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AN AUTOMATIC UNDERWATER CAMERA SYSTEM

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by Russell J. Jirberg
Lewis Research Center
Cleveland, Ohio

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by Russell J. Jirberg

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio

ABSTRACT

A special purpose automatic underwater camera system was designed and operated during the summer of 1970 to obtain a time-lapse photographic record of the algae growth and sedimentation at the bottom of mid-Lake Erie. The system was built around a conventional 35 mm camera and electronic flash unit. Automatic control circuitry enabled it to operate unattended at the bottom of the lake for extended periods of time. Details of the system's design and operational characteristics are presented.

INTRODUCTION

During the summer of 1970 the problem of oxygen depletion and nutrient regeneration in Lake Erie's central basin was the subject of a comprehensive investigation. The study, labeled Project Hypo, was a joint effort by the Water Quality Office of the Environmental Protection Agency for the United States and the Canada Centre for Inland Waters for Canada. With the goal in mind of determining the mechanisms responsible for the accelerated eutrophication of the lake, a broad spectrum of physical, chemical, and biological factors were monitored throughout the lake's central basin.

The study was aided by visual and photographic observations of the lake conditions made by divers using a hand-held underwater camera.

However to obtain nearly continuous photographic documentation of lake bottom conditions, an automatic underwater camera system was specially designed and built for Project Hypo. This camera, together with an electronic flash unit as a source of illumination, sat just off the bottom in mid-Lake Erie and automatically photographed the bottom at one hour intervals. Up to 10 days of unattended operation was possible while taking up to 250 color photographs, one per hour, before retrieval and reload was required. In this way over 400 color photographs were taken in a time-lapse sequence. Presented here are the details of the construction and operation of the automatic underwater camera system.

SYSTEM DESIGN

The Camera

The camera system was designed and constructed by personnel at the NASA-Lewis Research Center in cooperation with the Water Quality Office, Cleveland, Ohio of the Environmental Protection Agency. As shown in figure 1, it is basically a two-part system. In one water-tight housing is contained a 35 mm motor-driven camera along with the timing and control circuitry, while in the other is contained the flash unit.

The camera is a commercially available 35 mm single lens reflex camera with motorized shutter release and film advance. It is equipped with a moderately wide angle (35 mm focal length) lens. However, due to refraction at the flat air-water interface at the housing, the field of view is more nearly that of a normal (50 mm) focal length lens. At a height of 1 meter off the bottom, the field of view encompasses an area of the bottom vertically below the camera measuring approximately 0.6×0.9 meters. The actual area photographed can be viewed by the diver through the large pentaprism finder looking directly through the rear panel of the housing.

Although the optics of the system, because of the flat viewing port, are not of the water-corrected variety, the distortions are neither obvious nor objectionable in the resulting photographs. Since the field of view for the purposes of the Project need not be too large, an extremely short focal length lens was not required. Hence, the flat viewing port was entirely acceptable.

With a maximum load of 250 frames (33-foot length of film), the camera can operate for roughly 10 days (taking one picture per hour) before retrieval and reload is required. After shooting 250 frames the operation of the camera automatically ceases in the event that the camera is not retrieved in time.

Control Ciruitry

Automatic operation of the camera is governed by a small battery-powered clock similar to that found in home wall clocks. Power for the clock is derived from a $1\frac{1}{2}$-volt "D" cell. This results in a very efficient timing device both in terms of reliable long term accuracy and low power consumption (one battery will power the unit for over a year).

A cam on the minute-hand shaft of the clock is used to actuate a microswitch (switch SW-2) as indicated in figure 2. By appropriately cutting the cam with a multi-lobe pattern, the camera could be triggered as frequently as minutes apart. For this study, a single-lobe cam was selected, giving a one hour picture interval.

As the microswitch is actuated, the silicon-controlled-rectifier SCR-1 is pulsed into conduction, discharging the 3000-μf capacitor through the coil of the relay. The relay is thus momentarily energized, producing a momentary voltage reversal between two of the control leads of the motor drive unit. The nature of the motor drive unit is such that a brief voltage reversal is all that is required to initiate the sequence of (1) tripping the shutter, (2) advancing the film, and (3) recocking the shutter. Thus with each pulse to SCR-1 through the clock-driven microswitch, one frame is exposed and the camera readied for the next frame.

Between exposures the 3000-μf capacitor is recharged through the 100 K-ohm resistor. Within a few seconds after the relay is tripped the current drain on the 12-volt battery returns to the microamp leakage level of the capacitor. The use of a capacitor discharge system conserves battery energy, and ensures that adequate energy is available to pulse the relay in the event that the battery is degraded by the cold environment of the lake. (The ambient temperature at the lake bottom is typically 8° C.) Primarily because of the need for extended operation at low temperatures, alkaline-manganese-zinc batteries were chosen in preference to the conventional carbon-zinc (Leclanche) type.

It should be noted that since low-force D.P.D.T. microswitches are not readily available, the SCR-relay-capacitor discharge circuit is a necessary complication. If such D.P.D.T. switches were available, they could be used to actuate the motor-drive unit directly, and hence reduce the circuit complexity.

Flash Unit

The flash unit is contained in a separate water-tight housing. This was done to allow a greater flexibility in positioning the light source in order to minimize the amount of light scattered into the lens by suspended matter, and to bring out texture in the target scene.

The unit is a commercially available item. It was, however, modified slightly to reduce the standby current drain on its battery. The light output of its xenon flash tube is a millisecond duration pulse of 4750 beam-candle power-seconds. Indicated in figure 2 is the flash gun circuit with the modified trigger section. The unit uses capacitor energy storage charged directly from a high voltage (510-volt) battery. Battery life is rated at 1000 flashes. However to ensure battery life for the 10 day time span, the total resistive load imposed by the trigger circuit was increased to 66 megohms. The standby battery current was thereby reduced to somewhat less than 10 microamps.

One additional modification was made to avoid directly cabling the high voltage (170 volt), high impedance trigger circuit between the flash unit and the camera housings. An SCR was added to the circuit to discharge the trigger capacitor through the trigger coil. Thus the interconnecting sync cable need carry only a brief current pulse from the 12-volt battery in the camera housing, through the shutter contacts, to the gate of the SCR. This also greatly simplified the design of the electrical feed-throughs. A pair of 6-32 screws threaded through the housing wall were adequate for the purpose. The impedance of the gate circuit is low enough that the feed-through terminals can be exposed to the water without being shorted out by conduction through the water.

Underwater Housings

The water-tight housings were constructed of annealed 1/2-inch thick acrylic plastic with rubber O-ring seals on the cover plates. Each was designed to withstand the hydrostatic pressures of the lake without the use of internal pressurization so as not to stress the camera and electronic components. Two "shelves" were included in the camera housing to support the large front and rear panels against the hydrostatic pressure. By locating the shelves immediately on either side of the lens, distortions due to a deflected viewing port were eliminated.

No attempt was made to determine the ultimate strength of either housing. Both, however, were hydrostatically tested to 65 psi or about 150 percent of the pressure experienced on the lake bottom.

The construction of the housings was also simplified by the fact that no mechanical feed-throughs had to be provided. Gravity sensing (mercury) switches (SW-1 and SW-3) in the battery circuits turn the units on when set in the intended position. The lens aperture and focus were preset before the camera was submerged.

In-Situ Mounting

The camera and flash unit were secured to a large angle-iron tripod as shown in figure 3. When lowered to the bottom of the lake the legs of the tripod sink into the sediment, and the tripod comes to rest with its lower panel essentially floating on the sediment. This locates the camera approximately one meter off the bottom looking vertically downward at a 0.6×0.9 meter area of the bottom adjacent to the tripod. The flash unit is positioned to one side, nearly 80^{o} off the vertical, to illuminate the bottom at a near glancing angle.

The site selected for the time-lapse study was the central monitoring station for the lake (Project Hypo station P). Instruments at this site included the full complement of meteorological, chemical, and biological monitors. Lines from these as well as the tripod were attached to a central surface marker bouy. Upon returning to the site, divers would retrieve the camera and flash unit, leaving the tripod in position. After reloading the camera and replacing the battery in the flash unit, both were returned to their positions on the tripod to resume the filming of the same area of the bottom.

OPERATIONAL CONSIDERATIONS

In general the camera system performed well and provided valuable information, particularly in regard to timing of the algae sedimentation, in noting subtle changes occurring on the bottom, and in revealing some unexpected effects of bottom currents on sediment resuspension. For a discussion of these and related topics, consult the several companion papers presented on Project Hypo at the 14^{th} Conference of Great Lakes Research, Toronto, April 1971. Project Hypo is also described in the NASA motion picture film C274 along with some of the photographs taken in the time-lapse sequence.

During the course of the study some unforeseen situations did arise in the camera's operation, while on the other hand some situations that were anticipated did not materialize. For example, it was thought that moisture condensing on the inside of the viewing port might present a problem. Initially in addition to enclosing several silica gel packets in the camera housing, the housing was flushed with dry nitrogen. Later the nitrogen flush was abandoned. No condensation was noted. Indications are that the humidity within the camera housing was quite low since occasional small static electrical discharges were recorded on the film presumably as the film was advanced through the camera.

Condensation was a problem, though, when the camera was brought to the surface. If the housing were immediately opened, moisture from the air would heavily condense on the camera and lens, which of course were at the 8° C temperature of the bottom waters. In the absence of some sort of changing bag on board ship that might be flushed with a dry atmosphere in which to open the housings, the camera was instead returned to shore, warmed and reloaded, and then later returned to the lake.

Also the attenuation of the illumination from the flash unit by the water was more severe than expected. With the flash unit $1\frac{1}{2}$ meters from the center of the field of view, and using Ektachrome type MS5256 film (ASA 64), the lens was set at f/11; a small aperture was desirable to obtain enough margin on the depth of field. Results indicate that f/5.6 would be a better choice for the exposure.

Finally, no problem was experienced with sediment clinging to the viewing port or to the housings in general - a point of initial concern.

CONCLUDING REMARKS

Our experience with this camera system indicates that a camera encased in a simple plastic housing can indeed be submerged to sit on the lake bottom and effectively log imagery data on the physical and biological mechanism taking place there. Through the use of automatic timing and triggering circuitry, the camera can operate unattended over extended periods of time periodically photographing the selected scene. This time-lapse photographic record is valuable for documenting both the subtle as well as the long term changes that occur.

In this study the photographs were spaced one hour apart. A review of these photographs shows that changes occur on the bottom over a time span somewhat shorter than the selected one hour interval. It would therefore be desirable in the future to shorten the picture-taking interval to perhaps every 10 or 15 minutes in order to better trace these changes. Such a timing modification is easily accomplished.

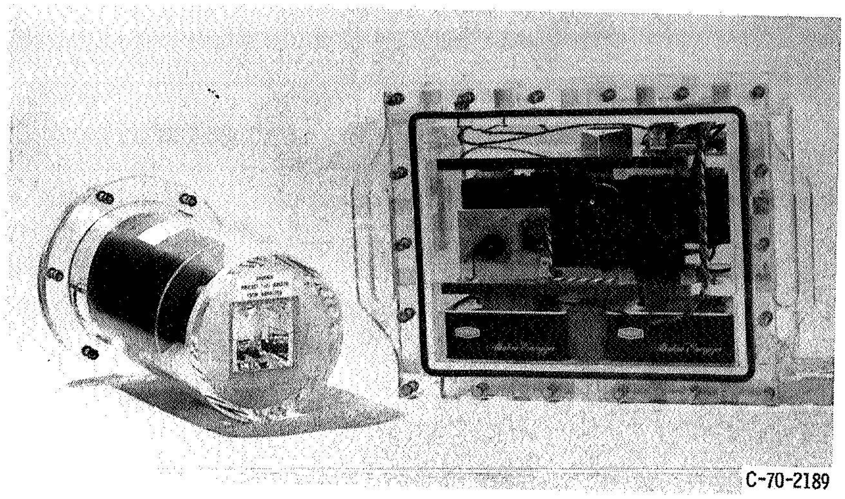
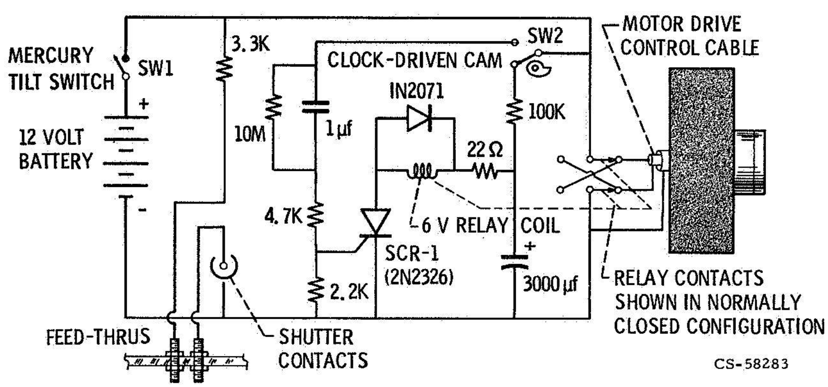
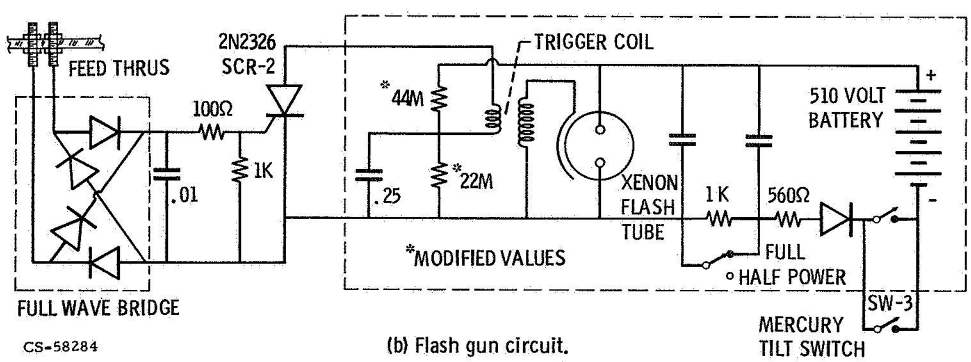


Figure 1. - Camera and electronic flash units in their water-tight housings.



(a) Camera control circuit.



(b) Flash gun circuit.

Figure 2. Camera control and electronic flash circuits for underwater camera system.

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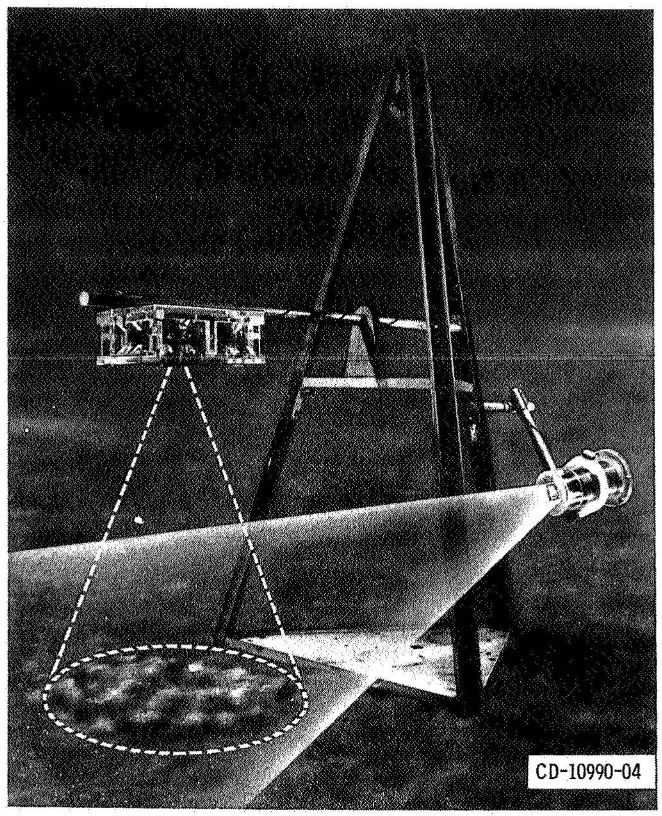

Figure 3. - Underwater camera and flash unit on tripod mount as situated on the lake bottom.