PROCESS FOR MANUAL SOLDER ASSEMBLY OF HIGH HEAT CAPACITY BOARDS

by

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Portsmouth

METALLURGY REPORT No. 2637

March 2000

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Approved by:

B.D.Dunn
Head of Materials and Processes Division
(Original has been signed by B. D. Dunn)

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1. Abstract

Various methods were explored in order to find acceptable ways of promoting solder penetration in high heat capacity through-hole boards.
Three supplementary heating methods were found to give acceptable results, each with particular advantages and disadvantages.

IR Lamp: convenient to use, but joints can be shadowed by component body. Fast response to changes in power setting. Component body reaches a higher temperature than the board surface.

Hot Plate with hot airstream: less convenient than the IR lamp due to length of time to reach operating temperature, some discomfort due to continuous heat output, and danger of operator touching hot surfaces. Better than IR regarding shadowing. Again, component body reaches a higher temperature than the board surface.

Hot Air gun: fast heat-up. Airstream can be easily directed to the component side of leads and lands to be soldered without significantly heating up the component body.

All of these methods can produce destructive temperatures on the board surface, so it is essential to have a surface temperature monitoring system such as the one used in this study in order to set up process windows.

A means of protecting components from excessive heating was successfully demonstrated.

No method can on its own be guaranteed to provide a complete solution to solder penetration problems. Other factors which affect solder penetration include the board design, solderability of the surfaces involved, the fit of the lead in the hole and the resulting capillary action, and the activity of the fluxes involved.

2. Introduction & Objective

When soldering through-hole components to plated-through-hole boards, most high-reliability specifications require complete solder fill of the plated-through holes (ECSS-Q-70-08A, 10.3.3 and Figure A-2).

In Space applications, resistance to vibration caused by the propulsion systems is an important characteristic. It is clear that a component supported by fully-filled plated-through holes is much stronger and less liable to vibration failure than one held by partially-filled holes.

Internal planes act as heat sinks resulting in a thermal gradient across the thickness of the board. If this gradient is sufficiently steep, then a soldering iron tip at the maximum permitted temperature of 360℃ (ECSS-Q-70-08A, 5.5.7) may not result in a high enough temperature at the other side of the board to permit solder penetration.

Board designers generally use thermal breaks at ground plane connections to plated-through holes and these reduce the thermal gradient.
In the quest for superior electrical performance however, board designers are sometimes forced to use many layers and in some cases to connect plated-through holes to internal planes without thermal breaks.

One such board used in the Columbus project is 2.32mm thick and has 12 layers with no thermal breaks. Boards such as these require special techniques to promote flow-through and the objective of this study is to propose, examine and compare a number of such techniques.

3. References, Literature Search & Previous Relevant Work

ECSS-Q-70-08A (European Cooperation for Space Standardization), 10.3.3 & Fig A-2: Complete flow-through required.

Metallurgical Assessment of Spacecraft Parts, Materials & Processes (Dunn), 6.12.2: Evidence of solder flowthrough required. Fig 6.21c shows section of joints, one with poor flowthrough.

Soldering in Electronics (Wassink), 12.4.2.3: recognises that a fully-filled hole is ideal, but indicates that a joint can be accepted if solder-side fillet only is good.
10.2.3: Soldering (from below) by heating with Hot air or Radiation.

Soldering & Surface Mount Technology, No 25, article on Capillary Flow Solder Wettability Test by PT Vianco and JA Rejent: shows that the capillary rise is reduced by a factor of 5 as the gap is increased from 80μm to 380μm. (Cf ECSS-Q-70-08A 8.4.2b which requires a gap of 150μm to 325μm (hole clearance of 300 –650μm). The article also illustrates the reduced capillary rise which can be expected from lead-free solders.

Soft-Soldering Handbook (Thwaites), 2.1.2 shows 130-μm to give maximum strength, but recommends larger gap for ease of assembly.
4.2.2.3 highlights causes of poor flowthrough other than heat sinking: incorrect fluxing, soldering conditions, parts solderability and poor fit of lead in hole limiting capillary action.

Soldering Processes & Equipment (Michael G Pecht), 7.3.2: Refers to use of desoldering temperatures up to 400°C on multilayer boards, and the need for auxilliary heating.

IPC-A-610B, Section 4.1: Class 2 requires 50% fill whilst Class 3 requires 75% fill; both these figures relate to boards with internal planes.

Highbury College Visit & Test Report: (Cardon, Matra Marconi Space) provides results of tests carried out on 12- and 14-layer boards on 3/11/99. Raises concern of component damage due to underside heating.

Solder Extraction Training Video 6030-0458: (Pace Inc) shows use of auxilliary heat to assist in solder extraction from populated through holes in multi-layer boards.

4. Equipment, Materials and Test Vehicles

4.1 Equipment

- Metcal STSS-02 Soldering station with power meter, 036 and 537 tips (see Appendix 2)
- Martin Hot-Beam-02 Infra-Red Lamp (20-120W)
- Pace HeatWave HS200 hot plate with programmable airflow through centre of plate
- Leister 7A1 Hot air system with fine and coarse nozzles (0-700W)
- Pace MBT250 desoldering station
- TC08 thermocouple datalogger by Pico Technology Ltd (see Appendix 1).

- Type K 'disc' thermocouples on 6.3-mm Ø x 0.3-mm brass discs for board surface temperature monitoring.
- Type K 'point' themocouples for airstream temperature measurement and for solder pad temperature monitoring.
- Düsenlehre 0-3mm Hole Ø Gauge.
- Simple clip-on component heat shield.

4.2 Materials
- Metalwerk Goslar Sn63 eutectic solder wire (1.0-mm Ø) with pure rosin flux core.
- Indalloy Microelectronics research kit: 5%In, 92.5%Pb, 2.5%Ag solder wire. This has a MP of 300°C and was used to secure thermocouples to the edge of plated-through holes.
- Multicore 6381-35 (ROL1) Flux. Note, ideally the same flux as that contained in the solder wire should be used, but it was felt that the use of a more active supplementary flux would reduce the significance of this variable.

4.3 Test Vehicles

• MIL-STD 2000 training board	2 layer, t=1.53mm	FR4	PTH Ø 0.84mm
• ESA training board	6 layer, t=1.83mm	FR4	PTH Ø 0.81mm
• VTC (Columbus) board	12-layer, t=2.32mm	FR4	PTH Ø 0.71mm
• PSR board (only for Tip characterisation)	14-layer, t=2.62mm	FR4	PTH Ø 1.01mm

4.4 Components
- 16-lead dual in line IC packages with pretinned leads for the two training boards. Lead section: 0.51 x 0.26mm.
  Note: this gives 'gaps' of 275µm and 290µm in 6-layer and 2-layer boards respectively; cf 325µm maximum (ECCS-Q-70-08A) and 380µm maximum (Vianco & Rejent).
- Augat socket for the VTC board. Lead Ø 0.55mm.
  Note: this gives a 'gap' of 80µm which according to Vianco & Rejent, should give optimum capilliary action.

<u>5. Methods</u>
5.1 Monitoring
Disc thermocouples were mounted on component side (cs) and solder side (ss) board surfaces using Kapton tape.
Point thermocouples were fixed to the cs and ss on edges of plated-through holes using Indalloy solder having an MP of 300°C. Although this solder failed to wet the thermocouples, it was possible to surround the them with sufficient solder to keep them in place. The MP of 300° was found to be sufficiently high not to release the thermocouples during the soldering trials when a 315° soldering iron was applied diametrically opposite on the same pad.
Each thermocouple was connected to a dedicated channel on the Pico TC08 datalogger.
Pico Technology software processed the data and provided graphs of the thermal responses at each site being monitored.

5.2 Soldering & Experimental Techniques
Test vehicles were cleaned with IPA and test sites were fluxed.

The dual in line package was mounted on a spacer to lift the shoulders of the leads off the edges of the plated through holes. This has the benefit of reducing the heat sinking effect of the shoulders as the solder wicks through the hole; it also avoids so-called sweat joints between the shoulders and the edges of the plated through holes which detract from the solder extraction / component removal process.
A clean soldering iron tip was then placed on the ss of the plated through hole, also contacting the component lead and a small amount of solder added to form a solder bridge.
A dwell time of about 2 seconds was allowed and then solder wire was fed into the joint between the point thermocouple and the tip.
If solder penetration was unsuccessful, the solder was removed and the trial repeated using successively longer dwell times up to about 6 seconds before feeding the solder wire.
It was found that increasing solder dwell times beyond 6 seconds did not improve the results, nor would this be desirable due to the probability of causing laminate damage and excessive intermetallic thickness.
Where soldering was still found to be unsuccessful, each of the following supplementary heating methods was tried:

- **Martin Hot-Beam-02 IR Lamp:** set at 110W and spaced at 25mm beneath the cs of the horizontally- positioned board; as soon as the board reached the desired temperature, soldering commenced.

Fig 5.1-1a: The Martin IR Lamp is positioned under the board holder.
The Martin controller is on the mid left.
The TC08 Datalogger is to the right of the controller.

Fig 5.1-1b: The Martin IR Lamp is positioned under the board with thermocouples in place.

- **Pace HeatWave:** set at 371℃ (surface temperature measured at 340℃) and spaced at 25mm beneath the cs of the horizontally-positioned board. The air supply was used until the board reached the desired temperature, at which point it was switched off and soldering commenced; on switching off the air supply, the board continued to heat up at a slower rate (see Appendix 12 between 100 and 115 seconds).

Fig 5.1-2: The Pace HeatWave hot plate is positioned under the board.
The Pace controller is on the upper centre.

- **Leister 7A1 Hot air system:** set at 1.5 (scale 1-6), blower speed 4.5 (scale 1-9). The air gun was mounted in a fixture with the nozzle positioned 10mm from the row of joints being soldered. The board was mounted vertically and soldering commenced as soon as the desired temperature was reached.
  This system can meet the requirements of both ESA PSS-01-738, 3.6.3 b & c (preheat to 70-100°and soldering at 260 -320°C surface temperature) and ESA PSS-01-728 Method 5.3 (air temperature range 200-300°C).

Fig 5.1-3: The Leister hot air system is positioned to the left of the vertically-positioned board.
The Leister controller is on the upper centre.

5.3 Thermal Response: comparison of the three methods

Method	Component side surface heat up rate °C/s (between RT & 100°C)			ΔT Comp side/Solder side (@ cs = 100°C)		
	2-layer	6-layer	12-layer	2-layer	6-layer	12-layer
Martin IR	**1.3**	**1.4**	**1.2**	**12**	**28**	**26**
Leister Hot Air	**17**	**5.6**	**7.7**	**57**	**57**	**70**
Pace Hot Plate	**3.4**	**1.7**	**1.1**	**29**	**41**	**20**

5.4 Other Methods of Promoting Solder Penetration

The following methods, which were excluded from this study, are also worth considering for specific applications:

- **2nd soldering iron, applied on component side:** already used widely in industry. Not suitable for sockets and other components where the leads and lands are inaccessible from the cs. Inconvenient as it requires a second operator.
  Note: excluded for initial soldering, but recommended for desoldering where access permits (see 5.6).

- **Oven Preheating:** this method is also widely used in industry, the board being preheated to a typical temperature of 100°C and then quickly taken to the soldering station for assembly. However, it is inconvenient for the following reasons:
  - Discomfort and danger of handling board at high temperature
  - Steady cooling of board during solder operation requires reheating after a number of joints have been completed

- **Pace Mini Thermojet:** another hot-air system which could be usefully employed for supplementary heating in a similar way to the Leister system. In standby mode however, the airstream is off and the heater element is on; when the airstream is first turned on, an initial air temperature of 400°C is experienced if Pace's recommended setting of 482°C is used.
  Once air flow is established, the digital readout drops and stabilises at around 445°C, whilst the air temperature varies between 320 and 360°C. Because this system uses a low-volume air flow, it needs to use a high air temperature to provide sufficient energy for solder flow.
  Although this system can meet ESA PSS-01-738 3.6.3 b & c which require preheat to between 70° and 100° followed by a surface temperature between 260° and 320°C measured on the laminate surface, the necessary air temperature is likely to exceed the 200-300°C range specified in ESA PSS-01-728 Method 5.3.
  It was therefore decided to exclude this system from the trials, although there will be applications where an air temperature within the acceptable range would provide adequate energy.

- **Optical Fibre Reflow:** this method, referred to in Soldering Processes & Equipment, 4.6.2 (Pecht) suggests the use of optical fibre bundles as a means of directing energy for solder reflow into inaccessible areas. Could be used for supplementary heating on the cs.

- **Solder fountain:** this system (available from Litesold) uses a miniature solder wave with a funnel'and fixturing to direct the wave to a single component site. This is not a supplementary heating method, but a complete soldering system. It is unlikely to be successful in all circumstances just as wave soldering does not always achieve complete solder penetration in high heat capacity regions; however, this method could be combined with any of the suggested methods of cs heating. For component removal there are circumstances (eg PGAś) where this can be the only successful method.

- **Intrusive Through-hole Solder Reflow:** again, not a supplementary heating system, this method helps to promote flow through. The pth is filled with solder paste before inserting the component; when the soldering iron is applied, the paste in the hole helps to transmit heat across the thickness of the board and then reflows along with the fed-in solder wire. Can be used with supplementary heating methods as well.
  This method was tried in Highbury College during the day of trials conducted with Matra Marconi Space, Velizy, and was found to give acceptable results. However, this would be a complicated process to qualify. Finally, solder extraction and component removal have been found to be almost impossible on boards which have *needed* this method to achieve complete solder flow through.

5.5 Component Temperature

During the day of trials conducted with Matra Marconi Space Velizy both the Martin IR and Pace HeatWave systems referred to above were tried. It was clear during these trials that component temperatures occasionally reached unacceptable levels.
In order to address this concern, the space between the cs and the lamp or hotplate was increased from 15mm to 25mm for this study. As expected this resulted in component temperatures being much closer to board surface temperatures (since the component height becomes less significant relative to the distance of the board from the heat source).
Also, a simple component heat shield was tried in order to limit component temperature rise. This was found to approximately equalise the temperatures of component and component-side surface temperature (Appendices 16a & 16b).

5.6 Solder Rework / Desoldering

The removal of solder from joints made in high heat capacity regions presents similar problems to the initial soldering process, therefore component side heating is equally necessary.
A Pace MBT250 Desoldering station with Pace Sodr-X-Tractor handpiece was used for the rework trials. Tip temperature was set at 360℃, the maximum permitted by ECSS-Q-70-08A.
All three methods of component side heating referred to in 5.2 & 5.3 were found to give satisfactory results.
When desoldering, the board is normally mounted horizontally with the solder extractor perpendicular to it. In this configuration, both gravity and capilliary forces have to be

overcome. By mounting the board vertically, with the extractor horizontal, all that needs to be overcome is the capilliary effect.
Perhaps for this reason, the hot air method of component side heating was found to give more repeatable desoldering results than the IR or hot plate methods.
Where access permits, a component side soldering iron can be more effective than all three above methods; since a vacuum solder extractor only requires one hand to operate (unlike the initial soldering process) the other hand may be used to apply the component side soldering iron; the board is again mounted vertically, and the extractor held horizontally in this method.
Whatever the method, fluxing on both sides is recommended.

6. Conclusions & Order of Merit

- **Martin HB02 HotBeam (IR Lamp):** Best results were obtained when the solder side temperature was allowed to reach 100°C (component side up to 30°C higher) before commencing soldering.
  If many solder joints have to be performed, it would be possible to establish a lower wattage setting to maintain a steady temperature once the desired temperature is reached. Unlike hot plate systems, the IR lamp responds almost instantly to changes in power setting. Accurate positioning of the lamp under the region being soldered is easily verified as the light shines through the vias.
  Appendix 13 shows measurements taken when using this process.
  Convenient to use, but joints can be shadowed by component body. Component body reaches a higher temperature than the board surface, but this can be addressed (see Appendices 16a & b).
  The Martin HotBeam system costs £575 plus £200 for a board holder.

- **Pace HeatWave (Hot Plate):** Best results were obtained using the air supply until the the solder side temperature reached 100°C (component side up to 45°C higher), switching it off and commencing soldering; on switching off the air supply, the board continued to heat up at a slower rate (see Appendix 12 where a reduced rate of heat rise can be seen between 100 and 115 seconds).
  Appendix 15 shows measurements taken when using this process.
  The HeatWave is less convenient than the IR lamp due to length of time to reach operating temperature, some discomfort due to continuous heat output, and danger of operator touching hot surfaces. Better than IR regarding shadowing. Again, component body reaches a higher temperature than the board surface (see Appendices 16a & b).
  The HeatWave system costs £275 and includes a board holder.

- **Leister 7A1 (Hot air system):** set at 1.5 (scale 1-6), blower speed 4.5 (scale 1-9). The air gun was mounted in a fixture with the nozzle positioned 10mm from the row of joints being soldered on the vertically-mounted board. In this case, heat up rates were so fast that the point at which soldering commenced had to be determined by the temperature on the component side. Best results were obtained when the component side temperature reached about 120°C before commencing soldering. At this point, the air flow rate was reduced to minimum on the Leister control unit, reducing the rate of rise (see Appendix 14 where reduced rate of heat rise can be seen between 28 and 36 seconds).

The Leister hot-air system gives very fast heat-up which although convenient, can also lead very quickly to destructive temperatures. The great advantage is that the airstream can be easily directed to the component side of leads and lands to be soldered without significantly heating up the component body.
This system can meet the requirements of both ESA PSS-01-738, 3.6.3 b & c (preheat to 70-100° and soldering at 260 – 320°C surface temperature) and ESA PSS-01-728 Method 5.3 (air temperature range 200-300°C).
The Leister 7A1 system costs £71 including the 5-mm nozzle used in this study.

All of these methods can produce destructive temperatures on the board surface, so it is essential to have a surface temperature monitoring system such as the one used in this study in order to set up process windows for the user's particular board and conditions.

No method can on its own be guaranteed to provide a complete solution to solder penetration problems. Other factors which affect solder penetration include the board design, solderability of the surfaces involved, the fit of the lead in the hole and the resulting capillary action, and the activity of the fluxes involved.

Overall Order of Merit Table

The following table gives a quick overview of the rankings awarded to each system for the applications evaluated in this study. The lower the number, the better in each case.

Method			Repeat-ability		Comfort (c)	Convenience (d)	Rework
Martin IR	1	1	2	2	1	1	4
Leister Hot Air	1	3	3	1	2	2	2
Pace Hot Plate	1	2	1	3	3	3	3
CS Soldering Iron	(a)	(a)	(a)	(a)	(a)	(a)	1

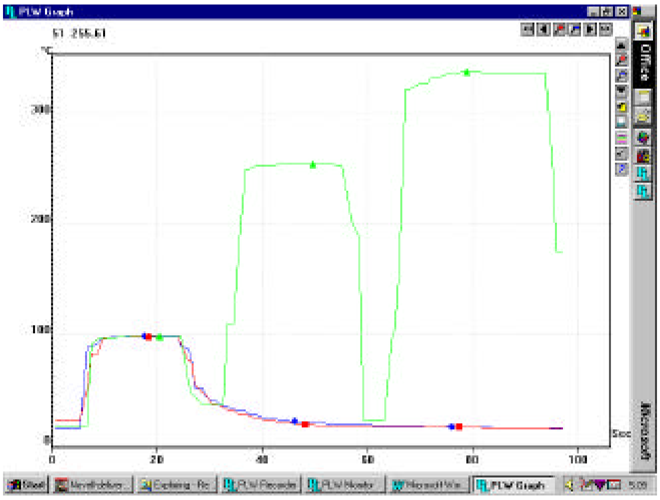
(a) component side soldering iron excluded from assembly trials; used for rework and only suitable where pin access is possible
(b) flow of solder may be observed with methods employing vertically mounted board (Leister); the IR lamp shines through the vias verifying alignment (Martin)
(c) constant heat output of Pace hot plate system was considered to be a source of discomfort
(d) 20-minute heat-up time of Pace system was considered to be inconvenient
(e) Costs are so similar (£71 - £75) that no ranking can be justified, although the Leister system does not include a board holder.

Appendices 1 & 2: Characterisation of Measurement System and Soldering Iron Tips

Appendix 1: Characterisation of Measurement System

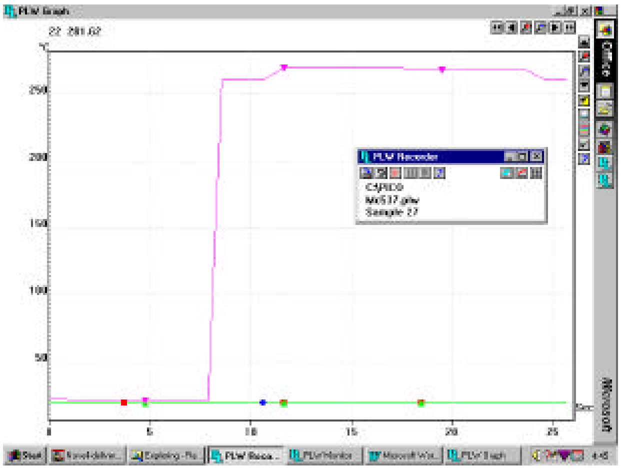
The following plot shows the response of three thermocouples (connected to a PC via a Pico TC08 datalogger) when simultaneously plunged into boiling water; one thermocouple was then contacted with a Metcal 537 tip followed by a Metcal 036 tip.

The graph verifies that all three thermocouples were responding similarly, showing an accurate 100°C for boiling water, one then rising to solder tip temperature at a rate of



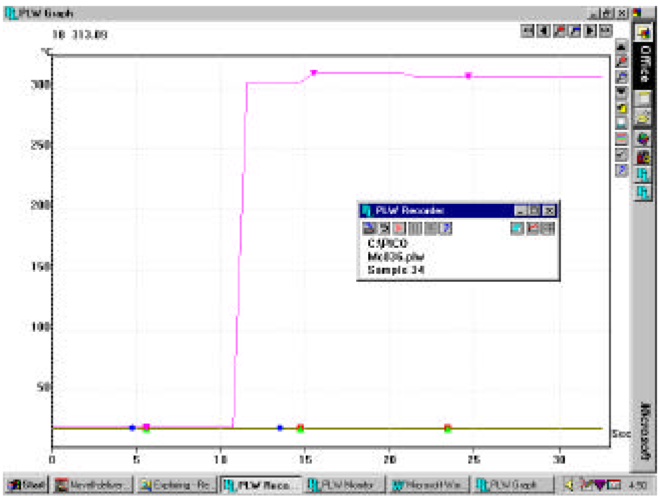
Graph A-1: Measurement System Response

Appendix 2: Characterisation of Soldering Iron Tips



Graph A-2-1: Metcal 537 No Load Peak Temp 269C (nominal 280°C)

With the 537 tip, the Metcal power meter peaks at 34W during heat up and idles at about 1.5W at a peak temperature of 269°C.
The power meter rises to 4W when applied to either the 2-layer training board, the 6-layer training board (‘difficult’ DIL site) or the Columbus VTR board. Note that this tip was only able to flow the solder satisfactorily on the 2-layer board, hence the power consumption did not respond to the higher thermal loads due to the poor heat transfer of solid solder.
The 537 tip was just able to flow the solder on easy DIL sites on the 6-layer training board, but only after excessive dwell time. All subsequent work used the Metcal 036 tip, see below.



Graph A-2-2: Metcal 036 No Load Peak Temp 313°C (nominal 315°C)

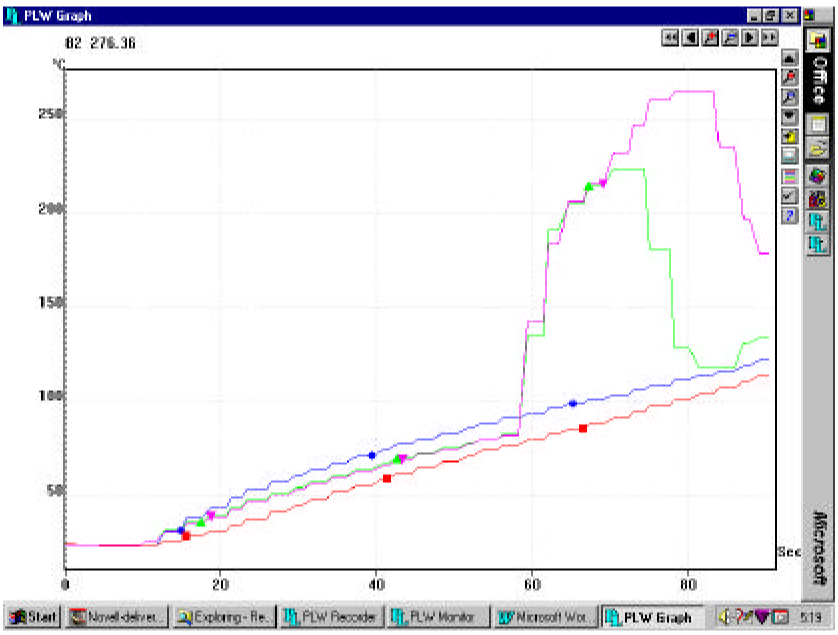
With the 036 tip, the power meter peaks at 32W during heat up and idles at about 3W at a peak temperature of 313°C.
The power meter rises to 5W, 8W, 9W and 11W when soldering 2-layer training board, 6-layer training board, Columbus VTC board and PSR board respectively. It was found that the 9-W consumption on the VTC board dropped to 6W when the cs was heated to 120°C using hot air.

The power figures recorded above show how the Metcal system responds to varying thermal loads. It is interesting to see the improved power delivery which occurs as soon as the solder melts and starts to conduct the heat through the joint; this is an effective demonstration of the importance of making a solder bridge when hand soldering. To maximise heat transfer, it is also important to use a tip size and geometry which will have the greatest contact area on the surfaces to be soldered; in this respect, the 036 tip is ideal, having a chisel-shaped tip, the width of which closely matches the diameter of the pad.

Appendices 3 – 6: Characterisation of Backheat Systems with Double-sided Boards

Appendix 3: Double-Sided Board, using Martin IR Backheat

The following graph shows the temperature curves for a simple double-sided board using IR backheat and a Metcal 537 tip. The red and blue traces show temperature response on ss and cs surfaces respectively; the purple and yellow traces show temperature response on ss and cs solder pads respectively, the sharp rise occurring when the soldering iron is applied.

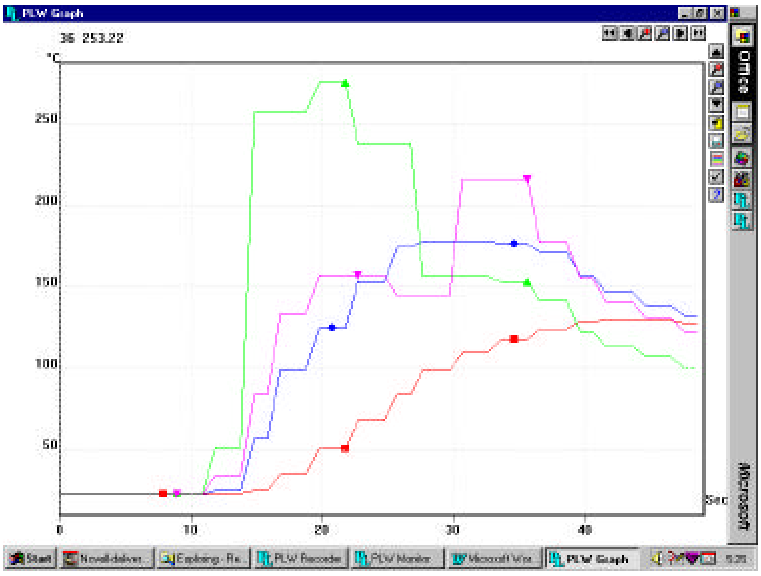


Graph A-3: Two-layer board, Metcal 537, IR backheat

- Surface heat-up rate from IR around 1.3°C/second
- Difference in temperature between cs and ss surfaces around 12°C @ cs = 100°C
- Difference in temperature between cs and ss solderpads around 18°C @ 230°C
  (*Note* the tip was held on the pad about 12s longer than necessary in order to observe the temperature build-up which , predictably, stabilised @ around 260°C)

Appendix 4: Double-Sided Board, using Leister Hot Air backheat, Fine Nozzle

The graph below shows that the fine nozzle (3mm x 1.3mm) gives a very rapid heat rise with a great risk of overshooting a safe temperature for the laminate (the Leister system can deliver up to 700W, about 20x the power of the Metcal iron).
The red and blue traces show temperature response on ss and cs surfaces respectively; the purple trace shows temperature response on ss solder pad, the sharp rise occurring when the soldering iron is applied (ignore the yellow trace which is from a detached thermocouple).
The nozzle geometry permits local heating of leads and lands without significant heat being applied to the component body.

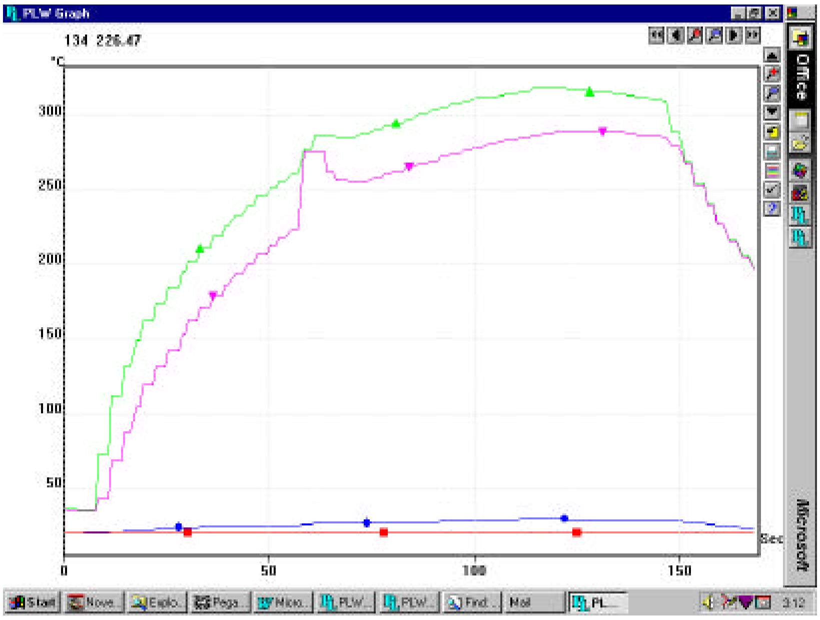


Graph A-4: Two-layer board, Metcal 537, Leister backheat, fine nozzle

- Surface heat-up rate from hot air is around 17°C/second.
- Difference in temperature between cs and ss 57°C @ cs = 100°C

Appendix 5: Double-Sided Board, using Leister Hot Air backheat, Coarse Nozzle

The graph below shows that the coarse nozzle (5-mm ID) gives a more gentle heat rise with a less risk of overshooting a safe temperature for the laminate.
The yellow trace shows the temperature rise on the component side, whilst the blue trace shows that on the solder side. The step in the blue curve corresponds to application of the soldering iron. A recommended process would involve starting the soldering process earlier and reducing the air supply on completion of soldering. In this case the air supply was left on to ascertain the peak surface temperature.
The heat controller was set to position 1.5 with a blower setting of 4.5 and the nozzle was positioned 10mm from the board surface; this gave a peak surface temperature of just under 320°C (acceptable according to ESA PSS-01-738 3.6.3c).

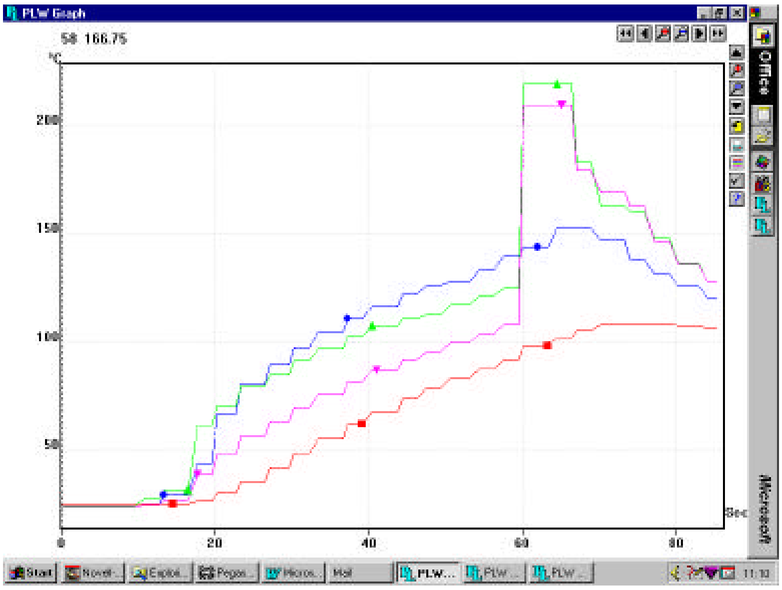


Graph A-5: Two-layer board, Metcal 537, Leister backheat, coarse nozzle

- Surface heat-up rate from hot air is around 17°C/second.
- Difference in temperature between cs and ss 57°C @ cs = 100°C

Appendix 6: Double-Sided Board, using Pace HeatWave HS200 Hot Plate

The Heat Wave controller was set to 371°C per Pace recommendations; the hot plate surface temperature at this setting was measured at 340°C.
The board was mounted 25mm above the hot plate and the airflow was 'on'.
The blue and red traces show the temperature response on the cs and ss surfaces.
The purple and yellow traces show the temperature response on the ss and cs solder pads with the application of the soldering iron tip.



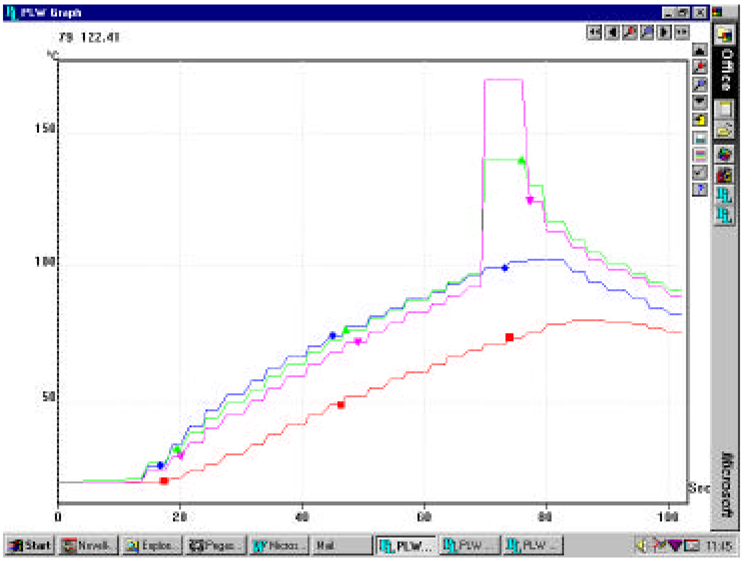
Graph A-6: Two-layer board, Metcal 537, Pace Hot Plate backheat

- Surface heat-up rate from hot plate is around 3.4°C/second.
- Difference in temperature between cs and ss around 29°C @ cs = 100°C
- 120°C cs surface temperature reached after 30s (cf Pace literature which quotes 54s for 2-layer board).

Appendices 7 – 9: Characterisation of Backheat Systems with 6-Layer Boards

Appendix 7: Six-layer Board, using Martin IR Backheat

Same conditions as Appendix 3, with 6-layer board replacing 2-layer one.

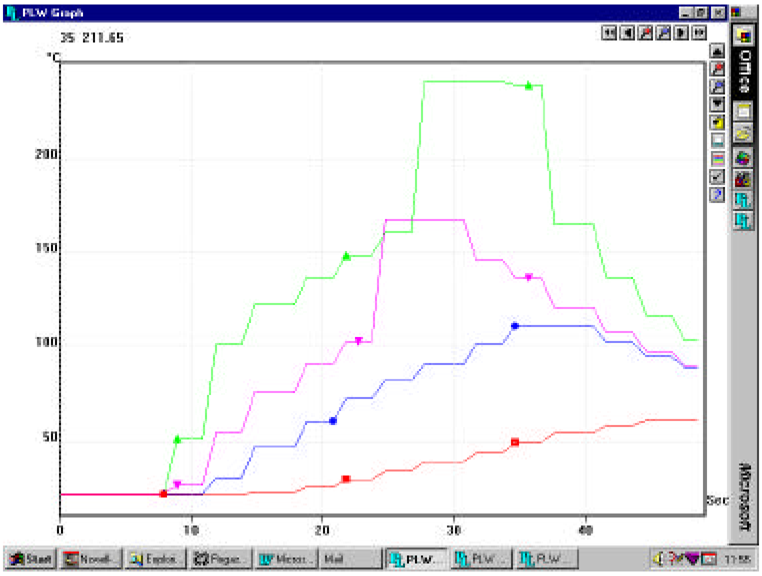


Graph A-7: Six-layer board, Metcal 036, Martin IR backheat

- Surface heat-up rate from Martin IR is around 1.4°C/second.
- Difference in temperature between cs and ss surfaces 28°C @ cs = 100°C

Appendix 8: Six-layer Board, using Leister Hot Air

Same conditions as Appendix 5, with 6-layer board replacing 2-layer one.

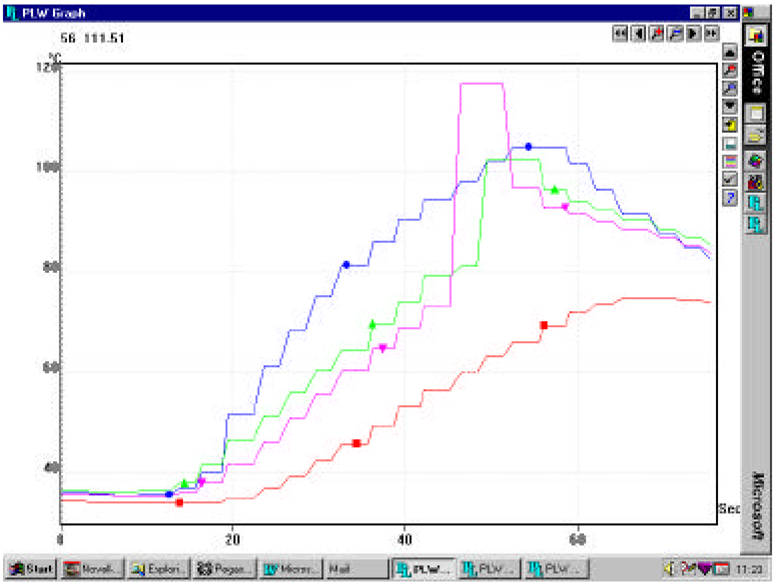


Graph A-8: Six-layer board, Metcal 036, Leister Hot Air

- Surface heat-up rate from hot air around 5.6°C/second
- Difference in temperature between cs and ss surfaces 35°C @ cs = 100°C

Appendix 9: Six-layer Board, using Pace HeatWave HS200 Hot Plate

Same conditions as Appendix 6, with 6-layer board replacing 2-layer one.



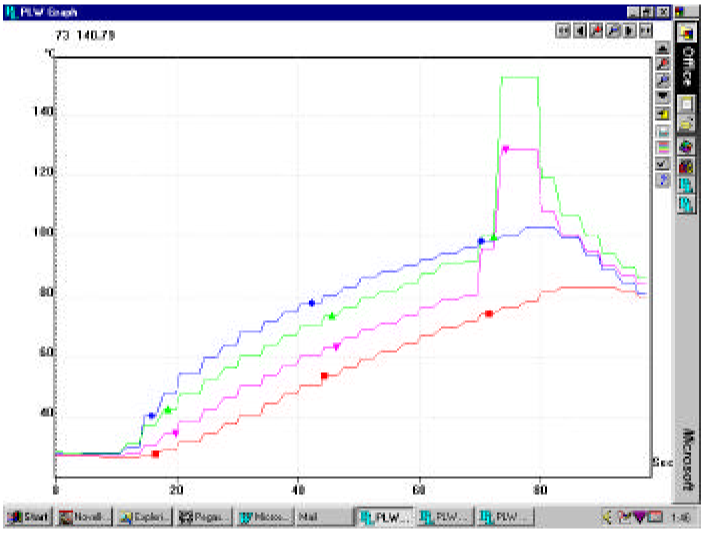
Graph A-9: Six-layer board, Metcal 036, Pace Hot Plate backheat

- Surface heat-up rate from hot plate is around 1.7℃/second.
- Difference in temperature between cs and ss surfaces 41℃ @ cs = 100℃
- 100℃ cs surface temperature reached after 35s (cf Pace literature which quotes 64s for 6-layer board).

Appendices 10 – 12: Characterisation of Backheat Systems with 12-Layer Boards

Appendix 10: Twelve-layer Board, using Martin IR Backheat

Same conditions as Appendices 3 & 7, with 12-layer board replacing 2- & 6-layer ones.

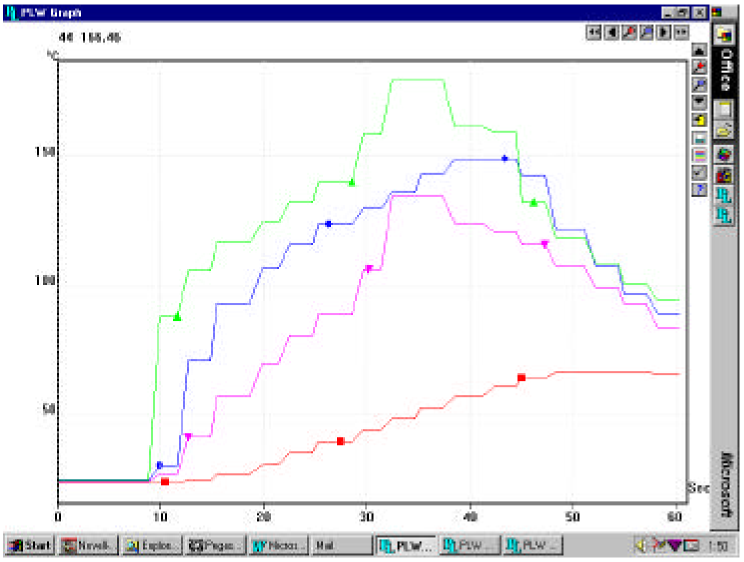


Graph A-10: Twelve-layer board, Metcal 036, Martin IR backheat

- Surface heat-up rate from Martin IR is around 1.2℃/second.
- Difference in temperature between cs and ss surfaces 26℃ @ cs = 100℃

Appendix 11: Twelve-layer Board, using Leister Hot Air

Same conditions as Appendices 5 & 8, with 12-layer board replacing 2- & 6-layer ones.

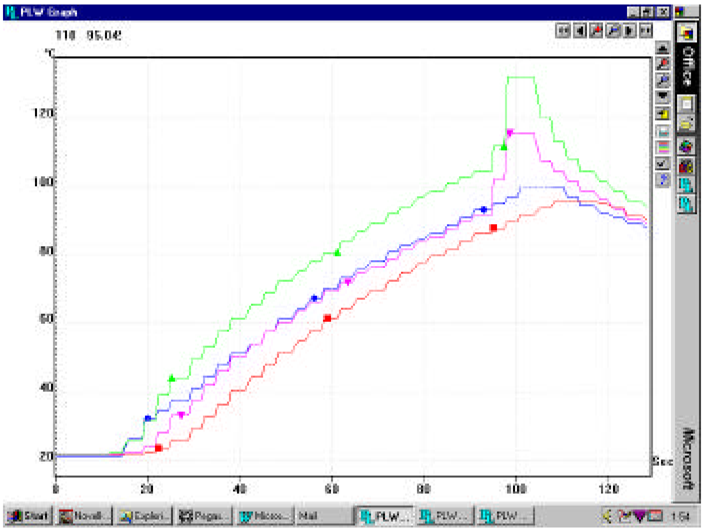


Graph A-11: Twelve-layer board, Metcal 036, Leister Hot Air backheat

- Surface heat-up rate from hot air is around 7.7℃/second.
- Difference in temperature between cs and ss surfaces 70℃ @ cs = 100℃

Appendix 12: Twelve-layer Board, using Pace HeatWave HS200 Hot Plate

Same conditions as Appendices 6 & 9, with 12-layer board replacing 2- & 6-layer ones.

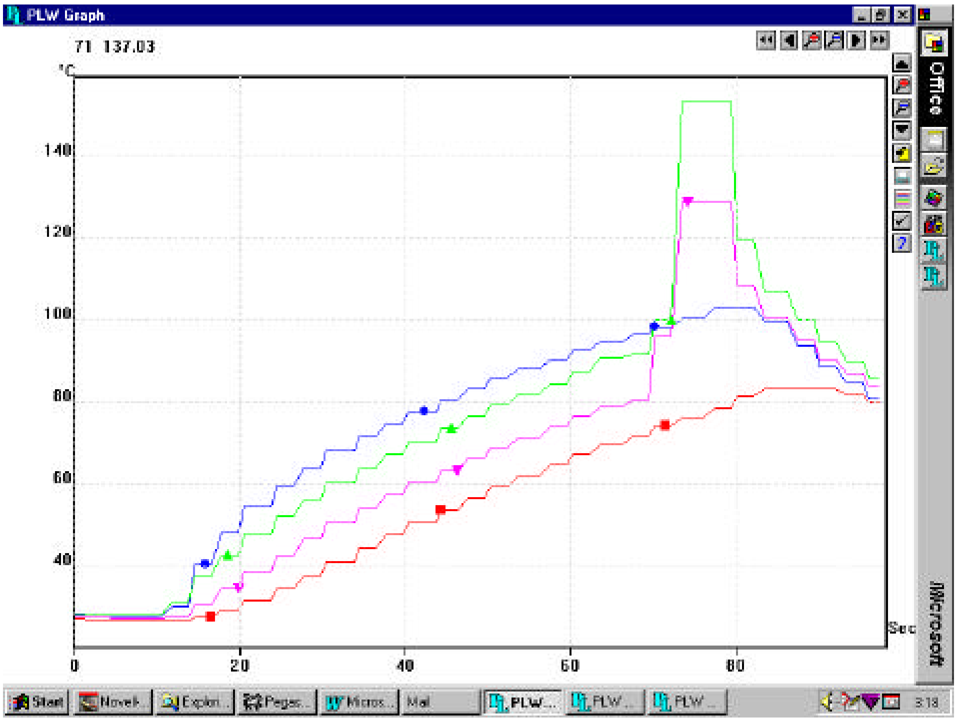


Graph A-12: Twelve-layer board, Metcal 036, Pace HeatWave hot plate

- Surface heat-up rate from HeatWave is around 1.1°C/second.
- Difference in temperature between cs and ss surfaces 20°C @ 100°C
- 100°C cs surface temperature reached after 60s (cf Pace literature which quotes 114s)

Appendices 13 – 15: Plots recording parameters used on 12-layer boards successfully soldered using IR, Hot Air and Hot Plate backheat systems

Appendix 13: Twelve-layer Board, successfully soldered using Martin IR Backheat

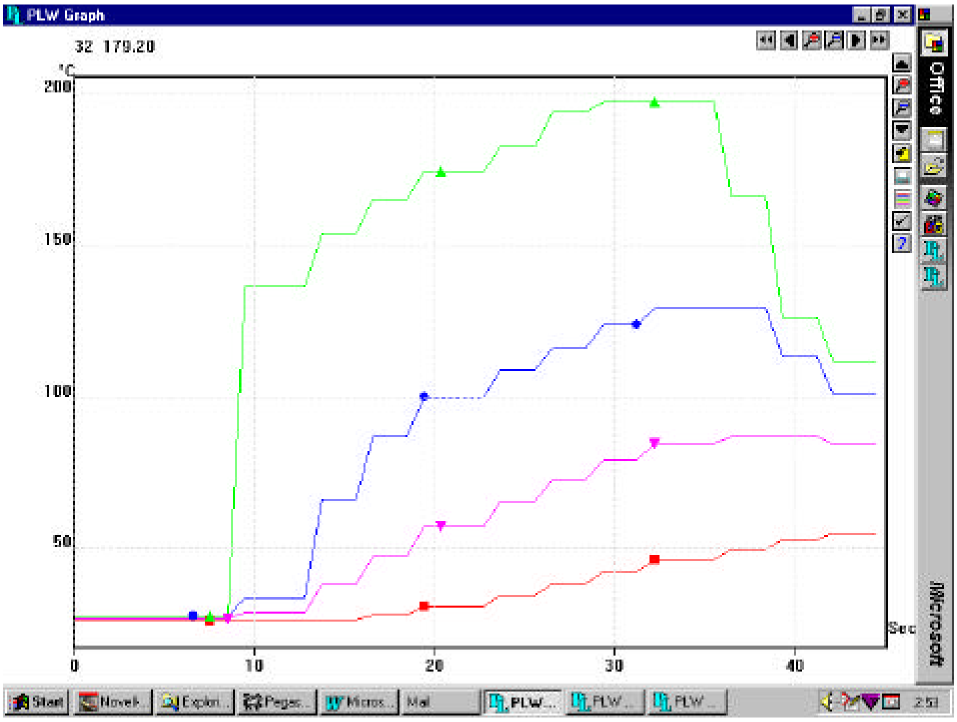


Graph A-13: Twelve-layer board, Metcal 036, Martin IR backheat

- Martin IR @ 110W, 25mm below board surface
- Soldering commenced when cs temperature reached 100°C

  Note: this was found to be a marginal setting, results being more repeatable when ss temperature was allowed to reach 100°C

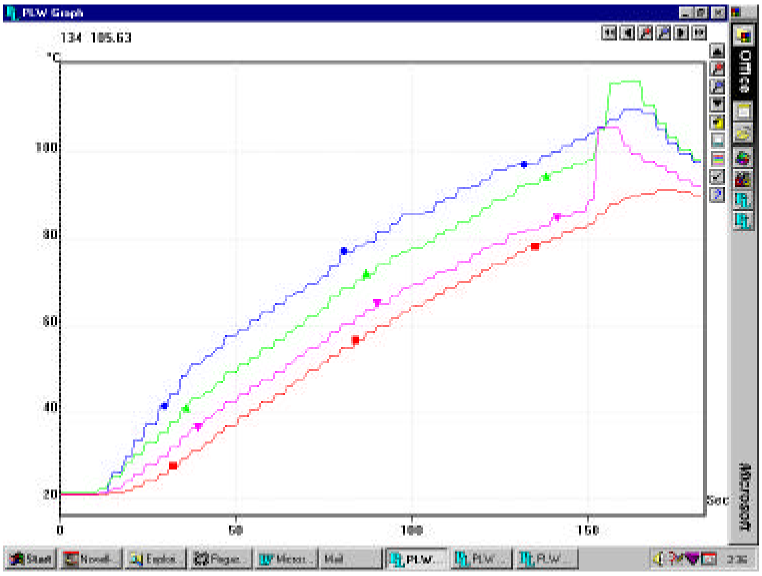
Appendix 14: Twelve-layer Board, successfully soldered using Leister Hot Air



Graph A-14: Twelve-layer board, Metcal 036, Leister Hot Air

- Leister heater set at 1.5 (scale 1-6), blower speed 4.5 (scale 1-9). The air gun was mounted in a fixture with the nozzle positioned 10mm from the row of joints being soldered.
- The board was mounted vertically and soldering commenced when cs temperature reached 130°C

Appendix 15: Twelve-layer Board, successfully soldered using Pace HeatWave HS200 HotPlate

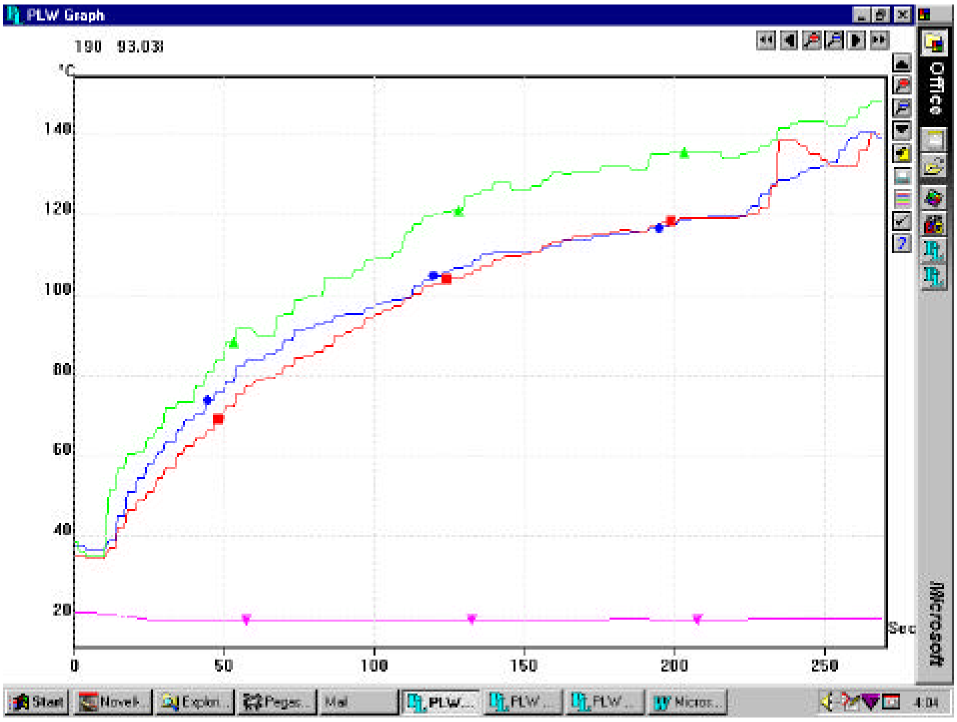


Graph A-15: Twelve-layer board, Metcal 036, Pace HeatWave

- Pace HeatWave set at 371°C, with hot plate 25mm below cs of horizontally-mounted board
- Soldering commenced when cs temperature reached 106°C

Appendices 16a & 16b: Benefits of a component heat shield

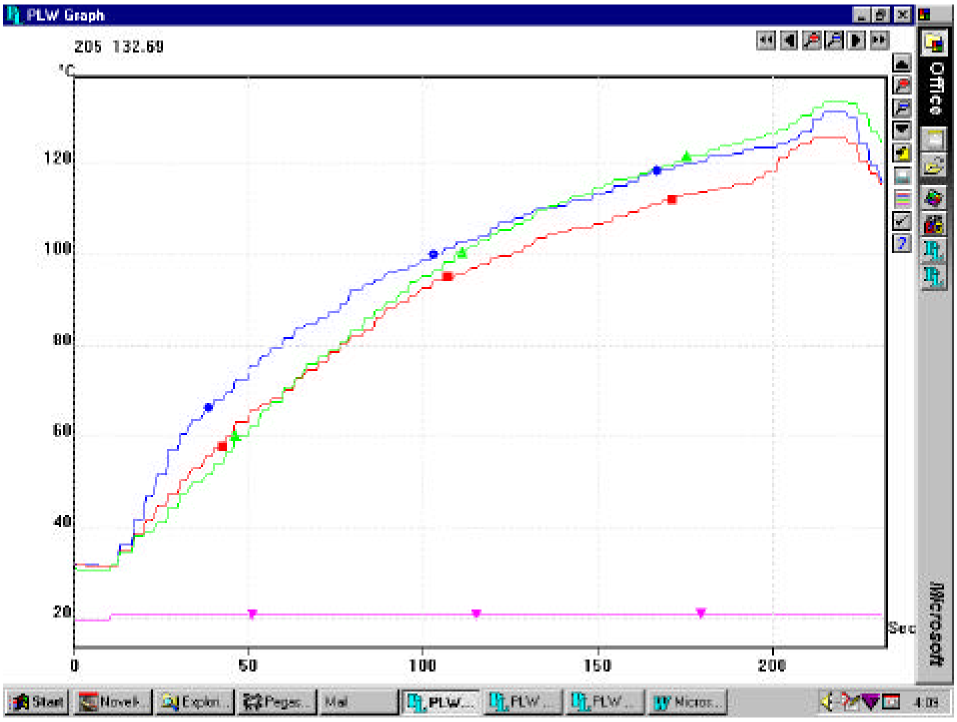
Appendix 16a: 6-Layer Board with HeatWave hot plate, no component heat shield



Graph A-16a: 6-layer board, Metcal 036, Pace HeatWave

The yellow trace shows the component temperature; it can be seen that the component is about 17°C hotter than the cs surface temperature.

Appendix 16b: 6-Layer Board with HeatWave hot plate, component heat shield



Graph A-16b: 6-layer board, Metcal 036, Pace HeatWave

The yellow trace shows the component temperature when a heat shield is clipped over the DIL; it can be seen that the component temperature now stays almost the same as the cs surface temperature (blue trace).
It is important to clip the shield over the body, not over the leads; clipping over the leads results in heat sinking during soldering and prevents solder penetration.

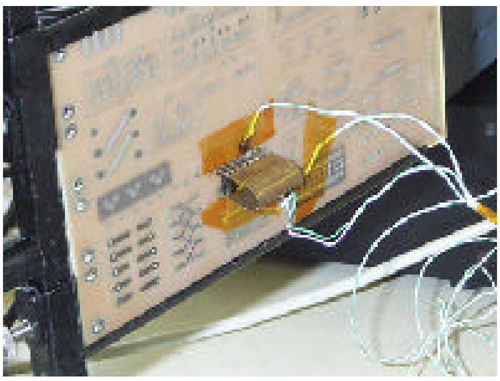


Fig A-16b: Heat shield in place

Acknowledgements

The author wishes to thank Dr B D Dunn of ESA-ESTEC for funding this project and Mr C Gilbert-Wood of Highbury College for supporting it.

February 25 2000

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