designed to reduce propeller accident rates. The actions were primarily educational and were largely effected through the Accident Prevention Program. The methods included lectures, handouts, posters, a film depicting an accident resulting from improper handpropping, and the release of FAA advisory circulars on the hazard of propellers. It seems probable that the combination of those actions resulted in the significant drop in the number of propeller accidents in the 4-year period from 1975 through 1978. Supplementary means of further reducing propeller-to-person accidents include additions to the flight instructor's manual and the Flight Training Handbook, strategically placed warning signs, and specified technical developments. The factors associated with propeller-to-person accidents clearly assign considerable responsibility to pilots to insure safety of their passengers in this regard.



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