# *Operating Manual*

Multiple Path Acoustic Flowmeter for Remote Areas

***KERN Elektronik AG***
*Measuring technology & electronics*
*Kammistrasse 11*
*CH- 3800 Interlaken*
*Switzerland*
*Tel + 41 33 823 74 04*

*http://www.affra.com*
*email: info@affra.com*
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# Procedure for Planning and Starting a Flow Measuring Project

## The Feasibility Study

**Requirements:**

Optional:
- Answered questionnaire

Essential:
- Cross-section
- Minimum stage
- Maximum stage
- Maximum velocity;
- Overview map of the geographical situation at least 2 km upstream and downstream
- Possible power supply

Desired results:
- Accuracy
- Data storage
- Data display
- Data transmission
- On line control of gates, control of stage, velocity or discharge
- Control of Wet / Dry – condition

The feasibility study is free of charge and without any obligation to either side. The purpose is to ensure that after the installation reliable data can be expected, and that no expensive exercises of any kind are undertaken before feasibility is most likely. After a positive result of the study, Stedtnitz Maritime Technology Ltd. will warrant the hardware for two years.

We are not liable for any other expenses such as the cost for auxiliary material, cable or labor cost.

## Planning

The planning items are already considered in the feasibility study. During the planning phase these items shall be finalized with the signed agreement of the customer.

### Hydraulic planning

All of the possible changes regarding the physical parameters of the site must be considered. Some include:

- Maximum and minimum velocities
- Maximum and minimum stage levels
- Turbidity
- Weed
- Turbulence
- Air entrainment
- Ice cover
- Worst case condition exercise
- The proposed positions of the transducers relative to the cross-section.
- What safety rules apply for ships traffic?
- Danger of vandalism?
- The proposed transducer cable routing.
- Lightning protection and grounding considerations
- A Survey of the trans-section (position of acoustic line under proposed angle crossing the river).
- The projection of the trans-section in the direction of the flow identical to the cross-section.
- Property rights, Government rules and laws, community bylaws.

The housing for the electronic units, including:

- Flow Meter
- Modem
- Data logger
- Battery
- Power supply [Battery, Solar, etc…]
- Surge arrestors

Preparing a list of material to be purchased:
A 12V-battery is always required, trickle charger necessary for 120V or 240VAC main power supply. Install surge arrestors for main power and phone line if applicable.

Cost estimate of material and labor cost

For better accuracy a computer simulation of the river might be necessary at extra cost. This is sometimes, not always required for accuracy better than 3%. It applies always for channels with vertical piers. (Rolling vortexes)

Usually the planning can be accomplished by visual inspection of the site and with a short meeting with customer officials to finalize the plan.

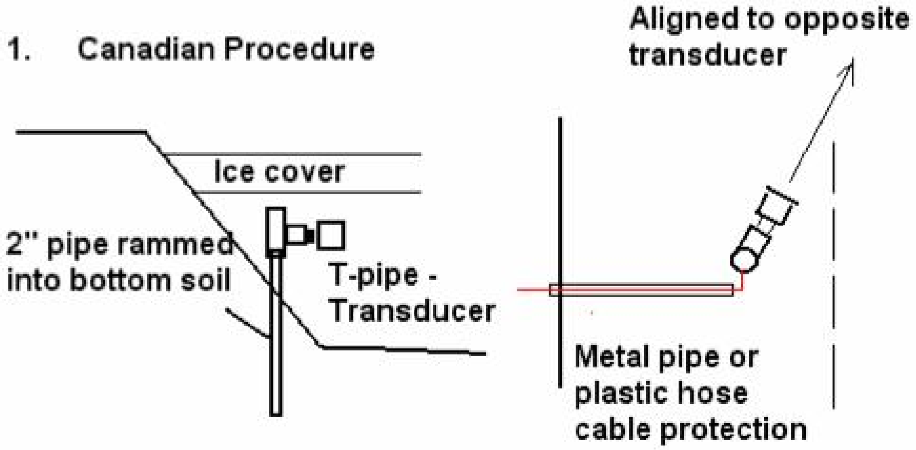
# Deltaflex Specifications

| | Metric | USA Standard |
|---|---|---|
| **Velocity Measurement** | | |
| o Range | -10 m/s … 0 m/s ... +10 m/s | -32 ft/s … 0.0 ft/s … +32 ft/s |
| o Resolution | 1 mm/s | 0.003 ft/s |
| o Repeatability | +/- 1 mm/s at > 7m path length | +/- 0.003 ft/s at > 26 ft PL |
| o Accuracy | +/-2 % | |
| o Max | +/-10 m/s (unless limited by acoustic conditions) | 32 ft/s |
| **Discharge Measurement** | | |
| o Accuracy | +/- 2% as compared with a conventional current meter | Provided programmed parameters match the site condition. |
| **Stage Measurement** | | |
| o Resolution | 1 mm/s | 0.003 ft/s |
| o Repeatability | +/- 2 mm | +/- 0.006 ft/s |
| o Accuracy | +/- 2 mm (within the full temperature and salinity range) | +/- 0.006 ft/s |
| **Temperature Measurement** | | |
| o Resolution | 0.01ºC | |
| o Accuracy | 0.05ºC | |
| **Salinity Measurement** | | |
| o Resolution | 1 ppt | |
| o Accuracy | 1 ppt | |
| **Velocity of Sound Meas.** | | |
| o Range | 1350 m/s to 1600 m/s | 4430 ft/s to 5250 ft/s |
| o Resolution | 0.001 m/s | 0.003 ft/s |
| o Repeatability | +/- 1mm/s at > 10 m path length | +/- 0.003 ft/s at > 26 ft PL |
| o Accuracy | as accurate as initial programming | |
| **Mechanical Dimensions** | | |
| o Size | 100 mm x 200 mm x 200 mm | 4 in x 8 in x 8in |
| o Weight | 2.6 kg | 6 lbs. |
| **Electrical Specifications** | | |
| o Nominal Power | 2.0 W [ 170mA@12V ] | |
| o Sleep Mode Power | 0.12 W [ 10mA@12V ] | |
| o Maximum Voltage | 32 V | |
| o Cut-Off Voltage | 10 V | |
| **Lightning Protection** | | |
| o Transducer lines | 350 V Cut-Off, 2 * 20000A | |
| o Power line | Cut-Off at >32 V | |
| o Data line | +/- 15V | |
| o SDI line | +5.2V/-0.7V | |
| **Transducer Specifications** | | |
| o Beam Width | +/- 10 degrees | |
| o Length | 50 mm | 2 in |
| o Max Cable Length | 1000 m | 3000 ft |
| o Recommended Cable | Shielded twisted pair at 100 Ohms *For example, Carol #C1202VW-1* | |

# DELTAFLEX

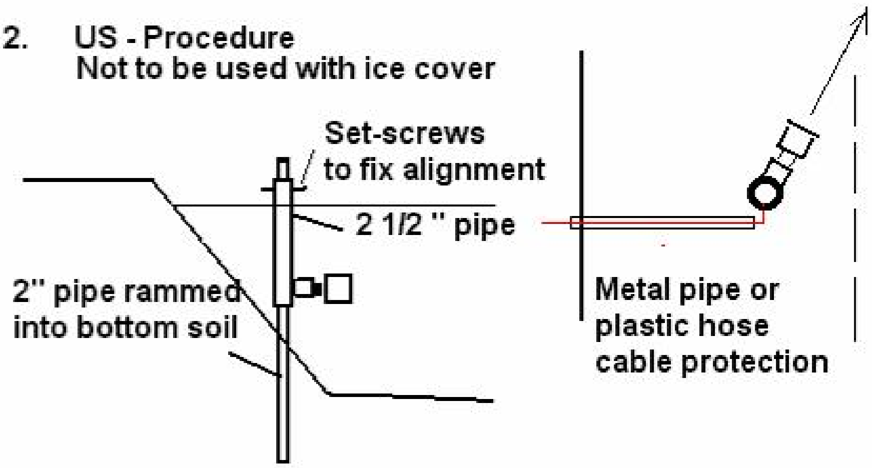
## TRANSDUCER MOUNTING PROCEDURES

### 1. Canadian Procedure

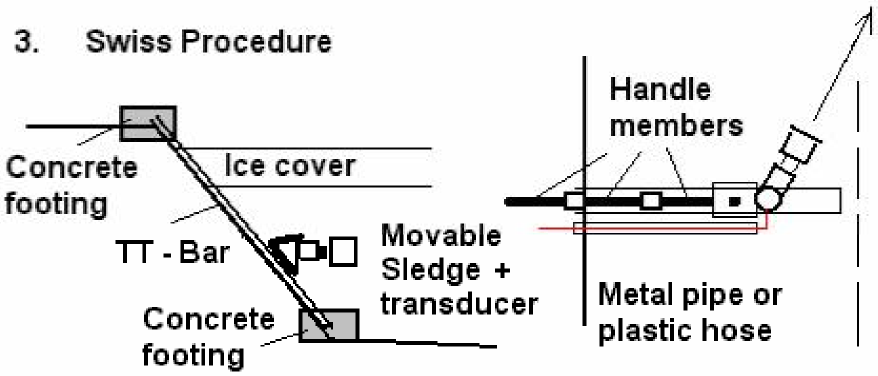



### 2. US - Procedure

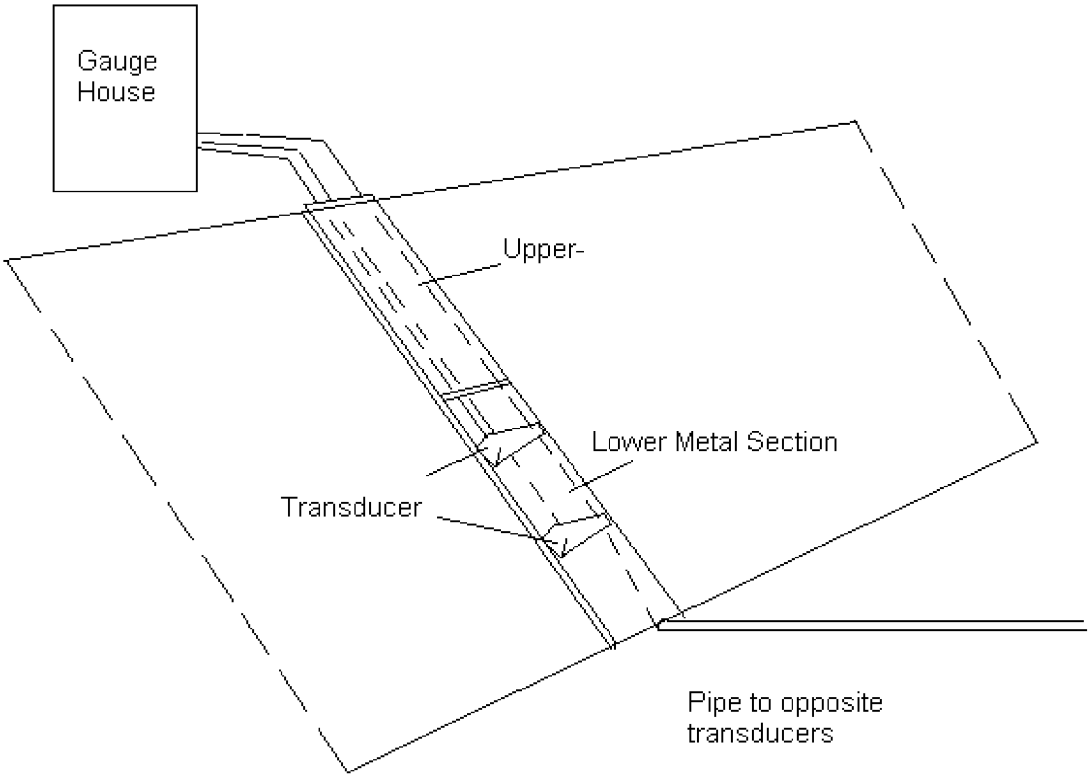
Not to be used with ice cover




### 3. Swiss Procedure

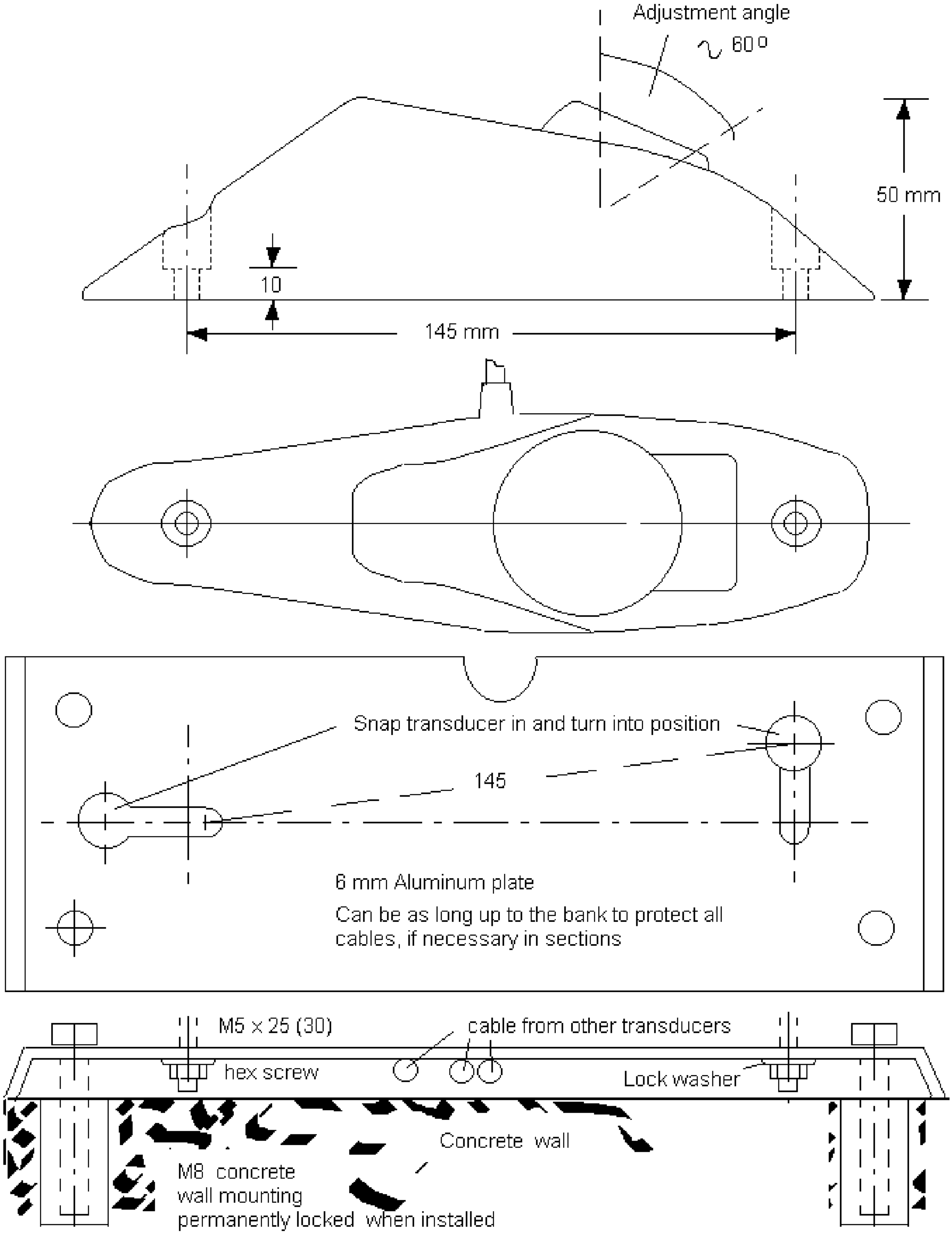


## Streamlined Transducer Mounting

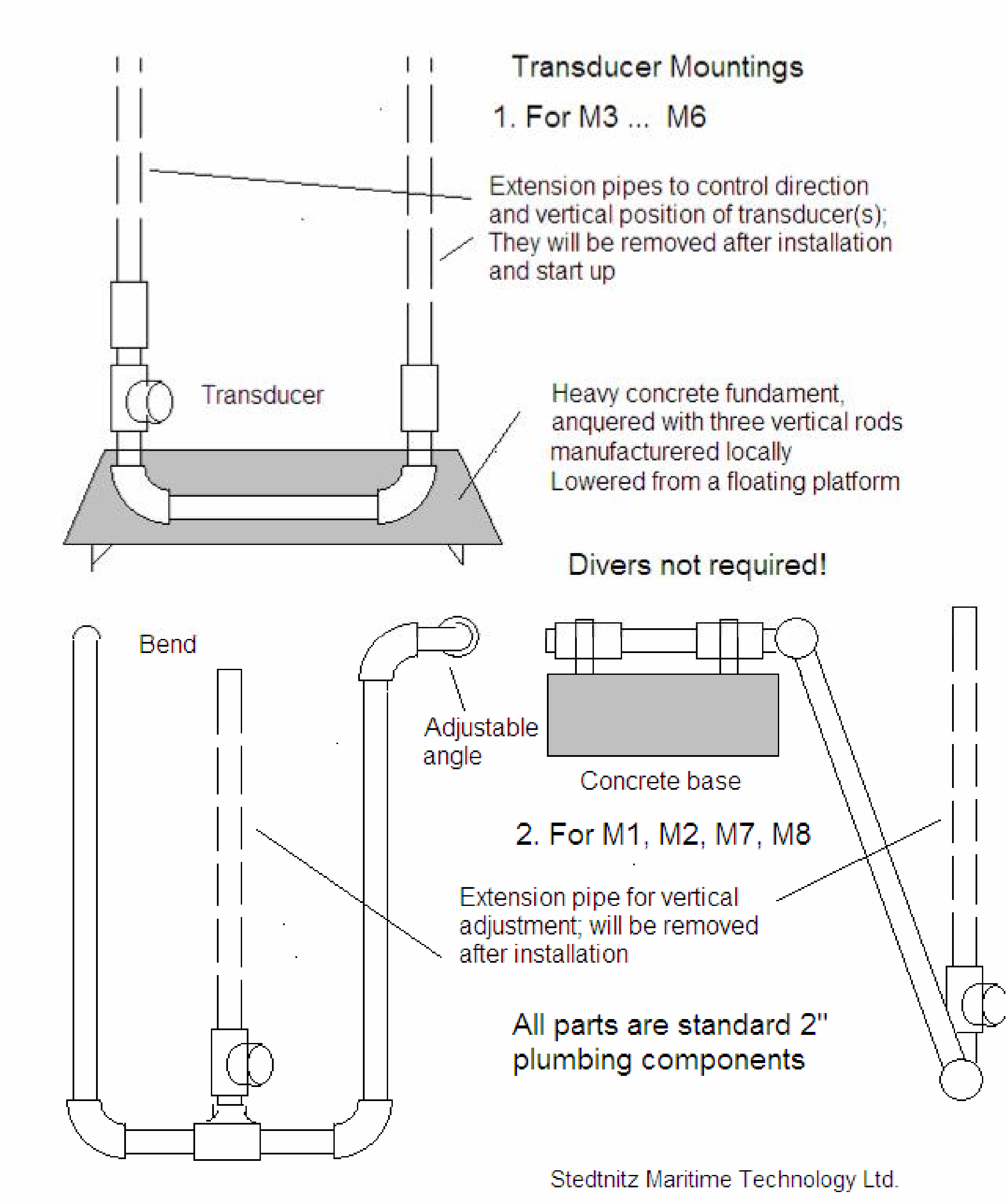


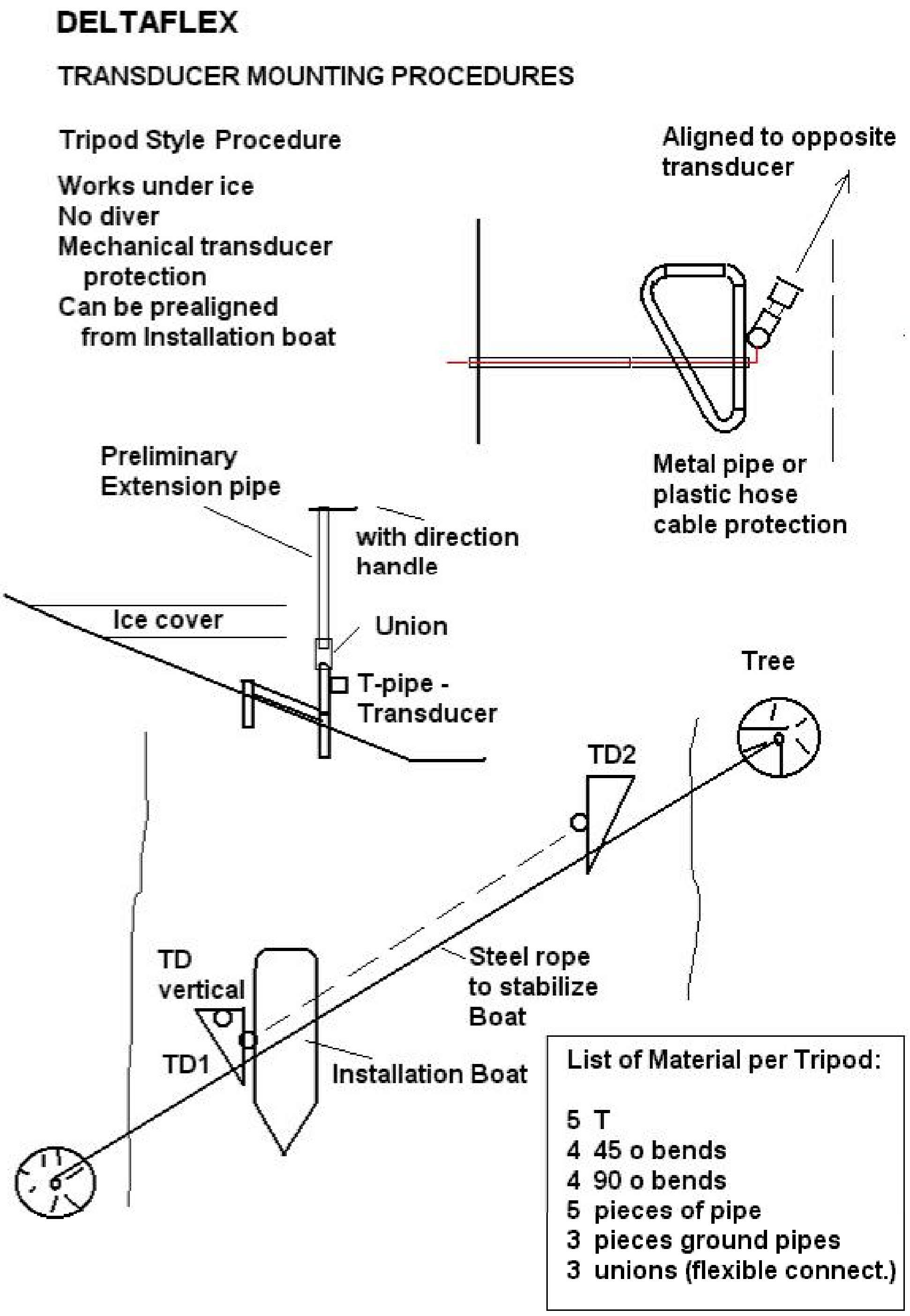

Schematic View of Installation

## Proposed Details of Streamlined Transducer Mounting



## Installation Example with 2 inch Plumbing Pipes



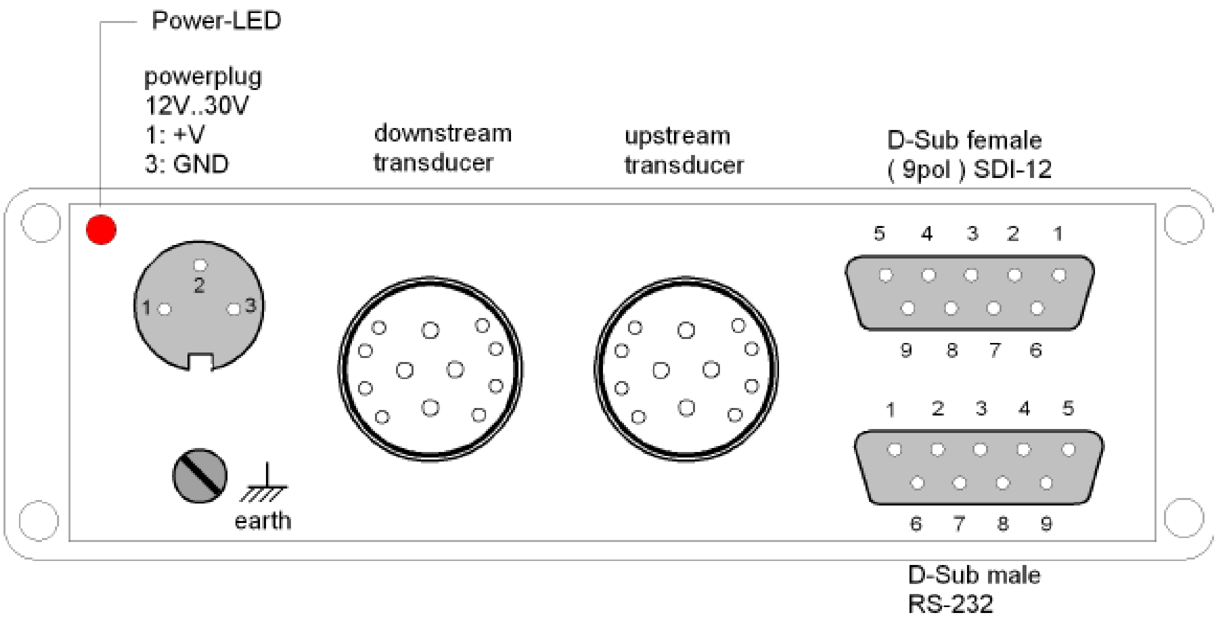

DELTAFLEX
TRANSDUCER MOUNTING PROCEDURES
Tripod Style Procedure
Works under ice
No diver
Mechanical transducer protection
Can be prealigned from Installation boat
Aligned to opposite transducer
Metal pipe or plastic hose cable protection
Preliminary Extension pipe
with direction handle
Ice cover
Union
T-pipe - Transducer
Tree
TD2
TD vertical
TD1
Steel rope to stabilize Boat
Installation Boat
List of Material per Tripod:
5 T
4 45 o bends
4 90 o bends
5 pieces of pipe
3 pieces ground pipes
3 unions (flexible connect.)

# *A Basic DeltaFlex™ Setup*

## Connecting the required cabling

- power
- RS-232 or SDI-12
- Upstream transducer
- Downstream transducer

| **RS-232:** | **SDI-12:** | **Transducer:** |
|---|---|---|
| RxD pin 2 | Data pin 1 | Channel 1: pin G – F |
| TxD pin 3 | | Channel 2: pin H - E |
| GND pin 5 | GND pin 7 | Channel 3: pin A - D |
| | | Channel 4: pin B – C |
| Mandatory for temperature measurement | | Shield: pin J, K, L, M |




## Step 1: Initializing the Deltaflex

Because extensive testing is done before the Deltaflex is shipped, there still may be test parameters stored in memory. To clear the leftover parameters from memory the system must be reset.

o From the MAIN MENU press '1' to enter the PARAMETER ENTRY MENU.
o Press '1' to reset the Deltaflex. It will ask you to enter 'Y' to reset or 'N' to cancel.
o After the Deltaflex has been reset, focus will return to the MAIN MENU and the clock will begin at 00:00:00.

After the reset has been initiated, the parameters can be entered. Some of the dimensional parameters such as path length and stage require a searching routine. During the installation, the approximate length and depth of all acoustic paths should be recorded. The basic rule can be remembered as: if it has a dimension, record it. The set up that follows is the basic requirement for a one path system. For additional paths, the set-up simply has to be repeated for each path. The Deltaflex can handle up to four independent paths.

## Step 2: Initializing the Global Parameters

Some values, such as the Velocity of Sound, are common to all of the Deltaflex channels. These options must be entered, or selected first. The absolute first step after a reset is the preliminary temperature calculation [*If applicable, the temperature sensor is located in the 'Red Faced' transducer*].

To Calculate the Water Temperature:

- From the MAIN MENU press '1' to enter the PARAMETER ENTRY MENU.

- From the PARAMETER ENTRY MENU press '5' to enter the MEASUREMENT PARAMETER MENU, from this menu press 'A' to calculate the temperature. After a few seconds the MEASUREMENT MENU will roll over. The temperature will be displayed at the top of the screen (If a temperature sensor was not installed, **Temperature Not Found** will be displayed).

When the temperature of the water is known, the **Velocity of Sound as a Function of Temperature and Salinity** chart at the back of this manual can be used to determine the proper velocity of sound to enter.

In fresh water the salinity can be assumed to equal zero, but if the system is installed in a river susceptible to tides, or carrying a substantial amount of fertilizer, the salinity must be taken into account. For example, if the water temperature is calculated as 7.67ºC in a fresh water stream, the velocity of sound would be entered as 1437.500m/s. If the temperature was calculated to 7.67ºC again but the salinity was known to be 20 ppt, the velocity of sound would be entered as 1462.300m/s.

Once the velocity of sound is entered, the Deltaflex will track the salinity and the velocity of sound continually.

## Step 3: Entering the Velocity of Sound

- From the MAIN MENU press '1' to enter the PARAMETER ENTRY MENU.
- From the PARAMETER ENTRY MENU press '5' to enter the MEASUREMENT PARAMETER MENU, from this menu press '1' enter the velocity of sound. The velocity of sound is entered as a decimal value, i.e. 1457.678. The unit is meters per second unless USA Standard is selected as the unit base.

## Step 4: Selecting the Stage (Vertical) Transducer

The stage measurement relies on the calculated velocity of sound. The method used to make this calculation involves reflecting an acoustic pulse against the surface of the water. The amount of time required for the entire trip is divided by two and multiplied by the velocity of sound.

**Important**
The stage (vertical) transducer must be connected in parallel with either the upstream, or downstream transducer of CHANNEL 1.

To select the location of the stage transducer:

- From the MAIN MENU press '1' to enter the PARAMETER ENTRY MENU.
- From the PARAMETER ENTRY MENU select '2' and wait for the operation to finish. When the measurement has been completed the following screen will be displayed:

```
STAGE TRANSDUCER SELECTION MENU

(1)Td up (2)Td dn
+1.418   +0.000
+1.419   +0.000
+1.418   +0.000

3: Repeat Calculation
4: Exit
```

- Select '1' then '4' and press enter if the stage transducer is connected to the upstream transducer of channel 1, otherwise select '2' then '4' and press enter. If you wish to repeat the measurement, select '4' and press enter.

## Initializing the Channel Specific Parameters

When all of the required global parameters have been initialized, the values which are specific to each channel can be entered. All of the steps which follow can be repeated for each of the extra paths installed by the user.

## Step 5: Calculating and Selecting the Path Length

The path length represents the consistent distance from the face of the upstream transducer to the face of the downstream transducer. The transit time between the upstream and downstream transducers will vary depending on the temperature and salinity of the water, but is compensated for via the calculated velocity of sound.

To calculate the path length for a selected channel:

- Select '1' to enter the PARAMETER ENTRY MENU, from this menu select either '5', '6', '7' or '8' to enter the CHANNEL PARAMETER MENU. The parameters are identical for each channel.

- From the CHANNEL PARAMTER MENU select '1' and press return to enter the PATH LENGTH CALCULATION MENU.

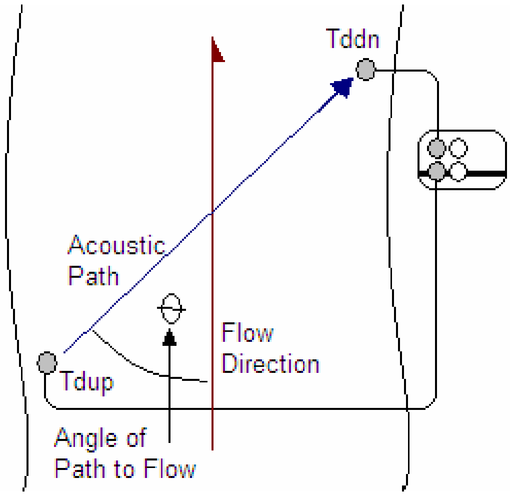
```
CHANNEL 1 PATH LENGTH SELECTION MENU
Path Length: NOT CALCULATED

 0:    7m to 10m        1:    10m to 20m        2:    20m to 30m
 3:   30m to 40m        4:    40m to 50m        5:    50m to 60m
 6:   60m to 70m        7:    70m to 80m        8:    80m to 90m
 9:   90m to 100m      10:   100m to 110m      11:   110m to 120m
12:  120m to 130m      13:   130m to 140m      14:   140m to 150m
15:  150m to 160m      16:   160m to 170m      17:   170m to 180m
18:  180m to 190m      19:   190m to 200m      20:   200m to 210m
21:  210m to 220m      22:   220m to 230m      23:   230m to 240m
24:  240m to 250m      25:   250m to 260m      26:   260m to 270m
27:  270m to 280m      28:   280m to 290m      29:   290m to 300m
30:  300m to 310m      31:   310m to 320m      32:   320m to 330m
33:  330m to 340m      34:   340m to 350m      35:   350m to 360m
36:  360m to 370m      37:   370m to 380m      38:   380m to 390m
39:  390m to 400m      40:   400m to 410m      41:   410m to 420m
42:  420m to 430m      43:   430m to 440m      44:   440m to 450m
45:  450m to 460m      46:   460m to 470m      47:   470m to 480m
48:  480m to 490m      49:   490m to 500m
50:  Enter Path Manually
51:  Exit to Channel Parameter Menu
PL >
```

- Select the value from this menu which best represents the length of the acoustic path. For example, if the path length was approximately 73.4 meters, the user would enter '7' since this range represents 70 to 80 meters. A few seconds will be required to complete the measurement.

If the exact path length is known, it can be entered by selecting option '50' and pressing enter; the path length is entered in millimeters. To exit the menu, type '51' and press return.

## Step 6: Entering the FB Value

The FB value represents the angle of the acoustic path to the flow of the river. This value is essential and must be entered.




The FB is calculated by using the following formula:

**FB = 2048/cos ?**

For example, if the acoustic path was at an angle of 34° to the average flow of the river, the FB would equal 2470.

To enter the FB:

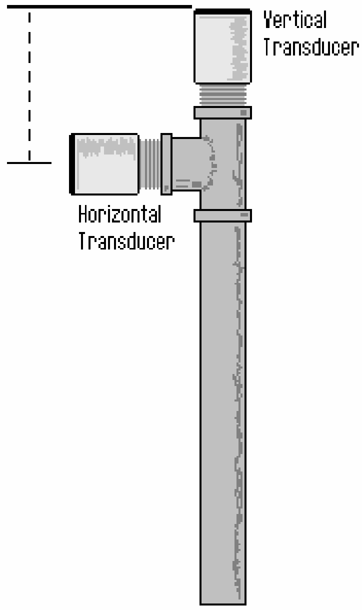
- Select '1' to enter the PARAMETER ENTRY MENU, from this menu select '5','6','7' or '8' (Depending on which path) to enter the CHANNEL PARAMETER MENU.

- From the CHANNEL PARAMETER MENU, select '2' to enter the FB value.

## Step 7: Entering the Vertical Transducer Face to Horizontal Path Offset

This option is required, by the Deltaflex, to determine the exact position of the reflected pulse. The distance between the face of the vertical (stage) transducer and the top of the horizontal transducer should be recorded during the installation process.

As an example, if the vertical transducer was 105 mm closer to the surface than the horizontal transducer, -105 would be entered. If the vertical transducer was the same distance, but below the horizontal transducer, +105 would be entered.




To enter the vertical transducer face to horizontal path offset:

- Select '1' to enter the PARAMETER ENTRY MENU. From this menu, select '5' to enter the MEASUREMENT PARAMETER MENU.
- Select '4', a prompt will ask for the offset. The offset must be entered in millimeters.

## Step 8: Entering the Discharge Array

This option is not mandatory, but if a discharge measurement is required, an array representing the cross-sectional area at different depths must be entered.

To enter the discharge array:

- Select '1' from the MAIN MENU to enter the PARAMETER ENTRY MENU. Once in this menu, select '5' to enter the MEASUREMENT PARAMETER MENU.
- Depending on which channel is being modified, select either '5', '6', '7' or '8' to enter the CHANNEL PARAMETER MENU. Press '5' to enter the X, Y array entry. The following menu will appear:

```
X AND Y DISCHARGE ARRAY ENTRY

X Array: 0 0 0 0 0 0 0 0 0 0
Y Array: 0 0 0 0 0 0 0 0 0 0

1: Enter X Array Entries
2: Enter Y Array Entries
3: Exit
A>
```

- Select '1' from this menu to enter the X array values and '2' to enter the Y array values. Enter '3' to exit from this menu.

## Step 9: Selecting a Measurement Output Method

The Deltaflex provides many different options for displaying and logging measurements, these methods include: SDI-12, clock controlled [internally logged], 4 to 20mA current output [additional board required], velocity controlled relay contact [additional board required]. The measurement output selection will depend on the application. A typical measurement output vehicle is SDI-12 since the Deltaflex can integrate seamlessly with other sensors on an SDI-12 bus.

The internal data logging option is gaining popularity due to the over-all cost reduction, and the high storage capacity of the Deltaflex.

The *Velocity Controlled Relay* option can be used to complete an external circuit if the velocity is above, or below a user set threshold. This method is effective for controlling gates or high current loads (MAX Current needed).

The *Analog Current Output* option allows the user to display either the velocity, stage, or discharge as a DC current within the range 4 to 20mA. The Deltaflex can output two independent DC current values.

## Step 10: Configuring the Deltaflex for SDI-12 Output

- Select '1' from the MAIN MENU to enter the PARAMETER ENTRY MENU. Once in this menu, select '6' to enter the SDI-12 Parameter Menu.

- From the SDI-12 PARAMATER MENU, the user can select either: '1', '2', '3' or '4' to select which measurements to output for the selected channel.

- Once the measurements have been selected for the respected channel, the device addresses can be selected by choosing option'5' of the SDI PARAMETER MENU. The lowest address will be assigned to channel one; successive addresses will be assigned to the remaining channels in numerical order.

- It is important to note that the active channels be used in numerical order also, **do not skip channels.**

## Step 11: Configuring the Deltaflex for Internal Storage - Clock Controlled Measurement

*Note: No matter which measurement gathering method is used, the Deltaflex will always store the measurement values, plus the date and time, in memory.*

- Select '1' from the MAIN MENU to enter the PARAMETER ENTRY MENU. From this menu select '4' to enter the CLOCK PARAMETER MENU.

- Once in this menu, select '1' to set the time and date.

- Select '2' to enter the date and time at which the 'measurement start' is desired.

- The integration time represents the amount of time the Deltaflex will use to constantly repeat the measurement cycle. The results will be stored in an array, and then averaged at the end of the measurement cycle. This value can be entered by selecting '3'. The minimum integration time is 45 seconds; the maximum is 15 minutes.

- The interval time represents the distance, in time, between two measurements. This value is by default equal to 10 minutes. It can be modified by selecting '4' from the CLOCK PARAMETER MENU.

## Step 12: Configuring for Velocity Controlled Relay Switching

*Note: An additional circuit board must be ordered and installed if this option is required*

From the MAIN MENU, select ‘5’ to enter the RELAY BOARD OPTION MENU. From this menu, select ‘0’ to enable the Relay Board. If the relay board has already enabled, this action will disable it.

Enter the velocity threshold values which will either, enable, or disable the relay contacts (refer to section 3 for more info on this option).

Select ‘5’ to review the entered velocity values.

## Step 13: Configuring the Analog Current Output

*Note: An additional circuit board must be ordered and installed if this option is required.*

From the MAIN MENU, select ‘A’ to enter the ANALOG OUTPUT OPTIONS menu. From this menu, select which value to send to a analog channel. The choices include: Stage, Discharge and Direct Velocity.

Within the ANALOG OUTPUT OPTIONS menu, the maximum and minimum analog values to represent can be entered by selecting ‘3’ and ‘4’ for analog channel 1, and ‘5’ and ‘6’ for analog channel 2.

Option ‘7’ can be used to test the functionality of the board, and the entered limits.

# Creating a HyperTerminal Connection with the Deltaflex

In order to program the Deltaflex, some sort of communication medium is required. Any terminal program which supports 9600 baud can be used. For this document HyperTerminal will be used as an example since it is supplied with Windows.

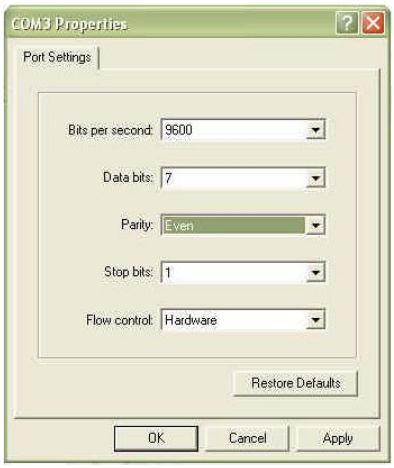
HyperTerminal can be located, usually, from the start menu through the following path:

**Start>**
**All Programs>**
**Accessories>Communications**


After opening HyperTerminal, the program will ask for a connection name. The name is solely the decision of the user, but it is recommended that a descriptive name be chosen, such as: Deltaflex Communication.


Click OK to continue.

HyperTerminal will ask for the location of the connection next, this can vary from computer to computer. COM2 is usually linked to the RS-232 port of most computers, but again, this can vary depending on the make and year of the computer.




Next, the connection properties will be required; enter the following values in this window:

| | |
|---|---|
| Baud Rate | : 9600 |
| Data Bits | : 7 |
| Parity | : Even |
| Stop Bits | : 1 |
| Flow Control | : Hardware |

Save the connection and create a shortcut to the desktop.

# Creating an Excel File from a Deltaflex Measurement Dump

The following procedure can be used to create an excel file from a dump of the measurements created by the Deltaflex AVM.

Start communications with the Deltaflex via HyperTerminal, this software is standard issue with Windows 95 and higher.
The baud rate settings are as follows: **9600 Baud, Even Parity, 7 Data Bits**.
The COMM port will depend on the user's computer.

Turn the Deltaflex off and connect it to a PC via the supplied data cable. Open HyperTerminal and turn on the Deltaflex, at this point the Deltaflex Main Menu will appear.

From the Main Menu, select option 4 to enter the **Measurement Display Menu.**

```
MEASUREMENT DISPLAY MENU

Enter selections as follows:

1125
||||_ 1 or 2 digits specifying number of records.
||___ 1 digit (1 or 2 only) specifying direction.
|____ 1 digit (1 to 4 only) specifying channel.

Use * after channel and direction to specify all records.

1125 = Channel 1, display forward, 25 records.
22*  = Channel 2, display backward, all records.

Date and time output          : Display time only

Date of first record          : 2004/04/19 08:00:00
Date of last record           : 2004/04/19 08:14:00
Number of records (753 max.) : 14

1: Display All Records Forward From First Record
2: Display All Records Backward From Last Record
3: Display Time Only
4: Display Date And Time
5: Display Date In Header When Date Changes
6: Clear Records
7: Exit to Main Menu

09:17:32 R>
```

The next step is to create a log file to record the data; this can be done in HyperTerminal by following this procedure:

a. Select TRANSFER on the HyperTerminal Menu Bar by either clicking on it with the mouse or by pressing ALT+T, from this menu select 'CAPTURE TEXT'.

b. A window will pop-up allowing the user to name the file. To change the location and name of the file, click on the browse button, and chose a location to save the file. Click Save.

c. After the file has been saved, click START to begin saving data.

Now that the log file has been initiated, the measurement data contained within the Deltaflex can be recorded. To dump the measurement data follow the instructions at the MEASUREMENT DISPLAY MENU.

**An Example:**

The user wishes to view and record the last 14 measurements made by the Deltaflex on channel 1. To accomplish this, the user would enter the following string: 1114

The first value [1, 2, 3, or 4] represents which channel to display. The second value [1, 2] represents the direction, oldest measurement to most recent, or vise-versa. The last value [1-753] represents the number of measurements to display. The wildcard character [*] can be used to display all of the available measurements on that channel.

| Time | Stage | Vd | Vr | Q | V/Sound | Temp | Gn | Rp |
|---|---|---|---|---|---|---|---|---|
| 13/05/2005 15:35 | 1.592 | 0.457 | 0.438 | 3637 | 1455.028 | 11.47 | 22 | 100 |
| 13/05/2005 15:37 | 1.593 | 0.462 | 0.461 | 3679 | 1455.031 | 11.46 | 24 | 100 |
| 13/05/2005 16:22 | 1.593 | 0.468 | 0.441 | 3727 | 1455.061 | 11.44 | 24 | 100 |
| 13/05/2005 16:29 | 1.592 | 0.469 | 0.453 | 3733 | 1455.079 | 11.42 | 24 | 100 |
| 13/05/2005 16:36 | 1.594 | 0.471 | 0.45 | 3753 | 1455.089 | 11.43 | 24 | 100 |
| 13/05/2005 16:43 | 1.593 | 0.471 | 0.448 | 3751 | 1455.145 | 11.45 | 24 | 100 |
| 13/05/2005 16:51 | 1.593 | 0.469 | 0.456 | 3735 | 1455.084 | 11.35 | 24 | 100 |
| 13/05/2005 16:58 | 1.594 | 0.466 | 0.456 | 3714 | 1455.193 | 11.38 | 22 | 100 |
| 13/05/2005 17:05 | 1.593 | 0.463 | 0.445 | 3687 | 1455.112 | 11.31 | 22 | 100 |
| 13/05/2005 17:12 | 1.593 | 0.453 | 0.445 | 3608 | 1455.117 | 11.35 | 22 | 100 |
| 13/05/2005 17:20 | 1.592 | 0.477 | 0.456 | 3796 | 1455.06 | 11.28 | 21 | 100 |
| 13/05/2005 17:27 | 1.592 | 0.453 | 0.434 | 3605 | 1454.996 | 11.3 | 22 | 100 |
| 13/05/2005 17:34 | 1.592 | 0.45 | 0.439 | 3582 | 1454.912 | 11.3 | 22 | 100 |
| 13/05/2005 17:41 | 1.593 | 0.481 | 0.448 | 3831 | 1454.837 | 11.3 | 22 | 100 |
| 13/05/2005 17:48 | 1.593 | 0.458 | 0.448 | 3647 | 1454.828 | 11.28 | 22 | 100 |
| 13/05/2005 17:55 | 1.593 | 0.471 | 0.444 | 3751 | 1454.751 | 11.22 | 24 | 100 |
| 13/05/2005 18:02 | 1.591 | 0.462 | 0.428 | 3675 | 1454.726 | 11.22 | 24 | 100 |
| 13/05/2005 18:10 | 1.592 | 0.467 | 0.448 | 3717 | 1454.67 | 11.2 | 24 | 100 |

After the Deltaflex has completed the dumping of the measurements, the log file started in HyperTerminal can be closed. This is done by reversing the procedure used to start the log file.

Select TRANSFER from the HyperTerminal menu bar, from this option select CAPTURE TEXT and then STOP.

1. To open the file in Microsoft Excel, select OPEN from the file menu in Excel. You may have to select *all files(*.*)* from the files of type to see the file.

2. During the opening procedure EXCEL will ask a few questions to determine how to organize the data in the spreadsheet. The first question will be in the form of a two checkboxes with the following selection: *a. Delimited, b. Fixed Width*. Choose Delimited.

3. SPACE must be selected as the delimiting character.

## Remote Diagnosis

The Deltaflex uses advanced DSP routines to extract information, such as, the direct and reflected velocity, from the acoustic pulses. The acoustic energy is converted to an electrical signal via the transducers. The electrical signal is then converted to a digital array via an *Analog to Digital Converter*.

In some cases it may be necessary to analyze the waveforms captured by the Deltaflex. The pulse information can be dumped into an excel *.csv [*comma separated values*]file allowing the user to determine if the transducers are operating as predicted, or if the system is operating properly.

**The FIFO Dump [dumpsf]**

To dump the contents of the FIFO, a log file has to be created. The dump can be saved to the log file by using HyperTerminal; HyperTerminal is supplied with every version of Windows after Windows 95. The steps for starting the log file are as follows:

a. Select TRANSFER on the HyperTerminal Menu Bar by either clicking on it with the mouse or by pressing ALT+T. From this menu select 'CAPTURE TEXT'.


b. A window will pop-up allowing the user to name the file. To change the location and name of the file, click on the browse button, and choose the location of where to save the file. Click Save. The file can have any name, but it should end in .csv, this will make it instantly recognizable by Microsoft Excel.

c. After the file has been saved, click START to begin saving data.


[A FIFO is a **f**irst **i**n **f**irst **o**ut buffer which allows for a high sampling rate]

d. At the Deltaflex MAIN MENU type **dumpsf**. A list of numbers will appear and start to scroll down the screen, it may take a few minutes to complete the dump since the FIFO size is 16K * 16bits.

e. Close the text capture by reversing the above process. The data can be examined in excel, or send to Stedtnitz Maritime Technology Ltd. For examination.

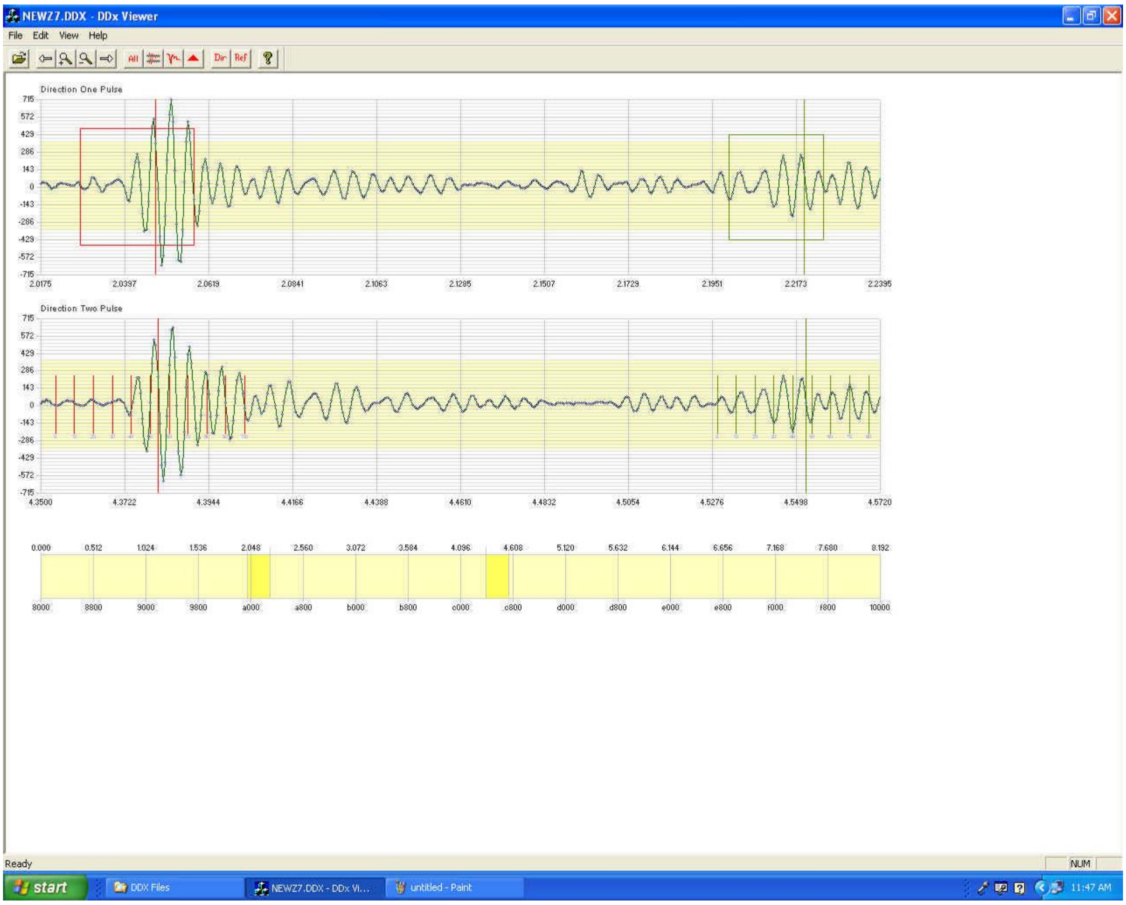
**The DDX Dump [dumpsfifo]**

Another method can be used to examine some of the finer details of the DSP routine results. Secondary software is required, and is available upon request. To create a DDX dump simply follow the same steps as the FIFO dump described above except:

a. Change the name of the file extension to .DDX instead of .CSV

b. After the log file has been started, type **dumpsfifo** at the main menu. This dump is requires less time than the normal FIFO dump.

When the dump is finished it can be sent to Stedtnitz Maritime Technology Ltd. for further examination, or the DFXViewer software can be used to inspect the file.



A Screen Shot of the DDX viewer.

# Frequently asked Questions

## What is the Best Way to Measure Discharge?

The cheapest and easiest way to measure discharge is to measure the stage. A non-linear Discharge / Stage relationship can be established using point by point comparison measurements at various stage levels. This is a time consuming work, which has to be repeated after each flood event. Extreme events will be never recorded because they are rare events.

The Discharge / Stage relationship is not only non-linear, it shows a hysteresis-effect between rising and falling flood. This can lead to additional errors as high as 10 %.

## Why Acoustic Flow-Measurement?

Acoustic Flow-Measurement delivers reliable data immediately after installation. After flood events only the cross-section must be resurveyed, which is easy. Accuracy relies on the transformation from (acoustic-) line- velocity to average velocity over the full cross-section area. The transformation is governed by so called stage dependent k – factors. These k – factors can be resolved either by computer simulation or/and by calibrating. They are stored in the Deltaflex and applied by interpolation between programmed fix-points.

## What applications require acoustic flow-measurement exclusively?

In case of backwater from weirs, power plants or merging rivers the relationship between discharge and stage fails completely. Flow and discharge may vary considerably over a wide range even with constant stage.

The same is true for tide areas, where the velocity reverses regularly. In this case stage amplitudes are 90 degrees phase - shifted compared to the velocity of the current.

It is widely unknown that waterway-connections between two lakes, or river-stretches between two weirs, can oscillate. The energy is delivered by short storm events or by the regularly opening of locks. The oscillating velocity can easily reach peaks of 0.3 m/s in both directions, superimposed by the steady flow in one direction. Only the continuous observation by acoustic flow- meter reveals this strange history of some rivers.

Under ice cover traditional discharge measurement by propeller type current meters or even ADCP moving boat is not applicable. Properly installed transducers of a DELTAFLEX system can reliably deliver data in summer and winter. K-factors however must be changed during the ice-covered season to compensate for the friction of the ice. K-factors can be changed easily remote-controlled via modem.

Two principles are known to measure the velocity of a river:

## 1.1 Transit time measurement used by the DELTAFLEX

| Advantage | Disadvantage |
|---|---|
| o Two transducer mountings<br>o High accuracy<br>o Zero offset<br>o Requires little minimum depth<br>o Low submerged value in water<br>o Accurately known, where<br>o velocity is measured<br>o Quasi continuous<br>o High reliability proven<br>o Moderate pricing<br>o Stage is measured accurately with little extra cost<br>o Temperature measurement is implemented<br>o Low Power | o Transducers must be aligned<br>o Reflector required if cable crossing must be avoided |

## 2.1 Doppler Measurement, permanent installation, either vertical or horizontal

| Advantage | Disadvantage |
|---|---|
| o One transducer mount<br>o Quasi continuous | o High submerged value in water<br>o Difficulty to measure at short path and at long range<br>o Difficulty to measure zero velocity<br>o Difficulty to measure in shallow water<br>o Difficulty to measure in clear water<br>o One Point Measurement |

## 2.2 Doppler Measurement, ADCP moving boat

| Advantage | Disadvantage |
|---|---|
| o Complete discharge measurement within a few minutes, faster compared to propeller type current meter<br>o Simultaneous cross-section survey<br>o Very versatile during flood events<br>o Applicable for wide rivers<br>o Accurate three dimensional record<br>o Complementary to DELTAFLEX to compare accuracy | o One shot measurement not usable for record of long time history<br>o Boat with crew required<br>o Not useful under ice shallow water restrictions |

### What is the advantage to have the capability of four independent acoustic paths?

**Application 1: Irrigation channels**

Irrigation channels are often connected via multiple culverts under roads. On both sides the water is spreading out into basins were the flow may be irregular. The best place to measure is therefore in the culvert itself. The flow is straight and regular and the shade prevents weed from growing. To limit the height of the road and to carry the discharge often many culverts must be placed side by side. This is calling for an acoustic line in each culvert that makes the installation expensive if one device is required for each culvert.

Multiple path capability of the Flow Meter is the economical answer.

**Application 2: Deep Water Channels with irregular flow**

In deep water channels where accommodation of many acoustic paths is no problem, multiple paths can be installed to provide velocity information about a certain horizontal segment of the total trans-section. The total discharge is simply the sum of the individual segments.

## What is the advantage of the DELTAFLEX configuration?

Sometimes the wind-driven surface moves in opposite direction compared with the flow in deeper water. A second path or even multiple paths on top of each other are desirable.

Each acoustic path requires a certain clearance to the bottom and to the surface depending on the length of the line. The longer the line, the more depth is required. Often the depth is not available to accommodate the clearance for more than one path.

Another problem with multiple paths systems is that one or more of the upper path may fall dry. This will call for more complicated software, because running lower than the necessary clearance will make the velocity value unreliable.

The DELTAFLEX solves this problem in a unique elegant way: it uses the acoustic path of energy reflected at the surface to retrieve additional velocity information of the upper layer of the river.

When the water level changes, the reflected path moves up and down along with the changing surface. It is the only way to measure the wind driven surface. For principle reasons no Doppler system is able to do it.

During the installation some care must be taken to align the transducers that the main beam can reach the opposite transducers straight and also via the reflected path. See installation rules in the appendix.

The DELTAFLEX takes a unique approach to determine precisely and unambiguously the Transit time of both transmission paths by using cross-correlation algorithms along with two specific keys. This avoids spikes in the data, thus allowing full automatic data post-processing.

## What is the advantage to measure the temperature?

The AFFRA – family of Transit Time Flow Meter, including the Deltaflex, does not require a temperature measurement to perform accurate velocity measurements over the full temperature range. It uses an algorithm that calculates, independently, the velocity of the water and the velocity of sound in the water. Combined with a temperature measurement, the measured velocity of sound can be used to calculate the salinity without any additional salinity sensor.

## What is the advantage to program Correction –Factors?

An Acoustic Flow Meter measures the line velocity, while Doppler Meters measure just a point velocity. None are identical with the average velocity in the whole trans-section. In case of the Transit Time Flow - Meter a correction factor is introduced that gives the relationship between Line Velocity and Average Velocity:

**K(S) = Vavg /Vline**

The discharge is calculated on line using the k – factor and the active trans-section area A(S) that is valid at a certain water level, called stage S.

**Q(S) = K(S) * A (S) * Vline**

The k – factor is a somewhat complicated function of the contour of the trans-section and the position of the transducers relative to the banks. It is also related to the ratio bottom-roughness / depth.

The k – factor can be obtained by the following procedures:

- Calibration step-by-step at various stages using classical current meter.
- Calibration step-by-step using an ADCP.
- Using the AFFRA Q – Profile software (free of charge) allowing immediate accurate discharge measurement at any velocity or stage.
- Using Infinite Element simulation software allowing immediate accurate discharge measurement at any velocity or stage.

The Infinite Element Software provides the capability to calculate the velocity distribution in the total trans-section even if the contour is unusual crooked. The model even works when the foreland is flooded. Often the contour of the river in the center is limited to 50 m, while the flooded land extends on both sites over 500 m to give an example. Only in the center the depth is sufficient to run an acoustic path. The complete measurement now is possible in conjunction with this simulation software.

## How does the DELTAFLEX determine the valid cross-section?

The cross-section is a non-linear function of the stage. This function is usually available in the Hydrologic Department for this river as table or chart. A copy of this table has to be programmed into the DELTAFLEX memory.

The valid cross-section is derived from the measured stage. The accuracy of the final discharge measurement relies on:

- precise stage measurement (DELTAFLEX)
- precise k-factors as function of stage (Calibration or Simulation)
- precise survey of the bottom contour (Survey)
- precise measurement of the flow velocity (DELTAFLEX)
- stable bottom contour over time (Nature)
- Stable roughness, not affected by weed or brush (Nature or maintenance)

## How does the DELTAFLEX manage to measure the stage precisely enough?

The DELTAFLEX measures with high precision the velocity of sound between the horizontal transducers, because the distance between the two remains constant over time. The stage is a function of the velocity of sound. If the velocity of sound is known the stage can be calculated accurately with a precision of +/- 1 mm.

The velocity of sound is related to the temperature and salinity content in the river. Both are taken into account automatically when the DELTAFLEX measures the velocity of sound.

Many measurements confirmed that the temperature from top to bottom differs not much more than 0.1 degree Celsius in flowing rivers. Floating debris and fish may cause echoes to occur lower than from the surface of the water. A vertical pipe with a diameter of a least 100mm can be used to guide the acoustic pulse, eliminating the noisy echoes.

## How does the DELTAFLEX manage to measure the line velocity precisely enough?

The software used to measure the velocity has been developed over many years and it matured with more and more practical experience. See Software Report.

With any path-length the accuracy of the line velocity is better than 1 mm/s, with worst case condition at 1 m path length.

## What is the advantage of transducer - mountings based on 2 inch pipes?

The DELTAFLEX – transducers have on one side a 2 "thread. This allows the use of the standard 2" pipe system including unions, bends and T – pieces. There is a written procedure available, how to use the 2" pipe system in the most economical manner. Usually the parts required for the installation of one pipe are available in any hardware store, thus making installation easy and inexpensive.

The DELTAFLEX transducers are easy to install because they have a relatively wide acoustic beam-width and an alignment along the line of sight is all it takes in the azimuth plane. As mentioned the elevation of the acoustic beam shall be directed to hit the opposite transducer as well as the surface in the center of the river.

## What is the advantage of streamlined transducers?

Streamlined transducers are designed to be mounted along concrete or metal piers. Some sewer canals exhibit high velocities and carry some debris. The streamlining avoids unnecessary turbulence and preventing debris from being hooked.

Fastening screws are difficult to remove in concrete material. It is therefore recommended to mount the transducers on metal sheets, which are permanently secured to the concrete wall. The metal sheets at the same time secure the transducer cables running underneath between the metal sheet and the wall. Follow the instruction data sheet.

## What can the software diagnosis tools do for you?

When the installation is done it is often useful to see what the signals look like.
The DELTAFLEX has the feature to display the received signal on the screen of the communicating laptop without the need of an oscilloscope. The displayed signal is available on file and can be sent to the manufacturer in case of troubleshooting requirements. This is particular helpful, when new customers are in the starting phase and wish to know that everything is o.k.

There are other support-programs in place which lend to ease the troubleshooting process.

## What are the basic rules for installation?

9 transducers are installed and 9 pairs of wire come into the gauge house and nobody knows to which transducer they are connected! Label cable ends immediately during installation procedure! Use a terminal to switch from transducer cable to the DELTAFLEX cable. Label all connections.

Provide full lightning protection. Provide a solid copper strip common to all systems 100 x 500 x 0.1 mm; connect this copper strip via 8 mm diameter wire to a ground rod! If not, at least all devices ground rod and cable shields shall be connected with solid copper wire.

Provide lightning protection for all connected devices! Ground the negative pole of the battery and the solar panel with solid copper wire.

Select a solar panel and battery for worst case conditions:

- Minimum daylight hours in the winter.
- At least 5 consecutive cloudy days.

40 W solar panels with control regulator to prevent overcharging is a good choice. Use an inexpensive, standard car battery as buffer.

Check the cable connections by measuring the resistance between the two active lines of each transducer (usually black and white) and each line to ground. For resistor values see scope of delivery.

Start Laptop communication program always before turning the DELTAFLEX on.

Leave a copy of the programmed parameters, specific site parameters and wiring information at the site in a plastic bag.

## What support do you get in case of installation problems?

Contact us via e-mail at affra@nrtco.net
Phone : 001 613 628 2064
Fax : 001 613 628 2265

Before any inquiry please send us the following site conditions:

- Map of the site, scale 1: 25000, 1; 1000 or any other scale within this range
- Trans-section along the acoustic line
- Cross-section perpendicular to the flow
- Possible minimum stage
- Possible maximum stage
- Possible maximum velocity

# Theory of Operation

## The Velocity Measurement

The Deltaflex belongs to the family of Transit Time Velocity Meter. It exploits the fact that sonic pulses run faster with the flow than in opposite direction. Therefore pulses are sent in both directions and precise transit time measurements as accurate as within 10 nanoseconds are carried out. This requires precisely working hardware and sophisticated software with mathematical tools like cross-correlation technique to determine the exact timing difference between both signals. The two transit times in both directions are called T12 and T21. The Transit times in both directions are:

$$T21 = \int_{o}^{x=L} \frac{dx}{C(x) + v(x)\cos a}$$

$$T12 = \int_{o}^{x=L} \frac{dx}{C(x) - v(x)\cos a}$$

$$\text{Line velocity } V = \frac{T12 - T21}{T12 * T21} * \frac{L}{2\cos a}$$

.

Important: The calculated velocity of the water V does not depend on the velocity of sound C in the water!

With

L = Path-length
C = Velocity of sound
@ = Angle between acoustic path and direction of flow
v(x) = Velocity of the water at distance x along the acoustic path
v = calculated line velocity along the acoustic path

The calculated line velocity is obtained as the difference of two transit times multiplied by the path-length and divided by the product of the two transit times and divided by twice the cosine of the angle between acoustic path and direction of the flow.

Each transit time is the integration of path-increments divided by the projected velocity of the water within this increment. The integrating effect provides smoothing of the measured velocity of the water (Space averaging), canceling the influence of vortices. More smoothing or reduction of variance can be achieved by time averaging. Increasing the integration time, in other words by averaging several independent measurements does this job.

## The Stage Measurement

The stage data, that is the height of the water level is used in the Deltaflex software for several purposes. The precise measurement is important because any error in stage measurement will produce more errors in determining the active cross-section area, which in turn is used to calculate the discharge.

To measure the stage St , the Deltaflex uses the travel time from the upward directed vertical transducer and the measured velocity of sound along the constant distance L of the horizontal path:

$$C = \frac{T12 + T21}{T12 * T21} * \frac{L}{2}$$

$$St = C(T,S) * T_3 /2 + Offset$$

**C is a nonlinear function of temperature T and salinity S.**

The offset is programmed into the Deltaflex and it is the height from sea level up to the surface of the vertical transducer.

Important: calculated C relies on transit times and the constant L, and not anymore on temperature and/or salinity.

DELTAFLEX – STAGE measurement is accurate to + / - 1 mm

Pressure sensors in contrast measure the weight and not the height. The stage measurement of pressure transducers is therefore dependent on the density of the water, which is indeed a function of temperature, salinity and air pressure. The air pressure must be measured separately with a second pressure transducer and subtracted. This doubles the error of each single pressure transducer.

The cross-section area is determined by echo-sounder survey. Normal echo-sounders usually are not specifically adjusted to the velocity of sound and the measured y-coordinates (depth) are prone to errors related to the velocity of sound. This means that the depth error can be as high as +/- 6%. Only a scientific echo-sounder will allow for adjustment of the velocity of sound. It should be noted that software corrections could be applied to the data in the post-processing.

Many echo sounders have a poor timing resolution and therefore the depth resolution is usually as poor as +/- 5cm. This increases the stage error and consequently the error of the active cross-section adding to the overall error of the discharge measurement.

## The Determination of Discharge

There are several solutions to obtain the average velocity, the key to solve the discharge equation:

Q = V average * A active

## Spatial Velocity Distribution

In a given cross-section the velocity is different at any spot, however following certain rules. Any spot is coupled hydraulically with its neighbors following Differential equations. Because of friction the velocity at the bottom and along the banks must be zero as side-condition.

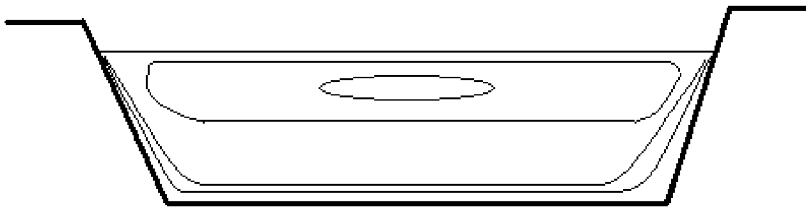


Fig. 1

The picture Fig. 1 shows a cross-section with lines of equal velocities. The maximum is the oval in the center of the river, often close to the surface.

## Propeller Measurement

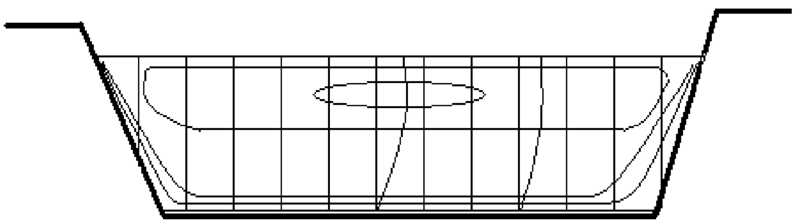


Fig. 2

Traditionally Propeller-current-meter measure the velocity distribution along vertical lines with equal distances between each other from one bank to the other. Two examples of the vertical distributions are shown in fig 2.

Integrating from top to bottom, multiplying with the related vertical cross-sub sectional areas and then summing over all subsections delivers the total discharge. Measurement is flawed by turbulence causing fluctuation of the discharge in the order of +/- 2 %. The method is time consuming and often the flow is not stable during the total measurement time. The limited number of verticals is an economical compromise.

Propeller measurements are often used to compare velocity and discharge measurements from electronic measurement devices, as Transit time AVM's or Doppler ADCP's. The mutual agreement is within the mentioned +/- 2%, the best possible estimate.

## Moving Boat ADCP Method

In the moving boat process the vertical velocity integration is performed by Doppler measurement of velocities within the vertical bins. By moving the boat across the river from one side to the other, a second integration is carried out. This gives the overall discharge. The moving boat operation is versatile and does not need any fixed installation. It requires a boat with crew or a remote operated vehicle. Applications are in flooded areas at any river width. It does not allow continuous operation to establish a data history of the site. Fig. 3

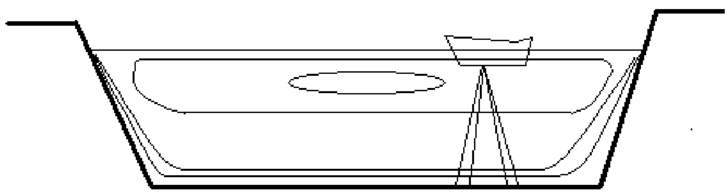


Fig. 3

## Multiple Path AVM approach

Transit Time AVM's, like the DELTAFLEX, are better suited to measure at regular intervals and produce a continuous record. This requires permanent installation of transducers. Other than propeller meters the measurement is based on velocity integration along horizontal lines Fig. 4.

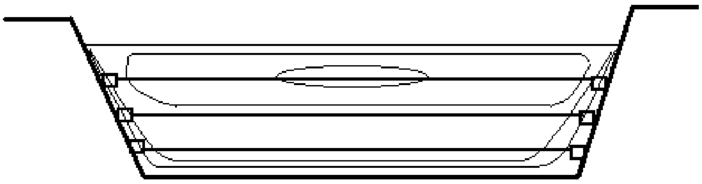


Fig.4

One possibility is to split the cross-section into horizontal subsections and dedicate one specific acoustic path to each subsection. Each line velocity is multiplied with the area of the related subsection.

This approach leads to many difficulties in reality:

- Many rivers are too shallow to allow the installations of several acoustic paths.
- Installation and maintenance cost increases proportional with the number of paths.
- The gain in accuracy by using several paths is marginal.
- The split into subsections require full operation of all paths to gather the true discharge as the sum of all subsections. Any drop-out of one or more paths will result in the collapse of the discharge value. Suppose the probability to drop out for one path is 1 %, then the probability to collapse of the discharge for a four-path system becomes 4 %!

Stedtnitz Maritime Technology Ltd. developed a different approach, allowing either single path or multiple path operation with redundant calculation of the discharge.

The link between line velocity and average velocity is the so called correction factor k(S), which is changing with the stage S (water level). The correction factor is defined as:

$$k(S) = V_{average} / v_{line}$$

and the discharge is given by:

$$Q = V_{line} * k(S) * A(S)$$

The calculated line velocity can be measured with crystal precision and the error rate is in the order of 0.000001. The problem is that the line velocity is not identical with the average velocity in the cross-section.

The correction factor as function of stage S can be designed to give the correct discharge for any path at any stage.

In a multi-path system the discharge is simply the sum of all calculated discharges divided by the number of available discharge results gained from each individual path. The discharge information is lost only when all paths drop out at once.

The probability to loose the discharge information is now:

Supposed Drop-out Probability $p_1$ of one path: 1%

For a two-path system the total drop out probability is:

$$p1 * p2 = 0.01^2 = 0.0001$$

This approach has the following advantages:

- A two-path system already achieves considerable reduced chance to loose discharge information. In a multiple-path system any path is allowed to drop out at any time without sacrificing the final result, provided at least one path remains operational.
- The accuracy is improved by averaging basically identical results from several paths, if available.
- The two- path approach allows cross-path configuration with reduced sensitivity to the direction of the current plus redundancy of the operation. It provides redundancy and reduced variance by averaging.
- Overall installation and maintenance cost is reduced.
- It is the best economical compromise in terms of cost and data integrity.

## Physical Restraints with Transit Time Measurements

Certain limitations apply for all Transit Time Velocity Meter, some also for Doppler devices.

Acoustic propagation laws dictate that acoustic energy will reach the opposite transducer via three ways:

- Direct (horizontal) connection

- Surface reflected path (almost same amplitude, but time delayed)
- Bottom reflected path (weaker, because of back-scattering in all directions)

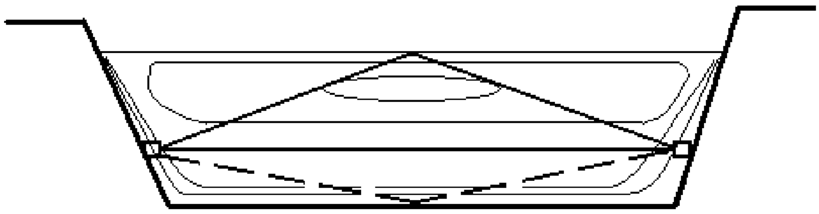


Fig 5.

Unfortunately due to the surface reflection, the reflected signal has an opposite polarity and almost equal amplitude when compared to the direct pulse. In shallow water the delay between the direct pulse and the surface reflection approaches zero; both signals annihilate each other. Under this condition the measurements become unreliable. A minimum delay of half a wavelength is required to avoid this situation. This requires a minimum depth above and below the acoustic path. The allowable operational area is shown in the diagram. Because of the poor reflection of the bottom, in practice the restriction regarding the bottom reflection can be dropped. The restriction regarding the surface reflection in practice reduces the maximum path length because of additional acoustic attenuation.

Often rivers are wide and shallow. As a consequence there is only space for one path alone and a multiple path becomes impossible (except cross-path situation with both paths at the same level).

## The Reflected Path Feature

The Deltaflex has a unique feature:

Due to special software routines it is possible to exploit the information contained in the reflected signal. The signal running the reflected way is loaded with the velocity information along this track. This solves two problems:

- Information about the velocity near the surface can be retrieved. It is often affected by wind.
- At low overall velocity there can be a substantial difference between the surface flow and the flow in the lower sections of the river. In some cases even the sign may be reversed.

The information from the reflected path is still experimental and not yet included to improve and correct the average velocity. This has two reasons:

- Use of the velocity information from the reflected path is not adopted by ISO standards.
- The reflected signal is not quite as reliable as the direct signal. Snow flakes or strong swell may reduce the access to the data.
- This additional data is supposed to give the operator additional judgment of the site condition

## Implementation of Discharge Measurement

The goal is to determine the discharge Q. It cannot be measured directly instead it needs to be synthesized by connecting several parameters into one equation:

**Q = Vline*K(S)*A(S)**

With:

V line = measured line velocity along the acoustic path
K(S) = stage dependent correction factor
A(S) = stage dependent active cross-section area

To compute the discharge, the active size of the cross-section area A(S) and the average velocity must be known. A table is stored in the Deltaflex memory as an array to allow the interpolation of the active cross-section area at a measured stage. Actually, in the array, the cross-sectional area is already stored after multiplication with the correct k-factor.

The Deltaflex multiplies internally the measured line velocity V line with the product K(S)*A(S). The array stores the product K(S)*A(S) as function of S as fixed points. With the precisely measured stage the interpolation between two fixed points gives the correct k-factor multiplied with correct cross-section area.

The process is prone to many errors:

- Echo-sounder errors of the contour of the cross-section
- Error in the programmed height of the vertical transducer
- Errors in programming the relation cross-section to stage
- Error to obtain the correct k-factors as function of stage
- Error not to switch between ice cover and no-ice cover at fall and spring

The k-factor relies on more parameters, which shall be known:

- Projected position of horizontal transducers relative to cross-section contour and actual water level
- Contour of the cross-section
- Roughness of the bottom contour (including upstream and downstream sections)
- Infinite element flow analysis

The above list should stress the point that careful programming is essential to obtain excellent results. Before, it requires full understanding of all parameters involved.

For rivers with a prisma contour with a ratio width/depth > 10 and smooth stable bottom, accurate discharge readings can be accomplished without complicated k-factor analysis. For more complicated cross-section contours more sophisticated software is recommended. Contact the manufacturer.

A basic understanding of the k-factor approach is derived from the following:

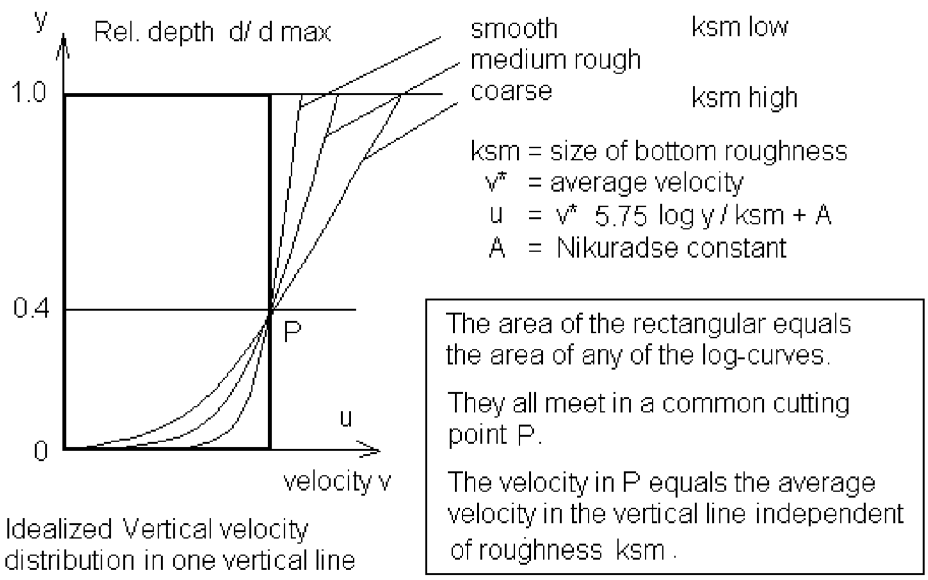



Fig. 6

The velocity distribution shown in Fig. 6 is what a vertically lowered propeller meter will measure. In reality these curves are randomly distorted and superimposed by short living vortices. The governing logarithmic rule is not readily recognized. Theoretically the average velocity is fully represented if all measurements would have taken place at 40% of depth from the bottom (no matter what device may be used). Please note that the roughness influence is removed at this depth. Above 40% of depth the (relative) velocity is higher, below it is lower than the average velocity.

With wide rivers with a flat bottom it is easy to approach this approximation ignoring the influence of both river-banks. This works also well with prisma contour cross-sections, which show consistent k-factors even when the stage is changing by +/_ 10% or more.

With this knowledge in mind we may reconsider the value of multi-paths systems. Actually, to measure higher or lower than at the 40% point will increase the error caused by unknown friction due to the roughness. Averaging measurements from higher and lower measurement points could reduce this error. This is precisely what US Geological Survey adopted as a rule for vertical propeller measurement (Measure at 30 and 60% of total depth and average).

Practical experience with many sites all over the world, confirm that stabile and accurate measurements are possible with just one path. Frequent comparison measurements compared with propeller current meter and ADCP reveal agreement within 2 %.

## Derivation of a proper K-Factor

As mentioned before in the ideal situation when the path runs at constant depth, 40% of total depth, the k-factor is 1.0. In reality there are river-banks and the influence cannot be ignored. Usually the Deltaflex measures an average current, which is a small amount too high and the line velocity must be multiplied with a k-factor around 0.98. The further the transducers are mounted away from the bank the higher the measured line velocity will be, and the lower should be the k-factor. This shows two facts: First the k-factor is always close to 1.0 and second it could be easily determined by calibration. As part of the quality control, the manufacturer recommends calibration from time to time and in some countries law requires calibration.

There is another method to determine the k-factor and this is done by computer simulation. The advantage of this approach is, that K-factors are available right at begin of starting up a new site. The results are reliable from the very beginning despite the fact that fine-tuning may be done later by improved calibration. Practical tests show that further improvement by calibration is hard to achieve due to the fluctuation nature of all flow measurements, no matter what method is used. It turns out that results vary from measurement to measurement within the +/- 2% range and nobody can prove which result is closer to reality.

In data sheets errors are usually specified as absolute velocity and stage errors. The specification of relative errors is avoided, because it leads to division by zero in case of still water, a situation forbidden by mathematical rules. Tank measurements show that indeed relative errors rise when the velocity approaches zero.

A rectangular shaped cross-section creates rolling vortices at both banks that distort the regular vertical logarithmic velocity distribution. This can lead to considerable discharge errors.

In other sites hydraulic instability occurs, where the width or depth of the river suddenly changes. Those sites are not suited for flow measurement, no matter what method is used. If this cannot be avoided, a site with slowly narrowing cross-section shall be preferred to those, where the cross-section widens slowly or abruptly.

Discharge is calculated based on precise cross-section measurement, precise measurement of transducer positions, correct k-factor calculation or determination, which involves even knowledge about bottom roughness. All these parameters usually are related to often-unavoidable errors, by far larger, than the errors caused by primary data coming from any kind of acoustic instruments.

For example, bottom roughness may change by growing weed or bush population near the banks, narrowing the active cross-section. Weed can disrupt acoustic transmission completely, particular when oxygen is produced in the leaves during daytime.

## One Path Acoustic Flow Meter

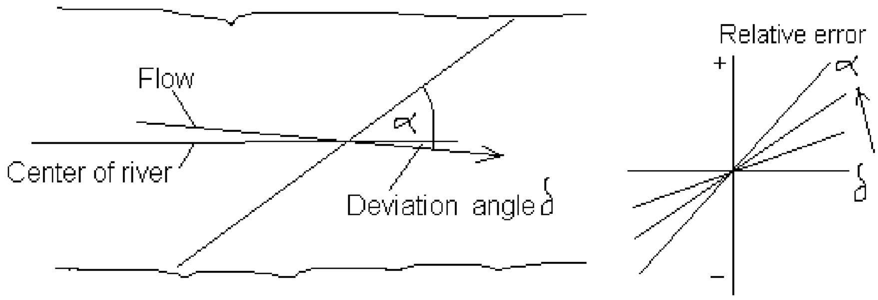
$$v_{real} = k(s) * Vline * \cos \alpha_{real} * FB * 1/2048$$

$$FB_{programmed} = 2048 / \cos \alpha_{programmed}$$

$v_{measured}$ = average velocity along acoustic line = Vline

$v_{real}$ = average velocity corrected for angle $\alpha$

$v_{average}$ = average velocity in total cross-section = $v_{real} * k$




$$\text{Deviation angle } \delta = \alpha_{pro} - \alpha_{real}$$

$$\frac{v_{error}}{v_{measured}} = \frac{\cos \alpha_{pro}}{\cos \alpha_{real}} \sim \delta * \sin \alpha = \text{relative error}$$

## Discharge Interpolation

The interpolation error can be reduced considerably by moving the fixed points of the array closer together where the function area A(St) has its strongest bend.

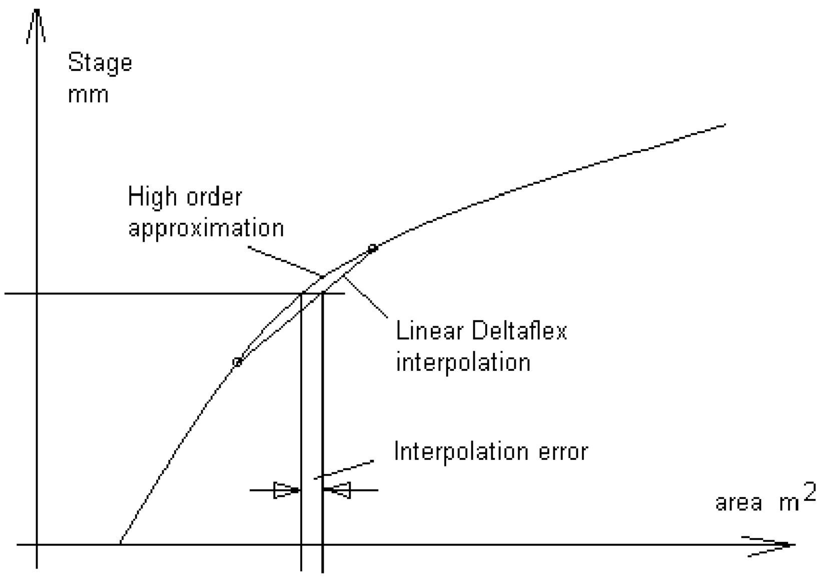



Fig. 7

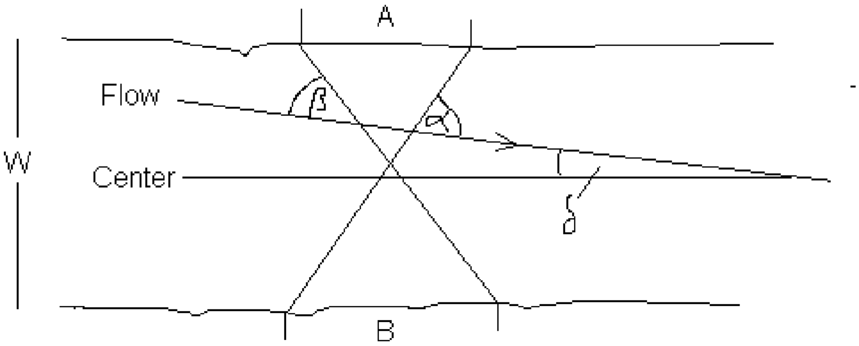
In case the measured stage happens to be between two fix-points the highest error will occur, Fig. 7, usually in the order < 0.5 %.

Linear approximation is used because it is easy to program and easy to understand in the field.

With moderate changes of the stage the error is small within the full range and can be ignored.

Programming Angle between Acoustic Path and Flow Direction

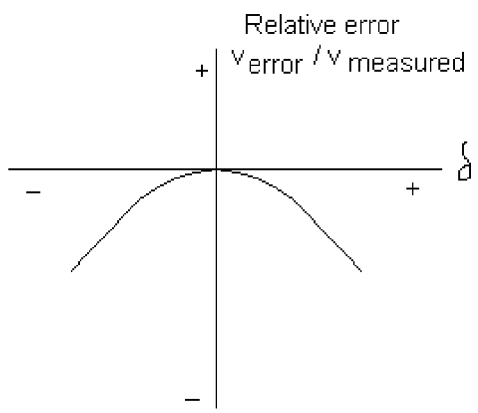
## Cross Path Acoustic Flow Meter




$$\frac{v_{error}}{v_{measured}} = \sim (1 - \cos \delta) \sim 0$$

$$FB_{programmed} = 2048/\cos \frac{(\alpha + \beta)}{2} \quad \text{programmed}$$

$$\frac{(\alpha + \beta)}{2} \cong \operatorname{atan} \frac{2W}{A + B}$$



The relative error becomes smaller with smaller $\alpha$,
it rises proportionally to $\delta$

$$Q = v_{average} * A$$
$$= v_{real} * k * A$$
$$= v_{measured} * \cos \alpha_{real} * FB * 1/2048 * k * A$$

k = correction factor related to shape of transsection, height of transducers, and roughness
k can be determined by calibration (comparison) or by simulation
k is always close to 1 +/- 5%

k * A can be programmed as array f (S) as function of the stage (water level)

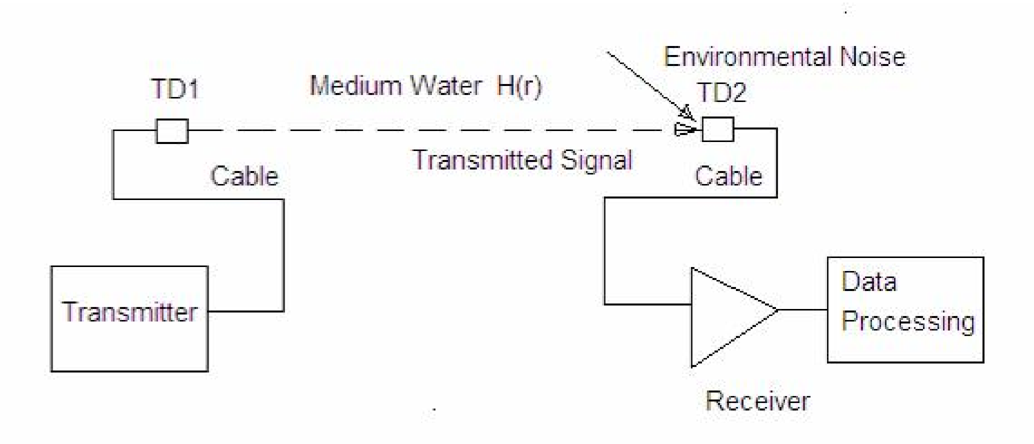
A = valid cross-section area at measured stage

v = valid k - factor at measured stage

Q = Discharge corrected for all errors

## Signal Processing

The setup of the Deltaflex represents the classical communication problem:




The transmitter generates a pulse sequence, which is sent with a power of 400 W peak along a cable with 100 Ohm impedance to the first transducer TD1. There electric energy is converted into acoustic energy, which is transmitted with a beam aligned to hit transducer TD2. Along with unavoidable environmental acoustic and electromagnetic noise the signal is picked up and converted back into electric energy. This energy is transferred eventually via cable to the receiver. It follows data post-processing to retrieve the velocity and stage information.

The acoustic signal suffers attenuation in the water:

$$TL = 20 \log \frac{(r)}{m} + \frac{(a_0)}{dB/km} * \frac{(r)}{km}$$

Further attenuation is introduced by the cables reducing the transmitted and received electrical energy. The cable attenuation at 200 kHz is approximately 8 dB/km; this value varies from brand to brand, and with diameter of the conductors.

The above equation for the Transmission Loss TL has two terms. The first is responsible for the geometric spread of energy which results in a loss according 1/r^2.

Sediment and/or air-bubbles cause the second term. Little is known, how the second dampening term is related to the sediment load in ml/qbm. This is because the particle size is involved giving maximum attenuation with a particle size of 4 micrometer. In rivers the distribution of particle size is rarely determined and it can change within a few minutes. A forecast is extremely difficult. The best we can do as manufacturer is to make the electronic device as sensitive as possible.

What happens when the attenuation is getting too high? The transmitted signal that traveled along the acoustic path, and became attenuated, is mixed with noise from the water and the environment (lightning, long wave transmitters). If the sent signal becomes weaker than the noise, the transit time cannot be revealed and the post-processing will exclude the data. It will create a gap in the data.

**What can be done?**

The transmitted power should be as high as possible. There are physical limits restricting the maximum power. One limit is the cavitation limit at the surface of the transducer.

The receivers should pick the signal with as low noise as possible. This is a design problem, which takes much care and skill, particularly to avoid interference from the noisy computer board in the neighborhood.

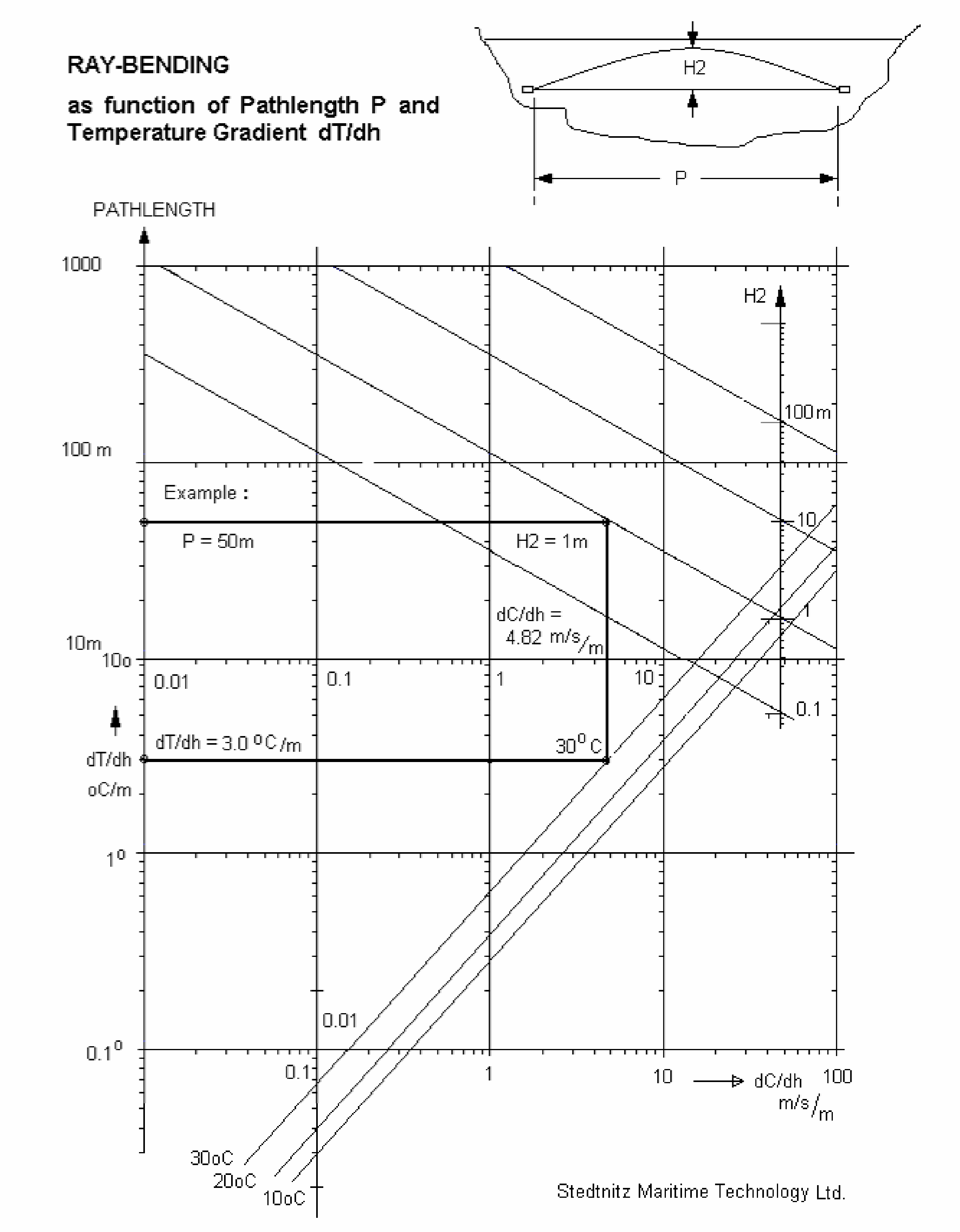
This is where the hardware design comes to its limits and more can be done with intelligent Signal Processing. Several mathematical tools are used in the Deltaflex post-processing procedure to enhance the signal to noise ratio.

Here is no place to go into details. It should be mentioned that stacking technique is used to improve the signal to noise ratio by 18 dB (as if the power is increased by a factor of 80) , bringing the virtual power level to 32 kW!

The correct timing of the received pulses is determined by a cross-correlation process that takes most of the computing time with millions of multiplication's involved. A timing resolution of 10 nanoseconds is achieved.

The minimum total time to perform one measurement is about 28 seconds. The necessary time to run the pulses through the water is roughly path-length divided by velocity of sound plus 4 milliseconds. It means that it takes only 75 ms for a path length of 100m to complete the transmitting – receiving operation for one measurement. Almost the entire time is used for processing purposes. Within the mentioned 75 milliseconds the water does not move very far, it seems to be frozen and both pulses running in both directions see precisely the same conditions.

To repeat a measurement immediately does not require initializing the automatic gain and it saves some time. Therefore usually 4 complete measurements can be completed within 1 minute and 10 seconds.


RAY-BENDING
as function of Pathlength P and
Temperature Gradient dT/dh
H2
P
PATHLENGTH
1000
100 m
10m
H2
100m
10
1
0.1
Example :
P = 50m
H2 = 1m
dC/dh =
4.82 m/s/m
10o
0.01
0.1
1
10
dT/dh = 3.0 oC/m
30o C
dT/dh
oC/m
1o
0.01
0.1o
0.1
1
10
dC/dh
100
m/s/m
30oC
20oC
10oC
Stedtnitz Maritime Technology Ltd.

## Ray Bending

Ray bending is caused by a temperature and/or salinity gradient. The temperature gradient occurs when low velocity water warms up at the surface, due to strong sunshine, and does not get mixed by turbulence.

A salinity gradient is observed in tide areas, when the heavier salt water from the sea underflows the lighter fresh water from inland.

Both of the above effects, temperature gradient and salinity gradient, can superimpose each other leading to severe, and often unstable ray bending. Physically speaking, the ray bending is caused by the simple fact that the sound runs faster in warmer water at the surface than in cooler water at the bottom. Because of the higher velocity of sound in salt water compared to fresh water the sound will run faster in salty areas.

For acoustic applications, not only the will the ray bending set limits to the allowable range, it will also degrade the propagation conditions. From light rays in air we know the affect of 'twinkling' objects, a propagation instability that changes the propagation path by random ray bending.

The unpleasant result is, in the case of a transit time flow-meter, the two flight paths to measure transit times see slightly different propagation conditions. The effect can be reduced by transmitting simultaneously in both directions, matching the propagation conditions as best as possible.

In sites with low water velocity, the worst case temperature gradients and salinity gradients should be determined before any installation. To obtain reliable data a conservative approach regarding the projected path length shall be taken.

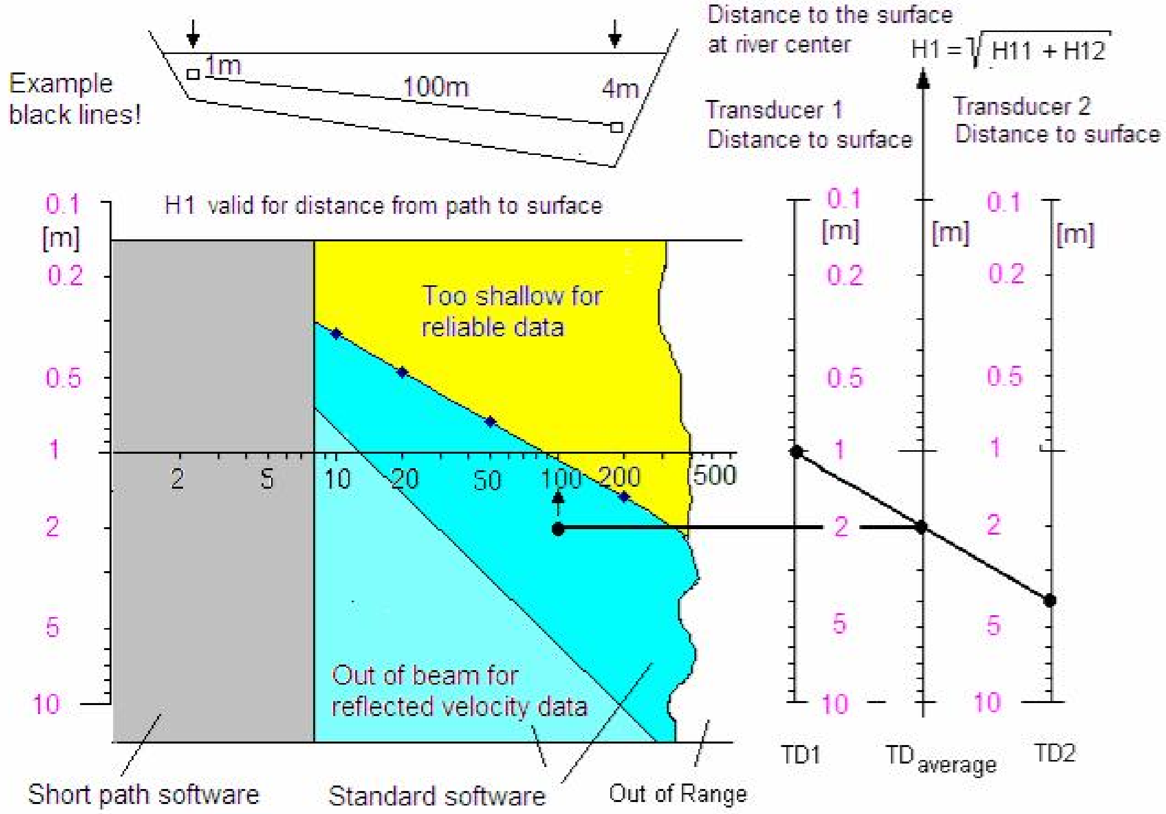
To put the problem into the right perspective a few measured results will illustrate the picture:

Regular running rivers with v = 0.2 m/s or higher:
Maximum observed temperature gradient: 0.1°C/m

Still water, strong sunshine v = 0.0 m/s:
Maximum observed temperature gradient: 3.0 °C/m

The examples do not mean that there may be areas where the temperature gradient found could be higher, anything that improves mixing of the water, like ship traffic, or weirs, will reduce the chance of temperature bending.

# Deltaflex Operational Area




Can be used intensively with Simulation Software

Example for transducer
TD1 = 1m
TD2 = 4m deep

Min. required distance H1 to surface at given path length

due to Ray-Bending
Sediment
Weed
Air Bubbles
Snow
**Range may be reduced considerably**

**How to use the diagram:**

Either:

From the given pathlength and the given average depth H1 check where your operational area is.

Or:

From the given transducer depth H1 find the maximum pathlength in the allowed operational area.

H1 is the effective minimum distance from the acoustic path to the surface or to the bottom, if one transducer is at H11 and the other one at H12.

Miminum depth valid without ray bending. H2, the additional depth to allow ray bending must be found by the Ray Bending Diagram.

The total minimum depth must be > 2 H1 + H2

# Deltaflex Menu Option Descriptions

## Parameter Entry Menu Options

### System Reset

This option clears all of the system parameters. When this option is selected the user will be prompt to confirm the reset with a yes or no prompt.

### Metric/USA Standard

Selecting this option will toggle the measurement unit type. If USA Standard is selected the measurement units will be based in feet. If metric is selected the base unit will be meters.

### Select Channels to Use

When this option is selected the following menu will appear:

```
>> Indicates an option that has been selected. Enter the number
beside an option to select/deselect it. When you hit ENTER the
option list will be redisplayed. Press Escape to exit.

Paths used     : >>1 >>2   3   4
Path           :    ^

1: >>Channel 1
2: >>Channel 2
3:   Channel 3
4:   Channel 4
5:   Exit

P>
```

The arrow beside the channel number indicates that the channel is enabled. To enable a channel enter the number corresponding to the channel you wish to activate and press enter. To disable the channel, repeat the same procedure. Most Deltaflex menu options operate like a toggle switch, selecting the option turns it on and off.

A string of numbers can also be entered at the prompt, for example, if channels on and two were to be selected, 125 could be entered at the prompt. This commands the system to select channels one and two, ‘5’ commands the system to exit from this menu.

## Clock Parameter Menu

When this option is selected the following menu will appear:

```
CLOCK PARAMETER MENU

1: Set Clock Date And Time
2: Set Measurement Start Date And Time
3: Set Measurement Integration Time
4: Set Interval Time Between Measurements
5: Set Discharge Average H-Hour
6: Back To Parameter Entry Main Menu
7: Exit To Main Menu

14:12:52 C>
```

This menu controls all of the system's clock parameters. If the Deltaflex is going to be used with a SDI data logger you can skip this menu. If you plan to use the system via an RS-232 connection or with the optional 'relay/analog current output board' the clock can be used to make scheduled measurements at user defined intervals.

Below is a brief description of each option within the Clock Parameter Menu.

### Set Clock Date and Time

This option allows you to set the date and time. The following screen will appear after this menu option is selected.

```
Clock fields are entered in the following order:


  CC YY MM DD HH mm SS
  || || || || || || ||_ Seconds: 00 - 59
  || || || || || ||____ Minutes: 00 - 59
  || || || || ||_______ Hours  : 00 - 23
  || || || ||__________ Date   : 01 - 31
  || || ||_____________ Month  : 01 - 12
  || ||________________ Year   : 00 - 99
  ||___________________ Century: 00 - 99

Delimiter characters between fields are optional. Entering 2 delimiter
characters in succession causes a field to be skipped.
Fields entered are right justified, so entering:   5,00   causes the
minutes
field to be set to 05 and seconds to 00 with all other fields left
unchanged.

Clock date and time  : 2001 10/05 14:12:57
Enter Clock Date/Time:
```

To change the time and date simply enter the desired 'time string' at the prompt. For example, if you wanted to set the date and time to August 10 2001 10:30:00 you would enter the following string: **2001 08 10 10 30 00** and then press enter. If you are interested in only changing the time you would enter **10 30 00**. All of the clock menus use this string format.

**Set Measurement Start Date And Time**

This option allows the user to enter the specific date and time the Deltaflex will start making measurements. Usually you would want the system to start making measurements immediately; therefor you could leave this option as is and the Deltaflex will set the start time behind the clock time.

**Set Measurement Integration Time**

The Integration time determines how many measurements will be made in a fixed amount of time. If the Integration time is set to one minute, for example, the system will make as many measurements as possible within one minute. After all of the measurements have finished they are averaged. The Deltaflex will store and output the average of the measurements. The interval time must always be larger than the integration time.

**Set Interval Time between Measurements**

This option allows the user to set the measurement frequency. For example, If the interval time was set to five minutes, the Deltaflex would measure all enabled channels at an interval time of every five minutes. The start time is automatically incremented after each measurement.

### Measurement Parameter Menu

When the measurement parameter menu is selected the following screen will appear.

```
MEASUREMENT PARAMETER MENU

Paths used      : >>1 >>2   3   4
Path            :    ^

1: Enter Observed Velocity Of Sound
2: Select Depth Sounding Transducer
3: Enter Depth Gain Adder
4: Enter Depth Reference Value
5: Channel 1 Parameter Menu..
6: Channel 2 Parameter Menu..
7: Channel 3 Parameter Menu..
8: Channel 4 Parameter Menu..
9: Velocity Sign Menu..
0: Discharge Setup Menu..
A: Back To Parameter Entry Main Menu
B: Exit To Main Menu

14:13:19 M>
```

This menu controls the measurement parameters for the Deltaflex. Below is a brief description of each option.

### Enter Observed Velocity of Sound

This option allows the user to enter an initial value for the velocity of sound. The initial value for this parameter is 1450.000 meters per second.

### Select Depth Sounding Transducer

For the Deltaflex to work properly a stage (vertical) transducer should be installed in conjunction with the horizontal transducers. The details for this installation will be discussed in another section of this manual. When selecting the depth sounding transducer the following menu will be displayed.

```
STAGE TRANSDUCER SELECTION MENU

(1)Td up (2)Td dn
+0.418   +0.403
+0.346   +0.407
+0.393   +0.407

3: Repeat Calculation
4: Exit
```

(1) The left column (Td up) represents 3 separate stage measurements made using the upstream transducer line. If the stage transducer is connected to the upstream transducer select this column by pressing ‘1’ and ‘4’.

(2) The right column (Td dn) represents 3 separate stage measurements made using the downstream transducer line. If the stage transducer is connected to the downstream transducer select this column by pressing ‘2’ and ‘4’.

If either of the stage measurements do not represent the depth of the vertical transducer, option ‘3’ can be entered to repeat the measurement. Note that the depth measured using this transducer represents the distance from the transducer face to the surface of the water not the entire depth of the river.

It is important to make note of which line the stage transducer is connected to. Sometimes a stage reading will be outputted on both lines. This is due to cross talk between conductors in the cables.

**Enter Depth Gain Adder**

This option allows the user to enter a static value that will be added to the depth gain. The depth gain is a value used by the amplifiers in the receiver circuit. This option is for testing purposes and should not be changed by the user.

**Enter the Depth Reference Value**

This menu option allows the user to enter an offset value to be added to the depth measurement. The offset will automatically be added to the measured depth. This option is useful when the depth is to be referenced to sea level.

**Channel Parameter Menus**

Menu Options ‘0’, ‘A’, ‘B’ and ‘C’ are used to change the parameters for each individual channel. To access the menu for a channel, the channel must be enabled first. To enable a channel use the ‘select channels to use’ option from the main menu.

The options within the channel parameter menus are common to each channel so the ‘channel 1 parameter menu’ will be used for describing each menu option.

```
CHANNEL 1 PARAMETER MENU

0: Enter Minimum Path Length
1: Calculate And Select Path Length
2: Enter FB Value
3: Enter Horizontal Gain Adjuster
4: Enter Vertical Transducer Face To Horizontal Path Offset
5: Enter Discharge Arrays..
6: Process Velocities Through Filter
7: Select Test Functions..
8: Add Offset To Velocity Measurement
9: Back To Measurement Parameter Menu
A: Exit To Main Menu
```

**Enter Minimum Path Length**

This option allows the user to specify the minimum path that the Deltaflex will measure. Normally the Deltaflex will not make measurements using path lengths less than 7 meters. If the minimum path length is set to '1', the Deltaflex will change modes to accommodate shorter path lengths.

**Calculate and Select Path Length**

This option will command the Deltaflex to search for the path length automatically. This option is mandatory. The user must select the range that the path is in, for example, if the path length is 43.567m, the user would enter '4'. If a path length cannot be found it can be entered manually by using option '50'. Below is the Path Length Selection Menu.

```
CHANNEL 1 PATH LENGTH SELECTION MENU
Path Length : NOT CALCULATED

 0:    7m to 10m         1:   10m to 20m         2:   20m to 30m
 3:   30m to 40m         4:   40m to 50m         5:   50m to 60m
 6:   60m to 70m         7:   70m to 80m         8:   80m to 90m
 9:   90m to 100m       10:  100m to 110m       11:  110m to 120m
12:  120m to 130m       13:  130m to 140m       14:  140m to 150m
15:  150m to 160m       16:  160m to 170m       17:  170m to 180m
18:  180m to 190m       19:  190m to 200m       20:  200m to 210m
21:  210m to 220m       22:  220m to 230m       23:  230m to 240m
24:  240m to 250m       25:  250m to 260m       26:  260m to 270m
27:  270m to 280m       28:  280m to 290m       29:  290m to 300m
30:  300m to 310m       31:  310m to 320m       32:  320m to 330m
33:  330m to 340m       34:  340m to 350m       35:  350m to 360m
36:  360m to 370m       37:  370m to 380m       38:  380m to 390m
39:  390m to 400m       40:  400m to 410m       41:  410m to 420m
42:  420m to 430m       43:  430m to 440m       44:  440m to 450m
45:  450m to 460m       46:  460m to 470m       47:  470m to 480m
48:  480m to 490m       49:  490m to 500m
50:  Enter Path Manually
51:  Exit to Channel Parameter Menu
PL >
```

The acoustic path must be covered in water in order for the Deltaflex to determine the path length. If there is no water coverage the path length should be measured physically and entered manually using option '50'.

**Enter FB Value**

This is another mandatory option. The value entered using this menu represents the angle of the path to the flow. The following formula can be used to calculate the FB value:

**FB = 2048/Cos Φ**

Where Φ is equal to the angle of the path to the flow of water.
For example a 45 degree path angle would result in the following: 2048/Cos 45 = 2896

**Enter Horizontal Gain Adjuster**

This option allows the user to enter a static value to be added to the horizontal gain value. It is recommended that the user leave this option as the default value.

**Enter Vertical Face to Transducer Offset**

This option allows the user to enter the offset between the acoustic path and the face of the vertical (stage) transducer. The offset is millimetres (depending on selected unit base) and is measured from the top of the path to vertical transducer face. For example, if one of the paths were 140mm above the stage transducer the user would enter –140 at this prompt.

**Enter Discharge Arrays**

This option allows the user to enter a pre-calculated discharge array. Using the data from this array, the Deltaflex can accurately determine the discharge using the velocity and stage data from a measurement. If this option is selected the following screen will appear.

```
X AND Y DISCHARGE ARRAY ENTRY

X Array: 0 0 0 0 0 0 0 0 0 0
Y Array: 0 0 0 0 0 0 0 0 0 0

1: Enter X Array Entries
2: Enter Y Array Entries
3: Exit

A>
```

In order to complete a discharge calculation the user has to enter a cross-section and stage array. This array is calculated from a study of the cross-section which represents the proposed site. A discharge value can be obtained from any of the four channels, but in order to do this a cross-section and stage array have to be entered for each channel.

There are 2 arrays for each channel and 10 elements to each of the arrays. The X-array defines the area while the Y-array defines the stage. The first entry should be left zero to avoid interpolation errors should the stage value fall below the expected minimum. Likewise, the last entries should correspond to a stage value that is above the expected maximum. You do not have to fill all 10 entries. You can use as many as you need to give you accurate discharge values, the values between entries are interpolated.

Each entry in the X-array (the area array) corresponds to an entry in the Y-array (the stage array). The entry in the Y-array represents a stage value, and the entry in the X-array is a cross-section area for that water level. To calculate the discharge, it is necessary to multiply the average velocity of the water with the valid cross-section, which is a function of the stage:

**Q = Va * A(S)**

*Where Q = Discharge*
*Va = Average velocity*
*A(S) = Cross-sectional area as a function of stage S.*

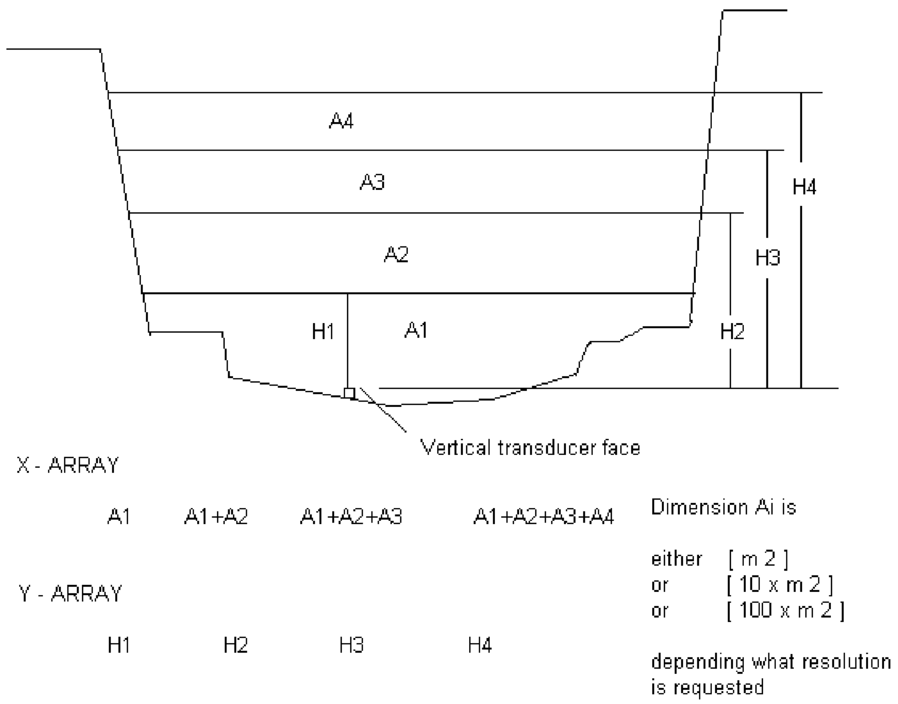
With the Deltaflex the equation needs to be modified slightly:

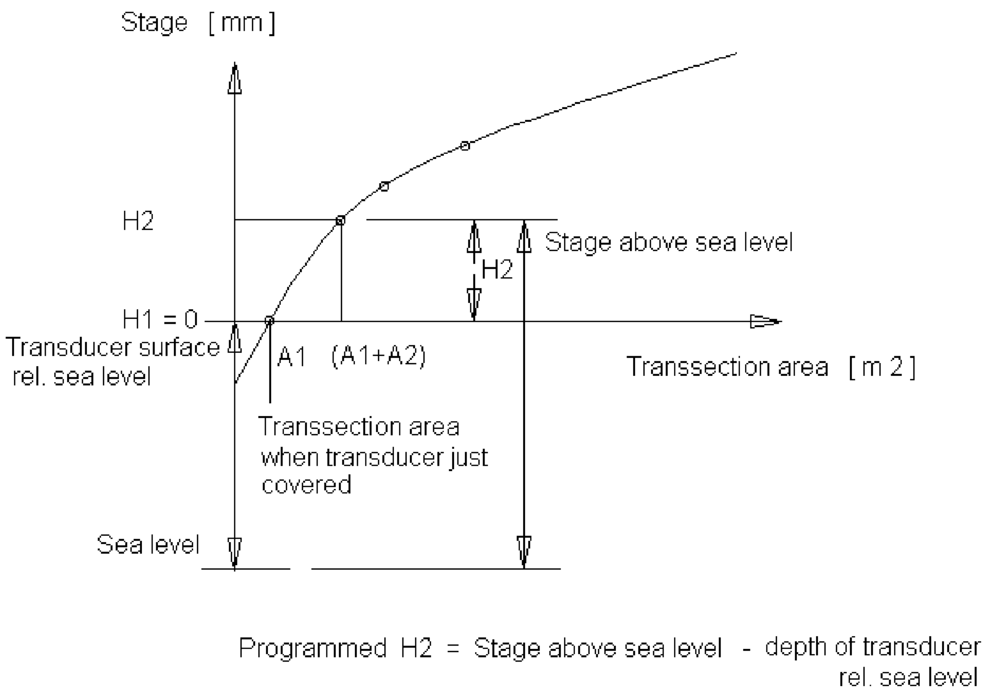
**Q = Vm * FB * K(S) * A(S)**

*Where Q = Discharge*
*Vm = Measured velocity along the acoustic path*
*FB = Geometric constant*
*K(S) = Correction factor as a function of stage, and related to:*

*1) The shape of the cross-section*
*2) The depth of the acoustic level*
*3) The roughness of the bottom*
*4) The position of the transducers*
*5) The roughnes of ice cover (if any)*

*A(S) = Cross-sectional area as a function of stage.*




The cross-section area as a function of stage is usually available as a drawn curve. The Deltaflex uses a polygon approximation of this curve and 10 corresponding points each for stage and cross-section area are provided in the arrays. It is recommended to use more entries where cross-sectional features change, and less entries where the features are uniform.

**Correction Factor K**

The measured velocity has to be multiplied with the appropriate correction factor K. This is because the Deltaflex measures the average velocity along the acoustic path at it's particular depth, but the measured velocity is not necessarily the same as the average velocity in the total cross-section. The K-factor equals the ratio of the (displayed) real velocity in the total cross-section to the measured velocity in the acoustic path. There are 2 ways to determine the K-factor:

1) The correction factor can be calculated using computer models of the site. They are slightly different for different stage levels. In any case the correction factor will be, in most cases, between 0.9 and 1.0. If the water level remains fairly constant and the level of the acoustic path is chosen to be about 60% of the total depth in the middle of the river, the error is marginal if no correction is applied at all. By applying the proper correction factors from the array, the accuracy of the measured discharge can be improved considerably over a wider range of water levels and errors in the +/- 2% range can be maintained.

2) The correction can be found by comparing current meter measurements with Deltaflex results. This is a very time consuming procedure because only one point of the curve "VMeter vs. VDeltaflex" can be obtained with one set of current meter measurements at a given velocity and water level of the river. Sometimes it takes years to find the values at the extreme ends of the curve because they are rare events.

**Calculating The Cross-section (X) Array Entries**

The Deltaflex provides 1 set of 10 numbers for the different stage levels and only 1 set of 10 numbers to accommodate K(S) and A(S). From the equation described above it can be seen that K(S) * A(S) is a product, which can be expressed as 1 number per stage point. Before the cross-sectional area is programmed into the Deltaflex, each value of the cross-section has to be multiplied with the appropriate K-factor at that particular stage. For example:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Stage S* | : | *0000* | *1000* | *1500* | *2000* | *2500* | *3000* | *from drawing* |
| *K(S) * A(S)* | : | *0100* | *0124* | *0256* | *0366* | *0444* | *0500* | *from drawing* |
| *Calc. K* | : | *0.900* | *0.945* | *0.972* | *1.000* | *1.043* | *1.060* | *from computer model* |

So, from this table we have the numbers that would be entered into the Deltaflex:

*Y-Array : 0000 1000 1500 2000 2500 3000*
*X-Array : 0090 0117 0248 0366 0462 0530*

In this example the units of measurement for the stage (Y-Array) is millimeters. The units of measurement for USA standard would be 1/1000 of a foot, so that a stage entry of 6125 is 6.125 feet.

**Add offset to Velocity Measurement**

This option allows the user to enter an offset to the direct velocity measurement. The default offset is zero.

**Velocity Sign Menu**

This menu is used to switch the polarity of a desired channel's velocity measurement. If this option is selected the menu on the next page will appear. The menu's options are self-explanatory.

```
Paths used     : >>1 >>2   3   4
Path           :   ^

1:   Reverse Observed Velocity Sign On Channel 1
2:   Reverse Observed Velocity Sign On Channel 2
3:   Reverse Observed Velocity Sign On Channel 3
4:   Reverse Observed Velocity Sign On Channel 4
5:   Back To Parameter Entry Main Menu
6:   Exit To Main Menu
```

## Discharge Set-up Menu

This menu allows the user to decide how the discharge value(s) will be stored and outputted to a recording device. Below is the discharge set-up menu and description of each option.

```
DISCHARGE DISPLAY MENU

Paths used      : >>1 >>2   3   4
Path            :    ^

1:   Individual Discharges, 1 For Each Channel
2:   One Discharge From Sum Of Discharges
3: >>One Discharge From Average Of Discharges
4:   Back To Parameter Entry Main Menu
5:   Exit To Main Menu

14:15:32 D>
```

'Individual Discharges' command the system to save individual discharges for each channel and output the values as required.

'One Discharge from the sum of the discharges' adds the value of all discharges measured by the system. Each channel can calculate a discharge value. The sum of the discharge values is stored in memory and outputted as a data string.

The average discharge is calculated from the average of all available paths, and is stored in memory. This value is also outputted as a data string.

## SDI-12 Parameter Menu

The SDI-12 menu allows the user to change parameters dealing with SDI-12 communications. Options in this menu are described on the next page.

**Select Channel 1 Measurements**

This menu option allows the user to select the type of measurement and the number of measurements to be sent via SDI-12 to a data-logger. The measurement choices include:

| | |
|---|---|
| Direct Velocity | Discharge as acre-feet |
| Reflected Velocity | Velocity of sound |
| Velocity Ratio | Measurement Quality |
| Discharge | Gain |
| Stage | Water Temperature |
| Discharge as day-second-feet(dsf) | Salinity |

All of the measurement can be selected and the SDI output string is assembled in the same order as the list.

**Select Device Address**

The Deltaflex uses, as a unique identification, a device address when used in conjunction with a SDI-12 data logger. After a reset the device address is set to zero. If you plan to use the Deltaflex on a SDI-12 data bus containing more than one sensor it is important to make sure each sensor has a different device address. The Deltaflex can be set to respond to one of ten different device addresses.

**Desktop Parameter Options**

This menu option allows to the user to change parameters related to PC/Deltaflex communications. Options include the ability to change the BAUD rate, selecting measurements to output via RS-232 etc. Below is description of each menu option.

**>>Time Displayed with Menu Prompts**

This option, if selected, will enable the display of the time stamp at the menu cursor. If this option is disabled, the time stamp is removed.

**>>Display Menu Prompts**

If this option is enabled, the menu prompts will be displayed.

**>>Display Help with Input Dialogs**

This option, when selected, will enable the display of a descriptive help dialog before most menu options. This option is enabled as default.

### >>Display Measurement Indicators

When this option is enabled the Deltaflex will output characters indicating what stage of measurement the system is currently executing. This option is enabled as default.

### >>Display Version Information

This option, when selected, will display the software version and compilation date at the beginning of the main menu. This option is enabled as default.

### Display Daily Discharge Average

This option allows the user to output a discharge value based on the average of all discharges measured during the period of one day.

### Select Measurement Display Fields

This option will display a large menu which allow the user to select which measurements will be displayed when 1) the measurements are dumped using the measurement display menu option (Main Menu Option 4) or 2) during a normal measurement the selected measurements will be sent to the screen of the users laptop/terminal. To select one or more of the measurements in this menu simply enter the number or letter which correspond to the measurement.

```
>> Indicates an option that has been selected. Enter the number beside
an option to select/deselect it. When you hit ENTER the option list will
be redisplayed. Press Escape to exit.

1: >>Individual
2:   Combined

3: >>Stage
4: >>Temperature

Path 1           Path 2           Path 3           Path 4
5: >>V Direct    C: >>V Direct    K: >>V Direct    S: >>V Direct
6: >>V Reflect   D: >>V Reflect   L: >>V Reflect   T: >>V Reflect
7:   Ratio       E: >>Ratio       M: >>Ratio       U: >>Ratio
8:   Discharge   F: >>Discharge   N: >>Discharge   V: >>Discharge
9: >>V/Sound     G:   V/Sound     O:   V/Sound     W:   V/Sound
0: >>Salinity    H: >>Salinity    P: >>Salinity    X: >>Salinity
A: >>Gain        I: >>Gain        Q: >>Gain        Y: >>Gain
B: >>Success     J: >>Success     R: >>Success     Z: >>Success

>:   Exit

M>>
```

### Select Measurement Path Displayed

This option allows the user to select which path's measurements will be displayed during operation via a laptop or terminal. The default for this option is path one.

### Select Baud Rate

This option will display the following menu which allows the user to select which baud rate to use when communicating with a laptop computer, or terminal.

To change the baud rate simply enter the number which corresponds the desired value and hit enter. The cursor [>>] will indicate the change.

Select '8' to change to the new baud rate. The Deltaflex will wait 45 seconds for the user to change the baud rate of the host PC to match the Deltaflex. If the baud rate of the host PC is not changed within the allotted time, the Deltaflex will change back to the original baud rate.

```
>> Indicates an option that has been selected. Enter the number beside an
option to select/deselect it. When you hit ENTER the option list will be
redisplayed. Press Escape to exit.

1:      300
2:      600
3:     1200
4:     2400
5:     4800
6: >> 9600
7:    19200
8:    Change To Selected Baud Now
9:    Exit

B>9
```

### Check Parameter Integrity

This option, when selected, compares the parameters used by the Deltaflex with a back-up copy of the parameters. The Deltaflex will report an error if the parameters have been corrupted.

**Parameter View Menu**

This menu allows the user to view the current parameters for each channel. When this option is selected the following screen will appear.

```
1: Channel 1 Parameters
2: Channel 2 Parameters
3: Channel 3 Parameters
4: Channel 4 Parameters
5: Exit to Main Menu
```

To view the parameters for one of the channels simply enter the number that corresponds to that channel and press 'enter'. The channel parameter screen is shown below.

```
Paths used      : >>1   2   3   4
Path            :   ^

Units: Metric

Current filter threshold value: 300
Current filter slope value    : 025
Current filter scale value    : 020
Current depth gain adder: 06
Current base value      : +00000000
Current Fb value        : 2048
Current gain adjuster   : +04
Current face distance   : -200
Current path length     : 22.792
Velocity Offset (mm)    :

X Array: 0 0 0 0 0 0 0 0 0 0
Y Array: 0 0 0 0 0 0 0 0 0 0

Start date and time          : 0110 10/12 01:41:00
Integration date and time    : 0000 00/00 00:00:00
Interval date and time       : 0000 00/00 00:01:00
Discharge H-Hour time        : 0000 00/00 00:00:00

Press any key...
```

## Memory Dump Menu

This menu option allows the user to search through the memory of the Deltaflex using 20 Bit addressing. This option is not useful for the typical user and intended for testing purposes only.

If this option is selected the following screen will appear.

```
1: Enter start address
2: Enter stop address
3: Dump memory
4: Exit
```

Option 1 allows the user to enter the starting address of the memory dump, for example, a typical address would be entered as 81FFF.

Option 2 is used to enter the stop address for the memory dump.

Option 3 dumps the memory from the start address to the end address. Pressing escape during the memory dump will exit from the menu.

## Measurement Display Menu

The measurement display menu allows the user to output up to 754 measurements via a RS-232 connection, i.e. a laptop or terminal. The measurements can be outputted from earliest to most recent or vise-versa. The number of measurements the user wishes to output can be controlled also. Using the *Select Measurement Display Fields* option of the desktop parameter menu the user can also select which measurements will be displayed. If the user has software such as PROCOMM, or any software platform which allows logging to a file, the measurements can be saved and later analyzed in a program such as Excel.

```
MEASUREMENT DISPLAY MENU

Enter selections as follows:

1125
||||_ 1 or 2 digits specifying number of records.
||___ 1 digit (1 or 2 only) specifying direction.
|____ 1 digit (1 to 4 only) specifying channel.

Use * after channel and direction to specify all records.

1125 = Channel 1, display forward, 25 records.
22*  = Channel 2, display backward, all records.

Date and time output          : Display date and time

Date of first record          : 2002/11/30 18:32:30
Date of last record           : 2002/11/30 18:27:30
Number of records ( 753 max.): 753

1: Display All Records Forward From First Record
2: Display All Records Backward From Last Record
3: Display Time Only
4: Display Date And Time
5: Display Date In Header When Date Changes
6: Exit to Main Menu

10:23:05 R>
```

### Display All Records Forward From First Record

This option allows the user to display all of the records currently stored in memory for a certain path. The order in which the records are displayed is earliest record to most recent. It is recommended that the format described at the beginning of the menu is used when outputting measurements.

### Display All Records Backward From Last Record

This option allows the user to display the records stored in memory in order from the most recent measurement to the earliest measurement. It is recommended that this option be used in a string as mentioned at the beginning of the *Measurement Display Menu.*

### Display Time Only

This option, when selected, will cause only the time stamp of each measurement to be outputted with each measurement.

### Display Date and Time

This option will cause the date stamp to be outputted with the time of each measurement.

### Display Date in Header When Date Changes

This option, when selected, will cause the date stamp to be outputted only when the date changes.

## Relay Board Menu

The Relay Control Board is an optional expansion for the Deltaflex AVM. It is designed to use velocity measurements to control external mechanical devices. Devices can include floodgates, indicator lights etc.

The Relay Board Menu allows the user to enter four threshold values. These values determine, from a velocity measurement, which relays to activate. The relay board is equipped with three relays. Two relays are used for control while the third relay is used to indicate if a measurement error occurred. The menu requires that the user enter two threshold values per relay. This is to avoid 'bouncing' relays. For example, if a threshold was set to 1.000 m/s and the Deltaflex measured a velocity of 1.002 m/s the relay would close, but if the next measurement were 0.998 m/s the relay would open. This problem can be avoided by entering two thresholds per relay. In the situation mentioned above the thresholds (menu options 1 & 2) could be set to turn the relay on at 1.000 m/s and turn the relay off at 0.990 m/s. This creates a dead zone avoiding the problem of relay bouncing.

Options '1' and '2' set the on and off thresholds for relay one while options '3' and '4' control the options for relay two. The relay board must be enabled (option '0') for the hardware to respond. Below are the options within the Relay Board Menu. Explanations follow on the next page.

```
0: ENABLE/DISABLE Relay Board
1: Set positive velocity threshold (RELAY ON)
2: Set positive velocity threshold (RELAY OFF)
3: Set negative velocity threshold (RELAY ON)
4: Set negative velocity threshold (RELAY OFF)
5: View velocity thresholds
6: Return to Main Menu
```

### Enable/Disable Relay Board

This option is used to enable or disable the relay control board. The status of the relay control board will be indicated at the top of the relay board menu. This option works like a toggle switch.

### Set positive velocity threshold (RELAY ON)

This option allows the user to set a threshold value which will activate (close) relay one when compared to a velocity measurement. The threshold value is in millimetres.

**Set positive velocity threshold (RELAY OFF)**

This option allows the user to enter a threshold value that will disable relay one when compared to a velocity measurement. The units the threshold value is represented in is millimetres.

**Set negative velocity threshold (RELAY ON)**

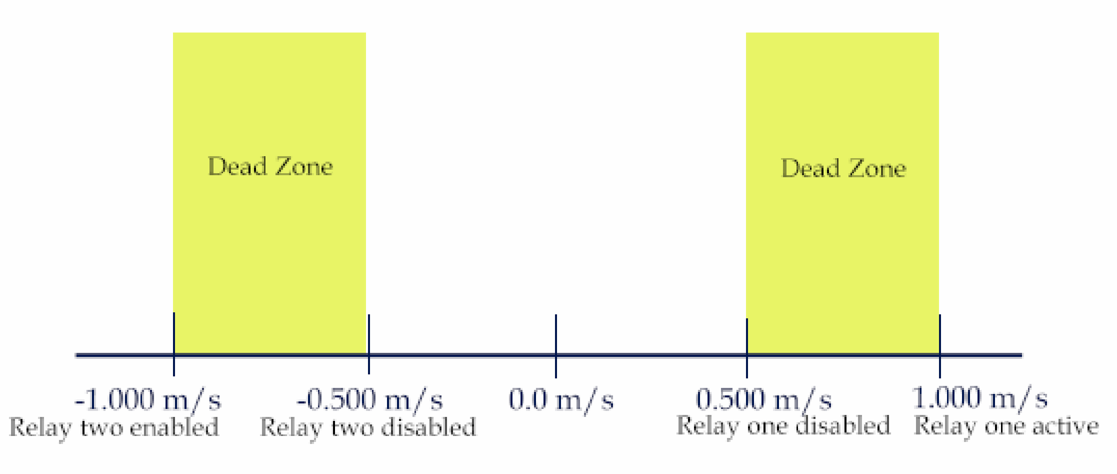
This option allows the user to enter a threshold value that will enable relay two when compared to a velocity measurement. The threshold value is in millimetres.

**Set negative velocity threshold (RELAY OFF)**

This option allows the user to enter a threshold value that will disable relay two when compared to a velocity measurement. The threshold value is in millimetres.

**View velocity thresholds**

This option is used to view the threshold values for relay one and relay two. After a reset, the threshold values are set to zero.




This diagram represents a situation where the thresholds used to activate relays one and two are set 1.000 m/s and –1.000 m/s respectively and the thresholds used to disable the relays on and two are set to 0.500 m/s and – 0.500 m/s.

## Measure All Channels

This option will measure all available channels. To measure all channels, the desired channels must be enabled and the parameters for each channel must be initialised to values that represent your installation. When this command is selected the Deltaflex will measure the channels in order from channel one to channel four.

The quantities that the Deltaflex can measure include:

1) **Direct Velocity** – The direct velocity is considered to be the line of site velocity, or the velocity along the acoustic path. The Deltaflex can measure velocities ranging from –4.000 m/s to +4.000 m/s.

2) **Reflected Velocity** – The reflected velocity represents the water velocity near the surface of the water.

3) **Stage** – The stage measurement represents the depth of the water. This value is measured from the face of the vertical transducer to the surface of the water.

4) **Temperature** – The temperature range is from +38 degrees Celsius to –5 degrees Celsius.

5) **Discharge** – The Deltaflex will calculate the discharge for each channel if a discharge array is entered using the 'Enter Discharge Arrays' from the 'Channel Parameter Menu'. The discharge measurement is recorded in cubic metres unless changed to USA standard.

6) **Gain** – This measurement reports the receiver amplifier gain. The maximum gain is 63. This value can be helpful when troubleshooting a site or determining weed coverage.

7) **Salinity** – The Deltaflex can determine the salt content of a river by using the measured temperature and the calculated speed of sound.

8) **Speed of Sound** – The Deltaflex calculates the speed of sound in metres per second. The speed of sound calculation can be read via a SDI-12 connection.

**Measure Channel (1 – 4)**

Options ‘7’, ‘8’,’9’ and ‘0’ allow the user to make instantaneous measurements of any channel. In order to use these options the channels you wish to measure must be enabled and the parameters for that channel must be initialised to the values that represent the physical characteristics of your site.

Before the Deltaflex is left on the site to record data, all of the active channels should be tested using the above options to determine if the installation is good and if the parameters are valid.

## Analog Output Options

With the addition of an optional Relay Control/Analog Add-in board, the Deltaflex can be configured to output measurement data in the form a 4 to 20mA electric current. The analog board contains two output channels. Both channels can be set independently.

The following measurements can be selected as output values for both output channels:

1: Direct Velocity
2: Discharge (either a single discharge or the average from each channel)
3: Stage

If a channel is selected to output a measurement, the range for that channel must be set. The range represents the minimum and maximum values that will be converted to an electric current. The range also determines the resolution of the current output.

For example, if a site had typical velocity measurements ranging from +0.120 m/s to 0.440 m/s the minimum range could be set to 0.100 m/s and the maximum range could be set to 0.500 m/s. This would result in a total velocity range of 400 mm/s and a current change of 40 uA for every 1mm/s change in velocity.

Below is the menu for the Analog Output Channels.

```
Analog Channel 1 Output : None
Analog Channel 2 Output : None

1: Change Analog[1] Output (Vel/Dis/Stg/None)
2: Change Analog[2] Output (Vel/Dis/Stg/None)
3: Set Analog[1] Maximum Limit
4: Set Analog[1] Minimum Limit
5: Set Analog[2] Maximum Limit
6: Set Analog[2] Minimum Limit
7: Force Velocity (Calibration)
8: Return to Main Menu
```

### Change Analog[1] Output (Vel/Dis/Stg/None)

This option allows the user to select which measurement to convert to an electric current. Once this choice has been made the limits must be set. This option reflects the output for channel one.

### Change Analog[2] Output (Vel/Dis/Stg/None)

This option allows the user to select which measurement to convert to an electric current. The converted measurement will be sent to channel two. The limits must set in order for this option to work properly.

### Set Analog[1] Maximum Limit

This option is used to enter the maximum limit. The limits are used to determine the range for measurements sent to the current output for channel one. If a measurement is above the set limit the analog output will not change.

### Set Analog[1] Minimum Limit

This option is used to enter the minimum limit for channel one. The combination of the minimum and maximum limits determines the range. If a measurement is out of range, the output will not change.

### Set Analog[2] Maximum Limit

This option sets the maximum limit for the channel two analog output. If the measurement is above this value the measurement is discarded and the analog output does not change.

### Set Analog[2] Minimum Limit

This option allows the user to set the minimum limit for the channel two analog output. If the measurement is less than the limit it is discarded and the analog output does not change.

### Force Velocity (Calibration)

This option is used to calibrate the analog board and the data recorder. To use this option the limits must set up. Once the limits are initialised the user can use this option to force a value to be converted to an electric current. For example, if the limits for one current output channel were set to 0.000 m/s and 1.000 m/s, the force velocity option could be used to check the operation of the analog output board. If a value of 0 was 'forced', the current output would equal 4.0mA. A value of 1.000 would cause the current output to change to 20.0mA.

**Power Off**

This option turns the power to the Deltaflex off to save power in between measurements. This option should be selected before the power is turned off via the switch on the front of the Deltaflex. If this option is selected all components of the Deltaflex will be disabled except the clock. If the Deltaflex is set up to make routine measurements using the clock it will power up to make a measurement and power down after the measurement finishes.

# A Basic Deltaflex Set-Up – Menu Version

## Step #1 - Calculating the Water Temperature

The Deltaflex has the ability to calculate the temperature of the water to a precision of 0.01°C. This measurement is required to determine the preliminary Velocity of Sound via the **Velocity of Sound vs. Temperature Look-Up Table**.

```
AFFRA Deltaflex from Stedtnitz Maritime Technology Ltd.

Version : D20_AO[15]
Compiled : 05/05/2005

MAIN MENU

1: Parameter Entry Menu
2: Parameter View Menu
3: Memory Dump Menu
4: Measurement Display Menu
5: Relay Board Options
6: Measure All Channels
7: Measure Ch 1
8: Measure Ch 2
9: Measure Ch 3
0: Measure Ch 4
A: Analog Output Options
B: Power Off

00:00:15 C>1
```

```
PARAMETER ENTRY MAIN MENU

Paths used     : >>1   2   3   4
Path           :    ^

Units: Metric

1: System Reset
2: Metric/USA Standard
3: Select Channels To Use..
4: Clock Parameter Menu..
5: Measurement Parameter Menu..
6: SDI-12 Parameter Menu..
7: Desktop Parameter Menu..
8: Check System Parameter Integrity
9: Exit To Main Menu

00:00:16 P>5
```

```
MEASUREMENT PARAMETER MENU


Water Temperature : +11.53 C
Temp Gain : 00
Paths used     : >>1   2   3   4
Path           :   ^

1: Enter Observed Velocity Of Sound
2: Select Depth Sounding Transducer
3: Enter Depth Gain Adder
4: Enter Depth Reference Value
5: Ch 1 Parameter Menu..
6: Ch 2 Parameter Menu..
7: Ch 3 Parameter Menu..
8: Ch 4 Parameter Menu..
9: Velocity Sign Menu..
0: Discharge Setup Menu..
A: Calculate Temperature
B: Back To Parameter Entry Main Menu
C: Exit To Main Menu

00:00:21 M>a
```

After 'A' is entered at this menu, the gain required to receive a strong signal from the temperature sensor will be calculated first. This will be indicated via the 'TG' symbols. After this has completed, the 'TC'symbol will appear indicating that the temperature value is being calculated. When the temperature has been calculated, the MEASUREMENT PARAMETER MENU will roll over and the water temperature, plus the gain will be displayed at the top of the menu.

### Step #2 – Entering the Velocity of Sound

From the calculated temperature, the user can now determine the proper value to enter as the Velocity of Sound. Refer the ***Velocity of Sound as a function of Temperature and Salinity*** chart at the end of this document.

```
MEASUREMENT PARAMETER MENU


Water Temperature : +11.55 C
Temp Gain : 19
Paths used      : >>1   2   3   4
Path            :    ^


1: Enter Observed Velocity Of Sound
2: Select Depth Sounding Transducer
3: Enter Depth Gain Adder
4: Enter Depth Reference Value
5: Ch 1 Parameter Menu..
6: Ch 2 Parameter Menu..
7: Ch 3 Parameter Menu..
8: Ch 4 Parameter Menu..
9: Velocity Sign Menu..
0: Discharge Setup Menu..
A: Calculate Temperature
B: Back To Parameter Entry Main Menu
C: Exit To Main Menu

00:00:33 M>1
```

↓ ↓

```
Units: Metric

Current C value                : 1450.000
Enter 8 digits for C (XXXX.XXX): 1453.600
```

**Step #3 – Calculating the Depth (Stage)**

Because the stage transducer can be wired in parallel to either, the upstream transducer, or the downstream transducer of channel 1, the Deltaflex must be instructed as to its location. The follow menus explain how.

```
MEASUREMENT PARAMETER MENU


Water Temperature : +11.55 C
Temp Gain : 19
Paths used     : >>1   2   3   4
Path           :   ^

1: Enter Observed Velocity Of Sound
2: Select Depth Sounding Transducer
3: Enter Depth Gain Adder
4: Enter Depth Reference Value
5: Ch 1 Parameter Menu..
6: Ch 2 Parameter Menu..
7: Ch 3 Parameter Menu..
8: Ch 4 Parameter Menu..
9: Velocity Sign Menu..
0: Discharge Setup Menu..
A: Calculate Temperature
B: Back To Parameter Entry Main Menu
C: Exit To Main Menu

00:00:47 M>2
```

```
STAGE TRANSDUCER SELECTION MENU

(1)Td up (2)Td dn

+1.594  +0.553
+1.590  +0.255
+1.592  +0.926

3: Repeat Calculation
4: Exit

S>14
```

In this case, the stage is connected to the upstream transducer so '14' is entered. It should be noted that '14' are individual commands, i.e. '1' and '4', and does not represent the number fourteen.

### Step #4 – Entering the Discharge Array

This step is only required if a discharge measurement is desired. If this array is left empty, the discharge will be set to zero. Each channel has an independent discharge measurement based that channels velocity and the stage. The discharge arrays can be entered by following the steps outlined below.

```
MEASUREMENT PARAMETER MENU


Water Temperature : +11.55 C
Temp Gain : 19
Paths used      : >>1   2   3   4
Path            :   ^

1: Enter Observed Velocity Of Sound
2: Select Depth Sounding Transducer
3: Enter Depth Gain Adder
4: Enter Depth Reference Value
5: Ch 1 Parameter Menu..
6: Ch 2 Parameter Menu..
7: Ch 3 Parameter Menu..
8: Ch 4 Parameter Menu..
9: Velocity Sign Menu..
0: Discharge Setup Menu..
A: Calculate Temperature
B: Back To Parameter Entry Main Menu
C: Exit To Main Menu

00:01:02 M>5
```

↓ ↓

```
CHANNEL 1 PARAMETER MENU

1: Calculate And Select Path Length
2: Enter FB Value
3: Enter Horizontal Gain Adjuster
4: Enter Vertical Transducer Face To Horizontal Path Offset
5: Enter Discharge Arrays..
6: Add Offset To Velocity Measurement
7: Enable Wet Sensor - DISABLED
8: Back to Measurement Parm Menu
9: Exit To Main Menu

00:01:06 M>5
```

```
X AND Y DISCHARGE ARRAY ENTRY

X Array: 0 0 0 0 0 0 0 0 0 0
Y Array: 0 0 0 0 0 0 0 0 0 0

1: Enter X Array Entries
2: Enter Y Array Entries
3: Exit

A>123
```

## Step #5 – Entering the Vertical to Horizontal Path Offset

```
CHANNEL 1 PARAMETER MENU

1: Calculate And Select Path Length
2: Enter FB Value
3: Enter Horizontal Gain Adjuster
4: Enter Vertical Transducer Face To Horizontal Path Offset
5: Enter Discharge Arrays..
6: Add Offset To Velocity Measurement
7: Enable Wet Sensor - DISABLED
8: Back to Measurement Parm Menu
9: Exit To Main Menu

00:01:27 M>4
```

↓

```
Current face distance   : +0000

Enter distance in millimeters that the vertical transducer
face is above (+) or below (-) the horizontal path.

mm: -100
```

## Step #6 – Entering the FB Value

```
CHANNEL 1 PARAMETER MENU

1: Calculate And Select Path Length
2: Enter FB Value
3: Enter Horizontal Gain Adjuster
4: Enter Vertical Transducer Face To Horizontal Path Offset
5: Enter Discharge Arrays..
6: Add Offset To Velocity Measurement
7: Enable Wet Sensor - DISABLED
8: Back to Measurement Parm Menu
9: Exit To Main Menu

00:01:33 M>00:01:34 M>2

Current Fb value      : 2048
Enter 4 digits for Fb: 2673
```

## Step #7 – Calculating the Path Length

```
CHANNEL 1 PARAMETER MENU

1: Calculate And Select Path Length
2: Enter FB Value
3: Enter Horizontal Gain Adjuster
4: Enter Vertical Transducer Face To Horizontal Path Offset
5: Enter Discharge Arrays..
6: Add Offset To Velocity Measurement
7: Enable Wet Sensor - DISABLED
8: Back to Measurement Parm Menu
9: Exit To Main Menu

00:01:39 M>1
```

```
CHANNEL 1 PATH LENGTH SELECTION MENU
Path Length : NOT CALCULATED
```

| | | | | | |
|---|---|---|---|---|---|
| 0: | 8m to 10m | 1: | 10m to 20m | 2: | 20m to 30m |
| 3: | 30m to 40m | 4: | 40m to 50m | 5: | 50m to 60m |
| 6: | 60m to 70m | 7: | 70m to 80m | 8: | 80m to 90m |
| 9: | 90m to 100m | 10: | 100m to 110m | 11: | 110m to 120m |
| 12: | 120m to 130m | 13: | 130m to 140m | 14: | 140m to 150m |
| 15: | 150m to 160m | 16: | 160m to 170m | 17: | 170m to 180m |
| 18: | 180m to 190m | 19: | 190m to 200m | 20: | 200m to 210m |
| 21: | 210m to 220m | 22: | 220m to 230m | 23: | 230m to 240m |
| 24: | 240m to 250m | 25: | 250m to 260m | 26: | 260m to 270m |
| 27: | 270m to 280m | 28: | 280m to 290m | 29: | 290m to 300m |
| 30: | 300m to 310m | 31: | 310m to 320m | 32: | 320m to 330m |
| 33: | 330m to 340m | 34: | 340m to 350m | 35: | 350m to 360m |
| 36: | 360m to 370m | 37: | 370m to 380m | 38: | 380m to 390m |
| 39: | 390m to 400m | 40: | 400m to 410m | 41: | 410m to 420m |
| 42: | 420m to 430m | 43: | 430m to 440m | 44: | 440m to 450m |
| 45: | 450m to 460m | 46: | 460m to 470m | 47: | 470m to 480m |
| 48: | 480m to 490m | 49: | 490m to 500m | | |

```
50:  Enter Path Manually
51:  Exit to Channel Parameter Menu

PL >2

Calculating...Gn
The Path Length was calculated successfully
Path Length : 22.748m
TX Gain : 17
```

### Step #8 – Selecting RS-232 Measurement Output

This step is optional. If SDI-12 is used as the data collection method, this step can be skipped.

```
>> Indicates an option that has been selected. Enter the
number beside an option to select/deselect it. When you hit
ENTER the option list will be redisplayed. Press Escape to exit.
Paths used      : >>1   2   3   4
Path            :    ^

1: >>Time Displayed With Menu Prompts
2: >>Display Menu Prompts
3: >>Display Help With Input Dialogs
4: >>Display Measurement Indicators
5: >>Display Version Information
6:   Display Daily Discharge Average
7:   Select Measurement Display Fields
8:   Select Measurement Path Displayed
9:   Select Baud Rate
0:   Exit
D>7
```

```
>> Indicates an option that has been selected. Enter the
number beside an option to select/deselect it. When you hit
ENTER the option list will be redisplayed. Press Escape to exit.

1: >>Individual
2:   Combined

3: >>Stage
4: >>Temperature

Path 1           Path 2           Path 3           Path 4
5: >>V Direct    C: >>V Direct    K: >>V Direct    S: >>V Direct
6: >>V Reflect   D: >>V Reflect   L: >>V Reflect   T: >>V Reflect
7: >>Ratio       E: >>Ratio       M: >>Ratio       U: >>Ratio
8: >>Discharge   F: >>Discharge   N: >>Discharge   V: >>Discharge
9:   V/Sound     G:   V/Sound     O:   V/Sound     W:   V/Sound
0: >>Salinity    H: >>Salinity    P: >>Salinity    X: >>Salinity
A: >>Gain        I: >>Gain        Q: >>Gain        Y: >>Gain
B: >>Success     J: >>Success     R: >>Success     Z: >>Success

>:   Exit
```

To select which measurements to output to the screen, simply enter the number, or letter, in a string, which corresponds to the desired measurement. The menu options toggle, therefore if a measurement is already selected, selecting it again will disable it.

### Step #9 – Selecting SDI-12 Measurement Output

If an SDI-12 data-logger is used in conjunction with the Deltaflex the SDI-12 parameters must be initialized. The user can select which measurements to output to the data-logger from the following menus.

```
PARAMETER ENTRY MAIN MENU

Paths used      : >>1   2   3   4
Path            :    ^

Units: Metric

1: System Reset
2: Metric/USA Standard
3: Select Channels To Use..
4: Clock Parameter Menu..
5: Measurement Parameter Menu..
6: SDI-12 Parameter Menu..
7: Desktop Parameter Menu..
8: Check System Parameter Integrity
9: Exit To Main Menu

00:03:15 P>6
```

```
SDI-12 PARAMETER MENU

Paths used      : >>1   2   3   4
Path            :    ^

Commands to avg: aM5! - aM9!
Commands to measure: aM! - aM4!

Mode                : Break - Reset

1: Select Ch 1 Measurements..
2: Select Ch 2 Measurements..
3: Select Ch 3 Measurements..
4: Select Ch 4 Measurements..
5: Select Device Address..
6: Back To Parameter Entry Main Menu
7: Exit To Main Menu

00:03:20 S>15
```

This menu operates by utilizing the same principal as the RS-232 measurement selection menu. To activate a measurement for output via SDI-12, enter the number, or letter, which corresponds to it. To remove the measurement, enter the number, or letter, which corresponds to it. The selection can be made by entering the selection as a string. For example, if the first five measurements were required, the user would enter **2345,** (measurement one was already selected).

```
CHANNEL 1 SDI-12 MEASUREMENT MENU

Paths used      : >>1   2   3   4
Path            :   ^

1: >>Direct Velocity
2:   Reflected Velocity
3:   Velocity Ratio
4:   Discharge
5:   Stage
6:   Discharge As day-second-feet (dsf)
7:   Discharge As acre-feet
8:   Velocity Of Sound
9:   Measurement Quality
0:   Gain
A:   Water Temperature
B:   Salinity
C: Back To Measurement Parameter Menu
D: Exit To Main Menu

00:03:22 S>2345
```

```
>> Indicates an option that has been selected.
Enter the number beside an option to select/deselect
it. When you hit ENTER the option list will be
redisplayed. Press Escape to exit.

Paths used      : >>1   2   3   4
Path            :   ^

0: >>Address 0
1:   Address 1
2:   Address 2
3:   Address 3
4:   Address 4
5:   Address 5
6:   Address 6
7:   Address 7
8:   Address 8
9:   Address 9
A:   Exit

A>01
```

Each path can have a separate SDI-12 address, in the example above, address 1 was designated for path 1.

### Step #10 – Setting the Internal Clock

If an SDI-12 data-logger is used to record the measurement data the clock does not have to be set, but if the Deltaflex is acting as the data logger, the internal clock must be set.

### Setting the Clock Date and Time

```
PARAMETER ENTRY MAIN MENU

Paths used     : >>1   2   3   4
Path           :    ^

Units: Metric

1: System Reset
2: Metric/USA Standard
3: Select Channels To Use..
4: Clock Parameter Menu..
5: Measurement Parameter Menu..
6: SDI-12 Parameter Menu..
7: Desktop Parameter Menu..
8: Check System Parameter Integrity
9: Exit To Main Menu

00:04:44 P>4
```

↓ ↓

```
CLOCK PARAMETER MENU

1: Set Clock Date And Time
2: Set Measurement Start Date And Time
3: Set Measurement Integration Time
4: Set Interval Time Between Measurements
5: Back To Parameter Entry Main Menu
6: Exit To Main Menu

00:04:46 C>1
```

```
Clock fields are entered in the following order:

  CC YY MM DD HH mm SS
  || || || || || || ||_ Seconds: 00 - 59
  || || || || || ||____ Minutes: 00 - 59
  || || || || ||_______ Hours  : 00 - 23
  || || || ||__________ Date   : 01 - 31
  || || ||_____________ Month  : 01 - 12
  || ||________________ Year   : 00 - 99
  ||___________________ Century: 00 - 99

Delimiter characters between fields are optional.Entering 2
Delimiter characters in succession causes a field to be skipped.
Fields entered are right justified, so entering:   5,00
causes the minutes field to be set to 05 and seconds to 00
with all other fields left unchanged.

Clock date and time  : 1901 01/01 00:04:47
Enter Clock Date/Time: 2005 05 13 15 00 00
```

## Setting the Measurement Start Time

```
CLOCK PARAMETER MENU

1: Set Clock Date And Time
2: Set Measurement Start Date And Time
3: Set Measurement Integration Time
4: Set Interval Time Between Measurements
5: Back To Parameter Entry Main Menu
6: Exit To Main Menu

00:04:46 C>2
```

```
  CC YY MM DD HH mm SS
  || || || || || || ||_ Seconds: 00 - 59
  || || || || || ||____ Minutes: 00 - 59
  || || || || ||_______ Hours  : 00 - 23
  || || || ||__________ Date   : 01 - 31
  || || ||_____________ Month  : 01 - 12
  || ||________________ Year   : 00 - 99
  ||___________________ Century: 00 - 99

Delimiter characters between fields are optional.Entering
2 delimiter characters in succession causes a field to be skipped.
Fields entered are right justified, so entering: 5,00
causes the minutes field to be set to 05 and seconds to 00
with all other fields left unchanged.

Start date and time  : 2005 05/13 15:00:00
Enter Start Date/Time: 2005 05 13 15 20 00
```

## Setting the Measurement Integration Time

```
CLOCK PARAMETER MENU

1: Set Clock Date And Time
2: Set Measurement Start Date And Time
3: Set Measurement Integration Time
4: Set Interval Time Between Measurements
5: Back To Parameter Entry Main Menu
6: Exit To Main Menu

00:04:46 C>3
```

```
Start date and time  : 2020 05/13 15:00:00
Clock fields are entered in the following order:

  CC YY MM DD HH mm SS
  || || || || || || ||_ Seconds: 00 - 59
  || || || || || ||____ Minutes: 00 - 59
  || || || || ||_______ Hours  : 00 - 23
  || || || ||__________ Date   : 01 - 31
  || || ||_____________ Month  : 01 - 12
  || ||________________ Year   : 00 - 99
  ||___________________ Century: 00 - 99

Delimiter characters between fields are optional. Entering
2 delimiter characters in succession causes a field to be skipped.
Fields entered are right justified, so entering: 5,00
causes the minutes field to be set to 05 and seconds to 00
with all other fields left unchanged.

Integration date and time  : 0000 00/00 00:00:00
Enter Integration Date/Time: 01 30
```

## Setting the Measurement Interval Time

```
CLOCK PARAMETER MENU

1: Set Clock Date And Time
2: Set Measurement Start Date And Time
3: Set Measurement Integration Time
4: Set Interval Time Between Measurements
5: Back To Parameter Entry Main Menu
6: Exit To Main Menu

00:04:46 C>4
```

↓ ↓

```
Integration date and time : 0000 00/00 00:01:30
Clock fields are entered in the following order:

  CC YY MM DD HH mm SS
  || || || || || || ||_ Seconds: 00 - 59
  || || || || || ||____ Minutes: 00 - 59
  || || || || ||_______ Hours  : 00 - 23
  || || || ||__________ Date   : 01 - 31
  || || ||_____________ Month  : 01 - 12
  || ||________________ Year   : 00 - 99
  ||___________________ Century: 00 - 99

Delimiter characters between fields are optional. Entering
2 delimiter characters in succession causes a field to be skipped.
Fields entered are right justified, so entering:5,00
causes the minutes field to be set to 05 and seconds to 00 with
all other fields left unchanged.

Interval date and time    : 0000 00/00 00:10:00
Enter Interval Date/Time : 05 00
```

## Velocity of Sound as a Function of Temperature and Salinity

| Temperature ºC | Salinity 0/00: 0 | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|---|
| 0.0 | 1402.5 | 1409.1 | 1415.8 | 1422.5 | 1429.1 | 1435.8 | 1442.5 |
| 0.2 | 1403.5 | 1410.1 | 1416.8 | 1423.4 | 1430.1 | 1436.7 | 1443.4 |
| 0.4 | 1404.5 | 1411.1 | 1417.7 | 1424.4 | 1431.0 | 1437.7 | 1444.3 |
| 0.6 | 1405.5 | 1412.1 | 1418.3 | 1425.3 | 1432.0 | 1438.6 | 1445.2 |
| 0.8 | 1406.5 | 1413.0 | 1419.7 | 1426.3 | 1432.9 | 1439.5 | 1446.2 |
| 1.0 | 1407.4 | 1414.0 | 1420.6 | 1427.2 | 1433.8 | 1440.4 | 1447.1 |
| 1.2 | 1408.4 | 1415.0 | 1421.6 | 1428.2 | 1434.8 | 1441.4 | 1448.0 |
| 1.4 | 1409.4 | 1415.9 | 1422.5 | 1429.1 | 1435.7 | 1442.3 | 1448.9 |
| 1.6 | 1410.4 | 1416.9 | 1423.5 | 1430.0 | 1436.6 | 1443.2 | 1449.8 |
| 1.8 | 1411.3 | 1417.9 | 1424.4 | 1431.0 | 1437.5 | 1444.1 | 1450.7 |
| 2.0 | 1412.3 | 1418.8 | 1425.4 | 1431.9 | 1438.4 | 1445.0 | 1451.5 |
| 2.2 | 1413.3 | 1419.8 | 1426.3 | 1432.8 | 1439.3 | 1445.9 | 1452.4 |
| 2.4 | 1414.2 | 1420.7 | 1427.2 | 1433.7 | 1440.2 | 1446.8 | 1453.3 |
| 2.6 | 1415.2 | 1421.6 | 1428.1 | 1434.6 | 1441.1 | 1447.7 | 1454.2 |
| 2.8 | 1416.1 | 1422.6 | 1429.1 | 1435.5 | 1442.0 | 1448.5 | 1455.0 |
| 3.0 | 1417.0 | 1423.5 | 1430.0 | 1436.4 | 1442.9 | 1449.4 | 1455.9 |
| 3.2 | 1418.0 | 1424.4 | 1430.9 | 1437.3 | 1443.8 | 1450.3 | 1456.8 |
| 3.4 | 1418.9 | 1425.3 | 1431.8 | 1438.2 | 1444.7 | 1451.2 | 1457.6 |
| 3.6 | 1419.8 | 1426.3 | 1432.7 | 1439.1 | 1445.6 | 1452.0 | 1458.5 |
| 3.8 | 1420.7 | 1427.2 | 1433.6 | 1440.0 | 1446.4 | 1452.9 | 1459.3 |
| 4.0 | 1421.7 | 1428.1 | 1434.5 | 1440.9 | 1447.3 | 1453.7 | 1460.2 |
| 4.2 | 1422.6 | 1429.0 | 1435.4 | 1441.8 | 1448.2 | 1454.6 | 1461.0 |
| 4.4 | 1423.5 | 1429.9 | 1436.3 | 1442.6 | 1449.0 | 1455.5 | 1461.9 |
| 4.6 | 1424.4 | 1430.8 | 1437.1 | 1443.4 | 1449.9 | 1456.3 | 1462.8 |
| 4.8 | 1425.3 | 1431.7 | 1438.0 | 1444.4 | 1450.8 | 1457.1 | 1463.5 |
| 5.0 | 1426.2 | 1432.5 | 1438.9 | 1445.2 | 1451.6 | 1458.0 | 1464.4 |
| 5.2 | 1427.1 | 1433.4 | 1439.8 | 1446.1 | 1452.5 | 1458.8 | 1465.2 |
| 5.4 | 1428.0 | 1434.3 | 1440.6 | 1447.0 | 1453.3 | 1459.6 | 1466.0 |
| 5.6 | 1428.9 | 1435.2 | 1441.5 | 1447.8 | 1454.1 | 1460.5 | 1466.8 |
| 5.8 | 1429.7 | 1436.0 | 1442.3 | 1448.7 | 1455.0 | 1461.3 | 1467.6 |
| 6.0 | 1430.6 | 1436.9 | 1443.2 | 1449.5 | 1455.8 | 1462.1 | 1468.4 |
| 6.2 | 1431.5 | 1437.8 | 1444.0 | 1450.3 | 1456.6 | 1462.9 | 1469.2 |
| 6.4 | 1432.2 | 1438.6 | 1444.9 | 1451.2 | 1457.5 | 1463.7 | 1470.0 |
| 6.6 | 1433.2 | 1439.5 | 1445.7 | 1452.0 | 1458.3 | 1464.5 | 1470.8 |
| 6.8 | 1434.1 | 1440.3 | 1446.6 | 1452.8 | 1459.1 | 1465.3 | 1471.6 |
| 7.0 | 1434.9 | 1441.2 | 1447.4 | 1453.6 | 1459.9 | 1466.1 | 1472.4 |
| 7.2 | 1435.8 | 1442.0 | 1448.2 | 1454.5 | 1460.7 | 1466.9 | 1473.2 |
| 7.4 | 1436.6 | 1442.9 | 1449.1 | 1455.3 | 1461.5 | 1467.7 | 1474.0 |
| 7.6 | 1437.5 | 1443.7 | 1449.9 | 1456.1 | 1462.3 | 1468.5 | 1474.8 |
| 7.8 | 1438.3 | 1444.5 | 1450.7 | 1456.9 | 1463.1 | 1469.3 | 1475.5 |
| 8.0 | 1439.2 | 1445.3 | 1451.5 | 1457.7 | 1463.9 | 1470.1 | 1476.3 |

| Temperature ºC | Salinity 0/00 0 | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|---|
| 8.2 | 1440.0 | 1446.2 | 1452.3 | 1458.5 | 1464.7 | 1470.9 | 1477.1 |
| 8.4 | 1440.8 | 1447.0 | 1453.1 | 1459.3 | 1465.5 | 1471.6 | 1477.8 |
| 8.6 | 1441.7 | 1447.8 | 1453.9 | 1460.1 | 1466.2 | 1472.4 | 1478.6 |
| 8.8 | 1442.5 | 1448.6 | 1454.7 | 1460.9 | 1467.0 | 1473.2 | 1479.3 |
| 9.0 | 1443.3 | 1449.4 | 1455.5 | 1461.7 | 1467.8 | 1473.9 | 1480.1 |
| 9.2 | 1444.1 | 1450.2 | 1456.3 | 1462.4 | 1468.6 | 1474.7 | 1480.8 |
| 9.4 | 1444.9 | 1451.0 | 1457.1 | 1463.2 | 1469.3 | 1475.4 | 1481.6 |
| 9.6 | 1445.7 | 1451.8 | 1457.9 | 1464.0 | 1470.1 | 1476.2 | 1482.3 |
| 9.8 | 1446.5 | 1452.6 | 1458.7 | 1464.8 | 1470.6 | 1476.9 | 1483.0 |
| 10.0 | 1447.3 | 1453.4 | 1459.4 | 1465.5 | 1471.6 | 1477.7 | 1483.8 |
| 10.2 | 1448.1 | 1454.2 | 1460.2 | 1466.3 | 1472.3 | 1478.4 | 1484.5 |
| 10.4 | 1448.9 | 1454.9 | 1461.0 | 1467.0 | 1473.1 | 1479.2 | 1485.2 |
| 10.6 | 1449.7 | 1455.7 | 1461.7 | 1467.8 | 1473.8 | 1479.9 | 1485.8 |
| 10.8 | 1450.5 | 1456.5 | 1462.5 | 1468.5 | 1474.6 | 1480.6 | 1486.7 |
| 11.0 | 1451.2 | 1457.2 | 1463.3 | 1469.3 | 1475.3 | 1481.3 | 1487.4 |
| 11.2 | 1452.0 | 1458.0 | 1464.0 | 1470.0 | 1476.0 | 1482.1 | 1488.1 |
| 11.4 | 1452.8 | 1458.8 | 1464.8 | 1470.8 | 1476.8 | 1482.8 | 1489.5 |
| 11.6 | 1453.6 | 1459.5 | 1465.5 | 1471.5 | 1477.5 | 1483.5 | 1489.8 |
| 11.8 | 1454.3 | 1460.3 | 1466.3 | 1472.2 | 1478.2 | 1484.2 | 1490.3 |
| 12.0 | 1455.1 | 1461.0 | 1467.0 | 1473.0 | 1478.9 | 1484.9 | 1490.9 |
| 12.2 | 1455.8 | 1461.8 | 1467.7 | 1473.7 | 1479.6 | 1485.6 | 1491.6 |
| 12.4 | 1456.6 | 1462.5 | 1468.5 | 1474.4 | 1480.4 | 1486.3 | 1492.3 |
| 12.6 | 1457.3 | 1463.3 | 1469.2 | 1475.1 | 1481.1 | 1487.0 | 1493.0 |
| 12.8 | 1458.1 | 1464.4 | 1469.9 | 1475.8 | 1481.8 | 1487.7 | 1493.6 |
| 13.0 | 1458.8 | 1464.7 | 1470.6 | 1476.5 | 1482.5 | 1488.4 | 1494.3 |
| 13.2 | 1459.5 | 1465.4 | 1471.3 | 1477.2 | 1483.2 | 1489.1 | 1495.0 |
| 13.4 | 1460.3 | 1466.2 | 1472.1 | 1477.9 | 1483.8 | 1489.8 | 1495.7 |
| 13.6 | 1461.0 | 1466.9 | 1472.8 | 1478.6 | 1484.5 | 1490.4 | 1496.3 |
| 13.8 | 1461.7 | 1467.6 | 1473.5 | 1479.3 | 1485.2 | 1491.1 | 1497.0 |
| 14.0 | 1462.5 | 1468.3 | 1474.2 | 1480.0 | 1485.9 | 1491.8 | 1497.7 |
| 14.2 | 1463.2 | 1469.0 | 1474.9 | 1480.7 | 1486.6 | 1492.5 | 1498.3 |
| 14.4 | 1463.9 | 1469.7 | 1475.6 | 1481.4 | 1487.3 | 1493.1 | 1499.0 |
| 14.6 | 1464.6 | 1470.0 | 1476.2 | 1482.1 | 1487.9 | 1493.8 | 1499.6 |
| 14.8 | 1465.3 | 1471.1 | 1476.9 | 1482.8 | 1488.6 | 1494.4 | 1500.3 |
| 15.0 | 1466.0 | 1471.8 | 1477.6 | 1483.4 | 1498.3 | 1495.1 | 1500.9 |
| 15.2 | 1466.7 | 1472.5 | 1478.3 | 1484.1 | 1489.9 | 1495.7 | 1501.6 |
| 15.4 | 1467.4 | 1473.2 | 1479.0 | 1484.8 | 1490.6 | 1496.4 | 1502.2 |
| 15.6 | 1468.1 | 1473.9 | 1479.6 | 1485.4 | 1491.2 | 1497.0 | 1502.8 |
| 15.8 | 1468.8 | 1474.5 | 1480.3 | 1486.1 | 1491.9 | 1497.7 | 1503.5 |
| 16.0 | 1469.5 | 1475.2 | 1481.0 | 1486.8 | 1492.5 | 1498.3 | 1504.1 |
| 16.2 | 1470.2 | 1475.9 | 1481.6 | 1487.4 | 1493.2 | 1498.9 | 1504.7 |
| 16.4 | 1470.8 | 1476.6 | 1482.3 | 1488.1 | 1493.8 | 1499.6 | 1505.3 |
| 16.6 | 1471.5 | 1476.9 | 1483.0 | 1488.7 | 1494.4 | 1500.2 | 1506.0 |
| 16.8 | 1472.2 | 1477.1 | 1483.6 | 1489.3 | 1495.1 | 1500.8 | 1506.6 |

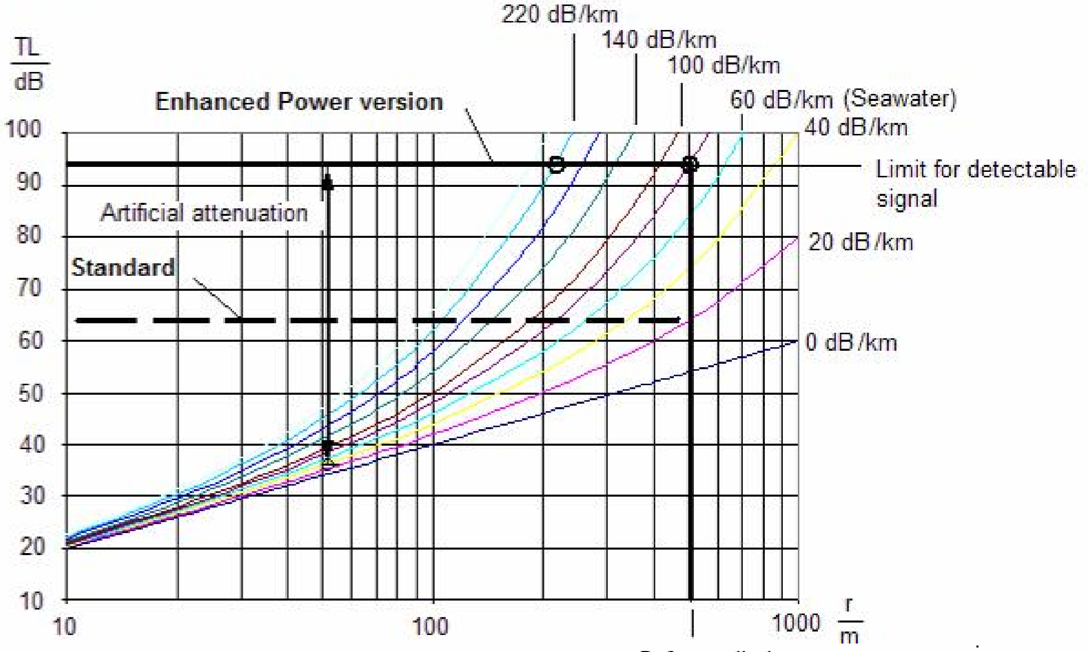
| Temperature ºC | Salinity 0/00 0 | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|---|
| 17.0 | 1472.8 | 1478.6 | 1484.3 | 1490.0 | 1495.7 | 1501.4 | 1507.2 |
| 17.2 | 1473.5 | 1479.2 | 1484.9 | 1490.6 | 1496.3 | 1502.1 | 1507.8 |
| 17.4 | 1474.2 | 1479.9 | 1485.6 | 1491.3 | 1497.0 | 1502.7 | 1508.4 |
| 17.6 | 1474.8 | 1480.5 | 1486.2 | 1491.9 | 1497.6 | 1503.3 | 1509.0 |
| 17.8 | 1475.5 | 1481.1 | 1486.8 | 1492.5 | 1498.2 | 1503.9 | 1509.6 |
| 18.0 | 1476.1 | 1481.7 | 1487.5 | 1493.1 | 1498.8 | 1504.5 | 1510.2 |
| 18.2 | 1476.8 | 1482.4 | 1488.1 | 1493.7 | 1499.4 | 1505.1 | 1510.8 |
| 18.4 | 1477.4 | 1483.1 | 1488.7 | 1494.4 | 1500.0 | 1505.7 | 1511.4 |
| 18.6 | 1478.1 | 1483.7 | 1489.3 | 1495.0 | 1500.6 | 1506.3 | 1511.9 |
| 18.8 | 1478.7 | 1484.3 | 1490.0 | 1495.6 | 1501.2 | 1506.9 | 1512.5 |
| 19.0 | 1479.3 | 1484.9 | 1490.6 | 1496.2 | 1501.8 | 1507.5 | 1513.1 |
| 19.2 | 1480.0 | 1485.6 | 1491.2 | 1496.8 | 1502.4 | 1508.0 | 1513.7 |
| 19.4 | 1480.6 | 1486.2 | 1491.8 | 1497.4 | 1503.0 | 1508.6 | 1514.3 |
| 19.6 | 1481.2 | 1486.8 | 1492.4 | 1498.0 | 1503.6 | 1509.2 | 1514.8 |
| 19.8 | 1481.8 | 1487.4 | 1493.0 | 1498.6 | 1504.2 | 1509.8 | 1515.4 |
| 20.0 | 1482.4 | 1488.0 | 1493.6 | 1499.2 | 1504.8 | 1510.4 | 1516.0 |
| 20.2 | 1483.1 | 1488.6 | 1494.2 | 1499.8 | 1505.3 | 1510.9 | 1516.5 |
| 20.4 | 1483.7 | 1489.2 | 1494.8 | 1500.3 | 1505.9 | 1511.5 | 1517.1 |
| 20.6 | 1484.3 | 1489.8 | 1495.4 | 1500.9 | 1506.5 | 1512.1 | 1517.6 |
| 20.8 | 1484.9 | 1490.4 | 1496.0 | 1501.5 | 1507.1 | 1512.6 | 1518.2 |
| 21.0 | 1485.5 | 1491.0 | 1496.5 | 1502.1 | 1507.6 | 1513.2 | 1518.7 |
| 21.2 | 1486.1 | 1491.6 | 1497.1 | 1502.6 | 1508.2 | 1513.7 | 1519.3 |
| 21.4 | 1486.7 | 1492.2 | 1497.7 | 1503.2 | 1508.7 | 1514.3 | 1519.8 |
| 21.6 | 1487.3 | 1492.8 | 1498.3 | 1503.8 | 1509.3 | 1514.8 | 1520.3 |
| 21.8 | 1487.8 | 1493.3 | 1498.8 | 1504.3 | 1509.8 | 1515.4 | 1520.9 |
| 22.0 | 1488.4 | 1493.9 | 1499.4 | 1504.9 | 1510.4 | 1515.9 | 1521.4 |
| 22.2 | 1489.0 | 1494.5 | 1500.0 | 1505.4 | 1510.9 | 1516.4 | 1521.9 |
| 22.4 | 1489.6 | 1495.0 | 1500.5 | 1506.0 | 1511.5 | 1517.0 | 1522.5 |
| 22.6 | 1490.2 | 1495.6 | 1501.1 | 1506.5 | 1511.7 | 1517.8 | 1523.3 |
| 22.8 | 1490.7 | 1496.2 | 1501.6 | 1507.1 | 1512.6 | 1518.0 | 1523.5 |
| 23.0 | 1491.3 | 1496.7 | 1502.2 | 1507.6 | 1513.1 | 1518.6 | 1524.0 |
| 23.2 | 1491.9 | 1497.3 | 1502.7 | 1508.2 | 1513.6 | 1519.1 | 1524.5 |
| 23.4 | 1492.4 | 1497.8 | 1503.3 | 1508.7 | 1514.2 | 1519.6 | 1525.1 |
| 23.6 | 1493.0 | 1498.4 | 1503.8 | 1509.2 | 1514.7 | 1520.1 | 1525.6 |
| 23.8 | 1493.5 | 1498.9 | 1504.4 | 1509.8 | 1515.2 | 1520.6 | 1526.1 |
| 24.0 | 1494.1 | 1499.5 | 1504.9 | 1510.3 | 1515.7 | 1521.1 | 1526.6 |
| 24.2 | 1494.6 | 1500.0 | 1505.4 | 1510.8 | 1516.2 | 1521.7 | 1527.1 |
| 24.4 | 1495.2 | 1500.6 | 1505.9 | 1511.3 | 1516.7 | 1522.2 | 1527.6 |
| 24.6 | 1495.7 | 1501.1 | 1506.5 | 1511.9 | 1517.3 | 1522.7 | 1528.1 |
| 24.8 | 1496.3 | 1501.6 | 1507.0 | 1512.4 | 1517.8 | 1523.2 | 1528.6 |
| 25.0 | 1496.8 | 1502.2 | 1507.5 | 1512.9 | 1518.3 | 1523.7 | 1529.0 |
| 25.2 | 1497.4 | 1502.7 | 1508.0 | 1513.4 | 1518.8 | 1524.1 | 1529.5 |
| 25.4 | 1497.9 | 1503.2 | 1508.5 | 1513.9 | 1519.3 | 1524.6 | 1530.0 |
| 25.6 | 1498.4 | 1503.7 | 1509.1 | 1514.4 | 1519.8 | 1525.1 | 1530.5 |
| 25.8 | 1498.9 | 1504.2 | 1509.6 | 1514.9 | 1520.3 | 1525.6 | 1531.0 |

| Temperature ºC | Salinity 0/00 0 | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|---|
| 26.0 | 1499.4 | 1504.7 | 1510.1 | 1515.4 | 1520.7 | 1526.1 | 1531.4 |
| 26.2 | 1499.9 | 1505.3 | 1510.6 | 1515.9 | 1521.2 | 1526.6 | 1531.9 |
| 26.4 | 1500.5 | 1505.8 | 1511.1 | 1516.4 | 1521.7 | 1527.0 | 1532.4 |
| 26.6 | 1501.0 | 1506.3 | 1511.6 | 1516.9 | 1522.2 | 1527.5 | 1532.8 |
| 26.8 | 1501.5 | 1506.8 | 1512.1 | 1517.4 | 1522.7 | 1528.0 | 1533.3 |
| 27.0 | 1502.0 | 1507.3 | 1512.6 | 1517.9 | 1523.2 | 1528.5 | 1533.8 |
| 27.2 | 1502.5 | 1507.8 | 1513.0 | 1518.3 | 1523.6 | 1528.9 | 1534.2 |
| 27.4 | 1503.0 | 1508.3 | 1513.5 | 1518.8 | 1524.1 | 1529.4 | 1534.7 |
| 27.6 | 1503.5 | 1508.7 | 1514.0 | 1519.3 | 1524.6 | 1529.8 | 1535.1 |
| 27.8 | 1504.0 | 1509.2 | 1514.5 | 1519.8 | 1525.0 | 1530.3 | 1535.6 |
| 28.0 | 1504.5 | 1509.7 | 1515.0 | 1520.2 | 1525.5 | 1530.8 | 1536.0 |
| 28.2 | 1505.0 | 1510.2 | 1515.4 | 1520.7 | 1525.9 | 1531.2 | 1536.5 |
| 28.4 | 1505.4 | 1510.7 | 1515.9 | 1521.2 | 1526.4 | 1531.7 | 1536.9 |
| 28.6 | 1506.9 | 1511.1 | 1516.4 | 1521.6 | 1526.9 | 1532.1 | 1537.4 |
| 28.8 | 1506.4 | 1512.6 | 1516.8 | 1522.1 | 1527.3 | 1532.3 | 1537.8 |
| 29.0 | 1506.9 | 1512.1 | 1517.3 | 1522.5 | 1527.8 | 1533.0 | 1538.2 |
| 29.2 | 1507.4 | 1512.6 | 1517.8 | 1523.0 | 1528.2 | 1533.4 | 1538.7 |
| 29.4 | 1507.8 | 1513.0 | 1518.2 | 1523.4 | 1528.6 | 1533.9 | 1539.1 |
| 29.6 | 1508.3 | 1513.5 | 1518.7 | 1523.9 | 1529.1 | 1534.3 | 1539.5 |
| 29.8 | 1508.8 | 1513.9 | 1519.1 | 1524.3 | 1529.5 | 1534.7 | 1539.9 |
| 30.0 | 1509.2 | 1514.4 | 1519.6 | 1524.8 | 1530.0 | 1535.1 | 1540.4 |
| 30.2 | 1509.7 | 1514.8 | 1520.0 | 1525.2 | 1530.4 | 1535.6 | 1540.8 |
| 30.4 | 1510.1 | 1515.3 | 1520.5 | 1525.6 | 1530.8 | 1536.0 | 1541.2 |
| 30.6 | 1510.6 | 1515.7 | 1520.9 | 1526.1 | 1531.2 | 1536.4 | 1541.6 |
| 30.8 | 1511.0 | 1516.2 | 1521.3 | 1526.5 | 1531.7 | 1536.8 | 1542.0 |
| 31.0 | 1511.5 | 1516.6 | 1521.8 | 1526.9 | 1532.1 | 1537.2 | 1544.4 |
| 31.2 | 1511.9 | 1517.1 | 1522.2 | 1527.3 | 1532.5 | 1537.7 | 1544.8 |
| 31.4 | 1512.4 | 1517.5 | 1522.6 | 1528.8 | 1532.9 | 1538.1 | 1545.2 |
| 31.6 | 1512.8 | 1517.9 | 1523.1 | 1528.2 | 1533.3 | 1538.5 | 1545.6 |
| 31.8 | 1513.3 | 1518.4 | 1523.5 | 1528.6 | 1533.7 | 1538.9 | 1546.0 |
| 32.0 | 1513.7 | 1518.8 | 1523.9 | 1529.0 | 1534.1 | 1539.3 | 1544.4 |
| 32.2 | 1514.1 | 1519.2 | 1524.3 | 1529.4 | 1534.6 | 1539.7 | 1544.8 |
| 32.4 | 1514.5 | 1519.6 | 1524.7 | 1529.8 | 1535.0 | 1540.1 | 1545.2 |
| 32.6 | 1515.0 | 1520.1 | 1525.2 | 1530.3 | 1535.4 | 1540.5 | 1545.6 |
| 32.8 | 1515.4 | 1520.5 | 1525.6 | 1530.7 | 1535.8 | 1540.9 | 1546.0 |
| 33.0 | 1515.8 | 1520.9 | 1526.0 | 1531.1 | 1536.2 | 1541.3 | 1546.4 |
| 33.2 | 1516.2 | 1521.3 | 1526.4 | 1531.5 | 1536.5 | 1541.6 | 1546.7 |
| 33.4 | 1516.7 | 1521.7 | 1526.8 | 1531.9 | 1536.9 | 1542.0 | 1547.1 |
| 33.6 | 1517.1 | 1522.1 | 1527.2 | 1532.2 | 1537.3 | 1542.4 | 1547.5 |
| 33.8 | 1519.5 | 1522.5 | 1527.6 | 1532.6 | 1537.7 | 1542.8 | 1547.9 |
| 34.0 | 1517.9 | 1522.9 | 1528.0 | 1533.0 | 1538.1 | 1543.2 | 1548.2 |
| 34.2 | 1518.3 | 1523.3 | 1528.4 | 1533.4 | 1538.5 | 1543.5 | 1548.6 |
| 34.4 | 1518.7 | 1523.7 | 1528.8 | 1533.8 | 1538.9 | 1543.9 | 1549.0 |
| 34.6 | 1519.1 | 1524.1 | 1529.1 | 1534.2 | 1539.2 | 1544.3 | 1549.3 |
| 34.8 | 1519.5 | 1524.5 | 1529.5 | 1534.6 | 1539.6 | 1544.6 | 1549.7 |

| Temperature ºC | Salinity 0/00: 0 | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|---|
| 35.0 | 1519.9 | 1524.9 | 1529.9 | 1534.9 | 1540.0 | 1545.0 | 1550.1 |
| 35.2 | 1520.3 | 1525.3 | 1530.3 | 1535.3 | 1540.3 | 1545.4 | 1550.4 |
| 35.4 | 1520.7 | 1525.7 | 1530.7 | 1535.7 | 1540.7 | 1545.7 | 1550.8 |
| 35.6 | 1521.1 | 1526.0 | 1531.0 | 1536.1 | 1541.1 | 1546.1 | 1551.1 |
| 35.8 | 1521.4 | 1526.4 | 1531.4 | 1536.4 | 1541.4 | 1546.4 | 1551.5 |
| 36.0 | 1521.8 | 1526.8 | 1531.8 | 1536.8 | 1541.8 | 1546.8 | 1551.8 |
| 36.2 | 1522.2 | 1527.2 | 1532.2 | 1537.2 | 1542.1 | 1547.1 | 1552.2 |
| 36.4 | 1522.6 | 1527.6 | 1532.5 | 1537.5 | 1542.5 | 1547.5 | 1552.5 |
| 36.6 | 1523.0 | 1527.9 | 1532.9 | 1537.9 | 1542.9 | 1547.8 | 1552.8 |
| 36.8 | 1523.3 | 1528.3 | 1533.3 | 1538.2 | 1543.2 | 1548.2 | 1553.2 |
| 37.0 | 1523.7 | 1528.7 | 1533.6 | 1538.6 | 1543.6 | 1548.5 | 1553.5 |
| 37.2 | 1524.1 | 1529.0 | 1534.0 | 1538.9 | 1543.9 | 1548.9 | 1553.9 |
| 37.4 | 1524.4 | 1529.4 | 1534.3 | 1539.3 | 1544.2 | 1549.2 | 1554.2 |
| 37.6 | 1524.8 | 1529.7 | 1534.7 | 1537.9 | 1544.6 | 1549.5 | 1554.5 |
| 37.8 | 1525.2 | 1530.1 | 1535.0 | 1540.0 | 1544.9 | 1549.9 | 1554.8 |
| 38.0 | 1525.5 | 1530.4 | 1535.4 | 1540.3 | 1545.3 | 1550.2 | 1555.2 |
| 38.2 | 1525.9 | 1530.8 | 1535.7 | 1540.6 | 1545.6 | 1550.5 | 1555.5 |
| 38.4 | 1526.2 | 1531.1 | 1536.1 | 1541.0 | 1545.9 | 1550.9 | 1555.8 |
| 38.6 | 1526.2 | 1531.5 | 1536.4 | 1541.3 | 1546.2 | 1551.2 | 1556.1 |
| 38.8 | 1526.9 | 1531.8 | 1536.7 | 1541.7 | 1546.5 | 1551.5 | 1556.4 |
| 39.0 | 1527.3 | 1532.2 | 1537.1 | 1542.0 | 1546.9 | 1551.8 | 1556.8 |
| 39.2 | 1527.6 | 1532.5 | 1537.4 | 1542.3 | 1547.2 | 1552.1 | 1557.1 |
| 39.4 | 1527.9 | 1532.8 | 1537.7 | 1542.6 | 1547.5 | 1552.5 | 1557.4 |
| 39.6 | 1528.3 | 1533.2 | 1538.1 | 1543.0 | 1547.9 | 1552.8 | 1557.7 |
| 39.8 | 1528.6 | 1533.5 | 1538.4 | 1543.3 | 1548.2 | 1553.1 | 1558.0 |
| 40.0 | 1529.0 | 1533.8 | 1538.7 | 1543.6 | 1448.5 | 1553.4 | 1558.3 |

## Deltaflex Range Forecast

based on measurements made October 14, 2004
at Renfrew Hydro site.
Path length: 41 m




Transmission loss as function of range r

$$TL = 20 \log\left(\frac{r}{m}\right) + \left(\frac{ao}{dB/km}\right) * \left(\frac{r}{km}\right)$$

| | | |
|---|---|---|
| Example 1: | Frequency dependent attenuation: | 70 dB /km |
| | Max. Range: | 500 m |
| Example 2. | Frequency dependent attenuation | 220 dB/km |
| | Max. Range: | 210 m |

Hardware condition: **Enhanced Power Version**

| | |
|---|---|
| Enhanced transmitting power | 6 dB |
| Common mode suppression coils | 15 dB |

Software:

| | | |
|---|---|---|
| AO9 including | | |
| Transmission power enhancement (Stacking) | 9 dB | |
| Total Signal/Noise Improvement | 30 dB | rel. Version SMT DX 200/*/12 |