DEVELOPMENT AND OPERATION OF TELEVISION FOR STUDYING FISH BEHAVIOR IN OTTER TRAWLS

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by

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TABLE OF CONTENTS

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ABSTRACT

Underwater television equipment (Image Orthicon) used for studying the behavior of fish in otter trawls is described. Development of the equipment, including the television chain itself and the accessory power source, lights, etc., plus some methods of using the equipment are explained. Considerable attention is devoted to problems of operation, particularly to the difficulties in handling the camera cable.

An extensive appendix gives in some detail the specifications of the television equipment used.

Underwater television was successfully used for the first time in connection with the Bikini atom bomb tests of 1947 (Schultz 1948). Since the Bikini tests, television has been used for such purposes as searching the ocean floor for sunken vessels and for parts of wrecked aircraft (Stamp 1953, Cross 1954), for making observations for marine engineering projects (Barnes 1956), and for investigating the biology and ecology of fish and other animal populations (National Research Council of Canada, 1953; Backus and Barnes 1957; Barnes 1952, 1953, 1955; Cuerrier et al. 1953; and Taylor 1953).

The operation of marine fishing gear has also been studied with underwater television. The U. S. Fish and Wildlife Service and U. S. Navy Bureau of Ships conducted a joint program to observe midwater trawls in Florida waters during October and November 1954. Subsequently, television equipment was used in Florida waters by the Fish and Wildlife Service to study fish traps and shrimp trawls (Sand 1955, Sand and McNeely 1956). The Fishery Research Board of Canada with the National Research Council of Canada used television equipment to study scallop drags in the Bay of Funday (Cameron 1955).

The present report describes television equipment developed at the Woods Hole Biological Laboratory of the U. S. Fish and Wildlife Service for studying the behavior of marine fish, principally haddock. This equipment was designed specifically to study the behavior of marine "groundfish" in otter trawls on the New England offshore banks.

DESCRIPTION OF THE EQUIPMENT

The Television Chain

The complete Image Orthicon television chain is shown in figure 1. For the benefit of those interested in the detailed electronic and mechanical characteristics of our equipment, we have included specifications and camera detail photographs in an Appendix.

The equipment was designed to provide maximum versatility. The proposed program of research necessitated that a number of specific requirements be included in the design. Special provisions made to ensure the fulfillment of each of these are considered in the following discussion.

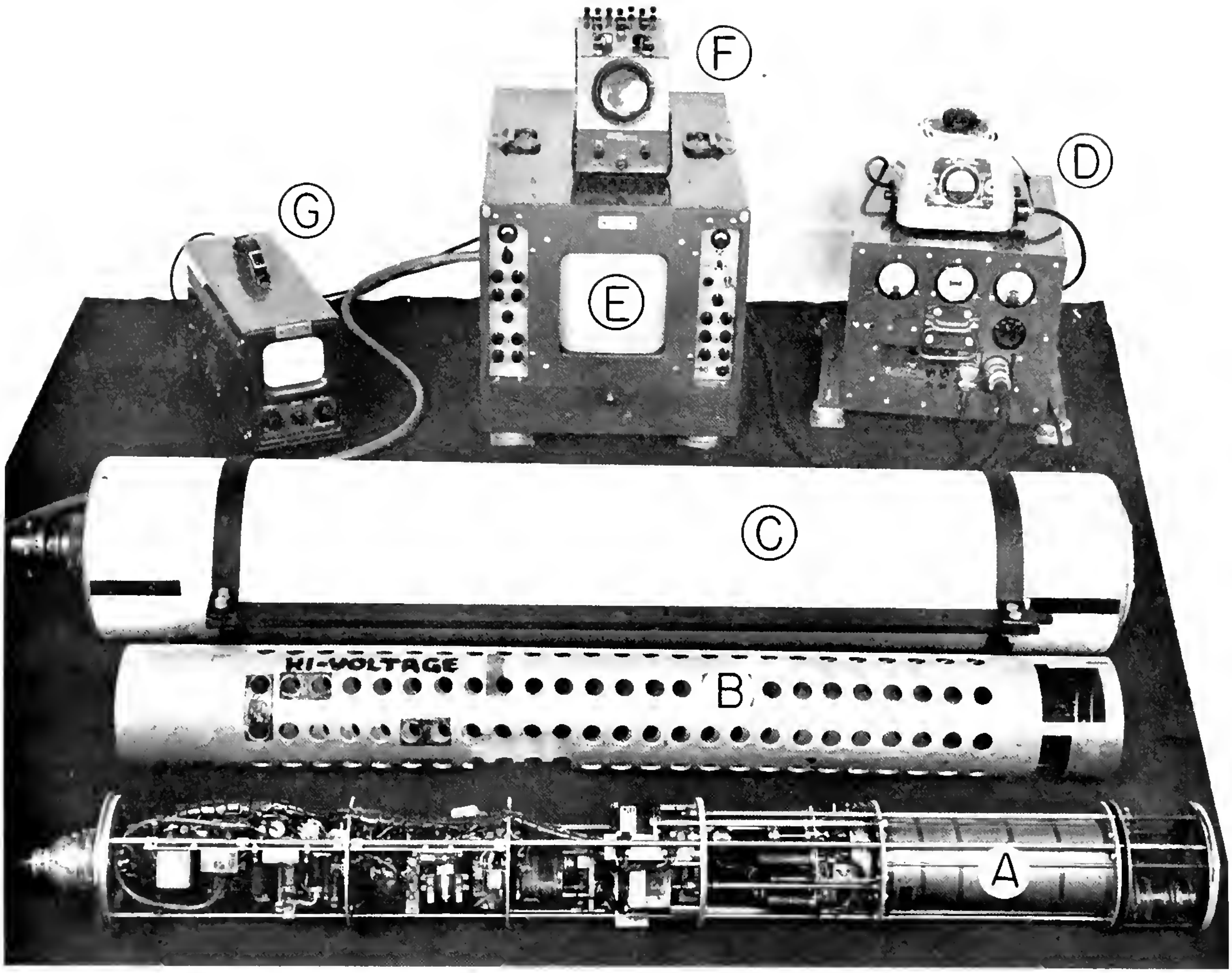

FIGURE 1.--COMPLETE IMAGE-ORTHICON TELEVISION CHAIN. INDIVIDUAL UNITS INCLUDE: (A) CAMERA, (B) PROTECTIVE SLEEVE, (C) WATERTIGHT HOUSING, (D) POWER SUPPLY AND VOLTAGE REGULATOR, (E) CAMERA CONTROL UNIT AND VIEWING MONITOR. THE OSCILLOSCOPE (F) AND SMALL MONITOR (G) ARE ACCESSORY EQUIPMENT.

1. <u>High sensitivity, good resolution, stable high-quality reproduction.</u>

To meet these requirements, an Image Orthicon camera was chosen because it can produce a picture of adequate quality with as little as one-half foot-candle of illumination. Other types, such as Vidicon or C. P. S. Emitron, require considerably more illumination. The disadvantages of Image Orthicon equipment are greater bulk, more complex circuitry, and higher cost. These were accepted, however, as high sensitivity is essential for observing fish under low illumination without risk of changing their behavior by use of artificial light.

2. <u>Compactness, low hydrodynamic resistance, good stability under tow, and ability to withstand pressure to 1,000 feet of depth.</u>

A cylindrical housing was chosen to provide maximum compactness and low hydrodynamic resistance. A 10-inch-diameter housing was used to give the unit slight (about 2 pounds) positive buoyancy in water. We could have used a housing of somewhat smaller diameter if buoyancy had been no object. The unit weighs approximately 130 pounds in air. The elongated cylindrical shape of the housing and detachable stablizing fins provide good stability under tow.

Anodized aluminum was used for the housing to combine corrosion resistance, minimum weight, and maximum strength. To withstand the 455 pounds-per-square-inch pressure at depth of 1,000 feet, the housing wall was made 7/16 inch thick and the 6-inch-diameter window at the front of the camera was made of 1-inch-thick tempered plate glass. For a detailed discussion of camera-housing requirements for underwater use, see Edgerton and Hoadley (1955).

The window, the back plate, and the cable connector were sealed with neoprene O-rings to prevent leakage. The connector is of a special type designed for ease of connection and removal of the cable (Appendix figure A-1), a great operational advantage in using underwater television.

3. Ruggedness, reliability, simplicity, and ease of access for maintenance.

The design of the above-water equipment (control unit and power supply) incorporated the normal precautions used with any marine electronic gear. All units were properly mounted to prevent excessive vibration and shock. Because space is normally a problem aboard vessels, the above-water equipment was designed for compactness; all components were housed in two major units (D and E shown in figure 1).

The neoprene-coated cable connecting the camera to the control unit was reinforced internally with a stainless-steel core providing a tensile strength of approximately 5,000 pounds. During normal use the cable is not subjected to more than 500 pounds' tension. Where severe strain is not likely to be encountered, a cable with a fiber core rated at 2,500 pounds can be used. Fiber-core cables are easier to handle because they are more flexible and less likely to kink.

The electronic components were hermetically sealed where possible, to provide further protection against leakage, condensation within the housing, and the usual extreme humidity at sea. In addition, all components were spray-coated with a moisture-resistant plastic. "Ruggedized" tubes and special mountings were used for protection against shock.

The camera, which generates considerable heat in operation, is cooled only by the surrounding water. Because overheating of the camera pickup tube can create serious operational problems, a temperature-sensitive element in the housing warns of excessively high temperatures.

A moisture indicator signals the presence of water in the housing to minimize water damage to the camera in the event of a leak. The sensing element is shown on the inside facing of the front ring of the camera in Appendix figure A-3.

The equipment was constructed in such a way that the camera could be removed from the housing simply by disconnecting the back plate and sliding out the whole unit, thus providing for ease of maintenance. The slender camera unit was encased in a perforated cylindrical sleeve to give it added rigidity. The various components were arranged to provide ready access for servicing.

4. Maximum versatility and adaptability.

The camera unit was equipped with three lenses of different focal lengths to provide for versatility in operation. Any of the three lenses may be brought into use in about five seconds through a remotely controlled, motor-operated lens turret. A remotely operated iris diaphragm was provided.

A very important feature was "gamma adjustment" which improves definition of underwater objects by providing control of gray shade. This was provided because underwater scenes generally lack contrast and appear very "flat."

An electronic process called blanking (which means elimination of the bright traces of the scanning beam from the end of one line on the screen to the beginning of the next) was provided for in the preamplifier. This is an important feature because it allows for interchange of cables of different lengths without the time-consuming process of removing the camera from the housing for adjustment.

Lights and fins were attached with brackets in such a way that they could be easily mounted on or removed from the housing. All-aluminum attachments were used whenever possible. When parts made of other metals had to be attached to the aluminum housing, insulating material between the different metals was used to reduce electrolytic action.

5. Economy and availability.

Television equipment is costly and, of the types available, the Image Orthicon system costs the most. The higher cost had to be borne, however, since this was the only system which provided sufficient sensitivity for our purposes. It was important for us to reduce costs to a minimum and yet to be able to secure the equipment for use within a reasonable period of time. Fortunately, a television system that met our needs had been developed for the U. S. Navy Bureau of Ships, as referred to by Sand (1955). Some changes were required to meet our specific requirements, but costs and construction time were substantially reduced by adapting this previously developed system to fit our needs.

By using a noninterlaced system, we eliminated the need for a synchronizing generator and substantially reduced the cost. Although some loss of resolution resulted, the present unit has been satisfactory for our use to date. A provision has been made for attaching a synchronizing generator if it becomes necessary.

Power Source

A major problem in operating television equipment aboard vessels is that of obtaining an adequate source of electric power. Our system requires a regulated 60-cycle supply of 110-120 - volt a.c. Small vessels normally have 32-volt d.c. systems, and conversion of these to 110-120 a.c. is not practical. Larger vessels (over 100 tons) generally have 110-120 - volt d.c. systems. Our experience has been that conversion to a.c. is often unsatisfactory because the frequency varies beyond the maximum permissible limit. In any event, installation of a converter is not practical for short-term use.

Research vessels often have a 110-120 a.c. system as part of their permanent equipment. This may be adequate for television if the frequency is well stablized and if other items of equipment which could cause interference are not operated from the same system.

Our solution to the problem of a proper basic power source is the use of a portable gasoline-driven generator which provides 2 1/2 kw. of 110-120 - volt a.c., 60 $\pm$ 3 cycles. This generator provides sufficient current for one 1,000-watt underwater light in addition to the basic system requirement of 700 to 1,000 watts.

As mentioned previously, we use a noninterlaced scanning system which, together with elimination of the synchronizing generator, obviates problems associated with frequency instability. This arrangement has the advantage of providing greater tolerance to frequency variation although some loss in picture resolution results.

Lights

We have used artificial light in our fishing-gear studies only when the camera was mounted inside the cod end of the trawl. In this instance, the lamps could be attached easily and safely to the rigid cod-end frame. Use of lights in other studies, such as those of the forward parts of the net, would require special considerations--either that the lights be mounted on the camera housing with a bracket, or suspended from the part of the net to which the camera is attached.

Lighting problems encountered in working with mounting stands, cages, or other similar devices have not been serious because lights may be very simply attached to almost any carrying vehicle. The use of lights complicates operations slightly, in that an additional wire must be handled with the camera cable. The light cable is usually taped or lashed to the camera cable. A single 1,000-watt diver's lamp has been found to be adequate for most of our illumination requirements. An illuminated cod-end scene is shown in figure 2.

OPERATION OF THE EQUIPMENT

Since most of our work with underwater television has been concerned with the escapement of groundfish from otter trawls, the following description will relate, for the most part, to methods used in observations of this type of gear.

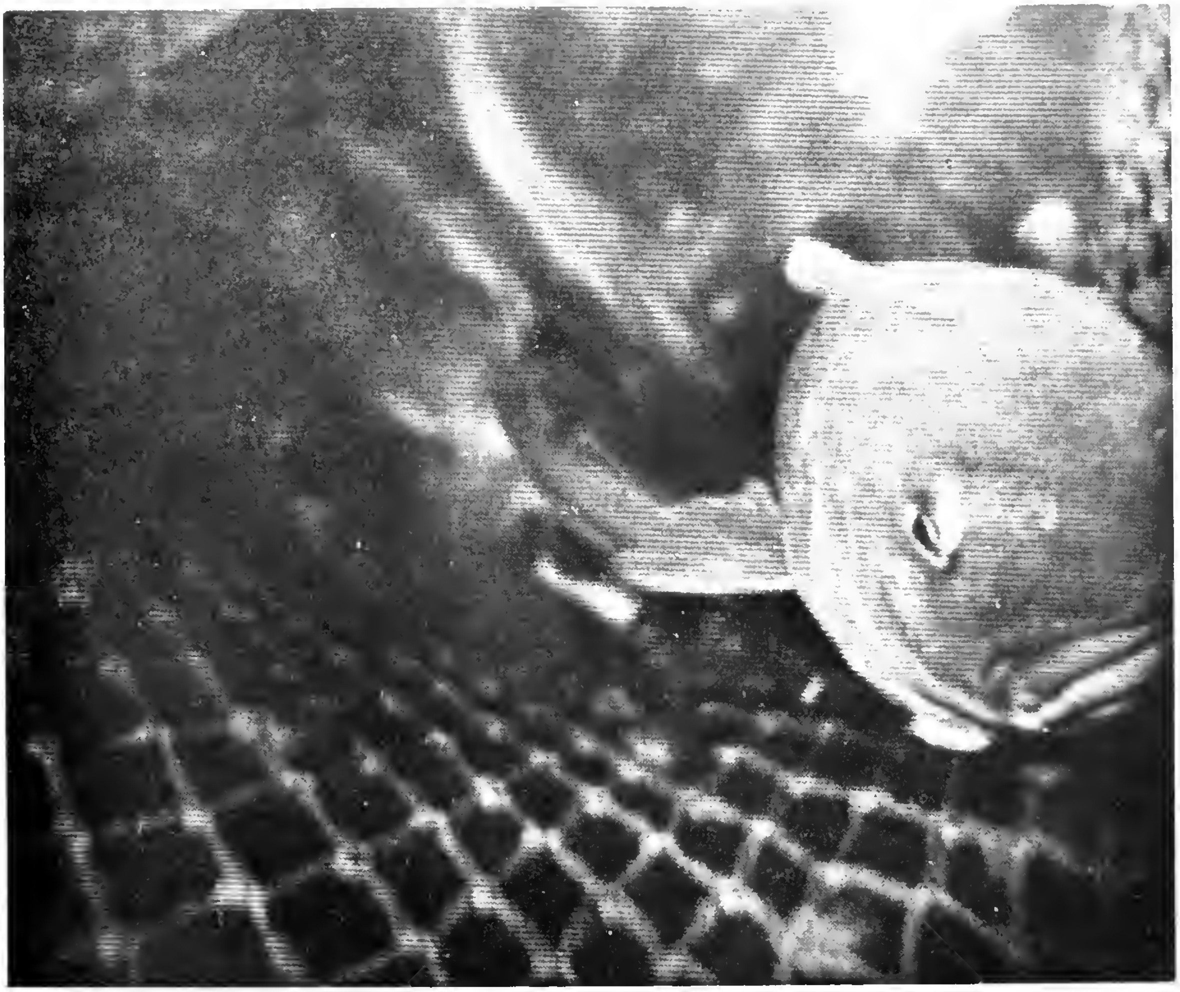

FIGURE 2.--COD-END SCENE ILLUMINATED BY 1000-WATT DIVER'S LAMP AND PHOTOGRAPHED FROM 10-INCH VIEWING MONITOR BY LEICA CAMERA AT 1/25 SEC., F 3.5 KODAK PLUS X FILM. THE FISH IS A COD.

Cod-End Observation

Since most escapement is believed to take place in the cod end, we concentrated our efforts on this part of the net. These operations were carried out aboard the 180-foot research vessel Albatross III. The typical New England type "No. 41 Yankee" trawl used in our studies is shown in figure 3. Knake (1958) gives a complete description of handling methods for this type of trawl.

The camera housing was supported inside the cod end by a cylindrical iron frame, 4 1/2 feet in diameter and 6 feet long (fig. 4). With accumulator-spring linkage for suspension of the housing, the camera performed well while the net was towed over rough ocean bottoms. With the camera mounted in this manner, we have observed the net continuously throughout tows lasting as long as three hours.

The operating procedure followed in observing the cod end of trawls is briefly outlined below.

Warm-up

While the fishing gear is being readied, the television system is given a 15- to 20-minute warm-up and check-out. (Image Orthicon cameras must be tested

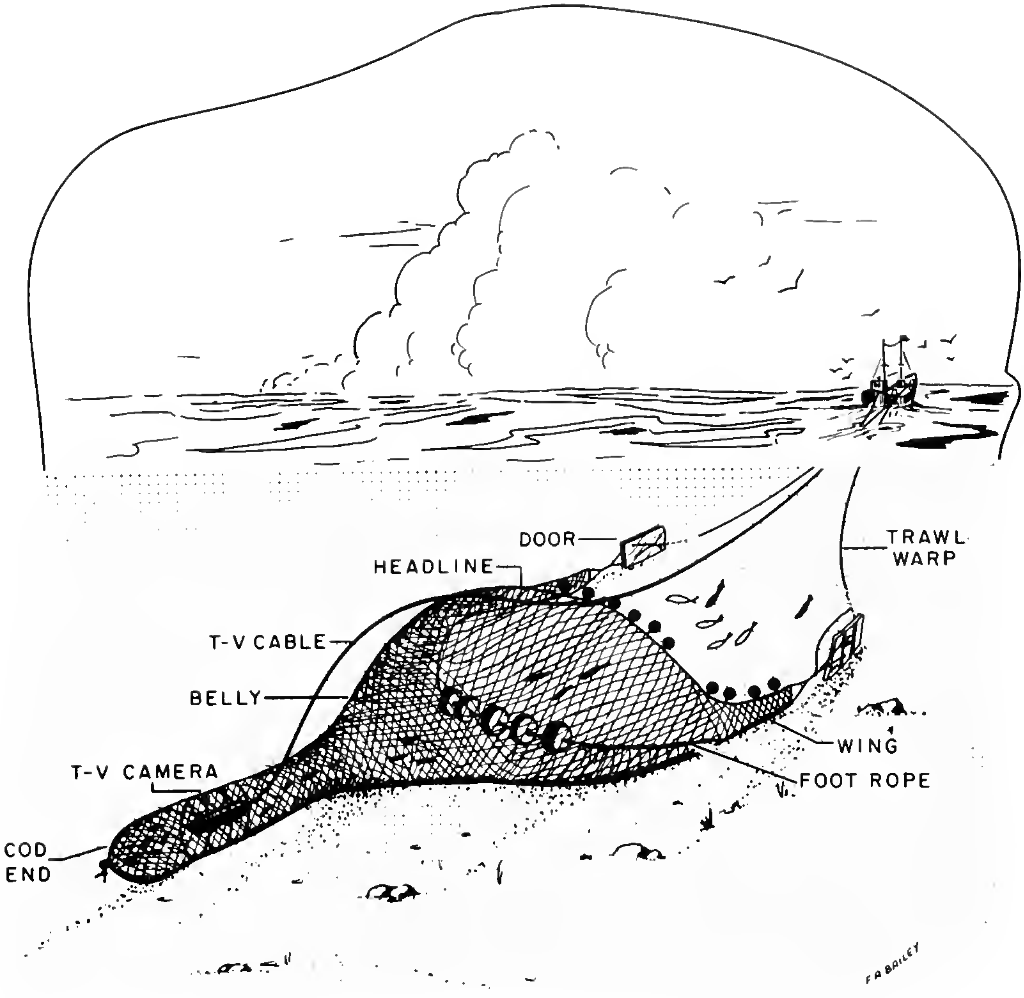

FIGURE 3.- TYPICAL NEW ENGLAND OTTER TRAWL.

after a warm-up period to ensure that all the circuits are operating efficiently.) The cod end, with frame and camera unit inside, is then lowered into the water to be checked for leakage.

Setting out

If after about five minutes' time no leaks are detected, the trawl is slacked away from the vessel and a measured amount of the camera cable is payed out--just enough to provide for optimum slackness. The cable is then lashed to the center of the head line of the net and the vessel steams ahead paying out the trawl warps. Great care must be exercised with the camera cable at this time to prevent it from becoming fouled with parts of the net and the otter boards.

As soon as the net has cleared the stern, the camera cable is payed out over the winch head through a snatch block on the boom (see fig. 10, page 12) at a rate in keeping with the rate of setting of the trawl warps. This is the most critical point in the cable-handling operation--too little slack will cause cable breakage, too much slack will cause fouling of the cable with the trawl.

Usually a length of camera cable and trawl warp amounting to three times the

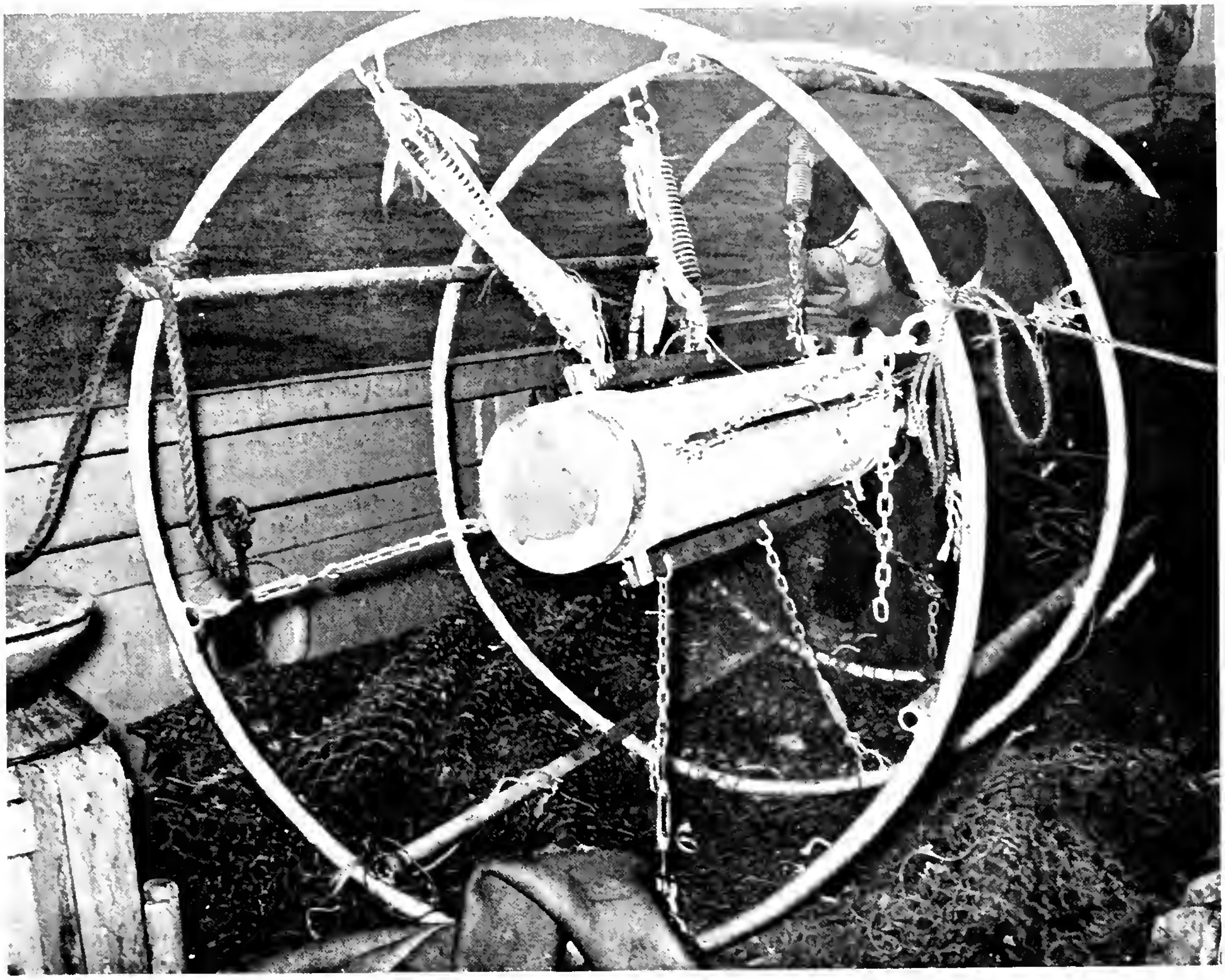

FIGURE 4.--CAMERA UNIT MOUNTED IN SUPPORTING FRAME USED IN COD END OBSERVATION WORK. (CAMERA LENS IS COVERED TO PROTECT THE PICKUP TUBE FROM EXPOSURE TO DIRECT SUNLIGHT).

water depth is payed out. An additional amount of slack in the camera cable (about 10 percent of its length) is allowed once the net is under tow to provide for wave action, slippage of the trawl winch brake (as in hang-ups), or any unexpected strain.

An electronics expert attends the equipment continuously during the tow to effect whatever adjustments are required. Improper action of the net may be detected from the television image and remedial measures quickly taken. Observations of the gear and activities of the fish are recorded as written notes, audio tape recordings, and still or motion pictures.

Hauling back

The trawl is hauled back with particular attention paid to hauling the camera cable at the same rate as the trawl cable. As the trawl comes alongside, great care must be exercised in handling the cable. A slack cable at this point may be cut by the propeller or become snarled with the net.

The cable is detached from the head line, and the net is rapidly hauled aboard. The cod end with the camera unit is brought alongside, hoisted over the rail, lowered to the deck, and the cod end emptied of fish (fig. 5). A lens cover is placed over the glass window to prevent damage to the Image Orthicon pickup tube from prolonged high light intensity.

When the equipment is used for studies other than the specific one described above, certain modifications in handling procedure are necessary. The basic points discussed, however, are generally applicable to any operation that requires the attachment of the camera to a trawl net.

In addition to the cod-end observations described above, we have mounted the underwater television camera on top of the cod-end frame in order to observe, from outside the cod end, the behavior of fish passing through the meshes (fig. 6). No important additional problems arose with this technique except that some additional floats were required to help maintain the frame in its proper orientation and so prevent the cod end from rolling. Rolling could have serious consequences with the camera outside the cod end.

FIGURE 5.--HAULING THE COD END UNIT ABOARD.

Other Operations

Preliminary studies of fish behavior in the forward parts of the trawl required an entirely different method of rigging the camera unit. For this work, the camera was suspended from adjustable chain bridles fastened to the upper belly of the net (fig. 7) and depended mostly on the rigidity of the netting under tow for vertical orientation. We also added floats for additional support and reinforced the top belly with rope stringers laced across and along the netting. The camera attached in this position enabled us to observe the behavior of fish near the ground line and lower belly of the net and also on the bottom slightly ahead of the net. 1/

Attempts to study fish behavior in otter trawls by towing the camera free in the water from a second vessel proved unsatisfactory, mainly because low visibility during the work made it impossible to approach the moving net properly. The net appeared

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1/ Results of these preliminary studies and those of the cod-end work described above are shown in the film, "Underwater television studies of fish behavior," produced by the Bureau of Commercial Fisheries Biological Laboratory, Woods Hole, Massachusetts.

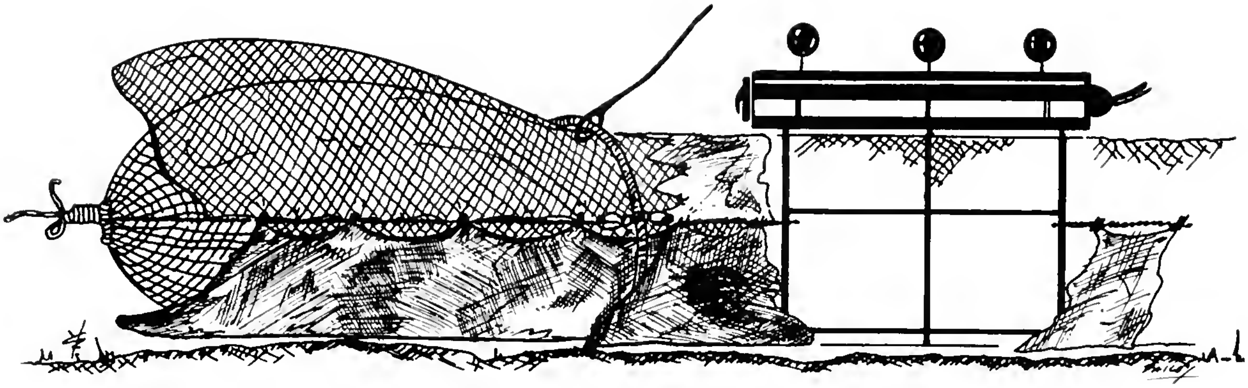

FIGURE 6.--DIAGRAMMATIC SKETCH OF POSITIONING OF THE TELEVISION CAMERA TO VIEW OUTSIDE OF COD END.

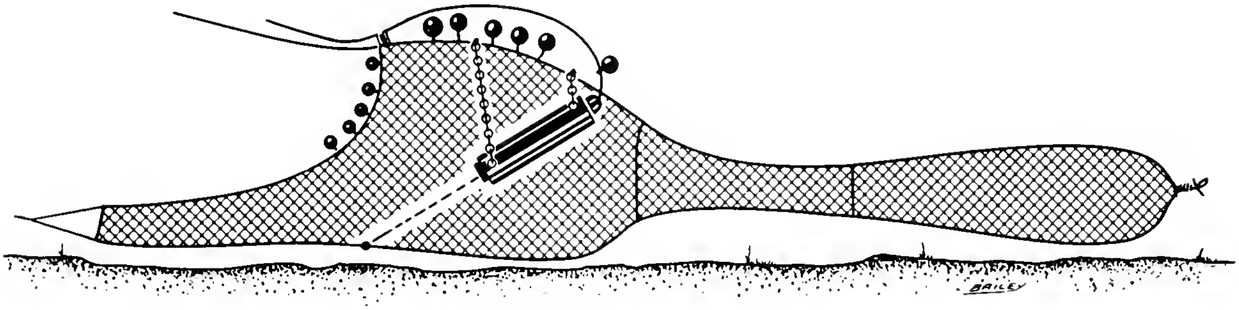

FIGURE 7.--DIAGRAMMATIC SKETCH OF POSITIONING OF THE TELEVISION CAMERA TO VIEW FORWARD PARTS OF THE TRAWL.

on the television monitor too late to make towing-cable adjustments, and the camera fouled with the net. This approach was suspended in favor of attaching the camera directly to the net. In very clear water and under well-controlled conditions this method could be used successfully.

The versatility of our television system has permitted its use in studies other than those connected with fishing gear. The camera has been used to observe bottom fauna by attaching it to a mounting stand. We have also used the mounting-stand arrangement to study the behavior of fish by fitting it out as a cage (fig. 8). This particular study was conducted to determine the condition of fish after tagging and their subsequent return to the bottom.

Cable Handling Problems

Very few problems involving function of the camera unit were encountered in the otter-trawl work. Most of the problems were associated with the handling of the cables. We have listed the conditions that create handling problems and the precautionary measures we have used. The problems fall into four major categories:

1. Cuts and abrasion of the neoprene covering.

These occur more frequently than one might think and in ways that often cannot be accounted for. If the covering is cut, water will get into the electric cables and short them, resulting in equipment failure. The smaller cuts can often be successfully

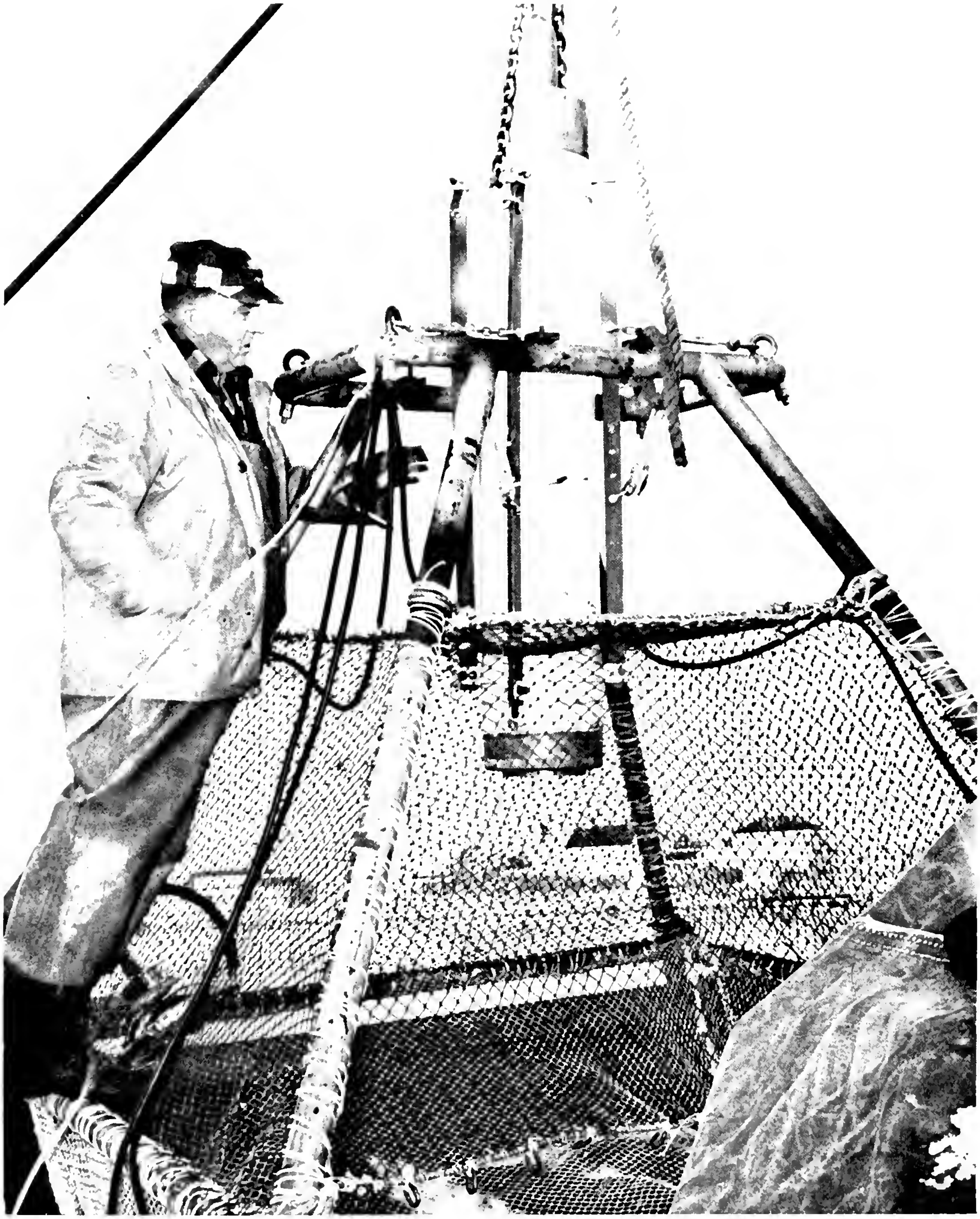

FIGURE 8.--TELEVISION MOUNTING STAND FITTED OUT AS A CAGE FOR STUDY OF FISH BEHAVIOR.

FIGURE 9.--KELLEMS GRIPS ATTACHED TO CAMERA CABLE AND ACCESSORY LIGHTING CABLE.

mended, but a serious cut which allows the passage of salt water along the conductors renders the cable unfit for use. A damaged cable may be repaired by cutting away a considerable part of it, until all the wet cable is removed, and then splicing the ends together. It has been our experience that these splices are often unsatisfactory in operation, even though done in a most careful and workmanlike way. It is advisable to discard a cable that is defective--an expensive procedure, since the cable costs about $1.25 per running foot.

Abrasion results in the same sort of failures as cuts. Abrasion damage can be prevented only by careful handling of the cable.

2. Kinking of the cable.

Care should be taken to prevent sharp bends when handling the cable, or kinks will occur which may result in breakage of one or more of the conductors. This problem quite often develops at the connector. Steel-core cable is much more susceptible to kinking damage than is standard fiber-core cable.

3. Excessive strain.

This may result in breakage of the conductors or separation of the solder joints at the connecting pins. In order to minimize the strain at the joints, we have used a device called a "Kellems grip" (fig. 9). Other than the use of such devices, only the exercise of extreme caution and advance consideration of specific operating conditions will minimize these problems.

4. Fouling of the cable.

As previously pointed out, one of the greatest problems encountered in using the

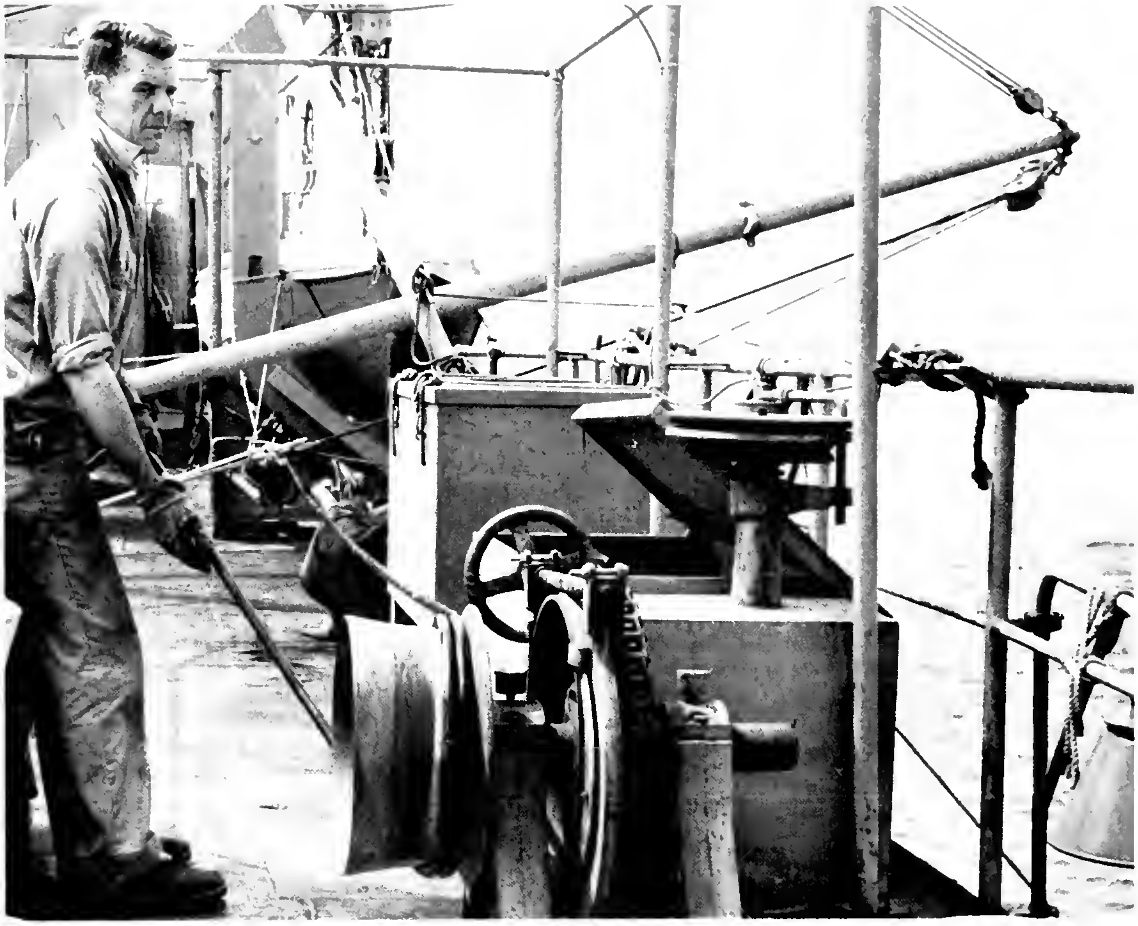

FIGURE 10.--HANDLING TELEVISION CAMERA CABLE IN BOAT DECK OF ALBATROSS III WITH SPECIALLY DESIGNED WINCH.

camera with fishing gear is the danger of fouling the camera cable with the net, otter boards, and towing warps. To prevent fouling, the amount of slack in the camera cable must be held to a minimum as it is being payed out or hauled back. The use of a propeller guard is advisable to reduce the possibility of fouling the cable with the vessel's propeller.

Aboard the Albatross III the cable is handled from the boat deck at the stern where it is stored in a large open box which provides for easy removal and replacement. This arrangement also prevents damage to the cable which might occur if it were allowed to lie unprotected on the deck.

We have developed a special 3-speed, reversible winch for handling the camera cable which makes it possible to control the amount of slack in the cable and to haul back quickly in case of emergency (fig. 10). The large-diameter winch head minimizes the possibility of kinking. An intercommunication system between bridge and boat deck is used for coordinating the handling of the trawl and the camera cable.

Recording Techniques

Photographic recording of our television image is accomplished primarily with a standard spring-wound, 16 mm. motion-picture camera operated at 24 frames per second. Use of a standard motion-picture camera results in the condition known as banding or shutter-bar on the film. This condition is always present in a nonsynchronized system but can be obviated through the use of a special shutter on the motion-picture camera which will synchronize its frame rate with the 30 frames-per-second scanning rate of the television camera. A large-capacity film magazine is desirable to avoid missing important scenes. The standard camera is adequate for research purposes; but to obtain film suitable for public showing, a synchronized system must be used.

A useful technique which may be used in film recording is that of writing pertinent information on the protective window in front of the picture tube with a glass-marking pencil. The information is permanently recorded on the film and yet may be erased easily from the glass for the entry of new information.

Single photographs are obtained with any of several good-quality still cameras. The low light intensity of the television image requires a fast lens and fast film for satisfactory photographs. Information on photographing the television image is available from many sources (American Cinematographer 1956, Barnes 1953, Cross 1954, Eastman Kodak Company 1956, Morgan and Lester 1955, Zworykin and Morton 1954).

A tape recorder is a valuable addition to the recording equipment for experimental underwater television work. It provides a ready method for recording all data on operational conditions and control adjustments as well as observational comments.

DISCUSSION

Visibility

Most of our work was carried out in the offing of Cape Cod, Massachusetts, from Pollock Rip Lightship north to Stellwagen Bank, and in Cape Cod Bay at depths of 6 to 40 fathoms (near 42° N. latitude, 70° W. longitude). The range of visibility under natural illumination varied considerably, depending upon amount and type of turbidity. Maximum light penetration was ensured by working on clear, sunny days from two hours past sunrise until two hours before sunset. Under ideal turbidity and light penetration conditions it was possible to view an object some 40 feet from the camera.

Consistently good results were obtained during spring and autumn with natural light down to about 22 fathoms. In most instances we were concentrating on haddock which we were usually able to find in 18 to 22 fathoms. At these depths, visibility was usually limited to a maximum of about 15 feet. The maximum depth in which we have been able to observe fish in the net without artificial light was 38 fathoms.

Possible Improvements in Equipment

Our field experience has brought to light certain modifications and refinements of the equipment which could result in even greater operating efficiency.

Camera

The one important improvement indicated for the camera unit is the provision of rollers on the camera carriage to permit the camera to be slid in and out of the housing more easily. The aluminum supporting rings of the present carriage scrape against the housing, making removal difficult. Electrical problems may also arise from the resulting aluminum scrapings.

Camera cable

As pointed out above, many equipment failures arise from cable troubles, a good many of which might be eliminated by incorporating the underwater television cable into the trawl warp. Certain new problems arise, of course, such as the necessity for a special arrangement to provide for transmission of circuits past the winch to the control unit. Special motor driven cable reels which eliminate the necessity for slip rings are available and can be used for some purposes. Conductors for lighting circuits can also be incorporated into the towing cable, further simplifying operations.

We are developing a new connector in which the stainless-steel core will be anchored at the camera connector. This connector will eliminate much of the strain on the individual conductors in the cable which occurs with the present type.

Camera control unit

The camera pickup tube occasionally require electronic realignment necessitating removal of the camera from the housing, since the controls for this purpose are now mounted in the camera unit. This operation would be greatly simplified by housing such controls in the camera-control unit.

General Remarks

The success of underwater television in studying stationary objects is so firmly established and well documented that we scarcely need comment on the subject. We have experienced little difficulty in observing the bottom and bottom invertebrate fauna. The high sensitivity of Image Orthicon television requires only the addition of a limited number of standard underwater lamps to obtain good pictures at the bottom in depths beyond the limits of natural illumination. Cable problems in this usage should not be serious in depths up to 100 fathoms. The effect of currents may be overcome by using a heavily weighted mounting stand.

Observing fishing gear in motion is somewhat more difficult than observing the bottom because of the operational problems which have been related on previous pages. Many more applications than we have described would be possible except that the visibility in New England waters is usually limited to 10 to 20 feet. This relatively short range of view greatly limits the use of television. If observation of the gear alone is the object, a wider opportunity is provided since the work can be carried out where visibility conditions are ideal, probably in more southerly waters. The limitations on geographical range of species to be studied usually restrict the choice of working area.

Studying behavior in otter trawls is possible because the gear guides the animals into a restricted area. Observing unconfined fish in the sea is an entirely different matter. Attempts to observe individual and unconfined fish will be limited to brief unsatisfactory glimpses of fleeting forms. However, some application to the locating of masses of fish at the bottom or in the mid-depths seems feasible. The evaluation of underwater television for this work must await the development of suitable vehicles. Various types so far developed for other purposes have not been applicable to this work, although some encouragement is afforded by developmental work going on at present in this field, mostly for military purposes.

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APPENDIX

SPECIFICATIONS: MOD. 1000-W IMAGE ORTHICON UNDERWATER TV CHAIN

Schematics and mechanical drawings, which were too extensive to reproduce herein, are available from the Woods Hole Fishery Biological Laboratory or from the manufacturer: Diamond Power Specialty Company, Lancester, Ohio.

I. Camera House

A. Shape and size: cylindrical; 10 inches in diameter; 56 inches in length; 64 inches overall, including connector.

B. Weight: 130 lbs. (incl. camera), buoyancy in water + 2 lbs.

C. Material: aluminum, anodized, thickness--0.44 inches.

D. Window: optical quality plate glass, 1 inch thick, 6-inch diameter.

E. Pressure resistance: 445 p.s.i. minimum.

F. Accessories:

1. "Wet mount": 150° plastic lens.

2. Stabilizers: detachable fins, bracket.

II. Camera Unit - General

A. Size: 6 inches diameter, 50 inches length.

B. Weight: 51 pounds.

C. Pickup tube: Image Orthicon (5820).

1. Sensitivity: approximately eye response to light--0.5 foot candle.

2. Operating temperature limits (ambient): 50° C. maximum on body, 30° C. minimum on face of Image Orthicon.

3. Resolution: 400 lines, vertical; 600 lines, horizontal.

D. Type of reproduction: Monochromatic.

E. Scanning: 525 lines at 30 frames per second, noninterlaced.

F. Distance from camera to camera-controlled unit: 1000 feet (maximum).

G. Tube complement: 12.

H. Optical focus: Servo controlled, carriage movement.

I. Illumination control: remote controlled iris adjustment.

J. Gray level: Gamma-Control.

K. Lens system: remote controlled 3-lens turret with following lenses:

1. 28 mm., f/3.3.

2. 39 mm., f/2.0.

3. 75 mm., f/2.0.

L. Leak indication: resistance bridge, signal light.

M. Temperature indication: resistance element, metered.

III. Camera Control Unit - General

A. Size: width, 17 inches; length, 24 inches; height, 15 1/2 inches.

B. Weight: 101 pounds.

C. Material: steel cabinet, aluminum chassis.

D. Screen: 10-inch aluminized cathode-ray tube (10FP4A).

E. Tube complement: 22.

F. Operating temperature limits: 0° F. to 125° F.

G. Controls, front panel

1. Camera

   a. Iris
   b. Blanking
   c. Gamma
   d. Video gain
   e. Vertical linearity
   f. Horizontal centering
   g. Vertical centering
   h. Height
   i. Width
   j. Electrical focus
   k. Horizontal frequency
   l. Vertical frequency
   m. Image focus
   n. Beam focus
   o. Target
   p. Beam
   q. Servo-optical focus
   r. Turret
   s. Target bias, off-on
   t. Lens selection indicator
   u. Iris indicator
   v. Moisture indicator

2. Minitor

   a. Brilliance
   b. Contrast
   c. Focus
   d. Horizontal hold
   e. Width
   f. Height
   g. Vertical linearity

IV. Power Supply - General

A. Size: width, 17 inches; length, 16 inches; height, 12 inches.

B. Weight: 75 pounds.

C. Material: steel cabinet, aluminum chassis.

D. Power requirements: 105-120 volts, 50-400 cycles, 700 watts, single phase.

E. Tube complement: 10.

F. Meters

1. Voltmeter: input voltage
2. Elapsed time: total operating hours.
3. Milliameter

   a. Regulated B+ voltage
   b. Unregulated B+ voltage
   c. B+ current
   d. B- voltage
   e. Temperature

G. Operating temperature limits: 0° F. to 125° F.

H. Controls

1. On-off switch
2. B+ adjustment
3. B- adjustment

V. Electrical Requirements

A. Camera

1. Input

   a. 7.5 W., a. c. power for optical system motors.
   b. 40 W., a. c. power for heater transformer.
   c. D. C. regulated voltage, 350 volts at 250 ma.

2. Output

   a. Picture signal, 2 volts peak-to-peak, black positive polarity.

B. Monitor

1. Input

   a. Video signal, 1.3 volts peak-to-peak, black positive polarity.
   b. D. C. regulated power, 350 volts at 270 ma.
   c. External RETMA synchronizing signal, 2 volts min., peak-to-peak, negative polarity.

d. 70 W., a. c., power for heater transformers and monitor fan.

2. Output

a. Video signal, 2 volts peak-to-peak, 73 ohms impedance, black negative polarity.

C. Power supply

1. Input

a. A. C. voltage, 105-120 volts.

b. A. C. power, 600 watts.

c. Frequency, 50-400 CPS.

2. Output

a. D. C. power (regulated), 350 volts at 520 ma. and -105 volts at 1 ma.

VI. <u>Cables</u>

A. Camera to camera-control unit

1. Size: 0.81 inches diameter - 1,000 feet maximum.

2. Conductors: 28: 4, #18 A.W.G.; 21, #22 A.W.G.; 3 coaxial, 51 ohm impedance.

3. Jacket: Neoprene.

4. Weight: approximately 0.5 lbs. per foot.

5. Pressure resistance: 445 p.s.i. minimum.

B. Power supply to camera-control unit

1. Size: 0.81-inch diameter, length 12 feet.

2. Conductors: 11.

3. Jacket: Neoprene.

C. Camera-control unit to monitor

1. Type: coaxial, 73 ohms.

2. Length: 100 feet (500 feet, maximum).

D. Camera connector: "Twist on", watertight (455 p.s.i. minimum pressure resistance).

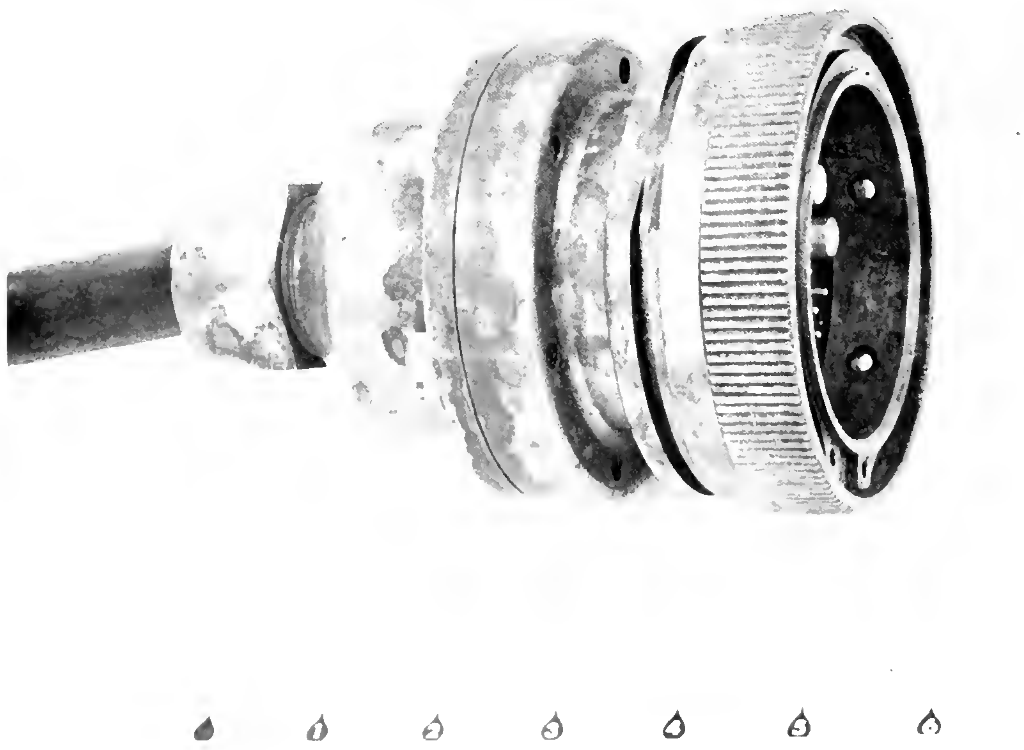

FIGURE A-1.--SPECIAL WATERTIGHT CONNECTOR DEVELOPED FOR USE WITH UNDERWATER TELEVISION.

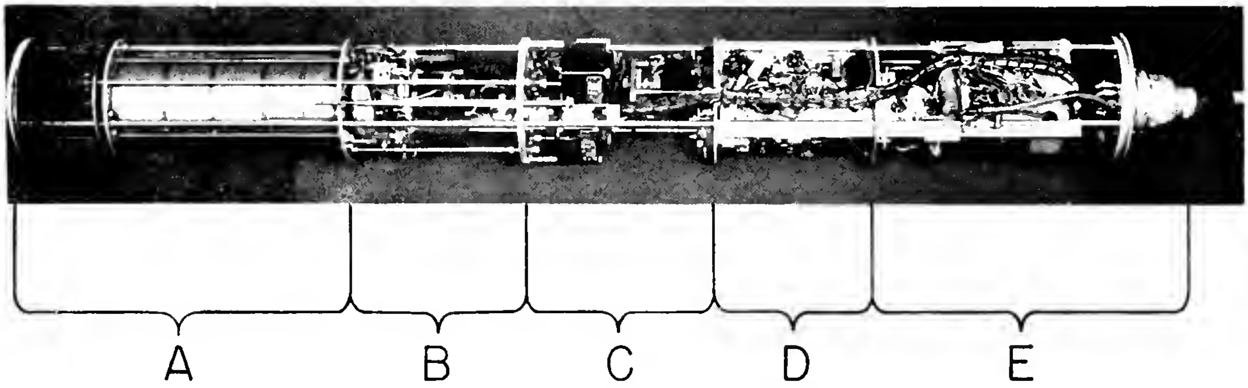

FIGURE A-2.--TELEVISION CAMERA, SECTIONS A-E.

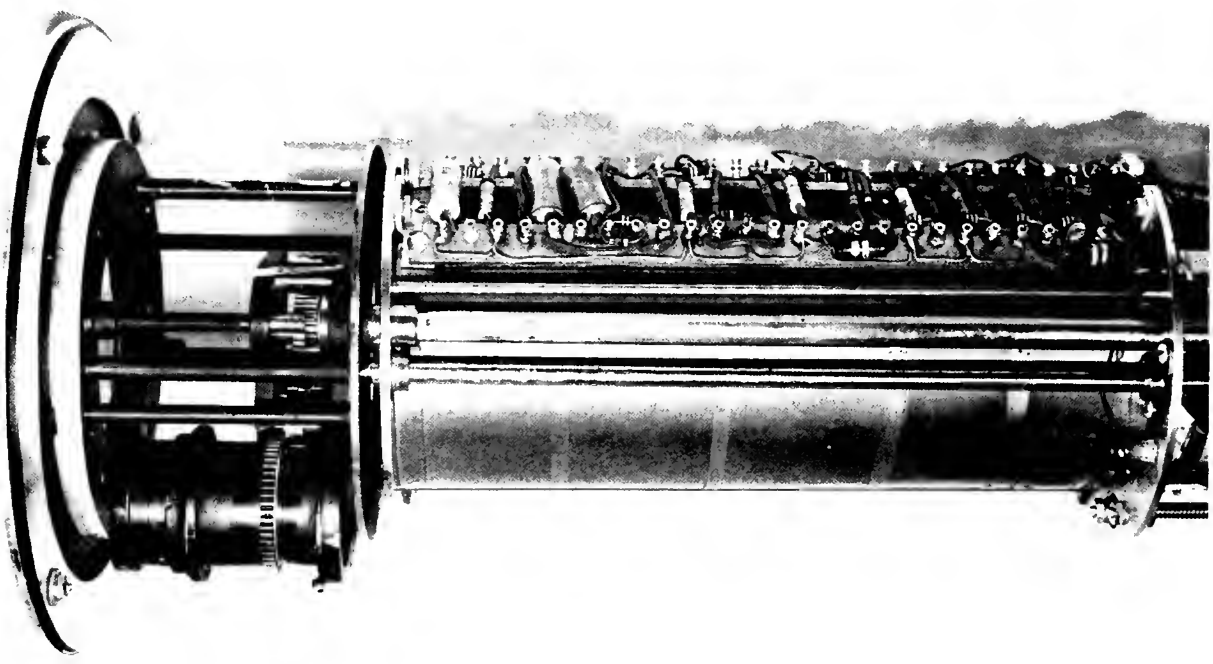

FIGURE A-3.--TELEVISION CAMERA DETAIL, SECTION A.

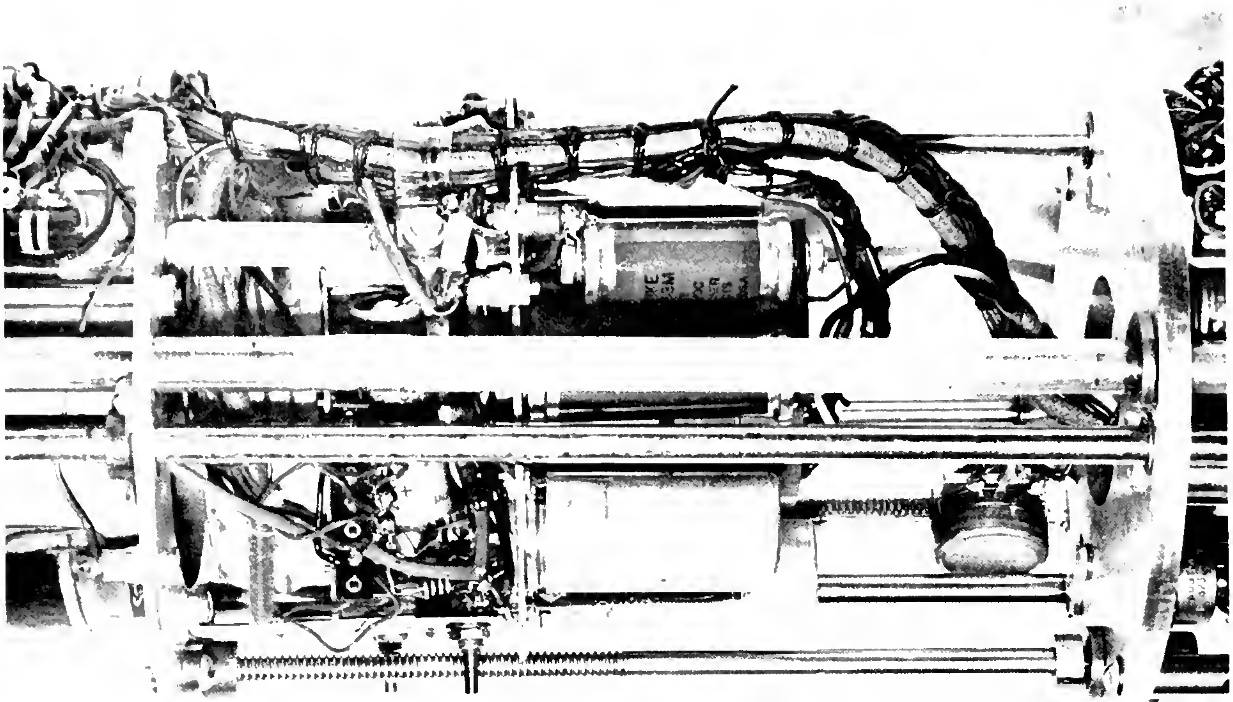

FIGURE A-4.--TELEVISION CAMERA DETAIL, SECTION B.

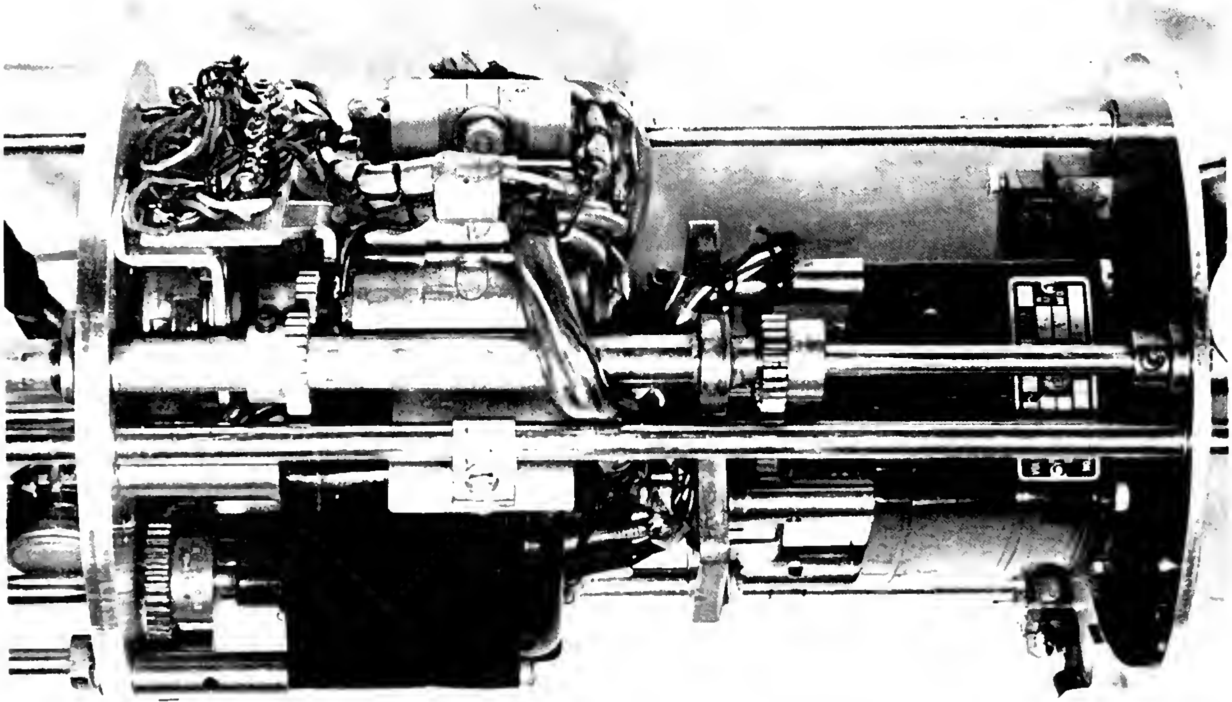

FIGURE A-5.--TELEVISION CAMERA DETAIL, SECTION C.

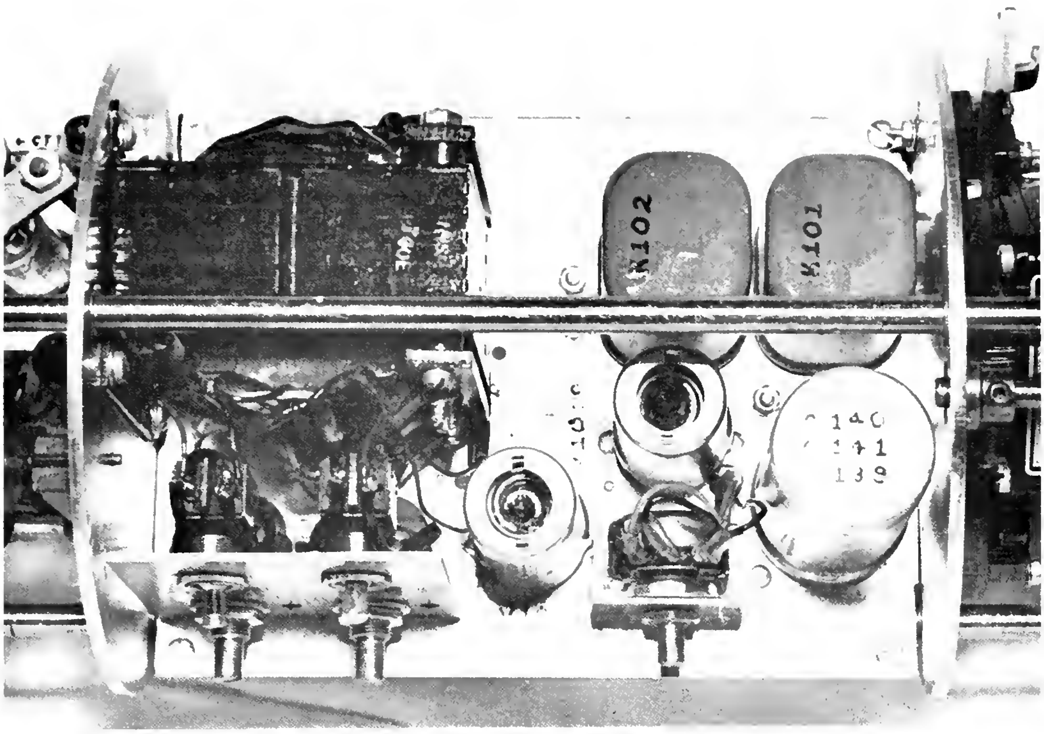

FIGURE A-6.--TELEVISION CAMERA DETAIL, SECTION D.

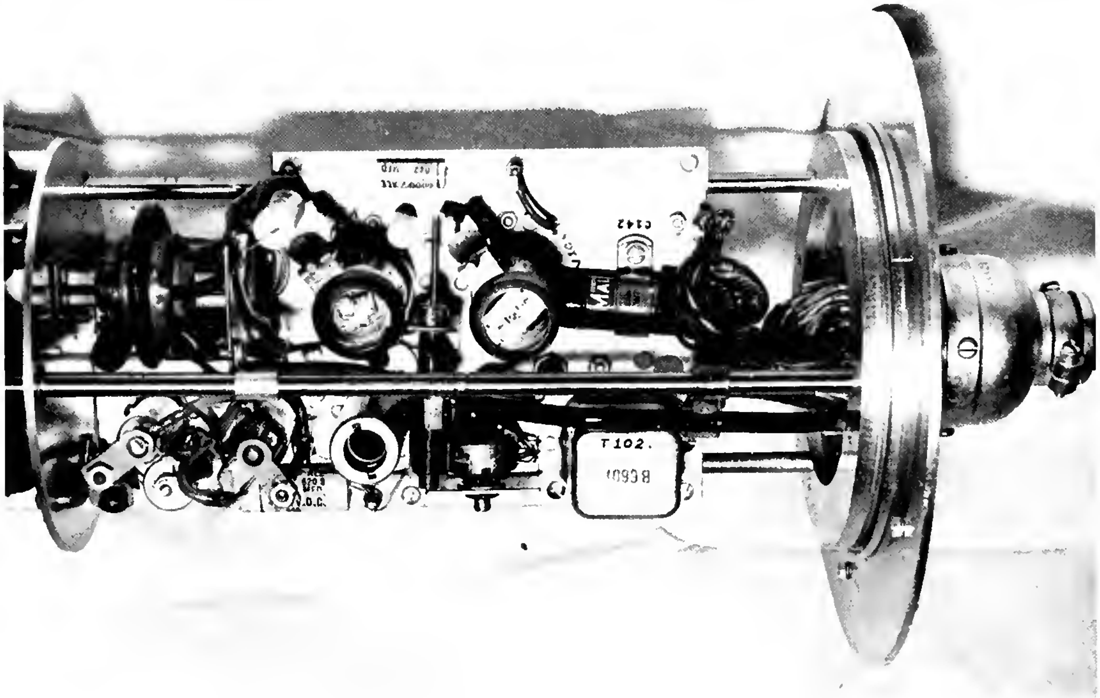

FIGURE A-7.--TELEVISION CAMERA DETAIL, SECTION E.

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