COMPARISON OF STANDARD AND HEART-PACER TYPE 3RD ELECTRODES IN DESIGN VARIABLE CELLS

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ABSTRACT

Nine packs of General Electric (G.E.) sealed aerospace nickel-cadmium cells were put on life test at the Naval Weapons Support Center in Crane, Indiana in February 1979 under the Design Variable Program. Each 5 cell pack contained one cell with a standard sensor signal electrode and one cell with a new heart-pacer sensor signal electrode. Testing was discontinued in May 1983 and the signal electrode performance data was studied. It was found that the heart-pacer electrode generally provided a greater voltage swing over a cycle; that both types of electrodes lost significant sensitivity during life, and that both types of electrodes show great signal variation from cell to cell.

INTRODUCTION

In 1977, the G.E. Battery Business Department patented a new sensor signal electrode (heart-pacer electrode) for use in sealed aerospace nickel-cadmium cells and announced that this new type would replace the standard signal electrode when existing supplies were depleted. The differences in construction of these electrodes are shown in Table I. Since any change in the manufacture of aerospace Ni-Cd cells requires qualification, a program to test the new electrode was proposed and implemented by David Baer as a part of a larger test program, Design Variables. The cells used in this program were G.E. 12 a-h sealed aerospace Ni-Cd cells. One pack was a control pack with the standard cell construction. The other 8 packs contained cells with various design changes. Testing began at the Naval Weapons Support Center in Crane, Indiana in February 1979 and was discontinued in May 1983. The Design Variable Program Test Regime is shown in Table II. A formal report on the Design Variable Program was given at the 1978 Goddard Battery Workshop.

SIGNAL ELECTRODE TEST RESULTS

In reviewing the data on the signal electrodes it was discovered that both signal electrodes performed consistently in only 3 out of the 9 packs on test, packs 3D, 3G, and 3H. In all other packs, the signal generated by the electrode varied from pack to pack and cycle to cycle in a particular pack. Because of a pressure transducer malfunction in pack 3H, packs 3D and 3G were used for this comparison of performance.

Figure I shows a comparison of the standard and heart-pacer electrode performance in pack 3D near the beginning of life. From the plot it can be seen that the heart-pacer electrode produced approximately a 350 mV signal swing over a cycle while the standard electrode swing was only 100 mV. There was a 113% recharge for that cycle and a pressure delta of 9 psia.

Figure II is a comparison of the signal performance of the 2 electrodes near the end of life. It appears that the standard electrode is now out performing the heart-pacer type, but this performance reverse is not as clear cut as it appears and is not indicative of the trend that is shown in the Standard Electrode Life Performance Comparison shown in Figure III. As can be seen, the trend with age was for the electrode signal to slowly degrade through cycle 17200. Then, near the end of life, the electrode suddenly produced a better signal and swing than ever before. This is partly explained by looking at the percent return for that last cycle. From cycle 17200 to cycle 23257 it increased from 108% to 119% and also caused the cell pressure delta to increase dramatically from 4 psia to 20 psia as Figure IV shows. This pressure increase was probably responsible for the performance improvement during that last cycle.

While the increase in percent return produced a greater pressure delta in the standard electrode cell, it procuded no effect in the heart-pacer cell. There the pressure delta slowly decreased over the entire life ending at 2 psia on cycle 23257 as Figure VI shows. In Figure V, the signal degradation is shown for the heart-pacer electrode. It was a slow degradation from about cycle 200 to cycle 17200 with the signal swing remaining good throughout. It was not until cycle 23257 that the electrode showed a dramatic loss of signal. Hence, the great reversal in performance shown in Figure II also had as a contributing factor the rapid signal loss of the heart-pacer electrode between cycles 17200 and 23257.

The data from Pack 3G was studied next. The life degradation of the heart-pacer electrode in pack 3G is shown in Figure VII. It was the same type of degradation as was shown for the heart-pacer electrode of pack 3D, the only difference being a more rapid occurrence of signal fall-off. Here, a noticeable amount of degradation was seen by cycle 5200, whereas before significant sensitivity loss was not evident until cycle 17200. Figure VIII shows that cell pressure was consistent over life with no great changes appearing.

The standard electrode life plot, Figure IX, shows a more consistent degradation in pack 3G than that shown in pack 3D. In 3G there was no great signal increase at the end of life, even though the percent recharge and cell pressure again made a dramatic increase in the last few cycles as is shown in Figure X. The signal magnitude and swing was not good in the standard electrode of Pack 3G (80 mV to 90 mV), but was consistent with Pack 3D.

CONCLUSIONS

The heart-pacer signal electrode generally produced a signal of higher magnitude and greater voltage swing than the standard signal electrode, although both types of signal electrodes lost considerable sensitivity with life. This loss of sensitivity with life and the great signal variation from signal electrode to signal electrode of the same type would make the implementation of a reliable signal electrode charge control system very difficult, if not impossible.

Some contributing causes of poor performance in the electrodes could be: the large volume of KOH present in cells of this design, and the lack of significant pressure variation over a cycle especially in the cells with the heart-pacer signal electrode.

REFERENCES

1. Baer, D.; Cell Design and Manufacturing Changes During the Past Decade; p. 49, NASA Conf. Pub. 2088, The 1978 Goddard Space Flight Center Battery Workshop; Nov. 14-16, 1978.

TABLE I

SIGNAL ELECTRODE CONSTRUCTION

Heart Pacer Electrode	Standard Electrode
• Nickel Plated Steel Substrate Coated with Sintered Nickel Powder.	• Nickel Plated Steel Substrate Coated with Sintered Nickel Powder.
• Impregnated with Cadmium, Silver Treated, and Coated with a Hydrophobic Fluorocarbon Polymer.	• Coated with a Hydrophobic Fluorocarbon Polymer.
• External Resistor: 10 OHM	• External Resistor: 300 OHM

TABLE II

DESIGN VARIABLE PROGRAM TEST REGIME

- Temperature: 20°C
- Depth of Discharge: 40 Percent
- Orbit Period: 90 Minutes
- Charge Current: 9.6 Amps $\left(\frac{C}{1.25}\right)$ To a Voltage Limit
- Discharge Current: 9.6 Amps $\left(\frac{C}{1.25}\right)$

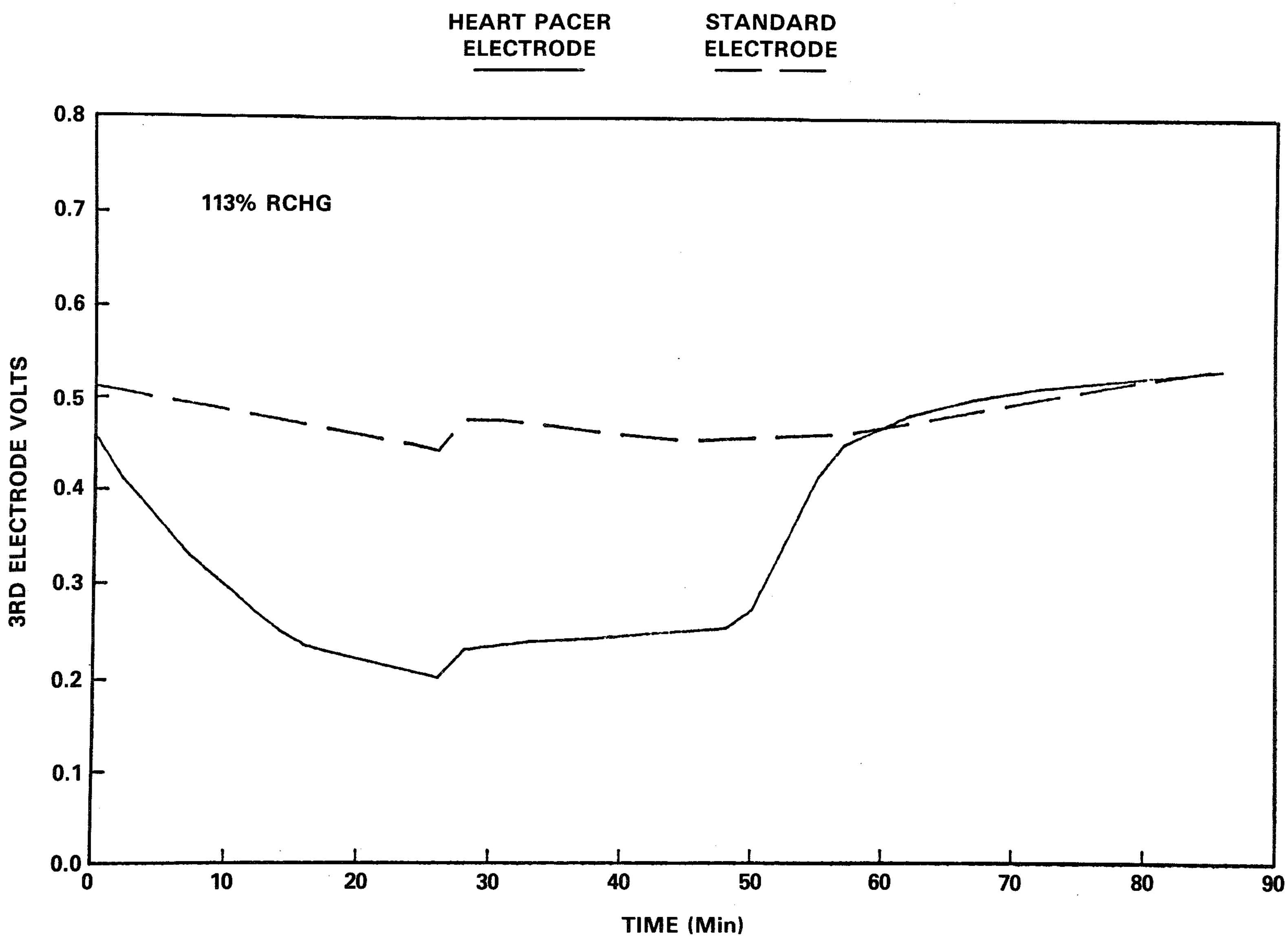

FIGURE I DESIGN VARIABLE 3RD ELECTRODE STUDY TYPICAL CYCLE DATA, PACK 3D, CYCLE 222

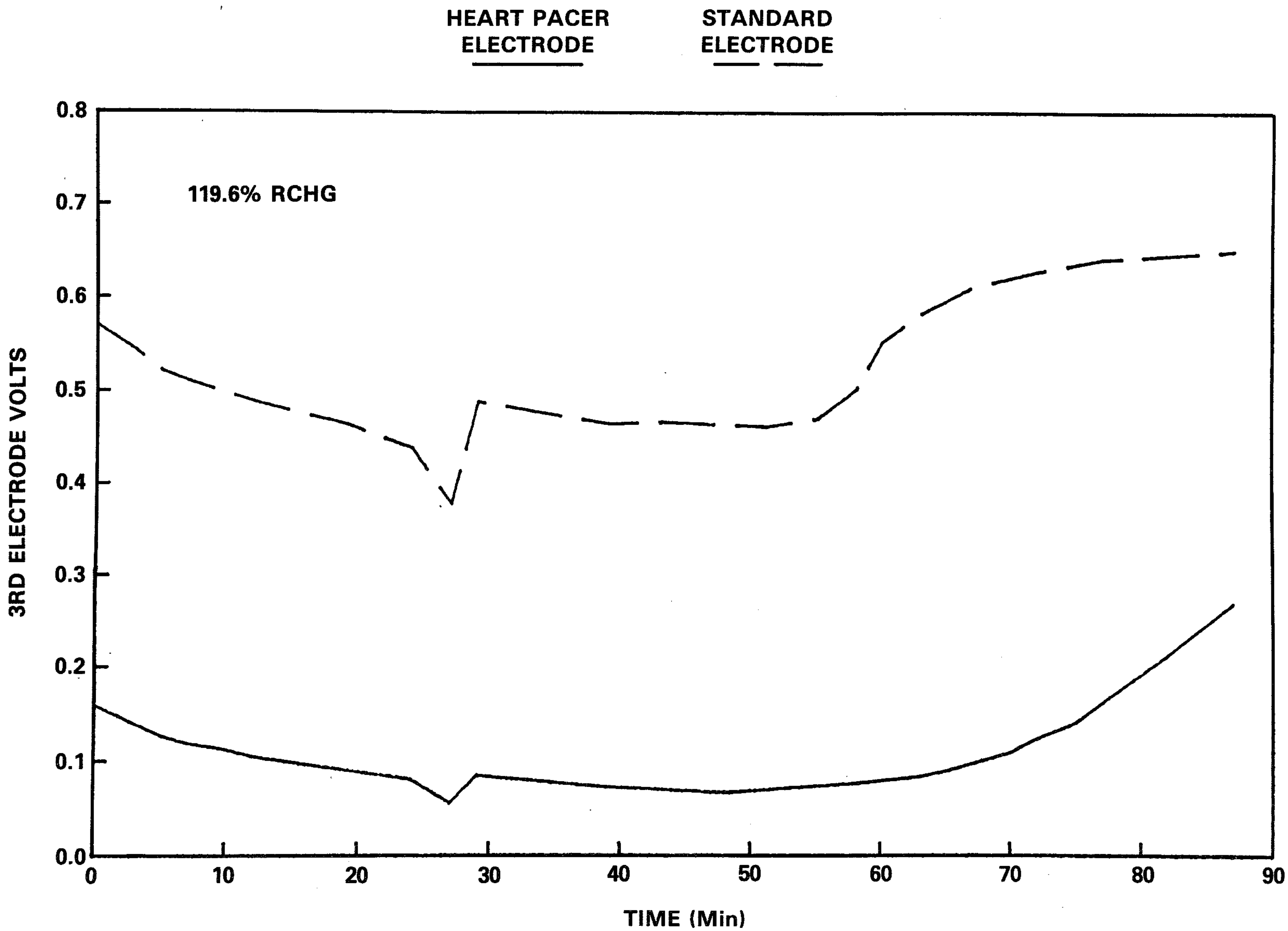

FIGURE II DESIGN VARIABLE 3RD ELECTRODE STUDY TYPICAL CYCLE DATA, PACK 3D, CYCLE 23257

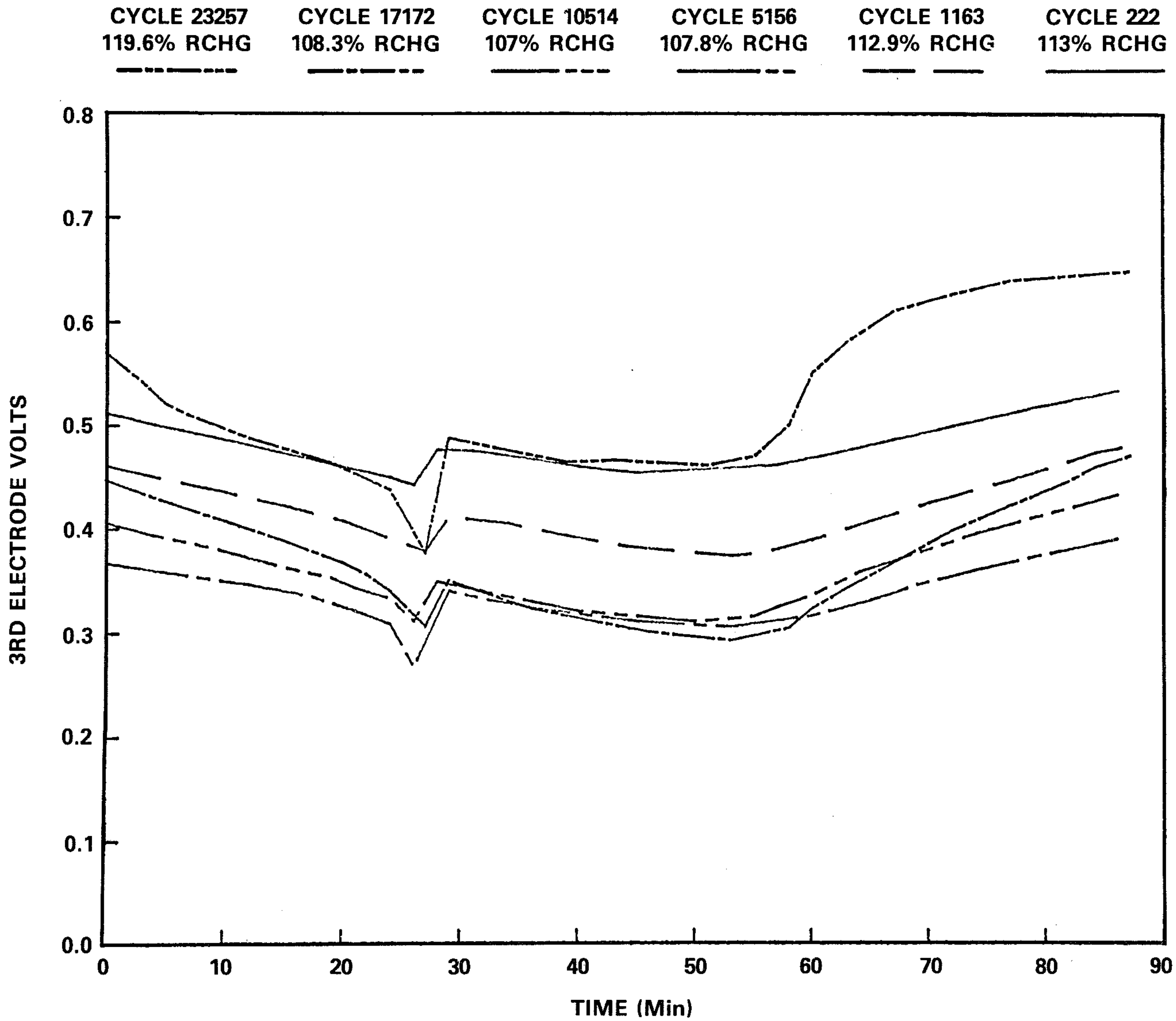

FIGURE III DESIGN VARIABLE 3RD ELECTRODE STUDY STANDARD 3RD LIFE BY TYPICAL CYCLE, PACK 3D

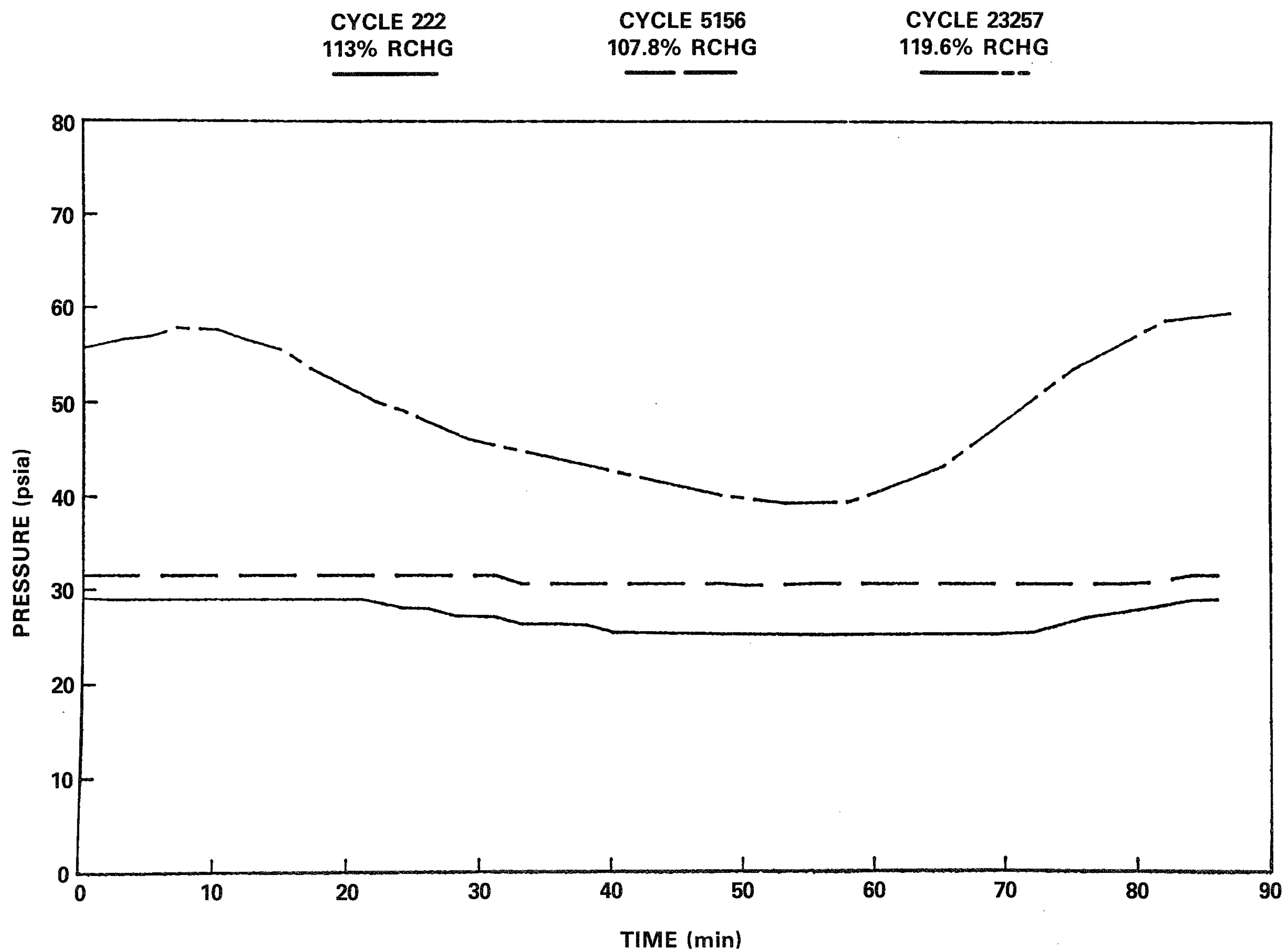

FIGURE IV DESIGN VARIABLE 3RD ELECTRODE STUDY STANDARD CELL TYPICAL CYCLE PRESSURE, 3D

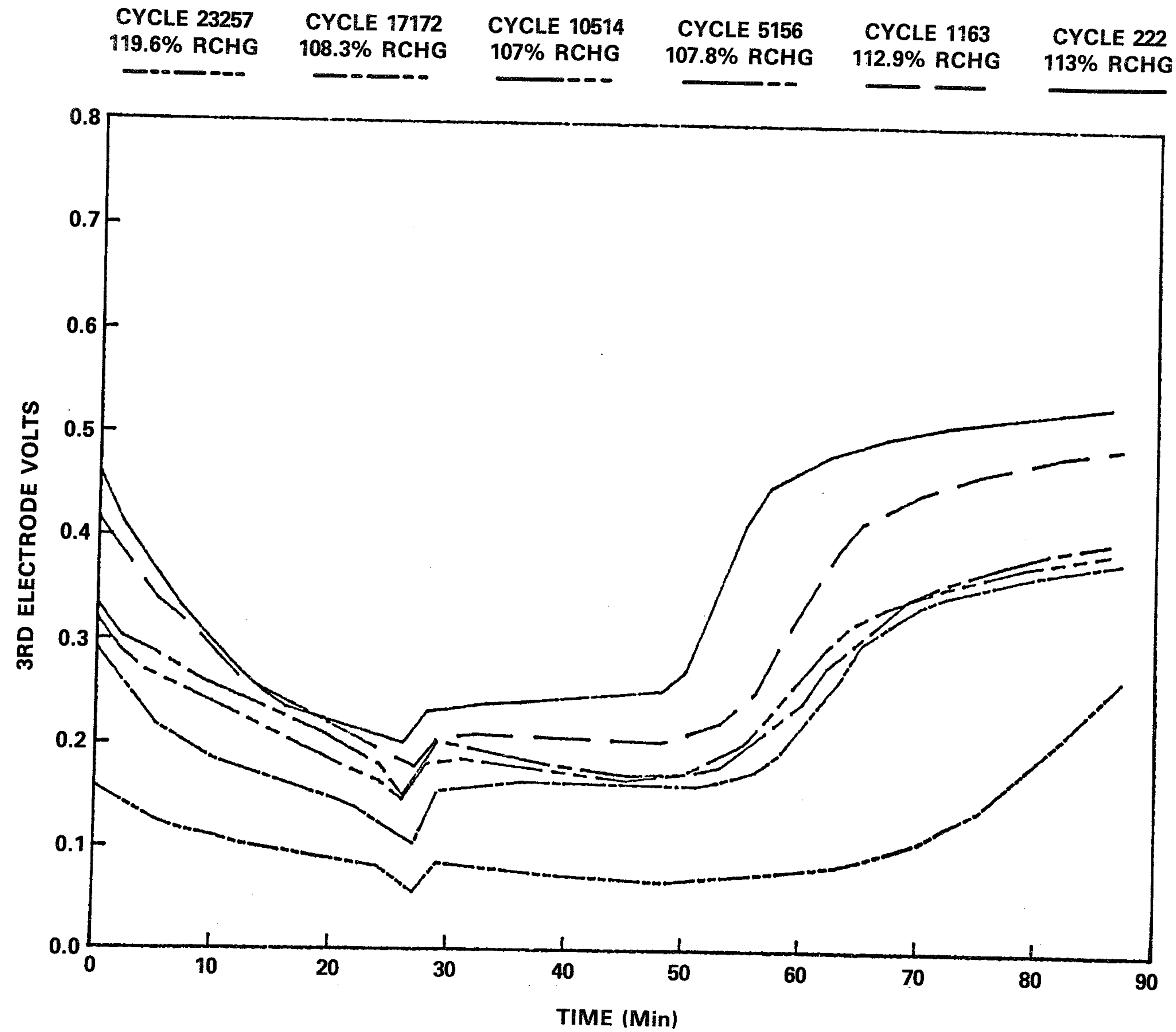

FIGURE V DESIGN VARIABLE 3RD ELECTRODE STUDY HEART PACER LIFE BY TYPICAL CYCLE, PACK 3D

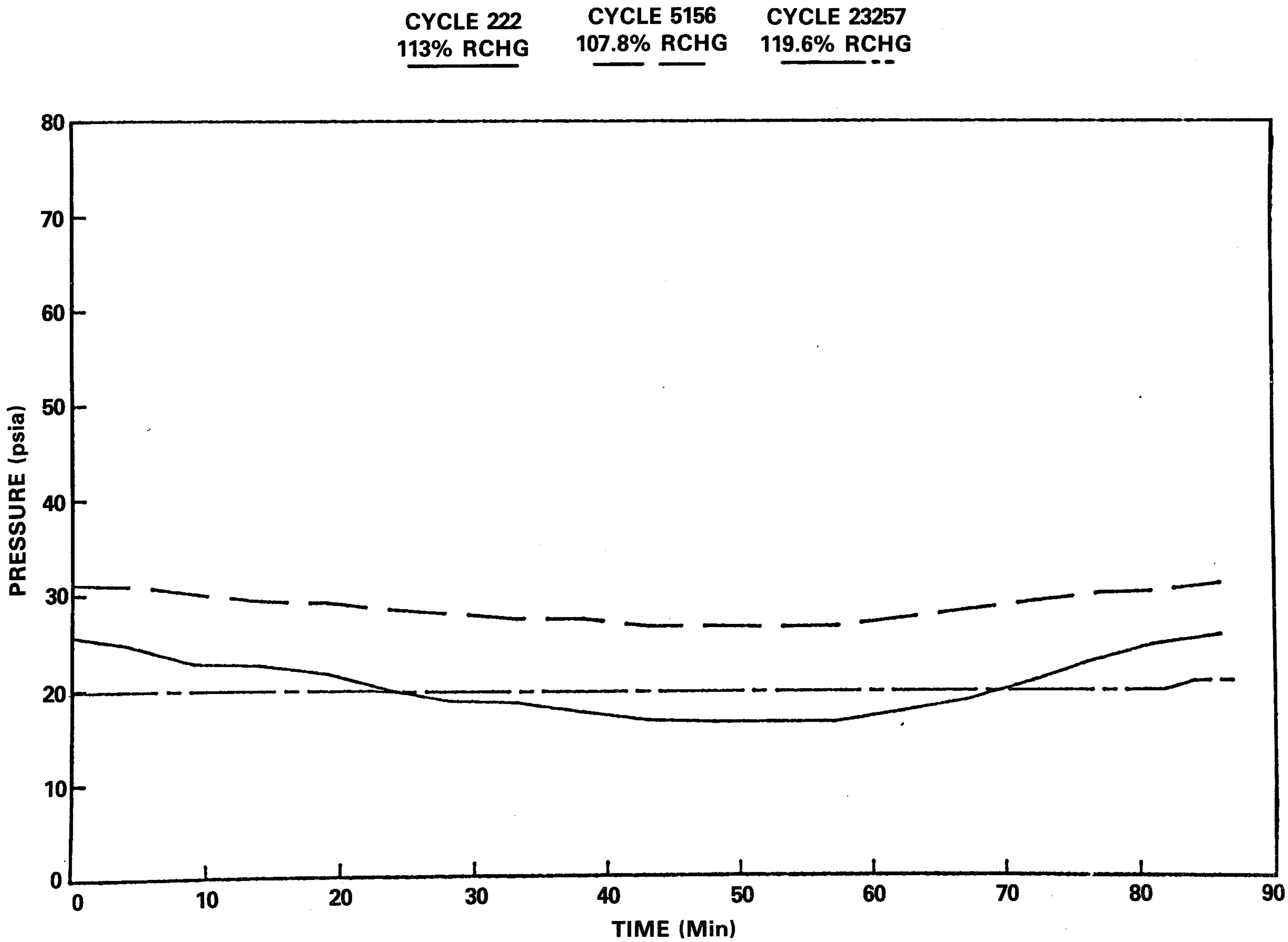

FIGURE VI DESIGN VARIABLE 3RD ELECTRODE STUDY HEART PACER CELL TYPICAL CYCLE PRESSURE, 3D

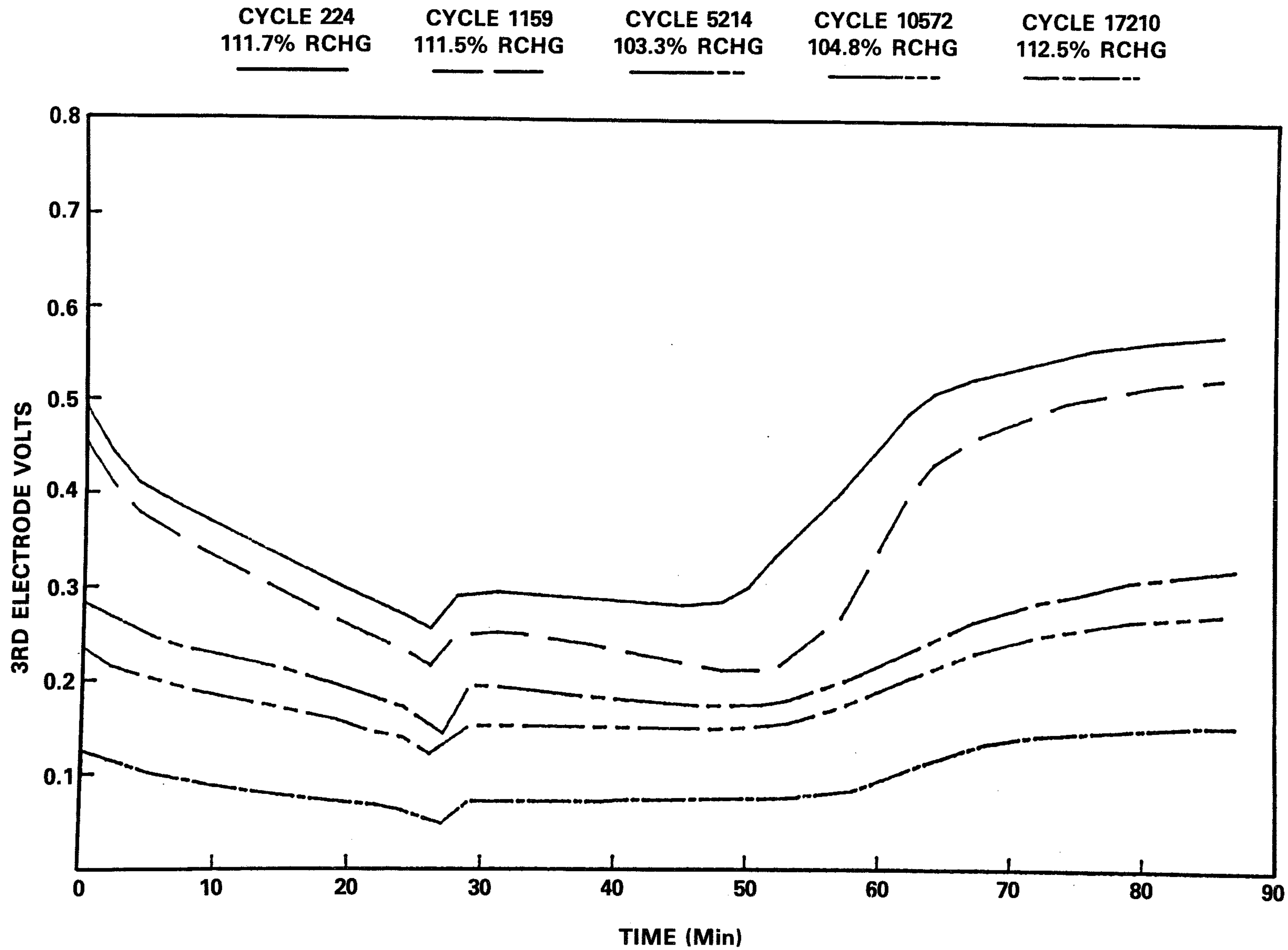

FIGURE VII DESIGN VARIABLE 3RD ELECTRODE STUDY HEART PACER LIFE BY TYPICAL CYCLE, PACK 3G

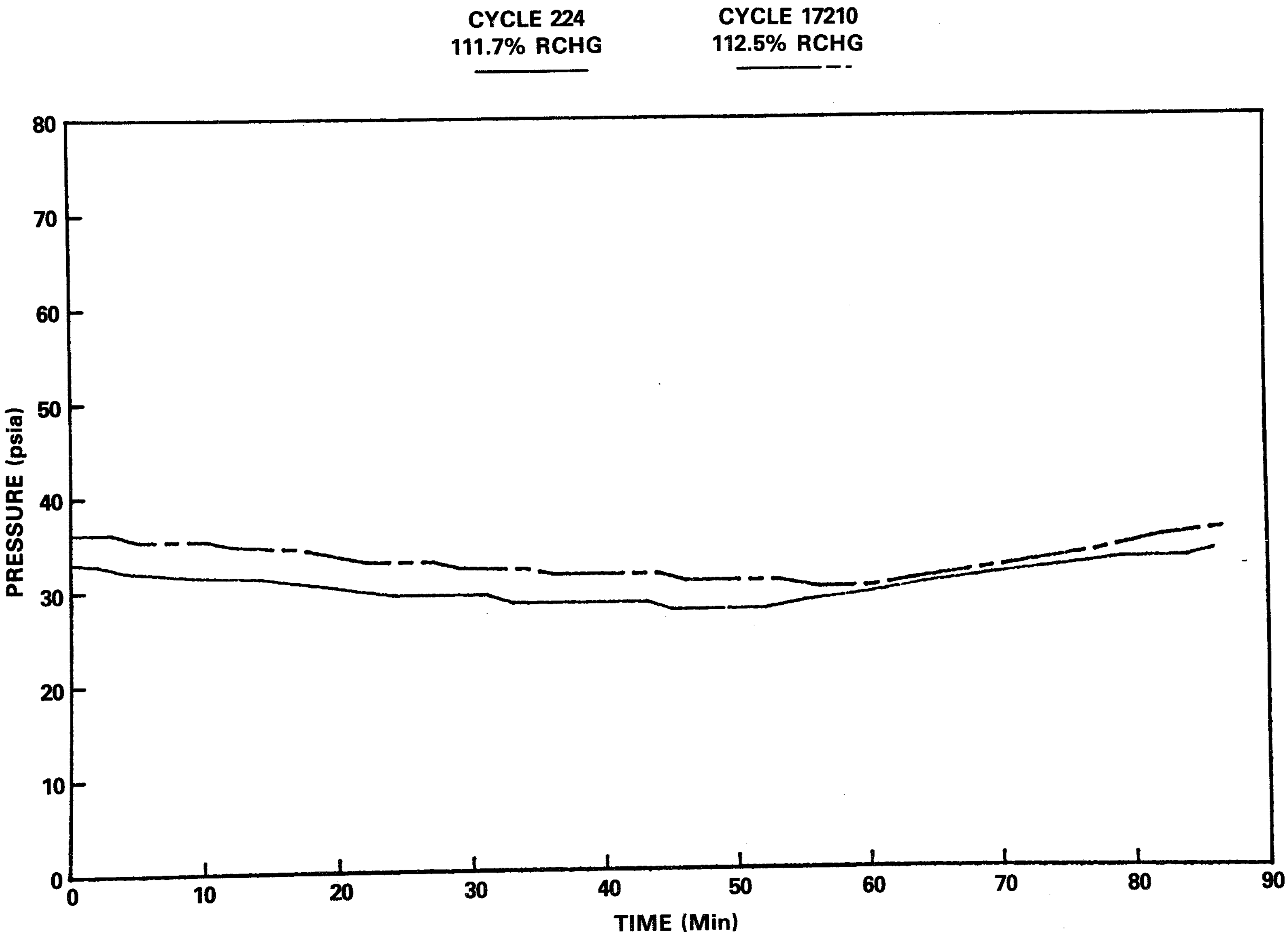

FIGURE VIII DESIGN VARIABLE 3RD ELECTRODE STUDY HEART PACER CELL TYPICAL CYCLE PRESSURE, 3G

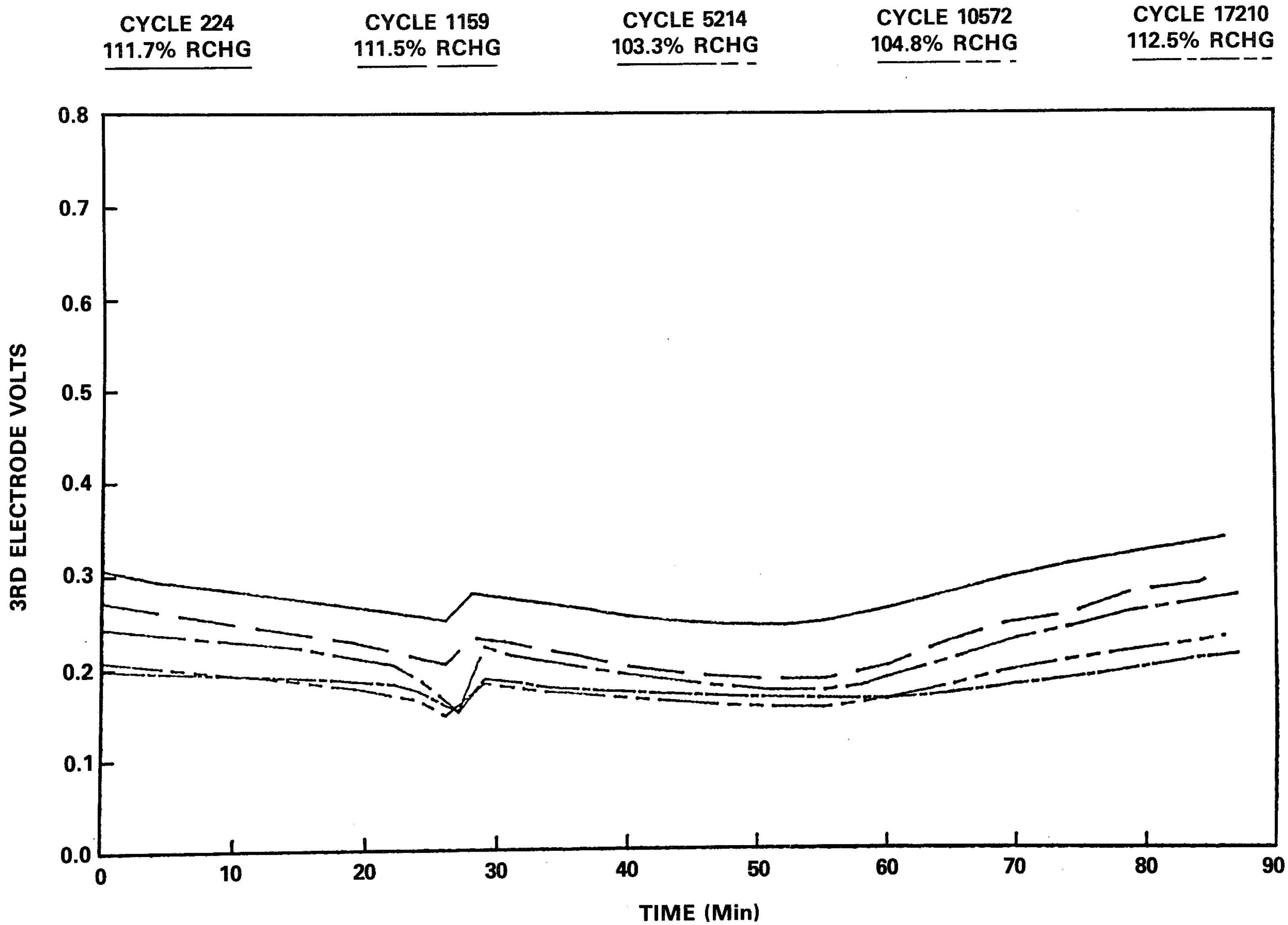

FIGURE IX DESIGN VARIABLE 3RD ELECTRODE STUDY STANDARD 3RD LIFE BY TYPICAL CYCLE, PACK 3G

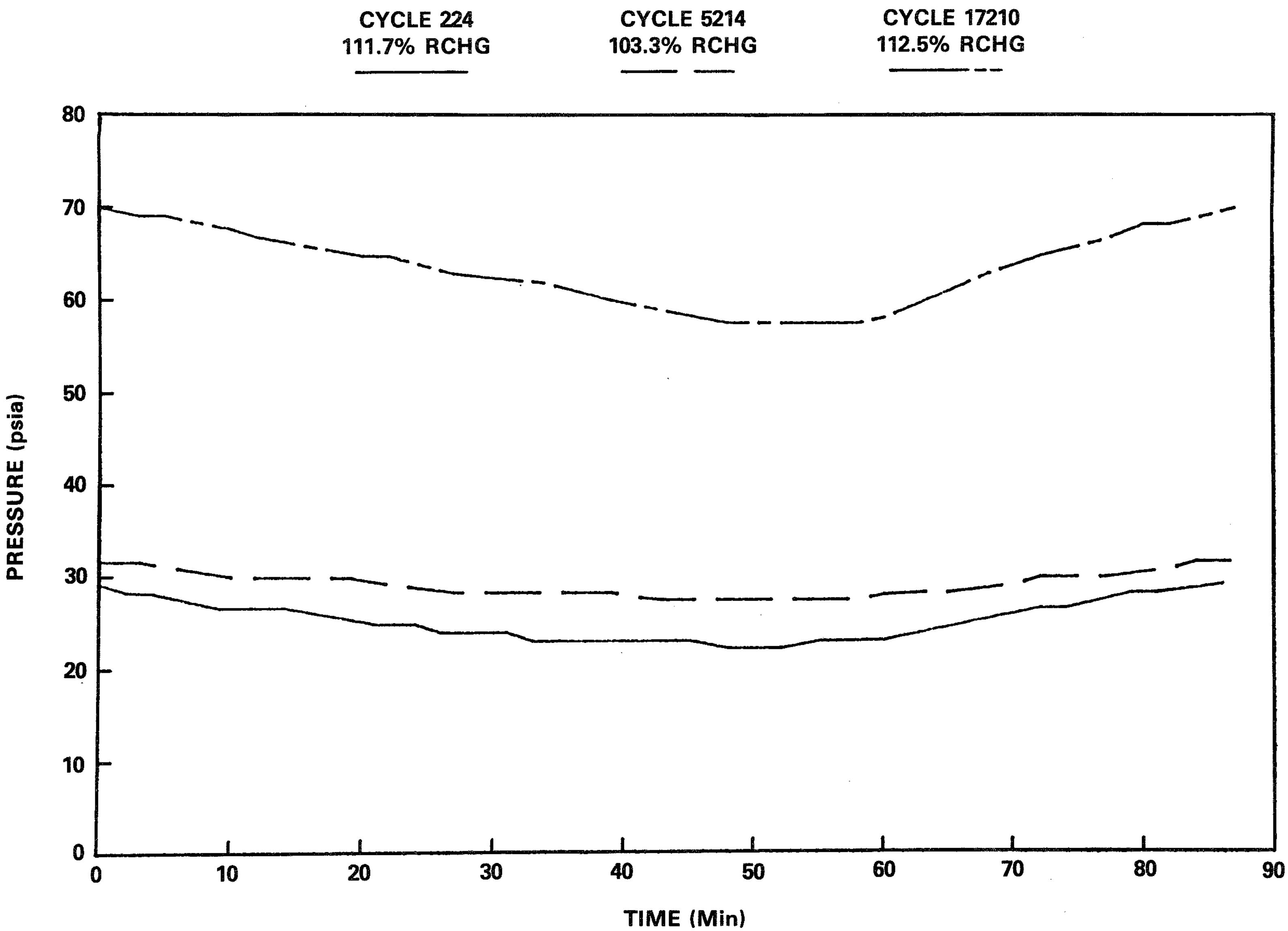

FIGURE X DESIGN VARIABLE 3RD ELECTRODE STUDY STANDARD CELL TYPICAL CYCLE PRESSURE, 3G

Q. Ritterman, Comsat: I guess you are talking about a nickel cadmium cell or a bunch of nickel cadmium cells with two different types of charge control electrodes?

A. Morrow, GSFC: Signal electrodes.

Q. Ritterman, Comsat: Oh signal electrodes. And you didn't get any variation in pressure. I mean that's what I essentially saw. What does each electrode respond to? I mean normally the signal electrode responds to some sort of oxygen pressurized, the hydro directs the proportion of pressure. The old GE signaling electrode is just the minute you start getting any amount of oxygen you start getting a rise. I guess your auxilliary electrode is your signaling electrode is attached to be resistant to the negative electrode. A whole bunch of things I didn't understand. What the cycle was, how wet the cells were in respect to CC's of KOH per amp hour? Could you identify the cells?

A. Morrow, GSFC: Dave is a little more up on the design variable cells than I am.

A. Baer, GSFC: For the most part they had around 4CC's per amp hour.

A. Ritterman, Comsat: Yeah that should still be enough to give you a little better recombination than you've got.

A. Baer, GSFC: I think the thing that puzzled us was at the beginning of life some of them weren't too bad and at the end of life when you expect the cells to start drying out you weren't getting the expected pressure rise.

Q. Ritterman, Comsat: Are you charging it at about the same rate that you were discharging?

A. Baer, GSFC: Yes. I think there was about 9.6 amps for a 12 amp per hour cell.

Q. Rogers, Hughes Aircraft: The electrode that you have I assume, it is suppose to react with oxygen?

A. Morrow, GSFC: Right.

Q. Rogers, Hughes Aircraft: You've got cadmium on it. Now I guess I see two competing reactions. How does the electrode know what to do?

A. Morrow, GSFC: The new electrode was designed for heart pacer applications and in that they really have to watch what the oxygen pressure does since it will be inside the body. So what they did was they tried, they wanted to put silver on the electrode which would, silver is a little more catalytically active with oxygen so it would produce a higher voltage and the cadmium is placed in contact with the silver so that it holds it more to the electrode not letting silver oxide form and therefore migrate to the cells.

A. Baer, GSFC: Howard, let me say this is GE's reference electrode and all we are doing is comparing the two. It's what they want to switch to and we want to compare the two to see if they are compatible. The electrode wasn't our idea, I guess is what I'm saying.

A. Rogers, Hughes Aircraft: The reason for my question is that you were talking about a cadmium electrode which normally is not used as an oxygen recombination electrode.

A. Morrow, GSFC: Right.

A. Rogers, Hughes Aircraft: That's what the question came from.