

N94-28133

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**HIGH RATE LITHIUM/THIONYL CHLORIDE
BIPOLAR BATTERY DEVELOPMENT**

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**1993 NASA AEROSPACE BATTERY WORKSHOP
November 16 -18, 1993
U.S. Space and Rocket Center
Huntsville, AL**

Program Tasks and Accomplishments

- Improved on existing method of manufacturing bipolar plates, Figs. 1A and 1B
- Developed novel method for manufacturing large sheets of carbon cathode material. These cathodes performed better than standard cathodes made by calendaring a wetted carbon/TFE mixture in single cell tests during continuous discharge at 25A with 10% duty cycle to 1.0V, Figs 2 and 3

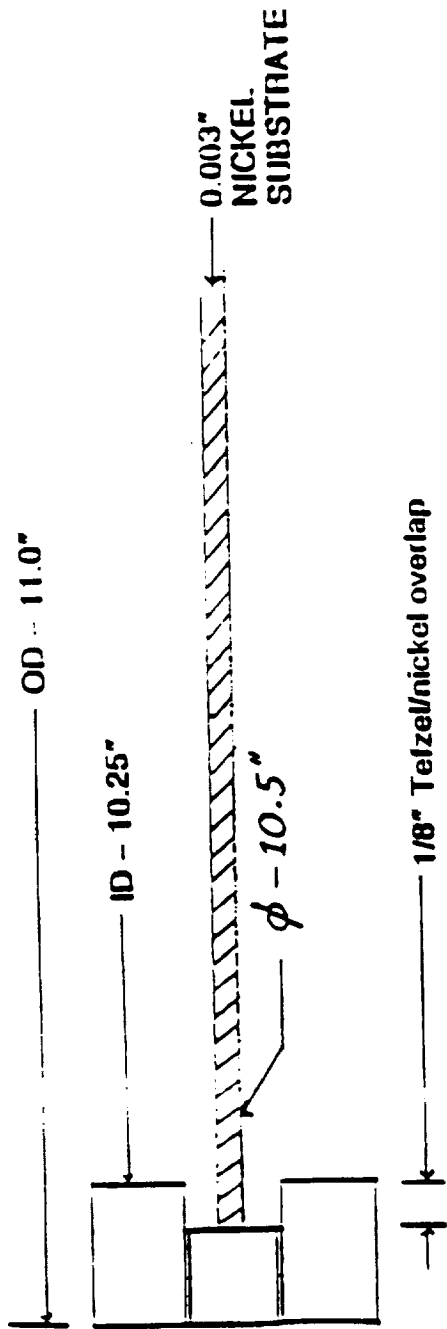


FIG. 1A. TEFZEL/NICKEL SANDWICH PRIOR TO COMPRESSION MOLDING

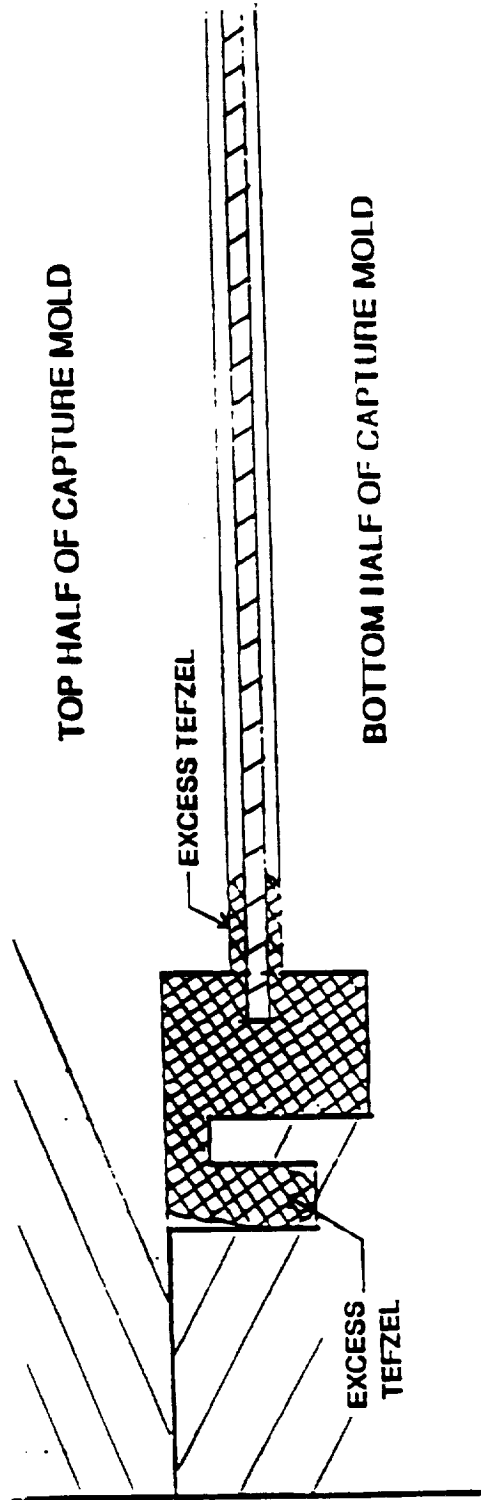


FIG. 1B. TEFZEL/NICKEL SUBSTRATE CONFIGURATION AFTER COMPRESSION MOLDING

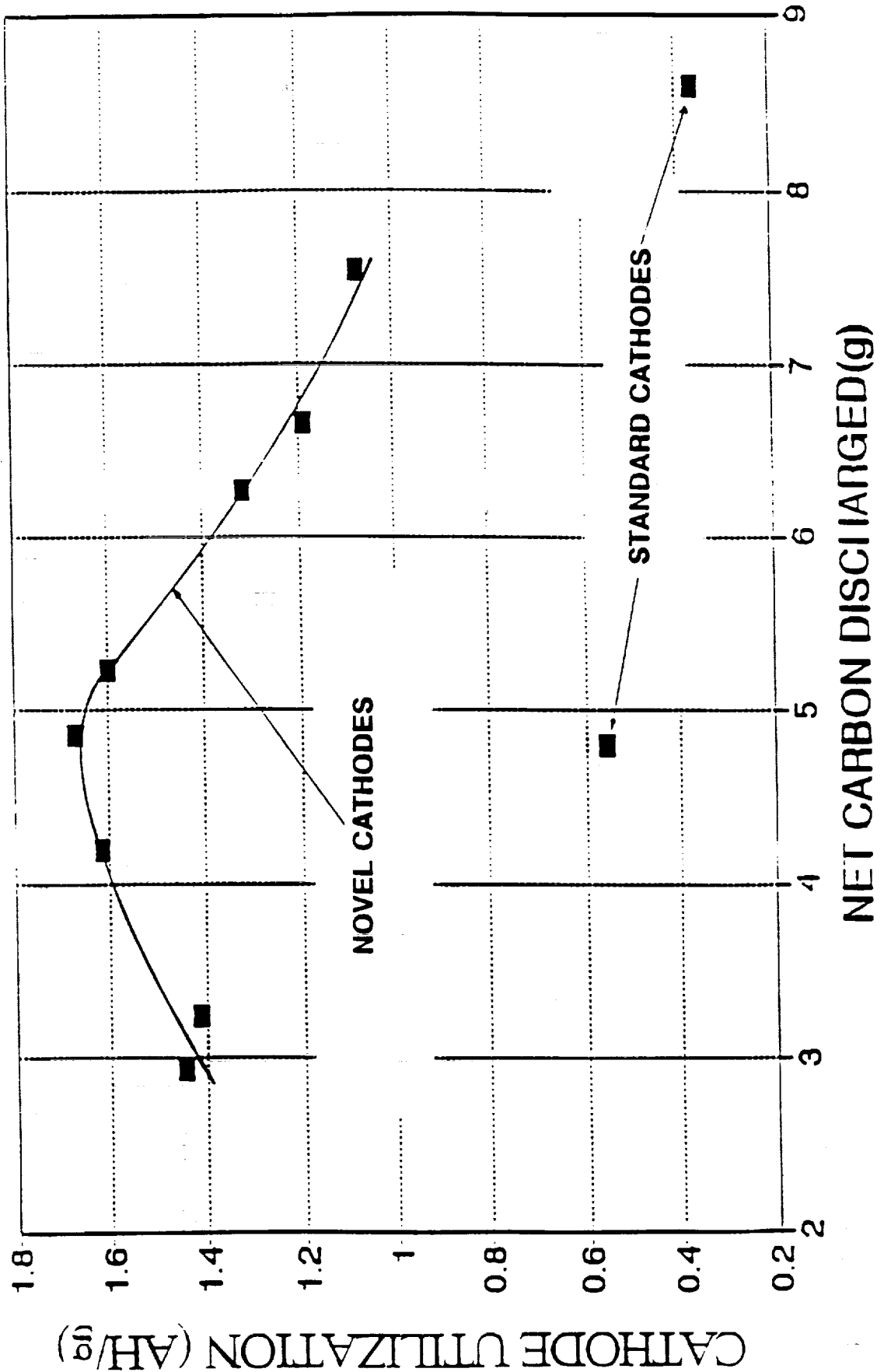


FIG. 2. CATHODE UTILIZATION (Ah/g) VERSUS CATHODE CARBON WEIGHT

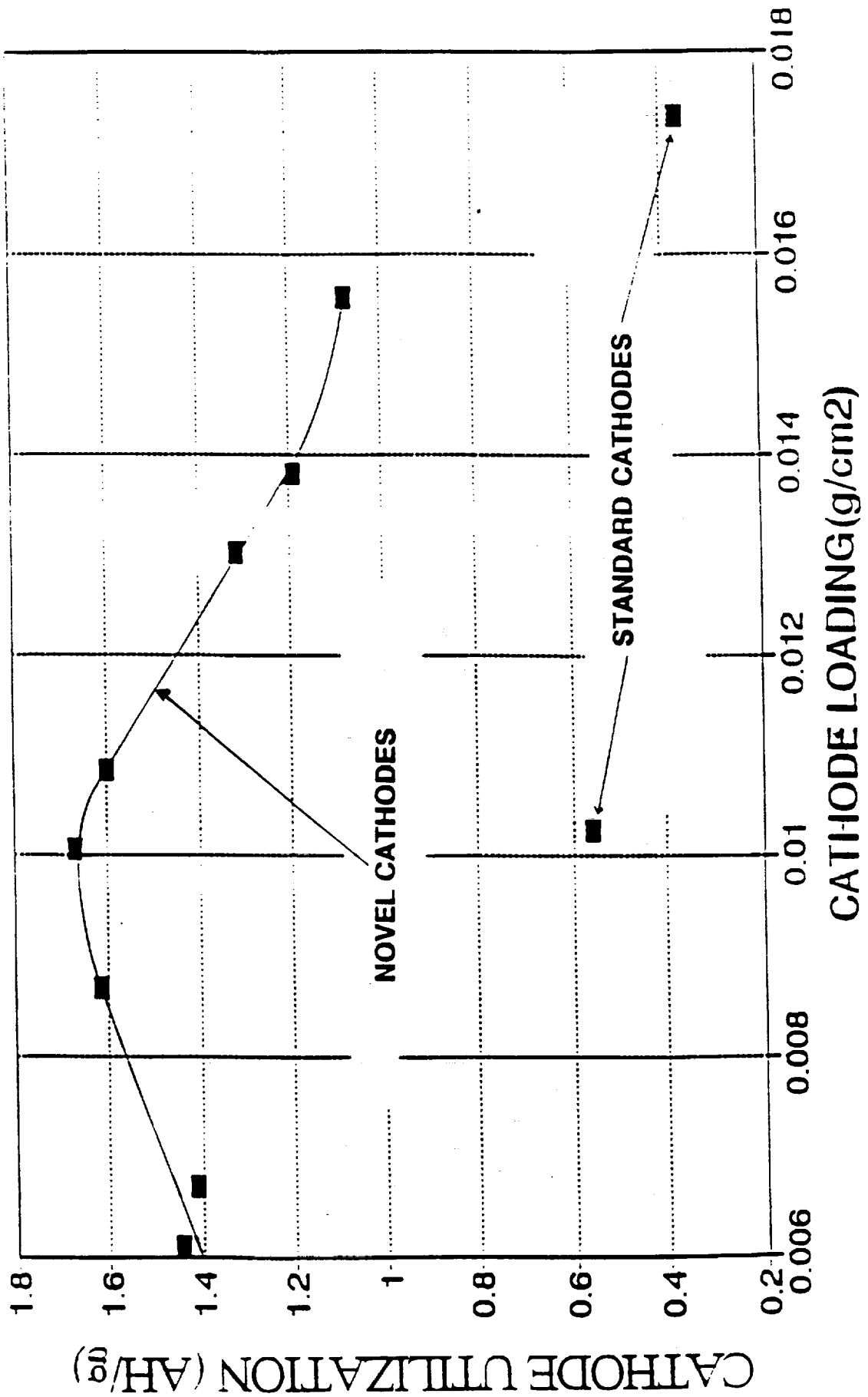


FIG. 3. CATHODE UTILIZATION (Ah/g) VERSUS CATHODE LOADING (g/cm²)

Program Tasks and Accomplishments(continued)

- A standard 40 wt% low surface area / 60 wt% high surface area carbon composition was selected for cathode evaluation in single cell 20 second pulse discharge tests at 25A and 10% duty cycle, Fig. 4 to 8
- Developed cell design and the procedures for assembly of stacks containing up to 150 cells in bipolar configuration, stack sealing, and the activation of individual cells, Figs. 9A, 9B, and 9C

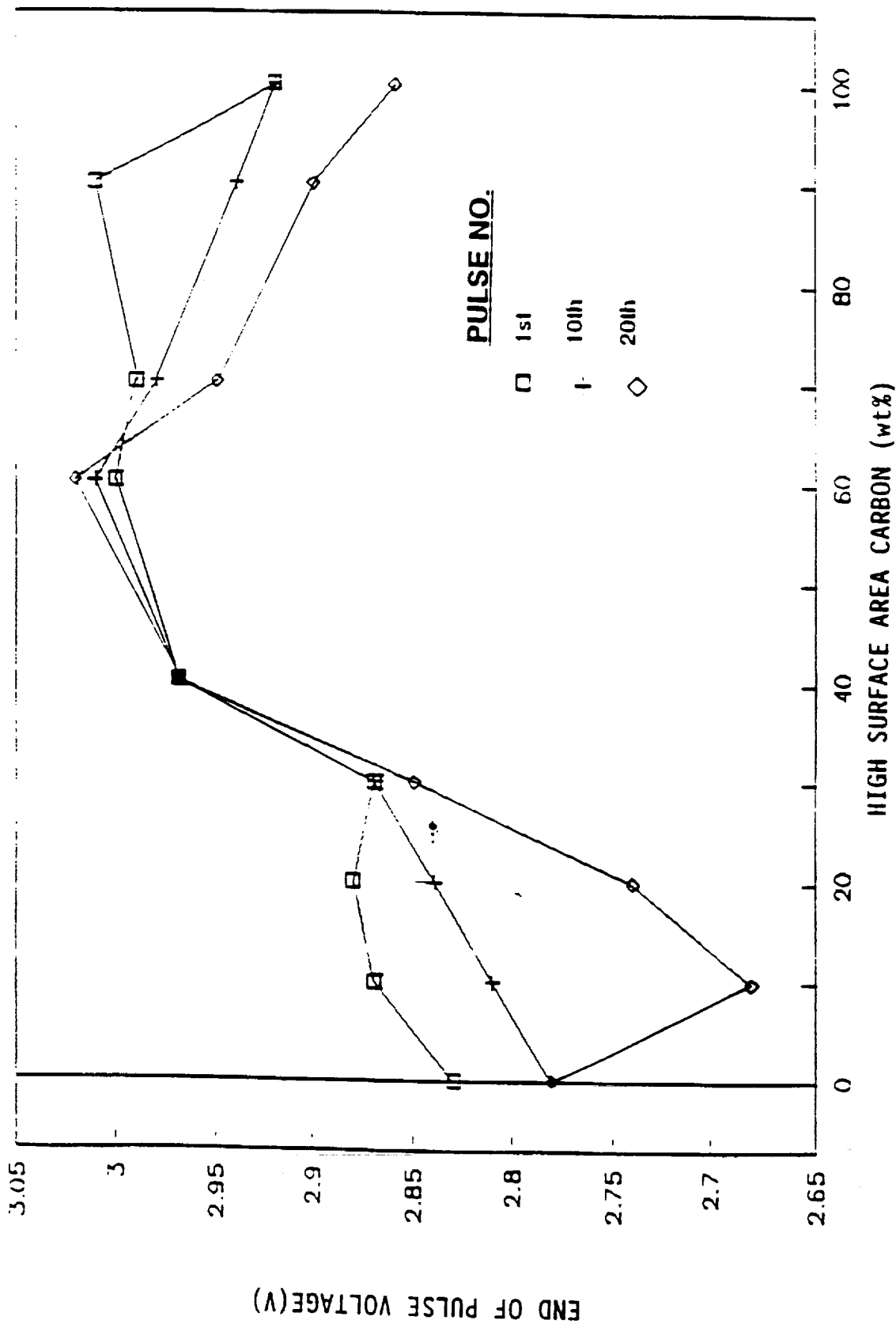


FIG. 4 EOPV VERSUS CARBON COMPOSITION. TWENTY 20-SECOND PULSES

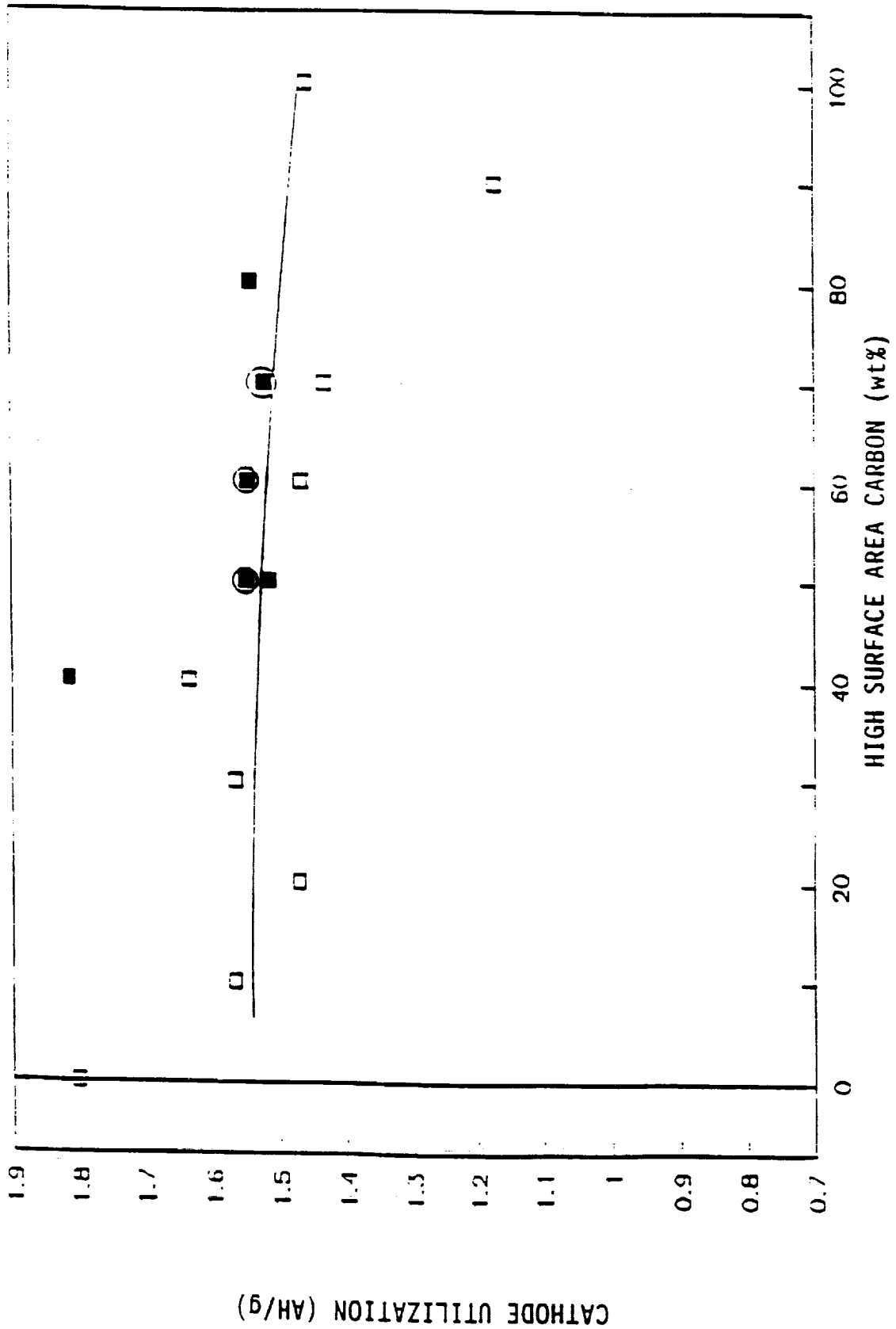


FIG. 5. CATHODE UTILIZATION (Ah/g) VERSUS CARBON COMPOSITION. UTILIZATION INCLUDES CONTINUOUS DISCHARGE TO 1.0V AFTER 400 SECONDS OF PULSE DISCHARGE. OPEN SQUARES-DATA FROM TESTS IN FIG. 4. SOLID SQUARES W/O CIRCLES-ADDITIONAL TESTS.

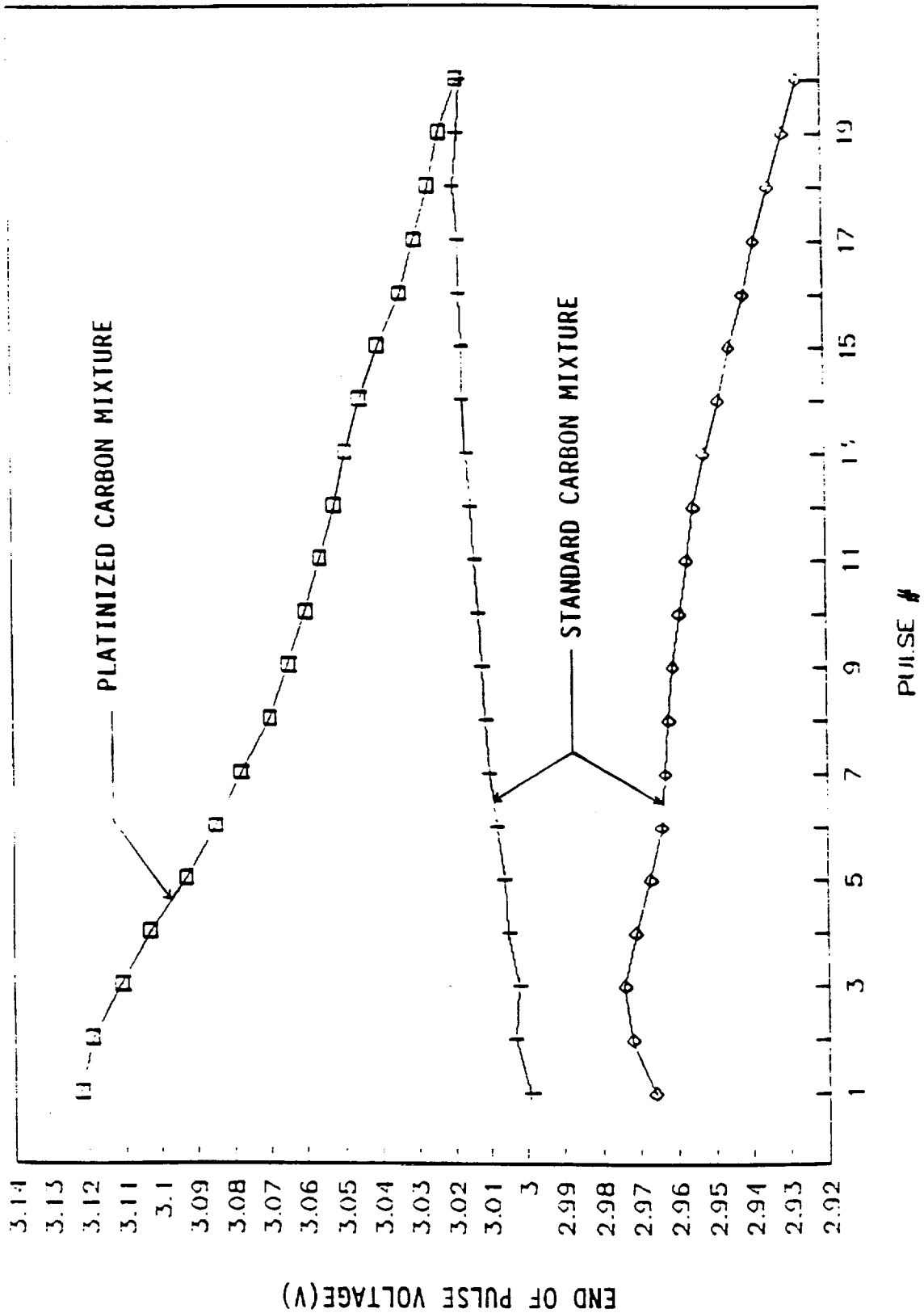


FIG. 6. COMPARISON OF PLATINIZED AND STANDARD 40/60 CARBON CATHODES

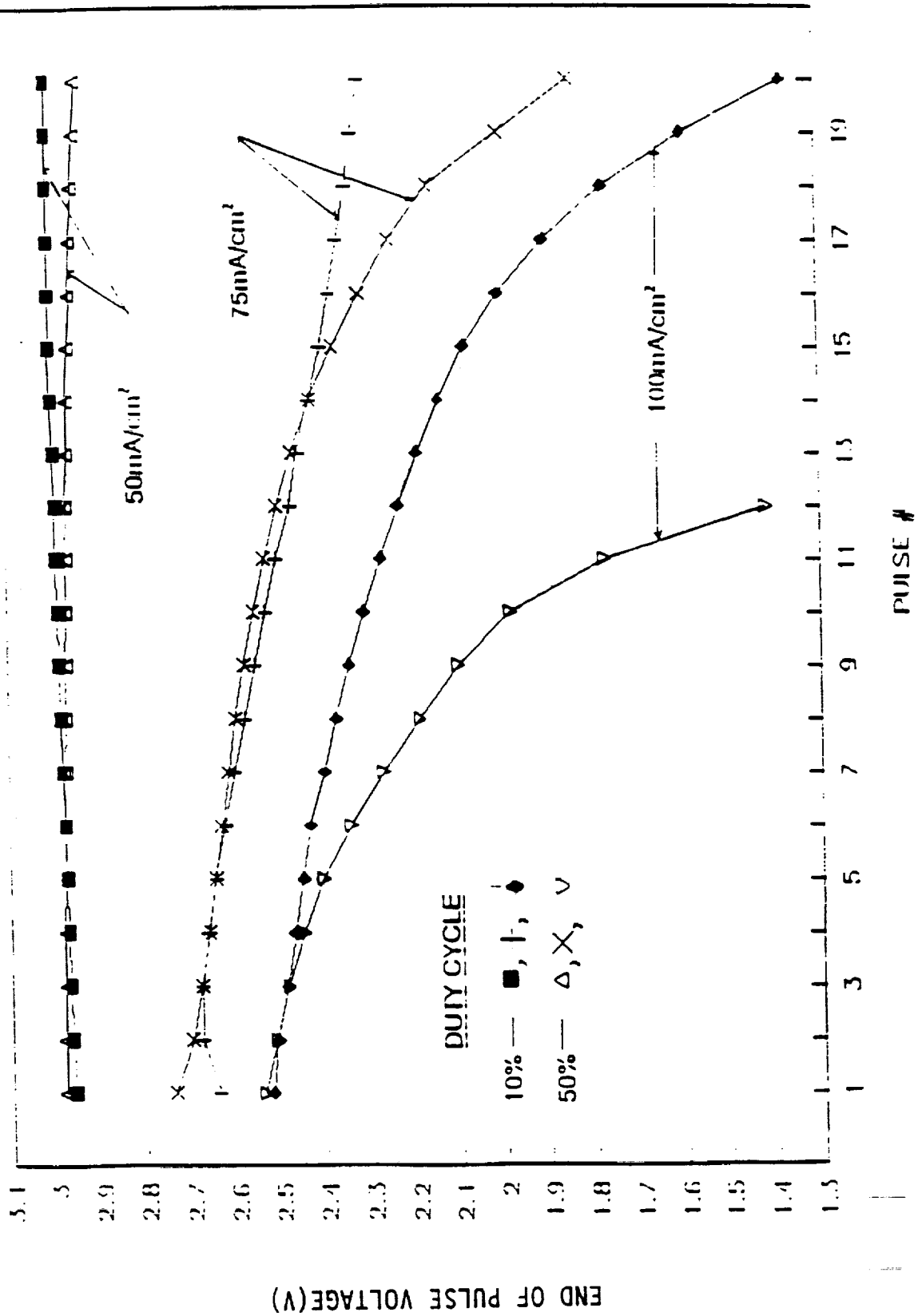


FIG. 7. EFFECTS OF CURRENT DENSITY AND DUTY CYCLE ON END OF PULSE VOLTAGE

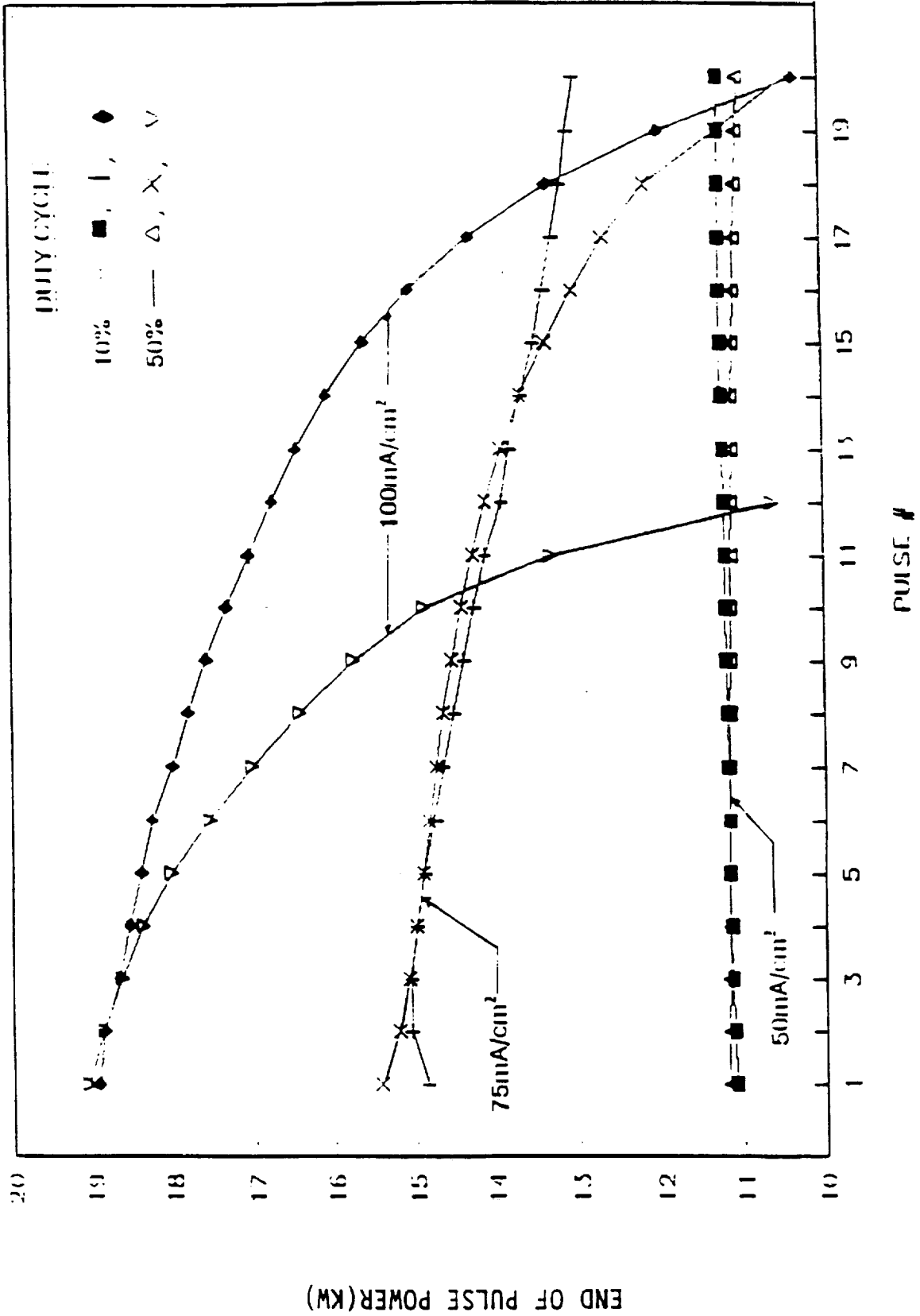


FIG. 8. EFFECTS OF CURRENT DENSITY AND DUTY CYCLE ON EOPP FOR A 150-CELL BIPOLAR STACK

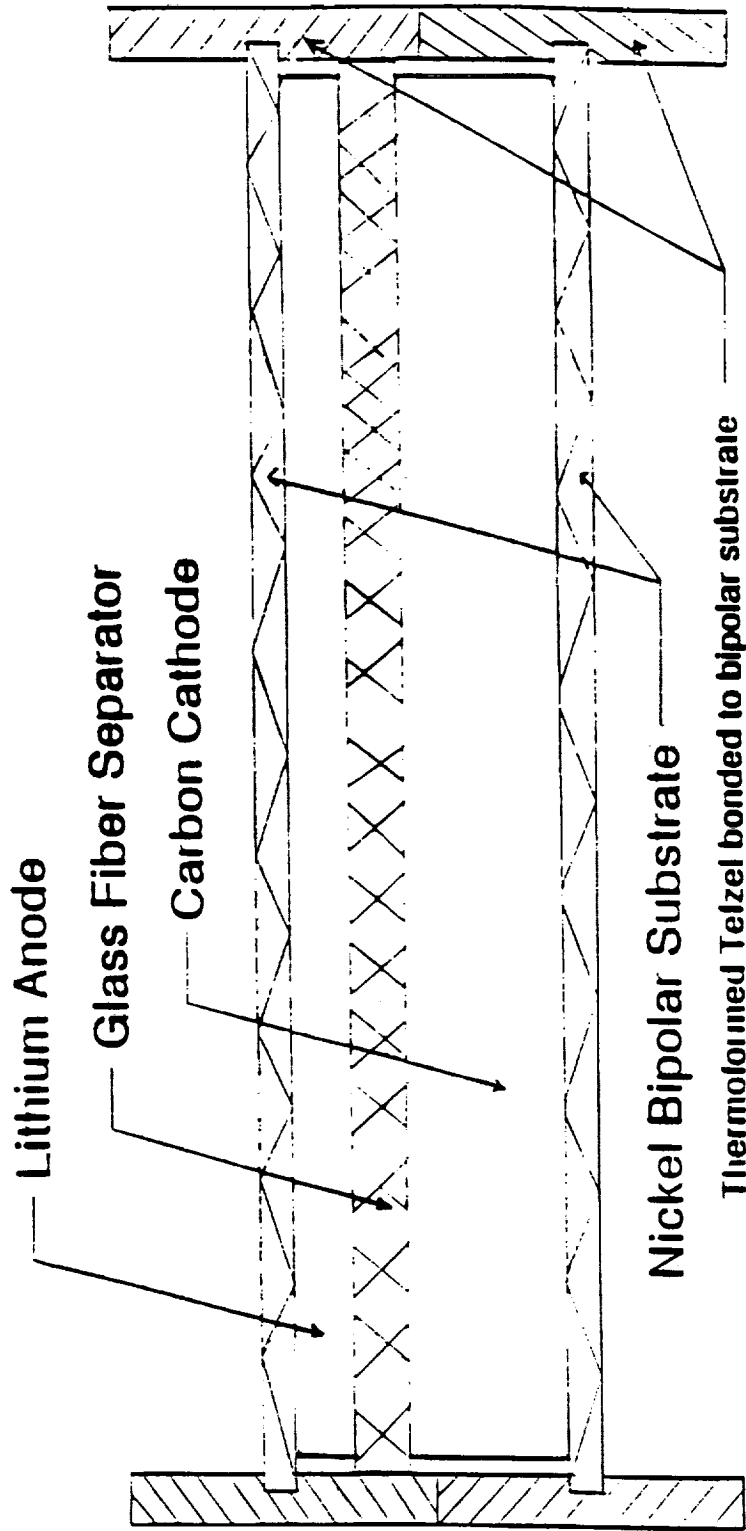


FIG. 9A SINGLE CELL COMPONENTS IN STACK SUBASSEMBLY

Tefzel Sealing

HEAT SOURCES

Heating elements from 330 to 900 Watts

PROCEDURE

- Prepare module surface for sealing
- Increase seal thickness by melting Tefzel surface with heat source
- Add fiberglass/Tefzel composite layer
 - increases thickness*
 - improves strength*

FIG. 9B

Multicell Stack Fabrication

- Assemble stack components
- Compress stack to final height
- Three quarter" seal of stacked Tefzel rings
- Electrolyte activation
- Complete Tefzel seal

FIG. 9C

Program Tasks and Accomplishments (continued)

- Evaluated single cells assembled with bipolar stack hardware during constant power Sonobuoy pulse discharge tests (20 second pulse, 10% duty cycle). A 9.25 inch diameter cathode was selected for the torpedo size Sonobuoy battery module, Figs. 10 and 11
- Evaluated 4-cell and 10-cell bipolar stacks and a 50-cell bipolar stack during constant power Sonobuoy pulse discharge tests, Figs. 12 - 15

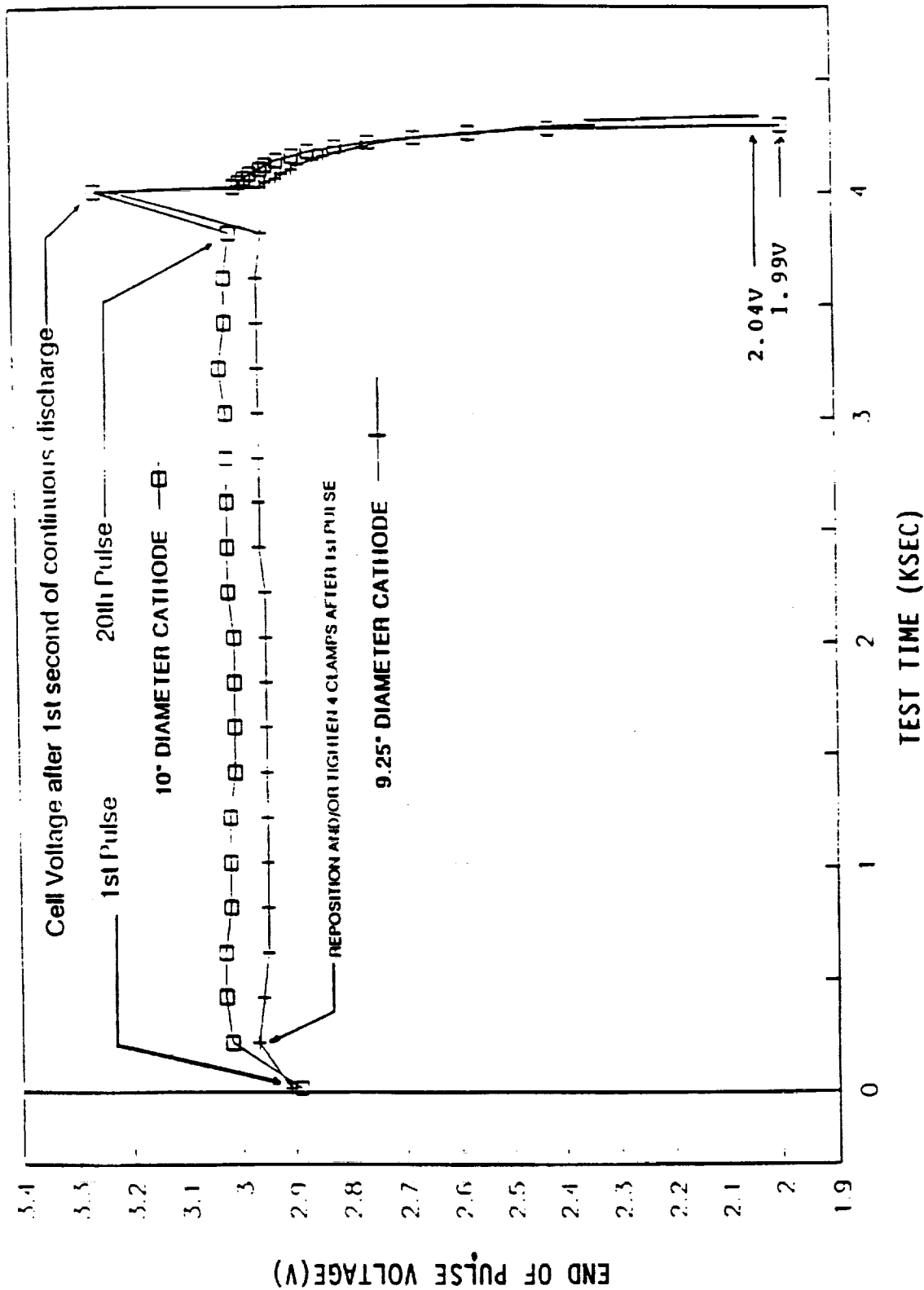


FIG. 10. EFFECT OF CATHODE DIAMETER ON EOPV DURING SINGLE CELL CONSTANT POWER (71.4w) PULSE AND CONTINUOUS DISCHARGE TEST

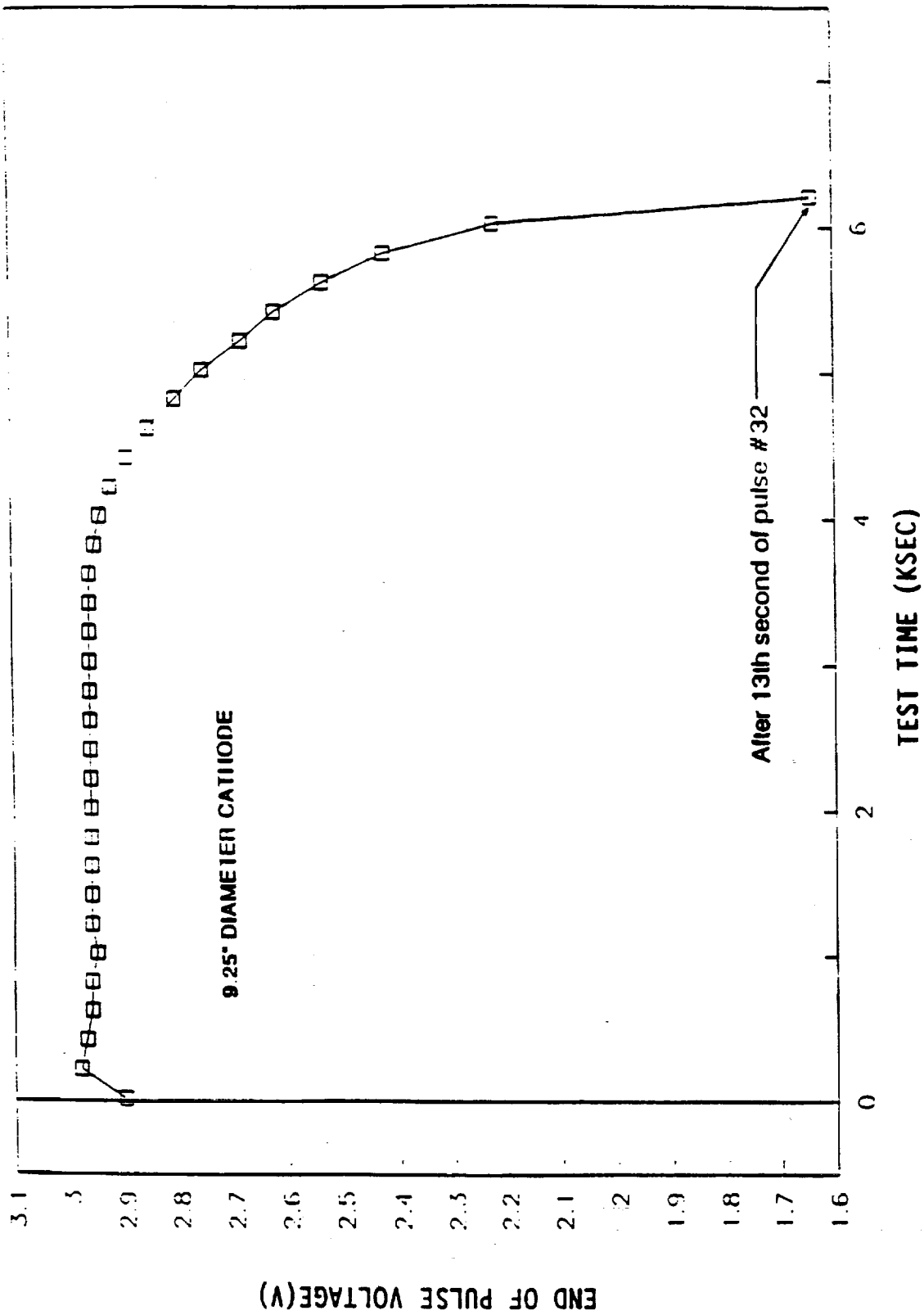


FIG. 11. FIRST SINGLE CELL CONSTANT POWER (71.4W) CONTINUOUS PULSE DISCHARGE EVALUATION OF CATHODE FOR LARGE SIZE SONOBUOY BATTERY

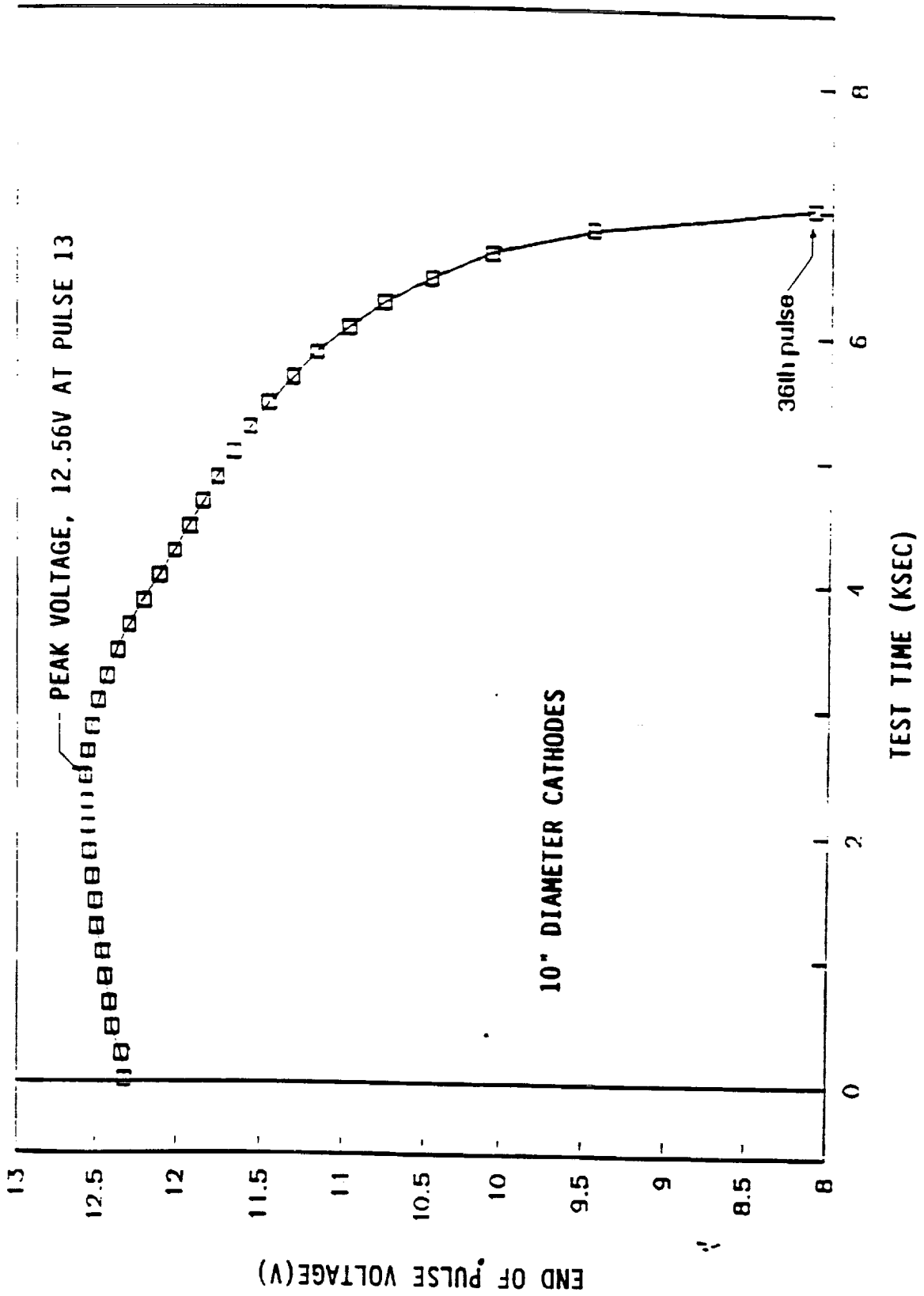


FIG. 12. EOPV FOR 4-CELL STACK DURING CONSTANT POWER (286W) CONTINUOUS PULSE DISCHARGE

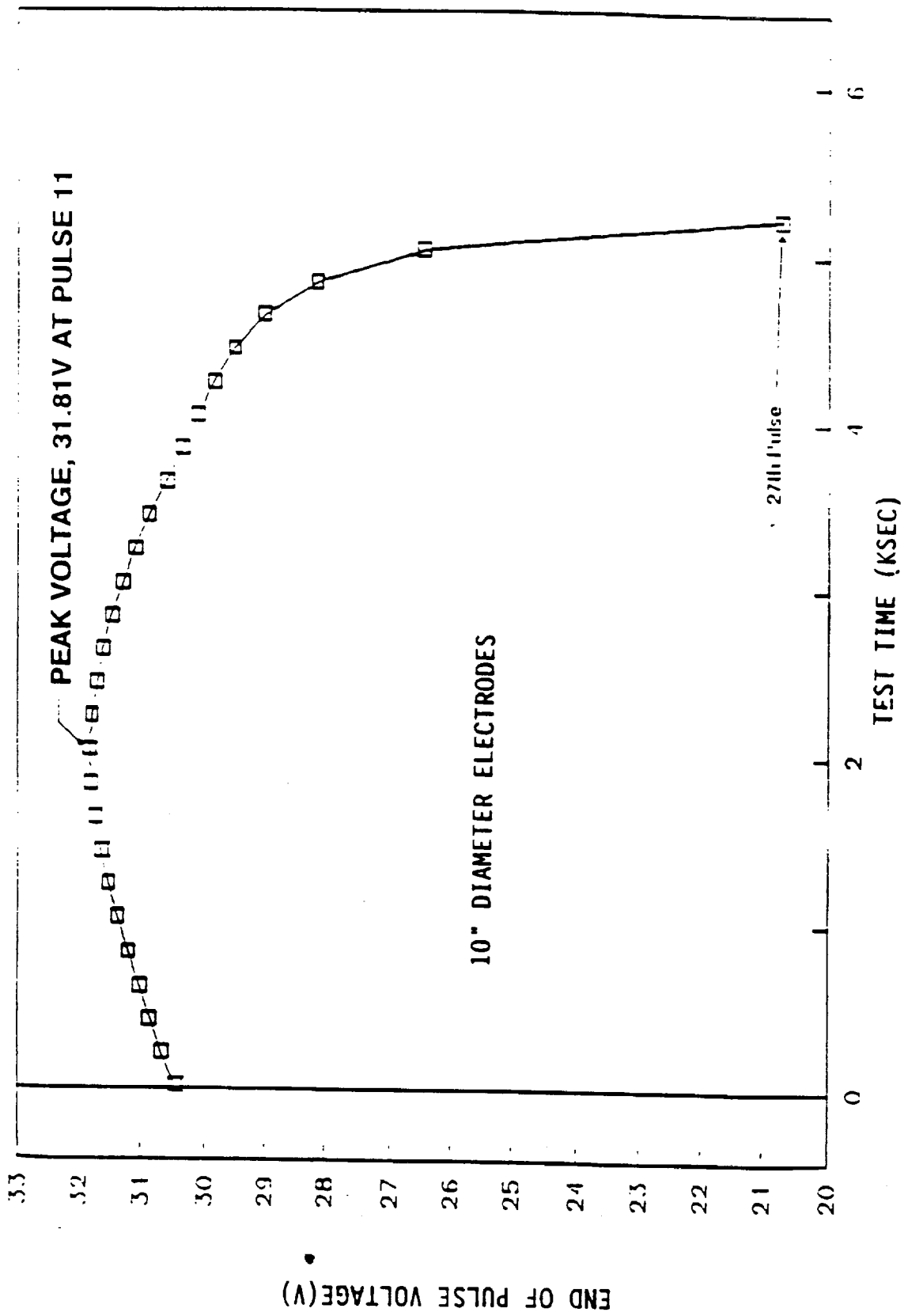


FIG. 13 EOPV FOR FIRST 10-CELL STACK DURING CONSTANT POWER (714W) CONTINUOUS PULSE DISCHARGE

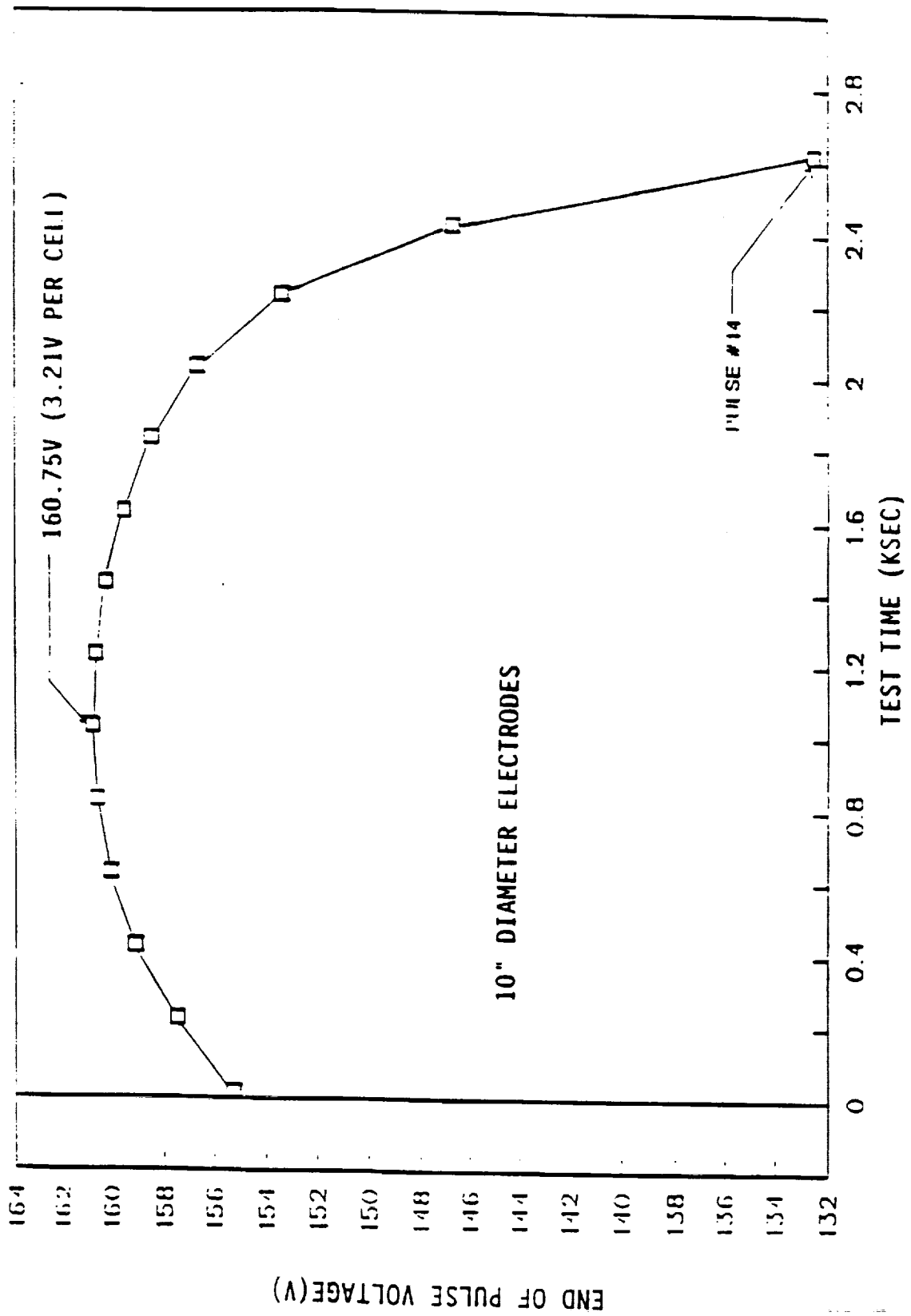


FIG. 14. EOPV FOR FIRST 50-CELL STACK DURING CONSTANT POWER (3570W) PULSE DISCHARGE

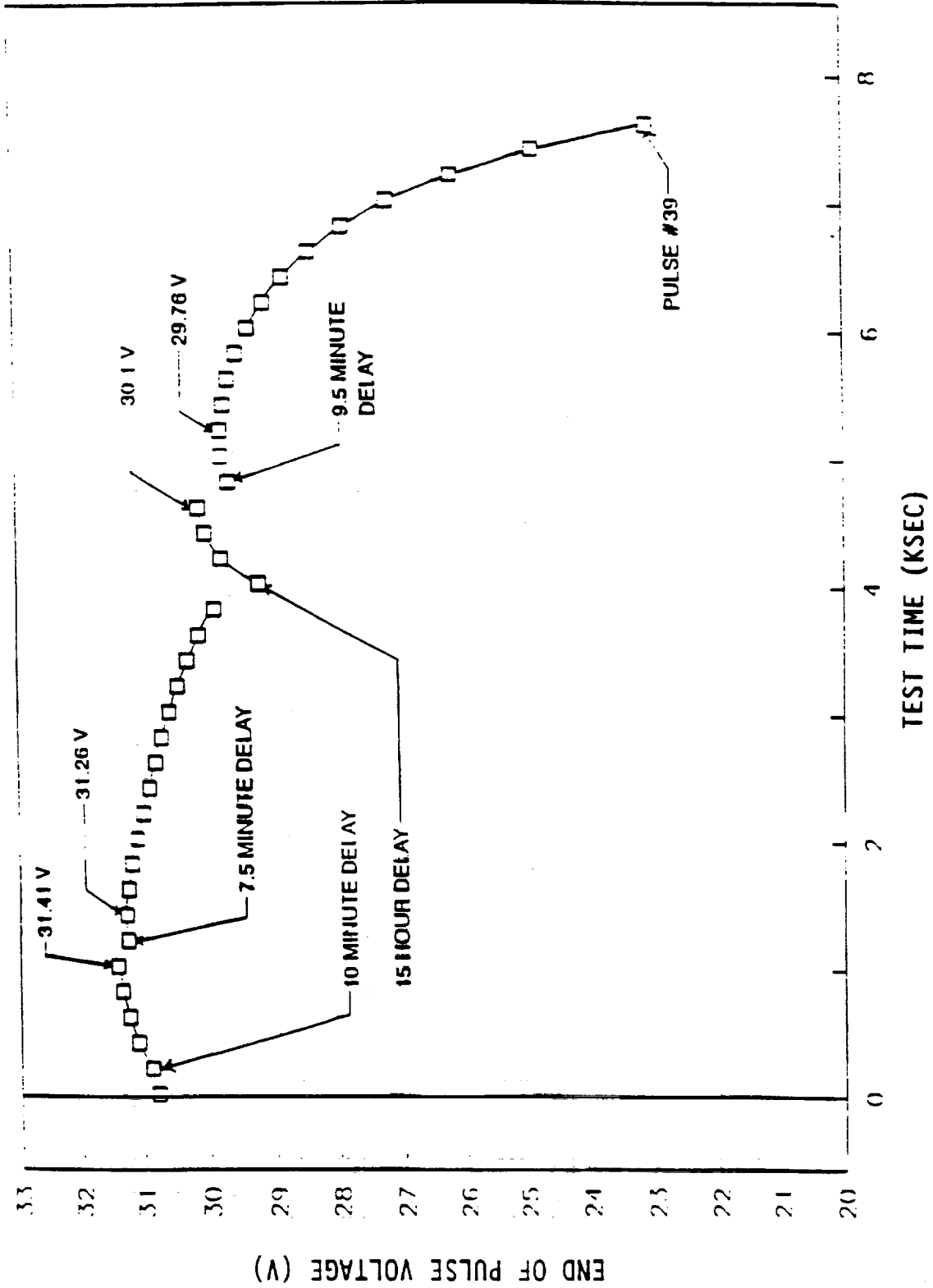


FIG. 15. EOPV FOR THIRD 10-CELL STACK DURING CONSTANT POWER (714W) PULSE DISCHARGE TEST. TEST DELAYS WERE DUE TO AN INSTRUMENTATION/ SOFTWARE PROBLEM

Program Tasks and Accomplishments (continued)

- Conducted first 10.7kW constant power Sonobuoy pulse discharge test, Fig. 16
- Reducing TFE content improved cathode performance. Ten-cell stacks containing high and low TFE cathodes, respectively, were assembled for comparison during a polarization pulse test with current densities in the range of 0.1 to 100 mA/cm², Fig. 17

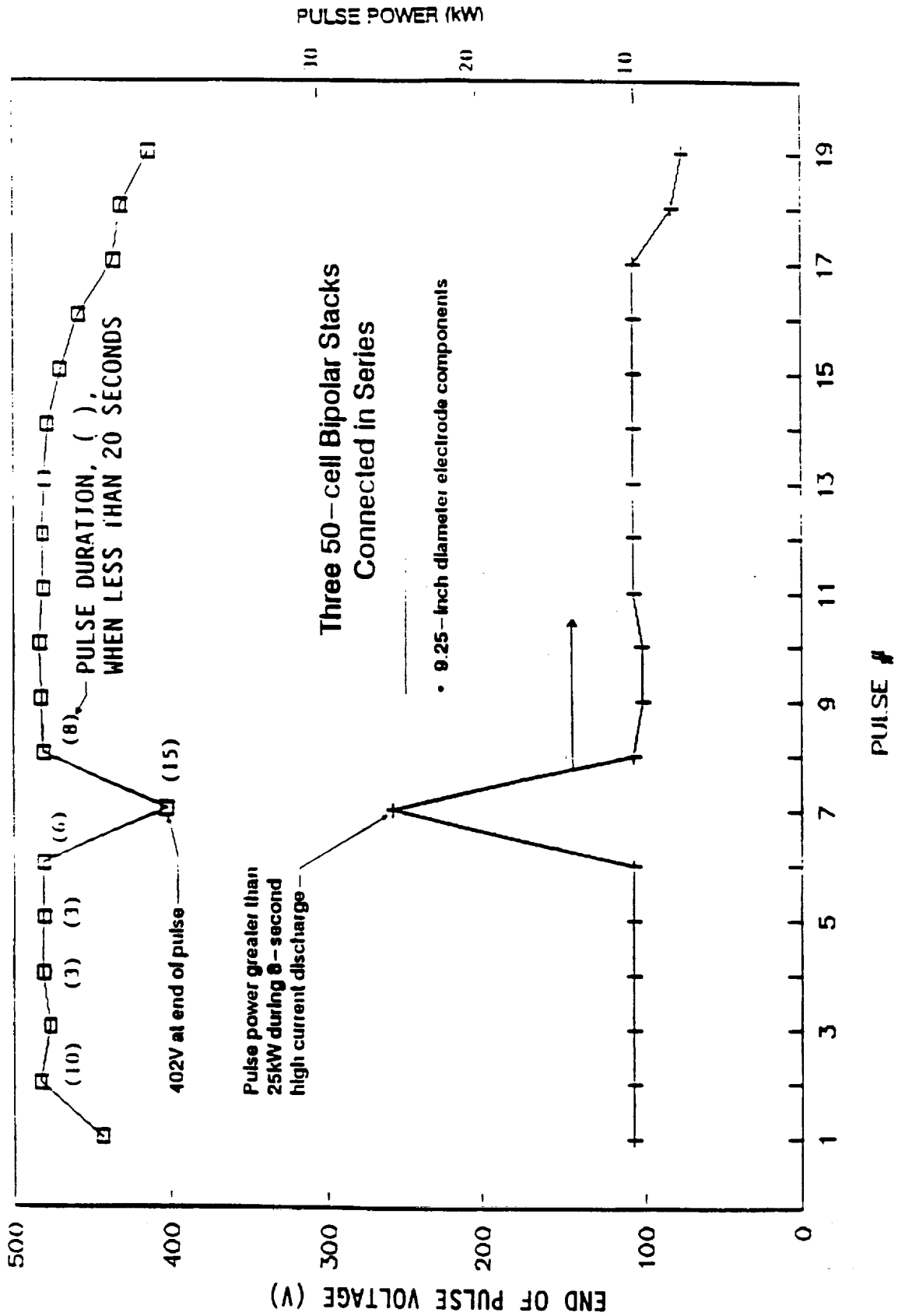


FIG. 16. EOPV FOR FIRST 150-CELL BIPOLAR CONFIGURATION OF THREE 50-CELL STACKS CONNECTED IN SERIES DURING CONSTANT POWER (10.7kW) PULSE DISCHARGE TEST

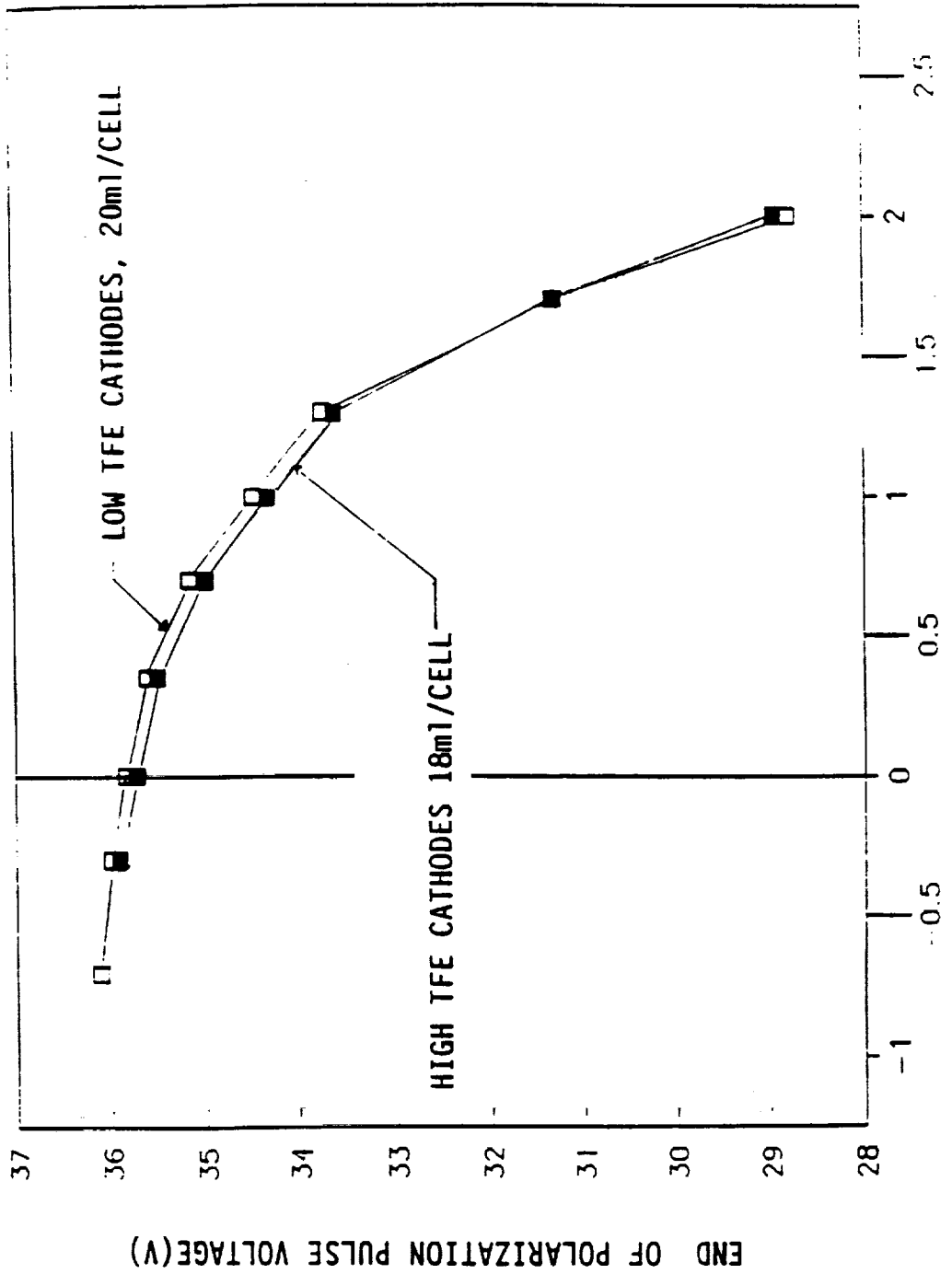


FIG. 17. END OF POLARIZATION PULSE VOLTAGE FOR HIGH AND LOW TFE CATHODES

Program Tasks and Accomplishments (continued)

- Polarization profiles for high and low TFE cathode 10-cell stacks at a pulse current density of 50 mA/cm², Figs. 18 and 19
- High and low TFE cathodes were compared during constant power Sonobuoy pulse discharge tests, Fig. 20
- Comparison of polarization pulse test results for the second and third 150-cell 10.7kW bipolar modules, Fig. 21

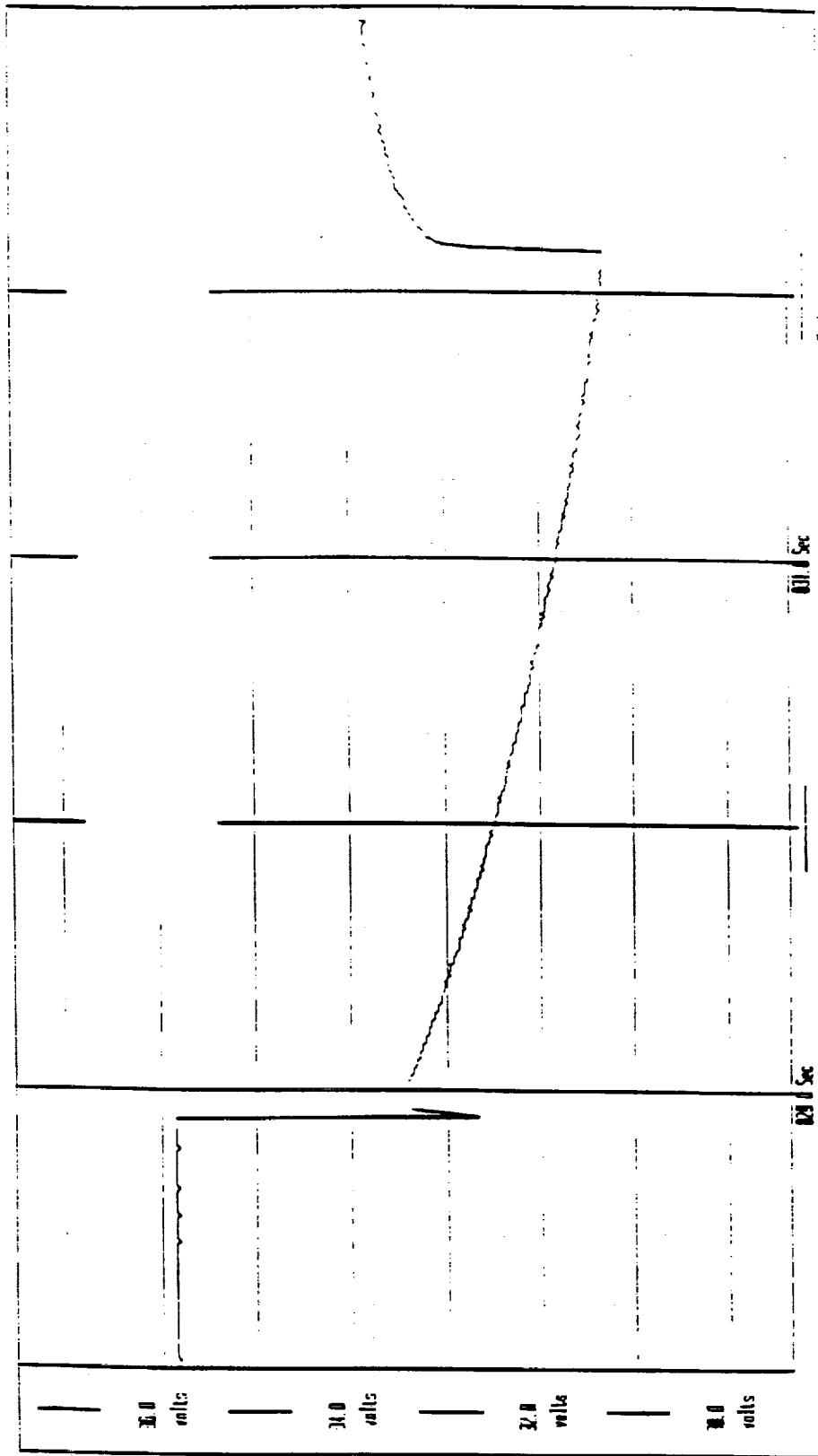


FIG. 18. VOLTAGE PROFILE FOR HIGH TFE CATHODES IN A 10-CELL STACK DURING THE THREE SECOND 20A POLARIZATION CURRENT PULSE.

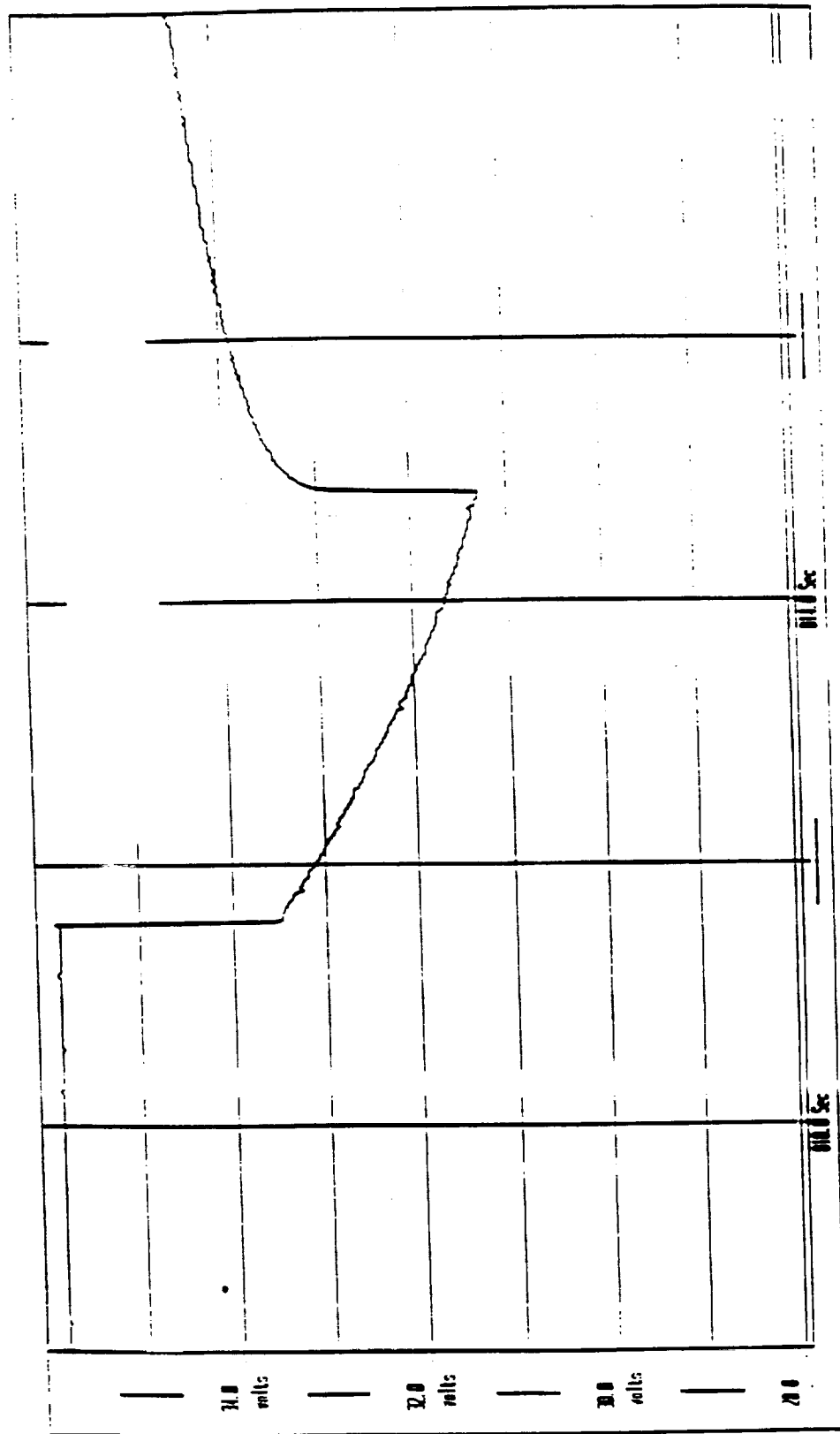


FIG. 19. VOLTAGE PROFILE FOR LOW TFE CATHODES IN THE THIRD 10-CELL STACK DURING THE THREE SECOND 20A POLARIZATION CURRENT PULSE

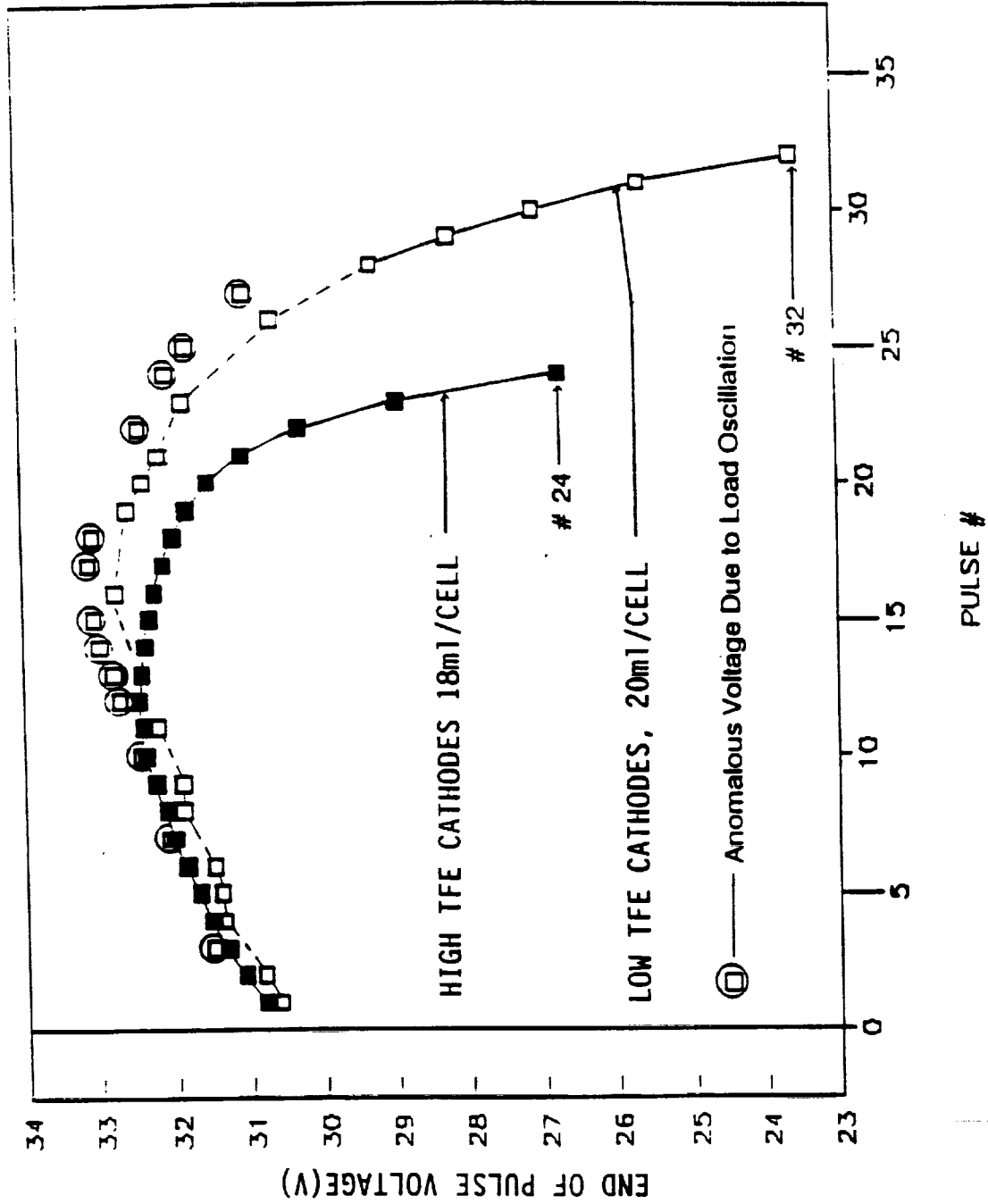


FIG. 20. COMPARISON OF HIGH AND LOW TFE CATHODES DURING 10-CELL STACK PERFORMANCE TESTS.

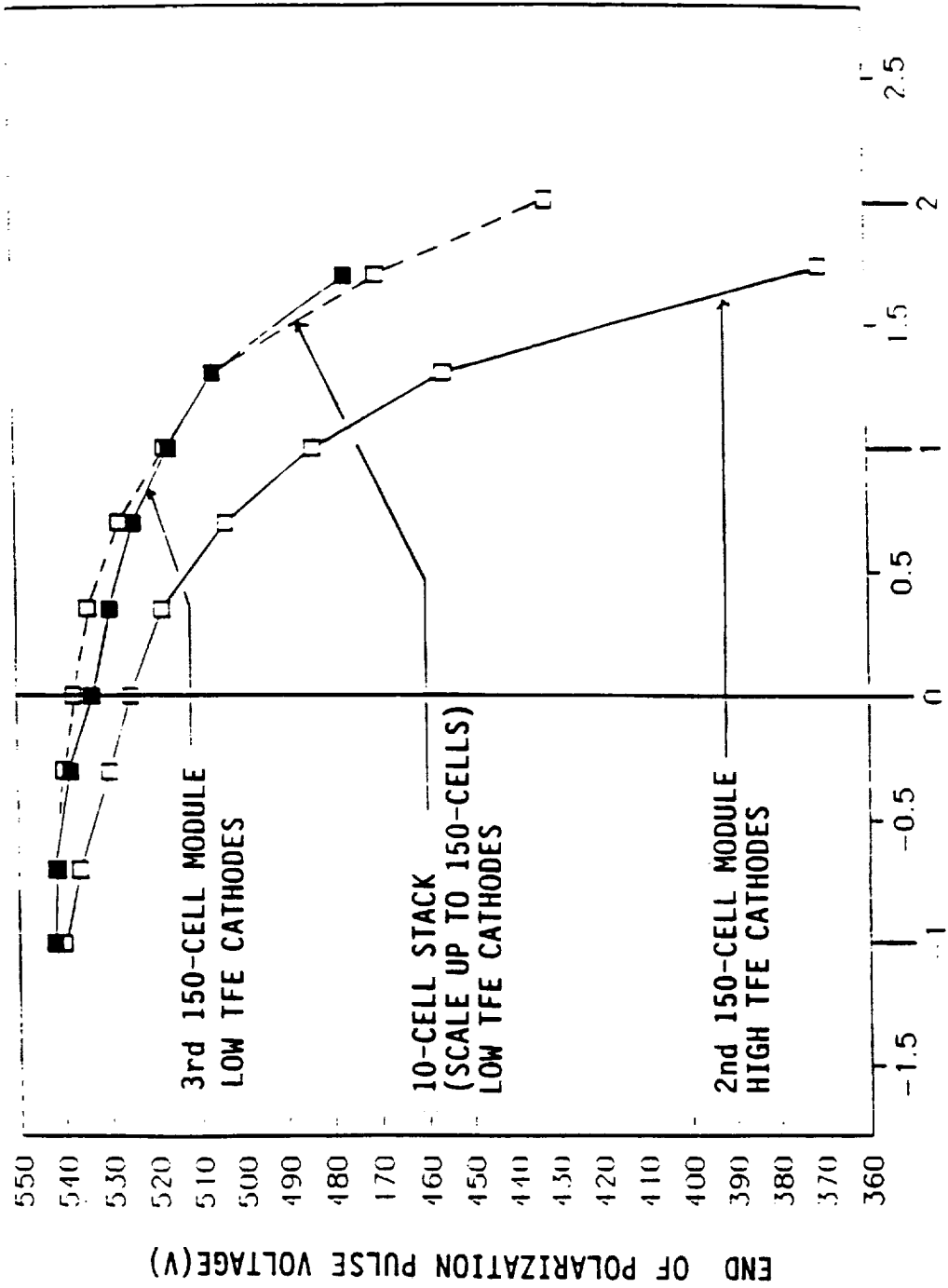


FIG. 21. COMPARISON OF POLARIZATION CURVES FOR 2ND AND 3RD 150-CELL MODULES WITH THE THIRD 10-CELL STACK

Program Tasks and Accomplishments (continued)

- Polarization profile for third 150-cell 10.7kW bipolar module at a pulse current density of 50 mA/cm², Fig. 22
- Third 150-cell 10.7kW bipolar module constant power Sonobuoy pulse discharge test, Fig. 23

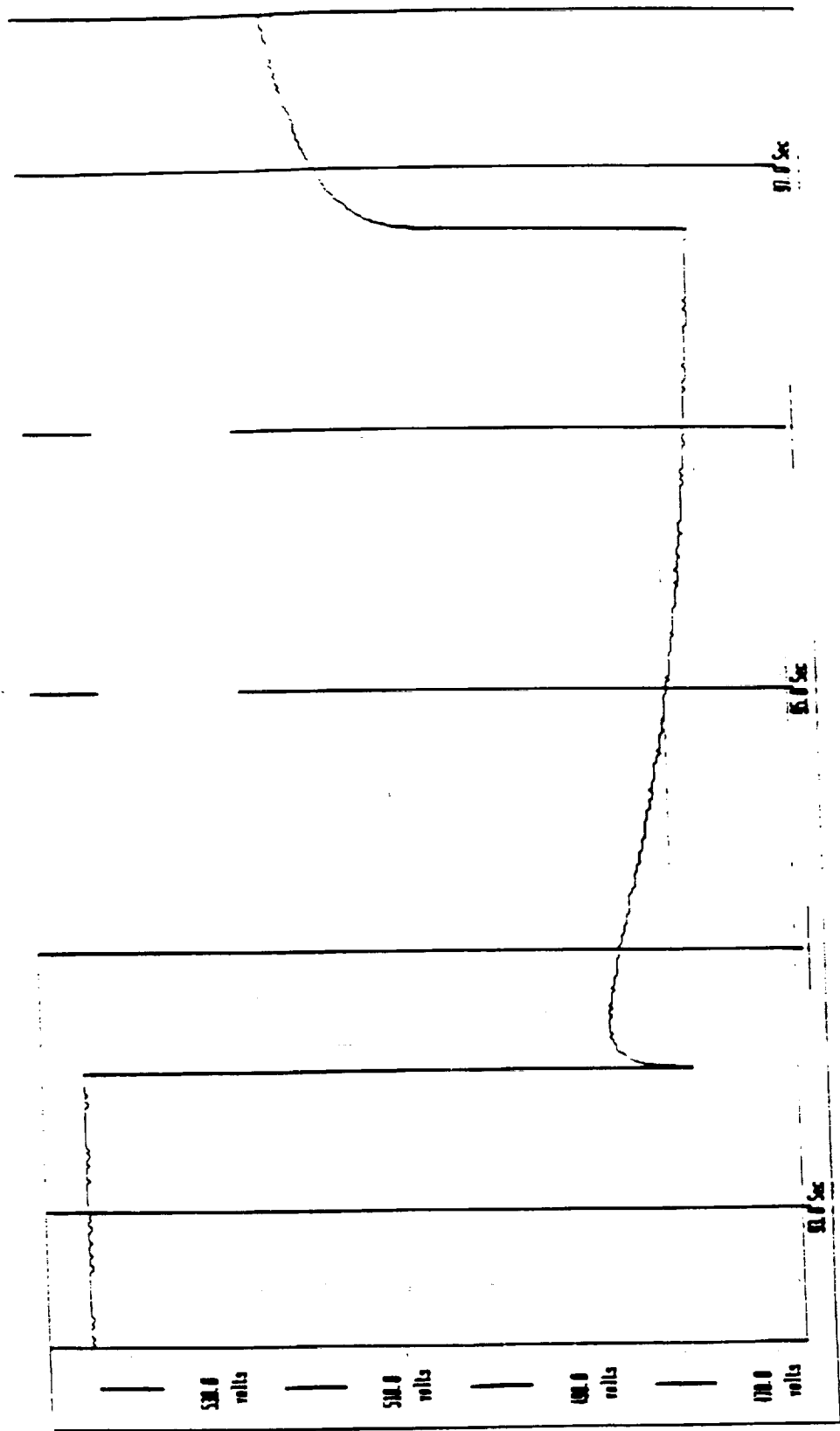


FIG. 22. VOLTAGE PROFILE FOR LOW TFE CATHODES IN 3RD 150-CELL MODULE

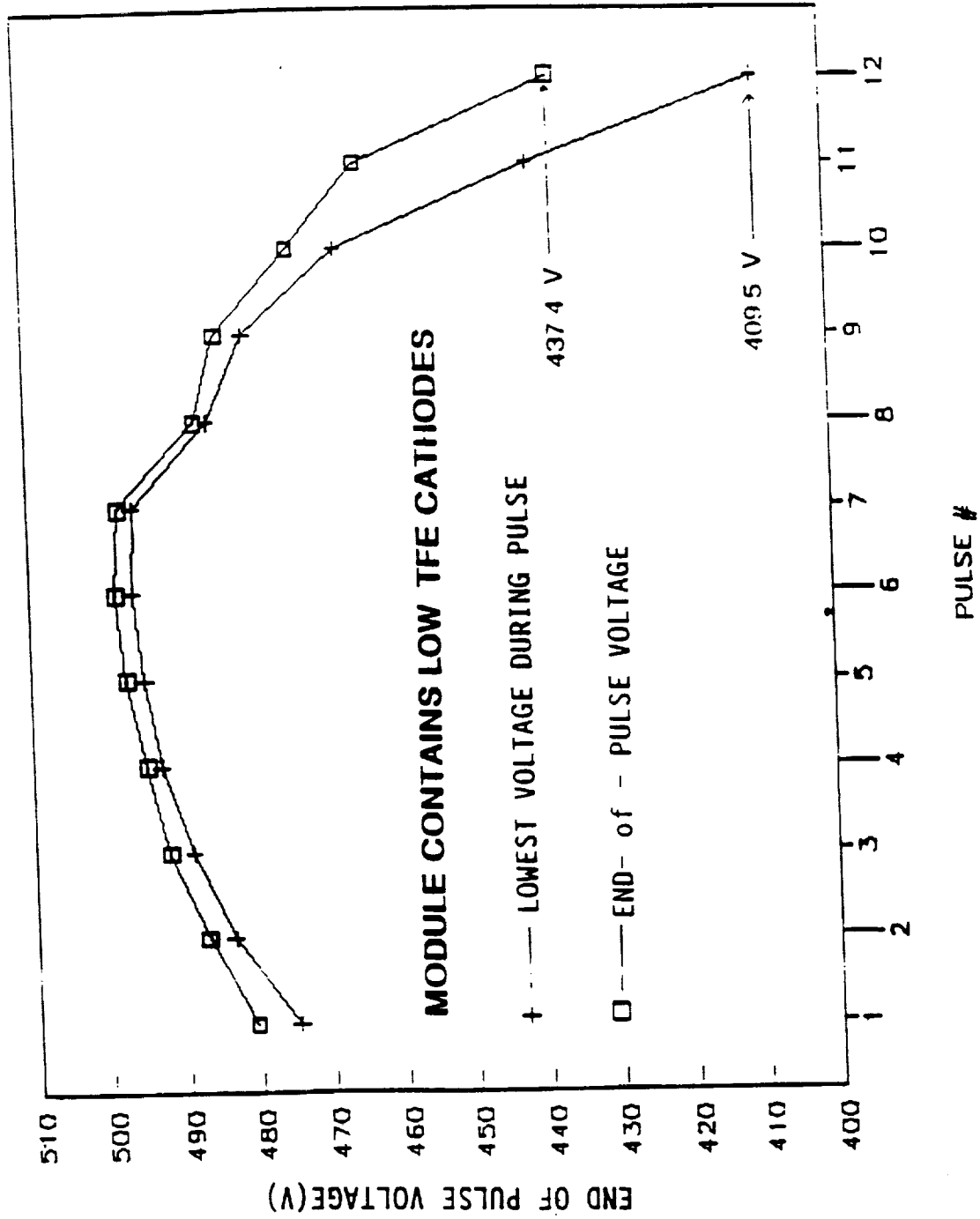


FIG. 23 THE LOWEST VOLTAGE AND EOPV FOR EACH PULSE OF THE THIRD 150-CELL MODULE DURING THE 10.7kW CONSTANT POWER PULSE TEST

PROGRAM SUMMARY

- Developed manufacturing capability for producing large quantities of uniform cathodes and bipolar plates
- Developed assembly, sealing, and activation procedures for fabrication of battery modules containing up to 150 cells in bipolar configuration
- Successful demonstration of a 10.7kW 150-cell module: constant power pulse discharge; 20 second pulse, 10% duty cycle

RECOMMENDATIONS

- Modify capture mold to improve integrity of the bipolar plate at the periphery of the Tefzel insulation
- Improve stack sealing method using "modified" bipolar plates
- Demonstrate improved sealing method and electrolyte activation under full stack compression with large module test

ACKNOWLEDGEMENTS

Yardney would like to thank the NAVSWC group and ONR for their support of this work, which was performed under Contract N60921 -91 -C -0124

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