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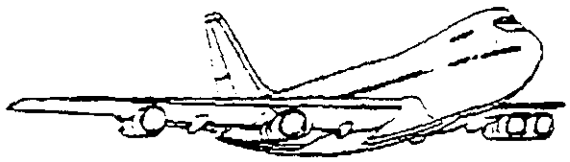

UNUSUAL ATTITUDE RECOVERY - 747 100/200

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Introduction

Aircraft incidents and accidents involving extremes of attitude and speed are quite rare nowadays, thanks to the greatly improved stability and control characteristics of modern jet transports compared with their predecessors.

As a rule, contemporary aeroplanes do not suffer the stability and control degradation at high speed and Mach number involved in the serious and numerous 'jet upset' incidents affecting early jet airliners.

However, there remain a number of potential factors that could cause attitude and speed excursions. These might become extreme if not quickly corrected, because of the high momentum and low drag characteristics of modern airliners.

Some of the potential threats include severe turbulence, strong standing waves, attitude indication failure, structural or control failure, and inadvertent reverse thrust in flight, as appears to have been the case in the recent 767 accident.

Whatever the cause, the aim should be to correctly identify the situation and apply the appropriate recovery technique before the excursion develops to the point where the structural integrity of the aircraft is threatened.

747 HANDLING CHARACTERISTICS

Most of the problems involved in unusual or extreme attitude situations are related to the associated extremes of speed or Mach No. It is reassuring to know that the 747 is unaffected by serious stability or control degradation at either extreme, and exhibits extremely good qualities both at high speed, high Mach, and at low speeds right down to the stall.

Stability

Lateral and directional stability remain good throughout and present no difficulties.

The 747 remains laterally level in the stall in any configuration. Spiral stability is very positive at low speed and altitude, diminishes slightly as these increase, but remains positive in the cruise.

Longitudinal static stability is generally good throughout, with stick forces becoming light at aft c.g. However, there are two areas of somewhat diminished longitudinal stability, both particularly related to the aft c.g. case. 76

The first of these occurs at high Mach No. at aft c.g., when longitudinal stability becomes roughly neutral. The aircraft will fly between about 0.84 and 0.90 True Mach No. with virtually no stick force gradient against speed.

This potential problem area diminishes in significance when one considers the excellent qualities of the 747 at 0.92 TMN upwards. There is a nose-up pitch equivalent to an approximate 20lb. pull on the control column at about 0.94 TMN, which gives a tendency towards natural overspeed recovery.

Stability at 0.97 TMN is positive, and controllability is plentiful so overspeed recovery presents no serious problems.

The second area of diminished longitudinal stability is in the approach to the flaps-up stall. Here the aircraft would tend to decelerate from about 1.3 Vs to the stall with zero stick force if it were not for the operation of the stick nudger. The gentle push applied by this device throughout the stick shake regime restores an adequate level of stability down to the stall. There is no nose-down pitch at the stall with flaps up.

Controllability

Pitch and roll control are good throughout, with plenty of authority right down to the stall and up to 445 kts EAS and 0.97 TMN. Boeing have flown the aircraft to 0.99 TMN without encountering difficulty.

Roll response to rudder diminishes at high Mach No, becoming zero at about 0.97 TMN with speedbrakes extended. (As the aircraft yaws, the outer wing is accelerated deeper into compressibility).

This does not present a problem as recovery from high bank angles does not involve the use of rudder to assist roll rate.

In summary, the generally excellent stability and control characteristics of the 747 allow the use of relatively straightforward and natural techniques for recovery from extremes of attitude and speed.

Buffet Boundaries

For information, here are some examples of approximate g levels at which high-speed buffet onset occurs.

-236 a/c, 300,000 kg)	FL330 : 1.43g
0.90 True Mach No.)	FL260 : 1.98g

In practice these boundaries are conservatively drawn, and it is possible to apply further g before buffet becomes noticeable to the crew. During flight tests it was 76
found that on an aircraft at 285,000 kg, 0.90 TMN at FL280, 2.25g could be applied without noticeable buffet.

Therefore sufficient manoeuvre capability exists for recovery from overspeed conditions.

To complete the picture, here are a couple of examples of low-speed buffet boundaries:

	'g'	Buffet Onset IAS
-236, 300,000 kg, FL330	1.0	222 kt approx.
	0.5	120 kt approx.

This shows that care must be taken when increasing the load factor following recovery from low speed situations.

RECOVERY TECHNIQUES

Because of the high momentum, high thrust and low drag of the 747, the potential for an extreme overspeed is high in the event of an upset. Additionally the wing has fairly poor lift capabilities at low speeds with flaps up, so the penetration of the stall to any depth could involve great loss of height. Our recovery techniques will aim at minimising exposure to these areas without applying undue stress to the airframe.

The aircraft can be upset in two basic modes, attitude and speed. These can occur in combination and usually do.

In general, recovery from unusual attitudes and speeds requires flying the aircraft out in a smooth and co-ordinated manner using a logical combination of roll control, pitch control, speed brakes and thrust levers as appropriate. Rudder should not be used - we have already seen that roll response to rudder may diminish to zero, and rudder inputs at high speed could cause structural problems.

Although recovery action should not be delayed unduly, it is important to confirm correct identification of the situation first. Particularly attitude and speed indications should be cross-checked for validity.

Low Speeds

a. Moderate excursions, down to stick shake onset

Pitch down gently and simultaneously apply G/A or max continuous thrust as appropriate. If the stick shaker operates apply the recovery action described in the FTSG (01-07-01). This involves pitching down 8-10° to an attitude of approx. +5°, simultaneously applying G/A thrust if below 14000ft or max. continuous if above. As the speed increases recover the level flight. Take care not to re-encounter continuous stick shake as incidence increases. 76

b. Extreme excursions, down to the full stall

A generous pitch-down input should be applied and held until the airspeed starts to increase rapidly. Simultaneously apply the appropriate maximum thrust to minimise height loss. A stall at high weight and altitude requires a steep recovery attitude to clean up the airflow, approx. 10° nose down should be effective. Recover from the ensuing dive gently, avoiding secondary stalls.

High Speeds

a. Moderate excursions, up to about 420 kts IAS/MO.93

Close thrust levers (bear in mind anti-icing considerations) and extend speed brakes. If accelerating in a descent, pitch up gently, if high Mach buffet is encountered don't pull beyond its threshold. There will also be buffet from the speedbrakes. Resists the temptation to use stabiliser trim: stick forces should not be excessive.

b. Extreme excursions above 420KIAS/MO.93

This situation will usually be coupled with a steep nose-down attitude. The recovery technique is as for moderate excursions. The nose-up pitch tendency of the aircraft at about 0.94 TMN, combined with the nose up pitch with speedbrake will assist recovery. The amount of up elevator applied should be related to the extent of the excursion and rate of speed rise. There is a greater likelihood of encountering high Mach buffet, again don't pull into it.

Steep Nose-up Pitch Attitudes

a. Up to about +30°

Pitch down smoothly, avoid going below zero g unless essential. Simultaneously apply the appropriate maximum thrust to minimise the speed decay.

b. From +30° up to about +50°

Pitch down until just into the negative g area, simultaneously applying maximum thrust. Airspeed may reach very low levels at the top of the manoeuvre. Continue pitching down until the attitude reaches 10° nose down, then gradually relax the forward pressure on the control column. 76
When level flight is regained, back pressure will need to be held until the airspeed has gained its original value.

c. Above +50°

There would be a very real danger of running out of elevator control if the previously described technique was attempted in this situation. Therefore roll on 80-90° of bank and allow the nose to fall through the horizon. Then roll the wings level and pitch up smoothly as the airspeed increases to regain level flight.

Steep Nose-Down Pitch Attitudes

a. Up to about -20°

Pitch up, attempt to avoid applying more than about a 1g increment. If necessary close thrust levers and extend the speed brakes to prevent a speed excursion. If one occurs, apply the technique already discussed.

b. Beyond -20°

Here very high speeds will inevitably be involved, quick and decisive recovery action is called for. Promptly extend the speedbrakes, apply back pressure to the control column and close the thrust levers. Continue to apply back pressure until just inside the high Mach buffet region, or until a 1g increment has been applied, whichever comes earlier, and hold it there.

Don't be tempted to pull harder than this in an attempt to achieve a less alarming attitude more quickly, otherwise the aircraft might suffer structural problems. For similar reasons avoid using stabiliser trim.

As the aircraft returns to level flight, ease off the back pressure. Now a decreasing forward pressure will be required until the airspeed returns to its pre-excursion value.

Large Bank Angles

In isolation, large bank angles present no problem. Simply level the wings using roll control alone. However at large bank angles the nose will drop into the turn and ultimately a pitch and speed excursion will develop. Any attempt to pitch up in this situation will merely tighten the spiral. The aircraft must be recovered laterally before longitudinal recovery is attempted. Therefore, roll the wings level, then deal with any pitch or speed excursion as previously described.

For completeness, the full range of possible scenarios has been discussed.
However, it is considered that some are very unlikely to be met, for example,
extreme nose-up pitch attitudes and full-stall encounters. Extreme nose down pitch 76
attitudes are much more likely to be encountered in association with high bank
angles than in isolation.

ATTITUDE INDICATION

The recovery techniques described assume valid attitude indication throughout. However, the possibility of attitude indicator failure must be considered. Before taking any recovery action both ADI's and the standby attitude indicator should be cross-checked (not forgetting the visual horizon), both to positively identify the current attitude and to ascertain the validity of the instrument to be used for recovery. In some circumstances hand-over of control may be necessary.

The installation on the 747 should never leave the crew totally without valid attitude information, no matter how extreme the attitude.

The ADI's (supplied from their associated INS platforms) have full freedom in roll and pitch.

The Standby attitude indicator has full freedom in roll and "controlled precession" in pitch. (The instrument is designed to do a 180° "twizzie" at pitch attitudes of + and - 85° to preserve orientation. However, because of the angle of the panel in which it is mounted on the 747, this occurs at -101° and -60°).

SUMMARY

The excellent stability and control characteristics of the 747 throughout and beyond the normal operating range make extreme attitude and speed encounters unlikely. If such an encounter should occur these same characteristics should lead to relatively straightforward recovery.

The recovery techniques described in detail above may be summarised as follows:

1. First confirm identification of the situation by cross-checking flight instruments, particularly all three attitude indicators. Ensure a valid instrument is being used for the recovery.

2. Disengage AP and AT if appropriate.

3. Deal with any roll excursion first, using roll control alone.

4. When the wings are substantially level, any pitch or speed excursion can be dealt with using the appropriate combination of pitch, thrust levers and speed brake. 76

   When pitching the aircraft down try to avoid significant negative 'g' application.

   When pitching up, try to avoid more than 1g increment, and don't pull too far into the Mach Buffet.

5. When the aircraft is safely under control in stable flight there may be many consequent considerations to be addressed. In particular terrain clearance should be quickly established and ATC liaison resumed to guard against collision risk.

   If the speeds or load factors experienced in the manoeuvre were very high, the airframe or controls may have been weakened or damaged. This should be considered in the subsequent handling and speed control of the aircraft. A landing at the nearest suitable airport might be prudent.

incident the turbulence was so appalling that on several occasions all three crew members were attempting to control the aeroplane, power was going from idle to full and all combinations of full primary control angles were being used. Not having been there and suffered this ride, I am aware that it is a bit of a sauce to comment on the manner in which the report suggests the crew managed the aeroplane. However, writing this in the peace and calm of an office as opposed to flying through severe turbulence, it would seem reasonable to make the following observations:—

(a) Only one pilot should fly the aeroplane. It is unlikely that two pilots will work in perfect unison and the second man will only compromise the first. This rule also extends to control of power. If the captain decides to make a power change, but has both his hands fully occupied, he should call for whatever he needs and the second pilot should make the change strictly in line with the commands.

(b) Unless it is clearly necessary, don't change the power. Net thrust takes a long time to run down and run up again. This, together with the inertia of the aeroplane, makes it unlikely that even a major change in thrust will be effective in less than about ten seconds, by which time the original need for change may have been superseded by an opposing one. The speed brakes however should be used; their effect is immediate and their rate of operation very high.

(c) Don't use the rudder. This is virtually an unqualified recommendation because of the always poor and frequently reversed effect of rudder at high Mach number and the possibility of structural problems due to large angles in an overswing manoeuvre at high speed.

(d) Use height to control the wilder divergencies of airspeed and Mach number, but come back to level flight as soon as the divergency has been contained.

(e) Finally, be very conservative in the use of the lap-strap sign. If there is any doubt whatever, switch it on; and require the cabin staff to strap themselves in immediately they are satisfied that the passengers and equipment are secure.

The 'jet upset'

A final word on the rather loosely labelled 'jet upset.' This type of high speed dive manoeuvre does not always follow from an upset in high altitude turbulence. High speed dives have also stemmed from the quiet dropping

out of an autopilot which has gone unnoticed by the crew, and from the pilot flying to a failing or failed attitude indicator.

What should you do to avoid this? The answer is: keep your eye on the ball. It doesn't matter what systems trouble you might have run into, let the rest of the crew sort it out while you (the pilot in charge of the aeroplane at the time) maintain a constant watch on the actual flight path. In the event of a suspected failed attitude indicator, immediately check both against the standby, reject the failed one and fly on one of the good ones.

Recovery from upsets

Jet aircraft are more likely to become upset simply because they are jet aircraft; and when they have become upset they are more difficult to bring back under control and need a lot more space in which to do it.

A review of the Table of Differences in Chapter One shows this to be true in many of the areas connected with en route flight. Compared with a piston-engined aircraft the jet aircraft is different in the following ways, all of which are relevant to upsets:—

(a) It has higher momentum, an enormous amount of thrust and low drag, all of which give it gross overspeed potential.

(b) It can fly high and fast, thus exposing itself to the hazards of high Mach number instability, reduced manoeuvrability and restricted speed ranges.

(c) It suffers poor lift at low speeds and much greater height losses if the stall is penetrated to any depth.

(d) It needs devices like variable incidence tailplanes, Mach trimmers and yaw dampers which can malfunction or fail thus reducing the level of handling qualities even further.

All the above characteristics have been explained in detail and their influence on the stability and controllability of the aeroplane should be well understood by the reader.

An aeroplane can be upset in two basic modes — *attitude* and *speed*; it can be rolled or pitched too far and get too slow or too fast. Before we go on to discuss gross upsets let us first define and discuss moderate upsets. A moderate upset is an excursion to a defined degree beyond any normal limit and the following definitions would seem reasonable:—

(a) Too slow = not slower than the stall warning.

(b) Too fast = not faster than V_{MO} + 30 knots or M_{MO} + 0.03 Mach number.

(c) Excessive pitch = not beyond 30° nose up and 20° nose down.

(d) Excessive roll = not more than 60° bank.

A gross upset will then be anything beyond these limits.

Recovery from moderate upsets

This is not difficult — it is just a question of recognising the condition and flying the aeroplane smoothly out of it. No instruments will have toppled and the aeroplane will not be going fast enough to involve any really significant reduction in controllability.

If you get down to the stall warning or stick shake, apply down elevator to reduce incidence and more thrust (if at low thrust setting) to reduce the height loss. Then fly a required flight path which is the best compatible with accelerating the aeroplane back to normal flying speed and keeping the height loss to a minimum. If in doubt, and in a position where you can afford a height loss, trade height for speed and get back to a proper flying speed as quickly as possible. Don't relax until the sink rate has been arrested and the aeroplane is straight and level again.

If you get too fast, fly your recovery according to the amount by which you are too fast and the rate at which you are accelerating. Reduce thrust and operate the speed brakes if necessary. If you are accelerating fast down hill then pull the nose up, reduce thrust to idle and operate the speed brakes. Be prepared for the buffet with speed brakes and the buffet with 'g' if at high Mach number. Don't use the longitudinal trim unless stick forces become very high and then only in a short burst, because nearly all variable incidence tailplanes are very effective at high speed and consequently induce a large 'g' increment.

If you get too much nose up, push gently to reduce attitude. Don't come below zero 'g' unless it is essential. Apply up to full thrust to maintain speed over the top.

If you get too much nose down, pull up to recover to level flight. Don't pull more than 1g increment estimated unless it is essential. If at high speed reduce thrust to keep the speed down. If at high Mach number don't pull much beyond the buffet threshold.

If you are at a large bank angle remember that the nose will be falling down into the turn. Don't try to screw the aeroplane out of this position immediately by assisting ailerons with rudder because excessive sideslip will be induced and the recovery in roll might be a lot quicker than you bargained for. It is better to fly the aeroplane out on ailerons alone in a gentle diving turn.

A number of these upsets can occur in combination. Don't delay the recovery; but don't rush it either. Just get at it in a smooth and co-ordinated fashion keeping a strict check on your progress in *attitude*, *speed* and *height*. Don't relax until the aeroplane is properly back under control and trimmed-out straight and level again.

Recovery from gross upsets

By definition now these are speed excursions down to the stall and up to V_{DF} or M_{DF}, pitch attitudes exceeding 30° nose up and 20° nose down and roll angles exceeding 60°.

Let us take this in two parts; one, where the primary attitude references are still working and, two, where they have toppled. Before we go into this rather hairy field we should remind ourselves of the following possibilities:—

(a) Reduced rolling ability due to aileron effect reducing with Mach number, possibly very high stick forces at high speeds and virtual loss of rolling ability due to spoiler blow back on some types.

(b) Reversed rudder effect at very high Mach numbers compounding the difficulties in roll.

(c) Reduced control in pitch due to elevator effect reducing with Mach number, very high stick forces at very high speeds, limited elevator capability due to jack-stalling at very high stick forces, the extreme sensitivity of tailplanes at high speeds and the fact that some stabiliser drives stall in the face of very high stick forces.

(d) Reduced manoeuvrability at high weights and high altitudes and the certainty of high buffet in positive 'g' manoeuvres at high Mach number.

(e) The effects of failure or loss of yaw dampers and Mach trimmers.

Before the budding jet pilot decides to stick to piston-engined aircraft he should remember that each jet transport has only a few of these possible deficiencies, and furthermore that you don't get into upsets if you fly properly!

Gross upsets, primary attitude indicators still reading This is a bit like recovery from moderate upsets, only more so. If a modern jet transport gets grossly upset, because of its high momentum and low drag, it will quickly reach an extreme attitude and speed from which recovery will need a vast amount of height and will be made more difficult by a certain reduction in controllability and manoeuvrability. Some of the milder jet upsets to date come within this category and have involved a descent at extreme attitudes and very high speeds. Although there is little evidence of pure stalling, or wild excursions steeply upwards, we should cover all of the following five cases:—

(a) *Recovery from the full stall* is similar to recovery from stall warning except that full down elevator should be applied and held until a rapidly increasing airspeed is seen. At the same time apply full thrust to keep the height loss to a minimum. In the recovery from the dive take care you do not again increase incidence to another stick shake. A heavy aeroplane stalled at high altitude needs a good steep recovery attitude initially in order to get the airflow cleaned up and flowing in the right direction. Too early an attempt to recover from the dive will surely bring the aeroplane close to the stall again.

(b) *An excursion to a very high speed* is usually combined with a steepish nose down attitude. In terms of speed alone the recovery action is, in quick order; reduce to idle thrust (not, however, in a steep descent on a type with reducing elevator effect) and extend full speed brake, then pull the nose up to increase the rate of speed reduction. There will be buffet from the brakes and from the 'g' if at high Mach number.

(c) *A very steep nose up attitude* is fortunately rare. Up to about 50° nose up (if you have proved positively that you are at this angle) push just into the negative 'g' area, apply full thrust and the recovery should be good, though unpleasant. Remember that if you have done this you might be very slow over the top; keep the recovery going to about 10° nose down then gently ease off the push force as the speed builds up. Because of the effect of static stability the aeroplane will be seeking a return to the original trim speed which means that at any lower speed it will want to go nose down. Having returned to level flight at a lower speed you will therefore have to hold a decreasing pull force until you regain your original speed. Having contracted, as it were, to talk this subject out we must cover the extreme nose up case with a rapidly falling airspeed. *If you have positive proof* that you are in excess of 50° nose up you might stall or run out of elevator effect during the push over; so roll the aeroplane to near 90° of bank (while you still have the speed to do so) and allow the nose to fall. Recover smoothly as the airspeed builds up again.

(d) *Recovery from a very high speed dive* must be made quickly and with some determination. Pull full speed brake and then pull into the buffet a little way if at high Mach number or an estimated 1g increment if at high speed. When you arrive at the position where the speed stops increasing you've got it made. Just hang on and it will come around nicely. Ease off the pull force as the aeroplane returns to level flight. Now remember this: if you were upset from a, say, *trimmed* 260 knots cruise at, say, 35,000 ft. and you finish up at 390 knots at 22,000 ft. the longitudinal stability will have exerted itself and the aeroplane will be seeking to return to 260 knots; this means that it will want to pitch fairly hard nose up. So, if you want to maintain 22,000 ft. for a while, you are going to have to push quite hard. Don't trim this push force out — just wait for the speed to decay. If you should suffer a reduced elevator effect at very high speed or Mach number there is not a lot you can do about it except to hang on tight. As the Mach number falls with reducing altitude the elevator effectiveness will return and recovery will be made progressively. If the aeroplane should be forced to a steep dive angle

so as to achieve a high speed very quickly, do not reduce the power on those low-thrust-line-engined types known to be short of elevator effectiveness in the recovery; the nose down trim change with reduced thrust cannot be afforded. It is better to leave cruise power set and wait until you have proved that you have enough up elevator effect before you start reducing power. On those types which suffer a stalled stabiliser drive in the face of high elevator loads the recovery is not necessarily difficult or disturbing if you follow the recommended drill (see page 41). Simply keep the trim button activated and ease off the elevator load. As the force falls through the critical value the stabiliser will run and recovery will be effected. Remember to ease off the pull force as the stabiliser responds.

(e) *Large bank angles*, in isolation, are recovered in the same way as moderate bank angles. Don't use the rudder — just roll it out smoothly on the ailerons. Now remember this : if you are upset at a large bank angle in a steep dive *you must recover the aeroplane laterally before you recover it longitudinally* otherwise you will simply pull into an ever-tightening spiral. So roll it substantially level first then recover in pitch. If you are at very high Mach number in a type on which you are not sure of the rudder effectiveness in the way in which it rolls the aeroplane then *leave the rudder alone* and recover on ailerons only.

Gross upsets, primary attitude indicators toppled. First let it be said that many of the later attitude indicators retain full freedom in roll. A manoeuvre including inverted flight from a roll therefore leaves the horizon still functioning. These horizons have about 85° freedom in pitch so it is most unlikely that a civil jet transport so equipped will ever suffer a toppled primary attitude indicator. Some of the very latest horizons have what is known as controlled precession in pitch around the vertically up, and vertically down, attitudes. At these points the instrument does a 180° twizzle so that it reads properly keeping the sky and the ground in the right place, and again as the other datum is traversed to bring it back to normal presentation. Different symbols identify straight down (the *nadir*) and straight up (the *zenith*) and the controlled precession is quite obvious. These instruments are effectively fully aerobatic and they will not topple. However, there are a number of jets flying with instruments that will topple, so the subject should be covered.

In order to keep this treatment within reasonable bounds a simple analysis has first to be done and certain assumptions made. If a civil transport aeroplane is upset sufficiently violently to topple the attitude indicators it is a fair bet that the pilot will be disorientated and not know what position he is in. The first thing to do therefore is *nothing*; if you do not know what position you are in you cannot know how to get out of it. So wait until the aeroplane settles into a recognisable manoeuvre before you take hold of it.

The aeroplane will certainly finish up by descending; in a straight dive, erect or inverted, a spiral or a spin, erect or inverted. To date there has been no recorded instance of an aeroplane spinning out of an upset. Furthermore, judging from conversation with military personnel, it is a fair bet that the inverted spin is not in the repertoire of civil jet transport aircraft. The erect spin, however, is still a possibility. We need therefore to cover four of these cases.

(a) *The spin* is recognised by a high rate turn on the turn indicator (ignore the slip reading — it can be stuck hard either side in a modern aeroplane), a general sloppiness of the controls (if manual) a lot of banging and clattering *and a fairly low airspeed.* The recovery is effected by applying hard opposite rudder against the turn, strictly centralising the ailerons and pushing forward the control column. When the turn indicator comes off its stop centralise the rudder. You will be left in a steep dive (see later).

(b) *The spiral* is recognised by a high rate turn on the turn indicator and not much slip, a definite feel of increasing speed *and a rapidly increasing airspeed.* Recovery is effected by recovering lateral level first by applying aileron against the indicated turn until it is substantially central, then centralising the ailerons. You will be left in a steep dive (see later).

(c) *The inverted dive* will be obvious by all the loose equipment flying around the flight deck and the fact that you are hanging on your straps. The recovery in this case is simply to roll the aeroplane on the ailerons for about 8 secs. flat; this is *approximately* the time it will take the average *older* jet transport to roll through 180° (for the newer aeroplanes it could be nearer 4 secs.). Whether or not you judged it properly you will most probably find yourself near enough right way up in a spiral (see above).

(d) *The erect steep dive* will be confirmed by a rapidly increasing airspeed. Maintain lateral level on ailerons by keeping the turn indicator substantially central, then pull up elevator. Maintain up elevator until the airspeed stops increasing — this means that you are passing through the level flight attitude — then *push*, because at the much increased speed the stability will be causing a strong nose up pitch (remember?). Now wait for the altimeter to steady and fly on both altimeter and airspeed for pitch control and the turn indicator for lateral control. You are now home and dry. Just press the fast erect button on the standby horizon and relax. If you should have overcooked the dive recovery and find yourself rushing uphill, push until the speed stops decreasing; this

identifies the level pitch attitude again. Now change to a pull and slowly relax as the speed increases, and maintain altitude.

Note that the above drills, particularly (d), are absolutely conditional upon the thrust not being altered from its original cruise setting. If it should be altered, then the relationship of stick force to speed will be lost and the search for level flight will have to be made through intelligent use of the VSI and altimeter. These recoveries are *not* overwritten. If you have the ability and personal discipline to fly them using the basic instruments, recovery can be guaranteed from the most extreme positions.

Instrument failures

Finally some advice on flight techniques in the event of failure of various flight instruments. The secret of most techniques of course is *the known relationship between configuration, attitude, power and speed.* Let us put aside failure of single instruments because these are usually well duplicated and backed up by the read-across from other related instruments. There are two areas which need to be discussed:—

(a) A total (temporary) failure of all pressure instruments (airspeed, altitude, VSI and Mach) should not cause you any distress. In an en route climb at night for example you should know that, if you maintain climb power, compass heading, wings level and a typical climb attitude on the horizon indicator, you are bound to continue the climb in a broadly acceptable manner. Similarly in any other configuration; the relationship of power and attitude will give you a safe airspeed and/or rate of descent or climb.

(b) A total (temporary) failure of all attitude information is just as easily coped with. Maintain lateral level by reference to the compass and turn indicator; maintain pitch attitude by reference to airspeed and height associated with a known power.

As a conclusion to this sub-chapter it is suggested that the reader will agree that it is easier to avoid falling into a hole than to dig yourself out having fallen in. All the recovery techniques elaborated here are quite flyable and work out in practice. But they need practice. Better of course to avoid the need to apply them in real life altogether.

Good as we all think we are, there comes a time when we are forced to find out just how good we really are. Under demanding conditions keep your eye closely on the aeroplane's flight path and watch any tendency for it to start sneaking away. Prepare yourself for the 1 in ? chance when things have gone wrong by keeping up your instrument flying ability. Go back and find out just how a turn and slip indicator works, practise flying without