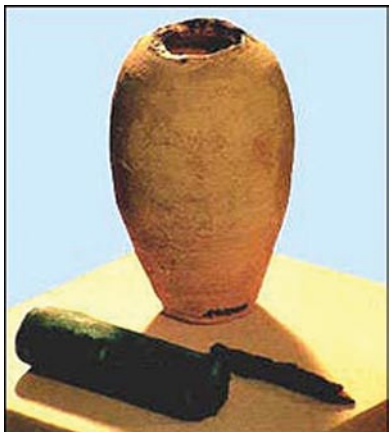
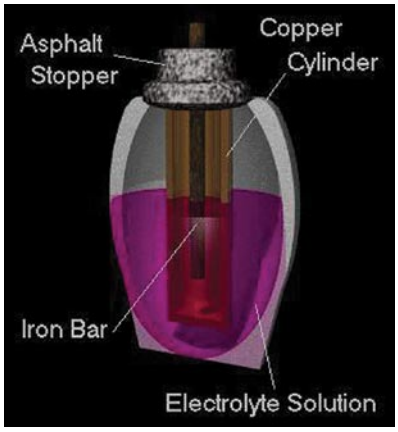
A Brief History of Batteries and Stored Energy

by M. Jeffrey Oakes
Sterling Oakes Services

I thought that having worked around batteries of all types, shapes, and sizes since 1980, that I knew just about all there was to know about them. I also thought that it would be easy to put this article together in the short time I was given to do so. I was wrong on both counts. Due to the limit on the size of this article I was not able to expound much on any one achievement. I found that different references conflicted slightly on the time line and those instances have been referenced and noted. For more information on batteries, you can visit www.IHateBatteries.com.

250 B.C. In the late 1930's several earthenware jars supposedly made as far back as 250 B.C., were unearthed during excavations at Khujut Rabu near Baghdad. The typical jar was 5-1/2 inches tall and contained a copper cylinder with its bottom capped by a copper disk and sealed with bitumen or asphalt. An iron rod was suspended from an asphalt stopper at the top of the copper cylinder into the center of the cylinder. The rod showed evidence of having been corroded with an acidic agent such as wine grape juice or vinegar. German Archaeologist Dr. Wilhelm Konig theorized that these clay jars were galvanic cells or batteries supposedly used for gilding copper with silver by electroplating. To help support this theory König also found copper vases plated with silver dating from earlier periods. However, some believe that these jars were also used for electroplating jewelry with gold or were used as an electroacupuncture device, or even to store sacred scrolls.





'Baghdad Battery' and 'Key Components of Baghdad Battery'

1651 German chemist Johann Rudolf Glauber in his "Practice on Philosophical Furnaces" described a safety valve for use on chemical retorts. Today we use Glauber's valve as the basis for the pressure vents on sealed batteries to prevent rupture of the cells when the pressure rises.

1681 French physicist and inventor Denis Papin is credited with the invention of the pressure release valve used to prevent explosions in pressure vessels, although safety valves had, in fact, been described by Glauber thirty years earlier.

1745 Dutch physicist and mathematician Pieter van Musschenbroek and his student Andreas Cunaeus working in Leyden, Holland, are the first to store electricity in a bottle. They called it the Leyden jar. A similar device was also invented at the same time by Ewald Jurgens Von Kleist, Dean of the Cathedral of Kammin in Germany. This is really a large capacitor whose design was improved by English astronomer John Bevis in 1747.

Mid 1700s Carpatho-German mathematician, physicist, and doctor at the University of Göttingen, Johann Andreas Segner, invented a reactive water turbine, the Segner-wheel, still produced today for use in small hydro sites.

1752 Johann Georg Sulzer discovered what is to be known later as the battery tongue test when he noticed a tingling sensation when he put two dissimilar metals, just touching each other, on either side of his tongue.

1752 Benjamin Franklin invented the lightning rod, proposed a "fluid" theory of electricity, and outlined the concepts and language to describe them such as positively and negatively charged current flow, conductors, armature, electric shock, electrician, and battery, which we still use today.

1757 French botanist Michel Adanson proposed a new theory that the discharge from the Senegalese (electric) catfish could be compared with the discharge from a Leyden jar. The ability of certain fish, eels or stingrays to inflict electric shocks had been known since antiquity.

1759 German mathematician Franz Maria Ulrich Theodosius Aepinus published his book, "An Attempt at a Theory of Electricity and Magnetism."

1772 John Walsh proved Michel Adanson's theory by drawing a spark from an electric eel. It is quite possible that news of Walsh's experiment influenced Galvani to begin his own experiments with frogs.

1786 Professor of anatomy at Bologna Academy of Science in Italy, Luigi Galvani, demonstrated what we now understand to be the electrical basis of nerve impulses from his experiments with dead frogs.

1800 Alessandro Volta of the University of Pavia, Italy, invented the voltaic pile and discovered the first practical method of storing/generating electricity.

'Alessandro Volta' and 'Volta's Pile'

1800 English scientists William Nicholson and Anthony Carlisle, experimenting with Volta's chemical battery, accidentally discovered electrolysis and initiated the science of electrochemistry.

1803 German physicist Johann Wilhelm Ritter first demonstrated the elements of a rechargeable battery and was one of the first to identify polarization. Unfortunately there was no practical way to recharge it other than from a voltaic pile until someone invented a charger many years later.

1807 Humphry Davy with over 250 cells made the largest battery ever built at the time to isolate compounds in various solutions. The next year Davy used his batteries to create and arc lamp.

1812 Venetian priest and physicist Giuseppe Zamboni developed the first high voltage leak proof "dry" batteries or Zamboni pile with terminal voltages of over 2000 volts. Though not much current was available (about 10-9 amperes) they were able to hold a charge for fifty years before complete discharge.

1816 British chemist William Hyde Wollaston built a system that allowed him to hoist the costly metal plates out of the electrolyte in the cells. This was the forerunner of the reserve battery and a system copied by many battery makers in the nineteenth century.

1820 American chemist Robert Hare, by using spiral wound electrodes, increased surface area and developed high current galvanic batteries.

1821 Prussian physicist Thomas Johann Seebeck discovered a voltage existed between the two ends of a metal bar when one end was cooled and the other heated. This is a thermoelectric effect now called the Seebeck effect or the Peltier-Seeback effect and is the basis of thermocouples and thermopiles that create electrical heating elements.

1828 French physiologist and biologist René Joachim Henri Dutrochet discovered osmosis using a semipermeable membrane.

1828 French engineer Claude Bourdin coined the word turbine derived from the Latin word for whirling or a vortex. The main difference between early water turbines and water wheels is a swirl component of the water which passes energy to a spinning rotor.

1832 Michael Faraday of the Royal Institution in London used a copper disc rotating between the poles of a horseshoe magnet to produce a small direct current. It became know as the Faraday disc.

1836 British chemist John F. Daniel is credited with in inventing the first nonpolarizing cell when he invented the Daniel cell which used two electrolytes and was very similar to the constant current cell developed by French physicist Antoine-César Becquerel in 1829.

1839 to 1842 Inventors Sir William Robert Grove and Bunsen created improvements to batteries that used liquid electrodes to produce electricity. Bunsen (1842) and Grove (1839) invented the most successful.

1853 Moses Gerrish Farmer patented an improved battery.

1859-1860 French inventor Gaston Plante developed the first practical rechargeable lead acid battery. This type of battery is primarily used in cars today.

1866-1868 French railway engineer Georges Leclanché developed the first practical battery product to be commercialized, the Leclanché cell.

1872 British electrical engineer Josiah Latimer Clark invented the Clark standard cell.

1874 A Frenchman named M Clamond developed the thermoelectric battery called the Clamond pile or thermopile based on the Seebeck effect.

1879 British inventor Henry Albert Fluess developed a closed circuit system that was called the rebreather

1880 Frenchman Emile Alphonse Fauré patented pasted plates for manufacturing lead-acid batteries.

1881 J.A. Thiebaut improved the Leclanché cell and patented the first battery with both the negative electrode and porous pot placed in a zinc cup.

1881 Carl Gassner invented the zinc-carbon cell that became the first commercially successful dry cell battery.

1882 French chemists Felix de Lalande and Georges Chaperon develop the first alkaline electrolyte, the Lalande-Chaperon cell.

1892 British born American chemist Edward Weston invented and patented the saturated cadmium cell known as the Weston Standard cell.

1896 American engineer William W. Jacques developed a carbon battery.

1897 German researcher W. Peukert developed the empirical law C = I nT known as the Puekert Equation. It states that the faster a battery is discharged the lower its available capacity.

1899 Waldmar Jungner invented the first nickel-cadmium rechargeable battery.

1900-1901 American Thomas Edison patented an alkaline rechargeable cell, the nickel iron (NiFe) battery.

1901 Russian Michaelowski patented the rechargeable nickel zinc battery.

1910 In Berlin, Germany, Dr. Theodor Sonnenschein (former student of Max Plank) founded the factory Akkumulatorenfabrik Sonnenschein to manufacture vented batteries for traction automotive.

1915 Willard Storage Battery Company improved automotive lead batteries with plate separators and hard rubber cases.

1915 French physicist Charles Fery developed an alternative air depolarizing battery.

1926 Sonnenshein became OEM supplier to the car industry.

1932 English mechanical engineer Francis Thomas Bacon developed the first practical fuel cell system.

1934 Elektrotechnische Fabrik Sonneberg in Germany was the first to manufacture lead acid batteries with a gelled seal.

1938 Sonnenschein opened a new factory in Berlin.

1939 The US Navy coined the acronym SCUBA (Self Contained Underwater Breathing Apparatus) to refer to their military diver's rebreather sets.

1941 American inventor B.N. Adams filed for a patent on the water activated battery. It was awarded in 1943.

1942 Frenchmen Emile Gagnan and Jacques Cousteau developed the first open-circuit SCUBA diving equipment, the Aqua-Lung.

1944 American independent inventor Samuel Ruben developed the mercury button cell. This was licensed to a company owned by Philip Rogers Mallory. Ruben and Mallory went on to found the Duracell Company.

1946 Sonnenschein opened a new factory in Budingen.

1947 Frenchman Neumann developed a seal for the nickel-cadmium battery enabling a practical recombinant system.

1949 Canadian Lew Urry invented the small alkaline battery.

1951 American Philip Edwin Ohmart of Cincinnati, Ohio, invented the first nuclear battery which converts radioactive energy directly to electrical energy.

1954 Gerald Pearson, Calvin Fuller, and Daryl Chapin invented the first solar battery.

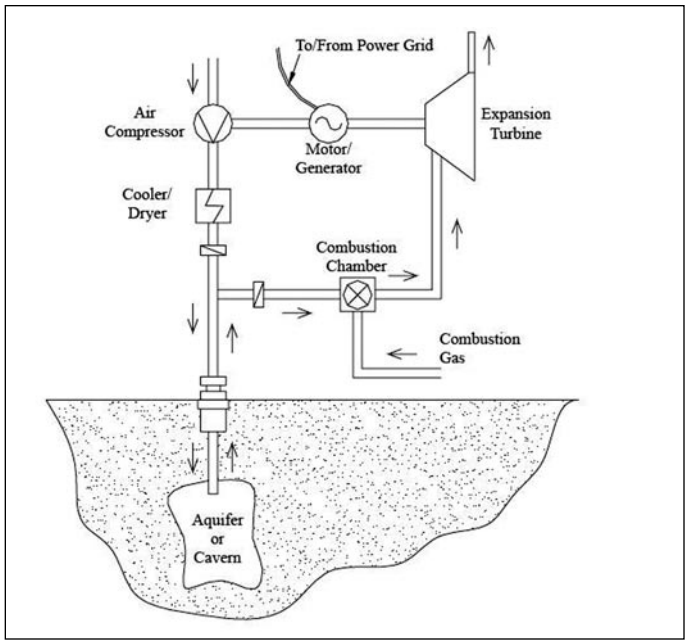
1957 German Otto Jache, working at Sonnenschein Battery, patented and started the production of the first recombinant "dryfit" Gel SLA or VRLA battery.

1959 Canadian Lew Urry patented the first modern primary alkaline battery. The battery we know was introduced by Ever Ready and Duracell between 1968 and 1970.

1964 Russian Dr. N.V.Geulia patented the first super flywheel battery.

1971 American research engineer Henry Thomas Sampson patented the gamma electric cell.

1978 Even though the compressed air energy storage (CAES) technology had been in use for over 20 years, the first CAES plant, a 290 MW facility was opened in Huntorf, Germany.



'Compressed-Air Energy Storage'

1979 American researcher John B. Goodenough, working at Oxford University perfected the lithium-ion rechargeable battery technology.

1980 UK Atomic Energy Authority in Harwell patented the first Zebra sodium/nickel chloride cell.

1980 The high power density, deep cycling absorptive glass mat or AGM lead acid battery was invented, and sealed valve regulated lead acid batteries were commercialized.

1987/88 Sonnenschein built a new factory (Weiden/Germany) for gel 2 volt cells.

1988 A 40 MWH lead acid load leveling battery delivering 5000 amperes at 2000 volts (10 MW) for 4 hours is installed by Southern California Edison (SCE) at Chino, California

1989 Britain's National Power Company started work on a load leveling battery employing Regenesys - Flow Battery - technology. The initial project for TVA is a 12 MW, 120 MWh battery.

1989 American physicist Paul M Brown US patented the Betavoltaic battery which converts nuclear energy into electricity.

1990 Commercialization of the NIMH battery occurred.

1990 The first volume introduction of lithium secondary cells for consumer applications took place.

1991 An improved CAES 110 MW plant commenced operation in McIntosh, Alabama.

1991 Swiss scientist Michael Grätzel and co-workers at the Swiss Federal Institute of Technology patented the Grätzel solar cell, a regenerative battery.

1991 Sonnenschein joined the CEAC group.

1992 Austrian born Karl Kordesch of Canada patented the reusable alkaline or rechargeable alkaline manganese battery (RAM) battery.

1992 Joe Pinkerton formed Magnetic Bearing Technologies to commercialize magnetic bearings.

1992 Sonnenschein shut down their Berlin plant (termination of starter battery manufacturing).

1993 John Cooper, working at the Lawrence Livermore Labs, patented the zinc air refuelable battery.

1994 Bellcore patented the plastic lithium ion (PLI) technology or solid-state battery.

1995 The pouch cell, made possible by lithium PLI technology, was introduced.

1995 CEAC group was bought by Exide (USA).

1995 David Clifton and Joe Pinkerton of Magnetic Bearing Technologies conceived a low-cost integrated steel flywheel motor-generator as an alternative to lead-acid batteries.

1995 Duracell and Intel developed the Smart Battery system for Intelligent Batteries and proposed the specification with its associated SMBus as an industry standard.

1995 Energizer introduced on-cell battery condition indicator or fuel gauge for consumer cells.

1995 BMW abandoned flywheel energy storage after a test technician was killed and two others were injured when the containment enclosure failed.

1996 Researchers Theodore O. Poehler and Peter C. Searson at The Johns Hopkins University demonstrated an all-plastic battery. Despite claims that the cells are inexpensive and easy to manufacture, products using the technology have so far not appeared in the consumer marketplace.

1996 Magnetic Bearing Technologies applied for the first of many patents for their motor/generator flywheel innovations. Later that year they changed the name to Active Power and raised initial funds for commercial development.

1997 Active Power shipped the first commercial dc backup power system to a customer in Florida

1999 Active Power applied for patent on Integrated Flywheel UPS. Their uninterruptible power supply utilizing thermal energy storage lays the groundwork for future development of the TACAS (thermal and compressed air storage) technology.

2000 Dr Randell Lee Mills, a Harvard-trained medical doctor and chemist who also studied biotechnology and electrical engineering at MIT, proposed the hydrino hydride battery. The hydrinos produced by this process have unique physical and chemical properties which make many new applications possible.

2000 Exide bought GNB Technologies (USA) and named the company Exide Technologies.

2000 Active Power used public stock offering to fund production facilities and continued technology development.

2002 Various patents were filed on nanomaterial used in lithium and other batteries to achieve increases in charge and discharge rates of 10 to 100 times.

2002 Commercialization of thin film batteries or solid-state lithium polymer began based on patents from ORNL.

2003 University of California, San Diego developed tiny robots they call "smart dust." These robots are smaller than a grain of sand and powered by nano batteries.

2003 German multiutilities group RWE, the new owners of National Power (now renamed Innogy) abandoned the Regenesys battery project. The project was never completed after it spent $250 million over 14 years

2003 The world's largest battery was connected to provide emergency power to Alaska's second-largest city, Fairbanks. The battery will provide 40 megawatts of power - enough for around 12,000 people - for up to seven minutes.

2003 Finnish metallurgist Rainer Partanen patented the rechargeable aluminum air battery and achieved very high energy densities using nanotechnology.

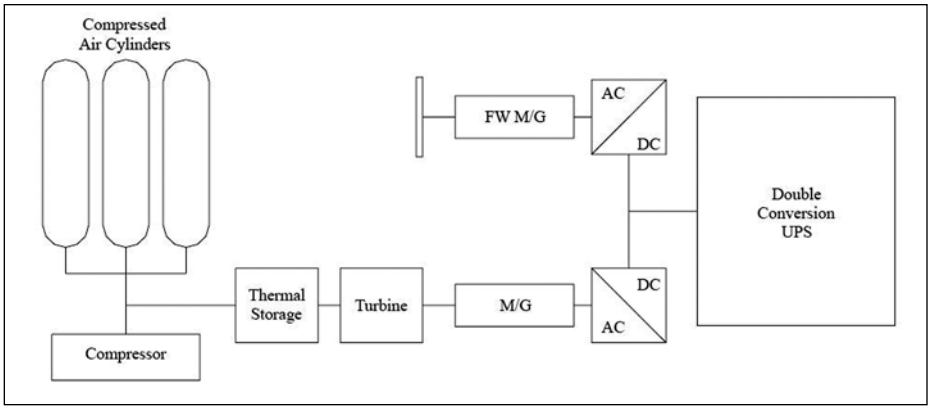
2003 Active Power applied for patent on a thermal storage device for TACAS technology. The TACAS system is a combination of several mature energy storage technologies. The breakthrough was deciding to take elements of both flywheel and compressed-air energy-storage (CAES) technology to create a self-contained energy-storage system. Compressed air and thermal energy drive an expansion turbine for long-duration outages and actually give off breathable air that is 55° F at 14.7 PSI, while a small flywheel system gives instantaneous response to load changes and short outages.

2004 Toshiba developed a direct methanol fuel cell (DMFC) small enough to power mobile phones.

2005 Korean bioengineer Ki Bang Lee, working at Singapore's Institute of Bioengineering and Nanotechnology, developed a paper battery powered by urine. It is for use as a simple, cheap, and disposable power source for home health tests for diabetes and other ailments.

2005 Japanese Masaharu Satoh working at NEC in Japan developed a small, light weight, low capacity, high power battery which runs for only a short period but can be charged and discharged at 100 degrees Celsius called the Organic Radical Battery (ORB).

2006 Active Power received UL certification and began production of the thermal and compressed air storage system or TACAS called CoolAir DC. The main components of the CoolAir DC system are:



'CoolAir DC diagram'

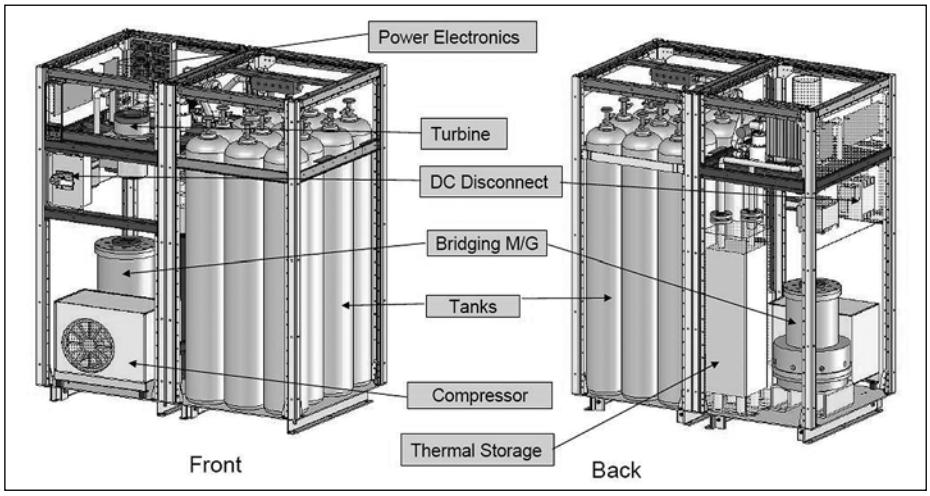
Compressed-Air System
CoolAir DC begins with compressed air stored in conventional gas cylinders or pressure vessels.

Thermal Storage Unit (TSU)
The heart of CoolAir DC is a self-contained thermal storage unit (TSU), which eliminates the need for an outside source of combustible gas. A well insulated chamber holds a stainless steel core heated to about 1300° F with internal passages to transfer its stored heat to regulated compressed air at about 400 PSI and near 32° F.

Flywheel Energy Storage
Cost and manufacturability were paramount for the CoolAir DC energy storage system so the resulting all-new flywheel design is a model of austerity.

Expansion Turbine
The heated compressed air at low inertia is used to spin a simple single-stage expansion turbine to reach full operating speed (70,000 rpm) in about a second. This turbine is extremely simple and compact.

The Complete CoolAir DC System
The figure below shows a block diagram of CoolAir DC. The TSU is maintained at full operating temperature and the compressed-air cylinders are kept fully charged. The flywheel system stays continually online with the dc bus which allows for precise regulation during load shifts and for very short outages (up to 3 seconds in duration). When CoolAir DC detects a longer outage, it activates the control valves and sends compressed air through the thermal storage unit and into the expansion turbine. The turbine and attached alternator reach operating speed, assume the load, and begin to recharge the flywheel in approximately one second. The total time required to regain full readiness is proportional to the discharge time. By comparison to conventional batteries, thermal storage has excellent energy density — up to 3 times more joules/cubic foot than lead-acid batteries.



'CoolAir DC Component Layout'

The most remarkable aspect of CoolAir DC is that all three energy storage technologies are mature and well-proven. The only novelty is bringing them together into a commercially viable product.

Energy storage has come a long way over the years. However there is still a lot of ground to cover until we reach a perfect solution that is reliable, energy dense/efficient, environmentally friendly, price competitive, safe to make and use, and at the end of its life cycle reclaim.

M. Jeffrey (Jeff) Oakes has been active in the UPS and battery field since his days in the United States Marine Corps. In 1992 he ventured out on his own, founding his company, Sterling Oakes Services. The letters SOS have become well respected across the nation as the go-to people for solving power supply problems in hospitals, universities, and communications companies. Sterling Oakes Services is headquartered in Houston, Texas, at 3625 Willow Bend #106, Houston, TX 77054. Jeff's contact information is jeffoakes@sterlingoakes.com.