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16. Abstract

The National Transportation Safety Board has explored the factors associated with 17,312 general aviation accidents which occurred from 1972 through 1976 involving 17,498 light, single-engine, fixed-wing aircraft. These aircraft accounted for 81.0 percent of the accidents, 76.0 percent of the fatal accidents and 69.2 percent of the fatalities involving general aviation aircraft during that period.

The factors examined included aircraft make, model, configuration -- such as tailwheel or tricycle landing gear and high- or low-wing configuration — the pilot, and the environment. Certain aircraft makes, models, and characteristics were shown to be associated with high accident rates.

As a result of this study, a recommendation concerning the need for additional flight exposure data has been issued to the Federal Aviation Administration.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

SPECIAL STUDY

Adopted: May 31, 1979

SINGLE-ENGINE, FIXED-WING GENERAL AVIATION ACCIDENTS 1972-1976

INTRODUCTION

The National Transportation Safety Board has studied statistically general aviation accidents involving single-engine, propeller-driven, fixed-wing, light (under 12,500 pounds) aircraft 1/ (single-engine aircraft). The study included data from accidents from 1972 through 1976.

From 1972 through 1976, there were 21,366 general aviation accidents, including 3,517 fatal accidents with 6,941 fatalities. Single-engine aircraft accounted for 17,312 or 81.0 percent of those accidents, 2,673 or 76.0 percent of the fatal accidents, and 4,806 or 69.2 percent of the fatalities. Included in the 17,312 accidents are 186 collisions between aircraft. Each aircraft involved in a collision is coded separately. This produces 17,498 accident records for the 17,498 aircraft involved in the 17,312 accidents. Clearly, the single-engine aircraft category was by far the largest contributor to general aviation losses from 1972 through 1976.

Resources have not been available to investigate all of these general aviation accidents in the same detail, and even if the resources were available, it is not always possible to obtain the data necessary for a thorough understanding of all accidents. For example, general aviation aircraft often crash in remote locations where there are no witnesses and often the aircraft is destroyed and all occupants killed. In addition, general aviation aircraft under 12,500 pounds generally do not contain flight data recorders or cockpit voice recorders, which limits investigative efforts. Further, many of these accidents are minor and do not involve field investigations. Although some valuable data are collected in each of the accidents, all data elements are not always available from individual accidents to support any

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1/ In 1976, light aircraft were redefined as aircraft weighing 12,565 pounds (5,700 kilograms) or less. Thus, it is possible that the data analyzed include some aircraft which would have been considered heavy before the change. It is not likely that this change has had any effect on the results of this study.

real safety improvement. Therefore, the Safety Board chose to explore statistically the safety of the general aviation system in order to determine areas of improvement.

Numerous highly interrelated variables are involved in these accidents including the pilot, the manner in which he operates the aircraft, the weather and terrain in which and over which the aircraft is flown, the type of flying, maintenance of the aircraft, the aircraft design, and the manufacturing process. The study, which was a purely statistical comparison of Board data, did not indicate how all these variables contributed to the accidents.

In particular, the attempts to assess the effect of pilot characteristics such as experience (total flight time, time in type, and time last 90 days), type of certificate, age, and medical waivers, and the effects of environment including flight in IFR conditions, unfavorable winds, high density altitude and terrain lead to the same conclusions: A lack of exposure data has prevented the effective assessment of the role of the pilot and the environment in these accidents. However, of significance is the fact that the Safety Board has determined that the pilot was a cause or related factor in 86 percent of these single-engine aircraft accidents and in 90 percent of the fatal accidents, while the airframe was cited as a cause or factor in less than 1 percent of all accidents and only 2 percent of the fatal accidents.

Further, all of the aircraft included in this study have been certified as meeting the minimum standards imposed by the Federal Aviation Administration regulations.

Accordingly, in light of this and the unknown effects of the roles of the pilot, of the weather and terrain, and of the operation, maintenance, design and manufacture of these aircraft, the Board does not view this report as a criticism of any manufacturer, and stresses that these findings should not be construed as evidence that any of the above aircraft are unsafe or that certain manufacturers build aircraft that are not safe.

The Board does believe that the magnitude of these unanticipated differences dictates that these findings be published. The Safety Board further believes the findings indicate the need for research and analysis by the aviation industry which will provide an understanding of the pilot/aircraft/environmental system issues raised in the study, and that this report will act as a catalyst in initiating this needed effort.

The study employed three statistical techniques — frequency distributions, automatic interaction detector, and the contingency table technique. The frequency distributions, or numerical counts of the data variables, served as an audit of the data files to determine the specific information coded in the files. This technique was also used to develop a general description of the factors in a typical single-engine aircraft accident.

The Automatic Interaction Detector (AID) program was developed by the University of Michigan at Ann Arbor. This multivariate analytical technique can be used to explore the interrelationships of as many as 41 data variables and explain the variance of the records as a combination of the variables. AID is useful in searching out patterns in the data. An advantage of AID, or any other multivariate technique, is that the amount of data that a researcher can explore by two- and three-way analyses is limited by the researcher's capacity for handling large data sets.

The AID program was first applied to the subset of the data where weather was coded as a cause or factor to explore the feasibility of applying this technique to Safety Board data. Certain incompatibilities between the AID technique and the data increased the time, expense, and complexity of using this technique. Most data analyses, therefore, were performed using the contingency tables.

Contingency tables are two-way tables displaying the joint frequency distribution of two variables. Contingency tables are useful for assessing the relationship among two or more variables, since a sequence of two-way tables can be generated and the joint-frequency distributions can be analyzed statistically to determine whether or not the variables are statistically independent, or conversely whether they are related.

Section I of this report presents the results of the frequency distribution of the data variables in the 17,498 accident records. A composite description typical of a single-engine aircraft accident generated from the frequency distributions was analyzed. Based on this analysis a group of accident variables describing the aircraft, pilot, and environment was selected for further analysis of their interrelationships. Section II presents the results of the contingency table analyses of aircraft make, model, and design for accidents in general, for specific types of accidents, for pilot experience, and for environmental factors.

Section I

CHARACTERISTICS OF SINGLE-ENGINE AIRCRAFT ACCIDENTS

Characteristics Typical of Accidents

Frequency distributions were obtained for 163 of the 285 data fields available for the storage of data variables associated with the 17,498 accidents. These 163 variables were selected based on their predetermined relevancy to accident causation. The frequency distribution audit of the data base revealed a significant number of blank data fields. That is, no information of any kind was stored for these accident variables. For example, 113 data fields had no data stored in them for 14,000 or more records of the 17,498 single-engine aircraft involved in accidents.

Some of the data fields probably were left blank because the accident variables allocated to these fields were not germane to the accident; some data fields were left blank because the data was not or could not be collected; some data fields were left blank because, although the data was collected, it was not mandatory that the data be coded into the computer system; still others were blank for unknown reasons.

Many of the accident variables were alphanumeric. Both alphanumeric coding and blank data fields present some difficulties in the analysis of data using the available analytical programs.

A list of factors describing the aircraft, the pilot, and the environment is contained in Table 1. The list provides a composite description typical of the single-engine aircraft accident and contains 25 variables which were obtained from the frequency distributions.

Many variables were not presented in Table 1 because there were too many blank data fields or entries labeled "unknown" to permit a sufficient degree of confidence that the data were representative of the accident population. Variables were not considered if 50 percent or more of the accident records contained blanks and unknowns for a specific variable. Some variables were eliminated because their distributions were virtually without any distinctive pattern and, therefore, provided no information useful to the analysis.

As shown in Table 1, 40 percent of the accidents involved aircraft manufactured by the Cessna Aircraft Company and 25.0 percent involved aircraft manufactured by Piper Aircraft Corporation. There are substantially more Cessna-built aircraft flying more hours each year than any other aircraft. Also, there are more Piper Aircraft Corporation airplanes flying more hours than any other airplane except those manufactured by Cessna. Therefore, these percentages

TABLE 1

CHARACTERISTICS TYPICAL OF SINGLE-ENGINE AIRCRAFT ACCIDENT

AIRCRAFT CHARACTERISTICS

Manufacturer	Accidents
Cessna	7,061
Piper	4,482
Beech	962
Makes	
Cessna 150	2,111
Piper PA-28	1,800
Cessna 172	1,373
Cessna 182	878
Landing Gear	
Tricycle Fixed	8,343
Tailwheel Fixed	5,897
Tricycle Retractable	2,523
Engine Make	
Continental Motors Corp	8,389
Lycoming Division Avco Corp	7,444
Operator	
Private Owner	9,180
FBO	3,153
Aerial Application	1,834
Aircraft Damage	
Substantial	13,179
Destroyed	4,161
Fire	1,154

OTHER ACCIDENT CHARACTERISTICS

Type of Accident	Accidents
Engine Failure	4,069
Collisions with Obstacles	2,582
Ground Loop	2,519
Stalls	1,993
Collisions with Ground/Water	1,278
Hard Landing	1,240
Phase of Operation	
Landing - Flare-Touchdown	2,850
Initial Climb	2,242
Landing Leveloff	2,850
Landing Roll	2,585
In-flight Normal Cruise	1,921

PILOT CHARACTERISTICS

Pilot Involved	Accidents
Pilot in Command	17,481
Certificate	
Private	8,087
Commercial	4,232
Student	2,353
Kind of Flying	
Noncommercial Pleasure	9,772
Instructional	2,676
Aerial Application	1,784
Noncommercial Business	1,194
Medical Certificate	
Class III	5,017
Class II	4,936
Class III with Waiver	3,252
Class II with Waiver	2,635
Pilot Ratings	
Single-engine land	11,355
Single-multiengine	2,546
Single-engine instrument	1,174
Pilot Experience (in hours)	
Total Time $\leq$ 1,750	16,860
Time in type $\leq$ 450	16,207
Time last 90 days $\leq$ 352	14,867
Pilot Age	
21-30	4,721
31-40	5,069
41-50	4,214
51-60	2,108

ENVIRONMENTAL CHARACTERISTICS

Conditions of Light	Accidents
Daylight	15,036
Night-dark	1,347
Dusk	659
Type of Weather Conditions	
VFR	16,220
IFR	992
Below Minimums	83
Type of Flight Plan	
None	14,857
VFR	1,994
IFR	431
Airport Proximity	
On Airport	8,140
Beyond 5 miles	4,824
1/4 mile-5 miles	2,922
In Pattern	908
Wind Velocity	
15 knots or less	87%
Cloud Condition	
Clear	9,990
Scattered above 1,000 ft.	2,666
Overcast	1,436
Visibility	
5 miles or more	15,487
1 mile to 5 miles	857
1 mile or less	626
Precipitation	
None	15,897
Rain	641
Obstructions to View	
None	14,651
Haze	1,142
Fog	856

should not be construed to mean that these two companies manufacture aircraft that are less safe or more accident-prone than aircraft manufactured by other aircraft manufacturers.

Similarly, the particular aircraft contained in the list of aircraft models in Table 1 should not be considered less safe or more accident-prone than any other. These aircraft models have the most active aircraft, flying more hours than any other makes and models. These arguments hold for all of the variables listed in Table 1. Further examination and analysis are required to determine whether any of the factors highlighted in Table 1 are illustrative of a problem area or are indicative of particularly dangerous characteristics. The list does provide an overview of factors involved in typical single-engine aircraft accidents, and in conjunction with the exploratory AID analyses, it identified a number of the accident variables worthy of further analysis by contingency tables.

The contingency table analyses provided valuable insights into the interrelationships of a number of the accident factors, including aircraft make and model, certain aircraft design characteristics such as landing gear and wing configuration, pilot flight experience, certain environmental factors, and types of accident. These specific variables were included in the analysis, not only because the frequency distributions and the AID analyses indicated they were particularly relevant to accident causation, but also because data on these variables were stored in a sufficient number of accident records to determine the relationship of these variables to accident risk.

The annual trend of single-engine aircraft accidents is compared with the overall general aviation accident history in Figure 1. Although there was a slight decreasing trend in overall general aviation accidents and fatal accidents, the number of single-engine aircraft accidents, fatal accidents, and fatalities remained relatively unchanged from 1972 through 1976.

The number of flight-hours 2/ logged by these two categories of aircraft increased during that period. (See Figure 2.) Thus, the rates per 100,000 flying hours of accidents, fatal accidents, and fatalities involving those categories of aircraft have decreased over this period. (See Figure 3.)

To explore the relationship of type of accident to the other accident variables, 10 broad accident type categories were analyzed: Collisions with ground or water, collisions with obstacles, stalls, engine failures or malfunctions, midair collisions, in-flight airframe failures, ground loops, hard landings, overshoots, and undershoots. Some of the 10 categories are combinations of 2 or more detailed

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2/ Exposure data providing the number of hours flown annually by all general aviation aircraft for 1972 through 1976 was obtained from the Federal Aviation Administration. Certain changes in the data collection methods of the FAA introduced some questions of data consistency. (See Appendix A.)

FIGURE 1

ACCIDENTS, FATAL ACCIDENTS, AND FATALITIES
GENERAL AVIATION, SINGLE ENGINE

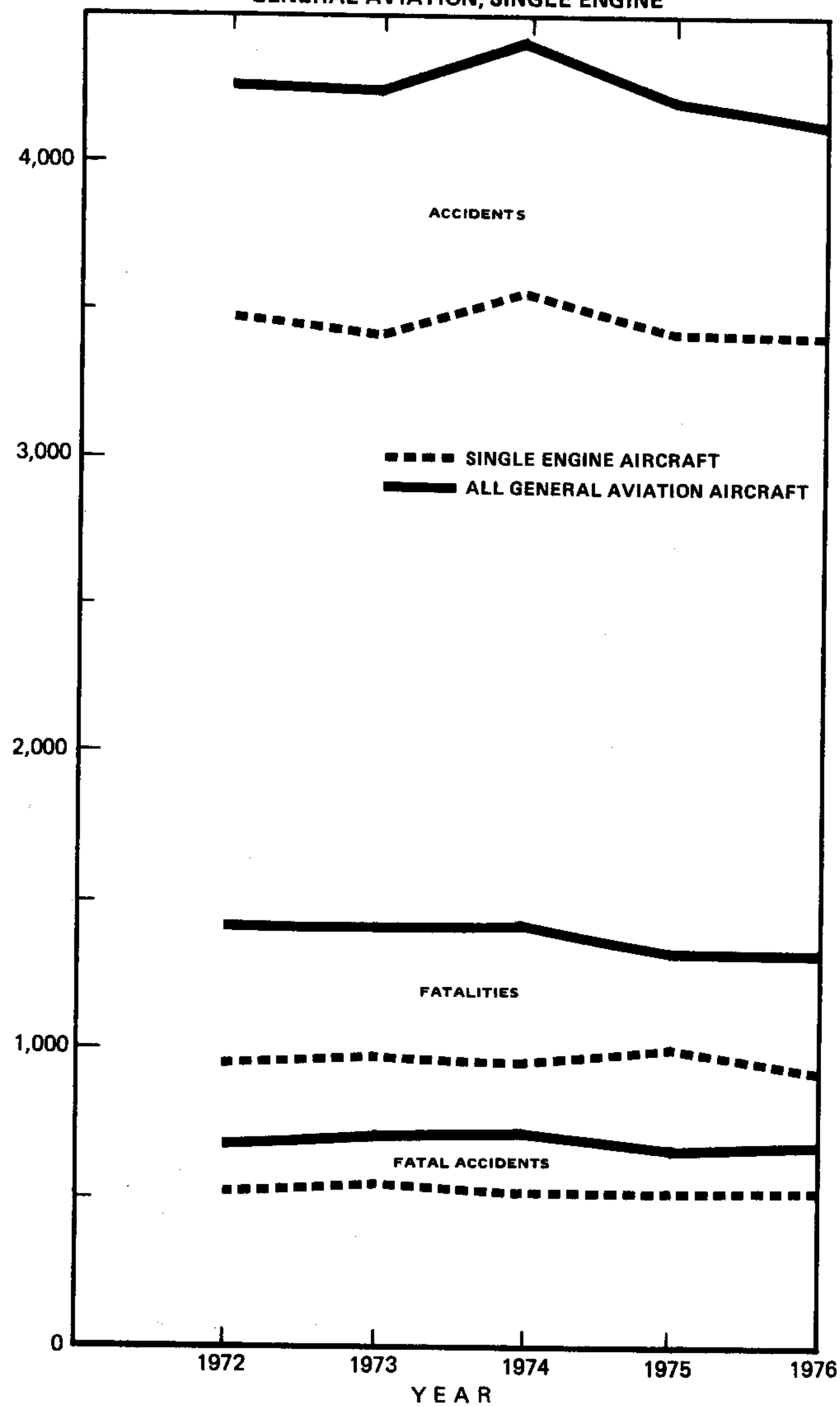


FIGURE 2

HOURS FLOWN ANNUALLY

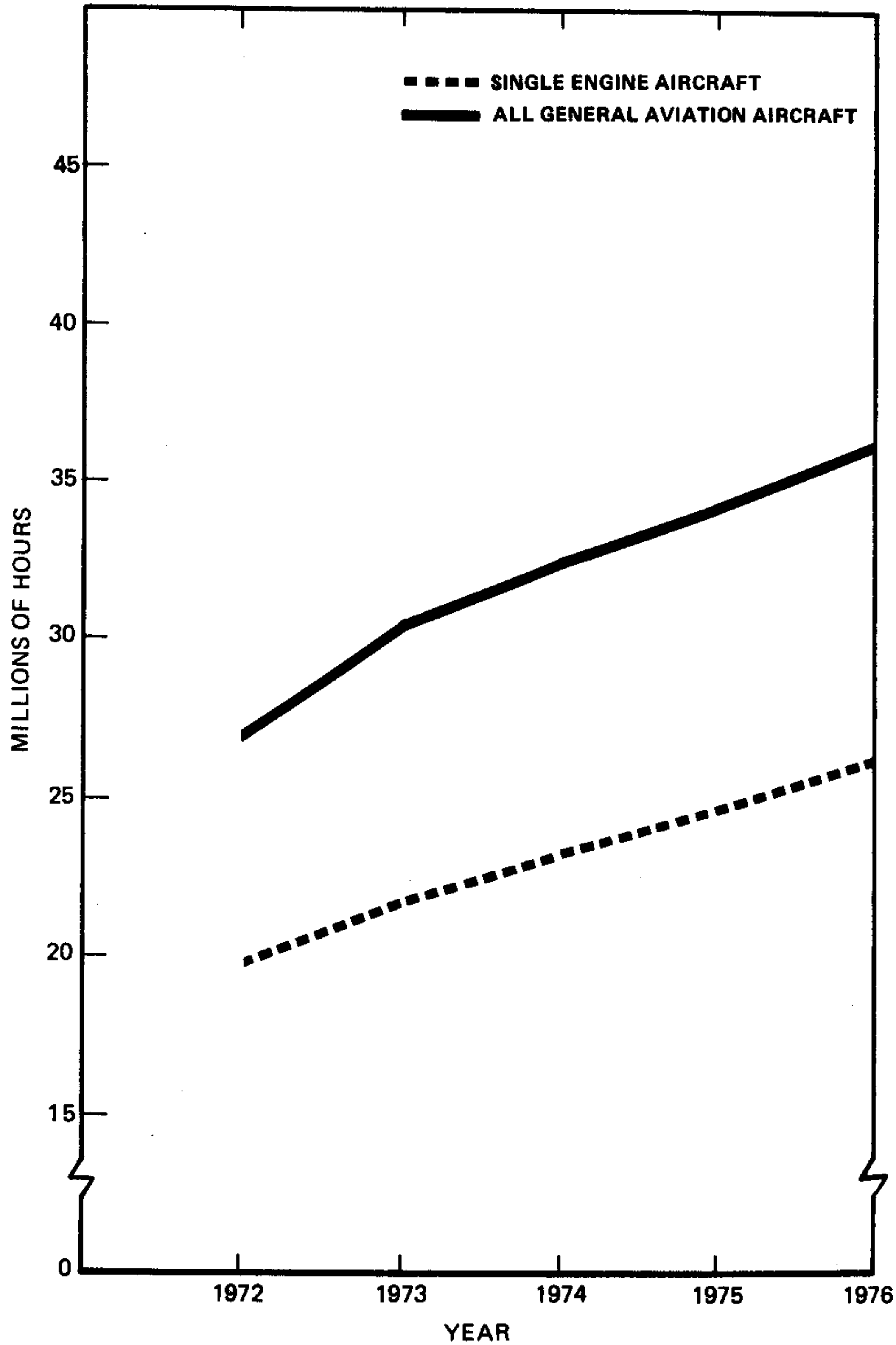
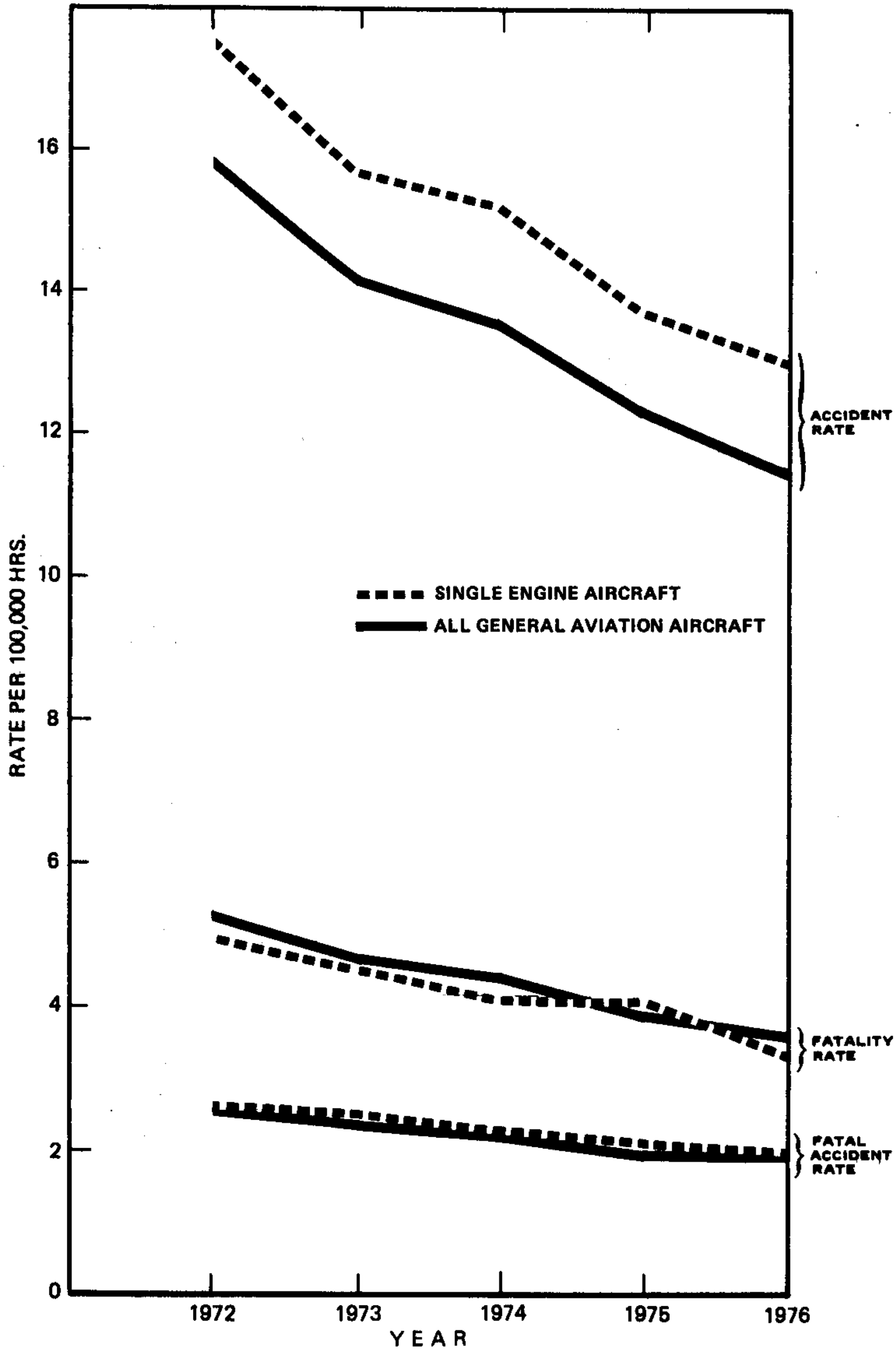


FIGURE 3 RATES OF ACCIDENTS, FATAL ACCIDENTS AND FATALITIES



Safety Board accident types. These 10 categories of accident types account for almost 90 percent of all accidents involving these aircraft.

When classifying types of accidents, some first types of accidents are normally followed by or require typical second types of accident. For example, engine failure or malfunction is coded as a first type of accident only when a subsequent accident occurs before completion of the flight, such as an accident on forced or precautionary landing after losing engine power. In this study, only the first type of accident has been included, because it provides a more accurate statistical assessment of the relationships between the accident variables.

The most frequent single-engine accident type is engine failure 3/, followed by collisions with obstacles and ground loops. (See Figure 4.) The number of engine failures increased from 1972 through 1976, while the other major categories of accidents either remained fairly constant or decreased slightly.

The most frequent fatal accident was collision with ground or water, followed by stall accidents and collisions with obstacles. (See Figure 5.) Engine failures or malfunctions are fourth on the list of the most frequent fatal accident causes. Ground loops, hard landings, undershoots, and overshoots are generally less severe types of accidents.

Examination of Selected Aircraft Makes and Models

To examine the role of aircraft make, model, and configuration in accidents, specific aircraft makes and models were selected for inclusion in the study. All aircraft makes and models with 500 or more active aircraft in the year 1976 were included. 4/ Thirty-three aircraft makes and models constitute the sample derived from this selection criterion. Aircraft designed specifically for use in aerial application flying were excluded because differences in both aircraft design and type of flying placed these aircraft outside the scope of this study. A list of the aircraft included in the study, their landing gear and wing configurations (high- or low-wing), and other pertinent characteristics is presented in Table 2.

There were 13,935 of the selected aircraft involved in 13,814 accidents, or 79.8 percent of the 17,312 single-engine aircraft accidents from 1972 through 1976. There were 2,251 of these aircraft involved in fatal accidents which resulted in 4,338 fatalities. Further, these 33 selected aircraft accounted for 103,285,497 flying hours or 89.3 percent of the 115,686,698 hours flown by the active single-engine aircraft fleet during that period. The total number of accidents,

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3/ Engine failures include, in addition to actual powerplants failure, such items as fuel starvation and exhaustion and carburetor and induction system icing.

4/ The FAA was the source of data on active number of aircraft in the U.S. general aviation fleet in 1976.

FIGURE 4

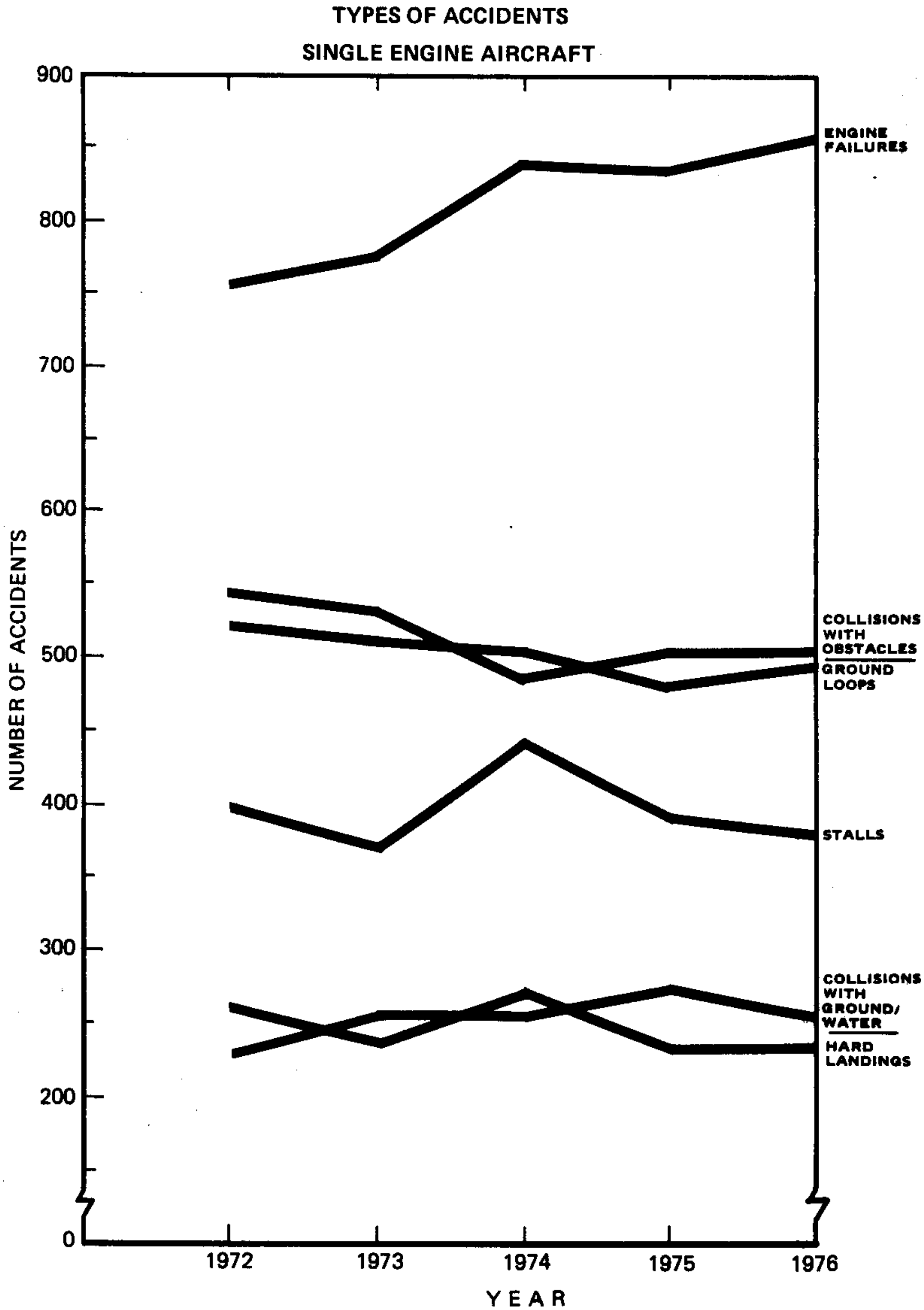
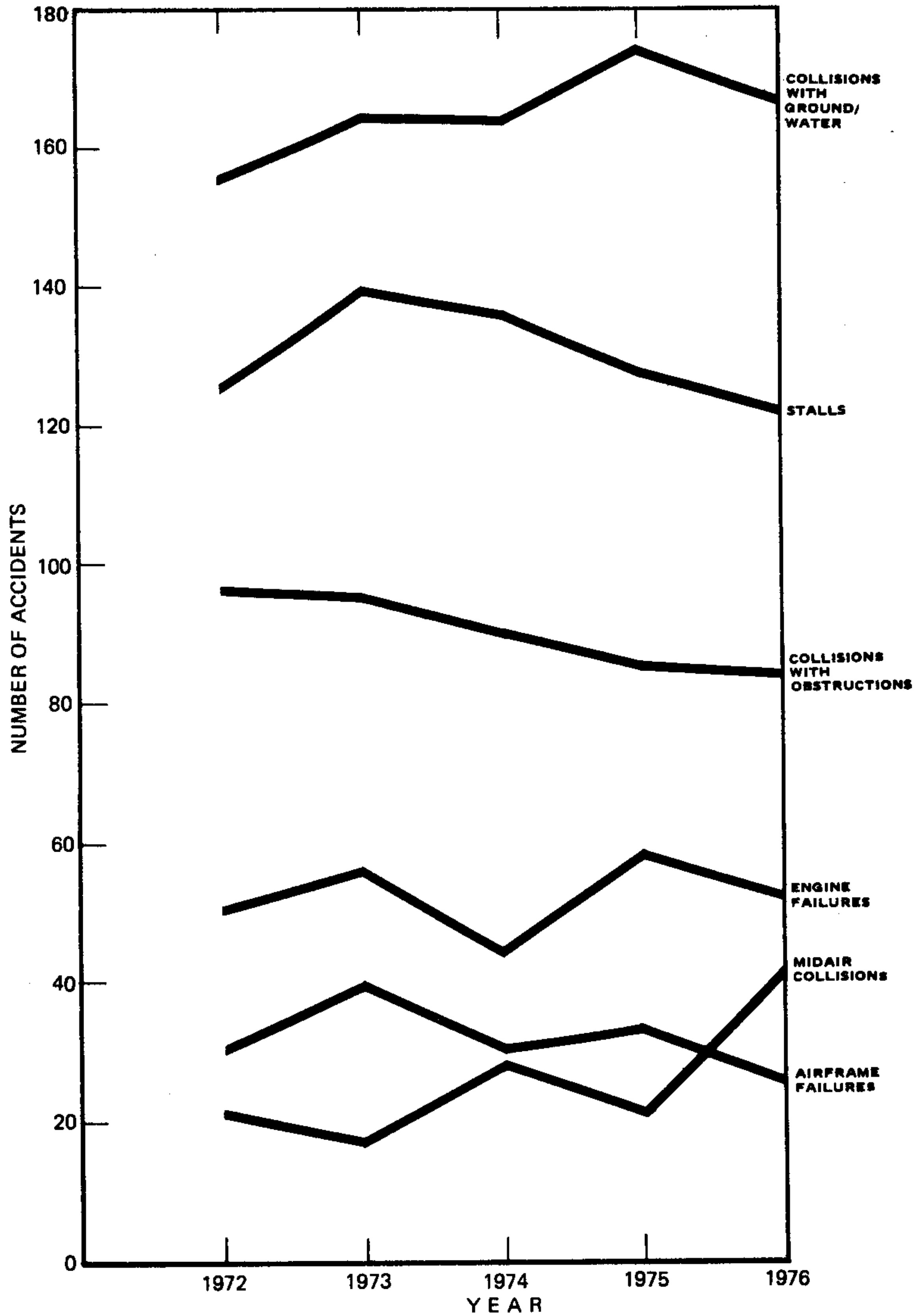

TYPES OF ACCIDENTS
SINGLE ENGINE AIRCRAFT
900
800
700
600
500
400
300
200
0
NUMBER OF ACCIDENTS
1972
1973
1974
1975
1976
YEAR
ENGINE FAILURES
COLLISIONS WITH OBSTACLES
GROUND LOOPS
STALLS
COLLISIONS WITH GROUND/ WATER
HARD LANDINGS

FIGURE 5

FATAL ACCIDENTS BY TYPE OF ACCIDENT
SINGLE ENGINE AIRCRAFT



fatal accidents, and fatalities for 1972 through 1976 are presented in Table 3 for the 33 selected aircraft. The data are also presented in Table 3 as rates based on 100,000 flying hours. The accident and fatal accident rate data are presented in bar chart form for convenience of the reader. (See Figure 6.)

The 33 selected aircraft were listed in order of their accident rates from highest to lowest. (See Table 4.) The five aircraft with the highest accident rates and the five aircraft with the lowest accident rates are shown in Table 5. The mean accident rate for the group of aircraft with the highest accident rate is four times that of the group with the lowest accident rate. One significant difference between the two groups is the substantially greater number of hours flown by the group with the lower rate (38 times as many). The higher rate group accounted for 3.8 percent of the single-engine accidents and 1.4 percent of the single-engine flying hours. The aircraft in the lower rate group accounted for 36.3 percent of the single-engine aircraft accidents and 54.3 percent of the single-engine flying hours. Flying time appears to be a factor in accounting for the difference between these two groups.

Another difference between the groups is that the higher rate group is configured with tailwheels, while the lower rate group has tricycle landing gear. Further, the higher rate group is composed of aircraft, the first production models of which are older than that of the lower rate group, and only one of the five aircraft in the higher rate group is still in production. The association between higher accident rate and older, tailwheel aircraft flown relatively few hours annually is more clearly illustrated in Table 6.

The 33 aircraft listed in Table 4 were divided into 3 groups of 11 aircraft each, beginning with the aircraft having the highest accident rate. The high accident rate group had a mean accident rate of 30.40 per 100,000 hours; the middle-rate group had a mean rate of 19.52; and the low-rate group had a mean rate of 10.45. The aircraft in the higher rate group were flown significantly fewer hours than the low-rate group — about 10 percent of the hours flown by the low-rate group. The high-rate group was composed of 10 tailwheel aircraft and 1 tricycle gear aircraft, while the low-rate group contained no tailwheel aircraft.

The mean for the year of initial design and production of aircraft was between 1943 and 1944 for the high accident rate group, between 1954 and 1955 for the middle group, and about 1960 for the group with the lowest accident rate. Many of the aircraft in the various groups were improved significantly over time, while others remained relatively unchanged for long periods of time. Production of some of the aircraft was discontinued shortly after introduction and 10 of the 11 aircraft in the high accident rate group are no longer in production. Product support, including availabilty of parts and service, may be limited on some of these older aircraft.

All of these factors could be related to the accident rate differences of these aircraft. However, a relationship apparently exists between older aircraft and higher accident rates. Further study of these aircraft to determine more precise causes of the substantial rate disparity is warranted. Corrective action,

TABLE 2

33 SELECTED AIRCRAFT

AIRCRAFT MAKE AND MODEL	LANDING GEAR CONFIGURATION	WING CONFIGURATION	SEATS	DATE OF INITIAL MODEL PRODUCTION	POWER LOADING LBS/HP
Aeronca 11	Tail Wheel	High Wing	2	1945	20.9
Aeronca(Bellanca) 7	Tail Wheel	High Wing	2	1945	11.5-18.7
Bellanca 14-19	Tricycle	Low Wing	4	1950	10.0-13.7
Beech 23	Tricycle	Low Wing	4	1962	12.7-15.0
Beech 33, 35, 36	Tricycle	Low Wing	5/6	1950	11.6-15.5
Cessna 120/140	Tail Wheel	High Wing	2	1946	17.0
Cessna 150	Tricycle	High Wing	2	1959	15.0
Cessna 170	Tail Wheel	High Wing	4	1948	15.5
Cessna 172	Tricycle	High Wing	4	1956	15.2
Cessna 175	Tricycle	High Wing	4	1958	13.4
Cessna 177	Tricycle	High Wing	4	1968	14.0-15.7
Cessna 180	Tail Wheel	High Wing	4/6	1953	12.2
Cessna 182	Tricycle	High Wing	4	1956	12.2
Cessna 185	Tail Wheel	High Wing	4/6	1961	12.7
Cessna 195	Tail Wheel	High Wing	4	1947	11.2
Cessna 206	Tricycle	High Wing	6	1964	12.6
Cessna 210/205	Tricycle	High Wing	6	1964	10.9-12.6
Forney(Ercoupe)	Tricycle	Low Wing	2	1940	16.8
Globe GC-1	Tail Wheel	Low Wing	4	1945	13.7-18.5
Globe(Stinson)108	Tail Wheel	High Wing	4	1945	14.3
Grumman(Yankee)AA-1	Tricycle	Low Wing	2	1969	13.9
Grumman(Traveler)AA-5	Tricycle	Low Wing	4	1972	14.7
Luscombe 8	Tail Wheel	High Wing	2	1937	16.4-19.4
Mooney M-20	Tricycle	Low Wing	4	1955	16.3
Navion	Tricycle	Low Wing	4	1946	10.9-13.4
Piper J-3	Tail Wheel	High Wing	2	1938	18.7
PA-12	Tail Wheel	High Wing	2	1944	15.5
PA-18	Tail Wheel	High Wing	2	1950	11.6-16.6
PA-22	Tricycle	High Wing	4	1951	12.5
PA-24	Tricycle	Low Wing	4	1958	11.9-12.3
PA-28	Tricycle	Low Wing	4	1961	12.4-15.5
PA-32	Tricycle	Low Wing	6	1965	11.3-13.1
Taylorcraft(BC)	Tail Wheel	High Wing	2	1940	22.0

TABLE 3

TOTAL ACCIDENT RECORDS
1972-1976 TOTALS

TABLE 3

TOTAL ACCIDENT RECORDS
1972-1976 TOTALS

AIRCRAFT MAKE AND MODEL	FLYING HOURS	ACCIDENT RECORDS	ACCIDENT/ 100,000 HRS.	FATAL ACCIDENT RECORDS	FATALS/ 100,000	TOTAL FATALITIES	FATALITY RATE/ 100,000 HRS.
Aeronca 11	170,576	53	31.07	9	5.28	14	8.21
Aeronca(Bellanca) 7	2,246,639	635	28.26	103	4.58	146	6.50
Bellanca 14-19	669,323	143	21.36	38	5.68	90	13.45
Beech 23	1,842,879	324	17.58	46	2.50	100	5.43
Beech 33, 35, 36	6,894,256	602	8.73	176	2.55	416	6.03
Cessna 120/140	1,115,038	320	28.69	19	1.70	26	2.33
Cessna 150	20,531,623	2,111	10.28	276	1.34	432	2.10
Cessna 170	1,109,994	302	27.21	35	3.15	72	6.49
Cessna 172	15,142,220	1,373	9.07	222	1.47	447	2.95
Cessna 175	601,403	91	15.13	11	1.83	20	3.33
Cessna 177	1,921,595	288	14.99	42	2.19	59	3.07
Cessna 180	1,942,835	413	21,26	25	1.29	50	2.57
Cessna 182	7,755,556	878	11.32	157	2.02	323	4.16
Cessna 185	953,530	169	17.72	14	1.47	30	3.15
Cessna 195	213,086	82	34.48	8	3.75	13	6.10
Cessna 206	1,848,170	242	13.09	31	1.68	61	3.30
Cessna 210/205	2,682,797	408	15.21	83	3.09	178	6.63
Forney(Ercoupe)	620,879	177	28.51	24	3.87	34	5.48
Globe GC-1	194,099	73	37.61	18	9.27	24	12.36
Globe(Stinson)108	525,910	200	38.03	12	2.28	23	4,37
Grumman(Yankee)AA-1	1,158,597	304	26.24	56	4.83	78	6.73
Grumman(Traveler)AA-5	680,301	102	14.99	20	2.94	52	7.64
Luscombe 8	553,883	253	45.68	28	5.06	43	7.76
Mooney M-20	3,243,442	367	11.32	79	2.44	171	5.27
Navion	552,260	89	16.12	21	3.80	50	9.05
Piper J-3	867,656	234	26.97	42	4.73	58	6.68
Piper PA-12	428,114	117	27.33	15	3.50	27	6.31
Piper PA-18	2,074,701	479	23.09	83	4.00	110	5.30
Piper PA-22	2,028,059	434	21.40	66	3.28	126	6.21
Piper PA-24	2,601,126	437	16.80	76	2.92	175	6.73
Piper PA-28	17,576,654	1,830	10.49	347	1.97	703	4.00
Piper PA-32	2,118,861	301	14.21	58	2.74	173	8.16
Taylorcraft(BC)	419,435	104	24.80	11	2.62	14	3.34
TOTALS	103,285,497	13,935	13.49 Av.	2,251	2.18 Av.	4,338	4.20 Av.

FIGURE 6

TOTAL AND FATAL ACCIDENT RATES (PER 100,000 HOURS)
BY AIRCRAFT MAKE AND MODEL
1972 — 1976

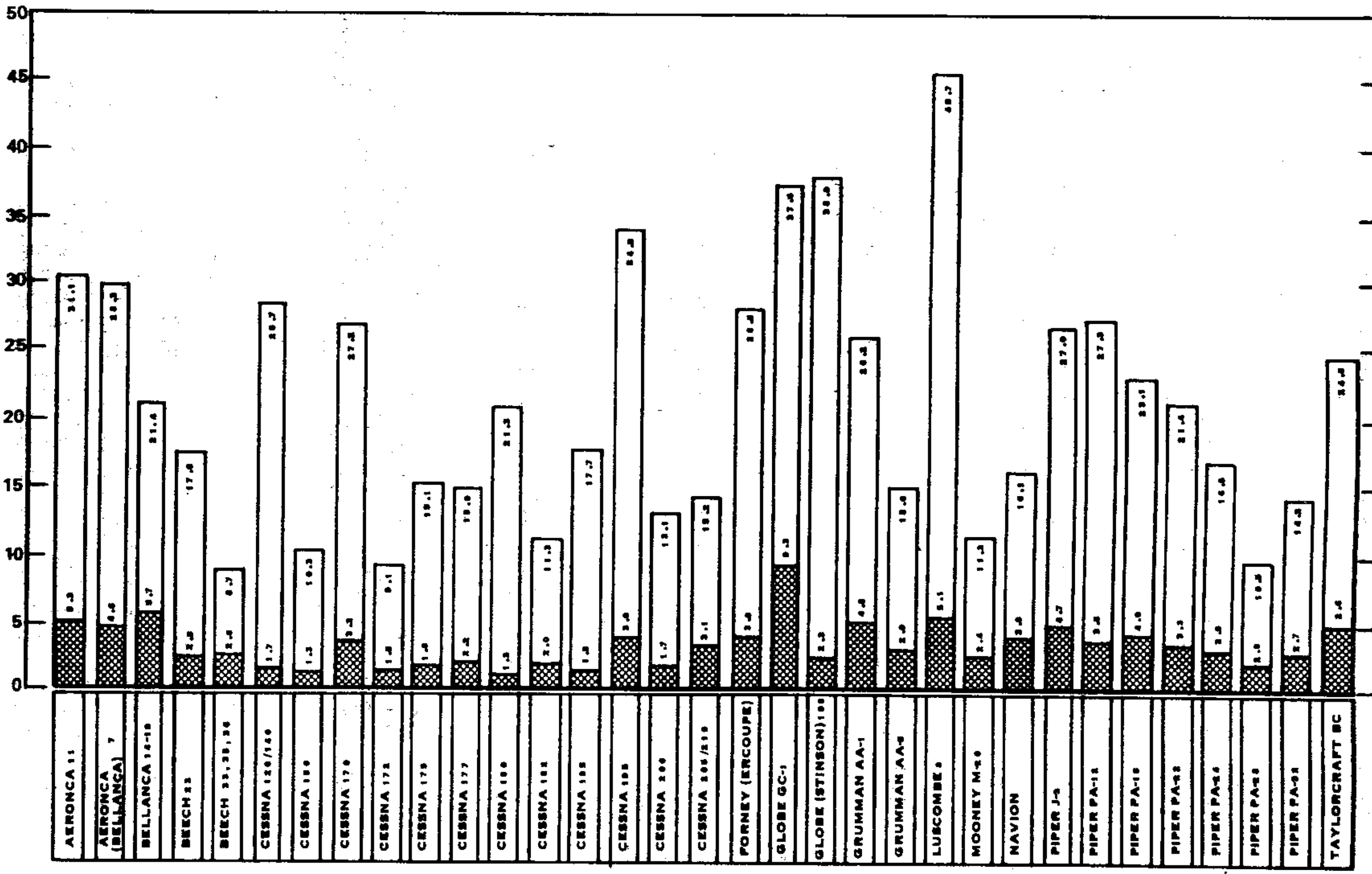


TABLE 4

SELECTED AIRCRAFT RANKED BY ACCIDENT RATE

AIRCRAFT	ACCIDENT RATE	FLYING HOURS IN 100,000 HRS.	ACCIDENT RECORDS
Luscombe 8	45.68	5.539	253
Cessna 195	34.48	2.131	82
Globe(Stinson)108	38.03	5.259	200
Globe GC-1	37.61	1.941	73
Aeronca 11	31.07	1.706	53
Cessna 120/140	28.69	11.150	320
Forney(Ercoupe)	28.51	6.209	177
Aeronca(Bellanca) 7	28.26	22.466	635
Piper PA-12	27.33	4.281	117
Cessna 170	27.21	11.100	302
Piper J-3	26.97	8.677	234
Grumman(Yankee)AA-1	26.24	11.586	304
Taylorcraft(BC)	24.80	4.194	104
Piper PA-18	23.09	20.747	479
Piper PA-22	21.40	20.281	434
Bellanca 14-19	21.36	6.693	143
Cessna 180	21.26	19.428	413
Cessna 185	17.72	9.535	169
Beech 23	17.58	18.429	324
Piper PA-24	16.80	26.011	437
Navion	16.12	5.523	89
Cessna 210/205	15.21	26.828	408
Cessna 175	15.13	6.014	91
Cessna 177	14.99	19,216	288
Grumman(Traveler)AA-5	14.99	6.803	102
Piper PA-32	14.21	21.189	301
Cessna 206	13.09	18.482	242
Cessna 182	11.32	77.556	878
Mooney M-20	11.32	32.433	367
Piper PA-28	10.49	175.767	1,830
Cessna 150	10.28	205.316	2,111
Cessna 172	9.07	151.422	1,373
Beech 33, 35, 36	8.73	68.943	602

TABLE 5

AIRCRAFT WITH FIVE HIGHEST ACCIDENT RATES

AIRCRAFT	ACCIDENT RECORDS	FLYING HOURS	ACCIDENT RATES
Luscombe 8	253	553,883	45.68
Cessna 195	82	213,086	34.48
Globe(Stinson)108	200	525,910	38.03
Globe GC-1	73	194,099	37.61
Aeronca 11	53	170,576	31.07
TOTALS	661	1,656,554	39.90 (mean rate)

AIRCRAFT WITH FIVE LOWEST ACCIDENT RATES

AIRCRAFT	ACCIDENT RECORDS	FLYING HOURS	ACCIDENT RATES
Beech 33, 35, 36	602	6,894,256	8.73
Cessna 172	1,373	15,142,220	9.07
Cessna 150	2,111	20,531,623	10.28
Piper PA-28	1,830	17,576,654	10.49
Mooney M-20	367	3,243,442	11.32
TOTALS	6,283	63,388,195	9.91 (mean rate)

TABLE 6

AIRCRAFT CHARACTERISTICS BY ACCIDENT RATE GROUPING

	Low Accident Rate Group	Middle Accident Rate Group	High Accident Rate Group
No. of Aircraft	11	11	11
No. of Accidents	8,185	3,304	2,446
No. of Flying Hours	78,314,100	16,925,500	8,045,900
Mean Accident Rate	10.45	19.52	30.40
Landing Gear Configuration			
Tailwheel	-	4	10
Tricycle	11	7	1
Wing Configuration			
High Wing	6	6	9
Low Wing	5	5	2
Average Dates of Initial Model Production	1960	1955	1944
Current Production Status			
In Production	10	7	1
Out of Production	1	4	10
Manufacturer			
Beech	1	1	-
Bellanca	-	1	1
Cessna	6	3	3
Grumman	1	1	-
Mooney	1	-	-
Piper	2	3	2
Other	-	2	5

where possible, should be taken to reduce the accident rates of the aircraft in the higher rate group.

The 33 selected aircraft have been ranked in Table 7 in order of fatal accident rate. Then in Table 8 the 33 aircraft were divided into 3 groups of 11 aircraft each, based on the ranking of their rates of fatal accidents. The characteristics of the three groups do not exhibit the same contrasts as the total accident rate comparisons of Table 7. The difference in hours between the three groups is large, but not as large as in the comparison of total accident rates. Although the aircraft in the high-rate group are significantly older than the aircraft in the low-rate group, the difference of 11 years is less significant than the 16-year difference between the high- and low-rate groups based on total accident rates. Further the tailwheel-tricycle comparison, which was distinct in the comparison based on total accident rate, is far less obvious in the fatal accident rate comparison. The same is true when comparing the number of aircraft still in production with those no longer in production, although the out-of-production group does have a mean fatal accident rate about 50 percent higher than the rate for the aircraft still in production. (See Table 9.) One interesting feature is that 10 of the 11 aircraft in the low fatal rate group are high-wing aircraft.

There is another remarkable feature of the summary of the fatal accident rate ranking presented in Table 8. The 11 aircraft in the group with the lowest fatal accident rates include 9 aircraft manufactured by Cessna, 1 manufactured by Piper, and 1 manufactured by a company no longer producing aircraft. The middle and high-rate groups include the remaining three Cessna-built aircraft, five of the six Piper aircraft, the two aircraft built by Beech, the two built by Bellanca, the two built by Grumman, the one by Mooney, and the six built by companies no longer producing aircraft. Of the single-engine aircraft manufactured by the 6 companies still producing aircraft, (Beech, Bellanca, Cessna, Grumman, Mooney, and Piper), 3 of the 12 Cessna aircraft and 4 of the 7 Piper Aircraft are no longer in production; all other aircraft manufactured by these 6 companies are still in production. (See Table 9.)

There are a number of factors which could be related to the statistics analyzed in Tables 6 through 9. They include the type of accident, the kind of flying, accident causes, pilot experience, operating conditions such as unimproved air fields, and environmental factors such as weather.

Accident Types

The accident rates per 100,000 flying hours for the 10 categories of specific types of accidents were calculated for each of the 33 selected aircraft. (See Tables 10 and 11.) From these data, the selected aircraft have been ranked on an accident rate basis, from high rate to low rate, for each of the 10 accident types. (See Tables 12-21.) The aircraft have been divided as evenly as possible into three groups, based on accident rate for each of the specific types of accident involved. Data summarizing specific features or characteristics of the aircraft involved in each of the three accident rate groups have been presented in Table 22 for each of the 10 accident types.

TABLE 7

SELECTED AIRCRAFT RANKED BY FATAL ACCIDENT RATE

AIRCRAFT	FATAL ACCIDENT RATE	FLYING HOURS PER 100,000 HRS.	FATAL ACCIDENT RECORDS
Globe GC-1	9.27	1.941	18
Bellanca 14-19	5.68	6.693	38
Aeronca 11	5.28	1.706	9
Luscombe 8	5.06	5.539	28
Grumman(Yankee)AA-1	4.83	11.586	56
Piper J-3	4.73	8.677	42
Aeronca(Bellanca) 7	4.58	22.466	103
Piper PA-18	4.00	20.747	83
Forney(Ercoupe)	3.87	6.209	24
Navion	3.80	5.523	21
Cessna 195	3.75	2.131	8
Piper PA-12	3.50	4.281	15
Piper PA-22	3.28	20.281	66
Cessna 170	3.15	11.100	35
Cessna 210/205	3.09	26.828	83
Grumman(Traveler)AA-5	2.94	6.803	20
Piper PA-24	2.92	26.011	76
Piper PA-32	2.74	21.189	58
Taylorcraft(BC)	2.62	4.194	11
Beech 33, 35, 36	2.55	68.943	176
Beech 23	2.50	18.429	46
Mooney M-20	2.44	32.433	79
Globe(Stinson)108	2.28	5.259	12
Cessna 177	2.19	19.216	42
Cessna 182	2.02	77.556	157
Piper PA-28	1.97	175.767	347
Cessna 175	1.83	6.014	11
Cessna 120/140	1.70	11.150	19
Cessna 206	1.68	18.482	31
Cessna 185	1.47	9.535	14
Cessna 172	1.47	151.422	222
Cessna 150	1.34	205.316	276
Cessna 180	1.29	19.428	25

TABLE 8

FATAL ACCIDENTS

	Low Fatal Accident Rate Group	Middle Fatal Accident Rate Group	High Fatal Accident Rate Group
No. of Aircraft	11	11	11
No. of Accidents	1,156	665	430
No. of Flying Hours	69,914,500	26,505,400	8,769,500
Mean Accident Rate	1.65	2.51	4.90
Landing Gear Configuration			
Tailwheel	4	3	7
Tricycle	7	8	4
Wing Configuration			
High Wing	10	5	6
Low Wing	1	6	5
Average Dates of Initial Model Production	1957	1954	1946
Current Production Status			
In Production	8	6	4
Out of Production	3	5	7
Manufacturer			
Beech	-	2	-
Bellanca	-	-	2
Cessna	9	2	1
Grumman	-	1	1
Mooney	-	1	-
Piper	1	4	2
Other	1	1	5

TABLE 9

FATAL ACCIDENTS

AIRCRAFT NO LONGER IN PRODUCTION

AIRCRAFT	FATAL ACCIDENTS	FLYING HOURS 100,000 HRS.	FATAL RATE PER 100,000 HRS.
Globe GC-1	18	1.941	9.27
Aeronca 11	9	1.706	5.28
Luscombe 8	28	5.539	5.06
Piper J-3	42	8.677	4.73
Forney(Ercoupe)	24	6.209	3.87
Navion	21	5.523	3.80
Cessna 195	8	2.131	3.75
Piper PA-12	15	4.281	3.50
Piper PA-22	66	20.281	3.28
Cessna 170	35	11.100	3.15
Piper PA-24	76	26.011	2.92
Taylorcraft(BC) *	11	4.194	2.62
Globe(Stinson)108	12	5.259	2.28
Cessna 175	11	6.014	1.83
Cessna 120/140	19	11.150	1.70
TOTALS	395	120.016	3.29 (mean rate)

AIRCRAFT STILL IN PRODUCTION

AIRCRAFT	FATAL ACCIDENTS	FLYING HOURS 100,000 HRS.	FATAL RATE PER 100,000 HRS.
Bellanca 14-19	38	6.693	5.68
Grumman(Yankee)AA-1	56	11.586	4.83
Aeronca(Bellanca) 7	103	22.466	4.58
Piper PA-18	83	20.747	4.00
Cessna 210/205	83	28.828	3.09
Grumman(Traveler)AA-5	20	6.803	2.94
Piper PA-32	58	21.189	2.74
Beech 33, 35, 36	176	68.943	2.55
Beech 23	46	18.429	2.50
Mooney M-20	79	32.433	2.44
Cessna 177	42	19.216	2.19
Cessna 182	157	77.556	2.02
Piper PA-28	347	175.767	1.97
Cessna 206	31	18.482	1.68
Cessna 185	14	9.535	1.47
Cessna 172	222	151.422	1.47
Cessna 150	276	205.316	1.34
Cessna 180	25	19.428	1.29
TOTALS	1,856	878.787	2.11 (mean rate)

* The Board is aware that production of this aircraft has resumed, but the accidents involve the older aircraft.

The data indicate that the group of aircraft accounting for the high rate of collisions with ground or water are older model aircraft -- aircraft for which initial design and production took place more than 25 years ago — and are associated with fewer total hours flown in these aircraft. The accident rate for the high-rate group is about twice that of the low-rate group. (See Table 22.)

The 11 aircraft accounting for the high rate of collisions with obstacles are also older model aircraft associated with fewer total flying hours. Another feature of this group is that the high accident rate group consists of nine aircraft with tailwheels and only two with tricycle landing gear. The mean accident rate for the high-rate group is about 2.7 times that of the low-rate group.

The 11 aircraft accounting for the high rate of stall accidents (stall, stall-spin, stall-spiral, and stall-mush) are also older model aircraft and consist of 9 high-wing aircraft and only 2 low-wing aircraft. Because of the generally accepted view that stalls can be facilitated by inadequate engine power, the ratio of aircraft gross takeoff weight to engine horsepower of the aircraft involved in this accident category was examined. The high-rate group had a weight-to-horsepower ratio of 16.7, almost 30 percent larger than the 13.0 power loading of the low-rate group. Indeed, from these data a relationship appears to exist between increasing rate of stall accidents and decreasing ratio of engine power-to-aircraft weight. The mean accident rate of the high-rate group is almost seven times greater than the mean rate for the low-rate group.

TABLE 10

The data on engine failure accidents also show that the high-rate group involves older model aircraft flown fewer hours than the low-rate group. There does not appear to be any relationship between rate of engine failure and landing gear or wing configuration. The mean engine failure accident rate for the high-rate group is a little more than three times greater than that of the low-rate group. The data on midair collisions do not show the same relationship between accident rate and older model aircraft with fewer flying hours. Midair collisions do appear to have one feature in common with the previous four accident types. The low-rate group includes more Cessna aircraft than all other aircraft combined. In all of these serious accident types, which were previously shown to be correlated with fatal accidents, only 1 of the 12 aircraft built by the Cessna Aircraft Company was included in the high-rate groups, except for the high-rate stall group which includes 2 Cessna-built aircraft. This is not surprising in light of the previously observed lower fatal accident rate of Cessna-built aircraft.

The data on midair collisions also show that 97 of the 196 aircraft involved in midair collisions were either the Cessna 150 or the Piper PA-28. (See Table 16.) Both of these aircraft are flown significantly in instructional flying and are thus often flown in high traffic environments. Nonetheless, it is significant that these two aircraft account for almost one-half of all midair collisions involving the 33 selected aircraft and almost 75 percent of the involvement by the high-rate midair collision group. This high-rate group has a mean midair collision accident rate more than three times that of the low-rate group.

TABLE 10

33 SELECTED AIRCRAFT BY ACCIDENT TYPE

ACCIDENTS

AIRCRAFT MAKE AND MODEL	COLLISION W/GROUND & WATER	COLLISION W/OBSTACLES	STALL	ENGINE FAILURE	AIRFRAME FAILURE	MIDAIR COLLISION	GROUND LOOP	HARD LANDING	UNDERSHOOT	OVERSHOOT
Aeronca 11	-	10	14	7	1	-	73	-	1	2
Aeronca(Bellanca) 7	37	86	136	95	6	7	168	27	13	11
Bellanca 14-19	21	17	4	40	10	2	14	-	4	4
Beech 23	22	35	26	66	5	-	43	66	8	36
Beech 33, 35, 36	64	62	65	153	40	8	38	20	15	16
Cessna 120/140	11	41	28	75	3	1	87	15	6	8
Cessna 150	111	279	292	510	5	56	281	282	72	73
Cessna 170	14	30	48	32	4	1	110	21	4	11
Cessna 172	135	248	117	214	4	25	152	107	40	152
Cessna 175	7	18	5	21	-	1	3	6	6	8
Cessna 177	18	40	34	64	3	1	31	50	2	17
Cessna 180	22	60	21	63	6	4	126	18	3	11
Cessna 182	97	122	28	161	9	11	82	168	19	94
Cessna 185	11	24	14	26	-	1	45	4	4	3
Cessna 195	1	4	1	10	2	-	47	1	1	5
Cessna 206	16	24	10	61	2	2	32	24	6	15
Cessna 210/205	42	41	19	114	9	2	29	22	9	24
Forney(Ercoupe)	9	29	8	59	6	-	17	18	15	4
Globe GC-1	5	9	10	24	2	-	6	5	2	2
Globe(Stinson)108	5	24	11	56	-	1	71	1	3	7
Grumman(Yankee)AA-1	13	32	49	101	1	1	33	35	11	11
Grumman(Traveler)AA-5	9	25	12	15	-	2	10	7	3	16
Luscombe 8	10	22	32	42	3	5	72	13	9	6
Mooney M-20	46	32	26	111	6	2	21	10	2	33
Navion	6	8	10	40	5	-	2	2	2	3
Piper J-3	14	36	51	66	2	1	18	9	5	3
Piper PA-12	4	20	14	28	-	-	20	1	6	4
Piper PA-18	45	78	114	70	-	6	81	9	9	17
Piper PA-22	33	65	36	115	6	7	56	14	17	29
Piper PA-24	35	41	24	94	11	6	33	13	15	42
Piper PA-28	165	316	140	416	28	41	239	142	105	141
Piper PA-32	26	63	12	93	5	2	30	9	15	22
Taylorcraft(BC)	9	15	27	16	1	-	15	2	-	-
TOTAL (Select)	1,063	1,956	1,438	3,058	185	196	2,085	1,121	446	830

TABLE 11

33 SELECTED AIRCRAFT BY ACCIDENT TYPE

ACCIDENT RATES

AIRCRAFT MAKE AND MODEL	COLLISION W/GROUND & WATER	COLLISION W/OBSTACLES	STALL	ENGINE FAILURE	AIRFRAME FAILURE	MIDAIR COLLISION	GROUND LOOP	HARD LANDING	UNDERSHOOT	OVERSHOOT
Aeronca 11	-	5.88	8.21	4.10	0.59	-	7.86	-	0.59	1.17
Aeronca(Bellanca) 7	1.65	3.83	22.47	4.23	0.27	0.31	7.48	1.20	0.59	0.48
Bellanca 14-19	3.14	2.54	0.60	5.98	1.49	0.30	2.10	-	0.60	0.60
Beech 23	1.19	1.90	1.41	3.58	0.27	-	2.33	3.50	0.43	1.95
Beech 33, 35, 36	0.93	0.89	0.94	2.22	0.58	0.12	0.55	1.45	0.21	0.23
Cessna 120/140	0.99	3.67	2.51	6.73	0.27	0.09	8.99	1.35	0.53	0.71
Cessna 150	0.54	1.35	1.42	2.48	0.02	0.27	1.37	1.37	0.35	0.35
Cessna 170	1.26	2.52	4.38	2.88	0.36	0.09	9.91	1.89	0.36	0.99
Cessna 172	0.89	1.63	0.77	1.41	0.03	0.17	1.00	0.71	0.26	1.00
Cessna 175	1.16	2.99	0.83	3.48	-	0.16	0.17	1.00	0.99	1.33
Cessna 177	0.94	2.08	1.77	3.33	0.16	0.05	1.61	2.60	0.10	0.88
Cessna 180	1.13	3.08	1.08	3.24	0.31	0.21	6.49	0.93	0.15	0.56
Cessna 182	1.25	1.57	0.36	2.08	0.12	0.14	1.06	2.17	0.24	1.21
Cessna 185	1.15	2.51	1.47	2.73	-	0.10	4.72	0.42	0.41	0.31
Cessna 195	0.47	1.87	0.47	4.69	0.94	-	22.06	0.47	0.47	2.34
Cessna 206	0.87	1.30	0.54	3.30	0.11	0.11	1.73	1.30	0.32	0.81
Cessna 210/205	1.57	1.52	0.71	4.25	0.34	0.07	1.08	0.82	0.33	0.89
Forney(Ercoupe)	1.45	4.67	1.29	9.50	0.97	-	2.74	2.90	2.41	0.64
Globe GC-1	2.58	4.64	5.15	12.36	1.03	-	3.09	2.58	1.03	1.03
Globe(Stinson)108	0.95	4.57	2.09	10.65	-	0.19	13.50	0.19	0.57	1.33
Grumman(Yankee)AA-1	1.12	2.76	4.23	8.71	0.09	0.09	2.85	3.02	0.95	0.95
Grumman(Traveler)AA-5	1.32	3.67	1.76	2.20	-	0.29	1.47	1.03	0.44	2.35
Luscombe 8	1.81	3.97	5.78	7.58	0.54	0.90	13.00	2.35	1.62	1.08
Mooney M-20	1.42	0.98	0.80	3.42	0.18	0.06	0.65	0.31	0.37	1.01
Navion	1.09	1.44	1.81	7.84	0.90	-	0.36	0.36	0.36	0.54
Piper J-3	1.61	4.15	5.88	7.61	0.23	0.12	2.07	1.04	0.57	0.34
Piper PA-12	0.93	4.67	3.27	6.54	-	-	4.67	0.23	1.40	0.93
Piper PA-18	2.17	3.76	5.49	3.37	-	0.30	3.90	0.43	0.43	0.81
Piper PA-22	1.63	3.20	1.78	5.67	0.30	0.35	2.76	0.69	0.83	1.33
Piper PA-24	1.35	1.57	0.98	3.61	0.42	0.23	1.29	1.29	0.57	1.61
Piper PA-28	0.94	1.79	0.80	2.37	0.16	0.23	1.36	0.81	0.59	0.80
Piper PA-32	1.23	2.97	0.57	4.39	0.24	0.09	1.42	0.42	0.70	1.03
Taylorcraft(BC)	2.15	3.57	6.44	3.81	0.24	-	3.58	0.48	0.95	-

TABLE 12

COLLISION WITH GROUND AND WATER

AIRCRAFT	RATE	ACCIDENTS
Bellanca 14-19	3.14	21
Globe GC-1	2.58	5
Piper PA-18	2.17	45
Taylorcraft(BC)	2.15	9
Luscombe 8	1.81	10
Aeronca(Bellanca) 7	1.65	37
Piper PA-22	1.63	33
Piper J-3	1.61	14
Cessna 210/205	1.57	42
Forney(Ercoupe)	1.45	9
Mooney M-20	1.42	46
Piper PA-24	1.35	35
Grumman(Traveler)AA-5	1.32	9
Cessna 170	1.26	14
Cessna 182	1.25	97
Piper PA-32	1.23	26
Beech 23	1.19	22
Cessna 175	1.16	7
Cessna 185	1.15	11
Cessna 180	1.13	22
Grumman(Yankee)AA-1	1.12	13
Navion	1.09	6
Cessna 120/140	0.99	11
Globe(Stinson)108	0.95	5
Piper PA-28	0.94	165
Cessna 177	0.94	18
Beech 33, 35, 36	0.93	64
Piper PA-12	0.93	4
Cessna 172	0.89	172
Cessna 206	0.87	16
Cessna 150	0.54	111
Cessna 195	0.47	1

TABLE 13

COLLISION WITH OBSTACLES

AIRCRAFT	RATE	ACCIDENTS
Aeronca 11	5.88	10
Forney(Ercoupe)	4.67	29
Piper PA-12	4.67	20
Globe GC-1	4.64	9
Globe(Stinson)108	4.57	24
Piper J-3	4.15	36
Luscombe 8	3.97	22
Aeronca(Bellanca) 7	3.83	86
Piper PA-18	3.76	78
Cessna 120/140	3.67	41
Grumman(Traveler)AA-5	3.67	25
Taylorcraft(BC)	3.57	15
Piper PA-22	3.20	65
Cessna 180	3.08	60
Cessna 175	2.99	18
Piper PA-32	2.97	63
Grumman(Yankee)AA-1	2.76	32
Bellanca 14-19	2.54	17
Cessna 170	2.52	30
Cessna 185	2.51	24
Cessna 177	2.08	40
Beech 23	1.90	35
Cessna 195	1.87	4
Piper PA-28	1.79	316
Cessna 172	1.63	248
Cessna 182	1.57	122
Piper PA-24	1.57	41
Cessna 210/205	1.52	41
Navion	1.44	8
Cessna 150	1.35	279
Cessna 206	1.30	24
Mooney M-20	0.98	32
Beech 33, 35, 36	0.89	62

TABLE 14

STALL

AIRCRAFT	RATE	ACCIDENTS
Aeronca(Bellanca) 7	22.47	136
Aeronca 11	8.21	14
Taylorcraft(BC)	6.44	27
Piper J-3	5.88	51
Luscombe 8	5.78	32
Piper PA-18	5.49	114
Globe GC-1	5.15	10
Cessna 170	4.38	48
Grumman(Yankee)AA-1	4.23	49
Piper PA-12	3.27	14
Cessna 120/140	2.51	28
Globe(Stinson)108	2.09	11
Navion	1.81	10
Piper PA-22	1.78	36
Cessna 177	1.77	34
Grumman(Traveler)AA-5	1.76	12
Cessna 185	1.47	14
Cessna 150	1.42	292
Beech 23	1.41	26
Forney(Ercoupe)	1.29	8
Cessna 180	1.08	21
Piper PA-24	0.98	24
Beech 33, 35, 36	0.94	65
Cessna 175	0.83	5
Piper PA-28	0.80	140
Mooney M-20	0.80	26
Cessna 172	0.77	117
Cessna 210/205	0.71	19
Bellanca 14-19	0.60	4
Piper PA-32	0.57	12
Cessna 206	0.54	10
Cessna 195	0.47	1
Cessna 182	0.36	28

TABLE 15

ENGINE FAILURE

AIRCRAFT	RATE	ACCIDENTS
Globe GC-1	12.36	24
Globe(Stinson)108	10.65	56
Forney(Ercoupe)	9.50	59
Grumman(Yankee)AA-1	8.71	101
Navion	7.84	40
Piper J-3	7.61	66
Luscombe 8	7.58	42
Cessna 120/140	6.73	75
Piper PA-12	6.54	28
Bellanca 14-19	5.98	40
Piper PA-22	5.67	115
Cessna 195	4.69	10
Piper PA-32	4.39	93
Cessna 210/205	4.25	114
Aeronca(Bellanca) 7	4.23	95
Aeronca 11	4.10	7
Taylorcraft(BC)	3.81	16
Piper PA-24	3.61	94
Beech 23	3.58	66
Cessna 175	3.48	21
Mooney M-20	3.42	111
Piper PA-18	3.37	70
Cessna 177	3.33	64
Cessna 206	3.30	61
Cessna 180	3.24	63
Cessna 170	2.88	32
Cessna 185	2.73	26
Cessna 150	2.48	510
Piper PA-28	2.37	416
Beech 33, 35, 36	2.22	153
Grumman(Traveler)AA-5	2.20	15
Cessna 182	2.08	161
Cessna 172	1.41	214

TABLE 16

MIDAIR COLLISION

AIRCRAFT	RATE	ACCIDENTS
Luscombe 8	0.90	5
Piper PA-22	0.35	7
Aeronca(Bellanca) 7	0.31	7
Piper PA-18	0.30	6
Bellanca 14-19	0.30	2
Grumman(Traveler)AA-5	0.29	2
Cessna 150	0.27	56
Piper PA-28	0.23	41
Piper PA-24	0.23	6
Cessna 180	0.21	4
Globe(Stinson)108	0.19	1
Cessna 172	0.17	25
Cessna 175	0.16	1
Cessna 182	0.14	11
Beech 33, 35, 36	0.12	8
Piper J-3	0.12	1
Cessna 206	0.11	2
Cessna 185	0.10	1
Piper PA-32	0.09	2
Cessna 120/140	0.09	1
Cessna 170	0.09	1
Grumman(Yankee)AA-1	0.09	1
Cessna 210/205	0.07	2
Mooney M-20	0.06	2
Cessna 177	0.05	1

TABLE 17

IN-FLIGHT AIRFRAME FAILURE

AIRCRAFT	RATE	ACCIDENTS
Bellanca 14-19	1.49	10
Globe GC-1	1.03	2
Forney(Ercoupe)	0.97	6
Cessna 195	0.94	2
Navion	0.90	5
Aeronca 11	0.59	1
Beech 33, 35, 36	0.58	40
Luscombe 8	0.54	3
Piper PA-24	0.42	11
Cessna 170	0.36	4
Cessna 210/205	0.34	9
Cessna 180	0.31	6
Piper PA-22	0.30	6
Aeronca(Bellanca) 7	0.27	6
Beech 23	0.27	5
Cessna 120/140	0.27	3
Piper PA-32	0.24	5
Taylorcraft(BC)	0.24	1
Piper J-3	0.23	2
Mooney M-20	0.18	6
Piper PA-28	0.16	28
Cessna 177	0.16	3
Cessna 182	0.12	9
Cessna 206	0.11	2
Grumman(Yankee)AA-1	0.09	1
Cessna 172	0.03	4
Cessna 150	0.02	5

TABLE 18

GROUND LOOP

AIRCRAFT	RATE	ACCIDENTS
Cessna 195	22.06	47
Globe(Stinson)108	13.50	71
Luscombe 8	13.00	72
Cessna 170	9.91	110
Cessna 120/140	8.99	87
Aeronca 11	7.86	73
Aeronca(Bellanca) 7	7.48	168
Cessna 180	6.49	126
Cessna 185	4.72	45
Piper PA-12	4.67	20
Piper PA-18	3.90	81
Taylorcraft(BC)	3.58	15
Globe GC-1	3.09	6
Grumman(Yankee)AA-1	2.85	33
Piper PA-22	2.76	56
Forney(Ercoupe)	2.74	17
Beech 23	2.33	43
Bellanca 14-19	2.10	14
Piper J-3	2.07	18
Cessna 206	1.73	32
Cessna 177	1.61	31
Grumman(Traveler)AA-5	1.47	10
Piper PA-32	1.42	30
Cessna 150	1.37	281
Piper PA-28	1.36	239
Piper PA-24	1.29	33
Cessna 210/205	1.08	29
Cessna 182	1.06	82
Cessna 172	1.00	152
Mooney M-20	0.65	21
Beech 33, 35, 36	0.55	38
Navion	0.36	2
Cessna 175	0.17	3

TABLE 19

HARD LANDING

AIRCRAFT	RATE	ACCIDENTS
Beech 23	3.50	66
Grumman(Yankee)AA-1	3.02	35
Forney(Ercoupe)	2.90	18
Cessna 177	2.60	50
Globe GC-1	2.58	5
Luscombe 8	2.35	13
Cessna 182	2.17	168
Cessna 170	1.89	21
Beech 33, 35, 36	1.45	20
Cessna 150	1.37	282
Cessna 120/140	1.35	15
Cessna 206	1.30	24
Piper PA-24	1.29	13
Aeronca(Bellanca) 7	1.20	27
Piper J-3	1.04	9
Grumman(Traveler)AA-5	1.03	7
Cessna 175	1.00	6
Cessna 180	0.93	18
Cessna 210/205	0.82	22
Piper PA-28	0.81	142
Cessna 172	0.71	107
Piper PA-22	0.69	14
Taylorcraft(BC)	0.48	2
Cessna 195	0.47	1
Piper PA-18	0.43	9
Piper PA-32	0.42	9
Cessna 185	0.42	4
Navion	0.36	2
Mooney M-20	0.31	10
Piper PA-12	0.23	1
Globe(Stinson)108	0.19	1

TABLE 20

OVERSHOOT

AIRCRAFT	RATE	ACCIDENTS
Grumman(Traveler)AA-5	2.35	16
Cessna 195	2.34	5
Beech 23	1.95	36
Piper PA-24	1.61	42
Piper PA-22	1.33	29
Cessna 175	1.33	8
Globe(Stinson)108	1.33	7
Cessna 182	1.21	94
Aeronca 11	1.17	2
Luscombe 8	1.08	6
Piper PA-32	1.03	22
Globe GC-1	1.03	2
Mooney M-20	1.01	33
Cessna 172	1.00	152
Cessna 170	0.99	11
Grumman(Yankee)AA-1	0.95	11
Piper PA-12	0.93	4
Cessna 210/205	0.89	24
Cessna 177	0.88	17
Piper PA-18	0.81	17
Cessna 206	0.81	15
Piper PA-28	0.80	141
Cessna 120/140	0.71	8
Forney(Ercoupe)	0.64	4
Bellanca 14-19	0.60	4
Cessna 180	0.56	11
Navion	0.54	3
Aeronca(Bellanca) 7	0.48	11
Cessna 150	0.35	73
Piper J-3	0.34	3
Cessna 185	0.31	3
Beech 33, 35, 36	0.23	16

TABLE 21

UNDERSHOOT

AIRCRAFT	RATE	ACCIDENTS
Forney(Ercoupe)	2.41	15
Luscombe 8	1.62	9
Piper PA-12	1.40	6
Globe GC-1	1.03	2
Cessna 175	0.99	6
Grumman(Yankee)AA-1	0.95	11
Taylorcraft(BC)	0.95	4
Piper PA-22	0.83	17
Piper PA-32	0.70	15
Bellanca 14-19	0.60	4
Aeronca 11	0.59	1
Piper PA-28	0.59	105
Aeronca(Bellanca) 7	0.59	13
Piper PA-24	0.57	15
Piper J-3	0.57	5
Globe(Stinson)108	0.57	3
Cessna 120/140	0.53	6
Cessna 195	0.47	1
Grumman (Traveler) AA-5	0.44	3
Piper PA-18	0.43	9
Beech 23	0.43	8
Cessna 185	0.41	4
Mooney M-20	0.37	12
Cessna 170	0.36	4
Navion	0.36	2
Cessna 150	0.35	72
Cessna 210/205	0.33	9
Cessna 206	0.32	6
Cessna 172	0.26	40
Cessna 182	0.24	19
Beech 33, 35, 36	0.21	15
Cessna 180	0.15	3
Cessna 177	0.10	2

TABLE 22. AIRC

	COLLISION WITH GROUND OR WATER			COLLISION WITH OBSTACLES			
	Low Accident Rate Group	Middle Accident Rate Group	High Accident Rate Group	Low Accident Rate Group	Middle Accident Rate Group	High Accident Rate Group	Low Acc Rate G
No. of Aircraft	10	11	11	11	11	11	
No. of Accidents •	567	262	271	1,177	399	380	
No. of Flying Hours	66,196,666	21,317,342	15,600,913	79,041,190	14,766,511	9,477,796	58,745
Mean Accident Rate Per 100,000 Hours	0.86	1.23	1.74	1.49	2.70	4.01	
Landing Gear							
Tailwheel	4	3	6	1	4	9	
Tricycle	6	8	5	11	7	2	
Wing Configuration							
High Wing	8	5	7	6	7	8	
Low Wing	2	6	4	5	4	3	
Average Dates of Initial Model Production	1954	1959	1946-1947	1955-1956	1957	1946	
Manufacturer							
Beech	1	1	-	1	1	-	
Bellanca	-	-	2	-	1	1	
Cessna	6	5	1	6	5	1	
Grumman	-	2	-	-	1	1	
Mooney	-	-	1	1	-	-	
Piper	2	2	3	2	2	3	
Other	1	1	4	1	1	5	

	INFLIGHT AIRFRAME FAILURES			GROUND LOOP			
	Low Accident Rate Group	Middle Accident Rate Group	High Accident Rate Group	Low Accident Rate Group	Middle Accident Rate Group	High Accident Rate Group	Low Acci Rate Gr
No. of Aircraft	9	9	9	11	11	11	
No. of Accidents	60	45	80	910	275	900	
No. of Flying Hours	70,045,513	15,506,537	12,469,488	79,700,198	12,250,993	11,334,306	27,699,
Mean Accident Rate Per 100,000 Hours	0.09	0.29	0.64	1.14	2.24	7.94	0
Landing Gear							
Tailwheel	1	5	4	-	3	11	
Tricycle	8	4	5	11	8	-	
Wing Configuration							
High Wing	6	7	3	5	5	11	
Low Wing	3	2	6	6	6	-	
Average Dates of Initial Model Production	1958-1959	1952	1946-1947	1957	1954-1955	1947	1!
Manufacturer							
Beech	-	1	1	1	1	-	
Bellanca	-	1	1	-	1	1	
Cessna	5	4	1	5	2	5	
Grumman	1	-	-	-	2	-	
Mooney	1	-	-	1	-	-	
Piper	2	2	1	3	2	2	
Other	-	1	5	1	3	3	

22. AIRCRAFT SUMMARY DATA FOR ACCIDENT TYPE.

	STALL (ALL)			ENGINE FAILURE			MIDAIR COLLISION		
ccident Group	Low Accident Rate Group	Middle Accident Rate Group	High Accident Rate Group	Low Accident Rate Group	Middle Accident Rate Group	High Accident Rate Group	Low Accident Rate Group	Middle Accident Rate Group	High Ac Rate
11	11	11	11	11	11	11	9	8	
380	427	488	523	1,715	697	646	11	53	
77,796	58,745,768	34,200,997	10,338,732	76,356,734	18,214,945	8,713,818	4,303,854	35,578,006	48,96
4.01	0.73	1.43	5.06	2.25	3.83	7.41	0.08	0.15	
9 2	1 10	3 8	10 1	3 8	5 6	6 5	3 5	3 5	
8 3	6 5	6 5	9 2	8 3	7 4	6 5	5 3	7 1	
1946	1956	1956	1948	1959	1953	1946-1947	1959	1952-1953	1953
- 1 1 1 - 3 5	1 1 6 - 1 2 -	1 - 4 1 - 2 3	- 1 2 1 - 3 4	1 - 8 1 - 1 -	1 1 3 - 1 3 2	- 1 1 1 - 3 5	1 - 5 1 1 1 -	- - 5 - - 1 1	

	HARD LANDING			OVERSHOOT			UNDERSHOOT		
cident Group	Low Accident Rate Group	Middle Accident Rate Group	High Accident Rate Group	Low Accident Rate Group	Middle Accident Rate Group	High Accident Rate Group	Low Accident Rate Group	Middle Accident Rate Group	High Ac Rate
11	10	11	11	11	11	10	11	11	
900	160	283	678	277	308	245	184	172	
4,306	27,699,618	32,162,619	42,583,361	53,970,693	31,922,590	16,972,779	61,159,842	30,697,520	11,42
7.94	0.58	0.88	1.59	0.51	0.96	1.44	0.30	0.56	
11 -	6 5	4 6	3 7	5 6	4 7	4 6	2 9	7 4	
11 -	8 3	7 3	5 5	6 5	7 4	7 3	8 3	7 4	
1947	1951	1955-1956	1953-1954	1950	1957	1952	1956	1954	
- 1 5 - - 2 3	- - 3 - 1 4 3	- 1 5 1 - 3 -	2 - 4 1 - - 3	1 2 4 - - 2 2	- - 5 1 1 3 1	1 - 3 1 - 2 3	1 - 8 - 1 - 1	1 1 3 1 - 4 1	

Data on in-flight airframe failures also show a relationship between the high-rate group and older model aircraft flown fewer hours. There does not appear to be a strong association with a particular landing gear or wing configuration.

Examination of the data in Tables 17 and Table 22 shows that the high-rate in-flight airframe failure group contains six older, out-of-production aircraft and three other aircraft, the Bellanca 14-19, (including the 17-30 and 17-31 series); the Beech Bonanza models 33, 35, and 36; and the Piper PA-24. The six older, out-of-production aircraft account for only 19 in-flight airframe failures and are part of the high-rate group because of the relatively few hours flown annually. The latter three aircraft account for 61, or more than three-fourths, of the 80 in-flight airframe failure accidents of the high-rate group and about one-third of all the 185 airframe failure accidents involving aircraft of the selected group. All three of these aircraft have in-flight airframe failure accident rates significantly higher than the mean rate of 0.18 for the 33 selected aircraft: The Bellanca 14-19 rate is more than eight times the mean rate, the Beech 33, 35, and 36 rate is more than three times the mean rate, and the Piper PA-24 rate is more than twice the mean rate. These high rates of in-flight airframe failures will be discussed later. The mean in-flight airframe failure rate of the high-rate group is seven times that of the low-rate group.

The data in Table 22 show a relationship between ground loops and older model aircraft associated with fewer hours flown in these aircraft. More significantly, ground loop accidents correlate highly with tailwheel aircraft, a fact which comes as no surprise. The high-rate group consisted of 11 aircraft with tailwheels and no tricycle aircraft, while just the reverse was true of the low-rate group. Also, the aircraft in the high-rate group were all high-wing aircraft. Further, the high-rate group contains five aircraft manufactured by the Cessna Aircraft Company and only two Piper-built aircraft. The mean ground loop accident rate for the high-rate group is seven times greater than that of the low-rate group.

The data in Table 22 do not indicate a relationship between rate of hard landings, hours flown, and age of aircraft. In fact, the aircraft group with the most total hours flown is the high-rate group. The high-rate group has more tricycle gear aircraft than tailwheel aircraft, but the distribution with hard landing accident rate does not indicate as strong a relationship between hard landings and tricycle gear as was indicated in Table 22 between ground loops and tailwheels. It is also significant that the mean hard landing accident rate for the high-rate group is only 2.7 times as great as that of the low-rate group, compared with the ratio of 7 to 1 between the high- and the low-rate groups in ground loop accidents. Another feature is the absence of any Piper-built aircraft in the high-rate group, which includes 4 of the 12 Cessna-built aircraft and both of the aircraft built by Beech. However, no distinct trends in aircraft characteristics appear to exist in hard landing accidents. This suggests that the pilot's role is dominant in this accident type.

The data for overshoot and undershoot accidents provide little additional information. Neither accident type appears to be related to aircraft model design, age, or configuration. There does not appear to be any significant relationship between the high-rate group and aircraft manufacturer. However, the low-rate group in undershoot accidents includes seven Cessna aircraft and no Piper aircraft. The mean rates of the high-rate groups for undershoots and overshoots are about 2.5 times greater than the mean rates of the lower groups.

In six of the accident types, the high-rate group is associated with older aircraft which are flown considerably less each year than the lower rate groups. Five of these six accident types -- collision with ground or water, collision with obstacles, stall, engine failure, and in-flight airframe failure — are the most severe accident types. This observation is compatible with the previous observations relating older model aircraft with high accident rates and high fatal accident rates.

An interesting feature of ground loops, hard landings, and overshoots is the inclusion in the higher accident rate categories of more Cessna-built aircraft than was the case for the first five accident types (at least three Cessna aircraft were included in the high-rate categories in these three landing-type accidents). These three accident types are not only less severe in general than the first five accidents, but are more generally thought to be associated with low pilot flight experience and perhaps even with instructional flying.

Pilot Time

In examining the effect on accidents of pilot experience, three relevant experience factors were shown by the frequency distribution studies to be present in a sufficiently high percentage of the accident records to be representative of the accident population. They were pilot total time, pilot time in type, and pilot time in the last 90 days. It was necessary to segment into discrete increments of time the relatively continuous distributions of these three categories of pilot flight time to analyze these data. Pilot-time-in-type and pilot-time-in-the-last-90-days distributions generally have been segmented into time increments of 1 to 25 hours, 26 to 100 hours, 101 to 200 hours, and more than 200 hours. Pilot total time generally has been segmented into time increments of 1 to 50 hours, 51 to 100 hours, 101 to 200 hours, 201 to 500 hours, and more than 500 hours.

In analyzing the relationships of these three categories of pilot experience to accidents involving the 33 selected aircraft, the distributions observed in the accident records must be compared with an expected distribution. The expected distribution should be the flight experience distributions of the entire pilot population flying the 33 selected aircraft. No data of this type, however, are collected by the FAA or any other source known to the Safety Board.

The importance of this exposure data to the analysis of the relationship of the pilot-to-aircraft factors involved in accidents cannot be overstated. Many facets of the pilot factor, including experience, training, age, occupation, type certificate, and rating could be examined in relation to the specific aircraft makes, models, or designs identified with accidents. Exposure data are required before comparisons can be made. Whether pilots with 1 to 25 hours time in type have more difficulty with certain makes, models, or designs of aircraft than pilots with more than 200 hours time in type cannot be determined without knowing how many hours are flown annually by all pilots with 1 to 25 hours in type and by all pilots with more than 200 hours in type. The same is true for any of the accident comparisons of pilot factors mentioned above. Many attempts were made in this study to analyze the effects on accidents of these various pilot factors without these exposure data. Accident distributions of pilots with low and high flight experience in certain categories of aircraft were compared with accident distributions of similar pilot categories for the total 33 aircraft. It was determined that the conclusions drawn from these comparisons were potentially misleading. Appropriate exposure data are essential so that comparisons can be made on a rate basis. A comparison which provides some insight into the relationship of pilot experience and accidents is presented in Appendix B.

Environment

The Safety Board concluded that weather was a cause or related factor in 3,438 accidents, or 25.3 percent of the 13,571 accidents involving those 33 aircraft makes and models where causal assignment was made. Weather was a cause or related factor in 970 fatal accidents or 44.7 percent of the 2,172 fatal accidents involving the 33 aircraft makes and models where causal assignment was made by the Safety Board. It is significant that weather involvement is substantially greater in fatal accidents than in nonfatal accidents where weather is assigned as a cause or factor in 2,393, or only 21.7 percent, of the 11,399 nonfatal accidents with causal assignment.

Table 23 presents the type of weather conditions involved with total accidents and fatal accidents ranked on the basis of the number of accidents involved with each type of accident. The accident rate per 100,000 flying hours for each type of weather condition is also presented. Unfavorable wind conditions is the most frequently occurring weather condition assigned as a cause or factor in accidents involving the 33 aircraft and is the least important of the 10 weather conditions in fatal accidents. Unfavorable wind conditions are often involved with nonfatal accident types such as ground loops. Low ceiling, fog, and rain--the second, third, and fourth most frequent weather conditions involved with all accidents -- are the most frequent types of weather condition assigned in fatal accidents involving the 33 aircraft.

Terrain was assigned as a cause or a factor in 4,182 accidents or 32.1 percent of the 13,571 accidents involving the 33 selected aircraft where a causal assignment was made. Terrain was a cause or factor in 609 or 28.0 percent of the 2,172 fatal accidents involving these aircraft where causal assignment was made by the Safety Board. Unlike weather, terrain had a lesser association with fatal accidents than with nonfatal accidents (terrain was involved in 3,753 or 32.9 percent of the nonfatal accidents).

TABLE 23

ACCIDENTS AND FATAL ACCIDENTS
WHERE WEATHER WAS A CAUSE OR FACTOR
33 SELECTED AIRCRAFT

TOTAL ACCIDENTS

Weather Conditions	Accidents	Rate
Unfavorable Wind Conditions	1,277	1.24
Low Ceiling	813	0.79
Fog	582	0.56
Rain	321	0.31
High Density Altitude	318	0.31
Conditions Conductive to Carburetor/Induction System Icing	256	0.25
Downdrafts, Updrafts	230	0.22
Thunderstorm Activity	186	0.18
Snow	162	0.16
Icing Conditions (Sleet, Freezing Rain, etc.)	139	0.13

FATAL ACCIDENTS

Weather Conditions	Fatal Accidents	Rate
Low Ceiling	602	0.58
Fog	403	0.39
Rain	236	0.23
Thunderstorm Activity	109	0.11
Snow	107	0.10
High Density Altitude	85	0.08
Turbulence Associated with Clouds and/or Thunderstorms	82	0.08
Icing Conditions (Sleet, Freezing Rain)	71	0.07
Downdrafts, Updrafts	51	0.05
Unfavorable Wind Conditions	43	0.04

A ranking, by frequency of occurrence, of the major types of terrain conditions assigned by the Safety Board to an accident site is presented in Table 24 for total accidents and for fatal accidents. The accident rate per 100,000 flying hours also is provided. High obstructions is the most frequently occurring type of terrain condition involved with total accidents and with fatal accidents. In fact, in over 85 percent of fatal accidents where terrain is a cause or factor, high obstructions are the terrain condition involved. Rough or uneven terrain is the second most frequent terrain condition involved in total accidents but is third on the fatal accident list — accounting for less than 3 percent of the terrain-caused assignments in fatal accidents.

TABLE 24

ACCIDENTS AND FATAL ACCIDENTS
WHERE TERRAIN WAS A CAUSE OR FACTOR
33 SELECTED AIRCRAFT

TOTAL ACCIDENTS

Terrain Conditions	Accidents	Rate
High Obstructions	2,140	2.07
Rough/Uneven Terrain	990	0.96
Other	493	0.48
Wet, Soft Ground	338	0.33
High Vegetation	238	0.23
Snow-Covered	148	0.14
Sandy	80	0.08

FATAL ACCIDENTS

Terrain Conditions	Fatal Accidents	Rate
High Obstructions	532	0.52
Other	57	0.06
Rough/Uneven	14	0.01
Snow-Covered	6	0.01
Sandy	3	-
Water (Glassy and Rough)	3	-
High Vegetation	2	-

Section II

SELECTED AIRCRAFT MAKE AND MODEL FINDINGS

The Safety Board analyses presented in the previous section regarding the relationship of aircraft make, model, and configuration with accidents, fatal accidents, and specific types of accidents show that:

1. Landing gear configuration is associated with --
   a. accidents in general,
   b. collisions with obstacles,
   c. stalls, and
   d. ground loops.

2. Wing configuration appears to be less of a factor in accidents than landing gear configuration.

3. Cessna-built aircraft have a lower mean fatal accident rate than aircraft manufactured by Beech, Bellanca, Grumman, Mooney, and Piper and appear to be associated with lower rates of severe types of accidents.

4. Older model aircraft (aircraft for which initial design and production took place more than 25 years ago) and especially out-of-production aircraft appear to be associated with high rates of --
   a. accidents in general,
   b. most of the severe and thus fatal accidents, and
   c. ground loop accidents (most older aircraft have tailwheels).

5. Along with six older model aircraft no longer in production, the Bellanca 14-19 (including 17-30 and 17-31 series models), the Beech Bonanza (models 33, 35, and 36), and the Piper PA-24 aircraft appear to be associated with high rates of in-flight airframe failure accidents.

6. The Cessna-150 and the Piper PA-28 appear to be associated with a large number of midair collisions.

7. Aircraft with low engine horsepower-to-aircraft weight appear to be associated with high rates of stalls (these are often older aircraft).

Three accident types — ground loops, in-flight airframe failures, and stalls-- have a sizable difference in accident rates between the low-rate and high-rate groups; the ratio of the rates of the two groups is seven or more.

Landing Gear Configuration

Of the 33 selected aircraft, 19 are configured with a tricycle landing gear while 14 are configured with tailwheel landing gear. As the following tabulation of total accidents and fatal accidents in the period 1972 through 1976 shows, the mean accident rate for the group of aircraft with tailwheels is more than twice that of the group of aircraft with tricycle landing gear:

TABLE 25

EFFECT OF INSTRUCTIONAL FLYING ON TAILWHEEL - TRICYCLE

	Total Flying Hours	Accidents/ Rate	Fatal Accidents/Rate	Fatalities Rate
Tailwheel Aircraft	12,815,496	3,434 26.80	422 3.29	650 5.07
Tricycle Gear Aircraft	90,470,001	10,501 11.61	1,829 2.02	3,688 4.08

The fatal accident rate for the tailwheel aircraft group is only about 50 percent higher. Thus, tailwheel aircraft appear to be involved in a higher percentage of relatively minor accidents than tricycle gear aircraft. Also, as previously observed, most tailwheel aircraft, excluding those designed specifically for aerial application, are older than, and not flown as often as, aircraft with tricycle landing gear. These observations could indicate that low pilot time in type or low pilot time recently obtained could be factors in tailwheel aircraft accidents. Other factors such as type of flying, operation from unimproved airfields, and level of maintenance (including availability of parts) could be involved.

A further observation is that most single-engine aircraft flight training is conducted in aircraft with tricycle landing gear. During 1972 through 1976, the 19 tricycle aircraft examined in this study were flown over 22 million hours in instructional flying while the 12 tailwheel aircraft examined were flown only slightly more than a half million hours in instructional flying. This, in conjunction with the fact that the accident rate for instructional flying is lower than the overall general aviation accident rate 5/ could account for a part of this difference between accident rates for tailwheel and tricycle gear aircraft. The accident rate for the 1972 through 1976 period, excluding instructional accidents and flying hours, is shown in Table 25. Although instructional flying did have some effect on the accident rate comparison between tailwheel and tricycle gear aircraft, the effect was not large. With instructional flying excluded, the accident rate for tailwheel aircraft was still more than twice that of the tricycle gear aircraft group.

Table 26 presents a comparison of the rates per 100,000 flying hours of each of the 10 types of accidents for tailwheel aircraft and tricycle gear aircraft. Clearly, tailwheel aircraft are far more closely associated with ground loops than are tricycle gear aircraft. The ground loop rate for tailwheel aircraft is almost seven times that of the tricycle gear aircraft. This considerable difference in the rate of occurrence of these less severe accidents undoubtedly is associated with the fact that the ratio of total accident rate is greater than the ratio of fatal accident rate for the two aircraft groups.

Table 26 also shows that the rates of the first six accident types (these are the more severe accident types) of the tailwheel group are higher than those of the

5/ NTSB Annual Review of Aircraft Accident Data, U.S. General Aviation, Calendar Year 1976.

TABLE 25

EFFECT OF INSTRUCTIONAL FLYING ON TAILWHEEL - TRICYCLE
ACCIDENT RATE COMAPRISON

	Tailwheel Aircraft			Tricycle Gear Aircraft		
	Accidents	Flying Hours	Accident Rate	Accidents	Flying Hours	Accident Rate (per 100,000 Hrs.)
All Flying Accidents	3,434	12,815,496	26.8	10,501	90,470,001	11.61
Instructional Accidents	333	531,020		2,232	22,200,230	
Accidents Less Instructional Accidents	3,101	12,284,476	25.24	8,269	68,269,771	12.11

TABLE 26

COMPARISON OF ACCIDENT TYPES FOR TAILWHEEL AND TRICYCLE GEAR AIRCRAFT

Type Accident	Tricycle Gear		Tailwheel	
	Accidents	Rate	Accidents	Rate
Collision with Ground/Water	875	0.96	188	1.46
Collision with Obstacles	1,497	1.65	459	3.58
Stall	917	1.01	521	4.06
Engine Failure	2,448	2.70	610	4.76
In-Flight Airframe Failure	155	0.17	30	0.23
Midair Collision	169	0.18	27	0.21
Ground Loop	1,146	1.26	939	7.32
Hard Landing	995	1.09	126	0.98
Undershoot	376	0.42	70	0.55
Overshoot	740	0.82	90	0.70

tricycle gear group. Further, the rate of stall accidents, in particular, is considerably higher for the tailwheel group. One possible factor contributing to this difference in stall accident rates is the higher mean power loading of the tailwheel group. The mean power loading (pounds/horse power)for the tailwheel group is approximately 15.9 lbs/hp or about 18 percent higher than the 13.4 lbs/hp mean power loading of the tricycle group. Another possible factor is that the tailwheel aircraft group has a higher rate per 100,000 flying hours of assignment of the cause/factor "unwarranted low flying"--1.10 vs. 0.31. Further, they are involved in more aerial application "kind of flying" than are the tricycle group, even though there are no aircraft in either group of the 33 selected aircraft designed for aerial application flying.

Various pilot factors such as flight time, age, certificate, and ratings could also account for some for these differences in the accident rates. A ranking of accident types by pilot experience for both landing gear configurations is presented in Appendix C. However, without exposure data, the analyses which might provide real insight into the relation of the pilot to these differences between tailwheel aircraft and tricycle gear aircraft cannot be performed.

The effect of weather and terrain on the accident rates of the tailwheel and the tricycle gear group has also been reviewed. Weather was assigned as a cause or factor in 724 or 23.9 percent of the 3,027 accidents involving tailwheel aircraft where causal assignment was made. Weather was a cause or factor in 2,629 or 25.8 percent of the 10,180 tricycle aircraft accidents where causal assignment was made. The tailwheel group was involved in 101 fatal weather-related accidents or 26.6 percent of the total accidents where causal assignment was made. The tricycle group was involved in 859 fatal weather-related accidents or 48.8 percent of the total accidents where causal assignment was made. Weather seems to have been a more important factor in fatal accidents involving tricycle aircraft than it was for the tailwheel group. This could be related, in part, to more extensive use of tricycle aircraft in cross-country flight and greater use of tailwheel aircraft locally.

Terrain was a cause or factor in 29.8 percent of the accidents where causal assignment was made involving the tailwheel group and 32.2 percent of the accidents involving the tricycle group. Terrain was a cause or factor in 20.0 percent of the fatal accidents involving tailwheel aircraft, and 29.8 percent of the fatal accidents involving the tricycle group. Detailed weather and terrain cause/factors were examined but did not provide further insight into these statistics. Unfavorable wind conditions and low ceiling were dominant weather conditions in total accidents, and low ceiling and fog the dominant weather conditions in fatal accidents for both aircraft groups. "High obstructions" was the dominant terrain type for both fatal and nonfatal accidents for both aircraft groups. The broad and detailed cause/factor tables for the accidents involving both the tailwheel and the tricycle aircraft groups were generated and reviewed. No obvious reasons for the differences in accident rates were readily apparent.

Fatal Accident Comparison by Manufacturer

A comparison of the mean fatal accident rates of the selected single-engine aircraft manufactured by the six companies included in this study currently producing such aircraft (Beech, Bellanca, Cessna, Grumman, Mooney, and Piper) is presented in Table 27. The mean fatal accident rate of the Cessna-built aircraft (1.65) is lower than the mean rate of each of the other five manufacturers' aircraft. Significance tests indicate that the Cessna rate is different from the others at a level of at least 0.005. The mean fatal accident rates of Beech, Mooney, and Piper are almost the same (approximately 2.50) and the rates of Grumman and Bellanca are considerably higher (4.13 and 4.84, respectively). The mean fatal accident rate of the group of 33 selected aircraft is 2.18. Thus, the Cessna mean fatal accident rate is lower than the mean rate of the 33 selected aircraft while the mean rates of the other five manufacturers are higher than the mean rate of the 33 selected aircraft.

Table 28 presents a comparison by accident type of the mean accident rates per 100,000 flying hours for each of the six manufacturers. The Cessna aircraft have a lower mean accident rate than those of the other manufacturer's aircraft for most of the first four type of accidents listed in Table 28 (the accident types accounting for most of the fatal accidents). The only exceptions are Beech and Mooney, both of which have lower mean rates of occurrence of collisions with obstacles and stalls. However, both of these manufacturers have higher rates of collisions with ground or water and a higher rate of engine failures than the Cessna aircraft.

The effects of weather and terrain have been examined. In addition, the broad and detailed cause/factor tables for the accidents involving these aircraft were generated and reviewed. No obvious explanations of the differences in fatal accident rates between these groups of aircraft were apparent.

One factor which immediately stands out as a possible unique contributor to the difference in fatal accident rates is the exposure of these aircraft to accident risk, i.e., the number of flight hours. The data in Table 27 indicate a substantial difference in the number of hours flown over the 5-year period in aircraft built by the 6 manufacturers, ranging from a low of about 1.84 million hours in the 2 Grumman aircraft to a high of 55.82 million hours in the 12 Cessna aircraft.

Aircraft manufactured by Cessna and by Piper were flown a large number of hours and significantly more than the aircraft of the other manufacturers; these two manufacturers' aircraft accounted for almost 81 percent of the hours flown by the 33 selected aircraft and 72 percent of the hours flown in the entire active single-engine fleet during the 5-year period. Thus, a comparison of the accident data involving the aircraft included in this study of these two manufacturers should discount, to a large extent, the effects of exposure time and enable the factors associated with the low Cessna fatal accident rate to be elicited, if possible.

TABLE 27

FATAL ACCIDENT RATE COMPARISON BY MANUFACTURER

	Fatal Accidents	Flying Hours (In 100,000's)	Mean Fatal Accident Rate (Per 100,000 Hrs.)
Beech	222	87.372	2.54
Bellanca	141	29.159	4.84
Cessna	923	558.178	1.65
Grumman	76	18.389	4.13
Mooney	79	32.433	2.50
Piper	687	276.953	2.48

The number of fatal accidents shown for each manufacturer is the total of the number of fatal accidents for each model produced by that manufacturer included in this study.

TABLE 28

MANUFACTURER'S MEAN ACCIDENT RATE COMPARISON BY ACCIDENT TYPE

	BEECH	BELLANCA	CESSNA	GRUMMAN	MOONEY	PIPER
	8.74*	2.92*	55.82*	1.84*	3.24*	27.70*
Collision w/Ground/Water	0.98	1.99	0.87	1.20	1.42	1.16
Collision w/Obstacles	1.11	3.53	1.67	3.10	0.99	2.24
Stall	1.04	4.80	1.11	3.32	0.80	1.41
Engine Failure	2.51	4.63	2.42	6.31	3.42	3.18
In-flight Airframe Failure	0.52	0.55	0.08	0.05	0.18	0.19
Midair Collision	0.09	0.31	0.19	0.16	0.06	0.23
Ground Loop	0.93	6.24	1.84	2.34	0.65	1.72
Hard Landing	0.98	0.93	1.29	2.28	0.31	0.72
Overshoot	0.38	0.58	0.75	0.76	0.06	0.93
Undershoot	0.60	0.51	0.31	1.47	1.02	0.62

* Flying Hours in Millions of Hours

The Cessna-built aircraft were flown about twice the number of hours flown in Piper-built aircraft. However, this factor should not have a significant effect on accident or fatal accident rate comparisons since both groups of aircraft were flown so extensively during the 1972 through 1976 period.

Conceivably, the larger amount of instructional flying performed in Cessna-built aircraft (since the fatal accident rate in instructional flying is known to be very low) could have an effect on this difference in fatal accident rate. Table 29 shows the effect of instructional flying on the fatal accident rates of these two groups of aircraft. Eliminating instructional flying does decrease somewhat the difference in fatal accident rates. However, the fatal accident rate for the Piper-built aircraft remains approximately 42 percent higher than the fatal accident rate of the Cessna-built group when instructional flying is eliminated.

Differences in the pilot groups flying the aircraft manufactured by the Piper Aircraft Corporation and by the Cessna Aircaft Company could possibly account for a part or even all of the differences in the fatal accident rates of these two groups of aircraft. A ranking of accident types by pilot experience for Cessna-built aircraft and Piper-built aircraft is presented in Appendix D. Again, lacking exposure data, the ranking of accident types by category of pilot flight time for each aircraft group remains the only pilot data that can be reviewed.

Obviously, it would be desirable to learn what unique factors or characteristics associated with the Cessna aircraft, their pilot population, or the operation and usage of the aircraft, including the environment, contribute to the lower Cessna mean fatal accident rate.

Age of Aircraft

The analysis of additional data including ranking of accident type by pilot experience categories, weather and terrain involvement, and a brief review of the cause/factor tables failed to provide any additional insight into the apparent relation between a high accident rate and older model aircraft. It is conceivable that a correlation exists between accidents involving older model aircraft and inferior maintenance, servicing, inspection, product support, pilot familiarity with the aircraft, and perhaps even high power loading. However, additional research will be required to understand these observations and generate the proper remedial action.

In-flight Airframe Failures

The 33 selected aircraft were involved in 185 in-flight airframe failures from 1972 through 1976. The mean rate of in-flight airframe failures was 0.18 per 100,000 flying hours. Three aircraft, the Bellanca 14-19, the Beech Models 33, 35, and 36, and the Piper PA-24 accounted for 61 or about 33 percent of these airframe failures. The Beech 33, 35, and 36 and the Piper PA-24 were both flown a substantial number of hours (6.8 and 2.6 million hours, respectively) during that period. The Bellanca 14-19 was flown less than 1 million hours (669,323 hours); however, it had the highest rate of in-flight airframe failures. The tabulation below compares these three aircraft with the total accidents and mean accident rate of the selected aircraft group:

TABLE 29

FATAL ACCIDENT RATES FOR SELECTED PIPER AND CESSNA AIRCRAFT, EXCLUDING INSTRUCTIONAL FLYING

SELECTED PIPER MODELS

	Fatal Accidents	Flying Hours	Mean Fatal Accident Rate (Per 100,000 Hrs.)
All Kinds of Flying	687	27,695,300	2.48
Instructional Flying	13	6,180,580	0.21
All Flying Except Instructions	674	21,514,720	3.13

SELECTED CESSNA MODELS

	Fatal Accidents	Flying Hours	Mean Fatal Accident Rate (Per 100,000 Hrs.)
All Kinds of Flying	923	55,817,800	1.65
Instructional	14	14,645,850	0.10
All Flying Except Instructional	909	41,171,950	2.21

	In-flight Airframe Failures	Rate
33 selected aircraft	185	0.18
Bellanca 14-19	10	1.49
Beech 33, 35, 36	40	0.58
Piper PA-24	11	0.42

It is clear that all three aircraft have in-flight airframe failure rates considerably higher than the mean rate of the selected aircraft group. The remaining six aircraft makes and models in the high-rate group of in-flight airframe failures are not being discussed because of the smaller number of airframe failures and hours flown and the fact that these aircraft are no longer in production.

It is significant that all 40 of the in-flight airframe failures of the Beech 33, 35, and 36 involved the V-tailed models (Beech 35). Obviously attention should be focused on this model.

In-flight airframe failures could be the result of many factors. Aircraft structural problems could be the cause. Operation of the aircraft beyond its capabilities is a possible pilot cause of these accidents, and weather could be a factor. Table 30 presents a comparison of five broad cause/factors for the three aircraft and the selected aircraft group. For both the Bellanca 14-19 and the Beech 33, 35 and 36, the percentage of fatal and total accidents (where causal assignment was made) was greater than that of the selected group where airframe, powerplant, and weather were assigned as a cause or factor (except for the Bellanca 14-9 total accidents involving weather). The significance of the higher assignment of these cause/factors is not known but certainly deserves additional attention because of the fatal nature of such accidents. The Piper PA-24 differs significantly from the selected group only in the greater percentage of assignment of weather as a cause/factor in fatal accidents. The following tabulation shows that all three models have a higher percentage of assignment to the miscellaneous acts and conditions category "separation in flight". However, the percentage of assignment of this detailed cause/factor is considerably higher for the Bellanca 14-19 and the Beech 33, 35, 36 than for the Piper PA-24.

	Separation in flight			
	Fatal Accidents	(percent)	Total Accidents	(percent)
33 Selected Aircraft Group	116	5.3	164	1.2
Bellanca 14-9	7	18.4	9	6.4
Beech 33, 35, 36	36	20.6	38	6.5
Piper PA-24	7	9.5	9	2.1

TABLE 30

BROAD CAUSE FACTORS COMPARING BELLANCA 14-19, BEECH 33, 35, 36 and PIPER PA-24

	PILOT		AIRFRAME		POWER PLANT		WEATHER		TERRAIN	
	Fatal	Total	Fatal	Total	Fatal	Total	Fatal	Total	Fatal	Total
33 Selected Aircraft	1,975 90.9%	11,912 87.8%	46 2.1%	125 0.9%	111 5.1%	1,515 11.2%	970 44.7%	3,438 25.3%	609 28.0%	4,362 32.1%
Bellanca 14-19	31 81.6%	115 82.1%	4 10.5%	6 4.3%	3 7.9%	19 13.6%	19 50.0%	31 22.1%	11 29.0%	50 35.7%
Beech 33, 35, 36	162 92.6%	492 83.7%	11 6.3%	13 2.2%	13 7.4%	98 16.7%	98 56.0%	172 29.3%	46 26.3%	161 27.4%
Piper PA-24	70 94.6%	361 83.8%	1 1.4%	5 1.2%	4 5.4%	55 12.8%	44 59.5%	91 21.4%	17 23.0%	97 22.5%

Without exposure data, it is not possible to assess the role of the pilot in these accidents. Further study of the detailed cause/factor tables provided no immediate answers. Again, the high-rate group were, on average, older model aircraft.

Midair Collisions

The only remarkable feature of the midair collisions and the selected aircraft is that 97 or about 50 percent of the 196 accidents involved the Cessna 150 and the Piper PA-28. Both of these aircraft are used extensively as trainers and thus often operate in the high density environment of airports. Additional research is needed to determine what portion of these accidents involve training and what portion do not involve training, whether the training flights were solo or dual, or whether these accidents result from training techniques or aircraft design such as limited visibility.

CONCLUSIONS

A number of observations were made in this study associating certain single-engine aircraft makes, models, and configurations with high rates of total accidents, fatal accidents, and specific accident types.

It was demonstrated that landing gear configuration is a factor in accidents. In particular, aircraft configured with tailwheels had an overall mean accident rate more than double that of aircraft with tricycle landing gear. Further, the mean accident rate of the tailwheel aircraft group was higher than that of the tricycle group for 8 of the 10 specific accident types examined, including all of the more severe accident types. The mean accident rate of the tailwheel group was especially high for ground loops, stalls, and collisions with obstacles. Weather and terrain involvement in total accidents for both groups did not appear to differ greatly. Weather and terrain was a more significant factor in fatal accidents involving the tricycle group than in the fatal accidents involving the tailwheel group. Also, unfavorable wind conditions appeared to be slightly more of a factor for tailwheel aircraft, which undoubtedly was related to the high rate of ground loops by this aircraft group.

The mean fatal accident rate per 100,000 hours of the Cessna-built aircraft included in this study (1.65) was significantly lower than the mean fatal accident rates of the other five manufacturers still producing aircraft—Beech (2.54), Bellanca (4.84), Grumman (4.13), Mooney (2.50), and Piper (2.48). Effects of weather and terrain were not remarkable. The lack of pilot exposure data precluded the assessment of the pilot factor; and the cause/factors did not help to explain the lower fatal accident rate of the Cessna-built aircraft.

The Bellanca 14-19, the Beech 35 (V-tail), and the Piper PA-24 accounted for about one-third of all in-flight airframe failures of the selected group of 33 single-engine aircraft. All three aircraft had in-flight airframe failure rates significantly higher than the mean rate of the selected group—the Bellanca 14-19 having the highest rate of all the aircraft at 1.49 per 100,000 flying hours. The Beech 35 (V-tail) models had the largest single number of such accidents (40) accounting for almost 22 percent of the group total. Airframe separation was assigned as a cause or factor in a significantly higher percentage of the fatal and nonfatal accidents involving the Bellanca 14-19 and the Beech 35 than the selected group. Weather was a more significant factor in fatal accidents involving these three aircraft than for the selected group and may be associated with the airframe failures.

The Cessna 150 and Piper PA-28 account for almost half of the midair collisions involving the selected group of aircraft. The influence of instructional flying on these accidents is not known, but it could be significant.

Older model aircraft appeared to be associated with high rates of fatal and nonfatal accidents. Many of the older aircraft are tailwheel-configured and the association with ground loop accidents was obvious. The high rate of stall accidents among older aircraft and among tailwheel aircraft was possibly related to higher power loading.

It was not possible to assess the significance of the pilot's role in any of these observations because of the lack of appropriate flight exposure data. A precise understanding of the observations and, thus, the development of remedial action will depend on determining the role of the pilot. Thus, the Safety Board concludes that the Federal Aviation Administration should begin to collect adequate exposure data.

All of the above findings are the result of numerous factors including the pilot, the type of usage the aircraft receive, the manner in which the aircraft are operated, and the aircraft engineering design and fabrication methods. Additional research is required by the appropriate governmental agencies and the aircraft manufacturers if the issues described above are to be resolved.

RECOMMENDATIONS

Based on the results of this study, the National Transportation Safety Board recommended that the Federal Aviation Administration:

> "Generate, through a stratified sampling of general aviation pilots, the date, duration, aircraft make and model, the geographical location of the flight, and the flight time in IFR, high density altitude, and wind conditions, all on a per flight basis; the data collected should include the pilot's total time, time in each type aircraft flown, age, occupation, certificate, and medical waivers. (Class II, Priority Action) (A-79-44)"

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PHILIP A. HOGUE
Member

APPENDIX A

Change in Exposure Data Collection Process

Data on the annual number of hours flown in all general aviation aircraft by make and model and for specific kinds of flying were obtained from the FAA. Before 1977, the FAA requested this exposure data on the same form used annually by all aircraft owners to revalidate their aircraft registration. However, beginning in 1977, the FAA announced a new program for collecting exposure information on general aviation operations. This new statistical sampling procedure involved a survey questionnaire mailed to a random sample of 31,000—about 15 percent-- of general aviation aircraft owners. The survey solicited information relating to hours flown, aircraft location, and other pertinent data. The FAA has found discrepancies between the results of this new survey technique and estimates based on the historical data collected using the prior methodology.

The errors in the exposure data used in this report have been determined by the FAA to amount to less than 4 percent over the period of this study. The Safety Board believes that these errors do not significantly affect the findings of this report. Further, these exposure data were the only such data available.

APPENDIX B

Pilot Time as a Factor in Single-Engine Accidents

One comparison which can provide some insight into the effect of experience on accidents is presented in Tables B1 through B3. Table B1 presents, for the 33 selected aircraft, the distribution of accident type by various categories of pilot total time. Table B2 presents the same type of data for categories of pilot time in type and Table B3 presents the data for categories of pilot time in the last 90 days.

The tables show which accident type is most prevalent for each experience category of pilots. For example, the most prevalent accident type for pilots with 1 to 50 hours total time is ground loops, followed by hard landings and engine failures. The most prevalent accident type for experienced pilots (pilots with greater than 500 total hours flight experience) is engine failures, followed by collisions with obstacles and then ground loops. From Table B2, it can be seen that for pilots with 1 to 25 hours time in type, ground loops are again first, but engine failures are second, and hard landings are third. The first three accident types for the pilots with high experience in type are the same as those for the high total time pilots.

The particular format used in presenting the data in Tables B1-B3 (listing the accident types and providing the number of accidents in parentheses) was chosen to emphasize the fact that the number of accidents of a specific type cannot be compared meaningfully between pilot experience categories. These data can only be compared if the appropriate exposure data are available. For example, it is possible that the engine failure accident rate for pilots with total time of 101 to 200 hours is higher than that of pilots with total time of 201 to 500 hours. Without the appropriate exposure data, the comparison has no meaning. However, it can be concluded that the accident type experienced most often by low total time pilots is ground loops, while pilots with higher experience have more engine failure accidents than any other type. Thus, these comparisons do provide some information, although far more information could be obtained if the exposure data were available.

TABLE B1

ACCIDENT TYPE BY PILOT TOTAL TIME
33 SELECTED AIRCRAFT

TABLE B1

ACCIDENT TYPE BY PILOT TOTAL TIME
33 SELECTED AIRCRAFT

	1-50 Hours	51-100 Hours	101-200 Hours	201-500 Hours	Over 500 Hours
1.	Ground Loop (437)	Engine Failure (275)	Engine Failure (402)	Engine Failure (656)	Engine Failure (1,406)
2.	Hard Landing (367)	Ground Loop (251)	Ground Loop (314)	Collision w/Obstacles (455)	Collision w/Obstacles (716)
3.	Engine Failure (211)	Collison w/Obstacles (217)	Collision w/Obstacles (286)	Ground Loop (357)	Ground Loop (595)
4.	Collision w/Obstacles (155)	Hard Landing (180)	Stall (205)	Stall (309)	Stall (520)
5.	Stall (130)	Stall (153)	Overshoot (177)	Collision w/Ground/Water (251)	Collision w/Ground/Water (410)
6.	Overshoot (86)	Overhsoot (122)	Hard Landing (167)	Overshoot (190)	Overshoot (238)
7.	Collision w/Ground/Water (52)	Collison w/Ground/Water (111)	Collision w/Ground/Water (165)	Hard Landing (173)	Hard Landing (212)
8.	Undershoot (48)	Undershoot (47)	Undershoot (74)	Undershoot (97)	Undershoot (171)
9.	Midair Collsion (26)	Midair Collision (22)	Inflight Airframe Failure (26)	Inflight Airframe Failure (39)	Midair Collision (87)
10.	Inflight Airframe Failure (4)	Inflight Airframe Failure (13)	Midair Collision (25)	Midair Collision (31)	Inflight Airframe Failure (76)

TABLE B2

ACCIDENT TYPE BY PILOT TIME IN TYPE
33 SELECTED AIRCRAFT

	1-25 Hours	26-100 Hours	101-200 Hours	Over 200 Hours
1.	Ground Loop (795)	Engine Failure (928)	Engine Failure (423)	Engine Failure (846)
2.	Engine Failure (678)	Ground Loop (603)	Collision w/Obstacles (276)	Collision w/Obstacles (470)
3.	Hard Landing (491)	Collision w/Obstacles (571)	Stall (204)	Ground Loop (335)
4.	Collision w/Obstacles (390)	Stall (409)	Ground Loop (197)	Stall (302)
5.	Stall (280)	Hard Landing (383)	Collision w/Ground/Water (120)	Collision w/Ground/Water (210)
6.	Overshoot (266)	Collision w/Ground/Water (302)	Overshoot (116)	Overshoot (150)
7.	Collision w/Ground/Water (185)	Overshoot (270)	Hard Landing (88)	Hard Landing (127)
8.	Undershoot (105)	Undershoot (138)	Undershoot (70)	Undershoot (106)
9.	Inflight Airframe Failure (360)	Midair Collision (64)	Midair Collision (22)	Midair Collision (50)
10.	Midair Collision (33)	Inflight Airframe Failure (42)	Inflight Airframe Failure (18)	Inflight Airframe Failure (37)

TABLE B3

ACCIDENT TYPE BY AIRCRAFT PILOT TIME LAST 90 DAYS
33 SELECTED AIRCRAFT

TABLE B3

ACCIDENT TYPE BY AIRCRAFT PILOT TIME LAST 90 DAYS
33 SELECTED AIRCRAFT

	1-25 Hours	26-100 Hours	101-200 Hours	Over 200 Hours
1.	Engine Failure (1,306)	Engine Failure (1,088)	Engine Failure (224)	Engine Failure (143)
2.	Ground Loop (1,114)	Collision w/Obstacles (608)	Ground Loop (125)	Collision w/Obstacles (90)
3.	Collision w/Obstacles (808)	Ground Loop (556)	Collision w/Obstacles (114)	Stall (47)
4.	Hard Landing (739)	Stall (425)	Stall (98)	Ground Loop (44)
5.	Stall (575)	Overshoot (295)	Collision w/Ground Water (42)	Collsion w/Ground/ Water (22)
6.	Overshoot (420)	Collision w/Ground/Water (276)	Overshoot (42)	Hard Landing (20)
7.	Collision w/Ground/Water (345)	Hard Landing (257)	Hard Landing (35)	Undershoot (15)
8.	Undershoot (219)	Undershoot (130)	Undershoot (32)	Midair Collision (13)
9.	Midair Collision (74)	Midair Collision (51)	Midair Collision (20)	Overshoot (13)
10.	Inflight Airframe Failure (52)	Inflight Airframe Failure (45)	Inflight Airframe Failure (3)	Inflight Airframe Failure (3)

Appendix C

Pilot Time and Landing Gear

Some indication of the role of the pilot in this tailwheel-tricycle gear phenomenon can be gleaned by ranking the frequency of occurrence of accident type for pilot flight time categories for the two aircraft configurations. Tables C-1 through C-6 present pilot flight time data in this manner. Table C-1 presents the 10 accident types ranked by frequency of occurrence in five categories of pilot total time for the tailwheel aircraft group. Tables C-2 and C-3 present the accident type rankings for pilot time in type and pilot time in the last 90 days for the tailwheel group. Tables C-4 through C-6 present the same data for the tricycle gear aircraft group.

It can be deduced from Table C-1 that ground loop accidents are the most frequently occurring accidents for all of the categories of pilot total time considered in this study. It cannot be inferred from Table C-1 that experience in the form of flight time has no effect on ground loops in tailwheel aircraft. It is possible that the rate of occurrence (per 100,000 flying hours) of ground loop accidents decreases with increasing experience even though ground loops remain the most frequently occurring accident type in tailwheel aircraft for pilots with more than 500 hours total time. It can be seen from Tables C-2 and C-3 that the highest time in type and time in last 90 days pilot groups had more engine failure accidents than ground loop accidents. This could indicate that flight experience does have some effect on accident types since the ordering of ground loops and engine failures has changed.

A comparison of the data in Tables C-1 through C-3 with the data in Tables C-4 through C-5, shows that the order of occurrence of accident types for pilots with various levels of experience is different for the tailwheel and the tricycle gear groups. Interpretation of these differences, and thus understanding the role of the pilot in this tailwheel-tricycle phenomenon, must await the collection of appropriate exposure data.

TABLE C1
ACCIDENT TYPE BY PILOT TOTAL TIME
TAILWHEEL AIRCRAFT

TABLE C1

ACCIDENT TYPE BY PILOT TOTAL TIME
TAILWHEEL AIRCRAFT

	1-50 Hours	51-100 Hours	101-200 Hours	201-500 Hours	Over 500 Hours
1.	Ground Loop (73)	Ground Loop (84)	Ground Loop (140)	Ground Loop (184)	Ground Loop (336)
2.	Hard Landing (24)	Engine Failure (34)	Engine Failure (61)	Engine Failure (139)	Engine Failure (294)
3.	Collision w/Obstacles (19)	Stall (28)	Stall (58)	Stall (122)	Stall (195)
4.	Stall (19)	Collision w/Obstacles (25)	Collision w/Obstacles (50)	Collision w/Obstacles (110)	Collision w/Obstacles (180)
5.	Engine Failure (12)	Hard Landing (21)	Hard Landing (20)	Collision w/Ground/Water (52)	Collision w/Ground/Water (86)
6.	Collision w/Ground/Water (7)	Overshoot (6)	Overshoot (10)	Overshoot (31)	Overshoot (33)
7.	Overshoot (5)	Undershoot (5)	Collision w/Ground/Water (10)	Hard Landing (20)	Undershoot (32)
8.	Undershoot (4)	Collision w/Ground/Water (3)	Undershoot (6)	Undershoot (16)	Hard Landing (31)
9.	Inflight Airframe Failure (2)	Inflight Airframe Failure (0)	Midair Collision (3)	Inflight Airframe Failure (4)	Inflight Airframe Failure (15)
10.	Midair Collision (1)	Midair Collision (0)	Inflight Airframe Failure (1)	Midair Collision (3)	Midair Collision (14)

TABLE C2

ACCIDENT TYPE BY PILOT TIME IN TYPE
TAILWHEEL AIRCRAFT

	1-25 Hours	26-100 Hours	101-200 Hours	Over 200 Hours
1.	Ground Loop (341)	Ground Loop (217)	Ground Loop (98)	Engine Failure (168)
2.	Engine Failure (113)	Engine Failure (158)	Engine Failure (81)	Ground Loop (146)
3.	Stall (69)	Stall (120)	Stall (72)	Collision w/Obstacles (120)
4.	Hard Landing (62)	Collision w/Obstacles (119)	Collision w/Obstacles (63)	Stall (112)
5.	Collision w/Obstacles (59)	Collision w/Ground/Water (37)	Collision w/Ground/Water (24)	Collision w/Ground/Water (48)
6.	Collision w/Ground/Water (23)	Hard Landing (35)	Overshoot (21)	Overshoot (16)
7.	Overshoot (20)	Overshoot (27)	Undershoot (10)	Undershoot (15)
8.	Undershoot (14)	Undershoot (20)	Hard Landing (4)	Hard Landing (13)
9.	Inflight Airframe Failure (3)	Midair Collision (6)	Midair Collision (4)	Inflight Airframe Failure (10)
10.	Midair Collision (3)	Inflight Airframe Failure (1)	Inflight Airframe Failure (3)	Midair Collision (7)

TABLE C3

ACCIDENT TYPE BY AIRCRAFT PILOT TIME LAST 90 DAYS
TAILWHEEL AIRCRAFT

TABLE C3

ACCIDENT TYPE BY AIRCRAFT PILOT TIME LAST 90 DAYS
TAILWHEEL AIRCRAFT

	1-25 Hours	26-100 Hours	101-200 Hours	Over 200 Hours
1.	Ground Loop (416)	Ground Loop (245)	Ground Loop (65)	Engine Failure (28)
2.	Engine Failure (215)	Engine Failure (196)	Engine Failure (43)	Ground Loop (25)
3.	Stall (152)	Collision w/Obstacles (143)	Stall (33)	Collision w/Obstacles (21)
4.	Collision w/Obstacles (137)	Stall (139)	Collision w/Obstacles (29)	Stall (17)
5.	Hard Landing (71)	Collision w/Ground/Water (53)	Collision w/Ground/Water (10)	Overshoot (3)
6.	Overshoot (42)	Hard Landing (30)	Overshoot (7)	Midair Collision (3)
7.	Collision w/Ground/Water (35)	Overshoot (28)	Undershoot (7)	Collision w/Ground/Water (3)
8.	Undershoot (24)	Undershoot (23)	Hard Landing (5)	Inflight Airframe Failure (2)
9.	Midair Collision (7)	Midair Collision (6)	Midair Collision (3)	Hard Landing (1)
10.	Inflight Airframe Failure (5)	Inflight Airframe Failure (5)	Inflight Airframe Failure (1)	Undershoot (-)

TABLE C4

ACCIDENT TYPE BY PILOT TOTAL TIME
TRICYCLE GEAR AIRCRAFT

	1-50 Hours	51-100 Hours	101-200 Hours	201-500 Hours	Over 500 Hours
1.	Ground Loop (364)	Engine Failure (241)	Engine Failure (341)	Engine Failure (517)	Engine Failure (1,112)
2.	Hard Landing (343)	Collision w/Obstacles (192)	Collision w/Obstacles (236)	Collision w/Obstacles (345)	Collision w/Obstacles (536)
3.	Engine Failure (199)	Ground Loop (167)	Ground Loop (174)	Collision w/Ground/Water (199)	Stall (325)
4.	Collision w/Obstacles (136)	Hard Landing (159)	Overshoot (167)	Stall (187)	Collision w/Ground/Water (324)
5.	Stall (111)	Stall (125)	Collision w/Ground/Water (155)	Ground Loop (173)	Ground Loop (259)
6.	Overshoot (81)	Overshoot (116)	Stall (147)	Overshoot (159)	Overshoot (205)
7.	Collision w/Ground/Water (45)	Collision w/Ground/Water (108)	Hard Landing (147)	Hard Landing (153)	Hard Landing (181)
8.	Undershoot (44)	Undershoot (42)	Undershoot (67)	Undershoot (81)	Undershoot (139)
9.	Midair Collision (25)	Midair Collision (20)	Inflight Airframe Failure (25)	Inflight Airframe Failure (35)	Midair Collision (73)
10.	Inflight Airframe Failure (2)	Inflight Airframe Failure (13)	Midair Collision (22)	Midair Collision (28)	Inflight Airframe Failure (61)

TABLE C5

ACCIDENT TYPE BY PILOT TIME IN TYPE

TABLE C5

ACCIDENT TYPE BY PILOT TIME IN TYPE
TRICYCLE GEAR AIRCRAFT

	1-25 Hours	26-100 Hours	101-200 Hours	Over 200 Hours
1.	Engine Failure (565)	Engine Failure (770)	Engine Failure (342)	Engine Failure (678)
2.	Ground Loop (454)	Collision w/Obstacles (452)	Collision w/Obstacles (213)	Collision w/Obstacles (350)
3.	Hard Landing (429)	Ground Loop (386)	Stall (132)	Stall (190)
4.	Collision w/Obstacles (331)	Hard Landing (348)	Ground Loop (99)	Ground Loop (189)
5.	Overshoot (246)	Stall (289)	Collision w/Ground/Water (96)	Collision w/Ground/Water (162)
6.	Stall (211)	Collision w/Ground/Water (265)	Overhsoot (95)	Overshoot (134)
7.	Collision w/Ground/Water (162)	Overshoot (243)	Hard Landing (84)	Hard Landing (114)
8.	Undershoot (91)	Undershoot (118)	Undershoot (60)	Undershoot (91)
9.	Inflight Airframe Failure (33)	Midair Collision (58)	Midair Collision (18)	Midair Collision (43)
10.	Midair Collision (30)	Inflight Airframe Failure (41)	Inflight Airframe Failure (15)	Inflight Airframe Failure (27)

TABLE C6

ACCIDENT TYPE BY AIRCRAFT PILOT TIME LAST 90 DAYS
TRICYCLE GEAR AIRCRAFT

	1-25 Hours	26-100 Hours	101-200 Hours	Over 200 Hours
1.	Engine Failure (1,074)	Engine Failure (864)	Engine Failure (169)	Engine Failure (114)
2.	Ground Loop (685)	Collision w/Ground/Water (443)	Collision w/Ground/Water (72)	Collision w/Ground/Water (53)
3.	Hard Landing (661)	Ground Loop (295)	Stall (60)	Stall (24)
4.	Collision w/Ground/Water (656)	Overshoot (262)	Ground Loop (53)	Hard Landing (17)
5.	Stall (401)	Stall (257)	Overshoot (34)	Ground Loop (16)
6.	Overshoot (375)	Hard Landing (224)	Collision w/Ground/Water (31)	Undershoot (15)
7.	Collision w/Ground/Water (308)	Collision w/Ground/Water (216)	Hard Landing (29)	Collision w/Ground/Water (15)
8.	Undershoot (193)	Undershoot (106)	Undershoot (24)	Overshoot (8)
9.	Midair Collision (67)	Midair Collision (43)	Midair Collision (16)	Midair Collision (8)
10.	Inflight Airframe Failure (45)	Inflight Airframe Failure (39)	Inflight Airframe Failure (2)	Inflight Airframe Failure (1)

Appendix D

Pilot Time and Aircraft Make and Model

Tables D-1 through D-4 present accident type rankings for the Cessna-and Piper-built aircraft for pilot total time and pilot time in type. Pilot time in the last 90 days was not included because it provided no additional information regarding the fatal accident rate differences between the Piper and the Cessna aircraft. Tables D-1 and D-3 indicate that the ranking of accident type for both groups of aircraft was the same for the low total time pilot category (students). Ground loops are the most prevalent accident type in this pilot time category while engine failure accidents are the predominant accident type in all higher pilot total time categories for both aircraft groups. It would appear from an examination of the data in Tables D-1 through D-4 that ground loops are a more dominant accident type for the Cessna pilots. This would be expected since the ground loop accident rate is higher for the Cessna group than for the Piper group. However, exposure data would be necessary to ascertain which pilot categories were having more trouble with particular accident types.

TABLE D1

ACCIDENT TYPE BY PILOT TOTAL TIME
CESSNA AIRCRAFT

	1-50 Hours	51-100 Hours	101-200 Hours	201-500 Hours	Over 500 Hours
1.	Ground Loop (253)	Engine Failure (148)	Engine Failure (176)	Engine Failure (253)	Engine Failure (601)
2.	Hard Landing (234)	Collision w/Obstacles (137)	Ground Loop (146)	Collision w/Obstacles (199)	Ground Loop (339)
3.	Engine Failure (148)	Hard Landing (118)	Collision w/Obstacles (127)	Ground Loop (163)	Collision w/Obstacles (332)
4.	Collision w/Obstacles (102)	Ground Loop (108)	Hard Landing (118)	Stall (127)	Stall (208)
5.	Stall (87)	Stall (85)	Overshoot (97)	Collision w/Ground/Water (122)	Collision w/Ground/Water (177)
6.	Overshoot (48)	Overshoot (64)	Stall (96)	Hard Landing (106)	Hard Landing (135)
7.	Collision w/Ground/Water (26)	Collision w/Ground/Water (52)	Collision w/Ground/Water (79)	Overshoot (85)	Overshoot (124)
8.	Undershoot (26)	Undershoot (18)	Undershoot (31)	Undershoot (37)	Undershoot (55)
9.	Midair Collision (17)	Midair Collision (15)	Midair Collision (15)	Midair Collision (12)	Midair Collision (45)
10.	Inflight Airframe Failure (-)	Inflight Airframe Failure (1)	Inflight Airframe Failure (4)	Inflight Airframe Failure (5)	Inflight Airframe Failure (24)

TABLE D2

ACCIDENT TYPE BY PILOT TIME IN TYPE

TABLE D2

ACCIDENT TYPE BY PILOT TIME IN TYPE
CESSNA AIRCRAFT

	1-25 Hours	26-100 Hours	101-200 Hours	Over 200 Hours
1.	Ground Loop (387)	Engine Failure (449)	Engine Failure (187)	Engine Failure (420)
2.	Hard Landing (314)	Collision w/Obstacles (310)	Collision w/Obstacles (134)	Collision w/Obstacles (229)
3.	Engine Failure (247)	Ground Loop (308)	Ground Loop (107)	Ground Loop (196)
4.	Collision w/Obstacles (171)	Hard Landing (242)	Stall (90)	Stall (140)
5.	Stall (136)	Stall (191)	Overshoot (60)	Collision w/Ground/Water (93)
6.	Overshoot (130)	Overshoot (155)	Hard Landing (58)	Hard Landing (87)
7.	Collision w/Ground/Water (75)	Collision w/Ground/Water (144)	Collision w/Ground/Water (53)	Overshoot (77)
8.	Undershoot (39)	Undershoot (55)	Undershoot (29)	Undershoot (37)
9.	Midair Collision (17)	Midair Collision (37)	Midair Collision (7)	Midair Collision (28)
10.	Inflight Airframe Failure (6)	Inflight Airframe Failure (7)	Inflight Airframe Failure (5)	Inflight Airframe Failure (14)

3LE D3

ACCIDENT TYPE BY PILOT TOTAL TIME
PIPER AIRCRAFT

	1-50 Hours	51-100 Hours	101-200 Hours	201-500 Hours	Over 500 Hours
1.	Ground Loop (125)	Engine Failure (71)	Engine Failure (129)	Engine Failure (230)	Engine Failure (403)
2.	Hard Landing (68)	Ground Loop (66)	Collision w/Obstacles (100)	Collision w/Obstacles (163)	Collision w/Obstacles (259)
3.	Engine Failure (37)	Collision w/Obstacles (53)	Ground Loop (78)	Ground Loop (87)	Stall (173)
4.	Collision w/Obstacles (33)	Overshoot (43)	Stall (57)	Stall (87)	Ground Loop (117)
5.	Stall (27)	Collision w/Ground/Water (41)	Collision w/Ground/Water (56)	Collision w/Ground/Water (80)	Collision w/Ground/Water (116)
6.	Overshoot (27)	Stall (35)	Overshoot (49)	Overshoot (62)	Overshoot (75)
7.	Collision w/Ground/Water (16)	Hard Landing (28)	Undershoot (27)	Undershoot (40)	Undershoot (73)
8.	Undershoot (12)	Undershoot (21)	Hard Landing (26)	Hard Landing (36)	Hard Landing (36)
9.	Midair Collision (7)	Midair Collision (6)	Inflight Airframe Failure (13)	Midair Collision (14)	Midair Collision (30)
10.	Inflight Airframe Failure (1)	Inflight Airframe Failure (8)	Midair Collision (6)	Inflight Airframe Failure (13)	Inflight Airframe Failure (13)

TABLE D4

ACCIDENT TYPE BY PILOT TOTAL TIME

TABLE D4

ACCIDENT TYPE BY PILOT TOTAL TIME
PIPER AIRCRAFT

	1-25 Hours	26-100 Hours	101-200 Hours	Over 200 Hours
1.	Engine Failure (217)	Engine Failure (274)	Engine Failure (121)	Engine Failure (231)
2.	Ground Loop (188)	Collison w/Obstacles (163)	Collision w/Obstacles (93)	Collision w/Obstacles (166)
3.	Collision w/Obstacles (142)	Ground Loop (156)	Stall (61)	Stall (110)
4.	Overshoot (85)	Stall (102)	Ground Loop (43)	Ground Loop (81)
5.	Hard Landing (76)	Collision w/Ground/Water (95)	Overshoot (34)	Collision w/Ground/Water (66)
6.	Collision w/Ground/Water (71)	Hard Landing (83)	Collision w/Ground/Water (32)	Overshoot (50)
7.	Stall (68)	Overshoot (83)	Undershoot (29)	Undershoot (48)
8.	Undershoot (39)	Undershoot (51)	Hard Landing (14)	Hard Landing (24)
9.	Inflight Airframe Failure (15)	Inflight Airframe Failure (16)	Midair Collision (14)	Midair Collision (18)
10.	Midair Collision (11)	Midair Collision (13)	Inflight Airframe Failure (3)	Inflight Airframe Failure (9)