OPERATING MANUAL FOR THE R100 DIGITAL VIBRATION-TIME TOTALIZER

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CONVERSION FACTORS

The inch-pound units used in this report may be converted to metric (International System) units by the following factors.

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.40	millimeter (mm)
pound (lb)	0.4536	kilogram (kg)

Abbreviations

ac	alternating current
CMOS	complementary metal-oxide substrate
dc	direct current
g	acceleration of gravity
Hz	hertz
IC	integrated circuit
R100	digital vibration-time totalizer
V	volt
LCD	liquid crystal display

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ABSTRACT

A vibration sensor that monitors the running time of pumps to determine water withdrawal by various public-supply, agricultural, and industrial groups has been developed in response to a need demonstrated by data-gathering activities of the U.S. Geological Survey's National Water-Use Information Program.

This sensor, the R100 digital vibration-time totalizer, attaches to monitored equipment, such as a pump, motor, or pipe facility, and senses vibration to determine running time. Battery-powered and packaged for field environment, the R100 can be left unattended for as much as 1 year. Time is recorded to the nearest 0.01 hour, or 36 seconds.

This operating manual for the R100 digital vibration-time totalizer describes the R100's principle of operation and gives installation guidelines and instructions for battery replacements.

INTRODUCTION

The results of data-gathering activities in the National Water-Use Information Program of the U.S. Geological Survey have indicated the need to monitor the running time of pumps to help determine water use by various groups, such as public-supply, agriculture, and industry. Vibration is the common element in many different types of pumps used in water withdrawal and conveyance. By attaching a vibration sensor to the equipment and using the sensor output to start and stop a time totalizer, the running time of pumps can be recorded.

The R100 digital vibration-time totalizer (R100), a vibration sensor combined with a digital clock, was developed at the Survey's Hydrologic Instrumentation Facility, Stennis Space Center, Mississippi. The R100 physically attaches to the monitored equipment, such as a pump, motor, or pipe facility, and senses vibration to determine running time. The R100 is battery-powered and packaged for field environment and may be left unattended for as much as 1 year. Time is recorded to the nearest 0.01 hour, or 36 seconds.

The R100 is a self-powered timing device that is used to monitor the running time of equipment. The unit, which is 5 inches long by 2 1/2 inches wide by 2 1/4 inches high, weighs about 1 pound. When the unit is attached to operating equipment that has a vibration potential in excess of the threshold, it can detect when the equipment is turned on. A cumulative lapse-time clock starts when the equipment is put into service and stops when the equipment is turned off. The accumulated running time is displayed on an 8-digit liquid-crystal display (LCD) to a resolution of 36 seconds. The display will show cumulative hours up to 999999.99 with automatic roll-over indicated on the display by the appearance or disappearance of a dot in

the upper left-hand corner. The equipment's running time, between inspections, is obtained directly to the nearest 0.01 hour by subtracting the difference between the digital-display readings.

The R100 has replaceable batteries and electronic circuitry that can be repaired or replaced. It is packaged for direct exposure to all environmental elements in the field, including intermittent wetting but not direct submergence.

The purpose of this report is to provide the user of the R100 with a simple explanation of the principle of operation, installation guidelines, and battery replacement instructions. The discussion is limited to operations that can be performed in the field. The R100 should be returned to HIF's Field Service and Supply Section for repair.

PRINCIPLE OF OPERATION

The electronic components of the R100 are designed around two CD4007 complementary metal-oxide substrate (CMOS) integrated circuits (IC), a timing-counter display module, and a vibration-sensing transducer. The vibration sensor is a piezoelectric element that can convert vibrating energy into an electrical ac signal. The amount of electrical energy, in millivolts, produced by the sensor is proportional to the physical acceleration and frequency imparted by the vibrating equipment. The voltage produced is affected also by the orientation of the sensor, which has its axis of greatest sensitivity normal to the bottom of the R100 unit.

Because the signal voltage produced by the sensor element is very small, it must be amplified to a level that will turn on the timing module. This is accomplished with a two-stage amplifier (fig. 1) with gain from about 100 to 200 for different frequency signals within the frequency spectrum of 20 to 2000 Hz. A second IC (fig. 1) is used as a level converter, a filter, and a threshold detector. When no vibration occurs, the voltage at point C (fig. 1) is about 2.3-V dc, which causes the voltage at point E (fig. 1) to inhibit time accumulation. When the voltage from the sensor raises to a proper level for a finite duration, the voltage at point C (fig. 1) will be held below 1.0-V dc and point E (fig. 1) is forced to zero, which activates the counting module. One digit will be added to the accumulated display every 36 seconds as long as the above conditions prevail. Internal counters in the timing module save and accumulate fractions of seconds of time; thus the resolution for any series of on-and-off cycles is $\pm$36 seconds.

An analog filter is included to reject any short-duration transient vibration, which may originate from other associated equipment that does not relate to the equipment being monitored.

An important consideration in the R100 design performance was limiting the battery current to under 30 microamperes; therefore, fresh batteries should last more than 2 years under operating conditions.

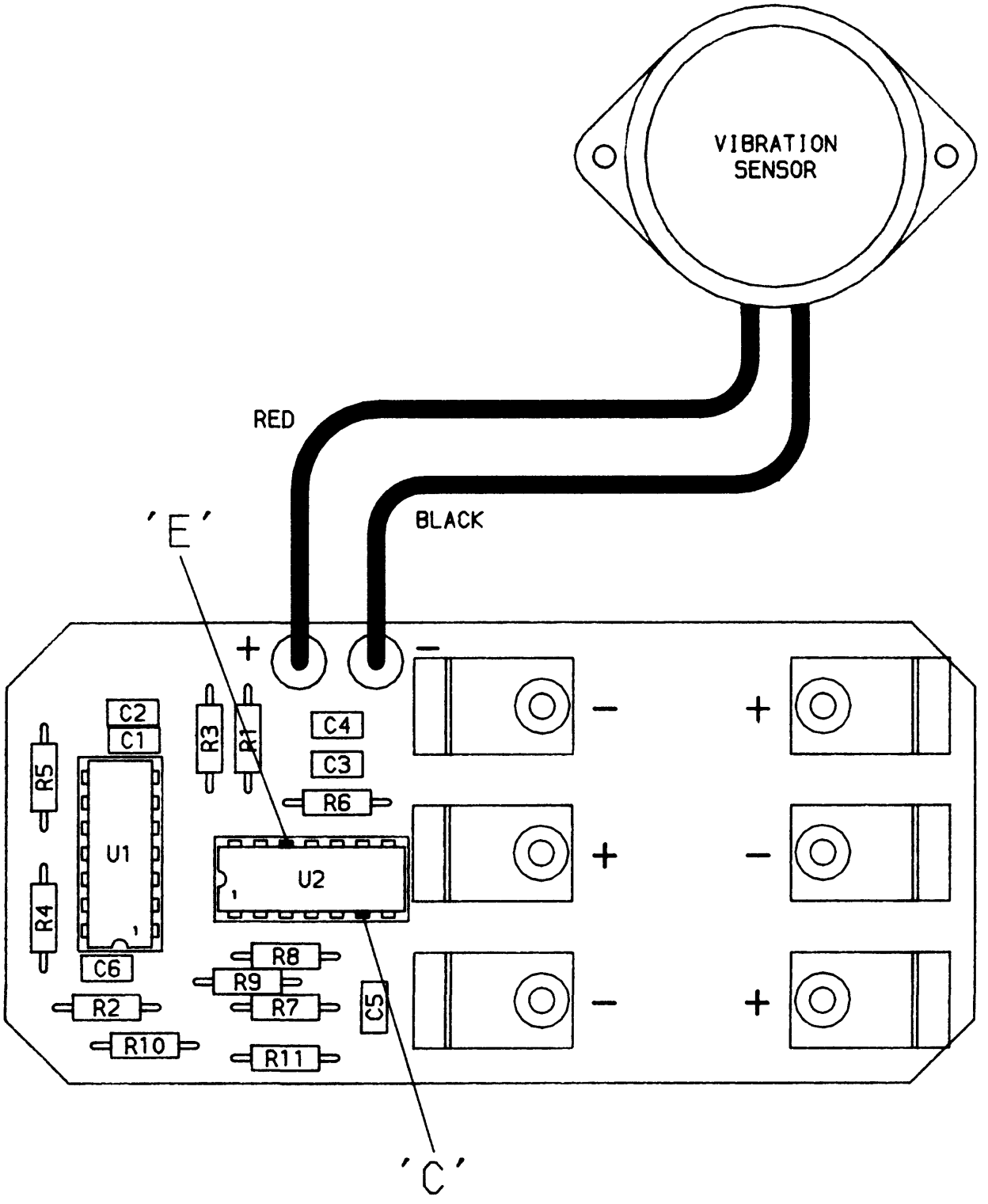

Figure 1.--Bottom surface of circuit-board, component layout. U1 is an integrated circuit that acts as a two-stage amplifier. U2 is an integrated circuit used as a level converter, a filter, and a threshold detector. Batteries used should be 1.5 volt AA alkaline.

INSTALLATION

The R100 needs to be attached directly to the pump or some appendage of the pump (motor or pipe) that can transmit vibration originating from the pump being monitored. Vibration intensity and frequency can be highly variable. This is primarily a result of wide differences in physical characteristics of materials and their modulus of elasticity.

The presence of vibrating energy is easily detectable by human touch, but its magnitude often is deceiving because it is frequency dependent. The R100 vibration sensor has a minimum sensitivity threshold that is dependent on frequency, amplitude, and duration. The threshold level is satisfied by a vibration in the frequency range between 20 and 2000 Hz and a sustained acceleration of 0.5 g or more. This means that a minimum vibrating energy must be continuously present for periods of 0.5 second or more to satisfy the sensitivity threshold that can turn on the timing module. There is no maximum vibration level determined at this time; however, dropping the unit on a hard surface could permanently damage the internal vibration-sensing element, which can be replaced.

The direction of the vibration or the plane of strongest surface displacement is an important concern when installing the R100 because it is most sensitive to displacement normal to the bottom of the package. It is on this surface that the R100 is mounted most easily. The R100 can be mounted any place on the pumping equipment where sufficient surface vibration will be transferred to the timer.

Figure 2 shows a typical pipe installation that can be used to mount the R100 to a pipe. The installation materials used are ordinary plumbers' strapping, readily available in most hardware stores, and a stainless steel product sold under the trade names of "Make-A-Clamp,"[1,2] "Klutch Klamp,"[3] or "Band-it."[4]

"Make-A-Clamp" is a stainless steel product that is cut to length in the field; screw-tightening ends are attached to take up the tension. The banding stock should go around the pipe and the R100 mounting flange and should be tightened securely. This procedure will clamp the R100 rigidly to the pipe and ensure that the R100 vibrates with the pipe. For either strapping method, the banding stock should be riveted to the bottom flanges of the R100 to assure that the totalizer will not slip from under the band and fall off. The existing holes in the banding material and R100 align well enough to allow a 9/16-inch by 5/16-inch split brass rivet to join the two.

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1 Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.
2 Make-A-Clamp is a registered trademark of Breeze Clamp Products.
3 Klutch Klamp is manufactured by Dyna Systems, Inc.
4 Band-it is manufactured by Houdaille, Inc.

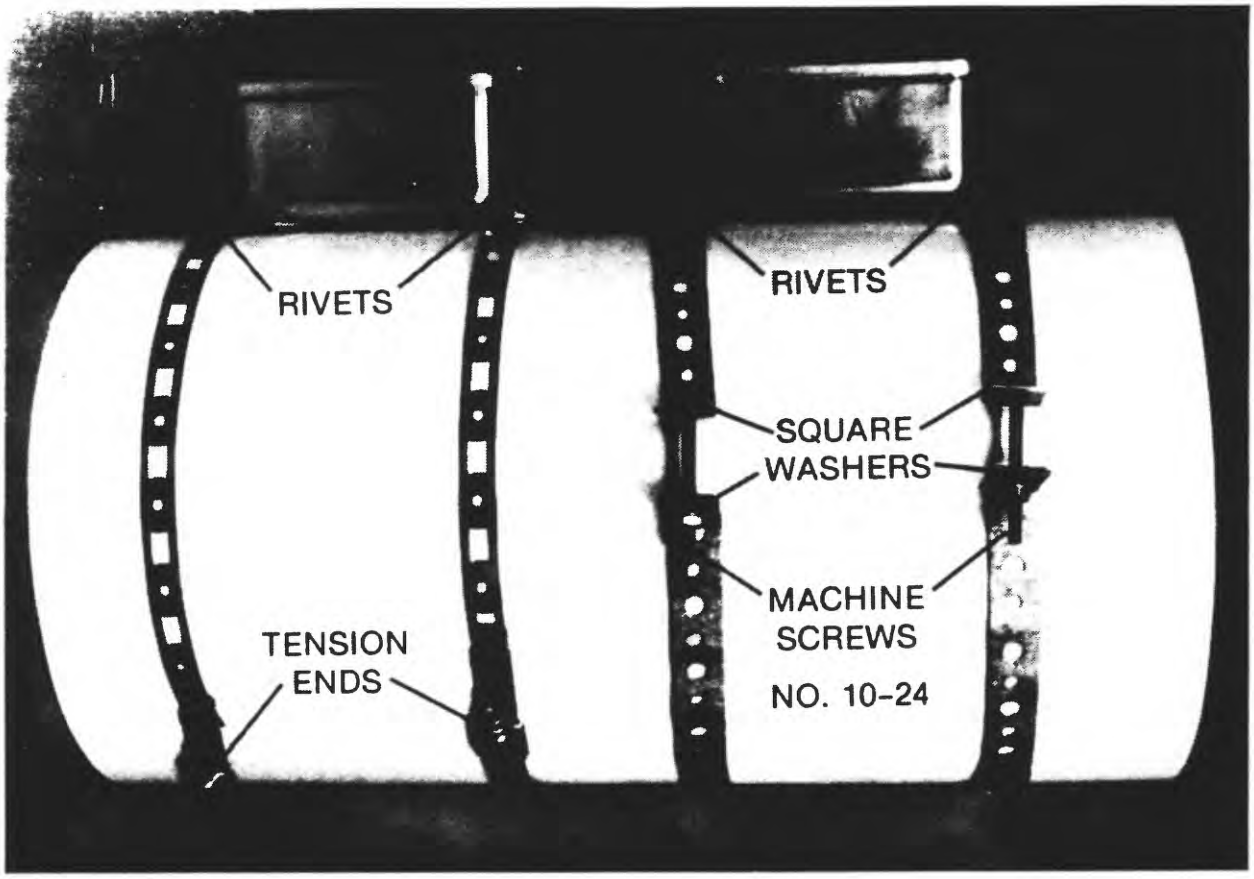

Figure 2.--Digital vibration-time totalizer attachment methods. Banding goes over the top of the flanges and rivets.

Location for installation of the R100 should be chosen where the pipe is vibrating enough to turn on the R100 when the pump is running and to ensure that the totalizer is off when the equipment is not running. Validation of proper installation and adequate vibration can be easily accomplished by observing a change on the display when the equipment is running. A check for transient vibration should also be done when the equipment is off.

Because acquisition of some of these mounting materials is difficult, a kit of "Make-A-Clamp" products is available from the HIF as an accessory item that can be ordered with the R100. Each kit contains enough rivets, end pieces, and strapping to band five R100's to an 8 inch-diameter pipe.

A note of caution on exposure of LCD's to prolonged direct sunlight: the heat will eventually discolor them and, with extreme heating, the LCD may turn black. Cover or shade the display window, if possible.

BATTERY REPLACEMENT

The R100 uses three AA, 1.5-V batteries that are connected in series. The R100 must be opened and the electronic circuit board removed from the case to replace the batteries that are mounted on the bottom of the board. The R100 should be serviced once each year. Servicing consists of replacing the batteries, desiccant capsules, cover gasket, and the plastic seals on the screws that secure the cover. The R100 uses three AA, 1.5-V batteries, which the user purchases locally, connected in series. The remaining items are in the R100 service kit that is available from the HIF warehouse.

The data that is stored in the device will be lost when battery voltage falls below the proper level or when the batteries are removed. Any numerical display value should be recorded prior to battery replacement.

Observe the following order for replacing the desiccant: plastic spacer, lower pad, electronic circuit board, upper pad, gasket and cover. Figure 3 shows the digital vibration-time totalizer assembly.

Place fresh desiccant capsules in the bottom of the case, two to each side of the sensor, and plastic filler plate on top of the sensor. The large piece of cut foam material should be placed in the box in the correct orientation to allow the circuit board assembly to rest against it. Be sure the wire leads from the vibration sensor are not broken off or jammed near the top of the case, where they may pinch under the lid. Replace the rubber gasket with a new one and carefully reseal the lid so the gasket material is completely showing around the edges. Further information about opening the case and resealing the cover is included in the battery-service kit available from the HIF.

The battery contacts are made of spring steel to hold the batteries securely and should be free from contact corrosion. The correct placement or orientation of the battery is indicated on the electronic circuit board by symbolic representation. (See fig. 1.) Make sure the batteries are correctly oriented when placed into the battery contacts. Incorrect placement, even momentarily, will damage the R100 electronic components.

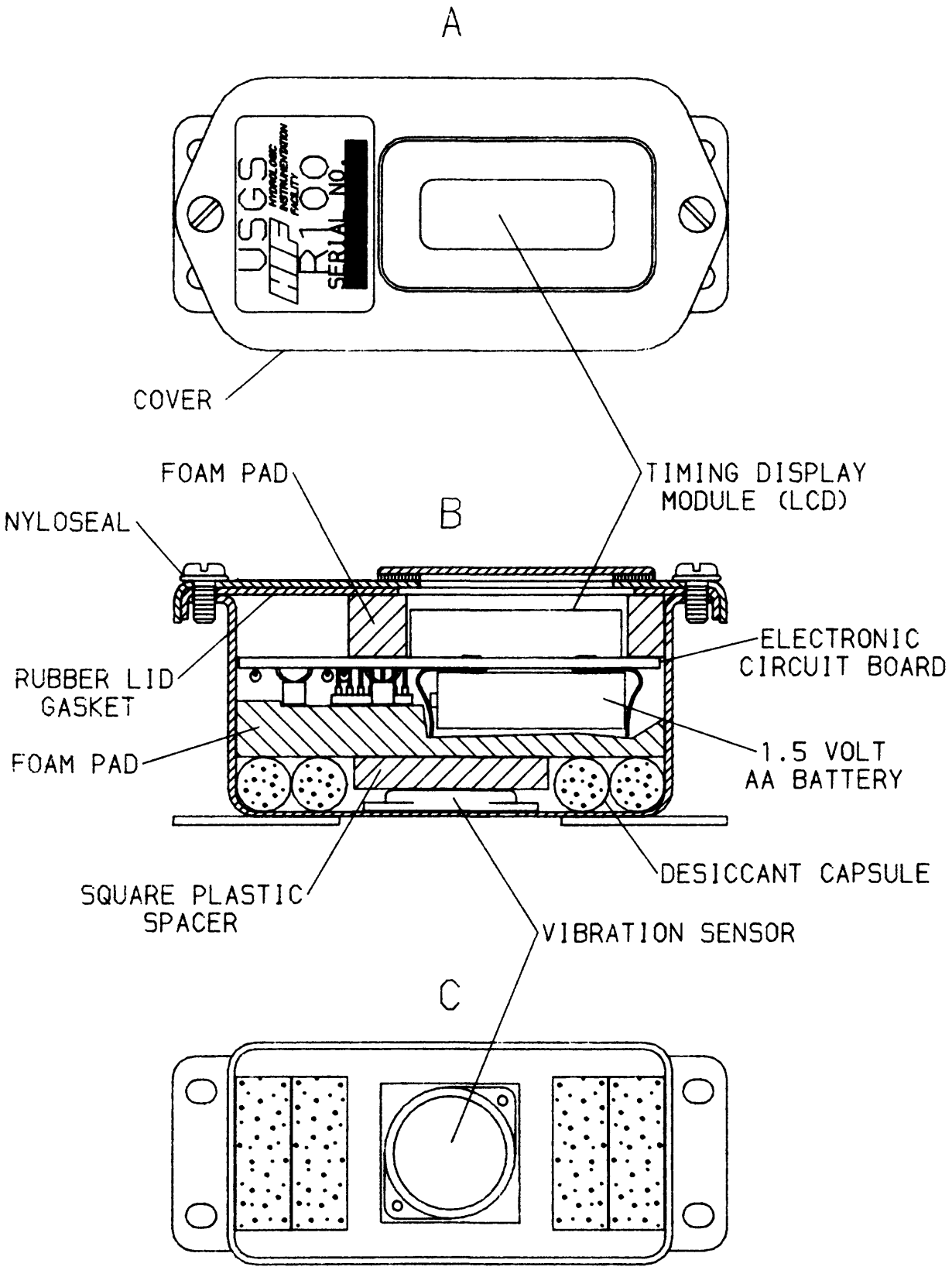

Figure 3.--Digital vibration-time totalizer assembly.

A. Cover of enclosure

B. Cross section of digital vibration-time totalizer

C. Bottom inside of enclosure.

The batteries should not remain in service for longer than 1 year, because they may leak and damage the internal electronic components. Batteries also will lose energy over long periods of storage. For best operation of the unit, alkaline-type cell batteries should be used.

When fresh batteries are installed, the display may show a minimum of three digits, a decimal point, and a small black dot in the upper left-hand corner of the display window. If random digits other than zero appear, these can usually be cleared by a momentary interruption in power. Removal of the middle battery is all that is required. This action may have to be repeated a number of times, allowing 10- to 30-second intervals before replacing the battery.