



AlphaCell™ SMU-C Series Batteries

Technical Manual

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AlphaCell™ SMU-C Series Batteries Technical Manual

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NOTE:

Photographs contained in this manual are for illustrative purposes only. These photographs may not match your installation.



NOTE:

Operator is cautioned to review the drawings and illustrations contained in this manual before proceeding. If there are questions regarding the safe operation of this product, please contact Alpha Technologies or your nearest Alpha representative.



NOTE:

Alpha shall not be held liable for any damage or injury involving its enclosures, power supplies, generators, batteries, or other hardware if used or operated in any manner or subject to any condition not consistent with its intended purpose, or is installed or operated in an unapproved manner, or improperly maintained.

Contacting Alpha Technologies: www.alpha.com

OR

For general product information and customer service (7 AM to 5 PM, Pacific Time), call

1-800-863-3930,

For complete technical support, call

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Safety Notes

Review the drawings and illustrations contained in this manual before proceeding. If there are any questions regarding the safe installation or operation of the system, contact Alpha Technologies or the nearest Alpha representative. Save this document for future reference.

To reduce the risk of injury or death, and to ensure the continued safe operation of this product, the following symbols have been placed throughout this manual. Where these symbols appear, use extra care and attention.

ATTENTION:

The use of ATTENTION is only for specific regulatory/code requirements that may affect the placement of equipment and installation procedures.



NOTE:

A NOTE gives readers additional information to help them complete a specific task or procedure.



CAUTION!

The use of CAUTION indicates safety information intended to PREVENT DAMAGE to material or equipment.



WARNING!

WARNING presents safety information to PREVENT INJURY OR DEATH to the technician or user.

Battery Safety Notes



WARNING!

Lead-acid batteries contain dangerous voltages, currents and corrosive material. Battery installation, maintenance, service and replacement must be performed only by authorized personnel.

Chemical Hazards

Any gelled or liquid leakage from a valve-regulated lead-acid (VRLA) battery contains dilute sulfuric acid, which is harmful to the skin and eyes. Emissions are electrolytic, and are electrically conductive and corrosive.

To avoid injury:

- Servicing and connection of batteries shall be performed by, or under the direct supervision of, personnel knowledgeable of batteries and the required safety precautions.
- Always wear eye protection, rubber gloves, and a protective vest when working near batteries. Remove all metallic objects from hands and neck.
- Batteries produce explosive gases. Keep all open flames and sparks away from batteries.
- Use tools with insulated handles, do not rest any tools on top of batteries.
- Lead-acid batteries contain or emit chemicals known to the State of California to cause cancer and birth defects or other reproductive harm. Battery post terminals and related accessories contain lead and lead compounds. Wash hands after handling (California Proposition 65).
- Wear protective clothing (insulated gloves, eye protection, etc.) when installing, maintaining, servicing, or replacing batteries.
- If any battery emission contacts the skin, wash immediately and thoroughly with water. Follow your company's approved chemical exposure procedures.
- Neutralize any spilled battery emission with the special solution contained in an approved spill kit or with a solution of one pound bicarbonate of soda to one gallon of water. Report a chemical spill using your company's spill reporting structure and seek medical attention if necessary.
- Always replace batteries with those of an identical type and rating. Never install old or untested batteries.
- Do not charge batteries in a sealed container. Each individual battery should have at least 0.5 inches of space between it and all surrounding surfaces to allow for convection cooling.
- All battery compartments must have adequate ventilation to prevent accumulation of potentially dangerous gas. Ventilation should prevent trapped hydrogen gas pockets from exceeding a 1% concentration as per regulation 70E of the National Fire Protection Agency (NFPA).
- Prior to handling the batteries, touch a grounded metal object to dissipate any static charge that may have developed on your body.
- Never use uninsulated tools or other conductive materials when installing, maintaining, servicing, or replacing batteries.
- Use special caution when connecting or adjusting battery cabling. An improperly connected battery cable or an unconnected battery cable can make contact with an unintended surface that can result in arcing, fire, or possible explosion.
- A battery showing signs of cracking, leaking, or swelling should be replaced immediately by authorized personnel using a battery of identical type and rating.

Equipment Cautions

- Do not operate NiCd and lead-acid batteries in the same room. NiCd emissions will neutralize the lead-acid solution, rendering the battery useless.
- Overcharging the battery can result in a loss of capacity and excess release of gas.

Recycling and Disposal Instructions

Spent or damaged batteries are considered environmentally unsafe. Always recycle used batteries or dispose of the batteries in accordance with all federal, state and local regulations.

1.0 Introduction

The SMU-C series of Valve Regulated Lead Acid (VRLA) batteries is designed to meet the needs of modern electronic equipment. The success of the AlphaCell SMU-C series is due to a product design purpose-built for the needs of critical backup requirements, and an industry-leading manufacturing technology which delivers product consistency. Safety, reliability, and long service life in standby applications are the result.

1.1 Features

- Require no additional water throughout their life cycle, reducing maintenance costs.
- Specifically designed to meet the requirements of modern electronic equipment.
- Compatible with commonly available recharging systems.
- Compact construction and excellent performance at high rates of discharge provide big savings in volume and weight compared to conventional vented batteries.
- SMU-C batteries offer substantial savings in installation and maintenance costs compared to conventional vented batteries. No specifically designed rooms are required and only minimal maintenance is needed during the life of the battery.
- Smaller, more compact, and lighter than traditional batteries, SMU-C batteries are supplied filled and charged so they can be immediately installed directly into cabinets or on easily assembled racks (also available from Alpha).
- With a minimum 10 year design life, the SMU-C batteries are highly reliable and fully comply with established international standards. The SMU-C range has been fully tested with respect to charge and discharge characteristics, cycle life, recombination efficiency, mechanical strength, vibration life, and flame retardancy.

1.2 Typical Electrical and Mechanical Specifications

Type	Normal Voltage (V)	Rated Capacity C20 (Ah)	Rated Power (15min, 1.75V, W)	Dimensions L x W x H (in/mm)	WT (lb/kg)
SMU-C 6-4.5	6	4.5	14.6	2.76 x 1.85 x 4.21 / 70 x 47 x 107	1.8 / .82
SMU-C 6-7	6	8.0	32.4	5.94 x 1.34 x 3.94 / 151 x 34 x 100	3.0 / 1.4
SMU-C 6-12	6	13.2	54.1	5.94 x 1.97 x 3.94 / 151 x 50 x 100	4.2 / 1.9
SMU-C 12-4.5	12	4.5	14.6	3.54 x 2.76 x 4.21 / 90 x 70 x 107	3.7 / 1.7
SMU-C 12-7	12	8.0	32.4	5.94 x 2.56 x 3.98 / 151 x 65 x 101	5.6 / 2.5
SMU-C 12-12	12	13.2	54.1	5.94 x 3.86 x 3.98 / 151 x 98 x 101	8.8 / 4.0
SMU-C 12-14	12	14.0	56.0	5.94 x 3.86 x 3.98 / 151 x 98 x 101	9.3 / 4.2
SMU-C 12-18	12	20	73.7	7.13 x 3.03 x 6.57 / 181 x 77 x 167	13.2 / 6.0
SMU-C 12-26	12	28	98.3	6.89 x 6.54 x 4.92 / 175 x 166 x 125	19.6 / 8.9
SMU-C 12-28	12	28	98.3	6.50 x 4.96 x 7.17 / 165 x 126 x 182	18.7 / 8.5
SMU-C 12-30	12	30	98.3	6.57 x 4.96 x 6.93 / 167 x 126 x 176	22.5 / 10.2
SMU-C 12-35	12	35	138	7.68 x 5.12 x 7.09 / 195 x 130 x 180	23.2 / 10.5
SMU-C 12-40	12	41	152	7.76 x 6.50 x 6.69 / 197 x 165 x 170	30.2 / 13.7
SMU-C 12-55	12	56	197	9.02 x 5.43 x 8.98 / 229 x 138 x 228	37.5 / 17.0
SMU-C 12-65	12	66	231	13.98 x 6.58 x 7.21 / 355 x 167 x 183	50.0 / 22.7
SMU-C 12-75	12	76	265	10.16 x 6.61 x 8.90 / 258 x 168 x 226	50.7 / 23.0
SMU-C 12-90	12	92	305	12.01 x 6.61 x 8.90 / 305 x 168 x 226	63.7 / 28.9
SMU-C 12-100	12	102	364	12.99 x 6.77 x 8.70 / 330 x 172 x 221	68.3 / 31.0
SMU-C 12-120	12	122	438	15.94 x 6.89 x 9.25 / 405 x 175 x 235	83.8 / 38.0
SMU-C 12-134	12	136	381	13.43 x 6.77 x 11.34 / 341 x 172 x 288	93.7 / 42.5
SMU-C 12-150	12	154	546	19.09 x 6.77 x 9.45 / 485 x 172 x 240	99.2 / 45.0
SMU-C 12-200	12	202	568	20.55 x 9.37 x 9.29 / 522 x 238 x 236	134.5 / 61.0

Table 1-1, General Electrical and Mechanical Specifications by Model
(Specifications courtesy of manufacturer)

Torque Specification

Torque specifications are 8.0Nm (75lbf-in). Torque all terminal connections to the specified value. Improper torquing can result in loose connections or damaged terminals.

1.0 Introduction, continued

1.3 Operating Conditions

Because SMU-C batteries, which are valve regulated and virtually sealed, do not give off perceptible amounts of gas under normal operating conditions, they can be installed in the same environment where people live and work.

- Acceptable ambient operating temperature: -40°F to 131°F (-40°C to 55°C)
- Ideal ambient operating temperature: 68°F to 77°F (20°C to 25°C)
- Ambient humidity: ≤ 95%
- Operating room or area: ventilated and not fully sealed

1.4 Capacity

Battery capacity is rated in Ampere hours (Ah) and is the quantity of electricity that can be supplied during discharge (See Table 1-1).

The actual capacity is related to the utilization ratio of the active positive and negative materials within the battery. The utilization ratio is influenced by the depth of discharge, the structure of the battery, and the manufacturing technology. During normal usage, the factors that influence the actual capacity are discharge rate, depth of discharge, end voltage, and temperature.

- The higher the discharge rate, the lower the available capacity.
- As batteries get colder, the available capacity is reduced. This is related to the kinetics of the electrochemical reactions and the resistivity of the electrolyte (See Fig. 1-1).

NOTE:

Although the battery can be operated at temperatures below 5°F (-15°C), the capacity and ability to discharge will be dramatically decreased. Similarly, temperatures approaching 122°F (50°C) will increase water loss and corrosion of the plates, resulting in a shorter battery life.

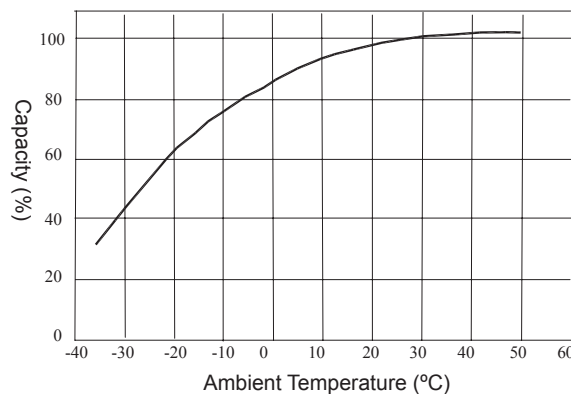


Fig. 1-1, Available Capacity vs. Ambient Temperature

1.0 Introduction, continued

1.5 Temperature and Battery Life

High temperatures can harm the battery and reduce its lifespan. Battery life decreases by 50% per 15°F (~ 9°C) above the standard operating temperature of 77°F (25°C).

To minimize battery damage:

- Use temperature compensated chargers.
- Never allow the battery's temperature to exceed +131°F (+55°C).
- Make sure operating area is properly ventilated, so heat cannot accumulate.
- Provide at least 0.39" (10mm) of space between batteries to enhance convective cooling.
- Visit sites annually to check for shorted cells, improperly set voltages, filter cleaning on ventilation systems, etc.

1.6 Internal Resistance and Short-circuit Current

The internal resistance of the battery is affected by temperature and charge state. The internal resistance is lowest when the battery is fully charged.

Type	Internal Resistance (m Ω)	Short Circuit Current (A)
SMU-C6-4.5	22	273
SMU-C6-7	14	429
SMU-C6-12	10	600
SMU-C 12-4.5	35	343
SMU-C 12-7	20	600
SMU-C 12-12	16	750
SMU-C 12-14	16	750
SMU-C 12-18	14	857
SMU-C 12-26	12	1000
SMU-C 12-28	12	1000
SMU-C 12-30	12	1000
SMU-C 12-35	10	1200
SMU-C 12-40	9.5	1263
SMU-C 12-55	6.0	2000
SMU-C 12-65	6.0	2000
SMU-C 12-75	5.5	2182
SMU-C 12-90	5.2	2308
SMU-C 12-100	5.0	2400
SMU-C 12-120	4.5	2667
SMU-C 12-134	4.0	3000
SMU-C 12-150	4.0	3000
SMU-C 12-200	3.8	3158

Table 1-2, Internal Resistance and Short Circuit Current at 77°F (25°C)



CAUTION!

A short circuit current will decrease the voltage of the battery to 0V, and damage the internal components.

2.0 Charging Procedures



NOTE:

Take measurements before and after charging and during discharge to help track changes and problems. Use a form (see Section 6.0), to record the results. Wait two hours after charging before taking final measurements in order to allow the electrolyte to cool sufficiently.



CAUTION!

If the heat generated as a result of charging exceeds the rate at which heat can be transferred out of the battery, thermal runaway can occur and excessive overheating will result.



NOTE:

Refer to your particular charger's manual for specific instructions regarding charger setup and operation.

2.1 General Charge

The limited current and constant voltage recharge method, also known as the modified constant potential method, satisfies the need to have the battery quickly recharged while ensuring maximum battery life. Figure 2-1 shows the relationship between current, voltage, and charge for the SMU-C 12-100.

When to Charge

- After installing or discharging the battery.
- If the battery has been stored for more than three months and the open circuit voltage is lower than 12.6V/block.

General Charge Procedure

1. Charge the batteries with a constant current no greater than $0.2C_{20}$ A until an average voltage of 13.8V/block at 77°F (25°C) is reached.
2. Continue charging, reducing the current to maintain a constant voltage of 13.8V/block.

Fast Charge Procedure

1. Charge the batteries with a constant current no greater than $0.2C_{30}$ A until an average voltage of 13.8V/block at 77°F (25°C) is reached.
2. Continue charging, reducing the current to maintain a constant voltage of 13.8V/block.
3. The batteries will be fully charged in 18-24 hours when the voltage is a constant 13.8/block and the charge current has not needed adjustment for three continuous hours.

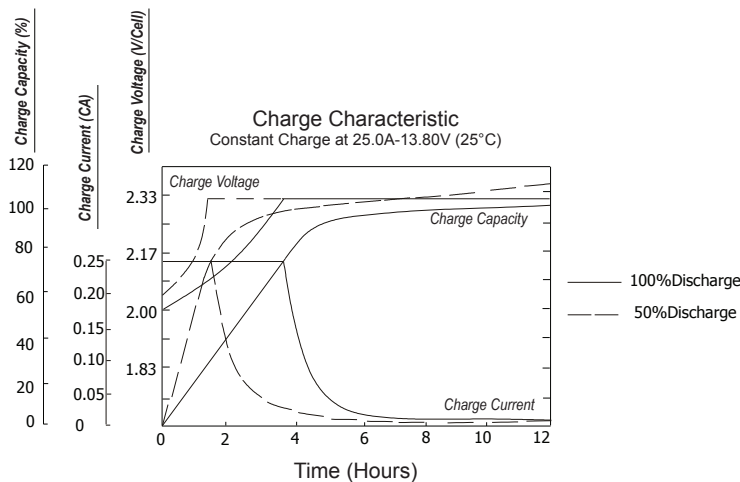


Fig. 2-1, Charge Characteristics Curve (SMU-C 12-100 with initial $0.1C_{20}$ A current and limit voltage 13.8V/Cell)

2.0 Charging Procedures, continued

2.2 Floating Charge

A float charge keeps the battery in a fully charged state with a small but constant current to automatically cover capacity loss resultant from self discharge and other discharges.

At 25°C, the proper floating voltage for the C series is 13.68V/block. The temperature compensate coefficient is -32.4mV/°F/block (-18mV/°C/block).

Ambient Temperature °F (°C)	Floating Voltage (Vpc)
32 (0)	13.73
41 (5)	13.72
50 (10)	13.71
58 (15)	13.70
68 (20)	13.69
77 (25)	13.68
86 (30)	13.67
95 (35)	13.66
104 (40)	13.65

Table 2-1, Floating Voltage at Different Temperatures



CAUTION!

If the floating voltage is higher than indicated in Table 2-1, then the floating current is also higher than ideal and will accelerate corrosion of the grid and shorten the life of the battery. If the floating voltage is lower, the battery will not be kept in fully charged state, which will crystallize the PbSO₄ (Lead Sulfate), decrease the capacity, and also shorten the life of the battery.

2.3 Discharge

The end voltage is the lowest voltage the battery can be discharged to without causing damage. Usually, the 20 hour rate (C₂₀) end voltage of a C battery is 10.5V/block. Although the battery can be discharged below this voltage, doing so will not discharge any more capacity and can affect its lifespan. It may be impossible to recharge a battery after several over-discharges. After a discharge, recharge the batteries as soon as possible to maximize battery life. See Section 5.0 for discharge specifications.

Discharge Current (A)	Discharge End-Voltage (Vpc)
$I < 0.2C$	10.5
$0.2C \leq I < 0.5C$	10.2
$0.5C \leq I < 1.0C$	9.30
$I \geq 1.0C$	7.80

Table 2-2, Discharge End-Voltage

3.0 Storage

All lead acid batteries experience self-discharge while in open circuit storage. This causes circuit voltage and capacity to decrease (see Fig. 3-1).

During storage please note:

- The self-discharge rate is related to ambient temperature. The lower the temperature, the less the discharge. Batteries should be stored in a clean, ventilated, and dry location with an ambient temperature of 32°F to 95°F (0°C to 35°C).
- It is important to track open circuit voltage which is related to the density of the electrolyte. If the open circuit voltage is lower than 12.6V/block, or the batteries have been stored for three months, the batteries should be charged to avoid damage caused by self-discharge.
- All batteries should be fully charged before storage. Record the storage date and next supplemental charge date in a maintenance record (See Fig. 4-2).

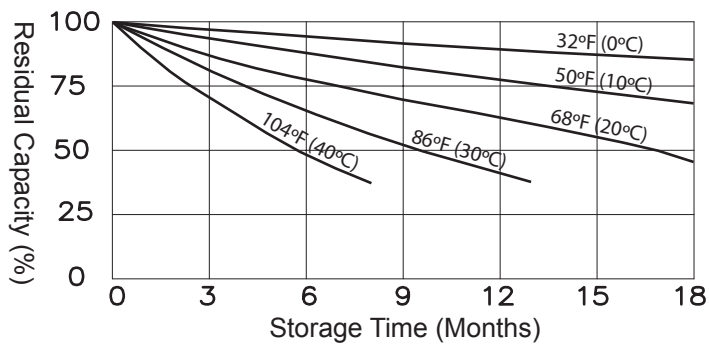


Fig. 3-1, Capacity vs. Storage Time

4.0 Maintenance

4.1 Recommended Maintenance Tasks

In order to prolong battery life, perform regular maintenance and inspections.

Monthly Maintenance

- Keep the batteries and battery room clean.
- Measure and record the ambient temperature of the battery room.
- Check for damage and overheating evidence on the terminal, container, and lid.
- Measure and record the total voltage and floating current of the battery system.

Quarterly Maintenance

Measure and record the floating voltage of every on-line battery. If the voltage of more than two cells is less than 13.0V after temperature adjustment, discharge the battery and then recharge at the float rate. If the problem still exists, conduct yearly or three-year maintenance procedures. If the problem persists, please contact Alpha Technologies.

Yearly Maintenance

- Check for loose connections.
- Conduct a discharge test to check the exact load, discharging 30-40% of the rated capacity.

Three-Year Maintenance

After three years of operation, conduct an 80% capacity test annually.

4.0 Maintenance, continued

Type:		Place:	
Test Status:		Qty:	
Total Voltage (V):		Room Temperature:	
Current (A):			
No.	Voltage (V)	No.	Voltage (V)
1		13	
2		14	
3		15	
4		16	
5		17	
6		18	
7		19	
8		20	
9		21	
10		22	
11		23	
12		24	
Visual check:			

Fig. 4-1, VRLA Battery Regular Maintenance Record

5.0 Discharge Specifications

5.1 Discharge Data with Constant Current

Amperage values for each battery model as a function of time and voltage @ 77°F/25°C.

SMU-C 6-4.5									
End voltage	5Min	10Min	15Min	30Min	1h	3h	5h	10h	20h
1.60V	17.6	10.9	8.25	5.03	3.20	1.40	0.86	0.47	0.25
1.67V	16.5	10.4	7.94	4.81	3.16	1.35	0.84	0.46	0.24
1.70V	15.1	10.0	7.75	4.38	3.06	1.26	0.82	0.46	0.24
1.75V	14.8	9.69	7.50	4.16	2.92	1.22	0.80	0.46	0.23
1.80V	13.3	9.25	6.81	3.85	2.73	1.17	0.76	0.45	0.23
1.85V	11.7	8.81	6.13	3.54	2.54	1.13	0.71	0.44	0.22

SMU-C 6-7									
End voltage	5Min	10Min	15Min	30Min	1h	3h	5h	10h	20h
1.60V	39.0	24.3	18.3	11.2	5.69	2.50	1.53	0.83	0.45
1.67V	36.6	23.0	17.6	10.7	5.61	2.40	1.49	0.82	0.43
1.70V	33.5	22.2	17.2	9.71	5.44	2.24	1.46	0.82	0.43
1.75V	32.9	21.5	16.6	9.22	5.18	2.17	1.43	0.82	0.42
1.80V	29.4	20.5	15.1	8.54	4.85	2.08	1.34	0.80	0.41
1.85V	26.0	19.6	13.6	7.86	4.52	2.01	1.26	0.79	0.40

SMU-C 6-12									
End voltage	5Min	10Min	15Min	30Min	1h	3h	5h	10h	20h
1.60V	65.0	40.4	30.5	18.6	9.38	4.12	2.52	1.37	0.74
1.67V	61.0	38.4	29.3	17.8	9.26	3.96	2.46	1.36	0.71
1.70V	55.9	37.0	28.7	16.2	8.98	3.70	2.41	1.35	0.70
1.75V	54.8	35.8	27.7	15.4	8.55	3.57	2.36	1.35	0.69
1.80V	49.0	34.2	25.2	14.2	8.01	3.43	2.22	1.32	0.67
1.85V	43.3	32.6	22.6	13.1	7.46	3.31	2.08	1.30	0.65

SMU-C 12-4.5									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	17.6	10.9	8.25	5.03	3.20	1.40	0.86	0.47	0.25
1.67V	16.5	10.4	7.94	4.81	3.16	1.35	0.84	0.46	0.24
1.70V	15.1	10.0	7.75	4.38	3.06	1.26	0.82	0.46	0.24
1.75V	14.8	9.69	7.50	4.16	2.92	1.22	0.80	0.46	0.23
1.80V	13.3	9.25	6.81	3.85	2.73	1.17	0.76	0.45	0.23
1.85V	11.7	8.81	6.13	3.54	2.54	1.13	0.71	0.44	0.22

5.1 Discharge Data with Constant Current, continued

Amperage values for each battery model as a function of time and voltage @ 77°F/25°C.

SMU-C 12-7									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	39.0	24.3	18.3	11.2	5.69	2.50	1.53	0.83	0.45
1.67V	36.6	23.0	17.6	10.7	5.61	2.40	1.49	0.82	0.43
1.70V	33.5	22.2	17.2	9.71	5.44	2.24	1.46	0.82	0.43
1.75V	32.9	21.5	16.6	9.22	5.18	2.17	1.43	0.82	0.42
1.80V	29.4	20.5	15.1	8.54	4.85	2.08	1.34	0.80	0.41
1.85V	26.0	19.6	13.6	7.86	4.52	2.01	1.26	0.79	0.40

SMU-C 12-12									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	65.0	40.4	30.5	18.6	9.38	4.12	2.52	1.37	0.74
1.67V	61.0	38.4	29.3	17.8	9.26	3.96	2.46	1.36	0.71
1.70V	55.9	37.0	28.7	16.2	8.98	3.70	2.41	1.35	0.70
1.75V	54.8	35.8	27.7	15.4	8.55	3.57	2.36	1.35	0.69
1.80V	49.0	34.2	25.2	14.2	8.01	3.43	2.22	1.32	0.67
1.85V	43.3	32.6	22.6	13.1	7.46	3.31	2.08	1.30	0.65

SMU-C 12-14									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	67.4	41.9	31.6	19.3	9.81	4.31	2.63	1.43	0.77
1.67V	63.2	39.8	30.4	18.4	9.68	4.14	2.58	1.42	0.75
1.70V	57.9	38.3	29.7	16.8	9.38	3.86	2.52	1.41	0.74
1.75V	56.8	37.1	28.7	15.9	8.94	3.74	2.47	1.41	0.72
1.80V	50.8	35.4	26.1	14.8	8.37	3.59	2.32	1.38	0.70
1.85V	44.8	33.8	23.5	13.6	7.80	3.46	2.17	1.36	0.68

SMU-C 12-18									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	88.6	55.1	41.6	25.4	14.2	6.24	3.81	2.08	1.12
1.67V	83.2	52.3	40.0	24.3	14.0	6.00	3.73	2.06	1.08
1.70V	76.2	50.4	39.1	22.1	13.6	5.60	3.65	2.05	1.07
1.75V	74.7	48.8	37.8	21.0	13.0	5.41	3.57	2.04	1.04
1.80V	66.9	46.6	34.3	19.4	12.1	5.20	3.36	2.00	1.01
1.85V	59.0	44.4	30.9	17.9	11.3	5.01	3.15	1.97	1.00

5.1 Discharge Data with Constant Current, continued

Amperage values for each battery model as a function of time and voltage @ 77°F/25°C.

SMU-C 12-26									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	118	73.5	55.5	33.8	19.9	8.74	5.34	2.91	1.57
1.67V	111	69.7	53.4	32.4	19.6	8.40	5.23	2.88	1.52
1.70V	102	67.2	52.1	29.4	19.0	7.84	5.11	2.87	1.49
1.75V	99.6	65.1	50.4	27.9	18.1	7.58	5.00	2.86	1.45
1.80V	89.1	62.2	45.8	25.9	17.0	7.28	4.70	2.80	1.41
1.85V	78.7	59.2	41.2	23.8	15.8	7.02	4.41	2.76	1.38

SMU-C 12-28									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	118	73.5	55.5	33.8	19.9	8.74	5.34	2.91	1.57
1.67V	111	69.7	53.4	32.4	19.6	8.40	5.23	2.88	1.52
1.70V	102	67.2	52.1	29.4	19.0	7.84	5.11	2.87	1.49
1.75V	99.6	65.1	50.4	27.9	18.1	7.58	5.00	2.86	1.45
1.80V	89.1	62.2	45.8	25.9	17.0	7.28	4.70	2.80	1.41
1.85V	78.7	59.2	41.2	23.8	15.8	7.02	4.41	2.76	1.38

SMU-C 12-30									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	118	73.5	55.5	33.8	21.3	9.36	5.72	3.12	1.68
1.67V	111	69.7	53.4	32.4	21.0	9.00	5.60	3.09	1.62
1.70V	102	67.2	52.1	29.4	20.4	8.40	5.48	3.07	1.60
1.75V	99.6	65.1	50.4	27.9	19.4	8.12	5.36	3.06	1.56
1.80V	89.1	62.2	45.8	25.9	18.2	7.80	5.04	3.00	1.52
1.85V	78.7	59.2	41.2	23.8	17.0	7.52	4.72	2.96	1.47

SMU-C 12-35									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	165	103	77.6	47.4	24.9	10.9	6.67	3.63	1.96
1.67V	155	97.6	74.7	45.3	24.5	10.5	6.53	3.60	1.90
1.70V	142	94.1	72.9	41.2	23.8	9.80	6.39	3.59	1.87
1.75V	139	91.2	70.6	39.1	22.7	9.47	6.25	3.57	1.82
1.80V	125	87.1	64.1	36.2	21.2	9.10	5.88	3.50	1.77
1.85V	110	82.9	57.6	33.4	19.8	8.77	5.51	3.45	1.72

5.1 Discharge Data with Constant Current, continued

Amperage values for each battery model as a function of time and voltage @ 77°F/25°C.

SMU-C 12-40									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	183	114	86.0	52.4	28.4	12.5	7.63	4.15	2.24
1.67V	172	108	82.7	50.1	28.1	12.0	7.47	4.11	2.17
1.70V	158	104	80.8	45.6	27.2	11.2	7.31	4.10	2.13
1.75V	154	101	78.2	43.3	25.9	10.8	7.15	4.08	2.08
1.80V	138	96.4	71.0	40.1	24.3	10.4	6.72	4.00	2.02
1.85V	122	91.8	63.8	36.9	22.6	10.0	6.29	3.95	1.98

SMU-C 12-55									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	236	147	111	67.6	39.8	17.5	10.7	5.71	3.09
1.67V	222	139	107	64.7	39.3	16.8	10.5	5.66	2.98
1.70V	203	134	104	58.8	38.1	15.7	10.2	5.63	2.93
1.75V	199	130	101	55.9	36.3	15.2	10.0	5.61	2.85
1.80V	178	124	91.6	51.8	34.0	14.6	9.41	5.50	2.78
1.85V	157	118	82.4	47.6	31.7	14.0	8.80	5.43	2.72

SMU-C 12-65									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	278	173	130	79.5	46.9	20.6	12.6	6.85	3.70
1.67V	261	164	125	76.0	46.3	19.8	12.3	6.79	3.57
1.70V	239	158	122	69.1	44.9	18.5	12.1	6.76	3.52
1.75V	234	153	118	65.7	42.8	17.9	11.8	6.74	3.43
1.80V	209	146	108	60.8	40.0	17.2	11.1	6.60	3.33
1.85V	185	139	96.8	56.0	37.3	16.5	10.4	6.51	3.26

SMU-C 12-75									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	319	199	150	91.3	54.0	23.7	14.5	7.89	4.26
1.67V	299	188	144	87.4	53.3	22.8	14.2	7.82	4.12
1.70V	274	182	141	79.4	51.7	21.3	13.9	7.78	4.05
1.75V	269	176	136	75.4	49.2	20.6	13.6	7.76	3.94
1.80V	241	168	124	69.9	46.1	19.8	12.8	7.60	3.84
1.85V	212	160	111	64.3	43.0	19.1	12.0	7.50	3.77

5.1 Discharge Data with Constant Current, continued

Amperage values for each battery model as a function of time and voltage @ 77°F/25°C.

SMU-C 12-90									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	366	228	172	105	65.4	28.7	17.5	9.55	5.16
1.67V	344	216	165	100	64.5	27.6	17.2	9.46	4.98
1.70V	315	208	162	91.2	62.6	25.8	16.8	9.42	4.90
1.75V	309	202	156	86.6	59.6	24.9	16.4	9.39	4.78
1.80V	276	193	142	80.2	55.8	23.9	15.5	9.20	4.65
1.85V	244	184	128	73.9	52.0	23.1	14.5	9.07	4.54

SMU-C 12-100									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	437	272	205	125	72.5	31.8	19.4	10.6	5.72
1.67V	410	258	197	120	71.5	30.6	19.0	10.5	5.52
1.70V	376	249	193	109	69.4	28.6	18.6	10.4	5.44
1.75V	369	241	187	103	66.1	27.6	18.2	10.4	5.29
1.80V	330	230	169	95.8	61.9	26.5	17.1	10.2	5.15
1.85V	291	219	152	88.1	57.7	25.6	16.0	10.1	5.01

SMU-C 12-120									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	526	327	247	151	86.7	38.1	23.3	12.7	6.85
1.67V	494	310	237	144	85.6	36.6	22.8	12.5	6.61
1.70V	452	299	232	131	83.0	34.2	22.3	12.5	6.50
1.75V	443	290	224	124	79.1	33.0	21.8	12.4	6.33
1.80V	397	277	204	115	74.0	31.7	20.5	12.2	6.16
1.85V	350	264	183	106	69.0	30.6	19.2	12.0	6.03

SMU-C 12-134									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	469	322	235	141	88.4	36.6	25.6	14.2	7.06
1.67V	422	293	228	137	88.3	36.4	25.4	14.0	7.04
1.70V	401	283	220	134	88.0	36.4	25.4	13.9	7.04
1.75V	356	261	208	131	87.1	36.2	25.2	13.6	7.00
1.80V	322	243	198	127	86.0	36.0	24.9	13.4	6.76
1.85V	244	200	172	117	85.1	35.9	24.7	13.2	6.35

5.1 Discharge Data with Constant Current, continued

Amperage values for each battery model as a function of time and voltage @ 77°F/25°C.

SMU-C 12-150									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	656	408	308	188	109	48.0	29.4	16.0	8.64
1.67V	616	387	296	180	108	46.2	28.7	15.8	8.34
1.70V	564	373	289	163	105	43.1	28.1	15.8	8.21
1.75V	553	361	280	155	99.8	41.7	27.5	15.7	7.99
1.80V	495	345	254	144	93.4	40.0	25.9	15.4	7.78
1.85V	437	329	229	132	87.1	38.6	24.2	15.2	7.56

SMU-C 12-200									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	700	480	350	210	132	54.6	38.2	21.2	10.5
1.67V	630	438	340	204	132	54.4	37.8	20.9	10.5
1.70V	598	422	328	200	131	54.4	37.8	20.7	10.5
1.75V	532	390	310	196	130	54.0	37.5	20.4	10.5
1.80V	480	362	296	190	128	53.8	37.2	20.0	10.1
1.85V	364	298	256	175	127	53.6	36.9	19.7	9.48

5.2 Discharge Data with Constant Power

Wattage values for each battery model as a function of time and voltage with constant Watts per cell @ 77°F/25°C.

SMU-C 6-4.5									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	30.8	19.8	15.1	9.06	5.77	2.49	1.45	0.94	0.50
1.67V	29.8	19.3	14.9	8.88	5.74	2.41	1.44	0.93	0.49
1.70V	28.0	19.1	14.8	8.31	5.63	2.30	1.43	0.93	0.48
1.75V	28.2	19.0	14.6	8.06	5.53	2.25	1.41	0.92	0.47
1.80V	25.8	18.7	13.6	7.69	5.21	2.18	1.37	0.90	0.46
1.85V	23.4	17.8	12.3	7.20	4.90	2.12	1.33	0.88	0.44

SMU-C 6-7									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	68.4	43.8	33.4	20.1	10.3	4.43	2.58	1.71	0.90
1.67V	66.0	42.7	33.0	19.7	10.2	4.29	2.57	1.70	0.86
1.70V	62.6	42.3	32.7	18.4	10.0	4.10	2.53	1.69	0.85
1.75V	62.2	42.2	32.4	17.9	9.83	4.00	2.51	1.66	0.83
1.80V	57.2	41.5	30.1	17.1	9.27	3.88	2.43	1.62	0.81
1.85V	51.9	39.4	27.3	16.0	8.71	3.77	2.36	1.58	0.79

SMU-C 6-12									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	114	73.0	55.7	33.5	16.9	7.30	4.25	2.82	1.48
1.67V	110	71.2	55.0	32.8	16.8	7.08	4.24	2.80	1.43
1.70V	104	70.5	54.5	30.7	16.5	6.76	4.18	2.78	1.41
1.75V	104	70.3	54.1	29.8	16.2	6.60	4.14	2.73	1.37
1.80V	95.4	69.2	50.1	28.4	15.3	6.41	4.02	2.67	1.34
1.85V	86.5	65.7	45.5	26.6	14.4	6.21	3.89	2.60	1.31

SMU-C 12-4.5									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	30.8	19.8	15.1	9.06	5.77	2.49	1.45	0.94	0.50
1.67V	29.8	19.3	14.9	8.88	5.74	2.41	1.44	0.93	0.49
1.70V	28.2	19.1	14.8	8.31	5.63	2.30	1.43	0.93	0.48
1.75V	28.0	19.0	14.6	8.06	5.53	2.25	1.41	0.92	0.47
1.80V	25.8	18.7	13.6	7.69	5.21	2.18	1.37	0.90	0.46
1.85V	23.4	17.8	12.3	7.20	4.90	2.12	1.33	0.88	0.44

5.2 Discharge Data with Constant Power, *continued*

Wattage values for each battery model as a function of time and voltage with constant Watts per cell @ 77°F/25°C

SMU-C 12-7									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	68.4	43.8	33.4	20.1	10.3	4.43	2.58	1.71	0.90
1.67V	66.0	42.7	33.0	19.7	10.2	4.29	2.57	1.70	0.86
1.70V	62.6	42.3	32.7	18.4	10.0	4.10	2.53	1.69	0.85
1.75V	62.2	42.2	32.4	17.9	9.83	4.00	2.51	1.66	0.84
1.80V	57.2	41.5	30.1	17.1	9.27	3.88	2.43	1.64	0.83
1.85V	51.9	39.4	27.3	16.0	8.71	3.77	2.36	1.58	0.80

SMU-C 12-12									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	114	73.0	55.7	33.5	16.9	7.30	4.25	2.82	1.48
1.67V	110	71.2	55.0	32.8	16.8	7.08	4.24	2.80	1.43
1.70V	104	70.5	54.5	30.7	16.5	6.76	4.18	2.78	1.41
1.75V	104	70.3	54.1	29.8	16.2	6.60	4.14	2.74	1.37
1.80V	95.4	69.2	50.1	28.4	15.3	6.41	4.02	2.71	1.34
1.85V	86.5	65.7	45.5	26.6	14.4	6.21	3.89	2.62	1.32

SMU-C 12-14									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	118	75.7	57.7	34.7	17.7	7.64	4.45	2.94	1.55
1.67V	114	73.8	57.0	34.0	17.6	7.40	4.43	2.93	1.49
1.70V	108	73.0	56.5	31.9	17.3	7.07	4.37	2.91	1.47
1.75V	107	72.8	56.0	30.9	17.0	6.90	4.33	2.87	1.44
1.80V	98.9	71.7	52.0	29.5	16.0	6.70	4.20	2.83	1.40
1.85V	89.7	68.1	47.1	27.6	15.0	6.50	4.06	2.80	1.34

SMU-C 12-18									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	155	99.6	75.9	45.7	25.7	11.1	6.44	4.27	2.24
1.67V	150	97.1	75.0	44.7	25.5	10.7	6.42	4.24	2.16
1.70V	142	96.1	74.4	41.9	25.0	10.2	6.33	4.24	2.16
1.75V	141	95.8	73.7	40.7	24.6	10.0	6.28	4.16	2.08
1.80V	130	94.4	68.4	38.8	23.2	9.71	6.08	4.11	2.03
1.85V	118	89.5	62.0	36.3	21.8	9.41	5.89	3.97	2.00

5.2 Discharge Data with Constant Power, *continued*

Wattage values for each battery model as a function of time and voltage with constant Watts per cell @ 77°F/25°C

SMU-C 12-26									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	207	133	101	60.9	35.9	15.5	9.02	5.97	3.14
1.67V	200	129	100	59.7	35.7	15.0	8.98	5.94	3.02
1.70V	190	128	99.2	55.9	35.0	14.3	8.87	5.90	2.99
1.75V	188	128	98.3	54.2	34.4	14.0	8.79	5.74	2.91
1.80V	173	126	91.2	51.7	32.4	13.6	8.52	5.62	2.82
1.85V	157	119	82.7	48.4	30.5	13.2	8.24	5.54	2.73

SMU-C 12-28									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	207	133	101	60.9	35.9	15.5	9.02	5.97	3.14
1.67V	200	129	100	59.7	35.7	15.0	8.98	5.94	3.02
1.70V	190	128	99.2	55.9	35.0	14.3	8.87	5.90	2.99
1.75V	188	128	98.3	54.2	34.4	14.0	8.79	5.74	2.91
1.80V	173	126	91.2	51.7	32.4	13.6	8.52	5.62	2.82
1.85V	157	119	82.7	48.4	30.5	13.2	8.24	5.54	2.73

SMU-C 12-30									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	207	133	101	60.9	38.5	16.6	9.67	6.40	3.36
1.67V	200	129	100	59.7	38.2	16.1	9.63	6.36	3.24
1.70V	190	128	99.2	55.9	37.5	15.4	9.50	6.32	3.20
1.75V	188	128	98.3	54.2	36.9	15.0	9.42	6.24	3.12
1.80V	173	126	91.2	51.7	34.8	14.6	9.13	6.16	3.04
1.85V	157	119	82.7	48.4	32.7	14.1	8.83	6.08	2.92

SMU-C 12-35									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	290	186	142	85.3	44.9	19.4	11.3	7.47	3.92
1.67V	280	181	140	83.5	44.6	18.8	11.2	7.42	3.78
1.70V	265	179	139	78.2	43.8	17.9	11.1	7.37	3.73
1.75V	264	179	138	75.9	43.0	17.5	11.0	7.28	3.64
1.80V	243	176	128	72.4	40.6	17.0	10.6	7.19	3.55
1.85V	220	167	116	67.8	38.1	16.5	10.3	7.09	3.41

5.2 Discharge Data with Constant Power, *continued*

Wattage values for each battery model as a function of time and voltage with constant Watts per cell @ 77°F/25°C

SMU-C 12-40									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	321	206	157	94.4	51.3	22.1	12.9	8.53	4.48
1.67V	310	201	155	92.5	51.0	21.4	12.8	8.48	4.32
1.70V	294	199	154	86.6	50.0	20.5	12.7	8.43	4.27
1.75V	292	198	152	84.0	49.2	20.0	12.6	8.32	4.16
1.80V	269	195	141	80.1	46.3	19.4	12.2	8.07	4.05
1.85V	244	185	128	75.0	43.6	18.8	11.8	7.98	4.00

SMU-C 12-55									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	415	266	203	122	71.8	31.0	18.0	11.7	6.00
1.67V	400	259	200	119	71.4	30.0	18.0	11.6	5.91
1.70V	379	256	198	112	70.0	28.7	17.7	11.5	5.82
1.75V	377	255	197	108	68.8	28.0	17.6	11.3	5.70
1.80V	347	252	182	103	64.9	27.2	17.0	11.2	5.62
1.85V	315	239	165	96.8	61.0	26.4	16.5	11.0	5.53

SMU-C 12-65									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	487	312	238	143	84.7	36.5	21.3	13.9	7.28
1.67V	470	304	235	140	84.1	35.4	21.2	13.8	7.02
1.70V	446	301	233	131	82.5	33.8	20.9	13.7	6.93
1.75V	443	300	231	127	81.1	33.0	20.7	13.5	6.76
1.80V	408	296	214	121	76.5	32.0	20.1	13.3	6.67
1.85V	370	281	194	114	71.9	31.1	19.4	13.2	6.62

SMU-C 12-75									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	560	358	273	164	97.5	42.1	24.5	16.0	8.40
1.67V	540	349	270	161	96.9	40.7	24.4	15.9	8.10
1.70V	512	346	268	151	95.1	38.9	24.1	15.8	8.00
1.75V	502	345	265	146	93.4	38.0	23.9	15.6	7.90
1.80V	468	340	246	140	88.1	36.9	23.1	15.4	7.72
1.85V	425	322	223	131	82.8	35.8	22.4	15.2	7.62

5.2 Discharge Data with Constant Power, *continued*

Wattage values for each battery model as a function of time and voltage with constant Watts per cell @ 77°F/25°C

SMU-C 12-90									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	643	412	314	189	118	50.9	29.6	19.6	10.3
1.67V	620	401	310	185	117	49.3	29.5	19.5	9.94
1.70V	588	397	307	173	115	47.1	29.1	19.4	9.81
1.75V	584	396	305	168	113	46.0	28.9	19.1	9.57
1.80V	538	390	283	160	107	44.7	28.0	18.9	9.49
1.85V	488	370	256	150	100	43.3	27.1	18.6	9.32

SMU-C 12-100									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	767	491	375	225	131	56.4	32.9	21.8	11.4
1.67V	740	479	370	221	130	54.7	32.7	21.6	11.0
1.70V	701	474	367	207	128	52.2	32.3	21.5	10.9
1.75V	697	473	364	201	125	51.0	32.0	21.2	10.6
1.80V	642	466	337	191	118	49.5	31.0	20.9	10.5
1.85V	582	442	306	179	111	48.0	30.0	20.5	10.3

SMU-C 12-120									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	923	591	451	271	156	67.5	39.3	26.0	13.7
1.67V	890	576	445	266	156	65.4	39.1	25.9	13.2
1.70V	844	570	441	249	153	62.5	38.6	25.4	13.0
1.75V	838	568	438	241	150	61.0	38.3	25.1	12.7
1.80V	772	560	406	230	141	59.2	37.1	24.7	12.4
1.85V	700	531	368	215	133	57.4	35.9	24.3	12.2

SMU-C 12-134									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	773	533	415	265	174	70.2	48.9	28.4	14.1
1.67V	733	527	411	260	168	70.2	48.9	28.0	14.1
1.70V	685	513	405	253	164	70.2	48.9	27.8	14.1
1.75V	638	480	381	247	163	69.1	48.4	27.3	14.0
1.80V	572	446	358	240	160	68.2	47.6	26.8	13.5
1.85V	458	370	312	220	158	67.9	46.9	26.3	12.7

5.2 Discharge Data with Constant Power, *continued*

Wattage values for each battery model as a function of time and voltage with constant Watts per cell @ 77°F/25°C

SMU-C 12-150									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	1151	737	562	338	198	85.2	49.6	32.9	17.2
1.67V	1110	718	555	331	196	82.5	49.4	32.6	16.6
1.70V	1052	711	550	310	193	78.8	48.8	31.6	16.4
1.75V	1045	709	546	301	189	77.0	48.3	31.4	16.0
1.80V	963	698	506	287	178	74.7	46.8	30.8	15.6
1.85V	873	663	459	269	168	72.5	45.3	30.4	15.3

SMU-C 12-200									
End voltage	5Min	10Min	15Min	30Min	1Hr	3Hr	5Hr	10Hr	20Hr
1.60V	1154	796	620	396	260	105	73.0	42.4	21.1
1.67V	1094	786	614	388	251	105	73.0	41.8	21.0
1.70V	1022	766	604	378	245	105	73.0	41.5	21.0
1.75V	952	716	568	368	243	103	72.2	40.7	20.9
1.80V	854	666	534	358	238	102	71.0	40.0	20.2
1.85V	684	552	466	328	236	101	70.0	39.3	19.0

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