parallel the speed of the constant current towards the south reaches 4 km., near the 80th it is 6 km. and near the 75th parallel it is 9 km. a day.

At the end of August 1939, reaching the northernmost point of her drift, the *Sedov* began quickly to descend to the south-west, becoming gradually drawn into the Greenland current. From December 1, 1939, the drift proceeded due south, almost parallel to the drift of Papanin's North Polar Expedition, almost at the same speed with which the latter had drifted in that region two years previously.

During the period of its drift, Papanin's North Polar Expedition descended about 1,120 nautical miles to the south latitudinally. This route was covered under the influence of the constant current and local winds. If account is taken of the data of Shirshov and Fedorov concerning the direction and speed of the current, it appears that about 600 nautical miles of the total length of the drift was due to the accompanying sea currents, and only 520 nautical miles to accompanying winds. At the same time, the theoretical drift for the *Sedov* was shorter than the actual drift by 550 nautical miles, because when plotting it, we gave consideration only to local winds.

Taking into account the observations and calculations of Shirshov and Fedorov, we attempted to calculate the entire drift of Papanin's Expedition caused, on one hand, by the distribution of atmospheric pressure, and on the other, by the constant current. The results of this calculation made by myself with the help of my assistant, Mr. Somov, are of interest. Comparing the actual position of Papanin's North Polar Expedition on February 1, 1938, with the theoretical position, calculated according to my formulæ, with due account of the constant current, we find that the actual position of the Expedition differed from the theoretical position only by 50 miles in latitude, or only by 5 per cent of the total length of the drift in latitude. This comparison may be regarded as bordering on the limits of accuracy with which the original data were obtained.

DEVELOPMENT OF LONG-RANGE AIRCRAFT*

AEROPLANES as a means of transport become increasingly attractive as their range increases. For short journeys the saving in time is often negligible, especially in a country in which other forms of carriage are well developed, but on long routes, particularly trans-oceanic services, the time saved may amount to days or even weeks. Long range demands large fuel capacity, and the peculiar conditions in aircraft may reduce the pay load until it becomes uneconomic, and eventually the limiting range is reached over which no pay load can be carried. The principal problem associated with this is the difficulty of taking a heavily loaded aeroplane off the ground. When flying free, a heavier-than-air-craft is capable of carrying a much bigger load than that which it can lift off the surface of a normal aerodrome. The hazard of a heavily loaded take-off is considerable, particularly when the machine has just left the ground. If at this moment there should be an engine failure (and it is a time when engines appear to be liable to fail, due possibly to some small maladjustment during their overhaul since last being run, which develops into a failure catastrophically) the results will almost certainly be serious, as it is necessary to land at high speed with little or no choice of landing site.

It was with these points in mind that Sir Alan Cobham began several years ago to develop his system of refuelling in flight. His aim was to allow an aircraft to take off light, with very little of the required fuel on board, which on a long-range machine may amount to as much as 25–30 per cent of its all-up loaded weight. Its take-off would thus be comparatively safe, as its preliminary run would be short and the climb away from the ground relatively steep until it has reached a safe operating height. A flying tanker would then come alongside and deliver the fuel to give it range. This scheme has been successful in the regular operation of the North Atlantic service by Imperial Airways Limited last summer, in which the *S*.30 flying boats were refuelled at Foynes or Botwood before they commenced the ocean crossing. These flights are to be resumed during this summer, and will probably continue until the ice on Botwood Harbour closes them down for the winter.

Many methods of assisting the take-off have been suggested, and they may be classified under four headings :

(1) *Improvement of Thrust.* (*a*) Controllable pitch airscrews. (*b*) Ground boosting of the power plant, including the use of high-octane fuel.

* Based upon (1) "Report on the Effects of Large Increments in Wing and Power Loadings on the Performance of Aircraft" by Marcus Langley; (2) "Static Electricity in Relation to Refuelling in Flight" by Marcus Langley and H. M. Barlow; (3) "Landing Speed and Ceiling in Relation to Refuelling in Flight" by Marcus Langley Flight Refuelling Limited, Ford Aerodrome, Yapton, Arundel, Sussex.)

(*c*) Catapulting, inclined runways, etc. (*d*) Mayo Composite aircraft.

(2) *Reduction of Drag.* Reduction of coefficient of friction by means of bogey on rails, concrete runways, etc.

(3) *Improvement of Lift.* (*a*) Flaps of various designs, including mechanical variation of wing camber. (*b*) Makhonine's span-wise variation of area. (*c*) Use of slipstream and angle of thrust line relative to wing, according to the Crouch-Bolas patents. (*d*) Mayo Composite aircraft.

(4) *Reduction of Weight.* Addition of fuel, subsequent to the take-off, by the methods of Flight Refuelling Ltd.

Combinations of these methods are found in the design of most modern transport and military aircraft. Thus it is now usual to fit an air liner with controllable-pitch airscrews, ground-boosted power plants, and low-drag flaps, to gain some advantage from the slipstream in improved lift, and to operate it from aerodromes having concrete runways. It is only by these methods that loadings as high as those now used are possible, but these are far from being the optimum loadings in flight.

Certain of the methods, particularly those which imply the use of specially prepared aerodromes, are not suitable for military aircraft. Others are not particularly suitable for passenger purposes. For example, the acceleration of a catapult used for a passenger transport would have to be relatively low, and consequently its design would be elaborate, and its cost, weight and dimensions prohibitive. In any event, unless such methods assist the initial climb in order to clear obstructions outside the aerodrome, as well as shorten the take-off run, they provide only a partial solution of the problem. This suggests an alternative classification of these methods :

(*a*) those which are substantially safe ; and
(*b*) those which introduce a hazard.

Under the second heading might be put catapults, inclined runways, over-sized aerodromes, and, in fact, any method the assistance of which is withdrawn at the moment the aircraft leaves the ground.

Refuelling is of greatest value in allowing the operation of trans-oceanic air routes of 3,000 miles or more, where no intermediate landing is possible. There is an agreed international limit for take-off run by which a civil aircraft must be able to clear a 60 ft. barrier 656 yards from its starting point. It is possible to design a normal modern air liner capable of carrying a reasonable pay load over a distance of 3,000 miles, and to keep within this limit of take-off. Additional range, demanding extra weight of fuel, can only be had at the expense of lengthening the take-off run and reducing the angle of climb, or alternatively reducing the pay load. If the machine were refuelled after leaving the ground, its take-off could be reduced by half.

A similar air liner could be designed which, with the aid of refuelling, would be able to fly 5,000 miles with about the same pay load as that carried by the normal machine for 3,000 miles, and its take-off run would still be less than 400 yards with an angle of climb of $11\frac{1}{2}°$. The corresponding normal aircraft would require more than 1,000 yards if it had to take this load off the ground, and it could climb at an angle of only 5°.

Many practical problems have had to be solved before the process could be considered sufficiently safe and reliable for everyday use. A complete set of equipment has been developed for both the tanker aircraft and the machine which receives the fuel. Flying problems have had to be explored, so that the operation could be carried out in any condition of weather in daylight or at night.

It is now simple and quick. The receiving aircraft flies a straight and level course when it has climbed to its operating height. It streams out a hauling line with a sinker weight attached through the receiver coupling in its tail, and the tanker comes up behind and to one side, and fires a line across this. The contact thus having been established, it is a simple matter to attach the nozzle of the hose pipe to the receiving aircraft's hauling line. The hose is paid out and the nozzle pulled by a windlass into the coupling, where it is retained by hydraulically operated claws. During this coupling-up process the tanker has climbed into the refuelling position above, behind and to one side of the liner. Approximately 200 ft. of hose is used for a separation between the aircraft of 100 ft. The hose thus trails back in a hairpin bend, and if it were to break or come adrift it would fall clear of both machines. The coupling is non-jammable and is fitted with an automatic release, so that the nozzle will come away should it be necessary for the aircraft to part in an emergency. For the Atlantic service, a 2-in. bore hose was used, and with a gravity head of 60 ft. the rate of flow was of the order of 110 gallons a minute. The whole process of transferring 800 gallons took 12–15 minutes, of which about five minutes was spent in making contact and getting the hose across, and some seven minutes in actually passing the fuel.

Among the many interesting secondary problems were those associated with static electricity. The two aircraft might be at a different potential and charges might be built up in the hose pipe due to friction. There was a further chance of electrification by splash as the petrol rushed into the receiving tanks. Methods have been evolved to overcome all these possible dangers. The two machines are completely bonded together throughout the whole process by means of the spiral steel wire armouring on the outside of the hose pipe. The whole system is flushed through with nitrogen from the tanker both before and after the passing of the petrol. At the moment of break-away, the contents of a bottle of methyl bromide are automatically sprayed into the receiver coupling, and the final contact is eventually broken in mid-air by snapping a weak link in the hauling line as the aircraft part company.

It is difficult to foresee all of the ramifications of the post-War developments of civil aviation, but the establishing of rapid transport of mails and passengers over the long ocean routes between the continents is one of the most obvious. This will scarcely be possible as a self-supporting economic proposition with present-day aircraft, unless in the meantime some revolutionary discoveries are made either in the aerodynamic design of aircraft, or in the design of power units. It is possible to visualize at least an approach to this ideal by making use of refuelling in flight, using the most up-to-date design of aircraft as now accepted. During the War its development is going on, but little may be said about its possibilities for military purposes.

OBITUARIES

Dr. R. T. Gunther

We regret to record the death on March 9 of Dr. Robert William Theodore Gunther, a great student of science and the founder in the Old Ashmolean Building of the Oxford Museum for the History of Science. With him there passes the last of the Oxford science tutors appointed in the early and middle 'nineties and a learned, aloof, enigmatic, single-minded and essentially good man.

Gunther was born in 1869, the eldest son of Dr. Albert Günther, the zoologist, and educated at University College School, London, and Magdalen College, Oxford. He had wide scientific interests as a boy—in geography, chemistry, practical mechanics and biology. The combined influences of his father and of Ray Lankester, whom Gunther greatly admired, led him to take his B.A. degree in biology. He obtained, as one could in those days, a first class in morphology in 1892, and shortly afterwards was appointed tutor in science at Magdalen. A few years later he became a fellow. Few men read science at Magdalen in the 'nineties, and Gunther, unlike the busy tutor of to-day who divides his time between work and research in the laboratory and tutorial hours in college, was a free man. He went with an endowment to Naples to work in the Marine Laboratory there, and between 1897 and 1914 travelled widely, studying the natural history of lakes in Persia and the geology of extinct volcanoes and surveying the entire coast-line of Italy. His first publications were on subjects in biology and geology, but his intense devotion to the memory of Prof. Charles Daubeny of Magdalen College helped to deflect his interests from the present to the past, from Nature to documents and instruments, from research in laboratories to pieces in museums. His history of the Daubeny Laboratory of Magdalen College came out in 1904, and annotated registers of those who had worked in it were published in 1916 and 1924. His love of collecting material relating to the past and arranging it for publication was shown in his monographs on his own family, on his wife's family, on the monuments in Magdalen Chapel, and similar subjects, brought out in the period 1910–14.

After the War of 1914–18, Gunther devoted himself to collecting for exhibition scientific and mathematical instruments of the past, especially of Oxford's past, and to editing the little-known or forgotten works of Oxford's early scientific men, of whom Robert Hooke was first favourite. In the period 1920–37 he brought out no fewer than eleven volumes on these men and their works, in addition to works on astrolabes, early libraries, and other subjects. Anything 'early' and 'scientific', even in Cambridge, whatever its present relevance or value, interested him greatly and, he believed, would interest others too. One old instrument, blunt and rusty, one old book, with a few good scientific ideas in it, gave him joy when ninety-nine particle-counters or up-to-date text-books left him lukewarm. It was unfortunate that some of the publications received adverse and even trenchant criticism. It was not that Gunther was constitutionally inaccurate or that he would not take sufficient trouble with his material; it was that he would do everything himself. He never collaborated or took advice. He went his own way. He did his best. When up against a difficulty he preferred to surmise rather than to seek someone who knew the answer. This temperamental weakness was best revealed in his large work on early astrolabes where criticism which he could have got in Oxford, indeed, in his own College, was delivered more vigorously than helpfully after, instead of before publication.

During the War of 1914–18 Gunther became curator of the Botanic Garden in Oxford, and from 1920 until 1923 the librarian of Magdalen. In the 'twenties the rooms in Daubeny's buildings, where he was amassing his instruments and books, with Daubeny's eighteenth century chemical-ware as its nucleus, were needed as lecture rooms and laboratories. Gunther took it ill when his College asked him to leave and take the material elsewhere. There was,