OWL Data Loggers

Reference Guide

OWL Data Loggers

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WELCOME

Congratulations on your purchase of a JR-1000 data logger. We are confident that you will find it to be a most valuable and useful tool for your data collection applications.

This Reference Guide is designed to be used hand-in-hand with TrendReader Standard software and frequently refers to TrendReader Standard conventions and procedures. To get the most from your logger, please take time to familiarize yourself with TrendReader Standard and its Reference Guide.

For important information on how JR-1000 data loggers work and how to use them, read the Introduction to JR-1000 chapter. It will give you an overview of how the loggers work and how to configure them for your application. Next, read the chapter that deals with JR-1000 logger you have.

SECTION 1   OWL Data Logger

1.1   Introduction to OWL Data Loggers

OWLs are easy-to-use, battery-powered data loggers. Pocket-sized and rugged, they can be used in a wide range of environmental and industrial applications. There are a number of models available to directly measure and record variables such as temperature, electric current, analog voltage, and current loop. Each model can reliably record up to 10 years of time-based data for later analysis using TrendReader software on your computer.

1.1.1   Features

The OWL logger features:

- optical data transfer
- optical flashing alarm
- selective measurement ranges
- holds over 32,000 readings
- Polyurethane water-tight case
- Noryl Plastic water-tight snap case
- water-tight connector for external inputs
- typical 10 year battery life
- on-board serial identification
- mounting magnet and locking hole

1.1.2   Description

OWL Data Loggers record readings continuously at a fixed sample interval. Using an optical data link, it transfers these readings to your computer for analysis with TrendReader software.

Self-contained operation and its small size permit easy installation. The internal lithium battery typically lasts up to 10 years or at least 1,000 backups. Unique identification names stored in each logger allow for convenient tracking.

A 32,768 byte unlimited-write-cycle memory is used to store the measurements from an 8-bit (equivalent to 10-bit resolution on narrow ranges) analog-to-digital converter while a quartz crystal oscillator keeps track of time.

1.1.3   How OWL Data Loggers Take Readings

OWL Data Loggers can store 32,767 readings. Once the memory is full, the OWL can be setup to either bump the oldest reading to make room for the newest (sliding window of 32,767 readings) or stop recording.

You can set the frequency at which your logger takes readings through the software. At a sample rate of eight seconds, one reading is taken every eight seconds and saved to memory. As you slow the sample rate the logger begins to average readings before saving them to memory. To do this the logger takes a reading every eight seconds, but instead of transferring this directly to the logger's memory, it stores the reading in a buffer (a temporary memory) where it is retained until the sampling interval is over.

When you backup a logger's data onto your computer, the correct time and date are referenced to each reading. All readings are then individually time and date stamped and processed by an equation associated with the data logger channel. The result is a collection of accurate time-based data ready for detailed graphing and analysis.

1.1.4   How to use OWL Data Loggers

Using your OWL Data Logger for most applications is a simple process. With proper planning, setup, installation and retrieval of your data logger, you can be assured that the information you collect will be both correct and useful. This section provides general procedures for using OWL Data Loggers. For additional and specific information on these steps, refer to the chapter in this manual that deals with the particular OWL model you have.

How to Communicate
In order to setup or get your logged data, you must interface the OWL with your computer using the LIC-101 Interface Cable. The LIC-101 can be either plugged into or pointed at the logger's optical port in order to send a setup or retrieve logged data.

Planning
Proper planning is the key to successful data logging. Time spent in this stage will help you save time and frustration later. To help you plan, answer these questions:

- *What exactly do I want to measure?*
- *Where is the best place to measure?*
- *How long do I want to monitor for?*
- *Should other variables be monitored simultaneously?*

Setup
To setup your OWL data logger you must first have TrendReader Software installed and running on your computer. You can then configure your logger with various software setup options.

Set Sample Rate
Always confirm the sample rate (how often the logger takes readings) to make sure it will be acceptable for your application. You can alter the frequency at which your OWL Data Logger records readings by changing the sample rate. You can choose rates from between 8 seconds and 12 hours in 4 second increments. In Fast Read mode, you can select intervals between 0.2 and 10 seconds.

To help determine which sample rate you should choose, answer these questions:

- *How long do I need to record data?*
- *How much time will elapse between when I retrieve the logger and download the data to my computer (for example, the trip back to the office)?*
- *How often do readings need to be taken?*

Making External Connections
If you are using your OWL Data Logger to monitor external modules, sensors, or circuitry, make sure the connections are secure.

Clear Memory
Before sending your logger out into the field to collect data, clear the logger's memory. This will help keep the collected files smaller as well as decrease the time needed to backup the logger later. Note that clearing your OWL's memory is automatic if you make setup changes (for example, assign different equations, change sample rates, etc.)

Test
You can directly read the values that your OWL data logger is sensing using the Realtime capability of TrendReader software. This test gives you the opportunity to check your logger setup and make any necessary changes before starting the logging session.

Label
OWLs can be setup with a description that can be put into the logger's memory. It is recommended that you use this feature in order to know what each graph refers to.

1.1.5   Installation

Mounting
Use the magnetic backing to conveniently mount your logger on metal surfaces like ductwork or electrical control cabinets. If you're concerned about theft, lock your logger to a permanent fixture using the locking tab or take advantage of its small size and hide it completely out of view. Because OWL loggers are so light, you can use special mounting methods like Velcro® fasteners to secure them to almost any surface. Make sure your logger's mounting method will last the full length of your data logging session.

Do not rely on the logger's magnetic strip for adhesion if the mounting surface is uneven, unstable or above 65° C (150°F).

Keep Track

Make sure to keep a record of where you have placed each logger in a building or system plan. You will save time looking for them when your data gathering session is over. Also, keep track of when you placed the loggers in the area you are monitoring. This will help when producing graphs on your computer. It may be helpful to label (shipping tag) each logger so you can properly identify and differentiate it from other loggers.

Analysis

After sufficient time has passed for the logger to obtain a representative profile of data, it is time to analyze the information. If you are retrieving the logger from the field, bring it back immediately to your computer for analysis.

In order to analyze your OWL logger's data, you must first transfer a backup copy of its data to your computer. To do this, see Backup in the TrendReader guide. After transferring your information to the computer, the data is automatically copied to disk and time and date stamped.

You can find a detailed description of all software functions in the TrendReader guide.

1.1.6   General Specifications

General

Size:	60 x 48 x 19mm (2.4" x 1.9" x 0.75")
Case Material:	Polyurethane
Case Weight:	80g (2.8 oz.)
Snapcase Material:	Noryl® Plastic
Snapcase Weight:	54g (1.9 oz.)
Operating Limits:	-40 to 70°C. (-40 to 158°F.) and 0 to 95% RH (non-condensing)
Clock Accuracy:	+/-2 seconds/day
Battery:	3.6 Volt Lithium, 1 Amp-hour
Power Draw:	5 to 10 microamps (continuous)
Battery Life:	Ten years projected
Alarm Type:	Optical red LED

Memory and Data Inputs

Memory Size:	32,767 readings

Readings:	Continuous (first in, first out) or stop when full at user-programmable intervals between 0.2 seconds and 12 hours.
Resistance to X-rays:	Tested for protection against a 160 kV 150 mA-sec. dose @ 38 in. F.F.D. (about 100 times that of an airport X-ray machine). Tested for protection against Gamma Ray (equivalent to 0.1337 - 1.38 mega volts) IR 192 - 28 curies @ 30 second exposure source to object distance 5".

1.1.7   Approvals

For our U.S. Customers:

ACR's circuitry design has been tested and found to comply with the limits for Class A digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his/her expense.

For our Canadian Customers:

ACR's circuitry design does not exceed Class A limits for radio noise emissions as set out in Schedule V to VIII of the Radio Interference Regulations of Communications Canada.

Specifications are subject to change without notice.

1.2   OWL Software Driver

TrendReader software uses a software driver to communicate with OWL data loggers. The software driver takes the form of two windows. The Status window, shown when you contact the logger, is used to display the settings currently stored in the data logger. The Setup window, shown when you select Edit Setup, is used to alter the current settings and apply the changes to the data logger. The settings are divided into two main sections: Status and Channel. Status contains information about sampling, memory and triggering. The channel of the logger contains information about the description, equation and Realtime value, and range. You can control the level of detail that you see for the settings by clicking on the "+" and "-" buttons at the left side to expand and collapse the nodes.

Owl 22544 - OWL-100-Int. Temp.						
Status	Actively Logging					4 / 32767 Readings
Sampling Interval	Mode	Hours		Minutes	Seconds	
	Normal	0		2	32	
Memory	Usage	Size		Start Time		End Time
	Stop When Full	32767		1/9/2007 3:35:35 PM		3/8/2007 7:05:19 AM
Channel	Description			Reading Stored	Reading Now	Next Reading At
	Storage Room B			4	24.52 °C	1/9/2007 3:45:50 PM
Calibration	Low	Mid				
	0.0000	0.9766				

When you want to clear the logger's memory and start a new logging session with new parameters, select **Edit Setup** from TrendReader. In the Edit Logger Setup window, make any necessary changes. To implement your changes, you can either click on **Apply** or **OK**. OK will implement the changes and close the window whereas Apply will leave the window open, thereby allowing you to make changes in other features.

Edit Logger Setup					
Owl 22544 - OWL-100-Int. Temp.					
Sampling Interval	Mode	Hours	Minutes	Seconds	
	Normal	0	2	32	
Memory	Usage	Size	Start Time	End Time	
	Stop When Full	32767	15/01/2007 10:20:14 AM	14/03/2007 1:49:58 AM	
Flash	Type	High Trigger	Low Trigger		
	Until Full	24.22 °C	15.12 °C		
Channel	Description	Equation		MidPoint	+/- Range
	Storage Room B	OWL ET-016 Thermistor [200]		11.49 °C	13.52 °C
Calibration	Low	Mid			
	0.0000	0.9766			

Help   OK   Apply   Cancel

When you backup a logger, a window pops up with a progress bar showing the time remaining. However, OWL loggers store data in a compressed format and the application does not know ahead of time how much data is stored. Therefore, the progress bar and time remaining displayed may not be accurate.

1.2.1   Logger Channel

When you contact the logger, the logger status is displayed. The Channel line gives the description, the number of readings stored, the Realtime value, and the time of the next reading. The Realtime value is based on the equation that you select for the channel. The equation is selected in the Setup window but is not shown in the Status window.

⊟ Owl 28745 - OWL-100-Int. Temp.				
⊞ **Status**	Actively Logging			32767 / 32767 Readings
⊟ **Channel**	**Description**	**Reading Stored**	**Reading Now**	**Next Reading At**
	ACR OWL Info Logger, Int. Temp	32767	19.87 °C	11/12/2009 1:48:14 PM
⊟ **Calibration**	**Low**	**Mid**		
	0.0000	0.0000		

To set the description, click on the Description field and enter the name.

🔲 Edit Logger Setup				_ □ ✕
⊟ Owl 28745 - OWL-100-Int. Temp.				
⊞ **Sampling Interval**				
⊞ **Memory**				
⊞ **Flash**				
⊟ **Channel**	**Description**	**Equation**	**MidPoint**	**+/- Range**
	Storage Room B	OWL ET-016 Thermistor [200]	11.38 °C	13.39 °C
⊟ **Calibration**	**Low**	**Mid**		
	0.0000	0.0000		
Help		OK	Apply	Cancel
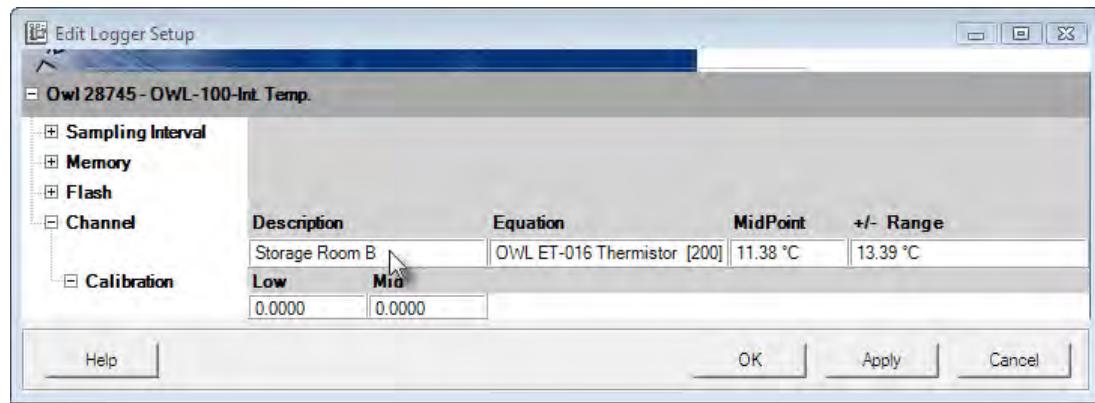
The logger collects and stores raw data readings. An equation is used to transform the raw data into measurement units, such as °C, with the current reading shown as a Realtime value. You can use built-in equations or you can create your own custom equations. See Equations in the TrendReader guide for further information. To set the equation, click on the Equation

field and select the equation from the drop-down list. *
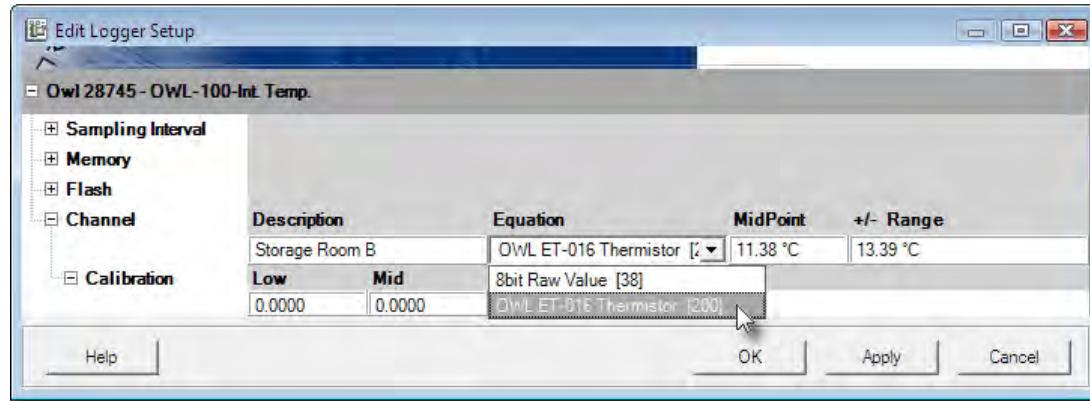
* Note that if a custom equation is not available when Edit Setup... is selected (e.g.: deleted) then the equation will be shown as unknown. If a new equation is not selected the Realtime value will not display correctly. If the logger is backed up the channel will be disabled then changes to the equation can be made in the graph using the Lines Tab in Graph Settings.

For OWL 100 and 200 loggers you can set a range for the readings, thereby allowing you to increase the resolution of the readings. To set the range click on either the MidPoint or Range field. Next, click on the small button that appears at the right. This will pop up a form allowing you to select the midpoint and range by simply dragging the bar.
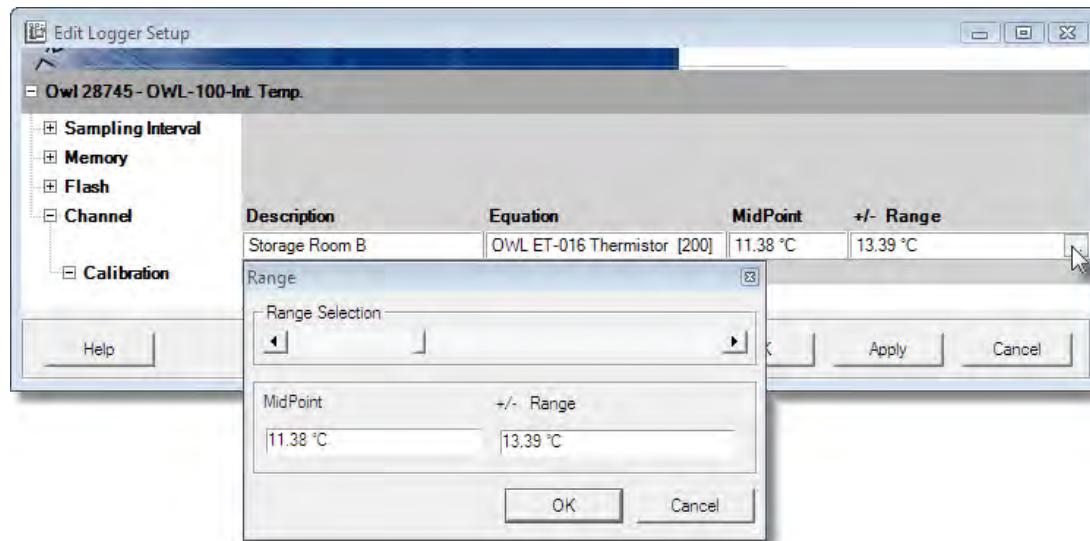
For OWL 300 and 400 loggers you can set the minimum and maximum values for the range for the readings. To set the range click on either the Range Min or Range Max fields. Next, click on the small button that appears at the right. This will pop up a form allowing you to

select the maximum and minimum range values by simply dragging the bar.
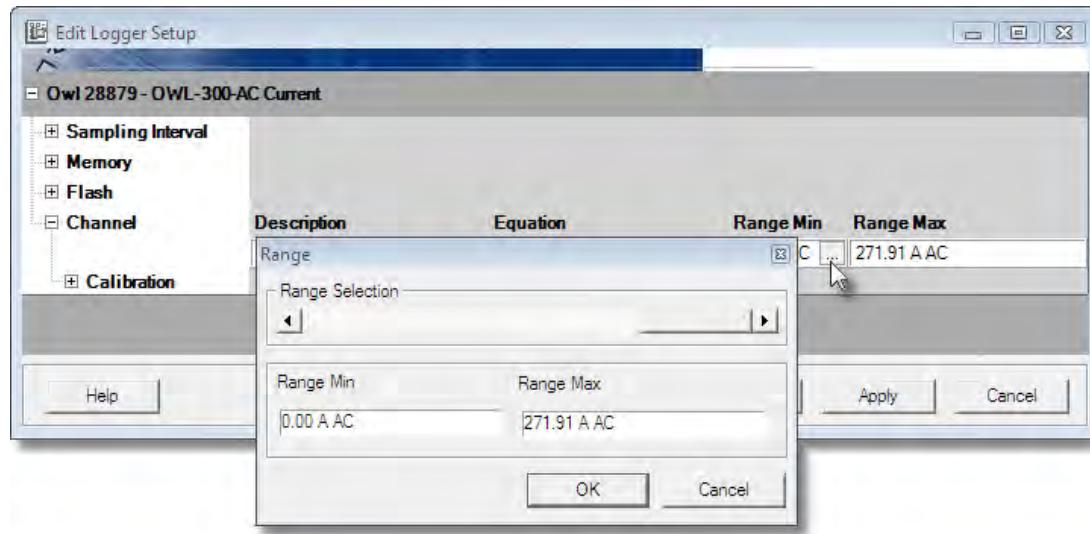
The OWL 500 does not have an adjustable range but does display the default range settings for information.
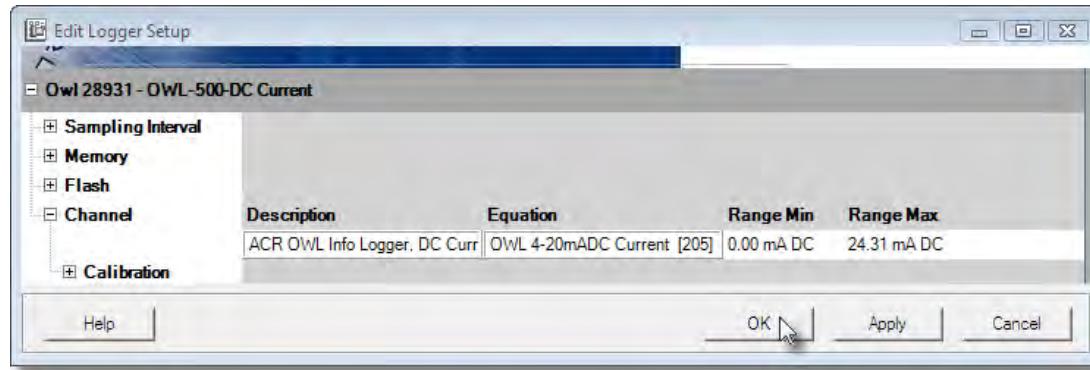
For any of the loggers, if the input value exceeds the range, the maximum range value will be recorded. To find out more about ranges available for temperature loggers, see Appendix A Temperature Ranges.

1.2.1.1   Channel Calibration

The Calibration subsection shows the Low and Mid calibration values. These values are used to adjust the readings of the logger in order to make the output more accurate. To set each calibration value, click on the appropriate calibration field and enter the value.
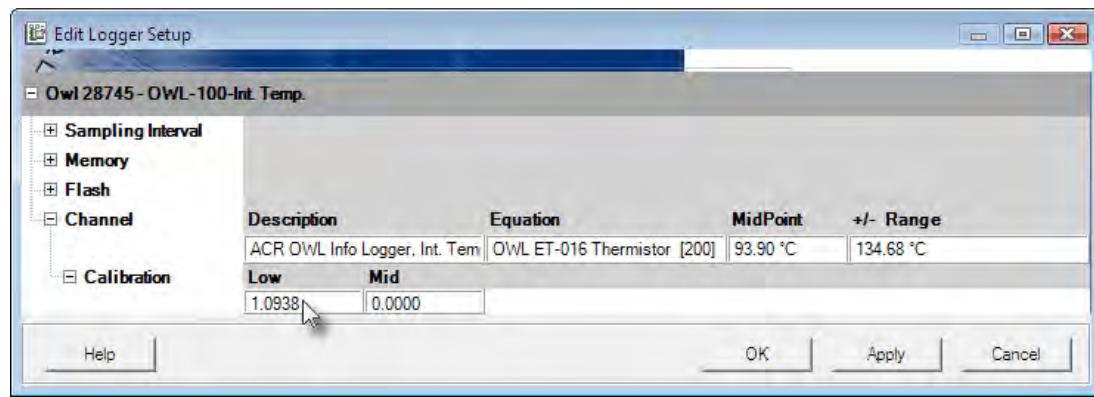
1.2.2 Logger Status

When you contact the logger, the logger status is displayed. The Status line indicates whether the data logger is actively logging, waiting to start or dormant. If you set up the logger with no delay, it will immediately start logging and the status will show the number of readings, or samples, that have been taken. If you want to have the logger wait before it starts logging, set the start time accordingly. The Status subsections are Sampling, Memory, and Triggering.
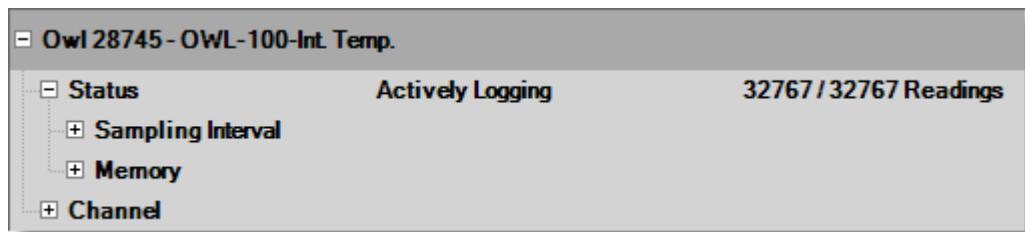
1.2.2.1 Logger Sampling

The sample rate is the frequency with which a logger takes readings. The Sampling subsection indicates if the data logger is performing in a regular or fast sampling mode and what the sample rate is. In normal sampling, the rates available are from once every 8 seconds to once every 12 hours, while in fast sampling, the rates can be as quick as 5 times per second.

To set the logger for regular sampling, click on the Mode field and select Normal. To set the sample rate, click on the desired time unit and select the value from the drop-down list as

shown.
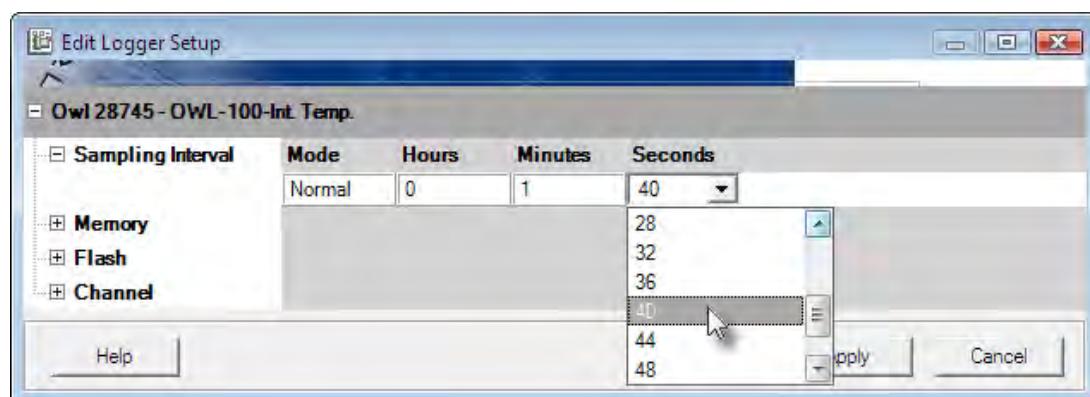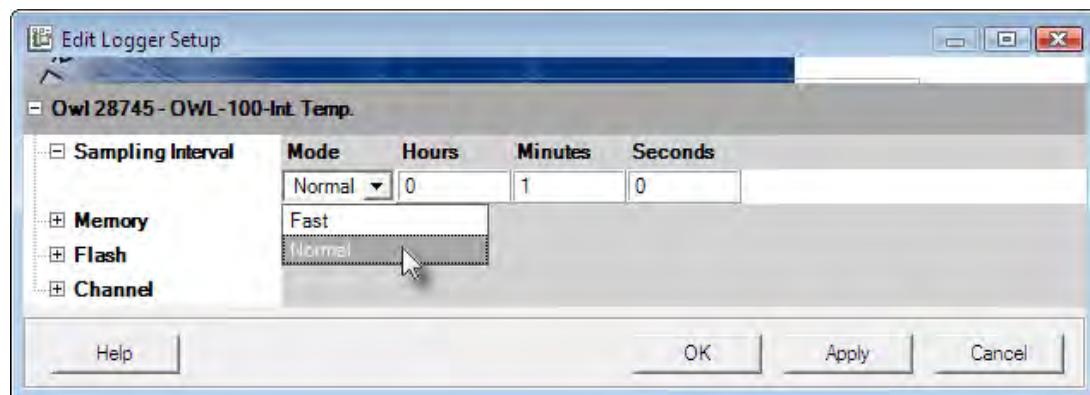
To find out more about sample rates and to view a set of sample rate tables, see Appendix B Sample Rates.

1.2.2.1.1 Fast Sampling

With the fast sampling mode, you can select sample rates from 0.2 seconds (5 readings per second) to 10 seconds. The only memory mode available is "Stop When Full".

To set the logger for fast sampling, click on the Mode field and select Fast. Next, click on the desired time unit and select the value from the drop down list.

*Note that in fast sampling mode the logger will stop recording when you communicate with it.
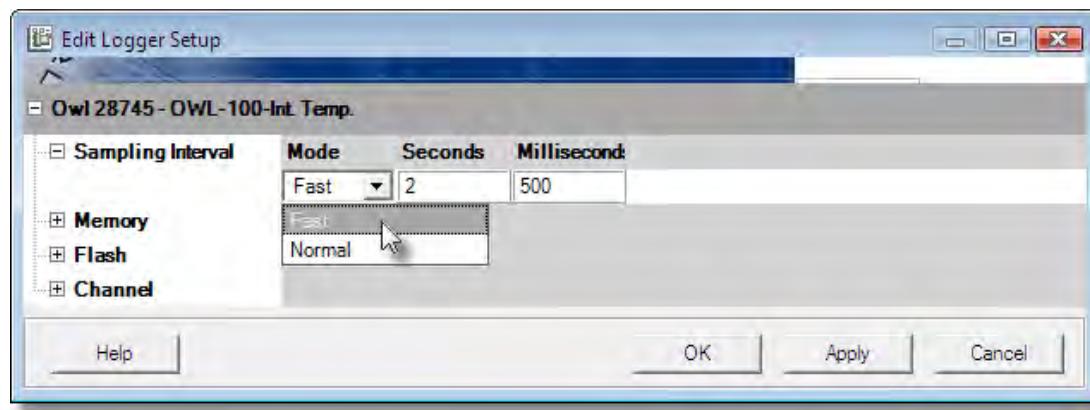
1.2.2.2   Logger Memory

The Memory subsection indicates how the data is stored in memory and what the start and end times (or capacity) are for the data logging. In the FIFO (First In, First Out) mode, the logger continually stores data and when the memory limit is reached, the new readings start to overwrite the oldest readings. Using this method, the logger is always collecting data, but only saves the most recent data in its memory. In the Stop When Full mode, when the memory limit is reached, the logger stops recording.

The length of time for data capture of the logger is determined by the sampling rate. To find out more about how the capacity is affected by the sample rate, see Appendix B Sample Rates.

Usage
To set how the logger stores its data, click on the Usage field and select FIFO or Stop When Full.
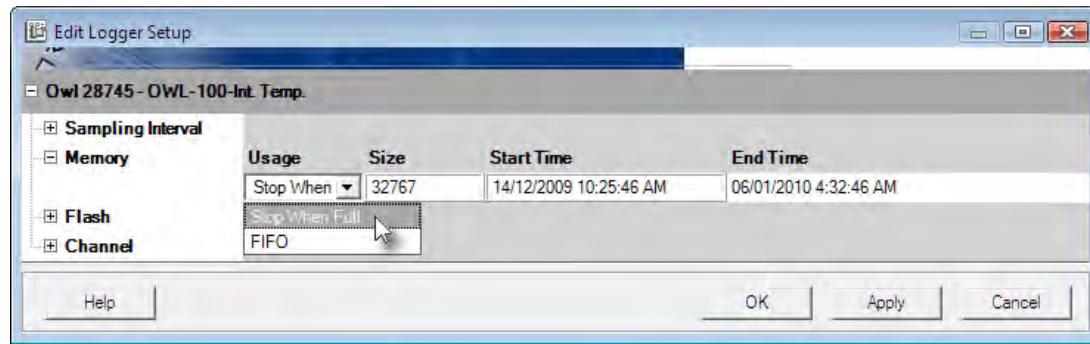
Start Time
To set when the logger will start recording click on the Start Time field. Next, click on the small button that appears at the right. This will pop up a form allowing you to set the date and time. Highlight the date or time and enter the appropriate value. You can also click on the drop-down list arrow to bring up a calendar. You can set the logger's starting time for up to 6

days, 1 hour, and 38 minutes ahead.
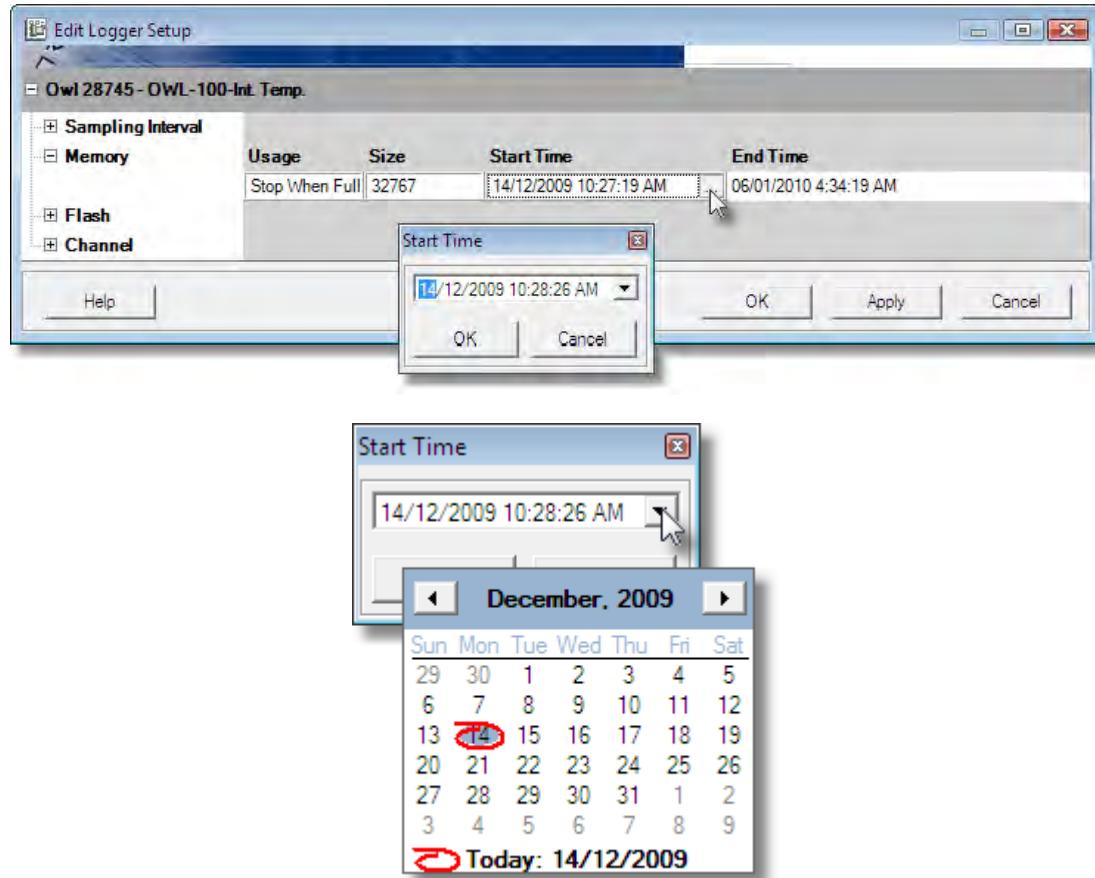
Note that the logger will begin to record based on the Trigger and Flash settings once the Start Time has been reached.

Size
If you do not want to use the entire memory to store readings, click on the Size field and enter the new size. The End Time will adjust automatically.
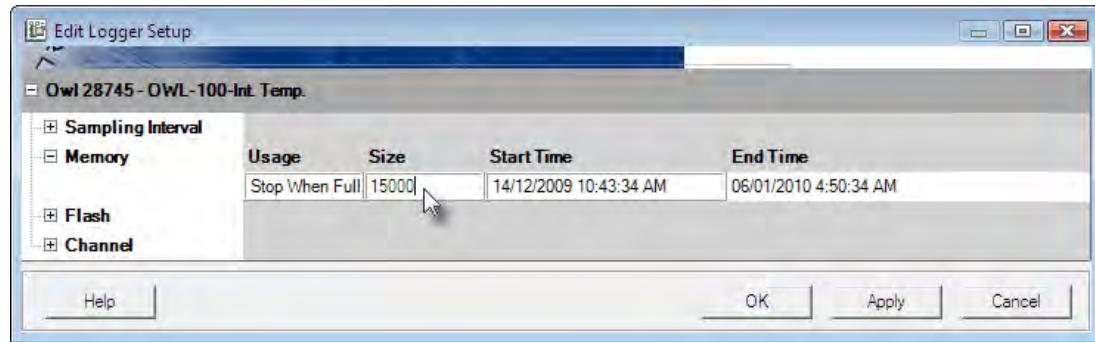
1.2.2.3   Logger Triggering

High & Low Triggers

Triggers are used to indicate when any reading has exceeded preset thresholds and begin logging once the limit has been crossed.

The Trigger Threshold values for the OWL Logger are based upon the Equation and limited by the Midpoint/Range selected. If you change the Range values the High and Low Trigger values will also change. The maximum High Trigger will not exceed the maximum Range value and the minimum Low Trigger will not be less than the minimum Range value.

 * For the OWL, the High and Low Triggers enable you to set upper and lower limits inside which the OWL will not log depending on the Flash mode you select. The Alarm and Failsafe Alarm Flash modes will allow the logger to record within the trigger limits.

To set the High or Low Trigger, click on the trigger's field. Next, click on the small button that appears at the right. This will pop up a form where you can drag the slider bars to set the appropriate trigger level.
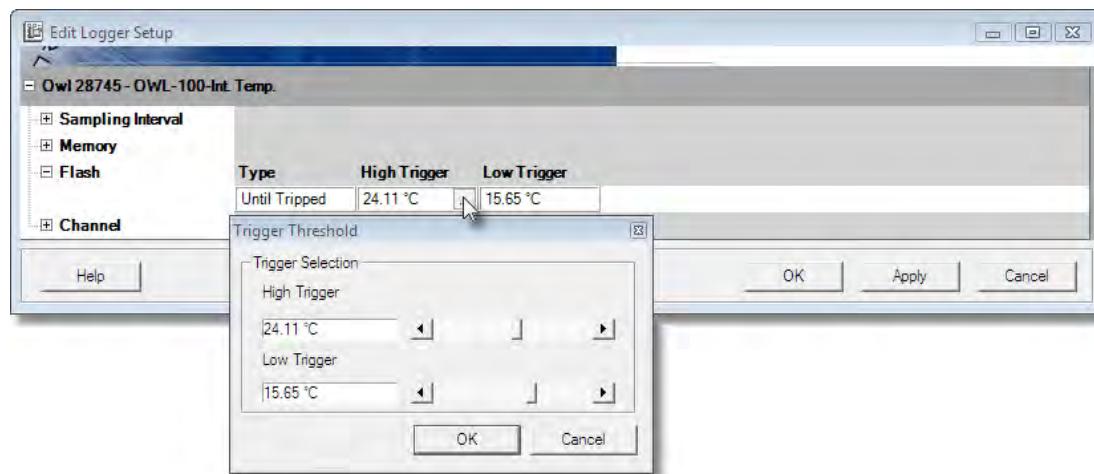
Flash Type

The Flash selection, shown only in the Edit Setup window, indicates under which conditions the logger's light will flash and when logging will start. The light flashes every 8 seconds and the Flash function is not available in fast sample mode. The Flash modes available are:

- **Off**: the light will never flash.
- **Until Tripped:** the light will flash until the OWL starts logging.
- **Until Full:** the light will flash until the logger is full.
- **While Logging:** the light will flash while the logger is taking readings.
- **Always:** the light will always flash.
- **Alarm:** the light will blink after an event (note that the logger will log within the trigger limits, but will only flash after exceeding the trigger).
- **Failsafe Alarm:** the light will flash before the event (note that the logger will log within the trigger limits, but will flash when exceeding the trigger).

To set the Flash mode, click on the Type field and select the mode from the drop-down list.
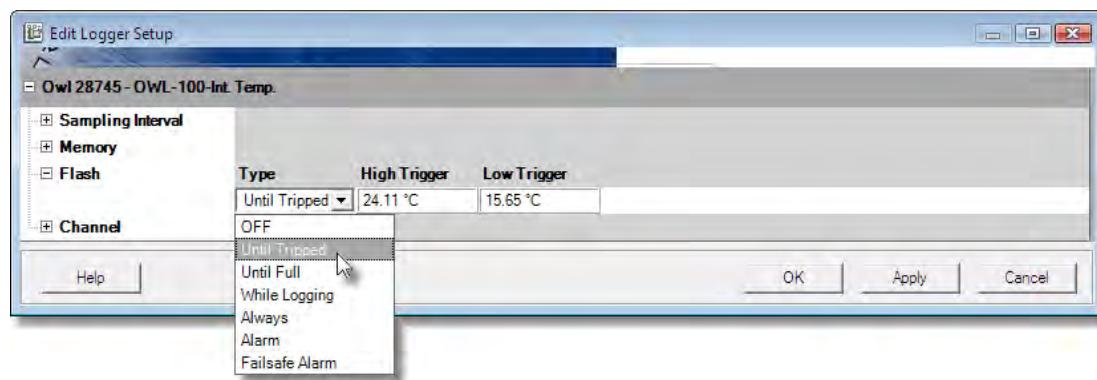
* Note that if the Start Time has been set to a delay that starts after the trigger limit has been crossed the logger will not start to log until the Start Time is reached. Once the Start Time has been reached the logger will record based upon the Trigger and Flash settings as noted above.

1.3   OWL Temperature Data Logger (Internal Sensor)

Features

The OWL Temperature Data Logger with the Internal Sensor offers temperature recording in a small, water-resistant enclosure. In addition to its rugged construction, the logger can be setup to record a wide range of temperatures, all configurable by a few, easy keystrokes.

1.3.1   Description

The Internal Sensor Temperature Logger uses an on-board thermistor to record changes in temperature. The model available is the OWL-100 which operates from -40 to 70°C (-40 to 158°F).

1.3.2   Setup and Use

TrendReader allows you to select the size of a range and a midpoint for the range. Choosing the size of range allows you to control the resolution: a smaller range results in a higher resolution for the readings. Choosing the midpoint allows you to control where the highest resolution will occur: readings closest to the midpoint of a temperature range are higher in resolution than those at each end of the range. See Appendix A Temperature Ranges for a list of the available ranges.

The steps required to configure the OWL Temperature Logger are as follows:

1.   Run TrendReader Software and choose the Internal Sensor equation.
2.   Select a range that best fits the expected data.
3.   Refer to the OWL Software driver for other options.

1.3.3   Specifications

Internal Temp. Logger

Sensor type:	NTC thermistor 10kΩ @ 25ºC (77ºF)
Range:	-40 to 70ºC (-40 to 158ºF)
Accuracy:	±0.5ºC @ 25ºC (±0.9ºF @ 77ºF)
Resolution:	0.5ºC @ 25ºC (0.9ºF @ 77ºF) Better than 1.0ºC (1.8ºF) between -25 and 70ºC (-13 and 158ºF) Better than 2.0ºC (3.6ºF) between -40 and -25ºC (-40 and -13ºF)

Specifications are subject to change without notice.

The accuracy and resolution can be increased by using the narrow range feature.

1.3.4   Applications

- testing and balancing HVAC systems

- monitoring temperature of perishable goods

- checking and settling tenant complaints

- providing environmental data

- verifying food processes

1.4　OWL Temperature Data Logger (External Sensor)

Features

The OWL Temperature Data Logger with the External Sensor offers temperature recording in a small, water-resistant enclosure. The connection between the temperature probe and the logger is water-resistant. There are four temperature probes available that can monitor a wide range of temperatures, and custom equations can be written to use other probes.

1.4.1　Description

The External Sensor Temperature Logger uses a thermistor type probe to record changes in temperature. The models available are:

Table 2-1: External Temperature Models

Model	Probe	Range
OWL-200	Supplied with 2m (6ft.) PVC cable	
OWL-200	ET-004 Low Temperature	-60 to 55ºC (-75 to 130ºF)
OWL-200	ET-016 General Temperature	-35 to 95ºC (-30 to 200ºF)
OWL-200	ET-081 High Temperature	10 to 170ºC (50 to 335ºF)
OWL-200	ET-086 Oven Temperature	70 to 255ºC (155 to 490ºF)

1.4.2　Setup and Use

TrendReader allows you to select the size of a range and a midpoint for the range. Choosing the size of range allows you to control the resolution: a smaller range results in a higher

resolution for the readings. Choosing the midpoint allows you to control where the highest resolution will occur: readings closest to the midpoint of a temperature range are higher in resolution than those at each end of the range. See Appendix A Temperature Ranges for a list of the available ranges.

The steps required to configure the OWL Temperature Logger are as follows:

1.   Run TrendReader Software and choose the External Sensor equation corresponding to the attached probe.
2.   Select a range that best fits the expected data.
3.   Refer to the OWL Software driver for other options.

1.4.3   Specifications

ET-016 General Purpose Probe

Description:	NTC thermistor and cable potted into the end of a 25mm (1") long by 5mm (3/16") diameter cylindrical stainless steel tip.
R25 Value:	10 k ohms
Range:	-35 to 95°C (-30 to 200°F)
Max Temp.:	150°C (300°F)
Accuracy:	±0.2°C (±0.36°F) between 0 to 70°C (32 to 158°F) ±1.0°C (±1.8°F) between -40 to 150°C (-40 to 302°F)
Resolution:	0.5ºC @ 25ºC (0.9ºF @ 77ºF) Better than 1.0ºC (1.8ºF) between -25 and 70ºC (-13 and 158ºF) Better than 2.0ºC (3.6ºF) between -40 and -25ºC (-40 and -13ºF)
Cable:	8m (26ft) standard length with Teflon® protective jacket, water-resistant / chemical-resistant splice, PVC jacket to IP67 connector.
Equation:	200

The resolution can be increased by using the narrow range feature.

ET-004 Low Temperature Probe

Description:	NTC thermistor and cable potted into the end of a 89mm (3½") long tapered stainless steel penetration tip with 89mm (3½") long by 19mm (¾") diameter tapered plastic handle.
R25 Value:	2,252 ohms
Range:	-60 to 55°C (-75 to 130°F)
Max Temp.:	150°C (300°F)

Accuracy:	±0.2°C (±0.36°F) between 0 to 70°C (32 to 158°F) ±1.0°C (±1.8°F) between -60 to 100°C (-76 to 212°F)
Resolution:	0.5ºC @ 0ºC (0.9ºF @ 32ºF) Better than 1.0ºC (1.8ºF) between -50 and 40ºC (-58 and 104ºF) Better than 2.0ºC (3.6ºF) between -65 and -50ºC (-85 and -58ºF)
Cable:	5m (16ft) standard length with Teflon® protective jacket, water-resistant / chemical-resistant splice, PVC jacket to IP67 connector.
Equation:	201

The resolution can be increased by using the narrow range feature.

ET-081 High Temperature Probe

Description:	NTC thermistor and cable potted into the end of a 25mm (1") long by 5mm (3/16") diameter cylindrical stainless steel tip.
R25 Value:	100k ohms
Range:	10 to 170°C (50 to 335°F)
Max Temp.:	190°C (375°F)
Accuracy:	±0.5°C (±0.9°F) between 75 to 175°C (135 to 347°F)
Resolution:	0.5ºC @ 85ºC (0.9ºF @ 185ºF) Better than 1.0ºC (1.8ºF) between 25 and 140ºC (77 and 284ºF) Better than 2.0ºC (3.6ºF) between 140 and 170ºC (284 and 338ºF)
Cable:	8m (26ft) standard length with twisted-pair Teflon® insulated wire, water-resistant / chemical-resistant splice, PVC jacket to IP67 connector.
Equation:	202

The resolution can be increased by using the narrow range feature.

ET-086 Oven Temperature Probe

Description:	NTC thermistor and cable potted into the end of a 25mm (1") long by 5mm (3/16") diameter cylindrical stainless steel tip.
R125 Value:	26,266 ohms
Range:	70 to 255°C (155 to 490°F)

Max Temp.:	275°C (525°F)
Accuracy:	±1°C (±1.8°F) between 120 to 260°C (248 to 500°F)
Resolution:	0.6ºC @ 150ºC (1.1ºF @ 302ºF) Better than 1.0ºC (1.8ºF) between 100 and 200ºC (212 and 392ºF) Better than 2.0ºC (3.6ºF) between 200 and 250ºC (392 and 482ºF)
Cable:	8m (26ft) standard length with twisted-pair moisture-proof Teflon® coated glass yarn, water-resistant / chemical-resistant splice, PVC jacket to IP67 connector.
Equation:	203

The resolution can be increased by using the narrow range feature.

1.4.4   Applications

- testing and balancing HVAC systems

- monitoring transportation and storage temperatures

- providing data for energy management studies

- optimizing hot water temperatures

- testing ovens and freezers

1.5   OWL Electric Current Data Logger

Features

The OWL Electric Current Data Logger is a versatile equipment performance logger. It is useful for recording a single phase of alternating current without having to interrupt circuitry under test. It offers added protection against high voltage spikes, such as lightning, with optical isolation between logger and computer.

1.5.1   Description

The Electric Current Logger uses an external clamp-on-current probe to measure and record alternating current. The following models are available:

Table 3-1 Electric Current Models

Model	Probe	Range	Eqn
OWL-300	none	must have modified probe	
OWL-300	A60FL	60 Hz - 5, 25, 100, 250 Amps	206
OWL-300	A65FL	50 Hz - 5, 25, 100, 250 Amps	206
OWL-300	A70FL	60 Hz - 10, 50, 250, 500 Amps	207
OWL-300	A75FL	50 Hz - 10, 50, 250, 500 Amps	207

How It Works

The OWL Data Logger measures electric current through an external current probe. The probe is a transformer with its internal coil serving as the secondary winding and the current-carrying conductor being measured serving as the primary winding. The output of the probe (which is the input to the logger) is conditioned through internal circuitry. The probe

produces an output of approximately 260 microamps full scale for each range available on the current probe. Readings from the current probe are scaled into amperage units through equations (in TrendReader software) that match the current probe and its range setting.

1.5.2   Setup and Use

The procedure for setting up the OWL Electric Current Data Logger is as follows:

1. Plug the current probe into the receptacle on the logger.

2. Adjust the range switch on the current probe to suit your application. A good way to verify a conductor's maximum range is to check the circuit breaker or fuse rating. Then set the range on your current probe to suit. Since the probes do not give predictable readings below 10% in any range, always choose the lowest range possible to encompass the full range of data you want to record.

3. Run TrendReader Software and choose the equation number that matches the probe being used - Refer to Table 3-2. Then select the range corresponding to the logger's switch setting. Note the software shows the highest possible reading which allows for a small amount of overshoot. Therefore, if the switch setting is 5 on an A60FL/A65FL then choose the 5.438 A range in software.

4. Refer to the OWL Software driver for other options.

WARNING: DO NOT CHANGE RANGE SWITCH WITHOUT ALSO SETTING LOGGER

Table 3-2 Current Probe Ranges

	A60FL / A65FL **Equation 206**		**A70FL / A75FL** **Equation 207**	
Range	**Switch**	**Full Scale**	**Switch**	**Full Scale**
0	5	5.438 A	10	10.88 A
1	25	27.19 A	50	54.38 A
2	100	108.8 A	250	271.9 A
3	250	271.9 A	500	543.8 A

Precautions
1. **DANGER: High voltage may be present!** Do not clamp a current probe around a conductor without the logger connected to it. This avoids sparking and prevents the connectors from prematurely deteriorating.

2. The OWL Electric Current logger can only be used with current probes from ACR Systems (altered Amprobe Instruments models A60FL, A70FL, A65FL and A75FL). These probes provide low voltage DC current in proportion to the signal being measured. They have a convenient snap connector added to protect against harsh environments. DO NOT use any other probe unless approved by ACR in writing.

3. The OWL Electric Current logger can record current in accordance with the ranges

available on the A60FL, A65FL, A70FL and A75FL probes. Always make sure the current you will be recording will fall into the appropriate range you set on the current probe.

1.5.3   Current Probes and Accessories

OWL Electric Current loggers come with a choice of current probes modified to plug into the logger with no tools. These clamps can be used with a number of accessories to fit most typical applications.

Low Currents
To log very low currents (such as monitoring the operation of electrical appliances), the probe can be used with a Line Splitter. The Amprobe A47L Energizer multiplies the signal to the logger by ten times over a range of 0.1 to 15A. It also allows effective splitting of a two-line conductor, allowing measurements without the need to enter electrical panels or junction boxes.

For European applications, Amprobe's model A47CL is available with screw-in European round prongs, two extra British-type prongs and British fuse plug adapter. Contact your local ACR representative for pricing and delivery of this product.

High Currents
You can monitor current ranges higher than those available on a standard probe by using it with an additional transformer. For this purpose Amprobe Instruments has available their Amptran® CT50-2 a 50 to 1 transformer (to monitor currents up to 3000 amps). Contact your ACR representative for availability on these probes.

1.5.4   Specifications

Current Probes

Output Current:	260 µA full scale into 400 ohms.
Cable:	2m (6ft.) length with PVC jacket to IP67 connector.
Accuracy:	±4.0% of full scale above 10% of range
Ranges:	The following table lists the usable range available for each setting.

Table 3-3. Current Probe Usable Ranges

A60FL / A65FL Equation 206		A70FL / A75FL Equation 207	
Switch	**Range**	**Switch**	**Range**
5	0.5 to 5 A	10	1 to 10 A
25	2.5 to 25 A	50	5 to 50 A

100	10 to 100 A	250	25 to 250 A
250	25 to 250 A	500	50 to 500 A

1.5.5   Troubleshooting

The OWL Electric Current logger seems to give wrong readings. What's wrong?

- If the graphs seem incorrect, check the equation number assigned to the graph file. This equation number **must** correspond to the model number of the current probe used. Refer to Setup in this chapter for a table of equations to use with the various current probes and settings.

- If your equation numbers are correctly assigned and you are still getting incorrect readings, it may be because you are measuring currents below 10% of the range. To correct this, make sure the range setting on the probe is at the lowest possible range that will encompass the readings you are interested in. For example, do not use the 250 amp range for recording currents below 25 amps. Use the 25 amp setting instead as it offers ten times the resolution of the 250 amp range.

1.5.6   Applications

- checking air conditioning and mechanical equipment

- auditing energy use in commercial buildings

- determining tenant electrical consumption

- tracking environmental conditions

- confirming control sequences

1.6   OWL DC Voltage Data Logger

Features
The OWL DC Voltage Data Logger provides a versatile means of recording a variety of signals in a small, water-resistant enclosure. It can be configured for easy interface with common transducer outputs.

1.6.1   Description

The DC Voltage Logger can measure and record analog DC voltage covering 32 ranges from 120mV to 38.4V full scale. The model available is the OWL-400.

How it Works
The logger uses a precision 2.5V reference voltage to convert the analog signal to a digital value. A set of voltage divider resistors on the front end (before the analog to digital conversion) allows for 16 different input ranges. The voltage reference has its own 20:1 resistor divider network making a set of low ranges. This doubles the number of selectable ranges to 32 in total. The digital values are then processed into engineering units by an equation in TrendReader software.

1.6.2   Setup and Use

This section provides guidelines to follow to get started with the OWL DC Voltage Logger.

1.   Connect the cable supplied to the signal being measured - see Figure 4.1

2.   Run TrendReader Software and choose the DC Voltage equation.

3. Select a range that best fits the expected data - see Table 4-1. DC Voltage ranges are picked to match the transducer's full scale output value. For example, if a transducer with a 0 to 5 volt output is used then range number 18 which measures up to 7.3 VDC gives the best resolution.

4. Refer to the OWL Software driver for other options.
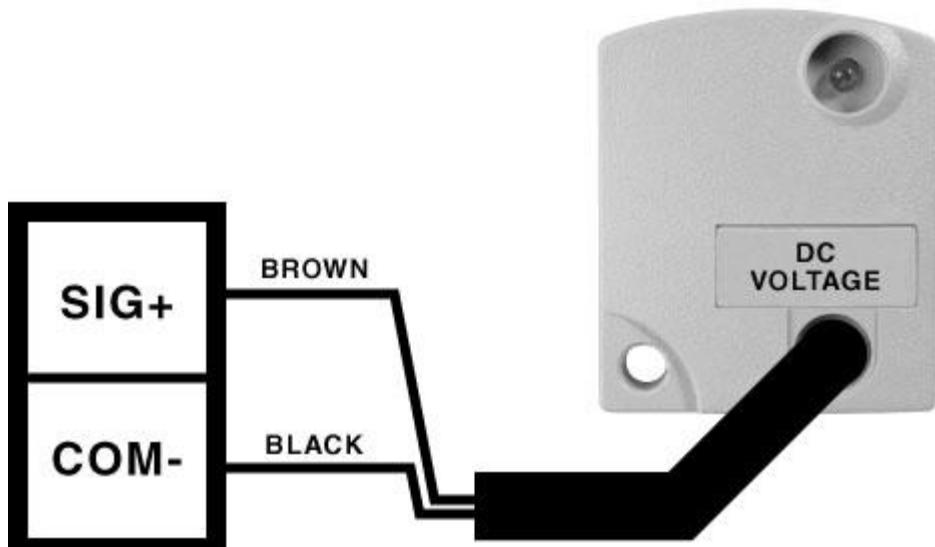
Figure 4.1: DC Voltage Wiring

Table 4.1: DC Voltage Ranges

Range	Full Scale	Range	Full Scale
0	121.0 mVDC	16	2.431 VDC
1	241.9 mVDC	17	4.863 VDC
2	362.9 mVDC	18	7.294 VDC
3	483.9 mVDC	19	9.73 VDC
4	605.8 mVDC	20	12.18 VDC
5	726.8 mVDC	21	14.61 VDC
6	848 mVDC	22	17.04 VDC
7	969 mVDC	23	19.47 VDC
8	1.093 VDC	24	21.96 VDC
9	1.214 VDC	25	24.39 VDC
10	1.334 VDC	26	26.82 VDC
11	1.455 VDC	27	29.25 VDC
12	1.577 VDC	28	31.71 VDC
13	1.698 VDC	29	34.14 VDC
14	1.819 VDC	30	36.57 VDC

15	1.940 VDC	31	39.00VDC

1.6.3   Specifications

Voltage Input

Ranges:	0 to 120mV, 240mV ... 1.92V 0 to 2.40V, 4.80V ... 38.4V
Max Voltage:	±40VDC
Accuracy:	±1% full scale
Resolution:	0.5% (8 bits)
Input Impedance:	> 100k ohms
Cable:	2m (6ft) length with PVC jacket to IP67 connector
Equation:	204

1.6.3.1   Choosing Transducers

A *transducer* is defined as a device that receives energy from one system and retransmits it, in a different form, to another system. A *transmitter* is a term usually reserved for transducers in a current loop circuit. In this section, the terms transducer and transmitter will be used interchangeably.

For a transducer to be useful, the retransmitted signal must be compatible with standard instrumentation. For the OWL DC Voltage logger, this is in the form of an analog DC voltage.

Many compatible transducers exist for measuring such variables as temperature, relative humidity, pressure, speed, pH and more. You can obtain these from a wide variety of manufacturers or distributors. An extensive listing of sensors and companies is published yearly by *Sensors* Magazine.

To figure out what to look for when choosing transducers, it is helpful to know a few technical terms and how they relate to use with your OWL data logger.

Excitation Voltage
This term refers to the input voltage that a transducer requires in order for it to work properly. It is either specified as a range (for example, 9 to 30 volts DC) or a specific voltage (for example, 10 volts DC). When a range is specified, it means you can use an unregulated power supply (such as a battery) as long as voltages within the range are provided. Usually, if a specific voltage is required, it means you require a regulated power supply.

When an unregulated power supply is specified for the excitation voltage, a regulated one may also be used. The reverse, however, is not true. Millivolt pressure transducers, for example, usually require regulated power supplies.

Maximum Impedance

An important consideration when choosing transducers is the requirement for input or loop impedance. This simply refers to how much resistance your instrumentation (for example, the OWL logger) can have before it will begin to cause problems. For voltage inputs, a very high impedance is usually required (greater than 10k ohms). This prevents the unnecessary draining of current from the transducer circuit. The OWL DC Voltage logger's input is high impedance (greater than 100k ohm). Check the specifications for the transducer you intend to use to ensure the OWL's input impedance is acceptable.

Three-Wire Transducers

Three-wire transducers have three connections: a supply (excitation) voltage input (V+IN), an output voltage (SIG+) and a common (COM-). A three wire transducer can be identified by reviewing the wiring diagram and looking for a single common connection. These types of transducers are the most popular and are recommended for use with the OWL - see Figure 4-2.
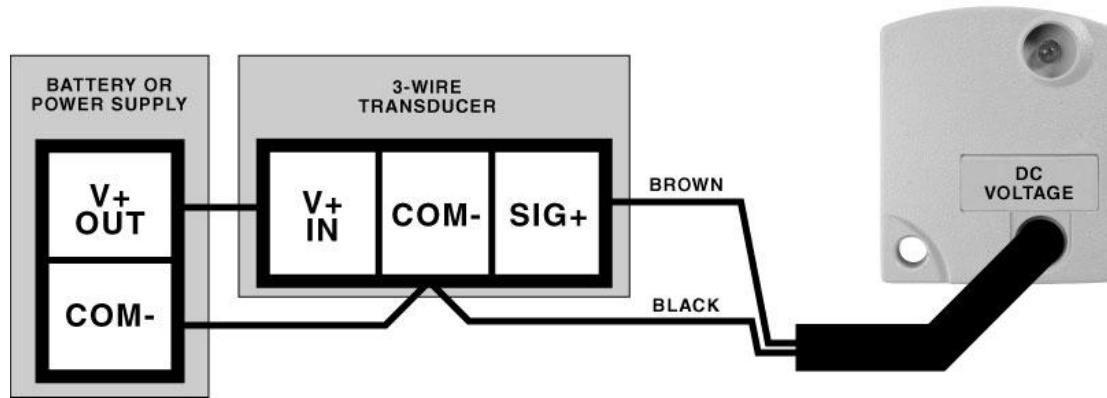
Figure 4-2: Three Wire Transducer Connection

Four-Wire Transducers

Four-wire transducers fall into two categories: line-type and Wheatstone bridge types. The isolated supply appears as a line operated or isolated common that has no electrical connection to the output - see Figure 4-3. The bridge transducer provides a differential output

(+/-), usually in the millivolt range - see Figure 4-4.
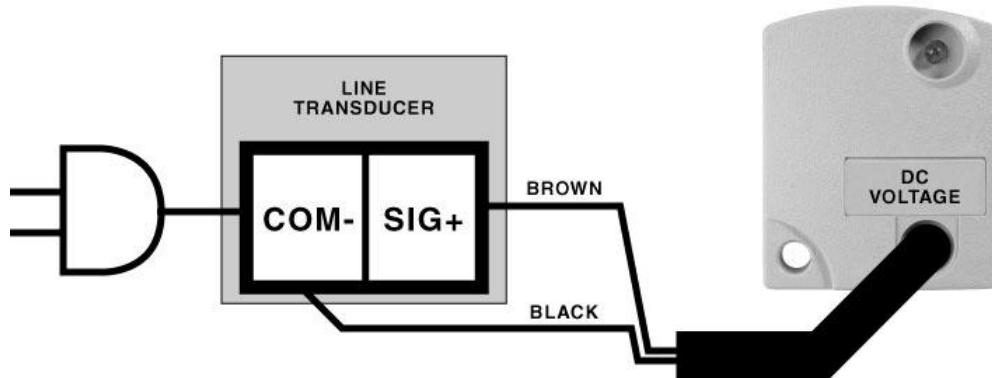
Figure 4-3: Line Type Transducer Connection
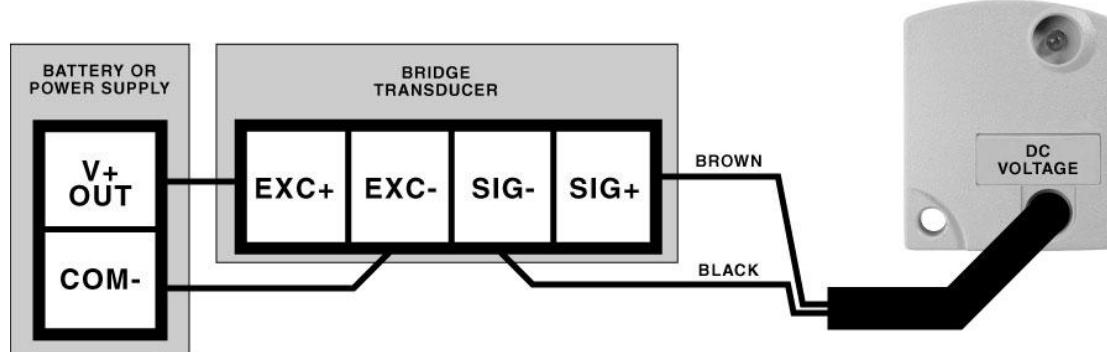
Figure 4-4: Bridge Type Transducer Connection

Output
The specified output of a transducer will determine whether it is compatible for use with the OWL DC Voltage logger. The input range selection makes the logger directly compatible with almost any DC Voltage transducer output.

1.6.4   Applications

- monitoring transducer outputs

- checking process controller signals

- providing laboratory data

- determining random event times

- recording speed

1.7 OWL 20 mA Data Logger

Features

The OWL 20mA Current Data Logger provides a versatile means of recording a process signal in a small, water-resistant enclosure. It is made to connect to 4-20mA type transmitter current loops.

1.7.1 Description

The 20mA Current Logger measures and records analog 0 to 24mA signals common in process control and instrumentation environments. The model available is the OWL-500.

How it Works

Current flow through a loop is logged by measuring the voltage drop across an internal 100 ohm input resistor. This voltage drop is accurately gauged by comparing it to a highly-stable voltage reference before conversion to a digital value by the A/D converter. The digital values are then processed into engineering units by an equation in TrendReader software.

1.7.2 Setup and Use

This section provides guidelines to follow to get started with the OWL 20mA Current Logger.

1. Connect the cable supplied into the current loop being measured - see Figure 5.1

2. Run TrendReader Software and choose the 20mA Current equation.

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3.   Refer to the <u>OWL Software driver</u> for other options.
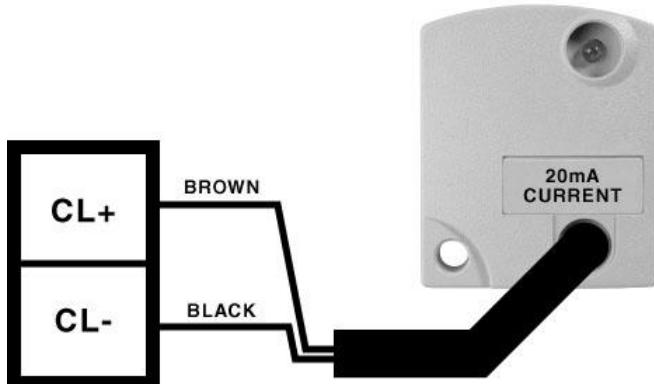
Figure 5-1: 20 mA Current Wiring

1.7.3   Choosing Transmitters

A transmitter is a term usually reserved for transducers in a current loop circuit. A transducer is a device that receives energy from one system and retransmits it, in a different form, to another system. For a transmitter to be useful, the signal must be compatible with standard instrumentation. This is analog DC current for the OWL 20mA Current logger.

Many compatible transducers exist for measuring such variables as temperature, relative humidity, pressure, speed, pH and more. You can obtain these from a wide variety of manufacturers or distributors. An extensive listing of sensors and companies is published yearly by *Sensors* Magazine.

To figure out what to look for when choosing transducers, it is helpful to know a few technical terms and how they relate to use with your OWL data logger.

Maximum Impedance
An important consideration when choosing transducers is the requirement for loop impedance. This simply refers to how much resistance the instrumentation (for example, the OWL logger) can have before it will begin to cause problems. For current loop inputs, it is advantageous to have a very low impedance (the OWL 20mA Current logger has a 100 ohm impedance). This helps to minimize the voltage requirements and power consumption of the circuit. Check the specifications for the transmitter to ensure the OWL's input impedance is acceptable.

Two-Wire Transmitters
Two-wire transmitters are transducers that form part of a current loop circuit. They vary the current flow in accordance with changes in the variable with which they are sensing. Most two-wire transmitters have a 4-20mA output. The connections are usually marked positive current loop (CL+) and negative current loop (CL-). A transmitter can be found in a wiring diagram by looking for a single common path. This type of transmitter is very popular and can

be used with the OWL - see Figure 5-2.
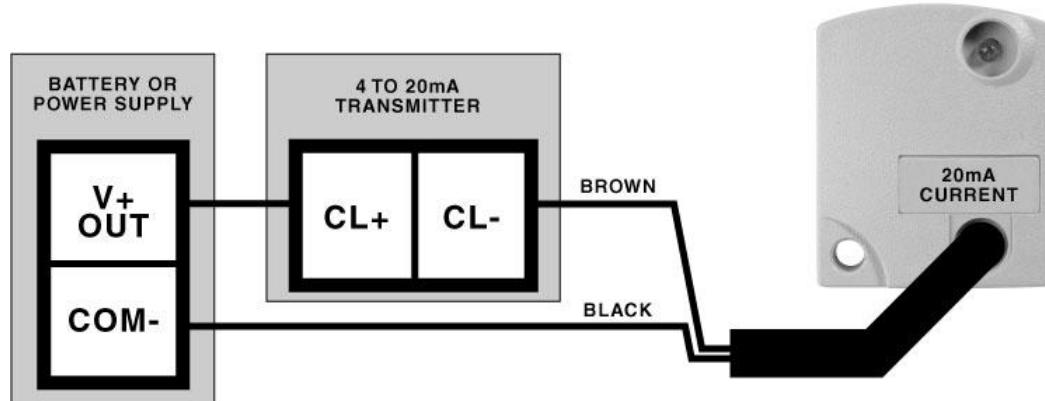
*Figure 5-2: Two Wire Transmitter Connection*

Output
The specified output of a transmitter will determine whether it is compatible for use with the OWL 20mA Current logger. The most popular transmitter output is 4-20mA which can be used with the 0 to 24mA input on the OWL.

1.7.4   Specifications

Current Input

Ranges:	0 to 24 mA
Max Voltage:	±7 VDC
Accuracy:	±1% full scale
Resolution:	0.5% (8 bits)
Input Impedance:	100 ohm
Cable:	2m (6ft) length with PVC jacket to IP67 connector
Equation:	205

1.7.5   Applications

- obtaining environmental data using transmitters such as:
    1. conductivity
    2. pH probe
    3. turbidity
    4. carbon dioxide
    5. dissolved oxygen

- checking fluid level

- analyzing pneumatic and hydraulic pressures

- monitoring flow-meters

- testing process control loops

1.8 APPENDIX A Temperature Ranges

Temperature
Ranges

1.8.1 Temperature Ranges

The OWL Data Logger allows selection of ranges for each temperature equation entered. Use the following table to determine the most suitable range.

The list is sorted by midpoint and the size on either side follows the "±" sign. For example, the range 10.8 ± 47.1 °C (51.4 ± 84.8 °F) measures between -36.3 °C (-33.4 °F) and 57.9 °C (136.2 °F).

The tighter the range, the better the resolution. For example, if room temperatures are to be measured then a range large enough to account for the biggest fluctuation is picked. This might be 20.33 ± 8.72°C (68.60 ± 15.69°F) in a warm climate. This is among the smallest of ranges so the resolution is going to be better than:

    0.05 °C (0.09 °F) @ 20.3 °C (68.6 °F)
    0.10 °C (0.18 °F) between 12.7 °C (54.9 °F) and 27.9 °C (82.2 °F)
    0.20 °C (0.36 °F) between 11.6 °C (52.9 °F) and 29.1 °C (84.3 °F)

*Note that the OWL temperature ranges are only applicable to the OWL-100 (Internal Sensor) and the OWL-200 (External Sensor) Data Loggers.

Table A-1: Temperature Ranges in Celsius

Range	Equation 200	Equation 201	Equation 202	Equation 203
0	-60.03 ± 27.84 C	-78.37 ± 24.30 C	-25.33 ± 35.01 C	18.7 ± 44.2 C
1	-50.54 ± 29.82 C	-70.14 ± 25.86 C	-13.21 ± 37.96 C	34.0 ± 48.0 C
2	-46.16 ± 32.63 C	-66.39 ± 28.23 C	-7.5 ± 41.8 C	41.3 ± 52.9 C
3	-44.69 ± 31.07 C	-65.10 ± 26.85 C	-5.7 ± 39.9 C	43.5 ± 50.4 C
4	-36.96 ± 32.77 C	-58.46 ± 28.18 C	4.4 ± 42.5 C	56.3 ± 53.8 C
5	-35.60 ± 35.09 C	-57.33 ± 30.16 C	6.3 ± 45.6 C	58.8 ± 57.8 C
6	-34.09 ± 33.42 C	-56.00 ± 28.69 C	8.2 ± 43.5 C	61.1 ± 55.1 C
7	-33.80 ± 10.01 C	-55.48 ± 8.59 C	7.67 ± 13.02 C	60.31 ± 16.50 C
8	-31.61 ± 33.98 C	-53.88 ± 29.13 C	11.4 ± 44.4 C	65.3 ± 56.3 C
9	-29.43 ± 34.48 C	-52.03 ± 29.51 C	14.3 ± 45.1 C	68.9 ± 57.3 C
10	-29.07 ± 36.67 C	-51.76 ± 31.38 C	14.9 ± 48.0 C	69.7 ± 60.9 C
11	-25.73 ± 35.34 C	-48.87 ± 30.18 C	19.2 ± 46.5 C	75.2 ± 59.0 C
12	-24.11 ± 35.71 C	-47.50 ± 30.47 C	21.4 ± 47.1 C	77.9 ± 59.8 C
13	-22.45 ± 10.80 C	-45.77 ± 9.21 C	22.57 ± 14.27 C	79.22 ± 18.13 C
14	-22.61 ± 36.07 C	-46.23 ± 30.74 C	23.4 ± 47.7 C	80.5 ± 60.5 C
15	-21.23 ± 36.39 C	-45.06 ± 30.99 C	25.2 ± 48.2 C	82.8 ± 61.2 C
16	-20.29 ± 6.76 C	-43.92 ± 5.75 C	25.37 ± 8.96 C	82.76 ± 11.38 C
17	-20.41 ± 38.82 C	-44.41 ± 33.04 C	26.5 ± 51.4 C	84.4 ± 65.4 C
18	-19.35 ± 15.31 C	-43.17 ± 13.02 C	26.77 ± 20.31 C	84.58 ± 25.81 C
19	-18.73 ± 36.99 C	-42.94 ± 31.45 C	28.6 ± 49.1 C	87.1 ± 62.5 C
20	-17.58 ± 37.26 C	-41.97 ± 31.66 C	30.1 ± 49.6 C	89.1 ± 63.0 C
21	-17.2 ± 39.6 C	-41.68 ± 33.67 C	30.8 ± 52.8 C	90.0 ± 67.1 C
22	-16.49 ± 37.53 C	-41.05 ± 31.86 C	31.6 ± 50.0 C	90.9 ± 63.6 C
23	-15.42 ± 11.32 C	-39.80 ± 9.60 C	31.92 ± 15.09 C	91.10 ± 19.19 C
24	-15.47 ± 37.78 C	-40.19 ± 32.05 C	33.0 ± 50.4 C	92.7 ± 64.1 C
25	-14.4 ± 40.3 C	-39.32 ± 34.21 C	34.6 ± 53.9 C	94.8 ± 68.6 C
26	-13.55 ± 38.24 C	-38.57 ± 32.41 C	35.6 ± 51.1 C	96.0 ± 65.1 C
27	-12.66 ± 38.46 C	-37.82 ± 32.58 C	36.8 ± 51.5 C	97.5 ± 65.5 C
28	-11.80 ± 38.67 C	-37.09 ± 32.74 C	38.0 ± 51.8 C	99.0 ± 66.0 C
29	-11.9 ± 41.0 C	-37.26 ± 34.70 C	38.0 ± 54.9 C	99.1 ± 69.9 C
30	-10.97 ± 38.87 C	-36.40 ± 32.89 C	39.1 ± 52.2 C	100.5 ± 66.4 C
31	-9.4 ± 39.3 C	-35.09 ± 33.18 C	41.2 ± 52.8 C	103.2 ± 67.2 C
32	-8.7 ± 39.4 C	-34.47 ± 33.32 C	42.2 ± 53.1 C	104.5 ± 67.6 C
33	-7.84 ± 7.33 C	-33.36 ± 6.19 C	42.01 ± 9.87 C	103.93 ± 12.57 C
34	-8.0 ± 39.6 C	-33.87 ± 33.46 C	43.2 ± 53.4 C	105.7 ± 68.0 C
35	-7.3 ± 39.8 C	-33.29 ± 33.59 C	44.2 ± 53.7 C	106.9 ± 68.4 C
36	-7.7 ± 42.1 C	-33.74 ± 35.53 C	43.7 ± 56.7 C	106.4 ± 72.3 C
37	-6.08 ± 12.02 C	-31.91 ± 10.13 C	44.46 ± 16.22 C	107.07 ± 20.67 C
38	-6.79 ± 16.61 C	-32.54 ± 14.01 C	43.62 ± 22.40 C	106.02 ± 28.54 C
39	-5.9 ± 42.6 C	-32.21 ± 35.90 C	46.2 ± 57.5 C	109.6 ± 73.3 C
40	4.61 ± 12.24 C	-30.67 ± 10.32 C	46.46 ± 16.56 C	109.61 ± 21.11 C
41	-4.2 ± 43.0 C	-30.79 ± 36.24 C	48.5 ± 58.3 C	112.5 ± 74.3 C
42	-2.60 ± 12.28 C	-28.98 ± 10.34 C	49.18 ± 16.66 C	113.08 ± 21.24 C
43	-2.7 ± 43.4 C	-29.48 ± 36.56 C	50.7 ± 58.9 C	115.3 ± 75.2 C
44	-0.10 ± 7.70 C	-26.85 ± 6.47 C	52.49 ± 10.48 C	117.29 ± 13.36 C
45	0.42 ± 12.52 C	-26.44 ± 10.51 C	53.28 ± 17.05 C	118.32 ± 21.75 C
46	0.2 ± 44.2 C	-27.11 ± 37.14 C	54.6 ± 60.2 C	120.3 ± 76.9 C
47	1.02 ± 17.44 C	-25.97 ± 14.65 C	54.24 ± 23.78 C	119.57 ± 30.34 C
48	1.5 ± 44.5 C	-26.03 ± 37.41 C	56.4 ± 60.8 C	122.6 ± 77.6 C
49	2.7 ± 44.9 C	-25.00 ± 37.66 C	58.1 ± 61.4 C	124.8 ± 78.4 C
50	3.06 ± 12.72 C	-24.22 ± 10.67 C	56.90 ± 17.39 C	122.94 ± 22.20 C
51	3.9 ± 45.2 C	-24.02 ± 37.90 C	59.7 ± 61.9 C	126.9 ± 79.1 C

Range	Equation 200	Equation 201	Equation 202	Equation 203
52	6.1 ± 45.8 C	-22.22 ± 38.35 C	62.8 ± 62.9 C	130.8 ± 80.4 C
53	7.58 ± 13.08 C	-20.44 ± 10.94 C	63.10 ± 17.99 C	130.86 ± 22.99 C
54	7.1 ± 46.1 C	-21.37 ± 38.56 C	64.2 ± 63.4 C	132.6 ± 81.0 C
55	8.1 ± 46.4 C	-20.56 ± 38.77 C	65.6 ± 63.8 C	134.4 ± 81.6 C
56	9.0 ± 46.6 C	-19.78 ± 38.96 C	66.9 ± 64.3 C	136.1 ± 82.2 C
57	9.55 ± 13.24 C	-18.79 ± 11.06 C	65.82 ± 18.26 C	134.33 ± 23.34 C
58	9.23 ± 13.34 C	-19.07 ± 11.15 C	65.37 ± 18.39 C	133.77 ± 23.50 C
59	10.20 ± 8.20 C	-18.22 ± 6.85 C	66.62 ± 11.32 C	135.34 ± 14.47 C
60	10.8 ± 47.1 C	-18.3 ± 39.3 C	69.4 ± 65.1 C	139.3 ± 83.3 C
61	11.38 ± 13.39 C	-17.27 ± 11.17 C	68.35 ± 18.51 C	137.57 ± 23.67 C
62	11.43 ± 18.60 C	-17.27 ± 15.52 C	68.57 ± 25.71 C	137.89 ± 32.88 C
63	11.6 ± 47.4 C	-17.6 ± 39.5 C	70.6 ± 65.5 C	140.8 ± 83.8 C
64	12.4 ± 47.6 C	-16.9 ± 39.7 C	71.7 ± 65.9 C	142.3 ± 84.4 C
65	13.07 ± 13.53 C	-15.86 ± 11.28 C	70.70 ± 18.74 C	140.57 ± 23.98 C
66	13.2 ± 47.8 C	-16.3 ± 39.9 C	72.8 ± 66.3 C	143.7 ± 84.9 C
67	14.06 ± 8.40 C	-15.01 ± 6.99 C	71.95 ± 11.65 C	142.16 ± 14.90 C
68	15.32 ± 19.04 C	-14.03 ± 15.85 C	73.98 ± 26.45 C	144.82 ± 33.86 C
69	16.14 ± 13.78 C	-13.31 ± 11.47 C	74.96 ± 19.17 C	146.03 ± 24.54 C
70	17.40 ± 8.57 C	-12.23 ± 7.12 C	76.60 ± 11.94 C	148.11 ± 15.29 C
71	17.54 ± 13.90 C	-12.14 ± 11.55 C	76.92 ± 19.37 C	148.54 ± 24.80 C
72	17.86 ± 14.06 C	-11.88 ± 11.68 C	77.36 ± 19.60 C	149.11 ± 25.10 C
73	18.88 ± 14.01 C	-11.03 ± 11.64 C	78.78 ± 19.56 C	150.93 ± 25.06 C
74	18.70 ± 19.43 C	-11.22 ± 16.14 C	78.70 ± 27.12 C	150.86 ± 34.74 C
75	20.33 ± 8.72 C	-9.79 ± 7.23 C	80.70 ± 12.20 C	153.36 ± 15.63 C
76	20.14 ± 14.12 C	-9.98 ± 11.71 C	80.55 ± 19.74 C	153.20 ± 25.30 C
77	21.67 ± 19.77 C	-8.76 ± 16.39 C	82.87 ± 27.71 C	156.21 ± 35.52 C
78	22.49 ± 14.31 C	-8.03 ± 11.86 C	83.85 ± 20.08 C	157.42 ± 25.75 C
79	23.59 ± 14.41 C	-7.12 ± 11.93 C	85.40 ± 20.24 C	159.41 ± 25.96 C
80	24.0 ± 95.5 C	-9.1 ± 79.2 C	94.4 ± 134.7 C	172.9 ± .2 C
81	24.66 ± 14.50 C	-6.24 ± 12.00 C	86.89 ± 20.40 C	161.33 ± 26.16 C
82	25.35 ± 8.98 C	-5.64 ± 7.43 C	87.75 ± 12.65 C	162.40 ± 16.23 C
83	25.67 ± 14.58 C	-5.40 ± 12.06 C	88.33 ± 20.55 C	163.17 ± 26.36 C
84	26.74 ± 20.37 C	-4.57 ± 16.84 C	90.03 ± 28.74 C	165.39 ± 36.89 C
85	27.54 ± 9.10 C	-3.83 ± 7.52 C	90.84 ± 12.85 C	166.37 ± 16.49 C
86	27.59 ± 14.75 C	-3.82 ± 12.18 C	91.04 ± 20.83 C	166.65 ± 26.74 C
87	28.50 ± 14.83 C	-3.06 ± 12.24 C	92.33 ± 20.97 C	168.31 ± 26.92 C
88	28.96 ± 20.63 C	-2.74 ± 17.03 C	93.17 ± 29.20 C	169.44 ± 37.50 C
89	29.58 ± 9.21 C	-2.15 ± 7.60 C	93.72 ± 13.04 C	170.07 ± 16.74 C
90	29.39 ± 14.90 C	-2.33 ± 12.30 C	93.59 ± 21.10 C	169.93 ± 27.10 C
91	29.40 ± 15.04 C	-2.32 ± 12.41 C	93.61 ± 21.30 C	169.96 ± 27.36 C
92	30.24 ± 14.98 C	-1.63 ± 12.35 C	94.80 ± 21.23 C	171.48 ± 27.27 C
93	31.46 ± 9.31 C	-0.59 ± 7.67 C	96.40 ± 13.21 C	173.50 ± 16.98 C
94	31.02 ± 20.88 C	-1.04 ± 17.21 C	96.10 ± 29.63 C	173.20 ± 38.07 C
95	32.93 ± 21.11 C	0.53 ± 17.38 C	98.82 ± 30.04 C	176.70 ± 38.61 C
96	33.73 ± 15.42 C	1.24 ± 12.70 C	99.77 ± 21.97 C	177.88 ± 28.24 C
97	34.88 ± 9.49 C	2.22 ± 7.81 C	101.26 ± 13.54 C	179.76 ± 17.41 C
98	36.44 ± 9.58 C	3.51 ± 7.87 C	103.50 ± 13.69 C	182.64 ± 17.61 C
99	36.38 ± 21.53 C	3.37 ± 17.69 C	103.77 ± 30.78 C	183.1 ± 39.6 C
100	37.94 ± 9.66 C	4.73 ± 7.93 C	105.64 ± 13.83 C	185.39 ± 17.80 C
101	37.49 ± 15.76 C	4.33 ± 12.94 C	105.15 ± 22.56 C	184.80 ± 29.03 C
102	37.97 ± 21.73 C	4.67 ± 17.84 C	106.05 ± 31.13 C	186.0 ± 40.1 C
103	39.35 ± 9.74 C	5.89 ± 7.99 C	107.66 ± 13.97 C	187.99 ± 17.99 C

Range	Equation 200	Equation 201	Equation 202	Equation 203
104	39.48 ± 21.91 C	5.90 ± 17.97 C	108.22 ± 31.46 C	188.8 ± 40.5 C
105	40.80 ± 16.06 C	7.04 ± 13.16 C	109.91 ± 23.09 C	190.93 ± 29.74 C
106	40.91 ± 22.09 C	7.07 ± 18.10 C	110.28 ± 31.77 C	191.5 ± 40.9 C
107	41.97 ± 9.88 C	8.04 ± 8.09 C	111.44 ± 14.23 C	192.86 ± 18.33 C
108	42.2 ± 105.2 C	5.5 ± 86.2 C	122.4 ± 152.1 C	209.7 ± 196.5 C
109	43.20 ± 9.95 C	9.05 ± 8.14 C	113.21 ± 14.35 C	195.15 ± 18.50 C
110	43.57 ± 22.42 C	9.25 ± 18.35 C	114.13 ± 32.37 C	196.4 ± 41.7 C
111	44.39 ± 10.02 C	10.02 ± 8.19 C	114.93 ± 14.47 C	197.36 ± 18.66 C
112	44.81 ± 22.58 C	10.26 ± 18.46 C	115.94 ± 32.65 C	198.8 ± 42.1 C
113	45.53 ± 10.08 C	10.95 ± 8.24 C	116.58 ± 14.59 C	199.48 ± 18.81 C
114	46.47 ± 16.58 C	11.67 ± 13.54 C	118.10 ± 24.02 C	201.49 ± 30.98 C
115	46.02 ± 22.73 C	11.25 ± 18.57 C	117.69 ± 32.92 C	201.0 ± 42.5 C
116	47.68 ± 10.20 C	12.70 ± 8.33 C	119.69 ± 14.81 C	203.50 ± 19.10 C
117	47.17 ± 22.88 C	12.19 ± 18.68 C	119.37 ± 33.19 C	203.2 ± 42.8 C
118	48.70 ± 10.26 C	13.54 ± 8.37 C	121.18 ± 14.91 C	205.42 ± 19.24 C
119	48.95 ± 16.81 C	13.69 ± 13.71 C	121.71 ± 24.44 C	206.15 ± 31.54 C
120	49.69 ± 10.32 C	14.35 ± 8.41 C	122.62 ± 15.02 C	207.29 ± 19.38 C
121	49.35 ± 23.16 C	13.96 ± 18.88 C	122.54 ± 33.69 C	207.3 ± 43.5 C
122	50.65 ± 10.37 C	15.13 ± 8.45 C	124.02 ± 15.11 C	209.09 ± 19.51 C
123	50.38 ± 23.29 C	14.80 ± 18.98 C	124.06 ± 33.93 C	209.2 ± 43.8 C
124	51.25 ± 17.02 C	15.57 ± 13.86 C	125.07 ± 24.83 C	210.49 ± 32.06 C
125	51.39 ± 23.42 C	15.62 ± 19.07 C	125.53 ± 34.16 C	211.1 ± 44.1 C
126	52.36 ± 23.54 C	16.41 ± 19.16 C	126.95 ± 34.39 C	213.0 ± 44.4 C
127	53.39 ± 17.22 C	17.31 ± 14.01 C	128.20 ± 25.19 C	214.54 ± 32.55 C
128	53.8 ± 111.5 C	14.7 ± 90.8 C	140.9 ± 163.9 C	234.1 ± 212.6 C
129	56.7 ± 82.9 C	18.4 ± 67.4 C	139.7 ± 122.2 C	231.1 ± 158.3 C
130	57.26 ± 17.59 C	20.45 ± 14.28 C	133.90 ± 25.87 C	221.91 ± 33.46 C
131	59.04 ± 17.76 C	21.90 ± 14.40 C	136.53 ± 26.18 C	225.31 ± 33.88 C
132	60.74 ± 17.93 C	23.27 ± 14.52 C	139.03 ± 26.48 C	228.55 ± 34.28 C
133	62.34 ± 18.08 C	24.56 ± 14.63 C	141.41 ± 26.77 C	231.64 ± 34.67 C
134	65.33 ± 18.37 C	26.98 ± 14.84 C	145.86 ± 27.31 C	237.40 ± 35.40 C
135	66.73 ± 18.51 C	28.11 ± 14.94 C	147.95 ± 27.57 C	240.12 ± 35.75 C
136	68.09 ± 18.64 C	29.20 ± 15.03 C	149.97 ± 27.82 C	242.75 ± 36.09 C
137	69.38 ± 18.77 C	30.24 ± 15.12 C	151.92 ± 28.06 C	245.27 ± 36.42 C
138	69.7 ± 120.5 C	27.1 ± 97.2 C	166.8 ± 181.1 C	268.6 ± 236.1 C
139	71.84 ± 19.02 C	32.22 ± 15.30 C	155.60 ± 28.52 C	250.05 ± 37.04 C
140	73.00 ± 19.13 C	33.16 ± 15.38 C	157.36 ± 28.74 C	252.34 ± 37.34 C
141	74.14 ± 19.25 C	34.07 ± 15.46 C	159.07 ± 28.96 C	254.56 ± 37.63 C
142	75.23 ± 19.36 C	34.94 ± 15.54 C	160.72 ± 29.17 C	256.71 ± 37.91 C
143	75.7 ± 124.0 C	31.8 ± 99.7 C	177.0 ± 188.0 C	282.2 ± 245.5 C
144	78.1 ± 92.3 C	35.3 ± 74.1 C	173.4 ± 140.0 C	275.6 ± 182.7 C
145	79.1 ± 86.4 C	36.3 ± 69.3 C	173.8 ± 131.2 C	275.8 ± 171.1 C
146	81.0 ± 127.1 C	35.9 ± 101.8 C	186.0 ± 194.1 C	294.2 ± 254.0 C
147	85.8 ± 129.8 C	39.5 ± 103.8 C	194.0 ± 199.7 C	305.1 ± 261.7 C
148	91.7 ± 98.6 C	46.0 ± 78.5 C	195.8 ± 152.5 C	305.3 ± 199.7 C
149	93.9 ± 134.7 C	45.7 ± 107.2 C	208.2 ± 209.6 C	324.3 ± 275.5 C
150	97.5 ± 136.9 C	48.4 ± 108.7 C	214.5 ± 214.1 C	332.9 ± 281.8 C
151	100.9 ± 138.9 C	51.0 ± 110.1 C	220.5 ± 218.4 C	341.0 ± 287.8 C
152	103.1 ± 96.9 C	55.1 ± 76.6 C	213.3 ± 152.2 C	328.4 ± 200.1 C
153	104.0 ± 140.8 C	53.3 ± 111.4 C	226.1 ± 222.4 C	348.6 ± 293.4 C
154	109.7 ± 144.3 C	57.7 ± 113.8 C	236.4 ± 229.9 C	362.8 ± 303.9 C
155	110.5 ± 107.5 C	60.4 ± 84.6 C	227.4 ± 170.7 C	347.8 ± 225.1 C

Range	Equation 200	Equation 201	Equation 202	Equation 203
156	112.4 ± 146.0 C	59.6 ± 114.9 C	241.2 ± 233.4 C	369.4 ± 308.9 C
157	114.9 ± 147.5 C	61.5 ± 116.0 C	245.9 ± 236.8 C	375.8 ± 313.7 C
158	117.7 ± 111.0 C	65.9 ± 87.0 C	239.9 ± 178.1 C	364.6 ± 235.5 C
159	117.3 ± 149.0 C	63.3 ± 117.0 C	250.3 ± 240.0 C	381.9 ± 318.3 C
160	118.7 ± 104.0 C	67.0 ± 81.5 C	239.8 ± 167.0 C	363.9 ± 220.7 C
161	121.8 ± 151.9 C	66.7 ± 118.9 C	258.7 ± 246.2 C	393.5 ± 327.1 C
162	124.0 ± 153.2 C	68.3 ± 119.8 C	262.7 ± 249.2 C	399.1 ± 331.3 C
163	124.0 ± 114.1 C	70.7 ± 89.2 C	250.9 ± 184.8 C	379.6 ± 244.9 C
164	126.0 ± 154.5 C	69.8 ± 120.7 C	266.6 ± 252.1 C	404.5 ± 335.5 C
165	128.0 ± 155.8 C	71.3 ± 121.6 C	270.4 ± 254.9 C	409.7 ± 339.5 C
166	129.6 ± 116.9 C	74.9 ± 91.1 C	260.9 ± 190.9 C	393.2 ± 253.5 C
167	131.8 ± 158.2 C	74.1 ± 123.2 C	277.5 ± 260.3 C	419.7 ± 347.2 C
168	133.6 ± 159.3 C	75.4 ± 123.9 C	281.0 ± 262.9 C	424.5 ± 350.9 C
169	135.3 ± 160.4 C	76.7 ± 124.7 C	284.4 ± 265.4 C	429.2 ± 354.6 C
170	137.0 ± 161.5 C	77.9 ± 125.4 C	287.7 ± 267.9 C	433.8 ± 358.2 C
171	139.3 ± 121.8 C	82.3 ± 94.4 C	278.5 ± 201.8 C	417.2 ± 269.0 C
172	140.1 ± 114.2 C	83.3 ± 88.4 C	277.7 ± 189.1 C	415.4 ± 252.0 C
173	143.7 ± 124.1 C	85.5 ± 95.9 C	286.3 ± 206.8 C	428.0 ± 276.1 C
174	147.7 ± 126.2 C	88.5 ± 97.3 C	293.8 ± 211.5 C	438.2 ± 282.8 C
175	148.4 ± 118.2 C	89.5 ± 91.1 C	292.7 ± 198.2 C	436.0 ± 264.9 C
176	151.4 ± 128.1 C	91.3 ± 98.6 C	300.8 ± 216.0 C	447.9 ± 289.3 C
177	155.7 ± 121.8 C	94.9 ± 93.5 C	306.2 ± 206.4 C	454.6 ± 276.7 C
178	158.3 ± 131.7 C	96.4 ± 101.0 C	313.7 ± 224.3 C	465.9 ± 301.4 C
179	161.5 ± 133.4 C	98.7 ± 102.1 C	319.8 ± 228.3 C	474.3 ± 307.1 C
180	162.2 ± 125.0 C	99.7 ± 95.6 C	318.3 ± 213.9 C	471.4 ± 287.6 C
181	164.5 ± 135.1 C	101.0 ± 103.2 C	325.7 ± 232.1 C	482.5 ± 312.7 C
182	167.4 ± 136.6 C	103.1 ± 104.2 C	331.3 ± 235.8 C	490.3 ± 318.1 C
183	172.9 ± 139.6 C	107.1 ± 106.1 C	341.9 ± 242.9 C	505.1 ± 328.4 C
184	173.4 ± 130.8 C	108.0 ± 99.4 C	339.9 ± 227.5 C	501.4 ± 307.4 C
185	175.5 ± 141.0 C	108.9 ± 107.0 C	346.9 ± 246.3 C	512.2 ± 333.3 C
186	177.9 ± 142.3 C	110.8 ± 107.9 C	351.9 ± 249.6 C	519.2 ± 338.2 C
187	178.4 ± 133.4 C	111.7 ± 101.1 C	349.6 ± 233.8 C	515.0 ± 316.5 C
188	180.3 ± 143.6 C	112.5 ± 108.8 C	356.6 ± 252.8 C	525.9 ± 342.9 C
189	183.1 ± 135.8 C	115.1 ± 102.6 C	358.9 ± 239.8 C	528.0 ± 325.3 C
190	184.9 ± 146.2 C	115.8 ± 110.4 C	365.8 ± 259.0 C	538.8 ± 352.1 C
191	187.5 ± 138.1 C	118.3 ± 104.1 C	367.6 ± 245.4 C	540.3 ± 333.7 C
192	187.1 ± 147.4 C	117.4 ± 111.2 C	370.2 ± 262.1 C	545.1 ± 356.5 C
193	189.2 ± 148.5 C	118.9 ± 111.9 C	374.5 ± 265.0 C	551.2 ± 360.9 C
194	191.3 ± 149.7 C	120.4 ± 112.7 C	378.7 ± 267.9 C	557.2 ± 365.2 C
195	195.6 ± 142.4 C	124.1 ± 106.9 C	383.8 ± 256.1 C	563.2 ± 249.5 C
196	199.3 ± 144.4 C	126.8 ± 108.1 C	391.4 ± 261.2 C	574.0 ± 357.0 C
197	202.9 ± 146.3 C	129.4 ± 109.4 C	398.7 ± 266.1 C	584.5 ± 364.4 C
198	206.3 ± 148.1 C	131.8 ± 110.5 C	405.8 ± 270.9 C	594.7 ± 371.5 C
199	212.7 ± 151.6 C	136.4 ± 112.8 C	419.3 ± 280.1 C	614.0 ± 385.3 C
200	215.7 ± 153.3 C	138.5 ± 113.8 C	425.7 ± 284.5 C	623.2 ± 391.9 C
201	218.7 ± 154.9 C	140.6 ± 114.8 C	432.0 ± 288.8 C	632 ± 398 C
202	221.5 ± 156.5 C	142.6 ± 115.8 C	438.1 ± 293.0 C	641 ± 405 C
203	226.9 ± 159.5 C	146.4 ± 117.7 C	449.8 ± 301.2 C	658 ± 417 C
204	229.5 ± 160.9 C	148.3 ± 118.6 C	455.5 ± 305.2 C	666 ± 423 C
205	232.0 ± 162.3 C	150.0 ± 119.5 C	461.0 ± 309.1 C	675 ± 429 C

Table A-2: Temperature Ranges in Fahrenheit

Range	Equation 200	Equation 201	Equation 202	Equation 203
0	-76.1 ± 50.1°F	109.1 ± 43.7°F	-13.6 ± 63.0°F	65.6 ± 79.5°F
1	-59.0 ± 53.7°F	-94.3 ± 46.6°F	8.2 ± 68.3°F	93.2 ± 86.4°F
2	-51.1 ± 58.7°F	-87.5 ± 50.8°F	18.6 ± 75.2°F	106.3 ± 95.1°F
3	-48.4 ± 55.9°F	-85.2 ± 48.3°F	21.8 ± 71.8°F	110.4 ± 90.8°F
4	-34.5 ± 59.0°F	-73.2 ± 50.7°F	39.9 ± 76.5°F	133.4 ± 96.9°F
5	-32.1 ± 63.2°F	-71.2 ± 54.3°F	43.3 ± 82.0°F	137.8 ± 104.0°F
6	-29.4 ± 60.1°F	-68.8 ± 51.6°F	46.7 ± 78.3°F	142.0 ± 99.2°F
7	-28.84 ± 18.01°F	-67.86 ± 15.46°F	45.81 ± 23.44°F	140.56 ± 29.71°F
8	-24.9 ± 61.2°F	-65.0 ± 52.4°F	52.6 ± 79.9°F	149.5 ± 101.3°F
9	-21.0 ± 62.1°F	-61.6 ± 53.1°F	57.8 ± 81.3°F	156.0 ± 103.1°F
10	-20.3 ± 66.0°F	-61.2 ± 56.5°F	58.9 ± 86.5°F	157.5 ± 109.7°F
11	-14.3 ± 63.6°F	-56.0 ± 54.3°F	66.6 ± 83.7°F	167.3 ± 106.3°F
12	-11.4 ± 64.3°F	-53.5 ± 54.8°F	70.5 ± 84.8°F	172.2 ± 107.7°F
13	-8.41 ± 19.45°F	-50.39 ± 16.57°F	72.63 ± 25.69°F	174.60 ± 32.63°F
14	-8.7 ± 64.9°F	-51.2 ± 55.3°F	74.1 ± 85.8°F	176.8 ± 109.0°F
15	-6.2 ± 65.5°F	-49.1 ± 55.8°F	77.4 ± 86.7°F	181.1 ± 110.2°F
16	-4.52 ± 12.17°F	-47.05 ± 10.35°F	77.66 ± 16.12°F	180.97 ± 20.48°F
17	-4.7 ± 69.9°F	-47.9 ± 59.5°F	79.7 ± 92.6°F	184.0 ± 117.7°F
18	-2.84 ± 27.56°F	-45.71 ± 23.44°F	80.19 ± 36.57°F	184.2 ± 46.5°F
19	-1.7 ± 66.6°F	-45.3 ± 56.6°F	83.5 ± 88.4°F	188.8 ± 112.4°F
20	0.4 ± 67.1°F	-43.6 ± 57.0°F	86.3 ± 89.2°F	192.3 ± 113.5°F
21	1.1 ± 71.3°F	-43.0 ± 60.6°F	87.5 ± 95.0°F	194.0 ± 120.8°F
22	2.3 ± 67.5°F	-41.9 ± 57.4°F	88.9 ± 90.0°F	195.7 ± 114.4°F
23	4.25 ± 20.37°F	-39.64 ± 17.28°F	89.45 ± 27.16°F	195.98 ± 34.54°F
24	4.2 ± 68.0°F	-40.3 ± 57.7°F	91.4 ± 90.7°F	198.9 ± 115.4°F
25	6.1 ± 72.6°F	-38.8 ± 61.6°F	94.3 ± 97.0°F	202.6 ± 123.5°F
26	7.6 ± 68.8°F	-37.4 ± 58.3°F	96.1 ± 92.1°F	204.8 ± 117.2°F
27	9.2 ± 69.2°F	-36.1 ± 58.6°F	98.3 ± 92.7°F	207.6 ± 118.0°F
28	10.8 ± 69.6°F	-34.8 ± 58.9°F	100.4 ± 93.3°F	210.3 ± 118.8°F
29	10.5 ± 73.8°F	-35.1 ± 62.5°F	100.3 ± 98.9°F	210.3 ± 125.9°F
30	12.2 ± 70.0°F	-33.5 ± 59.2°F	102.4 ± 93.9°F	212.9 ± 119.6°F
31	15.1 ± 70.7°F	-31.2 ± 59.7°F	106.2 ± 95.0°F	217.7 ± 121.0°F
32	16.4 ± 71.0°F	-30.0 ± 60.0°F	108.0 ± 95.6°F	220.0 ± 121.7°F
33	17.90 ± 13.19°F	-28.06 ± 11.14°F	107.62 ± 17.77°F	219.08 ± 22.63°F
34	17.7 ± 71.3°F	-29.0 ± 60.2°F	109.8 ± 96.1°F	222.3 ± 122.4°F
35	18.9 ± 71.6°F	-27.9 ± 60.5°F	111.5 ± 96.6°F	224.5 ± 123.1°F
36	18.1 ± 75.7°F	-28.7 ± 64.0°F	110.6 ± 102.1°F	223.4 ± 130.1°F
37	21.05 ± 21.63°F	-25.43 ± 18.24°F	112.03 ± 29.20°F	224.72 ± 37.21°F
38	19.78 ± 29.89°F	-26.57 ± 25.23°F	110.5 ± 40.3°F	222.8 ± 51.4°F
39	21.3 ± 76.6°F	-26.0 ± 64.6°F	115.1 ± 103.5°F	229.2 ± 132.0°F
40	23.71 ± 22.04°F	-23.20 ± 18.57°F	115.62 ± 29.81°F	229.30 ± 37.99°F
41	24.4 ± 77.4°F	-23.4 ± 65.2°F	119.3 ± 104.9°F	234.6 ± 133.7°F
42	27.32 ± 22.11°F	-20.16 ± 18.61°F	120.52 ± 29.99°F	235.55 ± 38.24°F
43	27.2 ± 78.2°F	-21.1 ± 65.8°F	123.2 ± 106.1°F	239.5 ± 135.3°F
44	31.82 ± 13.85°F	-16.33 ± 11.64°F	126.49 ± 18.86°F	243.13 ± 24.05°F
45	32.75 ± 22.53°F	-15.60 ± 18.93°F	127.91 ± 30.69°F	244.97 ± 39.15°F
46	32.3 ± 79.6°F	-16.8 ± 66.8°F	130.3 ± 108.4°F	248.6 ± 138.3°F
47	33.84 ± 31.40°F	-14.75 ± 26.37°F	129.6 ± 42.8°F	247.2 ± 54.6°F
48	34.7 ± 80.2°F	-14.8 ± 67.3°F	133.5 ± 109.4°F	252.7 ± 139.7°F
49	36.9 ± 80.8°F	-13.0 ± 67.8°F	136.6 ± 110.4°F	256.7 ± 141.0°F
50	37.51 ± 22.90°F	-11.60 ± 19.21°F	134.42 ± 31.31°F	253.3 ± 40.0°F
51	39.0 ± 81.4°F	-11.2 ± 68.2°F	139.5 ± 111.4°F	260.4 ± 142.3°F

Range	Equation 200	Equation 201	Equation 202	Equation 203
52	42.9 ± 82.4°F	-8.0 ± 69.0°F	145.0 ± 113.2°F	267.5 ± 144.7°F
53	45.64 ± 23.55°F	-4.79 ± 19.70°F	145.58 ± 32.39°F	267.5 ± 41.4°F
54	44.7 ± 83.0°F	-6.5 ± 69.4°F	147.6 ± 114.1°F	270.7 ± 145.8°F
55	46.5 ± 83.4°F	-5.0 ± 69.8°F	150.0 ± 114.9°F	273.9 ± 146.9°F
56	48.2 ± 83.9°F	-3.6 ± 70.1°F	152.4 ± 115.7°F	277.0 ± 148.0°F
57	49.19 ± 23.84°F	-1.83 ± 19.91°F	150.48 ± 32.87°F	273.8 ± 42.0°F
58	48.61 ± 24.01°F	-2.32 ± 20.06°F	149.67 ± 33.10°F	272.8 ± 42.3°F
59	50.37 ± 14.76°F	-0.80 ± 12.33°F	151.92 ± 20.37°F	275.61 ± 26.05°F
60	51.4 ± 84.8°F	-0.9 ± 70.8°F	156.9 ± 117.2°F	282.7 ± 149.9°F
61	52.48 ± 24.10°F	0.92 ± 20.11°F	155.03 ± 33.32°F	279.6 ± 42.6°F
62	52.57 ± 33.47°F	0.92 ± 27.93°F	155.4 ± 46.3°F	280.2 ± 59.2°F
63	52.9 ± 85.2°F	0.3 ± 71.1°F	159.0 ± 117.9°F	285.5 ± 150.9°F
64	54.4 ± 85.6°F	1.5 ± 71.4°F	161.1 ± 118.6°F	288.2 ± 151.8°F
65	55.53 ± 24.35°F	3.46 ± 20.30°F	159.25 ± 33.74°F	285.0 ± 43.2°F
66	55.8 ± 86.0°F	2.7 ± 71.7°F	163.1 ± 119.3°F	290.7 ± 152.7°F
67	57.30 ± 15.11°F	4.99 ± 12.59°F	161.52 ± 20.96°F	287.89 ± 26.83°F
68	59.58 ± 34.27°F	6.75 ± 28.52°F	165.2 ± 47.6°F	292.7 ± 61.0°F
69	61.05 ± 24.81°F	8.05 ± 20.64°F	166.92 ± 34.51°F	294.9 ± 44.2°F
70	63.31 ± 15.42°F	9.99 ± 12.82°F	169.88 ± 21.49°F	298.60 ± 27.51°F
71	63.58 ± 25.02°F	10.15 ± 20.79°F	170.45 ± 34.86°F	299.4 ± 44.6°F
72	64.15 ± 25.30°F	10.62 ± 21.02°F	171.25 ± 35.27°F	300.4 ± 45.2°F
73	65.98 ± 25.22°F	12.15 ± 20.94°F	173.81 ± 35.21°F	303.7 ± 45.1°F
74	65.66 ± 34.97°F	11.80 ± 29.04°F	173.7 ± 48.8°F	303.6 ± 62.5°F
75	68.60 ± 15.69°F	14.38 ± 13.02°F	177.26 ± 21.95°F	308.05 ± 28.13°F
76	68.26 ± 25.41°F	14.03 ± 21.08°F	176.99 ± 35.53°F	307.8 ± 45.5°F
77	71.00 ± 35.59°F	16.22 ± 29.51°F	181.2 ± 49.9°F	313.2 ± 63.9°F
78	72.49 ± 25.76°F	17.54 ± 21.35°F	182.93 ± 36.14°F	315.4 ± 46.3°F
79	74.47 ± 25.93°F	19.18 ± 21.47°F	185.72 ± 36.43°F	318.9 ± 46.7°F
80	75.2 ± 171.9°F	15.7 ± 142.5°F	201.9 ± 242.5°F	343.2 ± 311.8°F
81	76.38 ± 26.09°F	20.76 ± 21.59°F	188.41 ± 36.71°F	322.4 ± 47.1°F
82	77.63 ± 16.17°F	21.85 ± 13.37°F	189.94 ± 22.77°F	324.31 ± 29.21°F
83	78.21 ± 26.25°F	22.28 ± 21.71°F	190.99 ± 36.98°F	325.7 ± 47.5°F
84	80.13 ± 36.66°F	23.77 ± 30.30°F	194.0 ± 51.7°F	329.7 ± 66.4°F
85	81.57 ± 16.37°F	25.11 ± 13.53°F	195.51 ± 23.13°F	331.46 ± 29.69°F
86	81.66 ± 26.55°F	25.13 ± 21.93°F	195.87 ± 37.50°F	332.0 ± 48.1°F
87	83.31 ± 26.69°F	26.48 ± 22.03°F	198.20 ± 37.74°F	335.0 ± 48.5°F
88	84.13 ± 37.14°F	27.07 ± 30.66°F	199.7 ± 52.6°F	337.0 ± 67.5°F
89	85.24 ± 16.57°F	28.14 ± 13.67°F	200.70 ± 23.47°F	338.12 ± 30.14°F
90	84.90 ± 26.83°F	27.80 ± 22.14°F	200.46 ± 37.98°F	337.9 ± 48.8°F
91	84.93 ± 27.08°F	27.82 ± 22.35°F	200.50 ± 38.35°F	337.9 ± 49.2°F
92	86.44 ± 26.96°F	29.07 ± 22.23°F	202.64 ± 38.22°F	340.7 ± 49.1°F
93	88.63 ± 16.75°F	30.94 ± 13.81°F	205.51 ± 23.79°F	344.31 ± 30.56°F
94	87.83 ± 37.58°F	30.12 ± 30.99°F	205.0 ± 53.3°F	343.8 ± 68.5°F
95	91.27 ± 38.00°F	32.95 ± 31.29°F	209.9 ± 54.1°F	350.1 ± 69.5°F
96	92.72 ± 27.76°F	34.23 ± 22.85°F	211.6 ± 39.5°F	352.2 ± 50.8°F
97	94.78 ± 17.08°F	36.00 ± 14.05°F	214.27 ± 24.37°F	355.57 ± 31.34°F
98	97.60 ± 17.24°F	38.31 ± 14.16°F	218.30 ± 24.64°F	360.75 ± 31.70°F
99	97.49 ± 38.76°F	38.06 ± 31.85°F	218.8 ± 55.4°F	361.5 ± 71.3°F
100	100.28 ± 17.39°F	40.52 ± 14.27°F	222.14 ± 24.90°F	365.70 ± 32.05°F
101	99.49 ± 28.37°F	39.79 ± 23.29°F	221.3 ± 40.6°F	364.6 ± 52.3°F
102	100.35 ± 39.11°F	40.40 ± 32.11°F	222.9 ± 56.0°F	366.8 ± 72.1°F
103	102.82 ± 17.53°F	42.60 ± 14.38°F	225.79 ± 25.15°F	370.39 ± 32.38°F

Range	Equation 200	Equation 201	Equation 202	Equation 203
104	103.1 ± 39.4°F	42.62 ± 32.35°F	226.8 ± 56.6°F	371.9 ± 72.9°F
105	105.44 ± 28.91°F	44.68 ± 23.69°F	229.8 ± 41.6°F	375.7 ± 53.5°F
106	105.6 ± 39.8°F	44.73 ± 32.59°F	230.5 ± 57.2°F	376.6 ± 73.7°F
107	107.55 ± 17.79°F	46.47 ± 14.57°F	232.59 ± 25.62°F	379.15 ± 33.00°F
108	107.9 ± 189.3°F	41.9 ± 155.2°F	252.4 ± 273.8°F	409.4 ± 353.8°F
109	109.77 ± 17.91°F	48.29 ± 14.66°F	235.79 ± 25.84°F	383.27 ± 33.30°F
110	110.4 ± 40.4°F	48.64 ± 33.02°F	237.4 ± 58.3°F	385.6 ± 75.1°F
111	111.90 ± 18.03°F	50.04 ± 14.75°F	238.87 ± 26.05°F	387.25 ± 33.58°F
112	112.7 ± 40.6°F	50.48 ± 33.23°F	240.7 ± 58.8°F	389.8 ± 75.8°F
113	113.95 ± 18.15°F	51.71 ± 14.83°F	241.84 ± 26.26°F	391.07 ± 33.86°F
114	115.64 ± 29.84°F	53.01 ± 24.37°F	244.6 ± 43.2°F	394.7 ± 55.8°F
115	114.8 ± 40.9°F	52.24 ± 33.43°F	243.8 ± 59.3°F	393.8 ± 76.4°F
116	117.82 ± 18.37°F	54.87 ± 14.99°F	247.45 ± 26.65°F	398.31 ± 34.39°F
117	116.9 ± 41.2°F	53.93 ± 33.62°F	246.9 ± 59.7°F	397.7 ± 77.1°F
118	119.66 ± 18.47°F	56.37 ± 15.06°F	250.12 ± 26.84°F	401.76 ± 34.64°F
119	120.10 ± 30.25°F	56.65 ± 24.67°F	251.1 ± 44.0°F	403.1 ± 56.8°F
120	121.45 ± 18.57°F	57.82 ± 15.14°F	252.72 ± 27.03°F	405.11 ± 34.89°F
121	120.8 ± 41.7°F	57.13 ± 33.99°F	252.6 ± 60.6°F	405.1 ± 78.3°F
122	123.17 ± 18.67°F	59.23 ± 15.21°F	255.23 ± 27.21°F	408.36 ± 35.13°F
123	122.7 ± 41.9°F	58.64 ± 34.16°F	255.3 ± 61.1°F	408.6 ± 78.9°F
124	124.25 ± 30.64°F	60.03 ± 24.95°F	257.1 ± 44.7°F	410.9 ± 57.7°F
125	124.5 ± 42.2°F	60.11 ± 34.33°F	258.0 ± 61.5°F	412.1 ± 79.4°F
126	126.2 ± 42.4°F	61.53 ± 34.49°F	260.5 ± 61.9°F	415.4 ± 80.0°F
127	128.10 ± 31.00°F	63.15 ± 25.22°F	262.8 ± 45.3°F	418.2 ± 58.6°F
128	128.9 ± 200.7°F	58.4 ± 163.5°F	285.6 ± 295.1°F	453.3 ± 382.7°F
129	134.1 ± 149.3°F	65.2 ± 121.3°F	283.4 ± 219.9°F	448.0 ± 284.9°F
130	135.07 ± 31.67°F	68.82 ± 25.70°F	273.0 ± 46.6°F	431.4 ± 60.2°F
131	138.28 ± 31.97°F	71.41 ± 25.92°F	277.7 ± 47.1°F	437.6 ± 61.0°F
132	141.33 ± 32.27°F	73.88 ± 26.13°F	282.3 ± 47.7°F	443.4 ± 61.7°F
133	144.21 ± 32.55°F	76.22 ± 26.33°F	286.5 ± 48.2°F	448.9 ± 62.4°F
134	149.59 ± 33.07°F	80.56 ± 26.71°F	294.5 ± 49.2°F	459.3 ± 63.7°F
135	152.12 ± 33.32°F	82.60 ± 26.88°F	298.3 ± 49.6°F	464.2 ± 64.4°F
136	154.56 ± 33.56°F	84.56 ± 27.06°F	302.0 ± 50.1°F	468.9 ± 65.0°F
137	156.89 ± 33.79°F	86.44 ± 27.22°F	305.5 ± 50.5°F	473.5 ± 65.5°F
138	157.4 ± 216.9°F	80.8 ± 175.0°F	332.3 ± 326.0°F	515 ± 425°F
139	161.31 ± 34.23°F	89.99 ± 27.54°F	312.1 ± 51.3°F	482.1 ± 66.7°F
140	163.41 ± 34.44°F	91.68 ± 27.69°F	315.2 ± 51.7°F	486.2 ± 67.2°F
141	165.45 ± 34.65°F	93.32 ± 27.83°F	318.3 ± 52.1°F	490.2 ± 67.7°F
142	167.42 ± 34.85°F	94.90 ± 27.97°F	321.3 ± 52.5°F	494.1 ± 68.2°F
143	168.3 ± 223.1°F	89.2 ± 179.4°F	350.5 ± 338.4°F	540 ± 442°F
144	172.5 ± 166.2°F	95.5 ± 133.3°F	344.2 ± 252.1°F	528.0 ± 328.8°F
145	174.3 ± 155.5°F	97.4 ± 124.7°F	344.9 ± 236.1°F	528.5 ± 308.0°F
146	177.9 ± 228.7°F	96.6 ± 183.3°F	366.7 ± 349.4°F	562 ± 457°F
147	186.4 ± 233.7°F	103.1 ± 186.8°F	381.2 ± 359.5°F	581 ± 471°F
148	197.1 ± 177.4°F	114.7 ± 141.2°F	384.4 ± 274.4°F	581.6 ± 359.5°F
149	201.0 ± 242.4°F	114.3 ± 192.9°F	406.7 ± 377.3°F	616 ± 496°F
150	207.5 ± 246.3°F	119.2 ± 195.6°F	418.1 ± 385.4°F	631 ± 507°F
151	213.5 ± 250.0°F	123.8 ± 198.1°F	429 ± 393°F	646 ± 518°F
152	217.6 ± 174.4°F	131.1 ± 137.9°F	415.9 ± 274.0°F	623.0 ± 360.2°F
153	219.2 ± 253.4°F	128.0 ± 200.5°F	439 ± 400°F	660 ± 528°F
154	229.5 ± 259.8°F	135.8 ± 204.8°F	458 ± 414°F	685 ± 547°F
155	230.9 ± 193.5°F	140.8 ± 152.3°F	441.4 ± 307.3°F	658 ± 405°F

Range	Equation 200	Equation 201	Equation 202	Equation 203
156	234.3 ± 262.7°F	139.4 ± 206.8°F	466 ± 420°F	697 ± 556°F
157	238.8 ± 265.5°F	142.8 ± 208.8°F	475 ± 426°F	708 ± 565°F
158	243.9 ± 199.8°F	150.6 ± 156.6°F	463.8 ± 320.6°F	688 ± 424°F
159	243.2 ± 268.2°F	146.0 ± 210.6°F	483 ± 432°F	720 ± 573°F
160	245.6 ± 187.2°F	152.6 ± 146.7°F	463.6 ± 300.6°F	687 ± 397°F
161	251.3 ± 273.3°F	152.1 ± 214.1°F	498 ± 443°F	740 ± 589°F
162	255.1 ± 275.7°F	154.9 ± 215.7°F	505 ± 449°F	750 ± 596°F
163	255.2 ± 205.4°F	159.3 ± 160.5°F	483.7 ± 332.6°F	715 ± 441°F
164	258.8 ± 278.1°F	157.7 ± 217.3°F	512 ± 454°F	760 ± 604°F
165	262.4 ± 280.4°F	160.3 ± 218.8°F	519 ± 459°F	769 ± 611°F
166	265.3 ± 210.4°F	166.9 ± 163.9°F	501.6 ± 343.6°F	740 ± 456°F
167	269.2 ± 284.7°F	165.3 ± 221.7°F	532 ± 468°F	787 ± 625°F
168	272.4 ± 286.7°F	167.7 ± 223.1°F	538 ± 473°F	796 ± 632°F
169	275.6 ± 288.8°F	170.0 ± 224.5°F	544 ± 478°F	805 ± 638°F
170	278.6 ± 290.7°F	172.3 ± 225.8°F	550 ± 482°F	813 ± 645°F
171	282.8 ± 219.3°F	180.1 ± 169.9°F	533.2 ± 363.2°F	783 ± 484°F
172	284.3 ± 205.5°F	181.9 ± 159.1°F	531.8 ± 340.4°F	780 ± 454°F
173	290.6 ± 223.3°F	185.9 ± 172.6°F	547.4 ± 372.2°F	802 ± 497°F
174	297.8 ± 227.1°F	191.3 ± 175.1°F	560.8 ± 380.7°F	821 ± 509°F
175	299.1 ± 212.7°F	193.0 ± 163.9°F	558.9 ± 356.7°F	817 ± 477°F
176	304.6 ± 230.6°F	196.3 ± 177.4°F	573.4 ± 388.7°F	838 ± 521°F
177	312.2 ± 219.2°F	202.8 ± 168.2°F	583.1 ± 371.5°F	850 ± 498°F
178	317.0 ± 237.1°F	205.5 ± 181.7°F	597 ± 404°F	871 ± 542°F
179	322.7 ± 240.2°F	209.7 ± 183.7°F	608 ± 411°F	886 ± 553°F
180	323.9 ± 225.1°F	211.5 ± 172.1°F	605.0 ± 385.1°F	881 ± 518°F
181	328.2 ± 243.1°F	213.7 ± 185.7°F	618 ± 418°F	900 ± 563°F
182	333.4 ± 245.9°F	217.6 ± 187.5°F	628 ± 425°F	915 ± 573°F
183	343.2 ± 251.2°F	224.7 ± 191.0°F	647 ± 437°F	941 ± 591°F
184	344.2 ± 235.4°F	226.4 ± 178.9°F	644 ± 410°F	935 ± 553°F
185	347.8 ± 253.7°F	228.1 ± 192.6°F	656 ± 443°F	954 ± 600°F
186	352.3 ± 256.2°F	231.4 ± 194.2°F	665 ± 449°F	967 ± 609°F
187	353.2 ± 240.0°F	233.0 ± 181.9°F	661 ± 421°F	959 ± 570°F
188	356.6 ± 258.5°F	234.5 ± 195.8°F	674 ± 455°F	979 ± 617°F
189	361.6 ± 244.4°F	239.2 ± 184.7°F	678 ± 432°F	982 ± 586°F
190	364.8 ± 263.1°F	240.4 ± 198.7°F	690 ± 466°F	1002 ± 634°F
191	369.5 ± 248.6°F	244.9 ± 187.4°F	694 ± 442°F	1004 ± 601°F
192	368.8 ± 265.3°F	243.3 ± 200.1°F	698 ± 472°F	1013 ± 642°F
193	372.6 ± 267.4°F	246.1 ± 201.5°F	706 ± 477°F	1024 ± 650°F
194	376.3 ± 269.5°F	248.7 ± 202.8°F	714 ± 482°F	1035 ± 657°F
195	384.0 ± 256.3°F	255.4 ± 192.4°F	723 ± 461°F	1046 ± 629°F
196	390.7 ± 259.8°F	260.2 ± 194.7°F	736 ± 470°F	1065 ± 643°F
197	397.2 ± 263.3°F	264.8 ± 196.9°F	750 ± 479°F	1084 ± 656°F
198	403.3 ± 266.6°F	269.2 ± 199.0°F	762 ± 488°F	1102 ± 669°F
199	414.8 ± 272.9°F	277.5 ± 203.0°F	787 ± 504°F	1137 ± 693°F
200	420.3 ± 275.9°F	281.4 ± 204.9°F	798 ± 512°F	1154 ± 705°F
201	425.6 ± 278.8°F	285.1 ± 206.7°F	810 ± 520°F	1170 ± 717°F
202	430.7 ± 281.6°F	288.7 ± 208.5°F	821 ± 527°F	1186 ± 729°F
203	440.4 ± 287.0°F	295.6 ± 211.8°F	842 ± 542°F	1217 ± 751°F
204	445.0 ± 289.6°F	298.9 ± 213.5°F	852 ± 549°F	1232 ± 762°F
205	449.6 ± 292.2°F	302.0 ± 215.1°F	862 ± 556°F	1246 ± 773°F

1.9   APPENDIX B   Sample Rates

Sample Rates

1.9.1   How a Data Logger Stores Readings

The sample rate of your data logger is the frequency with which it stores readings in its memory. A selected sample will apply for all channels on a SmartReader Plus.

If you set your data logger's sample rate to eight seconds, it reads its input channels and stores the readings once every eight seconds. If you choose a sample rate longer than eight seconds, the logger still reads its input channels once every eight seconds, and stores an averaged reading at the end of the sample interval you have chosen.

For example, if you use a two-minute sample rate, the data logger takes fifteen separate readings over each two-minute interval. At the end of each two-minute interval, the logger calculates the average of the fifteen readings, and stores that average in its memory.

1.9.2   Sample Rate Table

The following table lists the maximum time spans over which your OWL Logger will record readings. The time spans depend on the length of the sample rate. An OWL Logger has a memory capacity of 32,767 readings.

In the table, the *Sample Rate* column lists the available sample rates. The *Days, Hours, Minutes ,*and *Seconds* columns list the time spans over which your logger will record readings at each sample rate.

For example, an OWL Logger, using a sample rate of ten minutes, will store readings for 227 days, 13 hours and 10 minutes. After that time, depending on how it was set up, the logger will either continue to take readings and replace the oldest readings with the new readings, or it will stop taking readings.

Table B-1: OWL Logger Sample Rate

Sample Rate	Days	Hours	Minutes	Seconds
8 sec.	3	0	48	0
20 sec.	7	14	2	0
1 min.	22	18	7	0
2 min.	45	12	14	0
5 min.	113	18	35	0
10 min.	227	13	10	0

20 min.	455	2	20	0
30 min.	682	15	30	0

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