Telemetry Engineering and Fabrication Alternative Soldering Techniques for CFC Elimination

Kansas City Division

R. V. Howard

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TELEMETRY ENGINEERING AND FABRICATION ALTERNATIVE SOLDERING TECHNIQUES FOR CFC ELIMINATION

R. V. Howard

Published August 1995

Topical Report
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Abstract

In an effort to eliminate the need for chlorinated fluorocarbons (CFCs) for several production assemblies in Telemetry Engineering and Fabrication, an alternate soldering reflow process to replace the current vapor phase system was needed. After analyzing IR, convection, and recovery vapor phase soldering reflow methods, it was discovered that an improved process would result from the implementation of a new convection reflow system. The convection oven reflow method was evaluated by collecting data from visual inspections, shear, push, and cross-section tests on several surface mount devices.

Summary

Once the reflow method was decided upon, evaluation of several convection ovens led to the purchase of a Vitronics SMR800 convection oven. The Vitronics convection oven contains twelve heating and four cooling cells. In qualifying the oven for use on telemetry product, a matrix was developed from the baseline profile established. Reflow temperatures and soak times were varied according to the parameters set forth by each of the quadrants in the matrix. The belt speed and individual zone temperature were also varied to obtain the quadrant parameters.

Several printed wiring assemblies (PWAs) were run through the oven in each of the quadrants. The PWAs were given a visual inspection and sent to the lab for shear, push, and cross-section tests. The results of the shear and push data indicated the convection oven reflow process to be better than the vapor phase reflow system. The matrix also helps determine what quadrant parameters produced the best reflow results. Reflowing product in the C, G, and J quadrants (using profiles established in these quadrants) produced favorable results in the visual inspection, shear, push, and cross-section tests.

Discussion

Scope and Purpose

The vapor phase reflow soldering system was initially modified to reduce dependency on chlorinated fluorocarbons (CFCs) by replacing the Genesolv D fluid with SF-2. Further efforts to eliminate all chemicals that are either environmental or health hazards have lead to the research of a new reflow soldering process. Analyzing alternative reflow systems has led to a comparison between vapor phase and convection oven technology for use on telemetry product. Process characterization was done on the convection oven and data was compared to that of the vapor phase. The results of the comparison will aid in the qualification process for the convection oven.

Activity

Introduction

In an effort to eliminate the need for CFCs for several production assemblies in Telemetry Engineering and Fabrication, an alternate soldering reflow process to replace the vapor phase system was needed. This replacement was the Vitronics SMR800 convection oven. The convection oven contains 12 heating cells (6 upper, 6 lower) and 4 cooling cells (2 upper, 2 lower). Compressed air is supplied to each of the cells. This air is circulated inside a chamber (high-pressure gas) within each cell and heated for the heating cells. Small perforations in the heater/diffuser panel of each cell allow the heated air to flow into the chamber where the product is located. The product travels on a conveyor/belt system through the different temperature zones within the oven, ultimately resulting in the product's reflowed condition.

This report addresses the steps taken for qualifying the Vitronics convection oven for use on the telemetry programs.

Experiment 1

The telemetry programs are the first programs scheduled to use the oven and for which a PC&C qualification plan has been developed. A matrix was created based on the profile established for use in the qualification tests. The matrix is shown in Table 1.

Table 1. Convection Oven
Qualification Matrix

		Reflow Temp. -10	Reflow Temp. Normal	Reflow Temp. +10
Soak Time	-20%	A	B	C
	Normal	D	E	F
	+20%	G	H	J

The normal profile is in section E. From this profile, the reflow temperature was varied +/-10°C from the 203°C nominal, and the soak time was varied +/-20% from the 65-second nominal. The belt speed of the oven and the individual zone temperatures were varied to obtain the parameters for each quadrant. See Figures 1-5 for detailed information on the A, C, E, G, and J quadrant profiles. (All figures appear following the text.) The reflow temp and soak time parameters for the four corner quadrants are shown in Table 2.

Table 2. Parameters for Four Corner Quadrants

Quadrant	Average Reflow Temperature (°C)	Average Soak Time (Seconds)
A	191.3	50
C	215.5	47
G	190.8	80
J	215.1	80

The qualification tests started with quadrant E. Data was collected from visual inspections, shear, push, and cross-section tests on a variety of components consistent with the programs. The qualification tests then moved into the four corner quadrants (A, C, G, J). The four corner quadrants were selected first to determine how robust the process was. The results of the data from inspection, reflow, push, shear, and cross-section would determine whether the other quadrants (B, D, F, H) would need to be evaluated.

Four different style printed wiring boards (PWBs) were used in each of the corner quadrants. J-Lead components, chip caps, and LCCs were used to populate each of the PWBs. The assembly process used was repeated in each of the quadrants. Prior to any fabrication, the PWBs were spray cleaned with AP-20. All the components were tinned with 63/37 solder and cleaned prior to any placement. The chip caps received from the vendor were pretinned and did not need a second tinning. If the printed wiring assembly (PWA) contained back side components, solder paste was applied through a stencil onto the PWA. The components were placed by the pick and place machine and then reflowed. The PWA was cooled and the process was repeated for the top side components. The chip caps and J-Lead components were placed directly into the solder paste and then reflowed. The LCC components were done differently. Solder paste was applied and the PWB was reflowed without the LCC being placed. This created solder bumps on each of the LCC pads. After cooling, flux was applied to each of the solder bumps and the PWA air cured for fifteen minutes. The LCCs were then placed onto the solder bumps and the PWA was reflowed.

Results of Experiment 1

The PWAs from each of the quadrants were inspected after reflow. The results are listed in Table 3. The PWAs were photographed after reflow to illustrate the individual quadrant characteristics. See Figures 6-11.

Table 3. Visual Inspection Results for Qualification Matrix

BOARD #	COMPONENT TYPES	# OF SOLDER JOINTS	# OF FAILURES	TYPE OF FAILURE
A1	1-44 J-Lead, 35 Chip Caps	114	5	Solder Balls, C24, C33, C41, C10, C9
A2	4-44 J-Lead	176	0	
A3	1-44 J-Lead, 36 Chip Caps	116	4	Solder Balls, C10 , C21, C34; Poor Solder Flow C9
A4	1-44 J-Lead, 4-32 LCC	172	0	
C1	4-44 J-Lead, 7 Chip Caps	190	0	
C2	1-44 J-Lead, 35 Chip Caps	114	0	
C3	1-44 J-Lead, 36 Chip Caps	116	0	
C4	1-44 J-Lead, 4-32 LCC	172	0	
G1	4-44 J-Lead	176	0	
G2	1-44 J-Lead, 35 Chip Caps	114	3	Solder Balls, C35, C10, C24
G3	1-44 J-Lead, 36 Chip Caps	116	0	
G4	1-44 J-Lead, 4-32 LCC	172	0	
J1	4-44 J-Lead	176	0	
J2	1-44 J-Lead, 36 Chip Caps	116	0	
J3	1-44 J-Lead, 35 Chip Caps	114	0	
J4	1-44 J-Lead, 4-32 LCC	172	0	

The failure modes for both the push and shear testing fall into three categories. All tests were performed with the 44-pin J-Lead component. The three categories are

A - Component failure, where the component is damaged, usually cracking in an X fashion across the component. The component leads usually remain attached to the PWB.

B - Solder joint separation, where the component lead is separated from the PWB land or pad at the solder joint.

C - Land/Pad separation, where the land or pad is separated from the PWB and is still attached to the component lead via solder.

Fifteen PWAs were sent out for push and shear testing. A hole was drilled in the PWB to enable pushing the J-Lead from the bottom for the push test. Table 4 shows the results of the push and shear tests done on the qualification PWAs.

Table 4. Qualification Push and Shear Data Results

PUSH DATA

MATRIX & BOARD #	COMPONENT TYPE	COMP. DESIGN.	MAX. TENSILE LOAD (LB)	FAILURE MODE	AVERAGE
A1	44 Pin J-LEAD	P7	37	C	
A2	44 Pin J-LEAD	P9	64	C	60.00
A2	44 Pin J-LEAD	P10	79	A	
C1	44 Pin J-LEAD	P2	92	C	
C1	44 Pin J-LEAD	P3	64	C	
C2	44 Pin J-LEAD	P4	41	C	
C5	44 Pin J-LEAD	P8	78	C	
C5	44 Pin J-LEAD	P9	90	C	70.40
C5	44 Pin J-LEAD	P10	82	C	
C5	44 Pin J-LEAD	P11	45	C	
C5	44 Pin J-LEAD	P12	66	C	
C5	44 Pin J-LEAD	P13	75	C	
C5	44 Pin J-LEAD	P14	71	C	
G1	44 Pin J-LEAD	P13	40	C	
G1	44 Pin J-LEAD	P14	89	B	
G2	44 Pin J-LEAD	P6	37	C	
G5	44 Pin J-LEAD	P1	94	C	
G5	44 Pin J-LEAD	P2	87	C	75.90
G5	44 Pin J-LEAD	P3	73	C	
G5	44 Pin J-LEAD	P4	89	C	
G5	44 Pin J-LEAD	P5	96	C	
G5	44 Pin J-LEAD	P6	91	C	
G5	44 Pin J-LEAD	P7	63	C	
J1	44 Pin J-LEAD	P11	95	B	
J1	44 Pin J-LEAD	P12	111	A	
J3	44 Pin J-LEAD	P1	42	C	
J5	44 Pin J-LEAD	P15	54	C	
J5	44 Pin J-LEAD	P16	76	C	72.3
J5	44 Pin J-LEAD	P17	71	C	
J5	44 Pin J-LEAD	P18	70	C	
J5	44 Pin J-LEAD	P19	51	C	
J5	44 Pin J-LEAD	P20	94	C	
J5	44 Pin J-LEAD	P21	59	C	

SHEAR DATA

MATRIX & BOARD #	COMPONENT TYPE	COMP. DESIGN.	MAX. TENSILE LOAD(LB)	FAILURE MODE	AVERAGE
A2	44 Pin J-LEAD	S9	90	B	
A2	44 Pin J-LEAD	S10	*	C	86.50
A3	44 Pin J-LEAD	S7	83	C	
C1	44 Pin J-LEAD	S2	76	B	
C1	44 Pin J-LEAD	S3	81	B	75.00
C3	44 Pin J-LEAD	S5	68	C	
G1	44 Pin J-LEAD	S13	72	C	
G1	44 Pin J-LEAD	S14	77	B	74.33
G3	44 Pin J-LEAD	S6	74	C	
J1	44 Pin J-LEAD	S11	87	B	
J2	44 Pin J-LEAD	S1	55	C	71.00

*= NO DATA

A PWB was loaded with seven 44-pin J-Lead devices and reflowed with the vapor phase. The PWA had the same three types of push failures associated with it as the other evaluation PWAs. Comparing the average of the three failure modes between the convection oven and the vapor phase yields data results that are very close.

Table 5 is a list of the convection oven push data results broken down by the different mode failure types.

Table 5. Convection Oven Qualification Push Data Results (By mode failure type)

MODE B FAILURE ANALYSIS

MATRIX & BOARD #	COMP. DESIGN	MAX. TENSILE LOAD(LB)	AVERAGE
G1	P14	89	89
J1	P11	95	95
	TOTAL	184	92.00

MODE A FAILURE ANALYSIS

MATRIX & BOARD #	COMP. DESIGN	MAX. TENSILE LOAD(LB)	AVERAGE
A2	P10	79	79
J1	P12	111	111
	TOTAL	190	95.00

MODE C FAILURE ANALYSIS

MATRIX & BOARD #	COMP. DESIGN	MAX. TENSILE LOAD(LB)	AVERAGE
AI	*P7*	*37*	50.50
A2	P9	64	
C1	P2	92	
C1	P3	64	
C2	*P4*	*41*	
C5	P8	78	
C5	P9	90	70.40
C5	P10	82	
C5	P11	45	
C5	P12	66	
C5	P13	75	
C5	P14	71	
E1	*P22*	*47*	
E2	*P23*	*44*	
E3	*P24*	*45*	39.83
E4	*P25*	*40*	
E5	*P26*	*27*	
E6	*P27*	*36*	
G1	P13	40	
G2	*P6*	*37*	
G5	P1	94	
G5	P2	87	
G5	P3	73	74.44
G5	P4	89	
G5	P5	96	
G5	P6	91	
G5	P7	63	
J3	*P1*	*42*	
J5	P15	54	
J5	P16	76	
J5	P17	71	64.63
J5	P18	70	
J5	P19	51	
J5	P20	94	
J5	P21	59	
	TOTAL	2231	63.74

MODE C FAIL. ANAL.

MATRIX & BOARD #	COMP. DESIGN	MAX. TENSILE LOAD(LB)	AVERAGE
A2	P9	64	64.00
C1	P2	92	
C1	P3	64	
C5	P8	78	
C5	P9	90	
C5	P10	82	73.67
C5	P11	45	
C5	P12	66	
C5	P13	75	
C5	P14	71	
G1	P13	40	
G5	P1	94	
G5	P2	87	
G5	P3	73	79.13
G5	P4	89	
G5	P5	96	
G5	P6	91	
G5	P7	63	
J5	P15	54	
J5	P16	76	
J5	P17	71	
J5	P18	70	67.86
J5	P19	51	
J5	P20	94	
J5	P21	59	
	TOTAL	1835	73.40

Ninety-five chip caps were sheared off eight PWAs. Forty-eight of those were the large chip caps (1210), and 47 small chip caps (0805) were used in the evaluation. Those failures fall into just two categories (B and C) as mentioned earlier. Summarizing that data yields the results shown in Table 6.

Table 6. Maximum Shear Load (MSL)

		LARGE CHIP CAPS					SMALL CHIP CAPS				
MATRIX & BOARD #	CAP #	MSL (L)	AVER. MSL (L)	MSL (S)	AVER. MSL (S)	FAILURE MODE	MSL (L)	AVER. MSL (L)	MSL (S)	AVER. MSL (S)	FAILURE MODE
A1	1	23.50		25.00			10.00		11.20		
	2	36.50	31.80	28.50	26.00	B	10.00	10.50	9.40	10.40	B+C
	3	35.50		24.50			11.40		10.60		
A3	1	28.50		26.50			7.70		11.50		
	2	31.50	30.70	23.00	26.30	B+C	11.20	9.40	12.30	11.80	B+C
	3	32.00		29.50			no data		11.60		
C2	1	23.00		22.50			7.40		3.50		
	2	24.00	27.50	21.50	23.70	B	7.00	7.60	9.50	8.00	B
	3	24.00		27.00			8.50		10.90		
C3	1	31.50		23.50			6.80		12.60		
	2	21.00	26.50	26.50	23.70	B	12.50	9.40	11.40	11.00	B+C
	3	27.00		21.00			9.00		9.10		
G2	1	19.00		20.00			17.20		13.80		
	2	26.50	25.00	24.50	22.00	B	9.60	12.10	10.60	11.70	B
	3	29.50		21.50			9.40		10.80		
G3	1	21.00		24.00			7.80		12.60		
	2	29.00	24.80	26.00	26.20	B	9.30	8.90	13.90	12.40	B
	3	24.50		28.50			9.50		10.70		
J2	1	25.50		22.00			6.60		10.00		
	2	51.30	36.60	23.00	21.30	B	9.60	8.30	10.00	10.80	B
	3	33.00		19.00			8.70		12.60		
J3	1	20.50		24.50			10.00		9.50		
	2	32.50	26.20	30.00	25.00	B	13.40	11.00	9.40	10.30	B+C
	3	25.50		20.50			9.70		12.10		

(L) = push against long edge, (S) = push against short edge

Failure mode C (land/pad separation) was the most common in this evaluation. It attributed to 90% of the failures out of 39 pushed components. In summarizing this data, a pattern developed on a particular style of PWB. The PWA push data were consistently lower than current and previous push data results. All of the PWBs were manufactured out of plant and of the same lot. The vendor quality of the PWB was in question after analyzing the low results of the mode C failures. Delivery of the PWBs from the vendor was in an unusually expedient fashion.

The average for each of the failure modes between the two processes for push data is listed in Table 7.

Table 7. Comparison Between Failure Mode Averages and Processes

Failure Mode	Convection Oven	Vapor Phase
A	95	93
B	92	88
C	64	63

Readings are maximum tensile load (lb).

Four PWAs were sent to the lab for cross-sectioning tests. Two LCCs and one J-Lead device were cross-sectioned out of each corner quadrant. The joints were cross-sectioned and photographed at 40X power, checking for voids, non-wetting, etc. All eight of the LCC joints looked good with no voids or other solder defects present. On one of the four J-Lead joints cross-sectioned, a small void of approximately two mils in diameter is present close to the end of the "J" in the upswing area. The void is small in comparison to the overall 68-mil J-Lead solder footprint. The void is on the board that was from the A quadrant. (See Figures 12- 14.)

Conclusions

Evaluation of all the data collected from the experiments performed during the oven process control and characterization shows that the oven is capable of performing as well or better than the vapor phase process used in the telemetry department. The push and shear tests yielded results in the same range as the vapor phase, and the cross section showed that the convection oven process produces fewer voids. The standard profile (profile E) was created before these experiments were performed and is still the suggested profile to use. Even though profile A was the worst performing profile and should not be used; it still reflowed 99% of the joints on the board, showing that this profile is just on the outside edge of the oven's capability envelope. The other envelope edges are more determined by component environment restrictions, but profiles C, G, and J are inside the capability envelope of the oven.

Accomplishments

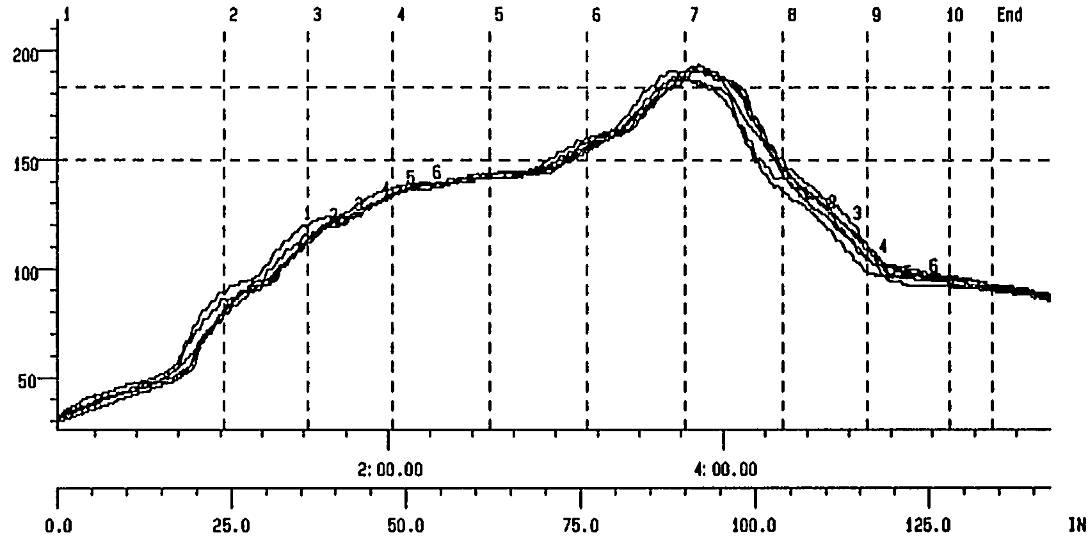
The control portion of these experiments consists of calibration and weekly monitoring. The oven temperature sensors were calibrated and are on a periodic calibration cycle through KCD metrology. The weekly monitoring is done using a generic test fixture with four thermocouples mounted to a nickel-plated copper plate. The thermocouples are monitored using the Datapaq which is also calibrated and is on a periodic calibration cycle. Figure 15 shows the data collected to date. Using this system shows the oven to be in good control in the heating zones. The cooling zones have more variation. These zones do not have a way to cool the air, allowing bleed-through from the last heating zone to raise the temperature in the cooling zones. After one hour these zones will stabilize as shown in Figure 16.

Future Work

The new business and programs coming to the department that contains surface mount devices will be evaluated and profiled for the convection oven. Product that contains a surface mount device not previously characterized will go through additional PC&C evaluations.

ALLIED SIGNAL AEROSPACE	Process:	Report Date : 04/15/1994
Site:	Product:	Line Speed : 24.0 in/min

Temperature (C) against Time (mins)



Zone Temp Settings

#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
0	130	155	160	150	185	245	0	0	0
0	130	155	160	150	185	245	0	0	0

Run Information

Paqfile : QUALIFICATION-12F
Operator :
Cycle Time :
Transducer Id : G611-1125-00
Number of Probes : 6
Sampling Interval : 00:00.20
Trigger Temperature : 40
Uploaded at : 9:24:00 on 12/17/93
Collection Started : 9:17:16 on 12/17/93

Comments

AVERAGE PEAK TEMP 191.3
, QUALIFICATION
####FINAL####

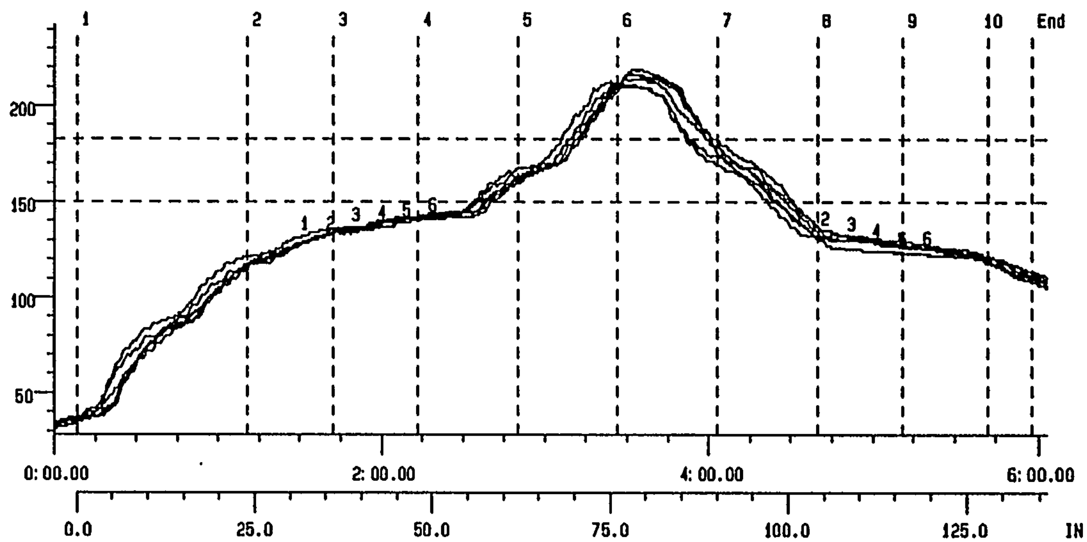
Max Slope by zone (deg C/sec)											Overall		Probes	Threshold temp: 183 (C)		Peak	
Zone Number											Max Slope	Time Reached		Time reached	Time over	Temp	Time reached
1	2	3	4	5	6	7	8	9	10	End							
3.5	2.5	1.5	1.0	1.5	3.0	-4.0	-2.5	0.5	-0.5	-1.0	3.5	00:47.80	1 component top	03:33.60	00:21.00	191	03:40.80
5.0	3.5	1.5	0.5	2.0	2.5	-5.0	-3.0	-1.0	-0.5	-0.5	5.0	00:45.00	2 side of component	03:37.20	00:20.80	188	03:41.60
4.5	3.0	2.0	1.0	1.5	2.5	-5.0	-3.0	-2.5	-0.5	-1.0	4.5	00:50.80	3 trailing edge of light compon	03:39.80	00:27.20	192	03:50.80
4.0	3.0	1.5	1.0	1.5	2.5	-4.0	-2.5	-2.0	-0.5	-1.0	4.0	00:49.60	4 leading edge of dark componen	03:41.60	00:22.60	190	03:48.40
3.5	2.5	1.5	1.0	1.0	2.5	-4.0	-2.5	-2.0	-0.5	-1.0	3.5	00:50.60	5 open corner of board	03:40.40	00:24.60	194	03:51.20
2.5	2.0	1.5	1.0	1.0	2.0	-2.5	-2.0	-2.5	-0.5	-1.0	2.5	00:50.00	6 back side of board	03:38.60	00:23.00	193	03:48.40

Probe Map

Figure 1. Quadrant A Profile

ALLIED SIGNAL AEROSPACE	Process:	Report Date : 04/15/1994
Site:	Product:	Line Speed : 23.0 in/min

Temperature (C) against Time (mins)



Zone Temp Settings

#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
0	130	155	155	155	190	280	0	0	0
0	130	155	155	155	190	280	0	0	0

Run Information

Paqfile : QUALIFICATION-18F
Operator :
Cycle Time :
Transducer Id : G611-1125-00
Number of Probes : 6
Sampling Interval : 00:00.20
Trigger Temperature : 40
Uploaded at : 14:45:00 on 12/17/93
Collection Started : 14:38:41 on 12/17/93

Comments

AVERAGE PEAK TEMP. 215.5
QUALIFICATION PROFILE
####FINAL####

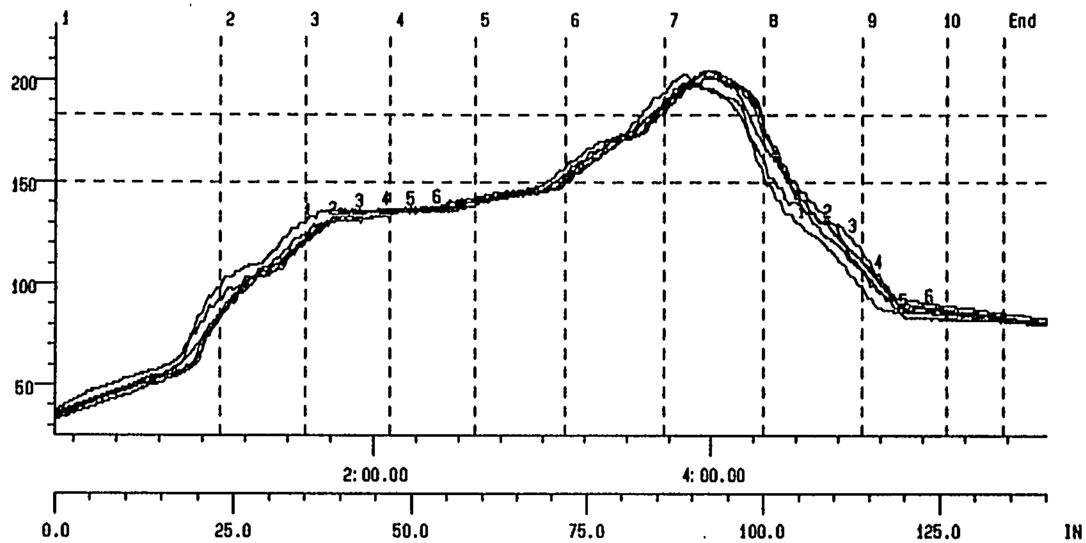
Max Slope by zone (deg C/sec)											Overall		Probes	Threshold temp: 183 (C)		Peak	
Zone Number											Max	Time		Time	Time	Temp	Time
1	2	3	4	5	6	7	8	9	10	End	Slope	Reached		reached	over		reached
5.0	1.5	1.0	2.5	4.0	-4.0	-2.5	-0.5	-1.0	-1.0	-1.0	5.0	00:20.40	1 component top	03:05.80	00:45.80	213	03:23.80
5.5	1.5	1.0	2.5	3.5	-5.0	-3.0	-0.5	-1.0	-1.0	-1.0	5.5	00:17.20	2 side of component	03:07.80	00:44.80	212	03:25.00
5.0	2.0	1.0	3.0	4.0	-4.0	-2.5	-2.0	-0.5	-1.0	-1.0	5.0	00:22.80	3 trailing edge of light compon	03:12.40	00:48.20	218	03:30.40
4.5	1.5	0.5	2.0	3.5	-3.5	-3.0	-2.0	-0.5	-1.5	-1.0	4.5	00:21.60	4 leading edge of dark componen	03:11.40	00:51.80	215	03:35.20
4.0	1.5	1.0	2.5	4.0	-3.5	-2.0	-1.5	-1.0	-1.0	-1.0	4.0	00:23.00	5 open corner of board	03:11.00	00:48.60	219	03:31.40
3.0	1.5	1.0	1.5	3.0	-3.0	-2.5	-2.0	-1.0	-1.5	-0.5	3.0	00:23.20	6 back side of board	03:09.40	00:50.20	216	03:29.40

Probe Map

Figure 2. Quadrant C Profile

ALLIED SIGNAL AEROSPACE	Process:	Report Date : 01/13/1995
Site:	Product:	Line Speed : 24.0 in/min

Temperature (C) against Time (mins)



Zone Temp Settings

#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
0	155	170	145	160	210	260	0	0	0
0	155	170	145	160	210	260	0	0	0

Run Information

Paqfile :
Operator :
Cycle Time :
Transducer Id : G611-1125-00
Number of Probes : 6
Sampling Interval : 00:00.20
Trigger Temperature : 40
Uploaded at : 9:22:00 on 12/03/93
Collection Started : 9:12:26 on 12/03/93

Comments

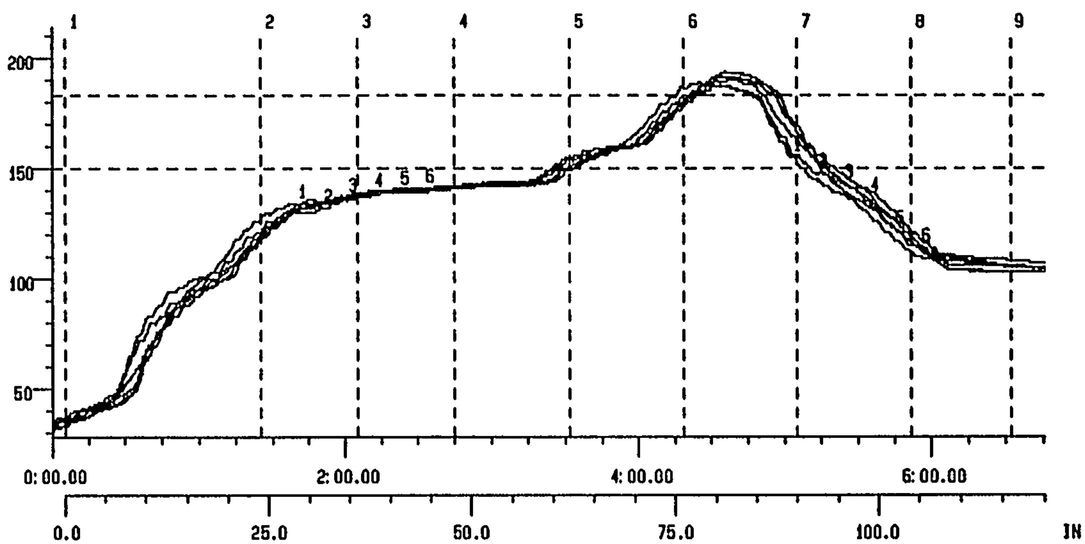
temp 73 degrees
humidity 32 per cent

AVERAGE PEAK TEMP. 202.5
QUALIFICATION PROFILE
****FINAL****

Max Slope by zone (deg C/sec)											Overall		Probes	Threshold temp: 183 (C)		Peak		Probe Map
Zone Number											Max	Time		Time	Time	Temp	Time	
1	2	3	4	5	6	7	8	9	10	End	Slope	Reached		reached	over		reached	
4.0	2.5	1.5	1.5	2.0	2.5	-5.5	-5.0	-3.0	-0.5	-0.5	4.0	00:56.00	1 COMPONENT TOP	03:34.80	00:35.40	203	03:49.80	
5.5	3.0	2.5	1.5	2.0	2.5	-6.5	-5.0	-3.5	-0.5	-1.0	5.5	00:53.40	2 SIDE OF COMPONENT	03:38.40	00:33.20	199	03:49.60	
5.5	3.5	2.5	1.0	1.5	2.5	-6.5	-5.0	-3.5	-0.5	-1.0	5.5	00:59.20	3 TRAILING EDGE OF LID	03:41.20	00:36.40	202	03:57.60	
4.5	3.0	2.0	1.0	2.0	2.5	-5.5	-4.5	-2.5	-0.5	-0.5	4.5	00:57.80	4 LEADING EDGE OF DARK	03:40.60	00:35.60	201	03:56.60	
4.0	2.5	2.0	1.5	2.5	2.5	-5.5	-5.0	-2.5	0.5	-0.5	4.0	00:59.20	5 OPEN CORNER OF BOARD	03:39.20	00:38.20	205	03:58.00	
2.5	2.5	2.0	1.0	1.5	2.0	-3.5	-3.0	-2.5	-0.5	-1.0	2.5	00:58.40	6 BACK SIDE OF BOARD	03:37.80	00:35.40	205	03:57.20	

Figure 3. Quadrant E Profile

ALLIED SIGNAL AEROSPACE	Process:	Report Date : 04/15/1994
Site:	Product:	Line Speed : 18.0 in/min



Zone Temp Settings

#1	#2	#3	#4	#5	#6	#7	#8	#9
0	135	160	150	150	170	225	0	0
0	135	160	150	150	170	225	0	0

Run Information

Paqfile : QUALIFICATION-24F
Operator :
Cycle Time :
Transducer Id : G611-1125-00
Number of Probes : 6
Sampling Interval : 00:00.20
Trigger Temperature : 40
Uploaded at : 11:35:00 on 01/05/94
Collection Started : 11:26:46 on 01/05/94

Comments

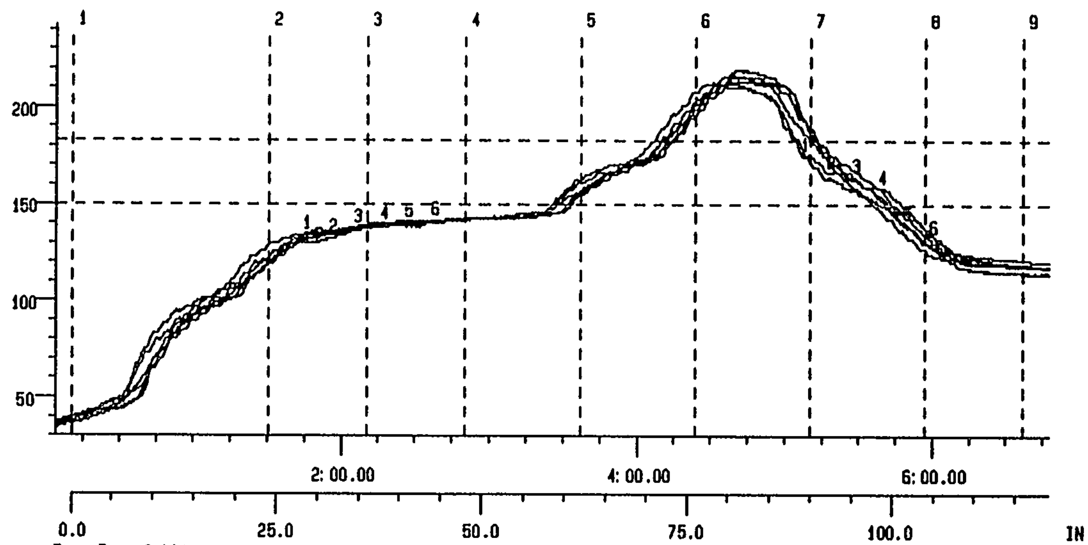
AVERAGE PEAK TEMP. 190.8
****** FINAL ******
FINAL FOR . QUALIFICATION
RUN.

Max Slope by zone (deg C/sec)										Overall		Probes	Threshold temp: 183 (C)		Peak		Probe Map
Zone Number										Max	Time		Time	Time	Temp	Time	
1	2	3	4	5	6	7	8	9	End	Slope	Reached		reached	over		reached	
4.5	1.5	0.5	1.5	2.5	-3.5	-2.5	-1.0	-0.5	---	4.5	00:31.80	1 component top	04:15.60	00:31.60	189	04:24.80	
5.0	2.0	0.5	1.5	2.0	-4.0	-2.5	-1.5	-0.5	---	5.0	00:29.60	2 side of component	04:18.20	00:31.40	188	04:25.80	
5.0	2.5	0.5	1.5	2.0	-4.0	-3.0	-2.0	-0.5	---	5.0	00:35.20	3 trailing edge of light component	04:23.40	00:35.40	192	04:33.80	
4.0	2.0	1.0	1.5	2.0	-3.0	-3.0	-2.0	0.5	---	4.0	00:33.40	4 leading edge of dark component	04:23.60	00:33.00	191	04:39.60	
4.5	2.0	0.5	1.5	2.0	-3.5	-2.5	-1.5	0.5	---	4.5	00:36.40	5 open corner of board	04:21.40	00:36.80	194	04:35.80	
3.0	1.5	1.0	1.0	1.5	-2.5	-2.0	-2.0	-0.5	---	3.0	00:36.20	6 back side of board	04:21.20	00:30.80	191	04:31.80	

Figure 4. Quadrant G Profile

ALLIED SIGNAL AEROSPACE	Process:	Report Date : 04/15/1994
Site:	Product:	Line Speed : 18.0 in/min

Temperature (C) against Time (mins)



Zone Temp Settings

#1	#2	#3	#4	#5	#6	#7	#8	#9
0	135	160	150	150	190	260	0	0
0	135	160	150	150	190	260	0	0

Run Information

Paqfile : QUALIFICATION-26F
Operator :
Cycle Time :
Transducer Id : G611-1125-00
Number of Probes : 6
Sampling Interval : 00:00.20
Trigger Temperature : 40
Uploaded at : 14:12:00 on 01/05/94
Collection Started : 14:02:58 on 01/05/94

Comments

AVERAGE PEAK TEMP. 215.1
****** FINAL ******
FINAL FOR
'QUALIFICATION RUN

Max Slope by zone (deg C/sec) Zone Number 1	2	3	4	5	6	7	8	9	End	Overall Max Slope	Overall Time Reached	Probes	Threshold temp: 183 (C) Time reached	Time over	Peak Temp	Peak Time reached	Probe Map
4.5	1.5	0.5	2.0	3.0	-4.0	-2.5	-1.5	-0.5	---	4.5	00:37.00	1 component top	04:06.60	00:58.00	213	04:30.60	
5.0	2.0	1.0	2.5	3.0	-5.0	-2.5	-2.0	-0.5	---	5.0	00:34.20	2 side of component	04:09.60	00:56.20	212	04:31.40	
5.0	2.5	0.5	3.0	3.0	-4.5	-3.0	-2.0	-0.5	---	5.0	00:40.40	3 trailing edge of light component	04:15.00	00:58.00	217	04:38.80	
4.5	2.0	0.5	2.0	2.5	-3.5	-3.5	-2.0	-0.5	---	4.5	00:40.20	4 leading edge of dark component	04:13.60	00:59.60	214	04:37.00	
4.0	2.0	0.5	2.5	3.0	-4.0	-3.0	-1.5	0.5	---	4.0	00:41.20	5 open corner of board	04:12.20	01:00.80	219	04:39.80	
2.5	1.5	0.5	1.5	2.0	-2.5	-2.0	-1.5	-0.5	---	2.5	00:39.80	6 back side of board	04:10.60	01:00.40	216	04:42.20	

Figure 5. Quadrant J Profile

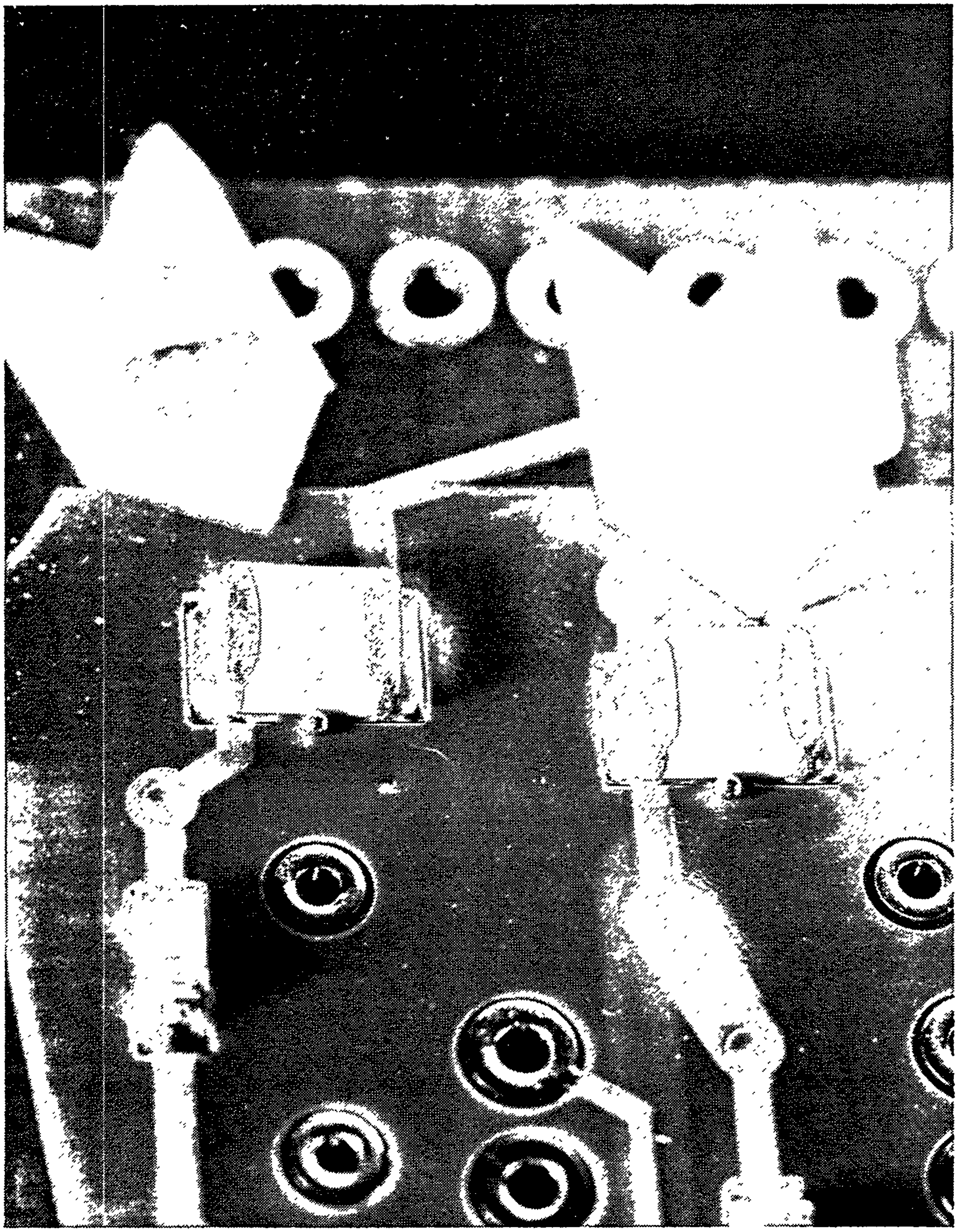


Figure 6. A3 Solder Balls

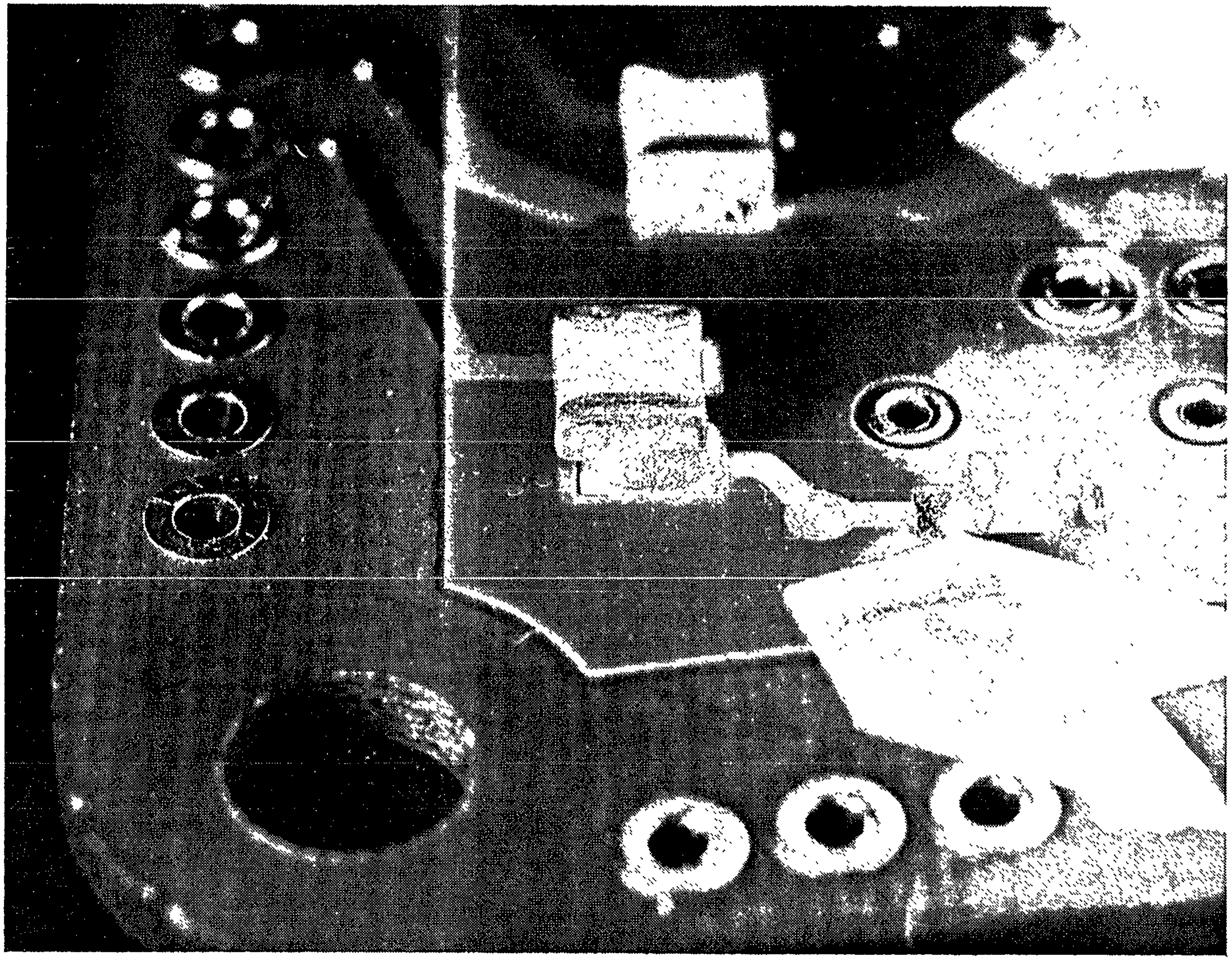


Figure 7. A3 C9 Poor Solder Flow

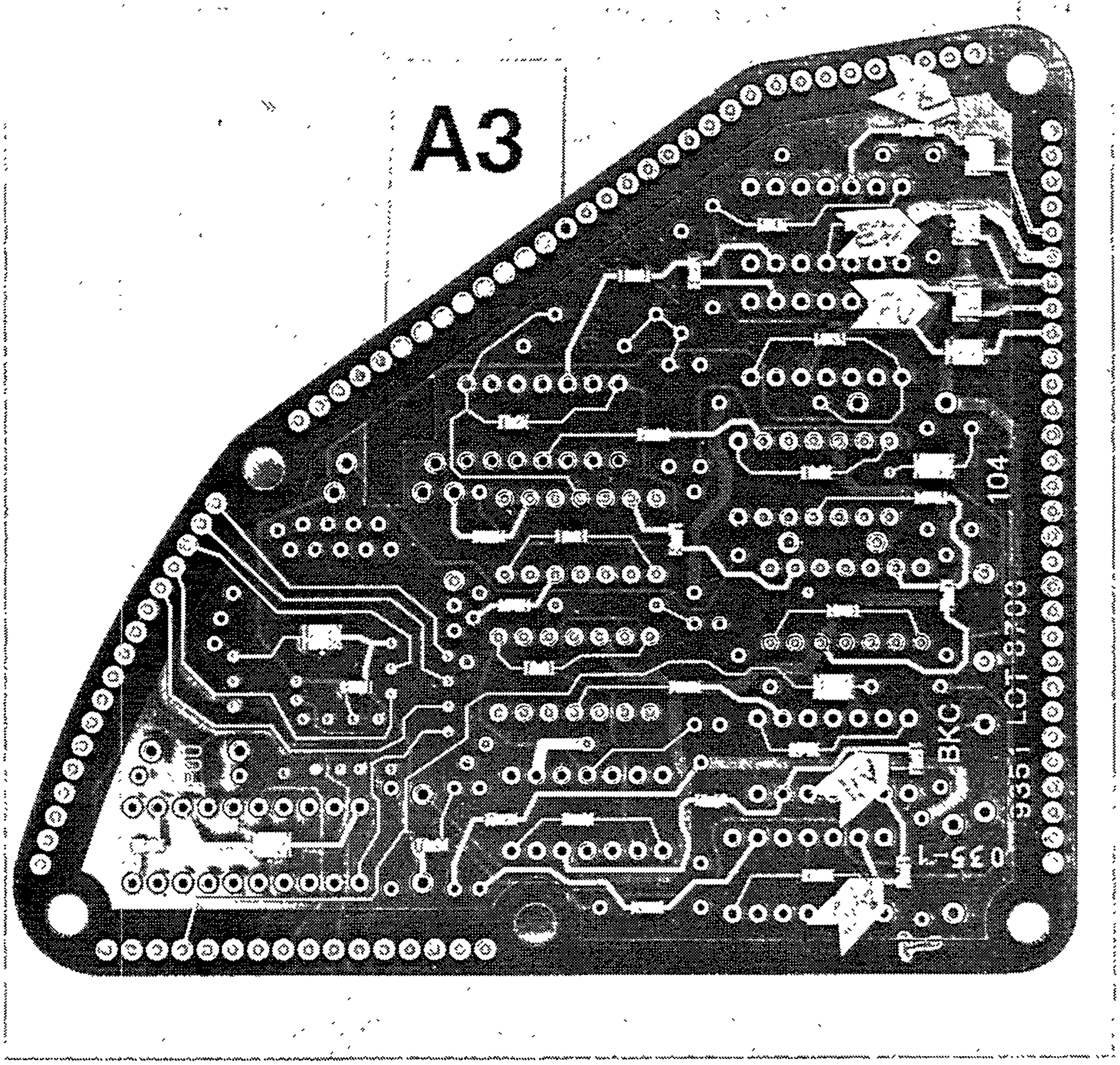


Figure 8. A3 Backside Overall

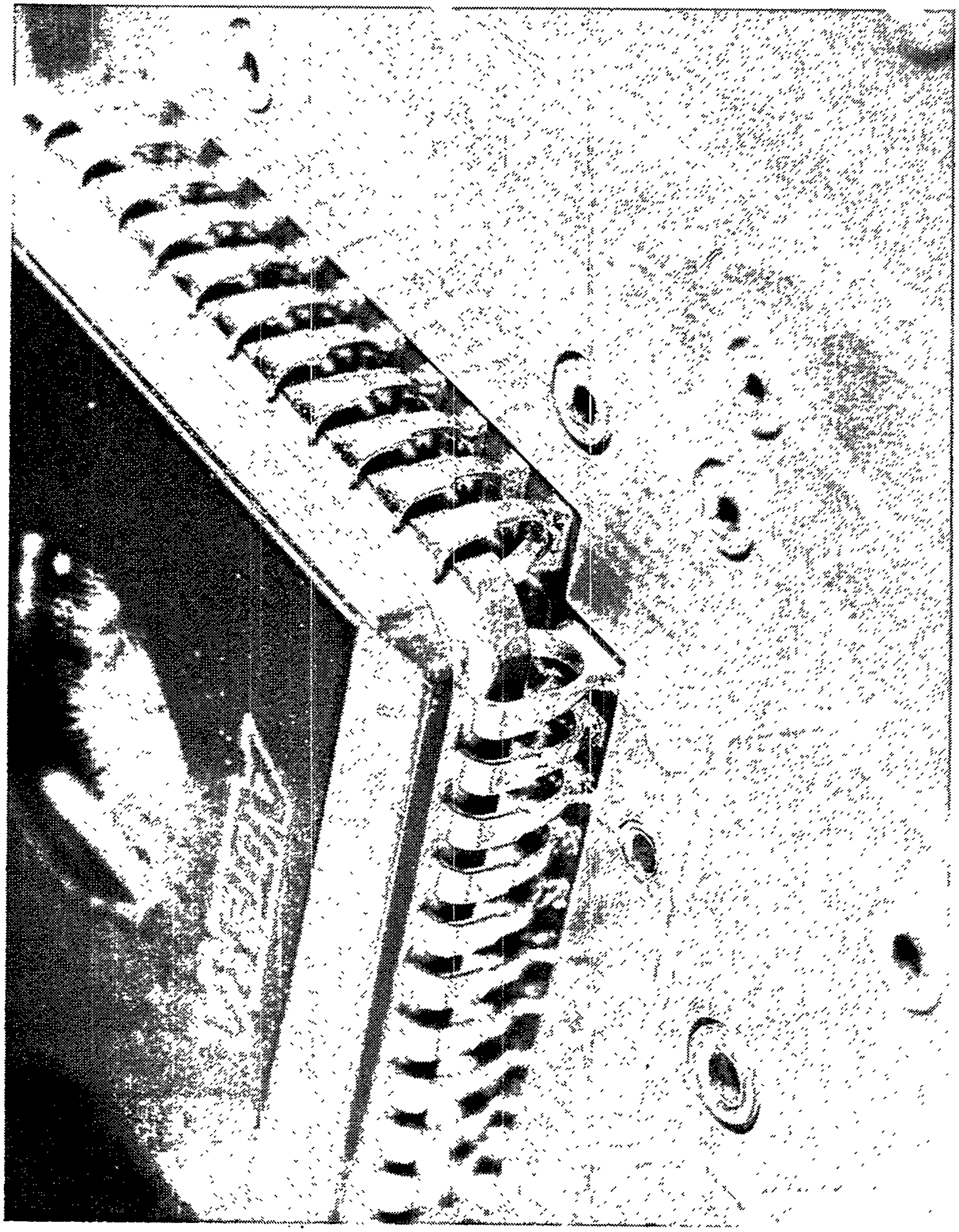


Figure 9. J1 Good Reflow J-Lead

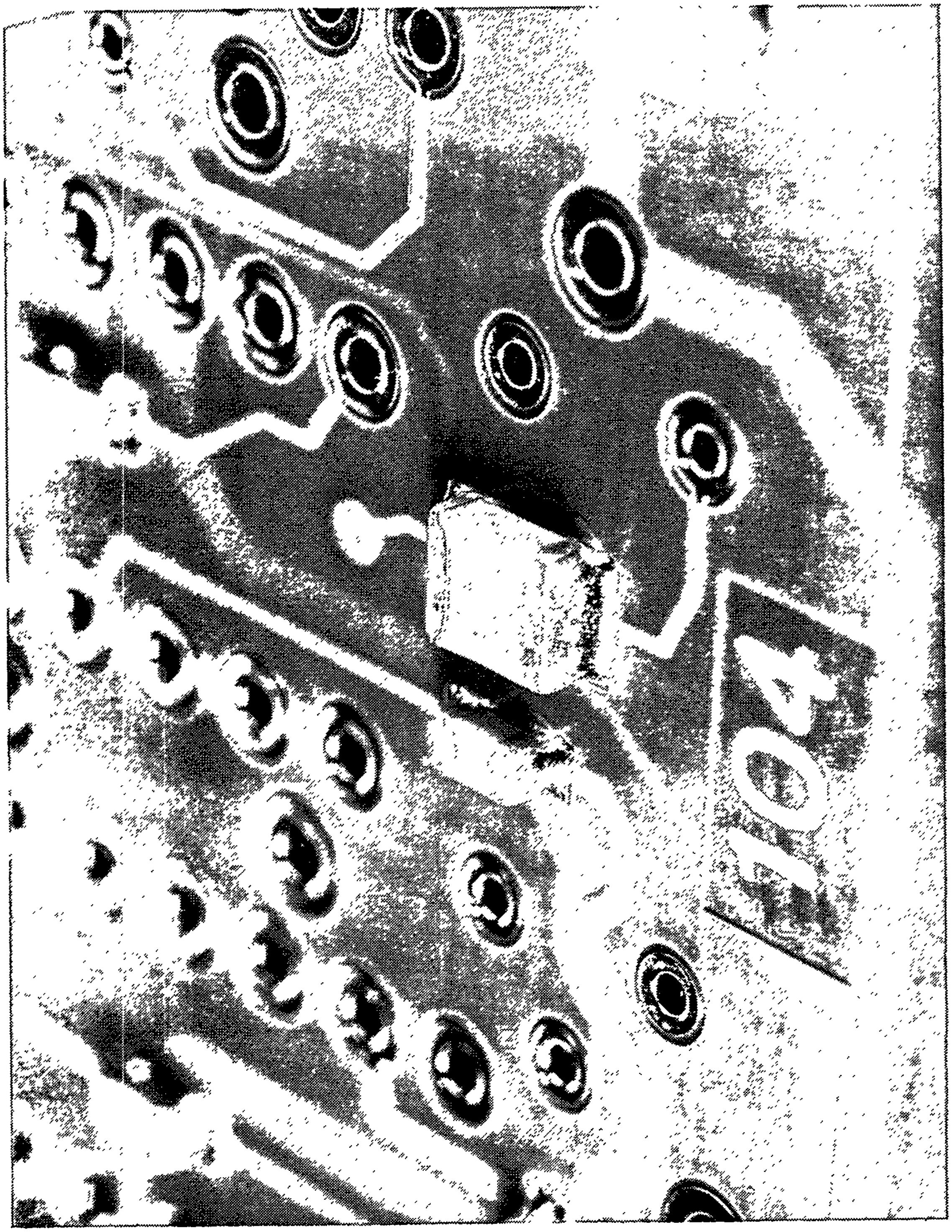


Figure 10. J2 Good Reflow Chip Caps

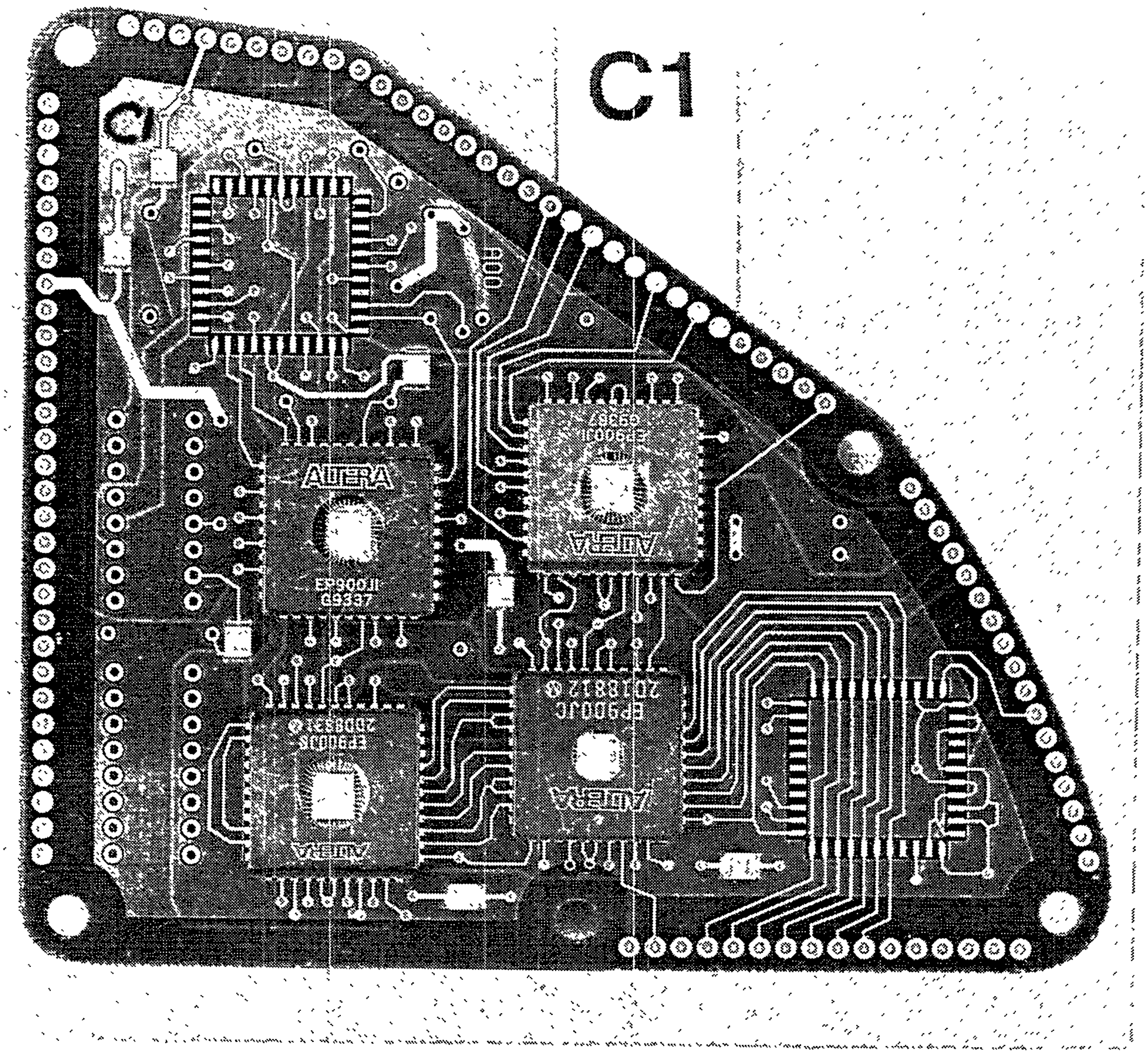


Figure 11. C1 Topside Overall

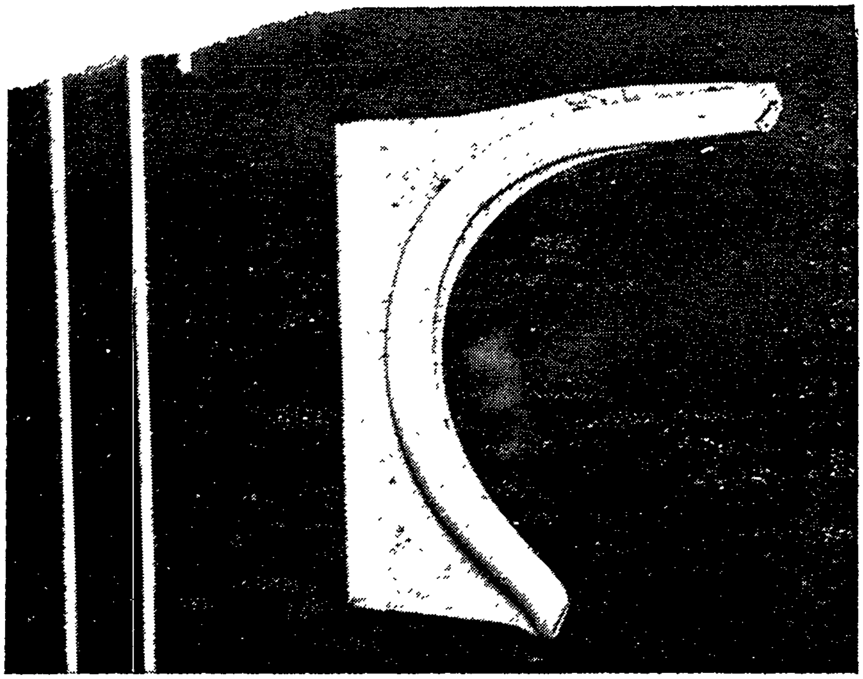


Figure 12. C4 Good LCC Cross Section

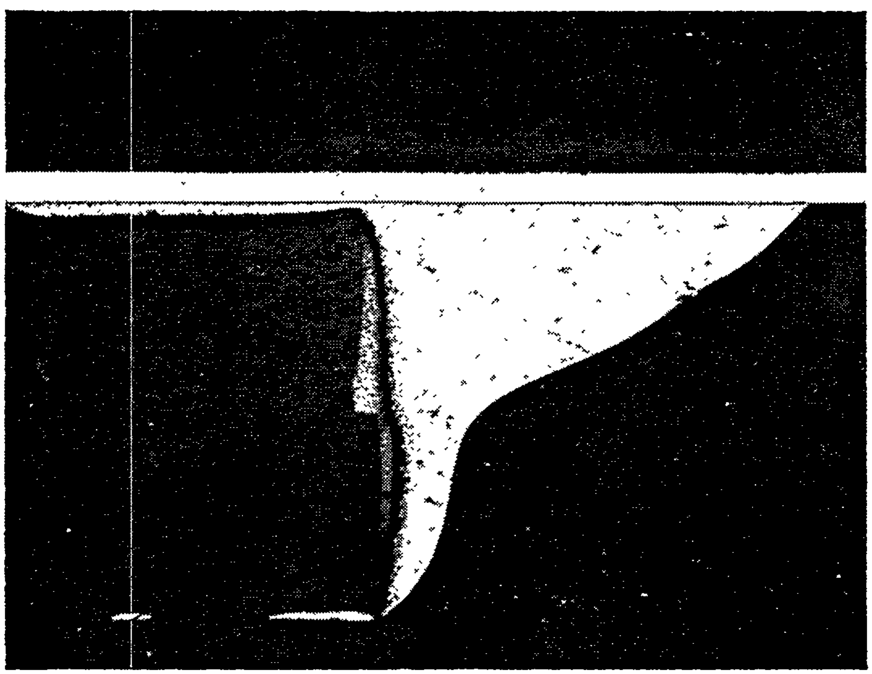


Figure 13. C4 Good J-Lead Cross Section

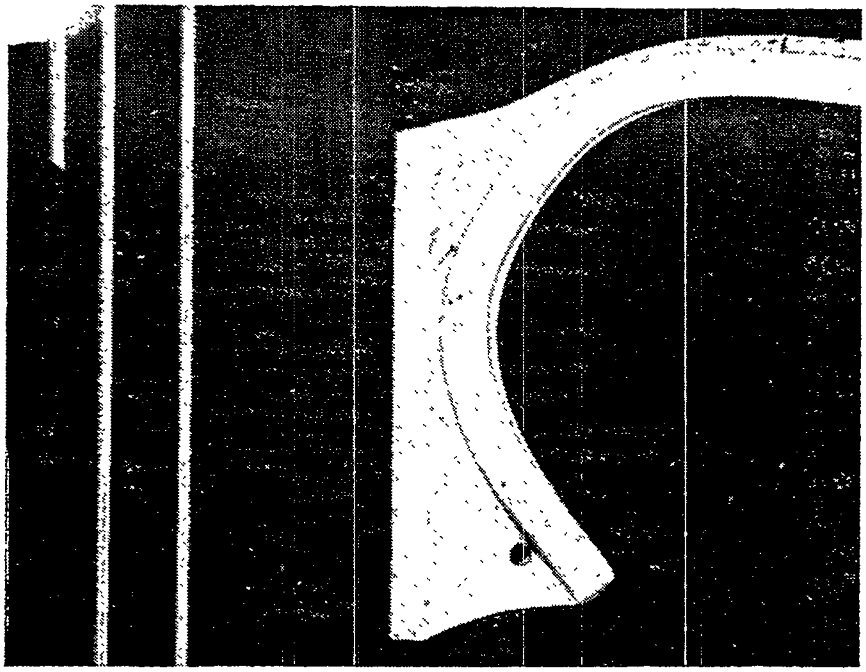


Figure 14. A4 Void J-Lead Cross Section

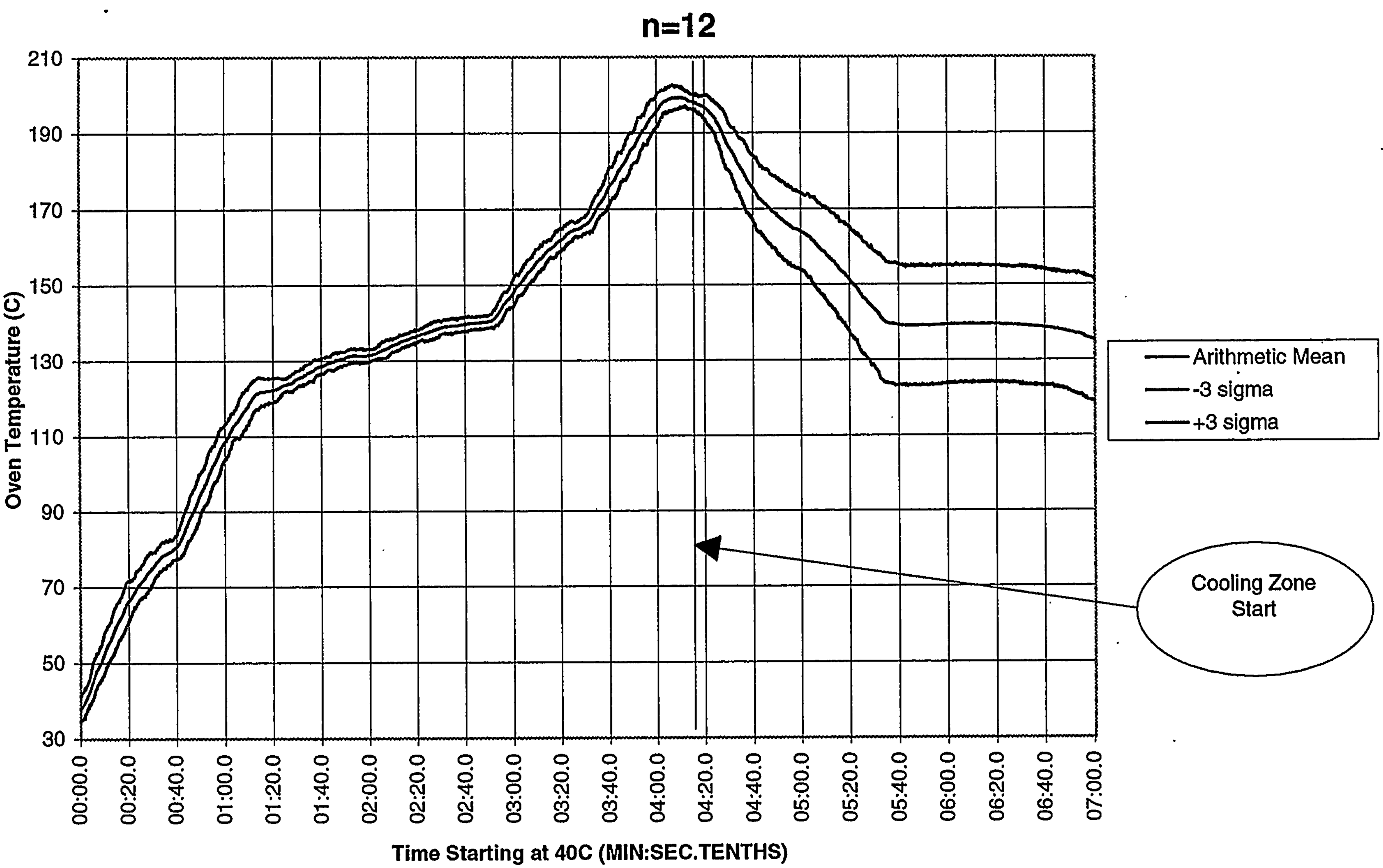


Figure 15. Oven Repeatability Data

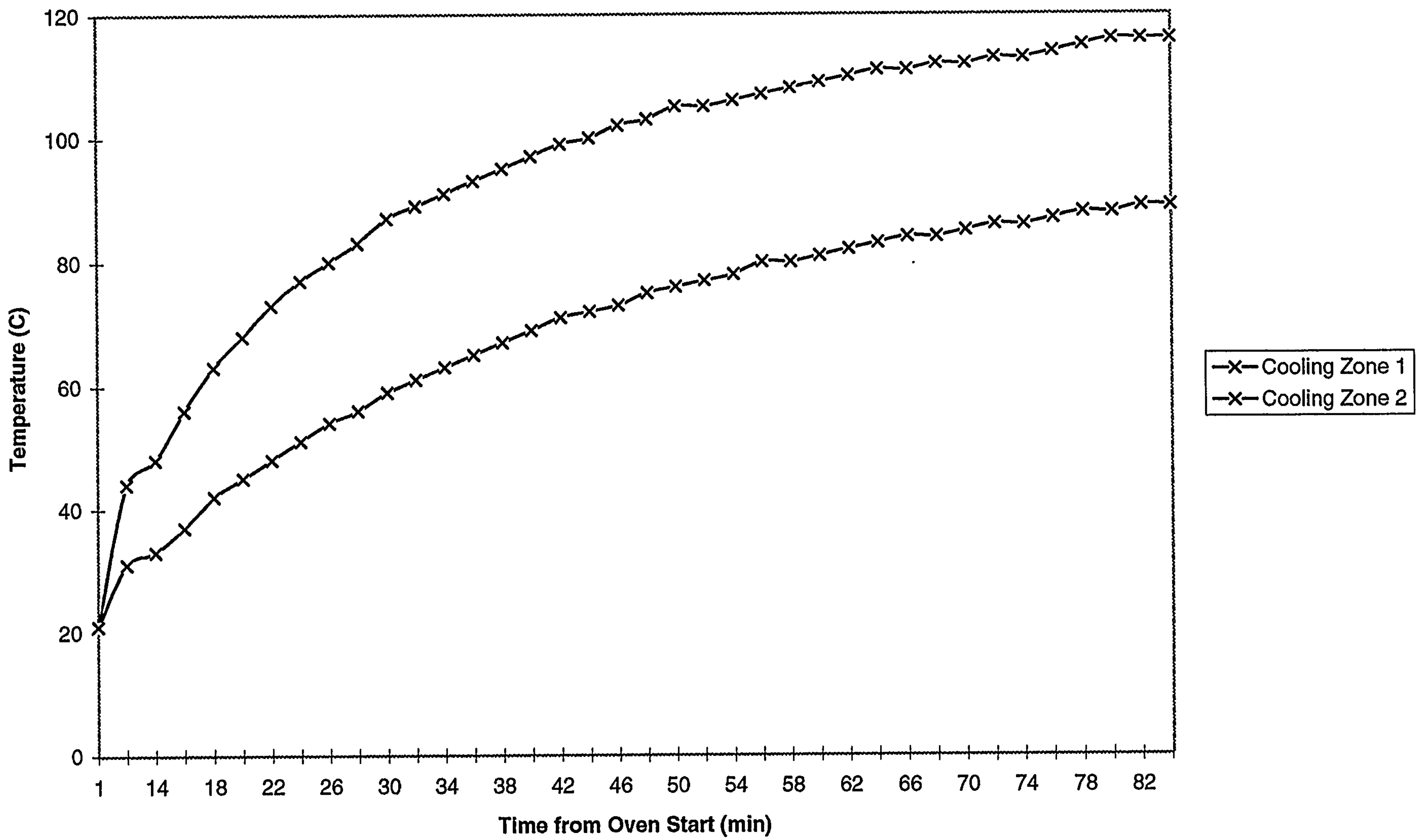


Figure 16. Cooling Zone Profile