Energywith Technical Report

No. 01 (May 2023)

Energywith Co., Ltd.

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Commentary

Technology Strategy

Report

President and Chief
Executive Officer
Masato Yoshida

On the Occasion of the First Publication of the EW Technical Report

On December 1, 2021, the Energy Business Division of the former Showa Denko Materials Co., Ltd. (current Resonac Corporation) become independent and Energywith Co., Ltd. (hereafter, EW) was established. The two new parent companies are Advantage Partners Corporation ("AP"), a Japanese private equity fund, and Tokyo Century Corporation ("TC"), an operating company. We will aim to shift from a specialized storage battery manufacturer to become an energy storage solution business, supported by two parent companies. The current business defines backup power supplies and golf carts as energy storage solution business. For these items, the storage battery is maintained and inspected after delivery. We are now establishing reliable relationships with customers while handling their problems and requests and offering ongoing after-sales service instead of selling off products in this way. We aim to expand the business by leading it up to the next order and encompass projects including new development elements.

We are proud that EW's storage battery products and technologies can contribute to decarbonization efforts in 2050. Moreover, the lead-acid battery is an excellent recycled product. EW will promote business operation, making a decarbonized society and recycling society its top priority. We have discussed the ideal situation of EW toward realizing a decarbonized society in 2050 and established a corporate philosophy accordingly. Originally, we focused our discussions on the younger generation who may participate actively in the center of EW on the active list as of 2050. We established the corporate philosophy "Energywith, adds new wisdom to energy storage and focuses on quality to provide people with reliability and safety as a "trusted energy storage solution company"." adding the thoughts of top management at launch time based on that discussion. The items to always keep in mind for business operation based on the corporate philosophy include "performance", "quality" and "marketing and sales skill". We define "performance" as not a function, but a function divided by cost. If the same function can be made at a lower cost, it means the "performance" is improved.

"Quality" is the most effective for profit source and we are convinced that quality No. 1 is global No. 1. We target customer satisfaction and aim to improve the motivation of employees involved in all departments related to manufacturing, including procurement, focusing on quality first to improve the product for customers.

Mastering the art of "marketing and sales skill" is vital for establishing strong customer relationships, so the sales style which has been accumulated from the former company as our DNA is highly applicable to this concept. In addition to the traditional sales style, the marketing and sales skill needs to be able to make new proposals on its own. Our goal is to evolve our storage battery business into an energy storage solution business by infusing it with innovative insights. Technical Report, we'll delve into our new business ventures, improvements in quality, cost reductions and proposal-based selling, not only emphasizing on functional performance aspects.

In 2022, the business landscape shifted dramatically. Skyrocketing prices for raw materials, primarily lead, shortages of components due to foreign conflicts and surging electricity bills became the new reality. We consider it crucial to run a business capable of withstanding such changes, as well as focusing on the environment for future management. Actions toward decarbonization, such as adopting self-consumption systems and improving the charging efficiency of storage batteries, are effective ways to mitigate electricity price volatility. In response to the changing business environment, we propose enhancing "performance" through cost reduction. Significant cost reduction will likely necessitate new element technologies. We'll also focus on augmenting the fundamental "high performance" of lead-acid batteries and accelerating our transition to a solution-based business model.

This report will briefly cover four key themes. The battery for vehicles, labeled as EN battery, is a novel product designed to comply with European specifications (EN standard). We anticipate a growing market for this product, leveraging the battery technology we've honed based on JIS standards. Another new product is a lithium-ion battery DC power supply, in the power supply business. While EW has halted the production of lithium-ion battery cells, we've procured cells externally to develop and launch a new product line of power supply devices and modules. Additionally, this report will discuss two themes related to Ni-Zn batteries. Zinc (Zn), like lead (Pb) and tin (Sn), is a metal with abundant resources. The nickel (Ni) electrode, a mature technology, is used in nickel-hydride batteries for hybrid cars. The zinc (Zn) electrode is a critical aspect for the development of this battery. We'll provide a detailed report on this subject. Aqueous solution is used for electrolyte, so this Ni-Zn battery is expected to be highly safety, and it is also highly recyclable. EW is positioning this Ni-Zn battery as a new battery to extend our energy storage solution business, along with our lead-acid batteries.

Our aim is to help you understand EW's strategic direction through this technical report. We sincerely appreciate your continued guidance and support.

Fundamental Technologies Supporting Main Products: Toward Transformation into Energy Storage Solutions Business

Shoichi Hirota

We have manufactured and sold lead-acid and lithium-ion batteries for the automotive and industrial applications, power supply equipment, caddie carts and energy storage systems on which these storage batteries were mounted from the day of predecessor company[1]. Details follow of the fundamental technologies supporting the current main products and their transformation into an energy storage solution business accumulated by our company.

1 Technology behind lead acid batteries

Lead-acid batteries, renowned for their safety and remarkable recyclability, prevail in foundational industries like infocommunications and the vehicle industry. To help meet evolving needs of automotive and industrial equipment within a decarbonized and recycling society, we have relentlessly striven to bring various aspects of lead-acid battery technology and performance forward.

Tuflong is the brand name of Energywith Co.,Ltd for the lead-acid battery employed for engine start-ups in vehicles has seen its scope expand. We have innovated batteries that align with the recently introduced alternator regeneration and idling stop systems, after emission-control regulations were tightened. Improving carbon and lignin additives, both of which major contributors to the cathode active material, helped us find a technology that enhances charge characteristics and durability performance, up to two times and 3.5 times better, respectively, comparing to to the existing product used for engine start-ups. While the aforementioned systems are becoming more generalized and new performance requirements are becoming less frequent, we continue to improve the technology to enhance quality. Recently, this involved exploring gas generation behavior during charging, focusing on its mechanism using a gas analyzer capable of real-time water decomposition measurements. This investigation was intended to resolve the contradictory phenomenon of charging characteristics and liquid reduction. Our findings validated the fact that our existing battery showed unchanged performance in terms of liquid reduction within the idling stop function usage environment. Consequently, we have identified new means of evaluating and enhancing performance[2]. These technological advancements have been channeled into the development of our new product, a battery adhering to the global standard 'EN' (European-Norm).

Simultaneously, for industrial lead-acid batteries, we have broadened our product scope to include storage batteries for standby applications (emergency power supply; medium/large size: MSE, MSJ, MU, UP series; small size: LHM, HF, HP, HSE series), lead-acid batteries designed for electric vehicles such as forklifts under the product brand 'LIFTTOP' and storage batteries catering to cycle applications, employed for peak shift/cut or mitigation of output fluctuation in synergy with renewable energy, characterized by our 'LL' series.

Figure 1. External appearance of the Tuflong series vehicle battery

Figure 2. External appearance of the lead-acid battery for electric vehicles (LIFTTOP product brand)

This report will introduce our 'LL' series, which has been optimized to enhance charge characteristics and durability and in so doing, support the effective use of electric power alongside solar power generation and output fluctuation smoothing for wind-power generation. Focusing on additive agents and leveraging simulation in our design approach is part of our strategy to minimize grid corrosion deformation, a core design requirement of industrial products similar to vehicle products and extend the expected lifespan of our products in the process[1]. In future, the ability to predict battery lifespan based on specifications and differing operating conditions of customers, such as energy sources like wind and solar and variations in customer operating methods, will be key. In this context, one prominent method for improving life prediction accuracy is data-driven simulation using in-depth analytical information gleaned from the storage battery. As we quantify the physical properties of batteries[3], we aim to establish a simulation methodology capable of predicting battery life, founded on storage battery analysis technology that evolves with each passing year.

2 Lithium-ion batteries and system development technology

To meet emerging needs such as a peak reduction or shift in the smart grid, a stable renewable energy supply and lifeline protection during power outages, the scope of our energy storage system is broadening. Our efforts have centered on creating and testing various energy storage systems, including large-scale stand-alone lithium-ion batteries and hybrid power supplies coupled with lead-acid batteries [1][4][5].

Since June 2016, we have participated in New Energy and Industrial Technology Development Organization (NEDO) demonstrations in Speyer City, Germany[6]. These focused on renewable energy self-consumption systems, as well as similar NEDO demonstrations of large-scale hybrid storage battery systems in Varel, Neddersassen, Germany and power system stabilization and hybrid storage battery in Poland [6-8].

These projects have elicited ample experience in system integration, including compliance with regulations for installing large-scale lithium-ion or lead-acid batteries. We've also worked on safety features, such as remote monitoring and automatic shutdown capabilities. We've developed software for system design to minimize energy consumption and optimal operation patterns as well as a Battery Management System (BMS) to oversee these functions, along with high-capacity and reliable lithium-ion batteries[1].

These system integration technologies have proven fruitful, spawning system products such as DC power supply devices and caddie carts equipped with lithium-ion batteries. Moving forward, we see opportunities to apply these technologies to energy storage system products in the renewable energy sector. Our plan is to meet the lithium-ion battery product needs of our customers in the fields in which we sell lead-acid batteries, by procuring and customizing appropriate lithium-ion batteries for specific uses, rather than manufacturing the lithium-ion batteries ourselves.

3 Lead-acid battery status detection technology

We developed a wireless monitoring device that automatically gauges the status of lead-acid batteries[9] and enables unmanned inspections by automatically measuring the condition of lead batteries used at data centers, where high reliability is crucial and the scale has increased in recent years. It uses impedance measurement data from high- and low-frequency areas of the lead-acid battery to estimate degradation[1].

First, the first generation (Gen.1) wireless monitoring device enabled automatic measurement of large-scale storage battery facilities. It included an update time display function with automatic measurement and a calendar to ensure safety, such as avoiding insulation breakdown from simplified harness installation work and contact with the harness.

Given that IoT is becoming increasingly popular we developed a second-generation (Gen. 2) device with a cloud server, enabling continuous remote monitoring of data across multiple installation sites. Gen. 2 improved upon Gen. 1 by enhancing the response to individual cells and the reliability of wireless communication. Expanding this technology to cover status detection and remote monitoring of storage batteries in renewable energy and mobility fields is expected, as well as monitoring the condition of data center lead-acid batteries.

4 Expansion into the energy storage solution business

We have described the fundamental technologies that support our mainstay products by reviewing their development to date. We intend to develop its existing business of manufacturing and selling storage batteries and to shift to the energy storage solution business. We define the energy storage solution as enhancing customer value by adding new wisdom to the storage battery. Specifically, we envision (1) an energy storage solution that enhances customer value by combining storage battery products, system products, maintenance services and battery status detection, (2) an energy storage solution that uncovers new customer needs and meets them by providing the product itself or a new service and (3) an energy storage solution that adds value for customers through synergies with the financial business of our parent company, Tokyo Century.

The data-driven simulation, energy storage system design technology and battery status detection technology mentioned are anticipated as core technologies supporting the energy storage solution business, for application in mobility and social infrastructure. We have also launched the development of the nickel-zinc (Ni-Zn) battery as a third energy storage device. It utilizes aqueous electrolyte same as lead-acid batteries ,and addresses the safety concerns associated with lithium ion batteries..

We aim to include this new type of battery in our storage battery product lineup and combine the fundamental technologies discussed above to create an energy storage solution. By doing so, we intend to meet the latent energy storage needs of our customers and venture into new business areas. This proactive approach reflects our commitment to remaining ahead and we look forward to delivering superior value to our clients.

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Energywith

Release of EN standard battery for ISS (idling stop vehicles)

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1 Abstract

Due to the shift to EV/HEV, automobile batteries in Japan are beginning to switch from starter batteries to auxiliary equipment batteries, and in line with this trend, battery types are also being replaced from JIS standard batteries to EN standard batteries. In 2018, our LN3EFB was installed as an OEM in SUV vehicles for North America and Europe.

The highly durable, high-quality batteries for vehicles with start-stop system LN2ISS (ENA375LN2ISS9B) and LN3ISS (ENA390LN3ISS9B) incorporating this technology have been released for the repair market. These batteries satisfy the EN standard test to support not only domestic cars but also imported cars, and have achieved the longest warranty* in Japan.

2 Features of technology

- By employing a double-lid design with a collective exhaust structure, the product offers flexibility in installation, fitting comfortably within car interiors or engine spaces.
- By using high-density paste for the positive and high charge acceptance paste for the negative , high durability against deep DOD (Depth-Of-Discharge) and PSOC (Partial-State-of-Charge) environments has been achieved. As a result, we have achieved the longest warranty in the industry as a battery for idling stop vehicles.
- The product also meets the stringent EN standard test requirements, making it suitable for both domestic and imported vehicles.

3 History of development

The domestic appetite for EN standard batteries continues to grow annually. Projections suggest that by 2025, EN batteries will be fitted in 40% of new domestic cars[1]. Concurrently, demand for imported cars and those featuring an idling stop function is also escalating, prompting us to design EN standard batteries specifically to meet these requirements.

Vehicles manufactured by European automakers that are fitted with an idling stop function require batteries that comply with the EN standard. EN50342-6 outlines the applicable requisites and testing methods. For those installed in vehicles produced by domestic automakers, JIS and SBA standards apply. However, while the JIS standard lacks developed testing methods for EN types, the SBA standard, though including shape-related regulations, fails to specify performance requirements and testing methods. Accordingly, we gauged the suitability of this development product via an endurance test determined by the OEM destination and by evaluating the EN50342-6 requirements for imported cars.

4 Technical content

The target performances and evaluation results of LN2ISS and LN3ISS are shown in **Table 1.** A 20-hour rate capacity and cold-cranking ampere (CCA) were set to ensure the performance rank would be higher than the batteries in the market. The charge acceptance was set referencing a JIS standard battery for the idling stop function. For the endurance test, we set the target values of each endurance test targeting the M1 level specified in EN50342-6. The water consumption performance was set targeting W3 specified in EN50342-6. The vibration test was conducted targeting V2 level applicable to standard-sized cars. As an ISS original test, the target performance was set to 50000 cyc under the OEM test conditions.

Table1. Target performance and evaluation result

Test item		Applicable test standard	LN2ISS		LN3ISS	
			Target value	Evaluation result	Target value	Evaluation result
Initial performance	Performance rank	SBA S 0102	375	>375	390	>390
	20-hour rate capacity	EN 50342-1	>60Ah	PASS	>70Ah	PASS
	CCA	EN 50342-1	>570A	PASS	>720A	PASS
	Charge acceptance	SBA S 0101	>41A	PASS	>58A	PASS
Durability performance	ISS original test	-	>50000cyc	PASS	>50000cyc	PASS
	25%DOD	EN50342-1	>450cyc	PASS	>450cyc	PASS
	17.5%DOD	EN50342-6	>765cyc (M1-Level)	PASS >1530cyc (M3-Level)	>765cyc (M1-Level)	PASS >1530cyc (M3-Level)
	50%DOD	EN50342-6	>150cyc (M1-Level)	PASS >150cyc (M1-Level)	>150cyc (M1-Level)	PASS >150cyc (M1-Level)
	MHT (Micro Hybrid Test)	EN50342-6	8000cyc Ce>50%	PASS	8000cyc Ce>50%	PASS
	Water consumption	EN50342-1	<8g/Ah (W3-Level)	PASS <4g/Ah (W4-Level)	<8g/Ah (W3-Level)	PASS <4g/Ah (W4-Level)
	Vibration resistance	EN50342-1	V2-Level	PASS (V2-Level)	V2-Level	PASS (V2-Level)

As the endurance test of EN50342-6 requires durability performance at each DOD, the type of anode active material was set to the high-density type to accomplish the target performance. It aims at suppression of muddying of the active material due to repeated charging through densification. For MHT (Micro-Hybrid Test), the cycle under the PSOC environment is repeated, meaning high charge acceptance is necessary. Accordingly, a high charge acceptance type of negative active material was selected to accomplish the target. For the positive/negative grid, a middle mesh was adopted for both positive and negative, with the balance between output characteristic and cost in mind.

All items met the requirements for domestic and imported cars. We could develop an EN standard battery achieving the longest warranty in the industry as a battery available for cars equipped with an idling stop function based on this result(**Figure 1**).

Figure 1. Tuflong EN (ENA375LN2ISS9B)

5 Future developments

- In September 2022, LN2ISS and LN3ISS were released. Customer-pleasing products will be provided by utilizing feedback from customers for future development.
- Reinforcing the production capability preparing for increased demand of EN standard battery.

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* An internal investigation (according to our research)

Energywith

Charge-discharge characteristics and technology for deterioration control of nickel-zinc battery

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1 Abstract

Nickel-zinc (Ni-Zn) batteries are secondary batteries using water-based alkaline electrolyte with high safety and have theoretical energy density of 347 Wh/kg. They use zinc as anode material, which is a cheap and abundant metal. Also, they are able to be recycled in principle and have a low impact on the environment. Accordingly, we have been developing them for automobile and industrial use.

Ni-Zn batteries have issues with cyclability resulting from internal short circuits caused by dendritic zinc and/or anode degradation caused by morphological change. We improved them in cyclability by adapting our new technologies such as separators, electrolyte additives, and binder for zinc anode . The performance of the developed Ni-Zn battery was evaluated under the test conditions for industrial use, and the results showed charge-discharge characteristics were superior to lead-acid batteries and cycle life performance equivalent to that of lead-acid batteries.

2 Features of technology

- The nickel-zinc (Ni-Zn) battery uses aqueous alkaline electrolyte and is very safe.
- New degradation control technology used for zinc electrodes has achieved a service life equivalent to a lead-acid battery.
- The nickel-zinc battery outperforms the lead-acid battery in terms of charge-discharge and is usable for high input/output applications.

3 Development history

Lead-acid batteries have been widely used to start up engines and for auxiliary machines of vehicles, to power automated guided vehicles and so on, as well as UPS backup power supplies. In recent years, lithium-ion batteries which are compact, light and feature high energy density have been spreading and expanding in various markets. However, the use of combustible organic electrolyte raises safety issues. Consequently, we have focused on a nickel-zinc (Ni-Zn) battery using aqueous alkaline electrolyte and with a high theoretical energy density of 347 Wh/kg as a new storage battery and promoted its development with automotive and industrial applications in mind.

The Ni-Zn battery is configured with a positive electrode, principally involving nickel oxyhydroxide and cathode (zinc electrode) using zinc, a reasonable and abundant resource. Accordingly, it can be recycled in a process resembling that of a nickel-hydride battery as a general rule and with a low environmental load. Conversely, issues with the zinc electrode include progressive dissolution of the zincate ion in alkaline electrolyte and the zinc deposition reaction upon charge and discharge, the occurrence of an internal short circuit due to dendrite growth and degradation due to morphological change[1-3]. In response, we have examined new separator technology and electrolyte additives as well as a cathode binder to suppress degradation and thereby improved the service life.

This report outlines the result of an evaluation comparing the charge-discharge characteristics of the developed Ni-Zn battery with those of the control valve-type lead-acid battery used for industrial purposes and the evaluation result when assessing the service life of the battery.

The specifications of the evaluated batteries are shown in **Table 1**. For the developed Ni-Zn battery, a newly examined binder material and additive agent were separately applied to the cathode (zinc electrode) and electrolyte. For the separator, a double-layered structure of non-woven fabric and microporous membrane was adopted. The 20-hour rate capacity of the evaluated Ni-Zn battery is 8.6 Ah. The storage battery used for comparison is a control valve-type lead-acid battery made by Energywith, which is a product deployed in the market for cycle use that features repeated charging and discharging as power sources for mobile objects such as unmanned guided vehicles.

Table 1. Specifications of evaluated batteries

	Item	Ni-Zn battery	Control valve-type lead-acid battery
Constitutional materials	Anode	Nickel oxyhydroxide	Lead dioxide
	Cathode	Zinc	Lead
	Electrolyte	Potassium hydroxide aqueous solution	Dilute sulfuric acid solution
	Separator	Non-woven fabric + microporous membrane	Non-woven fabric
Battery specifications	20-hour rate capacity	8.6 Ah	38 Ah
	Nominal voltage	1.65 V	12 V
	Dimensions (W x L x H)	77×20×90 mm	165×197×170 mm
	Weight	0.2 kg	15 kg

The discharge performance was evaluated at an ambient temperature of 25°C under the conditions shown in **Table 2**. The discharge performance of the Ni-Zn battery was evaluated by the capacity retention rate when changing the discharge current for a 20-hour rate (0.05 CA) capacity to 0.2 CA and 1 CA. Here, "CA" represents the magnitude of electrical current and the current that discharges 20-hour rate discharge capacity in one hour is set to 1 CA. If the 20-hour rate discharge capacity is 8.6 Ah, for example, 1 CA indicates 8.6 A. The discharge performance of the Ni-Zn battery when setting the capacity retention rate of the lead-acid battery for each discharge current is shown in **Figure 1**. The Ni-Zn battery shows 1.1 times the discharge performance compared to that of the lead-acid battery at 0.2 CA discharge and 1.7 times or more the discharge performance at 1 CA discharge. Based on this fact, we confirmed that the Ni-Zn battery was superior in terms of large-current discharge performance.

Table 2. Discharge performance evaluation conditions

Item		Ni-Zn battery	Control valve-type lead-acid battery
Charging	Method	Rated current/ voltage	
	Current	0.3 CA	0.3 CA
	Setting voltage	1.9 V	14.7 V
	Termination condition	Charging current attenuates up to 0.05CA	Total charging time of eight hours
Discharging	Method	Rated current	
	Current	0.05, 0.2, 1 CA	
	Final voltage	1.1 V	10.5 V (0.05 CA) 10.2 V (0.2 CA) 9.6 V (1 CA)

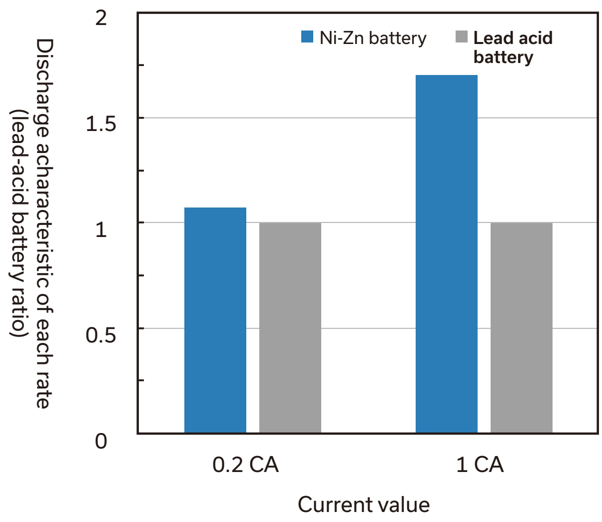

Figure 1. Discharge performance of developed Ni-Zn battery and lead-acid battery
Separately setting the capacity retention rate of lead-acid battery when 0.2 CA or 1 CA is discharged to 1

The charge performance was evaluated by charging time when charging under specified conditions and charge-discharge efficiency (%). Here, the charge-discharge efficiency represents the discharge capacity ratio relative to charging capacity as a percentage. The shorter the charging time, the lower the charging rate loss and the closer the charge-discharge efficiency is to 100%, representing superior charge performance. The evaluation conditions and charge performance are shown in **Table 3**. If charging is implemented at a rated voltage until the charging current attenuates to 0.05 CA (assuming a 100% charging rate for 20-hour rate capacity) after charging at a rated current of 0.3 CA, the charging time is 3.8 hours for both Ni-Zn and lead-acid batteries, however, while the discharge capacity for a 20-hour rate capacity of an Ni-Zn battery is 100%, that of a lead-acid battery is 96% and the charge-discharge efficiency of a Ni-Zn battery at this time is 100% and that of a lead-acid battery is 96%. If the lead-acid battery is charged up to 110% for a 20-hour rate capacity, eight hours of charging are required, with a discharge capacity of 99% and charge-discharge efficiency of 90%. Based on the results shown above, the Ni-Zn battery outperformed the lead-acid battery in terms of discharge efficiency and could be charged in less time, so we confirmed its superior charge performance.

Table 3. Evaluation conditions and charge performance of the Ni-Zn and lead-acid batteries

Item			Ni-Zn battery	Lead-acid battery	
Evaluation condition	Charge	Method	Rated current/rated voltage		
		Current	0.3 CA		
		Setting voltage	1.9 V	14.7 V	14.7 V
		Termination condition	Charging rate 100%	Charging rate 100%	Charging rate 110%
	Discharge	Discharge	Rated current		
		Current	0.05 CA		
		Termination condition	1.1 V	10.5 V	10.5 V
Charge performance evaluation result	Charging time (h)		3.8 h	3.8 h	8.0 h
	Discharge capacity (/20-hour rate capacity)		100 %	96 %	99 %
	Charge-discharge efficiency		100 %	96 %	90 %

The service life of the Ni-Zn battery was evaluated by a charge-discharge cycle test at an environmental temperature of 25°C. The charge is implemented under the same conditions shown in **Table 2**. The discharge is implemented in the rated current system that discharges an electrical current up to 1.1 V at the rated current of 0.3 CA. The cycle test was conducted until the capacity retention rate reached 60%, setting the initial discharge capacity to 100%. The cycle life characteristics of the Ni-Zn battery are shown in **Figure 2**, with the horizontal axis indicating the number of cycles. The first vertical axis indicates the capacity retention rate for the initial discharge capacity while the second axis indicates the charge-discharge efficiency. In addition, the cycle life characteristic when charging is implemented until total charging time, including 14.7 V averaged voltage charging reaches eight hours and an electrical current discharged at a rated current 0.3 CA up to 10.2 V[4] is shown in **Figure 2** as an example of the service life of a lead-acid battery made by Energywith. With the Ni-Zn battery developed, the average charge-discharge efficiency up to 470 cycles is 99.9% due to the effect of applying binder materials with strong interaction force for zinc applied to zinc electrodes, an organic additive with zincate ion elution suppression effect applied to electrolyte and a double separator structure comprising non-woven fabric and a microporous membrane and the occurrence of an internal short circuit due to dendrite growth on the zinc electrode[1-3] that has been an issue is suppressed. The life performance is 485 cycles, about 1.4 times that of Ni-Zn battery for which this technology is not used and the capacity retention rate is 60%. We confirmed that its performance was equivalent to that of a lead-acid battery.

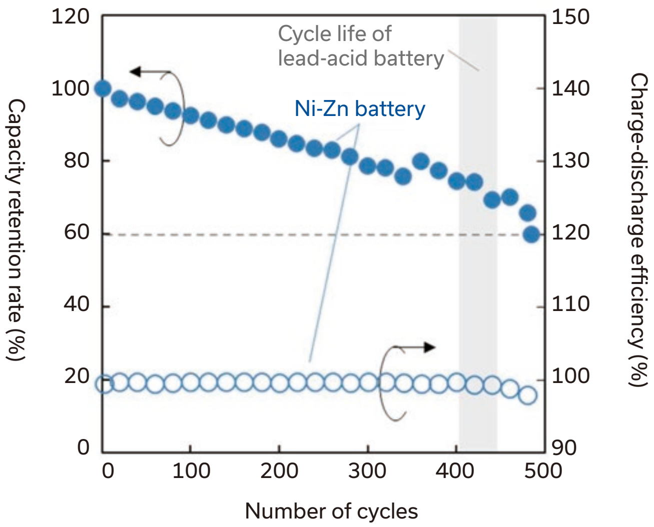

Figure 2. Cycle life characteristics of the Ni-Zn battery
The cycle life performance of a lead-acid battery indicates the number of cycles when the capacity retention rate reaches 60%.

5 Future developments

- Technology verification toward mass production
- Examining the application of recycled materials premised on battery recycling

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[Related patents]

Patent No. 7025097
Patent No. 7105525

Energywith

Cycle life characteristics of nickel-zinc battery for automotive applications

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1 Abstract

Nickel-zinc (Ni-Zn) batteries are secondary batteries using water-based alkaline electrolyte with high safety and no environmental risk in relation to the EU ELV Directive. They are able to be recycled in principle in the same manner as Ni-MH batteries. They use zinc as anode material, which is a cheap and abundant metal. Accordingly, we have been developing them for cars, especially used as starter and auxiliary batteries alternative to lead-acid batteries.

Cyclability is one of the issues of Ni-Zn batteries. We improved them in cyclability by adapting our new technologies such as separators, electrolyte additives, and binder for zinc anode. Our developed Ni-Zn battery offered no less CCA and charge acceptance performance than lead-acid batteries and approximately four times cyclability in light-load life test at 75 °C under evaluation for starter and auxiliary uses.

2 Features of technology

- Nickel-zinc (Ni-Zn) batteries use no lead or mercury and are unaffected by environmental regulations under the European ELV Directive.
- Their high-temperature durability is improved by original degradation control technology and the batteries can be mounted in the engine room.
- The batteries lasted about four times longer than lead-acid batteries in the cycle life test simulating automotive applications.

3 Development history

Automotive lead-acid batteries excel in durability under high temperature conditions and provide solid cold start performance, all at a low cost. Yet, with the advent of vehicle communication technologies, particularly wireless communication, power loads tend to increase when the vehicle is stationary or parked. In many instances, lead-acid batteries struggle to provide deep charge-discharge to supply this additional power. Furthermore, due to environmental concerns, the use of lead in automobiles may face future prohibitions under the European ELV (End of Life Vehicle) Directive. As a result, our focus has shifted to nickel-zinc (Ni-Zn) batteries as potential successors to lead-acid batteries for starter/auxiliary functions and we have actively pursued their development[1].

Though Ni-Zn batteries present an issue with the performance degradation of the cathode (zinc electrode)[2)-4)], it's worth noting that when installed in an engine compartment for starter/auxiliary purposes, the environmental temperature can exceed 70°C due to the outside air temperature and engine's radiant heat. This may further expedite performance degradation at high temperatures.

This report assesses the initial performance and lifespan characteristics of the developed Ni-Zn battery, conforming to automotive application standards, to validate its performance level as a starter/auxiliary device. For comparison, we've used a lead-acid battery for starter/auxiliary functions manufactured by Energywith.

4 Technical content

The specifications of the evaluated batteries are shown in **Table 1**. The constitutional materials of the developed Ni-Zn battery are shown in the previous report (1). We evaluated two types of cells of differing sizes. For the developed product 1, a single cell assuming the size of a LN1 lead-acid battery was evaluated. For the developed product 2, a single cell smaller than the developed product 1 was evaluated because of the easy electrode observation after the life performance test. The LN1 lead-acid battery used for the comparison is a product sold by Energywith for starter/auxiliary machines.

Table 1. Specifications of the evaluated batteries

Item		Ni-Zn battery		Lead-acid battery
Model		Developed product 1	Developed product 2	LN1
Battery	220-hour rate capacity	45 Ah	8.6 Ah	50 Ah
	Nominal voltage	1.65 V	1.65 V	12 V
	"Dimensions (W x L x H)"	157×23×153 mm	77×20×90 mm	175×207×190 mm
	Weight	1 kg	0.2 kg	13 kg

The discharge performance was evaluated by a cold-cranking ampere (CCA) conforming to JIS D 5301. This is a test simulating the engine start and an important index for an application to start that evaluates the discharge performance at low temperature; −18°C to clarify the performance difference. For the application to an auxiliary machine, CCA is also a focal point as a low-temperature output performance supporting the load of sophisticated electrical equipment. The result of separately comparing the CCA value of the developed Ni-Zn battery with that of the LN1 lead-acid battery for starter/auxiliary machines is shown in **Figure 1**. For the evaluation, the developed product 1 was used. We confirmed that the developed Ni-Zn battery showed a CCA value equivalent to that of a lead-acid battery and that the lead-acid battery could be alternated for the cold start performance.

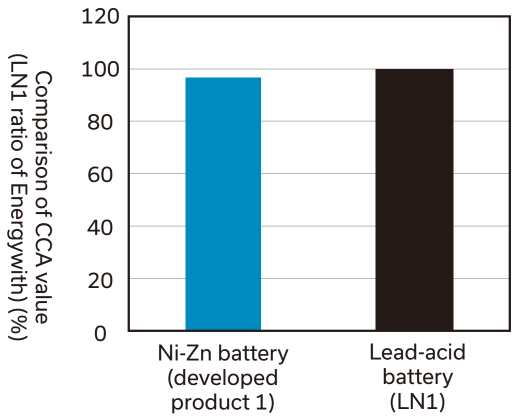

Figure 1. The test comparing the CCA value of the developed Ni-Zn battery (developed product 1) with that of the LN1 lead-acid battery for a starter/auxiliary machine made by Energywith conforms to JIS D 5301.

The charge performance was evaluated by regenerative charge acceptance performance conforming to the charge acceptance test 2 shown in JIS D 5301. This is a test that evaluates the extent to which the regenerative energy generated by vehicle deceleration can be charged to the battery. To evaluate the Ni-Zn battery, the developed product 1 was used. The test was conducted under the same conditions as those of the lead-acid battery, excluding the charging voltage and the charging voltage was tested under three conditions; 1.85, 1.88 and 1.90 V respectively to confirm the effect of voltage. The regenerative charge acceptance performance of the developed Ni-Zn battery and the LN1 lead-acid battery made by Energywith is shown in **Figure 2**. The vertical axis indicates the charge capacity ten minutes after starting charging when getting a charge at each voltage. For the charging voltage of Ni-Zn battery shown in **Figure 2**, the single cell 8 series conversion value is indicated for comparison with a lead-acid battery. If the charging voltage exceeds 15 V, the developed Ni-Zn battery shows a charging capacity equivalent to or exceeding that of a lead-acid battery and we confirmed that the lead-acid battery could also be alternated for the regenerative charge acceptance performance.

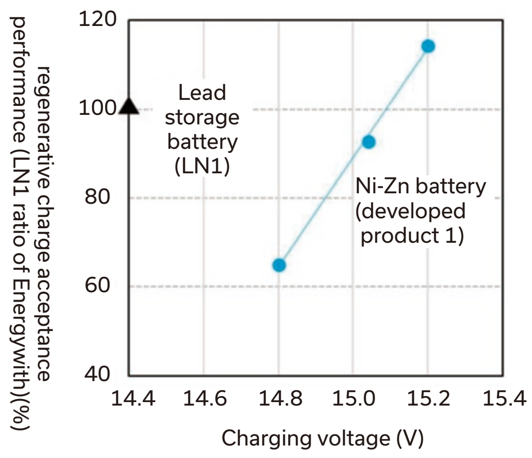

Figure 2. Regenerative charge acceptance performance of the developed Ni-Zn battery (developed product 1) and LN1 lead-acid battery made by Energywith
The test conforms to the JIS D 5301 charge acceptance test 2. The charging voltages were set to 14.8, 15.0 and 15.2 V (converting the single cell voltages 1.85, 1.88 and 1.90 V to 8 series) for the Ni-Zn battery and 14.4 V for the lead-acid battery.

We assessed battery life performance using a light-load life test, a cycle life test method that primarily simulates the usage of passenger cars and light commercial vehicles. This method aligns with the light-load life test outlined in JIS D 5301. We gauged the life performance by the number of cycles until the voltage dropped to 7.2 V in 30 seconds, during a continuous discharge of rated cold-cranking current (Icc) for 30 seconds. Regarding the environmental temperature, the test was carried out at 75°C, assuming a high-temperature environment in the engine compartment, along with the 40°C set by the standard. For the evaluation of the Ni-Zn battery, we used the developed product 2. **Figure 3** illustrates the voltage change within 30 seconds for both the developed Ni-Zn battery and the LN1 lead-acid battery, manufactured by Energywith, during the light-load life test. It's noteworthy that the charging voltage for the Ni-Zn battery shown in the figure is based on an eight-series single cell for comparison with the lead-acid battery. When compared to the light-load life performance of the lead-acid battery at 40°C, the developed Ni-Zn battery delivered four times the standard cycle life at both 40°C and 75°C. This significantly outperforms the lead-acid battery's light-load life performance. Post-life performance test electrode observations also confirmed that the developed Ni-Zn battery effectively curbed the common issues of morphological change in the zinc electrode and dendrite precipitation seen in existing Ni-Zn batteries.

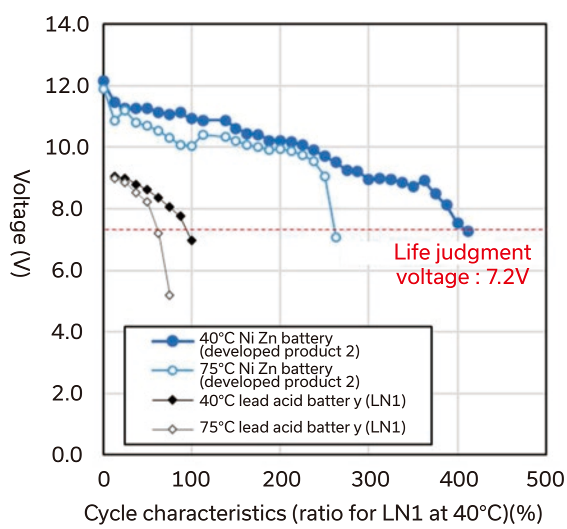

Figure 3. Result of the light-load life test for the developed Ni-Zn battery (developed product 2) and the LN1 lead-acid battery made by Energywith
The change in voltage in 30 seconds when an electrical current is continuously discharged for 30 seconds by a rated supply current for cranking a cold engine Icc complying with JIS D 5301 light-load life test is plotted. The environmental temperature is evaluated at 40 and 75°C respectively.

5 Future developments

- Technology verification toward mass production
- Development of batteries using recycled materials premised on recycling

[References]

1) Takuya Nishimura and others: Charge/discharge characteristics and degradation control technology of nickel-zinc battery , Energywith Technical Report(2023)
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[Related patents]

Patent No. 7025097

Patent No. 7105525

Commercialization of LiB DC power supply equipment

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1 Abstract

DC power supply equipment supplies DC power to important facilities such as the operation of receiving and transforming power, emergency lighting, starting private generator in the office buildings and the factories. Therefore, it has batteries to keeping power supply in any case, for example when power loss. Lead-acid batteries have been used for many years because they are inexpensive, highly safe, and recyclable. However it is issues such as large size and heavy weight, and maintenance and battery exchange. In recent years, Lithium-ion battery(hereinafter referred to as LiB) that has small size, light weight, long lifetime and easier to maintain, such as constant monitoring is expected to solve these issues. Conventional LiB DC power supply needs to have some safety measures using Battery Management System (hereinafter referred to as BMS) to keep safety against firing and fuming. However, if some troubles of these safety measures or BMS occur, it has possibilities to cause stopping power supply. Therefore, we have commercialized the LiB DC power supply with an LiB system which improved these issues.

2 Features of LiB DC power supply device

- Continuous power supply to normal load is available even if the load is defective.
- Safe continuous power supply is available even if the device is out of order.
- Maintenance time can be shortened by utilizing the continuous monitoring function of LiB.

3 History of development

The existing DC power supply devices that use lead-acid batteries tend to be bulky and heavy and require routine maintenance checks, such as measuring battery voltage, to ensure their operational health. This makes their installation challenging, especially in high-rise urban buildings or remote locations like mountainous regions and isolated islands. Because of these challenges, there's a growing interest in lightweight LiB which are known for their user-friendly maintenance and extended lifespan.

On the other hand,in conventional LiB system, if thermal runaway[*1] – a condition induced by overcharging or excessive current –occurs due to overcharging or overcurrent, there is possibility of smoke or fire, and safety measure are taken to prevent these from occurring.

The current LiB system comprises BMS, a BMS power supply, a storage battery breaker and a LiB with an in-built fuse. In the event of overcurrent during the charging or discharging of the LiB, the internal fuse self-interrupts the current. Moreover, if the BMS detects a battery failure, such as a voltage or temperature failure due to overcharging or discharging, or if the BMS itself malfunctions, it cut off of the storage battery breaker. In each instance, the system's safety is maintained by halting the LiB's charging or discharging processes. However, these measures, while necessary for safety, contradict the very purpose of a DC power supply device, which is to provide continuous power supply under any circumstances. Therefore, this aspect needs improvement. However, one advantage of the LiB system is the ability of the BMS to continuously monitor the battery, providing essential maintenance information. Using this information effectively could reduce maintenance time. Hence, we are focused on making use of BMS information for maintenance and have commercialized LiB DC power supply equipment with a LiB system that addresses these issues.

4 Technical content

(1) Improvement in power supply stop due to fuse cutoff in LiB

If an overcurrent flows into the load of an existing LiB system, the fuse in LiB self-interrupts and stops the power supply to a normal load too. Accordingly, we added a load fuse to ensure protective coordination[*2] so that it could be interrupted earlier than other parts that self-interrupt. This can separate a load in which overcurrent occurs and enables continued safe power supply to residual normal loads.

(2) Improvement in power supply stop due to cutoff of the storage battery breaker

If the BMS detects any failure of the storage battery or the BMS goes out of order, the existing LiB system interrupts the storage battery breaker to stop the charge-discharge process. If the storage battery is defective, the storage battery breaker has to be cut off to ensure safety. However, the storage battery is not defective when BMS is out of order, so we added a modification to ensure the storage battery breaker would remain uninterrupted. Even so, safety when continuing power supply cannot be ensured if the storage battery failure monitoring function when BMS malfunctions, so the monitoring circuit used for the lead-acid battery DC power supply device was left as an alternative device to make the minimum required monitoring function for continuous power supply redundant. This enables safe continuous power supply to LiB, even when BMS is out of order.

(3) Utilization of BMS information for maintenance

The existing LiB system is a system prevents the risk of thermal runaway of a storage battery via ongoing monitoring of voltage and temperature of the storage battery by BMS, advance notice to the user before the storage battery becomes defective and interrupt of the charge-discharge process when the storage battery is defective, for example. Utilizing the tool (software) that reads out the data obtained for BMS to monitor the storage battery can shorten the maintenance time.

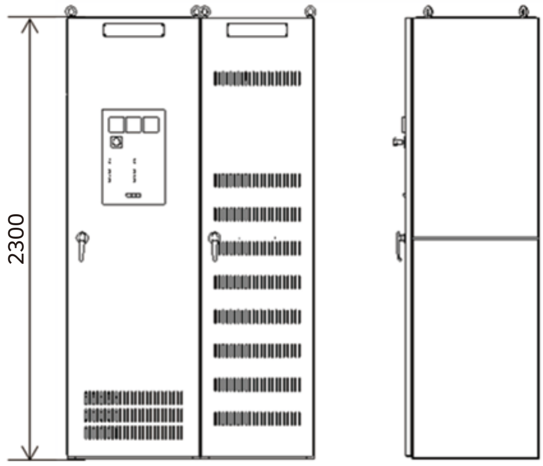
5 Product specifications

Table 1. Product specifications

Item			Unit	Specification
System	Rectification system		-	Single-phase full wave (mixed bridge method)/three-phase full wave (pure bridge method)
	Cooling system		-	Natural cooling or forced air cooling
	Rating		-	Continuous
AC input	Number of phases		-	Single-phase 2-line or three-phase 3-line
	Voltage		V	Single-phase 100, 105, 110, 200, 210, 220 Three-phase 200, 210, 220, 400, 415, 420, 440
	Voltage fluctuation range		±%	10
	Rated frequency		Hz	50 or 60
	Input power factor		% or more	Single-phase 60, three-phase 70
DC input	Charge mode		-	Floating charge mode
	Rated voltage		V	100V system
	Voltage adjustment range		% or more	±3 of rated voltage
	Voltage fluctuation range		Within ±%	2
	Output current	Single-phase input	A	10,20,30,40
		Three-phase input		10,20,30,40,50,75,100,150
	Current fluctuation range		%	0 to 100
	Maximum drooping current		-	120 of rated current
Usage environment	Ambient temperature		°C	0 to 40°C
	Relative humidity		%	25 to 85 (no dew condensation)
	Installation location		-	Interior with few harmful gas, salt content, dust at elevation 1000m or less

6 Applicable standards

- JIS C 8715-2 (applied to safety test of LiB)
- Storage battery system type approval (approval by Fire Service Act)
- 4800Ah/cell or more of storage battery system to which fire prevention ordinance is applied can be produced by applicable cubicle system.



[Notes]

*1 Thermal runaway: Generated heat causes more heat generation to disable the system.

*2 Carry out adjustment referencing characteristics of the safety device so that a defective part can be immediately separated from the system when an accident occurs.

Contact information

For any question relevant to the contents, please use the following contact form on our website :

https://www.energy-with.com/inquiry/

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