

*Nickel-Hydrogen Battery
Reconditioning*

Erik L Levine

SPACESYSTEMS/LORAL

12/3/96

1996 NASA Aerospace Battery Workshop

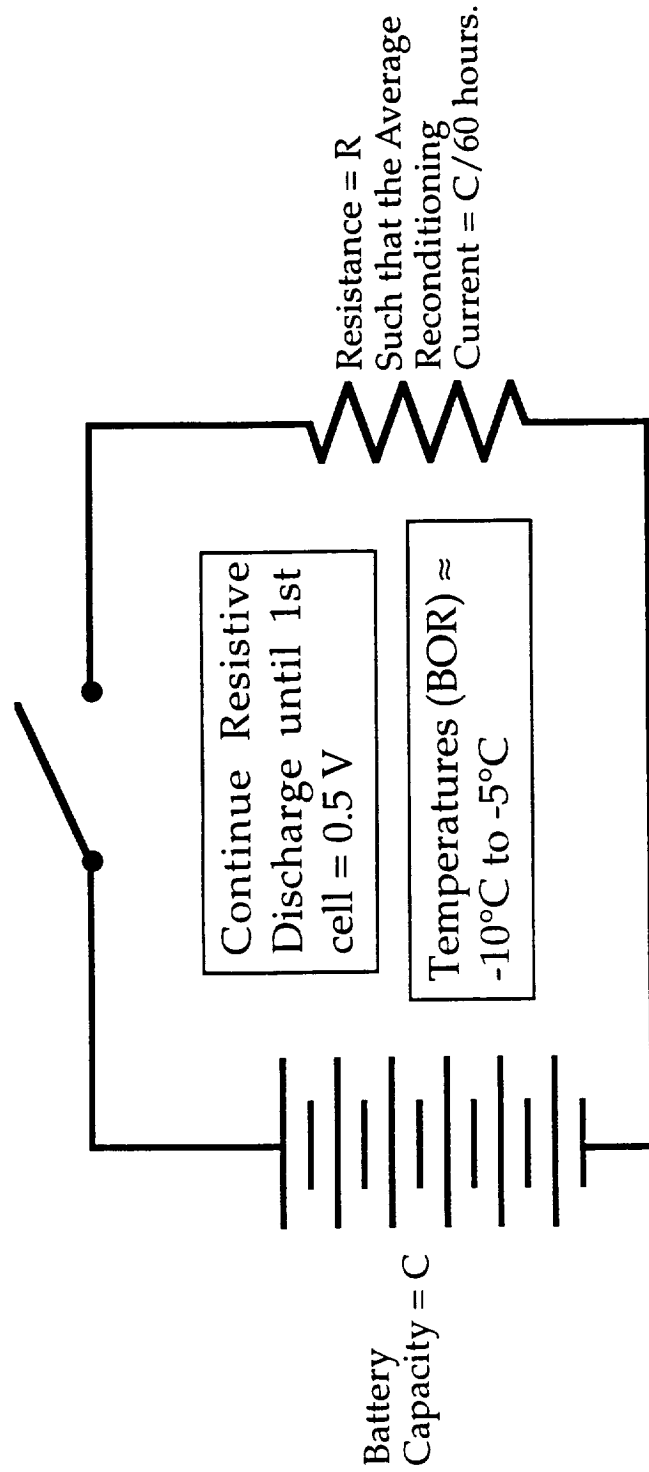
Outline

- ◆ **SS/L Reconditioning Implementation**
- ◆ **Reconditioning Conclusions**
- ◆ **Superbird Reconditioning - Pressure/Capacity Growth**
- ◆ **INTELSAT VII/VIIA Reconditioning - Cell Voltage Plateaus and Life Testing**
- ◆ **N-Star Reconditioning - Cell Voltage Plateaus (Capacity Fading and Recovery)**
- ◆ **Questions and Answers**

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SS/L Battery Reconditioning Implementation



Performed ≈ 2 - 3 weeks prior to each eclipse season
(i.e. early February and late August)

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Reconditioning Conclusions

- ◆ Provides no appreciable increase in performance

but, provides an excellent way for ...

- ◆ Measurement of pressure/capacity growth.
- ◆ Correlation with Life Test Data
- ◆ Verification of Capacity Fade and Recovery

and is therefore recommended when possible, but not required.

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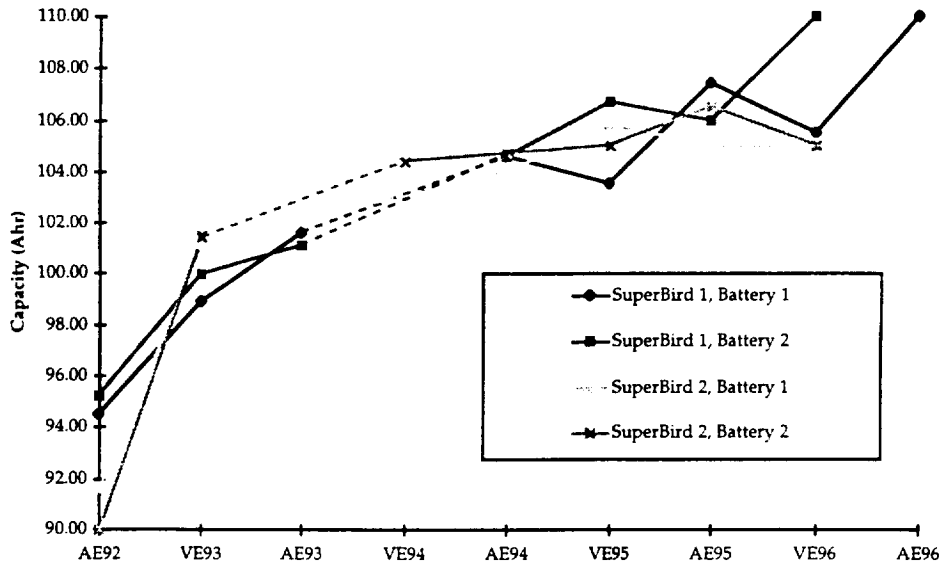
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- Battery performance being amp-hour capacity and cell voltages.
- Used mainly as a diagnostic tool and for trending data to observe any capacity reductions during life and to observe the presence and reduction any capacity fading / voltage second plateau.
- Only way to perform a consistent battery test since length of eclipses vary through the season and spacecraft power needs may change from season to season. Remember, the satellite is nothing more than a two terminal battery test station (right?) !
- Therefore on single bus satellites, anomalies in orbit, or LEO applications, it is not required to maintain performance.

Superbird Reconditioning and Capacity Trend

In Orbit Spacecraft Post Reconditioning Recharge Capacity



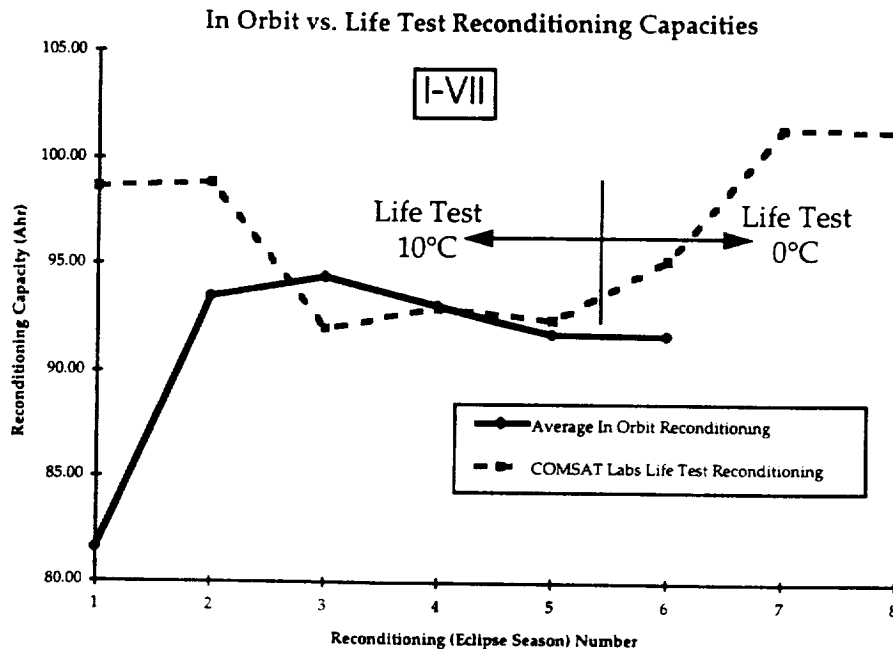
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- Superbird capacity growth chart. Note that increase in end of charge pressure corresponds almost exactly with the capacity increase (i.e. no pressure increase due to degradation of cell components). Capacity shown here is the pressure reading (via a strain gage on the battery cell) compensated for the cell temperature to get amp-hours.
- Trending to flatten out per predictions.
- Note that at times some of the batteries were not reconditioned but performance still increases.

I-VII In Orbit vs. COMSAT Life Test Reconditioning Capacities



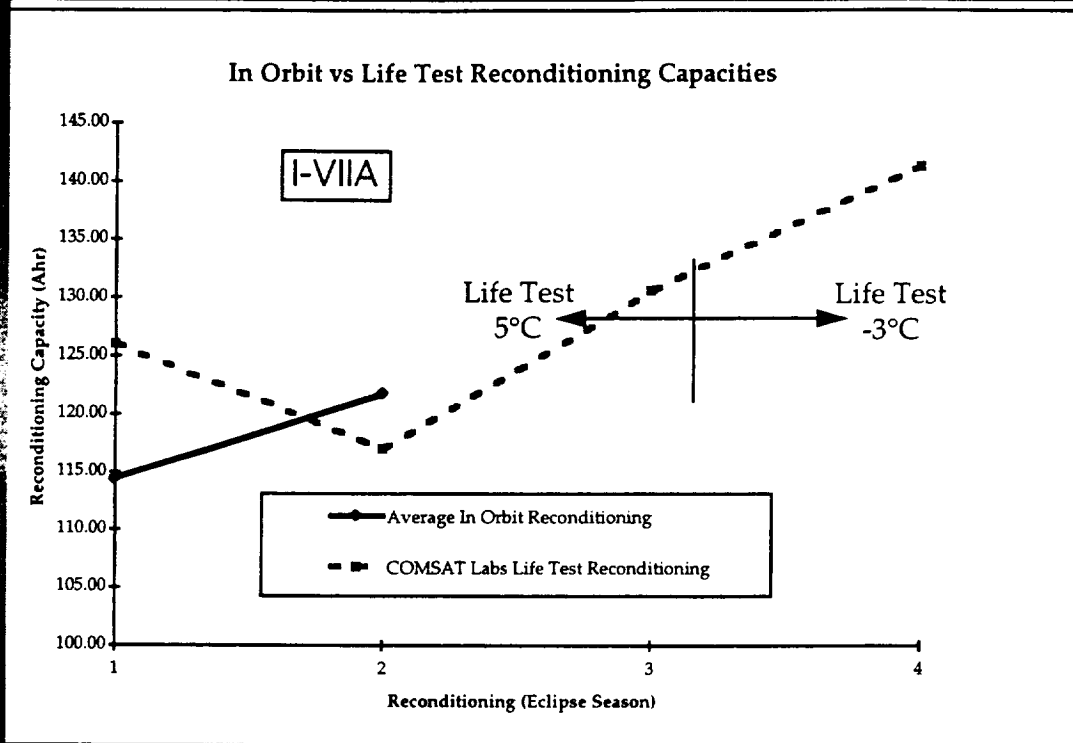
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- I-VII Life Test vs. In Orbit Reconditioning.
- Note that the life test batteries have more seasons than the actual orbit.
- Scale is quite zoomed up, so the data is actually pretty tight with a few percent.
- The life test battery was tested extensively before the the first reconditioning, so all of its capacity building was already done. Therefore the reconditioning data is constant (except for effect of changing temperature). The flight batteries however go through minimal acceptance testing only and thus still has potential for capacity building in orbit, which is shown by the increase in reconditioning capacities.
- Note effect of decrease in life test temperature on the COMSAT reconditioning.

I-VIIA In Orbit vs. COMSAT Life Test Reconditioning Capacities



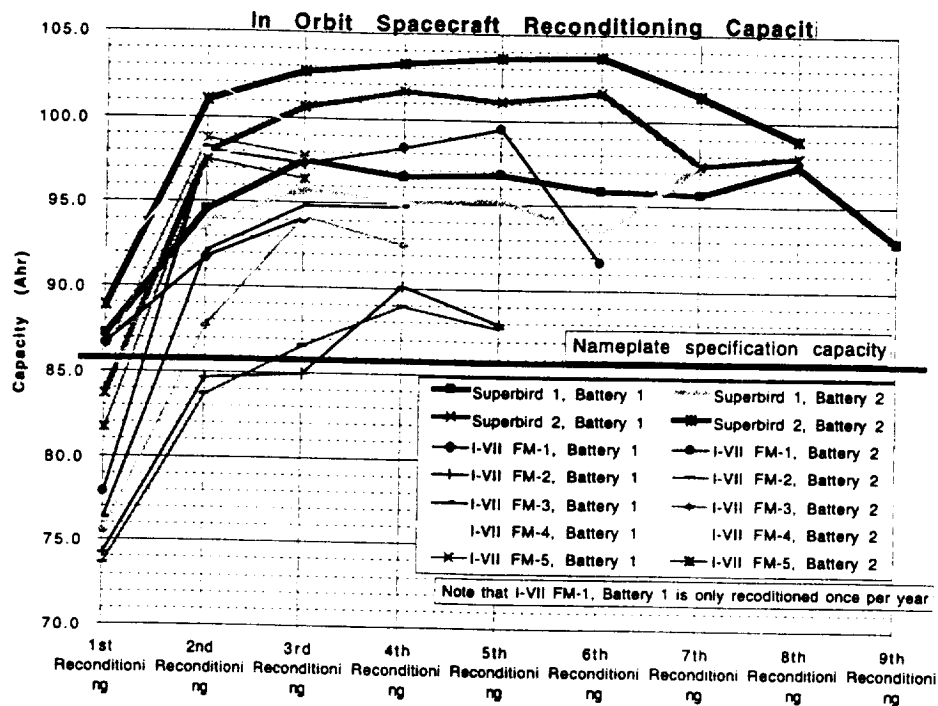
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- I-VIIA Life Test vs. In Orbit Reconditioning.
- Note that the life test batteries have more seasons than the actual orbit.
- Scale is quite zoomed up, so the data is actually pretty tight with a few percent.
- Note effect of decrease in life test temperature on the COMSAT reconditioning.

I-VII and Superbird In Orbit Reconditionings



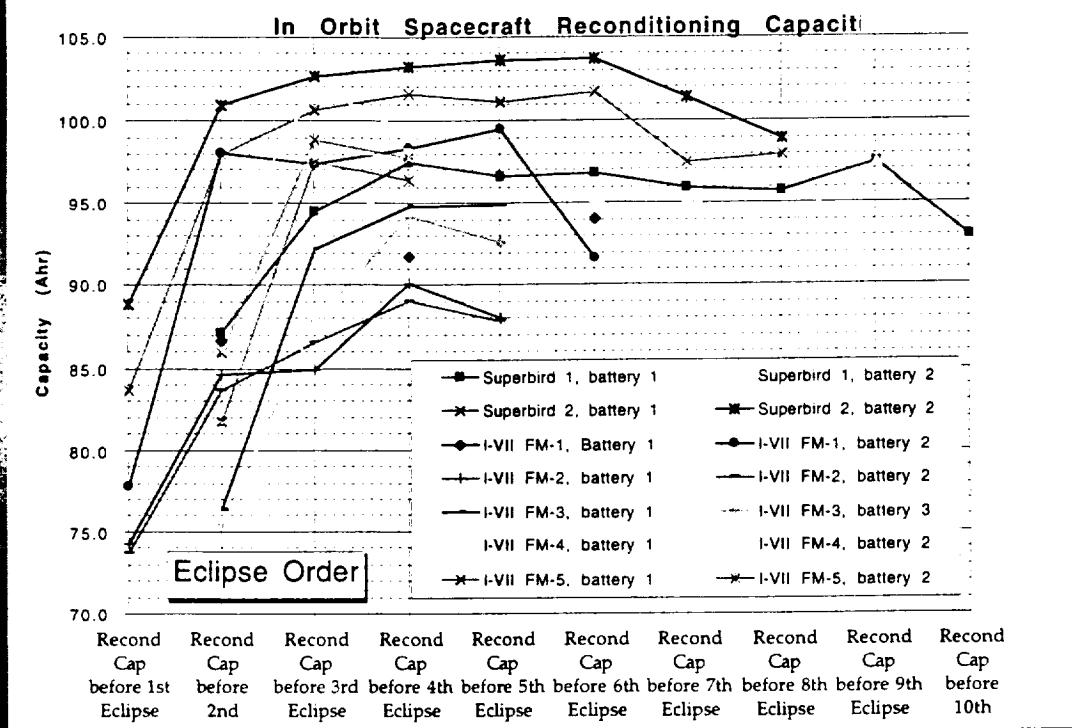
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- This chart shows the reconditioning capacities in reconditioning order (not necessarily chronological).
- Note the great capacity increase between the first and second reconditionings, on the order of 10% to 20%.
- Also note the nameplate capacity is 85.5.
- This chart includes Superbird and I-VII, both are 27-cell batteries with the same cell (Superbird has no diodes, though)
- Note decrease in capacity between last two reconditioning on the I-VII spacecraft is due to an in orbit change of the battery heater setpoint points (battery temperatures were increased).

I-VII and Superbird In Orbit Reconditionings



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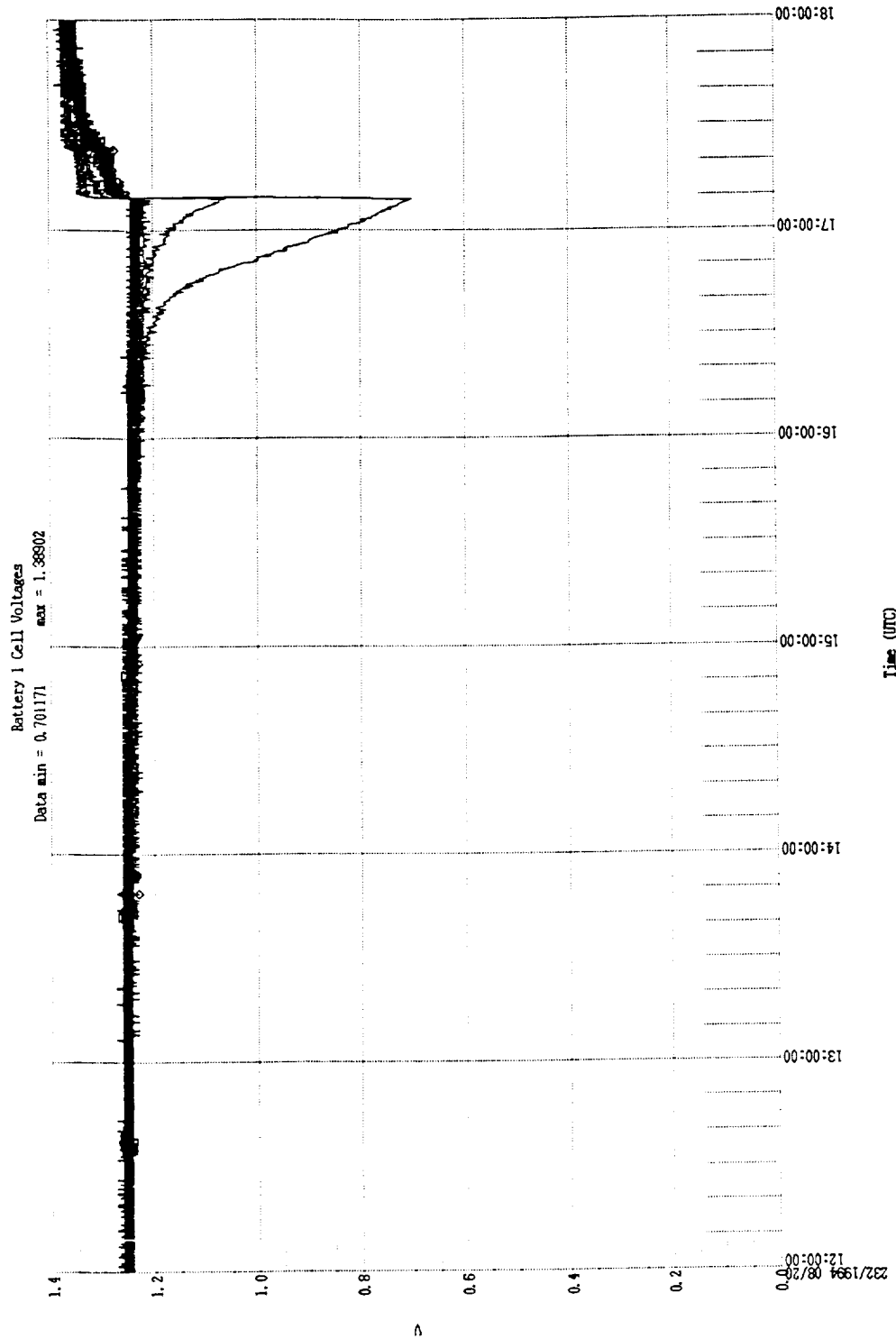
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- This chart shows the reconditioning capacities in order of eclipses. Mostly to show that some batteries were not reconditioned until after the 1st eclipse season, while others had one after launch before the 1st eclipse season.
- Of particular note is 701, battery 1 which is only reconditioned once per year (due to an anomaly). Its first reconditioning was between 1st and 2nd eclipses but its 1st reconditioning was similar to the 2nd reconditioning of battery 2 on the same spacecraft.

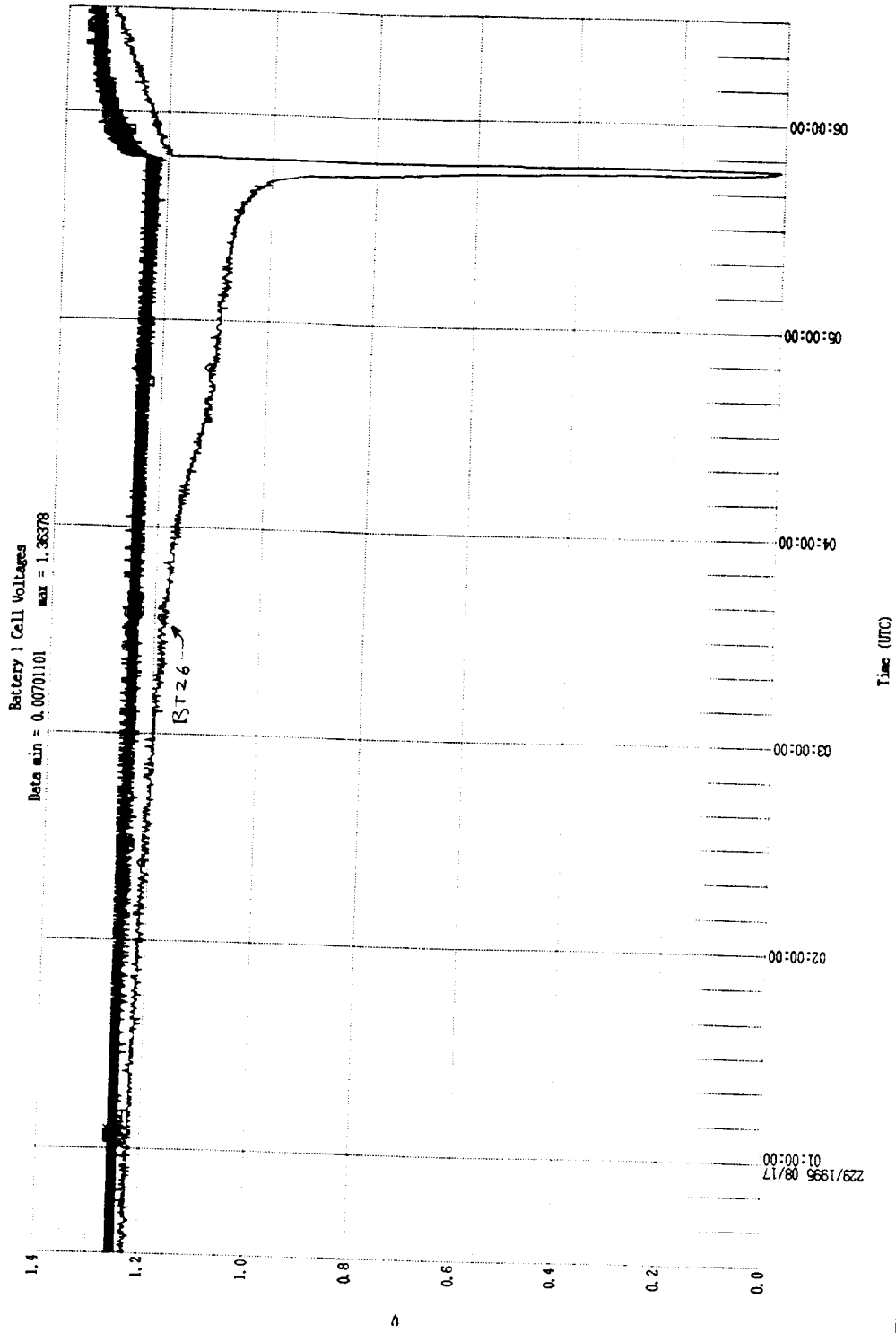
- The following graphs show the last 4 to 5 hours of reconditioning and up to the first hour of recharge from several spacecraft (I-VII FM1 and FM2, I-VIIA FM6, and N-Star FM-a and FM-b).
- This representation is an excellent way to monitor second voltage plateaus (capacity fading) and their recovery.

I-VII FM1, Battery 1, 1994 Autumnal Reconditioning Cell Profiles



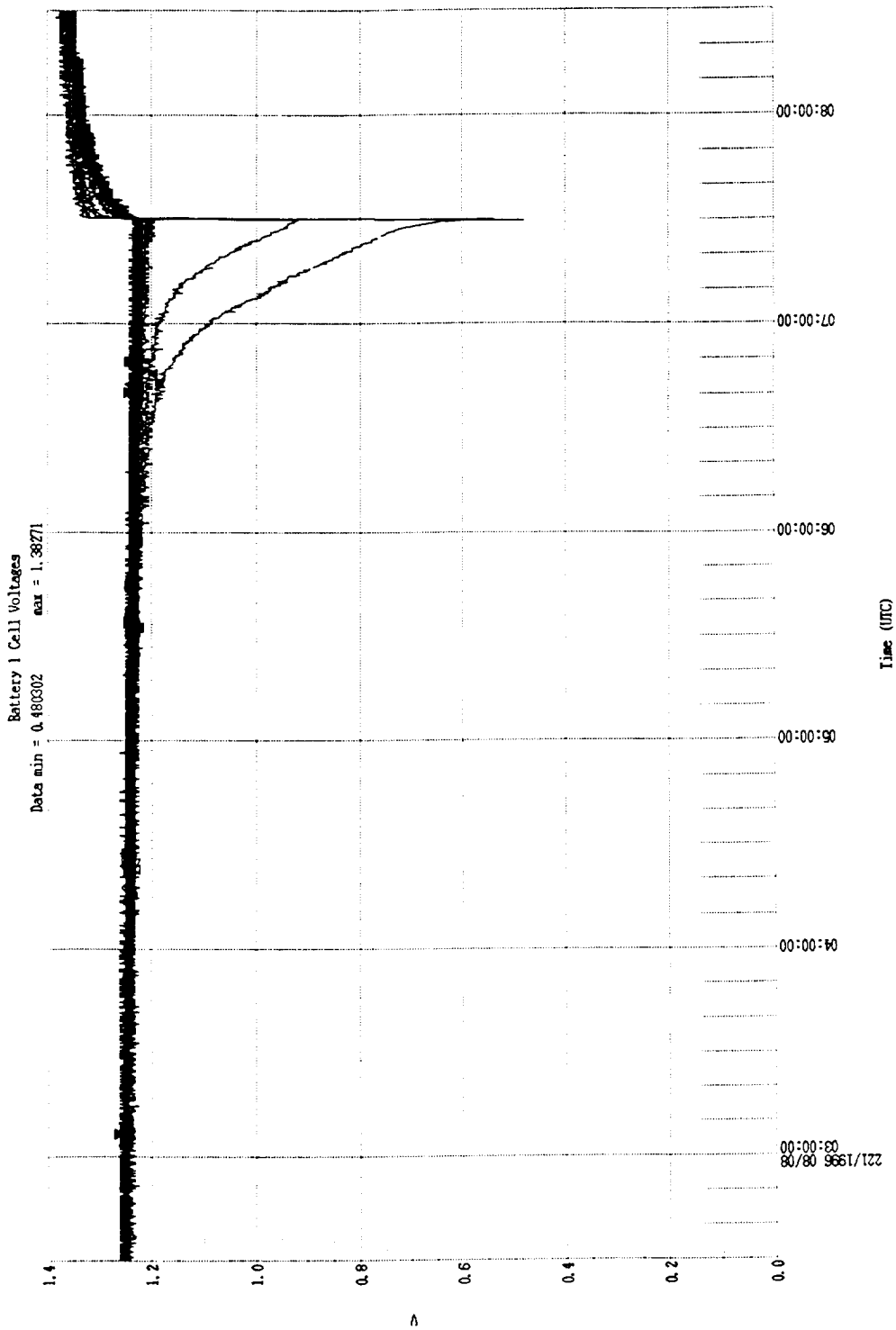
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I-VII FM1, Battery 1, 1995 Autumnal Reconditioning Cell Profiles



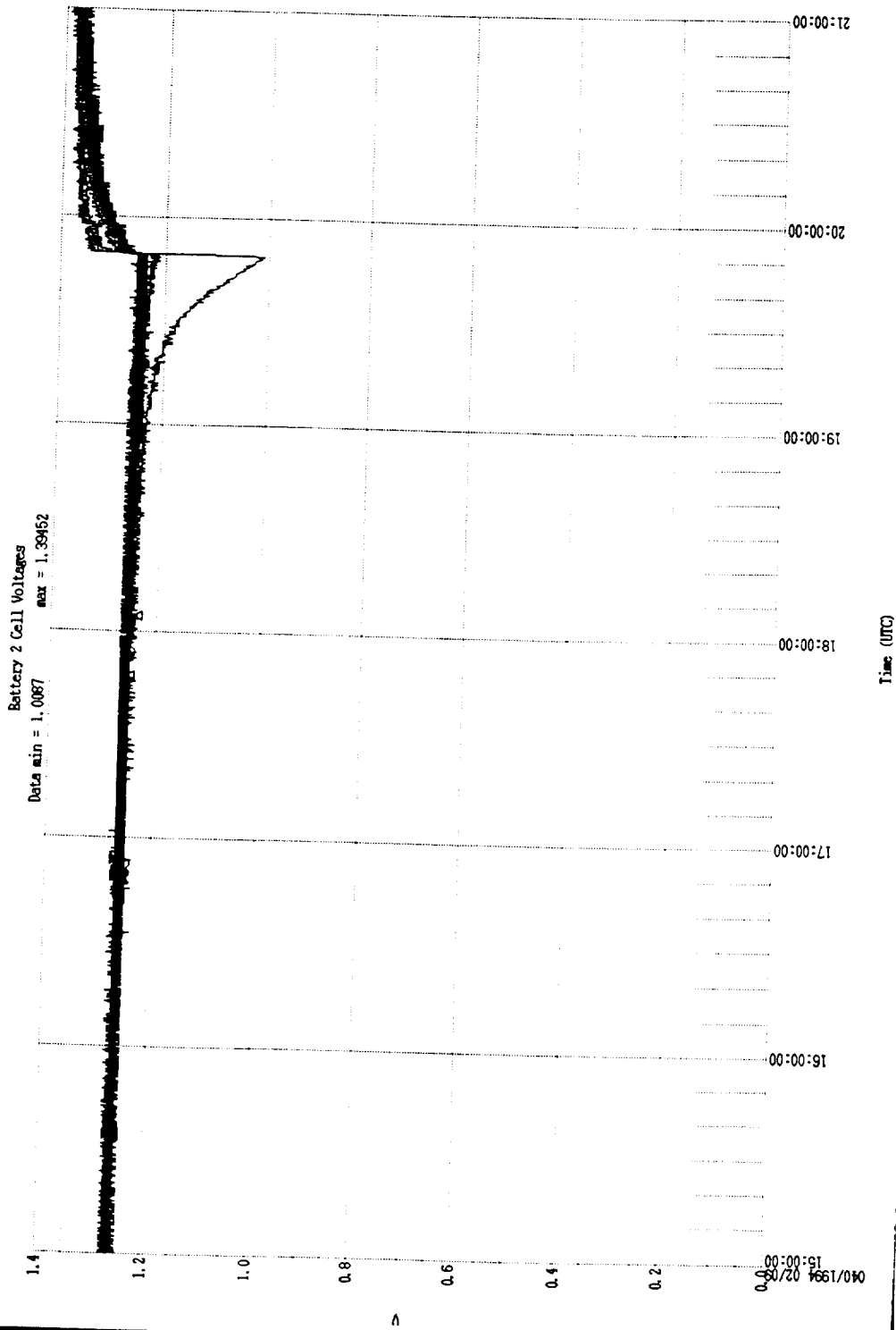
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I-VII FM1, Battery 1, 1996 Autumnal Reconditioning Cell Profiles



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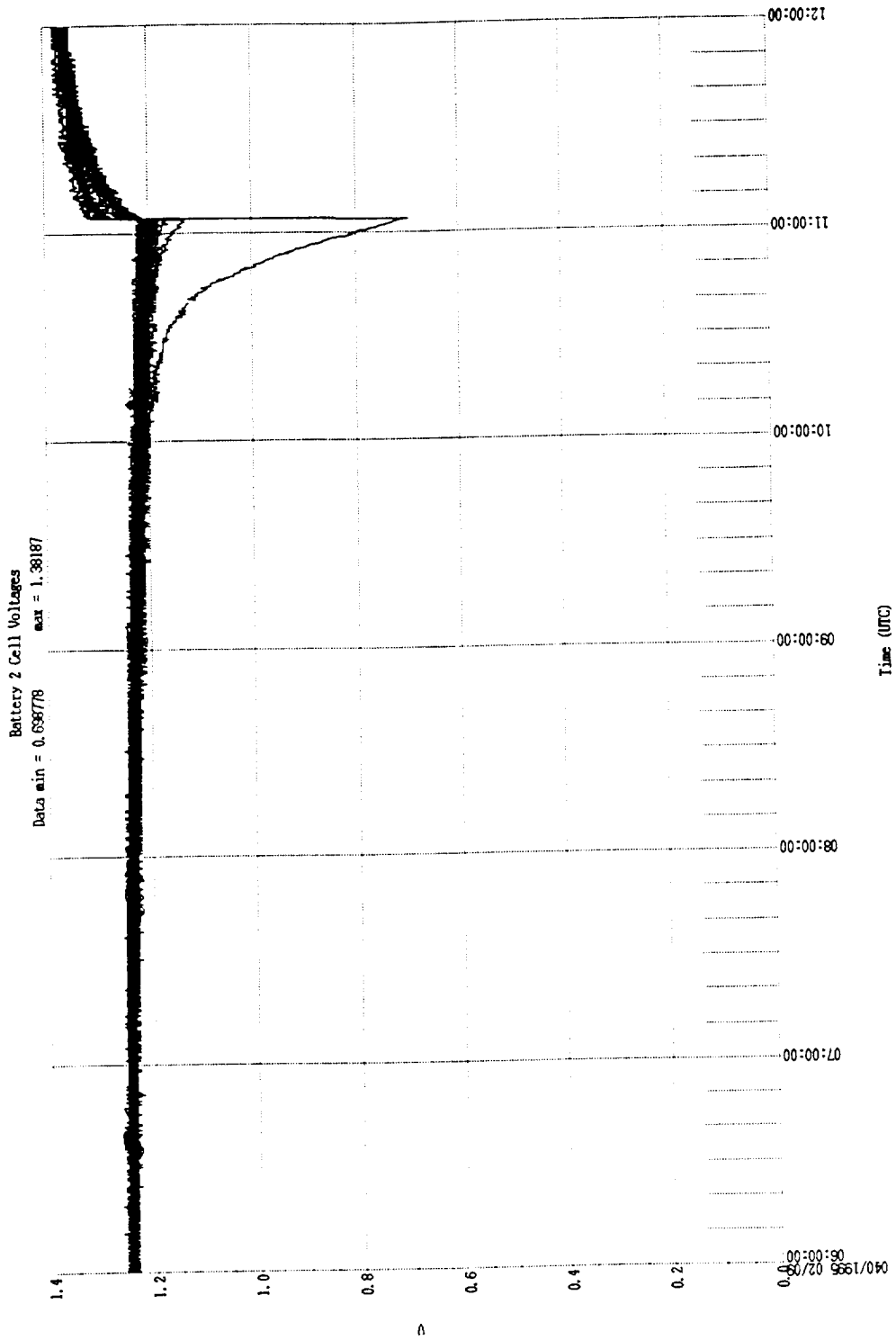
I-VII FM1, Battery 2, 1994 Vernal Reconditioning Cell Profiles



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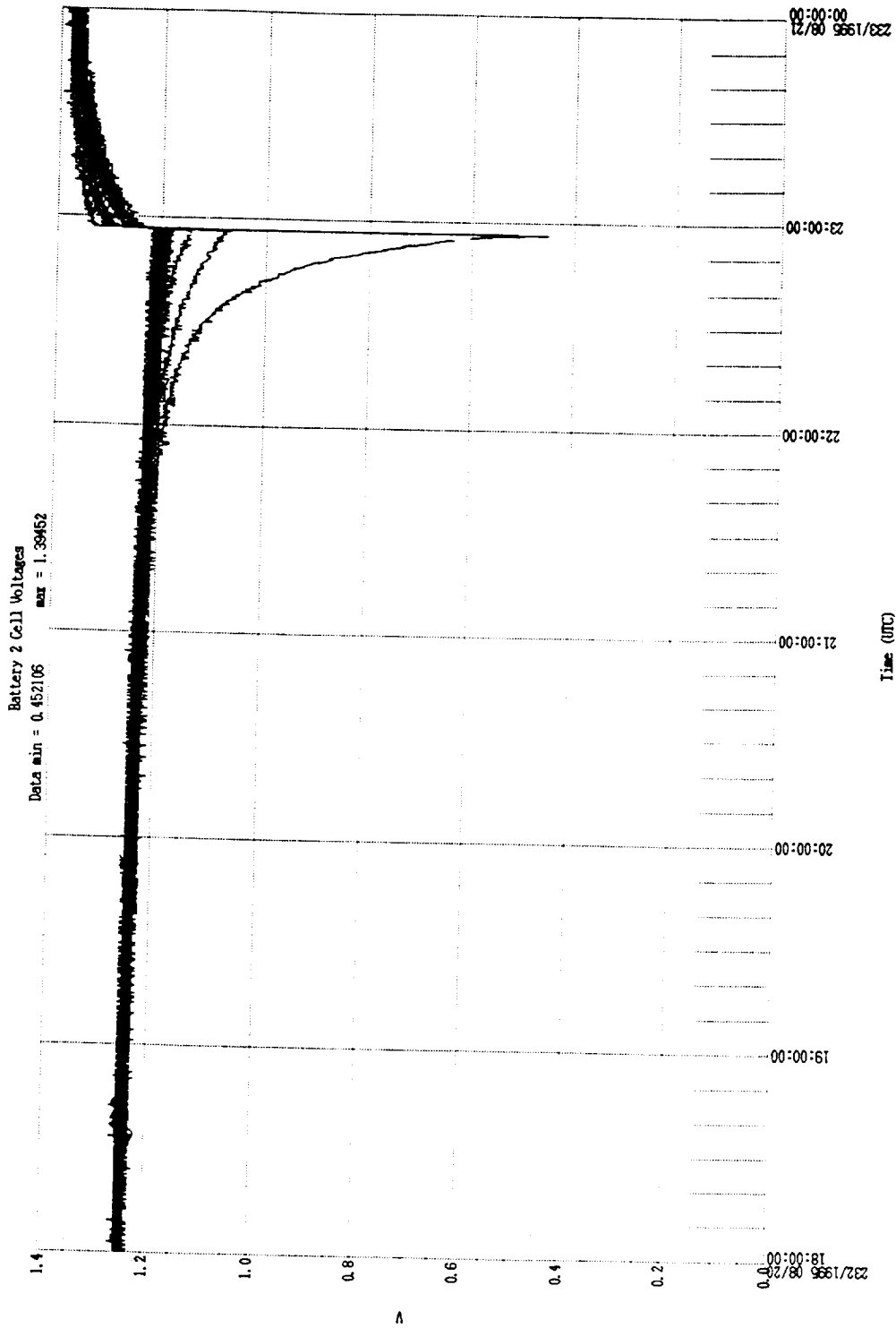
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I-VII FM1, Battery 2, 1995 Vernal Reconditioning Cell Profiles



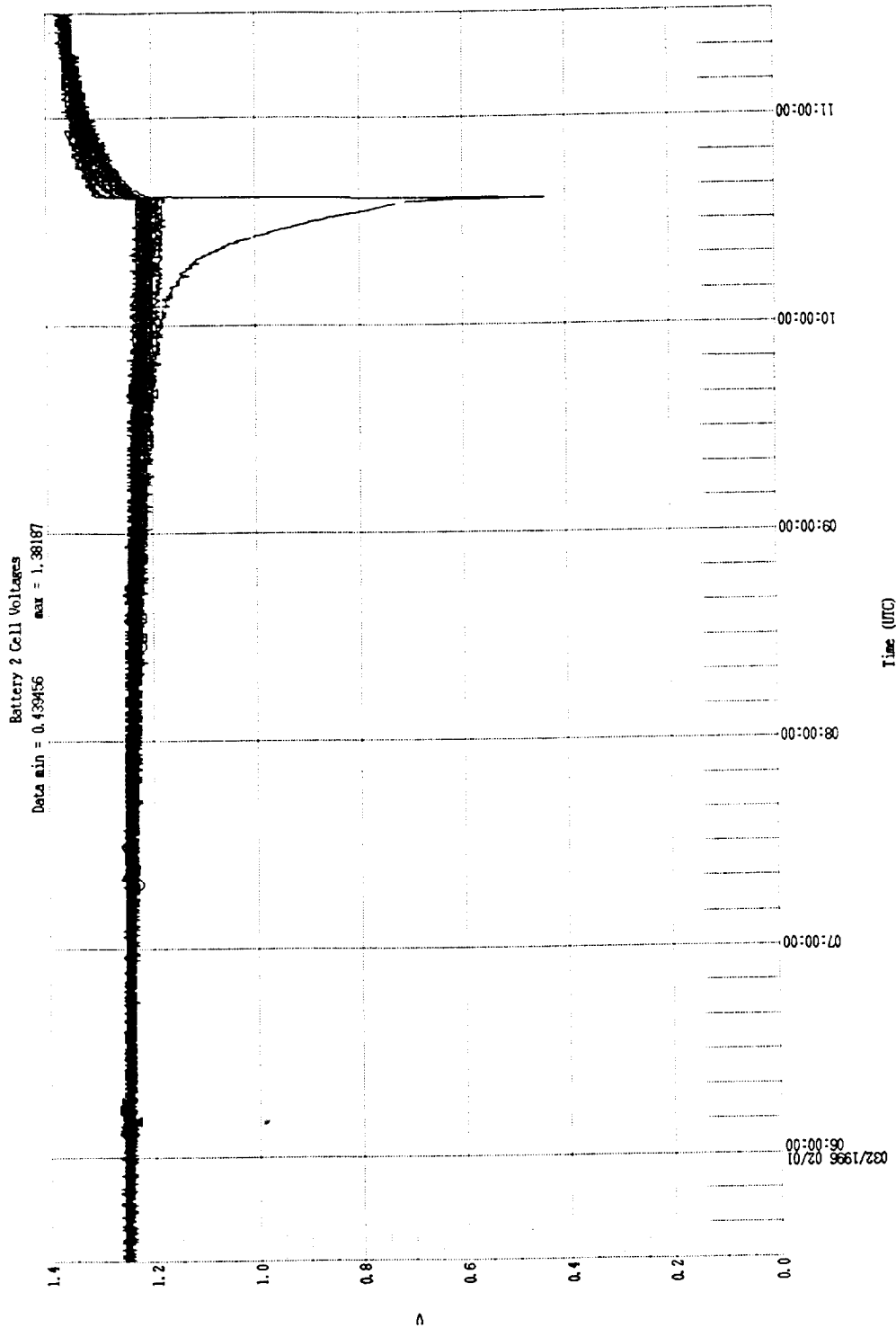
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I-VII FM1, Battery 2, 1995 Autumnal Reconditioning Cell Profiles



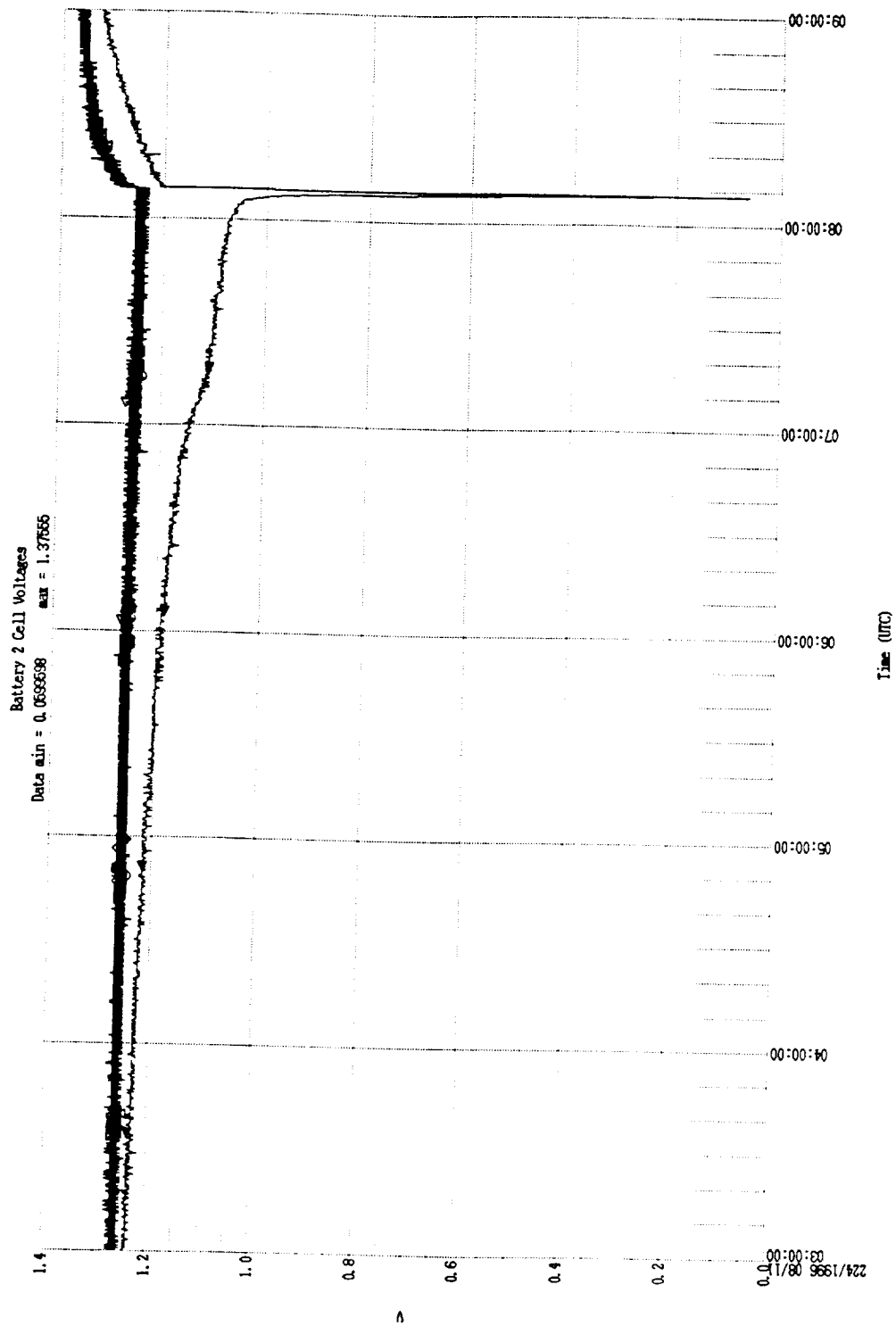
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I-VII FM1, Battery 2, 1996 Vernal Reconditioning Cell Profiles



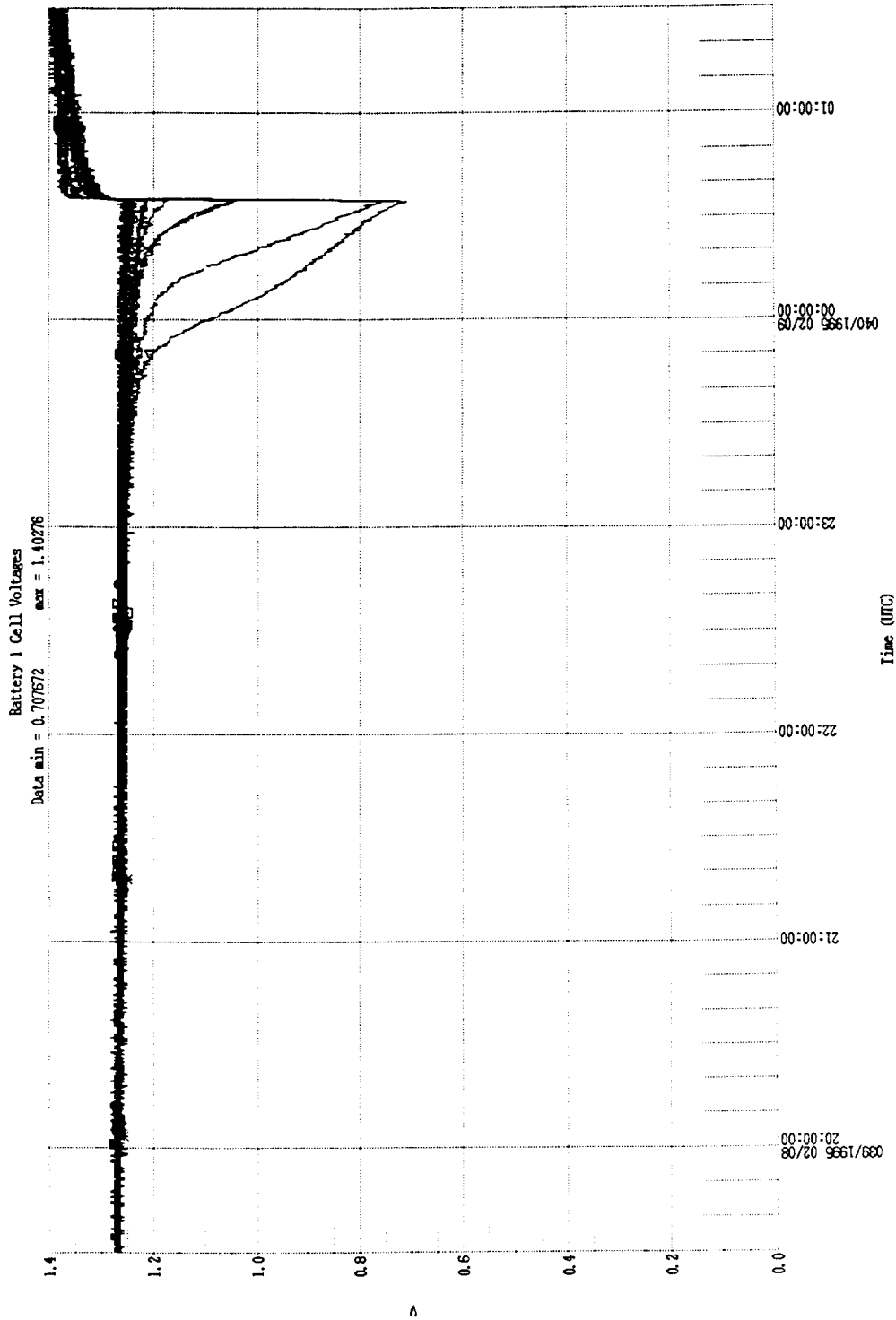
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I-VII FM1, Battery 2, 1996 Autumnal Reconditioning Cell Profiles



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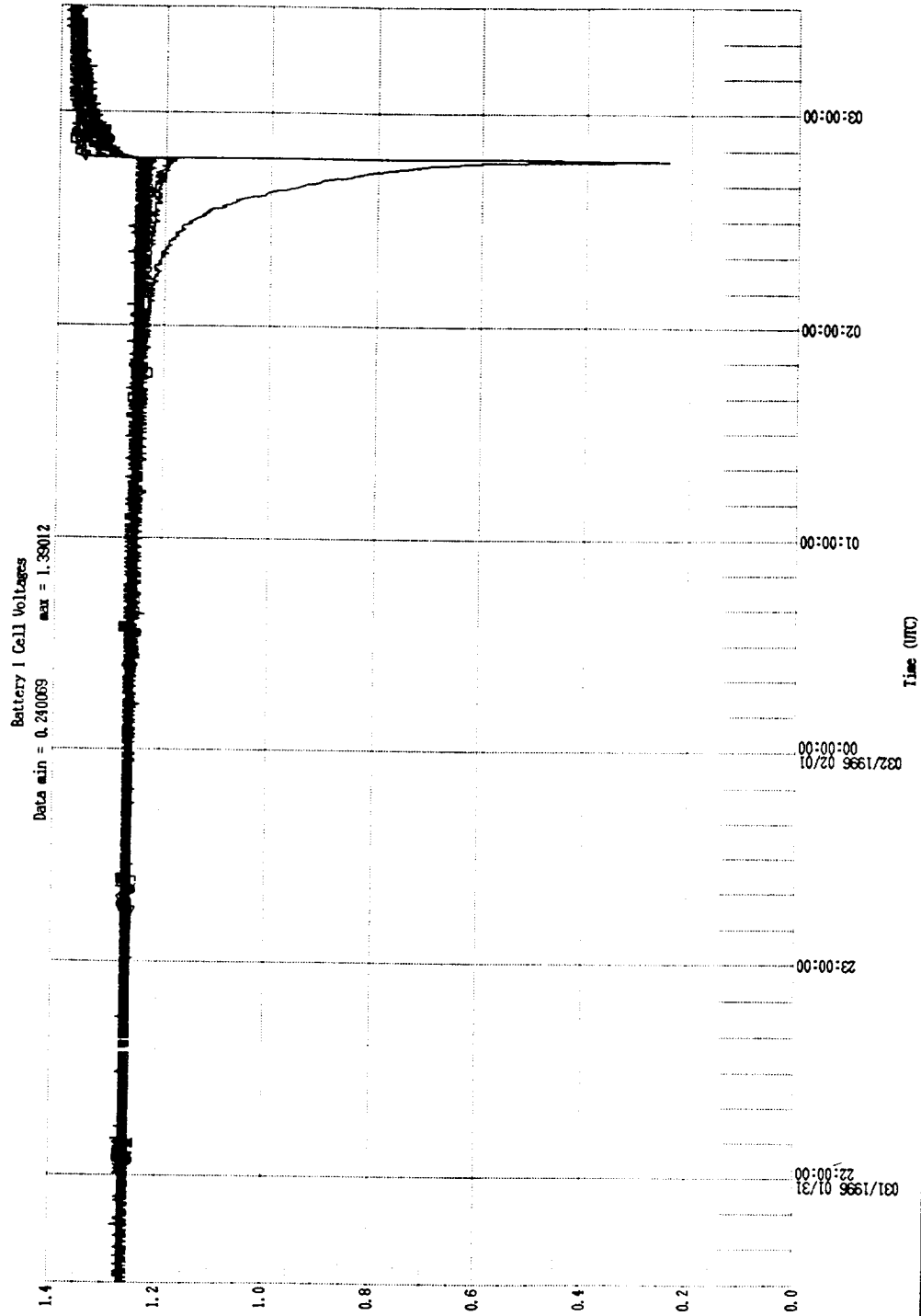
I-VII FM2, Battery 1, 1995 Vernal Reconditioning Cell Profiles



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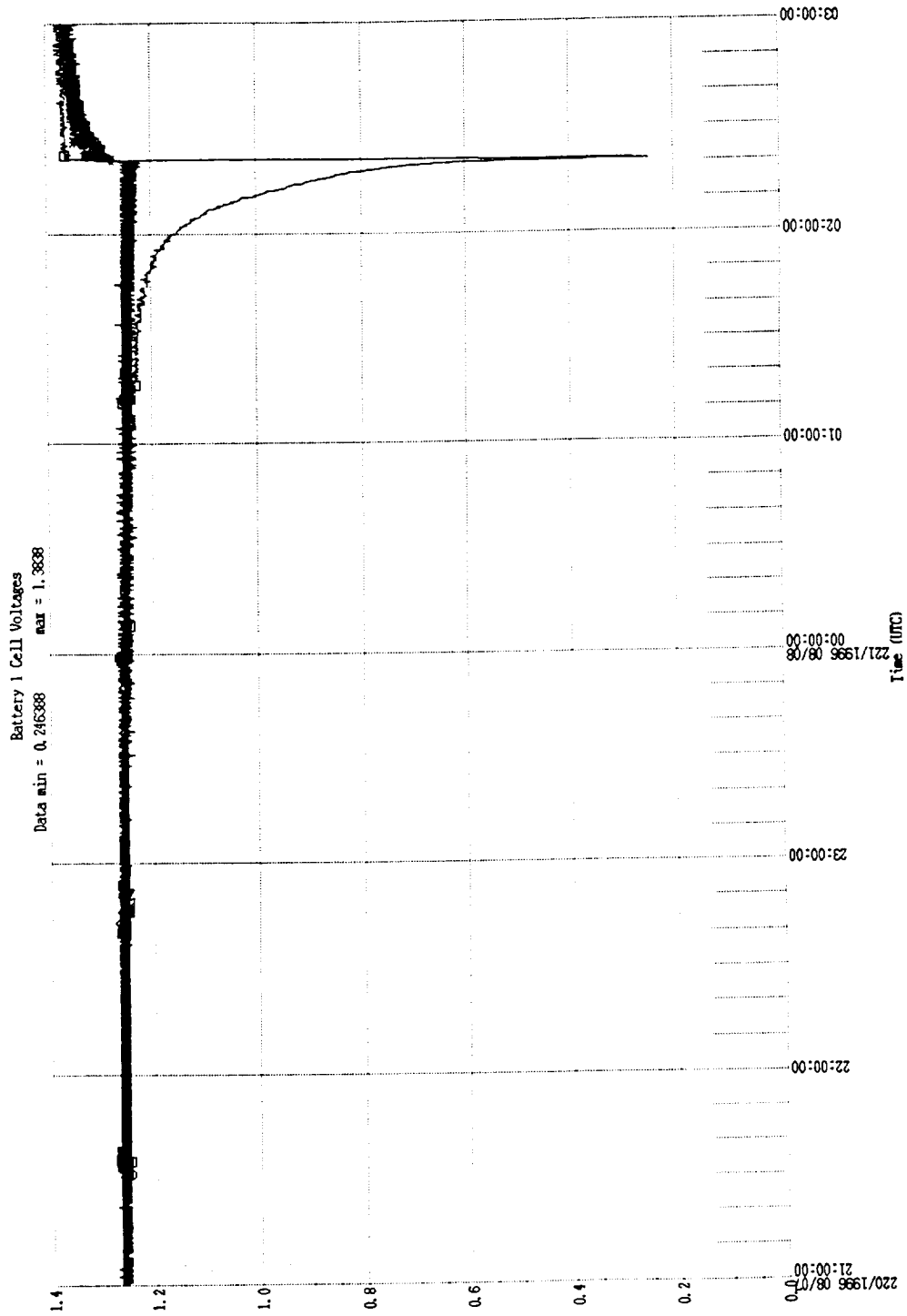
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I-VII FM2, Battery 1, 1996 Vernal Reconditioning Cell Profiles



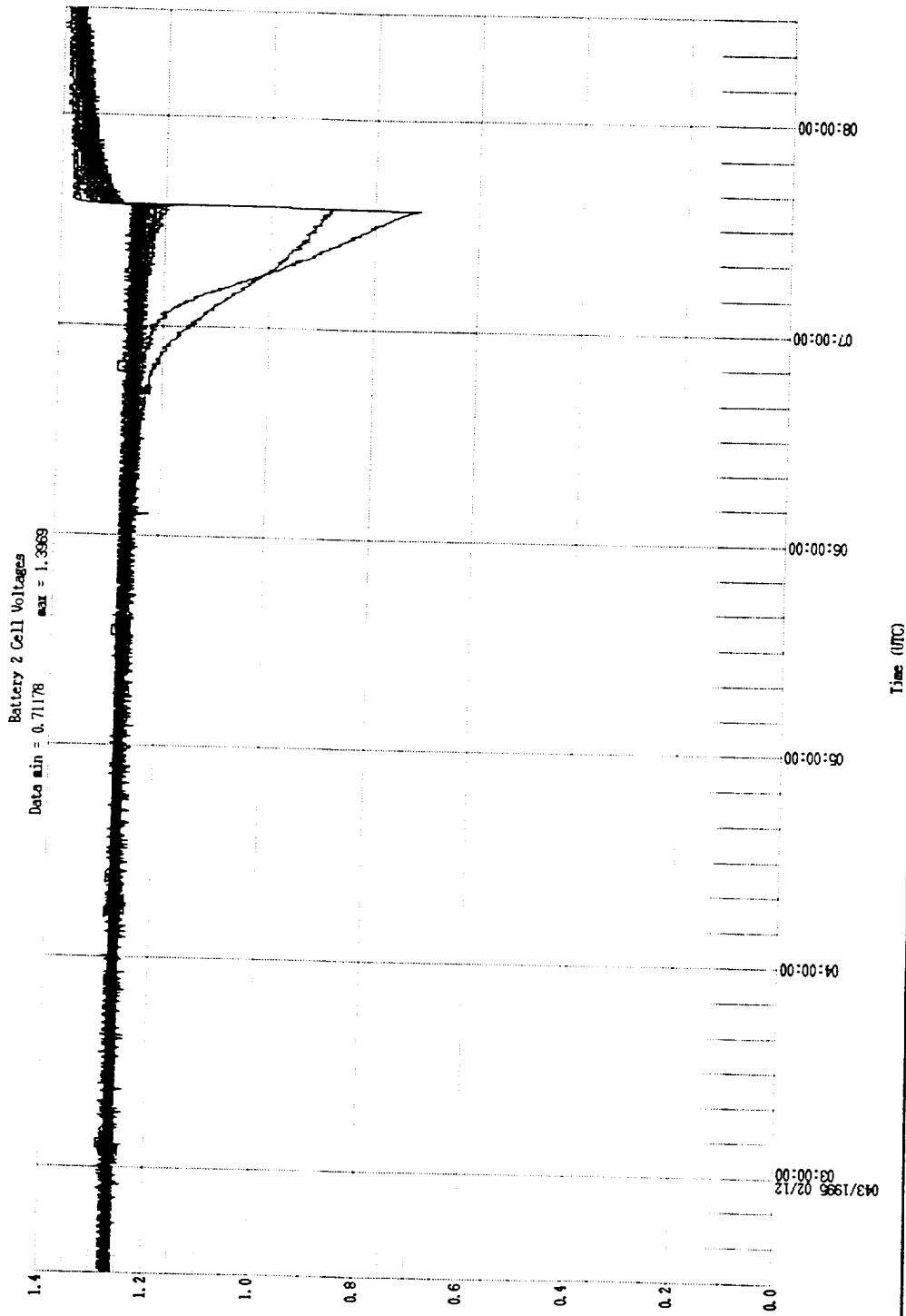
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I-VII FM2, Battery 1, 1996 Autumnal Reconditioning Cell Profiles



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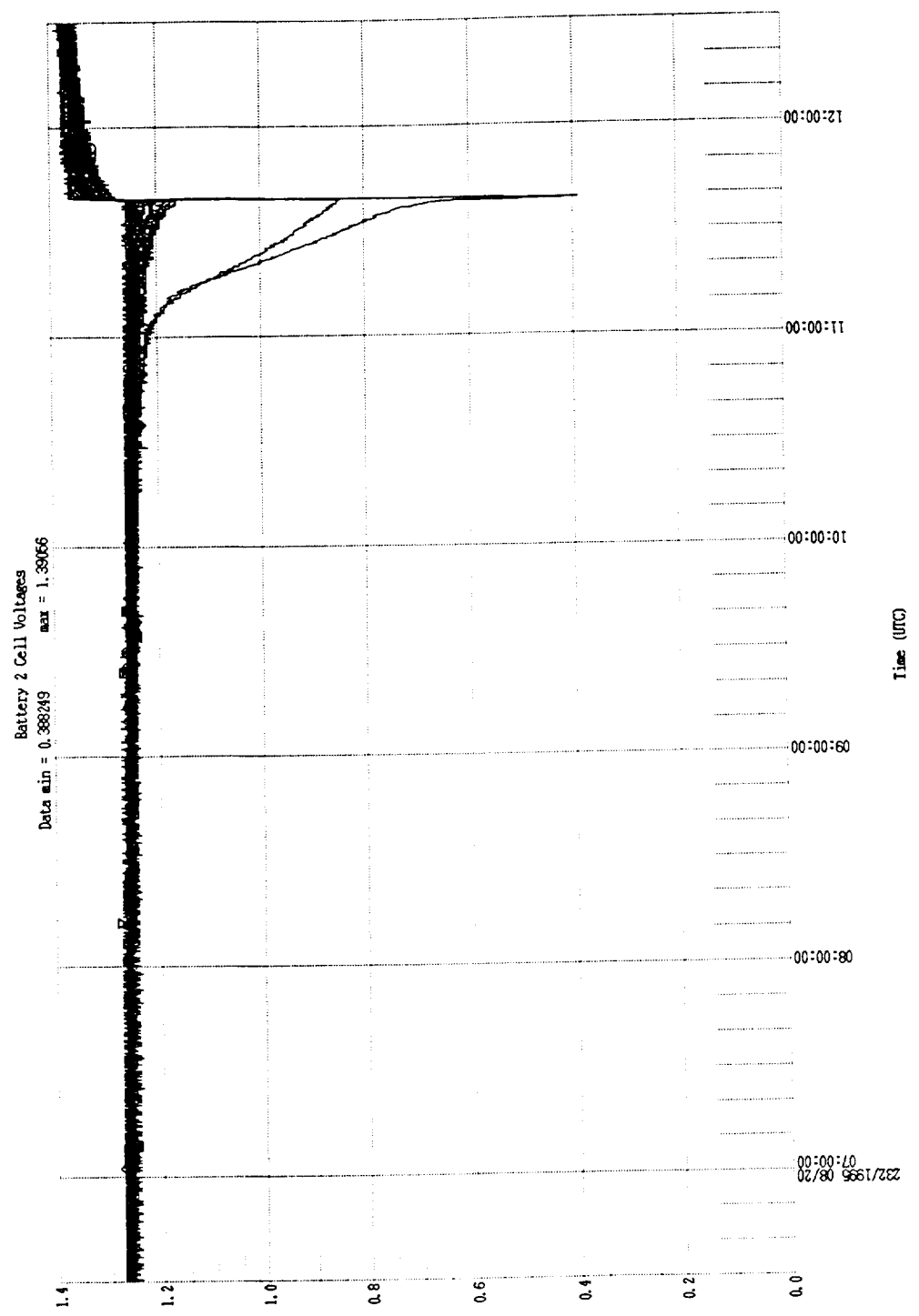
I-VII FM2, Battery 2, 1995 Vernal Reconditioning Cell Profiles



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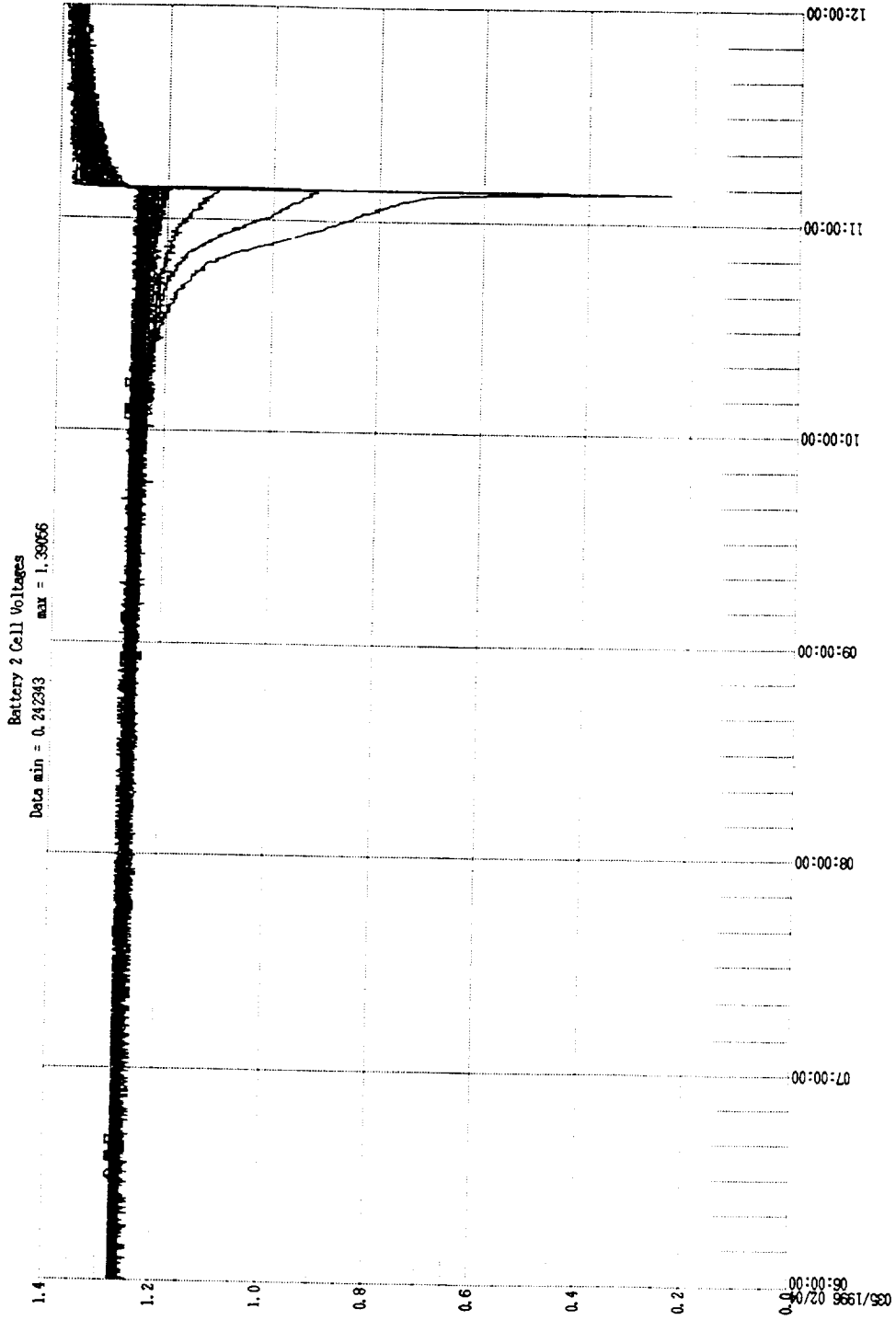
I-VII FM2, Battery 2, 1995 Autumnal Reconditioning Cell Profiles



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I-VII FM2, Battery 2, 1996 Vernal Reconditioning Cell Profiles

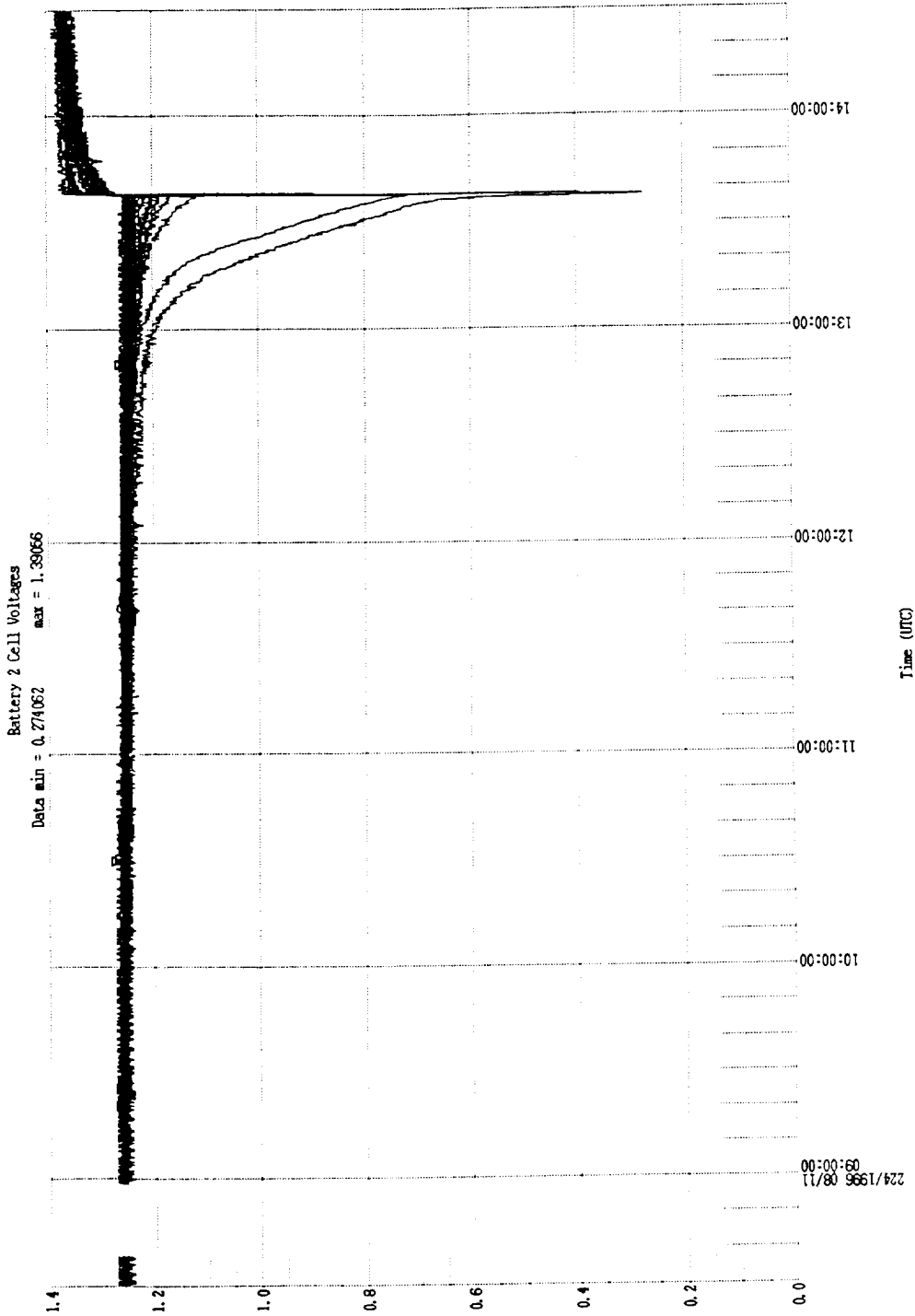
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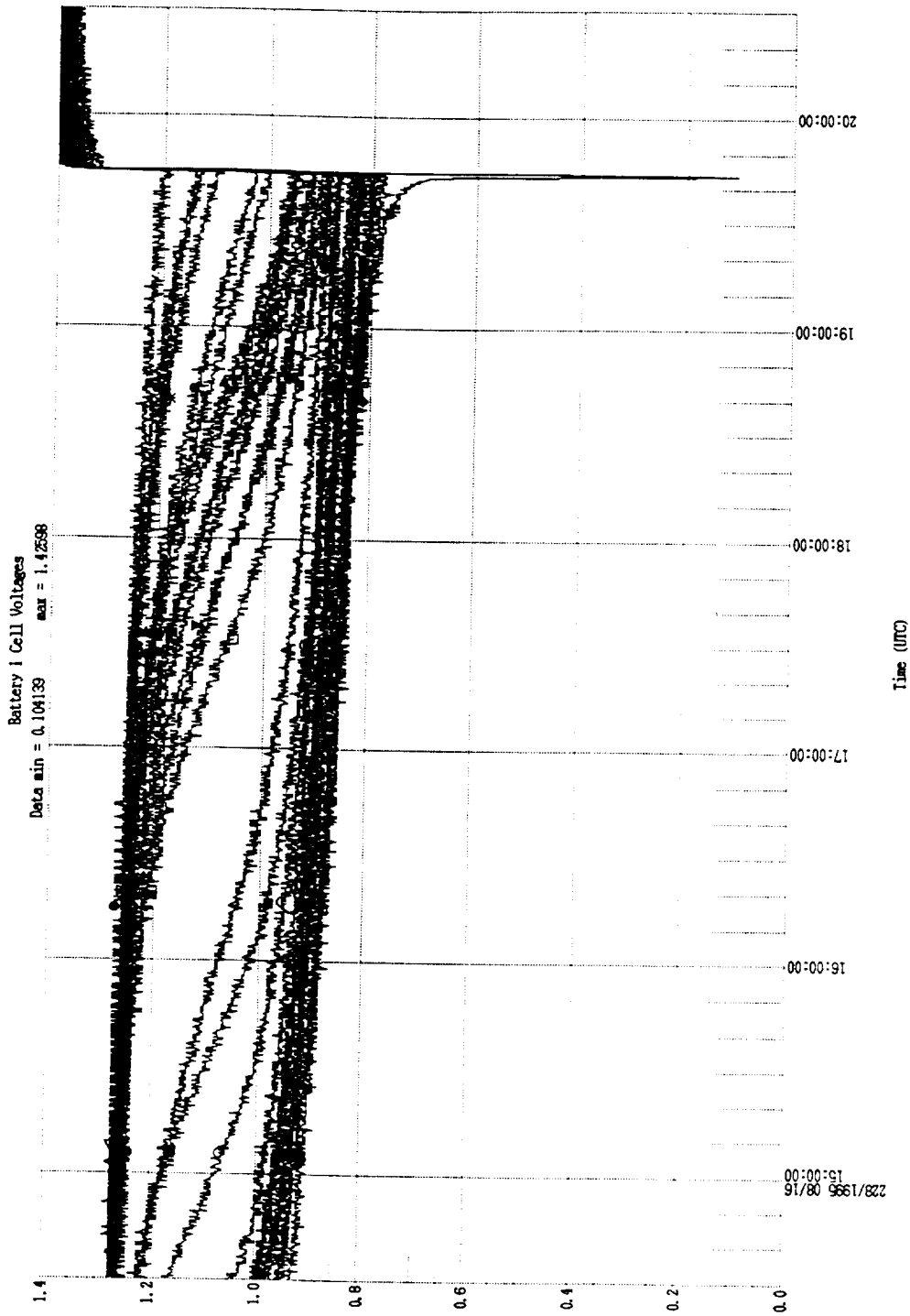
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I-VII FM2, Battery 2, 1996 Autumnal Reconditioning Cell Profiles



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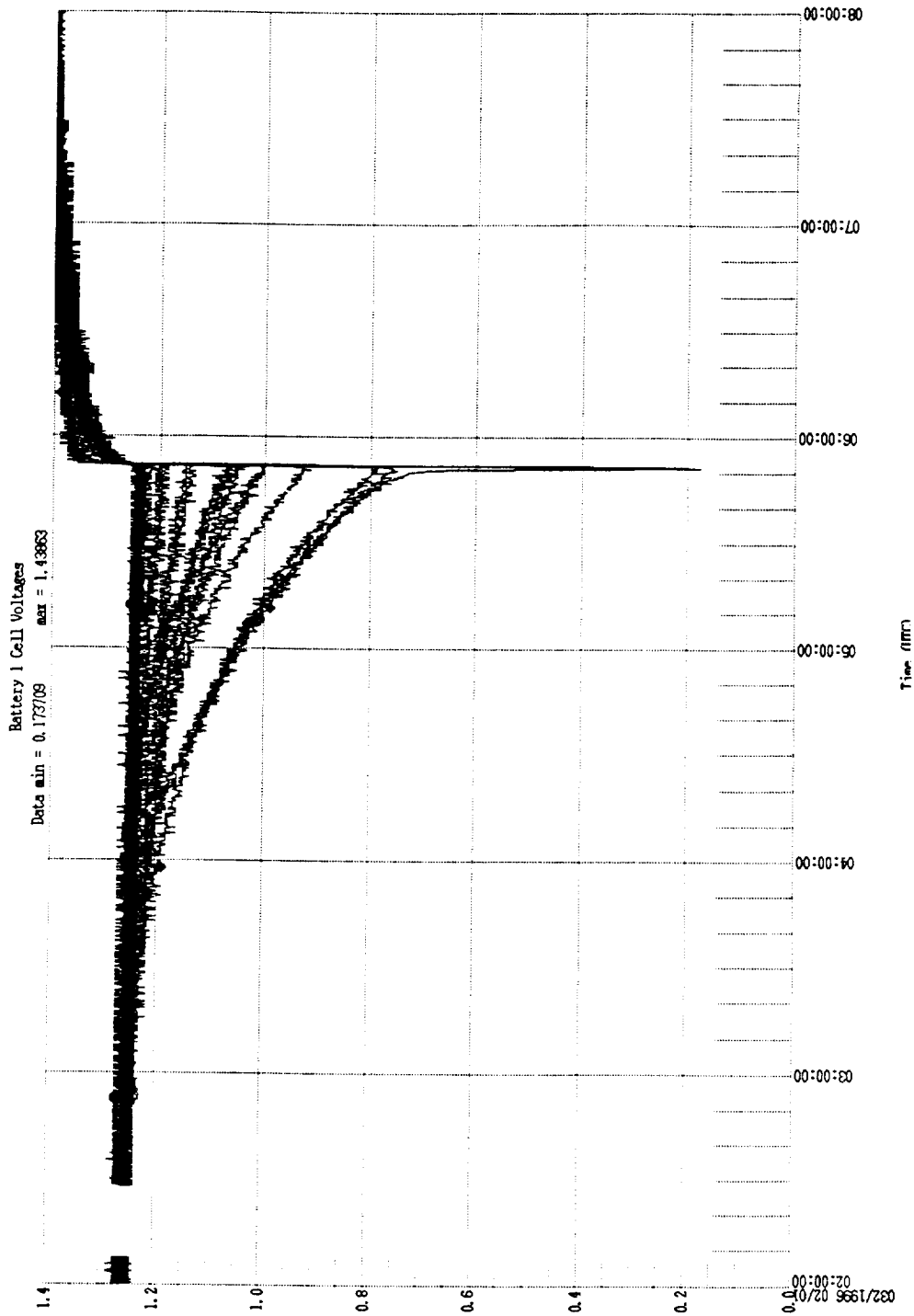
I-VIIA FM6, Battery 1, 1995 Autumnal Reconditioning Cell Profiles



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I-VIIA FM6 , Battery 1, 1996 Vernal Reconditioning Cell Profiles

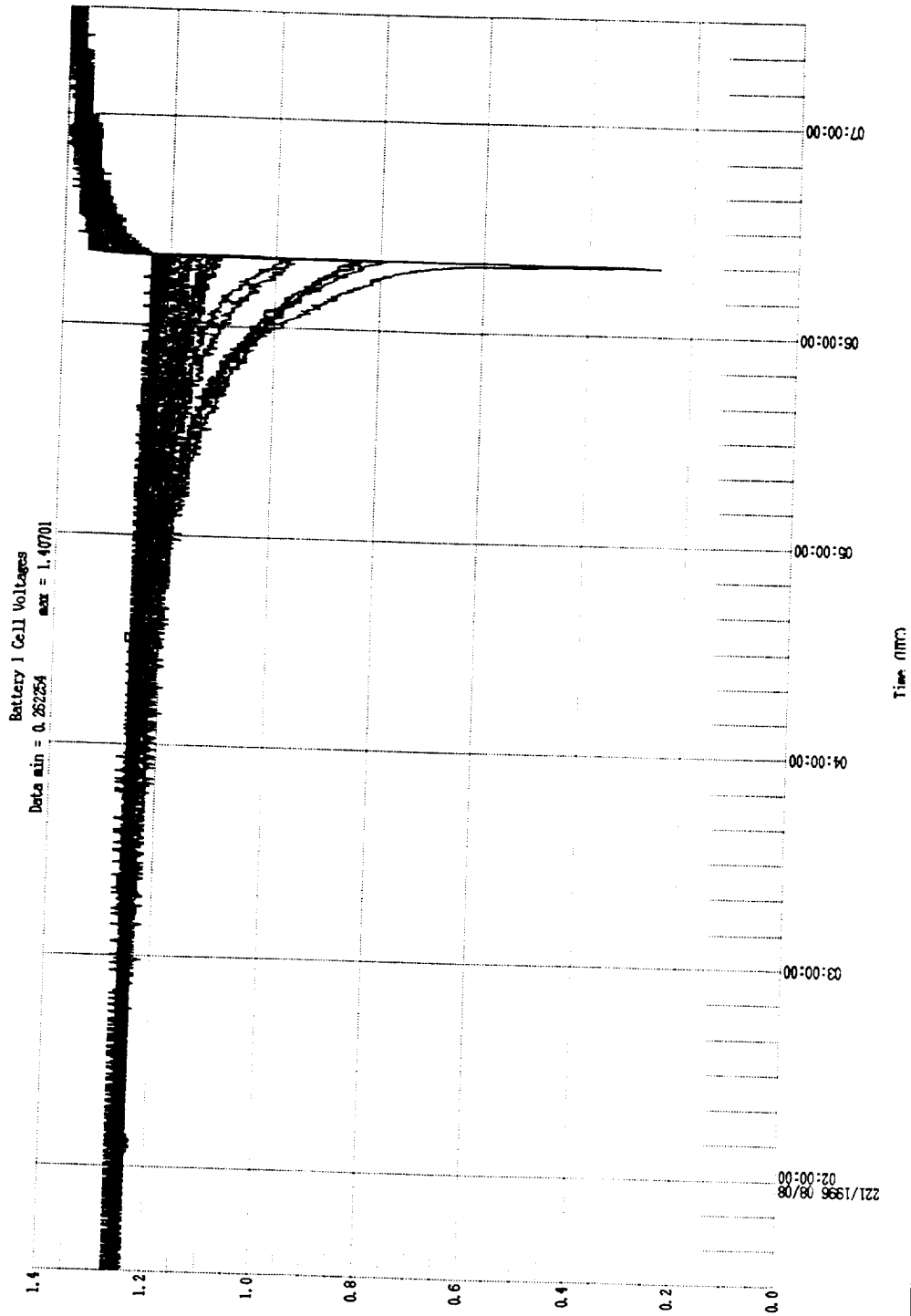
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I-VIIA FM6 , Battery 1, 1996 Autumnal Reconditioning Cell Profiles

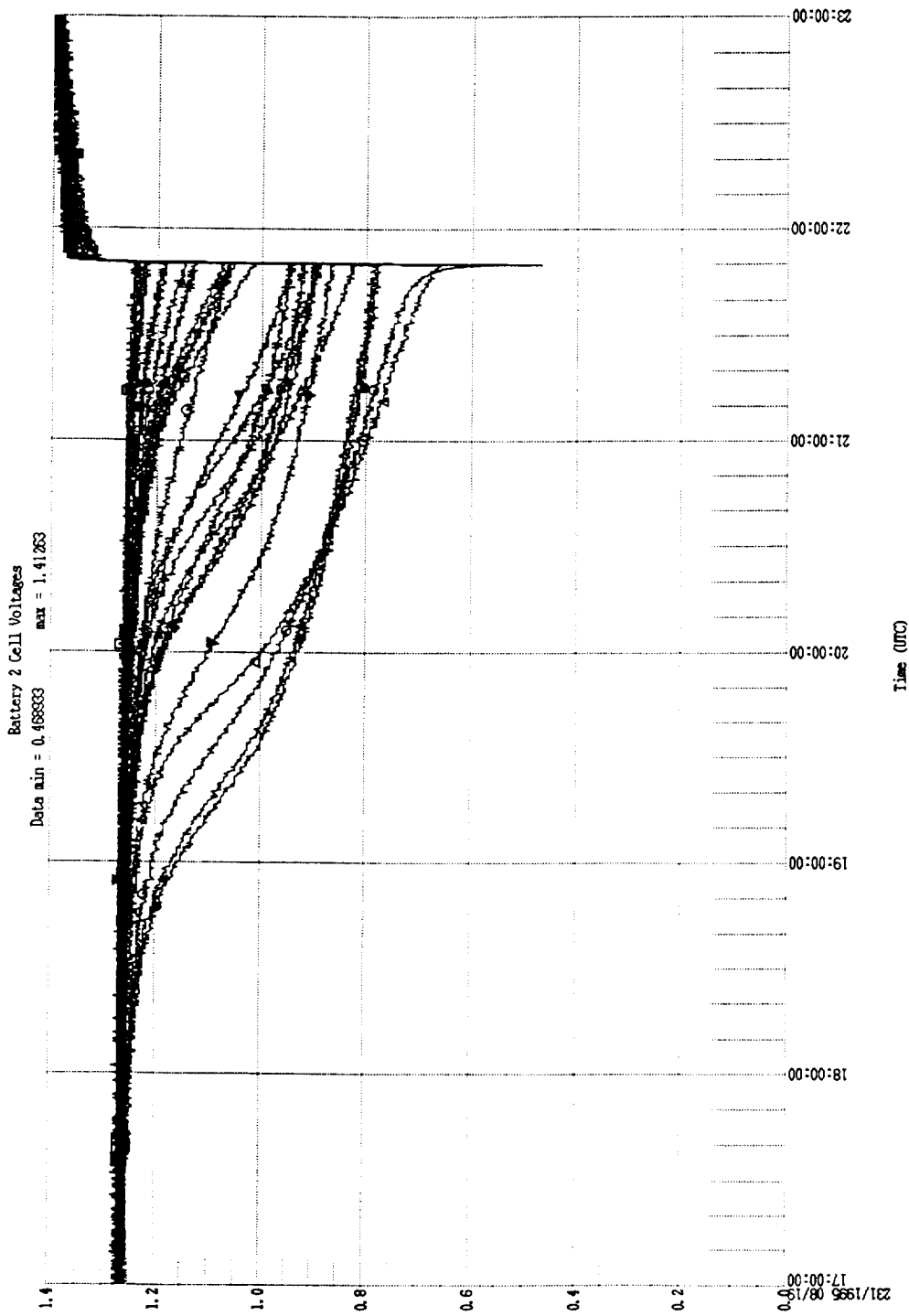
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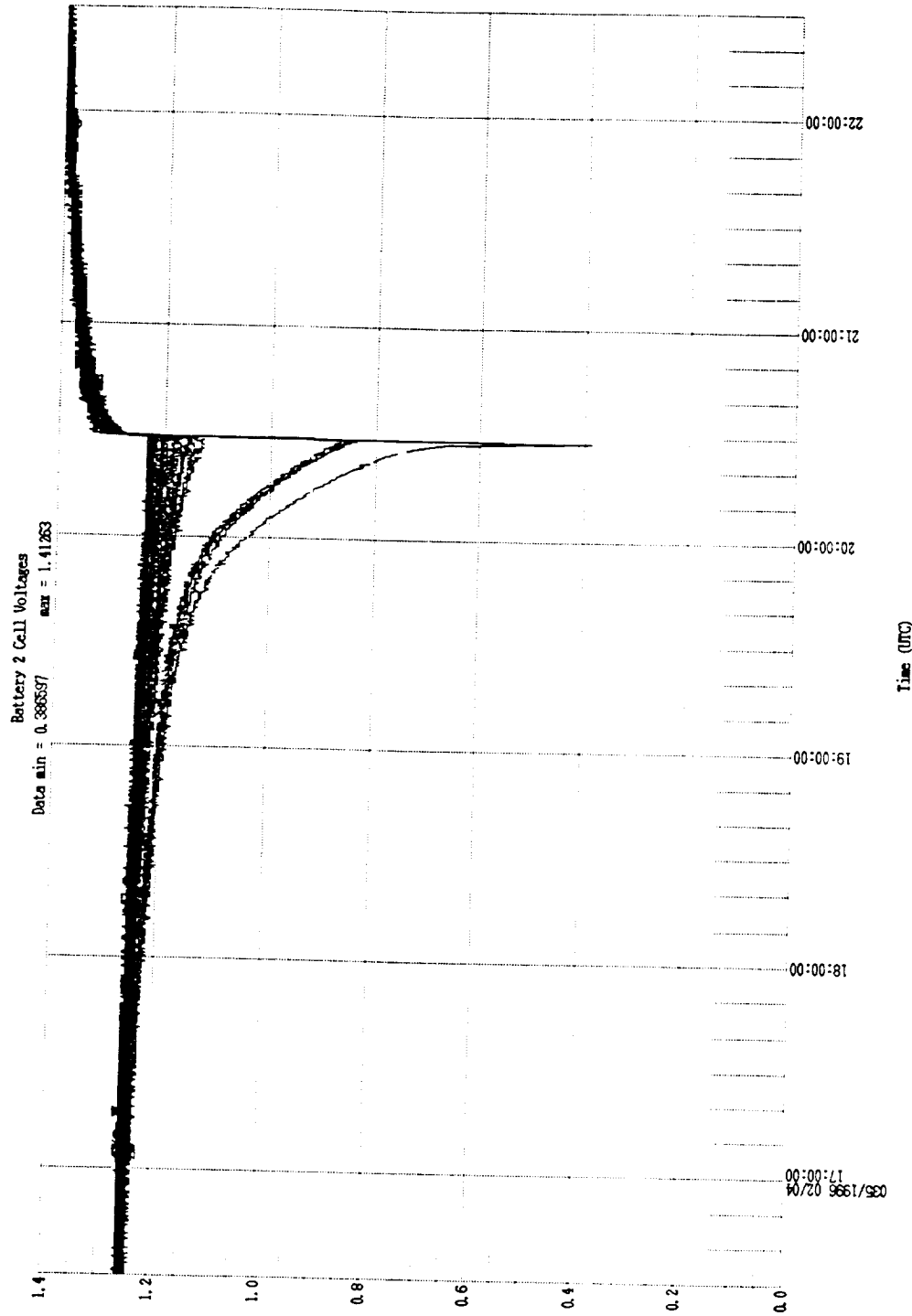
I-VIIA FM6 , Battery 2, 1995 Autumnal Reconditioning Cell Profiles



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I-VIIA FM6 , Battery 2, 1996 Vernal Reconditioning Cell Profiles

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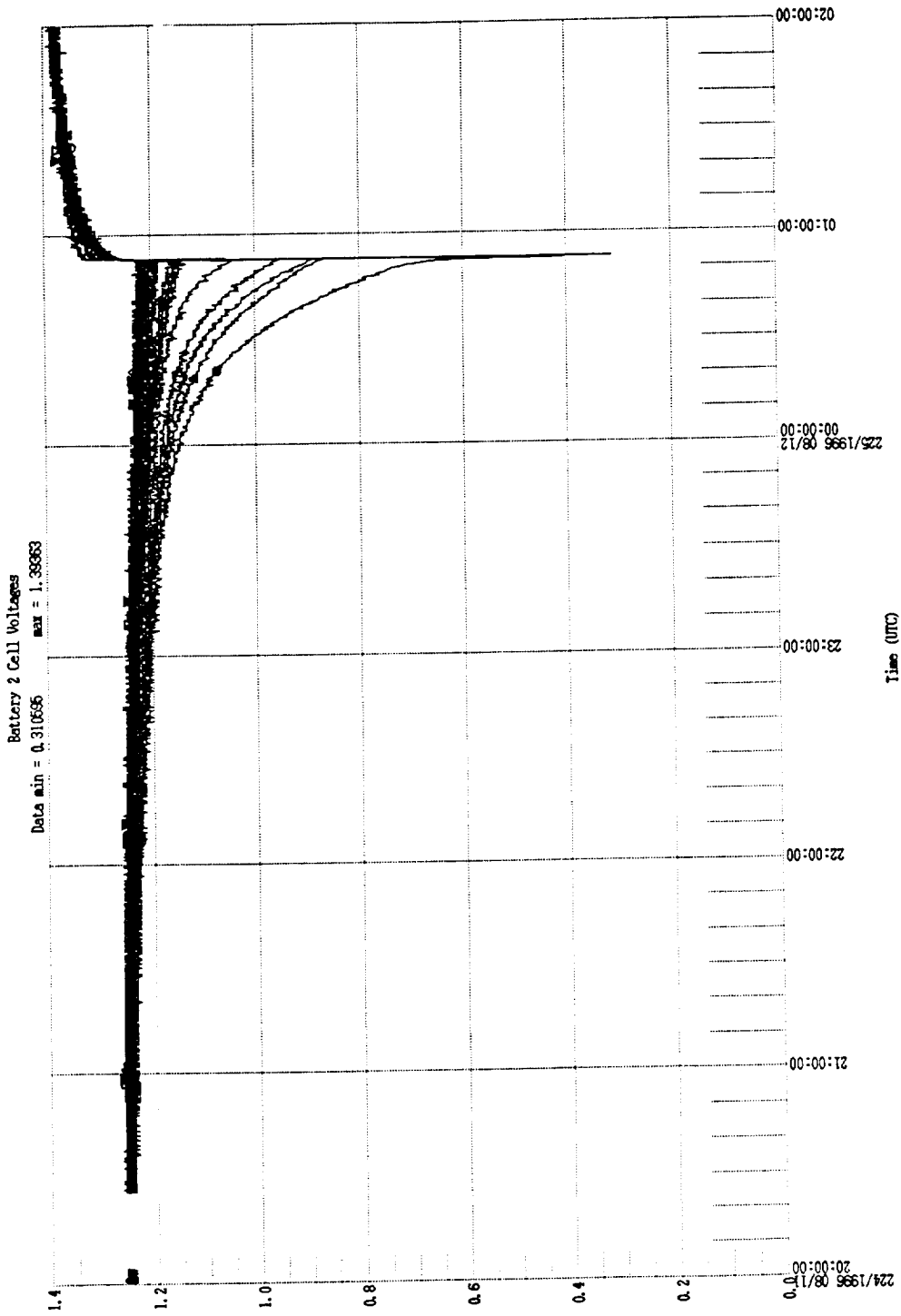


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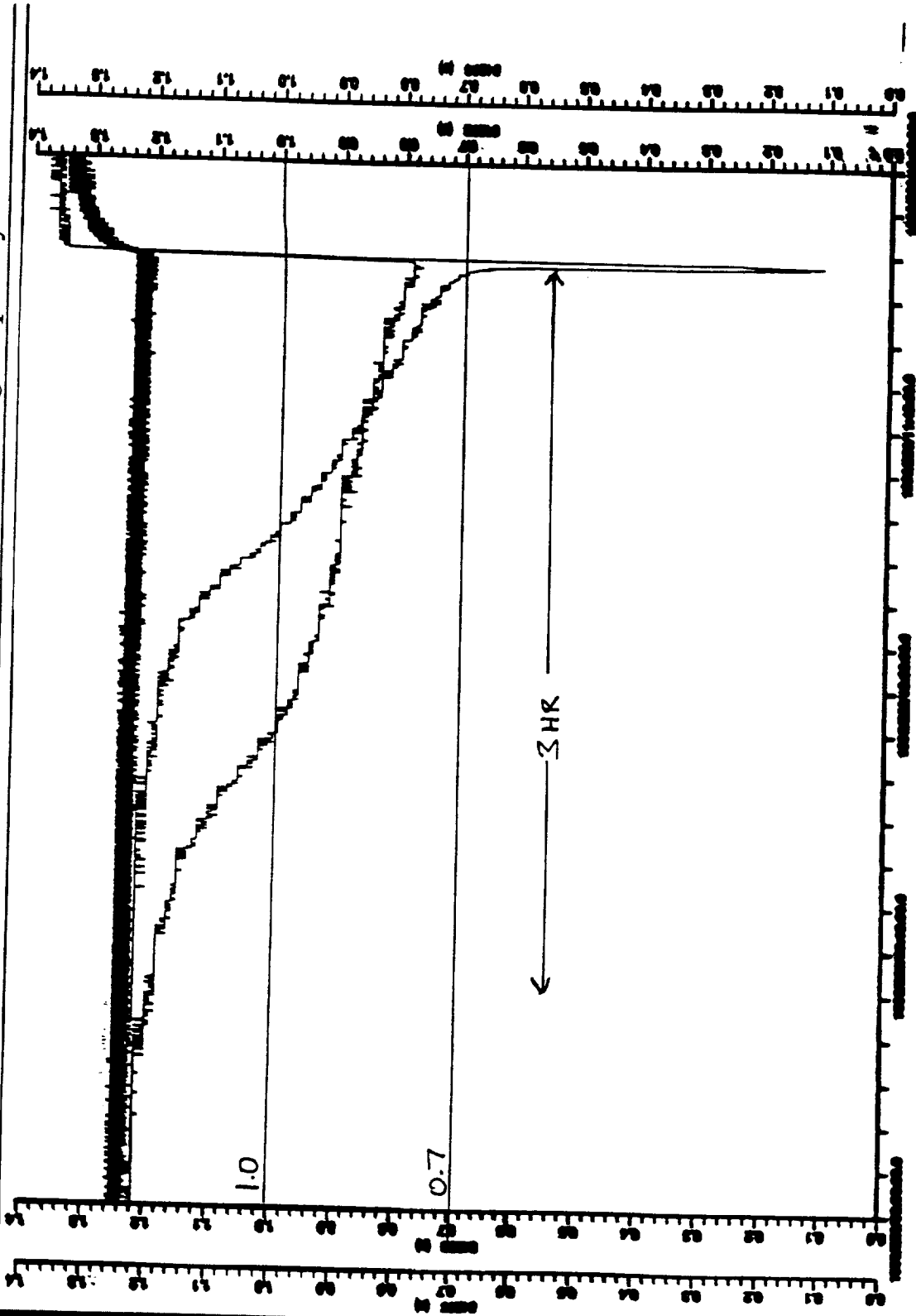
I-VIIA FM6 , Battery 2, 1996 Autumnal Reconditioning Cell Profiles

EVERETT-DORR-VIA-7 FULL CELL VOLTAGES (UP-DAT 2 NSB: 1 OF 1)



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N-Star FMa Battery 1, 1996 Autumnal Reconditioning Capacity

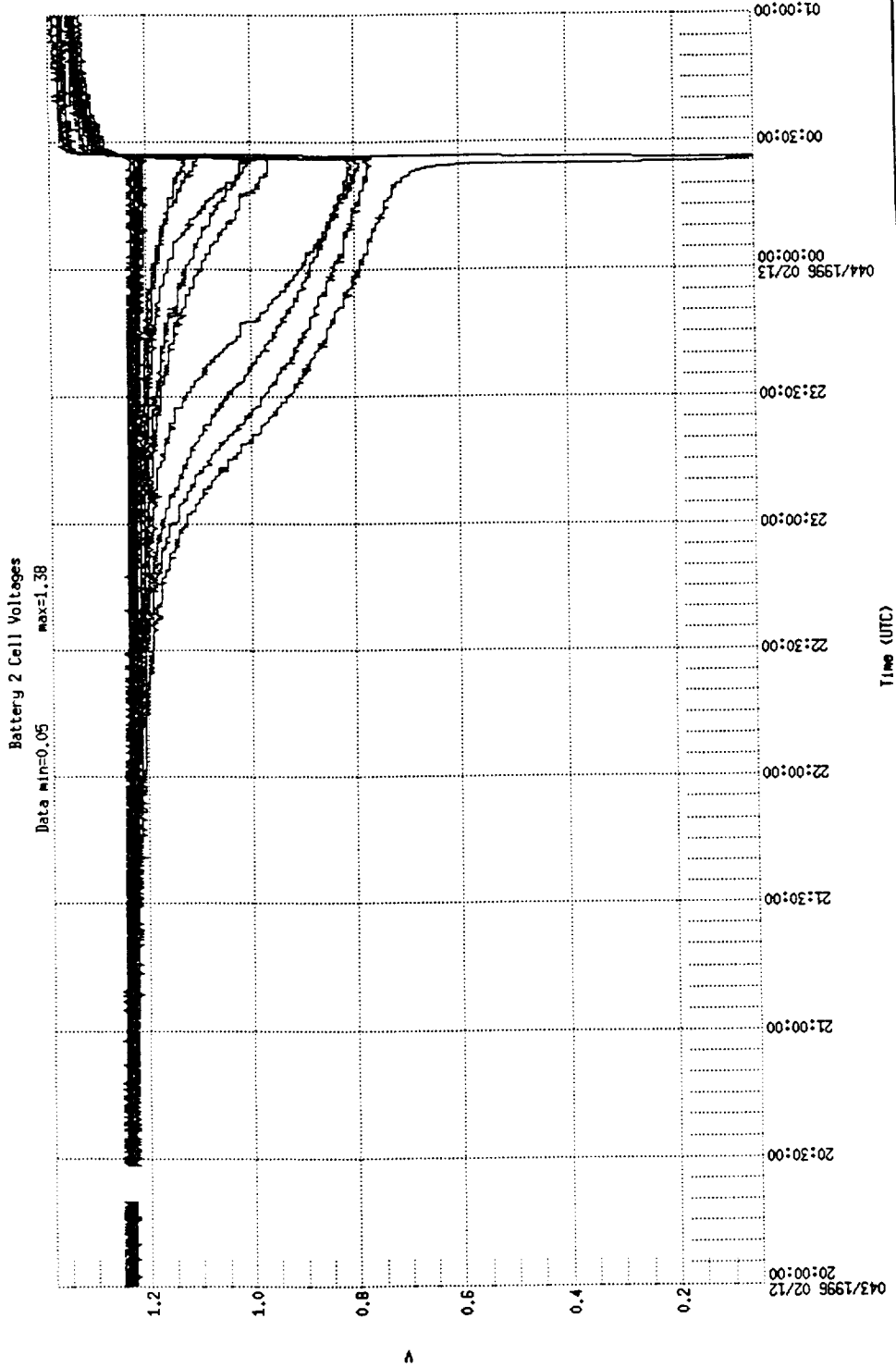


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N-Star FMa Battery 2, 1996 Vernal Reconditioning Capacity

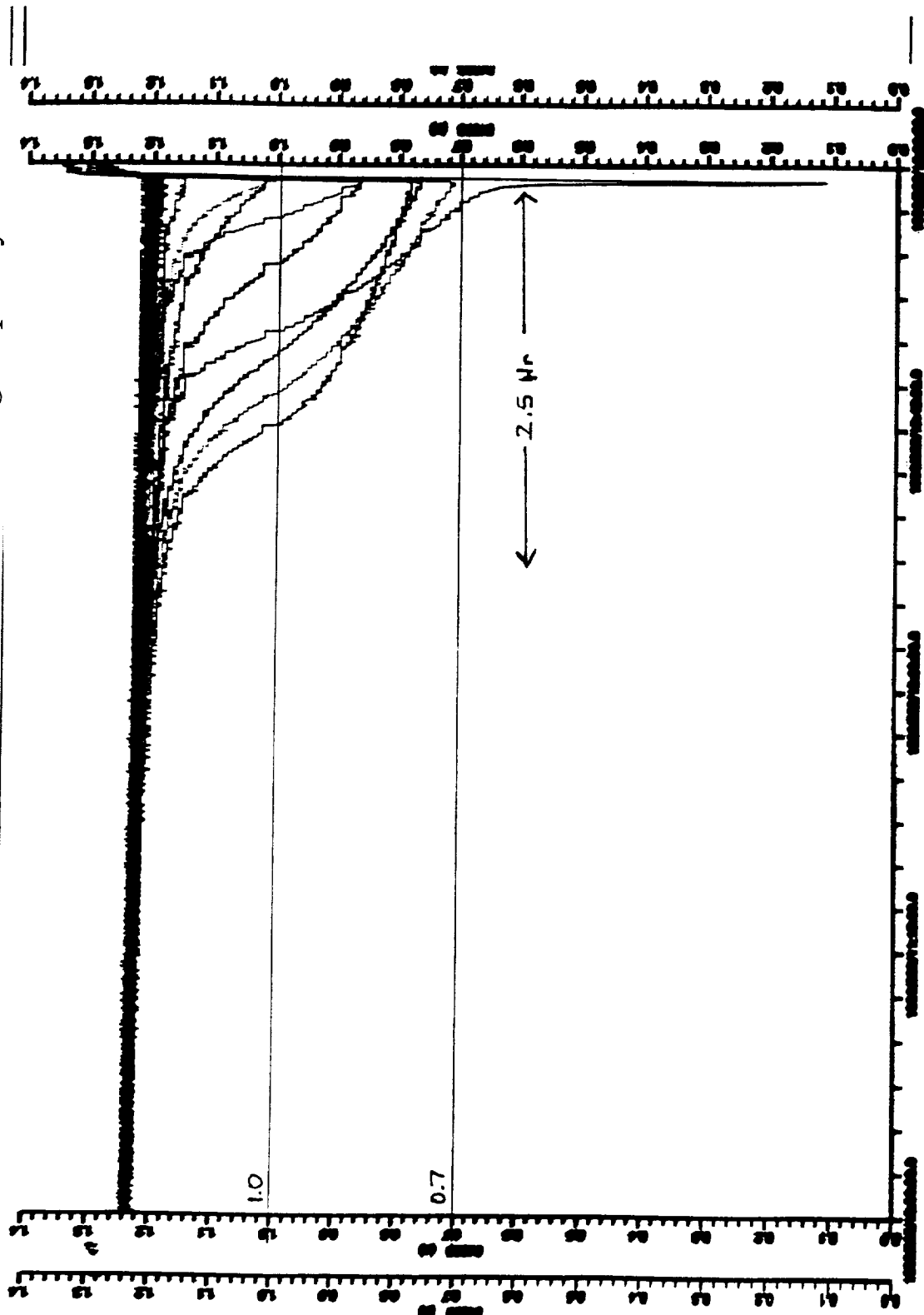
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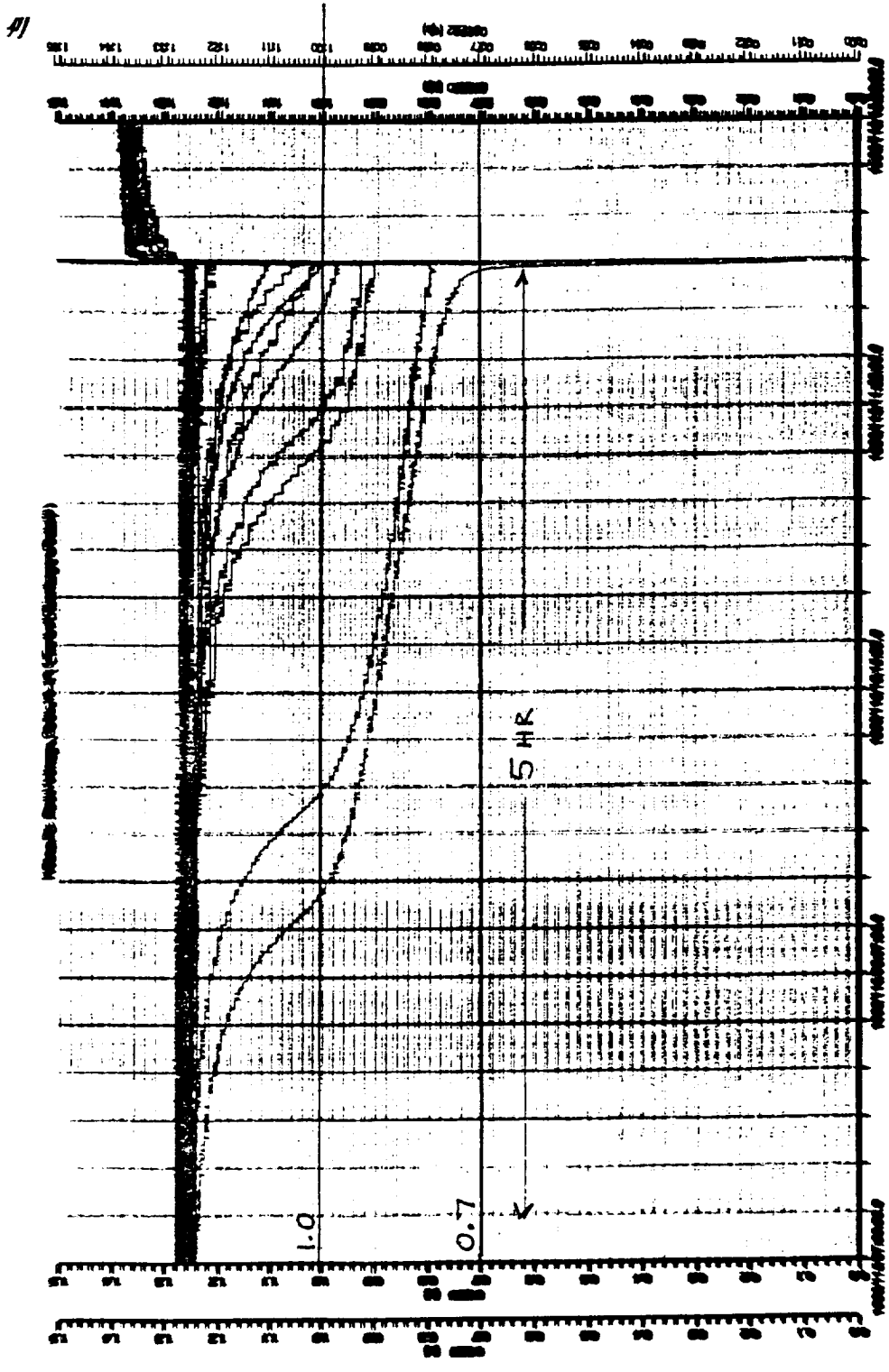
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N-Star FMa Battery 2, 1996 Autumnal Reconditioning Capacity



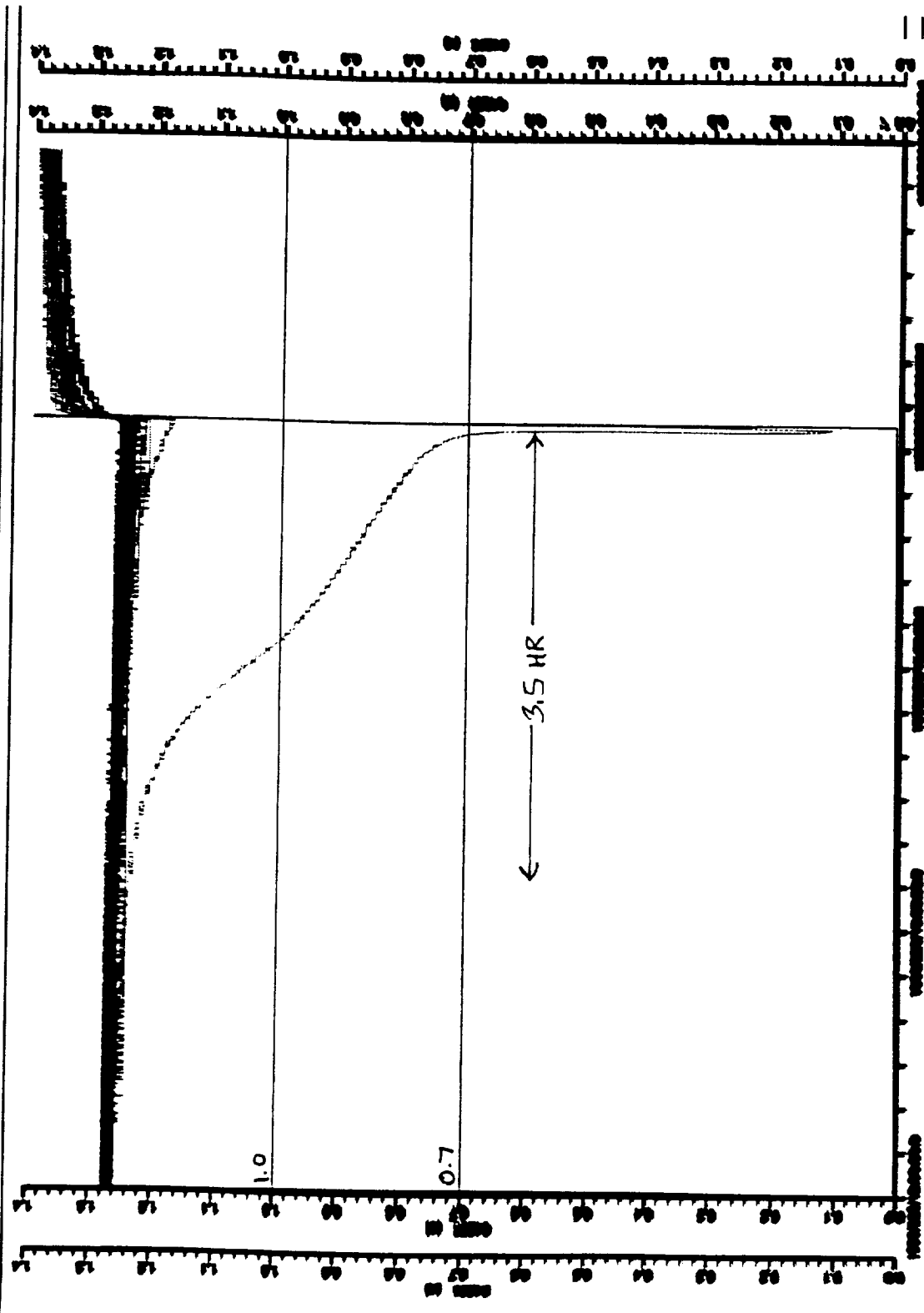
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N-Star FMB Battery 1, Post 1996 Vernal Equinox Reconditioning Capacity



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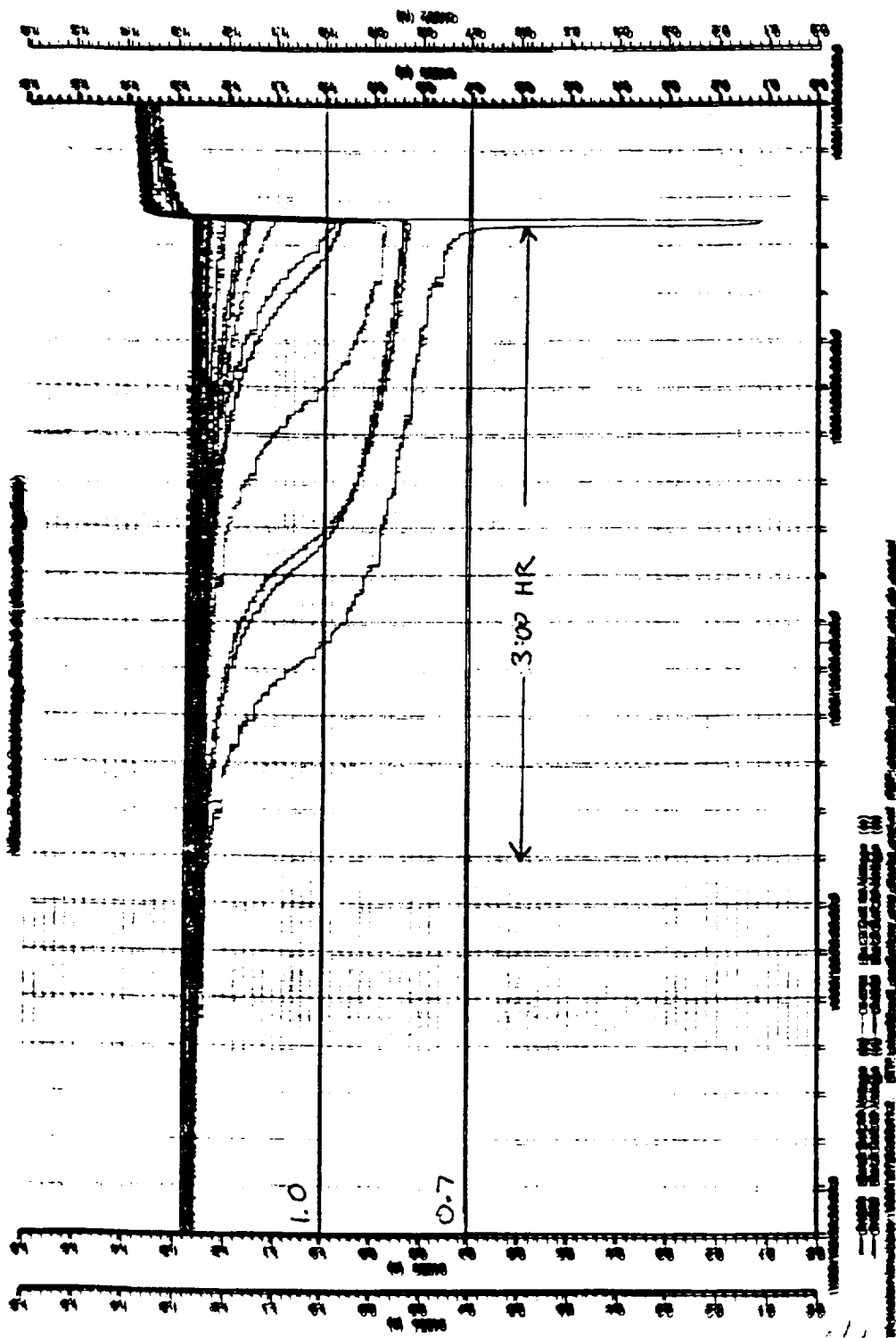
N-Star FMB Battery 1, 1996 Autumnal Reconditioning Capacity



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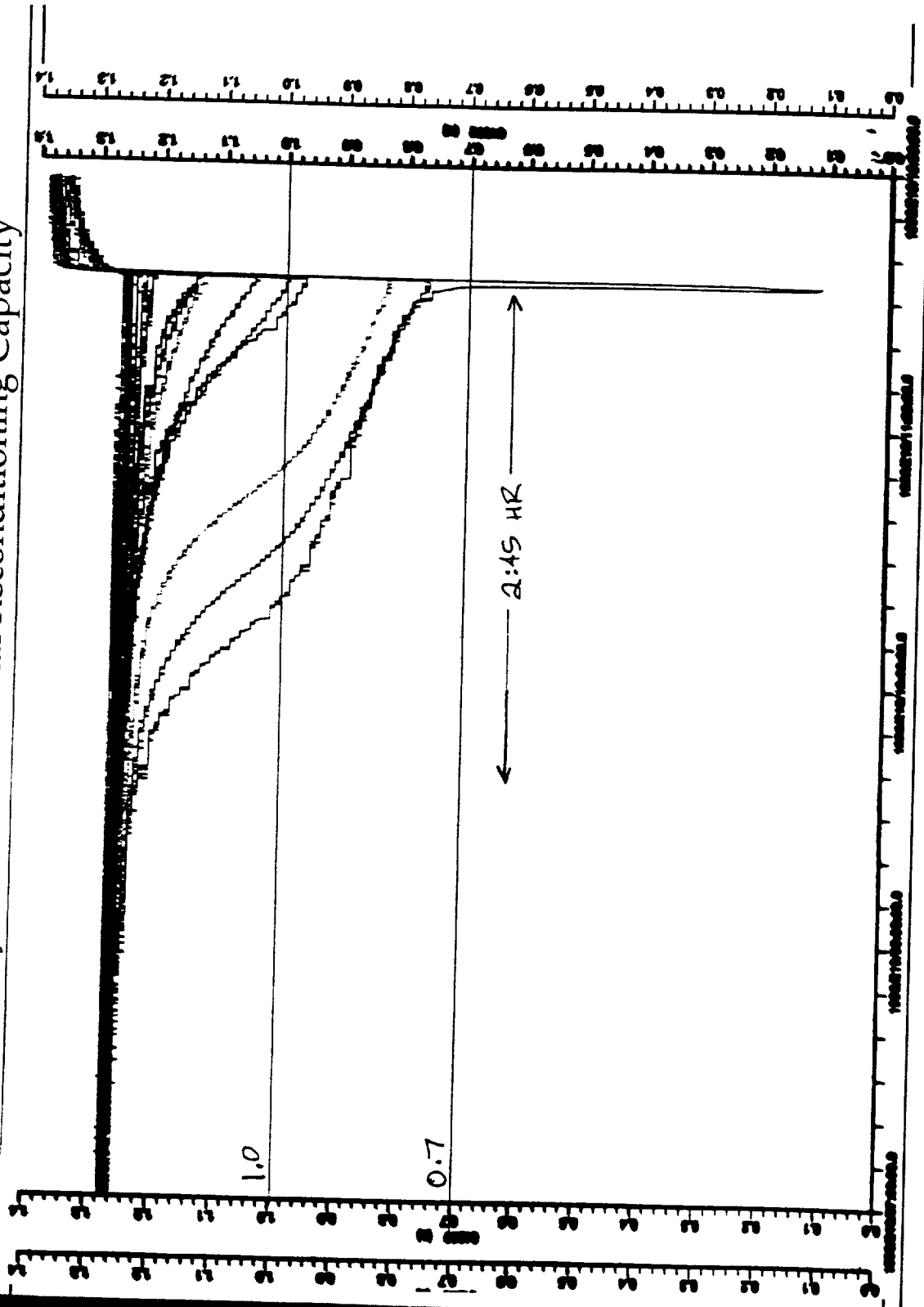
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N-Star FMB Battery 2, Post 1996 Vernal Equinox Reconditioning Capacity



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