SODIUM SULFUR BATTERIES FOR SPACE APPLICATIONS

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30 October 1991

1991 NASA AEROSPACE BATTERY WORKSHOP

PRESENTATION ABSTRACT

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Preliminary Title Sodium Sulfur Batteries for Space Applications

Brief Abstract In 1986, Eagle-Picher Industries was selected by the Air Force to develop sodium sulfur cells for satellite applications. Specifically, the development program was geared toward low earth orbit goals requiring high charge/discharge rates. A number of improvements have been made on the cell level and a transition to a complete space battery has been initiated at Eagle Picher.

The results of six months of testing a 250 watt-hour sodium sulfur space battery look very promising. With over 1,000 LEO cycles conducted on this first battery, the next generation battery is being designed. This next design will focus on achieving greater energy densities associated with the sodium sulfur chemistry.

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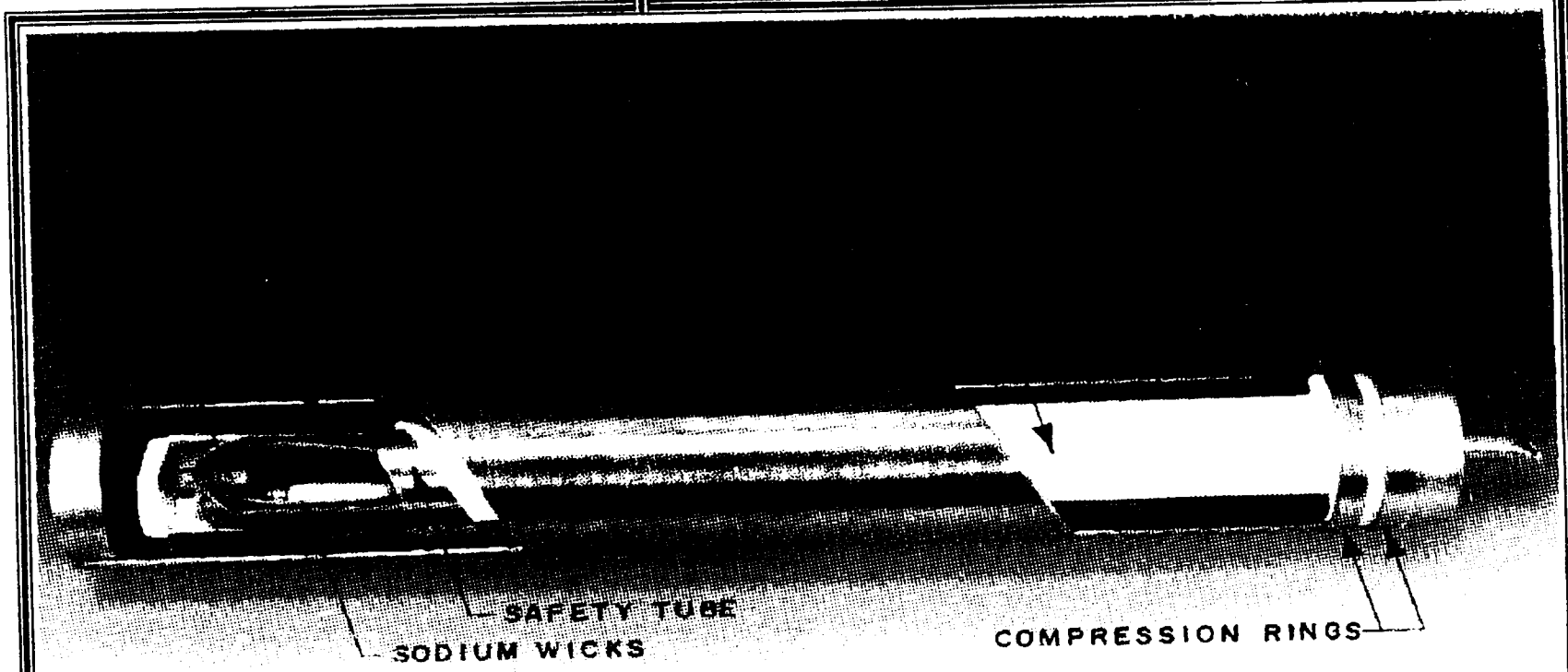
THERMAL-ORDNANCE OPERATION

Na-S BATTERIES



SODIUM SULFUR 40AH CELL

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Na-S BATTERIES

CELL DESIGN	A	B	C	D
DISCHARGE RATE	75 AMPS	75 AMPS	75 AMPS	75 AMPS
DISCHARGE TIME	33 MIN	32 MIN	35 MIN	35 MIN
AVE. VOLTS (DIS)	1.20 VOLTS	1.24 VOLTS	1.39 VOLTS	1.56 VOLTS
Whrs DISCHARGE	49.5 Whrs	49.9 Whrs	61.1 Whrs	67.7 Whrs
AVE. CHARGE RATE	33.5 AMPS	33.2 AMPS	34.81 AMPS	40.24 AMPS
CHARGE TIME	73 MIN	73 MIN	73.9 MIN	65.2 MIN
AVE. VOLTS (CHG)	2.44 VOLTS	2.43 VOLTS	2.44 VOLTS	2.39 VOLTS
Whrs CHARGE	98.6 Whrs	98.3 Whrs	104.6 Whrs	104.6 Whrs
EFFICIENCY (Whrs DIS/Whrs CHG)	50.20%	50.70%	58.40%	64.70%
SPECIFIC ENERGY	72.6 Whrs/Kg	73.1 Whrs/Kg	87.4 Whrs/Kg	98.6 Whrs/Kg
ENERGY DENSITY	159.2 Whrs/l	160.5 Whrs/l	196.0 Whrs/l	217.4 Whrs/l
END OF DISCHARGE RESISTANCE (mOhms)	8.8 mOhms	8.8 mOhms	6.4 mOhms	6.1 mOhms
F1 (%)	30.00	31.42	21.61	14.08

Note: F1 is a measure of the percent nonavailable theoretical cell capacity.

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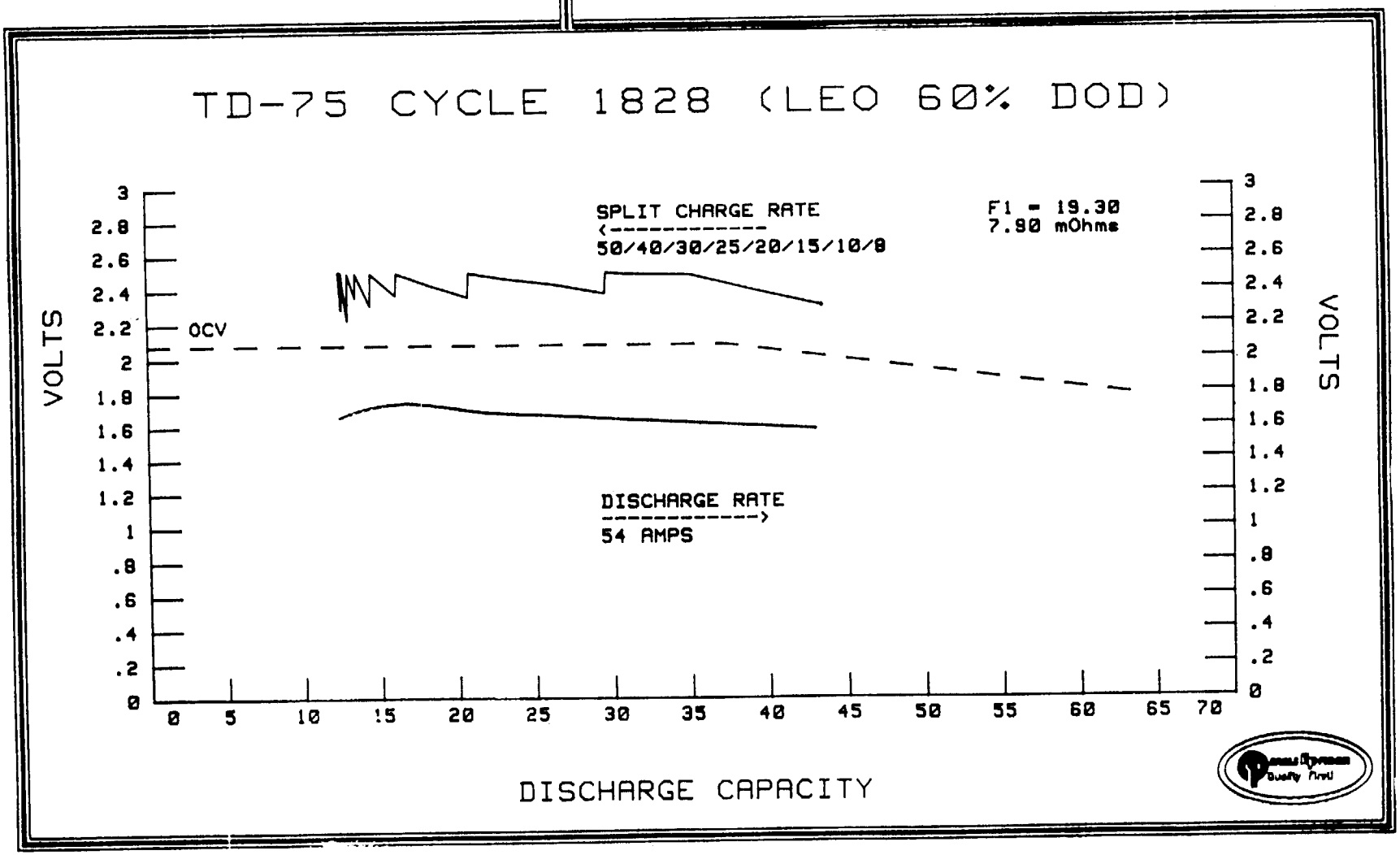

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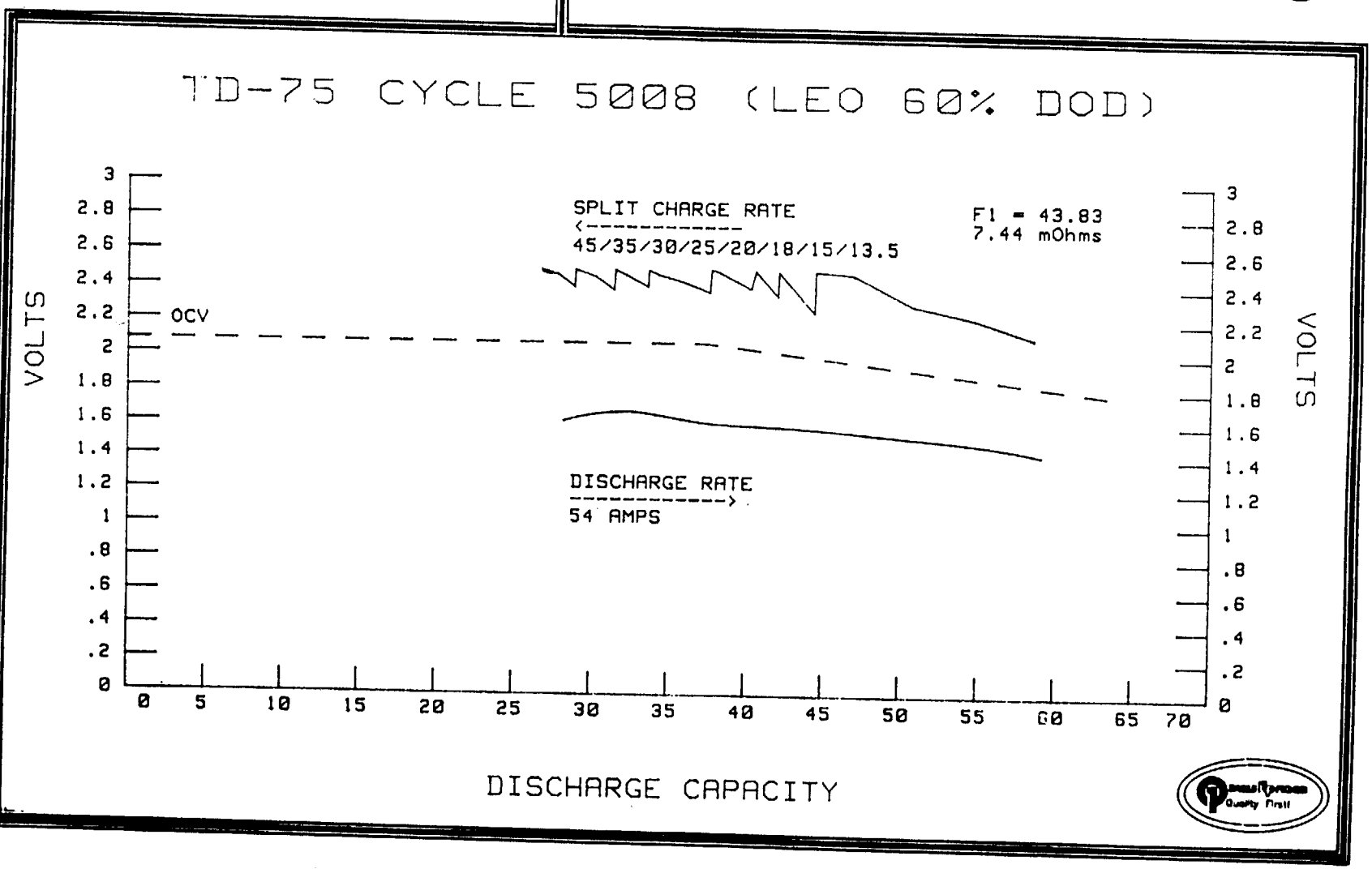

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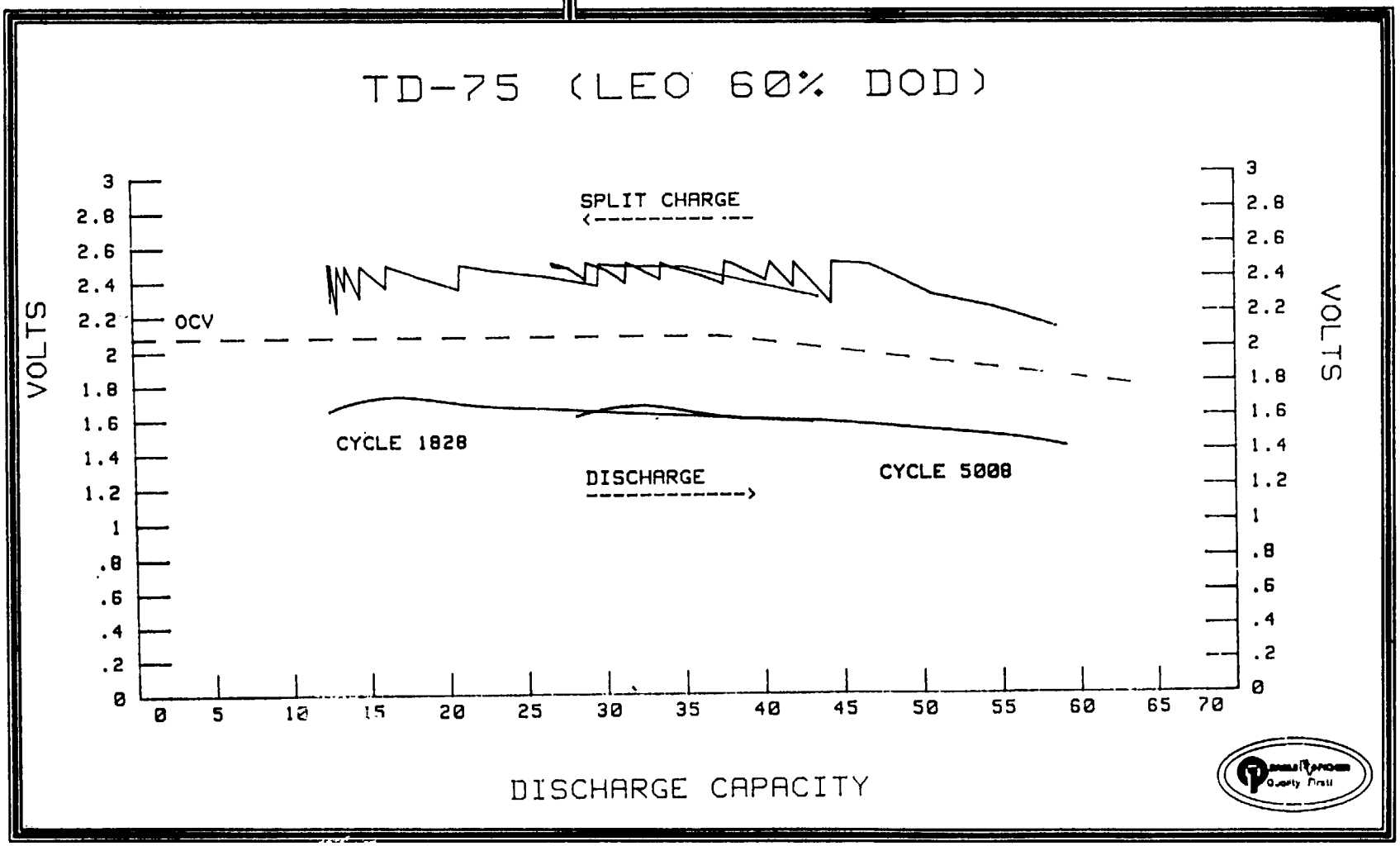
Na-S BATTERIES



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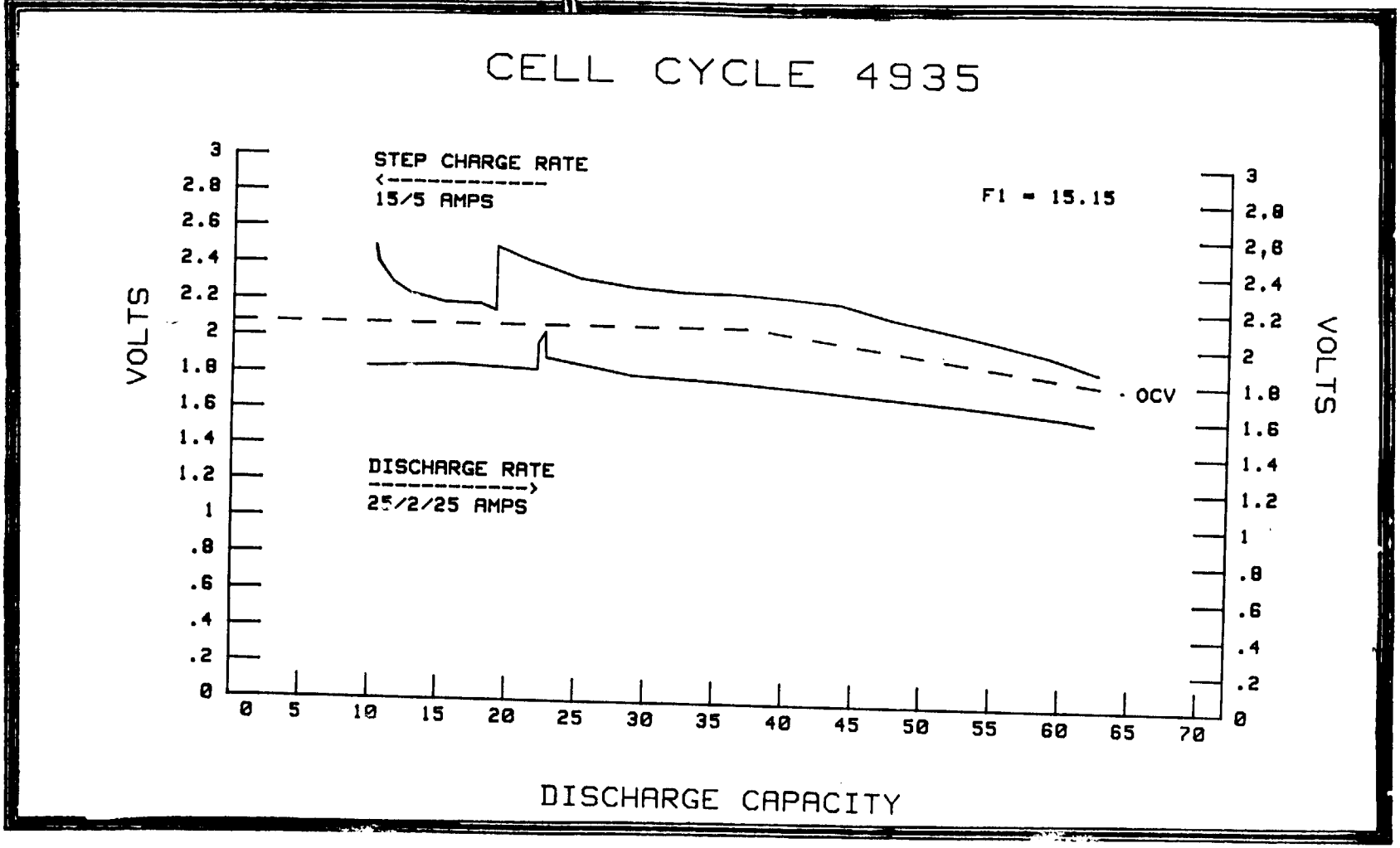

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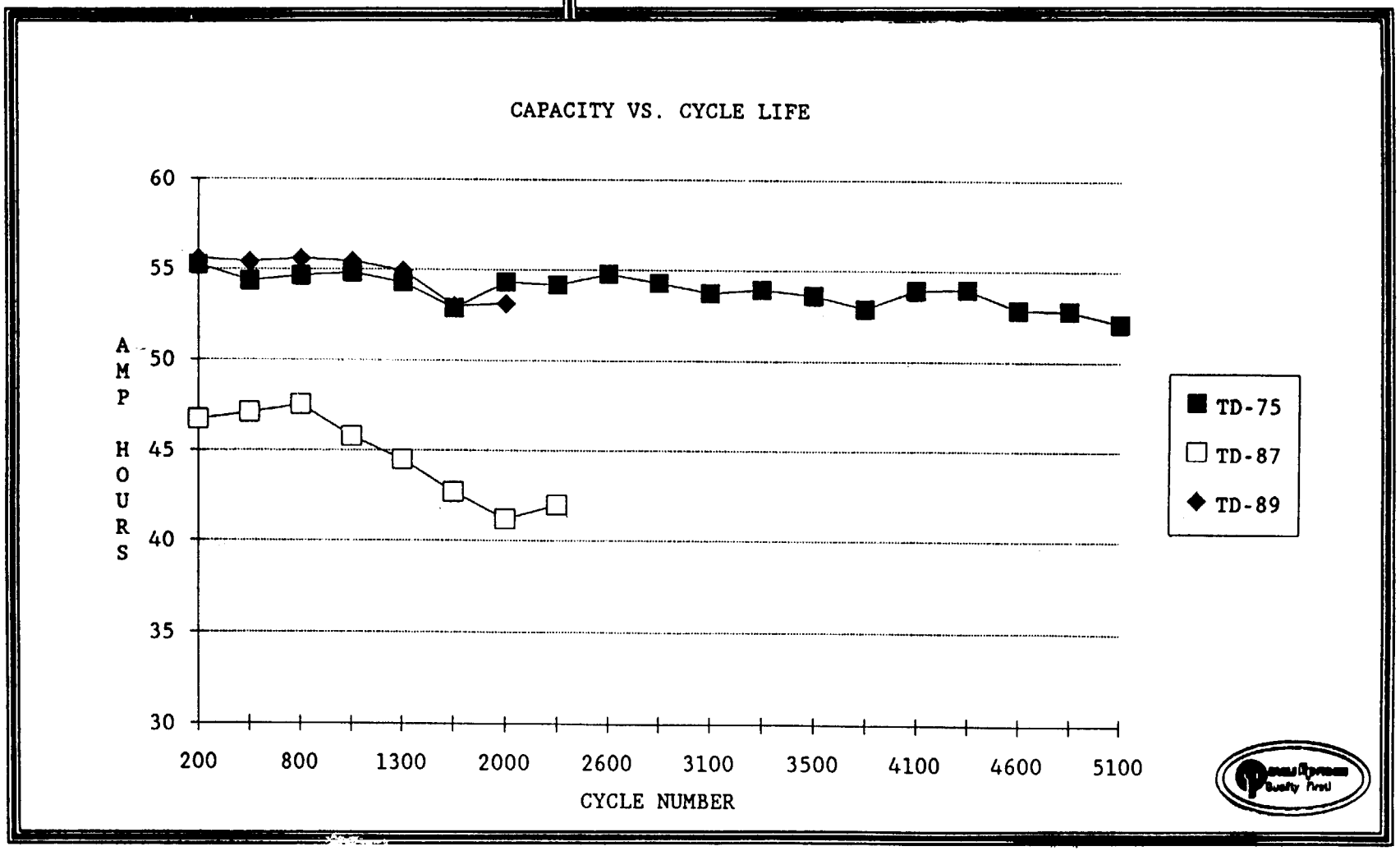

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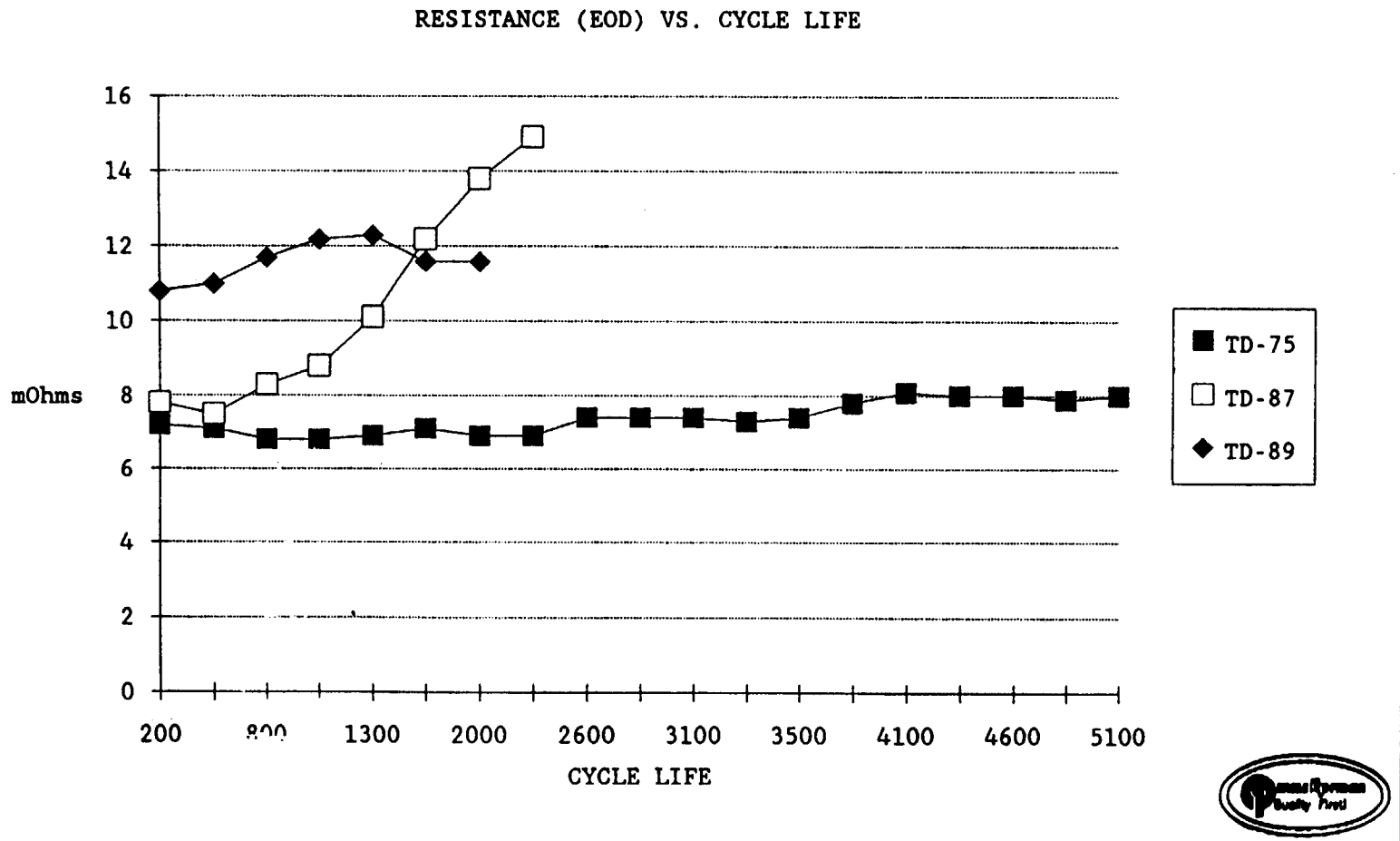

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Na-S BATTERIES

LIFE CYCLE TESTS

55AH CELLS DISCHARGED TO 60% DOD AT "C" RATE

CYCLES ACCOMPLISHED TO DATE: 7,200

AVERAGE VOLTS WHILE DISCHARGING: 1.50

AVERAGE VOLTS DURING CHARGE: 2.40

SPECIFIC ENERGY: 63.3 WH / KG

ENERGY DENSITY: 145 WH / l

E.O.D. RESISTANCE: .0088 ohms

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Na-S BATTERIES

LATEST CELL DESIGN

55AH CELLS DISCHARGED TO 60% DOD AT "C" RATE

CYCLES ACCOMPLISHED TO DATE: 5,000

AVERAGE VOLTS WHILE DISCHARGING: 1.63

AVERAGE VOLTS DURING CHARGE: 2.40

SPECIFIC ENERGY: 73 WH / KG

ENERGY DENSITY: 165 WH / l

E.O.D. RESISTANCE: .0075 ohms

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Na-S BATTERIES

IMPROVED CELL TECHNOLOGY AVAILABLE NOW

55AH CELLS DISCHARGED TO 60% DOD AT "C" RATE

AVERAGE VOLTS WHILE DISCHARGING: 1.75

AVERAGE VOLTS DURING CHARGE: 2.40

SPECIFIC ENERGY: 100 WH / KG

ENERGY DENSITY: 225 WH / l

E.O.D. RESISTANCE: .005 ohms

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Na-S BATTERIES

CELL - TO - BATTERY TRANSITION

1. CELL OPTIMIZATION AND DEVELOPMENT

   A. IMPROVED LOW - RESISTANCE CATHODE
   B. POROUS ANODE STRUCTURE
      LIGHT WEIGHT
      REGULATES / LIMITS AVAILABLE SODIUM FOR SAFETY
   C. FABRICATION OF LIGHT - WEIGHT MOLYBDENUM COMPONENTS
   D. DEFINE OPTIMUM ELECTROLYTE PARAMETERS
      BALANCE OF PHYSICAL / ELECTRICAL PROPERTIES
      TAILOR TO CELL REQUIREMENTS AND GEOMETRY
      PROCESS DEFINITION / FORMULATION
      INSPECTION CRITERIA

Quality First!

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Na-S BATTERIES

CELL - TO - BATTERY TRANSITION (CONTINUED)

2. CELL TESTING - BUILD STATISTICAL BODY OF DATA

   A. MONITOR TEMPERATURE AND ELECTRICAL DATA
   B. VARYING LENGTHS OF ORBITS
   C. OPTIMUM RECHARGE PARAMETERS VS. DOD
   D. ESTABLISH PERFORMANCE TRENDS DURING LIFE CYCLE
   E. DETERMINE VARIABILITY / CONSISTENCY WITHIN CELL POPULATION

3. INCORPORATION INTO BATTERY CONFIGURATION

   A. AIDED BY HISTORY OF NUMEROUS SECONDARY BATTERY CHEMISTRIES
   B. USE CELL - LEVEL RESULTS TO ACHIEVE BATTERY REQUIREMENTS
   C. FIX MEANS OF MONITORING AND ELECTRICAL CONTROLS
   D. PACKAGE FOR EFFICIENCY, RUGGEDNESS, AND SAFETY

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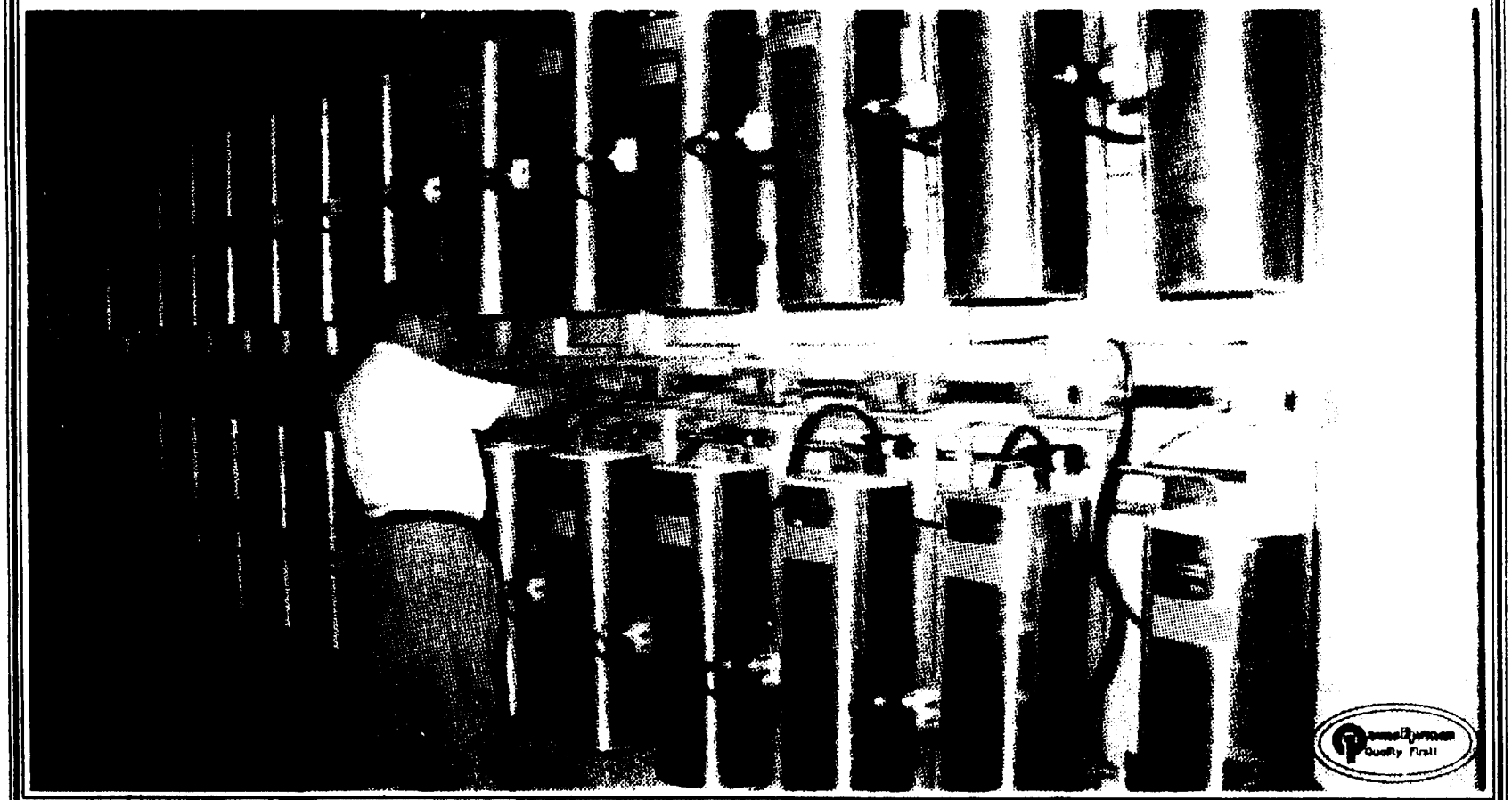
CELL TEST LABORATORY



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Na-S BATTERIES

THE NEXT GENERATION SPACE BATTERIES

EAGLE-PICHER INVOLVEMENT IN SODIUM SULFUR SPACE BATTERIES BEGAN IN 1986.

U.S. AIR FORCE SELECTED EAGLE-PICHER AS THE SOLE DEVELOPER FOR SODIUM SULFUR LEO CELLS.

EAGLE-PICHER'S EXPERIENCE IN NICKEL HYDROGEN SPACE BATTERIES PROVIDES A VALUABLE BASE FOR TRANSITIONING TO SODIUM SULFUR SPACE BATTERIES.

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Na-S BATTERIES

BATTERY STATUS

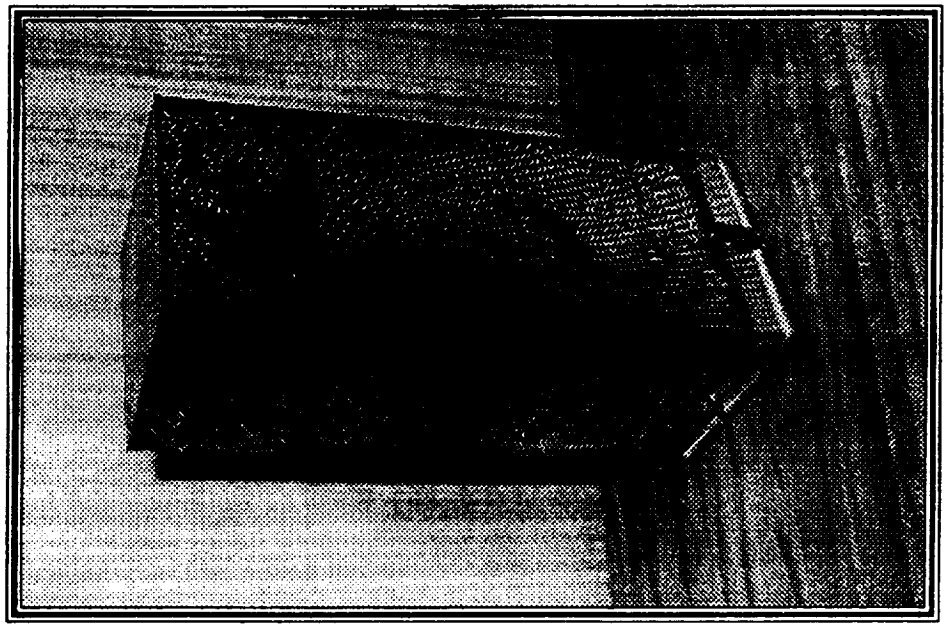
ENTRY LEVEL BATTERY EFFORTS FUNDED INTERNALLY

UNIT APPROACHING 1000 CYCLES
CONSTANT CURRENT CHARGE / DISCHARGE
NOMINAL 60% DOD (= 30 A.H.)

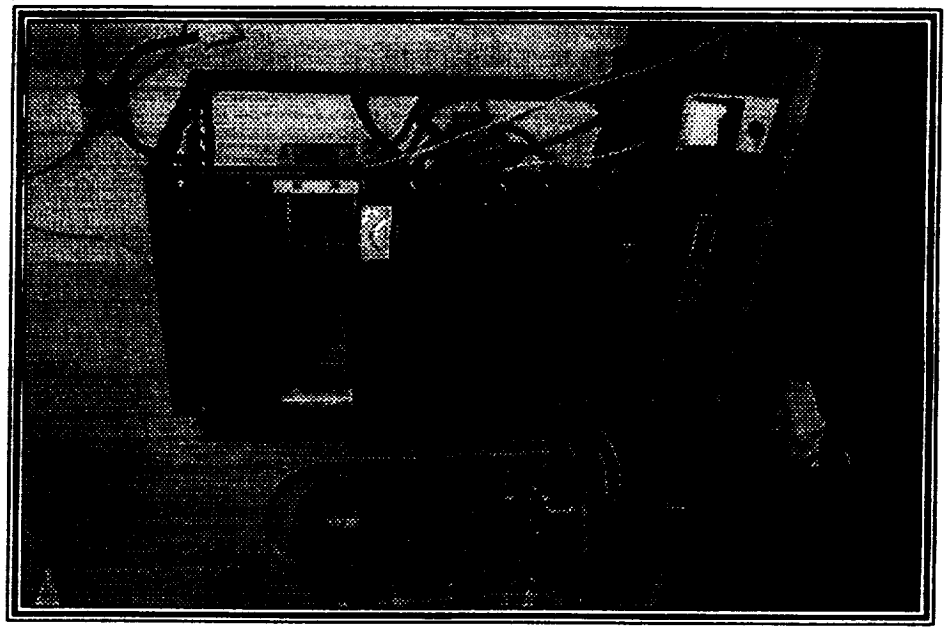
CYCLE CONTROLLED BY FIRST CELL TO ACHIEVE PRE-SET VALUES
(OTHERWISE BY CYCLE DEFINITION ONLY)

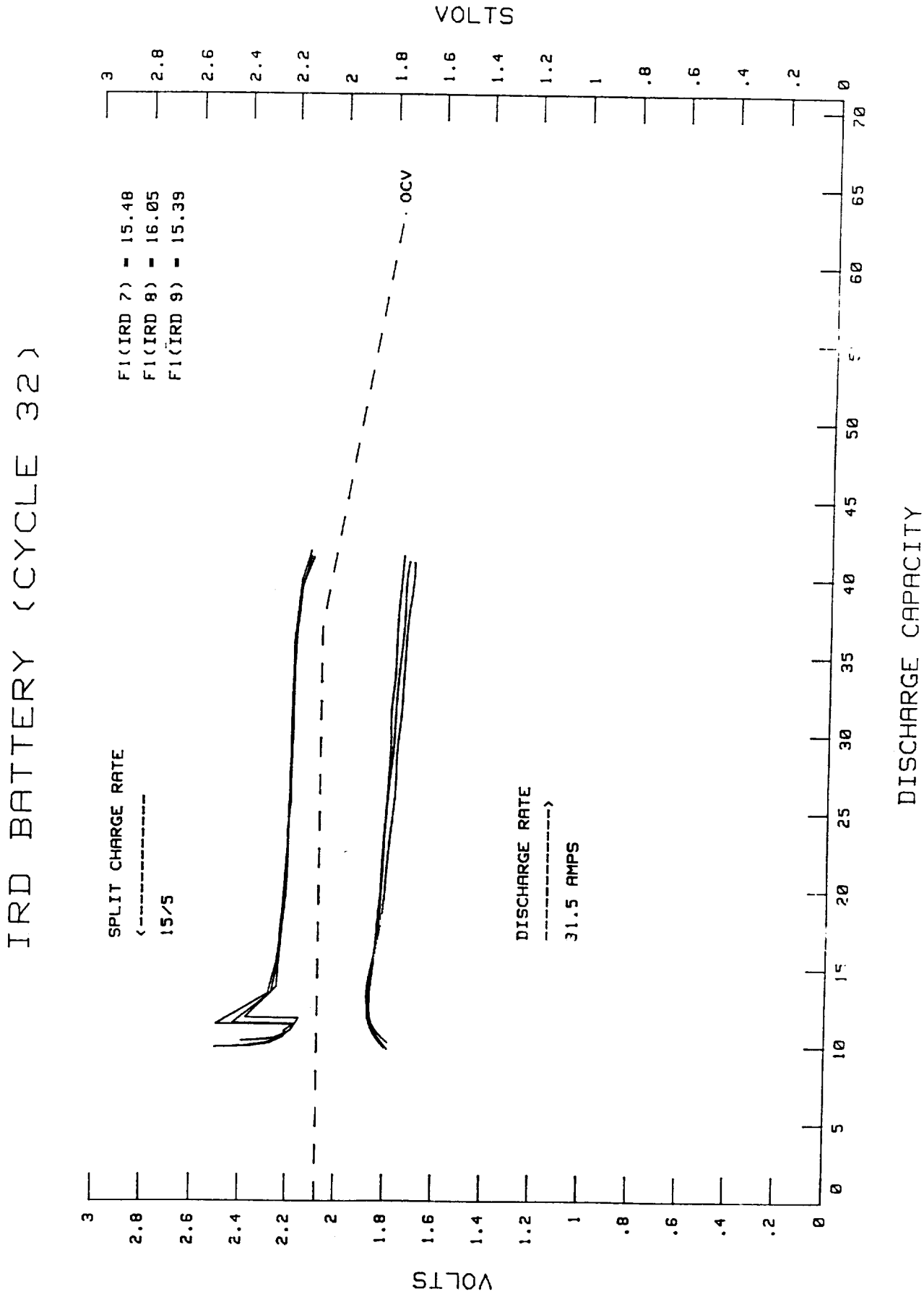
CALENDAR LIFE NOW FIVE MONTHS

Sodium Sulfur Battery



Battery Test Set-up




IRD BATTERY (CYCLE 32)
VOLTS
DISCHARGE CAPACITY
F1(IRD 7) = 15.48
F1(IRD 8) = 16.05
F1(IRD 9) = 15.39
OCV
SPLIT CHARGE RATE
<----------
15/5
DISCHARGE RATE
---------->
31.5 AMPS

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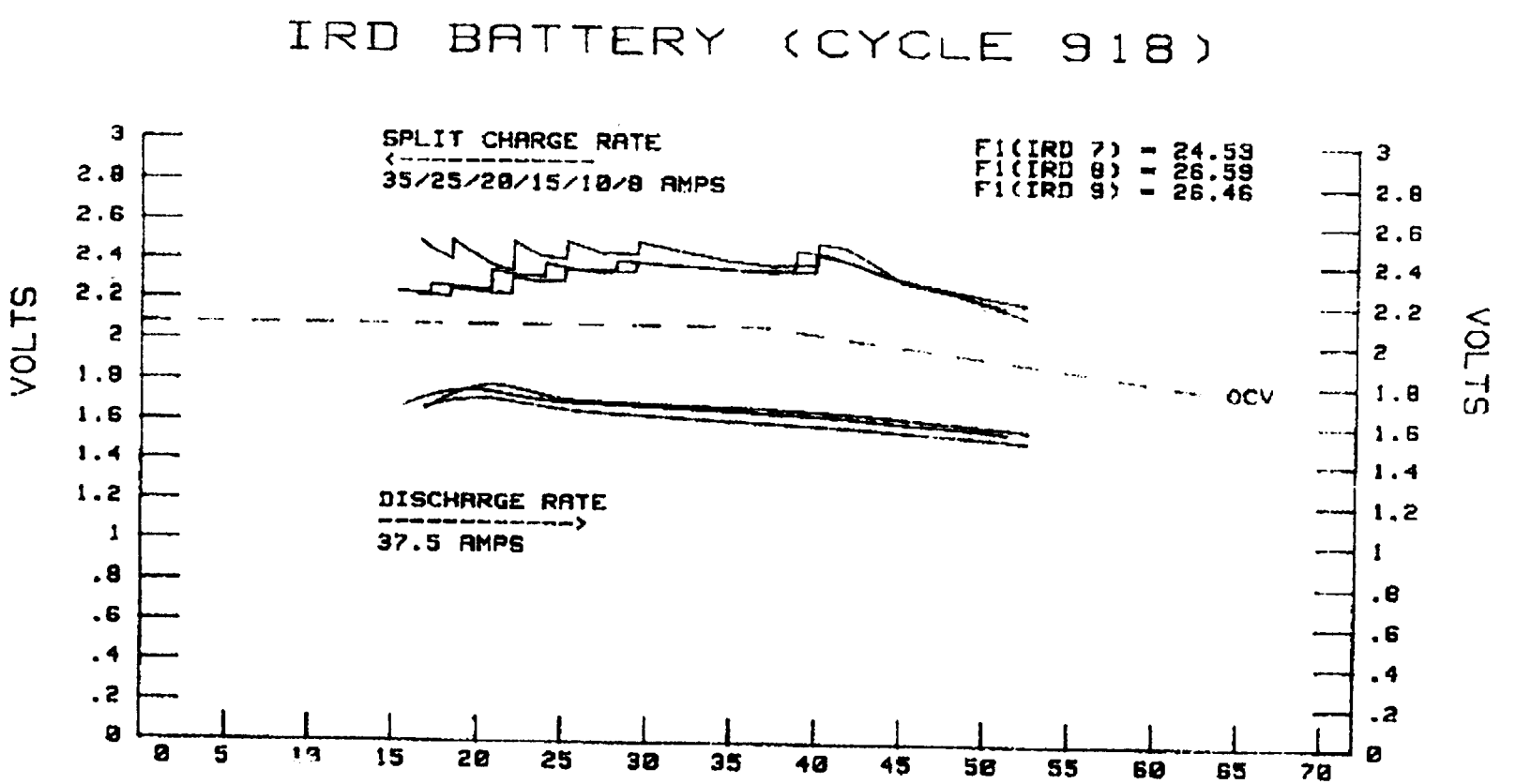

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Na-S BATTERIES

BATTERY DESCRIPTION

1. NUMBER OF CELLS DEPENDENT UPON USER SPECIFICATION
   (ENERGY, POWER, CAPACITY, VOLUME CONSTRAINT, CYCLE LIFE)

2. CELLS ORIENTED VERTICALLY
   INTERCONNECTS DEPEND UPON REQUIREMENT

3. EFFICIENT THERMAL ENCLOSURE TAILORED TO APPLICATION
   - "MONOLITHIC WALL"
   - MULTILAYER - EVACUATED WALL
   - PROVISIONS FOR ELECTRICAL HEATING
   - ACTIVE OR PASSIVE COOLING

4. MONITOR / CONTROLS
   - CELL / BATTERY VOLTAGE
   - TEMPERATURE (SAMPLED OR INDIVIDUAL)
   - ASSURANCE AGAINST EXCESSIVE CHARGE / DISCHARGE
   - PROTECTS MAY BE ELECTRICAL (SWITCHING)
   - OR PHYSICAL (FUSIBLE)