A Project Roughrider pilot discusses flight problems and gives some tips on the handling characteristics of straight wing, swept wing and delta configuration aircraft.

PILOT EXPERIENCES IN THUNDERSTORMS

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Why, as pilots, are we interested in severe storms? First and foremost it's a matter of survival. Another good reason is the damage caused to aircraft by hail and severe turbulence. Anyone who flys stands a chance of being caught in a situation which requires flying in the vicinity of thunderstorms. The psychological effect on the pilot who may never have encountered a severe thunderstorm may be serious. There are, however, factors that can enhance safe operations.

At the present time we are much better prepared to cope with severe storms than we were a few years back. My advice would be to avoid thunderstorms if possible; next best is to ask for radar vectors around or between storm cells.

In recent years NASA, the U.S. Weather Bureau, and the Air Force were involved in a program to investigate thunderstorms. The weather bureau was interested in learning more about the physical make-up of individual storms as well as a more accurate means of forecasting when and where storms are to appear. NASA wanted to acquire structural loads data to apply to aircraft which are being designed for the future. Civil jet application was also a prime area of interest. The Air Force was involved for three good reasons, the first being an engine problem with the F-102. We were also concerned with the handling characteristics of straight wing, swept wing and delta configured aircraft. We were interested in various engine-airframe marriages.

For instance, why does the J-57 engine act differently in the F-100 or F-101 from how it acts in the F-102 when exposed to ice crystals and heavy concentrations of water? What are some operating problems peculiar to supersonic flight? What damage does lightning, hail ınd water erosion do to an aircraft during a subsonic or supersonic penetration of a thunderstorm?

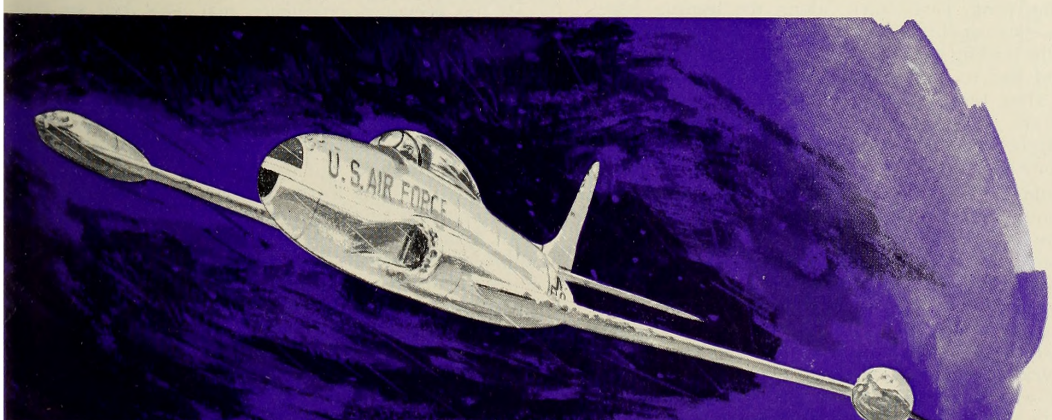
In this program, the Aeronautical Systems Division, AFSC, used various airplanes for thunderstorm penetrations. In 1960 we used an F-106, an F-102, and a T-33. Over 200 penetrations were made with these three aircraft. Since that was our first year of operation, much was to be learned about optimum speeds, flight control problems, FAA clearances and numerous other problems. My job while flying the F-102 was to establish throttle techniques to be used during penetration and to determine whether a continuous ignition system would prevent flameout during a long series of compressor stalls induced by ice crystals.

This would probably be a good place to mention a couple of unusual things which came as somewhat of a surprise: (1) liquid water at 40,000 feet where the outside air temperature ran well below freezing; and, (2) hailstones at 45,000 feet in completely clear air as far as five miles from the storm on the downwind side of the storm. A storm building several thousand feet in a matter of minutes is an amazing sight to behold! The reverse may occur and a storm may be gone in a matter of minutes. It is not unreasonable to observe storms building at a rate of 5000 fpm. For those who haven't seen this occur, it is really something to watch! Some of these storms top out at 70,000 feet or more. I have flown alongside a couple of storms at 50,000 feet with tops that were at least 10 to 15,000 feet above me.

Systematic procedures were established for the actual storm penetrations in order to minimize hazard and overcome some operating problems. The storms were traversed at all altitudes between 15,000 and 45,000 feet and a speed range from 175 knots IAS up to 600 knots IAS. Flight control problems were present in all aircraft but the seriousness varied with speed and also from one aircraft to the other. In the straight-winged T-33 with a .8 Mach limit, high speed or compressibility was a problem. With the airspeed near the mach limit of the aircraft, flight controls were stiff and when strong downward air currents were encountered it was hard to prevent the aircraft from exceeding its designed speed limit. This would no doubt be a problem in light aircraft as well. When the airspeed was slow (175 KIAS) in the T-33, control effectiveness was a problem. In other words, it was difficult to make the aircraft respond at the rate you would desire. Another problem at low speed was being able to maintain the airspeed with full power while attempting to hold a precise altitude during strong down currents. Each time a storm was penetrated an area of noticeable up currents would occur for a period of time as well as an area of down currents for a similar period of time. As it turned out a medium speed was best for the straight wing aircraft.

Flying the T-33 was something like riding a small boat in the ocean. There were times when it was impossible to hold both altitude and speed, so altitude was varied as necessary to maintain the desired indicated speed. The slower speed also helped reduce the turbulence problems by decreasing the effect of gusts and making for a smoother ride. Pitch control was as much a problem as roll.

In the delta wing aircraft, flight control problems were noticeably different from the straight wing. The big difference was pitch control. It was very easy to maintain any desired pitch attitude, regardless of speed. However, upsets in roll become quite interesting at times. On numerous occasions, with full aileron de-



flections against the roll, a bank of 45 degrees to 60 degrees would be attained. Again penetration speed was an important factor for consideration. It was always comforting to have plenty of speed with the F-102 in order to overcome the engine compressor stall problem. Two hundred and forty-one stalls were recorded during a single penetration which lasted approximately four minutes. As a result of this test we recommended that F-102 pilots avoid thunderstorms if possible. But if it's not possible, use continuous ignition to prevent flameout.

During 1960 the F-106 made supersonic passes with speeds up to 1.8 Mach number or about 1350 miles per hour. These penetrations were made a few thousand feet below the tops of the storm, mainly to see what would happen if someone inadvertently ran into a thunderstorm while making a high speed SAGE type intercept. The airplane responded so favorably, particularly the engine, that we decided to use the F-106 exclusively during 1961 to continue the gust loads research. We were thinking in terms of data for a supersonic transport or commercial carrier. It appeared from what NASA learned during 1960 that a speed would be reached above Mach 1 where the gust loads would level off and remain constant as well as making for a reasonably smooth flight through the storm. An analogy would be driving a car over a bumpy road where high speed gives a much smoother ride than some slower speed.

In 1961 the F-106 penetrations were made between 15,000 and 45,000 feet altitude and speeds up to 1.63 Mach number. Because of hail encounters at 1.6 Mach with extensive damage to the F-106, the decision was made to use the T-33 as a hail probe. This approach worked fairly well but it was still not the complete answer, because on two or three occasions the T-33 pilot reported no hail and a couple of minutes later the F-106 would come through the storm and get hit by hail.

Except for a couple of weak areas, the aircraft withstood the hail quite well. Actually the damage caused by water erosion was more serious than that caused by hail. Our engineers figured the impact pressure created by the water at 1.6 Mach was 18,000 pounds per square inch. This pressure would peel flush rivet heads out of the wing, particularly along the leading edge. The plexiglas canopy was worn down about one-fourth inch on the leading edge. Fiberglass antennas were worn away and had to be replaced. Most of the paint was missing after the first few penetrations. If continued flights were to be made at these high speeds, rivets and plexiglas would be of little value for external airframe construction.

Lightning was another interesting phenomenon which was encountered on numerous occasions. I feel sure there are certain storms where enough lightning is present to hit any type aircraft, regardless of size. Of all the aircraft used for penetrations the B-66 was hit most frequently. In fact, it was an excellent lightning rod. Damage to the aircraft was not extensive but I am not sure this could be said about the pilot's nerves. The aircraft became so charged with electricity that when it was discharged numerous small holes were burned in the trailing edge of the ailerons, wingtips, rudder and elevators. These same results held true with the T-33. I recall one particular storm which contained much more lightning than any other storm that I have ever seen. There were times when 15 or 20 bolts would be visible at the same time. Normally a pilot will see a flash or a lightning bolt or perhaps two or three bolts at the same time.

In addition to the lightning I was concerned about the individual who was riding in the rear seat. He was normally the "motor mouth" type but for about five minutes there was not a sound from the rear seat.

I would guess the airplane was struck by lightning 20 or 30 times during the pass with very little damage. The one thing that I clearly remember is that the hair on my head and arms literally stood on end. One time while looking toward the wingtip the aircraft discharged electricity and it appeared that a ten foot bolt of lightning left the front and rear of the wing fuel tank. A couple of lightning strikes were felt in the form of a bump. It was amazing how fierce the lightning looked yet it did so very little damage.

Naturally we experimented a great deal with various types of static dischargers, none of which worked very well. In 1962 the F-100 was equipped with 18 dischargers, three on each end of the horizontal tail, two at the top trailing edge of the vertical stabilizer and five on each wingtip. These dischargers were the only ones we used where communication was not lost some time during the storm. One discharger received a direct hit and actually fused together without doing damage to the aircraft.

During 1962 ASD chose an F-100 and a T-33 to participate in the program of collecting meteorological data for the weather bureau and the FAA. The F-100 was equipped with one high speed camera which operated at 1500 frames per second, for the purpose of taking pictures of hail. Clear pictures were never attained mainly because of poor lighting conditions. Another camera was carried for the purpose of taking pictures of water droplet size. Pictures of the water droplets turned out much better than the pictures of the hailstones. Liquid water content of the clouds was measured, and the electric field was measured in all directions from the aircraft. All these measurements were made in an effort to correlate the data with radar scope pictures for the purpose of more accurately defining the physical makeup of individual storms.

It has been my experience that what you see with the naked eye is certainly deceiving. One storm will be extremely black with only moderate turbulence and no hail. The next one may not look bad at all but as soon as you enter the storm you wonder what you are doing there. When we can look at a ground radar picture and receive an accurate evaluation of a storm a big step forward will have been made in air safety.

Much has been learned about the composition of thunderstorms and the operating problems associated with flying in this type of severe weather. But a vast number of problems remain unsolved and the weather bureau plans to continue their storm research for several years. Meanwhile my experiences have taught me to treat thunderstorms with great respect and to avoid them completely if possible. I think this would be sound advice for anyone flying because as a prophet once said, "Example is a dangerous lure; where the wasp got through the gnat is stuck." ☆