

Protection Against Electric Shock in Laboratory Sea-Water Systems

**by James M. Crossen,
with a contribution by Paul S. Galtsoff**

**Prepared 1966
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**U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
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FOREWORD

In January 2006, Jim Crossen brought this paper into the Editorial Office of the Northeast Fisheries Science Center (NEFSC). Jim indicated that he, as an employee of the Woods Hole Biological Laboratory of the Bureau of Commercial Fisheries (forerunner of the National Marine Fisheries Service), had authored the paper in 1966, but had not placed it in the *Woods Hole Laboratory Reference Document* series at that time. He felt that the information in the paper had some lasting value, and asked that the paper be handled in a manner to assure its retention by the NEFSC. Accordingly, the Editorial Office has issued this paper as an “unpublished paper” which will be included in the listing of 2006 reports prepared by NEFSC authors, and will be available through that listing on the NEFSC’s publications webpage (www.nefsc.noaa.gov/nefsc/publications/lists/lists.htm).

Workplace safety has always been a serious concern of organizations and their members, although one could argue that the subject has been taken more seriously in the 40 years between when this paper was prepared and when it was issued. What is not arguable is that workplace safety has been far more institutionalized in those four decades. Today, there are laws, regulations, agencies, and specialized/dedicated personnel all addressing aspects of workplace safety. Therein lies the importance of, and interest in, this paper: it largely reflects the “pre-institutionalized” approach to workplace safety. Individual initiative, investigation, fabrication, and evaluation were the means by which a potentially serious safety problem at the Woods Hole Laboratory was solved.

Jim Crossen authored all of the paper except for the section on “Fouling Analysis.” Paul Galtsoff, the Director Emeritus of the Woods Hole Laboratory, performed such analysis and wrote the associated section. Unfortunately, Tables 6 and 7 of the paper have been lost through the passage of time.

I have made some changes to the paper, and they need to be listed in order to differentiate between the paper as originally prepared and as issued. I prepared the title page, foreword, table of contents, and figure captions. In the original paper, most of the pages were not numbered; in the new table of contents, the implied page numbers of the various components of the paper are indicated by numbers within squared brackets. In the original paper, there were no figure captions associated with the figure images; I prepared those captions based upon the text descriptions and language. Additionally, at some point subsequent to 1966, someone had reviewed the paper and had scrawled a few comments directly onto the paper in pencil and ink. I removed those comments.

Jon A. Gibson
Biological Sciences Editor
Northeast Fisheries Science Center
April 19, 2006

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ABSTRACT

An electrical shock hazard can exist to personnel in modern sea-water systems which use hard rubber and synthetic piping. A method, non-toxic to marine life, is described herein which safeguards personnel against electric shock by the insertion of grounded platinized titanium electrodes in the system.

The Bureau of Commercial Fisheries Biological Laboratory at Woods Hole, Massachusetts, maintains a salt water supply system with a capacity of 76,000 gallons. This system provides a water supply for the main laboratory and for the public aquarium. A breakdown of the total water capacity is given in Table 1. A diagram of the salt water system at Woods Hole is shown in Figure 1.

Sea water supply systems for aquaria which have in the past used metallic piping, not utilize non-corrosive hard rubber and poly-vinyl-chloride (PVC) type plastics. While the latter has eliminated the problems of toxicity to fish inherent in the combination of salt water and metals, it has presented a potential shock hazard to personnel.

Modern sea water systems such as that at Woods Hole which supply experimental aquaria are carefully designed to avoid the use of metals. Most metals exposed to salt water corrode to some degree due to galvanic action resulting in the liberation of ions which are toxic to some marine organisms.

Chemically inert materials such as hard rubber, polyurethane, poly-vinyl-chloride, epoxy base sealers, vulcanite, ebonite, wood covered with black asphaltum are non-conductors of electricity.

The Woods Hole system utilizes "Uscolite," a synthetic rubber material (styrene acrylonitriles – butadiene copolymer) for the piping. The iron reservoir tank is coated with "Gunite,"

and insulating cement. Under certain conditions, that is, when water is not being pumped into the reservoir tank (see Figure 2) and is not being returned to the harbor through drains, a floating system exists without an electrical ground return.

Electrical Shock Incident

The following is an account of an electrical shock problem which took place in the main laboratory of the Woods Hole Biological Station.

Electrical shocks were being experienced from a tank in Room 112 (see Figure 3A and 3B). Upon investigating the source of trouble it was found that a potential of 50 volts alternating current (50 V.A.C.) existed between the salt water tank (A) and ground (B). A potential of 25 V.A.C. was found in the same supply line in the tank room (C). Tracing the voltage in the opposite direction isolated the source to Room 111, point (D). A defective immersion type heater element had corroded at a brazed seam allowing water to penetrate the housing. The heater had not been properly grounded through a low resistance, therefore an electric current entered the salt water line at point (D). When water was not being drawn into the tank in Room 11, the circuit was broken and no current flowed.

Because some water was flowing from the tank (A) in Room 112 to the drain (electric ground), a low resistance path equal to approximately 200 ohms existed. Therefore, the electric current passing through the shocked person's dry body was not dangerous to life (see Table 2). Normal dry skin affords a comparatively high resistance which allows only a small amount of current to flow through the body. However, the resistance of wet skin allows thousands of times more current to flow. The path of electric current through the body is vitally important. Current

flowing from one finger to another on the same hand would not pass through vital organs, such as a current passing from one hand to the other hand.

Safeguard Methods

A study was initiated to determine a method of effectively grounding any electricity which may accidentally become exposed to a part of the system. In order to safeguard against shock hazards the following should be done:

1. All electrical tools, appliances, instruments, especially those used in experimental tanks, i.e., immersion heaters, stirrers, metal cooling coils, electrodes for sensing oxygen, salinity, pH, etc., must be properly grounded. If the insulation in electrical equipment should break down, the frame and other metal parts of that equipment becomes energized. If a properly grounded wire is connected to the frame, the electrical current will follow the wire which is the path of least resistance.

Determine whether the electrical wiring is the three wire type or two wire type. New buildings, in accordance with the national electric code, have three wires, one of which is a ground to drain off potential shocks. This type is compatible with appliances having three prong plugs.

In a two wire system install a single conductor number 18 copper wire to all appliances and attach it to a screw on the appliance. Then attach the other end of the ground wire to the grounded outlet box. Caution: Attach the ground wire before inserting the plug in the outlet.

2. A method must be used to ground the salt water system without the use of toxic metals which would defeat the intended purpose of plastics. A study was made of materials which would meet the following requirements:

- (1) High corrosion resistance.

(2) Low electrical contact resistance.

(3) Freedom from fouling.

Graphite, titanium, and platinized titanium were selected after making a study of available materials. All of these materials are at the most noble (least corrosive) end of the galvanic series of Tables 5 and 6.

Samples of the above were placed in isolated tanks containing fish for a period of over three months. No toxic effects to the fish were apparent and no corrosion or pitting of the materials occurred.

ELECTRODE INSTALLATION

The 4 inch synthetic rubber pipe used throughout the Woods Hole system is tapped on the sidewall (see Figure 4) to accommodate stopcocks. A foam rubber material covers the piping for the purpose of eliminating water drippage. The tapped holes are 5/8 of an inch in diameter and are sealed with plastic plugs where stopcocks are not used.

The graphite rod used was National Carbon grade AGSR, #P2718. It was 5/16 of an inch x 6 inches and has an electrical resistivity of 8.40×10^{-4} ohms/cm. The titanium rod was 1/4 of an inch x 6 inches and has an electrical resistivity of 5.48×10^{-5} ohms/cm. The plastic plugs were machined to accept the rods and an epoxy resin was used to provide a watertight seal (see Figure 5).

The electrodes were inserted in the plastic supply lines and connected through a #12AWG copper wire and brass clamp to the copper pipe compressed air system which runs parallel to the sea water supply lines throughout the laboratory and aquarium. In other systems connection could be

made to metallic water pipes, steam pipes, or a low resistance source to the earth. Paint and other insulating material should be removed from the surface before attaching the ground clamp.

When using electrical apparatus in experimental tanks, portable probes (see Figure 6) should be suspended into the water and connected through a copper wire and clamp to a suitable ground.

ELECTRODE MAINTENANCE

Regular checks should be made annually to determine the contact resistance between electrodes. If the electrodes have become fouled, they should be thoroughly cleansed before being reinserted. A dilute hydrochloric acid (1 part acid, 3 parts water) is an effective solvent when necessary. Titanium and platinized titanium installed in the Woods Hole system since 1963 and 1965 respectively have shown no sign of corrosion or pitting. Only a small amount of fouling was present and it was easily brushed clean.

FOULING ANALYSIS

Examination of two electric probes removed from the Woods Hole Laboratory sea-water system on 15 March 1966.

General observation: Fouling is light on both probes. It consists of gray material adhering to metal.

No live organisms are visible to the naked eye.

Probe 1: Flat titanium strip covered in places with flaky material and loose sediment. Only about 10-15% of probe surface covered with fouling.

Microscopic examination reveals the following: completely, transparent, colorless scales with dark black particles embedded or attached to them. The black material is in form of irregular stars resembling deposit of sulfides of some heavy metal. Loose grayish sediment consists primarily of a mass of sponge spicules in places corresponding to the configuration of small bodies of live sponges. Spicules of calcareous sponges of the type of *Grantia* and many loose spicules of siliceous sponges are present in abundance. They are covered with organic detritus and give support to numerous sedentary infusoria, probably *Vorticella patellina* which appear to be in healthy condition. Occasional diatoms of the type of *Pleurosigma* and short colonies of *Melosira* were present. Two small live annelids were found: one of the *Terebellidae* and the other of *Sabellidae*. Both specimens too small for species identification. They were building tubes of loose sediment particles and sponge spicules. Small, not identifiable flagellates and infusoria, were occasionally seen.

Probe 2: The platinized titanium rod was covered with light material similar in appearance to that of probe 1. About 60% of probe surface was covered with fouling.

Fouling consisted primarily of loose sponge spicules of calcareous and siliceous sponges mixed with organic detritus. Few bottom diatoms of *Pleurosigma* type were present. Live *Vorticellae* were present.

No annelids were found and the transparent flakes with black particles were absent.

DISCUSSION

An account is given of methods and materials used in the Woods Hole sea-water system to safeguard personnel and fish against electric shock. Table 7 is a summary of the electrical resistivity of electrodes inserted in the sea-water supply lines.

The graphite rods installed in the pipe lines for well over a year have a very low contact resistance which is in part due to the material porosity. While this porosity provides a good ground, it also allows water to reach the clamp and copper wire causing corrosion. A conductive epoxy resin (Eccobond 60) which has a bulk resistivity of 50 ohms/cm and a resistance of less than 1 ohm/3 mils was used to seal the exposed surface of the graphite. This method of sealing is not satisfactory since some corrosion continues to exist.

The titanium rods inserted in the system in February, 1963 have a high contact resistance compared to graphite. Examination of the titanium after being exposed to the salt water line for a two year period showed no apparent corrosion or pitting. However, because it was desirable to improve the contact resistance, samples of platinized titanium were obtained and tested. Titanium by itself has a high electrical resistance because of a tenacious oxide film which forms on the surface preventing metallic ions from migrating into the sea-water. This film, however, also is responsible for the unusually high corrosion resistance of the titanium.

Therefore, by combining the two metals, with a thin coating of platinum on titanium, a low electrical contact resistance is realized without impairing titanium's corrosion resistance.

Platinized titanium rods have been installed in the Woods Hole system for over one year. They are inserted in the supply pipe lines at approximately every 30 feet and one in each room of the main laboratory's first floor.

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Table 1. Sea water capacity of Woods Hole system.

Standpipe	50,000 gallons
Aquarium	
Holding tanks	4,000
Exhibit tanks	9,000
Recirculating reserve capacity	13,000
Total aquarium water	26,000 gallons
Total system water	76,000 gallons

Table 2. Body reaction to electric current.

1,000 Milliamperes (ma) = 1 ampere

0.5 to 2 ma – Some sensation

2 to 10 ma – Muscular contraction

5 to 25 ma – Painful shock

20 to 200 ma – Heart convulsions

Over 100 ma – Paralysis of breathing

From Occupational Safety Aid MP-8-0

Table 3. Resistance values in ohms ().

Wet wood – 1,000 to 50,000/foot

#10 copper wire – 1/1,000 feet

Human body

 Dry skin – 100,000 to 500,000

 Perspiring – to 1,000

 In water – to 150

From Occupational Safety Aid MP-9-9

Table 4. Specific resistance* (According to Denzer).

Substance	Ohms/meter
Distilled water	1,000,000
Sea water	0.1
Steel	0.0000001

- Resistance of a water cube of a given size often referred to as conductance which is the reciprocal of resistance. The conductivity of water depends on the ionic composition and temperature.

From Electrical Fishing, FAO

Table 5. Galvanic Series.

Corroded end – least noble

Magnesium

Zinc

Aluminum

Steel

Iron

18-8 Stainless (active)

Lead

Tin

Nickel (active)

Brass

Copper

Monel

Nickel (passive)

Inocel

Chromium – Iron

18-8 Stainless (passive)

Silver

Graphite

Gold

Platinum

Titanium

Protected end – most noble

Figure 1. Diagram of overall salt water system at Woods Hole

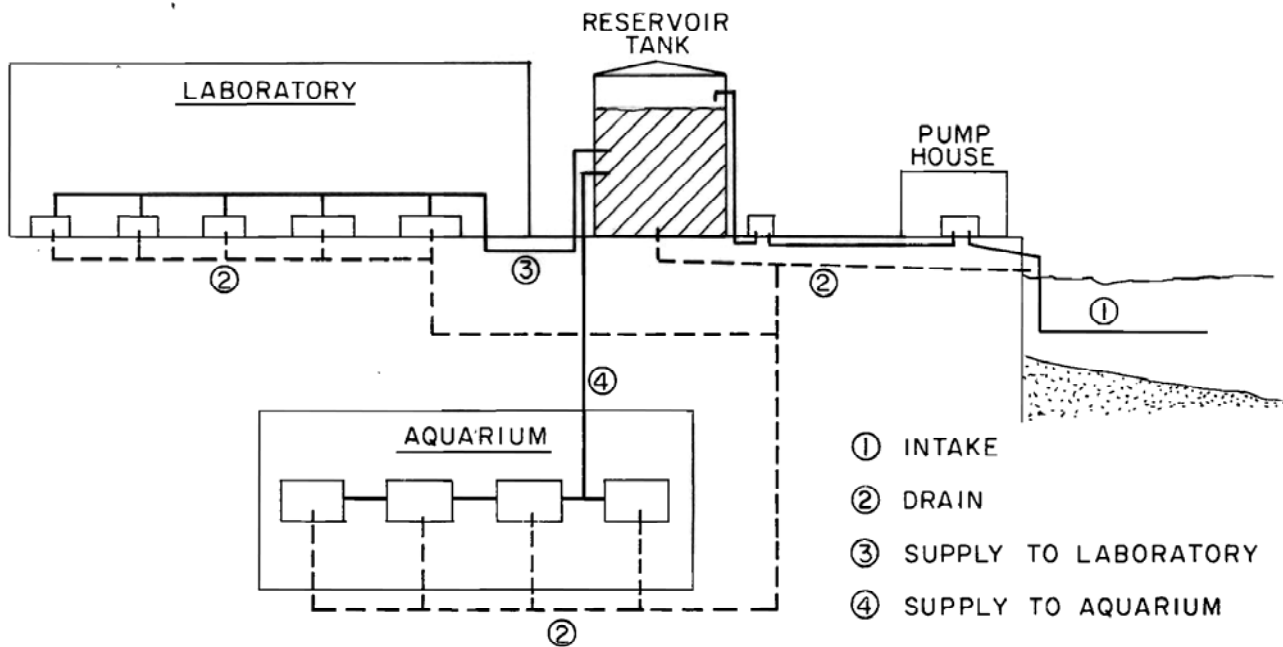


Figure 2. Diagram of salt water reservoir tank at Woods Hole

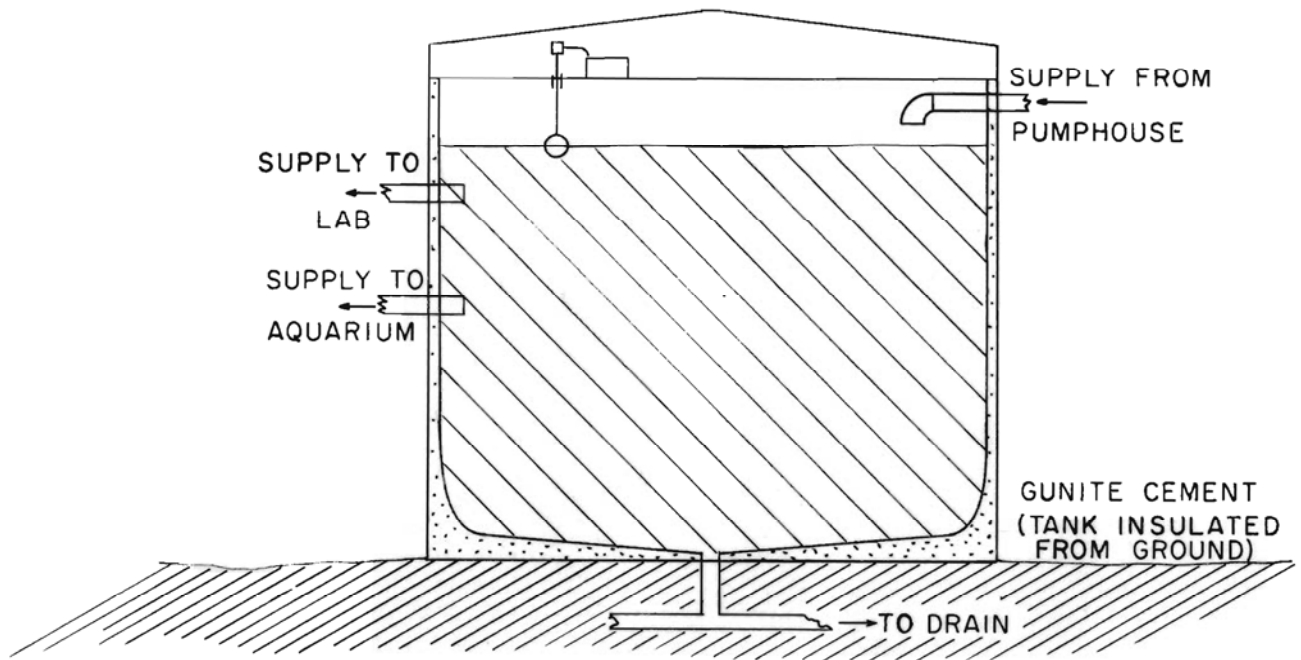


Figure 3. *A*: Diagram of salt water system for first floor of main lab (ocean side) at Woods Hole;
B: Diagram of salt water system for just Room 111 at Woods Hole

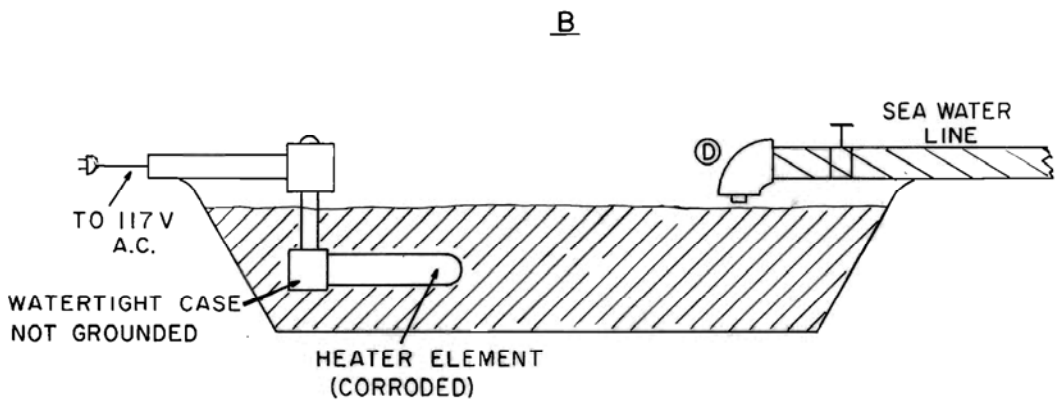
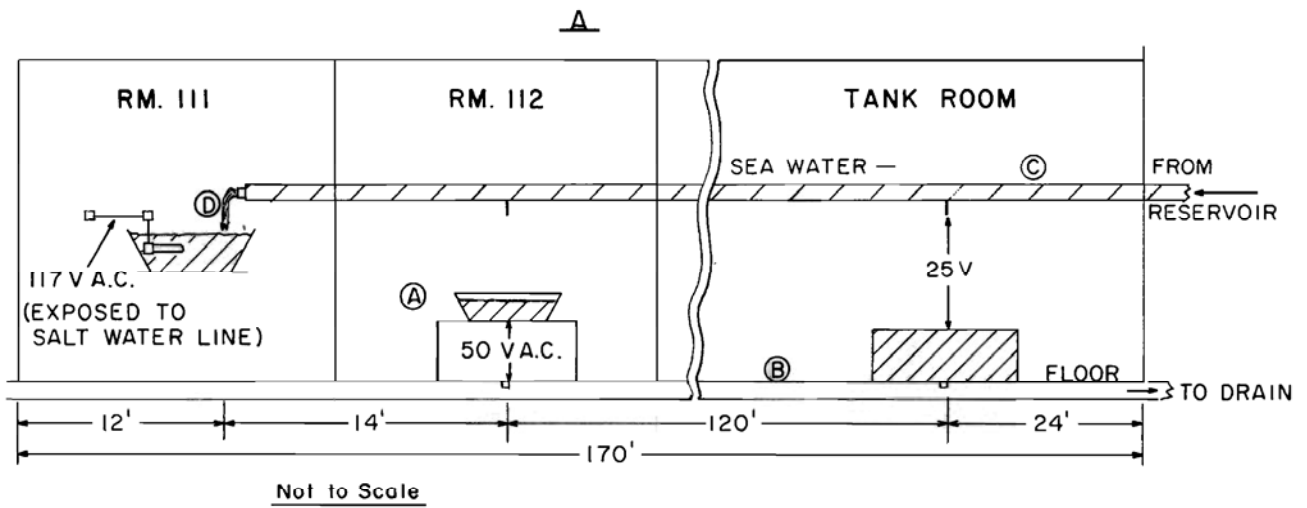


Figure 4. Pipe used throughout Woods Hole system, showing functional electrode setup.

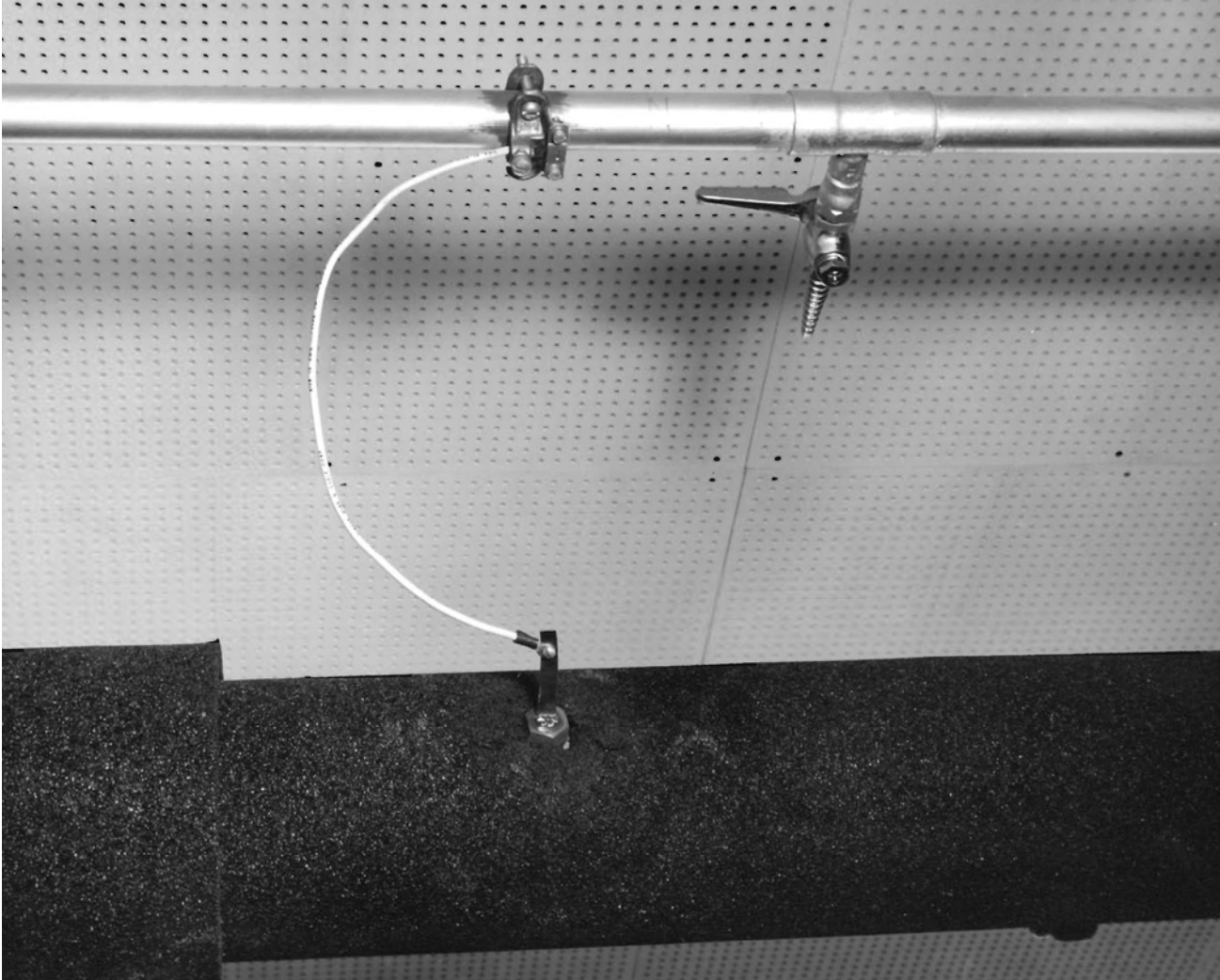


Figure 5. *Top*: Not-yet-machined, 5/8-inch, plastic plug; *Middle*: Not-yet-assembled, 5/16 x 6-inch, graphite electrode; *Bottom*: Assembled, platinized, titanium electrode.

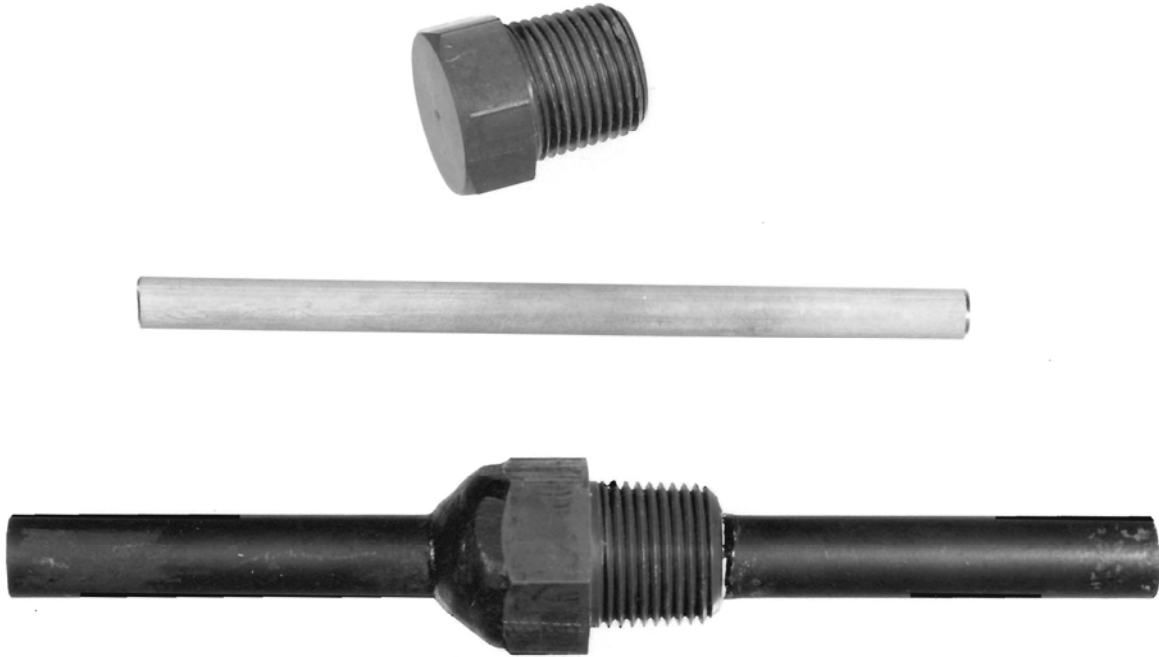
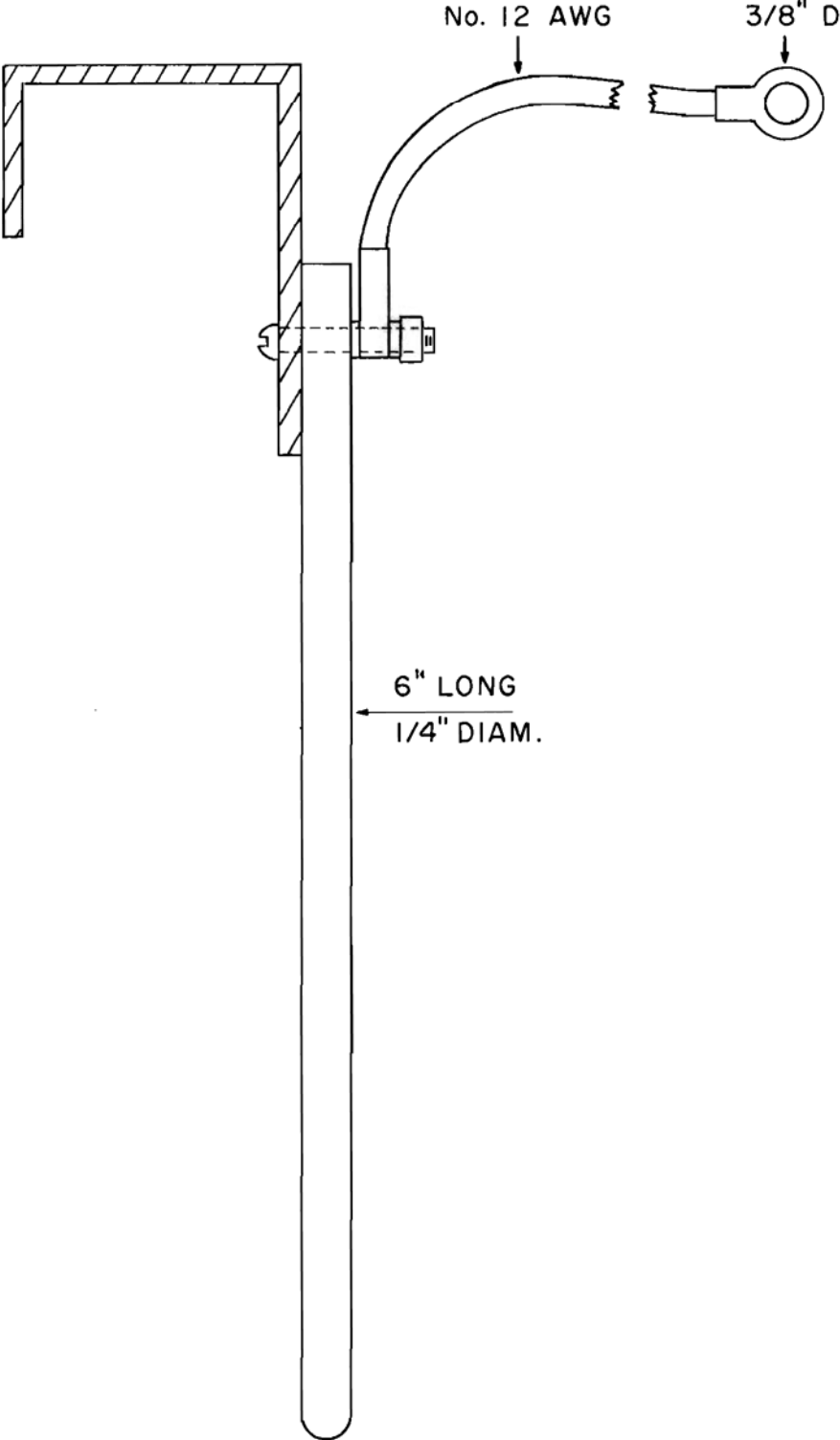


Figure 6. Diagram of portable probe.



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