WET Labs®

Transmissometer

C-Star

User's Guide

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C-Star User's Guide (cstar) Revision V 12 Dec. 2011

Return Policy for Instruments with Anti-fouling Treatment

WET Labs cannot accept instruments for servicing or repair that are treated with anti-fouling compound(s). This includes but is not limited to tri-butyl tin (TBT), marine anti-fouling paint, ablative coatings, etc.

Please ensure any anti-fouling treatment has been removed prior to returning instruments to WET Labs for service or repair.

C-Star Warranty

This unit is guaranteed against defects in materials and workmanship for one year from the original date of purchase. Warranty is void if the factory determines the unit was subjected to abuse or neglect beyond the normal wear and tear of field deployment, or in the event the pressure housing has been opened by the customer.

To return the instrument, contact WET Labs for a Return Merchandise Authorization (RMA) and ship in the original container. WET Labs is not responsible for damage to instruments during the return shipment to the factory. WET Labs will supply all replacement parts and labor and pay for return via 3rd day air shipping in honoring this warranty.

Shipping Requirements for Warranty and Out-of-warranty Instruments

1. Please retain the original shipping material. We design the shipping container to meet stringent shipping and insurance requirements, and to keep your meter functional.

2. To avoid additional repackaging charges, use the original box (or WET Labs-approved container) with its custom-cut packing foam and anti-static bag to return the instrument.
   - If using alternative container, use at least 2 in. of foam (NOT bubble wrap or Styrofoam “peanuts”) to fully surround the instrument.
   - Minimum repacking charge for C-Star meters: $120.00.

3. Clearly mark the RMA number on the outside of your shipping container and on all packing lists.

4. Return instruments using 3rd day air shipping or better: do **not** ship via ground.

Table of Contents

1. Specifications

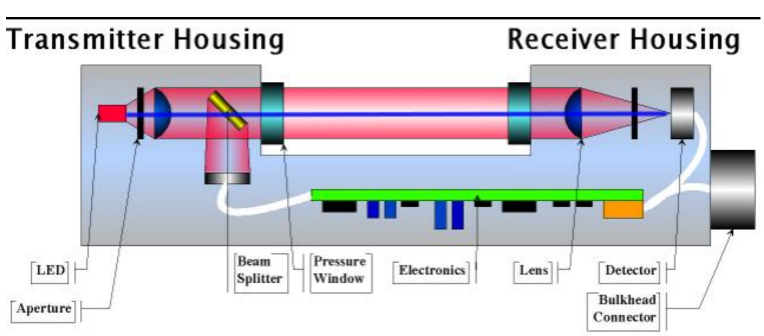
The C-Star transmissometer is available in four wavelengths:

- Red (650 nm): Best for particle dynamics, e.g. mass concentration estimates.
- Green (530 nm): Best for estimates of in-situ visibility.
- Blue (470 nm): Best for estimating blue light penetration.
- UV (370 nm): Experimental.

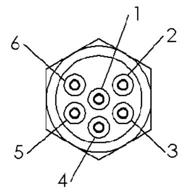
Mechanical	
Pressure housing	25 cm pathlength—9.3 x 6.4 x 47 cm 10 cm pathlength—9.3 x 6.4 x 29.2 cm
Overall length	25 cm pathlength (including bulkhead connector)—49 cm 10 cm pathlength (including bulkhead connector)—32 cm
Weight in air	25 cm pathlength—2.2 kg (copolymer); 3.6 kg (aluminum) 10 cm pathlength—1.8 kg (copolymer only)
Environmental	
Rated depth	600 m or 6000m (aluminum 25cm only)
Temperature error	0.02 percent F.S./deg C
Operating range	0–40 deg C
Long term stability	0.02 percent F.S./Hr
Electrical	
Output resolution	14 bit
Power input	7–15 VDC
Data output	0–16380 counts, 0–5 V
Connector	MCBH-6-MP
Power input	7–15 VDC
Operating current	35 mA (typ); 50 mA (max)
Sample rate	to 8 Hz
Optical	
Pathlength	10 or 25 cm
Acceptance angle	~1 deg
Wavelength	650, 530, 470, or 370 nm
Bandwidth (FWHM)	~20 nm (~10–12 for 370 nm)
Linearity	99% R^2

Specifications are subject to change without notice.

1.1 Functional Illustration



1.2 Connector

Pin	Function	MCBH-6-MP
1	Ground	
2	RS-232 RX	
3	Reserved	
4	V +	
5	RS-232 TX	
6	Analog out	

2. Instrument Operation

2.1 Deliverables

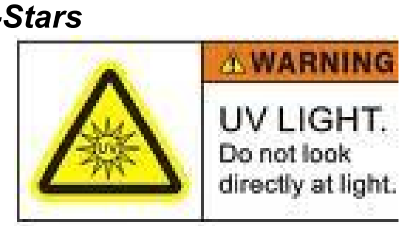
The standard C-Star delivery package includes the following:

- C-Star instrument
- A short pigtail lead with the mating connector to C-Star's bulkhead connector
- One lock collar for use with pigtail and to protect connector pins during shipping
- Calibration sheet
- CD with this user's guide, host software, and instrument-specific device file
- **Optional**: flow tube for bench-top use
- **Optional**: leak-resistant flow sleeves
- **Optional**: copper window rings.
- **Optional**: test cable, built with:
    a. An inline connector for providing power to the instrument from a 9V battery (user-supplied).
    b. An auxiliary analog out connector.
    c. A DB-9 serial interface connector.
    d. A six-socket connector for providing power and signal to the instrument.

2.2 Meter Setup and Functionality Check

UV LED Safety Note—370 nm C-Stars

- UV LEDs emit intense UV light during operation.
- Do not look directly into a UV LED while it is in operation, as it can be harmful to the eyes, even for brief periods.
- If it is necessary to view a UV LED, use suitable UV-filtered glasses or goggles to avoid damage to the eyes.
- Keep UV LEDs and products containing them out of the reach of children.
- Take appropriate precautions, including those above, with pets or other living organisms that might suffer injury or damage from exposure to UV emissions.



This label is affixed to all products containing UV LEDs.

1. Copy the contents of the CD to the host computer.
2. Connect the C-Star to the host computer. WET Labs recommends using the optionally available test cable for pre-deployment checkout.
3. Open the ECOView software from its location on your host PC. ECOView will prompt you to:
   a. Select the appropriate COM Port on the host PC. It will automatically detect the meter's baud rate (19200).
   b. Select the meter's device file. (This is also on the CD.)
4. Select the Raw Data tab.
5. Supply power to the meter. Incoming data should appear in the Raw Data tab.
6. Turn off power to C-Star after verifying that data is incoming.

2.3 Pre-Deployment Check

Check the light source with a piece of white paper in the light path.

Data is output from the instrument in the following order:

Column	Value	Example
1	Instrument serial number	CSTR-0000 11829 13838 13695 0.003 527
2	Reference counts	CSTR-0000 11829 13838 13695 0.003 527
3	Signal counts	CSTR-0000 11829 13838 13695 0.003 527
4	Corrected signal raw counts	CSTR-0000 11829 13838 13695 0.003 527
5	Calculated beam c, inverse meters	CSTR-0000 11829 13838 13695 0.003 527
6	Internal thermistor, counts	CSTR-0000 11829 13838 13695 0.003 527

1. Block the light path and check that the corrected signal raw counts is zero.

   ```
   CSTR-0000 12683 00000 00000 99.999 527
   ```

   The signal raw count value and the corrected signal raw count value should both go to zero. Blocked values of a few counts above or below zero are not significant and can be ignored. Blocked values greater that 50 counts are a cause for concern and may indicate an instrument that needs to be serviced. Clean the optics and re-test. If a high blocked value persists, contact the WET Labs support team. The calculated beam c value is not meaningful when the light value is blocked. The instrument outputs 99.999 for the calculated beam c with the signal blocked.

2. With an unobstructed light path check that the corrected signal raw counts approaches the clean air value on the instrument's calibration sheet and/or previous tracking values.

   ```
   CSTR-0000 12681 12977 12966 0.551 527
   ```

   Clean air values will only approach or equal the factory air values in very controlled environments. If you are at sea you should expect to get within 500 counts. On shore in a controlled environment you should get within 100 counts. Larger differences between the current air values and the factory air values are a cause for concern and may indicate an instrument that needs to be serviced. Clean the optics and re-test. If a large difference persists, contact WET Labs support.

3. Check for a "mid-range" value using a material that partially blocks the light, for example a piece of tape. Place half way between windows in beam path. Do not stick tape to window.

```
CSTR-0000 12683 10523 10510 2.651 527
```

Note

If the sensor locks up, remove power for approximately 5 seconds, then restart.

4. Prior to deploying the instrument in water the best practice is to squirt a dilute solution of detergent onto the instrument This will help keep the optics clean through the surface layer of the water. After each operation or exposure of the instrument to natural water flush the instrument with clean fresh water, paying careful attention to the exposed optical faces. It is very important to make sure that salt water does not dry on the instrument as salt crystals are very persistent and can be difficult to remove. After flushing, a few squirts of a dilute solution of detergent onto the optical faces followed by a final rinse with filtered distilled water will keep the optic surfaces clean.

Analog checkout of C-Star is straightforward.

- Apply 7–15 VDC to the instrument to provide power to the electronics. Ensure that positive voltage is applied to Pin 4, and common or ground is applied to Pin 1. A 9-volt battery makes a good power supply for bench testing. With the proper voltage applied to Pins 1 and 4, the LED should illuminate. This light is easily seen by placing a white card into the beam path.
- Connect Pin 6 (analog out) and Pin 1 (ground) to a digital multimeter. With no flow tube installed, the analog output voltage should closely agree with the air value on the calibration sheet, provided the instrument optics are clean and dry.

2.4 Deployment

C-Star can be deployed in either a non-pumped, open sample volume mode or a pumped configuration. If a pump is used with C-Star, you will need the optional flow tube. If you use a pump to flush the flow cell, the recommended flow rate is 20–30 ml/sec. A good pump for this purpose is Sea-Bird Electronics' SBE-5T. It is a small, low power pump that has an adjustable motor speed so flow rate can be precisely controlled.

2.4.1 Mounting

When mounting C-Star on a cage or lowering frame, take care to electrically isolate the instrument from the metal frame and clamps. A thin sheet of rubber or dielectric tape will prevent metal-to-metal contact. Place hose clamps around the upper and lower housings. Although the instrument is quite strong, be sure not to clamp the C-Star too tightly to avoid torquing the optical path, which can cause an offset to appear in the data.

The optional 6,000 m depth rated meter comes with a zinc anode mounted near the bulkhead connector. This anode should protect C-Star from normal galvanic action. If the anode should show rapid dissipation or the instrument case itself should show signs of pitting, check the system for stray potentials. C-Star's electronics are not grounded to the case. However, ground potentials between various instruments on a cage or lowering frame may attack the pressure housing, causing corrosion.

2.5 Data Collection

For digital operation, the C-Star must be connected to a host system that will receive a RS-232 signal at 19200 baud. The C-Star has no logging capability, so connecting it to a PC or data logger will allow you to save data.

For analog operation, the C-Star must be connected to a host system that will receive the analog voltage output and digitize it. Many oceanographic instruments such as CTDs, radiometers, and data loggers are equipped with analog input channels with on-board A/D converters.

2.6 Instrument Maintenance

This section describes routine processes to check that the instrument is functioning and that the instrument is providing good data. We also describe the routine maintenance required to keep the instrument functioning at its best.

Caution

If the pressure housing is opened for any reason, your warranty will be void. Additionally, the C-Star *must* be re-pressure tested prior to using in the field. We cannot be responsible for leakage that occurs after a user opens the instrument.

After each cast, or exposure of the instrument to natural water, flush with clean fresh water, paying careful attention to the pressure windows. Soapy water will cut any grease or oil accumulation. Be careful not to scratch the pressure windows when cleaning. Use lint-free tissues such as Kimwipes® for wiping the lenses.

When stored, the instrument should be protected from dust and particularly from stack blow-down if on deck. Prior to deployment, the instrument output should be evaluated. During deployments, instrument output should be tracked.

The meter's clean air output value (CSC_{air}) is provided on the factory calibration sheet. We recommend using the CSC_{air} value to:

1. monitor basic operation of the instrument,
2. decide when to clean the instrument,
3. determine when your instrument is clean.

Tracking the CSC_{air} value over time is the single best way to monitor the meter's performance and maximize its utility.

We recommend you assemble a maintenance kit that consists of:

- A 500 ml squirt bottle of a dilute detergent solution. A commercial detergent such as Microclean or Dawn works well. Two drops of detergent in a 500 ml squirt bottle filled with 0.2 or 0.4 µm filtered distilled and deionized water is sufficient.
- A 500 ml squirt bottle of 0.2 or 0.4 µm filtered distilled and deionized water.
- Lint-free laboratory wipes.
- Cotton or lint-free swabs.
- Compressed clean air source.
- A notebook for recording maintenance dates and tracking output.

2.6.1 Removing and Installing Optional Flow Tubes

Follow the steps below to remove, clean and re-install the optional flow tubes.

1. Remove the black plastic flow tubes by sliding the flow tube sleeves toward the middle of the flow tube. Lift the flow tube out.
2. Remove the O-rings.
3. Wash the flow tube with a mild detergent.
4. Rinse completely with water to ensure no soap residue is left inside the flow tube.
5. Place the tube in a protected area where it can dry out completely. Dry nitrogen can be used to blow dry the flow tube.
6. To reinstall, carefully replace the flow tube O-rings. Ensure the O-rings are not damaged in any way, as they will not seal properly. If damaged, replace with size 122 O-rings.
7. Ensure the windows are clean and dry. Since small amounts of moisture can affect the air readings, it is important to ensure that the meter is completely dry. Using dry nitrogen under very low pressure, flow the gas over the windows immediately before replacing the flow tube. This will remove any water or methanol trapped in the small grooves around the window.
8. Insert the flow tube into the meter, lining up the stainless steel cap screws with the grooves in the flow tubes. This will ensure that the feet on the ends of the flow tubes will not block the water flow. Slide the flow tube sleeves outward on both ends until the outside ring on the sleeve is flush with the C-Star body to secure the flow tube.

2.7 Data Analysis

C-Star outputs beam attenuation with internally applied scale factor and offset. The corrected signal count output values increase linearly with increasing transmittance over the instrument's measurement range. The output is proportional to the amount of light received by the detector. With the instrument in water, the corrected signal counts (CSC) or output voltage should vary from a minimum value equaling the dark value (obtained by a blocked beam reading) to a maximum signal equal to the corrected signal counts or voltage obtained during the clean water calibration (CSC_{cal}). The ratio of the signal output to the calibration output is the transmittance ratio and will vary from 0 to 1, or 0 to 100 percent. Transmittance is related to the beam attenuation coefficient c by the relationship:

$$\mathbf{Tr} = e^{-cx}$$

where *x* is the pathlength (10 or 25 cm) through the water volume. WET Labs has adopted the convention that the measured beam c is relative to the clean water calibration value, and hence does not include the beam attenuation coefficient for pure water at a given wavelength and temperature.

Note

Use your judgment to determine whether to discard single outlying data points.

2.7.1 Calibrated Instrument Output

C-Star transmittance is expressed as

$$\mathbf{Tr} = (CSC_{sig} - CSC_{dark}) / (CSC_{cal} - CSC_{dark})$$

where:

- CSC_{sig} is the measured output signal.
- CSC_{dark} is the dark offset for the instrument (factory-supplied). CSC_{dark} is obtained by blocking the light path.
- CSC_{cal} is the factory-supplied corrected signal counts for clean water.

The beam attenuation coefficient is calculated by:

$$c = - 1/x * \ln (\mathbf{Tr})$$

$$= - 1/x * \ln [(CSC_{sig} - CSC_{dark}) / (CSC_{cal} - CSC_{dark})$$

For analog operation, replace CSC with voltage.

The corrected signal count value is derived from the signal raw count value after correction for instrument variance due to temperature. Most of this variance is due to inherent output changes in the LED. The signal is corrected by applying a linear ratio with slope and offset coefficients based on an optical reference measurement. This is accomplished in the instrument firmware as follows:

$C_{sig} = M_{sig} * (C_{slope} * (M_{ref} / S_{ref}) + C_{offset})$

C_{sig} is defined as the Corrected Signal

M_{sig} is defined as the Measured Signal

C_{slope} is defined as the Correction fit Slope

C_{offset} is defined as the Correction fit Offset

S_{ref} is defined as the Set baseline Reference value

M_{ref} is defined as the Measured Reference

The correction slope and offset come from the equation of a best linear fit of relative signal to relative reference from a test temperature run. The temperature run is repeated with these coefficients loaded into the instrument to verify its internal correction performs to within the 0.02 percent full scale per deg C specification.

3. Device File

```
CSTAR 001
Created on 2010-Mar-25

COLUMNS=6
DKDC=1
CSTAR=5 4 2
DKDC=6
```

4. Calibration and Testing

Each C-Star is subjected to several tests including a clean water reading and blocked path to provide the calibration values required to obtain good data in the field. The calibration documentation provided with each instrument lists these values.

The clean water calibration is done using water from WET Labs calibration facility. It goes through several stages of de-ionization, UV screening and ultra filtering to remove particles, bacteria and ions. This water is used to obtain the reference value of the instrument provided on the calibration sheet.

The offset value is obtained by blocking the beam with the instrument clean and dry. This value is recorded and provided on the calibration sheet.

An air reading is also obtained with the instrument clean and dry. This value is used as a reference when cleaning the optics and as an aid in tracking instrument drift. C-Star comes with both digital and analog output. Full scale analog output is 5 V whereas full scale digital is 16380 counts.

There are two main steps in the tuning and testing of the C-Star. Calibration is performed before the unit is put in its enclosure. Final testing is done with the unit completely assembled.

Pure Water Reference

Clean, de-ionized water is used to set the reference signal. It is obtained by immersing the C-Star in clean water and measuring the average output signal over 30–45 seconds. This signal is provided as the CSC_{ref} parameter on the calibration sheet.

Response Time (Time Constant)

The response time for the C-Star is limited by the internal averaging for each measurement. This is the `ave` setting displayed in the Host software. In general, the response will be 2 samples or 2*x* the sample rate: one sample where the signal is transitioning and 1 sample at the new value. For example, an instrument set to output at 1 sample/second will respond full scale in 2 seconds. An instrument set to 16 samples/second will respond to a full scale change in signal in 1/8 of a second. The analog will respond at the same rate, provided that there is a high impedance load at the output.

Pressure

To ensure the integrity of the housing and seals, each C-Star is subjected to a wet hyperbaric test. The testing chamber applies a water pressure of at least 50 psi. C-Stars are spot checked to the full rated depth.

Mechanical Stability

The C-Star is subjected to a mechanical stability test. This involves subjecting the unit to mild vibration and shock. The air, water, and dark voltages must remain the same before and after the mechanical stability test.

Temperature Stability
To verify temperature stability, the instrument is run through a temperature profile. The instrument is brought from room temperature up to approximately 38 deg C then down to < 3 deg C and back to room temperature. This test is preformed twice, once to obtain temperature correction coefficients and again to verify that the instrument performs as expected.

Electronic Stability
This value is computed by collecting a sample once every second for twelve hours or more. After the data is collected, the standard deviation of this set is calculated and divided by the number of hours the test ran. The stability value must be less than 2.0 counts/hour.

Noise
Noise is computed from a standard deviation over 60 samples. These samples are collected at one-second intervals for one minute. A standard deviation is then performed on the 60 samples, and the result is the published noise on the calibration form. The calculated noise must be below 2 counts.

Final Water Blank Test
Clean, de-ionized, pure water is introduced into the sample volume. The output signal is recorded through a terminal program for 30-45 seconds. This test is repeated 3 times, cleaning between each sample.

Voltage and Current Range Verification
To verify that the C-Star operates over the entire specified voltage range (7–15 V), a voltage-sweep test is performed. The C-Star is operated over the entire voltage range, and the current and operation is observed. The current must remain constant at both voltages.

Linearity
A full scale linearity test is randomly performed on C-Stars to confirm linearity. This consists of using a multiple point suspended particle dilution series to characterize the response of the instrument to varying levels of turbidity. The linear regression value must be better than 0.9900.

5. Reference: Theory of Operation

In general, losses of light propagating through water can be attributed to two primary causes: scattering and absorption. By projecting a collimated beam of light through the water and placing a focused receiver at a known distance away, one can quantify these losses. The ratio of light gathered by the C-Star's receiver to the amount originating at the source is known as the beam transmittance (Tr). This is the fundamental measurement performed by the C-Star. Suspended particles, phytoplankton, bacteria and dissolved organic matter all contribute to the losses sensed by the C-Star. They, combined with the intrinsic optical properties of the water itself, govern the radiative transfer properties within the earth's natural waters. Thus, the information provided by the C-Star provides both an indication of the total concentrations of matter in the water as well as a value of the water clarity.

The appropriate LED light source (depending on the wavelength) provides light that is focused and collimated by an aperture and lens that transmits the light within a given narrow bandwidth. The light passes through a beam splitter so that a portion of the transmitted light can be monitored by the reference detector and used as feedback to account for variations in the LED source over time as well as changes in the instrument's internal temperature. The light enters the sample volume after passing through the first pressure window, transits the sample volume and enters the receiver optics after passing through the other pressure window. The light passes through additional focusing optics and finally strikes a silicon photodiode detector that converts the amount of received light to a corresponding voltage signal, which represents the amount of light received.

Appendix A: Terminal Communications

As an alternative to the ECOView host software, C-Star can be controlled from a terminal emulator or customer-supplied interface software. This section outlines low-level interface commands for this type of operation.

- baud rate: 19200
- data bits: 8
- parity: none
- stop bits: 1
- flow control: none

Command List

Command	Parameters passed	Description
!!!!!	none	Stops data collection; allows user to input setup parameters. Note that if the meter is in a sleep state, the power must be turned off for a minute, then powered on while the "!" key is held down for several seconds. If this does not "wake" the meter, refer to the ECOView user's guide Operation Tip to "wake" a meter in a low power sleep state to enable inputting setup parameters.
$ave	single number, 1 to 65535	Number of measurements for each reported value
$mnu	none	Prints the menu
$pkt	single number, 0 to 65535	Number of individual measurements in each packet
$rls	none	Reloads settings from flash
$run	none	Executes the current settings
$sto	none	Stores current settings to internal flash

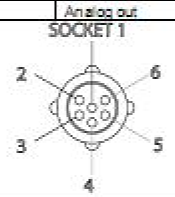
Appendix B: Adapter Cable

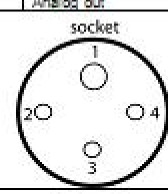
An adapter cable can be purchased to connect a 6-pin C-Star to any existing cabling. Note that if your application requires this adapter, it should be used as a cable extension. Disconnect ONLY at the 6-socket end, as it is a more robust connector.

C-Star MCIL-6–VMG-4 Adapter   # 210317

Verified: Impulse Technical Bulletin, D. Stahlke   Type: SOOW
Length: 10 in.

Conn 1: MCIL-6-FS		Conn 2: VMG-4MP	
Lock collar: MCDLS-F		Lock collar: G-MLS-P	
Contact	Function	Contact	Function
Socket 1	GND	Socket 1, socket 4	GND
-	N/C	--	--
-	N/C	--	--
Socket 4	V+	Socket 3	V+
-	N/C	--	--
Socket 6	Analog out	Socket 2	Analog out





Notes:

Cable to connect new 6-pin C-Star to old style C-Star cable.

Revision History

Revision	Date	Revision Description	Originator
A	10/07/99	Begin revision tracking	H. Van Zee
B	01/03/00	Update Theory of Operation, Instrument Operation, Data Analysis, and Specifications (DCR 5)	C. Moore
C	08/10/00	Correct beam divergence specification (DCR 9)	H. Van Zee
D	10/24/00	Misc. non-content-related corrections (DCR 67)	H. Van Zee
E	02/26/01	Update graphics, delete references to interference filter (DCR 79)	D. Hankins
F	5/30/01	Add leak-resistant flow sleeves to optional equipment; revise specifications to include 10 cm details (DCR 91)	H. Van Zee
G	11/15/01	Remove reference to 6061 aluminum (DCR 160)	A. Derr
H	12/10/01	Add specifications for digital C-Star (DCR 171)	W. Strubhar
I	01/09/02	Add test cable for digital output option (DCR 175)	D. Stahlke
J	05/29/03	Add digital specifications to section 4; delete digital test cable section (DCR 304)	H. Van Zee
K	06/23/03	Add 370 nm meter, correct green wavelength (DCR 310)	H. Van Zee
L	08/06/03	Add optional 6-pin digital connector pinouts (DCR 329)	D. Stahlke
M	1/13/06	Clarify warranty statement (DCR 481)	A. Gellatly, S. Proctor
N	1/19/06	Delete temperature correction Appendix (DCR 482)	H. Van Zee
O	4/24/06	Delete linearity error spec (DCR 496)	H. Van Zee
P	3/31/08	Replace 4-contact VMG with 6-pin MCBH connector as new standard (ECN 286, DCR 566)	M. Johnson, H. Van Zee
Q	12/16/08	Correct typo on p. 8 (DCR 642)	H. Van Zee
R	12/16/09	Revise warranty statement (DCR 687)	J. Rodriguez
S	6/16/10	Update C-Star to ECO electronics (DCR 703)	H. Van Zee, C. Wetzel
T	9/20/10	Add UV LED Safety Note (DCR 713)	H. Van Zee
U	10/6/10	Change warranty to one year (DCR 718)	M. Harwood
V	12/12/11	Add notes in case of lock up, outlying data (DCN 785)	J. Pearson, H. Van Zee