ten simultaneous recordings are made with the five instruments after which they are suspended from the bars on the sides of the helicopter. The helicopter is flown to the corners of the intended operation area for the day and the reference instruments are placed there, if possible on bench marks. Thereafter the air-borne instrument is flown to the predetermined vertical control points which are to be surveyed. These points are easily located in the air photos. Every time the helicopter is near a reference instrument the air-borne instrument is placed beside it and recordings are made. When the area of the day is ready, the reference instruments are picked up, but before picking up such an instrument, the point is measured with the air-borne instrument. After having returned to the base, all the instruments are placed on the ground and some ten recordings are made.

When the film has been developed, the negatives are studied under great magnification, and the data obtained give material for calculating air-pressure variations and differences which form the data for the height differences.

If the method is to be economic, it is essential that the work be well organized so that every minute of the rather expensive flight time of the helicopter is used. The proposed method will be suitable for rough or wet terrain where transportation is difficult and tedious. In Sweden, we have a fairly close net of points or lakes with the elevation surveyed, so we are perhaps not so prone to use the method here and to spend money for building the instruments in question; but in non-European countries, where the first survey is just going on, the method may well be used. The above description has been made in view of localities of this latter category, and in spite of the fact that no tests have as yet been made.

USE OF ALTIMETER AND HELICOPTER FOR ESTABLISHING VERTICAL CONTROL FOR PHOTOGRAMMETRIC MAPPING*

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DURING the 1949 field season the Topographic Division of the U. S. Geological Survey successfully established vertical control on an area of 5,750 square miles in central Alaska by means of helicopter and altimeter. For that reason we are very much interested in Mr. Fagerholm's article on establishing vertical control in remote areas through use of a helicopter and a self-recording statometer. It will, therefore, be the purpose of this paper to describe the Geological Survey's altimeter-helicopter method as used in central Alaska, and to compare it with Mr. Fagerholm's proposed statometer-helicopter method.

The field work on the central Alaskan project consisted of executing horizontal and vertical control for multiplex mapping of 21 quadrangles, each quadrangle being 15 minutes of latitude by 30 minutes of longitude. Final maps are to be published at 1:63,360 scale with 50 and 100 foot contour intervals, that is, 50 foot supplemental contours in the flat areas and 100 foot contours in the predominantly mountainous areas.

The area in general was about one-half rugged mountains, and the other half low gentle slopes or muskeg area, with numerous lakes and swamps. Elevations ranged from 1,000 to 7,800 feet above sea level. No point on any of the quadrangles was located more than 30 miles from an automobile road, spirit level line or a first-order triangulation station.

The whole area was covered with east-west flown vertical photography with

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cross-flights at each degree of longitude. Contact prints were furnished the field men upon which the proposed vertical and horizontal control had been planned. In planning the horizontal control, advantage was taken of the cross-flights to cut down on the number of points needed. Stapled photo mosaics at 1:96,000 scale were made up and furnished for each quadrangle. These mosaics were used in planning the work and as a guide for the helicopter pilots.

The area was worked from two widely separated camps which were located on highways. Each camp was moved three times during the season, as the work progressed, so that the base of operations would be within a convenient driving distance of the area being worked. The camps were similar, each having the following general equipment and personnel: 3 Wallace & Tiernan altimeters of a matched set of 6 (type FA 112, with a minus 1,000 to 6,000 ft. range), 1 Bell Model 47D two-place helicopter, 2 automobiles, enough camp equipment to feed and house a party of 12 men, sufficient triangulation instruments and equipment to supply four parties for third-order triangulation; 4 engineers, 4 field assistants, 1 cook, 1 helicopter pilot and 1 helicopter mechanic. The helicopter working in predominantly mountainous area was equipped with wheels for landing gear. The other, which worked in both mountains and flat, swampy area, was equipped with both wheels and floats for landing gear. The floats were used mostly on this ship because the helicopter so equipped could make landings on water, swamp or land. The floats slightly reduced the speed and general performance of the ship but were indispensable in the muskeg areas.

Each unit or quadrangle had approximately 25 vertical and 3 horizontal control points. A majority of the vertical control points were executed by altimeter survey. In many cases, horizontal control points had to be established merely to supply vertical angle elevation points for subsequent use as altimeter bases.

The altimetry was accomplished by the two-base method. The two bases were separated vertically beyond the limits of the points whose elevations were sought and located horizontally at the approximate extremities of the quadrangle. The altimetry on a unit or quadrangle was worked from one set of bases. Generally, the low altimeter base was located at a known elevation such as a bench mark on the road and the high base at a triangulation station at which an elevation was to be established by reciprocal vertical angles. Readings were recorded at 10 minute intervals on the base altimeters and, by having all watches synchronized, simultaneously readings could thus be assured. The helicopter was used concurrently for execution of the altimetry operation, as well as transportation of triangulation personnel. Field work was planned so that when there was inactivity in either triangulation or altimetry the personnel could use the helicopter to concentrate their efforts on the other phase of work needing completion. Such planning made possible fuller use of the helicopter and more effective use of the personnel.

In planning, a procedure was designed whereby a unit or full quadrangle could be worked without interruption so that the altimeter bases would have to be established only once. On remote base stations where the base tender had to be transported by helicopter, he was equipped with a two-way radio for necessary contact in case weather conditions made it necessary to temporarily postpone altimeter operations. He was also equipped with sleeping bag and food so that it would be possible for him to stay several days should it become necessary.

After the altimeter bases were manned with a base tender, the helicopter was used for transporting an engineer with the "roving" altimeter. By visiting the designated points, he thus established altimeter elevations for all required points on a quadrangle. Ties were made with the roving altimeter on many known elevations along the routes of flight. Often a second area unit or quadrangle could be worked the same day by keeping the altimeter base common to the two quadrangles intact and transporting the other base to the opposite side of the second quadrangle. Landings were made on or near all points whose elevations were desired, and on which altimeter observations were to be made.

In carrying out the altimeter surveys, many readings were taken at bench marks, triangulation stations and other points whose true elevations were known. The mean deviation of the many check points analyzed was about 6 feet; one deviated 14 feet and the rest varied from 2 to 10 feet. These data indicate that the two-base method carried out as outlined, gives satisfactorily accurate results for 50 and 100 foot contour mapping. Should greater accuracy be required, bases should be closer together horizontally, or more bases should be used for the same area. The latter is probably better since it gives several results for each determination, depending upon which two bases are used for the computation, and the results could be weighed according to the proximity to bases. It has been suggested that two or more altimeters of different makes be substituted for each altimeter in the two-base method. The merits of this method would have to be evaluated by extensive experimentation.

Having outlined our experiences on the central Alaskan project, I now wish to analyze Mr. Fagerholm's suggestion of using the helicopter with a self-recording statometer. Photogrammetrically, he has stated the requirements thoroughly and accurately, but his method of using the helicopter and the mechanism for obtaining differences of barometric pressure, we believe, are both subject to discussion if applied to our particular circumstances.

We presume, from Mr. Fagerholm's paper, that hovering can be done at will with a helicopter, regardless of the conditions. From our experience, hovering at elevations higher than 4,000 feet above sea level was extremely difficult. In elevations above 4,000 feet our helicopter had to have some forward motion, or had to utilize equivalent wind velocity to stay aloft. Direction and intensity of wind, elevation, ground effect, temperature and load are all factors affecting the ability of the helicopter to hover. Hovering actually consists of maintaining an equilibrium between the helicopter and the factors just mentioned. Should one of these factors suddenly change, the helicopter is subject to a change in position. For this reason most pilots are reluctant to hover more than is necessary.

The elevation points Mr. Fagerholm calls for are either in flat, brushless areas or on water. Both of these are ideal landing places. We believe that it would be cheaper to land and take a reading than to hover, since helicopter costs in our cases are computed on actual flying time, and the hovering consumes more flying time than landing. Another factor that Mr. Fagerholm did not mention is the airstream from the hovering helicopter which would make it extremely difficult and probably hazardous to manipulate the control cable of the recording statometer.

To be practical in design, the mechanism of the statometer could not be much longer than the 17 inches. Considering the specific gravity of alcohol, it is believed that this alcohol statometer is limited to a difference of barometric pressure of approximately 1,000 feet altitude above or below the initial starting point. These limits would be less than our requirements.

The mechanism of the recording statometer is quite complicated and may be subject to frequent failure. The failure of any self-reading device in our instance would disrupt the processing of work by one year. This can be clarified by explaining that all our field operations are performed during the short field season in the summer months, and all computations and photogrammetric compilations are performed in the office the following winter. It is for this reason that we have been hesitant in incorporating any self-reading devices into our procedure which have not been extremely well proven.

We have found that the altimeter-helicopter method of establishing elevations on picture points has been the most practical method in certain areas in Alaska. The foregoing discussion has been a comparison of our operational methods to an altimeter-helicopter procedure outlined by Mr. Fagerholm.

GROUND SURVEY PROBLEMS SOLVED BY HELICOPTERS*

IN THE past, the shortness of the Arctic summer, combined with the sometimes insurmountable difficulties encountered in transporting men and materials in the rugged mountains of the Yukon, limited seriously the amount of work which survey parties could achieve each year.

In 1950, however, the task of extending topographical survey farther than ever towards the Northern Ocean is being speeded by helicopter.

Two years ago, the Geodetic Survey of Canada, J. L. Rannie, Dominion Geodesist, sent out a survey party under F. P. Steers, on primary triangulation along the Alaska Highway. It was at this time that a helicopter was brought into play. Al Soutar of Weston Aircraft piloted the aircraft, while Bill Finlay and Hugh McGeach of the same company maintained it from a mobile trailer-workshop.

In 1949, P. E. Palmer, chief topographical engineer of the federal department of Mines and Technical Surveys sent out a survey party to Northern Quebec under the direction of H. N. Spence. Using a helicopter once more, this survey was the largest ever accomplished in one season.

This summer, three flying members of the Hiller 360 Helicopter Fleet are in the field. Two of the helicopters are based at Mayo in the Yukon. The third Hiller helicopter is being used by the Army Survey establishment, Department of National Defence, Ottawa, under the direction of Lieut.-Col. C. H. Smith, deputy director of Military Survey. Its operational coverage is in the territory adjacent to the Alaska Highway, west of Whitehorse.

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