REFUELLING IN FLIGHT

refuelling before a point at a distance one-quarter of the total distance from the start, because it has been seen that the maximum fuel capacity must be sufficient for half the total distance. Hence, all refuellings should take place within the second quarter of the route, and it is therefore obvious that little is to be gained by refuelling more than twice.

The reduction in the fuel capacity requirement due to refuelling over a water route is shown in Fig. 3. The reduction amounts to 33 per cent. for one refuelling, 43 per cent. for two refuellings, and 47 per cent. for three refuellings. In most cases more than one refuelling would not be worth while, but in some instances a further 10 per cent. reduction of the fuel capacity due to a second refuelling might be economic, though seldom, if ever, would the third refuelling be worth while.

A one-third reduction of the large quantities of fuel required for long sea routes is very considerable and may easily double or treble the payload. As an example, consider an aircraft which has a payload of 5,000 lb. for a route distance of 2,000 miles, and has a fuel consumption of 1 gallon per mile. If it is to be refuelled once *en route* the full payload will be reduced by one-third, or 667 gallons weighing 4,800 lb., so that the payload is increased to 9,800 lb., or nearly double.

The following table and Fig. 4 show how the fuel load is decreased and the payload increased by means of additional refuellings:—

No. of Refuellings.	Fuel load. lb.	Payload. lb.
0	2,000	5,000
1	1,333	9,800
2	1,143	11,170
3	1,066	11,720
4	1,033	11,970
5	1,015	12,090
6	1,008	12,140

Where islands are available, however, only in exceptional cases are they ideally placed for refuelling stations; but by means of aerial tankers based on such islands, the airliner can be met at the most economic points. If the island is beyond the halfway point on a direct route, refuelling would normally take place over the island. There is nothing to gain in the tanker flying to meet the receiver since the latter must be capable of reaching the island in an emergency; but where the island is located at less than half the distance, the rendezvous is arranged at some point beyond the island for which the fuel carried at the airliner's take-off is sufficient to carry it beyond the island to the rendezvous and back to the island, and the quantities of fuel at take-off and after refuelling are again equal.

Formulæ have been evolved for use in all possible cases and they take account of all such factors as number of islands, offset of islands from route, winds, fuel, and all other allowances including the extension of flight to alternative airfields in the event of an emergency.

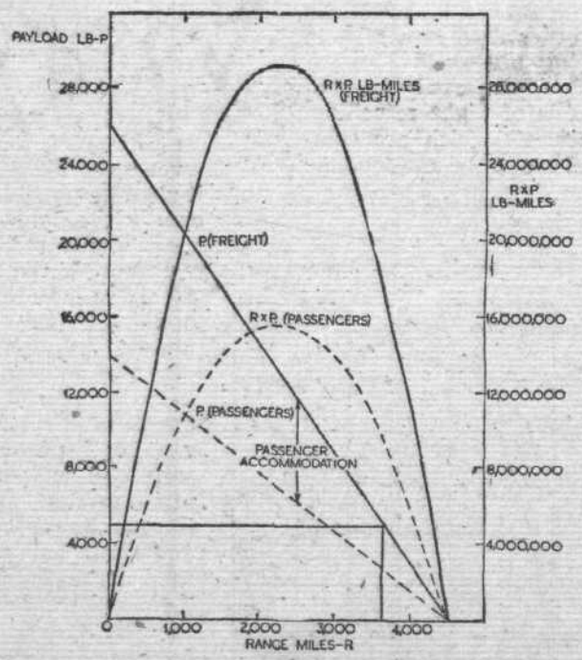

Fig. 5. Variation of freight load with range for given cruising conditions: if passengers are carried only, the broken line applies, if freight only, the full line, the difference being due to furnishings, galley equipment, etc.

One of the airline operator's biggest problems is the provision of sufficient fuel to avoid premature descent due either to headwinds, or to enforced detours for avoiding storms and bad weather. This inevitably results in generous fuel allowances being made for such contingencies which, in turn, means that vital payload is sacrificed; but even so, forced landing due to fuel shortage cannot entirely be ruled out. All this is changed with flight refuelling. A reasonable allowance for wind is made and on the few occasions when a headwind is encountered of velocity higher than that allowed for, the pilot summons a tanker from the most convenient refuelling base.

Existing aircraft may be adopted for use on a flight refuelled service, but for preference, specially designed aircraft should be employed.

Little modification is generally necessary for converting an airliner for flight refuelling, but short- or medium-range aircraft are the most suitable. In general, long-range machines have very limited payload capacity, so that if flight refuelling is resorted to no accommodation is available for the additional payload. In any case long-range aircraft are not economic.

Maximum Economy

The value of an air transport service between two given termini is measured in ton-miles, and for this to be a maximum the weights of freight and fuel load should be roughly equal. In some instances an airline may find it expedient to use a particular aircraft for carrying greater weight of freight over a shorter distance, or a smaller payload over, say, a long ocean crossing, but this can be done only at the sacrifice of economy.

Where the payload comprises passengers instead of freight, or a combination of both, the passenger seats, berths, furnishings, etc., should be included in the disposable load, i.e., the furnishings are regarded as part of the comforts carried for the use of the passengers *en route*, and as such they are considered as payload in the same way as crates and packing are included with freight.

For a given set of engine cruising conditions, Fig. 5 shows how the freight load varies with range, together with the variation of disposable load-distance units against range. If passengers are carried in place of freight the broken line curves apply, the difference between the full and broken lines being accounted for by the weight of furnishings, etc.

In other words, for an airliner to be suitable for any particular route, it should possess a capacity for fuel and oil equal roughly to half the disposable load, and the accommodation for passengers and freight should be such that its own weight plus the payload account for the remaining half of the disposable load. This is the fundamental consideration. It may be affected to some extent by consideration of frequency of service, but the fifty-fifty fuel-payload rule can be departed from only with loss of efficiency.

Actually, the available passenger or freight capacity, in terms of weight, should be somewhat in excess of the fuel capacity in order to allow for what is termed the payload factor, i.e., the average payload. This varies according to the route, season, and other factors, but a figure of 80 per cent. may be taken as a rough guide.

With a flight refuelled service the same conditions apply, except that the fuel load is taken as the normal fuel tank capacity and not the total fuel required