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PART I

AVIATION NEWS AND VIEWS

The Effect of Thunderstorms on Aircraft Operations

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The United States Thunderstorm Project (1946-49) remains the latest and most comprehensive source of information on the phenomena likely to be encountered in cumulo-nimbus clouds (thunderstorms) and their effect on the operation of aircraft. In the ensuing paragraphs the information obtained from this Project has been collated with general operating experience and the results of United Kingdom research carried out jointly by the Royal Aircraft Establishment, Farnborough, and the Meteorological Office.

The important fact which has emerged from this research is that 1,363 United States and more than 200 United Kingdom flights were carried out safely through cumulo-nimbus clouds, chosen particularly for their size and vicious appearance, in both frontal and semi-tropical storms. A Transport Command Research Project also resulted in 87 penetrations being safely made into the cores of 49 tropical cumulo-nimbus clouds. From this, however, it must not be thought that flying through cumulo-nimbus clouds is a matter to be considered lightly. During recent years a small, but significant, number of accidents to civil transport aircraft have occurred in which the turbulence experienced in cumulo-nimbus clouds appears to have been at least a contributory cause of the accident. In addition there have been a number of cases of injury to passengers during transit through areas of severe turbulence.

Formation of Thunderstorms

Thunderstorms have their origin in cumulus clouds. As the air becomes unstable the atmosphere attempts to regain its balance and re-establish a stable condition. The greater the instability the more forceful is the over-turning required for the atmosphere to regain equilibrium and increased amounts of cumulus and cumulo-nimbus are formed. A thunderstorm is the most violent manifestation of this over-turning in the atmosphere's struggle for stability. Each thunderstorm contains cells having a life cycle of between two and three hours and varying from one to five miles in diameter. Although such cells form the main body of a thunderstorm, other cells can form near to but separate from the main body of a thunderstorm and may themselves develop rapidly to serious proportions. Individual cells may be in any stage of development, but the majority in a storm are either at peak or dissipating stages. The cells in the developing or peak stage and their boundaries are the areas of greatest turbulence It is important to realize that the greatest turbulence may be experienced before lightning or thunder occurs. In fact, lightning in a cumulo-nimbus may be an indication that the storm has passed its peak. There is no sure method at present of finding the safest way through a storm area but limited experience of airborne radar* indicates that it can be expected to reveal the majority of centres of severe turbulence. It has been found that the visual appearance of a cloud does not permit an estimate to be made of the degree of turbulence likely to be encountered. The tops of thunderstorms may be as low as 10,000 feet in temperate latitudes, but are usually very much higher and may reach above 40,000 feet on occasions. In the investigation in the tropics the measured tops of the clouds penetrated were usually above 40,000 feet and on one occasion reached 55,000 feet.

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* Experience of Australian operators who had employed this equipment indicates that its intelligent use can contribute significantly towards the avoidance of areas of severe turbulence.

Flight Hazards

(1) Turbulence

The eddies and air currents which make up turbulence are intensified in thunder clouds. Eddies produce the gust effect with which all pilots are familiar, and the disturbed motions of the aircraft are dependent on the sequence, spacing and intensity of the gusts encountered. Steep gradient gusts are capable of imposing great loads on aircraft structures and the speed and wing-loading of the aircraft when these gusts are experienced are most important factors. The higher the aircraft's speed the greater are the loads imposed. At low speeds, though the loads are smaller, there is a danger of loss of control due to stalling. While gust velocities of considerable magnitude were observed on a small number of occasions during the U.S.A.F. Project, there is nothing to suggest that aircraft are being designed to too low strength standards. The best range of speeds at which aircraft should be flown in turbulence is referred to on pages 5 and 6 under "Safety Speed Range".

Vertical air currents or draughts are the huge columns of rapidly rising or descending air which comprise an integral part of the thunderstorm structure and attempts to maintain a constant altitude in strong draughts may be a pilot's first step towards loss of control. Up-draught velocities increase as height increases, and during the U.S.A.F. Project one aircraft flying at 26,000 feet experienced an upward displacement of 6,000 feet, though the maximum displacement on 90 per cent. of the flights was 2,000 feet. Down-draughts are usually not as strong as up-draughts, and their velocities diminish towards the lowest levels of a storm. They very seldom measure more than two to three miles across.

With regard to the possibility of a down-draught forcing an aircraft into the ground or dangerously close to it, the lowest altitude flown during the U.S.A.F. Project, with a few exceptions, was 6,000 feet and there were no instances where the aircraft at this altitude lost more than 2,000 feet. The down-draughts subsided when the aircraft broke clear of the clouds underneath the storm. Whilst the intensity of down-draughts normally diminishes towards the lowest levels, it should be remembered that they can extend below the base of the storm cloud and continue very close to the ground. One conclusion from the United States research was that it appears unlikely that a modern commercial aircraft flying at 2,000 feet above level terrain would be carried into the ground. However, it should be recalled that in 1951, at Fort Wayne in the United States, a Douglas DC.3 was, apparently, forced into the ground by a down-draught when flying over level terrain in exceptionally severe conditions. Present knowledge is not considered sufficient to support any hard and fast rules regarding the minimum safe altitudes to be flown above the terrain in thunderstorm areas. There is a relationship between rainfall and down-draughts and a pilot encountering heavy rain beneath cumulo-nimbus cloud should expect to lose height.

Severe turbulence appears to occur more frequently at some altitudes than at others. During both the United States and United Kingdom flight research the best heights for avoiding severe turbulence were found to be below 10,000 feet. Turbulence appears to increase with height up to rather less than half the total vertical extent of the cloud, and then to remain about the same with increasing height until the top third of the cloud is reached where it decreases with height. This supports the advice frequently given to pilots entering cumulo-nimbus cloud to fly at the lowest possible height, though, of course, ample terrain clearance must be allowed. Acute bumpiness in thunderstorms has been found to be very localised and limited in duration. One aircraft may experience very severe turbulence while another aircraft a short distance away–either horizontally or vertically—or making the same traverse a short time before or after, may find nothing out of the ordinary.

(2) Hailstones

There is no reliable method of recognising, in advance, a thunderstorm which may provide hailstones. Experience to date shows that hail is encountered infrequently and that heavy hail is extremely rare. For example, in 87 penetrations made into tropical storms hail was encountered seven times and was only once recorded as moderate to heavy. When it does occur it appears that the region of hail and its duration in a storm are relatively small. Aircraft are known to have encountered small showers of hailstones up to three inches in diameter, sustaining only superficial damage, although on other occasions there have been instances of windscreens being holed and splintered, perspex astrodomes shattered, de-icer boots ripped off and radiator fins badly bent. The risk of hail damage to aircraft, while not great, should not be ignored. The procedure to minimise the possible hazard of hail is to stay as far below freezing level as practicable and to hold the original course, since hail is usually a localised phenomenon. A high altitude, say 25,000 feet or above, offers the best alternative.

(3) Icing

About 400 of the traverses made during the U.S.A.F. Project were carried out at temperatures below 0°C. In only five of these traverses was clear ice encountered and then it accumulated to less than one-sixteenth of an inch. Wet snow packing on the leading edges of the wings was experienced during some 340 traverses, but did not build up to more than a quarter inch in thickness. At no time did airframe icing present a flight hazard to the Project pilots. Also during 500 miles of United Kingdom flight research in cumulo-nimbus clouds difficulty was experienced on only two occasions. The first occasion occurred at an early stage in the experiments and the flight was abandoned. On the second occasion very heavy airframe icing took place during a flight of about 25 miles along a line of cumulo-nimbus at temperaturees below freezing point. The probability of heavy icing undoubtedly exists if flight in cloud is prolonged at temperatures below zero. Carburettor icing proved more serious, the danger occurring between plus 18°C and minus 10°C outside air temperature. Pilots should be well briefed when to use carburettor heat.

(4) Lightning

A lightning strike can be a very unpleasant occurrence and may occur in, or beneath, cloud or between two clouds. The brilliant flash of the discharge, the smell of burning and the accompanying explosive noise may be alarming and distracting. An extended trailing aerial increases the possibility of a strike and, therefore, such aerials should be earthed and wound in. However, if the aerial winch has to be wound by hand, there is a risk of injury to the winch operator if a strike occurs whilst the winch is being operated. In such aircraft, therefore, if the aerial has not been wound in before entering an area where lightning strikes may occur it should be earthed and left trailing. Whilst many aircraft have been struck by lightning there is little positive evidence of serious damage to metal aircraft by the strike itself and the occupants are safeguarded by the aircraft bonding requirements. However, there is a danger that, in the turbulence of a storm, the disconcerting effects may lead to loss of control unless pilots are fully prepared. During night flying through thunderstorms cockpit lighting should be turned on fully to minimise the dazzling effects. Where two pilots are carried a further protection is for one of them to wear dark glasses.

(5) Static Electricity

This phenomenon will, generally, first be noticed as a noise in the radio, particularly on the high and medium frequencies. VHF reception is very much less affected. As the static electricity increases in severity the noise will increase and in extreme cases a visible discharge, known as St. Elmo's fire or corona, will be observed around some parts of the aircraft. This phenomenon is not confined to thunderstorms, but they are particularly favourable to its creation. Normally it is not dangerous, although there have been cases where a discharge has occurred across windscreens and plastic panels, causing them to break. This particular occurrence is fortunately rare.

The onset of manifestations of static discharge is likely to be delayed in aircraft fitted with discharge wicks, but they are still likely to be experienced in conditions particularly favourable to the generation of static electricity.

(6) Instrument Error

During a thunderstorm rapid pressure variations can occur. Frequently the ground pressure rises rapidly, stays high for several minutes, and then returns to its previous value. The largest pressure increases occur during periods of heavy rain. Instruments which depend on atmospheric pressure, particularly the altimeter and rate of climb indicator, may give faulty readings due to localised turbulence. However, during the flight research it was found that the differences between the radio and pressure altimeter readings were too small to be operationally significant.

Although all possible precautions are taken in the design of pressure heads, there is a possibility that heavy rain may cause an airspeed indicator to read low. It is considered that any liability to error may be reduced by the use of pitot head heaters. If, in cruising flight, the power has been selected which gives the safest speed before the storm is entered, any fluctuation in the airspeed readings can be disregarded provided a reasonably level altitude is maintained. This technique will, clearly, not cater for take-off or landing, especially as local pressure variations plus possible acceleration effects may upset the other instruments just when they are most needed.

Two other points worthy of note are, firstly, that during the United States trials every standard type of gyro instrument was tried and not one case of gyro toppling was reported; secondly, that a lightning strike may seriously affect magnetic compasses which should be checked as soon as possible afterwards.

Safety Speed Range

The loads imposed on a given type of aircraft in heavy turbulence depend directly upon the velocity of the gust encountered and the speed of the aeroplane. Reduction of speed, however, while reducing the loads imposed by gusts, may lead to loss of control. This is because a gust may change the direction of the airflow, in extreme cases sufficiently to cause a stall, even though the airspeed is relatively high. The speed at which a storm is penetrated, therefore, must be carefully chosen so as to be low enough to reduce the applied air loads, yet high enough to prevent stalling with resultant loss of control. Attempts to fight changes in height, and the making of turns, increase the strain on the control surfaces and may result in the aircraft reaching a dangerous attitude. It is imperative that control should not be lost, even temporarily, as the loads imposed during the subsequent recovery, together with the stresses

from gusts, may be sufficient to cause a major structural failure. For this reason it is safer to avoid any coarse movement of the controls, to let the aircraft ride the storm, and to maintain the same heading.

For the latest types of aircraft the safest speeds for flight in turbulence are specified in the Aircraft Flight Manual. For earlier types of aircraft these speeds are being included in the Manufacturers' Service and Instruction Manuals. Where no specific speed has yet been recommended a guide to the safest speed can be obtained by multiplying by 1.6 the stalling speed with flaps and undercarriage retracted.

Technique

Before take-off make a thorough analysis of the weather situation to determine the probable locations of thunderstorms. Plan the flight to avoid them. Special attention should be given to thunderstorms in the immediate vicinity of the airfield. If there is any risk of the aircraft flying into the influence of an active thunderstorm cell during the initial climb it will be advisable to delay take-off. Similarly, if other operational considerations are not critical, it will be advisable for arriving aircraft to delay approach and landing.

When a pilot finds that neither by visual nor airborne radar means is he able to avoid flying through a thunderstorm cell, the following procedures, evolved from research and operational experience, are recommended.

Approaching the Storm

1. If it is not possible to fly over the storm or around it, try to fly below 10,000 feet, but well clear of the terrain.
2. Dissengage the auto-pilot.
3. Set the power to give the safest speed for flight in turbulence, and adjust the trim for level flight.
4. Check the flight instruments, and note the vacuum pump switch position.
5. Check if it is necessary to switch on the de-icing equipment including carburettor heaters. Always switch on the pitot head heaters.
6. Tighten safety belts and secure any loose articles.
7. Reel in the trailing aerial. However, if the aerial winch is hand-operated and the aerial has not been wound in before entering an area where lightning strikes may occur, it should be earthed and left trailing to avoid the risk of injury to the operator. Turn off any radio equipment rendered useless by static.
8. At night turn the cockpit lights full on to minimise the blinding effect of lightning. If practicable, wear dark glasses.

In the Storm Cell

1. Devote all attention to flying the aircraft. Be prepared for turbulence, precipitation, icing and lightning, but do not allow them to cause undue alarm.
2. Concentrate on maintaining a level attitude. Do not correct for height gained or lost from up or down currents, unless it is absolutely necessary to clear obstructions. Use as little elevator control as possible. Do not chase the airspeed, but maintain the same throttle settings to avoid confusion arising from the airspeed indicator's fluctuations and errors.
3. Maintain the original heading—it is the safest way out. Do not make turns unless absolutely necessary as these increase the risk of losing control.

Flight through cumulo-nimbus clouds should be avoided whenever practicable as it involves the risk of damage through hail or lightning strikes and of encountering severe turbulence which, in addition to being unpleasant, may impose very heavy stresses on the aircraft. If it is impracticable to avoid such flights the procedures recommended above should be followed.

Temperature and Humidity

(Reproduced from Flight Safety Foundation, Pilots Safety Exchange Bulletin 55-105, 15th June, 1955)

All transport pilots know from practical experience that, on a very hot day, even though the air is dry, the airplane takes a much longer distance to get off the ground and, once off, does not climb as well as on a cool day. From experience they also know that if the day happens to be very hot and, in addition, "muggy", indicating high humidity, the airplane just doesn't want to "get up and go" at all and the climb performance has deteriorated. To sum this up right at the beginning, we can say that, in the first case, the high outside air temperature deteriorated both the engine power and wing lift and, in the second case, the high temperature, accompanied by high humidity, deteriorated the engine performance to a much greater degree and further aggravated the wing lift.

What is Lift?

Dealing first of all with the simple aerodynamic case, that is, the effect of temperature and humidity on wing lift, let us take a quick look at the lift formula:

$$\text{Wing lift} = \frac{P}{2} C_L S V^2$$

where C_L = Lift coefficient
P = Air density
V = Airplane speed
S = Wing area.

Considering the lift coefficient (C_L) and wing area (S) as constant we can say that the wing lift depends upon the air density and the airplane speed. As the outside air temperature rises the air density or weight decreases in proportion to the temperature rise, that is, the air gets "rarer". Therefore, the hotter the day the lower the air density and the less this hot air contributes to the wing lift to support the airplane.

High Humidity — Low Density

With respect to humidity, water vapor has a density of, or in other words, weighs only about 5/8th of dry air. Therefore, air that contains water vapor in any degree has a lower density than dry air, and since wing lift depends upon the air density, the lift naturally deteriorates. Therefore, summing up the above, if high outside air temperature and high humidity exist, the only way remaining to obtain the required wing lift is to increase the true airspeed, which in turn means a longer take-off run or, when airborne, a poorer rate of climb. In converse, if it is desired to keep the lift-off speed and rate of climb constant, a lower take-off weight can be used.

Power Loss Compounds Problem

Unfortunately, the aerodynamic effects above are compounded by the fall off in engine power due to high outside air temperature and high humidity. The gas turbine and reciprocating engine are both affected but the effects from each cause are in different magnitude. The effects on the piston engine will be discussed first and the gas turbine later.

F/A Ratio is Basic Problem

To explain the reasons for power decrease in the piston engine with increasing outside air temperature and humidity, let us review a couple of basic engine operating principles. To sustain proper combustion and to produce power, the correct mixture, by weight, of vaporized gasoline and air is required. (Actually efficient combustion of gasoline depends upon the 21% oxygen that the air contains). The weight of air that can be forced into the cylinders at constant power settings and operating conditions is limited by the aspirating or supercharging qualities of the particular engine. Opposed to this, the weight of fuel fed in to mix with the air can be pre-set by means of the carburettor or fuel metering pump—in fact, particularly at take-off powers, fuel is often fed in in greater quantities than required for perfect combustion. If developing 100% power for a given r.p.m. and manifold pressure were the only consideration, the ideal fuel-air mixture would be closely 1 lb. of fuel for each 12.5 lb. of air (12.5 : 1), which would give a perfect burning mixture for maximum power development in the cylinder. Any deviation, either way, from this "best power mixture" of 12.5 : 1, either towards a leaner or a richer mixture, will cause a percentage power loss.

High Temperature — Less Air

As the density of a given volume of air decreases with increase in temperature, there will be less weight of air delivered to the engine at high outside air temperatures and consequently, for the same r.p.m. and

part-throttle manifold pressure, the engine will develop less power than on a standard day (59°F). For supercharged engines which operate at full throttle at take-off, the intake of high temperature air has the effect of decreasing the supercharger compression ratio which in turn shows up as a decrease in the full-throttle height, that is, a decrease in the altitude at which the engine can develop take-off manifold pressure. At operation above this throttle-height the power decreases rapidly as the manifold pressure falls off quickly. This latter case actually represents a double power loss: that due to not being able to maintain take-off manifold pressure at full throttle and also the loss in power at the lower manifold pressure due to the decrease in intake air density caused by the high outside air temperature.

Air is Coolant Too

Because the outside air also serves as the engine cooling agent, the temperature of this air will have an effect upon the engine operating temperatures and in turn upon the amount that cowl flaps, radiator flaps, etc. (which cause drag), will have to be open. The engine operating temperatures affect the efficiency of the combustion process and therefore can affect the power output. If the engine is operated at temperatures above the recommended values, a power loss may be expected.

Effect of Humidity

Now, to take a look at how humidity can affect the power output of a piston engine. First, a quick review on just what is meant by humidity so as not to get it confused with such things as rain drops, fog droplets, or any water in the liquid state. Relative humidity may be defined as the percentage relationship between the weight of water vapor actually present in the air and the weight of water vapor which the air could actually absorb at that temperature. The weight of water vapor that the air can hold increases as the air temperature rises. If there is the maximum weight of water vapor present that the air can hold at a certain temperature, then the air is said to be (1) saturated, (2) relative humidity (R.H.) 100%, and (3) the air temperature equals the dewpoint temperature. If the air contains one-half the weight of water vapor that it could at that temperature, then the relative humidity is 50%.

Water Content Higher at High Temperatures

From the pilot's point of view, he immediately knows whether the humidity is high when he observes from the weather sequence that the outside air and dewpoint temperature are close together. For example, if these values are read as 90/77, reference to atmospheric tables would show 65% R.H., and if the values read 59/47, the relative humidity would also be 65%. However, at a 90°F temperature accompanied by humidity, the pilot knows that the wing lift is going to be adversely affected and that the high temperature is going to cause an engine power loss. Knowing also that the weight of water vapor in the air at 90°F is much greater than in the air at 59°F for the same relative humidity of 65%, he might expect, and rightly so, that there would be a greater power loss, for the same r.p.m. and manifold pressure, due to the greater weight of water vapor in the 90°F air. The inability of air to hold as great a weight of water vapor as the temperature decreases explains why at low temperatures, even if the relative humidity is high (temperature and dewpoint close together), the effect of humidity on performance is relatively small.

Water Vapour Contributes to Power Loss

Water vapour is an odorless, colourless, tasteless, invisible gas which should not be confused with visible water in the air in the liquid state in the form of raindrops or fog droplets. The entrance of raindrops or fog droplets into the engine air intake is in relatively small volume. At take-off power, the fuel-air mixture is already rich for cylinder cooling purposes and the entrance of heavy rain in the induction system, although it does not materially change the mass flow, may displace air which in turn tends to make the fuel-air mixture somewhat richer; this could cause a very small power loss.

The entrance of rain into the induction system cannot be thought of in the same terms as the take-off power increase accomplished by controlled water injection where the carburettor or fuel pump is set to meter to the "best power mixture" of approximately 12.5 : 1 to develop 100% power, the water being used for cooling the mixture at the intake valves and in the cylinders and, in addition, permitting an increase in the maximum allowable manifold pressure—this permits an increase in take-off power up to approximately 15 per cent.

The presence of water vapor in the air causes a percentage loss in take-off power by displacing an equivalent amount of dry air (oxygen) with incombustible water vapor and this, in turn, results in overrichening as the fuel control system meters fuel on a mass flow basis, not differentiating between dry air and water vapor. As the fuel-air ratio at take-off is already richer than "best power mixture", for cooling purposes, this further enrichening causes an additional loss in power. Furthermore, the combustion process in the cylinder is somewhat adversely affected by the presence of water vapor which causes a reduction in the effective combustion temperature. High humidity will also cause

a decrease in supercharger compression ratio which will lower the full-throttle altitude and cause more manifold pressure fall-off above full-throttle height.

Round-up

Summing up the above, for a piston engine aeroplane, the pilot, on a hot day, may expect the wing lift to deteriorate aerodynamically and the engine power to fall off; further, if the day is both hot and humid he may expect the wing lift and engine performance further to deteriorate. The above does not take consideration of any recourse to water injection as a power supplement, or cover engines fitted with torquemeters, or BMEP gauges where the manifold pressure may be increased beyond normal part-throttle take-off manifold pressure to restore part or all of the power lost due to a hot, humid day.

Jets

A word on the power losses incurred by jet engines under high temperature and humidity conditions. The gas turbine, at take-off, is much more severely affected by hot outside air than the reciprocating engine, the adverse effect being somewhat over twice that for the piston engine. This is to be expected, as the gas turbine derives its thrust or power from the mass flow of air through the engine. As the air density decreases with increase in temperature, the weight of air entering the gas turbine on a hot day, at a given engine r.p.m. is considerably less than on a standard day. Also, the compression ratio of the jet engine decreases with increased inlet air temperature, which further decreases the available thrust or power. Fortunately, to restore this power loss, recourse can be taken to automatic water injection which can restore the engine power to its normal take-off rating over a wide outside air temperature range.

Ram Boosts Power

On the other hand, the effect of high humidity on the gas turbine is very small compared to the effect on the piston engine. As mentioned above, the gas turbine depends upon mass flow to develop its power and although the humid air will have a lower density than dry air, there is a slight gain in available energy which partially offsets the decrease in mass flow. As opposed to the very small effect on the reciprocating engine at take-off power, the intake of rain, in the liquid state, into the gas turbine has the effect of increasing the power an appreciable amount; this may be particularly noticeable during heavy rain concentrations (this ignores the fitting of any power limitation device on the gas turbine).

Jet Recap

In briefly recapitulating the effects of high temperature and humidity on jet powered aircraft, the pilot may expect the wing lift to deteriorate the same as for a piston engine aeroplane. If water injection is applied to restore the very adverse effects of high outside air temperatures (which will probably be the case for civil operation), the gas turbine will not suffer in this respect. The power losses due to humidity can be expected to be small in nature and will more often than not, fall within the manufacturer's power prediction for the gas turbine.

A Few Words on Safety

(Reproduced from Pilot's Safety Exchange Bulletin 57-100 issued by Flight Safety Foundation — 21st January, 1957 — a reprint of an article in "The Airline Pilot" by Captain F. E. W. Smith)

The most important word in the language of airline pilots is "safety", a word and a thought which we can never ignore.

A popular misconcept is to allot positive value to the term "safety". We say that this is "safe" and that that is "unsafe", as if with "this" no harm can possibly befall us and with "that" we are sure to come to a bad end whatever we do. This is wrong definition for the word has only relative value, being more descriptive of how something is done, and by whom, rather than of the thing itself.

Risk is Ever Present

To explain, there is nothing which man does which does not involve taking a risk of some sort. People have killed themselves by getting out of bed, by eating, and even by sleeping. No one can go through a single day without taking innumerable risks of one kind or another, most of them small, some of them perhaps big. The term "safety" does not mean freedom from danger because there is no such thing, danger being about us always. It does mean the application of skill and knowledge to a given situation of risk, which results in a satisfactory reduction of the hazard.

Positive Values

Hazard and risk are terms which have positive value, in that they describe the amount of danger inherent in any given activity. Most of the duties of life contain little risk, some are hazardous and some so dangerous that few men will attempt them. These we say are unsafe, but we are misusing the term, for they may be unsafe or they may be safe depending on the knowledge, skill and suitability of whoever is doing them. A man conditioned to an undertaking of great hazard, who fully understands the dangers which oppose his success, and who possesses or has devised a "safe" method of combating these dangers, may actually be safer among his risks than he might be doing things which he considers are without hazard. The term "unsafe" as applied to any dangerous undertaking, relates to the improbability of avoiding the risks which are inherent. When methods have been devised which give the individual an acceptable chance of success over these risks, the activity becomes "safe"—for those who understand the methods and who are fitted to apply them. It is still "unsafe" for those who are not suited and who remain in ignorance.

There are innumerable examples of the truth of this statement and only a few days ago the writer witnessed an excellent one. A high rigger threw his hat in the air from the top of a 100 foot tree—and beat it to the ground. To say the feat was hair-raising is an understatement. To say it was risky is indisputable, for the hazards of that mad scramble down the tree were most evident. But to say it was unsafe is wrong, for the tree climber was a professional performer who had been doing the same stunt twice a day for a number of years, and who has never been hurt doing it. Similarly, there is a man in California who has made a good living for many years crashing aircraft for the movies. He has been hurt, at times, but he has not yet been killed, even though he makes an occupation of something at which most people are killed on their first try. It is obvious that he has devised safe methods of doing something which is very dangerous.

Three Reasons for Failure

When a stunt man finally is killed doing his specialty, it is popular to note his passing with the observation that his stunt was most unsafe. It would be more correct to say that his dangerous occupation had become unsafe for him at the moment of his accident and it is probable that one or more of three reasons will explain its cause. First, he may have been unsuited, for men often display more nerve than good judgment in their ambitions. Second, the performer, his awareness of danger dulled by over familiarity with his act, may have become careless in some way in the application of his techniques. Third, some hazard, unforeseen and hitherto unencountered, may have, in this instance, transformed an act which had been safe for him into one which was unsafe, and he had not been able to solve his problem in the limited time available to him.

The man who wishes to do the hazardous and live must first be suited to his task. Then he must maintain a constant appreciation of the danger of what he is doing, and hold in deep respect the forces of destruction which are about him. He must be vigilant in his search for hidden dangers, ones which he has not encountered and hopes he never will, but which may face him some day in a most unexpected way. When he has discovered these, he must try to devise techniques which will defeat them, for if they catch him unawares he will be lost.

Evaluating the Hazards

This abstract discourse on the relation between hazard and safety, and the life and death of the stunt man, is appropriate for pilots because flying is one of the world's most hazardous occupations. Yes, we who are accustomed to think of ourselves as sober and cautious men, pillar-of-the-community types, are actually closely related to the high rigger and the high-wire performer. For flying is simply loaded with risks. We are surrounded with them as we are instruments; risks of engineering, of construction, of maintenance, of performance, of traffic, of weather and of our own abilities. A good way of evaluating the actual net hazard of the occupation is to contemplate the chance which an ordinary individual, untaught and ignorant of aircraft, has of stepping into a modern aeroplane and successfully completing any kind of flight. The probability of such an attempt ending happily is comparable to that of the same individual, no less well prepared, duplicating the feat of the high rigger.

But as the rigger, with knowledge, skill and practice is able to perform his act with safety, so is the pilot. We learn to fly. We study out the many hazards inherent in our occupation and are taught techniques which remove them. This is the only safety in flight, for the risks are ever present, unchanged from the days of the Wright brothers. It is the improvement and invention of technique, both of pilot and engineer, the enormous increase in knowledge of the air, of aeroplanes and how to build them, that has made aviation the safe, effective transportation of today. These spectacular advances have not, however, made the air one bit less hazardous.

Two Causes

It was pointed out above, assuming suitability, that when an accident occurs in a hazardous occupation there are two causes. Either the individual involved has become careless, or has been faced with some hazard new to his experience which he has been unable to combat. This is always true in the air. Of carelessness little need be said, for its consequences are impressed on pilots at the earliest age. But it is perhaps advisable to point out that mistakes of carelessness are the errors of experienced men and occur because they have lost the awareness of danger which is essential to their survival. The carelessness of the green but potentially competent pilot is an indication of his lack of skill.

New hazards must be of a type which cannot be simulated in training for otherwise the pilot would be instructed on them. The word "new" also relates to the experience of the individual concerned for it is possible that the same thing has confronted others. Such are of two main types; those which can be controlled and those which cannot be controlled. A pilot is able to learn much about the first type for if such has happened to anyone who has been able to succeed over it, a contribution to the general knowledge is made. A pilot can only conjecture on the second type for there is seldom a witness reporting the encounter.

TWO REMEDIES

There are two ways of seeking safety from the new, or as yet unmastered, hazard. First is avoidance. If you feel unequal to the risks of tree climbing—don't climb trees. Avoid flying manoeuvres which might cause destruction of the machine, unless properly equipped and prepared to meet the emergency and armed with a plausible excuse to top off the parachute ride home. If your aircraft is a single engine V.F.R. job and you are not competent to fly on instruments—don't take an I.F.R. jaunt anywhere, any time.

The second way is to expand the limit of what can be done safely by education and equipment. This involves learning all there is to know about the hazards which can normally be expected, and about as many unusual ones as one can. It involves conditioning (meaning the attainment of a mental attitude) and of physical skill, which will enable the man concerned to do what he knows should be done when required. And it demands possession of proper tools for the job. The tree climber does not perform his act in running shoes, with a clothesline safety belt. He has spurs, a wide belt and a very special rope. So does the pilot need a good aircraft, proper instruments and sufficient radio equipment before he can make a regular feat out of flying to schedule.

It has been shown that the term "safety" means the doing of something dangerous in a way which removes the risk. It was also pointed out that it is popular to misdefine the term and use it as an expression of the actual danger which is involved. People would do better if they said: "this is unsafe *for me*". The latter expression limits the experience of him who uses it for, having proclaimed the act unsafe, positively and definitely, his only recourse is in avoidance. Had he used the first expression he would have recognized the possibility that, with training and experience, it could be safe—for him—and would thus permit an expansion of his capabilities. Pilots are no different to anyone else in their tendency to limit themselves in this way. While we would all disagree with an average man's statement that flying is unsafe, we do place arbitrary limits on what we will do in the air, and say that certain flying operations are unsafe (e.g., tornado flying). We neglect to add the words "for us", and thus rule out the possibility that some day a technique may be devised which will make such flying safe. We see our safety in accordance which, until we are equipped to meet the hazard, is of course the only thing we can do.

Mastery vs. Avoidance

Avoidance is a very basic right, for no human can be expected to take physical risks which are beyond his capability. No one is ever compelled to climb trees or to fly aeroplanes. However, to those who have chosen these occupations, avoidance is a luxury they can ill afford. In considering tree-climbing, it is easy to see that there is safety only in complete mastery. The sooner the rigger attains such skill that he is able to overcome all foreseeable dangers, and has thought out solutions to all situations which may conceivably arise, no matter how unexpectedly, the sooner his factor of safety becomes acceptable. The pilot is in exactly the same situation. If, for example, he has decided that it is unsafe to fly on instruments because, perhaps, of the danger of ice and turbulence which lurk in cloud, he will seek to avoid all cloud flying. This is fine—except that some day he will not be able to avoid the cloud and, because he has limited his skill and knowledge, he will be in great danger in a situation which another pilot would term routine.

Care and Competence

In any dangerous occupation, and flying is such despite statistics, the safety of avoidance is largely illusionary. The only safety is in care, which is a must, and competence, which is skill developed through study, practice and experience. The attainment of this competence is a continuing, continual process for no one can ever say he is master of *all* emergencies. Any pilot who stops his progress to an ultimate mastery of the air, who says to himself that he knows all he wants to, or needs to, know of flying, is deluding himself and is placing himself in a position where he must seek safety in avoidance. Once he has so decided his operation ceases to be safe.

Anticipation of emergencies, devising means of surmounting them, improving on existing techniques, all are highly profitable ways for a pilot to spend his time. For one thing, such activity makes him safety-minded, not chance-minded. For another, by continually expanding what he can do, it makes him progressively safer in the air, putting real value into his experience. No wild fancy is too improbable for consideration. Witness the incident over Korea, where a pilot who had passed out from lack of oxygen was brought down to a safe latitude by two other pilots. Had these men not previously conceived of just such an emergency, and thought out the solution, their friend would surely have died.

PART II

OVERSEAS ACCIDENTS

Grand Canyon Collision

(Based on report of Civil Aeronautics Board, U.S.A.)

(18/27/142)

A collision between two airline aircraft over Grand Canyon, Arizona, on the morning of 30th June, 1956, resulted in the destruction of both aircraft and the deaths of their 128 occupants. Both aircraft had departed from the Los Angeles International Airport, the first at 0901, a Lockheed Constellation model 1049A bound for Kansas City, Missouri, followed three minutes later by a Douglas DC.7 bound for Chicago, Illinois. The collision occurred approximately 90 minutes later, both aircraft falling into the canyon near the confluence of the Colorado and Little Colorado Rivers.

The accompanying diagram shows the routes proposed for the flights. Both were planned as high altitude, long range, non-stop operations, authorised to be planned and flown off airways over direct courses. Such flights, however, require a flight plan over the direct route with numerous reporting points indicated to clearly define the proposed route.

The operator of the L.1049 permitted flights off airways in instrument weather conditions but only on an I.F.R. flight plan with an assigned altitude. When operating 1,000 feet on top the company required adherence to visual flight rules. This aircraft departed on an I.F.R. flight plan specifying direct stages from Daggett, at a cruising altitude of 19,000 feet and a true airspeed of 270 knots. Despatch of the flight was routine and included approval of a routing change to Daggett. Approaching Daggett at 0921 a change in flight plan altitude assignment to 21,000 feet was requested but was refused by Los Angeles Air Route Traffic Control Centre as this altitude had been allocated to the DC.7. This information was passed as an explanation of the denial of 21,000 feet and not as a traffic advisory service. The L.1049 then requested and received a clearance to 1,000 feet on top. The last position report passed by this flight through its company radio at Las Vegas advised having passed Lake Mohave at 0955, 1,000 feet on top at 21,000, and estimating reaching the Painted Desert line of position at 1031.

Company instructions for the DC.7 flight did not permit flights in instrument weather conditions when operating off the airways. This flight departed on an I.F.R. flight plan specifying direct stages from the Palm Springs intersection, at a cruising altitude of 21,000 feet and a true airspeed of 288 knots. Despatch of the aircraft was routine and its route clearance corresponded to the flight plan. Position reports were passed to company radio over Riverside and Palm Springs intersection, the latter report indicating that the aircraft was still climbing to 21,000 feet and estimating reaching Needles at 1000 and Painted Desert at 1034. A further position report was passed to the Civil Aeronautics Administration's communications station at Needles stating that the flight was over Needles at 0958, at 21,000 feet, and estimating the Painted Desert at 1031.

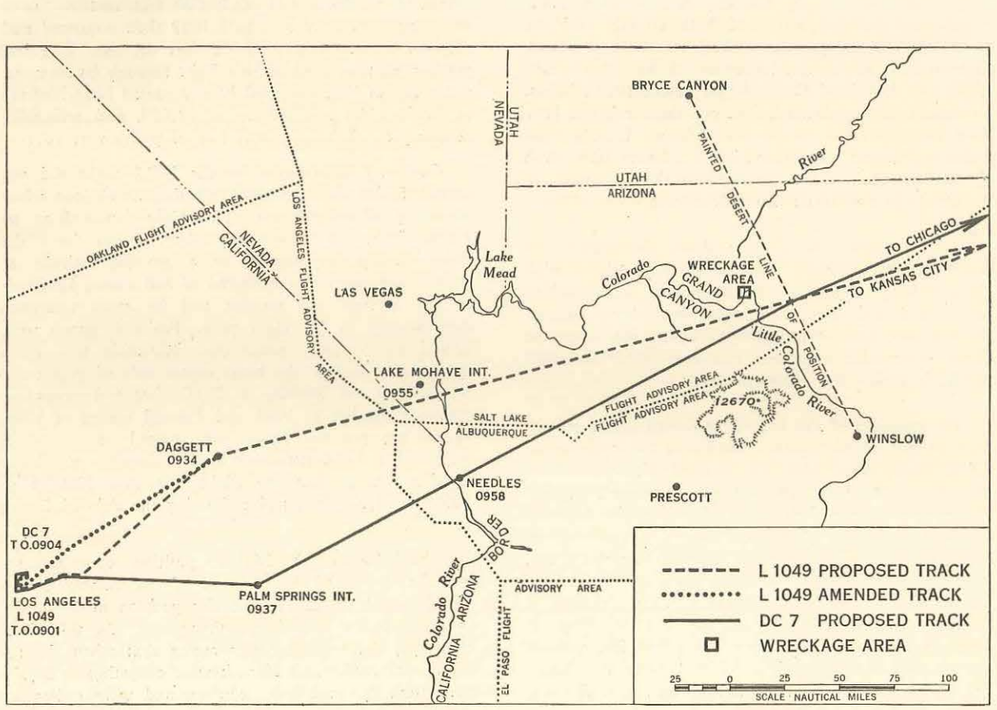
The L.1049's Lake Mohave position report was received at the Salt Lake Air Route Traffic Control Centre at 1001 and the DC.7's Needles position at 1013, the same controller receiving both reports. At this time, therefore, the controller was aware that when the reports were made both aircraft were operating at 21,000 feet, were on converging courses, and were estimating

the Painted Desert at the same time. He advised neither flight of this situation. The information available to the controller did not mean that the aircrafts' courses would converge on the Painted Desert line of position, but merely that both would pass the line, 175 miles in length, eastbound, at the same time.

Under the concept current in the U.S.A., Air Traffic Control undertakes to separate air traffic when it is operating under an I.F.R. clearance and operating within the controlled airspace. If instrument weather conditions exist and the above requirements are met all traffic will be separated. However, when visual flight conditions exist separation is only effected between aircraft operating under I.F.R. clearances, and not from V.F.R. traffic, much of which is unknown to Air Traffic Control. For this reason flights in visual conditions are required to provide their own separation regardless of flight plan or clearance.

Outside the controlled airspace the Air Traffic Control concept has not embraced the responsibility for separation of air traffic regardless of flight plan, clearance, or weather conditions. In this area the principal function of air traffic control is to monitor the progress of flights through the uncontrolled area so that an orderly flow of instrument traffic may be accomplished into the adjacent control area.

At the time of the accident, traffic advisory information to flights was offered at the discretion of the controller where control to air traffic was being exercised. Accurate and worthwhile traffic information depends on precise and timely movement reporting. Flights in the uncontrolled airspace are permitted greater flexibility to take advantage of wind and weather factors, and in this area navigational aids are insufficient to enable a flight to report its position with the precision essential to accurate advisory information. This was borne out by the progress of the flights of the aircraft involved in this accident. The time of the collision was ascertained from a radio transmission from the DC.7, ". . . we're going in", recorded at 1030.53. Both flights had progressed according to the established performance of the aircraft, making good their estimates between position reports until the segments immediately prior to the Painted Desert line of position. Both flights then estimated reaching the Painted Desert at 1031, but investigation showed that at this, the time of the accident,



both flights were approximately 3½ minutes' flying time from the estimated position.

Although knowledge of the projected flight paths of the aircraft could have prompted the Salt Lake controller to offer traffic advisory information on a voluntary basis, giving the best information available to him at the time, it was concluded that the existing control concept, air traffic control policies and procedures and the express duties of a controller did not require him to do so.

Analysis of available weather information indicates that the forecast conditions for the flights were reasonably accurate. Along their proposed routes scattered clouds commenced just east of the California-Arizona border, increasing, to the east, to broken cloud, then overcast with some breaks in the Grand Canyon area extending to slightly east of the accident site. Tops of this main weather coverage were approximately 15,000 feet, but near Grand Canyon Village the first of several scattered build-ups appears to have existed, isolated from others northeast of it, protruding through and above the lower clouds to approximately 25,000 feet. A rain area was noticed by pilots northwest of Grand Canyon Village. The overcast covered most, if not all, of the Grand Canyon.

Under the prevailing conditions each flight was required by company instructions to adhere to visual flight rules. It is unlikely that the pilot of the L.1049 would proceed into I.F.R. conditions after being informed that the DC.7 was in the area at 21,000 feet. The investigators were satisfied, therefore, that both flights were operating according to visual flight rules when the collision occurred, rendering the pilots responsible for maintaining separation between aircraft. Since no change of altitude was advised following the last position reports and there was no known reason for the flights to change altitude, it is considered reasonable to believe that the collision occurred at 21,000 feet.

The initial impact occurred with the DC.7 moving from right to left relative to the L.1049 and with the L.1049 moving to the right and aft relative to the DC.7. It appears that first contact involved the centre fin leading edge of the L.1049 and the left aileron tip of the DC.7. Instantly the lower surface of the DC.7 left wing struck the upper aft fuselage of the Constellation with disintegrating force, completely destroying the aft fuselage and the structural integrity of the left wing outer panel. As this occurred and the aircraft continued to pass laterally, the left fin leading edge of the Constellation and the left wing tip of the DC.7 made contact, tearing off pieces of both components. At the same time the No. 1 propeller of the DC.7 inflicted a series of cuts in the area of the aft baggage compartment of the L.1049. This entire sequence occurred in less than one-half second and in such a manner that an interlocking of the aircraft was virtually impossible.

The collision ripped open the fuselage of the Constellation and caused its empennage to separate almost immediately. This aircraft then pitched down and fell on a short forward trajectory to the ground. These factors suggest that the collision occurred in space over a position just west of the Constellation wreckage site. Most of the DC.7 left outer wing separated during the collision and its horizontal stabilizer was probably struck by pieces torn off the Constellation. It is believed that the DC.7 fell less steeply, probably on a turning path, to the ground.

The angle between the aircraft at the instant of impact was found to be approximately 25 degrees relative to their longitudinal axis. The DC.7 left wing was above the L.1049 relative wing plane, or the DC.7 was rolled approximately 20 degrees right wing down relative to the L.1049. The aircraft were orientated such that the vertical distance between their empennages was less than that between their nose sections. The difference as an angle was between 5 and 10 degrees. These aircraft attitudes were obtained from damage studies. They describe relative attitudes and do not necessarily reflect the orientation of the aircraft with respect to the ground.

There was no evidence found to indicate that malfunctioning or failure of the aircraft or their components was a factor in the accident. In the absence of survivors and eye-witness accounts, and in consideration of the many combinations of adverse factors which can result in a limited opportunity to see another aircraft, the investigators concluded that there was not enough evidence to determine whether or not there was sufficient opportunity for the pilots to avoid the collision.

The Board determined that the probable cause of the accident was that the pilots did not see each other in time to avoid the collision. It is not possible to determine why the pilots did not see each other, but the evidence suggests that it resulted from any one or a combination of the following factors; intervening clouds reducing time for visual separation, visual limitations due to cockpit visibility, and pre-occupation with normal cockpit duties, pre-occupation with matters unrelated to cockpit duties such as attempting to provide the passengers with a more scenic view of the Grand Canyon area, physiological limits to human vision reducing the time opportunity to see and avoid the other aircraft, or insufficiency of en-route air traffic advisory information due to inadequacy of facilities and lack of personnel in air traffic control.

Structural Failure in Flight – C.46 at Hollywood, South Carolina, U.S.A.

(Based on report of Civil Aeronautics Board, U.S.A.)

(18/27/111)

At approximately 2040 on 17th December, 1955, a C.46 crashed in a cornfield near Hollywood, South Carolina. The only occupants, two pilots, were killed and the aircraft was destroyed by impact and subsequent fire.

The Flight

The aircraft was engaged on a scheduled cargo flight from New York to Miami, Florida, with scheduled stops at Wilmington, North Carolina and Jacksonville, Florida. Flying on a V.F.R. flight plan the aircraft landed at Wilmington at 1857 and departed again at 1936, estimating Jacksonville at 2156. At approximately 2040, at a point near Hollywood, South Carolina, engines were heard by witnesses and lights were seen descending on an erratic path as the aircraft fell in several pieces to the ground.

Investigation

At the time of take-off from Wilmington, the aircraft was loaded to a gross weight of 47,994 lb. (maximum allowable 48,000 lb.) and its load was properly distributed.

The position report transmitted to Myrtle Beach Radio was "V.F.R. over Myrtle Beach radio 2003E en-route to Jacksonville". This transmission was intercepted by the captain of another C.46 northbound and near Charleston, South Carolina. Direct radio contact was established between the two captains and information was sought concerning surface winds, ground speed and other conditions encountered en-route from Miami.

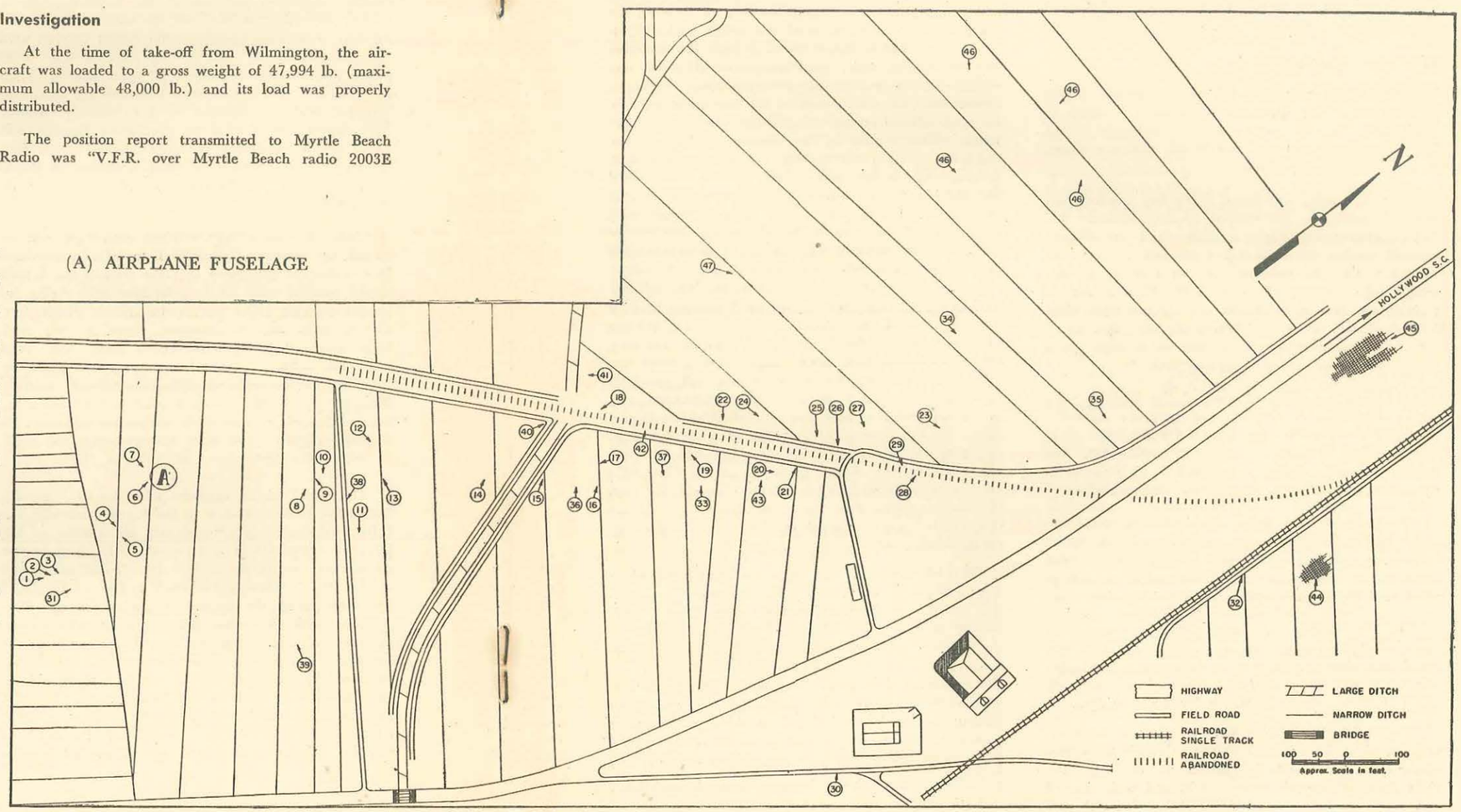
The captain of the northbound aircraft testified that his altitude was 7,000 feet and that he watched for but did not sight the other C.46; he concluded that the interest displayed in surface winds indicated flight at a low altitude, 2,000 to 4,000 feet. At 2032, a routine position report was passed to Charleston Radio and this was the last radio contact with the aircraft.

At 1927 and at 2027, the Weather Bureau, at Charleston, South Carolina, recorded the following observations; Ceiling unlimited, visibility 7 miles, wind calm.

The captain and first officer held airline transport

1. Left Landing Gear Uplatch
2. Left Engine Prop Blade
3. Lower Left Nacelle Piece, right hand side
4. 3 feet Left Inboard Elevator
5. Left Elevator Tip 6 feet
6. Flare
7. Belly Hydraulic Access Door
8. Thermos Bottle
9. Piece of Left Windshield
10. Left Nacelle Door (left side)
11. Right Front Fuel Tank
12. Piece of Fin Base
13. Small Piece of Nacelle
14. Small Piece of Wing
15. Right Flap Piece 4 feet - Inboard Piece Right Outboard - Nearby Fuel Tank Cradle (see 23)
16. Piece of Vertical Fin, Spar-Tank Cradle in Ditch
17. Rib, Fin
18. Left Stabilizer, 7 feet of Left Elevator V Tab, Piece of Red Filter Anti-Collision Light Found on Inboard Side of Outboard Hinge Bracket
19. Skin, Piece of Fin
20. Piece of Nose Rib Wing
21. Right Rear Fuel Tank
22. Fuel Tank Vent Line
23. Right Outboard Part of Right Outboard Flap (see 15)
24. Piece of Elevator Tab and Piece of Skin Unknown Oily Marked 24
25. Jepco Chart No. 19 and 20 and Piece of Stringer Bulb Angle Probably Wing Leading Edge
26. Piece of Wing Skin and Stringers.
27. 3 feet Wing Skin and Stringers
28. Leading Edge Right Wing 5 feet Inboard Side of Outboard Panel
29. Pieces of Flap Trailing Edge
30. Right Stabilizer 3 feet of Elevator and Elevator Trim Tab
31. Left Engine
32. Piece of Right Horizontal Stabilizer
33. Right Aileron Tip 8 feet
34. Right Elevator Tip 7 feet
35. Flap Well Piece, Right Wing Inboard of Outboard Wing Panel
36. Top of Rudder
37. Vertical Fin
38. Left Nacelle Door (Right Side)
39. Right Centre Fuel Tank
40. Left Landing Gear Splash Shield
41. Piece of Vent Line
42. Captain's Notebook (usually carried in shirt pocket)
43. Right Wing
44. Wingwalk
45. Airforce Radio Facility Book (shredded)
46. Maintenance Manual Cover and a few scattered pages
47. Pieces of Bonding from Hydraulic Lines Gang Blocks

(A) AIRPLANE FUSELAGE



licences. They had logged 10,000 hours and 3,300 hours respectively, and the captain had 731 hours on C.46s. The aircraft had flown a total of 1,304 hours of which 304 hours were flown since the major overhaul and conversion from a military cargo model C.46A to model C.46F under civil certification.

During the month preceding the accident pilot complaints of porpoising and of stiffness in the elevator tab controls were entered in the flight log of the aircraft on two occasions, and of porpoising owing to elevator controls or trim tabs or their rigging on four occasions. Maintenance entries in the flight log recorded a check of elevator tab rigging, a change of tension on the elevator Vee tab rod and replacement of the right and left elevator spring cartridges.

Wreckage Distribution

The aircraft fragments fell to the ground within an area measuring approximately 2,500 feet north to south and 700 feet east to west. Distribution of the larger fragments and the identity of each are shown in the accompanying sketch.

The right wing was found 1,118 feet northeast of the main wreckage, the vertical fin approximately 937 feet northeast, the right stabilizer and an inboard elevator section approximately 1,380 feet northeast by east, and the left stabilizer and an inboard elevator section approximately 825 feet north. Most of the remaining empennage, sections of the flap and right wing, left wheel well doors, the three right wing fuel tanks, sections of windshield, and various other small parts were strewn over the same general area.

The main wreckage consisted of the fuselage, wing centre section, right engine and propeller assembly, landing gears, and left wing. The entire left power package, including the engine, propeller, cowling, and the nacelle forward of the wing front spar, was found approximately 312 feet south of the main wreckage.

The fuselage, broken in two just forward of the cargo loading door, lay on its right side with the entire cockpit area demolished by fire. Fire damage extended along the floor from the nose and cockpit area rearward well beyond the trailing edge of the wing.

The left elevator and rudder spring cartridges were recovered but the right elevator spring cartridge was not found, although the bell crank to which it attaches was dug out of the ground at a depth of approximately two feet during a special search for the cartridge.

The entire right engine, with nacelle and propeller, was buried in the soft earth at approximately the centre of the cockpit area with the right centre section and the right inboard flap collapsed over it, and with charred cargo and the mangled overhead electrical panel over them. The left engine nose section was disintegrated and ground fire damage was evident around and to the rear of the carburettor as well as to the front and rear of the firewall on the left side. Careful examination of the engines and propellers revealed no indication that they had malfunctioned in any way.

Wreckage Examination

Nine pieces of the right horizontal tail were recovered. These accounted for the surfaces except for the portion of elevator between the third and fourth hinges from the tip. Examination of the stabilizer damage disclosed tension failures of the upper spar caps and stringers and compression buckling of those on the lower surface just outboard of the attach angles. Outboard of the failure line there were dents and scratches on the leading edge, skin tears, and diagonal skin wrinkles caused by the rearward-acting loads. The right elevator was severed at each of the four hinge stations, the most inboard failure being in line with the stabilizer failure. The portion of the elevator inboard of the fourth hinge from the tip was recovered at the main wreckage site in two pieces, both severely accordioned and flattened from inward-acting loads, indicating that they remained attached to the elevator torque tube through the fuselage until ground impact. The end of the spring tab cartridge was still bolted to its mounting bracket in the accordioned piece of elevator leading edge, but the cartridge was broken off and missing. The spring tab was torn in two by downward bending just outboard of the control horn. The outer portion (Item 24 in the sketch) had little deformation outboard of the fracture, while the inboard portion was extensively crumpled indicating that it had remained with the main wreckage until ground impact. The spring tab push-pull tube was still bolted to the control horn. At the forward end of the tube the fork end fitting of the spring cartridge shaft was still attached, the shaft having failed from overload. The right elevator trim tab and its controls were intact. Although the bushing required by Item 4 of Airworthiness Directive 47-51-2 was not installed, the idler rotated freely on the hinge bolt.

The left horizontal tail separated from the fuselage just outboard of the attach angles because of compression buckling of the stabilizer lower surface and tension failures of the upper surface. The upper surfaces of the stabilizer and elevator outboard of the second hinge from the tip were severely deformed by impact from an object moving downward. The outline of this damage area conforms closely to the shape of the tip and upper leading edge of the vertical tail. In this area there were numerous scratches in the surface of the skin. A small fragment of the Grimes anticollision light red filter was embedded in the stabilizer between the tip hinge bracket and the closing skin.

The Vee tab* with its counterweights was still attached and its controls were intact. The tab control cables were broken about three feet inboard of the stabilizer failure.

At the bell crank on the left end of the elevator torque tube the tab push-pull rod end was bent upward and broken off after very extensive deformation. The spring cartridge fork end was broken off from bending loads, with the broken off portions still in the bell crank attachment. The spring cartridge remained attached in the elevator nose section with the shaft bent; this bend in the shaft restricted motion of the plunger on the shaft, resulting in the shaft being free to reciprocate through a small range without any spring load. This spring cartridge bore the stamp "US AIR".

The main portion of the fin (Item 37) was found in one piece. Directly above the leading edge fracture, the leading edge was deformed by impact loads and the deicer boot was cut and scratched. One to two feet above the leading edge fracture the nose radius was flattened to the right by impact forces, with rivet scratches in evidence on the skin behind the deicer boot. The left side of the tip section was crumpled and scratched by impact with riveted metal. The Grimes anticollision light at the extreme tip of the fin was shattered by impact on the left side, as indicated by deformation of the base. At the bottom of the fin the skin, stringers, ribs, and multi-spars were severely fragmented by a combination of rearward impact forces and bending to the left.

The rudder was torn in two at the second hinge from the top. The lower portion of the rudder remained with the fuselage, held there by the push-pull rod still attached to the walking beam to which the rudder cables attach. The push-pull rods, walking beam at the fin spar, the spring cartridge and the tab horn were still attached and in operable condition except that the spring tab shaft was bent, restricting the spring travel. The balance weight remained attached to the upper portion of the rudder (Item 36). The spring tab and the lower portion of the trim tab were found at the main wreckage site with damage consistent with that to the lower portion of the rudder, indicating that they were still attached at ground impact. The upper portion of the rudder trim tab with the push-pull tube, idler, and tab motor still attached were found at the main wreckage site. The fracture at the bottom of the tab was consistent with the rudder fracture directly forward thereof.

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* Vee Tab — The left elevator trim tab on the C.46F; it has a spring-loaded shaft between the tab horn and the irreversible tab screw, and is rigged 20 degrees higher than the right elevator trim tab. When air forces on the Vee tab produce more than a fixed load in the spring-loaded shaft, the Vee tab will deflect downward and reduce the air forces on the tab until they balance the shaft load. This operation is designed to increase the longitudinal stability of the aeroplane.

The right wing outer panel failed just outboard of the attachment to the centre panel. In the fuel tank area there were many indications of compression buckling of the lower surface skin, stringers, and spar caps. On the upper surface the spar caps failed in tension after noticeable downward bending deformation. No evidence of fatigue cracking was found.

HISTORY OF THE AIRCRAFT AND ITS CONVERSION

The aircraft was manufactured for and operated by the U.S. Air Force as a C.46A, and was decommissioned and staked down for storage in the Egyptian desert.

Subsequently an Italian firm obtained possession of this aircraft, and the Curtiss-Wright company authorised this firm to convert C.43's to C.46E's, and provided them with an incomplete set of drawings relative to this conversion, which is identical to that for the C.46F insofar as the tail surfaces are concerned. In order to facilitate a satisfactory conversion an approved kit of parts from a C.46F elevator was obtained from an American firm.

Officials of the Italian firm testified to the effect that where specified material was not available the nearest available material was used such as: next thicker gauge in sheet dural, steel rods for dural rods, machined parts for castings, etc. In every case the strength of the material in the new part exceeded the strength of the material specified. Many of the newly installed parts were heavier than the original parts but the only vibration tests conducted were those in normal flight. No tests were conducted at maximum diving speed.

In the course of the investigation the rudder elevators, their tabs and their control mechanisms were compared with applicable Curtiss-Wright drawings specified on a drawing list provided by the Civil Aeronautics Administration. This comparison disclosed many nonconformities, a few of which are described below. Variations from specified dimensions, materials, and surface finish, together with a bow in the shaft, resulted in binding in the spring-loaded elevator Vee tab shaft assembly. The left elevator spring tab cartridge assembly had two concentric springs, neither of which conformed to the single spring specified. Both the inside surface of the larger spring and the outside surface of the smaller spring were polished by mutual interference in operation. In addition, the inside surface of the smaller spring and a collar on the shaft which extends through the spring were polished by interference with one another. Instead of bronze, oilite steel that was not corrosion resistant was used to make the plungers at the ends of the springs. On the right and left elevator spring tab push-pull tubes which parallel the elevator

torque tube, the clevises attaching to a common bolt at the centreline of the aeroplane, were made symmetrical instead of offset. This caused misalignment of the tubes. Skin gauges on the elevators and tabs were found to be heavier than specified.

Since both the right and left elevators and elevator tabs of the aircraft were severely distorted, with portions missing, it was impossible to determine the balance of these assemblies experimentally. To approximate the elevator balance it was decided to remove the balance weights from the aircraft assemblies and install them on a right-hand elevator assembly in possession of the operator, which was reported to be a spare manufactured by the Italian firm about the same time as those on the aircraft.

Balancing on this assembly indicated that the unbalance as measured from the hinge line was about half of the maximum permitted and the spanwise location of the c.g. was farther inboard.

Analysis

Ground impact marks made by dense pieces of the aircraft indicate that these parts were descending almost vertically. This, and the scatter of wreckage, prove that disintegration occurred at an appreciable altitude.

Examination of the wreckage disclosed that the left horizontal tail failed downward after it received a severe downward impact from the fin structure. Both the leading edge of the fin and the leading edge of the right horizontal tail were dented and scratched by impact with rearward moving objects. In addition, the fractures near the root end of the right stabilizer showed strong evidence of rearward tearing along with downward failure. Portions of the detached right wing also showed evidence of impact with other objects. From the above, it can be concluded that the right wing failure occurred before the structural failures of the tail surfaces and that portions of the separated right outer wing striking the tail surfaces contributed largely to their failure.

From the closeness of the nacelle and main gear doors of the fuselage wreckage it is apparent that the nacelle failure, which had caused the gear doors to be distorted to the left and torn off, occurred late in the sequence of structural disintegration, after the right wing and tail surfaces had separated from the aircraft and the main wreckage had descended appreciably. It appears probable, therefore, that the nacelle failure was caused by abnormal inertia loads resulting from the uncontrolled gyrations following failure of the wing and tail surfaces.

The nature of the structural distortions at the right outer wing panel and the downward deformation near the inboard end of all three separated fuel tanks indicate conclusively that the lower surface of the right outer wing panel buckled under high compressive loads and the wing bent downward before the upper surface failed. This sequence of failure results from downward acting loads on the wing which produce stresses in excess of the wing strength.

Excessive negative loads on the wing during cruising flight are likely to result from either failure or erratic operation of the horizontal tail surfaces. Since analysis of the damage indicates that failure of the tail surfaces resulted from, rather than caused, the wing failure, it appears most likely that the wing failure was caused by erratic operation of the horizontal tail controls.

Although examination of the elevator and elevator tab controls did not disclose evidence to prove beyond doubt the malfunctioning of these controls caused the aircraft to pitch down and overload the wing, it did disclose evidence that indicated this possibility. One possible cause is the noted binding in the spring-loaded Vee tab push-pull tube, which resulted from a bow in the shaft and numerous nonconformities in its construction. Pilot entries in the flight logs of the aircraft disclose records of repeated "porpoising" because of malfunction in the elevator or elevator tab control.

A possible cause of violent manoeuvres and concurrent excessive loads is erratic action of the elevator spring tab cartridges. The nonconforming plungers in the recovered left-hand cartridge could have caused binding on the shaft. Wear marks on the nonconforming springs and shaft collar indicate the possibility of erratic action owing to mutual interference. Although the condition of the missing right-hand cartridge is unknown, there is no reason to believe that it was better than the left-hand cartridge and its condition could have been worse. The fact that these spring cartridges were installed in the aircraft the day before the accident also tends to indicate the possibility of their malfunctioning having contributed to the accident.

Nonconforming clevises found on the elevator spring tab push-pull rods which parallel the elevator torque tube could also cause binding due to inadequate clearance of the rods with respect to other parts of the elevator torque tube.

Considering the above-mentioned nonconformities, together with others found during examination of the elevator tab controls, it appears likely that their cumulative effects could very well have caused sufficient erratic action of the tabs to pitch the aircraft nose-down and produce excessive negative loads on the wing.

These nonconformities were not detected by personnel of the Civil Aeronautics Administration, partly because of the unusual handling of the aircraft, through international channels, and partly because of the nonavailability of complete control file of technical data on the various models of the C.46.

Probable Cause

The Board determined that the probable cause of this accident was an inflight structural failure resulting from a violent pitch-down induced by the erratic action of nonconforming elevator tab controls.

Bristol 170 Out of Control at Fox, Canada

(Based on report of Civil Aviation Division, Department of Transport, Canada)

(18/27/90)

On 13th February, 1956, a Bristol 170 aircraft took off at about 0825 on a non-scheduled flight from FOX to CAM D with the pilot-in-command, co-pilot and flight engineer on board; the chassis and engine of a five ton dump truck was carried as freight. About one minute after take-off the pilot-in-command called the control tower and told them that his load had shifted to the rear. At 0827 when the aircraft was approaching the end of the downwind leg it was seen to assume a climbing attitude, fall into a spin to the right and crash to the ground. Also five seconds after the impact the aircraft exploded and caught fire. The three crew members were killed and the aircraft was destroyed.

Investigation

Examination of the wreckage showed that the elevator trim tab was in the maximum position for a nose down attitude of the aircraft, and the flaps were in the maximum down position.

The weight of the truck chassis and engine, according to the manifest and shipping list, was 12,000 lb. However, it was stated later by Company officials, that the weight on these forms was incorrect and that the actual weight was about 7,750 lb. This included two wooden skids which it was stated were 21 feet in length and made of 6in. x 6in. black spruce.

Assuming that the weight of the truck was 7,750 lb., the all-up-weight of the aircraft would have been 43,500 lb. The maximum permissible all-up-weight was 44,000 lb. It was calculated that when the truck slid to the rear, the position of the centre-of-gravity of the aircraft moved to about 108.5 inches aft of the datum, or 17.35 inches aft of the maximum permissible aft limit.

A portion of the lashing chain, taken from the wreckage for test, was determined to have had a breaking strain of about 3000 lb., while the recommended safe working load was 900 lb. It was also determined, from the Bristol 170 Maintenance Manual, that the tie-downs which were used in the aircraft, had a breaking strain of 4,000 lb and were recommended for a safe working load of 1,000 lb. The truck was not secured in accordance with the instruction contained in the Maintenance Manual, in that only six chains (without turnbuckles), and two ropes were used at eight tie-down points instead of fourteen chains, with turnbuckles, which should have been used at fourteen tie-down points. Company officials stated that turnbuckles were available in the aircraft.

It would appear that there was snow and ice on the bottom of the skids to which the load was attached and it is considered that a load considerably in excess of the breaking strain of both the chain and the rings would have been exerted during the acceleration of take-off. This combined with slackness in the chains due to the inadequate method of securing the truck could have produced an impact load sufficient to break the chain or the tie-down rings or both.

From approximate calculations it was determined that had the truck been secured at fourteen points as required by the Maintenance Manual the forces would have been distributed in such a manner that failure of the chains or tie-down points would not have been likely to occur.

The pilot-in-command held a valid airline transport pilot licence and had accumulated a total of about 8450 hours of flying experience of which 137 hours had been flown during the last 90 days. Although his log book was not available, he was believed to have had considerable experience on the Bristol 170 type.

The co-pilot held a commercial pilot licence which had expired medically 8th August, 1955, and he had accumulated a total of about 3000 hours flying experience of which about 115 hours had been flown within the last 90 days. This included about 55 hours on the Bristol 170 type of aircraft.

The flight engineer held a valid aircraft maintenance engineer licence which was endorsed for the Bristol 170 type of aircraft.

Weather was not considered to have been a factor in this accident.

Conclusions

The truck, which was not properly secured, broke free, probably during the acceleration of take-off and slid to the rear of the aircraft, causing the centre-of-gravity of the aircraft to move considerably aft of the maximum permissible aft limit. While attempting to return to land the pilot lost control of the aircraft which stalled, went into a spin and crashed.

PART III

AUSTRALIAN ACCIDENTS

Fatal Collision With Power Cables

(6/257/68)

A DH.82 flew into high tension power cables, crashed and burnt whilst engaged on low flying instruction in an authorized low flying area. The aircraft struck the cables whilst in level flight about 33 feet above the ground. The aircraft then struck the ground in a near vertical attitude, overturned and came to rest where it was destroyed by fire. The instructor and pupil pilot were killed on impact.

The aircraft had departed from Gilgandra Aerodrome at about 0930 and proceeded to the low flying area for the purpose of practising forced landings. The aircraft was under the command of the manager-instructor of the local aero club and was giving flying instruction on DH.82s to his pupil who was the holder of a private pilot licence.

The aircraft was observed by at least one eye-witness to pull up on completion of a simulated forced landing, after which he watched it fly out of view close to the ground in a north-westerly direction. About ten minutes later other witnesses in the area observed the aircraft to be flying in a southerly direction at about tree-top level. It was flying over cleared land when it was observed to suddenly dive into the ground and catch fire.

The instructor held a commercial pilot licence and a grading as a "C" class instructor. His total experience amounted to 956 hours, 390 hours of which were flown on instructional duties. His total experience on DH.82s was 52 hours.

The pupil pilot was the holder of a private pilot licence with a total experience of approximately 85 hours all of which had been flown on Austers.

There was no evidence to suggest that the aircraft was not engaged in deliberate low flying at tree-top level or that it was operating other than normally. The site of the accident was within the boundaries of the authorised low flying area but it is not known whether the instructor was aware of the presence of the wires. It was unfortunate that when approaching from the direction flown in this instance both poles carrying the cables were obscured by trees.

Cause

The cause of the accident was that whilst engaged on authorised low flying, the pilot failed to sight electric power cables in time to take avoiding action.

DH.82 Overturns Whilst Crop Spraying

(6/556/87)

On 1st October, 1956, at 1810 E.S.T., a DH.82 engaged in spraying, came into contact with a wheat crop and overturned in a field about 20 miles south of Port Pirie in South Australia. The pilot was not injured but the aircraft was extensively damaged.

The pilot had received some training and instruction in low level agricultural techniques, but had obtained no first hand experience on the work prior to this flight. After completing a number of trial runs under the supervision of an experienced agricultural operator, he took off late in the afternoon to spray a very large wheat field with the hormone weed killer. Several runs at a height of 10 - 15 feet were completed in east-west directions and on the final run into the east the pilot realised at about the mid-point that the wheels were in the crop. He applied back stick and full throttle but the aircraft would not lift and after continuing for about 300 feet the propeller struck the ground and the aircraft pitched forward onto its back. The average height of the crop was about 2½ feet and the final flight path was over slightly rising ground. There was no wind, only slight turbulence, and unrestricted visibility at the time of the accident, but the field had just come under cloud shadow as the final run commenced.

When the pilot first felt the wheels of the aircraft in the crop he was surprised as he thought at that stage he was ten feet above it. Such an error by a pilot whose judgment had proved reliable on other occasions suggests that perhaps he was trying too hard. It is unlikely that on his first flight under the instructor's eye he would be careless or lose concentration. On the contrary it is possible that he was too tense and in the narrowing of the field of observation which accompanies intense concentration he either did not observe the crop level for an over-long period or he neglected to take a long view of the terrain ahead.

Cause

The cause of the accident was that the pilot misjudged the height of the aircraft above the crop so that the undercarriage became entangled.

Auster Stalls Into Timbered Slopes

(6/256/506)

Late one afternoon in December, 1956, an Auster J5 took-off from a private strip in the New England district of New South Wales. Shortly afterwards it struck trees in mountainous country and caught fire. Both the pilot and the sheep dog accompanying him died in the accident. The aircraft was engaged on a private travel flight between pastoral properties managed by the pilot, who was also part owner of the aircraft. The accident occurred at a height of 2,700 feet above sea level and at a point some 33 miles west of Armidale.

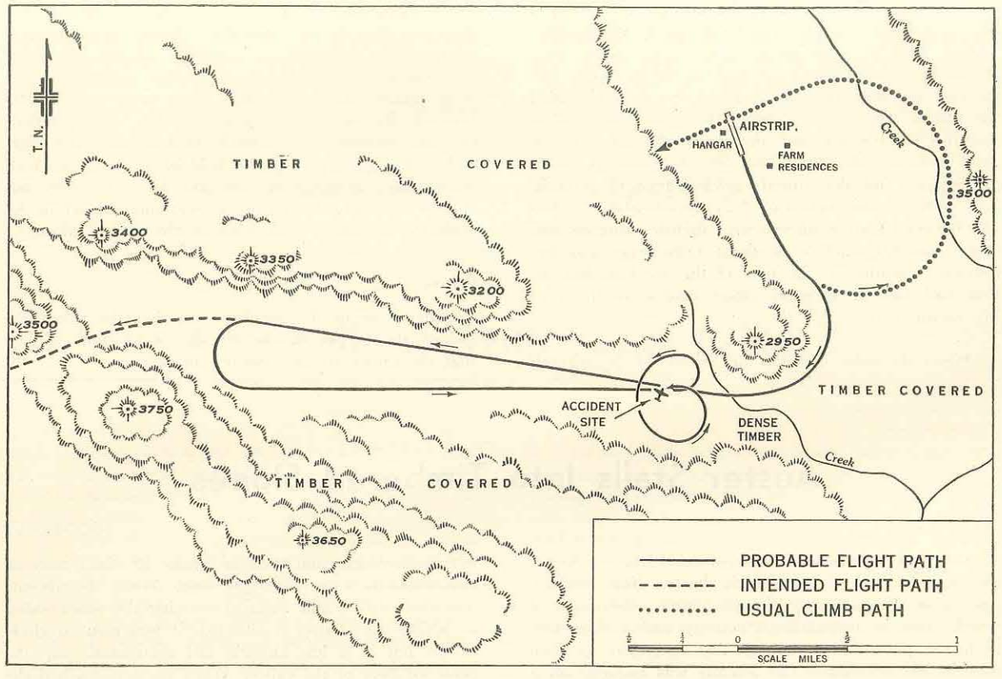
The pilot held a private licence and had 1,228 hours of flying experience of which 1,210 hours had been flown on the Auster J5. He had spent the day working on an out-station property and he was returning to his home station, some 42 miles distant, at the end of the day. It was also his custom to carry a sheep dog in the aircraft, restricted in the back seat by a chain attached to a fuselage member. On this occasion he remarked to an acquaintance that the dog was nervous whilst flying but nevertheless he was observed to place it untethered in the back seat.

The take-off was carried out with a slight tailwind component and it was noticed that the pilot did not follow his usual practice of carrying out a left-hand circuit, gaining height, before attempting to clear the hills bounding the strip on its western side. On this occasion, after travelling about one mile from take-off, the aircraft turned to the right into a narrow subsidiary valley, the floor of which rises steadily into the western hills (see diagram). The aircraft climbed along the line of this valley until it had almost cleared the highest terrain when it was seen to turn 180 degrees left losing height and then to retrace its flight path on approximately a reciprocal heading. When the aircraft was about half-a-mile short of entering the wider valley in which the airstrip is situated, it was seen to circle to the left at a low altitude and then crash into the timbered floor of the valley. When rescuers reached the aircraft about 30 minutes later it was burnt out and it is assumed that it had burst into flames very soon after impact.

The value of the wreckage examination was restricted by fire damage to the aircraft but the following points were established:

- The whole of the aircraft could be accounted for at the wreckage site;
- The aircraft had struck the tops of tall trees probably in a stalled condition and had fallen to the ground immediately below—impact damage was extensive but not indicative of severe impact forces;
- Propeller damage indicated that the engine was developing very little or no power at the time of impact;
- Both tanks contained fuel and the auxiliary was selected to the engine.
- Wing flaps were set in the take-off position;
- Examination of the fire damaged engine did not reveal any evidence of defect or malfunctioning which might have occurred prior to impact.

Although the pilot did not follow his customary route out of the valley, it appears from eyewitness



descriptions that the aircraft had almost reached the point where it would have crossed the highest terrain on the short route to the pilot's home station. He had hurried away so that he could call at another outstation en-route to his home (and this may well explain the right hand turn onto course) and yet the aircraft was turned about and retraced its track towards the departure strip for some two miles. The only feasible explanation for this is that some unserviceability developed in the aircraft which made it impossible, or at least inadvisable to continue the flight towards the home station.

During the turn the aircraft had dropped so low into the narrow valley it had been following that on its completion, the pilot apparently could not approach the strip direct and had to make for the junction of the two valleys before a left turn towards the strip could be attempted. However before the valley junction was reached, the aircraft apparently spun out of control into the trees from a very low height. There is no known reason why the pilot should voluntarily have turned back, in fact, in the circumstances of his departure, it was most unexpected.

No evidence of any structural failure occurring in flight has been discovered nor of any malfunctioning of flight controls. Apart from the final plunge into the trees the eyewitnesses were not alarmed by any unusual or sudden manoeuvres of the aircraft which might have been a manifestation of any such failures. However there is strong evidence, albeit circumstantial, of a substantial loss of engine power at the point where the aircraft turned back. Considerable height was lost in this turn despite the forbidding terrain not far below; at least two eyewitnesses noticed the absence of engine noise from this point on and, after the turn, the aircraft continued to descend below the level of the immediately adjacent hill-tops. It is certain that, at the point where the first turn was made, the aircraft had sufficient height to approach the strip direct if enough engine power to control the angle of descent had been available.

It is most unlikely that a pilot of this experience would leave flaps in the take-off position for some miles after becoming airborne, particularly when his selected flight path demanded the optimum climb angle, but it is most likely that a pilot without engine power and desperately endeavouring to stay in the air in the face of dwindling airspeed and height would select this amount of flap down, at least in the final stages of the

flight, to reduce the stalling speed as much as possible. The probability of engine failure is also consistent with the propeller damage which clearly indicates a condition of no power, or at least negligible power on impact.

A careful strip examination of the engine was carried out but no evidence was discovered which might confirm that an engine failure had occurred. Nevertheless, the whole engine had been subjected to intense heat in the fire which followed impact and this may well have destroyed vital evidence. Other possible explanations of the accident have been carefully considered including the possibility of the nervous and untethered dog interfering with the pilot's control of the aircraft but they do not provide satisfactory explanations.

It seems that the occurrence of a substantial loss of engine power is the most likely explanation of this accident but the evidence is not sufficiently strong to exclude all other possibilities and so the assessment of cause must remain as "undetermined".

Cessna Overturns in Forced Landing

(6/456/127)

When forced to land near Faita due to engine failure while en-route from Madang to Mt. Hagen, New Guinea, on a charter flight, a Cessna 170 was extensively damaged. The accident occurred at 1448 E.S.T. on 14th November, 1956. The pilot, the sole occupant, suffered only minor abrasions although the aircraft overturned in dense tropical undergrowth. Search aircraft located the Cessna within one hour of transmission of its distress call and survival equipment and supplies were dropped to the pilot the same afternoon. Rescue was effected by a ground party which walked into the accident site from Faita, the nearest landing strip.

The aircraft departed Madang at 1415 carrying fuel for the flight and three hours reserve. Thirty minutes after departure the pilot advised Madang aeradio that the engine was running roughly and he was attempting a landing on mud flats on a tributary of the Ramu River. One minute later he advised that oil pressure was zero and that the engine had failed. Nothing further was heard from the aircraft.

Apart from isolated sand and mud banks on the river, and some patches of kunai grass, the area in which the forced landing was made is covered with dense rain forest. The pilot manoeuvred for a landing on a clear sand patch but on getting closer to it realised it was too short, giving rise to the possibility of overshooting into the river. He then elected to land in very high grass beside the sand patch. This was achieved but the aircraft turned over and came to rest in the inverted position.

The pilot held a commercial licence and was qualified to operate over the route being flown. His experience amounted to 1423 hours of which 900 hours were flown in Cessnas.

Some of the smaller components of the aircraft were salvaged at the time of the rescue operation but due to the remoteness of the location, the engine was not recovered until some three months after the accident. Examination disclosed that the big end bearing cap of No. 5 connecting rod had separated from the rod causing considerable damage to the cylinder skirts, valve lifters and crankcase. A large hole in the crankcase at the base of No. 6 cylinder was apparently caused by jamming of a broken part between the crankcase and No. 6 connecting rod or its crank. The sequence of failure was traced back to fracture of the split pin securing the nut of one of the pair of bolts fastening the big end bearing cap of No. 5 connecting rod. The pin was thrown from the bolt allowing the nut to back off the bolt. The tips of the split pin were not found despite a careful search of the interior of the engine and of the lubrication system. However, from the condition of the ends of the shank of the pin it was concluded that the legs fractured at the point where they were bent around the nut in the locking process and it is considered likely that the fracture originated at the time the pin was fitted. The cause of the fracture of the split pin was not determined.

Cause

The accident was caused by fracture of a split pin in the big end assembly of No. 5 connecting rod resulting in power loss necessitating a landing on unsuitable terrain.

DH.82 Strikes Tree During Emergency Landing

(6/156/566)

During crop spraying operations at a low level, a DH.82 experienced engine failure and in the subsequent landing struck a fence in a field one mile north of the township of Cowarr in Eastern Victoria. The owner was the only occupant of the aircraft and he was not injured in the accident. The aircraft was extensively damaged but damage to other property was negligible.

The aircraft was flown to a field one mile south of Cowarr early in the morning of 7th September and spraying operations over a field one mile north of the township were commenced at about 0700 hours. The field being sprayed contained a young crop of barley 8 - 10 inches high and runs were being made north to south and vice versa. In the centre of and along a dry watercourse dissecting the field willow trees up to 25 feet high were growing. A full spraying run involved pulling up over these trees and then returning to spraying height (i.e., about 5 feet) to complete the run. During the last run when the aircraft was pulled up to pass over a 25 feet tree, the engine misfired several times, momentarily regained power and then cut out completely. Because of power lines crossing the flight path only 150 yards ahead, the pilot turned the aircraft to port to obtain longer landing run but failed to clear the post and wire fence. The aircraft pitched forward on its nose when the undercarriage caught in the fence. The area of operation was level ground only 250 feet above sea level and the wind calm with a visibility of 25 miles.

The pilot held a commercial pilot licence and his total aeronautical experience amounted to 1806 hours. He had 1200 hours on DH.82s and his experience in agricultural operations was 1050 hours.

A thorough examination of the aircraft and power plant failed to reveal any condition which could have caused the loss of power or any other condition which could have contributed to the accident.

Probable Cause

It is probable that the accident was caused by loss of engine power of an undetermined origin while the aircraft was in such a position that a forced landing could not be carried out on suitable terrain.

Norseman Overturns Following Engine Failure in Flight

(6/456/105)

Following an engine cut out, a Norseman landed short of the runway at Mt. Hagen, New Guinea, and overturned. The accident occurred at approximately 1055 E.S.T. on 4th October, 1956, while the aircraft was engaged on a charter flight from Minj to Tari. The pilot and a passenger, the only occupants, escaped with minor lacerations.

The aircraft departed from Minj with 95 gallons of fuel, sufficient for the out and return flight plus required reserves. This fuel was located in the two wing tanks, 45 gallons in the starboard and 50 gallons in the port tank. The outward flight to Tari was uneventful and the return flight to Minj was commenced at 1019.

When passing over Mt. Hagen at an altitude of 7,500 feet which was 2,000 feet above the level of Mt. Hagen Aerodrome the engine cut out. Except for the take-off at Minj and at Tari, the engine had been operating on the starboard tank and it was at about this time that the starboard tank would be exhausted. The pilot stated that he observed the fuel pressure gauge to be registering zero and changed over to the port tank which contained 50 gallons, less the quantity used during take-off at Minj and Tari. The hand pump was operated and fuel pressure of 6 lb. p.s.i. was obtained but the engine failed to develop power and fuel pressure could be maintained only by use of the hand pump. After a check failed to show the cause of the engine trouble, the pilot called Madang aeradio and advised of the engine failure and intention of landing at Mt. Hagen.

The aircraft was turned back towards the north-eastern end of the single runway and positioned for an approach into the north-west. However, the aircraft failed to reach the runway and touched down in ten feet high kunai grass 410 feet short of, and in line with, the runway. The aircraft then ran 100 feet on the wheels before nosing over into the inverted position.

Examination of the engine disclosed that the carburettor float chamber contained a quantity of water estimated at 2 - 3 tablespoons, and that water was also

present in the carburettor jet. No other defect which could account for the failure of the engine to develop power was found. The possibility that the water reached the carburettor other than by the fuel system was rejected and as the fuel filters were not contaminated it was concluded that the water was present in the float chamber prior to commencement of the flight and was flushed into the jets by the surge of fuel when the supply was renewed on selection of the starboard tank. The foregoing supposes that the initial power failure was caused by exhaustion of the fuel in the port tank and in view of the lack of evidence this was considered the most likely explanation.

The fuel pressure relief valve was also found to be obstructed by a small piece of an unidentified material which held the valve plate approximately 1/16th inch off its seat. This appeared to account for the failure of the engine driven fuel pump to develop pressure, as observed by the pilot. The required fuel pressure for the engine concerned is 3 - 5 lb. p.s.i. Tests were conducted on an identical engine and fuel system and it was found that with a 1/16th inch obstruction under the relief valve plate the engine driven pump developed 1.5 lb. pressure and the engine ran satisfactorily; in this test condition 6 lb. p.s.i. fuel pressure was developed by use of the hand pump. The valve plate and spring assembly was then removed from the relief valve unit and in this condition the pressure developed by the engine driven pump was 1 lb. p.s.i. and by the hand pump 3 - 4 lb. p.s.i.; again the engine ran satisfactorily. The tests indicate that with fuel available to the engine driven pump it should have developed pressure sufficient to register on the gauge, therefore it appears that the pilot's observations concerning fuel pressure were inaccurate.

The engine failed to regain power on the renewed fuel supply because of blockage of the carburettor jets with water. The initial cause of power failure was not established beyond doubt but in all probability was due to exhaustion of the fuel in the tank to which the engine was connected.

Cause

The cause of the accident was that the pilot misjudged the approach resulting in the aircraft undershooting the runway.

DC.3 Noses Over at Sydney

(6/256/221)

On 28th May, 1956, at 0930 E.S.T., a DC.3 engaged on a pilot training operation landed on Runway 25 at Sydney (Kingsford-Smith) Airport, skidded some 700 feet along the runway, and then tipped forward onto the nose. Both propellers were damaged and extensive damage caused to the nose section of the fuselage. None of the four persons on board was injured. After the nose section struck the runway the aircraft fell back onto the tail wheel.

The aircraft was under the command of a company instructor who occupied the right-hand pilot seat, and was being flown from the left-hand seat by a company navigator who was receiving DC.3 training with the objective of his eventual transfer to pilot duties. The latter pilot held a commercial licence and had accumulated 320 pilot hours. His experience on the DC.3 type was 8 hours 35 minutes gained on seven flights spread over the preceding fifteen months, the last flight being some five months before the accident. During these training flights he had carried out at least twelve landings and nine take-offs.

The pilot under training assumed control of the aircraft only a few minutes before the landing on which the accident occurred. Inspection of the runway revealed, except for a break of approximately 80 feet, skid marks indicating that the wheels of the aircraft were equally and continuously braked from the moment of touchdown until the nose of the aircraft struck the runway 710 feet further on. During the roll the instructor drew the trainee pilot's attention to the brakes being on and, when the skidding continued, finally called that park brakes were on. Immediately following this warning, the trainee pilot was observed by the instructor to depress the pedals as is required to release park brakes. This action was prompt and indicated that the trainee pilot was aware of what was happening and was familiar with the method of using the brake system.

The major part of the trainee pilot's experience was gained on an assortment of light aircraft including DH.84 Dragon, Miles Gemini, DHC.1 Chipmunk and Auster types, all of which have brakes operated by either differential mechanical or independent mechanical heel operated systems. He was, therefore, not unused to handling aircraft with braking systems of different types. He had shown no tendency to misuse the brakes on his previous landings in D.C-3s.

The evidence presented by the skid pattern, considered in conjunction with the trainee pilot's experience and his reaction to the instructor's advice concerning parking brakes, pointed to some reason for the brakes being on other than inadvertent application during the landing. It was concluded that the probable cause of the accident was that, at the time the aircraft landed and throughout the landing roll, the main wheels were not free to rotate due to the brakes being applied. The cause of the brakes being on was not determined.

PART IV

INCIDENT REPORTS

Some Facts About Flight Information

(6/357/260)

The captain of a DC.3 engaged on a regular public transport service reports that —

"When lodging my flight plan at Charleville for the Charleville to Longreach stage of this flight I was warned by the Aeradio operator of two light aircraft bound for Charleville, the first due at my time of departure and the other, a Gemini from Roma whose arrival time was given by phone by the pilot to Charleville Aeradio as between 0400Z and 0415Z. After take-off, just leaving the circuit area at 0325Z I passed about 100 feet above the Gemini and only after taking avoiding action. The aircraft passed immediately below me from my starboard side and I doubt if the pilot sighted me as he did not seem to take any avoiding action. It is very apparent that some light aircraft operators take reporting of flight details much too lightly, some not reporting flights at all and others reporting haphazardly. In this case the aircraft arrived at Charleville circuit 35 minutes ahead of his earliest E.T.A. and 50 minutes ahead of his latest E.T.A. It is apparent that he either left Roma considerably ahead of his E.T.D. or his flight time intervals were sadly in error, or guesswork. Had he stuck to the flight details as phoned to Charleville, this near collision would have been avoided. I admit, when told of his coming I considered him as presenting no danger whatever, as I expected to be approximately 100 miles away by his E.T.D. Charleville. This I think could or should be sufficient margin for errors in his E.T.A., but in this case was not. If the flight details as lodged by these operators cannot be relied upon, then it is a waste of time passing flight information to Airline Operators as it appears it can be misleading and dangerous. A collision with a DH.82 or Gemini can be just as fatal as a collision with a DC.6".

This report is a valuable one in that it draws attention to several points regarding the Aeronautical Information Service which are apparently not widely known.

When you are operating outside the controlled air space Air Traffic Control can only provide you with information of the movements of aircraft which are required, under AIP/RAC/1-9 to give pre-flight notification and repeat movement and position information.

Flight information can be "dangerous and misleading" to quote this pilot's words, if the information on which it is based is not accurate. There can be numerous aircraft engaged on flights outside control areas of which Air Traffic Control has no knowledge.

Many non-radio equipped aircraft submit flight details, for flight outside control areas, which involve a number of stopping places at which there are no means of communication. As the estimated time on the ground can only be approximate it will be seen that Air Traffic Control will not know with any degree of accuracy the position of these aircraft at any particular time, except when mandatory flight details are submitted to obtain an S.A.R. watch. However, to avoid unnecessary S.A.R. action pilots may, and usually do, give an L.T.R.A. later than E.T.A. in order to take care of any unexpected communication difficulties and/or delays.

Remember, that apart from not being aware of all aircraft movements outside control areas Air Traffic Control may not know accurately the positions of many of such aircraft. Therefore, when operating outside controlled areas it is vital to maintain a constant watch for other aircraft at all times.

Removal of Rudder Chocks

(6/557/19)

A DC.3 on a regular public transport service landed at Mount Gambier, which was a scheduled stop, while en-route to Melbourne. As the wind was about 20 knots and gusty, the captain requested that the rudder chock be placed in position. After a short stop-over the crew boarded the aircraft but omitted to remove the rudder chock. The captain started the engines then handed over to the first officer who was to carry out the take-off. The operations manual called for a full movement check of the flying controls prior to starting up but this was not done.

As the taxying was mostly downwind the first officer held the rudder in the neutral position and, although one turn was through 140 degrees no attempt was made to use the rudder before reaching the point where the run-up was carried out. At the completion of the run-up the check list items were called by the captain and carried out by the first officer who did not check the rudder for full movement as required, and this omission was not observed, or corrected, by the captain.

Shortly after take-off was commenced the aircraft veered towards the edge of the runway and, when it finally left the runway and it was obvious that the aircraft was getting out of control, the captain took over and abandoned the take-off. Inspection of the rudder revealed the rudder chock still in place.

In this incident, the rudder chock was the "off-set" type which caused the aircraft to swing in the early stages of the take-off run. The captain acted promptly and correctly in abandoning the take-off when the aircraft veered off the runway. There have been other instances in post-war civil-flying in Australia where take-offs have been attempted with chocks in the flying controls but fortunately these occurrences have not resulted in a serious accident.

Most omissions of items in check lists are revealed before a serious situation can develop, however, such is not always the case when the check for freedom of movement of flight controls is omitted. Recent accidents overseas amply demonstrate the disastrous results of the inadvertent omission or careless performance of this important check.

The fact that pilots rarely encounter any abnormality when checking for freedom of movement of controls is perhaps the prime reason why they are psychologically unprepared for the occasion when an obstruction is present. Therefore, it is imperative to ensure that the check for freedom of movement of controls, and where possible the correctness of sense be done quite consciously and not as a mere matter of routine. It should also be ensured that the actions of the pilot carrying out the cockpit check are closely observed by the person reading the check list.

Justification of Modification

(PRIVATE OWNERS TAKE NOTE)

(6/157/193)

Report received from the pilot of a Chipmunk:—

"On Monday, 8th April, 1957, after refuelling the aircraft we took off from Swan Hill and set course for Echuca. Some thirty minutes later a strong smell of fuel was apparent and on checking both fuel tanks, it was found that the port fuel cap was missing and a continuous stream of fuel was being sucked out of the tank. At this stage the port tank was showing half empty and the starboard tank full but within a very short space of time the port tank was sucked dry and the engine began to run intermittently, the engine picked up for a short period and we gained height and began to search for a suitable field. The engine stopped completely and the usual forced landing procedure adopted and carried out effectively without damage to the aircraft or occupants. The aircraft was pegged down and Air Traffic Control advised".

The primary cause of the forced landing was the pilot's omission to ensure that the port fuel cap was properly secured prior to departure. However, a contributory cause was the design of the fuel system which allowed the introduction of air into the fuel system following emptying of the port tank and this prevented the engine from receiving fuel from the starboard tank.

The Chipmunk fuel system is designed so that both tanks supply fuel simultaneously through non-return valves to a tee piece and from that point a common line leads to the engine through the "on-off" cock, fuel filter, pumps and carburettor. Such a system has the disadvantage that should one tank empty before the other (and there always seems to be a tendency for this to happen) air is drawn into the fuel system from the empty tank and the remaining fuel is therefore not available to the engine. This not only occurred on this occasion but has been the cause of a number of other forced landings.

Attempts have been made to correct this condition by modification to the venting system and to the non-return valves. However, it has been concluded by the Department that the only positive solution is the installation of a tank selector cock and this has now been made a mandatory modification on Chipmunk aircraft engaged in all categories of operations other than private.

Although the above modification is not mandatory for Chipmunk aircraft operated in the private category, it is strongly recommended that it be incorporated. A drawing of an approved scheme for this modification, which can be carried out by any approved workshop is available from the Department.

How's Your Priority?

Do you consider that you have experienced instances of unfavoured treatment by A.T.C.? Do you feel that A.T.C. have left you waiting and given unjust priority to another pilot? Well, if you do, we believe that you have jumped to incorrect conclusions as a result of being unaware of what was going on. You will agree that it has become increasingly difficult over the last few years to form a mental picture of the traffic situation existing at the time due to the numerous VHF radio communication frequencies in use en-route and in the terminal areas, and the traffic patterns used with multi-stacking procedures.

Have you considered the changes in the air traffic control system brought about by the introduction of new aircraft and operating techniques? Perhaps a brief survey of the present day position will ease your mind and help to maintain or improve still further the friendly spirit which already exists between pilots and controllers.

Firstly, Air Traffic Control does not grant traffic priorities to any aircraft except those in an emergency situation, those providing urgent medical service, and those used for the personal transportation of the Governor-General. All other aircraft, big or small, are treated on a "first come, first served" basis.

On occasions you may have been asked by A.T.C., when you were first in the take-off queue, to delay your departure and permit an aircraft of higher performance than yours to take-off ahead of you. Air Traffic Control does this, when traffic situations with possible long cumulative delays are apparent, in order to make best use of the airways. They request and appreciate your co-operation, which makes things easier for all concerned and achieves the minimum of inconvenience.

You, as a piston engine pilot may have had misgivings about "priority" when a "turbo-prop" aircraft, which unquestionably called for a taxi clearance long after you had left the terminal, was cleared for take-off in front of you? Your misgivings are understandable if you are unaware that, before calling for a taxi clearance, the pilot of the "turbo-prop" aircraft had earlier requested a start-up time. The nomination of a start-up time enables the aircraft to absorb separation delays before starting turbines. However, a position in the departure sequence is reserved for the aircraft. This is the same position that the aircraft would have occupied had turbines been started and taxying commenced as soon as the passengers were aboard. The start-up time is determined after an appreciation of the traffic separation requirements for en-route traffic and the airport controller's knowledge of expected surface movements. Any confliction which may occur later is a result of a combination of contingencies. Such conflictions are limited in actual practice because the traffic situation is being continuously kept under review and any required change is initiated when it becomes apparent that penalties to other aircraft are involved.

When weather makes it necessary for the high/low stack system to be put into operation at either Melbourne or Sydney then your altitude in the high stack has no bearing on your position in the approach sequence. Should you be holding at six or sixteen thousand feet an aircraft at ten thousand feet may be cleared to the low stack and given final approach clearance before you. Priority is not being granted, it simply means that that aircraft has been holding longer than you have. The high/low stack system permits aircraft to be cleared for final approach in order of E.T.A., whilst still allowing particular aircraft to hold at a preferred high altitude, and eliminates many of the frustrating delays common to a single stack system at a busy airport.

Remember there is no such thing as priority except in special circumstances. Just as you have a job to do so have A.T.C. To them one aircraft is the same as another regardless of type or markings.

Their job is to ensure the safe, orderly and expeditious flow of traffic. They cannot do this by giving favoured treatment to certain aircraft. If there is ever an occasion where you believe an aircraft has received favoured treatment the Department, particularly the Air Traffic Control staff, would like you to report the matter. Only in this way can misunderstandings be properly resolved.

Dip Stick Stops Engine

(6/657/62)

A DC-3 commenced a take-off from Mt. Magnet aerodrome on Runway 16, effective operational length 5,100 feet, at 0824 hours W.S.T. on 30th April, 1957. The aircraft was being flown by the first officer from the right-hand seat. The weather was fine, wind velocity 130/10 knots, density altitude 500 feet and the all-up-weight of the aircraft was 25,061 lb.

Just after the aircraft became airborne the undercarriage was selected up and a few seconds later the starboard engine suddenly lost power. At the same moment the fuel pressure was observed to be zero whereupon the wobble pump was operated. No pressure could be obtained however, and the starboard propeller was then feathered.

The aircraft was at a height of approximately 80 feet above the aerodrome and at an airspeed of about 95 knots when the engine failed. Take-off power was retained on the port engine and no difficulty was experience in achiving a rate of climb of 200-300 feet per minute at 95-100 knots I.A.S. At a height of 300 feet, rated power was selected and the climb continued at the same airspeed with a rate of climb in the order of 200 feet per minute. A normal circuit was carried out and the aircraft landed on Runway 16.

During the circuit, a cockpit check revealed that the starboard engine firewall shut off valve control was in the raised (shut off) position and could not be moved to the down (on) position. An inspection of the starboard engine on the ground revealed that the shut off control bell crank and rod in the wheel bay were bent so as to close the valves. Further, it was apparent that this damage had been caused by the shut off control linkage being struck by some object. On observing the nature of this damage the captain remembered resting the fuel dip stick in a lightening hole on the left side of the undercarriage upper truss after dipping the tanks, whilst he completed the pre-flight inspection. However, he was not sure that he had removed the stick from this position prior to take-off and thought that this may have been the object which struck the bell crank and rod. This belief was confirmed when the dip stick could not be located on the aircraft and was subsequently found in a mutilated condition two thirds of the way along the runway.

It is apparent that as the undercarriage retracted the dip stick was carried into the wheel bay where it stuck and bent the bell crank and rod and then fell away. The bending of these components closed the shut off valves—enough said!

COMMENTS: The moral of this incident is obvious and no comment is offered except to say that it is published as one of those simple things which could have had mighty serious consequences.

The captain concerned submitted a very candid report which was much appreciated. We are sure that he won't make such a mistake in the future and will be a better captain for this experience. It is far better, however, to learn from the other person's experience; thus if you have such an experience, which we hope you won't, let us know so that we can publicise it for the benefit of other pilots.

DESIGN NOTES

SURFACE CONTROLS

Elevator Control Cables

MURPHY'S LAW ** Demolished Transport

the Situation

CRASHING on take-off, a military transport was destroyed and three of the seven-man crew received fatal injuries.

Examination of the wreckage showed the elevator control cables were crossed where they connected to a sector wheel. This reverse movement of the elevator explained the fatal accident.*

the Hazard

Control system design safety provisions cited in the Air Force Handbook of Instructions for Aircraft Designers had not been followed in this instance.

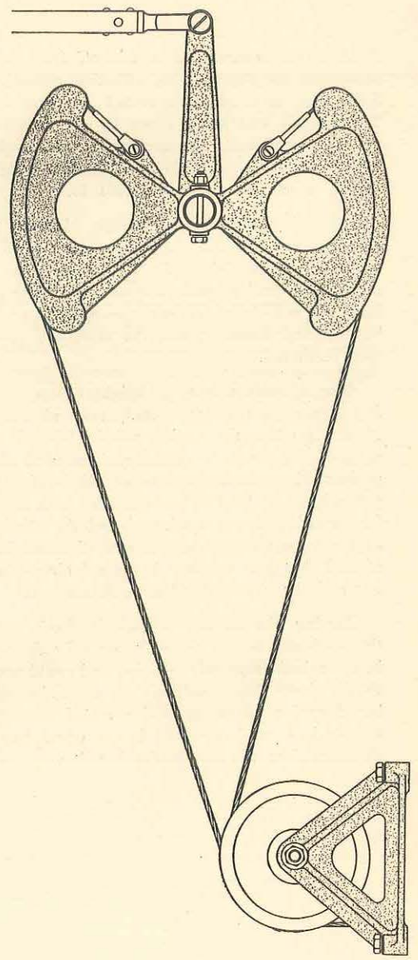
Note: Some aircraft engineers are likely to consider cross-connected cables as being an "elementary", and therefore insignificant design detail. That this is an erroneous assumption is proved by the records of repeated accidents due to this cause. It is definitely an engineering responsibility to prevent repetition of such occurences.

the Fix

Cross-connecting control cables can be prevented by designing connections with different types of fastening, distinct sizes, etc., which make it impossible to attach cables to the wrong fittings.

PRECEPT

The aircraft and its components must be protected against the effects of normally inadvertent or uncontrollable human errors or carelessness.



(By courtesy Flight Safety Foundation Incorporated)

*Ref: Directorate of Flight Safety Research, Office of The Inspector General, USAF, Norton AFB, Calif.

** Murphy's Law: *"If an aircraft part can be installed incorrectly, someone will install it that way."*