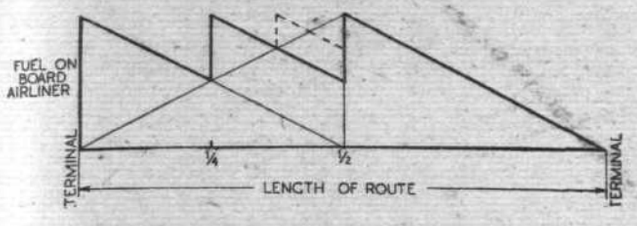


Fig. 2. Diagram showing that the optimum point of all refuellings should take place within the second quarter of the route distance.

trouble, and the fare can be kept surprisingly low.

But when we come to really long distances, and in particular long-distance non-stop flights, we are presented with a very different picture. It is fairly safe to say that a non-stop flight from London to New York, without refuelling in flight, will not be an economic proposition for several years to come, because the payload must be such a small proportion of the total weight. No doubt some non-stop air expresses will be run, but such services will, to some extent, be for a few wealthy passengers prepared to pay the very high fares required, or the fare may be kept to a reasonable figure by means of subsidisation in some form or other.

By landing in Ireland and Newfoundland, or in the Azores and Newfoundland, or the Azores and Bermuda in order to avoid the poor atmospheric conditions generally associated with Newfoundland, a very considerable reduction in fares will result. The cost of the through non-stop service will almost certainly be nearly double that of a service with one or two intermediate landings.

A Cold Douche

Major R. H. Mayo states*: "When we turn to the longer-haul service stretching across the world we find, unfortunately, a very different picture . . . and the fare-load factor table is not pleasant reading," and again, "For a service such as a direct London-New York service with a stage length of nearly 3,500 miles, the payload capacity will be such a small percentage of the all-up weight that expenditure per capacity ton-mile will soar up to a much higher level."

The realisation of the fact that fares must be very high for long non-stop flights comes as a cold water douche to many air transport enthusiasts to-day, and it is extremely doubtful whether the problem can be solved by any reasonably practical solution other than refuelling in flight.

Any short or medium-range aircraft can easily be converted for long-range work by means of flight refuelling. On the other hand, long-range aircraft which are compelled to carry vast quantities of fuel cannot be an economic proposition; instead, the fuel should be taken on board at suitable points along the route.

Clearly it could not be a paying proposition to refuel at too frequent intervals and the most economic stage must be somewhere between the two extremes. The world's geography, together with the various factors governing the design of present-day aircraft, determine this distance as approximately 2,000 still air miles, or between 1,000 and 1,500 statute miles depending upon wind and other conditions. It will also be seen that the requirements of overland and oversea routes are not the same, and should be considered separately.

In the case of refuelling over land routes, long non-stop flights are possible with the following benefits:—

(a) Intermediate landings between the main termini are avoided.

(b) The maximum quantity of fuel carried is considerably reduced with a corresponding increase in payload.

By avoiding intermediate landings the time taken to fly between main termini is greatly reduced, as the time saved includes that required for circling, descent and landing, refuelling on the ground and the re-climb to operational height. The essence of flight is speed. Normally the cost of increments of speed becomes progressively greater, since the power required is proportional to speed cubed. Hence it is easily seen that the achievement of a small increase in speed, at considerable cost, may be completely nullified by the effects of one intermediate landing. This factor becomes of far greater importance with the introduction of the various forms of jet propulsion.

The resultant reduction in the accident rate due to the elimination of hazards associated with intermediate landings and wear and tear of engines, landing gear, etc., has already been discussed. In many cases suitable intermediate landing grounds are not available.

As a simple example of the payload increase due to flight refuelling, the fuel required by an aircraft such as the York for a distance of 2,000 miles at an average consumption of 1.0 m.p.g. is 2,000 gall. or 14,400 lb. By refuelling once *en route* the fuel carried is halved and 7,200 lb. is therefore available as additional payload, which approximately doubles the normal payload.

For trans-oceanic flights two cases may be considered:—

(a) Where no intermediate islands offer possible landing grounds, refuelling may be made by one or more tankers using the same bases as the air-liners.

(b) Where intermediate landings are available as tanker stations.

In both cases the maximum fuel load is reduced by means of flight refuelling and payload is increased accordingly.

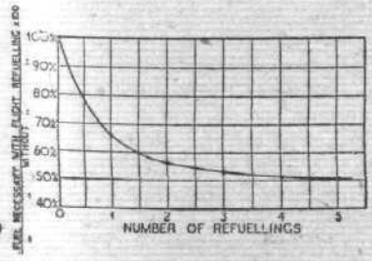
Guarding Against "Misses"

All over-water flight plans are based on the inflexible rule that it shall be possible for the airliner to return to a suitable base in the unlikely event of the rendezvous with its tanker not being realised. It may be mentioned that wherever possible the two aircraft are arranged to fly together in loose formation, the "escort" method, as opposed to the "encounter" method in which the tanker flies out to meet the liner.

Where no islands occur on the route, if the airliner is to be refuelled once only, the optimum point is one-third of the total distance from the starting base, and the maximum fuel carried by the liner at the start and after refuelling is sufficient for two-thirds of the total distance. Obviously the payload capacity is a maximum if the fuel load is kept to a minimum, and this is achieved by equalising the fuel carried at the start and after refuelling.

No matter how many times refuelling takes place there is nothing to be gained by refuelling beyond half-way, because at the half-way point the liner must have sufficient fuel for an emergency return to its starting base in case of failure to contact the tanker, and therefore it also has sufficient fuel to complete the course. Similarly, there is no advantage in

* "Some Aspects of Air Transport Economics," *The Shipping World*, 10th January, 1945. Also *Flight*, of Jan. 25th, 1945.



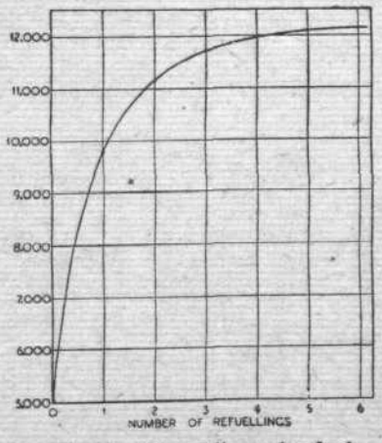


Fig. 3. (Above) Reduction in required fuel capacity by means of flight refuelling over-water routes. Fig. 4. (Right) Potential increase in payload for refuellings in flight. Aircraft is assumed to have 2,000 miles range, a normal payload of 5,000 lb. and a fuel consumption of one gallon per mile.