Rolls-Royce

ZEBRA battery

High energy density and lightweight, ideal for marine applications

Lightweight (40% of lead-acid)

High energy density

High power density

Safe and robust

Zero battery maintenance

Accurate charge monitoring

No emissions

Long life

Shock tested

Low through-life cost

Fault tolerant

Fast recharging

Simple thermal management

The ZEBRA concept

The advanced ZEBRA battery technology offers new levels of capability, performance, safety and cost-effectiveness to the navies and commercial shipping of tomorrow. ZEBRA provides a solution for the many problems currently experienced around the world with lead-acid battery installations.

Performance

As an example of the gains to be made, a ZEBRA module of 0.13m³ and 195kg outperforms a submarine lead-acid cell of 0.19m³ and 525kg, at all discharge rates. Over a one-hour discharge, the ZEBRA module delivers double the energy provided by the lead-acid cell.

Flexibility and range

ZEBRA can be packaged to accommodate almost any battery application and can be configured to fit into the available battery compartment. To meet specific customer requirements, modules are available in configurations ranging from 24V to 1000V and 2 to 50kWh.

General benefits

ZEBRA battery installations are in the region of 50% lighter than the equivalent energy storage in lead-acid batteries. This saving allows designers to utilise additional weight flexibility.

ZEBRA modules do not require topping-up, agitation or direct battery cooling, reducing the need for costly ancillary equipment. The sealed 'zero-emission' units

Typical ZEBRA battery module

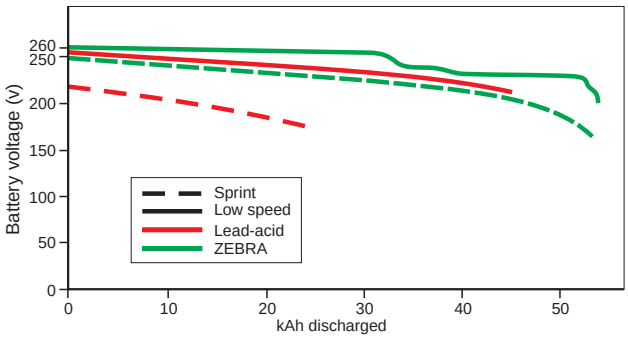
are cooled indirectly by battery compartment air. Conditioning charges and discharges are not required.

With advantages such as long life, zero battery maintenance and high reliability, ZEBRA can demonstrate a significant through-life cost effectiveness improvement when compared to lead-acid installations.

Installation

Rolls-Royce has developed installation proposals for ZEBRA batteries in conventional and nuclear submarines, with shock mounting systems proposed to suit standard construction battery modules and conductor arrangements which have a low magnetic signature. A similar arrangement would also be appropriate in stand-by power installations for surface ships.

Rolls-Royce has also undertaken work on submersible and submarine rescue vehicle applications for both instrument and traction batteries.



ZEBRA and lead-acid battery comparison: sprint and low speed endurance in SSK (identical battery compartment dimensions)

Fact Sheet

Submarine and submersible benefits

A battery with high energy density contributes directly to the operational capability of conventional submarines and submersibles by enhancing ship mobility and patrol endurance. ZEBRA provides excellent sprint reaction, performance and endurance thus increasing evasive capability and range.

ZEBRA also offers many benefits for the new generation of AIP (Air Independent Power) propulsion systems for submarines.

In nuclear powered submarines, the battery supports both nuclear safety and ship safety requirements. High energy density increases submerged endurance after reactor shut down, allowing more time for recovery action.

Surface ship benefits

A substantial battery capacity can provide stand-by power to facilitate use of the most economical modes of power generation, especially in ships with integrated full electric propulsion systems. It can also reduce the capital cost of a ship by permitting the installation of a reduced electrical generation capacity, where high peak loads and emergency requirements are design issues.

In addition to main battery applications, ZEBRA also offers many benefits for instrumentation and emergency stand-by battery arrangements.

Operation

The ZEBRA battery technology has no requirement for conditioning discharges. Full or partial recharges can be performed at any time, and may be left incomplete if continuation of charging is inconvenient.

The established charging procedures were devised with electric vehicle performance in mind - a rapid charge from zero to 80% can be achieved in 75 minutes. Re-specification of charging procedures for submarine applications might be expected to support the use of an intermediate rate of charging in all or part of the range from 80% charge to full charge. A full charge in about 4 hours seems to be a modest target.

The cell voltage characteristic presents a substantial natural barrier against overcharge, providing a definite 100% charged state, at which the charging current falls to zero, even if there is an over-voltage of as much as 18% above the OCV (Open Circuit Voltage).

Description

Key active ingredients are sodium chloride and nickel. Inside a safe-to-touch vacuum-insulated battery casing, cells of about 100 watt hours have an established operating temperature range of 250-350°C, which can be supported by electrical resistance heaters. Shelf life is indefinite, and independent of the state of charge.

Principle

Energy is stored by the transfer of sodium ions through a solid electrolyte of beta-alumina ceramic, leaving a coating of nickel chloride on the nickel powder granules of the positive electrode. A minimum operating temperature is defined by a liquid secondary electrolyte, sodium-aluminium tetrachloride. This melts at 155°C, but power output is better at higher temperatures. On cooling to ambient temperature, the cell contents freeze to relatively soft solids, which do not transmit severe mechanical forces to the ceramic electrolyte. There is no restriction on freeze/thaw cycles.

Production

The battery is assembled in the discharged state from safe and readily available materials. Sodium metal is not formed until the cell is charged. Recycling is simple, and has been demonstrated by the use of a 20 tonne container-load of ZEBRA cells as feedstock for stainless steel manufacture.

Typical battery specifications

		24 volt	278 volt	557 volt
Max capacity - 1hr discharge	(Ah)	288	72	36
Max capacity - 20hr discharge	(Ah)	336	84	42
Max energy - 1hr discharge	(kWh)	6	16.2	
Max energy - 20hr discharge	(KWh)	8.2	22.2	
Open circuit voltage	(V)	25.8	278.6	557
Min operating voltage	(V)	17.2	186	372
Max discharge current	(A)	n/a	224	112
Number of cells		80	216	216
Weight with BMI	(kg)	79.3	195	
Peak power	(kW)	n/a	32	
Ambient temperature	(°C)	-40 to + 70		
Length	(mm)	533	833	
Width	(mm)	350	533	
Height	(mm)	305	300	

ZEBRA batteries are manufactured in Switzerland by MES-DEA S.A.

Rolls-Royce®

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