STATOTHR
[redacted]

DIRECT IMAGE VIEWER,

SPECIFICATION FOR

10 July 1964

STATOTHR
[redacted]

DIRECT IMAGE VIEWER, SPECIFICATION
for

1.0 SCOPE

1.1 This specification describes the performance and technical characteristics of an Experimental Direct Image (High Resolution) Viewer. The Direct Image Viewer employs a unique optical approach, involving diffraction gratings, to provide an observer with an enlarged aerial image which can be viewed simultaneously with both eyes.

1.2 Major features of this viewer include the elimination of performance limitations imposed by the use of rear projection diffusion screens, and the achievement of high magnification viewing qualities comparable to advanced microscope viewing objectives.

2.0 APPLICABLE DOCUMENTS

2.1 The following drawings form a part of this specification:

STATOTHR [redacted]

Dwg. No. 7506L1	Layout Dual Magnification, Direct Image Viewer
Dwg. No. 7506L2	Assembly, XY Translator, Direct Image Viewer

3.0 REQUIREMENTS

3.1 Design - The overall configuration of the Experimental Direct Image Viewer specified herein shall be in
STATOTHR general conformance with [redacted] Drawing No. 7506L1. The viewer shall employ materials of highest commercial quality consistent with its intended performance and specified operating environments.

3.2 Performance Characteristics - The performance characteristics of the Experimental Direct Image Viewer shall consist of the following general values:

3.2.1 Magnification - Dual individual magnifications of 5X and 50X.

3.2.2 Observable Film Area - The observable film area shall consist of a nominal two (2) inch by two (2) inch square area in the film plane at 5X magnification, and two-tenths inch by two-tenths inch square area in the film plane at 50X magnification.

3.2.3 Film Size - The viewer shall possess a capability for viewing single frames of either 70mm or 5-inch film chips.

3.2.4 Exit Pupil Size - The nominal size of the composite exit pupil shall be 3.5 inches square.

3.2.5 System Resolution - At 5X magnification, the Experimental Direct Image Viewer shall be

capable of providing a system AWAR resolution of 60 lines per millimeter over the used field when referred to a high contrast target in the ~~object~~ plane. At 50X magnification, the viewer shall be capable of providing an (AWAR) of 200 lines per millimeter (ON AXIS) at the film plane with a high contrast target while employing commercially available lens. The resolution goal of the system when operating at 50X shall be 200 lines per millimeter as viewed in the object plane for a low contrast (1.6:1) target.

delete RESOLUTION

3.2.6 Light Intensity - The lamp intensity shall be variable and of sufficient brightness to allow the measurement of a 0.05 density difference over a required density range of 0 to 1.8. As a design goal, the viewer will provide a capability of measuring a desirable density difference of 0.02 over a density range of 0 to 2.5.

(200 FT. LAMBERTS OPEN GATE INTENSITY?)

3.2.7 Illumination Spectrum - The illumination of the viewer system shall be contained to a narrow band ~~within the 450-550~~ CENTERED AROUND 508 millimicron portion of the spectrum.

3.2.8 Film Positioning - The viewer shall incorporate a provision for remote film positioning through X and Y translations to permit full coverage viewing areas for either 70mm and 5-inch film chips.

3.2.9 Focusing - A manual fine focus controll shall be provided for each viewer lens magnification.

3.2.10 Film Temperature - The temperature of the film when mounted in the film plane of the viewer during operation shall not exceed ambient (75°F. more than 20°F. FILM DENSITY

3.2.11 Viewer Controls - The Experimental Direct Image Viewer shall contain a set of viewer controls, front panel mounted, consisting of the following:

3.2.11.1 Power - ON/OFF

3.2.11.2 ~~Lamp~~ Illumination Intensity

3.2.11.3 Magnification Selector, 5X and 50X

3.2.11.4 Lens Focus, 5X and 50X

3.2.11.5 Film Translation
± one inch X
± one inch Y } 2" total

delete

3.2.12 Power Consumption - The power consumption of the viewer shall be approximately 800 watts of 110 volts, 60 cycle, electrical power.

STATOTHR

3.2.13 Physical Size - (Reference [redacted] Dwg. No. 7506L1). The viewer shall consist of the following general dimensions: Length - 66 inches, height - 26 inches, width - 29 inches.

3.2.14 Weight - The weight of the viewer shall be approximately 150 pounds.

3.3 Theory of Operation - In direct viewing optical instruments, such as a microscope, the exit pupil is small, requiring that the operator place his eye close to the eye piece for satisfactory viewing. The present Experimental Direct Image Viewer, with its larger optical elements and diffraction grating, enlarges the exit pupil in a manner that the operator may view with both eyes the image and still have adequate head movement. In the absence of employing diffraction gratings in the present viewer, a single small exit pupil would exist, which would restrict the operator to the use of a single eye and no head movement when viewing at high magnifications. Through the insertion of the

gratings in the optical path, and the use of a narrow portion of the spectrum, many exit pupils are created, which when arranged side by side and placed both above and below one another, form a matrix of exit pupils in space providing an effective viewing area of 3.5 inches square, where the operator may place his eyes for viewing. This unique approach results from the use of a special field lens, and specially designed and built set of diffraction gratings. Near monochromatic light must be used in the viewer, or the diffraction characteristics of the gratings will produce a rainbow of images between matrix units (exit pupil images).

3.4 Technical Details

3.4.1 Viewer body, optical supports, and controls -

3.4.1.1 Chassis - The viewer frame will be constructed from aluminum jig plate, and rigid mounts will be supplied for all optical elements. The large field lens will be of a split design, and flange mounted to one-inch thick plates. The diffraction gratings will be mounted between the field lens elements and their one-inch separated flanges.

3.4.1.2 Film support and X-Y translation - The film support system, as shown in [redacted] Dwg. No. 7506L2, accomodates both 70mm and 5-inch film chips. The film will be held by a vacuum to a flat glass plate free of striations. The glass platen will be mounted on a mechanical mechanism which will provide controlled X and Y movement of 2 inches and translate the film 9 inches in X to change magnification.

STATOTHR

3.4.1.3 Objective lens mounting - The two lenses will be flange mounted with the position of the flange being manually adjustable for fine focus.

3.4.1.4 Auxiliary external equipment - Two pieces of vacuum receptacle. equipment will be placed within the viewer:

(1) The light source power supply will be repackaged and mounted along one side of the viewer enclosure;

(2) A small vacuum pump will be mounted so as not to induce any vibration to the optical path.

3.4.1.5 Viewer Housing - The viewer housing and enclosure will have a hinged section at the rear for access to the mechanism and for inserting film and lamp replacement. The front panel will contain the controls and provide the proper mask around the field lens and gratings.

3.4.2 Viewer Optics

3.4.2.1 Field Lens - A symmetrical design multi-element, 15-inch diameter, field lens will be used. The lens will image the exit pupil of the objective lens 20 inches from its rear nodal point. The lens shall be of a sufficiently high quality as not to degrade the high resolution image requirements of the viewer.

3.4.2.2 50X Magnification Components - VOIGTLANDER 1" F/ f-1 A large aperture photographic lens will be used

with a modified exit pupil producing a square opening. The resolution of the viewer is dependent upon this lens, and the best commercially available lens with an f number approaching unity will be used.

A multi-element condensed system will be used to concentrate the light to the small 0.2 x 0.2 inch square film area while filling the objective lens.

Field flatteners shall be employed to provide field curvature for optimum field lens operation.

3.4.2.3 5X Magnification Components - A commercially available 8.5 inch focal length lens will be modified to contain a square exit pupil equal in size to the 50X lens case.

The condenser system to be employed with this lens will concentrate and illuminate a 2 x 2 inch square area evenly.

Separate field flatteners will be used for the same purpose employed with the 50X system.

Two additonal small mirrors will be inserted in the path, one before and one after the lens to provide the dual 5X magnification. The mirror in front of the lens is movable to permit inserting it or removing it from the optical path. With film translation, the two magnifications are obtained.

3.4.2.4 Light Source - Two lamps and reflectors shall be employed, one for each lens. In addition, special interference filters will be employed to provide the narrow spectrum required.

3.4.3 Diffraction Grating - In order to obtain the unique optical multiplication of exit pupils required, special diffraction gratings are required. Two (?) gratings are employed to diffract the light into a multiplicity of exit pupils dispersed in two directions 90^{o} apart, thus providing a matrix of exit pupil images.

3.4.3.1 For the prescribed magnification levels and the size of the multiple exit pupil required, a minimum of nine (9) orders of diffraction are required, a central order and four (4) on each side. The difficulty of the grating design is that all orders should receive the same amount of energy so that each exit pupil appears of the same brightness to the observer.

3.4.3.2 The gratings shall be of a 10 x 10 inch ruled surface, which influences the field of view of the system and the observable film size. Special ruling techniques are required and will be used to produce these gratings.

3.4.3.3 The light is diffracted by one grating in one direction, and then each diffracted exit pupil is spread out in the other direction by a second grating. The

cascaded diffraction gratings produce a decrease in light intensity, which is then enhanced by the use of a narrow band light source. Compensation is provided in the condensers, high intensity lamps and the small f/number projection lens at the high magnification.

3.4.3.4 The nominal (based on exit pupil size) angular deviation of the various orders shall be:

First order	1^{o} 9'
Second order	2^{o} 18'
Third order	3^{o} 27'
Fourth order	4^{o} 35'

EXTRA ORDERS: MORE IN FEW?

The tolerance for each of the above deviations shall be $\pm$ 10% of the above angles.

3.4.3.5 Intensity variations throughout the nine orders shall be no greater than 40% between adjacent orders and no greater than a 2:1 ratio between the lowest and highest order in the nine central orders.

3.4.3.6 The transmission of the order which transmits the minimum amount of light shall be at least 7% of the light intensity falling on an individual grating.

.MAX 070%??

HALF IS REASONABLE & ACHIEVABLE.

STATOTHR [redacted]

3.4.3.7 The glass quality to be used in the manufacture of the diffraction gratings shall be greater than striae free through the faces.

3.4.3.8 A maximum of 10 arc minutes of slope error shall be a permissible planeness (figure) of the glass.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 The optical components will be inspected and tested to demonstrate compliance to the performance requirements stated in Section 3.2.

4.2 The diffraction gratings will be inspected and tested to show compliance to the performance requirements stated in Section 3.2

4.3 A set of complete viewer acceptance tests will be conducted to demonstrate satisfactory operation of all the functions and specifications stated in Section 3.0.

5.0 PREPARATION FOR DELIVERY

This viewer will be packaged and prepared for shipment and delivered in accordance with accepted commercial practices.

6.0 NOTES

None

TEST PROCEDURE
for
STATOTHR [redacted] DIRECT IMAGE VIEWER

Project 7506

1.0 SCOPE

1.1 The Direct Image Viewer employs a unique optical approach involving diffraction gratings to provide an observer with an enlarged aerial image which can be viewed simultaneously with both eyes.

1.2 This document lists the tests and inspections to be performed that, when satisfactorily completed, show that the viewer meets the specifications listed.

2.0 APPLICABLE DOCUMENTS

STATOTHR 2.1 [redacted] Specification for Direct Image Viewer, 25 August 1964.

2.2 Phase II Development of an Experimental Direct (Virtual) Image Viewer, 28 February 1964. (SECRET)

STATOTHR 2.3 [redacted] Drawing 7506L1 Layout Dual Magnification Direct Image Viewer

2.4 Handbook for Direct Image Viewer

3.0 REQUIREMENTS

2.1 This viewer has been designed to meet the general requirements set forth in Section 3.2 of the document listed in Section 2.1. Consideration has also been given to the objectives listed in the Secret document listed in 2.2.

This is a prototype experimental viewer and therefore only the minimum specifications were imposed to allow for flexibility in the design and manufacture.

Section 3.2 of the specifications is listed below for convenience in verifying the test procedures.

3.1.1 Magnification - dual individual magnifications of 5X and 50X.

3.1.2 Observable Film Area - the observable film area shall consist of a nominal two inch by two inch square area in the film plane at 5X magnification, and two-tenths inch square area in the film plane at 50X magnification.

3.1.3 Film Size - the viewer shall possess a capability for viewing single frames of either 70mm or 4 x 5 inch film chips.

3.1.4 Exit Pupil Size - the nominal size of the composite exit pupil shall be 3.5 inches square.

3.1.5 System Resolution - at 5X magnification, the experimental direct image viewer shall be capable of providing a system AWAR resolution of 25 l/mm over the used field when referred to a high contrast target in the object plane. At 50X magnification, the viewer shall be capable of providing an on-axis resolution of 200 l/mm at the film plane with a high contrast target while employing commercially available lens. The resolution goal of the system, when operating at 50X, shall be 200 l/mm as viewed in the object plane for a low contrast (1.6:1) target.

3.1.6 Light Intensity - the illumination system shall be variable and will present to the eye, with an open film gate, at least that amount of light flux as presented to the eye by a lambertian source with illuminance of 100 ft/ lamberts.

3.1.7 Illumination Spectrum - the illumination of the viewer system shall be contained in a narrow portion of the spectrum centered around 508.6 mμ.

3.1.8 Film Positioning - the viewer shall incorporate a provision for remote film positioning through X and Y translations to permit full coverage viewing areas for either 70mm or 5 inch film chips.

3.1.9 Focusing - a manual fine focus control shall be provided for each viewer lens magnification.

3.1.10 Film Temperature - the temperature of the film when mounted in the film plane of the viewer during operation shall not exceed ambient ($75^{o}F$) by more than $20^{o}F$ at an average density (silver) of 0.8.

3.1.11 Viewer Controls - the experimental direct image viewer shall contain a set of viewer controls, front panel mounted, consisting of the following:

3.1.11.1 Power - ON/OFF
3.1.11.2 Intensity of Illumination
3.1.11.3 Magnification Selector, 5X and 50X
3.1.11.4 Lens Focus, 5X and 50X
3.1.11.5 Film Translation
± two inch X
± two inch Y

STATOTHR

3.1.12 Physical Size - (Reference [redacted] Dwg. No. 7506L1). The viewer shall consist of the following general dimensions: length - 66 inches, height - 26 inches, width - 29 inches.

3.2 Theory of Operation

In direct viewing optical instruments, such as a microscope, the exit pupil is small, requiring that the operator place his eye close to the eye piece for satisfactory viewing. The present Experimental Direct Image Viewer, with its larger optical elements and diffraction grating, enlarges the exit pupil in a manner that the operator may view with both eyes the image and still have adequate head movement. In the absence of employing diffraction gratings in the present viewer, a single small exit pupil would exist, which would restrict the operator to the use of a single eye and no head movement when viewing at high

magnifications. Through the insertion of the gratings in the optical path, and the use of a narrow portion of the spectrum, many exit pupils are created, which when arranged side by side and placed both above and below one another, form a matrix of exit pupils in space providing an effective viewing area of 3.5 square inches, where the operator may place his eyes for viewing. This unique approach results from the use of a special field lens, and specially designed and built set of diffraction gratings. Near monochromatic light must be used with the viewer, or the diffraction characteristics of the gratings will produce multicolored exit pupil elements.

4.0 QUALITY ASSURANCE PROVISIONS

Acceptance test and inspection will be performed to show compliance with the requirements stated in Section 3.0.

4.1 Inspection

4.1.1 Inspect the viewer for overall workmanship in compliance with the statements made in Section 3.1 of the referenced specification. This statement is given below. The viewer shall employ materials of highest commercial quality consistent with its intended performance and specified operating environments.

Record comments in Section 6.1.1 of Data Sheet.

4.1.2 Determine physical size of machine and record in Section 6.1.2 of Data Sheet.

4.2 Operational Test Procedure

Details on how to perform the various steps and tasks required by this procedure are given in the viewer manual.

4.2.1 Prepare the viewer for operation. In performing this task connect volt and amp meter to the input line so that the power consumed may be measured and entered in Section 6.1.3.

4.2.2 Load the two film holders with 4 x 5 and 70 x 100 mm film chips.

4.2.3 Insert the 4 x 5 holder in the viewer.

4.2.4 Turn on the machine.

4.2.5 Vary the intensity over the full range.

4.2.6 Translate the film in X and Y over the entire format.

4.2.7 Check on the data sheet for compliance with requirements No. 3.1.3, 3.1.8.

4.2.8 Operate the 5X manual fine focus knob and run the image "through focus".

4.2.9 Change to 50X and operate the 50X manual fine focus knob to run the image "through focus".

4.2.10 Check on the data sheet compliance with requirements No. 3.1.1, 3.1.9 and 3.1.11.

4.2.11 Return to 5X magnification and remove the film chip.

4.2.12. Change the viewer to 50X.

4.2.13 Place a screen 13 inches in front of the viewer; at the exit pupil plane. Measure on this screen the size of the total exit pupil. Record this measurement on the data sheet, Section 6.1.6 for compliance with requirement 3.1.4.

4.2.14 Place a calibrated photometer probe in the exit pupil plane and measure the illuminance falling on the probe. The 3.5" x 3.5" exit pupil should contain 0.68 Lumens. This is equivalent to $\frac{32\ \mu\ \text{watts}}{\text{cm}^2}$.

Record the measurement made in Section 6.1.7 on the data sheet for compliance to requirement 3.1.6. As it can be shown by calculation that a lambertian source with an illuminance of 100 ft/lamberts places 0.68 Lumens in the exit pupil plane area.

4.2.15 Return to 5X magnification position.

4.2.16 Insert the 70mm holder containing the resolution target.

4.2.17 Translate the film so that the target appears in the center of the screen and adjust for best focus.

4.2.18 Read the resolution and record in Section 6.1.8 of the data sheet.

4.2.19 Move the target to all four corners of the viewing area and read and record the resolution on the data sheet. Verify that all readings are above the requirement stated in Section 3.1.5.

4.2.20 Center the resolution target and then translate to 50X.

4.2.21 Focus the lens and read and record the resolution on the data sheet in Section 6.1.9. Verify that the reading is above the requirement stated in Section 3.1.5.

4.2.22 Remove resolution target and replace with a film chip photograph.

4.2.23 Go through normal operations of scanning, viewing, focusing, changing magnification and so forth. Move head around to get an idea of latitude in head movement. Make any other checks that seem appropriate.

4.2.24 Record all comments in Section 6.1.10.

4.2.25 Comments on sections of requirements not covered by procedure.

1) Section 3.1.2 observable film area. With a grating aperture of 10 x 10 and the magnifications involved, the film areas observable are evident without testing. The optical dimensions are given in the Engineering Report.

2) Section 3.1.10, Film Temperature. There is no equipment available to measure this parameter. Therefore, the temperature rise listed in 3.1.10 cannot be actually determined. Satisfactory operation of the viewer, that is, no damage to the film, indicates that the temperature rise is within satisfactory limits.

4.2.26 Sign and date data sheet.

5.0 PREPARATION FOR DELIVERY

5.1 Inspect the shipping crate for suitability for shipment of the viewer. The shipping container is to be used for air freight delivery of the unit. In addition to the viewer, six spare projection bulbs and five copies of the instruction manual will be shipped.

6.0 NOTES

6.1 Data Sheet for Acceptance Test

6.1.1 Workmanship Comments

_____
(signature of inspector)

6.1.2 Physical Size

Length _____ Height _____ Width _____

6.1.3 Electrical Power Consumed (magnification being changed and lamp at full brightness)

60 cps Volts _____ Amps _____ Watts _____

6.1.4 Compliance with Requirements 3.1.3 _____
Compliance with Requirements 3.1.8 _____

6.1.5 Compliance with Requirements 3.1.1 _____
Compliance with Requirements 3.1.9 _____
Compliance with Requirements 3.1.11 _____

6.1.6 Size of exit pupil, compliance with requirement 3.1.4. Size (inches): _____.

6.1.7 Intensity of Illumination
Microwatts/cm^2: _____.

6.1.8 Resolution data 5X lens. Compliance with requirement 3.1.5.

Position	Resolution H	l/mm V	
On Axis			
Upper Right			
Upper Left			
Lower Right			
Lower Left			$\overline{HV}$
Average			

6.1.9 Resolution Data 50X Lens - compliance with requirement 3.1.5. On axis resolution: l/mm _____(h) _____(v) Average: _____.

6.1.10 Comments on General Viewer Operation:

6.1.11 Signatures of Participants:

STATOTHR [redacted]

Quality Assurance _____

Inspector _____

Project Engineer _____

Customer Representative _____

_____
(date)

DIRECT IMAGE VIEWER RESOLUTION DATA

Lens (on test bench)		Resolution On Axis	4°	6°	8°
50X	high contrast	600+	500	300	210
	low contrast	550	400	260	150
5X	high contrast	150	170	170	160
	low contrast	110	120	120	120

Viewer	Resolution On Axis	Edge	Corner
50X - Grating (customer's first)			
High contrast	200	145	145
Low contrast	145	115	125
Diffusion Screen			
High contrast	170	145	85
Low contrast	70	70	50
5X - Grating			
High contrast	20	20	20
Low contrast	20	16	16

50X - Grating (First trial 2 x 2 from Bausch and Lomb)

	On Axis	
High Contrast	228	
Low Contrast	180	(Exit pupil plane)
	228	(with head at window)

NOTE: The last data listed indicates that the viewer meets the design goal. Over 200 l/mm at a low contrast of 1.6:1.