A New Team of Projection Printers for Rectifying 9-Inch by 18-Inch High Tilt Photography

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ABSTRACT: *Two rectifying projection printers have been developed for mass production rectification of high-tilt, long focal-length, 9″×18″ aerial photography in a two-stage process. The first stage is accomplished with a transforming printer which is set manually to calculated settings for partial rectification. One setting is sufficient for an entire roll of film if the same nominal taking conditions prevail. The image is printed on roll film in a standard film magazine carried on the easel carriage.*

For the second stage, the partially rectified roll film is installed in the autofocusing rectifier and the complete rectification of each individual frame is accomplished by push-button control of magnification and tilt settings.

By means of the two-stage process, 9″×18″ photographs taken with aerial cameras of 12″ through 48″ focal-length and tilted up to 65 degrees may be rectified.

By means of the autofocusing rectifier alone, tilts up to 45 degrees may be rectified in a single stage with 24″ through 48″ focal length photography.

TWO new rectifying printers have been developed under the auspices of the Ground Photogrammetry Section, Aerial Reconnaissance Lab, Wright Air Development Center. By means of a two-stage process, one stage with each instrument, it is now possible to rectify aerial photographs up to 9″×18″ in size, taken with aerial cameras of 12″ through 48″ focal length and tilted up to 65 degrees.

For such two-stage, high-tilt rectification the transforming printer is set manually to calculated settings for partial rectification and isoline reduction in scale. The amount of reduction required is such that the recoverable image (at least 75 degrees from the nadir point) will print on 9″×18″ aerial camera film carried in a standard A-8B film magazine mounted on the easel carriage. Figure 1 shows the transforming printer with the film magazine in place. Once the printer has been set for the given taking conditions, an entire roll of aerial film may be printed without changing the instrument settings.

For the second stage the film is taken from the film magazine, developed, and installed in the negative carrier of the autofocusing rectifier, Figure 3. In this stage the image is magnified and printed on paper which is held in place on the large easel by means of suction. The autofocusing feature of this instrument facilitiates correcting each individual frame for the minor variations in tilt and scale which are invariably present. Complete rectification in this stage is assured by push-button positioning of the movable components to calculated scale settings; or the image may be adjusted to a control templet by empirical methods.[1]

In addition to the two-stage, high-tilt rectification capabilities just described the instruments are adjustable to a number of other procedures. The intermediate image may be printed on 9″×18″ glass plates instead of on roll film. A glass-plate holder is provided for mounting on the easel carriage of the transforming printer in place of the film magazine shown in Figure 1. Also, a special frame is provided for holding the developed glass plates in the negative carrier of the autofocus rectifier.

The transforming printer, as well as the

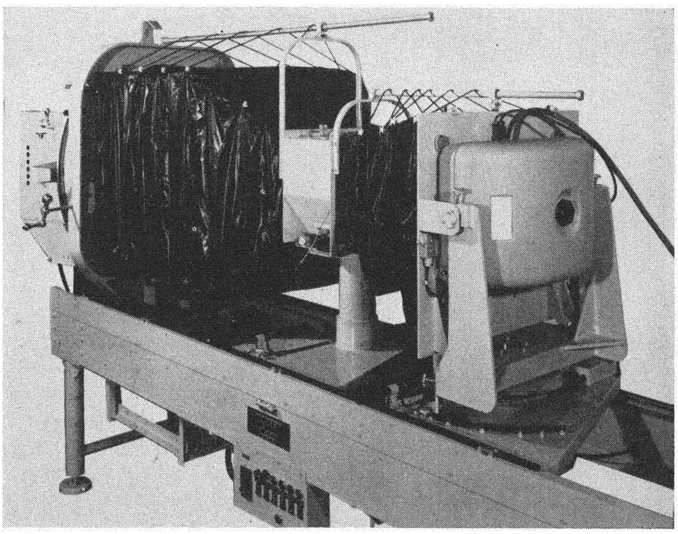

FIG. 1. The transforming projection printer equipped for printing on 9″×18″ roll film.

autofocusing rectifier, may be used for single-stage printing on either wet or dry paper. Two paper-holding easels are provided for each instrument. In each case one easel is equipped with a vacuum system, and the other easel with an unperforated surface for wet printing. The paper-holding easels for the transformer are 24″×43″ in size. Figure 2 shows the transforming printer with its vacuum easel installed. The easels for the rectifier are nominally 50″×72″ in size, but the wet easel is fitted with a removable extension which, when in place, makes it 96″ long.

The single-stage rectification range of autofocusing rectifier is shown in Figure 4. Each curve is identified by the focal-length of the negative being projected. A number of limiting conditions determine the shape of these curves. These are the lens field (90 degrees), the minimum acceptable angle of intersection of light rays with the easel (20 degrees), the mechanical limits of travel provided, and the easel size. Only the

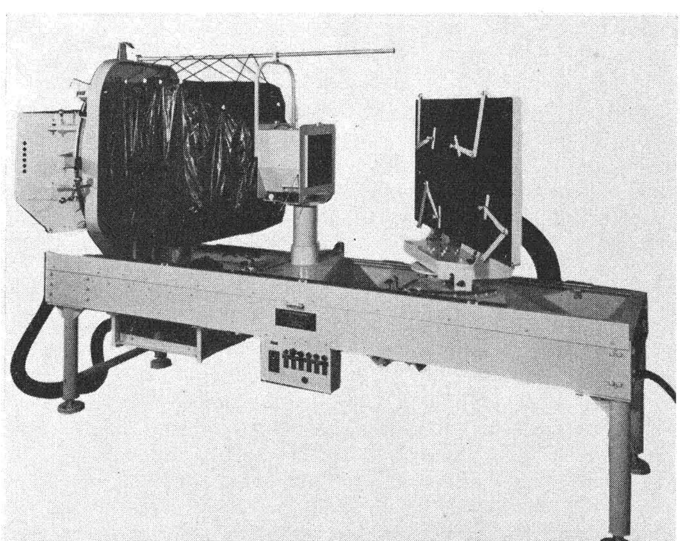

FIG. 2. The transforming projection printer with the interchangeable vacuum easel in place.

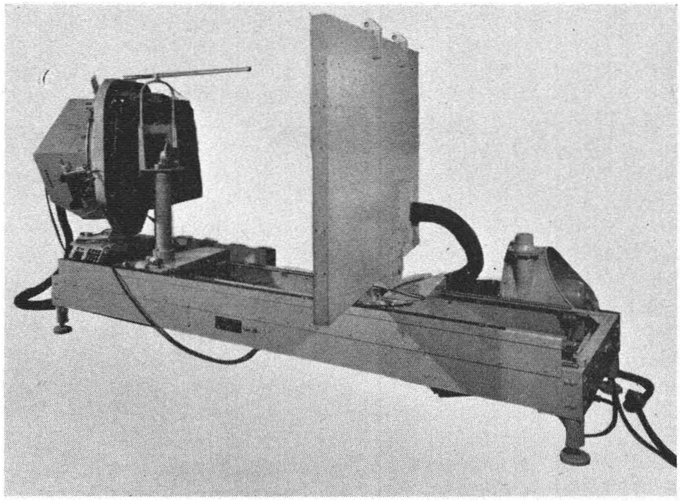

FIG. 3. The autofocusing rectifying projection printer.

12″ f and 24″ f curves require the use of the 96″ easel. Restricting the image length to 72″ would lower the upper portion of these two curves somewhat.

The rectification range of the transforming printer is smaller due to the shorter frame and smaller easels.

The over-all lengths of the transforming printer and autofocusing printer are 11 feet and $13\frac{1}{2}$ feet respectively. They are almost entirely of aluminum construction, thereby resulting in minimum weight.

A number of features of the two instruments are the same. These are of the horizontal, tilting-lens type of design. That is, the line connecting the principal points of object and image remains fixed and coincides with the center-line of the instruments. It is the line of reference for measuring conjugate distances and the tilt angle of negative, lens, and easel.

The lamphouses are identical. They each contain four 400-watt mercury-vapor lamps, an "alzak" aluminum reflector, a flashed opal glass diffusing-screen, and an adjustable glass pressure-plate. Forced air cooling is provided. They are hinge-mounted to the swing plate so as to facili-

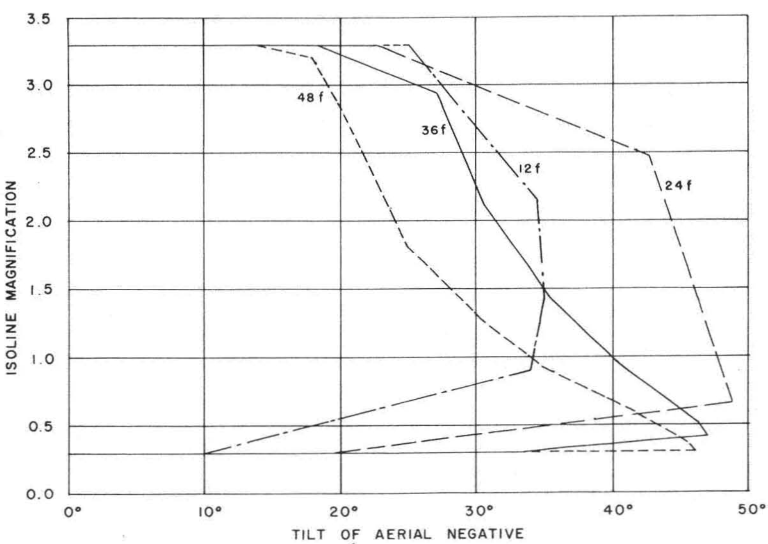

FIG. 4. Single stage range of the autofocusing rectifier.

tate the loading of film and the cleaning of the pressure and stage glass plates.

The swing plates are mounted to the negative carrier castings, and may be rotated through 360 degrees of "swing" by means of a hand crank. Fiducial mark alignment lines are provided on the stage glass for both 9″×9″ and 9″×18″ negative format sizes. Two pairs of film spool-brackets are provided for holding either 9½″ wide or 18½″ wide rolls of film. Each bracket is provided with a crank for winding the film, and with an adjusting knob for moving the bracket and spool parallel to the film spool axis.

Image stealers are provided for viewing the fiducial mark alignment from a convenient position behind the lamphouse. This is accomplished with small mirrors, two of which are mounted on slides for accommodating the two different format sizes.

The lens and easel carriages roll on stainless-steel tracks. The tracks are attached to the aluminum frames in such a manner as to maintain alignment and at the same time permit thermal elongation with respect to the frame.

Linear and angular scales and verniers are provided on both instruments for accurately setting conjugate distances and tilts. The linear scales are graduated in centimeters and the angular scales in degrees and minutes. Small neon lamps provide illumination at all verniers and index marks for setting to computed data under darkroom conditions.

To meet the wide rectification range required of these instruments, a lens of wide angular field and relatively long focal-length, as well as excellent optical characteristics, is necessary. Only one domestic lens design was found that meets these requirements. It is the Goerz Hypergon, and one of these is supplied with each instrument. They are both of 14″ nominal focal-length, 90 degrees field and f/22 maximum speed. Lens tests conducted by the National Bureau of Standards on both lenses showed that maximum image distortion occurs at the maximum half angle of 45 degrees. The distortion at this point and with a magnification of 1.0 was found to be 0.06 mm. Because they are not corrected for chromatic aberration, the effective focal-length varies with the wavelength of light transmitted. To overcome this lens deficiency a filter is used in the lamphouse of the transformer when printing on film. A filter is not necessary when printing on bromide papers because of the coincidence of the peak sensitivity of the paper with the 436 mμ wavelength light emitted by the lamps.

The printing time is exceptionally fast, considering the relatively slow lens. For example, with all four lamps on and with an average negative the required exposure is less than two seconds, when printing on Kodabromide F-2 paper at 1× magnification and zero degrees of tilt.

Both the transformer and rectifier are equipped with a master control panel, each containing a circuit-breaker type main power line switch with indicator lamp, individual switches for the projection lamps, indicating lights to warn of projection-lamp failure, vernier illuminating switch, vacuum-pump switch, and fuse holders. The lamphouse cooling blower starts automatically when the main line power switch is turned on.

The negative carriers rotate about a vertical axis located one-third the thickness of the stage glass in front of the negative plane. The lenses rotate about a vertical axis through the optical center. The easels rotate about a vertical axis through the image focal plane.

Because of the extreme distortion required of the bellows, it was found necessary to fabricate units of novel design. Standard bellows covering-material has been glued to a continuous spirally-wound, square spring-steel wire frame to produce the units shown in the photographs.

On the transforming printer all motions are hand operated, except for the film magazine drive, which is powered by an electric motor. Slow-motion screws on the movable elements facilitate accurate scale settings. These may be disengaged for rapid motion. The lens enclosure is equipped with a hinged top which permits access to the lens and shutter.

The rectifying projecting printer is completely autofocusing throughout its range of operation. The mechanisms[2] which make this possible are a Pythagorean band-inversor for magnification-control and a Carpentier-inversor for tilt-control. Tension in the bands of the Pythagorean band-inversor, which would otherwise be suitable only for vertical operation, is maintained by means of a constant-force spring-motor. Flexible-steel cables are mounted over the bands under light spring tension to prevent damage in case of band failure.

Reversible electric-motor drives are provided to directly vary magnification, lens tilt and easel tilt. Switches in a walk-around hand-held control box actuate these three motors through relays. Negative carriage tilt is automatically maintained at the Scheimpflug[3] condition by the Carpentier inversor. Limit switches safeguard all power driven motions against exceeding mechanical limits.

These instruments were originally delivered to the Ground Photogrammetry Section at Wright-Patterson Air Force Base, Ohio, and successfully passed acceptance tests at that installation. They have since been moved to the U.S.A.F. Aeronautical Chart and Information Center at St. Louis in order that additional tests may be performed with respect to operational suitability for mosaic compilation from high-oblique aerial photographs.

REFERENCES

1. Chapter IX, MANUAL OF PHOTOGRAMMETRY, 2nd edition, The American Society of Photogrammetry.
2. The Pythagorean and Carpentier inversors are fully described in *Photogrammetry*, by O. Von Gruber, American Publishing Co., and more recently in Reference 1.
3. The Scheimpflug condition specifies that for sharp imagery, the object, lens, and easel planes, extended, must all intersect at a common line in space.

*Mapping for the Mid Canada Line**

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ABSTRACT: *The Mid-Canada Line is part of the North American Radar Early Warning System and it is being constructed and paid for by Canada as her major contribution to this system. Siting of the radar station required a strip of 1:50,000 mapping fifteen to twenty-five miles wide extending across the continent at roughly the 55th parallel of latitude.*

This mapping was carried out by the Army Survey Establishment with the extensive assistance of other Canadian Government mapping agencies. Much use was made of radar altimetry and shoran controlled photography. The great value of these two new tools, where the terrain is difficult and time is an important factor, was clearly demonstrated.

THE North American Radar Early Warning System consists of three lines of detection stations. In the south, generally in the vicinity of the United States-Canadian border, there is the "Pine Tree" line. Roughly along the 55th parallel of latitude is located the "Mid Canada" line. In the far north, the "DEW" line is being established. While the construction of these systems is part of the co-ordinated United States-Canada defence programme and a high degree of international co-operation is involved in all three, the "DEW" line is basically a United States undertaking, whereas the "Mid Canada" line is being built, and paid for, by Canada. The latter is therefore the project which we in Canada have been most intimately associated from the mapping point of view, and it is the purpose of this paper to outline the general methods we employed in that mapping.

The requirement was for a strip of maps at a scale of 1:50,000 with a 25 foot contour interval having a minimum width of fifteen miles extending from coast to coast. Since there was insufficient time for additional ground surveys, it was agreed that

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