PART 3 : SECTION 1

CHAPTER 2

FLYING FOR ENDURANCE

Introduction

1. Flying for endurance implies flying under a set of conditions which realizes the minimum fuel flow and so the longest possible time in the air on the fuel available. The need for maximum endurance arises less frequently than that for maximum range but circumstances can arise which require aircraft to loiter, or stand-off, for varying periods of time during which fuel must be conserved. Whereas range flying is more closely concerned with specific fuel consumption and A.N.M.P.G., endurance flying is concerned with the gross fuel consumption, *i.e.* the weight of fuel consumed per hour.

Principles

2. Broadly, since the fuel flow is proportional to the thrust, the fuel flow is least when thrust is least ; therefore maximum level-flight endurance is obtained when the aircraft is flying at the I.A.S. for minimum drag, because in level flight thrust is equal to drag.

3. Maximum endurance is obtained at an altitude which is governed by engine considerations. Although for a given set of conditions the I.A.S. for minimum drag remains virtually constant at all altitudes, the engine efficiency varies with altitude and is lowest at the lowest altitudes, when the engine must be severely throttled to provide the low thrust required.

4. To obtain the required amount of thrust most economically the engine must be run at high r.p.m., *i.e.* at a large throttle opening. Therefore maximum endurance is obtained by flying at such an altitude that, with the engine running at or near optimum cruising r.p.m., just enough thrust is provided to realize the speed for minimum drag. Above the optimum altitude little if any additional benefit is obtained, and in some cases a slight reduction may be found owing to burner efficiency decreasing at or about the highest altitude at which level flight is possible at the speed for minimum drag. In general, optimum endurance is obtained by remaining between 20,000 ft. and the tropopause at the recommended I.A.S. and appropriate r.p.m. ; the greater the power/weight ratio of the aircraft the greater will the optimum height be. With aircraft having high power/weight ratios, maximum endurance is obtained at the tropopause.

5. The method given in para. 4 should only be used for maximum endurance if the aircraft is above or near the endurance ceiling, otherwise if the aircraft is climbed from a much lower commencing altitude, endurance will be reduced through the higher fuel flow required on the climb.

6. To sum up, therefore, when maximum endurance is required the aircraft should be flown at such an altitude that the thrust required to give the I.A.S. for minimum drag is obtained at an r.p.m. setting high enough to give reasonable engine efficiency. This r.p.m. should be as high as possible and therefore the altitude should also be kept high so that the thrust available just realizes the required I.A.S. It will rarely pay to climb to a higher altitude unless the commencing altitude is very low, and even then level flight at the recommended I.A.S. should be resumed as soon as the lowest economical height has been reached ; the extra fuel used to climb can neutralize any benefit gained by increased endurance at high altitude.

7. On engines having variable swirl vanes the consumption increases markedly if the r.p.m. are so low that the swirl vanes are closed. If the altitude is low enough to cause the swirl vanes to close at the r.p.m. required for minimum-drag I.A.S., the aircraft should either be climbed to the lowest altitude at which minimum-drag I.A.S. can be obtained with the swirl vanes open or the r.p.m. increased to the point at which the vanes open, accepting the higher I.A.S., or, on twin or multi-engine aircraft, one or more engines should be stopped and the remaining engines run at a more efficient r.p.m. to realize the speed for minimum drag.

Effect of Weight on Endurance

8. Drag and thrust at the optimum I.A.S. are proportional to the A.U.W. The lower the weight the lower the thrust and fuel flow. Endurance varies inversely as the weight and not as the square root of the weight as in range flying ; this is because in pure endurance flying the T.A.S. has no importance.

Effect of Temperature on Endurance

9. In general, the lower the ambient air temperature the higher the endurance, and vice versa. However, the effect is not marked unless the temperature differs considerably from the standard temperature for the altitude. In any case, the pilot can do nothing but accept the difference, since any set of circumstances requiring flying for endurance usually ties the aircraft to a particular area and height band.

Twin- and Multi-Engine Aircraft

10. When flying for endurance on twin- and multi-engine aircraft, one or more engines should be stopped, as applicable. In this way the live engines can be run at optimum cruising r.p.m. and so under most economical conditions for the thrust required.

Use of the Fuel Flowmeter

11. The flowmeter is a useful aid when flying for endurance. If the precise speed is unknown, the throttle should be set at the r.p.m. which realize the lowest indicated rate of flow with level flight for the particular altitude.

Reporting Procedure—Aircraft Endurance

12. Whenever reporting the remaining endurance of the aircraft, the pilot should give the *time* for which he can remain airborne. It is confusing and dangerous to report endurance in terms of gallons or weight of fuel remaining owing to the possibility of being misunderstood.


U/V LIGHTING
LOW