INTERNAL/EXTERNAL SHORT CIRCUIT PROTECTION FOR LI D CELLS	Propulsion and Power Division	
	B.J. Bragg	10/29/91

DEVELOPMENT OF INTERNAL/EXTERNAL SHORT CIRCUIT PROTECTION FOR LITHIUM D CELLS

NAS 9-18279

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INTERNAL/EXTERNAL SHORT CIRCUIT PROTECTION FOR LI D CELLS

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AGENDA

- HISTORICAL NEED
- PROGRAM OBJECTIVES
- COMPOSITE THERMAL SWITCH (CTS) DEVELOPMENT
- LABORATORY CELLS WITH CTS
- INCORPORATION INTO LITHIUM D CELLS
- RESULTS/CONCLUSIONS

NASA Johnson Space Center | Engineering Directorate

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HISTORICAL NEED

- AN "INTERNAL CELL SHORT" IS CONSIDERED A CRIT 1/1 FOR SHUTTLE ORBITER LITHIUM C, D, & DD CELL APPLICATIONS
  - CRIT 1/1 IS LOSS OF VEHICLE/CREW
  - INDICATES NO "POSITIVE CONTROL" AVAILABLE
- LITHIUM CELLS OF C, D, DD SIZES REQUIRE A "WAIVER" TO FLY
  - WAIVER APPROVAL JUSTIFIED BY "ACCEPTABLE RISK"
  - SUPPORT FOR WAIVER APPROVAL
    - HISTORICAL DATA BASE WITH NO SUCH FAILURES
    - EXTENSIVE MFG PROCESS CONTROL PROVISIONS
    - EXTENSIVE QUALITY CONTROL PROVISIONS
    - EXTENSIVE CELL/BATT ACCEPTANCE/LOT CERT TESTING
- APPLICATIONS WITH APPROVED WAIVERS
  - Li-BCX C CELLS: BATTERIES OF 2 & 3 CELLS EACH
  - LI-BCX D CELLS: BATTERIES OF 1, 2, 4, 8, & 16 CELLS EACH
  - LI-CF "DD" CELLS: BATTERY OF 12 CELLS

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PROGRAM OBJECTIVES

- DEVELOP POSITIVE CONTROL ACTIVATED BY TEMPERATURE
  - POSITIVE CONTROL LIKE A FUSE OR THERMOSTAT
  - MFG PROCESSES, QC, ATP, LCT ARE ALL INDIRECT CONTROLS
  - ACTIVATION TEMPERATURE OF 75 'C < T < 150 'C
- DEMONSTRATE CONTROL CONCEPT IN LITHIUM D CELLS
  - MUST BE COMPATIBLE WITH LI-BCX & LI-SOCL2
  - COVER PERFORMANCE UP TO 10 MA/CM2
  - IMPACT VOLTAGE < 5%
  - IMPACT CAPACITY/STORAGE LIFE < 10%
- DEMONSTRATE ABUSE TOLERANCE
  - INTERNAL/EXTERNAL SHORT CIRCUIT
  - CHARGING, OVERDISCHARGING, OVERTEMPERATURE
  - SHOCK & VIBRATION

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CTS DEVELOPMENT

- CONTROL CONCEPT IS PTC-TYPE CTS FILM
  - PTC (POSITIVE TEMPERATURE COEFFICIENT)
    - ELECTRICALLY CONDUCTIVE AT -40 'C TO +70 'C
    - STEP INCREASE TO INSULATOR AT 75 'C < T < 150 'C
  - CTS FILM TO REPLACE OR COAT CATHODE CURRENT COLLECTOR
  - CTS FILM IS SINTERED MIXTURE OF METAL & FLUOCARBON PARTICLES
    - DIFFERENT THERMAL EXPANSION COEFFICIENTS (3-30X) PROVIDE SWITCHING

- CTS IS YTP PATENT NO. 4,603,165 (1986)
  - VARIETY OF METAL PARTICLE SIZES AND PERCENTAGES
    - CONSIDER NI, MO, W OF 3-20 MICRONS
  - VARIETY OF FLUOROCARBON PARTICLE SIZES AND PERCENTAGES
    - TEFLONS (PFTE, FEP, PFA) OF 3-20 MICRONS
    - HALAR ECTFE
    - TEFZEL ETFE
  - USE COMBINATIONS IN VARIOUS FILM THICKNESSES

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- FABRICATION OF FILM
  - MATERIALS EVALUATED AS COUPONS (1 " DIA X 0.05" THK)
    - USED NICKEL POWDERS (INCO)
      - NI HDNP, 4SP, 123, 128 OF 3-20 MICRONS
    - USED FLUOROCARBON POWDERS (DUPONT)
      - TEFLONS MP1000-MP1500, TE3607, AND TEFZEL HT2020
      - PARTICLE SIZES OF 3-60 MICRONS
  - TECHNIQUES EVALUATED FOR COUPONS
    - COLD PRESSING (3600-5000 LBS F) WITH SINTERING @ 260-413 'C
    - SLURRIES OF WATER, POLYMER SUSPENSIONS, & ORGANIC SOLVENTS WITH SUBSEQUENT SINTERING
    - DOCTOR BLADING & SINTERING UNDER PRESSURE

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LABORATORY CELLS WITH CTS

- 15 CELLS BUILT
- CATHODE FABRICATION
  - NICKEL EXMET SUBSTRATE
  - 0.020" CTS FILM
  - CARBON THERMALLY BONDED OR PRESSURE BONDED
- CELL OF 0.22 AH AND 26 CM2
  - DISCHARGED AT 2 MA/CM2 AT VARIOUS TEMPS FOR CAPACITY AND POLARIZATION
  - CELLS HEATED FOR SWITCHING DEMONSTRATION
    - SOME DEMONSTRATED SWITCHING BETWEEN 136 'C AND 141 'C
    - SOME DID NOT SWITCH UP THRU 170 'C, AND INDICATED INCOMPLETE COVERAGE OF SUBSTRATE

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INCORPORATION INTO LITHIUM D CELLS

USED YTP BA6590 MODEL: SUB D CELL
- 10 AH CELL @ 2 AMPS
- CATHODE PLATE AREA OF ~ 535 CM2
- CATHODE THICKNESS OF 0.005"

CTS CELLS WITH 0.025" CATHODE THICKNESS MINIMUM
- MAXIMUM PLATE AREA OF 268 CM2 IN ABOVE CELL CASE
- 70 % CAPACITY DECREASE COMPARED TO BA6590
- CTS CATHODE HAS TWICE THE INTERNAL RESISTANCE

CONTROL CELLS: USED BA6590 CELL CASE WITH CTS ELECTRODE AREAS
- APPROACH CHOSEN FOR SHORT CIRCUIT TEST COMPARISON
- NOT POSSIBLE TO DIRECTLY COMPARE PERFORMANCE
- NEEDED LARGER MANDREL OR BETTER CARBON/EXMET CONTACT

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RESULTS/CONCLUSIONS

- QUALITATIVELY DEMONSTRATED PROTECTION
  - CTS & CONTROL CELLS INSULATED & SHORTED (20-40 M-OHMS)
  - CTS CELL WITH 10 % NICKEL SHUT DOWN ON SHORT CIRCUIT
    - 2.9 AMPS MAX CURRENT AT 0.05 VOLTS
    - REACHED THERMAL EQUILIBRIUM (41 'C) AFTER 5 MINUTES
    - BOTH CURRENT & VOLTAGE REDUCED AT 7 MINUTES
  - CONTROL CELL VENTED WITH LOUD REPORT & BURNED
    - 5 AMPS AT 0.5 VOLTS
    - REACHED 160 'C AT 11.5 MINUTES - VENTED
    - TOP AND BOTTOM BLOWN OFF
    - ELECTRODE MATERIAL EJECTED & BURNED
- PERFORMANCE OBJECTIVES NOT ACHIEVED
- OTHER ABUSE CHARACTERISTICS NOT ADDRESSED
- POTENTIAL FOR FUTURE WORK UNDER CONSIDERATION

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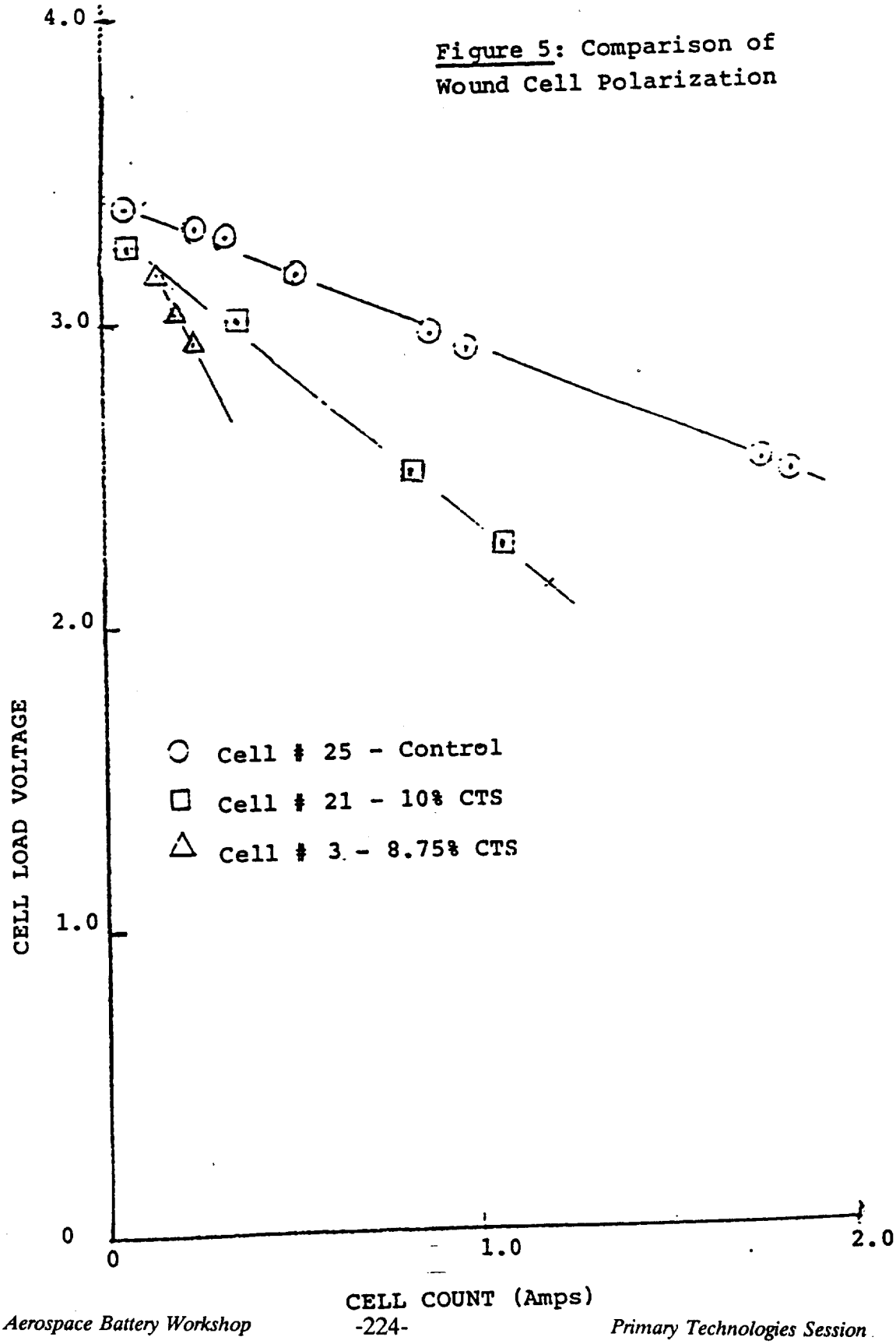
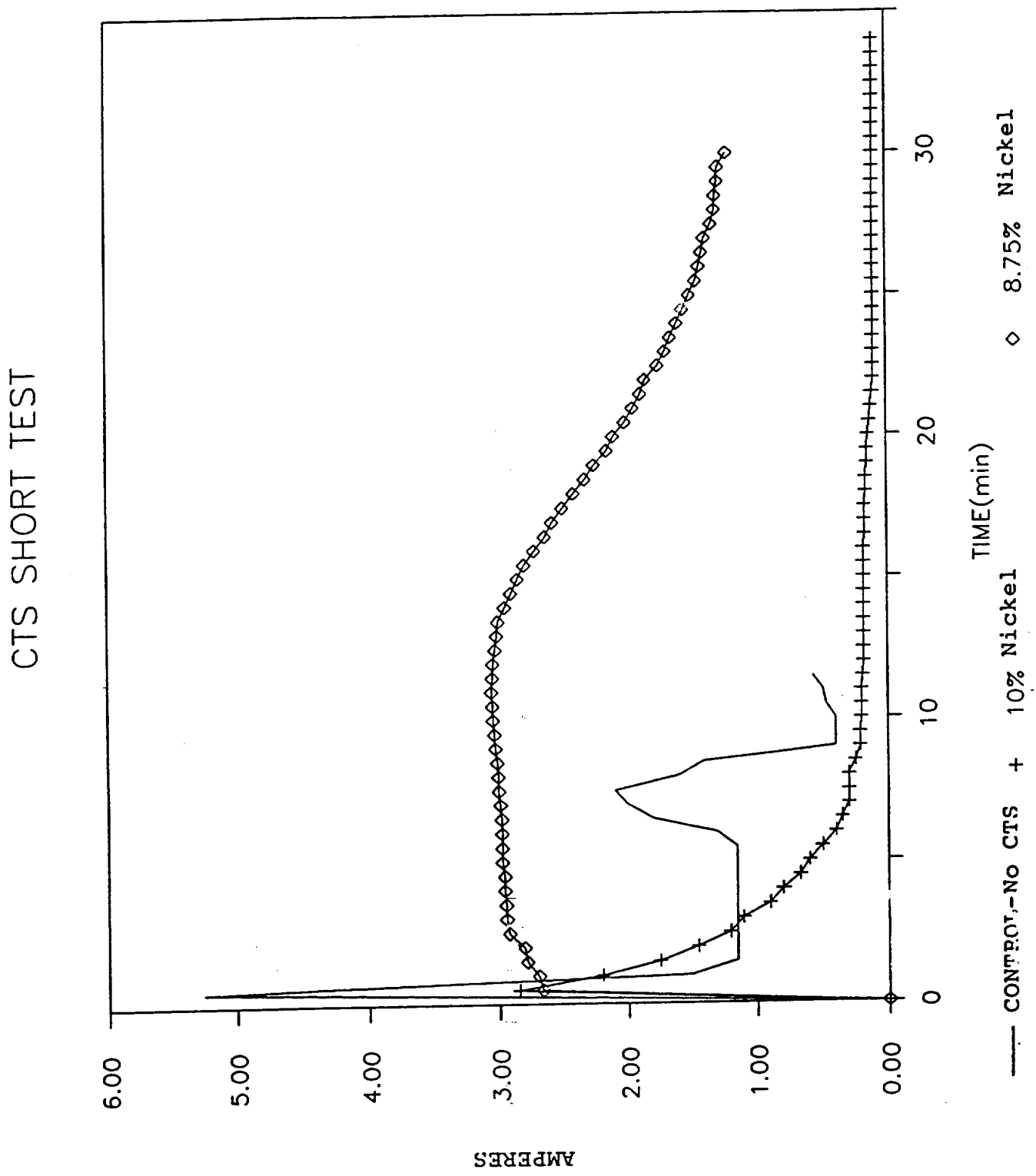


Figure 5: Comparison of Wound Cell Polarization


CTS SHORT TEST
AMPERES
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
10
20
30
TIME(min)
CONTROL-No CTS + 10% Nickel ◇ 8.75% Nickel
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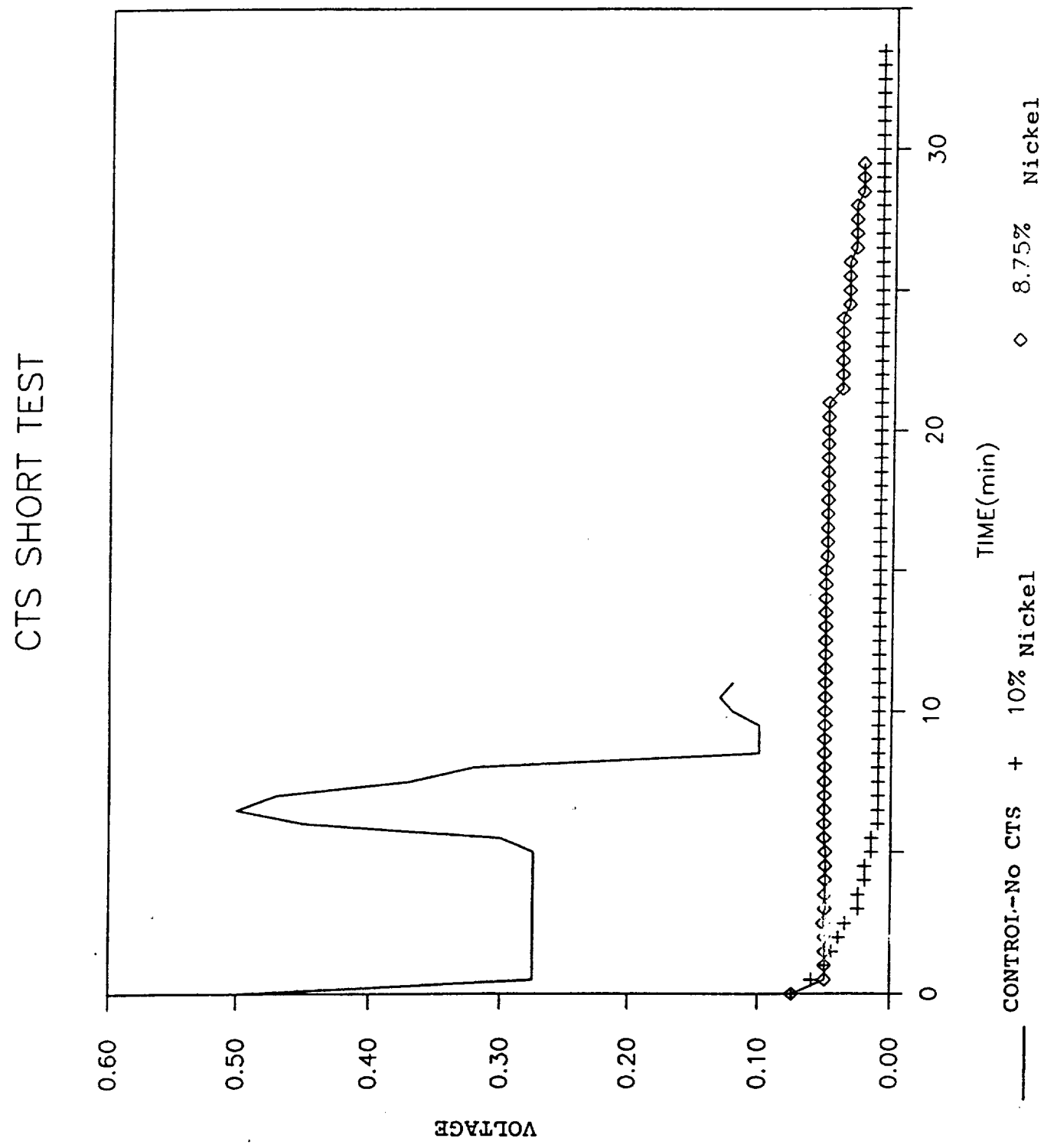
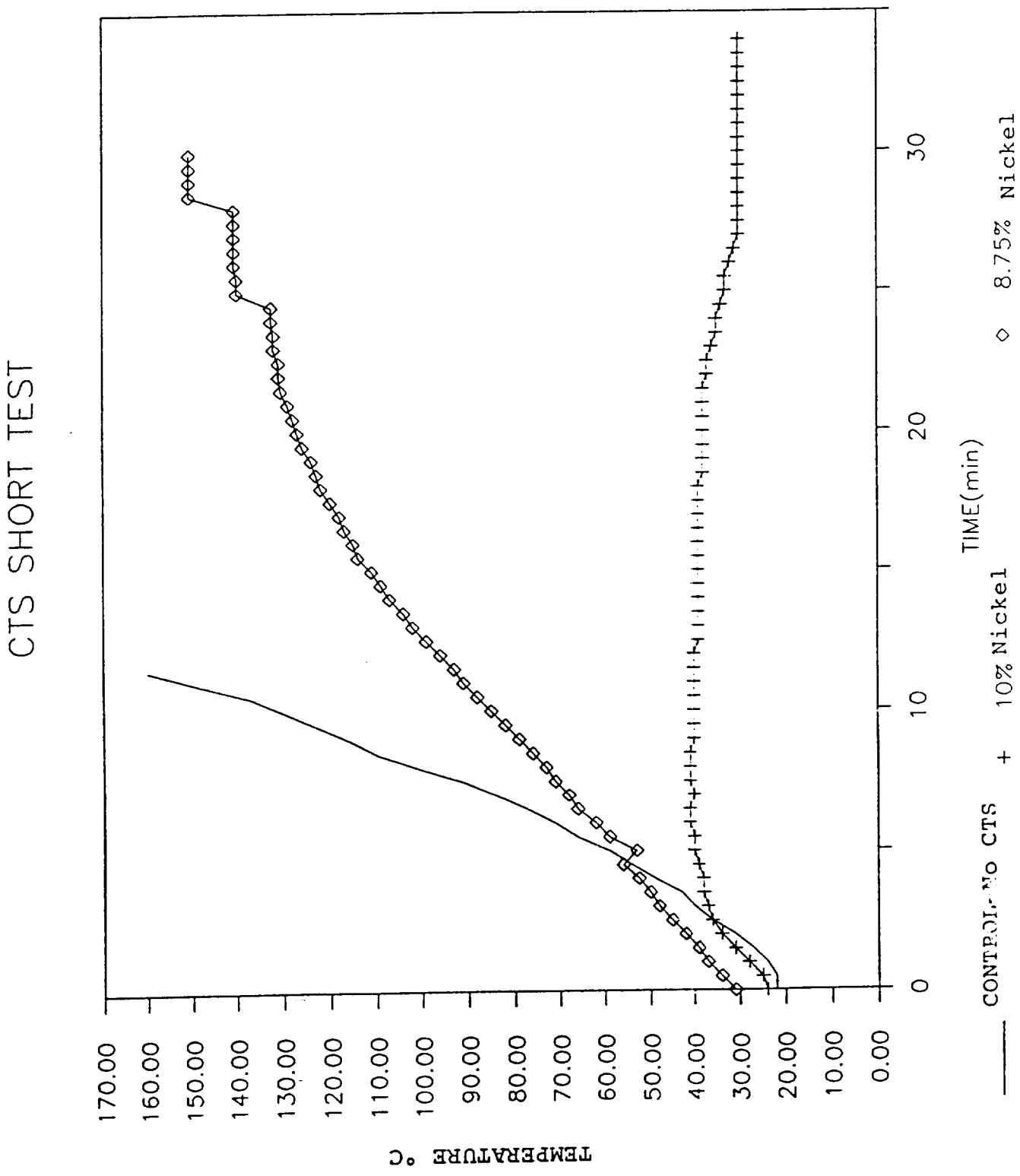

CTS SHORT TEST
VOLTAGE
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
10
20
30
TIME(min)
CONTROL-No CTS + 10% Nickel ◇ 8.75% Nickel
Yardney Technical Products, Inc., NAS 9-18279


CTS SHORT TEST
TEMPERATURE °C
170.00
160.00
150.00
140.00
130.00
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
10
20
30
TIME(min)
CONTROL-No CTS
+ 10% Nickel
◇ 8.75% Nickel
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