INCORPORATED AIR SAFETY INVESTIGATORS AUGUST 31, 1964

The Society of Air Safety Investigators

FIFTH ANNUAL INTERNATIONAL SEMINAR

"Accident Prevention Through Investigation"

1974

THE SOCIETY

OF

AIR SAFETY INVESTIGATORS

presents

"Accident Prevention Through Investigation"

FIFTH ANNUAL

INTERNATIONAL

SEMINAR

October 1-3, 1974

Quality Inn
Pentagon City
Washington, D.C.

MONDAY, SEPTEMBER 30, 1974

REGISTRATION - MEZZANINE

COCKTAILS - ARLINGTON ROOM

TUESDAY, OCTOBER 1, 1974

REGISTRATION - MEZZANINE

WELCOME: DONALD E. KEMP - President, SASI
Chief, Accident Investigation
Staff, FAA, Washington, D.C.

OPENING REMARKS: ALEXANDER BUTTERFIELD
Administrator, Federal Aviation
Administration

KEYNOTE ADDRESS: JOHN H. REED
Chairman, National Transportation
Safety Board

WEATHER

MODERATOR CHAIRMAN - ALAN I. BRUNSTEIN
Senior Meteorologist
NTSB, Washington, D.C.

GEORGE H. FICHTO — Scientist, Marshall Space Center

JIM ROWAN — Air Traffic Control Staff
FAA, Washington, D.C.

W. B. BECKWITH — Manager of Meteorology
United Airlines

SAMUEL V. WYATT — Aviation Safety & Quality
Control Program Leader,
National Weather Service

A. MARTIN MACY — National Air Transportation
Conferences, Inc.

MAX KARANT — Senior Vice President
Aircraft Owners & Pilots Association

WILLIAM HORN — Manager Airspace/ATC Service
National Business Aircraft
Association

COFFEE - Compliments of Seaward, Inc.

WEATHER

CONTINUATION OF PANEL DISCUSSION

SEMINAR LUNCHEON - ARLINGTON ROOM NORTH & BALLROOM WEST

SPEAKER — JACK EGGSPUEHLER
Chief of Aviation Division
Ohio State University

STALL SPIN

MODERATOR CHAIRMAN — EDWARD C. WOOD, Chief
Safety Coordination Division
Office of General Aviation
FAA, Washington, D.C.

J. S. BOWMAN — NASA Langley Research Center

J. M. PATTON — NASA Langley Research Center

HAROLD ANDREWS — Acting Director, Airframe Division
Department of the Navy

ROBERT J. WOODCOCK — Air Force Flight Dynamics Lab
Columbus, Ohio

RICHARD D. GILSON — Assistant Professor
Ohio State University

RICHARD F. BUSCH — Aircraft Owners & Pilots Association
Life Insurance Staff

DENNIS A. TUCK — Chief, Flight Test Branch, FAA
Washington, D.C.

COFFEE - Compliments of United States Aviation
Underwriters, Inc.

STALL SPIN

CONTINUATION OF PANEL DISCUSSION

QUESTIONS & ANSWERS PERIOD

ADJOURN

COCKTAILS - BALLROOM WEST - Compliments of General
Aviation Manufacturers
Association

WEDNESDAY, OCTOBER 2, 1974

INVESTIGATION PROCEDURES ADOPTED OVER THE
PAST TEN YEARS

MODERATOR CHAIRMAN - CHARLES O. MILLER, Director
Bureau of Aviation Safety
NTSB, Washington, D.C.

ROBERT D. RUDICH — Air Transportation Consultant
Alexandria, Virginia

DR. CAROL ROBERTS — Flight Recorder Laboratory
NTSB, Washington, D.C.

MUSHIR ALLAM KHAN — Safety Management Officer
Pakistan International Airlines
Corporation

DR. W. J. McARTHUR — Canadian Armed Forces,
President, Canadian Chapter of
SASI

EDGAR F. HARVIE — Accident Investigator
New Zealand Ministry of Transport

COFFEE - Compliments of Mexicana Airlines

INVESTIGATION PROCEDURES ADOPTED OVER THE PAST
TEN YEARS

CONTINUATION OF PANEL DISCUSSION

LUNCH

EMERGING PATTERN OF ACCIDENT PREVENTION

MODERATOR CHAIRMAN - JAMES F. RUDOLPH, Director
Flight Standards Service
FAA, Washington, D.C.

WILLIAM B. BECKER — Assistant Vice President - Operations
Air Transport Association of America

H. REID GLENN — Aviation Safety Investigator
Canadian Ministry of Transport

D. L. CORRE — Flight Safety Manager
British Aircraft Corporation-
Weybridge

H. PRATER HOGUE — Chief of Safety, Boeing
Commercial Airplane Company

L. I. DAVIS — Corporate Director of Product
Safety, Lockheed Aircraft Corp.

COFFEE - Compliments of The Singer Company

EMERGING PATTERN OF ACCIDENT PREVENTION

CONTINUATION OF PANEL DISCUSSION

QUESTIONS & ANSWERS PERIOD

ADJOURN

COCKTAILS - ARLINGTON ROOM NORTH & SOUTH
Compliments of Boeing Aircraft Company

BANQUET - BALLROOM EAST & WEST

BANQUET SPEAKER - JOHN L. BAKER, Special Assistant
to the President of ALPA

THURSDAY, OCTOBER 3, 1974

EMERGING PATTERN OF ACCIDENT PREVENTION

MODERATOR CHAIRMAN -	C. R. MELUGIN, JR., Deputy Director, Flight Standards Service, FAA, Washington, D.C.
STANLEY J. GREEN	Vice President & General Counsel, GAMA
FRANK McGOWAN	Aviation Supervisor Aviation Technical Department Insurance Co. of North America
WILLIAM R. STANBERRY	Executive Director, AOPA Safety Foundation

COFFEE

ACCIDENT INVESTIGATION INFORMATION DISSEMINATION

MODERATOR CHAIRMAN -	DONALD E. KEMP, President of SASI, Chief, Accident Investigation Staff FAA, Washington, D.C.
DAVE KELLEY	Chief, Information Systems Branch, NTSB, Washington, D.C.
WILLIAM B. BECKER	Assistant Vice President - Operations Air Transport Association of America
FREDERICK B. MACINTOSH	Director, Operational Services NBAA
WILLIAM R. STANBERRY	Executive Director, AOPA Safety Foundation
SUMMATION	DR. W. J. McARTHUR Canadian Armed Forces, President Canadian Chapter of SASI

ADJOURNMENT

TOUR - SMITHSONIAN - SUITLAND, MARYLAND

GOLF, ARMY-NAVY COUNTRY CLUB

SOURCES OF LOW LEVEL WIND SHEAR AROUND AIRPORTS

by

George H. Fichtl
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

and

Walter Frost
The University of Tennessee Space Institute
Tullahoma, Tennessee 37388

Low level wind shear over and around airports, heliports, etc. is a major aeronautical system operating hazard. Accordingly, from an aircraft safety investigation point of view it is worthwhile to keep this idea in mind. Low level wind shear is the result of the interaction of the large scale (synoptic scale) flow of the atmosphere with the surface of the earth. Because of the almost infinite variety of terrain at and around airports, a host of interactions and thus sources of wind shear are available to jeopardize the flight of aeronautical systems. This paper discusses these sources of low level wind shear in the context of aeronautical operating hazards.

INTRODUCTION

The subject of this paper concerns the sources of low level wind shear at and about airports. Wind shear is widely recognized as being a significant aircraft operating hazard during take-off and landing of aeronautical systems [1,2]. In fact, the Commission on Aeronautical Meteorology (CAeM) has recognized this hazard and has recommended at the recent Eighth Air Navigation Conference, held in Montreal, Canada, that there be an operational requirement for low level wind shear and turbulence information to be provided to aircraft at the commencement of the final approach and prior to take-off [3]. The Commission goes on to state that this information should indicate variations in wind direction and speed along the last 1000 meters of the glide path or along the first 1000 meters of the climb path.

As an airplane ascends or descends through the atmospheric boundary layer (approximately first 1 km of the atmosphere) it will experience changes in wind speed along the flight path which will result in increases or decreases in aerodynamic lift force depending on whether or not the shear corresponds to an increase or decrease of wind speed along the flight path [4,5]. The wind change or shear produces a near-instantaneous change in the lift force to which the aircraft and pilot take a finite time to respond. Accordingly, when wind shear is encountered in the boundary layer the airplane will respond by accelerating vertically away from the flight path. The net effect of the wind shear with pilot response could result in long or short landings. Other more subtle examples of the effect of wind shear can be cited. For example, Etkin [6] points out that wind shear can induce pitch, roll, and yaw moments during take-off or landing. More will be said about this point later.

From an accident investigation point of view, it is extremely worthwhile to keep in mind that wind shear does exist over and about runways. A broad synoptic scale view of air flow may oftentimes imply benign low level wind shear conditions for aircraft operations while in acuality the truth of the matter is that local conditions may result in locally severe wind shears in seemingly benign conditions on the synoptic scale. If local wind shear conditions were to result in an aircraft accident in a seemingly safe wind shear condition on the synoptic scale then they (local shear) might be overlooked as the source of the accident if the potential sources of local wind shear at the airport were not recognized.

Many of the sources of low level wind shear are common to the majority of airports, while others are unique to a particular airport. The uniqueness of the shear conditions can result from the distribution of buildings and natural obstructions at and around the airport, the distribution of terrain roughness, land/water interfaces, etc.

In this paper we shall discuss many of these sources of wind shear from an aircraft hazard point of view. Our discussion will be primarily concerned with the mean flow or steady-state wind shear conditions, i.e., the time averaged (2 minute average, for example) wind field. However, we will occasionally refer to shear resulting from atmospheric turbulence.

WIND SHEAR OVER HOMOGENEOUS TERRAIN

This section of the paper reviews wind shear conditions over flat terrain with reasonably homogeneous surface properties (roughness, specific heat, etc.). The discussion is primarily based on models of the horizontally homogeneous boundary layer derived from meteorological tower data, aircraft data, and theory. The models are reasonably accurate for flat terrain; however, care should be exercised when applying the models to a given situation because certain local conditions could exist at the site of application which would preclude their validity (sea breezes, obstacles, etc.). Nevertheless, many airports are characterized by sufficiently flat, horizontally homogeneous terrain to justify application of these models. Finally, knowledge of wind shear over flat terrain will aid the aircraft accident investigator in understanding the additional sources of wind shear that can occur at airports. These additional sources of low level wind shear shall be discussed later.

Reviews of low level wind shear over flat terrain from an aeronautical design and operations point of view have been given by Luers [7] and Fichtl [5,8]. In addition Luers and Reeves [14] have calculated the effects of low level wind shear on aircraft landing for a variety of aircraft configurations.

Overview of Flat Terrain Shear Flow

From a descriptive point of view the atmospheric boundary layer (approximately first kilometer of the atmosphere) in other than near calm conditions, can be divided into a constant wind direction layer and a wind turning layer. The constant wind direction layer occurs in approximately the first 150 m, give or take a few tens of meters [9]. The exact height of the constant wind direction layer depends on surface roughness, solar heating of the ground, latitude, etc. The turning layer occurs above the 150 m level and is characterized by a marked turning of the steady-state wind vector as altitude increases so that in the northern hemisphere, looking toward the earth, the wind vector normally turns clockwise as height increases. In certain extraordinary cases associated with sufficiently large synoptic scale horizontal temperature gradients (usually with cold fronts) the direction of rotation can be counterclockwise. This turning is a result of the interaction of horizontal pressure gradient forces, Coriolis forces and vertical gradients of vertical transport of horizontal momentum by atmospheric turbulence [10,11]. Typically in mid-latitudes the turning angle between the surface wind vector (at 10-meter level say) and the wind at the 1-kilometer level is approximately 20-30°. Departures of up to $\pm 180^\circ$ from this nominal turning angle can occur. The turning of the wind vector as described here is believed to be the source of wind shear which resulted in aircraft landing difficulties and aircraft accidents as reported recently by Kraus [2].

Constant Wind Direction Layer

Let us first examine the constant wind direction layer in more detail. The wind shear in this layer as experienced by an aircraft during take-off or landing is due to vertical variations in wind speed. The cause of the wind shear is a result of the fact that the steady-state wind speed must be equal to zero at the ground. Figure 1 contains a schematic plot of wind profiles from this layer for various stability categories. The strongest wind shears occur near the ground.

The neutral case corresponds to relatively high wind speed at the 10-meter level (wind speed $\gtrsim 10$ m sec^{-1}), so that mechanical production of turbulent kinetic energy is mostly in excess to buoyant production. The neutral wind profile is characterized by a logarithmic distribution of wind speed and has been verified many times for many sites [12,13] around the world.

The unstable wind profile is associated with strong solar heating of the ground and is thus associated with buoyant production of turbulent kinetic energy being in excess of mechanical production. The air adjacent to the ground is heated by conduction and results in convective mixing of the boundary layer. This mixing in turn results in a uniform vertical distribution of steady-state wind speed over the bulk of the constant wind direction layer, except in the layer immediately adjacent to the ground as can be seen in Figure 1. In this particular case the unstable wind profile is benign from an accident point of view. However, the turbulence levels associated with this profile can be rather strong resulting in a bumpy ride typical of hot afternoon flying conditions.

The stable wind profile is associated with nighttime conditions when thermal energy is transfered to the ground from the air by conduction and in turn radiated to space or to clouds. This boundary layer can lead to rather hazardous steady-state wind shear conditions from an aircraft point of view because in this boundary layer the associated negative buoyant forces tend to reduce the turbulence intensity levels. The reduction of the turbulence levels results in decoupling of the layers* which in turn results in the layers "slipping" relative to each other , thus resulting in larger mean flow wind shear conditions than would occur in the unstable and neutral boundary layers with all other things being equal (see Figure 1). Furthermore, if the negative buoyancy forces are sufficintly strong turbulence could cease altogether in certain layers resulting in rather complicated and perhaps dangerous wind profiles.

*Note in the unstable case with high turbulence intensity levels the mean flow momentum is relatively uniform because of the strong turbulent coupling between the layers.

The Wind Turning Layer

Let us now turn our attention toward the turning layer. In view of the multitude of possible combinations of mean flow pressure gradient, surface heating, and surface roughness that are available, a virtually infinite variety of wind profile shapes are possible for the flow in the turning layer. As noted earlier this layer is characterized by significant turning of the wind vector. Figure 2 is a schematic diagram of a hodograph of the flow in the atmospheric boundary layer. In the surface layer (altitudes $\lesssim z_1 = 150$ m) the hodograph shows very little turning. For altitudes greater than z_1 up to the top of the boundary layer at z_4 the profiles are characterized by significant turning of the wind vector.

A number of theories are available which are able to predict the behavior of the profile for a number of restrictive cases. For example in the neutral barotropic boundary layer which is the simplest model of the atmospheric boundary layer. Blackadar and Tennekes [15] provide a theory which can be used to calculate total turning of the wind vector between the top and bottom of the boundary layer. This theory is valid for the neutral case. This theory predicts typical turning angles on the order of 20-30^o. At this time the unstable boundary layer is in a state of controversy because two competing theories are available. One theory consists of a straight forward extension of the Blackadar and Tennekes model [15] and experimental data which tend to confirm this theory have been provided by Clarke [16]. Another theory due to Deardorff [17] rejects the fundamental hypotheses upon which the extension of Blackadar and Tennekes model to the unstable case are based. We will not dwell on this point except to say that both theories appear to be consistent in so far as they both predict smaller total turning angles than those found in the neutral boundary layer all other things being equal. The smaller turning angles are a result of convective turbulent mixing. Typically these angles are on the order of 10-25^o.

The stable turning layer is one the most least understood boundary layers because of the tendency for decoupling of the layers due to dimished turbulence intensity levels, as noted earlier for the constant wind direction layer. An attempt has been made to model this layer by Csanady [18]; however, this theory, as well as others, are merely speculative due to the sparsity of data and the large scatter that exists in the presently available data. In general, the net turning angles in the stable boundary layer tend to be larger than those found in the netural and unstable boundary layers. Typically these angles are on the order of 25-50^o. This is an additional reason for considering the nighttime stable boundary layer as being potentially the more hazardous boundary layer to aviation of three types (stable, neutral, unstable) considered here.

As pointed out earlier under certain extreme conditions, turnings up to ±180° can occur. If these do occur, they are associated with neutral and stable atmospheric boundary layers.

NONHOMOGENEOUS SHEAR FLOWS

In the previous sections we discussed shear flows over homogeneous terrain. However, the airport environment does not always satisfy the necessary conditions of reasonably homogeneous terrain. Thus, in this section we shall indicate some of the nonhomogeneous flow fields the aircraft safety investigator might keep in mind. The intent here is not to give an exhaustive treatment of the subject, but rather to point out kinds of effects that surface roughness discontinuities can produce. A recent paper by Logan [19] gives a review of the subject and also a new approach to the problem of computing flow fields associated with a surface roughness discontinuities. In addition, the reader is referred to references [20-27] for details on the subject.

Because of the explosive economic growth that occurs around airports, most of the major airports and many of the minor ones are surrounded by highly urbanized terrain. The resulting situation is one in which the flow over the surrounding terrain is characterized by roughness lengths (z_o) on the order of 1-2 m and the flow over the airport is characterized by relatively smooth terrain with roughness lengths on the order of 0.01-0.1 m. Accordingly, as the air blows from the urban area to the airport the flow field must, by necessity, undergo modification such that the flow over the airport is consistent with the associated surface roughness conditions. The consequence of this modification is the formation of an internal boundary layer as indicated in Figure 3. The upper boundary of this internal boundary layer grows as $x^{0.8}$, where x is distance from the surface roughness discontinuity. The flow in the internal boundary layer is characterized by the relatively small roughness lengths associated with airport environment, while the flow about the internal boundary layer is characterized by the surface roughness length associated with the surrounding urban area. Since the roughness over the airport is generally less than that over the city the air near the ground will acclerate as it blows from the city to the airport. Figure 4 schematically shows the modification that can occur in the logarithmic wind profile for both cases of smooth to rough and rough to smooth terrain flows. In the present context we are concerned with the latter. Thus, as an airplane takes-off it will first encounter the internal boundary layer and upon passing through the internal boundary layer interface it will encounter a sudden (nearly so) increase in vertical wind shear and vice versa for the landing case. In addition,to vertical wind shear the aircraft will also encounter horizontal variation (horizontal wind shear) in the steady-state wind below the interface due to the acceleration of the air downstream of the surface roughness discontinuity. To determine if these effects are important upon aircraft flight will require further study. Nevertheless, these effects and ones of a similar nature should be kept in mind during aircraft accident investigations.

The reverse of the above situation can occur if the airport is rougher than the surrounding terrain. An example of this situation is that of a body of water in place of the urban area indicated in Figure 3. In this case vertical wind shear will increase below the interface (see Figure 4 smooth to rough terrain).

The magnitude of the enhancement of the wind as it blows from the city to the airport can be as high as 50-100% depending on the distance of the point of concern from the surface roughness discontinuity. This could have important implications on the representativeness of runway wind speed measurements. Depending on the location of the runway anemometer from the surface roughness discontinuity the runway wind speed could be underestimated or overestimated or overestimated. Thus, care in siting meteorological instruments at airports should be exercized.

THE THUNDERSTORM

The violence of the thunderstorm and the threat it poses to aviation is well known. In addition to high turbulence intensity levels, the thunderstorm is a source of low level wind shear. Figure 5 is a schematic diagram of the flow associated with the cold air outflow in advance of the thunderstorm. The flow near the ground in the cold air region behind the windshift line is characterized by a horizontally nonhomogeneous high speed boundary layer following the thunderstorm. The nonhomogeneous character is not the result of horizontal variation in surface properties, as discussed earlier, but rather is the result of the fact that ahead of the windshift line in the warm area the flow is different from that in the cold air.

At the leading edge of the thunderstorm the wind speed increases rapidly in space. After the initial surge of cold air a horizontally uniform flow occurs; however, a secondary surge tends to occur due to the presence of a secondary vortex in the coldest air (see Figure 5). Nevertheless, sufficiently near the ground after the initial surge of cold air studies by Sinclair, et al. [60] appear to show that a logarithmic wind profile tends to be established, so that the comments in the previous sections relative to the logarithmic wind profile are applicable after the initial surge of cold air.

POTENTIAL AREAS OF FLIGHT DISTURBANCES DUE TO GROUND WIND SURFACE OBSTRUCTIONS

This section of the paper reviews the areas where potential flight hazards may be encountered due to disturbed flow fields created by surface obstruction to ground winds. The discussion is based primarily on aerodynamic data obtained in wind tunnels for flow around bluff-body models for which the mean upstream natural wind profiles over uniform homogeneous terrain is very well simulated with proper tunnel design. These data on the ohter hand may not accurately account for the large eddies and gusts inherent to the atmospheric boundary layer. Reliance upon them is given by the fact that the few reported full scale tests conducted in the natural atmosphere indicate that the mean flow fields extrapolated from wind tunnel models are reasonably correct.

Frost [28] has reviewed the literature pertaining to turbulent flow fields over bluff-bodies typical of individual buildings. Other surveys relevant to wind field around man-made surface structures are given in [29, 30, 31, 32].

Two-Dimensional Flow Fields

Most data for bluff-body flow is for two-dimensional geometries such as infinitely long fences and, rearward and foreward facing steps. Consider first a fence which might be used to simulate a long narrow structure. Figure 6 shows velocity profiles and streamlines for fence flow measured by Good and Joubert [33]. Superimposed on the flow field, assuming direct scaling, is the FAA recommended obstruction clearance surfaces for a STOL port and a typical STOL 6^{o} glide slope. The recirculating region extends approximately 16 fence heights, h, downstream and two fence heights vertically. Figure 6 illustrates that an aircraft approaching into the wind passes through the top of the recirculating zone experiencing initially a downdraft and then a strong updraft directly over the obsturction.

In addition to the change in vertical direction of the wind, the aircraft is exposed to a strong shear gradient throughout the region approximately 12 fence heights downstream to 1 fence height upstream. Etkin [6] shows that a linear wind profile causes an overshoot of the landing site for constant relative velocity approach. Leurs and Reeves [14], on the other hand, show that a logarithmic wind profile produces anundershoot for the same constant velocity approach. This effect has been confirmed by the present authors [34]. Obviously the undershoot is more hazardous since it tends to draw the aircraft toward the fence. However, the updraft due to the vertical flow over the fence counteracts the undershoot, also the experimental data indicate linear profiles which act to force the aircraft upward away from the fence. Caution in drawing conclusions from these data is required because they represent wind tunnel measurements with a well defined free stream velocity. In the atmosphere the flow must return to a logarithmic profile and wind profiles such as shown in Figure 7 may be expected. The flow field shown in Figure 7 is calculated with the MSFC/UTSI computer code for atmospheric boundary layer flow over surface obstruction and accounts for the turbulent shear and the logarithmic nature of the natural wind.

Figure 8 illustrates take-off over a fence. A potentially serious situation is encountered very near the obstruction at $x/h = 2$, where the aircraft which has been experiencing a tailwind suddenly encounters a reversalof flow and experiences a high head wind produced by the acceleration of the wind. To assess the quantitative influence of the flow field on the flight path mathematical models of the fluid mechanics are needed.

Some description of the flow in the recirculating zone is possible; for example, it is established that a shear layer emmanates from the edge of the fence and spreads out downstream. The velocity field in the shear layer has an error function distribution [35].

No analytical expressions describing the recirculating flow beneath the shear layer are presently available; however, we expect these models to be available in the near future.

Figure 9 shows crosswind landing or take-off conditions. The FAA recommended 4:1 transitional surface is indicated. One observes that at given heights, strong rolling moments are possible on the aircraft due to the wind vector having opposite direction along the wing. Again, until a mathematical model is developed, an estimate of the magnitude of this moment is not possible.

The wind field data used in the above discussion is based on wind tunnel studies over two-dimensional fences. Excluding the fact that these are not exact representatives of the atmosphere which is of a higher turbulent eddy scale and very gust, the fence geometry is also not typical of the types of obstruction geometries encountered around airports. The data for this geometry was used, however, since it is the most complete in the literature and it is indicative of flow disturbance around long narrow buildings.

Considerable wind tunnel data is also available for flow over a rearward facing step which tends to simulate a long very wide building where flow which separates at the leading edge reattaches on the roof. Figure 10 shows data from Tani, et al. [36] with the 6^{o} take-off path and obstruction clearance planes indicated, again direct scaling is assumed. Rearward facing step geometries have recirculating regions typically half of those for fences and thus as is apparent from Figure 10a, the recommended 15:1 FAA obstruction clearance surface appears appropriate for building characterized by rearward facing steps. Notice that during take-off the plane experiences no sudden changes in flow direction as with the fence and only a somewhat stronger shear flow than that which would occur over uniform terrain with the building absent.

Landing over long very wide buildings would require passing through the separated flow region near the front of the building similar to that of the fence. Hence, during landing the effects are expected to be the same as in Figure 6.

Figure 10b illustrates the flow field for landing parallel to the building. The center line of the runway is positioned according to the 4:1 transitional surface requirement and to the assumption of a 25 ft. building with a 300 ft. wide runway safety area. The figure indicates that cross-wind landings take place in a region where the separated flow reattaches to the ground. This is called the reattachment zone. Although the physics of the reattaching flow are not yet well understood [37], some semi-empirical predictive analyses are available from which an estimate of its effects on aircraft flight dynamics can be made. These effects will be discussed in a later report.

The fence and rearward facing step flow fields are expected to represent the limiting conditions for a typical long building. No detailed data for long buildings with cross sectional areas intermediate to the zero area fence and the infinite area step geometry are available in the literature. Qualitative flow visualization studies such as smoke flows indicate a flow pattern such as shown in Figure 11. The extent of the flow disturbance regions are not quantitatively known and cannot be scaled to compare with obstruction clearance and flight path requirements. It is evident, however, that the hazardous situation near the downwind edge of the roof during take-off through the recirculating region still exists. Mathematical models for this geometry are being developed at UTSI and are discussed in [34].

In addition to the strongly varying mean flow fields encountered during take-off and landing over bluff bodies regions of very intense turbulence are also present. Wind tunnel measurements of turbulence behind a model fence [35] and behind a rearward facing step [36] are shown in Figure 12. It is apparent that associated with the particularly hazardous mean flow field near the roof is also a region of intense turbulence. Figure 12 shows, as pointed out earlier, that the take-off flight path over a rearward facing step passes over the mean flow recirculating zone; however, it appears as if the turbulent free shear layer extends further downstream where the aircraft must pass through it. The extent to which the turbulence persists downstream is not well established since measurements of the rate of decay of the turbulence behind bluff bodies with distance downstream are scarce.

Hunt [29] gives mathematical evidence that turbulence intensity induced by individual block buildings decays more slowly than the velocity deficit in the wake, $\tilde{u}$, where velocity deficit decays as $\tilde{u} \propto h/x$ for long low buildings and $\tilde{u} \propto (h/x)^{3/2}$ for cube-like buildings. Hence it is anticipated that the turbulence shown in Figure 12 will persist into the flight path. Halitsky [38] reports that the aerodynam cally generated turbulence intensity as determined by excess over that of the atmospheric background flow appears to vary inversely with background flow turbulence.

For the shear immediately behind the separation point Plate [39] and Mueller, et al. [40] report that the shear stress distribution $u'w'/(u'w')_{max}$ is Gaussian in y/x. The introduction of this turbulence distribution into predictive models of aircraft motion in a turbulent atmosphere is now under investigation.

Three-Dimensional Flow Fields

The two-dimensional flow fields previously described give insight into potential problems of flight through winds disturbed by surface obstructions and are expected to be descriptive of very long buildings typical of the hangers and manufacturing complexes near airports. In general, however, most surface obstructions will be three-dimensional for which the wake regions are smaller but for which a number of other flow disturbances occur. These consist of regions of high velocity flow sweeping down and around the sides of buildings, Figure 13a longitudinal nal vortex shedding from slanted roofs, Figure 13b and vortex shedding (von Karman vortex streets) from the sides of tall narrow structures Figure 13c.

The extent of the recirculating wake behind three-dimensional block bodies in wind tunnels is correlated by Leutheusser and Baines [43] and shown in Figure 14. For fixed dimensions a and b the wake increases almost linearly with height, h. No Reynolds number dependence is given.

Measurements of velocities on a slab building model preceded by a low building [44] are shown in Figure 15. The wake extends beyond 2.5 building heights downstream at which point no further data is given. Both Figures 14 and 15 illustrate that the length of the recirculating zone behind a three-dimensional bluff body is considerably less than behind an infinitely wide rearward facing step and hence not likely to extend into the obstruction clear zone specifications of FAA nor into the flight path during take-off. The upward directed flow over the roof appears from Figure 15 to extend to one-half a building height above the body and an aircraft landing directly over the building would experience and up-draft as with the fence flow. It should be emphasized that for a VTOl aircraft the recirculating zone even for three-dimensional bodies is a very severe problem, see preliminary work of Krynytzky [45].

If the aircraft's approach or take-off is into the wind and toward either side of the building the previously mentioned vortices and downwash zones are encountered. It is apparent from the limited existing data that aircraft passing to the side of a tall building would experience a downwash as sketched in Figure 16.

The extent and location of the downwash for given wind directions is illustrated in Figure 17 as reported in reference [41]. Regions of increased speed extend downwind for a distance roughly equal to the height of the tall building.

Figure 18 displays computed velocity vectors indicating the flow field around a building like block structure. Although these three-dimensional computer solutions indicate the nature of the flow, the distance the flow disturbance extends from the building cannot be completely resolved since it is a function of the imposed mathematical boundary conditions. Thus, more knowledge about three-dimensional flows is required before conclusions may be drawn regarding satisfactory obstruction clearance planes, for V/STOL aircraft.

Figure 19 illustrates longitudinal vortices originating on the leading edge of three-dimensional bodies. Ostrowski, et al. [42] have measured pressure disturbances and smoke patterns produced by these vortices behind model buildings in wind tunnels. Comparing curves in Figure 19 shows more intense circulation occurs with increased angle of attack and sweep of a sloping roof. Hence, the architecture of buildings near airports may be significant in the creation of flight disturbances.

Figure 19 indicates that the pressure disturbances are measurable at least 2.5 building widths downstream and Figure 8b suggests they exist up to at least 3 buidling widths downstream. It is also interesting that Ostrowski, et al. [42] found the longitudinal vortices extend further downstream with decreasing building height. This observation coupled with the more intense disturbance due to a sloping roof (Figure 14) may explain the poor performance of the Trident automatic landing system reported by McManus [47]. He notes that the presence of a long hanger with a double apex roof at approximately 45° to the wind apparently created a disturbance which resulted in a landing impact close to the structural limits of the aircraft.

Model studies of tall buildings indicate von Karman vortex streets occur in the wake as illustrated in Figure 20. Again, there is no measurement in the atmosphere of these vortices behind buildings. Attention is drawn to the fact, however, they have been recorded in the upper part of the atmospheric boundary layer in the lee of several isolated islands [48]. Wind tunnel data although not extensive enough to provide a working mathematical model do indicate that the vortices may persist considerable distance downstream. For example, Figure 21 illustrates that the frequency of vorticity radiation at different elevation was easily measured 6 building widths downstream of a given model. Figure 22 additonally shows that the mean velocity is influenced at least 14 building widths downstream. Figure 23 shows that the instantaneous flow field an aircraft may encounter landing 6 building widths downstream. Insufficient data is available to answer the question as to whether these vortex street disturbances extend into the obstruction clear space designated by the FAA [50]; however, the aforementioned data do suggest a potential problem, which requires further research. An understanding of this problem may be available if knowledge gained from the extensive literature on aircraft trailing vortices is applied to building geometries. Once the vortices can be mathematically modeled their influence on an aircraft can be analyzed (see for example [51, 56].

Many other buildings and structural arrangements as well as natural terrain may create wind disturbances which will be appreciable under the less stingent obstruction clearance and flight path specification for V/STOl aircraft which heretofore have not effected CTOL aircraft. Reference [31] reports double vortex patterns measured behind two cylindrical columns. Reference [53] computes disturbances created by a trough such as a street between rows of buildings. High wind velocities may occur on the tops of quansit huts or hills as illustrated by the calculations of flow over an elliptical obstruction in Reference [54]. Numerous other fluid laboratory flow studies suggest regions where disturbed ground winds may generate dangerous flight conditions around V/STOL ports. Also of note is that in most of these laboratory studies the stratification or instability of the atmospheric boundary layer is not taken into account and these aspects of flow around buildings requires considerably more research.

AIRCRAFT RESPONSE CALCULATIONS

The motion of an aircraft may be determined theoretically once mathematical models of the discussed flow fields are available. Caution is necessary however in applying the standard text equations of aircraft motion (see for example [55]) since in most cases these equations incorporate simplifications and aerodynamic coefficients which are based on the assumption of uniform winds. Strong wind gradients can, for example, generate non-uniform wing and/or tail loading and additional roll, yaw or pitch moments due to differences in angle of attack at the wing than at the center of gravity which make the aerodynamic coefficient based on uniform wind implauisble. In turn the linearized form of the equations of motion which permit only small departures from a equilibrium state [56] cannot be applied when the wind field varies significantly with the spatially coordinate and hence no well defined equilibrium state exists.

One anticipates rolling moments due to wind gradients which would require rapid control response in order to avoid hard or asymmetric landings. Analysis of landing in wind over homogeneous terrain have been made for linear wind profiles employing a linearized theory [6,57] and for more general wind profiles using theory which assumes the longitudinal and lateral motion of the aircraft may be uncoupled [14]. The later is valid for wings level flight directly into the wind; however, the effect of a yawing or rolling angle is not taken into account.

Flight in winds near ground level over homogeneous terrain and particularly around buildings thus requires analysis employing equations of motion which include wind components which are time and spatial dependent and aerodynamic forces which are modified in accordance with the presence of the wind gradient.

CONCLUDING COMMENTS

The intent of this paper is to point out to the aircraft safety investigation community some of the potential sources of low level wind shear at and around airports. The paper is by no means exhaustive and much remains to be accomplished to better define low level wind shear for both aircraft design and operational applications. Perhaps through a better definition of these environments aircraft may be designed and operated such that they can negotiate and avoid harsh shear environments. At the present time operational equipment (other than rawinsonde, etc.) is not available to provide wind shear data on a routine basis at airports. A possible solution to providing wind shear data for operations is remote sensing equipment. Such equipment does exist; however, it needs to be developed such that it can be used in an operational environment. The availability of wind shear data in an operational context will be a positive step forward toward the elimination of wind shear as a source of aircrft accidents. In view of the goal of the aviation community to develop "all-weather" automatic landing systems the need for wind shear design environment definition for design studies is critical. If these wind shear environments are not properly specified, then automatic landing systems may be designed which are characterized by unacceptably high risks of encountering low level shear environments which excced the design and certification wind shear levels, thus, providing a potential future source of aircraft accidents. It is evident from the survey that mathematical models of wind shear, particularly over and around buildings, requires considerably more development in order to provide guidance material for the design of airports and aircraft, and for establishing requirements, criteria, and procedures for reporting wind shear to pilots.

REFERENCES

1. Melvin, W. W., 1971: Wind shear on the approach. Shell Aviation News, 393, 16-21.

2. Kraus, K., 1972: Aspects of the influence of low-level wind shear on aviation operations. International Conference on Aerospace and Aeronautical Meteorology, Washington, D. C., May 22-26, 1972.

3. ICAO Secretariat, 1974: Agenda Item 12: Meteorological observing systems at aerodromes, b) Low level turbulence and wind shear: Aeronautical Requirements for Wind Shear Data. Eighth Air Navigation Conference, AN Conf/8-WP/7, CAeM Ext. (74)/Dec 8.

4. Roberts, C. F., 1963: A preliminary analysis of some observations of wind shear in the lowest 100 feet of the atmosphere for application to the problem of the control of aircraft on approach, Vertical Wind Shear in the Lower Layers of the Atmosphere, TN 93, World Meteorological Organization, Geneva, Switzerland, pp. 203-218.

5. Fichtl, G. H., 1972: Wind shear near the ground and aircraft operations, Journal of Aircraft, Vol. 9, No. 11, pp. 765-770.

6. Etkin, B., 1947: Effect of wind gradient on glide and climb. Journal of Aeronautical Sciences, 14, 365-367.

7. Luers, J. K., 1973: A model of wind shear and turbulence in the surface boundary layer. NASA CR-2288, National Aeronautics and Space Administration, Washington, D. C.

8. Fichtl, G. H., 1974: Problems in the simulation of atmospheric boundary layer flows. AGARD Conference Proceedings No. 140, Advisory Group for Aerospace Research & Development, 7 Rue Ancelle, 92200 Neuilly Sur Seine, France.

9. Tennekes, H., 1973: The logarithmic wind profile. Journal of the Atmospheric Sciences, 30, 234-238.

10. Blackadar, A. K., 1965: A single layer theory of vertical distribution of wind in a baroclinic netural atmospheric boundary layer. Flux of Heat and Momentum in the Planetary Boundary Layer of the Atmosphere, The Pennsylvania State University Mineral Industries, Dept. of Meteorology, Final Rept., AFCRL Contract No. AF9604-6641, 140 pp.

11. Blackadar, A. K., et al., 1969: Investigation of the turbulent wind field below 150 m altitude at the Eastern Test Range. NASA CR-1410. National Aeronautics and Space Administration, Washington, D. C.

12. Lumley, J. L., and Panofsky, H. A., 1964: The structure of atmospheric turbulence, New Yor, Wiley, 239 pp.

13. Monin, A. S., and Yaglom, A. M., 1971: Statistical fluid mechanics: mechanics of turbulence, Vol. I., The MIT Press, 769 pp.

14. Luers, J. K. and Reeves, J. B., 1974: Effect of shear on aircraft landing. NASA CR-2287. National Aeronautics and Space Administration, Washington, D. C.

15. Blackadar, A. K., and Tennekes, H., 1968: Asymptotic similarity in neutral barotropic planetary boundary layer. Journal of the Atmospheric Sciences, 25, 1050-1056.

16. Clarke, R. H., 1970: Observation studies in the atmospheric boundary layer. Quarterly Journal of the Royal Meteorological Scoiety, 96, 91-114.

17. Deardorff, J. W., 1972: Numerical investigation of neutral and unstable planetary boundary layers. Journal of the Atmospheric Sciences, 29, 91-115.

18. Csanady, G. J., 1967: On the "resistance law" of a turbulent Ekman layer. Journal of the Atmospheric Sciences, 24, 467-471.

19. Logan, E., 1974: Atmospheric wind and stress profiles in a two-dimensional internal boundary layer. (to be published as a NASA Technical Memorandum).

20. Elliott, W. P., 1958: The growth of the atmospheric internal boundary layer. Trans. Amer. Geophys. Union, 39, 1048-1054.

21. Panofsky, H. A. and A. A. Townsend, 1964: Change of terrain roughness and the wind profile. Quart. J. Roy. Meteor. Soc., 90, 147-155.

22. Townsend, A. A., 1965: Self-preserving flow inside a turbulent boundary layer. J. Fluid Mech., 22, 773-797.

23. Townsend, A. A., 1965: The response of a turbulent boundary layer to abrupt changes in surface conditions. J. Fluid Mech., 22, 799-822.

24. Townsend, A. A., 1966: The flow in a turbulent boundary layer after a change in surface roughness. J. Fluid Mech., 26, 255-266.

25. Taylor, P. A., 1969: The planetary boundary layer above a change in surface roughness. J. Atmos. Sci., 26, 432-440.

26. Peterson, E. W., 1969: Modification of mean flow and turbulent energy by a change in surface roughness under conditions of neutral stability. Quart. J. Roy. Meteor. Soc., 95, 561-575.

27. Rao, K. S., J. C. Wyngaard and O. R. Cote, 1974: The structure of the two-dimensional internal boundary layer over a sudden change of surface roughness. J. Atmos. Sci., 31, 738-746.

28. Frost, Walter, 1973: Review of data and prediction techniques for wind profiles around manmade surface obstructions. AGARD Conference Proceedings No. 140 on Flight in Turbulence, Advisory Group for Aerospace Research and Development, 7 Rue Ancelle, 92200 Neuilly Sur Seine, France.

29. Hunt, J. C. R., 1971: The effect of single buildings and structures. Phil. Trans. of the Royal Society of London, 269, p 457.

30. Owen, P. R., 1971: The aerodynamics of buildings. Fluid Dynamic Transactions, 6, Part I, p 371.

31. Bearman, P. W., 1972: Some recent measurements of the flow around bluff bodies in smooth and turbulent streams. Symposium on External Flows, Bristol University, p. B.1.

32. Wind effects on buildings and structures. Proceedings of the Conferences on Wind Effects on Buildings and Structures, 1963, 1967, 1971.

33. Good, M. C. and Joubert, P. C., 1968: The form drag of of two-dimensional bluff-plates inversed in turbulent boundary layers. Journal of Fluid Mechanics, 31, 547-582.

34. Frost, Walter: Ground wind effects on aircraft performance in the vicinity of surface obstructions. Report in preparation under NASA Contract NAS8-27387.

35. Chang, Shih-Cheng, 1966: Velocity distributions in the separated flow behind a wedge shaped model hill. Engineering Research Center, College of Engineering, Colorado State University, Fort Collins, Colorado.

36. Tani, I., Iuchi, M. and Komoda, H., 1961: Experimental investigation of flow separation associated with a step or a groove. Aero. Research Institute, Univ. of Tokyo, Rept. No. 364.

37. Bradshaw, P. and Wong, F. Y. F., 1972: The reattachment and relaxation of a turbulent shear layer. Journal of Fluid Mechanics, 52, Part 1, 113-135.

38. Halitsky, James, 1968: Gas diffusion near buildings, meteorology and atomic energy. Editor David Slade, TID 24190, U. S. Atomic Energy Commission, 221-255.

39. Plate, E. J., 1971: Aerodynamic characteristics of atmospheric boundary layers. AEC Review Series, TID-25465, U. S. Atomic Energy Commission.

40. Mueller, T. J., Horst, H. H. and Chow, W. L., 1964: On the separation, reattachment, and redevelopment of incompressible turbulent shear flow, Trans. ASME, Journal of Basic Engineering, p. 221.

41. Penwarden, A. D., 1972: Wind environment around tall buildings. Building Research Station Digest 141, Garston, Watford WD2 7JR.

42. Ostrowski, J. S., Marshall, R. D., and Cermak, J. E., 1967: Vortex formation and pressure fluctuations on buildings. Proceedings of Wind Effects on Buildings and Structures, Vol. 1, University of Toronto Press.

43. Leutheusser, H. J. and Baines, W. Douglas, 1967: Similitude problems in building aerodynamics. Journal of Hydraulic Division, Proceedings ASCE, 35-49.

44. Sachs, Peter, 1972: Wind forces in engineering. Pergamon Press.

45. Krynytzky, A. J., 1972: Helicopter response to flows induced by tall buildings. M.S. Thesis, MIT.

46. Hotchkiss, R. S., 1972: The numerical calculation of three dimensional flows of air and particulates about structures. Proceedings of the Symposium on Air Pollution, Turbulence and Diffusion, New Mexico State University, Los Cruces, N. M.

47. McManus, R. M. P., 1971: Development of an approach and landing system with special reference to the effects of turbulence. Proceedings of International Conference on Atmospheric Turbulence, Royal Aero. Society.

48. Barnett, K. M., 1972: A wind-tunnel experiment concerning atmospheric vortex sheets. Boundary Layer Meteorology, 2, 427-443.

49. Maull, D. J. and Young, R. A., 1972: The wake of a bluff body in a non-uniform flow. Symposium on External Flows, Bristol University.

50. 1970: Planning and Design Criteria for Metropolitan STOL Parts FAA, AC159/5300-8.

51. Jones, W. P. and Rao, B. M., 1971: Airloads and moments on an aircraft flying over a pair of inclined trailing vortices. Aircraft Wake Turbulence and Its Detection, Plenum Press.

52. Ramirez, A. Jr., Rao, B. M. and Gonk, A. E., 1973: Longitudinal response of an aircraft due to a trailing vortex pair. Journal of Aircraft, 10, 638-639.

53. Chang, P. C., Wang, P. N. and Lin, A., 1972: Turbulent dffusion in a city street. Proceedings of the Symposium on Air Pollution, Turbulence and Diffusion, New Mexico State Univ., Los Cruces, N.M.

54. Frost, W., Maus, J. R., and Simpson, W. R., 1973: A boundary layer approach to the analysis of atmospheric motion over a surface obstruction, NASA CR-2182. National Aeronautics and Space Administration, Washington, D. C.

55. Etkin, Bernard, 1972: Dynamics of atmospheric flight. John Wiley and Sons, Inc.

56. Dobrolensky, Y. P., 1971: Flight dynamics in moving air. NASA TT F-600.

57. Gera, Joseph, 1971: The influence of vertical wind gradients on the longitudinal motion of airplanes. NASA TN D-6430.

58. Charba, J. P., 1972: Gravity-Current Model Applied to Analysis of Squall-Line Gust Front. Ph.D. dissertation, University of Oklahoma.

59. Marks, J. R., 1974: Acoustic radar investigations of boundary layer phenomena, NASA CR-2432. National Aeronautics and Space Administration, Washington, D. C.

60. Sinclair, R. W., R. A. Anthes, H. A. Panofsky, 1974: Variation of the low level winds during the passage of a thunderstorm gust front, NASA CR-2289. National Aeronautics & Space Administration, Washington, D. C.

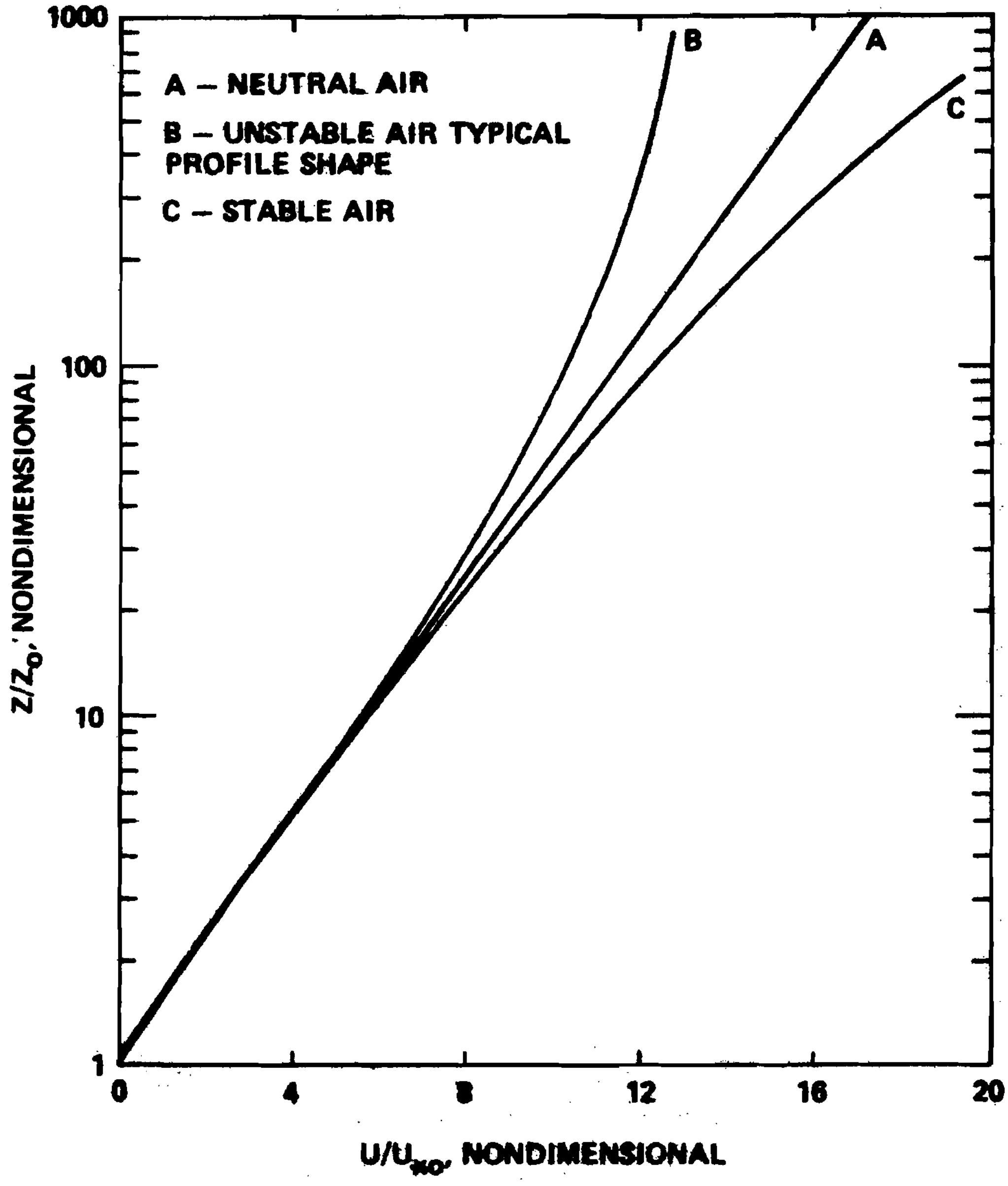


FIGURE 1. WIND PROFILES FOR VARIOUS STABILITY CONDITIONS OVER HORIZONTALLY HOMOGENEOUS TERRAIN. u_{*_o} AND DENOTE THE SURFACE FRICTION VELOCITY AND ROUGHNESS.

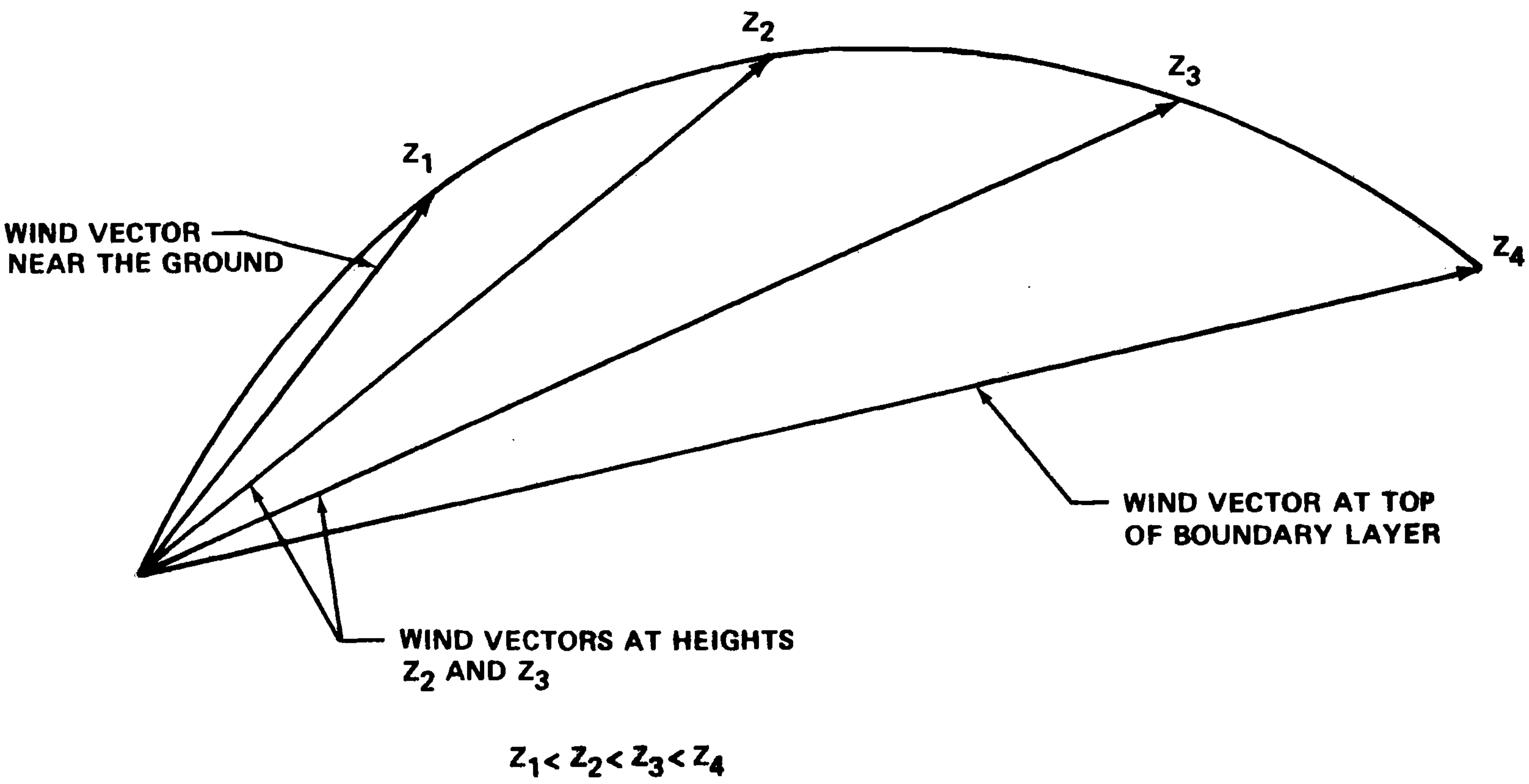


FIGURE 2. SCHEMATIC DIAGRAM OF HODOGRAPH OF ATMOSPHERIC BOUNDARY LAYER FLOW. NOTE THE CLOCKWISE TURNING OF THE WIND VECTOR AS ALTITUDE z INCREASES.

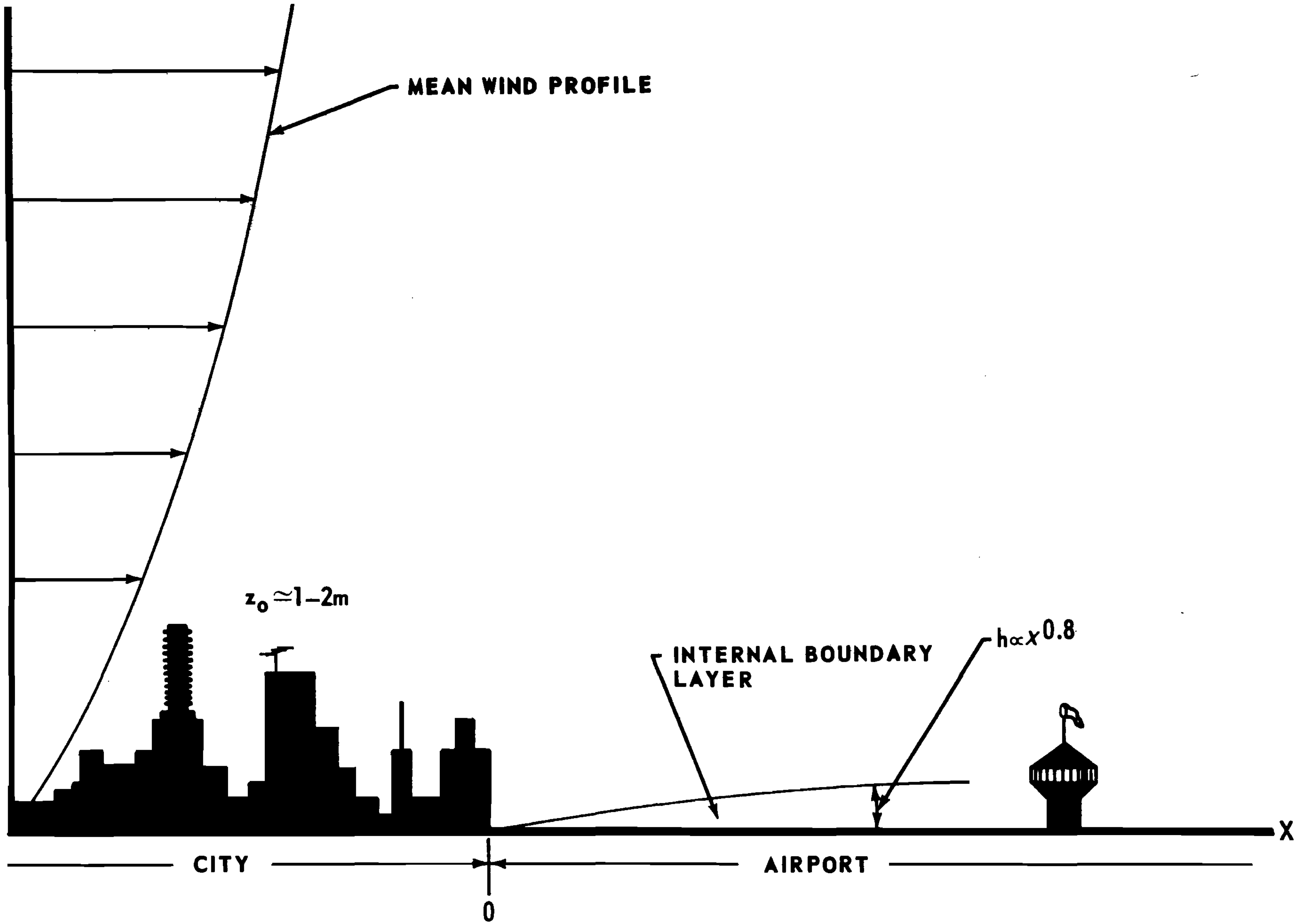


FIGURE 3. SCHEMATIC DIAGRAM OF THE INTERNAL BOUNDARY LAYER OVER AN AIRPORT RESULTING FROM AIR MOVING FROM ROUGH TO SMOOTH TERRAIN.

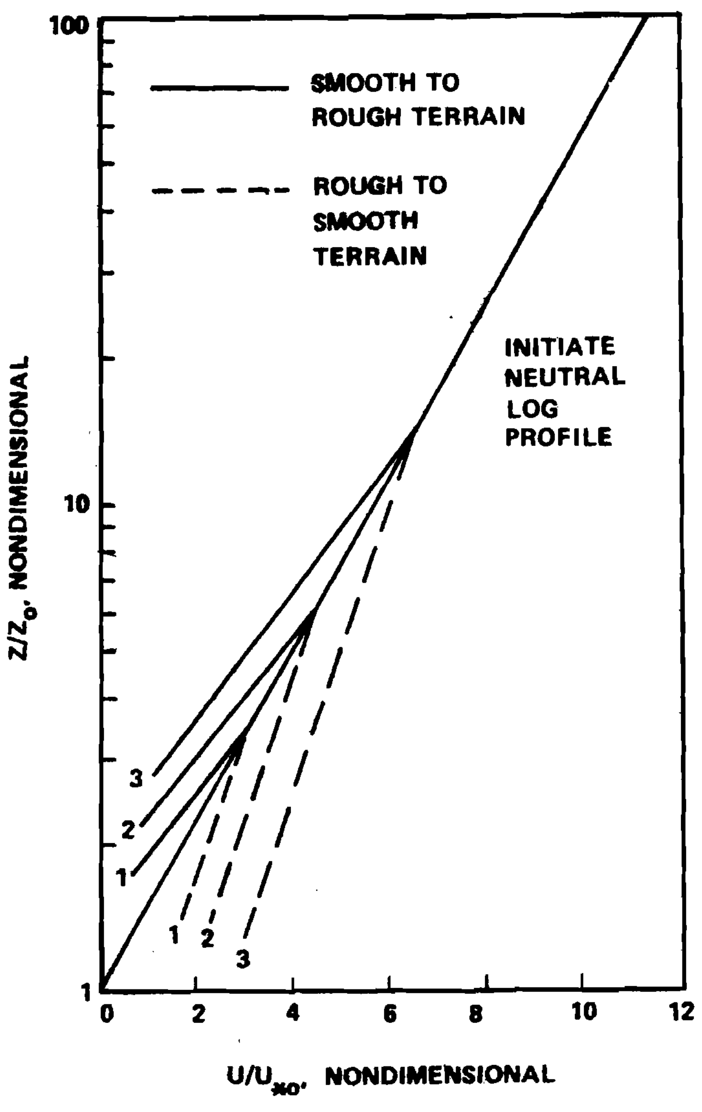


FIGURE 4. SCHEMATIC DIAGRAM OF THE VARIATION IN THE LOGARITHMIC WIND PROFILE DUE TO A DISCONTINUITY IN SURFACE ROUGHNESS. THE NUMBERS DENOTE THE SEQUENCE OF EVENTS FOLLOWING THE MEAN FLOW DOWNSTREAM FROM THE SURFACE ROUGHNESS DISCONTINUITY. u_{*_o} AND z_o DENOTE THE UPSTREAM SURFACE FRICTION VELOCITY AND ROUGHNESS.

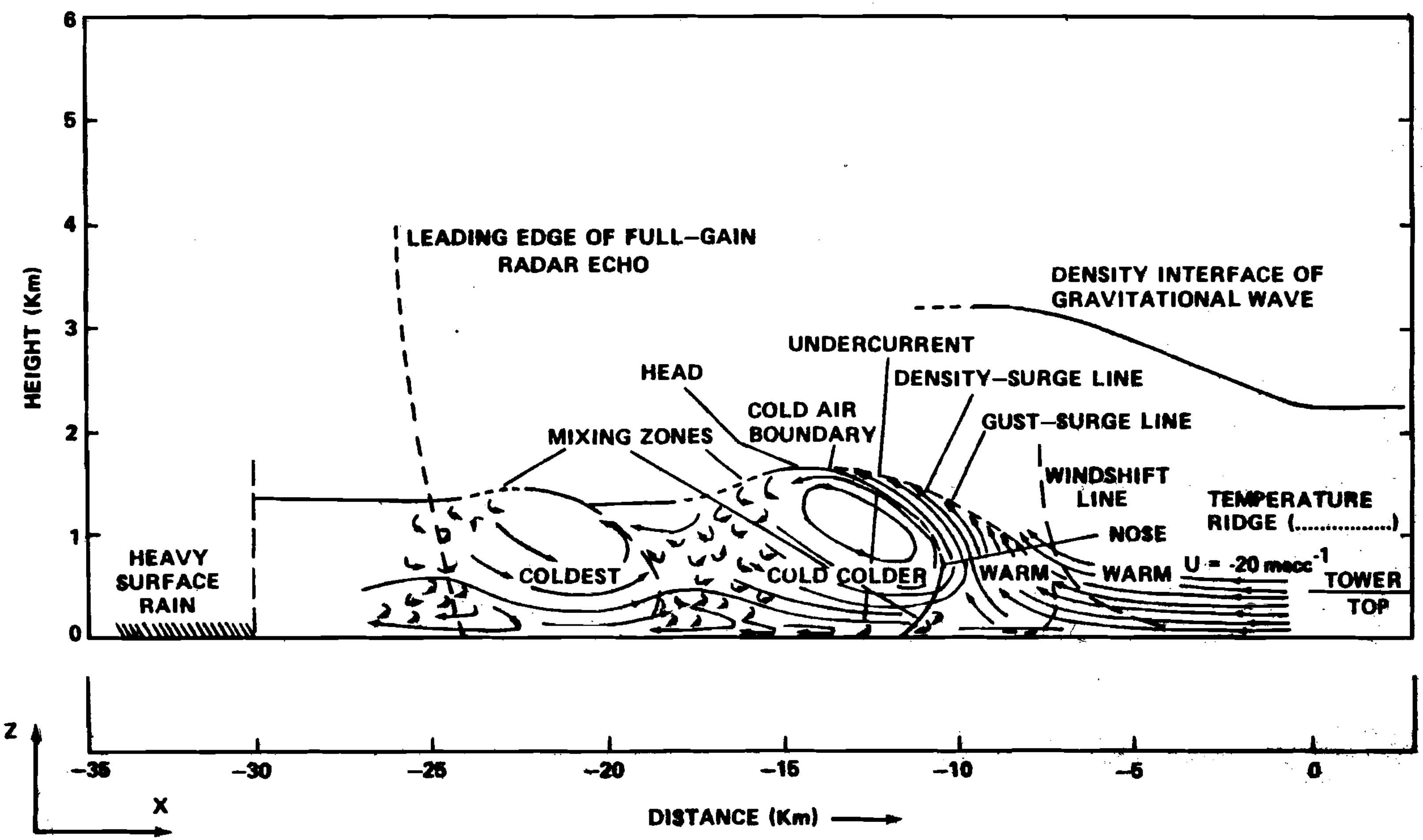


FIGURE 5. SCHEMATIC DIAGRAM OF THE STRUCTURE OF THE COLD AIR OUTFLOW FROM THUNDERSTORMS [58, 59].

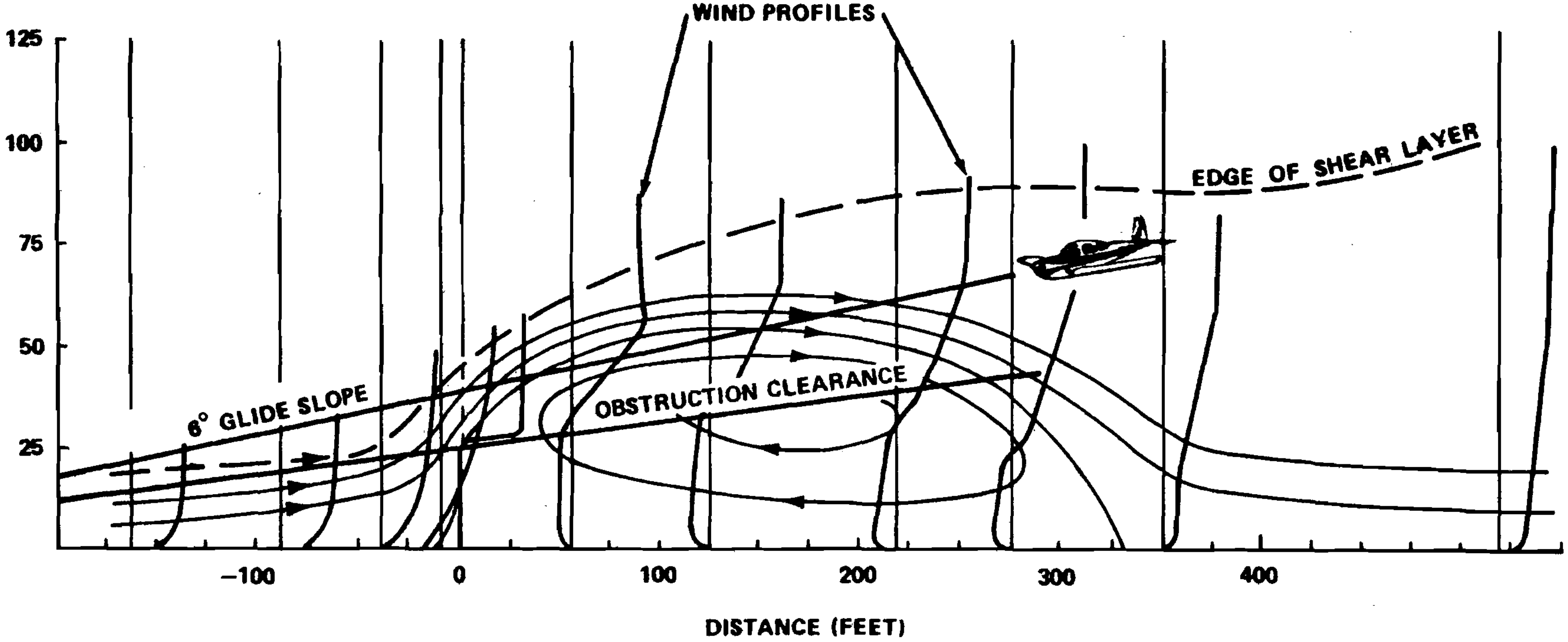


FIGURE 6. FLOW OVER A FENCE AND THE LANDING FLIGHT PATH OF A STOL VEHICLE THROUGH THE ASSOCIATED FLOW DISTURBANCE.

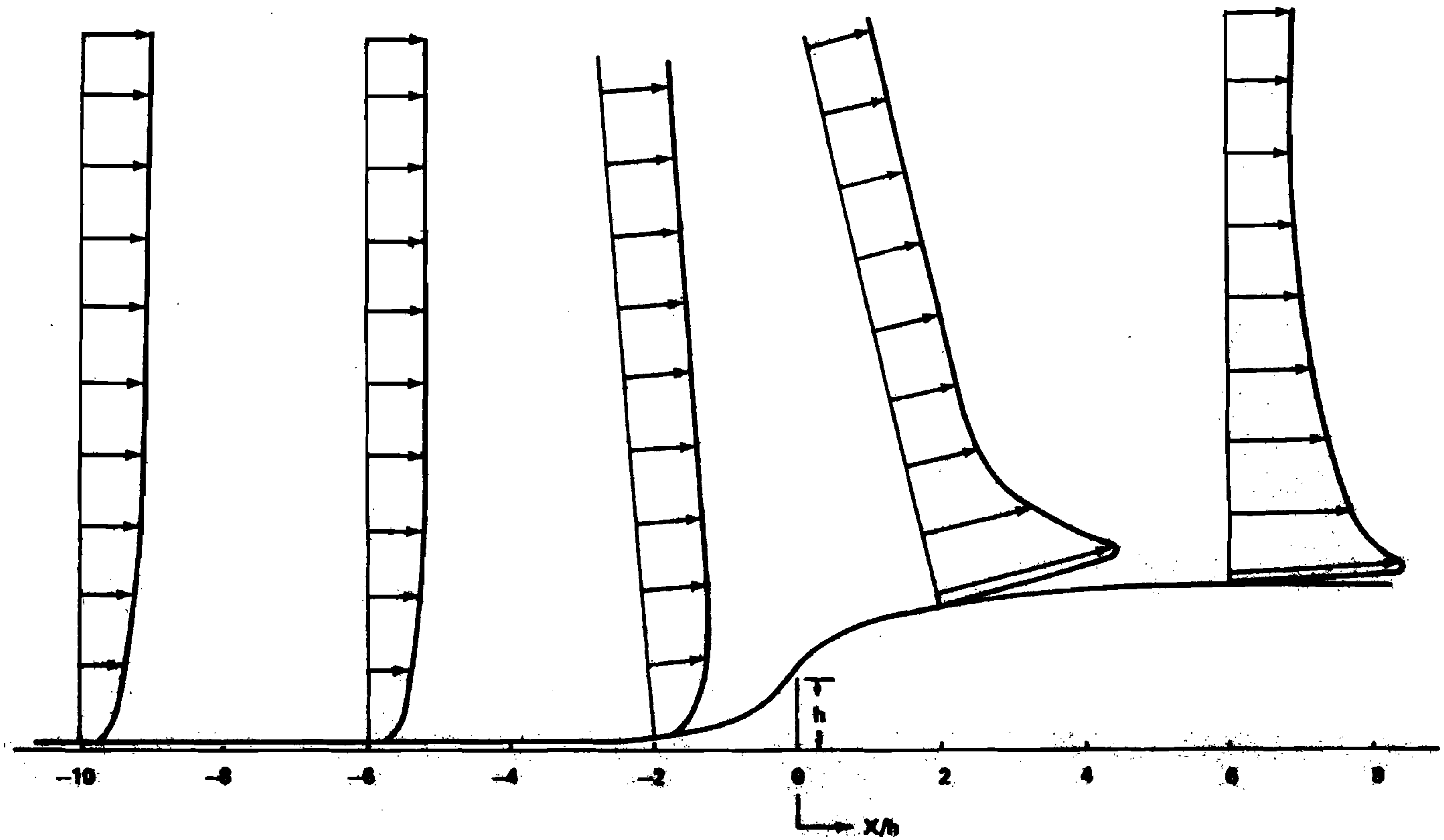


FIGURE 7. STEADY-STATE VELOCITY PROFILES OBTAINED FROM THE MSFC/UTSI COMPUTER CODE.

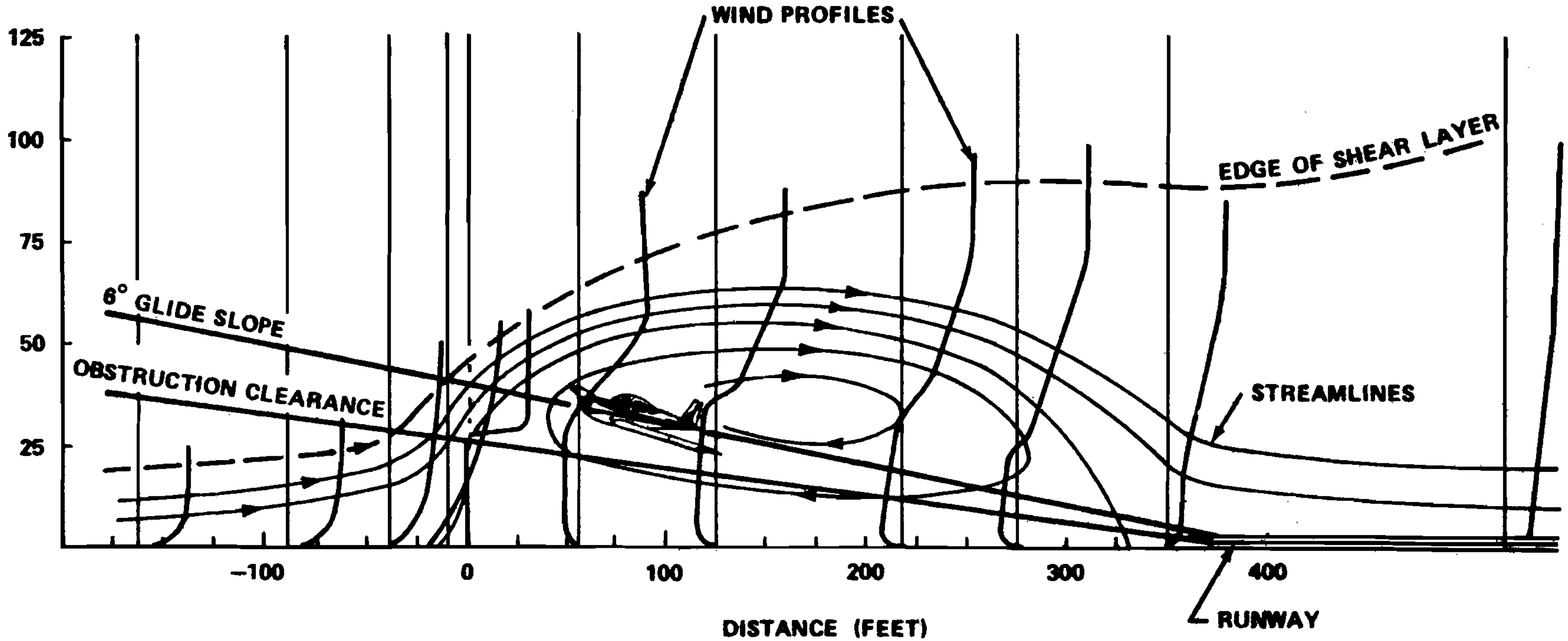


FIGURE 8. FLOW OVER A FENCE AND THE TAKE-OFF FLIGHT PATH OF A STOL VEHICLE THROUGH THE ASSOCIATED FLOW DISTURBANCE.

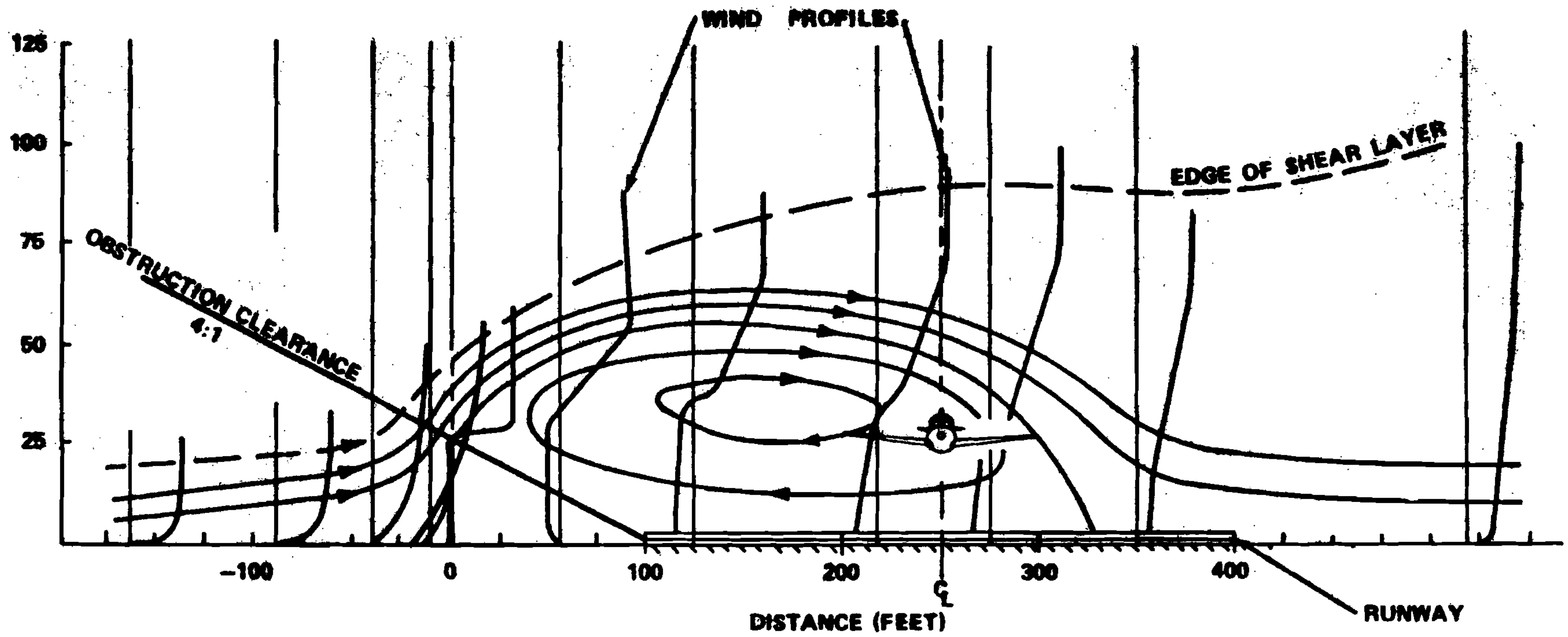


FIGURE 9. FLOW OVER A FENCE AS IN FIGURES 6 AND 8 FOR THE CROSSWIND CASE.

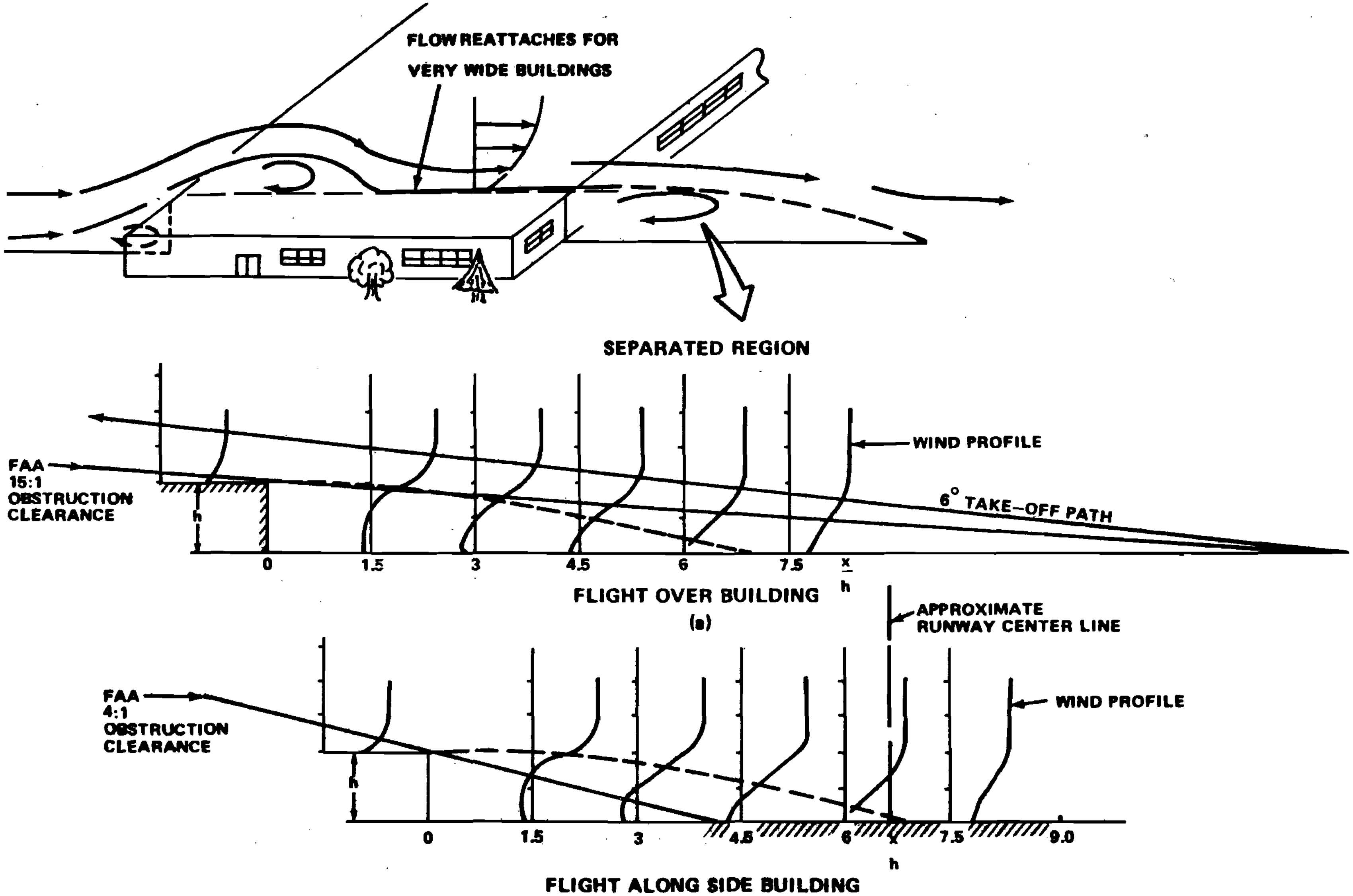


FIGURE 10. FLOW OVER A RELATIVELY WIDE, LOW BUILDING AND RELATIONSHIP BETWEEN THE WIND PROFILES AND THE RUNWAY ORIENTATION RELATIVE TO THE FLOW FOR THE HEADWIND CASE (a) AND THE CROSSWIND CASE (b).

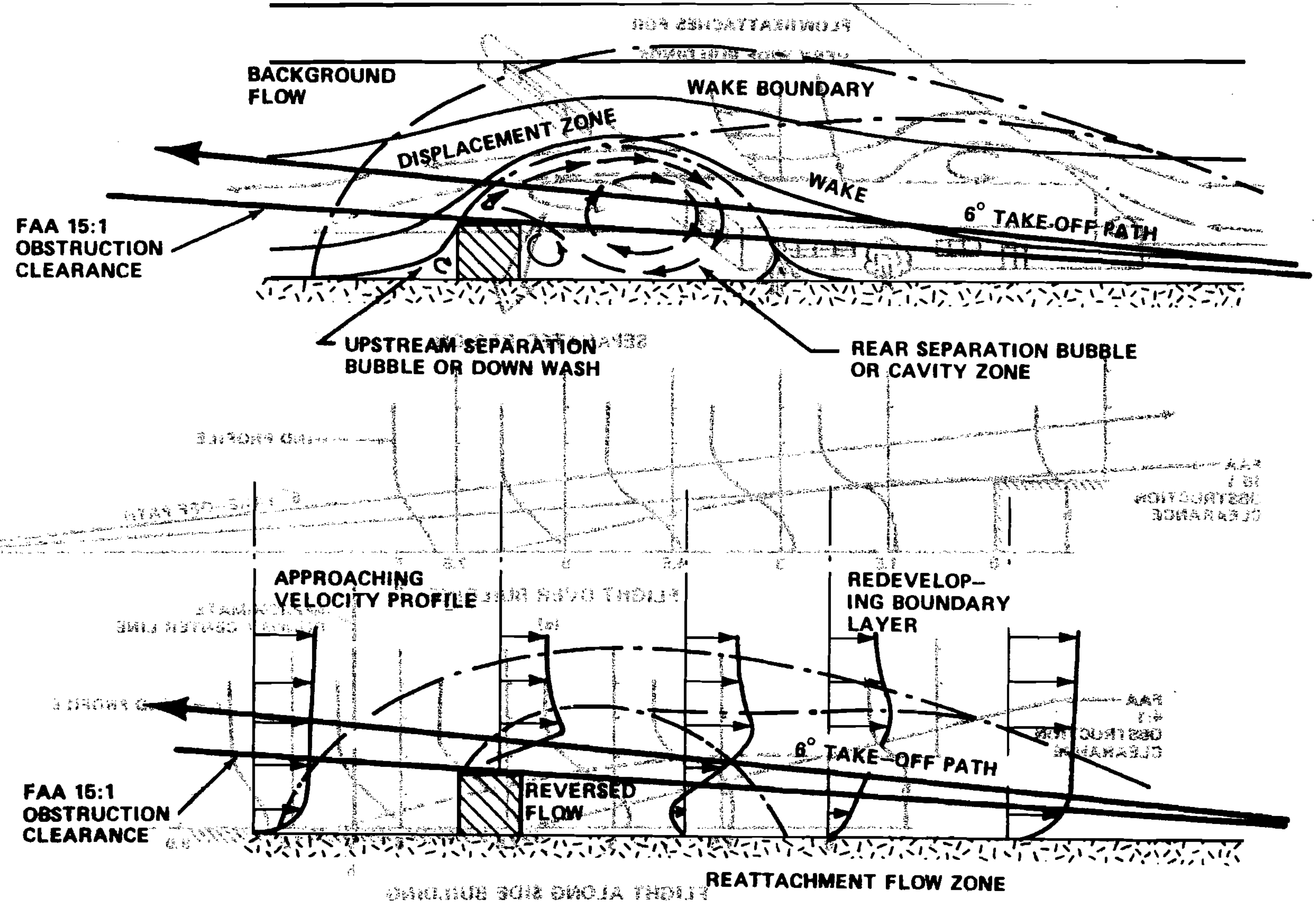
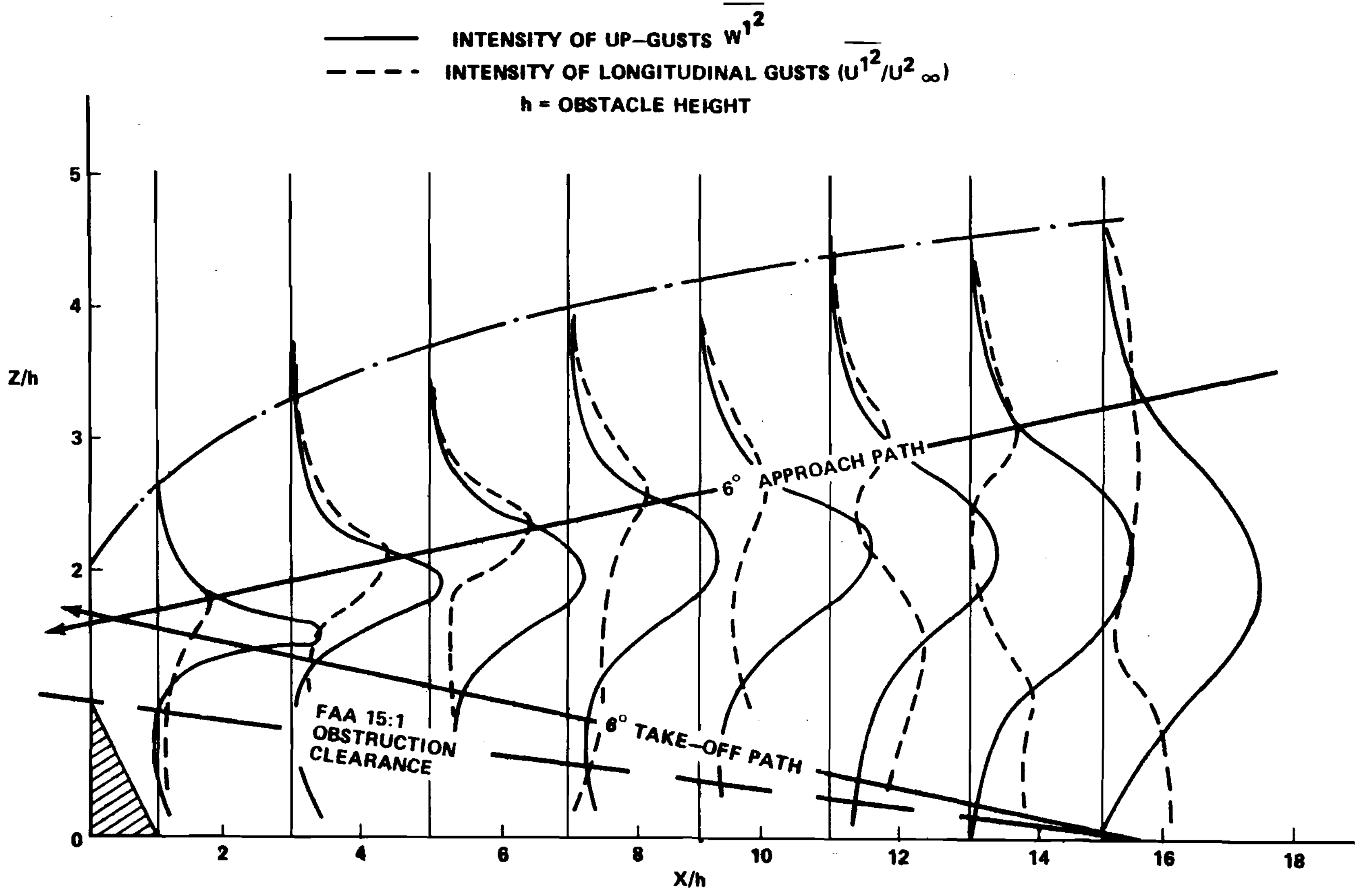


FIGURE 11. SCHEMATIC OF FLOW OVER A TWO-DIMENSIONAL SQUARE OBSTACLE AND THE TAKE-OFF FLIGHT PATH OF A STOL VEHICLE THROUGH THE ASSOCIATED FLOW DISTURBANCE.



(a) FENCE

FIGURE 12.a. GUST INTENSITY AS A FUNCTION OF POSITION DOWNSTREAM OF A FENCE AND THE TAKE-OFF AND LANDING FLIGHT PATHS OF A STOL VEHICLE THROUGH THE GUST INTENSITY PATTERN.

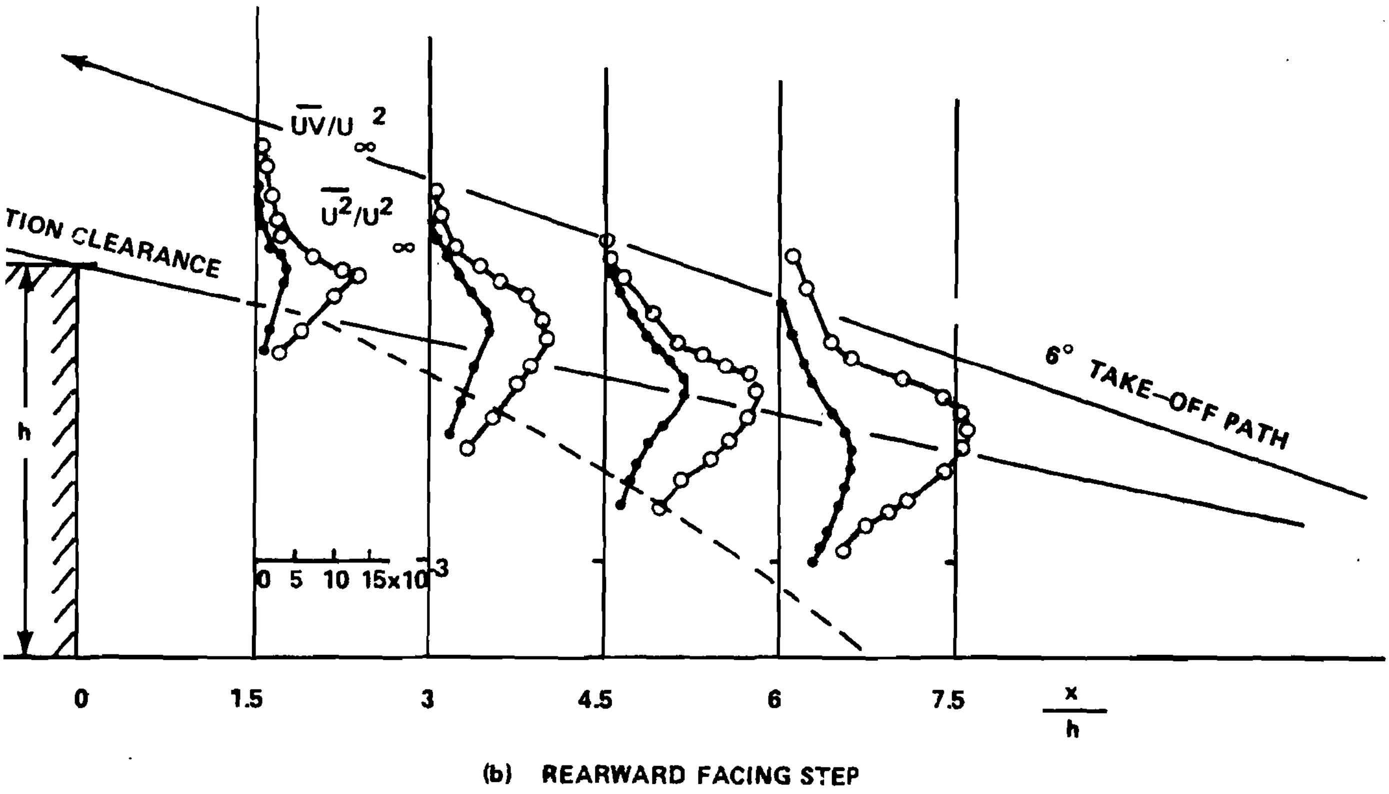
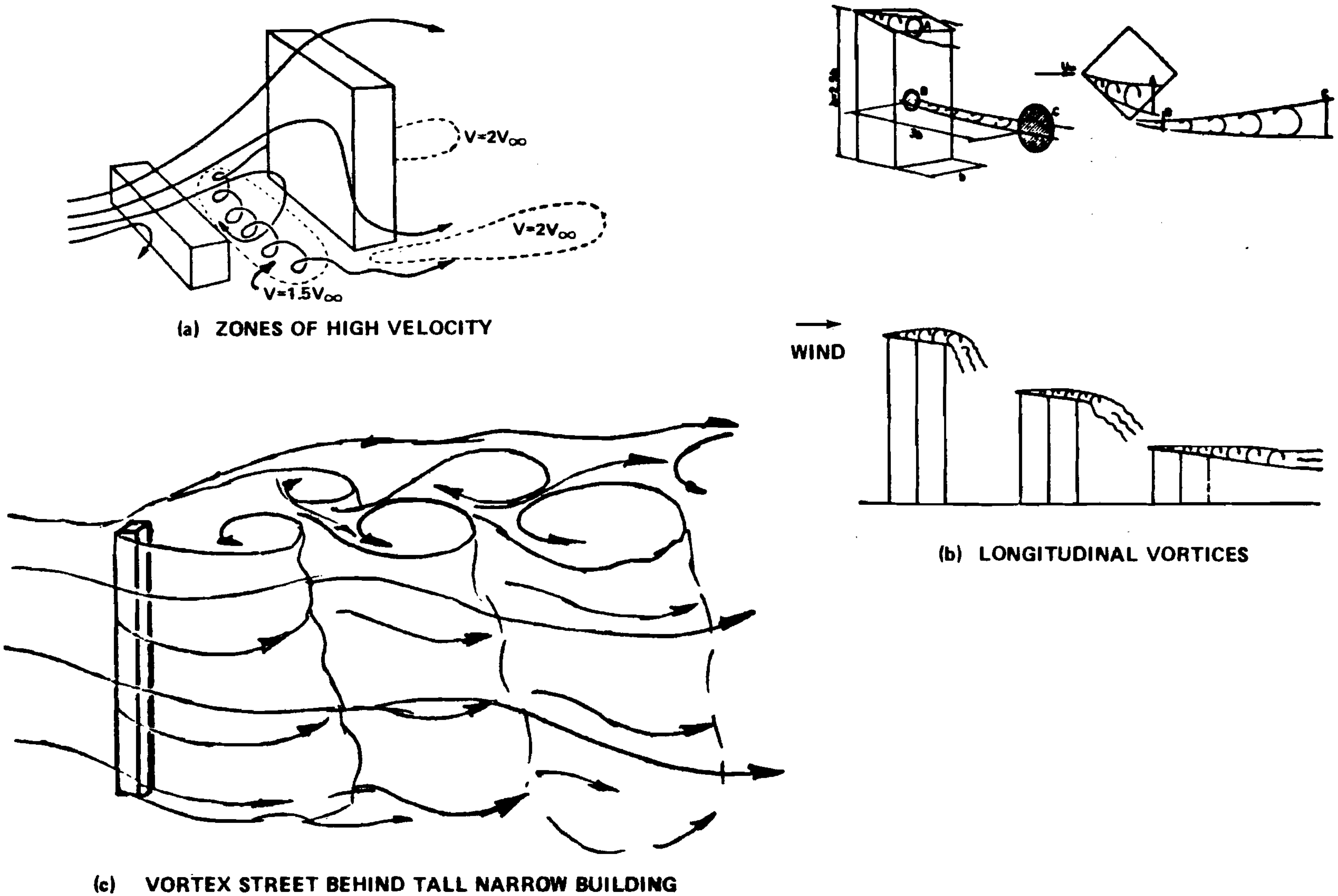


FIGURE 12.b. GUST INTENSITY AS A FUNCTION OF POSITION DOWNSTREAM OF A REARWARD FACING STEP AND THE TAKE-OFF FLIGHT PATH OF AN AERONAUTICAL SYSTEM.



(a) ZONES OF HIGH VELOCITY

(b) LONGITUDINAL VORTICES

(c) VORTEX STREET BEHIND TALL NARROW BUILDING

FIGURE 13. FLOW PATTERNS ASSOCIATED WITH THREE-DIMENSIONAL BUILDING GEOMETRIES.

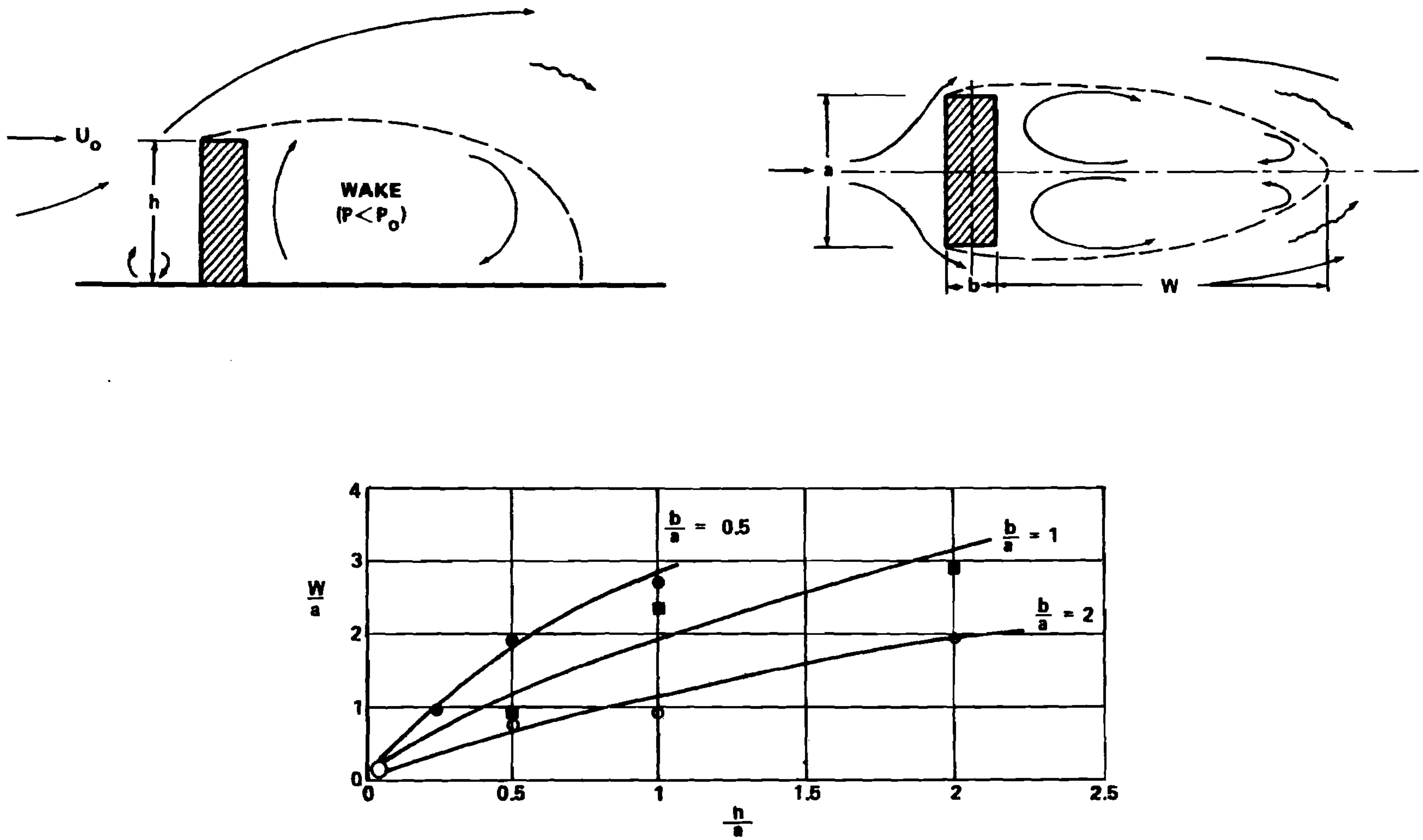


FIGURE 14. WAKE GEOMETRIES BEHIND A THREE-DIMENSIONAL BLUFF BODY [43].

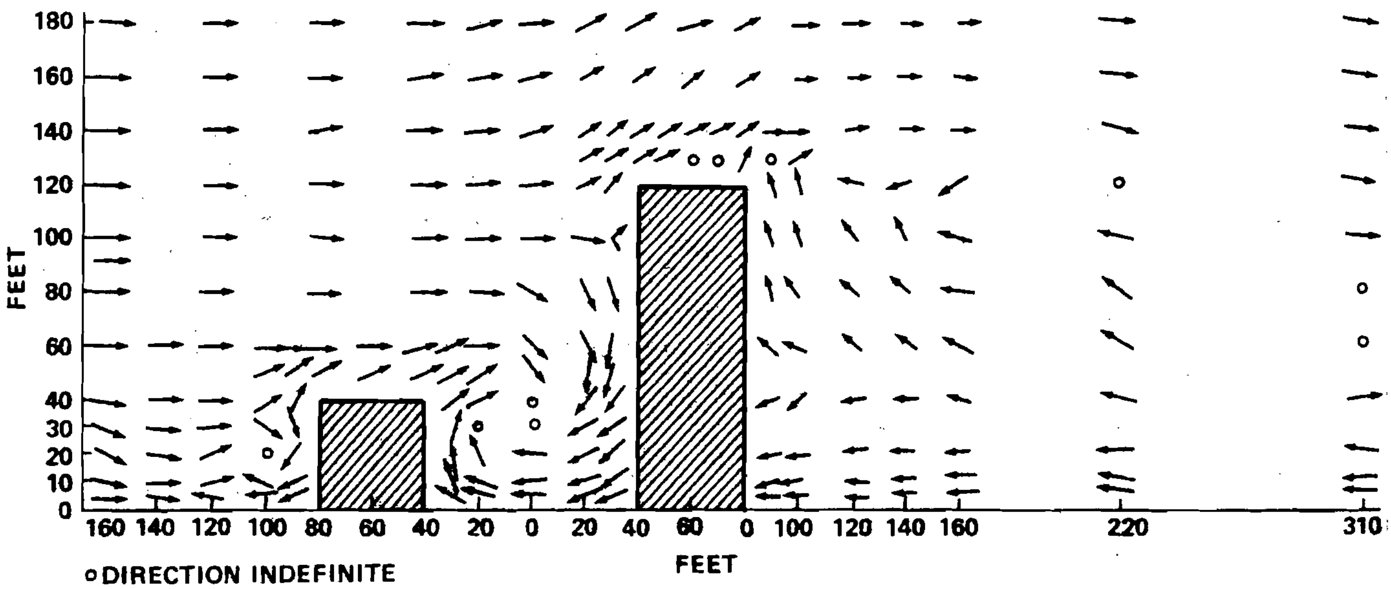


FIGURE 15. SLAB AND LOW BUILDING IN A GRADIENT WIND VELOCITY.

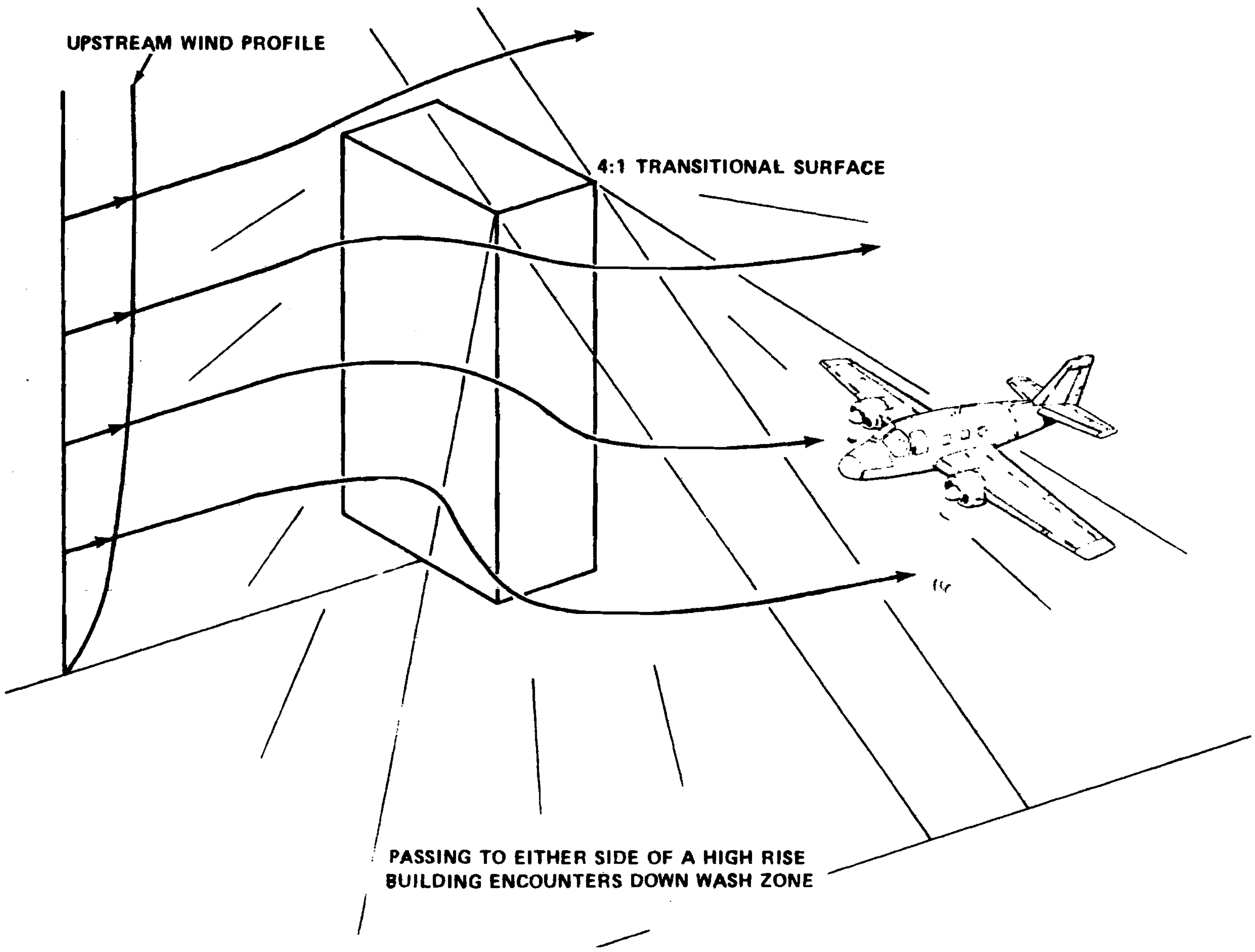


FIGURE 16. AN AIRCRAFT PASSING TO EITHER SIDE OF A HIGH RISE BUILDING ENCOUNTERS A DOWNWIND ZONE

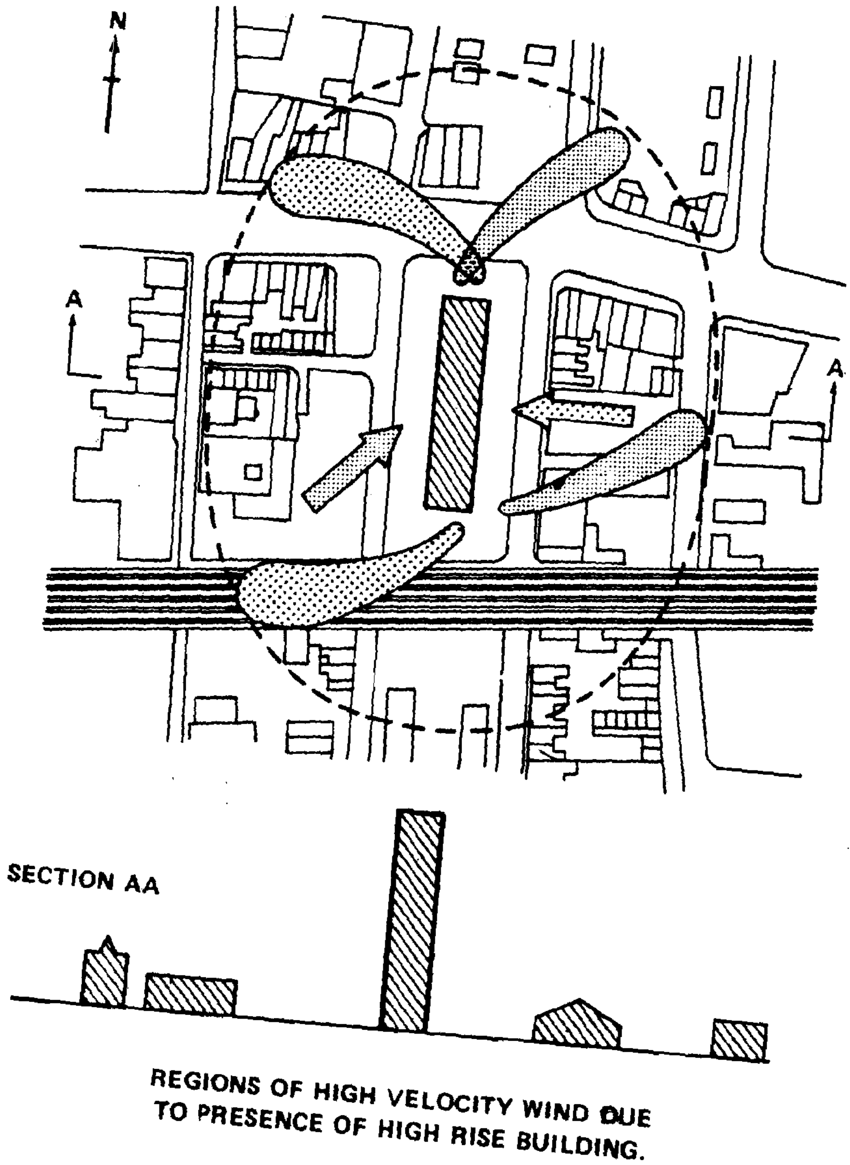
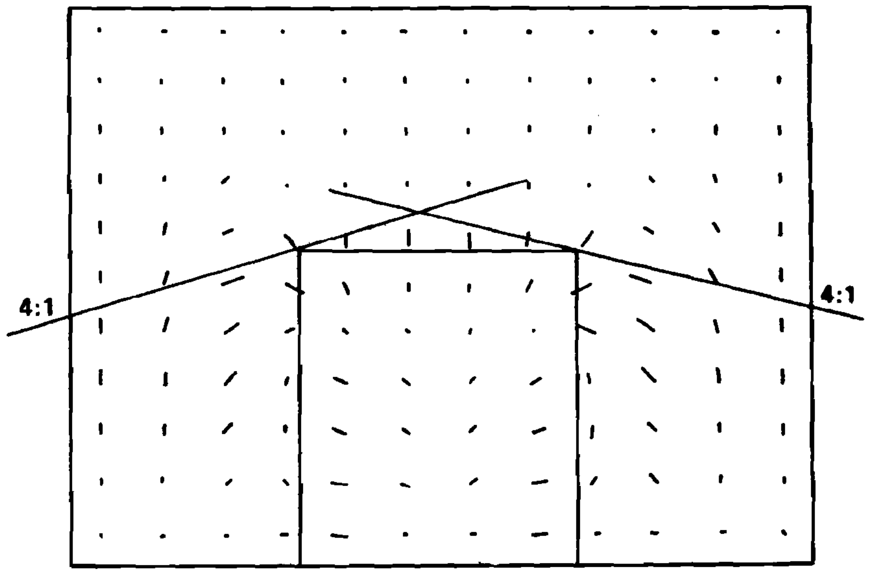


FIGURE 17. REGIONS OF HIGH VELOCITY WIND DUE TO PRESENCE OF HIGH RISE BUILDING [41].



PLANE VIEW OF THE VELOCITY VECTORS AS SEEN FROM ABOVE A SIMULATED BUILDING.

PLANE VIEW OF THE VELOCITY FIELD THAT EXISTS DIRECTLY BEHIND THE STRUCTURE AS SEEN FROM DOWNSTREAM

*LENGTH OF LINE SEGMENTS INDICATE VELOCITY MAGNITUDE

FIGURE 18. COMPUTED VELOCITY FIELDS ABOUT A THREE-DIMENSIONAL BLOCK BUILDING [46].

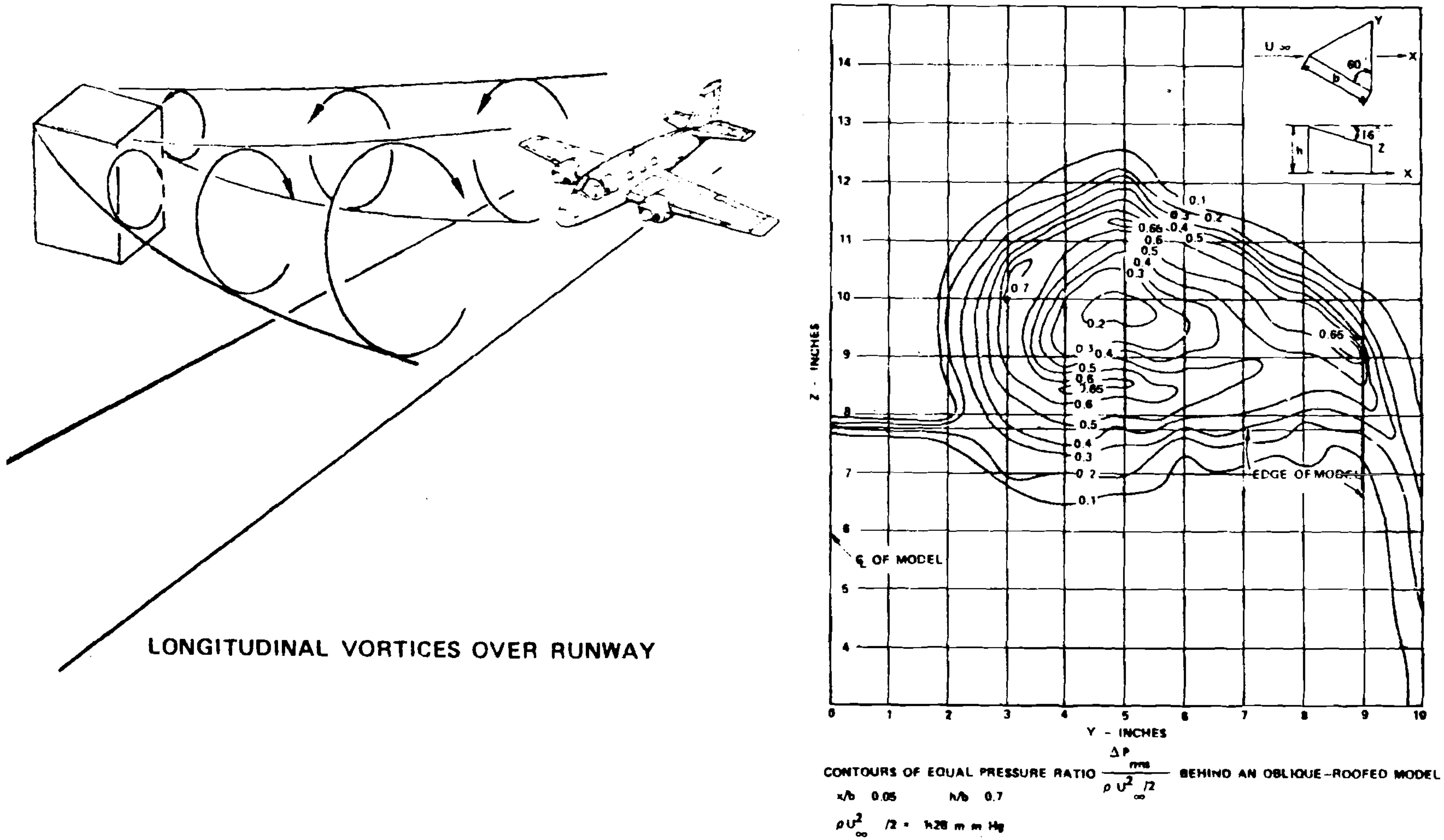


FIGURE 19. STRUCTURE OF LONGITUDINAL BUILDING VORTICES [42].

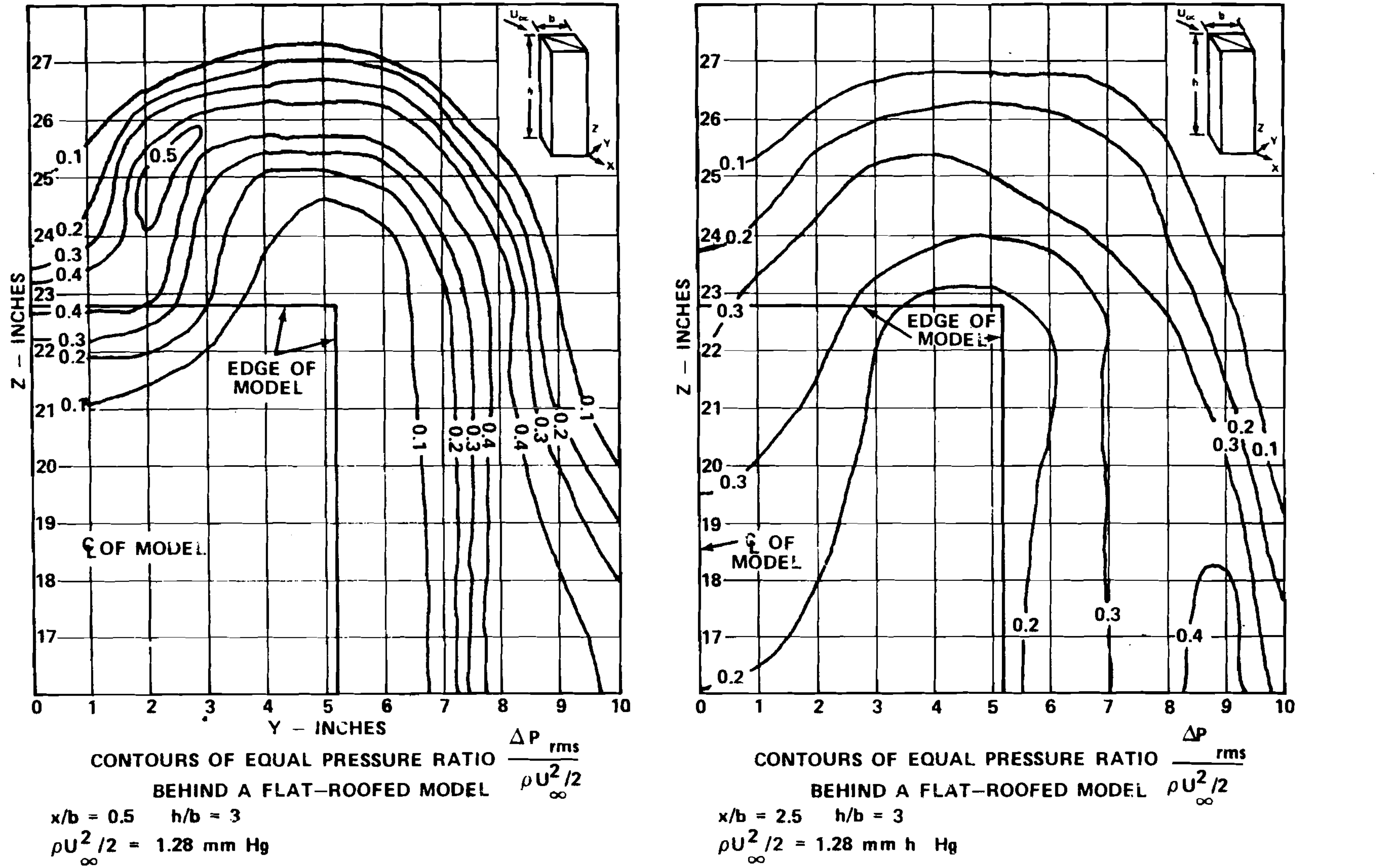


FIGURE 19 (continued). STRUCTURE OF LONGITUDINAL BUILDING VORTICES [42].

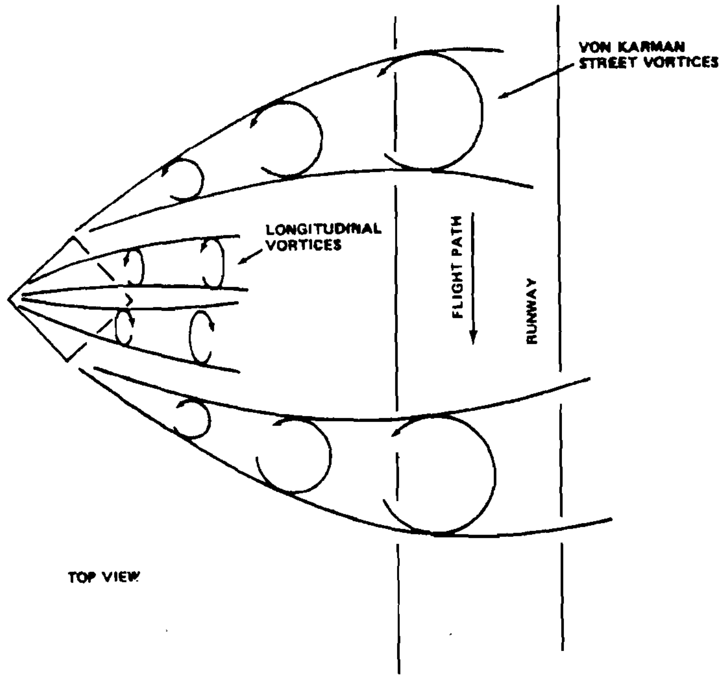


FIGURE 20. CROSSWIND FLIGHT PATHS THROUGH VORTICES

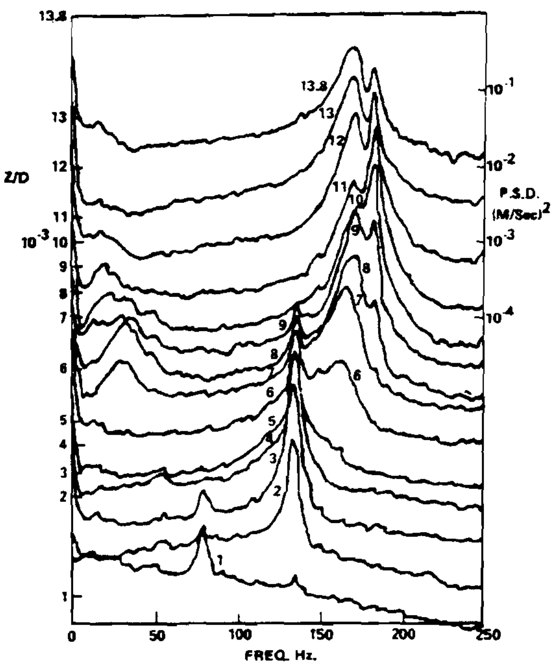


FIGURE 21. SPECTRA FOR VARIOUS z/D, L = 15D, SHEAR FLOW AT x = 6D [49].

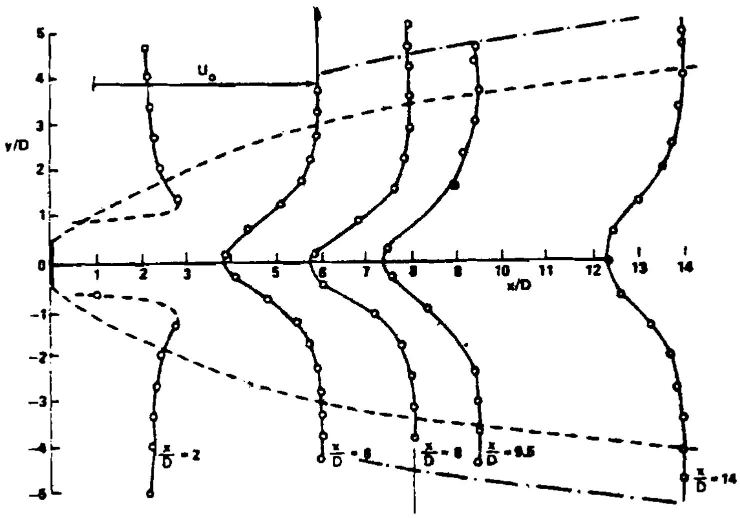


FIGURE 22. VELOCITY PROFILES IN THE WAKE OF A TWO-DIMENSIONAL FLAT PLATE -- TOTAL HEAD WAKE BOUNDARY -.- TURBULENCE-FREE WAKE BOUNDARY [31].

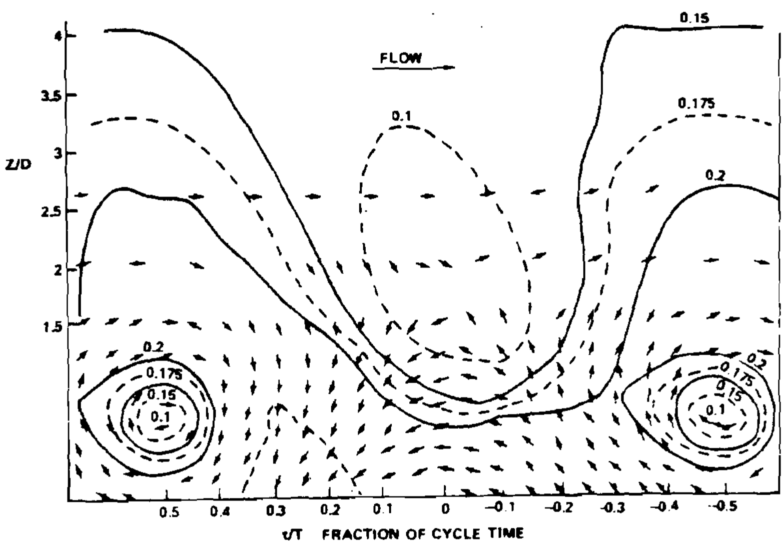


FIGURE 23. CONDITIONALLY AVERAGED CYCLE OF UPPER HALF OF FLAT PLATE WAKE AT x/D = 6, VORTICES STATIONARY. CONTOURS JOIN POINTS OF EQUAL FLOW SPEED, → LOCAL FLOW DIRECTION.

Air Traffic Accident Investigation
of
Weather Related Accidents

Air traffic control activity in aviation weather service covers a wide area of consideration. The FAA is concerned with the performance of controller personnel in the Flight Service Stations, the airport control towers and the air route traffic control centers. When a weather related aircraft accident/incident occurs, we look at the application of air traffic control procedures regarding dissemination of weather information.

The responsibilities of the flight service station specialist are many and cover all phases of the pilots briefing. Let us assume a pilot preparing for a crosscountry flight obtains a pre-flight weather briefing from the flight service specialist and an accident occurs. We begain our investigation by reviewing the FSS specialists pre-flight briefing for proper use of materials such as: hourly sequence reports, terminal forecasts, area forecasts, radar weather reports, upper winds, severe weather reports or forecasts, pilot reports and any other material which may be pertinent. The flight service specialist is also interested in post-flight weather information in the form of pilot reports. These reports can be of great value to the specialist in providing briefing to others. We are particularly interested in any areas of existing or forecast severe weather. The pre-flight phase of our or NWS responsibility is the basis for a pilot's decision to "go or no-go." A complete and accurate pre-flight briefing by the flight service specialist provides a reasonable safety factor to every pilot before he leaves the "blocks." When actual or forecast weather along the route on the surfacr or aloft indicates doubtful completion of a proposed VFR flight, the flight service specialist will advise the pilot "VFR Flight Not Recommended." Some examples of this are: May 3, 1974, N5286T was departing College Station, Texas VFR to Houston, Texas. The weather was forecast to be marginal VFR. The flight service specialist in his pre-flight briefing told the pilot "VFR flight not recommended." The aircraft departed and crashed 20 miles northwest of Houston, Texas with three fatalities. May 5, 1974, N56611 departed Pellston, Michigan on a VFR flight plan to Saginaw, Michigan. The flight service specialist advised against attempting a VFR flight because of existing weather conditions. N56611 departed on his proposed flight and crashed 3/4 of a mile southwest of Tri City Airport, Saginaw, Michigan. The four occupants were killed.

Another area of consideration when investigating weather related accidents/incidents is the proper handling of enroute advisories. First, and most important, is the severe weather which occurs or is forecast. This can be received in the form of a Pilot Report, SIGMET, or AIRMET. Timely dissemination of these reports is imperative to provide the user with current weather data. Pilot reports are solicited and should be volunteered, regularly to provide updates to existing conditions. SIGMETs are broadcast on the navigational aids to provide the user current and forecast information on severe weather areas. The normal communication process for enroute aircraft provides the specialist an opportunity to provide enroute weather information as required. However, we find in many cases the enroute communications by the user to be very limited.

The air route traffic control center provides some areas of enroute weather service. Although the primary function of an enroute controller is the separation of IFR aircraft, the air traffic manual provides procedures with respect to weather advisories. When a weather related aircraft accident/ incident occurs enroute, we review the application of ATC procedures by our enroute controllers.

The enroute ATC procedures manual requires controllers to be familiar with current weather prior to coming on duty and to remain aware of any pertinent changes in his area/sector and to provide certain weather information to aircraft in the system. For instance, the altimeter must be provided periodically to aircraft and to a descending turbojet prior to leaving flight levels and if ATIS information is not available or not received current weather at the destination airport must be given to an arrival aircraft prior to beginning an approach at a nonapproach control airport. Thedissemination of pilot reports is an area of concentration in the enroute environment. An enroute controller is required to pass information to appropriate users or other ground facilities when the report is significant. He must solicit PIPEP's when certain weather conditions exist including thunderstorms, icing and turbulence.

An enroute controller is required to advise, on initial contact, any aircraft entering his sector/area of significant weather which may affect his route of flight. These areas are considered when investigating an enroute controller's application of required procedures. We also look into those areas of additional services which should have been provided if traffic permitted. The enroute controller will issue weather echoes observed on radar and if workload permit, suggest radar navigation/guidance to avoid the observed areas. This additional radar assistance is only given when requested by the pilot and controller workload permitting. Separation of IFR traffic is always the primary responsibility of the ATC system. Our investigation attempts to determine if the controller provided the proper services under the control conditions at the time he worked the aircraft.

In the terminal area controllers' procedures differ appreciably from the other air traffic control specialties. A terminal controller is responsible for the issuing of current observed weather upon which the pilot makes his decision to depart, make an approach, or proceed to an alternate. When an aircraft accident/incident occurs in the terminal area, we investigate to determine if applicable procedures were properly followed. These include the required procedures and additional services if workload permitted. Each controller must become familiar with pertinent weather information when coming on duty and stay aware of current weather information needed to perform his duties. The requirement for handling and soliciting of pilot reports is the same as the enroute controller. The terminal controller is required to issue the current weather to arrival and departure aircraft whenever the existing weather falls below certain criteria, we examine the application of this requirement carefully. To assist in this requirement a controller uses direct reading instruments to provide current wind direction and velocity, altimeter setting and runway visibility or runway visual range when applicable. The terminal controller takes the official prevailing visibility when the value falls below four miles at the usual point of observation. We investigate the application of all these procedures which fall under additional services. Like the enroute controller, these services are primarily using the radar system to provide navigational guidance around weather areas.

All air traffic control radar systems have electronic cancelling circuitry to provide the best possible display for the control of air traffic. These circuits eliminate some areas of weather, at least partially, One circuit is designed to eliminate weather echoes on air traffic control radar and usually does a very satisfactory job. These factors must be considered when investigating air traffic services at radar facilities, to determine what radar information was displayed to the controller. To better classify and determine the operating efficiency of the radar system, we require the air traffic controller after an accident to provide in his statement the settings of controls on his radar display.

The air traffic control system is designed to provide safe, orderly and expeditious movement of aircraft, however, at times a part of that service is certainly weather related. Air traffic procedures require the controller to issue weather, solicit and disseminate pilot reports and provide advisories in other areas. When investigating aircraft accidents/incidents, we review the controller's performance with respect to these requirements and evaluate his application of procedures. Our primary goal is to provide for the safe movement of air traffic.

Airline Investigation of Weather Accidents and Incidents

by

W. Boynton Beckwith
United Air Lines

Airline meteteorology departments are today justified on the basis of contributing to safety, schedule reliability, good passenger service and optimum use of fuel, aircraft and flight crews. The National Weather Service provides most of the raw and processed weather data and many of the aviation forecast products on which airline operations may be planned. To meet the standards set for safety, service and profitability, airline meteorologists must fine tune the government forecasts, and produce their own special weather advisories. They must also be capable of providing quick update and amendment service to fill the gaps left by deficiencies in the state of the art of weather forecasting.

Many of the airline forecasting tools have had to be developed to meet changing operational requirements or to adapt to new facilities. In some cases they must have been made available for training and planning in advance of delivery of new equipment.

This is not a new responsibility, but is one that has been faced over the past four decades and has led to the now hackneyed expression that the one constant element in air transportation is change. Investigation of weather related accidents and incidents has played no small part in the development and refinement of the required forecasting tools. Some of this has come as feedback from a team effort with NTSB meteorologists with whom we have maintained an excellent rapport over the years. At other times the findings of aircraft incidents related to weather are used to advantage.

To put things in perspective, Figure 1 shows what today's airline weather problems are and how the focus has changed over the past 40 years due to changing technology. Not all of these factors necessarily have a strong impact on safety, but they do occasionally prevent meeting the goals established for maintaining an efficient transportation system.

We will not review in detail all of the elements shown in Figure 1, but will touch on three important ones - Fog, Thunderstorms and Clear Air Turbulence.

AIRLINE WEATHER PROBLEMS

1934		1974
Low clouds	····	
Fog	→	Fog
Snow and freezing rain	→	Snow and freezing rain
Aircraft icing	····	
Thunderstorms	→	Thunderstorms
Precipitation static	····	
Turbulence	→	Turbulence
Hail	····	
Wind shifts	→	Wind shifts
Strong cross winds	→	Strong cross winds
Mechanical turbulence	····	
Headwinds	→	Headwinds (and tailwinds)
	New problems	Clear air turbulence Low level wind shear High surface temperatures Wet runways Weather-induced air traffic delays

FIGURE 1

FOG

This element is as old as aviation and though much less of a problem today thanks to electronics, and better pilot training, it remains an important cause for accidents in the approach, landing and take-off regime. Forecasting the occurrence of dense fog down to the lower visibility values required today remains beyond the state of the art, even with the help of closely spaced weather measuring devices that have been studied in experimantal plots. If we could forecast fog accurately, the problem still remains of handling the aircraft safely in all cases where this environment exists.

Since we can't always plan diversions precisely on the basis of available forecasts, and since sophisticated hardware doesn't always do the job, there are many in the industry who feel that one solution is fog dispersal.

Effective programs for dispersing fog have been in existence for 12 years in the U.S. but on too limited a basis to significantly dent the fog problem. More sophisticated techniques do exist and others are in development which can be cost-effective for major airports when coupled with the CAT I or CAT II landing aids. Each airline accident involving fog simply emphasizes that more adequate support must be given to development of fog dispersal systems.

THUNDERSTORMS

As will be noted from Figure 1, two aspects of thunderstorms continue to pose threats to the safety record of airline operations - turbulence and the wind shift caused by the low level gust front.

Airborne radar has nearly eliminated the hazard of damaging hail and has greatly reduced turbulence encounters. The support given by the government weather radars should be acknowledged as an assist in planning for avoidance of thunderstorms.

Accidents caused by thunderstorms are still statistically significant as reported in NTSB records and many more encounters reach the attention of airline meteorologists as incidents.

Meteorological investigation of both accidents and incidents point to the need for more sophisticated detection equipment both aloft and on the ground. Although progress has been made in the refinement of ground radars and the related communications, the industry still hopes that some airborne device will some day be capable of detecting directly the worst turbulent zones within a thunderstorm cell instead of by inference from the precipitation patterns. This capability will have payoffs in fuel and time savings as well as minimizing exposure to the bone breaking turbulence along busy airways or on approach and departure corridors where there is not always enough elbow room to detour the heaviest cells.

Accident investigation has already exposed the subtleties of disturbed flow at cruise level along the flank and downstream from lines and clusters of strong thunderstorms. (Fig. 2) Scope photographs from National Weather Service ground radars and aircraft crash recorder tapes have revealed this evidence when composed with conventional weather data. This kind of new knowledge by itself will not improve accident or incident rates. It must be communicated to the flight crews through training, with information bulletins, and by revised flight operations policies.

The unpredictable gust front is an aviation problem which will probably not be completely solved until remote sensing devices such as the acoustic radar are installed at airports most vulnerable to this hazard - a hazard only for the unwary, the uninitiated, or the uninformed.

CLEAR AIR TURBULENCE

During a 4-day period in March 1956 several severe turbulence encounters occurred near Denver, while flights were crossing the Rockies in clear air. A number of passengers were injured, a few airframe rivets were popped and seat belts were torn loose from their anchors. Upon hearing of this violent weather, the president of a major airline ordered his Director of Meteorology to conduct such research as necessary to develop forecasting rules which might minimize future recurrences. The order seemed large at the time since mountain waves had been recognized for some decades as rough air producers. But with the help of pilot reports collected from military and civil aircraft including additional cases of what would now be defined as NTSB accidents, the well known UAL Mountain Wave nomogram was produced by Henry Harrison and his staff.

In the ensuing 18 years CAT forecasting has been refined extensively and expanded to include "non-mountain wave" situations. The most important ingredients which have given us the forecasting cues have come from accidents or incidents of CAT.

Figure 3 is a four-year record of such encounters classified as seve and including thunderstorm related incidents. It will be noted that only one-fifth of those charted are from thunderstorm situations - convincing evidence of the utility of airborne radar and the lack of an airborne CAT detector. The number of severe CAT cases might have been even higher but for some effective forecasting, flight planning and piloting.

The cluster of CAT cases in Colorado shown in Figure 3 clearly portr the influence of orographic features in producing the mountain wave typ of clear air turbulence - in these cases near Denver.

The earliest CAT forecasting capabilities and those that come neares to being applicable for pinpointing problem areas are associated with this type. Figure 4 shows the degree to which mountain wave CAT forecasting can be refined. This recognition is carried one step further in the establishment of preferred by-pass routes which are available when wave activity is strong on direct routes.

But not all CAT forecasting is capable of being so developed from the present state of knowledge and available coarse synoptic observation grids. Figure 5 depicts a fairly typical scatter pattern which defies efforts to forecast in a meaningful way.

Using all available pilot reports and analyses of moderate and severe CAT encounters (incidents and accidents) advancements are however being made in recognition of the synoptic patterns which relate to the worst cases. Such patterns are not yet reducible to computerization, but we are not far from that stage of refinement.

The NTSB has published figures indicating an average airline turbulence accident rate of .008 per million aircraft miles. Although this rate is lower than that found in other segments of aviation the airline industry is continually striving to improve the picture through research, improved forecasting and training. Accident and incident analysis of weather factors does truly play a significant part in improvement of the safety and reliability record in not only airline operations, but in all of aviation.

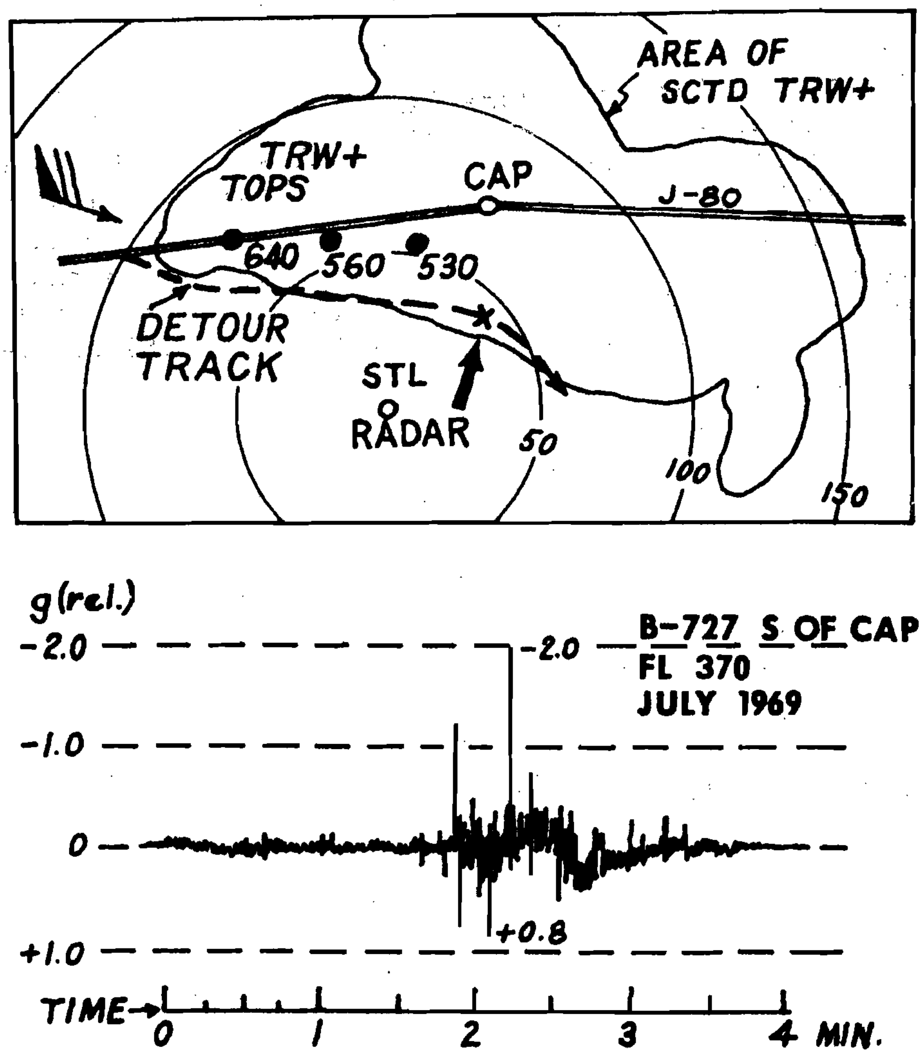


Figure 2. Analysis of severe case of CAT generated on flank of giant thunderstorm complex. Upper panel is constructed from NWS ground radar analysis, recorder tape and pilot's comments. Lower trace is a reproduction of the aircraft accelerometer trace. Detouring of the thunderstorm cells VFR was in accordance with accepted practices using a separation distance of 30 miles. The undisturbed wind field at flight level was 70 knots but suspected of reaching twice this value in the shear area where the encounter occurred.

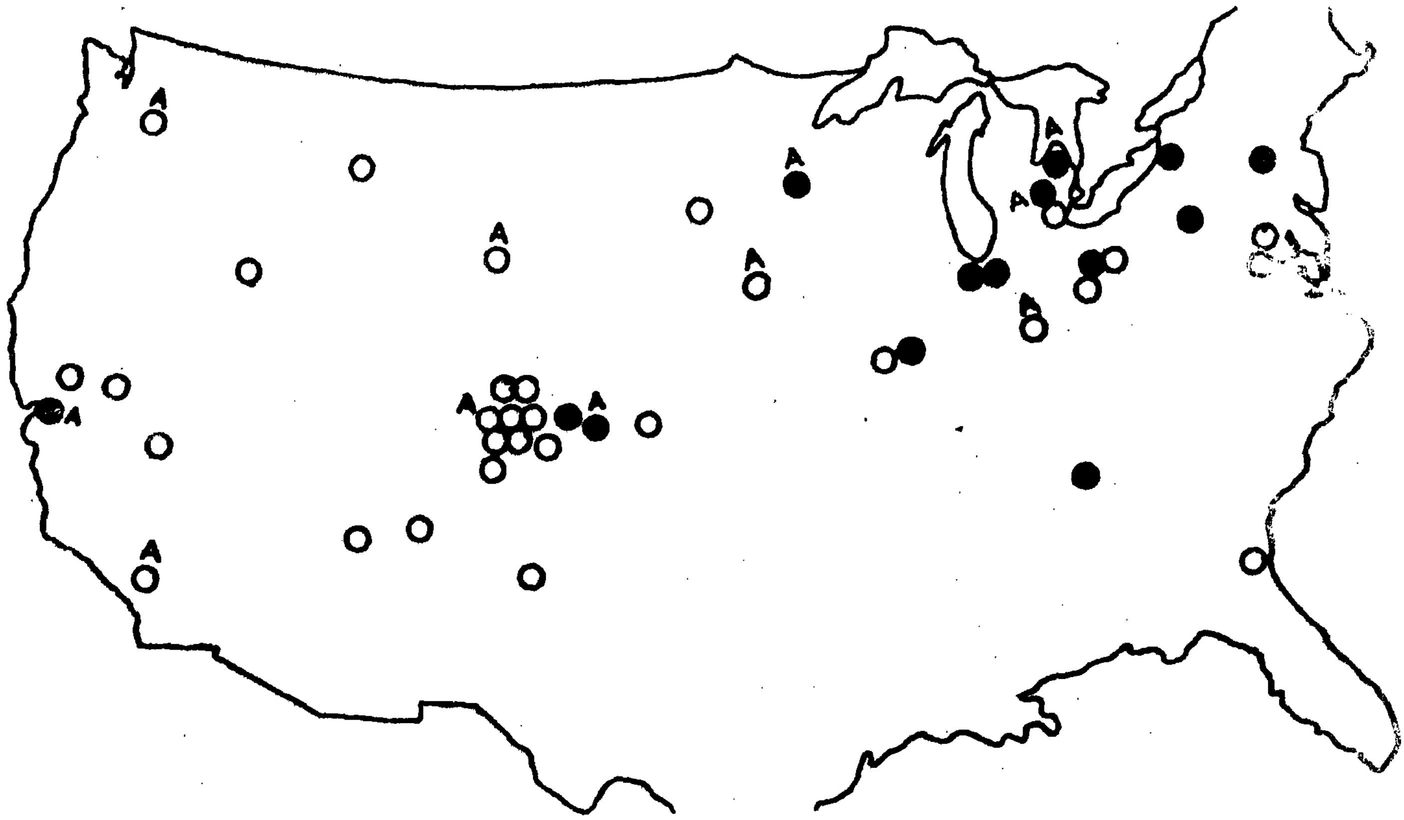


Figure 3. Plot of 45 severe turbulence incidents and accidents encountered over a 48-month period by one U. S. trunk airline. Solid circles are thunderstorm turbulence cases; clear circles are cases of CAT. Accidents as defined by NTSB are labelled "A".

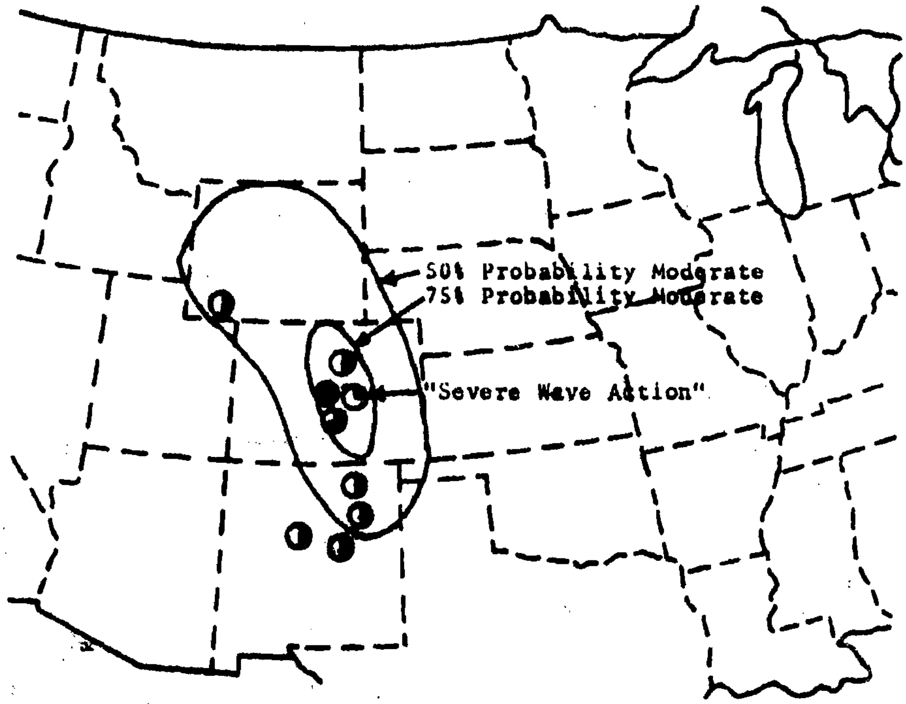


Figure 4. Forecast zone of mountain wave turbulence is shown with two degrees of probability in this figure. Verification is illustrated by later actual encounters of moderate to severe CAT occurring during the valid forecast period of 6 hours. Forecast also called for turbulence to be expected between Flight Levels 250 and 400. Symbols for turbulence intensity are shown in Figure 5.

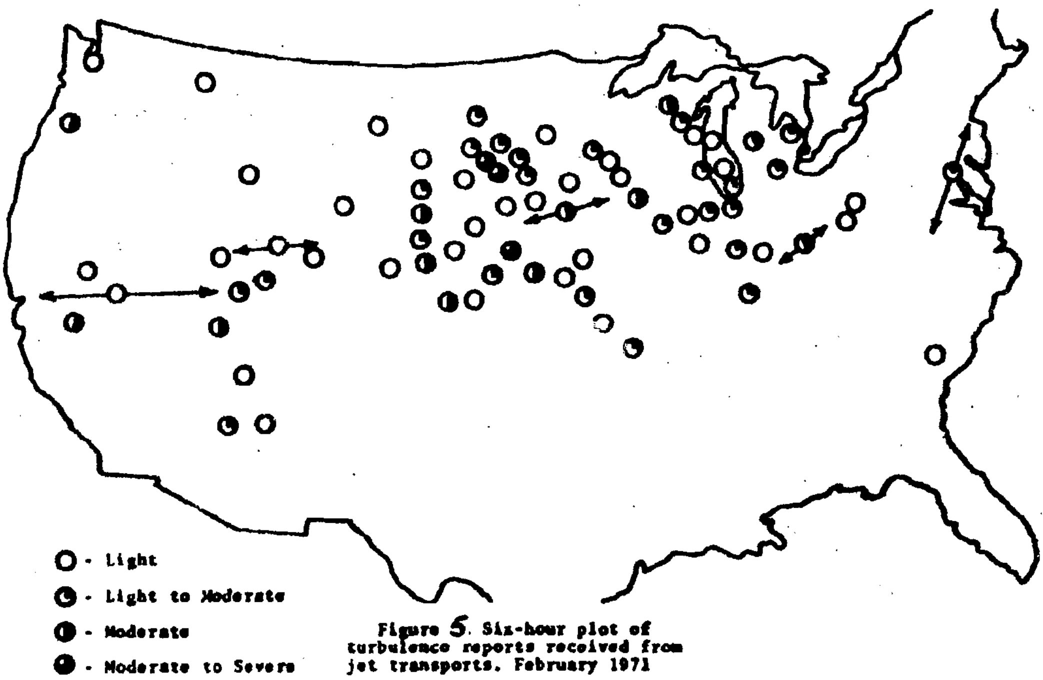


Figure 5. Six-hour plot of turbulence reports received from jet transports. February 1971

WEATHER INVOLVEMENT IN GENERAL AVIATION ACCIDENTS

(BY: S. V. WYATT - AVIATION SAFETY AND QUALITY CONTROL PROGRAM LEADER, NATIONAL WEATHER SERVICE)

I'M SURE ALL OF US HERE ARE CONCERNED ABOUT THE INCREASING NUMBER OF WEATHER-INVOLVED GENERAL AVIATION ACCIDENTS. THOSE OF US WHO ARE DIRECTLY CONCERNED WITH THE AVIATION WEATHER SERVICES AND THE WEATHER SUPPORT FOR SAFETY INVESTIGATIONS HAVE BECOME PARTICULARLY CONCERNED ABOUT THOSE ACCIDENTS WHICH OCCUR IN AREAS OF SEVERE WEATHER. BEFORE I GO ANY FURTHER I NEED TO DEFINE WHAT WE MEAN BY THE TERM WEATHER-INVOLVED ACCIDENTS.

WEATHER-INVOLVED GENERAL AVIATION ACCIDENTS, AS WE USE THE TERM HERE, SIMPLY MEANS THE ACCIDENT OCCURRED IN ADVERSE WEATHER CONDITIONS. THIS USE OF THE TERM DOES NOT REFLECT A WEATHER SERVICE DEFICIENCY. THERE IS A SMALL PERCENTAGE OF THE WEATHER-INVOLVED ACCIDENTS WHERE SERIOUS WEATHER SERVICE DEFICIENCIES HAVE BEEN CITED AS THE PRIMARY CAUSE OF THE ACCIDENT. WHAT WE ARE TALKING ABOUT IS THE WEATHER ENVIRONMENT IN WHICH THE ACCIDENTS OCCUR. ALL TOO OFTEN WE READ IN THE NTSB ACCIDENT BRIEFS - "NON-INSTRUMENT RATED PILOT CONTINUED THE FLIGHT INTO ADVERSE WEATHER CONDITIONS." IN OTHER WORDS THE PILOT FLEW INTO WEATHER CONDITIONS BEYOND HIS PILOTING CAPABILITY AND/OR THE CAPABILITY OF HIS AIRCRAFT.

OUR HEADQUARTERS AVIATION SAFETY AND QUALITY CONTROL STAFF HAS A CONTINUING PROGRAM FOR EVALUATION OF THE WEATHER FACTOR IN AIRCRAFT ACCIDENTS. THESE EVALUATIONS SHOW THE TRENDS IN THIS FACET OF AVIATION SAFETY. THE RESULTS OF THE ANALYSIS ARE USED AS FEED-BACK TO SUPPORT IMPROVEMENT IN OUR AVIATION WEATHER SERVICES. THE TABLES AND GRAPHS WHICH I WILL NOW PRESENT REPRESENT SIGNIFICANT TRENDS IN THE WEATHER-INVOLVEMENT IN GENERAL AVIATION ACCIDENTS. IN PARTICULAR, THEY REPRESENT THE CRITICAL NATURE OF THE WEATHER-INVOLVEMENT IN FATAL ACCIDENTS.

SLIDE 1 - THIS SLIDE SHOWS THE TREND IN GENERAL AVIATION ACCIDENTS AND FATALITIES AND THE ACCIDENT RATE SINCE 1962. LOOKING AT COLUMN 2, WE CAN SEE THE TREND IN THE TOTAL NUMBER OF GENERAL AVIATION ACCIDENTS DURING THE 12-YEAR PERIOD. YOU WILL NOTE THAT THE TOTAL NUMBER OF ACCIDENTS WAS ON THE INCREASE UNTIL 1968 WHEN THE NTSB CHANGED THE DEFINITION FOR "SUBSTANTIAL DAMAGE." THIS RESULTED IN FEWER TOTAL ACCIDENTS BEING REPORTED AND CONSEQUENTLY, WE HAVE TO START A NEW INDEX FOR TOTAL ACCIDENTS WITH 1968 RECORDS. LOOKING AT COLUMN 3 WHICH SHOWS THE TREND IN FATAL GENERAL AVIATION ACCIDENTS, YOU CAN SEE THAT THE CHANGE IN REPORTING RULES HAD LITTLE EFFECT ON THE NUMBER OF FATAL ACCIDENTS REPORTED. SINCE 1967 THERE HAVE BEEN MORE THAN 600 FATAL GENERAL AVIATION ACCIDENTS EACH YEAR. PRELIMINARY 1973 DATA SHOWS THE TOTAL NUMBER OF FATAL GENERAL AVIATION ACCIDENTS TO BE 701. LOOKING AT COLUMN 4 WHICH SHOWS THE NUMBER OF FATALITIES IN GENERAL AVIATION ACCIDENTS, YOU CAN SEE THAT THE NUMBER OF FATALITIES HAS INCREASED ABOUT 60 PERCENT DURING THE 12-YEAR RECORD PERIOD. THIS IS THE MOST ALARMING FACT BROUGHT OUT BY THESE RECORDS. COLUMN 5 SHOWS THE CONTINUED GROWTH IN GENERAL AVIATION FLYING HOURS. HOURS FLOWN HAVE ABOUT DOUBLED IN THE 12 YEARS. LOOKING AT THE LAST COLUMN, YOU CAN SEE THE TREND IN THE ACCIDENT RATE FOR GENERAL AVIATION. PLEASE NOTE THAT BEGINNING IN 1964 THE ACCIDENT RATE DECLINED AND LEVELED OFF AT A LOWER RATE. THIS IS THE MOST ENCOURAGING TREND IN THESE RECORDS. THE NEXT SLIDE SHOWS THIS POINT BETTER.

SLIDE 2. THIS SLIDE SHOWS A COMPARISON OF THE ACCIDENT RATE IN GENERAL AVIATION TO THE VOLUME OF FLYING. YOU WILL NOTE THAT WHILE THE VOLUME OF FLYING HAS INCREASED SUBSTANTIALLY OVER THE 12-YEAR PERIOD - NOW UP TO MORE THAN 28 MILLION HOURS FLOWN - THE ACCIDENT RATE HAS ACTUALLY DECLINED AND LEVELED OFF. THIS SUGGESTS THAT WE MUST HAVE DONE SOME GOOD IN OUR

EFFORTS TO CHECK THE ACCIDENT RATE. OTHERWISE THE RATE WOULD HAVE INCREASED AS THE VOLUME OF FLYING INCREASED. THE EFFORT I'M TALKING ABOUT IS IMPROVEMENTS IN WEATHER SERVICE SYSTEM THROUGH THE ESTABLISHMENT OF MORE BRIEFING OUTLETS AND A QUALITY CONTROL PROGRAM FOR AVIATION WEATHER SERVICES. ALSO IN THE EARLY SIXTIES WEATHER TRAINING ACTIVITIES FOR PILOTS WERE STEPPED UP TO TRY TO MAKE PILOTS AND THEIR INSTRUCTORS MORE WEATHER CONSCIOUS. THE EFFORTS INCLUDE WEATHER SEMINARS, PILOT REFRESHER CLINICS SPONSORED BY THE FAA, STATE AVIATION COMMISSIONS, AND THE AOPA AND THE FAA'S ACCIDENT PREVENTION SEMINARS. I BELIEVE YOU CAN SEE THAT WITH INCREASED VOLUMES OF FLYING IN THE FUTURE, THESE SAFETY MEETINGS WILL BECOME INCREASINGLY IMPORTANT.

SLIDE 3 - NOW LET'S TAKE A LOOK AT THE WEATHER-INVOLVEMENT IN GENERAL AVIATION ACCIDENTS. AS I INDICATED EARLIER, WEATHER SERVICE DEFICIENCIES HAVE BEEN CITED AS THE CAUSUAL FACTOR IN A VERY SMALL PERCENT OF THE GENERAL AVIATION ACCIDENTS. THIS IS NOT TO SAY THAT LIMITS ON OUR CAPABILITY TO MAKE WEATHER SERVICES READILY AVAILABLE TO PILOTS IS NOT PART OF THE PROBLEM.

IT IS A VERY SERIOUS PROBLEM WHICH WE HAVE RECOGNIZED AND ARE TRYING TO DO SOMETHING ABOUT. O.K., LET'S LOOK AT THE TRENDS IN WEATHER-INVOLVED GENERAL AVIATION ACCIDENTS. THE SECOND COLUMN ONCE AGAIN SHOWS THE TREND IN THE TOTAL GENERAL AVIATION ACCIDENTS SINCE 1964. AND AGAIN, YOU CAN SEE THE EFFECTS OF THE RULE CHANGE IN ACCIDENT REPORTING IN 1968. THE THIRD COLUMN SHOWS THE TREND IN THE WEATHER INVOLVEMENT IN TOTAL ACCIDENTS. I WILL COME BACK TO THIS FOR COMPARISON LATER ON. LOOKING AT COLUMN 5, YOU SEE THE NUMBER OF FATAL GENERAL AVIATION ACCIDENTS SINCE 1964. PLEASE NOTE THAT THERE WAS AN UPWARD TREND UNTIL 1968. SINCE THAT TIME THERE HAS BEEN A LEVELING OFF IN THE NUMBER OF FATAL ACCIDENTS UNTIL LAST YEAR WHEN 718 WERE RECORDED. NOW LOOK AT COLUMN 6. THIS SHOWS THE TREND IN WEATHER-INVOLVED

FATAL GENERAL AVIATION ACCIDENTS. YOU WILL NOTE THAT THE NUMBER OF THIS CATEGORY CONTINUES TO INCREASE EVEN AFTER 1968. THIS SUGGESTS THE OVERALL EFFORTS OF THE PILOT TRAINING PROGRAMS AND ACCIDENT PREVENTION PROGRAMS ARE DOING SOME GOOD, BUT MAYBE WE'RE NOT PLACING ENOUGH EMPHASIS ON THE IMPORTANCE OF WEATHER IN FLIGHT PLANNING AND FLIGHT OPERATIONS. LOOKING AT THE LAST COLUMN, YOU CAN SEE THAT WEATHER IS NOW INVOLVED IN A THIRD OR MORE OF THE FATAL GENERAL AVIATION ACCIDENTS. IT IS EASY TO SEE FROM THIS SLIDE AND THE NEXT ONE THAT WEATHER INVOLVEMENT IS MUCH MORE CRITICAL IN FATAL ACCIDENTS THAN IN THE TOTAL ACCIDENTS.

SLIDE 4 - IN THIS SLIDE YOU CAN SEE THAT WEATHER IS INVOLVED IN 32 TO 39% OF THE FATAL GENERAL AVIATION ACCIDENTS, BUT LOOKING AT THE TOTAL ACCIDENT PICTURE, WEATHER INVOLVEMENT ONLY ACCOUNTS FOR ABOUT 20% OF THE TOTAL ACCIDENTS WITH A HIGH OF 23% IN 1972.

SLIDE 5 - BECAUSE OF OUR DEEP CONCERN OVER THE SEVERE WEATHER-INVOLVED ACCIDENTS IN RECENT YEARS, WE TOOK A LOOK AT THE NUMBER OF GENERAL AVIATION ACCIDENTS WHICH OCCURRED DURING THE PERIOD 1970 TO 1972 IN ACTIVE THUNDER-STORM AREAS. YOU WILL NOTE THAT THE LARGE MAJORITY OF THESE ACCIDENTS INVOLVED VFR FLIGHT OPERATIONS. HOWEVER, THERE WERE SEVERAL EACH YEAR INVOLVING IFR FLIGHTS. OUR CONCERN OVER THIS TYPE OF ACCIDENT HAS LED TO THE ESTABLISHMENT OF FAA/NWS SAFETY GROUPS TO STUDY THE PROBLEMS ASSOCIATED WITH THESE ACCIDENTS AND TO RECOMMEND PROCEDURAL CHANGES TO HELP REDUCE SUCH ACCIDENTS. MUCH OF THIS EFFORT HAS BEEN DIRECTED TOWARD BETTER METHODS FOR DISSEMINATING WEATHER RADAR INFORMATION AND SEVERE WEATHER WARNINGS TO THE ATC SYSTEM AND THE AIRBORNE PILOT.

SLIDE 6 - THIS SLIDE SHOWS THE NUMBER OF AIRCRAFT ACCIDENTS INVOLVED IN AIRFRAME ICING DURING THE PERIOD 1964-1972. THIS IS THE ONLY SUMMARY WHICH SHOWS BOTH GENERAL AVIATION AND AIR CARRIER ACCIDENTS. THE REASON FOR DOING THIS WAS TO SHOW THAT AIRFRAME ICING IS NOT A SERIOUS PROBLEM FOR AIR CARRIER OPERATIONS, BUT IS BECOMING A MORE CRITICAL FACTOR IN GENERAL AVIATION ACCIDENTS. THE FACT THAT 58 GENERAL AVIATION ACCIDENTS IN 1972 WERE INVOLVED IN AIRFRAME ICING IS INDEED ALARMING.

SLIDE 7 - SEVERAL YEARS AGO, IT WAS SUGGESTED TO ME THAT IT WOULD BE INTERESTING TO COMPARE THE NUMBER OF FATALITIES IN WEATHER-INVOLVED GENERAL AVIATION ACCIDENTS TO THE NUMBER OF DEATHS CAUSED BY TORNADOES AND HURRICANES. THIS PROVED TO BE A VERY INTERESTING COMPARISON. SLIDE 7 SHOWS THE NUMBER OF HURRICANE AND TORNADO DEATHS FOR THE PERIOD 1964-1973 AND COMPARES THESE TO THE NUMBER OF DEATHS IN WEATHER-INVOLVED GENERAL AVIATION ACCIDENTS DURING THIS PERIOD. IT IS EASY TO SEE THAT MANY MORE PEOPLE ARE BEING KILLED EACH YEAR IN WEATHER-INVOLVED GENERAL AVIATION ACCIDENTS THAN BY HURRICANES AND TORNADOES COMBINED.

SLIDE 8 - THIS SLIDE GIVES A GRAPHICAL PICTURE OF THE COMPARISION I HAVE JUST BEEN DISCUSSING. THE NUMBER OF FATALITIES IN WEATHER-INVOLVED GENERAL AVIATION ACCIDENTS SHOWS A GENERAL UPWARD TREND UNTIL 1969. SINCE THEN IT HAS REMAINED NEAR THE 600 MARK. THE NUMBER OF HURRICANE AND TORNADO DEATHS VARIES SUBSTANTIALLY FROM YEAR TO YEAR. THE TOTALS REACHED A HIGH OF 373 IN 1965 AND A LOW OF 84 IN 1970. EXCEPT FOR THE PEAK YEARS OF 1965 AND 1969, WELL OVER TWICE AS MANY PEOPLE WERE KILLED IN WEATHER-INVOLVED GENERAL AVIATION ACCIDENTS THAN BY HURRICANES AND TORNADOES COMBINED. IF WE COMPARE THESE FATALITIES FOR 1973, WE FIND THE FACTOR TO BE 6 TO 1.

AS I INDICATED AT THE BEGINNING OF MY DISCUSSION, WE ARE DEEPLY CONCERNED ABOUT THE WEATHER INVOLVEMENT IN GENERAL AVIATION ACCIDENTS. I BELIEVE ALL OF US INSIDE OF GOVERNMENT AND OUT SHOULD DO EVERYTHING WITHIN OUR POWER TO HELP REDUCE THESE TRAGIC DEATHS.

GENERAL AVIATION ACCIDENTS, FATALITIES, RATES

YEAR	TOTAL ACCIDENTS	NO. FATAL ACCIDENTS	FATALITIES	AIRCRAFT-HOURS FLOWN (000) **	ACCIDENTS RATES PER 100,000 AIRCRAFT-HOURS FLOWN TOTAL	FATAL
1962	4,840	430	857	14,500	33.4	2.97
1963	4,690	482	893	15,106	31.0	3.19
1964	5,069	526	1,083	15,738	32.2	3.34
1965	5,196	538	1,029	16,733	31.1	3.22
1966	5,712	573	1,151 ##	21,023	27.2	2.73
1967	6,115	603	1,333 ##	22,153	27.6	2.72
1968 *	4,968 #	692 #	1,399	24,053	20.6	2.86
1969	4,767	647	1,495	25,351	18.8	2.55
1970	4,712	641	1,310	26,030	18.1	2.46
1971	4,651	662	1,405	25,512	18.2	2.59
1972	4,228	683	1,400 ##	27,300EST	15.4	2.52
1973P	4,180	701	1,340	28,200EST	14.8	2.49

P PRELIMINARY

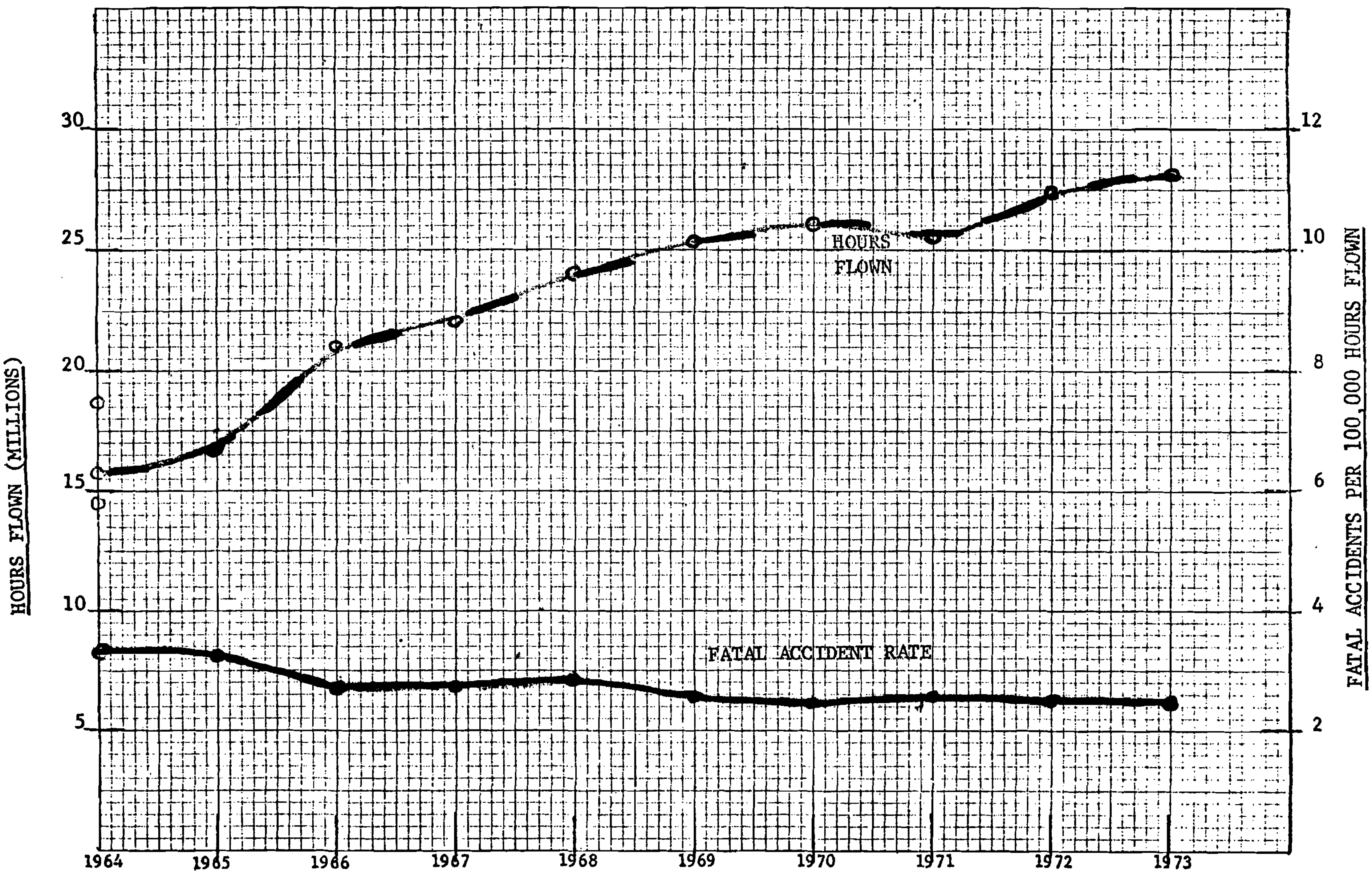
* COMMENCING JANUARY 1, 1968, THE DEFINITION OF SUBSTANTIAL DAMAGE WAS CHANGED, THEREFORE, FEWER ACCIDENTS WERE REPORTED. CARE SHOULD BE USED IN COMPARING WITH SIMILAR DATA FOR PRIOR YEARS.

THREE SUICIDE/SABOTAGE ACCIDENTS INCLUDED IN ALL COMPUTATIONS EXCEPT RATES.

INCLUDES AIR CARRIER FATALITIES 1966-2, 1967-104, 1969-82, 1972-51 WHEN IN COLLISION WITH GENERAL AVIATION AIRCRA

SOURCE FAA

SLIDE 1



GENERAL AVIATION ACTIVITIES vs. FATAL ACCIDENT RATE

SLIDE 2

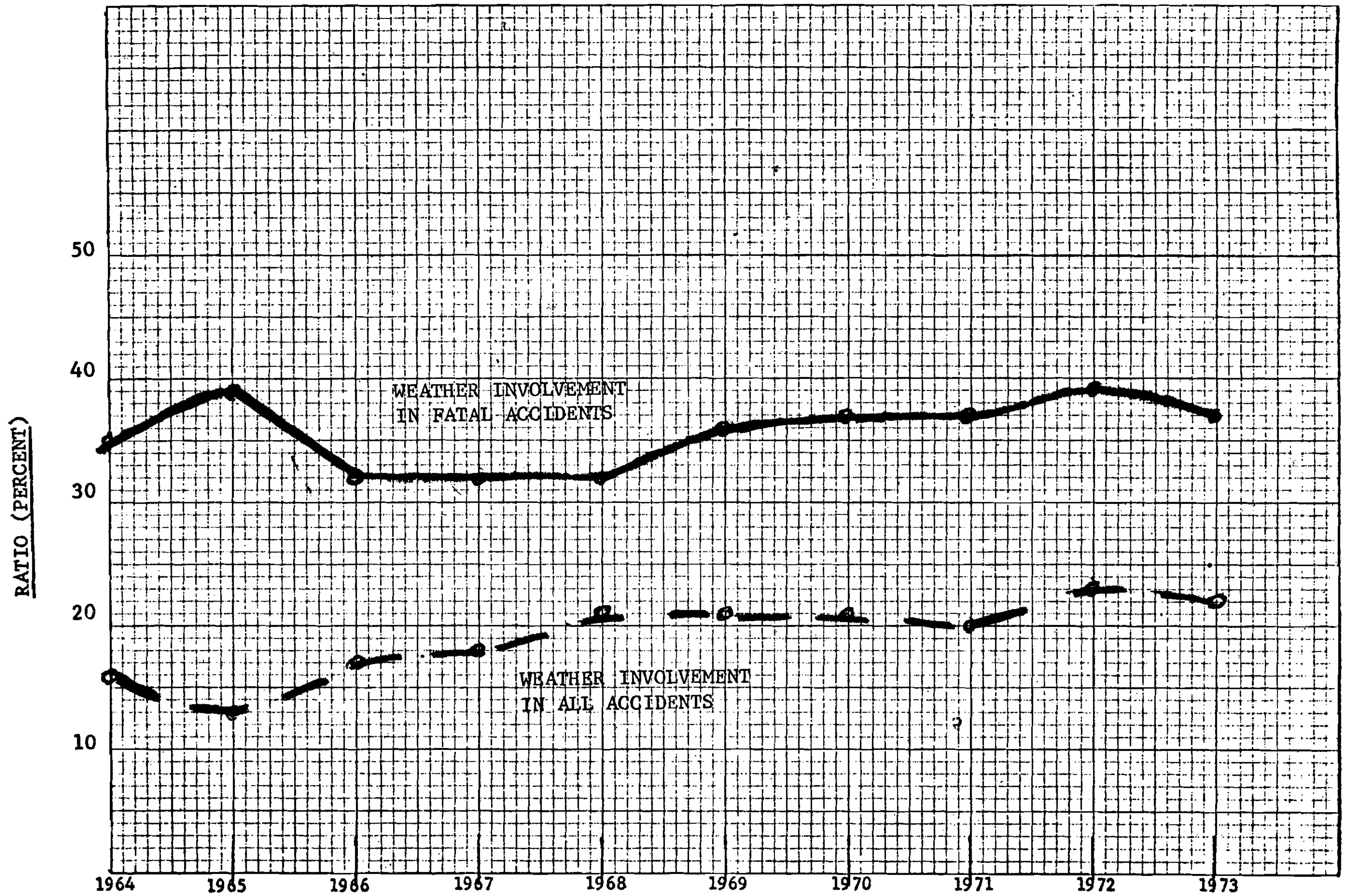
GENERAL AVIATION ACCIDENTS

YEAR	TOTAL ACCIDENTS	NO. WEATHER-INVOLVED ACCIDENTS (TOTAL)	PERCENTAGE WEATHER-INVOLVED ACCIDENTS (TOTAL)	TOTAL FATAL ACCIDENTS	NO. WEATHER-INVOLVED FATAL ACCIDENTS	PERCENTAGE WEATHER-INVOLVED FATAL ACCIDENTS
1964	5,069	798	16	526	182	35
1965	5,196	668	13	538	212	39
1966	5,712	896	17	573	187	32
1967	6,115	1110	18	603	194	32
1968	4,968*	1064	21	692	222	32
1969	4,767	981	21	647	232	36
1970	4,718	1014	21	641	237	37
1971	4,640	947	20	660	246	37
1972	4,136	969	23	655	260	39
1973 (preliminary)	4,289	958	22	718	269	37

* NTSB changed definition of "substantial damage" resulting in fewer reportable accidents

DATA SOURCE - NTSB

SLIDE 3



RATIO OF WEATHER INVOLVEMENT IN GENERAL AVIATION ACCIDENTS

SLIDE 4

GENERAL AVIATION ACCIDENTS IN ACTIVE THUNDERSTORM AREAS

YEAR	VFR FLIGHT	IFR FLIGHT	TOTAL
1970	42	6	48
1971	49	9	58
1972	25	6	31

DATA SOURCE - NTSB

SUMMARY OF AIRCRAFT ACCIDENTS INVOLVED IN AIRFRAME ICING

YEAR	NO. GENERAL AVIATION ACCIDENTS	NO. AIR CARRIER ACCIDENTS	TOTAL
1964	16	2	18
1965	17	1	18
1966	23	0	23
1967	33	2	35
1968	28	1	29
1969	56	0	56
1970	42	1	43
1971	39	0	39
1972	58	0	58

SOURCE - NTSB

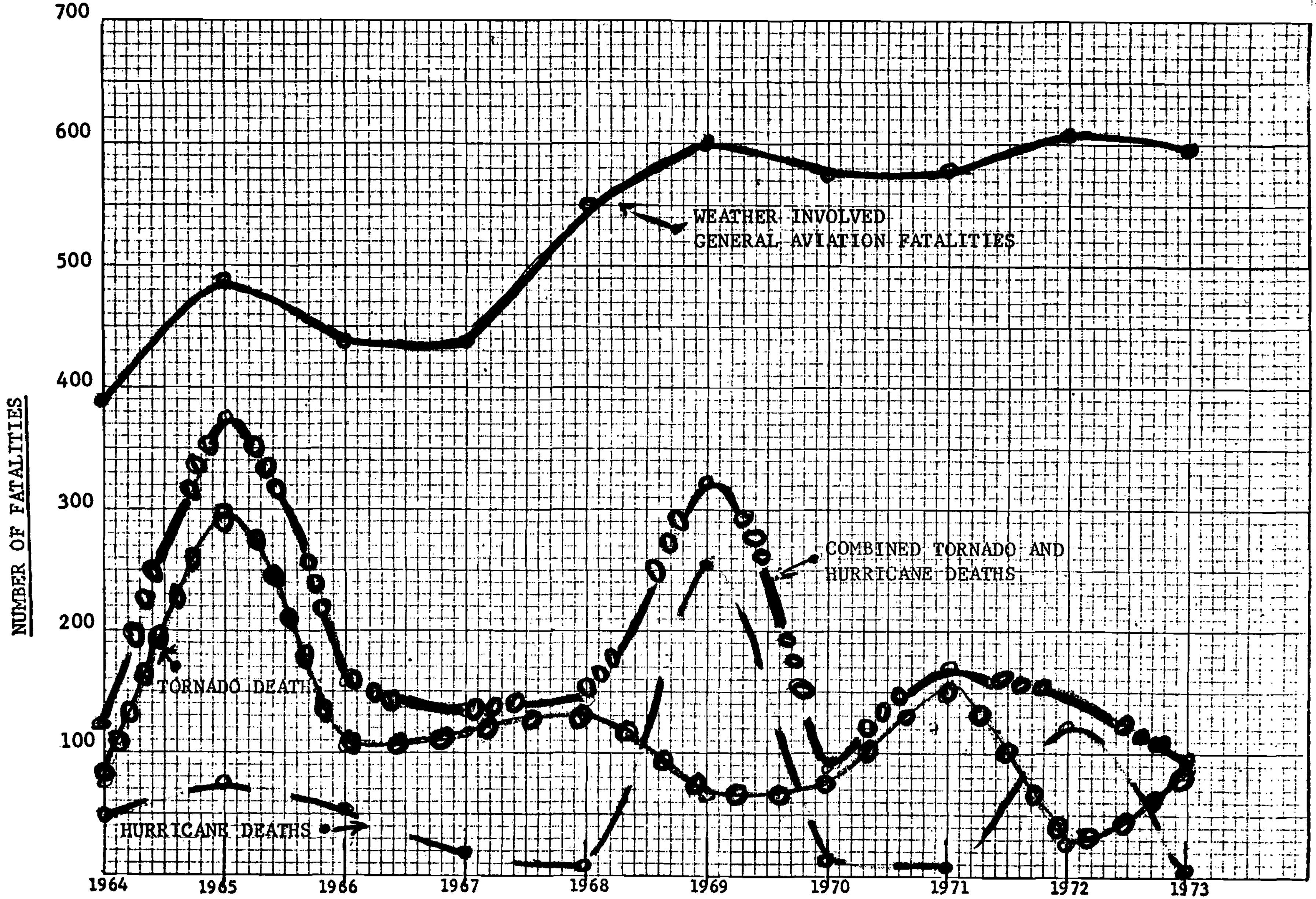
These aircraft accident records show the number of accidents in which airframe icing was determined to be a cause, or contributing factor, in the accident. As would be expected, airframe icing is not a serious problem for air carrier operations. On the other hand, it is becoming a more critical factor in general aviation accidents.

HURRICANE AND TORNADO DEATHS

WEATHER INVOLVED GENERAL AVIATION ACCIDENT FATALITIES

YEAR	HURRICANE DEATHS	TORNADO DEATHS	TOTAL	DEATHS
1964	49	73	122	389
1965	75	298	373	488
1966	54	105	159	436
1967	18	116	134	438
1968	9	131	140	549
1969	256	66	322	602
1970	11	73	84	574
1971	8	156	164	580
1972	122	27	149	606
1973	5	87	92	596

SLIDE 7



GENERAL AVIATION FATALITIES vs. TORNADO AND HURRICANE DEATHS

SLIDE 8

THE SOCIETY OF AIR SAFETY INVESTIGATORS

FIFTH ANNUAL SEMINAR

ARLINGTON, VIRGINIA

SEPTEMBER 30 - OCTOBER 3, 1974

WEATHER PANEL

COMMENTS OF:

A. Martin Macy
Vice President - Operations
National Air Transportation Associations

The theme of this Fifth Annual Seminar is "Accident Prevention through Investigation". This theme goes to the heart of accident investigation. Except perhaps for an effort to determine guilt in cases of liability, the only real value of accident investigation is preventing future accidents with the same causal factor or factors. In several areas of aircraft accident investigation, notably mechanical problems caused by maintenance and/or manufacturing/engineering deficiencies, accident investigators have done a truly remarkable job of accident prevention. Extremely subtle, sometimes almost totally hidden, clues to mechanical problems have been ferreted out and corrective action has been recommended and taken.

At least partly due to accident investigations, weather reporting has also been significantly improved in the last couple of decades. Runway visual range equipment has come into common use, more air traffic controllers at more positions have more current weather available to them to pass on to flight crews, and weather observing techniques have been improved. Yet in spite of these improvements we still have an alarmingly high number of weather related aviation accidents.

The National Air Transportation Associations, Inc. is the trade association of commuter airlines, air taxi/charter operators and "fixed base operators". We represent, therefore, commercial and professional air transportation in small aircraft. For this reason, the weather related aircraft accidents that worry us are not the typical general aviation accidents where non-instrumented rated pilots are "caught" in weather they are unable to handle. That is not to say that our industry is immune to this type of accident, but it is not generally a real problem in the pilot population employed by our members. The weather related accidents which cause us grave concern are those in which a competent flight crew flying an aircraft in which they are fully qualified hits the ground on an instrument approach. It is this group or category of accidents in which, we feel, accident investigation has contributed comparatively little to accident prevention.

The report on accidents of this type generally concludes with causal factors such as "descended below minimums" or "descended below safe terrain clearance altitude". While these statements are totally accurate, (there sits the airplane in the trees) they don't answer the nagging question: Why? Why does a competent trained pilot descend below minimums and continue his descent until he hits the ground? Why does an experienced flight crew, familiar with the terrain, descend below minimum terrain clearance altitudes? In many, perhaps most, cases the accident investigators can only shake their heads and say simply, "We don't know". This leaves industry with the unhappy choices of either suicidal flight crews or unexplained lapses into complete incompetence by highly experienced and qualified pilots.

None of this is to say that accident investigators have not spent many weary hours trying to puzzle out the "why: of these kinds of accidents. In some cases at least they have been able to suggest, if not absolutely prove, one or more reasons for the departure from a normal flight path. When these reasons are suggested, however, they more often appear to be strokes of sometimes brilliant intuition on the part of the investigator than the result of an established, proven deductive process.

The reasons for this are easy to understand. Aircraft accident investigation, after all, goes back to the Wright Brothers, literally. Until fairly recently it consisted almost altogether of analysing what went wrong mechanically. We have a hugh body of information and experience in analysing mechanical causes of accidents and since World War II in analysing operational causes of accidents. We have refined our engineering of the machine and our aeronautical procedures significantly because of the results of aircraft accident investigations. We now have airframes, power plants, electronic aids both in the air and on the ground, instrument approach procedures and communications devices which are almost infinitely reliable and which have backups for the rare occasion when one fails. We know how to investigate an accident with these factors in mind.

It is those unlucky individuals, designated by NTSB as "human factors" specialists, that are left to navigate pretty much unchartered seas. Why does a pilot do what he does when he has an accident? Well, why does anyone do what they do, any of the time? Dr. Sigmund Freud probably took the first more or less modern stab at answering that question, and a large number of people have been chewing on it ever since. Perhaps we need to chew on it from our highly specialized point of view a little more than we have.

I wonder if we have done all we could to provide the human factors accident investigators with basic research into the human factors that affect a pilot on an approach. I also wonder if there aren't a great many better sources of this type of study than fatal accidents. There are other times that a pilot deviates from the normal flight path and in most of those cases he does not wind up in the trees. If the pilot is by himself or just with his co-pilot we are not likely to hear about the occasion "officially". Under most circumstances, even if the tale is told in a hangar flying session, there is probably no practical way to follow up on the causes. What source do we have, then, for trying to analyse the reasons for these deviations? It seems to me that check rides under both FAR 121 and FAR 135 as well as simulator training offer a potential source. A pilot who deviates from the flight path, particularly from the proper descent profile, during an approach on a check ride pretty surely will bust his check ride. How much digging is done by the check pilot, the company for whom the pilot works or anybody else into the question of why he deviated from the flight path? We generally are concerned only with giving him some more training and getting him through the check ride the next time he takes it. We spend very few man hours digging deeply into the psychological, or possibly physiological, reasons for the deviation in the first place. Yet here is a perfect case study of the kind of problem that we face after a fatal accident when producing the information is extremely difficult. As the human factors specialists can testify, asking probing questions of a recent widow regarding the pilot's moods, feelings, habits, etc., shortly after the accident is seldom fruitful work. Both check rides and simulator training programs would appear to be capable of providing a wealth of information on mistakes which do not end up in accidents. Developing a program to make use of this information will require a concerted effort by one or more groups or organizations who are concerned solely with the safety aspects. NTSB and/or ALPA come to mind as logical parties; there are probably many others.

Do other fields of human endeavor, outside of aviation, have similar problems? Do firemen or doctors or other groups with highly specialized training occasionally suddenly deviate from a "normal" pattern for no obviously explainable reason? If so, has anyone done any work on determining why? Perhaps we could look at this, too.

In conclusion, we all have a tendency to do what we know how to do and put off, so far as possible, those things which we really don't know how to undertake. I think we, the entire aviation industry, may have been somewhat guilty of this in accident investigation. We absolutely know how to reconstruct the wreckage of an airplane to determine what mechanical fault caused the accident. We have gotten very good at analysing the procedures used by both the flight crew and those involved on the ground in handling the airplane through the airspace and determining if discrepancies in operational procedures were the cause of the accident. What we have not succeeded in doing very well, perhaps because we have not spent the time, effort, and money on it which was required, is to dig into the human factors elements which must be the underlying cause of an accident where operational and mechanical factors have been satisfactorily and totally eliminated. I believe that the time has come when, uncomfortable as it is, we must start looking into ourselves as causal factors and not stop with looking at the machine and the system. When we can do this with something approaching the degree of precision that we now look at the rest of the picture, perhaps human factors accident investigators will be able to contribute to accident prevention as much as their more technical brethren.

###

Preface

In the summer of 1973 the General Aviation Association's Council (GENAVAC) composed of the two (2) senior elected officials of the following organizations: Aviation Distributors and Manufacturers Association (ADMA) Aircraft Owners and Pilots Association (AOPA), General Aviation Manufacturers Association (GAMA), National Business Aircraft Association (NBAA), National Association of Flight Instructors (NAFI), National Pilots Association (NPA), and the National Air Transportation Association (NATA) established an Aviation Weather Requirements Committee. Committee members were Mr. Bill Horn (NBAA). Chairman, Mr. Dave Thomas (GAMA), Mr. A. Martin Macy (NATA). Mr. Larry Burian (NPA), Mr. Dave Sands (NAFI) and Mr. Jake Goodrich (AOPA).

This group in April of 1974 forwarded the GENAVAC Aviation Weather Requirements package attach #1 to Dr. Robert White (NOAA) and Mr. Alexander Butterfield (FAA). The committee members, FAA and NWS are conducting a continual dialogue in an effort to improve the weather products available to the pilot community. We are all well aware that this is only an initial, first cut at trying to put into perspective the diverse requirements of the vast general aviation aircraft fleet. However, we would hope that this might be a base or starting point that all parties interested in the weather problem could use, and through discussions further refine amplify, change, add to, or modify the product as time and circumstances direct.

AVIATION WEATHER

"WHAT CAN THE USER DO"

- A QUANDARY -

I must wear several hats during my short talk here this morning and it will be rather hard to determine when I switch from one to the other; however, the basic theme regardless of who I am, is, how do I satisfy the requirement for aviation weather.

As the Manager of Air Space/Air Traffic Control of NBAA I represent over eleven hundred companies that fly corporate and business aircraft. These range from helicopters and light pipeline patrol aircraft up through the L.A. Dodgers 720-B, so I am concerned about the entire spectrum of aviation weather. As the Chairman of GENAVAC's Aviation Weather Requirements Committee I have been attempting with many others to put in writing what we think are general aviation's weather needs. And as an interested and concerned individual I have been trying to figure out how to take all the information that has been gathered, collate and distill it and determine how two rather large government agencies can be simultaneously motivated to do something about the problem that general aviation thinks it has. Really we are not the only ones that think there is a problem. Accident investigators, statisticians, hospital attendants and morticians will verify that weather is a significant contributing cause in many general aviation accidents.

OK, so now we know we have a problem, what can we do to solve it? The first thing to do is identify the agencies that can help you solve the problem - in this case that is reasonably easy. National Oceanic and Atmospheric Administration (NOAA) with its operating arm the National Weather Service (NWS) and Department of Transportation with its operating arm The Federal Aviation Administration (FAA). Some of the people I work for ask the question why two agencies? If it's a weather problem shouldn't your primary contact be the NWS. For many reasons this is not the way the problem can be attacked and therein lies one of the major quandaries facing the user. Although we have many outstanding individuals in both organizations, the responsibilities are so divided, that we find it almost impossible to "get there from here".

EXAMPLE: If the NWS were able to develop an aviation weather products package that met each and every one of our requirements - we must still be able to disseminate this information. FAA is responsible for the dissemination.

If FAA has the fastest dissemination system in the world, I would still need a satisfactory weather product.

In real life "never the twain shall meet". Two separate government organizations - how do you effectively get them to move in the same direction at the same time? Without positive direction from the top, appropriate priority and funds, you cannot provide the needed support.

Within the FAA System Research and Development Services there are 21 active programs. If we established a priority order the weather programs would probably fall somewhere below 17. Therefore when funding cuts are ordered you can be assured that the weather projects will be in for some early slicing. Within NWS for many years aviation weather has not been one of their major areas of concern - funding has been sporadic and limited. We see signs of some changes in this philosophy, but we are concerned that the philosophical effort will not quickly release the attendant required funding.

The primary source of weather infromation for general aviation is the Flight Service Station. In August 1973 the final report of " A Proposal for the Future of Flight Service Stations" was submitted. The report was prepared as part of a comprehensive Flight Service Station evaluation requested by the Office of Management and Budget and directed by the Under Secretary of Transportation. Of great concern to me was that, when we review who the participants in the analysis were, we find no one listed from NOAA or the NWS. It is our contention that weather is the single most important ingredient that is offered by the FSS Station, regardless of how many FSS' we have, how fancy we make the electronics equipment that will allow a pilot to self brief himself, how many or few telephone lines and radio frequencies we provide - if we do not get accurate-real time weather information to the air-machine driver we have completely missed the ball.

EXAMPLE: How the two organizations can operate at cross purposes.

Letter Mr. Ballenger to users April 11, 1974, re: "Closing of Flight Service Stations -- Weather observations would continue to be provided by the NWS or by contract observers and given nationwide distribution."

NWS comments on DOT/FAA evaluation team report. "Where there is no control tower, contract observations or SAWRS arrangements would have to be used as much as practical.

We discourage using the contract observation alternative because it is most difficult to obtain contract observers, particularly at airports. Besides, the the study almost certainly underestimated the cost of contract observations in a continuous hourly program. Under this program, no special observations are made, reducing our capability to prepare terminal forecast amendments."

As has been proven over the years closing of a FSS is political dynamite, even if you get all but one Congressman or Senator to agree to scheduled closings, the one dissident can reverse the picture with an amendment. That stops the entire process. Therefore some other supporting activity must be offered in lieu of the FSS. It appears to us that the extension of the EFAS program throughout the country is the first order of business, FAA/NWS should coordinate with the users to establish a consolidated program that can be offered to OMB and the Congress and can be supported by all agencies.

We not only are concerned with the inability in many cases to receive weather from locations that might be desirous, but also the quality, timeliness and monitoring of the present sources of weather information. I personally have a very strong feeling that standardization and quality control are absolutely necessary if you desire any sort of a quality product. Within the NWS (7?) Quality Control Officers are available to train, monitor, and qualify aviation weather observors. They must also identify the weakness in the support provided by the aviation weather program. It is an absolute impossibility for these few individuals to provide anything but a superficial review of the many products that are prepared throughout the system. Although many inputs are utilized to establish weather forecasts, the touchstone that starts the entire process is the human weather observer. I would hazard a guess that a limited member of the products supplied to the aviation weather system receive any sort of serious review. This entire facet of the weather support must be reviewed and as a first step, more quality control officers assigned to the program-also the priority placed on their work must be upgraded. Anytime there is a NWS review of positions or a reduction in personnel this is the first office to be reduced. Within the FAA the only operational review to be accomplished would be through the evaluation staff of the Air Traffic Service at the Washington headquarters and the FAA regional evaluation staffs. Again I think we will find that reviewing the weather problem is rather low on the priority list of these rather limited staffs.

The Society of Air Safety Investigators' problem is very similar to that of the users of the system. Active vs. reactive. After an accident they must get involved, no choice in the matter. How much action can be undertaken before hand to establish a solid weather program, that would have prevented X number's of accidents? Understandably difficult to quantify, difficult to justify the people and funds necessary for these types of programs, but not an impossible task. If we can get the FAA/NWS responsible Safety personnel and the user community to determine what areas are important and focus in the short term on the attainable and then establish long term goals that will probably require studies and discussions to establish mutually agreed upon programs, we can hopefully bound the problem.

However difficult it may be, all parties must agree on certain areas of mutual interest and expend extra efforts to provide the aviation weather support that we mutually agree is necessary.

Just as sure as the sun rises every day, we know that somewhere throughout this country we are going to have weather that will affect the flight of several or many aircraft. These aircraft are also the best real time weather probes that we have at our disposal and I feel that we must make more extensive use of the capabilities that they offer. I must relate back to some of my military flying to note that even though extensive weather info was available to flight crews prior to flight, whenever special, unusual or extensive flight activity was involved we relied heavily on an airborne weather observor. This was particularly important when in air refueling activities. When repetitive operations were to be conducted in certain refueling areas, constant interchange of weather information concerning home base, enroute and refueling areas was accomplished between flight crews and the appropriate Air Traffic Control facilities. With the introduction of automated equipment in terminals and centers and the attendant reduction in communications between pilot and controller it appears that time is now available to establish special provisions to exchange real time weather info for the people who most need it, the pilot and the controller.

The single greatest problem that we have found since undertaking a certain amount of research in the weather area has been to ascertain who will make the major decisions that will determine what expenditures are to be made on certain weather projects. For the past year I have heard that Dr. White and Mr. Butterfield will get together to discuss how the weather program fits into each agency and what fine tuning can be done to make sure that they are in agreement as to how the responsibilities will be handled. I do not believe that they have held any such meeting and the clarification of issues has not been accomplished. Although the staffs of both agencies coordinate on many matters and work together on many projects. The major issues rarely seem to work up to where the Administrators can get into the act.

Many studies, presentations before Congress and meetings have been undertaken by persons much more erudite than I am, and many of these same statements have been made by NTSB, AOPA and other alphabet agencies. But yet, today the statistics remain about the same, about 1/3 of the general aviation fatalities are weather related. Is it not possible for the aviation users to combine their efforts with the safety organizations as a catalyst and finally move these two large government organizations FAA/NWS (or NOAA/DOT) into a position where they establish a mutually supportive program for aviation weather?

WH/te
Attachment

GENAVAC
AVIATION WEATHER REQUIREMENTS

POLICY STATEMENTS

The National Weather Service has the legislative authority and responsibility in the United States (as documented in appendix I of the Federal Aviation Administration (FAA), Environmental Science Services Administration (ESSA) memorandum of agreement, dated 9/2/65, to observe, collect and disseminate weather data for the general public, and specialized users such as agriculture, maritime, space and aviation. This authority includes overall responsibility for the pilot weather briefing program, in addition to the consolidation of aviation weather observation data and providing all aviation weather forecasts. Operational responsibility may have to be shared with other agencies. The National Weather Service must strengthen aviation weather services to meet user requirements, particularly in the area of pilot weather briefings.

To obtain the best use of public funds, including user trust funds, a group of user representatives should be established to review all aviation weather programs for the purpose of determining priorities and advising the National Weather Service and the Congress of the desirability and usefulness of programs for the budget.

Thousands of general aviation airplanes flying in the National Airspace System each day are an under-utilized source of weather information. It is highly desirable that increased use be made of these real-time weather observers. Simplified, standardized formats for pilot reports should be developed and specialized training should be designed to insure that the general aviation pilot population can report weather phenomena accurately. This perishable observed weather information must be entered into the forecasting and weather reporting system in a timely manner to improve the quality of information available to the flying community.

Increased activity in research and development is essential for improved weather observing and reporting equipment, with emphasis on automation capability that will provide the necessary weather data required for the takeoff and landing of general aviation aircraft.

Continuous feedback must be an integral part of the aviation weather program. Therefore, extensive monitoring and control of the aviation weather forecast product to include pilot evaluation and critique of the service is necessary.

SYSTEMS USERS

There are 3 basic categories of pilots that comprise the bulk of the general aviation pilot population. Aviation weather information should be tailored to support each of these pilot categories in planning flights as dictated by the operational requirement and aircraft configuration.

1) VFR only - Weather will cause cancellation of flight.

2) VFR/IFR (usually non-professional pilot) - This category requires the most detailed weather information of all three categories. Due to wide variations in experience levels, the pilot needs complete weather information upon which to base a go/no go decision.

3) IFR (Usually professional pilot) - The pilot will probably depart on a flight unless weather is unusually severe or forecast or reported to be below minimums. The pilot requires a wide spectrum of weather information for the selection of alternate airports or alternate routings.

(1)

REQUIREMENT

With the steady and constant increase in pilot weather briefings we are approaching the point where individual weather briefings for pilots will no longer be economically feasible, or even physically possible. However, general aviation requires that individual pilot weather briefings continue until such time as mass and/or automated pilot weather briefings are available as the primary means of aviation weather briefings. In addition, a back up system must be accessible to pilots by telephone or aircraft radio in unusual situations, such as primary system failure, inaccessability of the primary system or a requirement for additional weather data not available in the standard briefing.

(2)

REQUIREMENT

Restricted visibility is a significant hazard to general aviation, but it is very difficult or impossible to obtain realtime visibility information, especially at airports not regularly reporting aviation weather. Therefore, aviation surface weather observations for general aviation should be designed to provide additional and specific aviation weather data (when visibility is less than five miles) and aviation weather forecasts should be scheduled to provide maximum information between sunrise and sunset, normally the period of greatest general aviation activity.

REQUIREMENT

Valid aviation weather information reported by observers on the ground and in flight is delayed, trapped or lost within the aviation weather dissemination systems and is not available to general aviation pilots; therefore all valid aviation weather information must be entered into the government weather dissemination system and be made available to general aviation pilots on a timely basis. A requirement exists for the collection and dissemination of all aviation weather reports, both surface and in-flight, made by private, commercial, military and other government observing and reporting sources. Interchange procedures should be established to insure that the general aviation pilot, regardless of the type of aircraft flown or pilot qualifications, be provided accurate aviation weather information from any and/or all of these sources.

REQUIREMENT

Many general aviation weather related aircraft incidents and accidents are directly traceable to unexpected encounters with unusual or hazardous weather phenomena. Accurate and timely information on the scope and timing of hazardous weather must be available to the General Aviation pilot; therefore, priority should be given to the observation and dissemination of unusual or hazardous weather information and this information should be available to communications services for expeditious relay to affected pilots.

REQUIREMENT

General aviation pilots are responsible for determining that aviation weather conditions are suitable to successfully complete their planned flights. Because of the limited means of aviation weather dissemination and/or lengthy delays incurred by pilots in attempting to contact authorized aviation weather facilities, adequate aviation weather data and/or weather briefings are frequently unavailable for flight planning; therefore methods of mass dissemination of pre-flight aviation weather data to general aviation pilots is a priority requirement. That access to the aviation weather dissemination system must be available to the general aviation pilot through simple communication means.

REQUIREMENT

Approximately 98% of all aircraft in the United States are in the general aviation category. Thus this fleet which normally conducts its entire flight operation below 10,000' AGL has the greatest potential for accidents. The record indicates that approximately 1/3 of the fatal accidents involving these aircraft are weather related. The difficulty in obtaining adequate weather information contributes to some percentage of these accidents. Therefore, a thorough aviation weather briefing including forecast and real-time weather must be readily available to all general aviation pilots for flight planning, enroute and terminal operations.

Information on rapidly changing weather situations must be immediately available to pilots in flight.

(7)

REQUIREMENT

Airman training programs should be designed to insure that general aviation pilots have an adequate understanding and working knowledge of aviation weather phenomena in order to be able to anticipate and cope with inflight weather situations.

REQUIREMENT

The technical language used by weather briefers and the complex symbology of written/teletype weather information is difficult to understand, and is susceptible to misinterpretation by pilots. Therefore, weather information must be presented in a sufficiently clear manner that all general aviation pilots can interpret and understand the weather data and can report inflight weather accurately.

NASA - Langley

GENERAL AVIATION STALL-SPIN PROGRAM

By James M. Patton, Jr. and James S. Bowman

Abstract of Paper Proposed for
Tenth Anniversary of Air Safety Investigators
October 1, 1974
Arlington, Virginia

A dearth of design criteria for satisfactory light airplane spin characteristics has led the NASA Langley Research Center to institute a spin research program, to combine model and full-scale testing for several airplane configurations. Model testing, which will precede and pace full-scale testing, has been underway for over a year. Objectives are to improve safety and aid general aviation by development of a radio controlled model test technique and improved design criteria to aid in early prediction of full-scale spin characteristics.

A TACTUAL STALL DETERRENT

Richard D. Gilson
Dept. of Aviation

Robert E. Fenton
Dept. of Electrical Engineering

Ronald W. Ventola
Dept. of Electrical Engineering
The Ohio State University
Columbus, Ohio 43210

ABSTRACT

The number of aerodynamic stall/spin accidents can be greatly reduced by more effectively providing pilots with critical control information (e.g., angle of attack (α)). It appears as if this might be readily accomplished via a tactual display.

Here the efficacy of a kinesthetic-tactual display, as compared with two types of visual displays, was evaluated in both a highly structured approach-and-landing task and a less structured task involving tight turns about a point. The displayed quantity was the direct or indirect deviation (α_D-α) in angle of attack from a desired value α_D.

In the former, the performance with the tactual display was comparable with that obtained using a visual display of (α_0-α), while in the later, substantial improvements (reduced tracking error (57%), decreased maximum altitude variations (67%), and decreased speed variations (43%), were obtained using the tactual display. It appears that such a display offers considerable potential for inflight use.

I. INTRODUCTION

Aerodynamic stall/spin accidents are particularly lethal, accounting for 23.5% of the fatal general aviation accidents from 1967 through 1969.[1] Despite NTSB efforts in delineating the problem and suggesting various approaches, prevention of such accidents remains an elusive goal. The resulting hazard, faced by the ever-increasing number of small aircraft users, is among the most urgent safety problems of general aviation.

Aircraft are particularly stall prone during takeoff and landing operations. Under these circumstances, the combination of slow speed and "g" loading in banked turns results in a high angle of attack precisely when some of the heaviest demands are placed on a pilot. He must simultaneously control vehicle attitude, usually from visual cues outside the aircraft, and also airspeed which is obtained via a cockpit display. This results in a division of visual attention--a division which can be especially critical for "low-time" pilots who lack the experience to use relevant pitch, inertial and aural cues to estimate aircraft attitude (i.e., angle of attack) and detect an impending stall.

It is not surprising then, that some two thirds of general aviation accidents occur in either approaches and landings or takeoffs and departures.[2] The number of such accidents could probably be sharply reduced if critical control information were presented to a pilot so as not to interfere with either his visual perception of the general flight environment or his reception of auditory information.

An innovative approach towards stall deterrence is presented here. It involves the natural manipulation of a control handle, which contains an embedded dynamic tactual display, to determine a state (i.e., angle of attack (α)) of an aircraft.*

With such information available tactually, a reduction in the division of visual attention between cockpit displays and the outside environment can be achieved. It was therefore hypothesized that, using such a display, angle of attack could be more precisely controlled and inadvertent high angles of attack should be less frequent.

---

* This concept was originally developed in an OSU research program directed toward the development of a driver-operated device to control headway in car-following situations. Significant reductions in headway variance were obtained with respect to visual tracking--o.35 ft^2 versus 10.8 ft^2 with a target headway of 33 feet at 40 miles per hour.[3]

This concept was initially evaluated using a moving-based simulator in which subjects, who received information via either a kinesthetic-tactual display or a visual display, were assigned tasks analogous to those encountered in flight. Under the tactual display conditions, performance with both the primary tactual and secondary visual tasks were improved relative to visual conditions.[4] Subsequently, the following preliminary inflight study was conducted.

II. DISPLAY DESCRIPTION

A control loop, employed during a final approach to landing is shown in Figure 1.

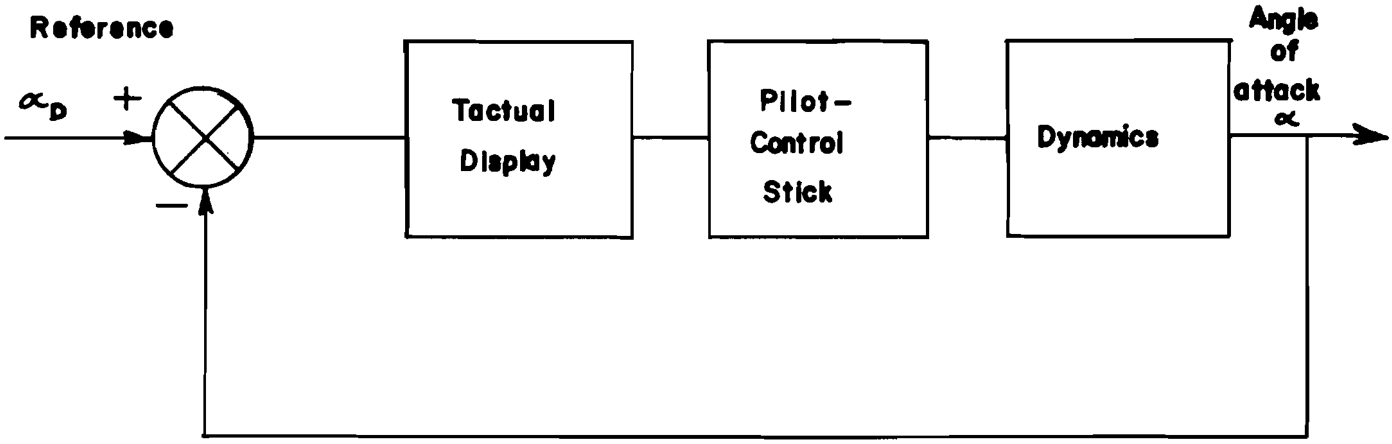


Fig. 1. Control Loop for Angle of Attack

The reference input is a desired angle-of-attack (α_D) which is of course, intimately related to the desired approach airspeed. The feedback signal is the measured angle-of-attack (α), and the display input is the difference between the two (α_D-α), i.e., a compensatory display is employed.

The kinesthetic-tactual display was built into the head of the aircraft control stick shown in Figure 2. This stick replaced the conventional type of stick which is shown at the co-pilot's position. The display, which is clearly shown in Figure 3, consists of a moveable finger which is shown here as protruding from the forward part of the control stick head, and recessed into the aft part. This protrusion corresponds to an unwanted increase in angle-of-attack, and a pilot would respond by moving the stick forward so as to decrease this angle and return the finger to its neutral or flush position. In Figure 4, the finger is shown as protruding "backward" which would require an aft corrective motion of the control stick. That is, a pilot would follow the finger to reduce the displayed error to zero.

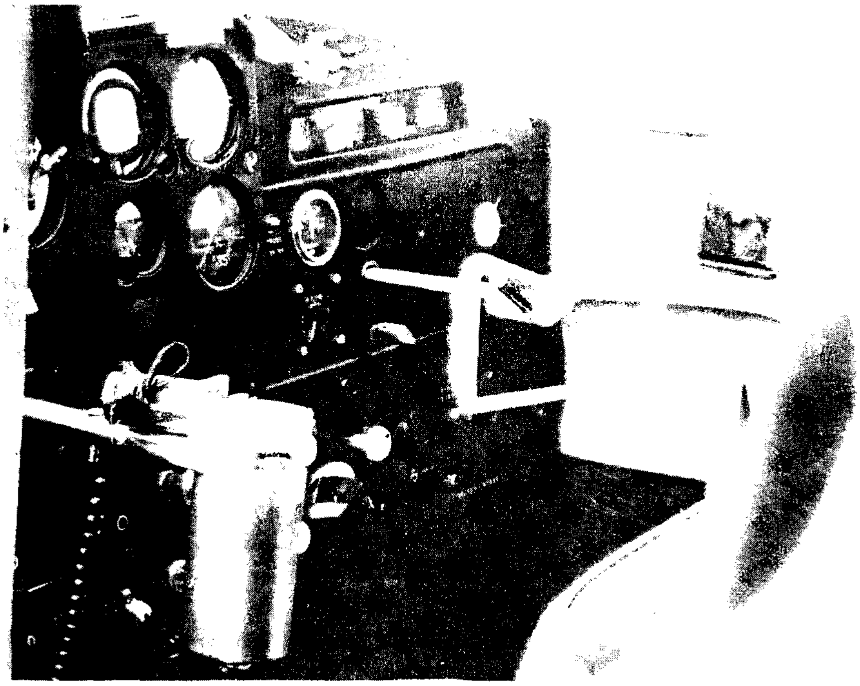


Fig. 2. Aircraft Control Stick with
Built-in Tactual Display

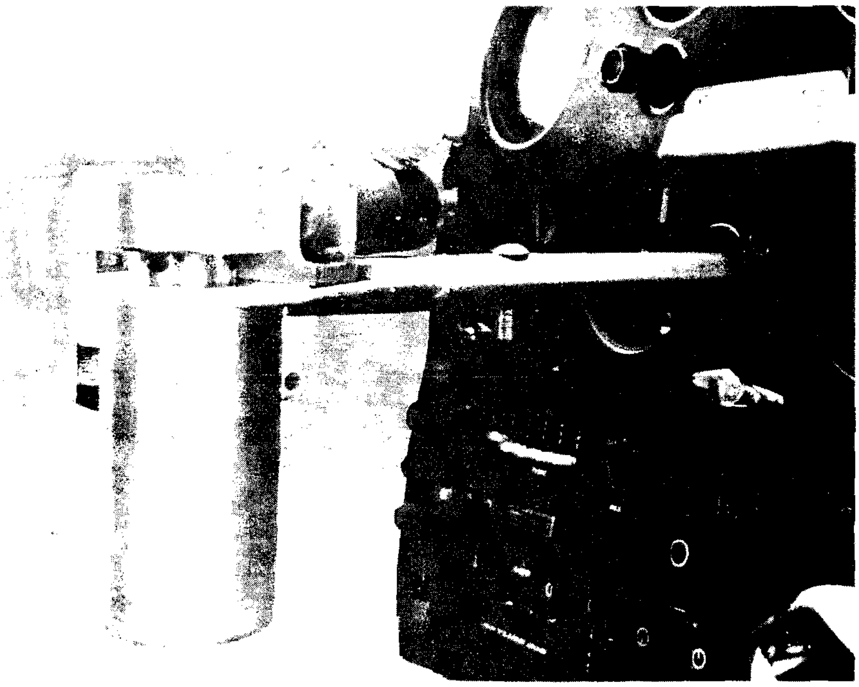


Fig. 3. Aircraft Control Stick with Built-in
Tactual Display--"Finger" Protruding
Forward.

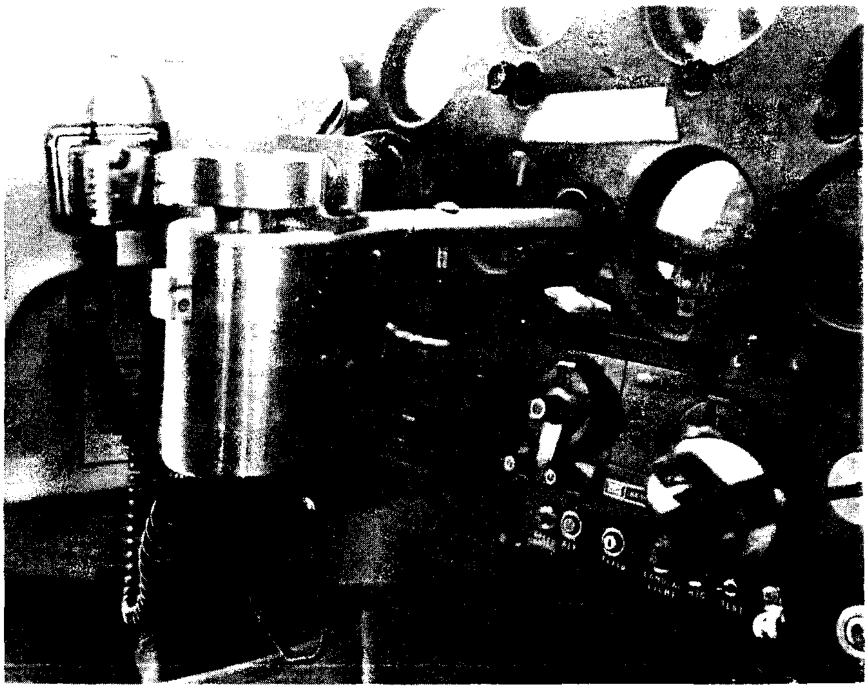


Fig. 4. Aircraft Control Stick with Built-in Tactual Display--"Finger" Protruding Backward.

III. EXPERIMENTAL DESCRIPTION AND RESULTS

Novice pilot behavior was considered under two conditions:

a) A final approach to landing.
b) The execution of a continuous tight turn around a point.

a) Final Approach Study

The general task employed is depicted in Figure 5. A flight instructor maneuvered the aircraft, a Cessna 172, into position for a final approach and turned the controls over to a novice pilot at Point A. The latter was instructed to conduct his approach at an airspeed of 72 mph and to remain aligned with the runway center line. He retained full control of the aircraft throughout the approach phase until his altitude decreased to some 50 ft; then the flight instructor took control and subsequently repositioned the aircraft for another approach.

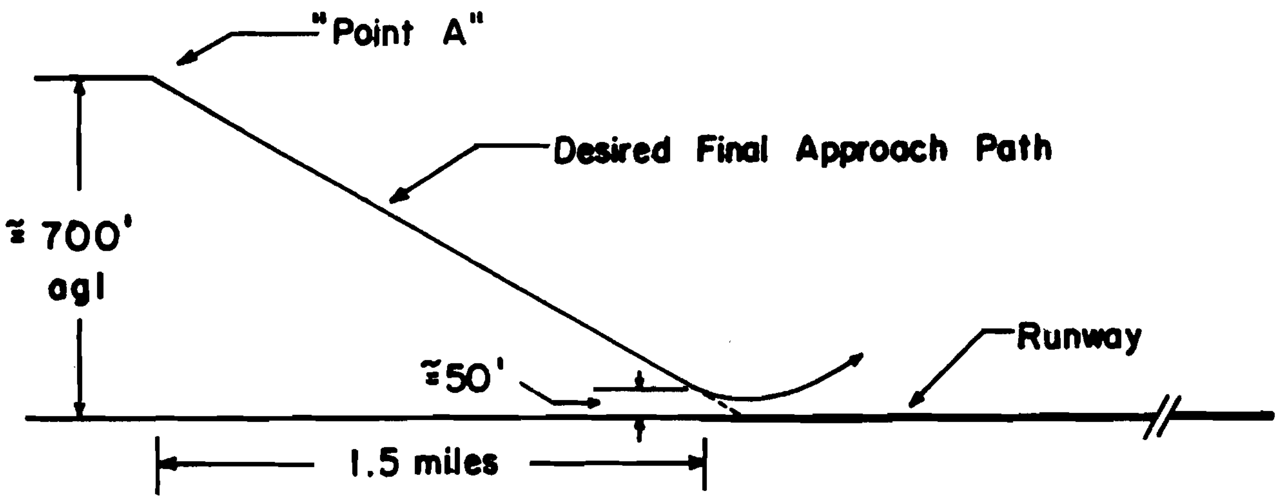


Fig. 5. Final Approach Detail.

The tests were conducted at the OSU airport with only limited air traffic present. Thus, the testing situation could be highly structured and each student could focus his full attention on the landing task.

Airspeed information, or some aspect of same, was provided in three ways with no more than one of these being used in any given approach.

1) A conventional visual display of airspeed.
2) A visual display of AOA-via a display which was mounted on top of the glare shield.
3) The tactual display.

Performance was assessed on the amount of time a subject exceeded a threshold of error in maintaining the desired angle-of-attack. It was hoped vehicle lateral position could also be used as a performance indicator; however, heavy traffic ruled out the use of the only locally available ILS facility.

Six students, each of whom was making his first flight, participated with each student making three approaches with each type of display. Counterbalancing was employed to evenly distribute any bias due to learning.

Some results are shown in summary form in Table I, where the % time beyond threshold is shown for each of the three display modes. Clearly, the least satisfactory performance, 25.3% time beyond threshold, was obtained with the airspeed indicator. A marked reduction to 14.7% was obtained with the visual and display--a result which is consistent with others previously reported. Also note that a similar improvement, almost as great as that from the visual and display, was obtained with the tactual display.

It appears worthwhile to make several additional comments here. First, the approach task was somewhat unrealistic in that the testing proceeded in the absence of the following:

	DISPLAY MODE		
	Airspeed	Angle of Attack (Visual)	Angle of Attack (Tactual)
% Time beyond threshold (Avg. of 17 runs)	25.3 %	14.7 %	16.5 %

Table I.

(a) The subject maneuvering into position for the final approach.
(b) Other air traffic.
(c) Ground-to-air communication.
(d) Also, in the visual AOA display condition, the subject's vision was always directed along the display.

Therefore, the task was the simplest form of an unloaded approach to landing. Second, it seems important to note that the subjects had never used the tactual display, until they were exposed to it in this flight situation.

b) Turn-around-a-point Studies

In order to evaluate the overall utility of the tactual display, novice pilot performance was next considered for turns around a point. Here each of three subjects was instructed to maintain a continuous tight turn at a fixed radius around a point while maintaining a constant speed of 85 mph. In essence, the pilot was now required to frequently direct his attention out of his side window and hence would not devote as much attention to a visual display. The summary results are shown in Table II. Here three quantities are displayed for each display condition.

	DISPLAY MODE		
	Airspeed	Angle of Attack (Visual)	Angle of Attack (Tactual)
% Time beyond threshold	23.4 %	20.8 %	9.4 %
Range of Airspeed (85 mph desired)	50-130 mph	50-130 mph	75-95 mph
Estimated Variation in Altitude (h_d = 800ft)	±600 ft	±600 ft	±200 ft

Table II.

1. % time beyond threshold.
2. Airspeed range.
3. Altitude deviations.

It is obvious that substantial performance improvement, with respect to all three measures, was obtained using the tactual display. It was also noted, although not explicit in the data, that improvements in both variance and maximum deviation were obtained for the tactual relative to the visual display conditions.

IV. CONCLUSIONS

Two obvious conclusions can be drawn from this limited preliminary study. First, in a highly structured (unloaded) approach-and-landing task roughly comparable results were obtained by using either a visual AOA display or a tactual one. This was despite the fact that the S's were not trained in the use of the latter. Next, according to the results of the second experiment, the tactual display was clearly superior when outside attention was required.

In more general situations, the use of this display would appear to combine a number of advantages:

(a) Its "compelling" nature makes it difficult to ignore--even in times of stress;
(b) Pilot reactions are less ambiguous because the display motion (1) is continuous, (2) is located at the point in space where the correcting action must be applied, and (3) is consistent with the yoke motion;
(c) Timely and correct responses are promoted, almost without conscious thought; and
(d) A pilot can exercise judgment with respect to its use.

It is believed that this display concept will provide a type of stall-deterrent that has not been previously available by providing accurate and continuous control of AOA and thereby minimizing the occurrence of excessive AOA. Hence, its general use may result in a reduction in stall/spin accidents particularly during demanding operational situations.

REFERENCES

1. Anon., "General Aviation Stall/Spin Accidents, 1967-1969," Special Study NTSB-AAS-72-8, National Transportation Safety Board, Washington, D.C., September 18, 1972.

2. Anon., "Annual Review of Aircraft Accident Data," Report Number: NTSB-ARG-74-1, National Transportation Safety Board, Washington, D.C., April 18, 1974.

3. Fenton, R.E., and Montano, W.B., "An Intervehicular Spacing Display for Improved Car-Following Performance," IEEE Transactions on Man-Machine Systems, Vol. MMJ-9, No. 2, June 1968, pp 29-35.

4. Gilson, R.D., and Fenton, R.E., "A Tactual Pilot Aid for the Approach-and-Landing Task," Proceedings of the 8th Annual Conference on Manual Control, Air Force Flight Dynamics Laboratory Technical Report TR-72-92, Wright-Patterson AFB, Dayton, Ohio, 1972.

COCKPIT VOICE RECORDERS: THE LAW AND THE PROFITS

by

ROBERT D. RUDICH

President
Air Transportation Consultants
Alexandria, Virginia 22307

on the occasion of the

FIFTH INTERNATIONAL SEMINAR

of the

SOCIETY OF AIR SAFETY INVESTIGATORS

Washington, D. C.

October 2, 1974

The title of the program this morning fits very nicely the time frame of the life cycle to date of the air carrier accident investigator's friend, the cockpit voice recorder, or, as it is more familiarly known, the CVR. This device was developed in the early 1960s in response to the demand by accident investigation authorities for assistance in reconstructing the pre-accident environment on the flight deck. It was made a requirement for carriage first by the Australian civil aviation authorities in 196~~4~~3 This action was followed by the implementation of the requirement by United States authorities as of July, 1966. There then came a period of waiting and watching by a number of other States for the results obtained from this tool, during which time a large number of airlines installed CVRs on their aircraft independent of any national requirement so to do.

After this "wait and see" period, which lasted for about three or four years, a considerable number of States adopted national regulations requiring the carriage and use of CVRs, and in 1972 the International Civil Aviation Organization (ICAO) in its 7th Air Navigation Conference adopted changes to Annex 6 to the Convention (Operation of Aircraft) which provide, essentially, as a Standard that after 1 January 1975 all turbine engine airplanes of a maximum weight of more than 27,000 kg. (59,525 lb.) certificated after 30 September 1969 shall carry a cockpit voice recorder; and as a Recommendation that, after 1 January 1975, all turbine engine airplanes weighing between 5,700 and 27,000 kg. <u>should</u> <u>be</u> equipped with a cockpit voice recorder. Unfortunately, this excludes such airplanes as the Boeing 707, 727 and 737, Douglas DC-8 and DC-9, BAC 1-11, VC-10, Ilyushin 62, and others which meet the above-cited weight categories but all of which were certificated prior to 30 September 1969. In many instances national regulations close this loophole, but unfortunately this is not univerally true.

So much for an abbreviated history of the law. Let us now turn to the profits. Apart from the obvious capability of reconstructing the conversation which transpired on the flight deck prior to an accident, it was discovered during the investigation of the first accident involving an aircraft of United States registry equipped with a CVR that there was considerably more data recorded on the tape than that contained in crewmembers' speech. These data include, but are not limited to, sounds associated with:

1. Engine operation.
2. Raising and lowering of landing gear.
3. Horizontal stabilizer trim actuation.
4. Electrical power source changeover.
5. Flap actuation.
6. Identification of radio aids to navigation.
7. Changes in air speed.

Some of these data were usable by the investigatory body unprocessed; that is, the sounds themselves became reference points without further interpretation. Others, however, required validation through the medium of test flights under controlled conditions, sound frequency spectrographic analysis of the recorded signals, and other processing methods.

Of particular interest was the development of the methodology for deriving turbine engine performance values through analysis of the resonances produced by certain stages of the compressor system of the engines, and which are audible on the flight deck.

It was noted that in instances where the aircraft involved was one with wing- or wing-pod-mounted turbine engines, the amplitude of these resonances was sufficient to be picked up by the cockpit area microphone of the CVR and thus recorded on the tape. Inquiry of the engine manufacturers revealed that an accurate measurement of the frequency of the predominant resonance was a valid technique for deriving quantitative data against which a determination of turbine or shaft rotation rates values could be derived. Other data sources can usually reveal altitude, indicated air speed, and outside air temperature. The resultant computations, made by others far more knowledgeable in their specialties than the author, produced expressions of thrust, or equivalent shaft horsepower in the case of the turbo-props.

There are certain limitations inherent in the application of this technique, however. The first one of these, obviously, is that it cannot be successfully applied to the derivation of data from rear-mounted engines. Secondly, because of the characteristics of certain brands of CVRs, which were dictated by the tape travel speed the manufacturer elected to use in his recorder, there is a point in frequency at which, although the engine resonance is perfectly audible on the flight deck, it will not be recorded on the CVR tape. Thus it is possible, for example, to obtain valid data regarding a Rolls-Royce 532-7 engine on a Piedmont Air Lines FH-227B all the way up to 15,000 shaft r.p.m., yet the data range is limited to 12,500 to 13,000 r.p.m. on the same type aircraft operated by Ozark Air Lines. Another example which comes to mind is the difference between recordings from a Western Airlines vs. a United Air Lines Boeing 737 at high rates of engine rotation (in the takeoff power regime).

Thirdly, there must be no competing resonances or sounds of equivalent or greater amplitude in the segment of CVR tape recording from which a derivation of engine performance is desired to be made.

The specific methodology and equipment utilized in deriving information regarding engine performance are discussed in Appendix A to this paper, for reference by those with a desire to know more about the subject.

The uses to which the derived data are put should be obvious to the initiated, but not all of us are initiated. Some of these uses are the development of a thrust-available vs. thrust-required curve, assessment of aerodynamic configuration by comparison of derived data with air speed and altitude information from flight data recorder (FDR) sources, determination of engine response times to power application, analysis of failure modes, and validation (or otherwise) of apparently excessive values of airspeed and changes of altitude as recorded on the flight data recorder foil. Most, if not all, of the foregoing applications have been made of engine performance data derived over the past seven years, with pronounced success.

Let us now turn to another procedure which came into being concurrent with the CVR's arrival on the investigative scene. I am referring to the development of a real time-, speech- and sound-annotated correlation of the flight data recorder readout graph. This may be produced in terms of direct-reading values as derived from the FDR or, by application of corrections for altitude, temperature and winds aloft, in the form of a two- or three-dimensional flight track.

Use of an overlay which describes the radio navigation/ approach aid systems and their concomitant cockpit flight instrument indications can provide information to the investigator which is useful in comparing flight crew actions as evidenced by aircraft dynamics recorded on the FDR to a standard set of conditions. Also, data derived from this combination of investigative procedures can be, and have successfully been, fed into computer driven flight simulators which have a visual output capability, thus effectively reconstructing not only the flight dynamics but also the visual stimuli available to the flight crew.

A prime example of the application of this technique is illustrated in the case of the Boeing 720B training flight which, while executing a 3-engine go-around after an ILS low approach with the same power configuration, suffered a catastrophic failure of the rudder boost system. There was a 600 foot ceiling with 3/4 mile visibility at the time. Immediately following the failure the aircraft went out of control and crashed, due to it being below Vmc_a with high asymetric thrust and manual rudder.

The accident data were programmed into the NASA Ames Laboratory simulator and a video tape was made of the visual display. On the sound track of the video tape was inserted the actual cockpit area microphone channel recording from the 720's cockpit voice recorder. The resultant composite film, which some of you have doubtless already seen, looks like this.

(Show video tape)

So much for the good news. Now for the bad news, and a pointing out of a problem area which needs working on, without sticking my neck out bv recommending a specific solution.

As with a good and faithful wife, whom one often never realizes how much he depends on until, at a time of need, she is missing because of illness or death, so it has been in the investigation of air carrier accidents and incidents when for one reason or another the CVR data are not available. In this country the loss of data in catastrophic accidents has been minimal, and in those very few instances it was attributable to long-term exposure of the recorder to elevated temperatures caused by post-accident fire in areas remote from crash rescue activities.

Experience has shown, however, that a need remains for improving the survival rate of the recorded information in minor accident cases. Note that I have referred to the survival of the information rather than of the recorder. Because of the very nature of the CVR, that is, that it is a continuous-loop tape recorder with a relatively short retention span, it is incumbent upon us as investigators to ensure, through all available means, that the operation of the recorder be stopped shortly subsequent to a ground-based accident in order that the record of pertinent flight deck sound data may be preserved.

The problems in this area usually stem from the failure to inhibit CVR operation subsequent to an accident which does not create the necessity for an engine shutdown, or which later involves the use of an APU or a ground-based power unit. As electrical energy continues, or is restored, to the CVR it operates in a normal manner, recording the "now" data and erasing that of 30 minutes ago. After a while all of the recorded material directly pertinent to the accident has been erased and lost forever.

There also remains the occasional problem of inadvertent and occasionally deliberate bulk erasure of the tape by a flightcrew member. However, since this is not a seminar devoted to law enforcement activities, any further discussion of this problem area will be held privately, if at all.

It is incumbent on the investigator and the investigatory authorities to continue to convey to the pilot fraternity the importance of affirmative action subsequent to a minor accident, to ensure retention of the recorded data, and to stress the fact that more often than not the record will assist the pilot in explanation of his actions, or at least provide a rational basis for his decisions. If, through ignorance or deliberate inaction, he fails to inhibit the operation of the CVR after the aircraft is on the ground, he is compounding not only his problems but those of the aircraft accident investigator, who seeks to prevent recurrence by dissemination of knowledge of what has transpired before.

APPENDIX A

DETAILED PROCEDURE FOR DERIVATION OF AIRPLANE TURBINE ENGINE ROTATION RATE VALUES FROM COCKPIT VOICE RECORDER TAPES

In order to achieve an acceptable order of accuracy in the values derived from the analysis of engine-compressor-generated resonances by spectrographic means it is absolutely necessary first to ensure to the greatest extent practicable that there is no timing error in any tape recording used in the process. This includes the original tape from the airplane involved in the accident. Since the cockpit voice recorder is generally unusable again following an accident where the technique delineated herein is to be applied, the question naturally arises as to how one can ensure timing accuracy of this recorder. The answer thereto is to employ external time references to the data on the tape.

Specifically, one establishes the precise time of the beginning of two or three air-ground-air communications which are known to be recorded on the CVR, by correlating these communications with their associated timing signal on the ground-based recorder in the appropriate air traffic control facility. By measuring the elapsed time between each of these transmissions, then adjusting the playback speed of the original CVR tape until the same precise intervals are achieved between the measured communications, you have now established that, whether or not it is being played at its nominal recording speed, the tape is moving at exactly the speed which it was at during the recording process.

The mechanics of the foregoing speed check must be undergone in respect to each calibration tape which is prepared from known data on other cockpit voice recorders.

Starting with an airplane of the same type as that involved in the accident, which is equipped with a newly overhauled cockpit voice recorder, the next step is to obtain, through the medium of a test flight, a tape which contains a recording of engine-derived resonances, each at least 10 seconds in length, while the engines are being operated at controlled levels. Illustrations of the foregoing are:

For Pratt & Whitney engines - 60%, 70%, 80%, 90% and 100% of N_1 speed.

For Rolls-Royce 532-7 engines - 11,000; 11,500; 12,000; etc., to 15,000 shaft r.p.m.

All operating engines should be at the same level, stabilized. Annotation should be made on the cockpit area microphone prior to each 10-second segment of tape recording. There should be no controllable external noise in the cockpit during the 10-second segments.

Upon removal of this calibration tape from the CVR, and the completion of the tape speed calibration discussed heretofore, a copy of the tapes should be made on a single reel---that is, both the accident tapes and the calibration tape should be copied onto the same tape using high quality rerecording equipment.

At this point it is necessary to employ equipment capable of producing a frequency spectrogram. The sophistication level of the hardware is directly proportional to the degree of precision required in the end product; e.g., if it is determined that ±1% accuracy is sufficient in analyzing the resonances from a JT3D-7 engine, then equipment such as the Voiceprint sound spectrograph may be used with success assured in meeting this standard. If circumstances such as a non-linear progression of thrust vs. r.p.m. exist (as in the General Electric CJ-805 engine) it becomes critical in certain r.p.m. ranges to determine this value to a much higher order of accuracy, such as ±0.2%. In these circumstances specialized laboratories such as GE's Research & Development Center at Schenectady, New York, must be consulted.

Assume with me that the problems discussed above have been resolved in favor of the ±1% accuracy figure. The tape copy must then be taken to somebody who has access to a Voiceprint Sound Spectrograph, and an understanding of what is required. A full-track copy of the calibration/accident tape copy is then made on the spectrograph and another cross-check is made to verify timing accuracy. At this juncture, if there is a difference between perceived time intervals and previously measured intervals, the investigator is out of options except to adjust percentage-wise in his computations for the difference in interpolating the values derived through analysis of the spectrograms.

The foregoing point requires further explanation. For example, as the full-track tape is played back on the spectrograph, if the perceived interval between previously timed transmissions is less than that derived during the timing exercise based on the ground-based ATC recording, the frequency values assigned to the resonances being measured must be reduced by the percentage of difference between the two sets of times. Conversely, if the perceived intervals are greater than the measured interval, the frequencies must be increased by the percentage of difference between the time intervals. The reason for this is that a tape, made at one speed and played back at a higher speed, will evidence higher frequencies than those present at the time of recording. Since we are dealing here with frequency measurement, we must ensure that what we are measuring represents what was originally recorded in the cockpit.

It will be found that because of the nature of the phenomenon producing the resonances the frequencies thereof will be linear in progression. Thus one establishes the frequency of the predominant resonance for each measured (and annotated) level of engine/shaft rotation on the calibration tape and then proceeds to select those segments of the accident tape for which engine performance data are required. By interpolation of the values derived at this juncture against the previously derived calibration values, rotation percentages/rates are determined for the accident aircraft's engines.

Should the reader desire further information, a consultation with the author of this paper (and developer of this technique) may be arranged by telephoning (703) 765-7097.

NATIONAL TRANSPORTATION SAFETY BOARD
Bureau of Aviation Safety
Washington, D. C.

THE FLIGHT DATA RECORDER AND THE NTSB'S NEW DATA REDUCTION STATION

By

Carol A. Roberts, Ph.D.
Electronics Engineer

ABSTRACT

The Digital Flight Data Recorder is a multi-parameter magnetic-tape flight recorder which was developed to allow recording of an increased number of flight data parameters, as required by FAR Part 121.343.

The flight data recording system, the tape format, and the synchronization scheme are described in this paper. The new data reduction station recently acquired by the National Transportation Safety Board is also described. This station is in keeping with the NTSB's mission of investigating civil aircraft accidents and of reporting the probable cause thereof.

I. INTRODUCTION

The National Transportation Safety Board is charged by Congress with the responsibility of investigating civil aircraft accidents and of reporting the probable cause thereof (Ref. 1).

Although aircraft flight recorders have been required by United States Federal Aviation Regulations (FAR) aboard large aircraft since 1957, these have been of the oscillographic type that engrave altitude, airspeed, heading, and vertical acceleration traces on metal foil as a function of time. A digital flight data recorder has since been developed which encodes 64 12-bit words per second on magnetic tape using Harvard BiPhase code (Ref. 2).

The Digital Flight Data Recorder (DFDR) is a multi-parameter magnetic-tape flight recorder which was developed to allow recording of an increased number of flight data parameters, as required by Federal Aviation Regulations, Part 121 (Ref. 3). The Regulation requires that all large aircraft, for which a type certificate is issued after September 30, 1969, that are turbine engine powered or certificated for operation above 25,000 feet altitude, be equipped with expanded parameter recorders. This includes the new generation of wide-bodied jets, namely, the Boeing B-747, the Douglas DC-10, and the Lockheed L-1011.

The National Transportation Safety Board supported the regulations which required the expanded parameter recorder and recommended its application to new and existing type aircraft. The Board submitted information on specific cases to show how the proposed additional data might have increased the speed and accuracy of past accident investigations. The Board asserted that the additional data would enable the investigator, for the first time, to define the external or environmental forces exerted on the aircraft and the control forces exerted on the aircraft by the pilot, and would display the aircraft's response to these forces. The Board further asserted that the utilization of the additional data would give the accident investigator the capability to study and analyze the "complex interactions between the man-machine environment, the capability for which, heretofore, has not been possible."

The amendment to Part 121 became effective on September 18, 1970. Appendix A gives a list of the new mandatory parameters, their range, minimum accuracy of recording and readout, and maximum sampling and recording intervals. The DFDR is capable of recording over 100 aircraft and flight parameters, although this number is well above that required by Part 121.

I. INTRODUCTION (Cont'd)

Part 121 requires that the recorded data be held until the aircraft has been in use for at least 25 hours of operating time. Hence, the DFDR manufacturers have built the recorder with a 25-hour recording capacity using a recycling magnetic tape. After 25 hours operating time, old data are erased as new data are recorded.

Appendix B gives information on foreign requirements and a list of the 96 parameters recorded by the Atlas Group (Air France, Alitalia, Lufthansa, Iberia, Sabena) for their DC-10-30 aircraft.

The DFDR is primarily designed to assist in promoting aviation safety. Its major function is to provide flight data in the event of an aircraft accident or incident, and to aid safety investigators in determining the probable cause of accidents.

II. FLIGHT DATA RECORDING SYSTEM

1. FDAU

The DFDR is supplied its signals from a flight data acquisition unit (FDAU), which acquires inputs from sensors on board the aircraft, converts them to digital form, and transmits them to the DFDR. The FDAU also generates the timing signals required to define bit, word, subframe, and frame time (see section II-3), along with synchronization control of transmitted data (sections II-4 and II-5).

The data emerge from the FDAU in the form of a serial stream in Harvard BiPhase format (section II-6). This signal stream is then recorded by the DFDR.

There are three companies in the U. S. who supply the digital flight data systems currently in use aboard commercial aircraft. These are Garrett AiResearch of Torrance, California; Hamilton Standard of Windsor Locks, Connecticut; and Teledyne Controls of El Segundo, California.

Appendix C lists the aircraft types for each U. S. carrier having DFDR equipment on board and the particular system in use on each type aircraft. As of May 1973, there were 108 B-747, 66 DC-10, and 22 L-1011 aircraft in service with U. S. carriers.

All systems have basic characteristics in common because certain design features are fixed by mutual agreement among the airlines in the form of the ARINC characteristics (Ref. 2).

II. FLIGHT DATA RECORDER SYSTEM (Cont'd)

2. The DFDR

There are two manufacturers of DFDR's in the U.S.A., Lockheed Aircraft Services Company (LAS) of Ontario, California, and Sundstrand Data Control (SDC) of Redmond, Washington.

The system supplier will install either recorder with his system at the option of the carrier. The two recorders differ in certain aspects, although both record 25 hours of data, and both satisfy the ARINC specifications.

The LAS DFDR records a little over 4 hours of data on one tape track, then reverses tape direction and records on another track. There are six data tracks on an LAS DFDR tape. Tracks 1, 3, and 5 are recorded in the forward direction and tracks 2, 4, and 6 in the reverse direction, as shown in Figure 1. After the recorder has switched through all six tracks, recording time has reached more than 25 hours, and recording is resumed on track 1, erasing the previous data and writing new data. Tape speed is 0.46 inches per second, data density is 1670 bits per inch. Mylar recording tape is used.

The SDC DFDR utilizes four tracks on a metal recording tape called Vicalloy. During operation one track is recorded at a time in a predetermined bidirectional sequence. Old data are erased before recording new data. When end-of-tape is sensed, the motor rotation direction is reversed, and the record electronics are switched to the next track. Recording time for one end-to-end pass of the tape is 6.25 hours. Tape speed is 0.43 inches per second, data density is 1786 bits per inch.

Both DFDR's are packaged in a 1/2 ATR long frame and weigh 25-28 pounds each. Both DFDR's have failure detection circuitry for monitoring the current to the recording head, the output of a tape motion sensor, and the power supply. If a failure occurs, an indicator illuminates in the cockpit. (Note: the FDAU has failure detection circuitry, also. The indicator is on the FDAU panel, however, and notice of failure is not usually transmitted to the cockpit).

The DFDR recording medium must survive under the most adverse conditions of fire, humidity, and water immersion, impact, penetration, and crushing forces. The survival aspects of the flight recorder are specified in TSO C-51a (Ref. 4).

II. FLIGHT DATA RECORDER SYSTEM (Cont'd)

3. Tape Format

Each second of recorded data is called a subframe, and four subframes comprise a frame, as illustrated in Figure 2. The first part of any subframe is a 12-bit* synchronization (sync) word which signals the start of the subframe and identifies it as subframe 1 or 2 or 3 or 4. Besides the sync word, each subframe contains 63 other words, each 12 bits long, as is shown in Figure 3 for subframe 1 of a typical aircraft DFDR installation. (It is to be noted that each airline may have a different arrangement of the data for each type of aircraft).

A given word slot in the subframe may contain the same aircraft or flight parameter as in other subframes, or it may contain a different parameter in each of the four subframes. In our example, heading is recorded in word 3 of all subframes, whereas the thrust parameter of engine number 1 is recorded only in word 33 of subframe 1. Word 33 of subframe 2 contains thrust of engine 2, and so on. Hence, more than 64 aircraft parameters may be recorded on a DFDR tape.

Another feature also greatly enhances the capacity of the recorder. Many aircraft parameters are of the on/off type, such as radio microphone keying, engine thrust reverser unlock and deploy, and central air data computer fail flag. Only one bit is needed to encode these. Since certain analog parameters require less resolution than others, the two least significant bits of these words may be omitted, and the vacant bit positions used to encode the on/off parameters. This is illustrated in Figure 3.

It may be desirable to record some parameters more than once per second. Vertical acceleration, for example, is recorded four times per second. Thus, four words per subframe (words 13, 20, 45, 61 in the example) are assigned to vertical acceleration. The author believes, however, that this sampling rate for acceleration parameters is not high enough. See Appendix D.

4. Sync Words

Consider Figure 3 once again. There are 64 words, each 12 bits long, for a total of 768 bits per second. A 2-hour flight, then, requires over 5.5 million bits to be completely recorded. Suppose you are handed a long piece of paper with 5 1/2 million 1's and 0's on it. How would you make sense out of it?

* "Bit is short for "binary digit." A bit can either be a 0 or 1. Using 12 bits, we can count from 0 to 4095.

II. FLIGHT DATA RECORDER SYSTEM (Cont'd)

First you would look for a place to begin a sync word. You would have your eyeballs tuned to look for any one of the following sequences:

111 000 100 100 (octal 7044, sync code for subframe 1)
000 111 011 010 (octal 0732, sync code for subframe 2)
111 000 100 101 (octal 7045, sync code for subframe 3)
000 111 011 011 (octal 0733, sync code for subframe 4)

You would mark off the beginning of any such sequence you found and count over 768 bits. You would then have found yourself one subframe of data.

Next, you would divide the 768 bits into 64 words of 12 bits each. You would then need a map similar to Figure 3 to tell what parameter was encoded in each word. Thus, it is essential that the sync code be present. Without it, no decoding can be done.

5. Sync Modes

The NTSB data reduction station begins a tape transcription by looking for any sync word. When one is found, the system is programmed to expect the next sequential sync word (SW) 768 bits later. Meanwhile, data from the subframe (SF) are preserved. If the next SW is found, the transcription continues. If the next SW is not found, the data just transcribed are flagged, i.e., a marker is set to indicate that these data are questionable. Hence, the system actually looks for 2 sync words, one before the data in the SF, one after.

A common problem encountered is to have one or more bits missing between sync words, which means that the SW are not always spaced 768 bits apart. Hence, flagged data must be carefully examined. A flag may indicate that some of the data in the SF may be invalid because one bit or more is missing in the serial data stream.

6. Harvard BiPhase Code

In what form are the 1's and 0's actually encoded on the tape? Consider the signal illustrated in Figure 4. This signal could represent magnetic flux on the tape itself, or a voltage into/out of a DFDR write/read amplifier. A phase transition in the middle of the bit cell indicates that the bit is a 1. No transition indicates that the bit is a zero. There is also a phase transition at the start of each bit cell.

III. NTSB DATA REDUCTION STATION

To process data from the flight data recorders, the Safety Board has recently purchased a complete data reduction station, a block diagram of which is given in Figure 5. The heart of the system is a minicomputer (PDP-11/40) with 24K parity core (Figure 5, box 8) and disk operating system (box 11). Peripherals include an alpha-numeric cathode-ray-tube (CRT) terminal (box 7), two industry compatible, 9-channel magnetic tape units (9 and 10), a high-speed printer/plotter (12), and a paper tape reader and punch (13). The system contractor, Teledyne Controls, supplied specialized hardware and software (computer programs) for our application. Specialized hardware includes: two DFDR readers so that the 1/4-inch tapes can be transcribed to 9-track tape without being removed from their crash-proof containers (boxes 1, 2); a reel-to-reel tape deck so that 1/4-inch tapes can be played in the normal manner if it becomes necessary to remove them from a damaged DFDR (box 3); a computer interface to reformat the Harvard BiPhase data stream from the preceding devices into computer-compatible format, i.e., NRZ (4); and an interface (6) for getting X-Y coordinate data from the metal-foil of the older type recorders into the computer. (The foil reader itself (5) is a high-precision measuring device in which a binocular microscope moves across a fixed platen in the X and Y directions under operator control. The operator depresses a switch when he has aligned the microscope properly and wishes to store the coordinates.)

The signal from the original DFDR tape (boxes 1, 2, or 3) is transcribed (reformatted and recorded) on to a 9-track computer tape. After a transcription tape is generated, it is played back on a 9-track tape machine which feeds the information to the computer. A program is called from disk which converts the taped data in raw form into the parameter values originally transmitted to the recording system by the aircraft sensors. The program called depends on the airline and type aircraft.

The software also includes a search routine for locating a specific flight among those recorded on the 25-hour tape, limit excedance and max-min routines, plotter and print routines. Operator commands are entered via the CRT terminal. Interaction between operator and computer is via the terminal, in question/answer mode. The computer asks questions which the operator reads on the CRT screen and answers via the keyboard.

The end result of a normal readout is a second-by-second listing of the data for as much of a given flight as desired, along with a plot of the data. The listing is the so-called "engineering units printout." The equipment can also generate a raw data (octal) printout. It can plot the data versus time in either strip-chart form (8 plots side-by-side, each 2 inches high) or in regular report-style form.

III. NTSB DATA REDUCTION STATION (Cont'd)

Planned for the near future is to adapt a routine now operational on a large machine to the PDP-11/40 which will prepare a ground track of the aircraft. This is very useful in cases involving thunderstorm activity, wake turbulence accidents, and midair collisions. The flight recorder data are corrected for estimated meteorological conditions, and any available radar or other position data to give estimates of the map position of the aircraft, its heading and ground speed.

IV. THE DFDR IN ACCIDENT INVESTIGATION

The DFDR, to date, has been used to investigate several accidents and incidents. In a recent accident case involving a DFDR (Ref. 5), examination of the wreckage disclosed no evidence which could be used to establish the cause of the accident. The investigation was thus highly dependent upon information derived from the aircraft's flight recorders. Among those parameters recorded on the DFDR were altitude, airspeed, heading, acceleration, some engine parameters, cockpit control positions, and control surface positions. Some parameters considered pertinent to the investigation were not recorded. However, it was possible to use the available recorded data to reconstruct the aircraft motion in space by employing the airframe manufacturer's six-degree-of-freedom computer simulation of the aircraft. The results showed that the flightpath was consistent with the established aerodynamic characteristics of the aircraft. This led the investigators to conclude that the aircraft and its systems were not factors contributing to the accident.

At least two other accidents to date have been solved directly by reading the data from the DFDR. In one of these, there were no survivors and, again, examination of the wreckage gave no clue as to the cause of the accident (Ref. 6, 7).

Wreckage in many cases no longer produces sufficient information to assess the causal factors of accidents involving today's sophisticated, fast, and heavy aircraft. In addition, necessary data cannot be obtained by examining complex hardware and avionic circuits, such as are contained in automatic flight control systems and navigation receivers, once power has been removed. Hence, the information recorded by the flight recorders has become of vital importance. The Safety Board believes that the present list of required parameters is inadequate and has submitted proposal No. 535 to the First Biennial Airworthiness Review, to be held at the Shoreham Hotel in Washington, D. C., on December 2-11, 1974. This proposed amendment to FAR 121.343 would require the recording of the following parameters, in addition to those already required:

IV. THE DFDR IN ACCIDENT INVESTIGATION (Cont'd)

1. Time (G.M.T.)
2. Automatic Flight Control System Status
3. Pilot Input/Control Surface Position - Three Axes
4. Spoiler Speedbrake Position
5. Flight Director Mode Selection
6. Localizer/Glide Slope Deviation
7. Hydraulic System Status
8. Electrical Bus Status
9. Fire Warning/Pressurization System Failure
10. Outside Ambient or Total Air Temperature
11. Strut Extension/Retraction Switch
12. Outer, Middle, and Inner Marker Passage
13. Radio Altitude
14. Longitudinal Acceleration
15. Increase the Vertical Acceleration Recording Interval from 4 to 10 Times Per Second (See Appendix D)

The author firmly supports the inclusion of the above parameters in FAR 121 and believes that they will supply a clearer understanding of the subtle causal factors of aircraft accidents, and produce more effective means of preventing future accidents.

V. SUMMARY

Expanded parameter flight recorder systems are required equipment on large U.S. aircraft certificated after September 30, 1969. The DFDR is capable of recording over 100 parameters, although this number is well above that required by FAR Part 121.

The DFDR is supplied its signals from a flight data acquisition unit (FDAU) which acts to convert inputs from the aircraft sensors into digital form. The recording unit stores 25 hours of flight data, and the tape is packaged so that it meets the crash survival requirements of TSO C-51a.

The data reduction station recently acquired by the National Transportation Safety Board has as its core a PDP-11/40 minicomputer with 24K parity core and disk operating system. Both DFDR tapes and metal foils from the older type recorders can be automatically processed.

Wreckage in many cases no longer produces sufficient information to assess the causal factors of accidents involving today's sophisticated, fast, and heavy aircraft. In addition, necessary data cannot be obtained by examining complex hardware and avionic circuits, such as are contained in automatic flight control systems

V. SUMMARY (Cont'd)

and navigation receivers, once power has been removed. Hence, the information recorded by the flight recorders has become of vital importance.

A well programmed DFDR will supply a clearer understanding of the subtle causal factors of aircraft accidents, and produce more effective means of preventing future accidents.

LOCKHEED AIRCRAFT SERVICE COMPANY
A DIVISION OF LOCKHEED AIRCRAFT CORPORATION

OVERHAUL MANUAL
DIGITAL FLIGHT DATA RECORDER
PART NUMBER 10077A500-103

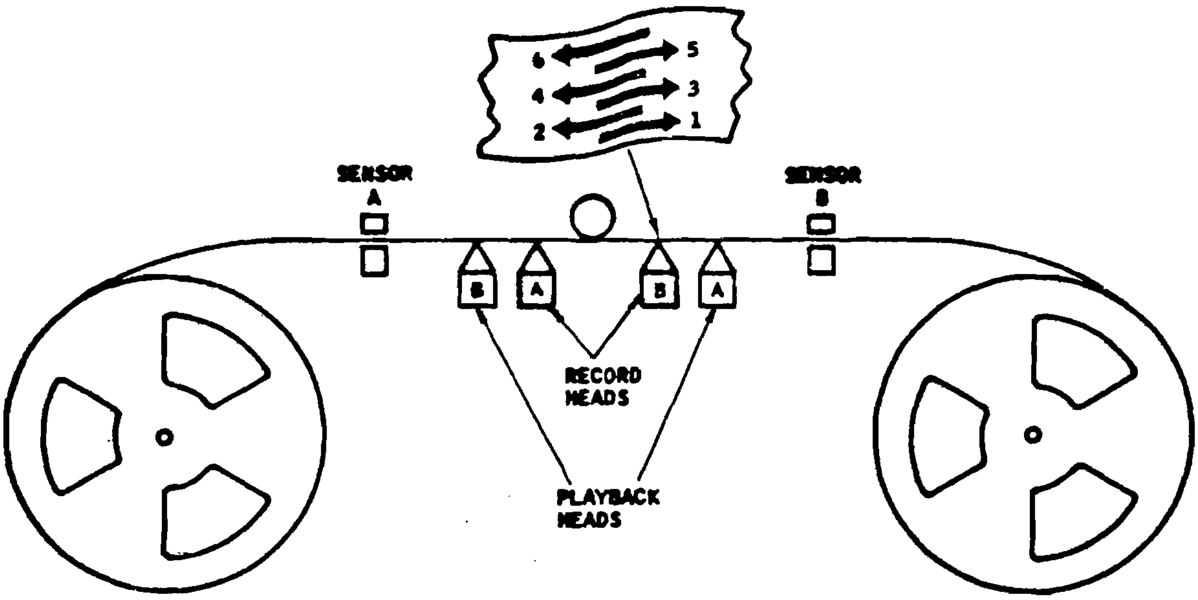
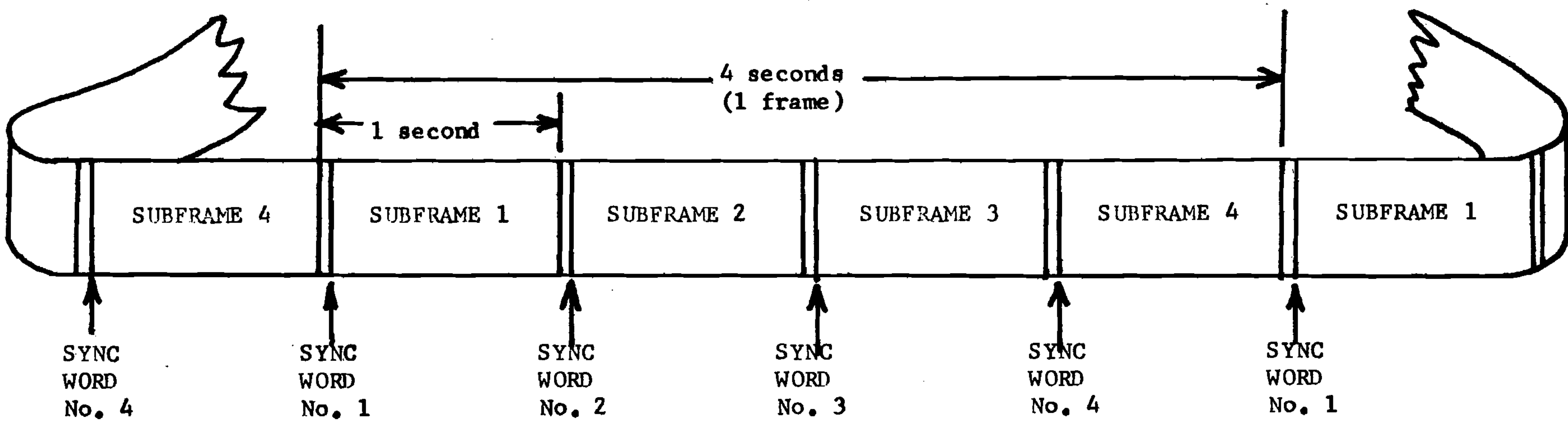


FIGURE 1. Tape motion during recording for LAS DFDR.

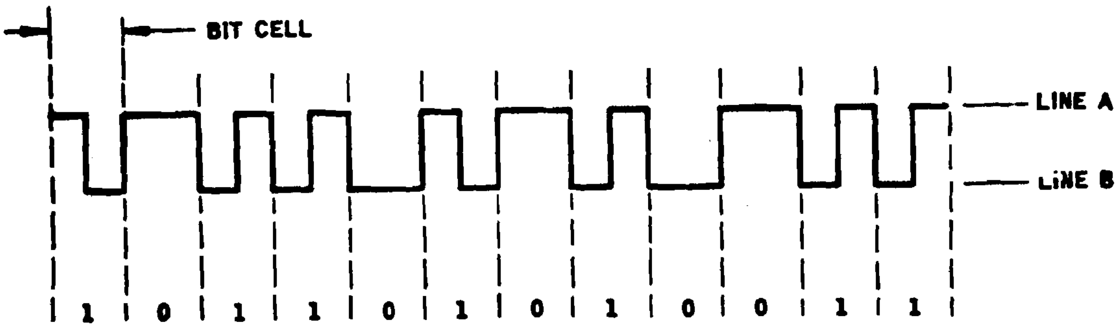


SYNC WORD	BINARY	OCTAL
1	111 000 100 100	7044
2	000 111 011 010	0732
3	111 000 100 101	7045
4	000 111 011 011	0733

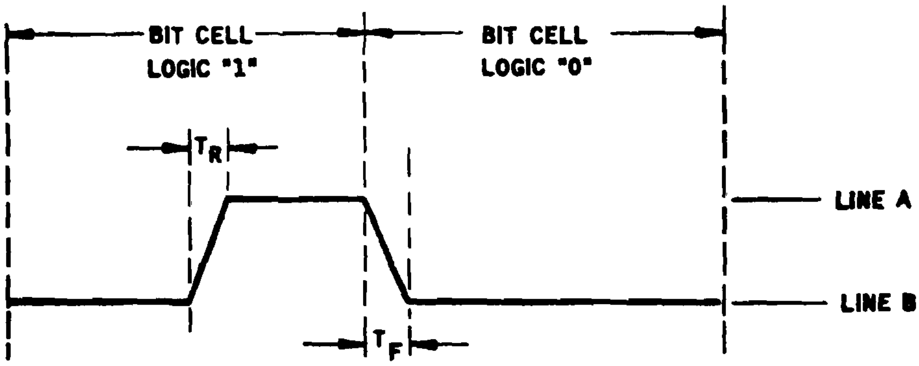
FIGURE 2. Tape layout for both LAS and SDC DFDR's showing frame and subframe structure. Only one track of the tape is depicted.

WORD 1 SYNC WORD bits 1-12	2	3 HEADING bits 3-12	4	5 FINE ALTITUDE bits 1-12	6	7 THRUST REVERSER UNLOCKED bit 1 DEPLOYED bit 2	8 RIGHT OUTBOARD ELEVATOR bits 3-12
9 LEFT INBOARD AILERON bits 3-12 VHF 1,2 bits 1,2	10	11	12 LOWER RUDDER bits 3-12 EVENT MARKER bit 1	13 VERTICAL ACCELERATION bits 3-12	14	15 LATERAL ACCELERATION bits 3-12	16
17 ROLL ATTITUDE bits 3-12 SLATS bits 1,2	18	19 AIR SPEED bits 1-12	20 VERTICAL ACCELERATION bits 3-12	21	22	23 COARSE ALTITUDE bits 1-5 ALT FLAG bits 6,7 A/S FLAG bits 8,9	24
25	26	27 UPPER RUDDER bits 3-12	28	29 VERTICAL ACCELERATION bits 3-12 SLATS bits 1,2	30	31 LATERAL ACCELERATION bits 3-12	32
33 ENGINE THRUST bits 1-12	34	35	36	37 G M T (GREENWICH MEAN TIME) bits 1-12	38	39 FLAPS bits 3-12	40 RIGHT OUTBOARD AILERON bits 3-12
41 LEFT INBD ELEVATOR bits 3-12 SLATS bit 2	42	43	44 LONGITUDINAL ACCELERATION bits 1-12	45 VERTICAL ACCELERATION bits 3-12 SLATS bit 2	46	47 LATERAL ACCELERATION bits 3-12 HF KEY 1,2 bits 1,2	48
49	50	51 PITCH ATTITUDE bits 3-12	52	53	54	55 PITCH TRIM POSITION bits 1-12	56
57	58	59 UPPER RUDDER bits 3-12	60	61 VERTICAL ACCELERATION bits 3-12 VHF 3 bit 1	62	63 LATERAL ACCELERATION bits 3-12	64

FIGURE 3. Layout of subframe 1 of the DFDR tape for a typical aircraft. Blank word slots can be used, if desired, to record additional parameters. Note that each word is 12 bits in length. If not all 12 bits of the word are used, as in word 9 (only bits 3-12 are used for aileron), the remaining two bits may be used to record on/off (binary or discrete) information such as radio microphone keying; in the case of word 9, VHF number 1 keying in bit 1 and VHF number 2 keying in bit 2.



DATA STREAM FORMAT
HARVARD BI PHASE CODE
(BIT VALUES SHOWN AS AN EXAMPLE)



WAVEFORM CHARACTERISTICS (PER ARINC 573)
HARVARD BI PHASE CODE (DFDR INPUT SIGNAL)

1. PEAK-TO-PEAK DIFFERENTIAL SIGNAL VOLTAGE BETWEEN LINE A AND LINE B, 4 VOLTS MINIMUM, 16 VOLTS MAXIMUM
2. T_R (RISE TIME) = T_F (FALL TIME) = 5 TO 50 MICROSECOND, 10% TO 90% VALUE
3. DUTY CYCLE - 50 ± 5% (1's)
4. BIT RATE (CONSTANT) - 768 BITS PER SECOND

FIGURE 4. Characteristics of the Harvard BiPhase data signal format.

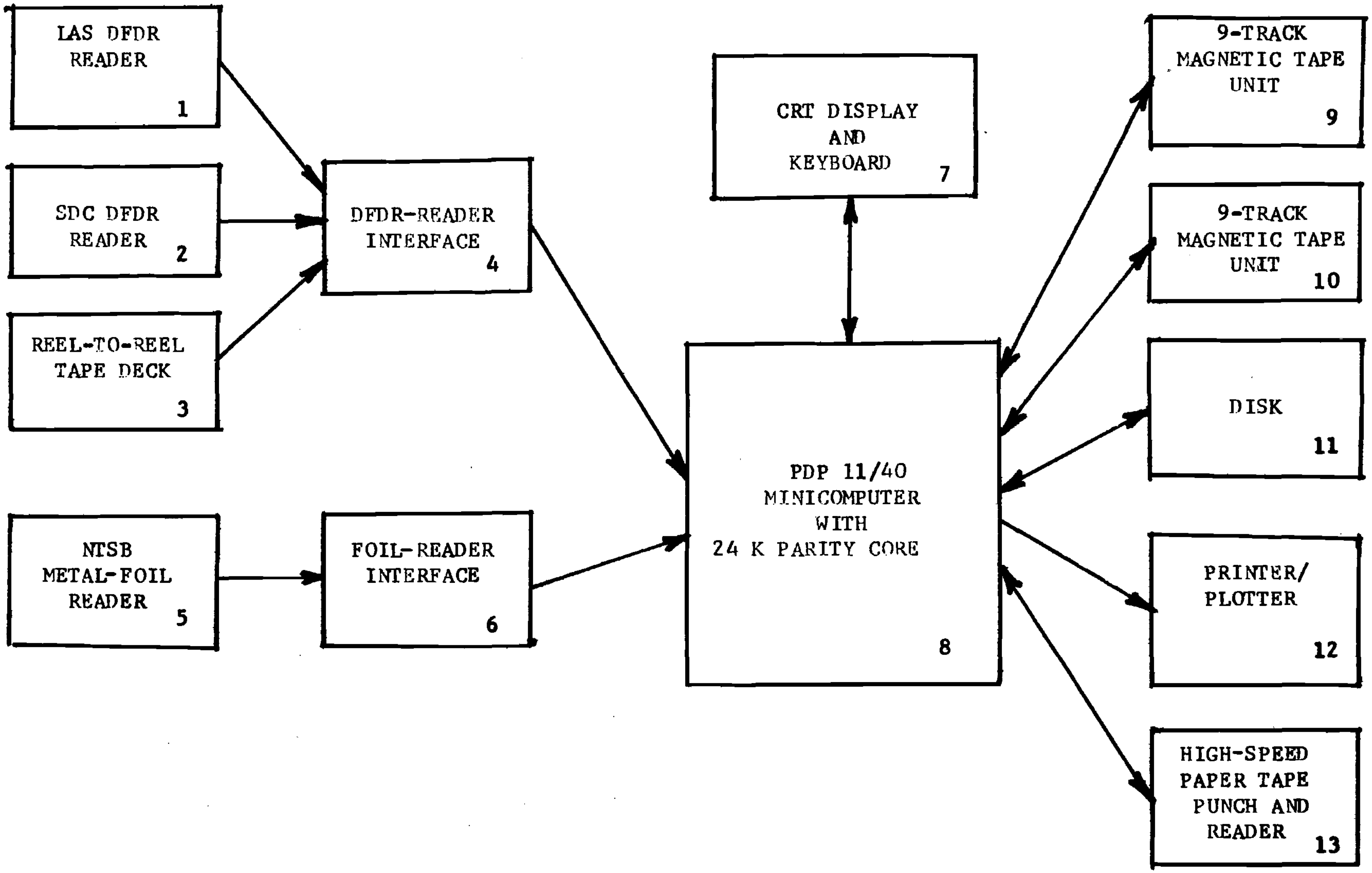


FIGURE 5. National Transportation Safety Board Data Reduction Station.

APPENDIX A

AIRCRAFT FLIGHT RECORDER SPECIFICATIONS AS DEFINED IN FAR PART 121, APPENDIX B (AMMENDMENT 121-66, EFFECTIVE SEPTEMBER 18, 1970)

Information	Range	Accuracy, Minimum (Recorder and Readout)	Recording Interval, Maximum (Seconds)
Time		±0.125% per hour, except accuracy need not exceed ±4 seconds	60.
Altitude	-1,000 ft. to max. certificated altitude of aircraft	±100 to ±700 ft. (see Table I TSO-C51a; FAR §37.150)	1.
Airspeed	100 to 450 KIAS or 100 KIAS to 1.0V_D whichever is greater	±10 knots at room temp. ±12 knots at low temp. (see Table III, TSO-C51a; FAR §37.150)	1.
Vertical Acceleration	-3g to ±6g	±0.2g stabilized, ±10% transient (see TSO-C51a)	0.25 (or 1 sec. in which ± peaks are recorded)
Heading	360°	±2°	1.
Pitch Attitude	±75°	±2°	1.
Roll Attitude	±180°	±2°	1.
Lateral Acceleration (in lieu of sideslip angle)	±1.0g	±.05g stabilized ±10% transient	0.25 (or 1 sec. in which ± peaks are recorded)
Sideslip Angle (in lieu of Lateral Acceleration)	±30°	±2°	0.5.
Pitch Trim Position	Full range	±1° or ±5% whichever is greater	2.
Control Column or Pitch Control Surface Position	Full range	±2°	1.
Control Wheel or Lateral Control Surface Position	Full range	±2°	1.
Rudder Pedal or Yaw Control Surface Position	Full range	±2°	0.5.

APPENDIX A (Cont'd)

AIRCRAFT FLIGHT RECORDER SPECIFICATIONS AS DEFINED IN FAR PART 121, APPENDIX B
(AMMENDMENT 121-66, EFFECTIVE SEPTEMBER 18, 1970)

Information	Range	Accuracy Minimum (Recording and Readout)	Recording Interval, Maximum (Seconds)
Thrust of Each Engine	Full range forward	±2%	4.
Position of Each Thrust Reverser	Stowed and full reverse		4.
Trailing Edge Flap or Cockpit Flap Control Position	Full range (or each discrete position)	±3°	2.
Leading Edge Flap or Cockpit Flap Control Position	Each Discrete position		2.
Angle of Attack (if recorded directly)	-20° to ±40°	±1	0.5.
Radio Transmitter Keying ("Data from which the time of each radio transmission either to or from ATC can be determined" [§121.343 (g)])	On-off		1.

APPENDIX B

FOREIGN REGULATIONS - ATLAS GROUP PARAMETERS

Several foreign governments have enacted regulations requiring expanded parameter recorders. Some foreign carriers not only have installed DFDR's aboard their wide-bodied aircraft, but have them aboard older aircraft as well.

I. CANADA

Canadian regulations stipulate that expanded parameter recorders be installed on any passenger-carrying, "turbine-engine powered pressurized aeroplane that (a) has a maximum certificated take-off weight of more than 12,500 pounds, and (b) is registered as a commercial aircraft under Part II of the Air Regulations," (Ref. 8). This includes Air Canada's B-727's, B-747's, DC-8's, DC-9's, and L-1011's. It includes corporate jets, such as Falconbridge Nickle Mines' G-2, Churchill Falls' DH-125, and Bell Telephone's F-20.

Mandatory parameters are listed in Table I.

II. AUSTRALIA

Australia's current Air Navigation Order states that a flight recorder installation is acceptable when the installation complies with the requirements of the U. S. Federal Air Regulations. This has been done because the major portion of Australian turbine aircraft was manufactured in the United States.

III. GREAT BRITAIN

Great Britain (Ref.9) requires, "A flight recording system [for conventional sub-sonic aircraft] comprising:

"(i) in respect of aeroplanes of less than 11,400 kg [25,000 lbs.] maximum total weight authorised either a 4 channel cockpit voice recorder or a flight data recorder capable of recording by reference to a time scale data from which the following information can be ascertained: the flight path of the aeroplane; the attitude of the aeroplane; and the basic lift, thrust and drag forces acting upon the aeroplane [see Table II, parameters 1-9];

"(ii) in respect of aeroplanes of 11,400 kg [25,000 lbs.] or over but less than 27,000 kg [60,000 lbs.] maximum total weight authorised a 4 channel cockpit voice recorder and a flight recorder capable of recording by reference to a time scale data from which the information specified in paragraph (i) can be ascertained [see Table II, parameters 1-10];

APPENDIX B

V. ATLAS GROUP

The Atlas Group (Air France, Alitalia, Lufthansa, Iberia, and Sabena) record 96 parameters on their DC-10-30 aircraft. A list of these is given in Table V. In addition, Alitalia records true heading and drift angle.

APPENDIX B

III. GREAT BRITAIN (Cont'd)

"(iii) in respect of aeroplanes of 27,000 kg [60,000 lbs.] maximum total weight authorised or over a 4 channel cockpit voice recorder and a flight data recorder capable of recording by reference to a time scale data from which the following information can be established: the flight path of the aeroplane; the attitude of the aeroplane; the basic lift, thrust and drag forces acting upon the aeroplane; the selection of high lift devices (if any) and airbrakes (if any); the position of primary flying control and pitch trim surfaces; cockpit warnings relating to engine fire and engine shutdown, cabin pressurisation, presence of smoke and hydraulic/ pneumatic power supply; outside air temperature; instrument landing system deviations; use made of automatic flight control system; radio altitude (if any); and the level of essential AC electricity supply." See Table II, parameters 1-26.

IV. FRANCE

French regulations (Ref. 10) require that "Commencing July 1, 1973, all aircraft with a maximum takeoff weight in excess of 14,000 Kg [30,800 lbs.] or authorized to transport more than 35 passengers and for which the original type airworthiness certificate, or equivalent document, is issued after September 30, 1969, must be equipped with a flight recorder system capable of recording ... [as a function of elapsed time]:

A. the trajectory of the aircraft,

B. the attitude of the aircraft on the trajectory,

C. the forces acting on the airplane and their origin,

D. the conversation and audible alarms in the cockpit."

A list of mandatory parameters, recording intervals, ranges, and precisions for sub-sonic aircraft are given in Tables III and IV. There are two columns, A and B, in the tables under "precision." In Category A, "the error must be measured between the value supplied by the aircraft system where the parameter is sampled [i.e., the FDAU] and the value retrieved after analysis." In Category B, "the error must be measured between the intrinsic value of the parameter and the value retrieved after analysis. The error can be classified by the aircraft manufacturer or operator in either one or the other of these categories."

A separate parameter list is required for supersonic aircraft of the Concorde type (Ref. 11).

TABLE I

CANADIAN MANDATORY FLIGHT PARAMETERS

1. Each flight data recorder shall record at least the following parameters:

   (a) time;

   (b) pressure altitude;

   (c) indicated airspeed;

   (d) vertical acceleration; and

   (e) magnetic heading.

2. Where an aeroplane is designated by an air carrier for the carriage of passengers, its flight data recorder, in addition to recording the parameters set forth in item 1, shall record:

   (a) force applied to control column or control column position;

   (b) force applied to rudder pedals or rudder pedal position;

   (c) force applied to control wheel or control wheel position;

   (d) position of horizontal stabilizer;

   (e) out-of-trim condition;

   (f) auto-pilot "on" - "off" selection;

   (g) engine power including

      (i) engine torque,

      (ii) engine RPM, and

      (iii) fuel flow;

   (h) ambient air temperature; and

   (i) pitch attitude.

TABLE II

GREAT BRITAIN MANDATORY FLIGHT PARAMETERS FOR CONVENTIONAL SUB-SONIC AIRCRAFT*

Parameter	Record Interval (Secs.) See Note 1	Minimum Range	Accuracy**	Remarks
Time	1		0.125% hour	GMT or elapsed time
Pressure Altitude	1	-305m (-1,000 ft) to max. certificated altitude of the aeroplane + 1524m (5,000 ft)	RSS value of scale error test of G.115 and recording and readout error ± 15m (50 ft)	
Airspeed	1	60 kts to V_{DF} +20 kts	Such that error will not exceed ±3% at speeds at and above the stalling speed of the aeroplane at the maximum landing weight	Accuracy related to pitot minus static pressure
Normal Acceleration (i.e. normal to the longitudinal and lateral axes of the aeroplane)	1/8	-3'g' to +6'g'	±0.086'g' measured at each increment of one 'g' from 1'g' datum (excluding long term datum drift)	

* Civil Aviation Authority Specification 10, Issue 1, May 1, 1974. (The parameter requirements for non-conventional sub-sonic and for supersonic aeroplanes will be the subject of consultation between the manufacturers, intending operators and the Civil Aviation Authority).

** Long-term Accuracy - The required parameter accuracy is quoted in Table II and is, in each case, the RSS (root sum squared) value, measured between the absolute value of the parameter (unless otherwise stated) and the final numerical presentation after read-out.

Repeatability - For any parameter within the range of Table II, the flight data recorder system should have a repeatability over a period of one minute in normal flight conditions at least five times better than the parameter accuracy quoted in Table II.

TABLE II (Cont'd)

GREAT BRITAIN MANDATORY FLIGHT PARAMETERS FOR CONVENTIONAL SUB-SONIC AIRCRAFT

Parameter	Record Interval (Secs.) See Note 1	Minimum Range	Accuracy**	Remarks
Compass Heading	1	360°	±2°	
Gyro Pitch Attitude	1/4	±80° or max. pitch angle normally available from the attitude transmitter	±2° or ±10% of increment from level flight indication, whichever is the greater	
Gyro Roll Attitude	1/2	±180°	±3° or 10% of increment from level flight indication, whichever is the greater	
Engine Power (each engine) EPR or P7 for turbojet aeroplanes. Torque and RPM for propeller driven aeroplanes (Note 2)	One engine to be sampled each sec (i.e. a 4-engined aeroplane will have a particular engine sampled every 4 secs but with a one second stagger between different engines. 3-engined aeroplanes may sample each engine every 4 secs if longitudinal acceleration is being recorded)	Full range	Such that thrust can be determined to within ±10% full thrust	
Flap Angle (Note 3)	1/2	Full range	Such that each gated position is unambiguously determinable from the record	Use of flap selector as data source will not be acceptable

TABLE II (Cont'd)

GREAT BRITAIN MANDATORY FLIGHT PARAMETERS FOR CONVENTIONAL SUB-SONIC AIRCRAFT

	Parameter	Record Interval (Secs.) See Note 1	Minimum Range	Accuracy**	Remarks
	"Press to Transmit" Action	1	Event mark		
	Lateral Acceleration	1/4	±1'g'	±0.02g or ±5% of increment from zero datum, whichever is the greater, (excluding long-term datum drift)	
2	Longitudinal Acceleration	1	±1'g'	As for lateral acceleration	
3	Reverse (each engine)	4 (1 second stagger)	Event mark		See parameter 8 re. three engined aeroplanes
4	Leading-edge high lift devices where fitted-position of cockpit control	1/2	Event mark		
5	Airbrakes or spoilers where fitted-position of cockpit control	1/2	Event mark		
6	Pitch Trim	1/2	Full range	±3% of full range	
7	Temperature	2	Covering OAT range of -90° C to ±45° C	Such that indicated OAT can be determined to within ±3° C	TAT, SAT, OAT etc. may be recorded

TABLE II (Cont'd)

GREAT BRITAIN MANDATORY FLIGHT PARAMETERS FOR CONVENTIONAL SUB-SONIC AIRCRAFT

Parameter	Record Interval (Secs.) See Note 1	Minimum Range	Accuracy**	Remarks
18 Undercarriage	2	Event mark		Indication of "Undercarriage in Transit"
19 Primary flying controls (Note 4)	1/4	Full range	±1/2° or 3% of full movement, whichever the greater	Control Surface Position
		Full range	±3% of full range	Control Input Position
		±222N (±50lbf) ±156N (±35lbf) ±666N (±150lbf)	±44N (±10 lbf) ±31N (±7 lbf) ±133N (±30 lbf)	Column Force Wheel Force Pedal Force
20 ILS Localiser Signal	1	±150 micro-amps	±3% of full range	
21 ILS Glide-slope Signal	1	±150 micro-amps	±3% of full range	
22 Radio Altitude	1	70m (230 ft) downwards	±0.6m (±2 ft) or ±3% of indicated height, whichever is the greater	If provided
23 Essential AC Voltage or Frequency	2	30% to 120% of normal value	±5% of normal value (Voltage) ±1% of normal value (Frequency)	Parameter to be selected on basis of value of data
24 Warnings (Note 5)		Event marks		
25 Automatic flight control system engagement (Note 6)	See Remarks column	Event marks		The record interval of parameters 24, 25 and 26 can be adjusted to suit 4 second frame

TABLE II (Cont'd)

GREAT BRITAIN MANDATORY FLIGHT PARAMETERS FOR CONVENTIONAL SUB-SONIC AIRCRAFT

Parameter	Record Interval (Secs.) See Note 1	Minimum Range	Accuracy**	Remarks
26 Automatic flight control system mode (Note 7)	See Remarks column	Event marks		See Remarks above

NOTES

(1) The record interval is the maximum time, ±1/64 seconds, between successive samples.

(2) Where auxiliary thrust units are provided it will be acceptable to record an event mark denoting the attainment and removal of a selected high level of power output.

(3) Where gated flap positions are provided and intermediate selections are not possible a record by means of event marks will be acceptable, provided that they are derived from the operating mechanism and not from the flap selector.

(4) Where there are only one or two control surfaces in each plane, measurement should be taken from each surface; where more than two surfaces are provided the measurement should be taken from a common stage (preferably that stage which is closest to the control surfaces) in the control run. "Column/Wheel/Pedal" forces will be an acceptable alternative to control surface deflections providing that the measurements are taken at, or immediately adjacent to, the operating controls. In complex systems it may be necessary, if not already covered by parameter 24, to monitor "Systems Status" in addition to Deflections/Forces.

(5) Warnings should cover the following:

Fire (Each Engine and APU)
Cabin Pressurisation
Other Red Light Warnings leading to engine shut down
Fuselage Smoke
Essential Hydraulic/Pneumatic Power

TABLE II (Cont'd)

(6) Autopilot Engagement of each control axis (i.e. Pitch, Roll, Yaw, Autothrottle and Autolift Devices) where these are independently selectable. Basic autopilot engagement to be recorded where axes are not independently selectable.

(7) Selection of each "Capture" or "Acquire" mode, and Autoland, to be recorded together with autoland selection (i.e. Prime Land).

TABLE III

FRANCE: LIST OF PARAMETERS PERMITTING RECONSTRUCTION OF THE FLIGHTPATH

Parameters	Recording Interval (Secs)	Range	Precision		Remarks
			A	B	
Time	60			±0.125% per hour	GMT or referenced to GMT
Pressure Altitude	1	-300 m to max. CDN*	±15 m		
Airspeed	1	50 Kt to 1.3 VMO	±3 Kt		
Heading	1	0 to 360°	±1°	±3°	
Vertical Acceleration	1/4	-30 m/s/s to + 60 m/s/s	±0.5%	±1.5%	
Markers (75 MHz)	1	Discrete	-	-	

*CDN Certificat de navigabilité (airworthiness certificate)

TABLE IV

FRANCE: LIST OF PARAMETERS PERMITTING RECONSTRUCTION OF ATTITUDE, FORCES ACTING ON THE A/C AND THEIR ORIGIN, ACCIDENTAL CIRCUMSTANCES AND THEIR ORIGIN

Subsonic Airplanes

Parameters	Recording Interval (Secs)	Range	Precision A	Precision B	Remarks
Pitch Attitude	1	±75°	±1°	±2°	
Lateral Attitude	1	±180°	±1°	±2°	
Angle of Attack	1/2	-20° to + 40°	±1°	±2°	(1)
Longitudinal Acceleration	1	±10 m/s/s	±0.5%	±1.5%	
Lateral Acceleration	1/4	±10 m/s/s	±0.5%	±1.5%	
Pitch Surface Control	1	Full range	±1°	±1° + 1%	
Roll Surface Control	1	Full range	±1°	±1° + 1%	
Yaw Surface Control	1/2	Full range	±1°	±1° + 1%	
Pitch Trim	2	Full range	±1°	±1° + 1%	
Flaps - Trailing Edge	2	Full range	±1°	±1° + 1%	(3) (2)
Flaps - Leading Edge	2	Discrete	-	-	(2)

Notes

(1) These parameters will be recorded if the aircraft possesses the sensor (measure of angle of attack, radio altimeter).

(2) The recording of these parameters can be effected either by position indicators of the cockpit controls or sensors placed on the flaps.

(3) The two most significant parameters will be recorded.

TABLE IV (Cont'd)

FRANCE: LIST OF PARAMETERS PERMITTING RECONSTRUCTION OF ATTITUDE, FORCES ACTING ON THE A/C AND THEIR ORIGIN, ACCIDENTAL CIRCUMSTANCES AND THEIR ORIGIN

Subsonic Airplanes

Parameters	Recording Interval (Secs)	Range	Precision		Remarks
			A	B	
Thrust of Each Engine	4	Full range	±0.5%	±2%	(3)
Reverse Thrust	4	Discrete	-	-	
Glide Slope Deviation	1	Full range	±0.5%	-	
Localizer Deviation	1	Full range	±0.5%	-	
Radioaltimeter	1	Full range	±0.5%	-	(1)
Signal Indicating that the approach will be made by an automatic system [coupled approach]	1	Discrete	-	-	

TABLE V

PARAMETERS RECORDED BY THE DFDR'S ABOARD THE ATLAS GROUP DC-10-30 AIRCRAFT

1. GMT
2. Radio Altimeter No. 1 (Coarse)
3. Radio Altimeter No. 2 (Fine)
4. Pressure Altitude
5. Computed Airspeed
6. Magnetic Heading
7. Vertical Acceleration
8. Lateral Acceleration
9. Longitudinal Acceleration
10. Total Air Temperature
11. Mach Number
12. Max. Allowable Airspeed
13. Pitch Attitude
14. Roll Attitude
15. LH INBD Ailerons
16. RH OTBD Ailerons
17. RH Flap 3 (RT, INBD)
18. LH INBD Elevator Position
19. RH OTBD Elevator Position
20. Upper Rudder Position
21. Lower Rudder Position
22. Horizontal Stabilizer Position (Pitch Trim)
23. Spoiler Position No. 3 Right
24. Spoiler Position No. 5 Left
25. Glideslope Deviation No. 1
26. Glideslope Deviation No. 2
27. Localizer Deviation No. 1
28. Localizer Deviation No. 2
29. Engine Thrust (N1), Eng. 1
30. Engine Thrust (N1), Eng. 2
31. Engine Thrust (N1), Eng. 3
32. Engine Core Speed (N2), Eng. 1
33. Engine Core Speed (N2), Eng. 2
34. Engine Core Speed (N2), Eng. 3
35. Oil Quantity, Eng. 1
36. Oil Quantity, Eng. 2
37. Oil Quantity, Eng. 3
38. Power Lever Angle, Eng. 1
39. Power Lever Angle, Eng. 2
40. Power Lever Angle, Eng. 3
41. Eng. Inlet Pressure (PT2)
42. Turbine Inlet Pressure (PT54), Eng. 1
43. Turbine Inlet Pressure (PT54), Eng. 2
44. Turbine Inlet Pressure (PT54), Eng. 3
45. Vibration Monitor 1, Eng. 1
46. Vibration Monitor 1, Eng. 2
47. Vibration Monitor 1, Eng. 3
48. Vibration Monitor 2, Eng. 1
49. Vibration Monitor 2, Eng. 2
50. Vibration Monitor 2, Eng. 3
51. Fuel Flow, Eng. 1
52. Fuel Flow, Eng. 2
53. Fuel Flow, Eng. 3
54. Exhaust Gas Temp., Eng. 1
55. Exhaust Gas Temp., Eng. 2
56. Exhaust Gas Temp., Eng. 3
57. Squat Switch
58. VHF Keying, XTR 1
59. VHF Keying, XTR 2
60. VHF Keying, XTR 3
61. HF Keying, XTR 1
62. HF Keying, XTR 2
63. Event Marker
64. Slat L/4A (#1)
65. Slat L/4B (#2)
66. Slat L/2A (#3)
67. Slat L/2B (#4)
68. Slat R/4A (#5)
69. Slat R/4B (#6)
70. Thrust Rev. Unlock 1
71. Thrust Rev. Deployed 1
72. Thrust Rev. Unlock 2
73. Thrust Rev. Deployed 2
74. Thrust Rev. Unlock 3
75. Thrust Rev. Deployed 3
76. Outer Marker
77. Middle Marker
78. Landing Gear Lever Down
79. Landing Gear Lever Up
80. A/P #1 CWS (Auto Pilot Engaged)
81. A/P #1 CMD (Auto Pilot Engaged)
82. A/P #2 CWS (Auto Pilot Engaged)
83. A/P #2 CMD (Auto Pilot Engaged)
84. Anti-ice Eng. 1 (Inlet Valve)
85. Anti-ice Eng. 2 (Inlet Valve)
86. Anti-ice Eng. 3 (Inlet Valve)
87. Start Valve 1
88. Start Valve 2
89. Start Valve 3
90. ISO. Valve SW 1-2
91. ISO. Valve SW 1-3
92. APU ISO. Valve
93. Wing Anti-ice Valve
94. Pack Mode SEL-1
95. Pack Mode SEL-2
96. Pack Mode SEL-3

APPENDIX C

DFDR SYSTEMS FOR U.S. CARRIERS

AIRLINE	AIRCRAFT	FLIGHT RECORDER SYSTEM MFGR
Air Illinois	HS-748	Ham-Std/LAS
American Airlines 1/	B-747 DC-10	Ham-Std/SDC Ham-Std/SDC
Braniff Airways	B-747	Ham-Std/SDC
Continental Airlines	DC-10	Teledyne/SDC
Delta Air Lines	B-747 DC-10 L-1011	Teledyne/LAS Teledyne/LAS Teledyne/LAS
Eastern Air Lines 2/	L-1011	Teledyne/LAS
National Airlines	B-747 DC-10	Garrett/LAS Garrett/LAS
Northwest Orient Airlines	B-747 DC-10	Teledyne/LAS Teledyne/LAS
Overseas National Airways	DC-10	Ham-Std/SDC
Pacific Southwest Airlines 1/	L-1011	Teledyne/LAS
Pan American World Airways	B-747	Teledyne/LAS
Seaboard World Airlines	B-747	Ham-Std/SDC
Trans International Airlines	DC-10	Ham-Std/SDC
Trans World Airlines 1/	B-747 L-1011	Teledyne/SDC Teledyne/SDC
United Airlines 1/	B-747 DC-10	Ham-Std/SDC Ham-Std/SDC
Western Air Lines	DC-10	Ham-Std/SDC
World Airways	B-747	Teledyne/LAS

1/ Has in-house facility for engineering units printout.

2/ Has in-house facility for generating strip chart readout.

APPENDIX D

SAMPLING INTERVAL - ACCELERATIONS

The tri-axis accelerometer of the digital recorder system contains a low-pass filter which has a 3-dB frequency of 4 Hz, and a roll-off beyond 4 Hz of 12-dB per octave. This simply means that the highest frequency out of the filter is effectively 4 Hz.

Suppose the aircraft encountered a situation where a 4-Hz acceleration were measured at the filter output. (The fuselage structural frequency for large transport type aircraft is between 3 and 4 Hz). At a sampling rate of 4 times per second (the rate at which vertical and lateral G's are sampled), information concerning this acceleration will be lost. Consider Figure D-1. Depending upon where the wave is sampled, the peak amplitude may or may not be detected; worse however, is the fact that even if peak amplitude is sampled, the sampling rate is not high enough to detect both peaks. Effectively, this means that a 4-Hz acceleration signal will never be recorded as a 4-Hz signal. Rather, if normal analog signal reconstruction filters were used, the sampled output would appear as a 2-Hz signal (the signal would be "aliased" to 2 Hz). However, because the sample values are directly recorded by the DFDR, then plotted in graphical form, the DFDR plot would show a constant acceleration as illustrated in Figure D-1. Figure D-2 illustrates the situation for a single cycle of high-amplitude 4-Hz acceleration.

Lower frequencies fare better, as illustrated in Figure D-3 for a 2-Hz signal. The sampling frequency is twice the signal frequency, as required by the Nyquist sampling theorem.* Note that the frequency can be properly reconstructed, albiet the amplitude and phase may not be. If the signal peaks coincide with the sampling times, an accurate picture of the acceleration will be presented (Figure D-3 (a)). If, however, this coincidence is lacking, the amplitude and phase of the DFDR plot will not be accurate (Figure D-3 (b)).

An acceleration of 1-Hz or less can be recovered from the system with accuracy since the probability of sampling somewhere near the peak amplitude is reasonably high, and no aliasing occurs. See Figure D-4.

Because of the 4-Hz sampling frequency, an acceleration of greater than 2 Hz will never be seen on a DFDR readout. As is seen in Appendix C, Table II, Great Britain requires an 8-Hz sampling frequency for vertical acceleration.

---

* The Nyquist sampling theorem states that a signal must be sampled at a frequency which is at least twice as great as the highest frequency in its spectrum if it is to be reconstructed without aliasing.

APPENDIX D (Cont'd)

Longitudinal acceleration is sampled optionally at one, two, or four times per second, if it is recorded at all. If it is sampled twice per second, any longitudinal acceleration above 1 Hz will be aliased. Signals below 1/2 Hz can be accurately recovered.

Finally, the accelerometer is mounted at the center of gravity of the aircraft. Much larger accelerations have been experienced at the tail end of the B-747 aircraft in turbulence situations than at the c.g.

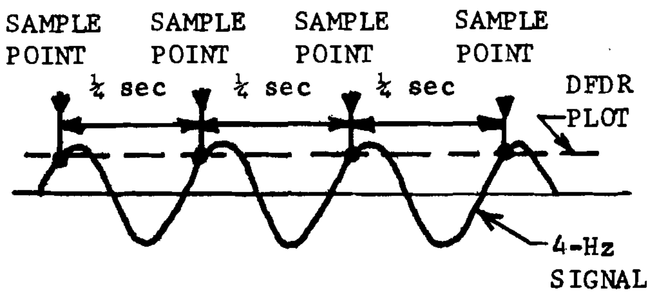


FIGURE D-1. 4-Hz acceleration signal with a 4-Hz sampling frequency.

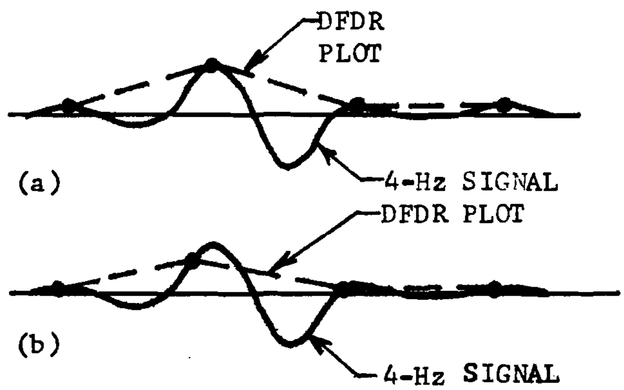


FIGURE D-2. A single cycle of high-amplitude 4-Hz acceleration signal with a 4-Hz sampling frequency assuming peaks of signal (a) coincide with sample times, and (b) do not coincide with sample times.

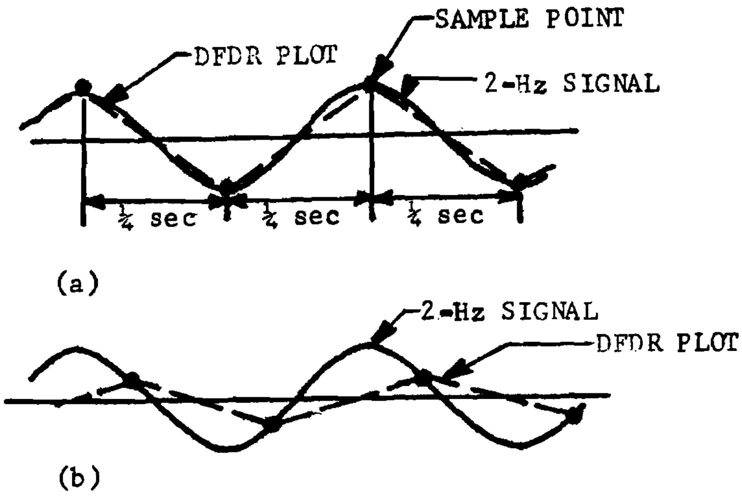


FIGURE D-3. 2-Hz acceleration signal with a 4-Hz sampling frequency assuming peaks of signal (a) coincide with sample times, and (b) do not coincide with sample times.

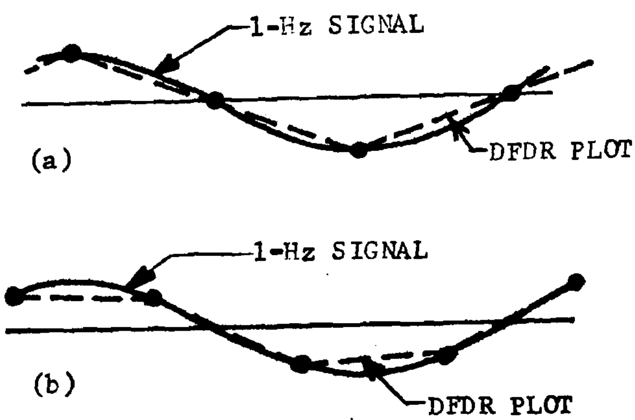


FIGURE D-4. 1-Hz acceleration signal assuming (a) coincidence of peaks and sample times, and (b) no coincidence.

REFERENCES

1. 14 CFR, 400.3 (Code of Federal Regulations, Title 14, Part 400, Paragraph 400.3), 9/8/67, as amended.

2. ARINC Characteristic 573-6, Aeronautical Radio, Annapolis, Maryland, 9/8/72.

3. 14 CFR, 21.343, 12/31/64, as amended.

4. 14 CFR, 37.150, 11/17/64, as amended.

5. Aircraft Accident Report No. NTSB-AAR-73-14, EAL at Miami, Florida, 12/29/72. (Available through National Technical Information Service, Springfield, Virginia, 22151).

6. Report of Board of Inquiry, Accident at Toronto, Air Canada DC-8-CF-TIW, 7/5/70, Catalog No. Z1-1970-1. (Available from Information Canada, Ottawa).

7. Laboratory Technical Report, Flight Recorder Group, LTR-FR-29, Air Canada DC-8-63CF-TIW, Accident at Toronto, 7/5/70.

8. Flight Data Recorder Order, Canada, (Air Navigation Order, Series II, No. 13), April 24, 1969.

9. Great Britain , Air Navigation Order 1972, as amended, Schedule 5, Paragraph 4(6), Scale S.

10. Journal Officiel de la République Française du 13 Octobre 1971: Arrete du 6 Septembre 1971, relatif aux systèmes en registreurs de vol [flight recorder systems].

11. Décision portant complément à l'arrêté du 6 Septembre 1971 relatif aux systèmes enregistreurs de vol, 4 Octobre 1973.

INVESTIGATION PROCEDURES ADOPTED OVER THE PAST TEN YEARS

******

Outline of Paper

Given By

MUSHIR A. KHAN

Aviation is one industry that warrants most critical strict adherance to the tried and established investigation procedures. In this industry, procedures related to all aspects play a very important role and when they are orthodoxly practiced and respected, safety begins to prevail and the aviation hazards begin to eliminate.

The procedures that have been adopted for the investigation of aircraft accidents over the past 10 years have indeed been of immense significance in the art of accident investigation. New concept has been given to the procedures of a/c investigation. Scientific methods and approaches have been adopted. The use of simulators, flight data recorders and voice recorders have been employed extensively in investigations; in fact the use of read-outs has become a procedure in every investigation and no investigation is considered perfect and scientific unless it is supported by the read-outs. There is only one deviation - when the read-out cannot be made available.

Accident investigation procedures have been acknowledged as the main factors for making safety more predominent and prevention of accidents more aggressive and widely effective. In order to make accident investigation more purposeful, informative and educative and lesson-giving, certain procedures have got to be established so as to make investigation rich and perfect.

The paper will cover the procedures that have been established over the past ten years to guide the investigator as to how he should plan out an investigation, the types of experts that have to be selected, the equipment and tools that are essential for a scientific investigation.

Following areas will be discussed with regard to accidents:

1) A/C operation
2) Aviation Meteorology
3) Witness interrogation of investigation
4) Flight data recorder read-outs
5) Flight simulation
6) Power plant
7) Airframe
8) Maintenance
9) Human element
10) Fires
11) Search and rescue
12) Safety standards during investigation on site
13) Planning of investigations
14) Survey of accident site for planning of tools, equipment and personnel.

The emphasis will be on aspects that involve human factors, such as incapacitation, illusions, hypnosis effects, habits that are contrary to safe procedures. It has been observed that in approach and landing accidents, human factors very often get directly involved, necessitating autopsy, tracing down medical history.

Importance of cockpit discipline and its relationship to human elements.

The paper will also discuss the main constituents of a good and logical investigation - the foresight, integrity, experience, devotion, understanding and safety orientation on the part of the investigator.

The paper will further discuss as an exclusive item, safety. How safety precautions are to be taken on the accident site. How certain types of cargo can be lethal if due precautions are not taken and expert's opinion not obtained. The chemical reaction on certain a/c components, when contaminated with sea water.

Besides, a discussion on meteorological phenomena that directly conflict with human limitations, for example, the "White Out" where a pilot is left without environmental references.

In short, investigation procedures when correctly set and applied would make investigation purposeful and handsomely contribute towards accident prevention. If the procedures are lacking its main constituents, investigation can be futile and just an uphill task with no gain.

DEVELOPMENTS IN
INVESTIGATION PROCEDURES OVER
THE PAST TEN YEARS

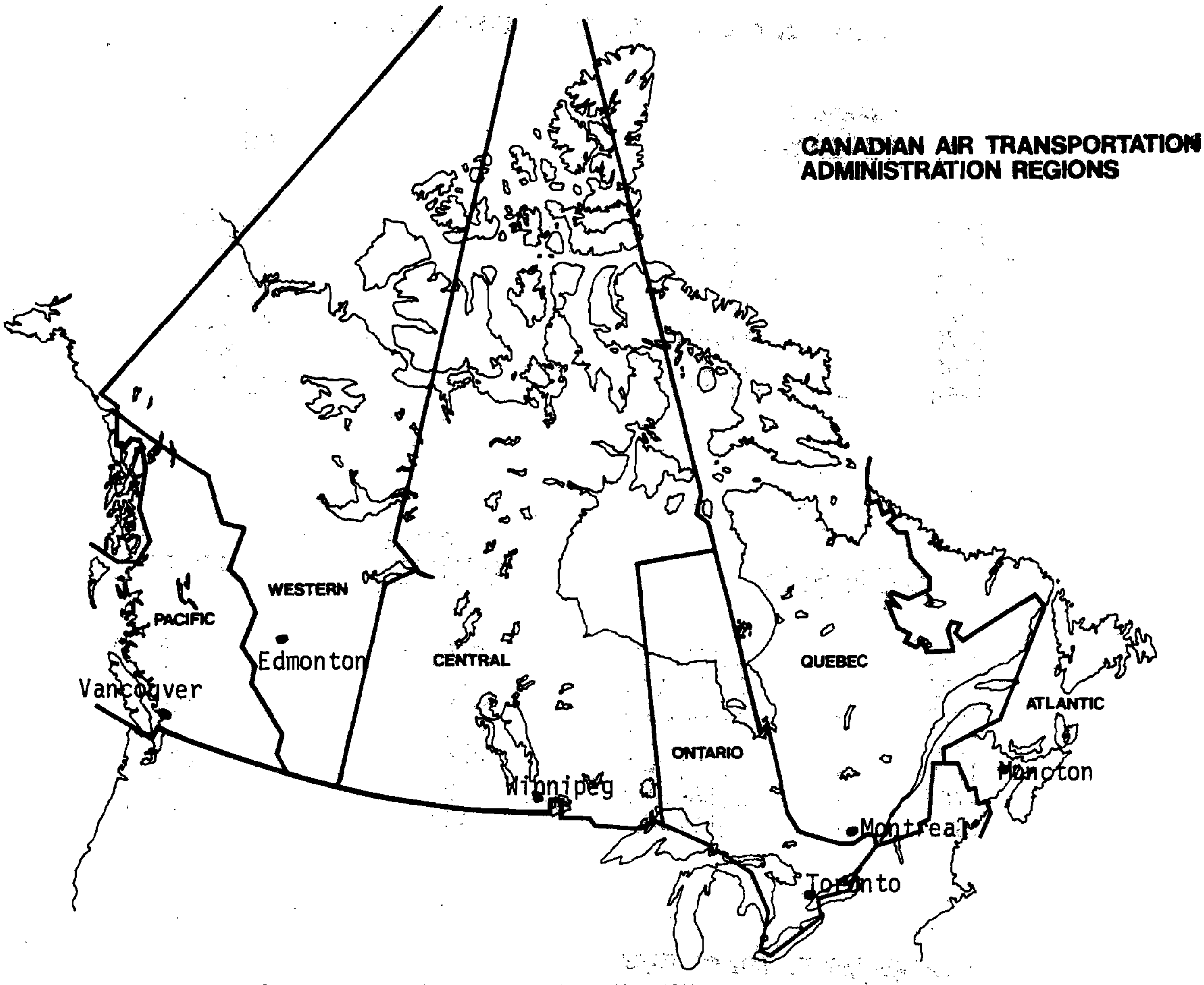
1) P.I.P.
   Planned Investigation Programme

2) S.P.A.N.
   Systems Performance Analysis Network
   (Under Evaluation)

H. REID GLENN
AVIATION SAFETY INVESTIGATOR
MINISTRY OF TRANSPORT
OTTAWA, CANADA

Last year, for those at the Toronto Seminar, you will recall that our Chief of Accident Investigation Mr. Hal Fawcett made a brief introduction on ELAN (Event Link Analysis Network). This is a technique, much alike the USA accident tree. This is used to do an orderly evaluation and analysis of an accident. At the same seminar the Superintendent of our Accident Laboratory Mr. Terry Heaslip described the PIP (Planned Investigation Programme) in so far as the Structures Group involved with a major accident was concerned. This year I will outline the PIP procedures with reference to the Operations Group followed by a brief description of our SPAN (Systems Performance Analysis Network). The latter I would like to emphasize is under evaluation at our Ministry Headquarters at the present time, but from our experience to date looks very promising. I would be pleased to answer any questions on both procedures during the normal question period.

I would like to add that anyone who wishes a copy of the PIP booklet please leave me your name and address afterwards and I will ensure that a copy is forwarded. I cannot do the same for the SPAN information because the programme is not operational yet.



ACCIDENT INVESTIGATION DIVISION

Headquarters/Ottawa/Chief	*Hal Fawcett
Atlantic/Moncton/Superintendent	*Harry Deyarmond
Quebec/Montreal/ "	*Don McLellan
Ontario/Toronto/ "	*Vic McPherson
Central/Winnipeg/ "	*Gerry Saull
Western/Edmonton/ "	*Jim Dick
Pacific/Vancouver/ "	*Cy Leyland

CANADIAN CIVIL AVIATION STATISTICS 1968-74

		AIRCRAFT REGISTERED	LICENSED PILOTS
1974	-	15,500*	42,975*
1973	-	13,800	39,852
1972	-	13,157	35,351
1971	-	12,066	35,491
1970	-	11,315	33,157
1968	-	10,772	33,089
1968	-	9,973	32,694

		FLYING HOURS	REPORTABLE ACCIDENTS	FATALITIES
1974	-	3,400,000*	800 *	175 *
1973	-	3,129,000	736	162
1972	-	2,870,074	613	166
1971	-	2,818,201	543	157
1970	-	2,633,347	530	223
1969	-	2,586,690	503	140
1968	-	2,591,047	462	121

* PROJECTED TO END OF 1974

NUMBER OF CANADIAN COMMERCIAL OPERATORS AT PRESENT - 800
1970 FATALITIES INCLUDE 109 (DC-8/TORONTO)

HOW TO USE PIP

Immediately upon notification of a major accident, the

ACCIDENT INVESTIGATION DIVISION WILL:

Carry out the required actions to PIP Event 1.

REGIONAL SUPERINTENDENT OF ACCIDENT INVESTIGATION WILL: (RSAI)

- determine from PIP checklists which items cannot await the arrival of the Investigator-in-Charge (IIC)
- commence action on the foregoing events
- be prepared to report to the Investigator-in-Charge on all action taken.

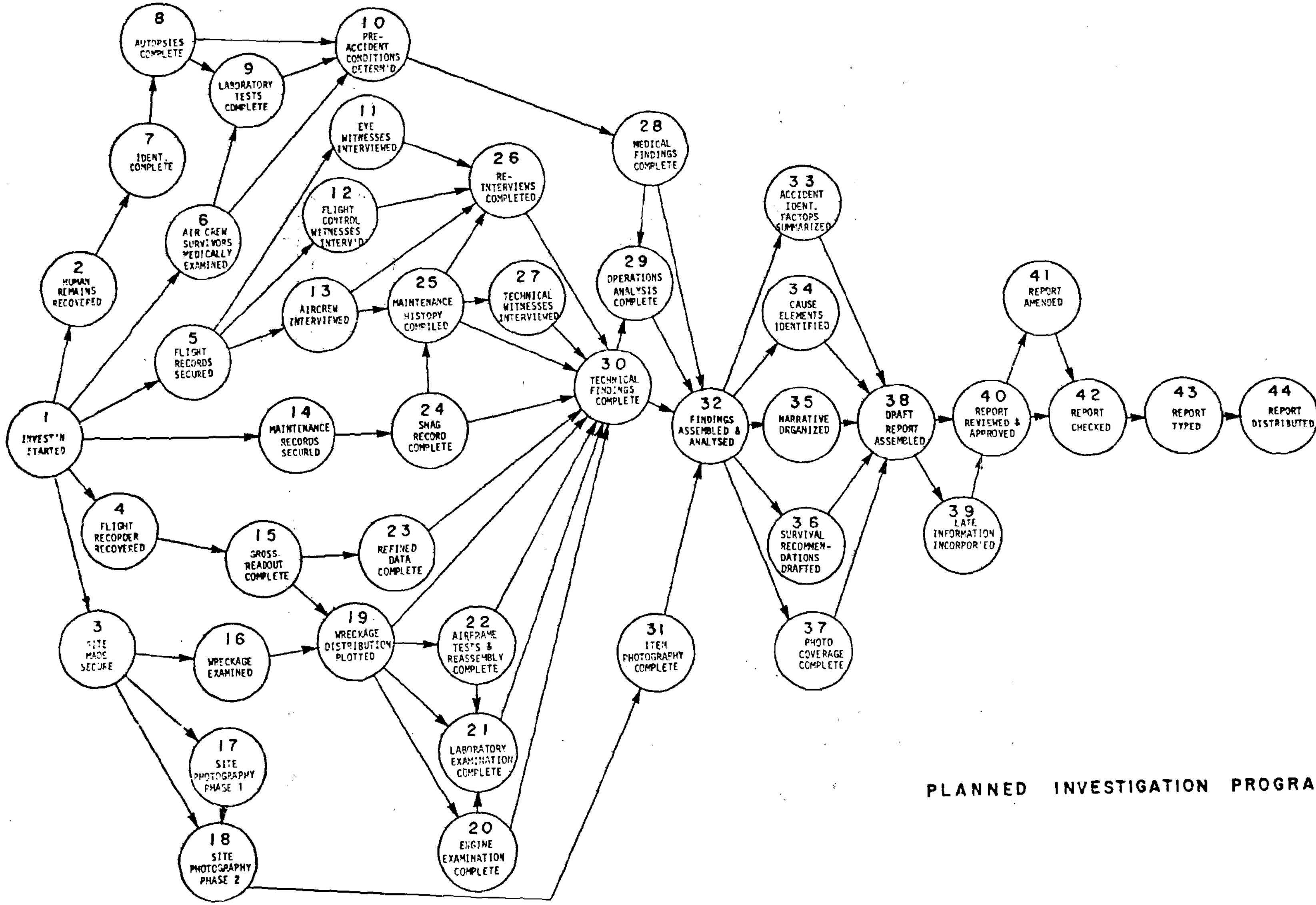
INVESTIGATOR-IN-CHARGE WILL: (IIC) (Headquarters-Operations)

- receive all data from CAIO and proceed to scene
- receive report from RSAI
- brief Group Chairman and supply them with:

  PIP checklists
  PIP Event Chart (small)
  PIP forecast sheets.

EACH GROUP CHAIRMAN WILL:

- review the PIP Group Checklist for his group
- forecast the time of starting and completion of each item on his checklist
- supply copy of forecast to Investigator-in-Charge
- commence action on checklist as soon as possible.



PLANNED INVESTIGATION PROGRAM

Figure 1

PIP CHECKLIST

To be completed from Accident Investigation at Headquarters immediately upon notification of a major accident.

1. DCA (Director Civil Aviation) advised of accident.
2. Investigator-in-Charge appointed in consultation with DCA. (usually done beforehand).
3. Deputy to Investigator-in-Charge appointed.
4. Support staff selected:

    (a) Construction personnel
    (b) Telecommunications and Electronics personnel
    (c) Meteorological personnel
    (d) Administrative personnel
    (e) Accounts personnel
    (f) Medical personnel
    (g) Public relations
    (h) Air Services personnel
    (i) Military personnel
    (j) Police
    (k) Other departments
    (l) State of registry
    (m) State of manufacture

5. Group members and chairman selected:

    (a) Operations
    (b) Weather
    (c) Air Traffic Control
    (d) Witness
    (e) Structures
    (f) Powerplants
    (g) Systems
    (h) Records and documents
    (i) Flight data and recorder
    (j) Human factors

6. Arrangements for expert advisors as required.
7. Public information release officer appointed.
8. Briefing of group chairmen planned.
9. Maps of specified scale obtained.

EVENT 5
OPERATIONS

To be completed as soon as possible after notification.

1. All group documents located and secured.
2. Pertinent documents obtained, including crew and passenger lists, cargo manifest, weight and balance, pre-flight weather briefing, flight planning, aircrew qualifications.
3. Aircraft route requested from investigator-in-charge.
4. Location of weather briefing documents requested from investigator-in-charge.
5. Pertinent documents and recording tapes obtained.

EVENT 6
OPERATIONS

PIP CHECKLIST

To be completed as soon as possible after notification.

1. Crew list obtained.
2. Location and condition of surviving crew determined.
3. Feasibility of completing examinations as prescribed in medical checklist determined.
4. Agreement of crew members to submit to medical examination obtained.
5. Arrangements for examination by competent medical practitioner completed and checklist provided.
6. Blood and urine samples taken for laboratory examination.
7. Details received from medical examiner:
    personal history including habits
    medical status and history including whether under medication
    pre-flight activities having human factors significance

EVENT 12
OPERATIONS

PIP CHECKLIST

To be completed immediately following event 5.

1. Flight planning document obtained and reviewed.
2. Flight despatch documents and organization obtained and reviewed.
3. Flight control (ATC) documents reviewed.
4. Copies of lfight control (ATC) tapes made from originals.
5. All weather briefing documentation received and reviewed.
6. Original ATC tapes returned to investigator-in-charge.
7. Transcripts made from tape copies.
8. Transcripts submitted to investigator-in-charge.
9. Weight, balance and loading data obtained and checked.
10. Aircraft servicing documents obtained and checked.
11. All available information on weather conditions along route collected, summarized and submitted to investigator-in-charge.

.../2

EVENT 13
OPERATIONS

PIP CHECKLIST

To be completed after events 5, 11, 12.

1. Pilot's statements obtained.
2. Aircrew interviews completed.

EVENT 26
OPERATIONS

PIP CHECKLIST

To be completed after events 11, 12, 13, 25, 27.

1. All interviews results received.
2. (a) Review data with investigator-in-charge for areas of conflict, errors or inconsistencies in statements.
   (b) Areas of conflict, errors or irregularities among eyewitnesses examined.
3. (a) List of persons to be re-interviewed in order to resolve conflicting evidence complied.
   (b) List of persons to be re-interviewed to resolve conflicting evidence compiled.
4. Questions prepared.
5. Re-interviews completed and findings submitted to investigator-in-charge.
6. Statements appended to original evidence.
7. Statements incorporated into original evidence.
8. Witness with weather testimony interviewed.

EVENT 27
OPERATIONS

PIP CHECKLIST

To be completed after event 25.

1. Interview results examined to determined adequacy of information and areas of conflict, errors or inconsistencies.
2. Witnesses with Systems testimony interviewed.

EVENT 29
OPERATIONS

PIP CHECKLIST

To be completed after events 26, 28, 30.

1. All Group interview findings received.
2. Technical, operations, and human factors findings reviewed and related to determine adequacy of information, areas of conflict, errors, inconsistencies.
3. Areas requiring clarification identified.
4. Procedure for achieving clarification determined and directed.
5. Received instructions from investigator-in-charge for further action.
6. Additional information received.
7. Plot of aircraft flight path incorporating information from all sources, completed.
8. Operational analysis completed with Structures Group assistance.

EVENT 31
OPERATIONS

PIP CHECKLIST

To be commenced as required by the Group Chairman.

1. Each group chairman's photo requirements received and photo services arranged.
2. Investigator-in-charge advised of final photographic requirements.

OPERATIONS GROUP REPORT FORMAT

- Crew list
- Crew qualifications - training
- Flight Planning
- Flight des patch
- Air craft loading
- Air craft flight path
- Air Traffic control involvement
- Crew actions
- Flight procedures - manuals, current practices, training
- Supporting documents (as appendices)

Group approved draft reviewed with 11C. Final report submitted to 11C.

MAJOR ACCIDENT REPORT FORMAT (By 11C)

- Title and name
- Description of occurrence
- Findings

SCOPE OF THE INVESTIGATION

1) Operational aspects
2) Tests and Technical analysis
3) Crew information
4) Aircraft information
5) Meteorological information
6) Aids to navigation
7) Communications
8) Aerodrame and around facilities
9) Flight recorders
10) Fire
11) Survival aspects

SPAN

We are developing in Ottawa a new, computer-related analysis procedure called "SPAN" *Systems Performance Analysis Network.* This is a new investigation tool and safety management information system, designed for evaluation and examination of accident, incident and hazard investigation data.

(I would like to emphasize that our "SPAN" is only under evaluation at the present time, however, we hope that it will be approved and operational in the near future.)

Up to the present time, in our investigative procedures, our investigators and analysts have been attempting to manually assign basic systems-related causes to aircraft accidents and incidents. This has in many cases involved considerable research. The sought-after end product has been a systems-related cause assignment and a subsequent accident prevention recommendation. Unfortunately, these recommendations, being sometimes related to a single occurrence, have not always had sufficient impact to generate corrective action. I give as an example the DC-8 Spoiler accident in Toronto in 1970. It took two other similar accidents to generate corrective action. We consider it clearly necessary to store an organized record of systems deficiencies in our computer.

Because we think that systems deficiencies or performance inadequacies should be recorded and identified, as they are important to accident prevention and safety research, we intend to put our computer to work more effectively. SPAN contributes to this by identifying the systems-related causes and performance assessments through a regularized procedure, and storing them. The benefits as we see them will be as follows:

- The research workload of our investigators and analysts will be reduced;

- Safety research activity will be facilitated;

- The most productive areas for accident prevention activity will be more clearly indicated;

- The information in the computer will lend itself to cost/effectiveness analysis techniques and will provide a sound basis for senior management decisions related to aviation safety programs.

"SPAN" is intended to accommodate either "accidents" or "incidents" and to provide the most direct route between *investigation* and *prevention.* With this system, combined with the present factual data being stored in our computer, practically all of the factual and judgmental information provided by investigators in the field will be put to use - rather than just part of it as is now the case.

The essence of "information" - as opposed to data - is that *information is data that has been evaluated for a particular purpose.* Our purpose is accident prevention. Span uses processed data that has been evaluated. It is perhaps unusual to combine "judgmental" information with factual data. Some purists consider it a dangerous step. In our case the quality of the judgments is the key; all personnel involved in the investigation and analysis procedure are highly trained and have had long experience in aviation.

Because of the experience level of our personnel, we say that the "buck stops here" and we put a judgmental factor on the accident. What is so new about "SPAN" is that our Analysts go much deeper than cause related findings. The "SPAN FINDINGS" that are assigned and coded need only represent a hazard or have

.../2

some flight safety potential. If you examine an incident, this is what the analysis should be all about. An incident is an accident that didn't happen but all the ingredients were there.

Further we have designed a double-check feedback system to minimize error. We believe the benefits of this step are great.

The "SPAN" approach recognizes that the responsibility of the Ministry of Transport is for the safe and orderly development of aviation in Canada. This responsibility is administered through the Ministry Civil Aeronautics organization which in turn has developed a number of "systems" to achieve this aim. The overall authority is clearly defined in the *Canadian Aeronautics act* and other legislation. The systems to which reference has been made are supported in regulations or standards.

Each system has its reflection in the air carriers in what is, in effect, delegated responsibility. Each system also has its feedback devices. The input to a system is at the Ministry of Transport; the output is visible in the safety of aviation services offered by the carriers.

Seven basic systems have been identified:

(1) Personnel competency

(2) Airworthiness engineering

(3) Air Traffic Control

(4) Aviation Safety Management

(5) Air Navigation Services (Airports/Weather/Telecom)

(6) Regulations

(7) Air Carrier Certification

Each of these systems is reviewed with respect to a particular occurrence as to its performance in the following areas:

- Standards
- Communication of Standards
- Monitoring
- Feedback of Information
- Enforcement

The performance of individuals, carriers, and the MOT is examined in great detail as specified in a "code book" and then entered in a computer file. This information is de-identified and is not intended for release to the public. It will be available for safety and accident investigation/prevention research purposes.

All accident and incident reports received from the field are now analysed by the "SPAN" technique. This does not call for any change in investigation or reporting procedures in the field, although Investigators have been briefed and are encouraged to broaden their investigative thinking and include appropriate systems information in their reports. A copy of each analysis sheet is mailed back to the field investigator. No comments are required unless he disagrees with the analysis.

This systems approach to analysis and storage of the operational aspects of accidents and incidents is, as far as we know, not used by other countries. The concept was developed in Ottawa in 1972-73 and experiments with the computer have been underway for the past eight months. A brief outline of items covered in the "Systems" is available to anyone interested. The complete procedure is relatively complex and includes appropriate coding books and reference manuals. "Software" for extraction and research purposes has been developed also.

AIRCRAFT ACCIDENT INVESTIGATION DIVISION

SPAN

Systems Performance Analysis Network

File: *Aircraft Type:* *Reg:*
Date: *Time:* *Operation:*
Locale: *Damage:*
Place:
Weather:
Pilot: *Total hrs. All:* *On Type:*
Last 90 Days All: *On Type:*

Casualties:
Description of Occurrence:

RELEASABLE INFORMATION

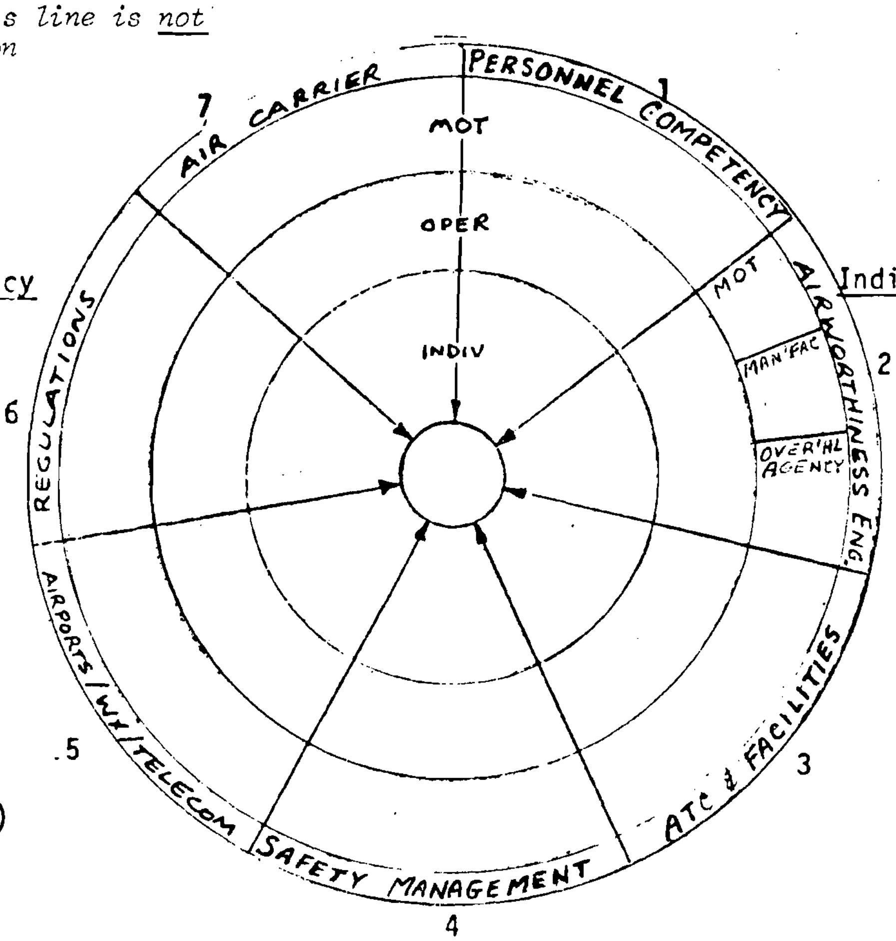
---

nformation below this line is not for Publication

CAIO — ☐
Coded ☐

Performance Inadequacy

Individual Error/Action



S-STANDARDS
C-COMMUNICATION of standards
W-COMPLIANCE with standards
M-MONITORING
F-FEEDBACK of information
E-ENFORCEMENT

O-OTHER (Specify)

X-VOLUNTARY (without knowledg of consequences)
Y-VOLUNTARY (with knowledge of consequences)
Z-INVOLUNTARY

SYS	FUNC	XYZ	ANALYSIS
			"IN PLAIN LANGUAGE"

AIRCRAFT ACCIDENT INVESTIGATION DIVISION
"SPAN" SYSTEMS PERFORMANCE ANALYSIS NETWORK

AMPLIFICATION OF THE 7 SYSTEMS
1. AIRMAN & PERSONNEL COMPETENCY

KNOWLEDGE

Regs & Procedure
Weather
Radio Aids
Aircraft Operations
Navigation
IFR & Procedures

PROFICIENCY

Skill
Currency
Experience
Airmanship

FLYING SCHOOL TRAINING (Pilots Trained within 2 Years)

Instructors
Flight Instruction
Ground Instruction

OTHER PERSONNEL

Ground Crewman
Airport Personnel
Weather Personnel
Other

2. AIRWORTHINESS ENGINEERING

Economics
Maintenance
Airworthiness Status
Modification Status
Type Certification, Design
Aircraft Equipment
Mechanical Failures
Operating Information

3. ATC & FACILITIES

Flight Planning
Departure, Enroute, Holding & Arrival Procedures
Emergencies
Flight Information
Special Procedures
Facilities & Navigation Aids (This includes all electronic ground installations)

4. AVIATION SAFETY MANAGEMENT

Response to Notification
Quality of Investigation
Supporting Data (Recommendations)
Message for Aviation Safety
Report Production, Analysis
Safety Bulletins, Safety Action
Medical Investigation
Human Factors Investigation*

5. AIRPORTS, WEATHER & TELECOM AIRPORTS

AIRPORTS: (Licensed - Unlicensed)

Fire & Crash Equipment
Airport Buildings
Lighting
Runway Markings
Runway Condition

WEATHER

Forecast Availability
Forecast Accuracy
Weather Observation
Weather Briefing - Availability, Quality
Continuous WX Broadcast
Sigmets
Surface and Upper Winds

INFO SERVICES & COMMUNICATION

Communications Coverage Over Routes
Communications At Uncontrolled Airports
Unicom
Altimeter Settings
Reports on Surface Wind
WX Info Broadcasts
H.F. & S.S.B. Radio

6. LEGISLATION & REGULATIONS

Aeronautics Act
Air Regulations
Air Navigation Orders

* Detailed human factors information will be on a separate "aeromedical" computer file.

7. AIR CARRIERS LICENSING & CERTIFICATION

"AIR CARRIER" means any person who operates a commercial air service.

Economics
Manuals
Operating Certificates
Managerial Personnel
Operational Control
Operations Specifications
Flight Crew Training

Standards for the above are laid down in ANO VII-2 and ANO VII-3.

AMPLIFICATION OF FUNCTIONS

S - STANDARDS: - (Too low, or not laid down)

Training
Competency
Regulations
ANO's
Aircraft Certification and Equipment
Aircraft Modifications
Maintenance
Operational Control
Manuals: (Operations, Flight, Cabin, Maintenance)
Airmanship
Airports
Nav Aids
Weather
Medical

C - COMMUNICATIONS: - Standards, Information and Knowledge which exists but was not effectively transmitted by:

MOT (including CAM)
Operator
Individual
Manufacturer

W - COMPLIANCE: - (Did not comply with) Standards laid down

Takeoff or Landing Limits
Air Regs
ANO
Operations Manual
Standard Operating Procedures
Flight Manual
Good Airmanship

Weather
Maintenance
Aircraft Modifications
Medical

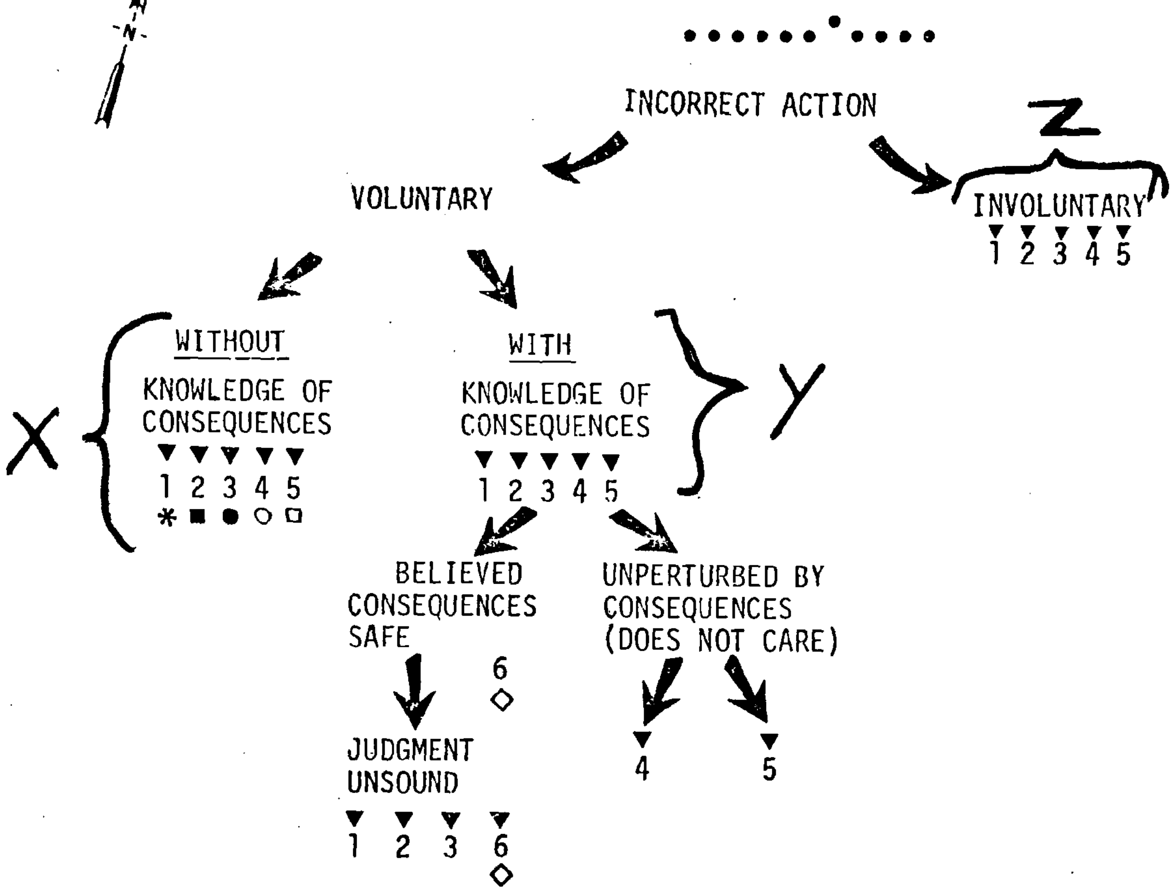
M - MONITORING: - (Part of, or the whole Aircraft Operation, including Maintenance and Economics not properly monitored or inspected by):

MOT (including CAM)
CTC
Carrier or Owner
Individual

F - FEEDBACK: - Information from irregularities and incidents which might cause an accident is not reaching Individuals, Operators and MOT (including CAM).

E - ENFORCEMENT: - Standards and regulations laid down but not being enforced by MOT Operator, or Individuals.

O - OTHER: - Undertermined findings, such as mechanical failures for undetermined reasons; findings which do not fit into any of the other functions. Comments on "OTHER" are mandatory.



* (1) PHYSICAL OR MENTAL PROCESSES AFFECTED BY ENVIRONMENT

■ (2) SUBJECT TO SENSORY ILLUSIONS

● (3) ACTED UPON BY EXTERNAL FORCES

○ (4) PHYSIOLOGICALLY ABNORMAL (INJURY, ALCOHOL, DRUGS, ILL-HEALTH)

□ (5) PSYCHOLOGICALLY ABNORMAL

◇ (6) POOR TRAINING, IGNORANCE, INDIVIDUAL APTITUDE VARIATION

Fig 2

THE EMERGING PATTERN OF ACCIDENT PREVENTION

(by David L. Corre, C. Eng. A.F.R.Ae.S.)

Any opinions expressed in this paper are entirely my own and do not necessarily represent the opinions of British Aircraft Corporation.

It is, I believe, the opinion of all investigators of accidents that Prevention is better than investigation. The latter is the end of the line and makes a very final full stop to the life of that aircraft, and, if a major disaster, of the lives of all on board. An accident is usually the result of a combination or permutation of adverse circumstances.

Prevention, although it is an "after the event" exercise similar to an accident investigation, should detect the significance of defects and integrate the human and the machine interface. Consequently, the spectrum of prevention is infinitely larger and more complex than a single aspect of machine defects or the operational human error taken separately. After all, the end product of an investigation is the cause which, if found and there is no reasonable doubt, is invariably a mistake or a number of mistakes.

The emerging pattern of accident investigation, therefore, leads me to believe that we should become more and more dependent on the Prevention of mistakes, but this, as I have said before, will be an "after the event" function and dependent itself on the knowledge of not only our own mistakes or defects, but also every other mistake or defect found by Operators and Manufacturers.

Probably one of the best allies of the Flight Safety engineer developed over the last ten years is the flight recorder which when used in conjunction with a system of mandatory incident reporting, can often show where and when the system, human or machine, started to go wrong. Taken to the extreme it has provided the answer to the 64,000 dollar question after a catastrophic accident within hours. However, this is to no avail unless the fitting of flight recorders is made mandatory on all public service aircraft; furthermore, the failure of any of the recorded parameters should constitute a "no go."

Following on from the development of the Flight Recorder was the innovation of the Cockpit Voice Recorder, the very presence of which should improve the flying discipline of crews.

On the ground, we have of course, the tape recordings of all air to ground communications, but what about a continuously running video tape of the Controller's radar plot? An endless tape of possibly 2 - hour length with a suitable marked on-time base, could often provide valuable information as to how aircraft got out of position after apparently flying copybook procedural turns, having passed over an NDB.

Electronics is probably emerging as the factor most influential on accident prevention. In addition, we can consider the "on board computer check out system" on the C.5 A. and the ground support computerised check-out system for the ill-fated T.S.R.2 weapons system; the ultimate in this field I suppose, being the "on-board" computer in the Apollo spacecraft.

No matter how quickly we develop and implement new methods of prevention and investigation, the industry seems to be always at least one step in front of us. As soon as we find a means of highlighting(and thus hopefully preventing) one kind of accident, another development takes place and we seem to be back to square one.

There is, of course, the kind of incident which could be so easily prevented by International Agreement. I refer of course to highjacking. Failure to ratify agreement on highjacking is an invitation to the extremist; the conclusion of a treaty of extradition spells instant frustration to the highjacker. An example of this is the elimination of highjacking between Cuba and South America, difficult to prove perhaps, but how many accidents has this prevented? Terrorism is a different problem again, generally carried out by desparate people, dedicated to hatred and destruction of mankind and themselves with it. Salutary sentences are of no use because imprisonment merely makes these people the keystone of further terrorist activity, so if one cannot deter, then one most detect in order to prevent. This is a field which is wide open to ideas - the determined suicidal terrorist armed with plastic explosive will probably get through the airport security screening checks for the simple reason that, out of necessity, these checks cannot be complete, i.e. the stripping of every passenger before entering an aircraft,which is utterly impractical if the airlines and airports - and security companies - are to remain in business. (Perhaps an international "streakers" set should replace the "jet set" !)

I don't want to sound like a Jeremiah all the time, so let me now turn to 'Ze Goot Nyooz.'

After the experience we in Great Britain gained following the Comet tragedies at the beginning of the 'jet age' in 1954, the integrity of aircraft structures throughout the western world at least, has embodied multi-load paths as a requirement of the airworthiness authorities. This'fail safe' in structures has been read-across" as it were to systems and electronics. The reason for the rapid change in basic design is one to which I will return later, namely good communications, or full and frank exchange of information between manufacturers and airworthiness authorities. The prevention of accidents caused by structural failure has benefited by those thousands of hours spent in Government Research Establishments testing specimens of our modern aircraft to destruction. This testing and its allied research is now accepted as a normal requirement.

As an eventual development of this exchange of experimental data and accident investigation results, I should like to see an International Airworthiness Authority set up, possibly under the auspices of I.C.A.O to whom manufacturers would submit their new aircraft for certification, instead of, as at present, to the National Airworthiness Authority in the country concerned, all of which may have different interpretations of the standards of airworthiness. If there was one world-wide civil aviation authority coordinating the judgements of these National Boards, then another step would have been taken towards a safer Air Transport Industry.

The days are over, thank goodness, when, on witnessing the first flight of their new prototype end in a smoking crater in the centre of the aerodrome, the designers shrugged their shoulders and hurried back to the drawing board hoping for better luck next time. Nowadays, there is no doubt that the aircraft will fly exactly as predicted for as long as predicted (i.e. the fatigue "life" is known) before the first aircraft takes to the air - a 5% error in drag calculations is probably the biggest worry for the present day designer.

The human factor has not been ignored in research either and work done in the Institute of Aviation Medicine in Great Britain is proving invaluable in detecting debilitating cardiac and respiratory diseases at an early stage. The incorporation of requirements for more stringent tests in the examination for pilots' licences has obviously reduced the accident rate due to the collapse of a pilot or flight engineer.

Getting our aircraft from A. to B. poses yet another set of problems, the solving of which has cost many lives along the way. The days when Sir Francis Chichester flew his Gypsy Moth around the world "aiming off" into wind by 5° or so, and then turning right to reach his destination, are a far cry from our Inertial Navigation systems of today, although there is nothing quite so reassuring as a sextant observation for telling the 'inner man' where he really is. This in itself is a 'fail safe' navigational system, provided your watch does not stop of course!

Air Traffic Control of aircraft is an example of where new problems arise almost daily. The increase in density of traffic over recent years seemed to be almost getting out of hand with machines orbiting V.O.R. beacons on arrival in terminal areas sometimes for as long as the entire flight had taken up to that point. Then the answer to the Air Traffic Controller's prayer seemed to arrive in the shape of the wide-bodied jet or'Jumbo' - "more people in less aircraft" - that really <u>was</u> the answer. With a density of aircraft reduced by a third all those schedules would be back on the rails again - but they reckoned without "Sod's Law" as we call it in Great Britain. What did we find? The aircraft required twice as much air as previous aircraft due to the wake turbulence so our schedules remain in a chaotic state as before and our aircraft routing has become even more complicated as the Air Traffic Controller tries to keep the machines not only from hitting one another, but from hitting about 5 miles or so of air behind them! But at least, from an accident prevention standpoint we are aware of the problem.

The weather, always a hazard to the airman, still exists as one of the greatest problems, but the development of the weather satelite and the rapid dissemination of its recordings to flight operations planning, air traffic control etc., must have helped to avoid many of the old fashioned accidents where aircraft suddenly found themselves in a thick fog or heading into a hurricane with consequent catastrophic results.

The only way to ensure that all the information is readily available is by uninhibited interchange of information. Mandatory reporting of incidents now introduced in the United Kingdom and which has been practiced by several other countries for some time is a step in the right direction, but this will only be of value if it is disseminated on a world-wide basis.

Inhibition is the worst enemy of Prevention as many operators and manufacturers know and who fear primarily the possibility of legal consequences arising from private litigation and understandably tend to be inhibited thereby.

As you will know the theme of uninhibited information exchange has been hailed as the undoubted panacea by every responsible body in the aviation business and has been discussed ad infinitum for many many years, but no really meaningful action on a world-wide basis has ever been taken. Certainly some organisations have taken a few faltering steps in this direction but these, in an universal context, are but a few cases of enlightenment in the stygian darkness of most of the aviation world's total ignorance of the "other fellah's" problems and his efforts to solve them.

So I put this question to the Seminar. When and what are you or your various Companies prepared to do about this vexing question of uninhibited information interchange? There has been too much "jaw jaw" and not enough "war war" by all as a conserted effort to solve this problem. There are several ways to combat this inertia, much of which originates from inhibition and perhaps the most promising is the complete omission of any reference to a particular operator or the registration number of the aircraft.

Can we not all agree to exchange uninhibited information of the factual evidence of every incident with a flight safety angle between all operators and manufacturers, no matter how large or small it may be? This could be done first on a basis of actual incidents with a safety flavour, and if successful, might be enlarged to cover defects of airframes, engines and operations in the widest sense. We would have to agree against the possibility that for the purpose of private litigation, the legal profession would be tempted to make such information part of their routine discovery of documentation for purposes of a law suit. However, if every incident has been "sanitized" it would make their task of identification pretty well impossible.

If we can agree to this as a feasible proposition, then like I.A.T.A., there will have to be a central memory bank for the use of all participants. This will have to be, by its very nature, far more comprehensive than anything that has been envisaged before now or that is in use at present.

This proposal may seem to be almost impossible at first sight, but we can draw comfort from the old saying about aviation which is "The Impossible we do at once, miracles take a little longer."

Let us, therefore, hope that by joining together, pooling all our incident reports, pooling all our ideas, disseminating that information and acting upon the recommendations thus evolved, the S.A.S.I. Seminar in the not too distant future will have presented to them a paper on this same subject "The Emerging Pattern of Accident Prevention" in which the most significant factor will be the promulgation of these ideas.

MANAGEMENT AND SAFETY*

(Panel Theme: Emerging Patterns of Accident Prevention)

The subject assigned to the panel is broad enough to allow various ideas to be expressed. I intend to voice some thoughts about the role of management in achieving the goals of engineering for system safety. In doing so, I intend to comment on the process that produces our modern aircraft. Considering the complexity of the product, the continuing race to use the latest "state of the art," and the competition, one must give the aircraft industry and airlines a lot of credit for producing such efficient machines and for establishing such outstanding safety records. Despite the problems of meeting high performance goals, the aircraft companies have standardized and systematized the manufacture of aircraft to the extent that one Chief Engineer described the companies as "Aircraft Making Machines."

It is in this process of making aircraft that I see an "emerging pattern." And it is certainly related to "Accident Prevention." We can see it more clearly if we separate the process into the usual phases: design, fabrication, test, production, and operations. (Figure 1) Although the total process is fairly continuous, each phase has its input and its output, and importantly its feedback of ouput to input. A particular phase might be illustrated by a diagram such as (Figure 2). The "inputs" to the Design phase include such things as customer "requirements," FAA regulations, industry design standards, and company design criteria. The outputs are engineering drawings, process control specs., and studies and analyses.

* Remarks by L. I. Davis, Lockheed Aircraft Corporation, at the Fifth International Seminar of the Society of Air Safety Investigators on October 2, 1974.

Illustrative of the feedback are reviews such as the "Preliminary Design Review" and the "Critical Design Review." This and other comparisons of output with input result in changes, the important changes requiring management review and decision.

An overview of the total development process, Figure 3, shows a system engineering pattern of input, output, and feedback (closed loop correction of variations between input and output). The output of the first phase, engineering drawings, etc., is the input to the fabrication phase, and the output of that phase is a working model that can be compared to the drawings, and so on down the line, until the final product in the hands of the airline produces results that can be compared with the original objectives. As the process grows into a reasonable production rate, the phases seem to merge, and lose identity; however, the feedback process continues. Deficiencies in manufacturing and in design are detected in functional tests, in acceptance flights, or in customer operations. The output, the performance of the product, is compared with drawings, or performance specifications, and somebody does something about the difference. If it is important, if it involves safety, management gets into the act, and, to the degree that it is well informed and acts promptly, ensures delivery of a quality product.

It is this role of management (taking action on input-output differences) that is the main point of this paper. I see the "Emerging Pattern" as a process in which management exploits the power of closed loop feedback control to ensure a safe product. I see it as "Emerging" because I feel there are certain characteristics of the process that are surfacing, that are being recognized and used by those companies that traditionally produce "quality" aircraft.

The terms "open loop," "closed loop," and "feedback" have become a part of our language; it is not necessary to be an electronic engineer to use them correctly. However, to develop the idea or analogy I wish to express, it is interesting to go back about fifty years —— to the time when electrical or electronic amplification was first studied in an analytical fashion (the days of Nyquist and Bode at Bell Labs, if I remember correctly), and borrow from them the relationships shown in Figure 4 which illustrate the power of feedback to reduce disparities between input and output.

The diagram illustrates an amplifier with forward gain, A, and feedback of a portion of the output, B, to the input. Ignoring phase shift, complex variables, and all that jazz, we can see that if we feed back a portion of the output so that it is compared with the input (negative feedback) and amplify the difference, we get the following expression for amplification (closed loop gain).

$$e_o = \left(\frac{A}{1 + A x B}\right) e_i .$$

And, if the amplification process introduces something that is not in the input, e.g., noise:

$$e_o = \left(\frac{A}{1 + A x B}\right) e_i + \left(\frac{1}{1 + A x B}\right) N.$$

A, the forward or open loop gain of the amplifier, and B, the feedback fraction, are chosen by the designer to optimize the fidelity of the output, and to achieve the necessary gain.

The feedback process in the phased development of an aircraft is similar to the feedback in a Hi Fi amplifier or a voltage regulator. The feedback factor, B, is the sampling of the output, the closing of the loop is the comparison with the input, and the forward gain term, A, is related to management emphasis and priority. The comparison of output and input is obvious; however, the attenuation of noise (errors or discrepancies) by the combination of sampling and management emphasis ($\frac{1}{1 + A \times B}$) is not so clear; at least as to its combinational significance. The electronic designer can choose A & B at will —— high gain devices are cheap, but the aircraft manager can't just pound on the table and order more and more detailed inspections, and pour on the overtime. If he does, he'll create a condition similar to the electronic type who increases A and B without regard for results —— the process will motorboat or oscillate, and the output will be useless. The analogy appears in another effect —— increasing the feedback has a definite limit in attenuating effects caused by defects in the process itself. If your amplifier has nonlinearities or phase delays (inadequate coupling or mismatched impedances), increasing feedback may just get you into more trouble. To make it work right, you have to find the defective elements in the forward loop and correct the deficiencies. Likewise, in the production phase of the aircraft process, if you find, for example, poorly made parts or over-torqued bolts, increasing the inspections in number and detail has limited value. You have to go into the process and correct the basic problem at its source, be it a worn tool or a poorly trained mechanic.

You may scoff at the comparison of a manufacturing process that takes years with an electronic amplifier that can reproduce a 1,000 c.p.s. square wave with a fidelity that indicates delays of only microseconds. But, it isn't the time scale that counts, it is the ratios that have meaning. A millisecond delay in the amplifier may mean a phase shift that prevents any meaningful use of negative feedback. In the aircraft making process, delays in finding the cause of an accident and correcting the process mean downtime for the fleet and loss of public confidence. If it takes you two years to realize the significance of an incident and make modifications, you not only expose the public to a continuing hazard, you also may not sell the next model —— the -X version that is on the drafting board. (Figure 5)

In conclusion, the "emerging pattern" I see is the unique ability of the "airplane making" process to handle safety in design and manufacture. Phased development, with comparison of output with input after each phase, and around all the phases, lends itself to identification and quick corrective action.

If we look at the loop that includes airborne operations, the voltage regulator analogy seems more appropriate. (Figure 6) A, the forward gain factor (management emphasis and priority) and B, the feedback factor (sampling and filtering the operational results) still apply. The regulator samples the output and detects a departure from some standard —— some level of safety in the aircraft analogy. It feeds back, with suitable filtering, a signal that is proportional to the seriousness of the deficiency. This signal, if the system is alert, is used to force corrective action.

You, as representatives of Air Safety Investigators, are key elements in the feedback loop. The quality of your investigations and the degree to which you can secure management attention and priority will greatly influence the ability of the aircraft and airline industry to maintain our present good safety record. Thank you.

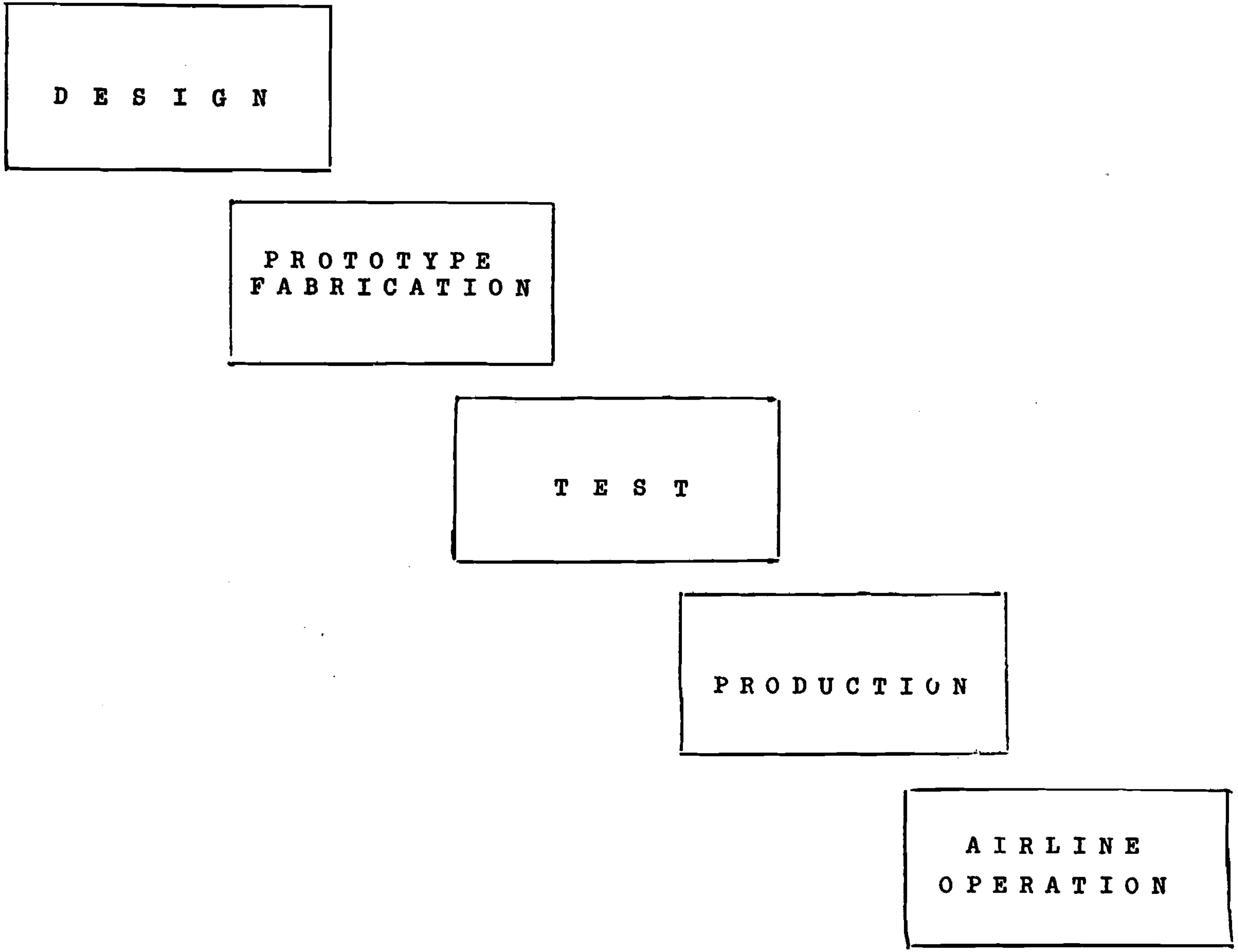

DESIGN
PROTOTYPE FABRICATION
TEST
PRODUCTION
AIRLINE OPERATION

FIG 1

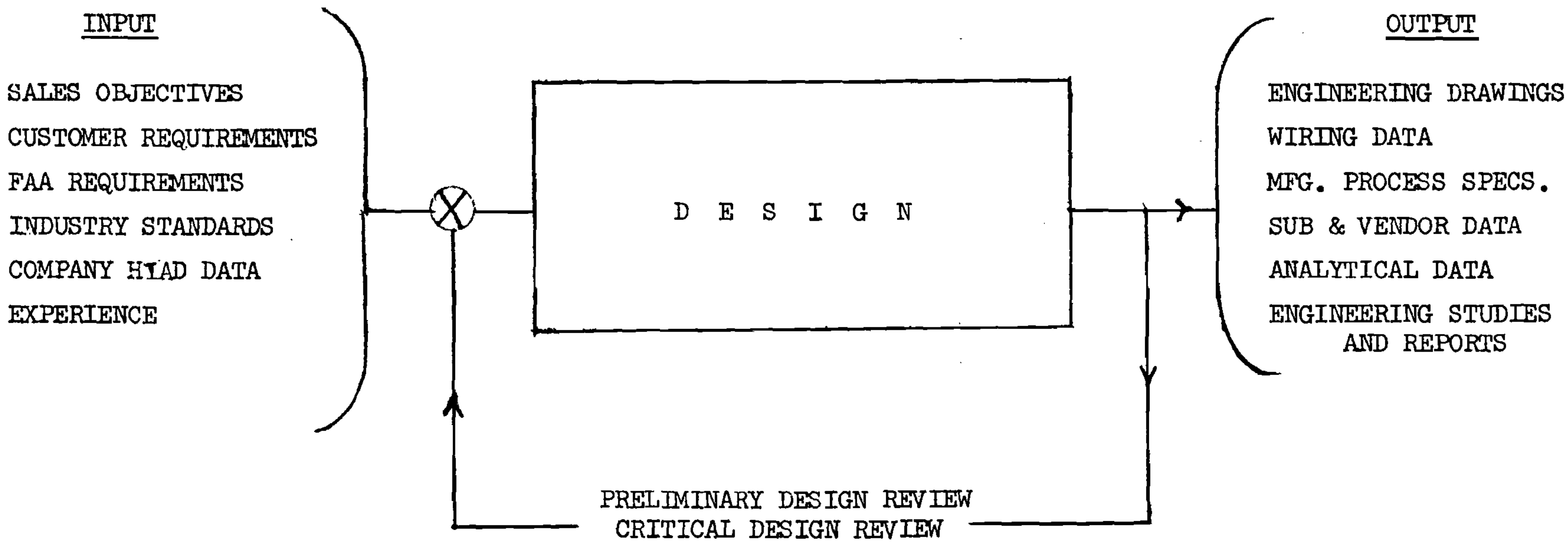
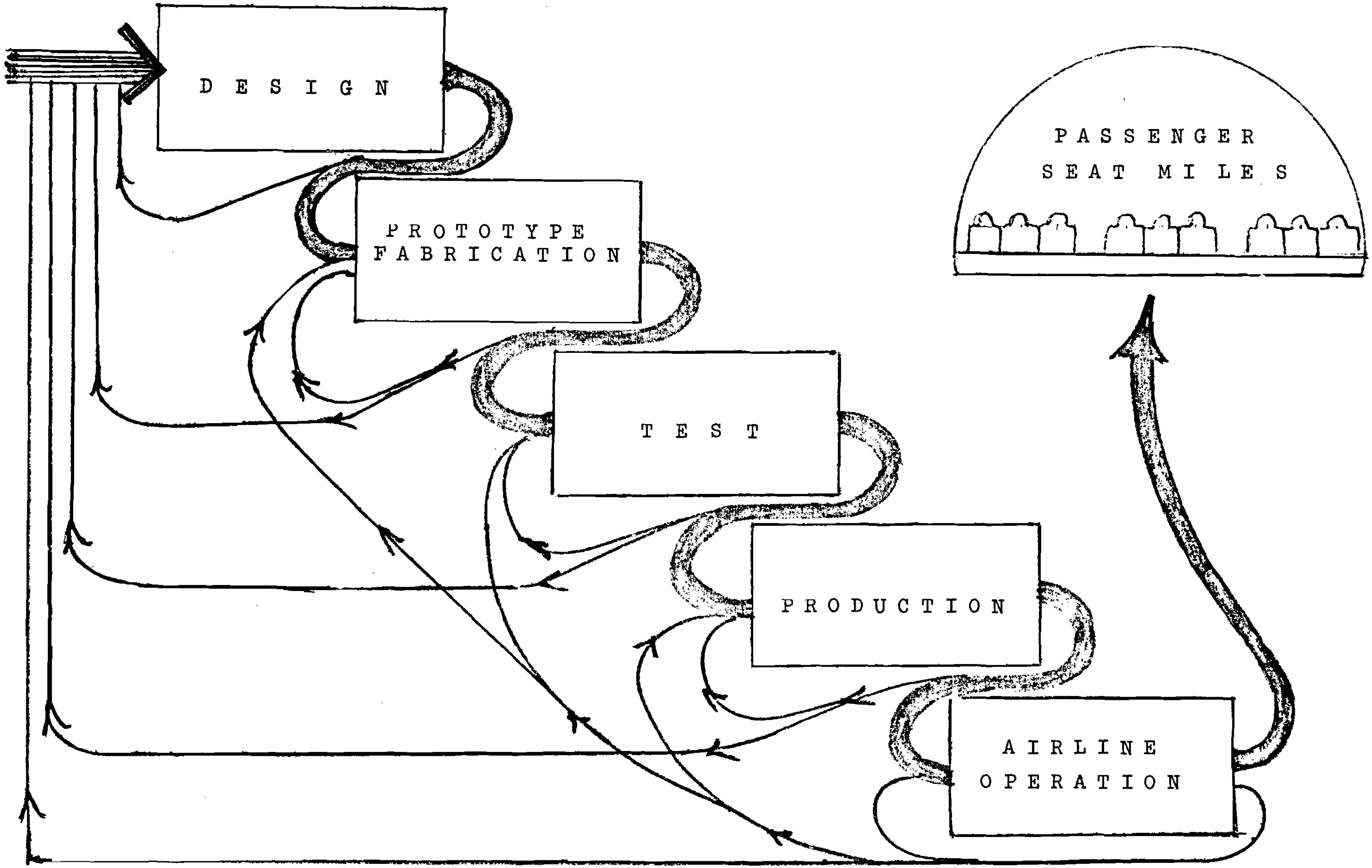
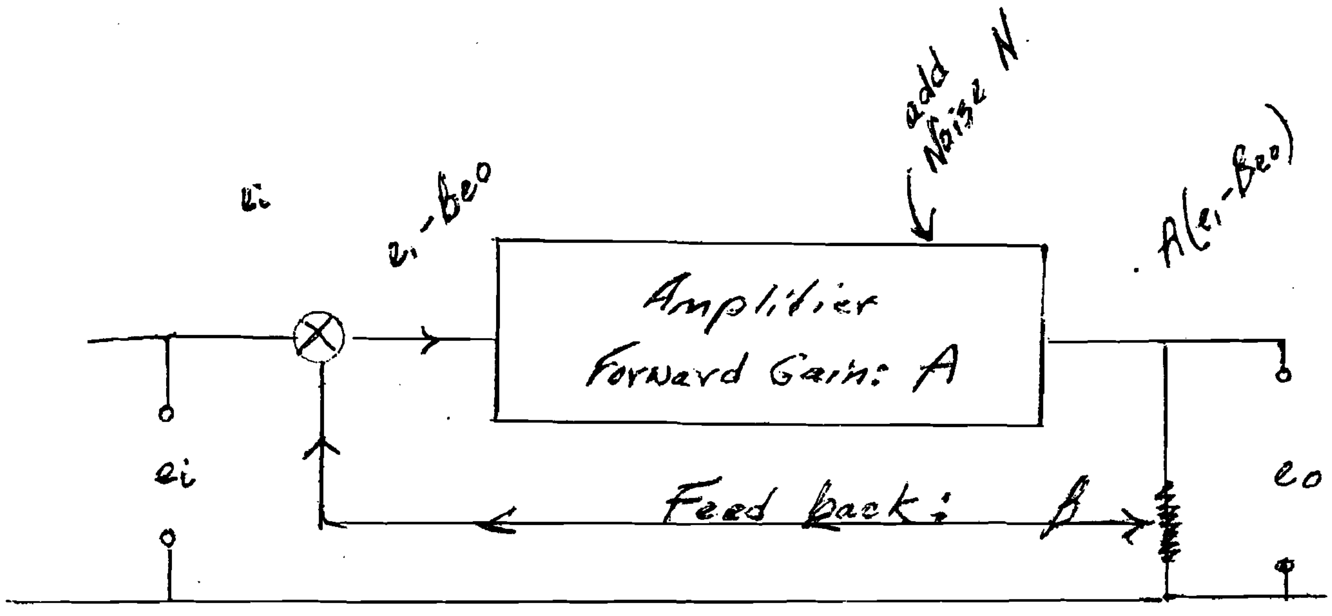

INPUT
SALES OBJECTIVES
CUSTOMER REQUIREMENTS
FAA REQUIREMENTS
INDUSTRY STANDARDS
COMPANY HEAD DATA
EXPERIENCE
DESIGN
OUTPUT
ENGINEERING DRAWINGS
WIRING DATA
MFG. PROCESS SPECS.
SUB & VENDOR DATA
ANALYTICAL DATA
ENGINEERING STUDIES AND REPORTS
PRELIMINARY DESIGN REVIEW
CRITICAL DESIGN REVIEW

FIG. 2.


D E S I G N
P R O T O T Y P E
F A B R I C A T I O N
T E S T
P R O D U C T I O N
A I R L I N E
O P E R A T I O N
P A S S E N G E R
S E A T M I L E S

F I G 3



without noise (N)

$$e_o = A(e_i - \beta e_o)$$
$$e_o(1+AB) = Ae_i$$
$$e_o = \left(\frac{A}{1+AB}\right) e_i$$

with Noise

$$e_o = A(e_i - \beta e_o) + N$$
$$e_o + AB e_o = Ae_i + N$$
$$(1+AB)e_o = Ae_i + N$$
$$e_o = \left(\frac{A}{1+AB}\right) e_i + \frac{1}{1+AB} N$$

Fig 4.

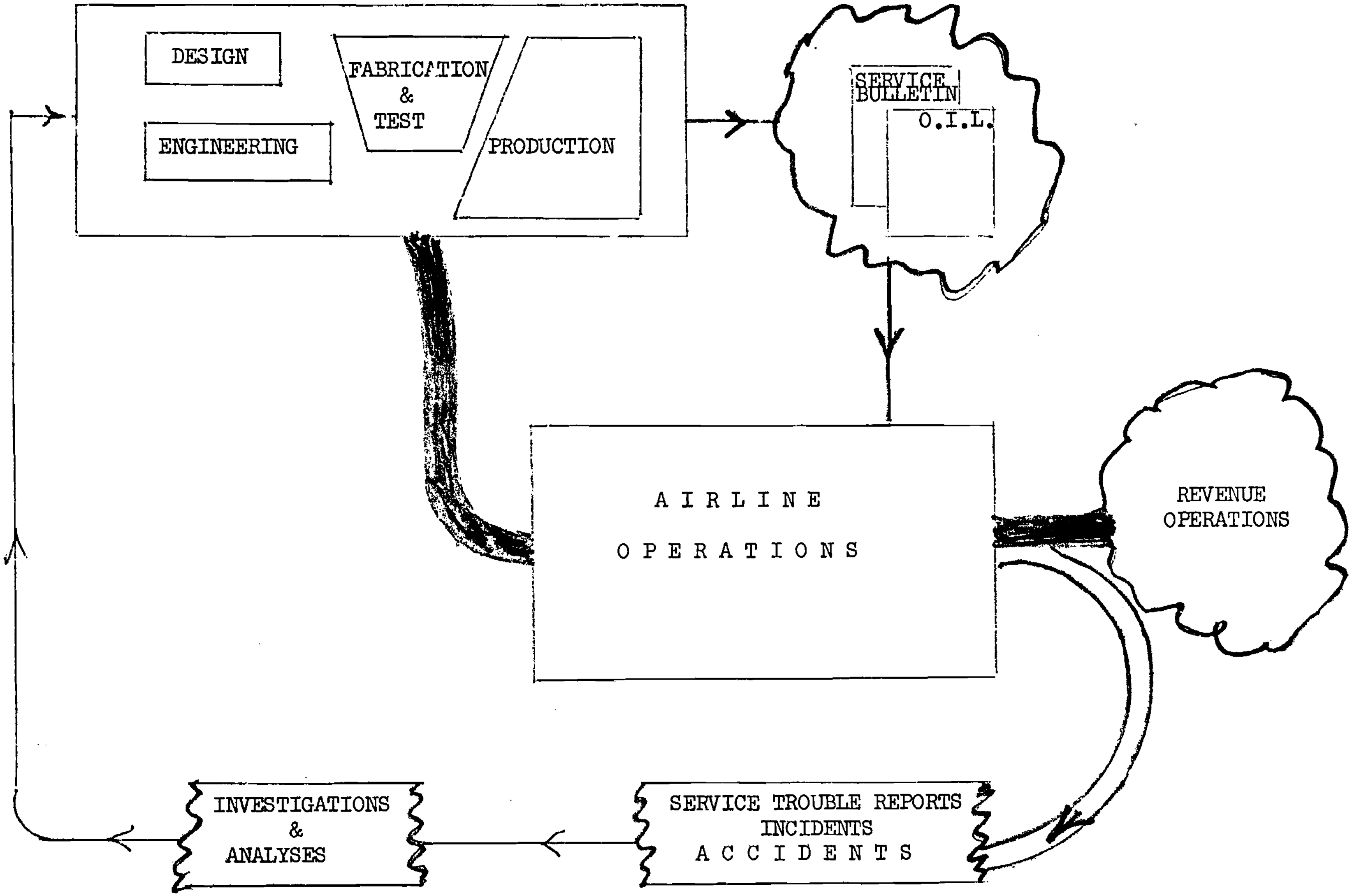

DESIGN
ENGINEERING
FABRICATION
&
TEST
PRODUCTION
SERVICE
BULLETIN
O.I.L.
AIRLINE
OPERATIONS
REVENUE
OPERATIONS
SERVICE TROUBLE REPORTS
INCIDENTS
ACCIDENTS
INVESTIGATIONS
&
ANALYSES

FIG. 5.

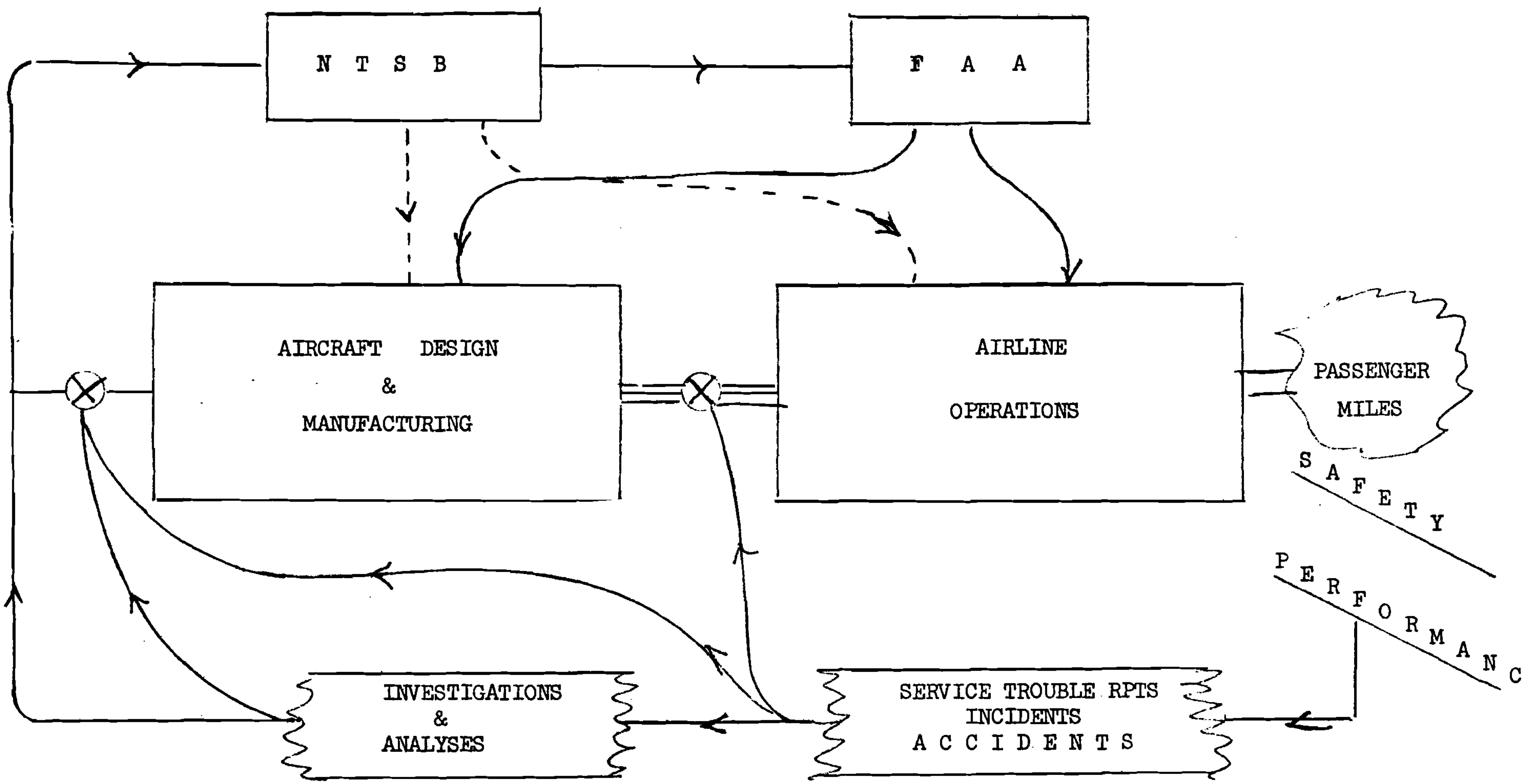

N T S B
F A A
AIRCRAFT DESIGN
&
MANUFACTURING
AIRLINE
OPERATIONS
PASSENGER
MILES
S A F E T Y
P E R F O R M A N C
INVESTIGATIONS
&
ANALYSES
SERVICE TROUBLE RPTS
INCIDENTS
A C C I D E N T S

FIG. 6.

WE CALL IT LOSS CONTROL

For the purposes of our discussion this morning, I'd like to emphasize that my remarks will be confined to the field of general aviation. That's the primary field of aviation that my company and most U. S. insurance companies are directly involved in today. The airline industry is usually covered by groups of insurance companies working together as a pool or syndicate and/or the London insurance market. Loss control to an insurance company means more than an improvement in the accident rate. A successful loss control program can mean the difference between profit and loss. If this seems to be a dollar-oriented, hard-hearted attitude, it might be well to think for a moment of what motivates people. I don't know of one manufacturer that sells airplanes at cost or any investigator working for free. Each of us, corporation or individual, must be concerned with income. Without some form of income and profit, few of us would stay in the business very long.

We in the aviation insurance industry are most interested in seeing the accident rate reduced to a minumum.

When I speak of the accident rate, it might interest you to know that I'm not referring to the published statistics we see each year as compiled from the accident reports submitted to the NTSB. These statistics are important and meaningful as far as they go, but they don't reflect the total picture of aviation losses. A significant number of losses reflecting hundreds of thousands of dollars and personal injury and death never get fed into the statistics because they did not meet the criteria of NTSB rule part 430. For example, we recently had a case where a corporate pilot was scheduled for a morning flight to fly one company executive to a distant city. Our pilot, being conscientious, started his pre-flight about an hour before takeoff time. About 45 minutes before takeoff, he conducted a run-up, planning on shutting down and waiting for his passenger in the FBO's lounge.

However, the passenger arrived while the pilot was still running the engines. Not knowing that he was the only passenger, he thought the plane was going without him. He proceeded to approach the plane from the rear along the fuselage and under the wing. By the way, it was an Aero Commander with a high wing. As he reached to knock on the pilot's window, he was struck in the head six times by the prop on the left engine. This accident will never show up in the official statistics since there was no intent to fly. We make no such fine distinction. In our book, this is an aviation accident. An aviation accident to us is anytime there is an injury or property damage covered by our aviation insurance contract.

Loss control goes much further than just preventing flying accidents. In addition to preventing accidents, we are also interested in minimizing the injuries and damage in those cases when an accident does occur. We all recognize the starting point or the base of the loss control effort is the Federal Aviation Regulations. Without this solid base, any safety program would stall out before it could get off the ground. The Regulations, as written, establish at least minimum safety standards and as a rule, are well enforced. We can always find isolated exceptions to this but overall, the FAA does a good job.

In our loss control program, we don't devote all our time determining if our policyholders comply with the FAR's. Our friends in the FAA take care of that for us pretty good. What we want to know is how far does the operator exceed the requirements of the FAR's. The FAR's establish minimum safety standards, and we all know that we can't survive on minimum safety standards very long, so it falls to us to consult with our assured and press for the safest possible operational environment for him.

This is accomplished in different ways. One is by recommending and insisting on certain performance on the part of the assured. These recommendations, we feel, will more closely approach realistic safety requirements. For example, I know of no requirement for a recently affluent, 100-hour total time, 55-year old, King Air owner/pilot, who flies for pleasure, to have more than a private ticket with a third class medical and now a bi-annual check ride in some flying machine, be it a 150 or a Piper Tri-Pacer and not necessarily a King Air. There is no requirement for a co-pilot nor even an instrument rating for the pilot as long as he stays out of the instrument environment. However, if this individual wants the protection of insurance, he'll have to change his ways a little.

Given the facts I have just described, I don't believe any company would care to provide coverage for his flight activities. I'm sure you will agree that this case could be an early loser, but we can't just stop there or eventually we will go out of business. Let's say we can talk with the pilot and convince him that he should obtain an instrument rating and take an annual proficiency flight check in his King Air and carry a co-pilot on all IFR flights and into all high density airports. Now we would have a reasonable risk that we could live with. This the insurance industry can do even though the FAR's don't require it. I call this loss control.

It's long been company policy that it is more sensible to control losses rather than pay claims. To this end, we have a staff of specialists in loss control in just about every line of business we insure. This includes factories, hospitals, elevators, yachts, trucks, aircraft, cargo, including air cargo. I could go on and on.

The primary function of this staff is to uncover potentially dangerous conditions or practices and then to recommend corrective measures. The conditions are normally noted during our survey of the operation, be it a corporate fleet, a third level airline, an FBO, or a private owner/operator.

The corrective recommendations are generally given to the responsible individual orally during the course of the survey or at the end of the visit. They are then followed up with written notification. These recommendations are, as far as possible, economically feasible to the particular operator. It's unrealistic to recommend something that we could never hope to achieve. For example, in the case of the King Air pilot I spoke about earlier, it would be ridiculous to suggest that he employ a co-pilot full time. It would be nice but rather expensive. However, we don't and we didn't hesitate to recommend that a co-pilot be utilized on all IFR flights and flights intc high density areas. In addition, we wouldn't hesitate to recommend that that same individual use 1500 feet and five miles as his VFR minimums due to the relatively high speed of his aircraft.

Take the case of the scheduled commuter airline operating under part 135. Under that Regulation, they can, for certain equipment, get authority to operate single pilot, auto pilot while carrying passengers. We don't believe that that is the safest way in the world to operate an airline. Where ticket-buying passengers are concerned, we believe in having two qualified pilots up front. Let's go further while we're on the subject of third levels. The Regulation says that if they have less than 20 passenger seats, they don't have to carry cabin attendants. That's all well and good until the day they happen to go spinning down the runway spreading parts all over. Now is when those passengers can use some qualified help. Without a stewardess, all we have is the flight deck crew, and if they got knocked all over the place, we don't even have them. Wouldn't you think that the owners, the pilots, the FAA, or somebody, would require the crew to wear a shoulder harness? They don't! Believe me, it's a common recommendation from us.

The third level airline industry is a fascinating and mushrooming segment of our business. It can go nowhere but up, and soon it's going to require a whole new set of Regulations. Again, though, economics must play an important part in the writing of those Regulations.

Let's turn to the general aviation FBO for a few minutes. Here's a group of individuals, each of them trying to operate at a profit. None wish to be responsible for an accident. They do the best they can within the bounds of their capability and knowledge. Each has his own idea of what constitutes good, safe practice. However, many of them get caught up in their own little world and don't have time to study the latest developments in accident prevention. I think it would surprise you to learn how many FBO's in this country dispense avgas and jet fuel but never think of making a contamination check. We prefer to see a daily check with an entry made on a log to show who did the check and what the results were. Look at the airport where the FBO is located. Have you ever landed at such an airport and found yourself fighting a crosswind even though you were complying with the direction shown by the tetrahedron? We find that it's not unusual since many operators tie the tetrahedron down and like to use it to designate the runway they desire be used. We strongly object to this, suggesting that they use instead a traffic "T" to designate the runway. How many times have you watched an airplane taxi up to a fuel pump and wondered if it would stop before it hit the pump? Every once in a while they do hit and sometimes it results in quite a colorful show. A 6-inch curb about 20 feet out from the pump eliminates the problem. We've been successful in having many such curbs installed in airports around the country.

Fire extinguishers. I can't recall ever seeing too many fire extinguishers around an airport. Many fuel pumps are without an extinguisher. I've seen a lot of unprotected hangars, yet maintenance is being performed including welding and painting. Often, the extinguishers are there, but you can't find them because their location is not identified or access to them is blocked or both.

Somebody has to help these operators to become aware of the conditions and to help them overcome their problems. I'm not too sure anyone, other than the insurance industry, gets involved in this area. Let's look at another phase of general aviation that's been long brushed to the side as being inconsequential and that's the sail plane business. Sail plane activity is increasing by leaps and bounds in this country as in all other countries and yet, to fly a sail plane in the United States today, to hold a sail plane pilot's certificate, there is no requirement to ever take a flight physical. Under FAR part 61, a student pilot, private pilot, or commercial pilot, in the case of glider operations, need only "certify that he has no known physical defect that makes him unable to pilot a glider".

This certification on the part of the pilot is good forever. Once he gets his certificate as a private pilot or commercial pilot, he never again has to even certify that he is still physically capable of flying the aircraft. Sail plane pilots have accidents too. I recently conducted a survey of accident reports covering a 5-year period on sail plane operations and I found that in about 50% of the accidents reported, the pilot did not have a medical certificate. But, there is no indication anywhere of what part the lack of that medical certificate played in the accident. One accident in particular was a collision with a parked airplane on the side of the runway at a local airport. When the investigator asked the pilot about this accident, he was told, "Well, they parked that airplane three feet further out today than they did yesterday". That's a pretty close tolerance as far as I'm concerned but what was more interesting was the fact that the pilot did not have a medical certificate so we have no idea of the condition of his eyes or his ability to judge three feet. On top of that, the pilot was 71 years old.

We have about five useful tools for loss control. Regulation, engineering, education, persuasion, and economic pressure; not necessarily in the order of their importance.

First, we can start with regulations. We've already discussed the FAR's. The basis of any accident prevention program is the regulations and their enforcement and we've agreed, or at least I've said that I agree, that the FAA does a good job in this field.

The next is engineering - the manufacturers designing the aircraft to be as safe as possible; designing crash survivability into the aircraft for those cases where the accident prevention program fails. I don't know if the day will ever come when we get standardized instrument panels and control systems but I think we're approaching it; at least, we're headed in that direction. From our end of the business, we're much concerned with the pilot who reaches for the flaps and retracts the landing gear on landing rollout. That's expensive, but engineering can and will, I think, someday help overcome it. Design-induced pilot error accidents must be eliminated.

The next subject is education. The education of a pilot or mechanic commences the day he first becomes interested in aviation. From then until he hangs up his wings or burns his coveralls, he must constantly study and learn more about this fascinating and fast moving industry. There are so many sources of information, however, that the average individual can't possibly keep up with all of the latest developments. It then falls to the professional safety types to sort it all out and make sure that the right information is brought to the attention of those who need it. We attempt to do this through our safety survey program, booklets, and other printed material and support of and participation in the FAA General Aviation Accident Prevention Program.

Persuasion. I think that the description of our own program of safety surveys, an eyeball-to-eyeball contact on the flight line, is a demonstration of what persuasion can do. By a friendly approach and discussion with the pilot, we can usually, not all the time, but usually, persuade them to adopt safer methods. The FAA Accident Prevention Specialists and Counselors use the same technique.

And finally, the last one is economic pressure. I know of no insurance company that would touch the King Air pilot as I first described him. Later, with the corrections as we suggested, he's an insurable operator. This is economic pressure and it can only be applied by an insuror.

I believe that you now will agree with me when I say that the insurance industry is an important participant in aircraft accident loss control. It can play an even bigger role if accepted as an equal partner in all phases of the aviation industry. We're not a manufacturer building a machine or its parts; we're not an operator like an airline or an FBO or an air taxi; we're not a user like shippers or corporate fleet operators, nor are we a regulator like the FAA or its counterpart in other countries. To put it simply, our business is loss control.

Although there is no single voice of the aviation insurance industry, I know that everyone in our business wants to see the accident rate reduced. This means all losses of every dimension. To help attain that objective, we stand ready to assist where needed and when invited, be it in industry forum, regulatory consultation, participation in official or unofficial safety clinics and training programs, or right on the flight line providing our clients with safety services.

* * * * * * * * * * * * * * *

DISSEMINATION OF AIRCRAFT ACCIDENT FINDINGS AND DATA

Presented
at
Fifth Annual Seminar
Society of Air Safety Investigators
Washington, D.C.
October 2, 1974

For NBAA:
Fred B. McIntosh
Director, Operational Services

The National Business Aircraft Association is a trade association and this fact alone sets the pattern and guidelines for our participation in accident investigations and promulgation of safety data. NBAA's 1,100 member companies, and please note I said companies and not pilots, operate approximately 2,200 aircraft ranging from single-engined types used in small business transport and pipeline patrol to BAC-1-11 and B-720 aircraft.

With this diversified fleet operating world-wide, our approach must be tailored to the needs and calibre of the crews flying and maintaining these aircraft.

As you might suspect, one of our largest tasks is killing rumors. Picture a group of business pilots waiting for their passengers in the pilot lounge at Page Airways, Washington National Airport, and one of them says "What do you think of Jim's accident? I just heard that they found the elevator trim in the full nose-up position and all the spoilers deployed". And "away we go"! By nightfall that version will be scattered through a dozen operations offices and to a hundred pilots.

No attempt was made to inquire who, what or where the information came from. It is unfortunate but this "wives club" approach is all too common in commercial aviation.

Thanks to the National Transportation Safety Board and the Federal Aviation Administration we are able, with additional inputs from the aircraft manufacturer and the owner/operator, to issue a confidential report of the basic facts confirming the accident, weather, injuries and/or fatalities and other pertinent data. This we usually accomplish in 48 hours. It serves two purposes: 1) The basic facts are there, and 2) NBAA members know that we are monitoring the investigation and perhaps even participating.

You can properly gather from this that we do not report, monitor or participate in every accident. This is true. Each accident is weighed against some simple but meaningful guidelines.

First, is it a member company's aircraft? Second, is it an aircraft of the type in common use by our members? Third, can we assist the FAA or NTSB because of our expertise in this type of aircraft? Fourth, has our member company requested our assistance? And fifth, is there something unique about this accident that the findings would be of special benefit to NBAA members from an operational or maintenance point of view?

Often times all of these factors are answered in the affirmative and at others one factor might trigger our interest and participation. An example of the first type is the current Grumman Gulfstream II training accident in South Carolina. An excellent example of the second type would be a non-member's MU-2 which crashed with a nicad pattery problem in VFR weather. In this latter case, since most of the MU-2's are operated by NBAA members and the then problem of "run away" batteries was the subject of intense joint investigation by NTSB, FAA and NBAA Technical Committee. The MU-2 investigation and findings when combined with other supporting data resulted in certain technical design specifications and criteria which has been, to a large extent, adopted by the business aircraft industry. The G-II investigation is still underway (at the time of this writing).

I'm taking your time to outline our procedures because almost from the initial report there is an increasing amount of feedback to our members on these accidents. With only a two-man technical staff in Washington, it is almost impossible to monitor or participate in every accident. NBAA has a 64-man Technical Committee that daily monitors the care and feeding of their aircraft. On each subcommittee there is at least one pilot and one maintenance specialist. These men are always available to assist in any way necessary should there be a problem arise about their aircraft. This can range from supply problems to pilot training and includes availability for accident investigation. When necessary any number of specialists or pilots who maintain or fly that particular model aircraft can be made available to the NTSB or FAA. Their reports are sanitized and approved as necessary by the Investigator-in-Charge and that data is made available to all NBAA members to whom it might be applicable. This is done either through our monthly Maintenance & Operations Bulletin (MOB) or if appropriate, we can issue a special bulletin.

I wish to stress that we try to make it a continuing process where possible. It is not unusual for one of the participants of the earlier conversation at Page to go to the telephone and call us and tell us what he had just heard and inquire as to its foundation in fact. He is given the appropriate information (if releasable) and we know that he usually returns to the conversation and attempts to set the record straight.

Needless to say, the final determination of Probable Cause is provided the membership when it becomes available. Quite often, airworthiness actions are taken while the investigation is still underway. These are published with an explanation outlining their relationship to the accident or incident being investigated. One-time spar inspections and limits on trust-reverser usage are typical examples.

But it is not enough to publish accident <u>findings</u>. Good piloting, good training, good maintenance and good airworthiness must be added to good judgment if we are going to profit by the piles of twisted metal and damaged lives.

NBAA works toward this goal in two additional ways:

1) Each year at our yearly convention, Maintenance and Operational meetings are held on 10 or 12 different aircraft. Sponsored and chaired by NBAA's Technical Committee, these meetings are the forum for review and discussion of accidents and incidents involving that type of aircraft. The attendence has continued to increase each year with 1973 bringing over 2,000 pilots and mechanics to these sessions.

2) NBAA publishes a Recommended Standards Manual which makes firm recommendations on maintenance, training and operational practices. This Manual is kept up-to-date by use of Management Aids which address themselves to a single subject, i.e. crew working hours, scheduling or accident reporting procedures. These have been widely extracted and republished around the world as has the MOB's.

There is much to be done. The training area is one that is of deep concern. The practical absence of sufficient visual simulators forces our kind of aviation to do more training in the airplane. Even though a commercial rating with instrument privileges is the minimum with over half having ATP's, there are better ways to train, particular procedural training than doing it "for real" in the airplane.

I would be remiss in closing without discussing NBAA's working relationship with the NTSB and the FAA. They are excellent. The FAA duty officer keeps us informed of accidents of interest and the NTSB honors our interest and request to participate. On certain occasions, they ask NBAA to participate because of the vast amount of operational and maintenance experience immediately available. We are pleased to assist in any way that we can.

Our hope, of course, is to minimize the need for these accident staffs. I know it is their desire as well.

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C.--20591

Safety Information

For Release:

Keynote Address
by
John H. Reed
Chairman
National Transportation Safety Board

ACCIDENT PREVENTION THROUGH INVESTIGATION

Before the
1974 Society of Air Safety Investigators Seminar
Quality Inn
Arlington, Virginia
October 1, 1974

It is a distinct honor to deliver the keynote address to those of you attending the Fifth Annual International Seminar of the Society of Air Safety Investigators.

Your Society is recognized throughout the world as the preeminent group of experts in the highly specialized profession of aircraft accident investigation. Your President, Donald E. Kemp, is one of our Nation's most respected aviation safety professionals and it has been my privilege to participate with him on a number of accident investigations. Don is certainly providing outstanding leadership to your fine organization.

The theme of your Seminar "Accident Prevention Through Investigation" is most appropriate. This is a premise to which the National Transportation Safety Board fully subscribes. Accident prevention is the moral responsibility of each and every member of SASI. Your expertise is needed to assist the Board in fulfilling its responsibility.

If we approached the problem in any other manner, the increase in accidents could constitute a problem of overwhelming proportions and the future development of aviation would suffer. To insure that this responsibility is properly fulfilled, there should be no screts in accident prevention. We should pass accident prevention ideas voluntarily and the crossflow of such information must be unimpeded by jealousies, jurisprudence or jurisdictions.

Before we get into methodology of prevention through investigation, I believe that I should point out the role of the United States in world aviation and its growth projections. Then we will have an idea of the corresponding increase of the magnitude of air safety problems and therefore be better prepared to solve them.

According to a 1973 report from the Aviation Advisory Commission, created by Congress in 1970 to outline the long range needs of our aerospace transportation system, the future growth in aviation will be significant. By the year 2000, they predict that the U.S. system capacity will have to be at least 7.4 times as large as the present one. This prediction is for the increase of passengers - - air cargo is forecast to expand even more rapidly.

In turn, this growth could, unfortunately, mean an increase in the number of accidents and incidents. However, if we continue to apply ourselves as we have in the past, the accident rate will decrease.

Positive thinking by all of us regarding accident prevention has made avaiation the safest and most expedient mode of transportation in the world today and there is no reason to believe that this condition will not continue. Such positive thinking is analogous with professionalism in conducting our investigations and then taking vigorous preventive action -- which is a must for success. Although other prevention sources, such as special studies, are fruitful and needed, the prime source of information is derived from the investigation of accidents and incidents.

The recent Turkish Airlines DC-10 accident near Paris is an illustration. As you know, under existing International Civil Aviation Organization agreements, the State of Manufacture participates in aircraft accidents occurring outside of its own country. In this case, a Turkish Airline, operating a U.S. manufactured airplane was involved in a catastrophic accident in France. Consequently, the Safety Board immediately dispatched three air safety investigators, one of whom was formally designated as the U.S. Accredited Representative to the French investigation of the accident, to the scene to participate in the inquiry.

Shortly after arrival, our investigators noted the striking similarity of the evidence with an American Airlines DC-10 accident which had occurred near Windsor Ontario, Canada in 1972. In that case, the aft left cargo door of the DC-10 separated from the aircraft and the rapid loss of cabin pressurization expelled cargo, including a casket containing a body, and caused the adjacent aft cabin floor to collapse downward into the cargo compartment. The collapse of the cabin floor caused the flight control system to jam or break, and severely limited control of the aircraft. However, in the American Airlines incident the crew was able to effect a safe emergency landing.

In the Paris crash, the aft cargo door was found approximately 10 miles from the main crash site and nearby there were 6 free fall bodies and 7 seats that had been expelled when the door had separated. Unfortunately, in the French case the floor damage apparently was greater than in the American Airlines case and the flightcrew was unable to maintain full control of their aircraft. The evidence indicated that partial control may have been regained because the aircraft hit the terrain in a relatively level flight attitude. The impact forces were so great that the entire airplane disintegrated and 346 people lost their lives in the disaster -- the worst in world aviation history.

All of the information and records that we had compiled as the result of the American Airlines DC-10 accident were immediately made available to the investigators of the French Government.

In the interest of accident prevention, the Safety Board's investigation of the American Airlines accident generated two major recommendations; the first, requiring a modification of the DC-10 cargo door locking system and the second, requesting the installation of vents between the cabin and the aft cargo compartment to minimize pressure loading on the cabin flooring in the event of sudden depressurization of the cargo compartment. If complete venting was not possible, the Board suggested that even partial would be beneficial. However, at the time of the Paris crash, all of the Board's recommended improvements had not been incorporated in the Turkish aircraft.

Another method of accident prevention is accomplished by the investigation of incidents but, due to the limited staffing of the Board and the number of accidents annually, the investigation of all incidents is not practical. Nevertheless, the Board's Washington Staff and its field offices are constantly alert for noteworthy incidents -- especially those that occur to late model aircraft.

Two such incident investigations that produced meaningful corrective action involved an Air France Boeing 747 incident on August 17, 1970 and a Continental Airlines DC-10 incident May 2, 1972. The 747 was 9 minutes out of Montreal for Paris when the No. 3 engine exploded. It was found that the No. 3's high pressure turbine module had been incorrectly assembled resulting in failure of the second stage turbine disc rim. Just four days after the incident, the Board issued three recommendations relating to the detection of discrepancies in turbine modules of JT9D engines such as are installed on 747 aircraft. Corrective action by the Federal Aviation Administration and industry was immediate.

In the second case, the DC-10 had departed Tucson, Arizona, on a training flight when the No. 2 engine low-pressure turbine assembly, turbine rear frame and reverser assembly separated from the engine. The Board determined that there had been a failure of a stiffener ring on the pressure tube located within the high pressure turbine shaft on the No. 2 engine. As with the first incident, immediate remedial action was taken.

During investigations, the Safety Board directs its attention to three basic principal subjects in determining causal areas. They are the airplane, the crew, and the facilities and services provided for aircraft operation. Safety problems stemming from these basic investigative areas include, among other things, pilot technique and training, aircraft design, air traffic control, airports and facilities, maintenance, human factors, rescue and survival, powerplants, weather and communications.

Any one or a combination of these areas may be related to the causal factors of the accident or incident and therefore be subject to examination for possible improvement.

Clearly one of the leading critical problem areas which we must not overlook during our investigations is the human element. This area includes the problems related to cockpit design, man/machine interface criteria, pilot training, judgment, experience, currency and leadership and the regulations and criteria under which he must operate. These areas also encompass the experience, training, and performance of all support personnel.

Another area that is constantly in need of change and improvement due to continued growth in aviation is our airports and their facilities which include air traffic control. Critical elements in this category include not only our airports, but the establishment of minimum standards and methods of regulation for airports. It includes the entire departure, en route, and approach and landing operations dependent upon and influenced by the airport, its guidance facilities, firefighting equipment, and its design and construction.

As members of SASI you must be constantly alert to identify these and any of the other areas that reflect a need for improvement. Some of the methods utilized to carry to an effective conclusion the prevention suggestions evolving from our investigations are: (1) Safety Board recommendations, (2) on-the-spot improvements formulated by the team personnel and carried out in coordination with the FAA, the manufacturers and, at times, the carrier, and (3) safety symposiums which, in turn, identify additional areas that need improvement.

Although all of these are important, the Board considers the safety recommendation to be its most effective device in working for improved transportation safety. It is our responsibility to insure that realistic, meaningful recommendations are made if we expect prevention productivity. A recommendation just for the sake of making a recommendation is neither desirable nor effective. If we believe that a recommendation is need to correct a deficiency we must come up with a reasonable, reliable, and effective correction. After a recommendation is made it must be followed up to insure that its intent is effectively carried out.

Safety is intangible in many ways -- none of us may ever know how many accidents were avoided by our investigations and recommendations. However, I have no doubt that a multitude of accidents have been prevented by recommendations originating from our investigations and by continued followup action.

I am sure that many of you have investigated repetitious accidents from the same cause and have asked yourselves -- where did the previous investigation fail? What recommendations were not effectively followed up that would have prevented the accident?

Safety Recommendations have been the Board's most important product since its inception 7 years ago. However, it has become apparent in recent months that a more effective method of safety recommendation followup was needed.

In the DC-10 accident near Ontario, Canada, in 1972, the Safety Board did everything right -- we defined the cause and we issued corrective recommendations. Tragically, the DC-10 crash in Paris proved that all of our recommendations had not been fulfilled in the proper way.

Consequently, the Board has established a new procedure to monitor the status of all recommendations and their degree of implementation. If the action indicated by the FAA, or other addressees does not satisfy the Safety Board, followup proceedings will be initiated immediately to work out a solution agreeable to both parties to satisfy the intent of the Board's recommendation.

The Board has established in the Bureau of Aviation Safety a Safety Recommendation Manager (SRM) who, in conjuction with a Safety Recommendation Officer in the Office of the General Manager, are responsible for the formulation of safety recommendations for Safety Board consideration. Upon Board adoption, the SRM will evaluate and advise the Board on followup action.

Recommendations resulting from the discovery of unsafe conditions uncovered by field investigations are forwarded to the Safety Recommendation Manager for evaluation and formulation as proposed recommendations for Board consideration. If, after careful analysis, the Board adopts the recommendations thay are then forwarded to the action agency. In aviation cases this is usually the FAA. Safety Recommendations are also released to the public.

Recommendations arising from major accident inquiries are followed through by the Safety Recommendation Manager. The recommendations are developed and prepared by the applicable team member in whose area the recommendation proposal originates. The SRM consults and coordinates with the Accident Investigation Manager, the Investigator in Charge, and the functional managers of the Bureau of Aviation Safety to assure that the proposed recommendations are sound, purposeful, and feasible for implementation before being submitted to the Board for adoption.

Recommendations do not await the preparation of the accident report but are issued expeditiously as soon as sufficient supporting factual information is developed.

I cannot overstress the need for effective recommendation followup by the addressee as well as by the Safety Board. Such action is just as important as the investigation. If, after careful consideration of all aspects of the response, the Board concludes that implementation action is not adequate the Board will followup with further recommended action.

The following recommendation statistics illustrate the activity of the Bureau and the Board in our never ending pursuit of accident prevention.

During the years 1970 through 1973, 547 aviation recommendations were issued. Of these, 426 resulted from investigations conducted by Board field offices and Washington-based teams. During 1973 the Board adopted 122 recommendations of which 35 pertained to approach and landing problems. Some of the other significant areas recommended for improvement were aircraft occupant survival and aircraft evacuation, hazardous materials, and inflight fire prevention.

In conclusion, our basic, primary goal in accident investigation is to utilize the information we obtain during the investigation of accidents and incidents to prevent other accidents through the recommendation-corrective action process.

THANK YOU

INVESTIGATION PROCEDURES ADOPTED OVER THE PAST TEN YEARS

By MUSHIR ALLAM KHAN
SAFETY MANAGEMENT OFFICER, PIA

PIA PAKISTAN INTERNATIONAL AIRLINES
KARACHI AIRPORT

PAKISTAN INTERNATIONAL AIRLINES
FLIGHT OPERATIONS DEPARTMENT
SAFETY MANAGEMENT SECTION

INVESTIGATION PROCEDURES ADOPTED OVER THE PAST TEN YEARS.

Investigation of aircraft accidents over the past ten years has attained a sophisticated status, has become a very specialized and scientific profession; based on well tried and established procedures, that have been derived from situations encountered by investigators during investigation of accidents; beside, also based on sound, observations made by investigators, with all integrity, devotion, deligence, honesty, of purpose, patience.

Investigations, that have been conducted according to the established procedures, have been informative, educative for manufacturers and operators. They have brought about procedures, to unearth facts and data from all the parameters of aviation industry accidents.

The procedures of the last decade have put into practice a uniform system of investigation, almost all over the world with few exceptions. The theme is to determine facts, conditions and circumstances that led to accidents, and provide immediate remedy; so that no second accident is caused by a factor, that has been responsible in some past accident.

In the last ten years, investigation procedures have been useful in determining the crash worthyness of aircraft, their capability and robustness of structure for the survivability of occupants. Predominantly the procedures aim to establish as to 'what happened' 'how happened' and 'why happened', with very balanaced and humane reference to accusatory aspects. The emphasis is mainly to keep the investigation purely confined to the technological & operational aspects.

Most of the procedures, have been found most lucarative and rich in the theme of 'prevention' and have made investigative techniques practical and acceptable. The findings have brought about marked improvements in the aircraft manufacturing, in flying patterns and in procedures.

The planning of investigation has also become so methodical, that all the preludes of investigations are so well organised, and arranged, that when investigation is in the process, there is no element of delay or bottlenecking, the scene of crash is surveyed by land or by air; approach to the area is plotted on the map; procedures to obtain local assistance is all spelled out. There is a full inventory of items, tools and equipment required. Quality of investigation depends very largely on the planning of investigation mission.

At planning stage the possible causation factors are listed and discussed among the experts; and the more salient and logical factors are weighed against the first hand information received from sources, that should be authentic and not fabricated. In the planning stage delay is discouraged for the reason that evidence get lost or mutilated through natural factors, and through the interference of irresponsible persons. Here it may be mentioned that Orille Wright, was the first to set the procedure of not permitting delay in investigation. He ordered that failed propeller of his aircraft, to be brought to his bed side in the hospital, where he was under treatment of injuries he received in his first and the only accident. This he did as there were no investigators in those days; and to avoid delay in noting the evidence.

Continued......../2.

The procedures donot confine investigations, to, just determine that errors of ommission or commission have been committed, but they go on to determine why errors have been committed, and how far human limitations have been victim of errors.

There have been procedures for organising experts groups, a very fine method of conducting detailed investigation covering all aspects of aircraft accident. The compliment of experts depend on the complexity of accident and also on the nature of terrain around the scene of crash.

The groups provide useful combination of views, rich experience, which can ultimately enrich the text of investigation with obvious specialist skill and knowledge. The groups can be effective, provided they are headed by a Chief, who should be a person of integrity, devoted to his profession. There must be absolute willingness, in thought and deed on the part of every one in the group to contribute their best in conducting investigation. The main function of the group is to establish facts directly related to accident, by employing specialized knowledge and specific experience with regards to the construction and operation of aircraft along with knowledge of the facilities, services, connected with aircraft operations. All along emphasis is laid that no issue is rejected or neglected in preference to a situation that appears convincing only on face value. No conclusion is drawn unless it has the concurrence of all.

Considerable amount of work gets completed on the site, and some shop testing of components power plants and structure necessitate despatching of the items to laboratories and to manufacturers. This requires special and careful attention during removal and retriving operation, so that basic evidence is not destroyed or mutilated, and testing is flawless.

Each group after completing their task, work with the data obtained, analyse it carefully in order to prepare a factual report indicating scientific and logical cause or causes; and recommendations which are considered vital from the point of view of accident prevention and air safety.

The procedures are rather elaborate and vital on the study of weather structure; voice and flight data recorders, witness interrogation methods, scrutiny of maintenance records, human factors and limitation, autopsy, wreckage examination, rescue operation, photography.

WEATHER:

With the capabilities of aircraft operating through weather except which is not in conformity with weather minimas; the study and analysis of weather is important whenever an accident is associated with it. A crash in the Alps occurred in weather; a deep weather research was initiated and it was found that 'white out phenomenan' was also a contributory factor. In another case an aircraft touched down much short of runway, when sky was overcast, with flat ground all snow bound, and there was no reference whatsoever, this could also have been a case of 'white out' . In all cases where weather is involved, a procedure is available to examine the weather.

WITNESS INTERROGATION:

Witness interrogation is of great significance; when it is carried in accordance with interrogation procedures witnesses are to be selected with great judgement, they should be persons of repute, of balance frame of mind, they should talk

CONTINUED......../3.

straight and to the point. It should be ensured that they are under no duress or apprehension and are not inclined to exxagerate and show off.

Their statements in my opinion should be talied with the relevant portion of the readouts..

SCRUTINY OF MAINTENANCE RECORDS:

Investigation procedures, greatly require their meticulous scrutiny; recalling the crash of a medium airliner, where cause could not be determined from the wreckage but the maintenance record clearly revealed that a control surface was not properly fixed and installed and it came off soon after the aircraft was airborne.

USE OF FLIGHT DATA & VOICE RECORDER READOUTS & SIMULATOR:

In investigation, read outs both of performance and cockpit conversation, play very important role, in establishing facts to a very reliable extent; and very pertinent information can also be collected for the purpose of investigation.

The flight recorder readout can be fed into the simulator programmer, where it can be seen as to how the aircraft behaved; this would give useful information, and would also show what flight conditions were encountered prior to the accident.

HUMAN FACTORS:

In the last decade, human factors have been given great attention for the reason that in some accidents, it was fairly well established that the crew was fatigued, had some social, physcli-gical and phsycological problems, ultimately leading to suttle or sudden incapaciation. There have been cases where a crew member at a critical stage of flight was occupied in work that was completely alien to his profession or assignment in the cockpit, this discrepency got noted during autopsy or other examinations.There have been accident where a crew member
/ cf was found in the wreckage with a pair/pliers in his hand, and his brief cases also contained some pairs of pliers. In another recent case in a demonstration flight, a report indicated that crew member was found dead at the scene of crash with a movie camera in his hand.

In one case of incapaciation, the injuries on the hand and on fingers of one crew member indicated that he was flying, and absence of injuries on the hand and fingers of the other crew member, gave evidence that his hands were not on the control column; there was other established evidence to indicate that the pilot in command collapsed and second pilot struggled to control the aircraft but failed.

A fair number of accidents have been attributed to human factors, and in some cases compounded by human elements. There have been cases where circumstances were not conducive to human limitations.

Procedures on human factors are not just limited to establish that error has been committed. But the procedures give further guidance to determine as to how human limitation can be compensated by better understanding of psychological, physiological and social factors. The medical history is given a careful study to find out how certain medical aspects of crew members

CONTINUED......./4.

involved in accident can be evaluated and examined to obtain information on medical and health aspects, for improvements.

Human limitations are also judged and examined in respect of illusions, hypnosis effects, erronuous interpretation. Fatigue and boredom. Such factors have often been contributory factors; and therefore they are given a treatment based on relevant procedures.

SEARCH AND RESCUE:

In accident aircraft may survive the impact forces and loads, and occupants survive, but if timely and prompt rescue and evacuation facilities are not available, a surviveable accident can become fatal, just for want of evacuation and rescue facilities. Definite procedures have been coined to survey/examine rescue facilities in accident investigation.

SAFETY PROCEDURES:

Safety procedures call for various precautions to be taken when a crash site is dangerously contaminated with fuel or the site is potent with the hazards of dangerous cargo. It is wise to confirm the details of cargo before working on the crash site. Whenever a crash is out in the sea, the procedures to observe safety rules particularly where magnesium is involved, which through contamination can become potential bomb of lethal magnitude.

At the crash site procedures demand to work with all care and safety orientated approach.

WRECKAGE EXAMINATION:

Examination of wreckage to extricate evidence is very important, and at times most pertinent and useful information is obtained. In one accidents, a movie camera was found intact; and it occurred to one of the experts that the film should be developed. The film gave a run down of events prior to crash. The film showed that aircraft was in a dive and had an abnormal attitude; this evidence gave lead to many other factors and clues. Meticulous examination of wreckage is very important and at time, the wreckage examination provide information on occurrence of fire, structural failure, loss of control and various other aspects.

PHOTOGRAPHY.

Photographyis a very important link in the investigation procedures, and at time good photographs give evidence, that is missed by eyes. Colour photography gives more details and covers light and shade effects better; and still better when a flash is used. It has been observed that a black/white photograph of a /and flap setting was not clear; but in colour photograph the setting was clear and pronounced enough to read the setting.

CONTINUED......./5.

The scene of crash and its various positions, and spread out of wreckage is better covered by 35 mm colour slides. These slides are useful during discussion among the experts and investigators.

Most current cameras and photographic devices, should be liberally used in investigation, as a definite procedure.

In conclusion may I endeavour to submit, that an investigation conducted within the frame work of sound and tried out procedures, augments flight safety and prevention of accidents.

REMARKS PREPARED FOR DELIVERY BY JAMES E. DOW,
DEPUTY ADMINISTRATOR, FEDERAL AVIATION ADMINISTRATION,
AT THE 5TH ANNUAL INTERNATIONAL SEMINAR,
THE SOCIETY OF AIR SAFETY INVESTIGATORS
WASHINGTON, D. C.
OCTOBER 1, 1974

I AM DELIGHTED TO BE HERE TO RENEW OLD FRIENDSHIPS AND TO MAKE NEW ONES AMONG MEMBERS OF THE INTERNATIONAL COMMUNITY REPRESENTED AT THIS 5TH ANNUAL SEMINAR. INDEED, I OFFER A SPECIAL WELCOME TO OUR GUESTS FROM OTHER MEMBER STATES, FOR I AM CONFIDENT THEIR VISIT WILL PROVE MUTUALLY PROFITABLE FOR ALL OF US.

BUT, IN PASSING, I MUST CONFESS SOME CURIOSITY AT THE INTENT OF THE MANAGERS RESPONSIBLE FOR PULLING THIS GATHERING TOGETHER. I NOTED WITH SOME DISMAY THAT THEY HAVE ELECTED TO CALL THIS MEETING A SEMINAR, RATHER THAN A SYMPOSIUM AS IT HAS BEEN ENTITLED IN PAST YEARS. WHETHER THIS CHANGE WAS DELIBERATE OR BY CHANCE, I CANNOT SAY. I DO THINK YOU SHOULD ALL KNOW THAT WEBSTER's THIRD NEW INTERNATIONAL DICTIONARY, ON WHICH ALL AMERICANS SO HEAVILY DEPEND FOR PRECISE MEANINGS, DEFINES SYMPOSIUM AS A "DRINKING PARTY FOLLOWED BY A BANQUET," I CAN ONLY HOPE YOUR MANAGEMENT's CHANGE AUGURS WELL FOR ALL OF US.

SERIOUSLY, I AM HIGHLY PLEASED TO HAVE BEEN INVITED TO ADDRESS THIS OPENING SESSION, FOR I CONSIDER THIS INTERNATIONAL GATHERING AS ONE OF THE MOST OUTSTANDING FORUMS FOR THE EXCHANGE OF AVIATION SAFETY INTELLIGENCE. AND IN THIS CONNECTION, YOUR SEMINAR THEME, "ACCIDENT PREVENTION THROUGH INVESTIGATION,"

STRIKES A PARTICULARLY RESPONSIVE CHORD IN MY MIND AND, INDEED, THROUGHOUT ALL ELEMENTS OF THE FEDERAL AVIATION ADMINISTRATION. SAFETY IS OUR BUSINESS, BUT, AT THE RISK ONCE MORE OF BEING FACETIOUS, WE ARE ALL DEDICATED TO ELIMINATING THE NEED OF YOUR SERVICES. AS A PRACTICAL MATTER, HOWEVER, THE NEED FOR YOUR EXPERTISE CONTINUES TO CLIMB IN BOTH INVESTIGATIVE AND PREVENTIVE ACTIVITIES AND YOU MAY BE SURE OF THE FAA's COMPLETE CO-OPERATION WITH SASI IN ALL MATTERS RELATING TO AVIATION SAFETY.

FOR THE BENEFIT PRIMARILY OF OUR FOREIGN VISITORS, I WOULD LIKE TO TALK A BIT ABOUT FAA's RECENTLY COMPLETED "OPERATION GROUND ASSIST." IT WAS A 30-DAY AVIATION SAFETY PROGRAM WHICH ENDED JULY 15, FROM WHICH, I'M CONFIDENT, OUR GENERAL AVIATION COMMUNITY PROFITED GREATLY. I KNOW THAT FAA INSPECTORS GAINED IMMEASURABLY FROM THE PROGRAM.

DURING THE COURSE OF THE SPECIAL 30-DAY PROJECT, FAA INSPECTORS VISITED SELECTED AIRPORTS THROUGHOUT THE NATION IN AN EFFORT TO RAISE THE LEVEL OF SAFETY AWARENESS AMONG PILOTS, FLIGHT INSTRUCTORS, AVIATION MECHANICS, AIRPORT MANAGERS AND OTHERS CONCERNED WITH GENERAL AVIATION. THE INSPECTORS CONTACTED 54,957 PRIVATE AND BUSINESS PILOTS AND 8,176 MECHANICS. IN ADDITION, THEY INSPECTED 28,309 AIRCRAFT.

DURING THE PROJECT, DEFICIENCIES AFFECTING 1,480 PILOTS, 163 MECHANICS AND 2,438 AIRCRAFT WERE DISCOVERED. MOST OF THESE DISCREPANCIES WERE OF A MINOR NATURE AND WERE CORRECTED ON THE SPOT.

"OPERATION GROUND ASSIST" EMPHASIZED CANDID DISCUSSION OF MUTUAL PROBLEMS AND LEARNING HOW TO SPOT DEFICIENCIES ON THE GROUND BEFORE THEY BECOME PROBLEMS IN THE AIR. I'M CONVINCED, AND I THINK YOU WILL ALL AGREE, MOST ACCIDENTS BEGIN BEFORE A PILOT GETS INTO THE AIRCRAFT.

VISITS WERE CONDUCTED BY FAA FIELD PERSONNEL DURING PEAK HOURS OF OPERATION, INCLUDING EVENINGS, HOLIDAYS AND WEEKENDS, WHEN EXPOSURE IS GREATEST AND MOST ACCIDENTS OCCUR. AIRPORTS VISITED INCLUDED THOSE SERVING RECREATIONAL AREAS, FLY-IN EVENTS OR LARGE NUMBERS OF PRIVATE AIRCRAFT.

I ALSO WROTE A LETTER TO ALL CERTIFICATED AIRMEN --- SOME 750,000 OF THEM --- EXPLAINING THE PURPOSES OF THE SAFETY CHECK PROGRAM AND SOLICITING THEIR VIEWS ABOUT SAFETY IN CASE THEY WERE NOT CONTACTED BY AN INSPECTOR. PRACTICALLY ALL WHO RESPONDED EXPRESSED APPROVAL OF THE PROGRAM OR OFFERED CONSTRUCTIVE RECOMMENDATIONS. SOME SAMPLES: "MORE SPIN RECOVERY TRAINING NEEDED" ... "WEATHER FLYING SHOULD BE STRESSED MORE" ... "SAFETY CHECKS SHOULD RUN THE YEAR AROUND."

SOME, NOT MANY, HOWEVER, THOUGHT THAT THE AGENCY WAS SNOOPING OR THAT IT WAS EXCEEDING ITS AUTHORITY IN CONDUCTING THESE CHECKS. BUT REALLY THESE CRITICISMS WERE FEW IN NUMBER COMPARED TO THE FEEDBACK RECEIVED FROM THE LARGE MAJORITY WHO REVEALED THAT THEY WERE JUST AS CONCERNED AS FAA IS ABOUT THE RISING NUMBER OF PREVENTABLE ACCIDENTS IN PRIVATE FLYING AND WANTED TO DO SOMETHING TO REVERSE THE TREND.

AS A MATTER OF FACT, NUMEROUS INDUSTRY ADVISORY GROUPS, ACCIDENT PREVENTION COUNSELORS, AND FLYING ORGANIZATIONS COOPERATED WITH FAA IN CONDUCTING THE PROGRAM. IT WAS THE

CONSENSUS THAT OPERATION GROUND ASSIST PROVED HIGHLY WORTH-WHILE AND SHOULD BE CONTINUED, PERHAPS ON A YEAR-ROUND BASIS. WE SHARE THAT CONVICTION AND ARE NOW WORKING ON A PRACTICAL PLAN TO IMPLEMENT IT.

FRANKLY, CONDUCT OF OPERATION GROUND ASSIST ON A SIMULTANEOUS BASIS THROUGHOUT THE 50 STATES WAS ECONOMICALLY COMPLEX AND, ADDITIONALLY, WORKED A VERY REAL HARDSHIP ON OUR INSPECTORS. TO PERFORM THEIR TASKS WITHIN THE SPECIFIED TIME, THE MAJORITY WORKED 12 to 16 HOURS DAILY, INCLUDING SATURDAYS AND SUNDAYS. THIS DEVOTION TO DUTY IS LAUDABLE TO SAY THE LEAST AND WE ARE DEEPLY APPRECIATIVE. HOWEVER, WE ARE CONVINCED, PARTICULARLY IN VIEW OF THE RESOUNDING SUCCESS OF THE PROGRAM, THAT WE CAN FIND A LESS COMPLEX MEANS OF ACCOMPLISHMENT.

CURRENTLY, WE ARE THINKING OF CONDUCTING THE PROGRAM ON A REGIONAL BASIS AND, PERHAPS, SEASONALLY IN AN EFFORT TO TOUCH BASES WITH MORE PILOTS AT ONE TIME. FOR EXAMPLE, IN ALASKA, THE IDEAL TIME TO CONDUCT SUCH AN INSPECTION PROGRAM WOULD BE AT THE BEGINNING OF ONE OF THE TWO MAJOR HUNTING SEASONS --- SAY, THE POLAR BEAR SEASON, WHICH BEGINS IN APRIL. AT SUCH TIMES VIRTUALLY THE ENTIRE GENERAL AVIATION COMMUNITY CAN BE FOUND AT AIRPORTS READYING THEIR PLANES AND EQUIPMENT. ANOTHER APPROACH WE ARE CONSIDERING, IS THAT MOST STATES AT SOME TIME DURING THE YEAR CONDUCT THEIR OWN "AVIATION AWARENESS" OR "AVIATION EDUCATION" PROGRAMS. IT WOULD SEEM TO ME BOTH A PRACTICAL AND MUTUALLY BENEFICIAL TIME FOR OUR REGIONAL FLIGHT INSPECTION TEAMS TO CONDUCT LOCAL VERSIONS OF OPERATION GROUND ASSIST IN CONSONANCE WITH STATE AVIATION PROGRAMS.

AT ANY RATE, WE ARE PLANNING OUR WORK AND WORKING OUR PLAN. I HADN'T INTENDED TO TAKE QUITE SO LONG TO DETAIL THIS LATEST ELEMENT OF OUR AVIATION SAFETY PROGRAM, BUT I DID WANT YOU TO KNOW THAT IT WAS NOT, AND IS NOT, A ONE-TIME PROJECT. FOR THOSE FAMILIAR WITH THE PROJECT, I ALSO WANTED TO LET YOU KNOW SOMETHING OF OUR THINKING WITH RESPECT TO OPERATION GROUND ASSIST's CONTINUANCE.

AS TO YOUR WORK IN THE FIELD OF AVIATION SAFETY, THE TITLE OF AIR SAFETY INVESTIGATOR IS ONE FOR WHICH EACH OF US IN THE FAA HAS GREAT RESPECT. IT CONNOTES A MOTIVE FAR BEYOND THE INVESTIGATIVE ASPECTS OF YOUR DUTIES. IT INDICATES AN INTENTION TO PREVENT ACCIDENTS FROM HAPPENING AS WELL AS TO INVESTIGATE THOSE THAT DO HAPPEN. IT DESCRIBES THE AIR SAFETY INVESTIGATOR NOT AS A SPECTATOR SITTING ON THE SIDELINES WAITING TO GO INTO ACTION NOT ONLY AFTER AN ACCIDENT HAS OCCURRED, BUT RATHER AS AN ACTIVE PARTICIPANT IN THE DAY-TO-DAY CHALLENGE OF AVIATION ACCIDENT PREVENTION.

THE CONTRIBUTIONS MADE BY THE SOCIETY OF AIR SAFETY INVESTIGATORS TO THE ADVANCEMENT OF AIR SAFETY, INDIVIDUALLY AND COLLECTIVELY, HAVE EARNED INCREASING RECOGNITION IN THE AVIATION COMMUNITY SINCE YOUR ORGANIZATION WAS FORMED IN 1964. YOUR GOAL IS RECOGNIZED NOT ONLY IN THIS COUNTRY BUT ALSO BY THE INTERNATIONAL COMMUNITY AS WELL. YOUR ORGANIZATION IS TO BE COMPLIMENTED ON THE FACT THAT THERE ARE 30 FOREIGN NATIONS REPRESENTED ON YOUR ROLLS.

WE IN THE FEDERAL AVIATION ADMINISTRATION APPLAUD THIS INTERNATIONAL SPIRIT AND STRONG DEDICATION IN ALL MATTERS RELATING TO AIR SAFETY, FOR IT IS A SUBJECT THAT OVERFLIES THE ARTIFICAL BOUNDARIES OF POLITICS SEPARATING NATIONS.

General Aviation
Manufacturers Association

Suite 1215
1025 Connecticut Ave., N.W.
Washington, D. C. 20036
(202) 296-8848

EMERGING PATTERN OF ACCIDENT PREVENTION

REMARKS OF STANLEY J. GREEN

VICE PRESIDENT

BEFORE THE SOCIETY OF AIR SAFETY INVESTIGATORS

OCTOBER 3, 1974

WHEN I LAST HAD THE PLEASURE TO SPEAK BEFORE THE SOCIETY OF AIR SAFETY INVESTIGATORS AT ITS THIRD ANNUAL SEMINAR IN OCTOBER OF 1972, I SPOKE A BIT ABOUT WHAT GAMA IS AND WHAT WE ARE DOING. I TRUST THAT BY NOW, OUR ACTIVITIES ARE SUFFICIENTLY WELL KNOWN SO THAT I MAY DISPENSE WITH THIS ASPECT. I ALSO COVERED A COMMON AREA OF CONCERN.

AT THAT TIME, I STATED THAT THE MANUFACTURERS OF GENERAL AVIATION AIRCRAFT AND EQUIPMENT HAVE A COMMON CAUSE WITH YOU, THE INVESTIGATORS OF ACCIDENTS, AND THAT CAUSE IS THE PREVENTION OF FUTURE ACCIDENTS. IT WAS BECAUSE OF THIS COMMON CAUSE THAT WE HAVE THE OBLIGATION AND THE NEED TO DEVELOP A BETTER RELATIONSHIP. I SAID THEN THAT WE NEED TO KNOW FROM YOU HOW WE CAN ASSIST EACH OTHER IN OUR COMMON GOAL OF PREVENTING ACCIDENTS BECAUSE, ASIDE FROM THE HUMAN CONSIDERATIONS, WE ARE FACING MONETARY CONSIDERATIONS RESULTING FROM PRODUCT LIABILITY SUITS OF A MAGNITUDE WE HAD NOT EVEN ANTICIPATED FIVE YEARS AGO.

THE LIABILITY SITUATION, SINCE I LAST SPOKE TO YOU, HAS BECOME EVEN WORSE AND OUR EFFORT TO PREVENT ACCIDENTS HAS BECOME MORE AND MORE AN ABSOLUTE NEED OF OUR INDUSTRY -- EVEN THOUGH THE ACCIDENT RATE IMPROVED

SUBSTANTIALLY DURING THIS TIME PERIOD. BUT AS I SAID, THIS IS THE ERA OF THE FANTASTIC CLAIM AND THE SPECTACULAR RECOVERY AND THIS IS THE ERA OF THE CONCEPT OF STRICT LIABILITY ON THE PART OF THE MANUFACTURER OF THE PRODUCT. CLAIMS AND RECOVERIES ARE STILL IN THE ASCENDANCY STAGE. OUR INSURANCE RATES ARE STILL RISING AND IT BECOMES AN ABSOLUTE NECESSITY TO DO WHAT EVER WE CAN TO FURTHER REDUCE THE ACCIDENT RATE. OUR CONCEPTS OF LIABILITY HAVE CHANGED OVER THE PAST TEN YEARS AND THE FACT IS THAT TODAY, THE MANUFACTURER HAS ONLY TWO DEFENSES IN AN ACCIDENT INVOLVING HIS PRODUCT. THESE ARE (1) THE MISUSE OF THE PRODUCT AND (2) THE ASSUMPTION OF RISK. MISUSE HAS COME TO MEAN THE USE OF A PRODUCT FOR OTHER THAN WHAT IT IS INTENDED, SUCH AS USING A SCREWDRIVER TO HAMMER IN NAILS. NEGLIGENCE OF THE PILOT IN HIS OPERATION OF THE AIRPLANE IS NOT GENERALLY USABLE AS A DEFENSE BY THE MANUFACTURER.

ASSUMPTION OF RISK IS NOT A FAILURE TO DISCOVER THE DEFECT OR DANGEROUS ASPECT, BUT RATHER THE DELIBERATE USE OF THE PRODUCT AFTER YOU HAVE DISCOVERED IT.

THIS CURRENT STATE OF LEGAL LIABILITY SIMPLY MEANS THAT FOR EVERY ACCIDENT THAT OCCURS, THE PROBABILITY IS THAT THE MANUFACTURER, ONE WAY OR ANOTHER IS GOING

TO WIND UP IN A LAWSUIT. AND, THOUGH WE MAY WIN, THE EXPENSES OF DEFENSE ARE GREAT.

TO COUNTER WHAT ARE FAIRLY STAGGERING EXPENSES TO THE INDUSTRY, INSURANCE COSTS AS MUCH AS SIX OR SEVEN PERCENT OF THE GROSS SALE PRICE OF THE PRODUCT, THE INDUSTRY INSTITUTED WHAT IS CALLED "LEGAL QUALITY CONTROL," ENCOMPASSING ALL ASPECTS OF THE DESIGN, MANUFACTURE AND SALE OF THE PRODUCT. LEGAL QUALITY CONTROL INVOLVES ALMOST EVERY WRITTEN OR SPOKEN REPORT OF ACCIDENTS, INCIDENTS, MALFUNCTIONS OR FAILURES THAT INVOLVED THE PRODUCT. OUR COMPANIES MUST ACCOUNT FOR EVERYTHING EVERY ACCIDENT INVESTIGATOR HAS SAID ABOUT THE PRODUCT AND DOCUMENT THE ACTIVITIES WE HAVE TAKEN IN RESPONSE TO THESE STATEMENTS.

OUR MEMBER COMPANIES HAVE ADOPTED THE PRACTICE OF APPOINTING SPECIFIC PEOPLE WITHIN THE COMPANIES TO WORK WITH THE GOVERNMENT ACCIDENT INVESTIGATORS WHENEVER ANY POSSIBLE PRODUCT MALFUNCTION OR FAILURE WAS EVEN SLIGHTLY SUSPECTED OF BEING A CAUSE OF AN ACCIDENT. BUT ALL THIS IS HINDSIGHT. WE DO WHAT WE CAN, BASED UPON THESE ACCIDENT ANALYSES, TO PREVENT FUTURE ACCIDENTS, BUT WE MUST CONTINUE AN AFFIRMATIVE PROGRAM TO ELIMINATE ACCIDENTS. IF WE CAN REACH THE POINT,

WHERE YOUR JOBS ARE OBSOLETE, GENERAL AVIATION, AS WELL AS ALL AVIATION, WILL BE IN THE GOLDEN AGE OF PROSPERITY. THE AIRCRAFT OPERATOR WHO DOES NOT BECOME INVOLVED IN AN ACCIDENT BECAUSE HE HAS ENJOYED A SAFE FLIGHT, IS A CUSTOMER FOR A NEW AIRCRAFT AND IS NO LONGER A POTENTIAL PLAINTIFF IN A SUIT AGAINST THE MANUFACTURER. SAFETY IS THE KEYSTONE TO THE UTILIZATION AND ACCEPTANCE OF GENERAL AVIATION. TRANSPORTATION BY GENERAL AVIATION WOULD CEASE TO BE VIABLE IF IT WERE PLAGUED BY ACCIDENTS.

THOUGH THE ACCIDENT RATE IN GENERAL AVIATION IS IMPROVING, ALL OF US WANT TO SEE THE RATE CONTINUE IN THE DOWNWARD TREND. IT IS NO COMFORT TO US THAT MORE PEOPLE ARE KILLED ANNUALLY AT GRADE CROSSINGS, IN PLEASURE BOATS, OR ON MOTORCYCLES THAN IN GENERAL AVIATION AIRPLANES, BUT THE COMPARISON PLACES THE GENERAL AVIATION ACCIDENT RECORD IN PERSPECTIVE. WE MUST NOT, AND WILL NOT, STAND ON PAST PROGRESS. WE MUST CONTINUE TO ADVANCE THE CAUSE OF SAFETY.

YOU HAVE HEARD, IN THE PAST TWO DAYS, ABOUT A NUMBER OF PROGRAMS DESIGNED TO REDUCE THE ACCIDENT TOLL. A MAJOR CONTRIBUTING FACTOR TO MANY ACCIDENTS IS WEATHER AND MUCH IS BEING DONE TO IMPROVE THE

QUALITY AND ACCESSABILITY OF BETTER WEATHER INFORMATION. GAMA, ALONG WITH OTHER GENERAL AVIATION ORGANIZATIONS, IS ACTIVELY WORKING WITH THE NATIONAL WEATHER SERVICE AND THE FAA IN THE EFFORT TO PROVIDE IMPROVED WEATHER INFORMATION. BUT WHAT DO YOU DO FOR THE PILOT WHO MAKES NO EFFORT TO FIND OUT WHAT THE WEATHER IS, OR IS EXPECTED TO BE, AT HIS DESTINATION. YOU'VE HEARD ABOUT THE MOST EXCELLENT NASA STALL/SPIN STUDY, IN WHICH GAMA IS PARTICIPATING ALONG WITH FAA. WE EXPECT THAT THE KNOWLEDGE LEARNED FROM THIS PROGRAM WILL MATERIALLY ADVANCE THE DESIGNS OF OUR FUTURE AIRCRAFT. BUT WHAT DO YOU DO FOR THE PILOT WHO IGNORES THE PROHIBITION AGAINST SPINS FOR HIS TYPE OF AIRCRAFT AND DELIBERATELY SPINS THE AIRCRAFT OR THE PILOT WHO IGNORES A PROHIBITION AGAINST ONE ENGINE OUT STALLS BELOW 5,000 FEET AND PURPOSELY PULLS ONE BACK DURING A TRAINING FLIGHT AT LESS THAN 1,000 FEET.

FOR THESE PEOPLE, IT IS DOUBTFUL THAT ANYTHING CAN BE DONE TO THE AIRCRAFT TO PREVENT THEM FROM BECOMING INVOLVED IN AN ACCIDENT. WE DO NOT BELIEVE, HOWEVER, THAT THERE IS NOTHING THAT CAN BE DONE. IF THE PILOT IS THE PRIME CAUSAL FACTOR OF THE ACCIDENT, WE MUST MODIFY THE PILOT -- NOT BY OUR USUAL MEANS OF ENGINEERING

DESIGN STUDIES, PROTOTYPE CONSTRUCTION, WIND TUNNEL TESTS, FLIGHT TEST PROGRAMS AND FINALLY, PRODUCTION LINE CHANGES -- BUT THROUGH EDUCATION.

MORE AND MORE THE MANUFACTURERS HAVE COME TO THE REALIZATION THAT, TO REDUCE OR ELIMINATE THE BULK OF THE ACCIDENTS, WE MUST IMPROVE - EDUCATE - THE PILOT.

DURING THE PAST TEN YEARS, MORE THAN ONE MILLION AMERICANS HAVE BEEN ISSUED STUDENT PILOT CERTIFICATES. WE MUST ENSURE THAT THESE PEOPLE BECOME EDUCATED, THINKING PILOTS. QUALITY INSTRUCTION IS AN ABSOLUTE NECESSITY AND, TO THIS END, GAMA WORKED WITH FAA IN THE EFFORT TO IMPROVE THE REQUIREMENTS IN PARTS 61 AND 141 OF THE FEDERAL AVIATION REGULATIONS.

THE MANUFACTURERS HAVE INTRODUCED NEW AND IMPROVED PILOT TRAINING PROGRAMS, UTILIZING THE MOST MODERN TEACHING METHODS AVAILABLE, LEADING TO PRIVATE, COMMERCIAL, AND INSTRUMENT CERTIFICATES. NEW PROGRAMS TO IMPROVE THE PROFICIENCY OF THOSE ALREADY FLYING ARE BEING IMPLEMENTED IN CONJUNCTION WITH FAR PART 61. THESE PROGRAMS, AS WELL AS EFFORTS LONG UNDERWAY BY THE AIRCRAFT OWNERS & PILOTS ASSOCIATION AND OTHER USER ORGANIZATIONS, ARE SHOWING POSITIVE RESULTS. PARTICULARLY WITH RESPECT TO THE MORE COMPLEX GENERAL

AVIATION AIRPLANES, MORE AND MORE COMPANIES ARE PROVIDING, AS PART OF THE SALES PRICE OF THE AIRCRAFT, BOTH FLIGHT AND MECHANIC INSTRUCTION IN THE SPECIFIC AIRCRAFT. THESE PILOT SCHOOLS ARE ALSO OPEN TO THE PURCHASER OF A USED AIRCRAFT, TO A NEW PILOT IN AN ORGANIZATION THAT OWNS ONE OF THE AIRCRAFT, OR AS REFRESHER COURSES. THE COURSES ARE BEING GIVEN MORE FREQUENTLY AND ARE TAILORED TO FIT THE NEEDS OF THE PILOT STUDENT. A NUMBER OF COURSES ARE TAUGHT OVER WEEKENDS. WE BELIEVE THAT THE OVERALL EFFECT OF THE NEW IMPROVED TRAINING PROGRAMS WILL BE AN IMPROVED SAFETY RECORD.

WE MUST CONSTANTLY REENFORCE THE KNOWLEDGE AND EXPERIENCE THAT THE PILOT HAS ACQUIRED. THE FAA'S BIANNUAL PROFICIENCY CHECK IS ONE MEANS BY WHICH THIS REENFORCEMENT PROCESS CAN BE ACCOMPLISHED. ANOTHER IS THE FAA'S ACCIDENT PREVENTION SEMINARS. THESE SEMINARS HAVE THE CAPABILITY OF REACHING THOUSANDS OF PILOTS, WITH USEFUL, CURRENT TOPICS OF INTEREST A NUMBER OF TIMES EACH YEAR. THE SEMINARS CAN COVER THE GAMUT OF PROBLEMS, INCLUDING WEATHER, FLIGHT PLANNING, ENGINE OPERATING TIPS AND THE LIKE, THAT ARE REFLECTED IN THE NTSB ACCIDENT REPORTS CITING PILOT ERROR IN OVER 80% OF ALL ACCIDENTS.

In response to these findings, GAMA made an all-out effort to reach the general aviation pilot community through support of the FAA-General Aviation Accident Prevention Program. We encouraged GAMA dealers and distributors to hold FAA safety seminars and clinics. In addition, representatives of GAMA companies participated in many of these programs. We also helped publicize and promote the FAA effort. To encourage attendance, GAMA offered 103 prizes, topped by a $30,000 airplane of the winner's choice.

During the period of time in which the program was conducted, June 1, 1972 to June 1, 1973, over 206,000 pilots attended 1600 safety clinics. The most impressive result of the effort was that during this program, the number of general aviation accidents decreased by 12% while the number of fatalities dropped by 5%. At the same time, FAA estimated that the total number of flying hours increased by 12%.

The FAA Accident Prevention Program may not deserve all the credit for this 22% reduction in the accident rate but surely someone must have done something right. The winner of the $30,000 airplane did something right by attending a clinic.

In the fifteen months of the Accident Prevention Program since the end of the GAMA sponsorship and the final drawing for an airplane, we have seen the curve flatten out and there are some indications that the accident rate is again increasing. Though GAMA's original objective was to publicize the accident seminars, and we thought we had done so and could get out of the direct line, we are considering getting back in. While the details have not yet been formulated nor has any formal announcement been made, the GAMA Board will consider, at its November meeting, sponsoring another airplane sweepstakes for the purpose of promoting the FAA accident prevention seminars. In order to better educate at these seminars -- in order that there be new useful material which will further provide a drawing card to the pilot population -- GAMA is also considering the development of some new programs, (films and film strip/lectures) done in a professional manner by a university or similar organization.

We all appreciate the heterogeneous nature of the general aviation fleet and the types of flying that are involved. Over 120 models of aircraft are currently being produced by U.S. manufacturers. These range from

LIGHT SINGLE-ENGINE TRAINERS TO INTERCONTINENTAL JETS FLYING AT AIRLINE SPEEDS. THE TYPES OF FLYING AND THE PROFICIENCY OF THOSE WHO FLY ALSO VARY WIDELY. FOR EXAMPLE, A SINGLE-ENGINE AIRCRAFT CAN BE FULLY EQUIPPED TO OPERATE IN HIGH-DENSITY AREAS AND BE FLOWN BY A HIGHLY PROFICIENT PILOT. THE SAME MODEL OF AIRCRAFT MAY OPERATE FROM A SMALL OUT-OF-THE-WAY PRIVATE AIRPORT WITH A STUDENT PILOT AND AN INSTRUCTOR.

IN ORDER TO HELP ACCOMMODATE THOSE PILOTS WHO FLY A PARTICULAR AIRCRAFT AND THOSE WHO FLY DIFFERENT TYPES OF AIRCRAFT TO THE INFORMATION THEY MUST KNOW ABOUT THE AIRCRAFT BEING FLOWN, GAMA IS ESTABLISHING A SPECIFICATION FOR WRITING PILOTS OPERATING MANUALS. IN THE PAST, PILOTS' OPERATING HANDBOOKS, WHETHER THEY WERE CALLED OWNERS' MANUALS, OPERATING MANUALS, OR SOMETHING ELSE, HAVE BEEN CRITICIZED FOR LACK OF UNIFORMITY AND FOR CONTAINING TOO MUCH OR TOO LITTLE INFORMATION. OUR WAY TO A BETTER SAFETY RECORD IS THROUGH EDUCATION AND THIS NEW, SOON-TO-BE ISSUED, SPECIFICATION WILL MAKE IT EASIER FOR THE PILOT TO LEARN. IN ACCORDANCE WITH THE SPECIFICATION, MATERIAL WILL BE IN THE SAME PLACE FOR ALL AIRCRAFT TYPES. AIRPLANE ENDURANCE, NO MATTER WHOSE AIRPLANE IT IS, WILL BE COMPUTED IN THE SAME MANNER. SPEEDS, RATES

OF CLIMB, TAKEOFF AND LANDING DISTANCES, AND ALL OTHER PERFORMANCE INFORMATION, WILL BE COMPUTED IN THE SAME MANNER SO THAT A PILOT WITH EXPERIENCE IN ONE AIRCRAFT TYPE WILL HAVE A "FEEL" AS TO WHAT ANOTHER AIRCRAFT CAN DO WHEN HE READS THE MANUAL FOR THAT OTHER AIRCRAFT.

THE PILOT OPERATING HANDBOOK SPECIFICATION WAS DEVELOPED TO ENSURE THAT A HANDBOOK MEETING THE SPECIFICATION PROVIDES MAXIMUM USEFULNESS AS AN OPERATING REFERENCE BOOK FOR THE PILOT. COMPLIANCE WITH THE SPECIFICATION WILL RESULT IN A VERY HIGH DEGREE OF STANDARDIZATION, BY PROVIDING UNIFORMITY OF ARRANGEMENT, DEFINITIONS AND PERFORMANCE INFORMATION. THE ARRANGEMENT OF THE HANDBOOK IS INTENDED TO ENHANCE THE INFLIGHT USEFULNESS OF THE BOOK. FOR EXAMPLE, THE SECTIONS ON LIMITATIONS AND EMERGENCY PROCEDURES ARE PLACED AHEAD OF THE SECTION ON NORMAL PROCEDURES, PERFORMANCE, AND OTHER SECTIONS, TO PROVIDE EASIER ACCESS FOR THE INFORMATION THAT MAY BE REQUIRED IN FLIGHT. THE EMERGENCY PROCEDURES SECTION WILL HAVE A RED PLASTICIZED TAB.

THE UNITS USED ARE THOSE THAT ARE MOST USEFUL TO THE PILOT. CALIBRATED AIRSPEED, FOR INSTANCE, IS USED ONLY WHERE IT IS NECESSARY TO COMPLY WITH THE FEDERAL AVIATION REGULATIONS, BECAUSE THE PILOT, AS

YOU WELL KNOW, OPERATES EXCLUSIVELY WITH INDICATED AIRSPEED. WE HAVE ALSO STANDARDIZED ON THE USE OF KNOTS THROUGHOUT THE SPECIFICATION. WE HAVE AVOIDED USING DERIVED TERMS, SUCH AS DENSITY ALTITUDE. CHARTS AND TABLES HAVE BEEN CONSTRUCTED SO THAT THEY MAY BE USED WITH DATA DIRECTLY AVAILABLE TO THE PILOT, SUCH AS PRESSURE ALTITUDE AND TEMPERATURE.

THIS DRAFT SPECIFICATION CONTAINS LITTLE, IF ANYTHING, NEW. IT IS A GUIDE TO INDUSTRY STANDARDIZATION OF PROVEN CONCEPTS, AND IT IS IN A FORM THAT IS GOING TO BE MOST USEFUL TO THE PILOT. IT WILL ENABLE THE PILOT TO KNOW HIS AIRCRAFT BETTER AND WILL CONTRIBUTE TO ACCIDENT PREVENTION. THE MANUAL WILL BE AVAILABLE BEFORE THE END OF THE YEAR. THE MANUFACTURERS WILL USE IT -- IN FACT, SOME ARE ALREADY AT WORK PREPARING THEIR 1976 MODEL HANDBOOKS IN THE NEW FORMAT.

THE GENERAL AVIATION AIRCRAFT IS A PRODUCT OF PROVEN DESIGN. IT IS RELIABLE AND IS SUBJECTED TO EXTENSIVE GOVERNMENT SUPERVISION DURING ITS DESIGN, MANUFACTURE, AND OPERATION. THE GENERAL AVIATION AIRCRAFT IS THOROUGHLY TESTED AND IS CONSTANTLY EVALUATED AND REEVALUATED. IT HAS UNDERGONE A SERIES OF CONTINUOUS REFINEMENTS TO INCREASE SAFETY OF FLIGHT AND WILL CONTINUE TO BE REFINED AND IMPROVED.

THE NASA/FAA CRASHWORTHINESS PROGRAM IN WHICH GAMA IS PARTICIPATING, IS BUT ONE EXAMPLE OF POTENTIAL IMPROVEMENTS VISIBLE ON THE HORIZON. THOUGH FURTHER DEVELOPMENT AND IMPROVEMENT TO THE AIRCRAFT WILL CONTINUE UNABATED, IT IS GAMA'S BELIEF THAT THE GREATEST REDUCTION IN THE ACCIDENT RATE WILL COME ABOUT THROUGH BETTER EDUCATION OF THE PILOT. IT IS TO THIS END THAT GAMA'S COLLECTIVE EFFORTS IN ACCIDENT PREVENTION ARE DIRECTED. I'VE CONFINED MY REMARKS TO JUST A FEW OF THE ACTIVITIES THAT ARE BEING UNDERTAKEN ON AN INDUSTRY WIDE BASIS THOUGH I'M SURE YOU RECOGNIZE THAT EACH MANUFACTURER HAS HIS OWN SAFETY IMPROVEMENT PROGRAM. EDUCATION IS THE KEY TO ACCIDENT PREVENTION.

THANK YOU.

ACCIDENT INVESTIGATION INFORMATION DISSEMINATION

PRESENTED TO
THE SOCIETY OF AIR SAFETY INVESTIGATORS
FIFTH ANNUAL INTERNATIONAL SEMINAR

OCTOBER 3, 1974
WASHINGTON, D. C.

BY

DAVID R. KELLEY
CHIEF, INFORMATION SYSTEMS BRANCH
BUREAU OF AVIATION SAFETY
NATIONAL TRANSPORTATION SAFETY BOARD

ACCIDENT INVESTIGATION INFORMATION DISSEMINATION

IT IS INDEED A PRIVILEGE AND A PLEASURE TO TALK TO THIS DISTINGUISHED GROUP OF SASI MEMBERS AND GUESTS ATTENDING THE FIFTH ANNUAL INTERNATIONAL SEMINAR. I WILL BE DISCUSSING WITH YOU, THE AVAILABILITY, DISSEMINATION, AND USE OF AIRCRAFT ACCIDENT INFORMATION AS A TOOL IN ACCIDENT PREVENTION - AND THEREBY I HOPE, IN A SMALL WAY, TO CONTRIBUTE TO YOUR SEMINAR THEME OF "ACCIDENT PREVENTION THROUGH INVESTIGATION". TOWARD THIS GOAL, I WILL BE DESCRIBING HOW WE, AT THE NATIONAL TRANSPORTATION SAFETY BOARD, DO BUSINESS, WHAT WE HAVE AVAILABLE, AND HOW WE CAN BE OF ASSISTANCE TO YOU.

THE INCIDENCE OF AIRCRAFT ACCIDENTS IS A FUNCTION OF EXPOSURE TO HAZARD. THE HAZARD MAY BE RELATED TO SUCH BROAD CATEGORIES AS MAN, MACHINE, AND ENVIRONMENT. CONTINUAL EXPOSURE TO THESE HAZARDS INCREASES THE PROBABILITY OF INVOLVEMENT IN AN ACCIDENT.

I SUGGEST THAT HERE LIES THE SUBSTANCE OF ACCIDENT PREVENTION; THAT IS, THE IDENTIFICATION OF THESE HAZARDS - WHETHER THEY BE THE SPECIFICS OF HUMAN FAILURE, THE DEFICIENCIES IN MACHINES, OR THE IMPACT AND INVOLVEMENT OF THE ENVIRONMENT -- AND THE SUBSEQUENT SYSTEMATIC PURSUIT OF REMEDIAL ACTION TO MINIMIZE, REDUCE, OR ELIMINATE THE HAZARD.

FOR THE VERY PURPOSE OF ACCIDENT PREVENTION, THE SAFETY BOARD HAS, IN USE, AN AUTOMATED AIRCRAFT ACCIDENT AND INCIDENT INFORMATION SYSTEM. THE PURPOSE OF THIS COMPUTERIZED SYSTEM IS TO MAINTAIN, RETRIEVE, ANALYZE, PRINT, AND DISSEMINATE AIRCRAFT ACCIDENT INFORMATION. THIS SYSTEM WAS IMPLEMENTED IN 1964 AND CONTAINS AN INDIVIDUAL RECORD OF EACH U. S. CIVIL AVIATION AIRCRAFT ACCIDENT BY CALENDAR YEAR TO DATE. AT AN ANNUAL OCCURRENCE RATE OF SOME 4 - 5,000 ACCIDENTS, WE PRESENTLY HAVE ACCUMULATED INFORMATION ON NEARLY 55,000 OCCURRENCES. THINK OF THIS! 55,000 RECORDS OF COMPREHENSIVE ACCIDENT INFORMATION. WHAT SHALL WE CALL IT? ACCUMULATED EXPERIENCE, TRACK RECORD, OR KNOWN PRECEDENT; REGARDLESS, THIS REPRESENTS A WEALTH OF INFORMATION THAT IS AVAILABLE FOR THE PURPOSE OF ACCIDENT PREVENTION.

WE HAVE INSISTED FROM THE BEGINNING AND WE CONTINUE TO STRIVE TOWARD THE PRECEPT THAT THIS DATA MUST BE DEVELOPED, DOCUMENTED, AND STORED IN A LOGICALLY INDEXED, WELL DEFINED AND STANDARDIZED FORMAT, AND RETRIEVABLE

IN PLAIN ENGLISH LANGUAGE (IN CONTRAST TO CODED DATA). THE NTSB MANUAL OF CODE CLASSIFICATIONS IS THE "BIBLE" FOR IMPLEMENTING AND MAINTAINING THIS INFORMATION STANDARDIZATION. THIS MANUAL CONTAINS THE 285 DATA FIELDS OF CODED AND DIRECT ENTRY INFORMATION THAT MAY BE RECORDED FOR AN ACCIDENT. FOR THOSE CODED DATA FIELDS, THE MANUAL CONTAINS THE PLAIN LANGUAGE DESCRIPTION THAT THE CODE STANDS FOR --- SOME 2,500 IN THE TOTAL SYSTEM. SOME DATA FIELDS ARE MANDATORY -- TYPE OF ACCIDENT, PHASE OF OPERATION, CAUSAL/FACTORS, INJURIES, AIRPORT PROXIMITY, PILOT DATA, AND ARE RECORDED ON ALL ACCIDENTS; WHILE THE REMAINING DATA FIELDS ARE CONSIDERED CONDITIONALLY MANDATORY AND ARE DOCUMENTED IF PERTINENT TO THE ACCIDENT. SUCH CONDITIONAL FIELDS MIGHT CONTAIN DATA RELATING TO FIRE, WEATHER, AIRPORT AIDS, AERIAL APPLICATION OPERATIONS, OR MIDAIR COLLISIONS.

THE NTSB AIR SAFETY INVESTIGATOR IS THE KEY AGENT INSTRUMENTAL IN DEVELOPING AND ENTERING ACCIDENT DATA INTO THIS SYSTEM. HE IS INTIMATELY FAMILIAR WITH THE CONTENTS OF THE MANUAL OF CODE CLASSIFICATIONS, AND HE IS FULLY AWARE OF THE REQUIREMENTS FOR STORING ACCIDENT INFORMATION. SO FROM THE ONSET OF HIS INVESTIGATION, HE IS ORIENTED AND GEARED TO DEVELOPING, DOCUMENTING, AND RECORDING SPECIFIC INFORMATION TO ENTER INTO THE AUTOMATED SYSTEM. THE INVESTIGATOR USING A CHECKLIST OF THE DATA SYSTEM REQUIREMENTS, PRODUCES A MORE THOROUGH AND COMPLETE INVESTIGATION; AND THE INFORMATION HE DEVELOPS IS IN A LOGICAL, INDEXED AND STANDARDIZED FORMAT.

IN CONJUNCTION WITH THE DATA BASE I HAVE JUST DESCRIBED, WE HAVE DEVELOPED AND ACTIVELY USE A SERIES OF COMPUTER PROGRAMS TO MAINTAIN AND DISSEMINATE THIS ACCIDENT INFORMATION. THESE PROGRAMS ARE COMPLEX AND DIVERSIFIED. SUFFICE TO SAY THESE COMPUTER PROGRAMS ARE DESIGNED TO INTERROGATE, CROSS INDEX, COMPUTE, AND PRINT THE ACCIDENT INFORMATION.

NOW, I WOULD LIKE TO FOCUS ON WHAT I BELIEVE IS THE MOST IMPORTANT PART OF THE AUTOMATED SYSTEM; THAT IS, THE DISSEMINATION AND USE OF THIS ACCIDENT DATA FOR THE PURPOSE OF ACCIDENT PREVENTION. ALL OF OUR EFFORTS INVOLVING INVESTIGATION, DOCUMENTATION, AND COMPUTERIZATION ARE FOR NAUGHT IF WE DON'T PUT THIS DATA TO GOOD USE. WE, AT NTSB, EXPEND CONSIDERABLE RESOURCES-BOTH MANPOWER AND FINANCIAL-TO DEVELOP, MAINTAIN, AND DISSEMINATE THIS ACCIDENT INFORMATION. WE ENCOURAGE ITS USE!

HOW DO WE DO IT? WE TRY TO PROVIDE THE BEST POSSIBLE INFORMATION TO THE RIGHT PERSON OR AGENCY WHO IN TURN CAN PUT IT TO USE. OUR PHILOSOPHY IS SIMPLY THIS: UTILIZE AND EXPLOIT THIS MASS OF COMPREHENSIVE ACCIDENT INFORMATION TO IDENTIFY AND DEFINE HAZARDS AND THEN SEEK REMEDIAL ACTION AND RESOLUTION OF THESE HAZARDS THROUGH EVERY MEANS AT YOUR DISPOSAL.

AS YOU MIGHT EXPECT, WE ARE A PRINCIPLE USER OF THIS INFORMATION IN-HOUSE. SOME EXAMPLES OF OUR USE INCLUDE:

1. SUPPORT CURRENT INVESTIGATIONS WITH BACKGROUND INFORMATION ON SIMILAR OCCURRENCES.
2. PROVIDE ACCIDENT HISTORY IN SUPPORT OF SAFETY RECOMMENDATIONS. (HOW SERIOUS IS THE PROBLEM?)
3. PREPARE RECURRENT ACCIDENT DATA PUBLICATIONS AND SPECIAL STUDIES. (ANNUAL PUBLICATIONS, STALL/SPIN AND ENGINE FAILURE/MALFUNCTION STUDIES.)

WE RESPOND, WITHIN THE LIMITS OF OUR STAFF AND BUDGET, TO REQUESTS FROM OUTSIDE THE SAFETY BOARD, SUCH AS:

1. OTHER GOVERNMENT AGENCIES INCLUDING FAA AND NASA
2. FOREIGN GOVERNMENTS
3. AIRCRAFT AND ENGINE MANUFACTURERS
4. ALPA, ATA, AOPA, NBAA, FSF

AND FINALLY, THE SAFETY BOARD MAKES THE TOTAL AUTOMATED ACCIDENT INFORMATION SYSTEM AVAILABLE FOR PURCHASE. THIS INCLUDES THE HISTORICAL FILES OF ACCIDENT INFORMATION, THE COMPUTER PROGRAMS TO MANAGE THE DATA, AND DOCUMENTATION ON HOW TO USE THE TOTAL SYSTEM. AT $4[illegible] TAPE AND CONSIDERING WHAT YOU GET, IT'S A GOOD EXCHANGE. SO IF YOUR OPERATION OR AGENCY HAS ACCESS TO A COMPUTER FACILITY, THEN WE ENCOURAGE YOU TO PURCHASE THE COMPLETE SYSTEM. YOU WILL THEN HAVE THE SAME POTENTIAL AND CAPABILITY AS WE IN TERMS OF RETRIEVING AND UTILIZING ACCIDENT INFORMATION. YOU MIGHT BE INTERESTED TO HEAR SOME OF THE ORGANIZATIONS/COMPANIES THAT HAVE TAKEN US UP ON THIS OFFER. VERY QUICKLY THEY INCLUDE:

AUSTRALIA, NEW ZEALAND, FEDERAL REPUBLIC OF GERMANY, FAA, ALPA, AOPA, UNIVERSITY OF SOUTHERN CALIFORNIA, STANFORD UNIVERSITY, PIPER, CESSNA, GURMMAN, NORTH AMERICAN ROCKWELL, FOREMOST INSURANCE COMPANY, MCDONNELL DOUGLAS, BOEING AND OTHERS. - WE ENCOURAGE AND WELCOME OTHERS.

ON THE INTERNATIONAL LEVEL, WE HAVE BEEN WORKING THE PAST TWO YEARS WITH THE INTERNATIONAL CIVIL AVIATION ORGANIZATION TOWARD DEVELOPING AN INTERNATIONAL AUTOMATED SYSTEM FOR REPORTING AND STORING ACCIDENT INFORMATION. HERE AGAIN IT IS MANDATORY TO ESTABLISH COMPATIBILITY IN EXPRESSION, STANDARDIZATION AND LOGIC TO ASSURE THAT THE INFORMATION IS SIGNIFICANT AND USEFUL. DURING THE RECENT JUNE AIG MEETING IN MONTREAL, THE DELEGATES ADOPTED A SYSTEM FOR STANDARDIZING AND REPORTING ACCIDENT DATA TO ICAO. WE REALIZE THAT CONSIDERABLE WORK REMAINS TO BE DONE, INCLUDING FINAL APPROVAL BY STATES; HOWEVER, WE BELIEVE IT WILL BE WELL WORTH IT WHEN THE DAY ARRIVES THAT ICAO HAS A REPOSITORY OF AIRCRAFT ACCIDENT INFORMATION REPORTED ON A WORLD WIDE BASIS.

IN CONCLUSION, I WOULD LIKE TO EMPHASIZE THAT THE OLD ADAGE OF <u>EXPERIENCE IS A GREAT TEACHER</u>, HOLDS TRUE IN AVIATION - ONLY - IF WE APPLY THESE LESSONS LEARNED TO AN ACTIVE AND PRODUCTIVE ACCIDENT PREVENTION PROGRAM. I'M SURE MANY OF YOU HERE HAVE HEARD JERRY LEDERER SAY OVER AND OVER AGAIN, "LEARN FROM THE MISTAKES OF OTHERS, YOU WON'T LIVE LONG ENOUGH TO MAKE THEM ALL YOURSELF. WE AT THE NATIONAL TRANSPORTATION SAFETY BOARD, STAND READY TO ASSIST YOU THROUGH THE DISSEMINATION AND USE OF AIRCRAFT ACCIDENT INFORMATION.

THE COMPUTER TECHNOLOGY TO STORE, RETRIEVE, AND PRINT ACCIDENT INFORMATION IS AVAILABLE, THE ACCIDENT EXPERIENCE HAS BEEN ACCUMULATED; THE RESPONSIBILITY NOW RESTS WITH EACH OF US TO WORK TOWARD A GREATER EXCHANGE AND A MORE PRODUCTIVE USE OF THIS INFORMATION.

THANK YOU

SPIN TRAINING - STALL SPIN ACCIDENTS

by

R. BUSCH

Since the end of World War II, there have been many studies concerning spin training and associated accidents. Some studies concluded that the reason for the many spin/mush type accidents was the design of aircraft; others claim that improper flight instruction caused the spinning accidents. Others concluded that aircraft design induced pilot error was the cause. The National Transportation Safety Board, the FAA and numerous other Government organizations have conducted extensive studies related to spin training accidents but, to date, all of these studies have varied opinions as to the main factors causing the accidents.

During the postwar period, 1945 - 1948, approximately 48% of all fatal general aviation accidents were attributed to some type of spin/mush accident. These figures are based on a National Transportation Safety Board study conducted in 1967 through 1969. The report also indicated that 24% of all the accidents occurring during the study period were spin related accidents. Though the accident percentages have been reduced considerably in recent years, almost 22% of all fatal accidents are stall spin related. This would indicate that the stall spin fatal accidents prove out a need for improvement. The big question is where? Should it be the design concept of the aircraft, the training for instructors, the training for students, the regulations governing certification, the stall warning indicators, new designs in spin recovery equipment, or aircraft that are incapable of spinning?. Just where do we start? That seems to be the big question.

I feel that there are a number of areas in which we could improve the man, the machine and the training. For example, the training required for private pilot does not require any type of spin training demonstration. Yet, there is an ever present possibility that the inexperienced pilot, while practicing power-off stalls in attempting to maintain directional control with ailerons exclusively, will enter an unbalanced flight condition which can progress very rapidly into an incipient spin. With power-off approach to landing, stalls can also degenerate into a spin. Aircraft turning from a base leg onto final approach when experiencing a tail wind on the base leg sometimes overshoot the turn to final approach and attempt to tighten the turn to relocate on final approach. Many a spin accident takes place because of this forced over-correction in attempting to line back up with the runway. It might be suggested in the training phase of the student pilot that he receive spin demonstration and spin recovery.

With respect to flight instructors, they are required to demonstrate all different types of stalls and to be capable of instructing students in the proper way to conduct these stalls. Yet, the only exposure the flight instructor receives to spins is a demonstration on approach to spin entry techniques by another flight instructor. If this training is minimal, and the flight instructor that has received this training attempts to pass it on to another flight instructor, eventually the instruction will deteriorate. A possible remedy to this would be specific time requirements for the flight instructor applicant to show a log book entry of one or more hours of spin training and this training written off by his instructor pilot as to his being qualified to recover and to demonstrate spins. This would preclude the necessity for the FAA to ride each flight instructor on the spin demonstrations.

Multi-engine training has been revised over the last few years to discontinue single-engine stalls. The apparent reason for this discontinuance is the number of stall spin accidents which have occurred as a result of multi-engine training. These situations might, in fact, be called design induced problems. That is not to say that the manufacturer of the equipment did not fulfill the FAR 23 requirements but, rather, the possibility exists that the requirements were not stringent enough to prevent a spin condition that was not recoverable. A possible solutionto this is a revision of Part 23-221 to a more realistic flight envelope. It is my understanding that the FAA is currently receiving proposals for the changes in Part 23 to more closely reflect this envelope.

Single-engine aircraft today, in any normal category, must be able to recover from a one-turn spin or a three-second spin, whichever takes longer. The normal category airplane must recover from this situation with no more than one additional turn with the controls used in a normal manner for recovering from a spin. This must take place both with the flaps retracted and extended, without exceeding the positive limit maneuvering load factor. There also can be no excessive back pressure during a spin recovery and it must be impossible to attain an uncontrollable spin in this configuration. For flaps extended condition, the flaps may be returned to during the recovery procedure.

Now take a fairly new, low-time private pilot who has received prescribed stall training which includes the recommended full-power recovery technique. Put him in a normal category airplane at an altitude that would allow for spin practice and imagine how many turns this new pilot would experience before he was able to recover if he entered a spin by mistake, then added full power, presuming that he had entered a [illegible] only. I am told that some aircraft in a spin for more than one or two turns begin to increase the rate of turn and begin to tighten up a bit, so this could pose a serious problem for an inexperienced pilot. Imagine that same pilot with spin demonstration and spin recovery training in an aircraft that has the requirements for aerobatic category. This is to say that the airplane must recover from any point in a spin in not more than one and one-and-one-half additional turns after normal recovery application of the controls. Also prior to normal recovery application of the controls, the spin test will have proceeded for six turns or three seconds, whichever takes longer, with flaps retracted, and one turn or three seconds, whichever takes longer, with flaps extended. However, beyond three seconds the spin may be discontinued when spiral characteristics appear with flaps retracted. I personally believe that the inexperienced pilot would have a better chance of recovering in the aircraft with the aerobatic spin test capability.

Multi-engine aircraft, because of the size and weight, would have difficulty meeting the aerobatic category without possibly damaging some of the electromechanical components. However, in a study conducted by the National Transportation Safety Board, Report No. NA-69-35, Evaluation of Improved Stall Warning Equipment, it was found that alerting a pilot of imminent stall through a stick shaker was 99% effective and that a horn that beeped or was intermittent was about 84% effective, while the continuous stall warning horn or continuous oral sound was only 64% effective. This report felt that the main advantage of the stick shaker was that the pilot was receiving the vibrating information directly and, therefore, was more inclined to make the correction for the impending stall. The investigation and possible changes of the stall warning indicators for large twin-engine aircraft under the 12,500 lb. category certainly bears looking into by the various government agencies and manufacturers.

I have noticed in flight instructing over the years that an applicant for a multi-engine rating, or for complex-type aircraft in a checkout never flies with the aircraft at maximum certificated gross weight. Many single and twin-engine aircraft capable of carrying six and even ten passengers assume an entirely different handling characteristic on takeoff, slow flight and landings. It might be appropriate in the training phase to have an airplane loaded to gross weight to reflect the change in handling characteristics of this heavier equipment.

The problems of stall spin accidents will be with us for a long time. The reduction of this type of accident can only be accomplished by a concerted effort by both the manufacturers and government agencies interested in the reduction of this type of accident. Within the next few years, with the airworthiness review going on and the many varied efforts that manufacturers are making, the goal to reduce these stall spin accidents will be reached.

BY

WILLIAM R. STANBERRY

Members of the panel, ladies and gentlemen:

The theme, the thrust, the purpose of this meeting of The Society of Air Safety Investigators is aviation safety. We and other groups have assembled together - down through the years since the first aviation fatality followed close on the heels of "Orville and Wilbur's" first effort at getting airborne at Kitty Hawk, N. C. We discuss, we appraise and pontificate about our efforts and our problem areas. A great deal of constructive interchange takes place I believe, following the formal meetings, at the adjacent saloon. We have accomplished a great deal down through the years.

A look at just a few statistics will put our subject into proper focus: ten percent of the fatalities result from intoxication; forty percent of the fatalities occur on week-ends; two-thirds of the victims had not bothered to learn proper procedures; eighty percent of the victims did not use the devices and equipment which may have saved their lives; sixty-five percent of the victims who had these pieces of equipment available did not use them. Half of the fatalities occur in clear weather. Now, before you jump to the conclusion that aviation is dangerous and the people who practice it are careless, these statistics are what the National Safety Council reports for the more than 7,000 annual fatalities from <u>drowning</u>!

There are three lessons in this for we who are concerned about aviation safety: The first lesson is that people who fly airplanes are a cross-section of people who do other things. There are people who won't put a life preserver on - even though it is required by law in many areas. And there are people who won't wear shoulder harnesses in an airplane. Evidently, there are people who feel they present a more cosmetic appearance with a sensitive altimeter in one eye and an airspeed indicator in the other. There are a few people who will take a nip or two and go boating. And there are people who will take a nip or two and go flying. Why, then, do we usually find our reaction to accidental drowning is a concern for the actions of an individual, while aviation accidents, frequently evoke condemnation of the activity? Why do we think "the damn fool should have had enough sense to wear a life preserver while in the boat" and then turn around and say "You'll never catch me going up in one of those dangerous things?" Psychologists could undoubtedly give us many scientific reasons for this. But, I believe, there are two simple explanations.

First, we have been guilty of creating an aura of mystery about aviation. We have set those who practice it aside as special creatures who should be immune to the same failings and frailties as other humans. We must remember that the original design specifications for a man called for an individual with two arms, and two legs capable of walking in an upright position on the surface of the earth while experiencing 1 "G" of gravity in daylight VFR conditions. I have not observed any evolutionary changes that have altered these physiological parameters.

And, Second, we have failed to properly educate and inform the public and the pilots to the degree we should. A recent study revealed that only 9% of the public understood the term "general aviation". This brings us to the second lesson from our statistics - Education. We must first educate the public - and in some ways the members of the public who are in positions of government - to be critical of the individual, the incident or the equipment which is involved in an aviation accident and to avoid sweeping condemnations and regulations which will penalize the many for the imperfections of a few. And we must educate the participants in aviation to the whole broad spectrum of potential hazards and to the safe and proper ways to conduct their activities. We should never create by law what can be accomplished by education. Man has created more than 32,200,00 laws merely to enforce the ten commandments. One is tempted to speculate what kind of a world we would have if this much energy had been expended in education and explanation of these ten rules.

The person who wants to do something will be better than the person who must do something. At one point during the Civil War, General George B. McClellan, then in command of the Union forces, was conducting a waiting campaign. He was so careful to avoid mistakes that little headway was evident. President Lincoln could have ordered him into action. But instead, Lincoln wrote a request: "My dear McClellan: If you don't want to use the Army, I should like to borrow it for awhile. Yours respectfully, A. Lincoln." You can bet the good general responded better to a request than an order.

The third lesson from our statistics is that we must display ingenuity in developing equipment and training which will make it easy for people to be safe. Sixty-five percent of the people who drowned from boating accidents had life preservers available, but did not make use of them. What a challenge it would be to design a life preserver that people would want to wear. And, in aviation, what a challenge it is to build into the airplane and the system what we can't build into the pilot. One such device which is a personal interest of mine, is an angle of attack indicator. The aircraft's angle of attack in all aircraft operations is one of the most critical elements of safe flying. Yet, in most aircraft, the pilot must guess at it based on experience or derive it from the readings of several different instruments. Of course, the easy answer for many is to suggest that the angle of attack indicator merely be a required instrument in every aircraft. But, as we have noted before, requiring something does not insure its usage. We must be creative enough to make pilots want to use the instrument and demand from the industry its further development. The angle of attack indicator is just one example. Perhaps some day, we will see aircraft with gear shifts for takeoff, climb, cruise and descent, thus eliminating the complexities of piloting much the same way as the automatic gear shift made automobile driving easier, but not necessarily safer.

I am in no way advocating that each of us must be our brother's keeper. We cannot design, build and regulate or even educate absolute safety. The individual who carelessly flies an aircraft exacts for himself a far more severe penalty in personal injury or death than can be meted out by any regulatory body.

It would seem therefore, that there are three principle points to continuing aviation safety.

First is to recognize today's safety record in context with other human activities. General aviation and air carrier fatalities, 1,567 in 1973, comprise only 3% of the total 60,118 fatalities experienced in our overall U. S. transportation system.

Second, is to emphasize education and training, and Third is to design, build and regulate in ways to make it easy and desirable to conduct our aviation activities safety. When the late, lamented Life magazine was getting started years ago, the first editor issued instructions to the editorial staff which is apropos to aviation safety. He wrote: "Let us never underestimate the intelligence of our readers, nor over-estimate the amount of information they have."

I believe our present inflationary economy presents a new challenge to the aviation educator. The decrease of discretionary funds will, I believe, cause the average general aviation pilot to re-direct his available flight time more to the recreational aspects, and point to point transportation with a degradation of proficiency resulting.

We must make our educational effort provocative in order to stimulate the educational "dropout" to maintain an adequate level of proficiency. This must be done to ensure our continuing and improving the excellent safety record we have.

Our greatest strides in continuing aviation safety will be made by never underestimating the intelligence or abilities of pilots, and never overestimating the amount of knowledge they have.

The key to <u>aviation safety</u> always has been, and always will be, professional well-constructed aviation training programs oriented to providing the basics and making absolutely certain that all participants are completely aware of the whole broad spectrum of the accident potential.

JAMES W. STARGEL'S PAPER - Presented by W. R. STANBERRY

ACCIDENT INVESTIGATION INFORMATION AND DISSEMINATION

In the past seven and a half years I have been privileged to work with members of the National Transportation Safety Board, the Federal Aviation Administration and industry in conducting flight instructor refresher courses throughout the United States. These courses have been attended by over twenty thousand flight instructors and flight instructor applicants, with experience levels ranging from 200 to 30,000 hours. I have found one common denominator in my contacts with this group. That is, the search for more knowledge as to the cause of aircraft accidents. Certainly in many cases our very survival depends upon the knowledge we have gained from our own experience or from the experience of others.

In general, through their own curiosity, these flight instructors may have acquired limited knowledge of accidents within their narrow area of operation or perhaps in the next city or county. However, seldom do they have adequate knowledge of the overall accident picture. As we all know, this picture can be very revealing.

As an example of this, I cite the case of the PA-30 Twin Comanche. Now I own one of these fine machines and regularly fly it all over the country. I think it is one of the finest light twins available, but it had a horrible track record in the beginning.

Suddenly, in the fall of 1967, we realized that there had been some fourteen isolated flat spin accidents involving this ariplane. July 1, 1970, Piper issued Service Letter No. 558 announcing the availability of the airflow modification kit, stating that its purpose was to improve operational characteristics during slow speed maneuvers. Efforts by the National Transportation Safety Board to make this an airworthiness directive were unsuccessful. With some 2,000 Twin Comanches in service, and in the absence of an airworthiness directive, installation of these kits naturally lagged.

On December 18, 1971, one and a half years after the issuance of this service letter, a Twin Comanche crashed in an open field near a midwestern town. The aircraft was observed to start a climbing left turn, then enter a spin. It continued to spin until it struck the ground. The aircraft was being flown on a dual instructional mission; both the instructor and the student were killed.

The aircraft was the one of two Twin Comanches owned by the area Piper distributor which did not have the airflow modification kit installed. The kit was on the shelf in the parts department. Ironically, the pilot was parts manager for the Piper distributor. The instructor was his chief flight instructor.

At that time there had been a total of 43 Twin Comanche stall/spin-flat spin accidents with 71 fatalities.

With the advent of the FAA placarded increase in the Twin Comanche VMC, a reminder to flight instructors that single engine stalls were not required, the modification kit provided by Piper, and an educational program in which we were involved, flat spin accidents with this aircraft slowly ground to a halt, but not before we had stacked up 49 Twin Comanches with 80 fatalities.

A similar situation has developed involving the American Yankee. For the years 1969-1973, there were 40 stall/spin accidents with these model aircraft, involving 24 fatalities. Many of the fatalities in both the Twin Comanche and the American Yankee involved flight instructors. It certainly seems to me that had these flight instructors been aware of the problems with these aircraft through timely dissemination of accident information surely some of these lives could have been saved.

The National Transportation Safety Board has a fine organization in the Bureau of Aviation Safety. The primary function of the Board is to promote safety in transportation. The Board is responsible for determining the cause or probable cause of transportation accidents and reporting the facts, conditions and circumstances relating to such accidents.

Its investigators are trained and equipped to do an unbelievably thorough investigation of aircraft accidents, and this they do. As we can well imagine, there are many jobs more pleasant than sorting out the pieces of tin and reassembling them, particularly when portions of the victims remain in the wreckage and they don't have a "clean" accident to investigate. Representatives of the FAA within their area of responsibility also do an outstanding job of investigating and reporting.

When the investigation has been completed, and the cause has been determinid by the National Transportation Safety Board, a very complete report is prepared and distributed to perhaps 2,000 interested parties.

Copies go to aviation publications, aviation trade magazines, the Department of Transportation, various committees of the Congress, and certain FAA personnel.

In the case of major accidents, reports are published under individual covers. Of course anyone who is interested may purchase a copy of the report if he knows of its existence, but what a shame that the essence of all this effort is not disseminated in such a manner as to assure maximum benefits to all.

What are we in industry doing about this situation? As you probably know, the AOPA pilot magazine has for years published accident briefs in its safety corner. This has been one of the most popular and informative features of the magazine. A few other publications have done the same. Organizations such as the American Bonanza Society, the Lawyer Pilot Bar Association, the Flying Physicians, and certain State aviation organizations have published accident report information in their newsletters as space permits. The FAA Accident Prevention Program newsletters published by some general aviation district offices carry limited information. The National Aviation Underwriters Accident Bulletin contributes to the overall picture. However, no organized approach exists, and we believe there should be one.

What can we do to provide for the orderly distribution of vital accident data? For one thing, the AOPA Air Safety Foundation is preparing an accident bulletin for coordinated distribution to all 36,000 flight instructors. This bulletin will include a narrative report on the entire spectrum of instructional accidents, as well as a brief synopsis of typical accidents which are particularly illustrative of problem areas such as I have previously mentioned. Hopefully, if this proves successful we shall be able to expand our coverage to include others, such as aircraft owners, flying clubs, and eventually, all pilots.

These bulletins will be coordinated with the manufacturers so as to remove any idea that they have been singled out for criticism. We are certain that they will be as anxious as we to provide timely information which may be instrumental in saving lives, and perhaps just as important, reduce some of their product liability problems.

We welcome the cooperation of all of you in this project. If it is instrumental in saving just one life, our time and effort will have been well spent.

AIR FORCE STALL/SPIN REQUIREMENTS

Robert J. Woodcock
Air Force Flight Dynamics Laboratory
Wright-Patterson AFB, Ohio
October 1, 1974

The stall/spin problems of fighter aircraft are generally much different from those of civil airplanes. In air combat there is a special premium on extracting the last bit of maneuverability. Fighters lose much more altitude in spin, and in recovery too, than do smaller, less heavily loaded aircraft. Also a typical fighter configuration may have several different modes of post-stall gyration and spinning, not all recoverable. Unnatural recovery techniques such as putting ailerons with the spin are often required. A steady flat spin has been particularly troublesome. Still, there are enough similarities between civil and military stall/post-stall problems that we can all benefit by sharing experience.

We really shouldn't blame the Navy for the F-4's stall/spin troubles. The F-4 was originally designed to be an air defense fighter, firing maneuverable missiles rather than engaging in dogfights. Yet because it was the first-line fighter available to the Air Force, we used it heavily in an air superiority role. Whereas the spin demonstrations for the Navy had used entries such as rudder kicks at stall, our pilots found that rapid turns at somewhat lower angles of attack would readily produce spins or post-stall gyrations. And the need for full utilization of the airplane's lift capability in combat made these departures from controlled flight a troublesome problem. Now new leading-edge slats have improved the airplane's capability, but it is still possible to lose control.

Large aircraft too have given us stall/spin problems. On long flights the C-133 would climb to an altitude approaching its absolute ceiling. Poor stall warning and a vicious stall while trying to fly there are thought to have caused the disappearance of several C-133 airplanes.

These are only two examples of recent problems we have had, but they illustrate our need for concern more than fifty years after stopping use of the spin as a tactical maneuver. A continuing shortsightedness has limited stall/spin research to a low level, relieved only briefly by occasional short flurries of activity when a high aircraft loss rate generates momentary interest. These examples clearly illustrate the reason we have become more concerned with the initial loss of control.

This changed philosophy is expressed emphatically by the Air Force Flight Test Center's new stall/post-stall/spin flight demonstration requirements, ~~MIL-S-83691A~~. For all airplanes including bombers and cargo types, the flight test program at high angle of attack builds up to the most severe maneuvers and control misapplications that ~~could be~~ expected for the aircraft type. The intent is to evaluate susceptibility to loss of control and recoverability from those departures encountered. The drafters want to see an airplane's behavior in circumstances more representative of operational use than is the usual rudder kick at the stall break. (And our experience, you have seen, leads to a literal interpretation of "operational use".) They had observed the ease with which some fighters entered spins during these new evaluation maneuvers, without trying to spin at all.

Earnest spin attempts are now reserved for fighters which survive the flight program described without spinning, and for any training airplanes which might be required to spin for instructional purposes. The latest military flying qualities requirements, MIL-F-8785B Amendment 2, similarly emphasize resistance to loss of control and to spinning.

The intent is to evaluate stall/spin "as the user would encounter these conditions" (FTC-TD-73-2, Background Information and User Guide for MIL-5-836[illegible]). Thus susceptibility during normal usage and expected abuse is emphasized over deliberate spin attempts, and explicit attention is given to recovery from the incipient motions as well as from developed spins.

On the same airplane a pilot might experience nose slice, rolling departures, oscillatory steep spins, steady flat spins, and still other forms of spin and post-stall gyration, depending upon the entry maneuver and subsequent pilot control actions. We would like him to be able to recover readily from all of these out-of-control situations with the same technique, or at least with compatible techniques. Whatever the motions, we do require safe, consistent recovery for all airplanes which are structurally designed for spinning.

For dependability we would like to see good stall/spin characteristics inherent in the airframe. But both our limited aerodynamic knowledge and the quest for maximum performance make this goal elusive, although analysis and free-flight model testing techniques are improving. As a fix, or even in the original design, angle-of-attack limiters and stability augmentation through the flight control system have been proposed for some aircraft - the F-111 and A-7, for example. Manufacturers' opinions on the merits of limiting seem to be a function of their aircraft's need. But in any case experience shows the necessity to evaluate thoroughly the effectiveness of such devices in flight.

The stall/spin flight program starts with Phase A, full stall: smooth 1-g and accelerated stalls and abrupt (for the type) 1-g stalls for all airplanes, and abrupt accelerated stalls and entries from tactical maneuvers for high-maneuverability airplanes. In Phase B, these stalls are repeated with controls briefly misapplied, intentionally or in response to unscheduled airplane motions. An airplane which departs or spins in this phase is termed "susceptible". (Departure and spin characteristics are rated separately.) That is the end of the line for large, heavy, low-to-medium-maneuverability airplanes; but the rest continue to Phase C. There the aggravated control inputs are held for at least 3 seconds. Passing this phase without departing or spinning earns the designation, "resistant". As mentioned, only highly-maneuverable airplanes are subject to deliberate post-stall-gyration, [illegible] and deep stall attempts. In the earlier phases tactical maneuvers are performed in these airplanes, with increasing severity and abuse. Then in Phase D critical control deflections are held the longer of 15 seconds or three spin turns before initiating recovery. (For spinnable trainer airplanes, a fully developed spin is required.) But "if the aircraft is extremely spin-susceptible, spins will occur in Phase A and that is where they will be evaluated."

The tactical maneuvers are likely to result in spins while holding nonstandard (not full pro-spin) controls. In the past, spin recovery instructions often have called first for full pro-spin controls to develop a steady spin for which a recovery technique has been proven. But large fighters with high wing loading can lose more altitude in developing and recovering from a steady spin than is likely to be available. Standard instructions are to eject if control is not recovered upon reaching 15,000 ft. altitude. Thus it is even more important to develop other techniques which will assure prompt recovery from earlier phases of the possible post-stall motions. This parallels the universal concern for loss of control at low altitude in terminal-area flight. "The emphasis in the test program should be placed on recovery from the initial out-of-control event."

Air Force experience with a modified fighter demonstrates the importance of emphasis on spin susceptibility. Originally flight tests had shown spins extremely difficult to induce, and consequently, a very safe airplane. But a modification which increased the attainable angle of attack apparently was just enough to cause some difficulty. Maneuvering at high angle of attack, a pilot of that version needs to keep in mind the possibility of spinning.

A successful stall/spin program, we see, requires several ingredients, recycled as necessary. First comes attention to high angle of attack in the airplane's design phase, to provide a configuration which is highly resistant to both departure and spin and also recoverable. Then a thorough flight test program is needed to check the airplane's susceptibility in operational use, determine the attainable out-of-control modes, and develop simple techniques for consistent, safe recovery. Also there is pilot training, which though not discussed herein is an important subject itself.

AIR FORCE STALL/SPIN REQUIREMENTS

Robert J. Woodcock
Air Force Flight Dynamics Laboratory
Wright-Patterson AFB, Ohio
October 1, 1974

The stall/spin problems of fighter aircraft are generally much different from those of civil airplanes. In air combat there is a special premium on extracting the last bit of maneuverability. Fighters lose much more altitude in spin, and in recovery too, than do smaller, less heavily loaded aircraft. Also a typical fighter configuration may have several different modes of post-stall gyration and spinning, not all recoverable. Unnatural recovery techniques such as putting ailerons with the spin are often required. A steady flat spin has been particularly troublesome. Still, there are enough similarities between civil and military stall/post-stall problems that we can all benefit by sharing experience.

We really shouldn't blame the Navy for the F-4's stall/spin troubles. The F-4 was originally designed to be an air defense fighter, firing maneuverable missiles rather than engaging in dogfights. Yet because it was the first-line fighter available to the Air Force, we used it heavily in an air superiority role. Whereas the spin demonstrations for the Navy had used entries such as rudder kicks at stall, our pilots found that rapid turns at somewhat lower angles of attack would readily produce spins or post-stall gyrations. And the need for full utilization of the airplane's lift capability in combat made these departures from controlled flight a troublesome problem. Now new leading-edge slats have improved the airplane's capability, but it is still possible to lose control.

Large aircraft too have given us stall/spin problems. On long flights the C-133 would climb to an altitude approaching its absolute ceiling. Poor stall warning and a vicious stall while trying to fly there are thought to have caused the disappearance of several C-133 airplanes.

These are only two examples of recent problems we have had, but they illustrate our need for concern more than fifty years after stopping use of the spin as a tactical maneuver. A continuing shortsightedness has limited stall/spin research to a low level, relieved only briefly by occasional short flurries of activity when a high aircraft loss rate generates momentary interest. These examples clearly illustrate the reason we have become more concerned with the initial loss of control.

This changed philosophy is expressed emphatically by the Air Force Flight Test Center's new stall/post-stall/spin flight demonstration requirements, MIL-S-83691A. For all airplanes including bombers and cargo types, the flight test program at high angle of attack builds up to the most severe maneuvers and control misapplications that could be expected for the aircraft type. The intent is to evaluate susceptibility to loss of control and recoverability from those departures encountered. The drafters want to see an airplane's behavior in circumstances more representative of operational use than is the usual rudder kick at the stall break. (And our experience, you have seen, leads to a literal interpretation of "operational use".) They had observed the ease with which some fighters entered spins during these new evaluation maneuvers, without trying to spin at all.

Earnest spin attempts are now reserved for fighters which survive the flight program described without spinning, and for any training airplanes which might be required to spin for instructional purposes. The latest military flying qualities requirements, MIL-F-8785B Amendment 2, similarly emphasize resistance to loss of control and to spinning.

The intent is to evaluate stall/spin "as the user would encounter these conditions" (FTC-TD-73-2, Background Information and User Guide for MIL-S-836[illegible]). Thus susceptibility during normal usage and expected abuse is emphasized over deliberate spin attempts, and explicit attention is given to recovery from the incipient motions as well as from developed spins.

On the same airplane a pilot might experience nose slice, rolling departures, oscillatory steep spins, steady flat spins, and still other forms of spin and post-stall gyration, depending upon the entry maneuver and subsequent pilot control actions. We would like him to be able to recover readily from all of these out-of-control situations with the same technique, or at least with compatible techniques. Whatever the motions, we do require safe, consistent recovery for all airplanes which are structurally designed for spinning.

For dependability we would like to see good stall/spin characteristics inherent in the airframe. But both our limited aerodynamic knowledge and the quest for maximum performance make this goal elusive, although analysis and free-flight model testing techniques are improving. As a fix, or even in the original design, angle-of-attack limiters and stability augmentation through the flight control system have been proposed for some aircraft - the F-111 and A-7, for example. Manufacturers' opinions on the merits of limiting seem to be a function of their aircraft's need. But in any case experience shows the necessity to evaluate thoroughly the effectiveness of such devices in flight.

The stall/spin flight program starts with Phase A, full stall: smooth 1-g and accelerated stalls and abrupt (for the type) 1-g stalls for all airplanes, and abrupt accelerated stalls and entries from tactical maneuvers for high-maneuverability airplanes. In Phase B, these stalls are repeated with controls briefly misapplied, intentionally or in response to unscheduled airplane motions. An airplane which departs or spins in this phase is termed "susceptible". (Departure and spin characteristics are rated separately.) That is the end of the line for large, heavy, low-to-medium-maneuverability airplanes; but the rest continue to Phase C. There the aggravated control inputs are held for at least 3 seconds. Passing this phase without departing or spinning earns the designation, "resistant". As mentioned, only highly-maneuverable airplanes are subject to deliberate post-stall-gyration, [illegible] and deep stall attempts. In the earlier phases tactical maneuvers are performed in these airplanes, with increasing severity and abuse. Then in Phase D critical control deflections are held the longer of 15 seconds or three spin turns before initiating recovery. (For spinnable trainer airplanes, a fully developed spin is required.) But "if the aircraft is extremely spin-susceptible, spins will occur in Phase A and that is where they will be evaluated."

The tactical maneuvers are likely to result in spins while holding nonstandard (not full pro-spin) controls. In the past, spin recovery instructions often have called first for full pro-spin controls to develop a steady spin for which a recovery technique has been proven. But large fighters with high wing loading can lose more altitude in developing and recovering from a steady spin than is likely to be available. Standard instructions are to eject if control is not recovered upon reaching 15,000 ft. altitude. Thus it is even more important to develop other techniques which will assure prompt recovery from earlier phases of the possible post-stall motions. This parallels the universal concern for loss of control at low altitude in terminal-area flight. "The emphasis in the test program should be placed on recovery from the initial out-of-control event."

Air Force experience with a modified fighter demonstrates the importance of emphasis on spin susceptibility. Originally flight tests had shown spins extremely difficult to induce, and consequently, a very safe airplane. But a modification which increased the attainable angle of attack apparently was just enough to cause some difficulty. Maneuvering at high angle of attack, a pilot of that version needs to keep in mind the possibility of spinning.

A successful stall/spin program, we see, requires several ingredients, recycled as necessary. First comes attention to high angle of attack in the airplane's design phase, to provide a configuration which is highly resistant to both departure and spin and also recoverable. Then a thorough flight test program is needed to check the airplane's susceptibility in operational use, determine the attainable out-of-control modes, and develop simple techniques for consistent, safe recovery. Also there is pilot training, which though not discussed herein is an important subject itself.