Devon Company: Rechargeable Battery Solutions for the Medical Market

Bobby Smith

Business Development and Applications Manager

Devon Company

Abstract:

This paper will focus on the comparison of the following rechargeable battery solutions available for the medical market from Devon Company; Nickel-Metal Hydride (NiMH), Nickel-Cadmium (NiCad), Lithium Cobalt Oxide (LCO), Lithium Nickel Cobalt Aluminum Oxide (LCA), Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Iron Phosphate (LFP), and Sealed Lead Acid (SLA). The general conclusion of the comparison is that the correct and most cost effective solution is dependent upon numerous factors associated with the specific application.

Introduction:

There are a wide variety of energy storage systems available for today's medical equipment market. Numerous primary (non-rechargeable) batteries and secondary (rechargeable) batteries are all vying for a stake in the growing industry. Each technology has its own qualities based on a variety of specific factors. Environmental conditions, operating temperatures, load requirements, portable or stationary use, cyclic or backup application, and calendar life are just a few of the determining factors.

Technology Comparison:

The three basic characteristics of each battery type are chemistry, voltage, and energy density. The most common battery chemistries are lead, nickel, and lithium. The voltage of a battery is dictated by the difference in potential of the materials used for the anode and cathode. The gravimetric energy density defines the capacity of the battery in weight. The following table will illustrate the nuances of the different rechargeable chemistries.

Specification	Lead Acid	NiMH	NiCd	Li-ion		
				Manganese	Cobalt	Phosphate
Energy Density (Wh/kg)	30-50	60-120	45-80	100-150	150-250	90-120
Cycle Life @ 80% DoD	200-300	300-500	1000	500-1000	500-1000	1000-2000
Nominal Cell Voltage	2V	1.2V	1.2V	3.6V	3.7V	3.2V
Self-discharge per month @ room temperature	5%	30%	20%	1-2%		
Charge Time (hours)	8-16	2-4	1-2	1-2	2-4	1-2
Discharge Cutoff Voltage/cell	1.75V	1V	1V	2.5V		
Charge Cutoff Voltage/cell	2.4V	charge based on voltage signature		4.2V		3.6V
Charge Temperature	-20°C to +50°C -4°F to 122°F	0°C to +45°C +32°F to 113°F		0°C to +45°C +32°F to 113°F		
Discharge Temperature	-20°C to +50°C -4°F to 122°F	-20°C to +65°C -4°F to +149°F		-20°C to +60°C +4°F to 140°F		
Overcharge Tolerance	High	Low	Moderate	Low		
Cost	Low	Moderate		High		

Lead Acid Solutions:

Lead acid has been around for over 100 years and will be a market force for the foreseeable future due to its low cost, matured state of development, and ruggedness. Common medical applications for Sealed Lead Acid (SLA) batteries include motorized wheelchairs, mobile medical carts, infant transport incubators, motorized hospital beds, and infusion pumps.

A motorized wheel chair, or Powerchair, is a wheelchair that is propelled by means of an electric motor rather than manual power. Motorized wheelchairs are useful for those unable to propel a manual wheelchair or who may need to use a wheelchair for distances or over terrain which would be fatiguing in a manual wheelchair. They may also be used not just by people with “traditional” mobility impairments, but also by people with cardiovascular and fatigue based conditions. Powerchairs are generally four-wheeled or six-wheeled and non-folding, however some folding designs exist. Four general styles of powerchair drive systems exist; front, center or rear wheel drive, and all-wheel drive. The electric motors of powerchairs are usually powered by 12 to 80 ampere-hour batteries, the smaller batteries are used in pairs to give the chair enough power to last at least one day between charges.

Mobile powered medical carts are an all-in-one workstation for healthcare professionals. These battery powered ergonomic carts can be equipped with integrated storage bins, computer, keyboard, monitor, printer, barcode scanner, and patient monitoring devices. SLA is used as a lower cost option to $LiFePO_4$ equipped carts. The mobile carts are powered by batteries that range from 35 to 55 ampere-hours. The battery is located in the base of most models and serves as a power source and counterbalance for the device. They are designed to remain in service for a full work shift without recharge.

A neonatal transport incubator is a device with an enclosure intended to contain a baby and having transparent section(s) which allow(s) for viewing of the baby, and provided with means to control the environment of the baby primarily by heated air within the enclosure, and suitable for the safe conveyance of the baby. The power source for these incubators is 12V SLA ranging from 35 to 55 ampere-hours.

Electric Hospital Beds feature electric motor controls that raise the head, foot and height of the bed frame with a push of a button. Medical / Surgical beds are the predominant bed style utilized for patient care in the United States. These beds are designed more for patient comfort and some sacrifice in medical practicability is acceptable. Patients assigned to these beds are generally in a stable medical condition and will have an extended hospital visit. These beds are powered by 12V SLA and some models use 6V SLA for memory backup.

A medical ventilator (or simply ventilator in context) is a machine designed to mechanically move breathable air into and out of the lungs, to provide the mechanism of breathing for a patient who is physically unable to breathe, or breathing insufficiently. The Emergency transport ventilators use 12V SLA.

An external infusion pump is a medical device used to deliver fluids into a patient's body in a controlled manner. There are many different types of infusion pumps, which fall into two main groups. *General* pumps include volumetric, syringe, ambulatory, and enteral. Insulin pumps fall into the *Specialty* pump group. Infusion pumps are capable of delivering fluids in large or small amounts, and may be used to deliver nutrients or medications – such as insulin or other hormones, antibiotics, chemotherapy drugs, and pain relievers. Some infusion pumps are designed mainly for stationary use at a patient's bedside. Others, called ambulatory infusion pumps, are designed to be portable or wearable. Some stationary pumps use 6V Sealed Lead Acid.

NiMH and NiCad Solutions:

Nickel Cadmium (NiCad) technology is mature and well understood, NiCad is used where long service life, high discharge current and extreme temperatures are required. NiCad is one of the most rugged and enduring batteries; it is the only chemistry that allows ultra-fast charging with minimal stress. Nickel Metal-Hydride (NiMH) is a practical replacement for NiCad. NiMH has only mild toxic metals and provides higher specific energy. NiCad and NiMH batteries are used in AEDs (automated external defibrillator), infusion pumps, electrical muscle stimulators, medical respirators, and surgical hand tools.

An automated external defibrillator (AED) is a portable electronic device that automatically diagnoses the life-threatening cardiac arrhythmias of ventricular fibrillation and ventricular tachycardia in a patient, and is able to treat them through defibrillation, the application of electrical therapy which stops the arrhythmia, allowing the heart to reestablish an effective rhythm. These devices are powered by primary and secondary batteries. 12V NiMH is a common power source for these devices.

As previously discussed, the infusion pump market is diversified in its use of energy storage. There are many examples of pumps that use 6V NiCad and 6V NiMH for battery solutions.

Electrical muscle stimulation (EMS), also known as neuromuscular electrical stimulation (NMES) or electromyostimulation, is the elicitation of muscle contraction using electric impulses. EMS has received increasing attention in the last few years because of its potential to serve as a strength training tool for healthy subjects and athletes, a rehabilitation and preventive tool for partially or totally immobilized patients, a testing tool for evaluating the neural and/or muscular function in vivo, and a post-exercise recovery tool for athletes. You will find NiMH and NiCad batteries in these portable units.

A medical respirator machine or ventilator is used to help someone breathe. These machines are usually found in intensive care units in hospitals, nursing homes and rehabilitation centers. There are also models that can be used at home for those who have chronic conditions. Smaller portable machines can be used by those who do not need to be confined to a bed. These can be powered by NiMH or Li-ion.

Surgical hand tools are instruments used to bore holes in bone for the attachment of surgical pins, plates, or screws or to remove decay and reshape teeth in preparation for a filling. The devices are precision instruments accommodating a variety of drill bits to cater for a range of applications in anything from dental to neurological surgeries. These can be powered by NiMH and Li-ion.

Li-ion Solutions:

Most promising battery chemistry, Li-ion is replacing many applications that were previously served by lead and nickel-based batteries. More delicate than most other chemistries, Li-ion needs a protection circuit for safety. Li-ion is more expensive than most other batteries, but high cycle count and low maintenance reduce the cost per cycle over many other chemistries. Li-ion batteries are used in continuous positive airway pressure (CPAP), infusion pumps, automated external defibrillators (AED), medical carts, patient monitoring systems, respirators, and surgical tools.

Continuous positive airway pressure (CPAP) is a form of positive airway pressure ventilator, which applies mild air pressure on a continuous basis to keep the airways continuously open in a patient who is unable to breathe spontaneously on his or her own. CPAP typically is used for people who have breathing problems, such as sleep apnea. These devices use Li-Ion for primary and backup power.

The diversity of the infusion pump market opens the door to all rechargeable chemistries. There are examples of devices powered by 7.4V to 14.8V Li-ion.

The portable AED market sees devices that use all chemistries of primary and rechargeable batteries. This products can use 14.8V Li-ion as the main power source.

As the same with lead acid opportunity, the mobile powered medical carts are an all-in-one workstation for healthcare professionals and powered by $LiFePO_4$ (iron phosphate) batteries. The iron phosphate batteries are often offered as an upgrade from the lead acid powered carts. The batteries range from 35Ah to 55Ah, with 40Ah being the standard requirement to remain in service for a full work shift without recharge.

Central patient monitoring systems are used to manage a wide range of medical environments including conscious sedation, respiratory therapy, sleep, emergency medical services, and transport. They have

become vital to care in operating and emergency rooms, intensive care and critical care units. These units use a variety of chemistries including 11.1V, 4.5Ah Li-ion.

Cordless surgical hand tools offer mobility and efficiency in the daily hectic environment of the hospital emergency room. Some of the tools resemble the types normally found in the common garage. One example of these products uses 10.8V Li-ion.

Conclusion:

In this paper I have offered a brief look into the various rechargeable battery solutions for the medical market. While some applications tend to have exclusivity to certain electro-chemistries, most are diversified in their use of power sources. With their comprehensive and diversified resources, Devon Company can supply all the demands of the medical industry. From the mature chemistries such as lead and nickel based solutions, to the newest Li-ion enhancements, Devon Company has a solution to fit the application.