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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, by TrendReader Software, on any IBM PC or 100% compatible computer.



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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

Software for the OWL includes:

- easy mode for non-technical users
- advanced options such as:
  1. stop when full or first-in first-out data storage
  2. time delayed startup
- high and low trigger points
- variable memory size
- programmable identification
- TrendReader™ interface
- optical wand for logger setup and data retrieval

1.2 Description

OWL Data Loggers™ record readings continuously at a fixed sample interval. Using an optical data link, it transfers these readings to an IBM PC or 100% compatible computer for analysis with ACR's TrendReader™ software. Self-contained operation and its small size permit easy installation. The internal lithium battery lasts typically 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.

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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 readings 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.

1.4 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 the PC. *The software section of this reference guide explains in detail how to configure your PC's communication port with your 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.

*see figure 1, next page

Set Sampling Rate

Always confirm the sampling 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 double clicking your mouse on the com port icon, pointing the wand at the logger, and select Setup, Sample Rate in TrendReader Software. You may choose any value between 8 seconds and 34 minutes in 4 second increments. The menu gives you the number of seconds to enter for the most common intervals: 8 seconds, 20 seconds, 1 minute, 2 minutes, 5 minutes, 10 minutes and 30 minutes. In fast read mode intervals between 0.2 and 10 seconds may be chosen.

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

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How long do I need to record data?
How much time will elapse between when I retrieve the logger(s) and download the data to my computer (i.e. the trip back to the office)?
How often do readings need to be taken?

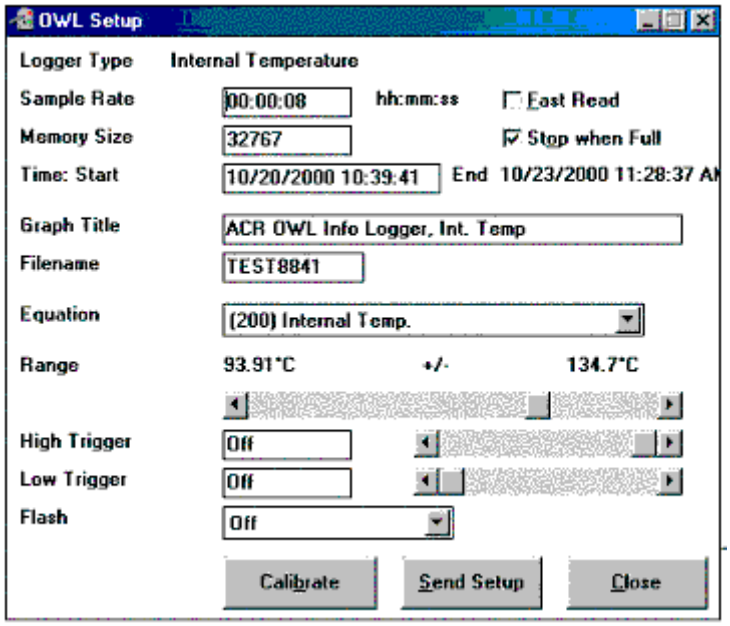


Figure 1

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, empty the logger memory. This will help to 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 (i.e. assign different equations, change filename, etc.)

Test

You can directly read the values that your OWL Data Logger is sensing by Examining the logger. To do this, double click on the com port icon, and point the LIC-101 wand at the logger's optical port. The current reading will be displayed. To retrieve updated readings, choose Close, then repeat the previous steps. You must examine the logger at intervals longer than the sample rate to retrieve a valid reading. (See Fig. 2.)

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.

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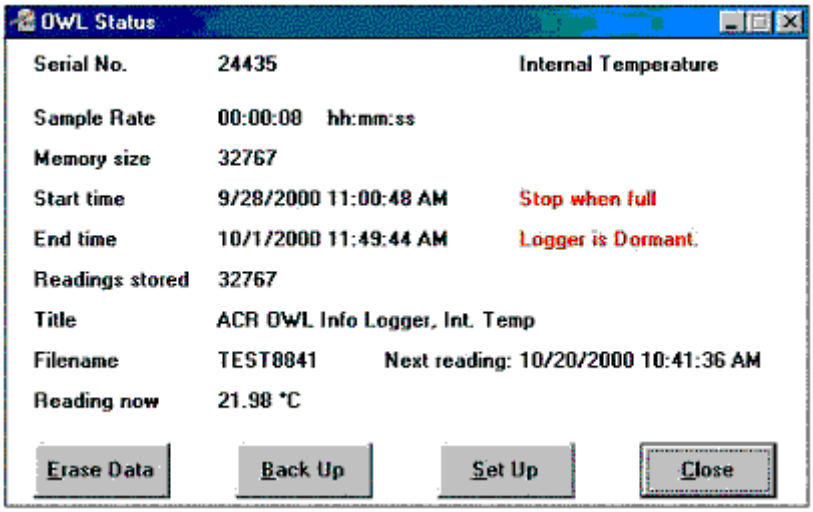


Figure 2

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, make sure to lock your logger to a permanent fixture using the special locking tab. Or take advantage of the OWL's small size and hide it completely out of view. Because OWL Data Loggers are so light, you can use special mounting methods like Velcro® fasteners to secure them to just about any surface. At any rate, make sure your logger is securely mounted to last the full length of your data logging session.

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

Keep Track

Be sure to keep a record of *where* you've placed each logger on a plan of the building or system. That way you'll save time in looking for them when your data-gathering session is over. Also, keep track of *when* you placed the loggers in the area you're monitoring. It will help when producing graphs on your computer.

Retrieval

After sufficient time has passed for you to obtain a representative profile of data, retrieve the logger and bring it back *immediately* to your computer for analysis.

Analysis

To analyze your OWL Data Logger, you must first backup the logger's data onto your computer. To do this, double click on the com port icon, Backup. The logged data is automatically saved to disk, time and date-stamped, and converted into the appropriate measurement units.

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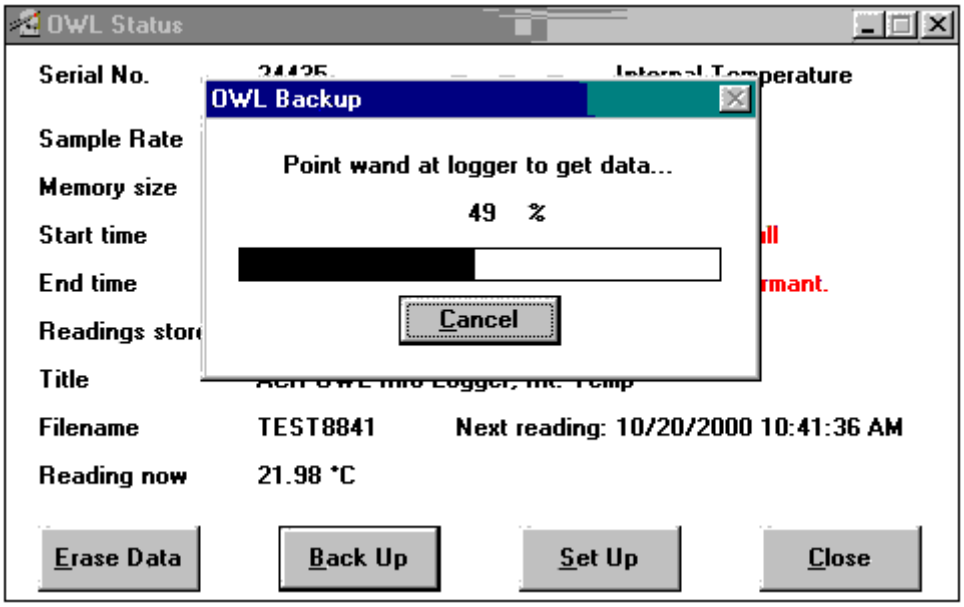


Figure 3

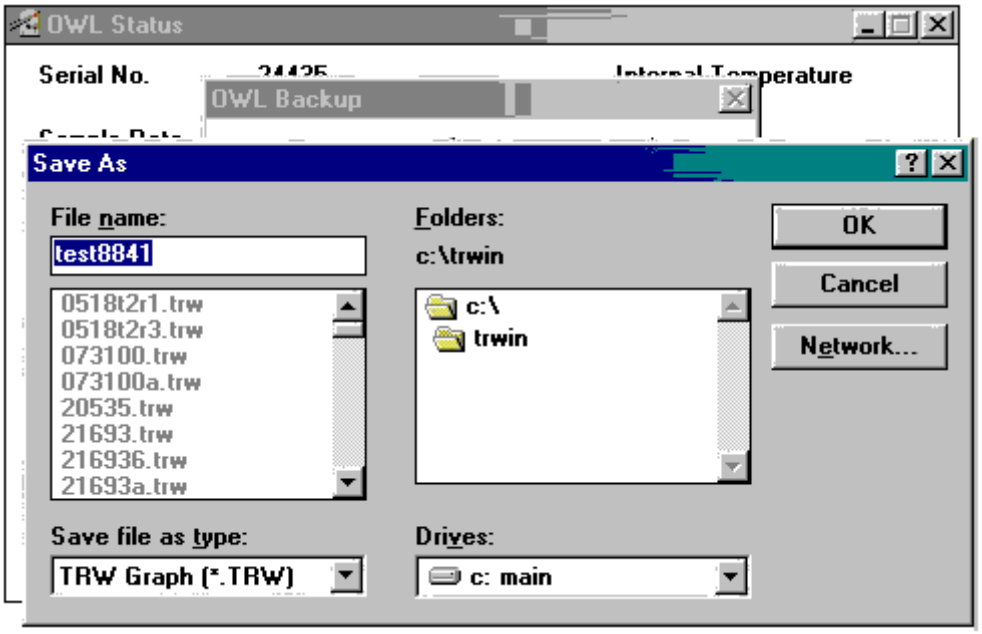


Figure 4

1.6 General Specifications

General

Size: 60 x 48 x 19mm (2.4" x 1.9" x 0.75")

Case Material: Polyurethane

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Case Weight:	80g (2.8 oz.)
Snapcase Material:	Noryl Plastic
Snapcase Weight:	54g (1.9 oz.)
Operating Limits:	-40° to 85°C. (-40° to 185°F.) and 0 to 100% Relative Humidity
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
PC Requirements:	IBM PC or 100% compatible with TrendReader software
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 30 minutes.
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".

1.7 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.

1.8 How to use this Guide

This Reference Guide is designed to be used hand-in-hand with the TrendReader Software Reference Guide. To get the most from our products, please take the time to familiarize yourself with TrendReader software and TrendReader manual. This Reference Guide frequently refers to TrendReader conventions and procedures, so time taken here will be well spent.

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For important information on how all the OWL Data Loggers work and how to use them, read *Introduction to Owl Data Loggers*. It will give you a general overview of how the loggers work and how to set them up for your applications. Then read the chapter that deals specifically with the type of data logger model you have.

1.9 Comments and Suggestions

At ACR Systems, we are dedicated to providing you with quality data logging products. We value customer comments and use them to develop products that meet the needs of our users. Please send us any comments or suggestions you may have on our Data Loggers or TrendReader Software, by mail, phone, fax, or email.

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1.10 Limited Warranty

ACR Systems Inc. warrants its "ACR Data Loggers" to be free from defects in workmanship, material and components for three years from date of purchase provided they are not abused or subjected to detrimental conditions. Software is warranted for one year from the date of purchase to operate in accordance with its programmed instructions. It is not warranted to be error-free. If the product does not perform in accordance with this Limited Warranty, ACR will, at its discretion, either repair or replace the product free of charge. There will, however, be a charge for freight and Canadian Customs Clearance (if applicable). Any replacement hardware or software will be warranted for the remainder of the original warranty period. To the maximum extent permitted by applicable laws, ACR Systems Inc. disclaims all other warranties, either expressed or implied including but not limited to implied warranties of fitness for a particular application. In no event shall ACR Systems Inc. be liable for any inconveniences, loss, damages etc. whatsoever arising out of the use of this product.

ACR's policy is not to proceed with any repairs or replacement unless first discussed with ACR's Technical Support Analysts and an RMA (Return Material Authorization) number issued.

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2 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.

2.1 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 -40° to 85°C (-40° to 185°F).

2.2 Setup and Use

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

1. Run TrendReader Software and communicate with the logger from the OWL Main menu by pointing the flashing wand at the logger's optical port. Once the Status menu is displayed select the Setup option.

2. Make sure the Internal sensor equation is chosen. Then select a range that best fits the expected data (see Appendix A for a list).

Selecting the range

TrendReader enables you choose the size of a range and to choose a midpoint for a range. The advantages of taking these two steps are:

1. The smaller the size of a range the higher the resolution of the readings.

2. The readings closest to the midpoint of a temperature range are higher in resolution than those at each end of the range.

   The first number (on the left above the slider bar) is the midpoint of the range you want to measure, and the second number (on the right) is the size of that range.

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3. Refer to the TrendReader manual for other options.

4. To start the logging session, point the wand at the logger then select Send Setup.

2.3 Specifications

Internal Temp. Logger

Sensor type:	NTC thermistor 10Ω @ 25ºC (77ºF)
Range:	-40º to 85ºC (-40º to 185ºF)
Accuracy:	±0.5ºC @ 25ºC (±0.9ºF @ 77ºF)
Resolution:	0.05ºC (0.09ºF) to 0.5ºC (0.9ºF) @ Center 0.10ºC (0.18ºF) to 1.0ºC (1.8ºF) Effective 0.20ºC (0.36ºF) to 2.0ºC (3.6ºF) Outside ±87%

2.4 Applications

Applications

- testing and balancing HVAC systems
- monitoring temperature of perishable goods
- checking and settling tenant complaints
- providing environmental data
- verifying food processes

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3 OWL Temperature Data Logger (External Sensor)



Features

The OWL Temperature Data Logger with the External Sensor offers temperature recording in a small water-proof* 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.

3.1 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 (6 ft.) 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)

3.2 Setup and Use

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

1. Run TrendReader Software and communicate with the logger by double clicking the com port icon and pointing the wand at the logger's optical port. Once the Status menu is displayed select the Setup option.

2. Make sure the External Sensor equation corresponding to the probe attached to the logger is chosen - see Specifications. Then select a range that best fits the expected data (see Appendix A

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for a list).

Selecting the range
TrendReader enables you choose the size of a range and to choose a midpoint for a range. The advantages of taking these two steps are:

1. The smaller the size of a range the higher the resolution of the readings.

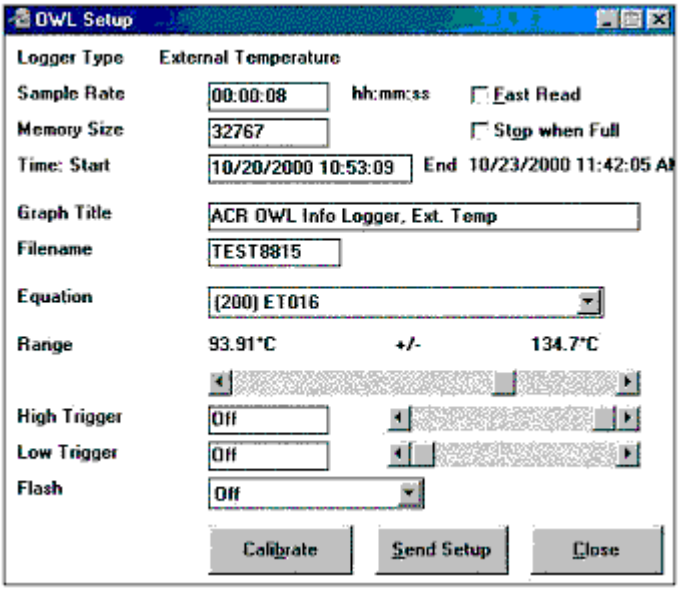


Figure 2.1

2. The readings closest to the midpoint of a temperature range are higher in resolution than those at each end of the range.

The first number (on the left above the slider bar) is the midpoint of the range you want to measure, and the second number (on the right) is the size of that range.

3. Refer to the TrendReader manual for other options.

4. To start the logging session, point the wand at the logger, then select Send Setup.

3. To start the logging session, point the wand at the logger, then select Send Setup.

3.3 Specifications

ET-016 General Purpose Probe

Description:	NTC thermistor and cable potted into the end of a 1" (25mm) long by 3/16" (5mm) diameter cylindrical stainless steel tip.
R25 Value:	10 KΩ
Range:	-35 to 95°C (-30 to 200°F)
Max Temp.:	150°C (300°F)

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Accuracy: ±0.2°C (±0.36°F) between 0 to 70°C (32 to 158°F)
±1.0°C (±1.8°F) between -80 to 150°C (-112 to 302°F)

Resolution: 0.05°C (0.09°F) to 0.5°C (0.9°F) @ Center
0.10°C (0.18°F) to 1.0°C (1.8°F) Effective
0.20°C (0.36°F) to 2.0°C (3.6°F) Outside ±87%

Cable: 8 m (26ft) standard length with Teflon® protective jacket, water-resistant / chemical-resistant splice, PVC jacket to IP67 connector.

Equation: 200

ET-004 Low Temperature Probe

Description: NTC thermistor and cable potted into the end of a 3-1/2" (89mm) long tapered stainless steel penetration tip with 3-1/2" (89mm) long by 3/4" (19 mm) diameter tapered plastic handle.

R25 Value: 2252 Ω

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 -80 to 150°C (-112 to 302°F)

Resolution: 0.05°C (0.09°F) to 0.5°C (0.9°F) @ Center
0.10°C (0.18°F) to 1.0°C (1.8°F) Effective
0.20°C (0.36°F) to 2.0°C (3.6°F) Outside ±87%

Cable: 5 m (16ft) standard length with Teflon® protective jacket, water-resistant / chemical-resistant splice, PVC jacket to IP67 connector.

Equation: 201

ET-081 High Temperature Probe

Description: NTC thermistor and cable potted into the end of a 1" (25mm) long by 3/16" (5mm) diameter cylindrical stainless steel tip.

R25 Value: 100 KΩ

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: 0.05°C (0.09°F) to 0.5°C (0.9°F) @ Center
0.10°C (0.18°F) to 1.0°C (1.8°F) Effective
0.40°C (0.72°F) to 4.0°C (7.2°F) Outside ±87%

Cable: 8 m (26ft) standard length with twisted-pair Teflon® insulated wire, water-resistant / chemical-resistant splice, PVC jacket to IP67

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connector.

Equation: 202

ET-086 Oven Temperature Probe

Description: NTC thermistor and cable potted into the end of a 1" (25mm) long by 3/16" (5mm) diameter cylindrical stainless steel tip.

R25 Value: 26.266 KΩ

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: 0.1°C (0.18°F) to 1.0°C (1.8°F) @ Center
0.2°C (0.36°F) to 2.0°C (3.6°F) Effective
0.5°C (0.9°F) to 5.0°C (9°F) Outside ±87%

Cable: 8 m (26ft) standard length with twisted-pair moisture-proof Teflon® coated glass yarn, water-resistant / chemical-resistant splice, PVC jacket to IP67 connector.

Equation: 203

3.4 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.

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4 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.

4.1 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. 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.

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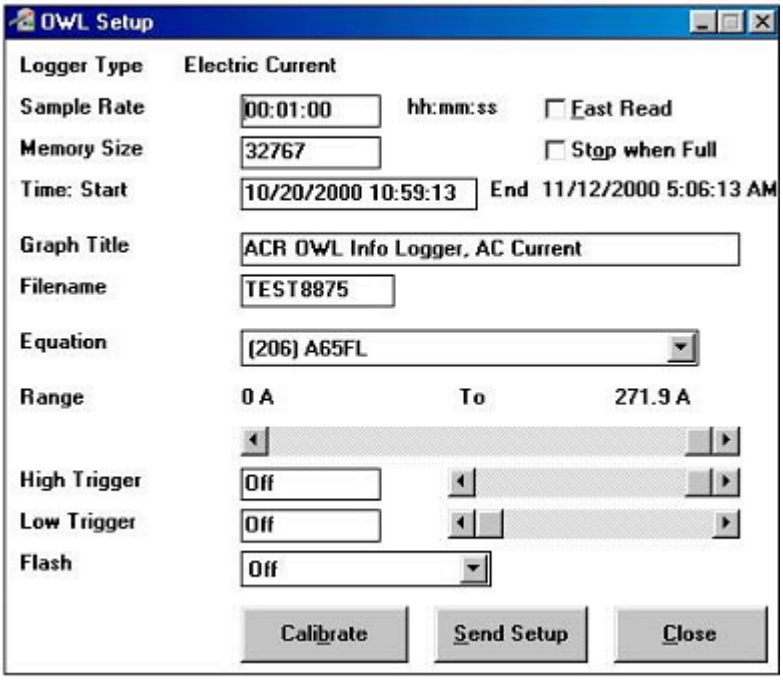


Figure 3.1

4.2 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 the 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 the probe to the next highest. To maximize the resolution of the readings, always choose the lowest range possible that will encompass the full range of data you want to record.

3. Run TrendReader Software and communicate with the logger by double clicking on the com port icon and pointing the flashing wand at the logger's optical port. Once the Status menu is displayed select the Setup option.

4. Make sure the equation number 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.

5. To start the logging session point the wand at the logger's optical sensor,then select Send Setup.

WARNING: DO NOT CHANGE RANGE SWITCH WITHOUT ALSO SETTING LOGGER

Table 3-2 Current Probe Ranges

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	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.

4.3 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, making 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

Monitor current ranges higher than those available on the standard probe by using it with an additional transformer. For this purpose Amprobe Instruments has available their Deca-Tran 10-to-1 Transformer (to monitor currents up to 600 amps) or, for even high measurements, 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.

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4.4 Specifications

Current Probes

Output Current: 260 µA full scale into 400 ohms.

Cable: 6 ft. (2m) length with PVC jacket to IP67 connector.

Accuracy: 2.5% of full scale.

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

4.5 Trouble-shooting

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 Table 3-2 for equations to use with the various current probes.
- If the equation numbers are correctly assigned and the measurements are still incorrect, it may be caused by poor resolution. To correct this, make sure the current range setting is the lowest possible that will encompass the readings. For example, do not use the 250 amp range on the A60FL or A65FL current probe for recording values below 25 amps. Use the 25 amp setting instead (it offers ten times the resolution of the 250 amp range).

4.6 Applications

- checking air conditioning and mechanical equipment
- auditing energy use in commercial buildings
- determining tenant electrical consumption
- tracking environmental conditions
- confirming control sequences

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5 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.

5.1 Description

The DC Voltage Logger can measure and record analog Direct Current 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 processed into voltage units by an equation in TrendReader Software.

5.2 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 communicate with the logger by double clicking on the com port icon and pointing the flashing wand at the logger's optical port. Once the Status menu is displayed select the Setup option - see Figure 4.2

3. Make sure the DC Voltage equation is chosen. Then select a range that best fits the expected data - see Table 4-1. DC Voltage ranges are picked to match the transducers 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.

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4. To start the logging session, point the wand at the logger then select Send Setup.

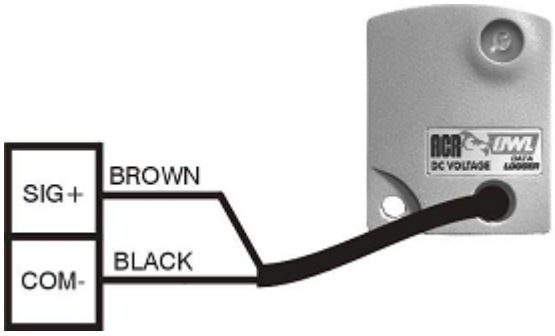


Figure 4.1: DC Voltage Wiring

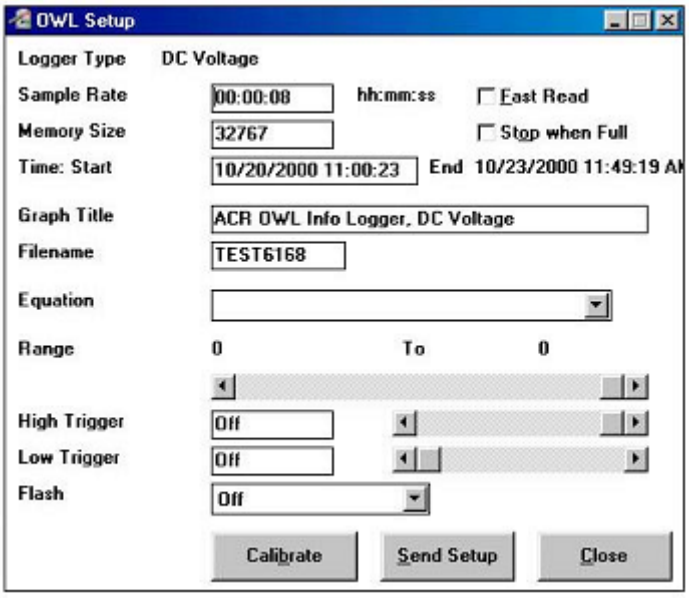


Figure 4.2

Table 4.1: DC Voltage Ranges

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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

5.3 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. For a transducer to be useful, the signal must be compatible with standard instrumentation. This is analog DC voltage for the OWL DC Voltage logger.

Many compatible transducers exist for measuring such variables as temperature, relative humidity, pressure, current, voltage, wind speed, pH and more. These can be obtained from many manufacturers and distributors.

To discern what to look for when choosing transducers, it is helpful to know a few technical terms and how they relate to measuring voltage.

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 as 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 a regulated power supply is needed.

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 impedance. This simply refers to how much resistance the instrumentation (for example, the OWL logger) can have before it will begin to affect the signal. 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 to ensure the OWL's input impedance is acceptable.

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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 4-3.

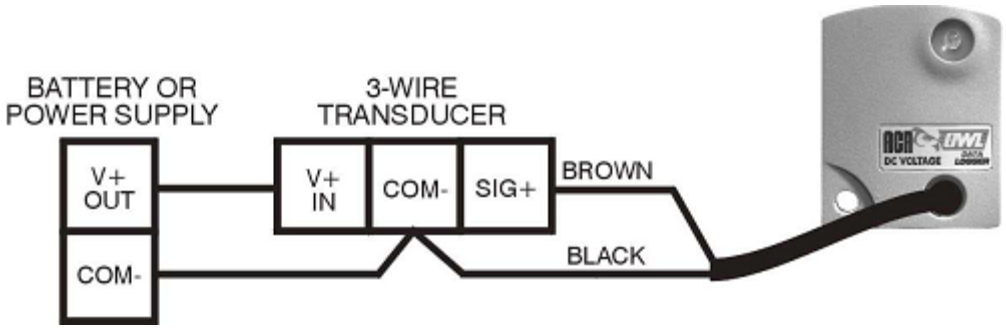


Figure 4-3: Three Wire Transducer Connection

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 4-4. The bridge transducer provides a differential output (+/-) usually in the millivolt range - see Figure 4-5.

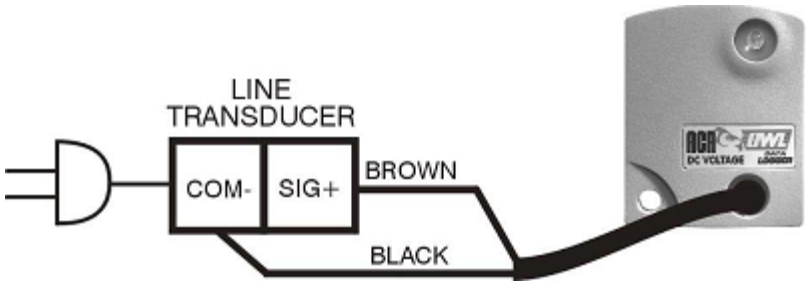
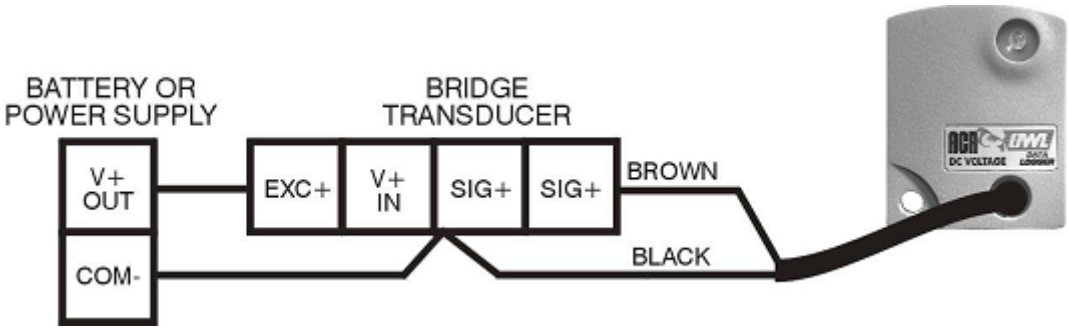


Figure 4-4: Line Type Transducer Connection



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Figure 4-5: 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.

5.4 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:	> 100 KΩ
Cable:	2m (6ft) length with PVC jacket to IP67 connector
Equation:	204

5.5 Applications

- monitoring transducer outputs
- checking process controller signals
- providing laboratory data
- determining random event times
- recording speed

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6 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.

6.1 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 0 to 24mA values by an equation in TrendReader Software.

6.2 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 communicate with the logger by double clicking on the com port icon and pointing the flashing wand at the logger's optical port. Once the Status menu is displayed select the Setup option - see Fig. 5-2A

3. Make sure the 20mA Current equation is chosen (#205 in DOS).

4. To start the logging session, point the wand at the logger then select Send Setup.

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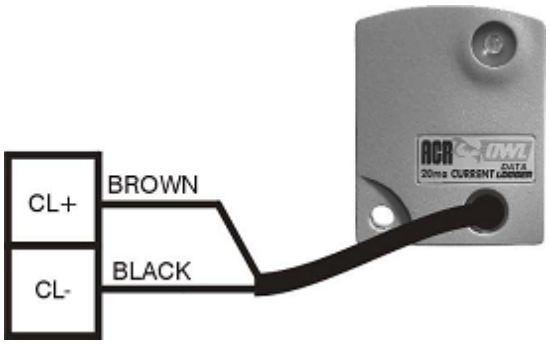


Figure 5-1: 20 mA Current Wiring

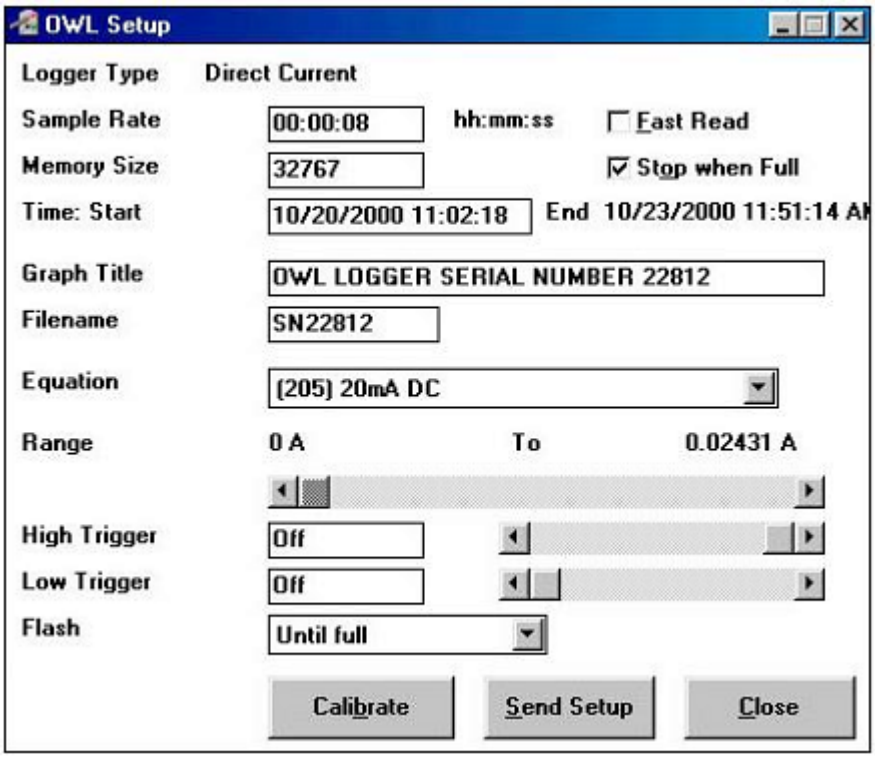


Figure 5-2A

6.3 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 transmitters exist for measuring such variables as temperature, relative humidity, pressure, current, voltage, wind speed, pH and more. These can be obtained from many manufactures and distributors.

To figure out what to look for when choosing transmitters, it is helpful to know a few technical terms associated with current loops.

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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.

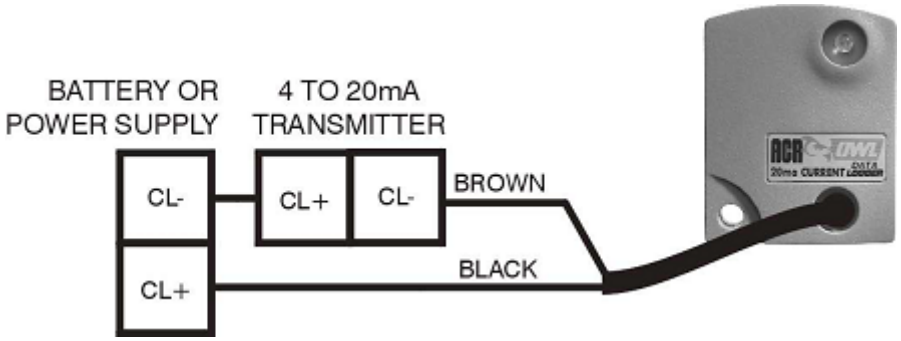


Figure 5-2: Two Wire Transmitter Connection

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.

6.4 Specifications

Current Input

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

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6.5 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

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7 OWL 200 and Custom Equations

The Owl Data Logger can also be used with other Negative Temperature Coefficient thermistor probes. Using Create Thermistor Equation in TrendReader For Windows, you can create an equation for situations where none of TrendReader's standard equations will work with the specific thermistor that you wish to use.

7.1 Creating a Thermistor Equation

Thermistor equations are for use with thermistor temperature sensors. To create a thermistor equation, choose Create Thermistor Equation from the Equation menu. The Thermistor Equations dialog box appears.

TrendReader assigns the first available equation number to the equation. This number appears in the Equation Number box (numbers 100 to 199 are reserved for custom equations).

The temperature is displayed in Celsius. (To change this to Fahrenheit or Kelvin, choose Units from the Options menu, then temperature and the unit of your choice).

Use your thermistor's temperature-resistance chart or your own calibration data to enter information in this dialog box.

1. In the Low temperature box, type a low temperature from your thermistor's temperature-resistance chart. (Use a temperature in the lower quarter of the chart's temperature data.)

2. In the corresponding Resistance box, type the corresponding resistance value for the low thermistor temperature.

3. In the Mid temperature box, type a temperature from the middle of your thermistor's temperature-resistance chart.

4. In the corresponding Resistance box, type the corresponding resistance value for the mid thermistor temperature.

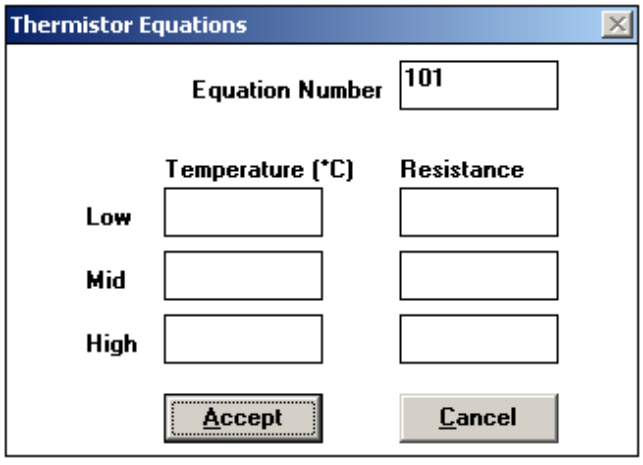


Figure 6.1

5. In the High temperature box, type a high temperature from your thermistor's temperature-resistance chart. (Use a temperature in the upper quarter of the chart's temperature data.)

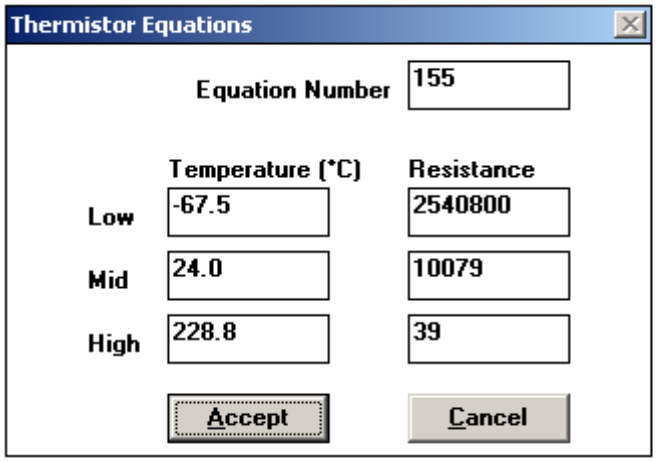
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6. In the corresponding Resistance box, type the corresponding resistance value for the high thermistor temperature.

7. Click Accept.

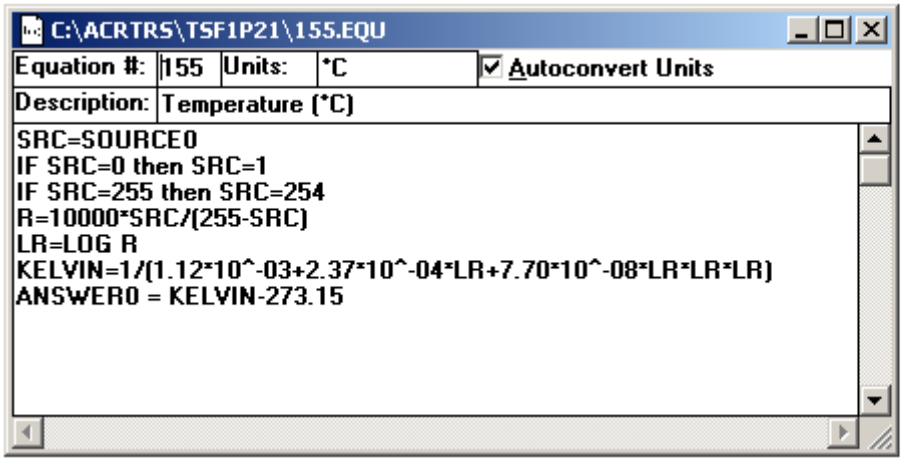
To see your equation, choose Open Equation from the Equation menu and select the equation number that TrendReader assigned to this equation from the Open Equation dialog box.

The equation generated will look like this:



An Example of 3 temperatures and their resistances

Figure 6.2



Entering three temperatures and their corresponding resistances, from the table provided by the manufacturer, (in this case, the ET-016 thermistor), yields an equation that looks like this.

Figure 6.3

The co-efficient from the thermistor equation that was created must be copied into the following equation using the variables listed above. From the created thermistor equation, the co-efficients found in the line 'KELVIN=' (in scientific notation) will now be entered into the line 'c=' in the following equation. This will now yield a calibrated thermistor reading for the specific thermistor. (in this example, the result will be the same as an ET-016 thermistor.

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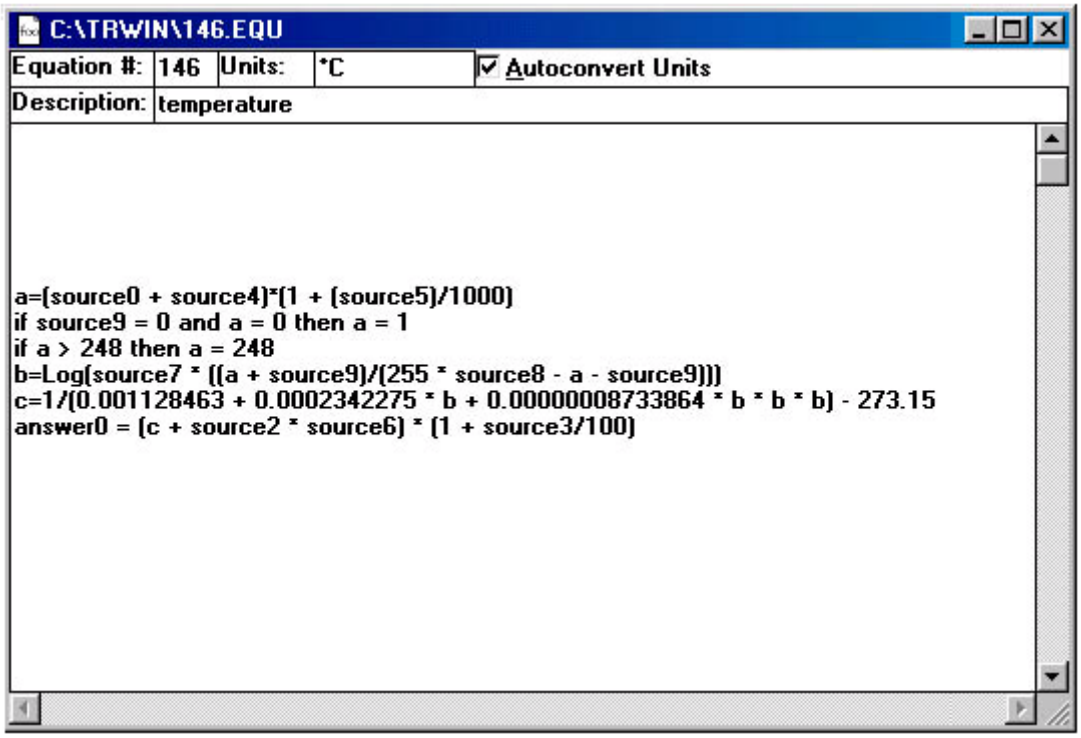


Figure 6.4

The input source variables for the OWL logger are listed in the following table:

Input source variable tables

Table 6-1: Input Source Variables for OWL Info Logger

Variable	Description
Source0	Internal reading between 0 and 248
Source1	Time in seconds between data points
Source2	Zero calibration value
Source3	Span calibration value
Source4	Factory zero calibration value
Source5	Factory span calibration value
Source6	Range size
Source7	Range resistor

7.2 OWL Calibration

Calibrating a logger is the process of adjusting it so that its readings correlate to the values it measures. Loggers are not calibrated at the factory.

If you want to calibrate the logger, click Calibrate to open the Calibrate dialog box.

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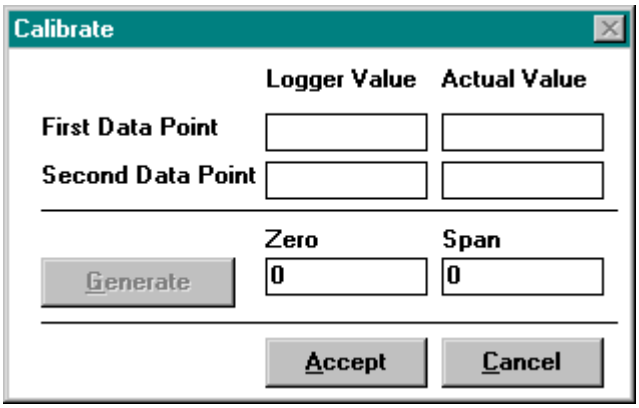


Figure 6-5

Please note that the range must be selected and saved before calibration. Calibration values only apply to that specific range.

You can calibrate OWLs by comparing them against values that you know to be accurate. When you have done this, you can enter the logger values and the actual values in the Calibrate dialog box.

For the two data points, choose two values that are as far apart as possible.

For example:

1. If you discover that at 100 the logger registers 100.3, type 100.3 as the First Data Point in the Logger Value box, and type 100 in the Actual Value box.

2. Then, if you discover that at 0 the logger registers 0.4, type 0.4 as the Second Data Point in the Logger Value box, and type 0 in the Actual Value box.

3. Click Generate. Values will appear in the Zero and Span boxes.

4. Click Accept.

This information still has to be sent to the logger.

5. Click Send Setup in the Setup window.

It is vital to follow the correct procedure when recalibrating an OWL. An OWL that has been calibrated will have values other than zero in the Zero and Span boxes. When you see values other than zero in the Zero and Span boxes, you must again test the logger's readings against readings that you know to be accurate before you enter any values in the Calibrate dialog box.

NOTE: Make sure range is set before you calibrate. Calibration only applies to that range.

To set the size of the range (not applied to OWL-500), click the left or right arrow (in OWL setup) until you find a range size that suits your purpose.

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8 APPENDIX A

APPENDIX

Temperature Ranges

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)

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

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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
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

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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
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

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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
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

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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

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

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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
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
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

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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
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

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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

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