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VIEWING EQUIPMENT FOR USE IN THE HRT CORE AND BLANKET VESSELS

J. S. Culver

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REACTOR EXPERIMENTAL ENGINEERING DIVISION

VIEWING EQUIPMENT FOR USE IN THE HRT CORE AND BLANKET VESSELS

J. S. Culver

MAR 1960

Date Issued

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VIEWING EQUIPMENT FOR USE IN THE HRT CORE AND BLANKET VESSELS

ABSTRACT

Several viewing devices were built or purchased and various viewing aids were developed to permit examination of the core vessel of the Homogeneous Reactor Test. The hole in the core vessel was viewed and photographed from both the inside and the outside. A number of simple periscopes were designed and fabricated. A small television camera was purchased, and manipulators were built to insert it in the core or in the blanket. A radiation-resistant 21-ft-long periscope was procured which is 7/8 in. in diameter and has a 180° field of view.

INTRODUCTION

The possibility of viewing the interior of the core and blanket vessels of the Homogeneous Reactor Test has been of interest since the beginning of operation of the reactor. A desire for information about the nature and extent of corrosion in the vessels stimulated interest originally, with the interest being heightened greatly in April 1958, when a hole formed in the core vessel. Observations of the hole itself, of the damage to the diffuser screens in the core inlet section, and of the vessel wall for general corrosion effects were the motivating desires in a program of procurement and development of viewing devices for use inside the core and blanket vessels. Some of the equipment was designed for general viewing and photography, while other devices were developed for specific limited applications. This report provides a complete listing of instruments that made a significant contribution to the visual observation of the reactor vessel; it includes descriptions of items procured by the HRT Operations Section and those purchased or developed by the REED Engineering Development Section.

Figure 1 is a diagram showing the core- and blanket-vessel assembly under the biological shield. It can be seen that the typical working distance is 18 to 20 ft, and access to the vessel interior is through small flanged openings. The access flange on the north side of the blanket vessel is 3 1/2 in. in inside diameter; the core access is nominally 2 in. in inside diameter, but due to weld shrinkage and push-through, the actual clear opening into the core is only 1.9 in.

A well-collimated beam of gamma rays emerges from any opening in the shield, with an intensity of from 200 mr/hr to several r/hr, depending on the time after shutdown. Measured gamma activity in the core itself is 6 to 8 x 10^4 r/hr.

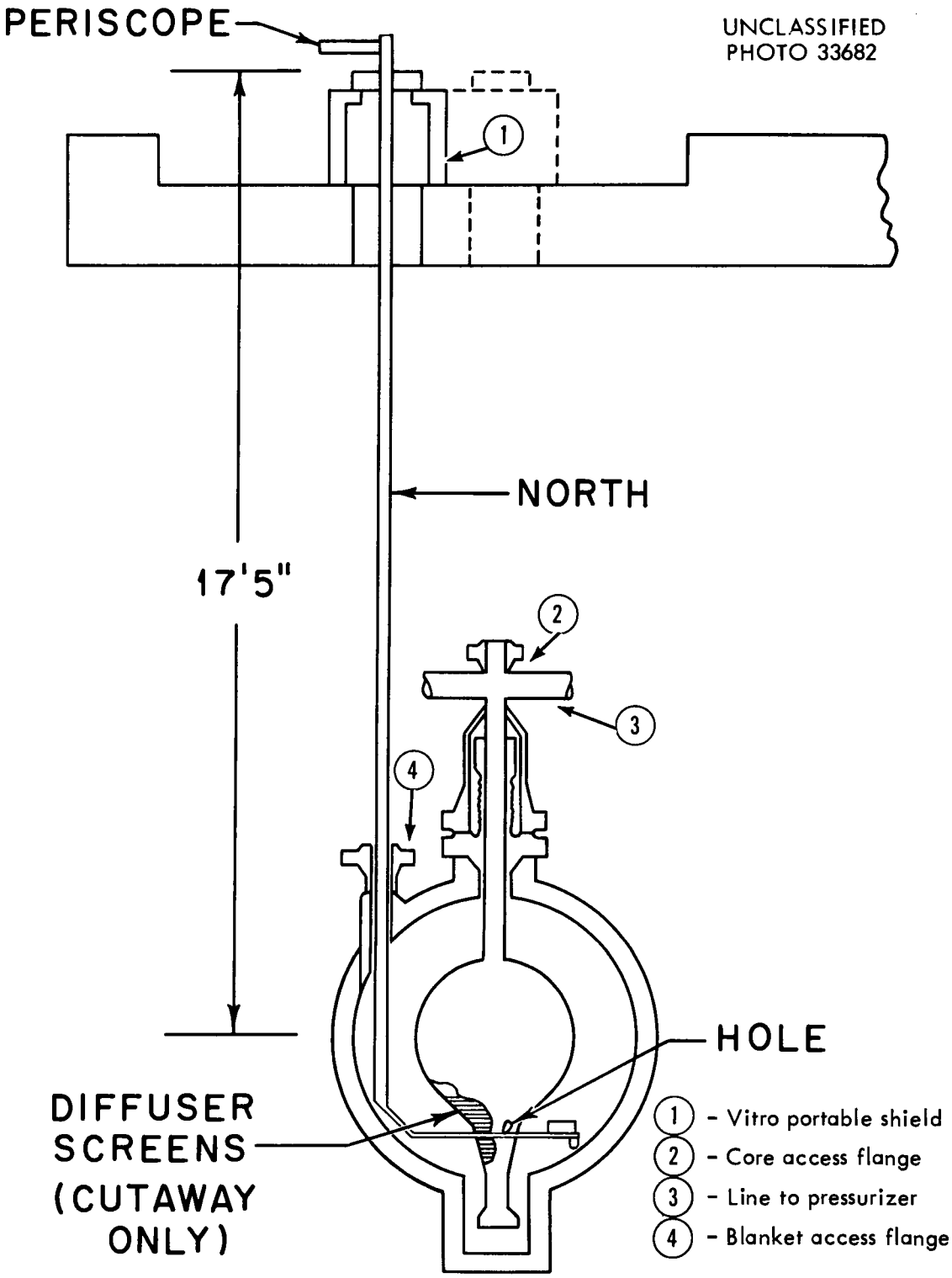

Fig. 1. Diagram of Core and Blanket Vessel Assembly Under the Biological Shield.

GENERAL VIEWING EQUIPMENT

Several viewing instruments were constructed at the Laboratory for general viewing in the core and blanket regions. Figures 2 and 3 illustrate two types of periscopes widely used.

Optical Periscope

The optical periscope shown in Figure 2 is the latest design and is so constructed that all lenses except the objective-lens system can be removed from the contaminated sheath and annealed to restore transparency after exposure to radiation. Conventional optical-glass lenses are used throughout, which limits viewing to about 2 hr in the intense radiation field in the core and blanket vessels. It is possible to remove the eyepiece and substitute a camera mount when desired. This type of instrument was used in the blanket viewing device which first observed the hole in the core and allowed it to be photographed. An Exacta 35-mm single-lens reflex camera was used for all the core photographs.

Tilting-Mirror Periscopes

Figure 3 illustrates the tilt-mirror periscope built for core and blanket viewing. The simplicity of the device makes it less expensive to build than the optical scope, and since it has no lenses in the barrel, it is not affected by radiation. The mirrors used are Alzac surface-coated glass.

A disadvantage of this type of instrument is the small field of view, which is limited to the projected area of the 1-3/10-in.-dia. lower mirror. For general viewing this requires a tedious scanning process or a series of photographs of small areas.

The usefulness of early models was impaired by low-angle reflection from the inside of the tube wall. Addition of the baffles, spaced a foot apart, plus a coat of flat black paint resolved this difficulty.

A 30-power surveyor's telescope is used for magnification of the image. The telescope is clamped in place and hence can be removed from a contaminated periscope and re-used.

VIEWING EQUIPMENT FOR SPECIAL APPLICATIONS

Due to the physical limitations imposed on any device inserted in the HRT core and blanket vessels, viewing instruments developed for special uses were variations of the basic periscopes described above.

"Piggy Back" Periscope

The "piggy back" version of the tilt-mirror periscope is shown in Fig. 4. This instrument was a shop modification of the standard model to provide a self-contained light source. Specifically, it was designed to be inserted through 2-in. holes that had been drilled in the diffuser screens of the core and to allow observation parallel to the screens. Since the space between screens varies from 1 3/16 to 2 3/8 in., the mirror and light source had to be very compact. Two GE No. 1489 light bulbs were clipped to the back of the mirror. During insertion the mirror is raised to the vertical position for compactness. For viewing, the mirror is rotated to the 45° position, exposing the light filaments from behind the mirror.

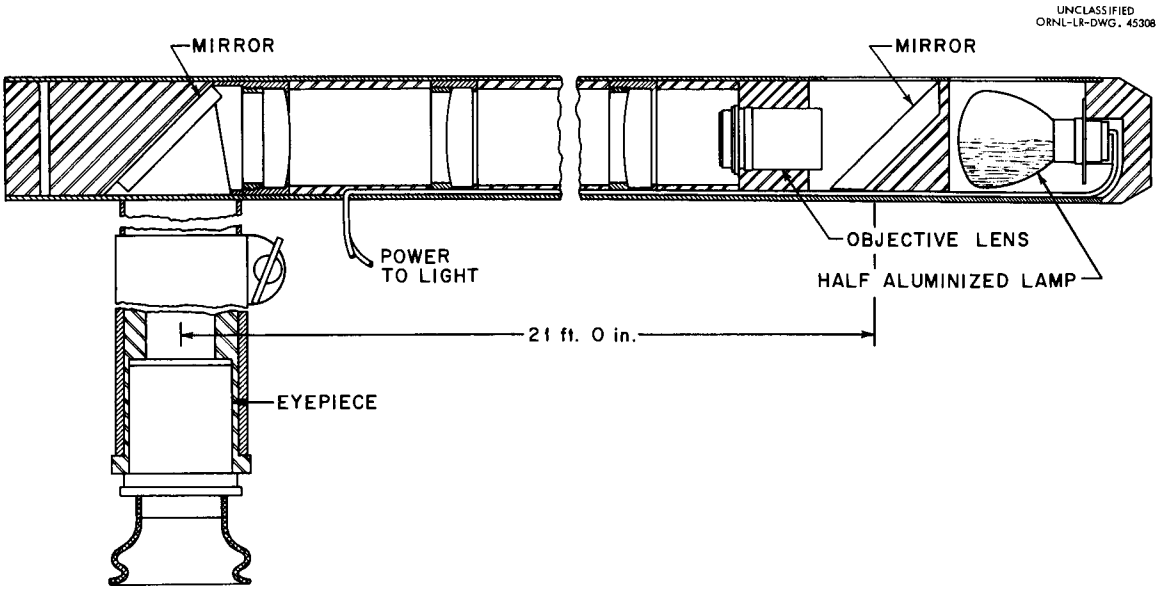

Fig. 2. Optical Periscope Assembly and Details.

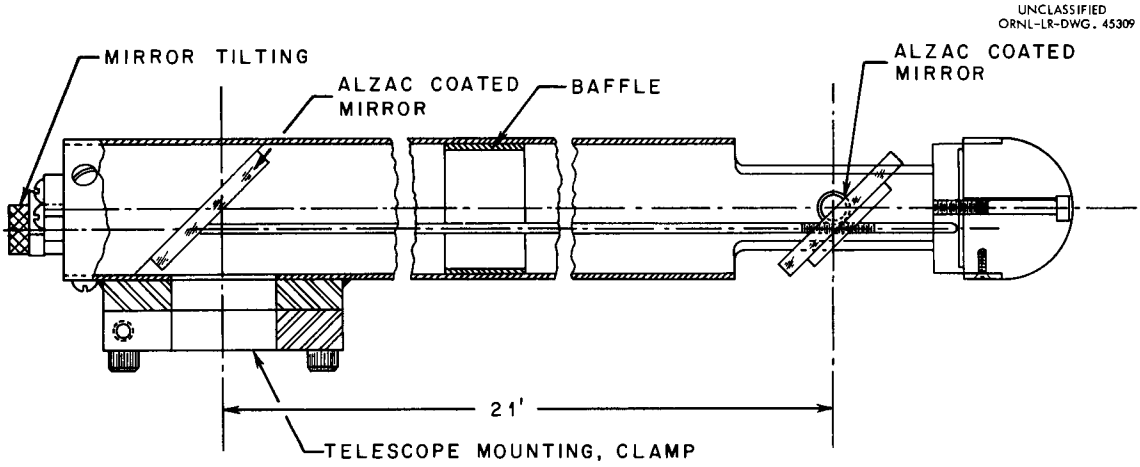

Fig. 3. Mirror Assembly, 1-3/4 in. OD x 21 ft Long.

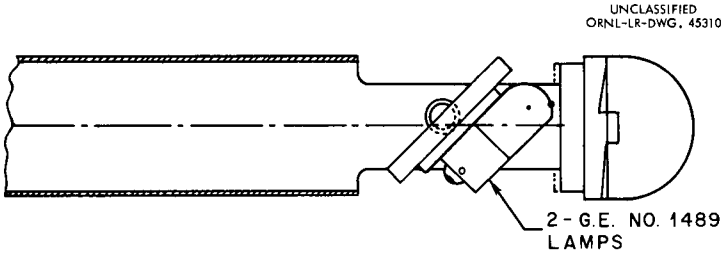

Fig. 4. "Piggy Back" Modification.

Figure 5 is a photograph of the hole taken with this instrument positioned between the fourth and sixth screens. The fifth screen can be seen edge-on in the middle of the hole.

Short Periscope for Viewing in Line 100

Interest in corrosive attack and possible solids deposition in the fuel circulating piping led to the construction of the short periscope for viewing in line 100 in the HRT. The core access flange is welded atop a tee which ties the pressurizer into the circulating fuel stream (see Fig. 1). By inserting the periscope in the tee, the interior of both the fuel circulating line and the stagnant pressurizer line can be observed.

The instrument, shown in Fig. 6, has two remotely controlled mirrors. One is used for observing the interior of the pipes, and the other to direct the light to the desired area.

Combination Periscope and Manipulator

Early viewing after the appearance of the hole in the core revealed 22 corrosion specimens that had fallen out of a specimen holder and were resting on the top diffuser screen. Since the outside diameter of the available periscopes was 1 3/4 in., it was apparent that grappling tools could not be inserted alongside a scope through the 2-in. access flange.

Figure 7 shows a combination of the lower end of the standard tilt-mirror periscope and a pair of remotely operated tongs, which successfully retrieved many of the corrosion specimens. The round mirror can be seen in a vertical position.

Folding-Arm Viewer

The device shown in Figure 8 was the final model of a series of three, designed to find the hole in the core from the blanket side. The horizontal arm and light source are pivoted in such a way that the entire mechanism can be made to hang vertically for insertion as shown in Figure 9. The square aluminum box to which the arm is hinged extends up through the Vitro shield and provides both a rigid support and an envelope to protect the periscope from particulate contamination. A window of nonbrowning fused pure silica at the lower end excludes contamination and still provides an unobstructed view of the image in the mirror.

After insertion through the blanket access port the arm can be raised to the horizontal with the light source hanging below. The mirror, which must be feathered for installation, can then be rotated to any desired position by the operator from above the shield. The device can be erected on either side of the core allowing it to scan the entire lower back side of the core vessel, one quadrant at a time.

Figure 10 shows the device erected in the full-scale core and blanket maintenance mockup.

Figure 11 is one of the first group of photographs taken of the hole in the core vessel with this device. The outline of the core vessel can be seen in silhouette at the left of the mirror. This picture was taken through one of the optical periscopes; however, tilt-mirror scopes have been used with success

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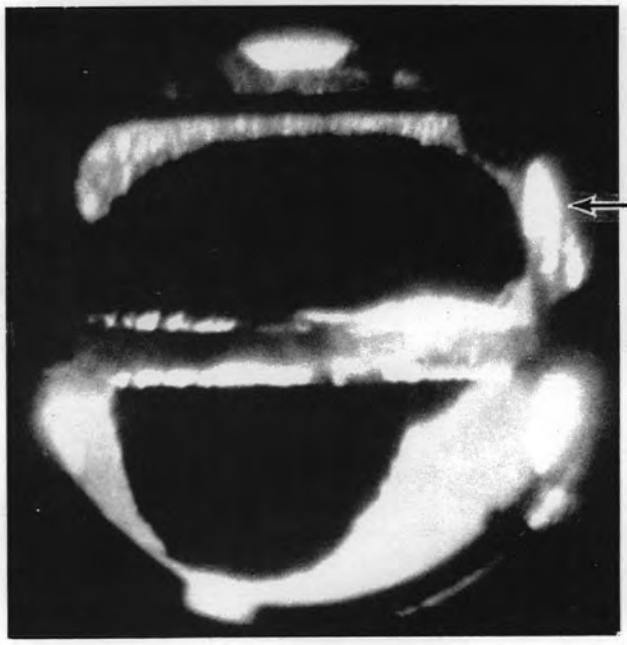

Fig. 5. Photograph of the Hole in the HRE-2 Core Vessel.

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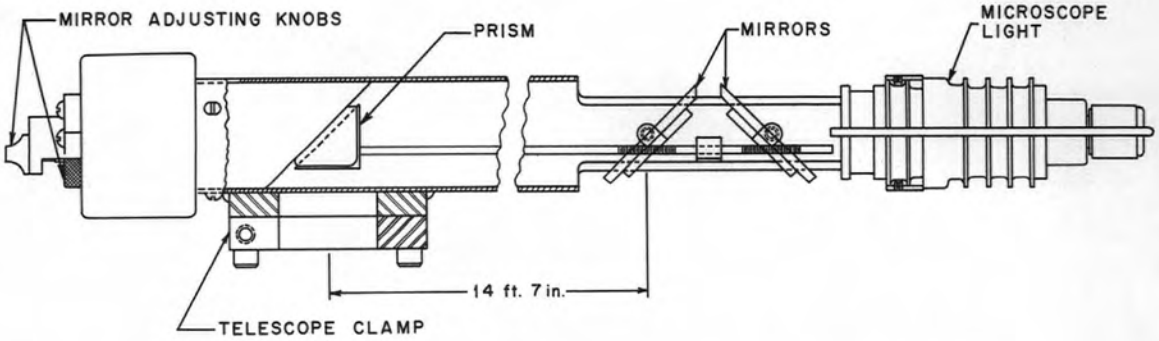

Fig. 6. Mirror Assembly, 1-3/4 in. OD x 14 ft 1-1/4 in. Long.

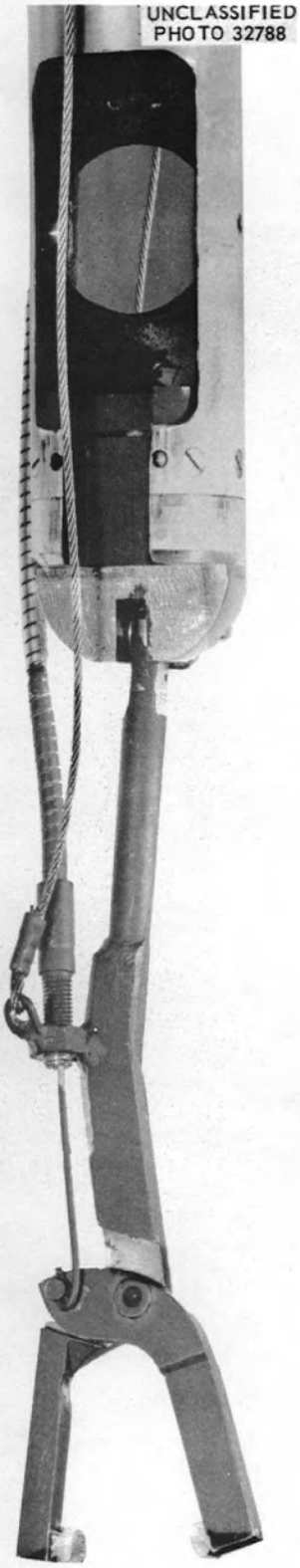

Fig. 7. Periscope-Tong Retrieving Tool.

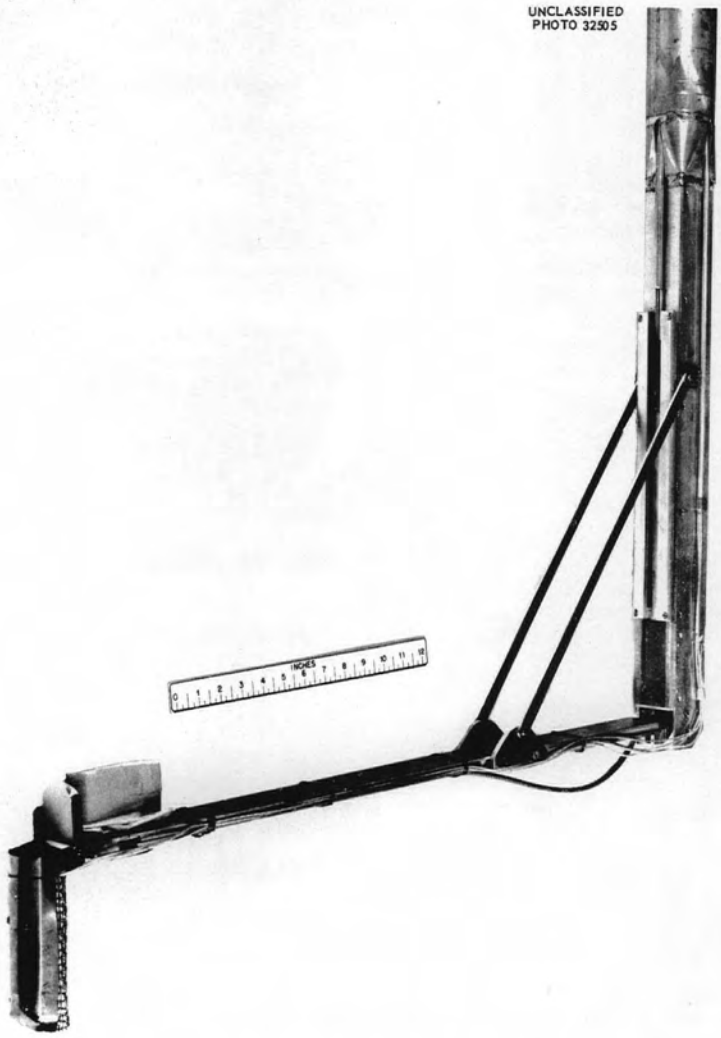

Fig. 8. Folding Arm Viewer (Erected Position).

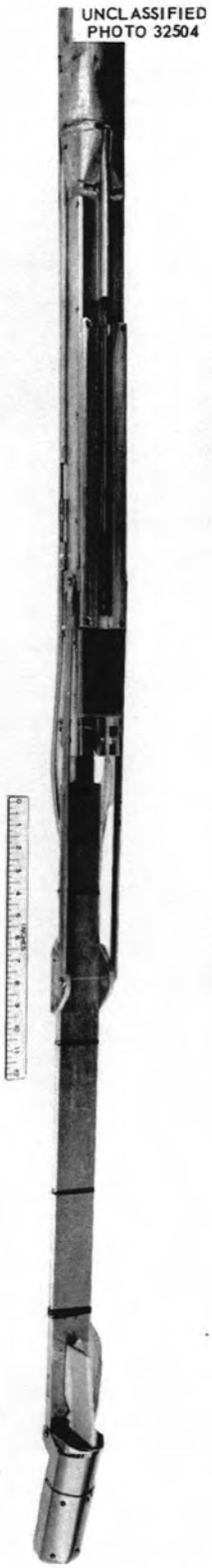

Fig. 9. Folding Arm Viewer.

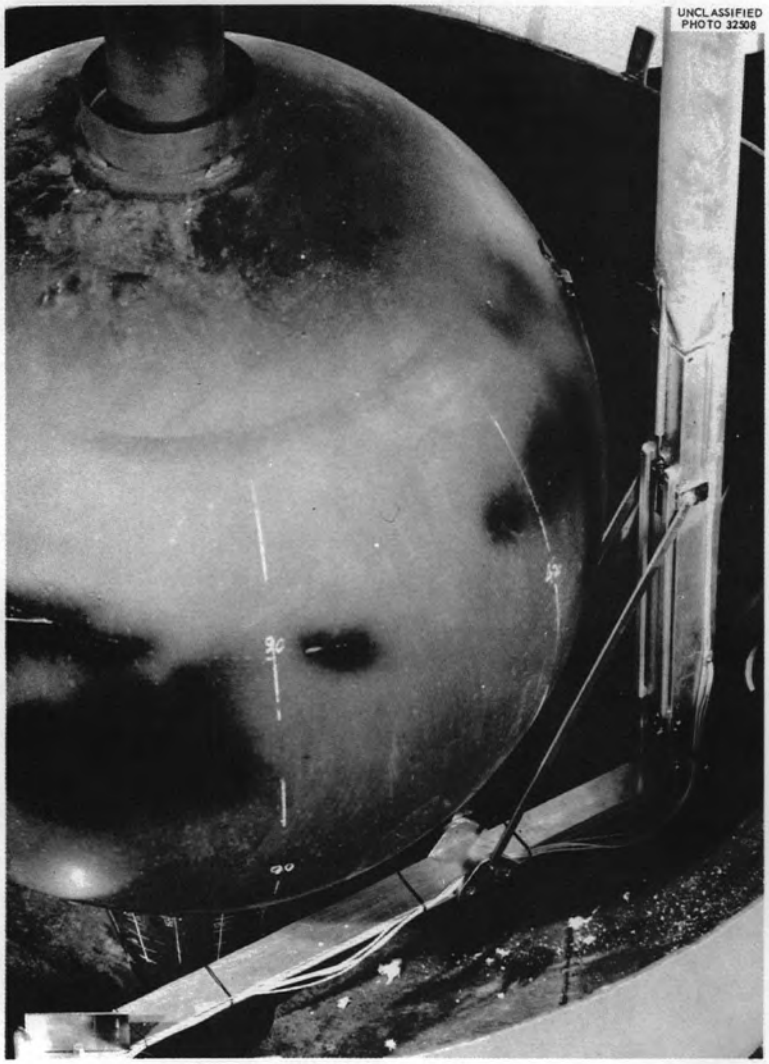

Fig. 10. Folding Arm Viewer Erected in Core and Blanket Maintenance Mockup.

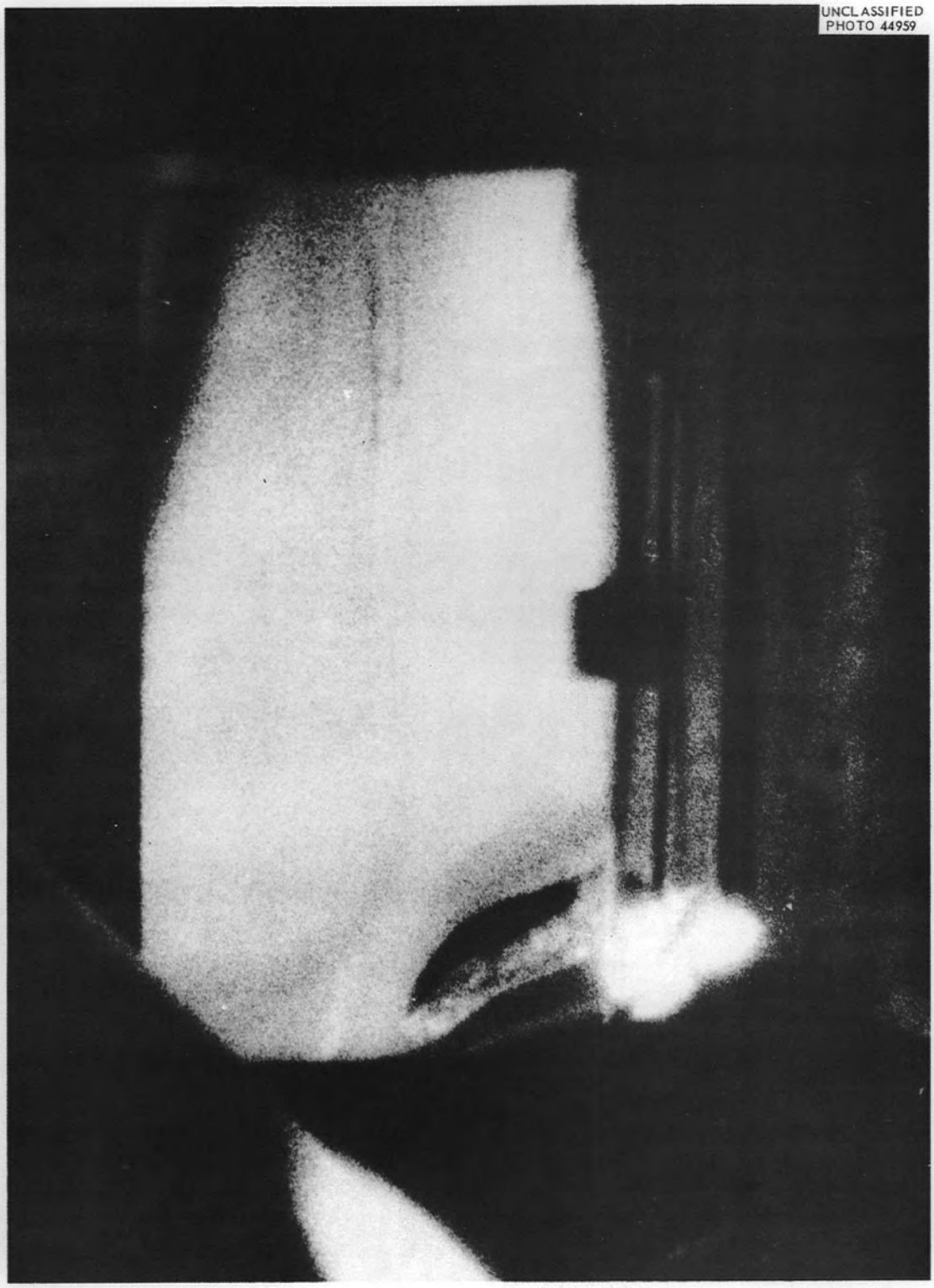

Fig. 11. Hole in Core Vessel as Seen in Mirror of Folding Arm Viewer.

also. A recent modification utilizes two 45° mirrors and a monocular installed directly on the viewing device, eliminating the need for a separate periscope.

External-Light-Source Viewing Device

Early viewing attempts in the HRT demonstrated the problems associated with viewing in a highly radioactive, contaminated environment. Most objects withdrawn from the core vessel showed 6 to 10 r/hr of activity and spread contaminated dust on the shield upon removal. In an effort to obtain limited viewing in the core vessel without danger of contamination, the external-light-source viewer was developed. Figure 12 shows the entire instrument.

In use, the instrument is clamped to the top of the Vitro shield over one of the openings and the image through the core access flange is brought to the 15-power spotting scope by means of a 45° Stellite mirror enclosed in the barrel. Light is supplied by the zirconium oxide arc light which can be seen in the top of the barrel. The light, collimated by a lens, passes through a 1/2-in. hole in the mirror and illuminates the diffuser screens sufficiently for manipulations to be carried out. Since there is no obstruction in the core opening, several long-handled tools can be inserted simultaneously to move screens, grapple for foreign objects, etc.

Since the periscope is focused on objects 20 ft away, the handles of tools appear only as blurs and do not seriously impair vision. The large objective lens renders the hole in the mirror invisible. Adjusting screws allow the light beam and optical axis of the apparatus to be adjusted independently until the optimum image is obtained. Because of the mirror the image is inverted, which makes manipulation somewhat tedious.

Omniscope

The Omniscope, shown in Figure 13, was purchased from the Lerma Engineering Company of Northampton, Massachusetts. It is 21 ft long but has an outside diameter of only 7/8 in. The objective lens is of novel design providing a 180° field of view. At 3 in. the power is 1X; at infinity, 1/3X. All optics are of nonbrowning glass, and the eyepiece is constructed to give an erect image. To prevent contamination of the expensive ($3500) periscope, it is enclosed in a protective sheath when inserted in the reactor vessel.

Two types of expendable sheaths were procured. One has a flat, nonbrowning glass window soldered into a 1-in.-OD brass tube. This arrangement reduces the field of view to 120° but is inexpensive and is adequate for most applications. The other type has the outer portion of the 180° objective lens soldered into the tube, providing the full field of view.

A camera mount and right-angle viewing attachment have been ordered for this instrument, which will allow detailed study of the core-vessel wall. The field of view at right angles will be 30° and the power 1X. Figure 14 is a view of the interior of the core vessel taken with the original instrument.

TELEVISION CAMERA

A special small television camera[1] was purchased from Dage Television Division of Thompson Ramo Wooldridge, Inc., for viewing inside the core vessel. Practically all electronic components susceptible to radiation damage were

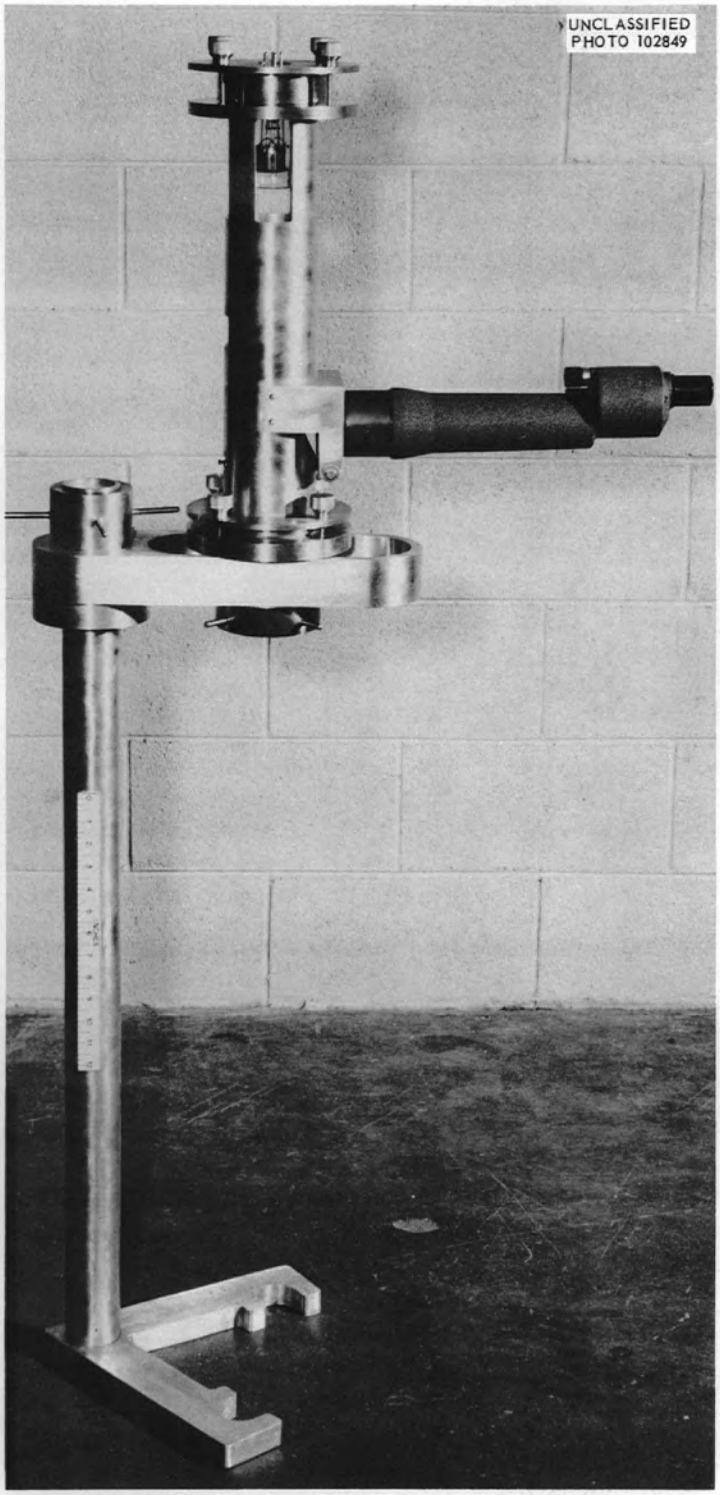

Fig. 12. External Light Source Viewer.

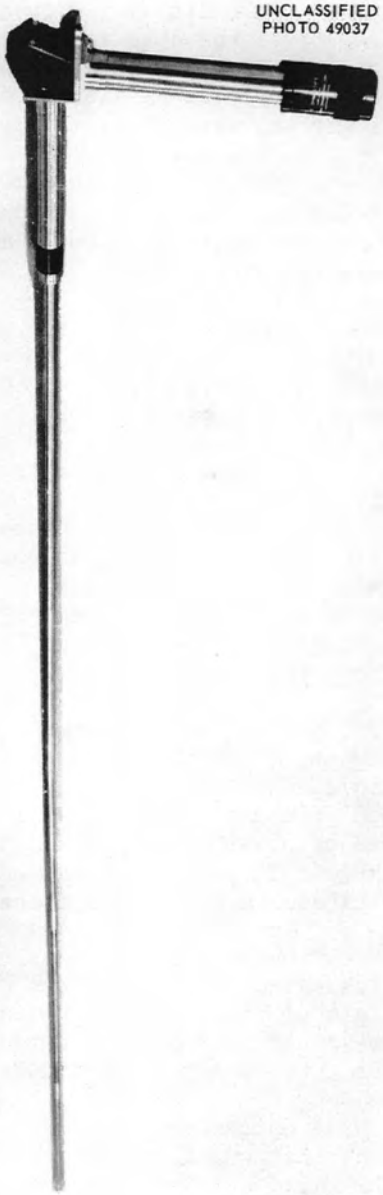

Fig. 13. Omniscope.

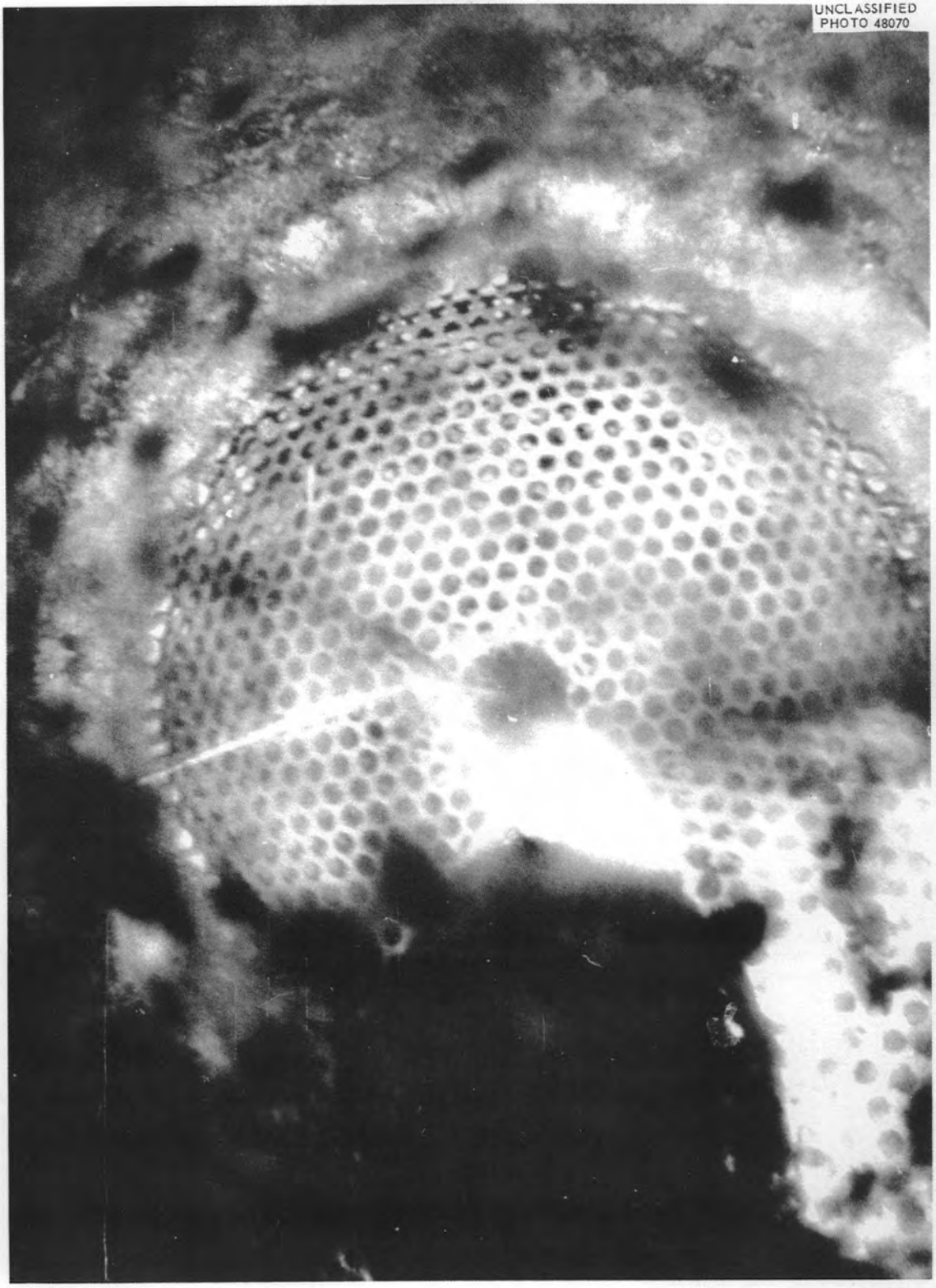

Fig. 14. Omniscope View of Core Vessel Interior Looking Down on the Diffuser Screens.

removed from the camera proper and installed in a preamplifier assembly which could be located as far as 10 ft distant. Figures 15 and 16 show the camera and preamplifier unit. The camera is only 2 in. in outside diameter and 8 1/2 in. long.

Recent tests of the camera unit, with a new Wollensak nonbrowning lens, have shown good resistance to radiation damage. The camera and lens operated satisfactorily for 200 hr in a field intensity of 4×10^5 r/hr produced by a cobalt source.

Blanket Television-Camera Manipulator

A manipulator was developed which would allow a television camera to scan the outer surface of the core. Since the elevation of the hole had been established as being below the top diffuser screen, it was apparent that the hole would have to be located from outside the core vessel. Furthermore, the hole was thought to be on the side of the vessel opposite the blanket access flange. This meant that for the camera to observe the hole after insertion through the blanket access flange, it would have to be maneuvered in the annular space between the core and blanket vessels. To this end the manipulator shown in Figure 17 was designed and built.

Three articulated links support the camera and its light source. The links can be rotated independently by hydraulic controls and their relative angular position is continuously indicated at the control panel. The camera, which observes the core in a 45° mirror, can be rotated about its axis remotely to provide vertical scanning.

To reach any general area in the core vessel, it is necessary to go through many steps in a programmed sequence. Such routines were worked out in the full-scale core-blanket maintenance mockup. As a continuous check on camera position a small model of the core and blanket was built, with a calibrated model of the manipulator installed. Progress of the manipulator in the reactor vessel can thus be followed and possible damage to the camera avoided.

Since the hole was observed and photographed with simpler equipment, the camera and manipulator have not been inserted into the reactor vessel to date.

Core-Vessel Scanning Mechanism for Television Camera

Although the interior of the core vessel has been observed and photographed on several occasions, viewing has always been limited to one observer at a time or a series of photographs of a given area. Since one or more monitors could be attached to the television camera, several observers could look at the vessel wall simultaneously and discuss what they see.

Since the small television camera was available and a suitable light source had been developed and tested, it was decided to design and construct a simple manipulator to insert the camera into the core for general viewing or to assist in manipulations. The new device, shown in Figure 18, supports the camera on a vertical tube which can be raised or lowered to provide vertical scanning. Horizontal scanning is obtained by rotating the tubular support.

To provide clearance for other tools it is desired that the camera be swung out of the way after insertion in the core vessel. It is also desirable to focus the camera after insertion. Both of these requirements are met by the

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Fig. 15. Television Camera with Mirror and Light.

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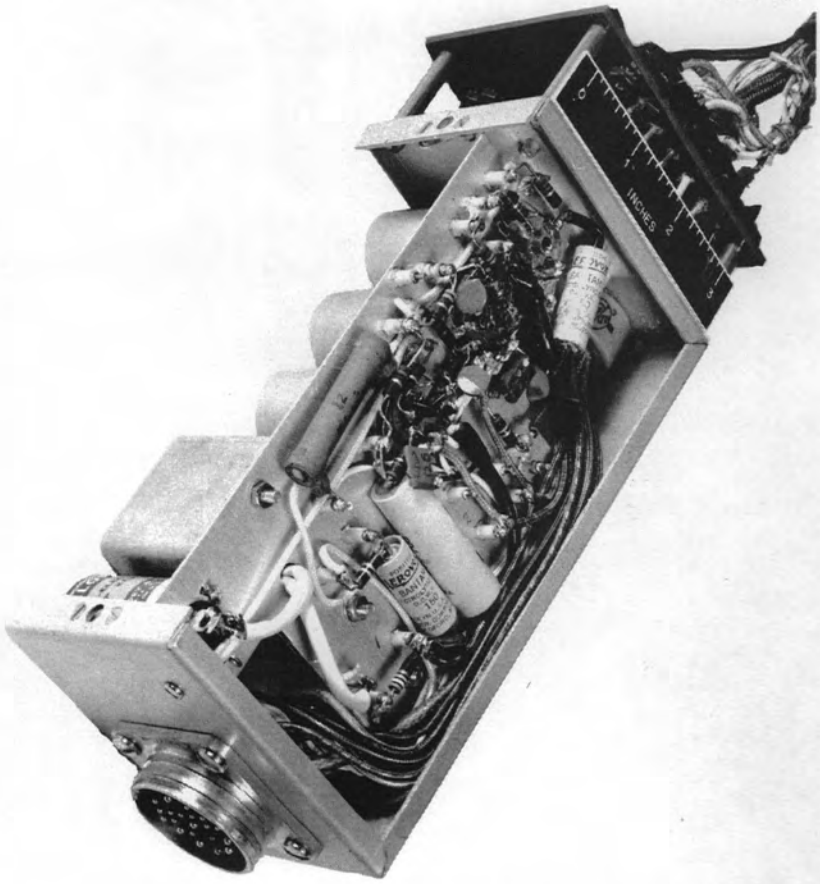

Fig. 16. Television Camera Preamplifier Unit.

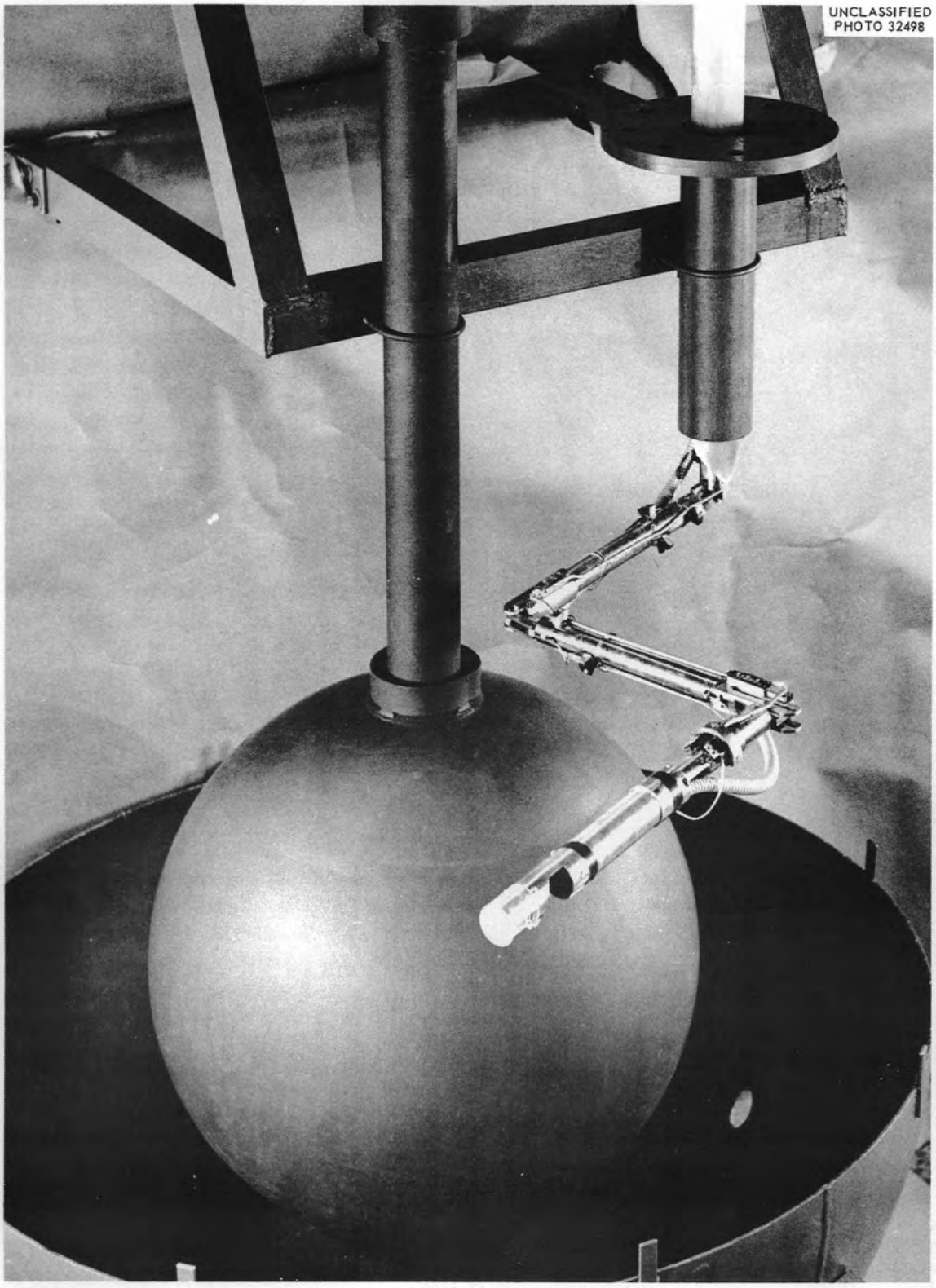

Fig. 17. Television Camera Manipulator Inserted in Core and Blanket Vessel Maintenance Mockup Demonstrating Articulation.

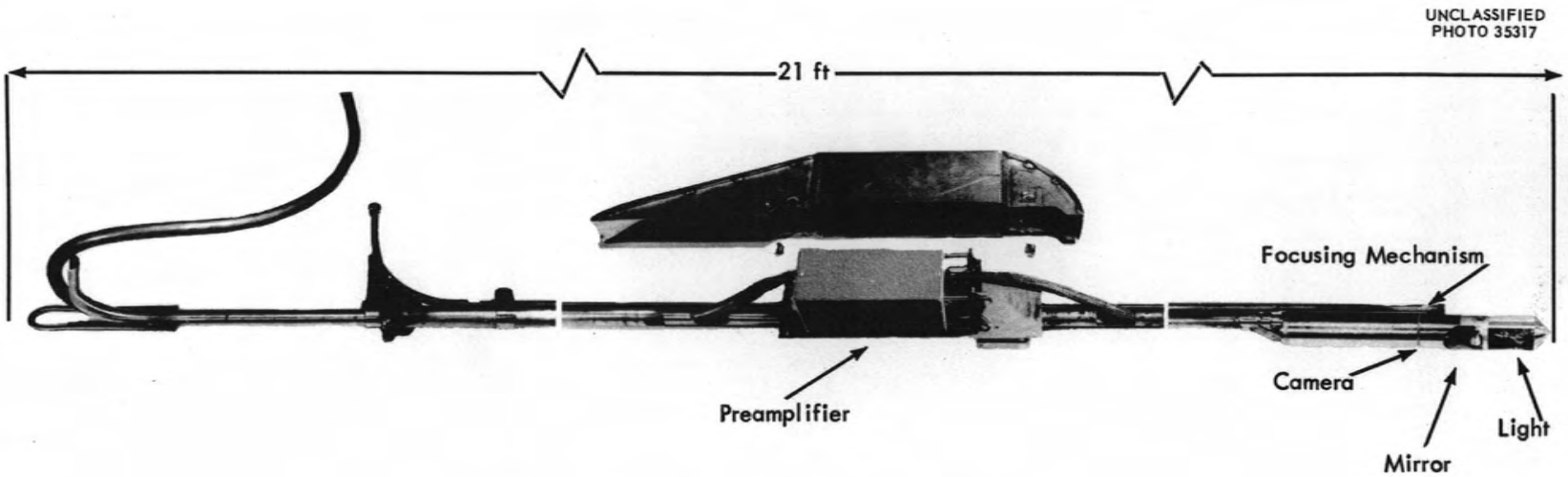

Fig. 18. Rigid Television Camera Manipulator.

support mechanism, which allows the assembly to be retracted into a compact 2-in.-dia assembly for insertion and then rotated away from the axis of the access flange, which simultaneously engages the focusing gear train.

The remote preamplifier assembly and shielding plugs developed for the blanket viewer were adapted for this simplified instrument.

LIGHTING DEVICES

Basic problems encountered in providing light for viewing and photography in the HRT are: restricted access, radiation damage, insufficient cooling, and the inherent fragility of light sources.

The life of instruments with self-contained light sources was frequently determined by the life of the light source. Since most devices read 6-10 r/hr when removed from the core, relamping is hazardous. Where possible, a spare bulb on a separate circuit has been included, or at least a double-filament globe used. Lamps are generally run at 50% to 70% of full power to prolong their life.

In general, it has been the practice to enclose a lamp in a housing or screen basket to protect the fragile glass envelope from damage during insertion or manipulation. These enclosures also protect the glass from thermal shock when the vessel walls are still damp.

Radiation Effects

The gamma field of 6 to 8 x 10^4 r/hr in the HRT core will turn glass brown or black in a few hours; however, a lamp that is burning "anneals" itself and remains useful. Spare lamps are normally run at 30% power to keep them clear until they are needed.

The most severe effect of radiation has been damage to the electrical leads carrying current to the lights. Common plastic and rubber insulation deteriorates and flexing of the leads causes failure. After a search for suitable insulation, one satisfactory commercial product was found. It is Alphalex varnish-impregnated Fibreglas, flexible tubing type PIF-130 insulation, class B, grade B, 4000-v rating (obtained from the Alpha Wire Company, New York). This insulation is used as a sleeve over bare copper wire and remains pliable after several days exposure.

Mechanical Considerations

Early attempts at viewing were made with photoflood lamps in the blanket, and with projector lamps in the core because of their small size. These are high-performance, short-lived bulbs with fragile filaments. Power was frequently lowered 50% to prolong filament life, and the loss in illumination compromised the original choice of a high-performance bulb.

Investigation of commercially available lamps turned up two types, either of which will go into the core or blanket. Figure 19 shows these lamps, both bare and enclosed in hardware-cloth baskets for use as drop-lights.

The small aircraft globe (GE 1047) is a rugged, two-filament lamp, drawing 70 w at 26 v. It is the size of an automobile headlight globe and emits a

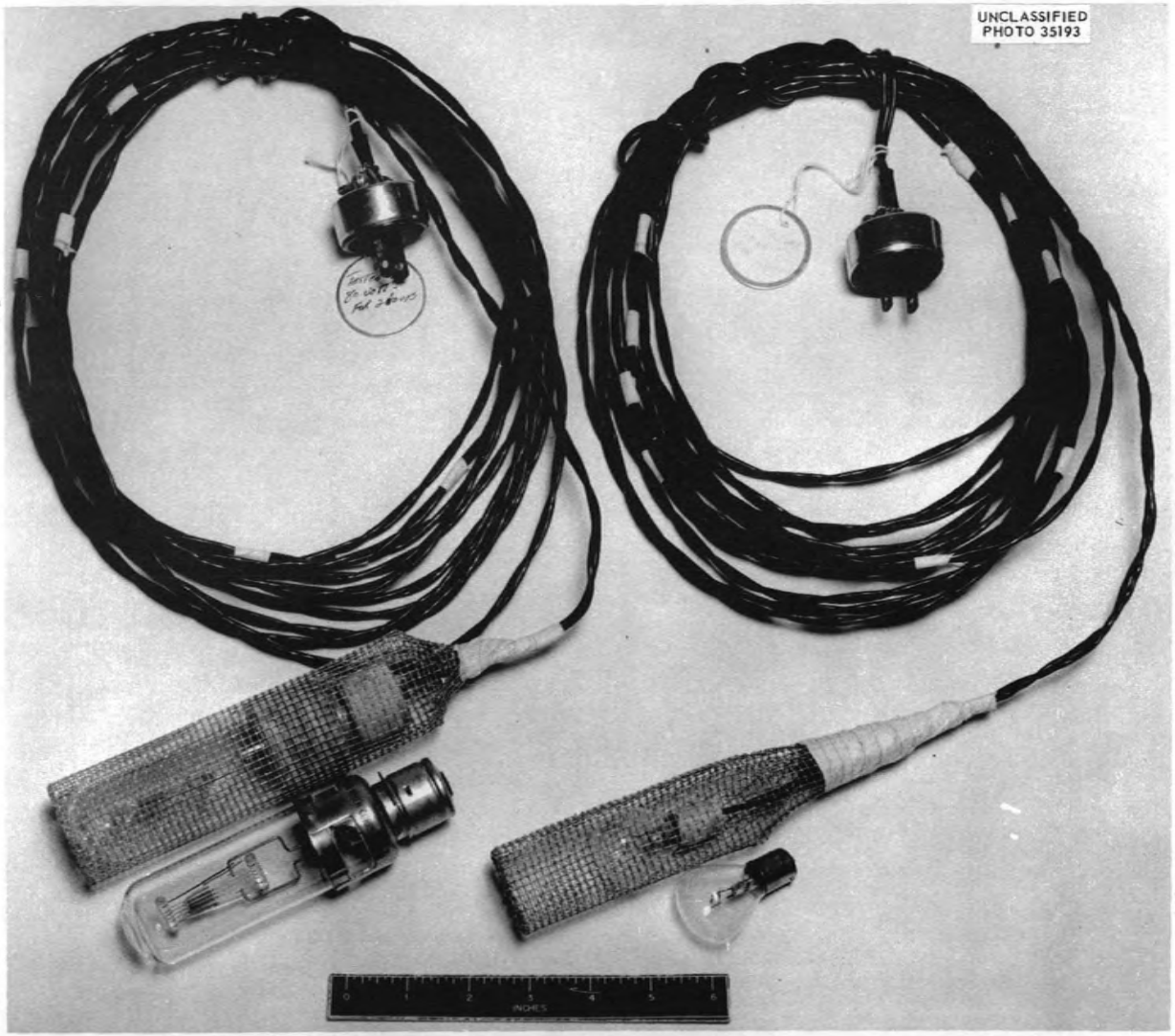

Fig. 19. Lamp and Cord Assemblies.

brilliant light for about 25 hr. The filament is rugged; when a test lamp fell on the bench, the glass envelope was shattered but both filaments were left intact.

The larger lamp is a 120-v 500-w outdoor spotlight globe (GE 500T 12/8). This lamp is designed to burn base up, which adapts it to drop-cord service. Its 1 3/4 in. outside diameter allows the enclosed version to be inserted into the core. This lamp, which provides brilliant general illumination, is normally the one used for general lighting in the reactor vessels. Lighting for the picture in Figure 14 was provided by this lamp.

CONCLUSIONS

Experience gained with viewing equipment in the HRT has demonstrated the usefulness of the simple mirror-type periscope in many applications. The versatility of this instrument makes it easily adaptable to special applications where the radioactive barrel can be discarded.

Where the wide-angle field or high-magnification of the multiple-lens type periscope is required, the optics should be of nonbrowning glass. Lenses of these materials, which are becoming increasingly available, are necessary to justify the initial cost of such a device. Where contamination is present, an expendable sheath with a plane window has proved satisfactory. The sheath costs about 10% of the price of the periscope and is a good investment.

The external-light-source viewer has proved a handy tool to use with long-handled manipulators, since it does not obstruct the access flange. An erecting eyepiece would be a welcome improvement to this instrument.

ACKNOWLEDGMENTS

The instruments described in this report are the work of people in several parts of the Laboratory. The author desires to acknowledge the contribution of the people directly responsible for the successful design, construction, and testing of these devices.

Optical periscope	R. J. Fox (design and construction)
Tilt-mirror periscope	R. J. Fox (design and construction)
"Piggy back" periscope	R. Blumberg and R. J. Fox (design and construction)
Short periscope for line 100	R. J. Fox (design and construction)
Combination periscope and manipulator	R. J. Fox, T. E. Haynes and D. Scott (design); D. Scott (development and operation)
Folding-arm viewer	R. L. Cauble, B. D. Draper, E. C. Hise, and R. Blumberg (construction, testing and operation)
External-light-source viewer	J. M. Robinson, J. Jones and E. C. Hise (design and construction)
Television-camera manipulator for blanket viewing	C. W. Collins, R. L. Cauble, P. P. Holz and R. L. Moore (design); P. P. Holz (development)

Television-camera manipulator for core viewing	R. L. Cauble, F. C. Zapp and J. Jones (design); P. P. Holz and R. L. Moore (testing)
Auxiliary lighting in core and blanket vessels	J. Buchanan (testing)

REFERENCE

[1]P. P. Holz, "Miniature TV Camera Manipulator," ORNL-CF-59-11-129, November 26, 1959.

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