Charging considerations of nickel-based chemistries in appliance type applications and the impact on proposed CEC standards

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Introduction

- CEC proposes to regulate “small” consumer battery charging systems (BCS)
  - BCS is comprised of charger and battery
- A significant proportion of these systems are for appliances and power tools
- A significant proportion of appliance and power tool BCS’s use NiCd or NiMH cells
  - Suitable for high discharge currents. Very safe and robust
- These cells have certain inherent characteristics that tend to lower efficiency
- CEC staff has repeatedly stated that it is not their intent to achieve energy savings through outlawing a particular chemistry.
- CEC proposal clearly fails to accommodate NiX systems

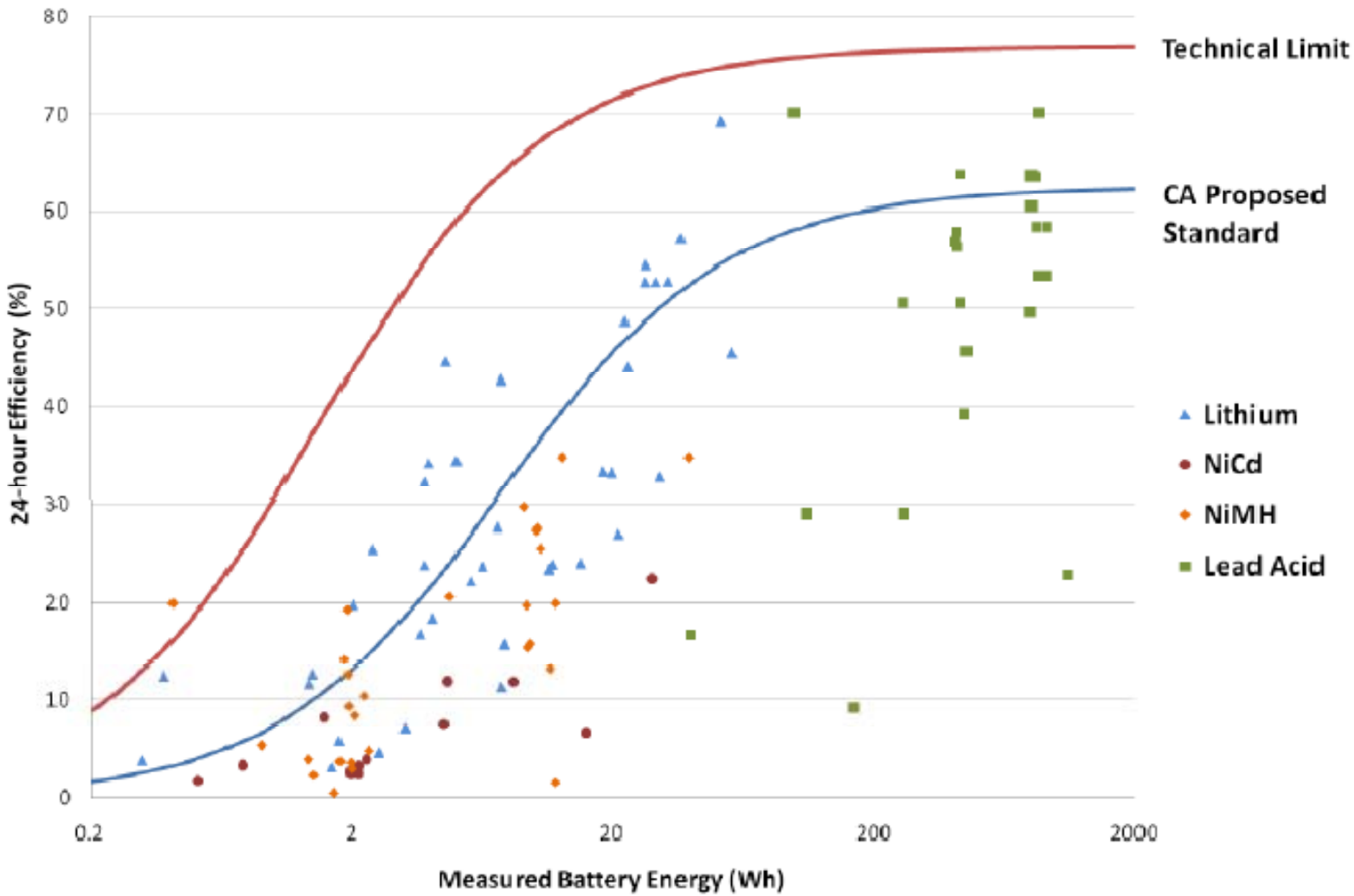
CASE proposal

- Pnb ≤ 0.3W
- Pm ≤ 0.5W
- E24 ≤ 12 + 1.6Eb
  - Based upon 60% conversion efficiency
    - Eb/0.60 = 1.6Eb
  - Also 24h x 0.5W (Pm limit) = 12Wh

E24 limit

- 24 hour combined active and maintenance
- CASE Proposal
  - E24 ≤ 12 + 1.6Eb
  - PG&E used “Active mode efficiency” (%) = Eb/E24
  - Proposal provided data points plotted
    - Charge efficiency vs. Eb
    - Compared to proposed limit line
    - No NiX systems comply above about 10 Wh
      - Represents most power tools and medium sized appliances
- CEC staff did not recommend change at March workshop
- Proposed regulation has essentially same requirement (for Eb ≤ 100Wh)

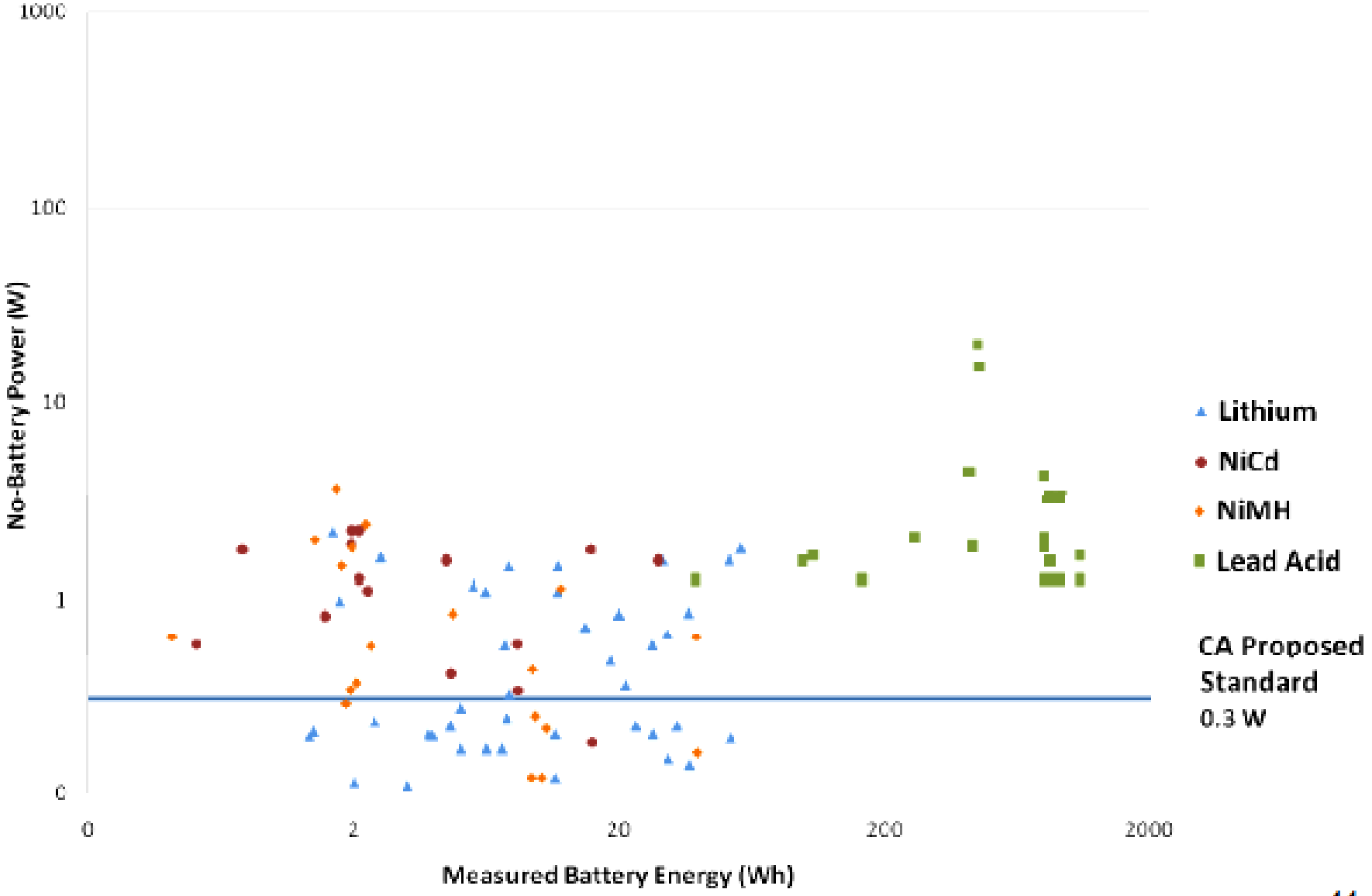
Active Mode Efficiency



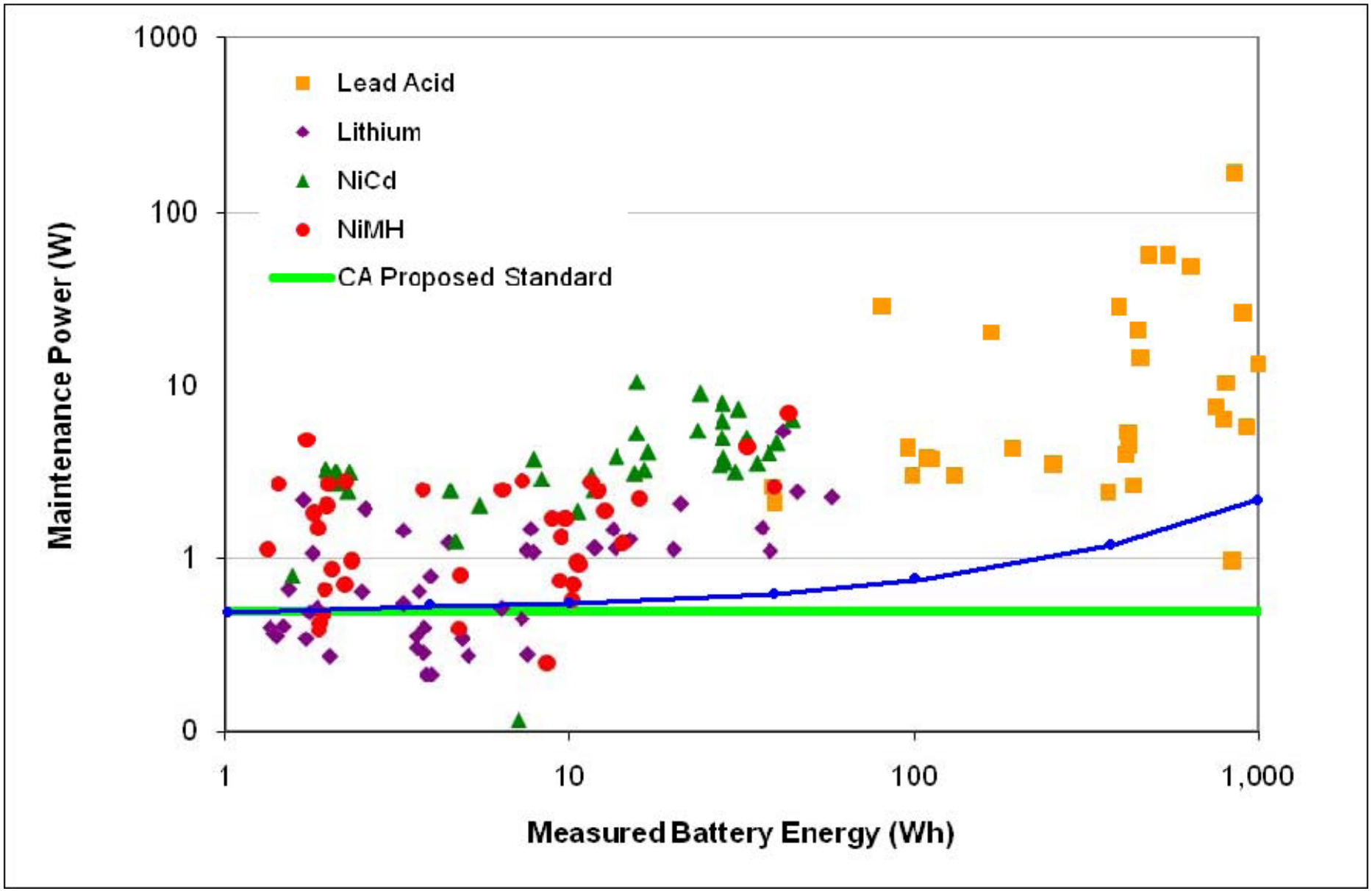
Pnb, Pm

- CASE Proposal
  - Pnb ≤ 0.3 W (only one NiX case that meets @ Eb>20Wh)
  - Pm ≤ 0.5 W
    - No cases of NiX systems that meet this level for Eb > 20Wh
- Staff proposal (March meeting)
  - Scaling based upon 3% daily self-discharge, 60% efficiency
  - Pm ≤ 0.5 + 0.0021Eb, no change to Pnb
    - Again, no cases of NiX systems that meet for Eb> 20 Wh
- Proposed Amendments
  - Combine Pnb and Pm
  - Pnb + Pm ≤ 1.0 + 0.0021Eb
    - Essentially the sum of the individual limits from March meeting +.2W
      - Y –intercept of blue line on graph is now 1.0W
  - Again, no cases of NiX that meet for Eb>20Wh

No Battery Mode Level



Original CASE and 1st Staff proposal



Summary of CEC proposals

- CEC proposals have failed to provide for Nickel based battery charging systems
  - Evidenced by no passing cases at mid Eb's
  - In principle, combining Pnb and Pm makes sense
  - Allows for typical design trade offs
- In principle, scaling Pm makes sense
  - Required maintenance power is related to size of battery
- In practice, the Pm allowance does not consider the real requirements of NiX systems
- Same is true of E24 limit
- These problems are all related to issues inherent in the nature of NiX cells and not poor BCS design
- This would effectively outlaw mid-power NiX systems

Example

- 18V (nominal), 2.2Ah NiCd battery
  - Eb = 40 Wh
  - Required maintenance current (C/40) = 55mA
  - Battery voltage during maintenance = 22.5V
  - Required power into <u>battery</u> = (.055)(22.5) = 1.24W
  - CEC allowance
    - Pnb +Pm = 1W + 0.0021(40) = 1.08W (into charger)
- Therefore even with 100% efficiency and Pnb=0, this NiX system would fail!

Nickel Chemistry issue

- These cells (NiCd & NiMH) have a significant self discharge rate that requires ongoing low-rate charging to maintain full charge
  - To provide for this, these cells are designed to be overcharged
  - Safe overcharging requires a secondary “recombination” reaction
    - Appliance and power tool applications require “sealed” cells
    - Consumes byproducts of charging reaction
    - Secondary reaction consumes much more power then self discharge
    - Typical recommended maintenance charge rates from C/50 – C/20
  - Effect of recombination is evident in bulk charging as well
    - “competes” with charge current, lowers “charge efficiency”
      - Typically value is 1.4, but is a function of charge rate

Development of alternative Pnb +Pm limit

- Start with Pm = 0.5W + k*Eb and Pnb = 0.3
  - K*Eb was 0.0021Eb at last workshop
  - Wish to recompute this coefficient to reflect effect of NiX
- Pm =0.5W + (Vbat(charged)*Im)/.6
  - Assume maintenance current, Im = C/30
  - Eb = Vbat(nom) * C
  - Vbat(charged) = 1.25*Vbat(nom)
    - Due to higher cell voltage during maintenance
- Substituting and reducing,
  - Pm = 0.5W + 1.25Eb/(30*0.6)
  - or, Pm = 0.5W + 0.07Eb
- Limit : Pnb + Pm ≤ 0.3W + 0.5W + 0.07Eb
  - Or, Pnb + Pm ≤ 0.8W + 0.07Eb
  - This would be closer to current proposal by the following adjustment:

    Pnb + Pm ≤ the greater of 1W or 0.7W + 0.07Eb

Development of alternative E24 limit

- Start with E24=12 + 1.6Eb
  - Comes from E24 = 24(.5) + Eb/0.6
  - That is, E24 = 24*Pm + Eb/η
  - First term is maintenance, second is active mode
  - Where η(eta) = conversion efficiency
- Active mode term
  - Must account for charge efficiency of NiX;
    - Typically between 1.2 – 1.6, chose 1.4
  - Assume η =.75 (higher then for maintenance)
  - Active mode is then 1.4*Eb/0.75 = 1.86Eb

Development of alternative E24 limit

- Maintenance term
  - 24*Pm
  - Pm = 0.5W + 0.07Eb
  - Substituting, 24(0.5 + 0.07Eb)=12+1.68Eb
- Putting it together;
- E24 ≤ 12+1.68Eb + 1.86Eb
- Combining, E24 ≤ 12+3.5Eb
- Propose setting a “floor” for very low Eb BCS’s
  - E24 ≤ the greater of: 20Wh or 12 + 3.5Eb

Summary

- Proposed limits would prevent outlawing of NiX, mid-power systems
- No feasible solution as evidenced by
  - PG&E/Ecos data
  - Engineering analysis
- Would have little effect on proposed CEC low power limits