AIR SURVEY AND PHOTOGRAMMETRY IN BRITISH COLUMBIA

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BRITISH COLUMBIA is unique among the nine provinces of Canada. Her area of some 366,000 square miles is predominantly mountainous, almost a third being high alpine barren, a third is sub-alpine slopes and plateaus, with the remainder made up of lower slopes, benches, valley floors, and plains, for the most part supporting or capable of producing valuable merchantable timber. Less than one tenth of the total area is classified as agricultural (including grazing), but this is highly productive.

A situation on the northwest coast of America gives B.C. a ringside seat in the arena of Pacific trade and strategy. It also makes her a port of entry for weather cycles moving in from the ocean and progressing easterly across the continent. Her latitude range from 48° 20′ to 60° North implies distinct winter and summer seasons, with coastal zones under the maritime influence for temperature and precipitation. The Cordilleran mountains, aligned southeast to northwest and separating deeply eroded valleys, lie athwart the path of prevailing southwesterly winds, hence there are wide variations in local climate through both longitude and altitude.

British Columbia has been last in line of the Canadian provinces to receive her quota from the western migration of population. It may be said that her million inhabitants, who have penetrated through the screening process all across the continent must be the rejects. Be it so, these fastidious "remnants" have proven their vigor and enterprise by amassing the greatest wealth, gaining the highest income from the largest production of all Canada, on a per capita basis.

In keeping with the geographic and economic factors which make B.C. a special case, there is an individualism perceptible in her citizens and their way of doing things, which may follow naturally from the circumstances of their choice of this province for a home. There may be found in this oasis, so remote from sophisticated world capitals, some unusual items of photogrammetric "flora and fauna" which have evolved "from within" to exploit niches in the environment, more or less unfettered by orthodox influence from outside.

Development

In the past, air photogrammetry in B.C. has been concerned mainly with vertical photographs. The perspective grid method of mapping from obliques, so conspicuously applied in the rest of Canada, was not practicable in our rough terrain. So we by-passed that interesting phase and instead, concentrated on the more laborious and more detailed use of verticals for larger scale mapping. The "taboo" on the "Canadian Oblique" method, was mitigated to some extent by the fact that, although arduous, mountain country lends itself to exploratory reconnaissance for broad lines of the topographic framework, exemplified in the classic maps by A.G. Morice, OMI, and Frank C. Swannell, DLS, BCLS (1, 2). It was not till just before the War, and more so recently, that we began to appreciate the possibilities of precision wide-angle oblique photography, not only for small-scale mapping, but also for propagation of horizontal and vertical control for larger scale mapping with standard vertical photo cover. Interesting developments along this line are anticipated as our post-war program gains momentum.

The first sizable air survey project in B.C. was done in 1929 with vertical photos by the R.C.A.F., in connection with a resources survey of a large railway development project in the northern Interior (3). This survey covered over 5,000 sq. miles, used the radial line method for final map scale of 2 miles per inch. Although not controlled to the standard of our present topographic program, it was completed in record time, and demonstrated the value of air photography. This job also familiarized a considerable number of our surveyors and engineers with the rudiments of plotting vertical photos.

The mountainous dimensions of B.C.'s topography have qualified our use of air photos for mapping. Even with verticals many liberties permissible in flat terrain cannot be taken, because the effects of tilt and scale variation assume intolerable magnitudes. However, the malady provides the remedy in that high relief facilitates triangulation, and can be exploited admirably by terrestrial photogrammetry for propagating a dense and reliable net of photo-control within units of the main trig framework.

The classic application of terrestrial photographic survey inspired by the late Dr. E. Deville, to mapping the Canadian Rocky Mountains took firm and healthy root in the B.C. Photographic Survey Division. This organization was built up by surveyors well versed in the method from previous work on the Alberta-B.C. boundary survey, which followed the backbone of the Rockies for some 400 miles. With simple and practical survey cameras designed by Deville, Figure 1 (they never aspired to the dignity of the name "phototheodolite"), these surveyors have done many years of systematic topo mapping in various parts of the province, long before air photos came into use (4). So B.C. had an active and enterprising nucleus of practical photogrammetrists, well versed in the problems of mountain topography, ready to tackle the air photo, when it first appeared. These men, and others familiar with their work, must read with amusement and irony, recent sensational publicity given to "rediscovery" of hoary possibilities of terrestrial photogrammetry, as an accessory to modern air survey. The vertical air photo is strong where the terrestrial photo is weak, and vice versa. The air vertical has the ideal perspective for maximum planimetric detail. It is weakest for the relative vertical positioning of ground features, for which it depends on second order differences of parallax. Also, the air station and the external orientation of the photo from it have, so far, depended on graphic resection. The terrestrial survey photo, taken from an occupied station of the control net, precisely oriented and levelled, is admirable for recording the vertical relationships of detail in rough country. The ground photo's delineation of planimetric detail is restricted however to such conspicuous features as may be identified in photos from another station commanding the same ground. Much is hidden, which the air view reveals completely.

It was only natural that the B.C. "Phototop" surveyors were quick to exploit the complementary virtues of the air views when they first became available, in supplementing their gound photos. By 1934, they had developed an effective procedure for combining the two types of photograph (5, 6). The method relegates the ground photos to the role of propagating horizontally and vertically controlled photo-points which are identifiable in the vertical airviews, to provide abundant and tight control for detail stereoscopic contouring and planimetry from the latter. The abundance of common identities between the air and the ground photos normally offered by mountainous country, permits direct plotting without complicated equipment. The simple stereoscope and epidiascope have sufficed.

Since the air photos have been panchromatic, the same type of emulsion is preferred for the ground views, to facilitate precise identification of common photo-detail. Preferably, the season of air and ground photography should match too, but this is not always feasible. The value of infra-red photography for horizontal penetration of atmospheric haze has been foregone too, because of the difficulty of correlating photo-detail with the panchromatic air views. It is possible however that infra-red could be used to a certain extent, on the basis of some systematic comparative study, and experience. Economy attendant on increasing the effective radius of the ground photo station by use of infra-red might justify some trial in this direction.

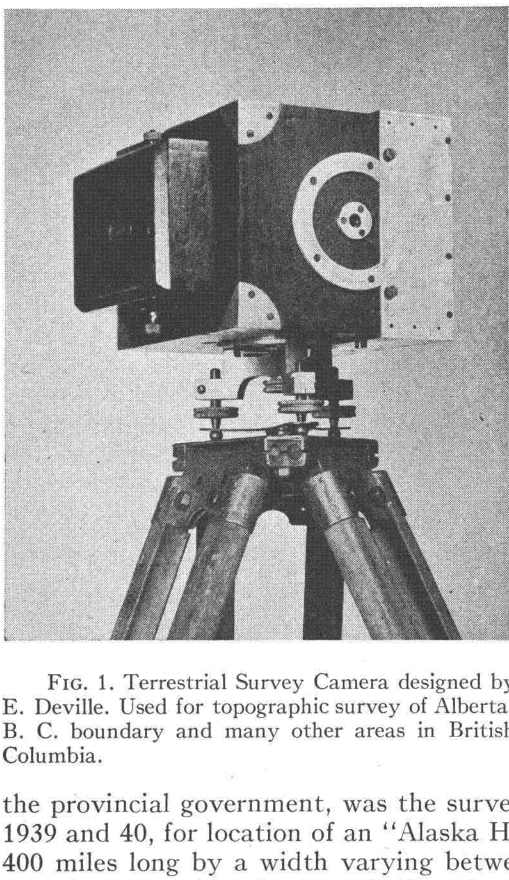

FIG. 1. Terrestrial Survey Camera designed by E. Deville. Used for topographic survey of Alberta, B. C. boundary and many other areas in British Columbia.

After more than a decade's application it is felt now that our established technique of aerophototopographic mapping is ready for some renovating, mainly to cut down laborious time-consuming point-by-point plotting in the office, by employment of suitable stereo-plotting aids, possibly stream-lining the field procedure to exploit precision wide-angle air obliques, and use of lighter and more efficient field equipment on the ground. Nevertheless, terrestrial photo-control will be retained as the most effective photogrammetric break-down of the basic trigonometry in country of high relief.

An interesting project embodying the methods just described, with vertical air photography by the provincial government, was the survey of the Rocky Mountain Trench in 1939 and 40, for location of an "Alaska Highway" (7, 8). The tract was nearly 400 miles long by a width varying between 10 and 15 miles, lying in almost a perfectly straight line, paralleling the Rocky Mountain range from Finlay Forks on the upper Peace River to the Yukon boundary near Lower Post on the Liard.

The Hydrographic Service, a federal authority, has been using vertical photography for many years in charting the West Coast. So complex are the features of innumerable islands and a deeply indented mainland coast that it is unlikely the job could ever be completed without the aid of air photographs.

As may have been surmised from introductory remarks, British Columbia's biggest industry is derived from timber. The B.C. Forest Service has made valuable use of air photographs in the survey and stock-taking of forest resources. A systematic beginning was made in connection with the Niskonlith and Shuswap Forest surveys in 1931. Verticals again were the practical medium, and after some initial skepticism, the air views very soon became regarded as indispensable (9, 10, 11, 12).

In connection with forest fire control, the Forest Service has also carried out a program of look-out photography whereby controlled panorama of eight terrestrial photographs, at 45-degree intervals and centred on the cardinal astronomic bearings, is taken from every forestry look-out station in the province. The look-outs are generally located on mountain tops, or on lesser eminences which command a strategic view of surrounding country. In many cases they are at, or near, triangulation stations. The standard survey camera, designed by the Topographical Survey of Canada, Ottawa, in 1930 was used. However, the instrument was modified to turn on a graduated horizontal circle so that, after initial orientation, any desired angle could be turned off, and a photograph exposed. Interchangeable with the plate-holder, an improvised eye piece with cross-hair graticule could be fitted, so that the camera itself, with

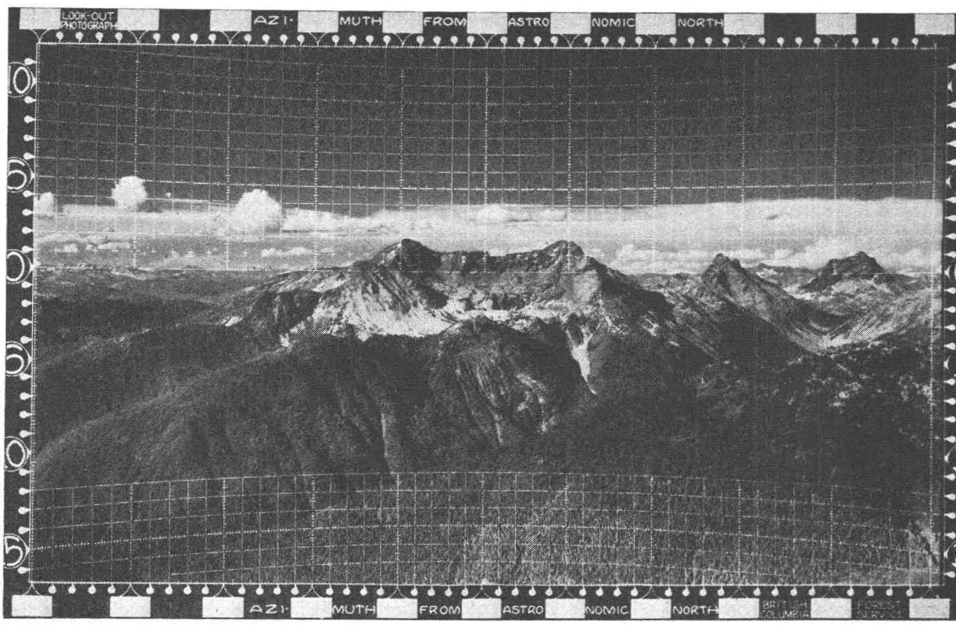

FIG. 2. B. C. Forest Service "Look-out" photograph. View N.E. from Joss Mountain near Revelstoke.

lens open could be sighted, as a telescope, on a reference object, providing the latter were near the horizon. With the horizontal circle oriented in this manner, and clamped, the eye piece was replaced with a plate holder, and the camera could be turned into any desired azimuth, and a series of photos taken, the orientation of which was exactly as required, referred to true north.

In making enlarged prints from the look-out photo negatives, a standard angular graticule transparency, with vertical straight lines for azimuth, and hyperbolae for angles of elevation and depression was registered in contact, emulsion to emulsion, and projected with the pictorial image onto the bromide paper. This automatically superimposed the angular graticule on each print. From field notes, the appropriate values of azimuth, in 5-degree intervals could be annotated in marginal panels provided. Values for vertical angles, being the same for all, were included in the master graticule (See Fig. 2).

Enough sets of these controlled panorama from each forestry look-out are made to supply the look-out man, the local forest ranger, the district office, and the head office in Victoria. The look-out man can use his set to give, by inspection, the azimuth and vertical angle to any smoke plume (or other object) visible from his station, without having to use an alidade or other instrument. At the local ranger station, the staff can, by reference to their copy, visualize exactly what the look-out man is seeing, and talking about. Many other uses of these look-out photos can be imagined, one being for "visibility mapping" i.e., studying and coordinating the look-out "coverage" of a region served by several look-out stations. Being accurate survey photographs, they are valuable as a supplement for mapping forest types and other features of the country. Among the negatives now accumulated on file, are many exquisitely beautiful views of mountain scenery, which for illustrative purposes may be printed without the grid.

In a mountainous country, any specialized natural resources atlas, to be at all comprehensive, must show the basic topography. It is regrettable that, even at this late date, we have not fully emerged from the waste and confusion which arose from the fact that the survey efforts by the various departments "have just growed, like Topsy,"—and our standard topographic survey, providing the ideal permanent base on which to overlay all specialized economic mapping, has not yet received the appreciation and support necessary for it to keep pace with the multifarious needs of a new and rapidly developing country. In the meantime, other departments and services have had to get on with their specialized mapping, dissipating an uneconomic proportion of their effort on "filling in" the topographic blanks. Some of this "topography" is very creditable as a side line, but it is not, nor was it intended to be, standard. The ground must ultimately be gone over once more, by the standard topo survey, and this in turn will necessitate a rehash of each resources atlas which "couldn't wait,"—an unfortunate state of affairs.

Air Survey Photography

In about 20 years operations the R.C.A.F. has done the largest share of air photography in B.C., aggregating between 60,000 and 70,000 sq. miles up to and including 1946. Commercial enterprise accounts for not more than 10,000 sq. miles. Since 1936, the B.C. Government itself has carried out a program of air survey photography, which now totals over 40,000 sq. miles. Altogether, not quite one third of the province has been covered with vertical photography. Some of the earlier work is becoming technically and economically obsolescent, and will have to be reflown.

From 1936 to 1940 inclusive, provincial government operations were done by the former Air Survey Section of the B.C. Forest Service. Demands on technical personnel by the Armed Forces interfered with provincial flying during the war years, but the R.C.A.F. carried on, and the U.S.A.A.F. covered a large proportion of the province with an early type of trimetrogon photography, part of which was badly obscured by cloud.

Post-war reorganization of provincial government air survey photography has consolidated all our operations in the new Air Survey Division of the Surveyor-General's Branch, Department of Lands & Forests. Air survey policy, and annual flying programs are formulated by a large and representative Interdepartmental Committee on Air Photography under the chairmanship of the Deputy Minister of Lands. Coordination with a similar committee of the Federal government at Ottawa is maintained so that photo flying by the R.C.A.F. and by the B.C. Air Survey Division will dove-tail.

To date, all provincial flying has been done with chartered commercial aircraft, in which government owned cameras and accessories are installed. All the work is under direct supervision of government engineers, and the air survey navigator and camera operator are government personnel. The pilot, who makes up the aircrew of three, has so far been an employee of the firm supplying the aircraft. Planning, operational details, equipment, photographic materials and processing, in fact all phases of the work except maintaining and flying the aircraft, are handled by the Air Survey Division. This arrangement has worked well pending the government's decision to acquire and operate aircraft of its own.

The geographic features of our environment influence all aspects of our air survey flying operations. The effective flying season is whittled down to less than four months, June to September. Persistent winter snow on the higher mountain levels delays the commencement of full scale activity well into June. Snow obscures so much ground detail that the photos would be technically and economically of little use. After the end of September, our northern latitude combined with the accidented relief causes an intolerable proportion of shadow interference in photographs exposed even at mid-day. The shadow nuisance further restricts daily flying to the six hours bracketing local solar noon, even in June. These limitations of the photographic day, and season, comprise a bitter pill for the air surveyor in B.C. Two months of good light intensity are lost on account of snow, before we can start our season, and to add insult to injury the months of May and October are the best weather months generally over the province.

Our records since 1936 show an average of 26 photographic days utilized in the four-month season, 3 days in June, 6 in July, 10 in August, and 7 days in September. These do not indicate the average expectancy over the whole province, but are merely from our operational records, embracing parts of a season here, and there, sporadically over the province. Nor are these particular days entirely without cloud. A typical phenomenon in fine settled summer weather is the gradual build-up of cumulus cloud over the crest of mountain ranges. Often by noon, this begins to spread out, and by mid afternoon may interfere with photography anywhere in the region. For this reason, first thing after take-off, the aircraft heads for the most rugged areas, if they are clear, and works there till the clouds chase it away. Then it finishes out the flight, if possible, over lower less rugged country, which may remain free of cloud until late afternoon. Another type of weather, more frequent possibly on the coast than in the interior, is morning fog at low levels, which may not dissipate till mid-day.

In planning the work, we try to include a variety of country in the authorized schedule from a particular base, so that local variations in cloud occurrence, which seem to follow physiographic boundaries, may be exploited to minimize the premature abandonment of flights. The navigator, as key man of our aircrew as far as the day's work is concerned, must decide as soon as the aircraft is high enough to look around, the best place to begin work, according to the cloud situation encountered, and to make an intelligent guess as to what is likely to develop from it. The navigator must also decide just when to retreat from an area over-run by the cloud "offensive," and the best alternative deployment of the remaining flight so the proportion of dead-head manoeuvering to useful photographic flying will be a minimum, and to stay up for the full time. This frequent "battle" with the clouds is really quite fascinating, but it calls for weather wisdom, discerning judgment, quick thinking, and of course enthusiasm for the work, to make each flight consistently yield the maximum in square miles well photographed.

On operations we stand by the aircraft every calendar day until early afternoon, regardless of bad looking skies overhead, just in case a sudden change might enable a useful flight. Normally, it is uneconomic to take off after 2 p.m., even if the sky should clear, because of impending shadow interference at 3 p.m. The nervous strain of making the decision to fly or not to fly, when conditions hover on the critical, can only be fully appreciated by actual experience. The frequency of cloudless, crystal clear nights in B.C. is, ironically, high.

During the past season, by cooperation of the Forest Service, an observation program for air photographic weather was organized to make use of forestry look-out stations, which are manned during the months of our normal flying season. The program embraces two purposes. Those look-outs which cover an area where air survey operations are actually in progress, report four times daily by radio to the district office, giving cloud occurrence, distribution, movement, and height, also visibility (haze). The air survey detachment listens in to these "scheds" and in this way is fully posted on the weather situation over the whole tract. The expense of abortive flights, only to confirm that the weather is non-photographic, is thus avoided. In addition to this direct operational service, all forestry look-outs in the province keep a systematic record of cloud occurrence as observed several times each day. At the end of each season, these data are sent in to the Air Survey Division for detailed analysis, together with data from official meteorological sources, for producing a series of air photo weather opportunity maps for the province, in short periods throughout the season. The value of this information for planning wide-spread air survey operations in accordance with the best probable weather opportunities in different regions can be imagined.

Although British Columbia is capable of producing some full dress forest fires, the loss of photographic days from excessive smoke has been less than 10%. It is arranged, if possible, to complete projects in the worst fire districts before the smoke reaches its seasonal climax, usually late in August. The density of smoke haze which becomes critical for obtaining useful photographs through a red filter seems to be just about the same as makes visibility too bad for navigating. In other words, as long as the smoke is not too thick to navigate the air survey strips, we can count on useful photographic results by use of the red A filter on panchromatic film.

The following types of aircraft have been used on charter:

Season	Type	Altitude/Sea Level	Range	Area, Vertical Photography
1936	Waco, floats	12,000 ft.	4½ hrs.	500 sq. mi.
1937	Waco, floats	10,000	do	2,400
1938	Waco, floats	13,000	do	7,100
1939	Fairchild 71C floats	17,000	5 hrs.	6,600
1940	Fairchild 71C floats	15,000	do	5,400
1946	Anson V wheels	17,500	6 hrs.	19,500
	Total area, vertical cover			41,500 sq. mi.

Amphibious landing gear is considered safest and most versatile for general operation in B.C., although facilities for wheels were greatly improved during the war. The Anson with wheels worked out very well during the 1946 season, using Vancouver, Patricia Bay, Comox, and Prince George air bases. The excellent facilities at these airports were not likely so fully appreciated by the younger air crew as by the older personnel who often had to improvise their own bases in the remote wilds. On the Finlay river in 1939 a long enough, straight enough length of river could not be found closer than 10 miles to the Hudson

Bay Company post where our aviation fuel had been cached. This meant keeping bachelors' hall on a sand bar, with the aircraft moored along side. Non-photographic days were devoted to fetching drums of gas in a flat-bottomed scow, through rapids down river. However, the Hudson Bay factor's wife made excellent chocolate cake.

Air survey flying over mountain country implies special problems in planning a job, and in doing it. Spacing of flight lines must allow for the highest peaks which may be 5,000 feet above the *average* level of the tract. There is no grid of road allowances or section lines measuring out miles and cardinal directions on the ground. A jumble of unmapped mountain peaks and ice fields is not a satisfactory turning point for the ends of a photographic strip. Too many landmarks can be worse than too few. We parcel up a large project into blocks bounded by major valleys, along which there is likely to be a bit of surveyed detail—a road, railway, a string of surveyed lots, or possibly a river traverse. If the official project boundaries follow an imaginary system of map sheets, we reach out, operationally, beyond these to pick up the nearest conspicuous topographic line. Subject to such variables, the blocks are laid out for a flight strip of about 50 miles length, and parallel to the average "grain" or direction of ridges and valleys, if any. Breaking up the work into main topographic subdivisions not only facilitates navigation along the strips, but economizes photo incidence on them. Those concerned with plotting or with costs will appreciate the importance of this. Vigilant attention is given to exposure interval which is altered to aim at the normal 65% over *local* ground. The camera operator must constantly check and adjust his interval, and it is routine for the navigator, who has the best view ahead, to warn the camera operator of impending gross changes in ground elevation. The forward and lateral coverage of wide-angle lenses is extremely sensitive to change of elevation in mountains.

Small Size Air Survey Cameras

Probably the most notorious display of provincialism in air survey practice in B.C. is our use of small size precision cameras in the air. A decade's application of the small camera principle provides solid foundation for our convictions in siding with the unorthodox minority on this controversial issue of applied photography. Pre-war experience with the 5×5-inch Eagle III camera with 5-inch Ross Xpres EMI lens was described in Photogrammetric Engineering a few years ago (13). At that time we were "pretty sure" of our ground, but were still psychologically on the defensive. Now, after a successful season applying war-developed improvements embodied in the new Eagle V, 5×5-inch camera with $3\frac{1}{4}$-inch Ross WA Survey lens (see Figure 3), to peace time civil requirements, we no longer feel so reticent. Instead, we must guard against over-confidence, lest we become like Pat who was sure the whole regiment was out of step but himself. Nevertheless, we do wonder how long most other authorities will persist in making their air negatives the expensive way, with ponderous over-size cameras.

In considering the implications of recording on a 5×5-inch negative, with a $3\frac{1}{4}$-inch lens, the same area of ground and the same amount of useful detail as may be obtained from the same air station on a 9×9-inch negative with a 6-inch lens, it is well to review the principles so clearly expressed by (the late) Dr. W. B. Rayton in 1938 (14). A 6-inch survey lens covering a 9×9-inch field has half the absolute resolving power of a 3-inch lens of similar design and quality covering a $4\frac{1}{2}\times4\frac{1}{2}$-inch field, but because the scale of the image on the larger negative is double that of the smaller for any given height, the size of the smallest ground object imaged successfully by either camera is the same. Only the limitation imposed by the grain of fast air film, with respect to the resultant resolving power in combination with that of the lens prevents us *in practice* from using, say a 1-inch lens to cover a $1\frac{1}{2} \times 1\frac{1}{2}$-inch negative in a diminutive camera for doing the same work as the conventional 9×9-inch size with a 6-inch lens. Multiplex diapositives could then be made by direct contact printing from the tiny negatives.—However, as Dr. Rayton pointed out, the resolving power of standard air film is sufficient to justify exploitation of the principle to the extent of a $3\frac{1}{4}$-inch lens covering a 5×5-inch field.

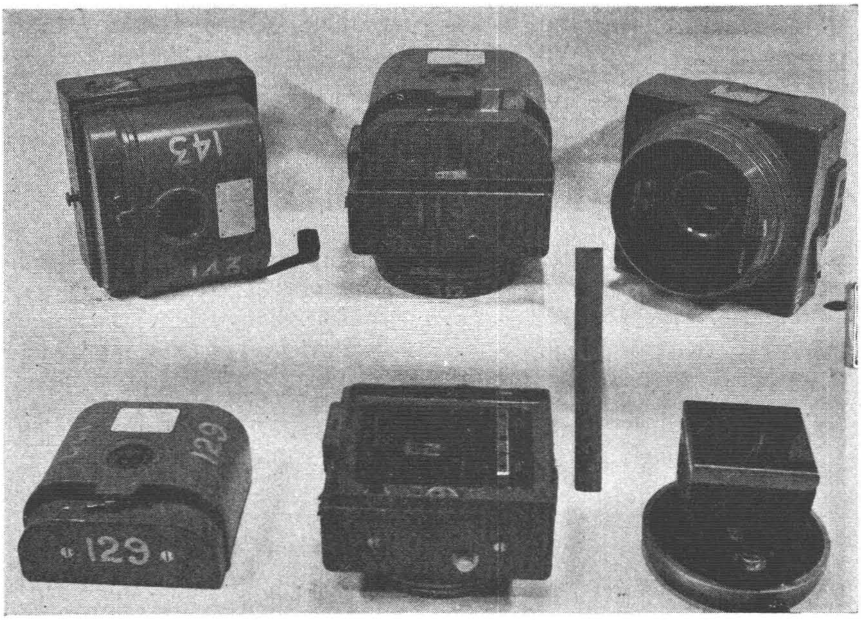

FIG. 3. Eagle V Air Camera with $3\frac{1}{4}$-inch F/5.5 Ross Wide Angle Survey Lens.

It is questionable if the smallest detail actually resolved in a 9×9-inch wide-angle negative is ever recovered, visibly, in the contact paper print, even under magnification. So unless the routine of enlarging the negatives to 18×18-or 27×27-inch prints is followed, the recovery of *all* the intrinsic detail of the negatives is never realized. Why not, then, use the 5×5-inch intercept of the same ground-to-air-station pyramid, and project these small negatives up to 9×9-inch prints? Such a procedure is surely a more rational utilization of the capabilities of lens and emulsion which the manufacturers have already given us.

Members of the Canadian Institute of Surveying who attended the 38th annual meeting in Ottawa, February 1945 were impressed by the surprising quality of definition in mosaics made up of enlarged prints from high altitude negatives of a 4-inch lens, exhibited by Mr. Virgil Kauffman, in connection with his address to the meeting (15). Mr. H. G. Fourcade, of South Africa, has advocated the use of a moderately small-size air camera as ancillary to his stereoplotter employing the projection principle (16).

To gain the advantages of the small size air camera, viz: lower initial cost, ease of handling and installing in the aircraft, economy of film, convenience in manipulations of the small film rolls in processing and in printing, the smaller volume of film storage, and the flexibility for enlarging to various ratios in normal sized enlargers—it is mandatory, if quality is to be maintained, that meticulous discipline govern each and every step in the whole sequence of operations which terminate in the final print. But this is hardly an onerous condition for those who (rightly) consider air survey a normal engineering activity, and as such it must be characterized by the utmost technical discipline as a matter of course. A wider margin for sloppy work is hardly a plausible excuse for using the large-size orthodox cameras in the air.

Specific Features of Camera and Lens

The Eagle V camera with $3\frac{1}{4}$-inch lens embodies several interesting features besides its small size. It is a fully precise survey camera in the modern sense. Automatic electrically driven magazine, body, and cone units are interchangeable. The film is supported and located precisely in the focal plane during exposure by a register glass, which is an integral part of the cone unit, so that the interchange of bodies and magazines does not disturb the precisely adjusted and calibrated optical constants (See Fig. 4).

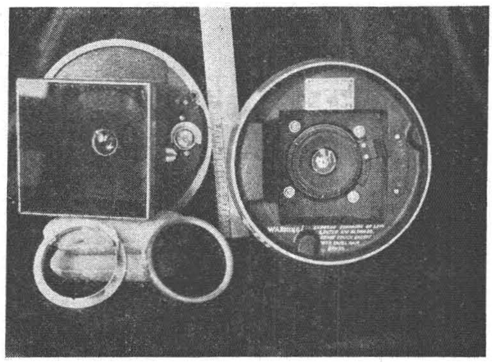

FIG. 4. Eagle V Cone Units with $3\frac{1}{4}$-inch Ross Wide Angle F/5.5 Survey Lens. The unit on the LEFT show film register-glass, light tunnel and back lens component, as seen from inside the camera. That on the RIGHT shows the front or outside view of the cone. The two filters shown are Minus Blue and Red A in bayonet type slip-on cells.

The film register glass, of 3.8 mm. thickness is in reality part of the optical system in the same sense as any one of the lens components, because the $3\frac{1}{4}$-inch F/5.5 Ross Wide Angle Survey lens was especially designed to compensate the extra-axial distortion inherent in the register glass. The calibration and distortion curves illustrated in Figure 5 are representative. These were derived from a normally assembled cone unit in routine tests. In this example, the extreme range of distortion, resultant of the combined lens proper and the register glass, is less than 0.05 mm, and is of the same order of magnitude as that of topographic safety aëro film, in the 5×5-inch negative (17).

Besides serving as a physical support for precise film register, free from the intricacies and errors of pneumatic back devices in magazines, the register glass in the Eagle V camera cone performs other useful services. It is made of Chance OY7 yellow polished optical glass which has a sharp spectral cut at 480 u, i.e. about the same as Wratten "Aero No. 2" (18). Under normal haze conditions, this built-in filter gives full correction, permits a smaller aperture setting, than "Minus Blue," and eliminates the two glass-air surfaces of the conventional filter fixed in front of the lens. If required, the denser filters, Wratten 12, and 25 may be used in the usual bayonet type slip-on cells in front of the lens. The colored register glass, of course, passes all the light transmitted by the heavier filter, just as the large hole cut in the door for the cat will also let the kittens through. (Is it not alleged that Newton cut smaller holes as well, for the kittens?)

On the under surface of the Eagle V register glass (that nearest the lens), a graduated neutral wedge filter of metallic rhodium is deposited by vacuum proc-

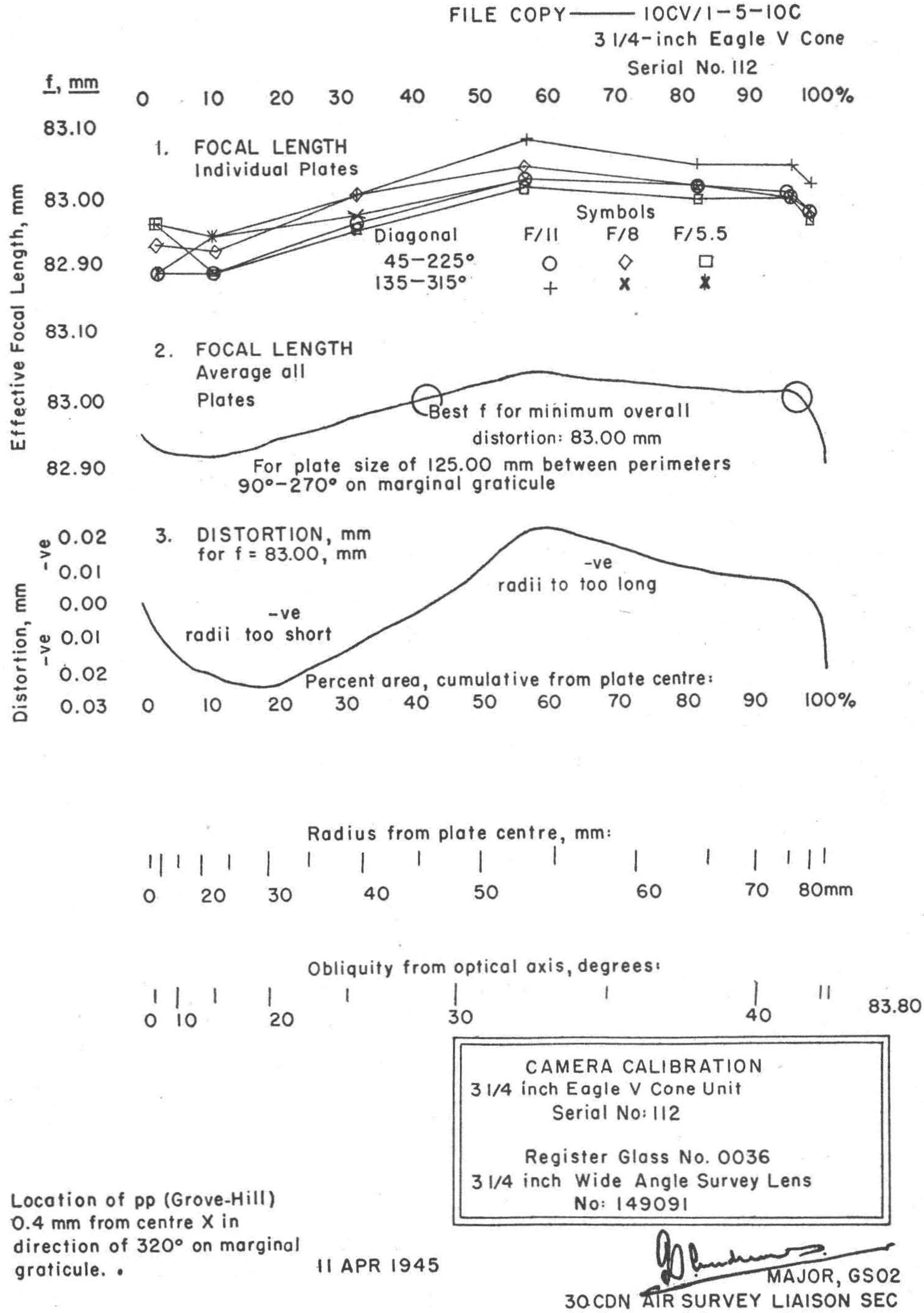

FIG. 5. Calibration, 3¼-inch Ross W A Survey Lens in Eagle V Cone Unit.

ess, to compensate the extreme vignetting and $\cos^4$ effects on off-axis plate illumination, characteristic of wide-angle lenses. The density gradient and limit of this rhodium wedge is such to equalize the illumination of the plate within a circumference about the centre containing half the area of the 5×5-inch negative. Beyond this, the light fall-off takes Nature's course unmodified to the corner (See Fig. 6). This modification, developed by the Army Survey staff of the Royal Canadian Engineers overseas, has effectively evened out the density of the routine negatives *in the camera* (19). This has simplified printing in the dark room, and has enhanced the resolving power of the whole photograph. We believe this method of equalizing illumination of wide-angle negatives at the

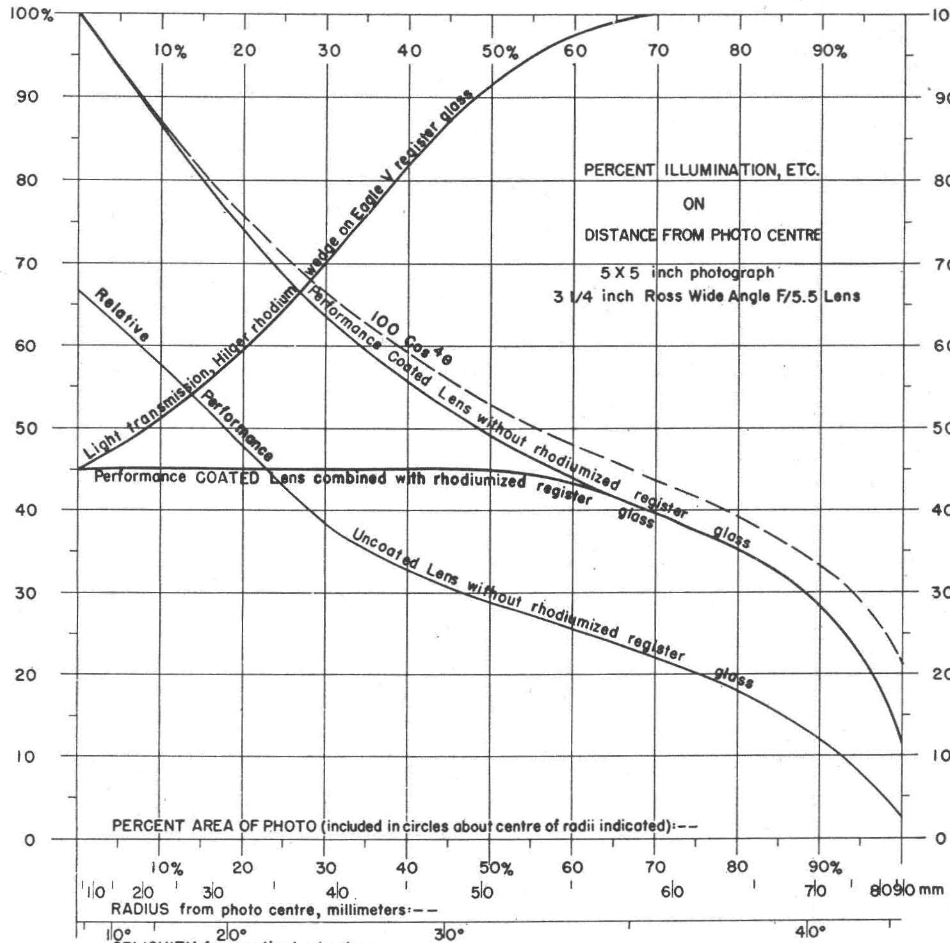

FIG. 6. Adapted from: "Rectifying the Extra-Axial Exposure Distortion of Wide Angle Air Survey Lenses" by G. S. Andrews, Royal Canadian Engineers, Canadian Army Overseas, March 1945, Figure 2.

focal plane is more efficient than correction applied in front of the lens by means of modified haze filters. It certainly imposes no restriction on use of the full range of lens apertures.

All glass-air surfaces of the optics in the $3\frac{1}{4}$-inch Eagle V cone unit are treated with cryolite anti-reflection coating. There are 10 surfaces in the lens proper, one on the under (protected) surface of the register glass, and two on the slip-on filter (if used). This treatment materially improves resolving power, marginal illumination, and effective speed of the whole optical unit. While efficient optically, cryolite is rather soft for use on exposed surfaces, calling for special supervision to prevent damage in operational practice (Fig. 4).

A convenient feature of the register glass is that any desired graticule may be photo-etched on its upper surface, for clear-cut automatic register on every negative. Ours carry a perimeter line close to the edge, on which are inconspicuous angular graduations referring to plate centre, marked by a cross. Each glass bears a serial number to identify the cone unit, for fool-proof reference to calibration and other data.

The Canadian Army overseas, during its wartime development of these improved Eagle V cameras, was able to instigate some useful study of the behavior of the 3¼-inch Ross Wide Angle Survey lens, particularly regarding effective *photographic* resolving power, under conditions simulating practical use (20). Tests were made on Microfile, Panatomic X, and Super XX emulsions with a test object of low contrast (0.2 density difference), said to be comparable to the density range of average terrain as photographed from the air. Wratten 12 and 25 filters, and various types of register glass, including the rhodiumized OY7 yellow, were used in the tests. These lenses were found to have a distance tolerance in the order of 0.3 mm for photographic "best focus" which centres on the distance for best visual focus on the axis at full aperture. This suggests that the lens may be focussed up visually for best photographic performance. The results tabulated below merit some study.

The coated lens, No. 144212 shows up better than the untreated specimens,

AVERAGE RESOLVING POWER

3¼-inch Ross Wide Angle Survey F/5.5 Lenses

Lines per mm. weighted on total 5×5-inch negative area

Low-contrast test object of 0.2 density difference, standard register glass, and filters indicated. R signifies radial lines, T tangential

Filter	Film	Aperture	*Lens No. 144212 R	T	Lens No. 144255 R	T	Lens No. 144277 R	T
Wratten 12:								
	Microfile	F/5.5	25	21	18.5	9.5	23	11.5
		F/8	34	31	24	15.5	35	21.5
		F/11	43	37	29	22	37	27
	Panatomic X	F/5.5	12.5	10.5	10.5	6.5	11.5	7.5
		F/8	16.5	14.5	13	9	14.5	10.5
		F/11	17.5	15.5	14	12	16	13.5
	Super XX	F/5.5	11	9	9	5.5	10.5	7
		F/8	14	12	11	7.5	12	9.5
		F/11	16.5	14	14	11.5	14.5	12.5
Wratten 25:								
	Panatomic X	F/5.5	13.5	11.5	No tests—			
		F/8	19.5	16.5				
		F/11	20	17				
	Super XX	F/5.5	12	10.5				
		F/8	16	14.5				
		F/11	17	14.5				

* Note: Lens No. 144212 was treated with cryolite anti-reflection coating. The other two lenses were untreated.

although the investigator hesitated to ascribe this to anti-reflection treatment. Analysis of these same specimens by the National Physical Laboratory, Teddington, for visual high contrast resolving power found lens No. 144212, then *uncoated*, was slightly inferior to lens No. 144277 for resolution of radial lines, and slightly better for tangential lines. It could be concluded from the above tabulation that the anti-reflection coating had moderately improved resolution of radial lines, and very appreciably improved the result with respect to tangential lines. The higher resolution on Panatomic X than on Super XX cannot be realized in practice because the slower fine grain emulsion requires a larger aperture to receive adequate exposure. The same condition offsets the advantage of a red filter. In parts of the world endowed with abundant light, it would be practicable to take advantage of combined use of Panatomic X and the Red A filter, with this lens at small aperture.

The tests indicate that these lenses are apochromatic, and it will be interesting to try out their performance with infra-red and with color film. For practical application in B.C., at the present time, the significant thing is the use of the smallest possible apertures compatible with the slowest shutter speed which the limits imposed by vibration and progress of the aircraft through the air will allow. Also, for the same reason, use of denser filters than required for adequate haze correction is to be avoided.

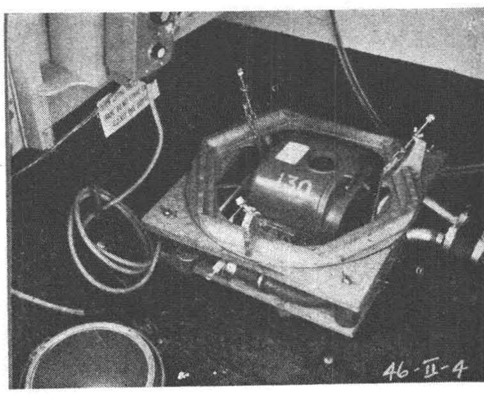

FIG. 7. Floating Suspension Vertical mount for Eagle V Camera as installed in Anson V aircraft. Note ducts for hot air jet to opposite corners of camera well.

In the past season, we obtained fully exposed negatives from 15,000 feet above ground by using 1/100 second shutter and F/11 aperture, with the built-in OY7 yellow filter, till about the first week in September at latitude 54° on photographic days with moderate haze.

In connection with the limitation to shutter speed dictated by high frequency aircraft vibration, a novel "floating suspension" type mount was improvised last summer for the Eagle V camera for adapting it to our requirements, which practically eliminated this source of trouble, especially significant with small cameras, due probably to their low moment of inertia. This mount, Figure 7, also dampens the effects of erratic lurches of the aircraft, in response to slight variations in air density and currents. The performance of the new mount is so good that we are contemplating trial of shutter speeds approaching the limits defined by normal image movement in flight combined with the effective resolving power of the lens. A resolution of say 0.1 mm. on the negative at 15,000 feet/ground represents about 18 feet. At 150 mph effective ground speed, this would not be appreciable, theoretically, in shutter speeds faster than 1/12 second. Actually we find, under good contrast, objects about 5 feet in size on the ground can be identified on good 9×9-inch enlarged prints from our negatives, at the height mentioned. It would appear then, that a shutter speed of 1/50 second would be permissible for routine conditions, which might offer the choice of a small stop (F/11), with either a finer grain film, or a denser filter on standard film.

Before leaving the subject of lenses, the $3\frac{1}{4}$-inch Ross provides a good example of the lower cost of these small lenses compared to that of the normal 6-inch size of the same type. One of the components of this lens is made of a special glass which gave some trouble in manufacture. From one of the early melts of this particular glass, it is alleged that only 7 flawless pieces large enough for the 6-inch lens were obtained. However, the same melt produced enough perfect small pieces for over 100 of the $3\frac{1}{4}$-inch lenses.

The $3\frac{1}{4}$-inch Eagle V cone unit is fitted with a sector (between-the-lens), type shutter which was designed and produced jointly by the makers of the camera and the lens, on special request of the Canadian Army Overseas. In spite of the small clearance, less than 1 mm., between the innermost lens components, which must also accommodate the iris diaphragm, a simple and effective 4-blade shutter was installed. It is provided with only two speed settings, 1/100 and 1/200 second. Tests of a specimen camera by the National Research Council, Ottawa (21), indicated a 60% efficiency when set for 1/200 second with aperture of F/5.5. The makers, however claim an average efficiency of over 80%. In any case, it should be good as we use it, with apertures of F/8 and F/11 set for 1/100 second. A breakdown test of 10,000 cycles discovered no failure of the shutter proper, but did disclose some trouble with the activating mechanism. This was corrected by the makers in subsequent units. Also, during our 1946 operation, minor trouble with the dampener device for controlling shutter speed was experienced. A simple local modification corrected it. This experience indicates emphatically that test and calibration of shutter performance must be a definite part of the operational routine. Otherwise all the other niceties of photographic practice aiming at consistently high quality negatives are futile. A simple, sturdy and portable apparatus for routine calibration of shutters at the operational field base is an urgent need, as yet unfilled.

No difficulty was met in providing heat control for the Eagle V camera as installed in the Anson V aircraft, which maintained the whole camera at temperatures between 50 and 60 degrees F., we believe this provision banished a troublesome horde of frosty photographic gremlins.

Processing

The range and variety of light intensity reflected to the camera over mountainous country is extreme. A sequence of only two or three exposures may run the whole gamut from alpine snow fields, blazing with actinic light, to sombre lowlands draped by unbroken stands of gloomy coniferous timber. Black clearwater streams from granitic country may join and mingle with white silt laden rivers disgorged from the glacier ridden Rockies, in a single vertical photo. Altitudinal variation in temperature, precipitation, exposure to wind and insolation, engender a most heterogeneous sequence of photogenic ground types. The mixture may include alpine barrens of rock and snow, subalpine grasslands blending gradually into dark mixtures of balsam and spruce below timber-line. These in turn give way to mixed stands of fir, cedar, white and lodge-pole pine, and larch on side-hill slopes. Lower down the dense timber may thin out to semiopen dryland fir and yellow pine, interspersed with bunch grass, and lower still treeless semi-arid benches and terraces of sage-brush and cactus may be encountered. Finally in the valley bottom a water course may be fringed with a belt of mixed hardwoods and conifers. The primordial picture is "retouched" here and there by man's whimsical brush,—logging, burnt forest, irrigation, field crops, overgrazing and erosion, roads and settlements. To portray all these elements, with their countless gradations and combinations on a single sequence of 3 or 4 vertical air photos, to the satisfaction of all the assorted specialists of this modern era, is almost more than a meticulous fabric of exposure, development and printing can be expected to achieve. We must aim at the best average all-purpose result, and when necessary, take care of residual desiderata by special printings.

It has been our practice, since 1936, to install a light meter in the aircraft, so that readings may be observed and booked at any time during flight. We now use the meter indications more as a seasonal and diurnal guide to exposure for average conditions, rather than for local variations on the ground, so rapidly passed over. However, frequent and representative meter readings are booked, which appear in an individual film report for each roll as a guide to the amount of development to give. In this respect, we like the short roll of 125 exposures, which allows greater flexibility and individual treatment of a day's film. We find too, that the 30 to 50 second interval between exposures gives the camera operator ample time to change magazines. When circumstances in the air are not too hectic, he rather welcomes this little chore to relieve the monotony.

FIG. 8. Spiral Developing Outfit for $5\frac{1}{2}$-inch film 60 feet in length.

Formerly we used the ordinary spool developing equipment, winding the roll back and forth from one spool to the other, but were never fully satisfied with the results. In 1946, we obtained from war surplus, a spiral developing unit produced for the British Air Ministry (22), for the service type F24 film, $5\frac{1}{2}$-inches wide by 60 feet long, the same dimensions used by our Eagle V's (See Fig. 8). After minor modification, this spiral developing unit has been given practical test, and the results are very promising. The loaded spiral, only 12 inches diameter by $5\frac{1}{4}$-inches deep, is dunked in cylindrical developing, fixing and washing tanks. Processing time is cut in half compared to the old spool equipment, and developing is even over the whole roll, equal to the best tray development of cut film. We expect the convenience and efficiency of this spiral equipment will double our developing output and materially improve the quality of our negatives. It is doubtful if this elegant method would be practicable with the unwieldy $9\frac{1}{2}$-inch film of proportionately greater length, from the large 9×9-inch cameras.

PRINTING

All our 5×5-inch negatives are projection printed to 9×9-inch size. Contact prints are made only rarely for special demands. Projection printing to the size mentioned is the last crucial step by which we endeavour to equate the small camera practique to the result obtained with the large 9×9-inch cameras. All improvements in the camera and film, all technical and practical achievements of the supervisory and operational personnel, survival of unavoidable hazards in flying (and there are many), and the high order of discipline maintained which have combined to produce the near perfect air negative, all come to nought if one element of the enlarging technique is at fault. Practical realization of Dr. Rayton's hypothesis depends on making enlargements in which the ulti-

FIG. 9. Portion of a tri-camera composite, Eagle V cameras, 5×5 inch negatives, $3\frac{1}{4}$-inch Ross Wide Angle Survey Lens: From original 9×9 inch enlarged prints. Taken vicinity Bowser Lake, B.C. approx. 129°50′W, 56°35′N, in connection with an aerial reconnaissance of the "A" route from Hazelton, B.C., to Alaska. Oblique is directed northwesterly toward Unuk, Iskut, and Stikine Rivers. Note the striking evidence of the "recession" of glaciers in these views.

mate detail may be seen *with equal ease* as would be normal in the contact print from a negative exposed in the air in a correspondingly larger camera.

Although our 9×9-inch bromides have, in the past, been of good quality, made with the conventional commercial enlarger, they have, we think lacked that "last little bit" of definition which would make them fully equal to good contact prints. Recovery of these last few crumbs of hard flinty detail has constituted the final problem in making our small camera technique unassailable. Now, however, by adaptation of another wartime development, the concentrated arc, this final requirement appears to be achieved. Combination of the new concentrated-arc lamp produced by the Electronics Division of the Western Union Telegraph Co., (23), with a high quality projection lens of adequate covering power in a precision condenser type enlarger, has at last enabled us to "arrive" at our objective.

Another item of war surplus equipment we obtained was one of the fixed focus enlargers developed and produced for the British Air Ministry by Kodak Ltd., Harrow, during the early years of the war, (24). This unit was designed to produce high quality 9×9-inch enlargements from the Service type F24 5×5-inch air negatives, on a mass production basis. It is equipped with a 13-inch Taylor, Taylor, Hobson Process F/8 lens, condenser, and *was* illuminated by a 125 watt high pressure mercury vapor lamp. For compactness, and portability, the projection, directed vertically downward from the lens is reflected obliquely upward by a front surface mirror placed a few inches below the lens, and inclined so that the reflected axis is about 30° to the vertical, focussing onto a glass platen which supports the bromide paper placed on it, sensitive side down. For our semi-permanent installation, the reflection feature has been eliminated, the lamp-house to objective assembly hoisted up high enough to project vertically downward directly to an image platform at convenient table height. Incidentally this eliminated two items which we weren't keen about, viz, inserting the negative emulsion-side up and projecting through the film base, to correct the image inversion from the single reflection, and the necessity to have a glass plate in front of the emulsion on the bromide paper. We like the use of gravity for stabilizing the paper, under a marginal frame, sensitive side up. Gravity also provides a convenient axis of reference for normalizing the whole apparatus with levels and plumb-bob. This arrangement also allows convenient opportunity for manual dodging of corners, and dense highlights by the operator, a feature which we have always felt contributed to better tone values in the print than is practicable in contact printers. The fixed focus feature is retained, temporarily, to push through the routine printing of our 1946 negatives. Later we plan to convert the apparatus for variable ratio projection.

The most significant modification to the enlarger, is, however, replacement of the original illumination, which comprised a luminous bulb, 2½ to 3-inches in diameter, which we considered appreciably detracted from the virtues of condenser projection, with the new Western Union concentrated arc lamp. For initial trial we have used the 25 watt C25 lamp with type 165 power unit. This lamp has a light source diameter of 0.73 mm, average candle power of 8.7, and maximum base temperature of 145°F. Obviously this lamp offers a very close practical realization of the theoretical pinpoint light source for condenser projection.

Prints made with the enlarger, modified as described, are conspicuously superior to anything we have been able to produce before, and realize at last the long cherished aim to reproduce in the bromide prints, in readily digestible form, all the useful detail intrinsic in high quality small scale negatives. By employment of advanced technical attainments in the three basic elements of projection printing, viz: intense concentrated illumination, strict regimentation of that illumination by condensers, and projection of the negative image by a high quality lens, none of the ancillary advantages of projection printing have been sacrificed, such as the ease with which manual dodging can balance out haphazard and systematic variation in negative density, and the finer gradations of tone values through a greater range of density which characterize the positive bromide emulsion in comparison to that of contact papers.

It is indeed fortunate that improvements in obtaining high quality air negatives with small-sized cameras, described in this paper, should be accompanied by this complementary forward step in making enlarged positives from them.

While on this subject, it may be mentioned that we have experienced an increasing demand for large-size blow-ups from the 5×5-inch negatives. Heretofore it was considered that 4-diameters from 5×5 to 20×20 was "scraping the bottom of the barrel" for clean-cut detail. With the new improvements mentioned, we believe that enlargement to 6 diameters will be within the bounds of propriety, especially with the average run of negatives from our new Eagle V's with $3\frac{1}{4}$-inch lens, stopped down to F/8 or F/11. It is often overlooked that a common motive for making large-size prints is merely to provide more physical space for delineating and annotating a finer breakdown of ground classification at large plotting scale, the qualitative identification of which is quite feasible in much smaller scale prints. It should be no tax on the imagination to appreciate how clumsy and costly the enlarger would have to be to provide the option of projecting 9×9-inch negatives to variable ratios, not even exceeding 3 diameters.

Conclusion

What the writer rather reluctantly began as "a few notes" on the B.C. aspects of the subject seems to have snowballed into a lengthy recital of photogrammetric responses to the environment. Permeating the discourse may be detected a "flavor" which is provincial rather than defensive. We have evolved, and proven, unusual practices which conform intimately and fluidly to the contour of our field. In a larger more wide-spread organization, such conceptions, if sprouted at all, may seldom have the opportunity to develop and survive in application. In a relatively small set-up we lose out on mass-production, highly stratified personnel, large resources in materials and equipment, facilities for involved research, and direct channels of communication with the other mighty ones of the photogrammetric world. On the other side of the ledger, we enjoy the advantages of a flexible, and close-knit organization, wherein a personal continuity throughout all the phases, in the air, in the field and in the office is possible. Add freedom to grope and probe where ingenuity, born of necessity may lead, and opportunity to combine generalization with specialization in an intimate and effective balance. We are fortunate to have capitalized so early on the various war-developed improvements for getting high quality air photographs at low cost. Now we must follow through with efforts to consolidate these advances with better organization and facilities on the ground for maintaining them, and for better use of the photos in plotting.

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