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LOSS PREVENTION IN NON-SCHEDULED CIVIL AVIATION*

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Aviation literature abounds with information about safety and the prevention of accidents. A tremendous amount of thought and activity is constantly devoted to the achievement of greater safety in the design and operation of airplanes. Accident records and statistics are zealously studied to determine where improvements can be made. But according to the former Bureau of Air Commerce and presumably the present Civil Aeronautics Authority, "An aircraft accident is an occurrence which takes place while an aircraft is being operated as such, as a result of which a person or persons are injured or killed or the aircraft receives appreciable or marked damage as a result of a failure of the aircraft structure or engine or through the forces of external contact, or through fire. For the purpose of analysis, an aircraft is considered as 'being operated as such' from the time the pilot or passengers board the aircraft with the intention of flight until such time as the pilot and passengers disembark from the aircraft upon completion of flight."

Without taking issue with the definition, everyone should recognize the fact that many losses occur outside this conception. Although these losses may not necessarily involve safety of passengers, of the public or of personnel, they do seriously affect aviation economics. For instance, when a hangar full of airplanes is destroyed by fire, no one's safety is necessarily involved, an accident as defined above has not occurred. But in one recent hangar fire, aviation suffered a loss of aircraft valued at \$300,000 or the equivalent of thirty dollars for each civil airplane in this country! Insurance companies pay out an average of \$2,000 per week for airplanes lost by fire alone. Furthermore, when a radio is stolen from an airplane, when a hangar collapses on airplanes stored in it, when a windstorm picks up a parked airplane and then hurls it down to crash or when a spectator stumbles over a tail wheel dolly and sprains his back, losses occur which may be far removed from safety as that word is usually understood in aviation. These losses

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in the end are paid for by airplane owners. Aeronautical Engineers therefore should be interested not only in the special study of safety to passengers and crew but also in the general study of loss prevention.

To cover completely the field of loss prevention would be impossible in a paper of this nature. These notes will be confined to some of the outstanding loss prevention problems in non-scheduled civil aviation such as windstorm, fire and particularly light airplane losses because light airplanes are involved in over 30% of all accidents while constituting about 22% of all civil airplanes. Furthermore, the light plane business is the fastest growing in aviation and therefore deserves special consideration right now. Moreover, what is true of the light airplane is also generally applicable to all airplanes.

Loss prevention or safety can be achieved in three ways: (1) By improvements in design, (2) by control or regulation or (3) by education or experience.

Regulation and education are governed largely by the design and characteristics of the airplane. For instance, if airplanes were designed that would not stall or spin, Federal regulation of spin testing or the education of student pilots in the danger of the stall/spin, would not be necessary. Certain physical standards like depth perception and the need for thorough education in landing technique result from the landing characteristics peculiar to the present conventional type of airplane. The need for regulation and safety education is therefore no compliment to the engineer. Regulation and education should vary inversely with improvements in design.

Pending improvements in design, the prevention of losses by wind and fire requires a minimum of regulation and a maximum of education. The number of airplanes lost by fire or windstorm last year is unknown because such losses, being outside the official definition of accidents, were not reported in the Bureau of Air Commerce analyses of accidents and no other agency is gathering the information. Perhaps the new Civil Aeronautics Authority will expand its activities to include all losses.

Light airplanes need not be caught in a storm to suffer damage by wind. Low wing loadings make them very susceptible to damage by winds of relatively small velocities. A light plane being operated by a novice in a wind of about 20 miles per hour (known as a moderate or fresh wind) or over is likely to be damaged seriously. Taxiing these planes in fresh winds requires skill and experience. Even winds less than 20 miles per hour are dangerous for light planes but proper instruction in the difficult taxiing problems pre-

sented by wind would eliminate most of the losses. Perhaps the tricycle undercarriage or some other change would enable safer operation latitude in operating them in strong winds. Until that time arises the pilot of a light airplane should be instructed to adopt the following suggestions:

1. Not to operate if wind conditions are very gusty or if wind is near or greater than 20 miles per hour. The light plane is then safest inside a hangar.
2. Check the wind forecasts before attempting any 'cross-country trips.
3. If caught in bad wind, land airplane a little faster than normal. Keep the tail up as long as possible.
4. Wait for help to roll the airplane to the hangar if taxiing is difficult.

Heavier airplanes usually suffer only in much stronger winds or in severe gusts and these losses often occur while the airplane is parked in the open.

Although winds may affect heavy airplanes less than light ones, fire has no favorites. Fire seems to occur in the strangest ways and often under peculiar circumstances. One plane was partly destroyed recently because the spark from a passing locomotive settled on the wing, setting it on fire. Another one was lost by an arc from an improperly installed radio antenna. Not long ago smoke was noticed coming from the bottom of a ship, with no one near it. Fire was found just behind the seat and baggage compartment. A few minutes before, the pilot with a cigarette in his mouth had reached in to get the log books. Evidently a spark had dropped from the cigarette through a space between the back of the seat and the door and had dropped down to the flammable fabric. In another case the wiring to the electric flares was only partly encased in a protective metal conduit. Wires from the radio ran parallel and close to the flare wires, inducing a current in them which set off the flares. This occurred while the radio was being checked in the hangar.

The spark from a welding torch floated into the belly of a ship being repaired and resulted in a complete loss. A mechanic was removing a battery when it arced igniting gasoline fumes from a leaking valve. One cold morning a mechanic started a fire in a coal stove with oil soaked gloves on his hands. One glove caught on fire, then the other caught and fell into a pail of gasoline resulting in the loss of five ships.

Static electricity either while refueling or spraying with dope or gasoline has caused several serious fires. Unprotected electric

light bulbs at the end of extension cords, when allowed to rest on fabric, are also a frequent cause of loss.

Another airplane was destroyed when a pan of gasoline which had formed under the dripping carburetor was ignited by a spark from the exhaust of a tractor which was being driven out of the hangar.

Fire in the air fortunately occurs less often than on the ground but it too usually results in total loss. In one case the fuel line on the left engine of a ship broke in flight. The pilot did not know what had happened because the fire, being in the blast of the air-stream within the cowl, was similar to a blow-torch flame, small but hot and hardly visible. The engine kept running although fuel pressure was falling and the pilot experienced other troubles. He landed safely but as soon as the airplane lost speed, the air blast no longer confined the blaze. It spread so rapidly that passengers had no time to save even their handbags. In another case the pilot became conscious of fire at 3,000 feet. It smelled like insulation, so he turned off the generator and the master switch that led from the battery to all electrical apparatus. As he was losing altitude, a passenger remarked that the rear of the cushion seemed to be getting hot. On removing the cushion, he found a small part of the upholstery smoldering. This was put out. When the passengers raised the lid under the seat cushion which gave access to the radio receiver and battery, large flames leaped in their faces. The flames were so big that the pilot decided not to use the extinguisher, fearing a combination of flame and extinguisher fumes would knock him out. The passengers closed the door, replaced the seat cushions to their usual position and sat down on them to keep the fire within the radio compartment. The pilot landed safely saving his passengers, but the ship was destroyed.

Several years ago the National Fire Protection Association studied the situation and came to the conclusion that 12% of all airplane losses were caused by hangar fires. Their analysis of 40 fires was as follows:

<i>Ignition of Inflammable Vapors</i>	<i>Number of Fires</i>
	13
Explosion, source unknown	4
Doping operations	2
Fire in engines	2
Oil burner	1
Washing plane with gasoline	1
Flames from exhaust of engine	1
Explosion of gas heater	1
Ignition by blow torch	1

	<i>Number of Fires</i>	
<i>Heating Appliances</i>	5	
Overheated furnace or stove		4
Coal stove tipped over		1
<i>Smoking</i>	4	
<i>Welding Operations</i>	3	
Welding gasoline tank		1
Acetylene torch set fire to fabric of plane		1
Fire in gasoline torch		1
<i>Miscellaneous</i>	5	
Acetylene torch ignited barrel of lacquer		1
Supposed short circuit		2
Lightning		1
Children and matches		1
<i>Supposed Incendiary</i>	2	
<i>Unknown</i>	8	
	—	
Total Fires	40	

Fire losses could be reduced if airplane owners, airport managers and ground personnel could be taught to respect the fire hazards that continually surround the airplane. Ignorance or lack of discipline among ground personnel is the most frequent cause of fire loss. Good hangar housekeeping should prevent fires from starting by proper installation and maintenance of electrical and heating equipment, by permitting no open flame within the hangar proper (limiting welding if necessary to locations near the door), by absence of flammable debris in the hangar, by exercise of self-control and discipline on the part of personnel in regard to smoking, welding, testing, doping, cleaning airplanes with gasoline and operating engines inside the hangar. To attack fires and keep them from spreading after they start, a supply of adequate fire extinguishers should be quickly accessible. It is of great importance to attack the fire when it is still very small because the usual extinguisher is not large enough to cope with larger fires, hence the great need for speed. Personnel should be instructed in the proper use of the various types of extinguishers (see First Aid Fire Appliances, Published by National Board of Fire Underwriters).

Crowded hangars always present a concentration of fire hazard. While it would be desirable not to have wings overlap and in fact to have each airplane separately stored in its own fire-proof hangar, the economics of hangar operation militate against such practice. Nevertheless, by good hangar construction and strict management, losses could be reduced appreciably. (See Construction and Pro-

tection of Airplane Hangars, National Board of Fire Underwriters.)

A good airport manager should periodically check his hangar as follows:

Airport Self-Inspection Report — Fire

(The airport management should appoint a fire inspector to check "Fire" hazards with this report.)

Take nothing for granted—See the object before you comment on it. Make someone responsible to adjust, repair, clean or admonish whenever required—the responsible person's name should be noted and he should be followed up. Make your comments and instructions specific.

LOCATION	HANGAR NO.
GENERAL APPEARANCE	ELECTRICAL EQUIPMENT
Crowding of equipment; ease of rolling equipment out; any equipment such as cars, that should not be in hangar. Look under staircases, in booths.	Conduits (Plugs should be 40" above floor).
FLOOR AND WALLS	Extension cords—insulation.
Especially corners; no oil, no papers, no debris; cleaned nightly.	Extension lamps (guards) used properly.
Roof trusses.	Motors—sparking.
Floors should be kept clear of accumulated grease or oil.	HEATING SYSTEM
DOORS	Overheating sparks, insulation, leaks.
Open easily, fire doors close easily (should be self-closing).	Heating system should be in separate vapor tight room. If by coal stove, should be about 18" above floor.
FIRE EXTINGUISHERS	DIRECT FIRE HAZARDS
Location (accessibility).	Anyone smoking (who).
Condition.	Anyone running engines (who).
Men should be instructed in operation of extinguishers. Hold drills every month.	Anyone welding (who) (extinguishers on welding stand). Extra man standing by with extinguisher.
STORAGE ROOM	Anyone soldering (who).
Clean. Condition of electrical equipment and conduits. Flares, paint, dope. Door should be spring closing.	Anyone doping or spraying (who).
LOCKERS AND CABINETS	Anyone cleaning ships with gas (who).
Neat, no inflammable materials, oily rags.	Any tanks overflowing or leaking.
WORK BENCHES	Adjoining fire hazards (dry grass, piled debris, railroads, etc.).
	OFFICE
	Doors, fire extinguishers, floor, waste cans, cleaned nightly, electrical conduits.
	LAVATORIES
	Clean

SHOP

Vapor proof bulbs, floors, walls, cleaned nightly, waste cans, benches, smoking, extension cords, lamps (see electrical equipment).

DOPE ROOM

Vapor proof bulbs, condition.

Electrical wiring, condition (There should be no plug outlets).

Switches (should be vapor proof).

Ventilation.

Windows and doors work easily.

Fire Extinguishers—number, condition.

Motors (any sparking).

Heating system.

Storage of dope, brushes, etc.

Daily cleaning.

Waste cans.

Smoking.

Shoes worn by workmen—sparks.

RUBBISH CANS & SELF CLOSING CANS
(for oily rags, waste)

Lids on, cleaned out daily.

SIGNS AND BULLETIN BOARD

Condition.

NIGHT WATCH PUNCH LOCK SYSTEM

OUTSIDE EQUIPMENT

Gas pumps & Trucks—condition (no refueling in hangar permitted).

Fire Extinguishers—condition.

Condition of hose.

Grounding wire and chain. (Tanks should be grounded both while being drained or filled.)

Fences, gates, roads.

Anyone smoking in vicinity during operations.

Check operation of fire alarm—condition of battery.

FIRST AID EQUIPMENT

Operating condition.

Fire Extinguishers.

Axes.

Cables and hooks.

Medical kit.

Fire extinguishers should bear tags showing last recharge date, should be recharged at least once per year and immediately after use. All extinguishers except carbon dioxide and carbon tetrachloride types must be protected from freezing. Hangar should be supplied with one 2½ gallon Foam extinguisher for each 2500 square feet of fire area or one 15 lb. carbon dioxide extinguisher plus one one-quart carbon tetrachloride extinguisher, a forty gallon Foam wheeled extinguisher for each 7500 square feet of fire area. Offices and waiting rooms should have a Foam or Soda Acid extinguisher for each 2500 square feet of area or less. Repair shops, storage rooms, engine testing rooms should be equipped with one 2½ gallon Foam extinguisher and a 15 pound carbon dioxide extinguisher, one one-quart carbon tetrachloride extinguisher for each 2500 square feet of area or less. Welding stands should be supplied with a one-quart carbon tetrachloride extinguisher. Filling stations or trucks should have several of these or carbon dioxide extinguishers.

Inspector..... Date.....

Keep this report on file, check fire hazards at least once per month and keep your eyes open in between.

Good practice for refueling and starting engines would be along the following lines:

(a) No smoking within fifty feet of the aircraft being refueled. 'No Smoking' signs should be displayed in prominent places.

(b) The engine should be stopped, switches in an 'off' position, and the engine cooled.

(c) The power on all radio transmitters and receivers should be off.

(d) The refueling equipment and the aircraft must be grounded.

(e) Gasoline should not be permitted to overflow from the tank. In hot weather, tanks should not be completely filled with cold gasoline which will subsequently expand and overflow. Even the spark from a steel tool dropping on concrete can set off gasoline fumes.

(f) Only those responsible for the refueling or the maintenance of aircraft should be allowed within fifty feet of the refueling operation.

(g) No aircraft should be refueled in hangars.

(h) A good felt strainer is preferable to a chamois.

(i) No refueling during Winter flying operations while the engine is being warmed by application of heat from plumber's stove or similar means.

(j) Fire extinguishers should be within easy reach of those refueling.

(k) When starting the engine, special care should be taken not to overprime, and if the aircraft is not fitted with a pressure type of fire extinguisher, it is a wise precaution to have a man present outside the aircraft with a portable fire extinguisher.

(l) In the event of a backfire, endeavor to keep the engine turning over so as to suck the flames up into the air intake.

(m) Do not start engines with pools of gasoline under the airplanes.

Fires in the air or in the carburetor can be fought as follows:

(a) Turn off gasoline.

(b) Open throttle fully.

(c) Switch off, after engine has ceased firing.

(d) Lose height by side slipping.

Students should be given practice in this routine until they carry it out without hesitation.

(a), (b) and (c) should also be used in the event of an engine catching fire on the ground.

The throttle is opened fully to use up as quickly as possible the gasoline in the carburetor.

Sideslipping is to prevent the smoke from entering the cockpit and the flames from spreading down the fuselage.

From the design engineer's point of view it seems that non-flammable fabric both in the upholstery and exterior covering would prevent many fires. Fuel lines that do not fracture or burn through so easily would also help and apparently they will soon be common practice in engine installation. Flame arrestors on carburetors would prevent many fires, especially in winter when a combination of over-priming and backfires results in many losses (ships should be turned tail to wind, so that flames will not lick backwards along fuselage). A code of good practice for the installation of all electrical equipment is very much needed. The design of cabins and seats so that sparks could not lodge in covers or fall under the floor onto fabric would also help.

The smaller need for welding and doping on riveted metal airplanes would reduce fire losses if the number of such ships in proportion to the total were greater.

Fires which occur after a forced landing or a crash might be reduced if heavy oil were used instead of gasoline. The retractable undercarriage and perhaps the tricycle undercarriage should have a favorable effect on reducing fires following a forced landing because the airplane is less likely to turn over on its back. If the stall/spin could be avoided in landing accidents, many gruesome fires following crashes might be avoided.

The problems affecting fire hazards are well known and recognized by engineers. Progress is being made towards their solution. But fire losses due to hazards that exist *now* can be reduced only by educating airplane operators and mechanics to the need for good housekeeping as well as the adoption of safe practices in operating and working around the airplanes.

According to the Bureau of Air Commerce records, non-scheduled flying is becoming safer. In the periods 1932 to 1937, the mileage flown by airplanes in non-scheduled operation increased about 32% while the miles flown per accident increased 50%. This is a good indication of the increasing reliability and safety of air travel achieved by design, regulation and education.

If accidents involving student instruction could be separated from these accident statistics, the record would probably be much better. However, approximately 20% (1 in 5) of all certificated airplanes were involved in an accident last year, and of that number 97% needed replacement of a major assembly, required complete overhaul or were completely demolished. Furthermore, with less than $\frac{1}{3}$ of the total number of all certificated airplanes insured, the insurance companies pay out an average of well over \$1,000 per day in aviation claims exclusive of airline claims. Although the general accident trend is improving, a study of ways and means of reducing accidents should show where important advances can be made.

It is estimated that at the end of 1937 there were about 2,000 light planes in this country. A light plane, as commonly understood in this country, is one which weighs under 1,500 pounds with a wing loading in the neighborhood of 6-10 pounds per square foot and a power loading of 19-26 pounds per horsepower. In the same year there occurred 592 accidents among these planes or an accident rate of 30% compared with 20% for all civil airplanes. This does not include airplanes lost by hangar fire because records are not available of all such losses. In the typical light plane accident, the airplane is severely damaged but not washed out; the injury to personnel is nil; the accident occurs while landing or taking off and it is caused by pilot error.

An analysis of these accidents shows that the nature of the accidents varies considerably with the make of the airplane. One make of airplane had a high percentage of take off accidents and a high percentage of pilot errors with a low percentage of engine failures. This airplane had a higher wing loading than others. Since the type of flying was the same for all, it is surmised that many of the accidents may have been due to pilots underestimating the speed and distance necessary for take off.

Another make suffered a comparatively high percentage of structural failures. This is rare and when it does occur it is not likely to be dangerous to personnel. It is likely, however, to cause considerable damage to the airplane.

A third make had an average showing with regard to damage to the aircraft but its personnel injury record was better than the others. A low percentage of pilot errors indicated good flying characteristics but a high percentage of forced landings might indicate that it was used a good deal for cross country work because many forced landings are due to fuel shortage or getting lost.

An analysis of accidents by class of flying shows a high per-

centage of accidents due to pilot error for instructional flying, a low percentage for commercial flying. See table 1. This emphasizes the need for competent instruction and close supervision of flight training. The fact that there are more accidents in instructional flying than in pleasure or commercial flying may be counterbalanced by the excess of instructional flying over other flying. Such an excess is indicated by the ratio of student permits to certificated pilots. The ratio is about 40,000 (possibly 20,000 active) to 18,000.

The classification of light plane accidents by class of pilots shows that 52% of the accidents involved student pilots. This was to be expected. See table 2.

Although Limited-Commercial Pilots number about 3% of the total certificated pilots in the country, they accounted for 6% of the light plane accidents and 30% of these were fatal. The severity of the accidents involving Limited-Commercial Pilots is possibly due to the limited experience and undue confidence. It is generally felt that over 50 and under 500 hours the average pilot's confidence exceeds his ability. The majority of Limited-Commercial Pilots fall in this class. Before that time they are certain that they do not know it all and after that time they again suspect limits to their ability. This reasoning would also apply to Private Pilots, but the record of the Private Pilot is improved by the caution of Private Pilots having over 500 hours. After 200 hours a Limited-Commercial Pilot will usually become a Commercial or revert to Private.

It is not advisable to discriminate against Limited Commercial Pilots as such but rather it is advisable to look with suspicion on a pilot with less than 200 hours flying unless much of it has been cross-country and a checkup reveals that his judgment and attitude towards safety are satisfactory.

Mr. James E. Hoskins, Chairman of the Aviation Committee of the Actuarial Society of America, in an address on Aviation Life Insurance to the National Association of State Aviation Officials in 1936, made the following comments on pilot mortality. These comments should not be confused with airplane accidents because less than 10% of aircraft accidents result in pilot fatalities.

"It appears that the most dangerous time in a pilot's career is not while he is taking instruction or in the early part of his solo flying, but for a period after he receives an advance license or military rating. At first he knows he is green and plays safe; eventually he gains skill; but there is an intermediate time when his self-confidence exceeds his ability.

"Pilots who have been involved in an accident in recent years

or have been disciplined for a serious violation of air regulations have a greater chance of a fatal crash than those who have not, although they might be expected to have become especially careful.

"No great difference has been observed between the younger pilots and those of more mature years. Perhaps this might be true but for the care exercised in licensing pilots." Note: This refers to mortality rate; young pilots have more accidents, however.

"The kind of flying is very important. Those kinds which are most closely supervised, either by yourselves and Uncle Sam, or by responsible owners, are clearly the safest, such as airline and military flying, and airplanes owned by corporations for business use. In the case of airline pilots, however, this is offset by their large number of annual hours in the air.

"The average amount of flying in the course of a year is by far the most important factor affecting the insurance company's problem of charging for a year's insurance."

Insofar as insurance rating is concerned, classification by type of license is not sufficient. A Commercial Pilot of long experience should be safer to fly with than a Private Pilot with a couple of hundred hours but if the former flies a thousand hours to the Private Pilot's fifty per year, he is a worse risk from the insurance companies' viewpoint. For that reason, Commercial Pilots usually pay a higher rate than Private Pilots. The exposure to hazard is greater.

In an old but interesting report the Actuarial Society of America have the following to say in 1932:

"There are indications that the mortality among students is relatively low, but that after obtaining a license, and particularly after qualifying for a Transport License, the pilot is liable to reach a stage where, in the words of a Navy Department report, 'The flash of over-confidence seems to carry the novice beyond the realm of his ability.'

"It appears that the mortality rate increases with amount of annual flying time, although not in direct proportion.

"Most of the available evidence indicates no material improvement in annual mortality rate after 500, or at the most 1,000 hours' experience has been passed. Evidence indicates that the annual mortality rate of pilots of long experience is not materially better than that of pilots having from 500 to 1,000 hours' experience.

"Furthermore, it appears that the proportion of pilots with records of accidents since 1927 is higher among young pilots than

among older pilots. That is to say, young pilots are more than usually liable to have accidents; and, having had accidents, have a high rate of mortality. The conclusion seems to be that applications from young pilots should be underwritten with especial care, to ascertain that they have neither an accident record nor characteristics which are liable to produce accidents."

These statistics and conclusions may be changed in the next two or three years by the new regulations which provide for the special approval of instructors, and by the attitude of the Civil Aeronautics Authority towards instructional flying.

The safest type of flying appears to be commercial with pleasure slightly better than instruction. The safest class of pilot is the Commercial, followed by the Private and Student. A student under good supervision should be safer than one under poor supervision. It would be useful and interesting to verify this, if it were possible. Limited commercial pilots have a worse record than students.

From the classification of accidents by nature, the deadliness of spins and stalls with or without engine power is outstanding. This contributed 46% of the light planes that were totally destroyed and 63% of the fatalities. See table 3.

It seems that the most outstanding need among light planes, and heavier airplanes too, is to design one that will not spin or whip into a dive after stalling or perhaps not stall at all. If such an airplane were used extensively, the accident rate would probably continue to be the same because of the human desire to push a machine to its utmost, but the severity of the accidents would be lessened.

It is interesting to note that a collision with another aircraft in flight is not necessarily fatal. Only three such accidents were recorded with light planes last year.

Collision in full flight with objects other than aircraft are usually fatal. Ninety-two per cent of these accidents were due to pilot error.

The fact that take-off accidents are more severe than landing accidents although not as frequent may reflect the fact that there is greater emphasis on landing technique than on take-off technique. Perhaps the tricycle undercarriage will simplify both techniques.

Engine failure as a cause of accidents is higher than any other cause except pilot error. The fact that there is a comparatively high proportion of severe accidents and aircraft damaged compared to severe personal injury leads to the conclusion that a pilot with a dead engine usually can put the airplane down with safety to himself if not to the airplane. See table 4.

A study of the tables reveals:

Nature of Accident by Frequency

(From Table 1)

Landing	32%
Take off	22%
Spin/stall engine OK	11%
Forced landing	10%
Taxiing	10%

<i>Most Damaging (From Table 3)</i>	<i>% Completely Demolished</i>	<i>% Resulting in Fatal Injury</i>
Spin/stall engine failure.....	75%	50%
Spin/stall engine OK.....	57%	43%
Collision with non-aircraft.....	52%	40%
Structural failure	37%	25%
Collision with aircraft	33%	33%

Many other interesting conclusions may be obtained from these tables but they indicate that pilot error is the most important cause of accidents with design and characteristics of the aircraft contributing largely. The frequency of landing, take off and spin/stall accidents is consistent with records of accidents involving heavier airplanes. Most engineers are well aware of this regrettable condition.

Because proper instruction is the best guarantee of loss prevention among student pilots, one group of insurance companies has itself undertaken the task of approving instructor pilots. A student pilot flying under the supervision of an approved instructor pilot is eligible to secure very inexpensive personal accident insurance. Seventy per cent of the applicants for approval as instructors have been approved.

Reasons for deferring the approval of an applicant are various. For example, a man who derives a major part of his income from an activity outside of aviation is seldom approved as an instructor. Applications have been made by policemen, postmen, factory workers, and other pilots who instruct only in their spare time. Unless the latter have outstanding records, their applications are deferred for three reasons:

1. Since these men are away from the field a good portion of the time, they do not know how the equipment in which they instruct is being used. The airplane may receive a very severe beating and get into a dangerous structural condition, yet these men might not know about it because of their absence from the field.

2. Since they have only a limited time in which to give in-

struction they are likely to hurry through their instruction and also are likely to take chances by instructing in bad weather.

3. The fact that they have another source of income might tend to make them less careful about the condition of their equipment and their flying operations in general.

Incidentally, the size and nature of the airport from which instruction is carried on is also considered in the approval of instructors. One pilot, who flies from a field which is considered too small, presents the argument that his students are better pilots because they learn to land in a small field. He adds that pilots who have learned to fly from larger fields find difficulty in getting into his small field although his students do it very easily. The reply to this argument was as follows:

"In general Student Pilots who learn to fly from small fields know how to handle themselves better when making forced landings than those who learn to fly from large fields. It has also been said that pilots who learn to fly in dangerous airplanes are better pilots than those who learn to fly in safe airplanes because they are practiced in the art of handling themselves under uncertain conditions. Pilots who learned to fly during the war are usually cited as examples.

"If this reasoning were applied to other activities, a person learning to drive a car for instance should not learn on a lonely road but rather should be taught at the corner of 42nd Street and Broadway! This policy would indicate that one should learn and practice under the most difficult and severe conditions in order to be safe under normal conditions. A good deal of merit exists in this reasoning except that it might prove expensive and it inhibits progress. The fact, so far as commercial aviation is concerned, is that successful instruction in the early days, when dangerous airplanes were used, was given only to 'supermen,' who had more 'guts' than the average, and therefore reacted better in emergencies. The others, who did not react safely, were killed. In these days, however, we are dealing with the *average* person in commercial aviation. It appears that the correct and safe procedure is to learn in the normal way at a normal field and to prepare for the difficult situations during the course of instruction."

The requirements for instructor approval by the insurance organization are not very stiff. They are designed to be minimum rather than maximum. The object is to shut out the instructor who is unqualified rather than reward outstanding merit. The requirements are:

1. A Commercial Pilot Certificate with an Instructor's Rating and at least 400 hours solo. This amount of time is required as it is felt that only after at least such an amount will the pilot have had sufficient general experience.

2. A few students licensed to indicate success and ability to impart knowledge and a demonstrated thoroughness and competence in instruction.

3. The planes used will be of suitable design with suitable engines and well maintained.

4. His general record will be reasonably good, i. e., no excess drinking, few or no accidents, good reputation, no recklessness. Concerning accidents, one or two are not grounds for deferring approval provided they were largely due to circumstances beyond the pilot's control.

5. Full time employment as an instructor. This restriction was put in to eliminate unfair competition to those who depended solely on instruction for a livelihood as well as to eliminate casual instructors. Exceptions are occasionally made, as for instance in the case of pilots who have a flying job which leaves them enough time for instruction.

Seventy per cent of the applicants have been approved, 30% have been deferred. Those deferred fall into the following classes. In some cases there were two or more reasons for deferring action.

Airport Unsatisfactory	9	5%
Not a full time Instructor	47	24%
Character, i. e., reckless, excess drinking, too impulsive, etc.	25	13%
Equipment obsolete or poorly maintained	7	4%
Flying unsatisfactory, i. e., incompetent instructor, lack experience, too many accidents, poor supervision	55	28%
Miscellaneous	16	8%
Under 400 hours	35	18%
	<hr/>	<hr/>
	194	100%

Among those deferred, examples of improper instruction were frequent. One instructor would not give spins to a student until just before the license test was due for fear of scaring the student. Civil Aeronautics Authority regulations require spin instruction before solo. Another pilot was giving spin instruction and was looking back at the student while so doing. He suddenly saw a tree go by, realizing the scarcity of trees at high altitudes above the ground, the instructor got to work and pulled the plane out in time to prevent a fatality. However, he hit so forcibly in the recovery that one side of the landing gear was washed out. Other pilots were

turned down for such physical defects as color blindness, fainting spells, etc. Lack of supervision or incompetent supervision was considered a serious flaw. In one case a student was permitted to snap-roll, loop and spin at 400 feet.

At this point, it should be advisable to emphasize that the typical professional pilot is a very sober, earnest individual, sincere in his desire to see aviation advance and very cooperative in his attitude towards safety. He is very far from the slap-dash type which popular imagination finds so romantic.

Besides insisting on minimum qualifications for an instructor pilot, it has been found necessary to outline desirable courses of instruction. These are merely recommended. Instruction procedure is not so important as thoroughness and constant supervision by a well qualified instructor. For example, in the outline which follows, taxiing instruction is given as one of the first of the courses. But one very successful instructor gives this last because he thinks taxiing is more difficult than learning to fly. The outline has been found satisfactory. It has been adopted by several flying schools and represents current good practice in flying instruction.

Recommended Outline of Instruction Toward a Private Pilot's Certificate

1. First Phase: Minimum training of eight flight hours.
 - (a) PRELIMINARY GROUND INSTRUCTION: Thorough familiarization with functioning of airplane, controls, engine, and instruments. Warning about: danger from propellers; difference between ground and air speed; leaving engine running with no one in cockpit; parking ship in strong winds; starting engine, switching, choking, priming, signals (student not to handle propeller). Advice against mixing liquor and flying. It is good policy to discuss the ensuing lesson with the student on the ground before taking-off.
 - (b) Taxiing to proficiency (handling of ship in gusty air).
 - (c) Air Work.
 - (1) Straight and level flight to proficiency.
 - (2) Gentle climbs and glides to proficiency.
 - (3) Gentle turns.
 - (4) Approaches for landing.
 - (5) Stalls, stressing approaches to stalls and recovery.
 - (6) A: Landings and take-offs.
B: Simulated forced landings from take-offs only from approximately 200 feet.
 - (7) Spins and recovery.
 - (8) Solo.
2. Second Phase: Minimum twelve hours. A check by the instructor before each of the first three solo flights and frequent checks at least ONCE EVERY THREE HOURS through all maneuvers required in the first phase.

This is to prevent student from feeling now that he had soloed, he can have ship any old time; also to compensate for changes in air conditions. Instruction in:

- (a) Figure 8's, gentle and steep.
 - (b) Simulated forced landings.
 - (c) Dual cross country trips with landings at other airports and a thorough check and review of all maneuvers of the first two phases.
3. Third Phase: Instructor's check of all maneuvers in phases one and two ONCE EVERY FIVE HOURS, stressing the following:
- (a) Precision maneuvers (spot landings, simulated forced landings, spins and figure 8's).
 - (b) Solo cross country.
 - (c) Complete Private Pilot's examination.

NOTE: The above is a logical and normal sequence of instruction to serve as a GUIDE to instructors, and to give a UNIFORMITY OF INSTRUCTION in a sequence that experience has shown to be one that insures the greatest progress by the student. Records of the student's progress should be kept.

It is further recommended that students be acquainted with control tower operation and flight plan procedure.

All the comments made thus far result principally from the existing characteristics of the airplane (design) and of existing control or regulation. These two agencies for increasing safety cannot be quickly improved. Too much physical and mental inertia would have to be overcome. The most logical and the easiest way for improving the safety record and preventing losses is by education and by disseminating the results of experience.

While generalizations are always dangerous, I should like to venture the thought, with my fingers crossed, that safety is achieved more readily by knowing how to operate safely that which we already have than by improvement in design. Human nature is so constituted that improvements in design are employed not to achieve safety but to take advantage of the greater utility which such improvements usually afford. A pilot may obtain an airplane with which it is possible to get in and out of a very small airport. Instead of considering this an emergency operation, he takes advantage of the design to actually operate regularly from such airports. This is a foible of human nature and is very much to be commended for its effect on design but its effect on accidents is not favorable, except indirectly.

Improvements in design usually make flying easier or make it more useful, thus inducing more people to fly. The mileage flown per accident seems to increase with greater use; hence the indirect influence of improvements on safety records. However, on the basis of number of airplanes per accident, the future seems pessi-

mistic. It must be admitted that the human element creates a greater hazard than the airplane itself.

An agency for the education of instructors would aid tremendously in promoting good instruction practice, in educating instructors in the finer points of the art, tipping them off on the best way to instruct in various types of ships, and informing them where instruction usually fails as indicated by accidents among students.

One type of ship is probably as good as another, so long as the instructor understands the limitations of the ship and imparts this knowledge to the student. For example, in a side by side ship with wheel control, many students get in the habit of resting their hands on the wheel, putting both hands on the wheel as though they were driving a car. Then when an emergency arises, when one hand should be on the throttle and one on the wheel, time is lost where time is most valuable. Instructors who are training in this type of ship should be advised of the situation and impart this knowledge to their students. Under the present hit-and-miss system of instruction, the student is only advised by chance or if he happens to get a really experienced instructor. The dangers of having the center of gravity too far back are not emphasized enough. Another point is the technique in coming out of a spin. The usual instructions are, "Kick opposite rudder and push the stick forward." One instructor of long experience knowing that many recent accidents were due to the failure to recover from spins, decided to see what would happen if he obeyed the usual instructions, "Kick opposite rudder and push the stick ahead."

He made his tests in a popular type of airplane widely used for instruction purposes. The engine was throttled slowly while the airplane was held in normal flight attitude till complete stall had occurred. At that time the elevator control was pulled straight back and full right rudder applied. After completion of two full turns of the resulting spin, the elevator control was pushed full forward and hard left rudder applied. Instead of coming out of the spin, the ship vibrated slightly, went over on its back and kept spinning in an inverted position. Operation of rudder to either side had little or no effect and the pilot was thrown violently against the belt. Recovery was effected by *pulling the wheel back*, applying right rudder until the spin became normal, after which the left rudder was applied with the wheel moved to a position $\frac{1}{4}$ back from neutral.

The violent motion and the inverted position proved very confusing to this pilot and in the case of a student being placed in the same position might easily result in complete loss of head and spin-

ning in, and probably has. At the end of twelve tests, this instructor concluded that recovery from a spin cannot necessarily be obtained by shoving the wheel or stick forward in every case. Recovery is effected slowly with resultant loss of altitude when the controls are neutralized. Furthermore, instructors should abandon the stick-full-forward explanation of recovery from spins unless it applies to a particular ship. They should instil in their students the idea that each ship may have slightly different characteristics.

These instances are merely mentioned to bring out the need for improving and disseminating the finer phases of instruction which are usually available only from very experienced instructors. These finer points often mean the difference between safety and a crash.

It is unlikely that the popular airplane of the future or, for that matter, of today will receive adequate maintenance unless the owners and pilots have the proper respect for and knowledge of maintenance. Thorough inspections at long intervals must be supplemented by continuous preventive maintenance. Airline experience has proved it, regulations require it but only education can show the need and desirability for it. Regulation cannot succeed without the owners' and pilots' cooperation, and that can be secured through education.

To show the need for education in maintenance and inspection, the following items are taken at random from typical inspection reports on various light planes made between the yearly government inspections. They show the need for training of owners and pilots in maintenance or inspection. Each item is from a different ship: (a) Left exhaust manifold flanges cracked; (b) Oil drain and gasoline strainer not saftied; (c) Fiber bushings missing from the elevator cables and from both rudder cables at the guide at the tail of the fuselage; (d) Hinges on the right side of the elevator to stabilizer evidently do not coincide causing considerable stiffness in controls and bending the tip end of the stabilizer when moved; (e) Oil drain pipe to tank twisted from removing the drain plug. Metal tipping on propeller dented and cracked; (f) Trailing edge of wings in bad condition. Entering edge badly dented in several places. Several ribs loose at trailing edge. Aircraft not grounded while refueling. Smoking in vicinity of fuel pumps; (g) Baffle for exhaust manifold loose. Oil tank loose. Brake cables frayed at wheels. Right front gas line loose. (h) Propeller hub bolt very loose; (i) Left aileron hinges near fuselage loose on spar; (j) Engine exhaust manifold where connected to cabin heater cracked and deteriorating. Stabilizer control worn and dirty. Fuel and

oil lines too dirty to inspect; (k) Large wet type battery installed at left side of pilot's seat for night flying. No battery box, no drain nor any special provision for installation.

An instructor should instil in his students a proper respect, not fear, for the existing characteristics of airplanes. He should encourage his students to fly within present day operating limitations and impart the knowledge required to judge the airworthiness of an airplane. Such instructors are hard to find except in the large schools and at old and well operated airports. Many instructors think they are doing the right thing when they have been improperly trained themselves. The training of good instructors will do more than any other act to increase safety and prevent losses.

In conclusion the need exists for an agency, probably Federal, which would undertake the education of new flying instructors, teaching them the best methods for imparting flying technique. This would have a more favorable effect on the accident rate and especially on the severity of accidents than any other movement in Aviation. While accident prevention is of tremendous importance to aviation, insufficient recognition has been given to losses caused by fire and windstorm, which are outside the common definition or conception of an airplane accident. These losses may not involve the safety of life but they do seriously affect the economics of aviation. Ground personnel and aircraft operators should be instructed to respect and adopt precautions against fire, windstorm and other hazards pending improvements in airplane design which will reduce them.

Table 1
ACCIDENTS PER CLASS OF FLYING
LIGHT PLANES, 1937

Damage to Aircraft

	Number				Per Cent			
	Inst.	Comm.	Pleas.	Tot	Inst.	Comm.	Pleas.	Tot
Washout	A 53	5	39	97	17	10	17	16 A
Major Overhaul....	B 135	27	102	264	44	56	43	45 B
Major Repair.....	C 117	16	93	226	38	34	40	38 C
Minor Repair.....	D 4	—	1	5	1	—	+	1 D
Total	309	48	235	592	100	100	100	100
	52%	8%	40%					

Injury to Personnel

Fatal	A 30	2	19	51	10	5	9	9 A
Severe	B 17	3	16	36	6	7	7	6 B
Minor	C 16	4	29	49	5	10	13	9 C
None	D 232	32	154	418	79	78	71	76 D
Total	295	41	218	554	100	100	100	100

Nature of Accident

Collision, full flight, with aircraft	A 3	—	—	3	1	—	—	1 A
Collision, full flight, with non-aircraft..	B 13	3	9	25	4	6	4	4 B
Spin/stall eng. fail..	C 5	—	3	8	2	—	1	1 C
Spin/stall eng. OK..	D 37	7	22	66	12	15	9	11 D
Forced Landing	E 28	4	27	59	9	8	12	10 E
Landing Accident ..	F 112	12	65	189	36	25	28	32 F
Takeoff Accident ..	G 57	9	64	130	18	19	27	22 G
Taxiing Accident ..	H 34	4	19	57	11	8	8	10 H
Fire in Air.....	I —	—	1	1	—	—	+	+ I
Structural Failure..	N 4	2	2	8	1	4	1	1 N
Miscellaneous	X 2	—	3	5	1	—	1	1 X
Indeterminate	Y —	—	3	3	—	—	1	1 Y
Not responsible..*	NR 14	7	17	38	5	15	8	6 NR
Total	309	48	235	592	100	100	100	100

Cause of Accident

Pilot	213	17	129	359	65	32	51	57
Structural Failure....	10	3	11	24	3	6	4	4
Weather	33	10	25	68	10	19	10	11
Airport	7	1	14	22	2	2	6	3
Miscellaneous	12	6	18	36	4	11	7	5
Engine Failure.....	38	9	34	81	12	17	14	13
Unknown	1	—	4	5	+	—	1	1
Not responsible	14	7	17	38	4	13	7	6
Total	328	53	252	633	100	100	100	100

* Planes involved in a collision but in no way responsible. The planes may be at rest, taking off, landing, or taxiing.

Table 2

ACCIDENTS BY CLASS OF PILOT
LIGHT PLANES, 1937

Damage to Aircraft

	Number					Per Cent				
	Com	LC	Pri	Stu	Tot	Com	LC	Pri	Stu	Tot
Completely Demolished	A 16	10	19	48	93	16	30	14	17	17 A
Major Overhaul	B 49	11	68	124	252	51	33	50	43	45 B
Major Repair	C 32	12	49	113	206	33	37	36	39	37 C
Minor Repair	D —	—	—	3	3	—	—	—	1	1 D
Total	97	33	136	288	554	100	100	100	100	100
	17½%	6%	24½%	52%						

Injury to Personnel

Fatal	A 8	4	11	28	51	8	12	8	10	9 A
Severe	B 9	4	11	12	36	9	12	8	4	6 B
Minor	C 11	6	14	18	49	12	18	10	6	9 C
None	D 69	19	100	230	418	71	58	74	80	76 D
Total	97	33	136	288	554	100	100	100	100	100

Nature of Accident

Collision, full flight, with aircraft	A —	—	1	2	3	—	—	1	1	1 A
Collision, full flight, with non-aircraft	B 9	2	3	11	25	9	6	2	4	5 B
Spin/stall eng. fail.	C 2	1	2	3	8	2	3	1	1	1 C
Spin/stall engine OK	D 8	5	15	38	66	8	15	11	13	12 D
Forced Landing	E 10	4	16	29	59	11	12	12	10	11 E
Landing Accident	F 32	7	41	109	189	33	21	30	38	34 F
Take-off Accident	G 24	11	39	56	130	25	34	28	19	23 G
Taxiing Accident	H 7	2	16	32	57	7	6	12	11	10 H
Fire in Air	I —	—	1	—	1	—	—	1	—	+ I
Structural Failure	N 4	1	—	3	8	4	3	—	1	1 N
Miscellaneous	X 1	—	1	3	5	1	—	1	1	1 X
Indeterminate	Y —	—	1	2	3	—	—	1	1	1 Y
Total	97	33	136	288	554	100	100	100	100	100

Cause of Accident

Pilot	42	22	83	212	359	40	58	56	69	60
Structural Failure	10	2	4	8	24	10	5	3	3	4
Weather	12	3	19	34	68	12	8	13	11	11
Airport	8	2	7	5	22	8	5	5	2	4
Miscellaneous	11	3	10	12	36	11	8	7	4	6
Engine Failure	20	6	23	32	81	19	16	15	10	14
Unknown	—	—	1	4	5	—	—	1	1	1
Total	103	38	147	307	595	100	100	100	100	100

NOTE: Accidents classified under NR (light airplane not responsible for the accident) were not considered in this table.

Table 3

CLASSIFICATION OF ACCIDENTS BY NATURE
LIGHT PLANES, 1937

Damage to Aircraft														
NATURE	A	B	C	D	Tot	PER CENT					PER CENT			
						A	B	C	D	Tot	A	B	C	D
						Read Across					Read Down			
A	1	1	1	—	3	33	33	34	—	100	1	+	+	—
B	13	11	1	—	25	52	44	4	—	100	14	4	+	—
C	6	2	—	—	8	75	25	—	—	100	6	1	—	—
D	38	23	3	2	66	57	35	5	3	100	40	9	1	40
E	7	30	22	—	59	12	51	37	—	100	7	11	10	—
F	12	87	90	—	189	6	46	48	—	100	12	33	40	—
G	12	76	42	—	130	9	59	32	—	100	12	39	19	—
H	—	16	40	1	57	—	28	70	2	100	—	6	18	20
I	1	—	—	—	1	100	—	—	—	100	1	—	—	—
N	3	3	2	—	8	37	37	26	—	100	3	1	1	—
X	—	3	2	—	5	—	60	40	—	100	—	1	1	—
Y	—	—	3	—	3	—	—	100	—	100	—	—	1	—
NR	4	12	20	2	38	11	32	52	5	100	4	5	9	40
Tot	97	264	226	5	592	16	45	38	1	100	100	100	100	100

Injury to Personnel

NATURE	A	B	C	D	Tot	PER CENT					PER CENT			
						A	B	C	D	Tot	A	B	C	D
A	1	—	1	1	3	33	—	33	34	100	2	—	2	+
B	10	3	3	9	25	40	12	12	36	100	19	8	6	2
C	4	—	—	4	8	50	—	—	50	100	8	—	—	1
D	28	14	6	18	66	43	21	9	27	100	55	39	12	4
E	—	2	12	45	59	—	3	20	77	100	—	6	25	11
F	5	8	11	165	189	3	4	6	87	100	10	22	22	40
G	1	8	13	108	130	1	6	10	83	100	2	22	27	26
H	—	—	1	56	57	—	—	2	98	100	—	—	2	13
I	—	—	—	1	1	—	—	—	100	100	—	—	—	+
N	2	—	1	5	8	25	—	12	63	100	4	—	2	1
X	—	1	1	3	5	—	20	20	60	100	—	3	2	1
Y	—	—	—	3	3	—	—	—	100	100	—	—	—	1
Tot	51	36	49	418	554	9	6	9	76	100	100	100	100	100

MEANING OF LETTERS

DAMAGE TO AIRCRAFT		INJURY TO PERSONNEL		NATURE OF ACCIDENT	
A	Washout	A	Fatal	A	Collision, full flight, with aircraft
B	Major Overhaul	B	Severe	B	Collision, with flight, with non-aircraft
C	Major Repair	C	Minor	C	Spin/stall eng. fall
D	Minor Repair	D	None	D	Spin/stall engine OK
				E	Forced Landing
				F	Landing Accident
				G	Take-off Accident
				H	Taxiing Accident
				I	Fire in Air
				N	Structural Failure
				X	Miscellaneous
				Y	Indeterminate
				NR	Not Responsible

Table 4
CLASSIFICATION OF ACCIDENTS BY CAUSE
LIGHT PLANES, 1937

Damage to Aircraft		CAUSE		*		Tot		PER CENT (Read Across)												PER CENT (Read Down)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
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* MI includes accidents whose cause was unknown of which there were four.

Under DAMAGE TO AIRCRAFT were 1 C, 3D; under INJURY TO PERSONNEL 4 D; under NATURE OF ACCIDENT 1 F, 1 X and 2 Y.

† NR accidents not included under INJURY TO PERSONNEL.

MEANING OF LETTERS

CAUSE OF ACCIDENT		DAMAGE TO AIRCRAFT		INJURY TO PERSONNEL			
A	Completely Demolished	C	Major Repair	A	Fatal	C	Minor
B	Major Overhaul	D	Minor Repair	B	Severe	D	None
PI	Pilot Error	A	Collision, full flight, with aircraft	H	Taxing Accident		
ST	Structural Failure	B	Collision, full flight, with non-aircraft	I	Fire in Air		
WE	Weather	C	Spin/stall eng. fail	N	Structural Failure		
AP	Airport	D	Spin/stall engine OK	X	Miscellaneous		
MI	Miscellaneous	E	Forced Landing	Y	Indeterminate		
EN	Engine Failure	F	Landing Accident	NR	In collision but responsible		
NR	In collision but not responsible	G	Take-off Accident				