South Bay Amateur Radio Association

Batteries 101

Agenda

- **Primary (single-use) Batteries**
  - Alkaline
  - Lithium
- **Secondary (rechargeable) Batteries**
  - Ni-Cad, NiMH
  - Lithium Ion
- **Real World Testing**
- **12v Batteries**
  - Lead Acid
  - Lithium Iron Phosphate (LiFePO4)

Alkaline

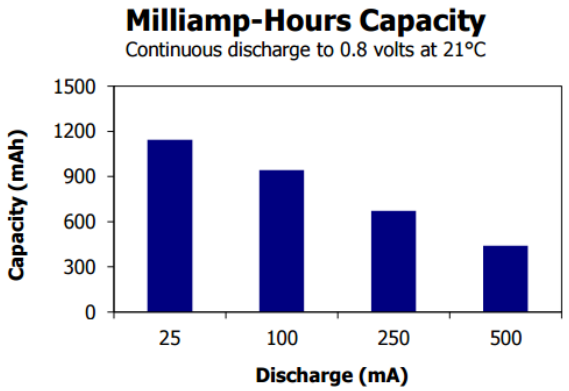
- **Pros**
  - Very low self-discharge (10 year shelf life)
  - Ubiquitous
  - Adapters available for most HTs
- **Cons**
  - Poor high current handling
  - Single use (non-rechargeable)
  - Possibility of leakage
  - Moderate energy density

Alkaline

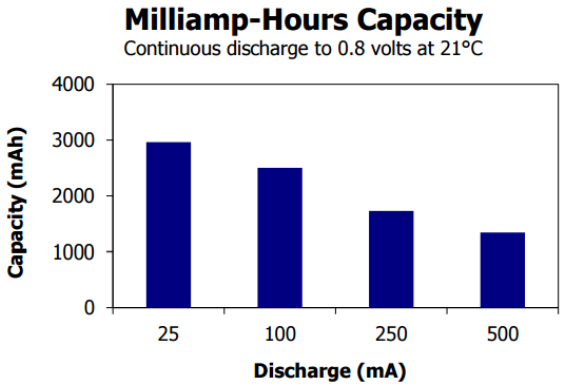
- **Alkaline batteries are 1.5v**
- **AAA**
  - 500 - 1,100 mAh*
- **AA**
  - 1,500 - 3,000 mAh*
- **C**
  - 4,800 - 8,000 mAh*
- **D**
  - 9,000 - 17,000 mAh*
- **9v**
  - 350 - 600 mAh*

***500 to 25 mA discharge current**

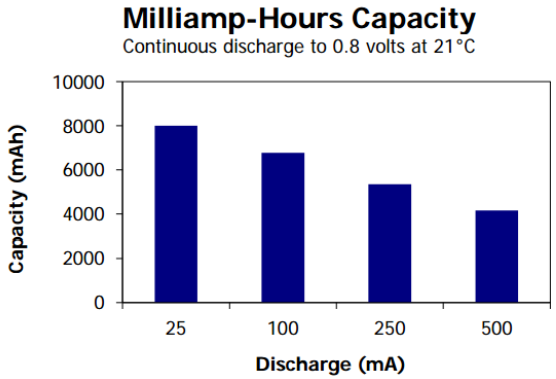
Alkaline (Energizer)



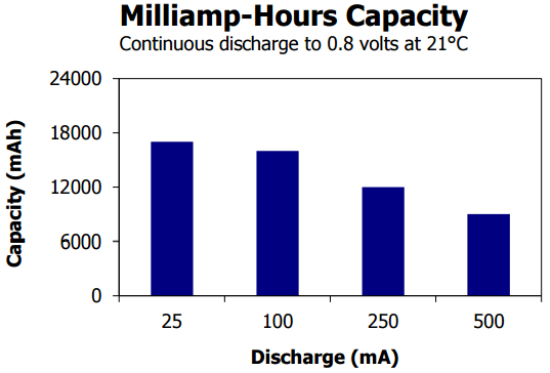
AAA



AA

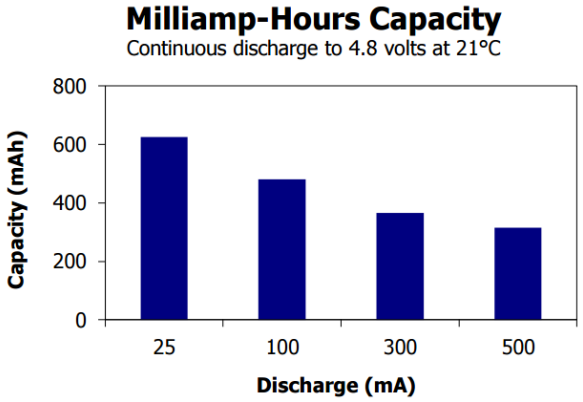


C



D

9v

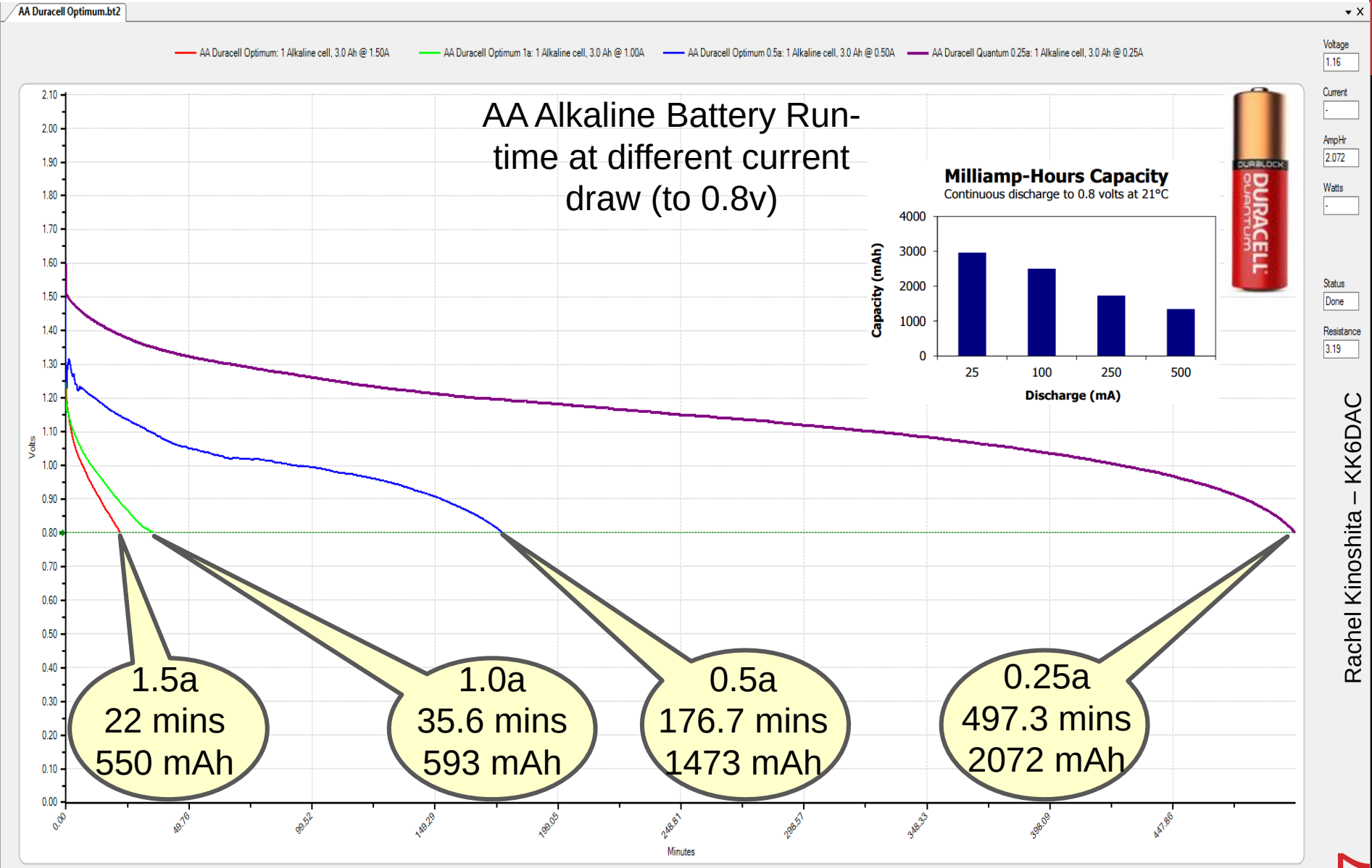


Source: http://data.energizer.com/

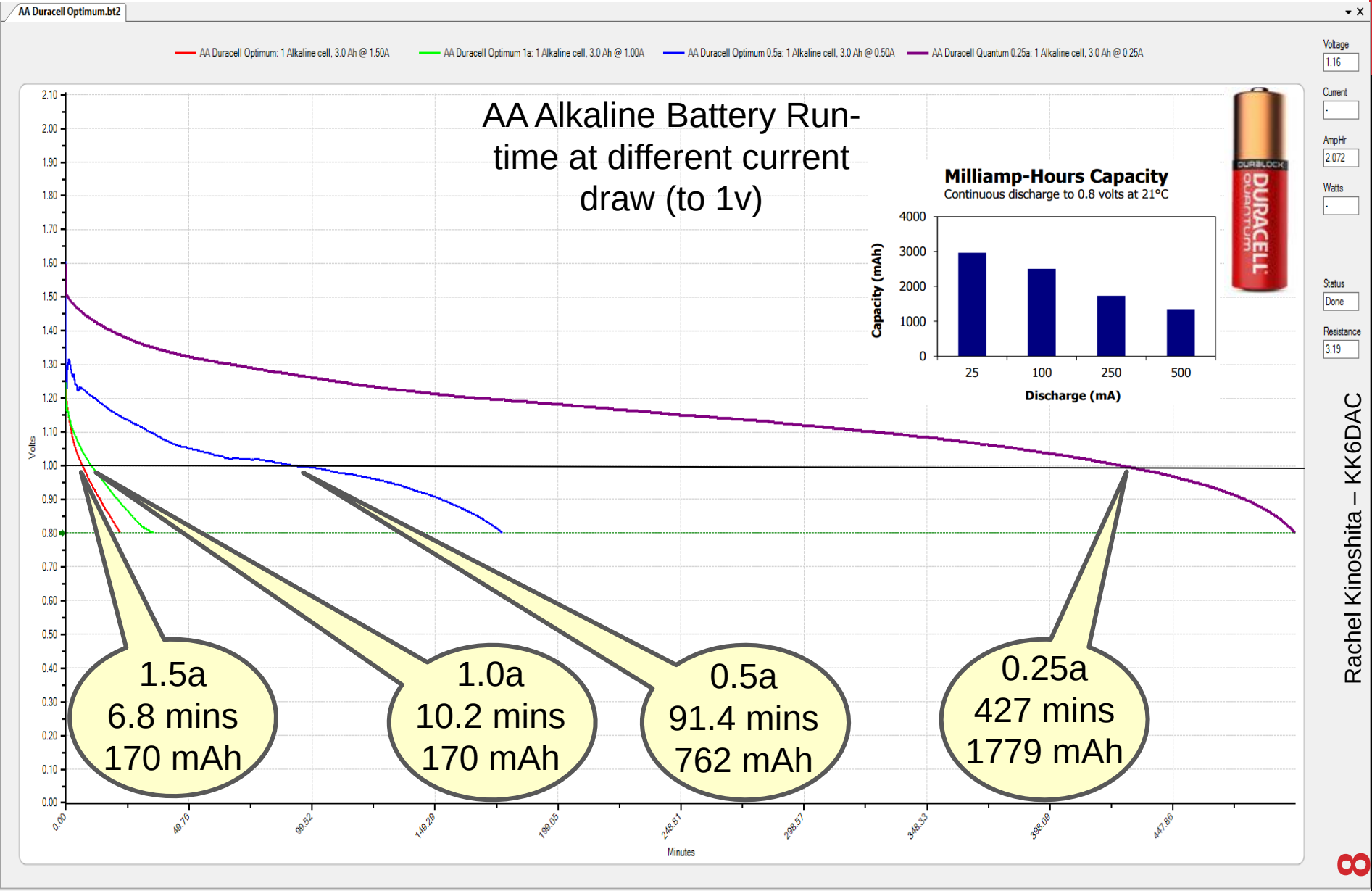
Alkaline (Peukert's Law)

- Peukert's Law – In lead acid batteries, as the discharge amps increase, the batteries available capacity decreases
- Presented by Wilhelm Peukert in 1897
- Has applications in alkaline batteries

Alkaline (Duracell Quantum)



Alkaline (Duracell Quantum)



Nickel Metal Hydride (NiMH)

- **Pros (Panasonic Eneloops and Tenergy Centuras)**
  - Good for high current applications
  - Rechargeable
  - Relatively long shelf life (retains 80% capacity after 1 year)
  - Will not leak
  - Adapters available for most HTs
- **Cons**
  - Moderate energy density
  - Only 1.2v vs 1.5v of alkalines

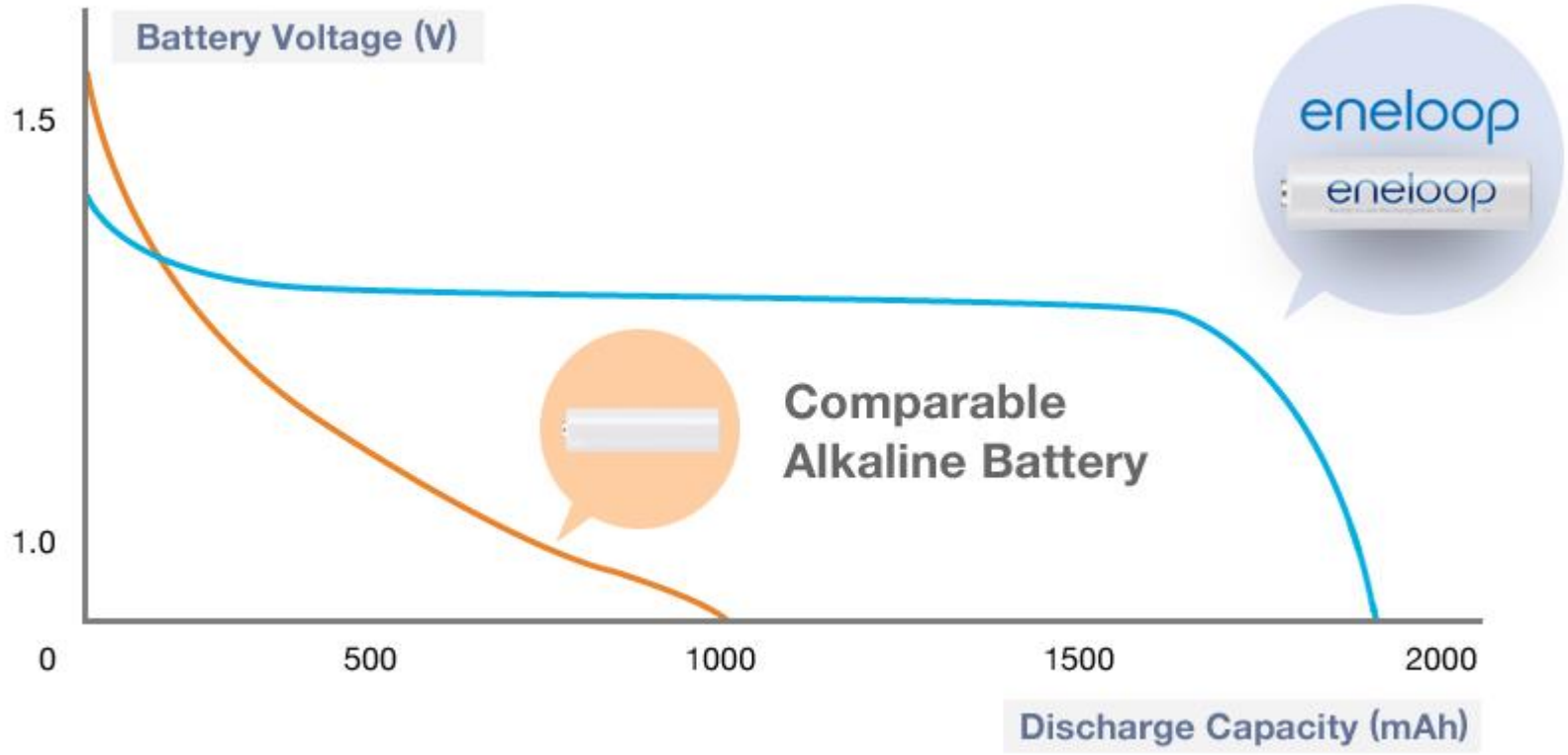
Nickel Metal Hydride (NiMH)

- **Nickel Metal Hydride batteries are 1.2v**
- **AAA – Panasonic Eneloop Low Self-Dischage**
  - 800 mAh*
- **AA – Panasonic Eneloop Low Self-Dischage**
  - 2,000 mAh*
- **C – Tenergy Centura Low Self-Dischage**
  - 4,000 mAh*
- **D – Tenergy Centura Low Self-Dischage**
  - 8,000 mAh*
- **9v – Tenergy Centura Low Self-Discharge**
  - 200 mAh*

***500 mA discharge current**

Nickel Metal Hydride (NiMH)

500 mA (0.5A) continuous discharge



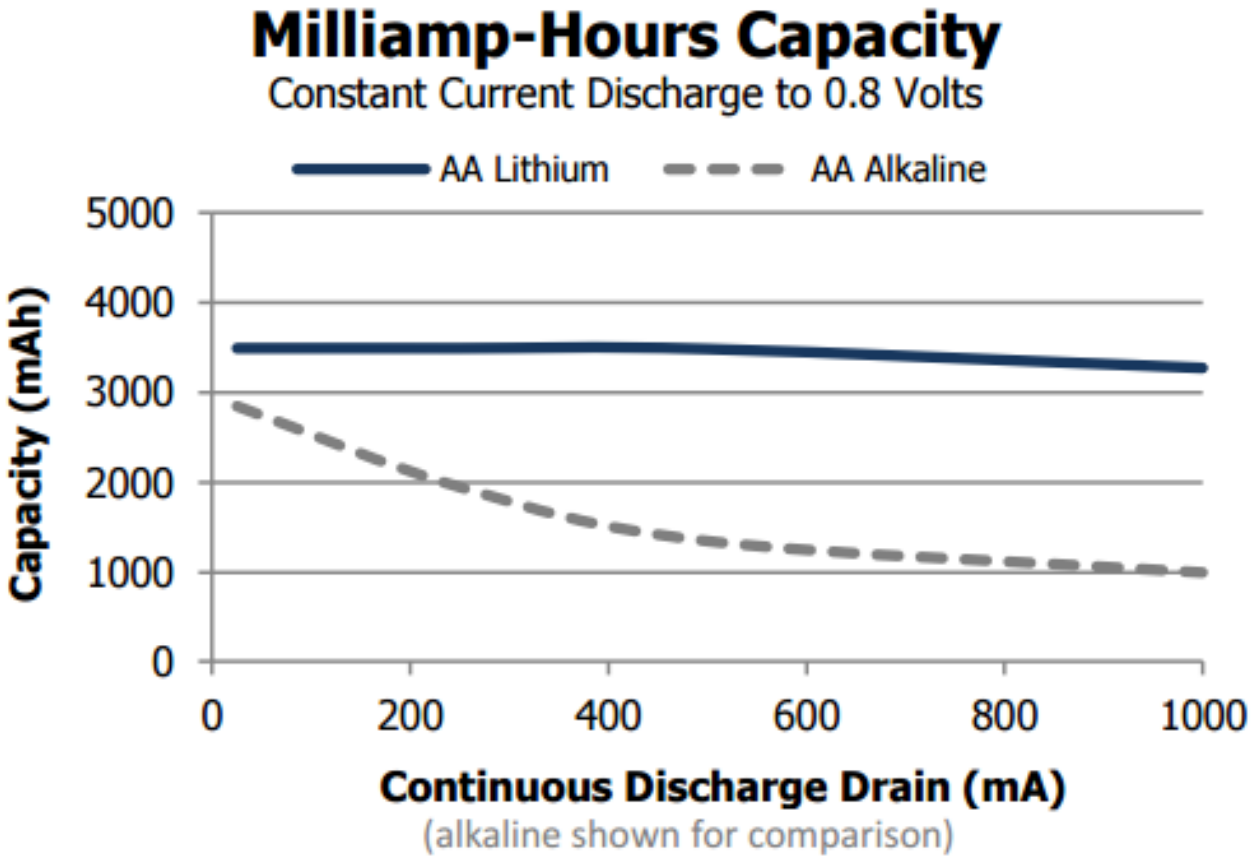
Source: https://www.panasonic.com/global/consumer/battery/eneloop/technologies.html

Primary Lithium

- **Pros (Energizer Ultimate Lithium)**
  - Good for high current applications
  - Very long shelf life (20 year shelf life)
  - Will not leak
  - High energy density
  - Adapters available for most HTs
- **Cons**
  - Expensive
  - Single use (non-rechargeable)

Primary Lithium

- **Primary Lithium batteries are 1.5v**
- **AA – Energizer Ultimate Lithium**
  - 3,500 mAh



Source: http://data.energizer.com/

Rechargeable Lithium Batteries

- **First proposed in 1973**
- **First rechargeable Lithium cell developed in 1980**
- **First commercial Lithium Ion battery developed in 1991**
- **Lithium Iron Phosphate battery proposed 1996**
- **Today Lithium batteries are found in smart phones, laptop computers, tablets, Bluetooth headsets, handi-talkies (HTs), cameras, flashlights, lanterns, power tools, electric bicycles, electric cars and so on**

Lithium Ion

- **Advantages**
  - Rechargeable
  - Very lightweight
  - Able to provide a great deal of energy in a short amount of time
  - Very low self-discharge
  - Will not leak
  - No outgassing
  - High energy density

Lithium Ion

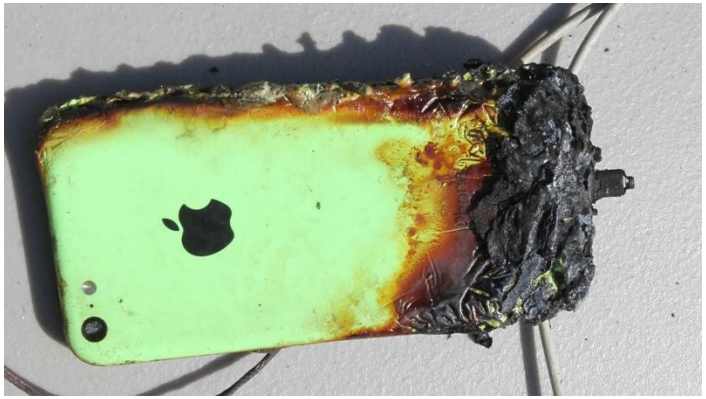
- **So why are we so afraid of lithium ion batteries?**

Lithium Ion

- **So why are we so afraid of lithium ion batteries?**
- **Yes, there were those hoverboards that caught on fire**

Lithium Ion

- **So why are we so afraid of lithium ion batteries?**
- **Yes, there were those hoverboards that caught on fire**
- **And those darned mobile phones**



Lithium Ion

- **So why are we so afraid of lithium ion batteries?**
- **Yes, there were those hoverboards that caught on fire**
- **And those darned mobile phones**
- **And yes, there were even a few electric cars**

Lithium Ion

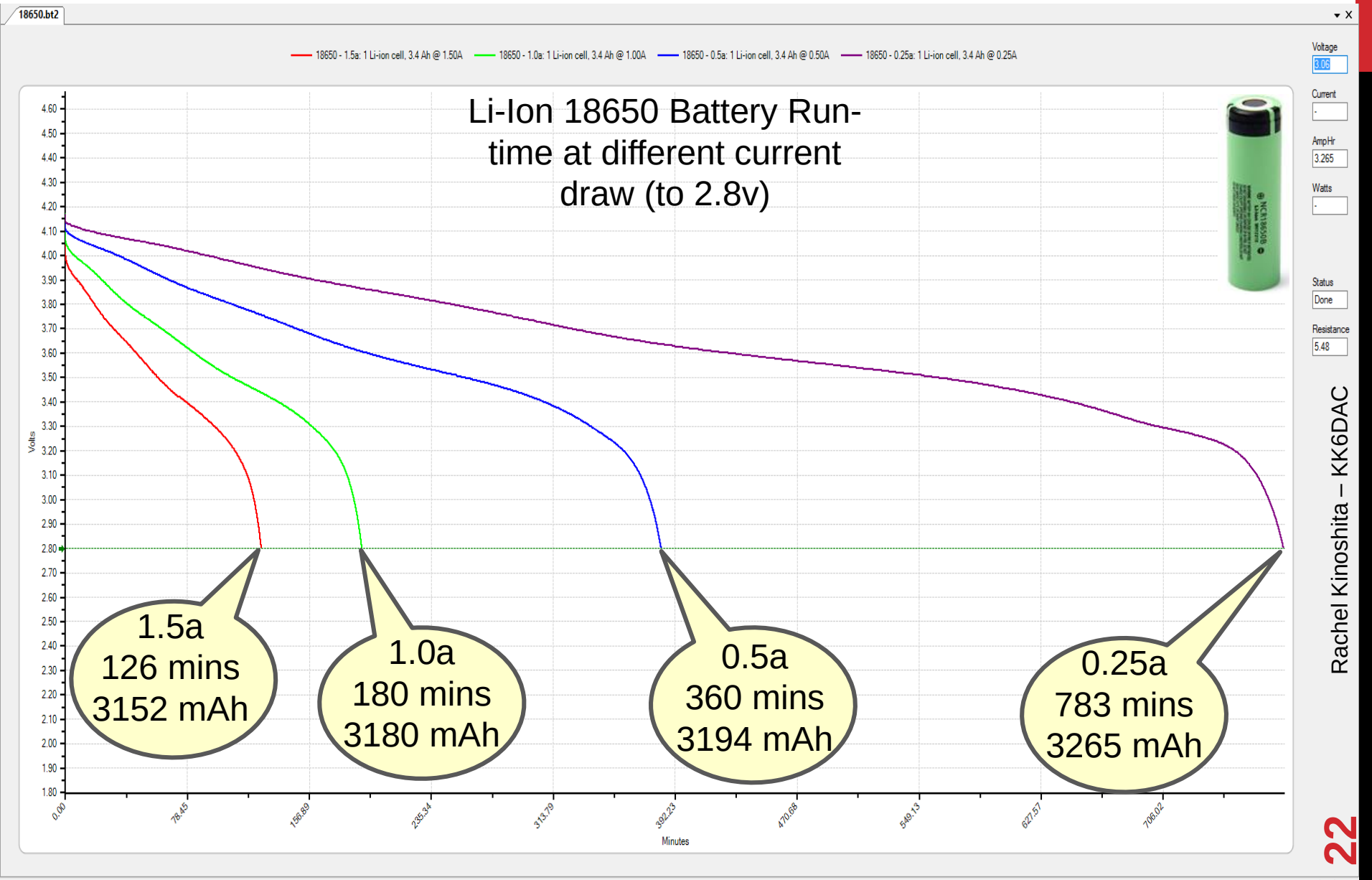
- **So why are we so afraid of lithium ion batteries?**
- **Yes, there were those hoverboards that caught on fire**
- **And those darned mobile phones**
- **And yes, there were even a few electric cars**

- **Hoverboards were using poor quality batteries to keep the costs down**
- **Samsung phone batteries also had quality control issues, but keep in mind, only 0.01% caught fire**
- **5 times more likely to experience a fire in a gasoline powered vehicle**

Lithium Ion

- **18650 batteries**
  - A little bigger than AA batteries
  - 3.7v
  - Recommend using ones with a protection circuit
  - Panasonic NCR18650B (3,400 mAh)
  - LG MJ1 18650F (3,500 mAh)
  - Used in many high output LED flashlights
  - Used in most USB Power Banks
  - Used in most laptop batteries

Li-Ion 18650 (Panasonic NCR18650B)



Lithium Ion

- **18650 for your FT-60**

Source: http://www.instructables.com/id/DYI-Lithium-battery-for-handheld-radio-Yaesu-FT-60/

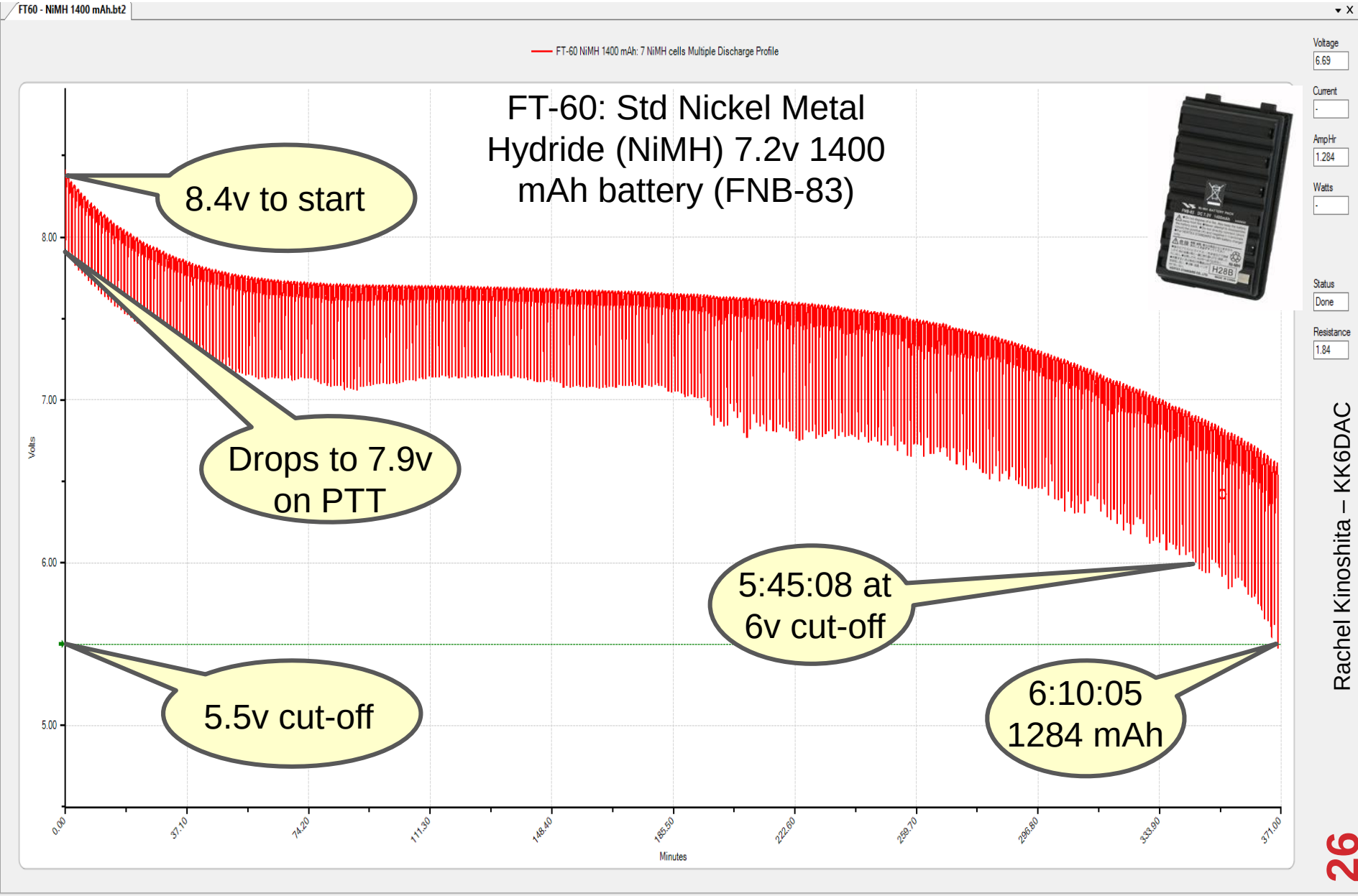
Test Methodology

- **West Mountain Radio Computerized Battery Analyzer (CBA) IV**
- **WMR CBA Software V2.4.16.0 with Extended License**
- **Custom (i.e. homemade) interfaces to the various battery packs**

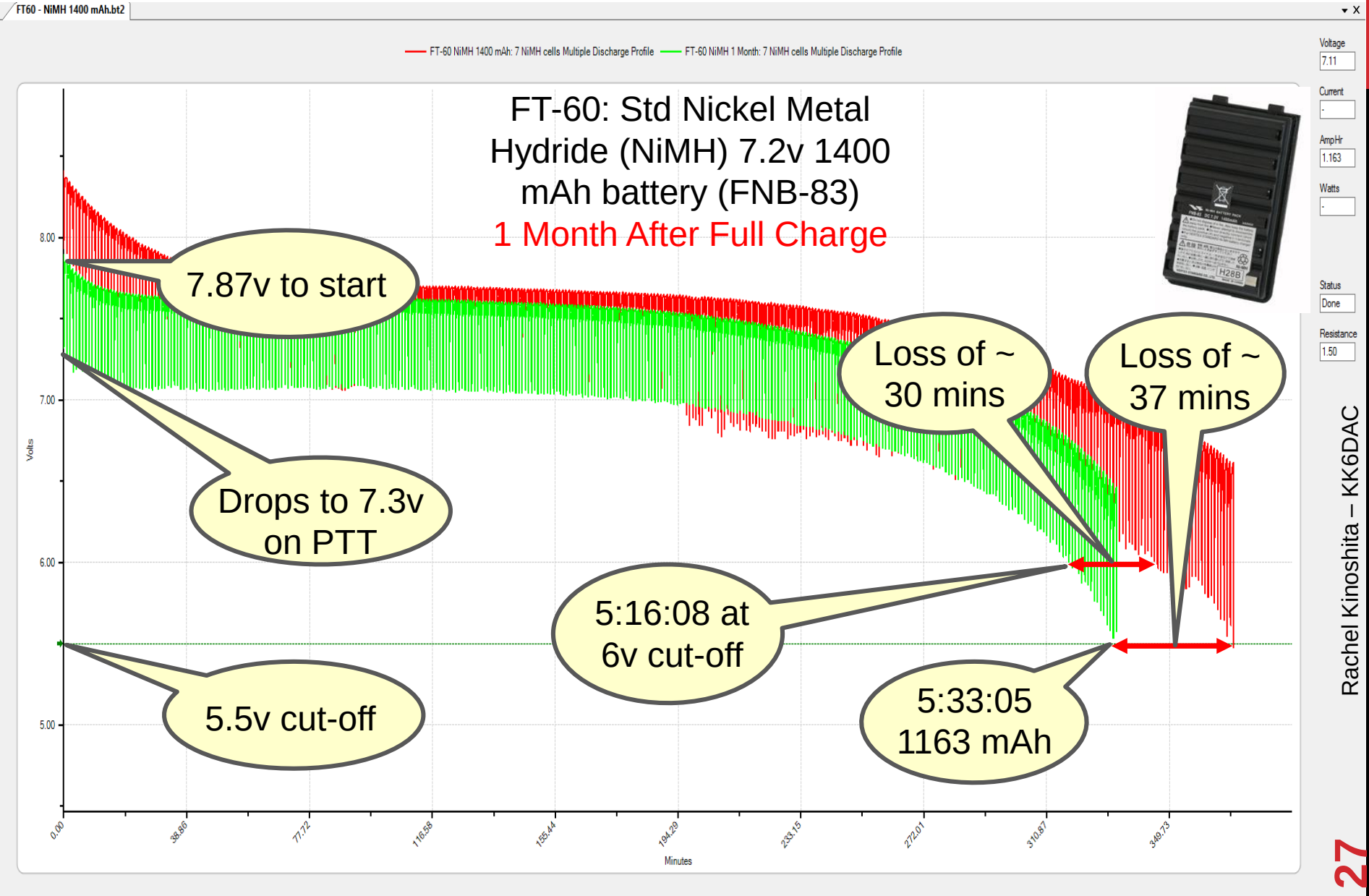
Test Methodology

- **Used the Multi-Discharge test using the following settings**
  - Low-Voltage cut-off: 5.5v
  - 1s steps until cut-off voltage is met
  - Three step discharge
    - 5s @ 1.6a (transmit)
    - 22s @ 0.2a (receive)
    - 33s @ 0.02a (idle)
- **All primary/single-use batteries were “fresh”**
- **All secondary/rechargeable batteries were fully charged before testing**

Test Results



Test Results



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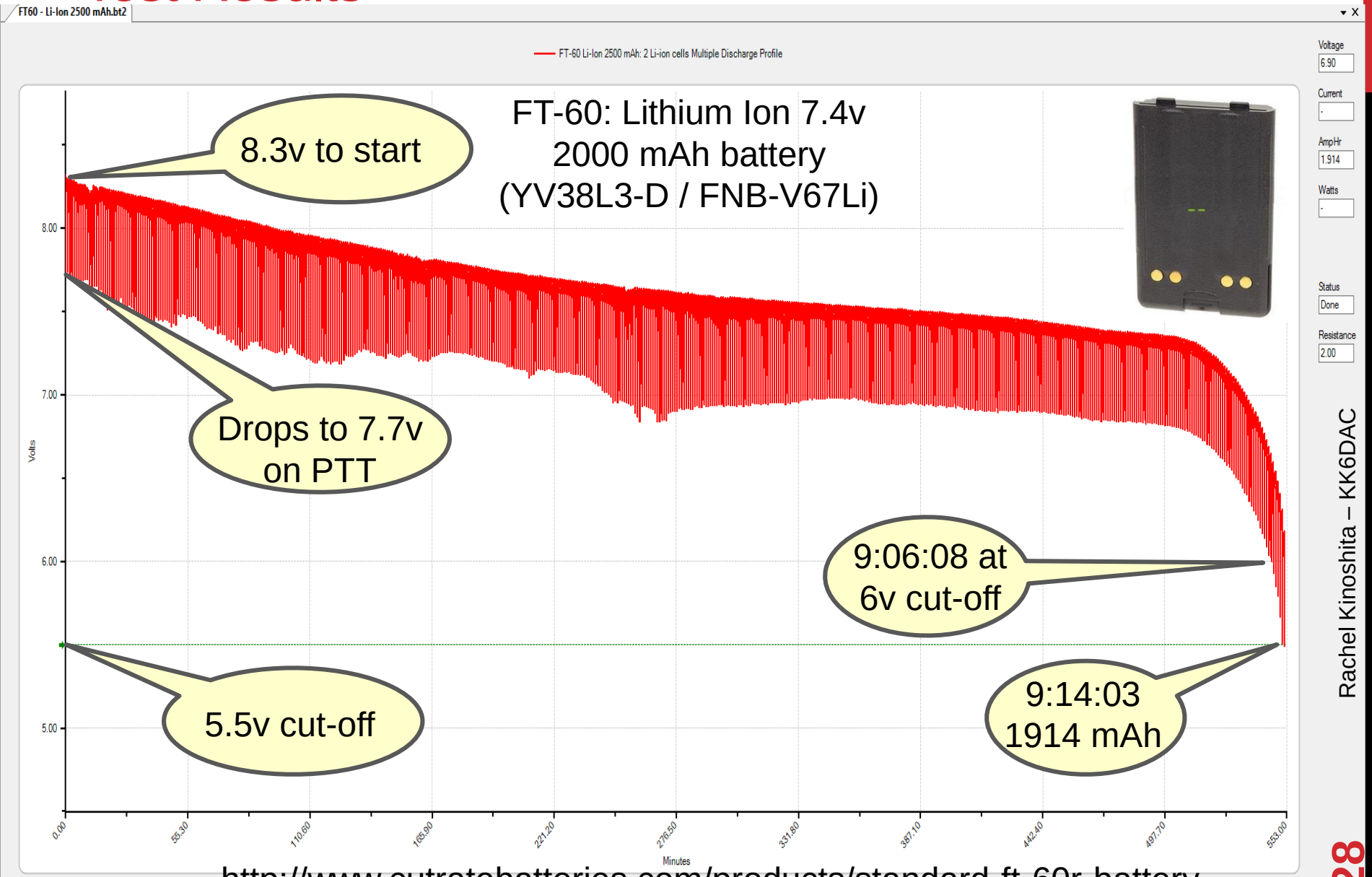
Test Results



http://www.cutratebatteries.com/products/standard-ft-60r-battery

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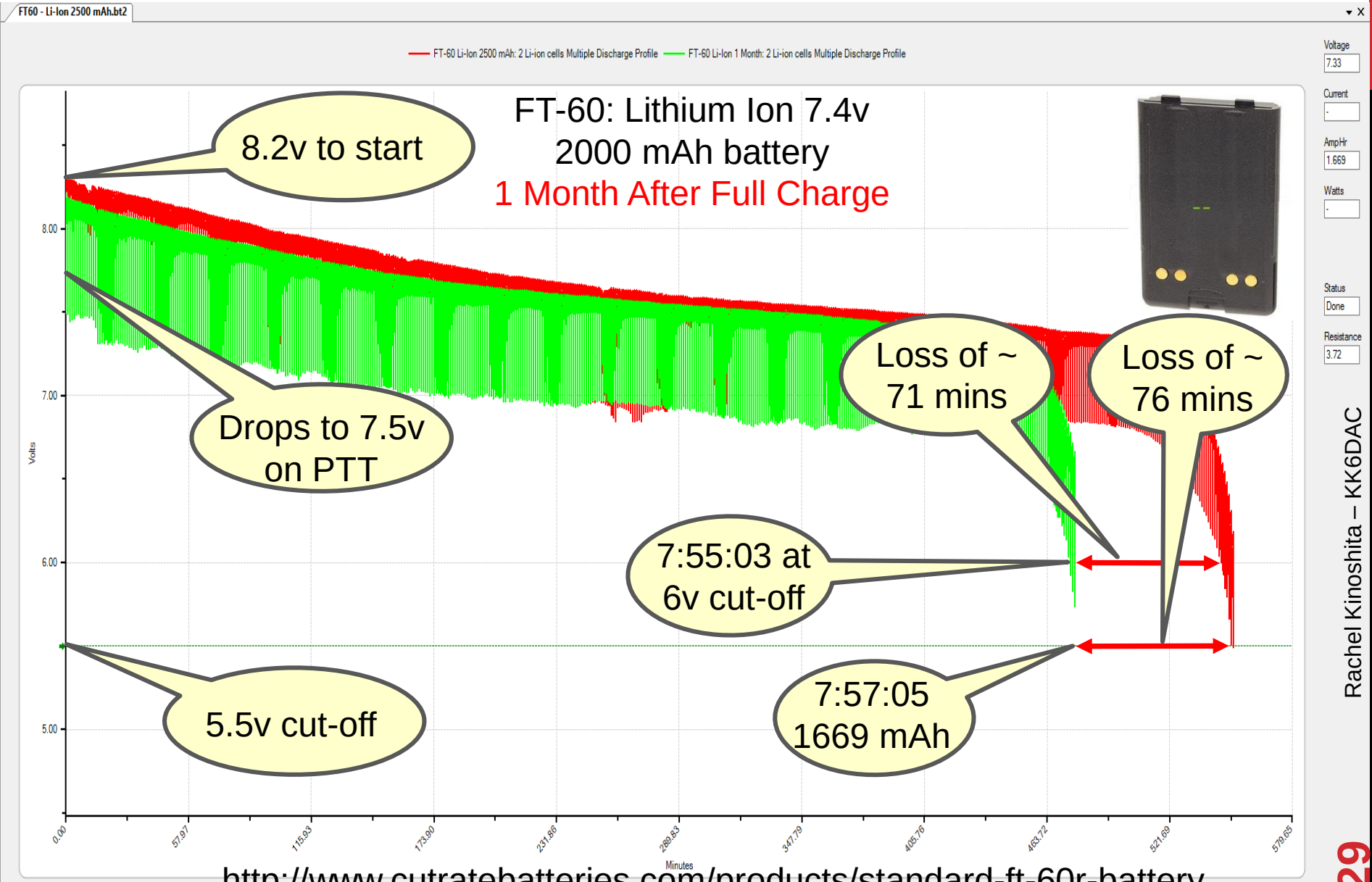
Test Results



http://www.cutratebatteries.com/products/standard-ft-60r-battery

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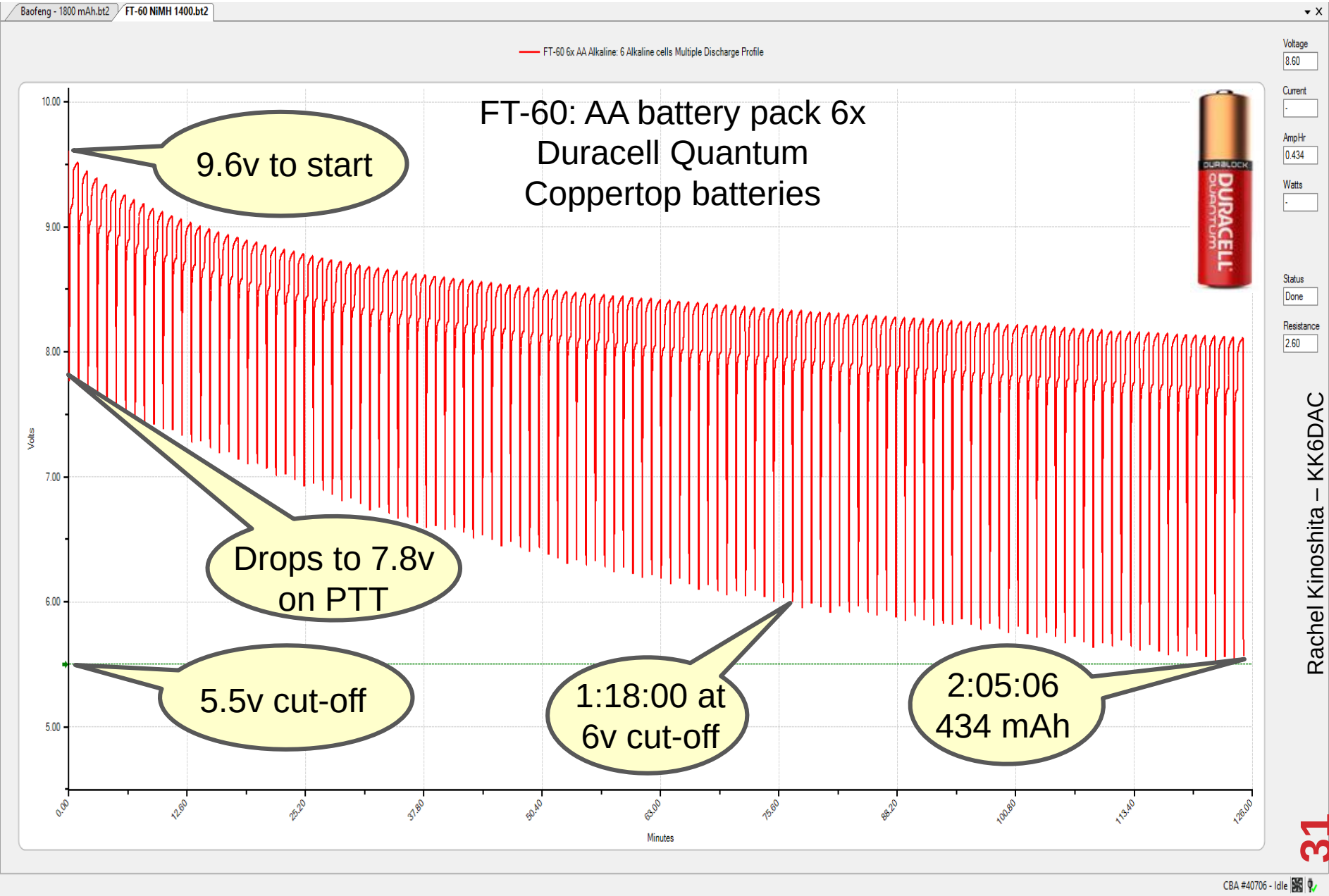
Test Results

Yaesu FT-60 Operating Manual – Page 10

Installation of FBA-25 Alkaline Battery Case

*“Note that the power output and battery life will be **much shorter** when using Alkaline AA cells. They should be considered an emergency backup power source only, for this reason”*

Test Results



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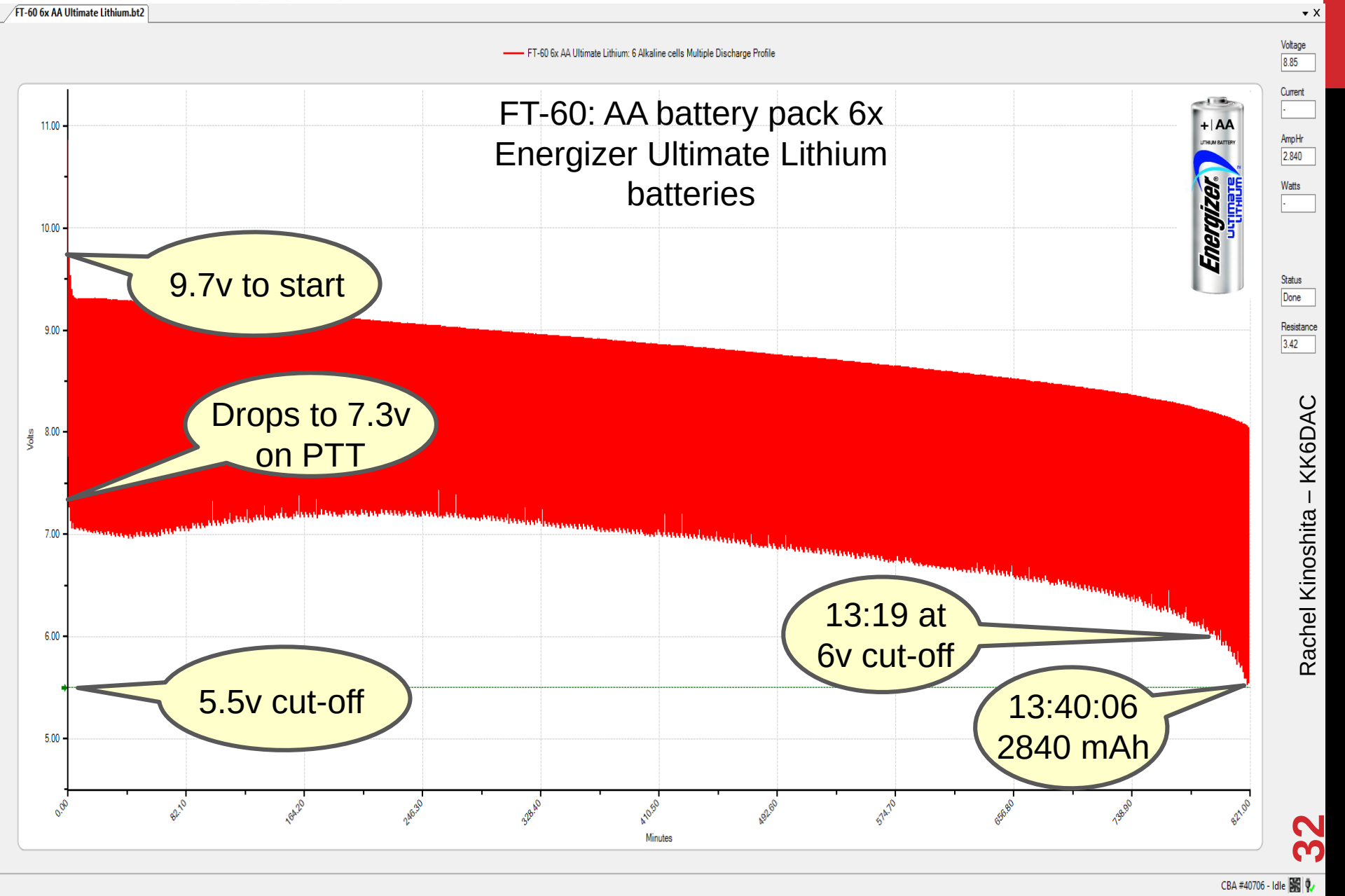
CBA #40706 - Idle

Test Results



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Test Results

61 alkaline batteries / $43.00 / 57.36 oz (3.5 lbs)

=

$9.00 / 3 oz

Alkaline: 1:18 to 6v
Lithium : 13:19 to 6v

Lithiums last 10.24x longer than Alkalines

10.24 x 6 batteries = 61

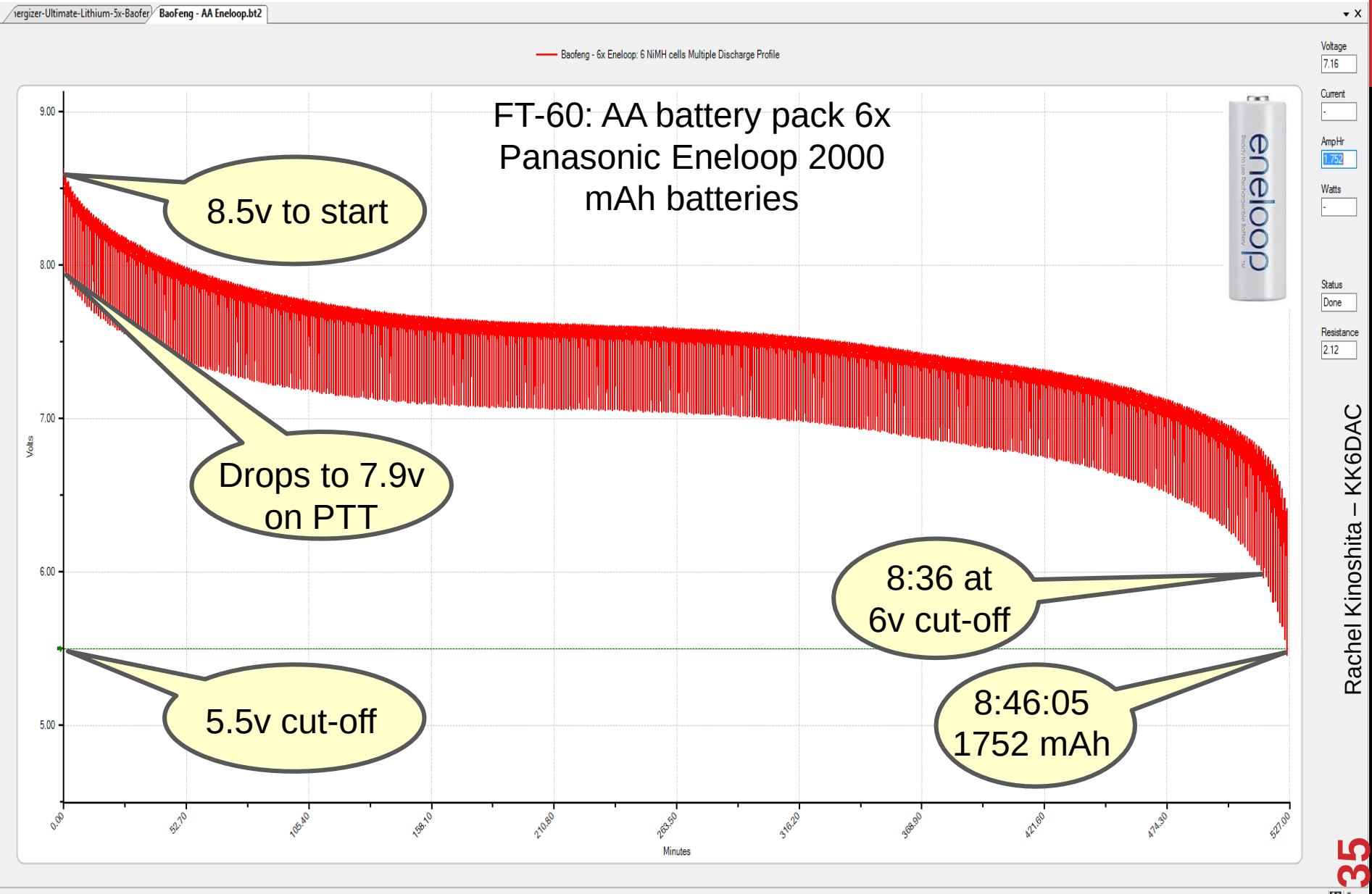
Test Results

Yaesu FT-60 Operating Manual – Page 10

Installation of FBA-25 Alkaline Battery Case

“The **FBA-25A** must not be used with rechargeable cells. The **FBA-25A** does not contain the thermal and over-current protection circuits (provided in the "FNB" series of Ni-MH Battery Packs) required when utilizing Ni-Cd or Ni-MH cells.”

Test Results



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CBA #40706 - Idle

Test Results

40 alkaline batteries / $27.77 / 37 oz (2.3 lbs)

=

$12.00 / 2.7 oz

Alkaline: 1:18 to 6v
NiMH: 8:36 to 6v

NiMHs last 6.62x longer than Alkalines

6.62 x 6 batteries = 39.7

Test Results

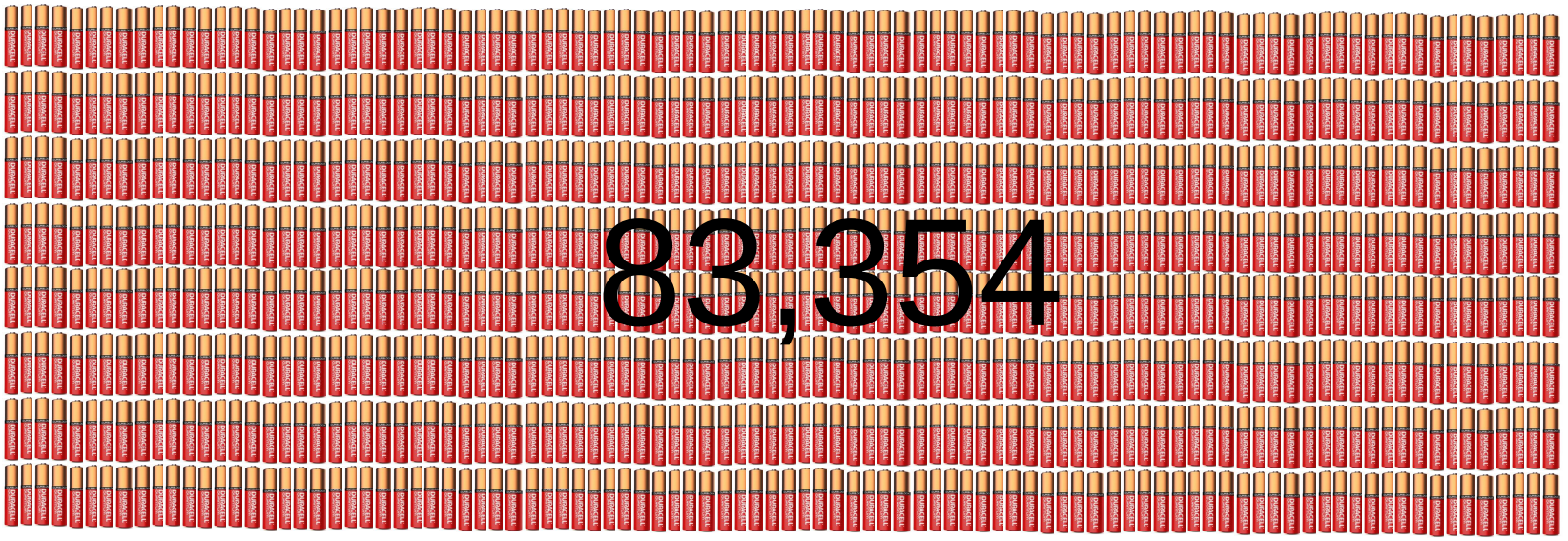
40 alkaline batteries / $27.77 / 37 oz (2.3 lbs)

But wait, the Eneloop's are rechargeable up to 2100 times

$12.00 / 2.7 oz

Test Results

$58,320 / 2.43 tons



=

$12.00 / 2.7 oz
(plus $50.40 to recharge then 2100 times)

- **It takes 20Wh or 0.02 kWh to charge one Eneloop**
- **All six would take 0.12 kWh**
- **We pay an average of $0.20 per kWh**
- **Charging all six batteries costs less than 2 ½ ¢**
- **To recharge them 2100 times would cost $50.40**

Test Results

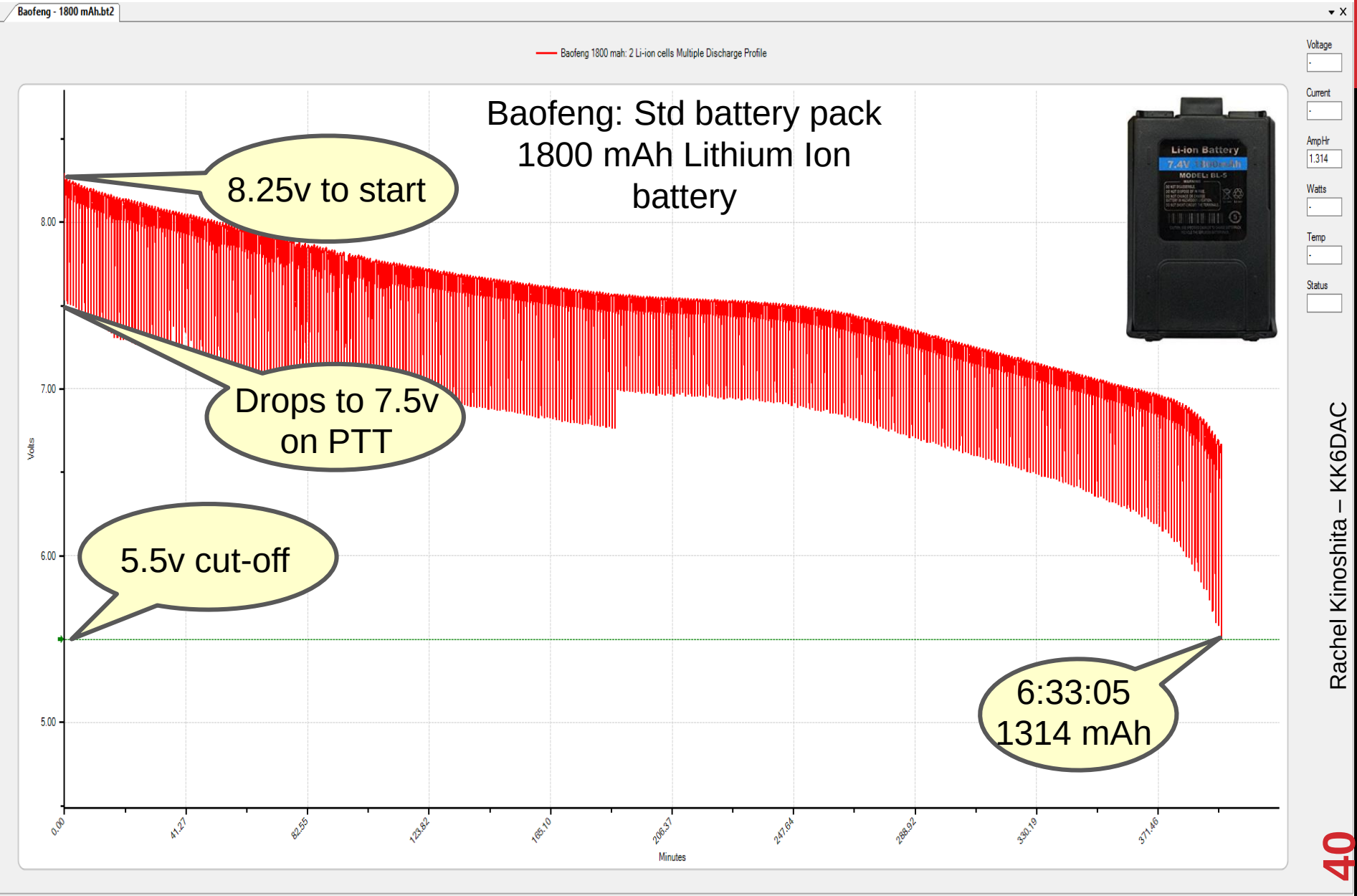
$12,206 / 254 lbs

=

$12.00 / 2.7 oz
(plus $50.40 to recharge then 2100 times)

- **It takes 20Wh or 0.02 kWh to charge one Eneloop**
- **All six would take 0.12 kWh**
- **We pay an average of $0.20 per kWh**
- **Charging all six batteries costs less than 2 ½ ¢**
- **To recharge them 2100 times would cost $50.40**

Test Results



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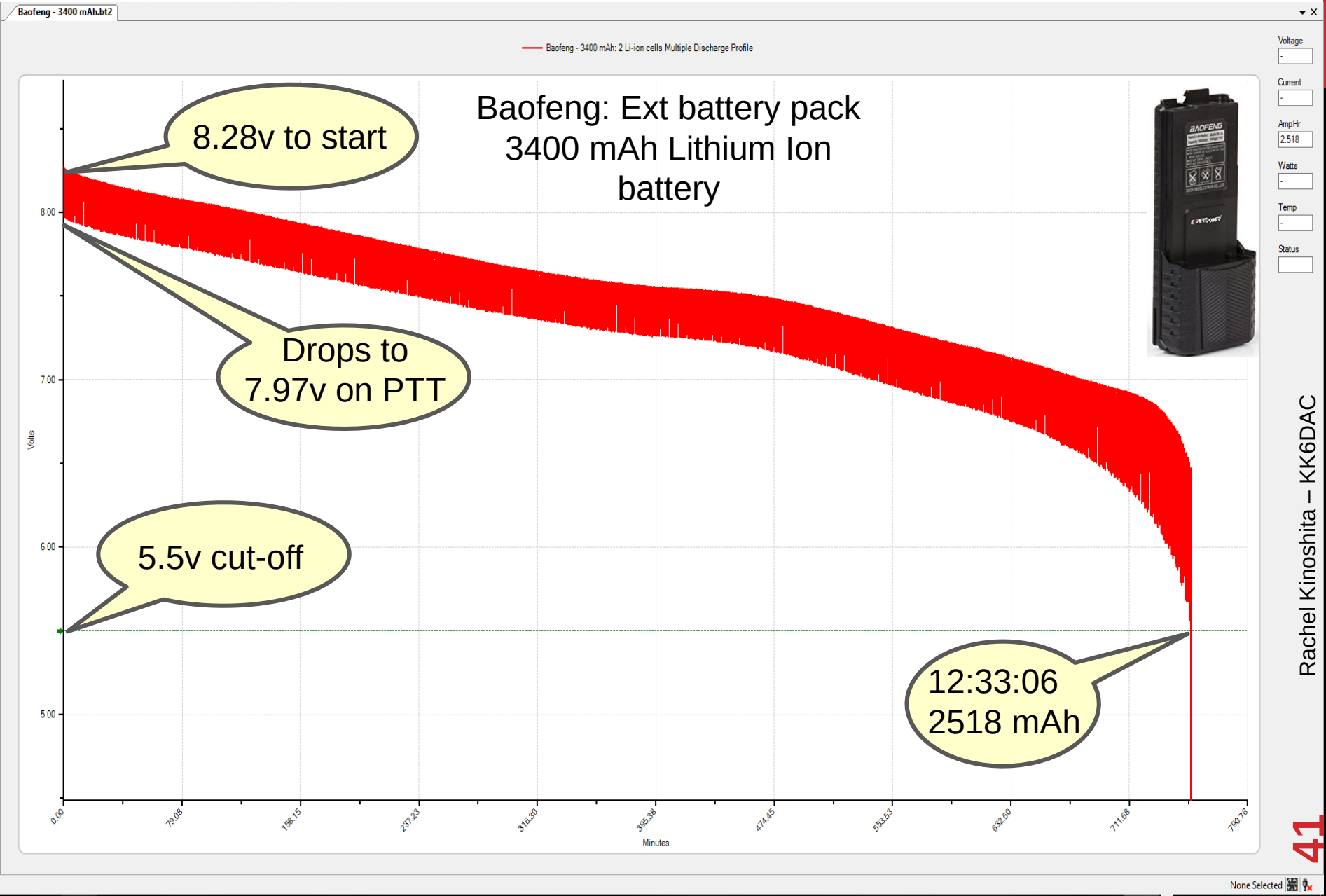
Test Results

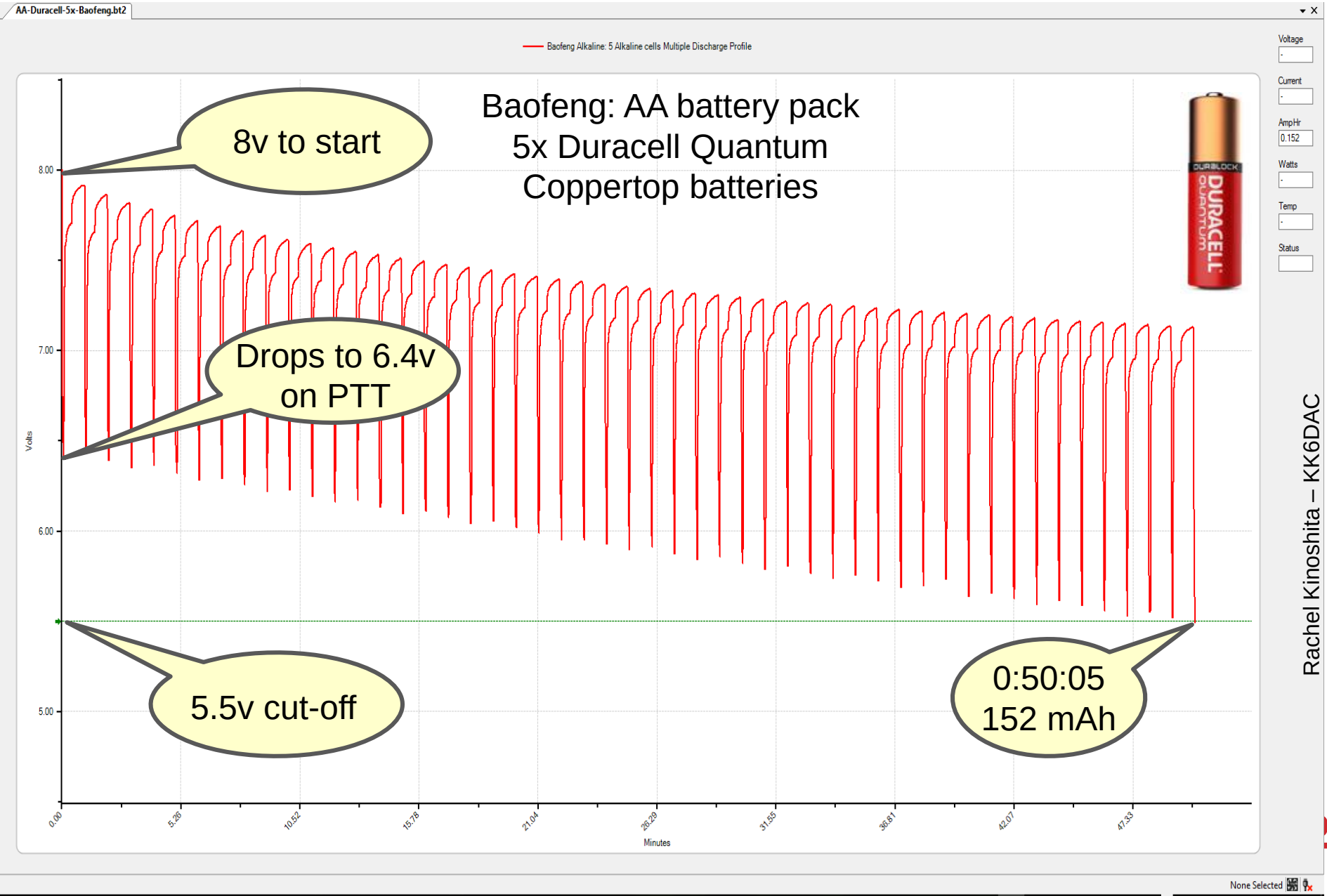


Test Results

Baofeng BL-5 AA Battery Pack
Uses 5x AA alkaline batteries (7.5v) plus an included dummy cell or 6x AA NiMH batteries (7.2v)

Unlike the FT-60 which can handle voltages from 9v to 6v, a Baofeng won't transmit if the battery voltage is higher than about 8v.

Test Results



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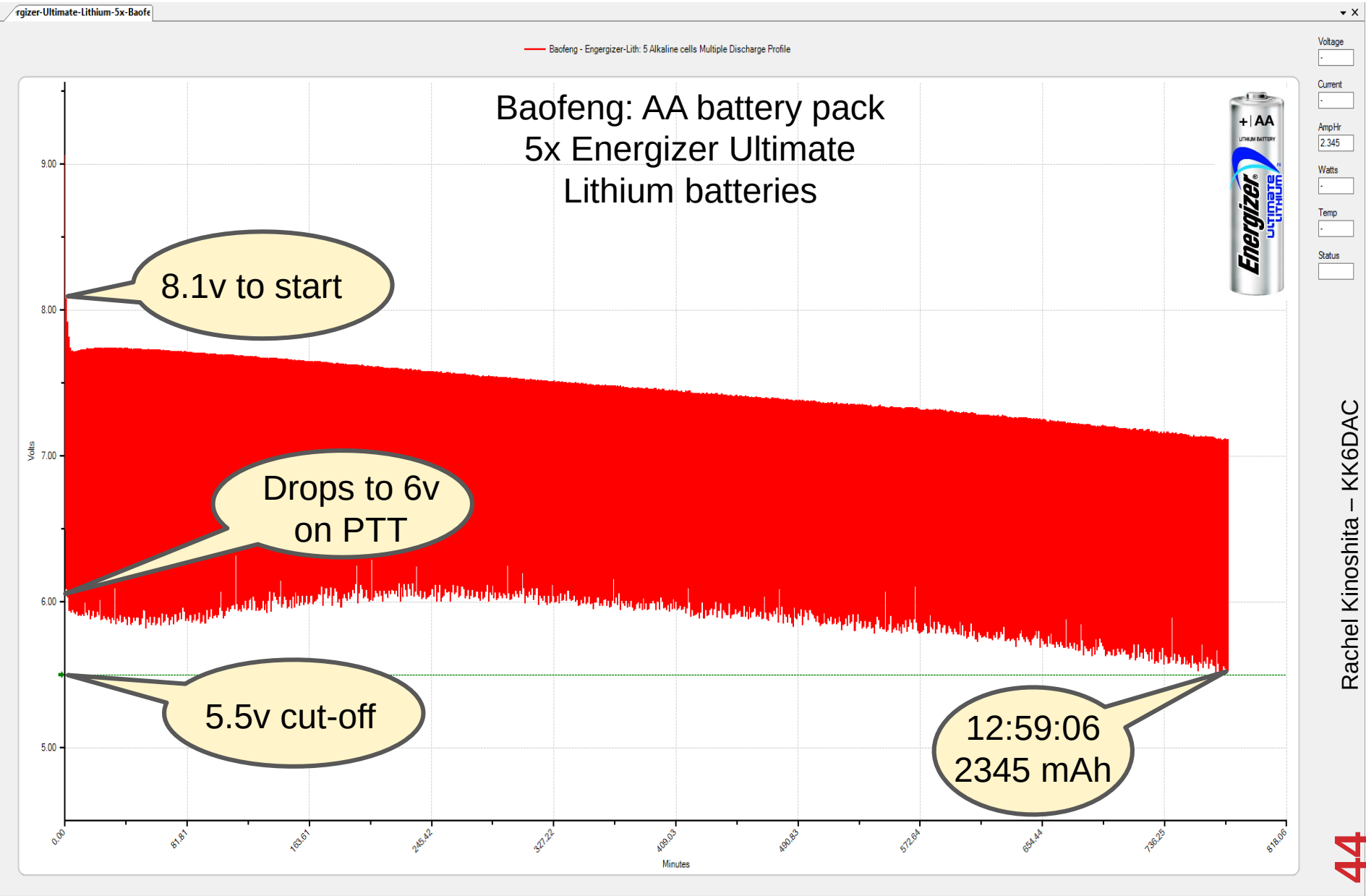
Test Results



Test Results

78 alkaline batteries / $54.60 / 73.32 oz (4.6lbs)

=

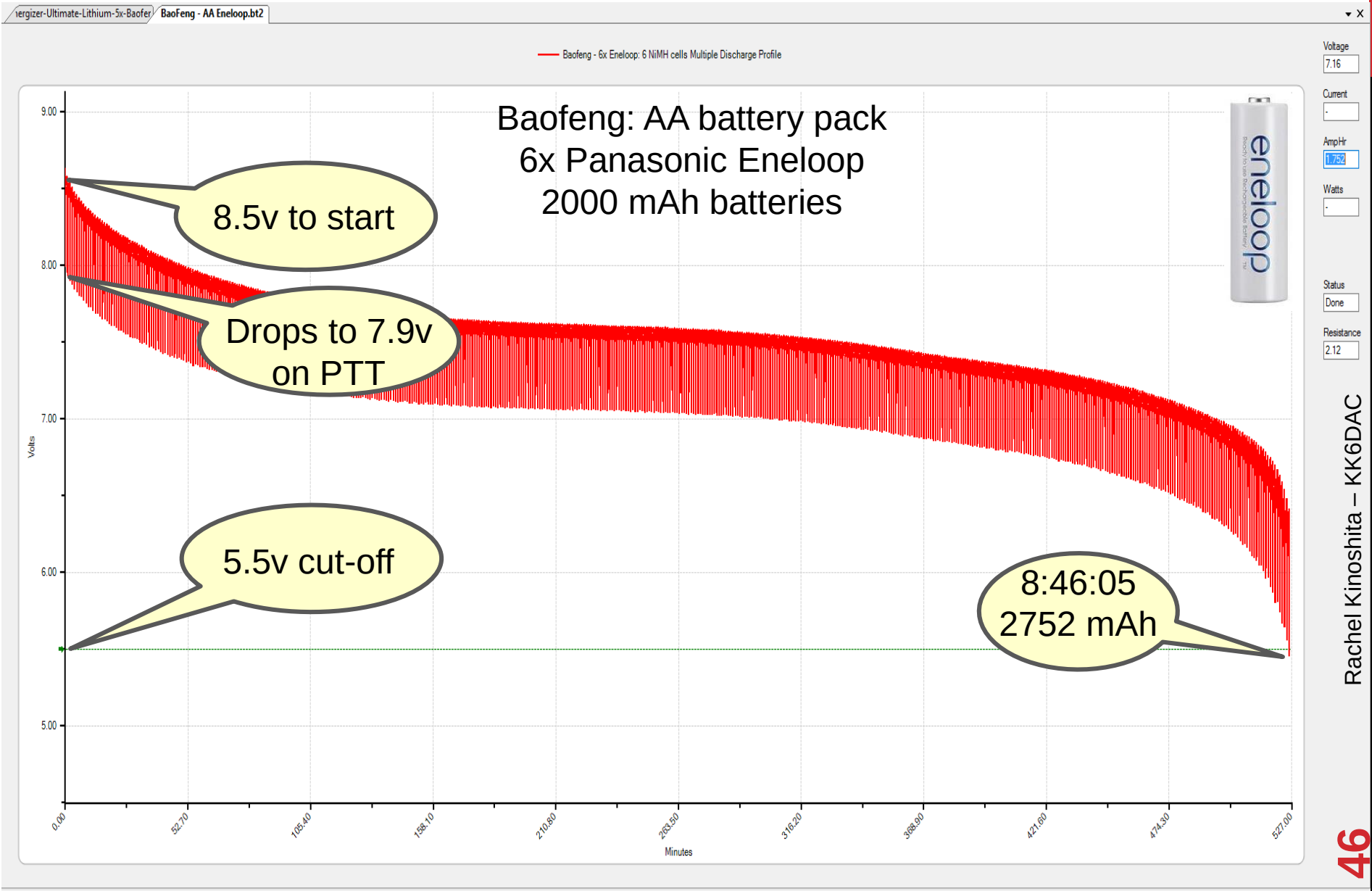
$7.50 / 2.5 oz

Alkaline: 0:50 to 6v
Lithium : 12:59 to 6v

Lithiums last 15.58x longer than Alkalines

15.58 x 5 batteries = 78

Test Results



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Test Results

53 alkaline batteries / $37.10 / 49.82 oz (3.11 lbs)

=

$12.00 / 2.7 oz

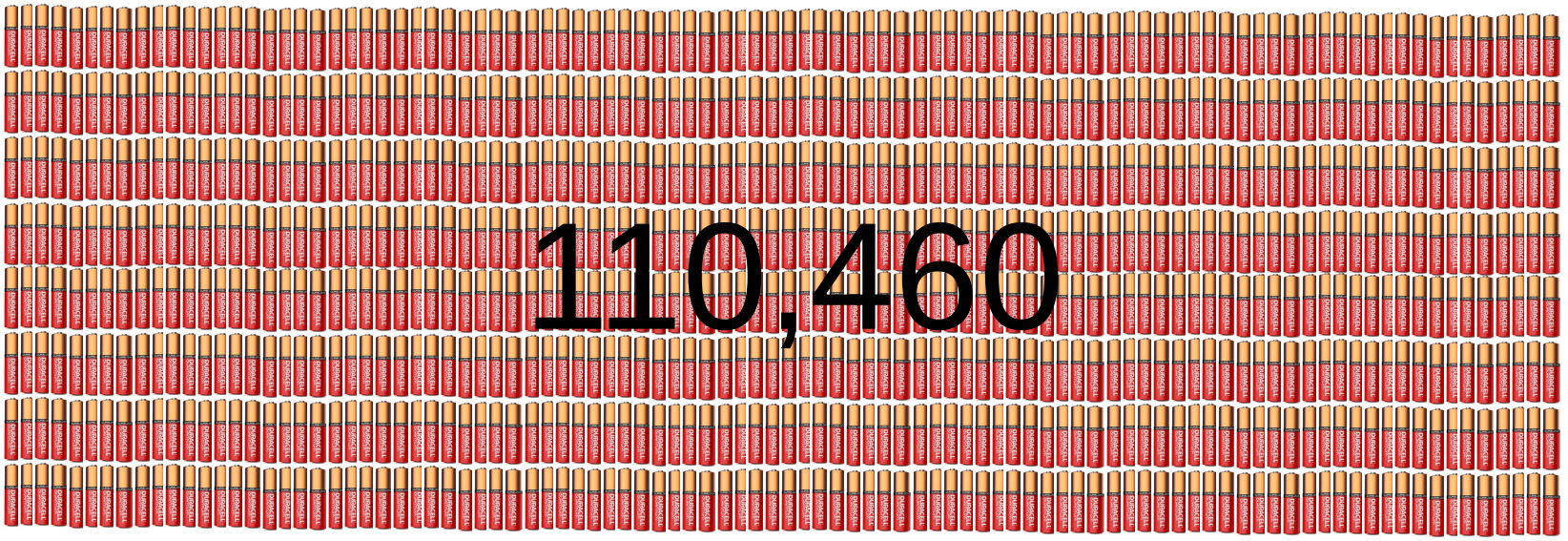
Alkaline: 0:50 to 6v
NiMH: 8:46 to 6v

NiMHs last 10.52x longer than Alkalines

10.52 x 5 batteries = 52.6

Test Results

$77,322 / 3.25 tons



=

$12.00 / 2.7 oz
(plus $50.40 to recharge then 2100 times)

- **It takes 20Wh or 0.02 kWh to charge one Eneloop**
- **All six would take 0.12 kWh**
- **We pay an average of $0.20 per kWh**
- **Charging all six batteries costs less than 2 ½ ¢**
- **To recharge them 2100 times would cost $50.40**

Conclusion

- **Use the highest capacity Li-Ion battery available for your radio**
- **When using the AA adapter**
  - Alkaline batteries are the worst choice. Use as the last resort
  - Energizer Ultimate Lithium batteries are the best choice for single-use batteries
    - Extremely low self-discharge (95% of capacity after 20 years)
    - Handles high current discharge
    - About $1.50 per battery
  - Panasonic Eneloop batteries are the best choice for rechargeable batteries
    - Relatively low self-discharge (85% of charge after 1 year)
    - Can be recharged up to 2100 times
    - Handles high current discharge
    - About $2.00 per battery
    - ***Never charge from the radio***

Small Battery Chargers

- **Maha PowerEx MH-C808M**
  - Can charge any combination of 8 AAA, AA, C, D (MaHa MH-C801D or MH-C800S if you only want to charge AA and AAA)
  - Fast and slow charge mode
  - Requires 120vac
- **NiteCore D4**
  - Can charge any combination of 4 **AA, AAA**, AAAA, C, 26650, 22650, **18650**, 17670, 18490, 17500, 18350, 16340, 14500, 10440
  - Can charge from either 120vac or 12vdc (adapter included)
- **Xtar Dragon VP4**
  - Can charge any combination of 4 AAAA, **AAA, AA**, A, SC, C, D, 10440, 14500, 14650, 16340, 17335, 17500, 17670, 18350, 18490, 18500, **18650**, 22650, 2550, 26650, 32650
  - 0.5a to 2.0a charging modes
  - Can charge from either 120vac or 12vdc (adapter included)

12v Batteries

- **Why 12v batteries**
  - Mobile radios
  - Recharge HT radios, mobile phones, tablets, laptops, rechargeable batteries, lighting, television, etc
  - Easy to charge from solar or from your car
- **Lots of different size batteries available from small 7Ah sealed lead acid (SLA) to large 100+Ah absorbed glass mat (AGM)**
- **Different chemistries available include lead acid, lithium iron phosphate (LiFePO4), Lithium-Ion…you can even make a 12v battery from alkaline or NiMH batteries**
- **Amp Hour Measurement is typically at 20 hours**
  - Peukert Effect
  - As the discharge amps increase, the batteries available capacity decreases

Batteries

- **Capacity (Amp Hour Rating)**
  - How many amps can be delivered over a period of time before the battery is completely dead

CAPACITY [B] Amp-Hours (AH) Trojan Group 27 - 100 AH AGM Battery				ENERGY (kWh)
5-Hr Rate 15.4 amps	10-Hr Rate 8.2 amps	20-Hr Rate 4.45 amps	100-Hr Rate 1 amp	100-Hr Rate
12 VOLT DEEP CYCLE AGM BATTERY				
77	82	89	99	1.19

Lead Acid

- Flooded (Automobile starter, Maintenance free, Deep cycle, Golf cart batteries)
  - Peukert constant = 1.6

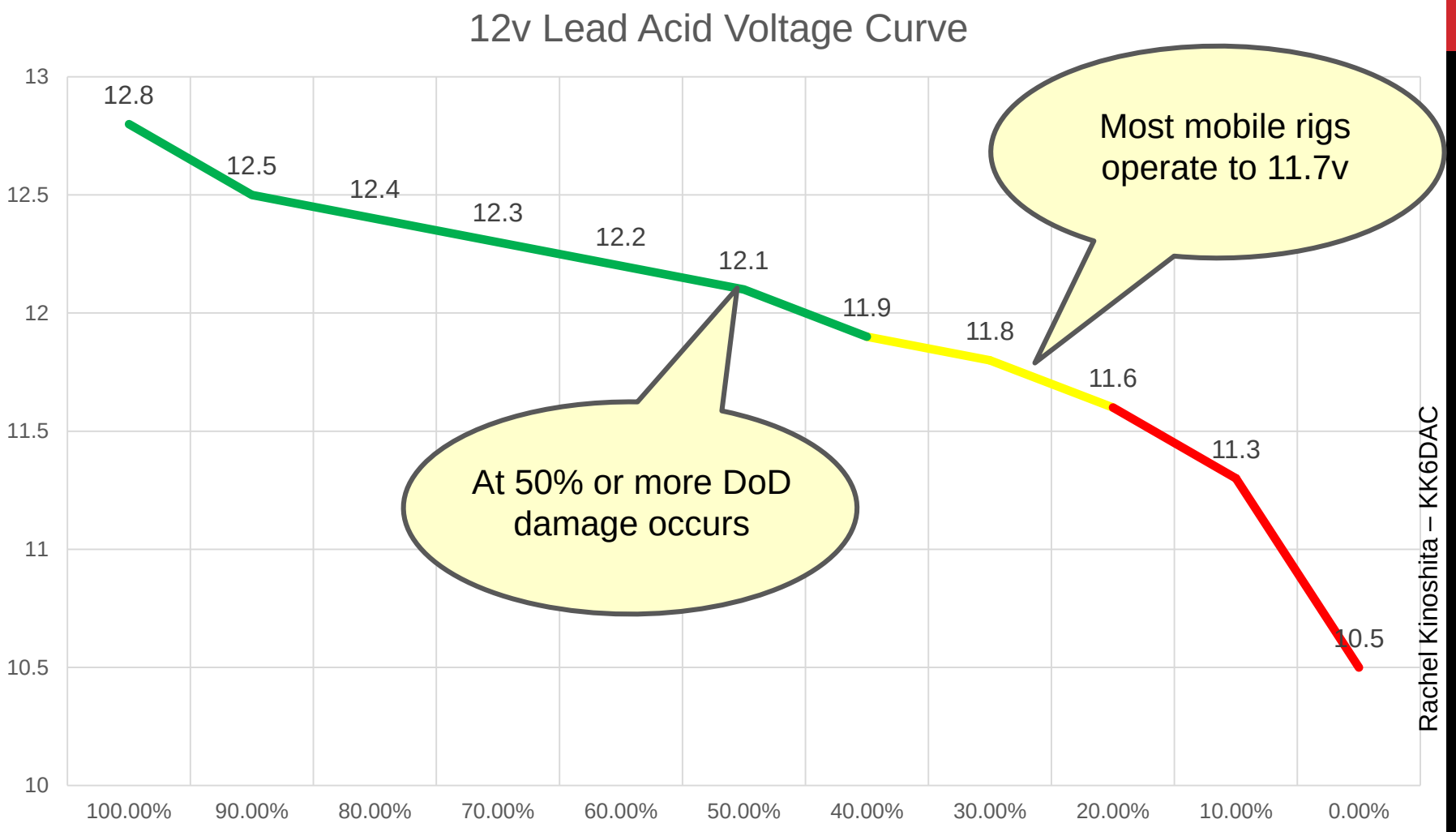
- Sealed Lead Acid
- Gel
  - Peukert constant = 1.25

- Absorbed Glass Matte (AGM)
  - Peukert constant = 1.15

Lead Acid

- **Pros**
  - Flooded (Automobile starter, Maintenance free, Deep cycle, Golf cart batteries)
    - Proven technology
    - Relatively inexpensive
  - Sealed/Gel
    - No outgassing
    - Can be installed in any position
  - Absorbed Glass Matte (AGM)
    - No outgassing
    - Can be installed in any position
    - Relatively long life (5+ years)
- **Cons**
  - Flooded
    - Heavy
    - Outgas
    - Spill hazard
  - Sealed/Gel
    - Heavy
  - AGM
    - Heavy
    - Expensive

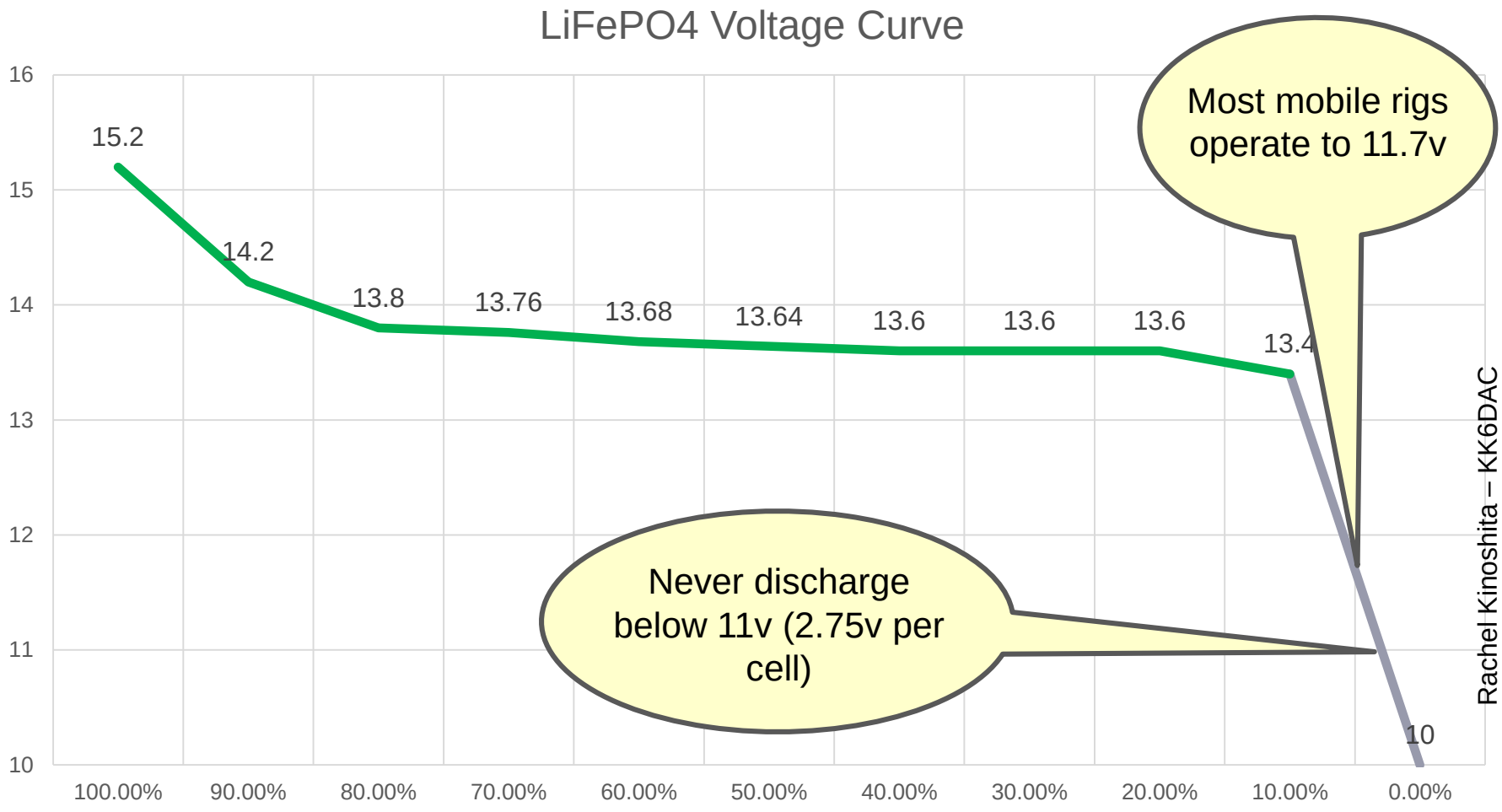
Lead Acid


12v Lead Acid Voltage Curve
13
12.5
12
11.5
11
10.5
10
12.8
12.5
12.4
12.3
12.2
12.1
11.9
11.8
11.6
11.3
10.5
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Most mobile rigs operate to 11.7v
At 50% or more DoD damage occurs
Rachel Kinoshita – KK6DAC

Lithium Iron Phosphate (LiFePo4)

- **Pros**
  - Very low self-discharge
  - Relatively flat discharge curve
  - Can be recharged thousands of times
  - At 3.2vdc per cell, 4 cells in series (4s) has a nominal voltage of 12.8v and max voltage of 14.2v
  - Will not leak
  - No outgassing
  - High energy density
  - Unlike Li-Ion, LiFePO4 is very safe
  - Can be field charged using a lead acid battery charger
  - Peukert constant = 1.01 or less
- **Cons**
  - Expensive
  - Must balance the cells using a proper LiFePO4 charger

Lithium Iron Phosphate (LiFePo4)



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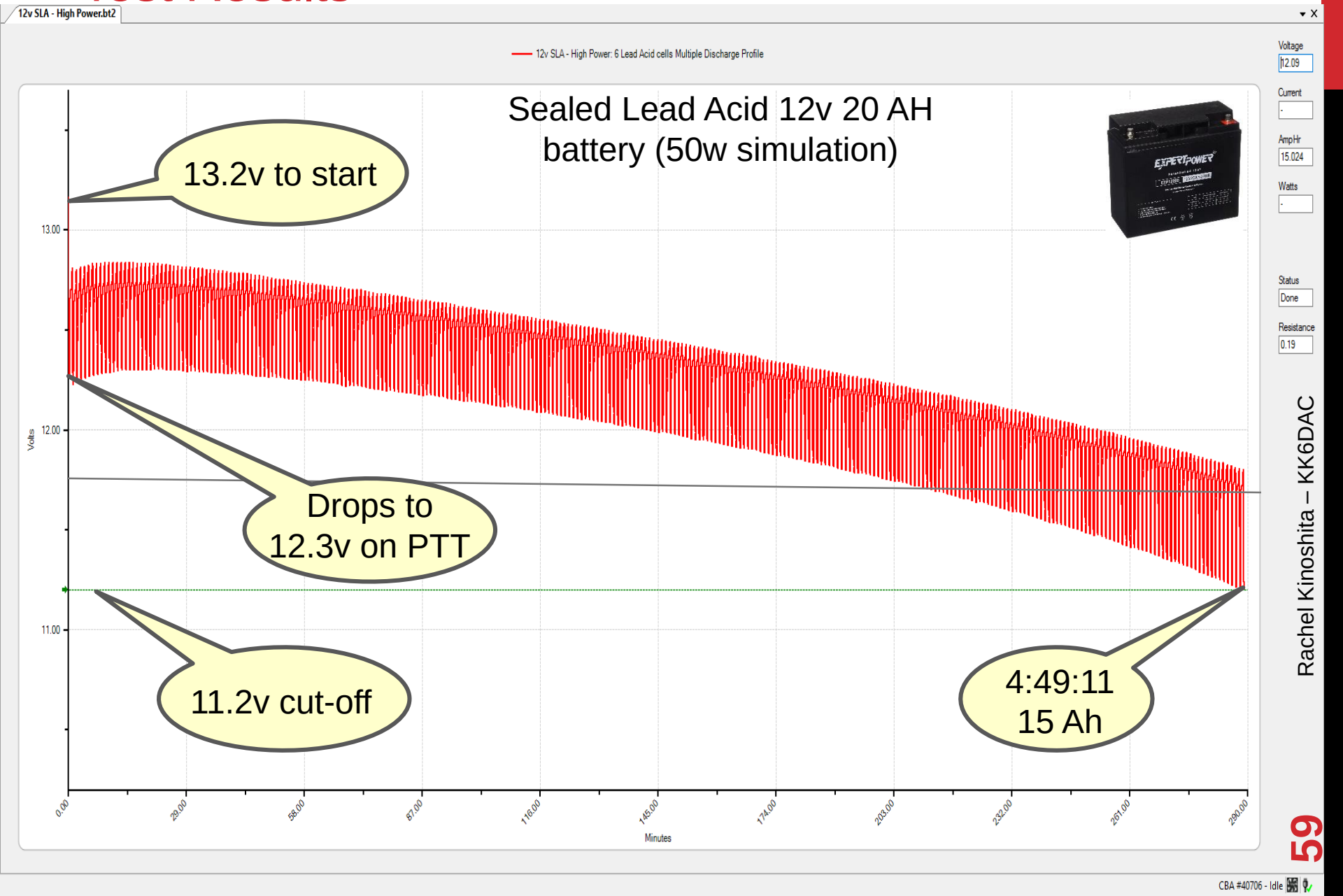
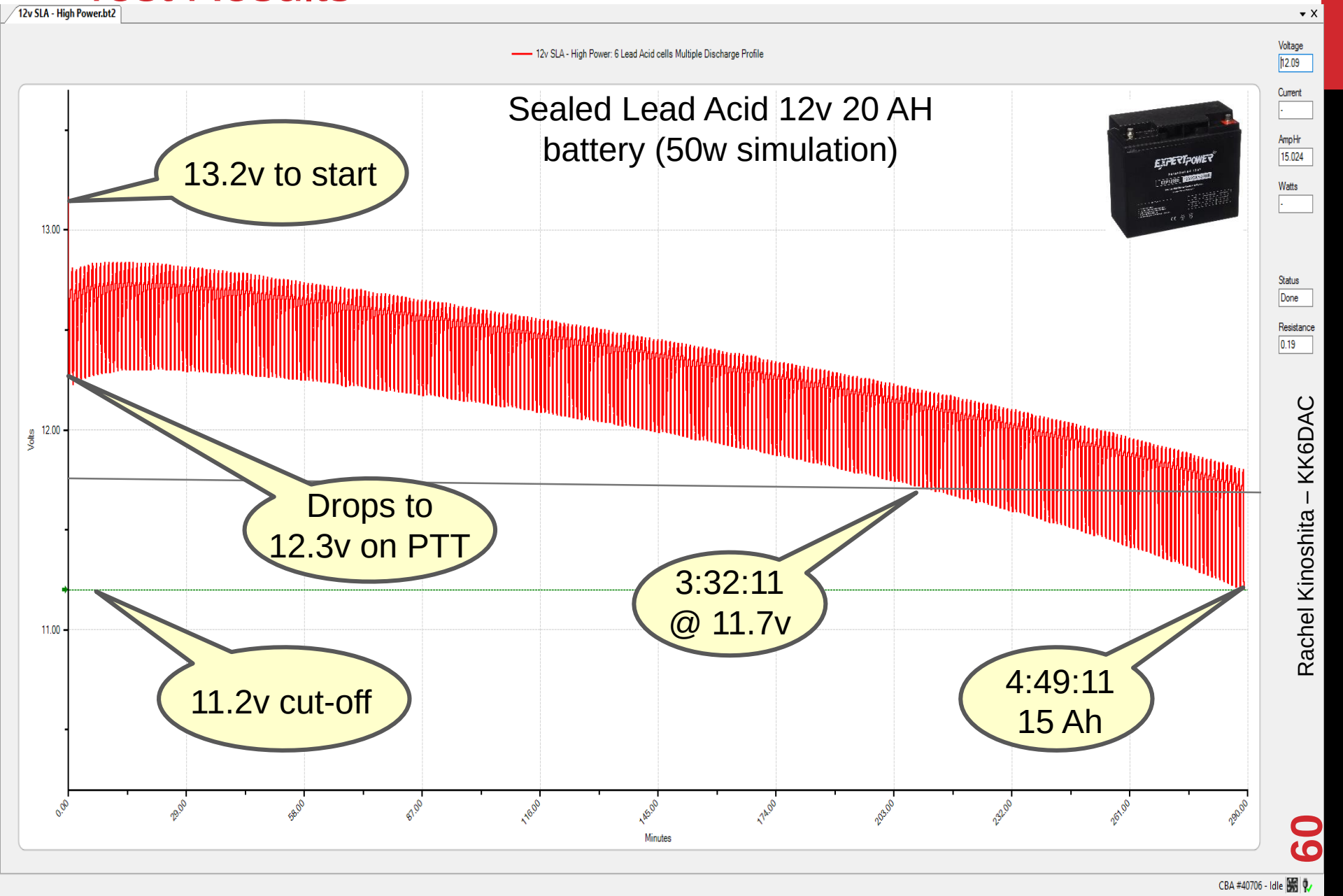
Test methodology

- **Used the Multi-Discharge test using the following settings**
  - Low-Voltage cut-off: 11.2v
  - 1s steps until cut-off voltage is met
  - Three step discharge (simulate 50w transmit)
    - 15s @ 10.3a (transmit)
    - 30s @ 1a (receive)
    - 15s @ 0.1a (idle)
  - Three step discharge (simulate 25w transmit)
    - 15s @ 6.5a (transmit)
    - 30s @ 1a (receive)
    - 15s @ 0.1a (idle)
- **Batteries were fully charged before testing**
- **Sealed Lead Acid battery used was an ExpertPower EXP 12200 12v, 20 Ah purchased on Amazon for $38.00; 12.5 lbs**
- **LiFePO4 battery used was a Bioenno BLF-1220W/A 12v, 20 Ah purchased at Ham Radio Outlet $192.95; 5.5 lbs**

Test Results



Test Results



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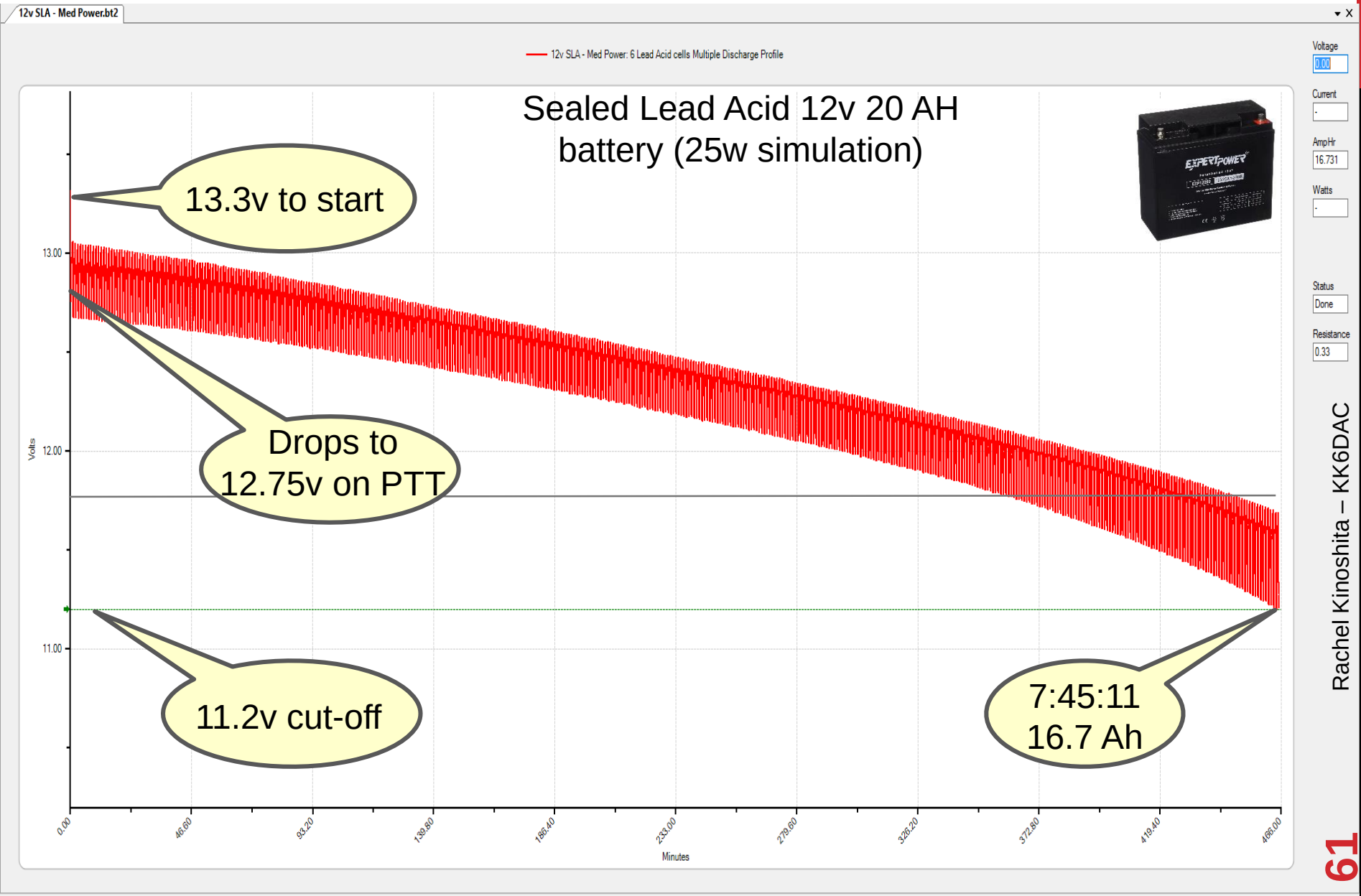
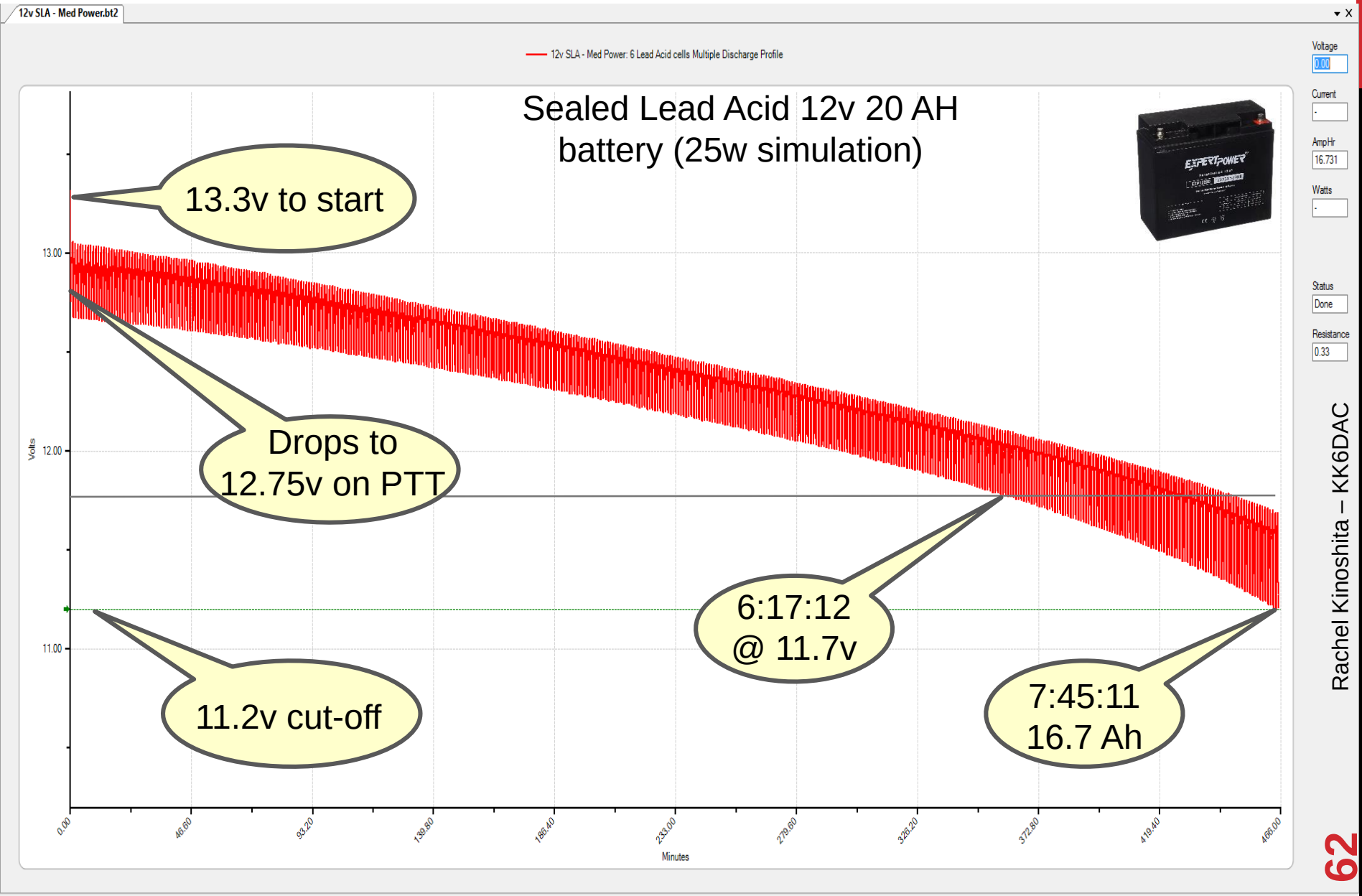
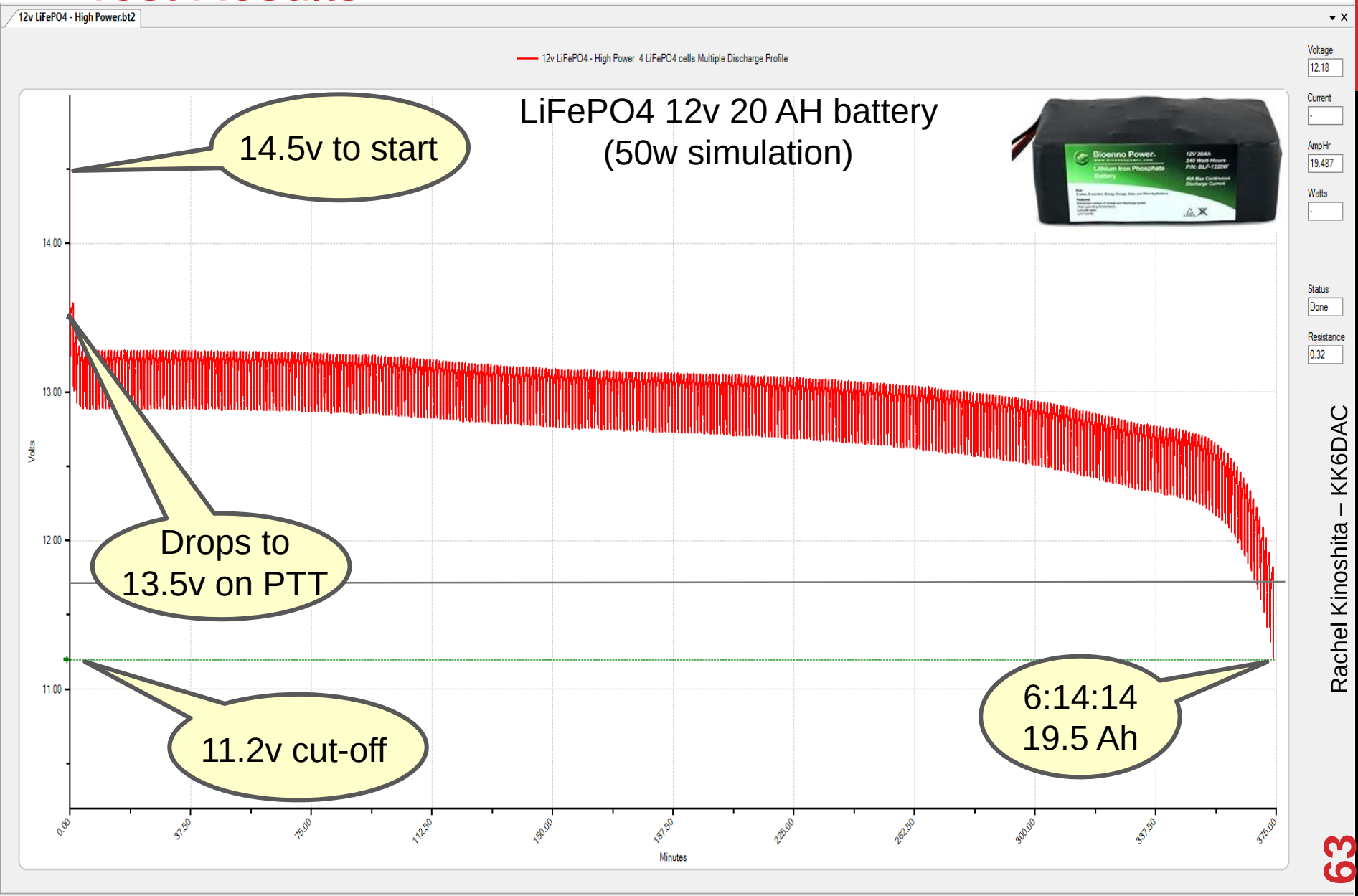
Test Results



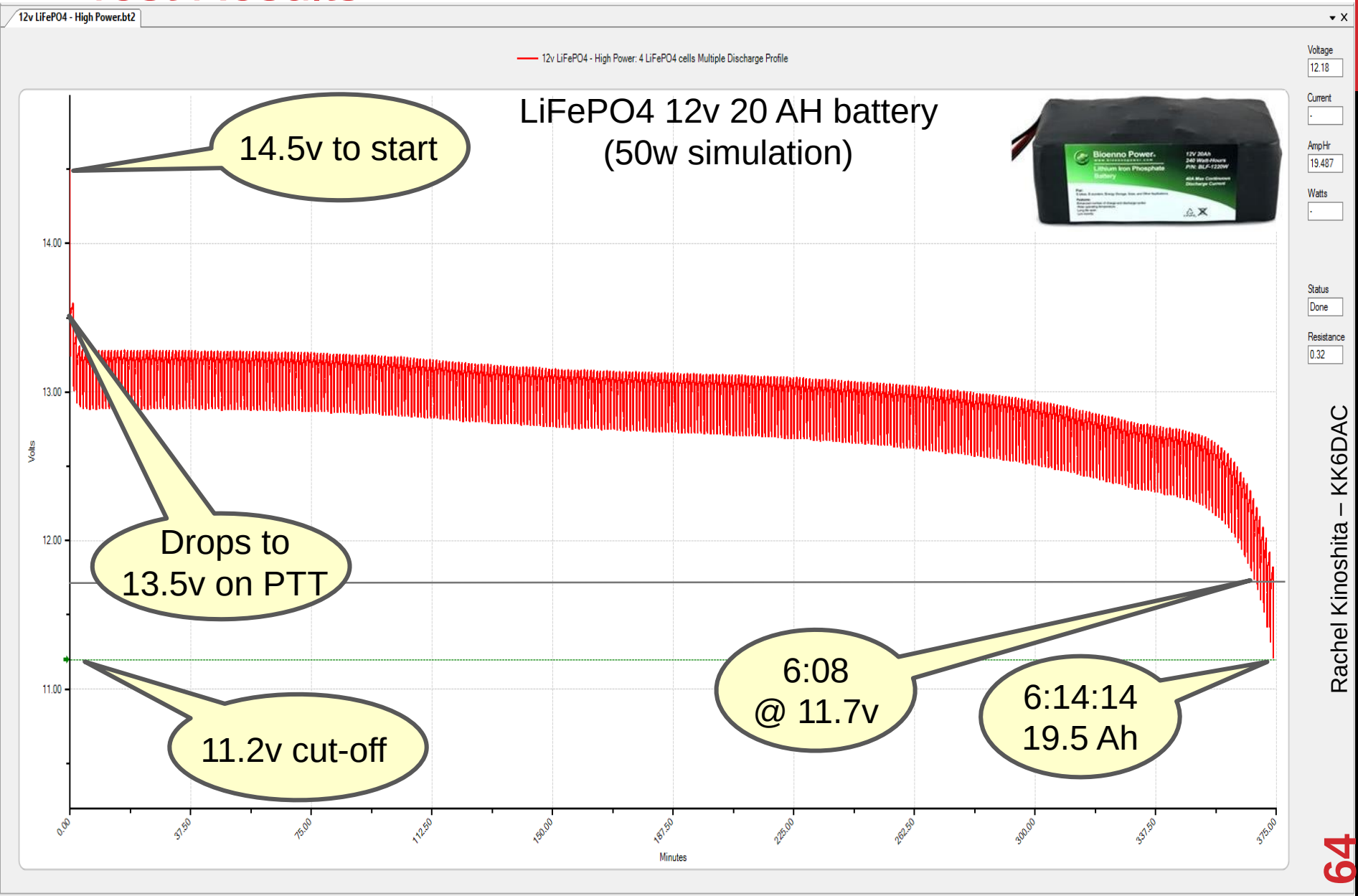
Test Results



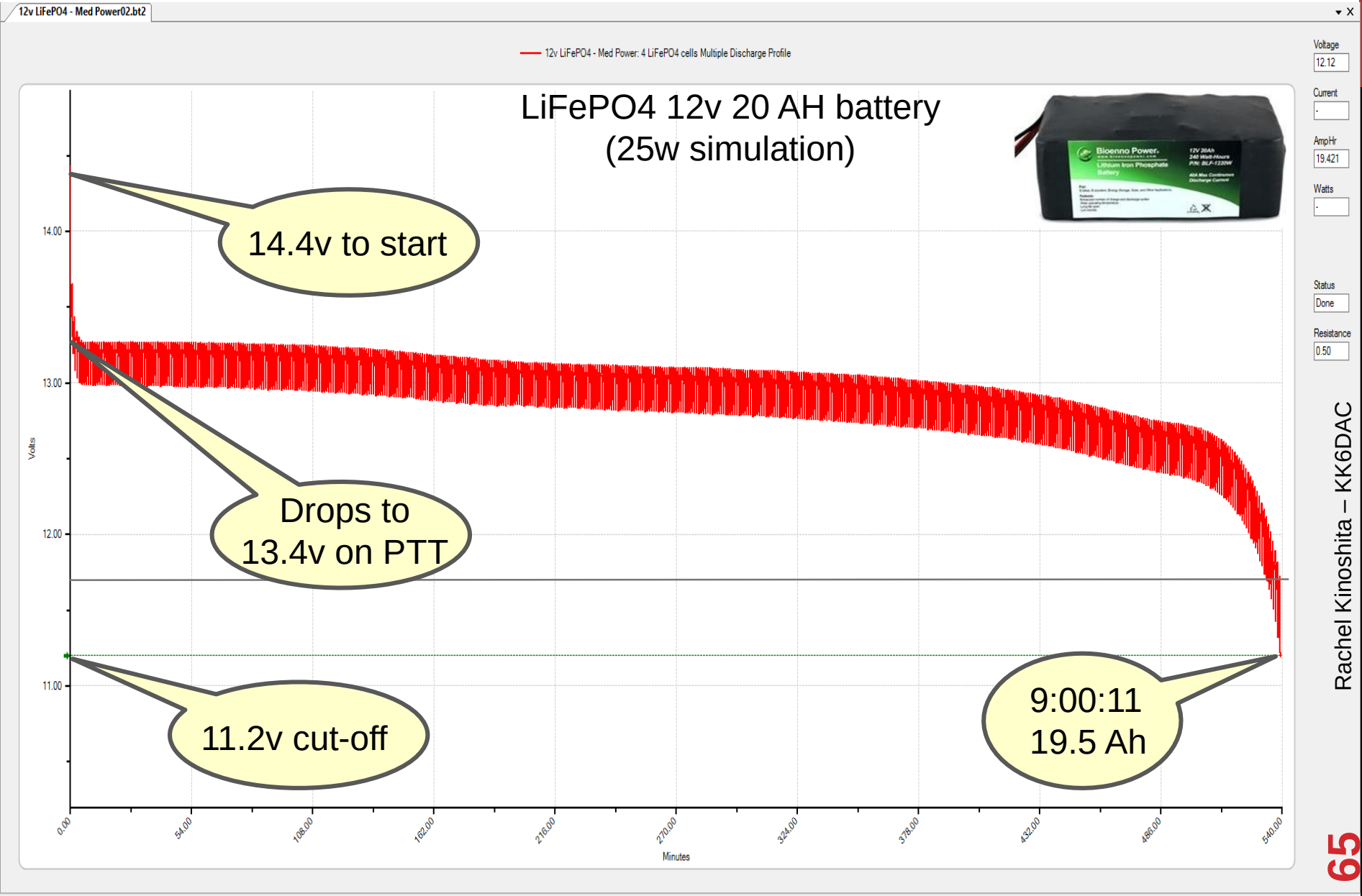
Test Results



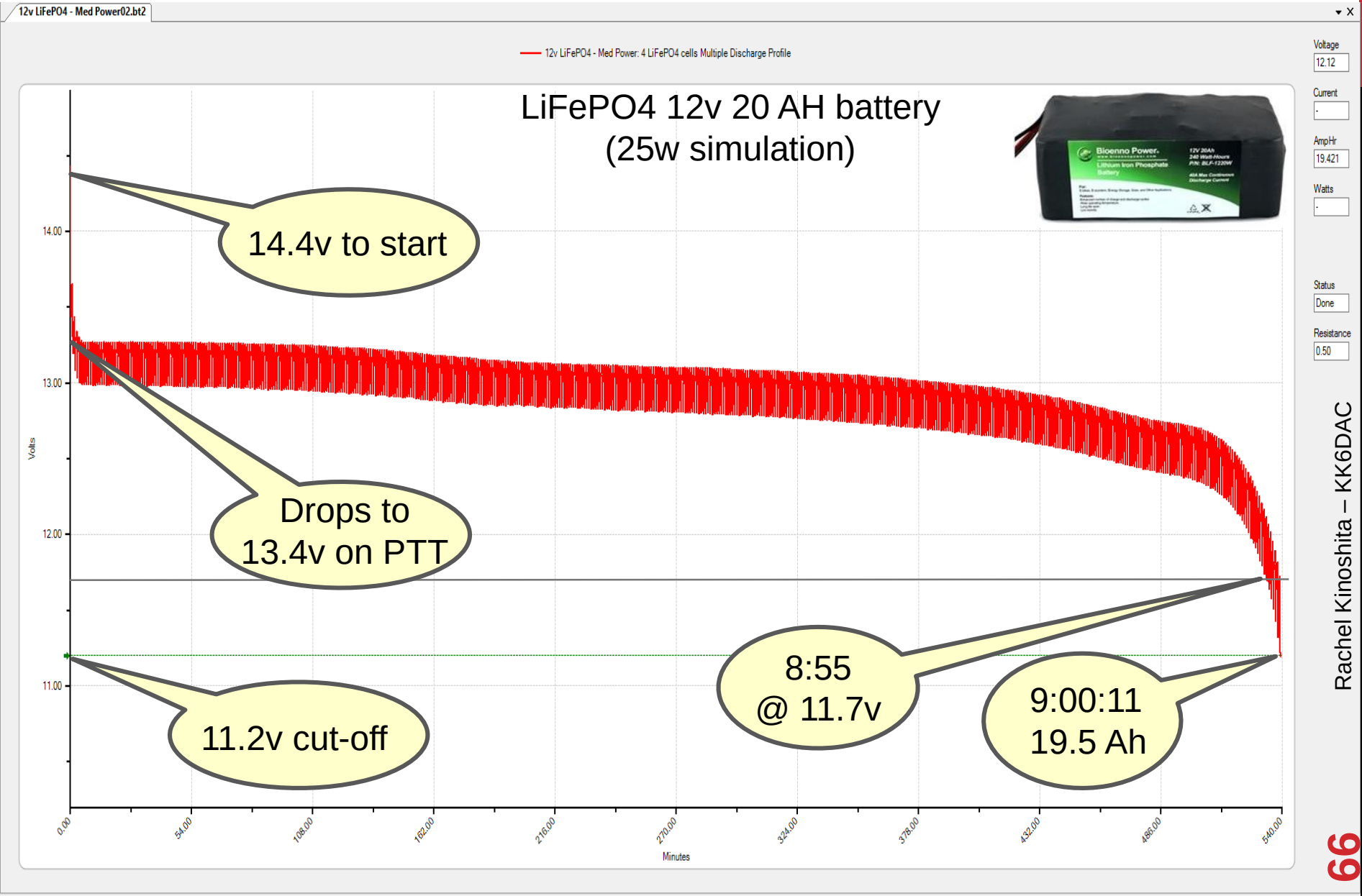
Test Results



Test Results



Test Results



Test Results

$53.00 / 17.5 lbs

3:32	4:49	6:17	7:45	Pb
6:08	6:14	8:55	9:00	LiFePo4
1.74	1.29	1.42	1.16	1.40

=

$192.95 / 5.5 lbs

Test Results

$213.00 / 70.1 lbs

Can be fully recharged up to 500 times

=

Can be fully recharged up to 2000 times

$192.95 / 5.5 lbs

Using Batteries in Emergency Communications

- **Post Katrina, FEMA was left with more trailers than they knew what to do with**

Using Batteries in Emergency Communications

- **The problem was exacerbated because many of the trailers had toxic levels of formaldehyde**

Using Batteries in Emergency Communications

- **In late 2014 / early 2015 the Menlo Fire District acquired a surplus FEMA Katrina trailer**

Using Batteries in Emergency Communications

- **Menlo Fire purchased the CERT trailer to provide a platform for communications during an emergency or disaster**
- **The trailer was outfitted with amateur radios, computers, monitors, a generator, antennas and other accessories necessary to operate**
- **In that configuration it required manual charging of the battery on a regular basis to prevent battery damage due to low voltage**
- **Generators require fuel, regular oil changes and have moving parts which can fail**
- **In a disaster, gasoline for the generator may become a scare resource**
- **Configuring the trailer to run stand-alone with only batteries and PV panels would ensure independent operations during a disaster**

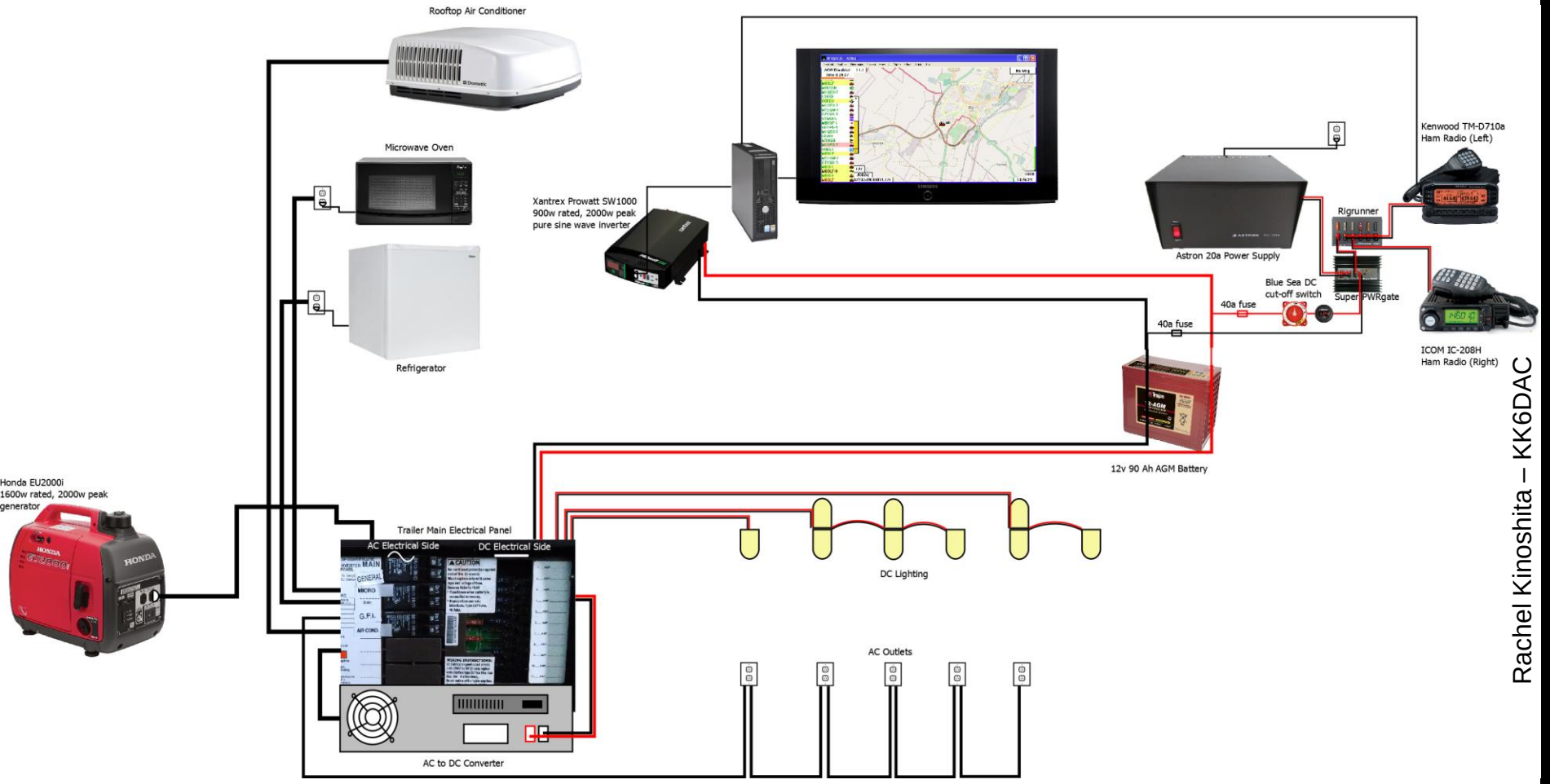
Menlo Park CERT Communications Trailer

Menlo Park CERT Communications Trailer

Menlo Park CERT Communications Trailer

Menlo Park CERT Communications Trailer

Menlo Park CERT Communications Trailer



Menlo Park - Proposed System

- **Batteries will automatically be maintained**
- **Trailer will always be ready to be deployed**
- **Provides sufficient power to run radios, computers and lights for an extended period of time**
- **Reduces or removes dependency on gasoline or propane generator**
- **Designed for growth**

Menlo Park - Proposed System

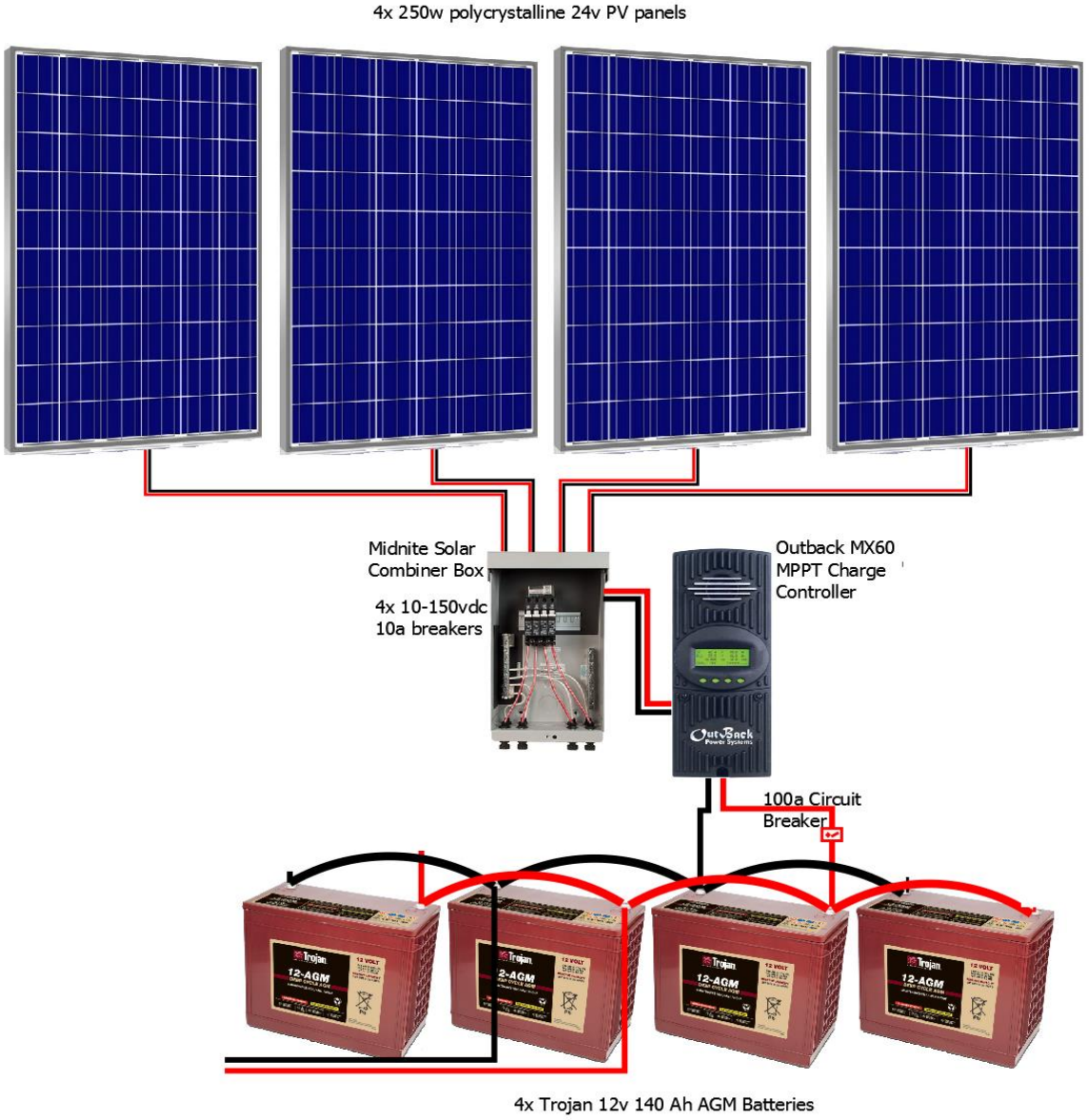
60A MPPT Solar Charge Controller

6 slot Solar Combiner box

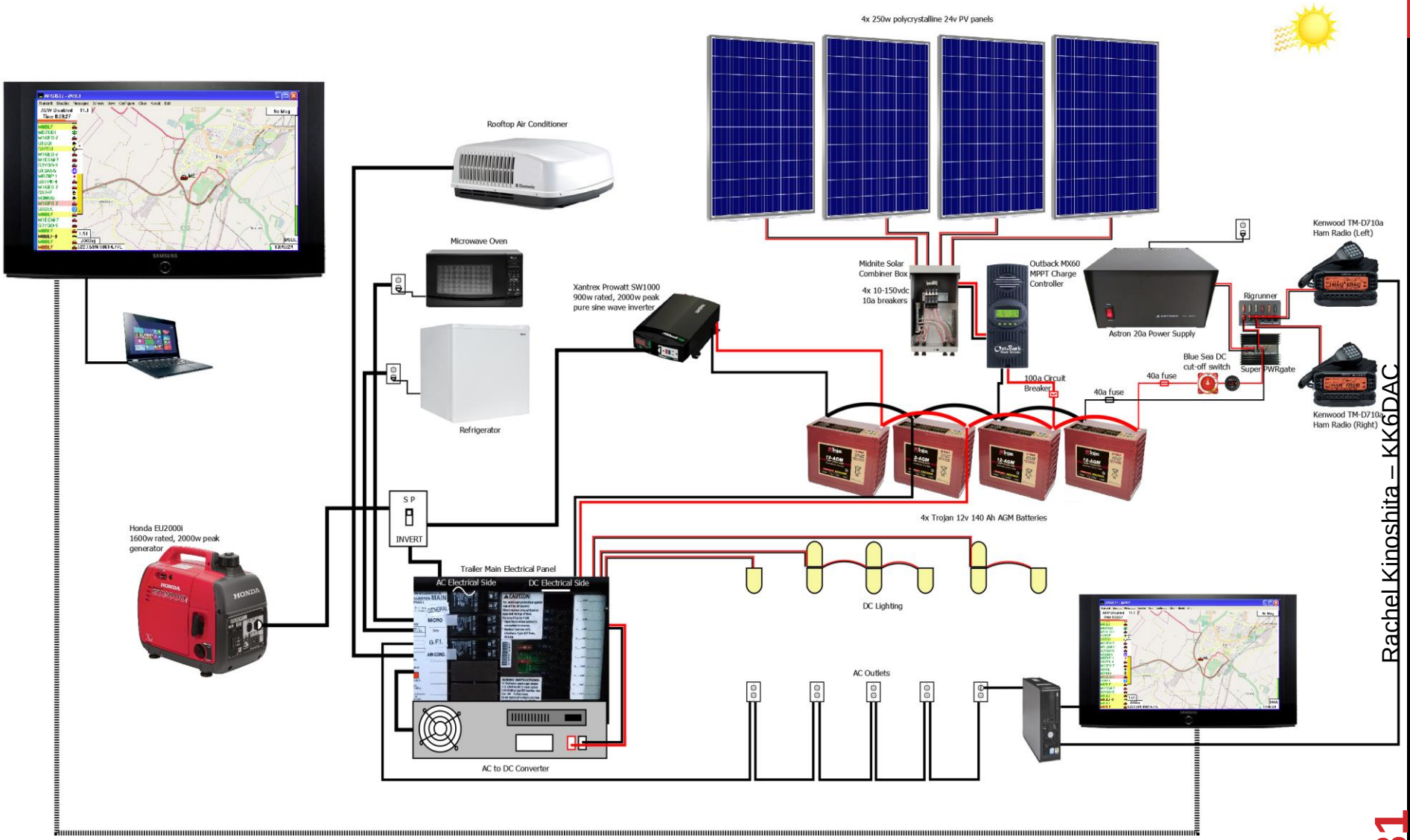
4x 250w PV Panels

4x 140Ah AGM Batteries

Menlo Park – Completed System



Menlo Park CERT Communications Trailer



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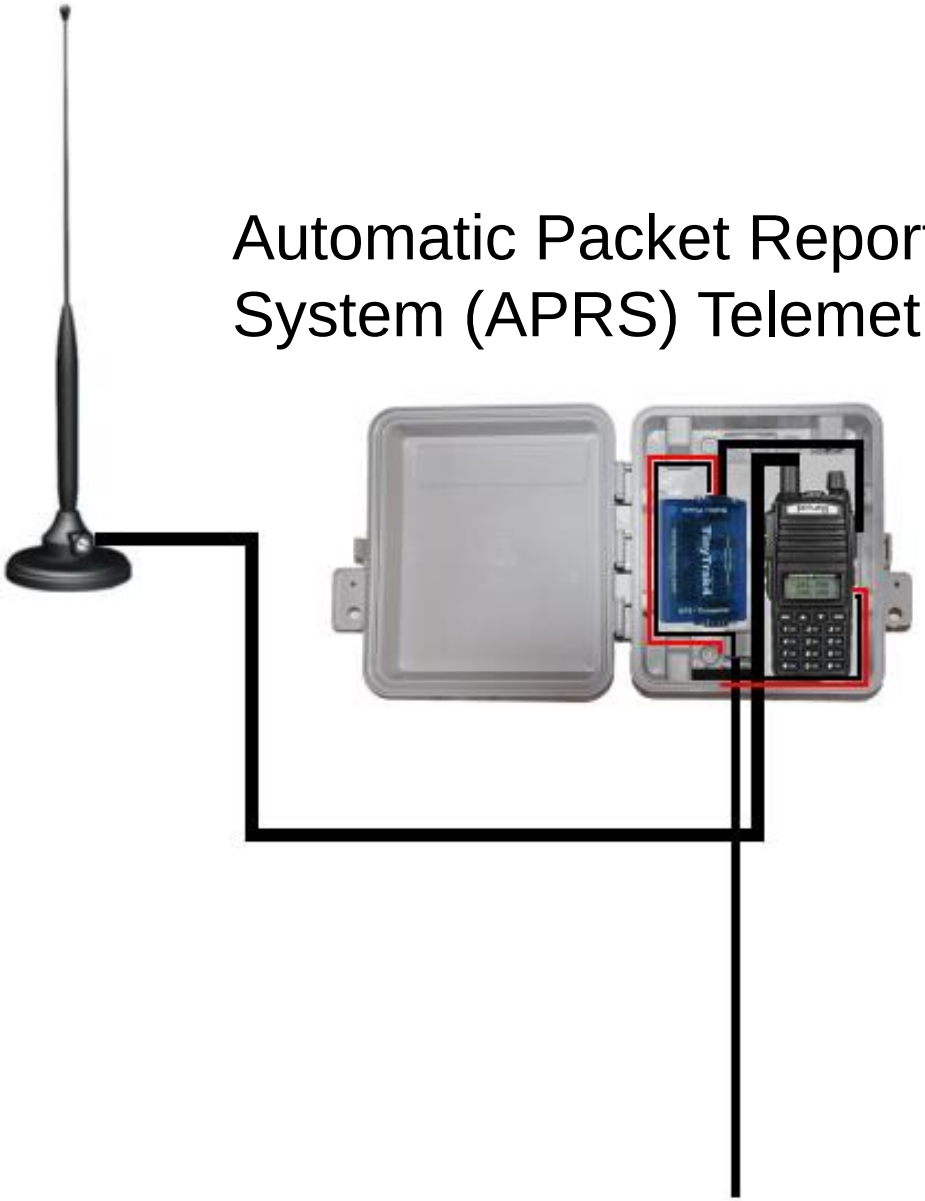
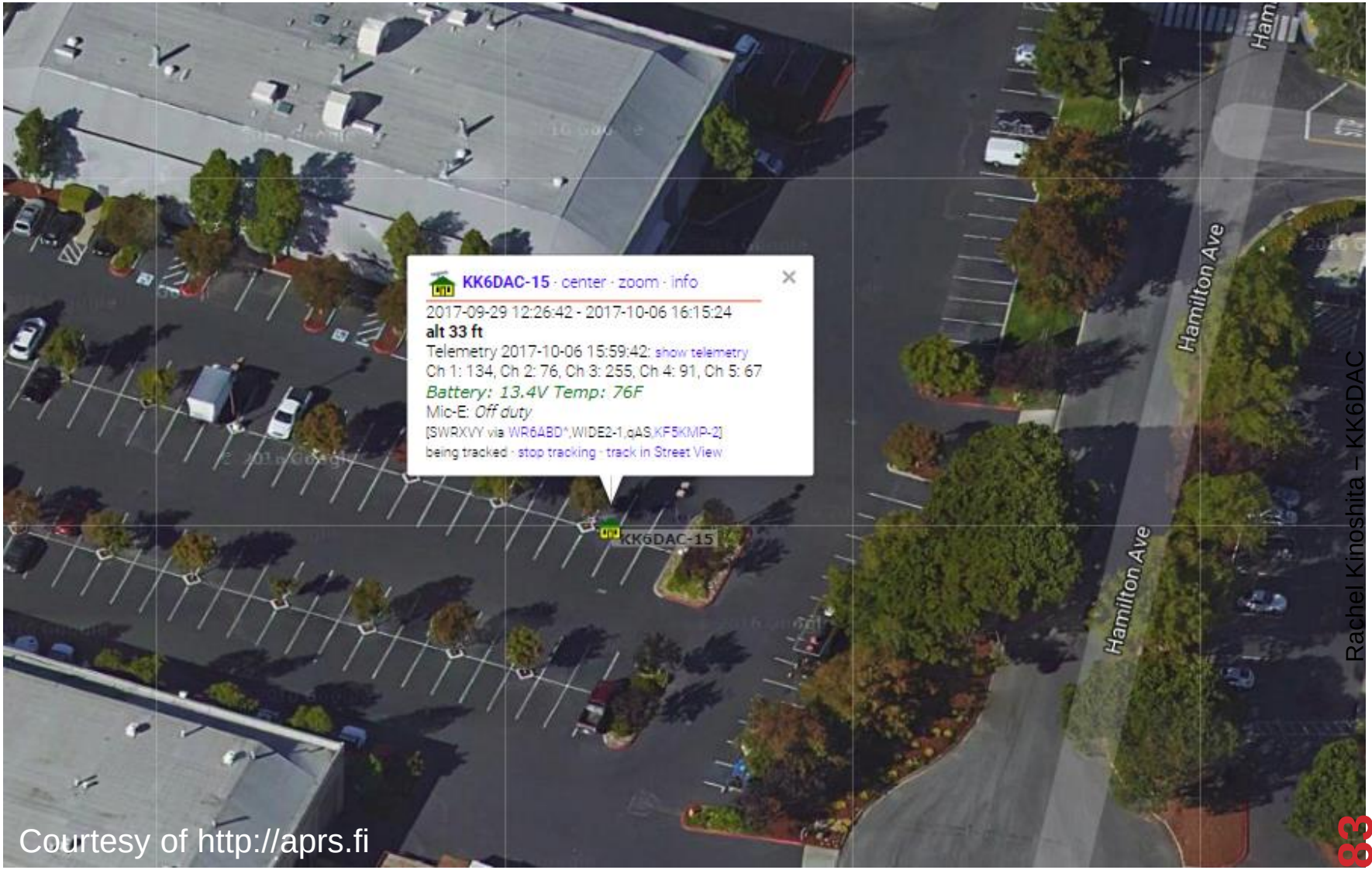
Menlo Park CERT Communications Trailer



Automatic Packet Reporting System (APRS) Telemetry

Menlo Park CERT Communications Trailer



Courtesy of http://aprs.fi

Menlo Park CERT Communications Trailer

Callsign: KK6DAC-15 Search Clear **Completed generating statistics (took 0.015 s).**
Real-time page updates enabled.

Start date (YYYY-MM-DD HH:MM): 2017-10-04 23:27:15 End date (YYYY-MM-DD HH:MM): 2017-10-06 23:27:15

It is possible to search using wildcards (*?) after a prefix. Example: VK*

Telemetry from **KK6DAC-15** - info

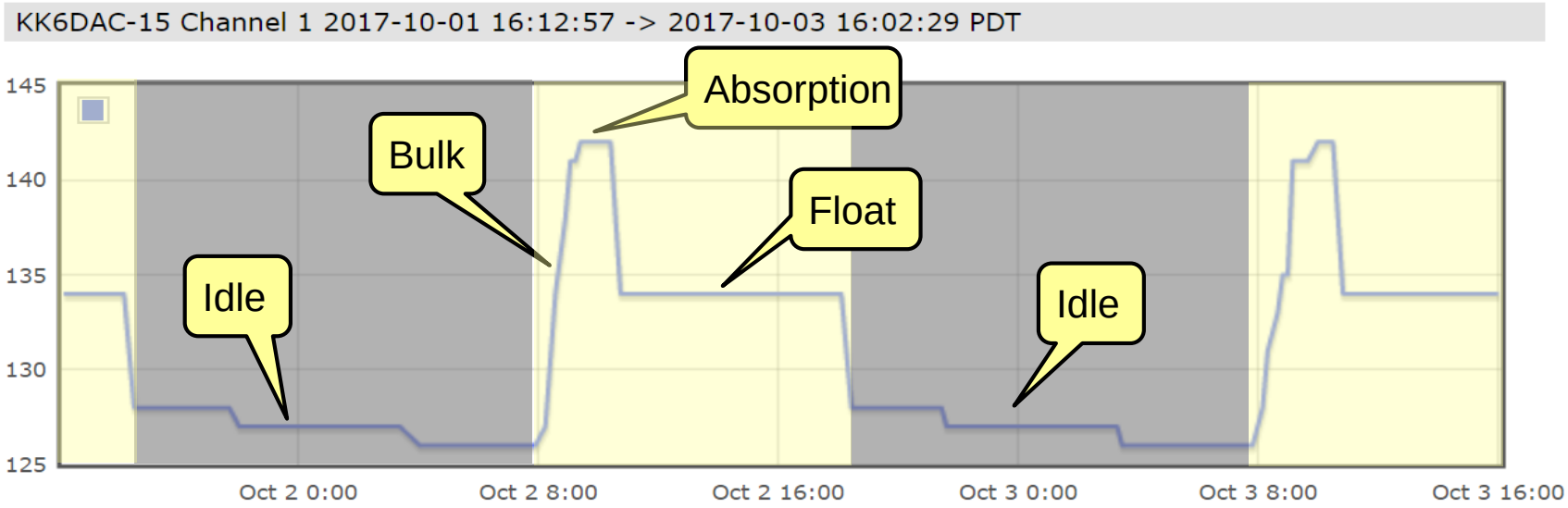
Comment: *Battery: 13.4V Temp: 77F*
Mic-E message: *Off duty*
Location: 37°28.69' N 122°08.98' W - locator CM87WL24AS - **show map** - **static map**
0.8 miles Northwest bearing 324° from East Palo Alto, San Mateo County, California, United States [?]
2.4 miles Northeast bearing 47° from Menlo Park, San Mateo County, California, United States
16.9 miles Northwest bearing 305° from San Jose, Santa Clara County, California, United States
25.2 miles Southeast bearing 144° from San Francisco, San Francisco County, California, United States
Last position: 2017-10-06 16:25:25 PDT (1m50s ago)
2017-10-06 16:25:25 PDT local time at East Palo Alto, United States [?]
Last telemetry: 2017-10-06 15:59:42 PDT (27m ago)
2017-10-06 15:59:42 PDT local time at East Palo Alto, United States [?]
Altitude: 33 ft
Values: Channel 1: 134 (TLM: 134 EQN: 0,1,0)
Channel 2: 76 (TLM: 76 EQN: 0,1,0)
Channel 3: 255 (TLM: 255 EQN: 0,1,0)
Channel 4: 91 (TLM: 91 EQN: 0,1,0)
Channel 5: 67 (TLM: 67 EQN: 0,1,0)
Bit sense: 1 2 3 4 5 6 7 8 (TLM: BITS: 11111111)

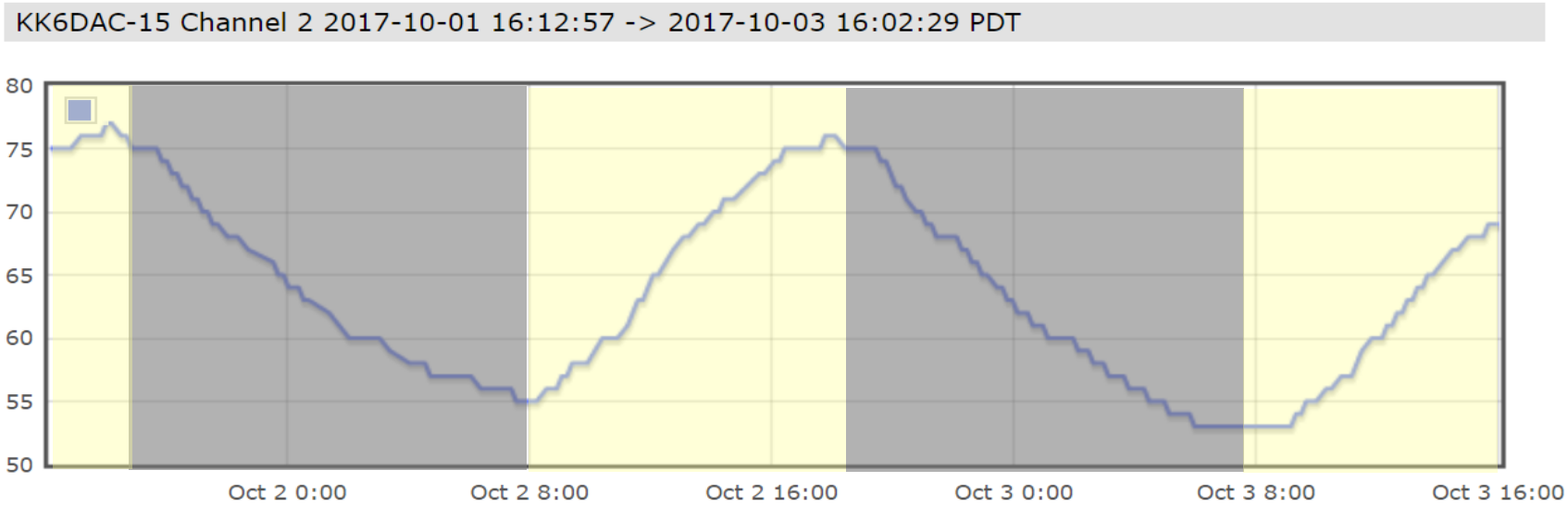
Telemetry history graphs for **KK6DAC-15**

[24 hours · 48 hours · week · month · year]

KK6DAC-15 Channel 1 2017-10-04 16:28:02 -> 2017-10-06 15:59:42 PDT

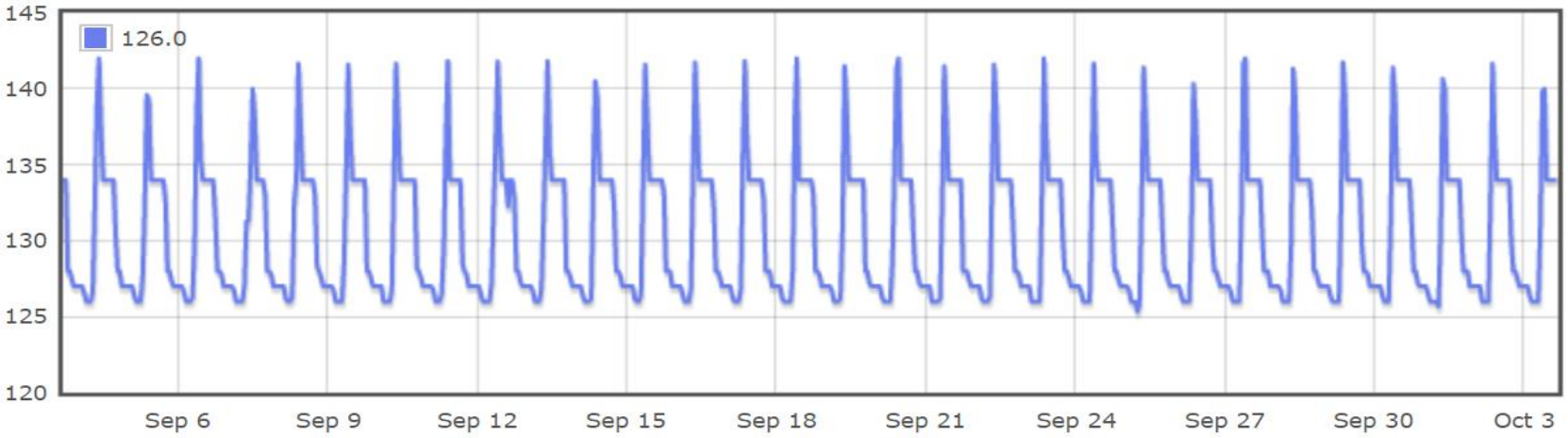
Menlo Park – 48 Hours of Collected Data



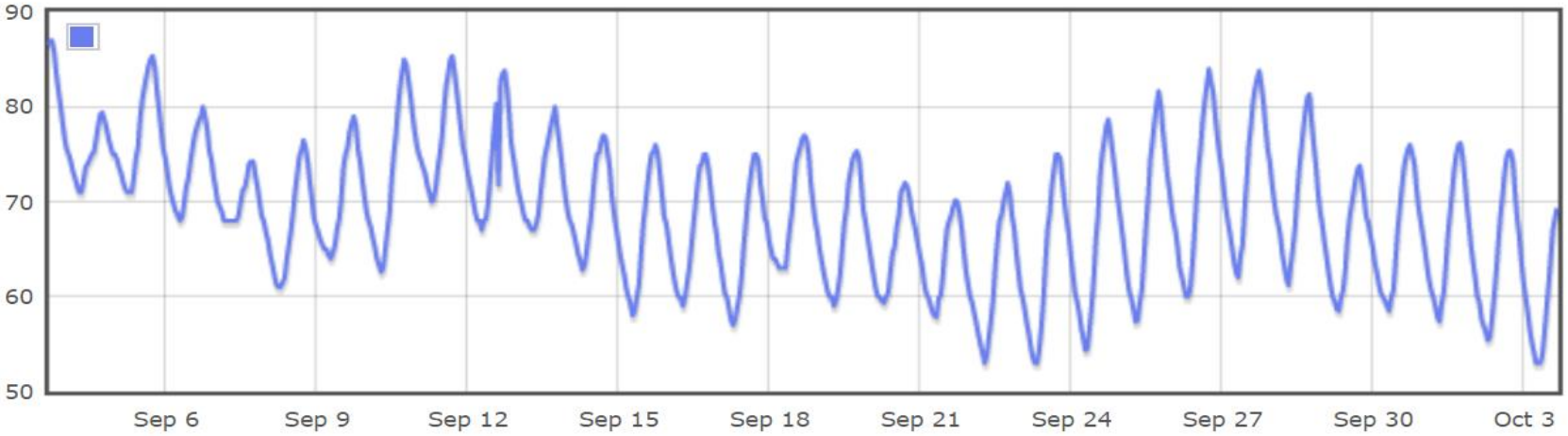


Menlo Park – 1 Month of Collected Data

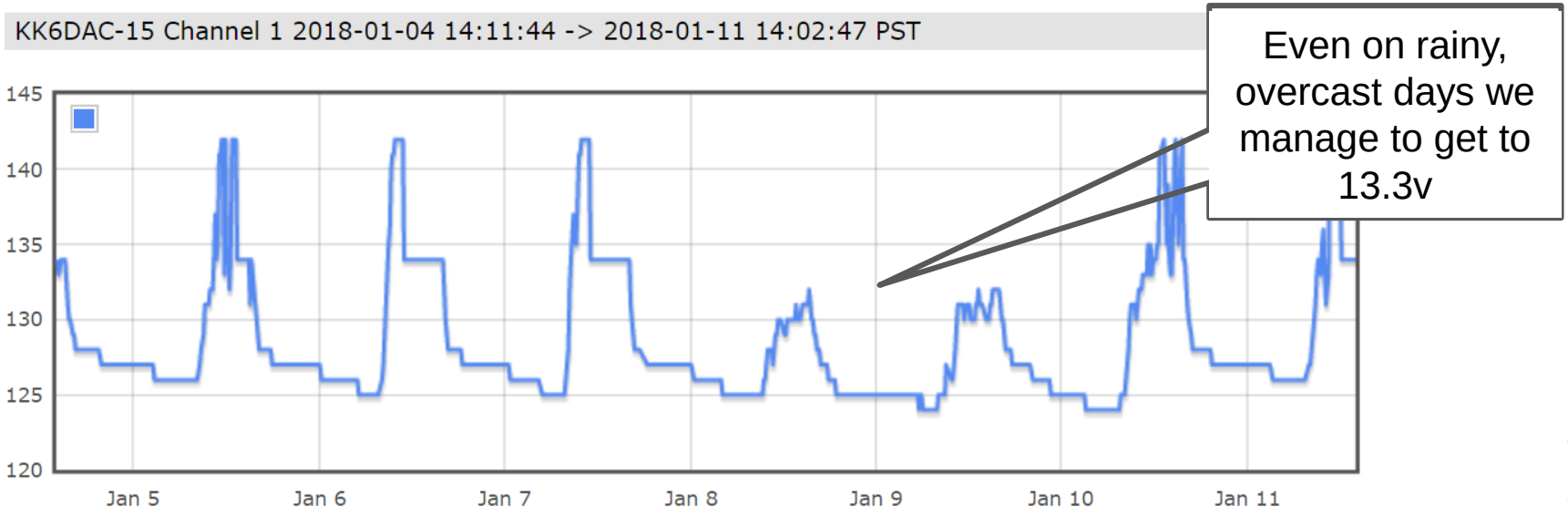
KK6DAC-15 Channel 1 2017-09-03 16:00:00 -> 2017-10-03 16:00:00 PDT

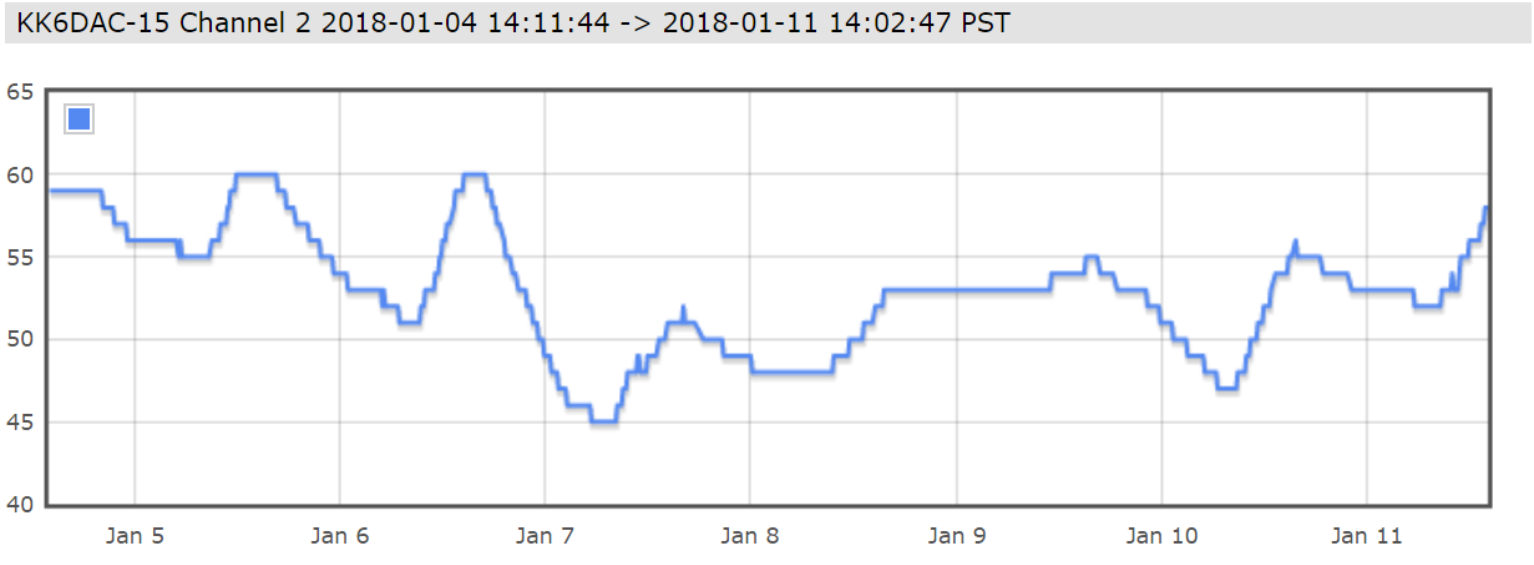


KK6DAC-15 Channel 2 2017-09-03 16:00:00 -> 2017-10-03 16:00:00 PDT



Menlo Park – How Are We Doing this Winter?





Menlo Park CERT – What Did it Cost?

Qty	Desc	Price	Total
4	Trojan 12v 140ah AGM Battery	$420.00	$1,680.00
4	Amerisolar 250w 24v PV panel	$170.00	$680.00
2	Solarline 50' cables with MC4 connectors	$44.00	$88.00
4	Aluminum Z bracket kit	$9.00	$36.00
1	Outback FX60 12-48v MPPT Charge Controller	$602.00	$602.00
1	Midnite Solar MNPV6 Combiner Box	$95.00	$95.00
4	Midnite 150VDC MNEPV DIN Mount Breaker	$16.00	$64.00
1	Misc wire and connectors	$200.00	$200.00
1	Lab bolts and sealant	$40.00	$40.00
1	Shipping	$400.00	$400.00
	Total		$3,885.00

Conclusion

- **Portable Operations**
  - Lead acid batteries are relatively inexpensive, but the trade-off is weight, capacity, self-discharge and overall life; Only sealed lead acid batteries should be used to prevent spillage
  - LiFePO4 batteries are less than half the weight of an equivalent SLA battery, has more useable capacity, can sit for long periods of time without losing much charge and has 4 times the life. The trade-off is price, but in the long-term they pay for themselves
- **Home / Base Operations**
  - Weight is less of an issue so lead acid batteries have fewer disadvantages. Never use flooded batteries inside the house due to out-gassing. Need to keep them on a float charge when not in use
  - LiFePO4 batteries will have a much longer life and will be easier to move around, but are expensive, especially for occasional use

Questions

KK6DAC@arrl.net