ANNEX 'B'

CANBERRA BRAKING TECHNIQUES

Introduction

1. In the interests of both safety and economy it is important to be able to stop an aircraft in the most efficient manner. To be able to do this under all prevailing conditions a pilot should understand the theory upon which the braking techniques outlined in Pilot's Notes are based. It is with this in mind that the following paragraphs have been included in the Instructor's Handbook.

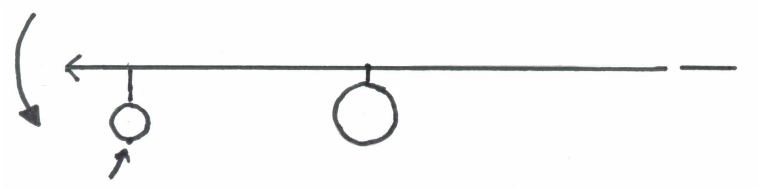
Considerations

2. The Nature of the Problem. In order to stop a Canberra after landing it is necessary to dissipate a very large quantity of energy (approximately 17,700,000 ft lb at the maximum AUW for landing and 12,630,000 ft lb at 30,000lb AUW) through one or more of the following media:
    a. Rolling Drag;
    b. Aerodynamic Drag;
    c. Wheel Brake.
3. The effectiveness of these three media is governed by a number of factors, namely:
    a. Tyre pressure and condition;
    b. Type of runway surface and its condition, e.g. wet or dry;
    c. Aircraft attitude and configuration, e.g. position of the flaps;
    d. The distribution of the AUW between the nose and main wheels;
    e. Condition of the wheel brakes;
    f. Method of using the wheel brakes;
    g. Ambient temperature – this affects the amount of energy to be dissipated, the total drag of the airframe and the cooling of the wheel brakes and tyres.
4. Wheel Slip. The difference between the speed of rotation of a braked wheel and an unbraked one, where the axles of both wheels are travelling over the same surface at the same rate, is known as "wheel slip". The amount of slip is a function of the total friction between the tyre and the surface upon which it is running, i.e. it will be greater the more slippery the surface. It has been found from trials that the maximum braking efficiency is obtained when the wheel slip is 4 to 6 ft/sec.
5. Wheel Spin Up. When the brakes are applied to a rotating wheel the wheel tends to spin down and if the frictional forces are low the spinning down may result in a locked wheel with consequent loss of braking. In order to minimise the chances of this happening it is essential to ensure that the wheels are given time to spin up before the brakes are applied. The time needed for this to happen is proportional to the 'slipperiness' of the runway.
6. Rolling Drag. Rolling drag depends on the amount of flexing of the tyres and the frictional effects between the tyre and the runway, and the wheel and its axle. The temperature rise in a tyre due to flexing is of the order of 20^{o}C per mile of travel. (This applies to aircraft tyres only). The total value of rolling drag is approximately 2% of the vertical load on the axle, which means, for instance, that a Canberra at an AUW of 50, 000lb would have a rolling drag of approximately 1000lb when just moving from rest. Because the main wheels are bigger than the nose wheels the rolling drag for any given speed is greatest

when the greater part of the effective weight of the aircraft (AUW minus lift) is distributed about the main wheels.

7. Aerodynamic Braking. When aerodynamic braking is employed lift is produced thus reducing the effective weight of the aircraft. This happens to such an extent that although the weight is distributed about only two wheels, as opposed to four when the nose wheels are on the runway, the weight on each main wheel is less than it would be with all four wheels on the runway.
8. The ‘Stick Back’ Braking Technique. From the foregoing it can be seen that rolling drag will be increased when the tyres are squashed as much as possible. This can be achieved by having the nose wheels on the runway and by bringing the control column backwards as soon as the aircraft decelerates under the influence of the wheel brakes. When the wheel brakes have been applied and the aircraft is decelerating the nose of the aircraft pitches down (figure 1). This has the effect of making the point of contact of the nose wheel on the runway a fulcrum. The fact that it is a travelling fulcrum does not affect the argument.

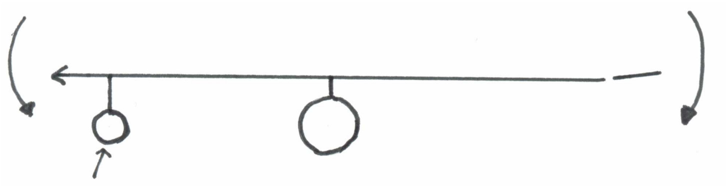
Nose down pitching moment due to braking. ‘X’



Fulcrum Figure 1

If we now apply ‘up’ elevator we get a down load on the tailplane and thus a nose up pitching moment (figure 2).

‘X’



Nose up pitching moment ‘Y’

Fulcrum Figure 2

This has a ‘nut-cracker’ action on the main wheels, squashing them and increasing the rolling drag **provided that ‘Y’ does not exceed ‘X’**. This is most important, and in practice care must be taken to ensure that the nose wheel oleo does not even start to extend, for this is a sign that ‘Y’ is greater than ‘X’. Another effect of this technique is that the main wheels slip less and more nearly reach the optimum of 4 to 6 ft/sec, thus increasing braking efficiency. Furthermore, because the wheels now have less tendency to spin down and lock, more braking can be applied, increasing ‘X’, then more ‘up’ elevator can be applied, increasing ‘Y’, and so on until a point is reached where the wheels are rotating so slowly that the brakes must be gradually released in order to prevent the aircraft stopping with a jerk. It can be seen that the three pre-requisites for using this technique are:

a. The aircraft must be decelerating under the influence of the wheel brakes;
b. Continuous braking must be employed;
c. Elevator response must be optimum. This is ensured by correct use of the tailplane trimmer.

9. Wet Runway Braking. When the runway is wet there is a reduced coefficient of friction between the tyres and the runway. This means that the wheels will take longer to spin up, be more prone to spin down and locking, and less likely to reach the optimum wheel slip. Thus the overall braking efficiency will be reduced.

10. Maximum Braking. The wheel brake system of an aircraft is designed to accept a given amount of energy in a given period of time. If either of these limits is exceeded then the system will fail. What will happen at the moment of failure depends on the nature of the brake system. In the case of the Canberra it is considered that the surface of the copper rotors will melt causing total loss of braking. As this happens there is a rapid loss of heat input, the copper will solidify and may jam the brakes, locking the wheels and bursting the tyres. In all probability this will be accompanied by fire in and around the brakes.

11. The maximum indicated speed at which the brakes can be used to stop the aircraft using the maximum braking technique, is known as the Emergency Maximum Brakes On Speed (EMBS). It is important to remember that EMBS will be lower if the brakes are already hot (from a recent landing for instance) than it would be if the brakes were cold. If the brakes are used at speeds in excess of EMBS then they will fail before the aircraft has stopped. As an illustration the following example is given: AUW = 53,000lb; ISA; nil wind; nil slope; dry runway; EMBS = 100kts. If the brakes are applied at 135kts they will be completely destroyed by the time the aircraft has decelerated to 90kts. (The recommended procedure for this type of situation is contained in Exercise 4 to the Standardisation Notes under the heading 'Abandoning Take-off'.

Practical Application

12. Normal Braking. After the aircraft has touched down and the nose wheel has been lowered onto the runway allow a second or so for the wheels to spin up. Then apply sufficient braking to slow the aircraft to walking pace by the time the end of the runway is reached. In a well executed landing run the amount of braking can be reduced progressively as the run continues. This method ensures maximum safety and minimum wear and tear of brakes and tyres.

13. Maximum Braking – Without Maxaret Units. After the wheels have been allowed to spin up apply as much brake as possible without skidding and bring the control column backwards, simultaneously increasing the application of brakes. The process should be continued throughout the landing run. The great difficulty with this technique is detecting the tendency of the wheels to spin down, because it must be remembered that maximum braking is no longer being obtained once the optimum wheel slip is exceeded. If the amount of deceleration appears to be decreasing, even though a fairly large amount of braking is being applied, release the brakes, move the control column forward, allow the wheels to spin up again and then restart the 'stick back' technique.

14. Maximum Braking – With Maxaret Units. In this case there is no difficulty with regard to the detection of spin down as the Maxaret units are designed to do just this. Therefore after the wheels have been allowed to spin up apply maximum braking, simultaneously bringing the control column progressively backwards. This process may be continued until the aircraft has stopped.

15. Wet Runway Braking – With or Without Maxaret Units. As pointed out in paragraph 5 a longer time is needed for the wheels to spin up when the runway

is slippery. As a guide some 2 to 4 seconds should be allowed during which time the aircraft will travel about 150 to 300 yards. Applying the brakes sooner than this is absolutely pointless, as it will result in wheel locking and subsequently a further period of time for the wheels to spin up. After the wheels have been allowed to spin up apply light intermittent braking with the control column held forward. As soon as some deceleration is felt start light continuous braking and use the ‘stick back’ technique. It is important to remember that the purpose of the intermittent braking is solely to determine whether the wheels have spun up sufficiently to allow the brakes to function without excessive spin down and wheel locking. If the wheels are felt to skid, or if a large puddle is about to be entered, release the brakes, move the control column forward, allow a further period for the wheels to spin up and start again with intermittent braking. Continue the process as above.

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