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1 INTRODUCTION

The Gamma-4 is a four-wavelength transmissometer that operates at ocean depths up to 500 meters. The optical path is completely open to natural water flow so no pumping is required (although an optional flow tube is available), and the instrument contains no moving parts. The electronics include an intelligent controller with internal logging and large flash memory capacity.

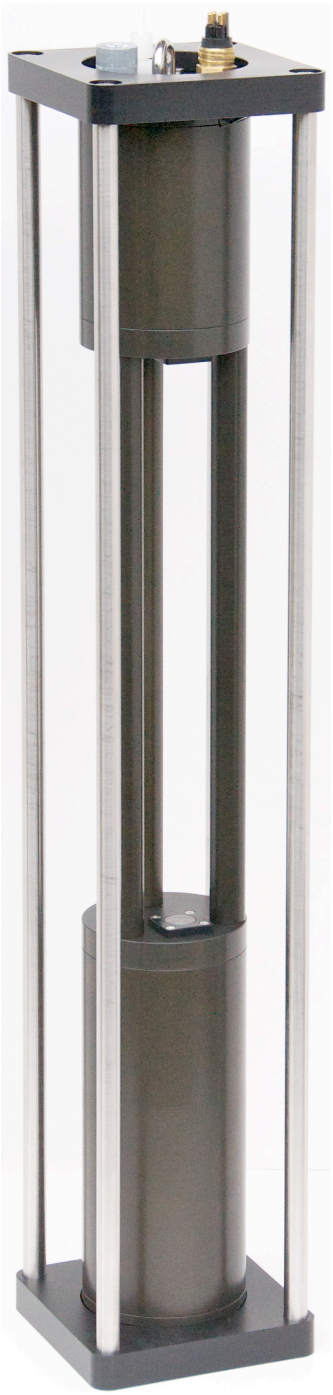

Figure 1. Gamma-4 in standard deployment cage

1.1 Opto-electronic Design

The four wavelengths are generated by separate LEDs. Each LED's current is controlled through software, and modulated at a frequency and phase that allows it to be distinguished from the others. The four LEDs are combined into one beam, directed through a 1 mm aperture at the focal plane of a 40 mm collimating lens. An aperture at the lens defines the final beam diameter of 10 mm.

The receiver also limits the incoming beam to 10 mm, and its 60 mm focal length and 1 mm focal-plane aperture limit the field of view to about 0.7° full width in water.

Ideal attenuation measurements require optics that completely reject all scattered light, regardless of how small the scattering angle. In practice, all transmissometers have finite acceptance angles, receive some scattered light, and therefore report attenuation values smaller than the theoretical value. The Gamma-4's optics are closer to the ideal than some transmissometers, and therefore it may report somewhat higher attenuation values than those instruments.

1.2 Mechanics

The Gamma-4 housing is constructed from hard-anodized aluminum. It comprises two main parts, one holding the light source and controller, and the other

holding the receiver. The two housings are linked by three standoff rods that are rigidly embedded in the housing end caps. One of the rods is slightly larger in diameter, and hollow, to accommodate wiring between the two parts.

The connector end cap, which has an eye that can be used for suspending the instrument, is located on the receiver side of the instrument, so that when suspended from the eye, the receiver will look down.

Figure 1 shows the Gamma-4 mounted in its standard deployment cage, which provide protection during handling and simplifies mounting to larger structures or multi-instrument packages. The cage is constructed from acetal plastic end plates and type 316 stainless steel hardware and rods. The end caps are 12.7 cm square, and the height of the cage is 67.9 cm.

1.3 Electronics

Two photodiode preamplifiers process signals from the reference and signal photodiodes. The two circuits are identical, except that the signal preamplifier has much higher gain. For both the reference and signal measurements, the signals from the individual LEDs are separated from each other through digital synchronous detection.

A powerful logging computer and 128 MBytes (minimum) of nonvolatile flash memory allow the Gamma-4 to operate autonomously, when provided with a suitable battery or other power source, for profiling or long-term sampling without a real-time electrical connections to the surface.

A high-resolution multi-channel digital-to-analog converter sets the LED currents under the control of the controller, allowing the current to be trimmed for optimum signal levels and balance between the wavelengths. The currents to the LEDs are modulated and synchronized with the analog-to-digital conversions so that the signals from the LEDs can be digitally isolated from each other and processed separately, even though they share detectors and preamplifier electronics. All signals are digitized at 1000 samples per second and digital filtering is applied to minimize noise in the final outputs.

2 QUICK START

2.1 Setup

- Install HydroSoft on your computer. HydroSoft 2.87 or later is required.
- Connect the power/data interface (PDI) cable to the appropriate RS-232 serial port on your computer, or to a USB-Serial adapter, and to a source of 12 to 24 V.
- Connect the PDI's underwater connector to the Gamma-4.
- Run HydroSoft by selecting it on the Windows Start menu.
- Click (or select Connect from the Instrument Menu).
- Click the Search button.
- After a short time HydroSoft should identify the instrument, load its calibration, and close the Connect dialog box.
- Select Set Date/Time... from the Gamma-4 menu.
- Click Set Time to synchronize the Gamma-4 clock with your computer's clock. This will take a few seconds. Then click Close to close the Date/Time dialog box.

2.2 Collecting Data

- Select Sampling Options... from the Gamma-4 menu.
- For testing purposes, we recommend the following settings:

  Sample Rate: 1 per second

  Start Delay: 1 seconds

  Burst mode: unchecked
- Select Plot Vs. Time from the Graph menu.
- Click

(or select Start from the Gamma-4 menu). This will cause data to be logged in the flash memory as well as sent to HydroSoft.
- If no data are visible after a short time, click , and the plot will zoom as needed to show all data.
- To adjust the way data are displayed, double-click on the graph, or select Properties... from the Graph menu.

- Click (or select Stop from the Gamma-4 menu).
- Close the open data file by selecting Close from the File menu, or clicking on the ☒ button. If desired, save the file when prompted.

2.3 Downloading Logged Data

- Select Get Data From Instrument from the Gamma-4 menu.
- After several seconds a directory of casts in memory will appear. The last cast listed should be the one you just recorded. If that cast is not already highlighted, click on it to highlight it, or click the Select All button.
- Click the Browse... button to select a directory in which to save downloaded data files. In the resulting dialog box, select a directory and click the Select button.
- If it is not already checked, check the Create calibrated data (.dat) files option.
- Click the Download button to begin transferring data casts.

2.4 Disconnecting

- After you are finished communicating with the Gamma-4, select Disconnect from the Gamma-4 menu. If asked "Stop the Gamma-4's logging before disconnecting?" click Yes.
- Unplug the PDI cable from the Gamma-4.

3 OPERATIONAL DETAILS

3.1 Power and Data Interface

Power Supply

The Gamma-4 requires a power source of 10 to 24 V at 0.75 W typical, 1 W maximum. The exact power consumption depends somewhat on the choice of wavelengths, since different LEDs have different efficiencies. With 470 nm and 532 nm channels, power is typically 1.2 to 1.3 W over the entire supply voltage range.

In sleep mode (see section 3.3), current consumption is less than 100 μA at 12V.

Connector

Data and power connections are through a SubConn MCBH4M connector (mating connector: MCIL4F). Figure 2 shows the connector pin assignments.

1 – Common
2 – V+
3 – Receive
4 – Transmit

Figure 2. Face view of MCBH4M male connector

Power/Data Interface (PDI) Cable

The optional PDI cable connects to the 4-pin connector, and provides a DB9F for connection to an RS232 port or RS232-USB adapter. It also provides a pair of binding posts, and a female barrel connector, for supplying power.

Data interface

Commands and data are transmitted via RS232 (8 bits, no parity, 1 stop bit). The default baud rate is 57600 baud, with standard rates from 2400 to 115200 supported. In HydroSoft, the baud rate can be changed from the Gamma-4 menu. See section 4 for information about commands, and Section 5 for data formats.

3.2 Data Sampling and Logging

Data are logged in flash memory according to parameters set with HydroSoft's Sampling Options... command, or with the LOG firmware command (section 4.2.9). Data casts are started and ended by the START and STOP commands (sections 4.2.12 and 4.2.13). Depending on the LOG settings, a data cast may also be started each time power is applied to the instrument.

During casts, every sample saved in memory is simultaneously transmitted from the serial port, unless the /N (no logging) option is included in the START command (section 4.2.12).

Individual samples can also be requested with the D firmware command (section 4.2.3), or with the single character control-D. Samples requested this way are not logged.

3.2.1 Using Power to Control Logging

Note that if you terminate a cast by removing power from the instrument (instead of sending the STOP command), a small number of samples at the end of the cast may be lost. This is because the Gamma-4 buffers data in RAM before saving them to flash memory. Data in RAM will be lost when power is removed. Normally only 10 seconds of data are in the RAM buffer at any time, so that is the maximum that could be lost.

3.2.2 Averaging and Packet Timing

Gamma-4 collects and averages data internally at 1000 Hz, and the values transmitted and logged are averages of these rapid samples. In general, a packet is an average of all the values collected since the previous packet, and until the moment the current packet is sent. In other words, if it is logging data once per second, the value reported at time X is actually the average of the value over the times from X–1 to X seconds. The time value reported in the packet is X, the end of the sampling interval. For sample periods up to 8 seconds, all the rapid samples are given equal weight in the average. For longer periods, older samples are given gradually decreasing weight.

At the beginning of a data cast, older samples are flushed from the average so that the first packet reported will include the same number of averaged samples as subsequent packets.

3.3 Sleep Mode

In sleep mode, all activity is suspended and current consumption falls to about 100 μA, but all internal memory is preserved (flash memory is always preserved, with or without power, but RAM is not). For example, if you change the LOG settings without using STORELOG (see section 4.2.14), the settings will be preserved during sleep but not during full power-down.

Sleep mode is useful primarily within a multi-instrument system where an automated controller sends commands, or in a long-duration deployment where data are collected in bursts. If a logging cast is in progress at the time of sleep, it will resume upon the next wake,

3.3.1 Sleep-Wake Details

In sleep mode, all activity is suspended and current consumption falls to about 100 μA. Sleep is initiated with the SLEEP command (see section 4.2.11). During sleep all settings and state information are maintained in battery-backed memory. If a logging cast is in progress at the time of sleep, it will resume upon the next.

Sleep is ended by any activity on the serial port input, or by the real-time clock if a sleep time was specified with the SLEEP command.

3.3.2 Low-Voltage Sleep

To prevent over-discharging external batteries, the Gamma-4 has a programmable low-voltage threshold; if the supply voltage falls below the threshold, the Gamma-4 will go to sleep. You can adjust the threshold, or turn off this function, with the VSLEEP command (see section 3.3.2).

3.4 Deployment

3.4.1 Mounting

The Gamma-4 is normally contained in a protective cage, as shown in Figure 1. This cage provides protection during normal handling, and can also facilitate mounting the instrument to another structure or multi-instrument package. The stainless steel rods of the cage can be strapped or clamped anywhere along their length.

For lowering directly on a cable, the Gamma-4 has an eye on its top end cap t

but **never** leave the Gamma-4 standing unsecured and unattended.

3.4.2 Real-time cable connection

If your deployment cable has the necessary electrical conductors, you can power the Gamma-4 and communicate with it in real time, including controlling it with HydroSoft. However the limitations of typical electrical cables make this impractical for applications that exploit the Gamma-4's extended depth capability. To provide adequate power to the instrument, the cable's round-trip resistance must be 100 ohms or less, and real-time communication may require even lower resistance. This limits practical cables to at most a few hundred meters length and possibly much less. If you intend to use a real-time cable connection for deployment, always test the cable and instrument beforehand, in the deployment configuration.

3.4.3 Battery-powered deployment

To deploy the Gamma-4 without a real-time cable connection, you will need a suitable external battery (providing 12 to 24 V) and cable for connecting the battery to

the Gamma-4. With a special Y-cable, you can connect both the battery and a computer, which you can use to start and stop logging. A simpler approach is to set the Gamma-4 to automatically start a cast when power is applied, perhaps with a delay, and control logging by connecting and disconnecting the battery. See section 3.2.1 for an important note about this technique. Also see the LOG command in section 4.2.9.

3.5 Cleaning

Cleanliness of the windows is critical to the Gamma-4's measurements. Because it is sensitive to fractions of a percent change in light intensity, even a tiny speck of contamination can make a significant difference in the readings. Fortunately cleaning is not difficult, and the instrument's sapphire windows are difficult to damage.

The degree of cleaning required depends on the environment in which the instrument is operating, and the deployment routine.

The most basic, but one of the best, cleaning steps is to rinse the windows with generous quantities of distilled or deionized water. You should always finish your cleaning process with a pure-water rinse, and it is highly advisable each time the instrument is withdrawn from the water, so as to prevent substances from drying onto the windows. If the water you are measuring is among the clearest natural waters, this alone is probably sufficient cleaning between casts.

For more thorough cleaning and work in "dirtier" waters, you can use solvents including

- ethanol,
- dilute detergent solutions, and
- lens cleaners (such as part number NT54828 at http://edmundoptics.com).

For the most thorough possible cleaning, use each of these in the order listed, and follow with a pure-water rinse. In relatively clear water it is adequate to do such a thorough cleaning only once per day. In water rich with growth, sediment, or oily substances, more frequent use of solvents may be necessary, always followed with clean water.

NOTE: do not use acetone or other harsh solvents, which can attack the plastic retaining rings and o-rings.

4 FIRMWARE COMMANDS

The Gamma-4 is configured and controlled with commands sent via its serial communication port. When you use HydroSoft, the commands needed for routine operation are generated automatically and you do not need to know the details. However you can type commands manually and view the instrument's replies directly, via HydroSoft's terminal window or a generic terminal program.

4.1 Protocol

The Gamma-4 communicates through a standard RS-232 serial connection, with 8 data bits, no parity, one stop bit, and no handshaking. The default baud rate is 57600, but it can be set to other standard rates from 2400 to 115200 through HydroSoft or the BAUD command described in section 4.2.1.

With two exceptions, the Gamma-4 waits until it receives a carriage return and/or line feed before responding to a command. The exceptions are

- the control-C character, which cancels certain commands and prompts an immediate reply of `Cancelled` if a command was in progress, and `Ready` otherwise.
- the control-D character, which is equivalent to the D command (section 4.2.3).

When it is not actively logging data, the Gamma-4 retransmits each character it receives. Character echo is disabled during logging so that commands can be sent without affecting the output data stream.

Commands are not case-sensitive. They are shown in upper case in this document simply for clarity.

Some commands accept arguments, which are separated from the base command, and from each other, by commas or spaces. That is, `COMMAND,arg1,arg2` is equivalent to `COMMAND arg1 arg2`. Arguments may be individually omitted if commas are used as placeholders for them. For example, if a command accepts three arguments, in the form `COMMAND,arg1,arg2,arg3`, you may adjust only *arg3* by entering `COMMAND,,,arg3`.

4.2 Common Commands

4.2.1 BAUD *newrate /S*

Reports the current baud rate of the instrument. If a valid *newRate* is specified (2400, 4800, 9600, 19200, 38400, 57600 or 115200), the rate will immediately change, unless the /S switch is included. If /S is included, *newRate* will be saved as the default rate to be used when the instrument is next reset..

Note that, because of the time required to transmit data packets, lower baud rates may limit the maximum sampling rate.

4.2.2 CLEARLOG

Deletes all cast files from flash memory, and resets the cast number to 1. Because this will result in permanent loss of data, the firmware asks for confirmation before proceeding. Deleting large and numerous files can take up to several minutes.

4.2.3 D

Sends a packet with the most recently collected data (averaged over the time since the previous packet was sent), in the format specified by the DATAFORMAT command. Note that a single control-D character can also be used to trigger the same response.

4.2.4 DATAFORMAT *formatNumber*

Sets the format of packets that will be sent during logging, cast downloads, and in response to the D command. As of firmware 1.00, formatNumber can either be 0 to indicate a “brief” packet or 1 to indicate a “full” packet (see section 5.1 for details).

4.2.5 DELCAST *castNumber*

Deletes the given cast (does not prompt for confirmation). Does not affect the current cast counter.

4.2.6 DIR /R *startCast endCast*

Displays a directory of the casts in flash memory, including their start times, durations and number of samples. If /R is specified, all casts will be listed in reverse order. If *startCast* and *endCast* are specified, only casts within that range of numbers will be listed. Do not use /R together with *startCast* and *endCast*; specify *endCast* less than *startCast* to display a range of casts in reverse order.

To cancel listing of a long directory in progress, send the control-C character.

4.2.7 DOWNLOAD *castNumber*

Sends the data from the given castNumber, if any, in the current data format.

4.2.8 ID

Displays identifying information about the instrument and its configuration. This is automatically used by HydroSoft when it connects to an instrument.

4.2.9 LOG *period delay startOnPower*

Displays the current logging settings, and changes them if valid values are provided. *Period* is the number of seconds between samples (which has a minimum value of 0.1). *Delay* is the number of seconds the first sample will be delayed after logging is initiated (not implemented in firmware version 1.00). If *StartOnPower* is set to 1, a cast will start automatically when power is first applied to the instrument. This is particularly useful for battery-powered deployments, as described in section 3.4.3.

NOTE: changes you make to the LOG parameters will not be retained when power is removed from the instrument, unless you use the STORELOG command (section 4.2.14) to make them permanent.

4.2.10 SENDCAL

Sends the entire contents of the instrument's internal cal file, if any, through the serial port.

4.2.11 SLEEP *seconds*

Sends the instrument into its low-power sleep mode. Logging and any other activities are stopped during sleep. If *seconds* is specified, the sleep will end after that time interval has passed. Otherwise it will sleep until woken by serial port activity.

4.2.12 START /N

Starts logging with the current log settings, using the next sequential cast number. If the /N switch is included, data will not be logged in memory, only transmitted through the serial port, and the cast number will remain unchanged.

4.2.13 STOP

Stops the current logging cast, if any.

4.2.14 STORELOG

Stores the parameters of the LOG command (section 4.2.9) in nonvolatile memory.

4.2.15 VER

Displays the installed firmware version.

4.2.16 VIN

Displays the input supply voltage to the instrument. The voltage reported will be slightly lower than the actual applied to the connector, because it is measured after the voltage passes through a protection diode. This is the same voltage that is reported in full data packets.

4.2.17 VSLEEP *voltage*

Display the supply voltage sleep threshold. If the input supply voltage falls below this value, the instrument will go into indefinite low-power sleep. This is intended to protect external batteries from overdischarge. To turn off this function, set the voltage to 0. For more about sleep functions, see section 3.3.

5 DATA PROCESSING REFERENCE

5.1 Data Formats

Data are transmitted in raw comma-separated decimal ASCII, with the following parameters:

time,signal1,signal2,signal3,signal4,reference1,reference2,reference3,reference4,pressure,temp1,temp2,temp3,Vin,bgnd,smin, smax, rmin, rmax, N

- **Time** is in seconds since midnight Jan 1, 1970, sometimes called "UNIX time."
- **Signal1** through **signal4** are raw digital counts measured by the signal detector from the two optical channels.
- **Reference1** through **Reference4** are the signals measured by the reference detector before the beam enters the water.
- **Pressure** is the raw digital reading of the pressure transducer.
- **Temp1**, **temp2** and **temp3** are temperatures measured at three different places within the instrument (not water temperature). The reported values are 100 times the actual temperature in C.
- **Vin** is the supply voltage input, in mV.
- **Bgnd**, **Smin**, **Smax**, **Rmin** and **Rmax** are state-of-health indicators showing the signal levels at different parts of the circuitry.
- **N** is the number of samples averaged to produce the packet. Normally this will be 1000 times the sample period in seconds.

If you use the DATAFORMAT command to set the data format to 0, a briefer version of the above is produced, which is identical except that it ends after temp3. The brief packets are sufficient for producing calibrated data, so you can speed downloads of large data files by selecting this format. The default DATAFORMAT setting is 1, producing the full packet shown above.

5.2 .RAW File Format

HydroSoft's .raw files start with a header similar to the following, but the exact contents or sequence of the header are not guaranteed to remain the same in all versions of HydroSoft.

```
[Header]
HydroSoftVersion=2.80
CreationDate=04/10/10 14:49:43
FileType=raw
DeviceType=Gamma-4
DataSource=G4100100
CalSource=Gamma-4
Serial=G4100100
Config=100
[EndHeader]
```

Following the header is a complete record of every byte received from the instrument. This will include data packets but may include other informational messages. In the following example, the "START" command sent by HydroSoft is echoed by the instrument, which also announces the start and end of the cast:

```
START
Starting cast 6 in 2 seconds.
1274885398.44,1,2,0,0,5588,-1938,-2278,2325,1117,12511,-23402,-
22826,-22015,-21489,504
1274885398.94,1,3,-1,1,5601,-1933,-2273,2325,1117,12511,-23404,-
22827,-22014,-21483,500
1274885401.94,0,-1,-1,0,5592,-1936,-2277,2326,1117,12513,-23399,-
22794,-22012,-21487,500
Stopped cast 6.
```

5.3 .DAT File Format

HydroSoft .dat files start with a header similar to the following. As with the raw header, the exact contents and format are not guaranteed, but the [Channels] and [ColumnHeadings] heading will remain the same. The [Channels] heading announces the names of the primary optical data from the instrument, as displayed in the legends of HydroSoft's graphs, listed one per line. The line following [ColumnHeadings] is a comma-separated list of the names of the parameters listed in the data lines.

```
[Header]
HydroSoftVersion=2.81
CreationDate=04/10/10 14:49:43
FileType=dat
DeviceType=Gamma-4
DataSource=Gamma-4
CalSource=Gamma-4
Serial=G4100100
Config=100
```

```
[Channels]
"c442"
"c470"
“c590”
“c700”

[ColumnHeadings]
Time,Depth,c442,c470,c590,c700,IntT

[Data]
```

After the [Data] heading, lines of comma-separated data will appear, containing the parameters listed under [ColumnHeadings], for example:

```
40324.6180722222,2.38790,0.201,0.152,0.1032,0.2018,22.83
```

- **Time** is expressed as the number days since the start of January 1, 1900, which is the native format of Microsoft Excel. The time of day, including fractions of seconds, is included in the fractional part of this number.
- **Depth** is in meters.
- **c1** through **c4** are the calibrated attenuation coefficients at the two wavelengths of the Gamma-4.
- **IntT** is the internal temperature of the Gamma-4, in C.

5.4 Calibration Formulas

The following formulas support compensation for several possible effects related to temperature and pressure. Depending on the characteristics of the individual instrument, some portions of the processing may be “turned off” by setting the applicable coefficients to zero in the factory calibration file.

5.4.1 Depth

Offset-adjusted pressure reading:

$$P(T) = P - P_0 - p(T) + p(T_{P0})$$

where P is the raw pressure reading direct from the instrument (in counts) and the temperature-related offset is

$$p(T) = k_{p1}T + k_{p2}T^2$$

Calibrated depth in meters of sea water:

$$D = k_{D1}P(T) + k_{D2}\left(P(T)\right)^2$$

5.4.2 Attenuation

Transmission adjusted for temperature and pressure:

$$\tau(T,P) = \left(\frac{S - S_0}{R - R_0} \right) \Big/ a_T(T) a_P(P)$$

where

T is the instrument's internal temperature in C,

P is the temperature-adjusted pressure reading $P(T)$ in digital counts,

$$a_T(T) = \sum_{n=0}^{5} k_{Tn} T \ ,$$

and

$$a_P(P) = \begin{cases} 1, & P < P_1 \\ 1 + k_{\tau PX} \dfrac{(P - P_1)}{P_2 - P_1}, & P_1 \le P \le P_2 \\ \left(1 + k_{\tau PX}\right) \displaystyle\sum_{n=0}^{5} k_{\tau Pn} P, & P > P_2 \end{cases}$$

where P_1 and P_2 are values of $P(T)$.

The fully calibrated attenuation coefficient is given by

$$c = \ln\left(\frac{\tau(T_{PW},0)}{\tau(T,P)} \right) \frac{1}{L}$$

where

L is the path length in meters

$\tau(T_{PW},0)$ is the transmission measured in pure water, at temperature T_{pw} and atmospheric pressure.

5.5 Calibration File Format

The calibration file, whether stored in the instrument or on the computer running HydroSoft, is a plain text file in the following format. The sequence of parameters is not guaranteed, and it is possible additional parameters could be added in future versions. Therefore any software that reads the file should identify parameters by their labels, not

their sequence. Also, parameters whose value is zero may be omitted. Table 1 shows the plain-text names used in the calibration file for the terms in the formulas above.

Any line in the calibration file may also include a comment after the parameter value, marked with a double-slash (//).

```
[General]
DeviceType=Gamma-4    // Saved by HydroSoft 2.80
Serial=C2100000
Label=HOBI
Config=100
MaxDepth=6000
CalTime= 1270080000 (04/01/10)

[Depth]
kp1=10.215
kp2=-0.1624
P0=1439
TP0=26.68
kD1=0.3619
kD2=0

[Attenuation 1]
Name=c470
Lambda=470
DeltaLambda=10
L=1.005
S0=-3
R0=0
kT0=0.9926
kT1=0.0031851
kT2=-0.0002447
kT3=4.8421e-6
kT4=0
kT5=0
P1=50
P2=103
kTauPX=0.1188
kTauP0=.66
kTauP1=1.0771e-5
kTauP2=-7.6957e-10
kTauP3=1.1615e-14
kTauP4=0
kTauP5=0
Tau0=1.00167
TPW=20.77

[Attenuation 2]
<Same format as Attenuation 1>

[End]
```

Table 1. Parameters as Named in the Calibration File		
Term	**Name in Cal File**	**Description**
k_{p1}, k_{p2}	kp1, kp2	Coefficients for temperature-related change in pressure offset
P_0	P0	Raw pressure reading at atmospheric pressure and temperature T_{P0}.
T_{P0}	TP0	Temperature at which P_0 was measured.
k_{D1}, k_{D2}	kD1, kD2	Coefficientss for conversion of digital counts to meters of sea water.
L	L	Path length in meters
S_0	S0	Raw signal with path blocked
R_0	R0	Raw reference with LED disabled
k_{T0}…k_{T5}	kT0…kT5	Transmission temperature coefficients
P_1, P_2	P1, P2	Pressure thresholds, in temperature adjusted counts, for $a_P(P)$
$k_{\tau PX}$	kTauPX	Coefficient of linear pressure correction $a_P(P)$
$k_{\tau P0}$… $k_{\tau P5}$	kTauP0…kTouP5	Coefficientss for polynomial pressure correction in $a_P(P)$
τ_0	Tau0	Temperature-compensated transmission in pure water, at atmospheric pressure.
T_{PW}	TPW	Temperature at which τ_0 measured.

6 MAINTENANCE, SERVICE AND SUPPORT

6.1 Maintenance

For best accuracy and to provide the longest life for your Gamma-4, we recommend you return it annually to HOBI Labs for maintenance and calibration.

Cleaning is the most important maintenance for users to perform. Cleaning of the windows, which affects measurement accuracy, is described in section 3.5. Overall cleaning is also important for protecting instruments against corrosion. Rinse the entire instrument thoroughly with fresh water after each use in salt water. Be sure the Gamma-4 is dry before packing it for extended storage.

6.2 Service and Support

For help and advice regarding the operation of your Gamma-4, contact HOBI Labs at support@hobilabs.com, or call our office at (520) 299-2589. You can also download manuals, software and other technical information from our website, www.hobilabs.com.

6.3 Equipment Return

To return your Gamma-4 to HOBI Labs for any reason, first contact us for a returned material authorization (RMA) number. You can fill out an RMA request form at our web site, or email us directly at support@hobilabs.com. The RMA is very important for tracking your equipment. Please be prepared to provide us with the instrument serial number, the address to which it should be returned after service, and any special requests. Upon issuing the RMA we will send you shipping instructions.

After we receive the equipment, we will inspect and test it, and send a description and cost estimate for any service required. We will not proceed with service until we receive your authorization for the cost.

Always ship your instrument in its original container, which is designed to protect it against rough handling.