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A SIMPLE CONSERVATIVE METHOD FOR CALCULATING SAFE STANDOFF DISTANCE FOR DIVING NEAR UNDERWATER ELECTRICAL SYSTEMS

W. H. MINTS

Navy Experimental Diving Unit, Panama City, Florida, U.S.A.

INTRODUCTION

Divers are frequently required to work in proximity to energized underwater electrical systems. Having a simple, straightforward, conservative method to calculate safe standoff distances from these electrical systems would be of great benefit to the diver. However, finding relevant guidance in a simple, usable format can be challenging. Much of the literature pertaining to underwater electrical safety is over twenty years old and in many cases addresses only a narrow aspect of the topic or is purely theoretical, having limited practical applicability.

METHODS

A review of the pertinent electrical safety literature yielded the necessary findings to construct a simple method for calculating safe standoff distance for diving near underwater electrical systems. By employing worst-case scenarios, this calculation method yields conservative, yet simple, guidance that is readily tabularized.

RESULTS

U.S. Navy underwater electrical safety guidance is contained in Volume 2 of the *U.S. Navy Diving Manual* and is based on guidelines adopted in 1987 from the Association of Offshore Diving Contractors (AODC) Code of Practice for the Safe Use of Electricity Underwater AODC 035. AODC 035 Appendix B — USEFUL FORMULAE gives formulae for calculating safe standoff distance for a diver in an electric field. This safe standoff distance is a function of the ratio of maximum fault current (I_o) to the safe body current (I_b) and depends highly on the conductivity of the water. The equations for seawater and fresh water are given below.

$$D_S = \left[1 + \frac{10^{-4} \bullet I_o}{I_b}\right]^{1/2} - 1$$

D_S is the safe standoff distance for <u>seawater</u> in meters.

$$D_f = \left[1 + \frac{I_o}{40 \bullet I_b}\right]^{1/2} - 1$$

D_f is the safe standoff distance for <u>fresh water</u> in meters.

Even though an electrical system may normally operate at a safe low DC voltage, a failure of a power supply component could apply a higher AC voltage potential to the device, with fault current limited only by the load circuit breaker. For example, to calculate the safe standoff distance for an electrical system that is protected by a 150 amp load circuit breaker and use the AODC 035 safe AC body current limit of 10 mA, we calculate (I_o) = 150 amps, (I_b) = .01 amps, and safe standoff distance for (I_o) = 150 amps in seawater is

$$\left[1 + \frac{10^{-4} \bullet 150}{.01}\right]^{1/2} - 1 = .58 \text{ meters} = 1.9 \text{ feet},$$

while a safe standoff distance for (I_o) = 150 amps in fresh water is

$$\left[1 + \frac{150}{40(.01)}\right]^{1/2} - 1 = 18.4 \text{ meters} = 60.3 \text{ feet}.$$

The above calculations show the tremendous difference between the safe standoff distances for fresh water and seawater. Since real-world harbor water (brackish water) has a safe standoff distance lying proportionally between the values for fresh water and seawater, the feasibility of performing real-time accurate water conductivity measurements and safe standoff distance calculations in the field is not practical. Therefore, it is prudent to take a conservative approach and use the safe distance for fresh water and the maximum current rating of the load circuit breakers supplying power to the electrical system. Safe standoff distance guidance must be simple and easy to use. Tabularizing of safe standoff distance values based on standard load circuit breakers ratings would provide this simplicity.

Table 1. Calculated values of safe standoff distances for standard load circuit breaker ratings.

LOAD CIRCUIT BREAKER CURRENT AMPS	SAFE STANDOFF DISTANCE (METERS)	SAFE STANDOFF DISTANCE (FT)
5	2.7	8.8
10	4.1	13.4
20	6.1	20.1
30	7.7	25.3
60	11.3	37
100	14.8	48.7
150	18.4	60.3
200	21.4	70.2
300	26.4	86.6

CONCLUSIONS

A simple conservative method for calculating safe standoff distance for diving near underwater electrical systems has been demonstrated. Tabularizing distance as a function of common load circuit breaker current ratings, provides a simple usable format for safe standoff distance guidance for the diver.