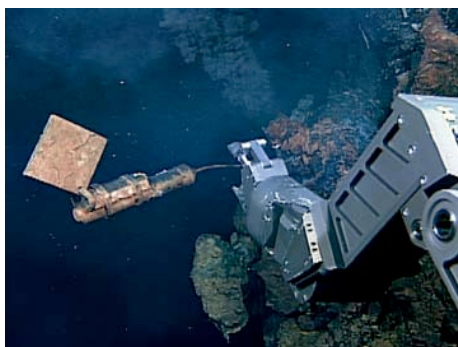
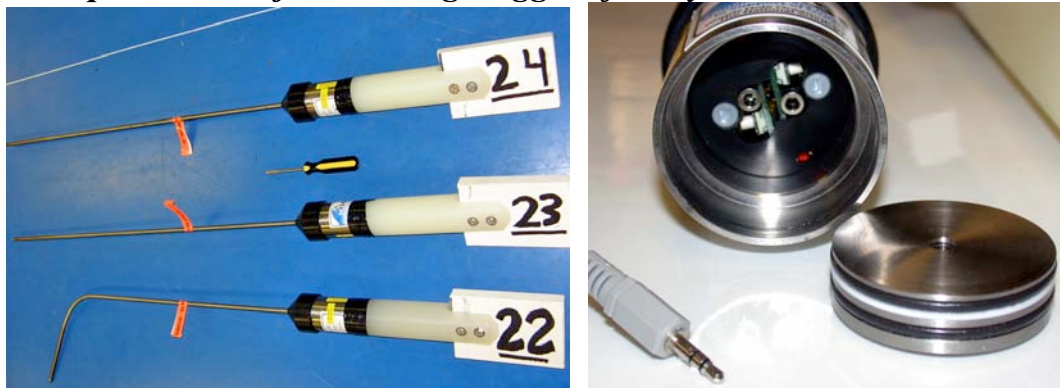
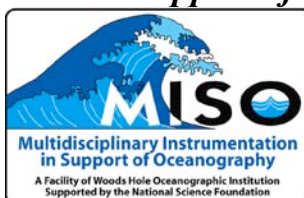


High-Temperature Self-Recording Loggers for Hydrothermal Vent Monitoring



Manual and User Guidelines
Daniel J. Fornari (dforanari@whoi.edu)
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Multi-disciplinary Instrumentation in Support of Oceanography -MISO Facility



1. Introduction

D. Fornari at WHOI helped to initially develop (with M. Olsson at DeepSea Power & Light-DSPL) high-T 'Hobo' fluid temperature loggers (~152°C - 417°C) over a decade ago, and DSPL provided them for many users in the oceanographic community for the past 10 years. These self recording loggers (Figures 1 and 2) are rated to 6000 m operating depth and have been pressure certified for use on Alvin. They have been used extensively and successfully at hydrothermal vents in the Pacific and Atlantic Oceans by numerous investigators over the years and the results have been published in numerous journal articles including: Fornari et al., [1996, 1998, 2003, 2004]; Fornari and Shank, [1999]; Langmuir et al., [1996]; Shank et al., [1998, 2001]; Sohn et al., [1998, 1999, 2005, in press]; Scheirer et al., [2006]). These types of loggers are currently in use at the East Pacific Rise 9° 50'N and the Juan de Fuca Ridge – Main Endeavour Field ISSs, and will be deployed in the Lau Basin in Fall, 2006 (C. Fisher, Penn State. U.).

Over the past two years, since DSPL stopped manufacturing these loggers and turned over to WHOI-MISO the drawings and related assembly and supplier information, I have provided refurbishment and supply services to various users. Two styles of loggers exist, as shown in Figures 1 and 2. The most recent (spherical housing) style has two Onset™ 32k recording chips, and a pressure barrier between the housing and the tip, that provides shipboard capability for refurbishment and redeployment as long as adequate supplies are on hand. The older style, cylindrical housings have been modified so that they now, too accommodate two Onset™ 32k recording chips. The main difference is that the old style cannot be refurbished at sea while the new ones can. The old style can be refurbished back at WHOI.

These loggers remain the only readily available, and relatively inexpensive self-recording high-T vent fluid temperature loggers, and they have provided important time-series information to R2K investigators working at various ISS sites. Most recently these loggers captured the 2005-2006 EPR eruption at 9° 50'N (K. Von Damm, pers. commun., unpubl. data, 2006) (Figure 3).

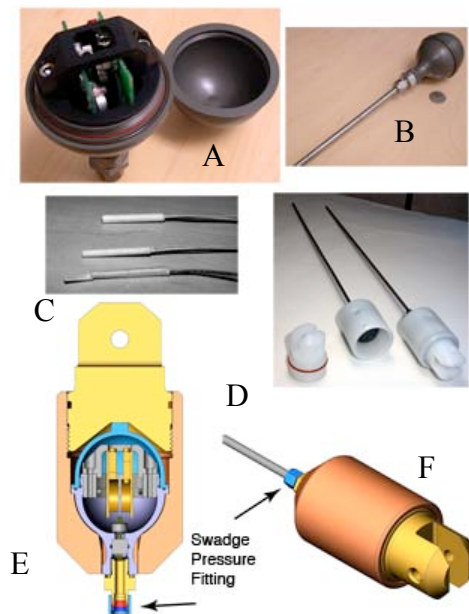


Figure 1. New-style (spherical housing) high-T logger. A) shows interior of spherical housing with 2 Onset™ computer chips (green wafers) visible. B) shows probe tip and housing (quarter for scale reference). C) RTD elements shown, lower one is raw RTD and upper two are encased in ceramic plug. D) loggers shown with polyethylene covers which also serve to attach syntactic foam for floatation. E-F) drawings of internal and external views of spherical high-T loggers showing location of Swagelok pressure fitting that seals tubing from the housing where the computer chips are stored. This configuration provides the ability to service the loggers at sea and replace tips that may have had to be broken off in chimney walls. In this case, the Ti tubing tips are replaced, as are the RTD elements and connector, and the unit can be placed back into service on the same cruise.

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Figure 2. (top) Cylindrical (old-style) high-T fluid temperature loggers currently manufactured and serviced by the MISO Facility. These loggers have been modified to accommodate two (2)- 32k Onset™ logging chips. When/if the tips are broken on recovery they must be returned to the facility for machining, re-welding and re-certification and installation of new logging chips. (bottom) Old style (cylindrical with MISO label) and new-style (spherical, gray housing) logger housings.

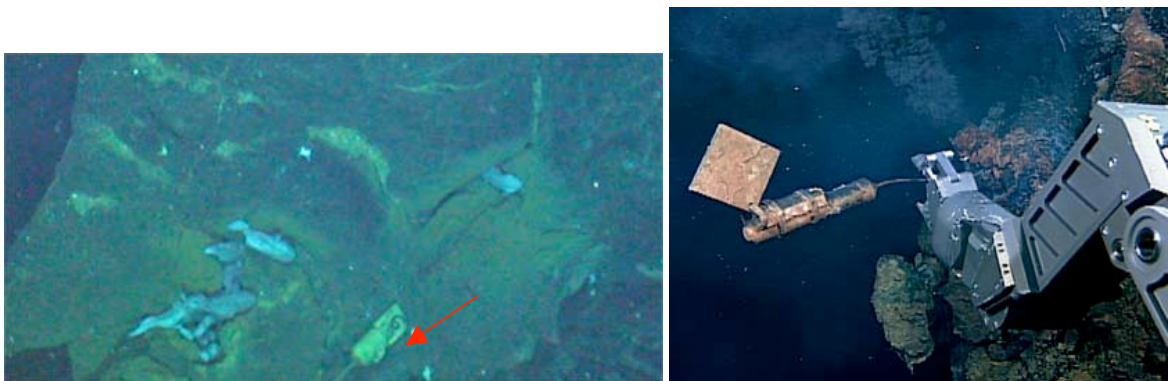


Figure 3. (left) New style logger (red arrow) imaged by *TowCam* on the R/V New Horizon cruise in M vent, EPR at 9° 50.6'N in May 2006. Data from this logger (recovered by Alvin in June 06) provide the first direct measurements of the impact of a volcanic eruption on hydrothermal vent fluid temperature (K. Von Damm, unpubl. data, 2006) and the correlation with microseismicity [Tolstoy et al., submitted]. (right) An old-style logger being extracted from a vent with Jason2's manipulator.

2. 'Old-style' high-T MISO fluid temperature logger (cylindrical housing) - Instructions

The following guidelines and specifications are provided to help users in the operation and maintenance of old-style fluid temperature loggers. Figure 4 shows the details of the housing, end-cap, interior access to the connectors on the Onset™ 32k logging chips for launching and downloading data, the serial download cable, and tubing bender supplied with each set of loggers.

For optimal performance, new batteries should be installed just prior to deployment to ensure the longest duration at cold bottom water temperatures. Even though the Li batteries that power the Onset™ chips are rated to last ~5 yrs, de-rating by approximately half of that duration for long exposure to 2-4°C bottom temperatures has been verified by numerous long deployments.

The bending of the tubing should be done either with the supplied flexible bender in order to prevent collapsing of the tubing or with a more conventional tubing bender. It is suggested that you leave ~ 6-8" from the tip of the tubing straight to facilitate pre- or post-deployment calibrations where the tubing has to fit into the calibrator block. The wiring inside the tubing 'floats' meaning it is not attached to the tubing interior so normal bending of the tubing will not impact the wiring to the RTD element inside the end of the tube. Normally the tubing is bent into a 'J' shape but variations to this are common depending on the morphology and characteristics of the hydrothermal vents to be instrumented. It is strongly suggested that you consult with the deep submergence vehicle pilots in regards to their suggestions for the shape of the bend to be adopted. When ever possible the tubing should be bent under controlled conditions on deck, not by the vehicle at depth. It is important to note that the scoring in the tubing ~ 6" from the housing is meant to collapse the tubing to facilitate retrieval if the instrument becomes cemented into the side of a vent chimney. The logger should be handled by the vehicle's manipulator from the tubing below the scoring or by the handle. Every effort should be made not to flex the instrument so that stress is put on the scored tubing.

2.1. Specifications

Instrument model name: WHOI- MISO Hi-T Logger (*old-style, cylindrical housing*)

Instrument Description: Cylindrical Ti housing, 30" scored probe, NO pressure barrier

Depth rating: 6000 meters (Alvin pressure certification supplied)

Temperature range: 152°C to 417°C

Sampling rate: variable from 0.5 sec to hours, each chip programmed separately

Memory capacity: 64k total, using two (2) 8-bit, 32k Onset™ Computer Stowaway chips each recording to one RTD sensor, conformal coating on chips and pressure tolerant components)

Energy supply: 3.6 VDC Li battery (5 year lifespan)

Duration of autonomous operation: ~2 years operational at depth

Accuracy: 2°C

Precision: 1°C

Calibration data: calibration data provided for 250°C, 300°C and 350°C

Dimensions: housing ~2" diameter, probe tip ~30" long (5/16" OD tubing)

Housing Weight (air/seawater): 0.6 kg (1.2 lb) in air, and 0.3 kg (0.6 lb) seawater

Instrument Weight (air/seawater): 1.4 kg (~3 lb) in air, just negative in seawater (with syntactic)

Housing material: titanium- Grade 2

Clock drift: estimated at <1 min over 12 months

Type of temperature sensor: RTDs (resistance temperature device) - 2 total per logger, both embedded in ceramic plug

Computer and software requirements: Windows2000 PC with serial connector (or USB to serial converter, Onset™ Boxcar® software, and serial download cable (software and cable supplied)



Figure 4. (A) Old-style housing, syntactic foam handle, and endcap. Download cable - mini-RCA plug - shown that connects to Onset™ logger chips in the housing. (B) Logger components: housing, end-cap, serial download cable, tubing bender. Each housing is serialized as is the end-cap. (C) Close up of housing insides, red arrow points to the connectors on each Onset™ recording chip. (D) Loggers ready for deployment, note 'J' bend in left-most logger. Red arrow points to electrical tape used to ensure that housing and handle do not unscrew. (E&F) Close-ups of scoring on the tubing (red arrows).

2.2. Housing, End-caps, Tubing Tips and Seal Surfaces

Housings, end-caps and tubing tips are all made from Grade 2 Titanium. Welding of tubing tips to housing is done in an oxygen-free environment. All seal surfaces have been machined to tolerance and the entire housing is rated to 6000 m depth and certified for Alvin operation. Each housing and end-cap is serialized and should be kept together. Seal surfaces in the housing and the end-cap (Figure 4C) should be kept free from dirt/dust and lightly lubricated with suitable Silicon O-ring grease prior to deployment. It is recommended that canned air be sprayed into the housing just prior to sealing to ensure a moisture-free environment in the housing during deployment. Tubing is scored (Figure 4E/F) to permit easy retrieval if cemented in a vent chimney wall. See 'Data Recovery' section (2.7) for handling the Onset™ chip if the tubing is broken and the housing floods at depth. The recorded data are normally OK and can be downloaded if routine procedures are followed.

2.3. Onset™ 32k logger chips, RTD Temperature Sensors and Batteries

The logging chips are made by Onset Computer Corp. They are 8-bit, 32k StowAway Temperature logger models with an external platinum RTD sensor that has a range of ~152°C to 417°C (Figure 5). Information about the Stowaway loggers can be found at: (http://www.onsetcomp.com/Products/Product_Pages/older_data_loggers.html).

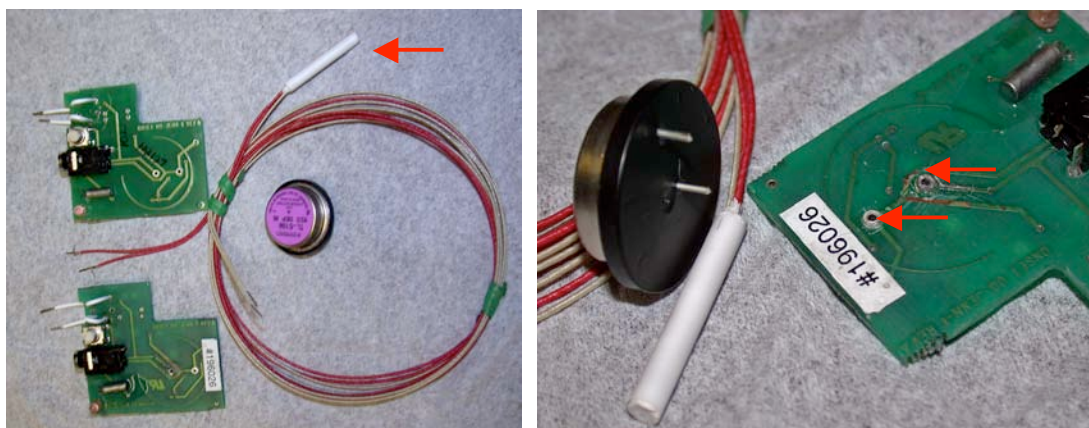


Figure 5. (left) Photo showing two Onset™ 32k memory chips used in the MISO loggers, the coil of wires connected to the ceramic plug (red arrow) that contains two (2) platinum RTDs, and the battery used in the chips. (right) Close-up of the RTDs encased in ceramic and the battery terminals. Battery plugs into the Onset™ chip (red arrows) in one direction only because of offset in battery terminals and their placement on the circuit board.

The platinum RTD sensor is specifically manufactured to measure temperatures in the ~152°C to 417°C range. Two RTDs are encased in high-temperature ceramic for each logger, to prevent damage to the fine wires that connect them to the Onset™ chips (Figure 5).

Batteries supplied with the logger are Lithium/thionyl chloride made by Tadiran Batteries Ltd. (Figure 5). They are user replaceable and can be ordered from: <http://www.tadiranbat.com/>. Care should be taken to properly dispose of the battery when normally discharged. Special instructions are provided below in Section 2.7 when the casing is flooded at depth as hydrogen and oxygen can be generated by electrolysis. MSDS sheets for these batteries are available at the following link at: <http://www.tadiranbat.com/primary.php>.

2.4. Launching the Logger and Downloading Data

The time on the Onset™ logging chips are set via the PC computer - **BE SURE TO SET THE TIME ON YOUR PC TO THE CORRECT DATE AND GMT TIME PRIOR TO LAUNCHING THE LOGGERS.**

The Onset™ logging chips are each launched via the serial cable that should be connected to the small mini-RCA jacks on the chips in the housing, and a PC computer, with Windows98™ or Windows2000™ operating system, running the Onset™ Boxcar® software (Figure 6). Software has been provided with the loggers. Instructions for using the software are provided in the user manual for Boxcar®. Additional information is available at the Onset™ site at: <http://www.onsetcomputer.com/>, and for the BoxCar® software at: http://www.onsetcomputer.com/Products/software_guide.html

It is suggested that care be taken when selecting the settings for recording data in terms of whether the average, maximum or minimum temperature are selected to be recorded (green arrow in Figure 6 (left)). This set up can have important implications for interpretation of the data.

When the logging chips are properly launched the small red LEDs visible in the housing flash every few seconds. Check the Onset StowAway documentation for additional information.

Downloading the data is done via the same serial cable and the Boxcar® software. It is strongly suggested that backups are made immediately of any data collected, and that the .dtf formatted files (Boxcar® format) are converted to delimited text files for ease of importing into other spreadsheet programs.

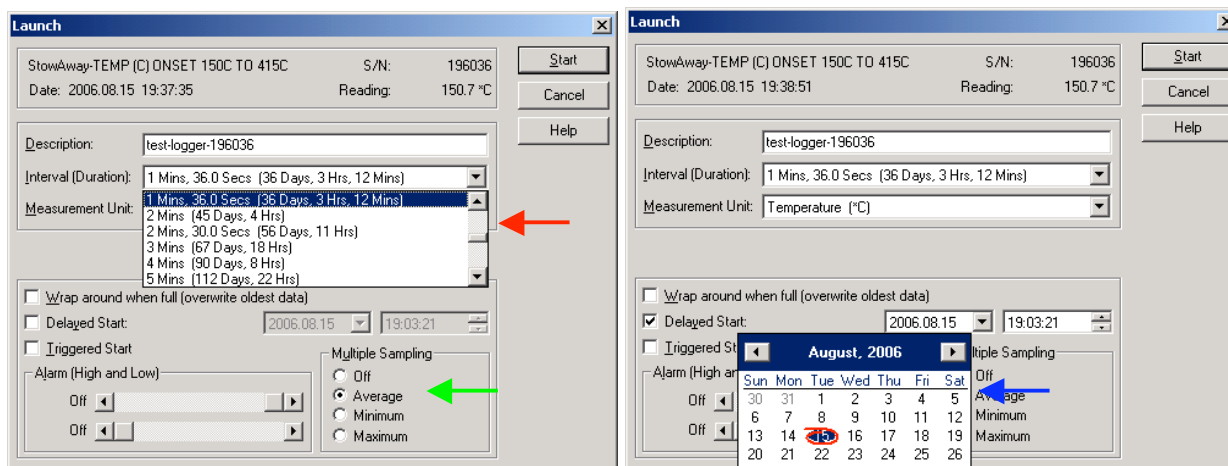


Figure 6. Screen grabs of Boxcar® software windows showing (left- red arrow) pull down menu for selecting recording interval and and sampling options (green arrow). Right screen grab shows pop up calendar (blue arrow) that appears when selecting 'delayed start' option. **REMEMBER TO SET THE COMPUTER DATE AND TIME TO GMT PRIOR TO LAUNCHING**

2.5. Syntactic Handle -Buoyancy in Seawater

Figures 4A and 4D show the polyethylene handle with the syntactic foam block (1" thick x 6" x 4"). The handle has a titanium, threaded rod (1/4-20 thread size) that is meant to screw into the housing end-cap. Use of some waterproof - 'never-seize' 'Aqualube™' compound ('blue' goop) is recommended. Several wraps of electrical tape should be used to tape handle to the housing to prevent unscrewing (red arrow in Figure 4D). The syntactic foam provides

adequate buoyancy in seawater for the logger to be slightly negative, so that the housing does not 'fall out' of the vent orifice after deployment.

2.6. Opening and Sealing the Housing

Rinse the housing well with fresh water after deployment and wipe dry with a soft cloth or paper towels. The end cap is retained using a snap ring as shown in Figure 7. To remove the snap ring, insert a small straight bladed screwdriver or a metal pick beneath the outer-end of the snap ring (red arrow in Figure 7) and pull up to extract it from the groove in the housing. Once it is out of the groove it can be gently pulled out in a spiral motion until it is free from the housing. Use a ¼-20 threaded rod or the handle to remove the end cap. Care should be taken to not jam the end cap or put it in the housing when it is tilted. It should be gently seated so it is flat and then pushed down to get the end cap past the groove that retains the snap ring.

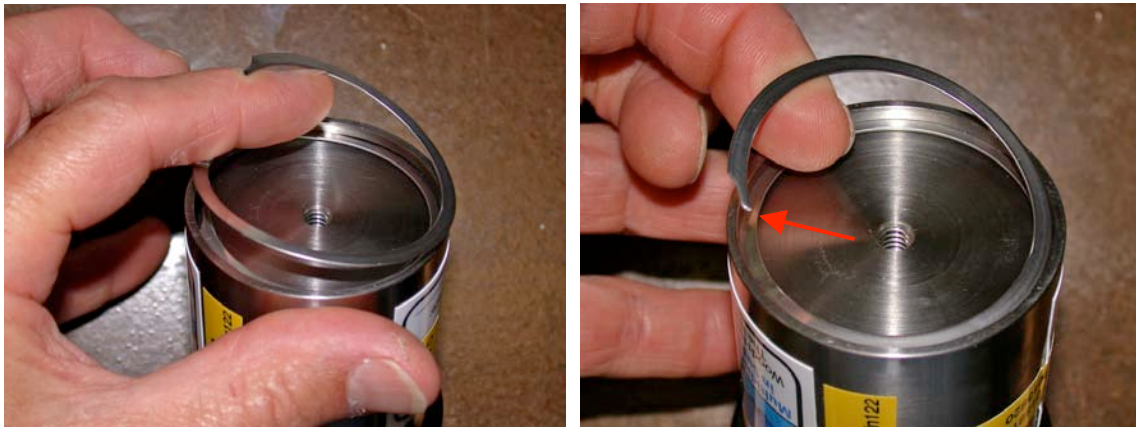


Figure 7. Left photo shows snap ring starting to be inserted into slot in the housing. Some times force has to be used to keep the end-cap in position while inserting the snap ring. Right photo shows the snap ring nearly inserted. Twist and guide the snap ring into the groove in the housing and make sure that the ring is fully seated so that the end cap is retained. To remove the snap ring, insert the blade of a small screwdriver and pull up the end of the snap ring and start unwinding it from the groove. It should come out easily once started.

2.7. Deployment Suggestions

bending the tubing, labeling the handle
excavation, nearby chimneys, placement in the vent orifice, subsequent sampling at that orifice...

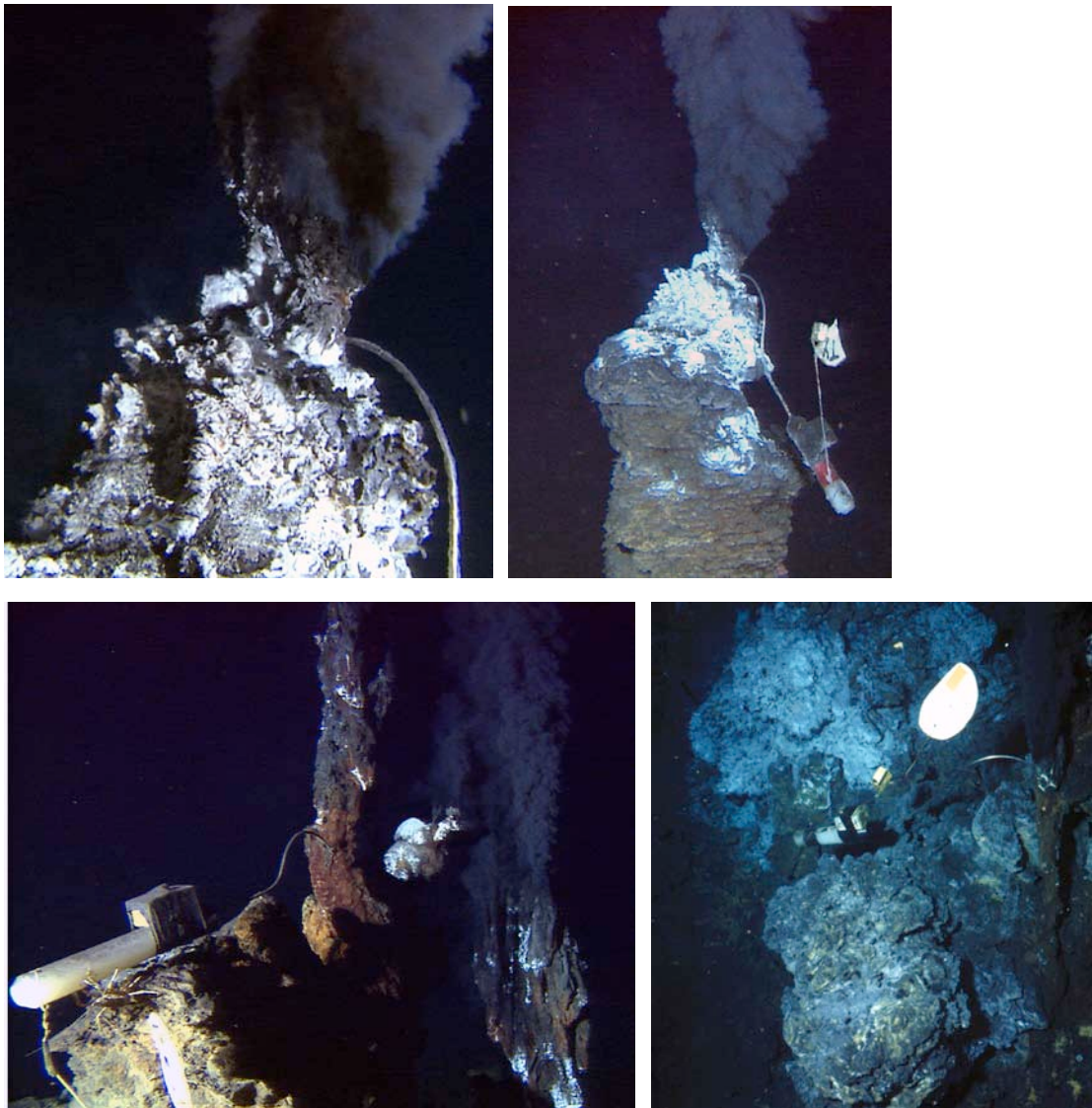


Figure 8. Examples of high-T logger deployments at hydrothermal vents at the EPR in the 9° 50'N area.

2.8. Data Recovery and Precautions if Housing Floods at Depth

If the housing floods because the tip is broken during extraction from the vent chimney the housing should be opened carefully. Immediately remove the battery from the Onset™ chip and discard following MSDS procedures. Rinse the Onset chip in distilled fresh water thoroughly and let dry in a fume hood or in a clean, dust free environment. You can use a low wattage bulb to supply some heat to speed up the drying. Let dry for ~1 day. When dry, insert a new battery (short the battery terminals for 1-2 sec with a screwdriver blade- that helps starts the current flowing in the battery) and the logger chip should blink its red LED light when power is applied. Then connect to the PC and download the data.

The housing, end-cap and handle should be returned to the WHOI MISO facility for refurbishment. Please include the Onset™ chip as well for evaluation after the data have been downloaded.

2.9. Calibration

Calibration of the loggers is done using an IEEE calibrated oven and an Omega hand held thermometer with a thermocouple probe that was also inserted into the oven block. Each Onset™ chip in each logger housing is set to record at the same time intervals using the delay function in the Onset™ Boxcar® software. Recording periods for calibration runs vary but are usually fast- 1-2 seconds. All PC clocks are set to GMT - the Onset™ chip takes its time from the PC clock when launched so it is important to be sure you set your computer's clock to GMT prior to launching the logger.

Calibration is normally done at several set temperatures, e.g., 200°C, 250°C, 300°C and 350°C for ~10 minutes (see Figure 9). Previous testing by plunging the hot tips into ice baths indicated that the response time of the RTD sensors is within a few seconds.

The temperature recorded by the handheld thermometer is also logged at the same interval as the logger. Tests done using the handheld thermometer indicate that the calibrator block is within a few degrees of the set temperature. Because there are 3 holes in the block, and variations occur when the loggers are inserted and removed from the calibrator, the temperature of the calibrator is usually a few degrees below the set temperature. Logger temperatures are normally very consistent (within ~ 1-2°C) once the calibrator equilibrates by having the logger in the block for ~5-10 min.

For each logger, data from the two chips are provided as both .dtf (Onset™ Boxcar® format) and .txt saved as Excel with the header information for each Onset™ chip preserved, and the file name including the serial number of the chip. A plot of the temperature data for each logger is usually saved as a .png or .jpg file and provided to the user.

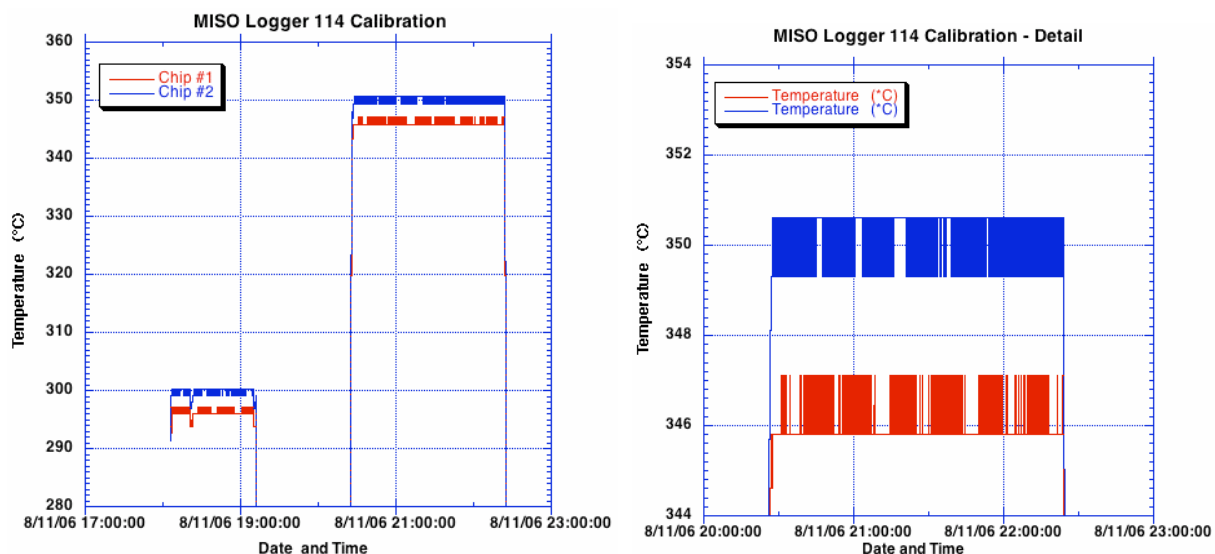


Figure 9. Example calibration data from MISO high-T logger s/n114. Note consistency of the readings despite the 3-4°C offset due to logger tip placement in the calibrator and positioning of the RTDs with respect to other openings in the calibrator block. Right plot shows detail of the 350°C calibration.

3. 'New-style' high-T MISO fluid temperature logger (spherical housing) - Instructions
****TO BE WRITTEN along same style as old logger****

Journal citations for published research using the high-T and low-T Loggers

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- Sohn, R.A., S.A. Humphris, J. Canales, Stochastic Analysis of Exit-Fluid Temperature Time-Series Data from the TAG Hydrothermal Mound: Events, States, and Hidden Markov Models, *Am. Geophys. Union, Eos*, 86(52), OS22A-06, 2005.