The McLane Zooplankton Sampler: An Autonomous, Time-Series, Zooplankton Sampling Instrument

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Abstract

The McLane Zooplankton Sampler (ZPS 6-50) is a re-engineered and thoroughly updated version of a decade-old instrument, the Butman-Doherty Plankton Pump. The new design incorporates the successful features of the old instrument while addressing a number of known shortcomings with innovative new materials and up-to-date hardware, software, and electronics. The design changes have been guided by the field experience of investigators who have used the original instruments and by the critiques generated during peer review of those early experiments.

I. Background

A number of significant technical challenges must be overcome to successfully collect zooplankton from the ocean. Samples must be collected with little or no damage to allow for accurate analysis in the laboratory. For example, some species of zooplankton can be crushed or even fragmented and lost when sea water is strained through a mesh filter. More robust species may survive straining, but then simply swim away from the mesh when pumping stops. Sealing the sample to prevent such escapes risks further damage to the collected zooplankton. The presence of the sampler creates shadows and distorts the flow field. These light and velocity gradients can trigger escape behavior in actively swimming species, introducing another form of bias into the sample.

McLane pump designs and control algorithms, among other unique features, limit differential pressure across collection filters. Even relatively delicate species of zooplankton can be filtered without severe damage and McLane time-series Water Transfer Systems (WTS) and single-sample Large Volume Water Transfer Systems (WTS-LV) are being used by a number of investigators to collect zooplankton. Unfortunately, these instruments do not address the other sources of sample bias discussed above, a shortcoming that was apparent to us and to our customers. Our discussions with interested researchers convinced us that there was a need for a time-series sampler specifically designed to collect zooplankton. Our knowledge of the strengths and weaknesses of the Butman-Doherty plankton pump [Doherty and Butman, 1990], developed during the late 1980s at the Woods Hole Oceanographic Institution (WHOI) with electronics and software supplied by the McLane Research Laboratories (MRL), provided a starting point for this development. Field experience, peer review, new technologies, and innovative materials have all contributed to the redesigned Zooplankton Sampler described in this paper.

Further information about the ZPS 6-50 is available directly from MRL and from the MRL web site.

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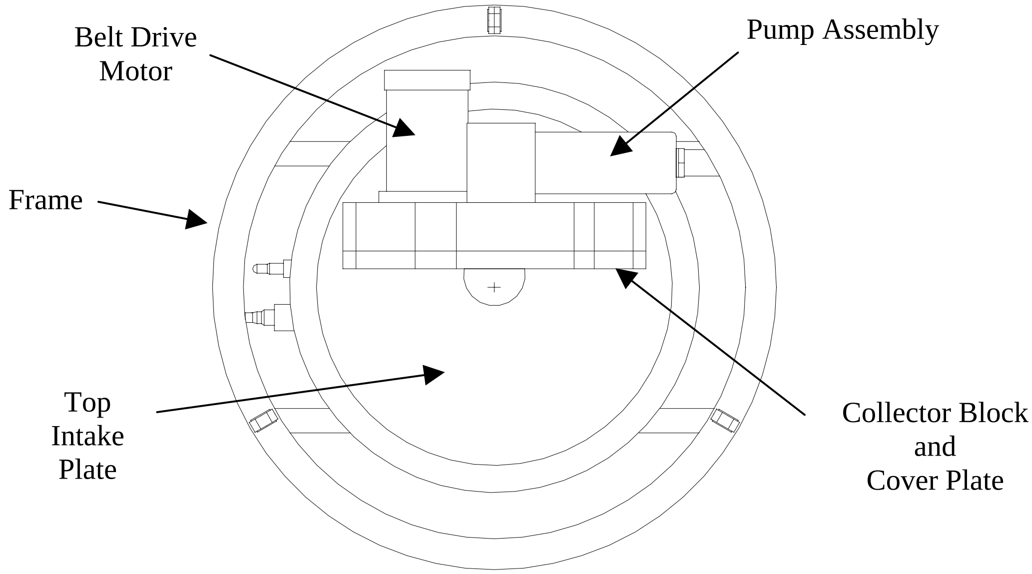
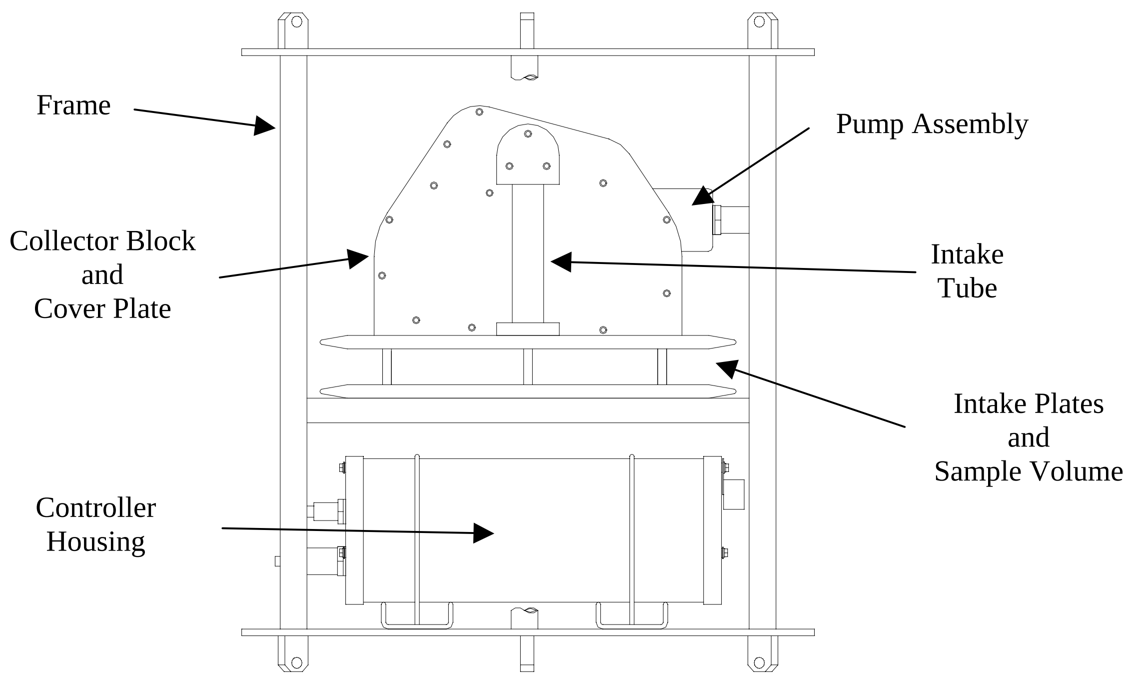
The listed .pdf file, available for download from the MRL web site, is the ZPS 6-50 manual (80 pages). It contains a complete description of the instrument and its operation, including an example deployment scenario and maintenance information.



Top View



Side View

Figure 1 - ZPS Overview

II. System Overview

There are four major components mounted within the ZPS frame: the controller housing, the pump assembly, the sample belt and belt drive assembly, and the intake flow path. (Please refer to Figure 1.)

The controller housing contains an advanced micro-controller, a 3-phase pump-motor driver, a stepper-motor driver, and the batteries. The micro-controller directs the pump and stepper assemblies as programmed by the operator through the McLane user interface. The 36 volt battery pack will last up to 12 months, depending upon the volume and flow rate of water being pumped for each sample. However, the limiting factors for deployment duration are most likely to be the speed and extent of biofouling and the retention of sample fixative, not the capacity of the battery. Aluminum and titanium controller housings are certified for use down to 5,500 meters. Plastic housings are certified for a depth of 300 meters.

The micro-controller automatically runs the ZPS system program, including the user interface, when the battery is connected. The menu driven software allows the user to test the system, enter deployment schedules and offload recovered data. To program and extract data from the ZPS, the operator will need an external communication device, such as a personal computer, with an RS-232 communication port.

The pump assembly includes the 3-phase brushless DC motor and the pump head. The motor is sealed in a pressure housing and operates in air at 1 atm. The motor is magnetically coupled to the pump head. The pump pressure housing is fabricated from either titanium or plastic to match the depth capability of the controller pressure housing. The pump head is a precisely machined, dual impeller, rotary design that provides accurate and even flow throughout its range. It was designed by McLane engineers for high volume and flow rate accuracy and for reliable operation at all depths. The pump is located downstream of the sample belt to prevent damage to collected specimens; zooplankton do not pass through the pump during the collection process.

The pump software completes a tight proportional-integral control loop around the pump and precisely tracks the programmed flow rate independent of battery voltage and other environmental forcing. Differential pressure across the active sample filter is dynamically calculated inside the control loop based on a model of the pump developed here in the McLane Research Laboratories. As material accumulates on a sample window, the flow rate is automatically adjusted to prevent an over-pressure condition sufficient to damage the collected zooplankton. To increase volume accuracy, the internal pump model continuously corrects for motor speed to flow rate conversion inaccuracies caused by the differential pressure. Finally, the pump software is sensitive to rapid clogging of the intake by organic (jelly fish, seaweed) or man-made (plastic bags) material and to sudden mechanical failures. Pumping is immediately terminated in these cases to preserve the existing sample.

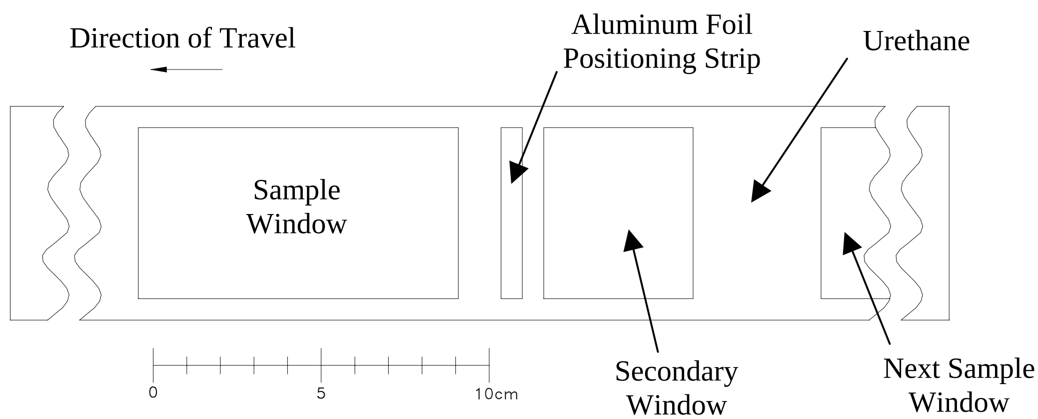


Figure 2 - ZPS Sample Belt

The sample belt is composed of a continuous strip of polyester mesh sandwiched between urethane layers in which sample windows have been formed. (Please refer to Figure 2.) Each belt contains 53 sample windows of which 50 are used in each deployment. Secondary windows in the belt, which trail the larger sample windows, provide a flow path for water as the belt is advanced at the conclusion of each sample acquisition. Pumping continues at a reduced rate as the belt advances to prevent the escape of collected zooplankton. As the belt advances into the sample

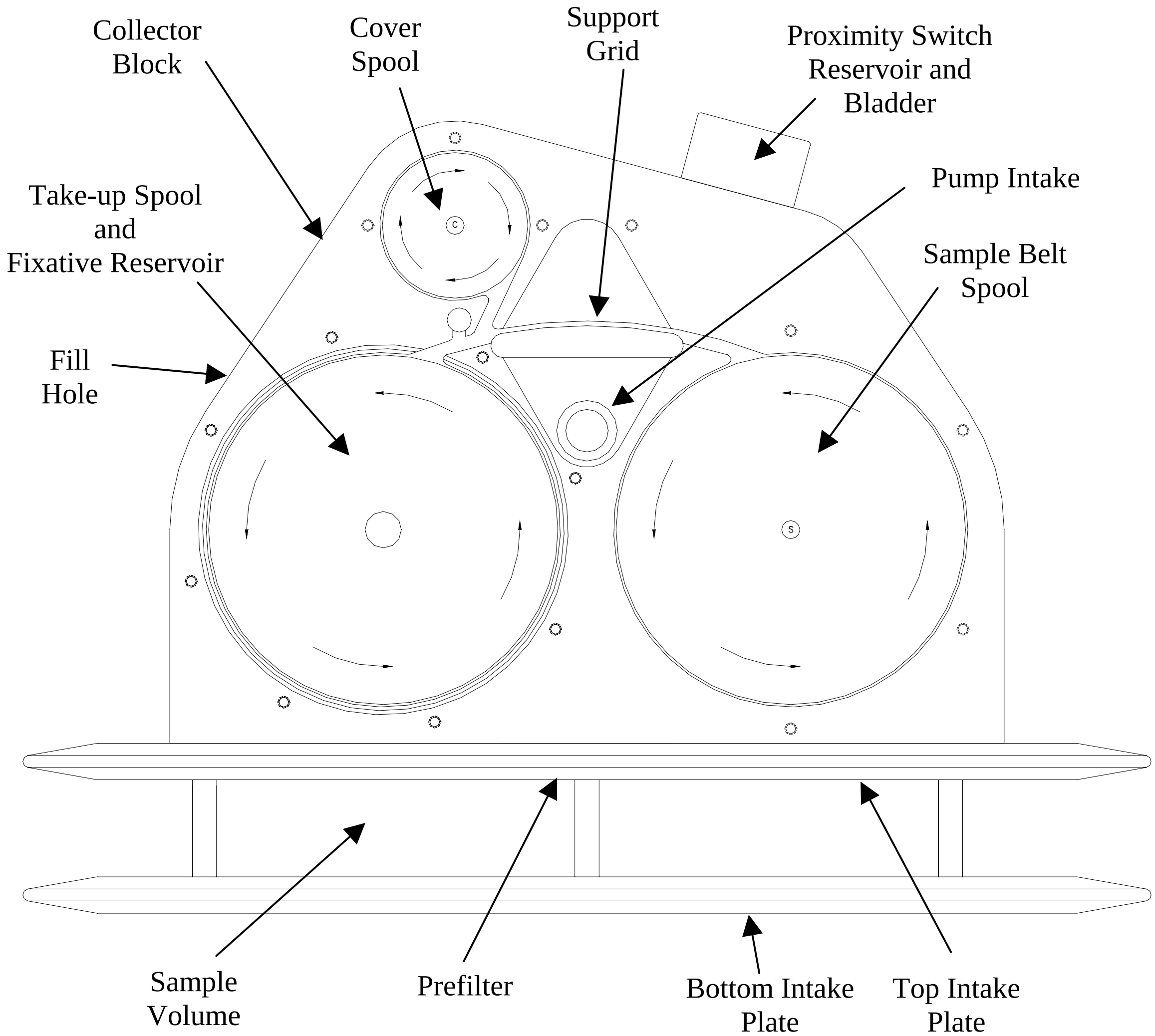


Figure 3 – Intake Flow Path

The intake tube (Figure 1) is not shown. During sampling water flows up through the intake tube from the sample volume. From the top of the intake tube the water flows into the collector block and down through the mesh window of the sample belt, which is supported on the grid. The filtered water is then exhausted through the pump.

fixative reservoir, a second continuous strip of polyester mesh covers the sample window. This process contains, isolates, and preserves each sample without physically crushing individual specimens. Physical damage is prevented by the thickness of the urethane layer forming the sides of the sample window and by the pressure limiting features of the software controlling the pump.

A stepper motor under the direction of the micro-controller advances the belt. The stepper motor is mounted inside an oil filled, pressure compensated, plastic housing and coupled to the take-up spool through a gear box. Precise positioning of the sample windows over the pump intake is achieved by monitoring the output of a proximity switch, which senses strips of aluminum foil embedded in the belt between the urethane layers.

At the discretion of the user, the system can be programmed to flush the intake path periodically between sample events to reduce the severity of biofouling. In addition to periodic flushing, a system flush can be scheduled before each sample with a user determined delay to allow a return to ambient conditions before the sample is acquired. In addition to removing biofouling from the intake path, flushing will keep the sample window mesh clear of zooplankton until the scheduled time of an event, thus reducing sample bias.

The intake flow path is designed with zooplankton behavior and ambient conditions in the ocean in mind. (Please refer to Figures 1 and 3.) This was done specifically to reduce sample biases to the greatest degree possible. The dimensions and shape of the sample volume between the intake plates and the curve of the plate edge reduce velocity gradients in the flow as it enters the sample volume under the influence of ambient currents or pumping. High velocity gradients can trigger escape responses in some species of zooplankton, behavior that would introduce a bias into a sample. Similarly, the plates are machined from clear polycarbonate to reduce the steepness of light level gradients around the periphery of the sample volume. The intake is through the top plate so that material or plankton falling through the water column and washed between the plates by ambient currents will not settle into the intake.

All of the system components are mounted inside a welded, commercially pure, titanium frame. The frame can be deployed as an in-line package on a high-tension ocean mooring system and provides mounting space for additional instruments.

References

Doherty, K. W., Butman, C. A., "A Time- or Event-Triggered Automated, Serial Plankton Pump Sampler", Advanced Engineering Laboratory Project Summaries – 1989", Edited by Daniel Frye, Ellen Stone, and Ann Martin, May 1990, Woods Hole Oceanographic Institution, WHOI-90-20, pp. 15-23.