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Forest Air Survey Leaflet No. 3

THE FORESTRY TRI-CAMERA METHOD OF AIR PHOTOGRAPHY

by

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THE FORESTRY TRI-CAMERA METHOD OF AIR PHOTOGRAPHY

Work has been carried on by the Dominion Forest Service with a view to the establishment of a type of air photography in which the securing of information for forest survey purposes will be the main objective. Otherwise air photography as required for peacetime application has been governed largely by mapping considerations, in which the measurement of horizontal distances and elevations has been the first step in the preparation of maps in which the portrayal of the topographical features is the primary consideration.

The requirements of the forester are in the sphere of fine photographic detail coupled with economy of photographic coverage. Considerable research has been conducted by the Dominion Forest Service in order to determine how the fine detail of the tree images may best be employed to provide timber estimates and other forest survey data. On the basis of this research a forestry tri-camera method of air photography is being put into practice. Superior information has been made possible by choosing the most suitable angle of view and by taking the photographs for the most part in the winter when the absence of deciduous foliage and the illuminating effect of the snow permit a more detailed view of the forest. At the same time the method provides economical coverage, this being secured by foregoing some of the rigid requirements of air photography for basic mapping purposes. In other words, maximum forestry information is available at minimum cost, while a main objective is to facilitate the making of detailed quantitative estimates. Except for the use of data analogous to volume tables as employed in forest surveys on the ground, these estimates will be made solely from air photographs and indications are that they will cost less than ground estimates except possibly in very dense stands, particularly where the trees are near the border line of merchantability, or where very intensive data are required.

The demand for a special forestry photograph is accentuated in cases where re-photography is required to obtain an up-to-date record of the forest conditions in circumstances where changes have taken place subsequent to the date of the original photography as conducted for mapping purposes. Forest conditions are dynamic rather than static owing to the cuts, burns, insect damage, disease and other depleting agencies which are continually at work, and to the factor of growth. Furthermore, the forestry tri-camera method may be used to advantage not only where a record of forest changes is required but also to provide improved forestry information throughout the area.

Origin

The abvious advantages of the low-angle, or steep oblique photograph for forestry purposes were stressed a number of years ago by the Dominion Forest Service, notably in a mimeographed article entitled, "The Use of Air Photographs for Forestry Purposes" which was published in 1935. Adequate obliquity of view facilitated the measurement of tree images and the identification of species, while at the same time the trees did not obscure each other to the same extent as in high-angle obliques. Moreover, the greater scope of the oblique photograph ensured far more economy of coverage than was possible in vertical photographs.

It was furthermore apparent at an early stage that a tri-camera mount would provide increased economy of operation and in the winter of 1933 the Royal Canadian Air Force conducted an experiment in which low-angle obliques were taken for forestry purposes and which illustrated the value of a tri-camera mount. Practical application was carried out for the first time in 1935 when tri-camera low-angle obliques were taken over an area of 360 square miles near Ottawa, where a survey was being made which led to the selection by the Federal District Commission of the present Gatineau Park. Subsequent uses of low-angle oblique photographs were described in 1937 in a publication entitled, "Air Photographs as Used by the Dominion Forest Service". In this publication the development of a suitable tri-camera mount was advocated, previous mounts having been of a temporary and unsatisfactory nature.

The first instance of the practical application of the forestry tri-camera method of air photography in its fully-developed form, which is as shown in Figures 1 and 2, occurred in the winter of 1946-47 on the occasion of the re-photography of the Riding Mountain National Park. This was carried out by a private company under contract with the Dominion Government, the specifications having been prepared by the Dominion Forest Service. The particular arrangement of the cameras in the aircraft did not in itself represent any special innovation but actually had a great deal in common with previous tri-lens and "trimetrogon" installations. The arrangement of the cameras is, however, important because it provides the best opportunity for the application of methods which have been developed during years of research.

During the early investigations of the application of low-angle photographs for forestry purposes it was thought that in some instances the method might be used where regular mapping

photographs had not yet been taken. Accordingly, with a view to enabling the low-angle oblique photographs to be used as an independent means of mapping, the Dominion Forest Service proposed that a mirror attachment be employed as a device by which an image of the horizon would be registered along the edge of the low-angle oblique, thus putting it on a par with the ordinary high-angle oblique in which the horizon lies within the scope of the lens and affords a basis of control for mapping purposes. The proposal was unique in that no auxiliary lens was employed, the image of the horizon being reflected through the regular camera lens. A report by the National Research Council in 1936 stated that, so far as optical considerations were concerned, the mirror attachment could be adapted to the determination of the angle of tilt in low-angle oblique photography.

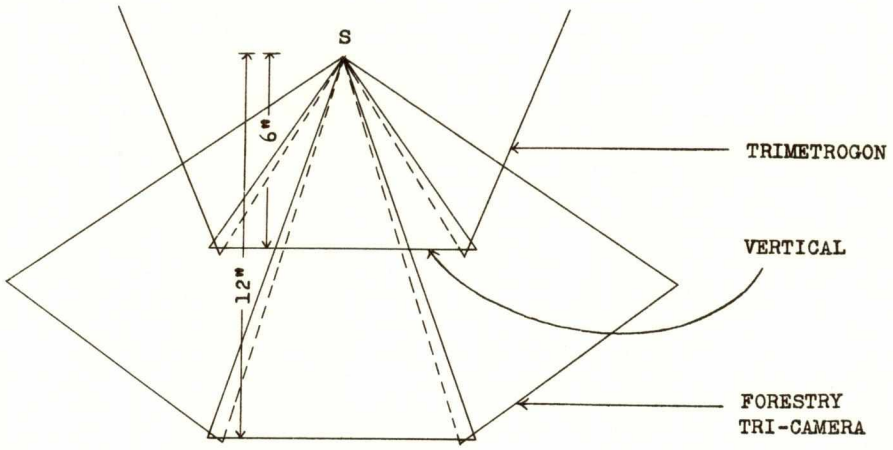
Comparison

The forestry tri-camera method aims at a compromise between vertical photographs taken with a 6-inch lens and tri-camera photographs taken with a 6-inch lens (trimetrogons). The object of this compromise is to secure maximum coverage together with optimum forestry information.

It will be noted in Figures 1 and 2 that the angular limits of the forestry tri-camera method have been adopted as the boundaries beyond which the obliquity of the view becomes too great and the trees are largely obscured by each other. In a comparison based on this limitation the forestry tri-camera method is much cheaper per square mile and also provides better tree images than the other methods, owing to the greater area on which a very favourable angle of view is maintained. At the same time, the forestry tri-camera photographs may be used to very good advantage for measuring shadows, determining crown closure, counting trees and for stereoscopic examination.

Figures 1 and 2 show that when the same average lateral scale (i.e., scale measured at right angles to line of flight) of 950 feet to one inch and the above-mentioned angular limit are maintained, the photographs must be taken from the following altitudes:

6-inch verticals	5,683 feet
Forestry tri-cameras	8,000 feet
6-inch tri-cameras (trimetrogons) ..	4,350 feet



Above: PHOTOGRAPH PLANES

Below: GROUND PLANES
and intercepts thereon at
angular limits as in
PHOTOGRAPH PLANES above
see also Figure 2

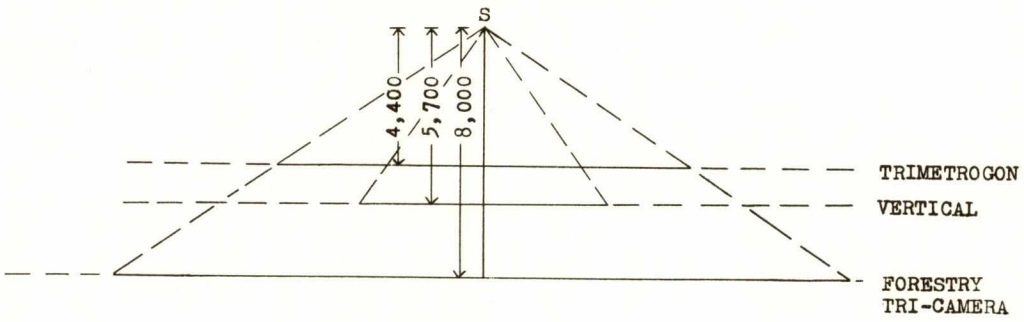
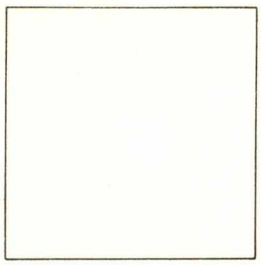
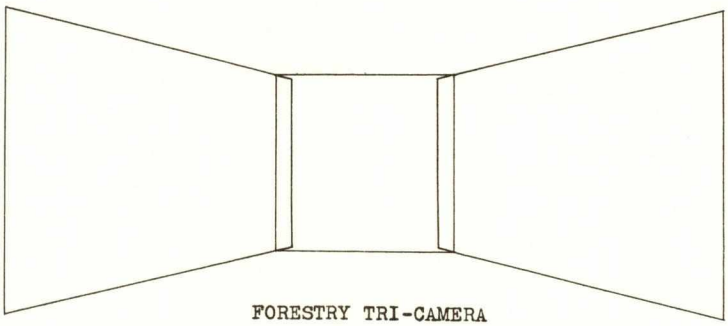


Figure 1



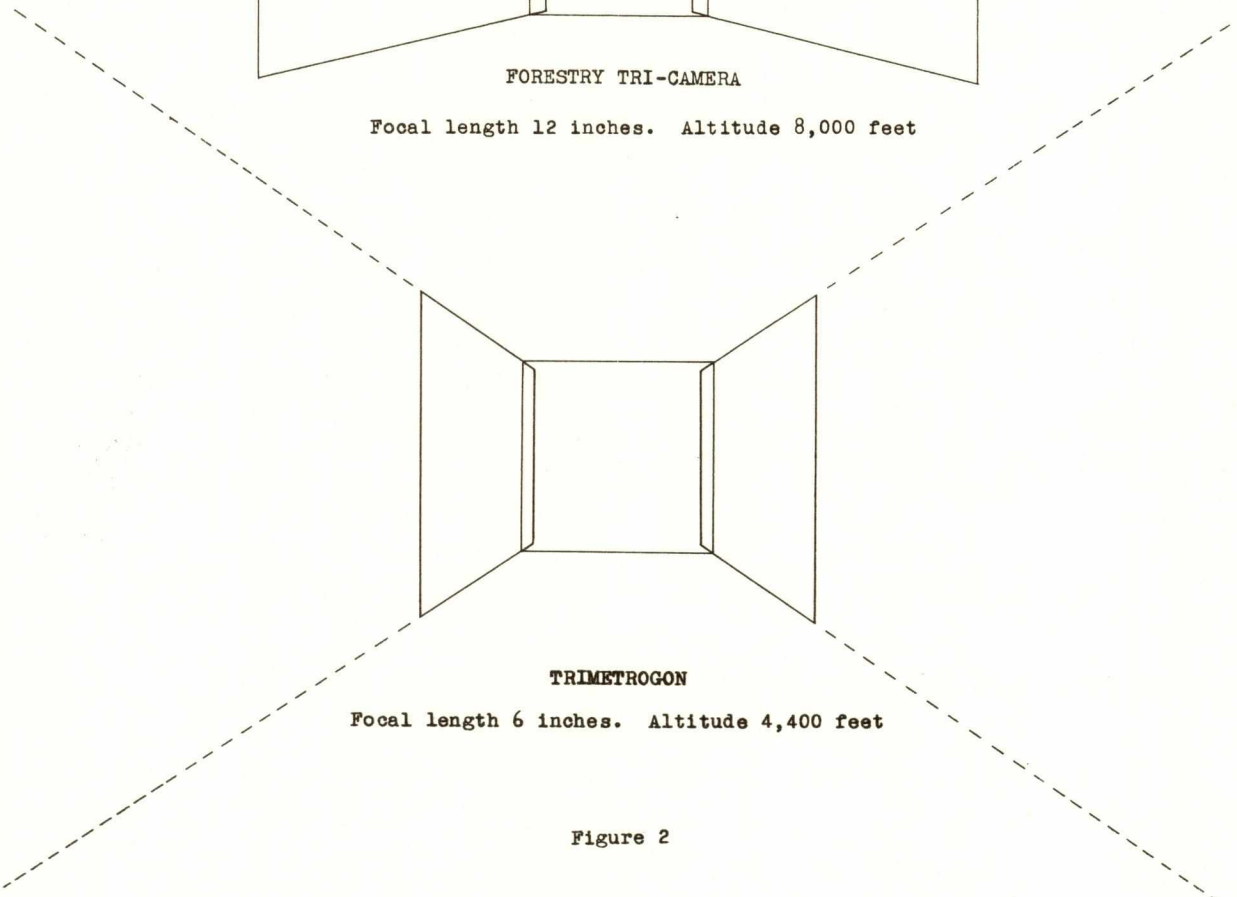
VERTICAL

Focal length 6 inches. Altitude 5,700



FORESTRY TRI-CAMERA

Focal length 12 inches. Altitude 8,000 feet



TRIMETROGON

Focal length 6 inches. Altitude 4,400 feet

Figure 2

Costs

It can be found by making measurements on Figure 2 that the coverage of the forestry tri-camera is 2.87 times as great as that of the 6-inch vertical. This ratio is based on the use of a format of dimensions of $8\frac{1}{2}$" x $8\frac{1}{2}$". It had been at first expected that a 9" x 9" format could always be used, in which case the favourable ratio would have been further increased The change in the format has been necessitated by special camera modifications.

While the above ratio is basic there are nevertheless various other considerations. For instance, the accessibility and size of the area to be photographed are factors which will result in a sliding scale of costs per square mile owing to the fixed "ferrying" charges to and from the area and other overhead costs.

Advantages which may tend to increase the ratio in favour of the forestry tri-camera method as compared to the ordinary vertical photography are as follows:

(1) The method is usually employed in the winter, when men and machines might otherwise be idle. Because of its more favourable angle of view the method gains more by use in the winter when tree detail is better seen.

(2) Gaps between the port, vertical and starboard photographs of a normally functioning forestry tri-camera assembly are impossible. Thus the risk of expensive re-flights is usually much less than in vertical photography.

(3) The method requires a much smaller percentage of lateral overlap.

On the other hand, some disadvantages of the forestry tri-camera method are:

(1) The employment of three cameras creates a greater risk of mechanical failures.

(2) Two extra apertures must be made in the aircraft for the installation of the additional cameras.

(3) The present lack of means for the suitable rotation of the three cameras to compensate for the "crab" of the aircraft occurring when the wind is in an unfavourable direction.

Research

In the work of the Dominion Forest Service the initial tree height calculations as made from tree images in oblique photographs were based on the use of a perspective grid. Subsequently, an azimuth grid which showed the traces of various depression angles was employed. In order to eliminate unnecessary calculations the tree height grid was devised by the writer in the pre-war years. More recently a "Pole Scale" has been developed for the measurement of both tree images and shadows in vertical and oblique photographs. The measurements which were formerly made by the tree height grid may now be carried out by means of such a scale. Furthermore, pole scales have been constructed for the measurement of shadows in low-angle obliques. Figure 3 illustrates various methods of measuring heights as developed specially for oblique photographs, particularly low-angle obliques. For general information on the calculation of tree heights from images and shadows in all types of air photographs see the following Dominion Forest Service publications:

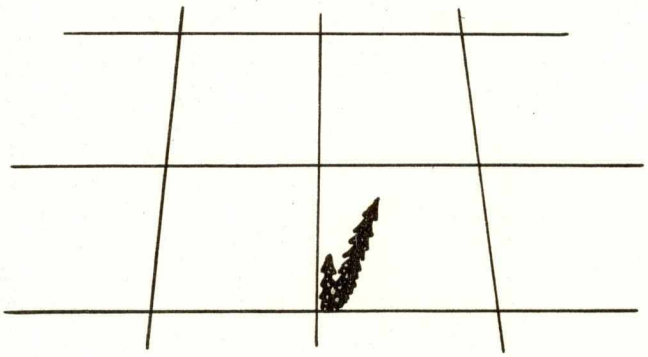
Aerial Forest Survey Research Note No. 1, "Determination of Tree Heights from Shadows in Air Photographs", 1942.

"Some Developments in the Use of Air Photographs for Forest Surveys," 1947.

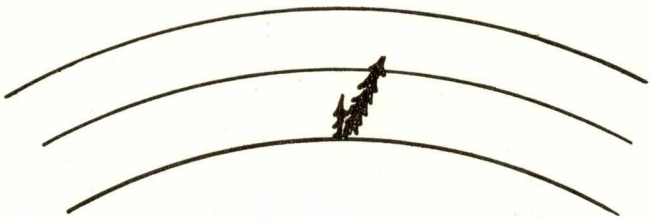
Forest Air Survey Leaflet No. 1, "The Pole Scale", 1948.

Forest Air Survey Leaflet No. 2, "The Shadow Height Calculator", 1948.

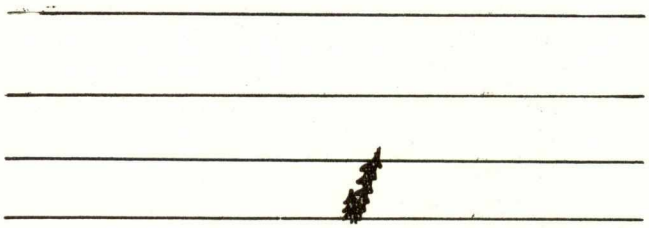
The presence of snow provides greater detail in the tree images, this being particularly important in the case of deciduous trees, the resolution of the photographic emulsion being greatly improved by the increased contrast. It has been found that in some cases at scales in the vicinity of 1,000 feet to one inch the detail of the individual deciduous trees is very good, they being distinct down to about 4 inches in diameter; even the mass of fine twigs in the crowns is recorded quite well. However, it has been noticed that while in certain cases deciduous trees are distinct against the dark background of the evergreens, at the same time their detail may be largely lost against the white background of snow. It is possible that, with suitable exposure and processing, photographs may be taken which will register both deciduous trees and evergreens to better advantage than at present. Related problems of the securing of fine detail for forest survey purposes have been placed before the Associate Committee on Photographic Research, National Research Council, at the request of the Associate Committee on Forestry, National Research Council.



PERSPECTIVE GRID

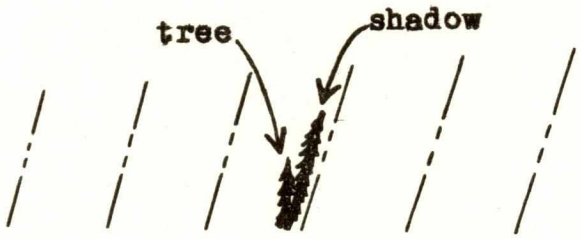


AZIMUTH GRID



TREE HEIGHT GRID

POLE SCALE FOR IMAGES



POLE SCALE FOR SHADOWS

FIG. 3

The taking of large-scale sample photographs which could be used to supply a key throughout the overall coverage of small-scale photographs promises a considerable advantage in interpretation and may, at the same time, aid greatly in the problem of obtaining fine forest detail, especially in the winter photography of deciduous trees. Some authorities have advocated the Sonne continuous strip camera for this purpose. Another method which might find immediate practical application is the use of an ordinary air camera or cameras equipped with the 12-inch lens, from altitudes of 2,000 to 4,000 feet, blurring being practically eliminated by exposure with a very fast shutter speed.

Practical Application

During the past two winters upwards of 4,000 square miles have been covered by the forestry tri-camera method and results in the work of timber estimating and plotting forest type boundaries have proved that the method will provide a better opportunity to analyse forest detail and to secure economy of coverage. In some instances the method was applied for the preparation of forest inventory maps on National Park lands, Indian reserves, forest experiment stations and in special instances on provincial lands. The method has been found to be very useful for general forest inventory purposes and also in detailed forest estimating. It is expected that some fairly comprehensive ground data will soon be available to check detailed quantitative estimates of pulpwood which have been prepared from the forestry tri-camera photographs. A test of the method as applied to saw timber is also being carried out, Dominion Forest Service methods, employing the width of the crown and the height of the tree as measured by means of the photographs, being used.

The type lines in the oblique photographs of the forestry tri-camera method may be plotted in various ways:

1. Through the medium of existing vertical photographs
2. By perspective grids
3. By making rectified prints
4. By means of a camera lucida device adapted for use with oblique photographs.

The first method has the advantage that the interpreter readily combines the information existing in the two sets of photographs.

While it has been found that a north and south direction of flight will provide more distinct and relatively longer shadows, nevertheless the fact that prevailing winds are from the west in many regions creates a condition in which the course of the aircraft is more easily maintained by flying in an east and west direction.

The forestry tri-camera method has been employed at altitudes of 7,000, 8,000 and 10,500 feet (see "Specification for Forestry Tri-camera Photography" as reproduced below).

Specifications

The specifications which have been used by the Interdepartmental Committee on Air Surveys, Ottawa, in calling for tenders on forestry tri-camera photography, are as follows:

SPECIFICATION FOR
FORESTRY TRI-CAMERA PHOTOGRAPHY

I. CAMERA

1. Lens and Format: Lenses of a focal length of approximately 12" shall be employed in conjunction with an approximately 8½" x 8½" or 9" x 9" format.

2. Filter: Unless otherwise specified a Wratten Aero No. 1 or a Wratten No. 12, or equivalents, shall be used.

3. Fiducial Marks and Focal Plane: The fiducial marks defining the principal point and the format shall be suitably registered but as these photographs are for forestry purposes only it is not necessary to have the fiducial markings on the body of the camera. There is no objection to the use of a register glass to hold the film in the focal plane and at the same time to register the principal point and the format.

4. Focussing and Calibration: The cameras shall be in condition as established by focussing, shutter and photogrammetric calibration, which shall be carried out by the National Research Laboratories at the expense of the operator.

II. EXPOSURE

The winter landscape presents a very great range of brightness. However, the exposure must be such that the images of the dark evergreens will be on the straight line portion of the characteristic curve of the negative material and shall be as near as can be risked to the toe of the curve. In order to minimize blurring caused by relative movement of camera and ground, the exposure instant shall not exceed 1/100th of a second. It may be pointed out that, for example, at Latitude 48 degrees, the amount of sunlight on February 28th is only 60% of the maximum occurring on June 21st. At the same time the crown of an evergreen tree remains practically the same as a subject for photography.

III. MOUNTING OF THE CAMERA IN THE AIRCRAFT

Three cameras equipped with lenses of approximately 12-inch focal length shall be used, one of which shall be pointed downward as nearly as possible in a vertical direction while the others shall be aligned obliquely downward to port and starboard at such an angle on each side that the field of view of the central camera will be overlapped by the fields of view of the other cameras to an extent of at least three degrees. The camera compartments shall be maintained at a temperature of between 50° and 80°. The camera shall be insulated from the vibration of the structure of the aircraft by a simple mount of sponge rubber and wood as prescribed by the National Research Laboratories. Each camera shall be supported so that the plane of support includes the centre of gravity of the camera.

IV. NEGATIVE MATERIAL

Unless otherwise specified Aero Super XX on topographic base or its equivalent or superior in physical and sensitometric characteristics shall be used in all operations. It shall be stored and handled in accordance with the manufacturer's recommendation.

V. PROCESSING THE NEGATIVE

The processing of the negative can be carried out by any means which lead to a reasonably uniform development throughout the roll. A mean gamma of 1.2 or less, depending on variations in the forest detail, would be suitable. The best possible definition in the tree images is desired regardless of results in the purely snow-covered areas. Sensitometric step-tablets should be printed at the beginning and at the end of every roll of film. Test of the final wash water shall show the negatives free of hypo content to ensure the longest term storage.

VI. PRINT PROCESSING

Prints should have the fullest tone scale compatible with available paper characteristics. Prints shall be on glossy double weight paper. Printing shall be carried out in such a manner as to provide the maximum detail in the dark evergreens at the expense, if necessary, of detail in the snow. Attention is called to the fact that the photographs are being taken for forestry, not mapping purposes.

VII. OVERLAP

The three cameras shall be exposed simultaneously and every effort should be made to maintain a forward overlap in the central photograph of between 50% and 60%, with, of course, a consequent degree of overlap in the side photographs. In the case of photographs taken from 10,500 feet a lateral overlap of less than one-half mile shall be unacceptable and every effort shall be made to secure a lateral overlap of one mile. These requirements will be relaxed to one-quarter mile and one-half mile respectively in the case of photographs taken from 7,000 and 8,000 feet.

VIII. ALTITUDE OF FLIGHT

When photography is called for with a 12-inch lens on the average scales of 800, 1,000 or 1,320 feet to one inch, the altitudes required will be respectively 7,000, 8,000 or 10,500 feet above the average height of the land surface. Average scale here means approximately that of a tri-camera set of three photographs. Every effort shall be made to maintain the required altitude and the photographs will be unacceptable if these altitudes are exceeded by more than 300 feet.

IX. CLOUDS, STATIC, AND SNOW OR ICE ON TREES

The photographs shall be free from clouds and cloud shadows and detail shall not be obscured by marks caused by static. Tree foliage shall be at least 90% free of snow or ice.

X. PERIOD

The photographs shall be taken while the snow covers the ground within the period from February 1st to April 15th, 1948, inclusive.

XI. PRINTS

Two sets of 10" x 10" prints shall be supplied.

XII. RECORDS

The following written records must be supplied by the contractor in acceptable form:

1. Contract number.
2. Line number,
3. Roll number.
4. Date.
5. Times of day at which the flight started and stopped. It is most important to specify which Standard Time is being used and whether Daylight Saving is in effect.
6. Number of lens used in the operation.
7. Filter used.
8. Lens aperture used.
9. Exposure time.
10. Name of base used for the operation.
11. Reading of altimeter at the base at time of takeoff.
12. True altitude of the operation above sea level.
13. Meteorological conditions during photography.
14. An index map in duplicate showing the geographical location of every fifth trio of exposures.

XIII. ANNOTATION OF NEGATIVES

1. The negatives in a roll shall be numbered consecutively, beginning from 1, in the direction of flight.

2. There shall be neatly recorded in one corner of the first negative of each roll the information required under XII 1, 2, 3, 4, 5, 6, 8, 9 and 12.

Dominion Forest Service,
Ottawa, Canada.
January 6th, 1948.

Scale of Obliques

The scale of both low-angle and high-angle oblique photographs may be determined by means of perspective grids, a description of which will be found in all comprehensive works on photogrammetry. It may, however, be desirable in cases when perspective

grids are not on hand to employ the following ready method of scale calculation. This method may be used to determine the scale at right angles to the principal vertical of the oblique photograph though it does not take account of the progressively changing scale which occurs along the principal vertical and which may be found graphically in the absence of a perspective grid by means of drawings similar to those shown in Figure 1.

In Figure 4

$$Sx = \frac{f}{\cos b}$$

$$SX = \frac{H}{\cos a}$$

But scale at any point $x = \frac{Sx}{SX}$

$$= \frac{f \cos a}{H \cos b}$$

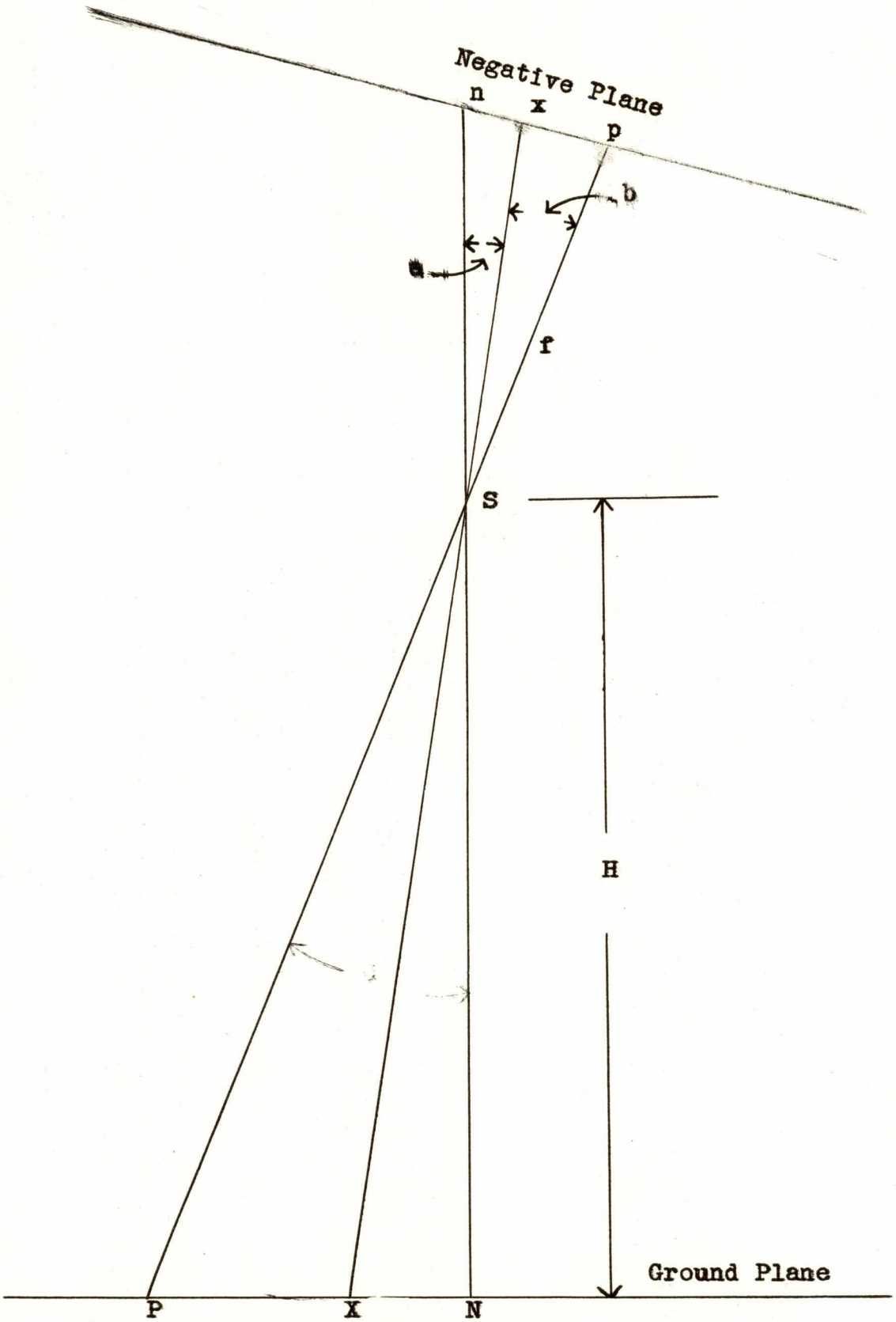


FIG. 4