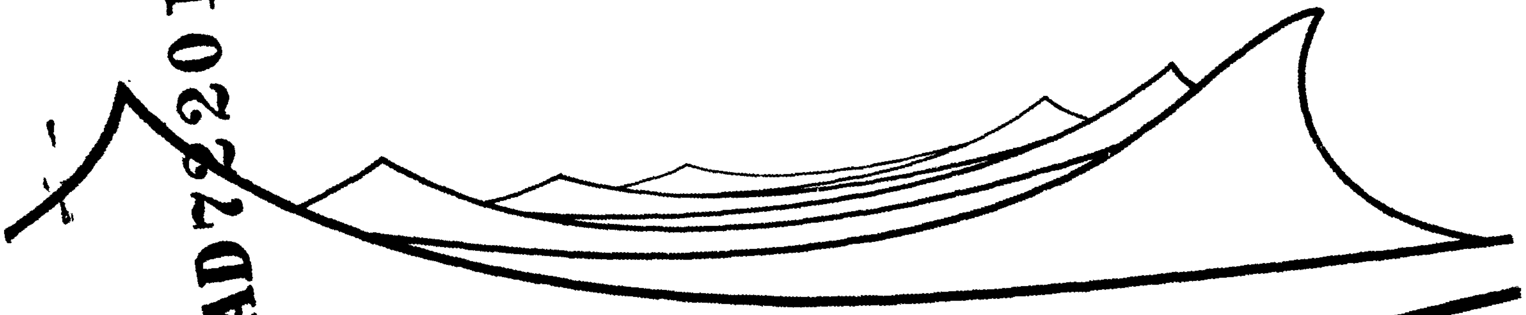

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A PRECISION DEEP-SEA TIME RELEASE

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by

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A PRECISION DEEP SEA TIME RELEASE

Abstract

A family of oceanographic instrument systems that descend freely to the ocean floor later to return to the surface are now in use. Vital to the free vehicle instrument system is a reliable and accurate programmable anchor release device. A release device capable of being easily programmed in one hour increments to a total of 1000 hours is described including results of test and field evaluation.

INTRODUCTION

During the past several years we have developed and put into use a family of autonomous free instruments (Ref. 1 and 2). These instruments descend freely to the ocean floor where they perform various preprogrammed tasks. At the end of their mission they are released from a ballast weight and returned to the sea surface by buoyant floats for recovery. A number of different types of release devices are described in Reference 2; however, several years of experience have shown that the magnesium-steel bimetal corrosion link is the most reliable. While this release device has been extensively used it has several serious limitations. The corrosion link is reliable due to the fact that it will always corrode in sea water and release - but wide ranges in timing have occurred. Occasionally, the sprayed steel coating has exfoliated, eliminating one side of the galvanic couple. This has caused timing errors of 100 to 200 percent, and has resulted in the loss of several instruments due to requirements to move the ship to another area at a particular time. Also, as the mission bottom time becomes longer the time error to release tends to become greater varying between 5 percent and 10 percent excluding exfoliation effects. Another serious limitation of this release is that in our particular configuration operation beyond five days becomes very erratic and, therefore, we have limited its use to that duration.

To overcome these problems and to provide for time durations greater than 120 hours we undertook the development of a reliable accurate release device. Our initial attempt during 1966 and 1967 was to work with industry in hopes of utilizing some of the technology developed in release devices for space exploration. Several attempts met with failure primarily because our market is small and oceanic applications have some unique problems which are unfamiliar to aerospace technologists.

Our several years of development work was not wasted. During the development and test phases we learned that, indeed, reliable electro-explosive accuators could be obtained and that these devices provided a great deal of reliability at reasonable cost. We also learned that electro-mechanical clocks would not reliably drive mechanical counters or switches and, therefore, we became convinced that an electronic clock and control were required for reliable low power operation. The subsequent availability of ultra-low power integrated circuits made the design of this clock and control system possible.

TIME RELEASE

The deep-sea time release (Fig. 1), was designed to provide easily programmable elapsed times up to 1,000 hours duration. It is a small, light-weight, self-contained device which will release loads up to 500 pounds in ocean depths up to 20,000 feet. The package is configured so that it is easily disassembled for service without use of tools, and complete functional check-out features are provided (Fig. 2).

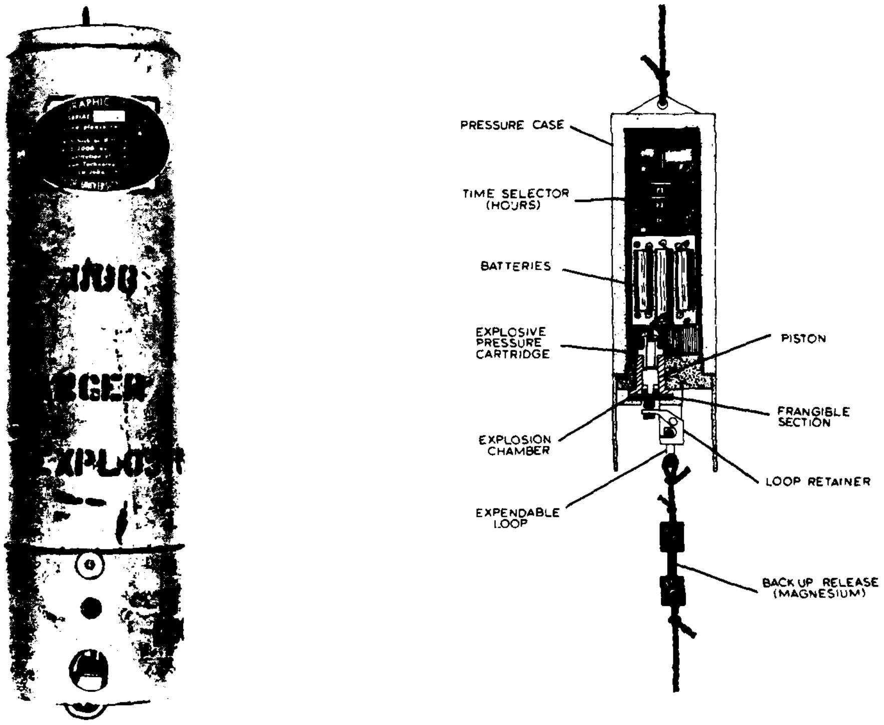


Figure 1. Time release.

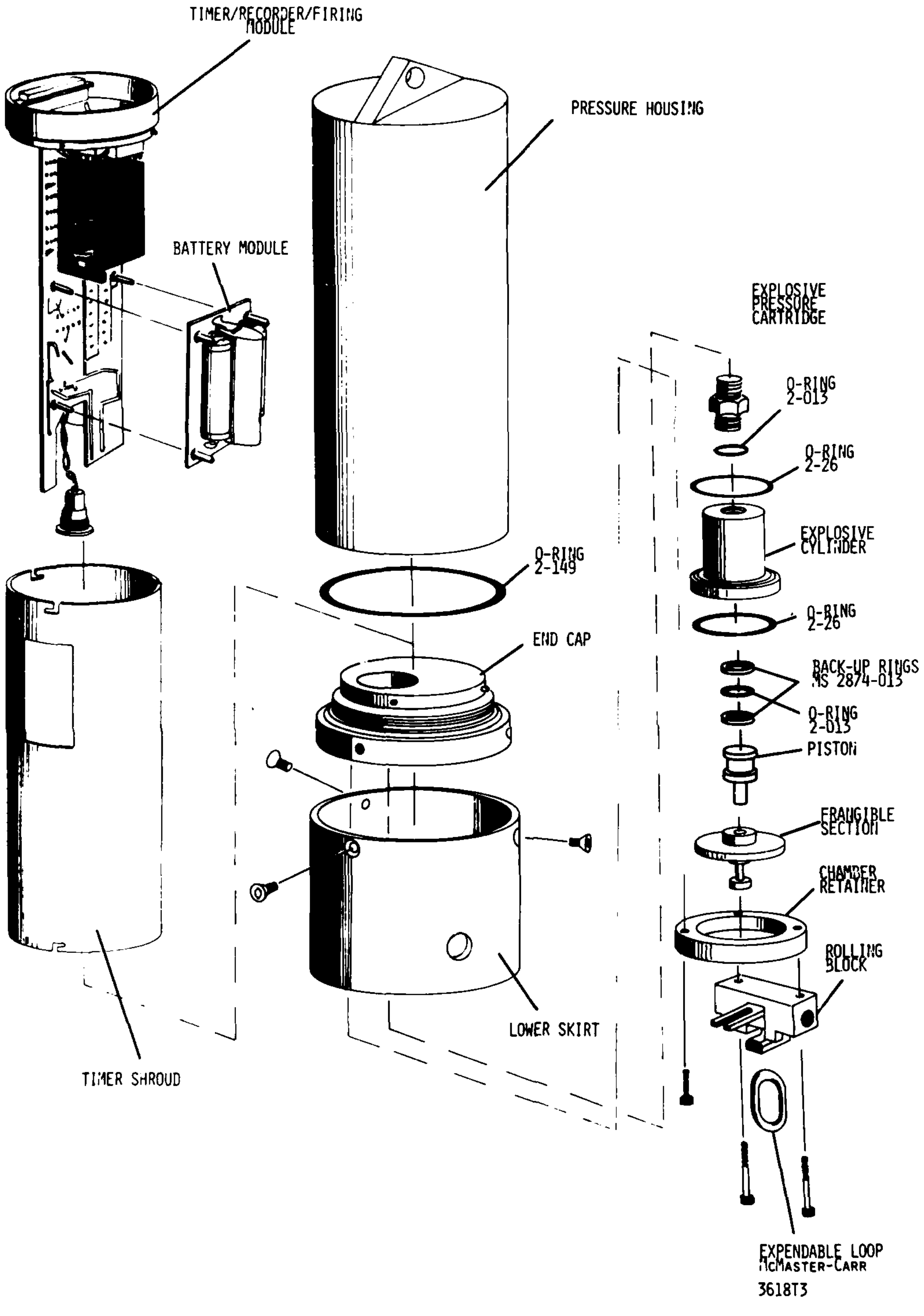


Figure 2. Time release assembly.

To establish an accurate time base, a low power crystal oscillator, which provides 0.01 percent timing accuracy operating at a frequency of 74,565 Hz, was utilized. This frequency, when divided by 2^{28}, provides one pulse per hour output. The factor 2^{28} was chosen because the available ripple counters came in seven stages per package and four of these packages were required to achieve one pulse per hour from a frequency greater than 10 KHz, (the lowest readily available NT cut crystal frequency). The ripple counters as well as all other integrated circuitry used, are complementary symmetry metal oxide semiconductor (COS/MOS). This type of circuitry is ideal for many oceanographic applications as the standby power in either one or zero state is the leakage current through an off MOS transistor, usually the order of nanoamperes. COS/MOS operates over the voltage range of 6-15 volts easily obtained from batteries; and has high noise immunity, typically 40 percent of the supply voltage.

The one-pulse-per-hour output from the ripple counter is fed into a three decade binary coded decimal (BCD) counter as shown in Figure 3. All the BCD counter output lines (both true and complement) are connected to a three decade BCD coded thumbwheel switch which performs the function of a programmable AND-gate.

When the count in the timer registers is coincident with the number set on the thumbwheel switches the pressure cartridge firing circuit is activated. This circuit then charges the energy storage capacitor from the 28 volt battery for approximately 120 seconds until a unijunction transistor fires, triggering a silicon-controlled rectifier (SCR) in series with the energy storage capacitor and the pressure

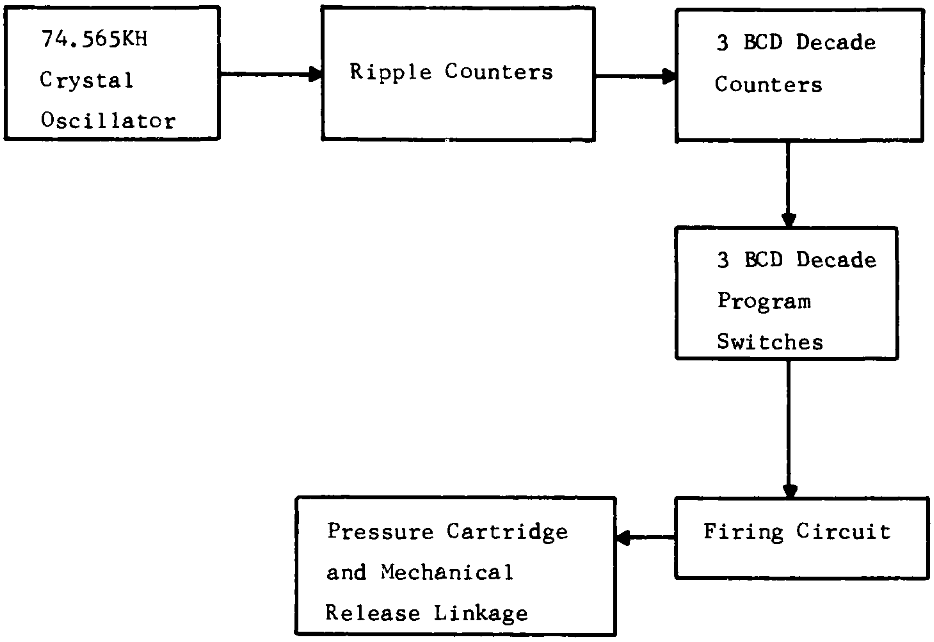
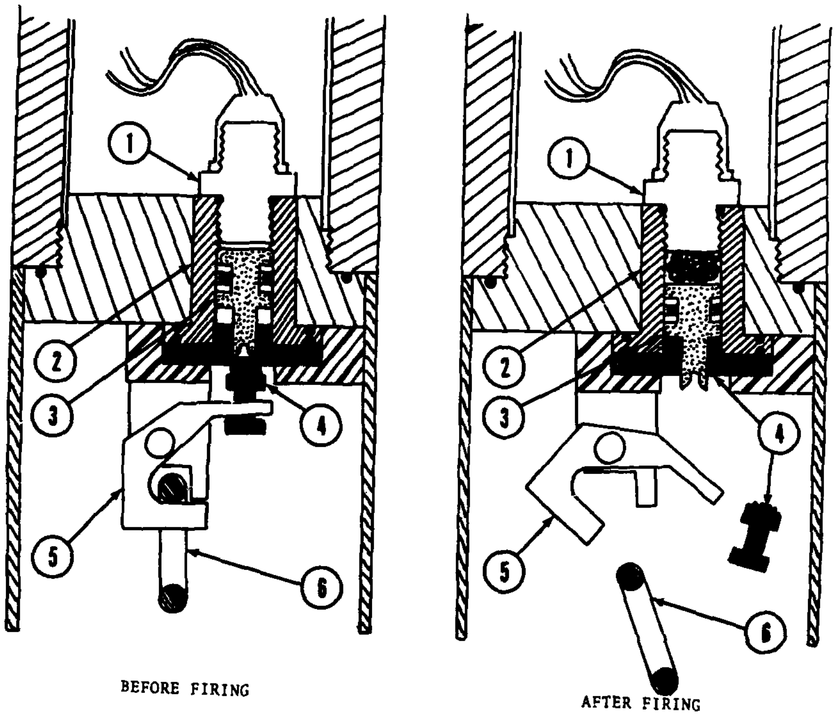


Figure 3. Block diagram of timed release.

cartridge. The energy stored in the capacitor is delivered to the pressure cartridge which has a resistance of one ohm. This low resistance requires that all losses including capacitor equivalent series resistance and SCR dynamic switching losses be held to a minimum in order to provide adequate firing energy for the pressure cartridge. Upon ignition of the gas-generating cartridge, pressure is released into a cylinder, causing a piston to move, shearing off a small aluminum retainer. This opens the locking hook and releases the ballast weight (Fig. 4).



BEFORE FIRING

AFTER FIRING

1. Pressure cartridge
2. Firing chamber cylinder
3. Piston
4. Frangible section
5. Locking hook
6. Expendable chain link

Figure 4. Time release mechanism.

Since specifications available on the components used in this circuit were not applicable we were forced to run specific evaluation tests in order to select the best standard components. In addition, no capacitor discharge pulse firing data was available for the pressure cartridge. After consultation with the manufacturer, we designed the circuit to provide a pulse of a minimum amplitude for the time required to fire all pressure cartridges under steady state conditions (Fig. 5).

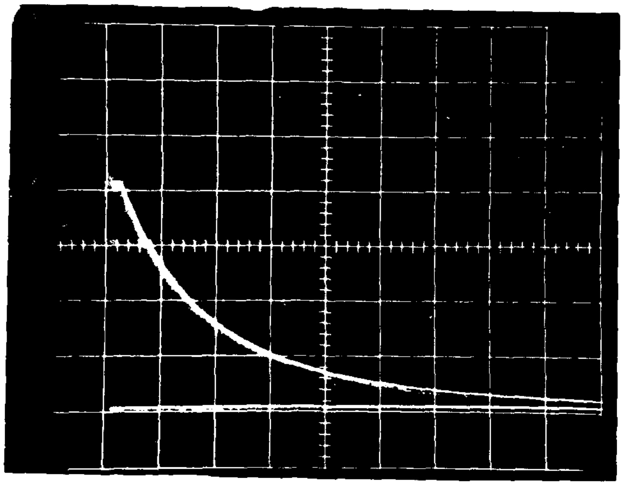


Figure 5. Oscilloscope trace of current pulse through pressure cartridge. Vertical scale 5 amperes per division. Horizontal scale 2 milliseconds per division.

This way we were able to utilize the large volume of reliability data accumulated for steady state firing conditions and avoid firing a large number of pressure cartridges to determine required pulse energy to fire reliably. This procedure results in greater required capacity for energy storage than the minimum that will fire the pressure cartridge but was the only way to achieve the proven reliability of the pressure cartridge. Since our basic assumption was that these pressure cartridges could be fired very reliably, we consider this point crucial to the design.

It was noted that after the energy storage capacitor remained in a no-charge state for long periods (several months) that initial leakage current was higher than our circuit charging current. This was a result of the capacitor losing its formation charge and having to be reformed. Potential problems on releases longer than 1,000 hours could be overcome by keeping the capacitor charged during the delay interval. We have not experienced any problems with the 1,000-hour timer in this regard.

In order to achieve small size of the entire assembly it was necessary to utilize high-energy density batteries. The clock and counter circuits operate from 8.1 volts consisting of two 4.05 volt 1,000 milliampere-hour mercury batteries connected in series. The battery has a 2800-hour life which yields a factor of three safety margin for the normal 1,000-hour operation. This type battery is generally not used at low temperature due to its increase in internal impedance resulting in large drops in output voltage. In this application, however, current drain is very small (300 microamperes) and the temperature effect is not a problem. A 28-volt mercury battery, supplies energy to the squib storage capacitor. Tests have shown that this battery charging the 2500 microfarad storage capacitor for 120 seconds can produce a 20-ampere peak pulse for at least 50 charge-discharge cycles at +8° C over a period of two hours. For purposes of reliability we generally limit each battery to three short operational missions and correspondingly less for longer duration missions.

All components are mounted on a printed circuit board which serves as the structural member for the timer portion of the release (Fig. 6).

The batteries are encapsulated on a small separate printed circuit which is plugged onto the main circuit board. This technique provides reliable battery mounting and electrical connections, yet retains simple, rapid battery exchange at sea.

Figure 6. Internal parts of timer.

Sealed thumbwheel switches are used and the entire printed circuit board is coated with a sealant to prevent moisture from affecting the operation of the timer. To provide both mechanical and electrical noise protection for the timer when removed from the pressure case, the timing module is housed inside an aluminum tubular shroud (Fig. 7). The shroud serves to mount the entire assembly to the bottom of the pressure case. This tube is easily disconnected from the pressure case and the electronics removed without tools by rotating the tube 10° and unlocking the assembly. This feature is particularly useful when working on a ship in rough seas.

Figure 7. Time module and shroud.

The timer assembly is housed inside a 6061-T6 aluminum pressure case which is hard anodized and painted. This pressure case protects the timer to pressures up to 10,000 pounds per square inch. Alloy 316 stainless steel is used on the exposed locking hook and cylinder assembly but these areas are kept small with respect to the aluminum area to minimize the effects of corrosion. To further protect the cases sacrificail zinc anodes can be used. The release mechanism uses no through-hull fittings or electrical feed-throughs so flooding and degradation of electrical insulation problems are minimized.

TEST UNIT

Even though the release is designed for ease of operation it is a complex device which requires careful checkout prior to deployment. Since there are no moving parts or other indications of proper timer operation, external checkout equipment is required to monitor operation of the timer. To make this a simple task and assure that a complete operational check through the entire system is properly performed prior to deployment, a special purpose test unit was designed (Fig. 8).

The test unit is connected to the timer by a 37 pin connector and cable assembly for checkout. The timer internal clock line is disconnected and routed through a selector switch on the test unit that allows the normal one-pulse-per-hour to be speeded up to 1-, 10-, and 100-pulses per second. This technique allows high timer counts to be quickly reached for rapid checkout. When the count selected by the thumbwheel switch is reached, an inhibit circuit disables the clock and

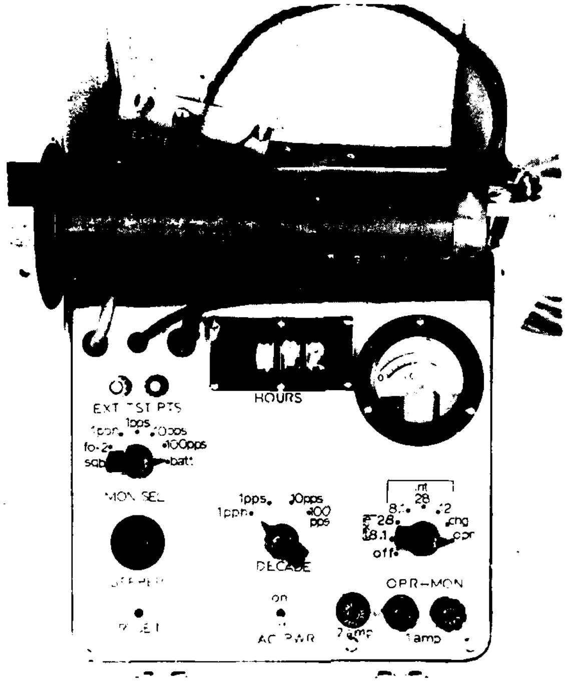


Figure 8. Test unit and timer module.

holds that count which is also displayed on the test unit decimal readout. The firing circuit is actuated and charges the energy storage capacitor which discharges into a dummy load resistor of one ohm. A circuit monitors this pulse and determines if the amplitude exceeds a preset value. A sonalert beeper sound if this present level is exceeded indicating acceptable squib firing current. An analog panel voltmeter displays the two battery voltages of the release and the batteries internal to the tester under load. A rotary switch selects which battery is measured and is also the main power and charging switch for the internal nickel-cadmium batteries.

TEST RESULTS

After the initial design and construction of the first release, tests were conducted on the entire system to determine clock timing accuracy and reliability of the squib firing circuit. Because the timer can be used for elapsed times of up to 999 hours, establishment of system timing accuracy is important. Initial tests of 1-, 8-, 11-, and 32-hour durations showed less than ± 2 seconds per day error for a 44- and 66-hour test respectively. A complete release was operated in our pressure test facility at 8,000 PSI and + 8° C for 70 hours. This test resulted in an average timing error rate of - 4.6 seconds per day. Two 48-hour tests had timing error rates of - 4 seconds per day. A 766-hour test at 8,000 PSI and + 4° C had a net timing error of less than one second after a correction was applied for an oscillator frequency deviation equivalent to a timing error of - 3.8 seconds per day. Most of the oscillator frequencies are several Hertz low which results in a predictable timing error between - 2 to - 4 seconds per day.

FIELD TEST RESULTS

The release has been used from Scripps vessels in 62 deep-water missions totaling 2300 programmed hours among 7 units (2 are now lost). Of the two lost, one release came up after the ship left the area and the other was lost due to a parted connecting line.

The timing errors and drift rates noted under laboratory test results would not be noticed in the field due to uncertain rise time of each autonomous vehicle. If very precise timing is required, the individual oscillator timing error can be corrected for the temperature of the environment. Since most deep-ocean applications are constant temperature it is possible to achieve accuracies of the order of several seconds per month.

There have been eleven failures, five of which resulted in early releases up to four hours and six resulted in no release. These six were recovered by a magnesium backup release. To the best of our knowledge nine of these failures are a result of vibration or shock occuring during launch. Tests have shown that the banana jacks and plugs that are staked to the main circuit and battery board showed voltage spikes on the main bass line under heavy handling. Also, power switch contacts have been shown to open under severe shock. These jacks and plugs are now additionally soldered to the circuit board and a large filter capacitor added across the electronics, but results from the field are not yet conclusive. Two of the eleven failures were the result of a faulty reset switch. The switch was a push button 4PDT type that is used to reset the ripple counters and the decade counters. Reports from the field stated that the switch plunger would not return which was noted after a mission failure. After consulting the factory, the problem was found to be the nylon plunger which absorbed moisture and expanded against its bushing causing the switch plunger to stick in the reset position. A spring return bat handle switch of the same manufacturer was used for replacement. The bat handle gives a positive indication of proper switch operation. Subsequent experience has shown this switch also sticks under some conditions, so we have replaced it with a completely different design push-type switch. One failure, in addition to eleven, was a result of the power switch being inadvertently turned off prior to a mission. This switch is now a locking lever type which must be raised to be operated.

There have been no cartridge failures but several anomalies have been noted. A red plastic cover over the primer port was not destroyed during a burn but had several small holes in it. The release operated properly however. The pressure cartridge exhausts into a closed chamber. When an expended cartridge is removed, care must be exercised until the pressure is relieved. On one occasion when an expended cartridge was being removed, a pin hole occurred at the glass connector seal causing gas to escape through the hole and not around the threads. Some releases have experienced blow-by around the cartridge O-ring due to an improperly machined part, but the releases operated properly.

CONCLUSIONS

These release devices have been operated over sixty times at sea under actual working conditions. Several deficiencies in components have been discovered and corrected. Recent tests indicated problems encountered during severe shock have been overcome and that these units will function during exposure to typical handling conditions at sea. Use of these releases at sea have demonstrated their ability to provide precise release times and their value to cruise planning and operation.

It is expected that further use of this type of release device will greatly enhance the value of autonomous oceanographic instruments.

FUTURE PLANS

We are presently building a number of new units which will utilize a simplified oscillator design and a prototype integrated circuit decade counter. These changes should ultimately result in increased reliability and reduced cost. It is planned to utilize these releases for longer than five-day durations without magnesium back-up releases in measuring deep-ocean currents in the Antarctic area. In this application, two releases will be connected together in such a way that operation by either unit will result in a release. This configuration should result in much higher reliability which will be necessary for use without backup magnesium corrosion releases.

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