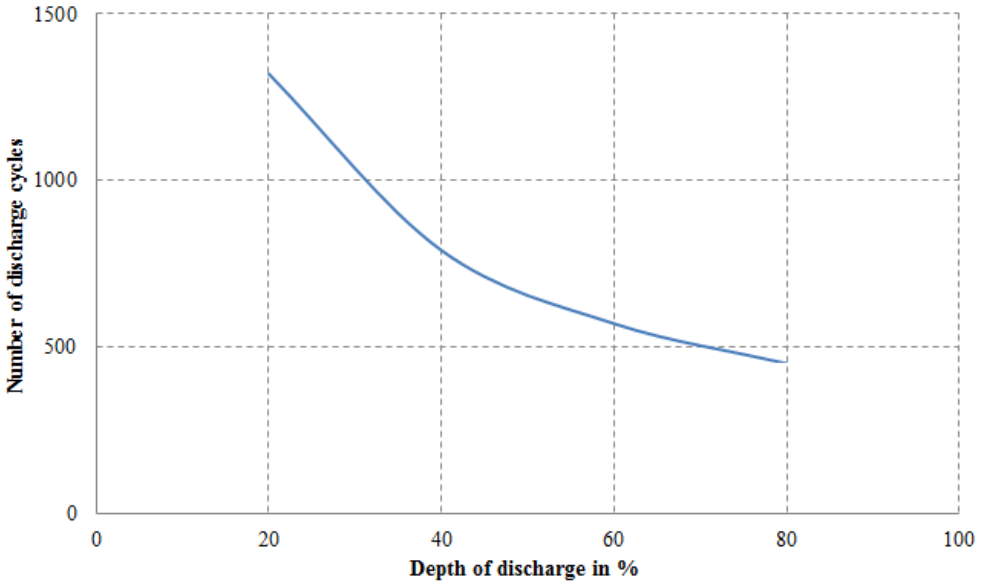
NARADA POWER SOURCE CO., LTD.

BATTERY CYCLIC PERFORMANCE CALCULATION AND ESTIMATION

V1.2, 7th May 2013

1. Ideal Cyclic Performance

1.1 GP Series Cyclic Test Result



Graph 1, Cycle life vs. DOD of GP Series with Ideal Charge Model

Table 1, data of cycle number

	Depth of Discharge/DOD			
	20%	40%	60%	80%
Cycle life	1320	790	570	450

1.2 Discharge & Charge Scenario (80%DOD)

1) Cycle method: Discharge with $2I_{10}$ for 4 hours (80% DOD), charge with $2I_{10}$ for 3.5hour + I_{10} for 0.5hour + $0.25I_{10}$ for 3.5hour. This is one cycle.

2) Residue Capacity determination: The batteries are discharged at 10 hour rate after every 50 cycles to test battery capacity. When residue capacity of 10 hour rate capacity is lower than 80%, test is ended.

After discharge at 10 hour rate after every 50cycles, the charge method is: charge 80% of discharged capacity with current of $2I_{10}$ + charge 20% with current of I_{10} + charge 20% with current of $0.4I_{10}$ (i.e. charge 120% of discharged capacity)

3) Temperature: 25℃

1.3 Advantage of Upper Constant Current Charge Model

Battery can be completely recharged within 8 hours.

The end charge voltage will be higher than 2.6Vpc, which is good for active material exchange.

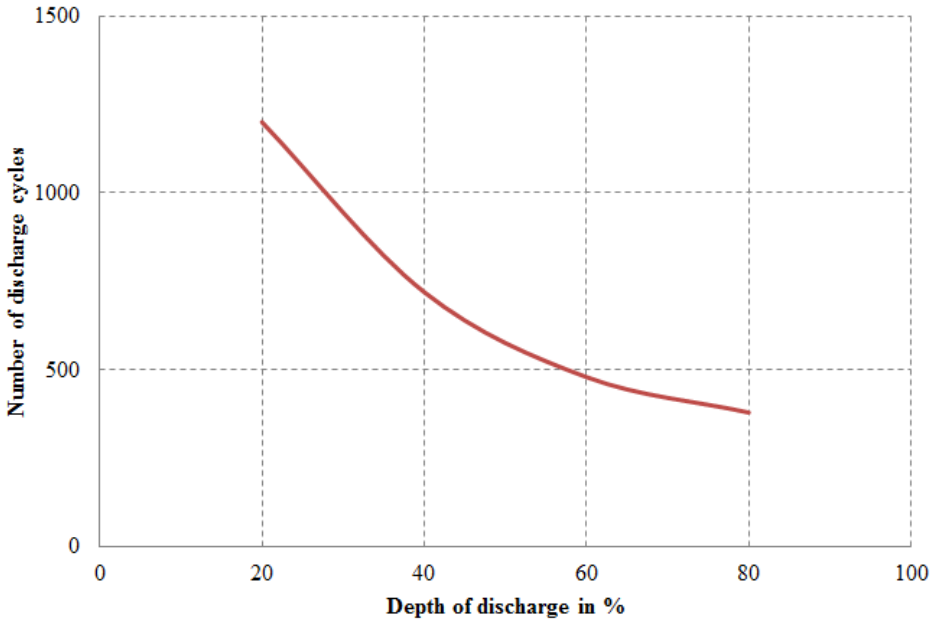
1.4 Disadvantage of Upper Constant Current Charge Model

It has risk of battery malfunction without voltage limited.

It isn't easy to manage charging in practice.

2. Practicable Ideal Cyclic Performance

2.1 GP Series Cyclic Test Result



Graph 1, Cycle life vs. DOD of GP Series with Practicable Charge Model

Table 2, data of cycle number

	Depth of Discharge/DOD			
	20%	40%	60%	80%
Cycle life	1200	720	480	380

2.2 Discharge & Charge Scenario (80%DOD)

1) Cycle method: Discharge with I_{10} for 8 hours (80% DOD), charge with constant voltage of 2.25Vpc and limited current of I_{10} for 24 hours. This is one cycle.
2) Battery failure determination: When the end voltage of daily discharge is lower than 1.80Vpc, test is ended.
3) Temperature: 25℃

2.3 Advantage of Upper Constant Current Charge Model

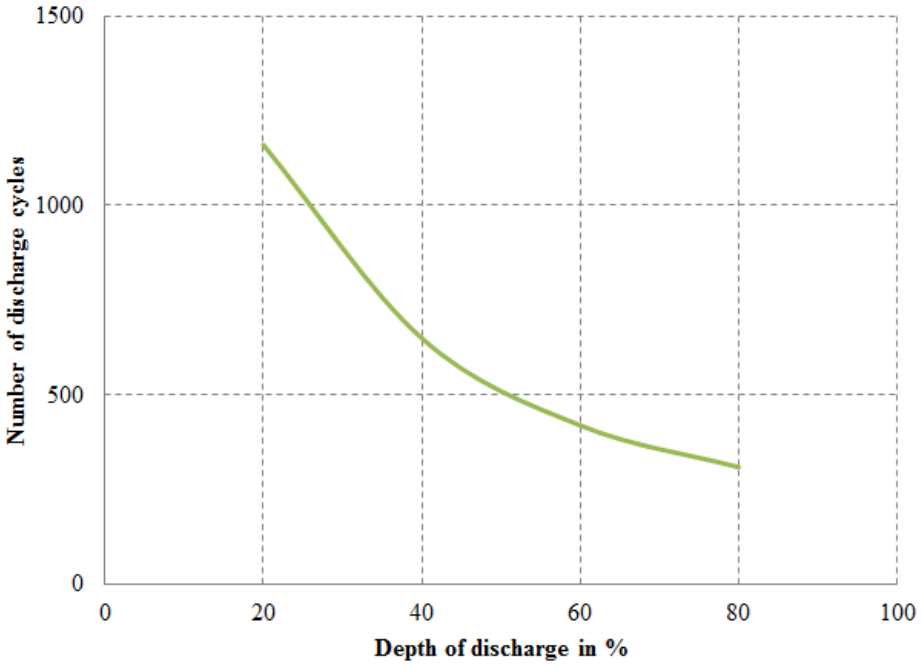
It is easy to manage charging in practice.
There is less battery malfunction risk because of charge voltage limited.

2.4 Disadvantage of Upper Constant Current Charge Model

Need long period charging of 24 hours to get battery completely recharged.
Have more chance for secondary reaction.

3. Practicable Daily Cyclic Performance

3.1 GP Series Cyclic Test Result



Graph 3, Cycle life vs. DOD of GP Series with Daily Cyclic Scenario

Table 3, data of cycle number

	Depth of Discharge/DOD			
	20%	40%	60%	80%
Cycle life	1160	650	420	310

3.2 Discharge & Charge Scenario (80%DOD)

1) Cycle method: Discharge model is customizable, total discharge capacity is 80% DOD, charge with certain constant voltage and limited charge current which are recommended by manufacturer based on customer's discharge model, but charge time shall be 10 hours at least. This is one cycle.

2) Battery failure determination: When the end voltage of daily discharge is lower than 1.80Vpc, battery is failed.

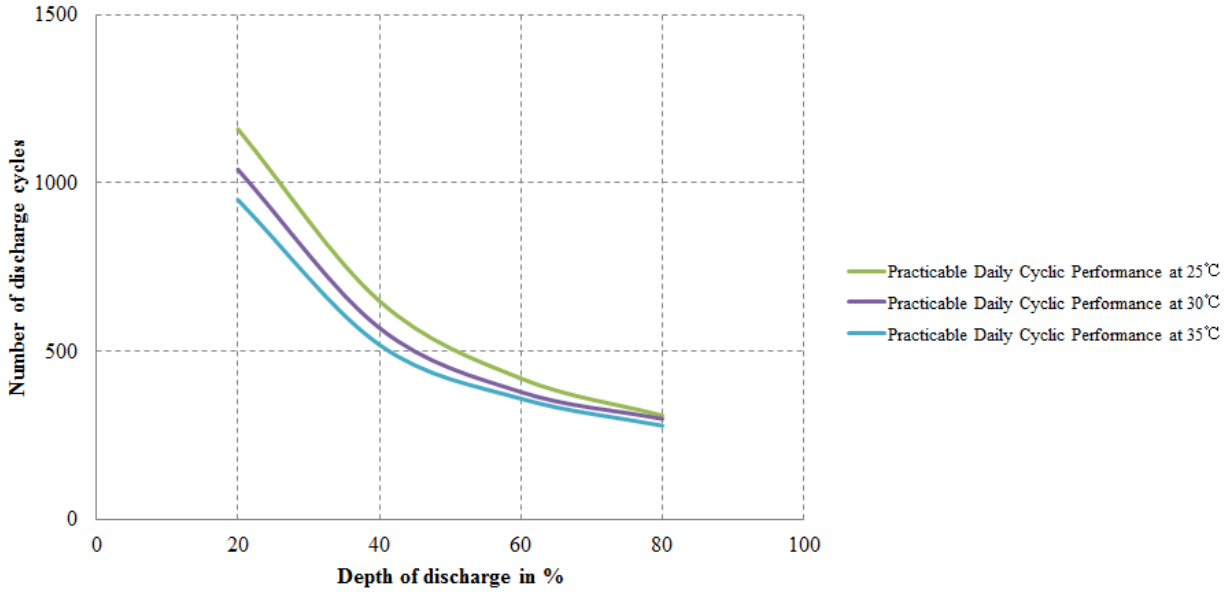
3) Temperature: 25℃

3.3 Upper Battery Cycle Life is Common Data

For practical daily cycle life, total charge & discharge time is constant of 24 hours. Different charge & discharge scenario will affect battery cycle life.

4. Practicable Daily Cyclic Performance vs. Ambient Temperature

4.1 GP Series Cyclic Test Result



Graph 4, Cycle life vs. DOD of GP Series with Daily Cyclic Scenario at Different Temperature

Table 4, data of cycle number

Cycle life	Depth of Discharge/DOD			
	20%	40%	60%	80%
25 ℃	1160	650	420	310
30 ℃	1040	570	380	300
35 ℃	950	520	360	280

4.2 Affect of Ambient Temperature

VRLA is an electrochemical battery, absolutely will be affected by ambient temperature. High temperature harm to cyclic application is not so terrible as to floating application. High temperature accelerates battery secondary reaction to shorten battery cycle life.

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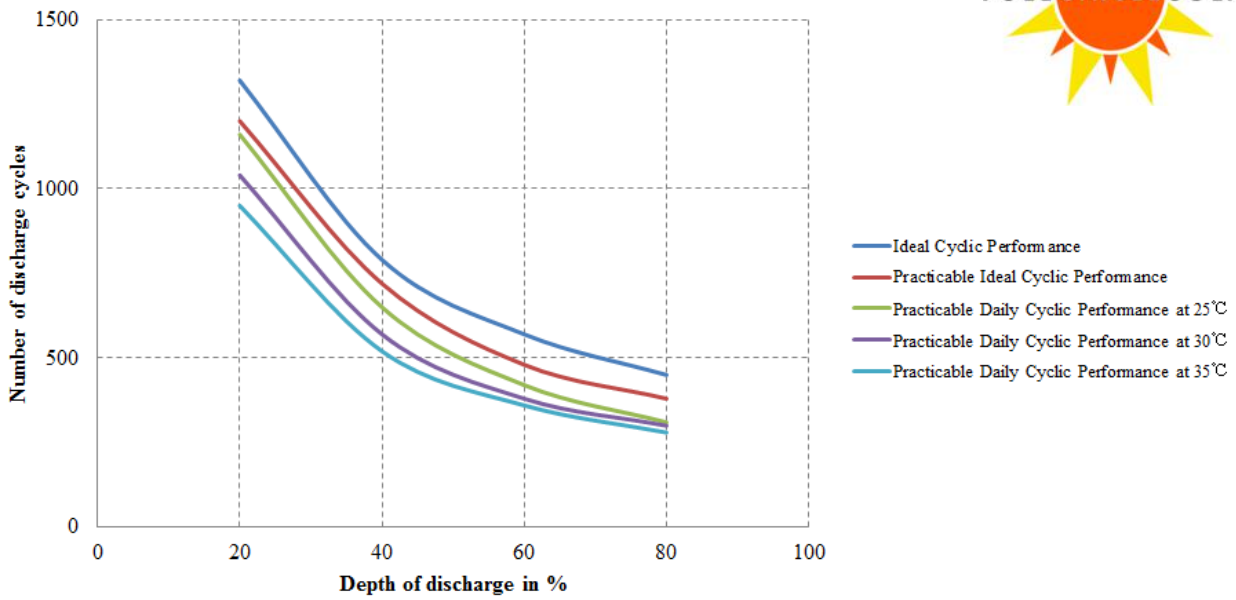
5. Comparison of Cyclic Performance at different conditions



Graph 5, Comparison of Cycle life vs. DOD of GP Series with Different Conditions

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