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PAR 243A

FINAL REPORT

Briefing Print Enlarger (BPE), Prototype Model

18 August 1967

Prepared by:

[redacted] 25X1

Approved by:

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Date: 14 September 1967

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SUMMARY

It was desirable to have an enlarger which would be relatively simple to operate, provide a wide range of magnification adjustable in small increments, handle negative film rolls rapidly, provide for handling large sheets of print stock easily, produce large prints, and have color printing capability.

The Briefing Print Enlarger (BPE) which was built on this project has a horizontal optical axis and provides continuously variable magnification from 3X to 60X through the use of a family of six quickly interchangeable objective lens and condenser sets. Two additional lens and condenser sets are being developed on a separate project (PAR 245, BPE High-Magnification Lens Sets) to extend the magnification range to 150X.

Negative film in roll form can be handled rapidly in all widths from 70mm to 9.5 inches. The negative is supported in a wet, glass-sandwich gate during printing. The print stock is supported by a 40-inch square vacuum easel. Exposure is controlled by varying lamp intensity and exposure duration. Printing capability is provided for both black-and-white and color materials. Exposure prediction is simplified by the presence of an easel spot-photometer. The entire optical system is isolated from building vibration. Precision focus calibration for every easel setting and corresponding magnification is built into the BPE and presented to the operator in easily readable digital form. A within-frame coordinate measuring system is provided, calibrated in millimeters, and presented to the operator by digital display. The only service requirement is electrical, plus an outside vent for expelling used, negative-gate fluid vapors.

Exhaustive testing indicates that the design requirements for the BPE prototype were met.

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SUBJECT: Briefing Print Enlarger (BPE), Prototype Model

TASK/PROBLEM

1. Design, fabricate, and test a prototype Briefing Print Enlarger (BPE) based upon tests and observations of the breadboard equipment developed on the combined PARs 202/224.

INTRODUCTION

2. It was desirable to have a new enlarger which would permit the rapid production of many additional types of prints now required in aerial reconnaissance laboratories and which would have improved performance in:

a. Ability to expose larger prints

b. Wider magnification range with adjustment in 0.25 to 0.4 percent steps

c. Handling of negative film rolls

d. Print stock handling

e. Color printing capability.

The BPE produced on this project may be considered the third-generation design following the 20X Precision Enlarger and the 10-20-40X Precision Enlarger.

3. This project, as described in the Task/Problem, was authorized on 13 December 1965 and the completed prototype instrument was delivered to the customer on 28 June 1967.

4. The studies in which the basic concepts for this project were developed and proved were performed on two earlier projects on this contract which were authorized in April 1964. PAR 202, Briefing Print Enlarger (10X to 60X Enlarger) was authorized to provide design studies and breadboard hardware to aid in the design of an enlarger for exposing 20- by 24-inch prints in the 10X to 60X range of magnification from roll form negatives. PAR 224, 3X - 15X Fluid Gate Enlarger, was authorized for similar studies and for breadboard hardware to aid in the design of an enlarger to provide 3X to 15X magnification from 70mm square portions of roll negatives and prints up to 40 x 40 inches on cut-sheet stock. Both of the requirements

applied to either black-and-white or color prints. As the work on the two projects progressed, it became apparent that a single basic enlarger frame with a series of interchangeable lens and condenser sets would meet both requirements. The two projects were therefore combined, and a single breadboard unit was built and tested. When that effort was completed, a proposal for this project was submitted. Instead of a written final report on the breadboard effort, a verbal report was made to three groups of customer personnel concerned. Information on those projects is presented below as background for better understanding of this project.

DISCUSSION

5. The Design Study (PARs 202/224, Briefing Print Enlarger/3X - 15X Fluid Gate Enlarger). The purpose of these projects was to provide an enlarger having a negative handling system, a high-performance specular optical system, and a glass-sandwich fluid-wetting negative gate similar to the ones on the 10-20-40X Precision Enlarger but with the extended capability of exposing larger prints over a continuously adjustable range of magnification. Design concepts were developed to balance the performance of the various parts of the system and to match the system performance to the needs of the user. Fabrication and testing of the breadboard model permitted practical evaluation of its performance. The experience gained in operating the breadboard model was very useful in refining the prototype design for this project (PAR 243A) for better dependability and operator convenience.

6. The Optical Design. To obtain 20- x 24-inch prints with an instrument of reasonable size, the field-angle coverage of the objective lenses was increased over that in the 10-20-40X Precision Enlarger. For a given focal length in a lens design, increased field-angle coverage is normally obtained at the expense of decreased performance on the lens axis. It appeared that lenses having an axial performance somewhat less than the lenses in the 10-20-40X Enlarger would preserve the information present in

the most sophisticated aerial photography currently available. It therefore appeared reasonable to attempt the design of lenses with wider fields. In the design study, a semifield coverage of $18^{\circ}$ to $20^{\circ}$ was decided upon for the lenses. With this angular coverage a 20- x 24-inch image is provided with a negative-to-easel (OAC*) distance of 50 inches. By providing 30 inches range of easel movement, to obtain OAC distances of 50 to 80 inches, the desired range of 3 to 60X magnification for the combined PAR 202/224 requirement was available with a family of six objective lenses.

a. The system was designed for a glass-sandwich-type negative gate, with index-matching fluid wetting of negative-glass interfaces, and specular illumination. A condenser lens system was designed for each of the six objective lenses to slightly under-fill the objective apertures with the image of the projection lamp filament.

b. Since prints made at any magnification will be viewed under similar conditions, the family of objective lenses was designed to provide approximately equal image sharpness at the print. The effective exit-pupil diameter (and therefore the diffraction pattern size at the print) was made about the same for each of the six lenses of the set.

c. In the optical design of the objective lenses, initial effort was upon a family of lenses which would expose color-blind print stock through a narrow-spectrum-band blue filter. For this family of lenses, the exit pupil was 0.6-inch diameter in the four lenses for magnification values up to 25X and the exit pupil diameter in the remaining two lenses was 0.45 inch. The Rayleigh criterion predicted 13 to 20 cycles/mm limiting resolution at the print (for diffraction-limited lenses) with 80 inches OAC. In the statement of design goals to the lens designer, it was requested that 90 percent of the computed rays fall within:

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* Over-All Conjugate

(1) A circle equal to the diameter of the first minimum of the diffraction pattern to $6^{\circ}$ off axis,

(2) A circle twice that diameter to $12^{\circ}$ off axis, and

(3) A circle four times that diameter to $18^{\circ}$ off axis.

Lenses meeting these requirements could be expected to produce prints from "perfect" negatives which appear excellent under unaided visual observation or when considered as copy for photomechanical reproduction.

d. The second effort in designing objective lenses for the BPE was on a family of lenses to expose color print materials with narrow-band, tri-color printing filters. The exit-pupil diameters were specified as two-thirds of those for the color-blind print material, with the same type of specification for concentration of the computed rays. As this effort progressed it became evident that most of the color-corrected family of lenses could, with minor changes, also meet the goals stated for the narrow-band, blue-light lenses.

e. A third effort was initiated to design "combination" lenses which could meet both sets of design goals. This was achieved for the five lenses of the family providing magnification up to 40X. Two different lens designs are required to meet the goals for the 40X to 60X magnification range. Because of the image quality in current and expected color original films, it did not appear likely that color enlargements over 40X will be required from the BPE. The 40X to 60X lens corrected for blue light only was established as the sixth member of the family of lenses.

7. <u>The Enlarger Arrangement</u>:

a. Studies of the enlarger arrangement were made concurrently with consideration of field angle coverage and film-to-print distance for the optical design. The 50 to 80 inches optical length was too great for a straight vertical axis design because of limitations in head-room and the inconvenient means for operator access to the negative and print stock ends of the system. Various folded-optical-path systems were considered but offered little reduction in size of equipment. The straight-horizontal-axis arrangement was chosen since it appeared to offer the most convenience to the operator and had the simplest mechanical construction.

b. The major mechanical requirements to be considered in designing the equipment were:

(1) Image quality in the prints must not be degraded either by building vibration or by vibration generated in the instrument itself.

(2) The following must be provided:

(a) A safe, rapid-handling system for finding a given image area in a large negative roll on the basis of frame number and image coordinate description, and placing it in the negative gate.

(b) A convenient means for print stock handling.

(c) A means of setting the lens focus accurately for any chosen magnification in the available range.

(d) The capability for exposing both black-and-white and color prints.

(3) The instrument must be convenient, dependable, and safe for use in critical, high-production operations.

c. It was, of course, necessary to develop one design concept to meet all of these requirements. This arrangement concept, as developed in the study, is shown schematically in Figure 1. Important features of the enlarger design concept are:

(1) <u>Vibration Control</u>. The print stock easel and its carriage, the objective lens, and the negative gate are mounted on the optical frame to form an assembly of high rigidity. To prevent image degradation that results from vibration, there must be no relative motion between the image projected from the negative gate and objective lens combination and the print stock held on the easel face during exposure.

(a) The effect of external vibration (or shock from the building) was eliminated by supporting the optical frame on shock mounts which are soft enough to filter out the high-frequency part of the external vibration which might excite resonance in the assembly on the optical frame. This assembly must be quite rigid to ensure that it has no low resonant frequencies. In the BPE, the optical frame assembly was designed to eliminate any resonant frequencies below about 70 Hz, and it is supported on shock mounts that provide resonant frequency of 15 Hz or less.

(b) Vibration in the assembly on the optical frame caused by sources within the enlarger must also be avoided. Precautions taken in the design to prevent such vibration are:

1. No motor or solenoid on the optical frame operates during the time of an exposure.

2. The exposure is started and ended by turning the lamp on and off; there is no mechanical shutter.

(2) Negative Handling. A proposed requirement for the BPE was the production of single prints from various image areas in roll form negatives having no more than one or two of the image areas in a given negative roll. In this kind of operation, handling of the negative rolls takes a substantial part of the total time required to produce the prints.

(a) The concept for the negative transport was based on designs the contractor's organization had produced for motorized re-spooling tables under other contracts. In these designs, the film-spool drive spindles are powered by a-c torque motors to which variable voltages are supplied from a gang of variable autotransformers. Manual rotation of the autotransformer shaft will simultaneously reduce the voltage supplied to one torque motor, thus reducing its torque output, and increase the voltage supplied to and the torque produced by the other. Manipulation of the autotransformer control will therefore cause the film to (1) wind in either direction between the two spools at adjustable speed or (2) remain stationary.

(b) Considerable speed and operation convenience is gained by providing spindle brakes to stop and hold the film at a chosen place. The spindle braking must be done carefully to prevent cinching, excess tension, or production of a slack loop in the film. In the re-spooling-table designs, a prony brake arrangement was used to brake the supply spool moderately and the take-up spool lightly for either direction of winding. To reduce the size and weight in the BPE transport, it was decided to substitute commercial electric brakes (magnetically applied friction brakes) for the specially built prony brakes of the original system. A system of varying the brake torques (by varying the brake coil voltages) in relation to the voltage applied to the torque motors was proposed.

(c) A film-driven, metering-roll mechanism to measure the along-the-film coordinate (X coordinate) was proposed. This mechanism concept featured the capability to survive high-speed slewing of the films and low frictional drag.

(d) The film transport arrangement permits the film web to be moved in the direction of its width over an incorporated viewer for observation and to position any point on the film width at the objective lens axis. Each of the film spindles is carried on a separate slide assembly. Each of the slide assemblies is driven by a lead screw coupled by toothed belts to their common drive motor to preserve the alignment between the spindles that is necessary for good film tracking.

(3) Print Stock Handling. In the first discussions on the 10X to 60X enlarger project (PAR 202), use of a roll holder for the print stock was considered. Studies which were made on problems of vibration control with a roll-holder system for the 20- x 24-inch prints indicated serious problems. Discussions of operational requirements revealed that there is often an urgent need to have a single print from a specified image as quickly as possible. Use of cut-sheet print stock along with suitable print processors could provide the quick response capability

conveniently. The 3X to 15X enlarger project (PAR 224) required a 40- x 40-inch easel area for 15X enlargements from the 70mm square negative area. With the proposed optical system, each of the four higher-magnification lenses of the family of lenses could expose 30- x 40-inch prints at the 80-inch OAC setting. This would make the large easel face required for the 3X to 15X enlarger (PAR 224) valuable for the 10X to 60X enlarger (PAR 202) also. It was therefore decided to develop a 40- x 40-inch easel for cut-sheet print stock to satisfy the requirements of both enlargers. This decision was the final step which permitted the two enlarger development programs to be combined.

(a) The horizintal optical axis of the enlarger and the corresponding vertical easel face made vacuum holding of print stock sheets very desirable. A rough breadboard model had shown the feasibility of using a turbine-type vacuum pump (or blower) to produce a pressure drop of about 0.5 psig through an easel surface made up of a grid of 0.06-inch-dia holes with one-inch spacing. A pressure drop that small is adequate to hold sheets 4 x 5 inches and larger (which are not curled) and the pressure/flow rate characteristics of available commercial blowers permits the holding of any size sheet from the smallest to one covering about 80% of the easel surface with nearly the same pressure drop at the easel surface. A major advantage of the system is that any size sheet may be placed at any position on the easel face without any need for adjusting the manifold control valves. To provide this convenience, approximately 2.5 horsepower is required to run the blower and a low noise level is present. Neither of these is believed to be unreasonable in this project.

(b) Curled print stock is a difficult problem for any vacuum holding system unless the edges can be mechanically held in contact with the easel surface. In this easel, a number of semi-rigid strips are laid over the lifting edges of the print stock and are held against the easel surface by the vacuum.

(4) The Lens-Easel Focus System. A major problem in making high-definition enlargements is to assure that the focus setting of the objective lens is accurate. Because the adjustment of the focus to best visual sharpness was much less precise than necessary, both mechanical and electrical analog autofocus systems were considered but rejected for lack of precision. The focus control system which was recommended after study uses an independent manual setting of the easel position and of the lens focus position using calibrated scales. The corresponding easel and lens settings are read from a numeric table.

(a) The easel position is controlled and measured by a ball-nut, lead-screw drive. By restricting the easel position to a discrete number of points spaced 0.2-inch apart over the 50- to 80-inch OAC range, the table provides a lens focus setting for each position. The 0.25 to 0.4 percent steps of magnification change available with this arrangement are small enough to be a practical equivalent of "continuously variable magnification".

(b) Experience with the 20X Enlarger and the 10-20-40X Precision Enlarger indicated that lens focus position should be controlled to a precision of about 0.0002 inch for the higher magnification lenses of the BPE lens family. The interchangeable lens assembly design from the 10-20-40X Precision Enlarger consisting of one negative gate glass objective lens and focus mechanism was adopted for the BPE. The design was modified to display the focus setting on a three-dial mechanical counter.

(c) As a further aid in setting lens focus, the table of corresponding values is mounted in an assembly coupled to the easel carriage drive to display only the lens focus setting which corresponds to the existing easel position.

(5) The Fluid Gate:

(a) The fluid gate arrangement as used in the 10-20-40X Precision Enlarger was thought desirable for the BPE. In this arrangement, the negative is clamped (using spring pressure) between two glass plates to

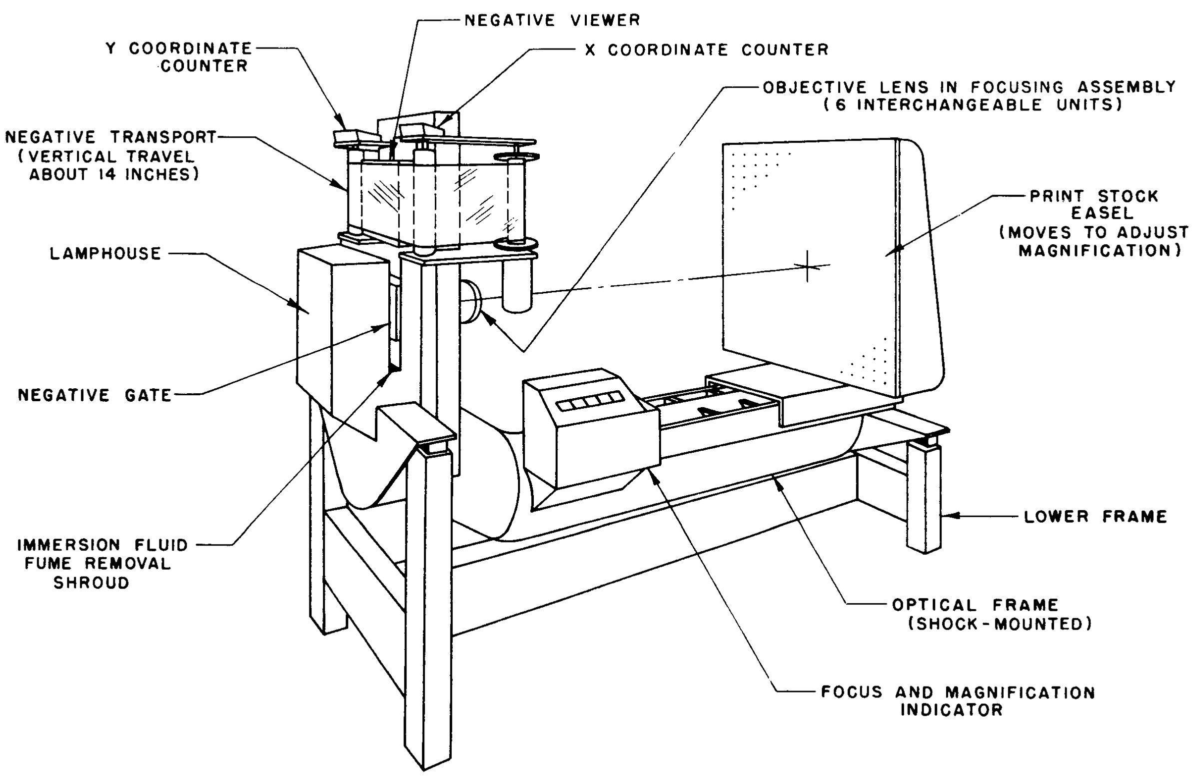



Figure 1. Enlarger Arrangement Concept from the Design Study

maintain flatness and focus position. A small quantity of refractive-index matching fluid (tetrachloroethylene) is injected between the film and glass surfaces (on both sides of the film with the gate open to provide a clearance of 0.03 to 0.06-inch) before closing the gate.

(b) The horizontal optical axis of the BPE and the corresponding vertical gate plane created a problem in holding enough of the injected fluid in the gate area to achieve full-area wetting as the gate closed. The design that was proposed for the vertical fluid gate is shown schematically in Figure 2. The important difference is the open Vee condition with a line contact between the bottom edges of the gate glasses and the film at the time of fluid injection. Surface tension holds a quantity of fluid in the bottom of the gate which is spread upward through the gate area upon closing.

(6) <u>Black-and-White or Color Exposure Capability</u>:

(a) The color exposure procedure chosen for the BPE provides for making exposures through red, green, and blue filters in sequence. An automatic operating sequence was proposed in which the filters are positioned one after another into the optical path for a timed exposure through each. Color balance control by operating the printing lamp at a different voltage level with each filter was also proposed. This would be achieved by providing three variable autotransformers each one capable of being connected to power the printing lamp with one of the three filters in the optical path. A single timer would control the exposure through each of the filters. In addition to controlling the color exposure sequence, the BPE controls would provide for a single exposure through the blue filter to achieve the narrow-band, blue-light exposure proposed for best image sharpness when the lenses for black-and-white print exposure are used. Extended exposures with switch control of the lamp's operation was proposed for use in set-up operations.

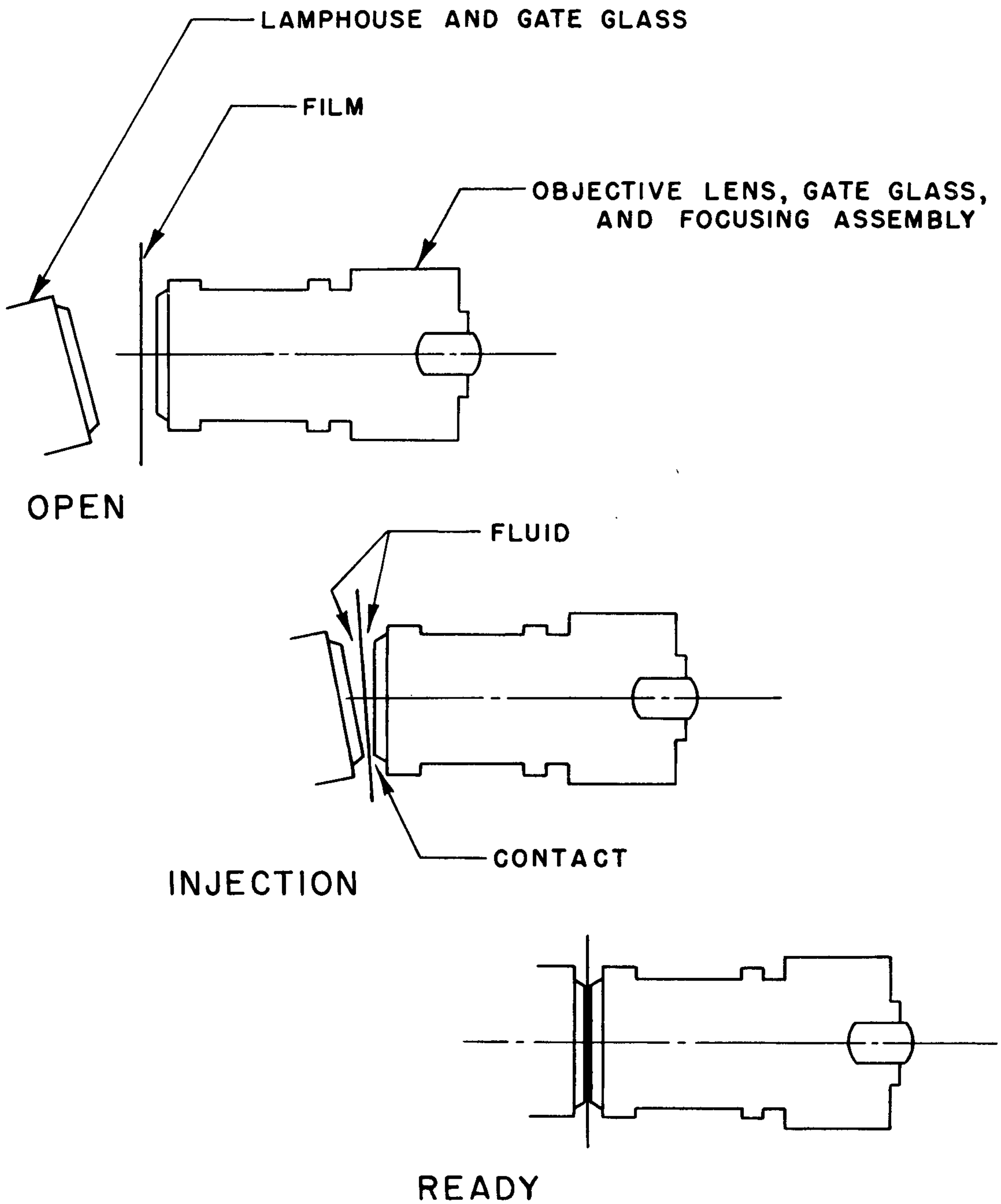


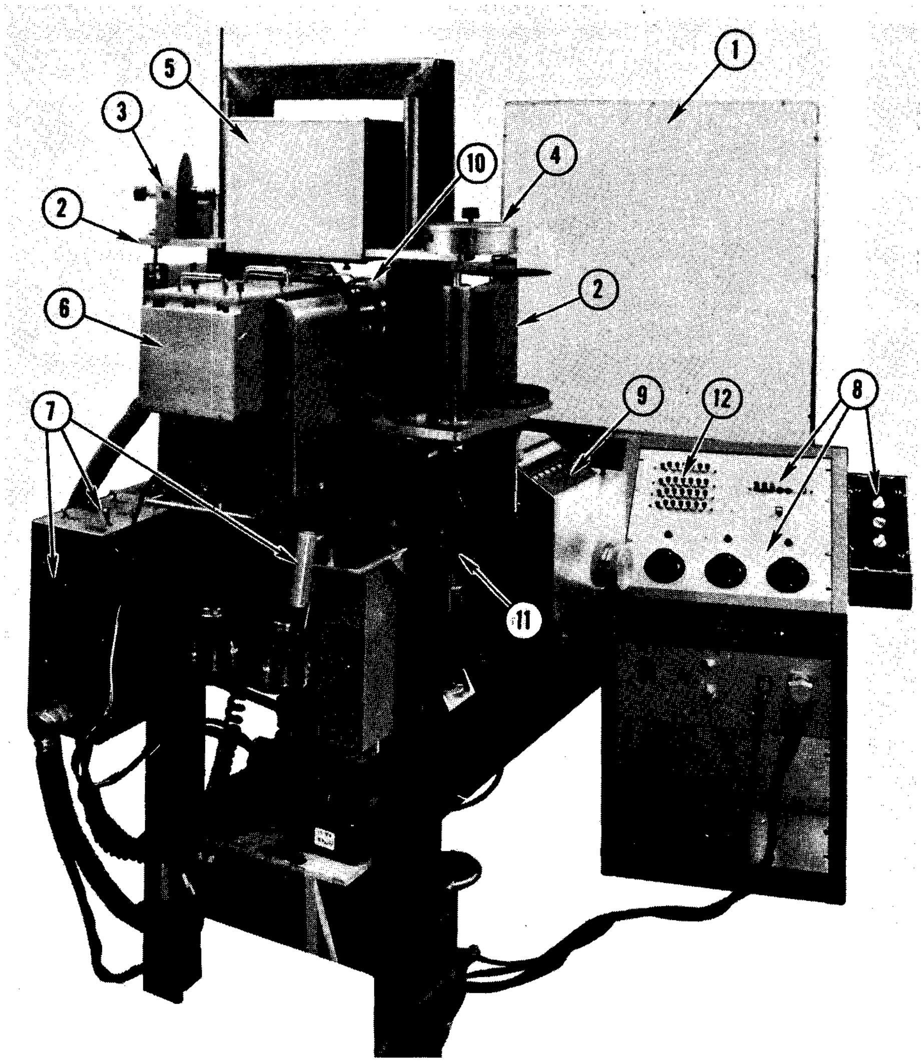

Figure 2. Vertical Fluid Gate

(b) The color filters were placed in the optical path between the lamp and the negative gate to prevent either (1) degradation of the image-forming beam or (2) lateral shift in the tri-color exposure from manufacturing imperfections in the filters.

8. The Breadboard Model (PAR 202/224):

a. In the course of the design study, certain parts of the proposed design were designated for breadboard testing. Models of the negative transport and of the vertical plane fluid gate were started early in the design study program. The performance of the new lens designs could best be evaluated by using them to make enlargements. To obtain meaningful results from such lens tests, a test bed much like the optical frame of the proposed enlarger was required. A breadboard model of the complete enlarger would provide a test bed for the sample lenses. Such a model would also permit evaluation of other features of the design proposal such as the rigidity of the optical frame, suitability of the focus control system, the performance of the print stock vacuum easel, and the convenience of the enlarger arrangement.

b. Figure 3 is a photograph of the breadboard model of the enlarger built under PAR 202/224 to test the new lens design samples and various mechanical designs and arrangements. The design principles used in the breadboard model were those described in the discussion of the design study above. In the course of the design work, two desirable innovations were conceived and incorporated in the model. The first innovation involved (1) use of an automatic computer to prepare the Focus/Magnification Table, (2) design of the table display unit (Figure 3, Item 9) and (3) use of the computer-data-output scroll as the table display copy. The second innovation was the incorporation of a commercial photoelectric photometer which permitted printing lamp intensity and exposure time to be pre-set. In the breadboard model, the photometer was arranged to measure irradiance in an 8-inch-diameter section of the image projected upon the print stock easel. Classification controls similar to those used in commercial color printers were incorporated in the output circuit of the photometer (Figure 3, Item 12).




1. Vacuum print stock easel
2. Negative transport
3. Y-coordinate counter
4. X-coordinate counter
5. Negative viewer
6. Lamphouse
7. Negative transport controls
8. Print exposure controls
9. Focus and magnification table display unit
10. Interchangeable objective lens assembly
11. Optical frame shock mount (one of four)
12. Photoelectric photometer classification controls

Figure 3. Breadboard Model of BPE (PAR 202/224)

9. Performance of the Breadboard Model (PAR 202/224). In October and November 1965, focus calibration and performance tests were made on the breadboard model enlarger. High-contrast resolution targets having the USAF 1951 format with spatial frequencies in the 80 to 800 cycles/mm range and having clear lines in a high-density background (more than 2.0) were used in focus and quantitative performance tests. High-quality, original-negative aerial photographs (made on Kodak High Definition Aerial Film, Type 3404 and having an estimated resolution of 80 to 90 lines/mm on the film) were also printed on Kodabromide paper to provide practical samples of the enlarger's performance.

10. Focus Calibration and Performance:

a. Focus calibration was performed by measuring the best focus setting at each of the three easel positions for each of the six objective lenses. A photographic focus series was made at each position (Wratten 96 filter, blue, and Fine Grain Positive Film print stock), and the prints were examined to find the focus setting in the series which produced the best edge-sharpness in the image. This data, combined with other measurements on each of the lenses made on a visual lens test bench, was used as the input for a computer program to generate the focus/magnification table for the enlarger.

b. A series of test prints was made of the high-contrast resolution target for five easel positions for each lens, on axis, using the lens focus settings predicted by the computer run. These prints showed resolving power equal to that observed for the optimum focus position in the focus calibration measurements. Table 1 shows the measured field coverage of the six lenses and the observed axial resolving power (high contrast) for the sample lenses compared to the diffraction limit of resolving power (Rayleigh criterion) for the relative aperture of each lens and the wavelength of the light used.

Table 1

BPE Lens Performance with Blue Filter (Wratten 98)

| Lens | Magnification Range Min | Magnification Range Max | Field Diameter of Negative (Inches) | Observed Axial Resolving-Power High-Contrast (Cycles/mm) | Diffraction Limit of Resolving Power Rayleigh Criterion (Cycles/mm) |
|---|---|---|---|---|---|
| A | 2.95X | 5.24X | 3.9 | 89 | 98 |
| B | 4.75X | 9.04X | 3.8 | 127 | 160 |
| C | 8.46X | 14.7X | 3.8 | 226 | 260 |
| D | 14.5X | 24.4X | 2.15 | 360 | 422 |
| E | 24.1X | 39.6X | 1.29 | 452 | 510 |
| F | 37.7X | 61.5X | 0.82 | 640 | 782 |





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(1) Demonstration Prints. A set of 18 black-and-white demonstration prints was made on Kodabromide paper from a high-quality aerial negative. A print was exposed to show the full field coverage of each of the lenses at each of three positions of the easel (minimum, maximum, and mid-range magnification). Image quality appeared to be excellent over the entire field of each lens. The grain structure of the negative film (Kodak High Definition Aerial Film, Type 3404) provided the only edges sharp enough to indicate how well the higher magnification lenses of the series performed. The images of the grain structure were separated over the full field of the lenses with only a minor indication of astigmatism at the edge of the field with the E and F lenses. This set of demonstration prints was delivered to the customer at the time of presentation of the verbal reports on the PAR 202/224 project.

(2) Color Performance:

(a) High-contrast resolution-target images, (black-and-white as used above) were exposed with the A, B, C, D, and E lenses on high-definition panchromatic film (Type 3404) through the red, green, and blue filters proposed for color printing. The resolving power observed in the blue-filtered images was essentially equal to that observed in the tests exposed on the color-blind Fine Grain Positive Film. The resolving power in the green-filtered images was less than that in the blue-filtered images, and that in the red-filtered images was still less than that in the green-filtered images. The loss of resolving power was closely proportional to the diffraction loss from the successively longer wavelength of the light transmitted by the green and red filters. The lens performance for color printing appeared to approach the diffraction limit also.

(b) In practical performance tests of color printing that were made about a year after the resolving power tests above, prints were exposed on SO 271 Reversal Print Film from a classified color original

(9.5 inches wide) on SO 121 Reversal Color Film. In test prints at 12X, 20X, and 40X, the color rendition appeared excellent, and the information content and edge sharpness appeared to match the image in the original film.

11. The BPE Prototype Design (PAR 243A):

a. The basic design which had been developed and the performance which had been demonstrated in the combined project PAR 202/224 was considered satisfactory, and the purpose of this project (PAR 243A) was to design, fabricate, and test a prototype enlarger based on that design.

b. In conferences between the contractor and customer personnel following tests and demonstration of the breadboard model, a list of design changes was agreed upon for incorporation in the prototype model. Some of the changes were to improve safety and convenience over the designs which had been used in the breadboard model to reduce cost. Other changes resulted from recognition of better arrangements after using the model. The changes formally agreed upon are listed below:

(1) Changes in the objective lens focus assemblies:

(a) To make the mounting and interchange mechanism quicker and safer to operate.

(b) To make the lens focus indication easier to read.

(c) To provide means for producing the correct lens-focus setting for projection through negative support material of various support thicknesses in addition to the emulsion-toward-the-lens condition.

(2) Changes in the negative gate and lamphouse assembly:

(a) To improve the mechanism for closing the fluid gate and to modify the fluid pump to deliver additional fluid needed to fill the large gate area.

(b) To provide a gate ventilation system to remove immersion fluid fumes efficiently, and provide for the collection of excess immersion fluid and its fumes.

(c) To provide means for evaporation and/or removal of the immersion fluid from the film after the negative gate is opened and before that section of film can be wound onto the roll.

(d) To use filtered air for efficient forced-air cooling of the lamp, condenser lenses, and color filters.

(3) Changes in the X- and Y-coordinate indicators to make them easier to read.

(4) Substitution of an easel spot-photometer for print exposure prediction instead of the broad area photometer system attempted in the breadboard model.

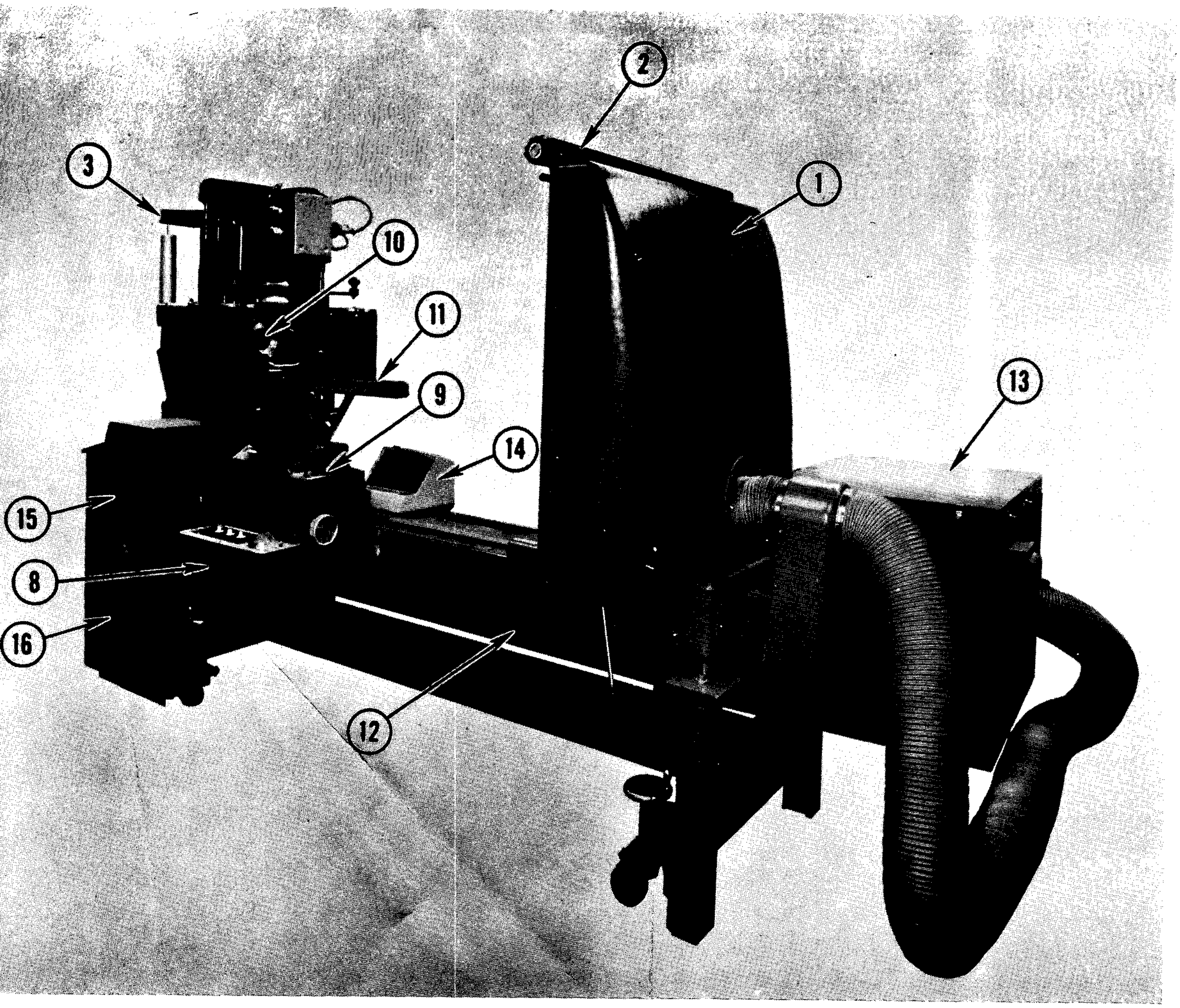
(5) Changes in the print stock easel to provide an opaque flat-white surface for use in making paper base prints and a black surface to use in making prints on transparent-base print stock.

c. In addition to the above specific design changes from the breadboard model, it was understood that the new design should (1) include changes to reduce the cost of fabrication of enlargers built after the first model, (2) present a finished appearance, (3) be easy to service, (4) have conveniently located operating controls, and (5) provide interlocks to reduce the possibility of damage to negatives.

d. Figure 4 shows two views of the completed Prototype Model BPE. By comparing them with Figure 3, Breadboard Model of the BPE, many of the design changes can be seen, such as elimination of the separate control console and improvement in the appearance of the unit over the breadboard model.

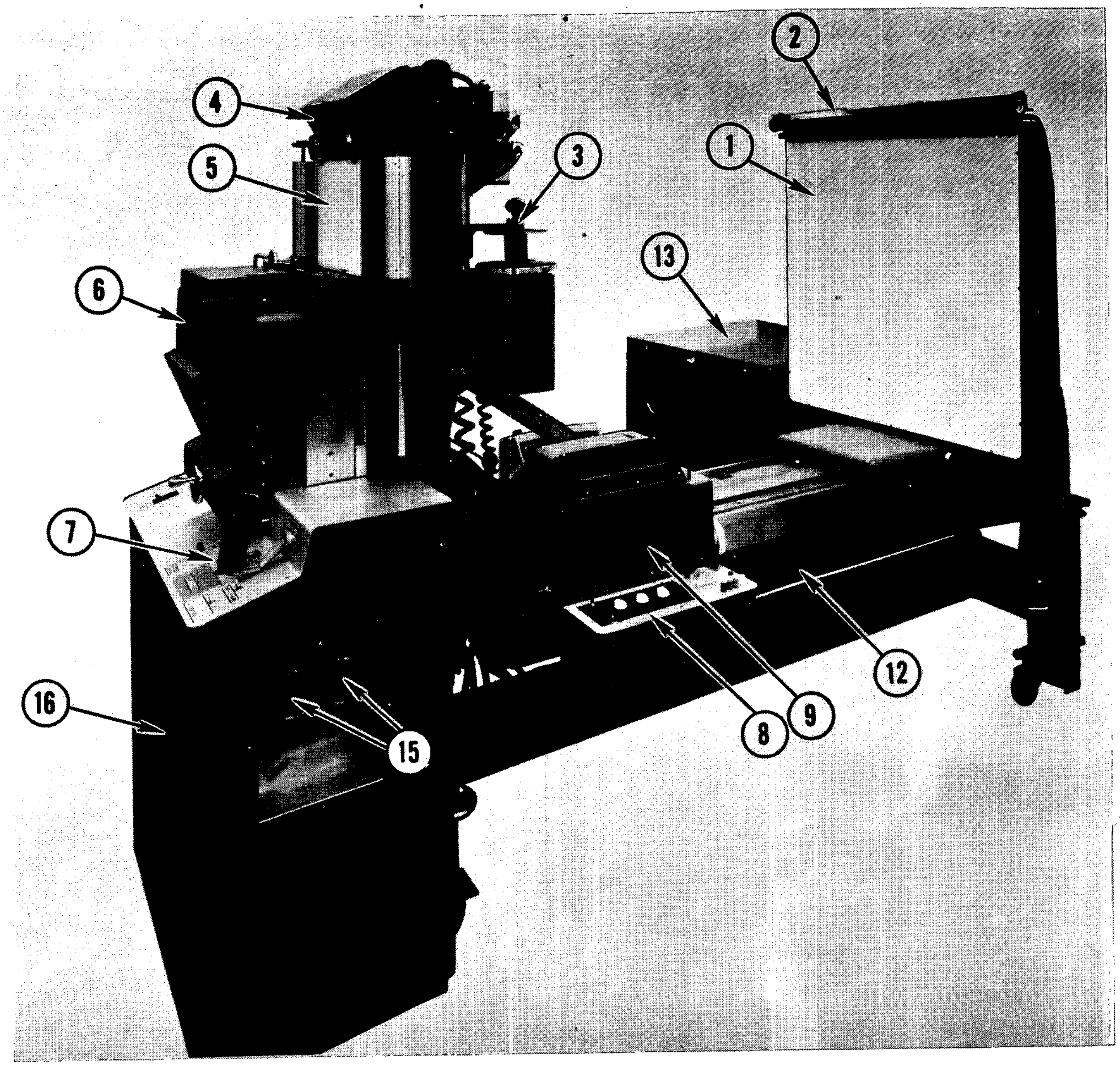
12. <u>The Objective Lens Focus Assemblies (see paragraph 11.b.(1) on page 19)</u>:

a. The new design for the objective lens focus assembly and the mechanism for interchange of the assemblies is illustrated in Figures 5, 6, and 7. A common carriage assembly design (Figure 5, Item 1) with two full-hand-size handles (Figure 5, Item 2) is common to all of the assemblies. In each carriage assembly there are a set of rollers (Figure 5, Item 7) and register pins (Figure 5, Item 8) used in loading or unloading and in locating the lens focus assembly on the enlarger. To install the lens focus assembly, it is placed on the loading ramp (Figure 6, Item 4)



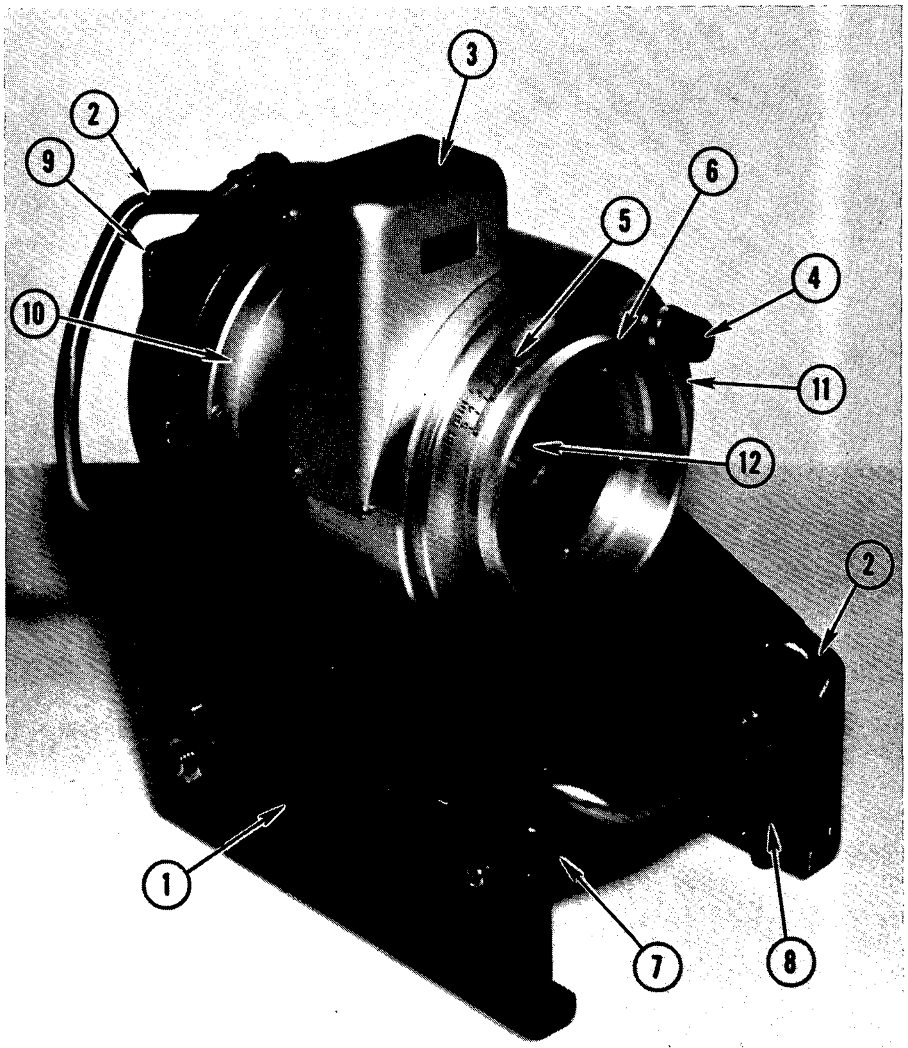

8. Print exposure controls (sub-control panel)
9. Focus and magnification table display unit
10. Interchangeable objective lens assembly
11. Loading ramp for objective lens assembly
12. Main optical assembly frame (on shock mounts)
13. Easel exhauster enclosure
14. Easel photometer meter unit
15. Fluid injection pumps and reservoir jars
16. Main electrical equipment cabinet

rototype Model BPE




1. Vacuum print stock easel
2. Dark screen pull-down cover for white easel face
3. Negative transport
4. Digital display for X- and Y-coordinate readout
5. Negative viewer
6. Lamphouse
7. Negative transport controls

Figure 4. T




1. Carriage assembly
2. Lifting handles
3. Focus indicator assembly (mechanical counter within cover is readable from the front of the assembly)
4. Focus shift control knob and locking collar
5. Focus shift scale
6. Knurled ring handle for lens focus adjustment
7. Roller for loading lens focus assembly (one of four)
8. Register pin for positioning assembly (one of six: four on bottom of rails, two on vertical surface below gate glass)
9. Gate glass assembly
10. Spacer sleeve
11. Focus thread assembly
12. Objective lens

Figure 5. Close-Up of One of the Interchangeable Objective Lens Focus Assemblies





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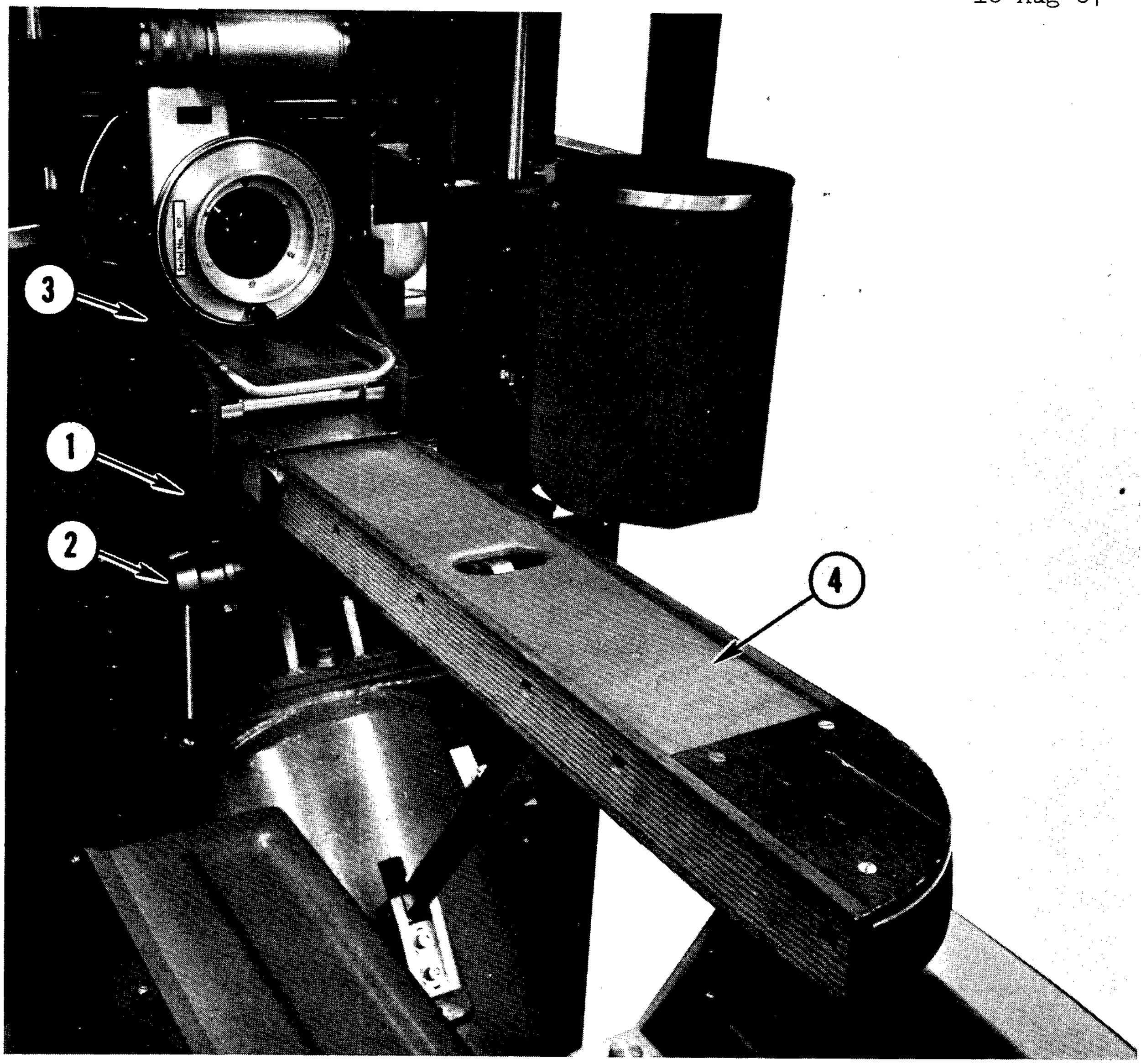
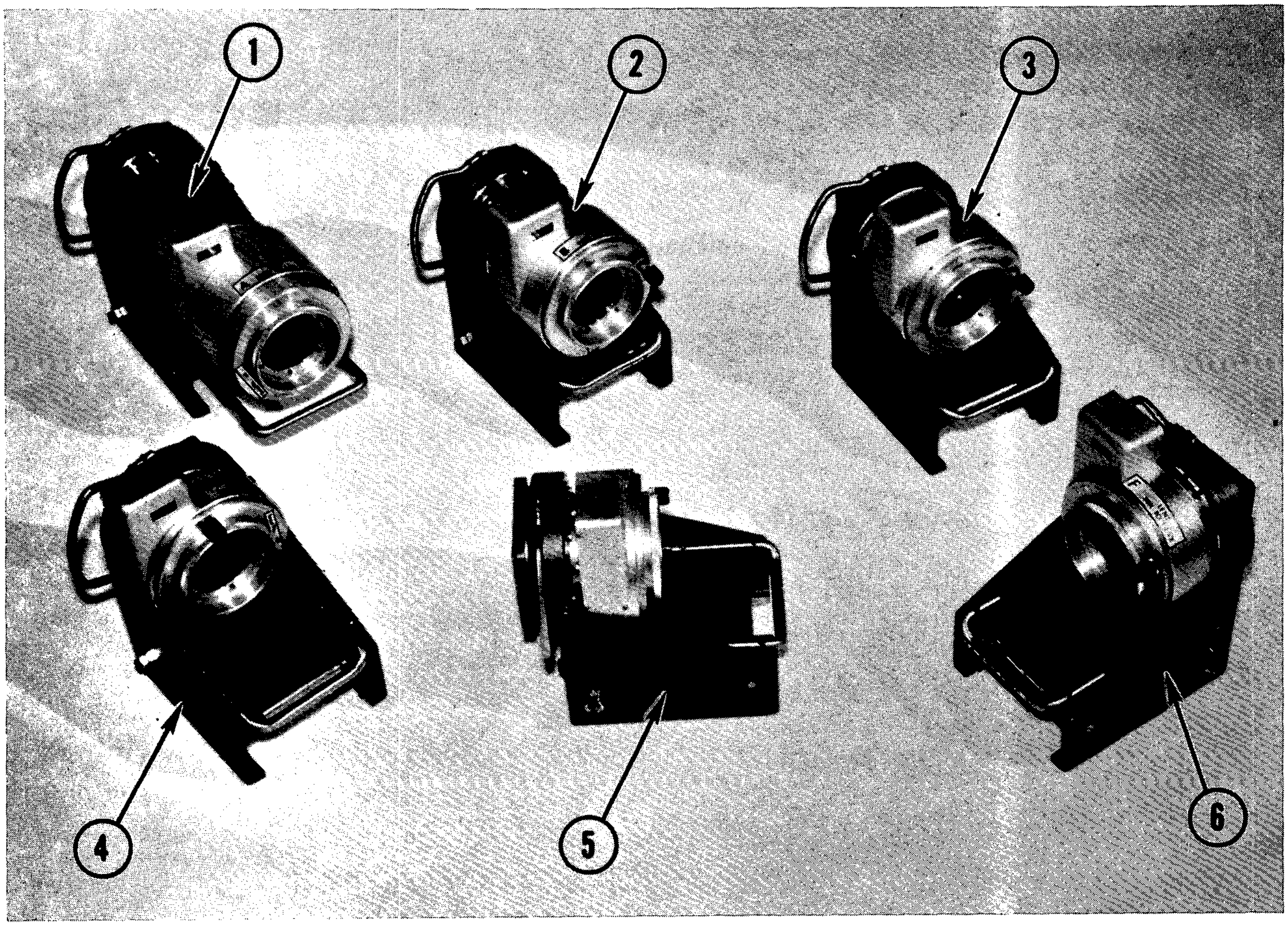



1. Support pedestal for lens focus assemblies
2. Locking lever for lens focus assemblies
3. Lens focus assembly
4. Hinged loading ramp (Can be lowered to clear beam projected from objective lens)

Figure 6. One of the Objective Lens Focus Assemblies Mounted on the BPE




1. Objective Lens A - 3.0 to 5.3X magnification
2. Objective Lens B - 4.8 to 9.0X magnification
3. Objective Lens C - 8.5 to 15.0X magnification
4. Objective Lens D - 14.5 to 24.7X magnification
5. Objective Lens E - 24.2 to 40.0X magnification
6. Objective Lens F - 38.0 to 62.5X magnification

Figure 7. The Six Objective Lens Focus Assemblies

manually, rolled along the ramp into position on the support pedestal (Figure 6, Item 1), and locked into position by moving the locking lever (Figure 6, Item 2) about 1/2 turn to the position shown. To lock the carriage into position, it is first lifted and four pins are pressed against the bottom surface of the rails on the support pedestal; the carriage is then moved along the track and two pins are pressed against the vertical reference plate on the end of the pedestal. The locking mechanism provides a spring-load of about 200 lb to hold the carriage against the register surfaces. The loading ramp is lowered so that it clears the beam of light projected by the objective lens. The lens focus assembly can be removed by reversing the steps in the above procedure.

b. Each lens focus assembly includes a gate glass (Figure 5, Item 2), the focus thread assembly, the mechanical counter focus indicator, and the objective lens. Each assembly is tested and calibrated; it is then used as a unit. This unit construction is the principal reason that the BPE can provide the focus accuracy necessary for making high-quality prints. The following two changes in the breadboard model were made in the design of this assembly:

(1) The focus indicator assembly was modified to make it readable from a position near the optical axis of the system, and

(2) An adjustable link was added in the coupling between the focus thread and the focus indicator to offset the lens focal plane to positions outside the surface of the gate glass.

c. In this design, the amount of focus shift is adjustable by a knob with a locking collar on the face of the assembly (Figure 5, Item 4), and its magnitude is indicated by an adjacent scale (Figure 5, Item 5).

d. The six assemblies for the prototype BPE are shown in Figure 7. The basic design and many of the individual parts of the six lens focus assemblies are the same. The differences among them are primarily in:

(1) The length of the spacer sleeve (Figure 5, Item 10).

(2) The range of focus adjustment.

(3) The amount of lens focus movement represented by each count of the focus indicator, and

(4) The absence of the focus shift adjustment in the "A" assembly.

The length of the spacer sleeve is varied to position the focus thread assembly to accommodate the various focal lengths of the lenses of the family. For the higher magnification lenses of the family (D, E, and F), the lens barrel design was made to permit positioning the optical elements from a common-mount shoulder position in the focus assembly.

e. The range of focus motion and the accuracy of focus position vary widely in the family of six lenses. To permit the focus for each lens to be set as rapidly and conveniently as possible, the lead of the focus thread and the coupling ratio between the focus barrel rotation and the focus indicator counter were made different among the assemblies. Table 2 shows the required range of focus adjustment, the focus movement per count of the focus indicator, the lead of the focus thread, and the amount of barrel rotation necessary to cover the range of focus adjustment for the various assemblies. The focus motion per count was selected so as to provide roughly three to six counts for the range of acceptable focus setting of each of the lenses. The range of acceptable focus settings for the lowest magnification lens assembly was found to be great enough that it is not necessary to adjust the focus setting for negatives mounted in the gate with the emulsion side away from the lens.

13. The Negative Gate and Lamphouse Assembly (see paragraph 11.b.(2) on page 19):

a. The new lamphouse design can be seen in Figure 4, Item 6; it is also shown in close-up views (both with and without the interchangeable condenser assembly in place) in Figure 8. The lamphouse is designed to move through a range of about two inches on a track roughly parallel to

Table 2

Objective Lens Focus Mechanism

| Lens Assembly | Nominal Lens EF (Inches) | Range of Focus Adjustment (Inches) | Focus Motion per Count (Inches) | Lead of Thread (Inches) | Range of Focus Barrel Rotation (Turns) |
|---|---|---|---|---|---|
| A | 10.66 | 2.252 | 0.002 | 0.200 | 11.3 |
| B | 7.17 | 0.713 | 0.001 | 0.200 | 3.6 |
| C | 4.80 | 0.246 | 0.000625 | 0.03125 | 7.9 |
| D | 3.06 | 0.090 | 0.0003125 | 0.03125 | 2.9 |
| E | 1.90 | 0.032 | 0.0003125 | 0.03125 | 1.0 |
| F | 1.24 | 0.013 | 0.00015625 | 0.03125 | 0.4 |



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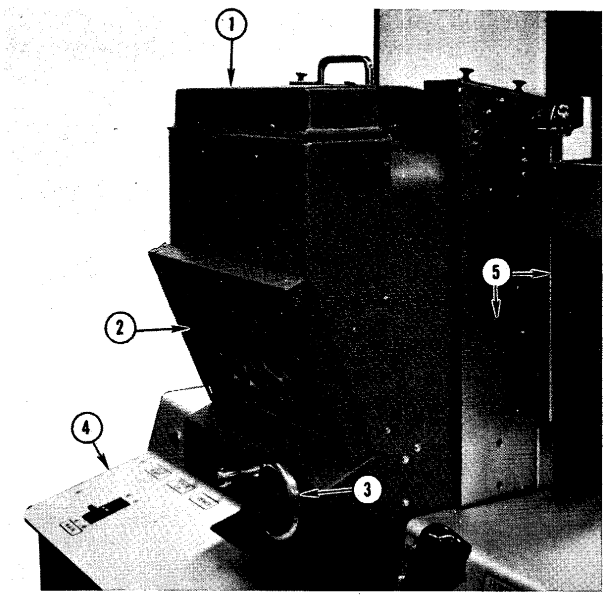
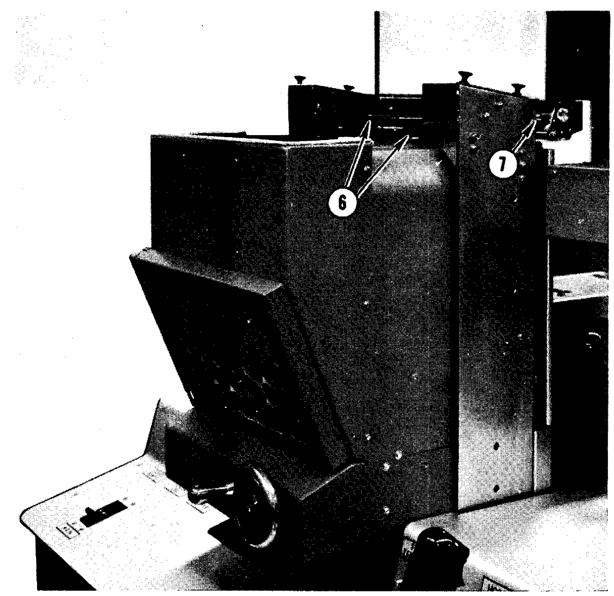



Condenser Lens Installed




Condenser Lens Removed

1. Condenser lens assembly
2. Air filter
3. Handcrank for moving lamphouse
4. Main control panel
5. Vapor shield
6. Nylon brushes for fluid removal
7. Heat lamp for fluid removal

Figure 8. Lamphouse with and without Condenser Lens

the optical axis of the objective lenses. Its motion is controlled by a crank arrangement through a gear reducer driven by the hand-crank (see Figure 8, Item 3).

b. The lamphouse portion of the negative gate is spring-mounted on the front of the lamphouse to provide the closing sequence illustrated schematically in Figure 2. The corresponding sequence for the gate on the prototype BPE is shown in Figure 9. In this design, the moving assembly which makes contact with the negative is of relatively low mass, thus reducing the possibility of impact damage to the film or to the gate glasses and restricting the force upon the film to essentially that produced by the springs.

c. The visible part of the system for removal of immersion fluid fumes and the collection of excess immersion fluid is the vapor shield (see Figure 8, Item 5). The space around the negative gate is enclosed by the shield except for the slot at the top and along the two sides for admitting the film web as it is lowered into the gate by the negative transport. Air is exhausted from the bottom of the shield enclosure by a blower having about 200 cu ft/min capacity and delivered to the building exhaust system to be carried outdoors. The continuous flow of air inward through the film slot, which combines with the normal downward flow of tetrachloroethylene fumes (the fumes are two to three times heavier than air), effectively prevents the fumes from escaping into the work area. Excess fluid from the gate and film drips into the liquid-tight bottom of the shield enclosure where it evaporates, its vapor being carried away by the exhaust.

d. Fluid is removed from the film after the negative gate is opened by evaporating it into the air flowing through the vapor shield. The negative transport is driven upward slowly, giving 15 to 25 seconds for the fluid to evaporate. A heat lamp with a 10-inch-long filament and operating at about 300 watts is mounted on one side of the film at the

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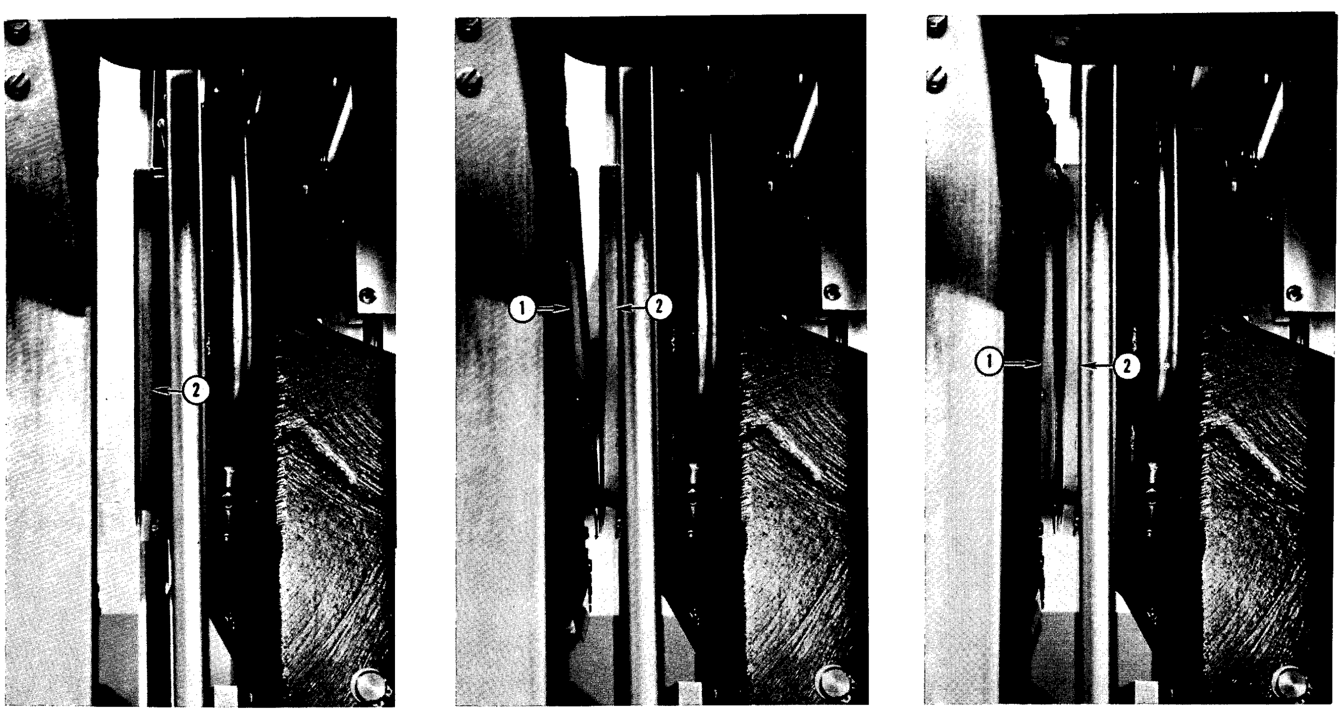


Gate Fully Open

Gate Ready for Fluid Injection

Gate Fully Closed

1. Glass plate spring-mounted to the front of the lamphouse
2. Glass plate mounted to the rear of the objective lens focus assembly

Figure 9. Negative Gate





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top of the vapor shield (see Figure 8, Item 7); its purpose is to raise the film and fluid temperature slightly to accelerate the evaporation rate. Some of the excess fluid from the negative gate forms a bead along the bottom edge of the negative web. In a normal printing cycle, there is sufficient time for that bead of fluid to evaporate before the negative is removed from the gate. However, a means of removing the bead of fluid was provided for the occasional unusual situation in which the negative web is removed from the gate immediately after fluid injection. Two long, nylon-bristle brushes (see Figure 8, Item 6) are provided, one on each side of the film; they are moved to contact the bottom edge of the film as the negative transport moves upward. The surplus fluid is removed into the brushes by capillary action except for a thin surface layer which evaporates in the normal manner. In some cases, complete removal of the fluid bead is not accomplished because it spreads along the film web beyond the ends of the brushes. It may therefore be necessary for the operator to wipe the bottom edge of the film if the gate is opened sooner than normal after the injection of immersion fluid.

e. A separate condenser lens and lamp assembly is provided for each of the six objective lenses discussed in the section on the optical system design study for the breadboard model. Each condenser and lamp assembly is mounted on a plate which serves as the top cover for the lamphouse. The six condenser lens assemblies for the BPE Prototype Model are shown in Figure 10.

f. Cooling of the lamphouse, condenser elements, filters, and lamps by forced air is accomplished using a flexible tube connected to the vacuum easel exhaust system to exhaust air from the bottom of the lamphouse. The air entering the lamphouse is passed through a filter (Figure 8, Item 2) and then upward through two ducts (Figure 11, Item 7) into the plastic cover of the condenser lens assembly (Figure 11, Item 3). That cover acts as a manifold to distribute the flow of air into slots in the mounting plate and downward over the condenser elements, filter

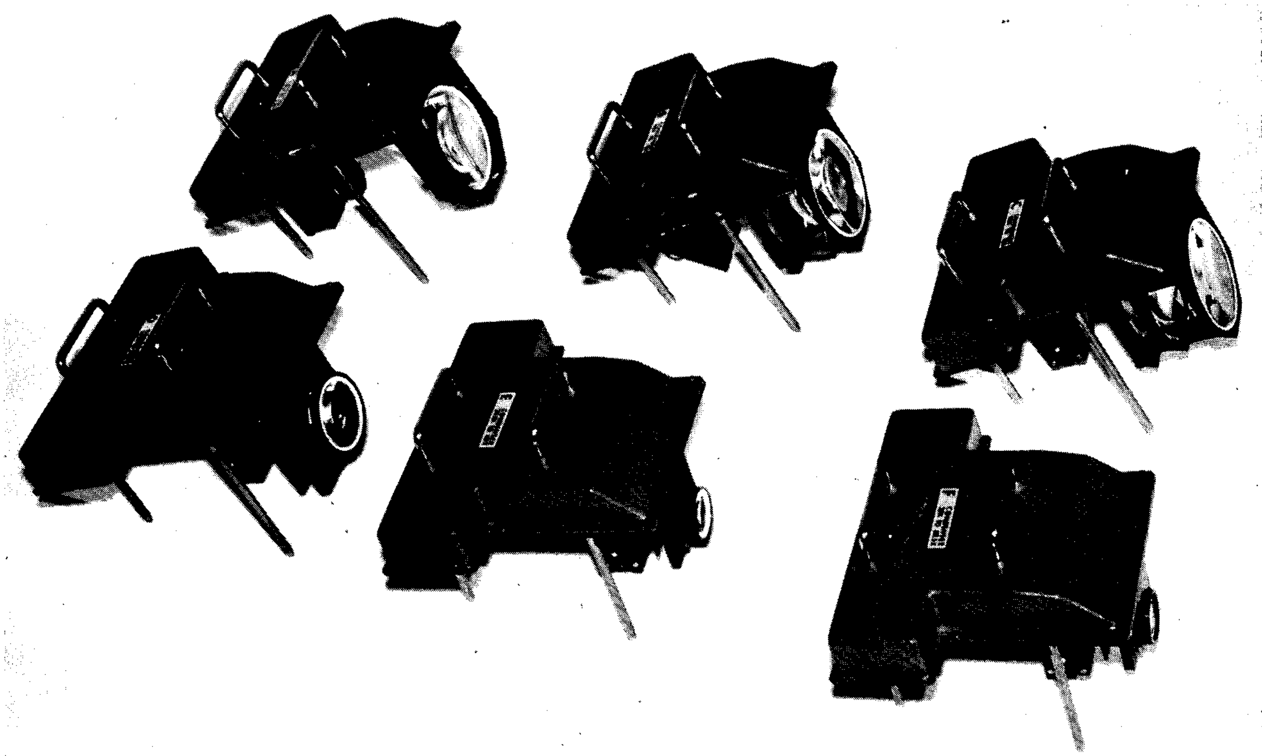
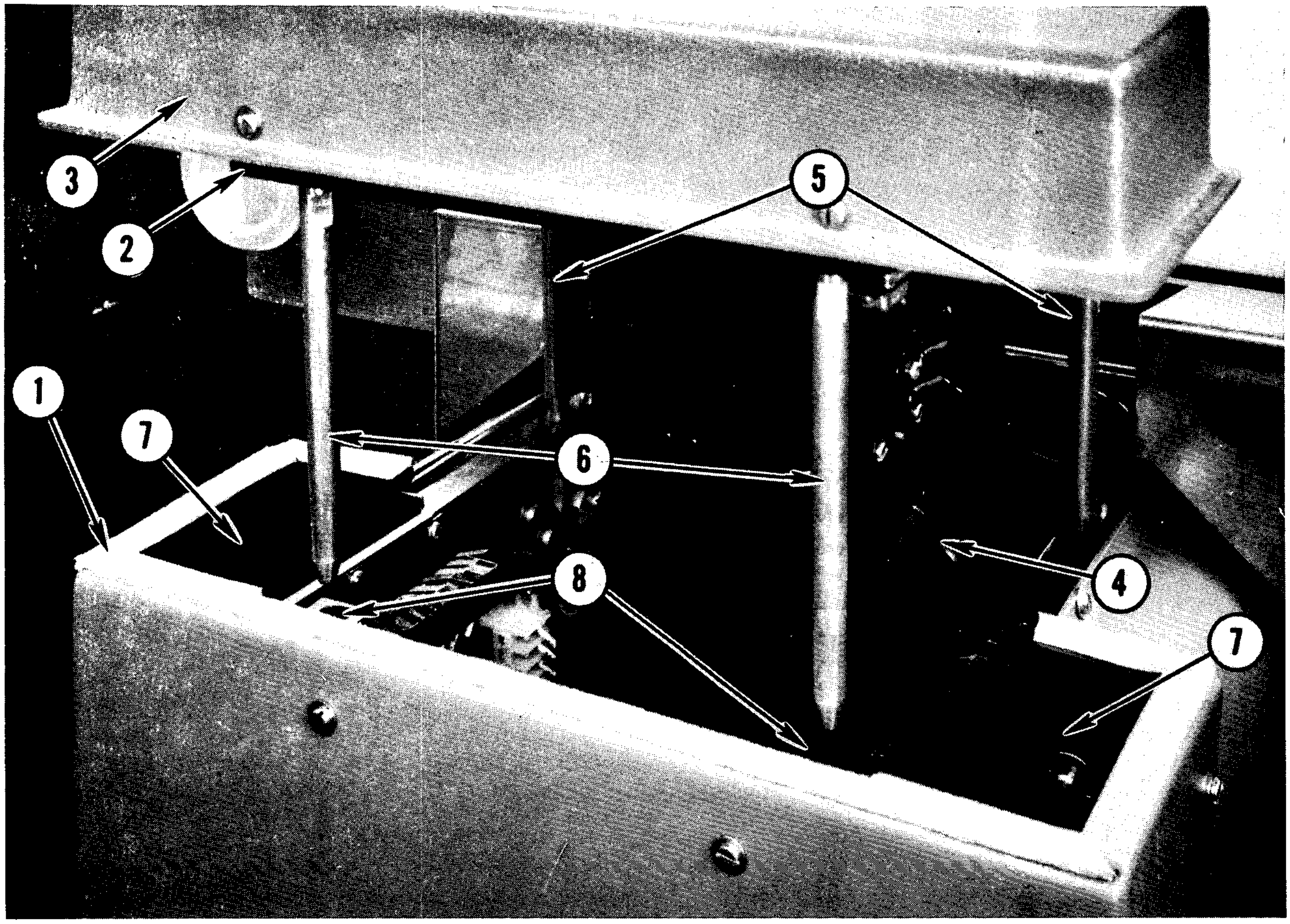


Figure 10. Six Condenser Lens Assemblies




1. Main body of lamphouse
2. Mounting plate for condenser assembly (lamphouse cover plate)
3. Ventilation air manifold of condenser assembly
4. Filter wheel assembly
5. Positioning rods for filter wheel assembly
6. Positioning rods for lamphouse cover plate
7. Ventilation air ducts
8. Sockets for positioning condenser assembly

Figure 11. Engagement of Condenser Lens Assembly into the Lamphouse

wheel and the lamp. Each mounting plate is cut out as required to guide the flow of air to the proper area in its particular assembly.

g. The filter position for each of the condenser designs is different with respect to the negative gate position. The filter wheel assembly is mounted on a ball bushing slide mechanism which permits it to be positioned to fit into the space provided in a given condenser assembly. Each condenser assembly has two pairs of guide rods which provide semi-automatic positioning of the filter wheel and the condenser assembly (see Figure 11). To lower a condenser assembly into the lamphouse, the two longer rods (Figure 11, Item 5) are inserted in the filter wheel assembly to align the filter wheel with the condenser optics. By lowering the condenser further, the two shorter rods (Figure 11, Item 6) can be inserted in matching sockets (Figure 11, Item 8) in the main lamphouse body.

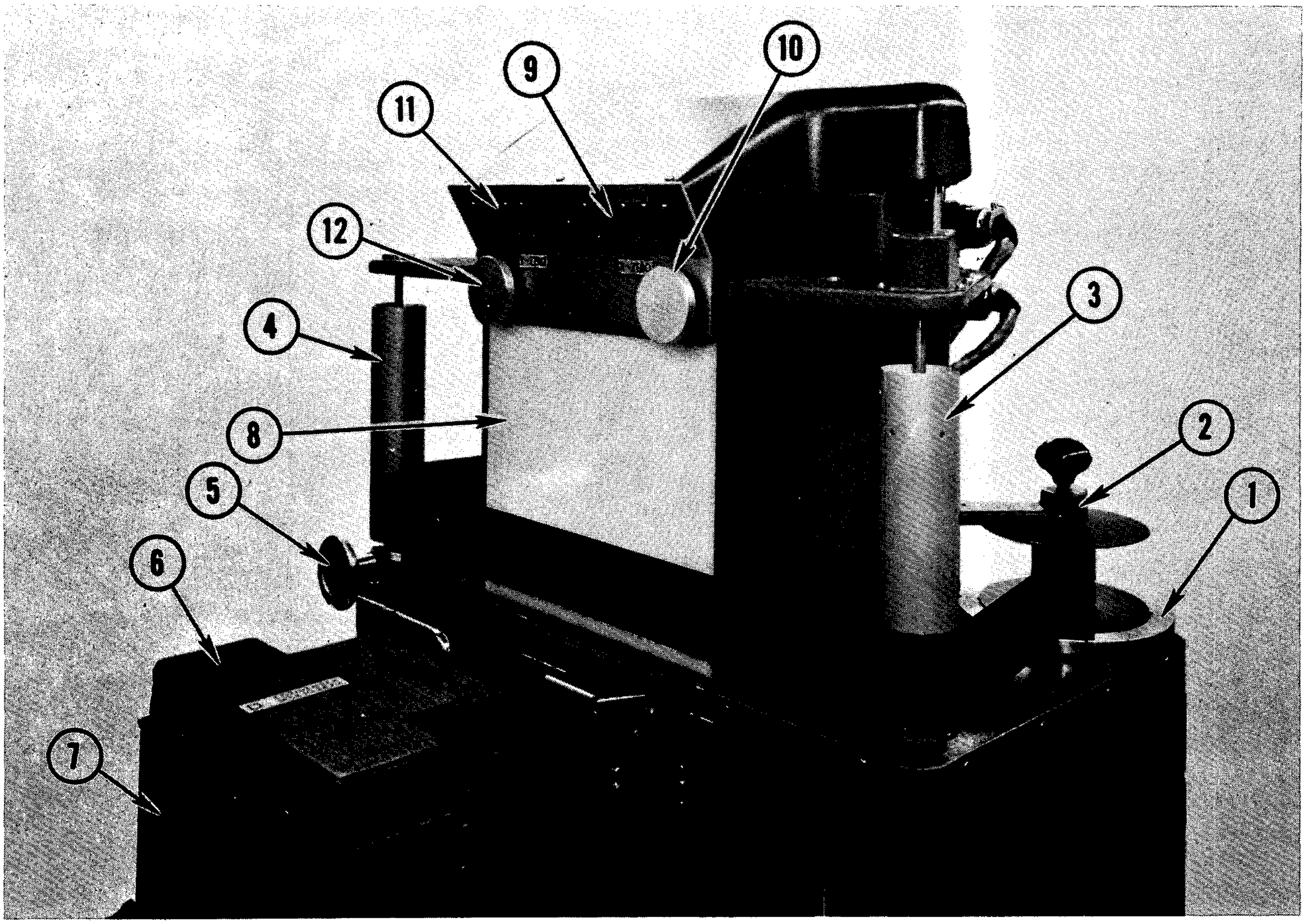
14. The X- and Y-Coordinate Indicators (see paragraph 11.b.(3) on page 20):

a. For the new BPE design, the cylindrical-scale system for the display of image-position coordinates in the negatives was replaced by analog-to-digital converters with digital-display projectors. The arrangement of the display units and the metering roller drive for the X-coordinate system is shown in Figure 12.

b. It was possible to provide digital display of the image coordinates in 3/4-inch-high numerals by minor adaptation of commercially available equipment. The adjustment of scale readings to correspond with fiducial mark locations on the film is accomplished by slip-clutches in the coordinate system drives.

15. Print Exposure Prediction (see paragraph 11.b.(4) on page 20):

a. The technique of projection print exposure determination (prediction) by photometry of a small spot in the image projected on the print stock easel is widely used in commercial and aerial photo labs. Since operators in the customer's laboratories were already skilled in this technique, it was agreed that the BPE should be so equipped to eliminate the need for training in another technique.




1. Film spool drive
2. Outboard film spool support
3. Metering roll for X-coordinate (horizontal) measurement
4. Idle spool in film transport
5. Manual adjustment knob for horizontal positioning of film
6. Interchangeable condenser assembly
7. Lamphouse
8. Film viewer
9. Digital display of X-coordinate
10. Zero adjustment for X-coordinate
11. Digital display of Y-coordinate
12. Zero adjustment for Y-coordinate

Figure 12. The Negative Transport, Film Viewer, and X-, Y-Coordinate Indicators

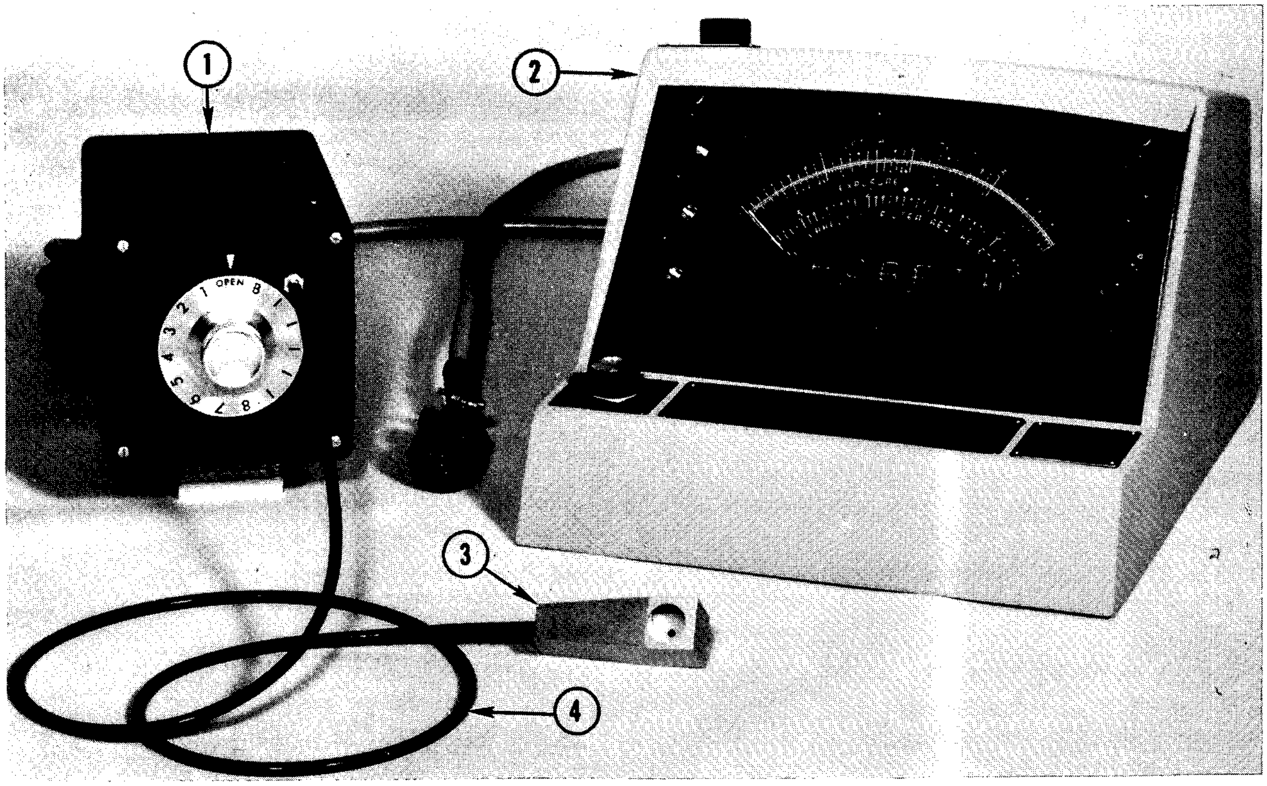
b. No easel photometer design was available which provided sufficient response for making color prints on the BPE with a suitably small aperture. Although the basic sensitivity of the Macbeth Color Analyzer, Model EP-1000 was found to be adequate, the transfer of energy from the probe aperture to the photomultiplier cathode was too inefficient. A breadboard model of an optical system which would improve the efficiency about 100 times was built and test results were satisfactory. The development of a special model of the Macbeth Color Analyzer——the Model 1000B——was subccontracted and the prototype model installed on the prototype BPE.

c. The special easel photometer assembly is shown in Figure 13. The probe assembly, Item 3, is placed in the projected image at the easel surface. The light which enters the 3mm-diameter aperture in that assembly is carried by the fiber optics bundle, Item 4, to the cathode of an end-on photomultiplier tube in the photomultiplier type housing, Item 1. This arrangement provides a low mass assembly for placement on the enlarger easel and allows the photomultiplier tube and its enclosure to be firmly mounted upon the enlarger. These benefits were of particular value for the vertical easel surface arrangement of the BPE.

d. Figure 14 shows the installation of the EP 1000-B easel photometer on the prototype BPE. The photometer meter box is positioned to make its scale readable by an operator standing at the sub-control panel (Figure 4, Item 8) where the exposure time and lamp intensity controls are located. Item 3 in Figure 14 shows the probe assembly mounted on a plastic adapter for holding it on the vacuum easel surface. The probe assembly is surrounded by a foamed elastomer ring to provide protection from accidental damage.

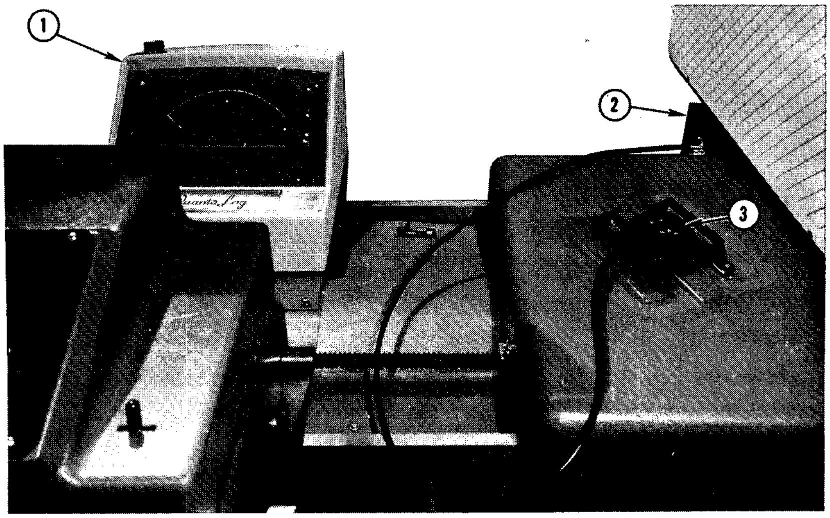
16. Print Stock Easel (see paragraph 11.b.(5) on page 20):

a. It is expected that the majority of the prints exposed on the BPE will be on paper-base stock. Tests and experience have shown that no serious flare effects arise in such prints from placing the print stock

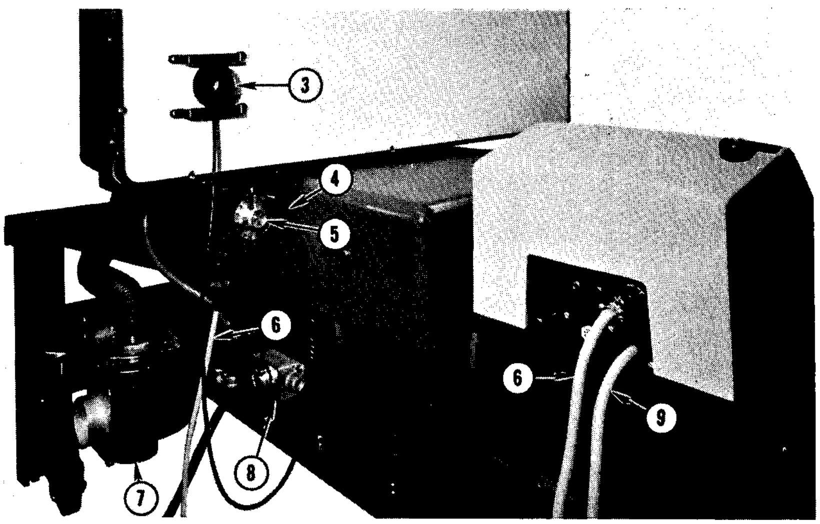



1. Photomultiplier tube housing
2. Photometer meter box
3. Probe assembly
4. Fiber optics bundle

Figure 13. Macbeth Quantalog Easel Photometer, Model EP1000-B




Front View




Rear View

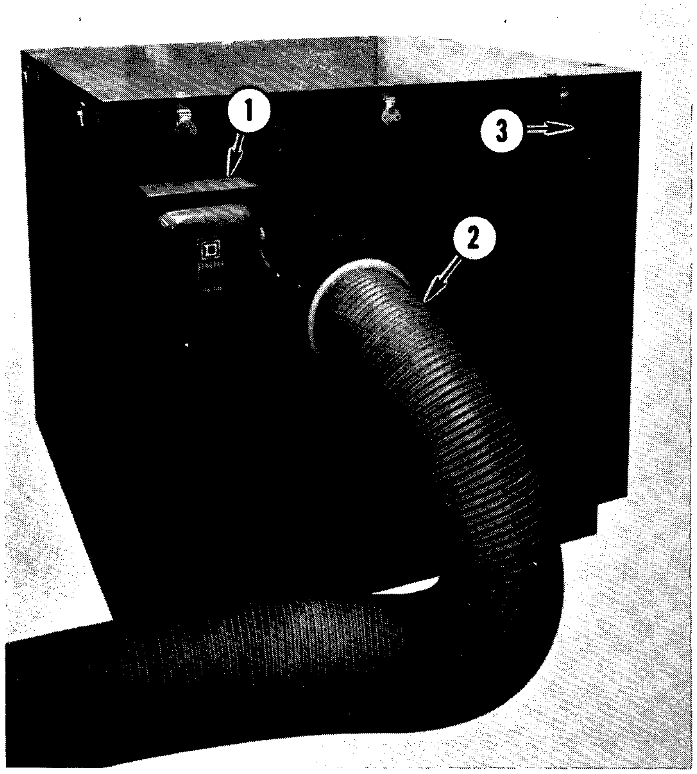
1. Photometer meter box
2. Photomultiplier tube housing
3. Probe assembly
4. Fiber-optics bundle
5. Filter selector knob
6. Cable connecting meter box to the photo-multiplier tube housing
7. Blower which exhausts vapor fumes from the negative gate
8. Receptacle for power cord of easel exhauster
9. Power cord for easel photometer assembly

Figure 14. Easel Photometer Assembly Mounted to Enlarger

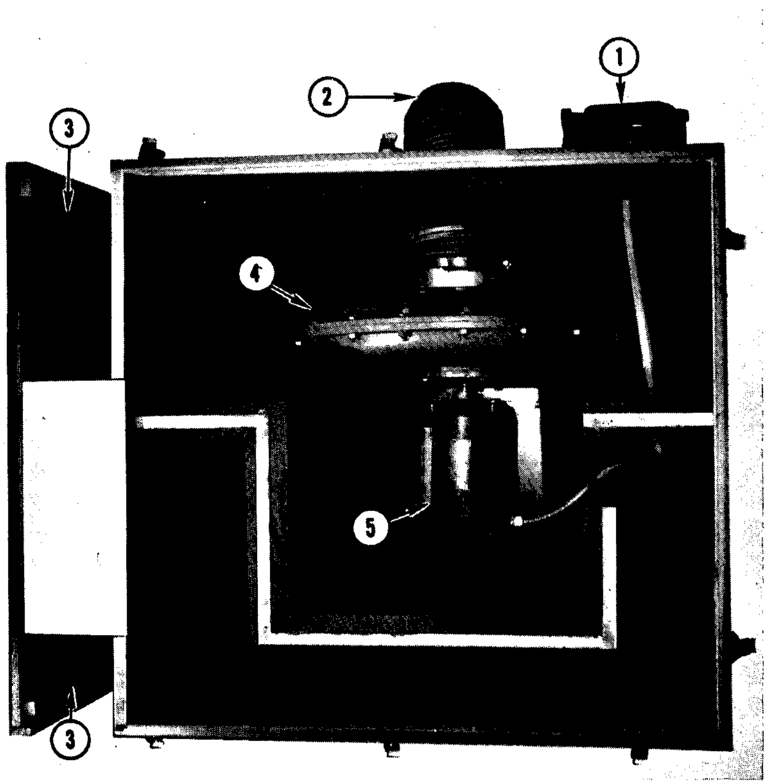
upon a white easel surface. Such a surface is convenient for observation of the projected negative image in preparing to make a print. In the breadboard BPE, the easel surface was of diffusing white acrylic plastic. There is considerable lateral spread when an image is projected on this material which destroys the apparent sharpness of the projected image. It was necessary to provide an opaque white coating to obtain the desired sharpness of the image when viewed on this easel surface. An acrylic plastic sheet like that used in the breadboard BPE was coated with flat white lacquer for the easel face of the prototype BPE.

b. When prints are exposed on transparent-base print stock, they show flare effects if exposed over a white easel surface. To provide a black backing when such prints are made, a porous black cloth can be laid over the vacuum easel surface. The cloth will be held in place by the vacuum; the cloth also allows air to flow through the easel face and to hold a sheet of print stock in place. The black cloth is mounted in a roller storage assembly across the top of the easel (Figure 4, Item 2). From this position, it can be conveniently pulled down over the easel surface when required.

c. The easel exhauster uses the same type commercial blower that was used with the breadboard BPE. Because of its relatively high rate of air flow (above 600 cu ft/min), it is desirable to locate the exhauster in the room with the enlarger so as not to disturb the darkroom air-distribution system. The blower was placed in an acoustic enclosure to eliminate noise in its exhaust air stream. Two views of the easel exhauster are shown in Figure 15: a front view of the assembly in operable condition, and a top view with the cover removed to show the labryinthine path for the exhaust air flow. The enclosure surfaces are covered with foamed elastomer which absorbs acoustical energy.




Front View




Top View (cover removed)

1. Safety cutoff switch
2. 7-inch I.D. flexible tube connecting rear of easel with the exhauster
3. Exhaust ports
4. Turbine blower
5. 3-hp induction motor

Figure 15. Easel Exhauster

17. The Electrical System. In the new design of the BPE, considerable engineering effort was spent on the electrical system (a) to improve the dependability of the equipment, (b) to physically integrate the electrical components and controls into the BPE structure, (c) to provide interlocks to protect the negative film, and (d) to provide indicators to aid the operator in controlling the enlarger. The Operation and Maintenance Manual has detailed descriptions of the electrical system and the enlarger controls.

18. The Magnification and Focus Table:

a. In the discussion of the breadboard BPE project, the customer's photo laboratory representatives expressed a desire for magnification up to 150 diameters. After preliminary consideration, it appeared that the upper limit of the magnification range could be extended beyond 60X to about 150X by providing two additional lens sets. On 9 June 1966, a project (PAR 245, BPE High-Magnification Lens Sets) was authorized to develop those lenses. The BPE design program had been modified earlier to provide the capability for two additional lens sets, for a total of eight. The revised design of the focus and magnification table display unit (Figure 4, Item 9) provided for eight columns of data, and the computer program was modified to calculate and print a table for up to eight lenses.

b. At the same time that these changes were made in the computer program, it was rewritten into FORTRAN H language for use on the IBM 360 computer which then became available in the contractor's facility. The program logic was also refined to make the magnification values which are printed in the table more accurate. Even with these refinements, however, the values shown for magnification may be in error by ± 1% because they are dependent on focal length measurements and not on calibrated magnification data.

CONCLUSIONS

19. The prototype model BPE which was fabricated, tested and delivered to the customer's facility, met design requirements.

20. This project provided a precision enlarger of new design for the aerial photo reconnaissance laboratory. The new precision enlarger provides improved performance in:

a. Ability to expose large prints,

b. The wide range of available magnification with effectively continuous range of adjustment,

c. Handling of negative film rolls,

d. Print stock handling, and

e. Color printing capability.

21. A specification for the BPE was developed as part of the design program and in conferences with customer's representatives (see Appendix A). The performance of the prototype model was equal to or superior to these specification requirements.

22. The set of manufacturing drawings which were prepared are suitable for fabrication of additional instruments by a competent optical equipment shop. These drawings depict the prototype instrument as delivered to the customer and in that form are under document change control.

23. The operational manual which was prepared and delivered to the customer with the prototype instrument was a preliminary edition which can be revised and released in more permanent form under another contract after more experience has been gained in production operation of the prototype BPE.

RECOMMENDATIONS

24. Make a description with price and delivery quotation for the BPE available to other photo-reconnaissance laboratory groups.



APPENDIX

BRIEFING PRINT ENLARGER (BPE) SPECIFICATION

1. EQUIPMENT APPLICATION

The enlarger shall be designed for rapid, convenient production of large photographic prints for unaided visual observation, as in group briefing or for report illustrations, from high-quality aerial photographic negatives in roll form.

2. DESCRIPTION

2.1 The enlarger shall have a horizontal optical axis with a movable print-stock easel to provide a range of negative-to-print distance from 50 to 80 inches. The print-stock easel, lens, and negative gate are to be rigidly coupled together by a massive steel structural member which is, in turn, isolated from environmental vibration by rubber-in-shear mounts.

2.2 The easel surface is to be 41 inches square and provide vacuum holding for cut-sheet print stock at any position on that surface.

2.3 A magnification range of 3X to 60X, with the range of negative-to-print distance described above, is to be achieved for black-and-white prints with a specially designed set of six lenses. The focal lengths of these lenses were chosen to provide a continuous range of available magnification, as shown in Table A-1, page A-2. Five of the six lenses are also suitable for color printing, providing magnification from 3X to 39X for color prints. To provide the necessary focus accuracy, each lens is to be mounted in its own focusing assembly, including a negative gate glass.

2.4 The required focus setting for each of the six lenses for various negative-to-easel distances (steps of 0.2 inch through the 50- to 80-inch range) will be displayed in a mechanism coupled to the easel drive to show only the focus setting and magnification for the particular lens and negative-to-print distance which exists. The lens focus will be set manually to make the focus indication counter on the focusing assembly agree with the displayed value from the tabulation.





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Table A-1

Nominal Magnification, EFL,* f-number, Minimum Axial Resolution, and Field Diameter Requirements

| Nominal Magnification | | Lens | | Minimum Axial Resolution | | Minimum Field Diameter | |
|---|---|---|---|---|---|---|---|
| M (Diameter) | OAC (Inches) | EFL (Inches) | f-Number | Negative (Cycles/mm) | Print (Cycles/mm) | Negative (Inches) | Print (Inches) |
| 2.95 | 57 | | | | 27 | | 10.9 |
| 3.77 | 65 | 10.75 | 17.8 | 80 | 21 | 3.7 | 13.9 |
| 5.24 | 80 | | | | 15 | | 19.4 |
| 4.75 | 50 | | | | 23 | | 17.6 |
| 6.48 | 62 | 7.17 | 12 | 113 | 17 | 3.7 | 24.0 |
| 9.04 | 80 | | | | 12 | | 33.4 |
| 8.46 | 50 | | | | 23 | | 31.3 |
| 11.0 | 62 | 4.85 | 7.8 | 200 | 18 | 3.7 | 40.6 |
| 14.7 | 80 | | | | 13 | | 54.4 |
| 14.5 | 50 | | | | 22 | | 30.5 |
| 18.5 | 62 | 3.06 | 5 | 320 | 17 | 2.10 | 38.8 |
| 24.4 | 80 | | | | 13 | | 51.1 |
| 24.5 | 50 | | | | 16 | | 30.4 |
| 30.8 | 62 | 1.90 | 4.2 | 400 | 13 | 1.24 | 38.2 |
| 40.3 | 80 | | | | 10 | | 50.0 |
| 38.5 | 50 | | | | 14 | | 30.4 |
| 48.2 | 62 | 1.24 | 2.8 | 550 | 11 | 0.79 | 38.1 |
| 62.7 | 80 | | | | 9 | | 49.5 |

* Effective focal length

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2.5 The illumination is to be produced by 300-watt tungsten projection lamps with condenser lenses. A separate condenser and lamp assembly is to be provided for each objective lens, and the assemblies are designed for convenient interchange in the lamphouse.

2.6 A three-aperture filter wheel whose position is selected from the control console shall be provided in the lamphouse. The filters are to be readily interchangeable to provide optimum exposure conditions for a variety of print materials.

2.7 Exposure control is to be accomplished from a control box on the side of the main enlarger frame. Exposures are started and ended by turning the projection lamp ON and OFF. The exposure time is controlled by a decade timer for times up to 111 seconds in 0.1-second steps. (Effective exposure is proportional to exposure time for exposure time greater than two seconds.) Irradiance level in the projected image is controlled by adjusting the voltage applied to the lamp. Three variable autotransformers are connected in such a way that a particular transformer supplies power to the lamp for each particular position of the filter wheel. Provision shall be made for extended-time projection through any of the filter positions for image observation or photometer measurement of the projected image. Timed exposures must be possible through any of the three filters as selected at the control box or through all three in sequence with the same time of exposure for each.

2.8 The roll-negative transport system shall wind the web horizontally between the two spindles mounted with their axes vertical. The transport system is to be movable up and down by a motor drive to place the film in front of a viewer or to lower it into the negative gate with the ability to place any point on the width of the web at the optical axis. Negatives 70mm to 9.5 inches wide mounted in flanged film spools (MS 26565, 12 Sept 62) up to 7.6 inches in diameter must be capable of mounting on the transport.

2.9 In the negative gate, the film is to be clamped between glass plates under spring pressure to hold it in the correct focal plane. When the gate is partially closed, it must be possible to inject a small quantity of index matching fluid (tetrachloroethylene) on each side of the film which sets the film and glass surfaces over the gate area upon full closure of the gate.

2.10 Interlocks are to be provided to prevent moving the negative while it is clamped in the gate. A ventilation system must be provided to remove the fumes of the immersion fluid to an outdoor exhaust. After the gate is opened, the transport system must be driven upward to move the wet film area past a liquid removal unit before it is possible to wind the film by motor drive into either spool.

2.11 An easel spot photometer is to be provided to aid in predicting correct print exposures for black-and-white or color materials.

2.12 A coordinate measuring system is to be provided to aid in positioning in the printing gate images which are described to the operator by coordinates of position within a given numbered frame of the roll of negatives. The unit of coordinate measurement in the system will be one millimeter.

3. PERFORMANCE

3.1 The nominal values of magnification (M), effective focal length (EFL), and relative aperture (f-number), are given in Table A-1 for the six lenses. The magnification achieved for a given negative-to-print distance (OAC) may vary ± 2 percent for various lenses of a production lot. The magnification value shown in the focus table may be in error by ± 1 percent from the true value.

3.2 The minimum axial resolution requirement of Table A-1 shall be applied to tests made in the following manner.

3.2.1 The test target material shall have at least 100:1 contrast, be in the USAF 1951 format, and provide 40 to 800 cycles/mm. The material shall have been exposed on Kodak Type 649GH film on the Microscope Resolution Target Camera at the contractor's facility. The test target polarity will be clear lines in a high density background.

3.2.2 Test prints on the BPE are to be exposed on Kodak Fine Grain Positive Film (or on equal product) with a Wratten 98 (W98) blue filter in the lamphouse filter position.

3.2.3 Resolution performance will be judged as the highest spatial frequency in the test target whose image is visually resolved in the print. The criteria for judgment of image resolution shall be those of Paragraph 3.6.2 of MIL-STD-150A.

3.2.4 An exposure series may be exposed to obtain the optimum resolving power. The lens focus setting shall be that predicted by the focus table.

3.3 The off-axis resolving power shall be measured at the same focus and exposure which provided the axial resolution data and to the same criteria. The same type of test target material shall be used, preferably on a common piece of film. The arithmetic average of radial and tangential resolving power for four radii of the field of view, separated by $90^{\circ}$, at a radial distance of 70 percent of the full field radius, shall be no less than 70 percent of the resolution measured on-axis.

3.4 The minimum field diameter at the negative, as specified in Table A-1, is primarily controlled by the various aperture diameters in the condenser system. The field diameter at the print is determined by the field diameter at the negative and the magnification. The specified field diameter at the print shall be measured with the negative-to-print distance adjusted to produce the corresponding magnification given in the first column of Table A-1.

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3.5 The temperature of a photographic density sample having a uniform density of 1.0 shall not be high enough to damage the sample at the stable temperature level. A sample of Type 3404 film shall be flashed and machine-processed to produce the required density. The film sample is to be inserted in the gate with immersion fluid and the enlarger is to be operated for twenty minutes continuously with the lamp at 115 volts and no filter in the filter wheel. At the end of this test, the film sample must show no evidence of heat damage.

3.6 The enlarger (4.80-inch lens, on-axis) shall provide exposure in sixty seconds on Kodabromide F2 paper to produce 0.1 density above fog level through a density of 2.0 (ASA diffuse density) in a Kodak Photographic Step Tablet with the W98 filter and the lamp operating at its rated voltage for 25-hour life at 80 inches OAC.

3.7 The log illuminance in the projected image of an open gate shall not decrease more than 0.30 below that on the axis at a point 0.8 of the maximum field radius from the axis.

3.8 The digital output of the coordinate measuring system, in either X- or Y-coordinate, shall be within 1 percent of the actual sample movement in millimeters, or within one count, whichever is greater.

3.9 The time-of-exposure as produced by the Lektra Labs Model TM-8 timer shall be within ± 5 percent of the timer setting for settings between 3.0 and 110 seconds. The variation of time-of-exposure for a succession of five exposures shall not exceed a range of 4 percent of the mean time-of-exposure for the set.

3.10 It is of extreme importance that the negative transport assembly or the negative gate and exhaust shroud not damage the valuable negatives to be printed by the Enlarger. Those areas shall be free of sharp corners, sharp edges, or burred surfaces which may scratch the film. A practical test to detect such items should be made by installing a piece of fresh, flashed, and processed film. The film should be run in both directions across the viewer and through the gate area. The gate should be closed with fluid injection and opened with the drying cycle, with the same film sample. The film should then be examined for possible damage in those handling operations.

4. ENVIRONMENT, SPACE, AND SERVICE REQUIREMENTS

The requirements of the Enlarger in these respects are given in the Installation Engineering Data, Drawing Number 1-023-B-513.