are present then certain eucalypts which are immune from such attack and regenerate freely. But we already have these hardwood forests (perhaps not so conveniently situated to-day as they would have been some years ago) and there are thousands of acres in early cut over indigenous forest, some of it already in heavy pole crop. The fine utilization record of *N. menziesii* must also be borne in mind, with no little importance attached to the fact that this timber is usually immune from attacks by the common house borer (*Anobium domesticum*) and the native longhorn (*Ambeodontus tristis*).

DISCUSSION ON AERIAL SURVEYING IN ITS RELATION TO FOREST RECONNAISSANCE.

By H. P. D. VAN ASCH and H. C. WICKETT.

Quite a number of those connected with milling in this country are at least curious to learn what fruits are being reaped from an aerial survey recently completed by the N.Z. Aerial Mapping Ltd., of Hastings, of a timber area at National Park, and to throw a little light on this subject the writers propose to outline briefly how this survey was undertaken and the advantages that have been found to exist in this work as an aid to forest reconnaissance.

There is no need to mention here that general timber cruising and surveying is a lengthy and costly business, and that on this account any new form of science, such as aerial mapping, is welcome if it is only able to improve on these two factors of time and cost. Then, again, shortage of supplies in the more accessible areas is causing milling operations to go back into remotely situated parts, perhaps in rough country, where surveying becomes increasingly difficult and indeed more costly. It is under these conditions, and where the eye of the camera is able to work with the same efficiency as on the easier country, that the greatest advantage is possibly achieved.

As far as is known, this has been the first controlled aerial survey of forest land in N.Z., and although the main purpose of this article is to discuss the value of the results obtained from the aerial method, it will be interesting to foresters and millers if the discussion is prefaced by a brief description of how this photographic mosaic map was produced.

Aerial Equipment:

The work was undertaken by a specially equipped photographic twin-engined machine fitted out in England with complete survey equipment, comprising a special aerial camera mounted on gimbals vertically over a hole in the floor of the cabin, with Aldis aiming sight and gyroscopical compass for maintaining accurate course, and with a special nose fitted with transparent panels to enable the pilot to get a clear view forwards and downwards.

The camera which is electrically driven and uses a film 150 ft. long by 7 in. wide, automatically records information relating to, and on the bottom of each negative, by four separate instruments each with its own lens set in such a manner that the image of each is focused on the main film-roll as it passes over the reels and across the main 9×7 Register glass. Each little panel records the number of the negative, the time to the second at which the exposure was made, the date card showing date and lens focal length, and lastly the altitude. The date and time of day allow one to work out the orientation for North from the shadows cast, while the lens focal length and height allow the negative scale to be found. The electrically driven intervalometer operates the camera shutter at a predetermined interval which is set according to the altitude of the machine, speed, and direction of the wind.

Weather :

For this work it is absolutely necessary to have a cloudless sky, as good lighting conditions are essential for good photography. Even small clouds lying underneath the machine would totally obscure the subject, or if to the side they would probably cast a black shadow over the area and so hide detail. Strong winds at the higher altitudes also make it difficult for the operating crew as in hilly country, such as the greater part of N.Z., these winds vary tremendously in force and make it almost impossible for the pilot to make a straight track or flight run.

Flying Operation :

Having decided on the scale at which the finished result is desired, parallel lines are ruled on the map, so spaced that the finished adjacent runs of prints will overlap each other by 25 to 30% laterally. It is usually arranged for the negatives to be half the scale of the final enlarged mosaic and for these to overlap each other by 60% in the fore and aft directions along the line of flight. The reason for this liberal overlap is to enable the surveyor or engineer to later study his area in relief with the aid of a stereoscope, which will be described later, and also to cause the central portion only of each print to be used in the final mosaic.

Having made his height the pilot sets his compass and makes a dummy run down the first ruled map line, while the camera operator checks the drift and levels up the camera and aiming sight. Both instruments are locked in the track direction of, say, 10° Port and the first run is reflown into wind at constant height and speed while the camera gathers in the detail of the ground below on to its film spools. Steadiness in flying is most important in order to prevent the aerial platform from tilting in any direction or from losing or gaining height. A good run should not vary 15 ft. in altitude and the fore and aft and lateral axis of the aircraft should be kept to within 2° of the true horizontal axis.

There are two important factors to be considered in determining what mean altitude and scale should be adopted. The first is one of accuracy of plan-view and the second one of wealth of detail required. In the first case it is generally agreed that good mapping and mosaic building should not be undertaken at an altitude less than ten times the difference between the hill-tops and valley bottoms, and secondly really good photographic detail of tree tops is not expected much over 6,000 ft. A compromise is therefore made to prevent discrepancies becoming uncontrollable where hill-slopes appearing on the edge of the photographs, and taken at too low an altitude, appear longer than they ought to because the oblique angle to the side of the lens has been too far from the vertical. The job in question was taken from an altitude of 6,600 ft. above the mean altitude of the area and the resultant mosaic enlarged to a scale of 12 in. to the mile. The pilot has to take considerable care in keeping the plane on a truly even keel when the camera is making each exposure, since a tilt of the plane from the horizontal will cause the camera to expose forward or aft or sideways of the true position, causing the scale of the photos to be distorted and giving an incorrect slope to the ground when the photos are viewed in the stereoscope.

Control:

It will be readily seen that with so many variables it is possible for errors to creep in in many ways. It is therefore essential that if a reliable map is to be made from the photos a certain amount of ground surveying is necessary to tie the work in; the greater the accuracy required in the whole map and in the detail, the more ground control is necessary. This control is obtained by fixing by survey work the relative positions and elevations of points which can be readily and exactly identified on the photos, such as buildings, fence intersections, single trees in clearings, etc. Of course, this work increases the cost of the survey but it is essential if accuracy is required and the determination of altitude by the stereoscope is impossible if elevations for prominent features are not plentifully scattered over the whole map area.

Office Procedure.

Developing:

The exposed films, 150 ft. in length and taken in the aerial survey camera, are developed on metal drums. Contact prints are then made from these 9 in. $\times$ 7 in. negatives. The serial number altimeter recordings, etc., also appear on the bottom of each print, which information is very essential, if only for the sorting up of the many hundreds of prints.

Scaling :

The contact print photos of the individual runs are pinned down on a table with detail on adjacent prints coinciding so that the result is a photographic representation of the strip of country covered by the run. Points being used for control which appear on that run are now picked out and the distances between them measured. The ratio of the measurement of a particular distance as it appears on the contacts and the measurement that distance should read on the finished map at the scale which has been decided upon will give the enlarging factor to be applied to all photos in that run between the two points concerned. Although the magnification from the contact prints to the prints for the map may have been decided upon at $1\frac{1}{2}$, it will be found that the actual factors required for use between pairs of control points may vary between $\times 1.47$ and $\times 1.53$ because of inaccuracies that have crept in through factors previously mentioned. This rectification during enlarging irons out most of the inaccuracies, and if sufficient ground control has been obtained, the enlarged and rectified prints will join together almost exactly into a mosaic map.

Mosaicing :

The term mosaic in aerial surveying is used in its literal sense and a mosaic is a set of photos joined together to give a picture of an area of country too large to be shown by one photo. A mosaic may be accurate or otherwise as will be appreciated from what has been said above, and it is proposed to call an accurate mosaic, the construction of which is being described here, a photomap.

The plywood board which is to carry the photomap is first drawn up as an ordinary survey map of the area to show all the control points which have been used to tie in the survey. The work can be plotted by any suitable means but it is considered that there is none better than the use of a system of rectangular co-ordinates, and obviously these co-ordinates should relate to the circuit origin of the land district in which the area lies. The grid lines for the co-ordinates are carried to the edges of the board and picked up after the photomap has been completed and drawn again across the surface of the map.

When the control points have been fixed on the board, the enlarged and rectified prints are pinned on to the board so that the points on the board coincide with their photos on the prints. When all the prints have been made to lie accurately they are pasted to the board and the co-ordinate grids drawn over them.

Plotting of Survey Data :

At this stage a photomap of bush country is just a vast expanse of grey dots devoid of anything that would give any idea of locality or orientation except for the grid lines or the bed of a large river or a patch of clearing or a man-made structure, and in places where forest reconnaissance is undertaken, these recognisable features are not plentiful. But if section boundaries, surveyed tram routes and grades are now plotted by means of co-ordinates, the photomap at once becomes intelligible to anybody with any knowledge at all of the area. If it were not possible to put new work on to the map from time to time, the map would become only a record of what existed years ago, but if it can be kept up to date, it is a photographic and accurate representation of affairs at the moment and it far surpasses any ordinary map and many reports in its wealth of detail. As a photomap usually becomes a fixture on an office wall, the only really practicable method of keeping it up to date is by plotting by co-ordinates.

Interpretation of Photomap :

Information that a forester or miller requires about an area of bush may all be classified under two headings—timber and access—and it is in its ability to convey information regarding these two matters that the aerial survey method stands or falls.

Timber :

In summing up the value of an area of bush one requires to know the species present and their quantity and quality. The writer considers that it is only occasionally possible to tell the species of trees from aerial photographs of New Zealand bush, but with National Park forest at least it certainly is quite easy to distinguish between millable and non-millable species as they appear on the photomap, but from the photo alone it is impossible to say which of the milling trees are rimu and which are matai, totara, etc. Colour and shape do not register in a vertically-taken photograph, size is no indication in a forest containing all age-classes, but site might with local knowledge and practice be very useful. The assumption that low-lying flats carried 80% kahikatea might be well founded in some districts or that high ridges carried only miro might be true in others. Of course, ridges might carry rimu or rata and flats rimu instead of kahikatea but a little ground work would soon show what generalisations were safe, or, in types of mixed species, what percentages of each were present.

The quantity of timber on an area depicted by a photomap can be arrived at approximately by means of a calculation of density in the various types. The number of heads of milling trees appearing on sample acres in the types can be counted and a total worked out on the basis of an average tree, or if figures are available for areas on the photomap which have been cruised the density of heads in the cruised area can be compared with that in the uncruised and a calculation made. Of course there is no guarantee that a large head tops a large milling log or any log at all in fact, and an average tree cannot be guessed but must be estimated from actual knowledge of the bush.

But there is no doubt that a fair approximation of the species and the volume of timber on an area can be obtained from a photomap with the aid of a little local knowledge. It is not possible to tell the quality of the trees in a bush from a photomap, only actual inspection of the types in the bush itself can do that.

Access :

Access or the lack of it will determine whether a bush can be worked or managed or not. It is the point next in importance to the bush itself. Milling concerns that have failed or have wasted money have usually done so on access and that largely because they could not get a mental picture of their whole undertaking, and of all the problems that confronted them before they started. The result was that they started the wrong way and had to give up or when they came to the difficulties they should have expected to encounter, they were unprepared for them and wasted money in overcoming them.

A photomap shows no relief but by means of a stereoscope and the contact prints it can be made to give a very good idea of topography. A stereoscope is an instrument having an arrangement of mirrors which allows pairs of photos to be viewed simultaneously. The photos used are adjacent pairs of contact prints from the flight runs and as they have at least a 50% overlap, half of one photo represents the same objects as appear on half of the other photo but viewed from a slightly different position of the plane. The stereoscope causes the eyes to see the similar halves simultaneously and gives the effect of normal stereoscopic vision. That is, the objects seen in the two photos appear in relief and a pair of photos of rough country appears much as a plasticine relief map and trees and buildings, hills and valleys appear just as they do to a person in an aeroplane. It is then a very simple matter to draw in the valleys and ridges and note the saddles and terraces on the photos and then transfer the information to the corresponding photo on the photomap. When this has been done for all the prints, the photomap becomes almost a relief map of the area and it is then not difficult to pick out probable tram and road routes, and hauler and mill sites. Details of the routes, etc., can then be studied again more closely in the stereoscope. There is no guarantee that these routes will be practicable, they have to be actually tried in the field to prove that, but extensive line-cutting and useless travelling over the country are obviated as only the most likely need be tried on the ground. The unlikely routes appear so on the photo but that cannot be said of them at times on the ground, also in rough inaccessible country it is often the best route that appears the most unpromising on the ground.

When sufficient elevation control points are available on the prints, it is possible to use a stereoscope to read differences in elevation in feet and thereby to draw on the prints contours which can be transferred to an ordinary topographic map. This is a laborious but not very difficult process for prints of open country, but bush and scrub varying in height from 150 ft. to 10 ft. so obscure the real ground level that the writers consider it to be impracticable to attempt quantitative stereoscopic work on prints of bush country. In any case topographic maps at contour intervals of anything over 10 ft. have very little practical use in timber access work, and in this class of work ground or air survey contour maps of any interval at all have a preparation cost out of all proportion to their usefulness.

Summary of Advantages of the Aerial Method.

1. The photomap gives milling timber density at a glance.
2. It can be used to give timber quantities and in some cases species.
3. It gives salient features of topography at a glance.
4. The stereoscope will give details of probable tram routes and hauler sites.
5. A vast amount of useless field work is obviated.
6. It presents a pictorial record of the present, past and future conditions.

Disadvantages.

1. The initial cost is high and can be undertaken only by concerns owning large tracts of forest, but the actual cost per acre is vastly less than what would be spent by such a concern on survey work giving no return.
2. In most cases the photomap alone will not give timber species.
3. Aerial surveying is sometimes held up for long periods by adverse weather conditions.
4. It does not do away with the logging engineer and surveyor, in fact he becomes more necessary as he must help to make and interpret the photomap.

Conclusion.

The single attempt made at the aerial surveying of forest land in New Zealand would seem to indicate that the method should have a definite place in forest reconnaissance work. It should be of interest chiefly to the Government, as not more than half a dozen private concerns hold areas of bush sufficiently large to warrant the expenditure necessary.