BATTERY AND CHARGE CONTROLLER BASICS, TESTING AND CHARACTERISATION

NCPRE, IIT Bombay

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Fourth Partner Energy – Our Vision

- Our objective is to be a Partner for sustainable change – solar is our focus.
- We aim to enhance the quality of human life while conserving our planet.
- We endeavor to do so by providing innovative products and services that harness the renewable resources, and provide our customers with superior quality at lower costs.
- Our ‘Fourth Partner’ is ‘YOU’.
  - Our customer, our supplier, our employee or any stakeholder.

Fourth Partner Energy – Background

- Started in 2010 with a focus on OFF grid solar energy market in emerging countries.
- We have a strong product design and manufacturing presence (products like lanterns, street lights, charge controllers, home lighting systems). Our operating team has over 10 years of experience.
- We specialize in design and installation of rooftop solar solutions for corporate and industrial clients
- We are developing our brand UMBER, as solar power packs transition to a B-2-C retail play.
- For solar thermal applications, we have invested significantly in basic CSP development and technology.
- We have executed a 66 kV Power Evacuation system on a turnkey basis, for a 5MW grid connected power plant near Rajkot, Gujarat.

FOURTH PARTNER ENERGY

UMBER

Our Clients

CHLORIDE A WHOLLY OWNED Subsidiary of - EXIDE INDUSTRIES LIMITED
CHLORIDE POWER SYSTEMS & SOLUTIONS LIMITED
(Formerly Caldyne Automatics Ltd.)

Andhra Bank
Where India Banks

ESCORTS

BVG
BVG INDIA LIMITED
A BHARAT VIKAS GROUP COMPANY

HBL

TITAN

ERNST & YOUNG
Quality In Everything We Do

BAAS EDUCATIONAL TRUST

एनटीपीसी
NTPC
A Maharatna Company

PHOTON

teri

इण्डियन ओवरसीज़ बैंक
Indian Overseas Bank
आपकी प्रगति का सच्चा साथी
Good people to grow with

GILBARCO VEEDER-ROOT

APCOB
THE ANDHRA PRADESH STATE CO-OPERATIVE BANK LIMITED
A Government Partnered Scheduled Bank

मिनरल एक्स्प्लोरेशन कॉरपोरेशन लिमिटेड (एम.ई.सी.एल.)
Mineral Exploration Corporation Limited (MECL)
(A Govt. of India Enterprise) An ISO 9001 : 2008 Certified Company

SBUT
THE SAIFEE BURHANI UPLIFTMENT PROJECT

ICICI Bank

salzer 25 YEARS

MILT

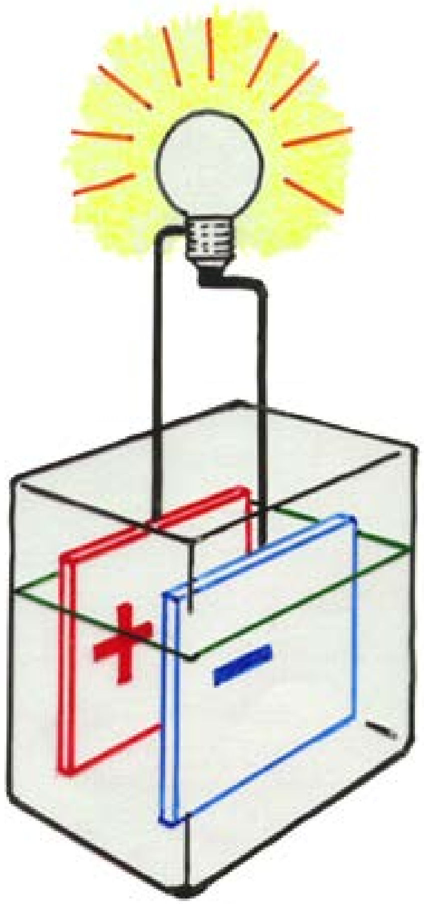
FOURTH PARTNER ENERGY

UMBER

TOPICS

- Battery concepts
- Types of batteries: Lead Acid, NiCd, and Li-ion batteries
- Battery basic terminology
- Battery Charging
- Characteristics of solar battery
- Lead Acid, NiCd, and Li-ion batteries comparative analysis
- Battery Testing
- Applicable Standards
- Charge Controller Testing

WHAT IS A CELL OR BATTERY?



Cell is a device that stores and converts the chemical energy into electrical energy by means of an electrochemical reaction.

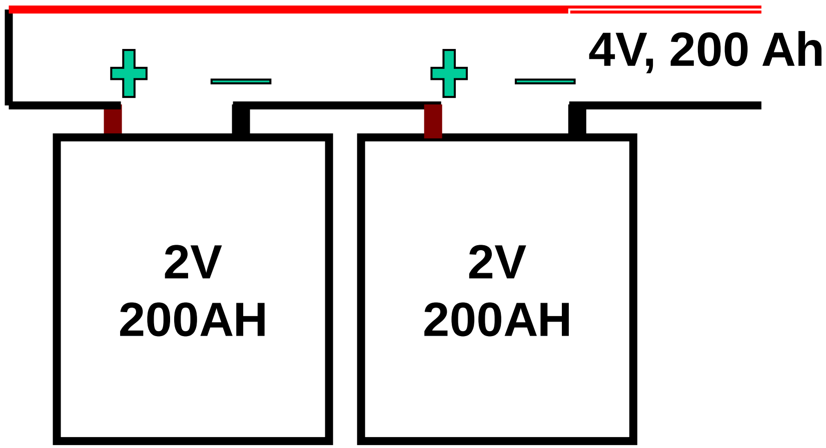
Battery consists of two or more cells electrically connected.

In common usage, the terms "battery" and "cell" are used interchangeably.

CELL CONNECTIONS

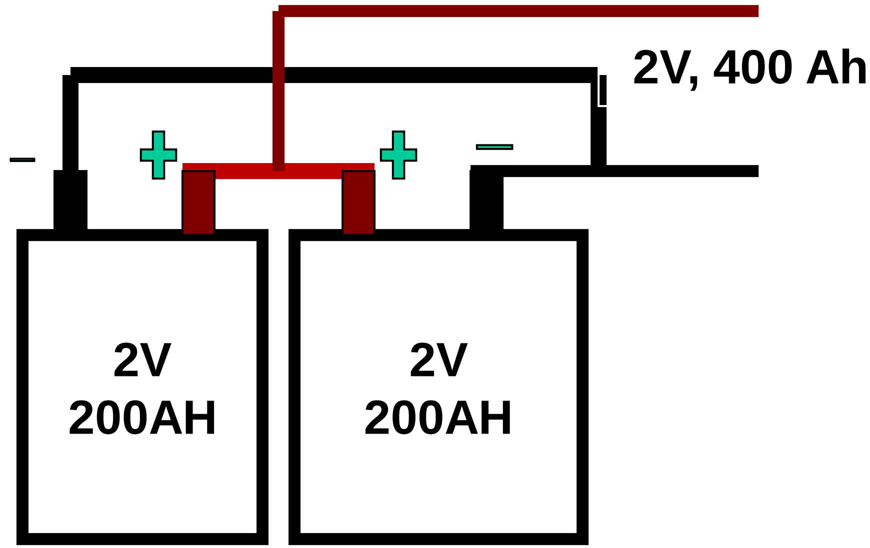
Series connection:

When opposite polarity of two or more cells are connected to each other and overall voltage is taken out, the total voltage becomes the sum of each cell voltage and the total capacity remains the same as of a single cell.

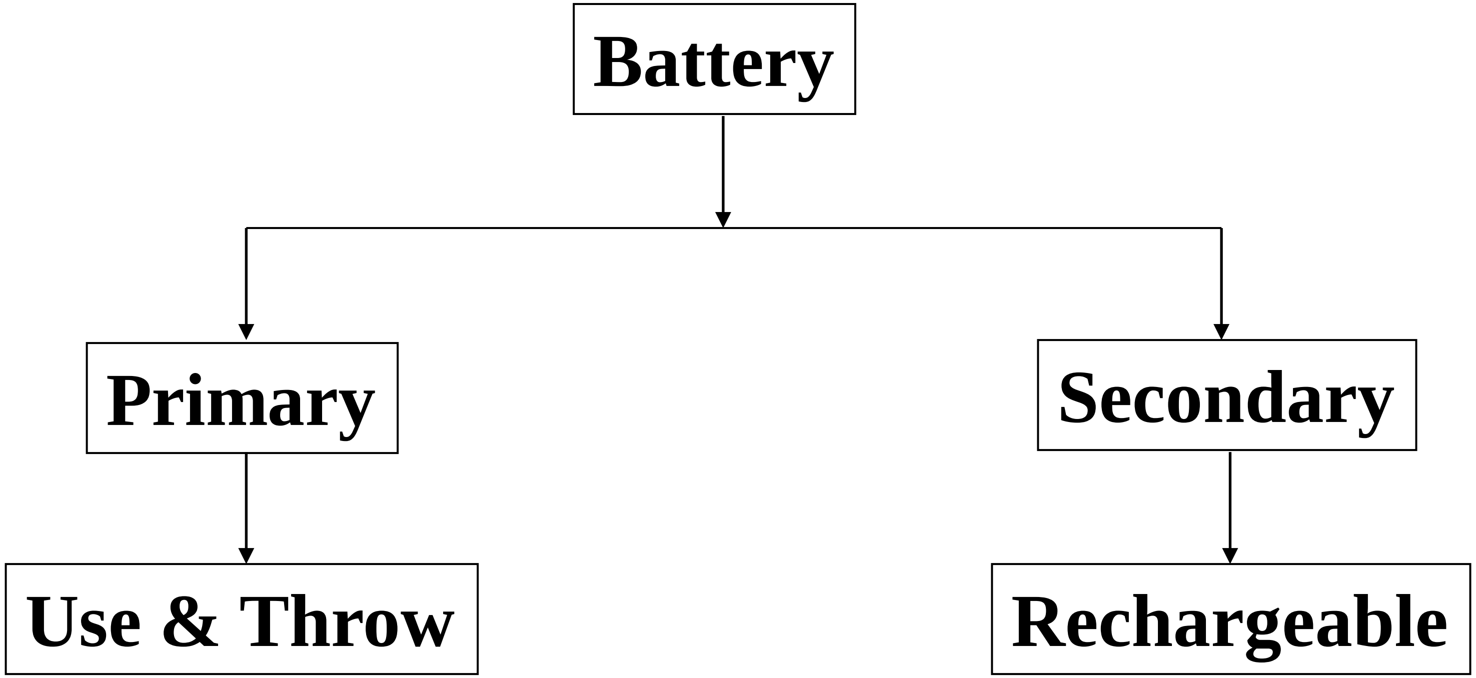


Parallel connection:

When similar polarities of two or more cells are connected and overall voltage is taken out from the cell(s) in the battery, the total voltage remains same as of a single cell but the total capacity becomes the sum of the capacity of all cells.



TYPES OF BATTERY



Lead Acid
Nickel Cadmium
Lithium Ion
Ni-MH etc

TYPES OF BATTERIES Contd….

Features	Lead Acid	Ni Cd	Li - Ion
Nominal Voltage	2.00	1.20	3.60
Design Life (Approx in Yrs)	10-20	10-20	10
Battery Management	Optional	Optional	Compulsory
Storage	06 months	01 Year – charged 10 year – uncharged	01 year
Cost	Low	High	Very High

BASIC TERMINOLOGY

Battery Capacity: Amount of energy stored in the battery.

Depends on …

1. Quantity of active materials
2. Amount of electrolyte
3. Surface area of the plates

Rated capacity: Amount of charge available in ampere-hours (Ah) when battery discharged at specified rate.

It is indicated on battery datasheet by 'C' rate.

- Battery capacity varies with the discharge rate.

Example:

Lead-acid battery rated for 200 Ah (10-hour rate) will deliver 20 amperes of current for 10 hours under standard temperature conditions before its terminal voltage reaches specified value.

BASIC TERMINOLOGY contd….

Charge & Discharge: Charge current is the electric current supplied to the battery and stored in it. Energy supplied to battery will be “charge current x time period x battery voltage”.

Discharge is the state when battery energy is being consumed by the connected load. Energy removed from battery will be “load current x time period x battery voltage”

State of Charge: the “state of charge” is a measure of energy remaining in the battery. It can be measured with the help of following.

- Multimeter – 2.12V (100%), 2.01V (50%), 1.75V (0%)
- Hydrometer – 1220, 1160, 1120 (20%), NA

<u>BASIC TERMINOLOGY</u> contd….

Cycle: Each charge period followed by its discharged period is called a cycle.

Cycle life: The number of cycles a battery is expected to last before its capacity drops to 80% is called cycle life. It depends on how deeply the battery is discharged. Lesser the DoD higher the cycle life.

Depth of Discharge (DoD): It is a measure of how much battery is discharged in a cycle before it is charged again. 60% DoD is equivalent to 40% state of charge (SoC).

PSoC: The battery is not being fully charged (100%) before they are discharged in a cycle.

TYPES OF BATTERY CHARGING

Freshening Charge: For extending storage period

Float Charge: Compensation for self discharge

Charger, battery, and load are connected in parallel

Boost Charge: Fast charging at higher voltage when battery discharges to higher depth

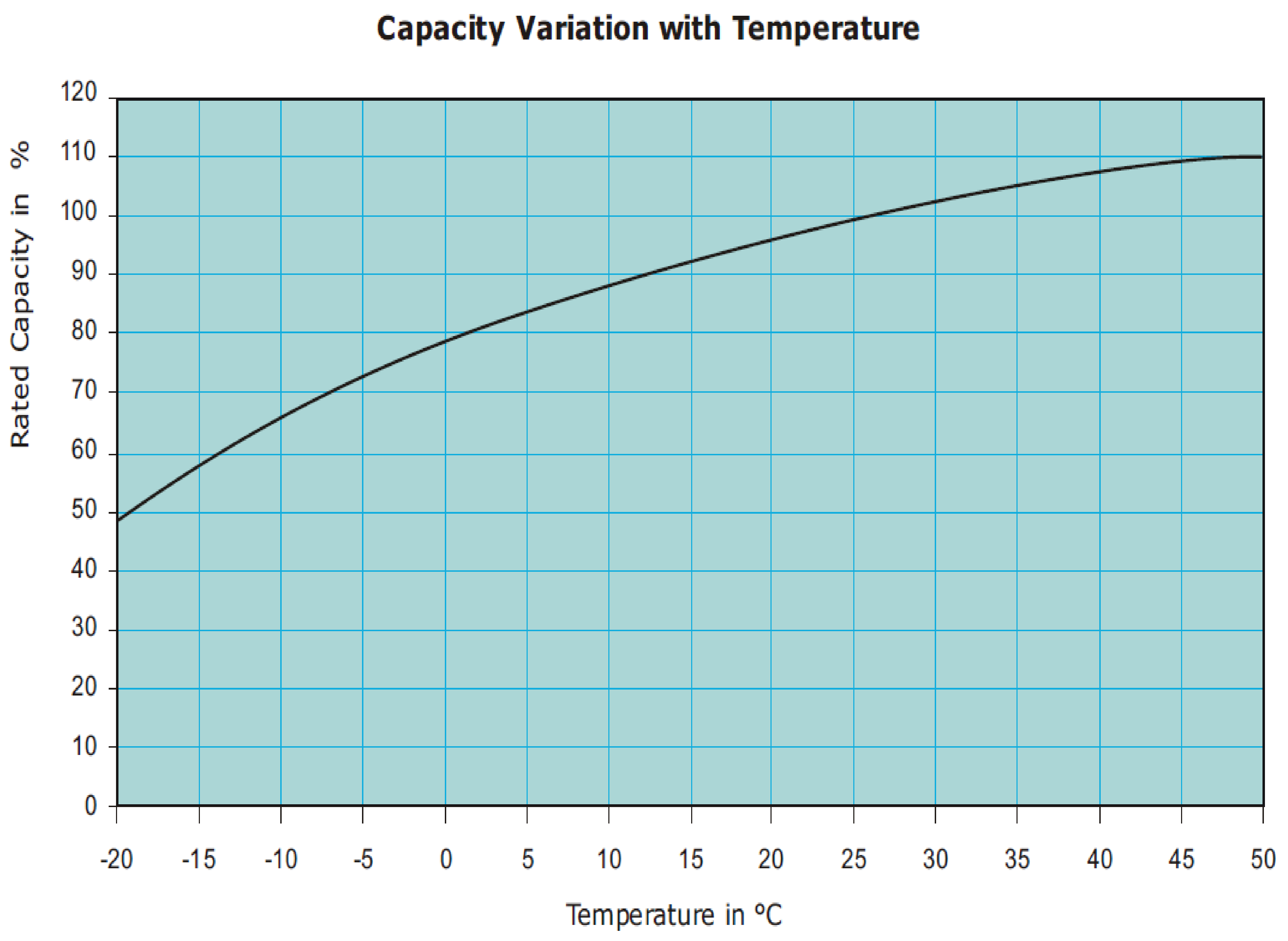
Equalization Charge: Equalize the cell voltage in Battery bank to avoid over/under charge of cells

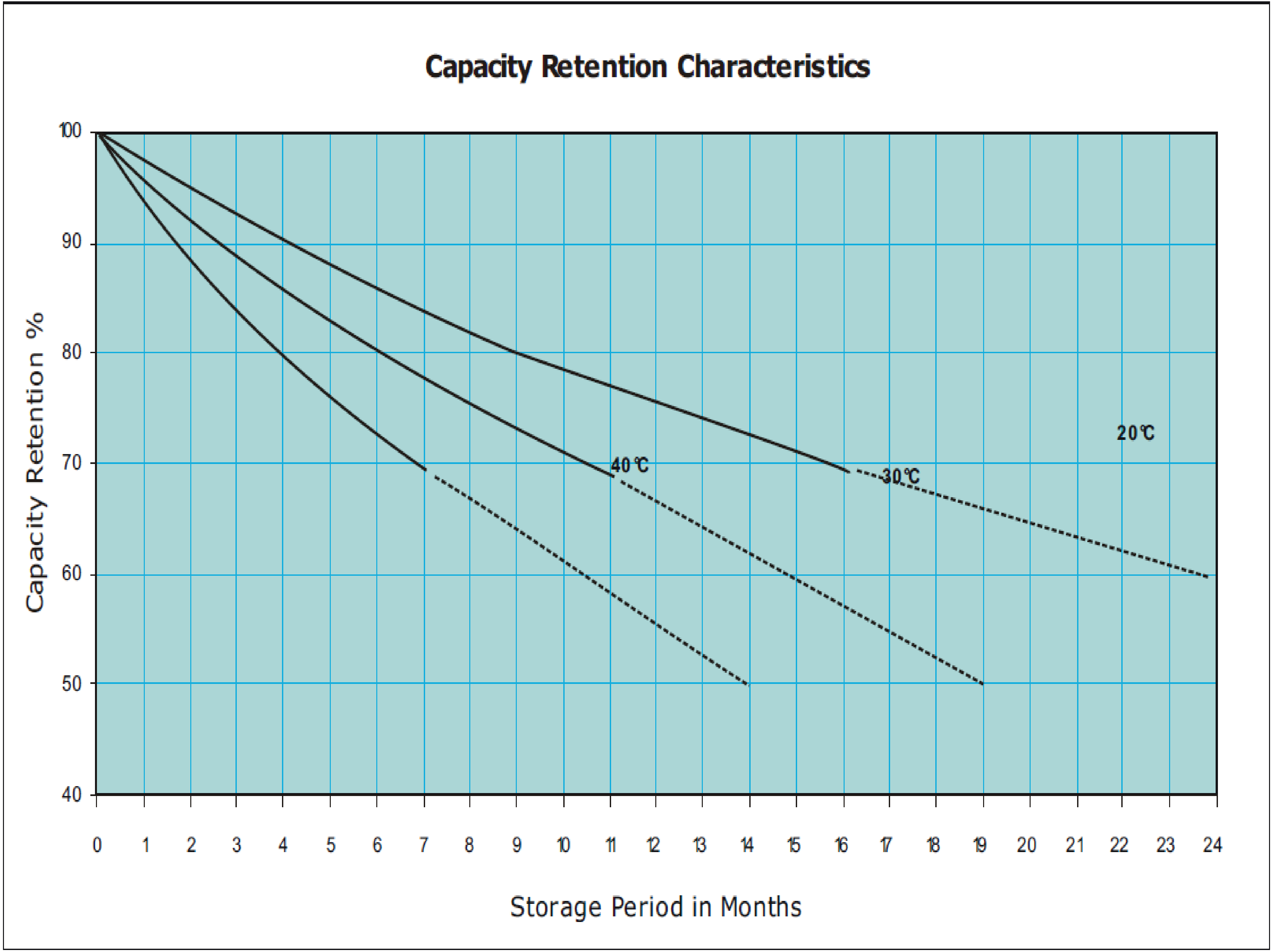
CHARACTERISTICS OF SOLAR BATTERY

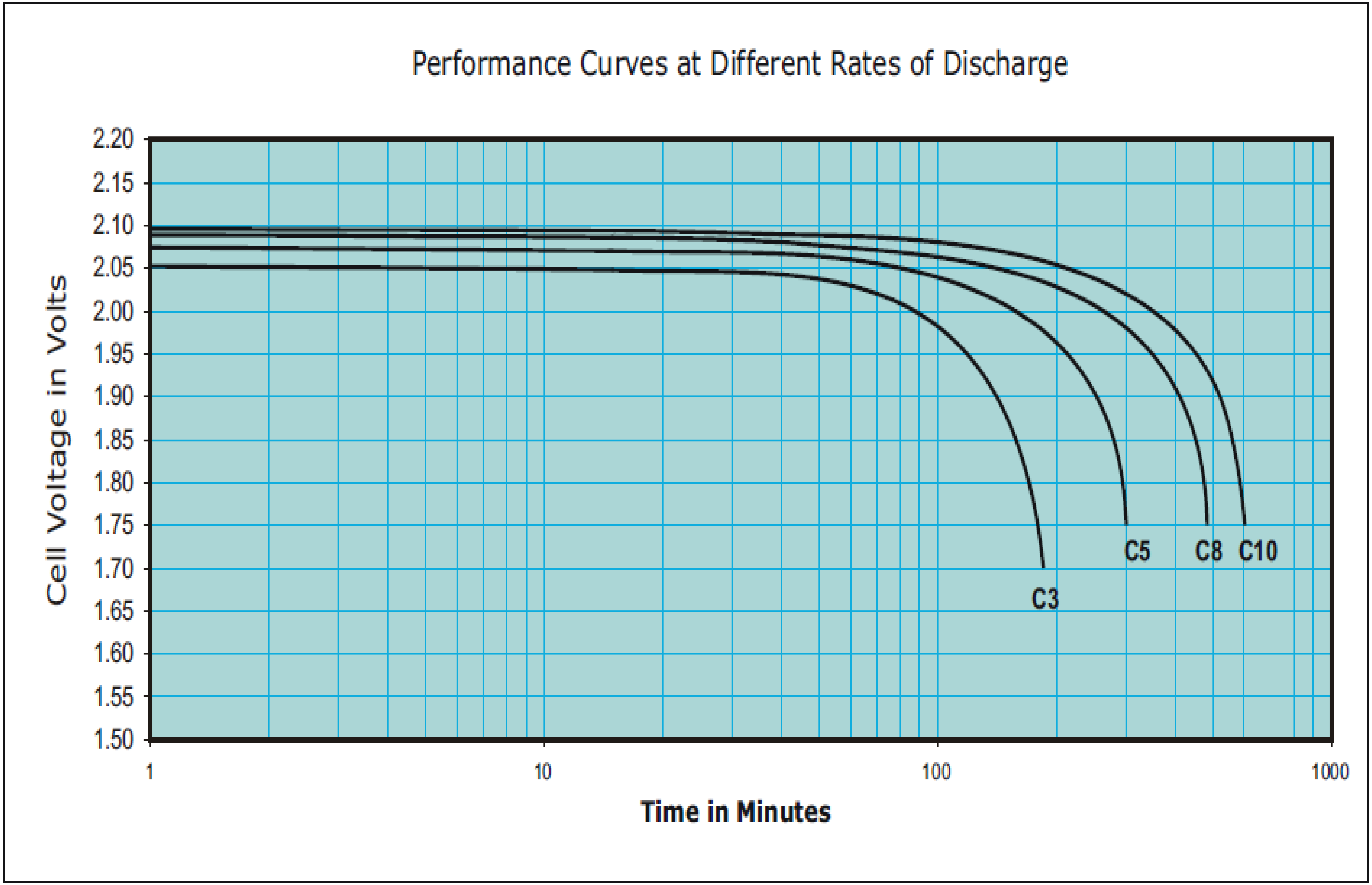
- Smallest size and weight - High Energy Density
- High cycle and float life
- Low self Discharge & Good Shelf life
- PSoC operation
- Charge Efficiency at PSoC
- Deep Discharge recovery
- Resistance to abuse
- Predictable performance

CHARACTERISTICS OF SOLAR BATTERY

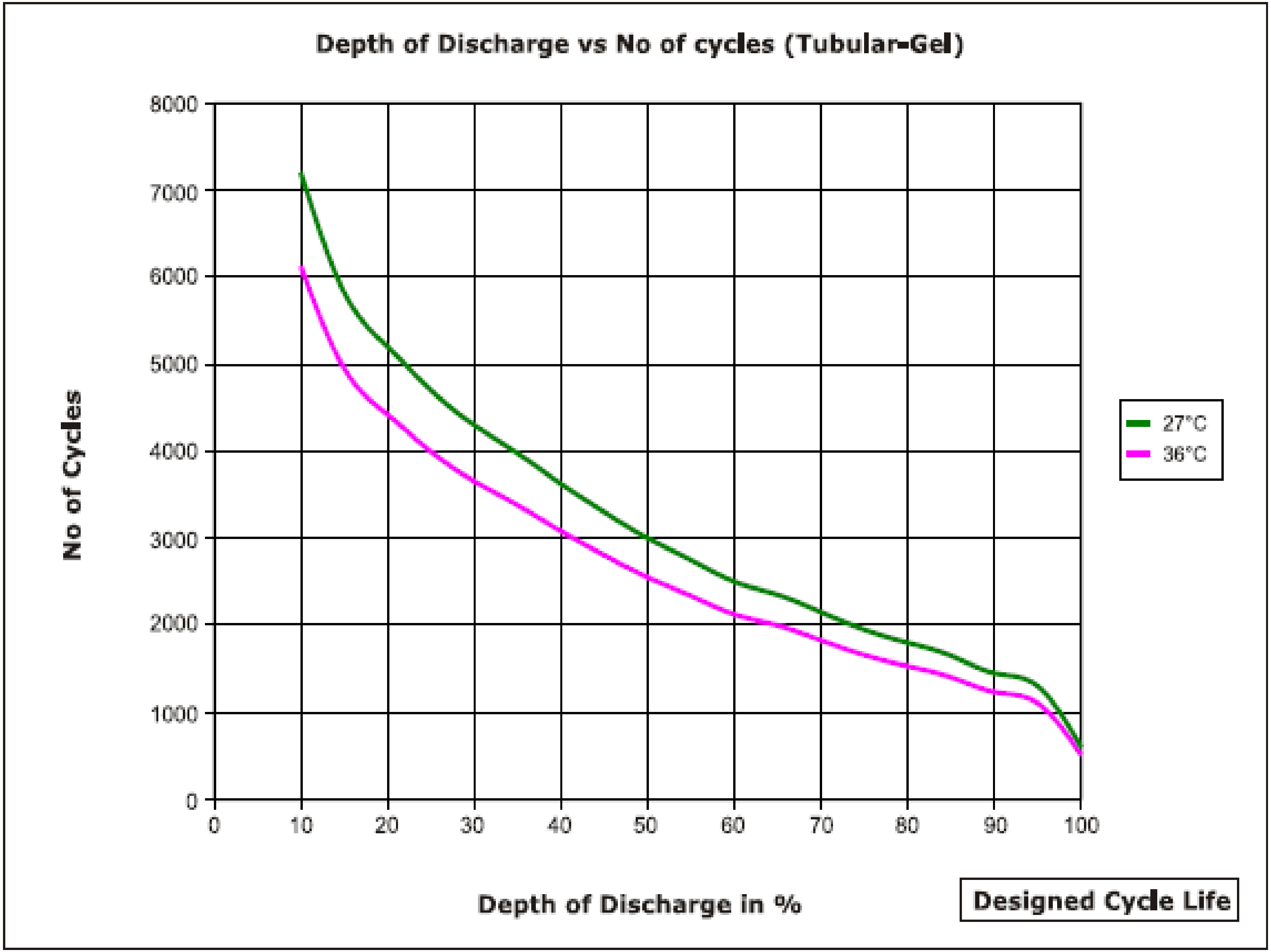
- Quick installation and commissioning
- Wide operating temperature and mechanical stress
- Low or no maintenance requirements Topping free
- Environment friendly
- Low cost


Capacity Variation with Temperature
Rated Capacity in %
120
110
100
90
80
70
60
50
40
30
20
10
0
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40
45
50
Temperature in °C


Capacity Retention Characteristics
Capacity Retention %
100
90
80
70
60
50
40
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
40℃
30℃
20℃
Storage Period in Months

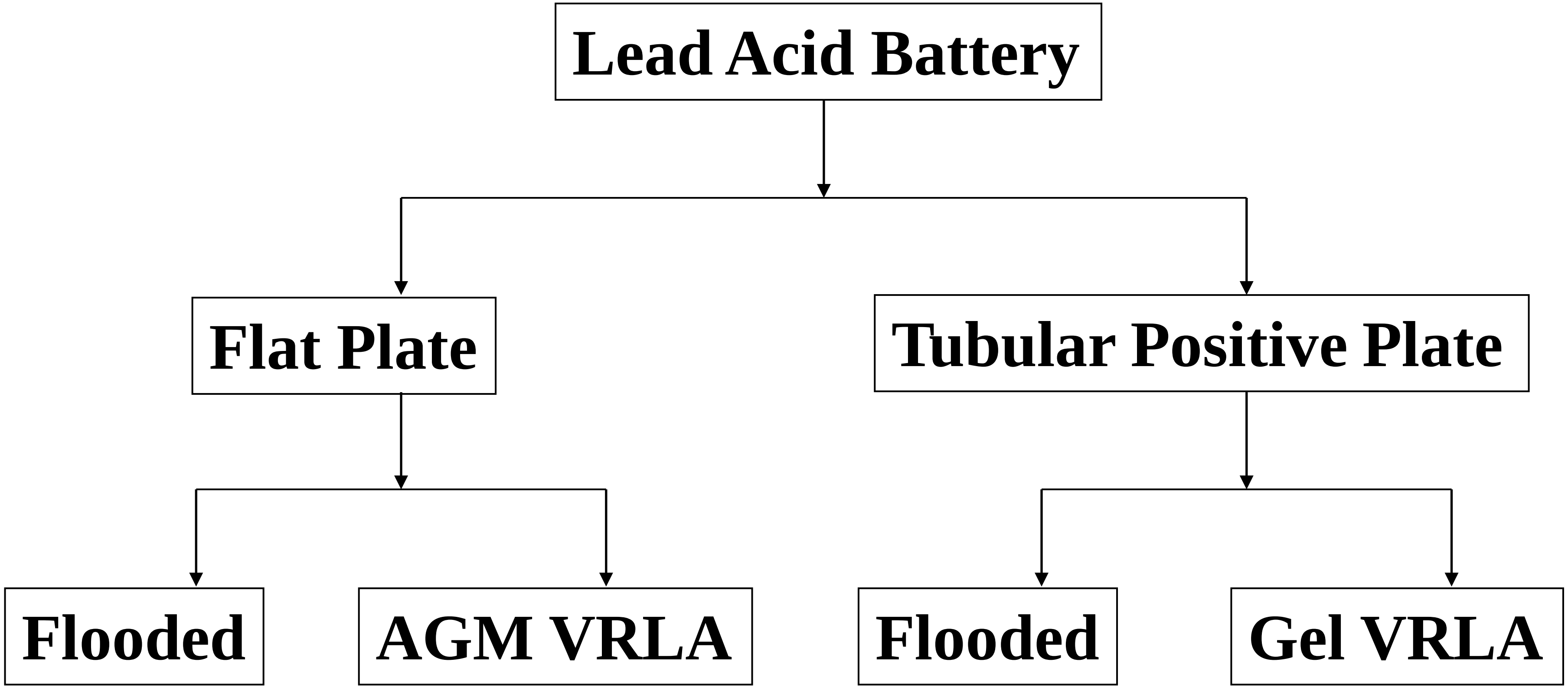


Performance Curves at Different Rates of Discharge
Cell Voltage in Volts
2.20
2.15
2.10
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
C3
C5
C8
C10
1
10
100
1000
Time in Minutes



Depth of Discharge vs No of cycles (Tubular-Gel)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
70
80
90
100
No of Cycles
Depth of Discharge in %
27°C
36°C
Designed Cycle Life

TYPES OF LEAD-ACID BATTERIES



Features of Flooded & VRLA LA Batteries

Flooded Lead-Acid Batteries

Electrodes/plates are immersed in electrolyte

Vented for gas escape

Distilled water must be added periodically

Sealed Lead-Acid Batteries

No free electrolyte

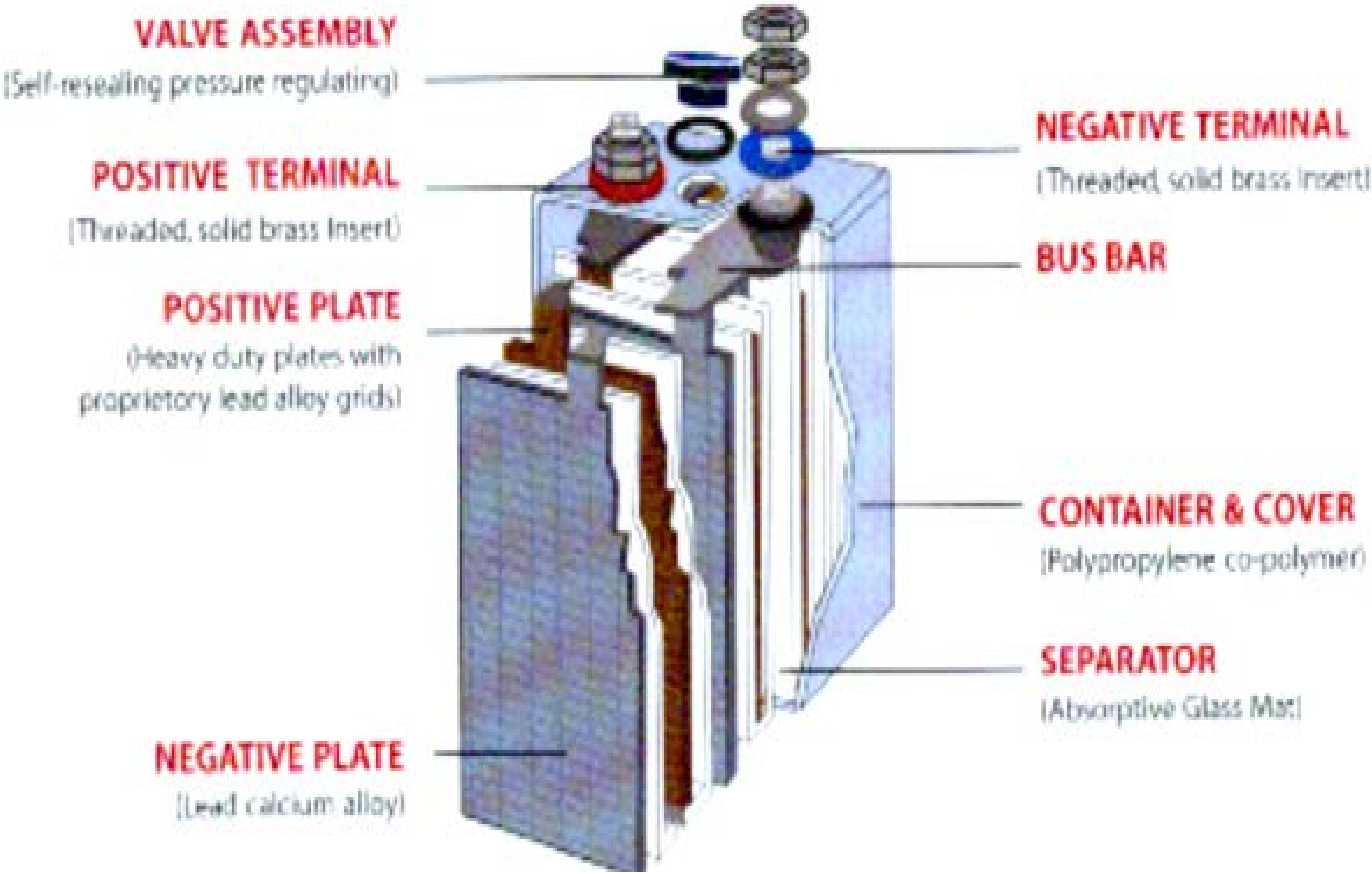
Oxygen recombination

Regulated vent to allow gases to escape at threshold pressure - **2 to 5 psi, depending on the battery design**

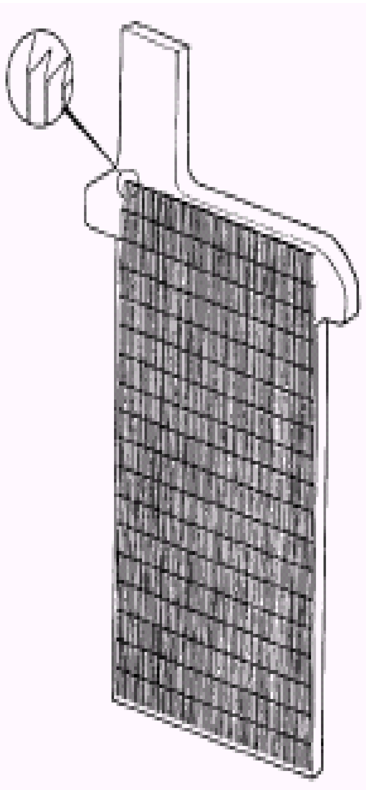
LA BATTERY PARTS

- +ve Electrode: PbO_2
- -ve Electrode: Pb
- Electrolyte: H_2SO_4
- Container: Polypropylene/Hard Rubber
- Separator: AGM (Absorbent Glass Mat)

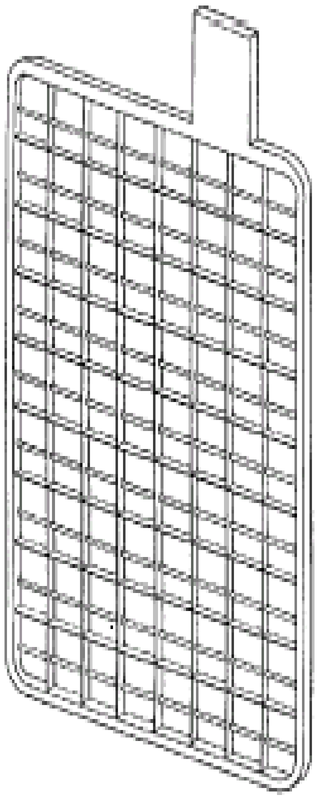
Exploded View - Triumph HP Cell



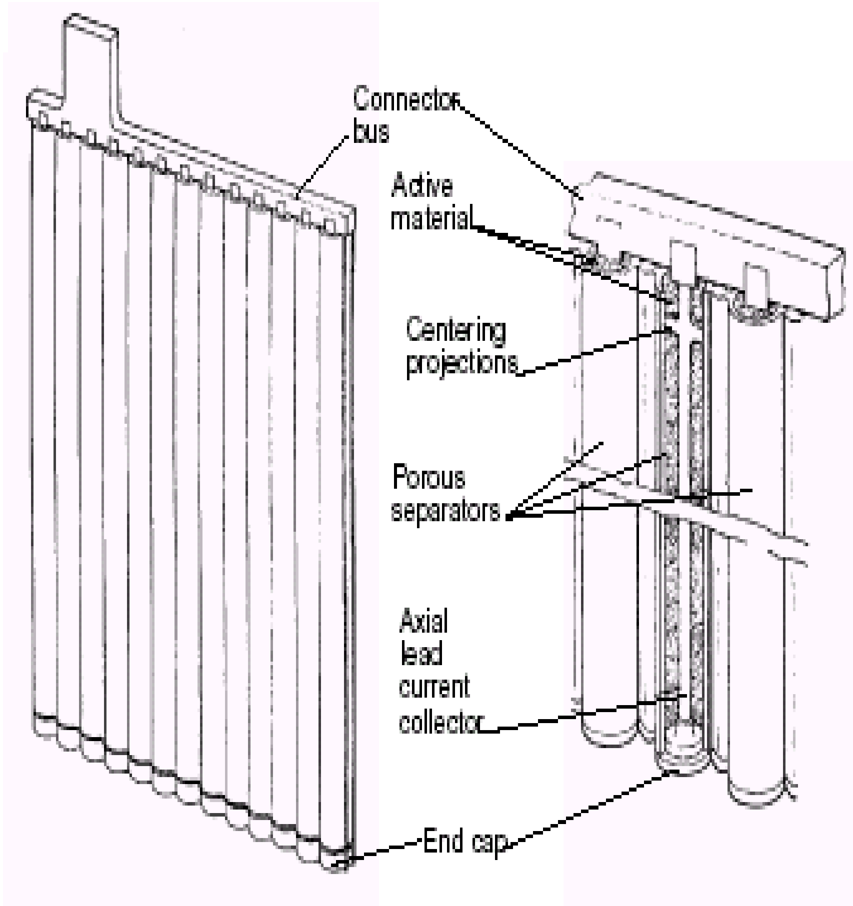
DIFFERENT TYPES OF LA PLATES



Plante



Flat grid



Tubular

DIFFERENT TYPES OF LA PLATES

Plate/Electrode

- Active material – Stores the charge
- Grid - Electrical conductor & support for active material

Different types of plates

- Plante plate: Active material has been electro-chemically produced over lead sheet
- Flat pasted plate : Active material has been supported by lead alloy mesh
- Tubular plate : The paste is held in micro-porous, non-conductive tubes (gauntlets)

CHEMICAL REACTIONS IN LEAD-ACID CELLS

1. **At the Negative Electrode:**

$$Pb + H_2SO_4 \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} PbSO_4 + 2H^+ + 2e^-$$

$E^0 = 0.356$ V

2. **At the Positive Electrode:**

$$PbO_2 + 2H^+ + H_2SO_4 + 2e^- \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} PbSO_4 + 2H_2O$$

$E^0 = 1.685$ V

3. **Overall Reaction:**

$$PbO_2 + Pb + 2H_2SO_4 \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} PbSO_4 + PbSO_4 + 2H_2O$$

$E^0 = 2.041$ V

PERFORMANCE COMPARISON OF LA BATTERIES

Performance requirement	Tubular LMLA	Flat plate (AGM)	Tubular gel
Maintenance (water top-up)	Maintenance Un-avoidable	Maintenance free (No top-up reqd)	Maintenance free No top-up reqd)
Stratification	High	Low	Nil
Cycle life	Good	Moderate	Excellent
Deep discharge recovery	Good	Moderate	Excellent
Partial state of charge operation	Excellent	Good	Excellent
Capacity at C120, C240	Excellent	Good	Excellent
Self discharge characteristic	Moderate	Excellent	Excellent
Low temperature operations	Moderate	Excellent	Good
High temperature operations	Excellent	Moderate	Excellent
Ease of installation	Initial charging required	Ready to use	Ready to use

NICKEL CADMIUM BATTERIES

Designed to perfection, Built to last

NICD BATTERY PARTS

- +ve Electrode: Nickel Hydroxide $Ni(OH)_2$
- -ve Electrode: Cadmium Hydroxide $Cd(OH)_2$
- Electrolyte: Potassium Hydroxide (KOH)
- Container : Polypropylene
- Separator : Micro porous PVC

NiCd Characteristics

Nominal Voltage	:	1.2 Volts
Float Voltage	:	1.40 – 1.42 Volts
Boost Voltage	:	1.53 - 1.70 Volts
Electrolyte	:	KOH of Specific gravity 1.20 ± 0.01
Operating temperature	:	- 50^{0}C to + 50^{0}C

NICD ELECTROCHEMISTRY

A. $2\,Ni(OH)_2 + 2\,OH^- \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} 2\,NiOOH + 2\,H_2O + 2\,e^-$ *V+= 0.49V*

B. $Cd(OH)_2 + 2\,e^- \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} Cd + 2\,OH^-$

V- = 0.809V

Over all reaction of a Nickel Cadmium Battery is as follows

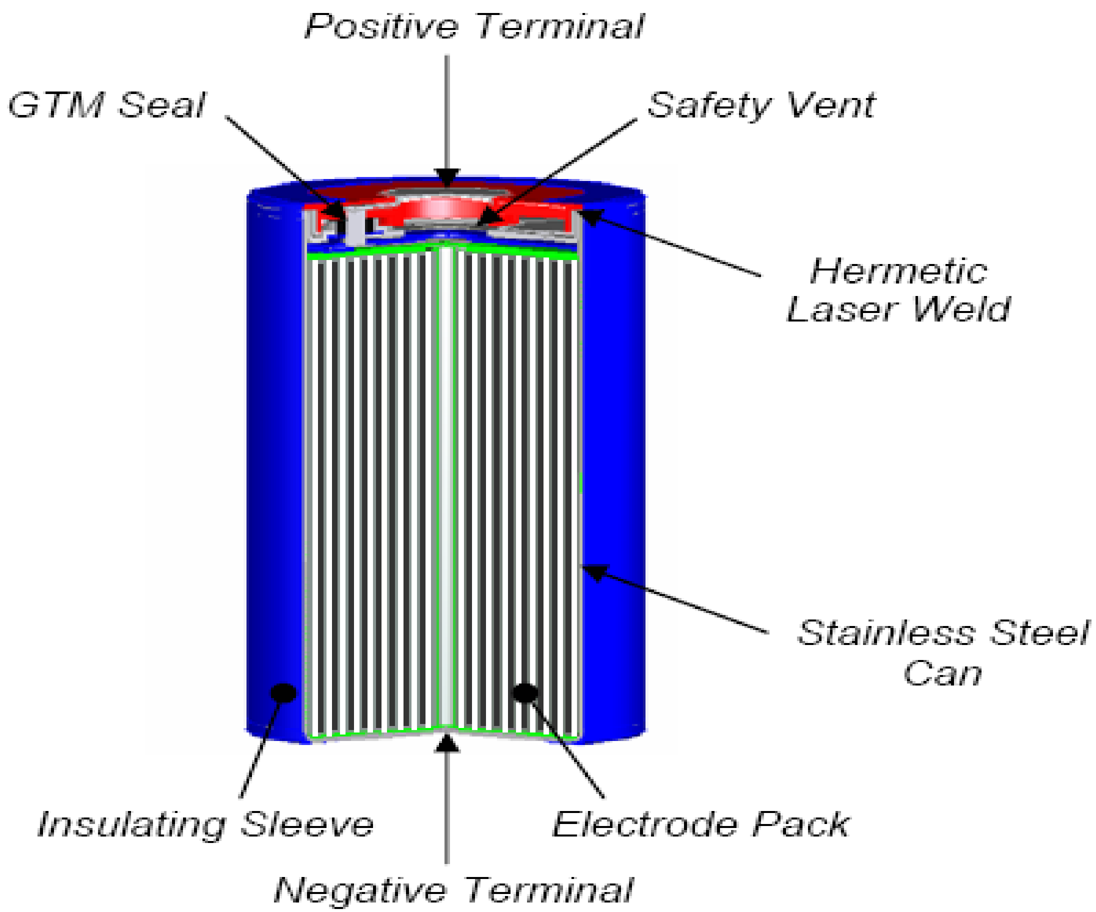
C. $2\,Ni(OH)_2 + Cd(OH)_2 \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftharpoons}} 2\,NiOOH + Cd + 2\,H_2O$

Potential difference of Ni-Cd cell shall be $V_o = 0.490 - (-0.809)$

$= 1.299$

*** Electrolyte does not take part in reaction; it is only a carrier of ions**

LITHIUM ION BATTERY



SALIENT FEATURES - LI BATTERIES

High Energy Density	Lithium Ion energy density is approximately **3 to 5 times** of a Lead Acid.
High Voltage	The maximum output operating voltage of our lithium-ion battery is **3.7v per cell** that exceeds three times higher than that of Ni-Mh, Ni-Cd battery (1.2V per cell).
High Rate Discharge	Lithium Ion Batteries offers approximately **45% more discharge capacity** than Lead Acid **at 2C** discharge rate.
Fast Charge	Fast charging is possible with a charger exclusive for the lithium ion battery (1CmA, 4.2V CC-CV).
No Memory Effect	Lithium ion batteries have no memory effect.
Long Cycle Life	Lithium ion batteries last over 5000 repeated charges and discharges.
Minimal Self-Discharge	Lithium Ion retains approximately **29% more capacity retained** by Lead Acid in **1 year** at 25'C and approximately **50% more capacity in 10 years.**
High Storage Characteristics	The residual capacity after 3 month storage is over 95%.

LITHIUM ION CHEMISTRIES

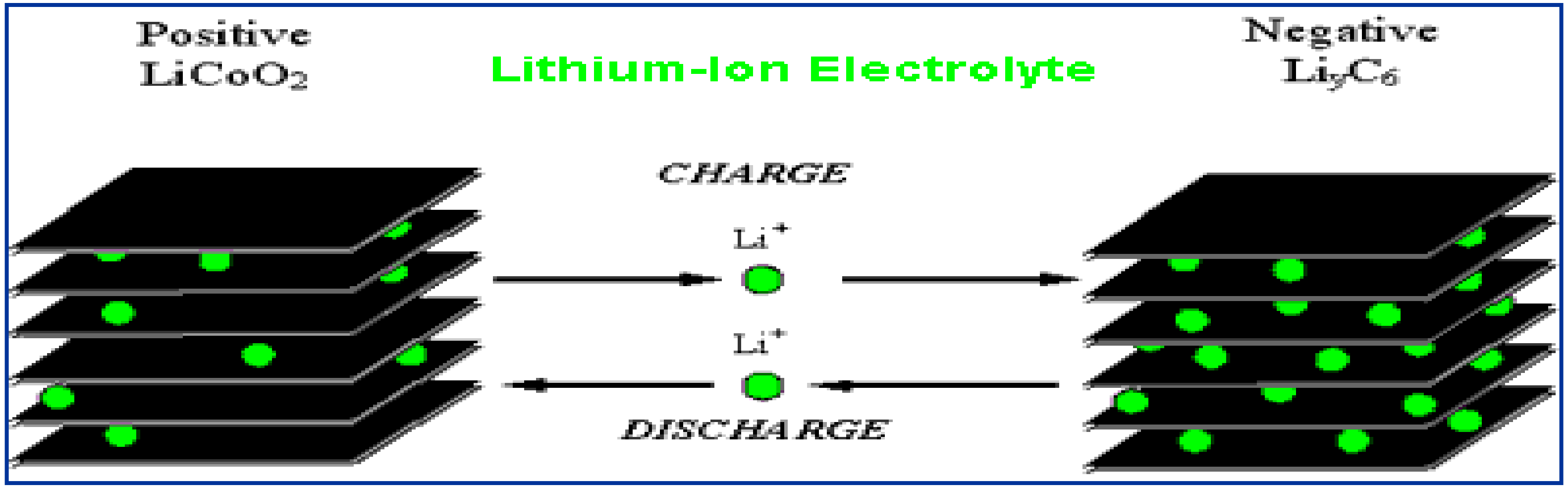
Cathode Materials

- Lithium metal oxides
- Li CoO2
- LiMn2O4
- Li FePO4
- ….. etc

Anode Materials

- Lithium metal
- Active Carbons
- Graphite
- Tin Oxides
- Others

HOW DOES A LITHIUM ION CELL WORK?

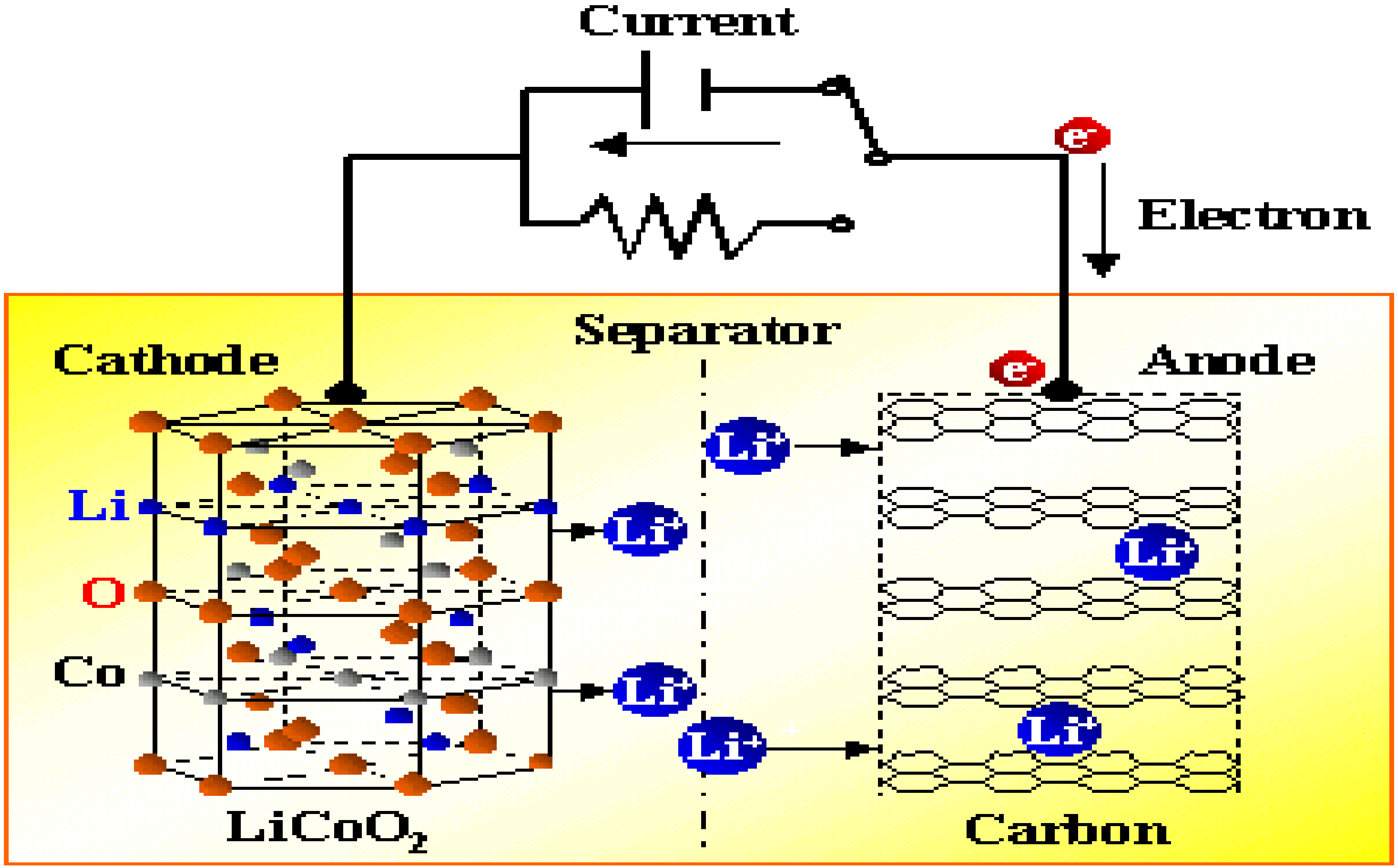


- <u>During the Charge Process</u>
- At the Cathode:
- $Li_xCoO2 \rightarrow Li_{(1-x)}CoO_2 + xLi^+ + xe^-$
- At the anode:
- $xLi^+ + xe^- + LixC6 \rightarrow LiC6$

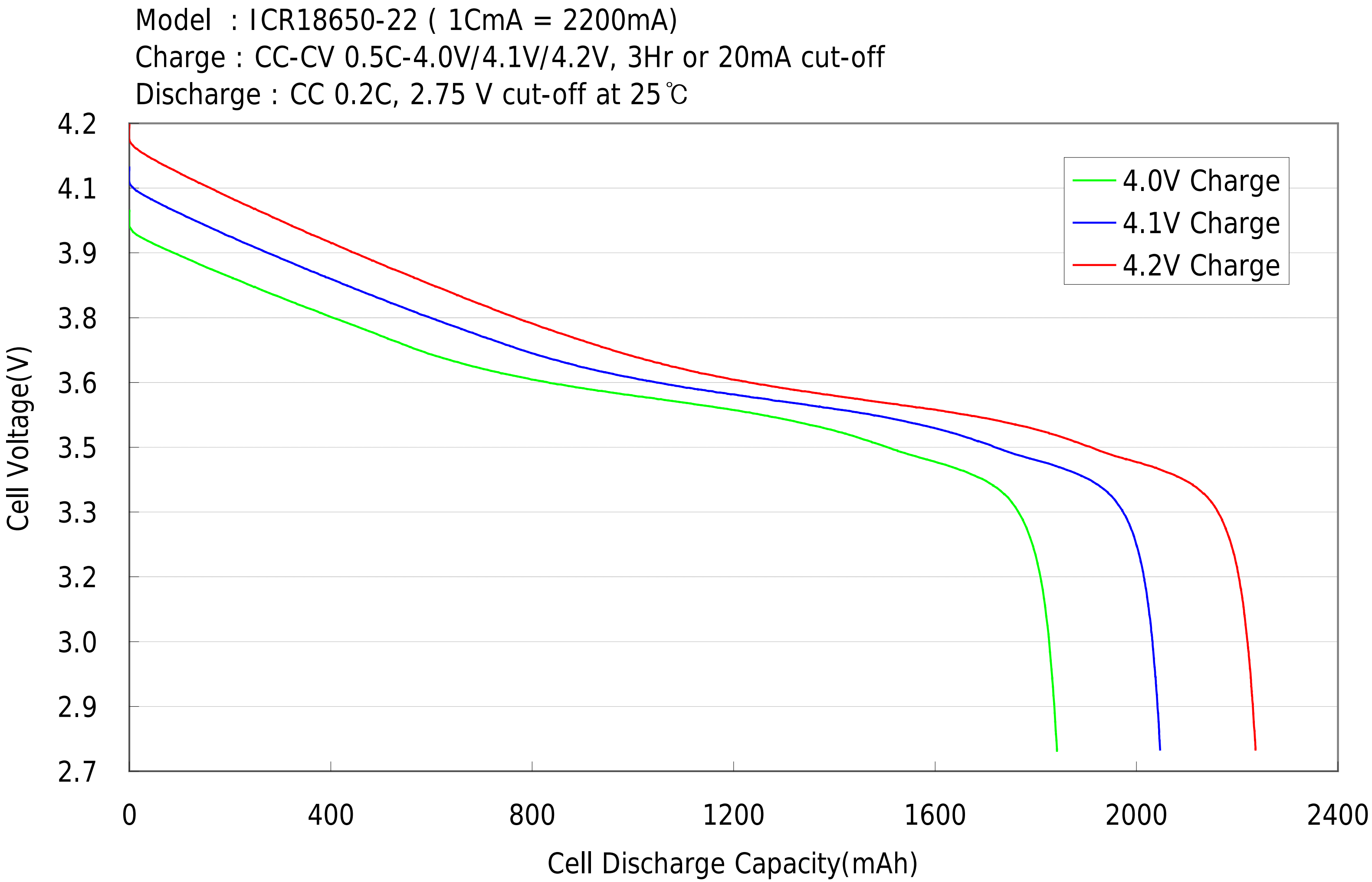
- <u>During the Discharge Process</u>
- At the Cathode:
- $Li_{(1-x)}CoO_2 + xLi^+ + xe^- \rightarrow LiCoO_2$
- At the anode:
- $LiC6 \rightarrow xLi^+ + xe^- + LixC6$

<u>Overall Cell Reaction:</u> $Li_xCoO_2 + C6 \rightarrow LiC6 + Li(1-x)CoO_2$ E = 3.0 ~3.6 V

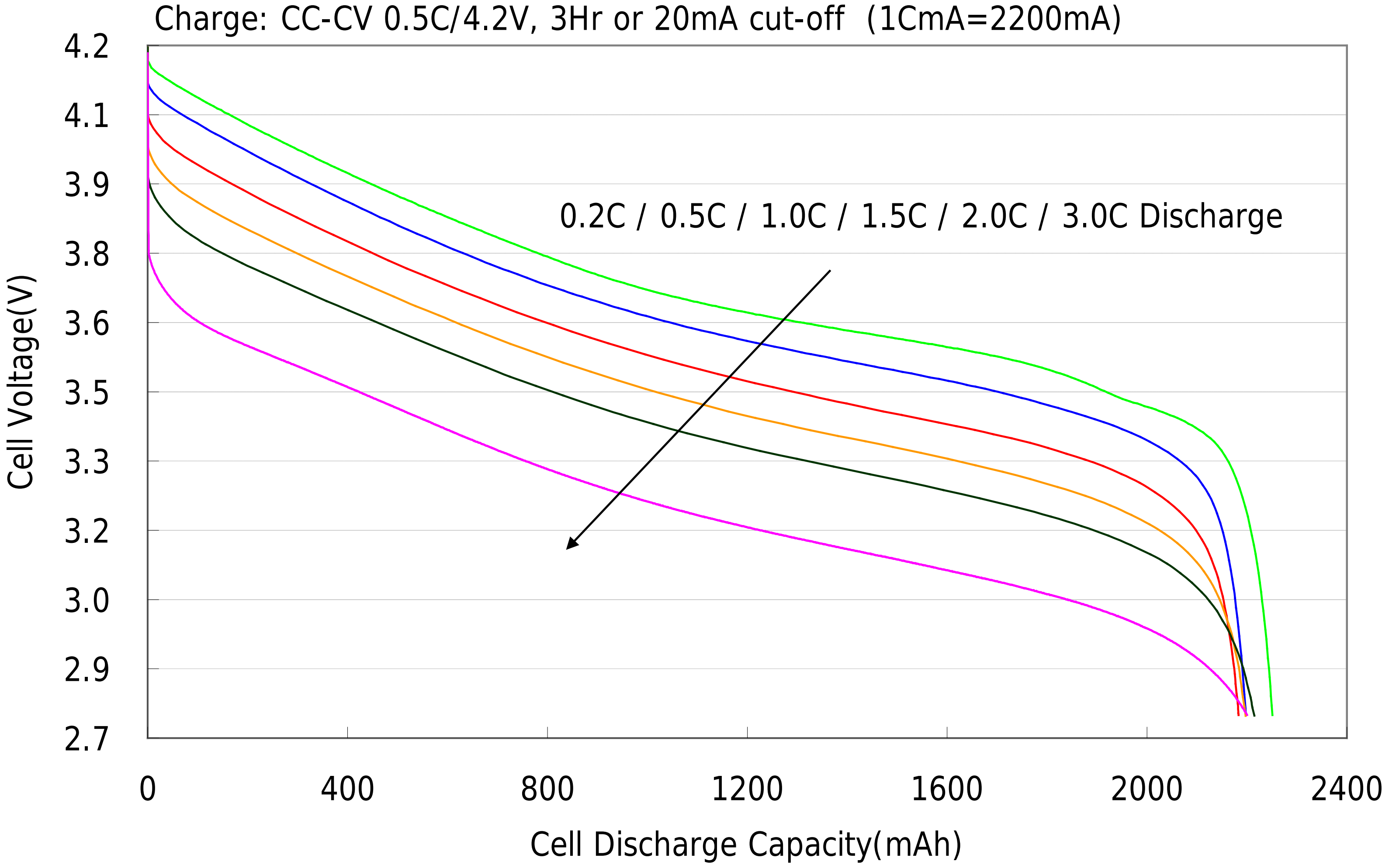
A LITHIUM ION CELL



CHARGE & DISCHARGE VOLTAGE CHARACTERISTICS



HIGH RATE DISCHARGE CHARACTERISTICS



COMPARATIVE ANALYSIS

Parameter	VRLA	Tubular GEL	Lithium poly
Charging efficiency	High	Lower	High
Space requirement	Large cell size, Huge space requirement	Large cell size, Huge space requirement	Smallest Size
Stacking	Horizontal or vertical	Up to 1500 AH : Horizontal or vertical >1500 AH: Vertically, in tiers	Horizontal is preferable ,Vertical is possible.
Self-discharge during storage, at an average temperature of 35°C.	50% self-discharge in 6 months. Recovery easy.	50% self-discharge in one year. Recovery easy.	< 2~3% / month (Retention >80% at 1year)
Cyclic Life **(to 80% DoD).**	1400 cycles at an average temperature of 35°C in normal environmental condition	Better than 2100 cycles at an average temperature of 35°C in normal environmental condition	> 5,000 cycles at 25'C(1C charge/discharge)

COMPARATIVE ANALYSIS

Parameter	VRLA	Tubular GEL	Lithium poly
Charging Requirement	Constant voltage charging by SMPS Power plants	Constant voltage charging by SMPS Power plants	CC-CV mode charge. Lower current (<1C) is better for cycle-life
Thermal runaway	Probable, yet rare	Not possible	No thermal runaway Even at the abuse test
Self-discharge during storage, at an average temperature of 35°C.	50% self-discharge in 6 months. Recovery easy.	50% self-discharge in one year. Recovery easy.	< 2~3% / month (Retention >80% at 1year)
Cyclic Life **(to 80% DoD).**	1400 cycles at an average temperature of 35°C in normal environmental condition	Better than 2100 cycles at an average temperature of 35°C in normal environmental condition	> 5,000 cycles at 25’C(1C charge/discharge)

COMPARATI VE ANALYSI S

Parameter	VRLA	Tubular GEL	Lithium Poly
High temperature performance	Average, with temperature compensation	Good	Good, Same or higher capacity than that of 25’C
Low temperature performance	Good	Good	Good, 80% at -10’C (1C)(Cycle-life degradation can happen)
Stratification	Negligible, no boost charging required.	Negligible, no boost charging required.	No limit (<1,000V)
End cell voltage	1.75V/cell	1.75V/cell	2.0V Minimum
Deep discharge recovery	Average, after 4 to 5 charge/discharge cycles	Average, after 4 to 5 charge/discharge cycles	Recovery >95% is possible within 1~2cycle
Charge efficiency	Excellent, 6 to 8 hours for 90% recovery	Slightly poor, 8 to 10 hrs for 90% recovery	Excellent,
Overcharging Performance	Poor, damages the battery.	Good	In a cell-level, 2C 10V overcharge can be guaranteed.

BATTERY TESTING

- Battery Testing
  - ✓ Visual Inspection/Verification of dimension
  - ✓ Leakage Test
  - ✓ Specific Gravity Checking – 1240

    SG27/(1+0.00007*(T-27))
  - ✓ Acceptance/Capacity Test at 10 hr rate
  - ✓ Storage Test
  - ✓ Endurance Test
  - ✓ Ah & Wh Efficiency Test

BATTERY TYPE TEST & ACCEPTANCE TEST

- Battery Type Test
  - ✓ Verification of constructions requirements
  - ✓ Verification of marking
  - ✓ Verification of dimension
  - ✓ Test of Capacity
  - ✓ Ampere-hour and Watt-hour capacity
  - ✓ Test of loss of capacity on storage
  - ✓ Endurance Test
- Battery Acceptance Test
  - ✓ Verification of marking
  - ✓ Verification of dimension
  - ✓ Test of Capacity

VERIFICATION OF DIMENSION

- Verification of dimension
  - Equipment Used: Need to check calibration date
    - Digimatic Caliper
    - Height Gauge
    - Steel Rule
    - Thermometer

    Test Conditions: Temperature = 25 deg C

    Test Procedure:

    To check length, width and height of the batteries with Steel Rule, Digimatic Caliper, and Height Gauge

    Requirements:

    Overall dimensions of the batteries shall not exceed the values given in the standard

VERIFICATION OF DIMENSION

Test Result:

Description	**Dimensions specified in the standard**	**Values observed**
Length (mm)	525	511
Width (mm)	295	211.27
Height (mm)	300	266.67
Result		**PASS**

VISUAL INSPECTION: CONSTRUCTIONAL REQUIREMENTS

- Constructional Requirements and Marking

  Test Procedure:

  Various components of battery viz. Battery Lids, Electrolyte Level indicator, Terminal post, connections, terminal connections, nuts & bolts, are examined visually.

  Requirements:

  All components/parameters of the battery shall comply with the specific requirements given in the IS standards.

VISUAL INSPECTION: CONSTRUCTIONAL REQUIREMENTS

Test Result: Visual Inspection

Description	Specific Requirements	Observations	RESULT
Battery Lids	Battery lid shall be provided in each cell	Battery lid provided in each cell	PASS
	Battery lid made up of Hard rubber shall be of deep sealing type	Battery are made up of plastic hence not applicable	---
	Battery lid made up of plastic shall be of deep sealing type or glued type	Battery lid are made up of plastic and are of deep sealing type	PASS
Electrolyte Level Indicator	Each cell shall have electrolyte level indicator for indicating lower and upper limits of electrolyte	Each cell is fitted with vent plug cum float guide	PASS
Terminal Post	Positive and Negative post shall be clearly identifiable	Positive and Negative post are clearly identifiable	PASS

VISUAL INSPECTION: CONSTRUCTIONAL REQUIREMENTS

Test Result: Marking

Description	Observation	RESULT
Source of Manufacturer	HBL Power Systems Limited (marked on self-adhesive sticker)	PASS
Ah Capacity at C10 Rate	12V 80Ah (marked on self-adhesive sticker)	PASS
Upper and Lower electrolyte level in case of transparent container	Batteries are made of opaque plastic container hence not applicable	--
Year of Manufacture	11-2014 (Nov 14 punched on terminal posts)	PASS
Country of Origin	INDIA	PASS
Each cell and battery may also be marked with standard (ISI) mark – Optional	Battery are not marled with ISI mark	--

LEAKAGE TEST

- Equipment Used: Water tank, compressed air

  Test Procedure:

  Cell is dipped into the water tank and air pressure is applied upto 10-11 psi.

  Requirements:

  Leakage is not permitted

  Test Result:

  If any leak path is there in the cell, air inside the cell comes out through the leak path which can be observed in the form of air bubble coming out from the cell.

CAPACITY TEST AT 10 hr RATE

- Equipment Used: Life Cycle Tester, Clamp Meter, Multimeter, Thermometer, Hydrometer.

  Test Procedure:

  Fully charged battery is discharged at C10 rate (8.0A for 80Ah battery) until on-load voltage of battery reaches 10.8V; recharge at 8.0A until voltage reaches 2.4V/cell (14.4V), charge further at 4.0A until voltage reaches 2.600 to 2.700V/cell (15.6V to 16.2V); rest for 12 hr.

  Requirements:

  Actual capacity obtained shall not be less than 100% of rated 10 hr capacity.

CAPACITY TEST AT 10 Hr RATE

Test Result:

Description	**Battery 1**	**Battery 2**
Open circuit voltage (V)	12.74	12.74
Electrolyte Specific Gravity	1.245	1.240
Obtained Capacity	86.4	87.1
Result	**PASS**	**PASS**

CAPACITY TEST AT 10 Hr RATE

Internal Test Result:

Capacity Test

Battery Make.................

Battery Model.............

Discharging Current ....

Battery S.No.......................

Test Type: C10

SR.NO.	DIS. CURRENT	START TIME	HRS	VOLTAGE	GRAVITY	TEMP

TOTAL RUNNING TIME OBTAINED =

AVERAGE TEMPERATURE =

AT 27*C = Ct+CtX r(27-t)/100

C10 =

%age =

AMPERE-HOUR AND WATT-HOUR EFFICIENCY TEST

- Equipment Used: Life Cycle Tester, Clamp Meter, Multimeter, Thermometer, Hydrometer.

  Test Procedure:

  Fully charged battery is discharged at C10 rate (8.0A for 80Ah battery) until on-load voltage of battery reaches 10.8V – 1st Discharge; recharge the battery at 8.0A until it receive an input equal to the capacity obtained in 1st discharge; Rest for 12 Hour; discharge the battery @ 8.0 A until on-load voltage reaches 10.80V – 2nd discharge

  Requirements:

  Ampere- hour efficiency and Watt-hour efficiency shall not be less than 90% and 75% respectively.

AMPERE-HOUR AND WATT-HOUR EFFICIENCY TEST

Test Result:

Description	**Battery 1**	**Battery 2**
Open circuit voltage (V)	12.59	12.56
Electrolyte Specific Gravity	1.240	1.235
Ampere-hour efficiency (%)	95.5	94.4
Watt-hour efficiency (%)	83.8	81.8
RESULT	**PASS**	**PASS**

ENDURANCE TEST

- Equipment Used: Life Cycle Tester, Hot water bath (upto 70 deg C), Clamp Meter, Multimeter, Thermometer, Hydrometer

  Test Procedure:

  Fully charged battery is placed in hot water bath maintained at the temperature of 40±3 deg C; The battery is overcharged @8.0A for 2000 hrs; Sequence of 2000 hrs over charge – 2 cycles of 300 hrs charging followed by discharge at 10 hr rate, 3 cycles of 200 hrs charging followed by discharge at 10 hr rate; 8 cycles of 100 hrs charging followed by discharge at 10 hr rate.

  Requirements:

  Battery shall give minimum of 9 hour back-up in the final discharge.

ENDURANCE TEST

Test Result:

1. Discharge @ 10 hr rate; 40 deg C after 2 cycles of 300 hour over charge

Description	**Battery sl. No.**
Open circuit voltage (V)	12.55
Electrolyte Specific gravity	1.235
Discharge duration (Hr: min)	11.58
Avg. Electrolyte temp during discharge	42.2
RESULT	**PASS**

ENDURANCE TEST

Test Result:

2. Discharge @ 10 hr rate; 40 deg C after 3 cycles of 200 hour over charge

Description	**Battery sl. No.**
Open circuit voltage (V)	12.71
Electrolyte Specific gravity	1.240
Discharge duration (Hr: min)	11.38
Avg. Electrolyte temp during discharge	41.4
RESULT	**PASS**

ENDURANCE TEST

Test Result:

3. Discharge @ 10 hr rate; 40 deg C after 8 cycles of 100 hour over charge

Description	**Battery sl. No.**
Open circuit voltage (V)	12.68
Electrolyte Specific gravity	1.240
Discharge duration (Hr: min)	11.02
Avg. Electrolyte temp during discharge	41.4
RESULT	**PASS**

LOSS OF CAPACITY ON STORAGE

- Equipment Used: Life Cycle Tester, Clamp Meter, Multimeter, Thermometer, Hydrometer

Test Procedure:

Fully charged battery is discharged at C10 rate (8.0A for 80Ah battery) until on-load voltage of battery reaches 10.8V; recharge the battery at 8.0A until voltage reaches 14.4V; further charge continued @4.0A until voltage reaches 15.6 – 16.2V – capacity test at 10hr rate (cycle-1), Capacity test @10hr rate repeated for 2^{nd} time (Cycle-2); After full recharge battery kept under storage in open circuit condition @27±5 deg C for 28 days; after completion of storage without giving any charge battery is tested for capacity @10 hr rate to 10.8V/battery.

Requirements:

Loss of capacity shall not exceed 10%

LOSS OF CAPACITY ON STORAGE

Test Result:

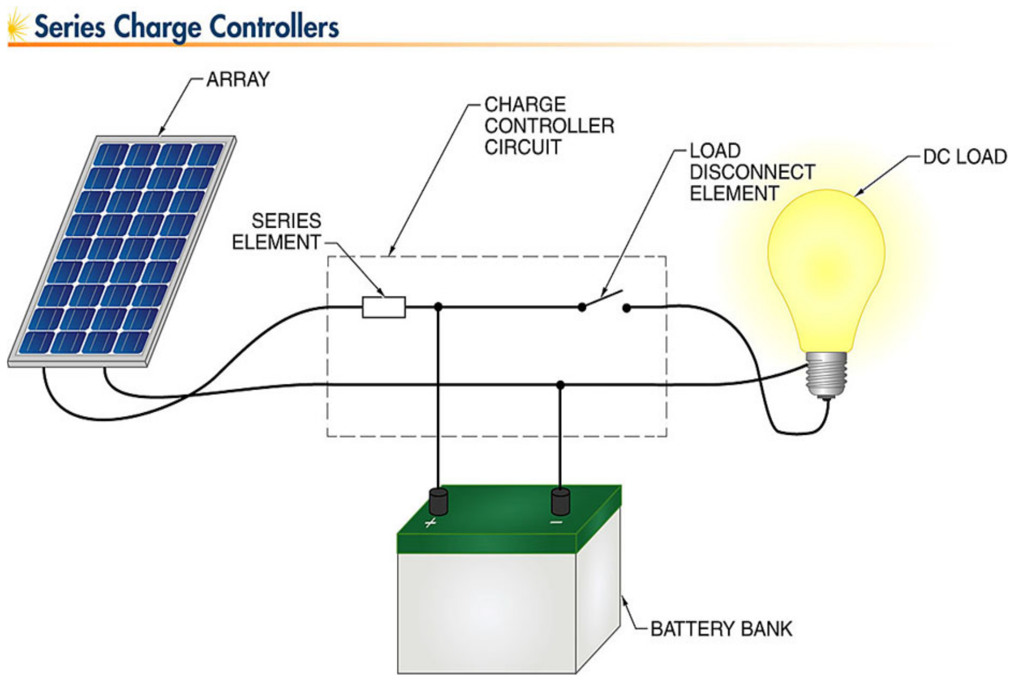
Description	**Battery 1**	**Battery 2**
Capacity Cycle 1	95.3	96.5
Capacity Cycle 2	95.7	96.3
Avg. Capacity	95.5	96.4
Ah efficiency (%)	93.3	94.1
Loss of capacity (%)	2.2	2.3
RESULT	**PASS**	**PASS**

CHARGE CONTROLLER

- Charges battery from a DC Source
- Prevents battery overcharge
- Blocks reverse current
- Prevent over-discharge from batteries
- Prevent electrical overload
- Uncontrolled/Controlled

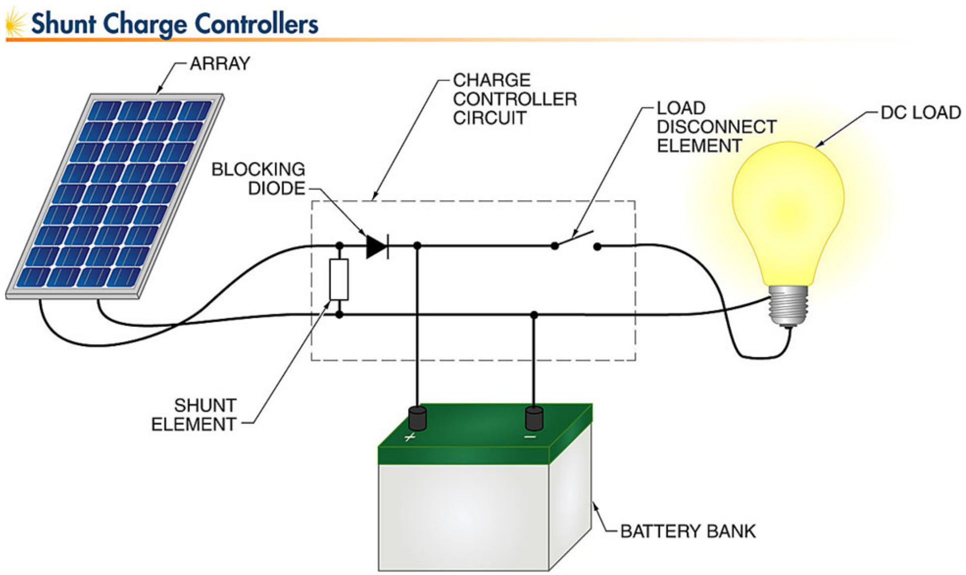
SERIES CHARGE CONTROLLER

Series charge controllers regulate charging current by opening the circuit from the array. As the battery reaches full state of charge, a switching



element inside the controller opens, moving the array's operating point on the I-V curve to the open-circuit condition and limiting the power output.

SHUNT CHARGE CONTROLLER

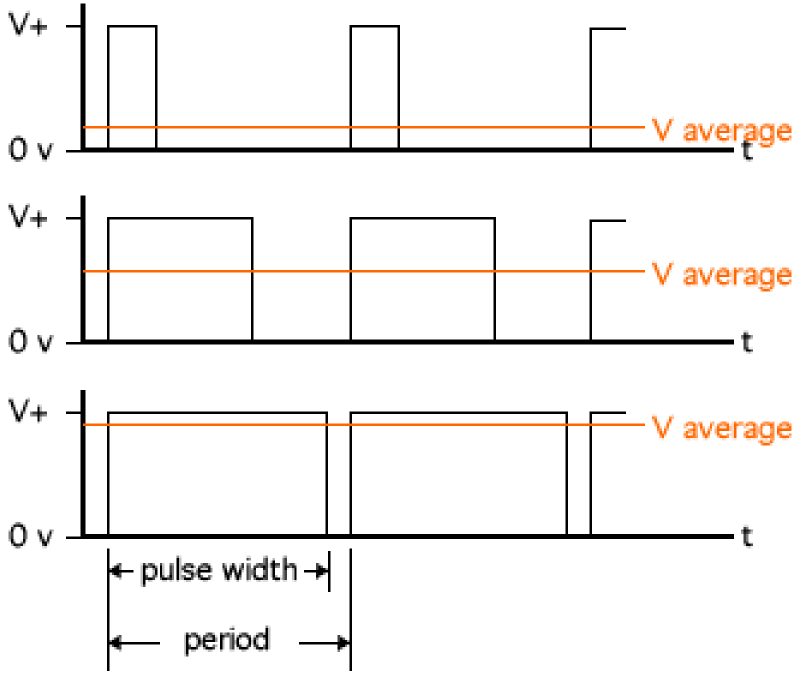


Shunt charge controllers regulate charging current by short-circuiting the array. Unlike batteries, PV devices are current-limited by nature, so PV modules and arrays can be short-circuited without any harm. A *shunt charge controller* is a charge controller that limits charging current to a battery system by short-circuiting the array. The array is short-circuited through a shunt element inside the charge controller, moving the array's operating point on the I-V curve very near the short-circuit condition and limiting the power output. All shunt controllers must also include a blocking diode in series between the battery and the shunt element to prevent the battery from short-circuiting.

PWM CHARGE CONTROLLER

Pulse-width modulation (PWM) simulates a lower current level by pulsing a higher current level ON and OFF for short intervals.

- Battery is charged using pulses of energy that can vary in length and speed according to battery condition.
- As the battery reaches capacity, the flow of energy is slowly tapered off as opposed to sudden cut off to reduce battery overcharging
- Ideal for situations where excess energy is often present
- Higher charging efficiency
- Rapid recharging
- Healthy battery at full capacity



MPPT CHARGE CONTROLLER

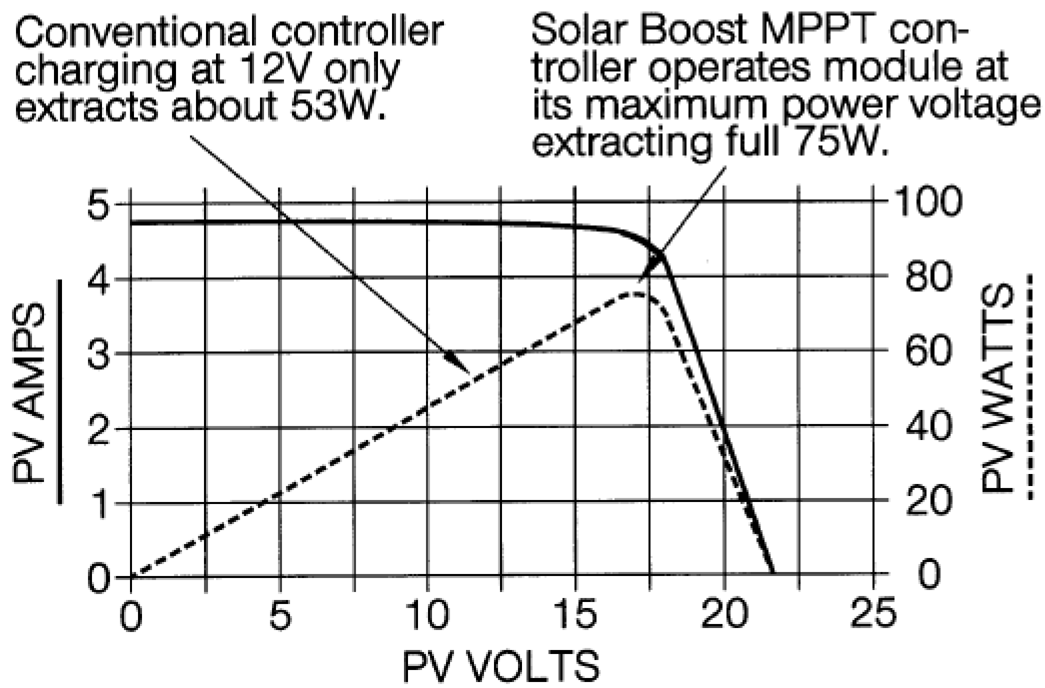
Maximum power point tracking manipulates the load or output voltage of an array in order to maintain operation at or near the maximum power point under changing temperature and irradiance conditions

- A MPPT controller adjusts the voltage output to take advantage of the Vpp and charge the battery more

- *Peak Power Voltage* (Vpp) is the maximum power point that a PV system can deliver; varies with temperature and sunlight intensity
- The power is transformed by a DC-DC converter circuit into another voltage and current required by the load/ battery.

MPPT CHARGE CONTROLLER

Conventional controller charges a discharged Battery by simply connecting the modules directly to the battery. This forces the modules to operate at battery voltage12V. The MPPT system operates the modules at 17V to extract the full 75W, regardless of present battery voltage. A high efficiency DC-to-DC power converter converts the 17V module voltage at the controller input to battery voltage at the output.



Typical 75W PV Module Power/Voltage/Current At Standard Test Conditions

CHARGE CONTROLLER TESTING

- Functional Testing
  - ✓ Visual Inspection
  - ✓ Self Consumption
  - ✓ Internal Voltage Drop
  - ✓ Voltage regulation Thresholds
  - ✓ Protections
  - ✓ Maximum current Resistance
  - ✓ DC-DC conversion Efficiency

CHARGE CONTROLLER TESTING

- IEC 60068-2 (1,2 14,30)

Test Equipment Used

- ✓ Programmable Environmental Chamber Votsch/VC³ 4100 Consumption
- ✓ Environmental Test Chamber KEW/PEC-HYG

DRY HEAT TEST

- Dry Heat Test

Pre-checks: Physical damages

Test Specifications:

Test temperature: +55ºC

One cycle Duration: 16 hrs

No. of cycles: one

Pot Checks: No physical damages observed

COLD TEST

- Cold Test

Pre-checks: Physical damages

Test Specifications:

Test temperature: -10ºC

One cycle Duration: 02 hrs

No. of cycles: one

Pot Checks: No physical damages observed

DAMP HEAT CYCLE

- Damp Heat Cycle

Pre-checks: Physical damages

Test Specifications:

Ramp up /down time: 3 Hrs

One cycle Duration: 12+12 hrs

No. of cycles: Three

Total Test Duration: 72 Hrs

Post Checks: No physical damages observed

CHANGE OF TEMPERATURE

- Change of temperature

Pre-checks: Physical damages

Test Specifications:

Test Temperature: Upper +55ºC, Lower -5ºC

Rate of change of temperature: 1ºC/min

Dwell time: 1hr at each temperature

No. of cycles: 5 cycles

Post Checks: No physical damages observed

CHARGE CONTROLLER SETTING

- Float Charging Voltage : 2.25 V/cell
- Boost Charging Voltage : 2.35 V/cell
- Charging Current Limit : 10 – 20% of BB Ah
- L.V.D. : 1.90 V/Cell
- H.V.D.: 2.40 V/Cell
- Temp. Compensation: 3 mV/ cell/ per degree celcius
- Ripple Contents: < 3%

APPLICABLE STANDARDS

Battery standards:

- IS 1651
- IS 13369
- IEC 61427
- IS 15549

Solar Charge Controller Standards

- IEC 60068-2 (1,2,14,30) – Environmental Testing