Incident Investigation Report
Electrical Shock Incident aboard *R/V Bay Hydro II* on March 31, 2009
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Background

R/V Bay Hydro II is a new survey vessel procured by NOAA's Office of Coast Survey to replace the aging *R/V Bay Hydrographer*. Due to budgetary and time constraints in the procurement cycle, the decision was made to build the new vessel to the specifications of a previously built vessel in service for the Mobile District of the US Army Corps of Engineers (*R/V Irvington*), and to modify the new vessel as necessary after delivery to fit the NOAA mission. This approach allowed FY2009 funds to be used for final outfitting of the vessel and kept the initial purchase price within the funds availability in FY2007 and FY2008. As a result of this funding strategy, there were several details of the new vessel that had to modified or fabricated during the months of January – April 2009. The final outfitting items were being completed using ship's force in combination with contracted labor. All work items needed to be completed before the Dedication Ceremony of the vessel scheduled on April 15, 2009.

Details of the Incident

The electrical shock incident occurred on Tuesday, March 31, 2009, while an employee was preparing to test the installation of an Uninterruptible Power Source (UPS). The system is a Ferrups Best Power 4.3 kVa system powered by 220VAC and utilizing a bank of (8) 12V deep cycle batteries wired in series to provided buffered power to the protected loads. The installation manual states that the UPS should be installed by a certified electrician in accordance with all local and federal regulations to prevent the hazard of electric shock. However, due to the limited funds availability and the number of items on the vessel that needed to be addressed during final outfitting, the OIC determined that the cross-decking of the UPS could be safely handled by the crew to free up money elsewhere. The project was deemed safe due to the level of documentation of the system's wiring. It should be noted that all the crew members have worked with electricity and electrical installations, but none of the crew hold any professional certifications.

The employee had been working on the project periodically over the previous two months starting with documenting the wiring in the original installation and comparing it to the OEM installation manual prior to cross-decking the UPS to the new vessel. On the day of the incident, the employee notified the OIC that the system was ready to be energized, start-up procedures executed, and diagnostics ran. Upon receiving notice of completion, the OIC energized the breaker and the two went to the starboard tank space to begin start-up procedures. At approximately 1128, the employee received a shock of 110VAC for approximately 3 seconds before the employee could be released from the source.

The shock occurred because L2 of the 220VAC input was wired to the internal ground on the UPS Bypass switch. The UPS Bypass was originally installed by a representative from the manufacturer. The original installation cable was 3-wire utilizing L1, L2, and Neutral, in all black cabling. The shipboard marine cable installed in the new vessel that supplies the AC power is 4-wire utilizing L1, L2, Neutral, and Ground (black, red, white, green, respectively). The original wiring inside the UPS was deteriorating and was replaced with standard Romex 3-wire cable which had the same performance

specifications as the wire used in the new vessel. As previously stated, all the wires in the original cable were covered with black insulation. The Romex is color coded black, white, and green. The error occurred when the employee installed the Romex in the UPS Bypass switch and reverted back to the standard color codes for 110V residential wiring where Black is L1, White is Neutral, and Green is Ground. In the UPS, there was no dedicated ground wire coming into the UPS Bypass switch (at least not as it was originally installed by the Ferrups rep). The Bypass switch is mounted to the server rack and the grounding mechanism had continuity with the server rack. The equipment and server rack are electrically isolated from the aluminum UPS foundation and hull of the boat by rubber isolation and shock absorption mounts.

The three wires installed in the UPS by the employee were L1 – black, Neutral – white, and L2 – green (not ground as the employee intended). By placing the Green (L2) wire in the Ground terminal of the UPS Bypass switch, 110VAC was inadvertently directed throughout the internal grounding mechanism of the UPS. This resulted in a charged server rack. The equipment housings and the server rack did not have grounding straps tied back into the vessel's electrical grounding system. The need for these grounding straps had been discussed, but they were not installed at the time of the incident. When a small wave rocked the boat, the employee reached for the server rack to steady himself and completed the circuit, discharging 110VAC into his right hand and exiting along his left arm, which was propped against the aluminum hull.

Contributing Factors and Lessons Learned

A sense of urgency to get the boat ready for the dedication ceremony created an environment where mistakes were more likely than if there had been no pressing deadline. Each member of the crew had a list of projects that they were working on and the crew would switch from one project to another when priorities changed or when a delay was encountered due to delayed arrival of materials or supplies. This multitasking of projects created a situation where minor details could be over looked. There had been a few setbacks in the installation of the UPS which heightened the sense of urgency to get the installation back onto schedule, namely the need to purchase new batteries and the lack of battery posts on the new batteries when they arrived. These added delays also created a sense of frustration with the employee which may have further distracted him. If the OIC or the employee had taken a few extra minutes to review the vessel's 1-line diagrams and the UPS wiring diagrams again, prior to closing the breaker and energizing the system, the error would have certainly been detected prior to the incident. Additionally, the lack of grounding straps on the equipment would have been recognized as well.

The use of non-standardized color coded wiring in the original installation and the mis-use of color code standards on the new installation created a situation where the purposes of the wires were confused. The color coded Romex was used because it was already present on the boat and would not require an ordering delay. Use of a matching 4-wire cable would have prevented the confusion and would have increased the safety of the system by tying the UPS system ground back to the vessel's electrical grounding system.

The lack of experience in working with electrical installations allowed a seemingly straight forward installation to turn into a potentially life threatening situation. If not coupled with the other contributing factors, there is no doubt in the OIC's mind that the employee could safely and properly wire the UPS. However, had an electrician been

contracted to do the job, the employee would have been free to work on other items and would not have been put in harms way or felt the urgency to complete the UPS installation. Safety was inadvertently compromised in an effort to save money.

During the installation of the UPS, a few assumptions were made but were not challenged by the OIC or the employee. One assumption made by the employee was that the UPS was previously wired for 110VAC due to the 3-wire cable used in the original installation. The assumption matched his experience in residential 110VAC wiring where three wires meant L1, Neutral, and Ground. Had this assumption been challenged, it is likely that the wiring error would not have occurred.

The use of a formalized Operational Risk Assessment may have highlighted some of the contributing factors and forced the crew to take a closer look at the situation. Every decision that is ever made involves some form of mental risk assessment, but formalizing a risk assessment often provides a more in depth analysis of the situation and could have prevented the chain of errors involved in this situation from resulting in a potentially life threatening incident.

During the final outfitting of the vessel, supplies, materials, and tools were being used on a daily basis and were being stored in the main cabin. Minor hazards were part of daily operations and the crew likely became complacent with some of these hazards that surrounded them, especially trip and fall hazards. The incident has resulted in a renewed safety consciousness on the vessel and non-critical time constraints have been removed.

Administrative Actions Taken

1. An electrician has been contracted to inspect/install the UPS to insure that no additional errors were made in the installation that may not have been discovered during the incident investigation and to prevent future incidents from occurring.

2. The main power distribution panel has been clearly labeled to identify all 220VAC breakers to prevent any confusion as to whether a double pole breaker is 220V or simply a higher amp 110V breaker.

3. For any work performed on equipment with an electric potential of greater than 50 volts, a DVMM will be utilized to check for correct wiring and any resulting potential to ground.

4. Before the commencement of any work on the electrical systems aboard, the OIC shall review the electrical systems wiring practices with the worker. Paying specific attention to the system being worked on, the wiring conventions used aboard and the voltage potential.

5. Formalized Operational Risk Assessments will be utilized for specific work items that have the potential for hazards to life or health.

6. The Romex cable used in the UPS installation has been removed to prevent further confusion once the contract electrician begins work.