UNDERWATER TELEVISION VEHICLE FOR USE IN FISHERIES RESEARCH

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UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, Secretary

Fish and Wildlife Service, John L. Farley, Director

UNDERWATER TELEVISION VEHICLE

FOR USE IN FISHERIES RESEARCH

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INTRODUCTION

There has long been a recognized need for better direct visual undersea observations to further research in fishing methods and equipment. The inability of fishery researchers to observe properly the characteristics of fishing gear in operation has allowed but a small measure of success by trial and error methods. Since most fishing gear in operation involves motion underwater, an improved means of continued observation was required to see and record fishing gear in operation and the behavior of fishes in and around the fishing gear.

Underwater television has been used to great advantage in the United States, Great Britain, and Canada in submarine salvage, undersea inspections, and in some fresh-water biological surveys. The U. S. Navy Bureau of Ships has for some time pursued the development of underwater television for various applications. The U. S. Fish and Wildlife Service initiated an experimental project to determine the practicability of the application of industrial television equipment to observations of fishing gear and fishing operations.

In November 1954, the U. S. Fish and Wildlife Service and the U. S. Navy Bureau of Ships conducted a joint operation using underwater television to teleview experimental trawling gear off Miami Beach, Florida. A motion picture of the televised observations was taken by kinescope photography. This operation was the first instance in which underwater television was used to observe and record a complete fishing operation at sea.

As a result of this and other early successful experiments a general design was drawn for a prototype remotely controlled underwater television vehicle to allow operation with existing industrial television equipment. The resulting underwater television vehicle described in this report was designed by the authors. It is the purpose of this report to describe the prototype underwater television vehicle, and to review its demonstrated utility as a practical research tool in fisheries and related marine investigations.

We wish to express our thanks to Mr. J. R. R. Harter, U. S. Navy Bureau of Ships; Mr. W. W. Torrington, National Research Council of Canada, and Mr. Norman Bean of station WTVJ-TV, Miami, Florida. The friendly cooperation and exchange of information extended to us has materially aided our undersea television work.

GENERAL DESCRIPTION

The design of the vehicle was dictated by operational and performance requirements determined from early experiments for use as a fishing gear research tool. Some basic considerations were ease in handling, maneuverability, and a useful working range down to 50 fathoms. It was found desirable to provide both horizontal and vertical scanning mechanisms for the television camera. Of importance was the ability of the unit to hover, to be placed on the bottom for extended periods of time, or to be moved through the water at speeds up to 3 knots. Practical considerations of time and available funds limited the selection of certain mechanical and electrical devices and materials used in the fabrication.

PRESSURE VESSELS CONSTRUCTION

Upper Chamber

Two sealed pressure vessels were constructed: the upper double chamber housed the vertical and horizontal control mechanism, and the lower cylindrical chamber housed the television camera (fig. 1).

The upper double chamber was constructed of standard 20" x 3/8" x 10" length and standard 10" x 5/16" x 10" length mild steel pipe. These pipes were closed at either end with plates and flanges which formed a water-tight compartment housing the control mechanism. Wall thickness for 1/4" hold down studs on the inside edge of the 20" by 10" pipe section was gained by welding in a circular ring of 1/2" by 1/2" key steel. The ring flange faces were then machined to insure positive seating and sealing of the gasket material. The cap joint was gasketed with 1/8" standard rubber plumber's gasket material. A loop of 1/2" round cold rolled steel was welded to the extreme top of the cap to effect a mount for supporting the vehicle (fig. 1). To prevent the possibility of leaks through the hold down nuts on the cap, close fitting 1/16" copper washers were used. End plates and flanges were fabricated from 3/8" hot rolled steel. All closed joints were electrically welded inside and out. Three tapered leg mounts of 3/8" plate were welded at equidistant intervals to the lower flange. A 1/2" hole was drilled at each leg mount tip for securing the removable tripod leg with 1/2" by 13" standard bolts. The tripod legs were constructed of standard 1-1/2" galvanized steel pipe 31" in length (fig. 1). Circular pads of 1/2" by 4" steel plate were welded to the bottom ends of the legs for use of the vehicle in bottom observations. In the upper ends of the legs 1/2" steel discs were welded in the sides of the pipes. One-half inch holes were drilled and tapped to provide means of securing legs to leg mounts. Three standard studs 3-3/8" by 1" were welded midway between the leg support plates for cross brace

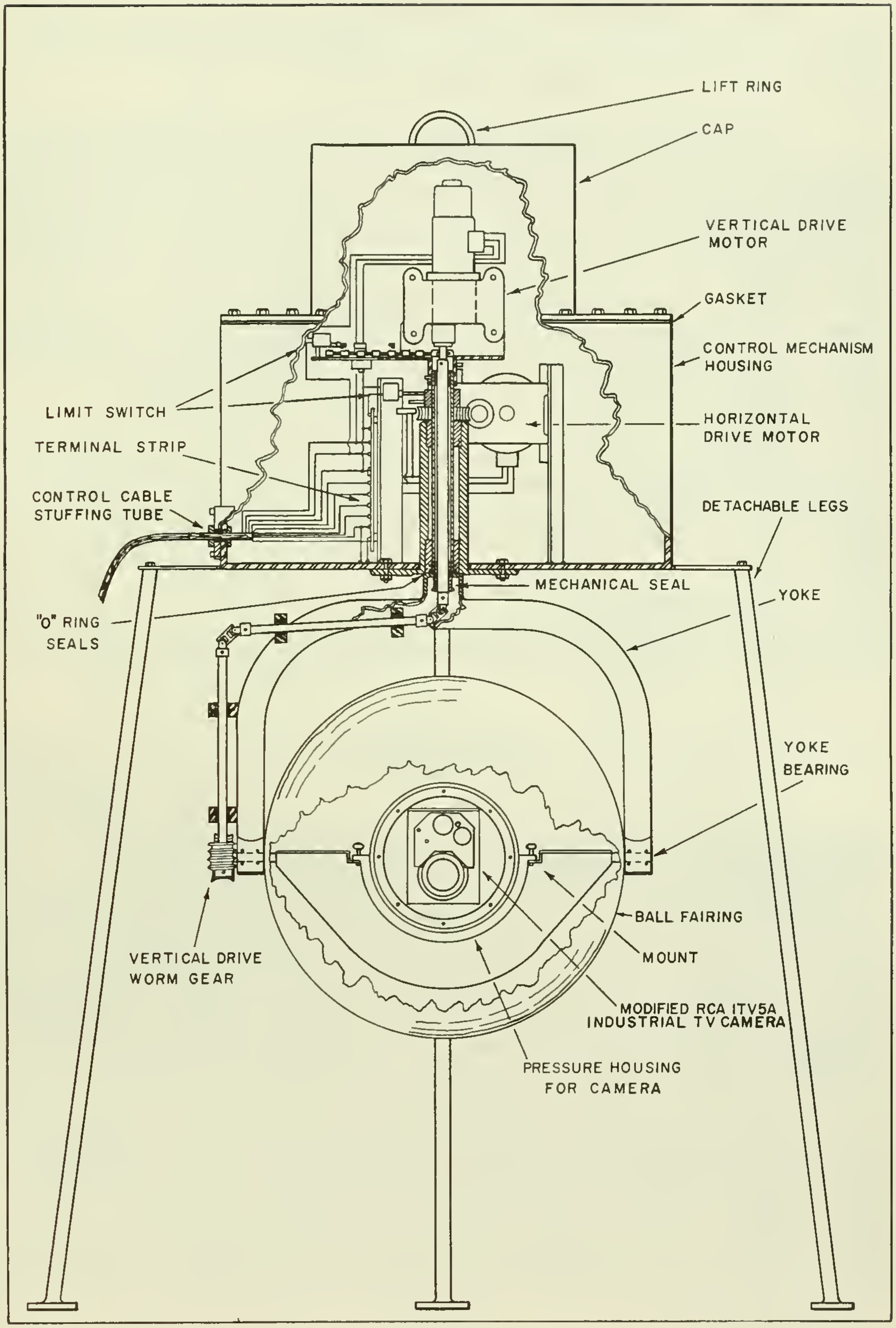

Fig. 1. Underwater Television Vehicle

leg stiffening attachment. The tripod legs may be removed when the vehicle is to be towed. To maintain a stable picture platform the towing vane or rudder of 1/2" marine plywood was attached as shown in photographs and drawings (figs. 2 and 10).

An access port 3" x 3" was cut at the lower rear of the 20" pipe section and eight 4/16" standard studs were installed for clamping the control-cable stuffing tube (fig. 1). This port allowed the drive control electrical cable to be disconnected from the vehicle assembly by means of a quick disconnect plug. The access port was sealed with 1/8" standard rubber plumber's gasket material. At the center of the lower flange a 5" hole was cut and six equally spaced holes were drilled around the perimeter to clamp and seal the main drive shaft housing. To seal the shaft housing 1/8" standard rubber plumber's gasket material was used. Two plates 1/2" x 4" x 6" were welded fore and aft of the cap assembly for attachment of tail assembly (fig. 1).

A standard 1/8" Schrader tank valve, used when pressurizing the vessel for deep water work was centered with and 1" above the access port. The upper chamber may be filled with air from any convenient source either compressed air bottles or an automobile tire pump. The valve was equipped with an 1/8" pipe cap which sealed the valve and prevented external water pressure from overcoming internal air pressure. The upper chamber was tested to 125 p.s.i. (pounds per square inch) internal pressure. Pressurized to 40 p.s.i. the unit can descent to 50 fathoms.

Lower Chamber

The camera vessel was made from an 18" length of standard 8" steel pipe (figs. 3 and 6) and was not pressurized. Circular rings of 5/8" steel were machined for "O" ring seals and welded to each end. The camera viewing port was a circular plate of lucite 1/2" in thickness drilled to fit eight evenly spaced 5/16" studs. A brass clamp ring 1/2" x 3/16" with stud nuts was used to hold the window tight against a 5/16" x 6-1/2" "O" ring seal thus assuring water-tight integrity. The rear cover was a circular plate of 3/8" brass plate with a stuffing tube for the camera cable. In a similar manner this plate with eight 5/16" studs, nuts, and "O" ring sealed the rear of the vessel.

The camera housing was held in place in the cradle with four thumb screws through eyes on the housing (fig. 3). The supporting frame was fabricated from one piece of 2" x 12" channel iron cut to form a cradle. Angle irons running the length of the camera housing were welded to the cradle to form a slide arrangement to hold the camera housing. At each end of the cradle steel shafting was welded

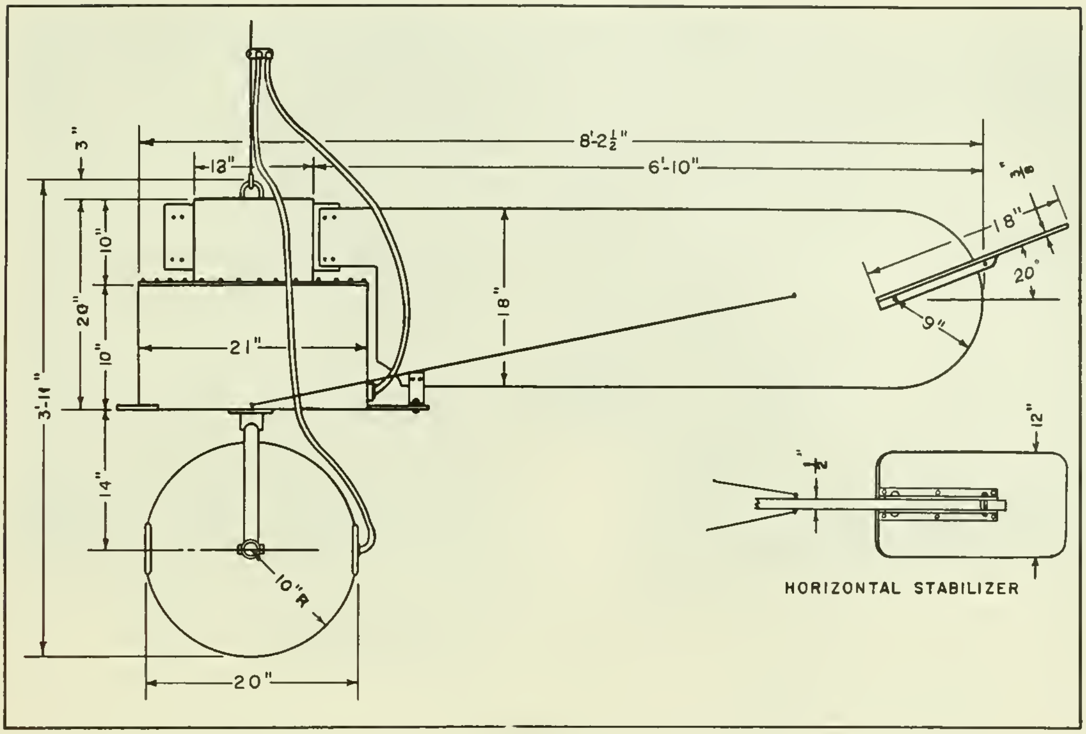

Fig. 2. Dimensions of Underwater Television Vehicle and Stabilizing Rudder

and machine fitted to insure proper shaft drive and housing support. Light metal framework was used to support the television camera within the pressure housing.

To provide a minimum of turbulence and to equalize drag effects at all camera housing attitudes while under tow a free-flooded ball fairing was added to the camera housing (fig. 3). The ball fairing was made of two interlocking hemispherical sections of 1/16" stainless steel. The forward section was welded to 4" x 4" x 1/8" pads that fitted over and were welded to cradle-shaft joints at each side. The rear section of ball fairing was held in place with equally spaced sheet metal screws which fastened it to the forward section. The rear section being removable allowed access to inner framework and hold down thumb screws. Ten inch circular holes padded with split rubber hose were cut at each end of the ball fairing to provide access to the camera through the rear seal plate and to give an opening for the camera lens.

Fig. 3. Camera vessel is shown with one-half the ball fairing removed. The worm and ring gear assembly which operates the vertical scanning is indicated by the number 1; the cradle supporting the camera housing by number 2.

CONTROL CONSTRUCTION

Movable Components

A vertical pedestal type hollow tube sealed shaft and bearing assembly entered the center of the floor plate flange (figs. 1 and 4b). The pedestal was 6" high with a wall thickness of 3/16" and bore of 2". Oil impregnated bearings 2" diameter x 1-1/2" long x 1-1/2" bore were pressed into both ends to form a support for the main drive shaft and a vertical thrust surface for support of the lower yoke assembly. A square groove 1/8" x 2-1/4" diameter was cut in the outside of the lower face of the bottom bearing for insertion of a 1/8" x 2-1/4" diameter rubber "O" ring which sealed the main shaft. A secondary water seal was made by installing another 1/8" x 2" "O" ring in a similar groove 3/8" from the lower face of the bottom bearing (fig. 1). The horizontal drive ring gear served as a vertical thrust bearing and supported the entire lower yoke assembly (fig. 4c). This ring gear was held in position by two through-thread Allen set screws placed so that a positive pressure was exerted on the lower "O" ring seal face. This positive pressure compressed the "O" ring about .010" and was effective with a minimum of .002" depression. With the slow scanning speed of 1 R.P.M. the thrust should not need adjustment within the life of the mechanism.

The vertical scanning drive shaft was sealed at its lower end by use of a standard spring loaded mechanical seal. It was supported by bronze bushings at either end which were pressed in the hollow

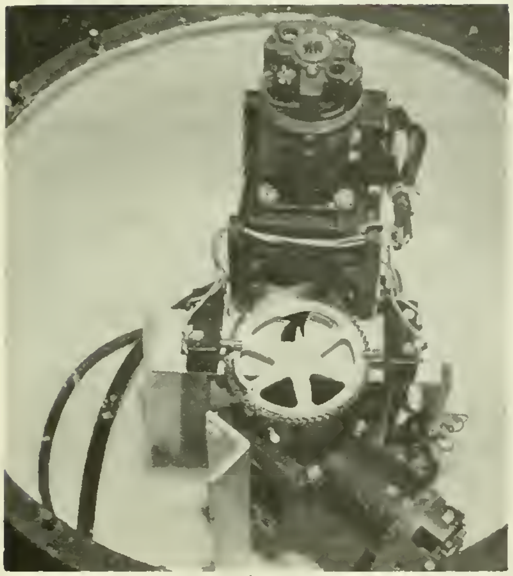

Fig. 4a. View of drive motor assemblies. Arrow indicates vertical limit switch cam.

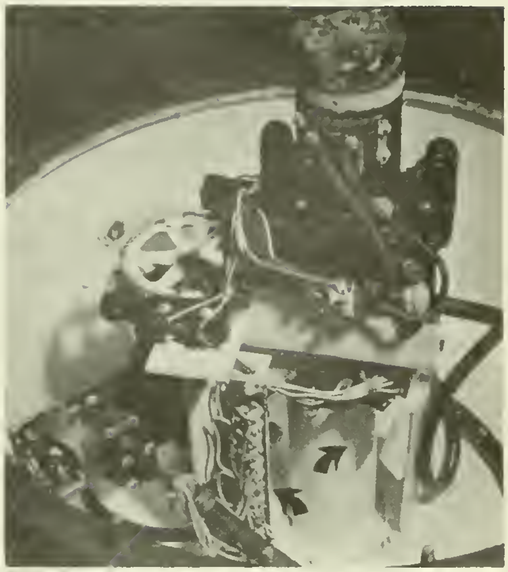

Fig. 4b. View of drive mechanism. Arrows indicate bearing housing pedestal and wiring terminal strip.

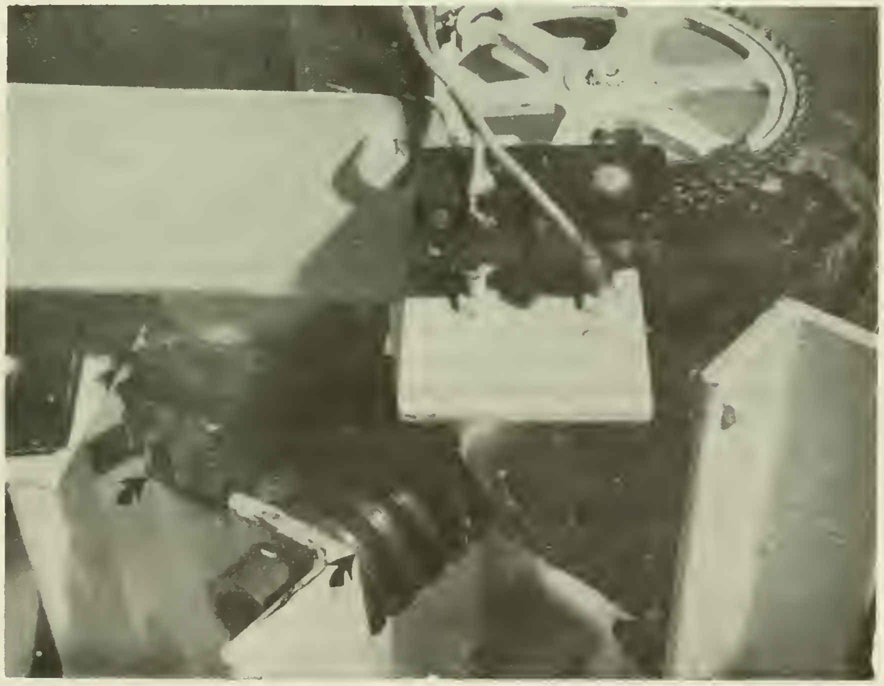

Fig. 4c. View of control mechanism showing vertical limit micro-switches. Horizontal worm and ring gear drive assembly is indicated by arrows.

horizontal scanning drive shaft. Double universal joints and 5/8" cold rolled steel rod made the linkage (fig. 8) to the yoke-mounted worm and ring gear. Secondary drive shafts were mounted in split bronze bushings and securely welded on the steel bushing housing. These were fabricated of 1" key stock welded to the yoke arms of the power suspension unit.

The yoke arms were fabricated of circular bent steel tubing 2-1/2" O.D. with 3/16" wall thickness (fig. 1). The camera housing and ball fairing was supported at the lower ends of yoke arms by fabricated steel split yoke bearing housings clamped to oilite bronze bushings. The vertical drive ring gear was held in place on the turret drive shaft with 3/8" Allen set screws (fig. 4c). Limit switch cams (fig. 4a) and a reversing switch cam were welded on a close fitting bronze ring that was secured with two 10 x 32 Allen set screws to the hub of the bronze horizontal-drive worm gear.

Drive Mechanisms

The vertical- and horizontal-drive motors were 24 volt D.C., 2 amp. gear head drive, aircraft-flap actuating motors. General Electric Model 5BA25DJ300 motors were selected for their low speed, high torque, and small size. A worm gear speed of 40 R.P.M. had a ratio to the ring gear of 40 to 1 which gave the 1 R.P.M. desired scanning speed. Both worm and ring gears were purchased as stock items. A shaft extension was installed to carry the worm gear and provided a shaft for a side-thrust outboard bearing. The outboard bearing, a combination end thrust and support bearing, was made of standard bronze bearing material. It was installed on the end of an 8" piece of 1" x 1" x 3/16" angle iron which was welded to the base plate of the upper pressure vessel (fig. 4c). Two other angle irons were similarly welded to make a raised support for the horizontal drive motor (fig. 4a). These were drilled to fit and 5/16" cap screws with nuts and lock washers were used to hold the motor in place.

The vertical drive motor was mounted on a bracket fabricated by welding and forming a section of 12 gauge galvanized sheet iron (fig. 4b). A welded collar on the lower side provided attachment of the bracket to the hollow horizontal scanning drive shaft. Positive location of the vertical drive motor base was given by 10 x 32 Allen head set screws set into drilled seats.

A direct coupling secured with set screws connected the vertical drive motor to the vertical scanning drive shaft. This coupling mounted a small 8 tooth sprocket wheel providing a chain drive to a larger 80 tooth cammed sprocket mounted on a small vertical shaft and welded to the vertical drive shaft motor base (fig. 4a). Limit switches actuated by cams were attached to the base and so arranged to engage when the camera cradle was pointed 80° down or 10° up (fig. 4a). A slight override on the motor after engaging limit switches gave an effective vertical scanning range of 100°. The override limit switches and automatic reversing switch for the horizontal drive were mounted on base welded lengths of 1" x 1" x 3/16" angle iron. With the override horizontal scanning of 370° was obtained. Three single pole, double-throw switches were employed in the panel to operate horizontal scanning, vertical scanning and horizontal manual-automatic controls. Each switch had a center off position. These are indicated on the wiring diagram (fig. 5). In order to use a minimum of control conductors the drive motors were connected to operate as single pole motors. This allowed the motors to be reversed by switching one wire.

A leak detector and warning device was installed in the upper pressure chamber so that the vehicle might be raised before any serious damage could result (fig. 5). A phenol laminated terminal strip was bolted to a base welded angle iron 1" x 1" x 3/16". Two pieces of bare strip copper 1/16" x 3/16" were mounted to the lower section of the terminal strip to serve as leak indicating electrodes. A sheet of resin impregnated fibre-glass .015" x 1-1/4" x 2" insulated the electrodes from the base plate. The space between electrodes was 1/16". The

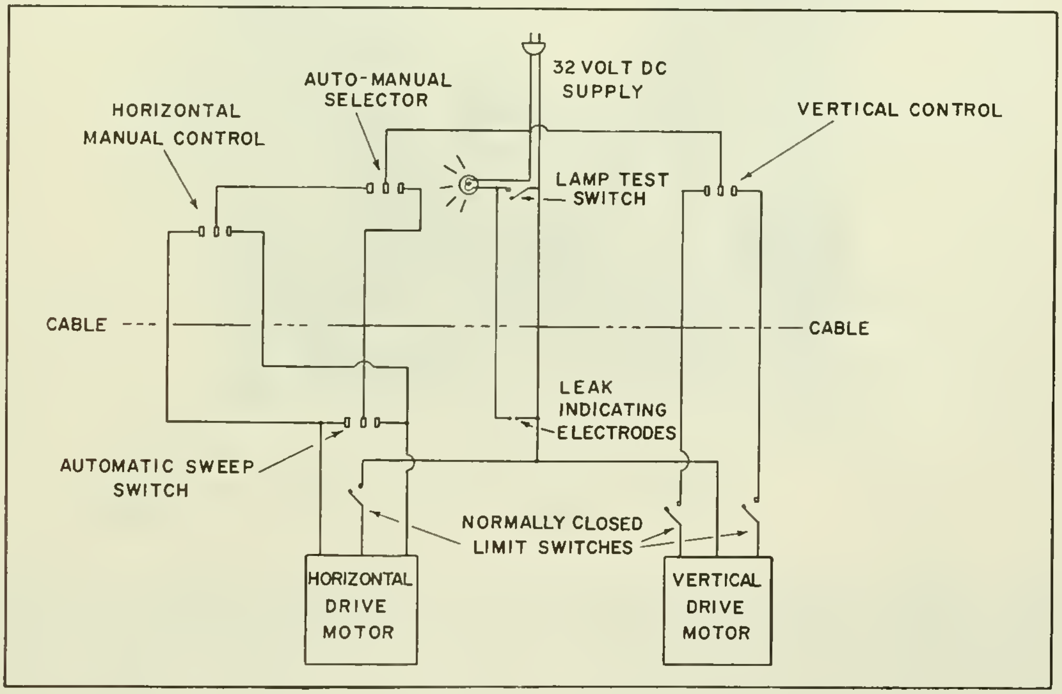

Fig. 5. Schematic Electrical System for Underwater Television Vehicle.

presence of sea water in sufficient quantity to short out the electrodes caused a circuit to be completed turning on a red warning light in the control panel on board ship. A lamp test switch was installed on the control panel to insure that lamp filaments were intact.

TELEVISION EQUIPMENT

The heart of the vehicle was the Vidicon industrial television equipment. The system employed was the one at hand, an RCA-ITV5, and its chief advantage was the relatively small size of the camera. The closed circuit system employed operated in a standard scanning frequency of 525 lines - 30 frames interlaced. Basically the unit consisted of a portable monitor control unit mounting a ten inch viewing screen, a relatively small camera about the size of a 16mm. movie camera, and 50 to 500 feet of multi-conductor cable (fig. 6).

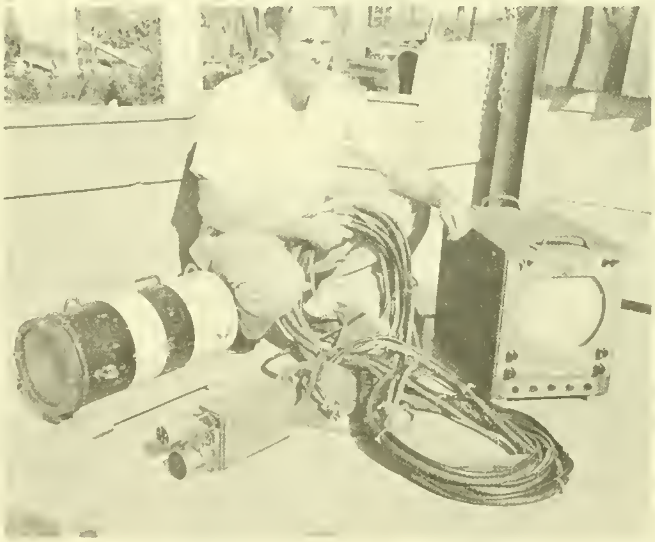

Fig. 6. Underwater-Television chain. Left to right- camera pressure vessel, T-V camera, multi-conductor cable and control monitor.

The camera unit contained a 1" 6198 Vidicon photo-conductive pick-up tube, video amplification stage, a blanking amplifier, optical focus, and iris control motors. The relatively compact control unit was a combination power supply, operator's control panel, and monitor smaller than the average home receiver. The monitor housed all controls for brightness, contrast, target, beam intensity, electronic focus, and optical focus. A radio frequency generator was provided to supply a video-modulated signal for optional use of additional monitors. Around this basic component the underwater television vehicle was constructed. Actually several modifications were necessary for use at relatively low light levels imposed in undersea use. For photographing the monitor screen the picture quality required fine control of light. A Service engineer adapted a simple differential gearing principle to the existing manual optical focus system to provide remote lens-aperture control of 16mm. C mount or wide angle lens in a range of f 2.8 to f 22.0 (fig. 7).

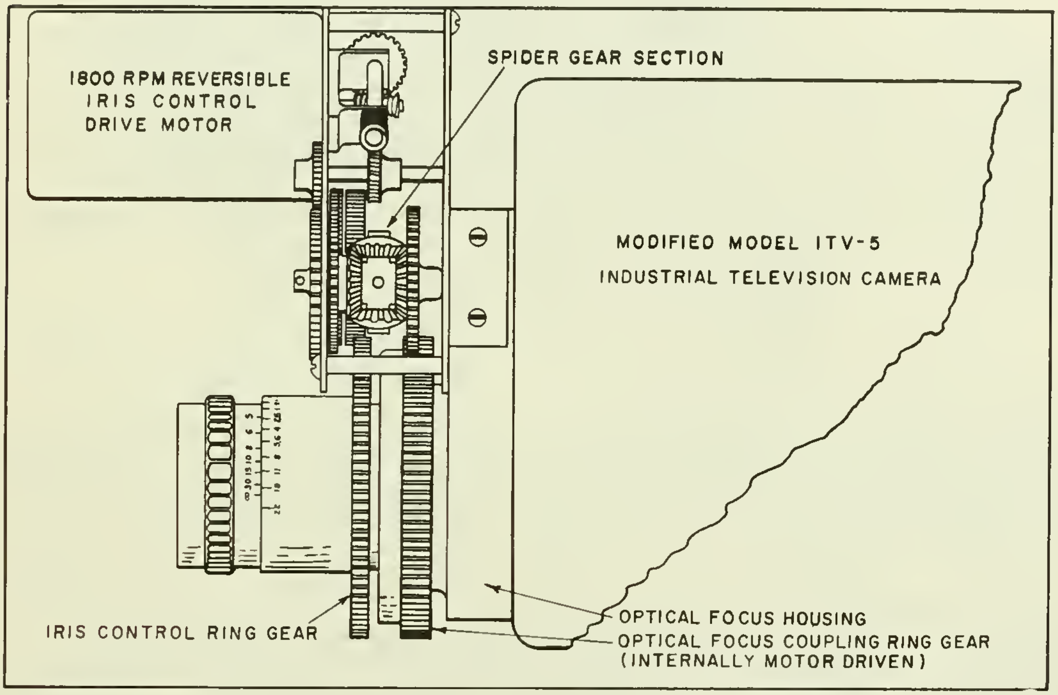

Fig. 7. Remote Iris Control Device for Modified R.C.A. Model ITV-5 Industrial Television Camera.

POWER SUPPLY

A reliable and stable source of 110 volt AC 60 cycle power was important to operate the commercial television equipment. To insure an adequate power supply, a 3 KW generator was used with motor generator set and voltage regulator. Portable power units were used satisfactorily but television performance was found to be only as reliable as the power source. A separate source of 24 volts DC power was used for the scanning drive unit.

The weight of the vehicle in air was about 400 pounds and about one-half as much when submerged. This required an extra cable for suspension in order to free coaxial television and vehicle control cables from excessive strain.

While not offered in any way as a final or ultimate design the resulting relatively uncomplicated combination of pressure vessels, mechanical devices and circuitry performed quite well.

USE OF VEHICLE IN UNDERSEA RESEARCH

With the television vehicle suspended overboard the operator on the ship above is afforded almost studio-like scene control under favorable water conditions. Whether placed on the bottom, just above the bottom or under tow, the power control assembly allows scanning of 360° in azimuth and 90° in elevation. The operator can manipulate all control functions from a single position and record observations by camera at will, free from human limitations of time, depth, and danger placed upon the diver. With the automatic or manually operated scanning facility the camera may be trained on moving objects.

The camera vehicle has been tested at depths to 62-1/2 fathoms when pressurized. Pressurization is not required at depths of 0 to 10 fathoms. In clearer water conditions, such as in the Gulf Stream, objects may often be viewed at distances of 60 to 70 feet. The diffused light underwater causes little or no shadow, resulting in somewhat flat images. While the camera is in motion, however, some impression of stereopsis may be present.

In water conditions where natural light levels are too low for the human eye the extra sensitivity of a television camera is often able to achieve higher resolution by the ability to integrate light. With the use of underwater lighting the television camera's useful depth range can be extended when water conditions permit (fig. 8). Regular photo-flood and photo-spot lamps can be used satisfactorily in depths to 10 or 11 fathoms, however, the individual ability of these lights to withstand pressure varies considerably. Quite satisfactory results for greater depths can be obtained by the use of Navy 1000 watt diving lamps. Care in positioning of the underwater lamps to the side of the camera can result in a good field of view, though back scattering of light due to turbidity of the water may reduce the effective viewing range to 10 feet or less. Tests thus far indicate that best results may be obtained by placing the underwater lamps to the side and as far as practicable ahead of the camera and at a converging angle to the line of camera view. This reduces illumination-to-object distances and assists in reducing back scattering of light to a minimum.

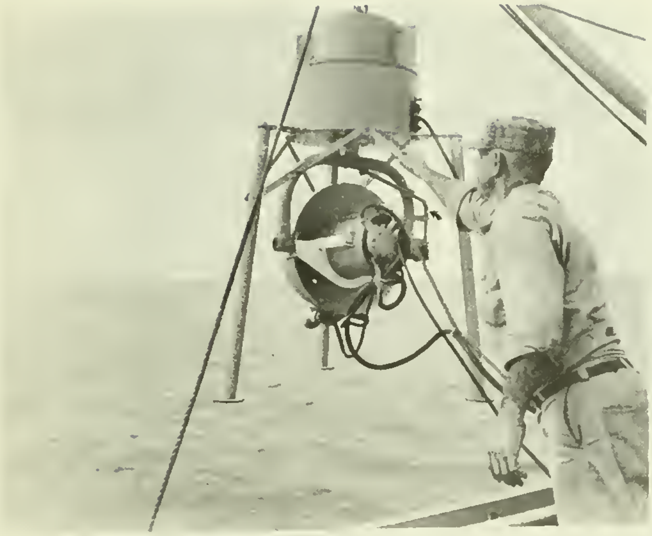

Fig. 8. Rear view of Underwater Television shows tripod legs, pressure vessels, camera cradle and cable attachments for underwater photo-flood lamp. Arrow indicates vertical drive linkage which operates vertical scanning.

Recording of observations at the monitor screen can be made by still or motion picture cameras. Kinescoping with the movie camera can be a very unique and complicated process involving expensive equipments as done by the television broadcast studios. Service engineers developed a relatively simple process using a 16mm. movie camera modified to operate with a synchronous motor with gear coupling to run at 15 frames per second. For best photographic results Service engineers found that the television camera screen should be reduced in contrast. The picture should have no bloom or spot, but brightness should be adjusted to a grey tone rather than black. In this manner very satisfactory recordings can be made from the screen of the monitor for later laboratory study.

The underwater television vehicle permits good observations of model trawls, otter boards, trolled lures, shrimp and lobster traps and other gears from close-ups to distances of 60 - 70 feet under favorable conditions (fig. 9). In addition to preliminary midwater trawl observations with the Navy in November 1954, the vehicle is used in continuing experimental fishing activities with trawling gear (fig. 10).

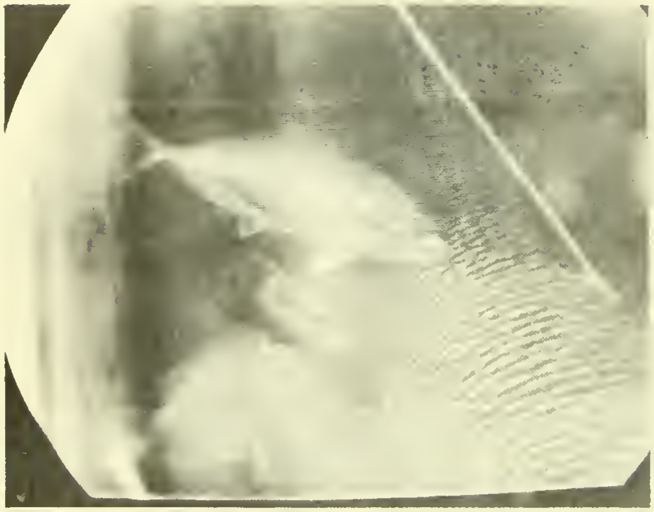

Fig. 9. Fish examining shrimp trap at night, as seen on Underwater Television monitor screen.

Fig. 10. Underwater Television Vehicle is rigged for towing with legs removed and ball fairing and control vane attached.

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