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TEST AND EVALUATION REPORT
LOW COST BINOCULAR MAGNIFIER

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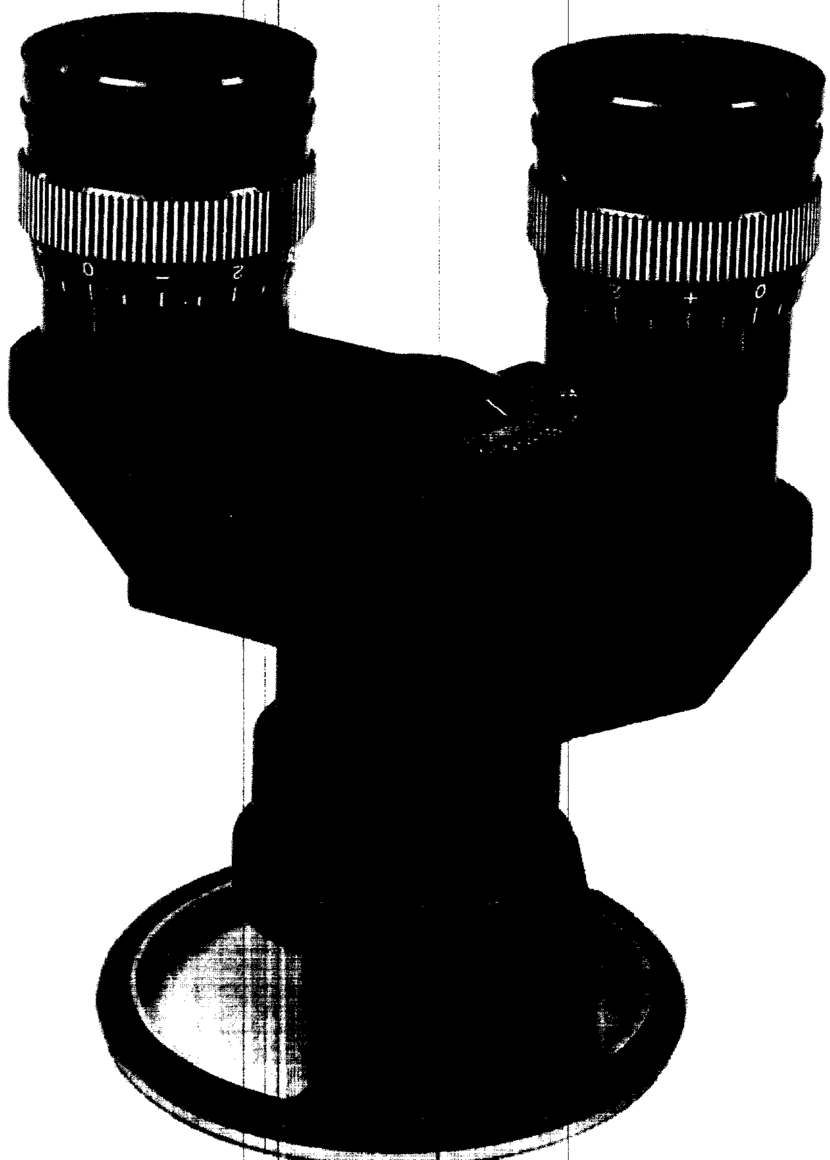

Figure 1. Binocular Magnifier

1. INTRODUCTION

The Low Cost Binocular Magnifier resulted from an effort to produce a binocular replacement for standard monocular tube magnifiers and thus gain the benefits of increased visual acuity and operator comfort. It was expected that the binocular magnifier would find use in place of the 7X tube magnifier to quickly inspect images on roll film and chips--with the added benefits of double the magnification and a raised head position.

The instrument is shown in Figure 1. The upper part of the magnifier has two independent eyepiece focusing adjustments and an adjustable interpupillary distance mechanism with scale. The base assembly contains an erecting prism which accomplishes image reorientation and a removable base ring. The optical schematic for the instrument is shown in Figure 2.

The binocular magnifier first underwent acceptance testing at NPIC during March and April 1973. Several deficiencies were uncovered which required correction by the manufacturer. It was returned to NPIC and again tested during the period 18 June to 27 July 1973. The operational components within the building then evaluated it for a 4-month period, which was completed on 2 November 1973.

This report reflects this final configuration. It does not include test results prior to modification.

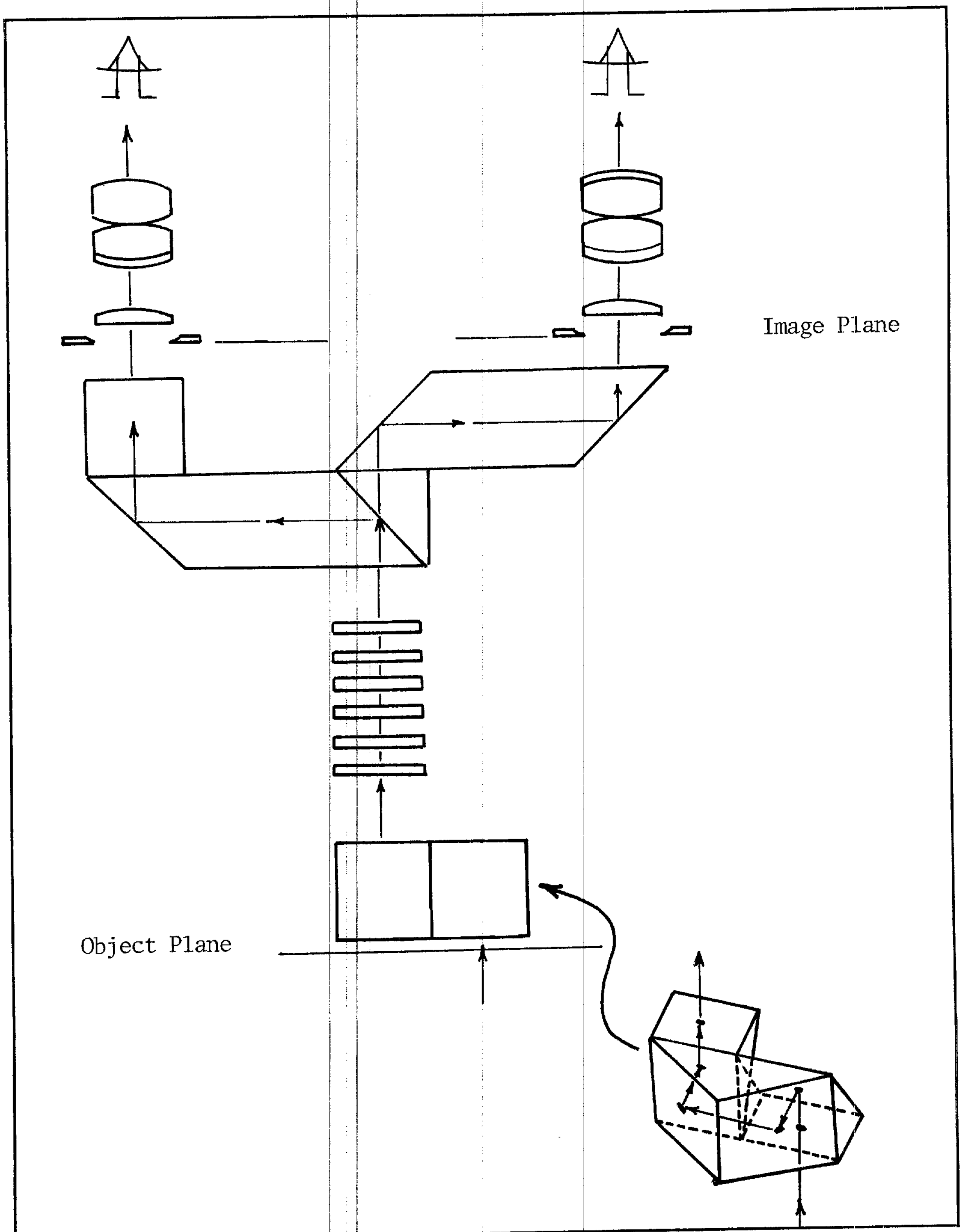

Figure 2. Optical Schematic

2. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary:

The prototype binocular magnifier complies quite adequately with all of its contractual requirements including magnification, distortion, resolution, field of view, eyepiece focusing, exit pupil size, exit pupil location, interpupillary adjustment, light transmission, binocular axes alignment, and physical size. However, its 1-1/2-pound weight does significantly exceed the 1 pound goal.

The device passed a critical engineering evaluation with high marks because of its compact, simple, and rugged design utilizing good mechanical and optical construction. Even the operational evaluation by PIs found the performance of the instrument itself to be very satisfactory for viewing transparencies. They did complain that the minimal working distance did not permit marking an area of interest or using it to view opaque prints.

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In addition, the operational evaluation clearly showed that [redacted] PIs who participated in the program do not recognize a need for such a larger and heavier than ordinary magnifier so long as they have a simple magnifier on a neck chain and a microstereoscope featuring zoom magnification conveniently available on a supporting carriage.

Conclusions:

- The price paid in size, weight, and minimal working distance has, in the viewpoint of the PIs evaluating this device, eliminated it from their consideration as a substitute for the monocular tube magnifier.
- The physical and optical features of this instrument place it in the family of viewing aids somewhere between the simple monocular tube magnifier and the very versatile but expensive microstereoscope. It appears that the binocular magnifier will find acceptance only for tasks which do not also require the immediate availability of a zoom microstereoscope.
- If additional procurement is made, several modifications should be considered to increase utility, acceptability, and maintainability. These are listed in the recommendations below.

Recommendations:

- Since this device is basically sound, both optically and mechanically, it should be considered for all transparency image inspection tasks where the primary requirements are hand-carry portability, 15X fixed magnification, and the visual acuity and comfort of good monoscopic binocular viewing.

- The utility of this binocular magnifier would be increased considerably if the working distance can be increased from the present one-fourth of an inch to a full inch or more. The manufacturer should be queried on this.

- The manufacturer has submitted sketches showing three different possible means for including a measuring reticle. The need for this feature should be evaluated if procurement is considered.

- The metal mounting base ring is bound to accummulate film-scratching nicks and scratches in normal use. These can be re-finished by maintenance personnel, but it is recommended that extra rings be acquired so that users can replace damaged ones in emergencies.

- A design modification to provide easy-to-make adjustments for vertical and lateral phoria corrections would eliminate image fusion difficulties experienced by some individuals.

- An investigation should be conducted to determine whether such phoria adjustments should be made available to the operators or only to maintenance personnel and whether it is also needed on stereo viewing instruments as well (see Sec. 3.2 for discussion).

3. TEST DETAILS

3.1 Acceptance Tests

These tests consisted primarily of examining and testing the instrument against its contractual specifications and design goals. These technical requirements are identified in this section by an asterisk.

3.1.1 Magnification

Test Method. Mount a diopter telescope on an angle measuring table so that their axes intersect at 90 degrees. Place the axis of rotation of the table so that it intersects the optical axis of the eyepiece and lies in the plane of its exit pupil. Measure the angle subtended by the diopter telescope positions when viewing the ends of a known or measurable distance in the object plane. Calculate the magnification using the formula:

$$\text{Mag.} = \frac{\text{angle subtended (deg)}}{2 \arctan \left[\frac{\text{length of object (mm)}}{508 \text{ (mm)}} \right]}$$

Test Results. Magnification measured 15.2X through each eyepiece.

* Nominal magnification - 15X $\pm$ 3 percent. Differential magnification - no more than 1 percent.

3.1.2 Distortion

Test Method. Use the technique for measuring optical magnification at the center and at the edge of the field of view.(1) Compare the on-axis magnification to that

(1) The available test target allowed for off-axis measurements to 90 percent of the fiew of view.

measured at the off-axis positions. The off-axis magnifications are first corrected to account for the fact that an off-axis image is foreshortened.

Test Results.

Position in Field of View	Percent Distortion At Each Eyepiece	
	Left	Right
Left edge	+4.8	+5.5
Center	0	0
Right edge	+2.5	+0.0

* Five percent or less.

TEB estimates that the measurement precision of this test is within 1 percent. Therefore, the distortion measurements fall within the stated limits. The positive sign of the test data denotes pincushion distortion.

3.1.3 Optical resolution

Test Method. Place a high contrast USAF 1951 Tribar resolution target (on film), emulsion side up, under the binocular magnifier. Read the resolution, using both eyes simultaneously, where both vertical and horizontal sets of bars are resolvable at the same time. The criteria for being resolvable are: 1) a clear space between each pair of adjacent bars and 2) each set of bars can be counted.

Test Results. Line pairs/mm/magnification power.

Position	Resolution (Median - Four Observers)	*
Axial	6.8	6.8
0.7 Field	5.4	5.4
0.9 Field	4.3	4.3

3.1.4 Field of view

Test Method. Place the binocular magnifier on a millimeter scale and read the scale at opposite sides of the field of view.

Test Results.

Left - 13.9 millimeters
Right - 13.6 millimeters

* 14 millimeters or greater.

While performing the above tests, it was noted that the two fields seen binocularly were not perfectly superimposed. The amount of displacement observed on the millimeter scale for three eyepiece separation distances is given below.

Field of View Displacement

Interpupillary Distance (millimeters)	Displacement (millimeters)
50	0.6
63	0.5
76	0.5

3.1.5 Eyepiece focus and focal plane

Test Method. Set each eyepiece to the zero diopter scale mark. Mount a diopter telescope over an eyepiece and focus it on the emulsion side of a test grid. Note the telescope diopter scale setting. Repeat the procedure for each eyepiece.

Test Results.

Diopter Telescope Readings

Left	Right
Ranged from 0 to -0.20 diopters	Ranged from -0.10 to -0.35 diopters

* 0 ± 0.25 diopters.

Each eyepiece is adjustable from +4 to -4 diopters.

The measurement precision of this test varies from observer to observer. The Test and Evaluation Branch, ESD/TSG, concludes that it can vary about +0.2 diopters and therefore the eyepiece zero is within acceptable limits.

3.1.6 Exit pupil diameter

Test Method. Place the binocular magnifier over a small illuminated aperture. Mount a diffusing screen over the eyepieces so that the exit pupils are clearly visible. Measure the exit pupil sizes with the aperture at the center of the field of view. Repeat with the aperture at the edge of the field of view.

Test Results.

Aperture Position	Exit Pupil Dimensions (millimeters) Left	Right	*
On axis	3.2	3.2	3 or greater
Edge of field of view	3.1	3.1	2 or greater

3.1.7 Eye clearance

Test Method. Locate the exit pupil by positioning a diffusing screen above the eyepieces and adjust the height of the screen until the smallest and sharpest spot of light appears on the screen. Measure the distance from the screen's imaging surface to the nearest surface of the eyepiece optics or supporting structure.

Test Results.

Highest Eyepiece Surface to Exit Pupil Left	Right
19.6 millimeters	19.5 millimeters

* At least 20 millimeters from last optical surface of lens to the front surface of eye.

The distance measured satisfies the intent of the specification by locating the instrument's "exit pupil position." This is not identical to "eye clearance" (defined in Human Engineering Design Guide Sections 2.3 and 4.1.2.5) which includes an observer's eye pupil positioning tolerance.

3.1.8 Interpupillary distance (IPD) adjustment

Test Method. Measure the distances between exit pupils on a diffusion screen positioned above the eyepieces at maximum and minimum IPD settings. Examine the locking device.

Test Results.

IPD Scale (millimeters)	Measured IPD (millimeters)	*
76	76.5	76 mm
50	51.0	50 mm

The IPD friction locking mechanism is similar to the type used on common binoculars. It operated adequately during the testing period with no adjustment needed to the three friction set screws. These screws extend slightly above the collar surface. The contractor had originally planned to replace them when shorter screws could be obtained. These replacement screws have not arrived to date.

3.1.9 Light transmission

Test Method. Use the United Detector Technology photometer with the microscope head (CM-13) to measure the light table output (at 10 inches from the source) and the throughput of the binocular magnifier. Adjust the head over each eyepiece in X,Y, and Z directions for maximum light output.

Test Results.

Left 29.5 percent - Right 29.9 percent

* Transmission - at least 33 percent. Differential transmission - less than 10 percent.

3.1.10 Convergence

Test Method. Mount the binocular magnifier on a sturdy test stand which allows the instrument to be translated horizontally. Position a camera so that the first surface of the lens lies in the eyepiece exit pupil plane. Set the eyepieces to zero diopters so that the image appears to be set at infinity to prevent the relative camera position from having an effect on the measurement. Place a crosshair target in the object plane of the magnifier and photograph its image through each eyepiece (a double exposure). Make sure the optical axis of the camera remains parallel for each exposure. The horizontal and vertical displacements of the crosshairs imaged on the photograph are the respective horizontal and vertical linear misalignments. Calculate the horizontal and vertical convergence or divergence angles by use of the following formula:

$$\text{Misalignment (angular)} = \arctan\left(\frac{\text{Linear misalignment on photograph}}{\text{Focal length of camera}}\right)$$

Test Results.

Horizontal Misalignment

Interpupillary Distance (millimeters)	Horizontal Convergence	*
76	1 degree 33 minutes	Less than 4 min. of arc convergence
63	2 degrees 6 minutes	
50	2 degrees 33 minutes	

To several observers a nonparallel system (which causes the eyes to converge) is more comfortable than the parallel system as specified. A parallel system causes the eyes to accommodate at infinity. However, a converging system allows the eyes to accommodate more comfortably if set for a distance of one meter. The Boeing Publication DK-702 recommends 2.5 degrees convergence, which is essentially that of the magnifier.

	Vertical Misalignment	
Interpupillary Distance (millimeters)	Vertical Divergence	*
76	None detected	Less than 2 min. of arc divergence
63	None detected	
50	16 minutes	

Measurements cannot readily be made of line separations less than 0.1 mm. This corresponds to a vertical misalignment error of approximately 3 minutes.

3.1.11 Image orientation

Test Method. Check for image rotation by examining the photographs obtained in the convergence tests. Nonparallel crosshair lines are an indication of image rotation. Inversion or reversion of an image can be checked visually with a resolution target.

Test Results. No evidence of image rotation was detected, nor did image reversion or inversion occur.

3.1.12 Image quality

No bothersome field curvature, coma, astigmatism, or lateral image color was noted during the testing program. The beam splitter consists of a pattern of totally reflecting dots covering exactly half of its surface area. These dots can be seen when the eyes are above the exit pupil plane, but they are barely perceptable when using the instrument in a normal manner.

3.1.13 Nonabrasive base

Test Method. Simulate a scan on the emulsion side of a fresh piece of film and examine it for scratches.

Test Results. Several tests with Type 1414 ultrathin base film showed only such slight scratching that the Test and Evaluation Branch considers it to be acceptable.

3.1.14 Provision for a reticle

Test Method. Examine the three sketches furnished by the contractor to determine if a reticle can be incorporated in a future design.

Test Results. The schemes for incorporating a reticle consist of: 1) a reticle placed in an arm which is mounted on the erecting prism cover. It can be swung into the image plane, 2) a reticle which can be inserted into the erecting prism cover assembly, 3) a reticle mounted in the removable base assembly. It is judged that each of these schemes could be incorporated into the design without excessively modifying the instrument. A comparative evaluation of these three concepts was not included in the T&E program conducted thus far.

3.1.15 Physical size

Test Method. Measure and weigh the instrument.

Test Results. The instrument body measures 1.7 inches thick, 4.4 inches wide (at maximum interpupillary distance), and 5.4 inches high. The base ring measures 3.1 inches diameter. The magnifier weighs 1 pound 8 ounces.

* Design goals 1.5 by 4.5 by 5 inches and 1 pound.

3.1.16 Stability

The instrument is stable when used on the horizontal surface of a 1540 light table and will not slide on clean film with the table tilted up to 15 degrees from the horizontal.

3.1.17 Miscellaneous

Operator and maintenance manuals are provided with the instrument. One gives basic operating instructions and includes instructions for the removal of the base ring. The other gives instructions for the removal and replacement of the eyepieces and the removal of the erecting prism cover. Both manuals satisfactorily follow the general recommendations called out in RED Specification DB-1003.

A compact carrying/storage case is provided with the instrument. Its overall measurements are 8.5 inches long, 6.6 inches deep, and 3.9 inches high.

3.2 Engineering Evaluation

The binocular magnifier is a rugged instrument of generally good mechanical and optical construction.

The magnifier has a removable chrome-plated base ring which is flattened and highly polished over the area which contacts the film. This ring can be easily unscrewed from its holder and replaced or repolished in the event that it should become scratched. The Test and Evaluation Branch recommends the purchase of extra base rings if more instruments are procured. This would allow the instrument to be used with a polished base ring at all times and thus keep film scratches at a minimum.

When the magnifier was initially delivered to NPIC, its two optical axes were seriously misaligned. This was evident from the fact that most people had considerable difficulty achieving binocular image fusion and also by the results of objective measurements of horizontal convergence and vertical misalignment. The instrument was returned to the manufacturer for correction, and the subsequent measurements and operational evaluations reported herein show acceptable performance for most viewers. This experience suggests that the horizontal convergence angle and vertical alignment is much more important for monoscopic viewing instruments such as this magnifier than for instruments being used in a stereo viewing mode. Recent progress in analyzing such viewing problems is reflected in NPIC's Human Engineering Design Guide, Section 4.1.2.8(f), which recommends that binocular instruments be designed with available adjustments to correct for both vertical and lateral phorias of operating personnel.

Therefore, the Test and Evaluation Branch recommends that such adjustment capability be included in any future development for binocular monoscopic viewing. However, it is not known if such adjustment should be made available to the user or only to maintenance personnel.

It is believed that there is less need for such adjustment capability on instruments which are used only for stereo viewing. In the latter case, the user accomplishes a substitute fine adjustment by shifting the relative position of the two objects to achieve best fusion for him. For this reason, it is also recommended that the need for phoria correction on stereo instruments be resolved by suitable, additional investigation. At the same time, it should be determined whether such adjustments on mono and stereo instruments should be available to the operator or only to maintenance personnel.

3.3 Operational Evaluation

The binocular magnifier was evaluated by all operating components located within the building. Verbal comments were received from three of these components and a written evaluation from the fourth. A summary of their most significant comments follows.

- The instrument does nothing to advance image exploitation techniques presently available to the photointerpreter. Photointerpreters would rather use microstereoscopes and conventional tube magnifiers, if available.
- No negative comments were received regarding the optical performance of the instrument.
- Not conveniently portable. The weight prohibits carrying the unit on a neck chain.
- The unit is too tall to leave on a 1540 light table. It can be swept off the table by movement of the microscope bridge.
- The instrument is more difficult to use than the tube magnifiers presently available to the photointerpreter.
- Opaque prints cannot be viewed, nor can the area of interest be marked on the film because of an exceedingly small working distance. Since the erecting prism cover is within one-fourth inch of the object plane, it physically restricts the area of interest and does not allow overhead light to shine on it.
- The metal eyepiece surfaces can scratch eye glasses.

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