PART 2 : SECTION 4

CHAPTER 2

INSTRUMENT FLYING

Introduction

1. Pilots must be able to operate their aircraft efficiently under all weather conditions, by day and night. In addition, accurate high-altitude, high-speed flight involves considerable reference to instruments. To achieve this, the standard of instrument flying must be high.

2. The experienced pilot controls the attitude of the aircraft by constant cross reference to all the instruments, but under some conditions giving more attention to certain instruments.

3. The following paragraphs discuss attitude flight, and explain the use of each instrument in relation to a particular condition of flight.

Cockpit Checks

4. The most important and vital requirement for accurate instrument flight is that the instruments should function correctly. All flying instruments must, therefore, be checked before take-off to ensure their serviceability.

5. Although most electrically driven gyros erect rapidly, some time must elapse before normal rotor operating speed is reached. When such artificial horizons are fitted, they should be switched on from $1\frac{1}{2}$ to 2 minutes before the instruments are checked, to allow time for the rotor to reach operating speed. This need only be done when the instrument is essential for the prevailing take-off and climb conditions. Air-driven gyros can be erected only by starting the engine.

PITCH CONTROL IN LEVEL FLIGHT

Considerations

6. The pitch attitude of an aircraft is the angle between the longitudinal axis and the plane of the true horizon. In flight the pitch attitude required to maintain any desired condition (rate of climb or descent, or level flight) is the result of the simultaneous effect of three variable factors : airspeed, altitude, and the all-up weight (A.U.W.). When the airspeed is changed, the angle of attack, and therefore the pitch attitude, must be changed to maintain a constant height. In comparison with the attitude required for level flight at normal cruising speed, the nose must be raised to maintain level flight at low airspeeds and lowered to maintain level flight at high airspeeds.

7. The A.U.W. of an aircraft affects the pitch attitude. To maintain height at the same I.A.S., the aircraft flies more nose-up at high A.U.W. than at low A.U.W. This effect is more noticeable at low than at high I.A.S.

8. Precise pitch control at high I.A.S. and high altitudes demands close attention and a smooth control technique. Most high-speed aircraft are particularly sensitive in the pitching plane and can be easily over-controlled, especially at high altitudes.

9. The instruments used to show movement in the pitching plane are the artificial horizon, altimeter, rate of climb and descent indicator (R.C.D.I.), and to a lesser degree in high-speed aircraft the air speed indicator (A.S.I.).

Artificial Horizon

10. The artificial horizon gives a direct and immediate indication of the pitch attitude of the aircraft. In visual flight, any required pitch attitude is set and maintained by raising or lowering the nose in relation to the true horizon. In instrument flight, the artificial horizon replaces the true horizon and exactly the same procedure is followed by raising or lowering the image aircraft in relation to the horizon bar.

11. By using the artificial horizon to measure the pitch attitude, the aircraft can be placed in approximately the correct attitude for any desired condition of flight. After this is done the other pitch instruments must be checked to determine if the pitch attitude is correct. The artificial horizon gives a slightly false indication immediately after rolling out from a turn ; this error causes no difficulty if the indications of the artificial horizon are cross referred with those of other pitch instruments, and small corrections made as necessary.

12. To avoid over-controlling when using the artificial horizon to make pitch corrections, control pressures should be light but positive. The R.C.D.I. can be used to determine when the pitch attitude is being over-controlled. Any movement of more than 200 to 300 f.p.m. from the desired vertical speed indicates over-controlling. The normal movement of the image aircraft when making corrections in pitch at an I.A.S. of up to 300 kts. should not exceed one width of the horizon bar. As the I.A.S. increases, pitch corrections must be smaller to prevent over-controlling. Thus at T.A.S. above 300 kts., corrections should not exceed half the width of the horizon bar and at T.A.S. above 400 kts. correction should not exceed a quarter of the width of the horizon bar. It can be seen that the artificial horizon must be watched very closely at high airspeeds to prevent over-controlling.

13. There are times when corrections of the magnitude described above will not be sufficient. The best control technique (Fig. 1) is to make a small correction and then check the other pitch instruments to determine if the correction is adequate. If the first correction is inadequate an additional correction of the same magnitude can be made immediately. This procedure normally corrects any deviation from a desired flight path. However, if the pitch attitude is allowed to change inadvertently by a fairly large amount, it should be brought back to the approximate attitude that had previously maintained the original flight path before applying any finer correction.

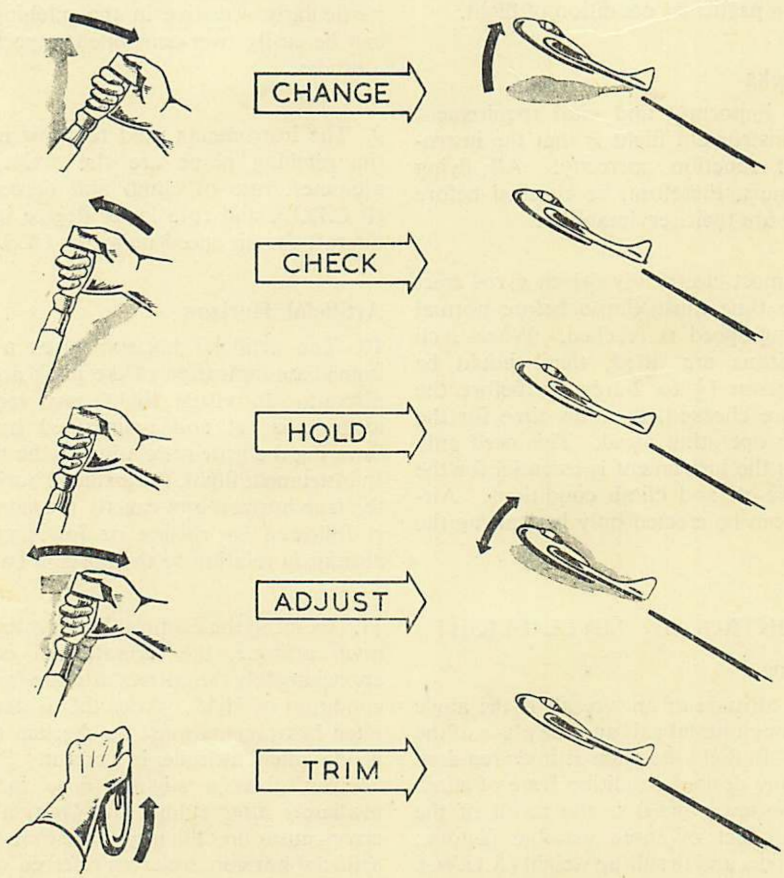

Fig. 1. Control Technique

Altimeter

14. The altimeter gives an indirect indication of the pitch attitude of the aircraft in level flight. Altitude should remain constant and any deviation from the desired altitude shows the need for a change in pitch attitude. The rate of departure from the desired height is an indication of the amount of deviation from level flight.

15. Corrective action should always be made promptly, with light pressures on the controls, to avoid the larger corrections which are required if correction is delayed. Although there is a slight lag in the indications of the altimeter when deviating from level-flight conditions, at low altitudes it may be considered to give a quick indication of a change in pitch attitude. At high altitudes the altimeter may appear to lag and the remaining pitch instruments must be cross-checked carefully to control the pitch attitude.

Rate of Climb and Descent Indicator (R.C.D.I.)

16. The correct use of the R.C.D.I. is essential for precise control of pitch attitude, particularly at high speed. This instrument does not give a positive indication of the pitch attitude but if a sound control technique is used it gives a positive indication of any change from the desired pitch attitude. When light control pressures are used, the initial movement of the R.C.D.I. indicates the trend of the vertical movement of the aircraft.

17. The R.C.D.I. should always be used in conjunction with the altimeter to maintain level flight. If the instrument indicates zero when the altimeter is stationary, any movement of the needle from the zero position indicates the need for an immediate change in pitch attitude. If this movement is detected immediately and corrective pressure applied, the altimeter, owing to its slight lag, usually indicates no change in height.

18. The amount that the altimeter has moved from the desired altitude governs the rate at which the aircraft should be returned to that altitude. If the deviation is 100 feet or less the rate of return should be no more than 200 to 300 f.p.m. A higher vertical speed requires too much attention to avoid over-shooting the desired altitude, thus detracting from the cross-check of the bank and power instruments. If the deviation from the desired height is more than 100 feet the rate of return should be doubled (400to600 f.p.m.). A deviation of more than 300 f.p.m. from the desired rate of return can be considered as over-controlling. Thus if attempting to regain lost height at a rate of 200 f.p.m., a rate greater than 500 f.p.m. indicates over-controlling.

19. The R.C.D.I. is a sensitive instrument and, like the altimeter, has a reversed error when the pitch attitude is changed abruptly. Owing to the nature of its mechanism, several seconds are required for the instrument to indicate the exact rate of change of height when a large pitch correction is made. For example, if the nose is lowered abruptly from a level flight attitude to an attitude that will give a 500 f.p.m. rate of descent, the initial indication will be a climb and there will be a noticeable lag before the needle indicates 500 f.p.m. descent. To overcome a tendency to chase the needle, corrections should always be made by reference to the artificial horizon and any correction made should be held long enough to allow the R.C.D.I. needle to stabilize. A further correction can then be made if required.

20. Occasionally the R.C.D.I. may indicate a climb or descent when the aircraft is actually in level flight (showing a need for re-calibration). This error must be allowed for when using the R.C.D.I. for pitch control. If the needle indicates a descent of 100 f.p.m. when the aircraft is in level flight this indication should be used as the zero position and any deviation from that position would indicate a change from level flight attitude.

Airspeed Indicator

21. The A.S.I. gives an indirect indication of the pitch attitude of the aircraft. For any given power setting there is only one pitch attitude at which altitude and airspeed are constant. If the airspeed increases, the nose is too low and should be raised and vice versa.

22. The value of the A.S.I. as a pitch instrument becomes less at high I.A.S. Whereas at low I.A.S. a change of 10 kts. may mean a gain or loss of height of about 100 feet, at high I.A.S. a 10-knot change may mean a gain or loss of 500 feet or more. In addition, the A.S.I. in high-speed aircraft covers a greater speed range and therefore the needle moves only a short distance for a change of airspeed of 10 knots. Consequently the A.S.I. is of less value as a pitch instrument at high speeds and is used primarily in level flight to determine the power to be used ; its use for this purpose is explained in paras. 46 to 48.

Trim

23. The importance of proper trim during instrument flight cannot be over-emphasized. It is difficult to maintain any desired flight condition in an untrimmed aircraft as the controls are so sensitive at high speed. Although the trimmer controls are convenient and easy to use, the aircraft should not be flown by using trim alone. Attempts to trim the aircraft to new pitch attitudes usually result in over-trimming and over-correction. The aircraft should therefore be placed in the desired pitch attitude and all pressure on the controls trimmed out.

24. It is possible for stick loads to be present that are being held unknowingly. Whenever the aircraft is in a steady flight condition, pressure on the controls should be relaxed and the instruments closely watched ; if the aircraft tends to change attitude, pressure should be applied to return to the original attitude and the trimmers used to correct the out-of-trim condition. With practice it is possible to recognize an out-of-trim condition and correct it without relaxing all pressure on the controls.

25. In jet aircraft, unlike propeller-driven aircraft, changing power has little effect on the trim, but in both classes of aircraft changes in speed may have a decided effect and the aircraft should be carefully trimmed during and after airspeed changes.

26. If electrically operated trimmers are fitted there is a possibility of the trim switches sticking in the actuating position and applying full trim. To guard against this the trim switch should be returned manually to neutral, even though spring-loaded to this position.

27. Good trim technique is essential for precise instrument flight. Some pilots may believe that they are able to fly the aircraft by manual pressures alone and need not trim to fine limits. However, they will find that manœuvres cannot be done properly unless the aircraft is properly trimmed. The degree of proficiency that can be attained when flying on instruments depends largely on how well the basic principles of trimming are applied.

Cross-Checking

28. The technique for interpreting the individual pitch instruments has been discussed, but proper interpretation of individual instruments alone is not enough. The indication of all available pitch instruments must be used to maintain precise control of the aircraft. This process is known as cross-checking. The importance of proper cross-checking cannot be over-emphasized. The ability to fly accurately on instruments depends primarily on three factors : instrument interpretation, instrument coverage, and aircraft control. Of these factors, the ability to read and interpret instruments is very important. A pilot can be outstanding in aircraft control, but unless he is able to determine the attitude of the aircraft accurately from the instruments his ability will be wasted.

29. In visual flight the attitude of the aircraft is determined by reference to the natural horizon, but if an accurate flight path is desired the flight instruments must be consulted. An illustration of the need for cross-checking flight instruments during visual flight is provided by the fact that a level *attitude* can easily be maintained visually but a constant *altitude* can only be assured by checking the altimeter.

30. Although it is not necessary to cross-check instruments in any particular sequence, there are certain instruments which must be watched more closely during particular manœuvres. For each manœuvre, or flight condition, there is one instrument that gives the most reliable indication of attitude. Thus in level flight the altimeter must be more frequently checked to see if the desired altitude is being maintained. In a climb at a given airspeed the A.S.I. must be watched closely. The appropriate instrument is called the *primary instrument* for the particular manœuvre.

31. The primary instrument is the one that gives the most pertinent or reliable information on the desired condition of flight and is usually the one that should be giving a constant reading. Thus the altimeter is always the primary pitch instrument in level flight (except in thunderstorms and other conditions of violent turbulence where strong vertical air currents tend to make altimeter indications unreliable). As already explained, any of the pitch attitude instruments can be used to hold a level attitude or, with the proper power setting, a reasonably constant altitude. Only the altimeter gives the pilot the exact information desired, which is whether the aircraft is maintaining a constant desired height. Therefore the altimeter is the primary pitch instrument for level flight and the other pitch instruments are supporting instruments, used as aids to hold the altimeter reading constant and to check its indications.

32. There are times when a supporting instrument should be watched as much as, if not more than, the primary instrument; for example, in level flight the artificial horizon is used to hold a constant attitude and to make any pitch corrections if the need for a change is shown by the altimeter. Deviations may be shown by a supporting instrument before they are noticed on the primary instrument ; if so, a correction is made immediately and the primary instrument quickly checked to determine if the correction is sufficient. Thus while the altimeter indicates that the pitch attitude is satisfactory, on checking the other instruments a deviation from zero may be noted on the R.C.D.I. ; an immediate correction should be made to the indication of the artificial horizon, and the altimeter watched to see if the correction is effective. Regardless of which instrument shows the deviation, a correction in pitch should be applied and the cross-check continued to determine the effectiveness of the correction. It should always be remembered that the sooner a deviation is noticed and a correction applied the smaller is the correcting movement.

DIRECTIONAL AND LATERAL CONTROL

Considerations

33. The lateral attitude is the angle between the lateral axis and the plane of the true horizon. To keep straight in visual flight, the wings must be kept level with the natural horizon. Assuming that the aircraft is properly trimmed in level flight any change in the lateral attitude results in a turn.

34. The instruments used for lateral control are the artificial horizon, the turn and slip indicator, and the compass.

Artificial Horizon

35. The artificial horizon gives a direct and immediate indication of the lateral attitude of the aircraft. In trimmed flight, the aircraft starts to turn when the wings are banked ; the turn is stopped by levelling the wings of the image aircraft in relation to the horizon bar. At low speeds this should be done by co-ordinated use of aileron and rudder ; high-speed aircraft flying at high I.A.S. need little or no rudder and if a gentle pressure is used for the aileron movement rudder pressure can be disregarded. However, when the bank is changed rapidly aileron drag is marked, and rudder should be used in the direction of movement to counter the adverse yaw.

36. The lateral attitude of the aircraft can be determined in two ways from the artificial horizon; by the position of the wings in relation to the horizon bar or by noting the position of the bank pointer in relation to the zero mark on the banking scale. Either of these may be used, but when turning, the bank index and the banking scale are more accurately and easily read ; the angle can only be estimated roughly from the positions of the image aircraft and horizon bar. In straight flight, since the wings of the image aircraft are close to the horizon bar, they give a sufficiently accurate indication of bank attitude and allow the pitch attitude to be observed simultaneously.

Gyro Compass

37. The gyro compass gives an immediate indication of bank when it deviates from the desired heading. If straight flight is desired, corrective action must be applied using the artificial horizon in conjunction with the turn needle as soon as a deviation in heading is noticed.

Turn and Slip Indicator

38. The turn needle gives an indirect indication of the lateral attitude of the aircraft. When the turn needle is centred the aircraft is in straight flight, and if the slip indicator is centred the wings are level. When the turn needle is deflected the aircraft is turning in the indicated direction. Thus if the turn needle moves to the left the aircraft is banked to the left and the needle must be re-centred by co-ordinated use of the controls to return to straight flight. Accurate interpretation of the turn needle requires close checking. Any deviation from the centre must be quickly corrected to maintain straight and level flight. This is particularly important at high speed when small deflections correspond to large angles of bank.

39. In turbulent air the needle oscillates quickly from side to side and interpretation of the fluctuations must be made to detect actual turning of the aircraft. If the needle fluctuates equally on both sides of the centre the aircraft is flying straight. If the deflection is greater on one side than the other the aircraft is turning in the direction of the greater fluctuation.

40. In high-speed aircraft using electrically driven instruments, if both inverters fail, the turn needle may be the only bank instrument in operation since some turn indicators operate on

D.C. power. Pilot's Notes deal with this point. Thus this instrument has the same importance that it has always had in suction-driven types and the pilot must be able to use it for bank control in emergencies. It may also be used to monitor the artificial horizon which tends to precess in the banking plane during turns.

41. The turn and slip indicator must be used at all times to determine whether the aircraft is being flown correctly ; if the indicator is not central, rudder is being used improperly or, in multi-engined aircraft, the power settings may be unequal.

Trim

42. If the aircraft is properly trimmed, it tends to remain laterally level and maintain a constant heading in smooth air. Incorrect adjustment of the aileron trim causes a tendency to bank, resulting in a turn unless the aileron and rudder trim tabs neutralize each other to produce a yawed attitude on a constant heading which is indicated by the slip indicator. Excessive pressure on the rudder (with the wings level) also produces a yawed attitude, which is specially undesirable in high-speed aircraft as it may cause a large reduction in airspeed through additional drag. A turn should not be stopped by use of rudder alone, except in the case of a yawing turn caused by engine failure in multi-engined aircraft.

Cross-Checking

43. Combined use should be made of all available bank instruments to ensure straight flight. The gyro compass and the turn needle show when the aircraft is turning ; the artificial horizon and the turn needle show the cause of the turn. In straight flight the heading is maintained primarily by reference to the gyro compass, which indicates any deviation from the desired heading. The artificial horizon is used to hold a constant laterally level attitude or to make any changes in bank required by the indications of the compass. In Mk. 4 compasses, if the monitoring fails the compass selector switch should be moved to the D.G. position and the instrument used as a direction indicator ; if complete failure occurs straight flight is maintained by using the turn needle as the primary bank instrument.

44. If the gyro compass indicates that the aircraft has deviated from the desired heading, the aircraft should be banked to return to the desired heading, the angle of bank used depending on the number of degrees the aircraft should be turned. A rule of thumb is that the angle of bank should not normally exceed the number of degrees to be turned with a maximum angle of bank of 30°. At high I.A.S. small angles of bank can be doubled without causing difficulty provided they do not exceed 30°.

45. When practising instrument flying it should be remembered that control of pitch and bank are of equal importance. Therefore, as the use of each of the bank instruments is learned, the pilot must include it in the sequence of cross-checking previously used. The greater number of instruments to be watched the greater must be the rapidity of the cross-checking.

THE EFFECT OF POWER ON STRAIGHT AND LEVEL FLIGHT

Power and I.A.S.

46. At any given I.A.S. the power setting determines whether the aircraft is in level flight, in a climb, or in a descent. For example, cruising speed, if maintained with cruising power, results in level flight. If the power is increased and the airspeed held constant, the aircraft climbs. Conversely if the power is decreased and the airspeed held constant the aircraft descends.

47. At a constant altitude the power determines the I.A.S., *i.e.* a high power results in a high I.A.S. and any reduction in power reduces the I.A.S.

Power, Altitude, and I.A.S.

48. To maintain a constant height and airspeed in level flight, the pitch attitude and power must be co-ordinated. If the height is constant and the airspeed is too high or too low, the power should be changed to obtain the desired I.A.S. While the power is being changed the altimeter should be closely watched and any deviation from the desired height should be corrected by appropriate pressure on the control column.

49. If the height is low and the airspeed is high, or if the height is high and the airspeed is low, a pitch correction alone may return the aircraft to the desired height and airspeed. If both airspeed and height are low or if both are high, a change in both pitch and power is necessary.

50. The altimeter is always the primary pitch instrument during level flight, whether flying at a constant airspeed or during changes in power and airspeed, and the gyro compass remains the

primary bank instrument. When changing airspeed the tachometer (on jet aircraft) is the primary power instrument until the airspeed approaches the desired figure, when the A.S.I. again becomes the primary instrument for power.

Increasing the I.A.S.

51. When increasing airspeed while maintaining straight and level flight, the instruments must be watched closely. The R.C.D.I. is particularly valuable in showing any tendency for the aircraft to gain or lose height. To counteract any tendency to climb, forward control pressure must be applied and elevator trim used to relieve the pressure. This is extremely important at high speed when control pressures must be kept light for accurate flying. As the I.A.S. increases, the pitch must be corrected to keep the altitude constant ; therefore the image aircraft is lowered in relation to the horizon bar on the artificial horizon. The artificial horizon should be used to make all pitch corrections and ensure a constant attitude until the other instruments indicate a deviation.

52. As the speed approaches the desired I.A.S. the power should be adjusted to maintain this figure. The initial power setting should be made as accurately as possible without interrupting the normal cross-check. After trimming the aircraft, the I.A.S. and tachometer should be checked to determine if the power setting is correct.

Reducing the I.A.S.

53. To reduce airspeed while maintaining straight and level flight, the power setting should be reduced to give the desired airspeed. Because the speed decreases slowly, the airbrakes may be used when the airspeed is to be reduced by more than 25 knots. The engine should not be throttled back too far to reduce speed as this complicates what is otherwise a simple procedure.

54. Although the reduction in power will have very little effect on control pressures, in some aircraft the airbrakes cause a sudden change of trim. To maintain level flight, this effect must be anticipated and corrective action taken when the airbrakes are opened. The change of trim should be counteracted by maintaining a constant attitude on the artificial horizon ; this may require considerable control pressure which can be relieved by trim. The pitch and bank instruments should be cross-checked to maintain straight and level flight and the tachometer checked to determine if the power setting is correct. As the I.A.S. decreases and the nose tends to drop, back pressure must be applied to maintain altitude, and trim used to relieve the pressure. As it is not possible to maintain a constant altitude with constant attitude and changing airspeed, the nose of the aircraft must be raised or lowered as required to keep the altitude constant.

General Considerations

55. Control of the pitch and lateral attitude to maintain a constant heading and altitude during airspeed changes can be carried out with a high degree of accuracy if the pilot has learned what to expect, how to make proper attitude corrections, and how to trim ; the tachometer must now be combined with the cross-check of the pitch and bank instrument to ensure straight and level flight. When the power is changed, the speed of the cross-check must be increased to cover the pitch and power instruments adequately.

TURNS

The Standard Rate Turn

56. Turns described in this section are those used in normal instrument flight and do not exceed a standard rate (Rate 1, or 3° per second) as indicated on the turn and slip indicator, or 30° bank as indicated on the artificial horizon. The T.A.S. determines the angle of bank necessary for a Rate 1 turn. At 200 knots T.A.S., about 26° of bank is required for Rate 1 turn, and at 400 knots T.A.S., 45° of bank. If the T.A.S. is such that more than 30° of bank is required for a Rate 1 turn, the turn should be made at half the standard rate to avoid banking too steeply.

Entering the Turn

57. The turn should be entered smoothly and as soon as pressure is applied the artificial horizon should be used as the primary bank instrument until the approximate desired degree of bank has been reached, at which point the turn needle becomes the primary instrument for bank. In a level turn, the attitude must be changed to compensate for the change in the lift caused by banking, and therefore the pitch instruments must be watched while rolling into the turn. It must be remembered that no corrective action should be taken until the flight instruments indicate a deviation from the desired condition of flight. As the nose of the aircraft is raised to hold height, power should be increased if necessary to maintain the desired I.A.S. Smooth technique is especially valuable at this time since the control pressures vary during entry into the turn.

58. When the desired angle of bank is reached it may be necessary to apply a slight opposite pressure on the control column to prevent the bank from increasing beyond the desired amount. If the bank is allowed to increase, more backward pressure is required to maintain level flight and this increases the rate of turn.

Leaving the Turn

59. To return to straight and level flight, the controlling pressures should again be smooth and the rate of roll on entering and leaving the turn should be the same. When pressures are applied to recover, the artificial horizon becomes the primary bank instrument. As the angle of bank is decreased the vertical component of the lift increases unless the nose is lowered to maintain the desired height. At the same time the power is reduced as necessary to maintain the desired airspeed. Since the artificial horizon precesses in a turn, lateral level should be cross-checked with the turn indicator to ensure level flight after rolling out.

Steep Turns

60. At high speeds high angles of bank are required for even moderate rates of turn. Because the angle of bank is increased in a turn, it is necessary to increase the backward pressure on the control column to give the required increase in angle of attack, and in a steep turn this backward pressure may be considerable.

61. Gain or loss of height in a steep turn can be detected by reference to the A.S.I., altimeter, and R.C.D.I. The artificial horizon will also indicate the pitch attitude, but at high angles of bank and high speeds it will be difficult to detect small but significant pitch changes from this instrument. At high speeds the R.C.D.I. gives the first indication of a change of pitch attitude. Corrections must be made instantly, by readjusting the angle of bank and pitch attitude, as soon as the R.C.D.I. indicates a deviation from level flight. When rolling out from the turn, the backward pressure on the control column must be released to prevent climbing.

CLIMBING

Introduction

62. For a given power setting and weight there is only one attitude that gives the best rate of climb. The best climbing speeds and power settings are given in Pilot's Notes.

Entering a Climb from Climbing Airspeed

63. To enter a climb while cruising at climbing airspeed, climbing power is set and at the same time the nose of the aircraft is raised to the climbing attitude, keeping the I.A.S. constant. When the power change is started, the airspeed indicator is the primary pitch instrument and any changes in the pitch attitude should be cross referred to the artificial horizon. The rate of attitude change and power application must be well co-ordinated to avoid any gain or loss in airspeed. The pitch attitude is held until the R.C.D.I. has stabilized at a constant rate, unless a deviation in airspeed is noted ; if the airspeed changes, a correction in pitch attitude must be made. When the R.C.D.I. stabilizes it is used to hold a constant pitch attitude since it shows a deviation in pitch sooner than the A.S.I. ; to correct changes in the vertical speed the pitch attitudes must be adjusted and the airspeed checked for any deviation. Thus the R.C.D.I. is used as an aid to control the pitch attitude of the aircraft but the final attitude is governed by the A.S.I., which is the primary instrument.

Entering a Climb from an Airspeed Higher than Climbing Airspeed

64. To enter a climb when the airspeed is higher than the climbing airspeed, climbing power is set and while the power is being increased the attitude is adjusted, by reference to the artificial horizon, to the approximate climbing attitude for the airspeed and power setting used. When the R.C.D.I. stabilizes, the rate of climb is held until the airspeed decreases to the desired reading. The pitch attitude is then adjusted to maintain the desired airspeed.

Levelling-Off from a Climb

65. The pitch attitude should be decreased as the desired height is approached ; if this is left too late, inertia causes the aircraft to overshoot the desired height. The higher the rate of climb, the sooner should levelling-off be started. Another factor governing the amount of lead required is the technique used to level-off. Practice and observation enables the amount of lead required for levelling-off under any conditions to be determined.

66. In levelling-off from a climb the attitude change must be co-ordinated with the reduction in power to hold the I.A.S. constant. When the level-off point is reached, smooth forward control pressure is exerted to lower the nose to the level

flight attitude and the power is reduced simultaneously to the level flight setting. The altimeter becomes the primary pitch instrument as soon as levelling-off is started, but the artificial horizon should be used while changing the attitude. Both changes should be completed just as the desired height is reached ; attitude and power are then controlled as described in the paragraph on level flight.

DESCENDING

Introduction

67. Descents at constant I.A.S. are used during instrument let-down procedures. The airspeed and power setting used depend on the height, aircraft configuration, and rate of descent desired. The descent can be made with the aircraft clean or with airbrakes and flaps extended.

68. The procedures outlined here apply to descents at any airspeed and with the aircraft in any configuration (airbrakes, undercarriage, and flaps either down or up).

69. During any descent in straight flight the gyro compass should be the primary instrument for bank control.

Entering a Descent from Level Flight at Descending Airspeed

70. To enter a descent while cruising at descending airspeed the power is reduced to the required setting and the nose lowered simultaneously to the correct attitude. If the airbrakes are to be used, they should be opened after the power is reduced. With the airbrakes out, considerable pressure may have to be used to hold the pitch attitude. The artificial horizon should be watched while making the initial change in the pitch attitude and then all control pressure trimmed out. The A.S.I. or machmeter is the primary pitch instrument when reducing power, but as in a climb the R.C.D.I. and artificial horizon are used as aids to hold the airspeed constant. If the change in the pitch attitude is followed by a change in the I.A.S., the artificial horizon and R.C.D.I. indications should be used to make adjustments. Throughout the descent the vertical speed must be held constant unless the A.S.I. indicates the need for a change.

Entering a Descent from an Airspeed Higher than Descending Airspeed

71. To enter a descent from an airspeed higher than descending airspeed, adjust the power and open the airbrakes if they are to be used. Maintain height until the airspeed approaches the descending airspeed, then proceed as in para. 70.

Levelling-Off from a Descent

72. As in the climb, the level-off from a descent must be started before reaching the desired height. The amount of lead used is governed by the rate of descent and the control technique used. When levelling-off from a descent, more lead is required than from a climb at the same vertical speed, because gravity is acting in the same direction as the inertia of the moving aircraft. The exact point at which the level-off is started depends on the rate of descent, type of aircraft, and height ; it may be as much as 3,000 feet above the desired height. At the level-off point the aircraft must be brought smoothly to the level flight attitude by back pressure on the controls. If the airbrakes are out they must remain out until level flight is attained, and then closed and the power increased at the same time to the required figure. As soon as the level-off is started, the altimeter becomes the primary pitch instrument. When the aircraft has reached the desired height, the A.S.I. indications become the primary ones for power adjustments and the normal level flight cross-check is resumed.

INSTRUMENT TAKE-OFF

Introduction

73. Rain on the windscreen, cloud base lower than reported, or possible vertigo at night, may make it necessary to go on to instruments during the take-off run or shortly after leaving the ground. For these reasons instrument take-offs should be practised frequently.

Cockpit Check

74. A complete cockpit check, including all the items necessary for visual flying, should be made before take-off and special attention should be given to gyro instruments. When cleared for take-off, align the aircraft along the centre of the runway, allow it to roll straight for a short distance to straighten the nosewheel or tailwheel and then stop the aircraft. Apply full brake and briefly re-check the artificial horizon to ensure that the image aircraft is in the correct attitude.

Take-Off Technique

75. With the brakes on, increase the power and briefly check the engine instruments and generators. Release the brakes and open the throttle to take-off power as quickly as possible.

Until the rudder becomes effective, any deviation in heading indicated on the gyro compass must be corrected immediately by careful braking; brakes should be used sparingly because their use lengthens the take-off run. Rudder should be used for directional control as soon as it becomes effective. During a cross-wind take-off, after applying rudder to correct the heading it may be necessary to hold pressure on the rudder to maintain the heading.

76. At the speed quoted in Pilot's Notes (on nose-wheel aircraft) sufficient back pressure should be applied to the controls to raise the nose-wheel and establish a climbing attitude on the artificial horizon. If this attitude is maintained the aircraft flies itself off the ground at a speed well above stalling speed. In tail-wheel aircraft the tail should be raised normally during the take-off run, and the attitude checked on the artificial horizon; the aircraft should be lifted off the ground when take-off speed is reached and then placed in the climbing attitude.

77. As the aircraft unsticks, the attitude should be kept constant and a straight heading maintained by holding the pitch attitude and keeping the wings level by reference to the artificial horizon. Small variations in pitch at this time may cause the aircraft to bounce on the runway or to stall. Directional control may be more easily maintained by additional reference to the gyro compass and turn needle. Before retracting the undercarriage, the altimeter must show a definite increase in height and the R.C.D.I. a definite rate of climb. The flaps should be raised only after a safe airspeed has been attained. Since the climbing speed of a jet aircraft is high, a vertical speed of 500 to 1,500 f.p.m. should be maintained until the climbing speed is approached. Trim may be used after take-off but should not be used to pull the aircraft off the ground; doing so may result in an excessively nose-up condition.

78. The gyro compass is the primary instrument for heading during the take-off run. When the aircraft approaches flying speed the artificial horizon is the primary instrument for pitch control and a supporting instrument for bank control. Of necessity, during an instrument take-off the cross-check must be very rapid and use made of the indications of all available flight instruments. *Allowance must be made for all acceleration errors affecting the instruments.*

GOING ROUND AGAIN

Technique

79. When it has been decided to go round again, sufficient power should be applied for the aircraft to climb away with undercarriage and flaps down; usually at least climbing power is required. Airbrakes, undercarriage and flaps should be retracted early and power adjusted if necessary. Throughout this procedure it is essential to keep straight by reference to the gyro compass and to cross refer constantly with the artificial horizon, A.S.I., and altimeter, because of the large change of trim which occurs while changing from a descending to an ascending flight path; this may be accentuated by changes in power and the raising of undercarriage and flaps.

RECOVERY FROM UNUSUAL ATTITUDES

Considerations

80. Unusual attitudes should not arise if the proper control technique is used. The angle of bank and the pitch attitude should be kept within the limits of the instrument.

81. Poor instrument interpretation, faulty control technique, or severe turbulence can cause the aircraft to assume an unusual attitude, and for this reason recovery from unusual attitudes must be practised under simulated instrument flight conditions, until the pilot is confident of regaining level or controlled flight by the use of instruments as quickly as possible and with the minimum loss of height.

82. The ideal recovery from any unusual attitude except spinning is made as follows :—

(*a*) All physiological sensations *must be ignored* and the instruments trusted completely.

(*b*) Any toppled instrument must be ignored (*e.g.* artificial horizon).

(*c*) The slip needle or ball must be centred with rudder, the turn needle with aileron, the speed adjusted by elevator movement assisted by the throttle and/or airbrakes.

(*d*) While centralizing the turn needle, care must be taken to impose only the very minimum amount of positive or negative *g* to avoid affecting the accuracy of the indications of the instruments.

83. Unusual attitudes can be classified under two main headings :—

(*a*) Attitudes characterized by increasing airspeed.

(*b*) Attitudes characterized by decreasing airspeed.

84. During recovery from unusual attitudes, including stalling and spinning, the artificial horizon may be toppled. If it has not toppled, it should be used to give pitch attitude and bank indication but the following paragraphs assume that recovery has to be made without the aid of this instrument.

Attitudes Characterized by an Increasing I.A.S.

85. In a steep dive, with the wings level or banked, all pitch instruments give an indication of a nose-down attitude. The I.A.S. will be increasing and the 'hundreds' pointer of the altimeter moving so rapidly that it may be difficult to read. In a very steep dive, especially when banked, the artificial horizon, if not already toppled, may be unreadable. The R.C.D.I. gives an indication of a marked rate of descent and if the dive is steep the needle will be on the stop.

86. Before any attempt is made to pull out of the dive, the wings must be levelled by centralizing the turn needle with the ailerons, at the same time correcting for any slip or skid with the rudder. Any attempt to pull out of the dive without first levelling the wings tightens and aggravates the spiral.

87. At the first indication of a steep dive, the wings should be levelled, the power reduced, and the airbrakes extended at the same time.

88. When the wings have been levelled, the aircraft can be pulled out of the dive. If the recovery is made harshly, the turn needle may remain hard against the stop or may flick across the dial even though the wings have been levelled.

89. When the I.A.S. stops increasing, the aircraft is in level flight or in a controlled dive. Level flight attitude can be regained by changing the pitch attitude slowly, while the airspeed is decreasing, by use of the R.C.D.I. and the altimeter. When the aircraft is practically level, the airbrakes, if used, should be retracted and normal cruising power applied.

90. In high-performance aircraft, owing to the high I.A.S. which can be achieved in a dive and the high inertia of the aircraft, it is better to use the altimeter instead of the A.S.I. to determine when the aircraft is approximately in level flight ; when the altimeter reading stabilizes the aircraft is in level flight.

91. **Inverted Dive.** If the aircraft is inverted there will be a reversal of airspeed and height indication with normal control movements, *i.e.* backward movements of the control column cause an increase of both airspeed and rate of descent. To recover, the wings must be levelled, power reduced, and airbrakes, if available, extended as in a normal dive. The aircraft should then be rolled right side up and normal recovery action taken.

Attitudes Characterized by a Decreasing I.A.S.

92. In aircraft with a comparatively low performance a steep nose-up attitude is indicated by a marked rate of decrease in airspeed and any bank is shown by the turn needle. In high-performance aircraft, owing to the large amount of inertia at the high airspeeds obtainable, a steep nose-up attitude may be reached without any marked decrease in airspeed but, in this attitude, the needle of the R.C.D.I. is against the stops and the altimeter "hundreds" pointer spins rapidly round the scale, showing an increasing altitude.

93. In the same way as in recovery from unusual attitudes at high speed, the wings must be levelled by reference to the turn needle and any slip or skid corrected by use of the rudder. If the nose-up attitude is steep, more power should be used to reduce the chance of stalling.

94. To recover from a nose-up attitude, a gentle forward pressure should be used on the control column. The indication of level flight is given when the needles of the A.S.I. and altimeter stabilize. The airspeed may still be low after level flight is regained but soon builds up to normal cruising speed. Level flight is maintained by reference to the altimeter and R.C.D.I.

95. **Recovery from Vertical Attitudes.**

(*a*) In high-performance aircraft, if a very high rate of climb is shown by the R.C.D.I. and the altimeter, followed by a moderate, then rapid reduction in airspeed, the aircraft may be in a near vertical nose-up attitude. To recover, the wings should first be levelled by reference to the turn needle, *and the control column held central.* The airspeed can be expected to fall off still further, and cross reference should be made to the altimeter and the R.C.D.I. to see when the aircraft stops climbing. It is important that all physiological sensations should be ignored and the instruments relied on implicitly. The aircraft may eventually stall but in any case the nose drops. When the airspeed starts to increase and the R.C.D.I. and altimeter show a loss of height, it should be ascertained by reference to the turn needle that the wings are level and the aircraft eased out of the dive. The airbrakes should be extended if necessary, to limit the speed.

(*b*) As the speed approaches the stalling speed, there is a decrease in the rate of climb shown by the R.C.D.I. and altimeter, until just before the stalling speed is reached when a rate of descent may be indicated. If full power is applied at this stage and forward pressure applied to the control column, recovery is made with the minimum loss of height. As the nose drops, the airspeed increases and when a safe margin above the stall has been reached, level flight can be regained by reference to the R.C.D.I., altimeter, and A.S.I.

(*c*) A wing may drop at the stall. On many aircraft the ailerons are effective at and below the stall and a dropped wing, shown by the turn needle, may be raised by aileron, care being taken to correct for slip and skid by use of the rudder. Pilot's Notes state when aileron control is available at the stall. On certain aircraft, however, the use of aileron near the stall aggravates the situation and no attempt should be made to centralize the turn needle with the ailerons ; any further yaw should be prevented by use of the rudder and only when the airspeed has reached a safe margin above the stalling speed should the ailerons be used to level the wings.

(*d*) Since the use of rudder at the stall is the normal method of initiating a spin, it is essential that the stalling characteristics of the aircraft and the degree of control effectiveness at and near the stall are known.

(*e*) When recovering from the dive, care must be taken not to raise the nose of the aircraft too quickly or an accelerated (*g*) stall may occur, necessitating further recovery action and resulting in the loss of more height.

SPINNING AND RECOVERY

Considerations

96. Unintentional spins during instrument flight occur only when the controls are mishandled, but all pilots should be able to recognize a spin from instrument indications. Strong physiological sensations are experienced when spinning, especially during the recovery when there is usually a very misleading and realistic sensation of spinning in the *opposite* direction. All such sensations *must* be ignored.

Instrument Indications when Spinning

97. The following are the instrument indications of a spin :—

(*a*) The artificial horizon is probably toppled, but even if it is not it may be unreadable because of the extreme attitude.

(*b*) The A.S.I. indicates a fairly steady fluctuation in the region of the stalling speed.

(*c*) A rapid loss of height is indicated by the altimeter.

(*d*) A high rate of descent is indicated by the R.C.D.I.

(*e*) A large rate of turn in the direction of the spin is indicated by the rate of turn indicator.

(*f*) Some degree of skid may be shown by the slip indicator.

Recovery Technique

98. To recover, throttle back and apply full opposite rudder, keeping the ailerons in the neutral position. After a slight pause move the control column progressively forward, ensuring that the ailerons are still centralized, until the spin stops. The following indications show when the spin has stopped :—

(*a*) The turn indicator needle flicks across the dial and then approximately centres itself. It is the flicking of the turn indicator needle that indicates that the rotation of the spin has stopped.

(*b*) The I.A.S. begins to increase rapidly.

99. When recovering from the dive, the approximate level flight attitude is shown by the airspeed indicator when it stops increasing and by the altimeter when the altitude stabilizes. The airspeed continues to fall off after the level flight attitude is reached. To climb after recovery from a spin, the climbing attitude must be attained initially by reference to the R.C.D.I. and altimeter while the speed falls to the climbing figure.

100. If the pull-out is at all harsh, the turn needle will flick again momentarily to indicate a full rate turn. This is caused by the effect of *g* in the pull-out, and correct indications will be given when the loading returns to normal. A steady deflection with an increasing airspeed, however, indicates a spiral dive and in this case the aircraft has to be levelled laterally before recovery can be made. The main difference between the instrument indications of the spin and the spiral lies in the airspeed, which increases to a high figure in the spiral but remains low in the spin. The difference is important ; the recovery action involves quite different control movements, and if the movement is not correctly identified the cure for one may aggravate the other.

101. **Inverted Attitude.** If the aircraft recovers from the spin in the inverted position, as shown by a reversal of airspeed and altimeter indications with normal control movements, the aircraft should be rolled right side up when sufficient speed has been attained and then brought back to level flight. Should the aircraft be spinning inverted, recovery is normal except that the control column should be moved back instead of forward until the spin stops. Normally the only indication to the pilot that the aircraft is in an inverted spin will be the negative loading, *i.e.* hanging in his straps and a possible slight tendency for the control column to move forward of its own account. When the spin has stopped, as shown by the turn indicator flicking, inverted flight recovery action can be taken.

INSTRUMENT FLYING AFTER ENGINE FAILURE

Considerations

102. In multi-engine aircraft, instrument flight on asymmetric power presents no problem provided the failure of an engine does not interfere with the correct functioning of the flight instruments. When it is known that an engine has failed, indications of slip or skid should be corrected by rudder and all necessary drills completed. If the flight instruments are air driven, check that the suction cock is selected to a live engine. When the instruments are electrically driven, it may be necessary to switch off some electrical services to conserve the battery if the generator output from the remaining engine is insufficient to operate all electrical services. If an engine fails while on instruments at a fairly low speed, it may be easier to throttle back all engines to maintain control initially and then smoothly reopen the throttles, trimming as necessary.

Suction-Driven Instruments on Single-Engine Aircraft

103. In single-engine aircraft with suction-driven instruments having no alternative source of supply, it will be necessary to descend below the weather as quickly as possible, as the instruments become unreliable about two minutes after the suction fails. It may be necessary to increase the speed above that for best range on the glide to achieve a faster rate of descent.

Electrically-Driven Instruments on Single-Engine Aircraft

104. In single-engine aircraft with electrically-driven instruments, the instruments will normally function long enough to enable the aircraft to descend below cloud if all unnecessary electrical services are switched off. There are some exceptions to this rule, however (see Pilot's Notes), but the aim should be to descend below the weather as soon as other circumstances permit.

CHANGING FROM INSTRUMENT TO VISUAL FLIGHT AND VICE VERSA

Introduction

105. One of the most important aspects of instrument flying is the change-over from instrument to contact (visual) flight when breaking cloud.

Visual to Instrument Flight

106. After a visual take-off which is soon to be followed by I.F. conditions, the change-over should be made immediately after take-off and cross-checking of the flight instruments should be commenced ; particular attention should be paid to the R.C.D.I., altimeter, and A.S.I., to ensure that the aircraft is climbing. The transfer from visual to instrument flight must be complete before cloud is entered *at any stage of the flight*.

Instrument to Visual Flight

107. When breaking through cloud on a descent, if there is only one pilot, a continuous movement of the eyes from the instruments to the ground and back again must be maintained. By constant cross-checking between the ground and the instruments it is unlikely that the aircraft attitude will vary to any marked degree. While cross-checking, the artificial horizon becomes the master instrument.

108. If there are two pilots, one should remain on instruments until full contact conditions prevail, while the other watches for the ground.

INSTRUMENT APPROACHES

Information Given in Pilot's Notes

109. Pilot's Notes for each type of aircraft gives three slightly different I.A.S., power, and flap settings that should be used during the appropriate stages of an instrument approach and landing. In all cases the figures apply with the undercarriage down.

Approaching

110. The approach is divided into three stages :—

(*a*) **Downwind.** This is the commencing stage during which the aircraft is manœuvring to a position from which the next stage can be started.

(*b*) **Base Leg and Final.** This is the initial stage of the approach proper, prior to reaching the glide path, during which the aircraft should be on or near the runway heading.

(*c*) **Glide Path.** This is the stage between base leg and final and the position at which the runway can be seen sufficiently well to complete the flight without further assistance.

111. The r.p.m., flap and I.A.S. combinations recommended for any particular aircraft type are those which have been found to be most suitable for the appropriate phase of the procedure either in level flight or to maintain the ideal rate of descent. These settings realize speeds which give adequate control during the approach and allow sufficient margin for small alterations for the rate of descent to be made without alteration in power. They also allow for a possible go-around and, with multi-engined aircraft, for engine failure.

Variations of the Recommended Power Setting

112. The recommended power setting varies slightly with differences in the prevailing conditions, particularly the A.U.W. and the wind strength. Under average conditions it should not be necessary to alter the power setting by more than about 500 r.p.m. with gas-turbine aircraft and 1 lb./sq. in. with piston-engine types.

Landing

113. As soon as the pilot establishes satisfactory visual contact with the runway and is satisfied that a landing can be made, the r.p.m., flap, and I.A.S. settings should be adjusted as for a normal landing in the prevailing condition.