# AIRCRAFT DESIGN-INDUCED PILOT ERROR

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Study Conducted by

Bureau of Safety
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design induced errors
pilot error

# PREFACE

The Aircraft Design-Induced Pilot Error Project is an evaluation and comparison of the accident records of 35 make and model airplanes. The intent is to assess the influence of numerous airplane-design factors or configurations in General Aviation Accidents wherein the pilot was determined to be a causal element. The program is based on all General Aviation Accidents that occurred in 1964, except those involving rotorcraft, agricultural-type airplanes, or those airplanes whose total active number was less than 500. Specific types of accidents were selected for evaluation based on their relative occurrence during the study year. Tabular results of the application of the Chi-Square Method are presented in the Appendix and serve as a basis for evaluation and discussion of various accident types.

Motivation for such a study stems largely from the fact that the vast majority of General Aviation Accidents involve the pilot as a causal element -- "pilot error." In 1964 alone, for instance, the pilot was held to be at least partially responsible in 4,195 such accidents, that is, in 83% of all General Aviation Accidents for that year. Of the 3,732 accidents that serve as the basis for this study, 3,147 (or 84%) involved the pilot as a causal element. Although the accident rates for the General Aviation Fleet have decreased somewhat over the past decade, the number of accidents and fatalities per year has risen. For example, in 1955 there was a total of 3,343 accidents involving 619 fatalities. In 1965 the accident total is estimated as 5,250 involving 1,018 fatalities.

Because of the startling number of accidents involving the pilot as a causal element, the Federal Aviation Agency established a flight research program entitled "Aircraft Design Induced Pilot Error." The first phase of this two-phase design compatibility program was to assess the influence of airplane design factors or configurations in General Aviation Accidents wherein the pilot was determined to be a causal element. After learning of the FAA interest and intent to develop such a program, the Civil Aeronautics Board offered to conduct this first phase study because of its role and responsibility for the investigation of aircraft accidents and the promotion of air safety. In addition, this provided an opportunity to relate the Board's wealth of accident statistics and related data to a dynamic safety function -- the prevention of accidents. The study was subsequently conducted by the Board's Bureau of Safety with financial assistance from the FAA. CAB/FAA Inter-Agency Agreement FA66WAI-108, dated September 3, 1965, provided for reimbursement to the Board for the services of non-Government consultants.

"Pilot Error" manifests itself more clearly in some accident types than others in terms of certain discrete, singular acts (or the lack of them). A pilot error associated with the movement of a handle or switch, for instance, can be quite specifically recorded in the accident report. An error associated with a ground-loop accident, on the other hand, and termed "failed to maintain directional control" may be descriptive but is inadequate in resolving the precise nature of the "error." In evaluating accidents characterized by errors of the former type, therefore, it was appropriate to place considerable emphasis on the accident reports themselves. In evaluating those characterized by the latter type errors, however, it was felt that the accident type discussion was supported more strongly by results of the Chi-Square statistical tests. It is here especially that we emphasize the statistical significance of the variations in accident-type frequencies between the various make and model airplanes.

Typical "pilot errors" in certain types of accidents appear more influenced by some airplane designs than others. Some, for example, do not induce the pilot to err directly, but either make it difficult for him not to err or preclude an effective response in some particular phase of flight. The aircraft owners manuals, since they are inextricably associated with the operation of the airplanes, also influence the pilot's actions and hence his "errors." The discussion of certain accident types, therefore, includes references to such manuals where pertinent. Pilot error is more often influenced than induced by design. Therefore, "design-induced error" may be interpreted to be the result of any factor which makes it difficult for the pilot to prevent an accident and not merely of a factor which causes or induces one directly. In summary, we believe that the total design as it relates to both performance and safety should be such as to permit the pilot to easily prevent an accident, even if it means correcting his own "mistakes."

All airplanes considered were certificated in accordance with Federal Airworthiness Standards, and, while the study as a whole emphasizes certain characteristics, factors or configurations that appear to influence pilot error, it is not intended to serve as an evaluation of the overall safety of the various models or as a criticism of any particular manufacturer. Comparisons are made only to assist in defining design characteristics that induce pilot error by identifying differences between airplanes that have significant variance in the frequency of specific accident types.

The Board wishes to acknowledge the cooperation and assistance of the various Government agencies, manufacturers, and individuals who have participated and assisted us with this study. It is our sincere hope that the information will be of considerable assistance in their design safety programs.

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# S U M M A R Y

This report presents an analysis of design-induced pilot error in general aviation accidents. It is based on a study fleet consisting of 35 makes and models of airplanes. The basis for selection of the study fleet, the make and models involved, and the accident types analyzed are presented in the Section on Scope and Coverage.

In making this study, the term "Design-Induced Error" was considered as including all factors that may have influenced the action or non-action of the pilot, and thus were related to the accident. Under this interpretation, factors that interfered with action which might have prevented the accident, and lack of data in flight manuals or published data requiring an unusual level of pilot competence are included among the factors inducing error.

The study has disclosed many factors that appear to induce pilot error within the scope of the above interpretation. These factors vary widely in nature for the accident types considered and among the airplane makes and models.

Airplane makes and models were grouped by type of utilization to provide a common exposure index, and by design parameters related to specific accident types. Frequency distribution of each accident type among the airplane types was determined on a basis of statistical significance, using the Chi-Square Test, for all grouping, as well as on a fleet-wide basis. Distributions were prepared based on flight hours, total number of accidents, and number of active aircraft.

It was found that certain types of accidents were related primarily to detail design. This was particularly true of accidents such as those involving retractable landing gear and mismanagement of fuel systems. In these cases improper sensing of controls, inadequate identification of controls, inadequate indication and/or warning to the pilot, and lack of standardization were found to be the major design factors.

In other cases, the factors involved were less clearly identifiable from the data available to the study group. It appears, however, that in many accident types that occur primarily in the take-off and landing phases, information available to the pilot in flight manuals is inadequate and may encourage practices that, while not necessarily unsafe, provide little margin for error or sub-standard performance. Included in this category are lack of data on critical crosswinds and on the affect of surfaces other than paved runways on take-off and landing distances; lack of adequate margins between stalling speed and recommended take-off, or approach speeds; and performance data based on flight-test demonstration but requiring a level of pilot skill beyond that of many general aviation pilots.

In some of the accident types considered, it was found that the frequency of pilot error as a causal factor was so low that detailed analysis was not considered to be warranted. Gear collapse and power-plant failure or malfunction involving pilot errors other than mismanagement of the fuel system were in this category. Other accident types were found not to be a problem with airplanes of certain configurations.

Examples are nose-over accidents to tricycle gear low-wing airplanes, and undershoot and overshoot accidents to twin-engine airplanes.

The frequency of stall accidents to single-engine aircraft certificated under CAR 3 and FAR 23 was found to be significantly lower than that of aircraft certificated under CAR 4a. This indicates that the requirements governing stall characteristics and stall warning in the later regulations have had an appreciable effect. With airplanes certificated under CAR 3/FAR 23 it was found that the majority of accidents of this type occur during the take-off or go-around phases of flight, even though the accident type includes all accidents involving stalls, spins, spirals, or mushing into the ground. The only exclusion is accidents in which the aircraft stalls onto the runway. These last accidents are coded as hard landings under the definitions used by the Board.

In hard landings to airplanes with tricycle-type landing gear, it was found that in most cases they result in failure or collapse of the nose gear, but not damage to the main gear. This would indicate nose wheel first contact, rather than contact at a high rate of sink in a nose-high attitude. One model airplane also had several gear collapse accidents involving failure of the nose-wheel shimmy dampener and fork, with evidence of prior cracks in the fork. It is, therefore, possible that the failure of the nose wheel in some accidents to this airplane that were reported as hard landings were the result of cracked forks, and did not actually involve pilot error in landing procedure.

An evaluation of ground-loop statistics discloses tricycle-gear airplanes, on the whole, to be far less prone to this accident type than tailwheel airplanes. Both types are discussed, although many of the latter are no longer in production. Differences in the frequency of ground loops among individual tailwheel airplanes are attributed largely to variance in center of gravity position while those among tricycle gear airplanes appear more related to specific design details of the nose gear.

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# AIRCRAFT DESIGN-INDUCED PILOT ERROR PROJECT

## AIRCRAFT DESIGNATION BY CONFIGURATION/CATEGORY

AIRCRAFT DESIGNATION

| CONFIGURATION/CATEGORY | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. HIGH WING/TAIL WHEEL | | X | | X | | | | | | | X | X | | | X | | | X |
| b. HIGH WING/ NOSE GEAR | X | | X | | | X | | | | | | | | X | | | X | X |
| c. LOW WING/ NOSE GEAR | | | | | X | | X | | X | X | | | X | | | X | | |
| d. HIGH WING | | | | | | | | | | | | | | | | | | |
| e. LOW WING | | | | | | | | X | | | | | | | | | | |
| f. TAIL WHEEL | | | | | | | | X | | | | | | | | | | |
| g. NOSE GEAR | | | | | | | | | | | | | | | | | | |
| h. FLAPS | X | | X | | X | X | X | X | X | X | | | X | X | X | X | X | X |
| i. NO FLAPS | | X | X | X | | | | | | | X | X | | | | | | X |
| j. CERTIFICATION/CAR 3 | X | | X | | X | X | X | | X | X | X | | X | X | X | X | X | |
| k. CERTIFICATION/CAR 4a | | X | | X | | | | X | | | | X | | | | | | X |
| l. SINGLE ENGINE | X | X | X | X | X | X | X | X | | | X | X | | X | X | X | | X |
| m. TWIN ENGINE | | | | | | | | | X | X | | | X | | | | X | |

| CONFIGURATION/CATEGORY | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| a. HIGH WING/TAIL WHEEL | | | | X | X | | X | | | | | | X | | X | | |
| b. HIGH WING/ NOSE GEAR | X | | | | | | | | X | | | | | | | | X |
| c. LOW WING/ NOSE GEAR | | X | | | | X | | X | | X | X | X | | X | | X | |
| d. HIGH WING | | | X | | | | | | | | | | | | | | |
| e. LOW WING | | | | | | | | | | | | | | | | | |
| f. TAIL WHEEL | | | X | | | | | | | | | | | | | | |
| g. NOSE GEAR | | | | | | | | | | | | | | | | | |
| h. FLAPS | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | | X |
| i. NO FLAPS | | | | | | | X | | | | | | | | X | X | |
| j. CERTIFICATION/CAR 3 | X | X | X | X | X | X | | X | X | X | X | X | X | X | | X | X |
| k. CERTIFICATION/CAR 4a | | | | | | | X | | | | | | X | | X | X | |
| l. SINGLE ENGINE | X | | X | X | X | | X | | X | X | X | X | X | | X | X | X |
| m. TWIN ENGINE | | X | | | | X | | X | | | | | | X | | | |

## AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## AIRCRAFT CODE DESIGNATIONS

| CODE | AIRCRAFT | CODE | AIRCRAFT |
|---|---|---|---|
| 003 | Cessna 210 Series | 057 | Cessna 205 Series |
| 006 | Cessna 120 Series | 060 | Beech D-18/E-18/G-18 |
| 009 | Piper PA-22 | 063 | Stinson 108 Series |
| 012 | Aeronca 11 Series | 066 | Piper PA-18 |
| 015 | Mooney M-20 Series | 069 | Cessna 170 Series |
| 018 | Cessna 172 Series | 072 | Beech 95 Series |
| 021 | Beech 35 Series | 075 | Piper J3/PA-11 |
| 024 | Globe GC-1 Series | 078 | Beech 95-55 |
| 027 | Piper PA-30 | 081 | Cessna 182 Series |
| 030 | Beech 50 Series | 084 | Navion Series |
| 033 | Piper PA-12 | 087 | Piper PA-24 |
| 036 | Taylorcraft B Series | 090 | Beech 35-33 Series |
| 039 | Piper PA-23 | 093 | Cessna 140 Series |
| 042 | Cessna 150 Series | 096 | Cessna 310 Series |
| 045 | Cessna 180 Series | 099 | Luscombe 8 Series |
| 048 | Piper PA-28 | 102 | Forney/415 Series |
| 051 | Aero Commander 500/600 Series | 105 | Cessna 175 Series |
| 054 | Aeronca 7 Series | | |

NATIONAL TRANSPORTATION SAFETY BOARD
Department of Transportation
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## GENERAL AVIATION ACCIDENT STATISTICS

### INTRODUCTION

The airplane accident statistics and the discussion and/or analysis of specific accident types in this report are related to small fixed-wing General Aviation accidents for the Calendar Year 1964. Particular emphasis was placed on the retrieval, analysis and presentation of accident data tailored specifically to assist in identifying areas of the aircraft design that might induce the pilot to err.

In 1964, the Civil Aeronautics Board initiated a new aircraft accident data coding system utilizing electronic data processing equipment. Pertinent parameters related to each accident investigated and/or analyzed by the Board are coded and stored on magnetic tape. These may number from 50 to 300 depending on the complexity of the accident. This information serves as the statistical basis for this study.

In order to assess the vast amount of statistical accident data available to the Board, two EDP programs were required and were implemented by the Board's Bureau of Accounts and Statistics. The first was an application of the Chi-Square statistical test of significance to pertinent accident data. The second was utilized to retrieve and print specific accident data related to both the pilot and airplane.

The number of active aircraft and their estimated flight time was obtained from the Federal Aviation Agency for each make and model within the study fleet. The flight time was tabulated according to specific kinds of flying.

SCOPE/COVERAGE

The type and number of airplanes in the study included all small fixed-wing airplanes except those used exclusively in aerial application or those whose total active model fleet numbered less than 500 at the end of the calendar year 1964. Also, any accident associated with aerial application was omitted from the study. The small fixed-wing aircraft is defined as one having a maximum certificated gross take-off weight of 12,500 pounds or less. A total of 35 airplanes was included in the study based on these criteria.

The study fleet accounted for 3,732 accidents, or 74% of all General Aviation Accidents in 1964. All the charts and tables presented in the Appendix depict data based on these 3,732 accidents. An exception is Chart #1 which presents accident rates for all United States General Aviation for a five-year period, 1960-1964.

A numerical three-digit identifier was assigned to each of the 35 make and model airplanes. These were numbered in arithmetic progression from 003 through 105 and are used throughout the report. Such a coding system expedited the retrieval of pertinent accident data and was a convenient designation in the tabulation of results of the Chi-Square statistical test.

## DESCRIPTION AND DEFINITION OF CODED ACCIDENT DATA

An assessment of the data within this report is enhanced by an understanding of the definition and nature of specific accident types and other related accident data such as phase of flight, kind of flying, etc. These definitions are presented in the following paragraphs.

The recent conversion of the Board's accident coding system to electronic data processing has greatly expanded its potential for use in accident prevention. The new system makes possible the storage of vast amounts of accident data on magnetic tape and provides a capability to cross-reference and tabulate selected accident parameters. This capability enhances both the retrieval and the study of accident data.

### Type of Accident

The type of accident is a description of the circumstances involved in the accident. Briefly it describes what happened. If necessary, two types of accidents may be coded for each occurrence. In this case the selection of first and second accident types depends on the sequence of occurrence. An example of an occurrrence where two types of accidents are coded might involve a ground loop coded as the first accident type followed by a nose-over as the second accident type. Infrequently there may be more than two accident types involved in an occurrence. Those selected as first and second then best describe the occurrence in terms of what happened, and are not solely dependent upon the sequence of events.

In cases where one accident type fully describes what happened, a second accident type is not coded. Nor is it coded in cases where the first accident type, involving loss of control, results in an inevitable collision with the ground.

Although 54 different types of accidents may be coded, 16 of them account for most of the accidents considered in this study. These 16 types and a brief explanation of each are as follows:

1. Ground-Loop Swerve - loss of directional control or sudden swerve while taxing, taking off, or landing.

2. Wheels-up Landing - landing gear not lowered and locked prior to contact with the ground.

3. Gear Collapsed - collapse of the gear due to mechanical failure other than malfunction of retracting mechanism.

4. Gear Retracted - retraction of the gear due to malfunction of the retraction mechanism or retraction of the gear due to inadvertent or premature retraction by the crew.

5. Hard Landing - stalling onto or flying into the runway or other intended landing area.

6. Nose-over/Down - nosing down onto ground, water, or runway, or going completely over on back.

7. Overshoot - landing too fast, or too far down the runway or other intended landing area, resulting in (a) running off the end of the landing area, including collisions which may result; (b) ground-looping, nosing down, or overturning off runway or intended landing area; (c) landing beyond the intended landing area.

8. Undershoot - landing or making contact with the ground short of the runway or other intended landing area. On VFR approaches, any

contact or landing short of the runway or intended landing area while on final will be coded as undershoot. On IFR approaches, an undershoot will be coded only after the field or intended landing area is in sight.

9. Collision with ground/water, controlled - collision with the ground or water wherein the aircraft is capable of being controlled and is under control of the pilot.

10. Collision with ground/water, uncontrolled - collision with the ground or water wherein the aircraft is capable of being controlled but is not under control of the pilot.

11. Collision with wires/poles - colliding with wires and/or poles regardless of the phase of flight. In the case of an overshoot or undershoot, collision with wires/poles will be coded as a second accident type.

12. Collision with trees - colliding with trees regardless of the phase of flight. In the case of overshoot or undershoot, collisions with trees will be coded as a second accident type.

13. Collision with fence/fence-posts - colliding with fence and/or fence-posts regardless of the phase of flight. In the case of an overshoot or undershoot, collision with fence/fence-posts will be coded as a second accident type.

14. Collision with ditches - colliding with ditches regardless of the phase of flight. In the case of an overshoot or undershoot, collision with ditches will be coded as a second accident type.

15. Stall, Spin, Spiral, or Mush - accidents in which the aircraft stalls, spins, or mushes into the ground or water. Doesn't include stalls resulting in a hard landing. In those cases, hard landing will be coded as the accident type. The manner of coding accidents for 1964

precluded an individual tabulation of these occurrences. As a result, all accidents related to these occurrences are considered collectively as a single type.

16. Engine Failure or Malfunction - occurrences of engine failure or malfunction. Includes engine stoppage, power interruption or power loss regardless of the cause. Engine failure or malfunction is used only in conjunction with another accident type unless serious or fatal injury and/or substantial damage results from flying parts.

Phase of Operation

The phase of operation is a description of the particular segment of the flight or ground operation during which the accident occurs. Briefly, it describes where in the flight the specific accident type took place. When more than one type of accident is coded for an occurrence, each type will have a corresponding phase. In other words, the first phase of operation will be that phase of flight in which the first accident type occurred. In the event that the first and second accident type occurred in one operational phase, the same phase is coded twice.

Injury Index

The injury index refers to the highest degree of injury associated with the occurrence. These are "fatal," "serious," "minor," and "none."

Kind of Flying

Kind of flying describes the purpose for which the aircraft is being operated at the time of the accident. For the purpose of this report, there are three broad categories:

1. Instructional Flying

Refers to flying accomplished in supervised training under [th]e direction of an accredited instructor.

2. Personal Flying

Refers to the use of an aircraft for purposes of pleasure, [pe]rsonal transportation, or in connection with a private business. It [in]cludes the following specific categories:

a. Pleasure

Flying by individuals in their own or rented aircraft [fo]r pleasure or personal transportation not in connection with their [oc]cupations or businesses.

b. Business

The use of aircraft by pilots (not receiving direct salary or [co]mpensation for piloting) in connection with their occupation or business.

3. Professional Flying

Refers to the use of an aircraft in various kinds of commercial [an]d non-commercial flying, and characterized by professional piloting. [It] includes the following specific categories:

a. Corporate/Executive Flying

The use of aircraft owned or leased and operated by a cor[po]ration or business firm for the transportation of personnel or cargo [di]rectly associated with the corporation or business firm, and flown by [pr]ofessional pilots receiving a direct salary for piloting.

b. Air-Taxi Operations

The use of an aircraft in transporting persons or cargo for [com]pensation.

c. Miscellaneous Professional Flying

Several other specific kinds of professional flying include: Aerial Mapping, Photography and Advertising, Power and Pipeline Patrol, and Fish Spotting.

Causes and Related Factors

In determining the probable cause of an accident, all facts, conditions and circumstances are considered. These are classified in broad categories related to the pilot, personnel, power-plant, weather, etc. More detailed causes are then selected within the scope of such broad categories. An example under the category "pilot" might be: "Failed to extend landing gear." More than one cause may be assigned to an accident. All causes so assigned are considered equally significant as related to the accident, and are commonly referred to collectively as the Board's "probable cause."

Related factors are used, in general, to reflect those elements of an accident which further explain or supplement the probable cause or causes. The coding of such factors enhances an understanding of the causal elements since it provides additional facts, conditions, and/or circumstances related to the accident.

Because more than one cause and/or factor may be assigned to an accident, the total of such causes and factors in Charts 3 and 4 and Table 4 of the appendix exceeds the total number of accidents.

An example of the application and assignment of a cause and a related factor is as follows: The airplane was flown into weather conditions which resulted in loss of control and an uncontrolled collision with the ground. The probable cause in this accident might be: "pilot - continued VFR flight into adverse weather conditions," and the related factor, "weather-rain; low ceiling."

Each cause and factor assigned to an accident is related to the accident type sequence and is coded as being associated with the first accident type, the second accident type, or both accident types.

## THE CHI-SQUARE STATISTICAL METHOD

Comparison of airplanes with high and low relative frequency of a specific type of accident provided the basis for identifying the design factors related to the accident type. For such comparisons to yield meaningful results, however, it was essential that the difference in accident frequency be statistically significant and not merely an apparent difference resulting from pure chance. To assure this, all frequencies were tested for significance by means of a Chi-Square distribution. The Chi-Square Test was selected because of the nature of the data and because it permitted both multiple and single degree of freedom analyses to be performed by a single calculation. This not only determined whether a significant variance existed in the frequency of a given accident type within a group of airplanes, but also identified individual airplane types which differed significantly from the mean.

For purposes of identifying qualitatively those airplane types that differed from the mean, significance levels of 5% and 0.1% were chosen arbitrarily as cut-off points. All airplanes that did not differ from the mean frequency of a given type of accident at the 5% level of significance were considered as average; those that differed at a significance level between 5% and 0.1% were classed as "high" or "low" depending on the sign of the variance; and those differing beyond the 0.1% level were classed as "very high" or "very low."

This classification and the cut-off points selected are based on the methodology proposed by Acheson J. Duncan in the paper, "Report on the Differential Accident Performance of Single Engine Non-Air Carriers," 1949-51.

In many statistical analyses using the Chi-Square method, the 5% and/or 1% levels of significance are used. While the 5% level has been used herein for the limits of what is considered average, it was believed that greater conservatism than normal should be used in classifying an airplane as having a "very high" or "very low" accident frequency. For this reason, the 0.1% level (only 1:1000 probability that the result is pure chance) was used instead of the more commonly used value of 1%.

Sample size was also checked for statistical significance, with a minimum theoretical frequency of 5 being taken as a lower limit. This value is accepted as a minimum in analysis with two or more degrees of freedom in Chi-Square analyses for "goodness of fit" to assure that the "tails" of the distribution are not distorted so as to bias the distribution. It was, however, believed applicable to the present study, as applied to values showing significant variance (i.e., near the "tails" of the curve) and values with smaller sample sizes are so indicated on the tables. Sample size is not shown on the tables for values not found to be significant, since these lie near the center of the distribution curve and would not be affected by a slight biasing of the ends of the curve.

Frequency distributions were computed, and charts are presented for each accident type based on the number of flight hours, the total number of accidents, and the number of active airplanes of each make and model. The first of these provides a comparison on the basis of an exposure index, and thus of the actual tendency of the airplane to be involved in the particular accident type. This distribution, therefore, is most pertinent to the identification of design features that may be causally related to the accident type. The second, based on total number of accidents, indicates those areas in which corrective action would be most productive in reducing the accident frequency of a particular make and model of airplane. The third, based on number of active airplanes, is presented for statistical reference only.

## AIRCRAFT GROUPINGS

In order to make more meaningful comparisons of accident frequencies among the various makes and models of airplanes, it was considered necessary to express the frequency in terms of an exposure index, and also to group the airplanes on a basis of type of utilization in order to eliminate operational variables that could obscure the effect of design differences. Flying hours appeared to provide the best exposure index for accidents other than those on take-off or landing, and grouping of airplanes so that average-flight duration was approximately the same for all airplanes in each group would permit use of the same index for accidents occurring in these phases of operation. It was decided that type of flying was, within reasonable limits, related to flight duration. It was further concluded that type of flying and pilot rating, as an over-all measure of proficiency and experience, were significant variables in defining accident risk.

A review was made of all data available in the records of the Civil Aeronautics Board and the Federal Aviation Agency that would provide an indication of type of utilization meeting the above considerations. It was concluded that the records of flying time by type of flying, tabulated by the FAA from the data reported on their Form 2350 provided the best basis for grouping the airplanes. These data were retabulated on the basis of the percentage of the total flight time in each of the eight categories used by the FAA. It was found, however, that using this number of categories did not result in clear-cut groupings, and that many of the groups resulting were too small to provide a statistically valid comparison of the airplane types in the groups. A study of the headings used in the FAA tabulation indicated that, for the purposes of this analysis, the types of flying could be combined into three major categories: personal transportation, including local and cross-country pleasure flying and non-commercial business flying by private pilots; instructional flying; and professional flying, including corporate flying by professional pilots, air taxi and charter operation, power- and pipeline patrol, etc. It was also concluded that, because of the differences in characteristics, single-engine and twin-engine airplanes should be treated separately.

On the basis of the foregoing, Groups I and II, based on single and twin-engine airplanes, respectively, were established according to type of flying.

Group III pertains to the study fleet as a whole, and Group IV consists of categories based on various airplane configurations and/or design parameters. Groups I, II, III, and IV are summarized as follows:

I. Single-Engine Airplanes

A. Personal Transportation

Airplanes in which at least 75% of the total usage was in personal transportation, as defined above, and not more than 20% in either of the other individual categories.

B. Personal Transportation plus Instruction

Airplanes in which at least 75% of the total flying time was in personal transportation and instructional flying combined, and not less than 20% in instruction. The one exception in this group is airplane 048, of which only 70% of the total usage was in these two categories, but since 30% of the usage was in instructional flying, this was considered to justify placing the airplane in this group.

C. Personal Transportation plus Professional Flying

Airplanes in which at least 75% of the total usage was in personal transportation and professional flying, as defined above, and not less than 25% of the total was professional flying.

II. Twin-Engine Airplanes

A. Professional Flying

Airplanes in which 75% of the total usage was in professional flying, and not more than 20% in either of the other individual categories.

B. Professional Flying and Personal Transportation

Airplanes in which at least 75% of the total flying time was in these two categories and at least 25% in personal flying.

In case of twin-engine airplanes, it was found that personal transportation did not represent more than 30% of the total usage for any airplane model, so that no separate category for personal transportation appeared justified. Similarly, the maximum instructional usage for any model airplane was approximately 5% of the total flying time, so no grouping involving instructional usage was warranted.

The specific utilization group associated with each airplane is shown on those appendix tables that depict results of the Chi-Square analysis.

III. Study Fleet Group

This group includes all 35 make and model airplanes and utilizes all accident statistics associated with them to determine and compare accident frequencies. It serves as an overall statistical reference and enhances an analysis of the results of accident evaluations based on other groupings.

IV. Parametric Groupings

For some specific accident types, a grouping based on a design parameter considered to have a relationship to the accident type has been used. An example of such grouping is the division of airplanes by nose-wheel or tail-wheel landing gear, in considering ground-loop accidents. All such breakdowns are discussed under the specific accident types for which they are used.

## ACCIDENTS INVOLVING ENGINE FAILURE OR MALFUNCTION

### I. GENERAL

Engine failure or malfunction is not considered to constitute an accident in and of itself, but is classified as an accident only when a subsequent accident of another type occurs, e.g., an accident during an attempted forced or precautionary landing, or a stall or spin in a twin-engine airplane following failure of one engine. Since engine failure is tabulated as an accident type only when there is a second accident type involved, the tabulation is not an indication of frequency of engine failure. The tabulation of engine failure as an accident type also includes failures from all causes, including mechanical failure of the engine or of powerplant accessories or systems.

For the purposes of this study it was therefore necessary to cross-tabulate the accident type by cause in order to isolate those accidents in which the powerplant failure was reportedly induced by pilot error. A relatively large number of such accidents involved mismanagement of the fuel system which is discussed in detail in the following pages. Certain other pilot causes related to this accident type are not discussed since they could not be explicitly related to design (fuel exhuastions), or because the circumstances and effects are so well known (water in fuel, etc.).

### II. Mismanagement of the Aircraft Fuel System

Mismanagement of the fuel system was identified as the probable cause of 98 airplane accidents occurring in 1964 in the 35 makes and models of general aviation airplanes selected for evaluation in this study.

For the purpose of this report, mismanagement of the fuel system means that engine failure because of fuel starvation occurred at a time when:

1. There was ample fuel aboard the airplane;
2. All systems related to the distribution of fuel, or to the determination of the amount of fuel in each tank were capable of normal operation; and
3. There was no evidence of fuel contamination.

The distribution of accidents involving mismanagement of the fuel system among the 35 makes and models of airplanes is shown in Table 4, and as shown on this Table, 9 of the 35 airplanes had no accidents from this cause. Among the other 26 airplanes, the number of cases varied from one each on eight airplanes to a maximum of 19 on one model. Seven of the makes and models accounted for 61 of the 98 cases, or 62%. The chart shows only the total number of cases, and does not reflect relative exposure.

Both multiple and single degree of freedom Chi-Squared analysis based on flight time were made for each utilization group for all single-engine and all twin-engine airplanes, and for the entire study fleet. It was found that on any of the above bases of analysis, the sample size for 28 of the 35 types was not adequate for a valid comparison of individual makes and models by means of the single degree of freedom analyses. No twin-engine type provided a statistically significant sample, and the overall frequency of this type of accident for twin-engine airplanes was only 0.049 per $10^4$ flight hours, or less than one accident per 200,000 hours.

Among the single-engine airplanes, the multiple degree of freedom analyses showed statistically significant variances, primarily as a result of airplanes 009 and 084, which were high, and airplanes 018, 042, and 081 which were low at the 5% level of significance or less. The sample size was adequate for all of these airplanes.

Because of the small sample size for most airplane models, and the specific nature of errors involved in fuel system mismanagement, it was decided in this case to review a large sample of accident reports. This review was made to determine significant differences in the fuel system designs in the various airplanes that may have influenced the pilots' incorrect action or failure to take action.

The sample of accident reports comprised 75 of the 98 cases, and included accidents to 17 of the 26 airplane types that had accidents from this cause. The airplanes considered included types with both relatively large and small numbers of accidents; however, none of those not included in the sample was involved in more than two accidents.

The examination of accident reports disclosed the following circumstances were present in the cases studied:

1. Auxiliary fuel tanks, or other tanks placarded against use in particular phases of flight, such as takeoff and climb, were used despite the prohibition.
2. Fuel quantity gauges were not selected to the tank in use.
3. Fuel was used from one tank until that supply was exhausted. Engine failure from fuel starvation occurred, but the fuel selector was not repositioned to a tank containing fuel.
4. Fuel was used from one tank until engine failure occurred from fuel starvation. The fuel selector was then positioned to a tank with fuel, but power was not recovered in time to prevent a forced landing.
5. Fuel selector was mispositioned to empty fuel tank, or to the "off" position, in the process of changing selector from one tank to another.

6. Takeoff was attempted on empty or near empty tanks.

All circumstances were not involved in all accidents, nor did they occur in each make or model of aircraft. Accordingly, each of the foregoing circumstances is discussed in the order given and as related to the particular aircraft involved. Numbers of accidents cited refer to the number in the sample of 75, and not the total number of cases.

A. <u>Improper Use of Auxiliary or other Tanks (Aircraft 021, 084, and 099.</u>

In each of these accidents, the aircraft was placarded against the operation attempted. While it may be argued that any system which permits fuel starvation in normal flight operations can be considered a design deficiency, we do not consider these instances to fall in the design-induced pilot error category. The reasons for this belief are as follows:

(1) The tank selection error occurred prior to takeoff in all but one case. Or, to state it differently, the pilot failed to select a proper tank at a point in flight preparation where time is not a critical factor. It occurred at a time when normal procedures, check lists, and the operator's handbook direct that the appropriate tank for takeoff be determined and a check of the fuel selector position be made.

(2) In none of these accidents was the tank in use selected in the belief that it was some other tank.

B. Fuel Quantity Gauges (Airplanes 0(3 and 084).

In these airplanes a single fuel quantity gauge is used to indicate the amount of fuel in two or more tanks. Thus, it is possible to have the gauge selected to one tank, but at the same time to be using fuel from another tank. While this arrangement can lead the pilot to believe erroneously that he is gauging the tank in use, the number of incidents was not great enough to conclude that this design, per se, induces pilots to commit a fuel mismanagement error. This is concluded, in part, from the fact that other aircraft have similar gauging systems, but were not involved in accidents for similar reasons. However, the two accidents merit discussion since a related problem is apparent in other accidents.

In both of these accidents, one tank was used until the fuel in it was exhausted and engine failure resulted. However, the fuel selector valve was not repositioned to a tank containing fuel, and the subsequent forced landing ended in an accident.

The fuel selector was not repositioned following engine failure because the pilots believed that the fuel selector and gauge were on the same tank. In this mistaken belief, and with fuel showing on the gauge, the pilot in each instance judged the engine failure to be for other than fuel starvation reasons.

Four similar instances of misjudgment of the reason for powerplant failure are discussed in the following paragraph.

C. Failure to Reposition the Fuel Selector Valve (Airplanes 009, 015, 021, 027, 039, 048, 072, 084)

In four of these instances, the pilot did not reposition the fuel selector because the fuel gauges erroneously still showed fuel in the tank in use. As in the two preceding instances, the number of these accidents in 1964 is too small to conclude that faulty fuel gauges are a cause for great alarm. However, these four accidents and the two preceding do demonstrate that incorrect information obscures the true problem. The result is the pilot's failure to correctly assess the nature of his difficulty and take appropriate action.

The faulty fuel gauge is a random problem for which there is no ready solution. The use of a single fuel gauge for multiple tank installations can be accomplished successfully, however, if the gauge operation is combined with movement of the fuel selector as is now being done on some general aviation airplanes. In this circumstance the gauge is always selected to the tank in use. It is recommended that in multiple tank installations not having separate gauges, a mandatory requirement for this arrangement be considered during the next Annual Airworthiness Review. A provision for checking fuel in tanks other than the one in use without moving the fuel selector should be included.

Airplane 015 was involved in four fuel mismanagement accidents that were directly related to the location of the fuel selector valve. In older models of this airplane, a small pilot, or one with short legs, cannot see the fuel selector from the normal piloting position, and in some instances, cannot reach it. This resulted in mispositioning of the selector in two instances, and a decision on the part of the pilots in two other instances not to reposition the selector. We are aware of these occurrences only because the subsequent forced landing resulted in an accident. As with the fuel gauges in the accidents discussed previously there may have been other similar incidents which did not come to our attention because the forced landing was successful.

The problems inherent in the location of the fuel selector valve in the 015 airplane was the subject of a recommendation to the Administrator on May 25, 1966.

D. Failure of the Engine to Respond when the Selector was Repositioned to a Tank with Fuel (Airplanes 015, 021, 048, 078, 084, 087, and 090)

Former Part 3 of the Civil Air Regulations and present Part 23 of the Federal Aviation Regulations provide that if the engine of a single-engine airplane can be supplied with fuel from more than one tank, it must be possible, in level flight, to regain full power and fuel pressure in not more than 10 seconds after switching to any full tank, after engine malfunction due to fuel depletion becomes apparent, while the engine is being supplied from any other tank. There is no mention of the use of boost or auxiliary pumps. On the other hand, there is no implication that the engine-driven pump or other normal supply means must alone be used in meeting the power recovery requirements.

Information furnished to the study group by the various manufacturers indicates that the 10-second requirement is barely met in some instances with fuel injector engines, even though the boost pump is used. One manufacturer provided informal test results that demonstrated a power-recovery time of 30 seconds when fuel boost pumps were not used. In another test conducted by a fixed base operator and aircraft distributor, a recovery time of 35 seconds was recorded when the boost pump was not used.

Data relating to fuel-injector engines supplied by one airplane manufacturer showed that power was recovered on one particular engine in eight seconds with or without the use of fuel-boost pumps.

Power recovery time for airplanes using engines equipped with carburetors instead of fuel-injector systems was generally well within the 10-second time limit with or without the use of boost pumps.

Only one of the 14 accidents in which the engine failed to recover power in time to prevent a forced landing (after the fuel selector was positioned to a full tank) involved a high wing airplane. In this instance the selector was moved too late, and although power was regained, it was not in time to prevent the forced landing.

The other 13 accidents in this category involved low-wing airplanes. In seven of the 13 reports, the use or non-use of the fuel-boost pump is not discussed. Four of the reports state that the boost pump was used when the fuel selector was repositioned to a tank with fuel, but power was not recovered. Two of the reports state that the boost pump was not used. In tests conducted under the supervision of an FAA Inspector following one of the accidents, it was discovered that when the fuel selector was repositioned from an empty auxiliary tank to a full main tank, the engine would not run properly unless the boost pump was used.

It is evident from some of the accident reports that when the engine failed to recover power after the fuel selector was repositioned, the pilots then tried another tank, and in a few instances turned the fuel selector back to the tank it had been on at time of power loss. The result of these repositionings of the fuel selector was to extend the power recovery time to a point where the forced landing was inevitable. As stated previously, there may have been similar situations that never came to attention because the forced landing was executed satisfactorily.

The Federal Aviation Regulations do not contain any prohibition, nor are there any warnings in owner's handbooks or manuals, against the practice of using fuel from one tank until engine failure from fuel starvation occurs. To the contrary, the practice of running one tank dry is recommended in the owner's handbook for airplane 009, which reads as follows:

> "To use the reserve fuel supply, first use the right tank until it is at least half empty, preferably completely empty." (Underlining supplied)

The owner's manual for Airplane 015 states under Fuel Management: "Use all the fuel in the second tank."

The owner's manual for one model of Airplane 021 states:

> "If desired, fuel can be drawn from either cell until engine operation indicates that the cell is empty." (Underlining supplied.)

> The manual continues: "(1) Retard the throttle to prevent overspeed condition. (2) Switch to other cell, visually checking the fuel selector valve. (3) Turn on the auxiliary fuel pump MOMENTARILY until power is regained. (4) Advance throttle to the desired position."

This is one of the few manuals that discuss the use of the boost pump under fuel management. The majority refer only to the use of the auxiliary pump under the emergency, or inflight engine failure section. However, it is also noted that the reason for capitalizing "MOMENTARILY" is not discussed, and the pilot is left in the dark as to what may happen if the pump is turned on and left on. The study group was informed that the result may be a too rich supply of fuel and consequent engine malfunction. There is also the possibility that the emphasis on "MOMENTARILY" may cause the pilot to turn off the boost pump before power is fully recovered.

The handbook for aircraft 048 contains what may be considered an invitation to exhuast the fuel in one tank in view of the lack of precision in fuel gauges. This handbook advises, "In order to keep the airplane in best lateral trim during cruising flight, the fuel should be used alternately from each main tank, and when they are exhausted, from each tip tank."

From the foregoing, it is evident that the pilots are being invited to run a tank dry as a matter of practice. However, they are given little or no information on the probable results, the length of time it may take to recover power, or the probability of not recovering it at all.

The accident records seem to indicate that the practice is common enough, either by design, inattention to the fuel supply, or inaccurate fuel gauges, to constitute a serious problem.

Notwithstanding the material in the owner's handbook or manual, or the lack of any prohibition in the Federal Aviation Regulations, there are many pilots who from experience believe that serious problems exist with respect to recovering the power on fuel injector engines if the engine is allowed to lose power because of fuel depletion. One major general aviation pilot's association considered the practice to be potentially so dangerous that the organization recommended against it to all its members. It should be noted, however, that not all failures to recover power were in fuel-injector type engines. What is apparent from the accident records is that while the power recovery time specified in the regulations is being met during type certification and production testing, actual in-service experience for various reasons is somewhat different.

Part of the reason for the difference between test and in-service experience may be from changes due to wear in the pump capacity to purge air from the fuel system as efficiently as it did under test conditions. Part of it may be in the length of time between power loss from fuel starvation and the repositioning of the fuel selector to a tank with fuel. Under test conditions, the pilot knows that power loss is going to occur, when it will probably happen, and the reason for it. Accordingly, there is no delay in repositioning the fuel selector. On the other hand, the general aviation pilot usually is taken unprepared by the power loss, and consequently, delay in selection of another fuel source can be expected.

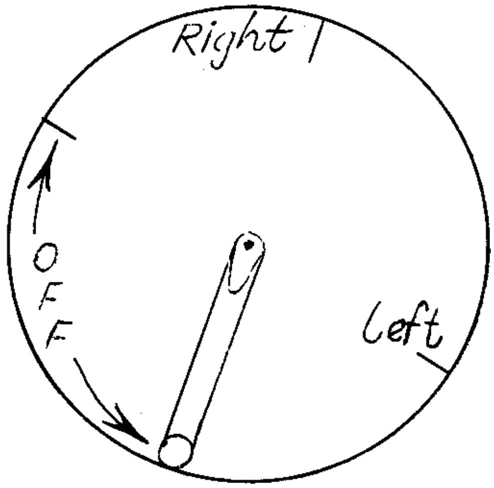
There are no data available that detail the effect on power recovery of varying amounts of air injected into the fuel distribution system when repositioning of the selector valve is delayed. In the absence of such information, the pilot is without means to make an adequate assessment of the problem, and in some instances has concluded that power loss was for other than fuel starvation reasons. This situation is considered to be within the framework of design-induced pilot error. In this context, it is noted that high-wing airplanes account for approximately 67% of the active general aviation aircraft in 1964. Except for the one instance previously mentioned, there were no accidents resulting from failure of the engine to regain power when the selector was positioned to a tank containing fuel.

Since the problem appears to be confined to low-wing airplanes, where a "head" of fuel pressure does not exist and purging of the fuel distribution system is dependent upon pump capacity, it is recommended that an evaluation of power recovery times without the use of auxiliary or boost pumps be made. If this evaluation demonstrates that these power recovery times are in excess of those specified in FAR Part 23, we recommend that, at minimum, appropriate information be provided to pilots by means of an Advisory Circular, the aircraft owner's handbooks, and the airplane approved flight manuals.

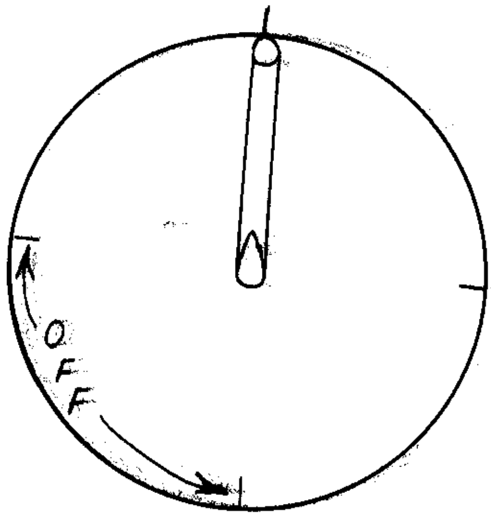
An alternative to running the engine on one tank until power interruption informs the pilot that all the fuel in that tank had been used would be the installation of a fuel low-level warning light. With this device, the pilot could use all available fuel in any tank in order to achieve maximum range, but at the same time the pilot would have ample warning of impending power loss. In the event he was involved with ATC communications, looking at a navigation chart, or observing other traffic, the light would focus his attention on the fuel supply, and tend to prevent power loss from fuel starvation. It is recommended that the subject of fuel low-level warning lights be included in the agenda for discussion at the next Annual Airworthiness Review.

E. Fuel Selector Valve Mispositioned in Aircraft 009, 015, 018, 021, 048, 066, 084, 087, 093.

There were 15 such instances in the nine airplanes involved. Statements submitted by pilots committing this error included comments that they were used to other airplanes, or different model airplanes, in which the fuel selector position for right or left tanks was different. A typical example is found in the fuel selectors for aircraft 009 and 048. In airplanes 009 and 048, the fuel selector location and operations are nearly identical. However, in Aircraft 009 the selector position deviates from what might be considered as a standard direction orientation with respect to the right and left tank locations. When viewed through the cabin doorway, or from a point opposite the selector, the appearance is as shown below:




In the course of this study, a similar drawing was shown to 30 pilots and 11 nonpilot individuals. They were advised only that the two otherwise unidentified radial marks on the circle were the two main tank positions, but were not labeled. The participants were then asked to position the selector to the left tank position. Without exception, the selector handle was positioned as shown on the following page.




This error is not unique to the participants in this small experiment, or to some of the pilots involved in the accidents. An article in the September 1965 issue of the Australian Department of Civil Aviation Safety Digest, discussing the confusion resulting from similar appearing, but different, functioning fuel selectors, describes two forced landings (which did not result in accidents). With respect to the selector (shown on the drawings) for aircraft 009, the article states, "The pilot said afterward that in turning on the fuel before starting he had moved the selector to the Vertical Position (actually the starboard tank), thinking it was the port tank." He went on to explain that the word "Right" in the placard warning didn't register as being the starboard tank.

In airplane 048, the tank positions on the fuel selector have been changed to an orientation more standard for most persons. This, in turn, is confusing to the pilot whose main experience is in the 009 airplane, and subsequently operates another such as the 048.

It is believed that any system which operates contrary to normal experience with similar devices in the course of daily life may be classified as a design which influences error. The fuel selectors in airplane 009 are in this category.

The 1964 reports in this classification disclosed that two accidents resulted from the pilots' belief that the fuel-selector valve had been repositioned to a tank with ample fuel when, in fact, it had not been moved. This occurred in both instances in airplane 021. Early models of this airplane have a combined auxiliary hand pump/fuel selector unit.

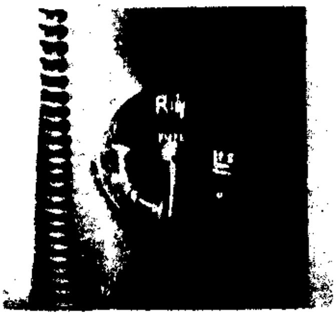
Changes in tank selection must be accomplished by depressing the auxiliary pump handle, which serves as a connecting shaft to the fuel selector valve. If the handle is not depressed properly, the fuel selector valve is not repositioned, although the top of the handle, which serves to identify the tank selection, will indicate that the valve was repositioned. When this error is made in the course of routine fuel management, and while some fuel still remains in the tank in use, the subsequent engine failure is unexpected. The cause is completely masked, since the selector points to a tank with fuel and corresponds to a position where the fuel quantity gauge indicates an ample fuel supply. This is considered to be a design which induces pilot error. In the two accidents discussed, the pilots believed the fuel selector had been repositioned to a tank containing ample fuel.

Aircraft 045 and 105 were not involved in any fuel mismanagement accidents. Aircraft 069, 081 and 018 have essentially the same fuel selector system, and were involved in only six fuel mismanagement accidents. In only one of these accidents was the fuel selector mispositioned to "OFF", to an intermediate position between "OFF" and the desired tank, or to a tank other than the one intended. The basic difference between the fuel system in these airplanes and the majority of the others in the general aviation airplane fleet is that the fuel selector has a both-tanks-on position, and the airplane is normally operated with the selector set to the "BOTH" position. It is significant that airplanes 018, 045, 069, 081, and 105 account for 24.4% of the active general aviation airplanes in 1964, but were involved in only one-half of one percent (0.5%) of the fuel mismanagement accidents. In contrast, airplanes 009, 021, and 090 represented 16.9% of the active general aviation airplanes in 1964, and although they flew 25% less hours than the previously mentioned airplanes, they were involved in 33% of all the fuel mismanagement accidents. It is apparent, therefore, that the design of the fuel supply system in these airplanes offers the pilots considerably more opportunity to err than does a system that permits fuel to be drawn from both main tanks simultaneously.

While this arrangement may be impractical in some instances because of other airplane design features, this system could have been used on at least two other airplanes.

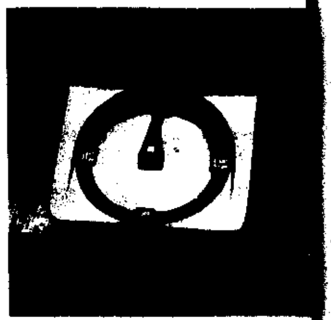
A review of the Photographs on Page 34 will demonstrate that there is virtually no uniformity in general aviation airplanes in the manner in which the fuel selector portrays the tank in use. As seen in the photographs, the long handle of the actuating lever is pointed to the tank in use in some instances, where in other airplanes using a similar selector, there is a small pointer opposite the long handle to indicate the tank selected. In still others, a double pointer is used to indicate the direction of fuel flow (e.g., airplane 087). And, as previously mentioned, airplane 009 used a similar selector, but the tank locations differed from installations in other airplanes.

These variations in design contribute to confusion and possible error when a pilot flies one make or model airplane, and then switches to another. The magazine article previously mentioned discusses the subject, and the 1964 accident records confirm that accidents occur for this reason. Accordingly, we recommend that consideration be given to standardization of the manner in which tank selection is identified. It is recommended that this subject be discussed during the next Annual Airworthiness Review with a view to amending FAR Part 23 to require standardized presentations, in the same manner as has been accomplished with landing gear and flap actuator controls.



1.

2.



3.

4.

5.

6.

The Selector in photo number 1 uses a tapered handle which is positioned to the fuel tank intended for use. In this respect it is identical in operation to selectors depicted in 2, 3, and 4. However, identical positions do not select identical tanks, i.e., the left and right tank locations on the selector face are not consistent. On Selectors 1, 2, 4, 5, and 6 there are two "off" positions. On Selector 3 there is one "off" and one "both" position.

Fuel Selectors in photos 5 and 6 do not use the handle to select the tank to be used. Rather, a pointer opposite to the selector handle designates the tank in use. If the selector handle is inadvertently used to determine the tank selected, the fuel valve will be in the off position.

Selectors 1, 4, and 6 have similar face plates. However, the location of the left and right tanks on Selector 6 are reversed from those on Selectors 1 and 4.



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F. Takeoff Attempted on Empty or Near Empty Tanks (Airplanes 003, 009, 030, 060, 069, 093, and 096)

These accidents are not considered in the design induced error category since the pilot had more than reasonable opportunity to ascertain the tank in use and the fuel quantity in the tanks.

## ACCIDENTS INVOLVING STALL, SPIN, SPIRAL, MUSH

All accidents involving stalls, spins, spirals, and mush are included in this category, regardless of whether this type of accident occurred alone or in conjunction with some other accident type as either the first or second type. In many cases, especially with twin-engine airplanes, stalls were associated with engine failure or malfunction.

It is recognized that there may have been cases in which this accident type was involved which were not so coded and, therefore, are not considered herein. Typical of such accidents would be those in which an in-flight structural failure was preceded by a high speed spiral, but in which there was no evidence of such a spiral, or such evidence was not contained in the accident report.

In the following discussion for simplicity of wording, the term "stall accidents" is used to refer to all accidents of the type, whether or not an actual aerodynamic stall was involved or a spin developed.

### A. Effect of Certification Basis on Stall Accidents

Both Group 1A and Group 1B included airplanes that were certificated under CAR 4a, as well as airplanes certificated under CAR 3 and FAR 23; there were no airplanes certificated under CAR 4a in Group 1C or either twin-engine group. In both groups that included CAR 4a airplanes, the Chi-Square distribution showed that the stall accident frequency for those airplanes was higher than that for CAR 3/FAR 23 airplanes at a level of significance of less than 0.05%, when analyzed on a basis of either flying hours or total numbers of accidents. It therefore appears that the adoption of requirements governing stall characteristics in the original version of CAR 3, and the subsequent addition of requirements for stall warning, have had a significant influence in reducing the frequency of accidents related to the stall.

In view of the fact that the airplanes certificated under Part 4a are obsolecent, no detailed analysis of characteristics of individual models as related to stall accidents was made for these airplanes. It is realized that changes in the stall characteristics of these airplanes would not be feasible. It is, however, recommended that consideration be given to a requirement for the installation of a stall-warning system on existing airplanes that were certificated under CAR 4a.

The difference in the frequency of this type of accident on these airplanes and those conforming to the later requirements, including adequate stall warning, would indicate that such a step might be an effective means of reducing stall accident frequency on the older airplanes.

B. Analysis of FAR 23 Airplanes

The following analysis is limited to airplanes certificated under CAR 3/FAR 23, with airplanes considered by usage groups. In Groups 1A and 1B, the multiple degree of freedom analysis showed no highly significant difference for either group. Differences in Group 1A were significant at the 1% level, primarily because of the influence of airplane 105, which had a stall accident frequency appreciably below the mean for the group, although a single degree of freedom analysis showed this difference to be significant only at the 2.5% level.

In Group 1C, airplane 066 had a stall accident frequency far above that of any other airplane in the group, and this difference was sufficient to cause a highly significant difference within the group. A review of the accident reports for this airplane, however, showed that many of the stall accidents in which it was involved occurred during abnormal or hazardous operation, including banner towing, hunting, search, and rescue, as well as acrobatics. Since such operations are not pertinent to the purposes of this study, this airplane was omitted from the analysis of stall accidents. Even with airplane 066 deleted, the multiple degree of freedom analysis showed a significant variation among airplanes in this group, primarily the result of high stall accident frequency on Airplane 033 and Airplanes 021 and 090 combined. It should be considered, however, that the flying time on Airplane 033 was inadequate to meet the test of sample size for valid statistical conclusions based on single degree of freedom analysis for this airplane.

C. Phase of Flight Relationship

In all three single-engine airplane groups, it was found that the majority of all stall accidents occurred on initial climb on take-off or go-around. These two phases of flight combined accounted for 64% of all stall accidents, being 71% of the total for Group 1A, 54% for Group 1B, and 74% for Group 1C. When stalls occurring during low passes and acrobatics were deleted from the total, the percentage of stall accidents occurring on take-off and go-around was 69% for the entire fleet, 73% for Group 1A, 61% for Group 1B, and 80% for Group 1C. The number of stall accidents occurring in these two phases of flight was greater than the number in any other phase for every airplane model in all three groups, with the single exception of Airplane 033 in Group 1C, for which two stall accidents occurred on take-off, four on landing, and one in flight. Accidents in the take-off phase alone accounted for 52% of the total for the entire fleet, 61% for Group 1A, 40% for Group 1B, and 65% for Group 1C. Neglecting accidents occurring during acrobatics and low passes, the values are 57%, 63%, 45%, and 70%, respectively.

Stall accidents during the landing phase, other than immediate forced landings, were between 10% and 13% of the total number in all three groups. Stalls during forced landings were a negligible percentage of the total except in Group 1B, which included an appreciable amount of instructional flying. In this group they accounted for approximately 9% of the stall accidents.

Stall accidents during the in-flight phase accounted for only approximately 14% of the total in Group 1A and Group 1C, and only 10% and 7% respectively, when stalls during low passes and acrobatics are deleted. In Group 1B, stall accidents during the in-flight phase accounted for 28% of the total, with approximately one-third of them during acrobatics and low passes. In general, the larger number of in-flight stalls in this group appears to be related to the lack of pilot proficiency and judgment, rather than airplane design. This may reflect the use of the airplanes for instruction and, subsequently, by pilots of low experience levels.

It thus appears that the commonly held opinion that accidents of the type being considered are primarily related to poor aerodynamic stall characteristics, spiral instability, and/or inattention to airspeed during landing or in-flight maneuvers, is not valid as applied to airplanes certificated under the present Federal Air Regulations, and that the major problem in stalls in related to initial climb on take-off or go-around. Therefore, if aerodynamic characteristics are a major factor, the problem is related to the stall at full power.

The above conclusion is related solely to accident frequency and not to severity. It may well be that accidents in the in-flight phase from causes such as spiral instability are, as a rule, more severe than stalls on take-off and result in more fatalities. This would not have been disclosed by the type of analysis performed in this study; an analysis using a weighted scale based on both accident frequency and severity would be required. Such an analysis was not considered to fall within the scope of this study.

The accident data are not adequate to explain the fact that Airplane 033 does not follow the general trend. The actual number of stall accidents for this type of airplane was small, and all were under widely different circumstances. Sufficient data were not available to the Board on the stall characteristics of this airplane as compared to other airplanes in the group to permit an analysis of possible aerodynamic factors involved.

D. Comparison of Airplanes 069 and 105

Among the airplanes in Group 1A, Airplane 069 had the highest frequency of stall accidents, while airplane 105 had by far the lowest. The ratio of stall accident rate per 10,000 flying hours for these two airplane models was greater than 10 to 1, and the difference between the two models was significant at 0.5%. Because of this and the general similarity between the two airplanes, a detailed analysis was made of the complete accident files of each of the 16 stall accidents to airplane 069, even though the rate for this airplane was not higher than the mean for the group at a significant level. Nine of the 16 accidents occurred during initial climb on take-off, and three more during initial climb on go-around. Only two stall accidents occurred during the landing phase, one of them involving an engine cowl that had come open after take-off and was fluttering in flight. The remaining two accidents occurred in flight, one of them during climb to cruise altitude with heavy frost on the airplane, and the other during a low pass by a pilot under the influence of alcohol. Thus it is seen that 75% of the stall accidents to this model airplane occurred either on take-off or go-around, and that at least three of the remaining four accidents did not involve any airplane characteristics pertinent to this study.

Analysis of the take-off and go-around accidents showed that all three of the stalls on go-around occurred with a strong, gusty cross-wind, and the same factor was involved in at least four of the nine take-off accidents. In addition to this, at least three of the take-off accidents occurred on grass fields. This may also have been the case in other accidents, but the field reports submitted by the investigator in many instances did not contain the pertinent information. It was also impossible to determine the influence of flap deflection on stalls during take-off, as the majority of the accident reports do not give the flap setting.

In contrast to this, there was only one stall accident to airplane 105, and this occurred on take-off. Comparison of available data on the two models did not disclose any differences that would account for the extreme variation in stall accident rates.

One major difference between the two airplanes is that airplane 069 has a tail wheel, while airplane 105 has a nose wheel. Because of the apparent effect of cross-winds on the accidents to airplane 069, it was considered possible that this difference was a factor in the variation in accident frequency for the two models. The review of the reports of the accidents to airplane 069, however, showed only one case involving premature lift-off because of control problems during the ground roll. This occurred during a take-off from an icy runway. A review was also made of stall accident frequency for all airplanes in terms of the landing gear configuration. No correlation was found. Airplane 069, as stated above, had the highest frequency in Group 1A; Airplane 093, also with a tail wheel, had the highest frequency in Group 1B, but not significantly above that of airplane 009 with a nose-wheel; and airplane 045, with a tail wheel, had the lowest take-off stall accident rate of any airplane in Group 1C. It is, therefore, concluded that the difference in ground-handling characteristics of airplanes having nose wheels and those with tail wheels is not a significant factor in take-off stall accidents.

Take-off instructions and data in the owners manuals were similar for airplanes 069 and 105. It was observed that there were no instructions for cross-wind take-off, or any data on critical cross-wind component. Furthermore, the tabulated data lists airspeed at 50-foot altitude, but no take-off speed, and gives distances to clear a 50-foot obstacle for take-off from a hard-surface runway with flaps deflected, although the instructions say that a normal take-off should be made with flaps up, and the flaps should be used only for a short-field take-off or take-off from grass. No data are included for the effect of a grass field on take-off distance. Data on the effect of altitude and temperature on take-off distance were also inadequate, being limited to tabulated data for a few specific altitudes and temperatures.

The only significant difference between the manuals for the two models lies in the fact that the manual for airplane 105 contains a table giving airspeed corrections at speeds near the stall, both for flaps up and flaps down. It was noted that for this airplane the airspeed indicator reads low by 7-10 miles per hour in the take-off range. It is therefore possible that the large difference in frequency of stalls following take-off between airplane 069 and airplane 105 stems from the fact that pilots are unknowingly taking off at higher speeds relative to the stall in airplane 105, because they do not realize that the speeds given in the take-off data are calibrated rather than indicated airspeeds.

E. Accidents Involving Airplanes 021 and 090

Airplanes 021 and 090 had a stall accident rate appreciably higher than the mean of Group 1C. The accident reports for these models were analyzed in detail, in the same manner as those for airplane 069. Out of a total of 27 stall accidents, 19 occurred on take-off and two on go-around, so that these two phases of flight accounted for 78% of the total. In this case, it was found that cross-winds were not a factor in any of the accidents, and it was noted that the owner's manual for the 1956 model of aircraft 021 and all subsequent modesl contained a critical cross-wind chart.

One of the take-off accidents can be deleted from consideration insofar as flying characteriatics are concerned, as it occurred on a ferry flight following extensive maintenance work, during which the cables to the left aileron had been reversed, so that application of right aileron moved both ailerons up. Of the others, three involved attempted take-off with ice on the wings. Five of the remaining 15 occurred on take-off from grass or dirt fields or strips.

In at least one go-around accident and one take-off accident, the description of the airplane motion appears to relate the stall to the severe rolling tendency with flaps down and power on reported by NASA in their evaluation of the handling characteristics of six General Aviation airplanes. In several other take-off accidents in which the airplane rolled to the left, it appears that this same type of motion was involved. The accident reports in many cases do not contain data on flap position, so no definite conclusion can be reached in this regard. It is possible that the rolling tendency of this airplane in a power-on stall may be a significant factor in its stall accident history.

Another factor that may be involved in the stall accidents on take-off on these model airplanes is premature gear retraction. The owner's manual for airplane 021 up to and including the 1958 model, recommended gear retraction "as soon as you have established a stabilized climb at 75 to 80 m.p.h." In the Manual for the 1960 model, the airspeeds were deleted from the statement. None of the manuals for airplane 090 give a gear retraction speed. In one accident report involving a 1960 model, the pilot stated that he made it a practice not to retract the landing gear below 100 m.p.h. because of loss of lift when the gear doors opened.

The information in the owner's manual varies greatly for various models of the airplane. In the manuals for models of airplane 021 up to 1960, the instructions are to apply back pressure on the stick at 60 m.p.h., "to bring the wings to a slightly positive angle of attack" and "the airplane should fly off at approximately 65 m.p.h." These same statements are made for both normal and short-field take-offs, although the instructions are to have wing flaps up for a normal take-off, and flaps down 20° for a short-field take-off. The distance given to clear 50 feet is shown as approximately 1,350 feet for a normal take-off at sea level at standard temperature with zero wind, and approximately 950 feet for a short field take-off under the same conditions. The 1960 manual lists 65 m.p.h. as normal take-off speed, and for the short-field case states "assume a nose-high attitude so that you break ground as soon as minimum flying airspeed is reached."

The 1961 and 1962 manuals for airplane 021 specify 65 m.p.h. take-off speed both for normal take-off with flaps up and for short field take-off with 20° flaps, yet the data on the charts for a sea level standard day with zero wind shows a distance over 50 feet of approximately 1,700 feet and a ground roll of approximately 1,326 feet with flaps up, as compared to 1,300 feet and 925 feet, respectively, for the case with 20° flap deflection. Thus, according to the charts, the airborne distance to climb to 50 feet is approximately the same for the two cases, but the 20° flap deflection reduces the ground roll to accelerate to 65 m.p.h. by approximately 400 feet or approximately 30%. It must be concluded that the distance given on the charts is incorrect for at least one of the two cases.

The manual for the 1964 model of airplane 021 gives a normal take-off speed of 81 m.p.h. with flaps up although the gross weight has only increased from 3,125 lbs. for the 1962 model to 3,300 lbs. for the 1964 model, or approximately 5%. The recommended short field take-off speed, with 20° flap for the 1964 model is 65 m.p.h., or the same as for the 1962 model.

The manual for airplane 090 up to and including the 1962 model lists a recommended normal take-off speed, flaps up, of 65 m.p.h., although the power-on stall speed with flaps and gear up is listed at 63 m.p.h. The charts of take-off distance in the same manuals list the take-off speed as 80 m.p.h.

It was found that the manuals for the 1966 model of airplane 021 and the 1965 model of airplane 090 had been revised to include curves of take-off speed and speed at 50 feet vs. weight, and complete charts of take-off distance in terms of weight, temperature, altitude and wind. These models, however, were not in service in 1964.

None of the manuals contain any data on take-off distance from other than hard surface runways. As previously stated the manuals do contain a chart of maximum safe cross-wind. The fact that there were no stall accidents under cross-wind conditions, despite the problem of control on airplane 021 reported by NASA, would indicate that the inclusion of this chart may be of real value to pilots.

F. Review of Owners Manuals

In view of the findings relative to the manuals for airplanes 021, 069, and 090, a review was made of the take-off data in the manuals on other makes and models of airplanes. Data on altitude and temperature effects were minimal in many cases, although complete charts were provided in a few cases; take-off speed was often not clearly specified, and in other cases the speed given provided no margin from stalling speed, apparently depending on ground effect, airplane acceleration, and the effect of power to provide a safety margin. No data on take-off from other than hard-surface runways was included in any manuals, and a few considered cross-wind or gave maximum safe values. It is therefore recommended that the various manufacturers critically review the adequacy of such data as is now presented in owners' manuals.

G. Twin-Engine Airplanes

The number of stall accidents to twin engine airplanes is so small that a statistical distribution is of questionable value in comparing individual models. There were only seven accidents to the three airplanes in Group IIA; three to airplane 051, three to airplane 060, and one to airplane 030. The highest rate was of the order of 0.1 per 10,000 flying hours. With this small sample size, no valid conclusions can be drawn from a statistical analysis. Of the seven accidents, four occurred on take-off and two on initial climb for a go-around. Failure of one engine was involved in three of these accidents. The only other accident occurred in flight during single-engine practice on a dual instruction flight.

For the airplanes in Group IIB there was a total of 21 accidents to the five models and the maximum number to any one model was five, so that here again, the sample size is too small for a Chi-Square analysis to be meaningful. Examination of accident rates, however, indicates a problem with airplane 027, which had a stall accident rate of 0.52 per 10,000 hours, as compared to 0.17 for the entire group. Of the five stall accidents to this model, three occurred during single-engine operation on instructional flights, two of which were solo and one a dual check for a multi-engine rating. In all three cases, the airplane entered a spin from which recovery was not affected. These accidents constituted 60% of the stall accidents, and 12% of all accidents to the model, yet instructional flying accounted for only 0.5% of the total usage.

A review of 1965 and 1966 accident reports relating to this airplane discloses that the occurrence of stalls followed by a spin with this model during single-engine operation has continued. In many cases it has been found that the airplane crashed in a relatively flat spin. The problem of stalls and spins on airplane 027 with one engine inoperative was the subject of considerable analysis and flight testing in 1964, and it was concluded that the airplane met the requirements of FAR 23. Nevertheless, on a basis of the findings of this study and the continued occurrence of such accidents, it is recommended that the problem be restudied to determine the specific characteristics of airplane 027 which are responsible for its relatively high stall accident frequency, and that the adequacy of the certification requirements in FAR 23 be critically reviewed. The stall-accident rate of airplane 027, in comparison to that of other airplanes in the same usage group, as discussed below, indicates that this airplane, and hence the requirements, are not representative of the present state of the art.

The unpublished comments of a certain group of pilots indicate that airplane 027, with both engines operating, has a strong rolling tendency in stalls at high power. Considering the situation with one engine inoperative, it is possible that the yawing moment due to asymmetric power at stalling speeds, combined with this rolling tendency flattens the spin. This could account for the fact that evidence in accidents indicates that the airplane crashed in a considerable flatter spin than had been experienced in flight tests on the two engines. With full power on one engine, most, if not all, of the rudder power would be used in overcoming the yawing moment from asymmetric thrust, so none would be available to oppose the spin until power was cut on the live engine. If this is not done promptly, it is possible that a flat spin results from which recovery is impossible. It is therefore recommended that the effect of single engine operation be included in the review.

The record of airplane 039 is in marked contrast to that of airplane 027. The two models had the same total number of stall accidents, but the flying time on airplane 039 was over five times as much as that on airplane 027, giving a stall accident rate of 0.095 per 10,000 hours as compared to 0.52. Three of the five accidents to airplane 039 followed an actual engine failure on takeoff; none occurred during instruction although the instructional flying on this model was close to 5% of its total utilization.

Considering the group as a whole, it is found that single-engine flight characteristics are the most important single factor in stall accidents, 11 out of the total of 21 accidents having occurred during one-engine operation. Seven of the accidents occurred in the take-off phase and two on go-around, with four of the seven involving single-engine flight. Eleven were during the in-flight phase, with seven occurring on one engine. As in the case of single-engine airplanes, stalls during landing approach were not a problem.

One stall accident to airplane 027 involved loss of both engines from fuel starvation, when a passenger in the rear seat apparently closed the fuel shut-off inadvertently with his feet. While this is not a design-induced pilot error, it is nevertheless an accident inducing design feature.

## GROUND-LOOP ACCIDENTS

### Accident Definition and Circumstances

The ground-loop type accident is defined as one resulting from a loss of directional control or a sudden swerve while taxiing, taking off, or landing. Circumstances and/or environmental conditions surrounding these accidents vary widely, both in description and degree. However, causative elements attributed to the pilot in command are in a majority of these cases described as:

(1) Improper operation of brakes and/or flight controls,

or

(2) Improper compensation for wind conditions.

The ground-loop accident reports were reviewed in an attempt to determine whether design factors could be explicitly related to the accident type. It soon became apparent, however, that any such relationship would best evolve from statistical test results and deductive reasoning. A consideration of some typical factors, circumstances and actions involved in this accident type is also helpful. These include the following:

(1) Crosswind gusts pick up the upwind wing and airplane veers to one side or the other of the runway or landing surface.

(2) Airplane nose wheel often collapses after crosswind gust picks up a wing.

(3) A loss of directional control resulting from "over control" during take-off or landing.

(4) Failure to use adequate or proper crosswind landing or take-off techniques with subsequent drifting or veering.

(5) Contacting the runway or landing surface in crabbed attitude.

(6) Loss of traction on slippery runways or landing surfaces.

(7) Failure to initiate a go-around or abort the take-off at the proper time.

(8) Veering or fishtailing on runway on take-off or "long landing."

(9) Misapplication of brakes and/or power.

(10) Wrong type of approach, configuration, or landing for existing wind conditions, i.e., wheel landing vs. full-stall landing.

(11) Taxiing or turning too fast for the existing wind conditions.

(12) Colliding with objects or obstructions adjacent to runway, especially snowbanks or those in farm fields.

(13) Landing on unimproved areas.

(14) Bouncing and/or porpoising with subsequent loss of control.

(15) Inadequate training, skill or experience.

Statistical Significance

An evaluation of first type ground-loop accidents on a study fleet basis (Group III) discloses that airplanes 054, 093, 069, 045, 099, 063, 066, 009, and 048 all had a relative frequency of occurrence of ground loops based on flight time that was considered to be higher or much higher than the statistical mean as noted on Appendix (11). The same result also applies to airplanes 006 and 024; however, the flight time of both was considered relatively small. All of these airplanes, with the exception of 009 and 048, are tail-wheel types. The former is a high-wing nose-gear configuration; the latter a low-wing nose-gear configuration.

A similar evaluation of Group III on an accident basis also discloses a relatively high frequency of occurrence for the same airplane, with the exception of 066, 054, and 024. If, therefore, an accident should involve any of the airplanes mentioned above except these, chances appear to be better than average that it will be a ground loop.

Similar evaluations of all these aforementioned airplanes on both an accident and flight-time basis within the scope of the utilization groups (Groups I and II) disclose much the same result with the exception of airplanes 006 and 063. It should be noted that while relative accident frequencies evaluated on an "accident basis" provide an excellent yardstick for potential safety and/or design improvement, they do not, unlike "flight time," measure the relative risk of having a particular type of accident. The airplanes with relatively few ground loops on a flight-time basis (ground-loop frequencies lower than or much lower than the statistical mean as noted) include 051, 021, 030, 042, 018, 015, and 087. The same applies to airplane 057, but its flight time was also considered to be relatively small. All of these airplanes are tricycle gear configurations. It also appears that airplanes 021, 081, 003, 015, 084, and 087 have better than average ground-loop records on an accident basis; i.e., <u>if</u> an accident should occur in one of these airplanes, the likelihood of a ground-loop type should be relatively small.

## Determining Pilot Error

Evaluating the exact nature and degree of pilot error in ground-loop accidents is virtually impossible. His precise actions and/or responses associated with those circumstances described on pages 51 and 52, for example, are not necessarily singular and discrete nor do they always reflect the omission or commission of some related singular action.

Whether or not a particular pilot response is completely effective in the prevention of a ground-loop accident may depend upon the airplane. Hence, a more positive viewpoint is based on an awareness that all airplanes are somewhat unique and require a certain degree of familiarization with their particular characteristics under varying circumstances. As a matter of record, however, there are airplanes, as noted above, that appear to be somewhat prone to the ground-loop accident type. It is our belief, therefore, that while certain configurations may not induce the pilot to err directly and thus cause the ground-loop accident, they do provide a relative affinity for the ground loop that may make it difficult or impossible for the pilot to prevent the accident under relatively adverse circumstances. The following discussion is an attempt to point out how some of these factors can affect the ground-loop occurrence.

## Tail Wheel Airplanes

Tail-wheel airplanes are inclined to ground loop more easily than those with tricycle gear primarily as a result of the location of the center of gravity behind the main landing gear. Inertia moments created in these airplanes, as a result of any curvilinear motion, tend to cause the airplane to swerve or veer since the effect is to increase the curvature by decreasing the radius of curvature; that is, the airplane's tendency to swerve becomes more pronounced as the swerve itself progresses. It is desirable to keep the center of gravity as close to the main landing gear as possible in order to minimize the airplane's ground-yaw inertia characteristics; however, its position is generally dictated, at least in part by considerations related to the airplane's tendency to nose over.

Airplanes equipped with swivel-type tail wheels preclude the generation of large yaw restoring forces necessary to counter adverse yaw inertia moments. As a result they contribute relatively little toward preventing ground loops. Also, the swivel spring restraint on tail-wheel airplanes represents a compromise between the requirements for lateral forces to restrain the swerve tendency and for easy steering at low speeds. It is doubtful, therefore, that the tail wheel makes any significant contribution to ground-roll stability in the initial phases of landing or the latter phases of takeoff where the majority of ground loops occur. Of course, the tailwheel has to be firmly on the ground in order to contribute any restoring moments to an adverse disturbance and braking during landing tends to unload the wheel and thereby further reduce its correcting or lateral force capability. As noted in the Chi-Square evaluation of the study fleet (Group III - First Accident type only), all those aircraft that appear prone to the ground-loop accident type are tail-wheel types with the exception of two tricycle gear airplanes, 009 and 048. Although the high-wing position of those tail-wheel aircraft in this former group might be cited as a factor in ground loops because of the greater ease of gust or turbulence upset, the aft center of gravity position is believed to be the primary influencing factor. In support of this conclusion, it was found that a Chi-Square computation based on all tricycle gear low-wing and all tricycle gear high-wing airplanes within the study fleet disclosed no significant difference between these groups on a flight-time basis.

A dramatic example of the effect of CG position in relation to the main-landing gear on ground-loop accidents is pointed up in a comparison of two airplanes, 069 and 045, which were "transitioned" from tail wheel configurations to tricycle gear configurations as airplanes 018 and 081. That the centers of gravity of both 069 and 045 are well aft of the main gear is indicated at least in a general way, in the owners flight manuals, where it notes that heavy initial braking may be used in the landing roll. This is an apparent indication that the danger of nosing over as a result of a CG position close to the main gear is relatively slight.

On the basis of a study fleet comparison (Group III -- First Accident type only), neither airplane 018 nor 081 was considered to have a significantly high ground-loop accident record. On the contrary, the record of 018 is considered to be better than the statistical mean on a flight-time basis, while 081 has a significantly good record on both a flight-time and an accident basis. The ground-loop records of both 069 and 045, however, were evaluated as significantly worse than the statistical mean on any basis! In addition, a Chi-Square evaluation of these corresponding models on a multiple degree of freedom basis discloses a highly significant variance. One of the most influential factors accounting for this substantial variance in ground-loop frequency between these models is undoubtedly the difference in landing gear configurations. The tricycle gear configuration, of course, has a relatively low frequency of occurrence because of its stable forward center of gravity position.

Nose-Wheel Airplanes

The tricycle gear airplane is basically ground stable with respect to adverse yaw inertia moments resulting from an external disturbance or an intentional pilot input. With the center of gravity ahead of the main landing gear, the inertia effect tends to align the airplane along a tangent to its particular ground path at any given time. The farther forward the center of gravity is located, the greater the ground roll stability of the airplane and the more rapid the convergence in a crabbed landing. Landing in a crabbed attitude in a nose-wheel airplane would result in the creation of inertia forces tending to align the airplane with the runway. In the tail-wheel airplane, however, just the opposite would be true; the inertia forces created would tend to cause the airplane to swerve or veer.

A statistical evaluation to determine the differences in the ground-loop records of tail-wheel airplanes and tricycle-gear airplanes discloses that this latter group is far superior to its tail-wheel counterpart. That is, chances of having a ground loop in a tricycle-gear airplane are much less than in tail-wheel airplanes.

Although not directly related to the kinematics of the airplane, the enhanced visibility during takeoff and landing of a nose-wheel equipped airplane can be a decided advantage in preventing a swerve or ground loop, especially so during landing or takeoff on relatively narrow runways in adverse wind conditions.

The nose wheel itself can contribute substantially to the ground roll stability characteristics of an airplane. A nose wheel that is free to caster will permit the inertia moments to stabilize the aircraft's motion or ground path. Few if any steerable nose wheels are totally unrestrained and completely free to caster; however, the important point with respect to ground loops is that the nose wheel caster restraint be minimized. It should, of course, be pointed out that a particular nose-wheel design results from a consideration of many factors, i.e., maneuverability, shimmy, turning radius, stability, etc. The ultimate design generally represents a compromise. For instance, the desirable characteristics of a nose-wheel designed solely to preclude ground loop during the landing phase would probably include, aside from a steering capability, minimum friction and maximum reversibility, that is, maximum freedom to caster. On the other hand, the same nose wheel designed to preclude ground loop during the takeoff phase might well be irreversible, that is, capable of being steered by the pilot but not deflected by external wheel forces. It is interesting to note in this regard that the majority of ground-loop accidents in both 009 and 048 occurred in the landing phase.

An understanding of the nose-wheel caster effect is enhanced by considering the results of landing in a crabbed attitude. In such an attitude, the inertia forces on landing contact tend to align the airplane with its initial path of flight, and if the nose wheel casters as it contacts the runway surface, the airplane straightens out and continues traveling in a straight line. Should the nose wheel fail to caster, however, the airplane will tend to veer or swerve from the runway surface since such action effectively thwarts or precludes the inherent ground-roll stability of the tricycle configuration.

In a statistical comparison of all single engine, tricycle gear airplanes within the study fleet, airplanes 009 and 048 are the only two having ground-loop frequencies considered to be much higher than the statistical mean of their counterparts [See Appendix (12)]. An evaluation of the study fleet (Group III, first accident type only) also disclosed that airplanes 009 and 048 were the only tricycle-gear airplanes to have a relative ground-loop frequency significantly higher than the statistical mean on any basis!

A review of pilot experience levels in both the 048 and 009 ground-loop accidents disclosed that about 70% of the pilots involved were students. It might be rationalized that the relatively low pilot experience level was a pertinent factor in the accidents, and to a certain extent, this is true. However, a survey of airplane 042 for the study year disclosed that this model, with an average ground-loop record statistically, was exposed to over five times as much instructional activity as recorded for 048. It was concluded, therefore, that the pilot-experience level alone could not have been responsible for the 048 and 009 variance.

Based on the above, it is believed that the relatively high frequency of ground loops in these airplanes may have been influenced by detail design of the nose-gear configuration. Those factors that appear significant include the degree of static nose-wheel trail, the type of steering linkage connection between nose wheel and rudder pedals (rigid in airplanes 009 and 048), and the magnitude of the pedal forces required for steering.

The manufacturer of airplane 048 has recently reduced the nose-wheel steering arc in order to reduce ground-steering forces, and has increased the static nose-wheel trail. Notwithstanding the express reasons for initiating such changes, the effect is to enhance the ground roll stability of the airplane by increasing the caster or swivel capability of the nosewheel in addition to making it more easily manuevered on the ground as a result of reduced pedal forces.

Ground-Loop Initiation

While all ground loops are the result of a loss of directional control, many are precipitated by a loss in lateral control whereby a wing, for example, contacts the ground as the result of a gust, and the airplane subsequently veers or swerves. An important parameter related to this ground-loop initiation mode is the ratio of the lateral wheel base to the height of the center of gravity. The larger this ratio, the smaller the tendency of adverse external forces to tip the airplane sideways. Thus, it would appear that low-wing aircraft might be naturally less susceptible to ground loops precipitated by gust upset than their high-wing counterparts since the low-wing configuration provides for a large lateral wheel base and a relatively low center of gravity. A computation comparing low-wing and high-wing tricycle gear configurations shows that the low-wing airplanes have fewer ground loops and appear significantly better at the 2½% level of significance on an accident basis. The same computation on a flight-time basis shows no significant difference. Because there was only one low-wing tail-wheel airplane within the study group, no similar computations could be made for the tail wheel configurations.

The wing first modes considered above are contrasted with those ground loops caused by pure loss of directional control with no wing contact during the incipient motion. This mode is related primarily to the location of the center of gravity relative to the main gear and the radius of gyration. A relatively large radius of gyration about a vertical axis through the main landing gear of tail-wheel airplanes reduces the swerve tendency, while the location of the center of gravity determines the magnitude of the inertia moments. It should be noted, of course, that the radius of gyration is not a design factor per se, but merely a resultant computation.

Other Design Parameters affecting the Ground Loop

Torsional flexibility of both the landing-gear structure and tires can markedly affect the capability of developing lateral or cornering forces. In addition, the softer the main landing gear tire, the more effective they are in reducing lateral or cornering loads responsible for precipitating veering or swerving. It is interesting to note that airplane 075, an airplane which utilizes a relatively large soft balloon-type tire (8.00 X 4 @ 12 p.s.i.)

was considered to have a much lower than average ground-loop frequency as compared to all other high wing, tail wheel airplanes in the study fleet (Group IV of the Appendix).

The location of the fuselage center of pressure determines the relative swerve or veering reaction of the airplane to crosswinds. A center of pressure location close to the main landing gear axis, as might be conceivable in some tricycle configurations, reduces this swerve tendency. Its position, however, is generally the result of a sensible compromise based on other important design considerations.

## ACCIDENTS INVOLVING RETRACTABLE LANDING GEAR

I. The accidents in this group involved landing gear retraction while the airplane was on the ground, and landings made with the wheels in the up position. There were 311 "wheels-up landings," and 154 "gear retracted" accident reports reviewed in this study.

For the purpose of this study, these accidents have been placed in subdivisions that include only those in which pilot error was evident. Accidents involving unwanted retraction of the landing gear because of mechanical failure of the extension/retraction mechanism have been eliminated from this group, as have those accidents involving wheels-up landings associated with engine failure or forced landings. These were eliminated since factors other than system design played a significant part in the pilots' actions, or failure to act, with respect to actuating the landing gear extension mechanism.

II. Types of Error

The resulting four classifications of actions within the retractable landing-gear-accident category are as follows:

1. Premature Retraction

In this classification are the accidents that occurred during the takeoff phase of flight and which were initiated by the pilots' attempt to retract the landing gear before flying speed was obtained. Also in this classification are those accidents occurring in the landing phase of flight in which the landing gear collapsed during the landing roll because of damage to the extension/retraction mechanism in the course of the previous takeoff. This damage occurred when the pilot placed the landing gear selector switch or lever to the "up" position during takeoff while most of the weight of the airplane was still supported by the landing gear. The takeoffs in these instances were accomplished successfully despite damage to the landing gear linkage, push-pull rods, or bellcranks.

There were 30 of these accidents in the 1964 records reviewed. Airplanes involved were: 015, 021, 024, 027, 039, 051, 060, 087, and 096. However, these accidents are not considered as design-induced since they occurred at a time, or flight phase, where there was no intent to operate some other system; e.g., flaps. Unusual conditions, obstructions, or emergency circumstances were not present to influence the pilot to retract the landing gear as quickly as possible.

2. Inadvertent Retraction.

Accidents in this classification, with three exceptions, are those in which the pilots placed the landing gear lever to the "up" position unintentionally while the airplane was on the ground. Most of these accidents occurred at a time when the pilots intended to actuate some other system such as flaps or landing lights. The total number of these errors could not be determined because the accident reports often did not identify the pilot's intention at the time of the inadvertent retraction. There was, however, enough information in many of the pilot's statements to lead to certain conclusions concerning the landing actuating levers or switches, their placement in the cockpit, and similarity to other switches or levers.

Aircraft 015, 021, 024, 027, 030, 039, 051, 072, 078, 084, 087, 090, and 096 were involved in 80 instances of inadvertent retraction of the landing gear in the records reviewed.

In context with inadvertent activation of the landing gear selector, CAA Technical Manual No. 103, September 1953, title: AIRCRAFT DESIGN THROUGH SERVICE EXPERIENCE, stated in part, "Service reports show numerous cases of confusion of the retractable landing gear controls with other controls . . ."

On October 1, 1959, Amendment 3-5 to CAR Part 3 became effective. The preamble to this amendment states "Accident records have shown that approximately one-sixth of all accidents with airplanes certificated under Part 3 have involved the misuse of the landing gear control. Incorrect operation of this control has been attributed to its proximity and similarity to the wing flap control. Therefore, Section 3.384 is being amended to specify the location and shape of the landing gear and wing flap controls to reduce the possibility of confusion." The amendment reads as follows:

> "(1) The wing flap or auxiliary lift device control shall be located centrally or to the right of the pedestal centerline or of the powerplant throttle control centerline and shall be sufficiently displaced from the landing gear control to avoid confusion.
>
> "(2) The landing gear control shall be located to the left of the throttle centerline or of the control pedestal centerline.

"(3) The control knobs shall be shaped in accordance with figure 3-13." (Flap control shaped like airfoil, landing gear control shaped like a wheel.)

The effectiveness of the control arrangements specified will be discussed further in this report in relationship to specific aircraft. At this point, however, it should be noted that the great majority of retractable landing gear airplanes in the general aviation fleet today were previously, and are presently, manufactured under type certificate issued prior to Amendment 3-5. Consequently, it is likely that the number of accidents involving inadvertent retraction of the landing gear will not be reduced significantly for many years to come because of the influence of these airplanes.

On some later models of these airplanes, modifications to the shape of the controls have been made, but the locations have not been changed to those desired by the regulation. As a result, it will be difficult to ascertain the full effect of the regulatory change at this time, although as discussed below, the data indicate a beneficial effect.

3. Failure to Assure Landing Gear Locked Down.

Accidents in this classification are those in which the landing gear lever or switch was moved to the down position by the pilot, but for various reasons the landing gear extended only partially and the gear collapsed upon touchdown. In most instances the pilots were unaware of the unsafe landing gear and took no action to extend it by use of the emergency landing gear extension system. However, this classification also includes accidents in which the pilot was aware of the unsafe condition of the landing gear and used the emergency system, but used it incorrectly.

Because of the incorrect use, the landing gears did not go into the down locks, and collapsed during the landing roll.

There were 97 accidents in this classification.

4. Failure to Extend

Accidents in this classification are those in which the pilot did not operate the landing gear lever or switch to the "down" position, and as a result, the aircraft was landed with the wheels in the retracted position. There were 121 accidents in this classification.

## III. TABULAR SUMMARY OF THE NUMBER OF OCCURRENCES

| Aircraft Make and Model | Inadvertent Retraction | Failure to Assure L/G Down & Locked | Failed to Extend |
|---|---|---|---|
| 051 | 3 | 1 | 1 |
| 060 | 0 | 2 | 1 |
| 090 | 3 | 2 | 3 |
| 021 | 41 | 15 | 26 |
| 030 | 2 | 0 | 3 |
| 078 | 2 | 0 | 0 |
| 072 | 5 | 1 | 3 |
| 003 | 0 | 2 | 12 |
| 096 | 7 | 5 | 1 |
| 024 | 1 | 1 | 3 |
| 015 | 5 | 12 | 13 |
| 084 | 1 | 1 | 11 |
| 039 | 3 | 12 | 14 |

(Summary of Occurrences, Cont'd)

| Aircraft Make and Model | Inadvertent Retraction | Failure to Assure L/G Down & Locked | Failed to Extend |
|---|---|---|---|
| 087 | 6 | 30 | 24 |
| 027 | 1 | 13 | 6 |

## IV. Statistical Analysis

The data were analyzed for the overall fleet and by utilization groups for each of the three sub-types tabulated above. In general, the number of airplanes and the number of incidents involved in each utilization group were too small to permit valid conclusions. The Chi-Square multiple degree f freedom analysis, on a fleet-wide basis showed a variation among airplane types that is significant at the 0.01% level for each of the types of errors tabulated above. For each type of error, however, the sample size for at least half of the airplane types was too small to yield significant comparison of individual models on the basis of a single degree of freedom analysis. A few airplane types did deviate from the mean at a highly significant level in each accident type. These were airplane 021 in inadvertent retraction; airplanes 087 and 027 in failure to assure L/G down and locked; and airplane 087 in failed to extend.

The accident types being considered are among those in which, as discussed in the preface, pilot error is clearly identifiable and directly related to the design. In addition there are so many variations among airplanes that influence of design variables can be identified only by considering all of the accidents involved for all airplane types.

In view of the above considerations, all accidents are reviewed and comparisons are made on a basis of percent of accidents related to percent of flying time in the disucssion of this accident type, rather than following the form used in most sections of this report.

## V. INADVERTENT RETRACTION

1. Airplane 051. All inadvertent retractions were by student pilots.

2. Airplane 060: There were no inadvertent retractions of the landing gear in this airplane.

3. Airplanes 090 and 021:

Airplanes 090 and 021 have nearly identical landing gear retraction/extension mechanisms. Accordingly, they are combined and considered together for this part of the report. There is, however, one noticeable difference between airplane 090 and early models of airplane 021, and between model 021 airplane with serial numbers less than D-6842 and later models of this airplane. This difference is in the configuration of the landing gear and wing flap controls. In 090 model airplane, and in 021 model airplane after serial number D-6842, the wing-flap control has the shape of an airfoil, and the landing gear control is shaped like a wheel, thus conforming to the design specified in CAR Part 3, Amendment 3-5. However, the location of these controls in all models 090 and 021 airplanes is in reverse to that specified in the regulation.

In the airplane of model 021 prior to serial number D-6842, the landing-gear control and the wing-flap control are included in a row of similar switches or more precisely, nearly identical switches. The accident records for early model 021 airplane appear to confirm the conclusions which led to the adoption of CAR Amendment 3-5 when they are compared to later model 021 and model 090 airplanes, although the sample on the later airplane was too small for a statistically significant comparison.

Model 021 airplane prior to serial number D-6842 comprised 22.2% of the active General Aviation Fleet having retractable landing gear. However, they accounted for 47.5% of all the inadvertent retraction accidents reviewed in this study. Conversely, model 021 airplane after serial number D-6842, and model 090 airplane comprised 5.6% of the active retractable landing gear general aviation airplane in 1964, and were involved in 7.5% of the inadvertent-retraction of the landing-gear accidents.

Factors involved in the 44 accidents in this classification with model 090 and 021 airplanes:

(1) Number occurring in daytime .................... 32

(2) Number occurring at night .................... 12

(3) Number occurring during landing roll ......... 43

(4) Number occurring during engine runup ....... 1

(5) Number of instances in which the landing gear control was moved by mistake when pilot intended to operate the wing flaps. ......... 35

- (a) Stated by pilot ........................ 21
- (b) Indicated by accident circumstances .... 14

NOTE: These circumstances are, e.g., those in which the pilot stated that the flaps were retracted during the landing roll, but were found in the down position during the accident investigation.

(6) Landing gear control moved instead of landing light switch . . . . . . . . . 1

(7) No reason given in accident report . . 8

The principal factor in these accidents is the similarity of the landing gear selector switch to the other switches in the older model airplanes. Since there were 4,631 of these airplanes active in 1964, it is likely that the accidents in this classification will continue to happen for sometime in the future. It is considered that 43 of the 44 accidents in this classification are within the design-induced pilot error category because of the similarity of the various controls and switches. This is concluded for 43 of the accidents despite the lack of information in eight of the reports, since these eight accidents also involved an unwanted retraction during the landing roll, and there was no mechanical malfunction.

4. Airplane 030

Both inadvertent retractions occurred during the landing roll. In one instance the pilot stated that he had moved the landing gear control by mistake for the wing-flap control. In the other, the accident circumstances point to the same conclusion. These airplanes had switches and controls nearly identical to those in early model 021 airplanes.

5. Airplanes 078 and 072

a. Since operation of the landing gear mechanism and controls are identical in both airplanes, they have been combined for statistical purposes in this part of the report.

b. Factors involved in the seven accidents in this classification are as follows:

(1) All occurred during daylight hours

(2) All occurred during the landing roll.

(3) Number of instances in which the pilot moved the landing gear control by mistake when he intended to operate the wing flap controls 6

(a) Stated by pilot 4
(b) Indicated by accident circumstances 2

(4) Reasons unknown

In one report the pilot stated that the landing gear control-flap control locations are opposite to those in aircraft 051 in which he had considerable experience. While this airplane has the wheel-shaped landing gear control and the airfoil-shaped wing flaps control, they are opposite in location to that in the Part 3 regulation. Although the number of instances in this study are too few to conclude that location, per se, influences pilots to err, it is evident that lack of standardization does contribute to pilot error probability. Previous studies confirm this conclusion.

6. Airplane 003

There were no accidents attributable to inadvertent landing gear retraction in this aircraft.

7. Airplane 096

Factors involved in the seven accidents in this classification are as follows:

(1) Number of occurrences in daylight conditions 4

(2) Number of occurrences at dusk 1

(3) Number of occurrences at night 2

(4) Number of instances where pilot operated the landing gear control by mistake instead of the wing-flap control 3

Note: One instance involved a student pilot on touch-and-go landings; one involved a passenger operating the flaps, at pilot's request; and one involved use of flap for high-speed descent. Upon reaching traffic pattern altitude, the gear was raised instead of the flap. Because of a power-on approach at this point, the warning horn did not sound.

(5) Gear selector moved accidently while turning off boost pumps and radio . . . . 1

(6) Circumstances unknown . . . . . . . . . . . 3

Note: In one instance where the probable cause of the accident was inadvertent retraction of the landing gear, it was found that under test conditions the right main gear would not go into the locked position unless assisted manually. There was insufficient information on which to base a conclusion in the other two instances.

From the foregoing it is apparent that factors other than system design were the principal elements in at least four of these inadvertent gear retractions. Accordingly, it is concluded that they do not fall in the design-induced pilot error category. Airplane 096 has the landing gear and wing-flap control configuration and location specified in the CAR Part 3 Amendment.

8. Airplane 024

The one inadvertent retraction of the landing gear in this airplane occurred when the pilot intended to raise the flaps during the landing roll. The landing gear and wing-flap control levers do not conform to the configuration or the location specified in the CAR Part 3 Amendment.

9. Airplane 015

a. This airplane does not have switches or levers which control the landing gear remotely through hydraulic or electrical systems. It has a mechanical system linked directly to the actuating handle. When the handle is in the "down" position, the landing gear is up.

conversely, when the handle is vertical, or in the "up" position, the landing gear is down.

b. Factors involved in the five instances of inadvertent landing-gear retraction are as follows:

(1) In one instance the student pilot receiving dual flight instruction thought the stall-warner signal was the landing gear warning horn sound, and recycled the gear to the "up" position.

(2) In one instance the passenger attempted to move his seat forward by pulling on the landing gear handle, causing it to come out of the "down" lock.

(3) Two of the instances involved actions of students during dual flight instruction periods. In one of these the landing gear was left in the "down" position during air work. On the prelanding check, the student repositioned the gear to the "up" position. Although the warning horn blew, it was so faint that neither the instructor nor student heard it.

(4) The fifth instance involved an inadvertent operation of the landing gear while the airplane was being taxied to the takeoff runway. The pilot had a total of six hours in the airplane and was used to an airplane with a handbrake located in nearly the same position in the cockpit as the landing-gear lever is in this airplane.

c. Since the circumstances of these accidents are so varied, it cannot be concluded that this design, per se, influences pilot error. However, there was one comment in the accident reports concerning confusion because of the action of the landing gear handle, i.e., when the handle is up, the gear is down, and vice versa.

10. Airplane 084

The single instance of inadvertent retraction of the landing gear in this airplane was by a student pilot receiving dual flight instruction. This airplane has the landing gear and wing-flap control configuration and location specified in CAR Part 3.

11. Airplane 039

In one of the three instances of inadvertent retraction of the landing gear, a passenger moved the landing gear lever. In two instances the pilots mistakenly retracted the landing gear instead of the flaps.

The sample is too small to conclude that the design, per se, induced the pilot to err. However, it is noted that while the landing gear and flap actuating levers have the configuration specified in CAR Part 3, Amendment 3-5, the locations are reversed.

12. Airplane 087

a. There were 2,806 model 087 airplanes of three series in the active general aviation aircraft fleet in 1964. Prior to serial number 2844 on one model, the flaps on all models were manually operated by use of a lever mounted on the floor. After serial number 2844, this model was produced with electrically operated flaps. On these latter airplanes, the configuration and location of the landing gear and wing-flap actuating switches are in conformance with Amendment 3-5 to CAR Part 3.

b. Factors involved in the six inadvertent retractions of the landing gear in these airplanes are as follows:

(1) All occurred during daylight hours.

(2) Four retractions occurred on the landing roll, one while the airplane was being taxied and one during touch-and-go landings.

(3) In four instances the airplane was equipped with manual flaps, and in two instances with electric flaps.

(4) Three instances involved dual flight instruction; one, a beginn er pilot; another, a pilot who had not flown for six months; and the third involved an initial checkout in the airplane.

(5) Three instances involved operation of the landing gear control instead of the flap control; one involved actuation of the landing gear control instead of the application of power for takeoff, and two involved spontaneous activation of the landing gear control switch for no obvious reason.

In view of the pilot skill levels in half of these accidents, and the variety of reasons for the inadvertent retraction in the other three, it cannot be concluded that the design influenced the pilots' actions unduly. However, in one instance the pilot commented that he had considerable experience in another make of airplane, 090 and 021, and that the locations of the flap control and landing gear control are reversed when compared to airplane 087.

13. <u>Airplane 027</u>

There was only one instance of inadvertent retraction of the landing gear in these aircraft. In this one incident, the airplane was equipped with an automatic landing gear retract/extend device identified as the "Guard System." The report did not clearly state whether this system was not turned on, or whether it malfunctioned. However, since only one case is involved, there is no basis upon which to conclude that this device, or design, influenced the pilot to err.

VI. Conclusions with Respect to Inadvertent Retraction

1. Fourteen of the 80 accidents were caused by the action of student pilots or passengers. The other 66 were caused by the actions of pilots with certificates ranging from private pilot to airline transport pilot. Since the great majority of these accidents involved qualified pilots, training activities are not considered as a significant causal factor.

2. Nearly all occurred during daylight hours when conditions of light within the cockpit were sufficient for proper identification of all controls.

3. In the 66 inadvertent retraction of the landing gear accidents in which students were not involved, there were 53 instances of the landing-gear control being operated by the pilot in mistake for the wing-flap control.

a. In the aircraft involved in 37 of these 66 accidents, the landing-gear control and wing-flap control switches were nearly identical in appearance and opposite to the location specified in CAR Part 3. While these airplanes accounted for 57.5% of the non-student, non-passenger involved inadvertent landing gear retractions, they flew only 21.7% of the hours accomplished by all retractable landing gear airplanes selected for review in this study.

b. In the remaining 29 cases in this group, there were six instances where the wing-flap landing-gear control levers or switches did not conform to either the configuration or location specified in CAR Part 3. There were 16 cases in which the configuration was in conformance to CAR Part 3, but the location was not. There were only seven of the 66 instances in airplanes that conformed to Part 3 in both configuration and location.

4. From an overall standpoint, the airplanes having the landing-gear and wing-flap control arrangement specified in CAR Part 3 were involved in only 18.7% of the total number of inadvertent landing gear retraction accidents reviewed in this study. These airplanes, however, accomplished 33.7% of the total 1964 flight hours for the 15 retractable landing-gear airplanes in this study.

From the foregoing, it is concluded that the majority of the inadvertent retractions were caused by airplane design factors. It is also concluded that the wisdom of Amendment 3-5 to CAR Part 3 has been demonstrated.

5. All but airplanes 024 and 015 have safety-limiting switches or hydraulic valves, as appropriate to the system. Accordingly, it is likely that the same error has been made many times without causing an accident. It is noted that these safety switches or valves are located on one main landing gear leg only, and in these accidents failed to perform their intended function. In this respect it is noted that the pilots handbooks sometimes note that the safety switch is to prevent inadvertent retractions on the ground when the airplane is <u>not</u> in motion. Accordingly, the protection afforded by this device is very limited and confined to periods of low hazard. Earlier handbooks do not make this distinction, and the pilots may be placing more reliance on this device than is warranted.

In some of these accidents the safety devices did not provide protection for the airplane while taxiing, or while on the landing roll, because of high strut pressure or because of rough or rolling ground that caused a rocking motion of the aircraft and subsequent irregular extension of the shock struts. Only one instance involved a faulty microswitch. It is likely that had there been at least two or more switches, one on each main landing gear and operating in series, these accidents could have been avoided. It is recognized that such protection as does exist has been provided by the manufacturer voluntarily since there is no requirement for such safety devices in CAR Part 3 or FAR Part 23. It is recommended that the question of the need for devices to prevent inadvertent retraction of the landing gear on aircraft certificated under Part 23 be included on the agenda for discussion at the next Annual Airworthiness Review.

VII. Failure to Assure Landing Gear Locked Down

1. Airplane 051

There was only one instance in this model airplane in which the pilot failed to assure that the landing gear was locked in the down position. The pilot had moved the control lever, but did not get it all the way into the "down" position. Because of turbulence, a power-on approach was made and the warning horn did not blow. However, it is noted that this airplane has wheel position indicators, and the the main gear is readily visible to the pilot. Accordingly, there was no design influence in this accident which initiated the pilot error.

2. <u>Airplane 060</u>

a. In both instances an electrical system malfunction was a contributing factor. In the first, the landing gear solenoid was not working. When the landing gear control was placed in the "down" position, the red "up" light went out, indicating the gear in-transit to the "down" position. However, the landing gear did not move to the "down" position. The pilot did not recall checking the "down" light. The warning horn failed to function to apprise him of the unsafe condition of the landing gear. In the second instance, the pilot was aware of an electrical malfunction in the landing-gear extension system, and used the manual handcrank to extend the landing gear. Upon feeling resistance to the crank, and finding that both the landing-gear position lights and the warning horn gave indications that the landing gear was locked in the "down" position, the pilot landed the aircraft. The gear collapsed during the landing roll. In subsequent tests it was discovered that 15 turns of the crank were required to lock the gear in the "down" position <u>after</u> the "down" position light showed the gear to be safe.

b. With respect to position indicators and warning devices, FAR Part 23, and previous CAR Part 3, provide that land planes with retractable landing gear must have a means to indicate to the pilot when the wheels are <u>secured</u> in the extreme positions. In addition, they must have an aural or equally effective warning device which operates when one or more throttles are closed until the gear is down and <u>locked</u>. Notwithstanding these requirements, the flight handbook for the airplane just discussed reads as follows:

"Gear position is monitored by a green (gear DOWN and locked) indicator light and a red (gear UP) indicator light controlled by switches on the right main gear. The lights are located adjacent to the landing gear position control switch. Because of the rugged mechanical linkage in the landing gear extension system, this indication is adequate. Secondary indications are available to the pilot letting him know that any one gear is not extended. If the right main gear is extended and the green light illuminates but an out-of-trim condition is sensed in the flight controls, the left main gear is not completely extended. If the nose gear does not extend, the pilot will notice the following after the gear indicator light illuminates:

"a. Retract motor will continue to run.
b. Landing gear clutch will slip.
c. As the clutch slips, the ammeter readings will reach 100 to 150 amperes each.
d. Retract motor circuit-breaker will trip in 1 to 3 seconds."

It appears that this airplane, with the source of information from only one main gear, does not meet either the intent or the word of the regulation. Any system which will permit a safe indication by the devices whose purposes are to tell the pilot that the gear is locked in the down position when it is not, makes it necessary for him in one to three seconds to determine that the indicators are wrong. Certainly such a design induces pilot error. The practice of using a single information source for the landing gear position indicators or warning horn is not unique to this airplane. It was found to exist on several aircraft with mechanically interconnected retraction/extension push-pull rods or cables to all three landing gears. This situation was the subject of a recommendation forwarded to the Administrator on June 7, 1966.

3. <u>Airplanes 090 and 021</u>

a. As in the previous classification of landing gear accidents, these two airplanes are considered together in this part of the study because the extension-retraction mechanisms are nearly identical.

b. Factors involved in the 17 accidents in this classification for model 090 and 021 airplanes:

| | | |
|---|---|---|
| Number occurring in daylight . . . . . . . . | | 13 |
| Number occurring at night. . . . . . . . . . | | 4 |
| Popped circuit-breakers . . . . . . . . . . | | 5 |
| On-landing gear motor . . . . . | 4 | |
| On-landing gear position lights | 1 | |
| Warning-horn malfunctions . . . . . . . . . | | 7 |
| Confirmed by test. . . . . . . . | 6 | |
| According to pilot . . . . . . . | 1 | |
| Electrical System Failure . . . . . . . . . | | 3 |
| Generator failed . . . . . . . . | 2 | |
| Battery failed . . . . . . . . . | 1 | |
| Power on Approach; no warning horn as result . . . . . . . . . . . . . . . . . | | 2 |
| Pilot lowered flaps instead of landing gear . . . . . . . . . . . . . . . . . . . . | | 1 |

(Note: This is included in "Power on Approach" above; pilot did not hear horn until too late.)

In 10 of these 17 cases, there was no aural warning because of inoperative horns, mispositioned throttle switches, power-on approaches, and generator or battery failures.

In six instances the pilots stated that they did not observe the position lights.

In two instances the pilots stated that the position lights showed the landing gear to be in the down position. However, in the majority of the reports, the observation or non-observation of the lights by the pilot is not discussed.

c. These airplanes accomplished 26.3% of the total flight hours for 1964 in the 15 makes and models of retractable landing-gear aircraft in this study, but were involved in only 17.5% of the accidents in which the pilot failed to assure that the landing gear was locked in the down position.

4. Airplane 030 and 078: There were no accidents in this classification in these airplanes.

5. Airplane 072: In the one instance in this airplane the landing-gear motor circuit breaker was faulty and did not make contact unless pushed. The landing-gear warning lights were inoperative until the circuit breaker was pushed. There was no mention of the warning horn.

6. Airplane 003: In one of the two accidents involving failure of the pilot to assure that the landing gear was down and locked, the nose wheel was not fully extended. This was known to the pilot, but the emergency system was not used. In the other, the pilot mistakenly lowered full flaps instead of operating the landing gear control. The pilot stated that he did not look at the landing gear position lights, but did retard the throttle fully and the horn "should have blown." The landing-gear horn failed to alert the pilot to the situation because of a loose wire.

7. Airplane 096: The circumstances in the five accidents in this classification in this airplane are as follows:

Electrical Failure . . . . . . . . . . . . . . . . . . 2

Note: In one instance the batteries were too low to complete the landing-gear extension. The warning horn blew weakly, but the pilot could not distinguish it from the stall warner.

In the other instance, the pilot extended the landing gear manually, but because of generator failure and complete loss of electrical power, was unable to determine the landing-gear position since both the position lights and the warning horn were not available.

Power-on Approaches. . . . . . . . . . . . . . . . . . 2

Note: No warning horn because throttles were not retarded until touchdown. One was in daylight; the other at night.

(Airplane 096, cont'd.)

Inoperative warning systems (both light and horn) . . 1

8. Airplane 015: This has a manual, mechanically operated landing gear system on all early models, and an optional electrically operated system on later model airplanes. All of the accidents in the "failure to assure that the landing gear was locked in the down position" classification occurred in airplanes with the mechanical system. The "down lock" is incorporated in a recess into which the handle used to move the gear to the "up" or "down" position fits. The landing gear down-position light siwtch is activated when the handle is pushed into the locking recess and the warning horn is silenced. Circumstances involved in the 12 accidents in this classification are as follows:

| | |
|---|---|
| Occurring during daylight .......................... | 8 |
| Occurring at night .................................. | 4 |
| Number of instances of inoperative warning horn .................................. | 3 |
| Number of instances in which warning devices erroneously showed the gear to be locked in the down position .................................. | 5 |

Note: In one instance, a tag on the ignition key became lodged between the gear handle and the back of the down-lock recess. In the other four instances, tests verified the fact that the position indicators were activated and the warning horn silenced before the handle was secure in the down-lock recess.

| | |
|---|---|
| Number of instances in which pilot stated he did not get the handle fully in the locked position .................................. | 3 |

Note: In none of these three cases was there discussion of the position lights or warning horn.

| | |
|---|---|
| Instances in which pilot knew the landing gear was not locked down but could not get gear handle into the locked position ............... | 1 |

In these accidents it is considered that eight, or 66.6% were in some measure design influenced. The instance of the ignition lock being above the landing gear handle-down lock recess is in this category, since keys are seldom carried loose or individually.

In most instances there are likely to be other keys (a carrying case or identification tags which can, and in this instance did, interfere with the operation of the landing gear). The manufacturer has since moved the ignition lock to another position on later model airplanes. The warning devices and position indicators which indicated a safe situation of the landing gear when it was not safe certainly contributed to pilot error, as did the absence of the required aural warning in three instances.

9. Airplane 084: In the one instance in this classification in this airplane, the pilot did not have the landing-gear actuating handle all the way into the locking detent.

10. Airplane 039:

The factors involved in the 12 accidents in this classification are as follows:

| | |
|---|---|
| Number occurring in daylight . . . . . . . . . . . . | 12 |
| Number occuring at night . . . . . . . . . . . . . . | 0 |
| Warning horn malfunctions . . . . . . . . . . . . . | 3 |
| Inoperative landing gear warning lights. . . . . . | 2 |
| Position lights . . . . . . . . . . . 1 | |
| Throttle-activated landing-gear handle light. . . . . . . . . . . 1 | |

Lights not observed by pilots........................ 2

Landing gear position lights dimmed.................. 1

Note: This airplane has automatically dimmed landing gear position indicator lights when the navigation lights or instrument lights are on. There was only one mention of these switches being in the position which would make it difficult to tell if the lights were on in the daytime.

No comment in the reports on observance or non-observance of position lights........................ 3

No comment in the reports on aural warning........... 3

In two instances the pilots stated that the position indicator lights gave a safe indication prior to touchdown. However, tests conducted subsequent to the accident in each instance were unable to duplicate the situation. Of interest, however, is that in both instances the nose-wheel collapsed.

In one accident it was discovered that with only an estimated 10 to 15 pound restraining force, the nose wheel could be prevented from going into the down-and-locked position. Hydraulic pressure then built up to 1050 PSI and returned the landing-gear selector handle to the neutral position, thus stopping further extension of the landing gear. This situation could occur during landing gear extension at high speeds. If power was maintained on the engines, the warning horn would not sound. As a result, a landing could be made with the nosegear in an unsafe condition, unless the landing-gear position lights were carefully checked. Since there was only one accident in these airplanes in which the automatic dimming feature of the landing-gear position lights was in any way involved, it cannot be concluded that this feature induces pilot error.

In order to determine pilot reaction to the size of the lights, several pilots with experience in this airplane were interviewed. None questioned had any problem with the size of the lights, nothing that in normal use, the brightness offset any question of size. However, some pilots did comment on the auto-dim system when the navigation lights were turned on at dusk. Under this condition of lighting, it was very difficult to see if the landing-gear position lights were burning. The solution to this situation by some of these pilots was to momentarily turn off the navigation lights to check the position of the landing gear. Others noted that if one of the throttles was retarded and the landing gear was not down, the red light in the landing gear control handle would flash, thus providing a back-up to the position lights.

11. Airplane 087:

These airplanes were involved in 30.9% of the accidents reviewed in this classification, but flew only 4.9% of the total flight hours accomplished in 1964 by the 15 general aviation retractable landing-gear airplanes in this study.

The factors involved in the 30 accidents in this classification by these airplanes are as follows:

| | |
|---|---|
| Number occurring in daytime . . . . . . . . . . | 20 |
| Number occurring at night . . . . . . . . . . . | 10 |
| Number of instances of tripped circuit breakers . . . . . . . . . . . . . . . . . . . . | 13 |

(NOTE: In two instances it was apparent from the accident damage that the circuit breaker was tripped when the landing gear switch was placed in the down position after landing. In the others, however, the gear was partially extended prior to touchdown, indicating that the circuit breaker had tripped with the landing gear in transit.)

Number of instances of inoperative warning horns.. 10

(NOTE: The horns were inoperative for many reasons; e.g., broken wire, missing bolts, pitted contacts, master switch off, tripped circuit breakers, etc. In addition there were three instances in which the pilots reported they did not hear the horn, although the horn operated satisfactorily on subsequent retraction checks.)

Number of instances of inoperative warning lights.. 6

(NOTE: In one instance this was because the battery master switch had been turned off instead of the fuel boost pump. In addition to these, there were three instances in which the pilots did not see the landing gear position light indicator because of the auto-dim feature on this aircraft. This device dims the landing gear position lights whenever the navigation lights are turned on. In one of these, the landing gear position lights did not light at all when the navigation lights were on because of poor solder connections which raised the resistance in the circuit to the point where the filament would not glow. There was no comment in the other reports concerning the position of the navigation light switch.)

Gear Selector Switch placed in the "off" position instead of the "down" position........... 1

In one instance the pilots stated that the landing-gear down-position light was not illuminated, but he believed the bulb was burned out since the warning horn did not blow. In three instances the pilot did not check the position lights.

Unsuccessful use of the manual emergency system ....... 4

Several of the accident reports note that the emergency extension of the landing gear by the manual system is extremely difficult at speeds over the recommended 100 miles per hour. However, none of the reports contained any information concerning the use of power at the reduced speed. Although there is a great amount of difference in the effort required to extend the gear manually at the same speeds when power is and is not used, there is no mention in the pilot's handbook of this fact, nor is there any recommendation to extend the gear with the power off when the emergency system is used.

The following table of pounds of pressure on the manual extension handle needed at various airspeeds with and without power was provided by the manufacturer:

| Airspeed IAS in mph | Pounds Pressure Power Off | Required Power On |
|---|---|---|
| 90 | 42 | 70 |
| 110 | 55 | 80 |
| 120 | 85 | 112 |

It is likely that this large increase in the effort needed to extend the gear (as a function of power and airspeed) is in some measure responsible for the number of unsuccessful attempts to use the emergency system. Better information should be provided in the airplane manuals.

12. Airplane 027:

These airplanes were involved in 13.5% of the accidents reviewed in this classification, but flew only 2.4% of the hours accomplished in 1964 by the 15 retractable landing gear general aviation aircraft considered in this study.

The factors involved in the accidents in this classification are as follows:

| | |
|---|---|
| Number occurring in daytime . . . . . . . | 12 |
| Number occurring at night . . . . . . . . | 1 |
| Number of instances of tripped circuit breakers. . . . . . . . . . . . . | 3 |
| Number of instances of inoperative warning horn . . . . . . . . . . . . . . | 6 |

Note: Landing gear warning horns did not function for these reasons:

* Generators off, battery dead - 3 instances;

Poor Connection;

Throttle microswitches not adjusted properly.

Number of inoperative landing gear position lights . . 4
(see * above) (three for same reason)

Number of instances in which the landing gear selector switch was positioned to "off" instead of "down." . . . . . . . . . . . . . . . . . . 2

Unsuccessful attempts to lower the landing gear with the manual emergency system . . . . . . . . . 3

Number of instances involving students . . . . . . . . . 2

f. With respect to the accidents initiated by failure of the pilots to place the generator switches to the "on" position, it is noted that prior to April 20, 1964, manufacturers' service letter on this subject, no part of the checklist called for putting the generators "on". Concurrent with the service letter, new decals, including the proper point at which to turn on the generators, were issued to registered owners of these airplanes.

In recent years a considerable amount of emphasis has been placed upon the use of the checklist in general aviation aircraft, and pilots have been criticized for any failure to use it that came to official attention. In view of this it would be concluded that the omission of an essential item such as "generators on" from the checklist is in the category of design which induces pilot error.

Presumably, the distribution of the new decals with the "generators on" item included will have solved this problem and contribute to a reduction in the accidents in this classification.

g. On these airplanes, the landing gear "up" position and amber light will flash if one of the throttles is retarded; however, if the landing gear is stopped in transit, neither the "down" nor "up" light will be illuminated. This is true also of most of the other retractable landing gear general aviation aircraft.

13. Airplane 024:

The only accident in this classification involved improper use of the emergency system.

## VIII. Conclusions with Respect to Accidents involving Failure to assure that the Landing Gear was Locked in the Down Position

Approximately 75% of these accidents occurred in daylight. However, there was only one instance in which sunlight striking the down-position light-indicator caused the pilot to believe the landing gear was locked in the down position.

In this regard, CAA Technical Manual No. 103, "Aircraft Design Through Service Experience," states: "Red warning lights are often used as the means to indicate if the gear is not secured in its extreme position. However, in actual operation, due to the effects of direct sunlight, it is often difficult to observe if the light is on. Accordingly, it is desirable to shield the lamp from the direct rays of the sun. In the past, numerous wheels-up landings can be attributed to failure to observe the lamp being on due to the adverse affects of direct sunlight."

Since there was only one accident in 1964 in this classification in which sunlight was a factor, it can be concluded that this problem has in great measure been solved.

The automatic dimming of the landing gear position lights has been demonstrated as a cause of pilot error. The airplane handbooks for all the airplanes having this feature emphasizes the fact that the lights will be dimmed when the navigation lights are turned on. However, in the cases studied there were comments by the pilots that they were not aware of this device. In the case of rental aircraft, it is doubtful that the renter will be very familiar with information in the handbook. In the two twin-engine aircraft with this device there is secondary feature which tends to reduce the possibility of error because of the dimmed light. This is the flashing red light in the landing gear control handle in the one airplane, and the flashing of the "up" position light in the other. However, there is no relieving feature associated with the auto-dim system on aircraft 087.

There were 10 accidents in which the landing gear position lights were not functioning. However, in six instances it was because of electrical-system failure, or because the generators were not turned on. Accordingly, there does not appear to be any appreciable problem with the operation of the landing gear position lights. However, of particular interest is the number of comments from the pilots indicating that they did not use the position lights to determine if the landing gear was locked in the down position. It is apparent that many pilots are relying on the aural warning signal rather than the lights to tell them if the gear is in an unsafe condition.

There were 34 instances in which the landing-gear-warning horn, for various reasons, did not function, and five instances where power-on approaches prevented the horn from being heard until too late to prevent the wheels-up landing. When reliance is placed primarily on the aural signal for indication of an unsafe landing gear situation, as the accident reports indicate, then malfunctions of this device contribute materially to pilot error.

Reliance on the aural signal is not confined to general aviation pilots. On April 15, 1964, the Federal Aviation Agency issued Amendment 40-41 to Part 40--Scheduled Interstate Air Carrier, Certification and Operation Rules, which provided that landplanes of over 12,500 pounds maximum weight must have a wing-flap actuated aural warning signal in addition to the other position indicating and warning devices related to the landing gear. This Amendment, in part, reads as follows:

> "All airplanes airworthiness regulations require, for airplanes with rectractable landing gear, that a means be provided for indicating to the pilot when the gear is secured in the extended and in the retracted positions; that, in addition, land-planes be provided with an aural warning device to function continuously when one or more throttles are closed if the gear is not fully extended and locked. The airplane airworthiness regulations that permit a manual shutoff for the aural warning device also require that it be installed so that reopening the throttles will reset the warning mechanism. A third safety provision, required in sub-paragraphs 4b.740 and 40.357 is the cockpit check procedure (checklist) to be used by the flight crew during all phases of operation.
>
> "The Agency finds, from a review of the accident record over the past eight years, that 17 inadvertent gear-up landing accidents involved airplanes operating under Parts 40, 41, and 42. Fifteen of these accidents involved a number of airplane models, irrespective of performance or type of powerplant used, whose maximum weight exceeded 12,500 pounds. Although these accidents did not result in either major injuries or fatalities, such accidents are potentially hazardous, particularly because of possible ignition of fuel which might be spilled.
>
> "From the Analysis of the accident record and from a study of operational practices relating to landing gear aural warning systems, the Agency finds that the currently prescribed throttle-actuated aural warning device and the other safety provisions are not sufficiently effective in preventing inadvertent gear-up landing accidents. The Agency further finds that installation of a wing-flap actuated aural warning system should reduce the number of such accidents, thereby eliminating the potential hazard to the airplane occupants and preventing damage to the airplane."

The study group believes that if the warning system, position lights, and checklists are inadequate in air carrier aircraft operated by two professional pilots, the problems must be equally as acute, if not more so, in general aviation aircraft operated by a single pilot. Accordingly, in view of the number of wheels-up landings during 1964, the Board on May 20, 1966, forwarded to the Administrator a letter recommending that a wing-flap-actuated aural warning signal be required on all landplanes certificated under Part 23 of the Federal Aviation Regulations.

In view of the large number of warning-horn failures, we conclude that these accidents fall in the design induced category.

There were 22 instances of tripped circuit breakers. When the tripped circuit breaker is combined with malfunctioning landing gear position lights, or malfunctioning aural warning systems, pilot error by virtue of a lack of information is likely.

On June 7, 1966, the Board forwarded to the Administrator a letter recommending studies to determine the cause of the large number of tripped circuit breakers associated with accidents in which the pilots failed to assure that the landing gear was locked in the down position, or failed to extend the landing gear.

IX. <u>Failure to Extend</u>

1. <u>Airplane 051</u>

There was only one accident in this classification in these airplanes. There was no information in the pilot's statement or investigator's report concerning the warning horn or landing gear position lights.

2. <u>Airplane 060</u>

There was only one accident in this classification. The pilot put the gear selector to the "neutral" position instead of "down."

3. <u>Airplanes 090 and 021</u>

Because of the similarity of these two airplanes, they are considered together for this part of the report.

The circumstances involved in the 29 accidents in this classification are as follows:

| | |
|---|---|
| Number occurring in daylight........... | 22 |
| Number occurring at night.............. | 7 |
| Number of instances of tripped circuit breakers.............................. | 2 |
| Number of instances of inoperative warning horns......................... | 13 |

Note: In addition, there were six power-on approaches, and as a result no horn. Also, in one instance the pilot was wearing earphones and could not hear the warning horn.

| | |
|---|---|
| Number of instances of inoperative landing-gear position lights........... | 0 |

As in the previous classifications, there was little mention of the pilots' observance of the landing gear position lights. In only one report is the comment that the pilot did not look at the lights. 76% occurred in daylight conditions. There were no comments concerning sunlight striking the landing gear position light lens. Accordingly, lighting conditions would not appear to be a factor in these accidents. In 69% of these accidents there was no audible signal to warn the pilot that the landing gear had not been extended.

4. Airplane 030

There were two accidents in this classification in these airplanes. In neither report was there any comment concerning the landing gear position lights. In only one was there any mention of the warning horn. In this instance it operated, but weakly, and the pilot stated that it just didn't register because the sound was like a radio beacon code.

5. Airplanes 078 and 072

Since these airplanes are so similar, they are considered together for the purposes of this report.

There were three accidents in this classification. In one, the landing gear motor circuit breaker had tripped In the second, the landing gear warning horn was inoperative. In the third a power-on approach prevented the horn from sounding until too late.

6. Airplane 003

The factors in the 12 accidents in this classification are as follows:

| | |
|---|---|
| Number occurring in daylight . . . . . . . | 10 |
| Number occurring at night . . . . . . . . | 2 |
| Number of inoperative warning horns . . | 5 |
| Number of power-on approaches and no horn until too late . . . . . . . . . . . | 5 |
| No information except pilot's statement that he forgot the gear . . . . . . | 2 |

7. Airplane 096

There was only one accident in this classification by these airplanes. This accident involved a power-on approach, and no warning horn as a result until too late to prevent the wheels-up landing.

8. Airplane 024

There were three accidents in this classification by these airplanes. In two instances the pilot was concentrating on events outside the cockpit and forgot to lower the landing gear. The other involved improper use of the emergency system.

9. Airplane 015

The factors involved in the 13 accidents in this classification by these airplanes are as follows:

| | |
|---|---|
| Number of instances in which the landing gear warning horn and landing gear position lights functioned normally, but were ignored by the pilots because of distractions outside the aircraft | 3 |
| Number of instances of inoperative landing gear warning horns | 5 |
| Power-on approaches | 2 |
| Number of reports in which there is no information on the operation of the landing gear warning horn or position lights | 3 |

(Note: It is likely that in at least one of these accidents, the warning horn was inoperative since the pilot stated that his first warning that the landing gear was not down was when the radio antenna on the bottom of the fuselage started dragging on the runway.)

10. Airplane 084

The factors involved in the 11 accidents in this classification by these airplanes are as follows:

| | |
|---|---|
| Number occurring in daytime | 9 |
| Number occurring at night | 2 |
| Number of instances of inoperative warning horns | 2 |
| Power on Approaches | 6 |

(Note: In one instance, the landing gear position down lights were on all the time during the flight, thus rendering them useless. In one instance the pilot was facing into the sun and could not see the landing gear position lights.)

No information in the accident report concerning landing gear position lights, power button or warning horns . . . . . . . . 3

11. Airplane 039

The factors involved in the 14 accidents in this classification in these airplanes are as follows:

All occurred in daylight hours.

(Note: There was no comment in any of these reports concerning the auto-dim feature of the landing gear position lights.)

Number of instances of inoperative landing gear warning horns . . . . . . . . . . . . . . 6

(Note: There were 3 reports which did not comment on the warning horn.)

Power-on Approaches . . . . . . . . . . . . . . 7

Inoperative landing gear position lights . . 2

(Note: In 9 of the reports, the pilots stated that they did not observe the landing gear position lights.)

Single-engine practice, power-on approaches . 3

12. Airplane 087

The factors involved in the 24 accidents in this classification by these airplanes are as follows:

| | |
|---|---|
| Number occurring in daylight. . . . . . . . . | 14 |
| Number occurring at night . . . . . . . . . . | 10 |
| Number of tripped circuit breakers. . . . . . | 5 |

(Note: All warning systems operating, but pilot distracted by events outside cockpit.)

| | |
|---|---|
| Number of inoperative landing gear warning horns . . . . . . . . . . . . . . . . . . . . . . . . | 9 |
| Power-on Approaches . . . . . . . . . . . . . . | 2 |
| Landing gear switch positioned to "off" instead of "down" . . . . . . . . . . . . . . . . | 4 |
| Miscellaneous . . . . . . . . . . . . . . . . . . | 6 |

Battery master switch off

Navigation lights on, landing gear position lights dim, but horn sounded.

13. Airplane 027

The factors involved in the six accidents in this classification by these airplanes are as follows:

| | |
|---|---|
| Number of instances occurring in daytime ... | 3 |
| Number of instances occurring at night ..... | 3 |
| Number of instances of tripped circuit breakers .................................... | 3 |
| Number of instances of inoperative warning horn ............................... | 2 |

## X. Conclusions with Respect to Accidents in the "Failed to Extend the Landing Gear" Classification

In a few instances the auto-dim feature, or sunlight conditions were factors in the pilots' failure to observe the landing gear position lights. However, these instances are so infrequent that cockpit lighting conditions do not appear to have a significant part in inducing pilot error with respect to the "failed" to extend the landing gear classification of accidents.

What is apparent with respect to the landing-gear position lights is that for various reasons many pilots simply are not using them. As in the previous classification of wheels-up landings, the principal device the pilot is using to determine that the landing gear is locked in the down position is the warning horn.

The 43 instances of landing-gear warning-horn failure in this classification, as in the 34 instances in the "failed to assure the landing gear was locked in the"down" position, indicates a deficiency that certainly induces pilot error. However, because of lack of information in the accident reports, it was not possible to determine if the deficiency is in the design of the horn, the throttle actuated micro-switches, or other components of the aural warning system, or whether the problem is simply inadequate maintenance. In any event, it is likely that a significant reduction in the number of pilot error, wheels-up landings can be made if the reliability of the aural warning system is improved.

In this regard it is believed that the wing-flaps-actuated device recommended in the Board's letter of June 7, 1966, would contribute substantially to a reduction in the number of wheels-up landings in general aviation aircraft.

As in the previous classification, tripped circuit breakers, particularly in airplane 087, are considered to have been a factor in producing pilot error. Improvements in this regard would contribute materially to a reduction in pilot-error, wheels-up landing accidents.

Power-on approaches were involved in 33 of the wheels-up landings in this classification, and in five in the previous classification. We believe that a wing-flaps-actuated aural warning device would contribute substantially to a reduction in wheels-up landings associated with power-on approaches. In this regard, it is interesting to note that at least one general aviation twin-engine aircraft handbook (airplane 039) recommends that on the approach "normally about 12" MP should be maintained to provide a reasonable approach angle." Since the landing gear warning horn micro-switches are typically set at 12 inches of manifold pressure, this recommended procedure very nearly defeats the intent of the regulations providing for the aural warning signal if the landing gear is not locked in the down position. If the airplane design is such that power must be used to achieve a "reasonable" descent angle, then this feature can influence the pilot to make a wheels-up landing; or, at the very least, will deprive him of the benefits of one of the devices considered necessary in the interests of safety.

It is recommended that for those aircraft requiring a power-on approach to avoid excessively steep descent angles, the throttle-actuator warning-horn microswitch be set at a manifold pressure high enough to provide adequate aural signal.

## XI. Miscellaneous Factors Related to Wheels-Up Landings

The problem of identical switches for the landing gear selector and flap selector was apparent in other areas in the course of this study. On a few occasions it was noted that battery master switches were turned off when the pilot intended to turn off the fuel-boost pump. The resulting complete electrical failure influenced wheels-up landings since there was insufficient current to operate the landing gear.

In comparing the selector switch locations in the early model airplanes in which this situation occurred with the selector switches in later models of the same airplane, it was noted that the battery master switch had been moved from its location immediately adjacent to the fuel boost pump switch, and relocated to another part of the panel. Confusion between the two was thus minimized and accidents attributable to this situation are practically eliminated.

While not related to this category of accidents there were other similar situations that came to the attention of the study group in the course of discussions with pilots. In two instances pilots of airplane 027 and airplane 096 reported that the ignition switches were inadvertently turned off instead of the fuel boost pumps. The result was an immediate loss of power that could have been critical had it occurred to less experienced pilots. If an accident were to occur for this reason, it could be very difficult to determine the true position of the switches because of severe cockpit disintegration. Accordingly, it is recommended that consideration should be given to discussing at the next Annual Airworthiness Review a requirement for guards to be placed over critical switches that are normally turned on and off only once during a flight. These switches should include, but not necessarily be limited to, the battery master switch, and to toggle-type ignition switches.

Further, consideration should be given to a requirement that these switches should be located remotely with respect to other switches that are used frequently, or which may be turned off during a critical phase of flight, e.g., boost-pump switches which are often turned off during initial climb.

In a few accidents there were comments that the landing gear aural warning signal sounded like the stall warner and could not be distinguished from the stall warner. In another instance the stall warner sounded like a radio beacon code signal and was accordingly ignored.

Part of the problem lies in the fact that the same or identical warning horns are used for both purposes. In most instances the landing gear aural warning is supposed to be identified by its regular, intermittent note generated by the flasher unit. The stall warner, conversely, has an intermittent, supposedly irregular signal which becomes steady when the stall is reached. In practice the intermittent regular landing-gear aural signal is difficult to distinguish from the intermittent, irregular stall warning which the pilot expects. Consequently, the signal fails in its intended purpose.

At least one manufacturer has attempted to solve this problem by using separate horns and separate operating frequencies in order to distinguish clearly between the two signals. As a result, the frequency for the stall warner is set at 1000 cycles per second, and the frequency of the landing gear warning horn is set at 500 c.p.s. In addition, the landing gear warning horn is connected to a flasher.

It is believed that this is a step in the right direction. However, the situation would be still further improved if the stall warning device could not be mistaken for the landing gear aural signal. As, for example, the case with a stick-shaker for stall-warning. A light signal for stall-warning will do equally well as far as separating the signals. However, this may be in turn confused for other emergency warning lights.

It is noted that NASA pilots conducting an evaluation of the handling qualities of general aviation aircraft considered the visual stall warning light to be unsatisfactory, and in some instances totally inadequate as a result of glare from the sun.

It is recommended that the subject of providing separate non-conflicting distinct warnings for landing gear position and stalls by devices which do not require a great deal of discrimination on the pilot be placed on the agenda for discussion at the next Annual Air-Worthiness Review.

## NOSE-OVER ACCIDENTS

### Accident Sequence:

The initial review of nose-over accidents indicated that many of them, particularly on tricycle-gear aircraft were second-type accidents, following landing gear collapse, ground loop, or similar accident types. It was believed that such occurrences do not fall within the purview of this analysis, in that the accident was induced by the prior accident type, rather than pilot error in relation to the design characteristics of the aircraft. Therefore, only those accidents in which the nose-over was the first type were included in the analysis.

### Parametric Groups:

A review of the break-down by utilization groups indicated that design parameters were more significant in the type of accident than type of utilization; therefore, a complete parametric study was made. Single- and twin-engine aircraft were treated separately. In the single-engine category, parametric groupings included tricycle and tail-wheel landing gear; high wing and low wing aircraft; high wing tricycle-gear and low-wing tricycle gear aircraft; aircraft with wing flaps and without wing flaps, with sub-breakdowns of high and low wing. In the case of twin-engine aircraft, it was found that there was only one first type nose-over accident to the eight aircraft types included in the studies. This occurred to airplane 060, the only airplane with a tail-wheel landing gear. In view of this record, it was concluded that nose-over accidents are not a problem with present-day twin-engine aircraft, and no further analysis was made.

Considering the single-engine airplane, as would be expected, tail-wheel gear airplanes had a significantly higher frequency of nose-over accidents than did tricycle-gear airplanes. Airplane 099 had by far the highest frequency of nose-overs of the tail-wheel gear airplanes, differing at a high level of significance from other airplanes in this parametric group. It is believed, however, that the factors tending to induce nose-over of tail-gear airplanes are so well known that no analysis or discussion is necessary.

Among the tricycle-gear airplanes there was a highly significant difference between high-wing and low-wing airplanes. The overall nose over accident frequency for low-wing airplanes is 0.033 per 10,000 flying hours, or one such accident per 300,000 hours. The frequency for all types involved was too low to permit a statistically significant comparison of the individual aircraft in this category.

Multiple degree of freedom analysis of the high-wing tricycle gear airplanes showed a variation within the group significant at the 0.05% level, as a result of the influence of airplanes 009 and 042. The first of these had a frequency above the mean for the group at the 0.05% level of significance, the latter below the mean at 0.1% level. There was no significant variation among the other airplanes in this parametric group. The accident frequency of airplane 042 was comparable to the mean of low-wing tricycle-gear airplanes, whereas the frequency for airplane 009 was comparable to that of airplanes with conventional landing gear.

Comparison of Airplanes 009 and 042

In view of the foregoing, the analysis of nose-over accidents was devoted primarily to the accidents to Airplane 009 and a comparison of the characteristics of this airplane with those of aircraft 042. The accident files on airplane 009 were thoroughly reviewed to determine the circumstances under which the nose-over accidents occurred. It was found that 44% of the accidents occurred during taxiing; 35% on landing (mostly during the landing roll); 11% during take-off roll, and the remaining 11% during static operation on the ramp. The accidents occurring during take-off and landing for the most part involved hitting soft ground, snow, etc., with either the nose wheel or one of the main wheels, whereas the accidents which occurred during taxiing or static operation involved a quartering tail wind, frequently with gusts. The majority of those in taxiing occurred as the pilot started to turn into the wind after taxiing downwind.

Careful comparison was made of the design characteristics of aircraft 009 and aircraft 042. The two aircraft are of the same general size and class. The landing gear geometry was comparable as regards both lateral and longitudinal wheel base. On both aircraft, the main landing-gear wheels are the same size as the nose wheel. The standard wheels on aircraft 042 are slightly smaller than those on aircraft 009, but the aircraft is also offered with special wheels and tires and of the same size as those on aircraft 009. The angle between the centerline of the airplane and the ground line between the nose wheel and one main wheel is of the same order of magnitude, with less than a 5% difference in the value of the tangent of the angle. The center of gravity of airplane 009, however, is appreciably higher than that of airplane 042, and is also slightly further forward, in terms of its location as a percentage of the longitudinal wheel base. The static ground angle of airplane 009 is 4° nose-up, while that of airplane 042 is 5°; however, airplane 009 is equipped with an adjustable stabilizer with 7½° of travel. The accident reports do not state the stabilizer setting, so no comparison can be made of tail incidence or its effect.

The criterion for overturning tendency presented in the NACA ACR "Note on Factors Affecting Geometrical Arrangement of Tricycle Type Landing Gears," by Carl J. Wenzinger and A. R. Kantrowitz, dated April 1937, was computed for the two aircraft. The criterion is the minimum value of the horizontal load factor at which the resultant acceleration vector through the c.g. can intercept the ground outside the line connecting the nosewheel and the main wheel contact point. The over-turning tendency is shown to vary directly with the height of the center of gravity, and inversely with the distance of the c.g. aft of the nose wheel and the sine of the half angle of the apex of the triangle formed by the landing gear. The value was found to be approximately 0.64 for aircraft 042 and 0.61 for aircraft 009. The difference of 0.03 does not appear to be great enough to account for the comparative accident records of the two airplanes. The value for both airplanes appears to be low, compared to the 0.80 in the example in the NACA report.

One possible factor is the difference in the type of main landing gear. It may be that the characteristics of the spring type gear on airplane 042 result in greater lateral motion of the gear under the influence of an overturning moment than occurs on airplane 009. This would increase the lateral wheel-base under dynamic conditions and hence effectively increase the value of the criterion given by the NACA. The data available are insufficient to permit quantitative evaluation of this possibility.

The NACA criterion, of course, is applicable only to those accidents to airplane 009 that resulted from hitting soft ground, etc., with one of the wheels; it does not apply to those accidents involving a quartering tail wind, and no data were found by the Board which provide a sound basis for a quantitative comparison of the two airplanes for this condition. It would appear that the variables involved would include tail length, horizontal tail area, including size of the elevator, angle of incidence of the tail in static attitude, tail surface, airfoil characteristics, and height of tail above the ground, and since the resultant force factor must have a lateral component, the characteristics of the up-wind wing, including spanwise location of center of lift.

In the absence of quantitative criteria for analyzing this condition, no direct comparison can be made of the design characteristics of the two airplanes.

A comparison was also made of the utilization of the two airplanes and the operating conditions under which the accidents to airplane 009 occurred.

It was noted that approximately 80% of the total utilization of airplane 042 was in instructional flying; 10% in professional flying, and only 10% in personal transportation, as compared to 40%, 10%, and

50%, respectively, for airplane 009. It might, therefore, be that stricter operational control of airplane 042 is a factor in the comparative nose-over accident frequency of the two airplanes, especially since the review of reports of accidents to airplane 009 showed that the majority of nose-overs with a quartering tail-wind occurred in winds of 25 miles per hour or better, with gusts in the range of 35 to 50 miles per hour. It would appear logical that in the case of instructional flying, operation of airplanes of this category under such wind conditions would be minimal. Also, there would be little, if any, operation from fields with soft spots, soft snow, etc.

On the other hand, it was found that approximately 25% of the accidents to airplane 009 occurred during instructional flying, and approximately 10% in professional flying, including two in air-taxi operations. It does not appear reasonable to assume that instructors and commercial operators who use airplane 042 uniformly have better judgment and exercise greater caution than those using airplane 009. It was found, however, that the owners manual for airplane 042 until 1964 contained a chart, "Taxiing Tips for Strong Crosswinds," showing recommended control positions for winds from various quarters and a special note on strong quartering tail winds. The chart in later manuals has been retitled, "Taxiing Diagram," but is otherwise the same. No such data are given in the manual for airplane 009, and it may be that this is a factor in the situation. Nevertheless, it must be concluded that the data presently available are not adequate to provide a full explanation of the significant difference in the frequency of nose-over accidents to these two airplane types.

It is recommended, however, that an investigation be made and quantitative criteria be established for the nose-over tendency of such airplanes under quartering tail-wind conditions, and that design requirements be established, both for this condition and for an allowable minimum value of the friction coefficient at a wheel, that will cause the airplane to nose-over.

## ACCIDENTS RESULTING FROM HARD LANDING

### Accident Definition and Circumstances

The hard-landing accident type is defined as one involving stalling onto or flying into the runway or other intended landing area. The term "stalling" as used in this context is intended to convey only that the airplane was dropped from a height sufficient to result in a hard landing. As noted in the definition of accident types, the occurrences of such stalls are not tabulated in the stall, spin, spiral, or mush accident-type category. It should also be noted that whenever the landing gear collapses as the result of a hard landing, the accident type "gear collapse" is coded as a secondary type.

As in other accident types the circumstances surrounding hard landings vary widely. In a majority of cases, however, those in which causal elements are ascribed to the pilot include the description "improper level off." Many of these accidents are precipitated by or related to the following environmental/operational factors or situations:

1. The myriad effects of gusts, crosswinds, downdrafts, and turbulence.

2. "Dropping the airplane in" at a height considerably above the runway surface.

3. Development of a relatively high rate of sink, coupled with an improper or inadequate flare.

4. Bouncing or porposing coupled with an improper or inadequate recovery.

5. Contacting the landing surface nose wheel first.

6. Those unique perceptive factors in night landings related to distance, speed and altitude.

7. Inadequate or improper short field approach.

Statistical Significance of Hard-Landing Accidents

The hard-landing accident frequency of airplanes 048 and 102 was evaluated as being "much higher than average" as shown on Appendix (17). The airplane groups shown thereon are related to the airplane utuiliztion based on an exposure index (Groups I and II) and the complete study fleet (Group III). Both airplanes are single engine, low-wing nose-gear configurations and an evaluation of both in parametric Group IV, Appendix 18, with respect to all low-wing airplanes, all low-wing tricycle gear airplanes, all tricycle gear airplanes and all single engine airplanes results in the same conclusion, i.e., a "much higher than average" number of hard-landing accidents on both a flight time and an accident basis. The relatively frequent occurrence of hard landings in these airplanes is apparent regardless of the grouping, basis, or accident sequence chosen for evaluation.

Other single-engine airplanes with a frequency of first-type hard landings considered to be simply "higher than average" when evaluated on a study fleet basis include: 084, 081, 054, and 036. The first two of these are low-wing and high-wing nose gear configurations, respectively, while the latter two are high-wing tail-wheel airplanes. A similar evaluation within the scope of the utilization groups yields the same result for airplanes 081 and 015. In addition, a Group IV evaluation for all twin-engine airplanes disclosed that the hard-landing frequency of 096 was also significantly high.

Those airplanes having a relatively low frequency of first-type hard landings based on an evaluation of the study fleet include: 045, 021, 030, 039, 051, and 060. These latter four are twin-engine airplanes, and although they appear to have better than average records within the scope of Group III, they are considered to be only average when compared with all other twins in the study group, and when evaluated within the utilization group. The evaluation of first type hard landings in utilization Group I also discloses that airplane 018, as well as 021 and 145, has a relatively low frequency of occurrence.

Airplane 021, a low-wing single engine tricycle configuration appears to have had a frequency of hard landings considered to be "much lower than average" when evaluated within Groups III and IV and "lower than average" within Group I. The configurations evaluated in Group IV included all low-wing airplanes, all low-wing tricycle gear airplanes, all tricycle gear airplanes and all single-engine airplanes. With respect to pilot proficiency, it was noted that less than 1% of the 1964 flight time of this airplane was classified as "instructional".

Airplane 045, a high-wing single-engine tail-wheel configuration had a frequency of hard landings that was considered to be "lower than average" when evaluated in Groups I, III, and IV. The configurations evaluated within this latter group included all high-wing, tail-wheel airplanes; all high-wing airplanes, all tail-wheel airplanes, and all single-engine airplanes. Again, it was noted that the instructional activity in this airplane accounted for less than 1% of its total flight time in 1964.

Although the hard-landing record of airplane 018 did not appear significant on the basis of a Group III evaluation, it was considered to be "lower than average" within the scope of Groups I and IV. The Group IV configurations included all high-wing tricycle gear airplanes, all high-wing airplanes, all tricycle-gear airplanes, and all single-engine airplanes. In contrast to airplanes 021 and 045, the instructional activity in this airplane (345,730 flight hours) accounted for approximately 25% of its total flight time in 1964. It would appear, therefore, that this airplane manifests a considerable tolerance to variations in pilot proficiency and technique as related to this accident type.

A Chi-Square comparison of hard-landing accidents involving all high-wing and all low-wing aircraft within the study fleet discloses no significant difference between the two groups unless airplanes 048 and 102 are removed. The low-wing group then appears to be better at the 2½% level of significance. Similar comparisons between tailwheel/nosewheel and flaps/no flaps airplanes (excluding 048 and 102) discloses that those with nosewheel or flaps are significantly better at the 5% and 1% levels, respectively.

Hard-Landing Accident Reports

A review of first-type hard-landing accidents involving airplane 048 discloses a substantial number caused by or precipitated by the airplane contacting the landing surface nose wheel first and/or bouncing or porpoising along the landing surface. These are in addition to several in which the pilot may have landed with the nose wheel in a crabbed attitude, or those wherein the pilot dropped the airplane in from an excessive height. Relatively few of the accidents, however, resulted from the latter.

A review of the accident reports involving airplane 102 discloses a number of occurrences or events similar to those involved in the hard landings of airplane 048. The circumstances or factors surrounding these accidents appear to include at least those numbered 1 through 6 in this section.

The conspicuous factor in most of these hard-landing accidents involving either airplane is the damage pattern--the majority involve damage confined to the nose gear, the propeller, the engine mounts, the cowling and wing tips Relatively few of these accidents involve damage to the main landing gears, such as might be sustained if it had been subjected to severe vertical impact loads. The term "Hard Landing", therefore at least in these cases, appears to be more properly or explicitly associated with damage of the nose gear or related structure.

Relationship to Pilot-Experience Level

Based on a sample of 16 first type hard-landing accidents involving airplane 102, eight involved students whose total flight-time ranged from 9 to 141 hours, and whose experience in this specific airplane varied from 2 to 25 hours. Six involved private pilots, with total flight times ranging from 103 to 310 hours and specific make/model times varying from 2 to 80 hours. The remaining two accidents involved flight instructors with total times of 1965 and 925 hours and corresponding make/model times of 61 and 8 hours, respectively, who were with students when the hard landing occurred.

Based on a sample of 34 first type hard-landing accidents involving airplane 048, 19 included airplanes operated by student pilots, 13 were operated by private pilots, and the remaining two involved instructor pilots with students at the time of the accident. Nineteen of the pilots involved had less than 25 hours of flight time in this make/model airplane; nine had between 25 and 50 hours, and six had between 50 and 125 hours.

Because a number of these accidents occurring to either airplane involved students or relatively low-time pilots, it might be rationalized that a relatively low-experience level was the determining factor. This may, as a matter of fact, be true. It is, however, in decided comparison to other makes and models where, apparently, this accident type is not as easily influenced or precipitated by comparable skill-levels or techniques. For instance, only 4½% of the total 1964 flight time of airplane 102 was classified as instructional, but students were involved in 10 or 63% of all first type hard-landings in this airplane. For airplane 048, such instructional time amounts to about 30% of its total and students were involved in 21 or 62% of its first type hard-landing accidents.

These figures are in sharp contrast to those for airplanes 009 and 042, both high-wing tricycle configurations, which were not significant on either a flight-time or an accident basis. This, despite instructional exposure amounting to 41% and 78% of their total times, respectively. These latter two figures incidentally represent a total instructional exposure of 1,153,820 hours, as opposed to a total of only 144,890 hours for airplanes 048 and 102.

It would appear, therefore, that pilot-experience level alone should not have been solely responsible for these accidents in 048 and 102; i.e., the relative ease of landing either of these airplanes safely appears to contrast sharply with the same operation in airplane 009 and 042 which appear less prone to this accident type in spite of a much greater exposure to relatively low-pilot experience levels.

Relationship to "Gear Collapse"

"Gear Collapse" is an accident type defined to be the result of a mechanical failure other than a malfunction of a retraction mechanism and is closely related to the hard-landing type accident. When it occurs as the result of a hard landing, for instance, it is coded as a second accident type. When it is coded as a first type of accident, it is, of course, on the basis of what actually happened first -- a mechanical failure.

An evaluation of the frequency of occurrences of first type "gear collapse" accidents involving airplanes 081 and 084 discloses both to have been significantly high. In addition, they both were considered to have had a "much higher than average" frequency of these accidents when compared against the records of all other nose gear aircraft in the study fleet. The same is true when these two are compared with all other high-wing, nose gear and low-wing nose gear airplanes, respectively.

Several gear collapse accidents involving airplane 081 resulted from a failure of the nose-wheel shimmy dampener and fork with evidence of prior cracks in the fork. The significantly high occurrence of both the "gear collapse" and "hard landing" type accidents suggests a relative weakness of the nose gear itself. That is, failures of the type mentioned could have been responsible for at least some of the accidents in this airplane that were classified as hard landings.

It is also interesting to note that none of those airplanes having a relatively low frequency of hard landings appears to have had any difficulty or problems with first type "gear collapse" accidents in any of the study groups. The record of airplane 018, as a matter of fact, indicates that the frequency of first-type gear collapse accidents was considered to be relatively low on a study fleet basis and also when compared with all other high-wing tricycle configurations in Group IV.

Landing Approach and Flare

Two important factors influencing an airplane's landing approach and subsequent flare are the approach speed and the lift to drag ratio in the landing configuration. The approach speed divided by the stalling speed, or the approach speed ratio, is a measure of the excess airspeed that is required to flare the airplane. The lift to drag ratio at a given approach speed determines the power setting required to maintain a fixed descent angle. The two ratios can be uniquely related, but, in general, the lower the lift to drag ratio, the higher the approach speed should be.

Airplane 048

The relatively high frequency of hard landings in 048 which appears to involve nose first contacts and substantial damage to the nose gear are, as previously mentioned, related to an improper or inadequate flare. While there is much general knowledge concerning the characteristics of the landing approach and landing flare, sufficient data are not available to the Board to determine precisely how the 048 design influences this accident type.

Airplane 102

This airplane incorporates a limited elevator control designed to preclude stalls. This feature necessarily limits the elevator power in the landing flare, the critical phase in which the airplane's rate of descent is checked just prior to touchdown. This can result in an inadequate flare and consequently a hard impact. Since it may be impossible to arrest the airplane's descent at relatively low approach speeds, it is imperative that an adequate excess speed margin be maintained throughout the approach -- a requirement that may be quite difficult and also quite critical in turbulent or gusty air.

It is also conceivable that the application of power in this airplane might be more critical than in other airplanes in situations involving relatively low airspeeds. Since elevator deflections required are inversely proportional to airspeed, it may be necessary that power lead the airplane's response by a considerably greater margin.

Also, since the flare capability may be enhanced by increased airspeed, some pilots might prefer an unusually fast, flat approach. This procedure, however, increases the likelihood of a nosewheel-first contact because of the relatively flat attitude of the airplane upon landing.

It would appear that the pilot is faced with somewhat of a dilema. If the approach speed is too high, he risks a nose-first contact; if too low, it may be impossible to flare the airplane. In order to preclude the nosewheel-first contacts, we understand that some owners limit full extension of the nosewheel strut by attaching a cable about six inches long between torque links on the nosewheel strut assembly. It would thus appear, based simply on such modifications to prevent it, that the risk of a nosewheel-first contact in this airplane was relatively high.

## OVERSHOOT ACCIDENTS

No highly significant variation is overshoot accident frequency was found in the multiple degree of freedom analysis of the utlization groups. The highest significance level found was at the 2.5% level for Groups IB and IC. Similarly, no airplane model differed from the mean of its own group at a very high level of a significance. The highest value was for Airplane 021 which was below the mean of Group 1C at the 1% level.

### Twin-Engine vs. Single-Engine Aircraft

The overshoot accident rate per 10,000 flying hours for twin-engine aircraft was less than that for single-engine types at the 0.05 level of significance. The twin-engine rates were of the order of 0.1 per 10,000 hours, so it can be concluded that this type of accident is not a problen for these aircraft. The reason for the difference between single and twin-engine aircraft could not be established. It is believed, however, that one or more of the following factors may be involved:

1. Improved glidepath control in the type of power-on approach commonly made with multi-engine aircraft;
2. The type of utilization involving operation primarily from regular airports with adequate hard surface runways;
3. The level of pilot experience and proficiency.

### Effect of Wing Position

A comparison was also made between low-wing and high-wing single engine aircraft in each utilization group and for the fleet as a whole. It was found that there was no significant difference in any case. It was also observed that in Group IC the aircraft with the highest rate and that with the lowest rate were both low-wing aircraft. It is, therefore, concluded that wing position is not a parameter affecting frequency of overshoot accidents.

Analysis by Utilization Groups

In Group IA, airplane 084 had an overshoot frequency above the group mean at the 2.5% level; no other airplane in the group differed even at the 5% level. Review of the accident files showed that approximately 45% of the overshoots to aircraft 084 occurred during attempted downwind landings. A check of reports on accidents to other aircraft showed that this is an abnormally high ratio, and that downwind landings are not an appreciable factor in overshoots generally. Aircraft 087, in Group IC, for example, had almost three times as many overshoot accidents as aircraft 084, but only one-quarter as many involving downwind landings. There is no apparent explanation of the propensity of pilots of aircraft 084 to land downwind, but this cannot be considered to be a design-induced error. If the downwind landings are deleted, the overshoot accident rate for airplane 084 is approximately equal to the mean for the group.

In Group IB, airplane 048 is above the group mean at the 2.5% level of significance, and airplane 075 is below the mean at the same level. Analysis of the group with each of these airplanes deleted in turn shows that neither airplane differs significantly from the rest of the group; the difference between the two airplanes, however, is significant at the 0.5% level. The two airplanes involved are of such completely different type that a parametric analysis to account for the difference is not feasible. One is a high-wing airplane without flaps, with tail-wheel type landing gear; the other a low-wing tricycle-gear airplane with flaps. Approach characteristics, speeds, and procedures are all different.

Analysis of which factor or factors account for the difference in overshoot frequency between these aircraft is considered to be beyond the scope of this study, as it would require flight evaluation of the two airplanes.

In Group IC there are again two aircraft that differ appreciably from the mean -- airplane 021 being below the mean at the 1% level of significance and airplane 087 being above the mean at the 2.5% level. The difference between the two airplanes is significant at the 0.05% level, but there is no significant difference between either airplane, and the remainder of the group with the other of the two airplanes omitted. Thus, it is concluded that neither airplane differs appreciably from the general level and that the difference is between the two aircraft.

The two aircraft involved in this case are of the same general type and are directly comparable. Recommended approach speeds, stalling speeds, etc., are similar so that a comparative analysis can be made.

Detailed analysis of the reports of accidents to airplane 087 shows that the majority of cases occur during landings on grass or dirt strips, frequently wet or slippery. Also in approximately half of the total number of cases, available runways were short -- several being only 1,200 feet. Altitude and temperature effects do not appear to have been involved. Of the cases in which these factors were reported, 85% occurred at altitudes of less than 1,500 feet, and 67% at temperatures below 80°F. In some cases, the approach was long, with touchdown near the mid-point of the runway, but this was not the general rule.

The accident reports in general contained no information on use of flaps either during approach or after touchdown, although in two cases it was stated that flaps were not retracted during the landing roll. Also, approach and landings speeds were not given in most reports filed by the FAA GADO. Therefore, no conclusions can be drawn as to the extent to which misuse of flaps or excessive landing speed may have been a factor. In two cases, in which speed is given, the approach was apparently at recommended speed, with touchdown at approximately $1.1V_s$.

Data in Owners' Manuals

The landing instructions and charts in the Owners' Manual for airplane 087 were studied carefully. It was found that an approach trim speed is recommended, but not a touchdown speed, and the charts of landing distance do not state the speeds on which they are based. While it can be assumed that the approach was at recommended speed, there is no way of estimating the touchdown speed that was used. The tabulated ground roll distances were found to correspond to a mean effective braking coefficient of as high as 0.36 at a landing speed of $1.1V_s$ and of 0.30 at $1.05V_s$.

In contrast to this, it was found that the landing performance charts in the Owners' Manuals for airplane 021 clearly state both the approach speeds and ground contact speeds on which they are based. For normal landings the contact speed is approximately $1.1V_s$, with values as low as 1.05 used only in the short field landing charts. The corresponding values of mean effective braking coefficient for normal landings was found to range from approximately 0.1 to 0.2 for various models of this airplane. The ground-roll distances are as much as three times those shown in the manuals for airplane 087. The higher values in the range was used in the Manual for 1964 models. The data did not provide a large enough sample on this version of the airplane to show whether the use of the higher value of braking coefficient in the published landing distances had resulted in any increase in frequency of overshoot accidents.

The manuals for both airplanes 087 and 021 state that landing distances are for dry, hard surface runways. Neither provides any information on the increase in landing roll to be expected on grass or dirt, either dry or wet. The effective braking coefficient corresponding to the distances given for aircraft 021, however, can reasonbly be expected to be achieved under most circumstances with ordinary proficiency in use of brakes; those for airplane 087 cannot be.

Futhermore, the longer distances given for airplane 021 would tend to discourage pilots from utilizing extremely short fields, whereas the shorter distances given for airplane 087 would encourage such operation. The fact that approximately 70% of the overshoots to airplane 087 occurred on grass or gravel fields, over 30% on wet surfaces and approximately 50% on runways less than 2,000 feet would indicate that the factors discussed above may be pertinent to the difference in the records of the two airplanes.

On a basis of the above analysis, it is recommended that published landing roll distances for other makes and models be reviewed in terms of the braking coefficient required. Since aircraft 021 had the lowest overshoot frequency, it can be used as a basis for comparison. If manuals for other aircraft were more conservative, a general reduction in overshoot accident frequency might be possible. It is also recommended that when landing distances are based on dry paved runways, and the aircraft type is such that operation from grass or dirt strips can reasonably be expected, it be required that at least a general correction factor be included in the manual.

As previously stated, in some cases at least, overshoot accidents to airplane 087 involved landing long. Data available to the Board do not permit evaluation of the comparative characteristics of this airplane and of airplane 021 that may be factors in this regard. Consideration should be given to a comparative review of flight characteristics, vision during the flare, etc., of the two airplanes that might affect the ability of a pilot of airplane 087 to control the point of touchdown precisely.

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## UNDERSHOOT

### Analysis by Utilization Groups

There was no statistically significant difference in undershoot accident frequency among the airplane models in Groups IA, IIA, or IIB, nor was the frequency of such accidents high enough for any of the airplanes in these groups to indicate that this accident type is a major problem. This was especially true of twin-engine airplanes, the highest rate for any model being 0.11 per 10,000 hours.

Airplane 048 in Group IB and airplane 087 in Group IC both had rates significantly higher than the other airplanes in their respective groups resulting in differences in the groups, based on multiple degree of freedom analysis, at a significance level of less than 0.05%. On the basis of single degree of freedom analysis, airplane 087 differed from the other airplanes in Group IC at this same level of significance, while airplane 048 differed from the other airplanes in Group IB at the 0.5% level. Analysis of the two groups with these airplanes omitted showed no significant variation among the other airplanes, and in these groups also, the rate was sufficiently low to indicate that undershoots were not a major safety problem. Detailed analysis of undershoot accidents is therefore limited to consideration of airplanes 087 and 048.

#### Airplane 087

This airplane is produced in several versions with different engine sizes. In addition, a production change was made in the wing-flap size and configuration on the 1962 model of one version with a larger engine. Three versions were involved in the undershoot accidents: one with a small engine, subsequently referred to as airplane 087-SE; and larger engine models with both the original and modified wing flaps, referred to as airplanes 087-$F_o$ and 087-$F_m$, respectively.

Review of the reports of the undershoot accidents shows that of the 19 accidents, five occurred to airplane 087-SE, three to airplane 087-$F_m$, and 11 to airplane 087-$F_o$. The precise number of each configuration in service in 1964 is unknown, but was approximated based on the total number of each model built and a prorated attrition rate. On this basis, the number of undershoot accidents per active airplane was the same for airplane 087-SE and airplane 087-$F_m$. The frequency of such accidents to airplane 087-$F_o$, on the same basis, was approximately 50% higher than that of the other two models. When the total number of undershoot accidents for the airplane type is adjusted to correspond to the frequency of the accidents to the 087-SE series, the multiple degree of freedom of analysis of Group IC no longer shows a highly significant difference. It, therefore, may be concluded that the characteristics of airplane 087-$F_o$ are responsible for the comparatively high undershoot accident frequency of this type of aircraft.

The stalling speed with flaps deflected is the same for aircraft 087-$F_m$ as for airplane 087-SE, while that for airplane 087-$F_o$ standard flaps is approximately 5% higher, corresponding to the increase in gross weight. The approach speed recommended in the Owners Manual, however, is the same for all three versions of the airplanes, resulting in a reduced margin above stall for airplane 087-$F_o$. This, in turn, would make the maintaining of approach speed more critical in this version of the airplane. Numerous pilot statements related to undershoot accidents in this version indicate that "downdrafts or gusts" were encountered on final approach. It is believed improbable that this occurred, particularly with this one version of this one airplane type. It appears more probable that the pilot, instead, encountered a rapid increase in rate of sink of the airplane and thought of the "down draft" as an explanation of the phenomenon. The accident reports make no reference to actuation or nonactuation of the stall-warning light, so the amount of loss of airspeed cannot be judged.

The modified flap installation was introduced in production in November 1961, and no airplane of this series has been produced with the original flap configuration since that date. Therefore, the design characteristic that appears to be the primary factor in inducing undershoot accidents to this type of aircraft has been corrected. It is recommended, however, that the approach speed for the existing 087-$F_o$ airplane be increased to maintain the margin above stall and that this be covered adequately in future cases where alternate versions of an airplane model have appreciable differences in stall speed. The problem of the margin between approach and stall speeds is also discussed in the section on Hard Landings.

Airplane 048

The high relative frequency of undershoot accidents to airplane 048, as compared to the other airplanes in Group IB, does not appear to be related to the design of the airplane. There is no appreciable difference between various versions of this model as there is in airplane 087. The majority of the accidents occurred during instructional flying and one-third of the total number was during short-field-landing practice with an instructor on board. In all cases the instructor pilot failed to take control in time to avert the accident. The other accidents occurred under a wide variety of conditions, including such factors as obscured vision from bugs on the windshield, inadequately marked runway, etc., which do not reflect aircraft design features.

## GEAR COLLAPSE

In considering this accident type, only those accidents in which gear collapse was the first accident type were considered. In addition accidents not involving pilot error were eliminated and these were further screened for design-induced errors.

The number of accidents remaining was found to be negligible for all models of airplane considered in this study. Some models did have a significantly higher frequency of gear-collapse accidents than the mean of their groups, but these were primarily material failure with no pilot involvement.

# F I N D I N G S

The following is a brief summary of the findings. Those for each accident type are discussed in detail in the various sections of this report, and reference to those sections should be made for more detailed information.

I. Accidents involving Stall, Spin, Spiral, Mush

1. The frequency of accidents of this type to airplanes certificated under CAR 4a is significantly higher than to airplanes certificated under CAR 3 and FAR 23.

2. For single-engine airplanes certificated under CAR 3/FAR 23, 64% of all accidents of this type occurred during initial climb on take-off or go-around.

3. Cross-winds appeared to be a major factor in stalls on take-off and go-around for at least one of the airplane types studied.

4. Take-off data in owners manuals were found to be inadequate in general, and this appears to be a factor in many stall accidents on take-off that are charged to pilot error.

5. In general, stall accidents are not a problem on twin-engine airplanes. One airplane model did have an accident frequency appreciably higher than the others, primarily involving inadvertent spins in single-engine operation.

II. Ground-Loop Accidents

1. Tricycle gear airplanes in general had a significantly lower frequency of ground-loop accidents than airplanes with tail wheels.

2. Two airplanes with tricycle gear had a ground-loop accident frequency significantly higher than any other airplane of this configuration, and comparable to that of tail-wheel airplanes.

3. It appears that the relatively high ground-loop frequency of the above two airplanes may have been influenced by detail design of the nose-gear configuration.

III. <u>Powerplant Failure of Malfunction</u>

1. Separate selector switches for fuel tanks and the fuel quantity gauges have resulted in the pilots having the gauge selected to a tank other than that supplying the engine.

2. Location of the fuel-selector valve lever in a position not readily accessible to the pilot has resulted in mispositioning and/or failure to reposition the selector lever.

3. Engine operation from one tank until the tank is completely empty, as recommended in some owner's manuals, and failure of the engine to recover quickly after a tank with fuel is selected, have been factors in some accidents. It appears that the time required for recovery of full power in service operation is appreciably greater than that demonstrated in tests and required by FAR 23, especially on low-wing airplanes with fuel injection systems.

4. Lack of standardization of fuel selector controls, and especially the use of similar controls with opposite sensing is a factor in inducing mispositioning of the selector.

IV. Nose-Over Accidents

1. First type nose-over accidents are not a problem on the twin-engine airplanes or the single-engine, low-wing airplanes with tricycle landing gear studied in this report.

2. One high-wing tricycle gear airplane had a first type nose over accident frequency that was significantly higher than that of any other airplane of this configuration, and comparable to the frequency of airplanes with tail wheels. Factors involved in the accidents to this one airplane are discussed in the report.

V. Hard Landings

A review of the accidents involving two airplanes having the highest frequency of hard landings (both tricycle configurations) discloses frequent occurrence of damage to the nose gear and related structure. Relatively few involved main landing gear damage such as might be sustained under severe vertical impact loads.

VI. Overshoot Accidents

Some airplane owners manuals do not contain information or correction factors for landing distances on other than dry, hard surface runways, nor do they specify the touchdown speeds upon which such distances are based. In addition, the landing distances given in at least one manual do not appear compatible with the proficiency of General Aviation pilots as a whole and may influence the overshoot by encouraging landings in relatively short fields.

VII. Undershoot Accidents

Only two of the airplanes in the study had a significant frequency of undershoots. The causes of those involving one of the airplanes appeared related to inadequate approach speeds which may have been based on information in the airplane flight manual.

VIII. Accidents Involving Retractable Landing Gear

1. The majority of accidents related to inadvertent retraction involved qualified pilots who inadvertently operated the landing-gear control instead of the wing-flap control.

2. Pilots may be placing considerably more reliance on landing gear safety switches than is warranted. In any event the degree of protection deserved to preclude inadvertent retraction and that actually afforded should be reviewed, resolved, and clarified at the next Annual Airworthiness Review.

3. Automatic dimming of the landing gear position lights, when navigation lights are turned on, can induce pilot error under certain conditions of light.

4. Pilots are apparently relying more on the aural warning signal rather than lights to detect an unsafe gear condition. In many instances, however, the warning horns did not function for various reasons. In addition, power approaches have precluded the horn from being heard until too late to prevent a wheels-up landing.

5. Tripped landing-gear circuit breakers combined with malfunctioning landing-gear position lights or malfunctioning aural warning systems tend to induce pilot error.

6. In practice, pilots experience some difficulty in distinguishing the intermittent regular landing gear aural signal from the intermittent irregular stall warning.

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## INDEX TO AIRPLANE REFERENCES



| Code Number of Airplane | Pages to which Referred |
|---|---|
| 003 | 35, 67, 72, 83, 96 |
| 006 | 52, 53 |
| 009 | 18, 21, 25, 29-30; 32-33; 35, 52, 55, 58-59; 105-108; 116 |
| 012 | |
| 015 | 21-23; 25, 29, 53, 64-65; 67, 73, 84, 97, 112 |
| 018 | 18, 29, 31-32; 53, 56, 113, 117 |
| 021 | 20-21; 23, 25, 29, 31-32; 38, 43-46; 53, 64-65; 67-71; 76, 81-82; 95, 112-113; 122-125 |
| 024 | 52-53; 64-65, 67, 73, 91, 97 |
| 027 | 21, 49-50; 64-65, 68, 76, 89, 99, 101 |
| 030 | 35, 47, 53, 65, 67, 71, 83, 96, 112 |
| 033 | 38, 40 |
| 036 | 112 |
| 039 | 21, 49, 64-65; 67, 75, 85, 98, 100, 112 |
| 042 | 18, 53, 59, 105-109; 116 |
| 045 | 31-32; 52, 56, 112, 113 |
| 048 | 14, 21, 23, 26, 29-30; 52, 55, 58-60; 112, 114-116; 118, 121, 126, 128 |
| 051 | 47, 53, 64-65; 67, 69, 72, 79, 94, 112 |
| 054 | 52-53; 112 |
| 057 | 53 |
| 060 | 35, 47, 64, 67, 80, 95, 104, 112 |

(Index to Airplane References, Cont'd)


| Code Number of Airplane | Pages to which Referred |
|---|---|
| 063 | 21, 52, 53 |
| 066 | 29, 37, 38, 52, 53 |
| 069 | 31, 32, 35, 40, 43, 46, 52, 56 |
| 072 | 21, 65, 67, 71, 83, 96 |
| 075 | 121 |
| 078 | 23, 65, 67, 71, 83, 96 |
| 081 | 18, 31, 32, 53, 56, 112, 117 |
| 084 | 18, 20, 21, 23, 29, 65, 67, 75, 85, 97, 112, 117, 121 |
| 087 | 23, 29, 32, 53, 64-65; 68, 75-76; 87, 98, 100, 122-129 |
| 090 | 23, 32, 38, 43, 44, 46, 65, 67, 69, 70, 76, 81 |
| 093 | 29, 35, 52 |
| 096 | 35, 64, 65, 67, 72, 73, 83-84; 96, 101, 112 |
| 099 | 20, 52, 105 |
| 102 | 112, 114-116; 118 |
| 105 | 31, 32, 37, 40, 41, 43 |

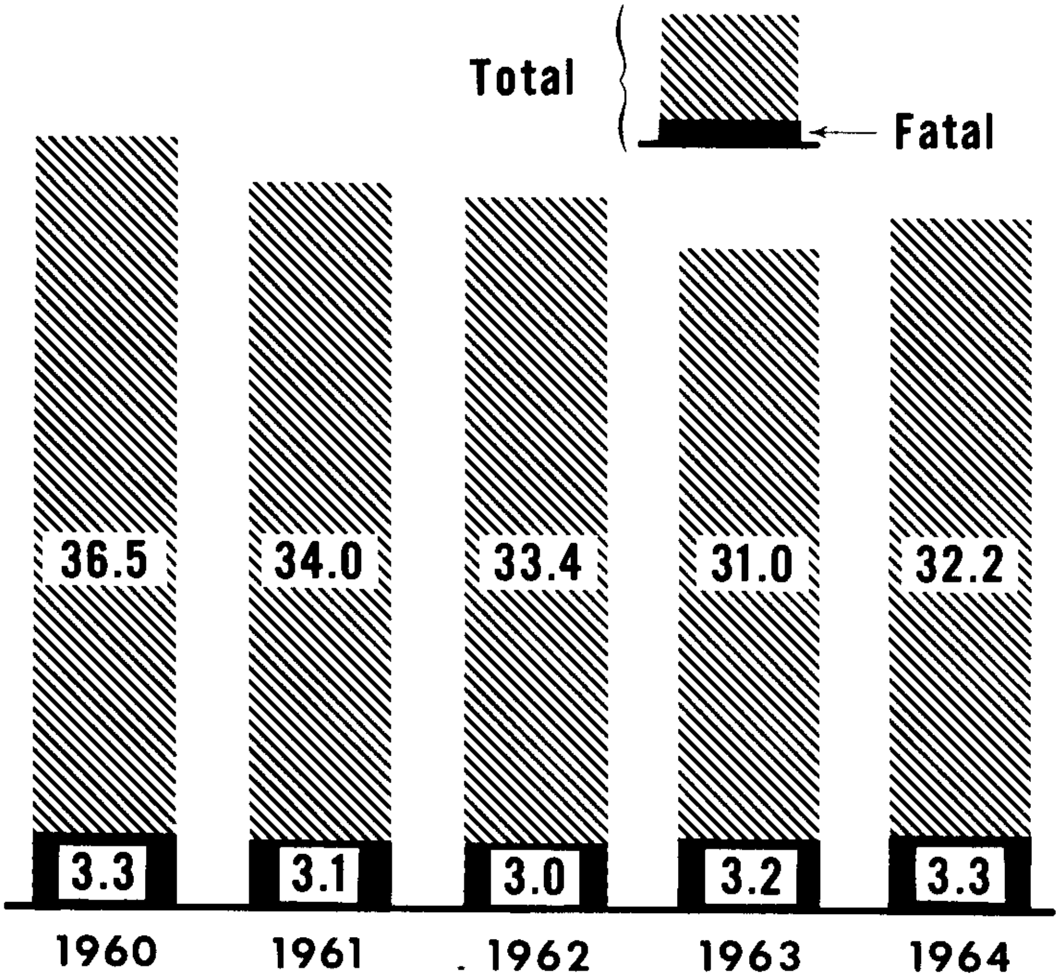
# APPENDIX

# CHARTS

## AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

# AIRCRAFT ACCIDENTS PER 100,000 HOURS

## TOTAL AND FATAL
## U.S. General Aviation
## All Operations
## 1960 - 1964




| | 1960 | 1961 | 1962 | 1963 | 1964 |
|---|---|---|---|---|---|
| Total Accidents | 4793 | 4625 | 4840 | 4690 | 5069 |
| Fatal Accidents | 429 | 426 | 430 | 482 | 526 |
| Fatalities | 787 | 761 | 857 | 893 | 1083 |
| Hours Flown (000) | 13121 | 13602 | 14500 | 15106 | 15737 |

Chart 2

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

TOTAL AND FATAL ACCIDENT RATES BY AIRCRAFT MAKE AND MODEL
GENERAL AVIATION DATA
1964

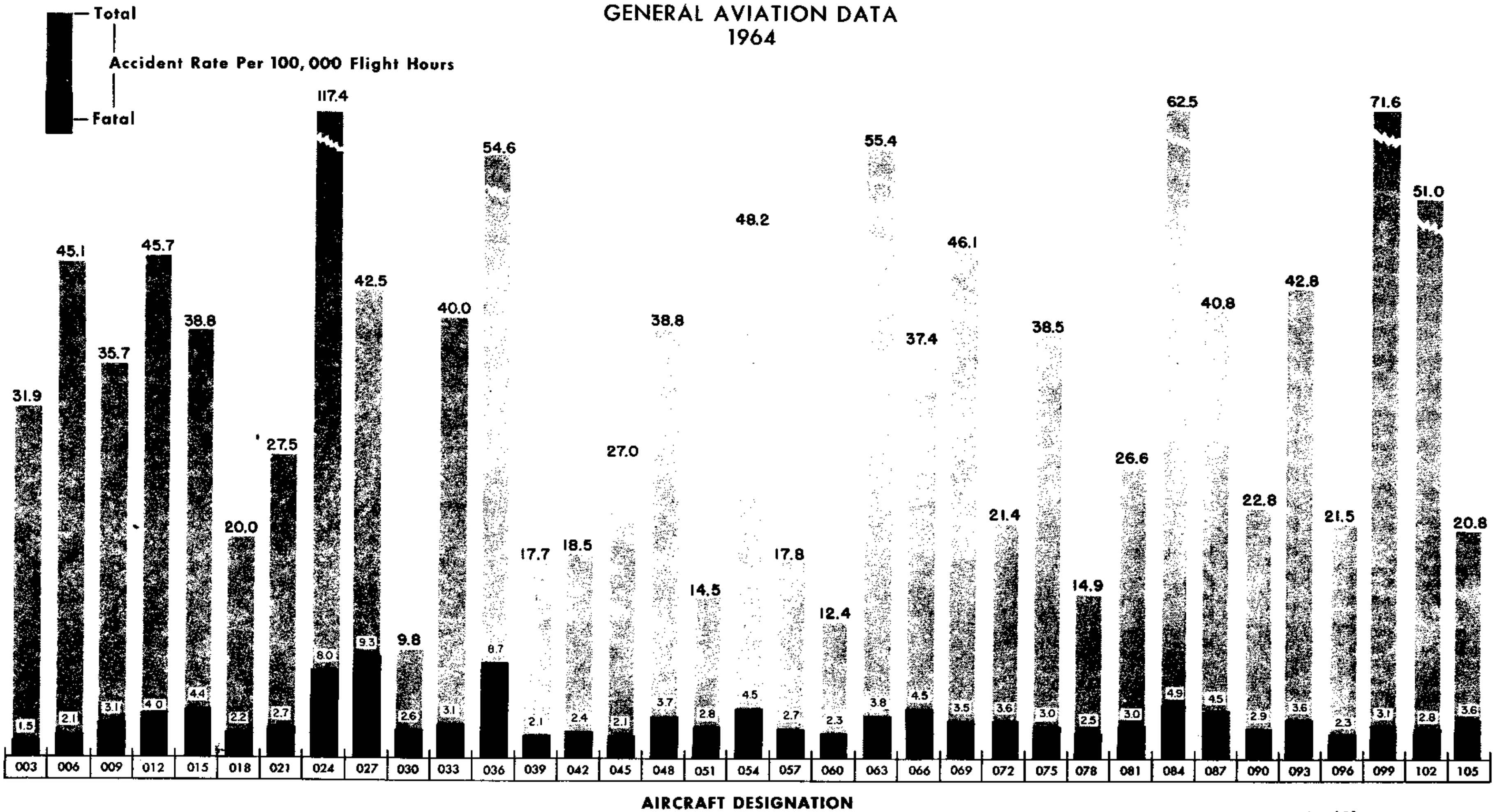
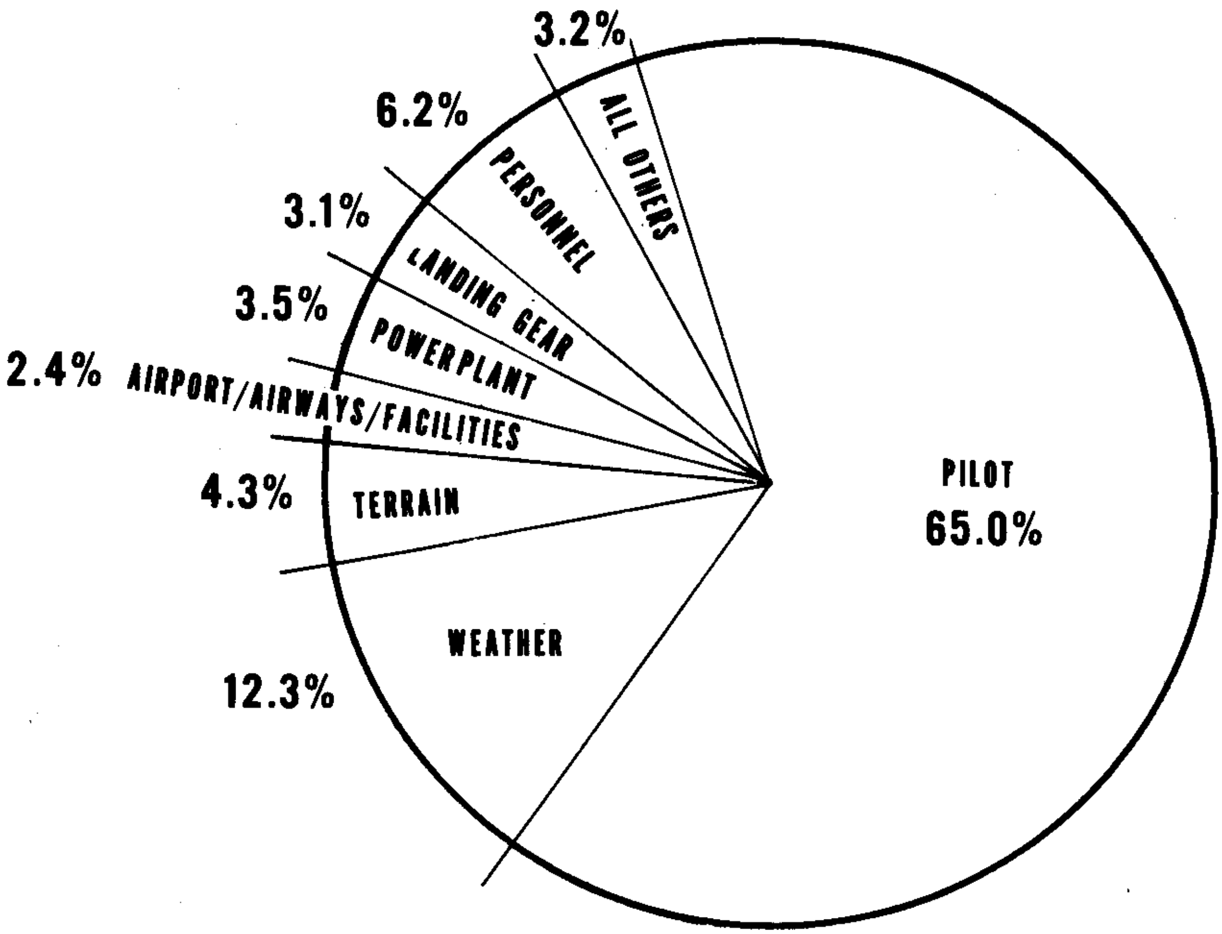


Chart 3

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## ACCIDENT CAUSES/FACTORS SUMMARY

### TOTAL ACCIDENTS



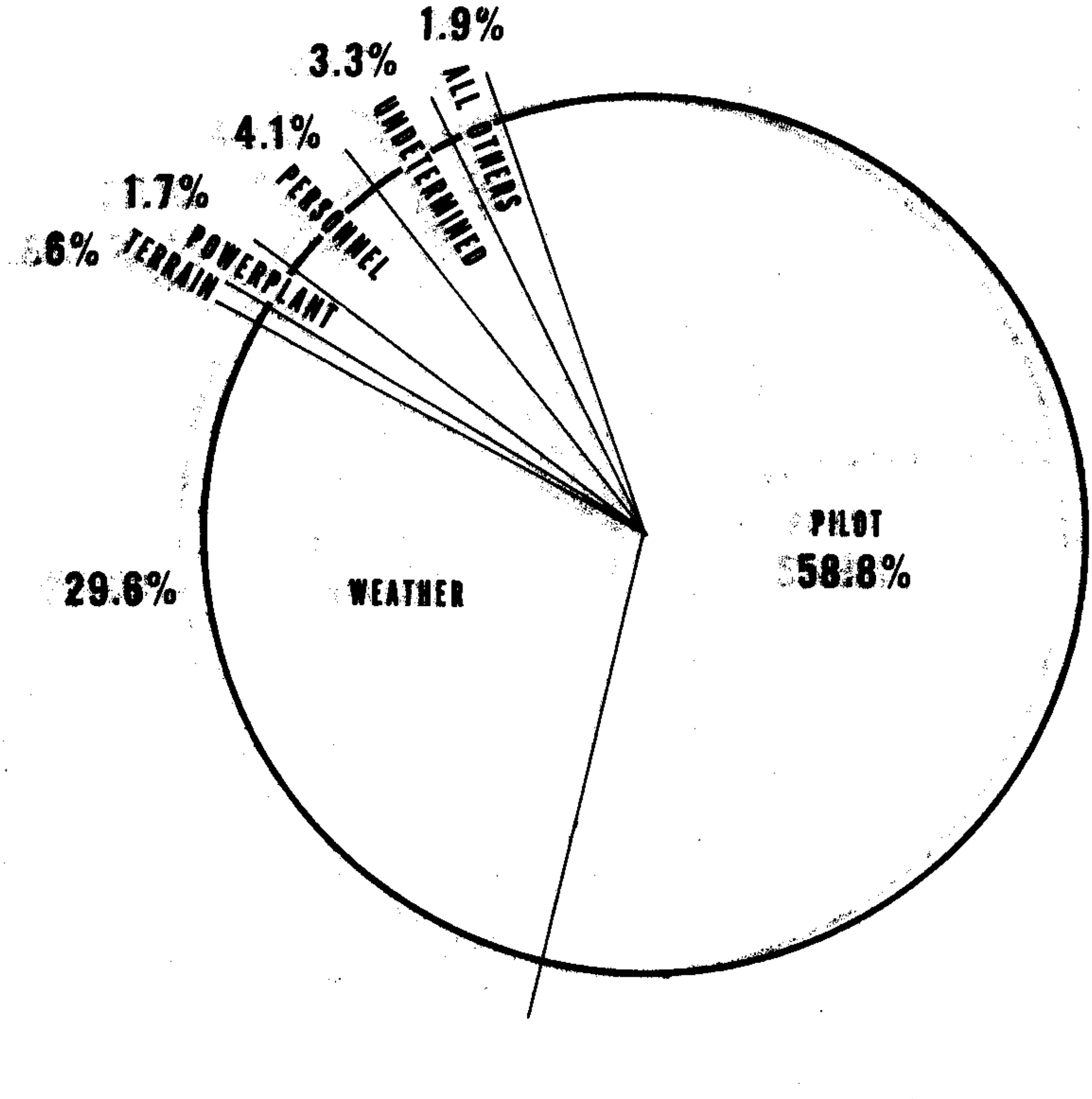

Note: The above chart is based on 3732 total accidents involving 35 make and model aircraft. Since more than one cause or factor may be assigned to a single accident, the total of causes and factors assigned to these accidents is 6272. The percentages were computed using this total.

Chart 4

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## ACCIDENT CAUSES/FACTORS SUMMARY

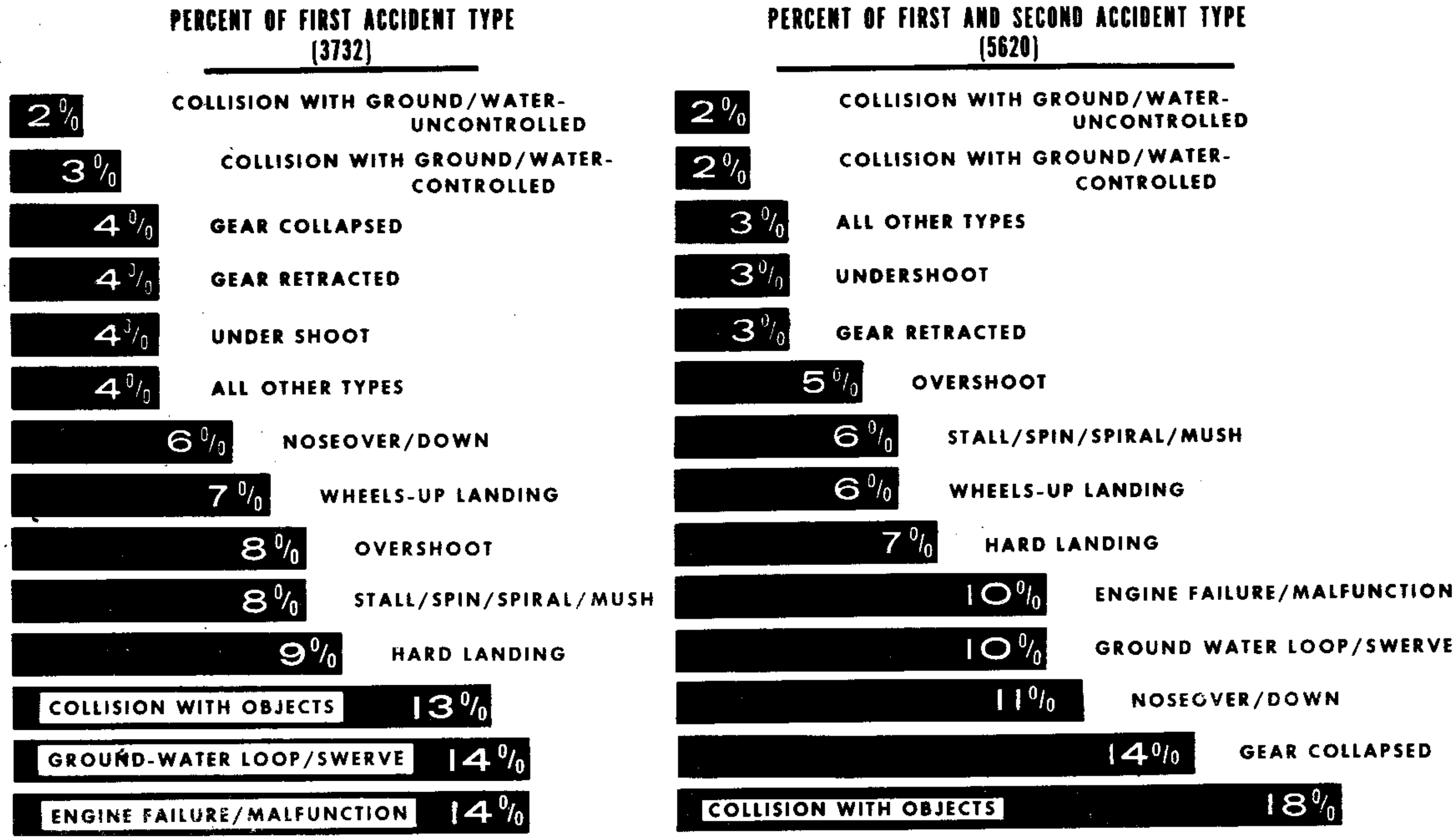
### FATAL ACCIDENTS




Note: The above chart is based on 379 fatal accidents involving 35 make and model aircraft. Since more than one cause or factor may be assigned to a single accident, the total of causes and factors assigned to these accidents is 981. The percentages were computed using this total.

Chart 5

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT
# SPECIFIC ACCIDENT TYPES EXPRESSED AS A PERCENTAGE
## General Aviation Data 1964



# APPENDIX

# TABLES

TABLE 1

AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT
TOTAL ACCIDENTS
VS
ACCIDENTS IN WHICH THE PILOT WAS CODED AS A CAUSE
BY MAKE AND MODEL

| Make & Model Designator | Total Accidents | Total Accidents In Which The Pilot Was Coded As A Cause | Percent, Pilot Involved Accidents of Total Accidents |
|---|---|---|---|
| 003 | 64 | 52 | 81% |
| 006 | 44 | 40 | 91 |
| 009 | 382 | 319 | 84 |
| 012 | 23 | 21 | 91 |
| 015 | 142 | 118 | 83 |
| 018 | 272 | 245 | 90 |
| 021 | 255 | 212 | 83 |
| 024 | 44 | 35 | 80 |
| 027 | 41 | 35 | 85 |
| 030 | 15 | 12 | 80 |
| 033 | 51 | 42 | 82 |
| 036 | 63 | 56 | 89 |
| 039 | 93 | 78 | 84 |
| 042 | 170 | 148 | 87 |
| 045 | 103 | 86 | 83 |
| 048 | 177 | 160 | 90 |
| 051 | 42 | 23 | 55 |
| 054 | 182 | 159 | 87 |
| 057 | 20 | 17 | 85 |
| 060 | 48 | 34 | 71 |
| 063 | 88 | 73 | 83 |
| 066 | 109 | 96 | 88 |
| 069 | 144 | 129 | 90 |
| 072 | 24 | 21 | 88 |
| 075 | 103 | 85 | 83 |
| 078 | 18 | 15 | 83 |
| 081 | 227 | 178 | 78 |
| 084 | 89 | 71 | 80 |
| 087 | 227 | 195 | 86 |
| 090 | 32 | 28 | 88 |
| 093 | 129 | 110 | 85 |
| 096 | 75 | 49 | 65 |
| 099 | 117 | 106 | 91 |
| 102 | 73 | 60 | 82 |
| 105 | 46 | 39 | 85 |
| TOTAL.... | 3732 | 3147 | 84% |

TABLE 2

AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT
FATAL ACCIDENTS
VS
FATAL ACCIDENTS IN WHICH THE PILOT WAS CODED AS A CAUSE
BY MAKE AND MODEL

| Make & Model Designator | Fatal Accidents | Fatal Accidents In Which The Pilot Was Coded As A Cause | Percent, Pilot Involved Accidents of Fatal Accidents |
|---|---|---|---|
| 003 | 3 | 3 | 100% |
| 006 | 2 | 1 | 50 |
| 009 | 33 | 29 | 88 |
| 012 | 2 | 2 | 100 |
| 015 | 16 | 12 | 75 |
| 018 | 30 | 26 | 87 |
| 021 | 25 | 21 | 84 |
| 024 | 3 | 2 | 67 |
| 027 | 9 | 7 | 78 |
| 030 | 4 | 4 | 100 |
| 033 | 4 | 2 | 50 |
| 036 | 10 | 9 | 90 |
| 039 | 11 | 8 | 73 |
| 042 | 22 | 19 | 86 |
| 045 | 8 | 7 | 88 |
| 048 | 17 | 15 | 88 |
| 051 | 8 | 6 | 75 |
| 054 | 17 | 15 | 88 |
| 057 | 3 | 3 | 100 |
| 060 | 9 | 6 | 67 |
| 063 | 6 | 5 | 83 |
| 066 | 13 | 13 | 100 |
| 069 | 11 | 11 | 100 |
| 072 | 4 | 3 | 75 |
| 075 | 8 | 7 | 88 |
| 078 | 3 | 2 | 67 |
| 081 | 26 | 22 | 85 |
| 084 | 7 | 7 | 100 |
| 087 | 25 | 22 | 88 |
| 090 | 4 | 4 | 100 |
| 093 | 11 | 8 | 73 |
| 096 | 8 | 7 | 88 |
| 099 | 5 | 5 | 100 |
| 102 | 4 | 3 | 75 |
| 105 | 8 | 8 | 100 |
| TOTAL..... | 379 | 324 | 85% |



AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT
TOTAL OF TYPES OF ACCIDENTS

Table 3

# Table 3

AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT
TOTAL OF TYPES OF ACCIDENTS
BY INDIVIDUAL MAKE AND MODEL
GENERAL AVIATION DATA 1964

MAKE AND MODEL DESIGNATION

| TYPE OF ACCIDENT | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NUMBER OF ACCIDENTS INVOLVED | 64 | 44 | 382 | 23 | 142 | 272 | 255 | 44 | 41 | 15 | 51 | 63 | 93 | 170 | 103 | 177 | 42 | 182 | 20 | 48 | 88 | 109 | 144 | 24 | 103 | 18 | 227 | 89 | 227 | 32 | 129 | 75 | 117 | 73 | 46 | |
| Ground/waterloop/swerve | 4 | 14 | 76 | 4 | 6 | 38 | 22 | 8 | 0 | 0 | 6 | 8 | 4 | 20 | 33 | 47 | 4 | 30 | 0 | 11 | 26 | 24 | 58 | 0 | 7 | 1 | 15 | 4 | 13 | 4 | 40 | 6 | 38 | 5 | 6 | 582 |
| Dragged wingtip, pod, or float | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wheels-up landing | 18 | 0 | 0 | 0 | 31 | 0 | 69 | 6 | 20 | 4 | 0 | 0 | 36 | 0 | 0 | 0 | 6 | 0 | 0 | 11 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 21 | 65 | 4 | 0 | 14 | 0 | 0 | 0 | 311 |
| Wheels-down landing in water | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Gear collapsed | 17 | 6 | 93 | 4 | 34 | 52 | 34 | 8 | 2 | 0 | 17 | 11 | 11 | 42 | 14 | 62 | 7 | 31 | 4 | 5 | 18 | 17 | 42 | 2 | 20 | 1 | 62 | 30 | 36 | 4 | 25 | 17 | 23 | 26 | 8 | 785 |
| Gear retracted | 1 | 0 | 0 | 0 | 17 | 0 | 58 | 5 | 5 | 2 | 0 | 0 | 7 | 0 | 0 | 0 | 10 | 0 | 0 | 2 | 0 | 0 | 0 | 6 | 0 | 2 | 0 | 3 | 20 | 3 | 0 | 13 | 0 | 0 | 0 | 154 |
| Hard landing | 7 | 4 | 46 | 1 | 19 | 31 | 13 | 4 | 2 | 0 | 5 | 7 | 2 | 26 | 7 | 38 | 0 | 25 | 5 | 1 | 10 | 12 | 12 | 1 | 13 | 0 | 42 | 10 | 15 | 2 | 17 | 7 | 5 | 20 | 5 | 414 |
| Nose over/down | 7 | 16 | 136 | 3 | 4 | 66 | 6 | 3 | 0 | 0 | 10 | 5 | 5 | 30 | 28 | 17 | 0 | 41 | 4 | 4 | 24 | 23 | 28 | 0 | 12 | 0 | 52 | 2 | 2 | 2 | 46 | 1 | 41 | 6 | 14 | 638 |
| Roll over | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Overshoot | 8 | 4 | 35 | 0 | 12 | 41 | 11 | 1 | 2 | 0 | 6 | 0 | 7 | 19 | 7 | 21 | 1 | 6 | 4 | 4 | 5 | 6 | 11 | 0 | 1 | 4 | 25 | 9 | 23 | 1 | 8 | 5 | 4 | 3 | 4 | 298 |
| Undershoot | 1 | 4 | 18 | 1 | 4 | 12 | 4 | 2 | 0 | 1 | 3 | 1 | 4 | 6 | 7 | 16 | 1 | 7 | 0 | 1 | 6 | 3 | 5 | 0 | 7 | 0 | 10 | 2 | 19 | 2 | 5 | 4 | 7 | 7 | 4 | 174 |
| Collision with aircraft | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Both in flight | 1 | 1 | 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 22 |
| One airborne | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 14 |
| Both on ground | 1 | 0 | 1 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| Collision with ground/water | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Controlled | 4 | 0 | 7 | 0 | 6 | 7 | 9 | 1 | 0 | 1 | 1 | 0 | 6 | 2 | 6 | 7 | 2 | 6 | 1 | 3 | 6 | 4 | 5 | 2 | 1 | 0 | 10 | 5 | 2 | 1 | 2 | 2 | 4 | 2 | 3 | 118 |
| Uncontrolled | 0 | 0 | 7 | 0 | 4 | 14 | 4 | 0 | 3 | 0 | 0 | 2 | 3 | 10 | 1 | 2 | 2 | 2 | 0 | 0 | 2 | 2 | 6 | 0 | 3 | 2 | 7 | 2 | 12 | 2 | 1 | 4 | 1 | 0 | 1 | 99 |
| Collided with | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Wires/poles | 1 | 2 | 18 | 1 | 2 | 15 | 5 | 0 | 1 | 1 | 1 | 2 | 6 | 12 | 2 | 6 | 2 | 7 | 1 | 2 | 5 | 2 | 2 | 0 | 7 | 1 | 8 | 3 | 8 | 1 | 9 | 0 | 6 | 4 | 4 | 147 |
| Trees | 1 | 4 | 24 | 2 | 12 | 26 | 7 | 5 | 1 | 2 | 1 | 9 | 1 | 13 | 7 | 13 | 1 | 15 | 3 | 1 | 5 | 8 | 8 | 1 | 17 | 2 | 11 | 4 | 7 | 2 | 2 | 3 | 11 | 7 | 4 | 240 |
| Residence (s) | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Other buildings | 0 | 1 | 4 | 0 | 2 | 4 | 5 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 2 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 6 | 2 | 1 | 0 | 0 | 1 | 1 | 1 | 2 | 41 |
| Fence, fenceposts | 0 | 1 | 11 | 2 | 1 | 15 | 7 | 3 | 2 | 0 | 4 | 1 | 3 | 6 | 4 | 12 | 1 | 8 | 1 | 2 | 1 | 0 | 4 | 0 | 3 | 1 | 8 | 4 | 14 | 1 | 8 | 0 | 2 | 4 | 1 | 135 |
| Electronic towers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Runway/approach lights | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Airport hazard | 0 | 0 | 2 | 0 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 14 |
| Animals | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 9 |
| Crop | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Flagman, loader | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ditches | 1 | 2 | 18 | 2 | 6 | 18 | 1 | 1 | 0 | 0 | 4 | 0 | 0 | 7 | 2 | 6 | 0 | 7 | 0 | 2 | 3 | 2 | 3 | 0 | 1 | 1 | 14 | 3 | 13 | 3 | 3 | 5 | 5 | 4 | 0 | 137 |
| Snowbank | 0 | 1 | 9 | 1 | 0 | 4 | 5 | 0 | 0 | 1 | 0 | 0 | 2 | 4 | 3 | 7 | 0 | 1 | 0 | 0 | 1 | 3 | 5 | 0 | 1 | 0 | 5 | 0 | 1 | 0 | 3 | 1 | 1 | 0 | 0 | 59 |
| Parked aircraft (unattended eng. not running) | 0 | 1 | 3 | 0 | 0 | 5 | 3 | 0 | 0 | 0 | 3 | 4 | 1 | 4 | 2 | 1 | 1 | 8 | 1 | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 4 | 1 | 1 | 1 | 3 | 2 | 0 | 1 | 2 | 56 |
| Automobile | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 14 |
| Dirt bank | 1 | 1 | 0 | 0 | 3 | 5 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 5 | 0 | 3 | 0 | 0 | 0 | 3 | 1 | 0 | 2 | 1 | 2 | 1 | 4 | 0 | 1 | 0 | 0 | 2 | 0 | 41 |
| Other | 1 | 1 | 7 | 0 | 2 | 6 | 5 | 1 | 0 | 0 | 1 | 1 | 3 | 4 | 8 | 3 | 1 | 4 | 1 | 1 | 1 | 5 | 3 | 0 | 2 | 0 | 7 | 1 | 10 | 1 | 1 | 4 | 2 | 0 | 2 | 89 |
| Bird Strike (collision with birds) | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Stall, spin, spiral, mush | 2 | 6 | 26 | 7 | 6 | 19 | 23 | 6 | 5 | 1 | 7 | 24 | 5 | 15 | 1 | 11 | 3 | 36 | 2 | 3 | 9 | 21 | 16 | 4 | 17 | 4 | 6 | 2 | 9 | 5 | 10 | 3 | 19 | 6 | 1 | 340 |
| Fire or explosion | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| In flight | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 11 |
| On ground | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| Airframe failure | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| In flight | 0 | 0 | 2 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 6 | 0 | 0 | 1 | 1 | 0 | 0 | 19 |
| On ground | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 4 |
| Engine tearaway | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Engine failure or malfunction | 5 | 4 | 66 | 7 | 21 | 26 | 32 | 6 | 3 | 3 | 9 | 14 | 15 | 24 | 12 | 18 | 6 | 24 | 2 | 9 | 15 | 17 | 15 | 2 | 20 | 2 | 25 | 23 | 28 | 5 | 22 | 6 | 17 | 21 | 7 | 531 |
| Propeller failure | 2 | 0 | 0 | 0 | 5 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| Propeller/rotor acc. to person | 0 | 0 | 2 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 17 |
| Jet intake/exhaust acc. to pers. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Propeller/jet/rotor blast | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Turbulence | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Hail damage to aircraft | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lightning strike | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Evasive maneuver | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Uncontrolled altitude deviations | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ditching | 1 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 13 |
| Missing acft., not recovered | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 10 |
| Other/miscellaneous | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Undetermined | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| TOTAL | 85 | 74 | 624 | 37 | 205 | 420 | 336 | 63 | 47 | 18 | 80 | 94 | 126 | 264 | 154 | 301 | 55 | 269 | 30 | 70 | 144 | 159 | 231 | 26 | 148 | 25 | 336 | 139 | 321 | 46 | 208 | 103 | 191 | 122 | 69 | 5620 |

NOTE: Tabular entries include the first and second accident types.

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT
## SPECIFIC PILOT CAUSES/FACTORS BY INDIVIDUAL MAKE AND MODEL
## GENERAL AVIATION DATA 1964

MAKE AND MODEL DESIGNATION

| PILOT CAUSES/FACTORS | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Att. operation with known deficiencies in equipment | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 3 | 0 | 1 | 1 | 1 | 0 | 0 | 16 |
| Att. operation beyond exp./ability level | 1 | 0 | 9 | 0 | 1 | 6 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 4 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 2 | 1 | 1 | 38 |
| Became lost/disoriented | 2 | 2 | 8 | 0 | 4 | 10 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 13 | 2 | 4 | 0 | 3 | 1 | 0 | 3 | 1 | 2 | 0 | 3 | 0 | 3 | 1 | 1 | 0 | 1 | 0 | 0 | 3 | 2 | 73 |
| Cont. VFR flt. into adverse weather | 6 | 1 | 15 | 0 | 9 | 22 | 12 | 3 | 4 | 1 | 2 | 1 | 4 | 11 | 6 | 12 | 0 | 8 | 2 | 2 | 9 | 1 | 4 | 0 | 4 | 1 | 18 | 2 | 15 | 1 | 2 | 4 | 1 | 3 | 6 | 192 |
| Cont. flt. into known area of severe turbulence | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Delayed action in aborting takeoff | 0 | 0 | 2 | 0 | 1 | 4 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 1 | 1 | 3 | 0 | 6 | 0 | 1 | 0 | 0 | 29 |
| Delayed in initiating go-around | 0 | 0 | 2 | 2 | 4 | 6 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 3 | 0 | 5 | 1 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 4 | 0 | 6 | 0 | 3 | 0 | 1 | 1 | 1 | 50 |
| Diverted attention from operation of aircraft | 1 | 0 | 4 | 0 | 4 | 1 | 5 | 1 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 4 | 0 | 0 | 0 | 1 | 0 | 0 | 39 |
| Exceeded designed stress limits of aircraft | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 |
| Failed to extend landing gear | 12 | 0 | 0 | 0 | 13 | 0 | 28 | 3 | 5 | 3 | 0 | 0 | 14 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 11 | 27 | 2 | 0 | 1 | 0 | 0 | 0 | 123 |
| Failed to retract landing gear | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Retracted gear prematurely | 0 | 0 | 0 | 0 | 5 | 0 | 13 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 3 | 0 | 0 | 0 | 34 |
| Inadvertently retracted gear | 0 | 0 | 0 | 0 | 6 | 0 | 43 | 1 | 3 | 2 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 2 | 0 | 2 | 6 | 3 | 0 | 6 | 0 | 0 | 0 | 86 |
| Failed to see and avoid other aircraft | 2 | 0 | 6 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 8 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 1 | 3 | 1 | 1 | 0 | 3 | 0 | 0 | 1 | 0 | 2 | 0 | 42 |
| Failed to see and avoid objects or obstructions | 0 | 1 | 10 | 1 | 3 | 9 | 3 | 0 | 0 | 0 | 1 | 1 | 2 | 6 | 2 | 1 | 2 | 4 | 0 | 3 | 1 | 2 | 0 | 0 | 8 | 0 | 10 | 0 | 3 | 2 | 3 | 2 | 3 | 1 | 2 | 86 |
| Failed to obtain/maintain flying speed | 0 | 1 | 11 | 7 | 5 | 8 | 13 | 5 | 3 | 1 | 8 | 19 | 2 | 12 | 0 | 6 | 1 | 27 | 0 | 0 | 8 | 17 | 14 | 4 | 12 | 2 | 5 | 1 | 5 | 2 | 7 | 1 | 12 | 2 | 0 | 221 |
| Misjudged distance, speed, altitude or clearance | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 3 | 0 | 0 | 0 | 2 | 1 | 0 | 20 |
| Failed to use or incorrectly used miscellaneous equipment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| Failed to follow approved procedures, directives, instructions, etc. | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| Improper operation of Powerplant and Powerplant controls. (Includes Prop.) | 0 | 1 | 9 | 0 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 2 | 3 | 1 | 5 | 1 | 2 | 0 | 2 | 0 | 1 | 2 | 0 | 1 | 1 | 0 | 1 | 2 | 0 | 3 | 1 | 2 | 51 |
| Improper operation of brakes and/or flight controls | 0 | 7 | 28 | 3 | 3 | 14 | 10 | 3 | 0 | 0 | 2 | 4 | 1 | 10 | 18 | 27 | 1 | 21 | 0 | 4 | 10 | 10 | 22 | 0 | 3 | 0 | 6 | 4 | 5 | 2 | 27 | 1 | 33 | 2 | 4 | 285 |
| Improper operation of flight controls | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 1 | 0 | 0 | 4 | 0 | 0 | 0 | 2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 19 |
| Premature lift-off | 1 | 1 | 3 | 0 | 2 | 7 | 5 | 2 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 0 | 3 | 0 | 0 | 0 | 3 | 5 | 0 | 4 | 1 | 1 | 0 | 5 | 1 | 1 | 0 | 3 | 2 | 1 | 58 |
| Improper level off | 6 | 3 | 40 | 1 | 16 | 25 | 8 | 2 | 1 | 0 | 4 | 6 | 2 | 22 | 4 | 33 | 0 | 20 | 4 | 1 | 5 | 8 | 13 | 1 | 9 | 0 | 31 | 9 | 8 | 2 | 12 | 5 | 6 | 17 | 5 | 329 |
| Improper IFR operation | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 10 |
| Improper in-flight decisions or planning | 3 | 1 | 6 | 0 | 3 | 3 | 4 | 1 | 0 | 1 | 0 | 0 | 1 | 3 | 4 | 3 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 8 | 4 | 5 | 0 | 0 | 0 | 2 | 1 | 2 | 60 |
| Improper compensation for wind conditions | 1 | 8 | 58 | 0 | 3 | 27 | 7 | 2 | 0 | 0 | 3 | 5 | 1 | 12 | 8 | 16 | 0 | 19 | 1 | 1 | 11 | 8 | 27 | 0 | 4 | 0 | 16 | 2 | 4 | 1 | 10 | 2 | 11 | 3 | 4 | ?72 |
| Inadequate pre-flt. preparation and/or planning | 1 | 1 | 19 | 1 | 5 | 13 | 10 | 2 | [illegible] | 0 | 3 | 5 | 3 | 4 | 5 | 3 | 2 | 13 | 1 | 5 | 4 | 5 | 8 | 1 | 7 | 3 | 7 | 4 | 9 | 1 | 8 | 2 | 5 | 9 | 3 | 174 |
| Inadequate supervision of flight | 0 | 1 | 14 | 0 | 3 | 4 | 1 | 2 | 3 | 0 | 1 | 0 | 6 | 12 | 0 | 6 | 0 | 8 | 1 | 1 | 1 | 3 | 3 | 0 | 3 | 1 | 3 | 0 | 3 | 0 | 2 | 1 | 3 | 4 | 1 | 91 |
| Lack of familiarity with aircraft | 0 | 1 | 4 | 0 | 5 | 6 | [illegible] | 0 | 3 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 4 | 2 | 0 | 2 | 2 | 2 | 1 | 1 | 0 | 0 | 1 | 6 | 0 | 0 | 3 | 2 | 3 | 0 | 55 |
| Mismanagement of fuel system | 3 | 2 | 19 | 2 | 5 | 0 | 13 | 0 | 1 | 1 | 1 | 2 | 4 | 0 | 0 | 6 | 0 | 0 | 0 | 1 | 3 | 3 | 4 | 1 | 1 | 0 | 1 | 7 | 5 | 3 | 5 | 2 | 1 | 2 | 0 | 98 |
| Exercised poor judgment | 2 | 0 | 15 | 2 | 5 | 16 | 9 | 0 | 2 | 1 | 0 | 3 | 2 | 4 | 4 | 4 | 0 | 9 | 0 | 0 | 4 | 3 | 6 | 1 | 7 | 1 | 12 | 1 | 12 | 0 | 1 | 5 | 6 | 3 | 3 | 143 |
| Operated carelessly | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 8 |
| Selected unsuitable terrain | 4 | 3 | 39 | 2 | 6 | 30 | 10 | 0 | 0 | 0 | 6 | 5 | 2 | 15 | 17 | 13 | 1 | 9 | 1 | 0 | 8 | 16 | 6 | 0 | 7 | 0 | 21 | 6 | 8 | 2 | 16 | 3 | 10 | 4 | 4 | 274 |
| Improper starting procedures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Started engine without proper assistance and/or equipment | 0 | 2 | 2 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 8 | 0 | 0 | 1 | 2 | 0 | 0 | 4 | 0 | 2 | 1 | 1 | 0 | 1 | 0 | 1 | 3 | 2 | 40 |
| Taxied/parked without proper assistance | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 5 |
| Failed to assure the gear was down and locked | 3 | 0 | 0 | 0 | 12 | 0 | 17 | 1 | 13 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | [illegible] | 0 | 0 | 0 | 1 | 29 | 2 | 0 | 5 | 0 | 0 | 0 | 101 |
| Inattentive to fuel supply | 0 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 9 |
| Failed to relinquish control | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| Control interference | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Spontaneous - Improper action | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 |
| Misjudged distance, speed, and altitude | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 |
| Misjudged distance and speed | 7 | 3 | 77 | 1 | 11 | 34 | 9 | 0 | 2 | 0 | 7 | 0 | 7 | 14 | 5 | 22 | 0 | 4 | 4 | 4 | 4 | 4 | 11 | 0 | 1 | 2 | 18 | 6 | 16 | 1 | 6 | 3 | 6 | 3 | 3 | 245 |
| Misjudged distance | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 6 |
| Misjudged distance and altitude | 0 | 4 | 10 | 0 | 2 | 10 | 1 | 2 | 0 | 0 | 1 | 1 | 2 | 5 | 4 | 7 | 0 | 5 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 10 | 0 | 4 | 3 | 5 | 4 | 1 | 107 |
| Misjudged speed and altitude | 0 | 0 | 3 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 24 |
| Misjudged speed | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Misjudged speed and clearance | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| Misjudged altitude and clearance | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 |
| Misjudged altitude | 1 | 0 | 4 | 0 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 1 | 2 | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 22 |
| Misjudged clearance | 0 | 1 | 4 | 0 | 1 | 5 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 4 | 2 | 1 | 0 | 4 | 0 | 0 | 1 | 3 | 2 | 0 | 0 | 0 | 6 | 1 | 3 | 0 | 1 | 0 | 0 | 1 | 0 | 41 |
| Intoxication | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 |
| Alcoholic impairment of efficiency and judgement | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 1 | 17 |
| Suffered heart attack | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Improper recovery from bounced landing | 1 | 1 | 3 | 0 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 7 | 0 | 5 | 0 | 1 | 0 | 0 | 1 | 1 | 5 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 37 |
| Fatigue | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| Incapacitation | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 12 |
| Physical impairment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Vertigo/disorientation | 1 | 0 | 3 | 0 | 0 | 4 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 22 |
| Carbon Monoxide poisoning | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Not alligned with runway/intended landing area | 0 | 0 | 8 | 0 | 1 | 6 | 0 | 0 | 1 | 1 | 0 | 0 | 3 | 7 | 0 | 2 | 0 | 1 | 1 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 3 | 1 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 43 |
| Misused or failed to use flaps | 0 | 0 | 1 | 0 | 0 | 3 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 9 |
| Unwarranted low flying | 1 | 0 | 4 | 2 | 2 | 5 | 1 | 1 | 1 | 0 | 0 | 4 | 0 | 6 | 1 | 2 | 0 | 10 | 0 | 0 | 3 | 4 | 3 | 0 | 7 | 0 | 3 | 0 | 0 | 0 | 4 | 0 | 1 | 0 | 0 | 65 |
| Landed at wrong airport | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Left aircraft unattended, engine running | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Flew into blind canyon | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 9 |
| Poorly planned approach | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 9 |
| Failed to use all available runway | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 8 |
| Failed to maintain directional control | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 1 | 2 | 0 | 16 |
| Selected wrong runway relative to existing wind | 0 | 1 | 9 | 2 | 1 | 6 | 3 | 2 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 3 | 1 | 0 | 1 | 4 | 2 | 2 | 0 | 4 | 0 | 1 | 0 | 1 | 50 |
| Other Direct Entry Pilot Cause/Factors | 0 | 0 | 2 | 1 | 0 | 2 | 4 | 1 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 2 | 1 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 27 |
| TOTAL | 59 | 47 | 419 | 29 | 153 | 321 | 250 | 46 | 51 | 17 | 52 | 75 | 97 | 202 | 99 | 211 | 21 | 219 | 26 | 36 | 98 | 120 | 167 | 25 | 112 | 24 | 222 | 77 | 242 | 30 | 142 | 59 | 136 | 85 | 51 | 4,020 |

**NOTE:** Tabular entries include those specific causes/factors for Pilot in Command, Copilot, Dual Student, and Check Pilot.

**Table 5**

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Total Accidents**

| AIRCRAFT DESIGNATION / SPECIFIC UTILIZATION GROUP | | 003 I-C | 006 I-A | 009 I-B | 012 I-A | 015 I-C | 018 I-B | 021 I-C | 024 I-A | 027 II-B | 030 II-A | 033 I-C | 036 I-A | 039 II-B | 042 I-B | 045 I-C | 048 I-B | 051 II-A | 054 I-B | 057 I-C | 060 II-A | 063 I-A | 066 I-C | 069 I-A | 072 II-B | 075 I-B | 078 II-B | 081 I-C | 084 I-A | 087 I-C | 090 I-C | 093 I-B | 096 II-B | 099 I-A | 102 I-A | 105 I-A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AIRCRAFT GROUP I AND II | BASIS FOR CHI-SQUARE EVALUATION | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | TOTAL FLIGHT TIME | | | ★ | | ● | ☆ | ○ | ★ 1/ | ★ 1/ | | | | | ☆ | | ★ | | ★ | ○ 1/ | | | | | | ● | | ○ | ● | ★ | | ★ | | ★ | | ☆ |
| | TOTAL ACTIVE AIRCRAFT | | | ● | ○ 1/ | ★ | ☆ | | ● 1/ | ★ 1/ | | ○ | | | ★ | | ★ | | | | | | ○ | | | ☆ | | ○ | ★ | ★ | | ☆ | | ● | ○ | ○ |
| AIRCRAFT GROUP III | TOTAL FLIGHT TIME | | ● 1/ | ● | | ● | ☆ | | ★ 1/ | ● 1/ | ☆ | | ★ 1/ | ☆ | ☆ | | ● | ☆ | ★ | ○ 1/ | ☆ | ★ | ● | ★ | | ● | ○ 1/ | ○ | ★ 1/ | ★ | | ★ | ○ | ★ | ★ 1/ | ○ |
| | TOTAL ACTIVE AIRCRAFT | | | ★ | ○ 1/ | ★ | ○ | | ● 1/ | ★ 1/ | ○ 1/ | | ○ | ○ | ☆ | | ★ | | | | ○ | ○ | ○ | | | ☆ | | | ● | ★ | | | | | ☆ | ☆ |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO..... |
|---|---|
| I & II | type of utilization group (personal, professional, or instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

**LEGEND**

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF TOTAL ACCIDENTS CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

**EXPLANATION OF TABLE**

Entries, or the lack of them, denote the relative frequency of occurrence of <u>total</u> accidents for each of the 35 make and model aircraft. Where no entry is depicted simply means that specific aircraft's total accident record for 1964 was not considered significant. That is, its total number of accidents was considered to be average or expected within the group tested. The criterion for the Chi-Square data and its interpretation is based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

1/ Sample size considered to be relatively small.

**Table 6**

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Ground-loop/swerve**

| | | AIRCRAFT DESIGNATION | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SPECIFIC UTILIZATION GROUP | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| | BASIS FOR CHI-SQUARE EVALUATION | ACCIDENT TYPE SEQUENCE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | | ○ | | | | | | | | | ○ | ★ | ● | | | | | | ★ | ★ | | ○ | | | ☆ | ○ | | ★ | | ● | ○ | |
| | | I only | | | | | | | | | | | | | | | ★ | ● | | | | | | ● | ★ | | ○ | | | ☆ | ○ | | ● | | ● | | |
| | TOTAL FLIGHT TIME | I and II | | | ● | | | ☆ | | | | | | | | ☆ | ★ | ★ | | ● | | | | ★ | ★ | | ○ | | ○ | ○ | | | ★ | | ★ | ○ | ☆ |
| | | I only | | | ● | | | ☆ | | ● 1/ | | | | | | ☆ | ★ | ★ | | ● | | | | ★ | ● | | | | ○ | ○ | | | ★ | | ★ | ○ | ☆ |
| | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | ○ | | | | | | ○ | | | ★ | ★ | | | | | | ● | ★ | | ☆ | | ○ | ○ | | | ● | | ● | ☆ | ○ |
| | | I only | | | ● | | | ○ | | | | | | ○ | | | ★ | ★ | | | | | | ● | ★ | | ☆ | | ○ | ○ | | | | | ● | ☆ | ○ |
| GROUP III | TOTAL ACCIDENTS | I and II | | ● | ● | | ☆ | | ○ | | ○ | | | | ○ | | ★ | ★ | | | | | ★ | | ★ | | ○ | | ☆ | ○ | ☆ | | ★ | | ★ | | |
| | | I only | ○ | ● | ● | | ○ | | ○ | | | | | | | | ★ | ● | | | | | ● | | ★ | | | | ○ | ○ | ☆ | | ● | | ★ | | |
| | TOTAL FLIGHT TIME | I and II | | ★ | ★ | | ○ | ☆ | ☆ | ★ 1/ | ○ | ○ | | | ☆ | ☆ | ★ | ★ | ○ | ● | ○ | | ★ | ● | ★ | ○ | | ○ | ☆ | | ○ | | ★ | ○ | ★ | | |
| | | I only | | ★ 1/ | ★ | | ○ | ○ | ○ | ★ 1/ | | ○ | | | | ○ | ● | ★ | ○ | ● | ○ | | ★ | ● | ★ | | | | ☆ | | ○ | | ★ | | ★ | | |
| | TOTAL ACTIVE AIRCRAFT | I and II | | ● | ★ | | ○ | | ○ | | | ○ 1/ | | | ☆ | | ★ | ★ | | | | | ● | | ★ | | ☆ | | ☆ | | ○ | | ★ | | ★ | ○ | |
| | | I only | | ● | ★ | | | | ○ | | | ○ 1/ | | | | | ★ | ★ | | | | | | | ★ | | ☆ | | ☆ | | ○ | | ● | | ★ | ○ | |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 7

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Ground-loop/swerve**

AIRCRAFT GROUP IV

| BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT DESIGNATION / SPECIFIC UTILIZATION GROUP — AIRCRAFT CONFIGURATION/CATEGORY CHARACTERIZED BY ALL.. * | ** ✓ | 003 I-C | 006 I-A | 009 I-B | 012 I-A | 015 I-C | 018 I-B | 021 I-C | 024 I-A | 027 II-B | 030 II-A | 033 I-C | 036 I-A | 039 II-B | 042 I-B | 045 I-C | 048 I-B | 051 II-A | 054 I-B | 057 I-C | 060 II-A | 063 I-A | 066 I-C | 069 I-A | 072 II-B | 075 I-B | 078 II-B | 081 I-C | 084 I-A | 087 I-C | 090 I-C | 093 I-B | 096 II-B | 099 I-A | 102 I-A | 105 I-A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL ACCIDENTS | a. HIGH WING/TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | ★ | | ☆ | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | ★ | | | | | | | | | | | | | | | | | | | | | | | | ○ | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | | | ★ | | | | | | | | | | | | | ○ | | | | | | |
| | d. HIGH WING | ✓ | ○ | ● | | | | | | | | | | | | | ● | | | | | | ● | | ★ | | ○ | | ☆ | | | | | | ★ | | |
| | e. LOW WING | ✓ | | | | | ○1/ | | | | | | | | | | | ★ | | | | | | | | | | | | | ○ | | | | | | |
| | f. TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | ★ | | ☆ | | | | | | | | | | |
| | g. NOSE GEAR | ✓ | | | ★ | | ○1/ | | | | | | | | | | | ★ | | | | | | | | | | | ○ | | ○ | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | ○ | ● | | | ○ | | ○ | | | | | | | | ★ | ● | | | | | ● | | ★ | | ○ | | ☆ | ○ | ☆ | | ● | | ★ | ○ | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | ★1/ | | | | | | | | | | | | | | | |
| TOTAL FLIGHT TIME | a. HIGH WING /TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | ★ | | ☆ | | | | | | | | ★ | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | ★ | | | | | | | | | | | | | | | | | | | | | | | | ○ | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | | | ★ | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | ○ | ★ | | | | ☆ | | | | | | | | ☆ | | | | | ○ | | ★ | | ★ | | ○ | | ☆ | | | | ★ | | ★ | | ○ |
| | e. LOW WING | ✓ | | | | | | | ○ | ★1/ | | | | | | | | ★ | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | ✓ | | | | | | | | ●1/ | | | | | | | | | | | | | | | ★ | | ☆ | | | | | | | | ★ | | |
| | g. NOSE GEAR | ✓ | | | ★ | | | | | | | | | | | | | ★ | | | | | | | | | | | ○ | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | ○ | ★ | ● | | ○ | ☆ | ☆ | ★1/ | | | | | | ☆ | ● | ★ | | ● | ○ | | ★ | | ★ | | | | ☆ | | ○ | | ★ | | ★ | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | ● | | | | | | | | | | | | | | | |
| TOTAL ACTIVE AIRCRAFT | a. HIGH WING/TAIL WHEEL | ✓ | | | | | | | | | | | | ○ | | | | | | | | | | | ★ | | ☆ | | | | | | | | ● | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | ★ | | | | | | | | | | | | | | | | | | | | | | | | ○ | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | | | ★ | | | | | | | | | | | | | | | | | | ○ | |
| | d. HIGH WING | ✓ | ○ | ● | ● | | | ○ | | | | | | | | | ● | | | | | | | | ★ | | ☆ | | ☆ | | | | | | ★ | | ○ |
| | e. LOW WING | ✓ | | | | | | | ○ | ●1/ | | | | | | | | ★ | | | | | | | | | | | | | | | | | | ○ | |
| | f. TAIL WHEEL | ✓ | | | | | | | | | | | | ○ | | | | | | | | | | | ★ | | ☆ | | | | | | | | ● | | |
| | g. NOSE GEAR | ✓ | | | ★ | | | | ○ | | | | | | | | | ★ | | | | | | | | | | | ○ | | | | | | | ○ | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | ● | ★ | | | | ☆ | | | | | | | | ● | ★ | | | | | | | ★ | | ☆ | | ☆ | | ○ | | ● | | ★ | ○ | ○ |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | ★1/ | | | | | | | | | | | | | | | |

NOTE: Group IV based on specific aircraft configuration groups, ie all low wing, all tricycle gear, etc., or certification category. All entries based on an evaluation of first accident type only.

* Groups IV a. through IV l. include only single engine aircraft

** Indicates aircraft configuration/category evaluated

1/ Sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, are based on an evaluation of specific aircraft configurations; ie, all low wing, all tricycle gear etc., or certification category, and reflect the relative frequency of the specific accident type noted for aircraft within that group. Where no entry is depicted simply means that aircraft's accident record was not considered significant. That is, the frequency of occurrence was considered average or expected within the group tested. The criterion for the Chi-Square data and its interpretation is based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 8

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Wheels-up Landing**

| | AIRCRAFT DESIGNATION | | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SPECIFIC UTILIZATION GROUP | | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| GROUP I AND II | BASIS FOR CHI-SQUARE EVALUATION | ACCIDENT TYPE SEQUENCE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACCIDENTS | I only | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL FLIGHT TIME | I and II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL FLIGHT TIME | I only | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I only | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP III | TOTAL ACCIDENTS | I and II | | | | | | | | | ● | | | | ● | | | | | | | | | | | | | ○ | | | | | | | | | |
| GROUP III | TOTAL ACCIDENTS | I only | | | | | | | | | ★ | | | | | | | | | | | | | | | | | ○ 1/ | | | | | | | | | |
| GROUP III | TOTAL FLIGHT TIME | I and II | | | | | | | | ● 1/ | ★ | ○ | | | | | | | ○ | | | ○ | | | | | | ○ | | ★ | ★ | | | ○ | | | |
| GROUP III | TOTAL FLIGHT TIME | I only | | | | | | | | ● 1/ | ★ | ○ | | | | | | | ○ | | | ☆ | | | | | | ○ | | | ★ | | | | | | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | | | ★ | | | | | | | | ○ | | | | | | | | | ○ | | | ★ | | | | | | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I only | | | | | | | | | ★ | | | | | | | | ○ | | | ○ | | | | | | ○ | | | ★ | | | | | | |

NO EVALUATION OF GROUP I AND II

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 9

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Gear Collapsed**

| | BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT DESIGNATION / SPECIFIC UTILIZATION GROUP / ACCIDENT TYPE SEQUENCE | 003 I-C | 006 I-A | 009 I-B | 012 I-A | 015 I-C | 018 I-B | 021 I-C | 024 I-A | 027 II-B | 030 II-A | 033 I-C | 036 I-A | 039 II-B | 042 I-B | 045 I-C | 048 I-B | 051 II-A | 054 I-B | 057 I-C | 060 II-A | 063 I-A | 066 I-C | 069 I-A | 072 II-B | 075 I-B | 078 II-B | 081 I-C | 084 I-A | 087 I-C | 090 I-C | 093 I-B | 096 II-B | 099 I-A | 102 I-A | 105 I-A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | | | | ○ | | | | ● | | | | | ★ | | | | | | | | | | | ● | | | | | ● | | ● | |
| | | I only | | | | | | | | | | | | | | | | | | ○ | | | | | | | | | ★ | ● 1/ | ○ | | | | | | ● 1/ |
| | TOTAL FLIGHT TIME | I and II | | | ● | | ● | ☆ | ○ | | | | ★ | | | ○ | | ★ | | | | | | | | | | | | ● | | | | ● | | ● | ☆ |
| | | I only | | | | | | | | | | | | | | | | | | | | | | | | | | | ★ | ● 1/ | | | ● 1/ | | | | |
| | TOTAL ACTIVE AIRCRAFT | I and II | | | | | ★ | ○ | ○ | | | | | | | ● | | ★ | | | | | | | | | ☆ | | | ★ | | | | ● | | | ○ |
| | | I only | | | | | | | | | | | | | | ● 1/ | | | | ○ | | | | | | | | | ★ | ★ 1/ | | | | | | | |
| GROUP III | TOTAL ACCIDENTS | I and II | | | | | | | ○ | | ○ | | | | | | | ★ | | | | | | | ● | | | | ● | ● | | | | | | ● | |
| | | I only | | | | | | | | | | | | | | | | | | ○ | | | | | | | | | ★ | | | | | | ○ | | |
| | TOTAL FLIGHT TIME | I and II | | | ● | | ● | ☆ | ☆ | ★ 1/ | | ○ | ● | | ☆ | ○ | ○ | ★ | ○ | | | ☆ | ● | | ★ | | | ○ | | ★ | | | | | ★ | ★ | |
| | | I only | | | | | | ○ | | | | | | | | | | | | | | ○ | | | | | | | ★ | ★ 1/ | | | ● 1/ | | | | |
| | TOTAL ACTIVE AIRCRAFT | I and II | | | ● | | ★ | | ● | | | ○ | | | ○ | ★ | | ★ | | | | ○ | | ○ | | | ○ | | | ★ | | | | | | | ○ |
| | | I only | | | | | | | | | | | | | | ● 1/ | | | | ○ | | | | | | | | | ★ | ● 1/ | | | | | ○ | | |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 10

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Gear Collapsed**

AIRCRAFT GROUP IV

| BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT CONFIGURATION/CATEGORY CHARACTERIZED BY ALL.. * | ** | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFIC UTILIZATION GROUP | | ✓ | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| TOTAL ACCIDENTS | a. HIGH WING/TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ●1/ | | | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | | | | ○ | | | | | | | | | | | | | | | | | | | | | ★ | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | ●1/ | | | | | | | |
| | d. HIGH WING | ✓ | | | | | | | | | | | | | | | | | | ○ | | | | | | | | | ★ | | | | | | ○ | | |
| | e. LOW WING | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | ●1/ | | | | | | | |
| | f. TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ●1/ | | | | |
| | g. NOSE GEAR | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | ★ | | ○ | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | ★ | | ○ | | | | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | ●1/ | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | | | | | | | | | | | | | ○ | | | | | | | | | ★ | | | | | | ○ | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL FLIGHT TIME | a. HIGH WING /TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ●1/ | | | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | | | | ○ | | | | | | | | | | | | | | | | | | | | | ★ | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | ★1/ | | | | | | | |
| | d. HIGH WING | ✓ | | | | | | ○ | | | | | | | | | | | | | | | | | | | | | ★ | | | | ●1/ | | | | |
| | e. LOW WING | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | ★1/ | | | ●1/ | | | | |
| | f. TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | ✓ | | | | | | ○ | | | | | | | | | | | | | | | | | | | | | ★ | ★1/ | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | | ○ | | | | | | | | | | | | | | | | | | | | | ★ | ★1/ | | | ●1/ | | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | ○ | | | | | | | | | | | | | | | | | | | | | ★ | 1/ | | | ●1/ | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL ACTIVE AIRCRAFT | a. HIGH WING/TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ★1/ | | | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | | | | ○ | | | | | | | | | | | | | | | | | | | | | ★ | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | ●1/ | | | | | | | |
| | d. HIGH WING | ✓ | | | | | | | | | | | | | | ●1/ | | | | ○ | | | | | | | | | ★ | | | | | | ○ | | |
| | e. LOW WING | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | ●1/ | | | | | | | |
| | f. TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ★1/ | | | | |
| | g. NOSE GEAR | ✓ | | | | | | ○ | | | | | | | | | | | | | | | | | | | | | ★ | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | ★ | ●1/ | | | | | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | | | | | | | | | ●1/ | | | | ○ | | | | | | | | | ★ | ●1/ | | | | | ○ | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

NOTE: Group IV based on specific aircraft configuration groups, ie all low wing, all tricycle gear, etc., or certification category. All entries based on an evaluation of first accident type only.

* Groups IV a. through IV l. include only single engine aircraft

** indicates aircraft configuration/category evaluated

1/ Sample size considered to be relatively small.
Airplane 093 was also certificated under CAR 4a.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, are based on an evaluation of specific aircraft configurations; ie, all low wing, all tricycle gear etc., or certification category, and reflect the relative frequency of the specific accident type noted for aircraft within that group. Where no entry is depicted simply means that aircraft's accident record was not considered significant. That is, the frequency of occurrence was considered average or expected within the group tested. The criterion for the Chi-Square data and its interpretation is based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 11

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Gear Retracted**

| | BASIS FOR CHI-SQUARE EVALUATION | ACCIDENT TYPE SEQUENCE | 003 I-C | 006 I-A | 009 I-B | 012 I-A | 015 I-C | 018 I-B | 021 I-C | 024 I-A | 027 II-B | 030 II-A | 033 I-C | 036 I-A | 039 II-B | 042 I-B | 045 I-C | 048 I-B | 051 II-A | 054 I-B | 057 I-C | 060 II-A | 063 I-A | 066 I-C | 069 I-A | 072 II-B | 075 I-B | 078 II-B | 081 I-C | 084 I-A | 087 I-C | 090 I-C | 093 I-B | 096 II-B | 099 I-A | 102 I-A | 105 I-A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | I only | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | TOTAL FLIGHT TIME | I and II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | I only | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | I only | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP III | TOTAL ACCIDENTS | I and II | ○ | | | | | | ★ | | | | | | | | | | ● | | | | | | | | | | | ○ | | | | | | | |
| | | I only | ○ | | | | | | ★ | | | | | | | | | | ● | | | | | | | | | | | ○ | | | | | | | |
| | TOTAL FLIGHT TIME | I and II | ○ | | | | | | ★ | ● 1/ | | | | | ○ | | | | | | | ● | | | | | | | | | | | | | | | |
| | | I only | ○ | | | | | | ★ | ● 1/ | | | | | ○ | | | | | | | ● | | | | | | | | | | | | | | | |
| | TOTAL ACTIVE AIRCRAFT | I and II | ○ | | | | | | ● | | | | | | ○ | | | | | | | ● | | | | | | | | ○ | | | | | | | |
| | | I only | ○ | | | | | | ● | | | | | | ○ | | | | | | | ● | | | | | | | | ○ | | | | | | | |

Column heads: AIRCRAFT DESIGNATION / SPECIFIC UTILIZATION GROUP

NO EVALUATION OF GROUP I AND II

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 12

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Hard Landing**

| | BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT DESIGNATION / ACCIDENT TYPE SEQUENCE | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SPECIFIC UTILIZATION GROUP | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | | | | ○ | | | | | | | | | ● | | | ● 1/ | | | | | | | | ★ | | | | | | ○ | ★ | |
| | | I only | | | | | | | ○ | | | | | | | | | ● | | | ● 1/ | | | | | | | | ★ | | | | | | | ★ | |
| | TOTAL FLIGHT TIME | I and II | | | | | ● | ☆ | ○ | | | | | | | | | ★ | | ● | | | | | | | | | ● | | | | | | | ★ | ○ |
| | | I only | | | | | ● | ○ | ○ | | | | | | | | ○ | ★ | | | | | | | | | | | ● | | | | | | | ★ | |
| | TOTAL ACTIVE AIRCRAFT | I and II | | | | | ● | ○ | ○ | | | | | | | ● | | ★ | | | | | | | | | ○ | | ● | | | | | | | ● | |
| | | I only | | | | | ● | ○ | ○ | | | | | | | ● | ○ | ★ | | | ● 1/ | | | | | | ○ | | ● | | | | | | | ● | |
| GROUP III | TOTAL ACCIDENTS | I and II | | | | | | | ○ | | | | | | ○ | | | ★ | ○ | | | | | | | | | | ★ | | ○ | | | | ○ | ★ | |
| | | I only | | | | | | | ○ | | | | | | ○ | | ○ | ★ | ○ 1/ | | ● 1/ | | | | | | | | ● | | ○ | | | | | ★ | |
| | TOTAL FLIGHT TIME | I and II | | | | | | ○ | ☆ | ● 1/ | | ○ | | | ☆ | | | ★ | ○ | ★ | | ☆ | ● | | | | | ○ 1/ | ● | ● | | | ● | | | ★ | |
| | | I only | | | | | | | ☆ | | | ○ 1/ | | ● 1/ | ☆ | | ○ | ★ | ○ | ● | | ○ | | | | | | | ● | ● 1/ | | | | | | ★ 1/ | |
| | TOTAL ACTIVE AIRCRAFT | I and II | | | | | ● | | ○ | | | | | | ○ | ★ | | ★ | ○ | | | ○ | | | | | | | ● | | | | | | ○ | ● | |
| | | I only | | | ● | | ● | | ☆ | | | | | | ○ | ★ | ○ | ★ | ○ | | ● 1/ | ○ | | | | | | | ● | | | | | | | | |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

**Table 13**

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Hard Landing**

AIRCRAFT GROUP IV

| BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT CONFIGURATION/CATEGORY CHARACTERIZED BY ALL.. * | ** | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFIC UTILIZATION GROUP | | ✓ | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| TOTAL ACCIDENTS | a. HIGH WING/TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | ☆ | | | | | | | | | ★ | | | | | | | | | | | | | ○ | | | | | ★ | |
| | d. HIGH WING | ✓ | | | | | | | | | | | | | | | ○ | | | | ●[1] | | | | | | | | ● | | | | | | | | |
| | e. LOW WING | ✓ | | | | | | | ○ | | | | | | | | | ★ | | | | | | | | | | | | | ○ | | | | | ★ | |
| | f. TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | ✓ | | | | | | | ☆ | | | | | | | | | ★ | | | | | | | | | | | ● | | ○ | | | | | ● | |
| | h. FLAPS | ✓ | | | | | | | ☆ | | | | | | | | ○ | ★ | | | ●[1] | | | | | | | | ● | | ○ | | | | | | |
| | i. NO FLAPS | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ○ | ● | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | | ☆ | | | | | | | | ○ | ★ | | | ●[1] | | | | | | | | ● | | ○ | | | | | ★ | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ●[1] | | | |
| TOTAL FLIGHT TIME | a. HIGH WING /TAIL WHEEL | ✓ | | | | | | | | | | | | | | | ○ | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ○ |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | ☆ | | | | | | | | | ★ | | | | | | | | | | | | | | | | | | ★ | |
| | d. HIGH WING | ✓ | | | | | | ○ | | | | | | | | | ○ | | | ● | | | | | | | | | | | | | | | | | |
| | e. LOW WING | ✓ | | | | | | | ☆ | | | | | | | | | ★ | | | | | | | | | | | | | | | | | | ★ | |
| | f. TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | ✓ | | | | | | ○ | ☆ | | | | | | | | | ★ | | | | | | | | | | | | ● | | | | | | ★ | |
| | h. FLAPS | ✓ | | | | | | ○ | ☆ | | | | | | | | ○ | ★ | | | | | | | | | | | | ●[1] | | | | | | | |
| | i. NO FLAPS | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ★[1] | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | ○ | ☆ | | | | | | | | ○ | ★ | | ● | | | | | | | | | | ● | | | | | | ★ | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ●[1] | | | |
| TOTAL ACTIVE AIRCRAFT | a. HIGH WING/TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | ● | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | | | | ● | | | | | | | | ● | | | | | | | | | | | | | | | | | | | | | ○ |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | ☆ | | | | | | | | | ★ | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | | | | | | | | | | | | | ★ | ○ | | | | ●[1] | | | | | | | | ● | | | | | | | | |
| | e. LOW WING | ✓ | | | | | ● | | ☆ | | | | | | | | | ★ | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | ● | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | ✓ | | | | | | | ☆ | | | | | | | ● | | ★ | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | ✓ | | | | | ● | | ☆ | | | | | | | ★ | ○ | ★ | | | | | ○ | | | | | | | | | | | | | | |
| | i. NO FLAPS | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ● | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | ● | | ☆ | | | | | | | ★ | ○ | ★ | | | ●[1] | | | | | | ○ | | ● | | | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ●[1] | | | |

NOTE: Group IV based on specific aircraft configuration groups, ie all low wing, all tricycle gear, etc., or certification category. All entries based on an evaluation of first accident type only.

* Groups IV a. through IV i. include only single engine aircraft

** Indicates aircraft configuration/category evaluated

[1] Sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, are based on an evaluation of specific aircraft configurations; ie, all low wing, all tricycle gear etc., or certification category, and reflect the relative frequency of the specific accident type noted for aircraft within that group. Where no entry is depicted simply means that aircraft's accident record was not considered significant. That is, the frequency of occurrence was considered average or expected within the group tested. The criterion for the Chi-Square data and its interpretation is based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 14

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Nose-over/down**

| AIRCRAFT DESIGNATION | | | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFIC UTILIZATION GROUP | | | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A |
| | BASIS FOR CHI-SQUARE EVALUATION | ACCIDENT TYPE SEQUENCE | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | ● | ★ | | ○ | | ☆ | | | | | ○ | | | ★ | ☆ | |
| GROUP I AND II | TOTAL ACCIDENTS | I only | | | ● | | ○ | | ○ | | | | | | | ○ | ★ | ○ | |
| GROUP I AND II | TOTAL FLIGHT TIME | I and II | | ● | ★ | | ○ | ☆ | ☆ | | | | | | | ☆ | ★ | ○ | |
| GROUP I AND II | TOTAL FLIGHT TIME | I only | | | ★ | | ○ | | ○ | | | | | | | ☆ | ★ | ○ | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I and II | | ● | ★ | | | ○ | ☆ | | | | | ○ | | | ★ | | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I only | | | ● | | ○ 1/ | | ○ | | | | | | | | ★ | | |
| GROUP III | TOTAL ACCIDENTS | I and II | | ● | ★ | | ☆ | ● | ☆ | | ○ | | | | ○ | | ● | ○ | ○ |
| GROUP III | TOTAL ACCIDENTS | I only | | | ★ | | ○ | ● | ○ | | | | | | ○ | ○ | ● | ○ | |
| GROUP III | TOTAL FLIGHT TIME | I and II | | ★ | ★ | | ☆ | | ☆ | | ○ | ○ | | | ☆ | ○ | | | ☆ |
| GROUP III | TOTAL FLIGHT TIME | I only | | | ★ | | ○ | | ☆ | | | | | | ○ | ○ | ● | | ○ |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I and II | | ● | ★ | | ○ | | ☆ | | | ○ | | ○ | ☆ | ● | ● | | ○ |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I only | | | ★ | | ○ | ● | ☆ | | | | | | ○ | | ● | | |

| AIRCRAFT DESIGNATION | | | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFIC UTILIZATION GROUP | | | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| | BASIS FOR CHI-SQUARE EVALUATION | ACCIDENT TYPE SEQUENCE | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | | ● | | | ○ | | ★ | ☆ | ☆ | | ● | | ★ | ○ | |
| GROUP I AND II | TOTAL ACCIDENTS | I only | | | | | ● | | | | | ● | | ☆ | | | | ★ | ○ | |
| GROUP I AND II | TOTAL FLIGHT TIME | I and II | ● | | | ● | ★ | | | | | ★ | ○ | ☆ | | ★ | | ★ | ○ | |
| GROUP I AND II | TOTAL FLIGHT TIME | I only | ★ | | | | ★ 1/ | | | | | ● | | ○ | | | | ★ | ○ | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | | ☆ | | ★ | ○ | ☆ | | | | ★ | ○ | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I only | | | | | ● | | | ○ | | ● | | ○ | | | | ★ | ○ | |
| GROUP III | TOTAL ACCIDENTS | I and II | | | | ● | | | ○ 1/ | | | ● | ☆ | ☆ | | ★ | ☆ | ★ | | ● |
| GROUP III | TOTAL ACCIDENTS | I only | ● | | | | ● | | | | | | | ☆ | | | ○ | ★ | ○ 1/ | |
| GROUP III | TOTAL FLIGHT TIME | I and II | ★ | | ☆ | ★ | ● | ● | ○ | | ○ | | ○ | ☆ | ○ | ★ | ☆ | ★ | | |
| GROUP III | TOTAL FLIGHT TIME | I only | ★ | | ○ | | ● | | | | | | | ○ | | ● | ○ | ★ 1/ | | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I and II | ● | | ○ | | | | ○ 1/ | ○ | ○ | | ○ | ☆ | | ★ | ○ | ★ | ○ | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I only | ★ | | | | | | | | | | | ○ | | | ○ | ★ | ○ | |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

**Table 15**

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Nose-over/down**

AIRCRAFT GROUP IV

| BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT CONFIGURATION/CATEGORY CHARACTERIZED BY ALL.. * | ** ✓ | 003 I-C | 006 I-A | 009 I-B | 012 I-A | 015 I-C | 018 I-B | 021 I-C | 024 I-A | 027 II-B | 030 II-A | 033 I-C | 036 I-A | 039 II-B | 042 I-B | 045 I-C | 048 I-B | 051 II-A | 054 I-B | 057 I-C | 060 II-A | 063 I-A | 066 I-C | 069 I-A | 072 II-B | 075 I-B | 078 II-B | 081 I-C | 084 I-A | 087 I-C | 090 I-C | 093 I-B | 096 II-B | 099 I-A | 102 I-A | 105 I-A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL ACCIDENTS | a. HIGH WING/TAIL WHEEL | ✓ | | | | | | | | | | | | ○ | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | ○ | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | | | | | | | | | | | ○ | | ○ | | | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | ✓ | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | ✓ | | | | | | | | ○ 1/ | | | | | | | | | | | | | | | | | | | | | | | | | ● | | |
| | g. NOSE GEAR | ✓ | | | ★ | | ○ | ★ | ○ | | | | | | | | | | | | | | | | | | | | ● | | ☆ | | | | | ○ 1/ | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | ★ | | ○ | ● | ☆ | | | | | | | ○ | ● | ○ | | ● | | | | | | | | | | | ☆ | | | | ● | ○ | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | | | | | | |
| TOTAL FLIGHT TIME | a. HIGH WING /TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ★ | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | ★ | | | | | | | | | | | ☆ | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | | | ● 1/ | | | | | | | |
| | d. HIGH WING | ✓ | | | ● | | | | | | | | | | | ☆ | | | | ● | | | | | | | | | | | | | | | ★ | | |
| | e. LOW WING | ✓ | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | | | ● 1/ | | | | | | | |
| | f. TAIL WHEEL | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ★ | | |
| | g. NOSE GEAR | ✓ | | | ★ | | ○ | | ○ | | | | | | | ○ | | | | | | | | | | | | | ● | | ○ | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | ★ | | ○ | | ☆ | | | | | | | ☆ | | | | ★ | | | | ● | | | | | | | ☆ | | ● | | ★ 1/ | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL ACTIVE AIRCRAFT | a. HIGH WING/TAIL WHEEL | ✓ | | | | | | | | | | | | ○ | | | | | | ● | | | | | | | | | | | | | | | ● | | |
| | b. HIGH WING/ NOSE GEAR | ✓ | | | ● | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | ✓ | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | | ★ | | | | | | | | | ○ | | | | | | | | | | | | | ○ | | | | | | | | ● | | |
| | e. LOW WING | ✓ | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | ✓ | | | | | | | | | | | | ○ | | | | | | ● | | | | | | | | | | | | | | | ● | | |
| | g. NOSE GEAR | ✓ | | | ★ | | ○ | ● | ☆ | | | | | | | | | | | | | | | | | | | | | | ○ | | | | | ○ | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | ★ | | ○ | | ☆ | | | | | ○ | | | ● | | | ● | | | | | | | | | | | ○ | | | | ★ | ○ | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | | | | | | |

NOTE: Group IV based on specific aircraft configuration groups, ie all low wing, all tricycle gear, etc., or certification category. All entries based on an evaluation of first accident type only.

* Groups IV a. through IV l. include only single engine aircraft

** Indicates aircraft configuration/category evaluated

1/ Sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, are based on an evaluation of specific aircraft configurations; ie, all low wing, all tricycle gear etc., or certification category, and reflect the relative frequency of the specific accident type noted for aircraft within that group. Where no entry is depicted simply means that aircraft's accident record was not considered significant. That is, the frequency of occurrence was considered average or expected within the group tested. The criterion for the Chi-Square data and its interpretation is based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 16

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Overshoot**

| | | AIRCRAFT DESIGNATION | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SPECIFIC UTILIZATION GROUP | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| | BASIS FOR CHI-SQUARE EVALUATION | ACCIDENT TYPE SEQUENCE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | | | ● | ○ | | | | | | | | | | | ○ | | | | | | | ○ | ● 1/ | | | | | | | | | |
| GROUP I AND II | TOTAL ACCIDENTS | I only | | | | | | ★ | ○ | | | | | | | | | | | ○ | | | | | | | ○ | ● 1/ | | | | | | | | | |
| GROUP I AND II | TOTAL FLIGHT TIME | I and II | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | ○ | | | ● 1/ | ● | | | | | | |
| GROUP I AND II | TOTAL FLIGHT TIME | I only | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | ○ | | | ● 1/ | ● | | | | | | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | ○ | | | | | ○ 1/ | | ● | | ★ | | ○ | | | | | | | ☆ | | | ★ 1/ | ● | | | | | | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I only | | | | | | | ○ | | | | | | | ● | | ★ | | ○ | | | | | | | ☆ | | | ★ 1/ | ● | | | | | | |
| GROUP III | TOTAL ACCIDENTS | I and II | | | | | | ★ | ○ | | | | | ○ | | | | | | ○ | | | | | | | ○ | ● 1/ | | | | | | | | | |
| GROUP III | TOTAL ACCIDENTS | I only | | | | | | ★ | ○ | | | | | | | | | | | ○ | ● 1/ | | | | | | ○ | ● 1/ | | | | | | | | | |
| GROUP III | TOTAL FLIGHT TIME | I and II | | | | | | | ○ | | | | | | | | | ● | ○ | | | | | | | | ○ | | | ● 1/ | ● | | | | | | |
| GROUP III | TOTAL FLIGHT TIME | I only | | | | | | | ○ | | | | | | | | | ● | ○ | | | | | | | | ○ | | | ● 1/ | ● | | | | | | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I and II | | | | | ● | ● | ○ | | | | | ○ | | ★ | | ★ | | ○ | | | | | | | ☆ | | | | ● | | | | | ○ | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I only | | | | | ● | ● | ○ | | | | | ○ | | ★ | | ★ | | ○ | | | | | | | ☆ | | | | ● | | | | | | |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

**Table 17**

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Overshoot**

AIRCRAFT GROUP IV

| | AIRCRAFT DESIGNATION | | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SPECIFIC UTILIZATION GROUP | | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT CONFIGURATION/CATEGORY CHARACTERIZED BY ALL.. * | ** ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL ACCIDENTS | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | | | | | ★ | | | | | | | | | | | | ○ | | | | | | | ○ | | | | | | | | | | |
| | e. LOW WING | ✓ | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | ✓ | | | | | | ★ | ○ | ○ 1/ | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | ✓ | | ● 1/ | | | | | | | | | ● | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | ★ | ○ | | | | | | | | | | | ○ | | | | | | | ○ | | | | | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | |
| TOTAL FLIGHT TIME | a. HIGH WING /TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | ○ | | | | | | | | | | |
| | e. LOW WING | ✓ | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | | | | ● 1/ | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | ✓ | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | | | | ● 1/ | | | | | | | |
| | i. NO FLAPS | ✓ | | | | | | | | | | | ● 1/ | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | ○ | | | ● 1/ | | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | |
| TOTAL ACTIVE AIRCRAFT | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | | ● | | | ★ | | | | | | ○ | | ★ | | | | ○ | | | | | | | ☆ | | | | | | | | | | |
| | e. LOW WING | ✓ | | | | | | | ○ | | | | | | | | | ★ | | | | | | | | | | | | | ● | | | | | ○ | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | ✓ | | | | | | | ○ | | | | | | | ● | | ★ | | | | | | | | | | | | | ● | | | | | | |
| | i. NO FLAPS | ✓ | | ● 1/ | | | | | | | | | ● | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | ● | ● | ○ | | | | | ○ | | ★ | | ★ | | ○ | | | | | | | ☆ | | | | ● | | | | | ○ | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | |

NOTE: Group IV based on specific aircraft configuration groups, ie all low wing, all tricycle gear, etc., or certification category. All entries based on an evaluation of first accident type only.

* Groups IV a. through IV l. include only single engine aircraft

** Indicates aircraft configuration/category evaluated

1/ Sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, are based on an evaluation of specific aircraft configurations; ie, all low wing, all tricycle gear etc., or certification category, and reflect the relative frequency of the specific accident type noted for aircraft within that group. Where no entry is depicted simply means that aircraft's accident record was not considered significant. That is, the frequency of occurrence was considered average or expected within the group tested. The criterion for the Chi-Square data and its interpretation is based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 18

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Undershoot**

| Group | Basis for Chi-Square Evaluation | Accident Type Sequence \ Aircraft Designation / Specific Utilization Group | 003 I-C | 006 I-A | 009 I-B | 012 I-A | 015 I-C | 018 I-B | 021 I-C | 024 I-A | 027 II-B | 030 II-A | 033 I-C | 036 I-A | 039 II-B | 042 I-B | 045 I-C | 048 I-B | 051 II-A | 054 I-B | 057 I-C | 060 II-A | 063 I-A | 066 I-C | 069 I-A | 072 II-B | 075 I-B | 078 II-B | 081 I-C | 084 I-A | 087 I-C | 090 I-C | 093 I-B | 096 II-B | 099 I-A | 102 I-A | 105 I-A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | | | | | ● | | | | | | |
| | | I only | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | | | | | ● | | | | | | |
| | TOTAL FLIGHT TIME | I and II | | | | | | | ○ | | | | | | | ○ | | ★ | | | | | | | | | | | | | ★ | | | | | | |
| | | I only | | | | | | | ○ | | | | | | | ○ | | ★ | | | | | | | | | | | | | ★ | | | | | | |
| | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | ○ | | | | | | | | | ★ | | | | | | | | | | | | | ★ | | | | | | |
| | | I only | | | | | | | ○ | | | | | | | | | ★ | | | | | | | | | | | | | ★ | | | | | | |
| GROUP III | TOTAL ACCIDENTS | I and II | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | | | | | ● | | | | | | |
| | | I only | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | | | | | | | | | | | |
| | TOTAL FLIGHT TIME | I and II | | ●1/ | | | | | ○ | ●1/ | | | | | | ○ | | ★ | | | | | ●1/ | | | | | | | | ★ | | | | ●1/ | ★1/ | |
| | | I only | | ●1/ | | | | | ○ | ●1/ | | | | | | | | ★ | | | | | ●1/ | | | | ●1/ | | | | ● | | | | ★1/ | ●1/ | |
| | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | ○ | | | | | | | | | ★1/ | | | | | | | | | | | | | ★ | | | | | | |
| | | I only | | | | | | | ○ | | | | | | | | | ★1/ | | | | | | | | | | | | | ★ | | | | | | |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 19

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Undershoot**

| AIRCRAFT GROUP IV | | AIRCRAFT DESIGNATION | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SPECIFIC UTILIZATION GROUP | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT CONFIGURATION/CATEGORY CHARACTERIZED BY ALL.. * | ** ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL ACCIDENTS | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | ✓ | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | ✓ | | | | | | | ○ | | | | | | | | | ★ | | | | | | | | | | | | | ● | | | | | | |
| | i. NO FLAPS | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | | ○ | | | | | | | | | ● | | | | | | | | | | | | | | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL FLIGHT TIME | a. HIGH WING /TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | ●1/ | | | | | | | | | | | | | | | | | | | ●1/ | | | | | | | | | | | | ●1/ | | |
| | e. LOW WING | ✓ | | | | | | | ☆ | | | | | | | | | ● | | | | | | | | | | | | | ● | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | ✓ | | | | | | | ○ | ●1/ | | | | | | | | ★ | | | | | ●1/ | | | | | | | | ● | | | | | | |
| | i. NO FLAPS | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | ●1/ | | | | | ○ | ●1/ | | | | | | | | ★ | | | | | ●1/ | | | | | | | | ● | | | | ●1/ | ●1/ | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ●1/ | | | |
| TOTAL ACTIVE AIRCRAFT | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | ✓ | | | | | | | ○ | | | | | | | | | ★ | | | | | | | | | | | | | ● | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | ✓ | | | | | | | ○ | | | | | | | | | ★1/ | | | | | | | | | | | | | ★ | | | | | | |
| | i. NO FLAPS | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | | ○ | | | | | | | | | ★1/ | | | | | | | | | | | | | ★ | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

NOTE: Group IV based on specific aircraft configuration groups, ie all low wing, all tricycle gear, etc., or certification category. All entries based on an evaluation of first accident type only.

* Groups IV a. through IV l. include only single engine aircraft

** Indicates aircraft configuration/category evaluated

1/ Sample size considered to be relatively small.

## LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

## EXPLANATION OF TABLE

Entries, or the lack of them, are based on an evaluation of specific aircraft configurations; ie, all low wing, all tricycle gear etc., or certification category, and reflect the relative frequency of the specific accident type noted for aircraft within that group. Where no entry is depicted simply means that aircraft's accident record was not considered significant. That is, the frequency of occurrence was considered average or expected within the group tested. The criterion for the Chi-Square data and its interpretation is based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 20

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Collision with Ground/Water: Controlled**

| Group | Basis for Chi-Square Evaluation | Accident Type Sequence | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Specific Utilization Group | | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| Group I and II | Total Accidents | I and II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ○ | | | | | | |
| Group I and II | Total Accidents | I only | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ○ | | | | | | |
| Group I and II | Total Flight Time | I and II | | | | | | | | | | | | | | | | ●1/ | | ●1/ | | | | | | | | | | | | | | | | | |
| Group I and II | Total Flight Time | I only | | | | | | | | | | | | | | | | ●1/ | | ●1/ | | | | | | | | | | | | | | | | | |
| Group I and II | Total Active Aircraft | I and II | | | | | | | | | | | | | | | | ●1/ | | | | | | | | | | | | ●1/ | | | | | | | |
| Group I and II | Total Active Aircraft | I only | | | | | | | | | | | | | | | | ★1/ | | | | | | | | | | | | | | | | | | | |
| Group III | Total Accidents | I and II | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Group III | Total Accidents | I only | | | | | | | | | | | | | ●1/ | | | | | | | | | | | | | | | | | | | | | | |
| Group III | Total Flight Time | I and II | | | | | | | | | | | | | | ○ | | | | | | | ★1/ | | | | | | | ●1/ | | | | | | | |
| Group III | Total Flight Time | I only | | | | | | | | | | | | | | ○ | | | | | | | ●1/ | | | | | | | ●1/ | | | | | | | |
| Group III | Total Active Aircraft | I and II | | | | | ●1/ | | | | | | | | | | | ●1/ | | | | | | | | | | | | ●1/ | | | | | | | |
| Group III | Total Active Aircraft | I only | | | | | ●1/ | | | | | | | | | | | ●1/ | | | | | | | | | | | | | | | ○1/ | | | | |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 21

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Collision with Ground/Water: Controlled**

AIRCRAFT GROUP IV

| BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT CONFIGURATION/CATEGORY CHARACTERIZED BY ALL.. * | ** ✓ | 003 I-C | 006 I-A | 009 I-B | 012 I-A | 015 I-C | 018 I-B | 021 I-C | 024 I-A | 027 II-B | 030 II-A | 033 I-C | 036 I-A | 039 II-B | 042 I-B | 045 I-C | 048 I-B | 051 II-A | 054 I-B | 057 I-C | 060 II-A | 063 I-A | 066 I-C | 069 I-A | 072 II-B | 075 I-B | 078 II-B | 081 I-C | 084 I-A | 087 I-C | 090 I-C | 093 I-B | 096 II-B | 099 I-A | 102 I-A | 105 I-A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL ACCIDENTS | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL FLIGHT TIME | a. HIGH WING /TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | | | | | | | | | | ○ | | | | | | | ● 1/ | | | | | | | ● 1/ | | | | | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | | | | | | | | | ○ | | | | | | | ● 1/ | | | | | | | ● 1/ | | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL ACTIVE AIRCRAFT | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | ● 1/ | | | | | | | | | | | ● 1/ | | | | | | | | | | | | | | | ○ 1/ | | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | ● 1/ | | | | | | | | | | | ● 1/ | | | | | | | | | | | | | | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

NOTE: Group IV based on specific aircraft configuration groups, ie all low wing, all tricycle gear, etc., or certification category. All entries based on an evaluation of first accident type only.

* Groups IV a. through IV l. include only single engine aircraft

** Indicates aircraft configuration/category evaluated

1/ Sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, are based on an evaluation of specific aircraft configurations; ie, all low wing, all tricycle gear etc., or certification category, and reflect the relative frequency of the specific accident type noted for aircraft within that group. Where no entry is depicted simply means that aircraft's accident record was not considered significant. That is, the frequency of occurrence was considered average or expected within the group tested. The criterion for the Chi-Square data and its interpretation is based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 22

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Collision with Ground/Water: Uncontrolled**

| | AIRCRAFT DESIGNATION | | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SPECIFIC UTILIZATION GROUP | | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| GROUP I AND II | BASIS FOR CHI-SQUARE EVALUATION | ACCIDENT TYPE SEQUENCE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | | | ● | | | | | | | | ● | | | | | | | | | ● 1/ | | | | | | ● | | | | | | |
| GROUP I AND II | TOTAL ACCIDENTS | I only | | | | | | ● | | | | | | | | ● 1/ | | | | | | | | | ● 1/ | | | | | | | | | | | | |
| GROUP I AND II | TOTAL FLIGHT TIME | I and II | | | | | | | | | ● 1/ | | | | | | | | | | | | | | | | | | | | ★ 1/ | | | | | | |
| GROUP I AND II | TOTAL FLIGHT TIME | I only | | | | | | | | | ● 1/ | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | | | ● 1/ | | | | | ★ 1/ | | | | | | | | | ● 1/ | | | | | | ★ 1/ | | | | | | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I only | | | | | ● 1/ | | | | ● 1/ | | | | | ★ 1/ | | | | | | | | | ● 1/ | | | | | | | | | | | | |
| GROUP III | TOTAL ACCIDENTS | I and II | | | | | | ● | | | | | | | | ● 1/ | | | | | | | | | | | | ● 1/ | | | ● | | | | | | |
| GROUP III | TOTAL ACCIDENTS | I only | | | | | | ● 1/ | | | ● 1/ | | | | | ● 1/ | | | | | | | | | | | | ● 1/ | | | | | | | | | |
| GROUP III | TOTAL FLIGHT TIME | I and II | | | | | | | | | ● 1/ | | | | | | | | | | | | | | ● 1/ | | | | | | ★ 1/ | | | | | | |
| GROUP III | TOTAL FLIGHT TIME | I only | | | | | | | | | ● 1/ | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | | | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | | | ★ 1/ | | | | | ★ 1/ | | | | | | | | | | | | | | | ★ 1/ | | | | | | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I only | | | | | | | | | ★ 1/ | | | | | ★ 1/ | | | | | | | | | | | | ● 1/ | | | | | | | | | |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 23

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Collision with Ground/Water: Uncontrolled**

AIRCRAFT GROUP IV

| | AIRCRAFT DESIGNATION | | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SPECIFIC UTILIZATION GROUP | | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT CONFIGURATION/CATEGORY CHARACTERIZED BY ALL.. * | ** ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL ACCIDENTS | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | | ● | | | | | | | | ● 1/ | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | ● | | | | | | | | ● 1/ | | | | | | | | | | | | | | | | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL FLIGHT TIME | a. HIGH WING /TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | | | | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | ● 1/ | | | | | | | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | ★ 1/ | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL ACTIVE AIRCRAFT | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | | | | | | | | | | ★ 1/ | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | ● | | | | | | | | ★ 1/ | | | | | | | | | | | | | | | | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | ★ 1/ | | | | | | | | | | | | | | | | | | | | | | | | | | |

NOTE: Group IV based on specific aircraft configuration groups, ie all low wing, all tricycle gear, etc., or certification category. All entries based on an evaluation of first accident type only.

* Groups IV a. through IV l. include only single engine aircraft

** Indicates aircraft configuration/category evaluated

1/ Sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, are based on an evaluation of specific aircraft configurations; ie, all low wing, all tricycle gear etc., or certification category, and reflect the relative frequency of the specific accident type noted for aircraft within that group. Where no entry is depicted simply means that aircraft's accident record was not considered significant. That is, the frequency of occurrence was considered average or expected within the group tested. The criterion for the Chi-Square data and its interpretation is based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

**Table 24**

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Collision with objects**
**(First Accident Type Only)**

| | AIRCRAFT DESIGNATION | | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SPECIFIC UTILIZATION GROUP | | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| GROUP I AND II | BASIS FOR CHI-SQUARE EVALUATION | ACCIDENT TYPE SEQUENCE | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACCIDENTS | 1 only | | | | | | | ○ | | | | | | | | | ○ | | | | | | | | | | | ● | | | | | | | | |
| GROUP I AND II | TOTAL FLIGHT TIME | 1 only | | | | | | | ○ | ● 1/ | | | ● | | | | | | | ★ | | | | | | | | | | | | | ● | | | | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | 1 only | | | | | | | ○ | | | | | | | ★ | | | | | | | | | | | | | | | | | | | | | |
| GROUP III | TOTAL ACCIDENTS | 1 only | | | | | | ● | ○ | | | | | | | ● | | | | ● | | | | | | | | | | | | | | | | | |
| GROUP III | TOTAL FLIGHT TIME | 1 only | | | | | | | ○ | ● 1/ | | | | ● 1/ | ○ | | | | ○ | ★ | | ○ | | | | | ● | | | | | | ● | | | | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | 1 only | | | | | | | ○ | | | | | | | ★ | | | | ● | | | | | | | | | | | | | | | | | |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

**Table 25**

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Stall (spin, spiral, mush)**

| Group | Basis for Chi-Square Evaluation | Accident Type Sequence | 003 I-C | 006 I-A | 009 I-B | 012 I-A | 015 I-C | 018 I-B | 021 I-C | 024 I-A | 027 II-B | 030 II-A | 033 I-C | 036 I-A | 039 II-B | 042 I-B | 045 I-C | 048 I-B | 051 II-A | 054 I-B | 057 I-C | 060 II-A | 063 I-A | 066 I-C | 069 I-A | 072 II-B | 075 I-B | 078 II-B | 081 I-C | 084 I-A | 087 I-C | 090 I-C | 093 I-B | 096 II-B | 099 I-A | 102 I-A | 105 I-A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | ●1/ | | | | | | | | ★ | | | ○ | | | ★ | | | | ★ | | | ● | ●1/ | ○ | ○ | | ●1/ | | | | | ○ |
| | | I only | | | | | | | | | | | ●1/ | ★ | | | ○ | | | ★ | | | | ★ | | | ● | ●1/ | ○ | ○ | | | | | | | |
| | TOTAL FLIGHT TIME | I and II | | | | ●1/ | | ○ | | ●1/ | ●1/ | | ●1/ | ★ | | ○ | ○ | | | ★ | | | | ★ | | | ★ | | ○ | ○ | | | | | ● | | ☆ |
| | | I only | | | | | | ○ | | ●1/ | | | ●1/ | ★ | | | ○ | | | ★ | | | | ★ | | | ★ | | ○ | ○ | | | | | ● | | ○ |
| | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | ○ | | | ●1/ | | | ★ | | | ○ | | | ★ | | | | ★ | | | | | ○ | ○ | | | | | | | ○ |
| | | I only | | | | | | | | | ●1/ | | | ★ | | | ○ | | | ★ | | | | ★ | | | | | ○ | | | | | | ● | | ○ |
| GROUP III | TOTAL ACCIDENTS | I and II | | | | ★1/ | | | | | | | | ★ | | | ○ | | | ★ | | | | ★ | | | ● | | ○ | ○ | ○ | | | | ● | | |
| | | I only | | | | | | | | | | | | ★ | | | ○ | | | ★ | | | | ★ | | | ● | | ○ | | ○ | | | | ● | | |
| | TOTAL FLIGHT TIME | I and II | | ●1/ | | ★1/ | | ○ | | ★1/ | | | | ★1/ | ○ | ○ | ○ | | | ★ | | ○ | ●1/ | ★ | ● | | ★ | | ☆ | | | | | ○ | ★ | | ○ |
| | | I only | | | | ●1/ | | ○ | | ★1/ | | | ●1/ | ★1/ | ○ | | ○ | | | ★ | | ○ | | ★ | ● | | ★ | | ○ | | | | | ○ | ★1/ | | |
| | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | | | ●1/ | | | ★ | | | ○ | | | ★ | | | | ● | | | | | ☆ | | | | | | ● | | ○ |
| | | I only | | | | | | | | ●1/ | | | | ★ | ○ | | ○ | | | ★ | | | | ● | | | | | ○ | | | | | | ● | | ○ |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

**LEGEND**

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

**EXPLANATION OF TABLE**

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 26

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Stall (spin, spiral, mush)**

AIRCRAFT GROUP IV

| BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT CONFIGURATION/CATEGORY CHARACTERIZED BY ALL.. * | ** | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFIC UTILIZATION GROUP | | ✓ | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B |
| TOTAL ACCIDENTS | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | | | | | | | ● 1/ | | | | ○ | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | | | | | | | | | | | ● | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | | | | | | | ★ | | | ○ | | | ★ |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | |
| TOTAL FLIGHT TIME | a. HIGH WING /TAIL WHEEL | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | | | | | | | ● 1/ | | | | ○ | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | ○ | | | | | | | | | | ● | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | ● 1/ | | ○ | | ★ 1/ | | | ● 1/ | ★ 1/ | | ○ | ○ | | | ★ |
| | m. TWIN ENGINE | ✓ | | | | | | | | | ● 1/ | | | | | | | | | |
| TOTAL ACTIVE AIRCRAFT | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | ✓ | | | | | | | | | | | | | | ● | ○ | | | |
| | k. CERTIFICATION/CAR 4a | ✓ | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | | | | | ● 1/ | | | | ★ | | | ○ | | | ★ |
| | m. TWIN ENGINE | ✓ | | | | | | | | | ● 1/ | | | | | | | | | |

| BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT CONFIGURATION/CATEGORY CHARACTERIZED BY ALL.. * | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIFIC UTILIZATION GROUP | | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| TOTAL ACCIDENTS | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | ★ | ● | | | | ○ | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | | | | ★ | | | ● | | ○ | | ○ | | | | ● | | |
| | m. TWIN ENGINE | | | | | | | | ● 1/ | | | | | | | | | |
| TOTAL FLIGHT TIME | a. HIGH WING /TAIL WHEEL | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | ● 1/ | ★ | ★ | | | | ○ | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | | | | ★ | ● | | ● | | ☆ | | | | | | ★ | | ○ |
| | m. TWIN ENGINE | | | | | | ● 1/ | | ● 1/ | | | | | | | | | |
| TOTAL ACTIVE AIRCRAFT | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | | | | | | | | | | | | | | | | | |
| | e. LOW WING | | | | | | | | | | | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | ★ | | | | | ○ | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | | | | ● | | | | | ○ | | | | | | ● | | ○ |
| | m. TWIN ENGINE | | | | | | | | | | | | | | | | | |

NOTE: Group IV based on specific aircraft configuration groups, ie all low wing, all tricycle gear, etc., or certification category. All entries based on an evaluation of first accident type only.

* Groups IV a. through IV l. include only single engine aircraft

** Indicates aircraft configuration/category evaluated

1/ Sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, are based on an evaluation of specific aircraft configurations; ie, all low wing, all tricycle gear etc., or certification category, and reflect the relative frequency of the specific accident type noted for aircraft within that group. Where no entry is depicted simply means that aircraft's accident record was not considered significant. That is, the frequency of occurrence was considered average or expected within the group tested. The criterion for the Chi-Square data and its interpretation is based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 27

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Engine Failure or Malfunction**

| Group | Basis for Chi-Square Evaluation | Accident Type Sequence | 003 I-C | 006 I-A | 009 I-B | 012 I-A | 015 I-C | 018 I-B | 021 I-C | 024 I-A | 027 II-B | 030 II-A | 033 I-C | 036 I-A | 039 II-B | 042 I-B | 045 I-C | 048 I-B | 051 II-A | 054 I-B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | | | ○ | | | | | | | | | | | | |
| GROUP I AND II | TOTAL ACCIDENTS | I only | | | | | | ○ | | | | | | | | | | | | |
| GROUP I AND II | TOTAL FLIGHT TIME | I and II | | | ● | | | ☆ | | | | | | | | ○ | | | | ● |
| GROUP I AND II | TOTAL FLIGHT TIME | I only | | | ● | | | ☆ | | | | | | | | ○ | | | | ● |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I and II | | | ● | | ● | ☆ | | | | | | | | ● | | | | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I only | | | ● | | ● | ☆ | | | | | | | | ● | | | | |
| GROUP III | TOTAL ACCIDENTS | I and II | | | | ● 1/ | | ○ | | | | | | | | | | | | |
| GROUP III | TOTAL ACCIDENTS | I only | | | | ● 1/ | | ○ | | | | | | | | | | | | |
| GROUP III | TOTAL FLIGHT TIME | I and II | | | ● | ● 1/ | | ☆ | | ★ 1/ | | | | ★ | | ○ | | | | |
| GROUP III | TOTAL FLIGHT TIME | I only | | | ● | ● 1/ | | ☆ | | ★ 1/ | | | | ★ | | ○ | | | | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I and II | | | ● | | ● | ○ | | | | | | | | ● | | | | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I only | | | ● | | ● | ○ | | | | | | | | ● | | | | |

| Group | Basis for Chi-Square Evaluation | Accident Type Sequence | 057 I-C | 060 II-A | 063 I-A | 066 I-C | 069 I-A | 072 II-B | 075 I-B | 078 II-B | 081 I-C | 084 I-A | 087 I-C | 090 I-C | 093 I-B | 096 II-B | 099 I-A | 102 I-A | 105 I-A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GROUP I AND II | TOTAL ACCIDENTS | I and II | | | | | ○ | | | | | | | | | | | ● | |
| GROUP I AND II | TOTAL ACCIDENTS | I only | | | | | ○ | | | | | | | | | | | ● | |
| GROUP I AND II | TOTAL FLIGHT TIME | I and II | | | | | ○ | | ● | | | ● | | | ● | | | ● | ○ |
| GROUP I AND II | TOTAL FLIGHT TIME | I only | | | | | ○ | | ● | | | | | | ● | | | ● | ○ |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | | | | ★ | | | | | | | |
| GROUP I AND II | TOTAL ACTIVE AIRCRAFT | I only | | | | | | | | | | ★ | | | | | | | |
| GROUP III | TOTAL ACCIDENTS | I and II | | | | | | | | | | ● | | | | | | ★ | |
| GROUP III | TOTAL ACCIDENTS | I only | | | | | | | | | | ● | | | | | | ★ | |
| GROUP III | TOTAL FLIGHT TIME | I and II | | | ● | | | | ● | | ○ | ★ | | | ● | ○ | ★ | ★ | |
| GROUP III | TOTAL FLIGHT TIME | I only | | | ● | | | | ● | | ○ | ★ | | | ● | ○ | ★ | ★ | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I and II | | | | | | | | | | ★ | | | | | | | |
| GROUP III | TOTAL ACTIVE AIRCRAFT | I only | | | | | | | | | | ★ | | | | | | | |

| AIRCRAFT GROUP | AIRCRAFT GROUP STATISTICS RELATED TO... |
|---|---|
| I & II | type of utilization group (personal, professional, and instructional) for single and twin engine aircraft. See page App(34) for explanatory details. |
| III | the study fleet consisting of the entire 35 make/model aircraft. |

1/ sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, denote the relative frequency of occurrence of this specific accident type for each of the 35 make/model aircraft. Where no entry is designated simply means that aircraft's record with respect to this accident type was not considered significant, that is, the frequency of occurrence was considered to be average or expected within the group tested. The criterion for, and interpretation of, the Chi-Square Data are based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

Table 28

# AIRCRAFT DESIGN INDUCED PILOT ERROR PROJECT

## SIGNIFICANCE OF GENERAL AVIATION ACCIDENT STATISTICS FOR THE YEAR 1964

**Engine Failure or Malfunction**

AIRCRAFT GROUP IV

| BASIS FOR CHI-SQUARE EVALUATION | AIRCRAFT DESIGNATION / AIRCRAFT CONFIGURATION/CATEGORY CHARACTERIZED BY ALL.. * | ** ✓ | 003 | 006 | 009 | 012 | 015 | 018 | 021 | 024 | 027 | 030 | 033 | 036 | 039 | 042 | 045 | 048 | 051 | 054 | 057 | 060 | 063 | 066 | 069 | 072 | 075 | 078 | 081 | 084 | 087 | 090 | 093 | 096 | 099 | 102 | 105 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SPECIFIC UTILIZATION GROUP | | I-C | I-A | I-B | I-A | I-C | I-B | I-C | I-A | II-B | II-A | I-C | I-A | II-B | I-B | I-C | I-B | II-A | I-B | I-C | II-A | I-A | I-C | I-A | II-B | I-B | II-B | I-C | I-A | I-C | I-C | I-B | II-B | I-A | I-A | I-A |
| TOTAL ACCIDENTS | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | | | ● 1/ | | ○ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | ● | | | | | | ● | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | | ● 1/ | | ○ | | | | | | | | | | | | | | | | | | | | | | ● | | | | | | ● | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL FLIGHT TIME | a. HIGH WING /TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | | ● | ● 1/ | | ☆ | | | | | | ★ | | ○ | | | | | | | ● | | | | ● | | ○ | | | | ● | | ★ | | |
| | e. LOW WING | ✓ | | | | | | | ○ | ● 1/ | | | | | | | | | | | | | | | | | | | | ★ | | | | | | ★ | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | ● | ● 1/ | | ☆ | | ● 1/ | | | | ★ | | ○ | | | | | | | ● | | | | ● | | ○ | ★ | | | ● | | ★ | ★ | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL ACTIVE AIRCRAFT | a. HIGH WING/TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | b. HIGH WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | c. LOW WING/ NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | d. HIGH WING | ✓ | | | ★ | | | ○ | | | | | | | | ● | | | | | | | | | | | | | | | | | | | | | |
| | e. LOW WING | ✓ | | | | | | | ○ | | | | | | | | | | | | | | | | | | | | | ● | | | | | | | |
| | f. TAIL WHEEL | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | g. NOSE GEAR | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | h. FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | i. NO FLAPS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | j. CERTIFICATION/CAR 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | k. CERTIFICATION/CAR 4a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | l. SINGLE ENGINE | ✓ | | | ● | | ● | ○ | | | | | | | | ● | | | | | | | | | | | | | | ★ | | | | | | | |
| | m. TWIN ENGINE | ✓ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

NOTE: Group IV based on specific aircraft configuration groups, ie all low wing, all tricycle gear, etc., or certification category. All entries based on an evaluation of first accident type only.

* Groups IV a. through IV l. include only single engine aircraft

** Indicates aircraft configuration/category evaluated

1/ Sample size considered to be relatively small.

### LEGEND

| SYMBOL | STATISTICAL SIGNIFICANCE | FREQUENCY OF OCCURRENCE OF THIS ACCIDENT TYPE CONSIDERED TO BE |
|---|---|---|
| "None Depicted" | Not significant at the 5% level | Average or expected |
| ○ | Significant at 5% level | Lower than average |
| ☆ | Significant at 1/10% level | Much lower than average |
| ● | Significant at 5% level | Higher than average |
| ★ | Significant at 1/10% level | Much higher than average |

### EXPLANATION OF TABLE

Entries, or the lack of them, are based on an evaluation of specific aircraft configurations; ie, all low wing, all tricycle gear etc., or certification category, and reflect the relative frequency of the specific accident type noted for aircraft within that group. Where no entry is depicted simply means that aircraft's accident record was not considered significant. That is, the frequency of occurrence was considered average or expected within the group tested. The criterion for the Chi-Square data and its interpretation is based on relative accident frequencies corresponding to the 5% and the 1/10% statistical significance levels.

## Airplane Utilization Groups

### I. Single-Engine Aircraft

#### A. Personal Transportation

Airplanes in which at least 75% of the total usage was in personal transportation, and not more than 20% in either of the other individual categories.

#### B. Personal Transportation Plus Instruction

Airplanes in which at least 75% of the total flying time was in personal transportation and instructional flying combined, and not less than 20% in instruction. The one exception in this group is airplanes 048, of which only 70% of the total usage was in these two catagories, but since 30% of the usage was in instructional flying, this was considered to justify placing the airplane in this group.

#### C. Personal Transportation Plus Professional Flying

Airplanes in which at least 75% of the total usage was in personal transportation and professional flying, and not less than 25% of the total was professional flying.

### II. Twin-Engine Aircraft

#### A. Professional Flying

Airplanes in which 75% of the total usage was in professional flying, and not more than 20% in either of the other individual categories.

#### B. Professional Flying and Personal Transportation

Airplanes in which at least 75% of the flying time was in these two categories and at least 25% in personal flying.

In the case of twin-engine airplanes, it was found that personal transportation did not represent more than 30% of the total usage for any airplane model, so that no separate category for personal transportation appeared justified. Similarly, the maximum instructional usage for any model airplane was approximately 5% of the total flying time, so no grouping involving instructional usage was warranted.



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