FLUKE®

Process Instruments

Datapaq® Reflow Tracker®

USER MANUAL

for use with
Insight™ *software*

Issue 4
MA5120A

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Datapaq is the world's leading brand of process temperature-monitoring instrumentation, and maintains this leadership by continual development of its advanced, easy-to-use Tracker systems.

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DATAPAQ PART NO. MA5120A

SAFETY WARNINGS

For safe use of Datapaq equipment, always:

- Take care to follow its supplied instructions.
- Observe any warning signs shown on the equipment.

Indicates **potential hazard**.
On Datapaq equipment this normally warns of high temperature, but, where you see the symbol, consult the manual for further explanation.

Warns of **high temperatures**.
Where this symbol appears on Datapaq equipment, its surface may be excessively hot (or excessively cold) and may thus cause skin burns.

Manual set in 10 pt Gill Sans.
User manuals are available in other languages; contact Fluke Process Instruments for details.

CONTENTS

Introduction

Datapaq® Reflow Tracker®, incorporating Insight™ software, is a complete system for monitoring and analyzing the temperature profiles of products within all types of soldering processes. Power and flexibility make it a perfect tool for process temperature monitoring, from commissioning and troubleshooting to process optimization, ensuring consistent quality of product, consistent oven performance and maximum efficiency. Innovative analysis techniques help in identifying problems, fine-tuning the process and reducing running costs.

Insight is available for the reflow industry in different levels of sophistication to meet the requirements of all applications.

- **Reflow Tracker Professional** – A high-end system, including the functionality of Surveyor (see below).
- **Reflow Tracker** – The standard system for wide application, including ability to perform hardwired telemetry and (with additional hardware and software) radio telemetry, Easy Oven Setup, and analysis of oven trends using Statistical Process Control (see below).
- **Reflow Tracker Basic** – A reduced feature set, but with full analysis options and wizard-driven procedures.
- **Reflow Lite** – Essential features for profile-gathering and simple analysis.

Reflow Tracker is equally useful for other soldering applications such as wave solder, vapor phase, curing ovens and rework stations.

Telemetry options allow full monitoring of temperatures in real time while a job is actually in the oven: hardwired telemetry is part of the standard system (see the dedicated *User Manual* supplied with your data logger), and Reflow Tracker can be specified to include the TM21 radio-telemetry system.

Statistical Process Control (SPC) allows easy analysis of the results of profile runs over time, highlighting trends in the performance of your process, and allowing potential problems to be identified and dealt with before they occur.

Easy Oven Setup (*not available in Insight Reflow Tracker Basic and Reflow Lite*) enables users rapidly and accurately to set up their ovens for new products and/or new solder formulations by predicting the recipes that should be used to achieve given temperature profiles – and with the **Surveyor** option (*Insight Reflow Tracker Professional only*) you can compare a reference profile (baseline survey) of your oven's ideal performance against a profile which has been obtained subsequently – by a relatively unskilled operator – in order to check whether the oven performance has deteriorated.

Powerful **reporting** facilities allow the user to generate customized printouts, including any or all of the analysis results or raw temperature data.

This manual contains the following sections:

- **Basic Hardware** (p. 11) – The standard system's thermal barriers and thermocouple probes, their specifications and their care and maintenance.
- **Reflow Temperature Profiles** (p. 19) – All the stages of obtaining a temperature profile from a typical reflow process, including the positioning of probes and using the profiles to correct faults in the soldering process.
- **Wave Solder** (p. 31) – Use of a Reflow Tracker system in a wave-solder process.
- **Easy Oven Setup** (p. 37) – Set up an oven for a new product by predicting an oven recipe. (*Not available in Insight Reflow Tracker Basic and Reflow Lite.*)
- **Surveyor** (p. 43) – Monitor an oven's performance in order to assess trends and check whether it has deteriorated. (*Insight Reflow Tracker Professional only.*)
- **Troubleshooting** (p. 51).

The dedicated *User Manual* supplied with your data logger should be read in conjunction with this manual. It provides information on operating the logger, including:

- Installing Insight and establishing communication between logger and PC.
- Resetting the logger with new data-collection parameters.
- Downloading the collected data to the PC.
- Use of hardwired telemetry.
- Troubleshooting logger problems.

For full details on use of the Insight software, refer to the **online Help system** available when the software is installed.

System Components

A typical Reflow Tracker system comprises:

- Data logger, with communications lead and charger; logger with radio-telemetry option includes internal transmitter.
- Receiver (radio-telemetry option only).
- Thermal barrier – to protect the logger during its time in the oven.
- Thermocouple probes.
- Insight Reflow Tracker software.
- User documentation:

- *Reflow Tracker User Manual*.
- Data logger *User Manual* (specific to the logger model).
- *TM21 Radio-telemetry System User Manual* (radio-telemetry option only).

Additional hardware is supplied with Wave Solder (p. 31) and Surveyor systems (p. 43).

*This manual, and other Datapaq user documentation, in **various languages**, is available on the Insight installation DVD included with Datapaq systems. During the software installation, you may select documents to be copied to your PC for rapid on-demand viewing through Insight.*

Basic Hardware

The standard Reflow Tracker system includes one or more thermal barriers and appropriate thermocouples.

For use of the data logger, and for other special-purpose hardware, see the documentation supplied with it.

Thermal Barriers

The thermal barrier provides the thermal and mechanical protection necessary for the data logger to survive in the hostile environment of reflow, wave-solder, vapor-phase and curing ovens.

A range of barriers is available to suit different loggers and different purposes. Specifications of barriers to fit the Datapaq DP5 logger are given below; these use Microtherm insulation for primary thermal protection.

WARNING

It is essential to use the correct Datapaq thermal barrier for your individual process, as supplied and approved by Fluke Process Instruments. Failure to use the appropriate approved barrier, or the use of a barrier in an unapproved manner (e.g. using above the specified temperature, or for longer than the specified time, or with insufficient opportunity for adequate cooling between profile runs), can cause catastrophic damage to the data logger or to other equipment, can endanger health, or (if lithium batteries are being used) may lead to severe injury or death. For the same reasons, never use a damaged thermal barrier.

Ensure that all dimensions of your logger/barrier/accessory assembly are such that it will fit comfortably within the oven through all stages of the process. Pay particular attention to handles, catches, etc., and to trailing thermocouples. Failure to do this can cause the assembly to jam in the oven with consequent overheating and potentially-severe damage to the equipment. Resultant battery-leakage, and the act of recovering the equipment, may cause skin burns and respiratory irritation.

Barriers for DP5 Logger Standard, 6-channel, DP5x60

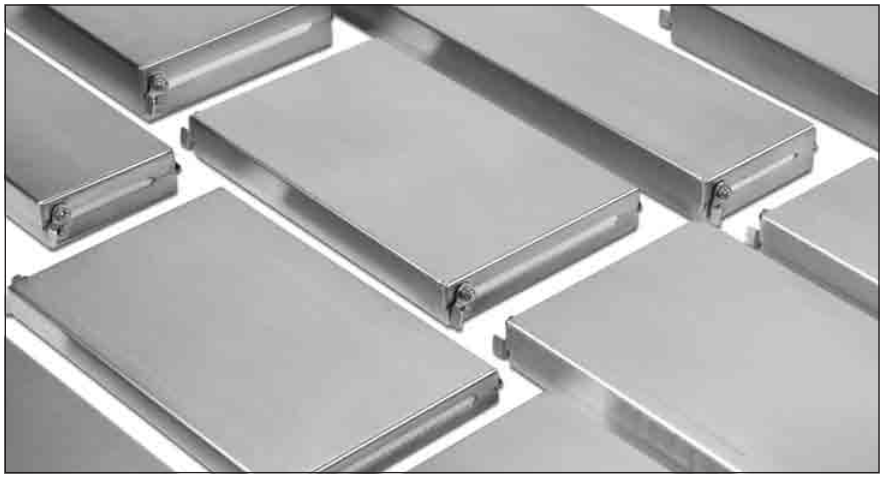
These barriers also fit Q18 standard 6-channel logger, DQ1860.

TB2015 – Most reflow soldering processes including lead-free

Temp °C	100	150	200	250	280
Duration (mins)	32	16	13	10	9
Dimensions	Height 25 mm 1.0 in.	Width 133 mm 5.2 in.	Length 210 mm 8.3 in.	Weight 0.7 kg 1.5 lb	

TB2064 – Low-height thermal barrier

Temp °C	100	150	200	250	280
Duration (mins)	25	12	9	8	6
Dimensions	Height 20 mm 0.8 in.	Width 133 mm 5.2 in.	Length 210 mm 8.3 in.	Weight 0.6 kg 1.3 lb	



Part of the range of Datapaq thermal barriers for the Datapaq DP5 logger.

TB2065 – Increased protection for frequent use or for long-duration processes

Temp °C	100	150	200	250	280
Duration (mins)	35	18	13	11	10
Dimensions	Height 29 mm 1.1 in.	Width 133 mm 5.2 in.	Length 210 mm 8.3 in.	Weight 0.7 kg 1.5 lb	

Barriers for DP5 Logger Super-slim, 6-channel, DP5x61

These barriers also fit Q18 super-slim 6-channel logger, DQ1861.

TB2066 – Low-height thermal barrier

Temp °C	100	150	200	250	280
Duration (mins)	21	11	8	6	6
Dimensions	Height 20 mm 0.8 in.	Width 88 mm 3.5 in.	Length 334 mm 13.1 in.	Weight 0.65 kg 1.4 lb	

TB2067 – Most reflow soldering processes including lead-free

Temp °C	100	150	200	250	280
Duration (mins)	28	15	11	10	8
Dimensions	Height 25 mm 1.0 in.	Width 88 mm 3.5 in.	Length 334 mm 13.1 in.	Weight 0.75 kg 1.7 lb	

TB2068 – Increased protection for frequent use or for long-duration processes

Temp °C	100	150	200	250	280
Duration (mins)	32	18	13	11	10
Dimensions	Height 29 mm 1.1 in.	Width 88 mm 3.5 in.	Length 334 mm 13.1 in.	Weight 0.8 kg 1.8 lb	

Barriers for DP5 Logger Narrow, 6-channel, DP5x62

These barriers also fit Q18 narrow 6-channel logger, DQ1862.

TB2020 – Low-height thermal barrier

Temp °C	100	150	200	250	280
Duration (mins)	25	13	10	8	7
Dimensions	Height 28 mm 1.1 in.	Width 84 mm 3.3 in.	Length 241 mm 9.5 in.	Weight 0.5 kg 1.1 lb	

TB2021 – Most reflow soldering processes including lead-free

Temp °C	100	150	200	250	280
Duration (mins)	36	18	13	11	10
Dimensions	Height 35 mm 1.4 in.	Width 84 mm 3.3 in.	Length 241 mm 9.5 in.	Weight 0.65 kg 1.4 lb	

Barriers for DP5 Logger, 12-channel, DP5x12

TB2100 – Low-height thermal barrier

Temp °C	100	150	200	250	280
Duration (mins)	25	13	10	8	7
Dimensions	Height 28 mm 1.1 in.	Width 133 mm 5.2 in.	Length 243 mm 9.6 in.	Weight 0.69 kg 1.5 lb	

TB2101 – Most reflow soldering processes including lead-free

Temp °C	100	150	200	250	280
Duration (mins)	36	18	13	11	10
Dimensions	Height 35 mm 1.4 in.	Width 133 mm 5.2 in.	Length 239 mm 9.4 in.	Weight 0.77 kg 1.7 lb	

Barriers for Q18 Micro Logger, DQ1804

TB2098 – Reflow soldering processes

Duration 10 mins at 200°C.

Dimensions	Height	Width	Length	Weight
	27 mm	57 mm	190 mm	0.4 kg
	1.1 in.	2.2 in.	7.5 in.	0.9 lb

TB3006 – Long-duration reflow soldering processes

Duration 14 mins at 200°C.

Dimensions	Height	Width	Length	Weight
	32 mm	71 mm	194 mm	0.6 kg
	1.3 in.	2.8 in.	7.6 in.	1.3 lb

Thermocouple Probes

Thermocouple probes utilize an effect by which an e.m.f. is produced in any electrically conducting material that is not at uniform temperature. The actual voltage measured is proportional to the temperature difference between the thermocouple's 'hot' and 'cold' junctions (the hot junction being the measurement junction, and the cold junction being the junction of thermocouple and measurement instrumentation).

The practical implementation of thermocouples requires sophisticated electronics to eliminate potential measurement errors which include poor linearity over the measurement range, and inaccuracy due to temperature variations at the cold junction. To accommodate these the electronics in the measuring system must simulate a temperature of 0°C at the cold junction, as well as compensating for any non-linearity over the range of thermocouple operation.

Over the years, 'standard' thermocouples have been developed using materials chosen for sensitivity, linearity (consistency of sensitivity over the useful temperature range), price and availability. Current standards include types K, N, R, S and T, each type being identified by its connector color. The standard thermocouple probe for reflow industry use is type K.

All Reflow Tracker systems are supplied with one set of PTFE-insulated thermocouple probes (part no. PA0210). Other probes available are:

- High-temperature glass-fiber-insulated (PA0215).
- Fine-wire, for use on ball grid arrays (BGAs) (PA1683).
- Special probes for wave-solder pallet (p. 31).
- Surveyor sensors. See p. 46.

All have green type-K connectors (conforming to IEC 60584-3).

WARNING

*Never connect thermocouples to **mains electricity**, nor allow thermocouples to touch an oven's **heating elements**. This could cause major injury or death. Take care when handling thermocouple cables to avoid accidental damage to the eyes by **sharp thermocouple-tips**.*

Thermocouple Specification

Probe Type	**Temperature Range**	**Cable Insulation**	**Accuracy of Probes Supplied by Datapaq** (ANSI MC96.1)
K	−150°C to 1,370°C	Glass fiber or PTFE	±1.1°C or ±0.4% at 0–1,250°C

The presence of a probe on the product adds to the product's thermal mass, changing – however slightly – its rate of heating and cooling. To minimize the probe's thermal mass, and therefore its affect on the product, the type K probes supplied with the Reflow Tracker system are constructed from 0.2-mm wire.

Thermocouple Cables

The practical operating temperature of the thermocouple probes is limited by the cable insulation material's temperature characteristics.

Probes insulated with **thin glass fiber**, impregnated with a silicone resin binder, are suitable for use at temperatures up to 500°C continuously and 700°C short term and **should be used if the probe cables could come into close proximity with infra-red heating elements**.

PTFE (polytetrafluoroethylene)-insulated probes are suitable for general-purpose use at temperatures up to 260°C. PTFE is a robust, flexible, non-stick material, with a low thermal mass and therefore a quick response time. This is the standard insulation for reflow use, though **it cannot be used when probe cables may be close to infra-red heating elements**.

WARNING

PTFE does not support combustion, but decomposes above 265°C producing small amounts of toxic fumes.

The important products from PTFE thermal decomposition are:

At Temperatures Greater Than:	Product
400°C	See note*
430°C	Tetrafluoroethylene
440°C	Hexafluoropropylene
475°C	Perfluoroisobutylene
500°C	Carbonyl fluoride*, which, in moist air, converts to the acid gas hydrogen fluoride

* May also be produced if PTFE tape is kept at 400°C for an extended time.

Health Hazard Data

- Inhalation of decomposition products from PTFE can produce 'polymer fume fever', which has symptoms similar to influenza.
- There is no risk from ingestion or skin contact.
- There are no medical conditions generally aggravated by exposure to PTFE.

Emergency and First-aid Procedures

- If there is accidental contact with PTFE fumes, remove the person concerned to clean air.
- Self-contained breathing apparatus and protective clothing should be worn when fire-fighting.

Reflow Temperature Profiles: Creation and Use

A temperature profile can be acquired by two means:

- **Without telemetry** – After the logger and product have been in the oven, data is downloaded from the logger into the PC to be displayed and analyzed by the Datapaq Insight software.
- **Using telemetry** – As the logger gathers data from the product inside the oven, this is transmitted directly to the PC by a **hard-wired connection** (serial telemetry) or by radio transmitter/receiver (**radio telemetry**). The temperature profile can be watched developing as it happens, i.e. in real time. For the use of hardwired telemetry, see your dedicated logger *User Manual*. For radio telemetry, see the *TM21 Radio-telemetry System User Manual*.

This chapter describes all the stages of obtaining a reflow temperature profile for a PCB while it is in the oven, without telemetry – from how and where to place the probes, to downloading the data into the software, ready to be analyzed.

To run a temperature profile in a wave-solder oven, see p. 31.

Before running your PCB and the data logger through the oven you will use the Insight software to reset the logger, i.e. to prepare it for receiving fresh data. After the logger has been retrieved from the oven, you will use Insight again to download the profile data and save it to disk.

In summary, the stages are as follows.

1. Choose positions for, and attach, the **thermocouple probes**.
2. **Setup communication** between the data logger and your PC (if this has not already been done for a previous profile run).
3. **Reset the data logger** so that it is ready to receive fresh data; in the process of doing this you will also be able to set the sample collection interval and the method used to trigger the start of data collection, and to check the logger's battery status.
4. Install the logger in its **thermal barrier**.
5. Run the PCB and logger/barrier through the **oven**.
6. **Download** the data from the logger into the Insight software.
7. If necessary, set the **oven start position** within the data.

8. Add any **additional information** that you wish to have recorded with the profile data.

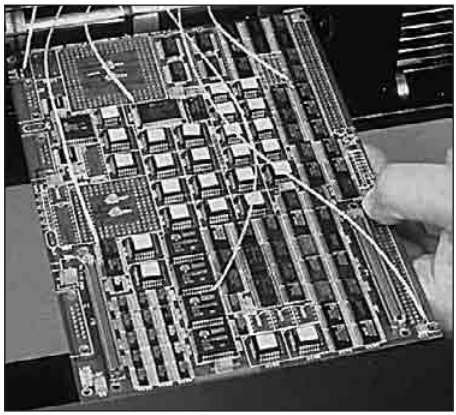
After this, Insight can be used to **analyze the profile data** as required.

Probe Location

Whatever the method of heating, the thermal mass of the PCB, its tracks and the components attached to them significantly influence the time taken for each physical element to attain a given temperature. Positioning of probes is thus crucial in ensuring that all key parts of the PCB follow a specified temperature profile, usually based on data from the solder-paste manufacturer.

Main Considerations

- Large ground planes absorb more heat and take longer to achieve reflow temperatures than narrow tracks.
- Large quad flat packs and ball-grid arrays absorb a lot of heat; they are also more susceptible to damage by thermal shock than most other components.
- Large surface-mount devices can shade the tracks to which they are to be soldered.
- The edges of the PCB heat more rapidly than the center.



Probes attached to the PCB and components.

- Is the track density even? If so, the heating may be more uniform; if not, there may be localized hot and cold spots.
- Is the board double-sided? If so, it may have to go through the oven twice: the bottom of the board must be kept below reflow temperatures or solder-ability could be lost, de-wetting experienced, and components could fall off.
- Is it a multi-layer board? If so, it is likely to have more copper and so require more heat, but it may heat more evenly.

Typical Probe Locations

- Locations likely to achieve the fastest rate of temperature increase, e.g. board edges and/or locations of components with low thermal mass.
- Locations having a high thermal mass which may require extra time to achieve reflow temperature.

- Locations shaded by large components, i.e. tracks under large quad flat packs and ball-grid arrays which may require extra time to achieve reflow temperature. Note that it may be necessary for thermocouple cables to exit via a hole to the underside of the PCB.
- The underside of double-sided boards.
- Ideally, to ensure profiling is reliable and repeatable, test samples of each type of PCB with thermocouples permanently attached should be kept specifically for this purpose.

Due to drying and slight changes in color, the test sample PCB's thermal characteristics have a tendency to change slightly each time it passes through the oven. Any obviously discolored boards should be discarded and replaced.

Probe Attachment

Good thermal contact between probe and product is essential if the probe is to reflect accurately the product's temperature. Poor thermal contact will at best result in slowing the rate at which the product heats the probe, and at worst prevent the probe achieving the temperature of the element on which it is mounted.

Good Practice

- Ensure probe tips are clean before attaching them to PCB or component.
- Secure probes along their length to ensure they remain in position, cannot foul elements in the oven, do not thermally shade the product, and will not experience excessive temperatures by being too close to heater elements.
- Use glass-fiber insulation when thermocouple cables will be in close proximity to infrared heating elements or experience temperatures in excess of 260°C.

For further guidance on **good practice in thermal profiling** – especially in probe attachment – see the following documents.

- *Moisture/Reflow Sensitivity Classification for Nonhermetic Surface Mount Devices.* IPC/JEDEC standard J-STD-020E.
  http://www.ipc.org/TOC/IPC-JEDEC-J-STD-020E.pdf
- *Guidelines for Temperature Profiling for Mass Soldering* (*Reflow & Wave*) *Processes*. IPC-7530A.
  http://shop.ipc.org/IPC-7530A-English-D
  http://www.ipc.org/TOC/IPC-7530.pdf
- *Thermal profiling of electronic assemblies*. NPL report MATC(A)50.
  http://publications.npl.co.uk/npl_web/pdf/matc50.pdf

Methods of Attachment

The following are the chief methods.

High-melting-point Solder

- Gives best repeatability but difficult to perform.
- Recommended for metal-to-metal attachment.

High-melting-point solder is used to attach thermocouples to the legs of components and to PCB tracks. It melts far enough above reflow temperature to ensure that the thermocouple remains in place.

To be successful, any low-melting-point solder must be removed, allowing high-melting-point solder to be applied directly to the metal to be joined. Use as little solder as possible, as follows.

1. Remove any low-melting-point solder. Clean the thermocouple then tin it using high-melting-point solder. Clean the component leg or PCB track to which the thermocouple will be attached. Tin it using high-melting-point solder.
2. Solder the thermocouple in place, using as little high-melting-point solder as is consistent with a satisfactory joint. Ensure the cable lies flat along the PCB.

SMA Adhesive

- Gives good results.
- Much easier to carry out than soldering, but adhesive needs to be cured.

The best results are obtained as follows.

1. Pre-form the thermocouple cable and hold it in place on the PCB with high-temperature tape, ensuring that the thermocouple tip is in good contact with the joint to be measured.
2. Place a small bead of SMA adhesive on the thermocouple tip.
3. Follow the manufacturer's specification to ensure correct curing of the adhesive: most SMA adhesives are heat-cured and this can be achieved by running the PCB once through the oven before the first data-collection run.

High-temperature Adhesive Tape

- A temporary means of holding cables in position on the PCB. For one-off trials only.
- If used in conjunction with aluminum tape, forms a reasonable method of attachment if high-melting-point solder or SMA adhesive cannot be used.

High-temperature (Kapton) tape is recommended as a means of restraining thermocouple cables where they run over the PCB (see below) but not of fixing

them to the measuring point. However, attachment is improved by using self-adhesive aluminum tape and deforming it to fit closely around the thermocouple tip; high-temperature tape placed over this will hold it in place during the profile run.

Restraining the Cable

The thermocouple cables must be routed from their points of attachment to the rear of the PCB to enable the data logger to follow the PCB through the oven.

1. Route the thermocouples from their points of attachment to the rear of the PCB.
2. Attach the thermocouple cables to the PCB at intervals, using high-temperature tape.

Preparing the Logger

- If the data logger is being connected to a PC for the first time, it is necessary to **enable communication** between them.
- The logger must also be **reset** before a profile run – using Insight software – to establish its data-collection parameters (not necessary if parameters are to be unchanged from the previous run).
- If there is any doubt that the logger's **battery charge** may be inadequate for the profile run, this must also be checked by using the reset procedure.

*For the procedures involved, see your dedicated **logger manual** or the Insight **Help system**.*

*Note that, since its last use, the **logger must have cooled below 35°C** (comfortable to hold without gloves).*

Installing the Logger in the Thermal Barrier

WARNING

It is essential to use the correct Datapaq thermal barrier for your individual process; see p. 11. Ensure that all dimensions of your logger/barrier/accessory assembly are such that it will fit comfortably within the oven through all stages of the process. Pay particular attention to handles, catches, etc., and to trailing thermocouples. Failure to do this can cause the assembly to jam in the oven with consequent overheating and potentially-severe damage to the equipment. Resultant battery-leakage, and the act of recovering the equipment, may cause skin burns and respiratory irritation.

*Ensure the **thermal barrier has cooled** sufficiently since its last use.*

1. Plug the **thermocouples** into the logger's numbered sockets. If you are using a process file, ensure that the probe/socket numbers on the logger correspond to those used to define probe numbers and locations in that file (see the Insight software for an introduction to process files: press function key F1, or select Help > Contents from the menu bar, and click the section 'Process Files: Oven, Recipe, Product').
2. If the trigger mode is start button, press and hold the logger's **start button** for about 0.5 second until the green LED starts to flash at the sample interval.

*Data-recording cannot start until the **logger has cooled** sufficiently from the previous run. If it is still too hot, pressing the start button will cause the logger-status red LED to give two quick flashes every second.*

If the battery has less than 20% of full charge, data-recording cannot start until the battery is charged.

The logger in place in its thermal barrier.

3. Ensure the **barrier's sealing surfaces are clean and undamaged**. A good seal between barrier and thermocouple cables is essential if the logger is to be protected. Put the **logger in place in the barrier**, laying the thermocouple cables across the sealing material to exit the barrier at the cutout, ensuring they are side by side and not crossing each other.
4. **Fit the lid**, ensuring a good seal around the thermocouple cables. Secure the lid's catches with the locking pins, if fitted.

WARNING

Take care not to trap fingers when closing the barrier lid.

Placing the System in the Oven

1. Place the instrumented PCB on the oven's conveyor with the thermocouple cables towards the rear.
2. As the board travels towards the oven feed the thermocouple cables carefully, ensuring they do not foul the oven.

WARNING

Never allow thermocouples to touch an oven's heating elements. This could cause major injury or death.

An instrumented PCB on its way into the oven (to the right), with the thermal barrier and logger following behind.

3. Load the logger and thermal barrier onto the conveyor some distance behind the PCB to ensure their thermal mass does not affect the PCB's heating and cooling. If the oven has an edge conveyor, place the thermal barrier on a carrier plate.

Removing from the Oven and Downloading Data

Recover the system from the oven as soon as the run is over.

WARNING

*The thermal barrier **and logger** will be **hot enough to burn skin** – even though their temperature will not be apparent. Use protective gloves.*

Failure to remove the logger quickly from the hot thermal barrier could damage the logger.

Do not remove the logger by tipping it out of the barrier. This can lead to injury by dropping the logger onto your body, and may damage the logger.

1. Open the thermal barrier. Placing it on a cold surface will increase its rate of cooling. (An additional thermal barrier should be purchased if insufficient time is available to allow it to cool between test runs.)
2. If data acquisition has to be stopped manually, press and hold the logger's red stop button until the red and green logger-status LEDs both flash once. A red logger-status LED flashing every 5 seconds indicates data stored in the logger but not yet downloaded to the PC.
3. **Download** the data from the logger to the PC using the Insight software. For the procedures involved, see your dedicated logger *User Manual* or the Insight Help system (under Contents, select Menu > Logger > Download).

Analysis of Reflow Temperature Profiles

For details of the many analyses that can be performed on your profiles, see Insight's Help system (under Contents, select Data Analysis).

These notes are not a comprehensive guide to the importance of temperature profiles in the reflow soldering process, but are intended to highlight possible faults associated with a poor profile shape. See p. 21 for other sources of guidance on the use of temperature profiles.

Profile Types

The two common profile shapes used in reflow soldering are the **Ramp Soak Spike** (RSS) and the **Ramp To Spike** (RTS, or tent profile). The RSS was developed when oven performance was such that a long dwell time was required to enable components of differing thermal mass to achieve the same temperature before the spike up to reflow temperature. With improvements in oven performance it has been possible to use a constant ramp up in temperature to the reflow temperature; this RTS profile is generally much easier to set up on the oven and avoids the double thermal shock to which small components can be subjected when using the RSS profile.

However, the use of lead-free solders requires higher soldering temperatures, and this – combined with the very wide range in thermal mass of modern SMT components – means that the RSS profile is still often the best solution. If this is the case, the temperature profile needs to be set up carefully in order to ensure compliance with both solder-paste specifications and with soldering-related aspects of component specifications.

Checking Profiles

Some soldering faults which can be caused by incorrect temperature profiles are described below.

- **Incomplete soldering** – There are numerous possible causes, one of which is insufficient heat energy input to the solder joint. This would usually be caused by too low a temperature before the reflow zone or too short a time above the liquidus temperature of the solder.
- **Tombstoning (drawbridging or Manhattan effect)** – A leadless component is lifted at one end during soldering, due to uneven wetting of the two terminations. This can be caused by many factors including PCB pad design and component layout. To help ensure that the two ends of the component are soldered at the same time, the profile shape should be adjusted to minimize the rate of heating as the liquidus temperature is reached.
- **Misalignment of soldered components** – This is a less severe manifestation of the problems that cause tombstoning, and thus the same remedies can be applied. Careful profiling, placing many thermocouples in the area affected, may reveal large temperature gradients in that area of the assembly. These may be alleviated by passing the PCB assembly through the process in a different orientation.
- **Component cracking/mechanical failure** – The cracking or fracture failure of small ceramic components can be caused if the change in temperature (heating or cooling) is too rapid. Use Insight software's Slopes analysis mode to find the maximum slope (temperature gradient, °C/s) and compare this to the limits set by the component manufacturer; these limits may well be different from any limits specified by the solder-paste supplier.
- **Solder balling/beading** – Often caused by excessive deposits of solder paste and then outgassing as the product is heated. It can be improved by reducing the rate of temperature rise in the ramp zone.
- **Poor wetting of solder joints** – If the cause is thought to be within the thermal processing of the assemblies, there may be oxidation of the leads and/or pads before the solder reaches liquidus. Possible remedies include reducing the dwell time in the middle part of the temperature profile or reducing the temperatures in this area.
- **Voiding** – Voids are generally caused by air trapped in 'via holes' in the component pad or by outgassing of the solvents within the solder paste. Changes to the temperature profile may improve this: either shortening the soldering time or slowing the ramp rate.

Statistical Process Control

SPC is a powerful feature of the Insight software which allows easy analysis of the results of your profile runs over time. Thus, by highlighting trends in the

performance of your process, potential problems can be identified and dealt with before they occur. (*Not available with all versions of Insight.*)

The Datapaq Surveyor system (p. 43) is an alternative means of assessing oven performance which requires you to use specific hardware first to quantify and then to run checks on the system to ensure it is still operating within limits. Using SPC on normal Insight paqfiles, on the other hand, requires only the analysis of your routine profile runs to assess trends in the oven's performance. Both systems have benefits and limitations, as shown below.

	Pro	Con
SPC on normal paqfiles	• Measures temperatures of the actual PCB assembly during the process. • Comprehensive report shows data from each probe separately. • Can monitor wave, vapor-phase and rework soldering processes, as well as reflow.	• Good thermocouple sensor connection is essential for best results. • If used on data obtained with standard test PCBs ('golden boards') and their associated thermocouples, these will degrade with repeated use, producing less reliable results. • Placing logger/PCB assembly on the conveyor requires care to ensure that thermocouple wires will not be trapped in the oven. • Need to ensure details of data-collection are standardized for all profiles.
Surveyor	• Unskilled operator can conduct routine profile runs to assess oven's performance. • Only one item to place on the oven conveyor. • Logger is reset, and results are saved, automatically. • Immediate confirmation of whether the oven is operating within specification for a given process. • Helps to ensure details of data-collection are standardized.	• Measures only the performance of the process, not the temperatures experienced by the actual product. • For reflow processes only.

Using SPC

Note that, for SPC results to be meaningful, the paqfiles analyzed must be consistent, i.e. they must relate to the same process (the same oven with the same recipe settings) and must have used the same test-piece with probes in the same positions. It is important that the test-piece is maintained in good condition.

An SPC analysis is easily carried out using SPC Setup Wizard (click  or  on the Insight toolbar, or select Tools > Wizards from the menu). This guides you through the following stages:

1. Select existing temperature profiles (paqfiles) on which the analysis will be based.
2. Choose which analysis results you will examine, and set a target value and acceptable limits for the results.
3. Insight then calculates the SPC results and displays them as a new graph in the Graph Window, and as tabulated data in the Analysis Window.

For each probe, the value of each paqfile's chosen analysis parameter (on the y-axis) is plotted against the data collection time of the paqfile (on the x-axis). Any trend in the results over time can thus be identified and compared with your specified target value and acceptable limits, which are shown on the graph as horizontal lines.

Functions that can be performed on an SPC analysis include:

- Modify it by changing:
  - the files used for the analysis;
  - the analysis results examined;
  - the target value and acceptable limits for the results.
- Save the results for future display and analysis.
- Print a detailed report of the results: from the main menu, select File > Print Options.
- Export the results for use in another software application.
- Email the full results.

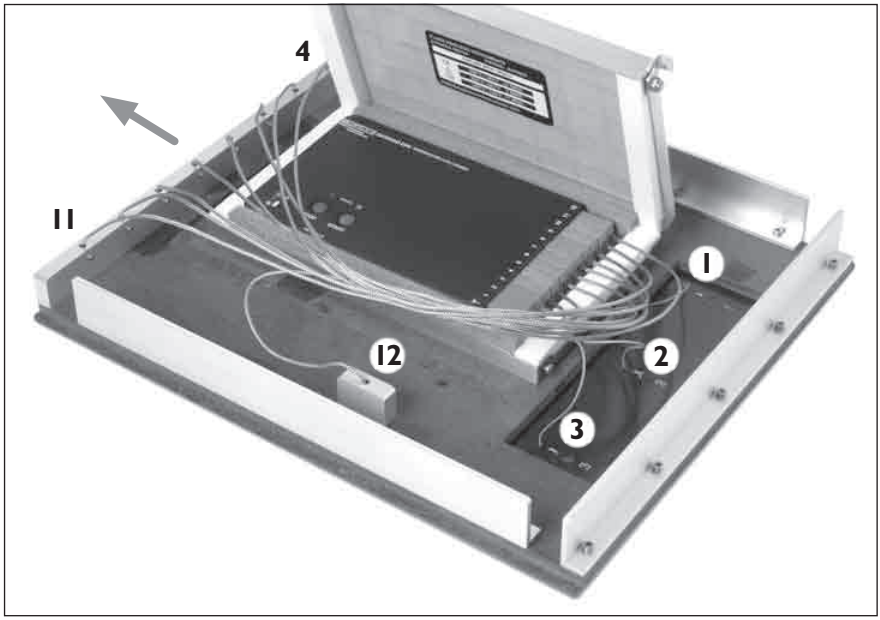
Full guidance on using SPC is provided in Insight's online Help: press function key F1, or select Help > Contents from the menu bar, and then in the Help system select Data Analysis > Statistical Process Control.

*For further features of the **Insight software** – particularly the use of process files – see the Help system.*

Wave Solder

The Datapaq Reflow Tracker system – and Insight software – can be used with both reflow and wave-solder ovens.

In the Wave Solder system, the logger (in its thermal barrier) is mounted on a flat pallet (part no. CS5000) which passes through the oven. Up to nine fixed thermocouples on the pallet measure conditions relating to the solder wave: the oven's line-speed and the contact length of the solder wave, and thus the contact time with the solder. Up to eight of the fixed thermocouples lie in front of the logger on the pallet's leading edge (i.e. entering the oven first) and one is towards the rear of the pallet. The vertical position of the fixed thermocouples can be adjusted in order to alter the depth of their penetration into the solder wave. The rear part of the pallet holds a dummy PCB (a 'test coupon') instrumented with three additional thermocouples which gather data on conditions in the oven's preheat zone.



Datapaq wave-solder pallet CS5000 with fixed dummy PCB at right and thermal barrier in place. All 12 thermocouples are connected to the logger inside the barrier, and the thermocouples' identifying numbers (see text) are shown. The pallet travels to the left, into the oven.

Reflow Tracker's Insight software identifies the thermocouples as follows:

- Thermocouples attached to the **PCB** are numbered 1–3.
- With a **6-channel logger**, the leading-edge thermocouples are numbered 4–5 and the rear thermocouple is number 6.
- With a **12-channel logger**, the leading-edge thermocouples are numbered 4–11 and the rear thermocouple is number 12.

*The Reflow Tracker system can also be used to profile the process **without a pallet** by attaching thermocouples solely to a product or test-piece, as in reflow profiling.*

Running a Wave-solder Temperature Profile

The process of running a wave-solder temperature profile is carried out using Insight's Wave Solder Wizard. A profile can be obtained in two ways:

- **Wave with Pallet** – Thermocouples are fixed to a flat pallet, on which the logger is also mounted, and this passes through the oven.
- **Wave** – Using a standard assembly of logger and thermal barrier (and no pallet), thermocouples are attached to a separate product or test-piece which passes through the oven, as in reflow profiling.

For a Wave profile run (i.e. without pallet), note that Wave Solder analysis is performed only on data from thermocouples on the underside of the PCB, i.e. those which make contact with the solder wave. These thermocouples must be specified.

Profiling method and (for a Wave profile) the thermocouple numbers used will be most conveniently specified by use of a **process file** which you apply to the profile data after the run has been performed (see below).

See the Insight software for an introduction to process files: press function key F1, or select Help > Contents from the menu bar, and click the section 'Process Files: Oven, Recipe, Product'.

Profiling method is specified by selecting the oven type in the process file or, alternatively, in the Process Details dialog (Oven tab).

As well as in the process file, the thermocouples used can be specified in the Process Details dialog (Recipe–Analysis tab) or in the Analysis Options dialog of the Wave Solder analysis.

Preparing the System for the Oven

WARNING

It is essential to use the correct Datapaq thermal barrier for your individual process; see p. 11. Ensure that all dimensions of your logger/barrier/pallet assembly are such that it will fit comfortably within the oven through all stages of the process. Failure to do this can cause the assembly to jam in the oven with consequent overheating and potentially-severe damage to the equipment. Resultant battery-leakage, and the act of recovering the equipment, may cause skin burns and respiratory irritation.

1. Connect the communications lead to the data logger and start the **Wave Solder Wizard** in the Insight software (click  or  on the Insight toolbar, or select Tools > Wizards from the menu). The wizard takes you through the necessary steps, one after the other, to reset the logger ready to perform a wave-solder run.
2. When instructed by the wizard, plug the **thermocouples** into the logger's numbered sockets, as follows.

   *It is essential to follow carefully the **wizard's instructions about probe positioning** – or the analysis of data will be invalid.*

   For a **Wave with Pallet** profile run, follow the connection diagram shown in the Wave Solder Wizard ('Position Probes' stage), as follows:
   - Channels 1–3 on the logger must be connected to the dummy PCB.
   - Channel 4 on the logger must be connected to the right-hand leading-edge thermocouple on the pallet (as viewed from above, with direction of travel pointing away from you).
   - Connect channel 5 (for a 6-channel logger) or channel 11 (for a 12-channel logger) to the left-hand leading-edge thermocouple.
   - The channel connected to the pallet's rear thermocouple must be number 6 for a 6-channel logger or number 12 for a 12-channel logger.

   *If using a **non-Datapaq pallet**, you must specify in the wizard the distance by which the rear thermocouple is behind the leading-edge thermocouples.*

   For a **Wave** profile run:
   - Attach thermocouples to the product or test-piece as required. The thermocouples used to monitor the wave (whose data is to be used subsequently in the Wave Solder analysis) must be fixed in such a way that they contact the main wave, i.e. on the solder side of the PCB; these thermocouple numbers must have been specified in Insight (see above). Other thermocouples can be connected to either side of the PCB as required.

3. After the thermocouples are attached, ensure the mating surfaces of the **thermal barrier** – mounted securely on the pallet, if used – are clean and undamaged. A good seal between the barrier and the thermocouple cables is essential if the logger is to be protected. Put the logger in place in the barrier, laying the thermocouple cables across the sealing material to exit the barrier at the cutout.
4. Press and hold the logger's **start button** for about 1 s until the green LED starts to flash. Insight automatically sets the sample interval at 0.05 s for all wave-solder profiles to ensure accurate line-speed and contact-time measurements.
5. **Close the barrier lid**, ensuring a good seal around the thermocouple cables.
6. Place the pallet/logger/barrier/PCB assembly (depending on configuration) on the oven's conveyor. With a pallet, ensure correct direction of travel, as marked on the pallet.

WARNING

Never carry the pallet assembly by holding the attached thermocouples. This can lead to injury by dropping the equipment onto your body, and may damage the equipment itself.

Removing from the Oven and Downloading Data

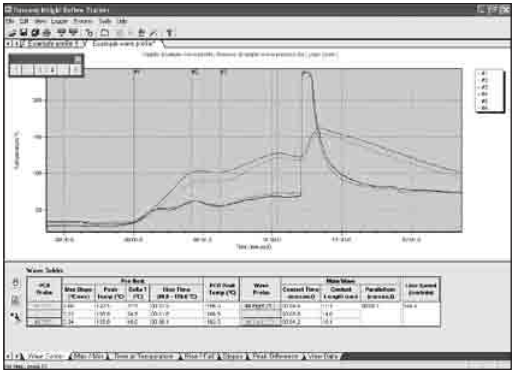
Recover the system from the oven as soon as the run is over. Open the thermal barrier and **remove the logger**.

WARNING

*The assembly, **including logger**, can be **hot enough to burn skin** – even though its temperature will not be apparent. Use protective gloves.*

Failure to remove the logger quickly from the hot thermal barrier could damage the logger.

Continue following the Wave Solder Wizard to **download** the data to the PC and, if required, choose a **process file** to be applied to the results. The temperature profile is then displayed on screen, with a Wave Solder analysis of the data shown beneath it.



Analysis of Wave-solder Temperature Profiles

For details of analyses that can be performed on a wave-solder profile, see Insight's Help system (under Contents, select Data Analysis > Wave Solder).

Note that the temperature profiles resulting from reflow and wave-solder ovens require different analyses, and consequently the data files (paqfiles) which Insight produces for each also differ and are not interchangeable – nor can a process file for one type of oven be applied to a paqfile from the other type; see Insight's Help system (under Contents, select 'Reflow or Wave Solder?').

Checking Profiles

The wave solder process (p. 31) is well understood and generally has a wider tolerance than reflow soldering. Some of the more common process faults that can be caused by the thermal profile are listed below. More comprehensive information is generally available on the websites of the larger wave-solder-machine suppliers such as Vitronics Soltec or Electrovert.

- **Insufficient solder flow** – Occurs when the solder has not had sufficient time to penetrate the holes around the component leads. There are numerous possible causes, but those that are related to the profile could be insufficient flux activation due to poor pre-heat temperatures or insufficient contact time with the wave. In each case, the profile should be used to verify the temperatures/times against those which are recommended. For the pre-heat zone, temperatures should be checked on the actual product in the area where the problem is seen, as component size and placement can affect the temperature reached.
- **Solder balling/beading** – There are many possible causes, but one related to the thermal profile is insufficient flux activation. In this case, the pre-heat temperature needs to be raised to increase paste activation in line with the manufacturer's recommendations.
- **Component cracking** – The most likely cause is too rapid a temperature change while moving from the pre-heat zone to the wave. After the wave, cooling is generally not forced, so the temperature gradient here is less severe.
- **Re-melting of top-side SMD joints** – If the solder on the top-side components is re-melted during subsequent wave soldering, the quality of the SMD solder joints will be compromised. The remedy is to reduce total heat input to the PCB during soldering, which may involve reducing the solder temperature and adjusting the pre-heat temperature.

Easy Oven Setup

Not available in Insight Reflow Tracker Basic and Reflow Lite.

Easy Oven Setup provides a rapid, simple and effective way to tune the settings of your reflow oven in order to produce the temperature profile you require for a specific solder paste and a specific application. It lets you achieve this in two different ways:

- **Profile Prediction** Alter the oven settings of an **existing temperature profile** to predict a new desired profile.
- **Recipe Prediction** Use the **specification of your solder paste** to create recipes predicted to produce the desired temperature profile.

*For full details of Easy Oven Setup and all other aspects of the Insight software – particularly data analysis and the use of process files – see the **online Help system** (on Insight's menu bar, select Help > Contents).*

Profile Prediction

By starting with an existing temperature profile, you may alter the oven settings which were used originally to produce it, and immediately see the predicted effect of those adjustments on the profile shape. By a succession of such predictions it is thus possible to arrive at a recipe which will produce a desired target profile. The stages are as follows.

1. Open the temperature profile (paqfile) to be used as the basis for prediction. Ensure that the paqfile has a process file (see above) associated with it, and that the oven start position is set correctly.
2. Click  or select Easy Oven Setup > Profile Predict.
3. The prediction is then performed, and the results are displayed in the main Graph and Analysis Windows.
4. In the Oven Settings grid, oven zone temperatures can be edited: enter new trial values in the 'New' column, and click  to predict and display a revised profile (if lower and upper oven zone temperatures have been set differently in the recipe of the original profile, both are shown); repeat this to modify the shape of the profile as necessary. Predicted results are listed first in the analysis grid, and in the graph window the predicted probe traces are overlaid (in brighter colors) on the original profile. To change the sort order of the probes in the analysis grid, click  or  .

5. To save the revised recipe, click  to the left of the Oven Settings grid.
6. To save the predicted profile, click  on the main toolbar, or select File > Save, or File > Save As > Prediction; the profile is saved as a prediction file with a .PRE extension.

*In order to ensure successful predictions, **unheated oven zones** must be specified.*

After a profile prediction has been performed, some parts of the process file that were applied to the original paqfile will affect the prediction and will therefore not be editable, e.g. adding a zone to an oven would invalidate the prediction and thus is not possible.

*You may **overlay** another paqfile and a tolerance curve on a prediction, e.g. to compare the prediction with an actual profile run.*

Prediction files produced by using the Rapid Oven Setup module in earlier versions of Insight – which also carry a .PRE extension – are not compatible with this software.

Recipe Prediction

By using data from your **solder-paste specification**, Insight will create recipes which are predicted to produce temperature profiles to match the solder's preferred usage conditions.

1. Setup **process limits** by assembling data from your solder-paste specification so that it can form the basis for a prediction: select Easy Oven Setup > Process Limits (see below).
2. Carry out the **prediction**: click  or select Easy Oven Setup > Recipe Predict (see p. 40).
3. Use the graphical and numerical display of the predicted temperature profiles and their analyses in order to **choose from, and to adapt, the predictions** created.

*In order to ensure successful predictions, **unheated oven zones** must be specified.*

Setting Process Limits

Selecting Easy Oven Setup > Process Limits runs the Process Limits Wizard in which you assemble data from your solder-paste specification so that it can form the basis for a recipe prediction.

Supplying data for four aspects of the desired profile shape is optional: Overall Profile Slopes, Ramp, Soak and Spike. For each of these, check the box to enable the setting of their parameters (this is disabled by default).

- **Overall Profile Slopes** Specify the maximum permitted **heating slope** (rate of temperature increase) for the profile (default 4.0°C/s) and the maximum permitted **cooling slope** (default −4.0°C/s; a negative value must be entered). If you wish, enter a single **target value** for the heating slope (default 2.0°C/s).
- **Ramp** Define the **temperature range** (default 25–150°C) for the ramp phase (the initial rise) of the desired profile, and its **target slope** (default 2.0°C/s).
- **Soak** If the desired profile is to have a soak (plateau) phase, define the **temperature range** (default 150–200°C) for the soak phase, and its permitted **range of duration** (time) (default 1–3 mins).

> *When 'Soak' is checked, the process limits will create a **ramp/soak/spike profile**. When unchecked, the profile will be a **simple tent profile**. The pictures in the dialog indicating the general profile shape, and the section being specified, change accordingly.*

- **Spike** Define the **temperature** (default 225°C) which should mark the bottom of the spike phase (the final rise) of the desired profile, and its **target slope** (default 2.0°C/s). (The desired peak temperature of the profile is specified later in the dialog under the 'Reflow' section.)
- **Reflow** Define parameters for the reflow phase of the desired profile (the period above liquidus): the permitted range for **peak temperature** (default 225–245°C), the **liquidus temperature** (default 217°C, for lead-free solder) and the permitted range for **time above liquidus** (default 1–1.5 mins). If you wish, enter a single target value for peak temperature (default 250°C) and for time above liquidus (default 1.5 mins). If you enter data for **time above temperature**, the Reflow Results analysis of the predicted profile will show the time spent above the given temperature by each probe.
- **Line Speed** If a single line speed is specified, it will be used for all predicted profiles (default 60 cm/min or 24 in./min). To produce predictions based on a range of line speeds, check **Use Optimized Line Speed** and enter minimum and maximum values (default 45–75 cm/min or 11.8–35.4 in./min).

After clicking **Next** in this dialog, you will be prompted to save your data as a **process limits file**. The filename will be saved with a .RPL extension. There is a default directory in which files are stored, but you can browse to a directory of your choice.

Generating Recipe Predictions

After setting up the process limits (see above), click  or select Easy Oven Setup > Recipe Predict to carry out a recipe prediction. By using data from your **solder-paste specification**, Insight will create recipes which are predicted to produce temperature profiles to match the solder's preferred usage conditions. When a prediction has been performed, the results are displayed in the main Graph and Analysis Windows where further trials and analysis can be carried out.

***Only one prediction can be open at a time**. If you already have a prediction open, you must close it before you can start a new prediction.*
*In order to ensure successful predictions, **unheated oven zones** must be specified.*

On starting a prediction, the **Select Process Limits dialog** opens:

1. Highlight in the list the process limits file appropriate to your recipe prediction. The process limits files shown for selection are those contained in the default directory, but you can also click **Browse** to locate files which you may have stored elsewhere. On the right of the dialog is shown a summary of the parameters contained in the selected process limits file, with a picture indicating whether the limits are for a simple tent profile or for a ramp/soak/spike profile.
2. Click **OK** in the dialog. The recipe prediction is then carried out.

Refining the Predictions

The **predicted recipes** are then listed in the Analysis Window in order of rank (shown by a **star rating**) according to the closeness of their expected result to the specified process limits; in calculating the recipes, the parameters in the limits that are given the highest importance are peak temperature and time above liquidus. Next to each recipe's rating is also shown its **line speed** and the **average of its oven-zone temperature settings**.

To list predicted recipes in an **alternative order** – by descending order of line speed, or of average temperature – click on the relevant column header. Click the header a second time to reverse the order.

Highlighting a recipe in the list displays the following for it:

- The **predicted profile** that the recipe is expected to produce. Marked on the graph are the permitted ranges for **peak temperature** and **time above liquidus** as specified in the process limits used. In addition, a tangent on the profile indicates the point of **maximum slope** for any probe; the number of the probe with this maximum slope is shown on a label adjacent.

- **Oven settings** – the set temperatures for each oven zone and the line speed.
- **Data analysis** for its predicted profile. The full range of analysis options is available. The contents of the **Reflow Results** tab reflect what was specified in the process limits used, though you may use the analysis options dialog to add or remove results from the display. Any entries in the analysis grid that are out of tolerance compared with the process limits are highlighted in red and an alarm is registered.

***Oven zone names** appear in a tooltip if the mouse is hovered over a zone number in the Oven Settings grid.*

The following control buttons are available:

Delete Recipe  Delete from the list any recipe you have created and do not wish to consider further (i.e. a user recipe – see below). If you previously saved the recipe (see below), it is deleted only from the list, not from disk.

Save Recipe  Save to disk any new or amended recipe you wish to keep. You must generate a new prediction from the amended recipe (see below) before you save it.

Create User Recipe  A new entry appears in the list (based on the currently highlighted recipe), for which you may edit oven zone temperatures (see below). User recipes are indicated by * next to the recipe number in the list.

Predict Profile  Predict the profile for the selected recipe (user recipes only) if you have made changes to oven zone temperatures. The new profile is shown in the Graph Window.

Options  Opens a dialog allowing specific probes to be excluded from the **maximum slope** calculation (see above). This is useful for excluding air probes (or failed probes) which show a very steep rise.

To edit a recipe's **oven zone temperatures**:

1. Select the recipe in the list.
2. Click  to create a user recipe based on it.
3. Enter new temperature and/or line-speed settings for the oven.
4. Click  to generate a revised profile.
5. If you wish, click  to save this new recipe file.

To **save the prediction**, click  on the main toolbar, or select File > Save, or File > Save As > Prediction; the profile is saved as a prediction file with a .PRE extension.

Troubleshooting the Predictions

Poor predictions can be due to problems or errors in any of the components of a prediction. Care must always be taken when entering data or performing runs. Common reasons for bad predictions are as follows.

- **Invalid zone length measurements** – The oven's actual zone lengths and those entered into the oven file are different.
- **Setting up active/passive zones improperly** – Check that you have correctly defined oven zones as either active (heated) or passive (unheated).
- **Entering wrong recipe settings into the oven** – The oven recipe settings (oven-temperature set points) and the actual set points on the oven during the profile run are different.
- **Entering wrong line speed for the oven** – The actual time spent in each oven zone will be different from that calculated.
- **Not allowing the oven to warm up or settle sufficiently** – This will result in actual temperatures that are different from the set temperatures or greater fluctuation in temperature while the oven settles.
- **Noisy oven** – Some ovens are inherently unstable or have large temperature differences across the belt width. Use Statistical Process Control (p. 27) or Surveyor (p. 43) to monitor your oven's performance.
- **Inconsistent attachment of thermocouples to the PCB** – The temperature as measured by the thermocouple is very dependent on the method used to attach it to the PCB.

Surveyor

Insight Reflow Tracker Professional only.

The stability of an oven's performance is typically monitored by recording the temperature profile experienced by a standard PCB (a 'golden board') as it passes through the oven – but this can be misleading, as changes in the golden board over time can themselves result in changes in the temperature profile recorded. Instead, the Surveyor system monitors the oven stability by running a standard instrumented **carrier frame** through it to gather temperature data as a survey **profile run**. The Insight software then automatically compares the results of this profile run with results from an existing temperature profile obtained when the oven was known to be operating correctly – a **baseline survey**. By this simple means, an operator can assess quickly whether or not maintenance or adjustment of the oven settings is required in order to maintain consistency. Temperature measurements are recorded by a Datapaq logger, in a thermal barrier, mounted on the carrier frame.

All profile-run data is saved automatically and quickly becomes a valuable database upon which longer-term analysis can be conducted in order to highlight trends in the performance of your process, and thus to identify and deal with potential problems before they occur. This is carried out simply and quickly by the Insight software using **Statistical Process Control** (SPC) analysis (see p. 49).

Setting up and using Surveyor involves the following stages:

1. **Configure your oven for optimum performance** – Your oven must be set up correctly, and producing defect-free product. Analysis with the standard Datapaq Reflow Tracker system will assist in achieving optimum results.
2. **Conduct a baseline survey** – In Insight, using Surveyor's Technician Mode (see p. 47), run a temperature profile and obtain a baseline survey (p. 48). This will be used as the reference against which future runs will be compared. You then specify permissible tolerances from the baseline survey.
3. **Train operators to perform routine profiles** – Using the Operator Mode, Surveyor will guide the operator through a profile run and compare the results with the baseline survey (p. 48). The operator will be given a simple pass/warning/fail result.
4. **Identify trends** – Use SPC to analyze a series of profile runs (p. 49) and thereby predict future oven performance.

*The Insight **online Help system** explains in full the functions and use of Surveyor, and the process of making selections and entering data in the wizards: click Help, and then Contents, on Insight's main menu; then, within Help, click on Contents headings and topics to expand and read them. In particular, see 'Using Surveyor' and (under 'Data Analysis') 'Statistical Process Control'.*
You may also click the Help button in any wizard dialog – or press the F1 key – to bring up help information relevant to that stage of the wizard.

Surveyor Hardware: Specifications and Use

Additional hardware used with Surveyor comprises:

- Carrier frame, with sensors (thermocouple probes, p. 46) fitted.

Carrier Frame

Chief features of the PA0878 frame:

- Easily adjustable to fit the oven's conveyor: width continuously variable from 100 to 350 mm (3.95–13.7 in.).
- Three fixed temperature sensors.
- Carries a Datapaq DP5 logger inside its thermal barrier.

The frame will carry different models of the DP5 logger: six-channel standard and narrow case formats (but not super-slim) and 12-channel (only six channels are used). Thermal barriers currently available for use with these logger models (p. 11) can be used with Surveyor.

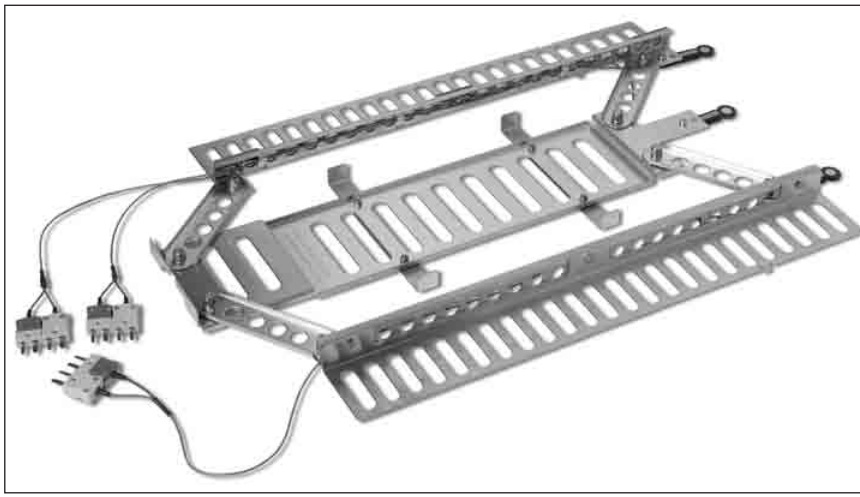
Dimensions	Height[1]	Width[2]	Length[3]	Weight[4]
	28 mm	100–350 mm	456–517 mm	0.93 kg
	1.1 in.	3.95–13.7 in.	18.0–20.4 in.	2.0 lb

[1] Height of the frame itself: 20 mm/0.8 in. above pin-chain, 8 mm/0.3 in. below pin-chain. Overall height of carrier-frame assembly depends on height of thermal barrier used.
[2] Remove side-plates for minimum width (see main text).
[3] Including sensors. Length is minimum when side-rails are fully extended.
[4] With sensors and side-plates attached.

Part numbers:

PA0883 Surveyor frame PA0878 with sensor plugs PA0885 (p. 46) to fit standard 6-channel DP5 logger.

PA0884 Surveyor frame PA0878 with sensor plugs PA0886 (p. 46) to fit narrow 6-channel and standard 12-channel DP5 loggers.



The Surveyor carrier frame, with three sensors (at right) and their plugs (at left) ready to attach to the data logger which will lie within the frame in its thermal barrier. Side-by-side sensor-plugs (PA0885) are shown; see text. The frame's side-rails are shown partially extended and with their side-plates in place.

Preparing the Frame

The carrier frame easily **adjusts to the width of the reflow oven**. If your oven has a pin-chain, it is recommended to use this for supporting the frame; otherwise, use the mesh-belt conveyor. If using the pin-chain...

- Push the side-rails in or out so that they fit on the oven's pin-chain. The side-rails will then remain in position; *do not tighten their clamping nuts*.
- For further flexibility in width, the side-rails are fitted with side-plates which may be unbolted and removed. The side-plates can be fitted at two different heights (using alternative fixing holes on the side-rails) to allow for variation in clearance above and below the frame in different ovens.

WARNING

Take care not to trap fingers in the Surveyor frame when adjusting its width.

The **thermal barrier** lies within the central section of the frame or within the barrier-retaining brackets which extend sideways from the central section. If the brackets are not needed (and in order to reduce the width of the frame to its minimum), they can be unbolted and removed.

Sensors

The frame has three fixed temperature sensors across its width, each sensor having two thermocouples – on its upper- and underside. Sensors are of two types, differing in the arrangement of their plugs, to suit different logger models.

Part numbers:

PA0885 Sensor with pair of plugs fixed side-by-side, for standard 6-channel DP5 logger.

PA0886 Sensor with pair of plugs face-to-face, for narrow 6-channel and standard 12-channel DP5 loggers.

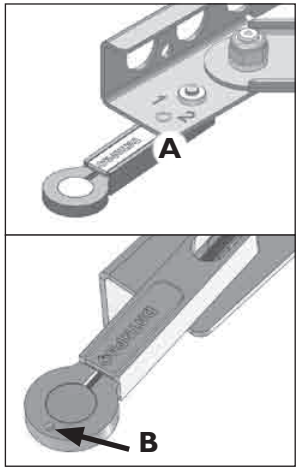
Fitting Sensors

*Correct connection and positioning of the sensors is **essential** to the functioning of the system. The sensor-mounting brackets are marked to assist this.*

- **Sensor brackets** on the frame are marked with **channel numbers** (**A**), and *each sensor must be connected to the corresponding sockets on the logger.*
- The **lower sensor** on each probe is marked by a **spot** at its tip (**B**). The **upper sensor** on each probe is unmarked.

Because of the plugs' pin sizes, they will only fit in the logger's sockets in one orientation – ***but do not force them****.*

Channels 1, 3, 5 are lower sensors.
Channels 2, 4, 6 are upper sensors.



Preparing for a Baseline Survey or Profile Run

1. Connect the Surveyor frame's sensors to the appropriate sockets on the logger (see above). *Connection of sensors to the correct sockets is essential.*
2. Using the Insight software, run the Baseline Survey Wizard or Operator Wizard (as appropriate) and follow its instructions, including resetting the logger.
3. When instructed, carefully place the logger into the thermal barrier and secure the lid.
4. Place the barrier assembly onto the Surveyor frame and place the frame on the oven's conveyor.

The system is now ready for use.

WARNING

It is essential to use the correct Datapaq thermal barrier for your individual process; see p. 11. Ensure that all dimensions of your logger/barrier/frame assembly are such that it will fit comfortably within the oven through all stages of the process. Failure to do this can cause the assembly to jam in the oven with consequent overheating and potentially-severe damage to the equipment. Resultant battery-leakage, and the act of recovering the equipment, may cause skin burns and respiratory irritation.

REMEMBER TO…

Ensure that the carrier is always adjusted correctly, with the two side rails set at the correct width for the oven's conveyor and parallel with each other.

Always allow adequate cooling time for the carrier, thermal barrier and sensors before further profile runs.

Always ensure that the sensors are plugged into the same thermocouple channels for every profile run and that they are the same as those used for the baseline survey. Failure to do this will invalidate the results.

Ensure when conducting profile runs that the oven settings are the same as those for the baseline survey. Failure to do so may result in false alarms. This applies not only to line speed and temperature settings, but also (in ovens where it can be changed) to the convection level.

OPERATOR AND TECHNICIAN MODES

Reflow Tracker Professional is run in one of two different modes – **Operator** or **Technician** – selected at startup.

Operator Mode

A simple step-by-step **Operator Wizard** guides the oven operator through a basic profile run, assessing the oven's performance against a pre-existing baseline survey. No other aspects of the Insight software are visible to the Operator. The technician can control access to the Operator Mode, and set options for the Operator Wizard to simplify its use for the operator.

Technician Mode

This mode is used to create a **baseline survey** for an oven. It also gives access to the full functionality of Insight, including:

- Extensive data analysis options.
- Process-parameter adjustment.
- Use of telemetry.

*You may **password-protect** use of Technician Mode: on Insight's main menu, select Tools > Options > Surveyor Technician Mode.*

*To **change between Operator and Technician modes**, Insight must be closed and restarted. Alternatively, run Insight a second time and open another mode to have Operator Mode and Technician Mode running simultaneously.*

Running a Baseline Survey and Setting Tolerances

Running the **Baseline Survey Wizard** in Technician Mode (see box) allows you to perform a baseline survey of a correctly functioning oven with given heater settings (defined in a recipe), thereby establishing an ideal temperature profile for a given process and defining limits – **tolerance bands** – within which the oven's performance must fall; limits can be defined to create either a single tolerance band or two bands – an inner and an outer.

To run the wizard, click  or  on the Insight toolbar, or select File > New > Baseline Survey from the menu bar. The wizard guides you through the whole process, but note especially the following.

- After setting the oven temperatures, it is essential to **wait until the oven has stabilized at these settings** before proceeding.
- Take care when **defining the tolerance band(s)**: too narrow a band will result in many false alarms during subsequent comparative profile runs, and too wide a band will allow the process to drift too far from the ideal before an alarm is produced. There are two key aspects to consider.
  - If no oven was specified at the start of the wizard, the tolerance band will apply to the entire baseline survey data. Thus it is then necessary, when defining the tolerance band, to specify the **start and end points of the band** in order to avoid analyzing irrelevant data collected before the Surveyor assembly enters the oven and after it has left it.
  - Once the start and end are defined, the tolerance band automatically created by the software can be modified manually as shown in the wizard. This may be advisable (e.g.) in areas of the oven where control is less critical (such as the entry hood, or the end of the cooling zone) and the tolerance band can thus be locally widened.

Performing a Profile Run

Profile runs to assess the oven's performance on a regular basis will normally be carried out simply by running Insight in Operator Mode (see box, p. 47), though the operator's role can also be carried out in Technician Mode by using the **Operator Wizard** (click  or  on the Insight toolbar, or select File > New > Profile Run from the menu bar).

The wizard guides the oven operator through a basic profile run, assessing the oven's performance against a pre-existing baseline survey. This involves:

- Preparing the logger for a profile run.
- Downloading the data to the PC after the run.
- Receiving a pass/warning/fail notification of oven performance.

- Saving the results and displaying them (graphically and numerically); they can also be printed.

WARNING

Never carry the Surveyor assembly by holding the attached thermocouples. This can lead to injury by dropping the equipment onto your body, and may damage the equipment itself.

*On removal from the oven, the assembly, **including logger**, will be **hot enough to burn skin** – even though its temperature will not be apparent. Use protective gloves.*

The operator will be given one of the following clear results in a 'traffic lights' display:

RED – Part of the profile falls outside the tolerance band (or, if two tolerance bands, outside the outer). *The production manager should be informed immediately.*

YELLOW (only if two tolerance band are defined) – Part of the profile falls outside the inner band but none of it is outside the outer band. *The oven may be drifting out of specification.*

GREEN – The whole profile falls within the tolerance band (or, if two tolerance bands, within the inner band).

Surveyor Index

If the profile run has been performed in Technician Mode, the downloaded results and analyses will be displayed graphically and numerically (they can also be displayed in Operator Mode, if this has been enabled by the technician).

A key feature of the results is the **Surveyor Index**, which gives a measure of the overall amount by which each probe's profile-run data differs from the baseline survey. It is calculated as the average (multiplied by 10) of the absolute differences in temperature between baseline survey and profile run for each data point. Surveyor Index figures are given a positive value if the profile-run data averages higher than the baseline survey, and negative if lower than the baseline survey.

Trends and Predictions with SPC

The main benefit of using the fixed sensors of the Surveyor system is that they provide consistent and comparable data on which subsequent Statistical Process Control (SPC) analysis can be conducted so that trends in the data can be identified and future oven performance predicted.

*For an alternative approach to identifying trends, using SPC on **normal Insight paqfiles**, see p. 28. Note that temperature profiles obtained using the Surveyor system will not match normal Insight paqfiles obtained from an instrumented PCB. The Surveyor sensors are designed to yield highly repeatable results enabling reliable SPC analysis to be conducted on the resultant dataset.*

Analysis is carried out using the **SPC Wizard**: click  on the Insight toolbar, or select File > New > SPC from the menu bar. Data from all profile runs associated with a particular baseline survey is automatically stored together in the same folder, so selection and analysis is made quick and easy. The process is fully described and discussed in the online Help (under 'Data Analysis' see 'Statistical Process Control').

SPC analyzes the profile-run data according to specified acceptable temperature limits, and by default these are taken as the (outer) limit specified when creating the baseline survey. In the final stage of the wizard you may, however, specify alternative limits, but note that this changes the values of USL and LSL used in the calculation of capability statistics. For a full explanation of the calculation of C_{pk}, P_{pk}, etc., see 'Statistical Process Control' in the online Help.

Troubleshooting

For problems in **communication between the logger and the PC** and for **logger download error messages**, see the 'Troubleshooting' chapter of the dedicated *User Manual* for your logger.

For **process problems** revealed by temperature profiles, see p. 26 for reflow and p. 35 for wave solder.

To troubleshoot problems with **predictions in Easy Oven Setup**, see p. 42.

Checking the Data

If you suspect that **invalid data** may have been introduced into your temperature profile (paqfile), perhaps by damaged thermocouples (see below), select the View Data tab in Insight's Analysis Window to view the raw data as downloaded from the logger. The various types of invalid data which may be contained in a paqfile are shown in the analysis grid as follows.

OC	Open circuit. (Will occur if recording starts before thermocouples are plugged in.)
NA	Telemetry data not received. Check antenna connectors.
LO	Temperature measured was below the range of the logger.
HI	Temperature measured was above the range of the logger.
***	Calculation cannot be performed (not necessarily because the data are invalid). Does not appear in View Data analysis mode.

Typical causes of invalid or interrupted data are:

- Damaged thermocouple cable.
- Thermocouple becoming detached from plug/logger.
- Faulty connection at thermocouple's hot junction.

Readings which are inconsistent with those of other thermocouples may be caused by a **short circuit** (see below). The thermocouple concerned must be replaced.

Open circuit readings can occur during a profile run if a thermocouple becomes damaged. The logger will then continue sampling on that channel, but, by default, an alarm will be registered. For further details of such alarms, or to disable the alarm, select Tools > Options > Run Alarms.

Thermocouples with an intermittent open circuit may produce spiky, erratic profiles. Note that spikes are inevitable when thermocouples are disconnected from a running data logger.

Testing the Logger and Thermocouples

Although thermocouples are generally robust, they can be damaged during handling. Use the following procedure to confirm the operation of logger and thermocouples after installation. Note that this test is not an alternative to calibration (see the dedicated *User Manual* for your logger), but will highlight a malfunctioning logger or faulty probes and thus avoid a wasted profile run.

Do one of the following:

- With a full set of thermocouples attached to the logger, and the logger connected to a PC running Insight, open the Logger Reset dialog or the Diagnostic section of the Communications Setup dialog; this shows current probe temperatures – *or*...
- Set up the system as if to monitor a profile run using hardwired telemetry (see the dedicated *User Manual* for your logger), and note the temperatures registered by the thermocouples as they are displayed in Insight – *or*...
- To test the thermocouples alone, use a digital thermometer (of a type to match the thermocouple type) and attach it to each thermocouple in turn.

Proceed as follows.

1. Note readings first at ambient temperature: thermocouples registering no data in Insight, or an open circuit with a digital thermometer (*OC* in the Communications Setup dialog), may be broken. Inconsistent readings may indicate an intermittent short circuit.
2. If a satisfactory ambient reading is recorded, apply heat to the thermocouple-tip via fingers or other heat source. An increased temperature should register.
   - If the reading does not change, the thermocouple is short circuit or has other damage and must be replaced.
   - If the temperature shows a decrease, the thermocouple connections are reversed.
3. Confirm correct operation at 100°C by placing the thermocouple-tip in freshly-boiled water.
4. Replace any damaged thermocouples and test again.

Datapaq Service Department

If you cannot resolve your problem, please contact your nearest Datapaq Service Department at Fluke Process Instruments. For contact details, see www.flukeprocessinstruments.com – or email as follows:

Europe, Asia (except China), Africa, Australasia – datapaqservice@flukeprocessinstruments.co.uk

China – service@flukeprocessinstruments.com.cn

Americas – auto-rma-us@fluke.com

The user may easily download and **email key diagnostic information** to Fluke Process Instruments:

1. Connect the logger to the PC with Insight running.
2. Select Logger > Setup > Advanced, or Help > Service.
3. Select a name and location for the downloaded file, and a destination for the email.

The file created is accessible to Fluke Process Instruments but is not designed to be opened by the user.

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Major entries are shown **in bold**.

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