

**PERFORMANCE AND ABUSE TESTING OF 5 YEAR OLD  
LOW RATE AND MEDIUM RATE LITHIUM THIIONYL  
CHLORIDE CELLS**

**2000 NASA AEROSPACE BATTERY WORKSHOP**

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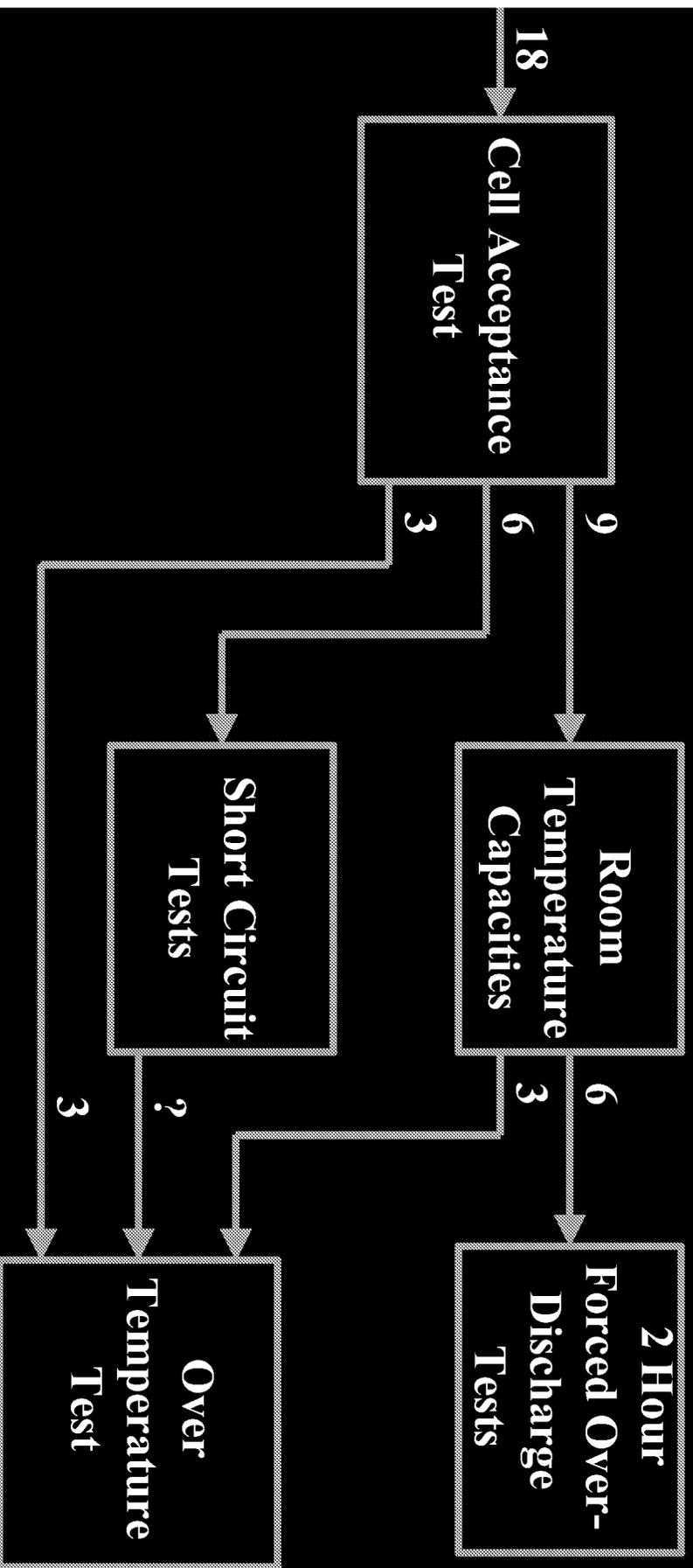
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## 5 Year Old Lithium Thionyl Chloride Cells Used In The Test (18 each type)

- Low Rate 'D' Part No. LTC-114
  - 14 Ahr (@50 ohms and 3.0V cutoff)
  - Sandia Design
- Medium Rate 'D' Part No. LTC-111
  - 12 Ahr (90 mA and 2.5V cutoff at 25 °C)
- Medium Rate 'sub D' Part No. LTC-115
  - 11 Ahr (100 mA and 2.0 V cutoff at 25 °C)
  - Sandia Design, Military Aviation qualified cell

# Test Plan (Overview)



# Cell Acceptance Test



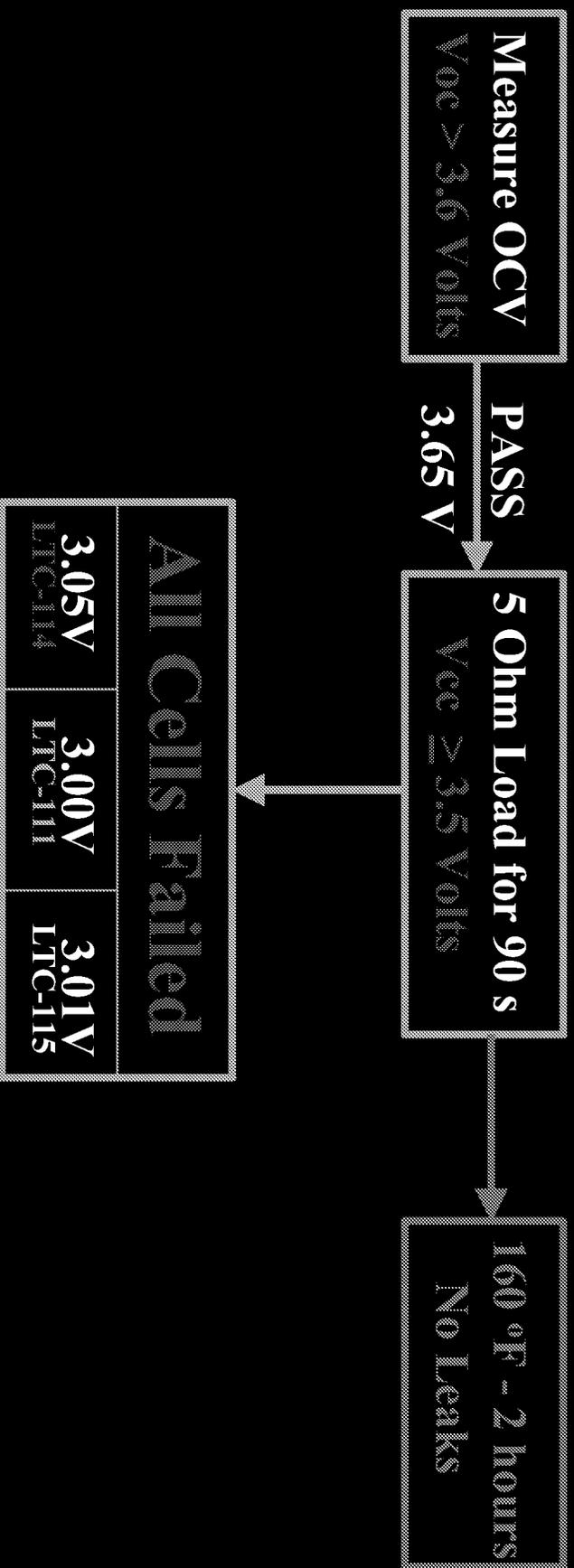
# Cell Acceptance Test Results

## All 54 Cells

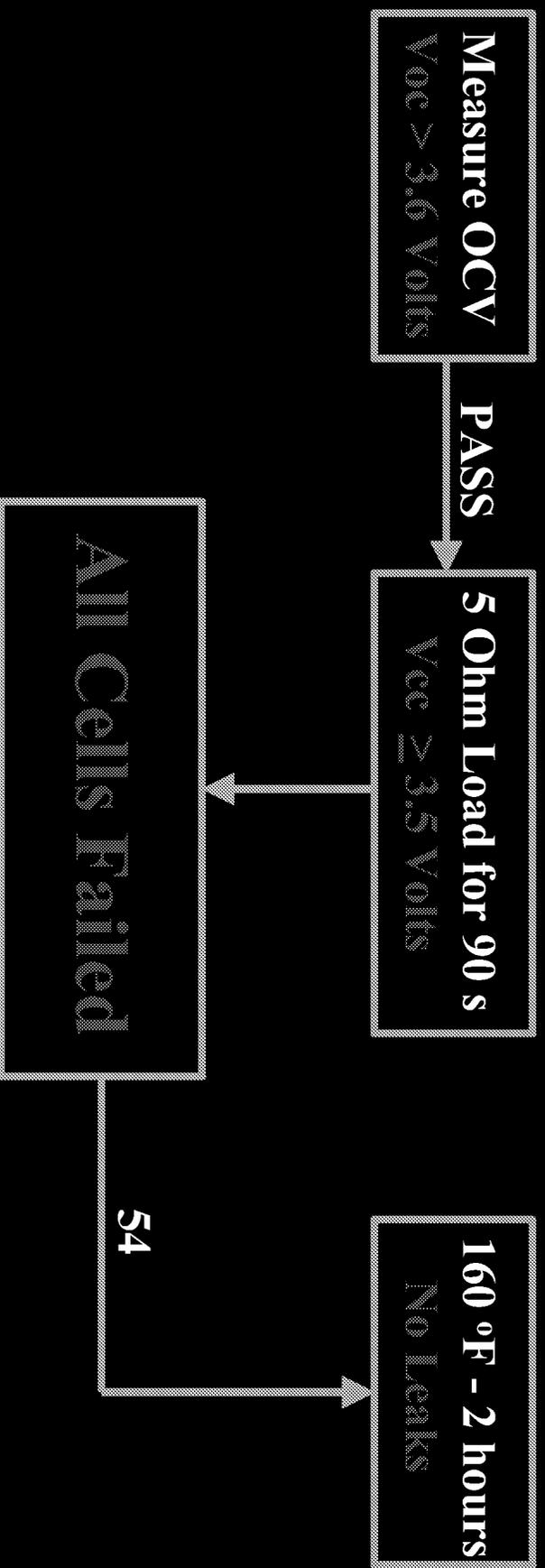


# Cell Acceptance Test Results

## All 54 Cells

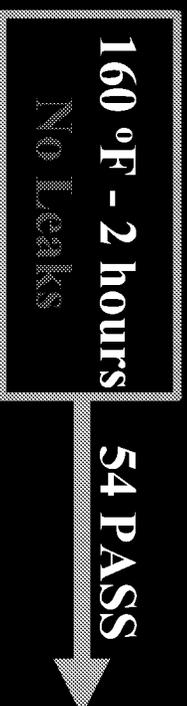


# Cell Acceptance Test (Revised)

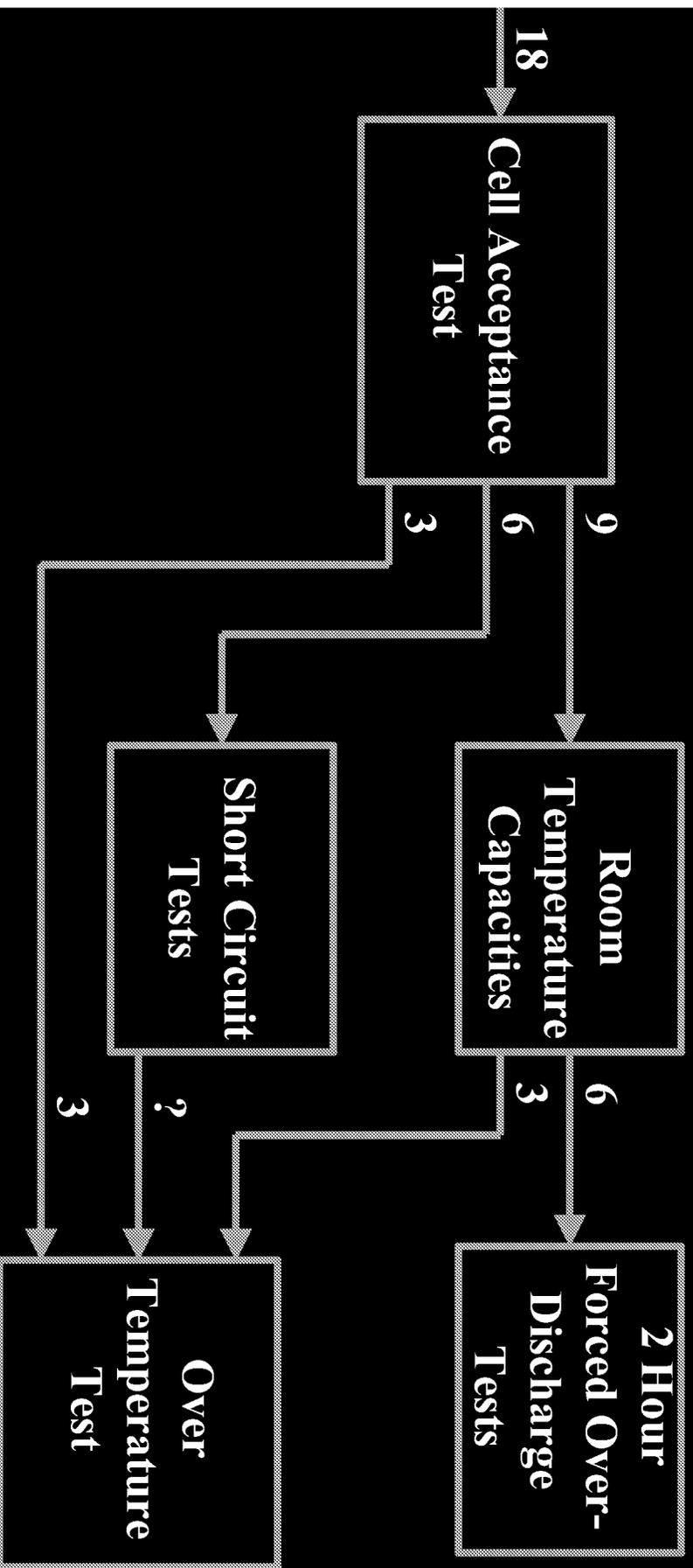


# Test Plan - Part 1

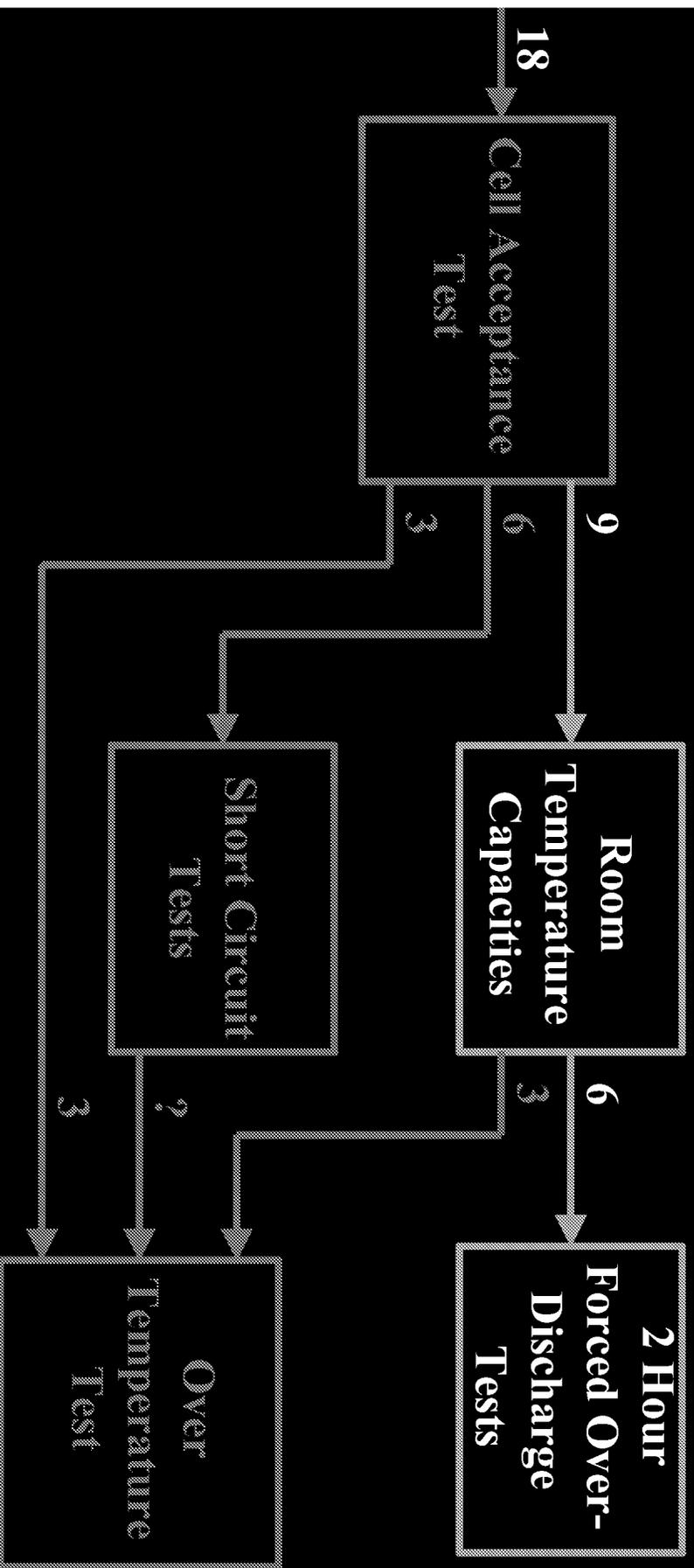
## Cell Acceptance Test Results



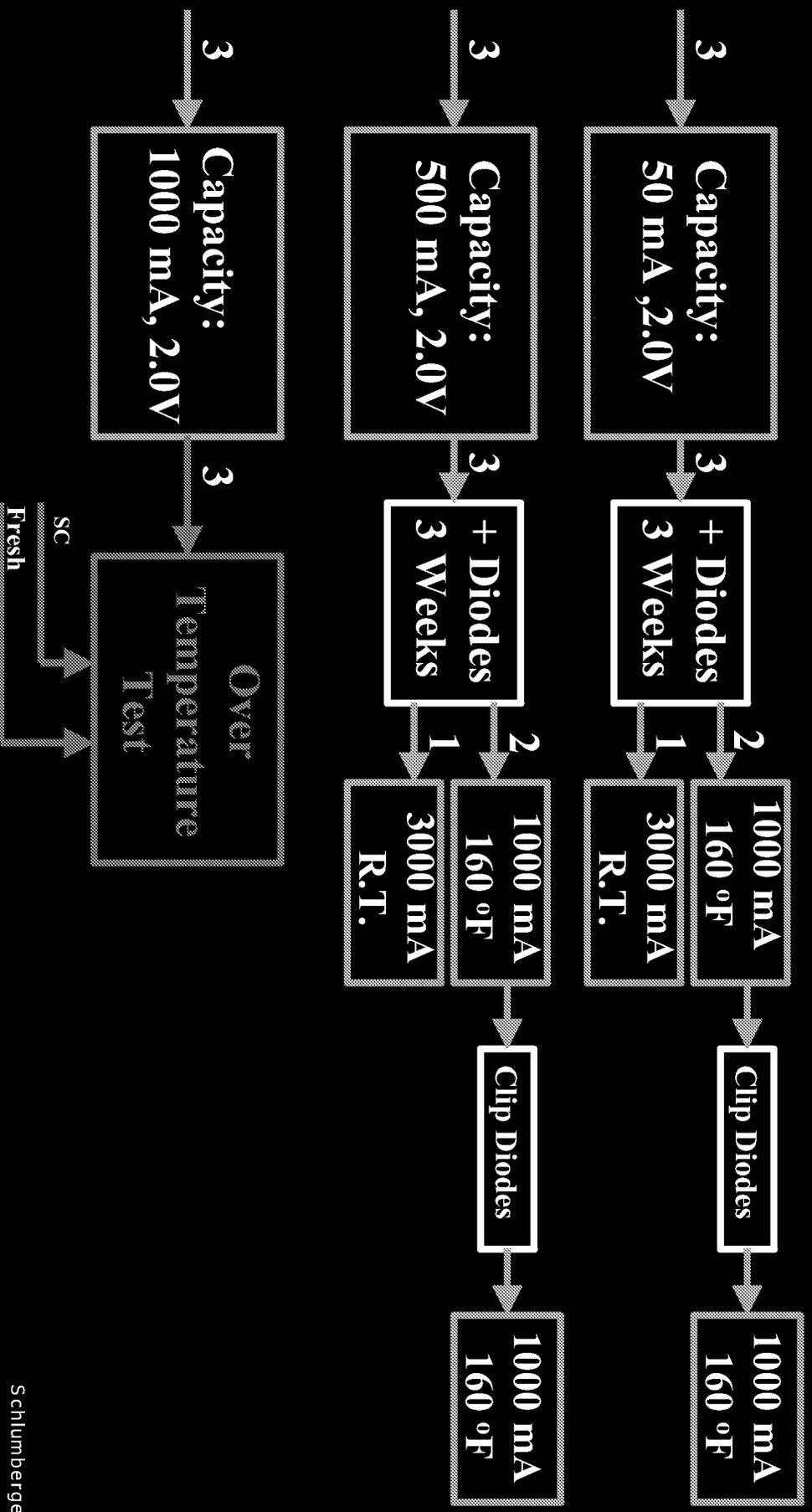
# Test Plan (Overview)



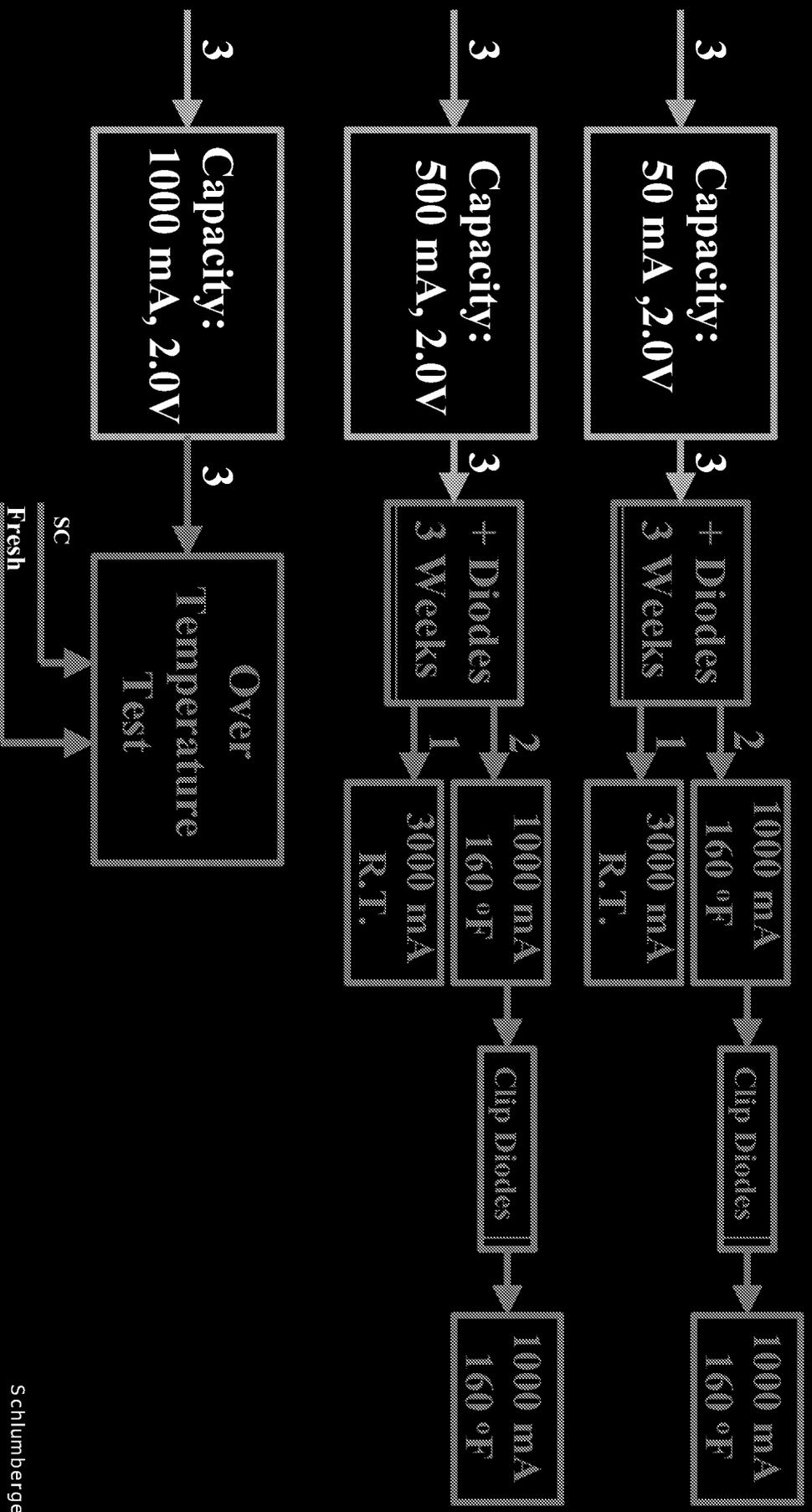
# Test Plan (Overview)



# Room Temperature Capacity and Forced Overdischarge Test



# Room Temperature Capacity and Forced Overdischarge Test



# Capacity Test Results

Capacity (Ah)											
50 mA			500 mA			1000 mA					
LTC-114	LTC-111	LTC-115	LTC-114	LTC-111	LTC-115	LTC-114	LTC-111	LTC-115	LTC-114	LTC-111	LTC-115
15.7	15.0	11.8	8.6	13.7	5.3	4.4	12.2	3.3			
15.6	14.9	12.7	8.9	13.8	5.6	4.9	12.8	3.1			
15.7	14.9	13.0	8.7	13.3	5.2	4.8	12.7	Note			

LTC-114      LTC-111      LTC-115

Rated Capacities: 14 Ah      12 Ah      11 Ah

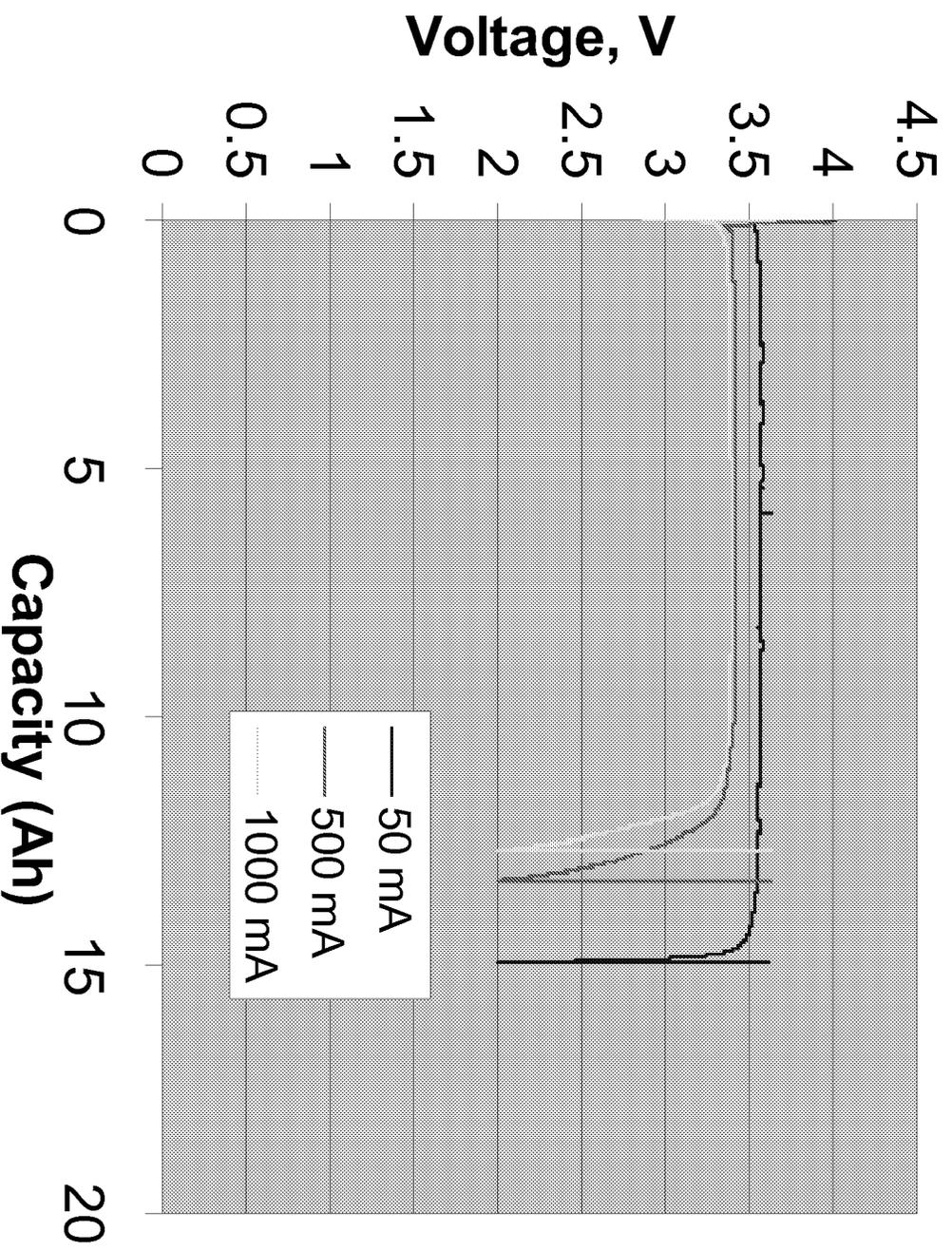
Note: One LTC-115 cell had tab break off and repair was not possible

# Average Cell Capacity

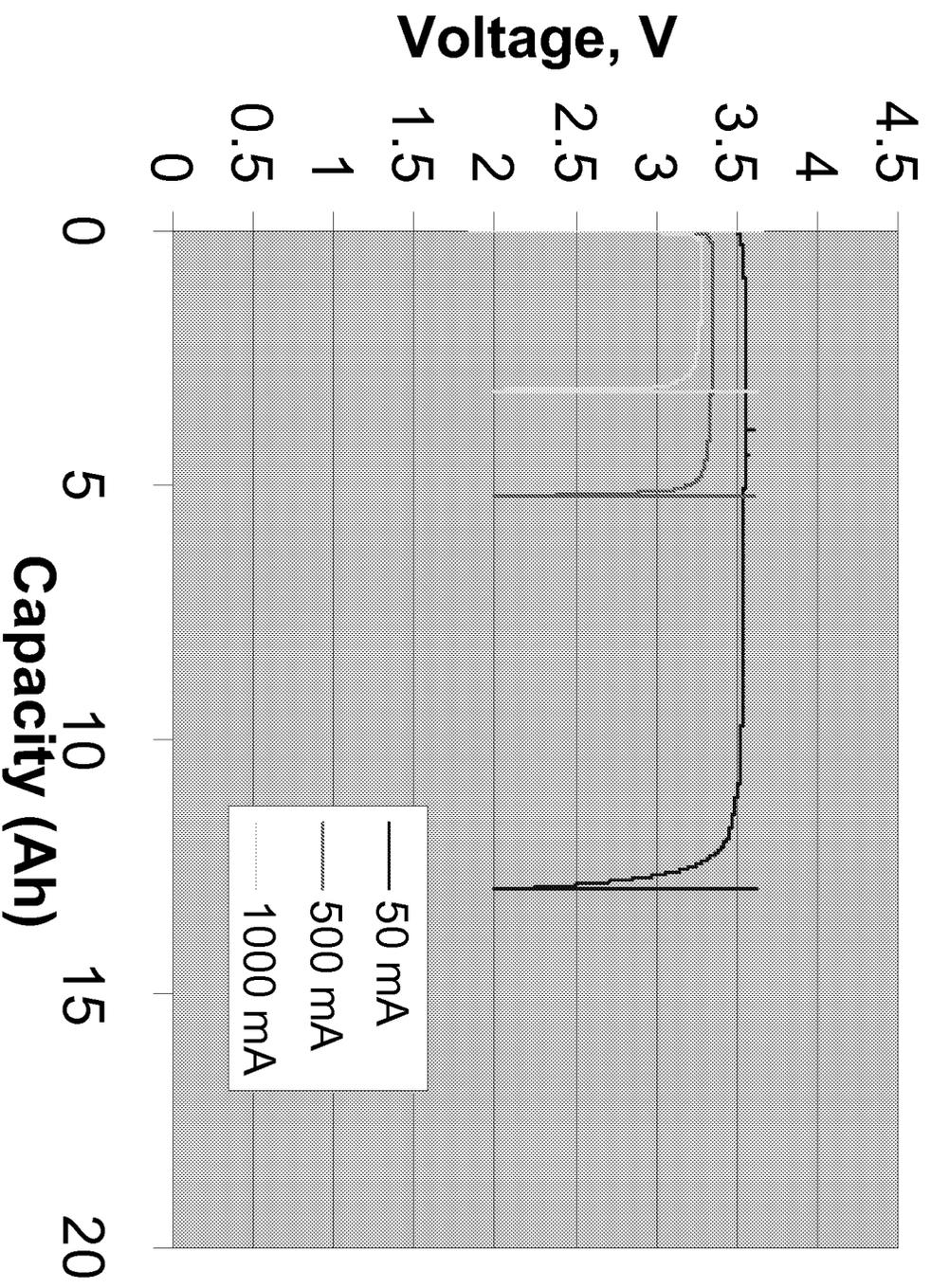
Rated Capacity (Ah)	LTC-114	LTC-111	LTC 115
	50 mA Capacity (Ah)	14	12
500 mA Capacity (Ah)	15.7	14.9	12.5
1000 mA Capacity (Ah)	8.7	13.6	5.4
1000 mA Capacity (Ah)	4.7	12.6	3.2

Rated Capacities: LTC-114 14 Ah    LTC-111 12 Ah    LTC 115 11 Ah



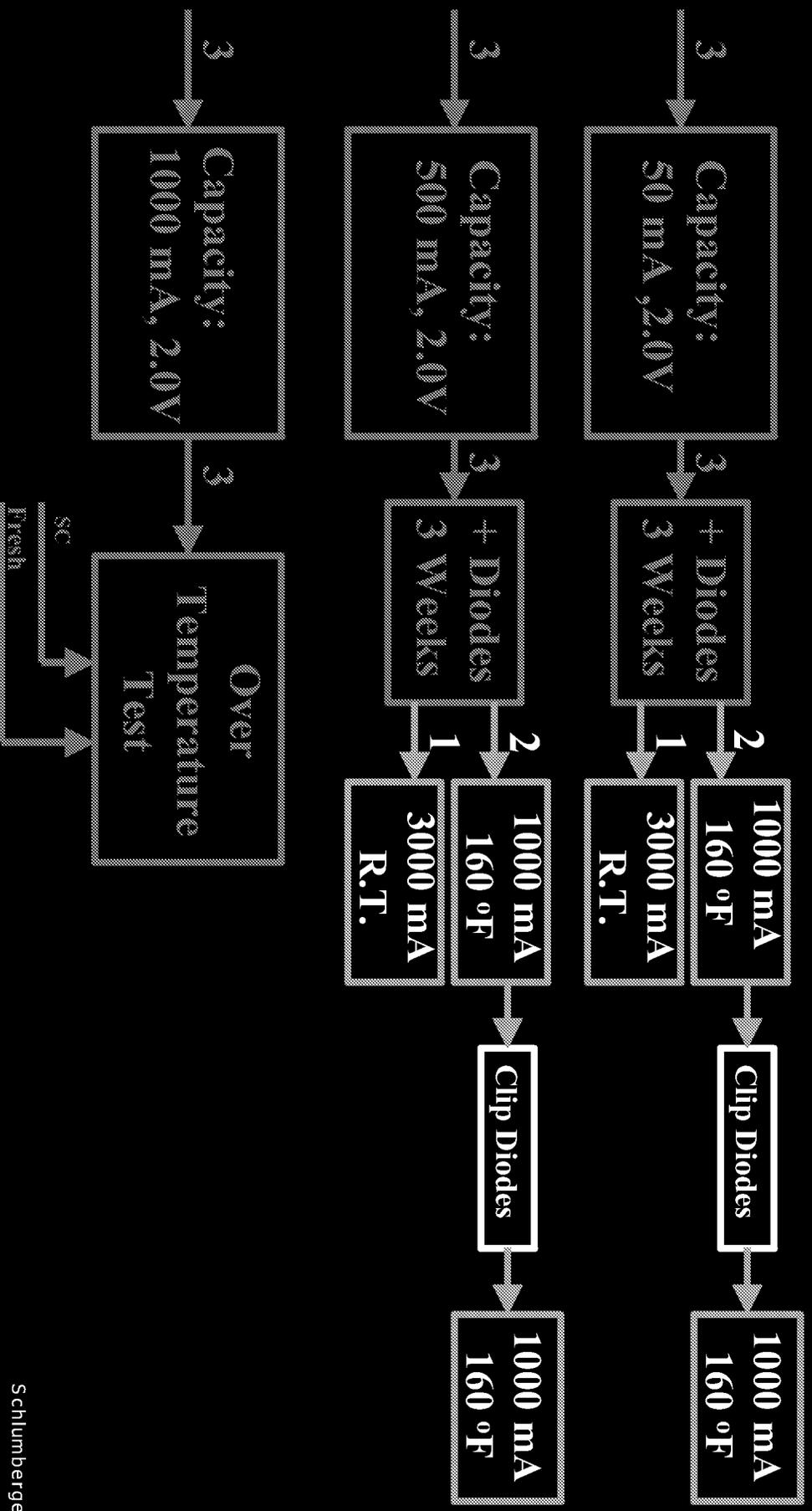


Typical Discharge Curves - LTC-111



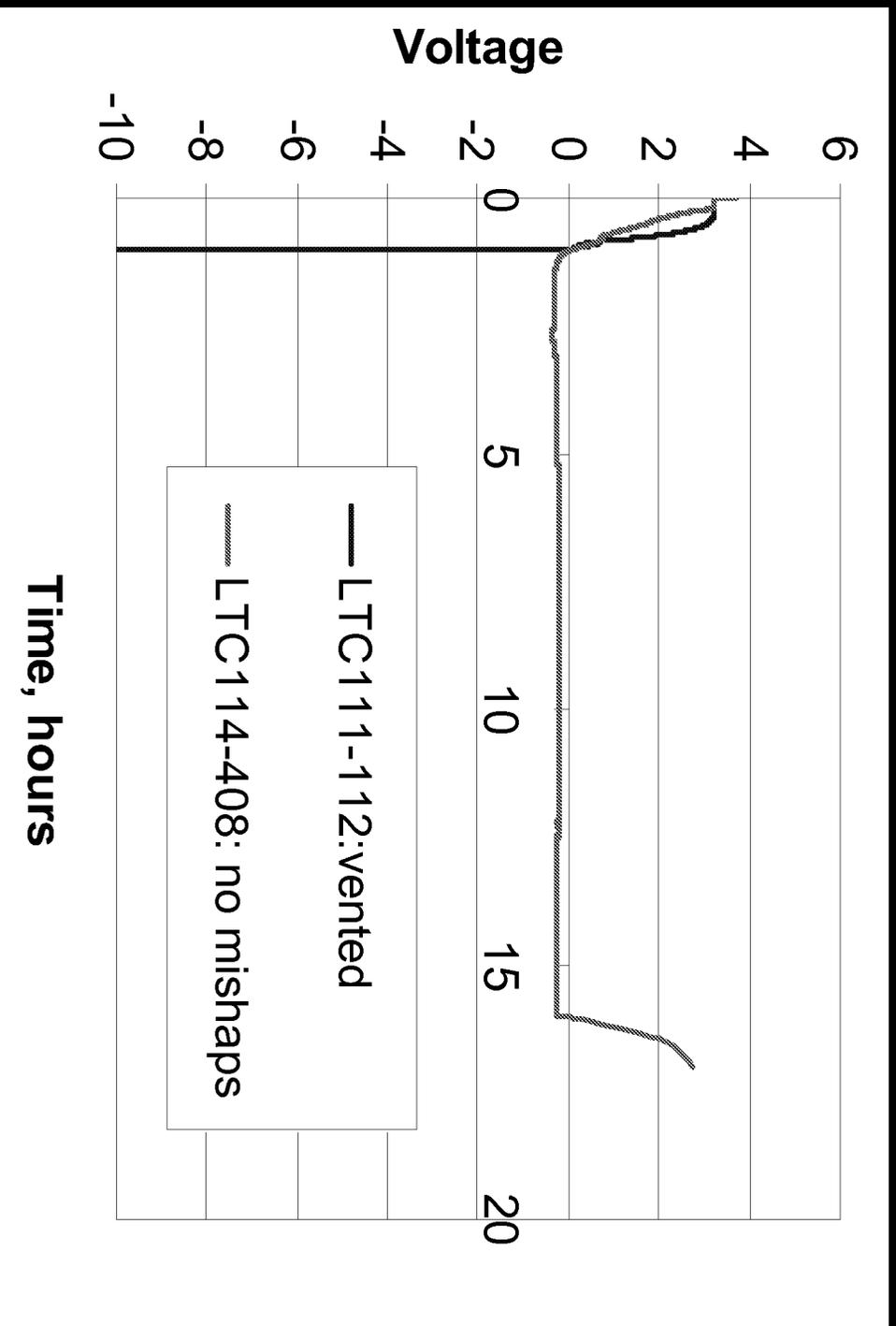
Typical Discharge Curves - LTC-115

# Room Temperature Capacity and Forced Overdischarge Test

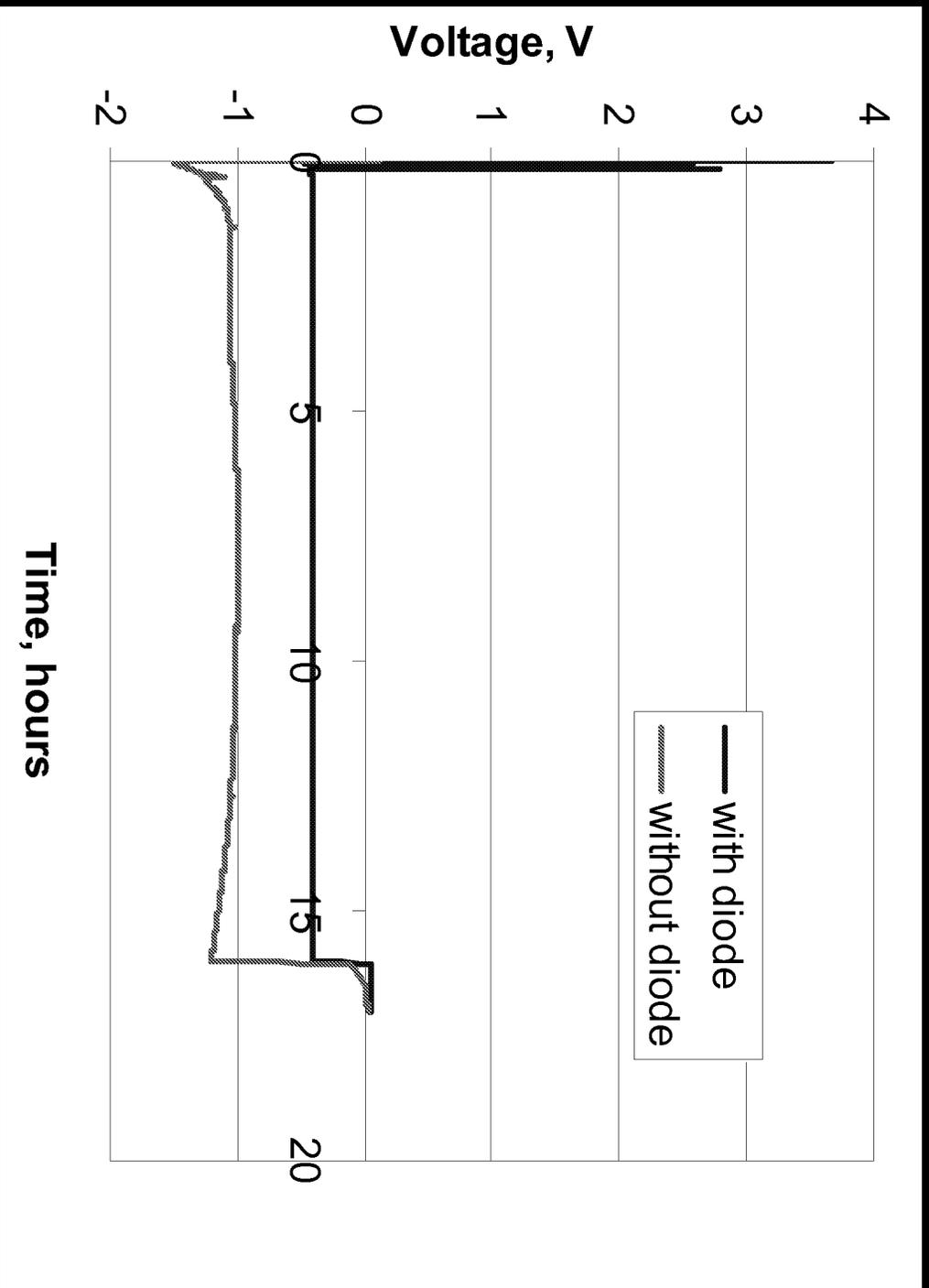


# 1 Amp at 160F Over-Discharge Test Results

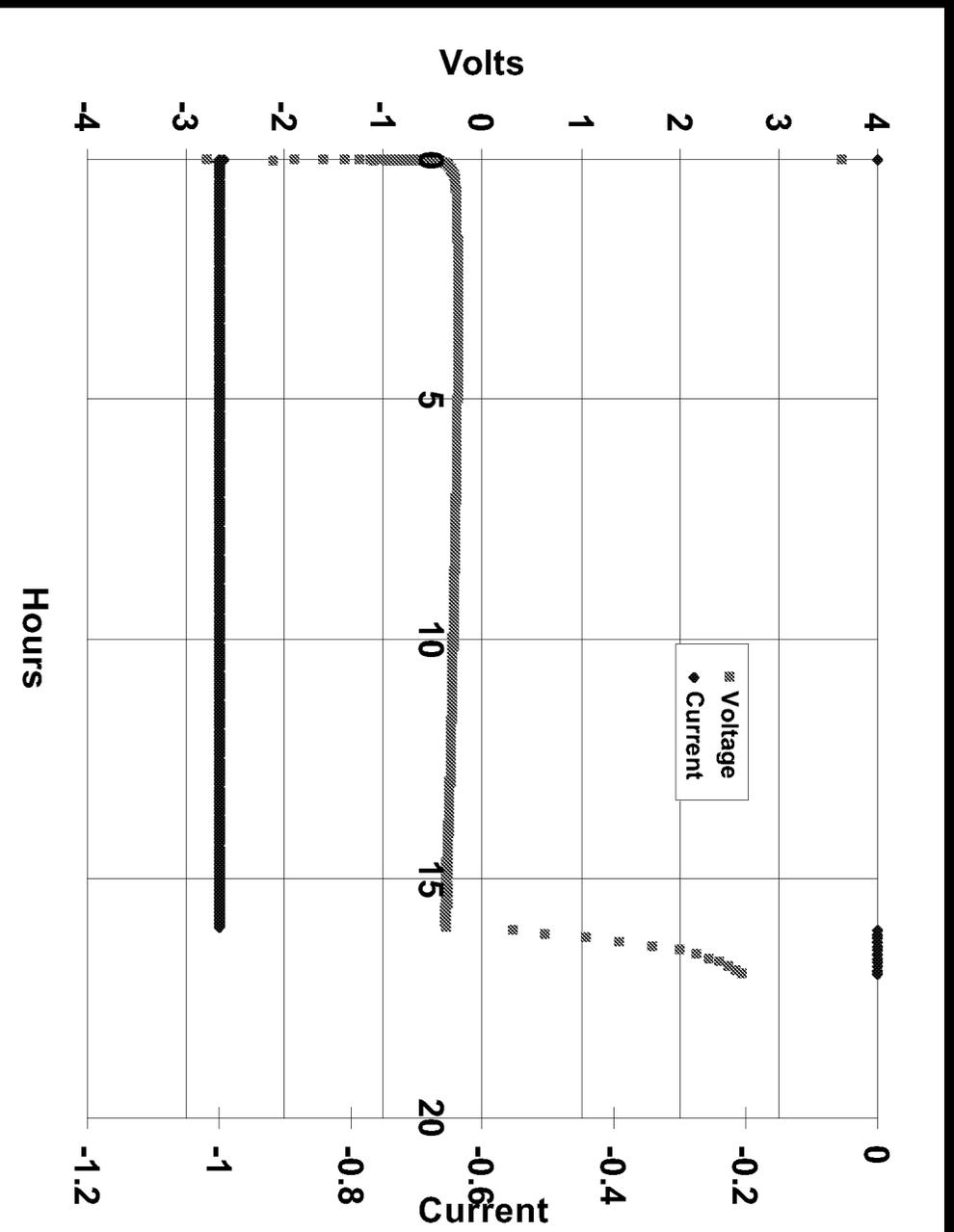
Cell Type	With Diodes	Without Diodes
After 50 mA discharge capacity test		
LTC-114	ok	ok
	ok	ok
LTC-111	ok	ok
	ok	ok
LTC-115	ok	ok
	ok	ok
After 500 mA discharge capacity test		
LTC-114	ok	ok
	ok	ok
LTC-111	vented	not available
	vented	not available
LTC-115	ok	ok
	ok	ok



Voltage behavior during 1 A over-discharge with diode at 160°F - LTC-111 (vented) and LTC-114 (no mishaps)



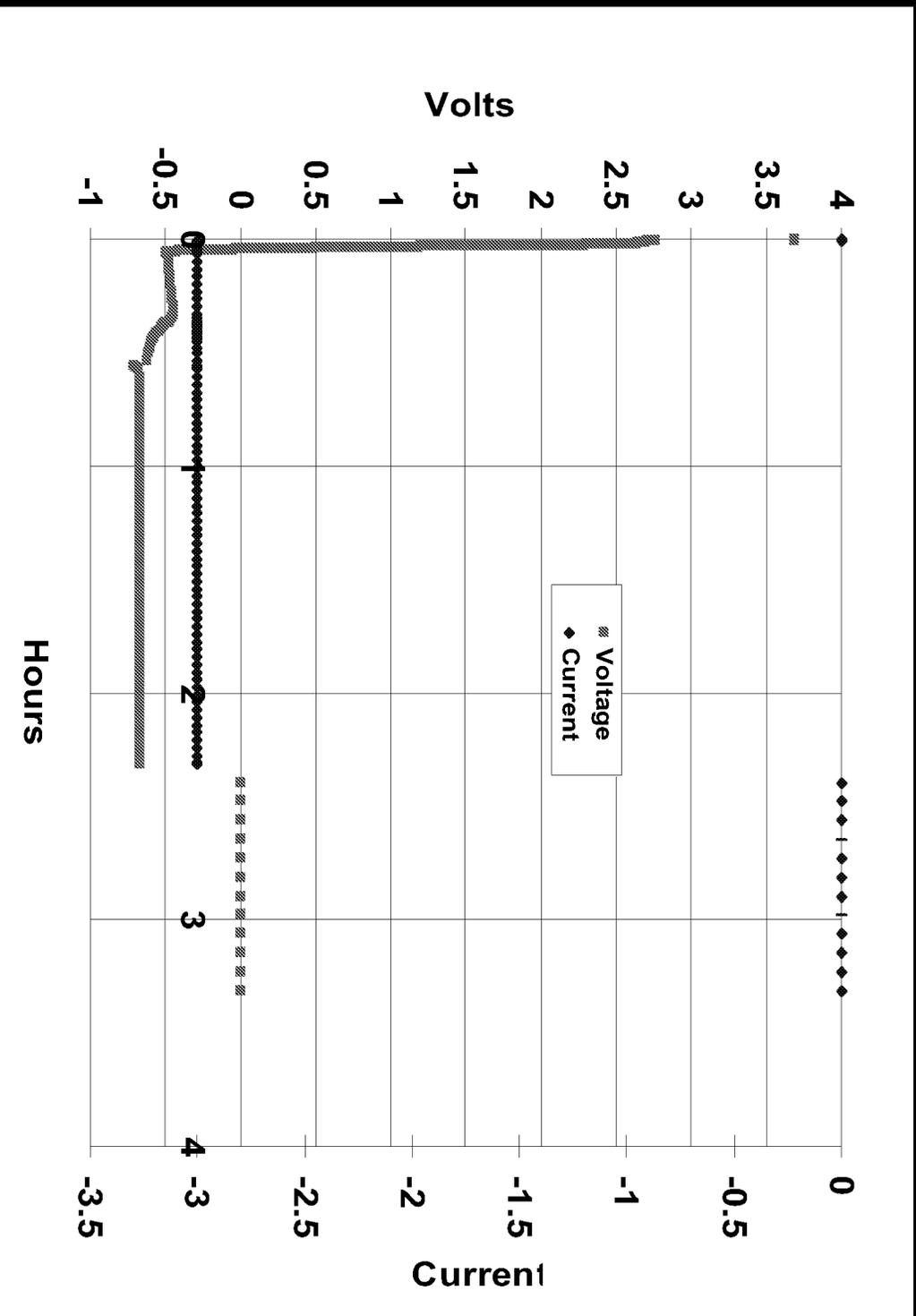
Voltage behavior during 1 A over-discharge with diode at 160 °F and afterwards without diode at 160 °F - LTC-111



Voltage behavior during 1 A over-discharge without diode  
at 160 °F - LTC-114

# 3 Amps at R.T. Over-Discharge Test Results

Cell Type	With Diodes
After 50 mA discharge capacity test	
LTC-114	ok
LTC-111	ok
LTC-115	ok
After 500 mA discharge capacity test	
LTC-114	ok
	vented
LTC-111	ok
LTC-115	ok

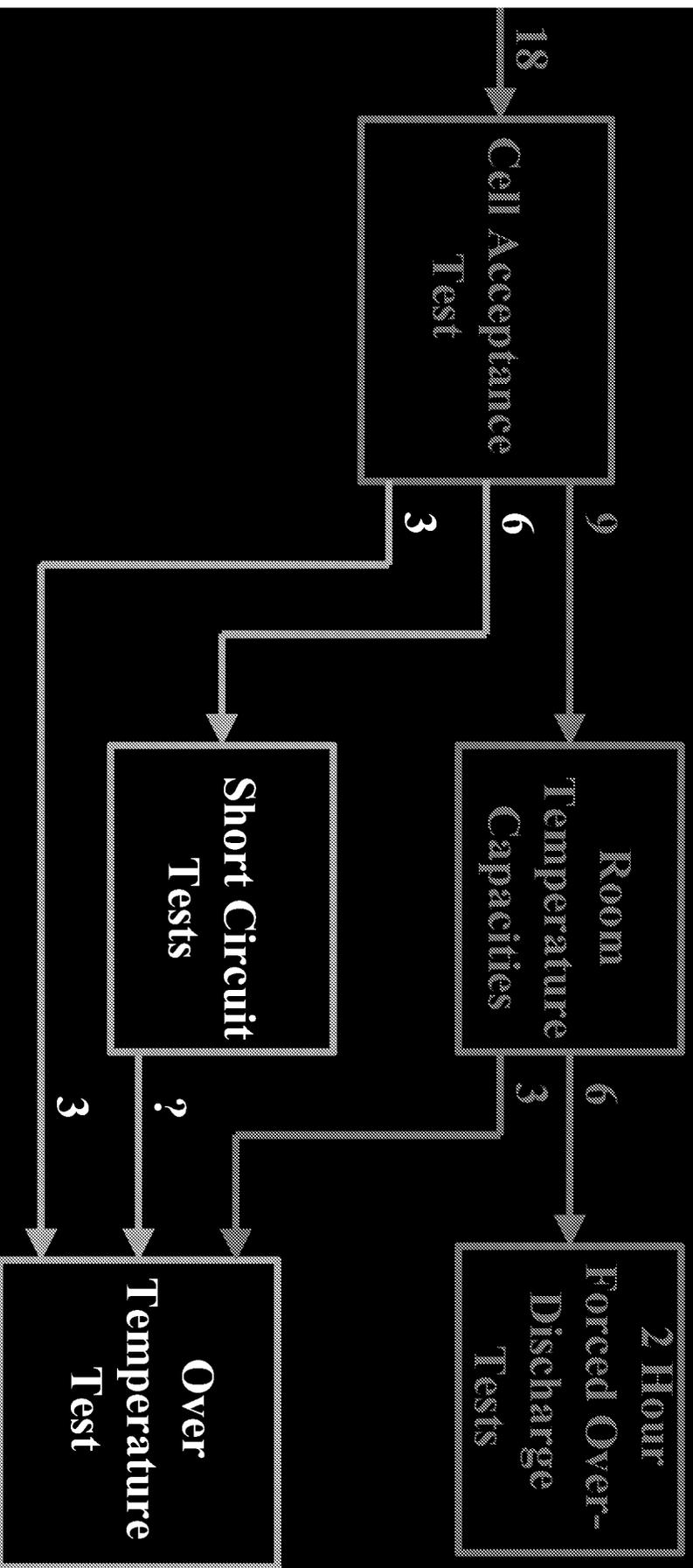


### 3 Amp Over Discharge Curve (Vented) - LTC-114



LTC-114 Cell Vented during 3A Over-Discharge

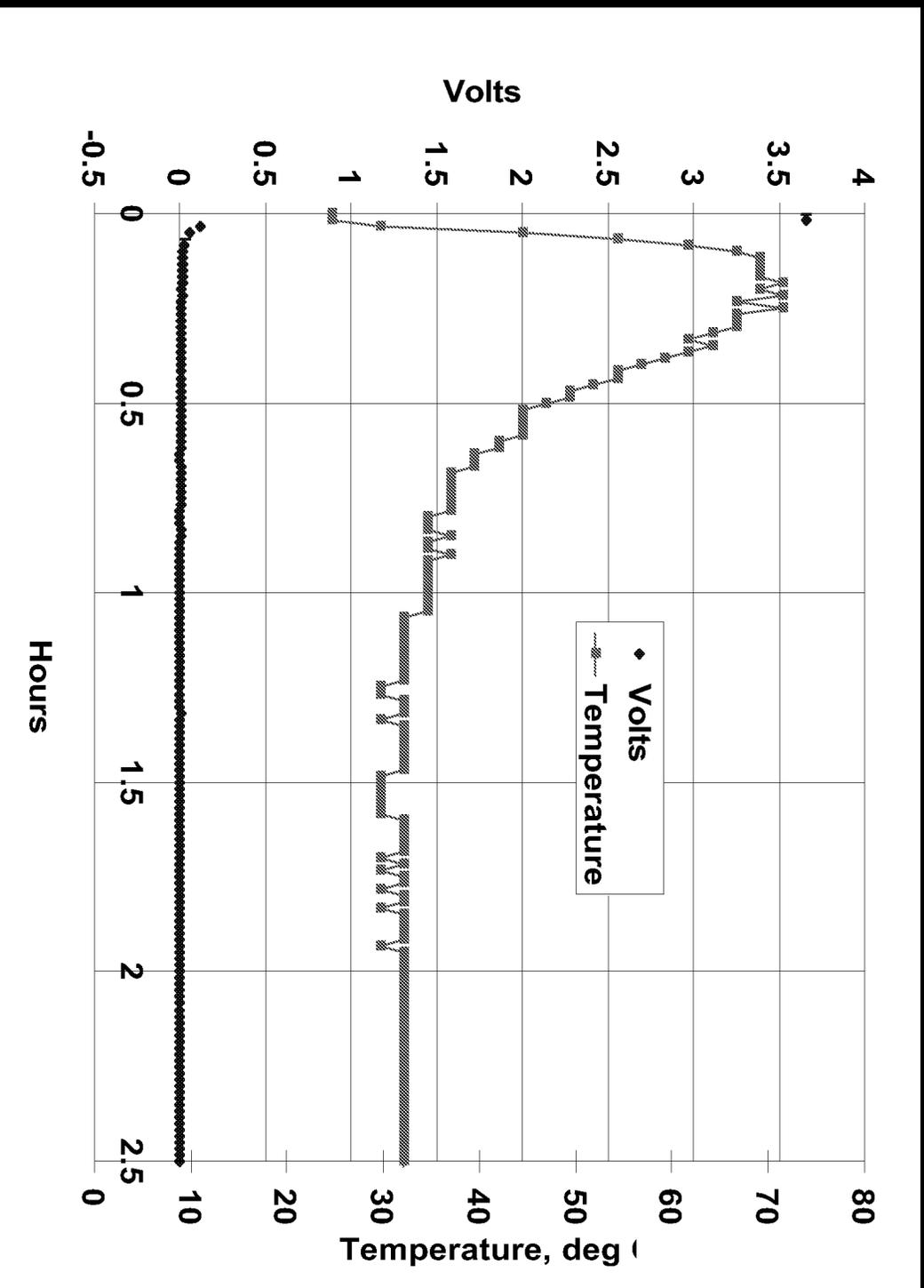
# Test Plan (Overview)



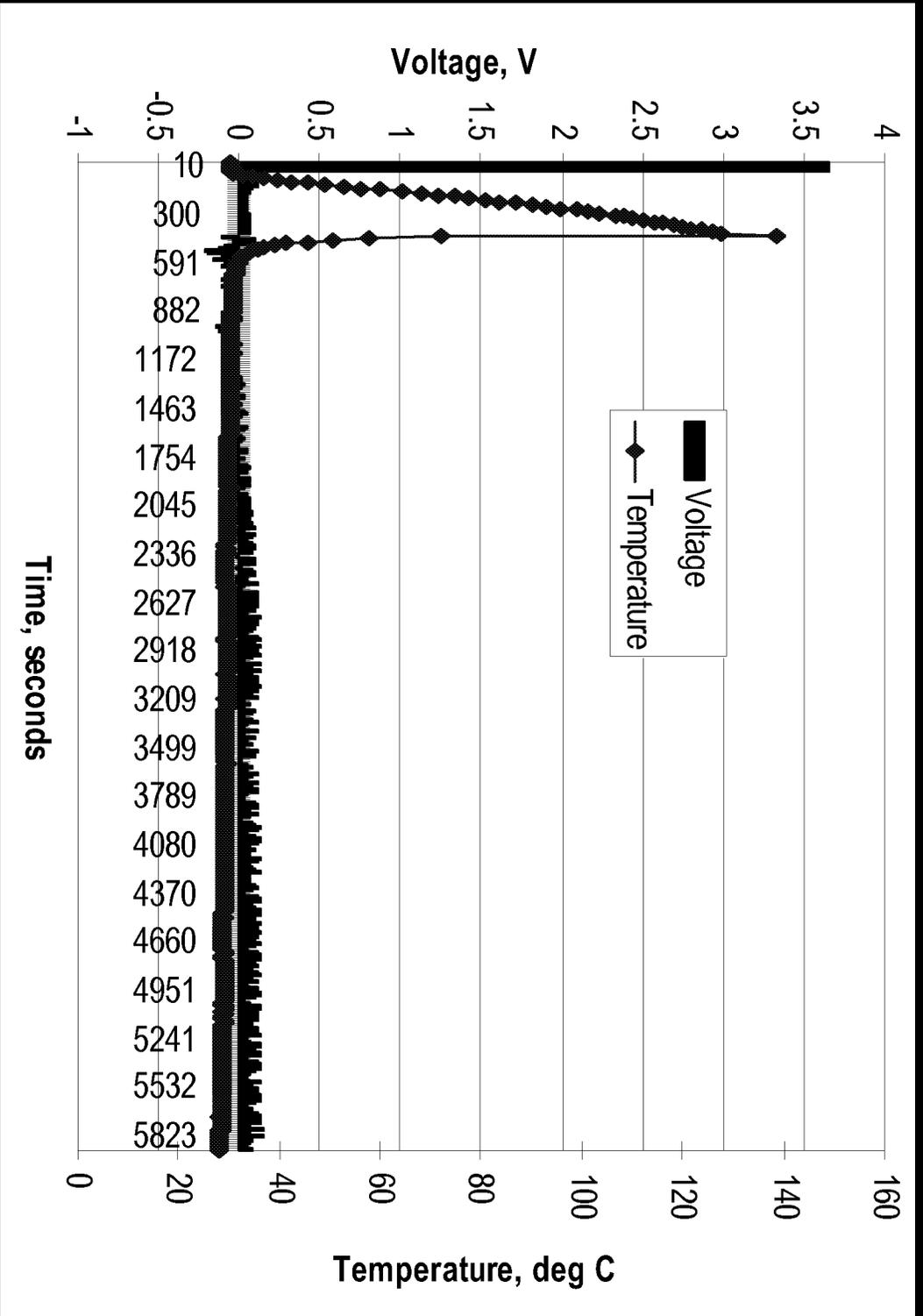
# Room Temperature Short Circuit Test Results

Cell Type	0.050 Ohm short	1 Ohm short
LTC-114	Ok - Cell open in 20 min.	Cell open in 1 hour
	Ok - Cell open in 15 min.	Cell open in 1 hour
	Ok - Cell open in 20 min.	Cell open in 1 hour
LTC-111	Exploded	Ok - No Mishaps
	Leaked	Ok - No Mishaps
	Exploded	Ok - No Mishaps
LTC-115	Cell open immediately	Cell open in 1 hour
	Cell open immediately	Cell open in 1 hour
	Cell open immediately	Cell open in 1 hour

**Note: Cells with 'Ok' went on to the Over Temperature Test**



Typical Short Circuit (50 mΩ) Curve - LTC-114



# Typical Short Circuit (50 mΩ) Curve - LTC-111

# Over Temperature Test Results

Condition	Samples	Status		
<b>After 1 A Discharge Capacity Test</b>	LTC-114	Ok up to 120 °C		
		Ok up to 120 °C		
		Ok up to 120 °C		
	LTC-111	Vented at ~115 °C		
		Vented at ~116 °C		
		Vented at ~120 °C		
	LTC-115	Ok up to 120 °C		
		Ok up to 120 °C		
		Ok up to 120 °C		
	LTC-114	Ok up to 120 °C		
Ok up to 120 °C				
Ok up to 120 °C				
Vented at ~100 °C				
LTC-111	Vented at ~100 °C			
	Vented at ~100 °C			
	Vented at ~100 °C			
<b>Short Circuit Test Survivors</b>	LTC-115	Not tested - All Cells Open Circuit		
			LTC-114	Vented at ~170 °C
				Vented at ~170 °C
				Ok up to 170 °C
			LTC-111	Ok up to 170 °C
				Ok up to 170 °C
				Ok up to 170 °C
<b>Fresh Cells</b>	LTC-115	Vented at ~120 °C		

# Conclusions

- Cells passed most of the acceptance test including consistent Voc of 3.65V and no mishaps during 2 hour 160 °F thermal exposure. However, all cells failed minimum loaded voltage under the 5 Ohm load test probably due to their 5 year storage conditions.
- The medium rate LTC-111 demonstrated very good discharge rate capability. The low rate LTC114 ‘D’ and the medium rate LTC-115 ‘sub D’ both showed significant capacity loss at high discharge rates of 500 mA and greater.
- The medium rate LTC-115 ‘sub D’ had 5% capacity dispersion at 50 mA discharge, while the LTC-111 had 0.2% and the LTC-114 had 0.4% capacity dispersion.
- The medium rate LTC-111 tend to explode or leak when force over-discharged at 160 °F following high rate discharge of 500 mA. The LTC-114 and LTC115 both survived 1 Amp over-discharge with and without diodes for 16 hours.

# Conclusions

- Most cells survived the 3 A over-discharge at room temperature for 2 hours. The cell that failed was the LTC-114 after high rate discharge of 500 mA similar to the results of the 1 A over-discharge test.
- Most cells opened during 0.05 Ohm short circuit test without incident but three LTC-111 cells exploded apparently due to a lack of a thermal cutoff switch. The LTC-114 cells exposed to a hard short of 0.05 Ohms recovered but the LTC-114 cells exposed to a soft short of 1 Ohm did not. This is probably due to the activation of a resettable fuse during a hard short.
- Fresh cells tend to survive exposure to higher temperatures than cells previously discharged at high rate (1 Amp). LTC-111 cells tend to vent at lower temperatures than the all LTC-114 cells and the LTC-115 cells that were previously discharged at rates exceeding 1 Amp.

# Acknowledgements

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