Assembly and Testing of the Ice Tethered Profiler

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Abstract- **In the spring of 2006, McLane Research Laboratories, Inc. was subcontracted by Woods Hole Oceanographic Institution (WHOI) to assemble and test the underwater profiler subsystem of the Ice-Tethered Profiler (ITP). Building on the existing ITP design, we refined the assembly and testing procedures with an eye for cost effective, yet rigorous processes. Since many of the internal components of the ITP came from the existing design of the McLane Moored Profiler (MMP) and the CTD end cap design is similar to the ARGO floats, we were able to focus more intently on the new features of this profiler. The standard MMP user interface was streamlined for the ITP field work and the profiling test in the McLane tank was expanded to include inductive communication testing. This testing includes a multi-day profiling deployment in our 15m fresh-water tank. Under these controlled conditions, we were able to obtain a baseline dataset of motor current, ballast, and profiler speed. The results of these tank tests indicate a profiling motor current of approximately 100 mA at a speed of 25 cm/sec. The estimated deployment endurance, based on a 240 Ah battery pack, is 400 days, 4 profiles per day, 1000 meters per profile. The total estimated vertical travel distance is 1500 km. As of September 15th, 2006 the ITP units deployed in August 2005 have executed and transferred 1581 and 1532 profiles (750 m profile length), respectively.**

Figure 1. ITP attached to the mooring wire in the McLane Research Laboratories test tank.

I. INTRODUCTION

In Spring 2006, McLane Research Laboratories, Inc. (MRL) was subcontracted by the Woods Hole Oceanographic Institution (WHOI) to manufacture and test the under-ice profiler subcomponent (Fig. 1) of the WHOI Ice Tethered Profiler System (ITP). We undertook this project after having successfully supplied internal components, electronics, software, and testing services during the previous deployment year. Our existing license agreement with WHOI for the McLane Moored Profiler (MMP) and the partnership on the prototype ITP provided a solid foundation for this technology transfer.

Many of the internal and some external components of the ITP are identical to the MMP – electronics, software, drive motor, inductive modem, battery, CTD, and mooring attachment [1]. But, the similarities do not extend to all of the external components. The pressure housing and CTD endcap are the functional equivalent of the ARGO float; the drive motor wheel assembly requires a complex coupler to mate with the cylindrical external surface; the motor is fixed to the pressure housing; and the guide wheels have spring attachments [2].

This subcontract allowed MRL, in partnership with WHOI to refine some of the assembly and testing procedures. In the course of this work, we were able to develop engineering data in the controlled environment of the 15 meter deep test tank at MRL. These procedures and data will be detailed in this paper.

II. MANUFACTURING AND ASSEMBLY

The primary goal of this technology transfer was to minimize functional changes to the successful prototype design while improving the manufacturability of the ITP. As such, we made very few changes to the actual design of the ITP itself, while noting features and parts that might be improved for the next deployment year.

The only mechanical change was the addition of a custom plastic container and tubing for the ballast lead. Since the hull of the ITP is both the pressure housing and the flotation, all of the internal components must be removed as an assembled unit. The modularization of ballast (~4 kg) made assembly easier. In addition, the final ballasting of the ITP is easier than the MMP because the aluminum hull is less sensitive to temperature effects and water absorption observed during the MMP ballast procedure.

Improvements for the next generation include removable pins on the guide wheel arms and a leverage aid on the inside of the drive wheel coupler.

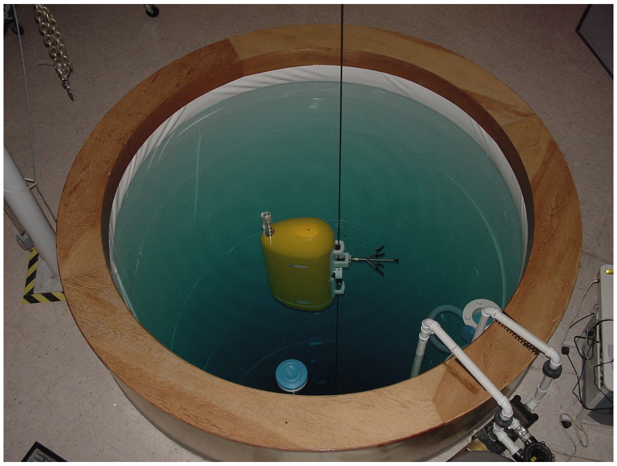

Figure 2. Overhead view of the 15 meter deep test tank at McLane Research Laboratories, Inc. (a full size MMP is deployed in the tank).

III. FIRMWARE

Similarly, the firmware controlling the profiling and inductive communication of the ITP remained functionally identical to the prototypes of the previous year. However, we did choose to simplify the user interface and remove configuration settings for non-existent sensors. In addition, the unused data columns in the engineering data files were removed in an effort to compress the file for efficient transfer via inductive modem.

IV. TANK TESTING

Once assembled, each ITP was tested in the controlled environment of the MRL test tank (Fig. 2). The 15 meter deep test tank permits a deployment with a top to bottom range of ~12 meters.

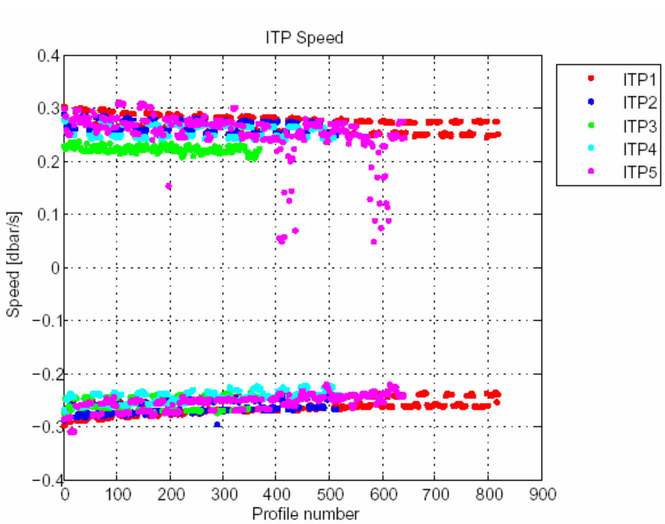

Figure 3. ITP speed for each profile of the tank test for all five units (positive speed is a down profile).

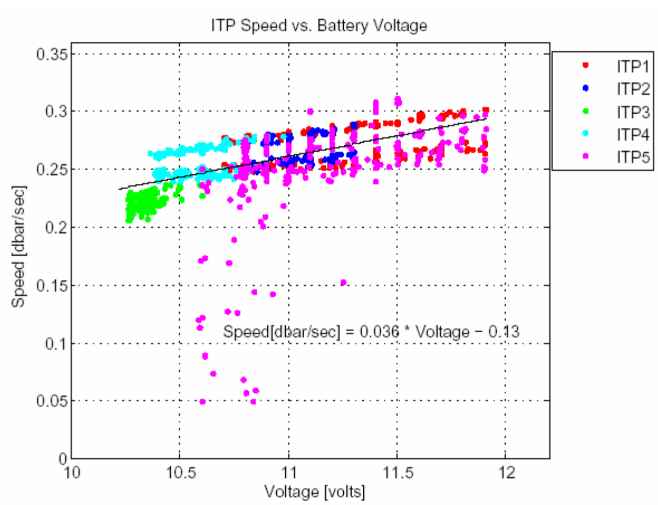

Figure 4. ITP speed as a function of battery voltage with a least squares fit of the downward profiles.

The chemistry of the fresh water pool is similar to a standard swimming pool and contains sufficient conductivity to support the inductive communication loop through the wire mooring rope. During each deployment, inductive communication was established and data files were transferred using a semi-automated surface controller programmed with the inductive modem protocol. Each tank deployment was a minimum of 48 hours; some were longer.

V. TEST RESULTS

A. Profiling Speed

The profiling speed of the ITP units fell in the range of 22-30 dbar/sec (Fig 3). The speed of each ITP was dependent upon the battery voltage of the alkaline test pack used during testing (Fig 4). The least squares approximation of this relationship for the down profiles was found to be

$$\textit{Speed (dbar/sec)} = 0.036 * \textit{Voltage} - 0.13. \quad (1)$$

The apparently slow speeds evident in the ITP5 deployment (purple) were determined to be a combination of heavy ballasting, low battery, and difficulty in the automated processing of very short profiles that hit an obstruction.

B. Motor Current

The figures of motor current (in mA) over the 12 meter vertical range of the deployments (Figs. 5-9) reveal the ballasting characteristics and available data of each test tank deployment. All of the engineering data files exhibit gaps in the data near the middle of the tank because no motor current data is recorded during the speed ramp from stationary to full speed over 30 seconds. At 25 dbar/sec, this corresponds to an approximately blanking distance of 7 meters.

ITP1 and ITP2 (Figs. 5 an 6) show the expected motor currents for a well ballasted profiler. The average motor current falls near 100 mA with small variability.

ITP5 (Fig. 9) appears to be slightly heavy as indicated by the slightly higher motor currents on the up profiles. In addition, the motor currents above 200 mA on the down profiles were due to the ITP hitting the stopper as a result of a slight mismatch between the programmed bottom stop pressure and the actual pressure at the physical stop. The drive motor is able to draw up to 600 mA in an attempt to move the profiler before the magnetic coupling releases.

ITP4 (Fig. 8) was slightly heavy and this resulted in a stronger motor current mismatch between the down and up profiles. The tight packing of data on the down profiles due the sinking ITP is evident.

The scattered data for ITP3 is due to the low battery voltage (Fig. 4) and corresponding slower profiling speeds, but the ITP was clearly light during the deployment. When properly ballasted the ITP drive motors draw an average of 100 mA during profiling.

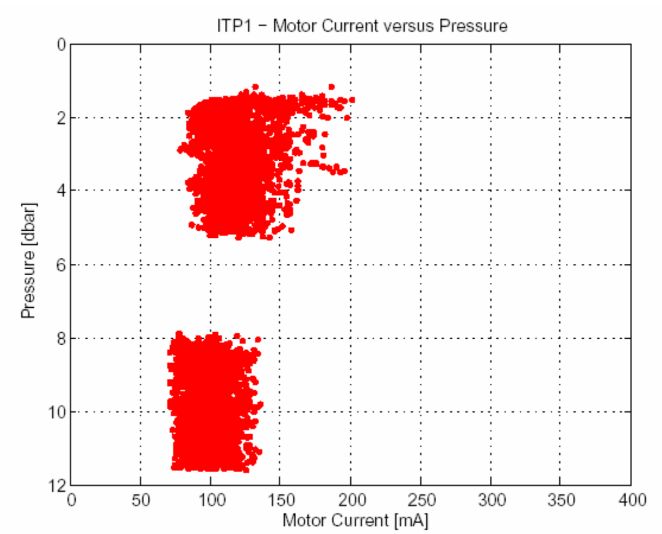

Figure 5. ITP1 motor current as a function of depth.

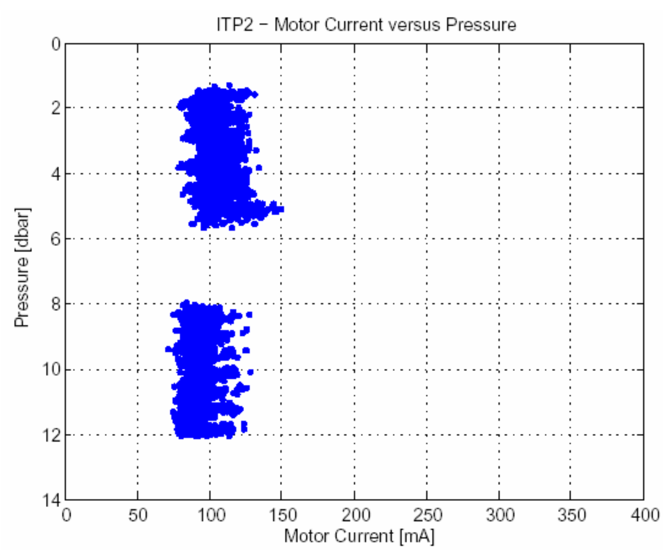

Figure 6. ITP2 motor current as a function of depth.

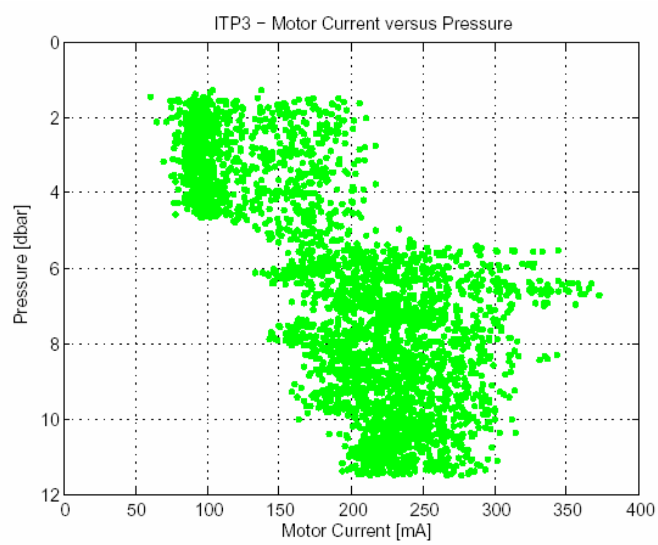

Figure 7. ITP3 motor current as a function of depth (ballasting was light).

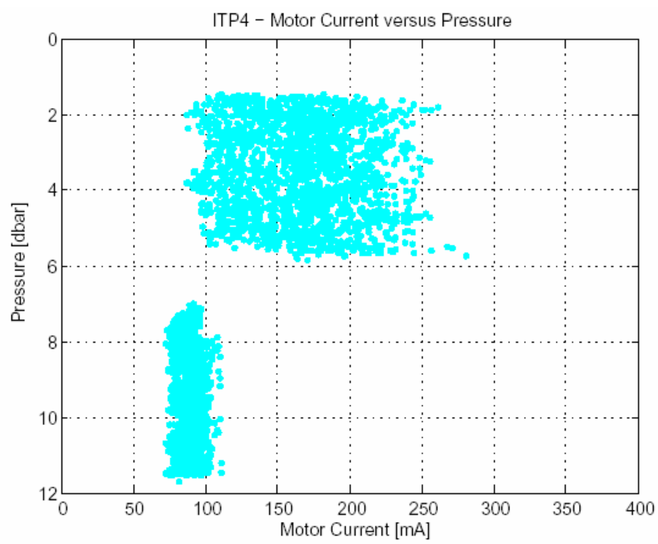

Figure 8. ITP4 motor current as a function of depth (ballasting was heavy).

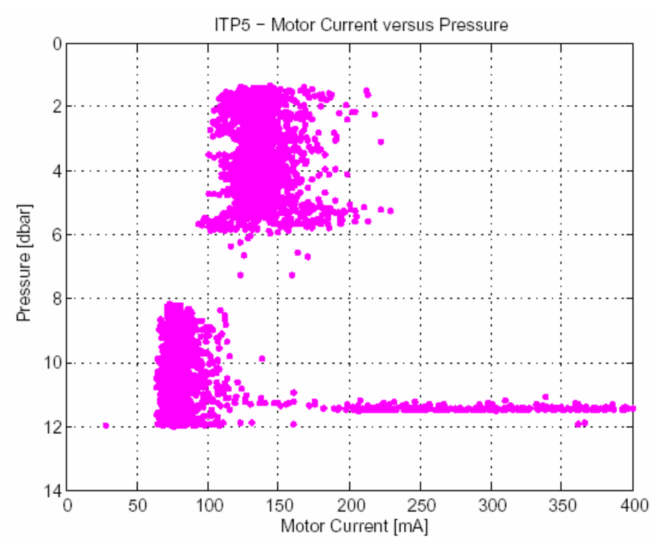

Figure 9. ITP5 motor current as a function of depth (ballasting was heavy and bumping occurred at the bottom).

This motor current, combined with the CTD current draw and power required to transfer data, corresponds to approximately 150 mAh per 1000 meter profile and 1570 profiles per full battery (~240 Ah). The ITP units deployed in the 2005 field season have traveled approximately 65% of this endurance and continue to profile. [3].

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[3] www.whoi.edu/itp