Advanced Manufacturing Technology

Lead-Free Reflow Profile Study

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Nabel Ghalib & Quyen Chu
Advanced Manufacturing Engineering
Jabil Circuit, Inc.
10800 Roosevelt Blvd.
St.Petersburg, Fl. 33716
727.803.3094
Quyen_Chu@Jabil.com

Girish S. Wable
Electronics Manufacturing Research and Services
Department of Systems Science and Industrial Engineering
State University of New York, Binghamton
Girish_Wable@Jabil.com

Outline

- Objectives
- Observed Specifications:
  - IPC-JEDEC 020B
  - JEITA ED 4701/301A
  - Paste Manufacturer Reflow Parameters Recommendations
  - Jabil Reflow Parameters Specifications
- General Procedure
- Project Details
- Profile Results for PCB-A, PCB-B, PCB-C, and PCB-D
- Results Summary
- Comments on Experiment

Objectives

- Determine whether the selected component/PCB configurations violate the maximum component body temperature according to existing IPC/JEDEC STD 020 and JEITA ED 4701/301A, while attempting to meet minimum solder joint temperature/time requirements
- Compare time and temperature values on various components for different board complexities

IPC-JEDEC STD 020B Component Classification Specification

Table 5-2 Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly		Pb-Free Assembly	
	Large Body	Small Body	Large Body	Small Body
Average ramp-up rate (T_L to Tp)	3°C/second max.		3°C/second max.	
Preheat – Temperature Min (Ts_{min}) – Temperature Max (Ts_{max}) – Time (min to max) (ts)	100°C 150°C 60-120 seconds		150°C 200°C 60-180 seconds	
Tsmax to T_L – Ramp-up Rate			3°C/second max	
Time maintained above: – Temperature (T_L) – Time (t_L)	183°C 60-150 seconds		217°C 60-150 seconds	
Peak Temperature (Tp)	225 +0/-5°C	240 +0/-5°C	245 +0/-5°C	250 +0/-5°C
Time within 5°C of actual Peak Temperature (tp)	10-30 seconds	10-30 seconds	10-30 seconds	20-40 seconds
Ramp-down Rate	6°C/second max.		6°C/second max.	
Time 25°C to Peak Temperature	6 minutes max.		8 minutes max.	

Note: All temperatures refer to topside of the package, measured on the package body surface.

Reflow Conditions	Pkg. Thickness ≥2.5 mm or Pkg. Volume ≥350 mm^3	Pkg. Thickness <2.5 mm and Pkg. Volume <350 mm^3

JEITA ED-4701/301A Component Classification Specification

- Component Classification Temp

Thickness	Volume (mm3)		
	<350	350-2000	>2000
<1.6	260C	260C	260C
1.6-2.5	260C	250C	245C
>2.5	245C	245C	245C

Table taken from ED-4701/301A

Paste Manufacturer Reflow Profile Recommendations

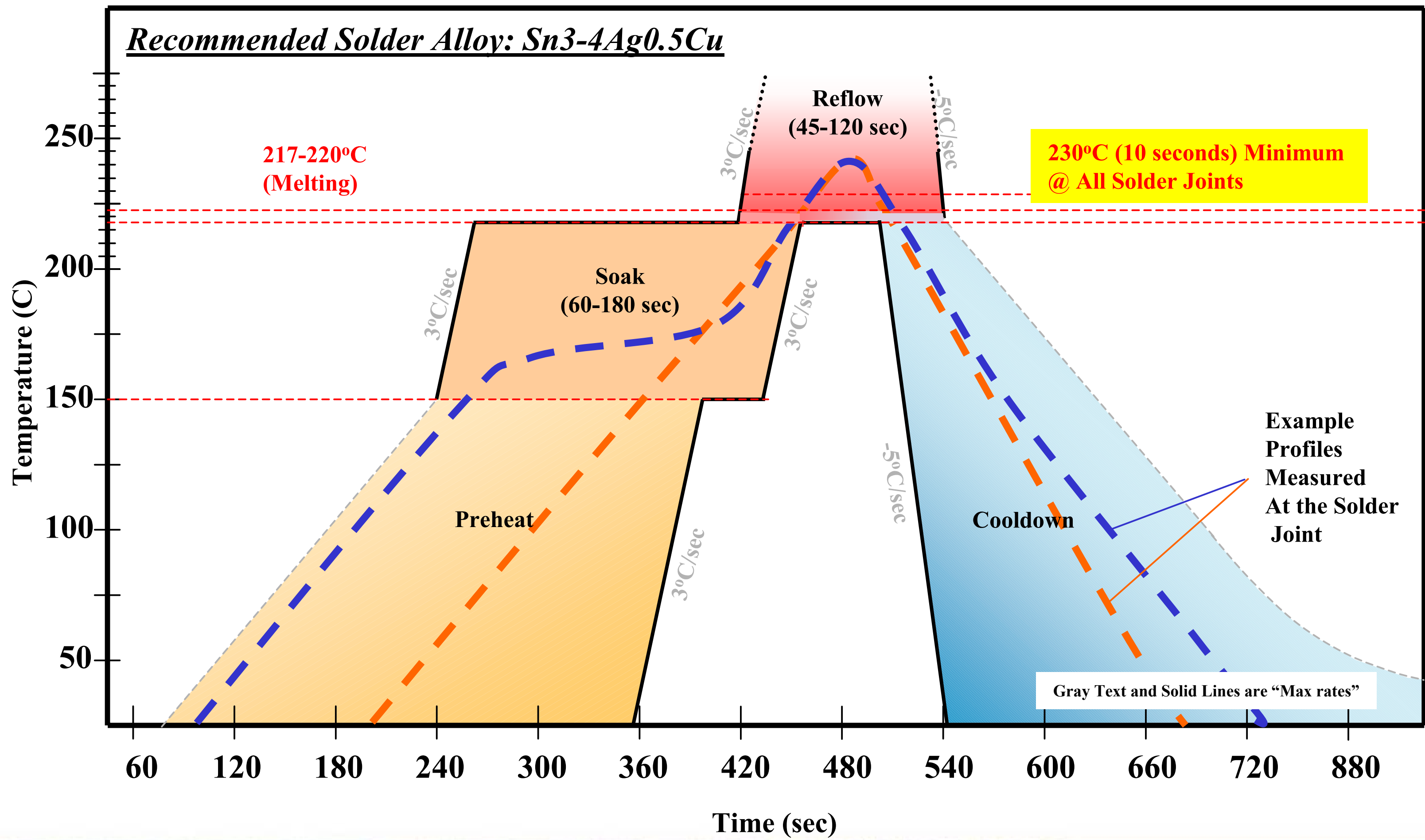
- Reflow specifications of two leading paste suppliers

Paste MFG	Ramp (C/sec)	Time >217C (sec)	Peak Temperature (T)
MFG-1	1-2	35-80	230 –240
MFG-2	0.5-2	30-70	238-248
Low-High Range	0.5-2	30-80	230-248

Yellow box indicates the combined reflow specification range.

Jabil Reflow Profile Specification

- Combines component package qualification requirements and paste specifications to establish a wide process window

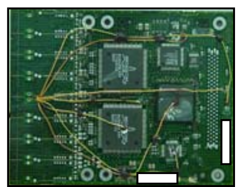


General Procedure

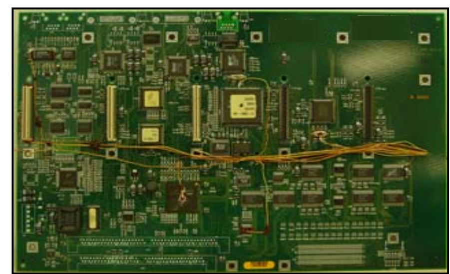
- Select test PCBA’s categorized as small, medium, and large which represent average to high complexity component mix and layout densities.
- Select high risk areas (hot and cold spots) to attach thermocouples.
- Develop reflow profiles for each board complexity.
- Compare results against IPC-JEDEC J-STD-020B and JEITA Comp. Specifications.
- Modify reflow profiles to achieve optimal package and solder paste requirements.
- Summarize findings.

Project Details

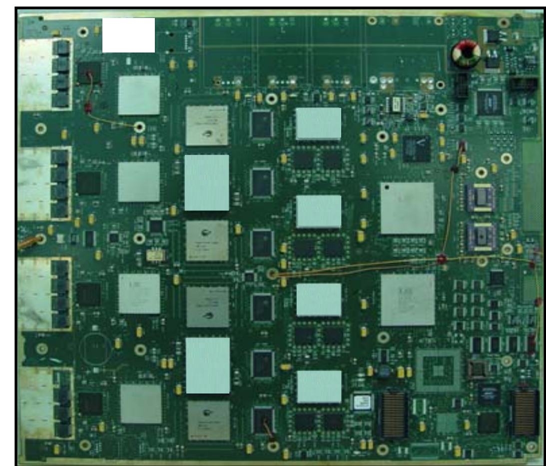
- Thermal Profiler
  - 9 Channel Profiler
- Reflow Oven
  - 10 Zone Oven
- Test PCBAs



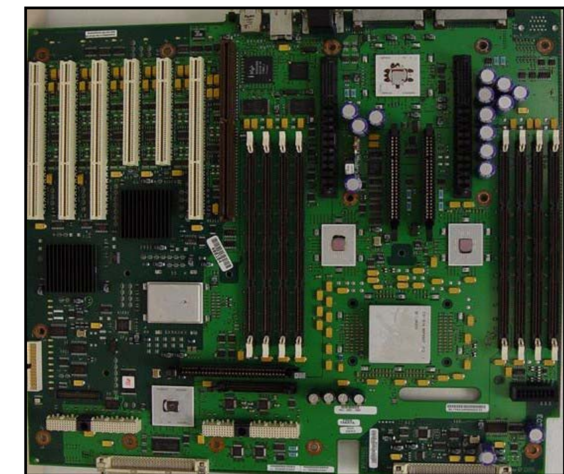
PCBA-A
6 x 4.6 x 0.093"



PCBA-B 13.4 x 8.7 x 0.062"



PCBA-C: 14.4 x 15.7 x 0.093"

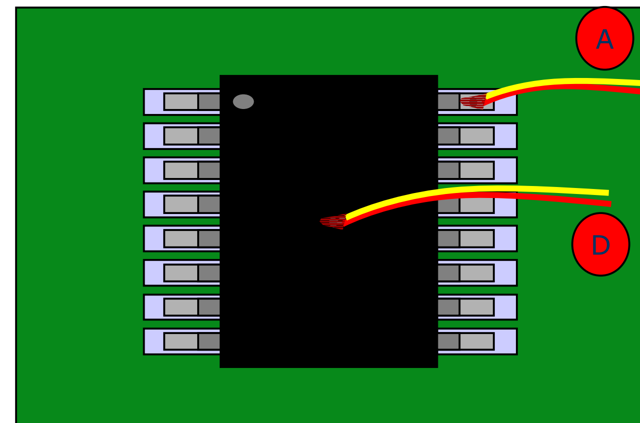


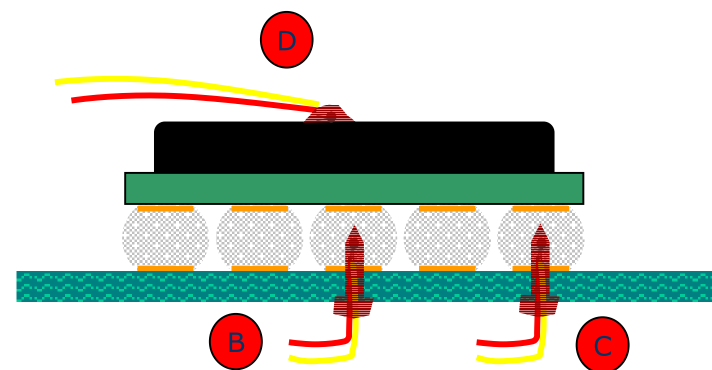
PCBA-D: 14.25 x 16.25 x 0.110"

Note :All PCBAs used in this study were Jabil MRB and customer donated non repairable products.

Thermo-Couple Attachment Method

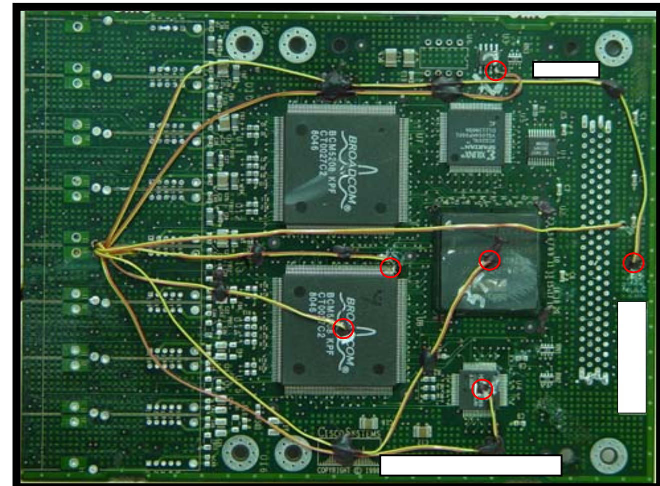
- Select hot spot (package body) and cold spot (solder joint) locations on PCBA
- Attach thermo-couples:
  - For leaded devices: Attach thermo-couple at solderjoint using high temp solder location A, and on top of component body using epoxy.
  - For Array Packages: Drill a ~30mil hole to approximate center of solderjoint. Apply epoxy in and around the hole, insert TC into hole.
    - Location A- foot of component lead
    - Location B- center of package
    - Location C- perimeter of package
    - Location D- top of component

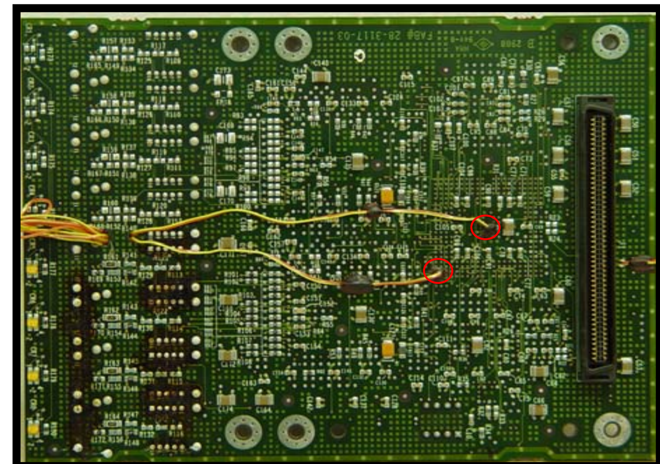




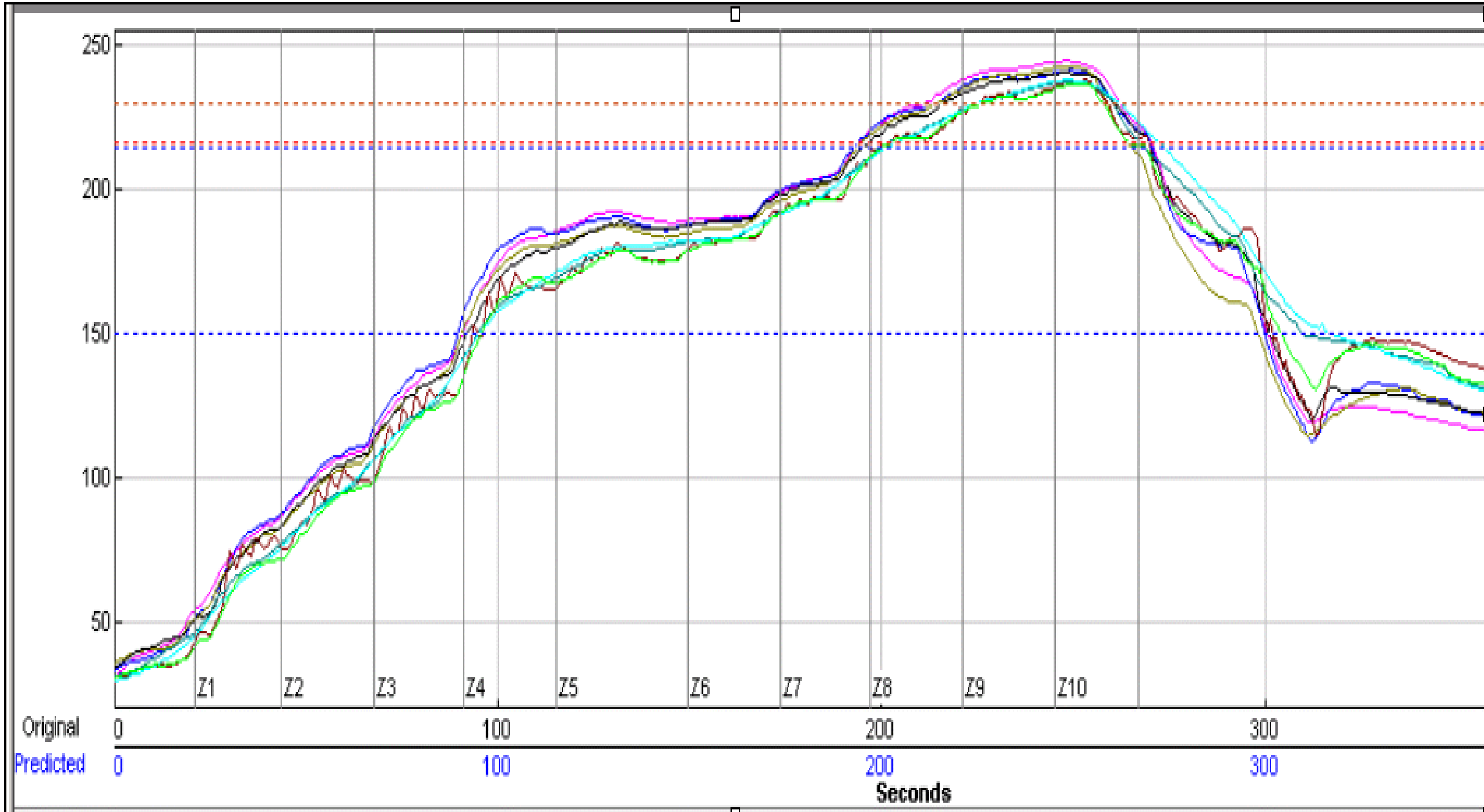
PCBA-A: Board Details & TC Attachment

- Board S/N: PCBA – A
- Length: 6 in.
- Width: 4.6 in.
- Thickness: 0.093 in.
- Targeted TC Locations:
  - TC1: Top of Cap
  - TC2: Top of QFP
  - TC3: Top of BGA
  - TC4: Lead SO8
  - TC5: Lead QFP
  - TC6: Corner Joint BGA
  - TC7: Center joint BGA
  - TC8: Top of QFP





PCBA-A: Reflow Profile (1st Attempt)



Belt Speed: 35 in/min

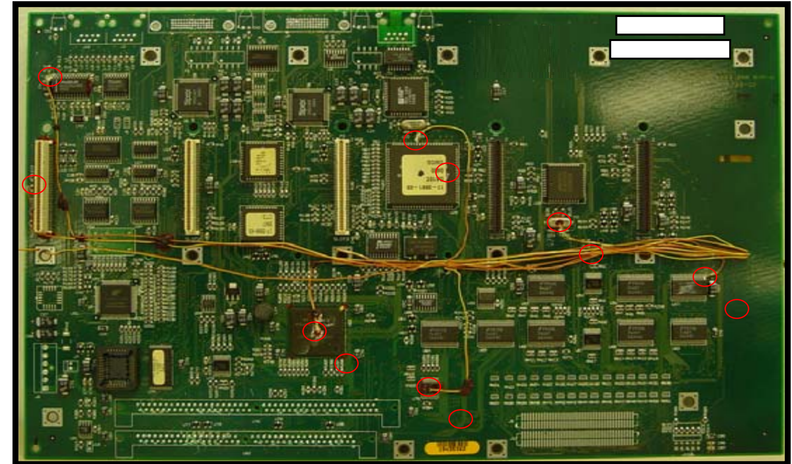
PCBA-A: Reflow Profile Parameters (1st Attempt)

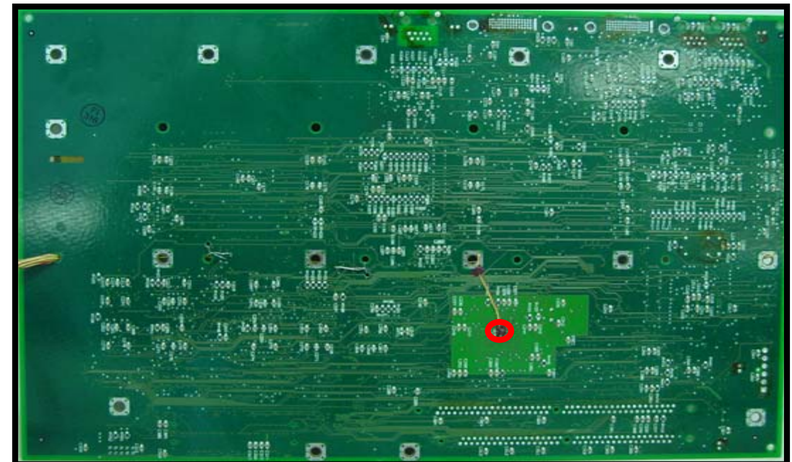
TC No.	Package Descript.	Package Dimension		Time >217C (sec)	Time >230C	Peak Temp (C)	Package Body Temp (C)	
		Volume (mm^3)	Thickness (mm)	P.MFG: 30-80 -SJ J-std: 60-150-Pkg JBL: 45-120-SJ	min. 10sec		020B	020C
TC 1	Top of Cap	805 Cap	0.6	76.5	51.9	245.5	250	260
TC 2	Top of QFP	1021.0	1.0	76.6	47.0	241.9	250	260
TC 3	Top of BGA	1057.0	2.0	69.3	45.2	243.2	245	250
TC 4	Lead SO8	32.4	1.6	72.9	45.4	241.6	-	-
TC 5	Lead QFP	2979.5	3.9	67.4	34.9	238.8	-	-
TC 6	Corner Joint BGA	1057.0	2.0	64.9	36.2	238.5	-	-
TC 7	Center joint BGA	1057.0	2.0	67.5	38.0	238.6	-	-
TC 8	Top of QFP	2236.0	2.0	61.7	32.8	237.3	245	245

Yellow boxes indicate TC attachment on package body.

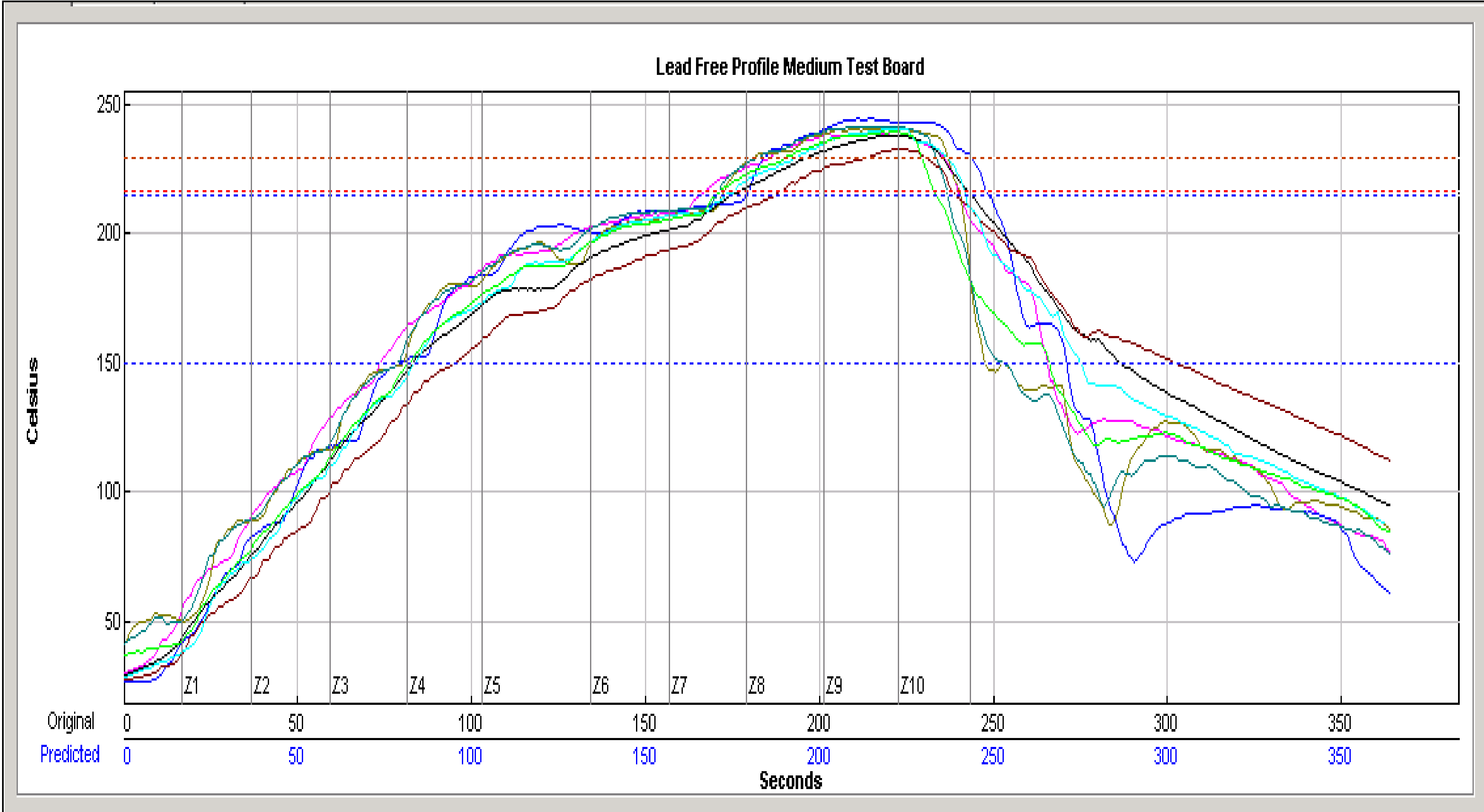
PCBA-B: Board Details & TC Attachment

- Board S/N: PCBA – B
- Length: 13.4 in.
- Width: 8.7 in.
- Thickness: 0.062 in.
- Targeted TC Locations:
  - TC1: Top SOIC 24
  - TC2: Connector Body
  - TC3: Top BGA
  - TC4: Center Joint BGA
  - TC5: Joint PLCC 84
  - TC6: Top SOIC 40
  - TC7: Lead SOIC 48
  - TC8: Lead SOIC 24





PCBA-B: Reflow Profile (1st Attempt)



Belt Speed: 36 in/min

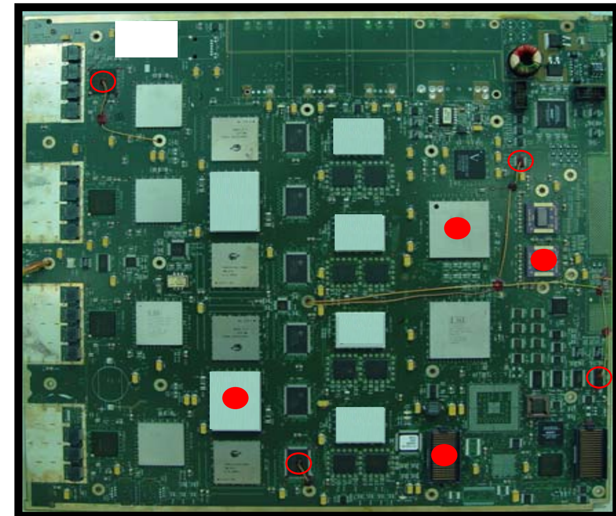
PCBA-B: Reflow Profile Parameters (1st Attempt)

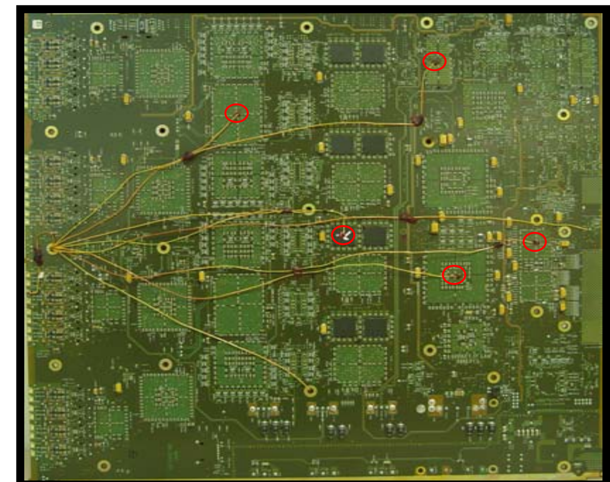
TC No.	Package Descript.	Package Dimension		Time >217C (sec)	Time >230C	Peak Temp (C)	Package Body Temp (C)	
		Volume (mm^3)	Thickness (mm)	P.MFG: 30-80 -SJ J-std: 60-150-Pkg JBL: 45-120-SJ	min. 10sec		020B	020C
TC 1	Top SOIC 24	256.5	2.4	75.5	51.4	241.9	250	260
TC 2	Connector Body	1400	3.7	77.9	59.2	245.6	245	245
TC 3	Top BGA	750	1.2	72.7	49.9	242.7	245	260
TC 4	Center Joint BGA	750	1.2	74.8	45.9	240.4	-	-
TC 5	Joint PLCC 84	3841.3	4.0	63.9	27.7	235.4	-	-
TC 6	Top SOIC 40	25.74	0.9	71.4	51.5	243.7	250	260
TC 7	Lead SOIC 48	302.0	2.4	74.6	48.8	243.0	-	-
TC 8	Lead SOIC 24	256.5	2.4	74.7	52.6	244.3	-	-

Yellow boxes indicate TC attachment on package body.

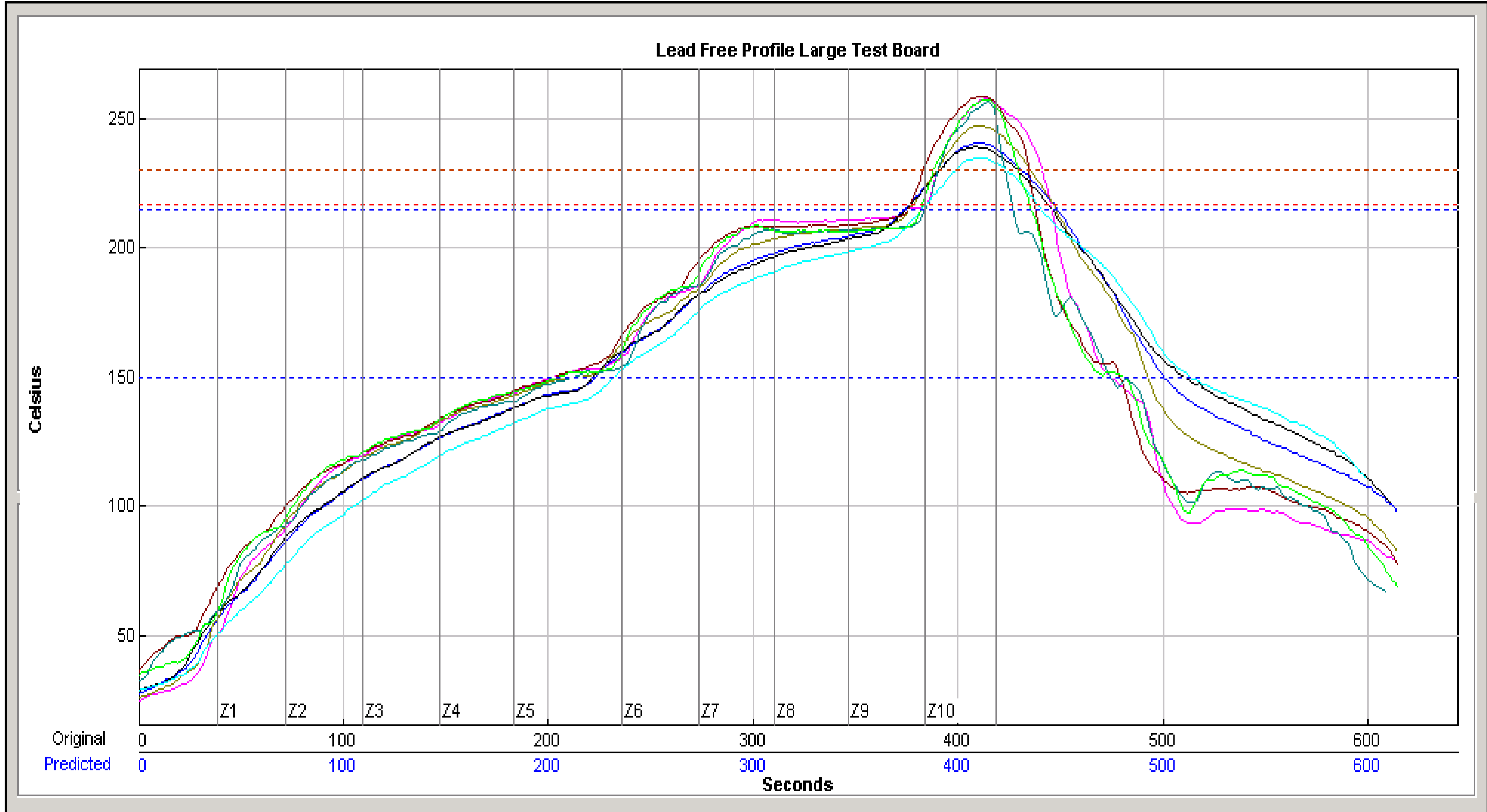
PCBA-C: Board Details & TC Attachment

- Board S/N: PCBA – C
- Length: 15.7 in.
- Width: 14.4 in.
- Thickness: 0.093 in.
- Targeted TC Locations:
  - TC1: Top of SOIC 48
  - TC2: Center Joint CBGA
  - TC3: Center Joint BGA Socket
  - TC4: Center Joint BGA
  - TC5: Top of SOIC 40
  - TC6: Top of BGA
  - TC7: Center Joint CCGA
  - TC8: Top of QFP





PCBA-C: Reflow Profile (1st Attempt)



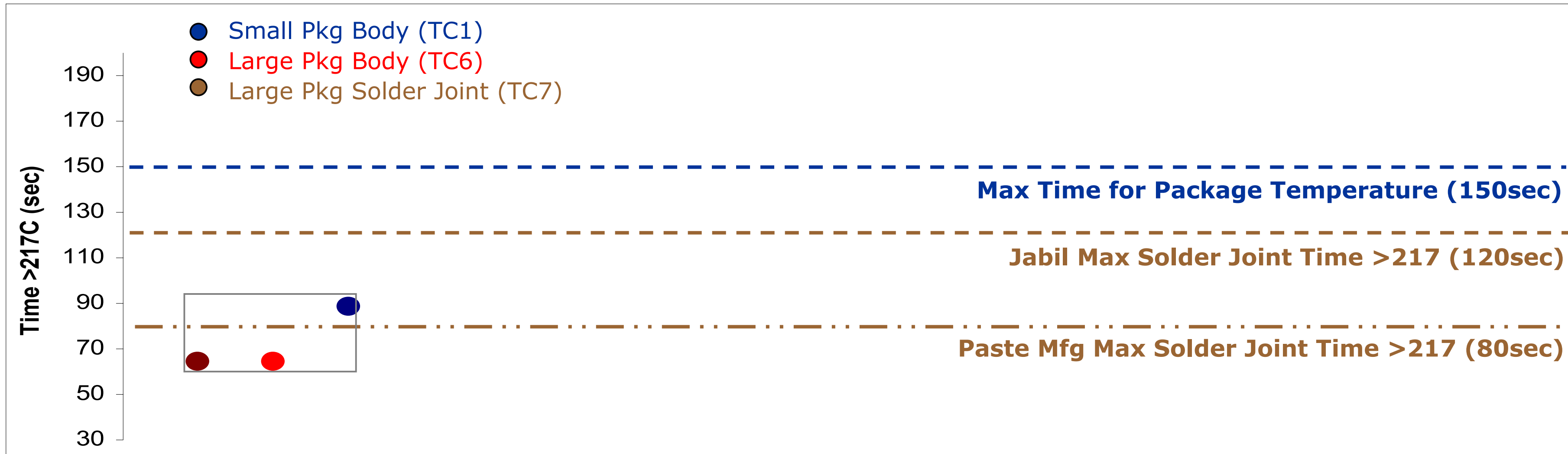
Belt Speed: 24 in/min

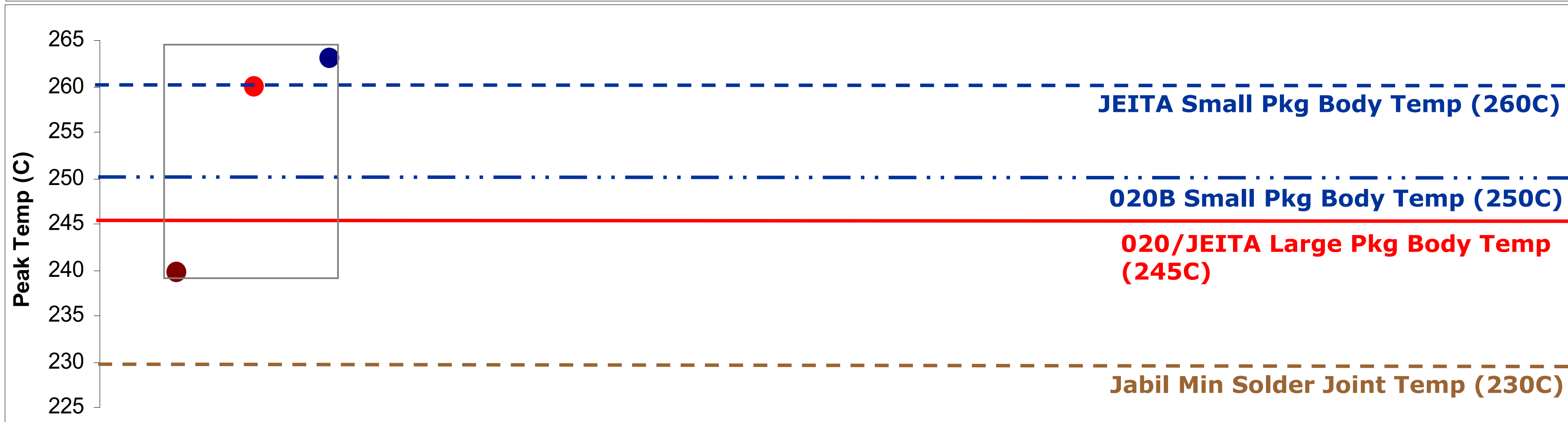
PCBA-C: Reflow Profile Parameters (1st Attempt)

TC No.	Package Descript.	Package Dimension		Time >217C (sec)	Time >230C	Peak Temp (C)	Package Body Temp (C)	
		Volume (mm^3)	Thickness (mm)	P.MFG: 30-80 -SJ J-std: 60-150-Pkg JBL: 45-120-SJ	min. 10sec		020B	020C
TC 1	Top of SOIC 48	91.2	0.9	88.4	62.7	263.2	250	260
TC 2	Center Joint CBGA	2226.4	4.6	84.1	52.1	245.9	-	-
TC 3	Center Joint BGA	4371.2	5.3	85.8	54.3	252.3	-	-
TC 4	Center Joint BGA	3763.8	2.3	78.0	48.7	243.8	-	-
TC 5	Top of SOIC 20	25.74	0.9	83.6	53.7	263.0	250	260
TC 6	Top of BGA	650.4	1.9	63.6	34.9	259.9	245	250
TC 7	Center Joint CCGA	8877.3	6.4	64.5	35.6	239.7	-	-
TC 8	Top of QFP	402.5	1.5	75.7	44.7	260.9	245	260

Yellow boxes: TC attachment on package body.
Red text: Package body temperature violation.

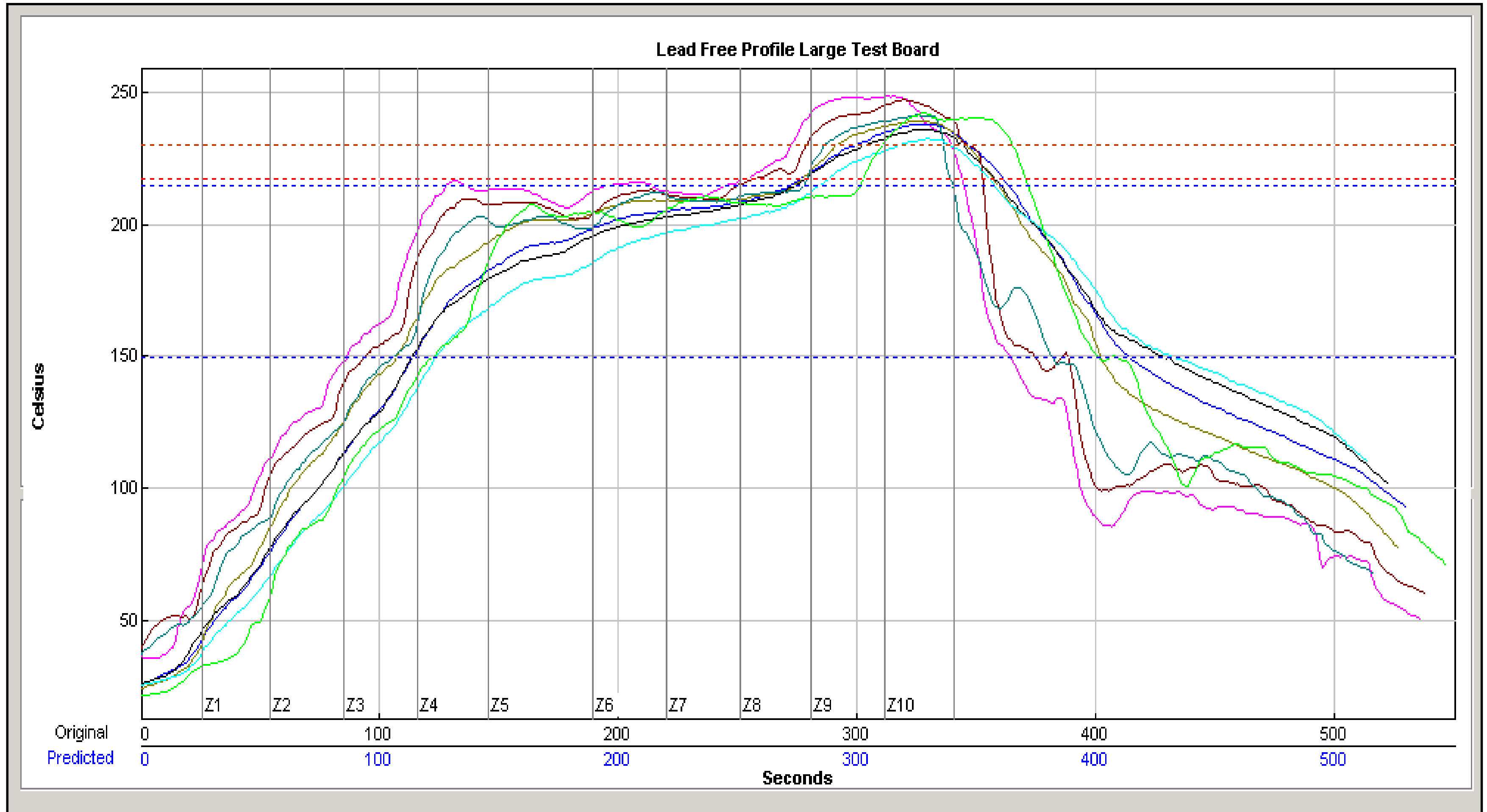
PCBA-C: Reflow Parameters Comparison (1st Attempt)





1st Attempt

PCBA-C: Reflow Profile (14th Attempt)



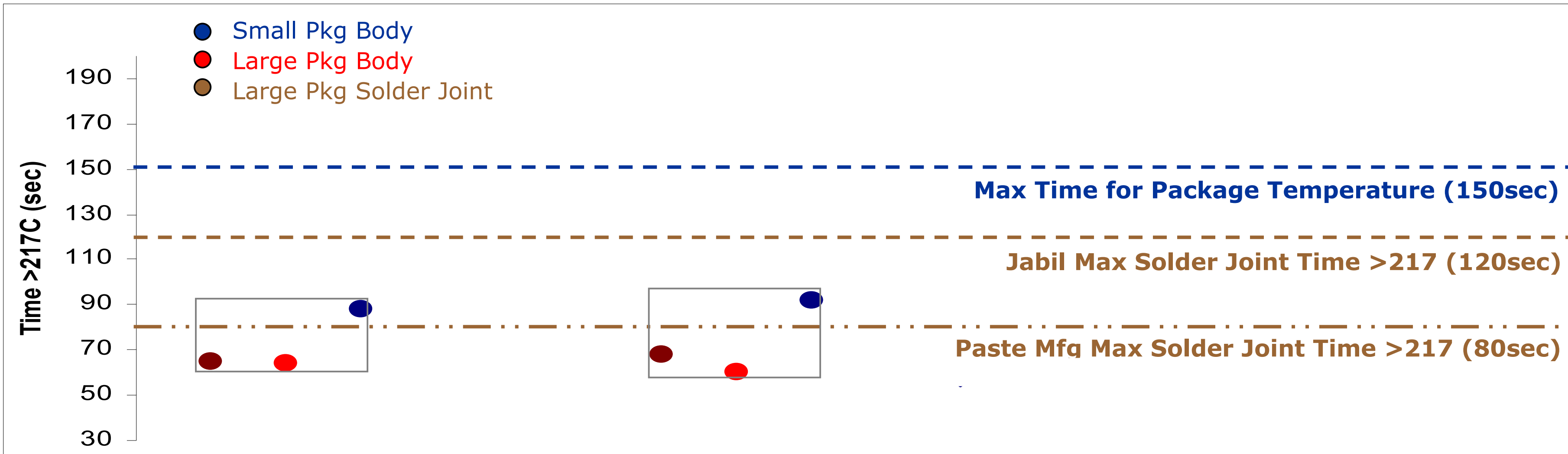
Belt Speed: 27 in/min

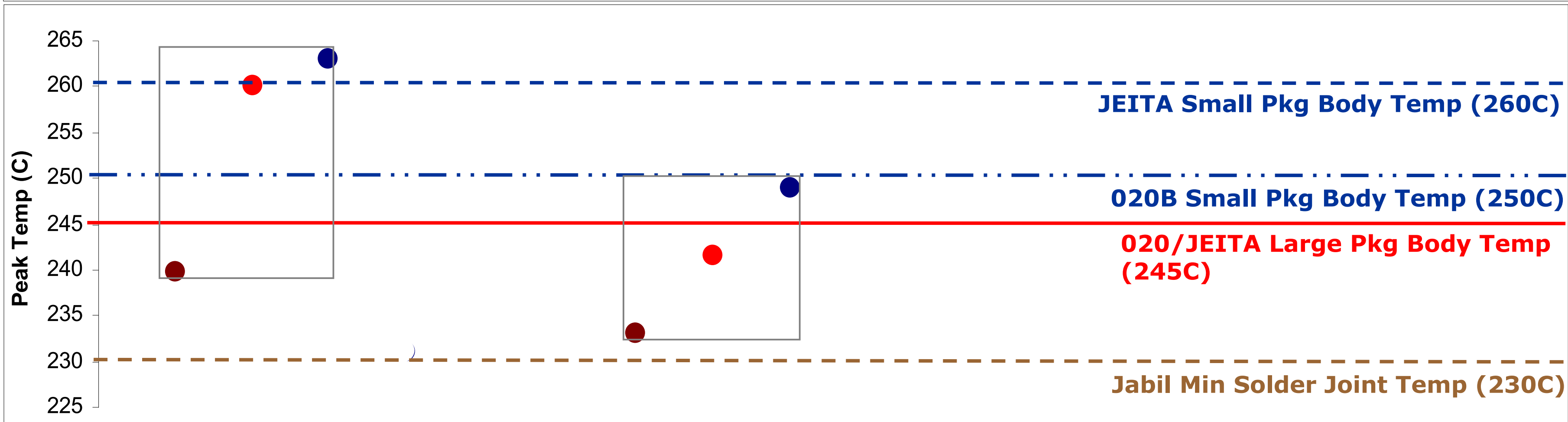
PCBA-C: Reflow Profile Parameters (14th Attempt)

TC No.	Package Descript.	Package Dimension		Time >217C (sec)	Time >230C	Peak Temp (C)	Package Body Temp (C)	
		Volume (mm^3)	Thickness (mm)	P.MFG: 30-80 -SJ J-std: 60-150-Pkg JBL: 45-120-SJ	min. 10sec		020B	020C
TC 1	Top of SOIC 48	91.2	0.9	92.3	67.2	248.9	250	260
TC 2	Center Joint CBGA	2226.4	4.6	86.1	47.7	238.0	-	-
TC 3	Center Joint BGA	4371.2	5.33	80.6	54.3	239.3	-	-
TC 4	Center Joint BGA	3763.8	2.25	81	40.7	236.0	-	-
TC 5	Top of SOIC 20	25.74	0.9	97.1	68.6	247.4	250	260
TC 6	Top of BGA	650.4	1.9	60.4	49.8	241.6	245	250
TC 7	Center Joint CCGA	8877.3	6.43	67.8	20.8	232.6	-	-
TC 8	Top of QFP	402.5	1.5	68.3	54.9	242.4	245	260

Yellow boxes: TC attachment on package body.
Red text: Package body temperature violation.

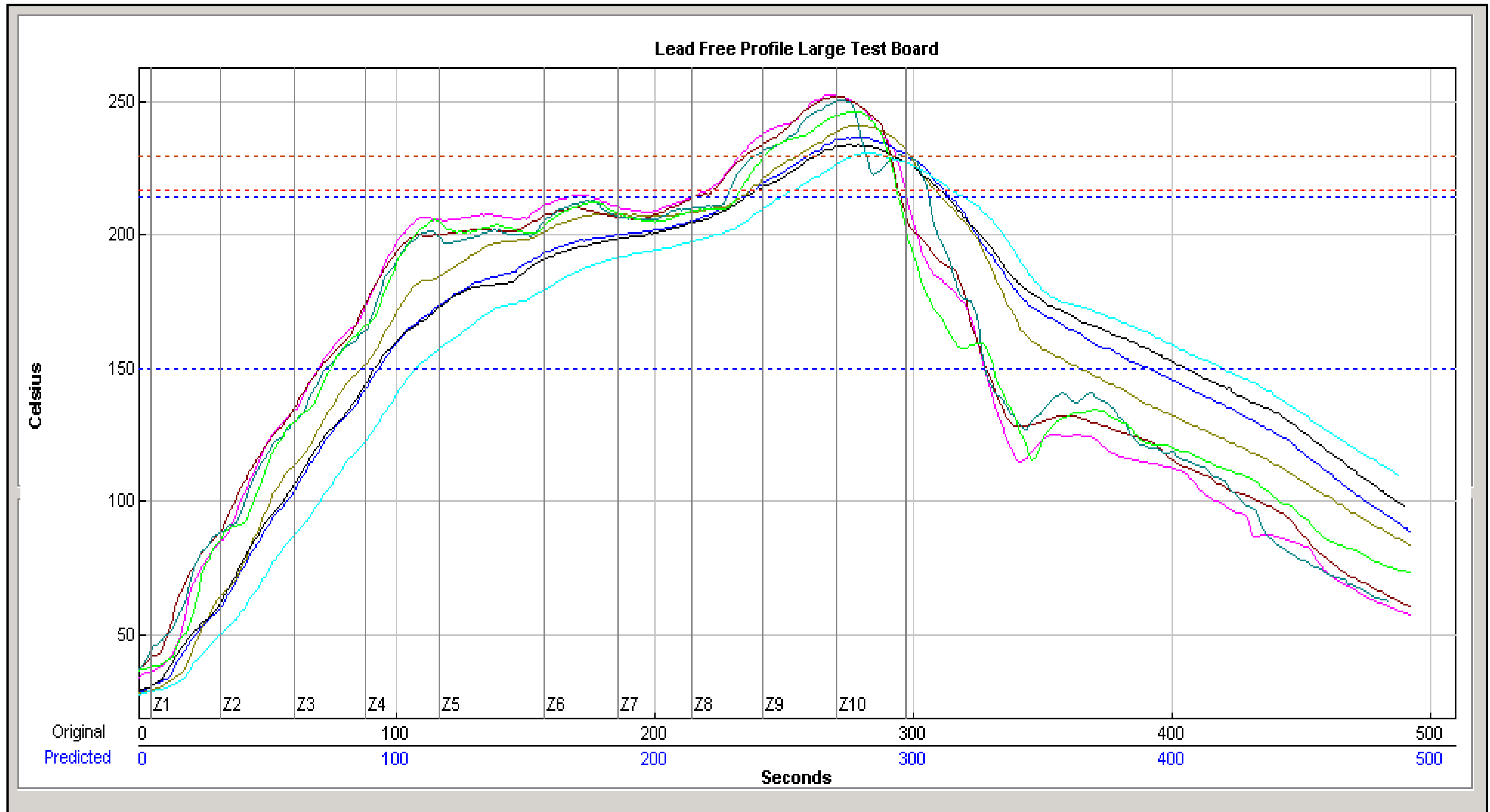
PCBA-C: Reflow Parameters Comparison (14th Attempt)





1st Attempt 14th Attempt

PCBA-C: Reflow Profile (32nd Attempt)



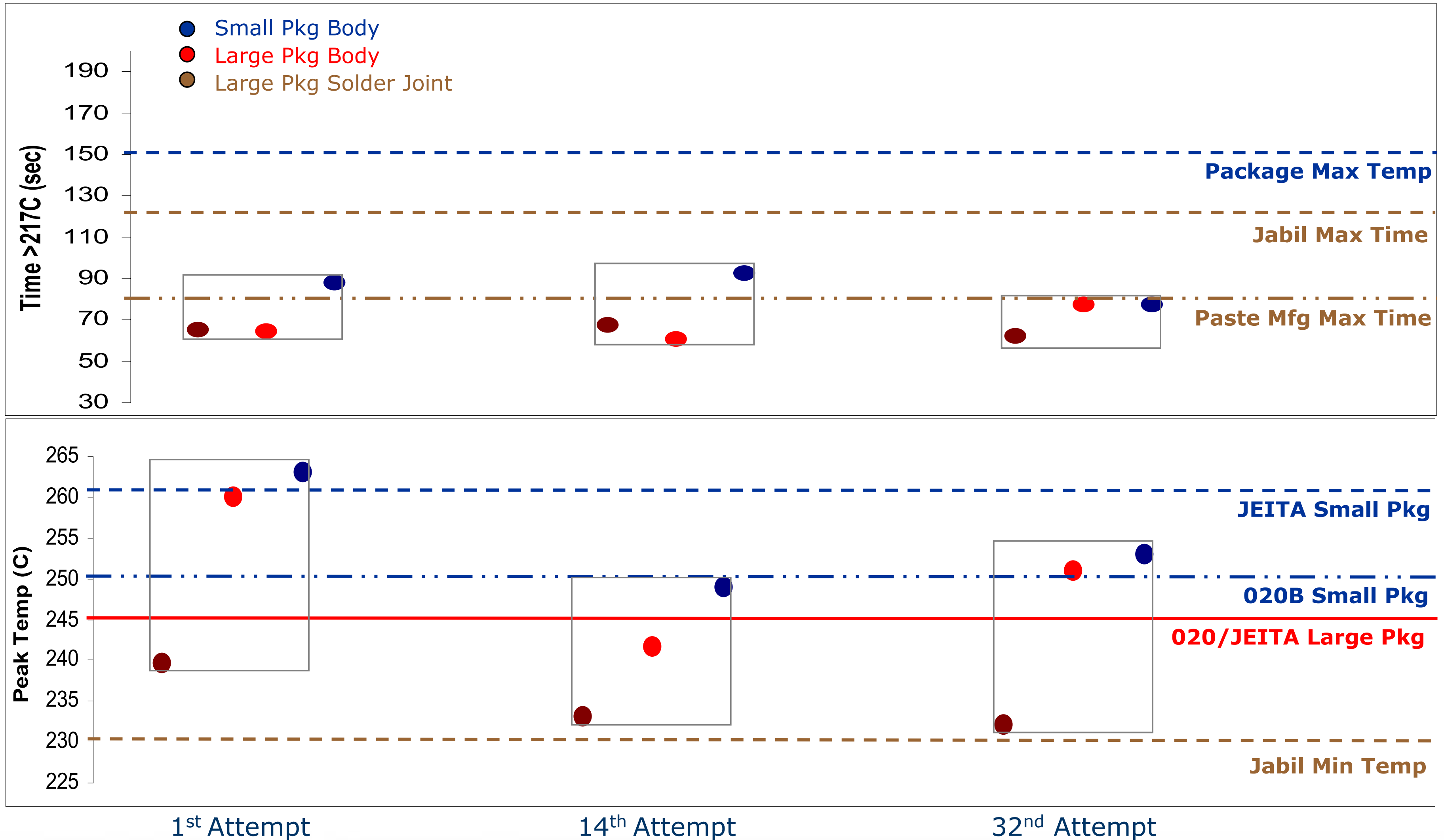
Belt Speed: 32 in/min

PCBA-C: Reflow Profile Parameters (32nd Attempt)

TC No.	Package Descript.	Package Dimension		Time >217C (sec)	Time >230C	Peak Temp (C)	Package Body Temp (C)	
		Volume (mm^3)	Thickness (mm)	P.MFG: 30-80 -SJ J-std: 60-150-Pkg JBL: 45-120-SJ	min. 10sec		020B	020C
TC 1	Top of SOIC 48	91.2	0.9	76.9	60.9	252.9	250	260
TC 2	Center Joint CBGA	2226.4	4.6	74.7	38.5	237.1	-	-
TC 3	Center Joint BGA	4371.2	5.33	72.3	43.8	242.0	-	-
TC 4	Center Joint BGA	3763.8	2.25	71.7	30.1	234.5	-	-
TC 5	Top of SOIC 20	25.74	0.9	72.0	56.3	252.5	250	260
TC 6	Top of BGA	650.4	1.9	76.5	46.8	251.3	245	250
TC 7	Center Joint CCGA	8877.3	6.43	62.0	12.6	231.5	-	-
TC 8	Top of QFP	402.5	1.5	61.0	48.2	246.8	245	260

Yellow boxes: TC attachment on package body.
Red text: Package body temperature violation.

PCBA-C: Reflow Parameters Comparison (32nd Attempt)



PCBA-C Package Temp Analysis Summary

- Optimal Reflow Profile for Package Peak Temp: Attempt 21
- Specification Analysis Breakdown
  - J-Std 020B Analysis

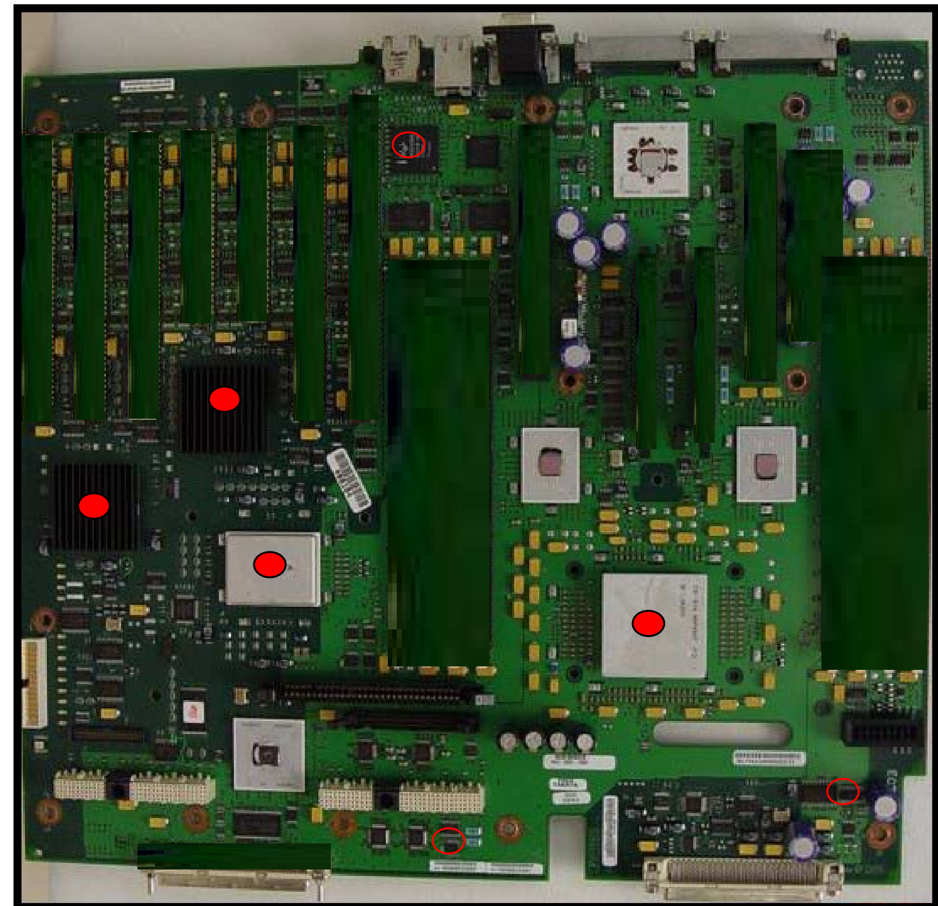
Volume (mm3)	
<350	>350
250C	245C

  - JEITA ED-4701/301A

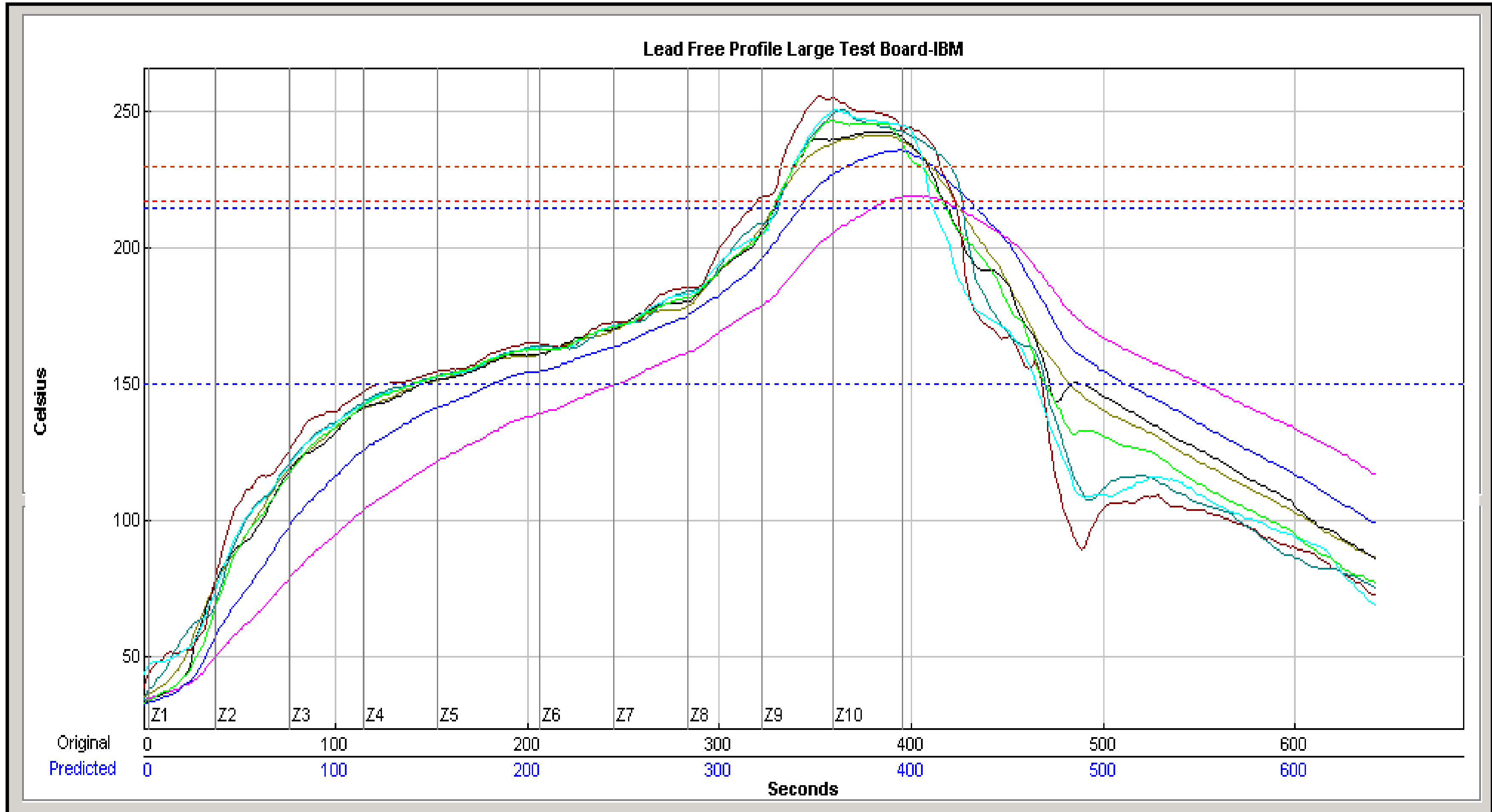
Thickness	Volume (mm3)		
	<350	350-2000	>2000
<1.6	260C	260C	260C
1.6-2.5	260C	250C	245C
>2.5	245C	245C	245C

PCBA-D: Board Details & TC Attachment

- Board S/N: PCBA–D
- Length: 16.25 in.
- Width: 14.25 in.
- Thickness: 0.110 in.
- Targeted TC Locations:
  - TC1: Center Joint CCGA Large
  - TC2: Center Joint CCGA MED
  - TC3: Center Joint BGA
  - TC4: Top of BGA
  - TC5: Top of LED
  - TC6: Top of SOIC 24
  - TC7: Lead PLCC 28
  - TC8: Top of BGA



PCBA-D: Reflow Profile (1st Attempt)



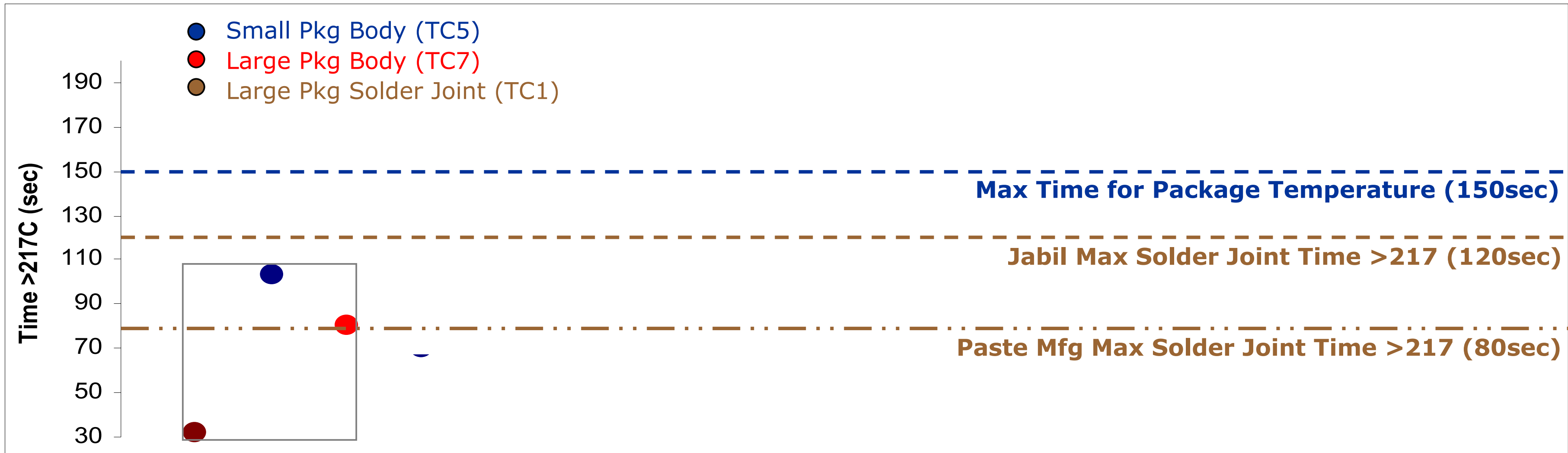
Belt Speed: 23 in/min

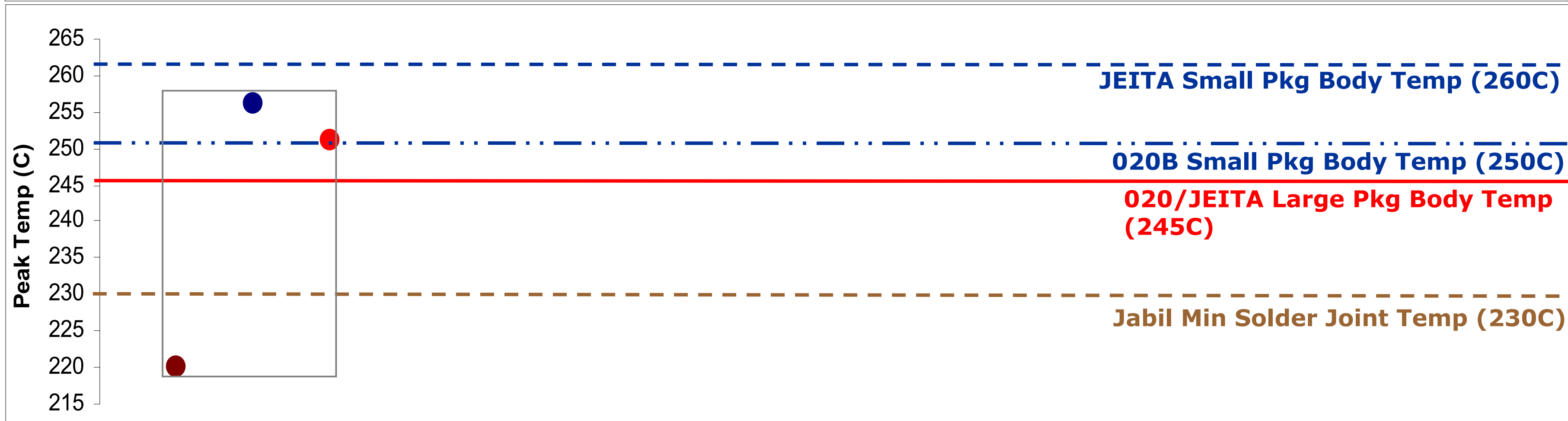
PCBA-D: Reflow Profile Parameters (1st Attempt)

TC No.	Package Descript.	Package Dimension		Time >217C (sec)	Time >230C	Peak Temp (C)	Package Body Temp (C)	
		Volume (mm^3)	Thickness (mm)	P.MFG: 30-80 -SJ J-std: 60-150-Pkg JBL: 45-120-SJ	min. 10sec		020B	020C
TC 1	Center Joint CCGA	9522.4	5.1	31.1	0.0	219.3	-	-
TC 2	Center Joint CCGA	4725.0	3.0	87.3	45.1	236.2	-	-
TC 3	Center Joint BGA	2643.8	1.9	93.5	68.8	241.7	-	-
TC 4	Top of BGA	2643.8	1.9	87.2	70.1	243.2	245	245
TC 5	Top of LED	17.7	0.8	103.6	83.3	255.8	250	260
TC 6	Top of SOIC 24	256.5	2.4	94.7	82.4	251.0	250	260
TC 7	Top of PLCC 28	435.6	3.6	80.0	67.8	250.7	245	245
TC 8	Top of BGA	410.1	0.9	87.2	65.9	247.1	245	260

Yellow boxes: TC attachment on package body.
Red text: Package body temperature violation.

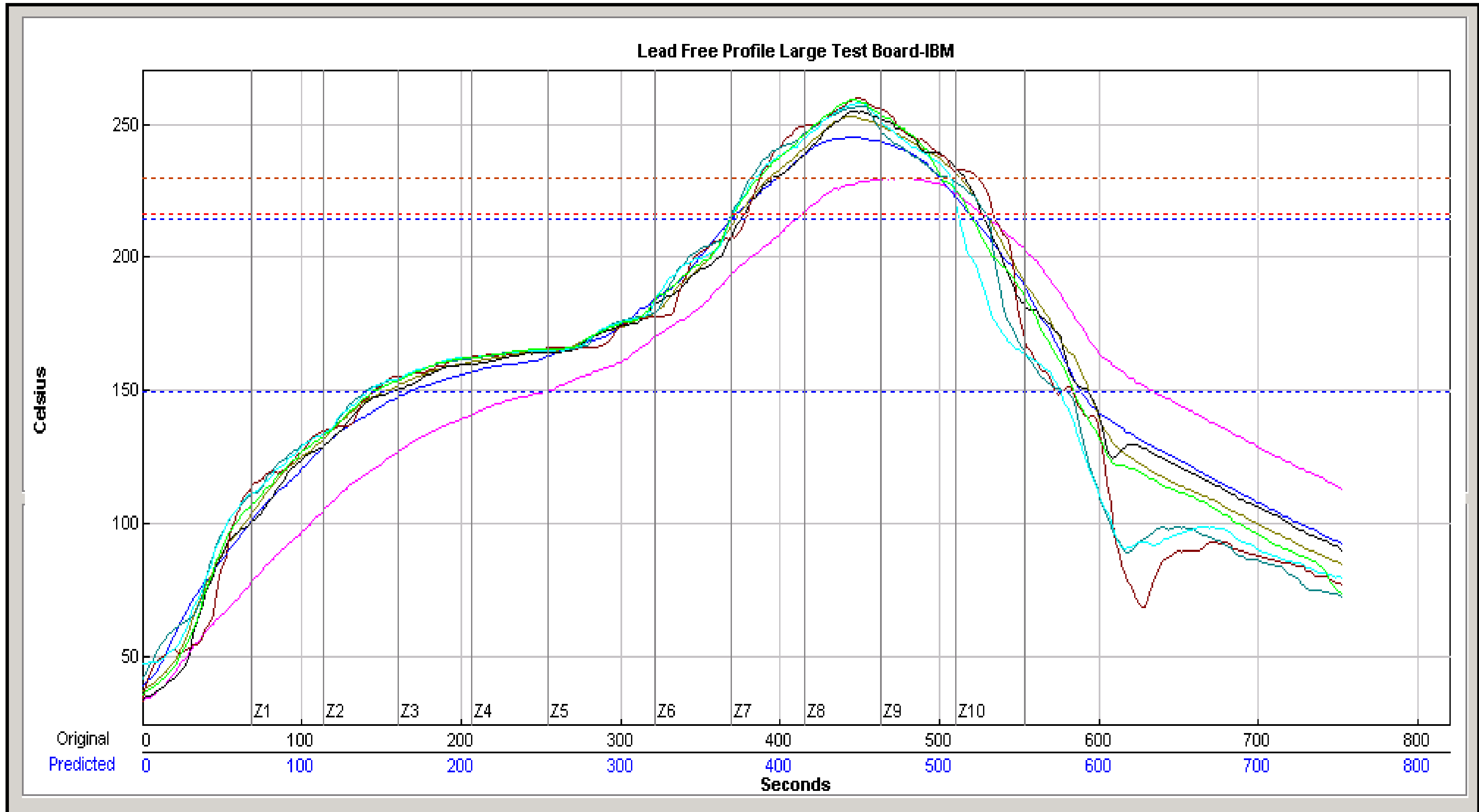
PCBA-D: Reflow Parameters Comparison (1st Attempt)





1st Attempt

PCBA-D: Reflow Profile (14th Attempt)



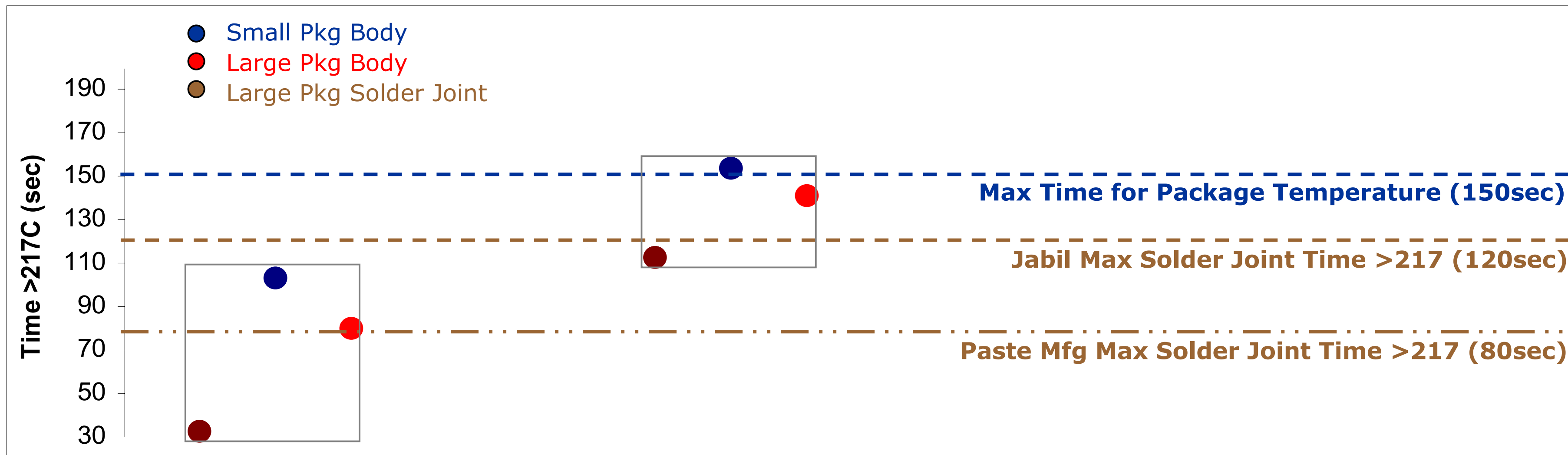
Belt Speed: 18 in/min

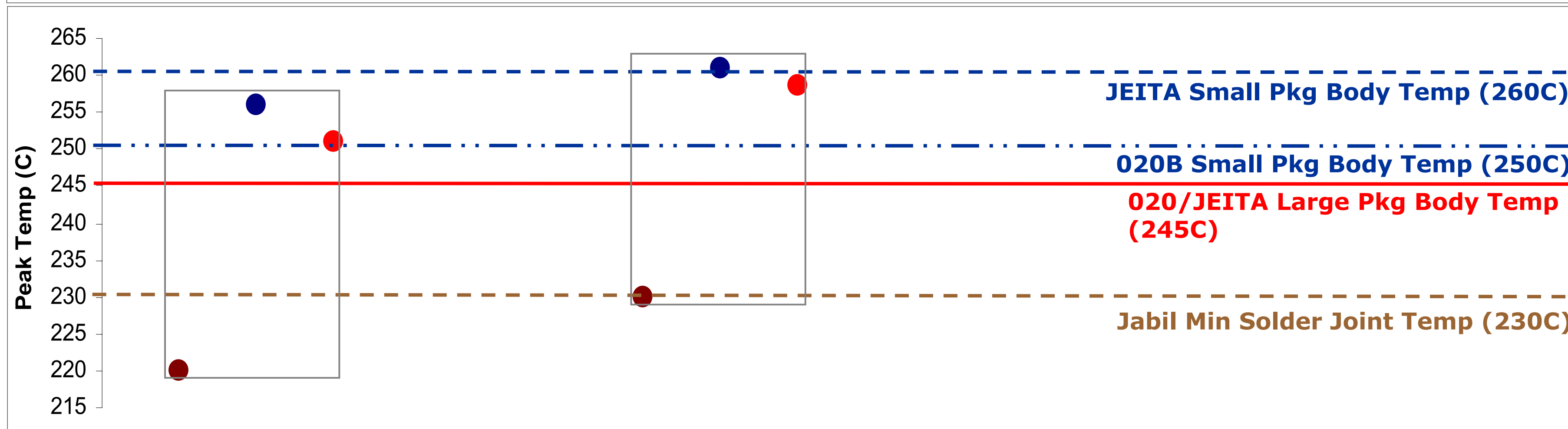
PCBA-D: Reflow Profile Parameters (14th Attempt)

TC No.	Package Descript.	Package Dimension		Time >217C (sec)	Time >230C	Peak Temp (C)	Package Body Temp (C)	
		Volume (mm^3)	Thickness (mm)	P.MFG: 30-80 -SJ J-std: 60-150-Pkg JBL: 45-120-SJ	min. 10sec		020B	020C
TC 1	Center Joint CCGA	9522.4	5.1	112.2	14.8	230.4	-	-
TC 2	Center Joint CCGA	4725.0	3.0	145.6	103.3	245.8	-	-
TC 3	Center Joint BGA	2643.8	1.9	154.3	121.1	253.4	-	-
TC 4	Top of BGA	2643.8	1.9	148.8	120.8	255.6	245	245
TC 5	Top of LED	17.7	0.8	153.7	137.8	260.8	250	260
TC 6	Top of SOIC 24	256.5	2.4	159	124.5	257.4	250	260
TC 7	Top of PLCC 28	435.6	3.6	141.1	123.4	258.6	245	245
TC 8	Top of BGA	410.1	0.9	147.4	115.3	259.9	245	260

Yellow boxes: TC attachment on package body.
Red text: Package body temperature violation.

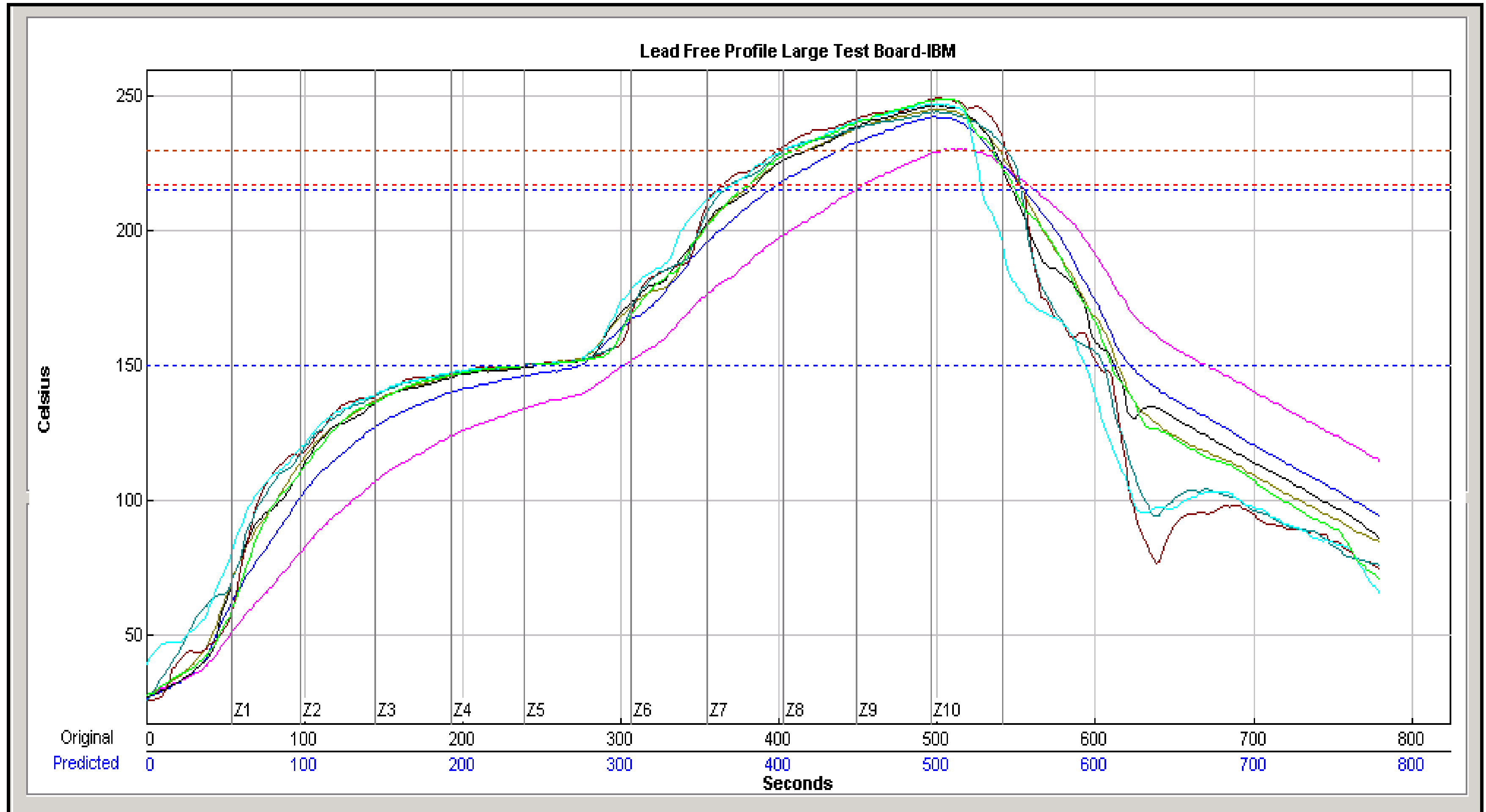
PCBA-D: Reflow Parameters Comparison (14th Attempt)





1st Attempt 14th Attempt

PCBA-D: Reflow Profile (21st Attempt)



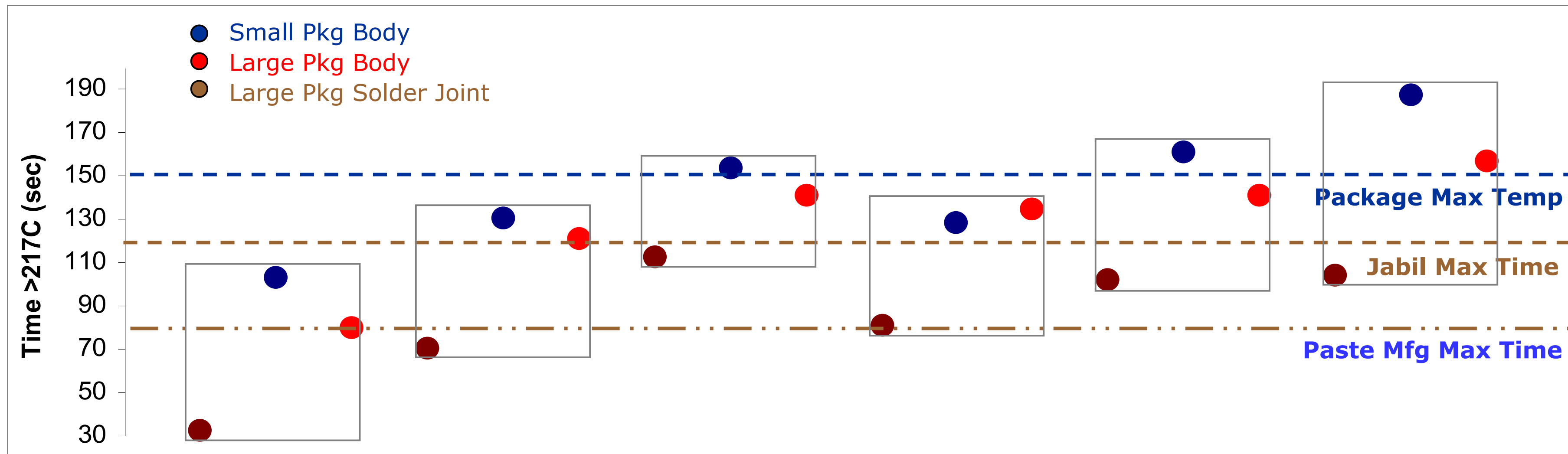
Belt Speed: 18 in/min

PCBA-D: Reflow Profile Parameters (21st Attempt)

TC No.	Package Descript.	Package Dimension		Time >217C (sec)	Time >230C	Peak Temp (C)	Package Body Temp (C)	
		Volume (mm^3)	Thickness (mm)	P.MFG: 30-80 -SJ J-std: 60-150-Pkg JBL: 45-120-SJ	min. 10sec		020B	020C
TC 1	Center Joint CCGA	9522.4	5.1	104.2	12.9	230.4	-	-
TC 2	Center Joint CCGA	4725.0	3.0	153.6	94	242.2	-	-
TC 3	Center Joint BGA	2643.8	1.9	170.1	120.2	245.1	-	-
TC 4	Top of BGA	2643.8	1.9	161.2	115.9	246.6	245	245
TC 5	Top of LED	17.7	0.8	187.1	144.4	249.3	250	260
TC 6	Top of SOIC 24	256.5	2.4	183.1	138.4	244.1	250	260
TC 7	Top of PLCC 28	435.6	3.6	157.2	120.4	247.0	245	245
TC 8	Top of BGA	410.1	0.9	167.3	125.9	249.1	245	260

Yellow boxes indicate TC attachment on package body.

PCBA-D: Reflow Parameters Comparison (21st Attempt)



Peak Temp (C)
265
260
255
250
245
240
235
230
225
220
215
JEITA Small Pkg
020B Small Pkg
020/JEITA Large Pkg
Jabil Min Temp

1st Attempt
14th Attempt
21st Attempt

PCBA-D: Package Temp Analysis Summary

- Optimal Reflow Profile for Package Peak Temp: Attempt 21
- Specification Analysis Breakdown
  - J-Std 020B Analysis

Volume (mm3)	
<350	>350
250C	245C

  - JEITA ED-4701/301A

Thickness	Volume (mm3)		
	<350	350-2000	>2000
<1.6	260C	260C	260C
1.6-2.5	260C	250C	245C
>2.5	245C	245C	245C

Results Summary

- Board A Package Summary
  - IPC-JEDEC J-STD 020B
    - Monitored packages met time/temp requirements
  - JEITA ED-4701/301A
    - Monitored packages met time/temp requirements
  - Paste Manufacturer Spec.
    - Monitored solder joints met requirements

- Board B Package Summary
  - IPC-JEDEC J-STD 020B
    - Monitored packages met time/temp requirements
  - JEITA ED-4701/301A
    - Monitored packages met time/temp requirements
  - Paste Manufacturer Spec.
    - Monitored solder joints met requirements

Results Summary

- Board C Package Summary
  - IPC-JEDEC J-STD 020B
    - Monitored packages met time/temp requirements
  - JEITA ED-4701/301A
    - Monitored packages met time/temp requirements
  - Paste Manufacturer Spec.
    - Monitored solder joints met requirements
  - Significant profiling effort required

Results Summary

- Board D package Summary
  - IPC-JEDEC J-Std 020B
    - Small packages
      - Borderline to max temp requirement
      - Violated time requirement
    - Large packages
      - Violated time/temp requirements
  - JEITA ED-4701/301A
    - "Small" packages
      - Met max temp requirement
      - Violated time requirement
    - "Large" packages
      - Violated time/temp requirements
  - Paste Manufacturer Spec.
    - Monitored solder joints violated requirements
  - Significant profiling effort required

  - To meet body temperature requirements, the body time at temp was violated and vice versa

Comments

- Reflow profile development was performed using "state of the art" reflow oven and profile optimization software
- Reflow profile development time was not typical of production
  - Typical production profile time: 4-8hrs
  - Profile investigation time: >24hrs per board type for the larger boards
- 2-3 assemblies were used to develop "reasonable" profiles for larger boards
  - Not typical of production
- Not all packages were monitored for a given board
  - Time-Temperature monitoring device has only 9 channels
  - Non-monitored packages may exceed time-temp requirements