

# The Effect of Solder Paste Reflow Conditions on Surface Insulation Resistance

**Dr. Karen Tellefsen and Mitch Holtzer**



[Karen.Tellefsen@alphaassembly.com](mailto:Karen.Tellefsen@alphaassembly.com)

[Mitch.holtzer@alphaassembly.com](mailto:Mitch.holtzer@alphaassembly.com)



# Outline/Agenda

- **Introduction**
- **Experimental Methodology**
- **Results**
- **Data Consolidation and Discussion**
- **Conclusions**
- **Q & A**



# Introduction

- Electrochemical reliability is a fundamental requirement for every circuit assembly.
  - How do reflow conditions, such as temperature and atmospheres, in an SMT process affects the electrochemical reliability?
    - Previous studies report mixed results
  - Surface insulation resistance (SIR) is an accepted standard for predicting reliability.

# Scope of This Study

- SIR measurements per IPC TM 650 Method 2.6.3.7 at 40°C and 90% R.H.
- IR spectra of raw solder pastes and flux residues
- Three large volume no-clean SAC305 solder pastes.
- Three reflow profiles:
  - Fast straight ramp low peak temperature short TAL
  - Fast straight ramp high peak temperature medium TAL
  - Long hot soak with a low peak temperature short TAL
- Reflow in air and nitrogen
- 18 combinations of paste, reflow profiles and atmospheres

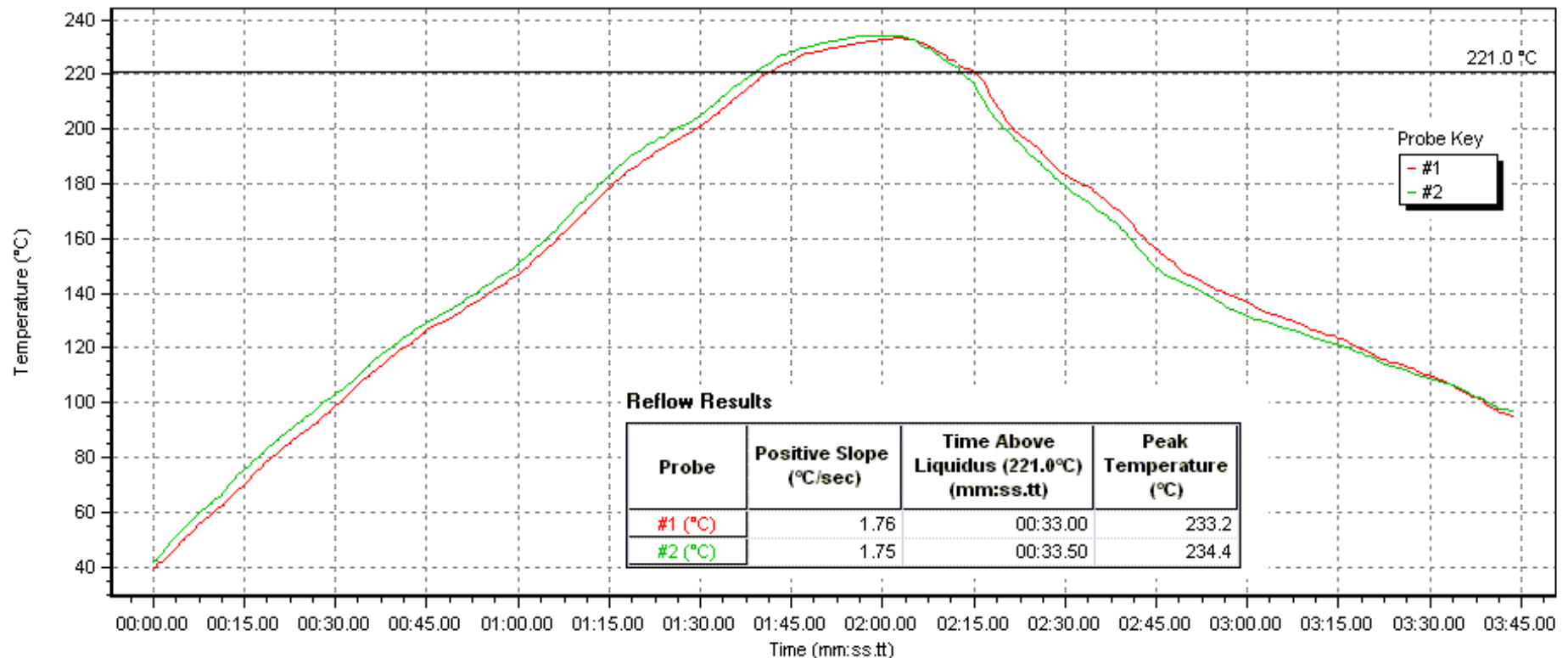
# Experimental Method

## ■ IPC-B-24 coupon preparation

- Cleaned in Ionograph in 75% isopropanol / 25% water at 45°C
- Baked at 50°C for one hour.
- Paste printed with 6 mil (0.15 mm) stencil.
- Reflowed using Electrovert OmniFlo 7 oven.
  - Air and nitrogen (>400 and <600 ppm O<sub>2</sub>) atmospheres
  - Three reflow profiles

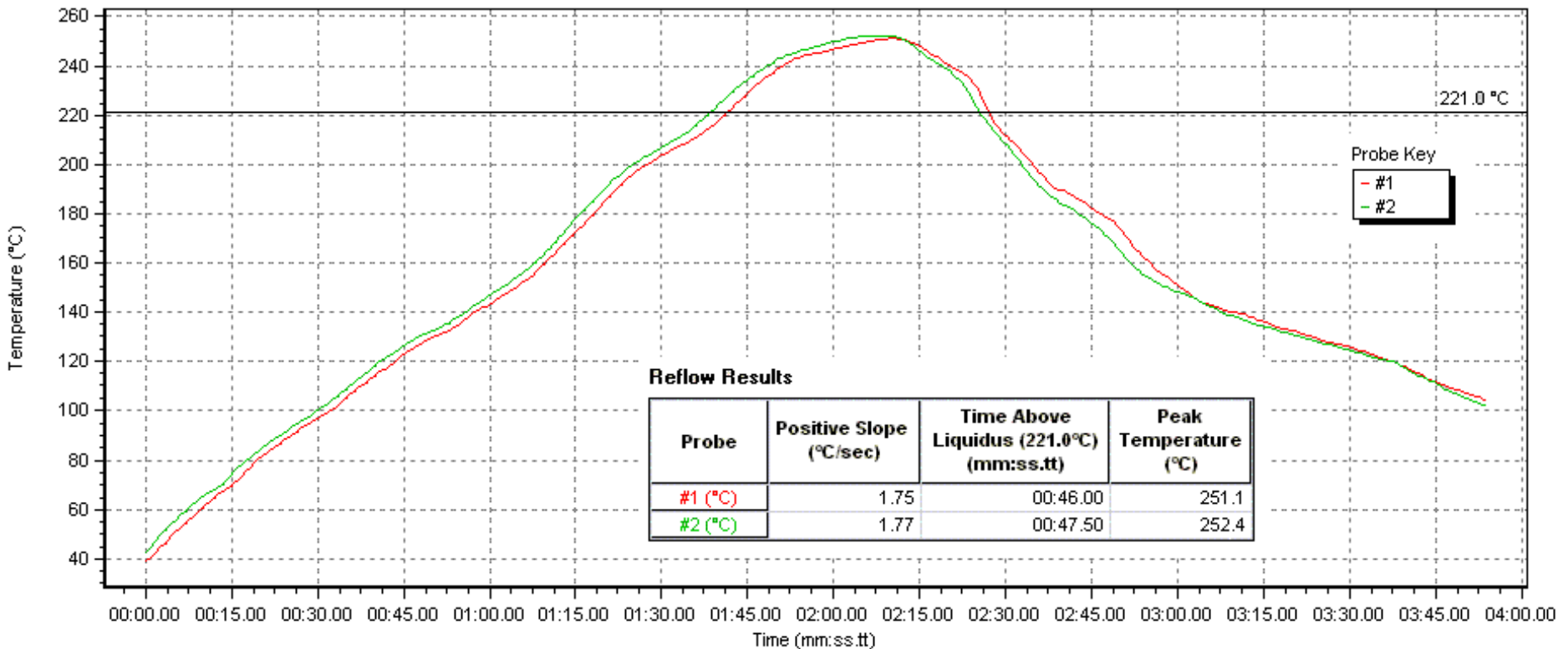
# Fast Ramp (Cold) Reflow Profile

1.5°C/s 230°C peak



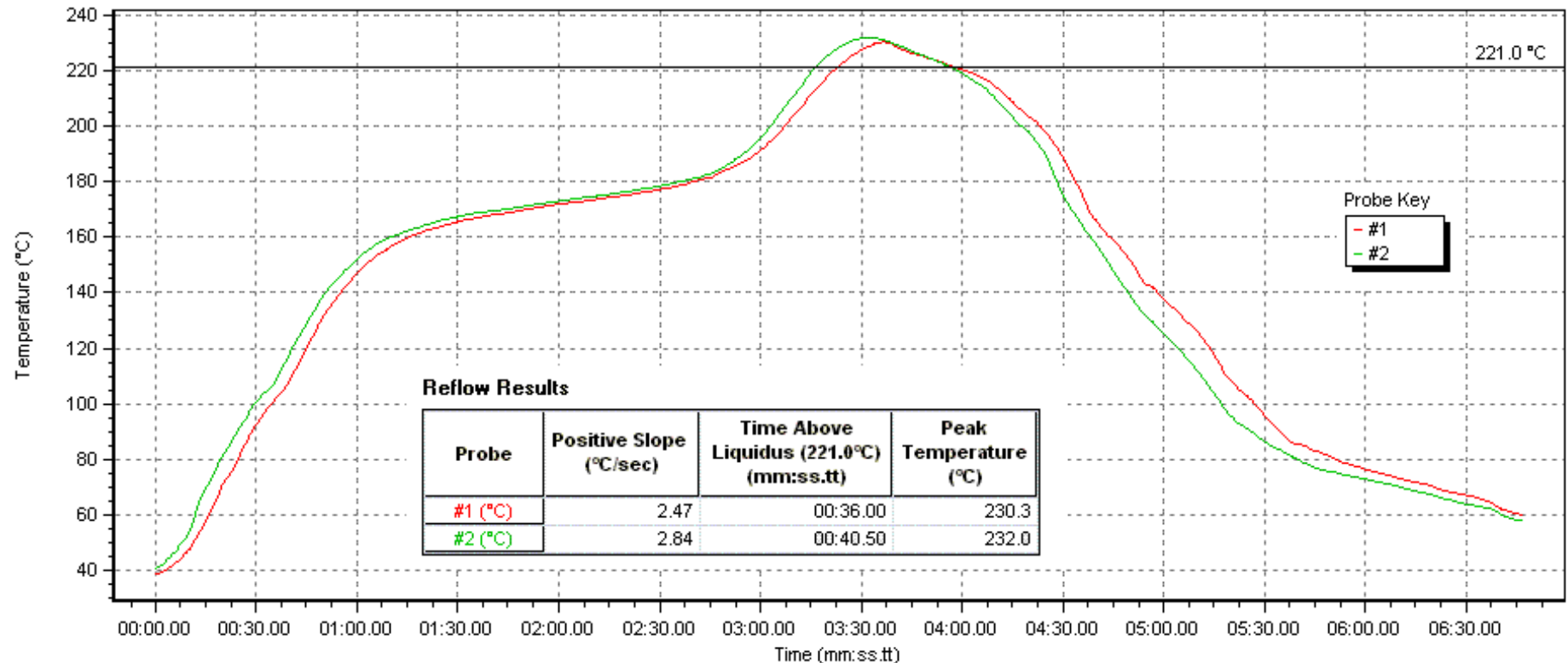
# Fast Ramp (Hot) Reflow Profile

1.5°C/s 252°C peak



# Long Hot Soak, Cold Reflow Profile

175°C soak 90 s 230°C peak







# IR Spectroscopy

- Perkin-Elmer Frontier spectrometer
  - Diamond coated ZnSe single attenuated reflectance window
- Spectra measured for:
  - All three unreflowed pastes
  - All 18 resuting flux residues

## Set up for IPC SIR measurements

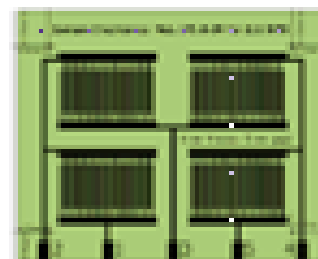
### IPC SIR Testing

#### J-STD-004B

- IPC-TM-650 sec. 2.6.3.7. 40°C 90% RH +12.5 V DC bias
- Measure SIR (at 12.5 V) every 20 minutes for 7 days
- Passing criteria: The SIR value  $> 1 \times 10^8 \Omega$  and no electromigration or corrosion to be seen
- Coupons :IPC-B-24/ modified
- Instruments: Auto-SIR attached with voltage supplier/SIRTS for supplying 12.5 V and ESPEC chamber



Fig3.Auto-SIR connected with ESPEC Chamber

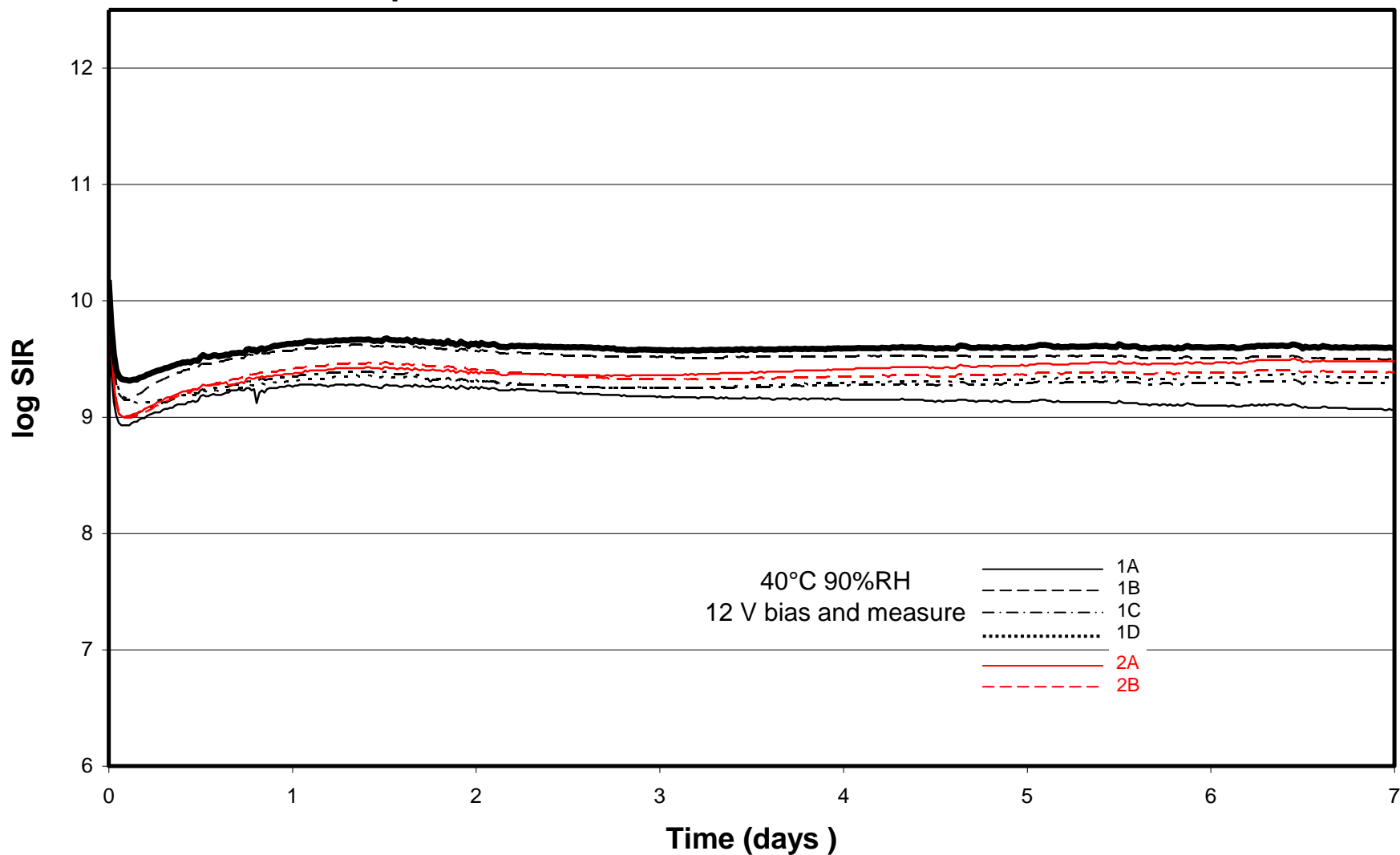


Modified IPC-B-24,  
0.5 mm spacing, 0.4  
mm lines Bare  
copper on FR4

# SIR Results Paste 1 SR 230°C air

P-1 SR230 Air

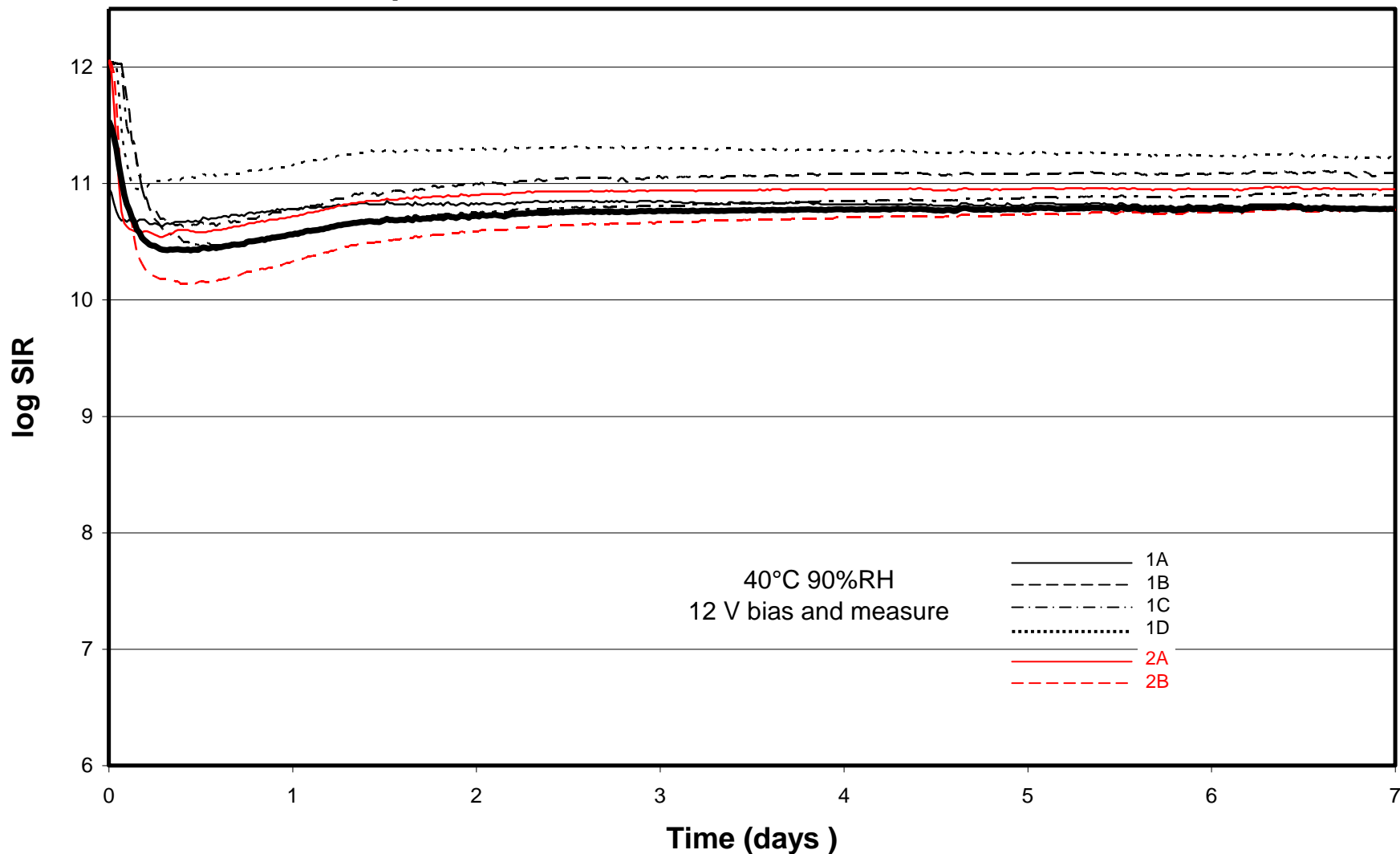
SIR per J-STD-004B / IPC-TM-650 Method 2.6.3.7



# SIR Results Paste 1 SR 252°C Air

P-1 SR250 Air

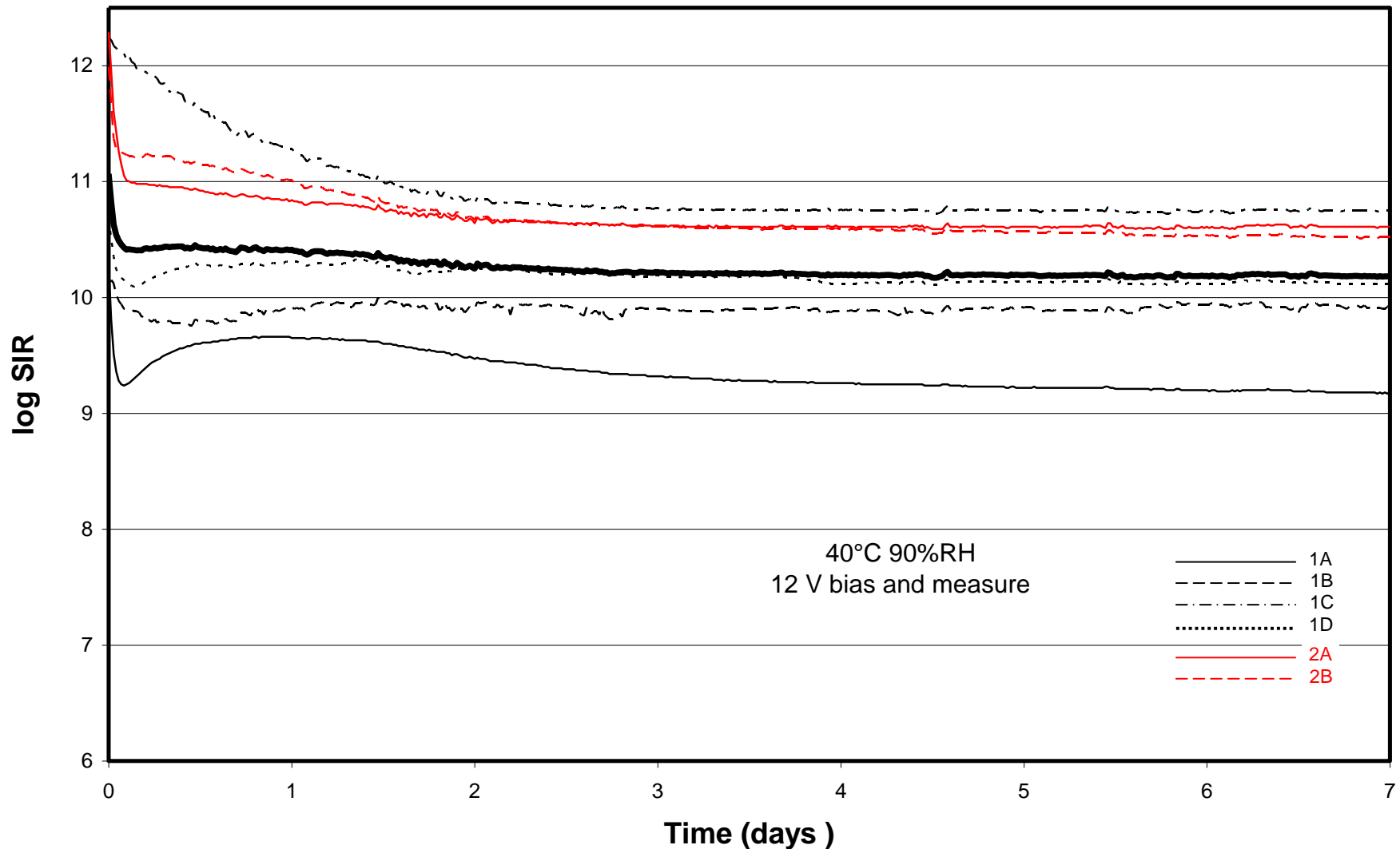
SIR per J-STD-004B / IPC-TM-650 Method 2.6.3.7



# SIR Result Paste 1 Hot Soak Air

P-1 Soak Air

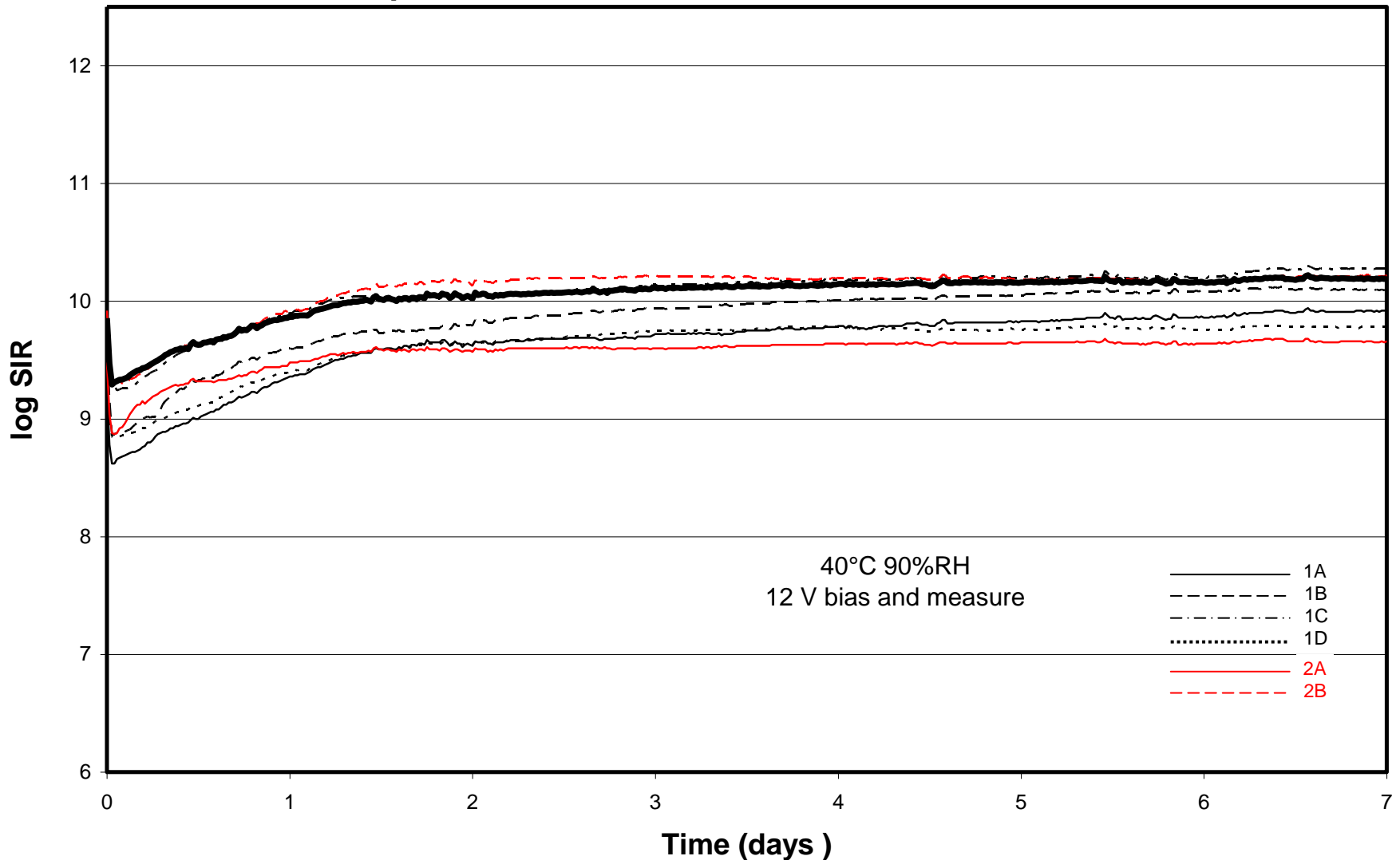
SIR per J-STD-004B / IPC-TM-650 Method 2.6.3.7



# SIR Results Paste 2 Hot Soak Air

P-2 Soak Air

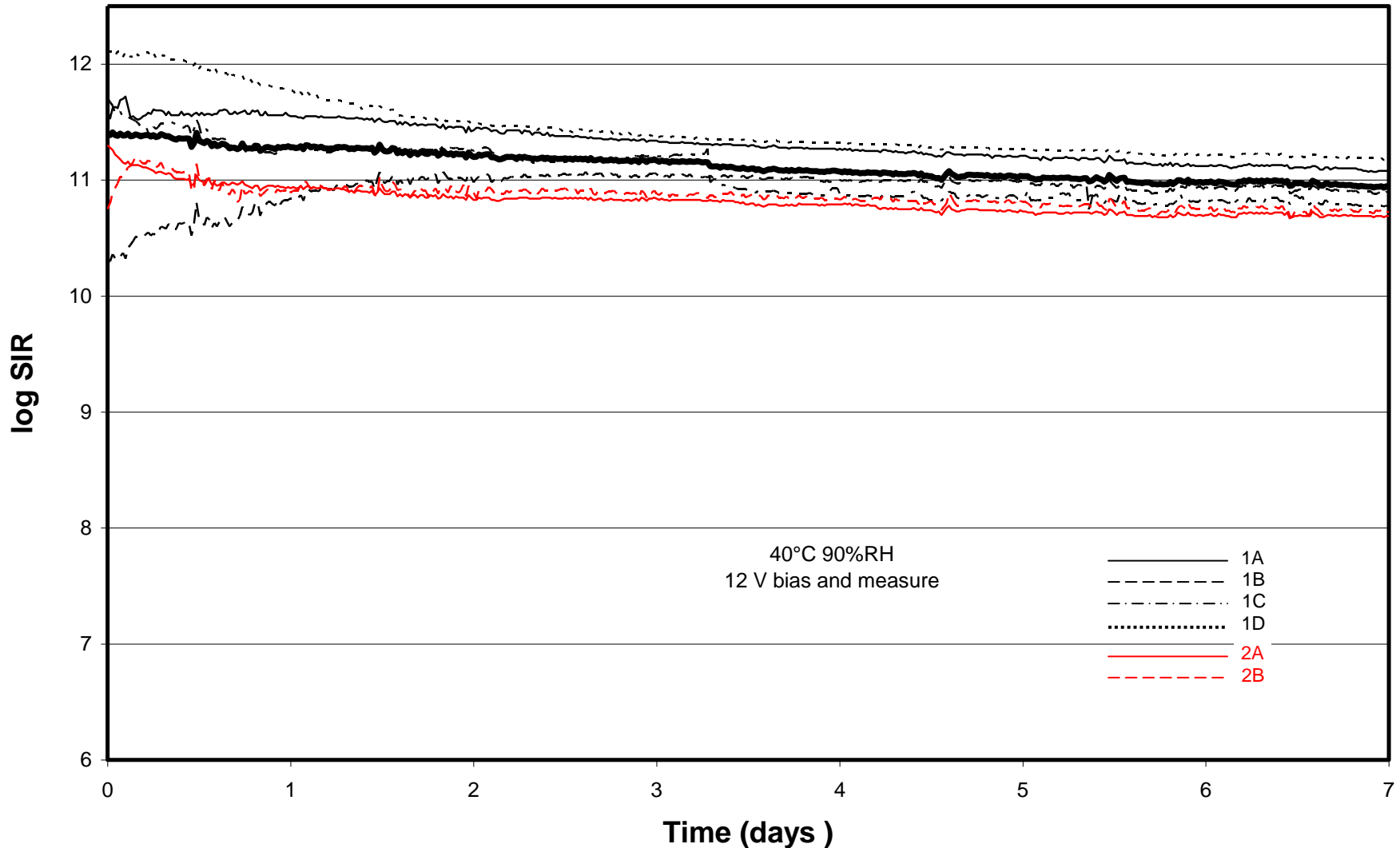
SIR per J-STD-004B / IPC-TM-650 Method 2.6.3.7



# SIR Result Paste 2 Hot Soak N<sub>2</sub>

P-2 Soak N2

SIR per J-STD-004B / IPC-TM-650 Method 2.6.3.7





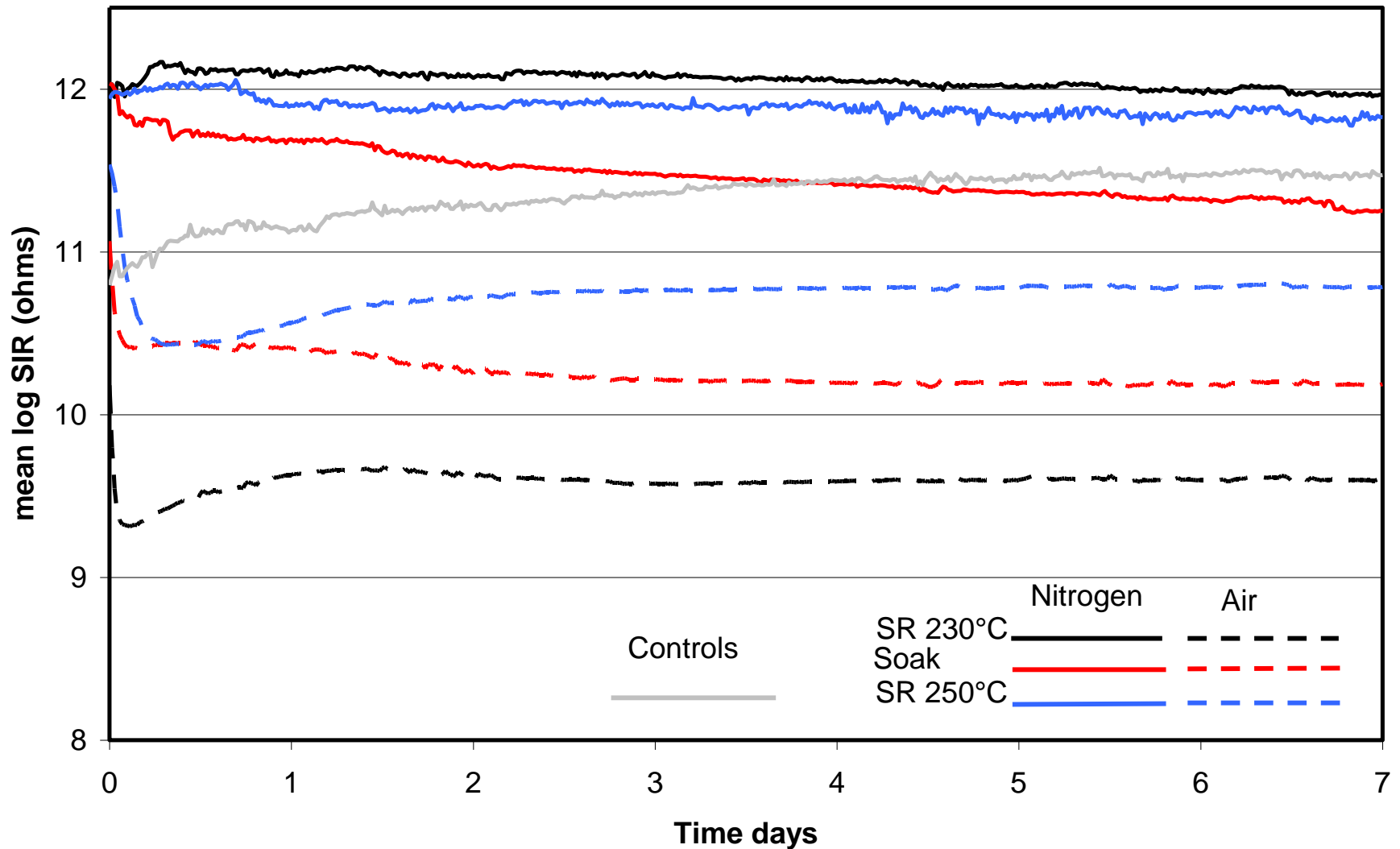
# Data Consolidation

- 18 log SIR time too much data to look at collectively.
- Plot mean log SIR vs. time for each paste studied.
  - Fewer plots to look at.
  - Details, such as data scatter, are obscured.



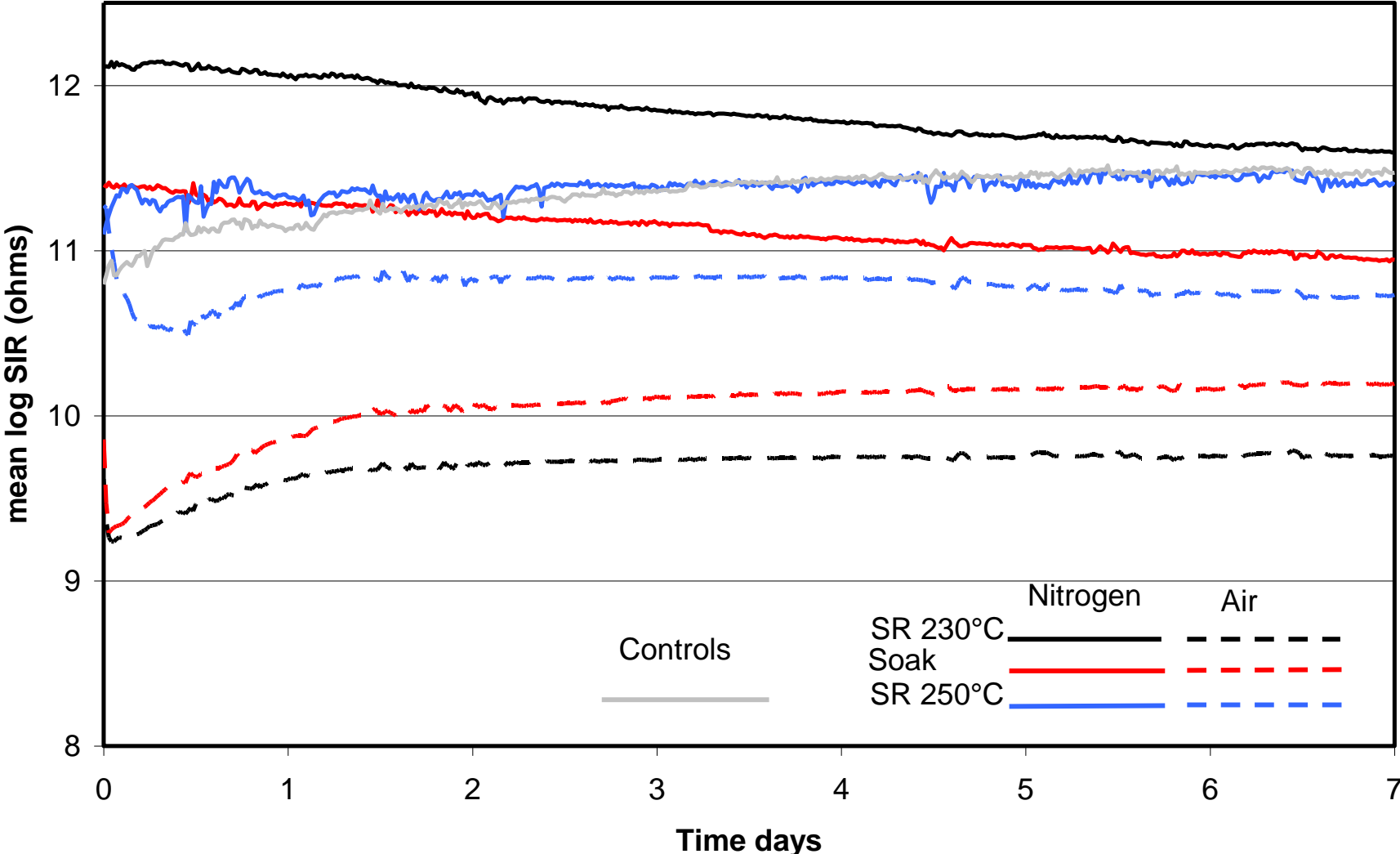
# Mean SIR for Paste 1 All Reflow Conditions

## Paste 1



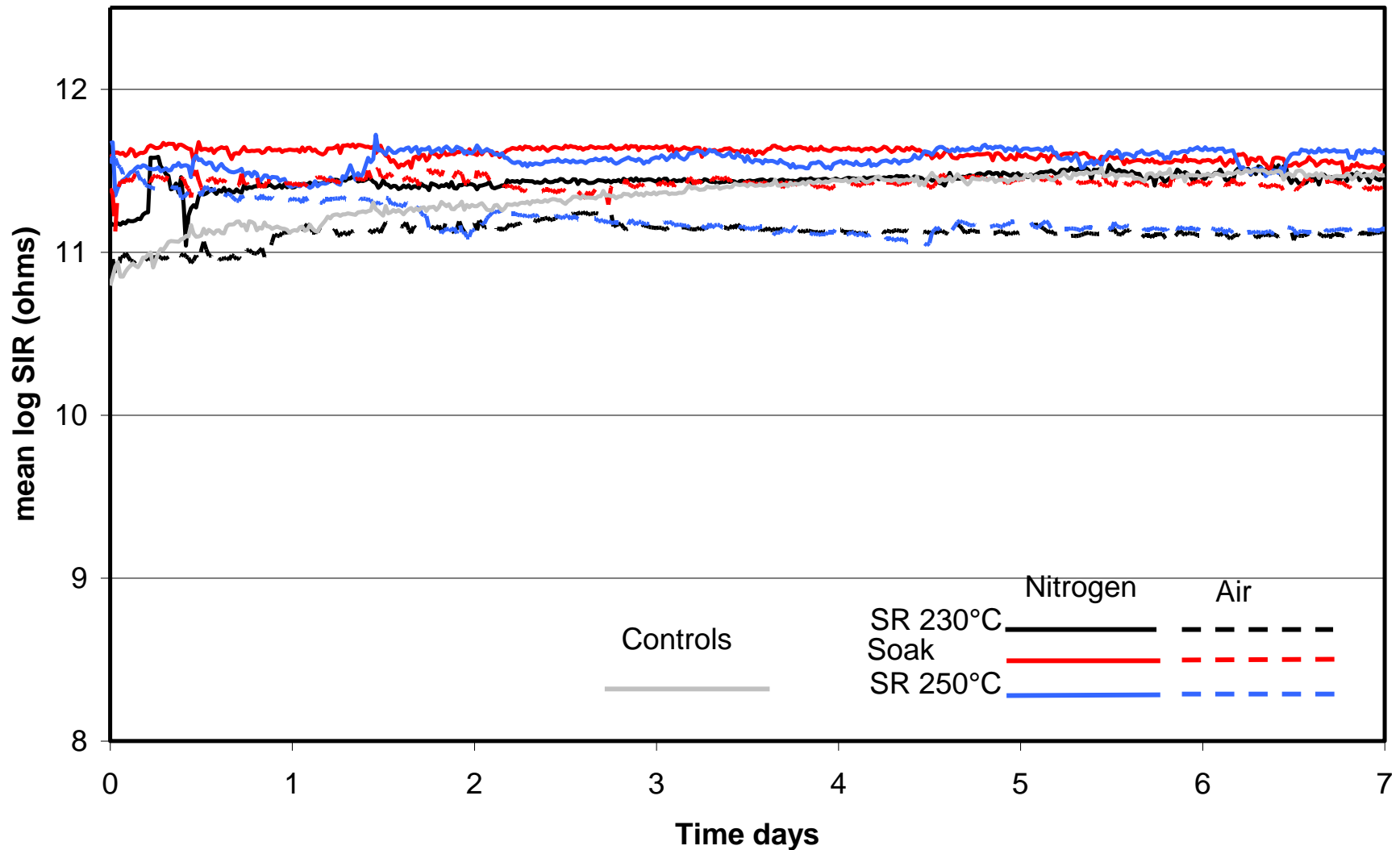
# Mean SIR for Paste 2 All Reflow Conditions

## Paste 2



# Mean SIR for Paste 3 All Reflow Conditions

## Paste 3



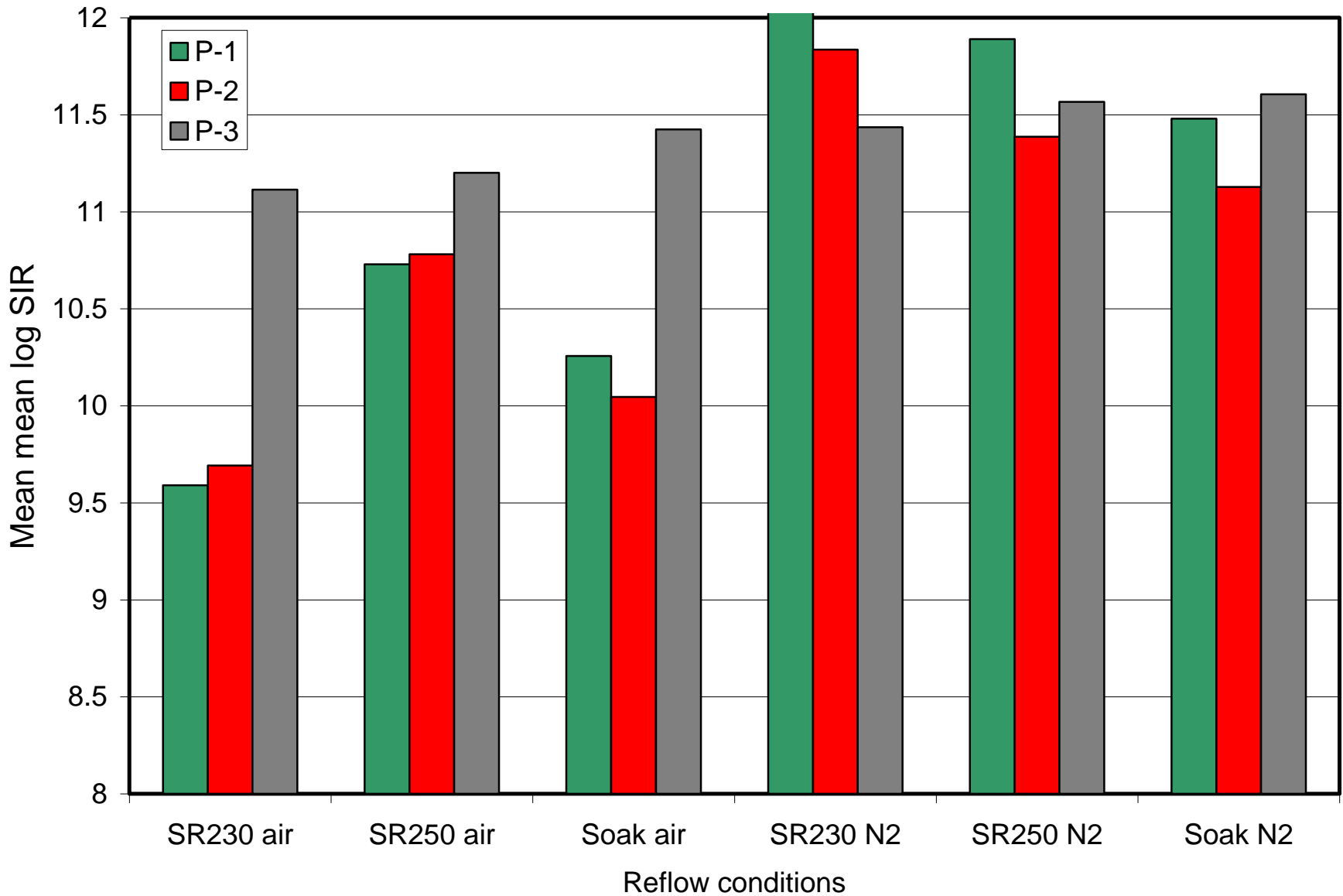
# Summary SIR Results

- SIR values increase with heat exposure in air atmosphere
  - This trend not observed in nitrogen.
  - More for pastes 1 and 2 than paste 3

Highest SIR SR250 > SOAK > SR230 lowest SIR

  - Pastes 1 and 2 have similar IR spectra with regard to reflow conditions, paste 3 is somewhat different.
- SIR values were higher for nitrogen than air.
  - More for pastes 1 and 2 than paste 3
- Microscopic examination showed no evidence of electrochemical migration or corrosion.

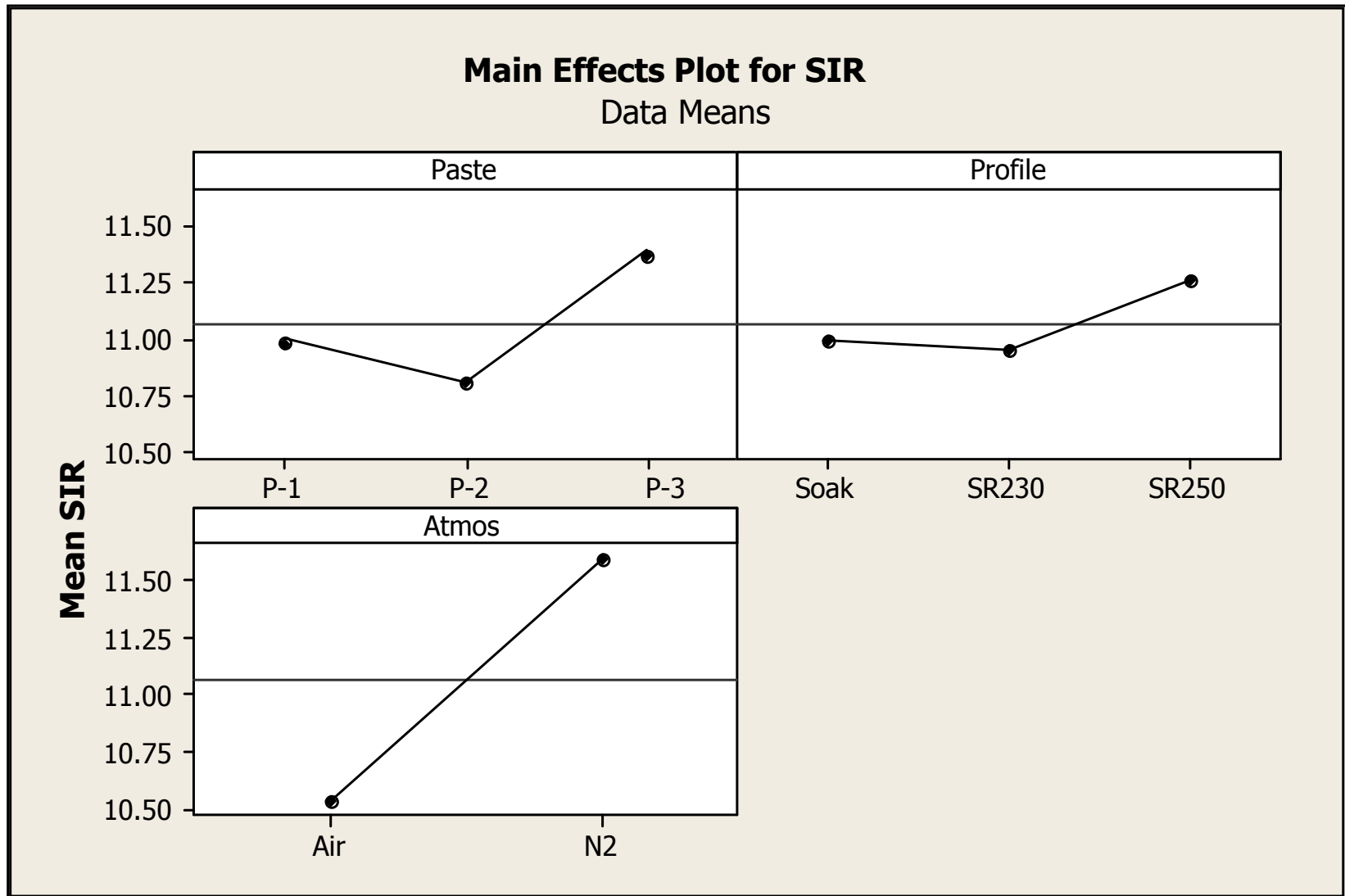
# Mean Mean Log SIR



# Mean Mean log SIR

- Paste 3 has the highest mean SIR values in air.
  - Especially for the coldest reflow condition
- In nitrogen, pastes 1 and 2 are higher than paste 3.
  - Paste 1 and 2 SIR actually decrease slightly with increasing applied heat in nitrogen.
  - SIR values for paste 3 change very little with reflow profile in nitrogen.
    - Interestingly, the IR spectra for paste 3 reflowed in nitrogen changed very little with reflow profile.

# Minitab Main Effects Plots





# Main Effects Plots

- Variable with the largest effect on SIR is atmosphere!
- Paste 3 generally had higher SIR than Pastes 1 and 2.
- Reflow profile had the smallest effect, with time above liquidus and peak temperature being more important than soak temperature.



# IR Spectra

- Peak height between 1720 – 1650  $\text{cm}^{-1}$  decreases with heat during reflow.
  - This effect is stronger in air than nitrogen.
  - This effect is smaller for paste 3 than pastes 1 and 2.
- Peak height between 1650 – 1575  $\text{cm}^{-1}$  increases with heat during reflow in air.
  - Not observe for nitrogen reflow.

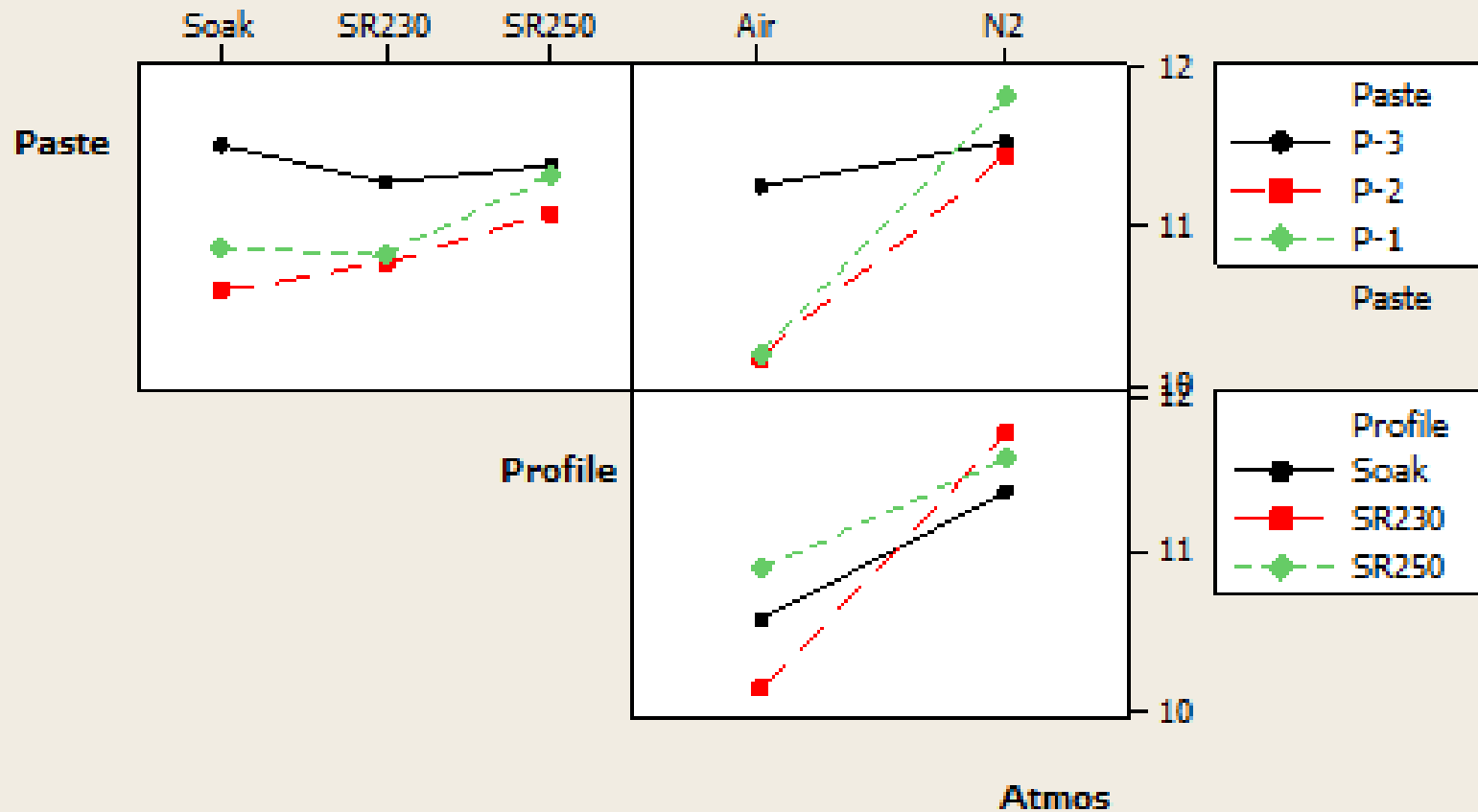
# IR Spectra Results

		normalized absorption maximum			
		Air		N2	
		1720-1650	1650-1575	1720-1650	1650-1575
Paste 1	Raw	1.014	0.288		
	SR 230	0.783	0.380	1.518	0.067
	SR 250	0.326	1.021	1.037	0.41
	Soak	0.488	1.158	0.859	0.178
Paste 2	Raw	1.088	0.316		
	SR 230	1.313	0.450	1.973	0.546
	SR 250	0.519	1.023	1.485	0.455
	Soak	0.467	1.038	1.492	0.488
Paste 3	Raw	1.324	0.163		
	SR 230	1.991	0.275	1.967	0.18
	SR 250	0.756	0.928	1.863	0.232
	Soak	0.773	0.944	2.427	0.086

# Minitab Interaction Plots

## Interaction Plot for SIR

Data Means



# Interaction Plots

- Paste 3 shows little change with reflow profile, pastes 1 and 2 do vary.
- All the pastes show a large effect on SIR with atmosphere, but it is smaller for paste 3 than pastes 1 and 2.
  - The IR spectra for pastes 1 and 2 change similarly with reflow profile and atmosphere, and more than paste 3 does.
- SIR for the coldest profile, straight ramp to 230°C, showed the largest difference with reflow atmosphere.

# Conclusions

- Reflow atmosphere has a strong effect on SIR values, with SIR being higher in nitrogen than air. This effect is more dramatic for some solder pastes than others.
- Higher temperature reflow profiles in air atmosphere provide higher SIR values. This is not the case in nitrogen.
- IR spectra of reflowed flux residue can provide insight into the nature of flux residue and how it affects SIR values.
- Different solder pastes may have different SIR dependence on reflow profile and temperature.



# Thank You!

Karen Tellefsen; Mitch Holtzer

Alpha

109 Corporate Blvd.

South Plainfield, NJ 07080