Acme Aerospace Inc., manufactures power supplies and high-performance, sealed FNC batteries for military and commercial aerospace, as well as industrial and satellite/ space applications.

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Acme NonStop Power

FNC Cell Technology

Sealed fiber nickel-cadmium battery systems
For commercial, military and space systems.

ACME AEROSPACE INC.

Introduction

The FNC cell technology was developed in the 1970's by the Deutsche Automobilgesellcsheft GmbH (DAUG) Research Laboratory, a joint venture of Volkswagen and Daimler-Benz (Mercedes). After ten years of development, DAUG formed a production partnership with Hoppecke, a German lead-acid battery manufacturer established in 1927. Under the DAUG-Hoppecke (now Hoppecke Batterie Systeme GmbH) partnership, FNC vented cell production began in 1982.

Four additional years of development by the Hoppecke Batterie Systeme GmbH Laboratory resulted in a sealed, zero-maintenance FNC cell, which was put into production in 1987.

With the development of the sealed FNC cell, Acme Electric Corporation purchased an exclusive license for production of FNC batteries in the United States and for sales to military and aerospace markets in the United States and Canada.

Acme Aerospace Inc., located in Tempe, Arizona, has complete engineering and manufacturing of sealed FNC batteries and integrated power electronics equipment for DC and AC power supply systems. Combined, Acme's sealed FNC batteries and power electronics form the basis of an advanced power system that is being selected for the most distinguished projects in military and commercial aerospace, as well as industrial and satellite/space applications.

FNC Plate Technology

The heart of the FNC battery is the fiber-structured electrode. The plates are made from a nickel-coated fiber matrix into which the cell's active material is firmly embedded. The electrode features close contact between the active material and the high surface area current collecting matrix while allowing excellent electrolyte penetration. This structure permits a complete and uniform utilization of the active material even at high discharge rates and low temperatures. Fiber-structured electrodes can be manufactured using the same technology for practically any required thickness between 0.5 and 10mm. This allows economical interfacing of the electrode thickness with the requirements set on the performance of a particular battery. The FNC battery has the same properties and basic characteristics over the entire range of applications independent of the plate thickness.

FNC Advantages

The major advantages of the FNC plate over conventional nickel-cadmium plates are shown below:

FNC Plate Characteristics

Optimum Electrode Pore Structure

- ***Improved Utilization of Active Material***
- ***Improved Low Temperature Performance***
- ***Superior Charge Efficiency***
- ***Improved Power Capability***

Elasticity of Plate Structure

- ***Extended Life***
- ***Increased Shock and Vibration Tolerance***

In the nickel-fiber substrate, each cubic centimeter of plate volume contains 300 meters of conducting filament. The density of this 90% porous current-collecting matrix allows an excellent utilization of the plate's active materials. The result is improved low-temperature performance, significantly higher power capability, and better charge efficiency.

The fiber substrate in the FNC plate allows elastic expansion and contraction during charge and discharge, absorbing the difference in volume between charged and discharged active material. This unique characteristic of the fiber structure eliminates one of the main failure modes commonly found in sintered plates: plate degradation.

The plate active materials, nickel-hydroxide and cadmium-oxide, are mechanically imbedded directly into the fiber structure, eliminating chemical impurities and process variables as there is no impregnation process involved. This direct mechanical-active material loading provides superior performance and a longer battery life.

Sealed FNC Cells

With the development of sealed FNC cell technology, the first zero-maintenance, high-rate prismatic nickel-cadmium battery was introduced.

In the sealed FNC cell, an inactive nickel-coated fiber plate is placed between two cadmium-filled plates. This effectively provides a split cadmium plate with an open, central region. This inactive section serves as a catalytic site for rapid oxygen reduction at the cadmium plate. This unique plate design is called the recombination plate.

The main oxygen pathway to the recombination plate is through the plate pores in contrast to conventional cells where the pathway is though the cell separator material. The recombination plate provides easy oxygen access to the large cadmium plate surface area. Hydrogen removal, when necessary in catastrophic situations, is provided by a recombination plate of platinum-palladium catalyzed plaque. This feature is not provided in conventional sealed cells.

As rapid oxygen recombination eliminates pressure buildup normally associated with sealed nickel-cadmium cells, high charge rates can be sustained even in the overcharge mode in FNC cells. The sealed FNC cell is manufactured with a negative internal pressure (0.1 bar absolute) which causes the atmospheric pressure to compress the cell and improve the hydraulic contact between cell components.

Sealed FNC Battery Characteristics

The sealed FNC cell has unique characteristics and superior performance:

- ***Zero-Maintenance***
- ***Ultra-High Power Capability***
- ***Superior Recharge Capability***
- ***No Capacity Fading***
- ***High Reliability***
- ***Long Cycle Life***

Zero Maintenance

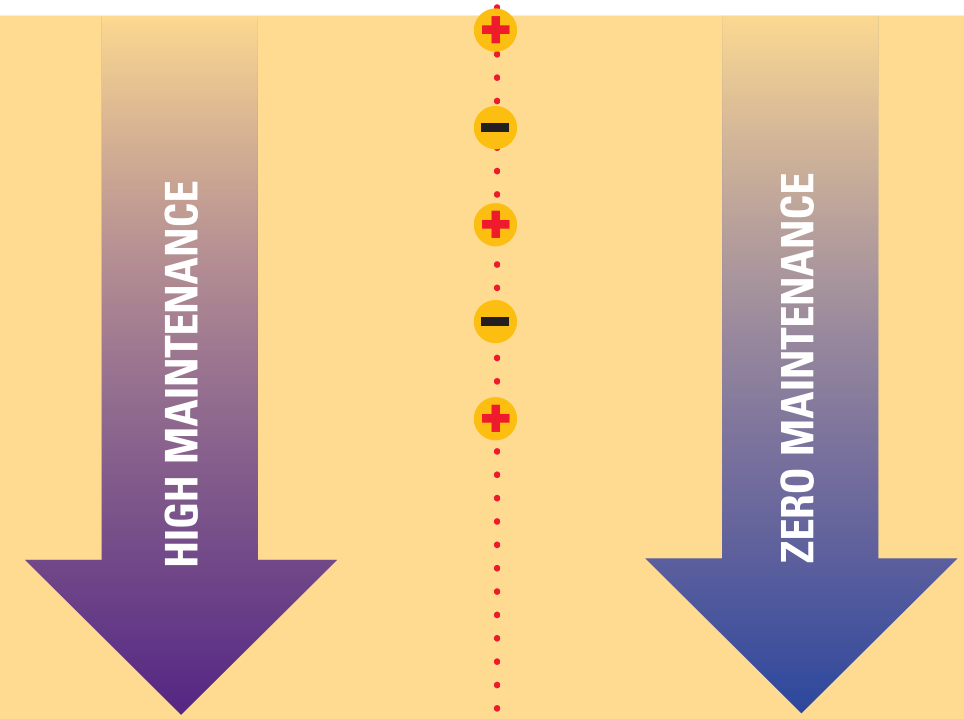
The main disadvantage of vented batteries is the cost associated with frequent application-related maintenance tasks such as the periodic restoration of water within the cells, etc. All rechargeable batteries much be over-charged to reach a 100 percent state of charge. In the nickel-cadmium battery, excessively charged portions of the nickel electrode generate oxygen and the cadmium electrode generates hydrogen. In vented batteries these gases, along with critical water vapor, are vented outside each cell and must be regularly replaced.

In the vented nickel-cadmium battery, operating at high temperatures, oxygen is generated form the nickel plate at a lower potential. This leaves the positive plate undercharged while the cadmium plate continues toward a fully charged state. The resulting plate imbalance reduces battery capacity; a processes commonly referred to as "memory." To regain the lost capacity, vented batteries require deep discharge conditioning.

During use, vented batteries may also over-boil electrolyte from the vent causing hazardous contamination. Regular battery cleaning is necessary to prevent corrosion.

The above-mentioned maintenance procedures are completely eliminated by Acme's patented sealed-cell design.

FNC CELL TECHNOLOGY



Vented Ni-Cd

During Overcharge:

- ***Water and gas are vented***
- ***Lost liquid must be replaced***

Plate Imbalance Requires:

- ***Individual cell deep discharge at service shop***

Electrolyte Can Spill From Vents

Cycle Capacity Degradation and Thermal Runway Limit Life of Battery

Sealed FNC

- ***Battery is completely sealed***
- ***Oxygen generated is quickly recombined within the cell***
- ***Plates and cells remain in balance***
- ***Capacity checks can be performed on installed battery***
- ***No spillage or corrosion***

Fiber structure and pure, active materials provide thousands of cycles without degradation

The gases, oxygen and hydrogen, generated during overcharge of a vented battery, must be vented to prevent explosive gas mixture. Small electrolyte particles vented with these gases can cause corrosion to sensitive equipment and must be closely monitored.

Nickel-cadmium batteries with sintered plates can show capacity degradation under frequent cyclic conditions due to fatigue of the sintered substrate. In addition, sintered plate nickel-cadmium batteries are susceptible to memory effect.

As vented nickel-cadmium batteries are charged with constant potential and the charging voltage is temperature dependent, vented cell batteries may suffer thermal runaway.

The sealed FNC battery completely eliminates the loss of any gases from within the cell. Oxygen generated is rapidly recombined at the cadmium electrode. This recombination process also keeps the plated in balance, eliminating the capacity loss that would otherwise result.

No deep cycling is required. Capacity checks, if desired, can be accomplished with the battery installed by using a portable discharge/charger unit.

Ultra-High Power Capability

A sealed FNC cell can sustain very high discharge currents. A large cell with a capacity of 47 Ah can be discharged at 2000 Amps for 10 seconds without damage. These high discharge currents are often required for Auxiliary Power Units (APU) In aircraft engine starting or direct engine starting.

The FNC cell also has extremely good performance at low temperatures. At -18C, the cell gives 90% of the one hour-rated capacity at +25C.

Superior Recharge Capability

Charging characteristics of the sealed FNC cells are simple, yet different form vented nickel-cadmium cells. Because of the gas recombination that takes place in the FNC cells, there is no rapid increase in charging voltage by the end of charge.

The recommended maximum charging voltage is 1.55V per cell corresponding to 31V for a 24V battery. From the users point-of-view, this means that the bus voltage can be maintained at a maximum of 31V at all times. This low voltage will protect other electrical equipment from over-voltage.

In addition, heat is generated during overcharge (instead of gas, which must vent in vented cells), providing a reliable parameter for charge control. Changing from a high rate of charging to trickle charging and charge termination can be determined by battery temperature rise (DT) or the slope of battery temperature rise (DT/DT).

The preferred charge for sealed cells is constant current with a maximum potential of 1.55 volts per cell. This provides an excellent charge rate while keeping the potential below the electrolysis level in which both hydrogen and oxygen would be generated. This potential is also sufficient to charge the battery at temperatures as low as -40C. For many applications, this means that a heater blanket is not required.

No Capacity Fading

The FNC recombination cycle maintains the charge balance between positive and negative plates, resulting in zero capacity fading. Capacity lost by cycling at high temperatures is typically recovered by normal discharge/charge cycling at lower temperatures. Deep discharge cycling is not necessary, eliminating the necessity for battery removal from the aircraft.

A completely charged FNC battery has sufficient gas recombination capacity to continue to accommodate a charge current equal to 2xC Amps (C=the battery-rated Ah capacity). Even higher rates are possible with the battery in a lower state of charge.

The elastic expansion and contraction of the fiber structure in combination with the mechanical loading of the active materials in the FNC cells has eliminated what is known in vented nickel-cadmium cells as the memory effect.

As the FNC cells do not exhibit the typical Ni-Cd capacity fading or memory effect, the full-rated battery capacity is available.

FNC CELL TECHNOLOGY

High Reliability

The valuable properties of the sealed FNC battery are a result of its unique construction. The active materials are contained in the flexible fiber substrate plates. The plates are welded together and submerged in an alkaline electrolyte. The cells are assembled in welded, stainless steel jars. The alkaline electrolyte does not take part in the electrochemical reaction. The potassium (K) in the potassium hydroxide (KOH) electrolyte is not active in the reaction. There is no corrosion of the active materials or current-carrying components typical of lead-acid batteries as the electrolyte in nickel-cadmium batteries as the electrolyte in nickel-cadmium batteries is acting merely as an ion conductor. Also, in contrast to the sulfuric acid in the lead-acid battery, the alkaline electrolyte density in the nickel-cadmium battery is not significantly changed during charge and discharge.

The above features translate into reliability and durability even at temperature extremes. It is also important to note there is no sudden death in the FNC battery due to corrosion, as often experienced in lead-acid technology batteries.

Long Life Cycle

Sealed FNC cells have shown outstanding cycle life at both low and high rates of discharge. A 47 Ah battery was subjected to accelerated, large APU start cycles at +31C, with the following characteristics:

1. ***Discharge 1000 Amps for 5.6 seconds***
2. ***Discharge 400 Amps for 25 seconds***
3. ***Charge 57 Amps to a positive temperature change of 2C***
4. ***Rest 4 minutes***
5. ***Repeat steps 1 through 4-250 times***
6. ***Capacity check cycle***

After the completion of 6100 of the above cycles, a 24V battery showed no capacity degradation at the one-hour discharge rate.

The FNC Mechanical Design

The sealed FNC prismatic cell case is made of stainless steel. The negative pressure within the cell (0.1 bar absolute) allows for pressure change due to oxygen generation during overcharge without causing the cell walls to expand. In addition, the external air pressure presses the vessel walls and plate assembly together, enhancing the hydraulic contact between the electrodes and providing mechanical rigidity.

A safety valve at the top of the cell is provided to allow excessive pressure to escape should the battery be abused to the point that the electrolyte boils. This condition might be caused by a severe overcharge where adequate heat dissipation is not provided. Under high temperature abuse (+100C and above), the safety valve will open approximately 1.6 bar over pressure, allowing waster vapor to escape. Electrolyte will not be expelled, even with the cell in an inverted position. When the cell is allowed to cool, the valve will reseal and the negative pressure cell will return to a normal operating condition. A reduction in cell capacity may be anticipated due to the loss of water from within the cell.

Positive and negative plates are connected to their respective terminal posts by nickel tabs. The tabs are attracted directly to the fiber plates by a patented welding process and then fastened directly to nickel-plated, solid copper terminal posts. The electrical path of each cell type is designed for maximum electrical performance.

Plate stacking is the same as previously discussed. Single nickel plates are separated from the cadmium plates by an electrolyte-wet separator. The cadmium plate is in three parts: two fiber frameworks carrying the cadmium-active material and one inactive fiber recombination plate placed between them.

FNC Battery Benefits

- ***Operates in any position***
- ***No hazardous or flammable gases***
- ***No spilled electrolyte***
- ***High shock and vibration tolerance***
- ***Shelf life greater than five years***
- ***Fail-safe***

Sealed FNC batteries may be operated in any position for any length of time. Self-discharge will occur during storage, but no cell degradation of damage will result.

Battery cells do not emit hazardous or flammable gases during charge or discharge.

There is no possibility of electrolyte being spilled or vented into the battery case.

Sealed FNC batteries are capable of withstanding high shock and vibration levels. Twenty-cell batteries have been tested to the F-16 specification (MIL-STD-810) by three independent laboratories. Performance levels of 9.84 g-rms endurance levels of 11.25 g-rms and shock at 15 g peak value have been achieved without failure.

Sealed FNC cells have a shelf life greater than five years.

Sealed FNC batteries are completely fail-safe. Even if subjected to extreme overcharge to the point of electrolyte boiling, the battery will not go into thermal runaway. Instead, the hot cells dry out, with the loss of water vapor causing the battery impedance to increase, the current will decrease.

After a time, the battery will no longer accept the charge current and it will cool down.

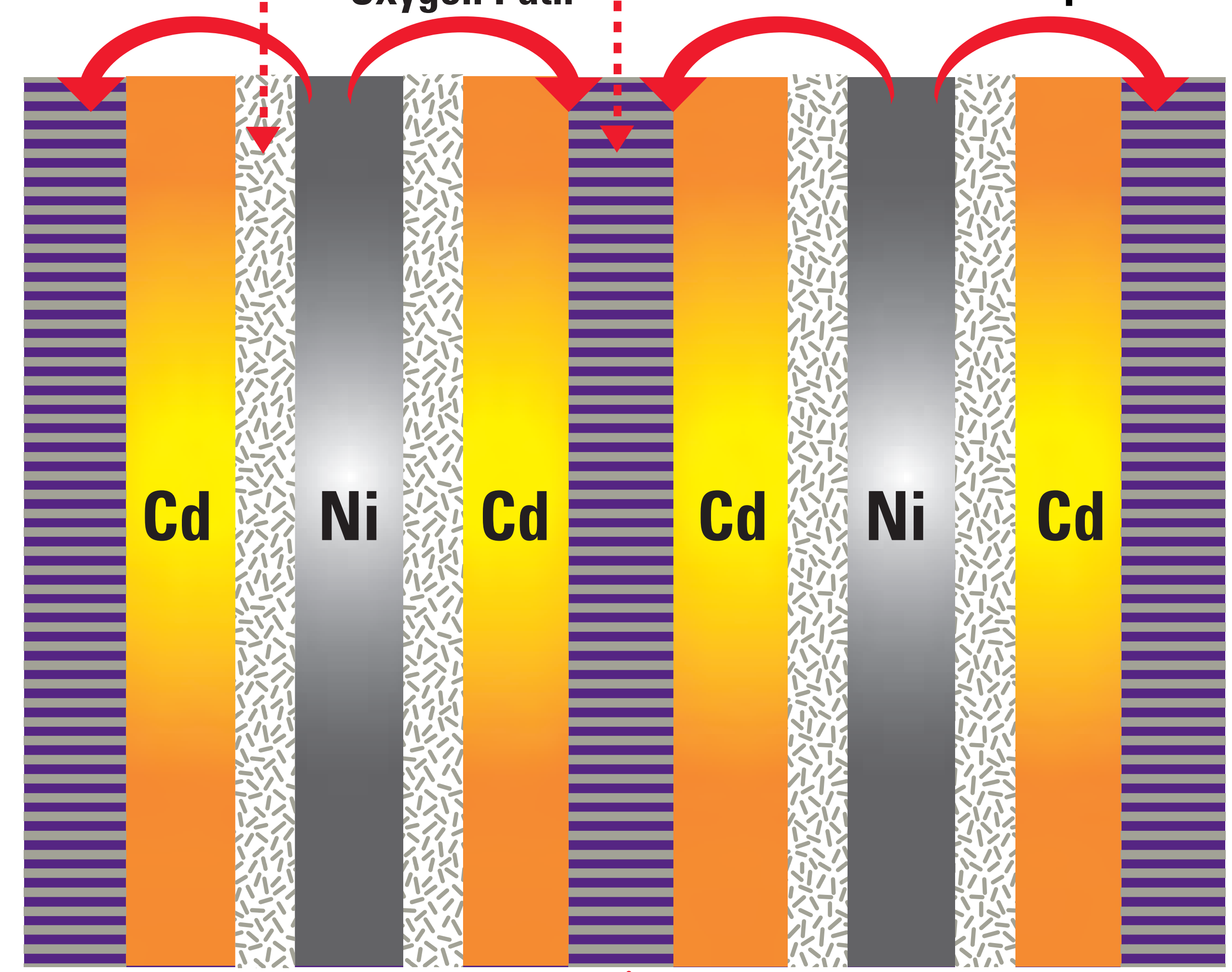
The sealed FNC battery offers significant improvement across every measure of operating performance. Because they last longer and require zero-maintenance, sealed FNC batteries reduce the total cost of ownership.

The FNC basic design provides a versatile building block for a multitude of dynamic applications; ground, air and space.

Coupled with Acme's advanced charge-control systems, the sealed, zero-maintenance, FNC battery systems are being selected for the world's most demanding applications.

FNC CELL TECHNOLOGY

Schematic Stack Design of a Sealed FNC Recombination Cell

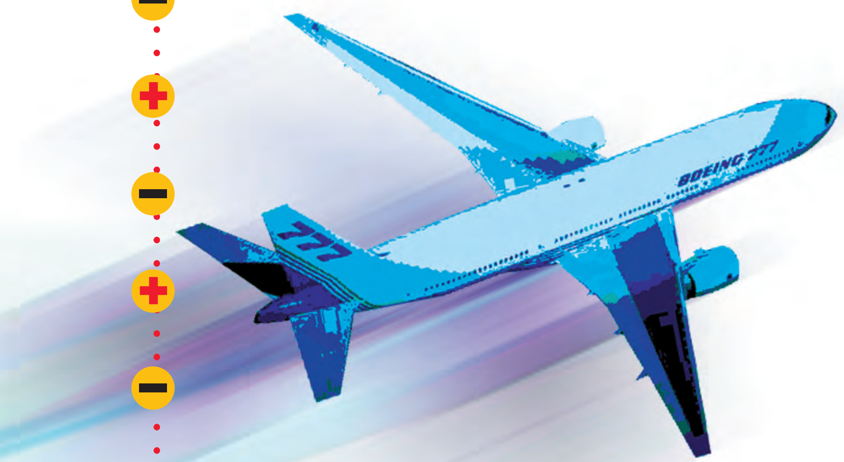


Standard Cell Ranges

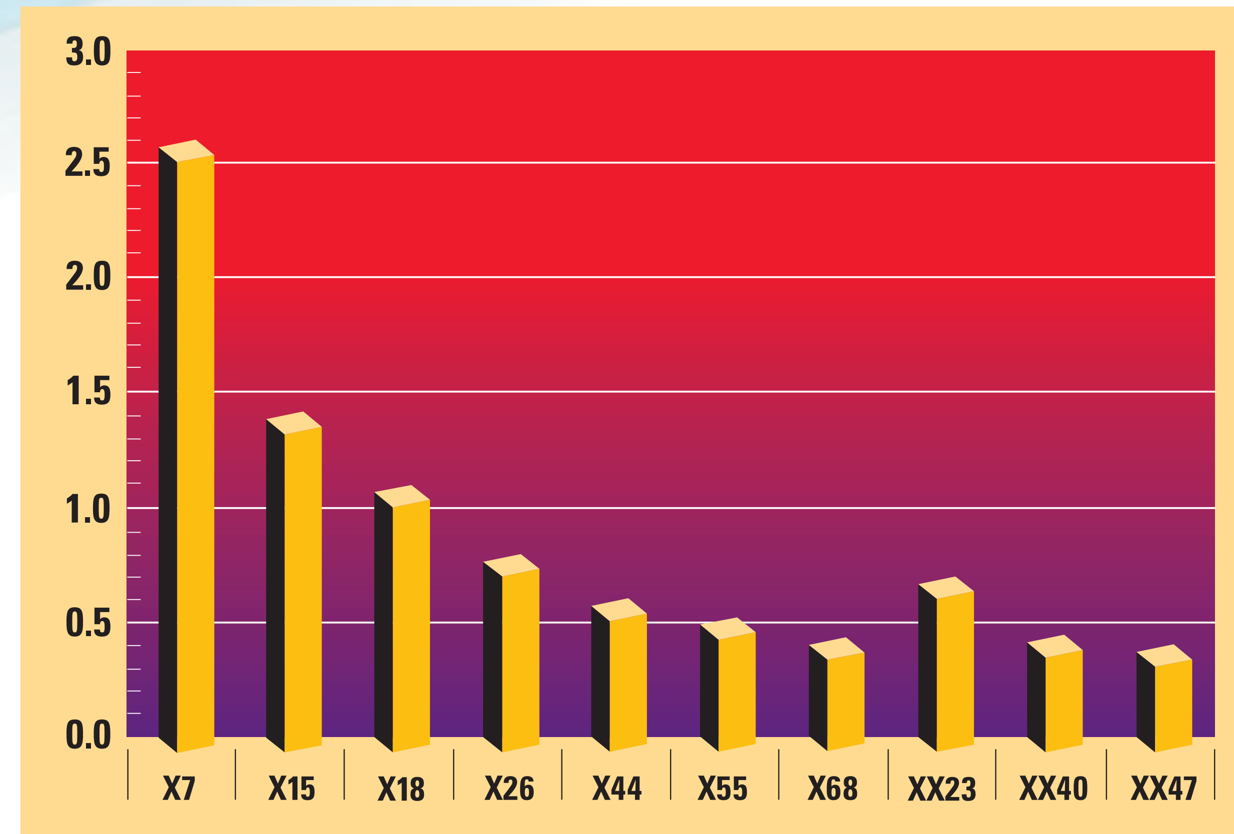
Cell Type	Rated Capacity	Weight (lbs.)	Weight (kg)	Length (in.)	Length (mm)	Width (in.)	Width (mm)	Height (in.)	Height (mm)
X7	6.5	0.63	0.28	2.24	57	.94	24	4.13	105
X15	15	1.25	0.57	2.41	61	1.14	29	7.03	178
X18	17	1.62	0.73	2.66	67	1.41	36	5.79	147
X26	26	2.50	1.13	4.53	115	.99	25	6.61	168
X44	44	3.80	1.72	4.53	115	1.62	41	6.61	168
X55	55	4.52	2.05	4.53	115	2.13	54	6.52	166
X68	68	5.71	2.59	4.53	115	2.33	59	6.52	166
X81	81	6.90	3.13	4.53	115	2.13	54	8.82	224
XX23	23	2.50	1.13	4.53	115	.99	25	6.61	168
XX40	40	3.79	1.72	4.53	115	1.62	41	6.61	168
XX47	47	4.52	2.05	4.53	115	2.13	54	6.52	166
H8	8	0.64	0.29	2.24	57	.94	24	3.93	100
H85	78	5.40	2.45	4.53	115	2.33	59	6.52	166

Additional cells available

Cell Impedance Temperature +25°C



MILLIOHMS (Fully Charged)



CELL TYPES