Return-to-Service Current Limit for Lead-acid Batteries

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Background Questions

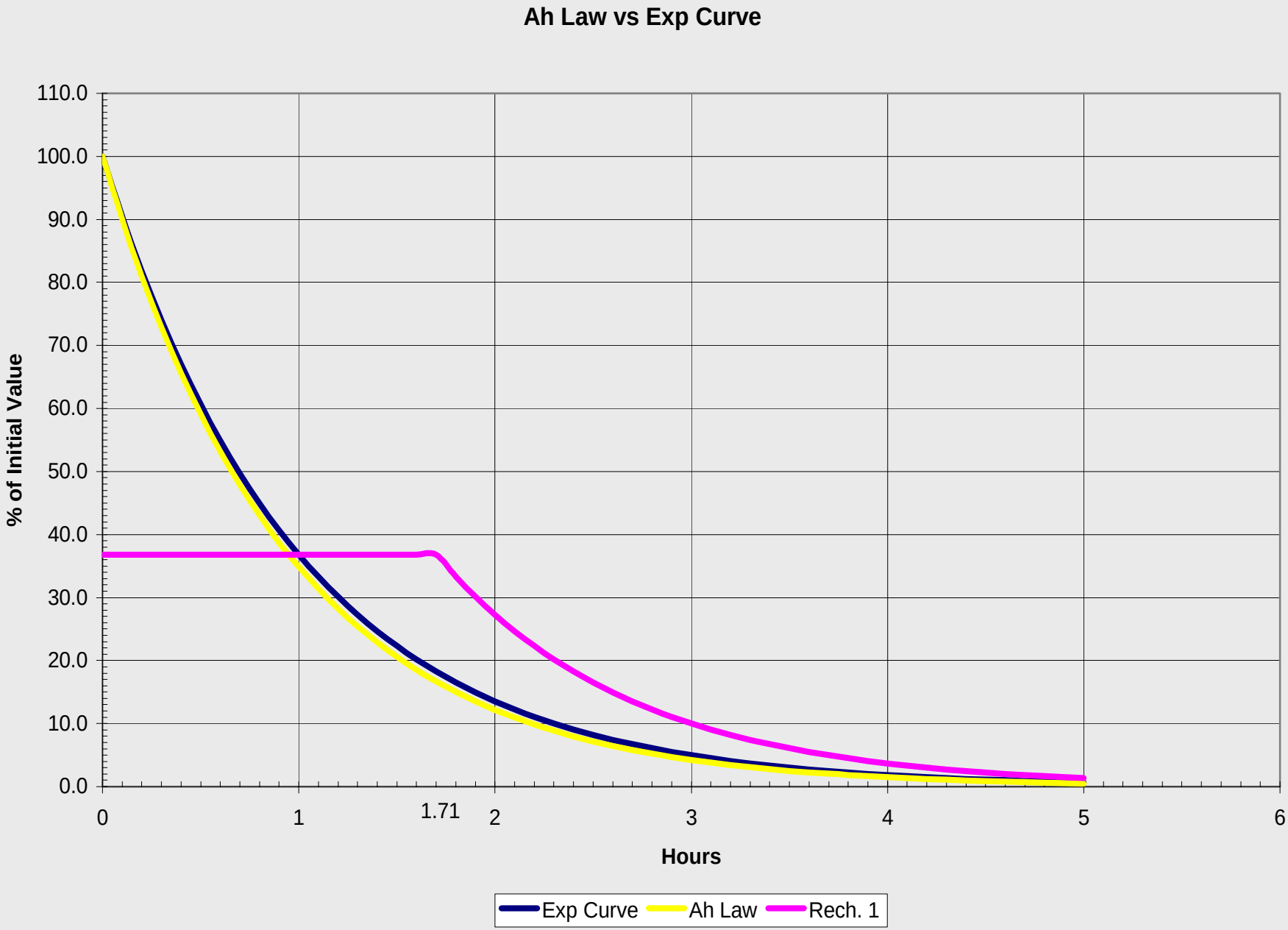
- When is most of the charge restored to a battery after a discharge test?
- How can you routinely determine the state of charge of a battery?
- Is there a limit you can use for these purposes?

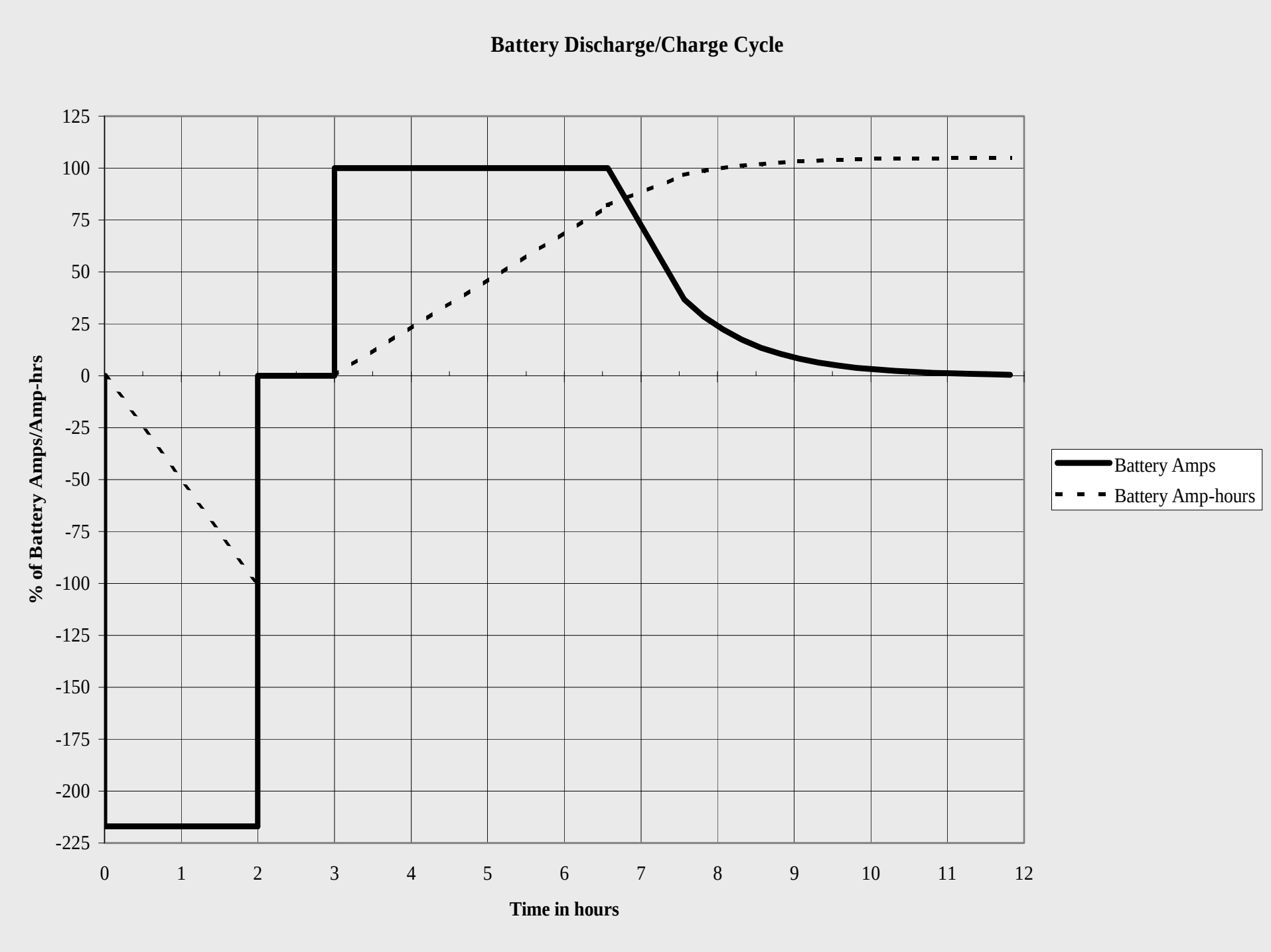
History

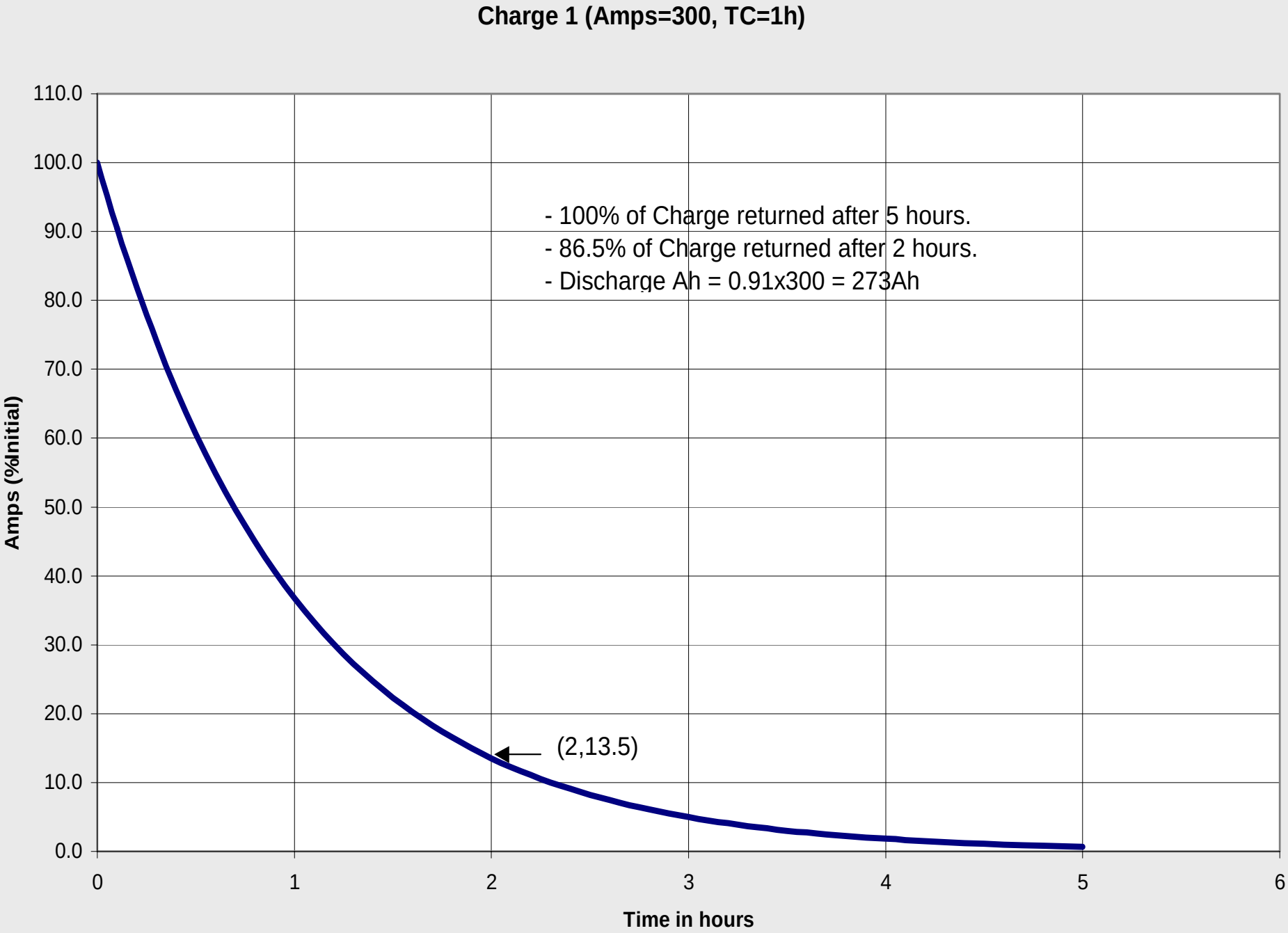
- Problems with using SG on Lead-Calcium
- Can’t measure SG on VRLA batteries
- Credits:
  - Hatch gathered much needed data (1988-now)
  - J. L. Woodbridge & The Ampere-hour Law (from 1935 technical paper)

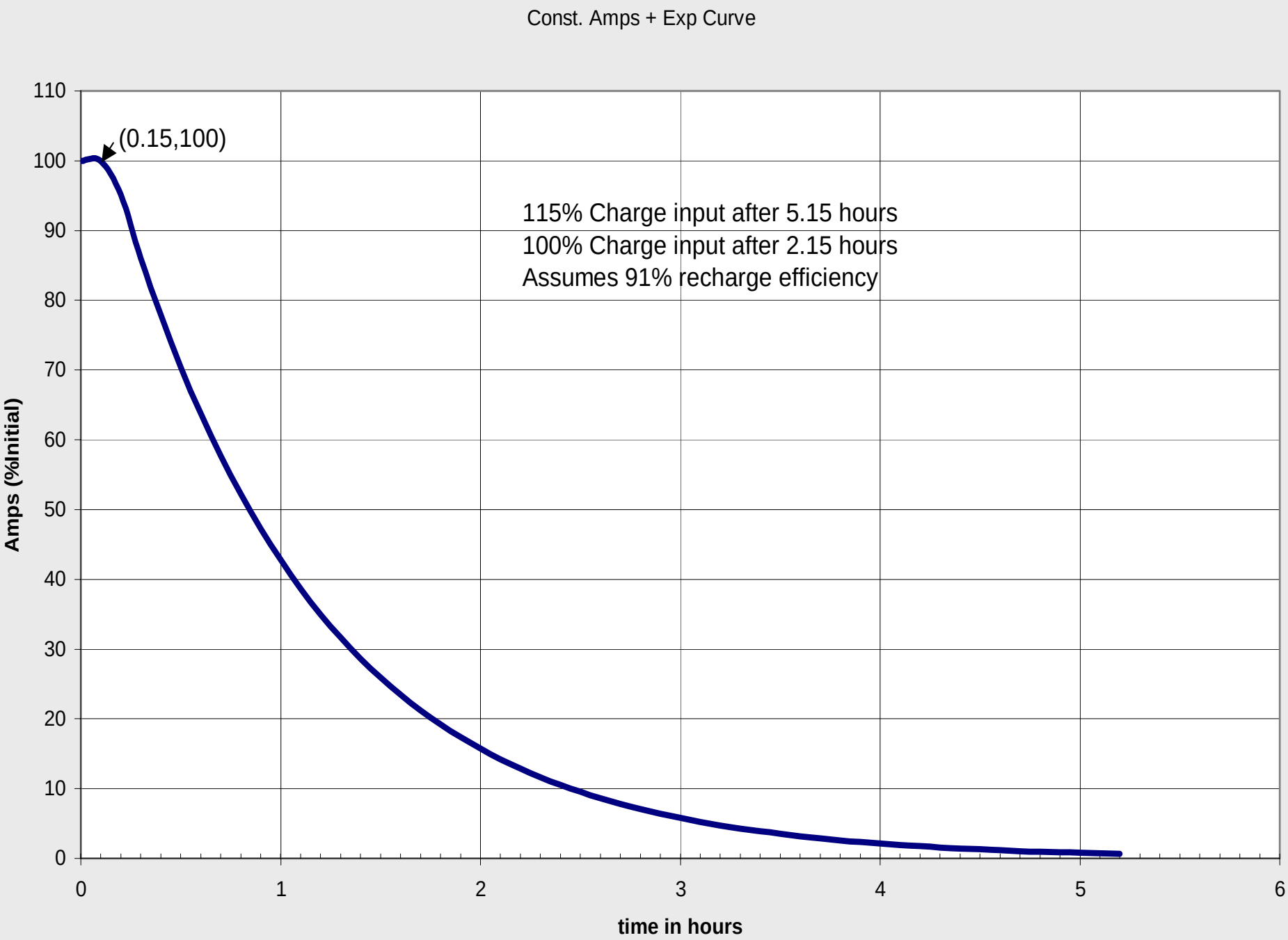
A Conceptual Approach

- The Ampere-hour law & the exponential
- The discharge-charge curve
- Two time constants and counting
- Accounting for margins & efficiency
- Return to service limit summary


Ah Law vs Exp Curve
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
% of Initial Value
0
1
1.71
2
3
4
5
6
Hours
Exp Curve
Ah Law
Rech. 1


Battery Discharge/Charge Cycle
% of Battery Amps/Amp-hrs
125
100
75
50
25
0
-25
-50
-75
-100
-125
-150
-175
-200
-225
0
1
2
3
4
5
6
7
8
9
10
11
12
Time in hours
Battery Amps
Battery Amp-hours


Charge 1 (Amps=300, TC=1h)
- 100% of Charge returned after 5 hours.
- 86.5% of Charge returned after 2 hours.
- Discharge Ah = 0.91x300 = 273Ah
(2,13.5)
Amps (%Initial)
Time in hours
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
1
2
3
4
5
6


Const. Amps + Exp Curve
(0.15,100)
115% Charge input after 5.15 hours
100% Charge input after 2.15 hours
Assumes 91% recharge efficiency
Amps (%Initial)
time in hours
110
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6

Return to Service Limit Summary

- Amount of charge under exp = I_O x TC.
- At t = 2TC, 86.5% of exp. charge completed if charge curve is only exponential.
- If design duty cycle uses more than charge amount under exponential, then SOC at 2TC >86.5% of total charge.
- As long as design margin exceeds % of remaining charge, RTS limit is acceptable.
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RTS Selection Procedure

1. What is charger dc output rating at minimum recommended float voltage?
2. What is max. continuous load current expected during recharge period?
3. Initial current, I_O, = Step 1 – Step 2
4. Preliminary RTS = I_O x 0.135

Checking RTS Limit

A. Total Charge = Duty cycle Ah/efficiency.
B. % of Charge @2TC = RTS x TC/Step A.
C. If Step B </= % Design Margin, RTS limit is acceptable. If not, adjust RTS limit downward and recheck.

Alternate Check Procedure

1. Determine initial charging current, I_O, as normally done above.
2. Calculate charge under exp. = I_O x TC.
3. If Amp-hours removed during design duty cycle >/= 1.15 x Step 2 above, then RTS limit is acceptable, regardless of design margin.

Example

- Lead-calcium battery is rated 1300 Ah at 2-h rate to 1.75vpc average.
- Design duty cycle removes 703 Ah.
- Recharge efficiency is 95%.
- Charger output amps = 328A @ min. float voltage of 2.20 vpc. House load = 45A.
- Time constant @2.20vpc = 2 h.
- Design margin = 15%, w/aging & tmp. also

RTS Limit Calculation

1. Charger output @ min. vpc = 328 A
2. Max. house load = 45 A
3. Initial current, I_O = 328 - 45 = 283 A
4. RTS limit = 283 x 0.135 = 38.2 or 35A, when rounded downward

- Now lets check this limit

RTS Limit Check

A. Total Ah to fully charge battery after a duty cycle discharge = 703/0.95 = 740 Ah.

B. % total Ah remaining at RTS =.

100 x (35 x 2)/740 = 9.5 %.

C. Since design margin = 15% > 9.5, RTS limit is acceptable.

However, what if margin decreases?

RTS Limit Alternate Check

1. Initial current = 283A.
2. Exp. Ah = 283A x 2h = 566 Ah.
3. Duty Cycle Ah = 703, which is > 1.15 x 566 = 651Ah, therefore RTS Limit is acceptable.

Conclusion

- Exponential charging characteristic when using constant potential charging can provide valuable information on battery state of charge (SOC).
- RTS limit for charging current can help assess battery condition after discharge test.

Various Time Constants