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# Spin Training for Pilots - Necessity or Irrationality?

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**SPIN TRAINING FOR PILOTS -  
NECESSITY OR IRRATIONALITY?**

Current Issues in Aviation Management  
(ATS 350)

## ACKNOWLEDGMENTS

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## ABSTRACT

Throughout the history of aviation, stall/spin accidents have claimed the lives of brave men and women who dared to attempt flight. Over the years, much debate has occurred over the spin phenomenon, with the FAA and the NTSB taking opposite sides about the necessity or irrationality of training America's aviators in spin recovery. This ATS 350 project will focus on the effectiveness of current legislation concerning private and commercial pilot license applicants. The requirements for said licenses, specifically the nonexistence of mandatory spin training for the applicants, will be examined and evaluated. The resultant outcome will hopefully be a standing argument for or against spin training, which may be used in the future to prompt new Federal legislation.

CONVENTIONS USED IN THIS PAPER

<u>NOTATION</u>	<u>DESCRIPTION</u>
AC.....	Advisory Circular
AOPA.....	Aircraft Owners and Pilot's Association
CFI.....	Certified Flight Instructor
CFII.....	Certified Flight Instructor - Instrument
CFMEI.....	Certified Flight Instructor - Multi-Engine
CG.....	Center of Gravity
EAA.....	Experimental Aircraft Association
FAA.....	Federal Aviation Administration
FAR.....	Federal Aviation Regulation
GAMA.....	General Aviation Manufacturers Association
IAS.....	Indicated Airspeed
NASA.....	National Aeronautics and Space Administration
NTSB.....	National Transportation Safety Board

Only the tip of the tail surfaces remain identifiable. The wings are twisted and mangled, and the airframe is a blackened mass of melted aluminum. The engine and propeller are completely deformed, having been forced into the cabin by the impact of the crash. This picture, while fictitious, may describe many hundreds of stall and spin accidents which result in 'inadvertent' loss of lives each year in America.

The term 'inadvertent', so often used by the NTSB, seems redundant. The pilot and unwary friends aboard the typical aircraft anticipated only the pleasure of flight, not the termination of their lives. People do not invest thousands of dollars in costly flight training, and tens- or hundreds- of thousands in even more expensive airplanes, with the intention of shortening their time on earth.

It has been said that, "The essence of good basic flight training is to provide pilots with a protective armor of knowledge about - and dependable motor reactions to - potential hazards in their incipient stages" (Mason, 1982). Pilots must not be overconfident; the overestimation of ability has caused more than one accident. However, a lack of confidence and uncertain reactions plague many 'fly for pleasure' pilots today. With a properly trained pilot, flying is a reasonably safe method of transportation. Unfortunately, as with any other mode of travel, it is only as safe as the individual at the controls.

This ATS 350 project will focus on the apparent effectiveness of current legislation concerning private and commercial license applicants. The requirements for said licenses, specifically the nonexistence of mandatory spin training for the applicants, will be examined and evaluated. While the subject of spin training and its relation to stall/spin accidents has been debated fervently over the last half-century, this undesirable and often unexpected maneuver which ended the lives of many pioneer aviators continues to surprise and kill pilots today.

When asked to instruct a new student in the procedures of flying an aircraft, every instructor is faced with difficult decisions concerning the training steps to be taken. The role of the FAA in flight instruction has always been to lay guidelines for competency in piloting, and to test the applicants on their skill in meeting those guidelines. The standardization of the flight test removes doubt as to the quality of the instruction received, and ensures the general competency of America's aviators.

Flight instructors have been limited, however, in providing instruction to students on the characteristics of and recovery from spins. In 1949, the government mandated that only applicants for instructor licenses be required to demonstrate competency in spin recovery, and furthermore classified spins as an aerobatic maneuver (which may only be performed with parachutes aboard for each occupant of the aircraft). These regulations



have severely limited the instructor in making personal judgments as to whether to will include spin demonstrations in his/her flight instruction.

From this limitation arises the spin training argument. Many instructors do not feel their students are safe and competent pilots without adequate training in spin recognition and recovery. In addition, instructors are bound by regulation and personal honor to provide 'competent instruction' to their students. "If a student dies of a stall/spin accident, could I have prevented it with proper instruction?" is a question no flight instructor ever wants to answer.

Spins have been the topic of discussion and debate since the first airplane crashed as a result of one. The exact date of the first lesson in spin recovery is not known, but it was common to teach spins to students before 1926, when Congress enacted laws governing commercial aviation (Mason, 1982). The primary function of the Aeronautics branch of the Department of Commerce was to establish procedures for licensing aircraft and pilots and to develop air traffic regulations for all to abide by (Mason, 1982).

As part of basic flight training, students licensed between 1926 and 1949 were required to demonstrate their skill by spinning an aircraft two turns in each direction. The area inspector (now normally a designated examiner), interestingly enough, watched the student's maneuvers from the safety of a lookout

tower (Mason, 1982). While spin training and demonstration prior to licensing were discontinued many years ago, they are still a popular topic among everyone from the student pilot to the Administrator of the FAA.

#### WHAT IS A SPIN?

The FAA's Flight Training Handbook states that a spin is "...an aggravated stall that results in autorotation. The airplane describes a corkscrew path in a downward direction. One wing is producing effective lift, and the airplane is forced downward by gravity, rolling and yawing in a spiral path" (Federal Aviation Administration, 1965).

This is a good written description of the pattern of a spin, but a few points deserve clarification. 'Autorotation', according to Webster, is defined as "...to turn around or cause to turn around a center point or axis without conscious thought, volition, or outside regulation" (Webster, 1989). Therefore, a spinning aircraft is not actually performing a maneuver per se, but is 'moving' out of the control of the pilot.

A second point to examine is the term 'effective lift' - not an implication that a wing is actually flying, but rather that one wing is producing more lift than the other, resulting in an imbalance of lifting force and a rolling moment. Both wings must technically be stalled for an airplane to spin; if one remains flying, a diving spiral will normally occur, which is quite different from a spin (Mason, 1982).

Thirdly, it is important to notice that the spinning motion is very complicated and involves simultaneous rolling, yawing, and pitching while the airplane is at high angles of attack and sideslip (Hoffman, 1976). The spin, as opposed to a spiral dive, occurs with both wings stalled and involves separated airflow in a region beyond the stall. Therefore the aerodynamic characteristics of the aircraft are very nonlinear - the relative wind does not travel along a straight line, but rather strikes the airplane at a curve, producing as an end result a very low IAS and autorotation. For a pictorial image of a spin, see Exhibits 1 through 3.

Spins exist in several varieties: over the top, out the bottom, flat, and inverted (Twombly, 1989). Due to the intrinsic complexity involved in differentiating spin types, however, (and the fact that such detailed information is unnecessary for one to be knowledgeable of training legislation), only the basic factors common to all spins will be examined.

The spin in general can be considered to consist of three phases: the incipient spin, the developed spin, and the recovery (Bowman, 1971). An illustration of these stages is given in Exhibit 2.

The incipient phase of a spin begins with an asymmetric stall - one wing becomes more stalled than the other, and the airplane begins to roll. Autorotational forces begin to develop due to one wing producing more lift, the other producing more

drag. The flight path begins changing from horizontal to vertical, and the axis of rotation appears somewhere ahead of the nose and begins to approach the airplane. The axis is often offset in the direction of rotation, and will approach the CG if the spin flattens out (Mason, 1982). All of these aerodynamic changes occur in four to six seconds (for most light aircraft), and consist of approximately the first two turns (Hoffman, 1976).

By one and a half to three turns (for most light aircraft), the spin will begin to appear fully developed, although some light airplanes will require up to six complete revolutions to reach the 'developed' phase. The fully developed spin is characterized by a stabilized turning rate and a flight path which is almost vertical (Hoffman, 1976). The autorotational forces (both aerodynamic and inertial) have established a fairly constant nose attitude, and are rotating the aircraft steadily with no control surface movement.

With proper control placement, the recovery phase begins. As the balance between the aerodynamic and inertial moments is broken by control surface movement, the rotational speed begins to decrease and the nose attitude steepens (Mason, 1982). The recovery stage ends when all rotation has ceased, and the airplane is quickly increasing airspeed in a diving attitude (Hoffman, 1976).

This is a spin. Nearly all airplanes are capable of exhibiting this phenomenon, albeit with widely varying characteristics (Mason, 1982). The numerous forces involved and the fact that no two airplanes spin alike make this maneuver quite complex and dangerous if entered inadvertently. While we do not have all the answers to spin-related questions, much research has been done (both formal and informal) so as to increase the knowledge available to aviators concerning this potential killer. But where has our new-found knowledge led us?

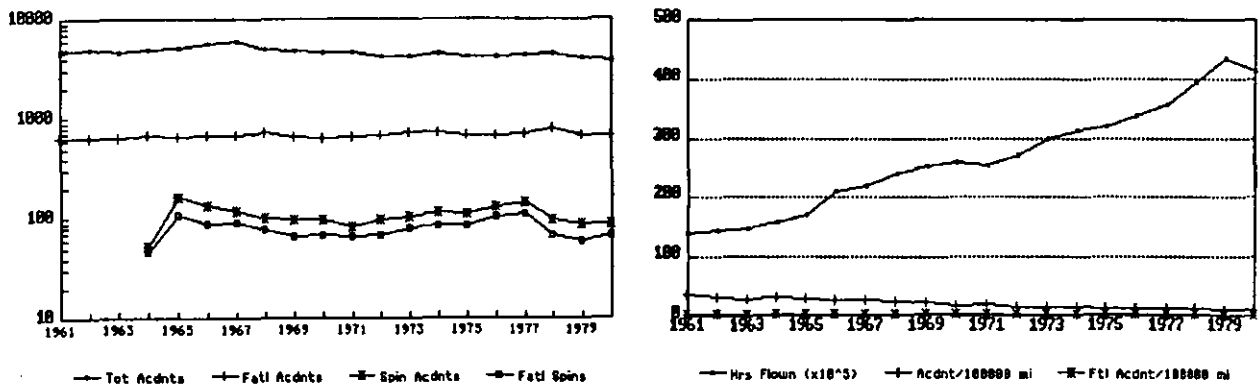
#### FACTS AND FIGURES

In an attempt to discern if a need exists for training today's aviators in spin characteristics and recovery procedures, an examination was made of aircraft accidents listed in the U.S. Civil Aviation Accident Reports, published annually by the NTSB. While accurate statistics for pre-1960 accidents are sketchy (actual accident records were not maintained by the Safety Board before 1964), some pertinent information was disclosed.

As indicated by the following graph, general aviation has proven to be a fairly safe business. Over the years, the number of hours flown annually has dramatically increased, while the total numbers of accidents, spin accidents, and fatal accidents has remained remarkably the same. General aviation is still going strong, and if its continually improving safety record is any predictor, it will continue to thrive throughout the nineties and into the twenty-first century.

# Figure 1

## General Aviation Accident Trends



If the accident figures given above are used to determine the need for spin training for America's aviators, it would be difficult at best to provide a solid argument for the training. Since the number of spin accidents has remained relatively constant since 1960, while the total number of aircraft hours flown annually has increased, the logical conclusion is that GA pilots have become safer, and are having fewer and fewer spin accidents:

While verified pre-1960 data are difficult to obtain, it is not impossible to find a few statistics (especially from those opposed to mandatory spin training, since the general aviation accident rate has improved over the years). One source stated,

"Some 30 years after spin training was dropped for all but CFI applicants, the incidence of fatal stall/spin accidents, as a percentage of all accidents, had declined seventy-five percent" (Twombly, 1989).

As far as the 'official' word of the NTSB is concerned, the Safety Board appears to have taken a pro-spin training position - a stance against the FAA's position of no spin training required. Six years after mandatory training was dropped, a recommendation was issued by the NTSB that spin recovery training should again be made a prerequisite for soloing. The FAA said no, citing public opinion for more intensive stall recognition and recovery training as the reason (Twombly, 1989).

In 1972 the NTSB tried again, this time with a full-blown three year study on general aviation stall/spin accidents. Included in the list of recommendations made in 1972 are:

- 1) The FAA should issue an Advance Notice of Proposed Rule Making to explore the potential of reducing stall/spin accidents through innovation in ground and flight training curricula.
- 2) The FAA should evaluate the feasibility of requiring at least minimal spin training of all pilot applicants.
- 3) The FAA, the AOPA, the National Pilots Association, the National Association of Flight Instructors, the Flight Safety Foundation, and the National Business Aircraft Association, through an individually ap-

propriate medium, should specifically advise pilots to guard against the occurrence of a stall/spin accident subsequent to an engine failure or malfunction (National Transportation Safety Board, 1972).

Once again, the FAA declined, stating the safety record as just cause; in 1945 through 1948, stall/spin accidents accounted for about forty-eight percent of all fatal accidents. In contrast, the four-year period of 1965 - 1968 saw stall/spin accidents accounting for only about twenty-seven percent of all fatal accidents (Hoffman, 1976). Since most stall/spin accidents begin during takeoff, while on approach, or as a consequence of 'buzzing' or performing aerobatics, reasoned the FAA, the pilot is too low to the ground to recover. Moreover, since there can be no spin without a stall, the training emphasis must be on recognizing and avoiding the onset of a stall (Twombly, 1989).

The Safety Board returned to the statistics, and in 1976 published its pro-spin training reasoning. The NTSB stated that the 1945 - 1948 spin accident rate was abnormally high due to the post World War II aviation boom - thousands of military pilots returned to civil pursuits, including light plane flying in an unstructured, non-precision environment. Additionally, the Safety Board added:

It is unclear whether this decline (1948 vs 1968) is due to CAR Amendment 20-3, which in effect eliminated spins and emphasized stalls, or to a change in aircraft and



flight discipline, or to a combination of these factors. However, the fact that the stall/spin accident rate remains as high as twenty-seven percent is in itself reason for efforts to lower the accident rate by improving stall/spin training (Hoffman, 1976).

#### U.S. VS CANADA - AN EXPERIMENT IN SAFETY

Undoubtedly, the most widely accepted 'scientific' method of testing a theory is found by maintaining two groups, altering in one group the particular variables involved, and comparing the results. Federal arguments aside, perhaps such a method is available in testing the pros and cons of mandatory spin training. The two groups under scrutiny are American pilots and Canadian pilots, and the laboratory is the airspace.

While many variables certainly go unchecked (and technically ruin the experiment), it surely must be worthwhile to compare Canada's aviation record to America's, for Canadian authorities did not follow the United States' lead concerning training requirements. Spin demonstration and recovery continues to be mandatory for the private license in Canada. A comparison of the large bodies of annual accident records produces staggering results: Canada's stall/spin accident rate is over ten times that of the United States (Collins, 1987).

While searching for ulterior factors which might incite such a high spin accident rate, many seem to rule themselves out. Canadian GA pilots fly more Cessna 172's than anything else, fol-

lowed by a wide assortment of Piper Cherokees, Gruman Tigers, Beech Bonanzas, and commonplace American twins (Collins, 1987). The Canadian fleet of aircraft is almost identical to the United States'.

While there does exist a climatological difference between the U.S. and Canada, many Canadian regulations which deal with weather are more stringent than their American counterparts. For example, VFR on top is prohibited in Canada (Collins, 1987). Additionally, trend analysis show Canada to have fewer severe thunderstorms than America. Weather is definitely a factor in many accidents, but Canadian pilots appear to be extremely cautious when flying in it. Records indicate that on average, only one percent of all Canadian stall/spin accidents occurred after "continuing VFR flight into adverse weather conditions" (Collins, 1987).

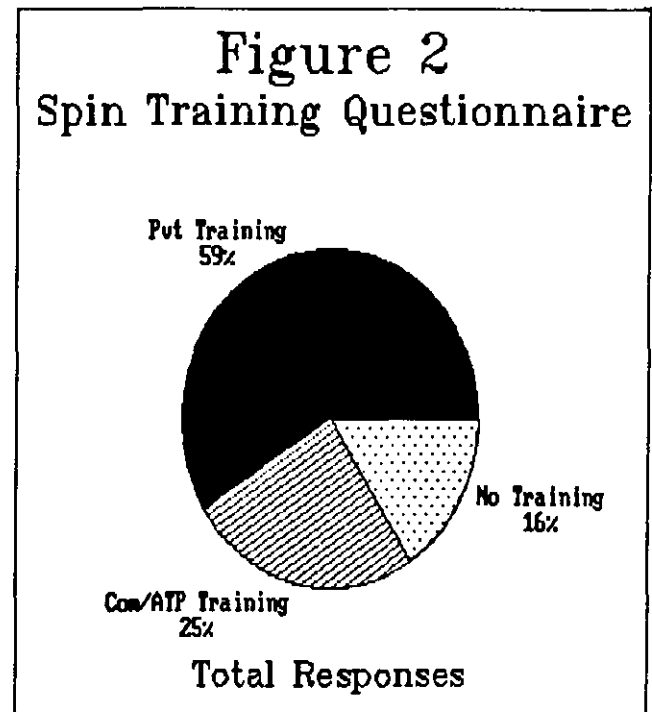
Opponents of mandatory spin training have always stated that some spin accidents will occur during the training, and that these would outweigh the benefits which are provided to students. Once again, the Canadian statistics seem to agree: "In 1981, Canada's stall/spin accidents associated with training amounted to twice the total stall/spin accident rate in the U.S." (Collins, 1987).

Admittedly, these comparisons of American and Canadian accident figures represent a collection of unsupervised data. Many variables exist which may nullify the validity of any hypothesis

derived from such a comparison. However, an extremely large variation in spin accidents is undoubtedly present, and warrants consideration before solidifying any decision concerning spin training, whether pro or con.

#### OPINIONS OF THE AVIATION COMMUNITY

As part of the research involved in forming a stance for or against mandatory spin training, a questionnaire was distributed among professional (fly for a living) and GA pilots (see Exhibit 4). As indicated by Figure 2, when expressed as a percentage of the total responses received, the results of the questionnaire were overwhelmingly in favor of a spin requirement for private pilot applicants.



In an attempt to more accurately measure the validity of each response based upon the experience level of the pilot, a system was developed to weight each opinion received. It was felt that actual hours flown should have the potential for precedence over pilot ratings, since a 5000 hour private pilot has undoubtedly more experience than a 300 hour CFI. However,

aviators with several certificates and ratings have received more instruction, and therefore should hold more weight than those without the additional ratings.

After carefully examining the data, a point system was implemented, with points being awarded as follows:

3/10 point for each certificate or rating	X.X
Approximate hours flown / 1000	+ Y.Y
Total points added to the category	N.N

For an example of the methods of the weighting, consider two aviators: Pilot A is a private pilot with an instrument rating and 3500 hours flown, Pilot B is a commercial pilot with instrument, multi-engine, CFI, CFII, CFMEI ratings but only 2000 hours. Their weighted scores are shown in Figure 3.

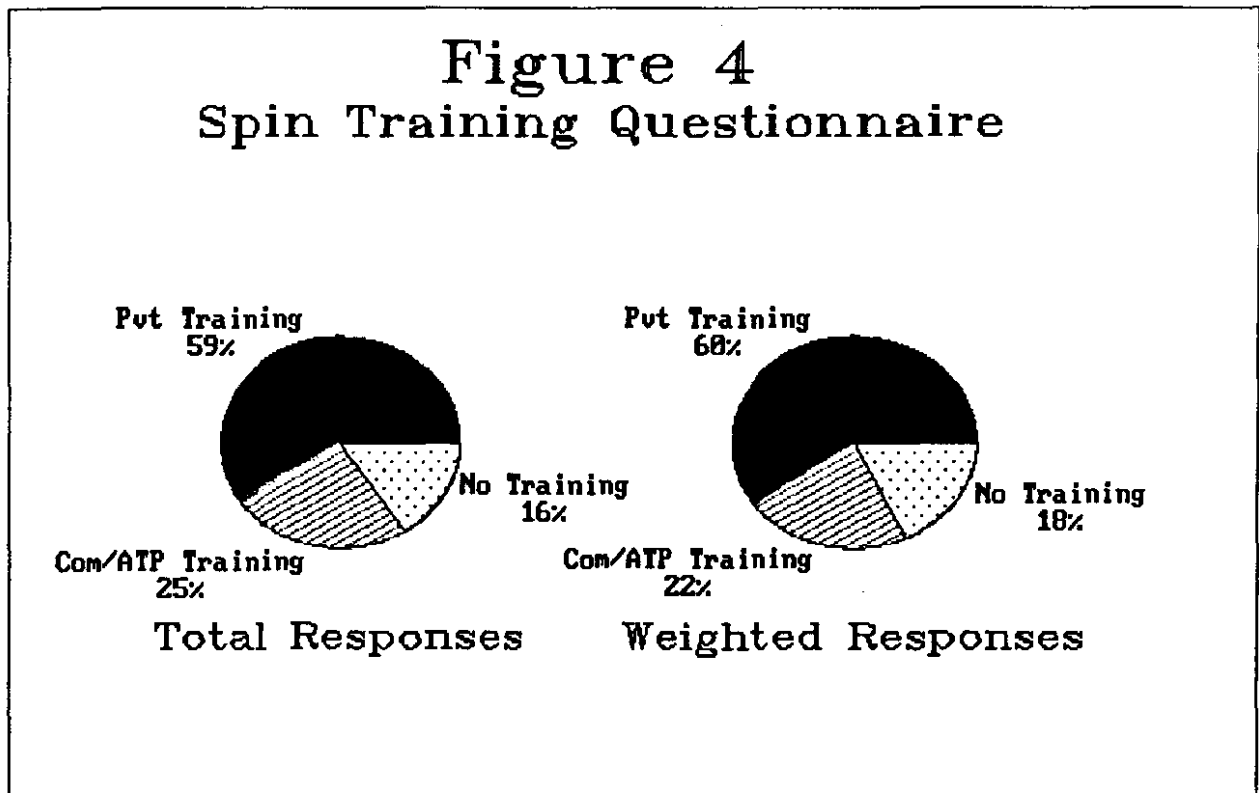
Pilot A		Pilot B	
Private	0.3	Private (assumed)	0.3
Instrument	0.3	Commercial	0.3
Hours (3500/1000)	3.5	Instrument	0.3
	<hr/>	Multi-Engine	0.3
Total	4.1	CFI	0.3
		CFII	0.3
		CFMEI	0.3
		Hours (2000/1000)	2
			<hr/>
		Total	4.1

As shown by Figure 3, Pilot B's extra training made up for 1500 hours of flight time, and the response was equally weighted with pilot A. Once all the results of the questionnaire were in and tabulated, the weighted scores were as follows:

<u>CATEGORY</u>	<u>WEIGHTED SCORE</u>
No spin training	46.7
Commercial & ATP training	57.2
Private spin training	159.8

When these scores are transposed into percentages and placed against the percentages of the total responses with no weight added, the values are not significantly different.

**Figure 4**  
**Spin Training Questionnaire**



## THE FAA TAKES ACTION

As becomes instantly apparent from the survey results, the overwhelming majority of the aviators surveyed believe that spin training would be beneficial and should be mandatory for private or at least commercial pilot applicants. Yet the FAA has repeatedly cited public opinion as a major factor influencing its stance against requiring spins to be taught. In an attempt to understand the position taken by the government, transcripts from a recent major congressional debate on spin recovery training were obtained.

The U.S. House of Representatives investigated the spin training dilemma in June of 1980. During the study testimonies of prominent aviators from across the country were presented to the Subcommittee of Investigations and Oversight. Included in the hearings were the opinions voiced by representatives of such agencies and organizations as the FAA, the NTSB, NASA, Piper Aircraft Corp., the EAA, AOPA, GAMA, selected test pilots, several military officials, and numerous others (U.S. Congress, 1980).

Unfortunately, a standoff ensued - an almost fifty/fifty split prevailed in the hearings, with some speakers for and some against mandatory spin training for private applicants. Apparently (from reading the transcripts), one side would argue vehemently for mandating the training, and would state excellent reasons for doing so. Then the anti-training side would be re-

lated by another speaker, who would give reasons for not requiring the training which were just as feasible and logical as those arguments from the pro-training side (U.S. Congress, 1980).

Possibly due to the apparent tie by the opposing speakers, no staunch conclusions were drawn by the Subcommittee. The hearings did prompt some action, though. Several revisions and amendments to FAR Part 61 (dealing with flight training) were discussed by the FAA, and after giving the matter due thought and process, an NPRM was issued in the Federal Register on May 26, 1989 which discussed the proposed changes to Part 61.

The most prominent proposals to amend current legislation are:

- 1) Modify FAR 61.105, .107, .125, .127, .183, .187, and Part 141, Appendices A and H to add stall and spin **awareness** (emphasis added) and recovery techniques to the basic subject areas airplane and glider pilots are required to study.
- 2) Modify FAR 61.49 to require flight instructor single engine land airplane or glider applicants to demonstrate spin entries, spins, and spin recoveries on their flight test if they have previously failed the oral or flight portion of a practical test due to deficiencies in the stall/spin area. (Federal Register, 1989).

As of August, 1990, the FAA is still considering these latest potential changes. A final ruling on the NPRM is expected in November, 1990, and an AC is already underway to instate the new regulations (Leonard, 1990). According to the contracted author of the AC, "The main focus of the training would be to incorporate the use of distractions, such as those cited in the

General Aviation Stall Awareness Training Study, into stall awareness training because this is where stalls (and subsequently spins) are most likely to occur" (Leonard, 1990).

These training modifications are slight, and will only minimally change the way most flight instructors and flight schools do business. While introducing distractions into maneuvers at minimum control airspeed may bring students closer to inadvertently entering a stall and possibly a spin, many people do not feel that only taking a student 'to the edge' is enough, as was evidenced through the public questionnaire. In an attempt to gather as many credible opinions as possible, fifty letters of inquiry were mailed to U.S. flight schools certificated under FAR Part 141.

#### OPINIONS - U.S. FLIGHT SCHOOLS

Unfortunately, of the fifty schools polled concerning their training procedures for private students, only six responses were obtained. (Incidentally, so as to dispel curiosity, the Flight Department of Southern Illinois University at Carbondale was not asked for a statement.) Of the six schools who replied, two give spin recovery training to private applicants, two do not, and two provide it on a "by student request" basis. Since six responses are undoubtedly not enough for an accurate mix, the results can not be considered in basing a decision for or against mandating spin recovery training.



## OPINIONS - INDEPENDENT AVIATION ORGANIZATIONS

In addition to the responses by Part 141 flight schools, official statements were obtained from the EAA, AOPA, and GAMA. Once again, the organizations queried are at a standoff: the EAA stringently regards spin training as something that every pilot should obtain, and has requested the FAA to mandate spin training several times (Waldren, 1990).

GAMA, on the other hand, opposes mandatory spin training. In an official statement responding to a government inquiry, GAMA's chairman stated, "Once we formally teach a pilot trainee to spin and recover, we must expect he is going to do it!...We believe that spins should not be required as part of the flight training syllabus..." (U.S. Congress, 1980).

Lastly, AOPA is not taking sides. According to one AOPA official, "Partly due to the different thinking on part of our members, AOPA as an organization does not hold to a stance in the spin/no spin training debate" (MacNair, 1990).

## AIRCRAFT MODIFICATIONS TO INCREASE SAFETY

Opinions and debates aside, some actions are being taken to prevent the stall/spin accidents which claim aviators' lives every year. These actions are in design and manufacturing, and reflect an attempt by our airplane builders to create the 'spinproof' aircraft. Research has been conducted over the last several years to identify means to improve the spin resistance of

light aircraft (DiCarlo, 1986), and while the totally 'spinproof' airplane may never become available, advances are being made which hold promises for the future.

These attempts at providing safer airplanes are not new; in the 1930's the engineering efforts of F. E. Weick at NASA's Langly Research Center led way to the Ercoupe. The Ercoupe incorporated limited elevator travel, a nose-down tendency, and a carefully designed wing stall progression which worked so well that the entire wing could not be stalled (Chambers, 1986). Interestingly enough, in the 40 years since the development of the Ercoupe, not even one is listed as ever having a spin accident (Chambers, 1986).

More concepts emerged in the 1940's and 50's which were later incorporated into the standard normal and utility category airplanes. Wing washout (a twisting of the wing to cause the wing root to stall before the wing tip), an increased wing aspect ratio, and limiting the rudder travel are all concepts implemented by Cessna, Piper, and others manufacturers to improve the stability of their aircraft (Phillips, 1986). While some advances have been made, and today's airplanes are much more stable than older models, anyone who has ever felt a Beech Sundowner or Piper Tomahawk enter a spin will undoubtedly agree that more spin resistance would be welcome.

Research continued into the seventies and eighties, and new methods of controlling the spin were developed. By extending wing chords and reshaping the leading edge of the outer wing panels to give a 'drooped' appearance, NASA researchers found new methods of controlling the progression of a stall (Chambers, 1986). The 'drooping wing' was evaluated and flight tested on four research airplanes, and the spin resistance of these aircraft improved so significantly that a new certification category of 'spin resistant airplane' was proposed to the FAA (DiCarlos, 1986).

#### CONCLUSIONS AND FINAL DECISION

As I entered into the research phase of this study, I must admit I was not unbiased. It was my opinion that spin training - knowing the 'outer limits' of yourself and your airplane, would undoubtedly make one a better pilot. In reviewing the pilot questionnaire, it seems that I was not alone in my position.

However, after what I feel was a thorough study of spins, spin training, and aircraft in general, I have been forced to change both my perspective and my opinion. Certainly, no CFI wants to carry the guilt which comes when anyone he/she taught perishes while flying. But just as that instructor can not be in the cockpit with each student all the time, he or she can not be held accountable for any or even every accident which occurs. If a student dies in a spins, provided the instructor fully taught

and equipped the pilot to avoid the threat, then the CFI is no more to blame than if the student flew into a level five thunderstorm.

The FAA, from its 'parental' perspective, must do what it perceives is best for all; i.e. will prevent accidents and spare lives. Looking long and hard at the safety record of Canada's GA pilots should make one suspicious that mandatory spin training is not effective. Moreover, it might be seen to cause more accidents than it prevents. The position which the FAA must take is one of not assuming responsibility for each individual, but rather laying the best guidelines possible to protect America's aviators.

Is spin training beneficial? To me, personally (the author holds a commercial license with instrument and multi-engine ratings), yes, it is. I have received training in spin recovery from a qualified instructor, and feel that I am a better pilot because of it. For some, however, being afraid enough of spinning to become very prudent at airspeed and attitude monitoring will serve the same purpose, and without the possibly frightening experience.

Perhaps one day every commonplace airplane will be spin-resistant, or maybe even spinproof. Perhaps the only people spinning will be those practicing their aerobatics. For now, though, I feel the way to prevent deaths is through spin avoidance training. Those who wish to learn to spin may do so,

but it seems that those who do not want to spin should be taught to be very careful about avoiding them. It can be done - many pilots today have never spun, whether intentionally or inadvertently, because they are careful to mind their airspeed and attitude. We who enjoy the wild maneuver must remember that the ultimate goal is not to teach all to spin and recover, but to save lives.

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APPENDIX A



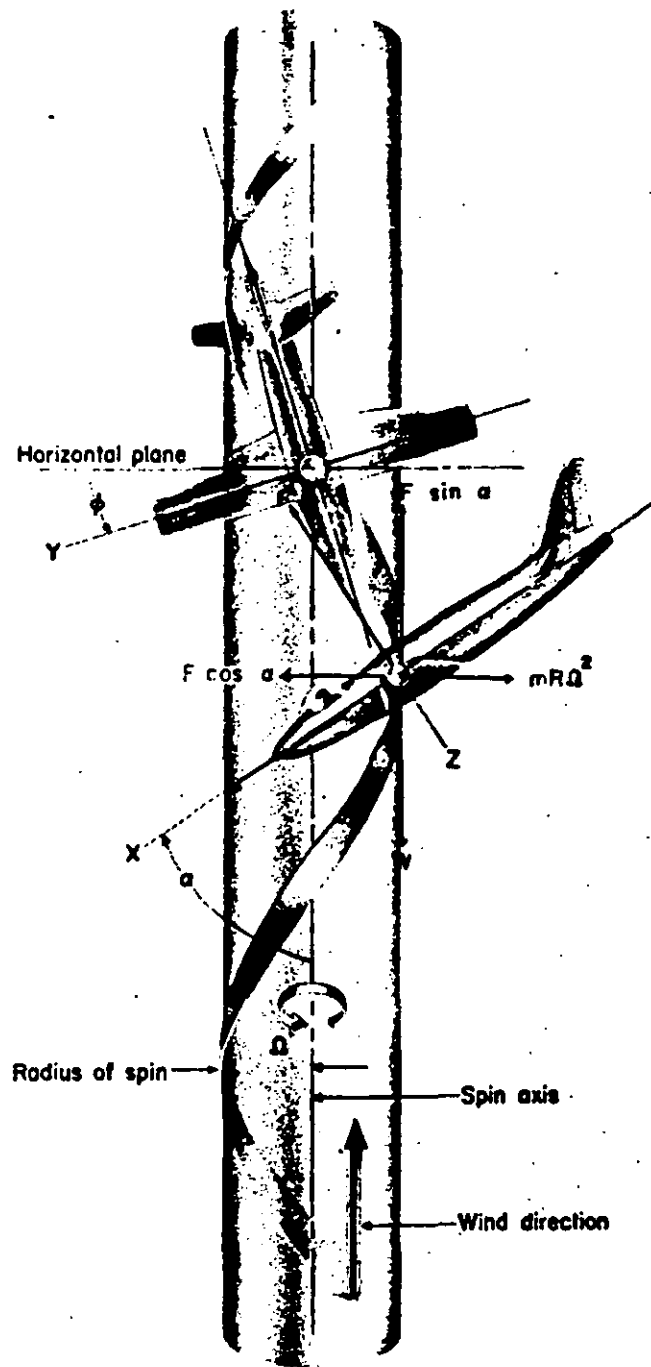


EXHIBIT 1 - TWO VIEWS OF A SPINNING AIRCRAFT

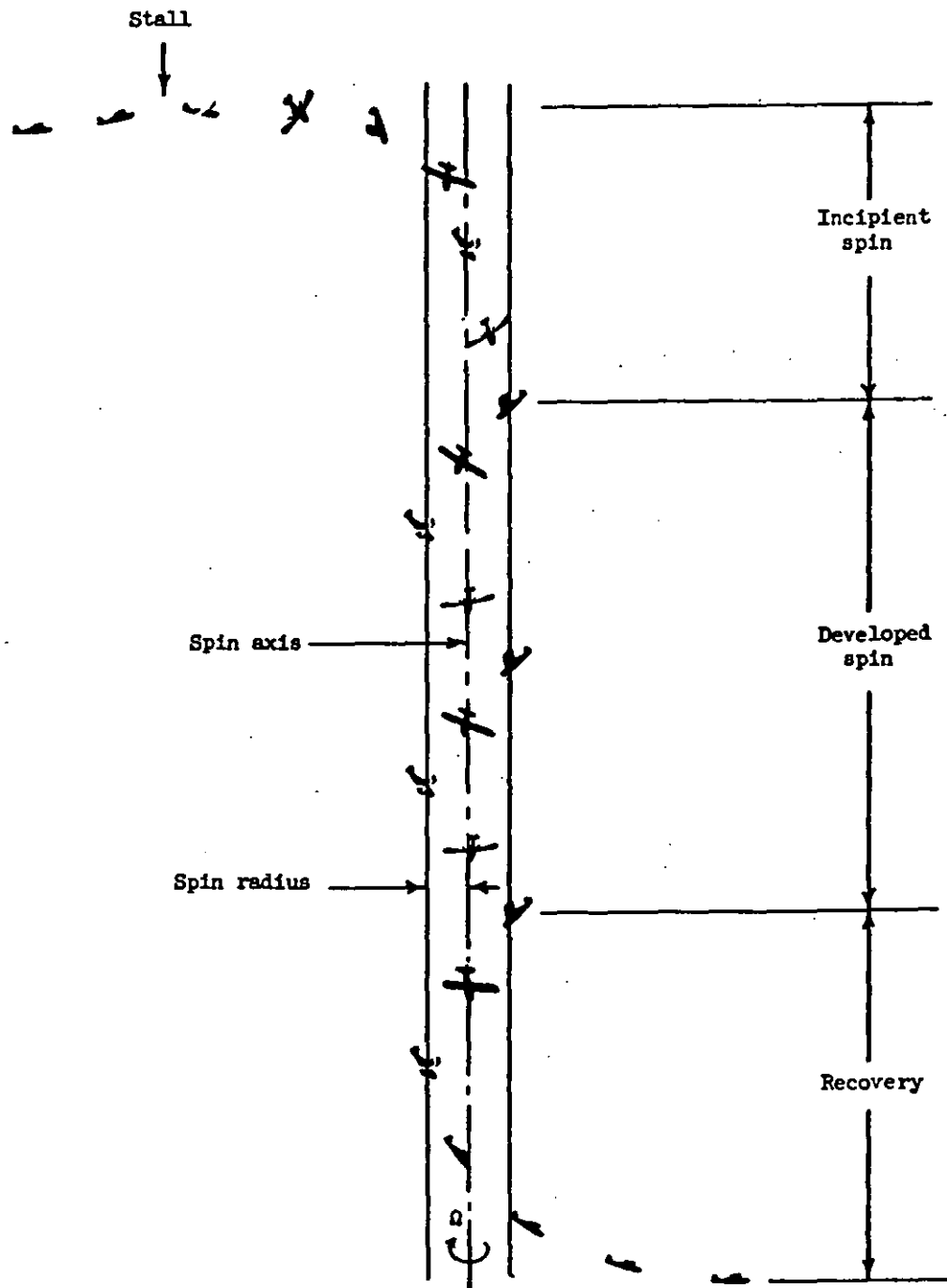


EXHIBIT 2 - ILLUSTRATION OF SPINNING MOTION AND PHASES

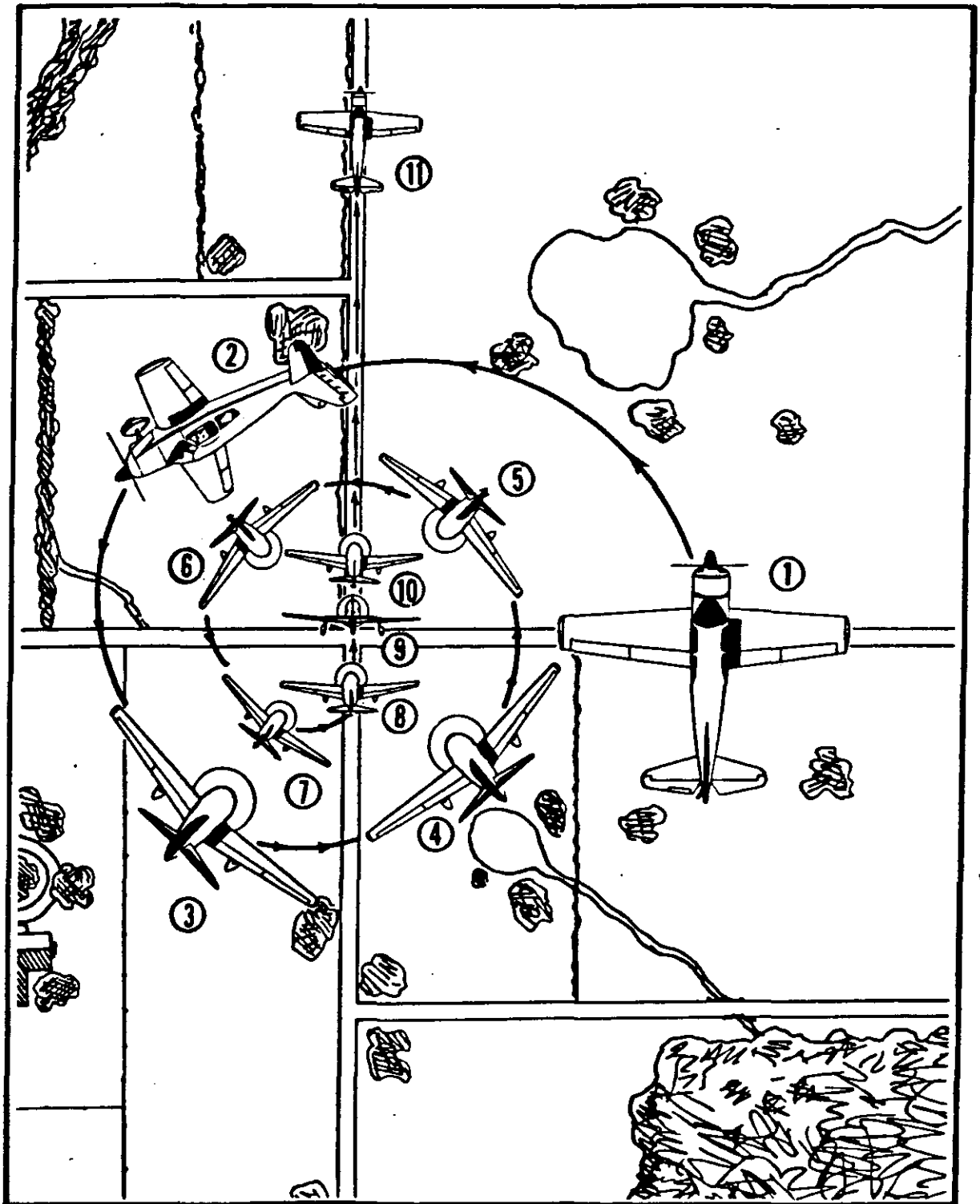


EXHIBIT 3 - THE SPIN VIEWED FROM ABOVE

Spin Training Questionnaire	
Pilot Name	Certificate(s), Ratings & Limitations
Apr. Hours Flown	
<input type="checkbox"/> I favor mandatory spin training for private pilot applications. <input type="checkbox"/> I favor mandatory spin training for commercial pilot applications. <input type="checkbox"/> I favor mandatory spin training for ATP applications. <input type="checkbox"/> I do not favor mandatory spin training.	
Related comments:	
Richard L. Hall 260 Sandcut Rd. Madisonville, Ky 42431	Free copies of the questionnaire results may be obtained by writing & requesting " Spin Training Results".

**AIRCRAFT FIRE HAZARDS -  
BETTER SAFETY LEGISLATION WILL SAVE LIVES**

University Honors Thesis  
(UHON 499)

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## ABSTRACT

An in-depth study of aircraft cabin fires and the subsequent deaths resulting from flame, heat, and toxic gases has prompted the Federal Aviation Administration to require public air carriers to replace cabin materials with flame-resistant fabrics, carpets, etc. However, no such legislation exists to protect the occupants of non-transport category aircraft from fire hazards. This thesis will examine the present danger found in all 'small' aircraft and study the devastating results which flammable aircraft cabins have had on human lives.

In addition, a look will be taken at some new technologies which offer practical solutions to this hazard, and possible future legislation concerning implementing these technologies will be discussed.

CONVENTIONS USED IN THIS THESIS

<u>NOTATION</u>	<u>DESCRIPTION</u>
FAA.....	Federal Aviation Administration
FAR.....	Federal Aviation Regulation
ATC.....	Air Traffic Control
NTSB.....	National Transportation Safety Board
AD.....	Airworthiness Directive
CO.....	Carbon Monoxide
HCN.....	Hydrogen Cyanide
HCL.....	Hydrogen Chloride
PVC.....	polyvinylchloride
ppm.....	parts per million
F.....	fahrenheit



There is a popular wall plaque in print about aviation which says, "Aviation in itself is not inherently dangerous. But to an even greater degree than the sea, it is terribly unforgiving of any carelessness, incapacity or neglect." Beneath these words is a shocking photo of a vintage biplane crumpled into the bough of a dead, leafless tree. While at first such a sight appears humorous, there is a dark reality which underlies the author's words. Today we are facing a serious safety problem in general aviation, one which should be almost non-existent, but instead is raging out of control.

The hazards of fire on board aircraft are not new; they have been known and feared as long as man has flown. Until recently, however, very little could be done to reduce or eliminate the potential of an on-board fire. Owners and operators had no choice but to fly aircraft with the interior furnishings supplied by the manufacturer, or possibly from a third party aircraft interior company. This grim reality has led to many horrible deaths and permanent disfigurements when people have been trapped in flaming cabins, surrounded by materials that burn or release toxic gases, and encased in a metal and glass airframe.

Since 1984, new technologies have emerged which can significantly reduce and sometimes eliminate the hazard of aircraft fires (Likakis, 1988). Dramatic advances have been made in materials and techniques which offer a means to render the aircraft cabin virtually fireproof. Owners and operators are no longer at the mercy of the manufacturer, but have the opportunity

to both reduce the flammability of their aircraft and increase the amount of time available for escape. While many of these modifications are not inexpensive, some can be implemented at a very small cost - and one life spared a gruesome death would certainly be worth the expense.

#### Aircraft Hazards - Fire

Ask any pilot what he/she considers the most terrifying emergency in an aircraft, and the response will almost certainly be "fire". Fire is one of the most significant hazards for any aircraft, whether commercial or general aviation. While an in-flight fire is certainly a serious threat, a post-crash fire is much more common. Accident reports often prove that many 'survivable' accidents produced fatalities when the aircraft burst into flames upon reaching the crash site (NTSB, 1965-1985).

One study examined 155 business and corporate transportation accidents which occurred in the United States over a three year period. Of the total 155 crashes, forty-one of these produced fatalities (26%). In twenty-nine of these 155 (18.7%), a post-crash fire occurred. While a crash and burn rate of under nineteen percent may seem small, it proves interesting that these twenty-nine crashes involving a post-crash fire account for more than forty-six percent of the total number of accidents with fatalities. With a bit of simple math (see Exhibit 1), an even more eye-opening fact is disclosed - a fatality occurred in 65.5% of all accidents involving a post-crash fire (Likakis, 1988).

On the average, a fire breaks out in around ten percent of all general aviation crashes (NTSB, 1965-1985). Like the corporate crashes previously cited, fires in general aviation accidents account for around half of the total fatalities (NTSB, 1965-1985). Therefore, it would be safe to say that if a fire breaks out in your aircraft, you have approximately a fifty/fifty chance of surviving the incident. Is there nothing which can be done to improve the odds?

In times past, the FAA has issued Airworthiness Directives (instructions for mandatory alteration to a particular model aircraft, without which the airworthiness certificate is invalid) concerning fire hazards in small airplanes. Items such as fuel lines routed through the cabin, or weak floorboards and wing spars have been addressed. These concerns seem overshadowed, however, by the flammability of the materials used to construct the cabin interior itself.

If wagering were to be accepted in aviation, it would be almost a sure bet that any particular light airplane has combustible materials built into the cabin, ready to ignite at a moment's notice. Virtually every aircraft ever built, from the ancient Cessna 120 to the giant Boeing 747, has materials on board which will readily ignite and cause fatalities in an otherwise 'survivable' accident (Accufleet, 1989). Probably the largest supporter of aircraft combustion, as well as being an emitter of poisonous gases, is polyurethane foam (see Exhibit 2) - the foam of choice for aircraft seats (Accufleet, 1989).

It has long been known that polyurethane foam poses a great threat in a fire. Firemen are always watchful of couches, chairs, and other furnishings which are constructed with polyurethane. It is also interesting to note that a leading safety magazine for aviators recommends tearing the foam out of the aircraft seats to use for tinder, should one crash in the winter and wish to build a campfire (Likakis, 1988). But seats are not the only problem evident today.

There are other flammable and combustion-supporting materials found in aircraft cabins. One such item, while not so dangerous during actual combustion, but rather after it burns, is door seals composed of cotton or silicone (Julis, 1990).

After flying in small aircraft, it becomes evident that some type of noise attenuation is necessary - extremely so - to block the large amount of low frequency noise generated by the rush of air around the airframe and by the engine and propeller. One method of noise control, as well as blocking the wind, comes by sealing airplane doors with either cotton cord or silicone rubber. Both are found today in light aircraft, and both will burn in a fire. The door seals should not, one might think, be much of a contributing factor to a raging fire, however, in-flight fires will grow extremely quickly when the door seals have been destroyed (Julis, 1990). The rush of oxygen-rich air around the door and into the cabin feeds the fury at an incredible rate, vastly reducing the time available to land and escape.

A fire inside the cabin would be horrifying and probably fatal while in flight, but luckily NTSB findings indicate that most fires start outside - either in the engine or the electrical circuits along the wings and tail. The firewall is the first defense against an engine fire; if your aircraft has an engine, it must have a firewall (FAR 23.1191). However, the firewall is no definite source of protection from heat and flame.

As directed by the FARs, any firewall has to pass a fairly tough test. A section of the proposed material must be able to accept a 2000 degree F blast of flame for fifteen minutes over a ten square inch area and not burn or melt through. However, this FAR is only for non-approved materials, and many metals are pre-approved for firewall use. For example, stainless steel of at least 0.015 inch thickness is pre-approved and does not have to be tested. While 0.015 inch thickness of stainless may well deflect a 2000 degree fuel- or oil-fed fire, it will undoubtedly get quite hot, possibly igniting materials on the inside. Since paper will ignite at only 451 degrees F, it would not be a good idea to have dropped a checklist on the floor just before an engine fire breaks out.

#### Aircraft Hazards - Smoke and Fumes

In the period from 1964 to 1974, more than 900 people lost their lives in transport aircraft accidents that involved fire. These fatalities resulted from accidents of two types: (i) an impact-survivable crash

followed by fire, or (ii) an in-flight fire that resulted in an accident. However, almost half of these fatalities (48 percent) were judged attributable to the direct effects of the fire itself. It is now recognized that the primary cause of death in most fires is the inhalation of incapacitating or lethal quantities of toxic gases or smoke. This is true whether the fire is in an aircraft cabin, a residential bedroom, or a high-rise commercial building (Crane, 1977).

As this excerpt from a FAA document indicates, there is no doubt as to the hazards presented by smoke and gaseous by-products of a fire. In an aircraft, the hazards are compounded by the fact that while in flight, there is literally no where to go to escape the fumes. Post-mortem studies have confirmed that most smoke inhalation victims had breathed sufficient quantities of CO and HCN to cause death or at least total incapacitation (Crane, 1977).

After these findings became well known, the FAA began a series of studies on aircraft fire toxicology. It has been determined that as little as 1500 ppm of CO can totally incapacitate laboratory rats (Crane, 1989), and that burning an average aircraft cushion will induce an atmosphere in the immediate vicinity of the seat of 7500 to 12,500 ppm of CO in under three minutes (Crane, 1987).

As stated before, CO is not the only toxic gas released during an aircraft fire. The effects of HCN on rats and humans alike have been carefully studied, with frightening conclusions. As little as 10 ppm of HCN can have deleterious effects on humans, and this can occur by simple skin contact (versus breathing it in). HCN is water soluble as well, meaning it will be absorbed through the eyes and mucus membranes. In fact, HCN is so potent, it is the gas of choice for criminal executions (Likakis, 1988).

Probably the largest generator of CO and HCN is the aircraft seat itself - the polyurethane foam which provides the cushion, and the PVC based (vinyl) portions of the seat cover. The smoke produced when an aircraft seat smolders or ignites is thick and black, usually carrying a great deal of soot - see Exhibit 3 (Likakis, 1988). This smoke and soot, in addition to CO and HCN, also contains a good sampling of HCL gas. HCL gas undergoes a chemical reaction and forms hydrochloric acid when it comes in contact with water, as it certainly will in the lungs and eyes. Quite obviously, a smoldering or flaming seat in an aircraft is a terrible threat; one which must be avoided at all costs.

One can not place all the blame for toxic fumes directly on the seat, however. Carpeting, especially carpeting with a foam cushion underneath, has been shown to emit large amounts of smoke and noxious fumes. A typical wool, latex and urethane carpeting produced toxic gases when ignited, which totally incapacitated laboratory rats in just five minutes (Crane, 1977).

In addition to supporting the blaze via the rush of air into the cabin, both cotton and silicone rubber door seals will readily ignite and produce toxic fumes which have been proven fatal to laboratory animals (Crane, 1977). For a sampling of the results found in one study of toxic emissions released when igniting aircraft materials, see Exhibit 5.

#### Tragic Examples

Unfortunately, time has proven that it does not take great quantities of smoke to fill an aircraft cabin. When seat cushions, carpets, headliners, or other materials ignite, the air will quickly become filled with fumes and smoke. In such instances, incapacitation and death can occur in only minutes from the deadly gases. The following are narratives of two examples of this fact which are sadly recorded in NTSB accident files.

File #3323 - Cessna 414; July 28, 1982; Lindale, Texas

At 7:22pm local time, the Cessna 414 began its takeoff roll from Garden Valley airport, a private strip near Lindale, Texas. The pilot held a commercial license, with instrument and multi-engine ratings, and had logged a total of 758 hours. The flight was intended to take a church group on a local flight.

The seven seat aircraft took off with four adults and eight children aboard. It lifted off 2000 feet down the runway and climbed in a nose high attitude, oscillating violently in pitch and gaining very little altitude. Twenty to thirty seconds after takeoff, the Cessna settled into thirty foot trees about 4200



feet from the point of lift-off and burst into flames. The airplane was about 445 pounds over maximum gross weight; occupants died of smoke inhalation.

There were no survivors. The accident investigators who arrived at the scene found the wings burned off (presumably from the fuel-fed fire), but the cabin was remarkably intact. All doors and emergency exits were closed; investigators reported there appeared to have been no attempt by anyone to escape the wreck. Many of the deceased were still wearing their seat belts.

Post-mortem studies on the twelve victims were even more convincing. There was found no evidence of any incapacitating injury - not even a single broken bone among all twelve. Further analysis determined the cause of all deaths to be inhalation of toxic gases. Those seated in the front of the aircraft perished from high levels of HCN, while those in the rear had even higher levels of CO.

File #86/02 - Flight 797; June 2, 1983; Covington, Kentucky

On June 2, 1983, Air Canada Flight 797, a McDonnell Douglas DC-9-32 was a regularly scheduled international passenger flight from Dallas, Texas, to Montreal, Quebec, Canada, with an en route stop planned at Toronto, Ontario, Canada. The flight left Dallas with five crewmembers and forty-one passengers on board.

About 7:03pm eastern time, while en route at about 33,000 feet, the cabin crew discovered smoke in the left aft lavatory. After attempting to extinguish the hidden fire and then contact-

ing ATC and declaring an emergency, the crew made an emergency descent and received vectors to the Greater Cincinnati International Airport in Covington, Kentucky.

At 7:20pm Flight 797 landed in Covington. As the pilot stopped the airplane, the airport fire department, which had been alerted by the tower to the fire, began firefighting operations. As soon as the aircraft stopped, the flight attendants and passengers opened the doors and emergency exits and began an emergency evacuation. About sixty to ninety seconds after the exits were opened, a flash fire engulfed the airplane interior. Eighteen passengers and three flight attendants exited from the cabin and the captain and first officer climbed out through their respective cockpit sliding windows. However, twenty-three passengers were unable to evacuate the plane and died in the fire. The aircraft was destroyed.

At the time of landing, witnesses reported that except for the first two feet from the cabin floor up, the airplane was completely filled with dense black smoke. The passengers breathed through wet towels which were distributed by the attendants when the flight crew shut down the air pressurization system in an attempt to delay the spread of the flames. The feed lines to the emergency oxygen system had ruptured after the lavatory caught fire, intensifying the blaze and expending the breathable air. Autopsies have determined that the twenty-three victims of Flight 797 perished due to thermal burns and smoke inhalation.

## New FAA Regulations

After the Air Canada tragedy of 1983, the FAA began an unprecedented series of studies and regulatory actions with the goal of improving fire safety in transport category aircraft. These studies were part of a broad program to enhance airliner safety and were the culmination of a number of factors, including advisory committee recommendations, congressional support, product oriented FAA technical programs, and accident pressures (Sarkos, 1988).

Because of the FAA's concern with the effects of combustible interior materials on accident survivability, great emphasis has been placed on developing programs for testing cabin safety in fire situations, and on the development of improved methods for testing materials which will be used in aircraft cabins. Products from these programs have been incorporated into a series of new regulations which are designed to minimize the hazard present during an aircraft fire.

In December, 1984, the FAA adopted FAR 121.312(b), which spells out new requirements for (among other things) fire-blocking seats. Under the new ruling, the fire resistance requirements for airline seats is tough. A seat is subjected to a 2000 degree flame for two minutes. It is then allowed to cool (or continue burning, as the case may be) for one minute. It is considered acceptable if it does not burn openly and any flames on the seat self-extinguish before the three minute time period

runs out. In addition, any drippings from the test specimen may not continue to flame for more than an average of five seconds after falling (FAR 25.853).

The regulation, incorporated into law in 1984, gave Part 121 operators (mostly the major carriers) two years to comply with fire resistant aircraft. After an initial period of confusion among those carriers which fly under Part 135 certificates (normally small regional airlines - the old 'commuters'), any operation with aircraft which could legally take off with a maximum of 12,500 pounds or more was required to comply with the rule (Likakis, 1988). The deadline for compliance was set at November 27, 1987, and today if one flies in a 727 he/she is in little danger from accidental fires on board.

But while airline passengers will enjoy the benefits of a safer cabin environment, anyone flying in a general aviation airplane (or a Part 135 aircraft under 12,500 pounds), is forced to ride in a cabin which has a flammable interior that can, and might, cause fatalities in the event of a crash or in-flight fire (Likakis, 1988).

Product categories which have been developed as a consequence of this effort include: (i) fire blocking layers for seat cushions, (ii) low heat/smoke release foams and fabrics, (iii) burnthrough-resistant cargo liners, (iv) heat-resistant evacuation slides, and (v) cabin crewmember protective breathing equipment (Sarkos, 1988). While these categories are wonderful for

the average airliner, they do not hold any promises for the average general aviation aircraft - too many differences exist between the 150 passenger jet and the four place aircraft.

An examination of the obvious is hardly necessary - how many general aviation aircraft have cargo liners, evacuation slides, or breathing apparatus? The attempt by the FAA to combat the fire problem aboard America's aircraft through regulation does not include small airplanes - the regulation itself states nothing concerning aircraft which do not meet the 12,500 pound 'large' category.

In addition, the studies sponsored by the government were designed to develop testing programs which work well for transport airplanes, but are hardly effective in the general aviation community. If only one of the four seats aboard a Cherokee catches fire, it will not matter if it can withstand a 2000 degree flame for three minutes and then will self-extinguish. While such regulations certainly provide a 'base' for testing, and would possibly prove effective for a large jet, they are hardly applicable to a small airplane with an emergency. New standards must be developed to prevent the possibility of a cabin fire, and new regulations are needed to ensure that the standards and materials which become available are implemented. Only then will there be an end to such tragedies as the Cessna 414 accident discussed earlier.

## Potential Solutions

Many of the fire hazards found in airplanes involve the polyurethane foam used in the seat cushion. But urethane cushions are replaceable, and the owner has several choices as to which foam cushion to use in his/her aircraft. Some provide only a basic fire resistance, while others can provide additional benefits, such as comfort, longevity, no toxic fumes, and shock energy absorption. Some are expensive, and some are less so. But if the ultimate result is safety, the money is well spent.

If the only concern of the owner is fire resistance, possibly the best choice available today is a product from IMI-Tech, an Illinois company. IMI-Tech produces and markets a product called Solimide TA-301, a fire-resistant foam designed for use as a cushion. Solimide has some qualities which are much sought after in the business of fireproofing aircraft - it remains soft and pliable down to about 300 degrees below zero, and has an incredible resistance to fire and flame. Testing has proven that the foam requires temperatures in excess of 2700 degrees F to produce even slight charring of the foam's surface, and even at that extreme temperature the foam will not emit smoke or gaseous particles.

Under normal conditions, Solimide will not burn at all. Other tests which were conducted by NASA and the U.S. Navy, have found that Solimide requires almost twice as much oxygen than is found in the Earth's atmosphere in order to ignite and actually burn (Roden, 1990). In one series of tests conducted at the

Johnson Space Center, three seats were set up with Solimide cushions and placed in a Boeing 737 fuselage test chamber. When a large pan of jet fuel was placed beneath the seats and lit, the bonfire raged for fifteen minutes before abating. The area where the flames had been in direct contact with the seats were charred and experienced some shrinkage, however, the rest of the seats and cushions showed no fire damage (Likakis, 1988).

Solimide as an airline seat has several advantages over urethane foam, however, some disadvantages had kept it out of the airline seat business until recently. It is lightweight and easy to design into airplane seats, and no expensive flame blocking layer is needed between the foam and the seat cover. Unfortunately, the foam was not very "cushiony", and did not wear very well. New improvements have been made in recent years to increase the comfort of seats made with Solimide, and the ruggedness of the foam is being addressed by IMI-Tech (Roden, 1990).

British Aerospace is currently testing the new version of Solimide seat cushions in actual service. They are looking at not only comfort, but durability as well - the foam is expected to last only one or two years as an airline seat (Likakis, 1988). The management of IMI-Tech believes, however, that Solimide may be well suited for general aviation or corporate use, where it would experience far less wear over the same time period as in a public airliner.

The last disadvantage to Solimide is price - at five to six dollars per board foot an average airplane seat cushion would cost six or seven times what the same cushion would if it were constructed with polyurethane foam (Likakis, 1988). Once again, the safest alternatives may prove to be the most expensive.

A second option to the wary aircraft owner is T-Foam, by AliMed, Inc. T-Foam was based on Temperfoam, originally developed as a shock and vibration absorber for NASA and the airlines. It therefore has an incredible ability to absorb impact shock, which has found favor with the U.S. Air Force. Earlier ejection seat and cushion combinations apparently damaged some servicemen by literally breaking their coccyx (tailbone) upon ejection. T-Foam is now used in many Air Force seats because of its unnaturally high shock absorption qualities. When the ejection seat fires, the foam receives the smack from the seatpan and not the pilot's coccyx (Likakis, 1988).

T-Foam is temperature sensitive, and gets quite hard when exposed to temperatures below forty-five degrees F. However, this is not as much of a problem as one might think. After sitting on a cushion made of T-Foam for a few minutes, it begins to act as a semi-liquid. The foam actually conforms to the shape of the individual, making it very comfortable. AliMed's president has been quoted as saying "It's like having a seat carved to your exact personal shape" (Likakis, 1988).



Concerning fire resistance, two versions of T-Foam are available which have passed the FAA specifications in FAR 25.853. As an additional benefit, the foams have been proven to emit fumes of very low toxicity when consumed by flame (Likakis, 1988). All foams however, by nature of foam, will burn if exposed to enough heat (Accufleet, 1989). Therefore, possibly the very best flame-resistant seat would be one which combines the safety of a fire-retardant cushion with a flame-blocking layer.

Aircraft seats are typically constructed of fire-retardant polyurethane foam and upholstery fabric, which previously was required to pass the vertical Bunsen burner test prescribed in FAR 25.853. However, under the conditions of a severe cabin fire, the foam core ignites readily and burns rapidly, significantly contributing to the spread of fire. The concept of a fire-blocking layer to encapsulate and to protect the polyurethane foam was recommended for evaluation and development by the Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee (Sarkos, 1988).

As noted in the above excerpt from a NATO document, the FAA set about conducting extensive research concerning aircraft fires, and as a result has determined the need exists for a fire-blocking layer around aircraft cushions (between the foam and the upholstery). The theory is to 'bag' or encase the foam cushion in a thin, highly fire-resistant layer which is completely airtight. The cushion may melt, but should not burn

since it will not receive sufficient oxygen. Any toxic gases which may be emitted from the cushion due to heat will be trapped by the fire-blocking layer (Downey, 1985).

Several companies have been successful in manufacturing fire-blocking layers which meet FAA criteria for use in U.S. airline seat manufacturing. Southern Mills Inc. has produced two fire-blocking materials from a blend of Kevlar and Nomex (see Exhibit 6). Southern Mills' fire-blocking layers have passed every test which the FAA could devise, and are very light, strong, and durable. The fabrics are regularly sold to several major airlines, including United, Delta, Pan Am, and Singapore (Bell, 1990).

The lower three seats shown in Exhibit 4 are protected by Southern Mills' fire-blocking fabric. As is evident from the photo, the layer would be extremely effective at restraining flames within an airliner. The same fire-blocking layer might help in a small airplane, but it is the flammable seat cushion which will probably be exposed to the ignition source first. Certainly, a fire-blocking layer would help overall, especially in a post-crash fire. But the first concern should be to eliminate the fire before it becomes a problem. Flame-resistant properties can be added to fabrics which are not normally fire retardant. Ocean Coatings, Inc. has introduced a new product, FFR-21, which is definitely a step in the right direction.

FFR-21 is a fire retardant for fabrics or paper which can be prepared by anyone, and applied to almost anything. Ocean says the retardant will not only dramatically increase the flame-resistant properties of a fabric, but will make it wear better and last longer. Garments treated by FFR-21 are expected to last thirty to fifty percent longer, and be highly fire resistant (Ocean, 1989). Additionally, the company claims that FFR-21 may improve the color retention of some fabrics, making them look better over long periods of time.

FFR-21 is very simple to mix and apply. It is sold as a white powder, and is mixed with boiling water until it dissolves. Fabrics may then be dipped into the solution, or it may be sprayed onto both sides of a fabric. The now fire-retardant fabric should not lose its pliability, although some initial stiffness may be noticed. According to Ocean Coatings, dry cleaning will not adversely affect garments treated with FFR-21, but laundering in water will remove the fire resistance. It is also not for use on acetate rayon or synthetic fibers (Ocean, 1989).

In other arenas of fire prevention, the firewall was discussed as being the first line of defense against engine fires. A product from Flame Control Coatings, Inc., #46081, has shown itself to dramatically increase the protection which a firewall is supposed to offer. No. 46081 is a flexible coating which may be applied to any flat surface to improve its resistance to flame. As an additional benefit, it is effective when applied to

surfaces which undergo extreme vibration for long periods of time. It may be applied via brush, roller, or air spray - much like a coat of paint.

In the presence of extreme heat, however, No. 46081 acts as no ordinary paint. It intumesces, or puffs up into what would appear to be small lumps of volcanic lava. This crusty coating acts as an insulator, protecting the underlying surface from the flames and dispersing the intense heat (Flame Control, 1990).

Originally manufactured for military ships and aircraft, No. 46081 is available to the public, and is currently used "...on aircraft, boats, offshore drilling rigs, fuel storage tanks, ammunition crates, and several other surfaces where it is essential to obtain the maximum thermal insulating protection possible under the severest of fire conditions" (Flame Control, 1990).

Flame Control No. 46081 is suitable for painted and unpainted metal, wood, and masonry (Flame Control, 1990). Its intumescent action protects the surface beneath it, and will extend the time available to land in the event of an aircraft engine fire.

A second product used to increase firewall protection is found in FPC foam, by Bisco, Inc. (see Exhibit 7). FPC is a silicone foam which possesses zero flame spread, low smoke generation, and extraordinary fire-blocking properties (Bisco, 1990). Bisco has tested a 1/16 inch thick layer of this incredible product against a 1900 degree F flame, and the tiny layer of silicone proved to be an effective barrier for over one hour.

This almost unbelievable product has more admirable features - it will slowly melt when exposed to extreme (2000 degree plus) heat, but is completely non-toxic and non-corrosive. It is available with or without a pressure sensitive adhesive backing, and in continuous rolls or custom slit widths (Bisco, 1990). It is approved under FAR 25.853, and is currently in use along many firewalls and under cowlings, as well as for cable and conduit insulation.

In addition to heat and flame protection is the need for flame-resistant soundproofing against normal engine noise. Many airplanes have some form of soundproofing installed along the firewall, in the sidewalls, and under the floor. However, this soundproofing is often nothing more than fiberglass battens stuffed into the open spaces. Fiberglass, while not a serious hazard in a fire (it would probably disintegrate from the flames too quickly), certainly offers no protection for the cabin's occupants (Accufleet, 1989).

Better soundproofing materials do exist. One such substance which will restrict the noise and also offer excellent fire-resistance is one which has already been discussed - Solimide TA-301. The same foam which is used in some aircraft seats is also manufactured for soundproofing applications in the cabin. Cut into small sheets and laid beneath the floors and inside the door panels, Solimide provides excellent sound and vibration dampening, while also adding fire protection.

In fact, Boeing has found several applications of Solimide in its aircraft, as has the military (which uses it primarily as a cockpit insulator). NASA also uses Solimide on the space shuttle, as well as on cryogenically fueled rockets. In the entire aerospace industry, Solimide is a known name; many satellites and rockets which come into intermittent contact with the sun's warmth and the coldness of space have Solimide as insulation (Likakis, 1988).

For general aviation aircraft, the same Solimide could be used for headliner padding, under carpeting (as foam padding), in the armrests and door panels, and various other places where insulation and/or padding is desired. The foam is very light, and very easy to handle.

Bisco, Inc. also has its entries in the light foam contest. For soundproofing use, Bisco HT-200 Silicone Acoustical and Fire Barrier (see Exhibit 7) is a plausible alternative. HT-200 is a silicone rubber designed for acoustical transmission loss and fire barrier applications (Bisco, 1990). It is a non-toxic, non-combustible replacement for vinyl and plastic and provides better sound resistance than fiberglass. HT-200 also meets FAR 25.853, and is claimed to produce "...virtually no smoke upon combustion" (Bisco, 1990). Its applications include engine cowling soundproofing, sealing aircraft doors, and firewall soundproofing. It is relatively heavy, but very thin and quite strong and resilient.

Bisco HT-603 is another silicone foam with outstanding fire- and electricity-resistant properties (see Exhibit 7). It is used in the aircraft and aerospace industry as gasketing, carpet underlay, vibration dampening, decorative trim, and headliner padding. HT-603 is certified by the FAA (having met FAR 25.853), and by Underwriters Laboratories as an electrical insulator. It also has an outstanding temperature range, remaining soft and pliable from -105 degrees to 400 degrees F (Bisco, 1990).

Today, airplanes are designed with aesthetics in mind. The owner who purchases a multi-million dollar aircraft wants everything to be perfect and complete. That includes carpeting, curtains, woodgrain veneer, etc. Weestex, Inc. has addressed the problem of flammable curtains with a new flame-resistant fabric, Sateen. Available at comparable prices to other fire-resistant fabrics, Sateen comes in many colors and thicknesses, and is used by major airlines and manufacturers alike for window curtains and draperies between cabin class sections. It is extremely pliable and sews and cuts easily, has excellent flame-resistant properties, and is low in toxicity when forced to ignite (Bischoff, 1990).

#### Conclusion

Many general aviation aircraft are privately owned and operated. Certainly, cost is a factor to these owners in fireproofing. However, the average privately owned (non-corporate) aircraft has only four seats. Moreover, a large per-

centage of general aviation aircraft are rented or leased to others. Simple calculations will show that a very small price increase to all customers would pay for fireproof seats and covers. The cost would therefore be transferred to the user, who certainly would not mind a small fee for his or her safety.

Since statistics clearly indicate that many deaths are a direct result of flammable aircraft interiors, why has the FAA not passed requirements concerning fireproofing all U.S. registered aircraft? Perhaps it is not financially feasible to mandate completely fireproof interiors for all planes in service. New aircraft, however, could be built and sold with flame-resistant materials, and airplanes currently in service could receive at least minimal-cost fireproofing. Simply coating the firewall with Flame Control's No. 46081, and treating the carpet and seats with Ocean Coatings' FFR-21 would do a lot for a little.

The fact that legislation exists for commercial carriers is indicative that the FAA believes a problem exists. Modern technology is available to greatly improve the safety of air travel in the 1990's. Only with new regulations, however, will aircraft owners and manufacturers add the more expensive materials to the original equipment list - and begin sparing innocent lives.



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Exhibit 1

Case study results of civil aircraft accidents in a three year period (Likakis, 1988).

155 accidents  
41 accidents with fatalities  
29 accidents with fires  
19 accidents with fatalities directly related to fires

19/41 = 46.3% of accidents with fatalities directly related to fires

$\frac{46.3\%}{X\%} = \frac{29 \text{ fires}}{41 \text{ accidents with fatalities}}$       X = 65.5% of all accidents with fires produced fatalities

Exhibit 2

*When the polyurethane foam in the typical aircraft seat is exposed to flames, it quickly becomes a blaze. From initial lighting to this fully engulfed condition took about two minutes. Most light aircraft seats in use today have exactly the same flammable materials.*



Exhibit 3

*Even after the flames are put out, a urethane foam aircraft seat covered with polyvinyl cushions will give off toxic fumes and copious amounts of smoke.*

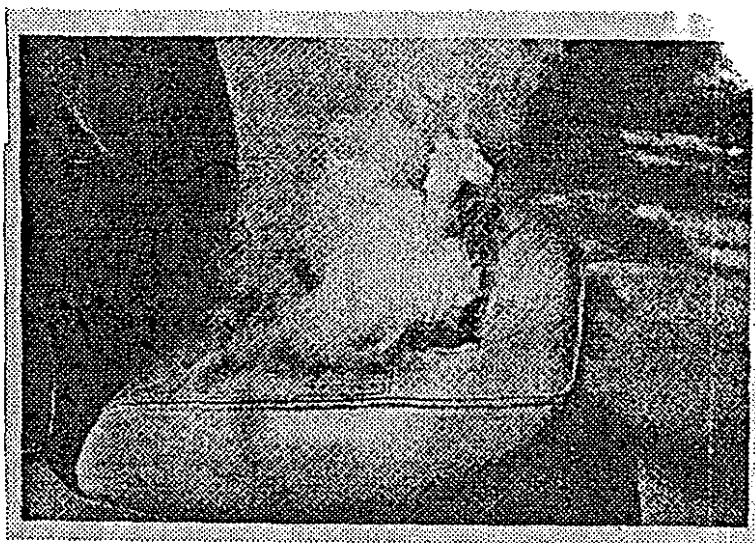
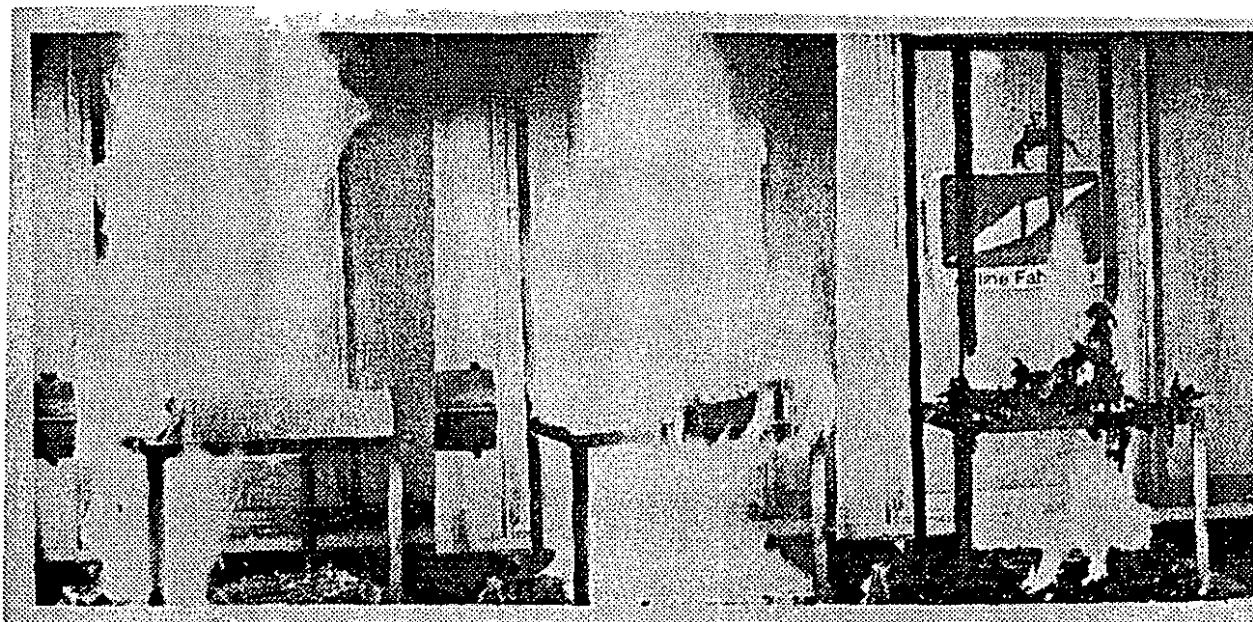


Exhibit 4



*Airline Fabricare of Houston, Texas, performs tests on fire-blocking materials. In the series at left, an unblocked cushion and cover are shown at one minute, two minutes, and three minutes after a torch is ignited. The flame is withdrawn at two minutes, but the seat burns to destruction.*

*With fire-blocking materials surrounding the seat cushion, the foam never gets a chance to burn. At one and two minutes there is no flame from the seat, and after the torch is extinguished, the seat will not support combustion.*



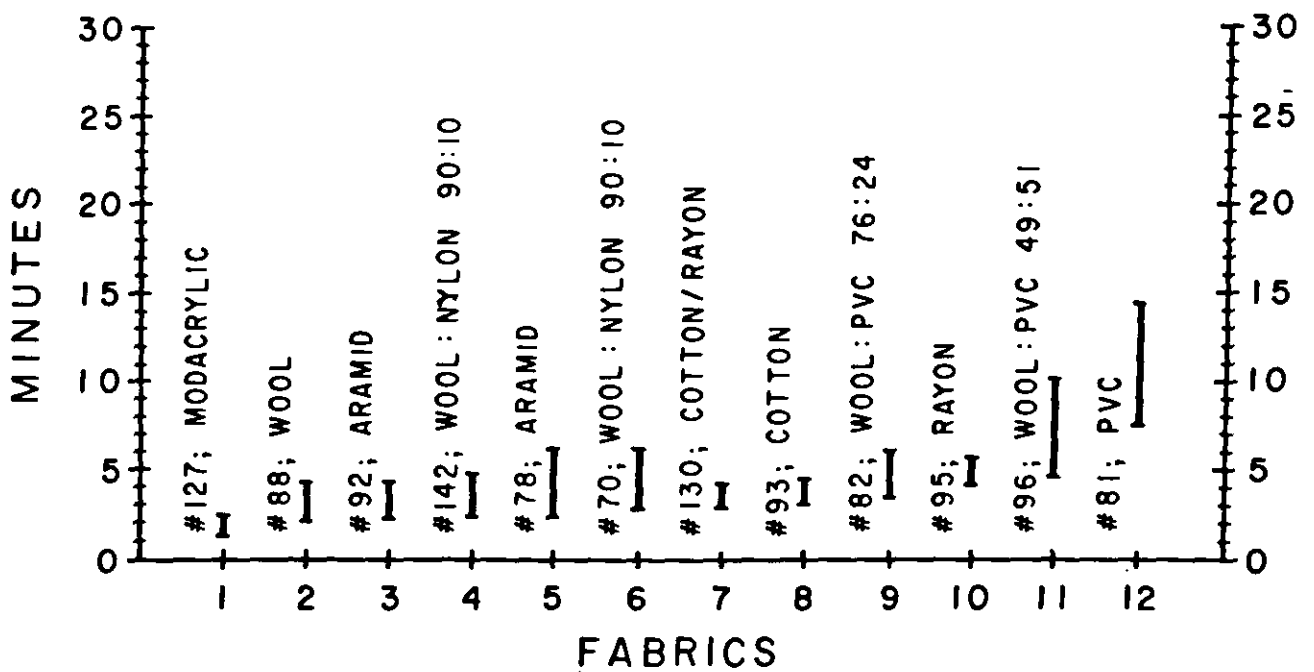
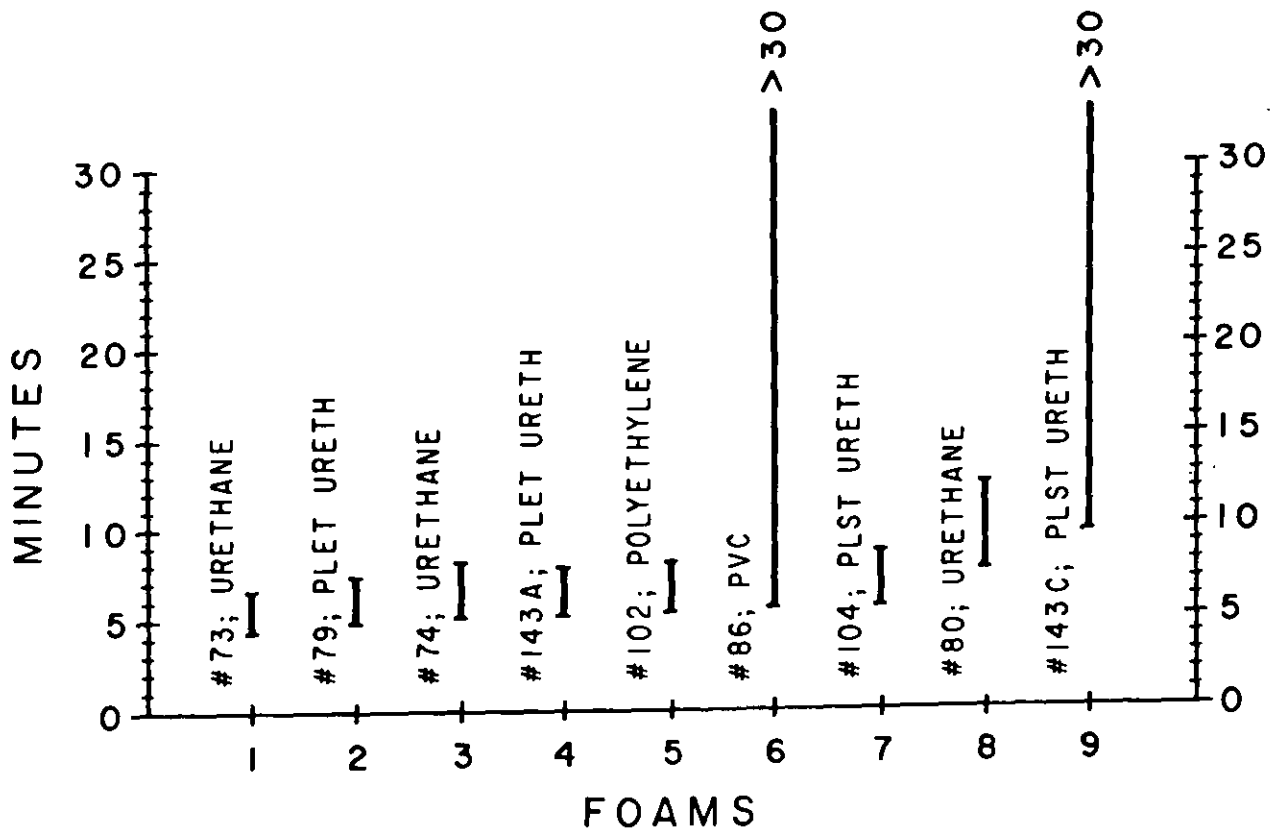


Exhibit 5

Relative toxicity of combustion products as measured by animal response time. Bottom bar represents time to incapacitation; top bar represents time to death (Crane, 1977).

## **Southern Mills**

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### Exhibit 6

A sampling of the fire-blocking layer developed by Southern Mills, Inc.; currently in use by many major airlines.

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## **Sample**

## **Technical Data**

**Batt:** 100% Kevlar®

**Scrim:** 100% Kevlar®/Nomex®

**Weight:** 8.5 oz./yd.<sup>2</sup> (288 glm<sup>2</sup>)

**Width:** 60" (1524 mm)

**\*FAA Seat Burn Test:** Pass  
(% Wt. Loss, 10% Max.)

**\*Seat Wear Test:** Pass

**\*Drycleaning Shrinkage:** Pass

\*Test data available upon request.

®Registered trademark of E.I. DuPont Company

## **S/757 NW Fire Blocking Layer**

(ix)

Exhibit 7