N92-22769

PRESENTATION TO

1991 NASA AEROSPACE BATTERY WORKSHOP

OCTOBER 29-31, 1991
U.S. SPACE & ROCKET CENTER
HUNTSVILLE, AL

PULSED POWER MOLTEN SALT BATTERY

CONTRACT NO. F33615-88-C-2911

AERO PROPULSION LABORATORY
WRIGHT LABORATORY, WL/POOS-2
WRIGHT PATTERSON AIR FORCE BASE, OH 45433

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INTRODUCTION

CHLORINE CATHODES

UNIT CELL DEVELOPMENT

CELL STACK DEVELOPMENT

SUMMARY

INTRODUCTION

CHLORINE CATHODES

UNIT CELL DEVELOPMENT

CELL STACK DEVELOPMENT

SUMMARY

INTRODUCTION

PHASE II PROGRAM GOALS

- **Develop and demonstrate a Li/Al/chlorine molten salt battery design**
  - Develop improved chlorine cathodes
  - Develop unit cell design
  - Demonstrate a stack/battery design

INTRODUCTION

CHLORINE CATHODES

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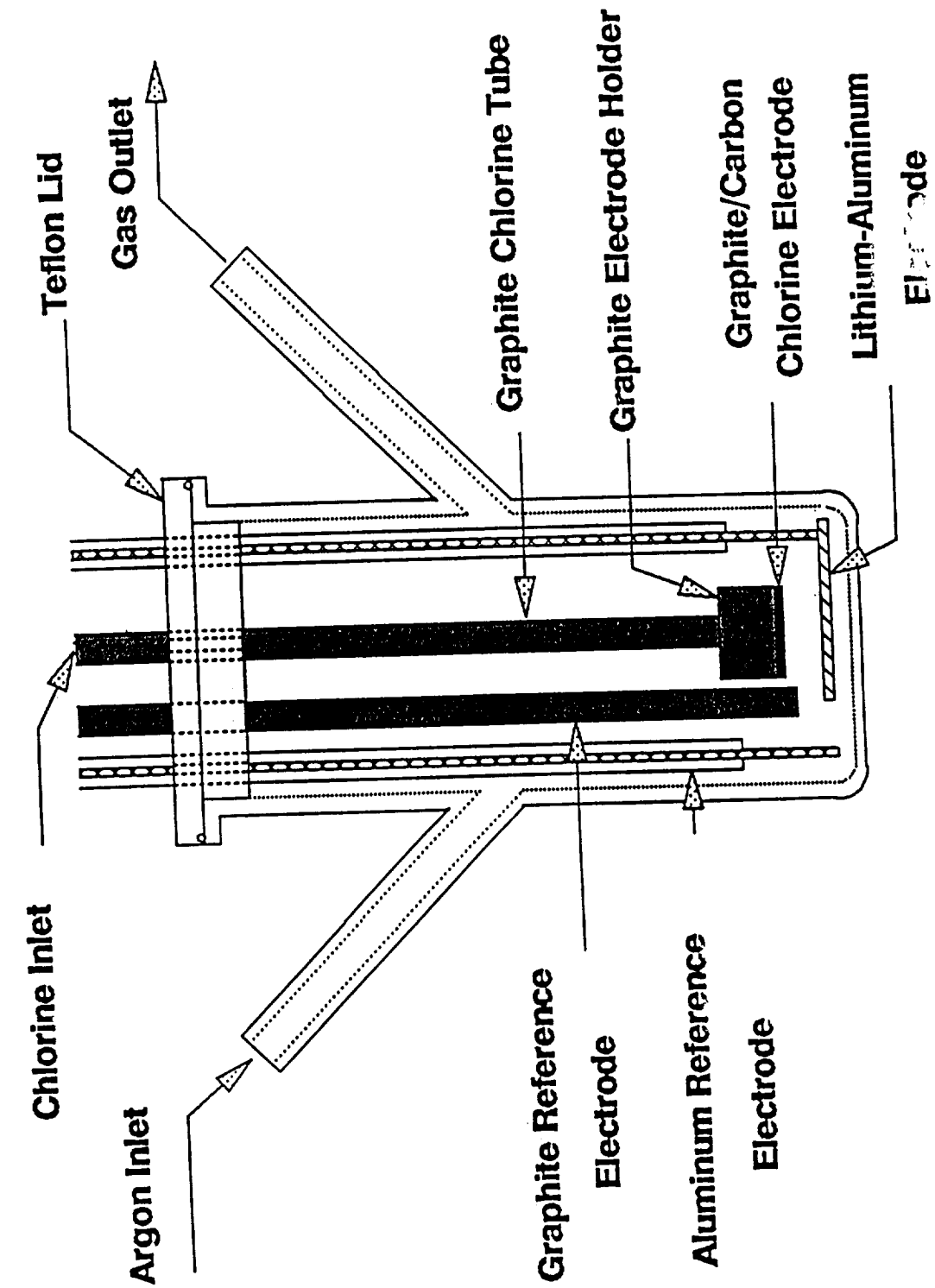
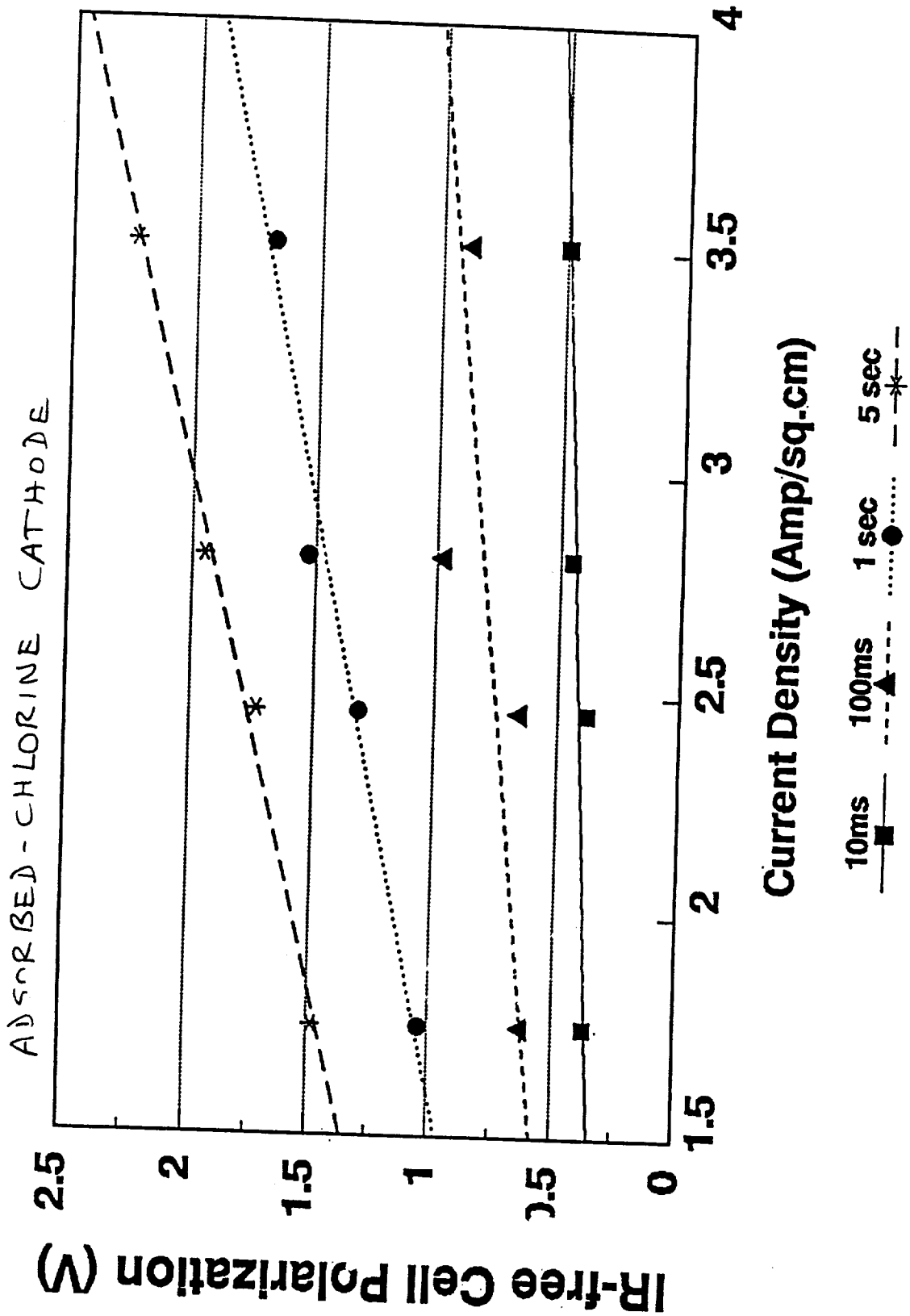
CELL STACK DEVELOPMENT

SUMMARY

CHLORINE CATHODES

- Uniform Pore Size Distribution
- Good Permeability to Chlorine
- Activated Surface
- Electrochemical Activation


Teflon Lid
Gas Outlet
Graphite Chlorine Tube
Graphite Electrode Holder
Graphite/Carbon
Chlorine Electrode
Lithium-Aluminum
Chlorine Inlet
Argon Inlet
Graphite Reference
Electrode
Aluminum Reference
Electrode


ADSORBED - CHLORINE CATHODE
IR-free Cell Polarization (V)
2.5
2
1.5
1
0.5
0
1.5
2
2.5
3
3.5
4
Current Density (Amp/sq.cm)
10ms
100ms
1 sec
5 sec

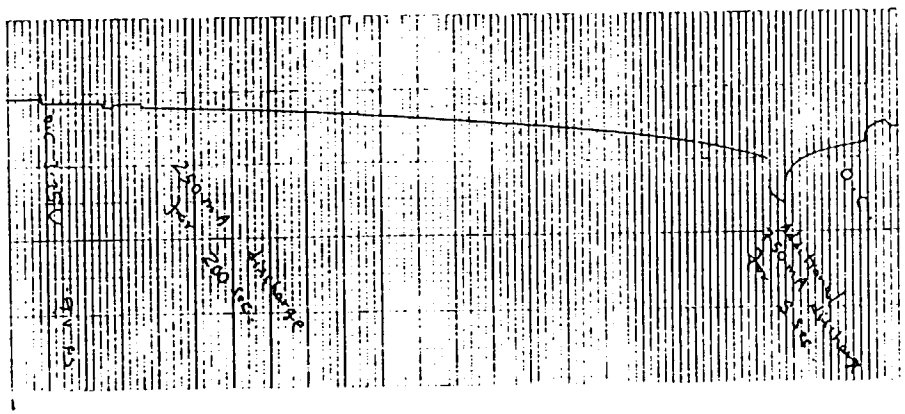
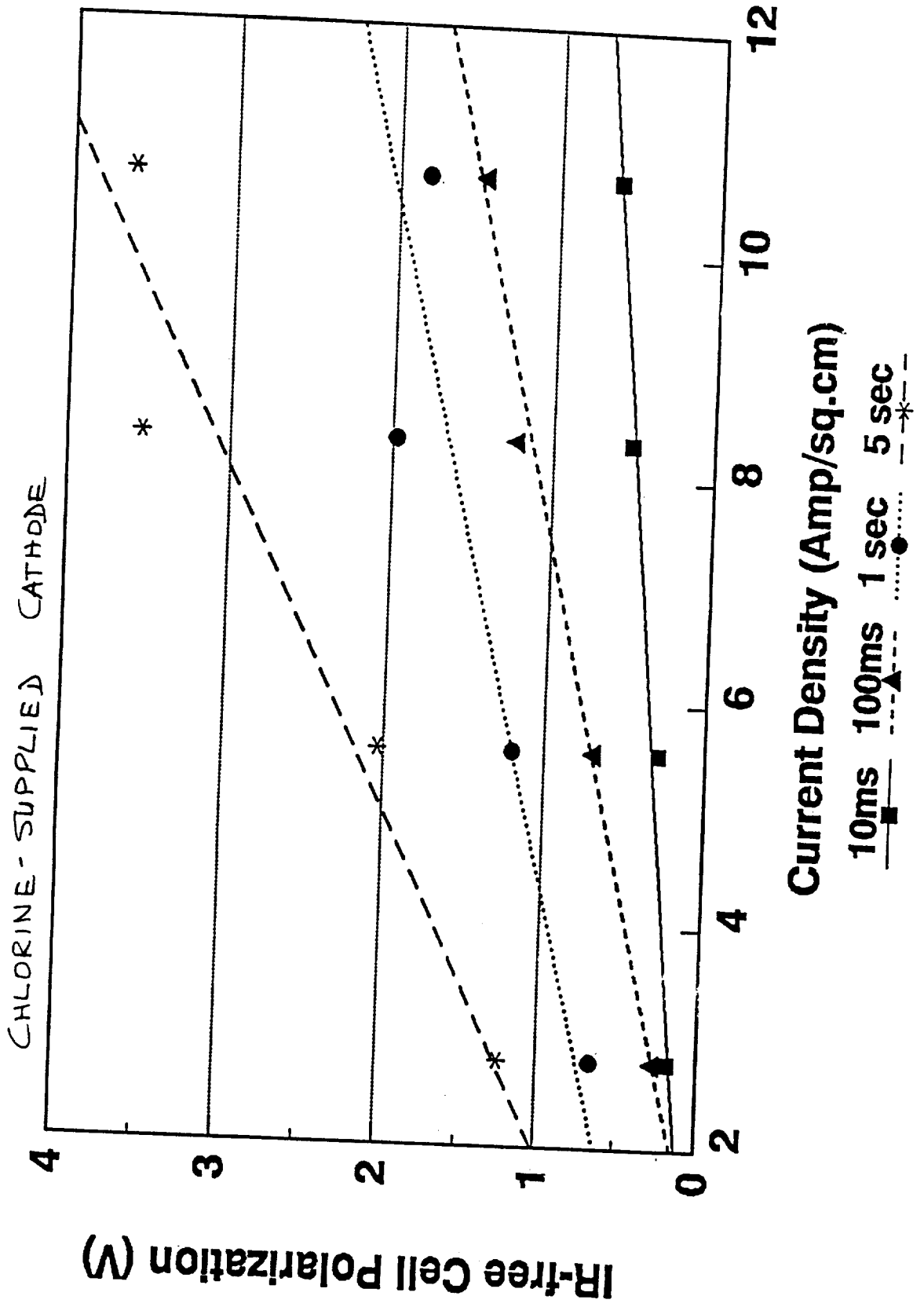
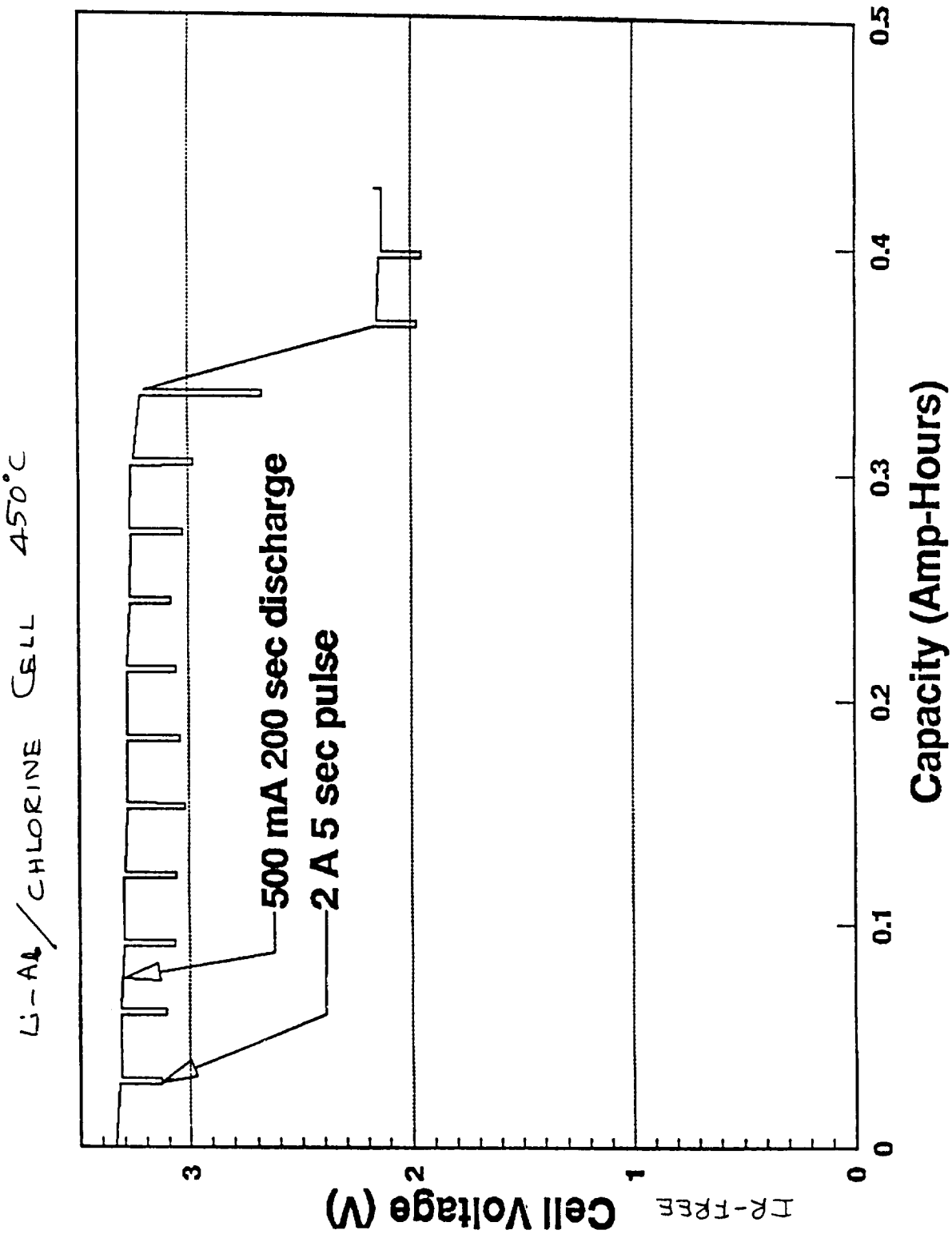
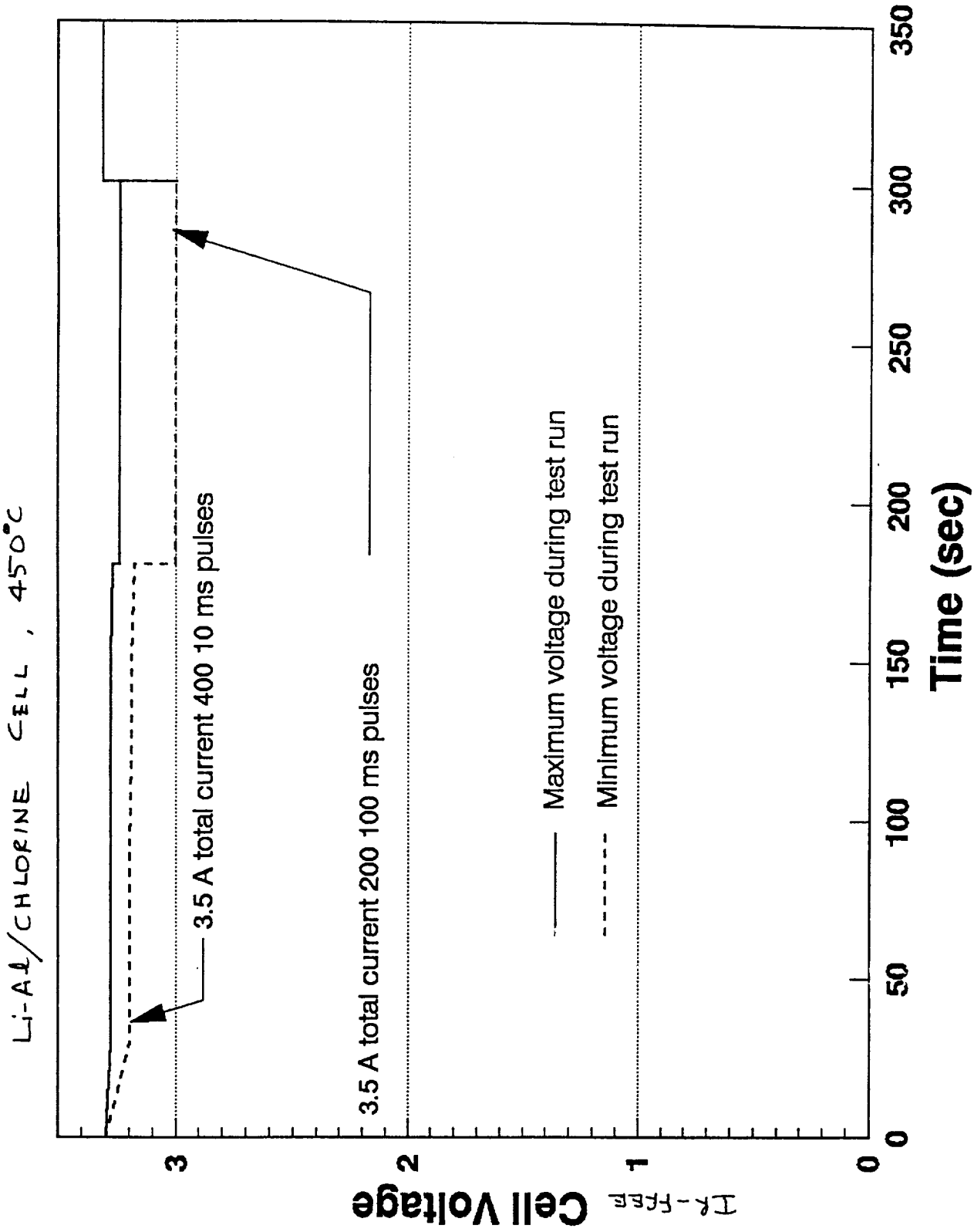


Fig. 5 Discharge characteristics for a Li-Al/carbon 8-9-2 absorbed chlorine cell under test cycle 1 regime, 250 mA for 200 sec followed by 1 A current


IR-free Cell Polarization (V)
0
1
2
3
4
2
4
6
8
10
12
Current Density (Amp/sq.cm)
10ms
100ms
1 sec
5 sec
CHLORINE-SUPPLIED CATHODE


Li-Al/CHLORINE CELL 450°C
500 mA 200 sec discharge
2 A 5 sec pulse
IR-FREE
Cell Voltage (V)
Capacity (Amp-Hours)
0
1
2
3
0
0.1
0.2
0.3
0.4
0.5


Li-Al/Chlorine Cell, 45°C
3.5 A total current 400 10 ms pulses
3.5 A total current 200 100 ms pulses
Maximum voltage during test run
Minimum voltage during test run
Cell Voltage
Time (sec)
0
1
2
3
50
100
150
200
250
300
350

Cathode Performance Summary

- Single Pulsing
- Repetitive Pulsing
- Steady State Discharge
- 200 sec Steady State Load + 5 sec Pulse
- Steady State Load + 100, 10 ms pulses

INTRODUCTION

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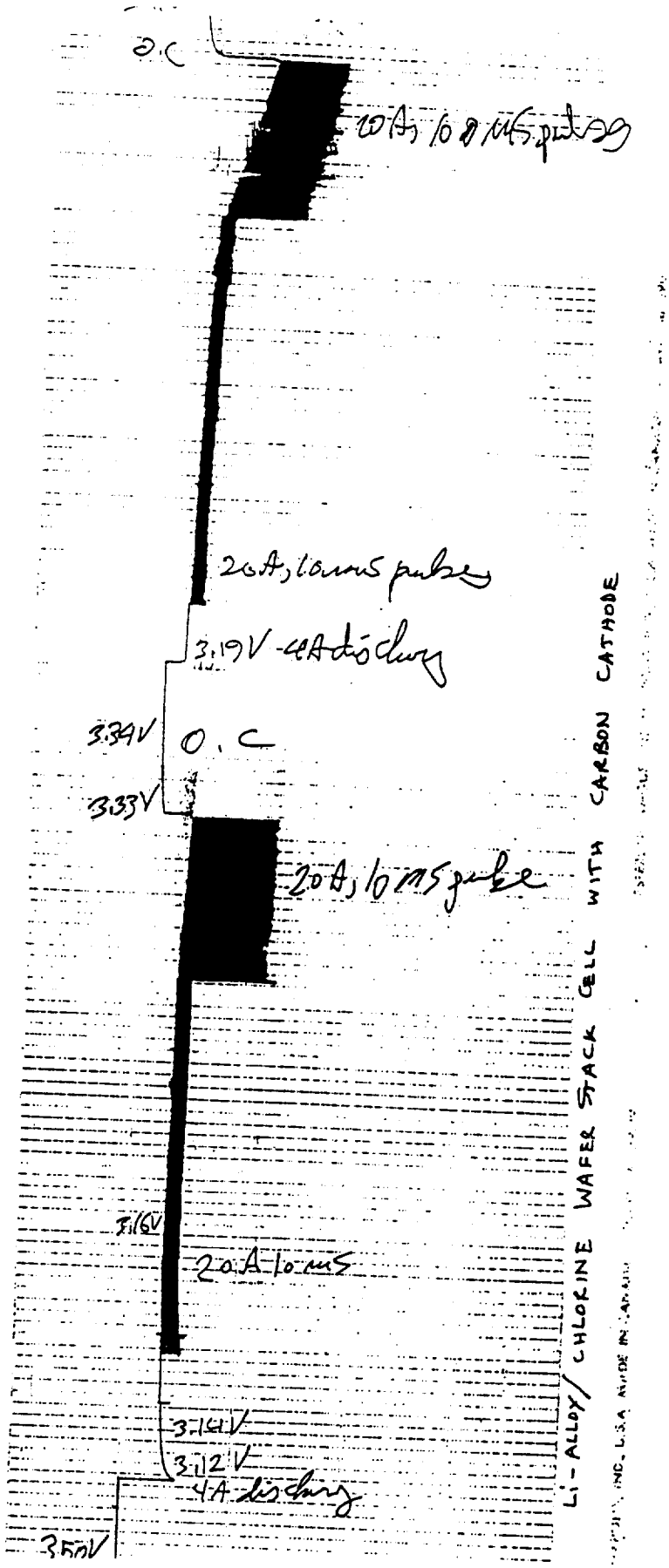
SUMMARY

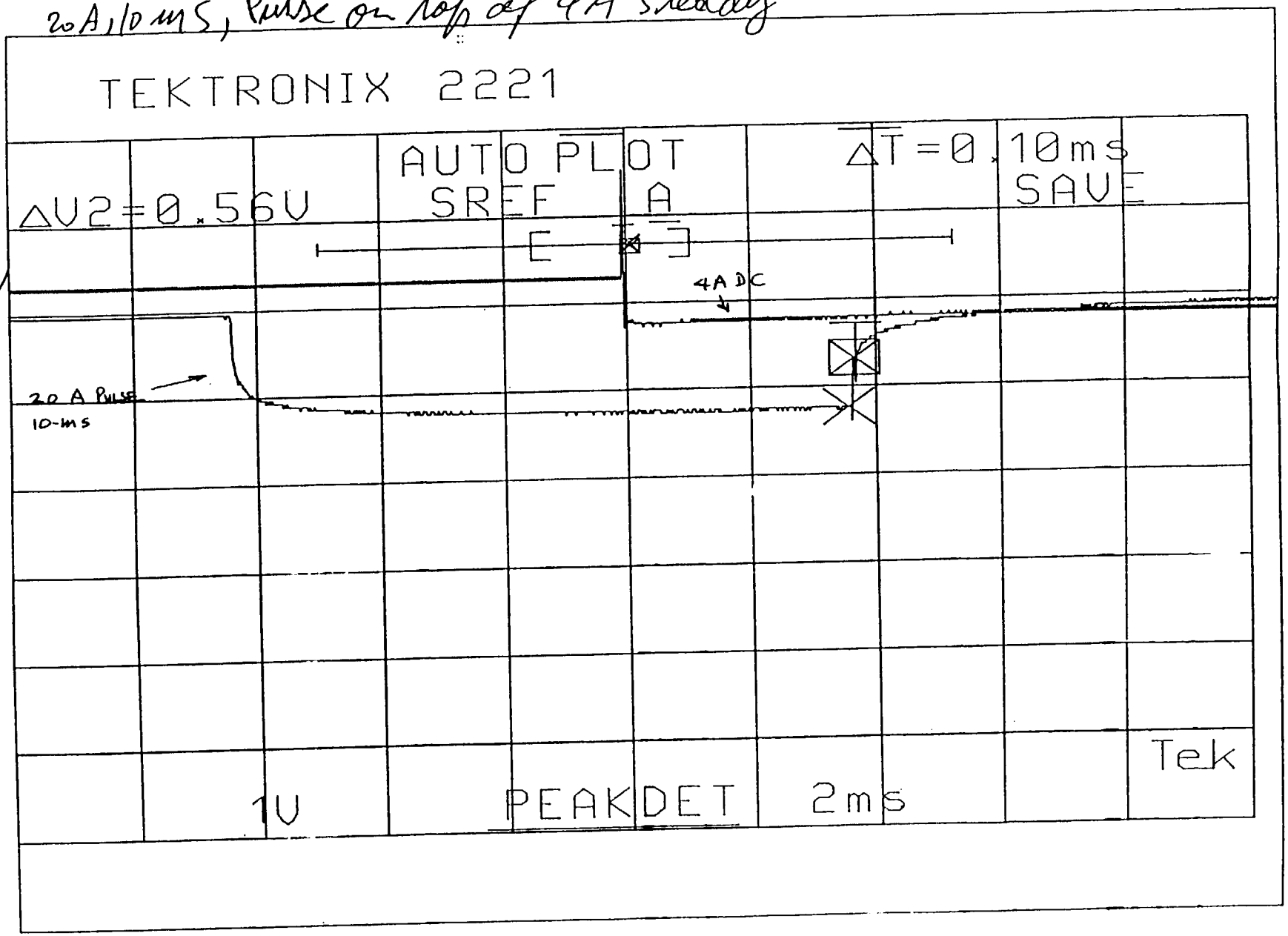
Cell Development

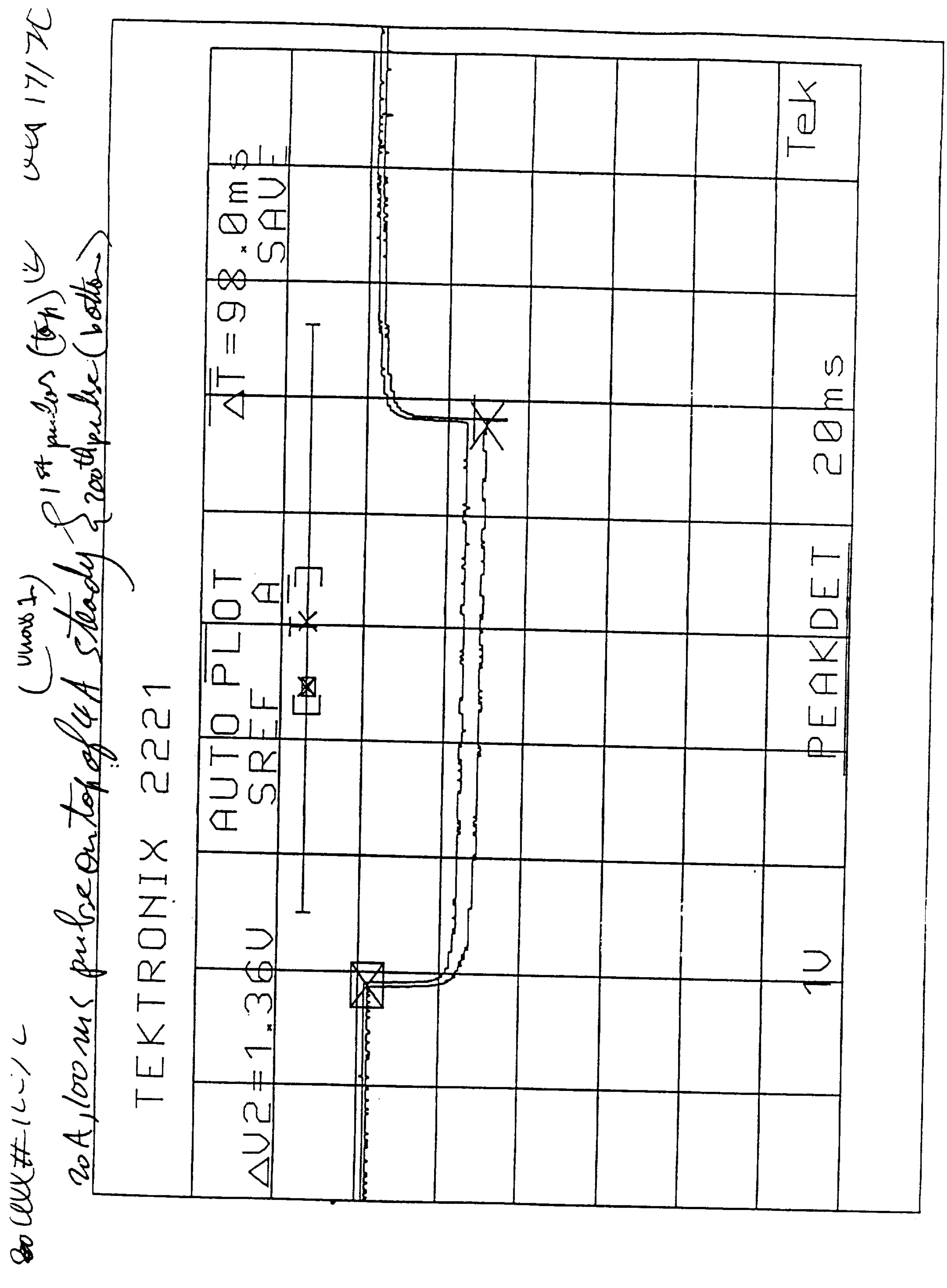
- **Test Hardware**
  - Glass Enclosure Cell
  - Anode Wafer in Stainless Steel or Ni Cup, Nickel leads
  - Cathode rests on EB salt wafer backed by graphite current collector
  - Chlorine fed to the wafer-ambient pressure
- **Test Regime**
  - Steady discharge load + 400 10 ms pulses + 200 100 ms pulses


O.C
20A, 10ms pulse
3.19V - 4A discharge
3.34V
O.C
3.33V
20A, 10ms pulse
3.16V
20A-10ms
3.14V
3.12V
4A discharge
3.50V
Li-ALLOY/CHLORINE WAFER STACK CELL WITH CARBON CATHODE

cell # 12-92 (trial 1) (c) oct 19/90

20A, 10 mS, Pulse on top of 4A steady




TEKTRONIX 2221
ΔV2=1.36V
AUTO PLOT
SREF
ΔT=98.0ms
SAVE
A
1V
PEAKDET
20ms
Tek

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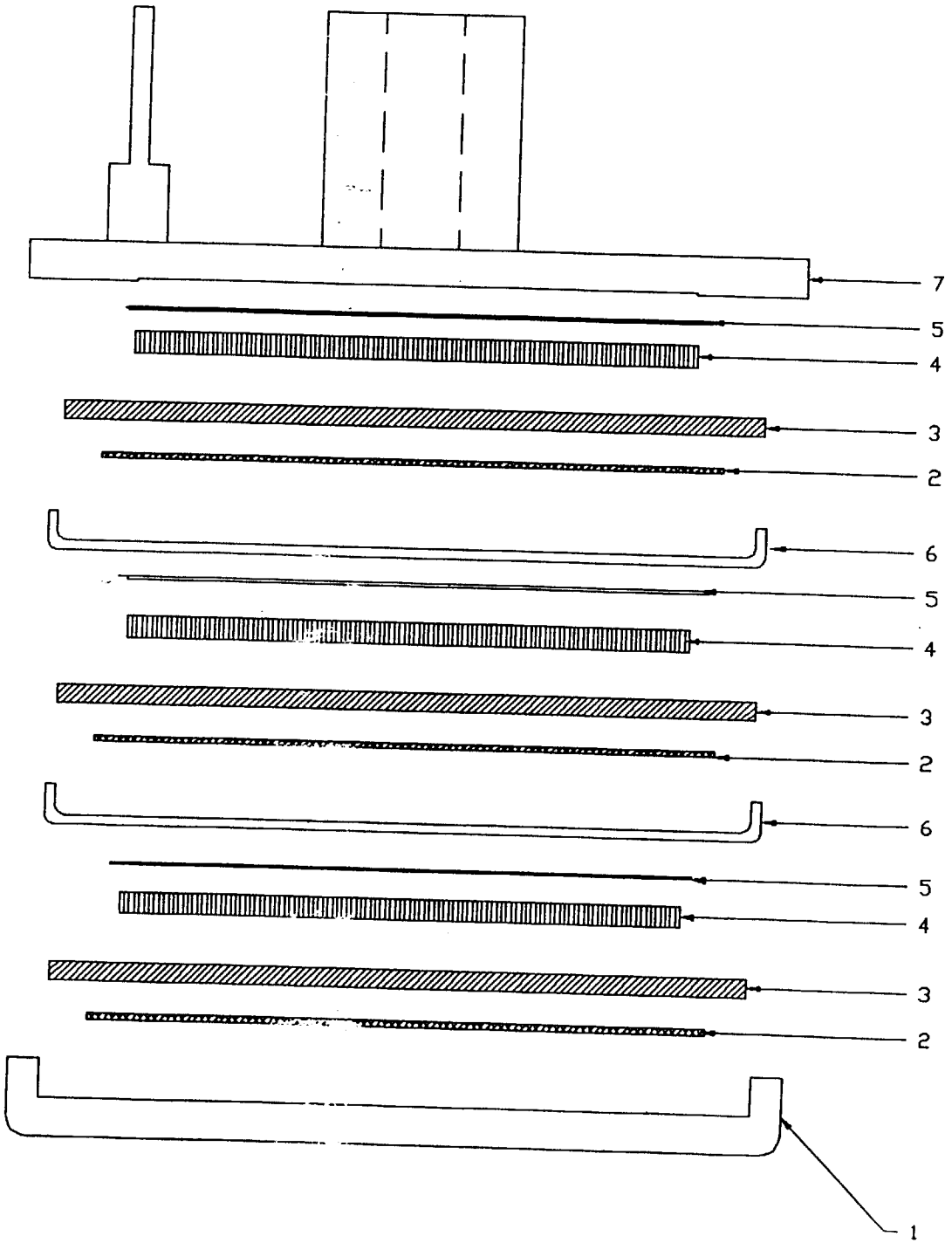
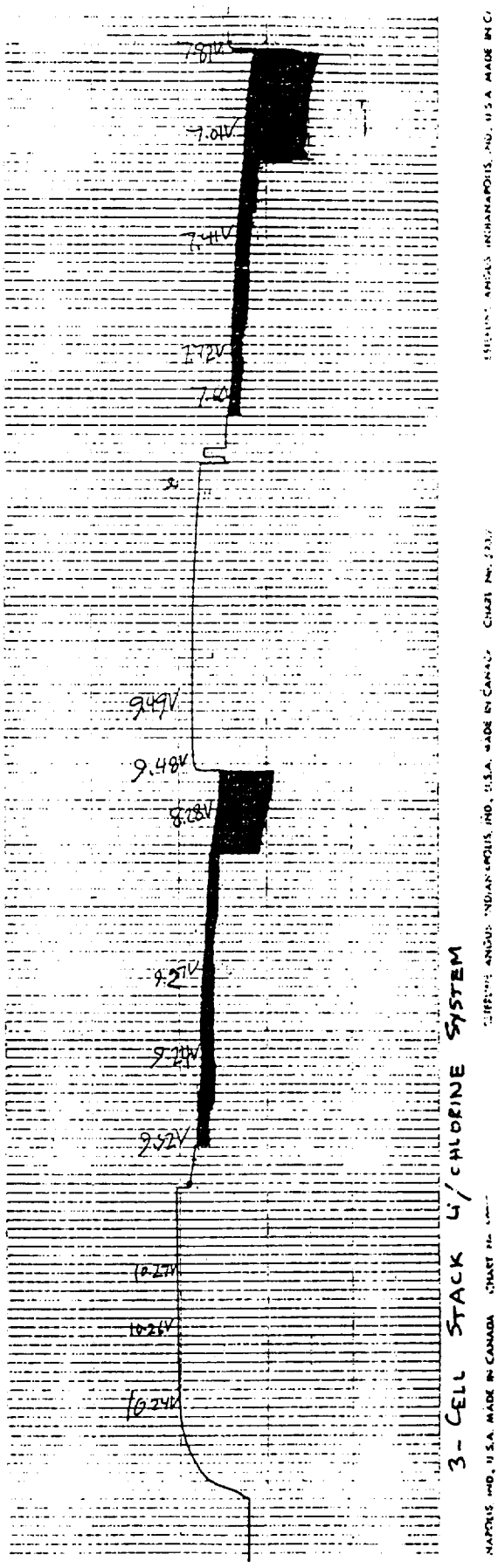
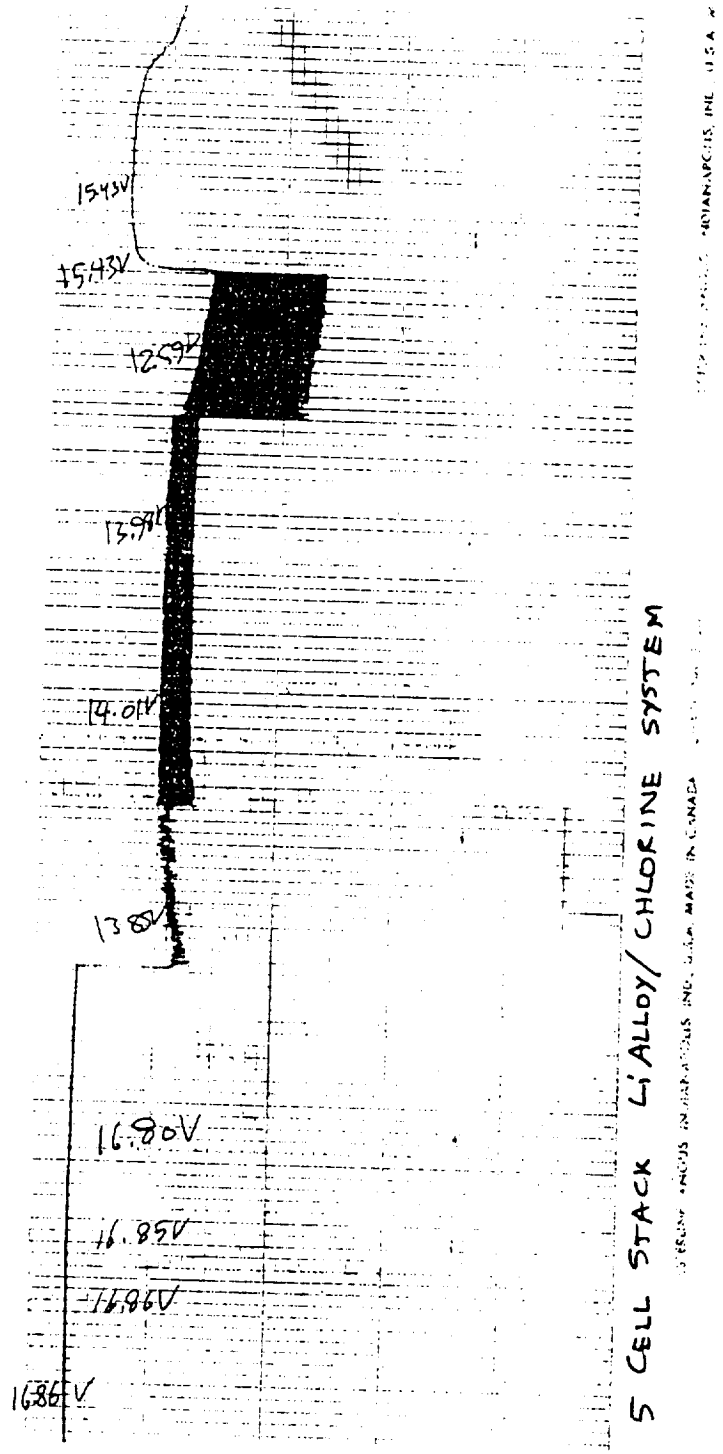


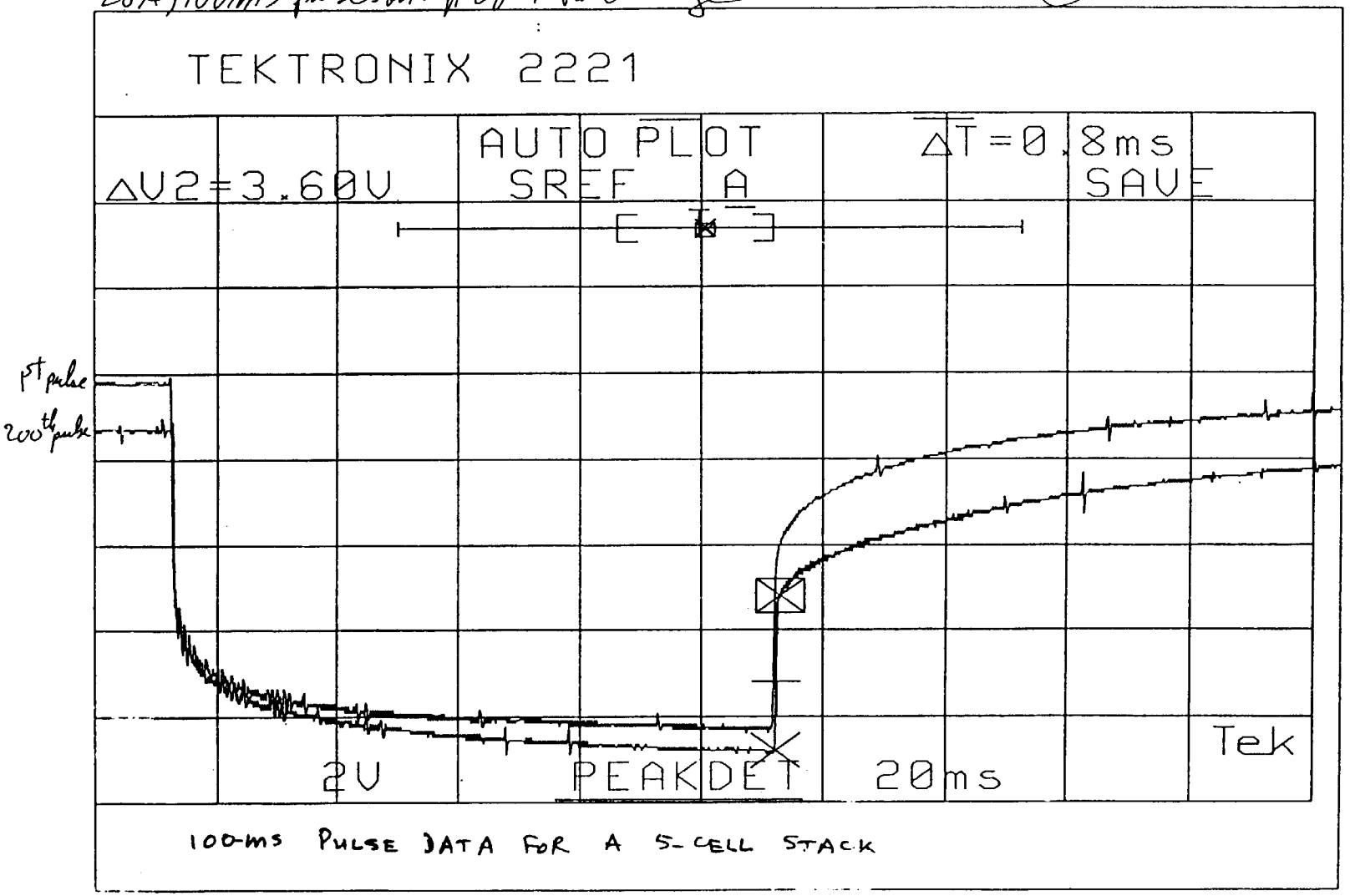
1. Anode Current Collector
2. Li-Al Anode
3. Salt Wafer
4. Carbon Cathode
5. Grafoil
6. Nickel Cup
7. Cathode Current Collector with Chlorine Feed Tube


7.81V
7.01V
7.41V
7.72V
7.40
9.49V
9.48V
8.28V
9.25V
9.21V
9.52V
10.27V
10.25V
10.24V
3- CELL STACK Li/CHLORINE SYSTEM

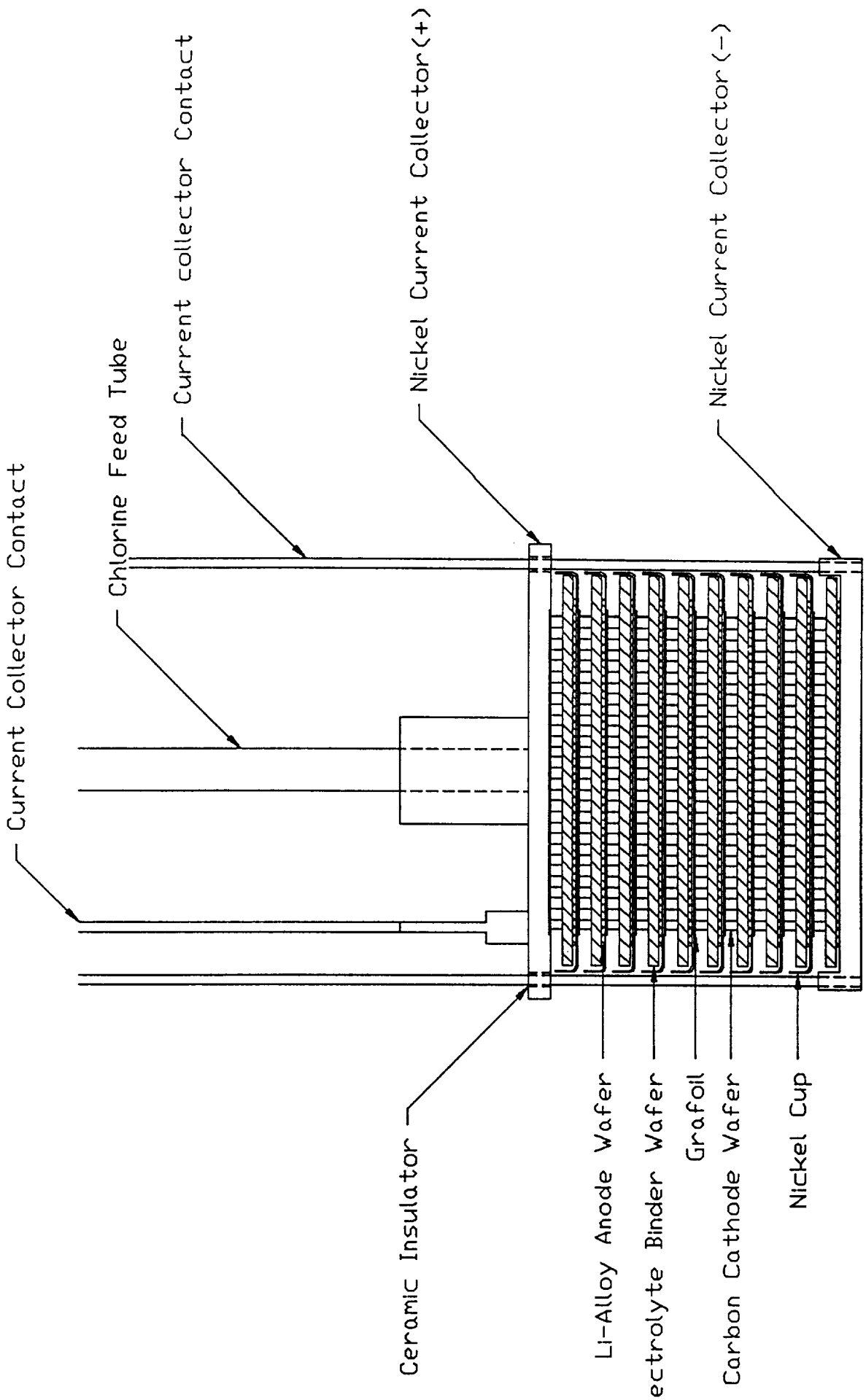

5 CELL STACK Li ALLOY/ CHLORINE SYSTEM
15.43V
15.43V
12.59V
13.99V
14.01V
13.8V
16.80V
16.85V
16.86V
16.86V

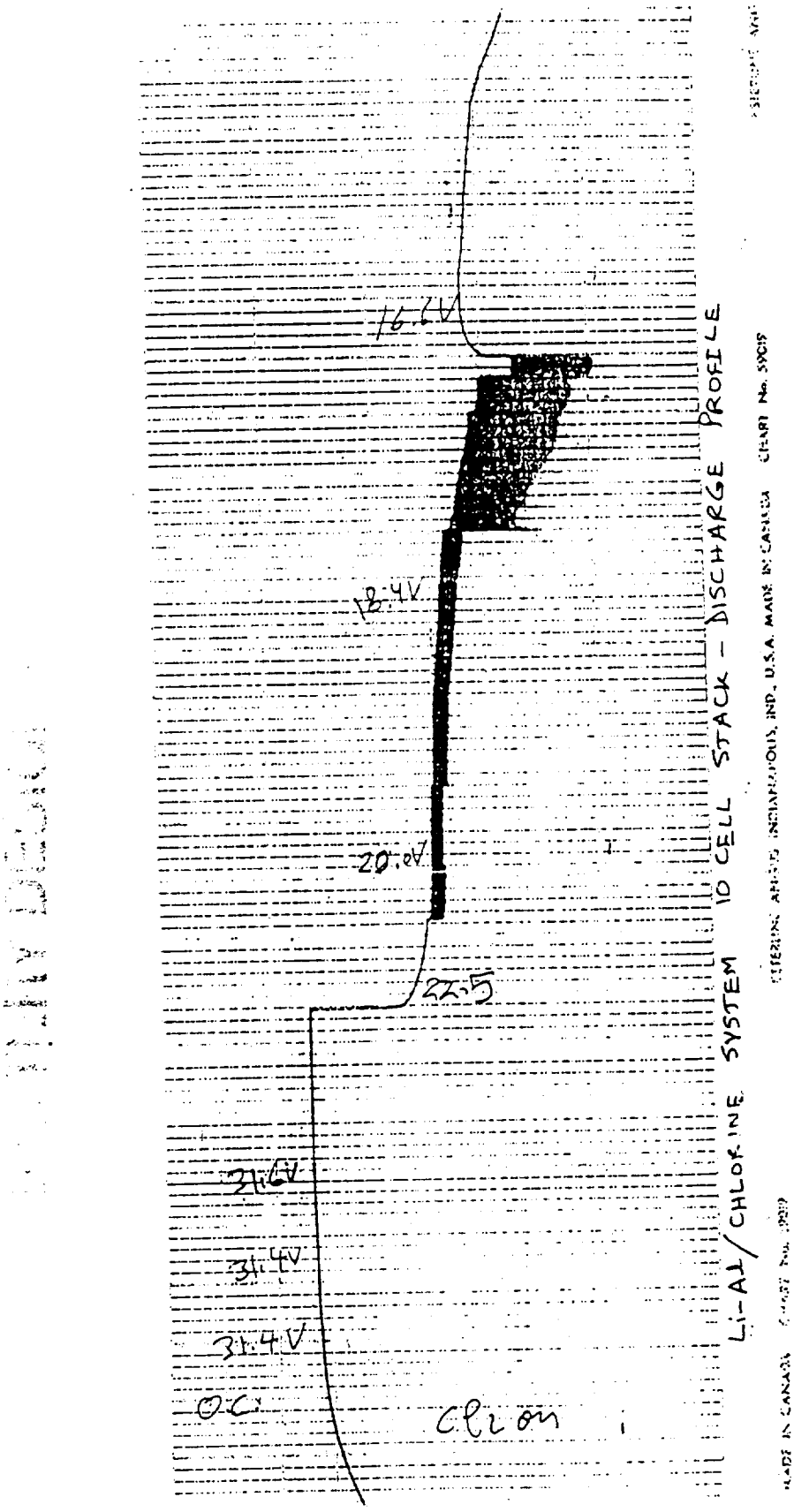
all #12 -146 (trial 1) (2) 11/17/9

20A, 100ms pulses on top of 4A discharge



100-ms Pulse Data for a 5-cell stack


Current Collector Contact
Chlorine Feed Tube
Current collector Contact
Nickel Current Collector(+)
Nickel Current Collector(-)
Ceramic Insulator
Li-Alloy Anode Wafer
Electrolyte Binder Wafer
Grafoil
Carbon Cathode Wafer
Nickel Cup


16.4V
18.4V
20.0V
22.5
21.6V
31.4V
31.4V
OC
Cl2 on
Li-Al/CHLORINE SYSTEM 10 CELL STACK – DISCHARGE PROFILE

BATTERY DESIGN PARAMETERS

Delivered Energy	56 Wh
Output Voltage	96 V
No. of Cells	40
Open Circuit Voltage	134 V
Capacity	0.56 Ah
Weight	1.34 kg
Volume	1.32 L
Current Density	0.25 A/sq. cm
Pulsing	1.00 A/sq.cm

POWER DENSITY

4A DC, 24A PULSE REGIME

	kW/kg 10 ms	kW/kg 100 ms	kW/L 10 ms	kW/L 100 ms
Cell	3.9	3.2	4.3	3.5
Stack (5-cell)	3.9	3.1	4.3	3.4
Battery	1.7	1.4	1.7	1.4

ENERGY DENSITY

4A DC, 24 A PULSE REGIME

	Wh/kg	Wh/L
CELL		
1 cycle	102	112
2 cycle	183	201
STACK	95	104
BATTERY	42	43

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- Carbon Cathodes with chlorine work well
- Li-Alloy/chlorine at 450 deg. C, 1atm
  - High Power capability
  - High energy density
  - DC + pulsing - 600 pulses
  - No initial peak
  - Can go to red heat without burn-up

SUMMARY

- Electrochemical performance at the cell and cell stack level under demanding test regime
- Engineering and full prototype development for advancing this technology is warranted

Nickel-Hydrogen Technologies Session

Organizers: *Joe Stockel*
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NASA Lewis Research Center

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