OPERATOR'S MANUAL

OBS-3+ and OBS300 Suspended Solids and Turbidity Monitors

Revision: 5/11

WARRANTY AND ASSISTANCE

This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. ("CSC") to be free from defects in materials and workmanship under normal use and service for **twelve (12) months** from date of shipment unless specified otherwise. ***** **Batteries are not warranted.** ***** CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CSC is not liable for special, indirect, incidental, or consequential damages.

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Non-warranty products returned for repair should be accompanied by a purchase order to cover repair costs.

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PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. (CSI) primarily for the US market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area:	1 in^2 (square inch) = 645 mm^2
Length:	1 in. (inch) = 25.4 mm 1 ft (foot) = 304.8 mm 1 yard = 0.914 m 1 mile = 1.609 km
Mass:	1 oz. (ounce) = 28.35 g 1 lb (pound weight) = 0.454 kg
Pressure:	1 psi (lb/in2) = 68.95 mb
Volume:	1 US gallon = 3.785 litres

In addition, part ordering numbers may vary. For example, the CABLE5CBL is a CSI part number and known as a FIN5COND at Campbell Scientific Canada (CSC). CSC Technical Support will be pleased to assist with any questions.

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Section 1. Introduction

The manual describes the operation, general use, and maintenance of the OBS-3+ and OBS300 turbidity and suspended-solids sensors. The OBS-3+ and OBS300 are identical except for the orientation of the optics. The OBS-3+ "looks" perpendicular to the length of the sensor, whereas the OBS300 "looks" out the end of the sensor. Throughout this manual any time OBS sensor is mentioned, it is valid for both the OBS-3+ and the OBS300.

The heart of an OBS® sensor is a near infrared (NIR) laser and photodiode for detecting the intensity of light scattered from suspended particles in water. Electrical connections are made with a molded-cable assembly terminated with an MCIL wet-pluggable underwater connector. With its unique optical design (U.S. Patent No. 4,841,157), OBS sensors perform better than most in situ turbidity monitors in the following ways:

- Small size and low power
- Highly linear response
- Insensitivity to bubbles and organic matter
- Ambient-light rejection and low temperature coefficient

OBS sensors are used for a wide variety of monitoring tasks in riverine, oceanic, laboratory, and industrial settings. They can be integrated in water-quality monitoring systems, CTDs, laboratory instrumentation, and sediment-transport monitors. The applications include:

- Compliance with permits, water-quality guidelines, and regulations
- Determination of transport and fate of particles and associated contaminants in aquatic systems
- Conservation, protection and restoration of surface waters
- Assess performance of water and land-use management
- Monitor waterside construction, mining, and dredging operations
- Characterization of wastewater and energy-production effluents
- Tracking water-well completion including development and use.

Conceptually, turbidity is a numerical expression in turbidity units (NTU) of the optical properties that cause water to appear hazy or cloudy as a result of light scattering and absorption by suspended matter. Operationally, a NTU value is interpolated from neighboring light-scattering measurements made on calibration standards such as Formazin, StablCal or SDVB beads. Turbidity is caused by suspended and dissolved matter such as sediment, plankton, bacteria, viruses, and organic and inorganic dyes. In general, as the concentration of suspended matter in water increases, so will its turbidity, and as the concentration of dissolved light-absorbing matter increases, turbidity will decrease. Descriptions of the factors that affect turbidity are given in Section 7. Like all other optical turbidity monitors, the OBS response depends on the size, composition, and shape of suspended particles, and for this reason, *the sensor must be calibrated with suspended solids from the waters to be monitored*. There is no ‘standard’ turbidimeter design or universal formula for converting NTU values to physical units such as mg l^{-1} or ppm. NTU values have no intrinsic physical, chemical or biological significance. Empirical correlations between turbidity and environmental conditions, established through field calibration, can be useful in water-quality investigations.

FIGURE 1-1. Dimensions of the OBS-3+ Sensor (left) and the OBS300 Sensor (right)

Section 2. Operation

OBS sensors detect suspended matter in water and turbidity from the relative intensity of light backscattered at angles ranging from 90^o to 165^o, in clean water. A 3D schematic of the main components of the OBS-3+ is shown in FIGURE 2-1. The OBS300 has the same components but they are arranged differently. The OBS light source is a Vertical-Cavity Surface-Emitting Laser diode (VCSEL), which converts 5 mA of electrical current to 2000 µW of optical power. The detector is a low-drift silicon photodiode with enhanced NIR responsivity, the ratio of electrical current produced per unit of light power in A W^{-1}. A light baffle prevents direct illumination of the detector by the light source and in-phase coupling that would otherwise produce large signal biases. A daylight-rejection filter blocks visible light in the solar spectrum and reduces ambient-light interference. In addition to the filter, a synchronous detection circuit is used to eliminate the bias caused by ambient light. The VCSEL is driven by a temperature-compensated voltage-controlled current source (VCCS).

The interface between the optics and the water sample is a window made of cast optical epoxy.

CAUTION Window transmittance must remain constant in order to prevent calibration drift, so keeping the OBS window clean is the most important maintenance item; see Section 6.

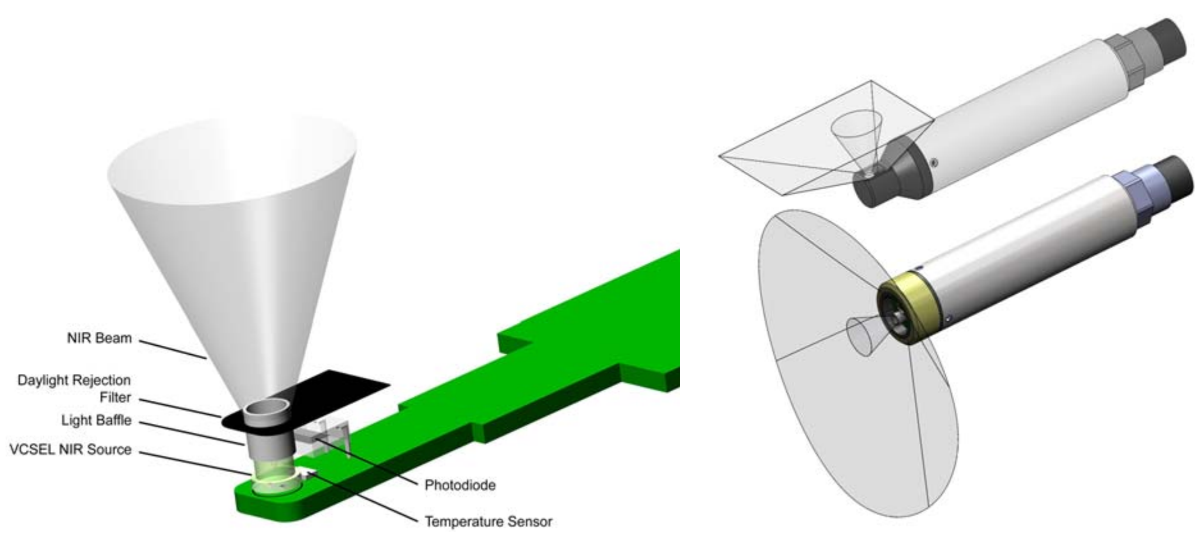

FIGURE 2-1. Components of the OBS-3+ (left) and Orientation Source Beam and Detector Acceptance Cone of the OBS-3+ (top right) and OBS300 (bottom right)

The beam divergence angle of the VCSEL source is 42^o (95% of the beam power is contained within a 42^o cone).

OBS-3 sensors must be connected to a host device such as a datalogger that provides power, digitizes signals, converts the signals to engineering units, and records the data. The OBS-3+ and OBS300 are dual range sensors having both has a low- and a high-range output. The standard low ranges are 250, 500, 1000, or 4000 NTU, and the corresponding high ranges are 1000, 2000, 4000, and 4000 NTU. OBS sensors can be purchased with a 4-20 mA current output on the low range and a 0 to 5 V voltage output on the high range. Voltage outputs can be 0 to 2.5 or 0 to 5 V; see specifications in Section 10. It is also possible to purchase sensors configured to operate from 5-V power, however, the output span is limited to 2.5 V.

Section 3. Preparing OBS Sensors for Use

3.1 Pre-deployment Tests

When the OBS sensor is received from the manufacturer, it should be bench tested to ensure that it functions properly prior to making field installations. Connect the red and black wires in the cable supplied with the unit to a 9- or 12-Volt battery; see FIGURE 3-1 and TABLE 3-1. Plug the cable into the unit and connect a datalogger or digital multimeter (DMM) across the blue (+ test lead) and green (- test lead) wires and wave your finger over the OBS sensor about 20 mm away from the window. The meter should indicate fluctuating signals ranging from a few mV or 4 mA to the span shown on the calibration certificate, 2.5, 5 V, or 20 mA; see FIGURE 3-2. Switch the + DMM test lead to the white wire and repeat the test. The results should be similar.

3.2 Electrical Connections and Cabling

FIGURE 3-1 shows the contact numbers for the MCIL/MCBH-5 connectors and TABLE 3-1 lists the electrical functions and wire colors. The user need only be concerned with the wire colors for the 8425 cable as the MCBH wires are not accessible. When a custom cable assembly is purchased from a third-party vendor to connect the OBS sensor to a current meter or CTD, the user will not have access to any of the wires listed in TABLE 3-1.

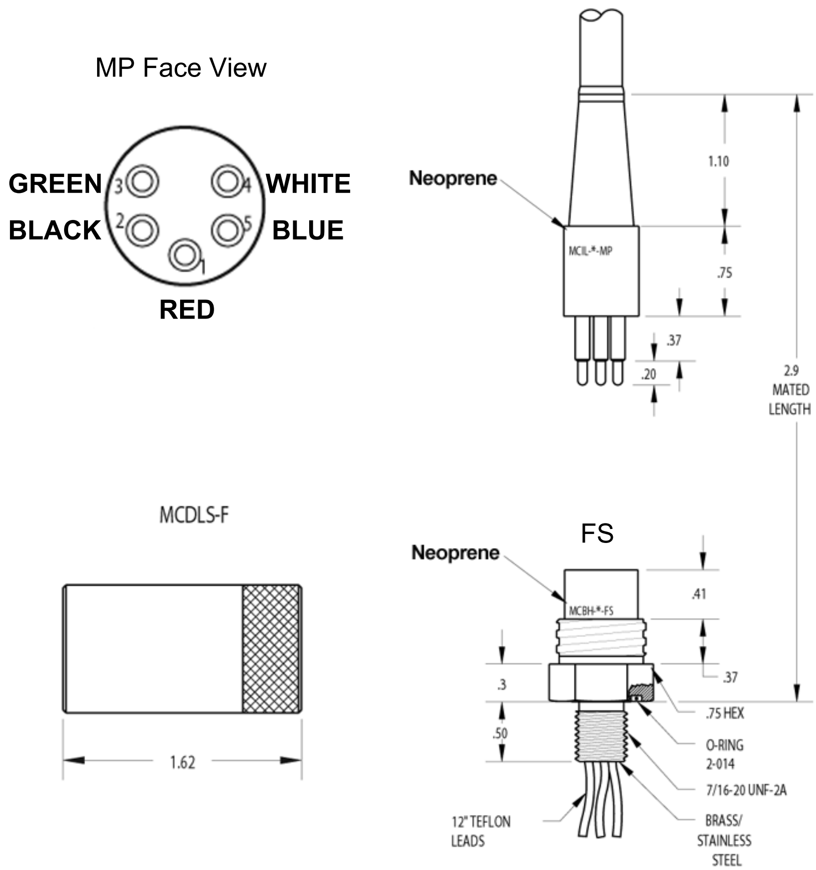

FIGURE 3-1. Pin Assignments for MCBH and MCIL Wet-Pluggable Connectors

TABLE 3-1. Pin numbers, electrical functions and wire color codes for OBS sensor bulkhead connectors.

MCBH-5-FS/MCIL-5-MP Contact Number	Electrical Function	Wire Color (MCBH)	Wire Color (8425)
1	Power (5 – 15V)	Red	Red
2	Power Ground	Black	Black
3	Signal Common	Green	Green
4	High Range Signal (4X)	White	White
5	Low Range Signal (1X & 4-20 mA)	Blue	Blue
No Connection	Cable Shield		Clear/Braid

3.3 Dataloggers and Other Host Devices

OBS sensors can be connected to dataloggers (FIGURE 3-2), current meters, and CTD instruments. These host devices can power an OBS sensor, digitize its analog signals, compute NTU and SSC values, and record the statistical result in FLASH memory. In order to make the conversion from digitized signals to engineering units (e.g., NTU, mg l^{-1}, and ppm), the host device must have the calibration equations in its operating program or the conversion must be done in post processing. FIGURE 3-3 shows a typical calibration certificate from which the calibration coefficients may be obtained.

NOTE When using some host devices, it is advisable to calibrate the OBS sensor while it is connected to the device exactly as it will be used. The reason for this is that the factory calibration is performed with a NIST-traceable digital multimeter and the numerical values reported by some host devices not NIST-certified will be different.

3.3.1 Datalogger Connection

TABLE 3-2 and FIGURE 3-2 show the recommended wiring configuration for connecting the OBS sensor to a Campbell Scientific datalogger; wiring to dataloggers manufactured by other companies is similar. In this configuration, single-ended analog inputs are used to measure the OBS sensors' voltage signal. The red power wire is connected to a switched 12 V channel, which allows the OBS sensor to be turned off when it is not making measurements. This reduces current consumption. Dataloggers that do not have a switched 12 V channel can use a relay to turn the OBS sensor off and on. Appendix A provides information about using a relay.

TABLE 3-2. Connection to Campbell Scientific Dataloggers

Color	Description	CR800, CR850 CR1000, CR3000 CR5000, CR23X	CR10X
White	High Range Signal	Single-ended Input	Single-ended Input
Blue	Low Range Signal	Single-ended Input	Single-ended Input
Green	Signal Ground	⏚	AG
Black	Power Ground	G	G
Red	Power	SW12V	SW12V
Clear	Shield	G	G

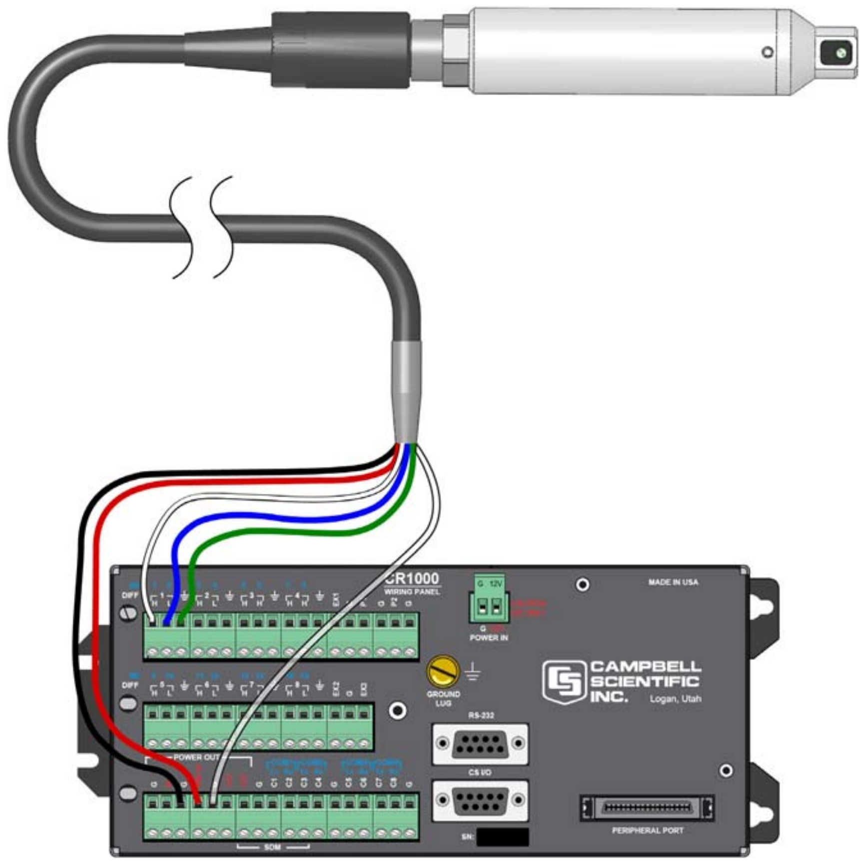

FIGURE 3-2. OBS-3+ connected to a CR1000 Datalogger (OBS300 has the same wiring)

NOTE The assignment of channel (e.g., SE1, SE2) may vary depending on application.

3.3.2 Datalogger Programming

Use Short Cut, CRBasic, or Edlog to program a Campbell Scientific datalogger to read the OBS sensor. Short Cut is the easiest and typically the preferred method for programming the datalogger. With Short Cut, choose the OBS-3+ sensor (for both the OBS-3+ and OBS300). Then, select your output preferences from a series of menus and Short Cut will create a custom program and wiring diagram.

CRBasic and Edlog are included in our PC400 and LoggerNet Datalogger Support Software Packages. CRBasic supports our newer dataloggers (e.g., CR200(X), CR800, CR1000, CR3000). Edlog supports our CR7 and most of our retired dataloggers (e.g., CR510, CR10(X), CR23X). These program generators use a single-ended voltage instruction (VoltSE in CRBasic or Instruction 1 in Edlog) to measure the high input range and another single-ended instruction to measure the low input range. The millivolt measurements are then converted to NTUs by using the coefficients provided on the Calibration Certificate.

We supply a calibration curve in units of both voltage and millivolts (see FIGURE 3-3 and FIGURE 3-4). If using the voltage curve's coefficients, the multiplier for the singe-ended voltage instruction needs to be 0.001. If using the millivolt curve's coefficients, the multiplier for the single-ended voltage instruction needs to be 1.0. Make sure you use the correct units.

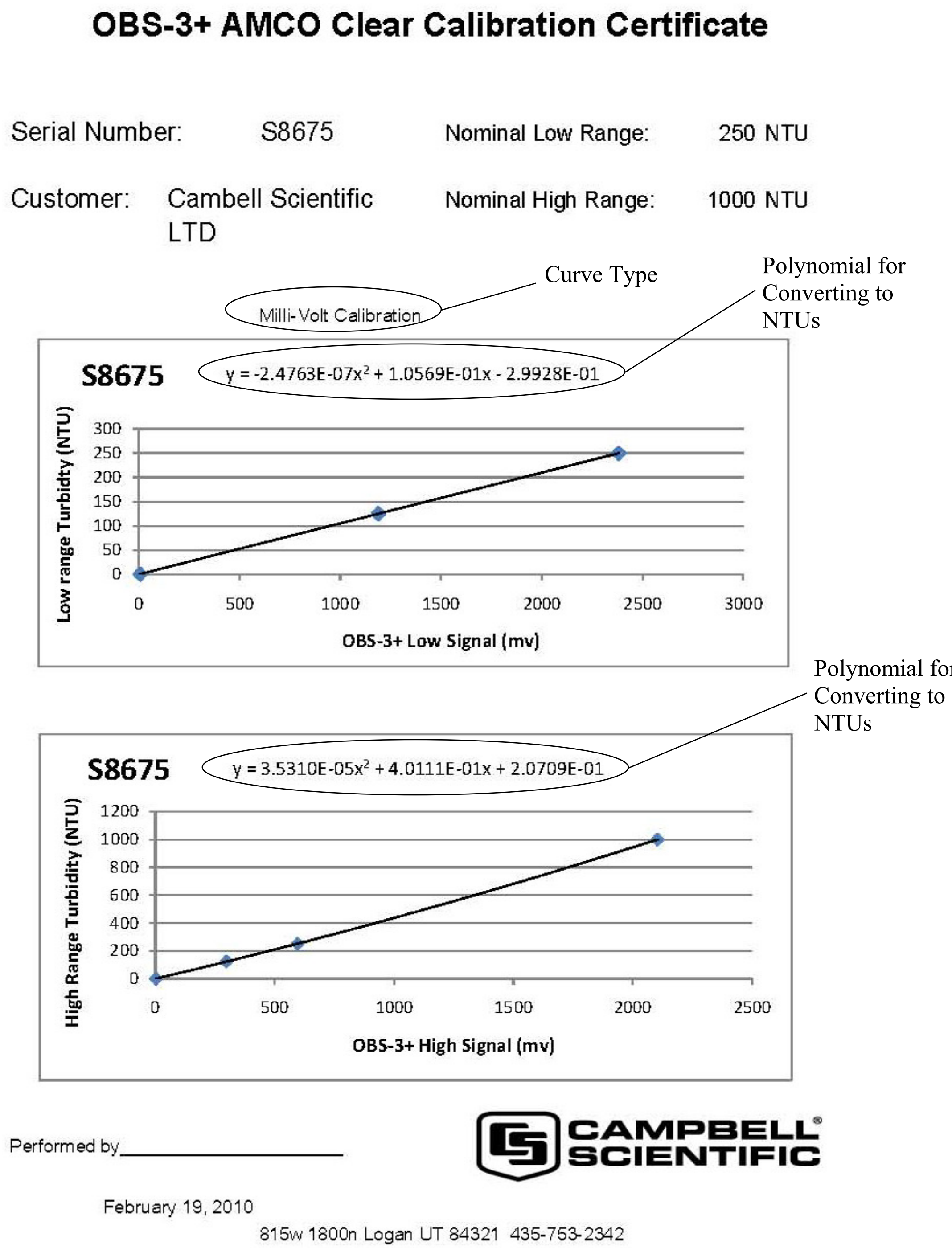

FIGURE 3-3. Calibration Certificate Showing Millivolt Coefficients

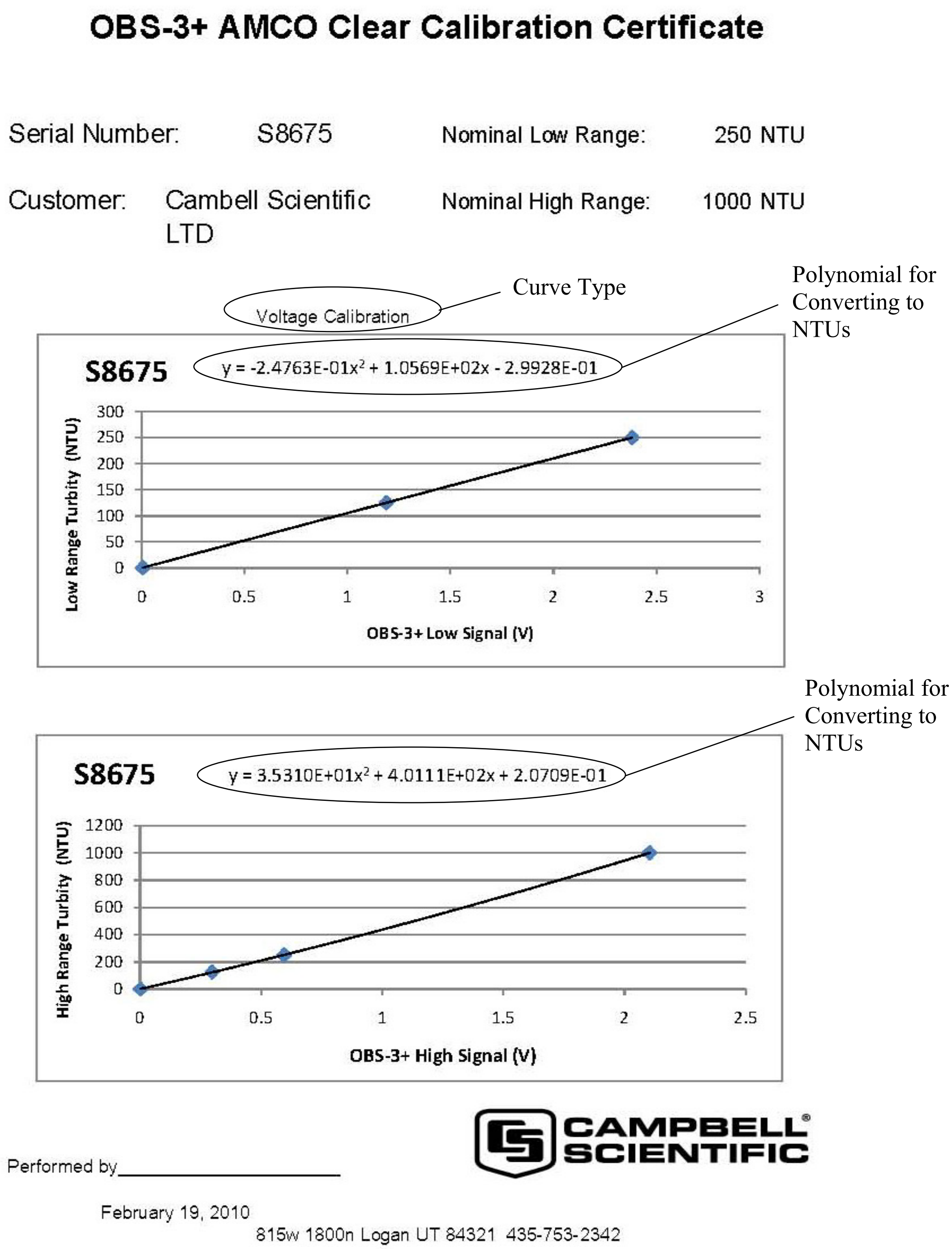

FIGURE 3-4. Calibration Certificate Showing Voltage Coefficients

Below is an example CR1000 program; programming for other CRBasic dataloggers is similar. The calibration values used in this program are from the calibration certificate shown in FIGURE 3-4. Calibration curves for both voltage and millivolts are provided. The example program uses the voltage curve's coefficients. The calibration values are different for each probe. Make sure you use the correct units. Examples of a CR10X program and CR200(X) program are in Appendix B and Appendix C.

The polynomial for converting to NTU_S from volts or millivolts is in the form:

$NTU_S = A(X)^2 + B(X) + C$

Where

X = volts or millivolts depending on the curve you are using

The polynomial for converting to NTU is at the top of each curve (see FIGURE 3-3 and FIGURE 3-4).

Example program for a Campbell Scientific CR1000 Datalogger using the Voltage Calibration Sheet

```
'CR1000 Series Datalogger

Public NTU
Public A(2), B(2), C(2), i, n, NTUX(21)

DataTable (Data_15m,1,-1)
    DataInterval (0,15,Min,10)
    Sample (1,NTU,FP2)

EndTable

BeginProg

n = 21
A(1) = -0.24763
    B(1) = 105.69
    C(1) = -0.29928
    A(2) = 35.310
    B(2) = 401.11
    C(2) = 0.20709

    Scan (5,Sec,10,0)

        SW12 (1)
        Delay (0,2,Sec)             'Delay 2 seconds

    For i = 1 To n                  'n = 21 in this case so 21 measurements will be made for both the
                                    'high and low input ranges.  A multiplier of 0.001 is used because
                                    'the coefficients are from the voltage calibration sheet.
            VoltSe (NTUX(i),1,mV5000,2,1,0,_60Hz,0.001,0)
            NTUX(i) = A(2) * NTUX(i)^2 + B(2) * NTUX(i) + C(2)      ' V to NTU high range
            Delay (0,45,mSec)       'Delay between measurements
        Next i

    SortSpa (NTUX(),21,NTUX()) 'now find the median value, which will best represent
        NTU = NTUX(11)              'the true NTU.  Big particles can cause errors that would
                                    'skew an average
```

```
    If NTU < 250    Then              'Use the low range channel to get a more accurate measurement
                                      'The value of 250 was chosen because it is the nominal low
                                      'range value of this OBS sensor.
        For i = 1 To n                'n = 21 in this case so 21 measurements will be made for both the
                                      'high and low input ranges
            VoltSe (NTUX(i),1,mV5000,1,1,0,_60Hz,0.001,0)
            NTUX(i) = A(1) * NTUX(i)^2 + B(1) * NTUX(i) + C(1)      ' V to NTU conversion
            Delay(0,45,mSec)          'Delay between measurements

    Next i

    EndIf

        SortSpa (NTUX(),21,NTUX())
        NTU = NTUX(11)

        SW12 (0)
        '-----------------------------------------------------------------

        CallTable Data_15m
        NextScan
EndProg
```

Section 4. Calibration

4.1 Turbidity

The normalized response of an OBS sensor to SDVB turbidity over the range from 0 to 4,000 NTU is shown on FIGURE 4-1. As shown on the inset, the response function is contained within region 'A', the linear region, of the universal response curve. However, there is residual nonlinearity that is removed by calibration and by computation of NTU value with a 2nd-order polynomial. This section explains how to do a turbidity calibration.

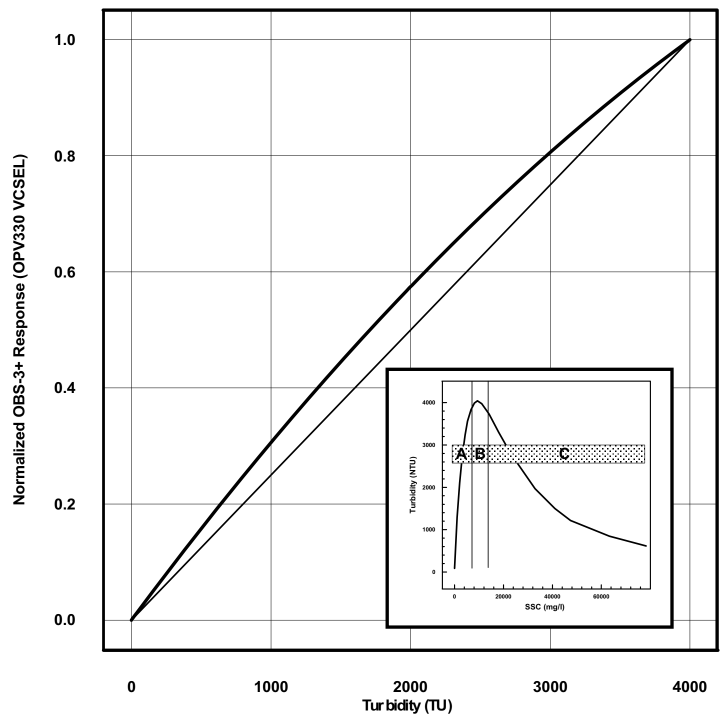

FIGURE 4-1. Normalized Response of OBS-3+ to Amco Clear Turbidity The inset shows the response function of an OBS sensor to high sediment concentrations.

Amco Clear® SDVB turbidity standards are used to calibrate an OBS sensor. SDVB standards are made for individual instruments and standards made for one model of turbidity meter can not be used to calibrate a different model. The standard values for calibrating OBSs are: 125 NTU (GFS Part No. 8428), 250 NTU (GFS Part No. 8429), 500 NTU (GFS Part No. 8430), 1,000 NTU (GFS Part No. 8431), 2,000 NTU (GFS Part No. 8432), and 4,000 NTU (GFS Part No. 8433). The standard values and volumes required for the standard low ranges are given in TABLE 4-1. SDVB standards have a shelf life of two years provided that they are stored in tightly sealed containers and evaporation is minimized.

TABLE 4-1. SDVB NTU values for turbidity calibrations in standard low ranges.			
Low Range	**1st Std. Value**	**2nd Std. Value**	**3rd Std. Value**
250	125 (1,000 ml)	250 (1,000 ml)	1,000 (500 ml)
500	250 (1,000 ml)	500 (500 ml)	2,000 (500 ml)
1,000	500 (500 ml)	1,000 (500 ml)	4,000 (500 ml)

The NTU values of the standards will remain the same as long as the ratio of particle mass (number of particles) to water mass (volume) does not change. Evaporation causes this ratio to increase and dust, bacteria growth, and dirty glassware can also cause it to increase. So: 1) always use clean glassware and calibration containers; 2) don't leave standards on the bench in open containers or leave the standard bottles uncapped. Perform the calibration as quickly as possible and return the AMCO solutions to their bottles 3) clean dirty sensors with a clean, alcohol-soaked cloth to sterilize it before dipping it into the standards; 4) transfer entire bottles between containers, avoiding aeration and shaking excess fluid off the glassware. Because of the intrinsic errors in the NTU value of formazin used by the SDVB manufacture (GFS Chemicals) and the dilution procedures, the uncertainty in the NTU value of an SDVB standard is ± 1% of the value indicated on the standard bottle. Consequently, the NTU value of one liter of standard in an uncovered 100-mm calibration cup will increase ~ 1% in 10 hours on a typical summer day (R.H. = 90% and air temp. = 18^o C). For example, the NTU value of a 2000-NTU standard in a 100-mm cup will increase by about 2 NTU (0.1%) per hour. TABLE 4-2 gives the increases for some other, commonly used standards.

TABLE 4-2. Change in NTU value resulting from one hour of evaporation[1] of SDVB standard, i.e. loss of water but not particles.				
	Nominal NTU Value			
Calibration-cup Size ∅ mm (∅ in.)	250	500	2000	4000
100 (4)	+0.26	+0.52	+2.10	+4.20
150 (6)	+0.60	+1.20	+4.80	+9.70

<u>Materials and equipment</u>: OBS sensor with test cable; datalogger or averaging DMM with test leads, 12V gel cell; large black polyethylene plastic tub (0.5 I.D. X 0.25 deep) for measuring the clear-water points. 100-mm and 200-mm black PE calibration cups. The 100-mm cups are used with standards with NTU values greater than 250 NTU and the 200-mm cups are used with the 125 and 250-NTU standards.

Setup

1) Plug the test cable into the OBS sensor; connect the red and black leads to the battery and clip the DMM or datalogger test leads across the blue (+) and green (-) leads.

2) Swab sensor with an alcohol-soaked towel to sterilize it.

Procedure

1) In a large black tub of fresh tap water, aim the OBS sensor so that it's the maximum distance from the sensor optics to the far corner of the tub (see FIGURE 4-2). Record a 10-second average of the low-range output. Record the average output on the calibration log sheet.

2) Swap the DMM or datalogger + test lead to the high-range output lead (white) and record a 10-secon average of the high-range output. Record the average output on the calibration log sheet.

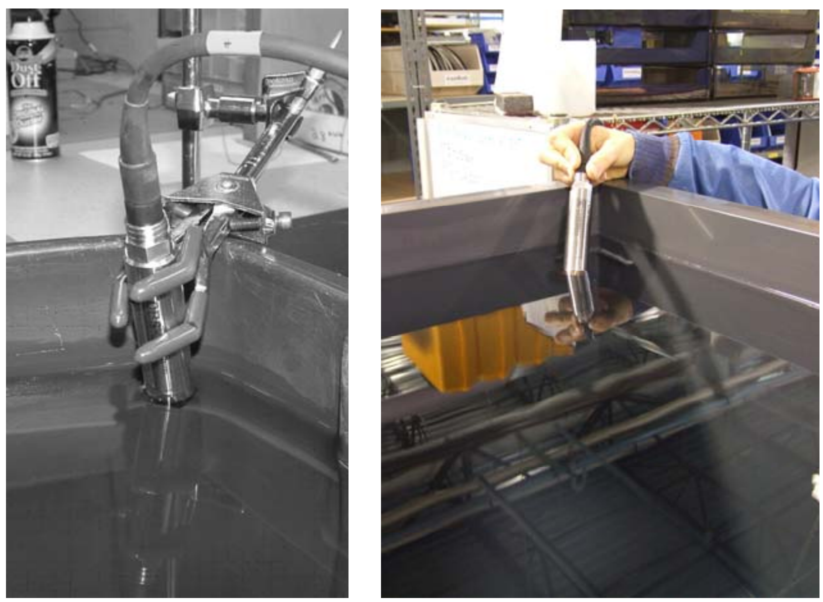

FIGURE 4-2. Position of OBS-3+ (left) and OBS300 (right) in Clean Tap Water in Big Black Tub

3) Pour the 1st SDVB standard into the appropriate size cup (see TABLE 4-1 and Materials and Equipment Section).

4) Position the OBS sensor in the cup as shown on FIGURE 4-3 and record 10-secon averages of the low- and high-range outputs. Record the average outputs on the calibration log sheet.

5) Pour the standard back into its container.

6) Wipe sensor with a clean dry towel to remove residual standard.

7) Repeat steps 3, 4, 5, and 6 for the other standards.

8) Perform 2nd-order polynomial regressions on the calibration data to get the coefficients for converting OBS signals to NTU values.

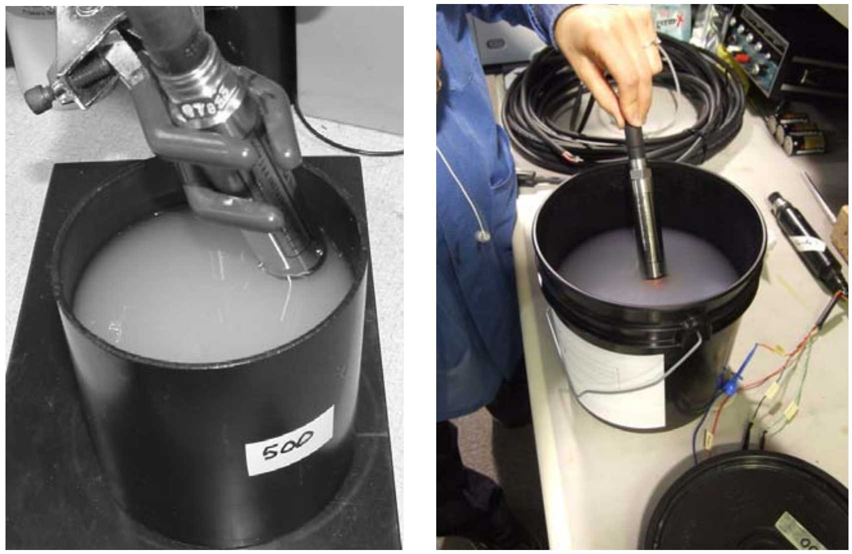

FIGURE 4-3. OBS-3+ (left) and OBS300 (right) in 500-NTU Amco® Clear Turbidity Standard in 100-mm Black Polyethylene Calibration Cup

4.2 Sediment

There are three basic ways to calibrate an OBS sensor with sediment. These are described in the following sections, however, only the procedures for dry-sediment are explained in this manual.

4.2.1 Dry-sediment Calibration

Dry-sediment calibration is a calibration performed with sediment that has been dried, crushed, and turned to power. This is the easiest calibration to do because the amount of sediment can be determined accurately with an electronic balance and the volume of water in which it is suspended can be accurately measured with volumetric glassware. Of the three methods, dry-sediment calibration causes the greatest physical and chemical alteration of the sediment. Alteration of the sediment size as a result of processing can significantly affect the calibration slope. FIGURE 7-1 shows for example that reducing the grain size by a factor of two during grinding can increase OBS sensitivity by a factor of two (see definition of sensitivity).

4.2.2 Wet-sediment Calibration

Wet-sediment calibration is performed with sediment obtained from water samples or from the bed of a river that has not been dried and pulverized. Consolidation and biochemical changes during storage and processing cause some alteration of wet sediment during storage, and for this reason, sediment and water samples should be stored at about 4^{o} C prior to use. The wet sediment is introduced into the sediment suspender as it comes from the field. This kind of calibration requires that water samples be withdrawn from the suspender after each addition of sediment for the determination of SSC by filtration and gravimetric analyses.

4.2.3 In situ Calibration

In situ calibration is performed with water samples taken from the immediate vicinity of an OBS sensor in the field over sufficient time to sample the full range of SSC values to which a sensor will be exposed. SSC values obtained for these samples with concurrent recorded OBS sensor signals and regression analysis establishes the mathematical relation for future SSC conversions by an instrument. This is the best sediment-calibration method because the particles are not altered from their natural form in the river (see Lewis, 1996). It is also the most tedious, expensive, and time-consuming method. It can take several years of water sampling with concurrent OBS measurements to record the full range of SSC values on a large river.

Materials and equipment: OBS sensor with test cable; dry, disaggregated sediment from the location where the OBS sensor will be used (sediment should be in a state where grinding, sieving, or pulverization does not change its particle-size distribution); averaging DMM or datalogger with test leads, 12V gel cell; sediment suspender (if a suspended is not available, use a 200-mm I.D. dark plastic container and a drill motor with paint-mixing propeller); electronic balance calibrated with ten-mg accuracy; 20-ml weigh boats; large black polyethylene plastic tub (0.5 I.D. X 0.25 deep) for measuring the clear-water points; 1-liter, class-A, volumetric flask; tea cup with round bottom; and teaspoon.

Setup

1) Check the balance with calibration weights; recalibrate if necessary.

2) Plug the test cable to the OBS sensor; connect the red and black leads to the battery and clip the DMM or datalogger test leads across the blue (+) and green (-) leads.

3) Add three liters of tap water to the suspender tub with the volumetric flash.

4) After measuring the clear-water signal (Step 1, Section 4.1), mount the sensor so that its end is 50 mm above the bottom of the suspender tub and secure it in the position that minimizes reflections from the wall; see FIGURE 4-4.

FIGURE 4-4. Portable Sediment Suspender (left) and OBS Beam Orientation in Suspender Tub (right)

SSC = $Wt_s [V_w + Wt_s/\rho_s]^{-1}$; where: Wt_s = total sediment weight in tub, in mg; V_w = volume of water in liters; ρ = density of water (ρ = 1.0 kg l^{-1} at 10^o C); and ρ_s = sediment density (assume 2.65 10^3 mg l^{-1});

Procedure

1) Record and log the clean-water signal as in Step 1, Section 4.1; see FIGURE 4-2.

2) Move the OBS sensor to the suspender as described in setup.

3) Weigh 500 ± 10 mg of sediment in a weigh boat and transfer it to the teacup. Record the weight on the calibration log sheet and add about 10 cc of water from the suspender tub to the teacup and mix the water and sediment into a smooth slurry with the teaspoon.

4) Add the sediment slurry to the tub and rinse the teacup and spoon with tub water to get all the material into the suspender.

5) Turn the suspender ON and let it run for 10 minutes or until the OBS signal stabilizes.

6) Take one-minute averages of the low- and high-range signals with the DMM or datalogger and enter them on the calibration log sheet.

7) Calculate the sediment-weight increment as follows: W_i = 2500 mg (RNG/V_x); where: W_i = the incremental weigh of sediment, RNG = the range of the OBS sensor (2.5V, 5V, or 16 mA), and V_x = the average output signal from step 6. Note: if the output is 4-20 mA, V_x will equal the output minus 4 mA. The resulting weight gives the amount of sediment to add to get five evenly spaced calibration points.

8) Add enough additional sediment to get one full increment of sediment, W_i ± 5%. Repeat steps 4, 5, and 6.

9) Repeat step 8 until five full increments of sediment have been added or until the OBS signals exceed the output range.

10) Perform 3^{rd}–order polynomial regressions on the data to get the coefficients for converting OBS output to SSC.

Section 5. Troubleshooting

WARNING

Do Not use a sensor with a stainless steel housing in seawater. This will void the warranty and cause corrosion and leakage.

The following three tests are used to diagnose malfunctions of an OBS sensor.

1) The **Finger-Wave Test** is used to determine if an OBS sensor is 'alive'. Power the OBS sensor and connect a DMM across the low- or high-range output leads (see Setup in Section 4). Wave your finger across the sensor window about 20 mm away from it. The DMM should show the output fluctuating from a few mV to the full-scale signal. If there are no signal fluctuations of this order, there is a problem that requires attention.

2) The **Shake Test** is done to determine if water has leaked inside the pressure housing. Unplug the cable and gently shake the sensor next to your ear and listen for sloshing water. This test gives a false negative result when the amount of water in the housing is large enough to destroy the circuit but too small to be audible.

3) A **Calibration Check** is done to verify if a working OBS sensor needs to be recalibrated. In order to be meaningful, the user must have a criterion for this test. For example, this criterion might be 5%. The sensor is placed in calibration standards with the 1^{st} and 2^{nd} NTU values listed in TABLE 4-1 and the DMM readings are logged. If either reading differs by more than 5% from ones reported on the factory calibration certificate, or the user own calibration data, then the sensor should be recalibrated. If the first two calibration points fall within the acceptance criterion, then the third value can be tested. The recommended frequency for calibration checks is quarterly when an OBS sensor is in regular use. Otherwise it should be performed prior to use. Calibration checks can be done in the field.

TABLE 5-1. Troubleshooting chart.

Fault	**Cause of Fault**	**Remedy**
Fails finger wave test	No power, dead battery	Replace battery and reconnect wires
	MCIL-5 plug not fully seated	Disconnect and reinsert plug.
	Sensor broken	Visually inspect for cracks. Return the sensor to manufacturer if cracks are found.
	Electronic failure. Units draws less than 11 mA or more than 40 mA.	Return the sensor to manufacturer.
Fails shake test	Sensor leaked	Return the sensor to manufacturer.
Fails calibration check	Aging of light source causes it to get dimmer with time.	Recalibrate (see Section 4)

Section 6. Maintenance

WARNING

There are no user-serviceable parts inside the sensor housing. <u>Do Not Remove the Sensor or Connector</u> from the pressure housing. This will void the warranty and could cause a leak.

The most important maintenance item is keeping the window clean. A SkotchBrite scouring pad works well for most types of window fouling. First wet the pad and then place it on a counter with a plastic-laminate top so that the side of the pad is aligned with the edge of the counter. Work the window of the OBS sensor back and forth on the pad until it is clean while removing as little epoxy as possible. If encrusting organisms such as barnacles or tube worms have attached to the sensor, it will have to be gently scraped with a flexible knife blade prior to using the pad. Some applications will result in pitting of the sensor face. Pits can be removed with abrasive cloth. Polish the sensor window as follows: 1) tape a strip of 400 grit wet-or-dry abrasive cloth to the edge of a counter (see above); 2) add a few drops of water to the abrasive and work the sensor window in smooth one-way strokes on the cloth using the counter edge as a guide; and 3) continue until the sensor is shiny and pit free. It is **<u>important to remove as little epoxy as possible</u>**.

WARNING

<u>Do not use solvents</u> such as MEK, Toluene, Acetone, or trichloroethylene on OBS sensors.

Section 7. Factors that Affect Turbidity and Suspended-Sediment Measurements

This section summarizes some of the factors that affect OBS measurements and shows how ignoring them can lead to erroneous data. If you are certain that the characteristics of suspended matter will not change during your survey and that your OBS was factory calibrated with sediment from your survey site, you only need to skim this section to confirm that no problems have been over looked.

7.1 Particle Size

The size of suspended sediment particles typically ranges from about 0.2 to 500µm in surface water (streams, estuaries and the ocean). With size, shape, and color remaining constant, particle area normal to a light beam will determine the intensity of light scattered by a volume of suspended matter. Results of tests with sediment shown on FIGURE 7-1 indicate a wide range of OBS sensitivity is associated with fine mud and coarse sand (about two orders of magnitude). The significance of these results is that size variations between the field and laboratory and within in a survey area during monitoring will produce shifts in apparent NTU and SSC values that are unrelated to real changes in sediment concentration. FIGURE 7-2 shows the difference in apparent turbidity that can result from different ways of disaggregating sediment.

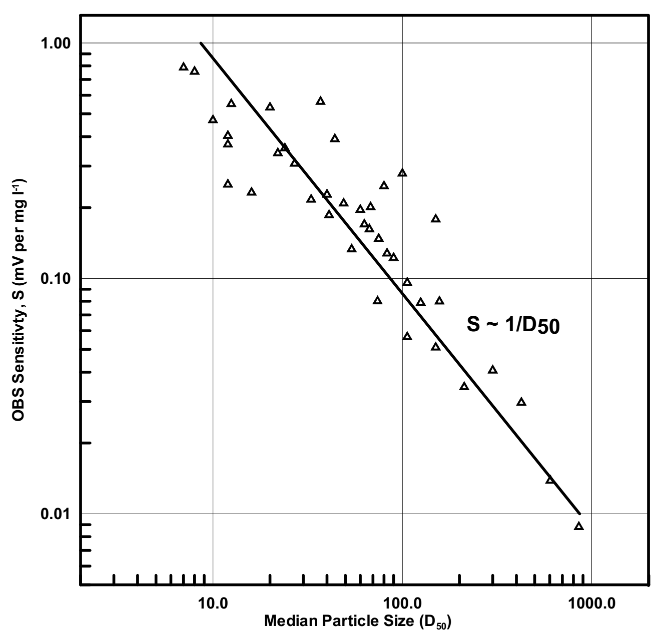

FIGURE 7-1. Normalized OBS Sensitivity as a Function of Grain Diameter

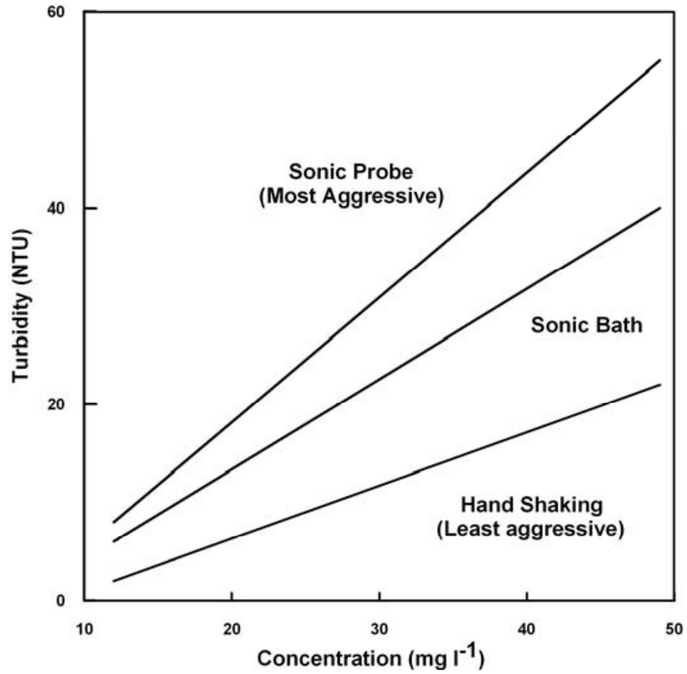

FIGURE 7-2. The Apparent Change in Turbidity Resulting from Disaggregation Methods

7.2 Suspensions with Mud and Sand

As mentioned in Section 7.1, backscattering from particles is inversely related to particle size on a mass concentration basis. This can lead to serious difficulties in flow regimes where particle size varies with time. For example, when sandy mud goes through a cycle of suspension and deposition during a storm, the ratio of sand to mud in suspension will change. An OBS sensor calibrated for a fixed ratio of sand to mud will therefore indicate the correct concentration only part of the time. There are no simple remedies for this problem. The obvious thing to do is to take a lot of water samples and analyze them in the laboratory. This is not always practical during storms when the errors are likely to be largest. Do not rely solely on OBS sensors to monitor suspended sediments when particle size or composition is expected to change with time at a monitoring site.

7.3 Particle-Shape Effects

In addition to size and flocculation/aggregation, particle shape has a significant effect on the scattering intensity from a sample and calibration slope of an OBS sensor. As the graph in FIGURE 7-3 shows, plate-shaped particle (clay-mineral particles for example), backscatter light about ten times more efficiently than spherical particles and angular shapes have intermediate scattering efficiency. OBS sensors are very sensitive to shape affects and this makes it very important to calibrate with material from the monitoring site. It is also essential that particle shape remain constant during the monitoring period.

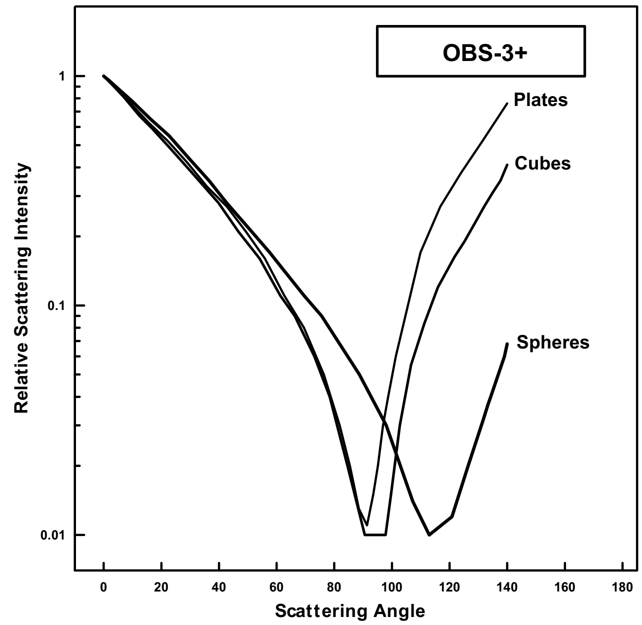

FIGURE 7-3. Relative Scattering Intensities of Grain Shapes

7.4 High Sediment Concentrations

At high sediment concentrations, particularly in suspensions of clay and silt, the infrared radiation from the emitter can be so strongly attenuated along the path connecting the emitter, the particle, and the detector, that backscatter decreases exponentially with increasing sediment concentration. For mud, this occurs at concentrations greater than about 5,000 mg/l. FIGURE 7-4 shows a calibration in which sediment concentrations exceeding 6,000 mg l^{-1} cause the output signal to decrease. It is recommended not to exceed the specified turbidity or suspended sediment ranges, otherwise the interpretation of the signal can be ambiguous. For example, a signal level of 2,000 mV (FIGURE 7-4) could be interpreted to indicate SSC values of either 3,000 or 33,000 mg l^{-1}. Factory calibrations are performed in the linear region designated ‘A’ on the graph.

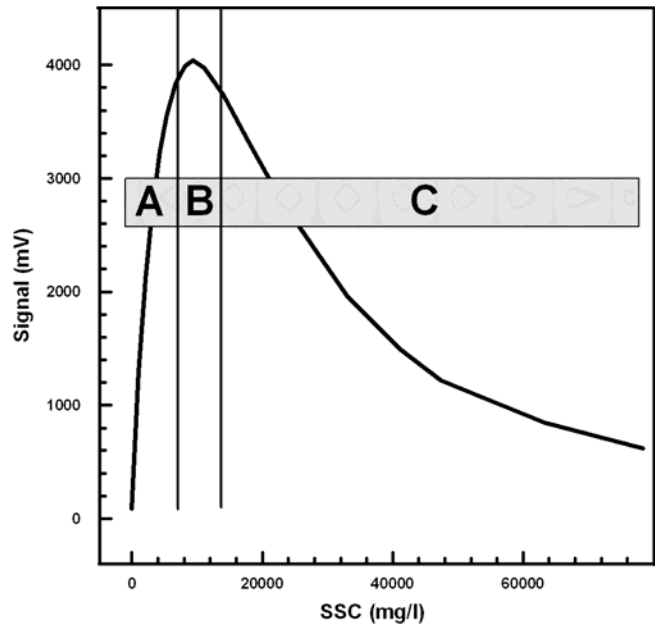

FIGURE 7-4. Response of an OBS Sensor to a Wide Range of SSC

7.5 IR Reflectivity—Sediment Color

Infrared reflectivity, indicated by sediment color, has a major effect on OBS sensitivity because with other factors remaining constant, it changes the intensity of light scattering. Although OBS sensors are color blind, test have shown that “whiteness”, color, and IR reflectivity are correlated. Calcite, which is highly reflective and white in color, will produce a much stronger OBS signal on a mass-concentration basis than magnetite, which is black and IR absorbing. Sensitivity to colored silt particles varies from a low of about one for dark sediment to a high of about ten for light gray sediment; see FIGURE 7-5. In areas where sediment color is changing with time, a single calibration curve may not work. Resulting errors will depend on the relative concentrations of colored sediments.

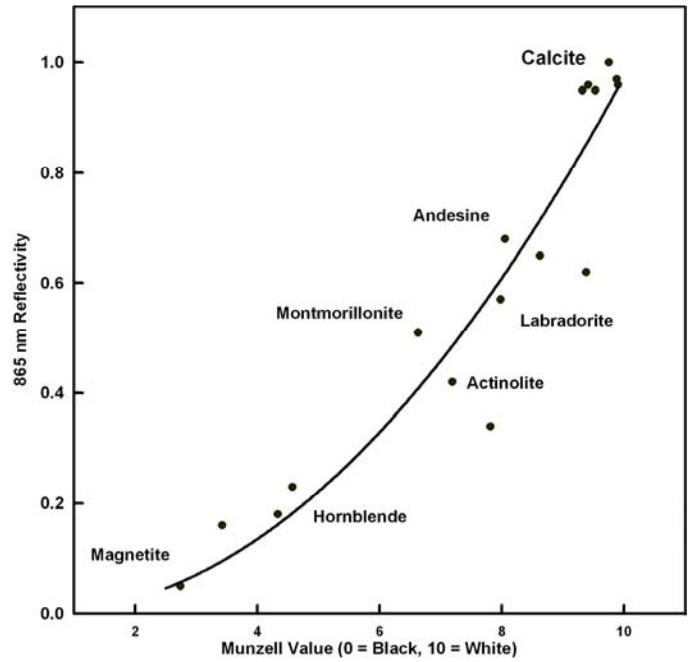

FIGURE 7-5. Infrared Reflectivity of Minerals as a Function of 10-Munzell Value

7.6 Water Color

Some OBS users have been concerned that color from dissolved substances in water samples, not colored particles discussed in Section 7.5, produces erroneously low turbidity measurements. Although organic and inorganic IR-absorbing dissolved matter has visible color, its effect on OBS measurements is small unless the colored compounds are strongly absorbing at the OBS wavelength (850 nm) and are present in high concentrations. Only effluents from mine-tailings produce enough color to absorb measurable IR. In river, estuary, and ocean environments concentrations of colored materials are too low by at least a factor of ten to produce significant errors.

7.7 Bubbles and Plankton

Although bubbles efficiently scatter light, monitoring in most natural environments shows that OBS signals are not strongly affected by bubbles. Bubbles and quartz particles backscatter nearly the same amount of light to within a factor of approximately four, but most of the time bubble concentrations are at least two orders of magnitude less than sand concentrations. This means that sand will produce much more backscatter than bubbles in most situations and bubble interference will not be significant. Prop wash from ships and small, clear-mountain streams where aeration produces high bubble concentrations are an exception to this generality and can produce erroneous turbidity values resulting from bubbles.

OBS sensors detect IR backscattered between 90° and 165° where the scattering intensities are nearly constant with the scattering angle. Particle concentration has the most significant effect in this region. OBS sensors are more sensitive, by factors of four to six, to mineral particles than particulate organic matter and interference from these materials can therefore be ignored most of the time. One notable exception is where biological productivity is high and sediment production from rivers and re-suspension is low. In such an environment, OBS signals can come predominately from plankton.

7.8 Biological and Chemical Fouling

Sensor cleaning is essential during extended deployments. In salt water, barnacle growth on an OBS sensor can obscure the IR emitter, the detector, or both and produce an apparent decline in turbidity. Algal growth in marine and fresh waters has caused spurious scatter and apparent increases of OBS output. The reverse has also been noted in fresh water where the signal increases after cleaning the sensor window. Prolonged operation in freshwater with high tannin levels can cause a varnish-like coating to develop on an OBS sensor that obscures the IR emitter and caused an apparent decline in turbidity. Cleaning algal and tannin accumulation off OBS sensors is required more often during the summer because warm water and bright sunlight increase biological and chemical activity.

Campbell Scientific sells two wipers from a third-party manufacturer: the Hydro-Wiper C with its own controller, or the Hydro-Wiper D that is controlled by a datalogger.

Section 8. References

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Lewis, Jack. 1996. Turbidity-controlled Suspended Sediment Sampling for Runoff-event Load Estimation. Water Resources Research, 32(7), pp. 2299-2310.

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Sutherland T.F., P.M. Lane, C.L. Amos, and John Downing. 2000. The Calibration of Optical Backscatter Sensors for Suspended Sediment of Varying Darkness Level. Marine Geology, 162, pp. 587-597.

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Zaneveld, J.R.V., R.W. Spinrad and R. Bartz. 1979. Optical Properties of Turbidity Standards. SPIE 208 Ocean Optics VI. Bellingham, Washington, pp. 159-158, 1979.

Section 9. Terminology

110 Rule: 100 ppm of 100-µm suspended sand will scatter light with the same intensity as 10 ppm of 10-µm suspended silt, other factors, such as size, shape and color, remaining constant.

Backscatter/forward scatter: The interaction of light with suspended particles, water molecules, and variations in refractive index that alters the direction of light transport through a sample without changing the wavelength. The angle between the direction of propagation of a source light beam and the direction of a scattered beam is the scattering angle. Forward-scattering refers to scattering angles less than 90º and backscattering refers scattering angle equal to or greater than 90º.

Calibration Slope: NTU or SSC value per mV or mA of OBS output. It is nearly constant in the linear region of the OBS response function but is a function of sediment concentration elsewhere.

Daylight-Rejection Filter: An optical bandpass filter that transmits near infrared light (760-1200 nm) and blocks visible light (390-760 nm).

Drift: A change in OBS output over time or with ambient temperature that is unrelated to the sample turbidity or SSC.

Interference: Properties of the sample, the environment, or measurement procedure that produce unintended and unknown shifts in turbidity or SSC.

Sample Volume: The water volume where the OBS infrared beam and suspended particles interact and the scattered light is detected. OBS sample volumes range from 25 to 12 x 10^4 mm^3, i.e. BBs to tennis balls, depending on turbidity.

Sensitivity: The ratio of output level (mV, mA, or NTU value) to suspended-sediment concentration, e.g.: mV per mg l^{-1}, mA per mg l^{-1}, or NTU per mg l^{-1}.

Suspended-Sediment Concentration (SSC): Mass or volume of sediment in a sample divided by the volume (or weight) of the sample expressed as mg l^{-1} (or ppm).

Synchronous Detection: A signal-processing technique for rejecting d.c. shifts wherein the gain is switched from -1 to 1 synchronously with the OBS clock. This technique limits the bandwidth and noise of a circuit.

Temperature Coefficient: The change in OBS output per unit of ambient temperature change expressed as ppm. For example, an OBS that indicates 100 NTU in a standard at 25^{o} C and 101 NTU in the same standard at 5^{o} C would have a temperature coefficient of -500 ppm.

Turbidity (conceptual definition): A numerical expression, in relative units, of the optical properties that cause water to appear hazy or cloudy when light to be scattered and absorbed by suspended matter. Turbidity is caused by sediment, plankton, bacteria, and viruses, organic acids, and dyes. In general, as the concentration of suspended matter increases, so will water turbidity, and as the concentration of dissolved light-absorbing matter increases, turbidity will decrease.

Turbidity (operational definition): NTU value is a number ranging from 0 to 10,000 that is computed by a turbidimeter from measurements of the intensity of light scattered from water sample and by interpolation between bracketing SDVB (Amco Clear®) calibration values.

Section 10. Specifications

Ranges

Turbidity (low/high):	250/1,000 NTU; 500/2,000 NTU; 1,000/4,000 NTU
Mud[1]:	5,000 to 10,000 mg l^{-1}
Sand[1]:	50,000 to 100,000 mg l^{-1}

[1] Range depends on sediment size, particle shape, and reflectivity.

Accuracy

Turbidity[2]:	2% of reading or 0.5 NTU
Mud[2]:	2% of reading or 1 mg l^{-1}
Sand[2]:	4% of reading or 10 mg l^{-1}

[2] Whichever is larger.

Height

OBS-3+:	14.1 cm (5.56”)
OBS300:	13.1 cm (5.15”)

Diameter:	2.5 cm (0.98”)
Weight:	181.4 grams (0.4 lbs)

Power

Voltage output:	5 to 15 Volts d.c./15 mA (Volts outputs)
4-20 mA transmitter:	9 to 15 Volts d.c./45 mA max. (4-20 mA output)

Operating wave length:	850 ± 5 nm
Optical power:	2000 µW
Drift:	<2% per year
Daylight rejection:	-28 dB (re:48 mW cm^{-2})
Maximum data rate:	10 Hz

Maximum depth

Stainless-steel body:	500 m (1640.5 ft)
Titanium body:	1500 m (4921.5 ft)

Appendix A. Datalogger Connection to a Relay

The CR10, CR7, CR510, and 21X dataloggers do not have a switched 12 V channel. Either the sensor can remain on or a relay may be used to switch the power on and off. Figure A-1 shows the relay connections.

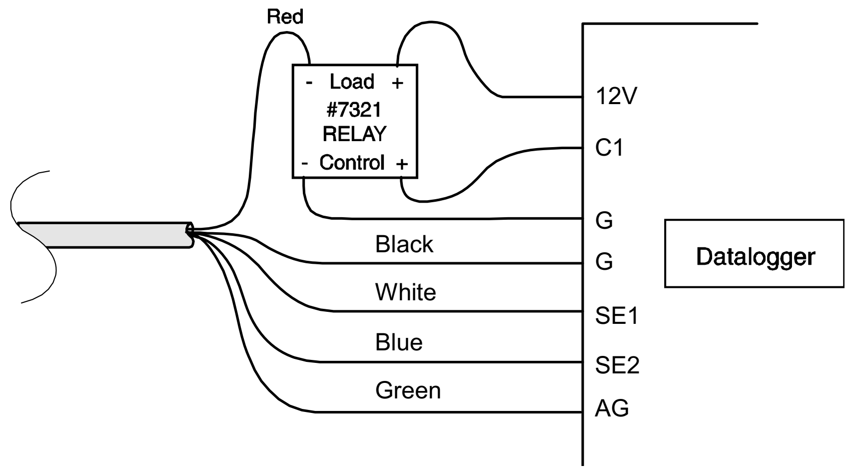

FIGURE A-1. Wiring Diagram for Connecting an OBS Sensor to an External Relay and a Datalogger

NOTE

1. The assignment of channel number (e.g., SE Channel 1 or C1) may vary depending on the application.

2. You may use a relay such as Campbell Scientific part #7321 instead of the switched 12 V connection on the CR10(X), CR1000, and CR23X wiring panel. Since the CR510 wiring panels do not have switched 12 V, you will need an external relay if you need to conserve battery power.

Appendix B. CR10X Example Program

The following example uses the voltage curve of the calibrations certificate provided in FIGURE 3-4. Since the coefficients of the voltage curve are used, the multiplier for Instruction 1 – Volt (SE) needs to be 0.001.

```
;{CR10X}

;OBS-3+  Turbidity Probe
;Blue              1H (SE1)
;White             1L (SE2)
;Green             AG
;Red               SW12V
;Black             G
;Red jumper   C8   SW12V CTRL

;This example is for a sensor that has output of 250 NTU
;on the low range and 1000 NTU on the high range.
;The calibration is in units of VOLTS.  If your calibration
;certificate is in mV then the "Mult" in the Volt SE instructions
;should be 1.
;
;**********************************************************

*Table 1 Program
  01: 5            Execution Interval (seconds)     ;5-second execution

;activate SW12V for turbidity probe, delay 3 seconds, then measure
1:  Do (P86)
  1:   48          Set Port 8 High

2:  Excitation with Delay (P22)
  1:   1           Ex Channel
  2:   0           Delay W/Ex (0.01 sec units)
  3:   300         Delay After Ex (0.01 sec units)
  4:   0           mV Excitation

3:  Beginning of Loop (P87)
  1:   0           Delay
  2:   10          Loop Count

    4:  Volt (SE) (P1)
      1:   1           Reps
      2:   2           2500 mV 60 Hz Rejection Range
      3:   1           SE Channel
      4:   3           -- Loc [ NTU_V_1   ]
      5:   0.001       Mult
      6:   0.0         Offset

5:  End (P95)
```

```
6:  Spatial Average (P51)
   1:    10               Swath
   2:    3                First Loc [ NTU_V_1   ]
   3:    2                Avg Loc [ NTU_Volts ]

NTU = -0.29928 + (105.69 * NTU_Volts) - (0.24763 * NTU_Volts^2)

; evaluate to see if value >250, where High range measurement should be taken via Sub1

7:  If (X<=>F) (P89)
   1:    1                X Loc [ NTU       ]
   2:    3                >=
   3:    250              F
   4:    1                Call Subroutine 1

8:  Do (P86)                                              ;switch off the 12V for turbidity probe
   1:    58               Set Port 8 Low

*Table 2 Program
   01:  0                 Execution Interval (seconds)

*Table 3 Subroutines

1:  Beginning of Subroutine (P85)
   1:    1                Subroutine 1

      2:  Beginning of Loop (P87)
         1:    0                Delay
         2:    10               Loop Count

            3:  Volt (SE) (P1)
               1:    1                Reps
               2:    25               2500 mV 60 Hz Rejection Range
               3:    2                SE Channel
               4:    3                -- Loc [ NTU_V_1   ]
               5:    0.001            Mult
               6:    0.0              Offset

      4:  End (P95)

      5:  Spatial Average (P51)
         1:    10               Swath
         2:    3                First Loc [ NTU_V_1   ]
         3:    2                Avg Loc [ NTU_Volts ]

      NTU = -0.20709 + (401.11*NTU_Volts) + (35.310*NTU_Volts^2)

6:  End (P95)

End Program
```

Appendix C. CR200(X) Example Program

The following example uses the voltage curve of the calibrations certificate provided in FIGURE 3-4. Since the coefficients of the voltage curve are used, the multiplier for the VoltSE instruction needs to be 0.001.

```
'CR200(X) Series Datalogger
'Boyd Bringhurst, CSI 3/05/08

Public batt_volt
Public NTU, NTU_SD
Public NTUarray(10)
Public n,i
Public A(2), B(2), C(2)

DataTable (NTUData,1,-1)
    DataInterval (0,1,min)
    Sample (1,NTU)
    Sample (1,NTU_SD)
    EndTable

BeginProg

    n = 10

    A(1) = -0.24763
    B(1) = 105.69
    C(1) = -0.29928
    A(2) = 35.310
    B(2) = 401.11
    C(2) = 0.20709

    Scan (5,Sec)
        Battery (Batt_volt)

        SWBatt (1 )
        Delay (2,sec)

For i = 1 To n

            'n=10 in this case so ten measurements will be made for both the high and low
            'input ranges.  A multiplier of 0.001 is used because the coefficients are
            'from the voltage calibration sheet
            VoltSe (NTUarray(i),1,2,0.001,0)
            NTUarray(i) = A(2) * NTUarray(i)^2 + B(2) * NTUarray(i) + C(2)

        Next i

        AvgSpa (NTU,10,NTUarray())
            StdDevSpa (NTU_SD,10,NTUarray())
```

```
If NTU < 250 Then

            For i = 1 To n

                  VoltSe (NTUarray(i),1,1,0.001,0)
                  NTUarray(i) = A(1) * NTUarray(i)^2 + B(1) * NTUarray(i) + C(1)

            Next i

            AvgSpa (NTU,10,NTUarray())
                  StdDevSpa (NTU_SD,10,NTUarray())

            EndIf

            SWBatt (0 )

            CallTable NTUData
      NextScan
EndProg
```

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