THE SMALL SCALE AIR SURVEY CAMERA

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THIS article constitutes a brief account of the experience of the British Columbia Forest Service with the Williamson (London) "Eagle III" Aircraft Camera, with the addition of a few comments which may be of interest in view of recent proposals for the development and use of air survey cameras of small size.

Considerations which led to the purchase of the Eagle III camera by the Forest Service early in 1937 were:

1. The need to carry out air survey photography independently of other agencies.
2. The advantage of owning camera equipment best meeting our requirements and chartering aircraft for the flying only.
3. Preference for small size, single lens, moderately wide-angle, square picture format, and shutter other than the focal plane type.
4. Smaller initial investment and lower operating costs.

Experience

Equipment

The Eagle III Aircraft Camera is a small size, but fully automatic air survey apparatus, producing a $5'' \times 5''$ negative on roll film $5\frac{1}{2}''$ wide by 55′ long. A glass register plate in the focal plane supports the film at instant of exposure, and a "louvre" type shutter is installed in the cone immediately behind the lens assembly. It has interchangeable magazines and lens-cones; may be operated by hand or automatically with 12 volt DC electric power. It may be mounted in adjustable gymbal support for vertical photography, or in hand mounting for obliques. The Forest Service equipment includes 3 separate lens-cones, a 5-inch Ross "Wide-Angle Xpres" F/4 used for routine work, a 6-inch Ross Wide-Angle Xpres F/4 as a reserve, and an 8-inch Dalmeyer Pentac F/2.9 for special jobs. Six film magazines of 115 exposure capacity each have been found adequate for this unit. Other items of the equipment comprise an electric intervalometer and spare, an electric rewind motor with flexible cable drive, a spare camera body, and a spare "louvre" shutter for each lens-cone.

Advantages of Small Scale Camera

We have had the impression that our employment of this "diminutive" equipment has been discountenanced by users of the larger orthodox $7'' \times 9''$ cameras, as being "amateur" and impractical. However, in view of the amount and quality of work done with it at a low cost per square mile, during the past three years, and in the light of modern trends in fast, fine-grain film, and small size, wide-angle lenses, we feel that our policy has been vindicated. Dr. W. B. Rayton,[1] has effectively refuted the inhibition "longer focal length, more detail," and he clarifies the correlation between resolving power of lens and emulsion with focal length. The 5-inch Ross Lens covers the $5'' \times 5''$ negative satisfactorily, especially at apertures of F/5.6 and smaller. This amounts to angular coverage of roughly 54° on the diameter and 72° on the diagonal of the negative. The optical pyramid with this combination covers a ground area com-

[1] "Future Possibilities in Aerial Photography"—W. B. Rayton, Photogrammetric Engineering, Vol. IV, No. 4.

parable to that of the $8\frac{1}{4}$-inch lens on a $7'' \times 9''$ negative, for any given altitude. (A convenient feature, too, is that the gross length of each side of the quadrat covered on the ground is equal to the height of the aircraft above the ground.) Thus with the 5-inch lens, a considerable saving in film and developing costs per square mile is enjoyed, while the smaller bulk and weight of camera and film rolls are a most agreeable feature in field, darkroom and storage. Spools containing enough film for 115 exposures are less than 6″ high and $2\frac{3}{4}''$ in diameter, and weigh, packed, about $2\frac{1}{4}$ lbs.

Work Done

The work done with this equipment in British Columbia is tabulated below, with distribution of costs:

Vertical Air Photography in British Columbia, with (Williamson) "Eagle III" 5×5 inch Camera

Overlaps: Forward 60%, Lateral 25%

	1937	1938	1939
Area photographed	2,430 sq. mi.	7,085 sq. mi.	6,600 sq. mi.
Number of photos	2,650	9,445	6,652
Mean altitude flown	10,000 ft.	13,000 ft.	16,500 ft.
	Cost Distribution		
Flying (by charter)	47.8%	46.8%	59.6%[2]
Film	10.1	13.2	8.3
Developing and annotation	2.7	4.3	2.3
Prints	10.8	11.9	7.6
Insurance	1.3	0.7	4.0
Personnel—salaries	12.2	8.7	8.4
Field and organization expenses	6.7	4.6	6.5
Depreciation and maintenance of equipment	8.4	9.8	3.3
	100%	*100%*	*100%*

Costs

The cost per square mile for this photography has been consistently at a low figure, believed to be unique in Canada, and comparable with lowest reputed costs in the U. S. A. This has been largely due to the saving in film and developing costs by virtue of the small scale negatives. We expect the equipment, with reasonable maintenance, will do similar work for quite a number of seasons yet. It will be agreed that experience has proved the worth of the smaller air survey camera from considerations of practical application and economy. What about photographic results?

Photographs

With regard to quality of photographs from the smaller camera, main considerations are—factors relating to the negative, and factors governing the quality of the projection prints.

Obviously anything which impairs the excellence of the small scale negative must be controlled to proportionately finer tolerances. In this respect we have found the performance of the Ross 5-inch lens remarkable for exquisite definition and freedom from distortion over the whole 5-inch negative. Random negatives on 1938 Eastman SS Pan film have been magnified over 4 diameters in printing for special purposes. The enlargements show no apparent loss of

[2] 1939 operations included work from remote points in the North with high fuel costs, and a slower, but more powerful aircraft.

definition, and the detail information on them is remarkable. Taken at 10,000′ above the ground, with the 5-inch lens, ground objects approaching 2′ in diameter under favorable conditions of contrast are discernible to the naked eye. Only in the extreme corners is a slight fuzziness apparent.

Effects of the glass register plate may require special attention in small scale cameras. We have evidence that, in our "Eagle III" camera, it shortens the 5-inch focal length by about 0.050″ at the centre to as much as 0.058″ at the edge of the negative. If this differential effect exceeds a required specification, the suction type of focal register at the back of the film might be necessary—although from the practical standpoint the glass register plate has the virtue of simplicity. It might be feasible to select a lens with distortion characteristics which would be compensated by those of the register plate.

Vibration

The problem of vibration-free installation of the small scale camera in aircraft seems, from our experience, to be more difficult than in the case of the large orthodox equipment. No doubt the smaller weight offering less inertia to the vibrating impulse permits a larger amplitude of vibration. Some early trouble with the "Eagle III" camera from this source was occasionally quite conspicuous, especially with the 5-inch lens, accentuated by wide-angle effects at the edge of the negative. This trouble was overcome by attaching a 4 pound lead ring to the distal end of the 5-inch cone, lowering the center of gravity of the operating camera assembly to a point near the intersection of the axes of support in the vertical mount. A further precaution was to alter the bearings in the mount from cylindrical to conical, with spring washers to maintain a snug contact—thus eliminating any tendency to "jiggling". The feet of the vertical mount support were adapted to float in thick layers of sponge rubber with adjustable retaining clamps to permit altering compression on the rubber. Elimination of vibration is one of the main features checked each year on test flights from the home airport before commencing the season's operations. Until we have vibrationless aircraft for photography, the use of small scale cameras for vertical photography will require careful attention to this potential source of defect.

Printing

Projection printing from small scale air negatives requires more rigid supervision and specification than contact printing from larger size negatives. However, once this is established, projection printing should offer no more difficulty than the contact technique—and it does have certain advantages. Every print is subject to any faults in the enlarging camera or in its use. Defects of the projecting lens such as distortion and poor definition will corrupt the prints, no matter how perfect the negative may be. False tilt may be introduced where the negative, print and lens axis are not in correct alignment.

Our practice has been to submit a test grid transparency, exactly the size of the negatives, and to have it printed to the specified projection. By carefully comparing proportions on the printed grid with the original, a check on distortion or faulty alignment and definition is quickly made. Our printing technique has been improved in other ways. Early practice was to make 8″×8″ prints without margins from the 5″×5″ negatives. These were held flat on the vertical printer easel by overlaying heavy plate glass. The practice is now discarded in favor of 9″×9″ prints with $\frac{1}{4}$″ white margin, on special mapping "distortion free" bromide paper, held flat by a heavy framing mask with no plate glass over-lay; we suspect the glass had a bad effect on definition, by secondary reflections, and might conceivably introduce an appreciable distortion toward the margin of the print. Projection printing is characteristically convenient and flexible for dodging in overexposed highlights, and holding back thin corners. Special jobs can be printed to any desired average scale. Costs of projection printing air photographs as compared to contact practice probably boil down to the basic difference in cost of bromide paper as against chloride paper.

COMMENT

In our use of this type of equipment, certain general points have come to light, through experience, which might be of interest in designing a future small scale camera.

Picture Format

It is hardly necessary to argue that the shape of the photograph be square instead of oblong. In North America we have been somewhat slow in outgrowing the "oblong complex." It is at last becoming generally recognized that the square photograph utilizes lens performance most efficiently, and improves the trigonometrical conditions of plotting by increasing the length of the air base in proportion to height above the ground.

Ruggedness

No matter how far the small scale feature is carried, in so far as the lens and film are concerned, the body and accessories of a serviceable air survey camera should be characterized by ruggedness and strength. There is really no point in going to extremes as far as economy of weight and bulk is concerned in such a camera. The punishment which an air survey camera must withstand, in practice, is well-known. Repairs in the field are costly and difficult. The chances of failure must be cut down to a minimum. The camera should be precision built so that replacements, either in the field or the laboratory, of worn or broken parts may be as simple and direct as possible.

Film Magazine

The question of size of film magazine deserves consideration. There has been a recent tendency by some camera makers to increase the capacity of the film magazine to accommodate several hundred exposures—presumably enough to last a whole flight without changing. This advantage is, of course, rather uncertain. Often the duration of a photographic flight is limited not by the range of the aircraft but by fickle weather. Further, with wider angle photography, the interval between exposures is increased, thereby lessening the number of exposures per flight. Higher altitude flying will work the same way. We have found with the "Eagle III" camera that a minimum of 15 seconds is required for changing magazines. For our routine flying, the average interval on vertical photography has been about twice that, so there has been ample time to change magazine without interrupting the sequence of a strip. However, in the future we can expect faster aircraft, and further, we may anticipate along with the high altitude flying, an increasing amount of low altitude work for intensive large scale photography of smaller areas. It may then become impracticable to change a magazine during the exposure interval on a strip sequence. A moderate increase in magazine capacity, say to 200 exposures and certainly not more than 300 exposures, might be recommended. This would mean probably at the most, not more than two changes during a flight. With small scale film, magazines and spools of such capacity would not be too massive.

We have found the acetate "safety" film base very brittle, and subject to breakage, especially under a hard pull as the core of the feed spool is approached. The fireproof advantages of the acetate film, however, are so great that in spite of its brittleness, it will be advisable to design a future film magazine to handle it with a minimum of strain.

A convenient feature of some makes of camera is a means of marking the space between two frames on the film with a perforation which can be located by "feel" in complete darkness. This allows cutting the film with impunity, for purposes of test developing small portions, so that the best treatment may be determined for the bulk of the roll.

Shutters

The problem of shutters for air survey cameras is one which probably occupies the minds of users as much as any feature of the equipment. The writer's experience is limited to the focal plane type in the early $7'' \times 9''$ cameras, and the "louvre" type shutter on the Williamson "Eagle III" camera. The fact that he is inclined to think the "between the lens" shutter is the best, is, therefore, not so much a tribute to the last, as a condemnation of the others. Incorporation in the air survey camera of some device, possibly a photoelectric cell, to indicate that the shutter is actually functioning during operations would eliminate, in case of shutter failure, a certain amount of "dead" flying, possible gaps in coverage of a tract, and some tension on already overloaded nerves. A feature of our routine in the air is to remove the magazine during each end-turn to inspect the operation of the shutter.

From the mechanical standpoint we have had very little trouble with the "louvre" shutter; it stands up well under the rigors of extended operations. However, it has certain photographic limitations which are not compatible with modern developments in air photography. It was evidently designed when longer focal-length, narrow-angle lenses were in vogue, and when wide apertures were necessary to adequately expose slower film. Under these conditions it gave excellent photographic results, in addition to its mechanical advantages. Now, with faster films, and short focal-length wide-angle lenses, apertures are reduced to improve definition and illumination to the edges of the negative. Under these conditions, the blades of the "louvre" shutter, being placed immediately behind the lens assembly, cause vignetting interference, resulting in uneven exposure bands on the negative. This effect is not noticeable at apertures of $F/5.6$ and we have secured many excellent negatives at $F/8$, with the 5-inch lens. Occasionally over snow, or very light ground, we have had to stop down to $F/11$ in which cases the banding effect has been conspicuous.

Another feature is that in the closed position there is a slight leakage of light between the shutter blades. With present day film, on high altitude work over snow-covered mountains, the exposure interval is long enough over the intense ground glare to cause a slight fogging of the portion of the film waiting to be exposed. Under ordinary conditions the effect of this leakage is insignificant, but it indicates a potential source of trouble in certain extreme conditions which should be recognized in designing shutters for the future.

It is the opinion of the writer that the problem of shutters for air survey cameras has not yet been adequately solved. The between the lens shutter although seemingly ideal from the optical standpoint has the practical disadvantage that the lens assembly must be disturbed to gain access to the shutter. This occasionally must be done in the field, under very unfavorable circumstances. The photogrammetric world would do well to offer a substantial prize for a satisfactory solution to the shutter problem. Is there an opaque medium, solid, liquid, or gas, which, under the influence of an electrolytic impulse becomes instantly transparent, and instantly resumes its opaque characteristic upon cessation of the electric charge? Such a medium, in the form of an enclosed optical cell could be installed as the ideal, absolute shutter for air survey camera—100% efficient, no moving parts, with any range of exposures available by simple timing switch control. Such a shutter could be sealed between the lens elements, or mounted in front or behind the lens. If a simple "black and white" medium cannot be discovered, possibly a colored medium could be combined with suitable filters to effect the necessary opacity.

"Screw on" filters are a nuisance in air survey cameras and a positive bayonet type attachment is much to be preferred.

Records

Some air survey cameras have devices for recording images of various instruments on the film in the spaces between the frames. The "Eagle III" camera includes a watch, a small aneroid altimeter, a numerical tally, and a note card. This device could be a useful feature of a future camera. A watch seems desirable, a statoscope for recording differences of altitude might be included in place of the crude aneroid altimeter, in which case differences of altitude as recorded with each exposure, correlated with occasional observed readings of a precision altimeter in the aircraft, with corrections for temperature, diurnal atmospheric pressure change, etc., could be compiled into a detail profile of the flight. The numerical tally has not been of much value in our experience, and might be replaced by a thermometer, a level bubble, or some other option. Convenient control of the illumination of these instruments is necessary to get suitably exposed images on films of different speeds. In air survey photography, be it oblique or vertical, it is not sufficient to get good photogrammetric negatives under a wide variety of conditions but it is necessary also to bring back a reliable record of the conditions under which each photograph was obtained. The sooner this can be done automatically the better, because operators have plenty to do in the air without the added burden of keeping a complete log of detailed minutae.

Projection Prints and "Focal Length"

Most photogrammetric compilations require that the focal length or principal distance be known, as this fixes the perspective proportions of the photograph. With contact prints, the focal length of the taking camera is generally used. In the case of projection prints, the camera "LPD" or focal length must be modified in proportion to the degree of enlargement, and this may vary according to specifications for particular jobs. This makes it desirable to contrive some direct means of determining the degree of enlargement of each, or any random print. In the case of cameras equipped with the glass focal register plate, the practice of having a scale in inches and tenths etched along the margins, will provide this means. The image of this marginal scale, appearing on every print, may be measured, the degree of enlargement determined, and the camera focal length increased accordingly.

Interchangeable Parts

In recent photogrammetric literature, considerable attention has been given to so-called "precision" air cameras, and there is some adherence to the view that "precision" is achieved merely by having all the units of the camera assembly fixed and sealed in one piece. However, when one thinks of the remarkable precision which is commonplace in the modern motor car industry, there seems no reason why a precision built camera should not have interchangeable lens cones and magazines, with the attending advantages of flexibility and versatility. Modern machine technique and metallurgy offer the camera maker a wide field for building durable high precision instruments with full range of interchangeable parts. The small scale air survey camera of the future offers much more scope from the standpoint of bulk and weight than has been the case with the large size equipment of the past. The advantages of chrom-steel and other alloys are open to us regardless of weight, instead of being confined to aluminium, since weight is not, in this case, a controlling factor.
