FL-1

Thermal Analysis System

User Manual

SYSCON SENSORS

Contents

Foreword

Thank you for purchasing the SYSCON Sensors FL-1 Thermal Analysis System. This User's Manual contains useful information about the functions, installation, wiring, operating procedures, safety, and troubleshooting of the FL-1. The user should carefully read and understand the contents of this manual prior to the use of this equipment. Using the instrument in manner not specified in this User Manual can damage the instrument.

Keep this manual in a safe place for quick reference in the event a question arises.

SYSCON Sensors makes no warranties as to the contents of this documentation and specifically any implied warranties of merchantability or fitness for any particular purpose. SYSCON Sensors further reserves the right to alter the specifications of the product without obligation to notify any person or organization of these changes. All Company and Product names are trademarks of their respective holders.

Before You Start

NOTE	Contains important information for proper operation of the instrument
⚠	Identifies conditions that may cause damage to the instrument or large errors in measurement
☠	Identifies conditions which may cause damage to the user. To avoid injury or death of personnel, the operator must refer to the explanation in the User Manual
Software Version	1.04.02 Build 2

⚠ **NOTE**

This product contains electronic boards and components which may be damaged by electrostatic discharge (ESD). When handling, care must be taken so that the devices are not damaged. Damage due to inappropriate handling is not covered by the warranty.

⚠ **NOTE**

If the FL-1 Thermal Analysis System is opened by personnel unauthorized by SYSCON Sensors, the Warranty is null and void.

List of Figures

List of Tables

List of Symbols

Symbol	Unit	Description
Bath	°F	Bath Temperature
TPK	°F	Peak Temperature
TPL	°F	Temperature of Primary arrest or Liquidus Temperature
TEN	°F	Temperature of Eutectic Nucleation
TEU	°F	Temperature of Eutectic Undercooling
TPS	°F	Temperature of Eutectic arrest or Solidus Temperature
TER	°F	Temperature of Eutectic Recalescence
TES	°F	Temperature of Eutectic Solidification
CE	%	Carbon Equivalent
C	%	Carbon
Si	%	Silicon
dT	°F	Undercooling
Sc	%	Saturated Carbon
Rm	N/mm^2	Tensile Strength
BH	N/mm^2	Brinell Hardness
FPE[1]	°F/second	First peak on eutectic plateau on the first derivative of temperature with time
ASE[1]	°F/second	Average slope of second stage of eutectic solidification
SF1	second	Shrinkage Factor 1 Time taken for temperature to drop 27°F (13°C) from TER

[1] Refer Chen, I. G., and D. M. Stefanescu. "Computer-aided differential thermal analysis of spheroidal and compacted graphite cast irons." *AFS Transactions* 92 (1984): 947-964.

SF2	No units	Shrinkage Factor 2 Angle of the first derivative of temperature with time at TES
<Variable Name> ′	<Units of variable>/second	First derivative of variable with time
UV	User defined	User defined Variable

Introduction

The FL-1 Thermal Analysis System is a dedicated thermal analysis and bath temperature measurement instrument designed for foundries. It predicts Iron chemistry parameters such as % Carbon Equivalent (**CE**), % Silicon, and/or % Carbon from the cooling curve of molten Iron. The FL-1 also measures and stores the molten metal bath temperature. These parameters are used for process control to diagnose changes in the metallurgical quality of molten metal.

SYSCON Sensors designed the first industrial thermal analysis instrument in 1978 and has more than 50 years of expertise in designing industry leading instruments and analysis devices. Extensive customer feedback and historical data have been used to ensure the FL-1 gives successful results for a wide spectrum of melts.

The FL-1 Thermal Analysis System has the following features:

- Accurate and stable temperature readings in high electrical noise environments common in foundries
- Completely programmable for user-specific applications
- Statistical process control for advanced analysis
- 15" LCD Easy to read, glove friendly touch screen
- USB and Ethernet ports for data transfer and network connectivity
- Rugged and dust-proof box ideal for foundry environment

Specifications

Operating Temperature	0˚F -122˚F (-17°C -50˚C)
Input Power	100 - 240 V 60 Hz AC Input
Thermocouple Input Type	4 – (standard config: 3 Type K and 1 Type S
Calibration Standard	IPTS 48 and IPTS 68
Precision	0.1°C (Cold Junction Sensor)
Storage	1000 measurements per channel
Connectivity	USB Ethernet
Weight	22 lb (9.98 kg)
Dimensions	17" W x 13.5" H x 4" D(43 cm x 34 cm x 10 cm)

Application

The FL-1 Thermal Analysis System is used to measure molten metal temperatures for an immersion/batch or continuous mode of operation. The thermocouple type is determined by the temperature range of the molten metal and the desired accuracy. The color codes and operating temperature limits (ANSI 96.1 Standard) for types S, R, B and K are listed in **Table 1**. The temperature limits are for the thermocouple wire diameter of 24-gauge wire for type S, R, and B and 8-gauge for type K. Temperatures above the recommended temperature cause the thermocouple wires to melt, resulting in an open circuit causing the FL-1 to display an error message.

Table 1: Thermocouple comparison (types S, R, B, and K)2

Thermocouple Type	Common Name	Alloy Type $\frac{Positive\ end}{Negative\ end}$	Plug and Jack color	Wire color $\frac{Positive\ end}{Negative\ end}$	Maximum Temp. °F (°C)	Recommended Operating Temp. °F (°C)
S	**10%**	**Platinum Rhodium – 10%**	**Green**	**Black**	3214 (1600)	2640 (1450)
		Platinum		**Red**		
R	**13%**	**Platinum Rhodium – 13%**	**Green**	**Black**	2912 (1600)	2640 (1450)
		Platinum		**Red**		
B	**6 / 30 %**	**Platinum Rhodium – 30%**	**White**	**Gray**	3272 (1800)	3100 (1700)
		Platinum Rhodium – 6%		**Red**		
K	**Chromel - Alumel**	**Nickel - Chromium**	**Yellow**	**Yellow**	2460 (1350)	2300 (1260)

[2] Preston-Thomas, H. "The International Temperature Scale of 1990 (ITS-90)." Metrologia 27.1 (1990): 3

Setup

This chapter discusses the setup procedure of the FL-1 Thermal Analysis System. The front and side views of the FL-1, highlighting the input connections and mounting locations are discussed. General guidelines for electrical connections to the FL-1 are presented. The setup procedure is simple with only the input power and thermocouple connections required.

Layout

The FL-1 Thermal Analysis System is shipped in a specially constructed box with foam inserts to prevent damage during shipment. Open the box and remove the FL-1 instrument. Verify that the following components are present.

✓1 FL-1 Thermal Analysis System
✓1 100–240 V AC Power Cable
✓1 USB thumb drive

The front panel consists of a 15″ LCD touchscreen (see **Figure 1**). The panel is secured with a key latch and is hinged on the right side for ease of access and servicing. The FL-1 Thermal Analysis System is designed to operate between 0°F – 120°F (-17°C – 49°C).

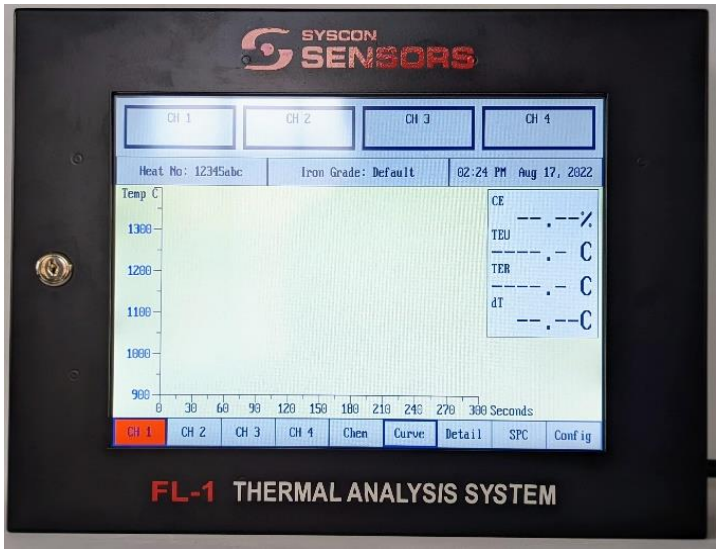


Figure 1: Front panel of FL-1

The right-side panel (see **Figure 2**) consists of AC Power input, 4 USB port, and 1 Ethernet port. The left-side panel (see **Figure 3**) consists of thermocouple inputs and a calibration port.

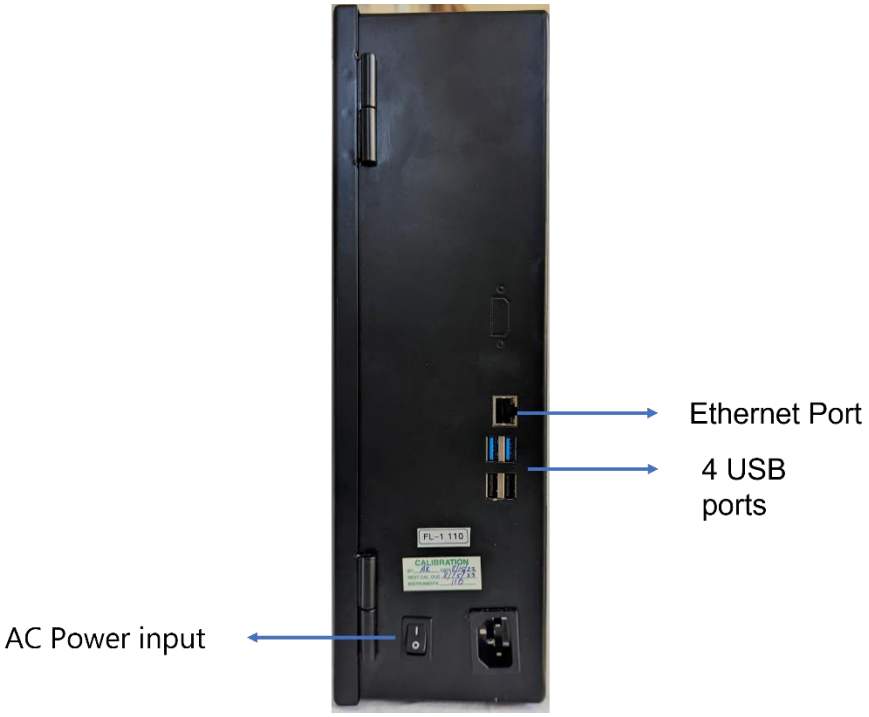


Figure 2: Right-side view of FL-1

NOTE

DO NOT operate the FL-1 Thermal analysis system above 130 °F (55 °C) since it may lead to internal electrical component failure.

Connectivity Ports

- 4 USB Ports

  The USB port is used to save Measured Data, User Programs, and Instrument settings or to restore User Programs and Instrument settings.

- 1 Ethernet port

The Ethernet port can be used to connect the FL-1 to a central plant network to monitor its operation and download (or save) Measured Data, User Programs, and Instrument settings; or to upload (or restore) User Programs and Instrument settings. It can also be used to connect the SYSCON Sensors Light Stack (LS-1) and the Scoreboard (SB-1).

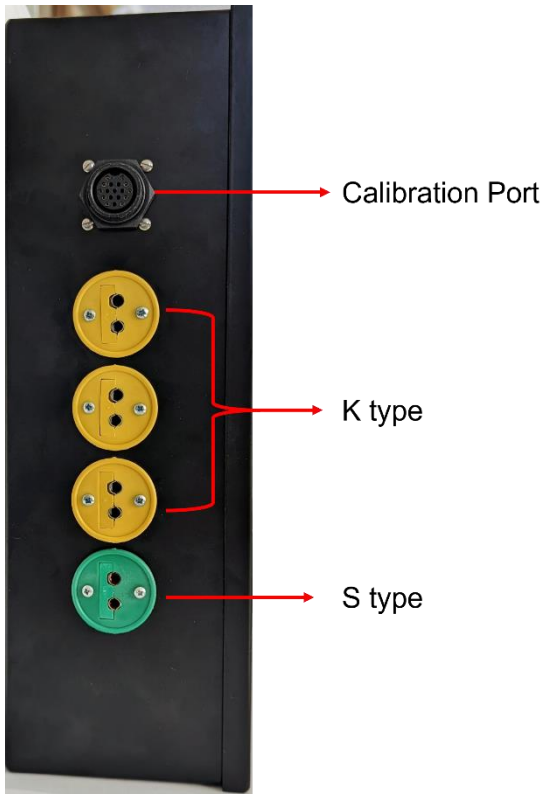


Figure 3: Left-side view of FL-1

Electrical and Thermocouple Wiring

The FL-1 Thermal Analysis System is designed to be used on a 100 - 240 V AC power source of 50 or 60 Hz frequency. Quick disconnect connectors are used to connect thermocouple inputs. The thermocouple input plug should match the type of thermocouple input panel otherwise, large errors (~100°F) may occur. When Type S, R, and/or K thermocouples are used, compensated lead wires must be used throughout. Serious errors will result when non-compensated lead wires (copper/copper) are used with these thermocouples.

For proper operation, it is essential that the proper polarity is maintained throughout the internal and extension wiring. Incorrect polarity results in additional thermocouple junctions, which leads to incorrect readings.

⚠ NOTE

Ensure that the FL-1 is properly grounded. Electrical noise in the power lines between current carrying conductors interferes with the operation.

A power line filter designed to eliminate this type of electrical noise may be required.

Contact SYSCON Sensors for assistance.

⚠ NOTE

The FL-1 Thermal Analysis System is pre-configured for a specific thermocouple input type and calibration standard. Large errors may result when the thermocouple mail connector is different from the female jack. Always be sure to use the correct thermocouple type for each port.

Mounting

The FL-1 Thermal Analysis System has the following mounting options:

1. VESA mount (100 mm X 100 mm pattern)
2. Surface mounting brackets (Removable)
3. Remove brackets and mount via mounting bracket mount holes.

All three options are labeled in **Figure 4.**

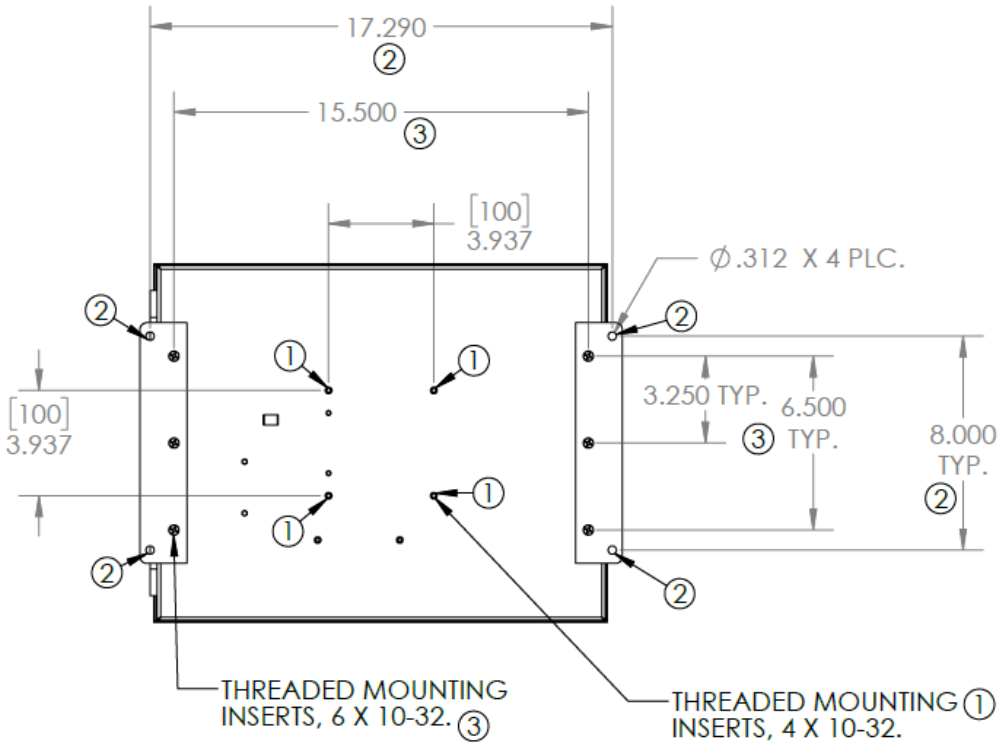


Figure 4: Mounting instructions

Operating Controls and Indicators

Home Screen

The home screen is the default screen displayed after the FL-1 boots up completely as shown in **Figure 5.** The overall layout of the display consists of:

- **Channel Status Indicator**
  Indicates status of measurement channels – Green for READY, Yellow for MEASURING, and Red for COMPLETE (Remove Cup).
- **ID bar**
  Displays Heat Number, Iron Grade, and Date & Time.
- **Main display**
  Displays the contents of the menu highlighted in Channel Menus.
- **Channel list**
  Enables the user to switch between Channels. Current channel highlighted in red color.
- **Channel Menus**
  Contains available options for each channel. The current menu is highlighted by blue border.

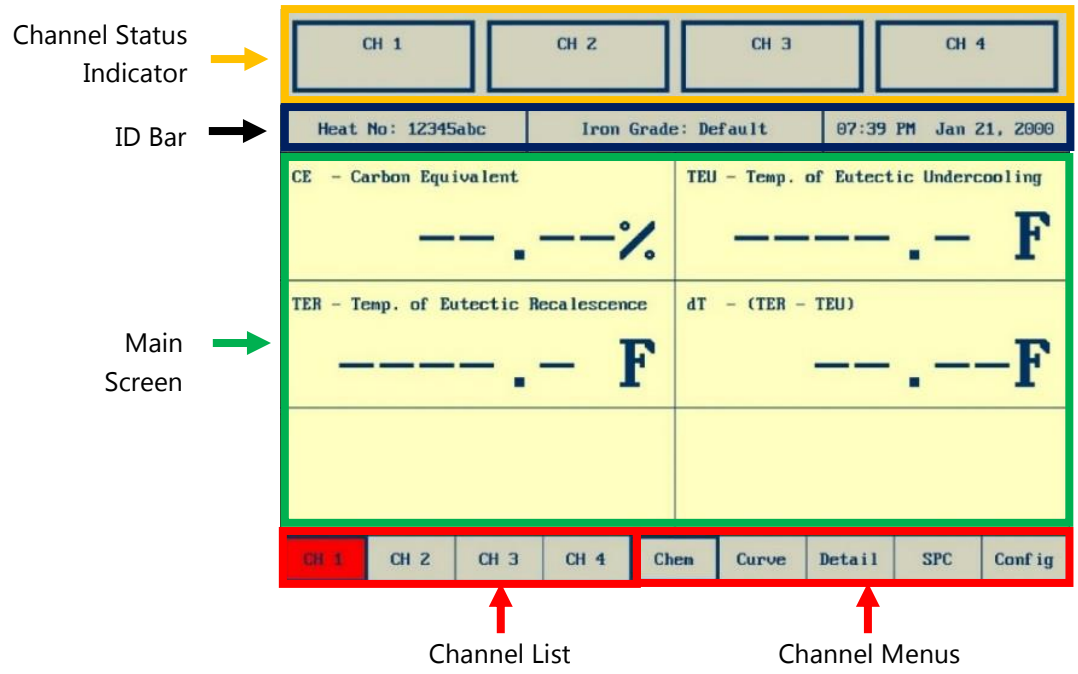


Figure 5: Main Screen

Channel Status Indicator

The measurement status is displayed for each channel with a colored (green, yellow, or red) rectangle on the display as shown in **Figure 6**. The meaning of the three colors for cup and bath temperature measurement are shown in **Table** 2 on the next page. If the box for a channel is unfilled as shown for Channel 1 in **Figure 6**, it implies that the FL-1 did not detect any thermocouple connected to that channel.

A good cup or probe (green light) implies that the electrical circuit that connects the thermocouples jacks to the contact block pins is complete. If the green READY light is not displayed, the thermocouple wire or the extension wires may be burnt out or the extension wire may not be in electrical contact with the contact block pins. The latter is frequently encountered with cups because of residue deposition on the cup stand. Refer to the chapter on **Maintenance**.

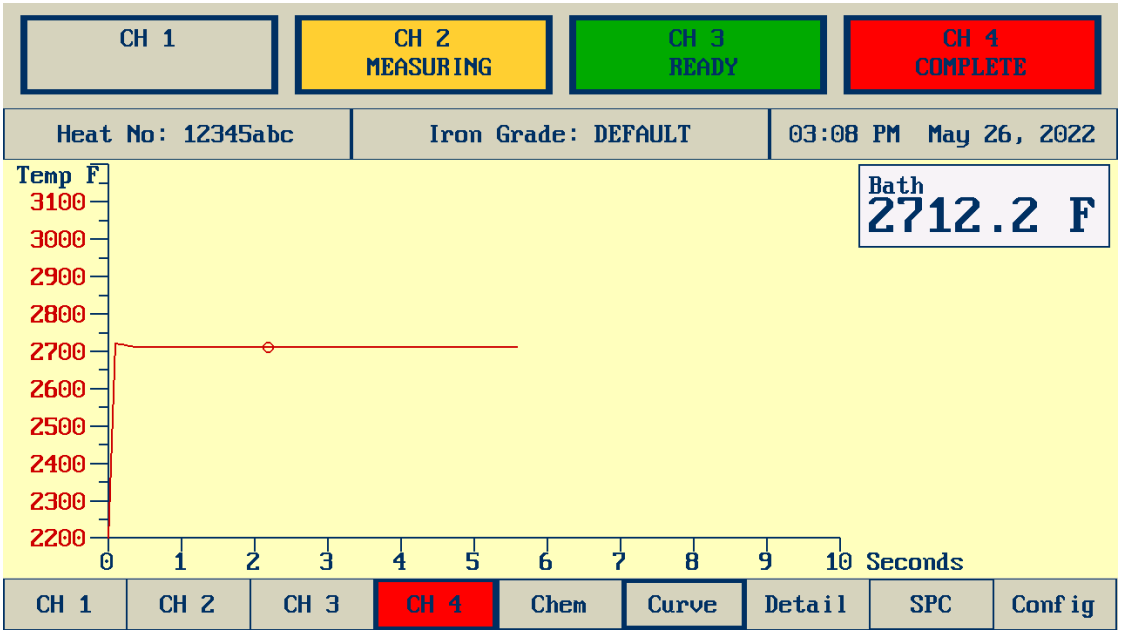


Figure 6: Measurement status shown for each channel.

Table 2: Measurement status details

Color	Status	Measurement Status
Green	**READY**	Thermocouple tip (sensor) makes electrical contact with the contact block and ready for measurement
Yellow	**MEASURING**	Temperature measurement in progress
Red	**COMPLETE**	Measurement complete. Remove thermocouple or take a new measurement

ID Bar

The ID Bar contains information to identify the current run. It consists of:

Heat Number (Heat No.)

The heat number takes alphanumeric inputs up to 8 characters and is commonly used to identify a batch or group of trials. Press the heat number button to modify it. The default heat number is 12345abc (**Figure 7:** Modify Heat Number).

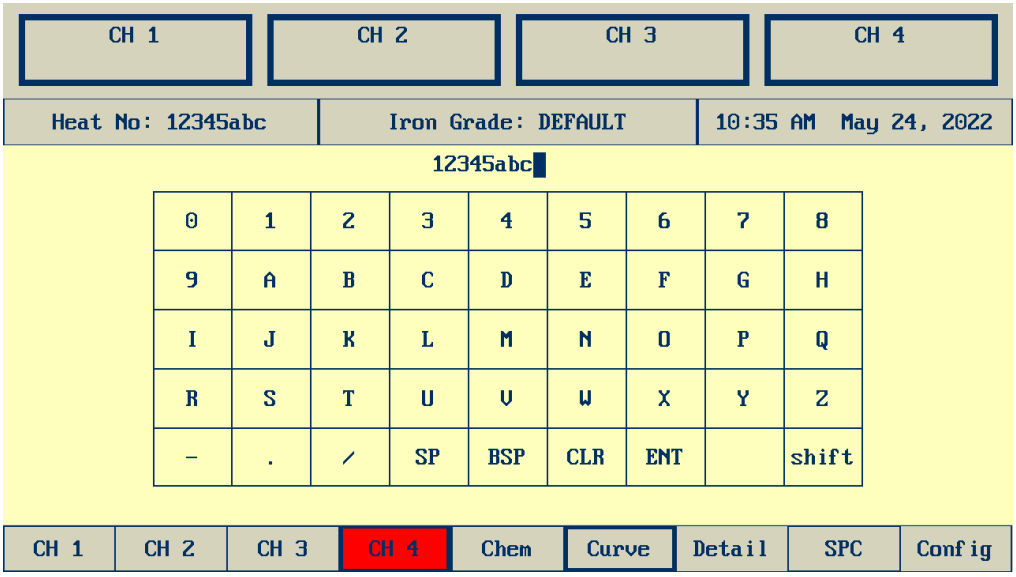


Figure 7: Modify Heat Number

Iron Grade

This allows the user to switch between different pre-defined Iron grades. Iron Grade contains the formulas and parameter settings used to compute the Iron Chemistry. These are accessed from **Config → < Enter Security Code > → Grade**. The FL-1 ships with the Default Grade setting and allows users to add up to 11 more grade options. Changing the Iron Grades applies to the next measurement to be taken.

Date & Time

The date & time are edited via **Config → < Enter Security Code > → System → Date & Time**.

Channel Menus

The channel menus consist of different display options for calculated variables – results summary **(Chem)**, detailed results **(Detail)** or cooling curve (temperature vs time) display **(Curve)**, post - processing **(SPC),** and Channel Configuration settings **(Config)**.

Chemistry (Chem)

Display selected results of current measurement in a matrix format, as shown in **Figure** 8Figure 8: Chem screen displaying selected . The list of variables displayed are edited via **Config → < Enter Security Code > → Chan → Probe Type → <Click on CE, C or Bath>**

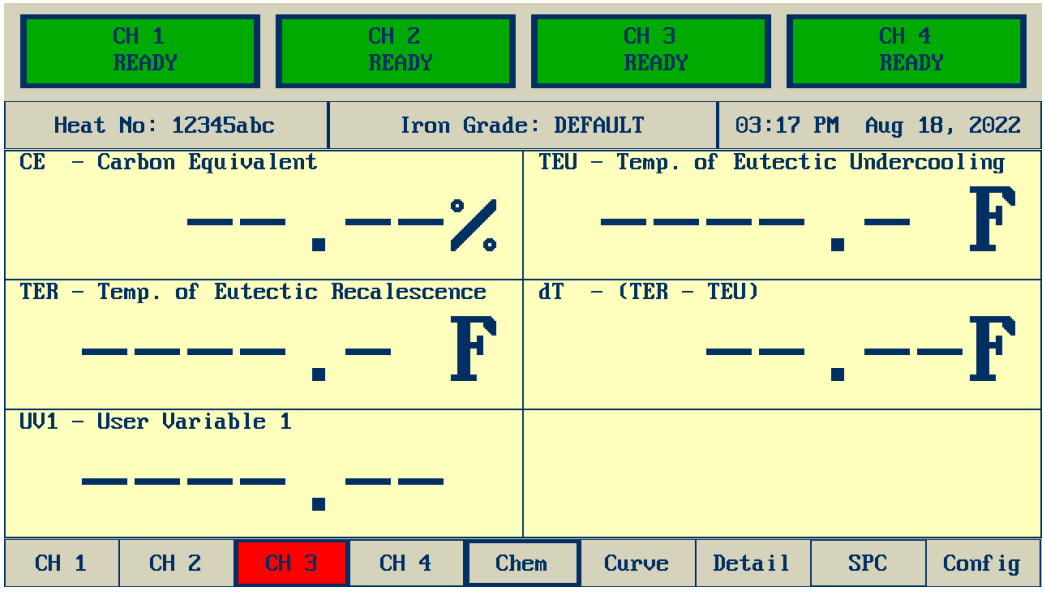


Figure 8: Chem screen displaying selected variables.

Detail

Displays results of current measurement of all variables – built-in and user-defined as shown in **Figure 9**.

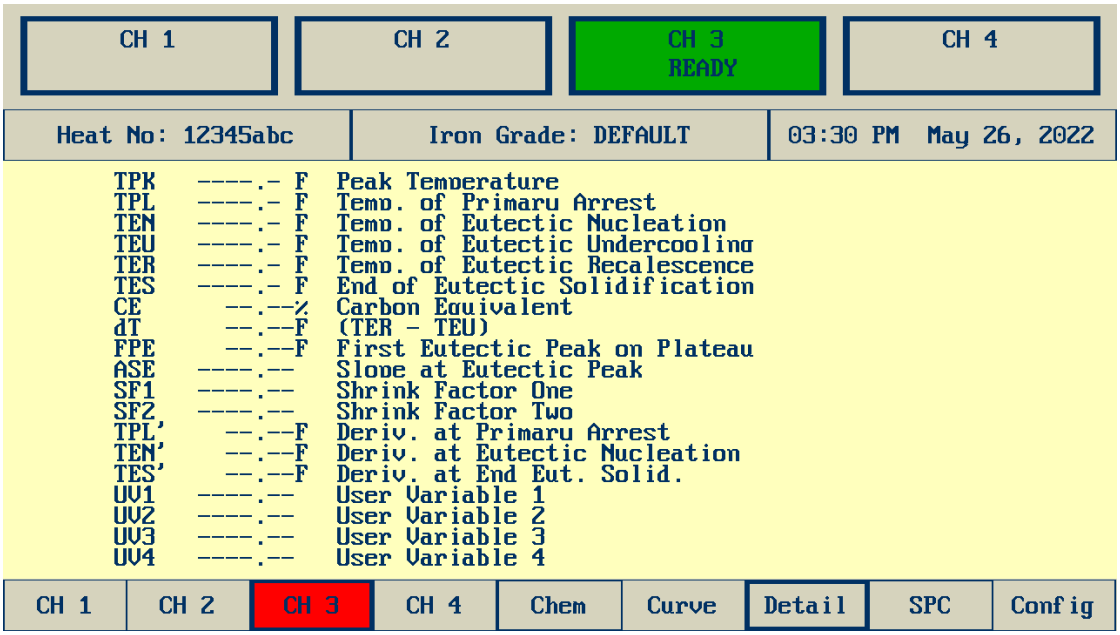


Figure 9: Detail Menu

Post Processing & Statistical Process Control (SPC)

This contains tools for Post Processing and SPC (see **Figure 10**). It contains all the variables available in the FL-1 Thermal Analysis System. If historical data is available, each variable can be plotted as an SPC function.

- **Curve Recall**

  Recall and view the measurement curves stored in memory.

- **Detail Recall**

  Recall and view the measurement details stored in memory.

- **Reprocess**

  Reprocess the current curve (cooling curve or bath temperature measurement) with different parameters. The user can change parameters via **Config → < Enter Security Code > → Grade → < Select Iron Grade > → Curve Parms** or **Var Lim**.

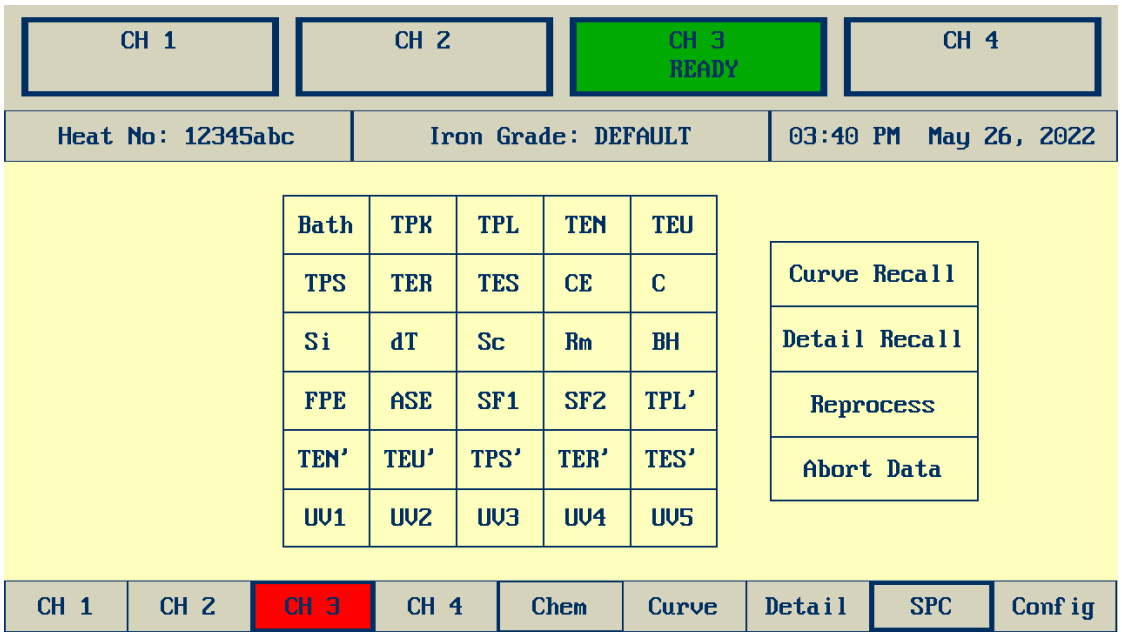


Figure 10: Post Processing & SPC Menu

Quick Start

Cooling Curve Analysis (Sampling Cups)

1. Plug the power cord in an outlet rated between 100 – 240 V. In 110 V power supply, the round pin on the power plug should go to a good ground in the wall outlet. In 220 V systems, the green wire should be connected to the ground.
2. Turn on the FL-1 Thermal Analysis System. It takes about 10 – 20 seconds to boot up completely, after which the home screen is displayed.
3. Place a cup on the stand and use Type K (yellow) thermocouple extension wire to connect the stand to the thermocouple input of the FL-1 Thermal Analysis System.
4. Ensure that the cup type in the FL-1 matches with the cup placed on the contact block. By default, Channel 1 (CH. 1) is setup for a (CE) non-Tellurium cup (Type K IPTS 1968) and CH. 2 and CH. 3 for a (C) Tellurium cup (Type K IPTS 1968). These can be reviewed or modified for each channel by **Config → < Enter Security Code > → Chan → Probe Type**
5. The Channel Status indicator displays a **GREEN Ready** light for the channel on which the thermocouple input is connected. This indicates that the FL-1 Thermal Analysis System is ready for a new cup temperature measurement.
6. Pour molten iron in the cup. The Channel Status indicator switches from **GREEN Ready** light to **YELLOW Measuring** light, indicating that the temperature measurement has started. The cooling curve is displayed in the Curve menu.
7. At completion, the **YELLOW Measuring** light switches to **RED Complete** light in the Channel Status Indicator. This means that the measurement is complete or is incomplete because it has timed out (default maximum time is 285 seconds).
8. The results are displayed in the **Chem**, **Curve**, and **Detail** menus.

Bath temperature measurement (thermocouple sensor)

1. Plug the power cord in an outlet rated between 100 – 240 V. In 110 V power supply, the round pin on the power plug should go to a good ground in the wall outlet. In 220 V systems, the green wire should be connected to the ground.
2. Switch ON the FL-1 Thermal Analysis System. It takes about 10 – 20 seconds to boot up completely. After which, the home screen is displayed.
3. Plug the correct thermocouple plug from the lance/probe to the female thermocouple jack in the FL-1. Ensure that the color of the thermocouple plug matches the color of the thermocouple jack in the FL-1.

4. By default, CH. 4 is configured to Type S IPTS 1968 thermocouple input. If the thermocouple is in place (see **Table 2**), the Channel status indicators display a **GREEN Ready** light for the channel on which the thermocouple input is connected. This indicates that the FL-1 is ready for a new bath temperature measurement.
5. When the thermocouple is immersed into the molten metal bath, the FL-1 starts the measuring cycle. The **GREEN Ready** light switches to **YELLOW Measuring** light on the Channel Status indicator.
6. At completion, the **YELLOW Measuring** light switches to **RED Complete** light in the Channel Status Indicator. This indicates that the measurement is complete or is incomplete because it has timed out (default maximum time is 7 seconds).

The results are displayed in the **Chem**, **Curve**, and **Detail** menus.

Lance/Immersion Probe temperature measurement guidelines

The proper immersion of the expendable thermocouple sensor into the molten metal can have a significant effect on the quality and reliability of the measurement. To get an accurate and reliable reading, SYSCON Sensors recommends the following procedure:

1. Immerse the probe quickly into the molten metal, penetrating the slag as quickly as possible. DO NOT force the tip of the probe onto or through hard slag as the probe may break.
2. When taking repeated measurements, allow the lance to cool between measurements. Contact block temperatures greater than 300°F (149°C) can cause erratic measurements.
3. Take measurements with gas stirring and oxygen blowing turned OFF. Wait at least 45 seconds after gas stirring to take a measurement.
4. Turn electrical power to the furnace OFF before taking a measurement. Electrical interference from the electrical field can cause erratic measurements. If the furnace grounding system is broken or corroded, electrical shock can result from taking temperatures when the furnace power is ON.

5. Stir for at least 3-5 minutes after alloy addition before taking a temperature measurement. Alloy additions affect temperature measurement if the probe is inserted in the alloy. Allow sufficient time for the alloy and the metal to be well-mixed before taking a measurement.

 **NOTE**

DO NOT use the expendable thermocouple sensors if they have been exposed to moisture and are wet. Excessive moisture will cause erratic measurements and can result in injury from violent metal splashing.

Always wear recommended Personal Protection Equipment

Shut down

1. Shut down the unit by using the power switch on the unit as shown in **Figure 2**.

Keypad

The keypad for FL-1 Thermal Analysis System (shown in **Figure 11**) is displayed on the touch screen and consists of alphabets (A-Z), numbers (0 – 9), and special symbols (. - /). If a specific user input requires only numbers, then only a numeric keypad is displayed.

- **ENT – Enter**

  Finalize the user input.

- **BSP – Backspace**

  Delete the last alphabet or number of user's input.

- **CLR – Clear**

  Clear the user input.

- **CAN – Cancel**

  Delete the user input and replace it with the previous input.

- **SP – Space**

  Insert a blank space.

- **shift – Shift**

  Toggle between uppercase and lowercase letters

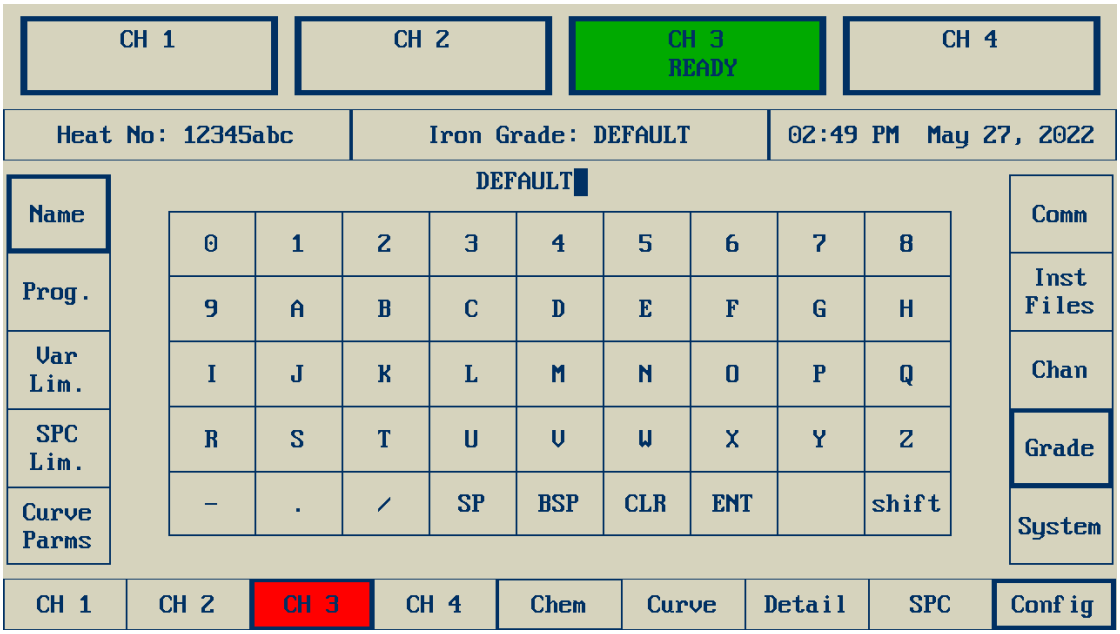


Figure 11: Touch screen keypad of FL-1

The keypad in **SPC** Menu (see **Figure 12**) enables the selection of a range of data. Hit **Select** to select the current row highlighted by a rectangular cursor. After a row is selected, it appears in red font. To select multiple rows, go to the first row using the **Up** or **Down** buttons, hit **Begin Range**, use the Up or Down buttons to move to the last row and select **End Range.**

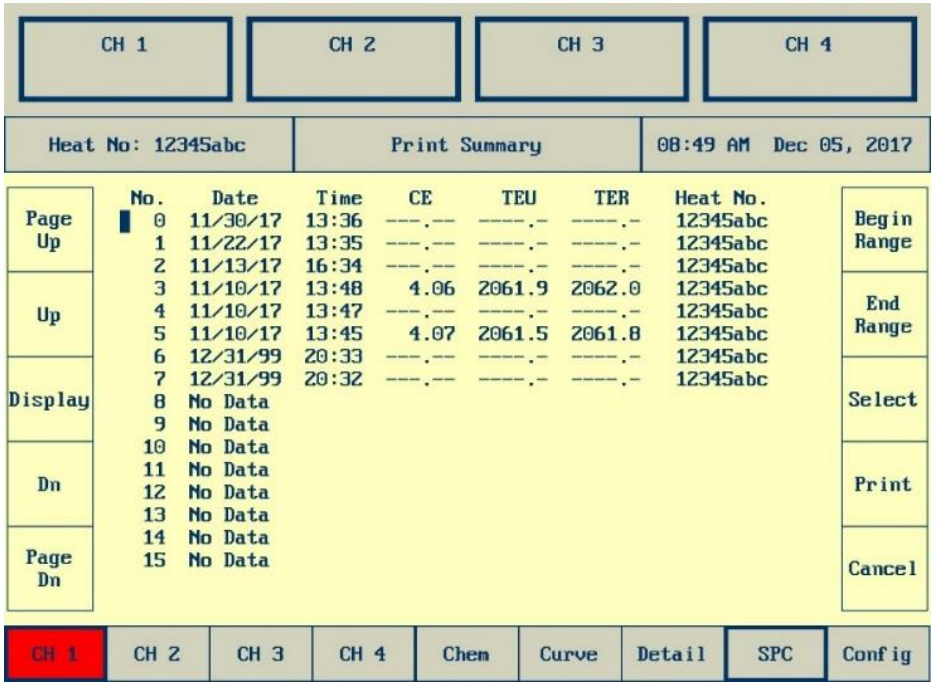


Figure 12: Keypad for SPC screen

Configuration Menu

The Configuration menu contains settings to extract or restore data, change measurement configuration, and modify calculation settings for each channel such as:

- Change cup type, calibration standard (IPTS 48/68), thermocouple input type.
- Save or restore Measured Data and instrument settings via USB thumb drive or Ethernet.
- Define new Iron grades and modify or create new formulas.
- Change displayed variables names.

Type the security code (Refer to the **Before You Start** section for the security code) using the keypad shown in **Figure 13**. Hit **ENT** when done.

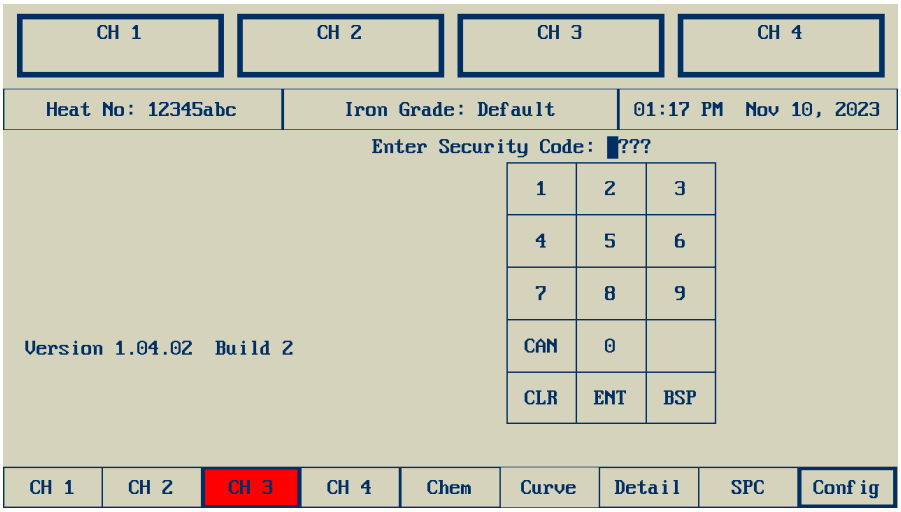


Figure 13: Numeric Keypad to enter the Security Code

NOTE

Use caution when modifying settings from the Configuration Menu. A 4-digit numeric Security Code (Refer to the **Before You Start** section) is needed to enter the Configuration Menu (see Figure 13).

When the correct security code is entered, the Configuration Menu **(Config)** comes up (see **Figure 14:** Configuration).

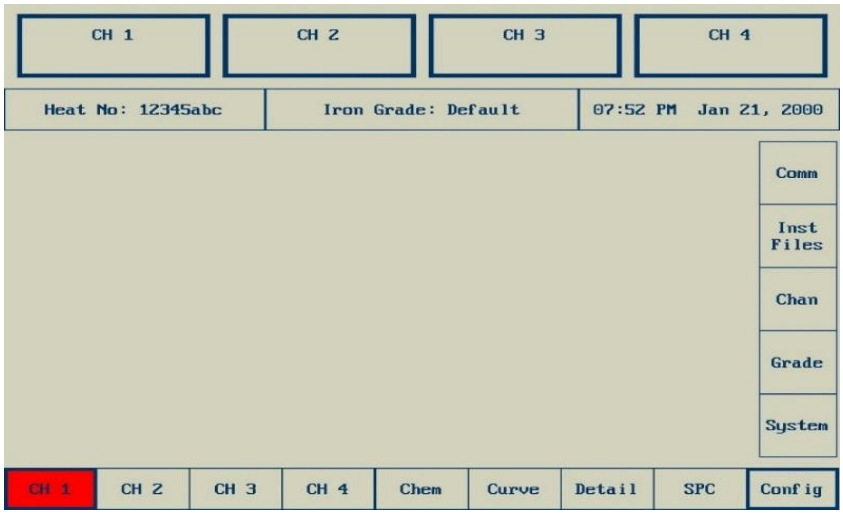


Figure 14: Configuration Menu

The **Config** Menu consists of the following options:

- **Comm – Communication**

  Ethernet settings can be configured in this section as shown in **Figure 15**. If an IP address is configured, other devices on the network can listen to specific port numbers to get run data (Bath temperature and Iron Chemistry) after a successful measurement.

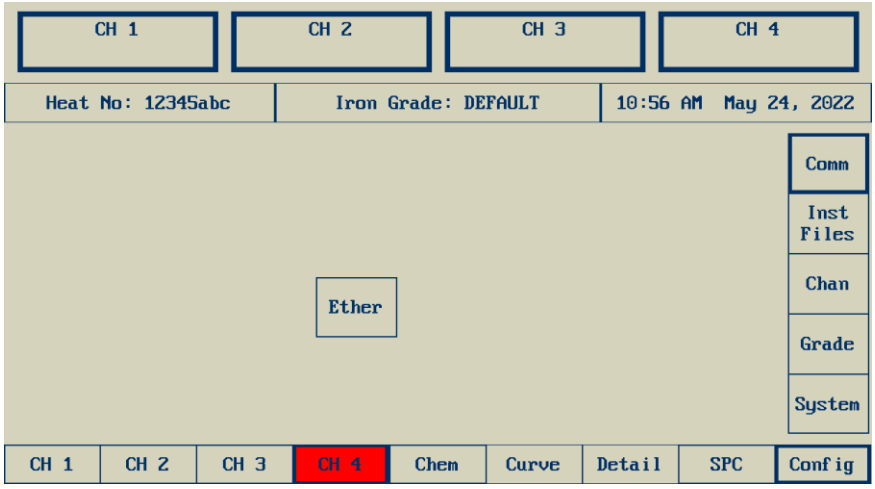


Figure 15: Communication tab in Configuration menu

Accessories for the FL-1 such as SYSCON Sensors LS-1 Lightstack and SYSCON Sensors SB-1 Scoreboard can be configured from this menu. LS-1 Lightstack is a remote LED that shows the measurement status (**Ready, Measuring, Complete)** for a channel. SB-1 scoreboard is a remote LED display which shows Iron chemistry and bath temperatures.

- **Inst Files – Instrument Files**

  Save or restore Measured Data (in TXT file format), user programs (in XML file format), and instrument configuration files (in XML file format) using USB or Ethernet ports as shown in **Figure 16**. These file formats are suitable for post-processing in Microsoft Excel.

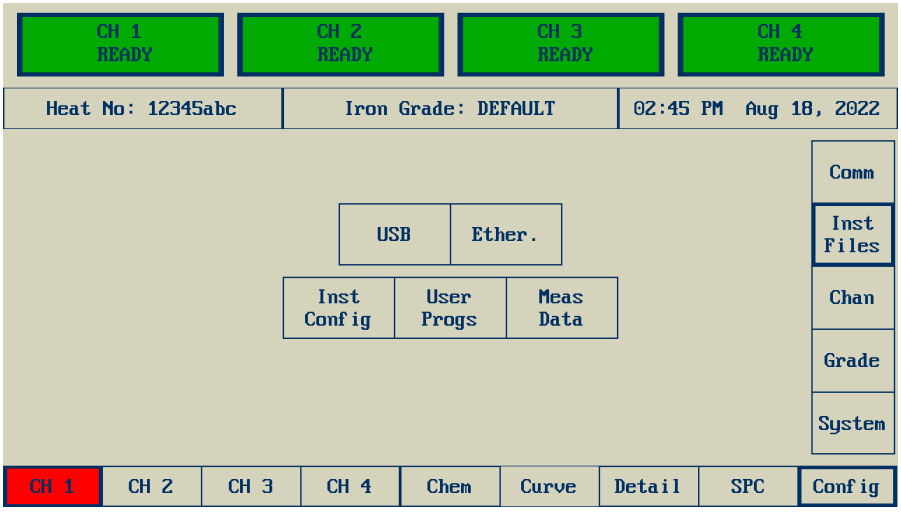


Figure 16: Instrument Files tab in Configuration Menu

- **Chan – Channel**

  Change Cup Type (Tellurium or Non-Tellurium), units of temperature measurement (°F or °C), activate or deactivate (default) sound alarm along with the channel status indicator (always ON), temperature scale display options as shown in **Figure 17**.

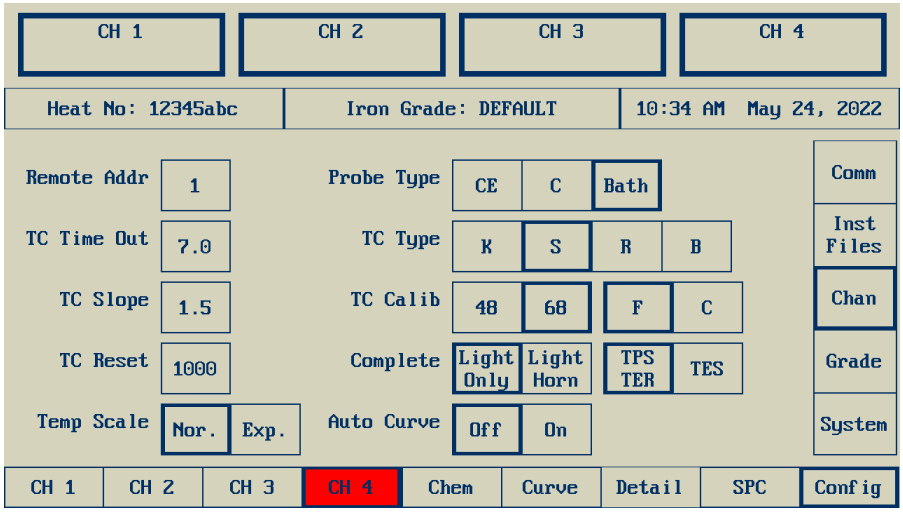


Figure 17: Channel tab in Configuration Menu

When CE or C is selected for a particular channel, a grid of six windows is displayed as show in **Figure 18**. The user can select each window and select a variable for the window. These variables will then show up on the Chem screen as shown in **Figure 8.**

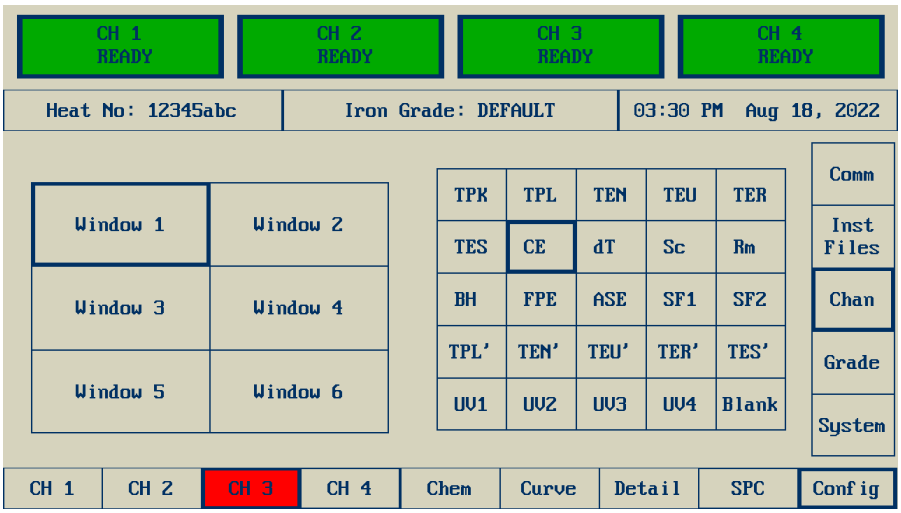


Figure 18: Channel tab, selecting Variables for Chem Screen

- **Grade – Iron grade**

  Add or modify Iron grades according to the type of Iron poured in the foundry. Up to 12 grades can be added. The FL-1 ships with a **Default** Iron grade (see **Figure 19**). Refer to the **Grade** section for details regarding the Iron grade. The Iron chemistry formulas (used to predict **CE**, %**C**, **Si**, etc.) used in the Default grade are developed from a regression analysis of historical cooling curve data and are suitable with minor modifications for most applications. These formulas can be modified to match the results from the metallurgy lab.

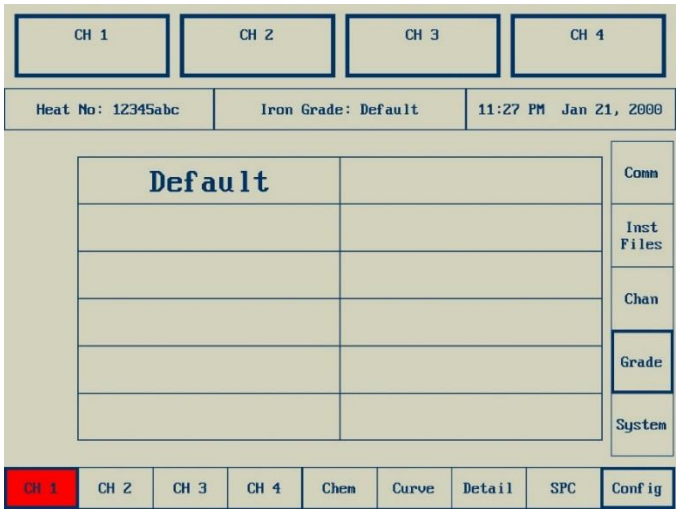


Figure 19: Grade tab in Configuration Menu.

- **System**

  Modify system settings such as date, time, displayed variable names, calibration, and extract raw data for troubleshooting.

> ⚠ **NOTE**
>
> Calibration settings can only be modified by persons authorized by SYSCON Sensors and requires a special calibration cable.
>
> **Contact** SYSCON Sensors for questions regarding calibration

Comm – Communication

- **Ethernet Port**

  An Ethernet port can be assigned an IP Address, a Broadcast Address, and a Netmask using the keypad. The host ID should be unique for each FL-1 and is used to form a wireless connection (SSID) with SYSCON Sensors Lightstack (LS-1) and Scoreboard (SB-1) (see **Figure 20**).

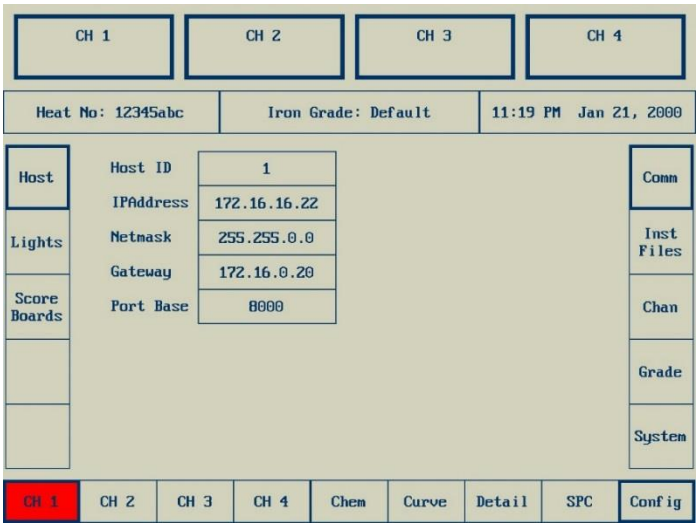


Figure 20: Ethernet port configuration screen in Communication tab

TTY programs such as PuTTY or Telnet can be used to establish a connection between a computer (or computers) and FL-1 Thermal Analysis System connected via Ethernet. The computer can access various output data by connecting to the IP address on different ports. These ports start by default at 8000 and can be changed according to preferred practice.

Inst Files – Instrument Files

Three data types can be extracted from **Inst Files** tab using USB and Ethernet ports – Instrument configuration **(Inst Config)**, User Programs **(User Progs),** and Measured Data **(Meas Data)**. The instrument configuration is a single XML file which contains all instrument settings for all channels such as Grade details, Curve parameters, custom formulas, channel configuration settings etc. Instrument Configurations can also be restored. This file can be viewed or edited in any word processing software such as Microsoft ® Word.

User Program is an XML file consisting of formulas used for calculating Iron chemistry parameters. This includes both built-in variables (such as **CE**, **%C**, **Si,** etc.) and user-defined variables for all channels. User Programs can also be restored. Measured Data consists of all variables – pre-defined and user defined in the FL-1.

The list of all variables is obtained using **Config → <Enter Security Code> → System → Var Names. Meas Data** (Measured Data) can only be saved.

Procedure – Save (or Restore) data using USB port

1. Plug any USB thumb drive in the USB port
2. Navigate to **Config** → < Enter Security Code > → **Inst Files** → Select **USB**
3. Select file type to be saved or restored – **Inst Config, User Progs** or **Meas Data**
4. If **Inst Config** or **User Progs** is selected, click on **Save** or **Restor**e to save or restore (Inst Config or User Progs to be restored should be in the XML file format on the inserted USB thumb drive).
5. To transfer **Meas Data**, select which measured data needs to be saved.
   Current – Save measured data from Current Channel
   CH 1-4 ALL – Save measured data from a user selected channel.
6. After data is successfully saved or restored, "Done" is displayed on screen.

NOTE

Save Instrument Configuration file before modifying Configuration settings. SYSCON Sensors also recommends saving Instrument Configuration file after unpacking the FL-1 Thermal Analysis System and prior to initial system operation.

Chan – Channel

Characteristics for each channel can be modified using this tab as shown in **Figure 17**.

- **Probe Type**

  Configure measurement type – cup temperature or bath temperature measurement. Two types of cups are used – **CE** are non-Tellurium for Gray Iron solidification and **C** are Tellurium cups for White Iron solidification (see **Table 3**). CH.1 is configured for **CE** (non-Tellurium) cup, CH.2 and CH.3 for **C** (Tellurium) cups and CH, 4 for bath temperature. According to standard foundry practice, Type K thermocouple inputs are used for cups and Type S thermocouple input for bath temperature.

  Table 3: Notation and Part Numbers of Tellurium and Non-Tellurium Cups

Cup Type	FL-1 Software Notation	Part Number
Non-Tellurium	CE	METACUP – CE
Tellurium	C	METACUP - C

- **TC Type** – Thermocouple Input type (Default: Type K for CH. 1,2,3 and Type S for CH. 4)

  Select Type K, S, R, or B. Ensure that the TC Input matches the male thermocouple connector type on the left panel for each channel.

> ⚠ **NOTE**
>
> Changing the TC Input type without changing the thermocouple connectors and internal wiring for a channel may result in erroneous or out of range temperature measurements.

- **TC Calib** – Thermocouple Calibration (Default: IPTS 1968)

Select between IPTS 1948 and IPTS 1968 thermocouple calibration standards.

> **⚠ NOTE**
>
> Thermocouple wires are different for IPTS 1948 and IPTS 1968 standards.
>
> Errors as much as 10°F may result for incorrect calibration standards depending on the thermocouple type.

- **Complete** (Default: Light Only and TPS/TER)

  Select the action at run completion – **Light Only** or **Light Horn**. **Light Only** displays measurement status lights in the Channel Status indicator bar and a remote Lightstack (if connected). Light Horn can sound an external alarm if added as an accessory. Select completion points shown in **Figure 21** - the temperatures at which the Channel Status indicator lights go from **YELLOW Measuring** to **RED Complete** if valid temperatures are detected – **TPS/TER** or **TES.**

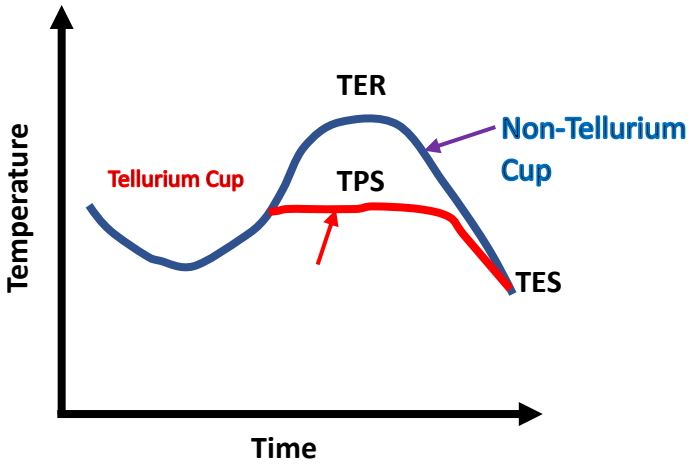


Figure 21: Completion Points for the cooling curve

- **Auto Curve** (Default: OFF)

  If Auto Curve is ON, the Curve menu is displayed at run completion.

- **Temp Scale**

Choose between Norm (Normal): 1800°F–2500°F and Exp (Expanded): 1100°F–2500°F. Norm is the default scale and is suitable for most applications.

- **TC Timeout** (Default: 300 seconds)

  Maximum time (in seconds) that the FL-1 waits for run completion. The Channel Status indicator displays a red light and stops the measurement after TC Timeout to prevent damage to the cup or the thermocouple wire.

- **Remote Addr** – Remote Address

  Used to connect to SYSCON Sensors Lightstack LS-1 and Scoreboard SB-1.

Grade

The **Grade** tab contains options to add or modify new Iron grades specific to the user (see **Figure 19:** Grade tab in Configuration Menu.). The FL-1 ships with the Default grade, which contains the formulas to calculate the variables such as **CE**, **C**, **Si** among others, which are of great importance to the Foundry. Up to 12 new grades can be added. To add a new grade, select a box in the 6 x 2 table (6 rows, 2 columns) in **Figure 19**. To modify existing grade, select Default. A new screen is displayed (see **Figure 22** which contains options to modify the grade settings.

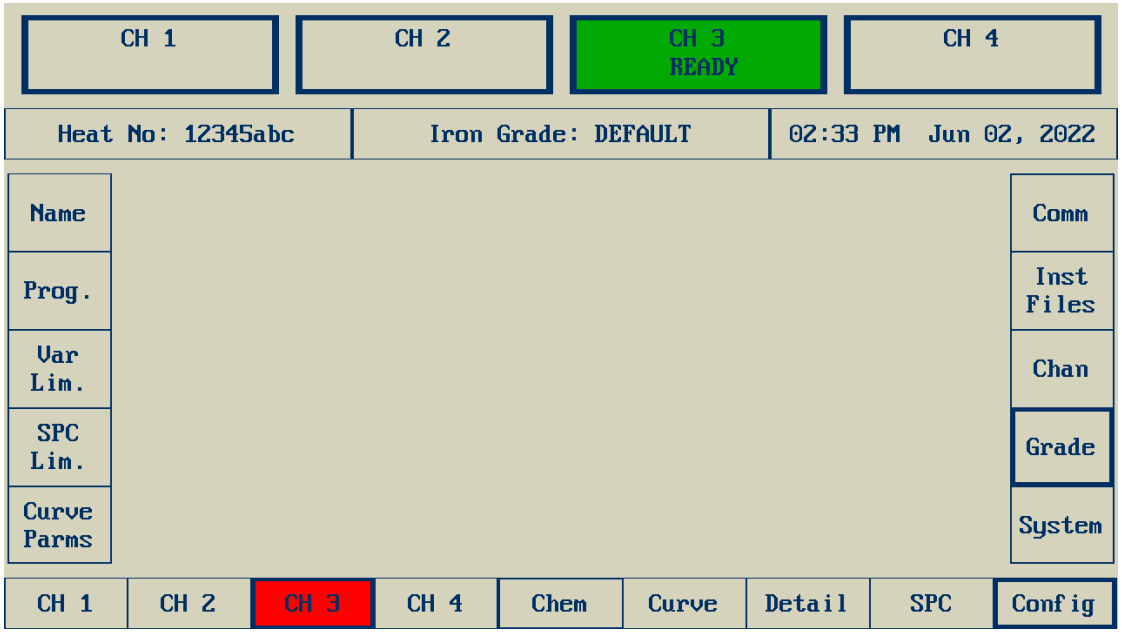


Figure 22: Add or Modify Grade settings.

- **Name**

  Add or modify **Grade** name using an alphanumeric keypad.

- **Prog – Program**

  Consists of programs to calculate pre-defined variables - **CE**, **C**. **Si**, **Sc**, **Rm**, **BH,** and user defined variables – User as shown in **Figure 23:** Pre-defined and User Defined programs to calculate displayed . To factory reset a program to the **Default** Iron grade with which the FL-1 ships (see **Table 4**), select the Factory Default (**Factory Def)**

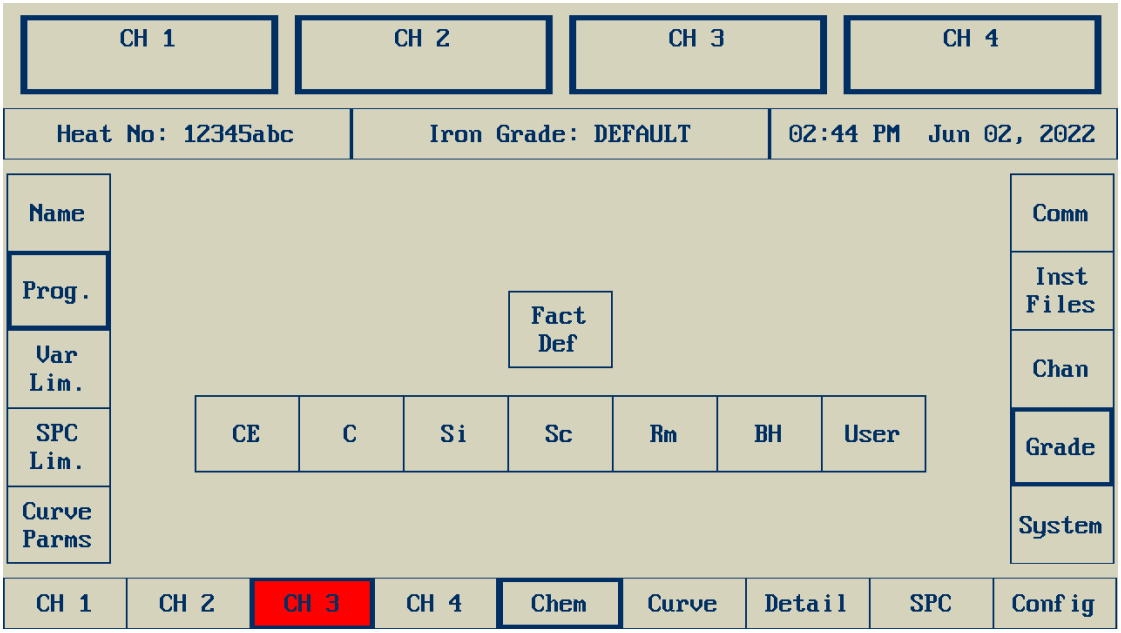


Figure 23: Pre-defined and User Defined programs to calculate displayed variables.

button and then select the program which needs to be reset.

A Program screen for calculating **CE** is shown in **Figure 24**. The Program name is displayed in the top left corner. The Program body, which consists of the line number, operation code, and instruction is shown on the left side. The operation code is a 3-digit combination of letters and numbers. The user needs to input the specific operation code to generate the instruction. If an incorrect operation code is specified, a **Bad Opcode** message is displayed for the corresponding instruction.

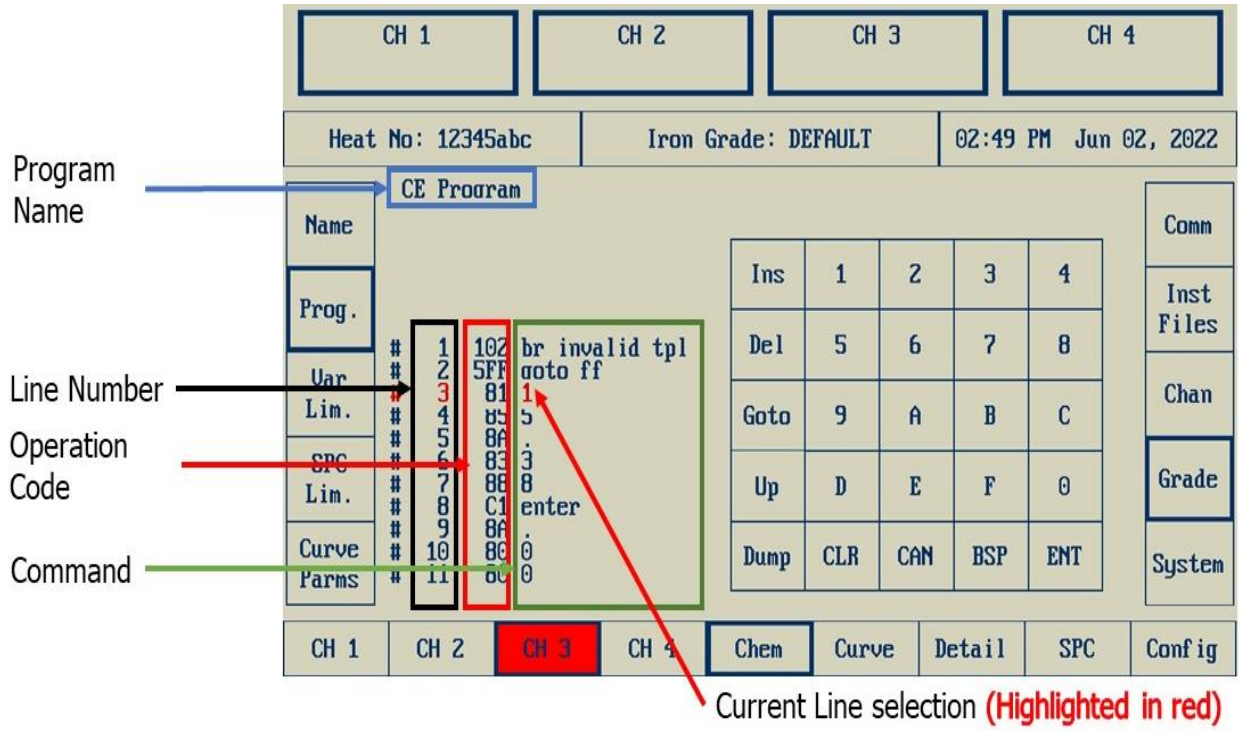


Figure 24: Program Screen

The keypad for creating new or modifying existing programs is like the alpha-numeric keypad for previous menus. However, it contains some new functionalities such as:

Ins – Insert

Insert new line.

Del – Delete

Delete a line.

Goto

Go to a specified line number. Line numbers are displayed to the right of the pound/ number/hash (#) sign (see **Figure 24**).

Up

Move the current line selection 1 line above.

Dump

Transfer user program using Ethernet ports.

ENT

Move the current line selection 1 line below.

BSP

Backspace 1 character.

An operation code is specified either on an existing or a new line. To specify an operation code:

1. To specify an Operation Code on an existing line, navigate to the line number using the **Goto** or **UP/ENT** buttons. To specify an Operation Code on a new line, press **Ins** (Insert).
2. Press Clear **(CLR)** to remove the contents of the selected line. The contents can be restored using the Cancel **(CAN)** button.
3. Specify the Operation Code and press **ENT**. If the correct Operation Code is specified, the desired instruction is displayed else Bad Opcode message is displayed.

The formulas in the programs are written in the algebraic or inline notation (see **Table 4**).

> **NOTE**
>
> For most applications, the user only needs to modify the constant terms highlighted above in bold in **Table 4**. These terms appear at the start of the program. Refer to the note on **User Programs** for more details.

Table 4: Equations for FL-1 variables in the Default grade

Variables	Equations in the **Default Grade**
CE	$\mathbf{15.38} - 0.005235\ \mathrm{TPL}$
C	$\mathbf{-6.76} + 0.00967\ \mathrm{TPS} - 0.00441\ \mathrm{TPL}$
Si	$\mathbf{0.0} + 3.0\ (\mathbf{CE} - \mathrm{C}) = \mathbf{0.0} + 3.0\ (22.14 + 0.00967\ \mathrm{TPS} - 0.000825\ \mathrm{TPL})$
Sc	$3.715 - 0.001278\ \mathrm{TPL}$
Rm	$\mathbf{0.0} + 9.81\ (102 - 82.5\ \mathrm{Sc})$
BH	$538.6 - 354.75\ \mathrm{Sc}$

- **Var Lim** – Variable Limits

  Specify the Maximum (**Hi**) and Minimum (**Lo**) Limits for variables (see **Figure 25**). The Hi Limit is displayed first, and the Lo Limit is displayed after pressing ENT. If the value of a variable falls outside the Lo and Hi Limits, it is displayed in red (otherwise it is shown in blue color).

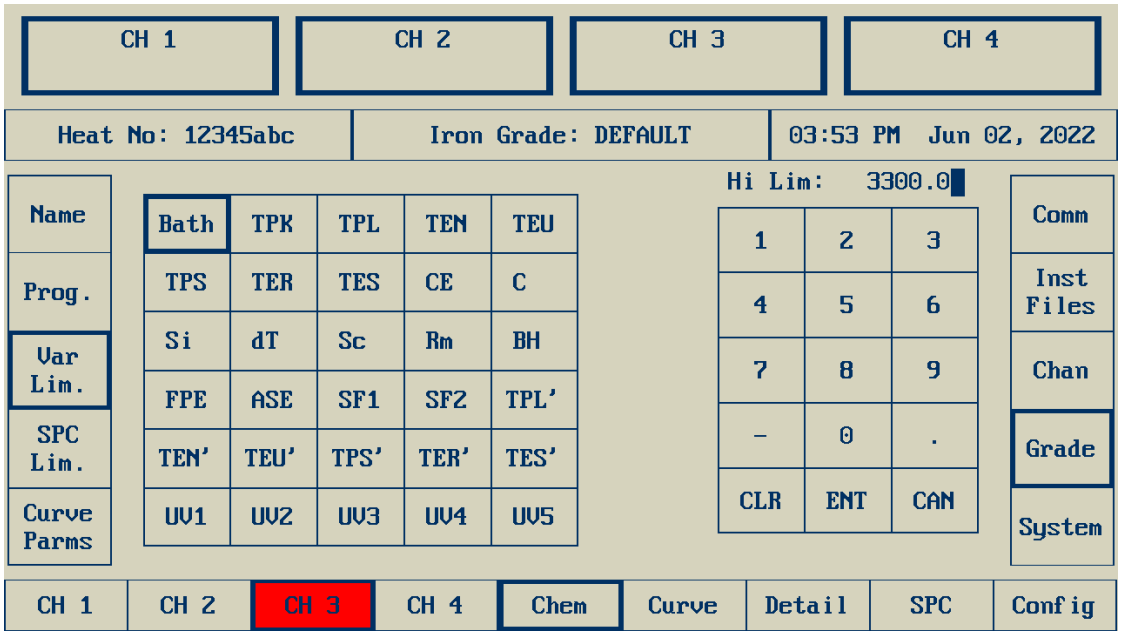


Figure 25: Modify variables limits of pre-defined and user defined variables.

- **SPC Lim** – Statistical Process Control Limits

  Specify the Upper Specification Limit (**USL**), Nominal value (**NOM**), Lower Specification Limit (**LSL**), and Range (**URL**) of a variable (**X**) (see **Figure 26**).

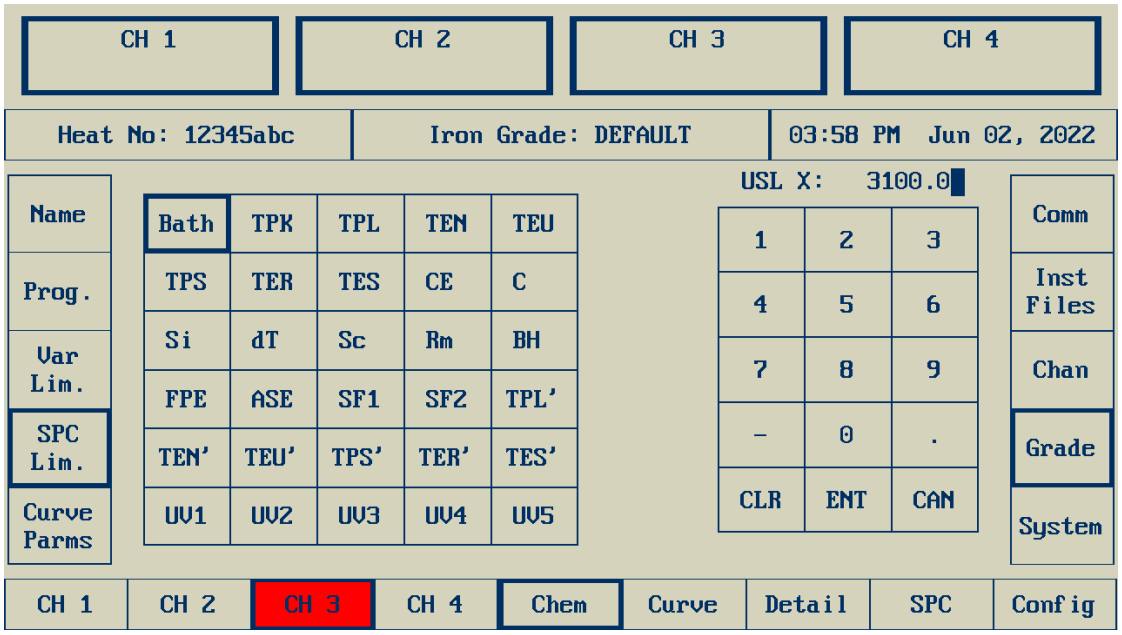


Figure 26: Specify Statistical Process Control variable limits.

- **Curve Parms** – Curve Parameters

  These parameters (see **Table 5**) influence the calculation of Peak (**TPK**), Liquidus (**TPL**), and Solidus (**TPS**). These temperatures (especially **TPL** and **TPS**) are used to calculate the variables as shown in the equations above. Hence, a change in the curve parameters influences the variables. After changing the Curve Parameters, the current cooling curve (for cups) or bath temperature curve can be reprocessed from the **SPC** Menu (refer to the note on **Post-Processing**).

Table 5: Curve parameters – description and default values

Curve Parameter	**Description**	**Unit**	**Default Value**
TPK Min	Minimum Peak Temperature	°F	2200
Sup Ht Min	Minimum Super Heat. Difference between the Peak (**TPK**) and Liquidus temperature (**TPL**)	°F	10
TPL Height	Temperature drop	°F	0.5
TPL Width	Time interval for temperature drop (**TPL Height**) to determine **TPL**	seconds	2
TPS Height	Temperature drop	°F	0.1
TPS Width	Time interval for temperature drop (**TPS Height**) to determine **TPS**	seconds	5

Figure 27Figure 27: Graphical interpretation of Curve parms illustrates the calculation technique of **TPL.** This technique is also used to calculate other temperature variables. The **TPL** is found from the inflection point of the first derivative (shown by red dashes) i.e. the point at which the sign of curvature changes. An imaginary box (shown in blue) is drawn on the cooling curve (shown in green) around this point. The box extends to the left and right of **TPL**. The width of the box is equal to the **TPL Width.** The left and right end points of the rectangle are denoted by L and R respectively. The condition for acceptance of **TPL** calculated above is:

$$\mathbf{T(t = t_L) - T(t = t_R) \leq \ TPL\ Height}\,,$$

where $\mathrm{T(t = t_L)}$ and $\mathrm{T(t = t_R)}$ denoted the temperature of the cooling curve (shown in green) evaluated at left and right end points respectively. If the temperature difference is greater than the **TPL Height,** a different inflection point is selected.

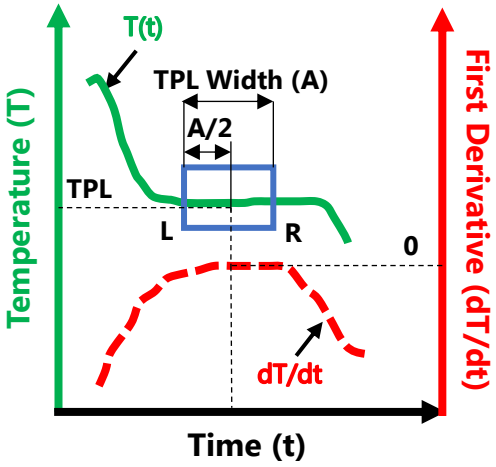


Figure 27: Graphical interpretation of Curve parms

System

System contains options to change system settings – date & time, variable names, toggle display to current channel after run completion, and current run deletion.

- **Date & Time**

  To modify the date and time, select Date or Time respectively from the Date & Time menu. The date is entered in a YY/MM/DD format and the time in a 24 hour format – HH:MM:SS (see **Figure 28**). It takes about 5 seconds for the FL-1 system to update the Date & Time.

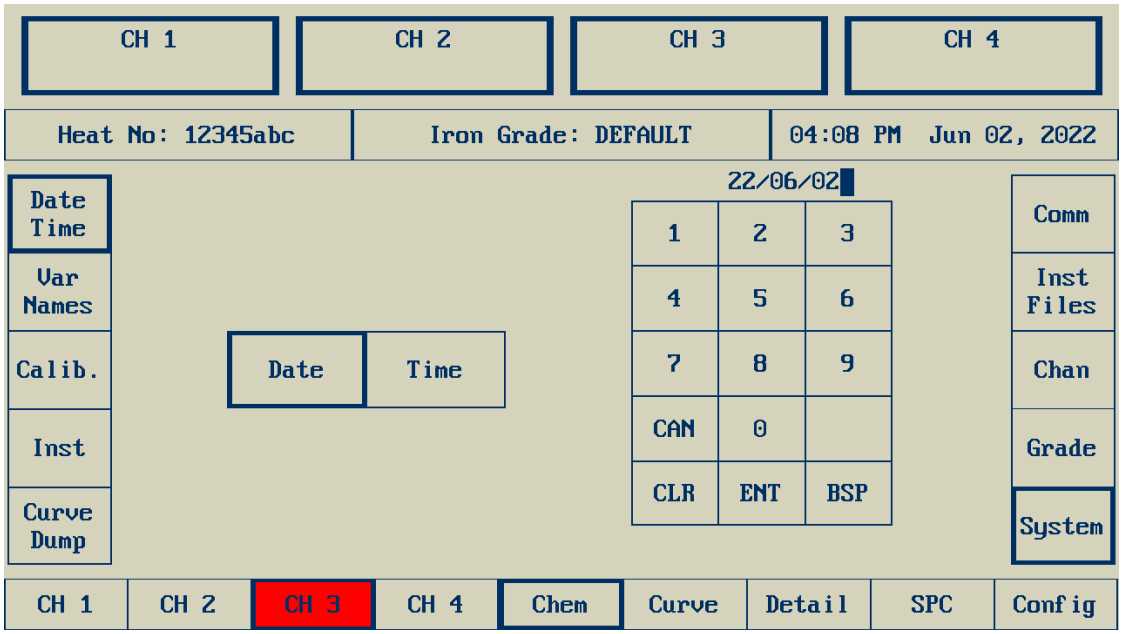


Figure 28: Modify Date & Time in the System tab

- **Var Names** – Variables Name

  Modify the display names of the variables using the alpha-numeric keypad shown in **Figure 29**.

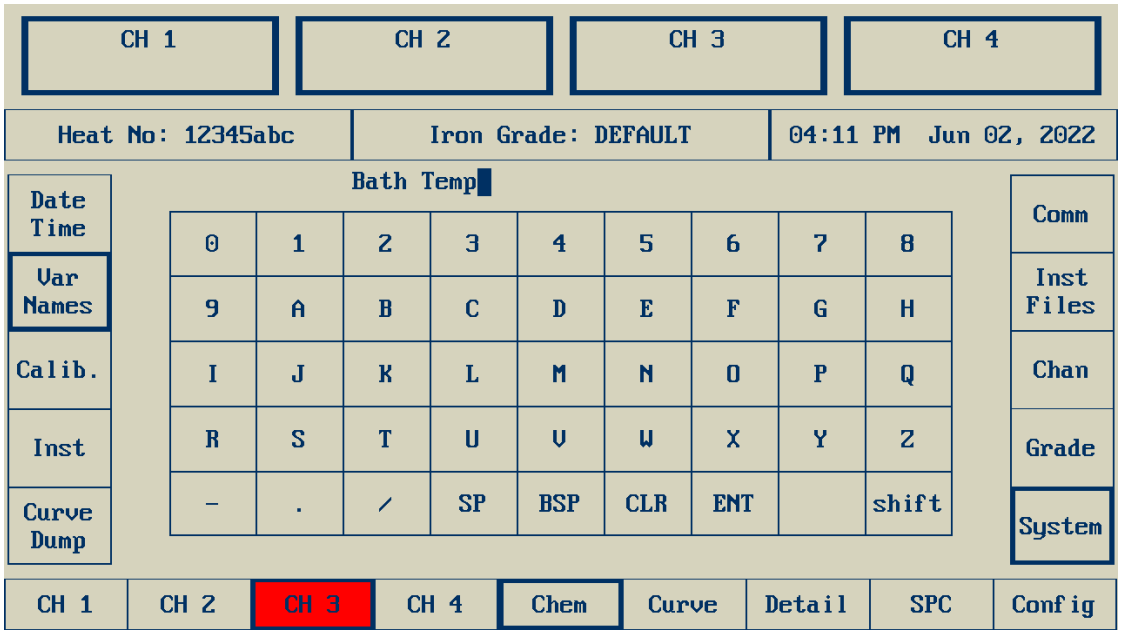


Figure 29: Modify display names of variables in the System tab.

- **Calib** – Calibration

  Modify FL-1 calibration settings for voltage and cold junction temperature compensation. This screen is locked to prevent inadvertent adjustments to the calibration, which would result in large errors in temperature measurement. A special calibration cable is required to modify the calibration settings. Any changes to the voltage calibration and cold junction temperature without the calibration cable plugged in the calibration socket won't have any effect.

> **NOTE**
>
> Instrument Calibration and Troubleshooting should only be done by SYSCON Sensors authorized personnel. Alteration of the calibration settings by unauthorized personnel will void the Warranty.
>
> **Contact** SYSCON Sensors for assistance regarding calibration and troubleshooting.

- **Inst** – Instrument Display

  Modify display system display settings. If the **Abort Enable** button is **Enabled** (Default is Disabled) as shown in **Figure 30**, an additional **Abort Data** button is displayed on the **SPC Menu**. This enables the user to delete the current run. This feature is generally used to delete an incomplete run. When the **Auto Chan** (Auto Channel) button is **Enabled**, the screen flips to the **Curve** menu at the beginning of a run.

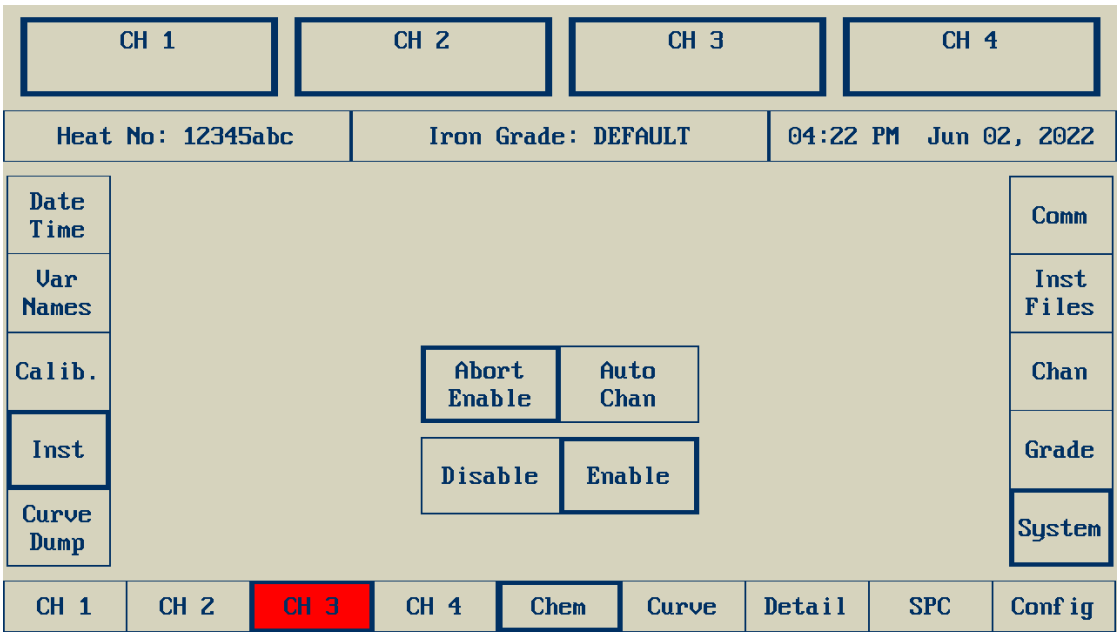


Figure 30: Instrument display settings in the System tab

- **Curve Dump** – Transfer data from the FL-1

  This is used for troubleshooting or development purposes. Select Data transfer mode - **USB**, **Ethernet** and select data type to be exported as a text (.txt) file – Temperature (**Temp**) or **Raw** as shown in **Figure 31**. **Temp** data contains the temperatures of the current channel from the beginning to the end of measurement. **Raw** contains the voltage counts before conversion to temperature and is used for debugging. The **Temp** or **Raw** data is exported for the current channel only. This is unlike the measured data (**Meas Data**) in **Inst Files** tab, where the user can select the channel number for data transfer.

NOTE

When a USB drive is plugged in the USB port, raw data for each run is automatically saved as a .txt file with the filename – raw_<timestamp>.txt, on the USB drive.

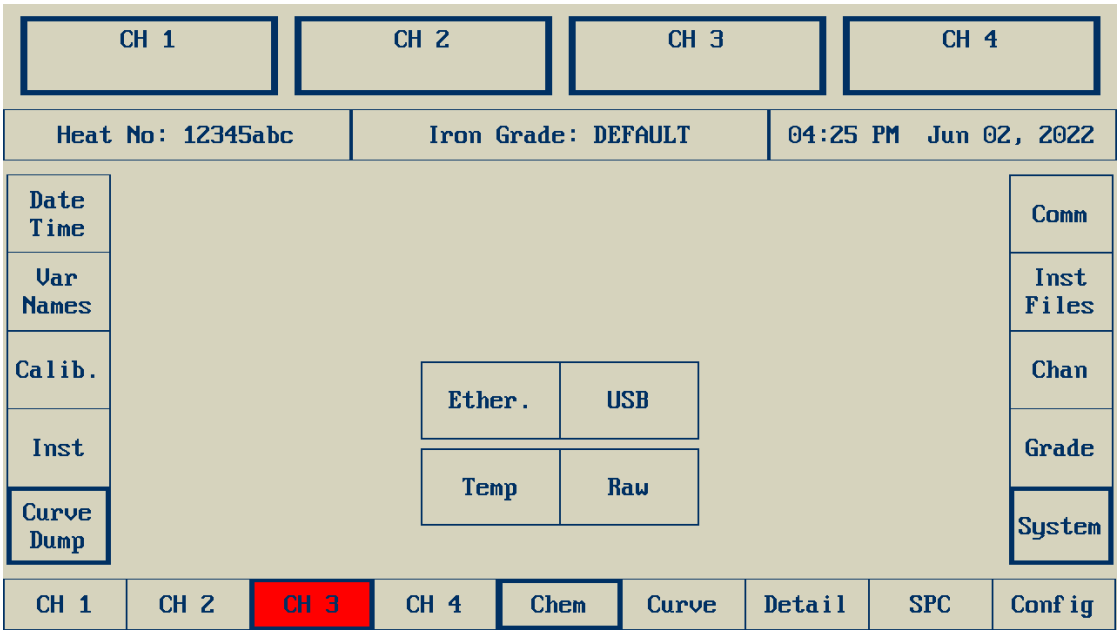


Figure 31: Data transfer for troubleshooting or development

User Programs

This chapter discusses the applications of user programs, basic structure of a user program and lists the Operation Codes (Opcodes) which need to be input by the user to generate an instruction. Default programs are provided for **CE**, **C**, **Si**, **Sc**, **Rm,** and **BH** (refer to the section on **Grade,** which gives an overview of User Programs). Up to 5 User Programs can be added for each grade. User Programs can be used for various applications:

- Display information on a remote display or a computer connected to a plant network.
- Modify calculations for variables such as CE to account for differences in metallurgical quality of melts across foundries.
- Compare and validate thermal analysis results from the Spectrometer.

Introduction

The FL-1 Thermal Analysis system can be programmed like a programmable calculator. This allows calculation of standard formulas such as **CE, C, Si,** and user defined calculations. Up to 1000 program steps may be entered for each of the twelve Iron grades. The program starts automatically at the end of a measurement cycle and can access all variables (see **Figure 24**) such as **TPK, TPL, TEN, TEU, TPS, TER, TES,** etc. Data can also be input through the user input keypad on the touch screen. Information can be displayed on the Main screen on **Detail** and **Chem** menus, or the information could be sent to a computer via the Ethernet port.

The FL-1 Thermal Analysis instrument contains a built-in calculator which uses Reverse Polish Notation (RPN). RPN specifies the operators after the variables for optimal efficiency in digital computation. The numbers are entered first followed by the operation. The order of entering those two numbers is the same in an equation from left to right. **There is no equal (=) key.**

For example, to add 2 and 3, a modern-day calculator (which uses algebraic notation), would do it inline as 2 + 3 followed by Enter sign.

In RPN, this is written as

1. 2 followed by Enter
2. 3 followed by Enter
3. Addition (+) operator followed by Enter (ENT) key on the keypad shown in **Figure 24.**

The RPN calculator uses a stack to evaluate operations. A stack can be imagined as a set of billiard balls (printed with numbers) filled in a tube and placed vertically. New balls can be added from the top only. Hence, each ball goes on top of the previous ball.

During a math operation, the **two topmost** balls pop out of the stack and are replaced by the result of the operation. For example, if the math operator is ADD and the two topmost numbered balls are 10 and 5, these two balls are replaced with the result of their addition (i.e. 15). This is pictorially explained in **Figure 32**.

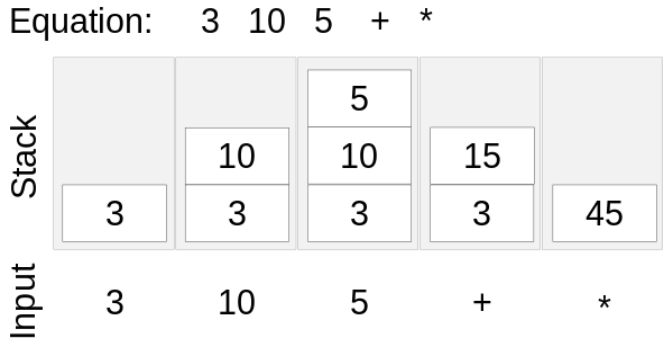


Figure 32: Stack representation of Reverse Polish Notation calculator[3]

NOTE

The FL-1 uses the degree Fahrenheit scale. All temperature variables must be entered in degrees Fahrenheit. However, the **Curve** menu can display the temperature vs. time curve in °F or °C.

Program Structure

The user program can be broken down into six different areas: decision statements, label statements, test statements, main body of the equation, and end statements.

- **Decision Statements**

  The decision statements are used to determine the flow of the program according to conditions. If a set of conditions are TRUE, the program evaluates a group of statements, else the program evaluates a different group of statements. For example, if **TPK**<2000, a user program can print the message Low Pouring Temperature, or else print the **TPK** value.

- **Label Statements**

  The label statements are identifiers placed at the beginning of a series of program steps. These labels are used to mark and provide access to various segments or routines within the user program. Labels are useful especially for program branching, which serves to modify how the program is executed for different measurement type.

- **Test Statements**

  The test statements are used to determine if the measured variables are invalid or if some other requirements are met before the calculator proceeds. These test statements are normally placed at the beginning of every different main body of the equation and after the label statement. The user must test to determine if the measured variable data is valid to ensure that the displayed output information is valid.

- **Main Statements**

  The main body of the equation contains all the user program steps needed to define the operation of the equation and complete the calculation for the present measurement. These equations can be simple straight-line equations, logarithmic equations, exponential equations, power equations, or any other type of equations needed to calculate the desired results.

NOTE

If the instrument is setup to display temperatures in degrees Celsius, convert the calculated temperature into degrees Fahrenheit before storing it in the User Variables for output.

- **Output Statements**

  The output statements allow the operator to determine how the output is displayed – when sent to a printer, the remote display unit, and/or the plant computer system. These output messages can either be one of the pre-determined formatted output messages, a custom output message, or a combination of both a custom output message along with one of the pre-defined formatted output messages.

- **End Statements**

The end statements are used to separate one equation from another equation area. There is always at least one end statement in the user program; the last step of the user program. After the first equation area, an end statement should be inserted between the succeeding equation area for them to be considered as separate equations.

Designing Program outlines using Flowcharts

A flowchart helps the user to design your programs by breaking them down into smaller groups of instructions. This is a common practice that makes a flowchart extremely useful in visualizing a complete program.

Flowcharts are drawn linearly, from top to bottom. This represents the general flow of the user program from beginning to end. Although flowcharting symbols vary, this user manual uses the convention of circles for beginning and end of the user program or routine, rectangles to represent the functional operation of the user program, and diamonds to represent decisions statements.

The design of a flowchart is determined by what the user program needs to calculate. Example – calculate **Si** from **CE** and **C** as shown in **Figure 24**,

$$\mathbf{Si} = \mathbf{0.0} + 3.0\ (\mathbf{CE} - \mathrm{C}) = \mathbf{0.0} + \ 3.0\ (22.14 + \ 0.00967\ \mathrm{TPS}\ - 0.000827\ \mathrm{TPL}).$$

NOTE

An application note (User Program reference guide) which details how to create and debug user programs is available to the customer on request.

Operation Codes

Operation Code (OpCode) can be entered using the keypad shown in **Figure 24.** Refer to the note on **Grade** for details regarding OpCode input. **Table 6** contains the list of *frequently used* OpCodes and the descriptions. Refer to the **Appendix A** for more OpCodes.

Table 6: List of frequently used OpCodes

OPCODE	COMMAND	COMMAND DESCRIPTION
CHECK IF VARIABLES ARE VALID		
102	BR INVALID TPL	Do not continue if TPL is invalid.
109	BR INVALID C	Do not continue if C is invalid.
10C	BR INVALID SC	Do not continue if Sc is invalid.
COMMON STATEMENTS		
000	END	Stop or end the execution of the calculator program.
0C0	NOP	No Operation instruction
0C1	ENTER	Terminate and enter the number on top of the stack (x)
0C5	CLEAR	Clears all numerical values on the stack.
NUMERICAL USER INPUT AND MATH OPERATIONS		
080	0	Enter the Number – 0
081	1	Enter the Number – 1
082	2	Enter the Number – 2
083	3	Enter the Number – 3
084	4	Enter the Number – 4
085	5	Enter the Number – 5
086	6	Enter the Number – 6
087	7	Enter the Number – 7
088	8	Enter the Number – 8
089	9	Enter the Number – 9
08A	.	Enter a Decimal Point
08B	e	Enter Scientific Notation Exponent
08C	+	Enter the Plus Sign
08D	-	Enter the Negative Sign
0B0	ADD	Returns the addition value of the two numbers on the stack (y + x)
0B1	SUBTRACT	Returns the subtraction value of the two numbers on the stack (y - x)
0B2	MULTIPLY	Returns the multiplication value of the two numbers on the stack (y * x)
0B3	DIVIDE	Returns the division value of the two numbers on the stack (y / x)
0B4	Y^X	Returns the value of the number on the stack (y) raised to the power of the number on the stack (x).
0AA	1/X	Returns the reciprocal of the number on the stack (x)

Network Connection Guide

This chapter describes the connection procedure of the FL-1 Thermal Analysis System with a computer via Ethernet cable The procedures described here are for a Windows® based operating system (Windows® 7 or later) using ***PuTTY,*** *a free and open-source SSH and Telnet client* (Version 0.70).

> **NOTE**
>
> **Contact** SYSCON Sensors for assistance regarding interfacing the FL-1 with other operating systems or custom quality control systems.

Connection via Ethernet cable

The default TCP/IP settings of the FL-1 (known as the **Host**) can be accessed from the **Comm** tab under the **Config** menu **(Config → <Enter Security Code> → Comm → Host).** These can be changed using the keypad displayed when a setting is selected.

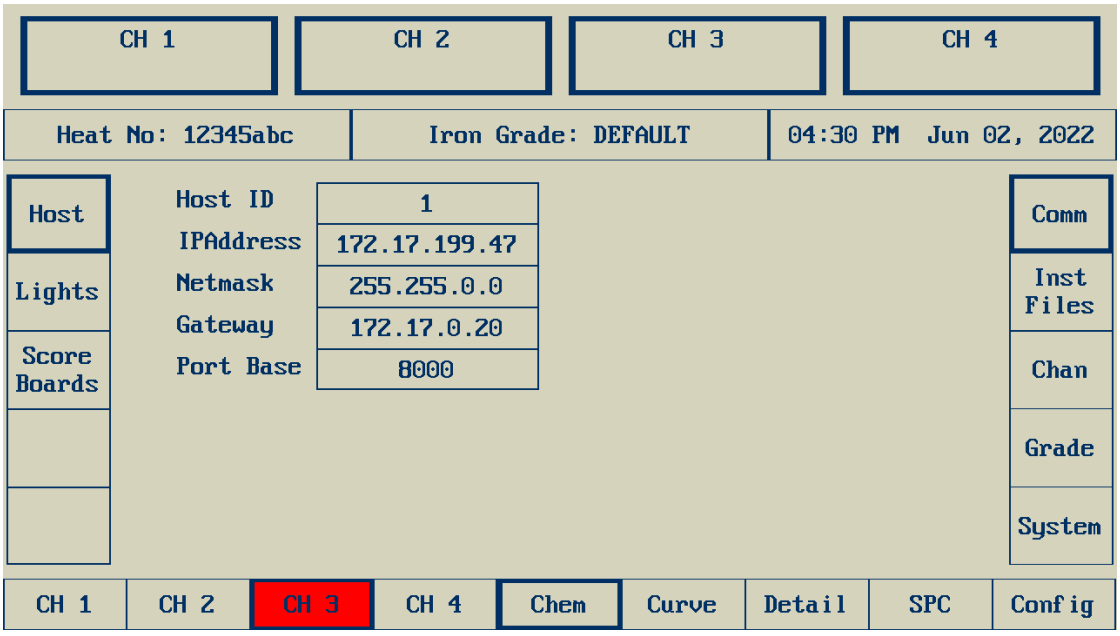


Figure 33: Network Configuration of the FL-1

- **Host ID**

  A Host ID is a unique identification number for the FL-1. If there are multiple FL-1 units in the same network, the Host ID should be different for each FL-1 unit to connect a SYSCON Sensors Lightstack or a Scoreboard. The default Host ID is 1.

- **IP Address**

  This denotes the **IP Address** of the FL-1. The default **IP address** is 172.16.16.22. The IP address consists of a Network ID and Host ID (not to be confused with the Host ID mentioned above and shown in **Figure 33:** Network Configuration of the FL-1). The Network ID is shown in underline bold red font in

  Table 7. For example, in the default IP address of 172.16.16.22, 172.16 is the Network ID and 16.22 is the Host ID. There are three classes of IP addresses – Class A, B, and C. For a computer network within a plant (i.e. Intranet), a set of IP addresses in each class are reserved known as Private IP addresses (see

  Table 7).

Table 7: Private IP address settings. Network ID highlighted in bold red font with an underline.

Class	Range of Private IP Address	Default Subnet Mask (Netmask)
A	10.0.0.1 to 10.255.255.254	255.0.0.0
B	172.16.0.1 to 172.31.255.254	255.255.0.0
C	192.168.0.1 to 192.168.255.254	255.255.255.0

- **Netmask**

  The default Subnet Mask for each class.

- **Gateway**

  The address of the default gateway.

- **Port Base**

The computer can connect to a FL-1 to obtain different data such as Measurement data, Instrument configuration, User Program etc. by "listening" to different ports. This is like tuning in to different channels on a radio; the channel numbers, which represent the radio frequency are the port numbers for an Ethernet based connection. The **Port Base** represents the base number from which the port numbers are calculated. For example, for the default **Port Base** of 8000, **Port Number** 8025 (see **Table 8**) listens to the Instrument Configuration. If the **Port Base** is changed to 4000, the new **Port Number** of 4025 will now listen to the Instrument Configuration. In a nutshell, the calculations of the **Port Number** are relative to the **Port Base**.

NOTE

The **Network ID** of the FL-1 shown in **Figure 33** should exactly match the Network ID of the computer or plant network to which the FL-1 needs to be connected.

Restart the FL-1 if the Port Base is changed.

Contact your Network Administrator or IT Department to determine the Host settings shown in **Figure 33**Figure 33: Network

Installing PuTTY

PuTTY is available from **www.putty.org/**. The latest version can be downloaded using the link provided in the **Download PuTTY** section on the website. Depending on the type of Windows® Operating System installed on the computer, select the 32-bit or 64-bit Windows Installer (.msi file) for download. After downloading this file, install it.

Procedure

1. Download and Install PuTTY on the computer to which the FL-1 will be connected.
2. Turn ON the FL-1.
3. Unplug existing Ethernet connections on the computer.
4. Connect the Ethernet cable between the FL-1 and the computer.
5. Access the Network settings of the computer Network and Sharing Center in the Control Panel.

6. The Local Area Network (LAN) connection is shown with a yellow warning symbol (see **Figure 34** since the IP Address is not specified. Select Local Area Connection shown in blue under Connections to open the Local Area Connection properties dialog box (see **Figure 35**).

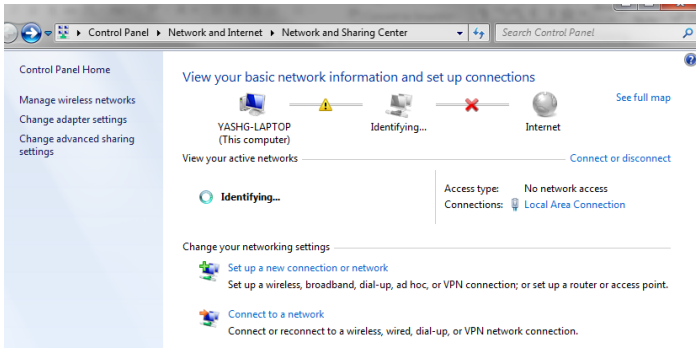


Figure 34: Network and Sharing Center screen before changing network settings.

7. Select Properties → Internet Protocol Version 4 (TCP/IPv4) → Properties to open the Internet Protocol Version 4 properties dialog box.

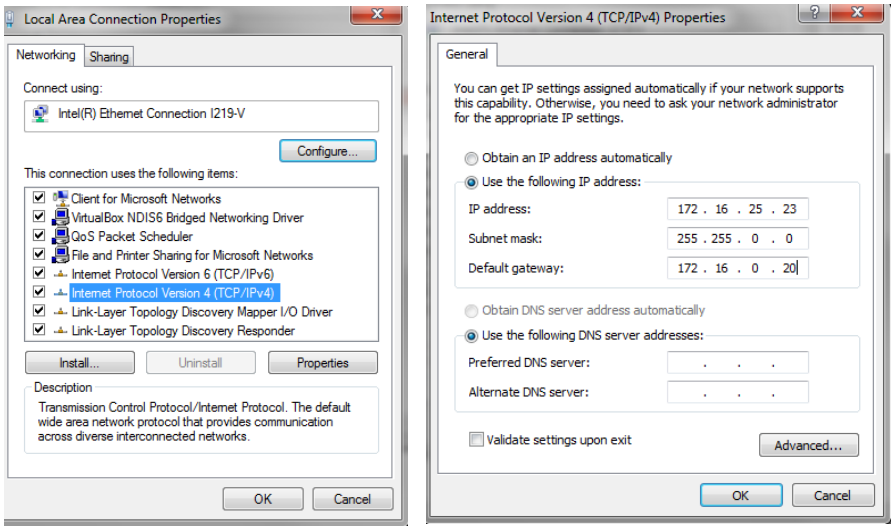


Figure 35: (a) Local Area Connection Properties Dialog box and (b) Internet Connection Properties

8. Enter the IP Address and Gateway (optional) shown in **Figure 35**.The Network ID of the specified IP Address (172.16.25.23) matches that of the FL-1 (172.16.16.22).

9. Click OK. The yellow warning symbol disappears, as shown in **Figure 34**, indicating that the connection was successful.
10. Open PuTTY. In the PuTTY configuration window (see **Figure 36**), enter the IP Address of the FL-1 and select Telnet under Connection Type. Specify the Port Number to listen to. Refer **Table 8** for details regarding port numbers. For future use, this setting can be saved by specifying a name under Saved Sessions and clicking Save.
11. Click Open. A new terminal window will open if the connection is successful. Perform the necessary action on the FL-1 screen (such as saving Inst Config) and the appropriate data will appear on the terminal screen.

This data can be conveniently transferred into Microsoft® Excel by copying it, using the left mouse button (left click), and pasting it directly in Microsoft® Excel or by selecting Paste → Text Import Wizard in the Home tab under Clipboard.

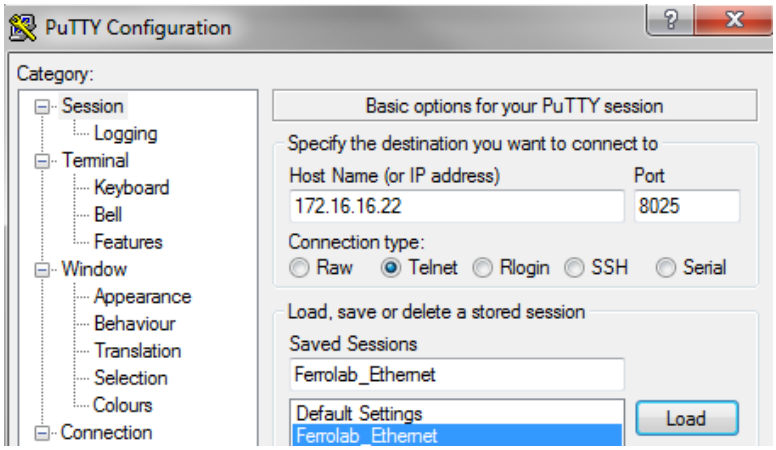


Figure 36: PuTTY setup screen to connect FL-1 to a computer or plant network.

NOTE

Contact your Network Administrator or IT Department to determine the correct configuration settings.

Port Numbers for Ethernet connection

The Port Numbers are relative to the default base of 8000. The default **Port Base** is configurable to anywhere the user has 26 free ethernet ports.

Table 8: Port Number details for Ethernet connection

Port Number	Description	Touchscreen Commands to perform the required action
8000 to 8003	Reserved for connecting Lightstack.(LS-1)	
8004 to 8011	Reserved for connecting Scoreboard (SB-1)	
8012	Display results from Scoreboard	
8013	Partial Data Export (includes results of all variables shown in **Figure 25**)	Refer to **Table 9**
8014	Complete Data export (includes temperature vs. time data and Partial export data)	Refer to **Table 9**
8015 to 8018	Display using Ethernet from built-in calculator	**OpCode: 0D3 – 0D6**
8019	Display data from **SPC** menu using Curve Recall and Detail Recall	SPC → Curve Recall / Detail Recall → <Select Data> → Print
8020	Display Summary Data from SPC menu	SPC → Curve Recall / Detail Recall → Print Summary
8021	Display data from a variable in SPC Menu	SPC → <Select Variable> → SPC Var
8022	Display Temperature or Raw data for troubleshooting	Config → <Enter Security Code> → System → Curve Dump → Ether. → <Temp or Raw>
8023	Display Program	Config → <Enter Security Code> → Grade → <Select Grade> → Prog → <Select Program to display data> → Dump → Ether
8024	Display any 1 of the 3 Inst Files	Config → <Enter Security Code> → Inst Files → Ethernet → <Select any 1 of Inst Config, User Progs or Meas Data>
8025	Display Inst Config	Config → <Enter Security Code> → Inst Files → Ethernet → Inst Config
8026	Display User Progs	Config → <Enter Security Code> → Inst Files → Ethernet → User Progs
8027	Display Measured Data	Config → <Enter Security Code> → Inst Files → Ethernet → Meas Data → <Select any 1 from Current, CH.1 – 4>

Table 9: Data Export settings for Ethernet

	Description	**Part**	**Full**
Data Export	At the end of each run, **after** the cup is removed	All variables. Variables not calculated represented with dashes (-).	Display data in **Part** + Temperature data for all times.

Maintenance

Historically, the most frequent cause of operating problems is the need for maintenance of the thermocouple hardware used with the unit. Often, contact blocks, compensated measurement cable inside the lance, and measurement cable from the probe (lance) to the FL-1 Thermal Analysis System are the primary reasons for bad or missed measurements. In the event of a problem, first check the polarity, continuity, and insulation resistance of the thermocouple and lead wire. The maintenance guidelines are presented in **Table 10**.

NOTE

SYSCON Sensors recommends that the FL-1 Thermal Analysis System instrument be checked against a voltage source such as a potentiometer of documented accuracy at six-month intervals to ensure continued accuracy.

SYSCON Sensors provides repair and maintenance services including recalibration.

Contact Us for more information on custom made portable testing devices and individual cabling needs.

Table 10: **Maintenance** guidelines for FL-1 Thermal Analysis System

Cause		Effect	Action
Operating Practices	Taking reading with furnace power on	Multiple electrical grounds created	Turn furnace power off
	Slag thickness	Measurement probe unable to penetrate to desired depth for an accurate and stable reading of molten metal temperature	Make measurements below the slag line
	Excessive melt temperature	Thermocouple wire melts causing an open circuit condition	Check allowable operating temperatures for thermocouple types (see Table 1: Thermocouple comparison (types S, R, B, and K))
Contact Block	Regular wear and tear	Corrosion results in poor electrical contact	Clean inside surfaces with wire brush Replace every 3 months or when probes become loose

Cause		Effect	Action
Measurement cable inside lance	Overheating **NOTE:** Since the insulation resistance of wires reduces at high temperature, the instrument may show GREEN Ready Light. However, the temperature readings may be incorrect	Breakdown of the insulation resistance between the internal wires of the cable causing a short circuit between the conductors.	Replace lance cable
External Measurement cable	Regular wear and tear Flexing Hot metal splashes	Breakdown of insulation causing an open circuit condition	Replace external measurement cable
Cable through a conduit or operator pulpit	Overheating Humidity	Causes short circuit	Ensure cable is not located close to a heat source Use an open wire tray for easy inspection
	Power lines (high voltage wires) run along with measurement cable	Erroneous readings due to faulty electrical signals	Isolate measurement cable from high voltage lines
Thermocouple connectors	Regular wear and tear	Faulty electrical connection	Replace when worn or erratic measurements are recorded

Ordering Information

Figure 37 depicts the range of SYSCON Sensor products for Thermal Analysis and Bath Temperature Measurement for the Foundry. **Table 11** contains the ordering information for these products.

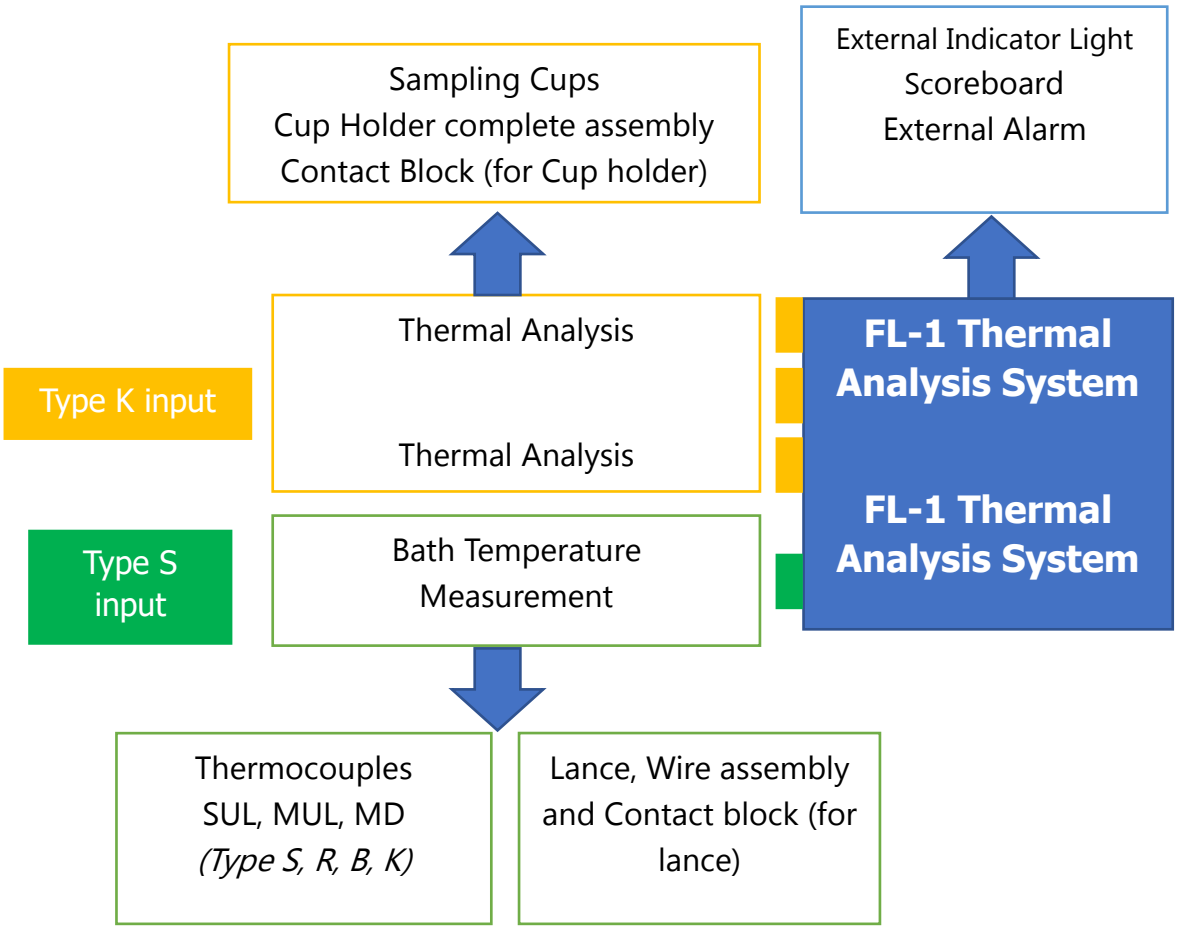


Figure 37: SYSCON Sensors Product Range for the Foundry

Table 11: Ordering Information for SYSCON Sensors products

Product Name	Part No.	Description
Accessories		
Lightstack	LS-1	External Indicator lights
Scoreboard	SB-1	Display results/messages from FL-1
Calibration Checker	CC-1	Check if FL-1 is in calibration
RS-232 Serial Interface	RS-232	Connect to auxiliary equipment via RS-232
RS-485 Serial Interface	RS-485	Connect to auxiliary equipment via RS-485
Thermal Analysis		
MetaCup CE	METACUP-CE	Non-Tellurium Cups
MetaCup C	METACUP-C	Tellurium Cups
Contact Block	CB-FL	Contact Block only for Cup Holder
Cup Holder complete assembly	CH-FL	Contact Block with Stand and Type Steel Braided Thermocouple Wire
Bath Temperature Measurement - Thermocouples		
Single-use Thermocouples	SUL-TYPE-XXYY	TYPE 1068 for Type S IPTS 1968 standard or 630 for Type B IPTS 1968 standard XX Length of cardboard tube 12”, 24”, 36”, 48”, 60”, 72” YY AL for Aluminum Cap or ST for Steel cap *Example: SUL-1068-24ST* *Is Type S 24” SUL with Steel cap.*

Product Name	Part No.	Description
Multi-use Thermocouples With protective Aluminum Foil (*All MUL's are Type S IPTS 1968)*	MUL-10-12FX	X Length of fiber sleeve: 5" or 9" Aluminum foil (optional) coated on remaining length for enhanced temperature resistance. *Example: MUL-10-12F9* *12" long Type S MUL with 9" fiber sleeve and 3" AL foil.*
Multi-use Thermocouples Without protective Aluminum Foil (*All MUL's are Type S IPTS 1968)*	MUL-10-X	X Total Length of MUL: 4", 6", 8", 12" *Example: MUL-10-4* *4" long Type S MUL with 4" fiber sleeve*
Multi-Dip Thermocouples	MD-10	Type S IPTS 1968 with long quartz tip
Bath Temperature Measurement - Lance		
Contact Block	CB-T1	Type S Contact Block
Complete Lance Kit For SYSCON Sensors TS-1 Handheld Digital Pyrometer	LW-AT48S	Lance along with Contact Block and Internal Steel Braided Thermocouple Wire 1. 48" lance with 12" bend and 45° bend angle 2. Part No: CB-T1 3. Type S Internal Steel braided wire
Complete Lance Kit For SYSCON Sensors FL-1 Thermal Analysis System and WM-1 Digital Temperature Measurement System	LM-T48S	1. Part No: LW-AT48S 2. 25 feet Type S Rubber Wire

Instrument Returns

To return an instrument to SYSCON Sensors for repair, certified calibration, and/or reprogramming, follow the procedure outlined below:

1. Visit www.syscon-intl.com/sensors/instrument-repair for all instrument returns.
2. Fill in the Repair and Calibration form, including the following information:
   - Description of the unit being returned
   - Model number of the unit being returned
   - Serial number of the unit being returned
   - Description of the problem
3. Once SYSCON receives your request, you will receive an email with an RMA Number along with a Customer RMA Form to include with your shipment.
4. Return the instrument to the address provided. Please place the RMA Form inside the box with your instrument and **mark your RMA number clearly on the outside of three sides of the box**.
5. After SYSCON Sensors has assessed your instrument, your Salesperson will contact you with a repair quote. SYSCON Sensors requires your approval before repairing any instrument that is not under warranty.
6. After your repair and calibration is completed, SYSCON Sensors will return your instrument to the address provided through the original RMA request, unless otherwise specified.
7. In the event your instrument is not repairable, you will be notified by your Salesperson. If a replacement is available, you will be issued a quote for the replacement upon inquiry. Non-repairable instruments can be returned to you at your preference.

> ⚠ **NOTE**
>
> To avoid damage to the instrument during the shipping process, return the instrument in the original shipping container whenever possible. SYSCON Sensors is NOT responsible for any damage to instrument(s) during the shipping process to SYSCON Sensors.

Troubleshooting

The troubleshooting guidelines are shown in **Table 12.**

Table 12: Troubleshooting guidelines for FL-1

Error Message	Guidelines
Insufficient Peak Temperature	• Reduce the Peak Temperature (**TPK**) from **Config → Grade → Curve Parms** • Determine the reason for the low pouring temperature of the melt
Broken Thermocouple	• Check if thermocouple wire in the cup has melted due to excessive temperature • Clean contact block since oxidized deposits prevent electrical contact between cup and stand • Increase the **TPL** and/or **TPS Width** and **Height** settings from **Config → Grade → Curve Parms** and **Reprocess** data from **SPC** menu
C or Si readings not calculated even though TPL was calculated	Increase the **TPL/TPS Width** and **Height** settings from **Config → Grade → Curve Parms** (see **Table 5**) and **Reprocess** data from **SPC** menu
C or Si is calculated but values are wrong.	• C or Si is calculated from TPL, if correct TPL is not found, the resulting C or Si values will be incorrect. • Check the curve to confirmif the right TPL is being picked. • Increase the TPL width setting s from **Config → Grade → Curve Parms** • Reprocess data from SPC
Screen freeze	1. Turn FL-1 OFF 2. Unplug the power cord connected to the unit 3. Wait for about 1 minute. Connect the power cord 4. Turn FL-1 ON Repeat the process if needed. If this issue persists, **Contact Us**

Ethernet cable connected to FL-1 not detected by computer	1. Turn FL-1 OFF 2. Unplug the power cord connected to the unit 3. Wait for about 1 minute. Connect the power cord 4. Turn FL-1 ON

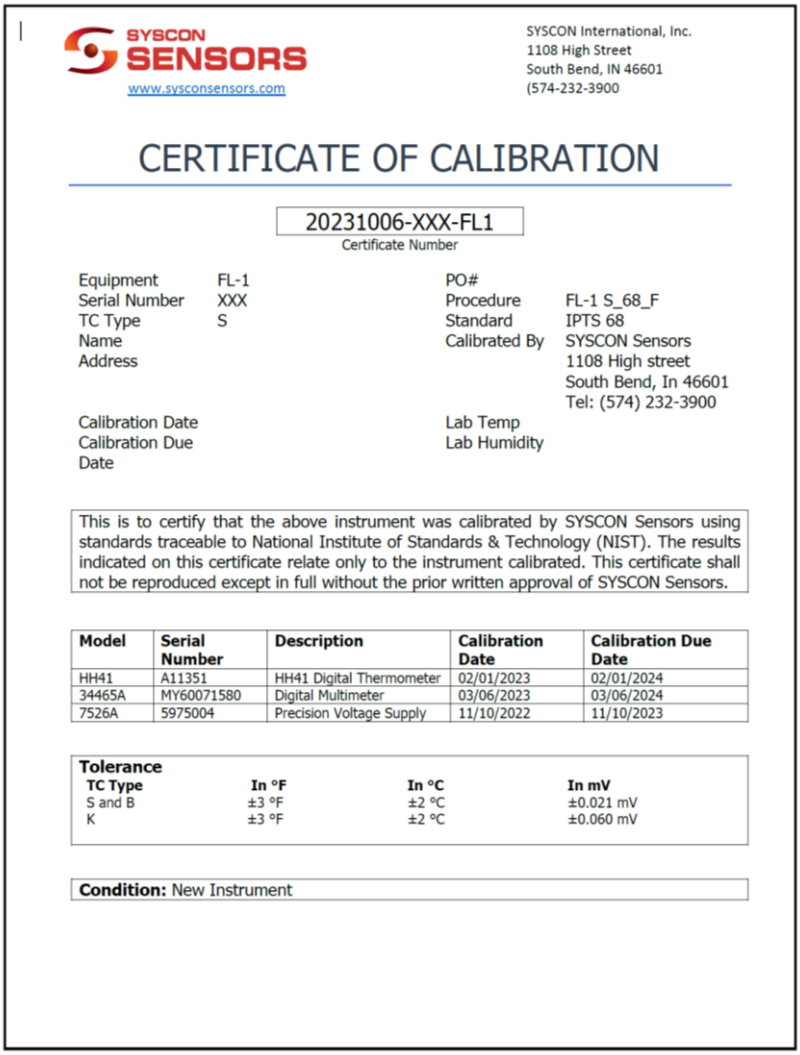
Quick Reference

Table 13: List of frequent user activities and touchscreen sequences to accomplish them.

User Activity	Touchscreen Key Sequence
Turn FL-1 OFF	Use the power switch to turn off the instrument.
Add or Remove display variables in the **Curve and Chem menu**	**Config** → **<Enter Security Code>** → **Chan** → **Probe Type** → <Select appropriate probe type> → <Choose variables to display for each window>
Save data to a USB drive **(Inst Config, User Progs, Meas Data)**	**Config** →**<Enter Security Code>** → **USB** → **<Select data to save>** → **Save**
Restore data from thumb drive **(Inst Config, User Progs)**	**Config** →**<Enter Security Code>** → **USB** → <Select data to restore> → **Restore**
Add or modify an Iron grade	**Config** → **<Enter Security Code>** → **Grade** → < Select Default to modify existing Iron grade or select other rectangles to add a new Iron grade>
Modify Curve parameters	**Config** → **<Enter Security Code>** → **Grade** → <Select Grade> → **Curve Parms**
Reprocess last measurement	**Config** → **SPC** → **Reprocess**
Modify **Date/Time**	**Config** → **<Enter Security Code>** → **System** → **Date/Time**

Calibration Certificate

All channels are calibrated individually. A Calibration Certificate (shown in **Figure 38**: Calibration Certificate)is provided which records data for all channels.



SYSCON SENSORS
www.sysconsensors.com

SYSCON International, Inc.
1108 High Street
South Bend, IN 46601
(574-232-3900

CERTIFICATE OF CALIBRATION

20231006-XXX-FL1
Certificate Number

Equipment	FL-1	PO#	
Serial Number	XXX	Procedure	FL-1 S_68_F
TC Type	S	Standard	IPTS 68
Name		Calibrated By	SYSCON Sensors
Address			1108 High street South Bend, In 46601 Tel: (574) 232-3900
Calibration Date		Lab Temp	
Calibration Due Date		Lab Humidity	

This is to certify that the above instrument was calibrated by SYSCON Sensors using standards traceable to National Institute of Standards & Technology (NIST). The results indicated on this certificate relate only to the instrument calibrated. This certificate shall not be reproduced except in full without the prior written approval of SYSCON Sensors.

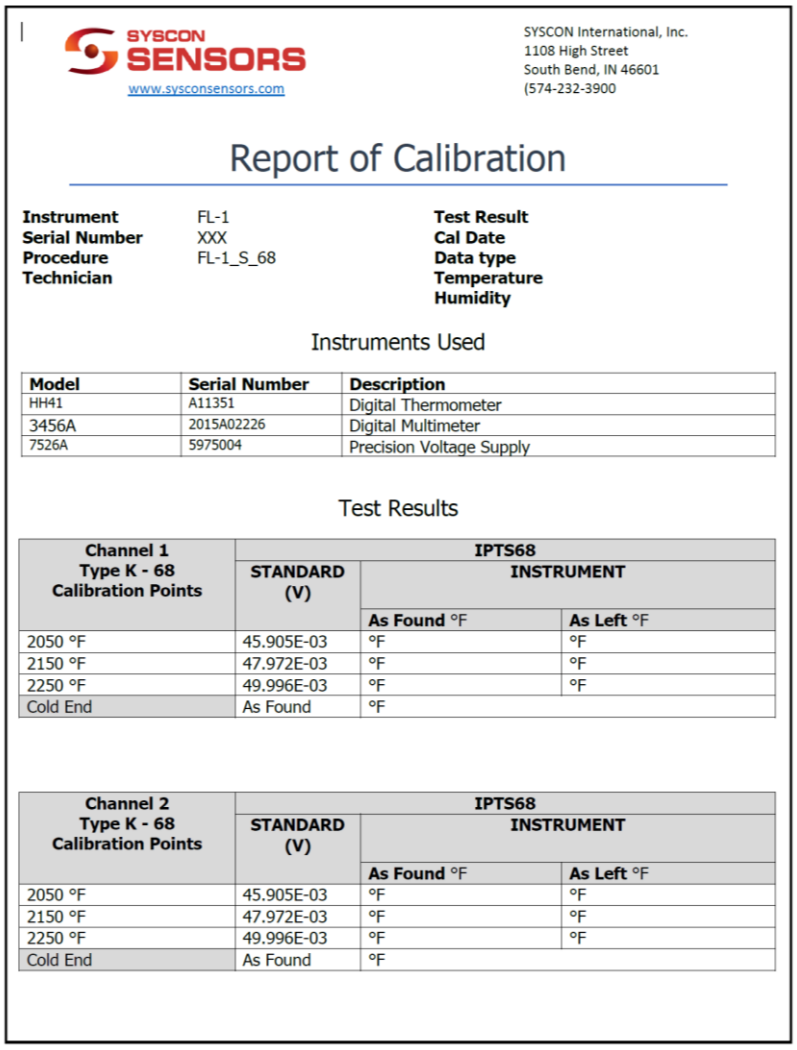
Model	Serial Number	Description	Calibration Date	Calibration Due Date
HH41	A11351	HH41 Digital Thermometer	02/01/2023	02/01/2024
34465A	MY60071580	Digital Multimeter	03/06/2023	03/06/2024
7526A	5975004	Precision Voltage Supply	11/10/2022	11/10/2023

Tolerance

TC Type	In °F	In °C	In mV
S and B	±3 °F	±2 °C	±0.021 mV
K	±3 °F	±2 °C	±0.060 mV

Condition: New Instrument

Figure 38: Calibration Certificate



SYSCON SENSORS
www.sysconsensors.com

SYSCON International, Inc.
1108 High Street
South Bend, IN 46601
(574-232-3900

Report of Calibration

Instrument	FL-1	**Test Result**	
Serial Number	XXX	**Cal Date**	
Procedure	FL-1_S_68	**Data type**	
Technician		**Temperature**	
		Humidity	

Instruments Used

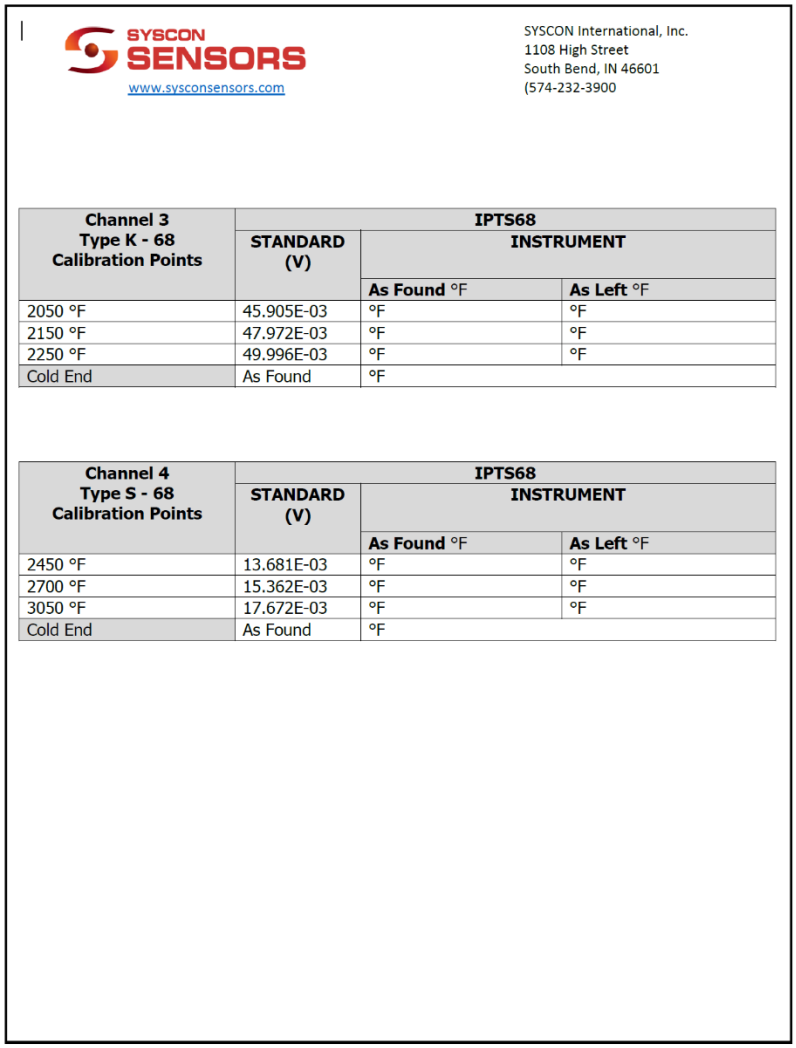
Model	Serial Number	Description
HH41	A11351	Digital Thermometer
3456A	2015A02226	Digital Multimeter
7526A	5975004	Precision Voltage Supply

Test Results

Channel 1 Type K - 68 Calibration Points	IPTS68		
	STANDARD (V)	INSTRUMENT	
		As Found °F	As Left °F
2050 °F	45.905E-03	°F	°F
2150 °F	47.972E-03	°F	°F
2250 °F	49.996E-03	°F	°F
Cold End	As Found	°F	

Channel 2 Type K - 68 Calibration Points	IPTS68		
	STANDARD (V)	INSTRUMENT	
		As Found °F	As Left °F
2050 °F	45.905E-03	°F	°F
2150 °F	47.972E-03	°F	°F
2250 °F	49.996E-03	°F	°F
Cold End	As Found	°F	

Figure 39: Report of Calibration (Channel 1 & 2)



SYSCON SENSORS
www.sysconsensors.com

SYSCON International, Inc.
1108 High Street
South Bend, IN 46601
(574-232-3900

Channel 3 Type K - 68 Calibration Points	IPTS68		
	STANDARD (V)	INSTRUMENT	
		As Found °F	As Left °F
2050 °F	45.905E-03	°F	°F
2150 °F	47.972E-03	°F	°F
2250 °F	49.996E-03	°F	°F
Cold End	As Found	°F	

Channel 4 Type S - 68 Calibration Points	IPTS68		
	STANDARD (V)	INSTRUMENT	
		As Found °F	As Left °F
2450 °F	13.681E-03	°F	°F
2700 °F	15.362E-03	°F	°F
3050 °F	17.672E-03	°F	°F
Cold End	As Found	°F	

Figure 40Report of Calibration (Channel 3 & 4)

Contact Us

SYSCON Sensors

Address:
1108 High Street

South Bend, Indiana, USA - 46601

Phone: +1 (574) 232 - 3900

www.sysconsensors.com

Appendix A: List of OpCodes

The built-in calculator uses the Reverse Polish Notation and Hexadecimal number system (base 16) rather than the normally used decimal system (base 10) because it shortens the OpCode.

The hexadecimal number system is a combination of numbers from 0-9 and letters from A-F. OpCodes are specified using this system. To convert a hexadecimal number to the decimal number format, multiply each digit with the corresponding power of 16.

For example, $(0\text{AE})_{16} = (0\ x\ 16^2 + 10\ x\ 16^1 + 14\ x\ 16^0)_{10}$

$= (0\ + 160 + 14)_{10} = 174$ in decimal format

OP CODE	COMMAND	COMMAND DESCRIPTION
NUMBERS		
080	0	Enter the Number – 0
081	1	Enter the Number – 1
082	2	Enter the Number – 2
083	3	Enter the Number – 3
084	4	Enter the Number – 4
085	5	Enter the Number – 5
086	6	Enter the Number – 6
087	7	Enter the Number – 7
088	8	Enter the Number – 8
089	9	Enter the Number – 9
08A	.	Enter a Decimal Point
08C	+	Enter the Plus Sign
08D	-	Enter the Negative Sign
COMMON MATH OPERATIONS		
0B0	ADD	Returns the addition value of the two numbers on the stack (y + x)
0B1	SUBTRACT	Returns the subtraction value of the two numbers on the stack (y - x)
0B2	MULTIPLY	Returns the multiplication value of the two numbers on the stack (y * x)
0B3	DIVIDE	Returns the division value of the two numbers on the stack (y / x)
0B4	Y^X	Returns the value of the number on the stack (y) raised to the power of the number on the stack (x).

OP CODE	COMMAND	COMMAND DESCRIPTION
0B5	X ←→ Y	Exchanges the contents of the X-register with the contents of the Y-register on the stack.
MATH OPERATIONS FOR 1 INPUT		
0A0	CHANGE SIGN	Changes the sign of the number
0A1	FLOOR	Returns the largest integer that is not greater than the number. Example: floor (99.01) = 99 ; floor (99.99) = 99
0A2	CEILING	Returns the smallest integer that is not less than the number. Example: ceiling (99.01) = 100 ; ceiling (99.99) = 100
0A3	ABS	Returns the absolute value of the number
0A4	SQUARE	Returns the square of the number
0A5	SQUARE ROOT	Returns the square root of the number
0A6	e^X	Returns the natural exponential (base e) of the number
0A7	NATURAL LOG	Returns the natural logarithm (base e) of the number
0A8	10^X	Returns the common exponential (base 10) of the number
0A9	LOG	Returns the common logarithm (base 10) of the number
0AA	1/X	Returns the reciprocal of the number on the stack (x)
TRIGONOMETRIC MATH OPERATIONS		
091	ARC SIN	Returns the arc sine of the number
092	COS	Returns the cosine of the number
093	ARC COS	Returns the arc cosine of the number
094	TAN	Returns the tangent of the number
095	ARC TAN	Returns the arc tangent of the number
0C6	PI	Enters the value of Pi (3.14159) on top of the stack (x)
0C7	DEGREES	Changes from radian mode to degree mode.
0C8	RADIANS	Changes from degree mode to radian mode. In radian mode, all trigonometric functions use radians instead of degrees.
MISCELLANEOUS OPERATORS		
0C0	NOP	No Operation instruction
0C1	ENTER	Terminate and enter the number on top of the stack (x)
0C2	INPUT	Break program and request numerical input from the operator, then enter this numerical number on top of the stack (x) and continue the program.
0C3	POP	Pop the numbers on the stack — Destroys the number (x) on top of the stack and moves all numbers in the stack up one position.
0C4	DUP	Duplicates the number on the stack — Copies the number (x) again on top of the stack and moves all numbers on the stack down one position.
0C5	CLEAR	Clears all numerical values on the stack.

OP CODE	COMMAND	COMMAND DESCRIPTION
OUTPUT OPTIONS		
0D0	FLUSH PRT BUF	Flush Print Buffer with no CR or LF via the selected RS-232 port.
0D1	PRINT PORT 1	Select RS-232 Port 1 for printing all following custom printer messages.
0D2	PRINT PORT 2	Select RS-232 Port 2 for printing all following custom printer messages.
0D3	ETHERNET PORT 1	Select Ethernet Port 8015 for printing all following custom printer messages.
0D4	ETHERNET PORT 2	Select Ethernet Port 8016 for printing all following custom printer messages.
0D5	ETHERNET PORT 3	Select Ethernet Port 8017 for printing all following custom printer messages.
0D6	ETHERNET PORT 4	Select Ethernet Port 8018 for printing all following custom printer messages.
0DD	SET DEC. DIG	Print format for printing values — Numbers right of decimal point.
BRANCH STATEMENTS To use branch statements in the program the two variables to be combined - variable 1 (y) and variable 2 (x) must be input (or recalled) before the branch statement. This statement is followed by the branch target label, which specifies the program where to go if the condition of the branch statement is met. If the condition of the branch statement is not met then the program skips the branch target label and continues with the next program instruction. This instruction pops the variable 2 (y) off the top of the stack leaving variable 1 on top of the stack (x).		
0E0	BR EQUAL	Branch if the values of the two numbers on the stack are equal (y = x) to the target label listed in the next program step. Example: To branch to Label 0 if the PPM variable is equal to 100, the program is: Step xxx 202 recall ppm Step xxx 081 1 Step xxx 080 0 Step xxx 080 0 Step xxx 0C1 Enter Step xxx 0E0 br if equal Step xxx 400 goto 00 Step xxx 500 label 0
0E1	BR NOT EQUAL	Branch if the values of the two numbers on the stack are not equal (y ≠ x) to the target label listed in the next program step.
0E2	BR IF GREATER	Branch if the values of the two numbers on the stack are greater than (y > x) to the target label listed in the next program step.
0E3	BR IF LESS	Branch if the values of the two numbers on the stack are less than (y < x) to the target label listed in the next program step.

OP CODE	COMMAND	COMMAND DESCRIPTION
0E4	BR GRE OR EQ	Branch if the values of the two numbers on the stack are greater than or equal (y ≥ x) to the target label listed in the next program step.
0E5	BR LESS OR EQ	Branch if the values of the two numbers on the stack are less than or equal (y ≥ x) to the target label listed in the next program step.
0E6	BR TO SUB	Branch to subroutine (Call) target label listed in the next program step. This branch statement must be followed by a branch target label. The branch target label tells the program where the subroutine starts in the program. The subroutine **must end with a Return (OpCode: 0E7)** from the subroutine to continue with the program from the point of call. Example: To branch to a subroutine at label 0, the program is: Step xxx 0E6 br to sub Step xxx 400 goto 00 ..... Step xxx 500 label 0 ..... Step xxx 0E7 ret from sub
0E7	RET FROM SUB	Return from subroutine. Returns to the next program step following the call to this subroutine.
0E8	BR ALWAYS	Branch always (Goto) to target label listed in the next program step. To use this branch statement in the program, follow the branch statement with a branch target label. The branch target label tells the program where to go for the next program instruction. Example: To always branch to label 0, the program is: Step xxx 0F8 br always Step xxx 400 goto 00 ..... Step xxx 500 label 0
0E9	BR IF METACUP HC	Branch to target label listed in the next program step if the probe type is a Metacup HC (Tellurium cup). To use this branch statement in the program, follow the branch statement with a branch target label. The branch target label tells the program where to go for the next program instruction.
0EA	BR IF METACUP CE	Branch to target label listed in the next program step if the probe type is a Metacup CE (non-Tellurium cup). To use this branch statement in the program, follow the branch statement with a branch target label. The branch target label tells the program where to go for the next program instruction if the measurement was from a carbon probe measurement.
0EB	BR IF BATH	Branch to target label listed in the next program step if the probe type is a bath. To use this branch statement in the

OP CODE	COMMAND	COMMAND DESCRIPTION
		program, follow the branch statement with a branch target label. The branch target label tells the program where to go for the next program
CHECK VARIABLE VALIDITY (CURRENT CHANNEL)		
100	BR INVALID BTH	Do not continue if **BATH** temperature is invalid.
101	BR INVALID TPK	Do not continue if **TPK** is invalid.
102	BR INVALID TPL	Do not continue if **TPL** is invalid.
103	BR INVALID TEN	Do not continue if **TEN** is invalid.
104	BR INVALID TEU	Do not continue if **TEU** is invalid.
105	BR INVALID TPS	Do not continue if **TPS** is invalid.
106	BR INVALID TER	Do not continue if **TER** is invalid.
107	BR INVALID TES	Do not continue if **TES** is invalid.
108	BR INVALID CE	Do not continue if **CE** is invalid.
109	BR INVALID C	Do not continue if **C** is invalid.
10A	BR INVALID Si	Do not continue if **Si** is invalid.
10B	BR INVALID DT	Do not continue if **dT** is invalid.
10C	BR INVALID Sc	Do not continue if **Sc** is invalid.
10D	BR INVALID Rm	Do not continue if **Rm** is invalid.
10E	BR INVALID BH	Do not continue if **BH** is invalid.
10F	BR INVALID FPE	Do not continue if **FPE** is invalid.
110	BR INVALID ASE	Do not continue if **ASE** is invalid.
111	BR INVALID SF1	Do not continue if **SF1** is invalid.
112	BR INVALID SF2	Do not continue if **SF2** is invalid.
113	BR INVALID TPLP	Do not continue if **TPLP** is invalid. (First Derivative with respect to time)

OP CODE	COMMAND	COMMAND DESCRIPTION
114	BR INVALID TENP	Do not continue if **TENP** is invalid. (First Derivative with respect to time)
115	BR INVALID TEUP	Do not continue if **TEUP** is invalid. (First Derivative with respect to time)
116	BR INVALID TPSP	Do not continue if **TPSP** is invalid. (First Derivative with respect to time)
117	BR INVALID TERP	Do not continue if **TERP** is invalid. (First Derivative with respect to time)
118	BR INVALID TESP	Do not continue if **TESP** is invalid. (First Derivative with respect to time)
119	BR INVALID UV1	Do not continue if **UV1** is invalid.
11A	BR INVALID UV2	Do not continue if **UV2** is invalid.
11B	BR INVALID UV3	Do not continue if **UV3** is invalid.
11C	BR INVALID UV4	Do not continue if **UV4** is invalid.
11D	BR INVALID UV5	Do not continue if **UV5** is invalid.
11E	BR INVALID HEAT NUMBER	Do not continue if **Heat number** is invalid.
11F	BR INVALID GRADE	Do not continue if **Grade** is invalid.
VARIABLE STORE (CURRENT CHANNEL): 200 – 21D The variables follow the same order as the **Check Variable Validity** section. Example: OpCode 202: STORE TPL and 21B: STORE UV3		
VARIABLE RECALL (CURRENT CHANNEL): 300 – 31D The variables follow the same order as the **Check Variable Validity** section. Example: OpCode 302: RECALL TPL and 31B: RECALL UV3		
VARIABLE PRINT (CURRENT CHANNEL): 400 – 41D The variables follow the same order as the **Check Variable Validity** section. Example: OpCode 402: PRINT TPL and 41B: PRINT UV3		
CH. 1 VARIABLE SELECT **ADD <u>020</u> TO CURRENT CHANNEL VARIABLE SELECTION**		
Example: **A. To store Ch.1 CE** 1. 208 – Store CE (Current Channel) 2. Add 020 3. 228 – Store Ch.1 CE	Example: **B. To print Ch.1 TPS** 1. 405 – Print TPS 2. Add 020 3. 425 – Print Ch.1 TPS	
CH. 2 VARIABLE SELECT		

OP CODE	COMMAND	COMMAND DESCRIPTION
ADD <u>040</u> TO CURRENT CHANNEL VARIABLE SELECTION		
Example: **A. To store Ch.2 CE** 1. 208 – Store CE (Current Channel) 2. Add 040 3. 248 – Store Ch.2 CE		Example: **B. To print Ch.2 TPS** 1. 405 – Print TPS 2. Add 040 3. 445 – Print Ch.2 TPS
CH. 3 VARIABLE SELECT **ADD <u>060</u> TO CURRENT CHANNEL VARIABLE SELECTION**		
Example: **A. To store Ch.2 CE** 1. 208 – Store CE (Current Channel) 2. Add 060 3. 268 – Store Ch.3 CE		Example: **B. To print Ch.2 TPS** 1. 405 – Print TPS 2. Add 060 3. 465 – Print Ch.3 TPS
CH. 4 VARIABLE SELECT **ADD <u>080</u> TO CURRENT CHANNEL VARIABLE SELECTION**		
Example: **A. To store Ch.4 CE** 1. 208 – Store CE (Current Channel) 2. Add 080 3. 288 – Store Ch.4 CE		Example: **B. To print Ch.4 TPS** 1. 405 – Print TPS 2. Add 080 3. 485 – Print Ch.4 TPS
500 – 5FF	GOTO IJ	Branch target label (Goto) use by the branch statement to identify what label statement to program should branch to if the branch statement is true. There are 256 possible target labels, where xx will = 00 to 255.
600 – 6FF **(IJ)**	LABEL IJ	Identify the branch statement jumps (call or goto). There are 256 possible labels, where xx will = 00 to 255.
700 – 7FF **(7IJ)**	M STORE IJ IJ → Memory location	Stores the value in memory location specified by the last two digits (IJ). Example: 708 M STORE 8. Stores the value in memory location 8. There are 256 memory locations from 00 to FF.
800 – 8FF **(8IJ)**	M RECALL IJ IJ → Memory location	Recalls the value located in the memory location specified by the last two digits (IJ). Example: 808 M STORE 8. Stores the value in memory location 8.
900 – 8FF **(9IJ)**	M PLUS IJ IJ → Memory location	Adds the value on top of stack (x) to the value stored in memory location specified by the last two digits (IJ). x + <Value in Memory IJ>

OP CODE	COMMAND	COMMAND DESCRIPTION
A00 – AFF (IJ)	M MINUS IJ IJ → Memory location	Subtracts the value on top of stack (x) from the value stored in memory location specified by the last two digits (IJ). Example: Subtract 1 from value stored in memory location 188 Step xxx 081 1 Step xxx 0C1 enter Step xxx ABC M minus 188 x - <Value in Memory IJ>
B00 – BFF (IJ)	M MUL IJ IJ → Memory location	Multiplies the value on top of stack (x) with the value stored in memory location specified by the last two digits (IJ) <Value in Memory IJ> * x
C00 – CFF (IJ)	M DIVIDE IJ IJ → Memory location	Divides the value on top of stack (x) into the value stored in memory location specified by the last two digits (IJ). <Value in Memory IJ> / x
D00 – DFF (IJ)	M PRINT IJ IJ → Memory location	Sends the value stored in memory location specified by the last two digits (IJ) to be printed via the selected RS-232 Port (Refer to the **Output Options** section in this table).

Appendix B: ASCII Symbols

Used for printing custom messages.

NOTE

OpCodes from 80–89 specify numbers for math operations. OpCodes 30-39 in ASCII symbols generate numbers only for **printing** (i.e. to print 2, specify OpCode 32) and should not be used for math operations.

OpCode	ASCII	Command Description
0	0	NUL
1	1	SOH
2	2	STX
3	3	ETX
4	4	EOT
5	5	ENQ
6	6	ACK
7	7	BEL
8	8	BS
9	9	TAB
A	10	LF
B	11	VT
C	12	FF
D	13	CR
E	14	SO
F	15	SI
10	16	DLE
11	17	DC1
12	18	DC2
13	19	DC3

OpCode	ASCII	Command Description
14	20	DC4
15	21	NAK
16	22	SYN
17	23	ETB
18	24	CAN
19	25	EM
1A	26	SUB
1B	27	ESC
1C	28	FS
1D	29	GS
1E	30	RS
1F	31	US
20	32	(space)
21	33	!
22	34	"
23	35	#
24	36	$
25	37	%
26	38	&
27	39	'

OpCode	ASCII	Command Description
28	40	(
29	41	)
2A	42	*
2B	43	+
2C	44	,
2D	45	-
2E	46	.
2F	47	/
30	48	0
31	49	1
32	50	2
33	51	3
34	52	4
35	53	5
36	54	6
37	55	7
38	56	8
39	57	9
3A	58	:
3B	59	;
3C	60	<
3D	61	=
3E	62	>
3F	63	?
40	64	@
41	65	A
42	66	B
43	67	C

OpCode	ASCII	Command Description
44	68	D
45	69	E
46	70	F
47	71	G
48	72	H
49	73	I
4A	74	J
4B	75	K
4C	76	L
4D	77	M
4E	78	N
4F	79	O
50	80	P
51	81	Q
52	82	R
53	83	S
54	84	T
55	85	U
56	86	V
57	87	W
58	88	X
59	89	Y
5A	90	Z
5B	91	[
5C	92	\
5D	93	]
5E	94	^
5F	95	_

OpCode	ASCII	Command Description
60	96	`
61	97	a
62	98	b
63	99	c
64	100	d
65	101	e
66	102	f
67	103	g
68	104	h
69	105	i
6A	106	j
6B	107	k
6C	108	l
6D	109	m
6E	110	n
6F	111	o

OpCode	ASCII	Command Description
70	112	p
71	113	q
72	114	r
73	115	s
74	116	t
75	117	u
76	118	v
77	119	w
78	120	x
79	121	y
7A	122	z
7B	123	{
7C	124	|
7D	125	}
7E	126	~
7F	127	□

Warranty

SYSCON SENSORS warrants its product, when properly assembled and installed as recommended, to be free from defects in material and workmanship, under normal use and service, for a period of one year from the original date of purchase. Purchaser is requested to retain the invoice as proof of the purchase date. THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING THE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

The warranty stated above shall not apply to any product which, in SYSCON Sensor's judgment, has been repaired or altered in any way to affect its reliability nor to any product which has been subject to damage by fire or accident, misuse, abuse, negligent handling, used outside its capabilities, or from lack of periodic inspection.

SYSCON Sensors' obligation under this warranty shall be limited exclusively to the repair or replacement of any products determined to be defective by an authorized SYSCON Sensors representative, whose determination shall be final. Any product claimed to be defective shall be returned to an authorized SYSCON Sensors service facility. SYSCON Sensors reserves the right to satisfy its warranty obligation in full by refund of the purchase price upon return to it of the defective products if an authorized representative of SYSCON Sensors determines that the nature of the defect precludes remedy by repair or replacement. In no event shall SYSCON Sensor's obligation hereunder exceed the purchase price. Purchaser shall bear all cost and expense for transportation of products to and from an authorized SYSCON Sensors service facility, including removal and installation, inspection, and testing.

IN NO EVENT SHALL SYSCON SENSORS HAVE ANY LIABILITY WHATSOEVER FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING FROM ANY CAUSE INCLUDING BUT NOT LIMITED TO: BREACH OF CONTRACT, BREACH OF WARRANTY, STRICT LIABILITY (IN TORT OR WARRANTY) OR NEGLIGENCE.