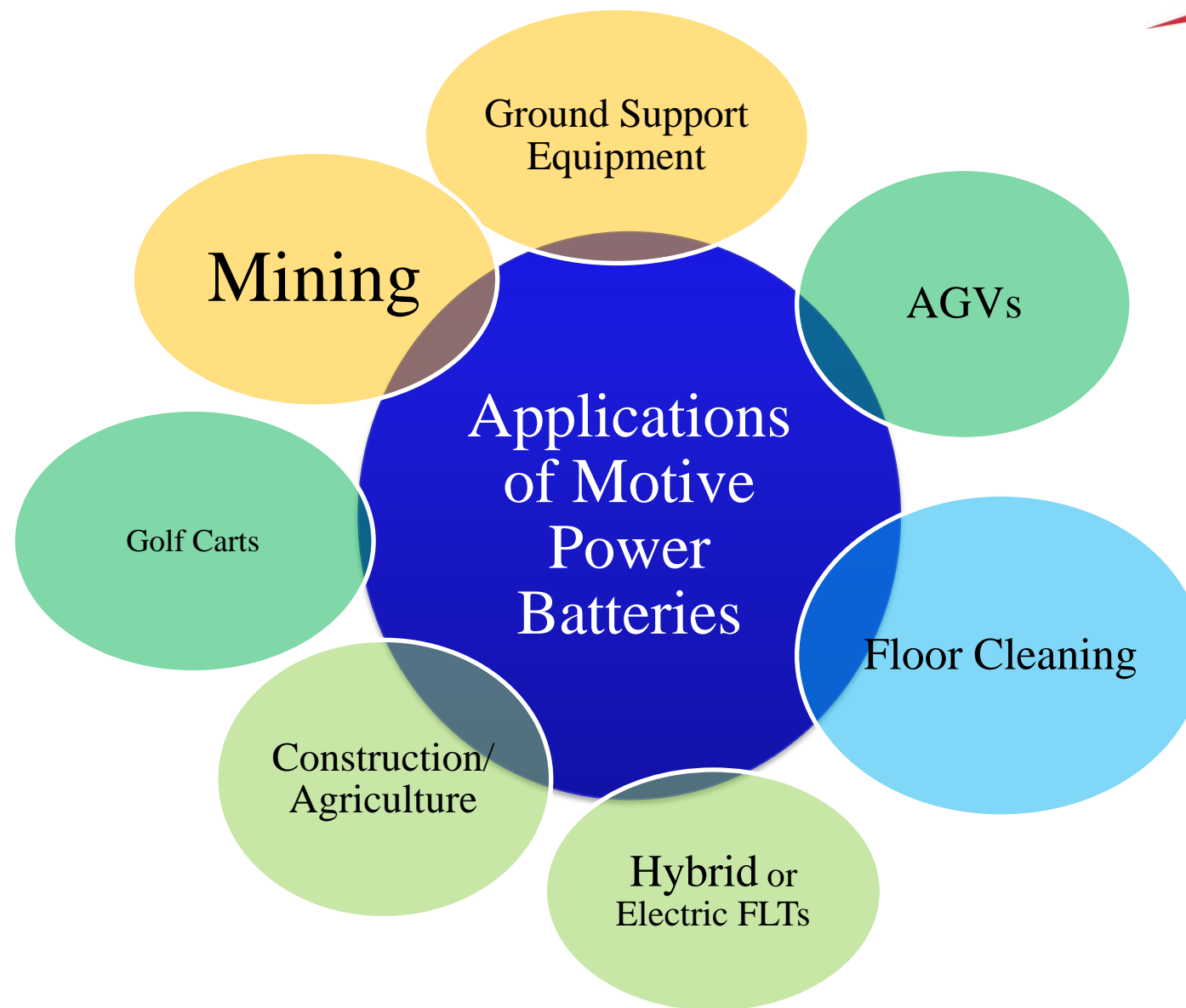


Maintenance Free Thin Plate VRLA Developments for Motive Power Applications

R. Kurian, P. Shumard, R.W. Evans.

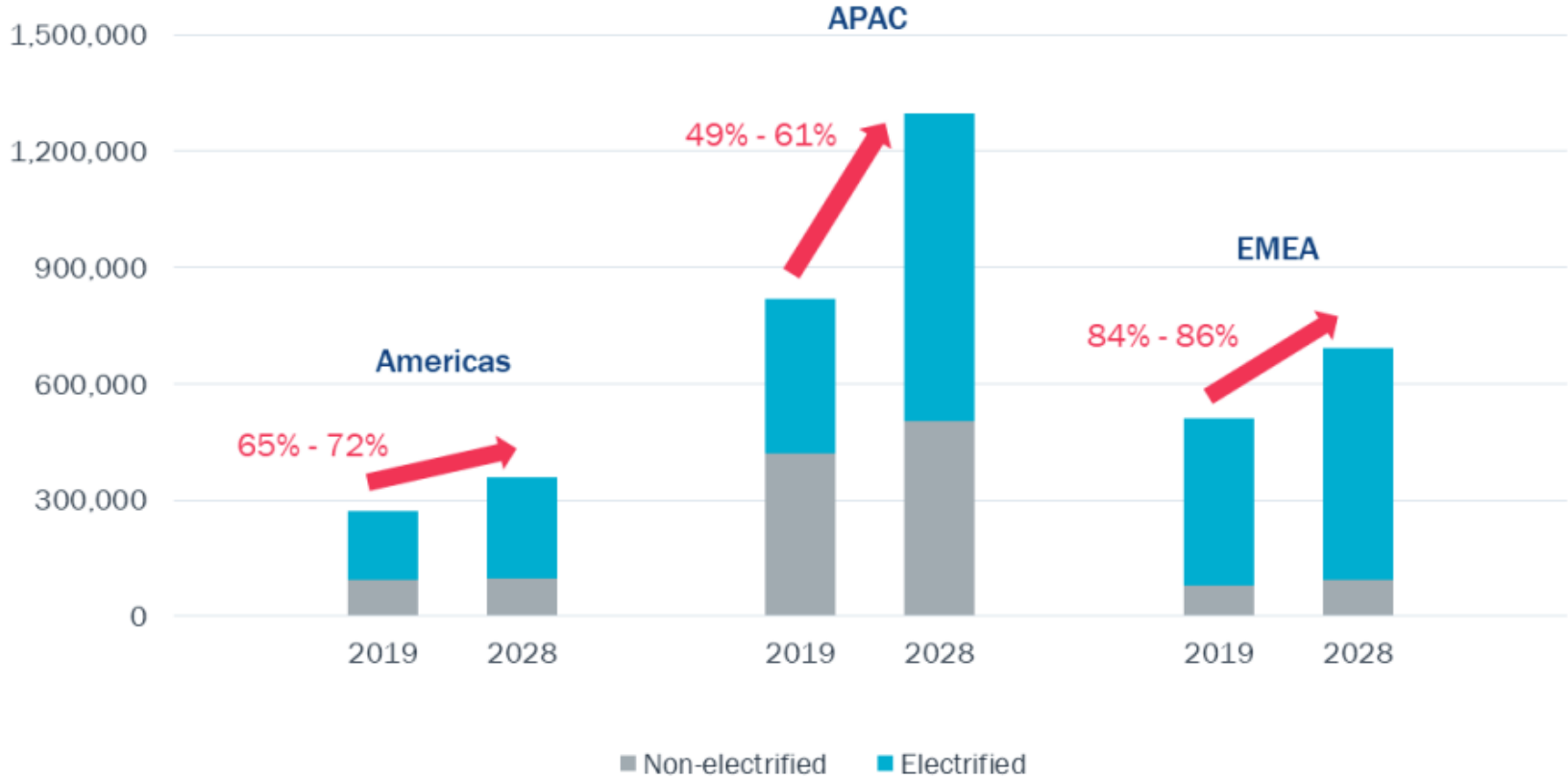
EnerSys, 2366 Bernville Road Reading, PA 19605, United States.



Percentage of shipped electrified trucks



Regional Fork Lift Market Electrification trend 2019 vs 2028



Source: Interact Analysis

© 2020 Interact Analysis

Government policy on emissions will be the main driver for the big jump expected in APAC

Away shift from Diesel to Electric



Factors influencing shift to Electric trucks

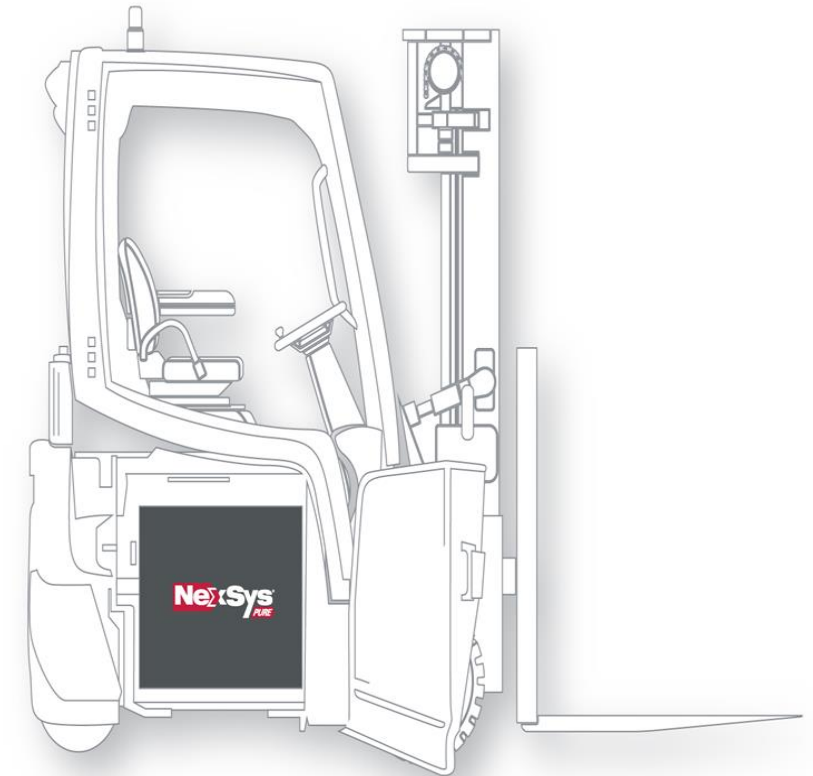
- Fuel **cost/shortage** of Fuel
- Shortage of **Labour** and rising **labour cost**
- Trend towards increased **automation**
- **Reduced maintenance with electric trucks**
- Proliferation of large distribution warehouses in recent years with **indoor environments** requiring **low noise/emissions**.
- Growth trend towards **e-commerce micro fulfilment** (companies build small **warehouses in residential areas-for same day deliver/specified slots**) – needs to be quiet due to residential areas.

- Flooded Lead batteries
- Maintenance Free batteries (VRLA Gel and VRLA AGM) no top ups and no spillage, insignificant gas generation due to recombination
- VRLA AGM TPPL (Thin Plate Pure Lead) – Maintenance Free + Fast/opportunity charge and PSoC operation
- Lithium ion
- Fuel Cells

Key TPPL Design features



- Thinner plates/large surface area/low internal resistance - **High power density with minimum on-load voltage drop**
- **Accepts high in-rush current, during charging/Regen Braking**
- Designed with high puncture strength Absorbed Glass Mat recombinant separator paper - ensures minimum water loss.
- **High purity Grid/electrode material/separator /acid - low self discharge and long storage/shelf life, extremely low gas emission.**
- **Shock & Vibration resistance** – High cell pack compression and built-in patented anti-vibration features - compliant to EN60068-2-27 Shock/ EN50342-1 Level 3&4 Vibration spec.
- **Long cycle life – Full or PSoC cycling**



TPPL Superiority in material handling applications



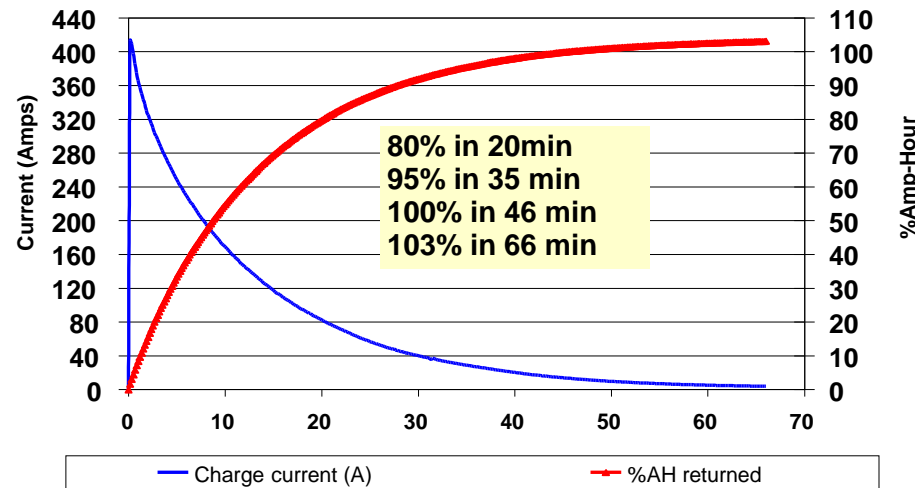
- ✓ Reduced operational cost – comes from
 - Maintenance free - No watering, Battery washing or acid spills
 - No battery swapping - One battery per truck
 - No need for dedicated battery charging room
 - Energy efficiency – low charge factor/regen charging/PSoC operation
- ✓ Environment friendly- reduced CO2 emission and water consumption
- ✓ TPPL Daily throughput –Technology capability Lab proven up to 500 % of the nominal capacity; 180 % in market applications. Typically Fast charge is limited to max 0.7C due to battery pack size and thermal management requirements.
- ✓ Ready for Wireless charging - eliminating dependency of operators to plug in.
- ✓ Intelligent System level connectivity- monitor multiple vehicles in multiple locations from your lap top, mobile and cloud service.

TPPL Fast Charge capability



|Can be charged with **unlimited current**

Due to - - - - Low internal resistance, High charge acceptance and advanced electrochemical design.

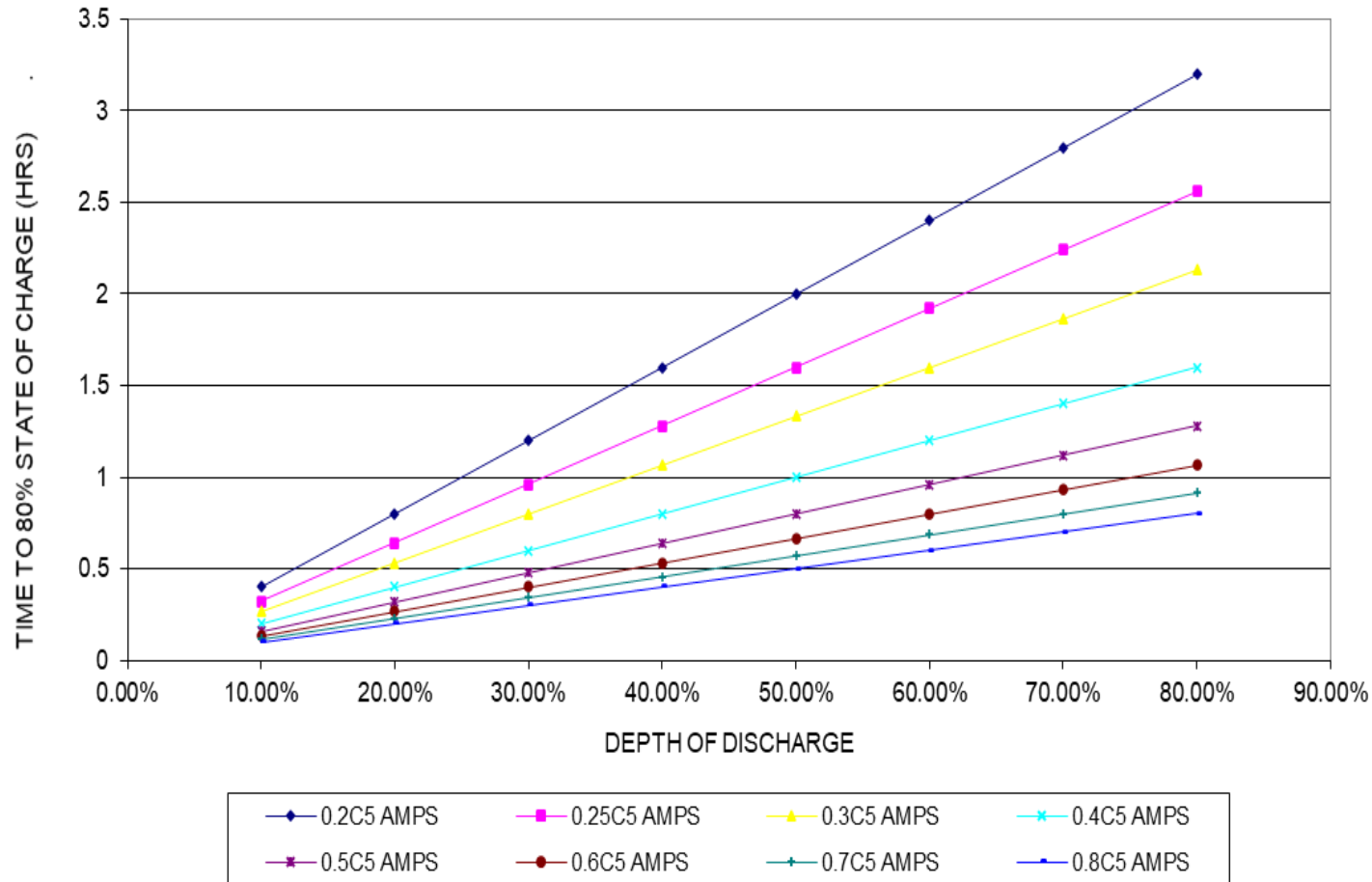


12V100AH TPPL charging capability @20degC, at2.45Vpc, with unlimited current limit, following 80% DoD C/5 discharge.

TPPL – Recharge time to 80% SoC



TIME TO 80% STATE OF CHARGE VS DEPTH OF DISCHARGE AS A FUNCTION OF CURRENT LIMIT (2.40 VOLTS/CELL)



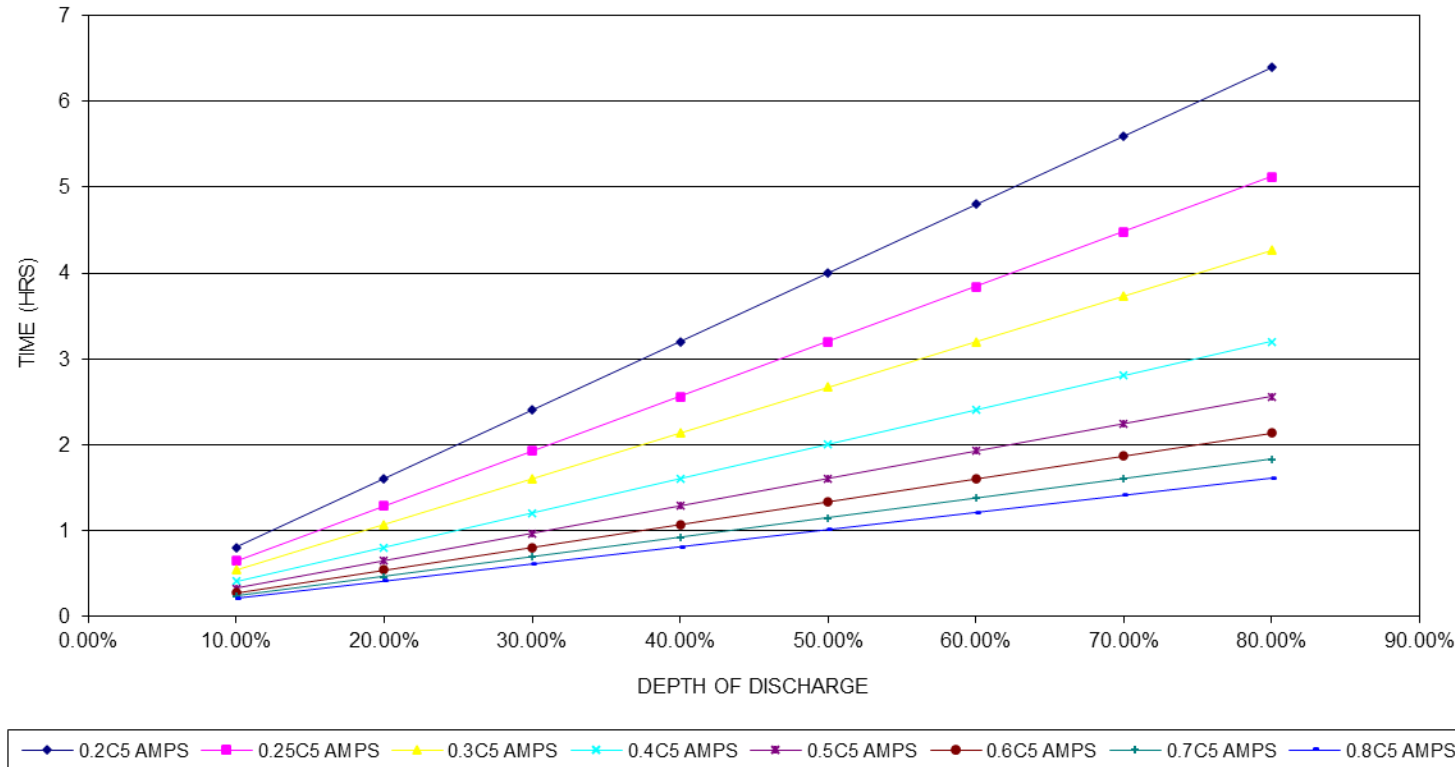
With 0.7C5 current limit, recharge time is <30 minutes from a 30 to 40% DoD state.

30 to 40% DoD
(typical Busy MP opportunity charge applications)

TPPL – Recharge time to 100% SoC



TIME TO 100% STATE OF CHARGE VS DEPTH OF DISCHARGE AS A FUNCTION OF CURRENT LIMIT (2.40 VOLTS/CELL)



To 100%
SoC
recharge
time is <1h

Accelerated cycle testing



Traditional Pb- acid batteries -

Low rate Discharge, typically 5h rate, 0.1 to 0.2C charge rate- long recharge time -
Battery swapping with shift change - charge in dedicated ventilated charging area.

TPPL batteries –

- Discharge & Charge at Higher C rate
- High daily throughput
- No battery swapping -- Utilise opportunity charge during or End of shift.
- Batteries typically experience shallow DoD with opportunity charge and regen braking charge.
- PSoC Operation with weekly full charge.

High daily throughput cycling examples

PSoC/FSoC cycling 20degC – 100AH battery

12V85Ah – 40 degC cycling with 50% DoD C1

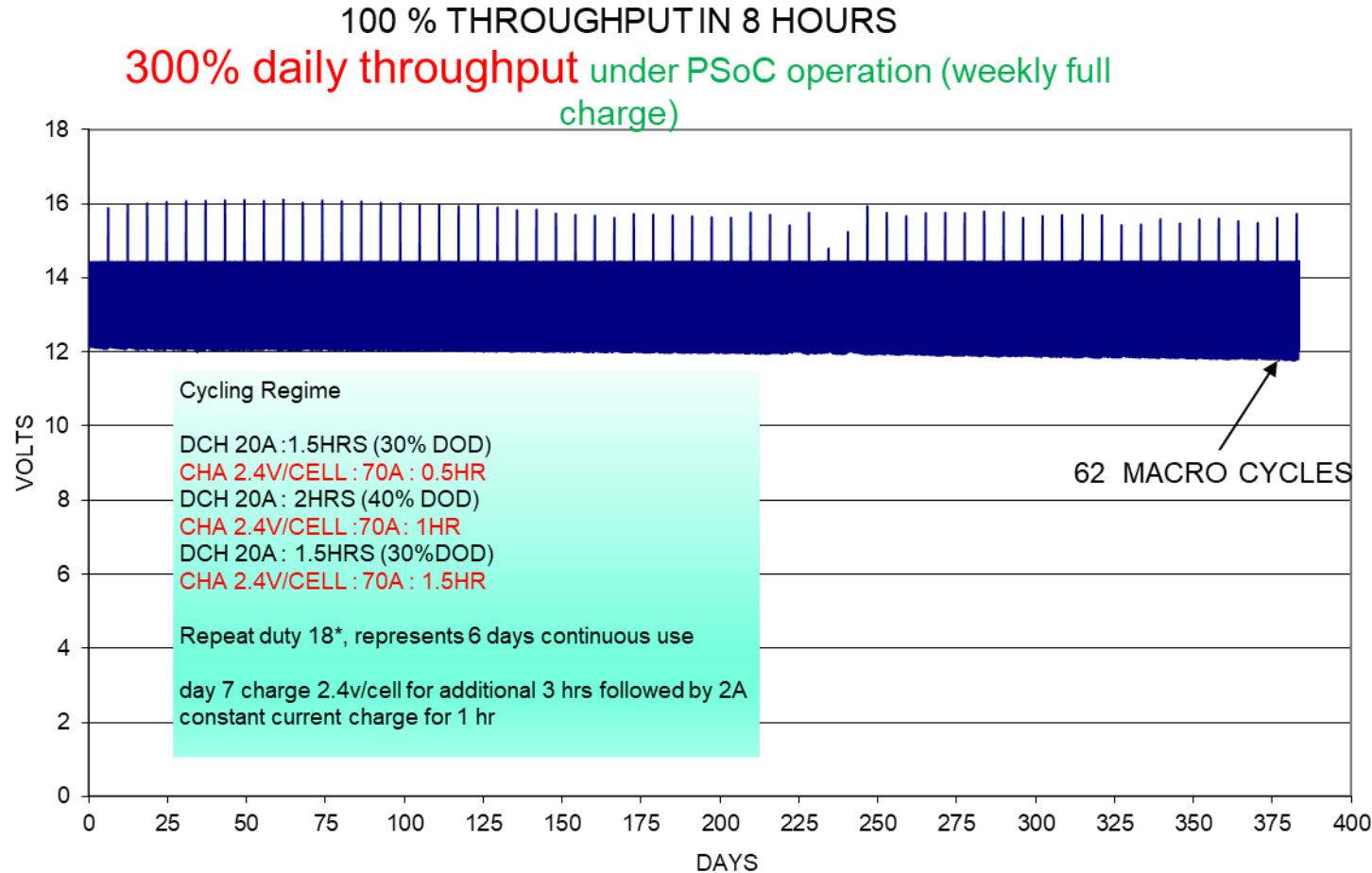
12V186Ah – 40 degC cycling with 50% DoD C2

48V 186Ah battery pack cycling with 50% DoD C2

Higher C rate discharge allows **Size down**
using lower AH capacity Battery pack

Less space in the truck
Reduced investment cost.

PSoC Cycling using 100AH TPPL battery



Total AH = 111600AH

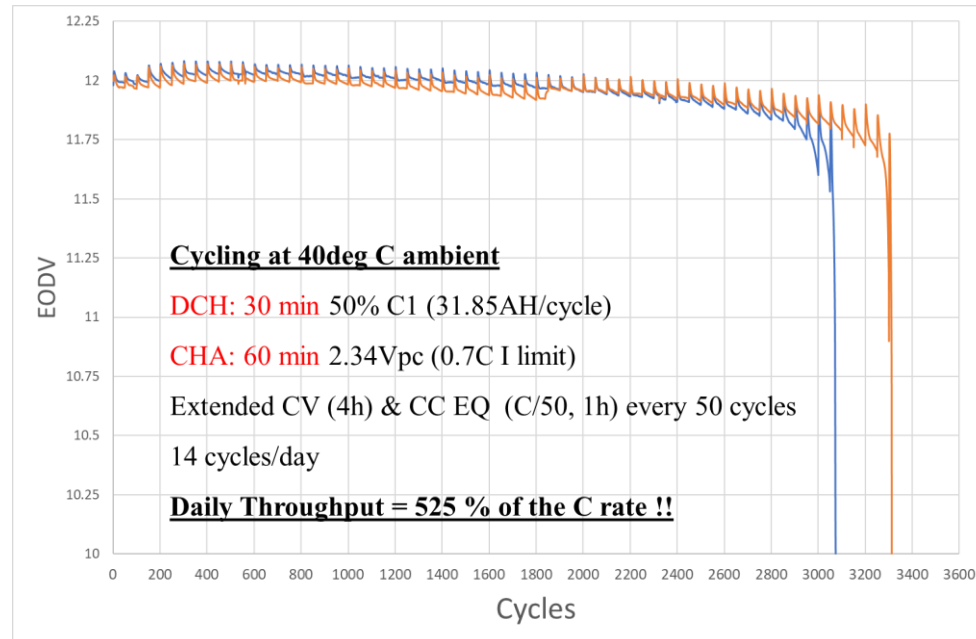
of cycles equivalent to --- 1116 (100% dod), 2000 (80% dod), 3400 (60% dod) or 5600 (40% dod) cycles

High rate Fast charge cycling



12V 85 AH TPPL 50% DoD C1 cycling at 40degC

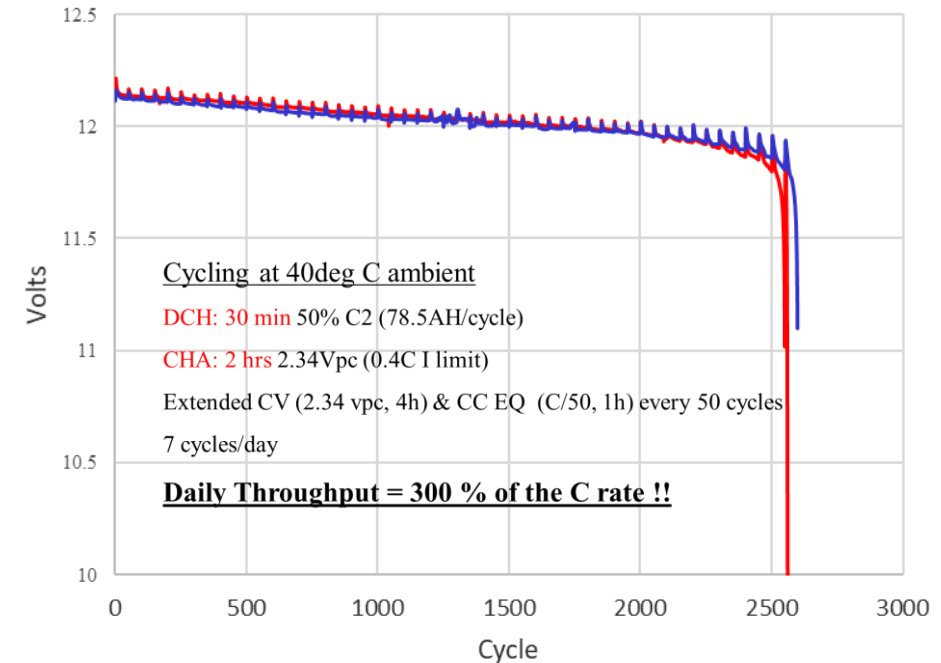
Daily throughput = 525%



Equivalent to 1550 x 80% DoD C5 cycles

12V 186 AH TPPL 50% DoD C2 cycling at 40degC

Daily throughput = 300%

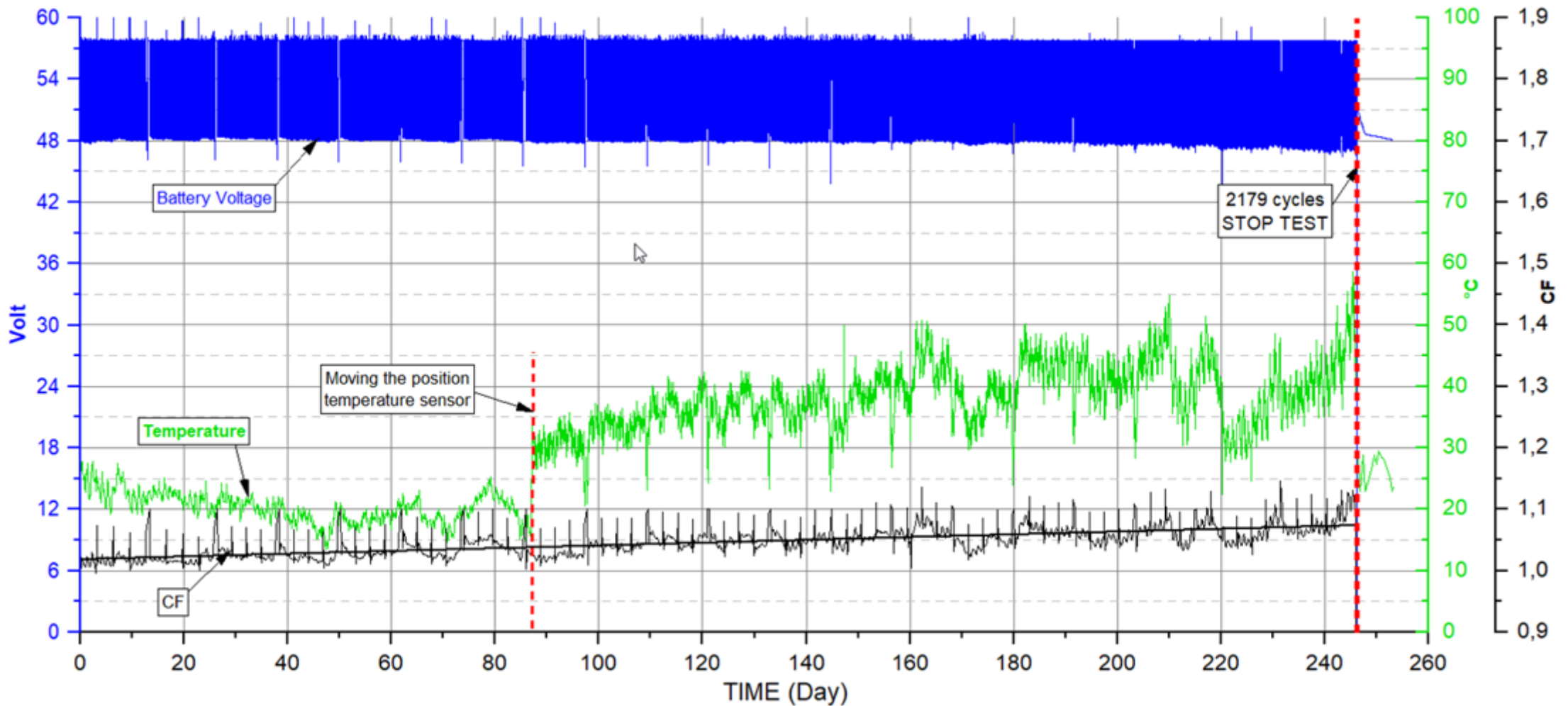


Equivalent to 1350 x 80% DoD C5 cycles

High rate Fast charge cycling – 48V 186AH pack



50% DoD C2(.43C), CHA 2.4vpc (0.7C)1.6h, every 25 cycles- C/50 CC, 1h; every 100 cycles 80% DoD 5h Cap check
340% Throughput /Day



Equivalent to 1200 x 80% DoD C5 cycles

Summary- TPPL advantage in busy Materials handling applications



- Onboard charging – no battery swapping
- Fast/opportunity charge & Regen braking charge/PSoC operation with high daily throughput.
- Dedicated chargers/algorithms keep water loss and grid corrosion to minimum level/maximise cycle life
- Provide maintenance free solutions to customers with Lowest TCO solution
- Environment friendly- indoor operation/low noise/emission
- High Energy efficiency.



Thank you for your attention !!