

Rework Process Reliability of Area Array Surface Mount Packages

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Abstract

Rework Process Reliability

- **Area Array Packages, ICs and discrete components are used in every space mission.**
- **These devices generally take up one half of the total Printed Wiring Board (PWB) area.**
- **These devices have specifications limiting temperature excursions during the attachment process.**
- **These specifications are generally accommodated by a well-controlled automated surface mount process.**

Abstract (Cont.)

Rework Process Reliability

- **Rework of these devices using hot gas and infra red are the predominant methods of attachment as well as removal for most printed wiring assemblies (PWAs) used in space applications.**
- **For long-term reliability of the system, the data on the rate of temperature rise, soldering time and peak temperature of the packages and PWBs must be evaluated.**

Abstract (Cont.)

Rework Process Reliability

- **By evaluating the effect of thermal excursions and formulating a safe manual soldering process for all the components/packages, each NASA program/project will be able to achieve a higher level of assurance by significantly reducing the risk for all NASA missions.**

Goals/Objectives

Rework Process Reliability

- **To assess the reliability of reworked components and printed wiring boards (PWBs) at the end of each of three rework cycles.**
- **To provide guidelines for using the hot gas and infra red rework stations for flight hardware.**

Background

Rework Process Reliability

- **Plastic and ceramic high-density packages have seen an increase in use in space flight applications.**
- **To reduce weight and size, the packages have become lighter and thinner, resulting in a more delicate package.**
- **The need to rework a board arises for various reasons:**
 - **Failure of the package/device**
 - **The packaged part may need to be salvaged for use on another board.**

Issues

Rework Process Reliability

- **Some of these packages/devices are very expensive (>\$10K per package) and some have very long lead-times, hence removal and salvage of the package is crucial to meet the launch schedule.**
- **Traditional rework methods using hot gas reflow and/or Infra red pose a challenge to protect the integrity and reliability of the packaged device.**

Specific Task Objectives

Rework Process Reliability

- **This work task will assess the reliability of individually attached high-density packages using a) The Eurotec SMT/BGA rework (computer controlled IR) system and b) The Zephyrtronics® rework system (convection).**
- **Solder joints for various plastic BGA packages attached to a polyimide substrate will be evaluated for their quality.**

Reliability Issues of BGAs

Rework Process Reliability

- **BGA devices are dominating the high pin-out package world, because they provide high pin-outs and very low profile chip stacking. Prior NEPP investigations through the BGA Consortium, have established:**
 - **The dependence of solder paste volume on printing parameters.**
 - **The dependence of BGA solder joint reliability is dependent on board thickness and die size within the BGA.**

Reliability Issues of BGAs (Cont.)

Rework Process Reliability

- **The dependence of the type of BGA solder joint failure on the thermal mismatch between the part and the board material.**

Summary of Rework Conditions

Rework Process Reliability

- **During reworking the boards, the process should be able to duplicate the thermal curve under which the board was originally manufactured.**
- **The time-temperature profile should be similar to that used for the original production reflow.**
- **By duplicating the processes and thermal conditions under which every board is manufactured, rework can be accomplished effectively and reliably.**

Summary of Rework Conditions (Cont)

Rework Process Reliability

- **In this way, the PCB assemblies can be put back into service with the same confidence as when they were first put into service.**
- **The PCB assemblies should be ramped up at 2 - 4 °C per second and preheated to a temperature of 130 - 150°C for a period of up to 2 minutes, just like the reflow oven.**

Summary of Rework Conditions (Cont)

Rework Process Reliability

- **By inserting a preheating step in the rework cycle, the benefits of preheating can be realized.**
- **Preheating activates the flux, removes extraneous volatiles from the flux, brings the metals to be soldered up to solder wetting temperatures, and elevates the temperature of the assembly in order to prevent thermal shock during exposure to the molten solder.**

Summary of Rework Conditions (Cont)

Rework Process Reliability

- **This cleansing from the activation of the flux just prior to reflow will enhance the wetting process.**
- **The two primary methods used in high volume PCB assemblies are infrared (IR) and convection (some furnaces use combined IR and convection). A good rework system should incorporate all of the qualities of one of these standard reflow methods.**

Summary of Rework Conditions (Cont)

Rework Process Reliability

- **Zephyrtronics® utilizes a portable, convective bottom-side pre-heater as well a temperature controlled top side convective heater to remove the SMD.**
- **Due to extremely efficient heat transfer, the Zephyrtronics® heater temperature is set at a relatively low value.**
- **Eurotec's rework system is intended for replacing parts on boards but is claimed to equally suited for installing them.**

Summary of Rework Conditions (Cont)

Rework Process Reliability

- **Eurotec system uses precision optics to present a double image of the underside of the BGA device and of the board lands.**
- **The device and board are then mechanically aligned and the solder reflowed.**
- **A computer controls the reflow operation with feedback from a non-contact thermal sensor (IR).**
- **A small vacuum probe is used to pick up and release the part.**

Task Remaining

Rework Process Reliability

- **Questions remain for the above two processes regarding the effectiveness of the reflow operation when the board material or the part material (epoxy, ceramic) changes.**
- **These changes will affect the emissivity of the materials involved and in turn the interpretation of the IR signature (for Erotec) as it is converted to a temperature.**
- **It is anticipated that the Zephyrtronics® rework station is less susceptible to these factors**

ASSEMBLY PLAN

Rework Process Reliability

- **To assemble 8 each test printed wiring assemblies using mechanical sample components.**
- **List of components is as follows.**

ASSEMBLY PLAN (Cont)

Rework Process Reliability

<u>PART NUMBER</u>	<u>DESCRIPTION</u>	<u>QTY/BD</u>
PCB008 Board-Polyimide	PWB	1
K-DPAK-TRB	DPAK	
1		
SO14GTR-3.8mm	SOIC14	4
SO20GTR-7.6mm	SOIC20	4
PLCC68-T	PLCC68	4
PLCC20-T	PLCC20	2
PLCC44-T	PLCC44	2
QFP44-10x8x3.9mm	QFP44	2

ASSEMBLY PLAN (Cont)

Rework Process Reliability

<u>PART NUMBER</u>	<u>DESCRIPTION</u>	<u>QTY/BD</u>
QFP100-14x20x0.65mm	QFP100	2
QFP208-28x0.5x2.6mm	QFP208	2
QFP256-28mmx0.4mm	QFP256	2
TV-46TAPE	MICROBGA	1
7343 Tantalum Cap	Tantalum Cap	1
SOT23-TR	SOT23	4
0402 SMR-PA	0402, RESISTOR	52
0603SMR-PA	0603, RESISTOR	42

ASSEMBLY PLAN (Cont)

Rework Process Reliability

<u>PART NUMBER</u>	<u>DESCRIPTION</u>	<u>QTY/BD</u>
0805SMR-PA-5K	0805, RESISTOR	36
1206SMC-PA	1206, CAPACITOR	32
TSOP32-8x18.4x.5mm	TSOP32	1
PBGA169-1.5mm-23mm	PBGA169	2
PBGA225-1.5mm-27mm	PBGA225	2
PBGA352-1.27mm-35mm	PBGA352	2

ASSEMBLY PLAN (Cont)

Rework Process Reliability

Assembly process sequence is as follows.

- a. Tin the QFP's with Sn63/Pb37 solder and visually verify the coplanarity of the leads.**
- b. Measure the ball height at selected locations and record.**
- c. Measure the selected BGA package height at four corners and record.**
- d. Perform solderability test on one sample PWB.**
- e. Serialize PWB from S/N RW 001 through RW 008.**

ASSEMBLY PLAN (Cont)

Rework Process Reliability

- f. Clean the PWA and bake at 100° C for min. 8 hours.**
- g. Print solder paste Sn 63 Eutectic on PWB side 1, using screen printer.**
- h. Measure the solder paste height at selected locations.**
- i. Place the components on the side 1 using Mydata pick and place.**
- j. Develop a reflow profile and reflow the PWAs in the vapor phase reflow system.**

ASSEMBLY PLAN (Cont)

Rework Process Reliability

- k. Clean the PWA in the Centrifugal cleaner and bake at 75° C for 30 minutes.**
- l. Repeat above process for the side 2 of the PWB using Airvac.**
- m. Verify the cleanliness of the first PWA with Ionograph.**
- n. Inspect the PWA for workmanship and verify integrity of the PWB and BGA daisy chain.**
- o. X-ray the BGAs to verify the solder joint quality.**
- p. Rework per Rework Process Matrix.**

ASSEMBLY PLAN (Cont)

Rework Process Reliability

REWORK PROCESS MATRIX

No	REWORK METHOD	REWORK ATTEMPT NUMBER	TYPE OF MATERIAL USED	PWA S/N	REWORK OPERATION
1	CONVECTION	1	RMA FLUX	001 - 004	REMOVE 1 EA. BGA225 (U7) and BGA 352 (U10). CLEAN AND INSPECT PADS AND BGAS
2	"	1	SCREEN Sn 63 SOLDER PASTE	"	INSTALL AND REFLOW NEW BGAS AT U7 AND U10. CLEAN AND INSPECT PWB AND BGA
3	"	2	RMA FLUX	"	REMOVE 1 EA. BGA225 (U7) and BGA 352 (U10). CLEAN AND INSPECT PADS AND BGAS
4	"	2	SCREEN Sn 63 SOLDER PASTE	"	INSTALL AND REFLOW NEW BGAS AT U7 AND U10. CLEAN AND INSPECT PWB AND BGA

ASSEMBLY PLAN (Cont)

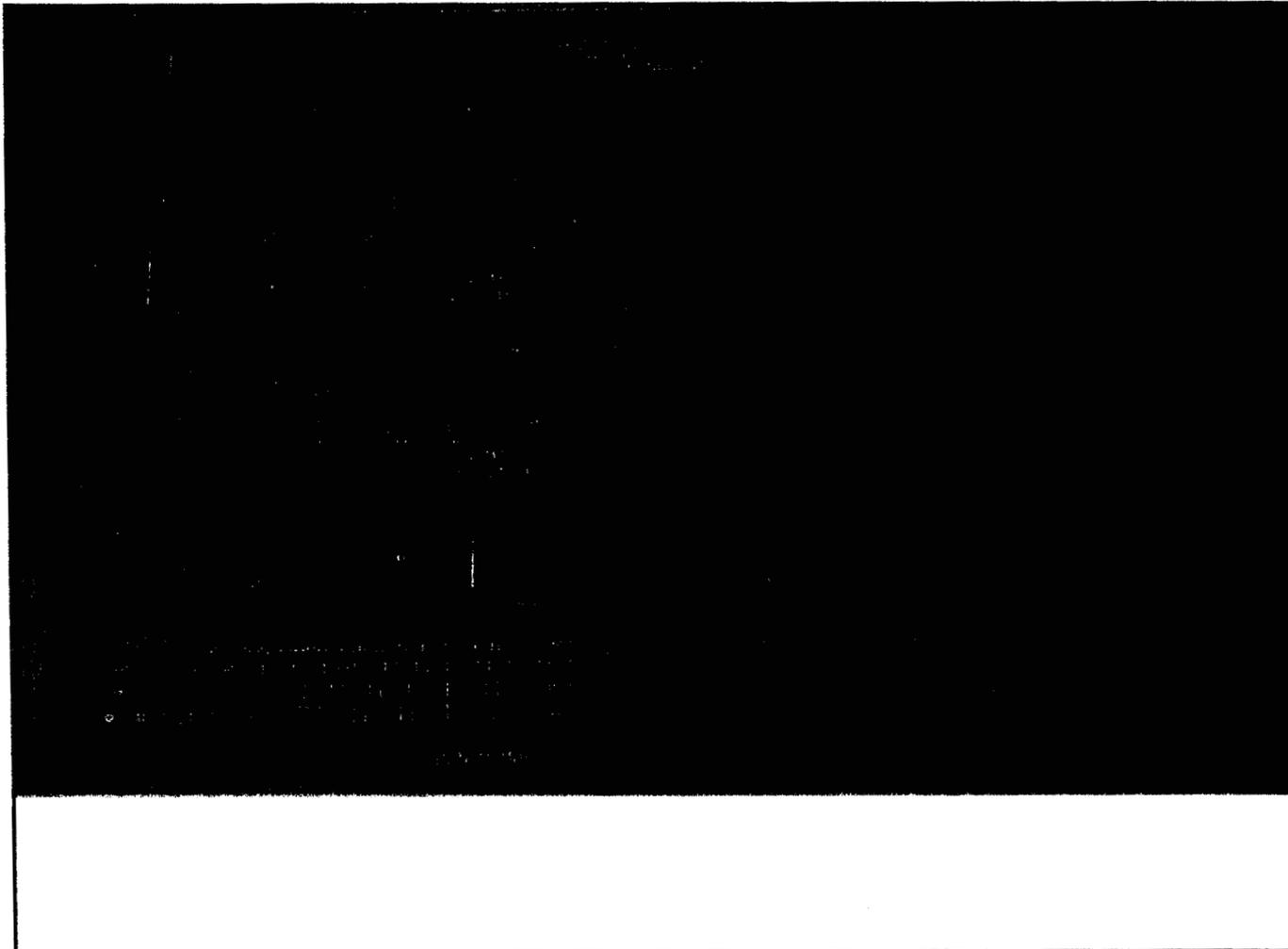
Rework Process Reliability

REWORK PROCESS MATRIX (CONT.)

No	REWORK METHOD	REWORK ATTEMPT NUMBER	TYPE OF MATERIAL USED	PWA S/N	REWORK OPERATION
5	CONVECTION	3	RMA FLUX	001 - 004	REMOVE 1 EA. BGA225 (U7) and BGA 352 (U10). CLEAN AND INSPECT PADS AND BGAS
6	"	3	SCREEN Sn 63 SOLDER PASTE	"	INSTALL AND REFLOW NEW BGAS AT U7 AND U10. CLEAN AND INSPECT PWB AND BGA

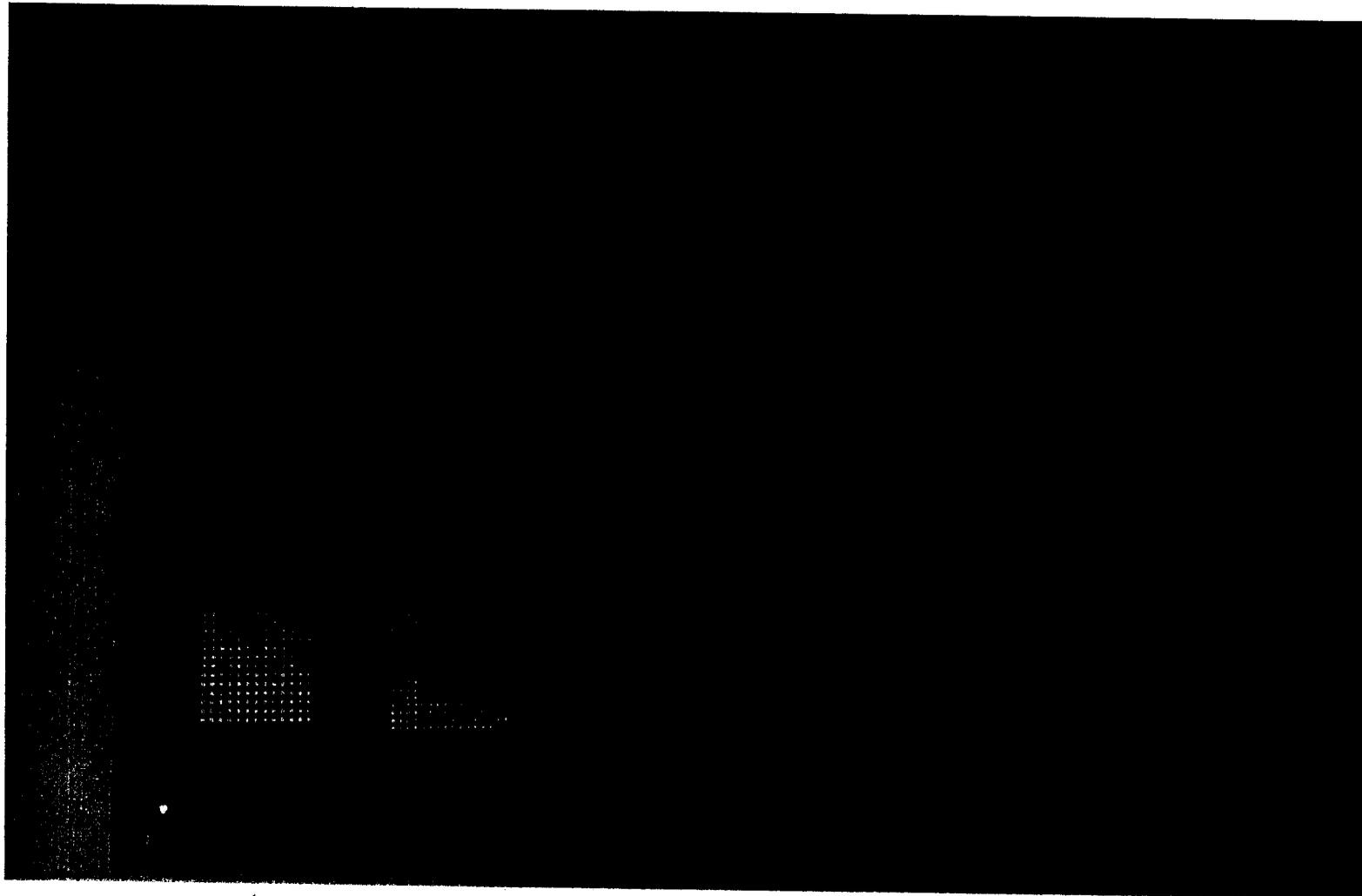
ASSEMBLY PLAN (Cont)

Rework Process Reliability



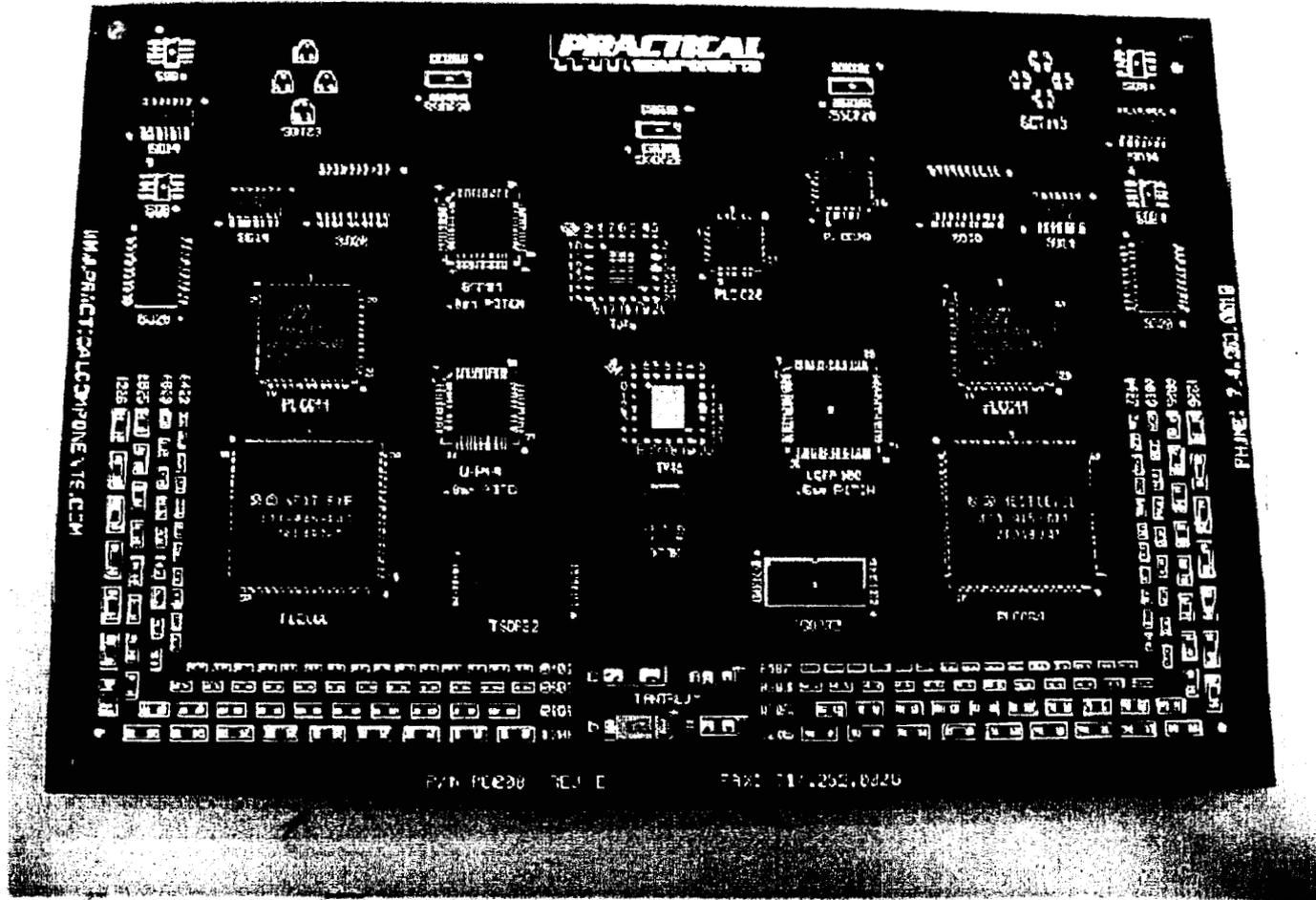
ASSEMBLY PLAN (Cont)

Rework Process Reliability



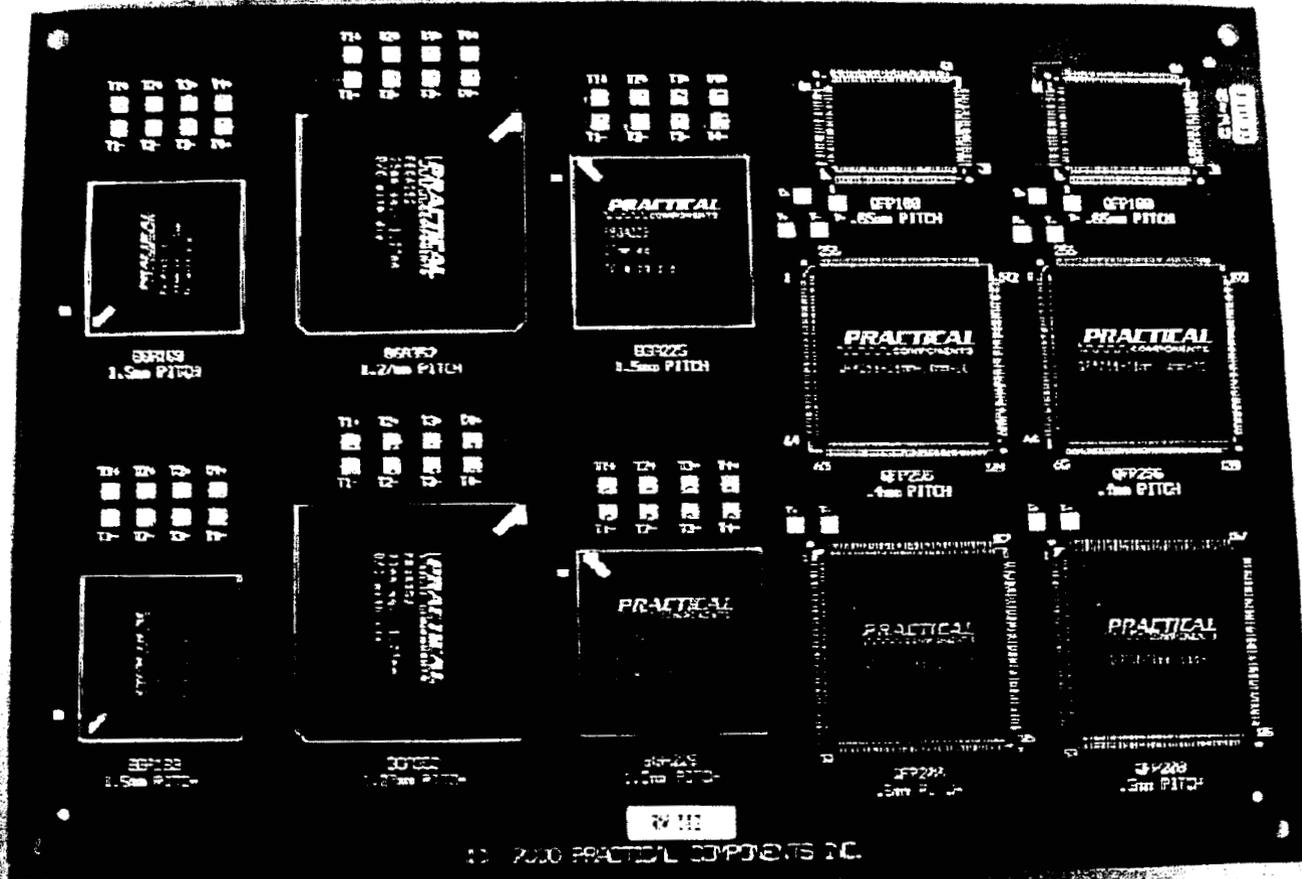
ASSEMBLY PLAN (Cont)

Rework Process Reliability

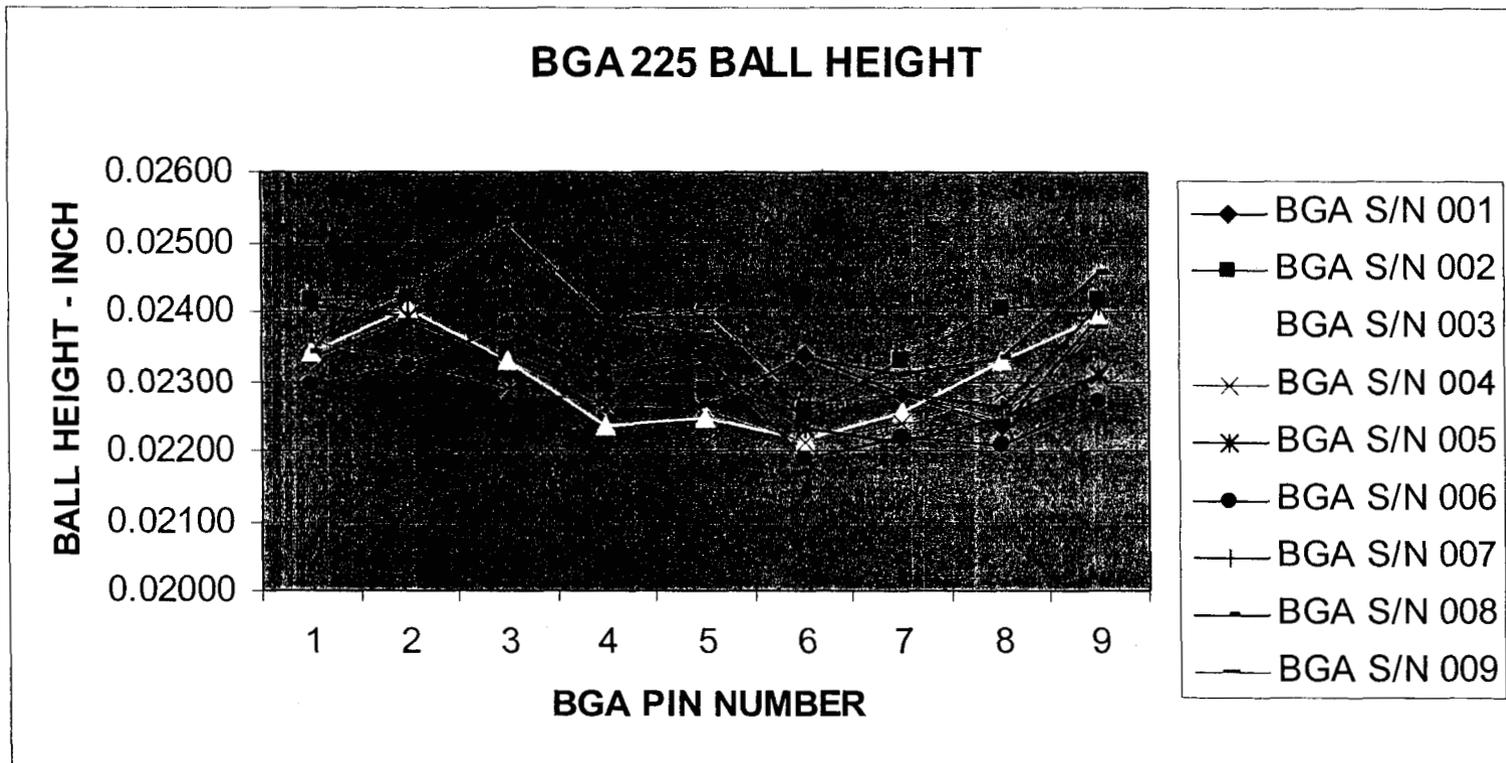


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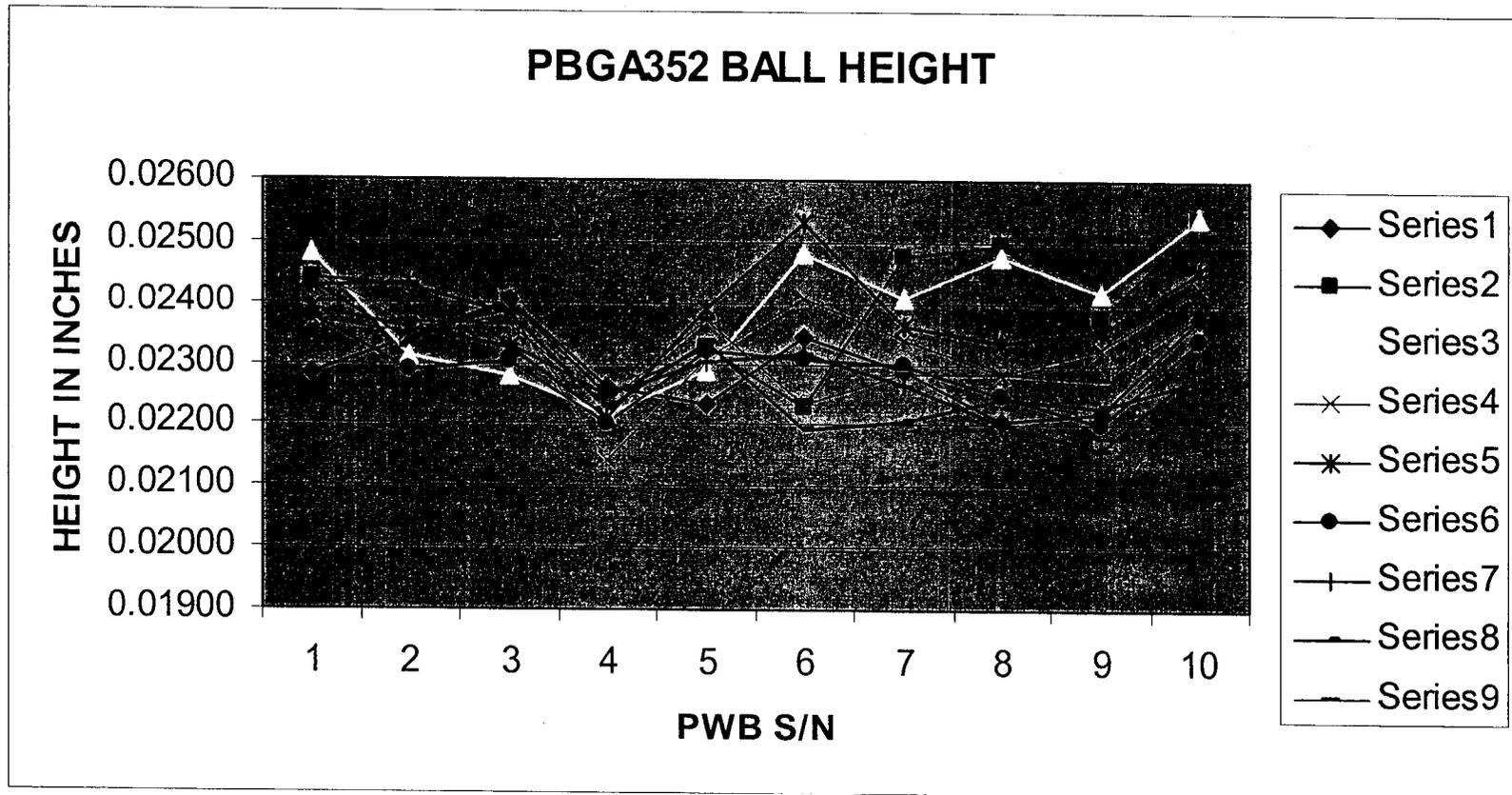
Rework Process Reliability



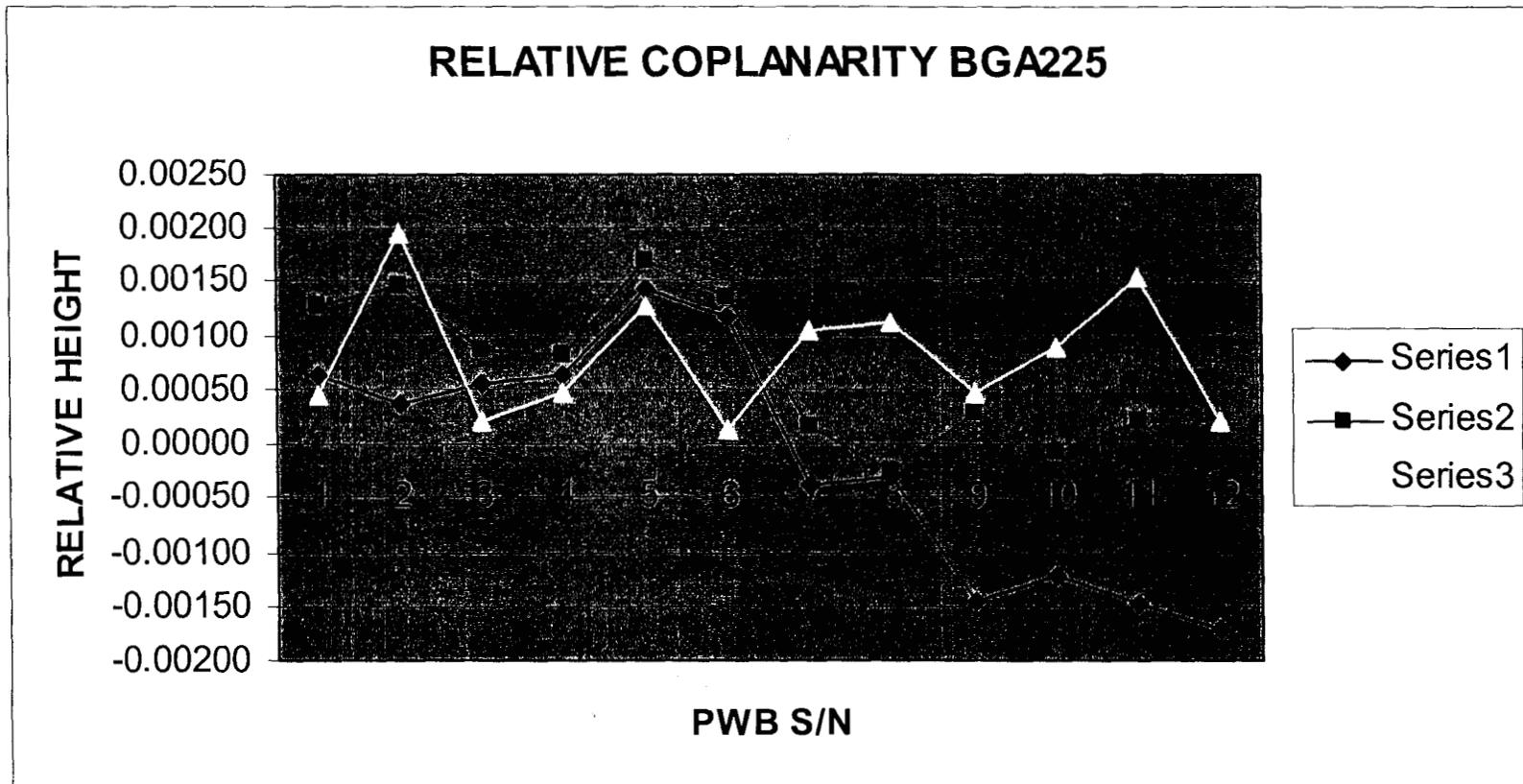
Rework Process Reliability



Rework Process Reliability

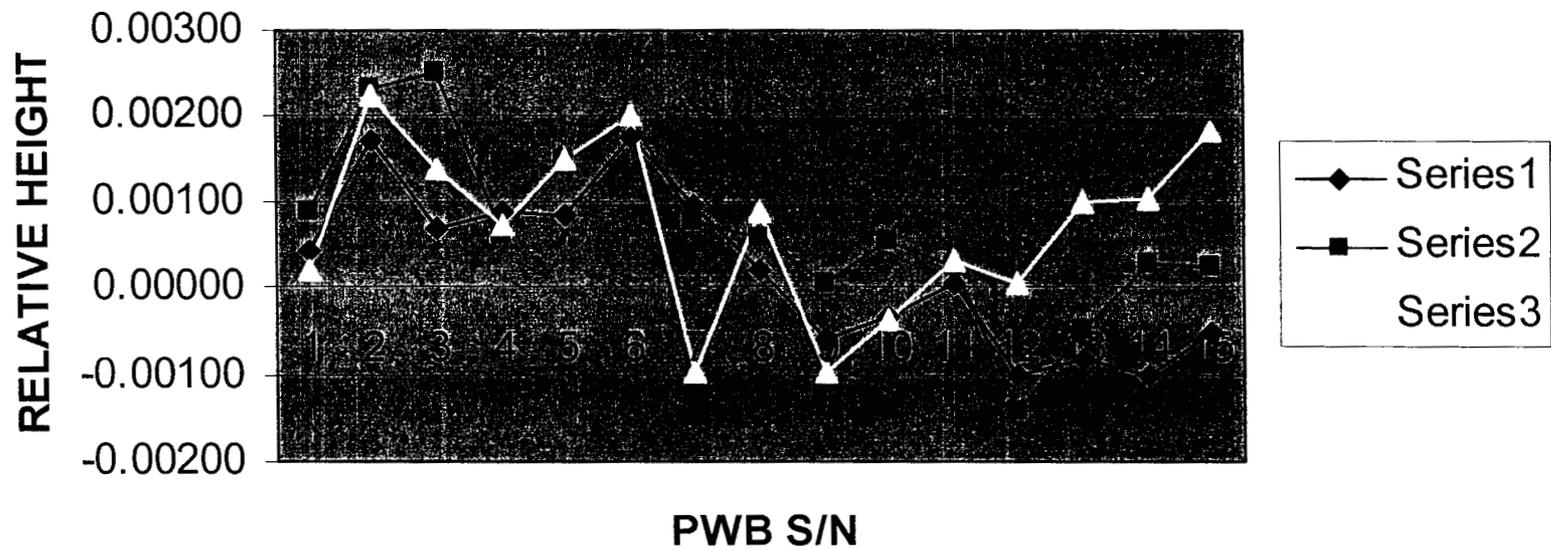


Rework Process Reliability



Rework Process Reliability

RELATIVE COPLANARITY BGA352



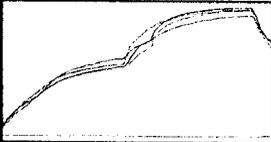
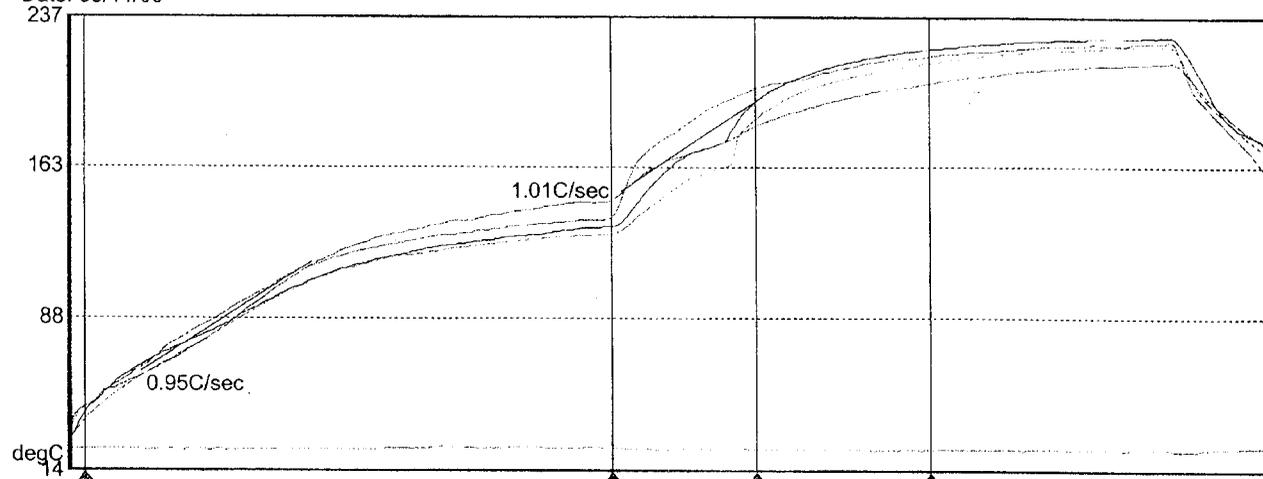
Thermal Profile for PBGA 352

Rework Process Reliability

ECU® SuperM.O.L.E.® for Windows V3.19 - NEPP_SOL_BGA352-7.msm
 File Tag: SM000247 Date: 09/11/03

M.O.L.E.® STATUS
 Max Internal T: 27C
 Battery: 5.00V
 Points: 392
 Active: 123450
 Interval: 00:00:01.0
 Date: 10/15/80
 Time: 22:14:02 V03.02

Tool status box

Value	C1 = 5	C2 = 177	C3 = 224	C4 = 280	Units
• Sensor 1 Location	24	25	24	24	degC
• Sensor 2 Location	45	147	183	204	degC
• Sensor 3 Location	45	138	202	218	degC
• Sensor 4 Location	39	130	187	214	degC
• Sensor 5 Location	42	133	196	221	degC

Summary Stats	Peak	Minimum	Max (+)Slope	Max (-)Slope	Time Above 183C	Time 150C-180C
• Sensor 1 Location	28.1	23.9	0.16	-0.08	0.0	0.0
• Sensor 2 Location	215.0	35.6	1.59	-1.83	158.0	40.0
• Sensor 3 Location	225.0	32.2	3.49	-3.65	176.0	17.0
• Sensor 4 Location	222.8	28.3	3.02	-2.78	159.0	24.0
• Sensor 5 Location	227.2	29.4	2.38	-2.78	162.0	28.0
RANGE	201.1	11.7	3.33	3.57	176.0	40.0

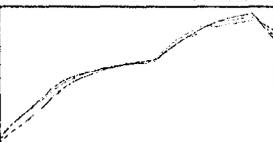
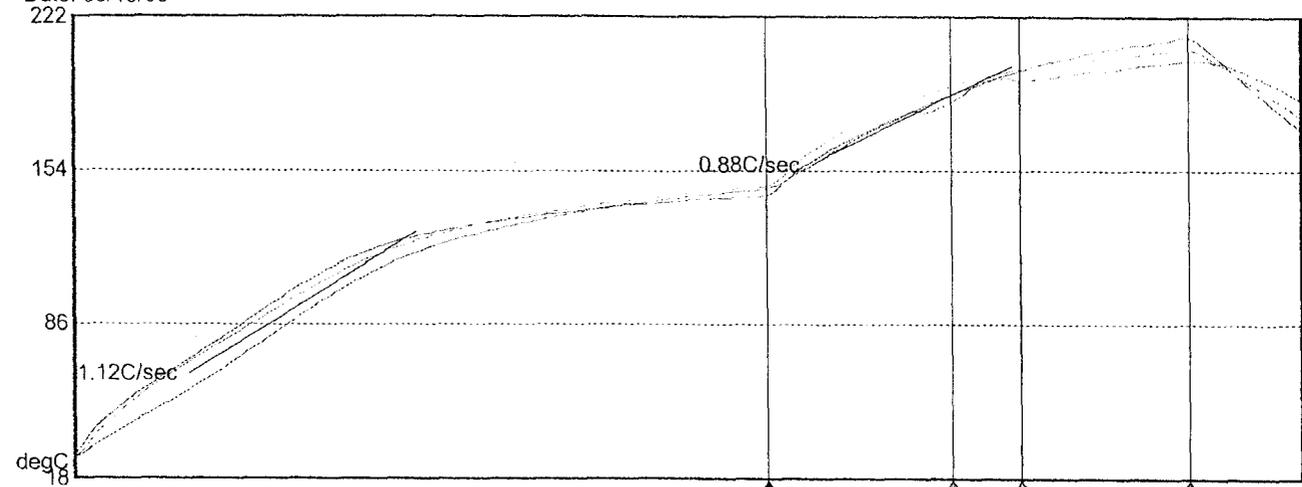
Thermal Profile for PBGA 225

Rework Process Reliability

SuperM.O.L.E.® for Windows V3.19 - NEPP_SOL_BGA225-3A.msm
 File Tag: SM000248 Date: 09/19/03

M.O.L.E.® STATUS
 Max Internal T: 20C
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 Points: 302
 Active: X234X0
 Interval: 00:00:01.0
 Date: 10/23/80
 Time: 19:40:28 V03.02

Tool status box

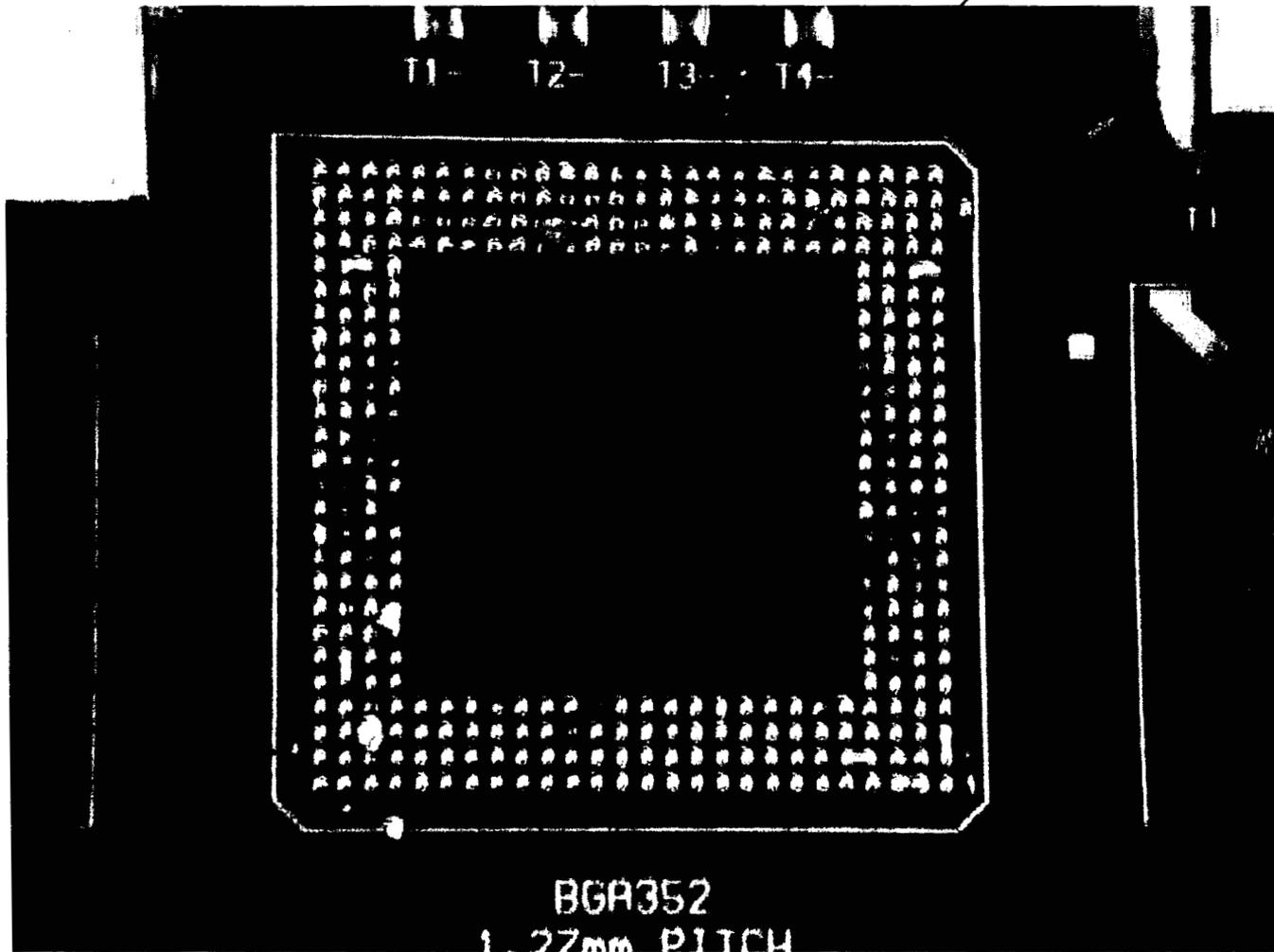



Value	C1 = 170	C2 = 215	C3 = 232	C4 = 273	Units
• OPEN	OPEN	OPEN	OPEN	OPEN	degC
• CORNER OF PBGA 225	143	187	198	213	degC
• CENTER OF PBGA 225	147	184	194	203	degC
• OPP CORNER OF PBGA 225	148	191	199	208	degC
• OPEN	OPEN	OPEN	OPEN	OPEN	degC

Summary Stats	Peak	Minimum	Max (+)Slope	Max (-)Slope	Time Above 183C	Time 150C-180C
• OPEN	789.4	799.4	0.00	0.00	302.0	0.0
• CORNER OF PBGA 225	213.3	28.3	2.31	-1.67	85.0	30.0
• CENTER OF PBGA 225	202.8	27.2	1.30	-1.02	88.0	31.0
• OPP CORNER OF PBGA 225	207.8	26.7	2.13	-1.29	54.0	26.0
• OPEN	799.4	799.4	0.00	0.00	302.0	0.0
RANGE	596.7	772.8	2.31	1.67	217.0	31.0

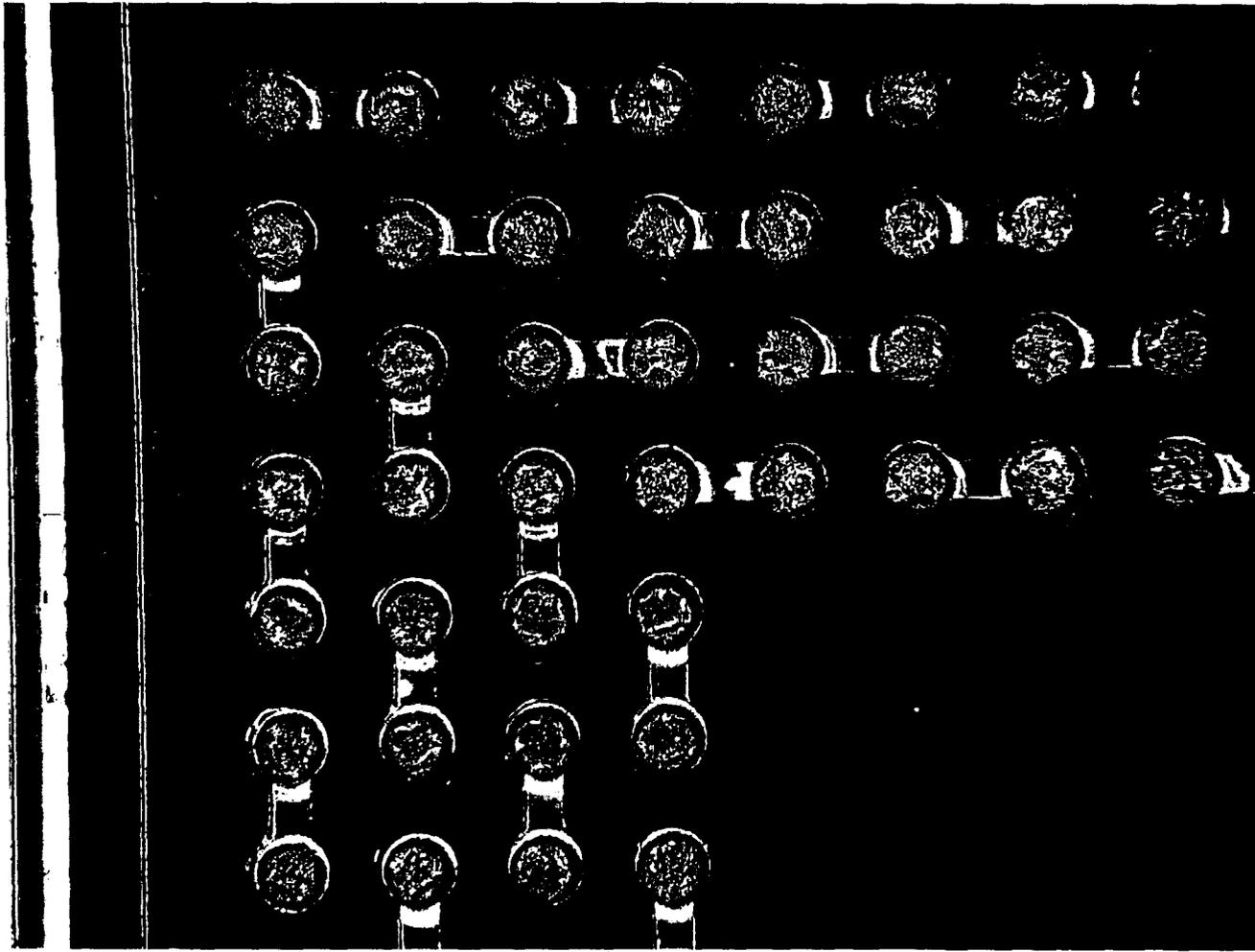
Rework Process Reliability

PBGA 225 Pads on PWB As They Appear After the Removal of
BGA Second Time



Rework Process Reliability

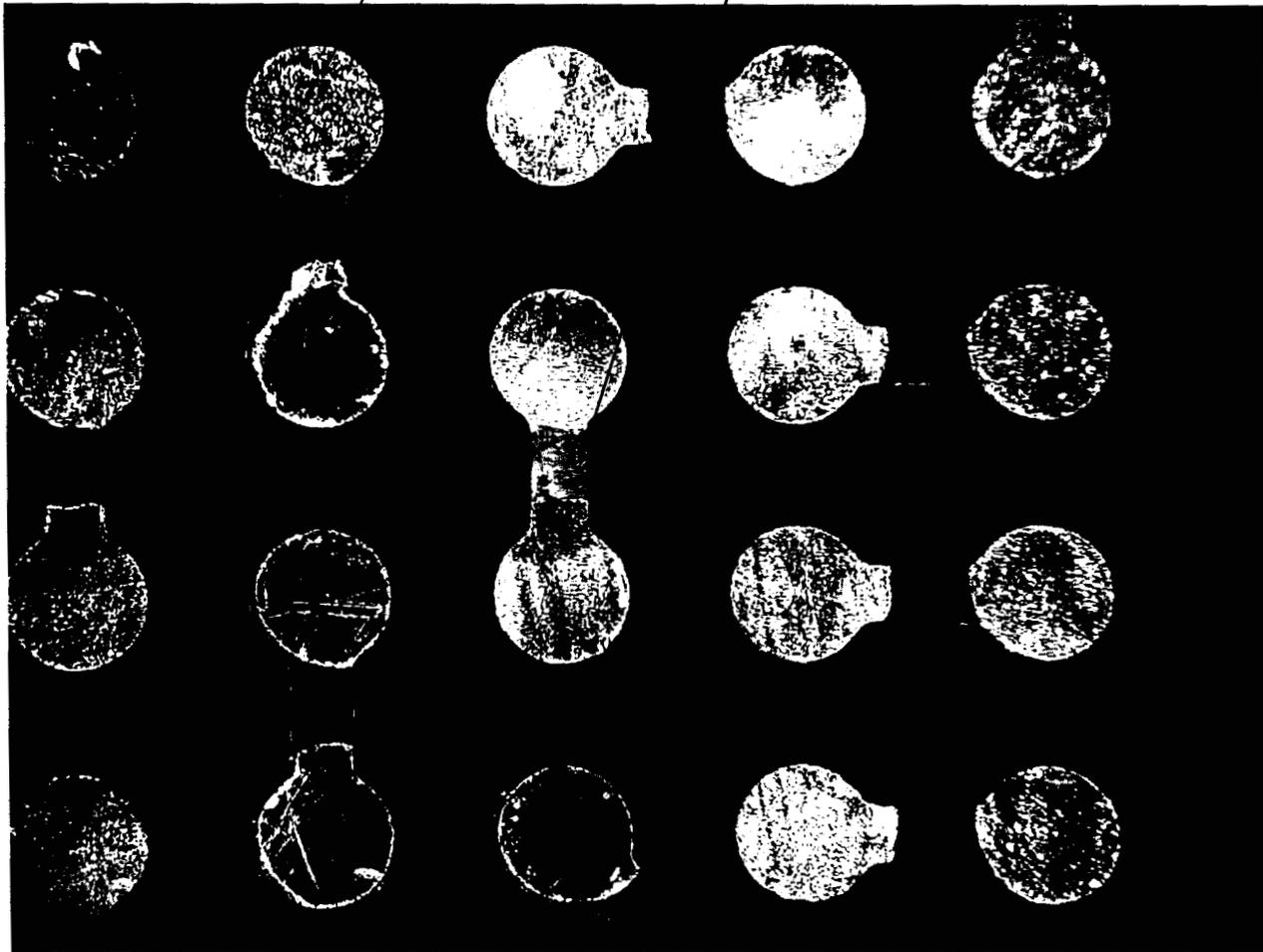
PBGA 352 pads on PWB as they appear after the removal of PBGA Second Time and clean up of excess solder.



Rework Process Reliability

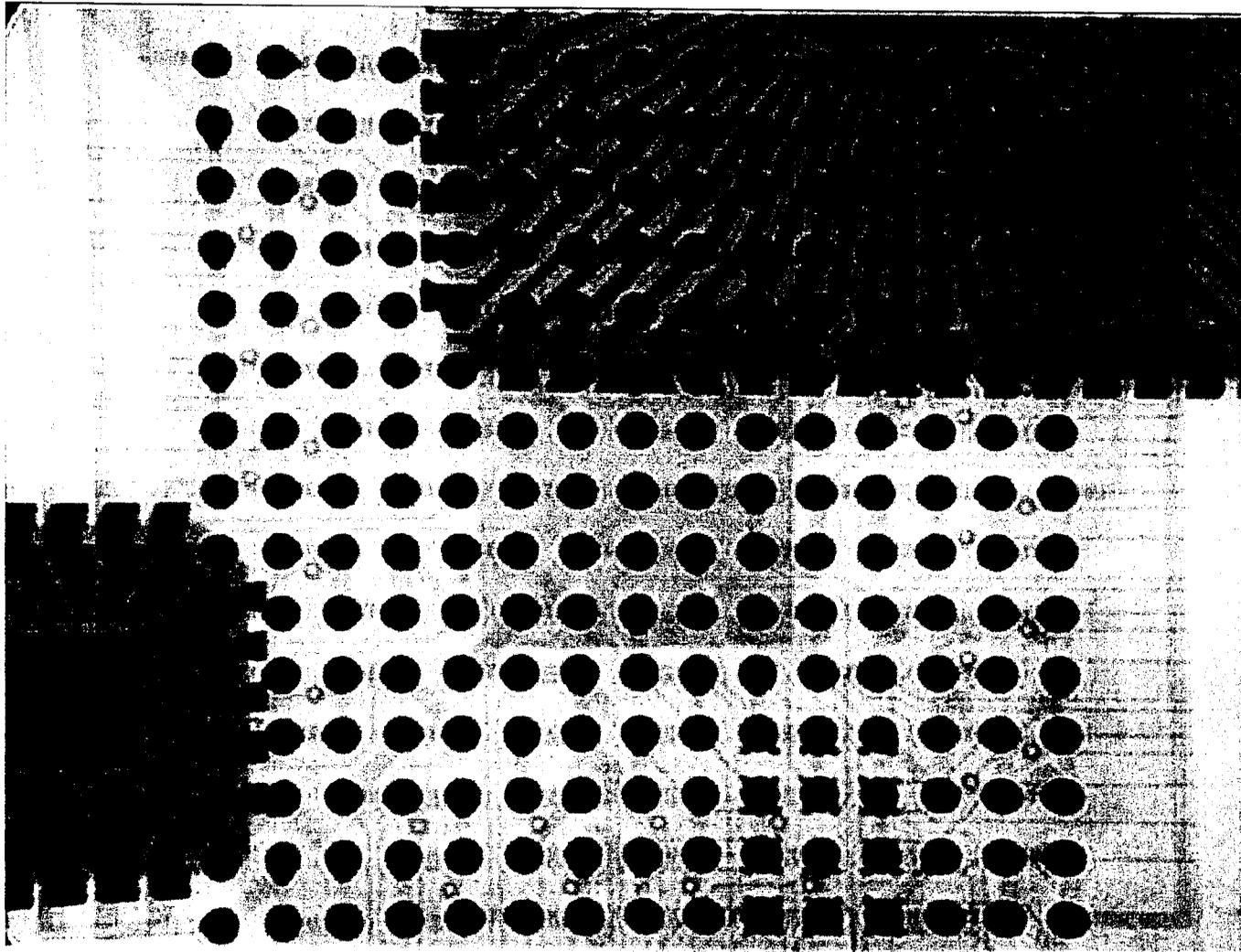
**PBGA 225 pads on PWB as they appear after the removal of
PBGA Second Time and clean up of excess solder.**

SOLDER MASK
PEELED OFF

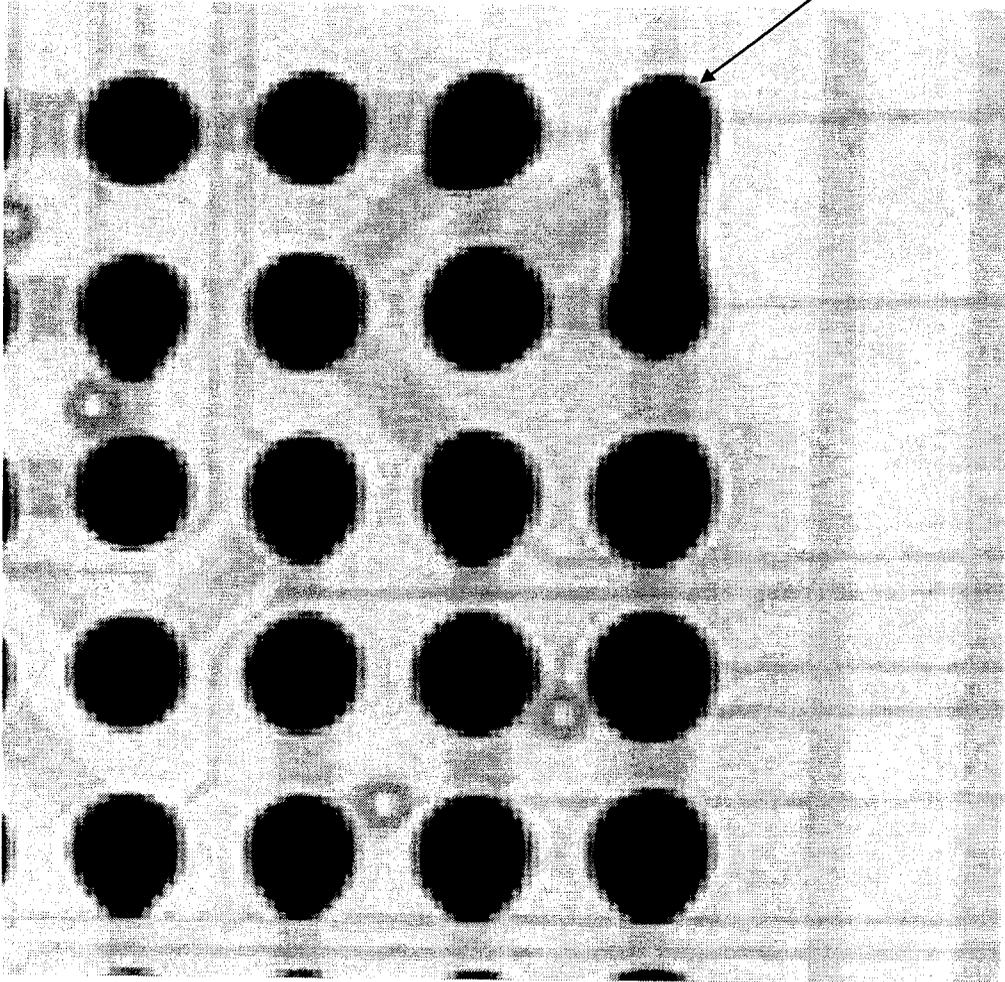


Rework Process Reliability

X-ray image of newly soldered PBGA 225 on PWB.

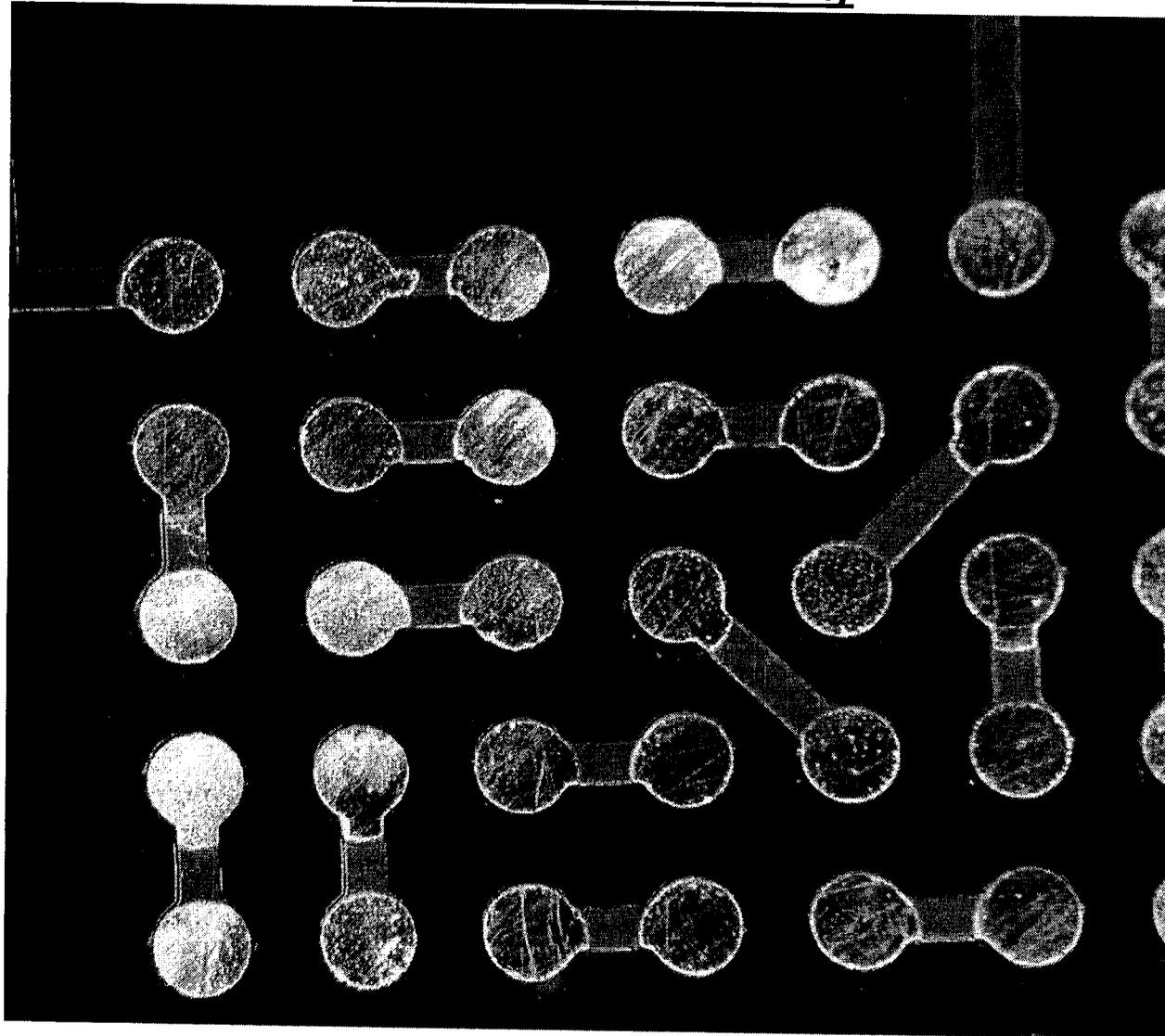


Rework Process Reliability
X-ray of Bridging Caused Due to
Solder Mask Peel off After Second Rework



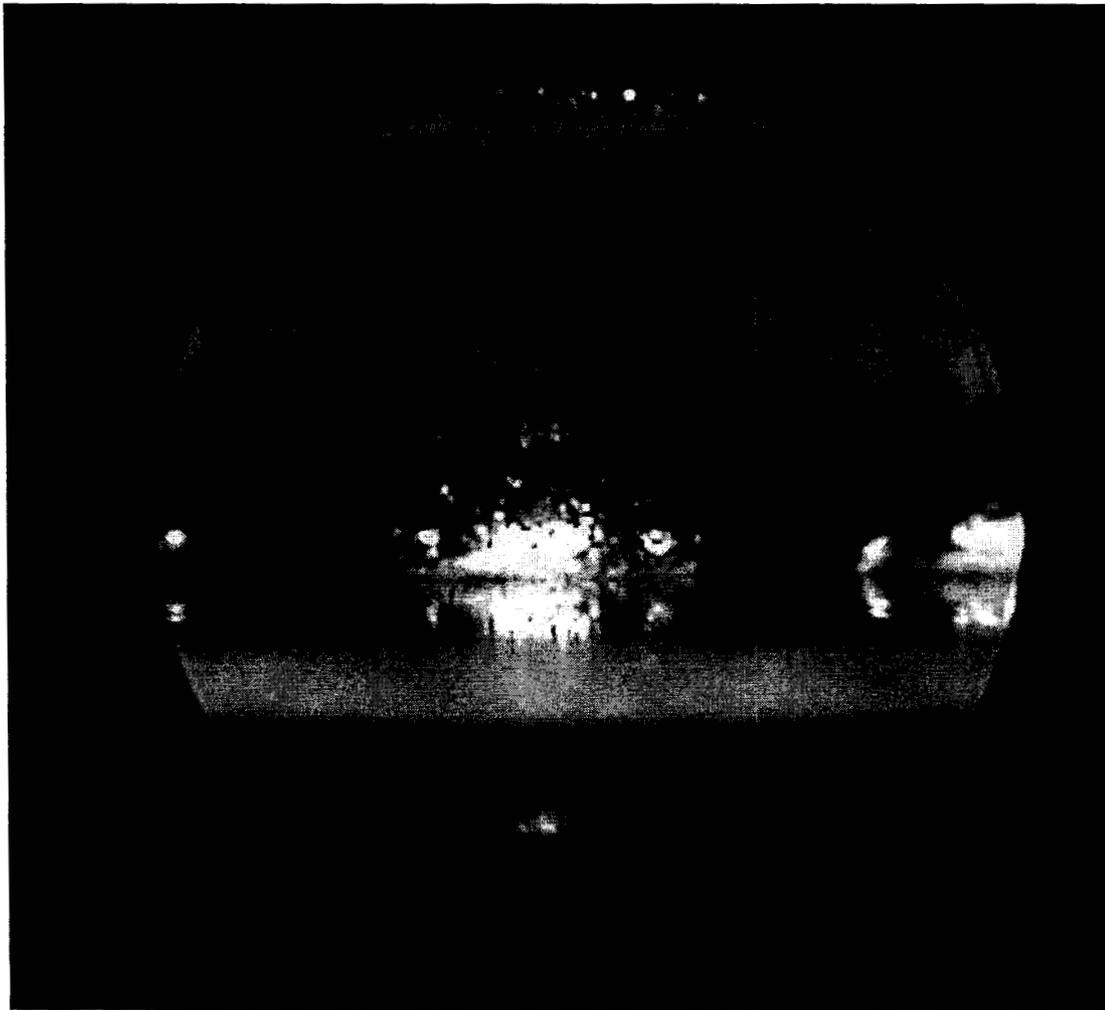
PBGA 225 Pads after first rework using convection method

Rework Process Reliability



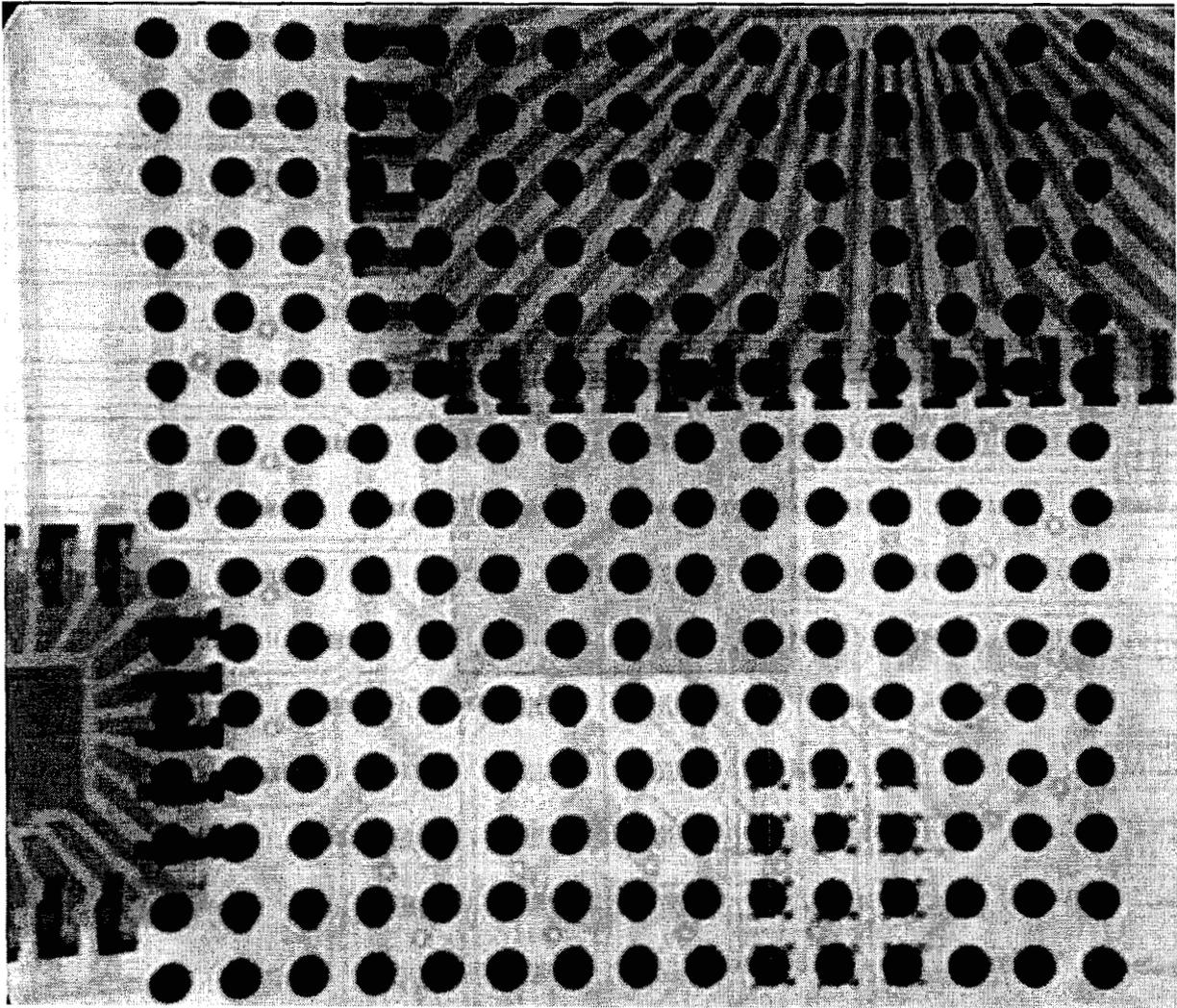
PBGA 225 Solder Joint after first rework using convection method

Rework Process Reliability

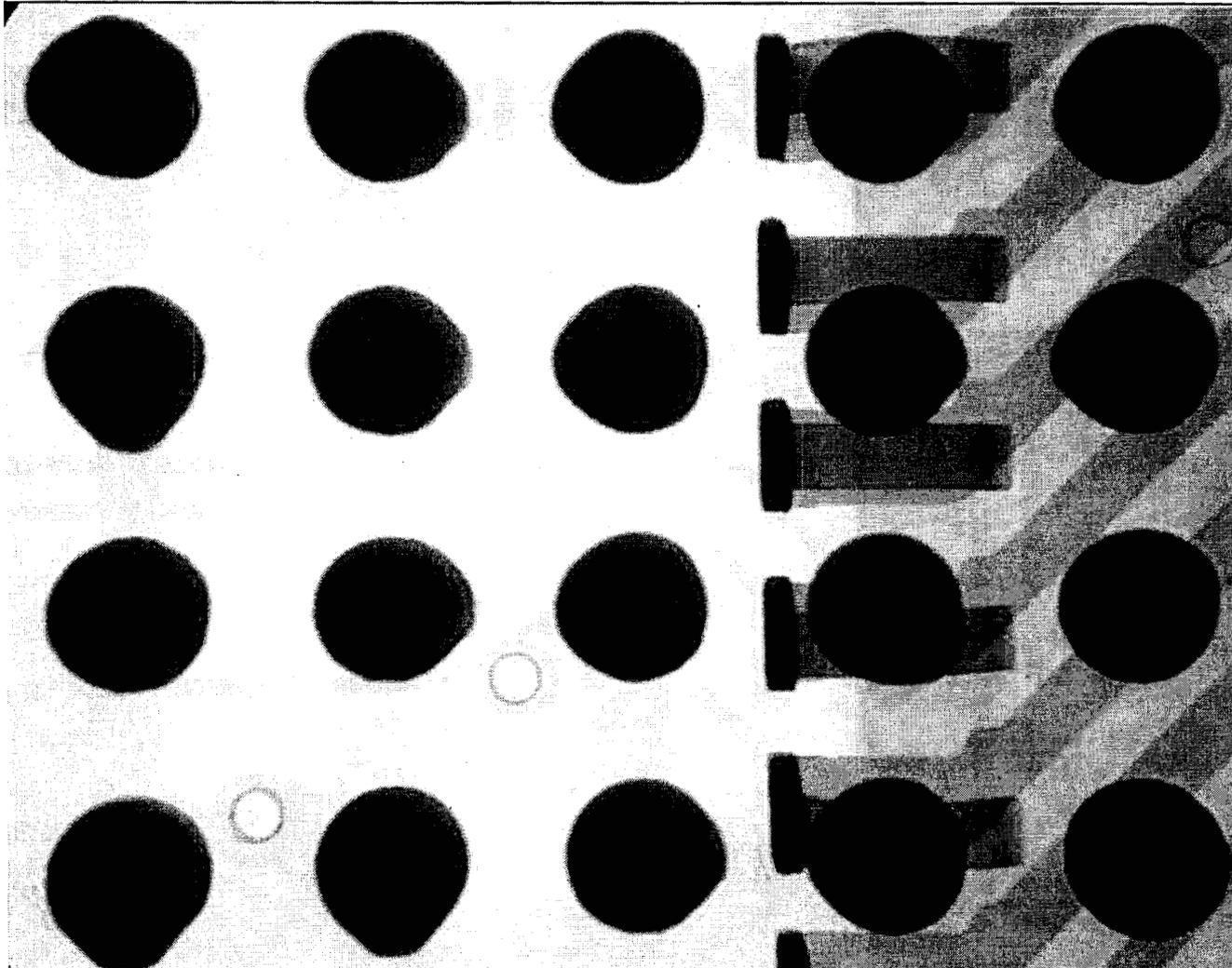


PBGA 225 X-Ray after first rework using convection method

Rework Process Reliability

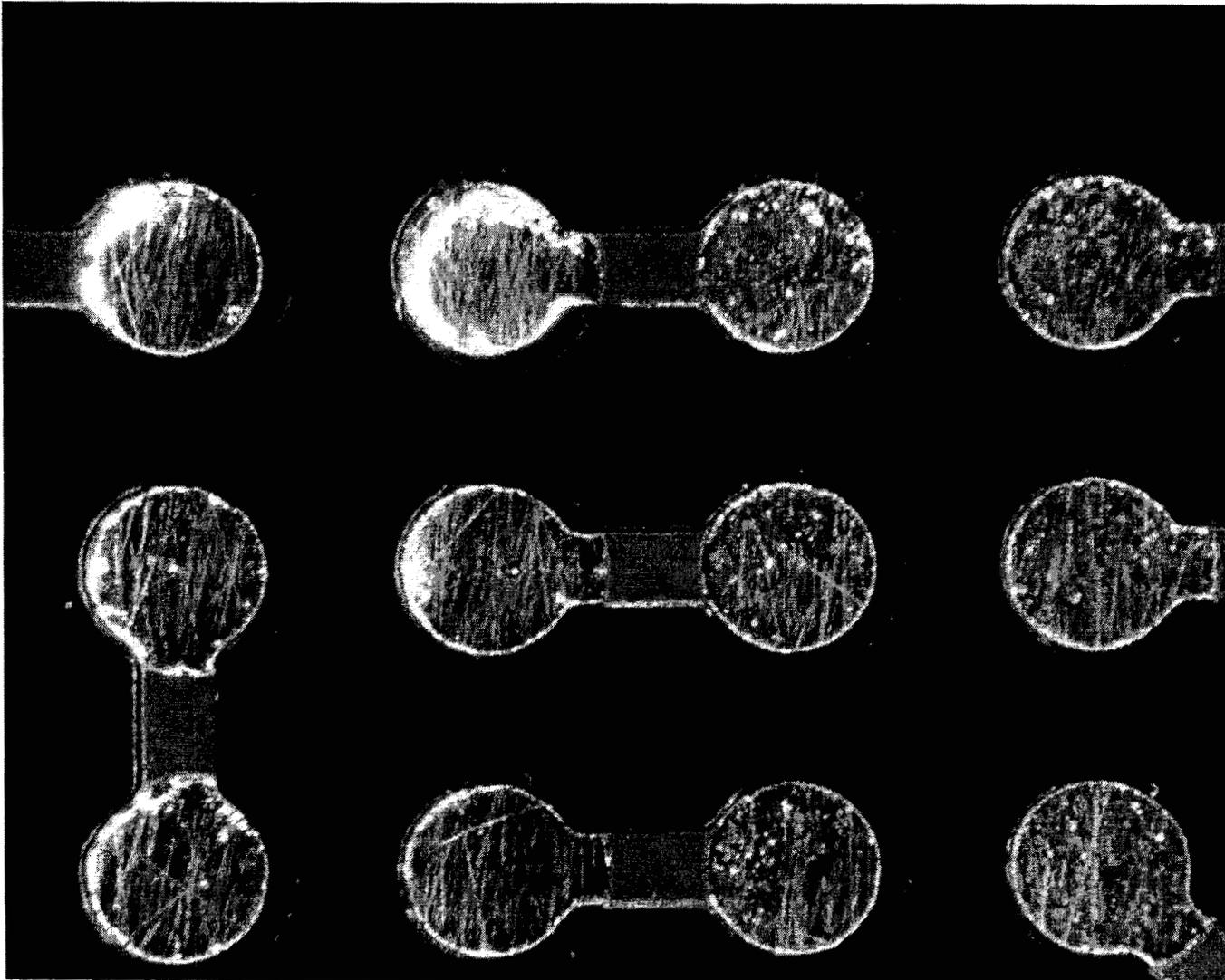


PBGA 225 X-Ray after first rework using convection method, Close Up
Rework Process Reliability



PBGA 225 Pads after first rework using Infra Red method

Rework Process Reliability



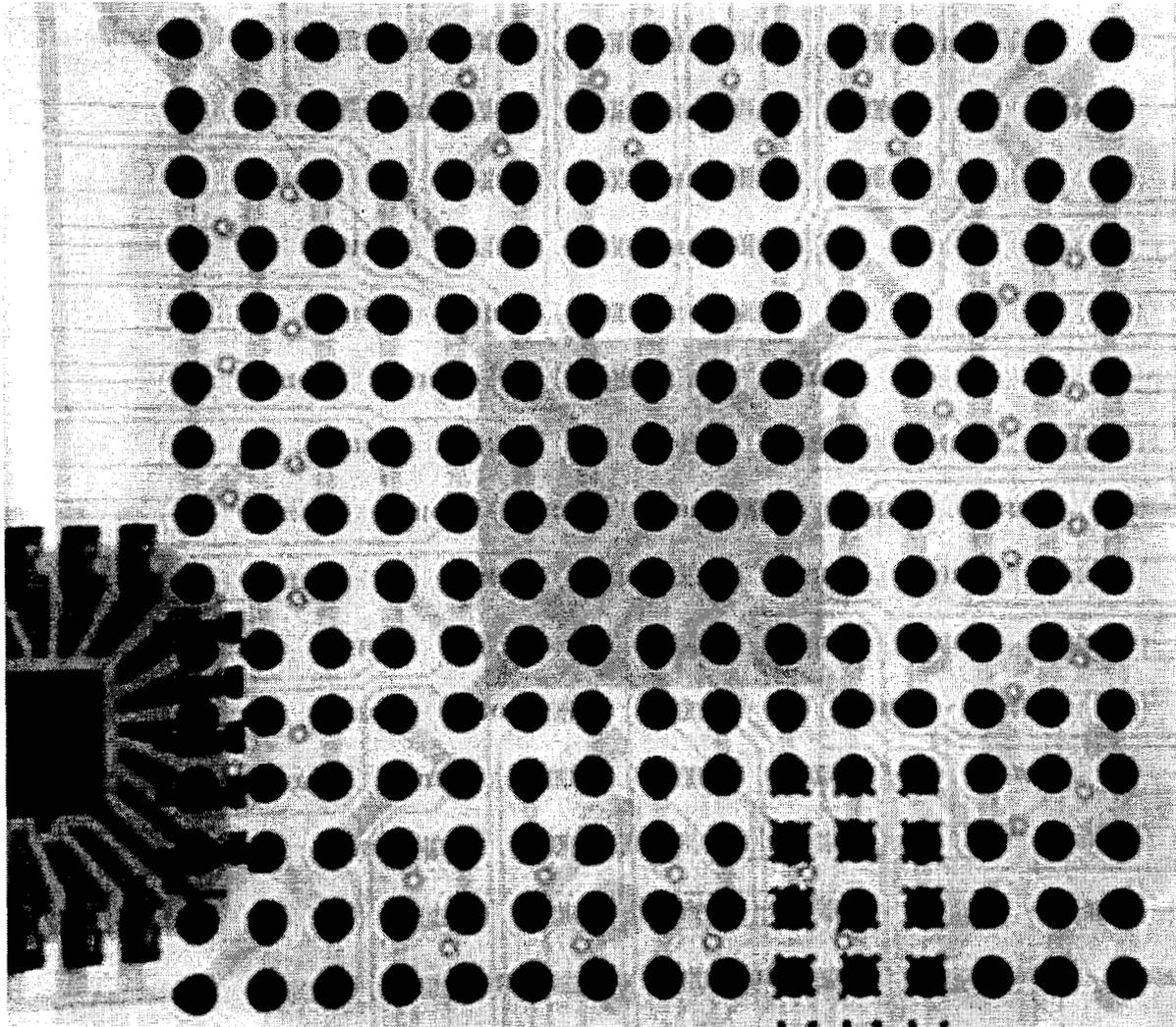
PBGA 225 Solder Joint After First Rework Using Infra Red Method

Rework Process Reliability



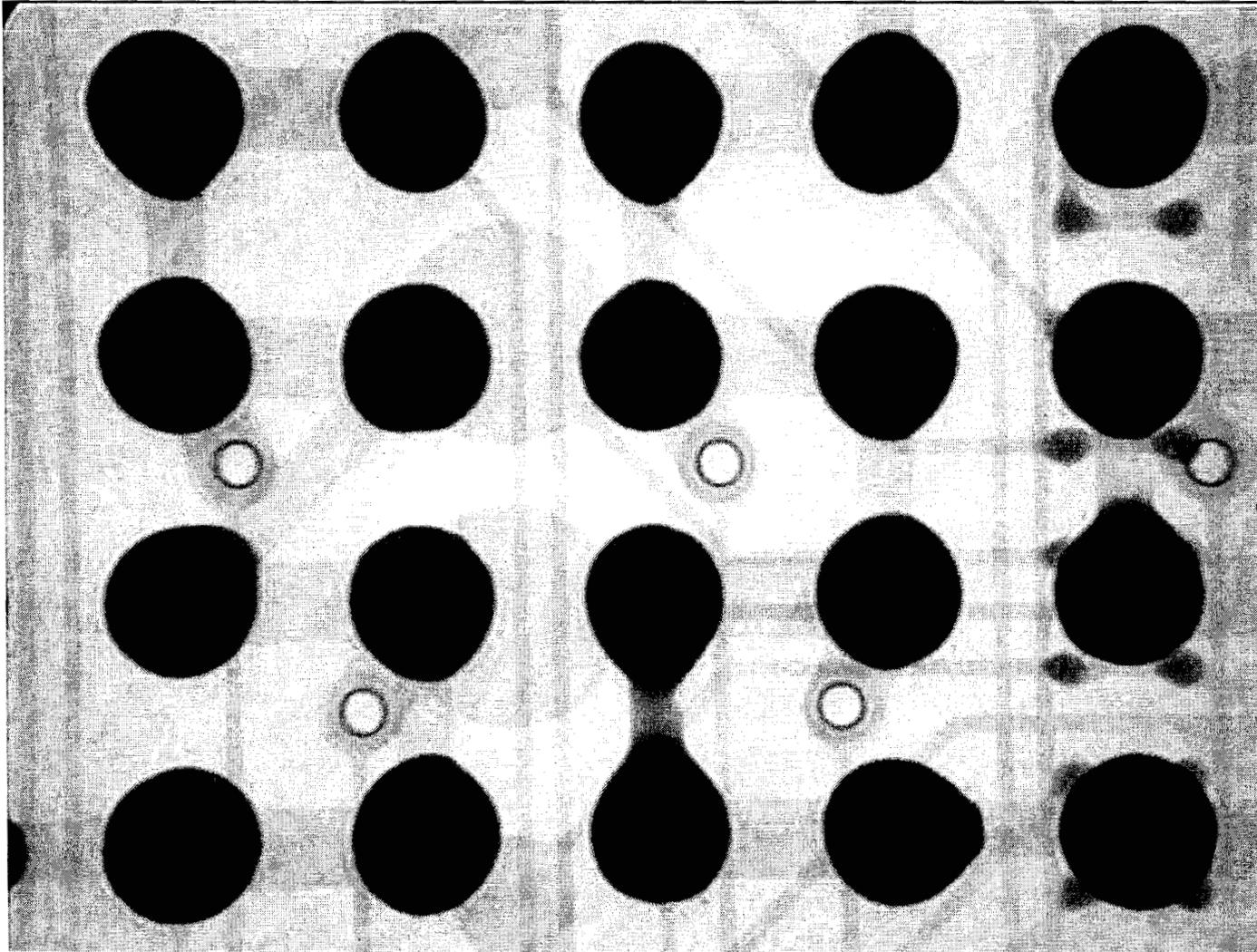
PBGA 225 X-ray After First Rework Using Infra Red Method

Rework Process Reliability



PBGA 225 X-ray After First Rework Using Infra Red Method, Close Up

Rework Process Reliability



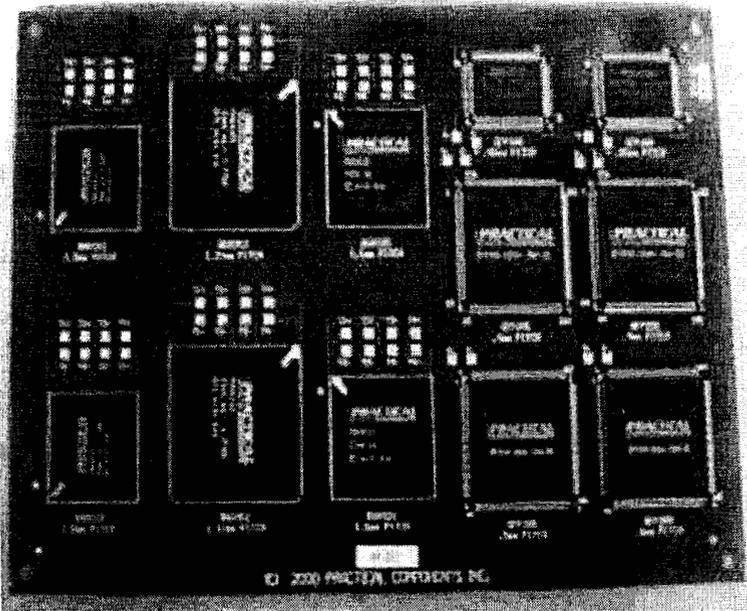
SUMMARY OF RESULTS

Rework Process Reliability

Evaluation board
with no power and
ground planes

Zephyrtronics
Convection rework

Eurotec
Infrared Rework



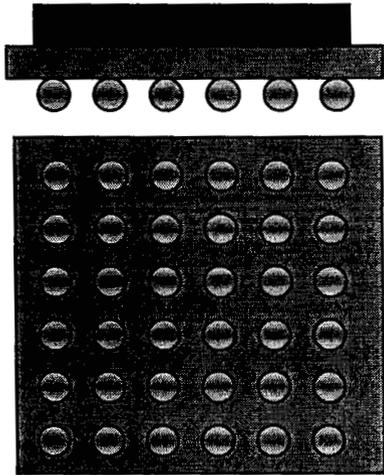
- No problems noted with rework.
- poor solder mask adhesion noted.

- Worst case PWB as IR energy from bottom heaters pass through the board and does not spread heat as well as a PWB with power and ground planes.

SUMMARY OF RESULTS (Cont)

Rework Process Reliability

Fully populated small (225) I/O 27 mm square BGA



Zephytronics

Convection rework

- solder spheres heat up from sides and center of package creating uniform heat flow.
- No problems noted during rework.
- No problem observed during printing and placement.

Eurotec

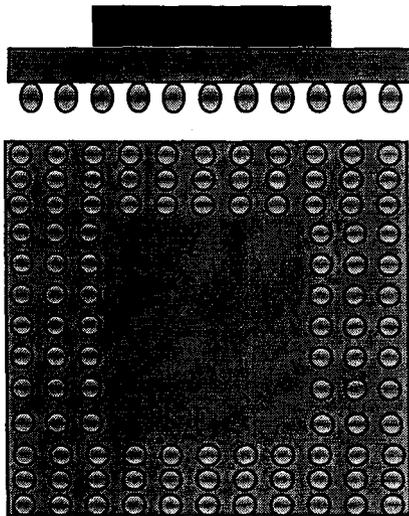
Infrared Rework

- No problems noted during rework.
- solder spheres heat up directly below black over-mold body

SUMMARY OF RESULTS (Cont)

Rework Process Reliability

Perimeter populated large (352) I/O 35 mm square BGA



Zephyrtronics Convection Rework	Eurotec Infra Red Rework
<ul style="list-style-type: none"> • Some uneven heating noted during rework. Required oversize nozzle to be used. • Solder bridging noted where solder mask peeled off. • Solder spheres heat up from sides and center of package. • Ideal for this type of BGA. 	<ul style="list-style-type: none"> • Significant problems noted during rework. • No solder spheres directly below black over-mold body • IR lamp power drops off radially from center • No power and ground planes to assist heating below.