illustrating how much these other factors are worth.

They are so important that Major Green's allowance for extra drag is insufficient if the fuselage size has to be increased very appreciably to take additional passengers. However, I will first adjust my assumptions to agree with those of Major Green.

What is the value of one pound of weight saved?

Major Green's assumptions are equivalent to a direct operating cost of 0.8 pence per seat-mile, which is of the right order for present operation of efficient aircraft of the class considered. The airframe life is taken as 15,000 flying hours at an average point to point speed of 200 m.p.h.

Each pound saved is equivalent to an extra one four-hundredth of a seat with a life of three million miles, a saving of

$(3{,}000{,}000 \times 0.8)/400 \times 0.8$ pence per lb.
$=$ £25 per lb. over the life of the airframe.

I regard this as a better measure of the direct effect of weight saving. It is not always true at present that weight saving necessarily means extra manufacturing costs and in any case the operator and manufacturer will have to decide how the saving is divided between themselves and the passengers when fixing the price of aircraft and spares.

What is the value of aerodynamic and power plant efficiency?

I assume that Major Green is thinking in terms of conventional petrol-engined aircraft with characteristics similar to the following (corrected to round figures):—

Total cruising power—1/20 b.h.p. per lb. of aircraft.

Petrol consumption 2/5 lb. per b.h.p. per hour.

Engine or airframe price—£1 per lb.

Fuel price—3d. per lb.

Price of one propeller—15 per cent. of an engine.

Engine and propeller life—6,000 hours.

Weight of engines—20 per cent. of aircraft weight.

Weight of airframe—25 per cent. of aircraft weight.

Average flying distance—1,000 miles.

Average fuel reserve—50 per cent.

From this additional data, it may be shown (as in the Appendix to this letter) that even when it is assumed that the engine size is already fixed by take-off or similar limitations:—

(i) 15 per cent. of the price of an engine is saved by each 1 per cent. reduction in fuel consumption.

(ii) More than 30 per cent. of the price of an airframe is saved by each 1 per cent. reduction in aerodynamic drag.

(iii) More than the complete price of a propeller is saved by every 1 per cent. overall increase in its efficiency.

Moreover, if the engine size is decided by its cruising power (as will become increasingly evident for higher speeds and altitudes), the savings are increased to

More than 50 per cent. of the airframe price per 1 per cent. drag reduction.

More than 167 per cent. of the propeller price per 1 per cent. overall increase in efficiency.

(The effect of fuel consumption is unchanged at 15 per cent.)

It will be appreciated that such estimates can only give the order of saving in the long run, since it might be difficult to take full advantage of small savings in an actual case. The exact values depend considerably on the circumstances, but the above typical values are sufficient to show that it is essential to take account of *all* the factors contributing to the efficiency of an aircraft. Just as a somewhat surprising figure of so many £ per lb. should not be translated as meaning that everything must be subordinated to attaining the lightest possible empty weight, so, in turn, an ever more surprising figure of the saving from every small increase in aerodynamic or power plant efficiency should not

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be interpreted by subordinating weight saving.

Taking a specific illustration from the above example, if the 1 per cent. reduction in engine fuel consumption can be attained only at the expense of $1\frac{1}{2}$ per cent. increase in the engine weight, no saving will result. Conversely a $1\frac{1}{2}$ per cent. reduction in engine weight is very worth while, but not if it results in an increase in fuel consumption of more than 1 per cent. (so long as it still uses the same fuel). I agree with Majoı Green that the largest bonuses from pure weight reduction is mostly obtainable from the equipment which is partly out of the control of the aircraft or power plant manufacturer.

All these factors do add up to show one extremely important conclusion. The simultaneous improvements in structure, power, plant, equipment, aerodynamic and other aspects of efficiency (compromised where necessary) have a bearing on the future economy, safety and usefulness of air transport which is out of all proportion to the cost of the aircraft employed.

Yours faithfully,

R. F. CREASEY.

APPENDIX

For simplicity, this analysis will neglect any minor factors.

Let W = aircraft weight in lb.

Considering the effect of a 1 per cent. change in each case, 1 per cent. less fuel is carried and burnt in maintaining the same speed.

∴Fuel weight saved per hour

$$=\frac{1}{100}\times\frac{2}{5}\times\frac{W}{20}=.0002W \text{ lb.}$$

Fuel cost saved per hour

$$=.0006W \text{ pence}$$

Weight saved on an average trip

$$=.0002\times\frac{1000}{200}\times 1.5=.0015W \text{ lb.}$$

(i) Saving over the life of the engines

$$=£\left\{\frac{.0006\times 6000}{240}+.0015\times 25\times\frac{6000}{15000}\right\}W$$

$=£.03$ W, which is 15 per cent. of the price of the engines.

(ii) Saving over the life of an airframe

$$=£.03\ W\times\frac{15000}{6000}$$

$=£.075$ W, which is 30 per cent. of the price of the airframe. In addition to this, there is the smaller wear and tear on the engines due to the smaller cruising output.

(iii) Saving over the life of the propeller $=£.03$ W (plus saving in engine wear and tear) which compares with £.03 W for the price of the propeller.

If the size of the engines is fixed by cruising output, the weight of engine can be reduced by .002 W lb. in the latter two cases.

This increases the saving in these two cases by $66\frac{2}{3}$ per cent., in addition to the saving in depreciation, ground service and overhaul with the smaller engines.

To the Editor.

Sir,—I have read with interest the discussion* on the training required for those engaged in civil flying, and was extremely disappointed to find that not only was the ability of our Royal Air Force aircrew grossly under-estimated, but also that those who protested against such under-estimation did so in such mild statements that their protests may have been overlooked. I would, therefore, like to add a few comments on the discussion, even though I am somewhat belated.

I am in the fortunate position, in viewing this subject, of having spent many years of active participation in civil aviation as a member of the greatest British air line; and to have coupled this experience with an active part in operations and in the control of operations throughout the Bomber offensive with its developments of midern equipment. I therefore know intimately and am a close personal friend of many air line pilots and at the same time I am in day to day touch with the flying crews of Bomber Command. I hope, therefore, that I can claim to view the problem with the knowledge of

* Journal, February, 1945.

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