Overview of Operations for Setup and Use of Alvin Heat Flow Probe with ProbeTemp software
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I. Overview of Alvin Heat Flow Probe system

UCSC has two Alvin-style heat flow probes built by WHOI personnel (Lane Abrams and colleagues) in 1995-96. Each probe has a 60 cm long lance, ~1 cm outer diameter (OD), with five thermistor sensors having 10 cm spacing. There is a heater wire running the length of the lance, for use in in-situ thermal conductivity measurements.

The lance is topped with a pressure case containing system electronics and topped with a deep-sea (water-tight) electrical connector. The system electronics comprise a simple computer with operating system, power delivery, A/D for data acquisition. System power comes externally, and there is no internal data logging.

The electrical connector on the lance is a female, four-pin, eight-connector design. Only four (4) of the connectors are used. The cable has the corresponding male connector, then ends with a "whip" of bare wires (or wires with pre-attached pins for use with Alvin/Jason). There are dummy connectors that mate with female/male electrical connectors and protect the contacts from corrosion. Dow 4 (or a similar) dielectric compound should be used when making connections with this system, to smooth insertion/removal, prevent water from weeping into the connector, and assure a good electrical connection.

The heat flow probe is operated from a PC (Windows or Mac) using a Java-based program that has a GUI for interaction with probe electronics. This software replaces C-based program that was delivered with the tools in 1996, communicating with the probe using a low-level command language, and allowing the user to monitor system performance during measurement. As described in the next section, the system can be tested on the bench before deployment to assure proper function and for training purposes, but be careful to not activate the heater wire in the probe unless the probe lance is fully submerged in water. Excessive heating of the probe in air could damage the thermistor string.

The Alvin heat flow probes were build before widespread adoption of USB connectors, so assume a serial connection to the computer. We generally use a USB-serial adapter to talk to the Alvin probes - this is often better than direct serial because (a) many computers no longer have a serial connector, (b) it can be hard to get a good serial connection, (c) serial connectors on computers are easily (and often) damaged. Be sure to test your selected USB-serial adapter and driver software in advance, to make sure you can communicate with the heat flow probe.

II. Operating Software

It is possible to communicate with the Alvin probe using a terminal emulator and a low-level command language, but responses will be in hexidecimal (see memo from Lane Abrams describing the probe language and operation with the original C program). Instead, we operate the probe and log data using a Java-based program (written by B. Morris, UCSC) that gives commands to the probes, receives and translates responses, presents a graphical display of operating data, and stores data in a file.

The Java program is called, "`TempProbe`" and comprises a jar file and a series of associated libraries and subroutines. We have verified function of the program using WinXP, Win7, and Mac (OS 10.X) computers. Update Java on the computer as needed, then copy over the complete TempProbe folder/file structure. Locate the main application (`TempProbe.jar`) and "double-click" to run. We assume at this point that there is a physical/electrical connection to the Alvin probe, including power and communications. This could be configured on deck or in the lab using a power supply, or on deck using the electrical system in Alvin or Jason. More about these connections below.

On startup, the `TempProbe` program shows a window with Measurement # on the X-axis and Temperature on the Y-axis. If needed, from the main menu choose File --> Select the serial probe port. Use the Device Manager on the PC to determine which port to select. Windows computers often get confused about serial communication, so best to restart prior to use of `TempProbe`.

From the main menu choose *ProbeControl --> Start Measurements*, then enter:
SampleID is ASCII data, used to name the output file. Other entries are integer or floating point.
Sample interval of 2 to 5 s generally works well. A faster sampling rate is generally not beneficial and can cause challenges in data processing.
Heater Level (0-20) should be higher to get a stronger signal for interpretation of thermal conductivity data. At the limit, greater heating could (potentially) lead to convection near the probe in sandy sediments, but we have found that 20 W/m tends to work well in most cases. For a pulse length of 20 s, this corresponds to 400 J/m. **NOTE:** Be careful with applying heat when testing the probe in the lab or on deck. The lance should be fully submerged in water to avoid overheating of the lance and sensors.
Heater Delay is time between start of data log and initiation of the heat pulse. Because the desired time is about 7 minutes, and it takes the pilots a few seconds to get set up and insert the tool (see below), generally good to set this for 8 minutes = 480 seconds.
Heater Duration is generally 20 seconds.
For testing in the lab, it may be beneficial to set lower heating, shorter delay, and shorter duration, because you are just verifying function.

User is asked to identify location for data to be stored and a file name. Choose your working directory, name the file, the program will add a .txt extension.

Other main menu commands:
Get serial number from probe: not working, not important.
Turn on the heater and ***Turn off the heater*** may be useful for testing in the lab, or if you started the probe during an actual measurement, did not plan on measuring TC, but decided to do this after starting the measurement.

Once the program is started, data should be displayed on the Java plot. You can zoom in/out by right-clicking on axes and otherwise change ranges and formats as desired. After collecting one dataset, you can clear the plot without closing the program by selecting *File --> Clear plot*. Once data are being collected, you can choose *Probe Control --> Stop Measurements* to end data collection.

III. Deck Testing the Heat Flow Probe System

There are two main modes of deck testing, using a power supply and connecting directly to a computer, and working through the sub system for power and communications. The former is useful to verify that the probe talks and computer is configured correctly. It can also be used for basic practice and training purposes when you don't have access to the sub.

Testing with the sub power and wiring is critical and should be completed before each dive. Let the DSRV crew know when you are ready, and go to the Jason van or into the Alvin ball for testing when they are ready. Sometimes you have to "hang around" a while until it is your turn. You can also ask the engineers when they think it will be time for testing.

To test the system using the sub, the engineers will have to connect the heat flow probe whip (male Marshall connector on one end, bare wires/pins on the other) to the vehicle through a junction box. There are drawings and other information in the documentation manual that you can copy and give to them to aid in making necessary connections. Please also provide a dummy connector so that the Marshall connector does not corrode on deck or during dives when the heat flow probe is not being used.

When the Alvin heat flow probe is attached to a power/comms cable, power should be off. This applies to both bench testing in the lab and testing with Alvin/Jason. Never connect the probe with power switched on. After connection is made and when you are ready, turn on power (bench testing with power supply) or request power from the pilot (testing with vehicle). Launch the Java app, set parameters as desired and run your test.

For bench testing, there is a special cable with a Marshall connector on one end and leads for connection with a power supply on the other end, plus a serial connector for the computer. The probe takes +26V (nominal) power. Connect the probe, computer, and power supply. Start with the Voltage and Current knobs on the power supply set to zero, then turn on the power supply. Turn the knob for Current slightly to right, then turn the Voltage knob to desired level (24-26V generally works well). You can fuss a bit with the Current and Voltage knobs - the probe will draw more current when collecting data and (especially) running the heater circuit.

At this point, you are ready to run a test. **NOTE:** Be careful with applying heat when testing the probe in the lab or on deck. The lance should be fully submerged in water to avoid overheating of the lance and sensors. You can run a simple test without heating - it is not necessary to test the heater wire before every deployment. Your main concern with testing is communication and using the software.

IV. Alvin Probe Dive Operations

The engineers like to configure the dive basket with minimal clutter. At the same time, they prefer to not empty, open, and fiddle with the underwater connector panels. This means that, once the heat flow probe is configured for use, the cable is likely to remain attached to the vehicle for the duration of the expedition (or at least several dives). The cable can be tied out of the way in the basket when not being used, to avoid tangling with other equipment. In addition, the heat flow probe is often put on a "rack" near the back of the basket for easy access when desired, also minimizing chances for getting tangled with the cable. Work with the dive team to select a suitable location. Also, we tend to wrap the pressure case (where the pilot will use the manipulator to hold the probe) with a rubber sleeve. This gives the manipulator something to grab onto, as the smooth steel pressure case is slick and can slide easily in a manipulator.

On the last extensive use of the heat flow probe with Jason in 2013, we had trouble with a weak short in the Marshall connector. The Jason crew preferred to use a low viscosity coating on the Marshall connector pins, rather than Dow 4. They then covered the connector with a rubber jacket filled with insulating grease, and that solved the problem. We have never had a leakage problem with Dow 4, and I prefer to use that, although I'll admit it can be tough to disconnect the Marshall connector. This might take some negotiation with the dive crew.

For making measurements during a dive, you should have a specific plan of where to put the probe. In general, it is best to make heat flow measurements co-located with seismic data, or at least in association with other geological, geochemical, or microbial data. You should have a listing of targets ready to go, and have plenty of datasheets for use during measurements to record critical information.

Before the first measurement of a dive, take some bottom water data to calibrate the probe sensors. Have the pilots hold the vehicle stationary close to the bottom...or they can set down, but that may kick up a lot of mud. Hold the probe in the manipulator, horizontally, in front of the sub. Get your computer connected to the probe as directed (a pigtail should have been labeled for "heat flow" in advance, in the sphere or in the van). Turn on power to the probe. Collect 3-4 minutes of data and verify that temperatures are stable and cold. This bottom water data is critical for processing penetration data.

Tell the pilot where you want to make the actual measurement. The goal is to insert the probe vertically (perpendicular to the bottom, if on a slope...unlikely but could be...), quickly (in 1-2 seconds?), smoothly, and without carving an arc with the tool. We want the probe to have a good thermal contact around the lance in all directions, and not be in an oval-shaped hole with an annulus around the sensors. Some pilots are highly skilled in inserting the probe smoothly and straight into the seafloor. Others will require some practice. Insertion or removal of the probe at an angle can damage the probe itself, and repeated bending/straightening could lead to strain hardening, cracking, and failure of the probe.

It is common to set down the vehicle prior to measurement, but will depend on setting, pilot preferences, etc. When in position with the sub and ready to insert the probe, request power on to the probe. Tell the pilot you are configuring the software, and ask to wait for your OK to insert the probe. Turn on software, set up for the measurement, fill out the first part of the data sheet. A typical configuration when collecting gradient and thermal conductivity data is: 8 minute delay, heater on for 20 s at 20 W/m, then 7 more minutes of data collection. When you are ready, start the probe and logging of data, allowing 3-4 measurements to assure all is OK. Now tell the pilot to insert the probe when ready. The pilot should push the probe in the seafloor with one continuous motion, all the way to the base of the pressure case, then let go of the probe. Letting go will help to reduce motion that disturbs the measurements.

Watch the probe response, fill out the datasheet, take notes, etc. There should be a smooth decay from frictional heating following insertion. Take a photo of the tool as deployed, from enough distance that you can see context. Extreme close ups of the tool provide little benefit. A measurement of gradient and thermal conductivity will take about 14-15 minutes total, whereas one without conductivity will take about 8 minutes. The thermal conductivity pulse should be big, maybe bigger than the insertion pulse. If you forgot to set up for the pulse when setting up the measurement, you can create one manually (*Probe Control --> Turn on the heater...*"). When you have enough data, take a "screen shot" and save to a file near the datafile. Then stop logging data and ask the pilot to power down the tool. Now the pilot can remove the tool from the seafloor, being careful to avoid bending the lance. While the pilot is putting the tool back in the basket/cradle, backup the data and screen shot onto a USB drive or other device. Mark additional information on the data sheet, as needed. Plan for your next measurement. Either quit `TempProbe` or clear the plot, getting ready for next measurement.

If there is significant probe motion during insertion, accurate interpretation of the data may be impossible. You can cancel a measurement if this occurs. Do this by stopping logging, turning off power to the probe, removing the probe from the seafloor, and finding a new measurement location (can be just 1-2 meters away). This is preferred to repeating the measurement without removing the tool from the seafloor because the initial measurement location will be disturbed for some time. Better to start fresh.

V. Data Processing

We process data using `SlugHeat`, a Matlab-based program that is based on the algorithm of Villinger and Davis (1987), as modified by Stein and Fisher (2001). The software provides a graphical interface for selection of data for processing, with integrated correction based on bottom water calibration, and runs a Monte Carlo analysis to assess uncertainties associated with thermal conductivity layering (values, depths). Processing Alvin heat flow probe data using `SlugHeat` requires creation of a specially formatted "penetration" file for each measurement. We have a script for this. The software runs on an older version of Matlab, so it will be best to bring data files back to UCSC for processing. That said, you can often estimate heat flow by looking at the plot of T versus time, and estimating the gradient between deepest and shallowest sensors (with a rough correction based on bottom water calibation).

Stein, J. S., and A. T. Fisher (2001), Multiple scales of hydrothermal circulation in Middle Valley, northern Juan de Fuca Ridge: physical constraints and geologic models, *J. Geophys. Res.*, 106(B5), 8563-8580.

Villinger, H., and E. E. Davis (1987), A new reduction algorithm for marine heat-flow measurements, *J. Geophys. Res.*, 92, 12,846-812,856.