SANYO DENKI

Technical Report

Feature | Technology for Protecting People

1980
Tsuiji Works

52
November
2021

COLUMN

Cover image:

Tsuiji Works

1980

In the 1970s, as computers began appearing, the office automation market rapidly expanded.

To meet these market needs, SANYO DENKI newly built Tsuiji Branch Works (current Tsuiji Works) in Ueda in March 1980, as a dedicated machining factory, following Shioda Works which was opened the previous year.

In 1982, both factories were expanded to meet increased stepping motor demand for use in printers and hard disk drives. Through these expansions, our production capabilities of cooling fans and stepping motors were greatly improved in terms of capacity and efficiency.

Currently, Tsuiji Works is used for a variety of operations such as assembling servo motor connectors and cables, assembling stepping drivers, assembling power distribution boards, producing control panels, and repairing servo motors and amplifiers.

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SANYO DENKI TECHNICAL REPORT

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Aiming to Develop Technology for Protecting People

Keiichi Kitamura Executive Operating Officer

In recent years, more and more products and information have become available and accessible to people, and our lives have become much more convenient. On the other hand, environmental problems keep emerging such as global warming and air pollution caused by the large-scale use of fossil energy and ocean pollution caused by plastic waste.

Against such a backdrop, organizations all over the world have launched initiatives aimed at protecting people and environments. Such examples include: Sustainable Development Goals (SDGs) defining 17 goals to be achieved by 2030; RE100, an initiative committed to shifting the electricity used in business activities to 100% renewable energy by individually set deadlines; EP100, an initiative to have more than 100 companies all over the world improve their energy efficiency by 50% by 2030.

Under our corporate philosophy of “aiming to help all people achieve happiness,” we focus on three technology topics in developing our products: technology for protecting the global environment, technology for using new energy sources and saving energy, and technology for protecting people’s health and safety. These technologies have a deep connection with technology for protecting people.

1. Promoting the use of renewable energy

One of our goals is to develop products that promote the use of renewable energy, including solar power, wind power, and biomass, to protect people from worsening conditions in living environments caused by global warming and environmental pollution. This aligns with one of the SDGs of “affordable and clean energy.”

For example, our power conditioners (renewable energy inverters) can efficiently convert power generated through photovoltaic power generation, wind power generation, hydroelectric power generation, and other forms of renewable energy into usable electricity, delivering clean energy to people all over the world. We will continue to develop a variety of power conditioners that make use of renewable energy. In addition to promoting the use of renewable energy through product development, we also aim to increase the ratio of renewable energy used to power our production factories.

2. Promoting energy conservation

Initiatives to save energy have become crucial in providing everyone with energy and protecting our living environments. In addition to developing eco-efficient products capable of high performance with less energy, we also aim to manufacture products in a way that reduces the amount of waste generated during production processes, reuses and recycles our products, and makes use of environmentally-friendly materials to bring our energy conservation efforts to the next level. We also continue to engage in initiatives to reduce the amount of energy used in our production processes. For example, we reduce the amount of energy required for production by designing products that can be manufactured more easily and by building efficient production lines.

3. Protecting people's lives and livelihoods from natural disasters

Power is crucial in protecting the lives and livelihoods of people during a natural disaster. Our power generation vehicles have been used to provide power in the event of a natural disaster. Our blowers have been used in the suction of smoke detection systems to prevent fires, and our stepping systems can be found in equipment that secures water in regions experiencing droughts. We will continue to develop highly reliable products that can be relied on not only to maintain our daily lives, but also in times of emergency.

4. Protecting people's health and safety

The products from our company's three business divisions can be found in many kinds of electrical equipment and the machines that produces the electrical equipment, playing important roles in ensuring the health and safety of people.

For example, several of our products can be found in a CT scanner. Our servo systems are used to drive its patient table, our fans are used to cool internals, and our UPSs are used as power backup. For production equipment, the safety functions of our servo amplifiers are used to control industrial robots, playing a role in protecting people's safety.

We will continue to provide products that have technology best suited to our customers' electrical equipment and production equipment, aiming at manufacturing that protects people's health and safety at a higher level.

Cooling Technology for Protecting People

Toshiyuki Nakamura

1. Introduction

In recent years, advances in computers and communication networks have made many electronic devices and information processing devices crucial to our daily lives. Fans are installed in these devices to dissipate heat. Our cooling fans offer best-in-class performance, long service life, and high reliability, and therefore they are used all over the world for a wide range of applications including ICT—5G base stations, servers, and data centers—and medical equipment and the energy field to support our daily lives and public infrastructure.

Moving forward, the more digitized society becomes, the more markets requiring cooling fans will increase as more devices are switched to electronic control. There will be growing demand to provide these fans with high performance at a smaller size.

This article introduces cooling technology using cooling fans that can be found in our daily lives.

2. Cooling Technology in Our Daily Lives

2.1 Technology that improves the ICT field

Due to the faster 5G communication speeds and expanded cloud services, the processing speed and amount of data processed by today's servers are increasing, generating more heat. The density of components inside equipment has also been increasing, and therefore the cooling fans that cool such equipment are required to have high airflow and high static pressure performance.

To improve the aerodynamic performance, we use fluid simulations to optimize the shape of fan impellers and frames and use a 3D printer to create and perform prototype evaluations. We also use 3-phase motors and strong magnets in drive circuits to increase the efficiency, resulting in high airflow, high static pressure, and low power consumption. Figure 1 shows a rack-mount server, and Figure 2 shows a 1U server. These applications require high airflow, high static pressure, and low power consumption, Our 40 × 40 mm fans are used in these applications, due to their high airflow, high static pressure, and reduced power consumption.

Fig. 1 Rack mount server example
(Photo provided by Super Micro Computer, Inc.)

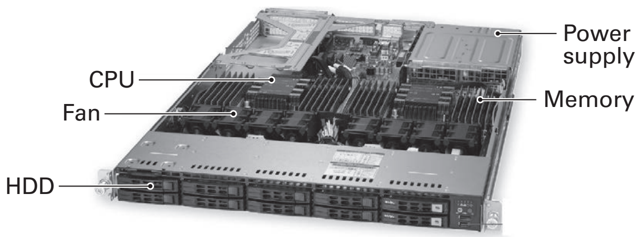

Fig. 2 1U server example
(Photo provided by Super Micro Computer, Inc.)

2.2 Technology that improves the medical field

In the medical field, more and more diagnosis devices are becoming digitized and high performance. Fans are used to cool the inside of these devices. Medical devices are used in quiet locations, and therefore quietness and high reliability are required.

In addition to carefully designing the shapes of fan impellers and frames, we reduced the electromagnetic switching noise generated from the motor for use in quiet environments. Figure 3 shows ultrasonic diagnostic equipment and Figure 4 shows a medical monitor for displaying x-ray images, where Our Silent Fans are used in both devices.

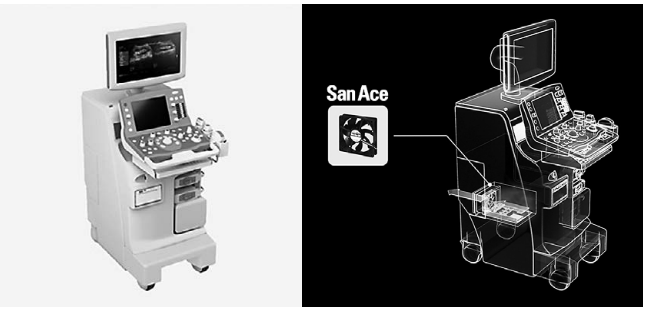

Fig. 3 Ultrasonic diagnostic equipment example

Fig. 4 Medical monitor example

Figure 5 shows a CT scanner. Our G Proof Fans are used in this application to cool the X-ray generating portion that rotates at high speed. The X-ray generating part rotates at high speed and generates a high level of G-force, so the cooling fan used in the equipment must be operable in high G-force environments. We achieved a G-force tolerance of 75 G by revising the materials used and newly designing fan shape and parts-mounting method based on strength analysis simulation data.

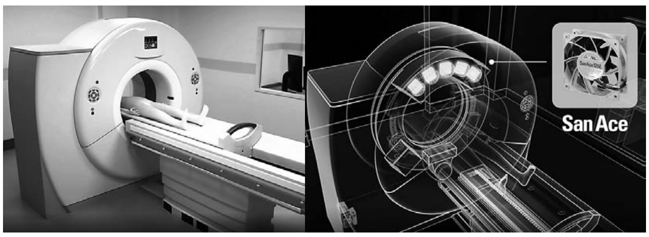

Fig. 5 CT scanner example

3. Cooling Technology for Future Society

As more and more devices are digitized, equipment cooling has become a major issue as more and more devices, including ICT equipment, are controlled electronically. Cooling fans with even better performance will be needed to resolve this issue. At the same time, manufacturers required to have their technology and products comply with Sustainable Development Goals (SDGs), which are initiatives aimed at protecting the environment. Of the 17 SDGs, the two that apply here are Goal 7 “Affordable and clean energy” and Goal 13 “Climate action.”

Also, IoT-based remote control and status monitoring of cooling fans have been increasingly required to increase the safety of equipment. The following sections introduce our technology that can meet these needs.

3.1 Technology that helps develop the energy field

Cooling technology plays an important role in resolving the issue of heat generated in equipment that converts sunlight, wind power, water power, and hydrogen fuel into electric energy. This equipment is mainly installed outdoors, and should therefore provide environmental durability (water and temperature resistance) and should not require service or maintenance over long-term use. High airflow and high static pressure cooling fans that are waterproof, temperature-resistant, and long lasting would therefore play a role in increasing the performance of energy conversion equipment.

Figure 6 shows an example where Splash Proof Fans are used to cool the inside of an inverter in a PV generation system. Figure 7 illustrates our Long Life Splash Proof Fans used to cool the inside of an EV quick charger. In this way, environmental durability technology contributes to the energy field.

Fig. 6 PV generation system example

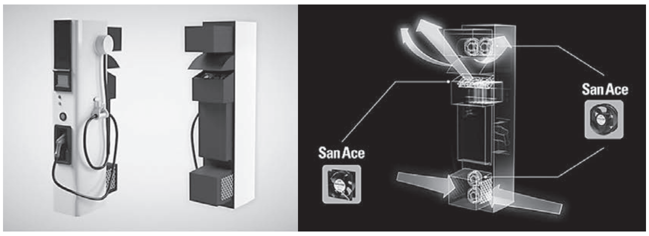

Fig. 7 EV quick charger example

3.2 Technology that helps saving energy and CO_2 emissions

When developing a cooling fan product, achieving higher airflow, higher static pressure, and longer life can reduce the space required for installation and the frequency of required maintenance, helping conserve resources.

Cooling fans can be made more eco efficient by improving the aerodynamic performance and increasing the motor efficiency to reduce the amount of power consumed while operating. Also, PWM control can also be used to add speed control functionality. This can be used to easily control the rotational speed of the cooling fan based on the amount of heat generated by the equipment, helping reduce power consumption.

Figure 8 shows that a new product, *San Ace 92* 9RA type, has a reduced power consumption. The new product consumes 44% less power than an existing product while maintaining the airflow vs. static pressure characteristics.

For details, refer to an article on this in this Technical Report.

3.3 Preventive maintenance

The needs for IoT-based control of cooling fans can be met by *San Ace Controller*, which can remotely control and monitor fans. Figure 9 shows an example system configuration of *San Ace Controller*. With this product, the status of cooling fans installed in areas that are difficult to service and maintain can be monitored, allowing users to create a maintenance plan based on the status. This controller can also be used with various sensors to automatically control cooling fans and efficiently cool or ventilate based on the status of equipment.

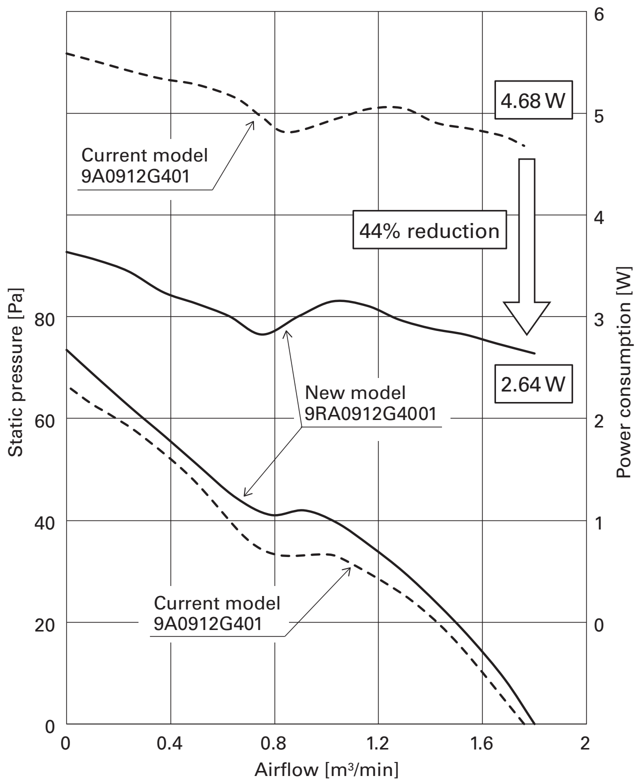

Fig. 8 Comparison of the new product *San Ace 92* 9RA type and an existing product

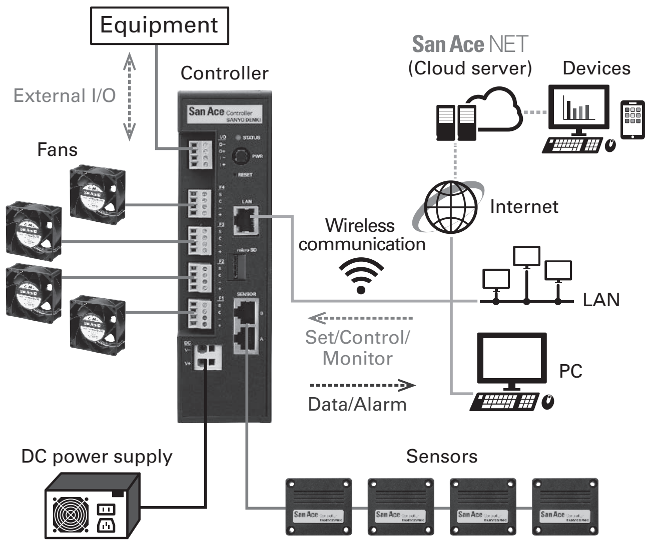

Fig. 9 *San Ace Controller* system configuration

Items used for monitoring can be set freely by the user. If measurement values deviate from these setting values, the user will be notified of the error via email, web browser screen notification, LED indicator on the main unit, or external output. The measurement data and alarm history are stored in internal memory and can be viewed on the web browser screen. Data can then be used to analyze equipment failure and develop new products, which can help make equipment safer and more secure.

4. Conclusion

This article introduced cooling fan technology that improves our daily lives and cooling technology that can contribute to future society.

Equipment has increasingly been controlled electronically. Improvements in cooling fan technology will help increase equipment performance, reduce energy consumption, and reduce the use of resources, contributing to protecting people's daily lives and the global environment.

To develop and provide products that protect people, we will continue to help our customers resolve issues and provide the best products for them.

References

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(2) SuperRack® Solutions by Super Micro Computer, Inc. https://mysupermicro.supermicro.com

(3) SuperServer 1029U-E1CR4 by Super Micro Computer, Inc. https://mysupermicro.supermicro.com

(4) Naoki Murakami and 7 others: "Development of *San Ace Controller*, an IoT Product for Remote Fan Control and Monitoring" SANYO DENKI Technical Report, No.48, pp.8–13 (2019.11)

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ø172 × 150 × 51 mm *San Ace 172AD* 9AD Type ACDC Fan and *San Ace 172AD* 9ADW Type Splash Proof ACDC Fan

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Takashi Kawashima Masato Murata

1. Introduction

AC-powered cooling fans are used in many applications, including air conditioners, inverters, and control panels. Re, there has been a growing need for reduced power consumption of devices in recent years. AC-powered fans have also been required to have a wider input voltage range for global use and water protection for use in more environments. We had offered the ø172 × 150 × 51 mm *San Ace 172* AC Fan (hereinafter, "current model"), but a new AC-powered fan that could meet these requirements had been needed.

In response, we developed *San Ace 172AD* 9AD type ACDC Fan, which features DC fan-level low power consumption despite its wide AC input voltage range, and *San Ace 172AD* 9ADW type Splash Proof ACDC Fan (hereinafter, "new models").

This article will introduce the performance and features of the new models as well as key points of development.

2. Product Features

Figures 1 and 2 show the appearance of the new products.

Figure 1 shows the appearance of the 9AD type, while Figure 2 is of the 9ADW type.

The features of the new products are as follows:

(1) Low power consumption
(2) High airflow and high static pressure
(3) Wide range of AC input supported

The 9ADW type also offers the following feature in addition to the above:

(4) IP56-rated* dust and water protection

Fig. 1 ø172 × 150 × 51 mm *San Ace 172AD* 9AD type

Fig. 2 ø172 ×150 ×51 mm *San Ace 172AD* 9ADW type

* IP56-rated protection
The IP Code, or Ingress Protection Code is defined by International Electrotechnical Commission (IEC) in the IEC 60529 standard "Degrees of Protection Provided by Enclosures (IP Code)" (IEC 60529:2001).

3. Product Overview

3.1 Dimensions

Figures 3 and 4 show the dimensions of the new models. The new models are compatible in size and mounting with the current model.

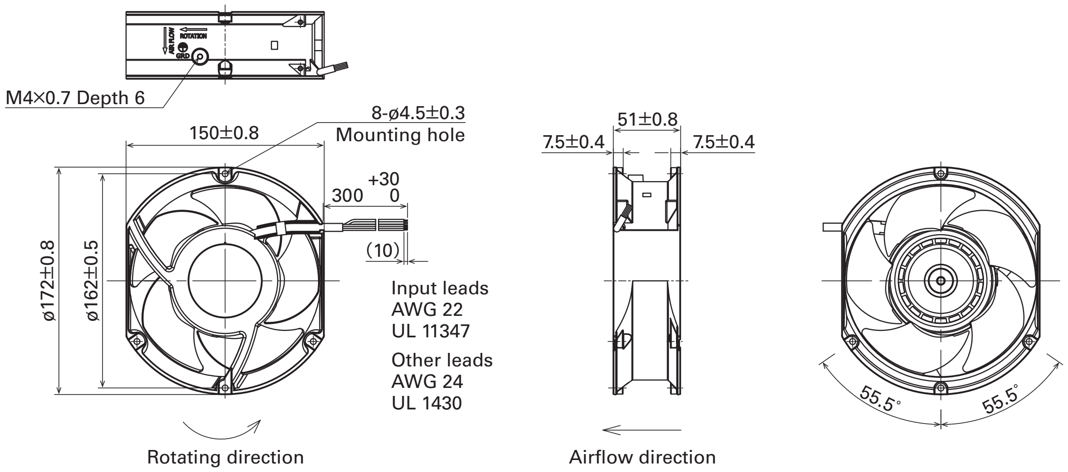

Fig. 3 Dimensions of the *San Ace 172AD* 9AD type (Unit: mm)

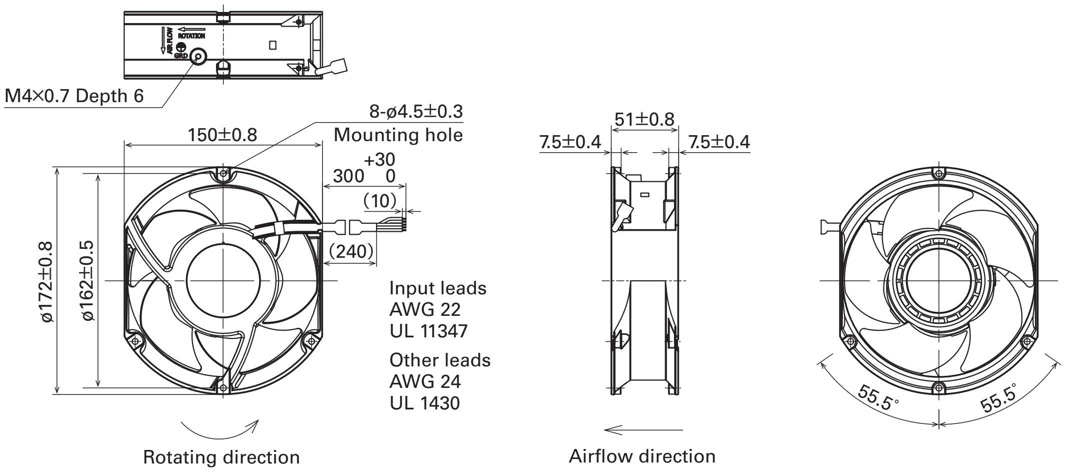

Fig. 4 Dimensions of the *San Ace 172AD* 9ADW type (Unit: mm)

3.2 Specifications

3.2.1 General specifications

Table 1 shows the general specifications of the new models. Both the 9AD type and 9ADW type share the same general specifications.

Table 1 General specifications of new models

Model no.	Rated voltage [V]	Frequency [Hz]	PWM duty cycle [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow		Max. static pressure		Sound pressure level [dB(A)]	Operating temperature range [°C]	Expected life [h]
							[m^3/min]	[CFM]	[Pa]	[$inchH_2O$]			
9AD5701P5H003 9ADW5701P5H003	100 to 240	50/60	100	0.3	17	3800	6.7	236	195	0.78	54	-20 to +70	40000 at 60°C (70000 at 40°C)
			0	0.08	3.2	1500	2.64	93	40	0.16	31		

* Input PWM frequency: 25 kHz
Note: The expected life at an ambient temperature of 40°C is for reference purposes only.

3.2.2 Airflow vs. static pressure characteristics

Figure 5 shows the airflow vs. static pressure characteristics for the new models. The airflow vs. static pressure characteristics do not change over the input voltage range of 100 to 240 V.

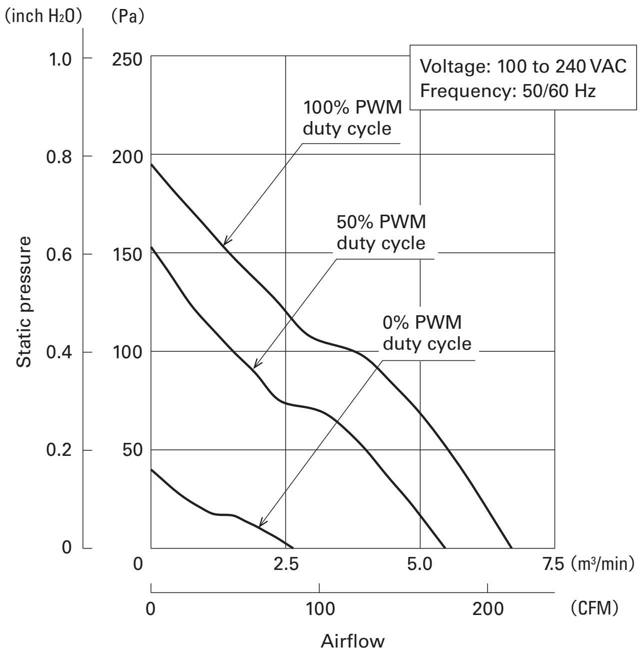

Fig. 5 Airflow vs. static pressure characteristics of new models

3.2.3 PWM control function

The new models have PWM control function and are capable of controlling fan speed.

3.3 Expected life

The new models have an expected life of 40,000 hours at 60°C (survival rate of 90%, run continuously at rated voltage in free air and at normal humidity). The expected life of the current model is 25,000 hours under the same conditions, so the expected life of the new models is 1.6 times longer than the current model.

4. Key Points of Development

Compared to the current model, the new models achieve lower power consumption, higher airflow, and higher static pressure with the size unchanged. In addition, the 9ADW type also provides dust and water protection.

The key points of development are explained as follows.

4.1 Impeller and frame design

Figure 6 compares the shapes of the impellers and frames for the current and new models.

When redesigned the impeller and frame by conducting numerous simulations for various combinations of parameters such as the number, length, and angle of blades, and the shape of the frame, and by prototype testing. In this way, we determined the design for optimized airflow performance.

4.2 Circuit design

We designed the new models to be compatible with a wider 100 to 240 VAC voltage range, improved the efficiency of the AC-DC conversion circuit to reduce power consumption, and optimized the motor-driving DC voltage. We encountered an issue with the 9ADW type where the temperature of PCB and electronic components would rise due to the PCB being sealed in an enclosure. We managed to suppress the temperature rise with a structure such that the heat from electronic components would dissipate through the frame.

4.3 Water-resistant design

Figure 7 shows the appearance of the live part of new models. We provided the 9ADW type with IP56-rated dust and water protection by coating its motor in resin and housing the circuit in the space between the frame and cover. We also reduced the amount of resin in the coating to make the product lighter.

Fig. 6 Shape comparison between the new and current models

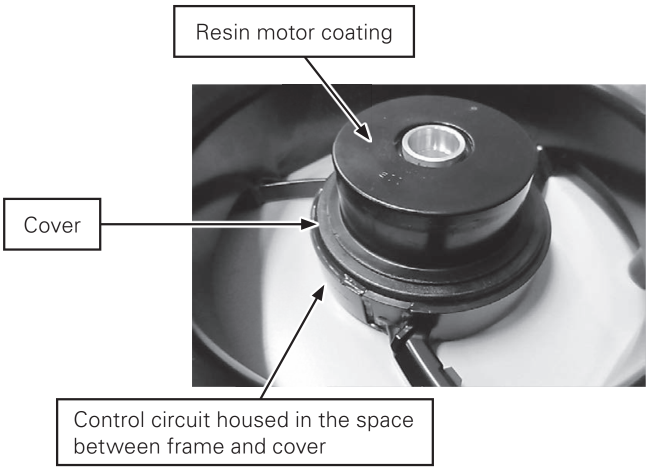

Fig. 7 Appearance of the live part

5. Comparison of New and Current Models

5.1 Comparison of airflow vs. static pressure characteristics

Figure 8 compares the airflow vs. static pressure characteristics of the new and current models. The new models have 3% higher maximum airflow than the current model while maintaining the same maximum static pressure. On the estimated system impedance (ventilation resistance) curve in the figure, the operating airflow of the new models is 27% higher than the current model.

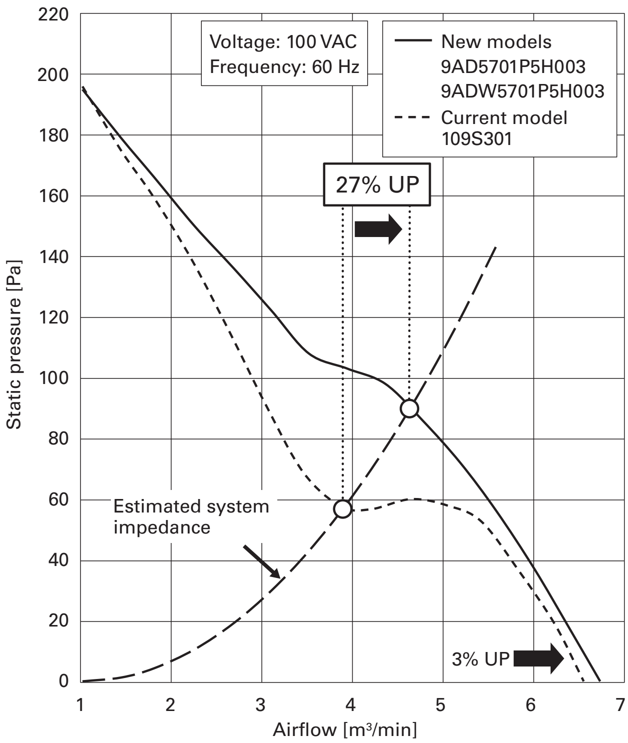

Fig. 8 Airflow vs. static pressure characteristics of the new and current models

5.2 Comparison of power consumption at an equivalent performance level as the current model

Figures 9 and 10 compare power consumption of the current and new models at equivalent cooling performance. The figures show that power consumption drops 48% at 60 Hz and 58% at 50 Hz compared to the current model when the speeds of the new models are reduced with PWM control to match the cooling performance of the current model.

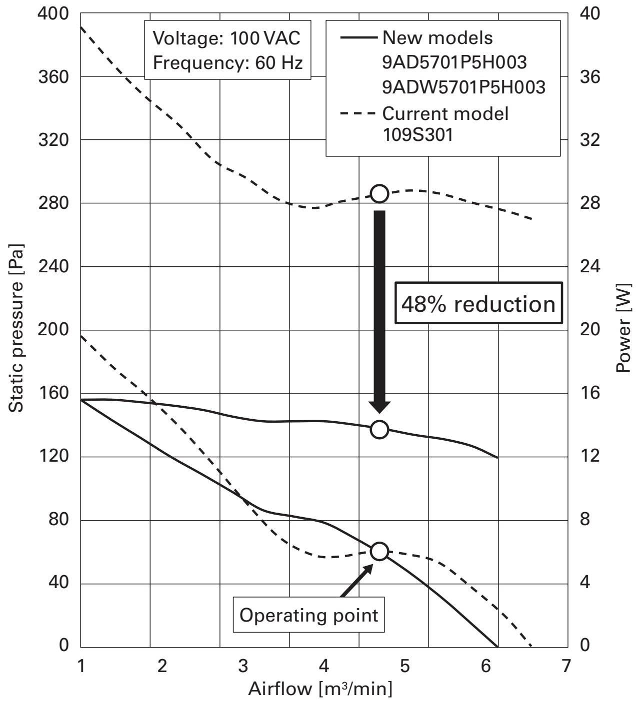

Fig. 9 Power consumption comparison between new and current models (100 V, 60 Hz)

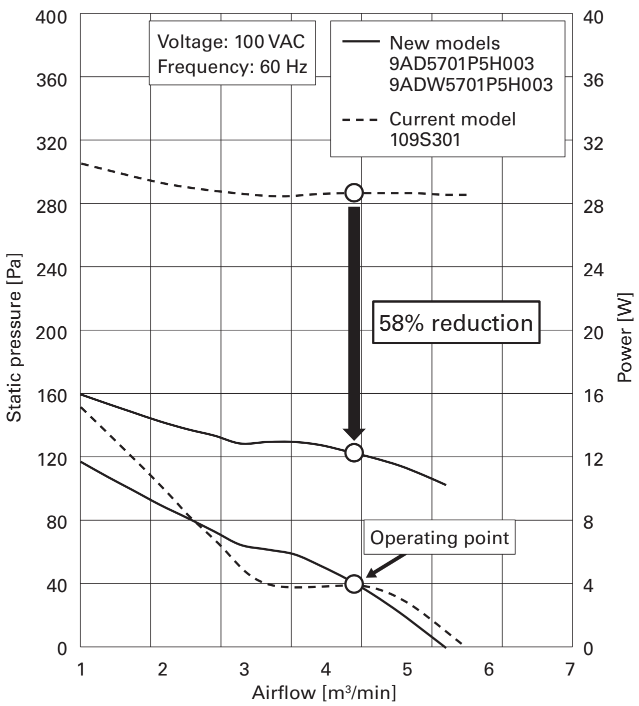

Fig. 10 Power consumption comparison between new and current models (100 V, 50 Hz)

6. Conclusion

This article introduced some of the features and performance of the *San Ace 172AD* 9AD type ACDC Fan and the *San Ace 172AD* 9ADW type Splash Proof ACDC Fan.

The new models achieved lower power consumption, higher airflow, and higher static pressure without changing the size of the current model. They can be used in a wider range of applications with a wider input voltage range and the 9ADW type's dust and water protection.

We will continue providing products that can meet market needs to help our customers create new value.

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Development of Low Noise Fans *San Ace 60, San Ace 80, San Ace 92,* and *San Ace 120* 9RA Type

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1. Introduction

In recent years, measuring devices, amusement devices, medical equipment, and AV devices have become more compact and higher performance. As a result, these devices are generating more heat, requiring more effective cooling fans. At the same time, as these devices are often used near people, cooling fans for them are required to operate quietly.

To meet such market demands, we developed and launched the new *San Ace 60*, *San Ace 80*, *San Ace 92*, and *San Ace 120* 9RA type Low Noise Fans (hereinafter, "new models").

This article will introduce the features and performance of the new models.

2. Product Features

Figures 1 through 4 show the appearance of the new models.

The new models generate less noise, consume less power, and offer longer service life while maintaining the size and cooling performance compared to our current models—9R type for 60 × 60 × 25 mm and 80 × 80 × 25 mm, 9A type for 92 × 92 × 25 mm, and 9G type for 120 × 120 × 25 mm.

Fig. 1 60 × 60 × 25 mm *San Ace 60* 9RA type

Fig. 2 80 × 80 × 25 mm *San Ace 80* 9RA type

Fig. 3 92 × 92 × 25 mm *San Ace 92* 9RA type

Fig. 4 120 × 120 × 25 mm *San Ace 120* 9RA type

3. Product Overview

3.1 Dimensions

Figure 5 through 8 show the dimensions of the new models.

The new models come in four sizes of 60 × 60 mm, 80 × 80 mm, 92 × 92 mm, and 120 × 120 mm with a depth of 25 mm shared by all. We have made these size variations available for customers selection to meet a wide range of requirements.

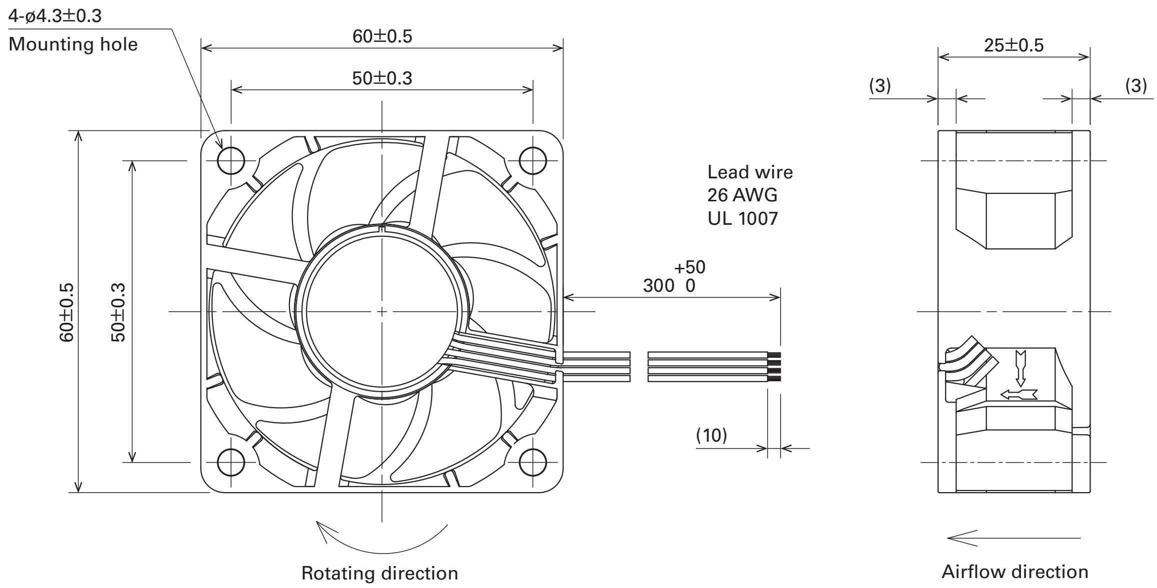

Fig. 5 Dimensions of the new *San Ace 60* (unit: mm)

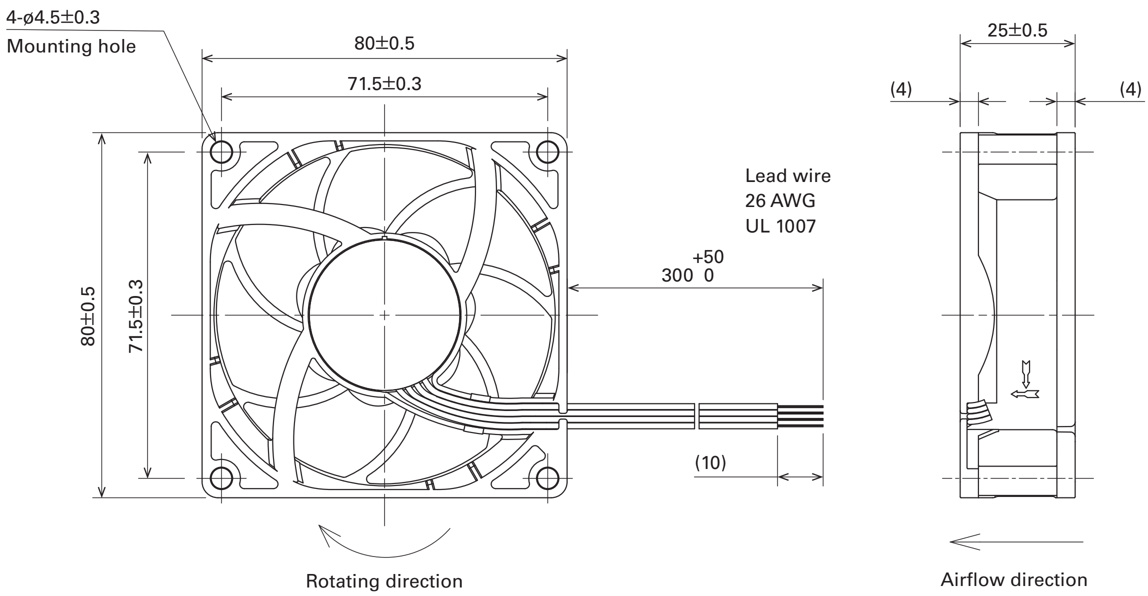

Fig. 6 Dimensions of the new *San Ace 80* (unit: mm)

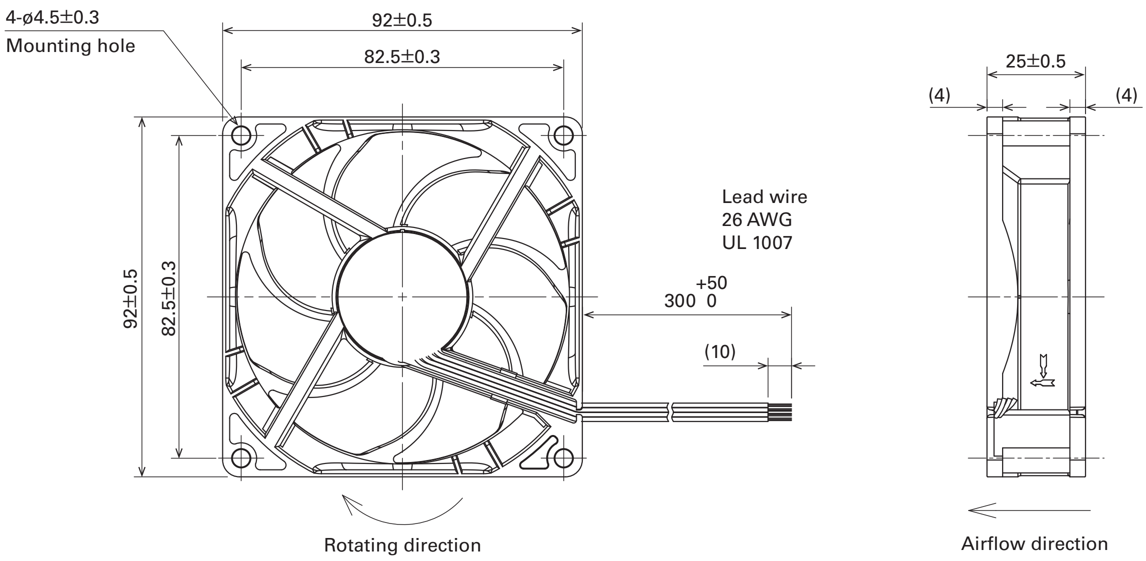

Fig. 7 Dimensions of the new *San Ace 92* (unit: mm)

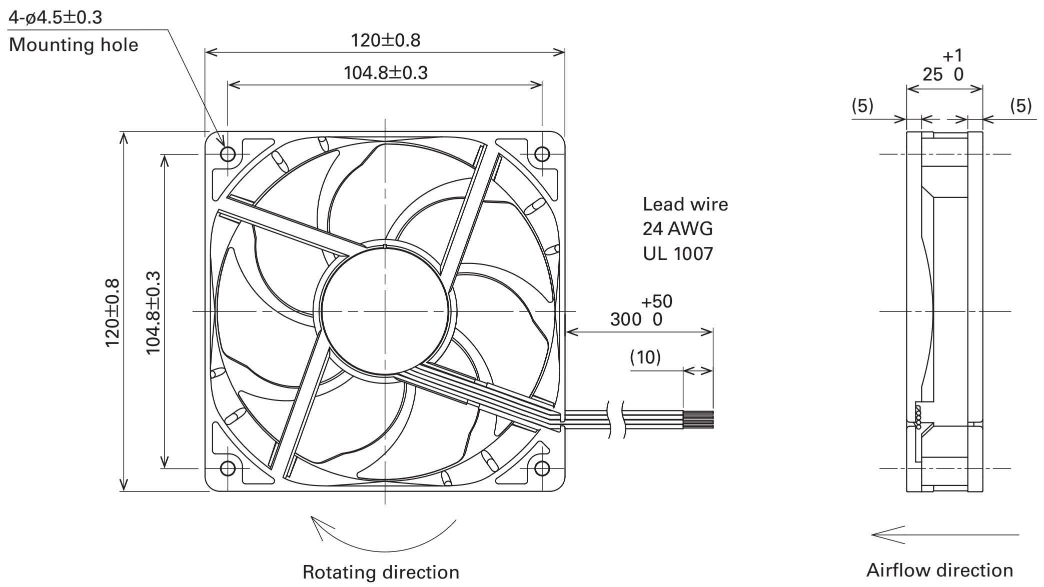

Fig. 8 Dimensions of the new *San Ace 120* (unit: mm)

3.2 Specifications

3.2.1 General specifications

Table 1 shows the general specifications of the new models.

The lineup is available in 12, 24, and 48 V rated voltage variants for each size for use in a wide range of applications and for replacement of our conventional models.

Figures 9 through 12 show the airflow vs. static pressure characteristics of the speed variant models of 12 V rated voltage model. With all the rated voltage and speed variant models counted, the lineup includes 10 models for each of the 60 and 80 mm sizes, and 13 models for each of the 92 and 120 mm sizes. The new models operate quieter than the current models with the equivalent cooling performance. There are available in a variety of sizes to allow customers to choose the one best suited to their equipment.

Also, the new models listed in Table 1 are equipped with a PWM control function for fan speed control according to the temperature within equipment, contributing to energy savings as well as quieter operation.

Table 1 General specifications of new models

Model no.	Size	Rated voltage [V]	PWM duty cycle* [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow [m^3/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH_2O]	Sound pressure level [dB(A)]	Operating temperature range [°C]	Expected life [h]
9RA0612P4J001	60×60 ×25 mm	12	100	0.35	4.2	7,700	1.1	38.8	130	0.52	41	-20 to +70	60,000 at 60°C (90,000 at 40°C)
			30	0.05	0.6	1,900	0.27	9.5	8.1	0.03	13		
9RA0624P4J001		24	100	0.18	4.32	7,700	1.1	38.8	130	0.52	41		
			20	0.03	0.72	1,700	0.24	8.5	6.5	0.02	11		
9RA0648P4J001		48	100	0.1	4.8	7,700	1.1	38.8	130	0.52	41		
			20	0.03	1.44	1,800	0.25	8.8	7.1	0.03	12		
9RA0812P4G001	80×80 ×25 mm	12	100	0.22	2.64	5,000	1.4	49.4	83	0.33	37		
			30	0.03	0.36	1,100	0.3	10.6	4	0.01	11		
9RA0824P4G001		24	100	0.11	2.64	5,000	1.4	49.4	83	0.33	37		
			20	0.02	0.48	1,000	0.28	9.8	3.3	0.01	10		
9RA0848P4G001		48	100	0.07	3.36	5,000	1.4	49.4	83	0.33	37		
			20	0.02	0.96	1,700	0.47	16.5	9.6	0.04	14		
9RA0912P4G001	92×92 ×25 mm	12	100	0.22	2.64	4,200	1.8	63.5	73.5	0.29	37		
			30	0.03	0.36	1,000	0.42	14.8	4.1	0.016	11		
9RA0924P4G001		24	100	0.13	3.12	4,200	1.8	63.5	73.5	0.29	37		
			20	0.03	0.72	1,000	0.42	14.8	4.1	0.016	11		
9RA0948P4G001		48	100	0.07	3.36	4,200	1.8	63.5	73.5	0.29	37		
			20	0.03	1.44	1,400	0.6	21.2	8.1	0.033	14		
9RA1212P4G001	120×120 ×25 mm	12	100	0.55	6.6	4,500	3.68	130	120	0.48	47		
			20	0.06	0.72	1,250	1.02	36	9.2	0.037	15		
9RA1224P4G001		24	100	0.28	6.72	4,500	3.68	130	120	0.48	47		
			20	0.05	1.2	1,750	1.43	50.5	18.1	0.073	22		
9RA1248P4G001		48	100	0.15	7.2	4,500	3.68	130	120	0.48	47		
			20	0.03	1.44	1,650	1.34	47.3	16.1	0.065	21		

* Input PWM frequency: 25 kHz. Speed is 0 min^{-1} at 0% PWM duty cycle.
Note: The expected life at an ambient temperature of 40°C is for reference purposes only.

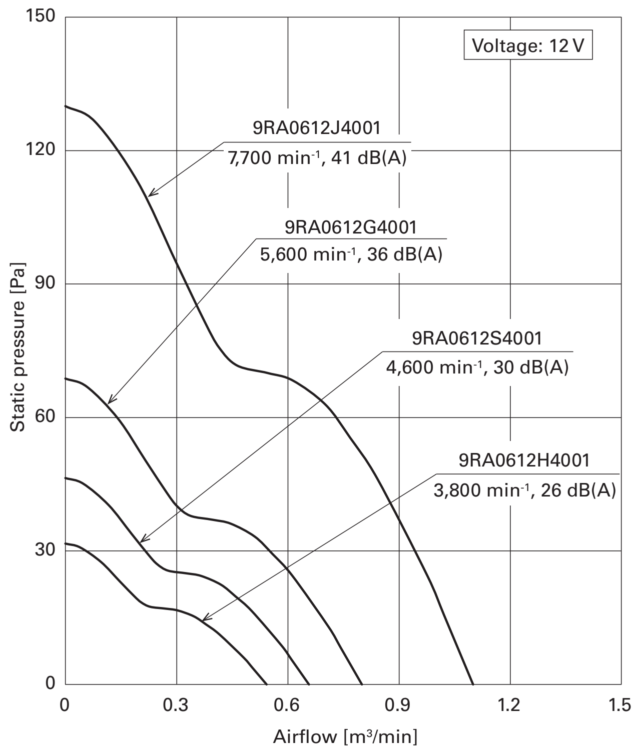

Fig. 9 Airflow vs. static pressure characteristics of the new *San Ace 60*

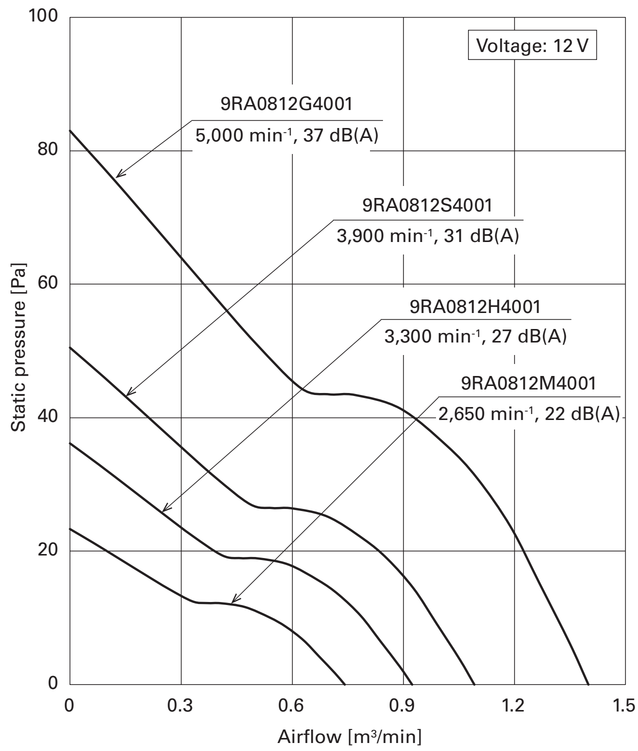

Fig. 10 Airflow vs. static pressure characteristics of the new *San Ace 80*

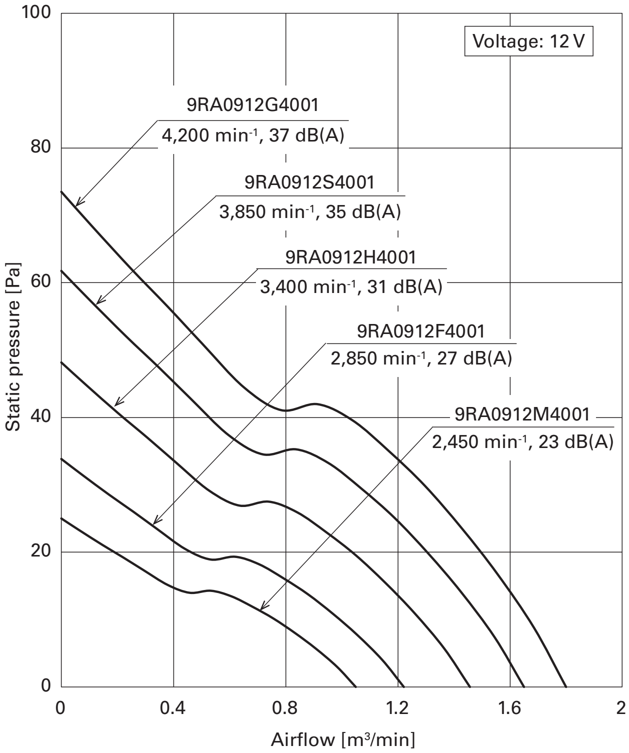

Fig. 11 Airflow vs. static pressure characteristics of the new *San Ace 92*

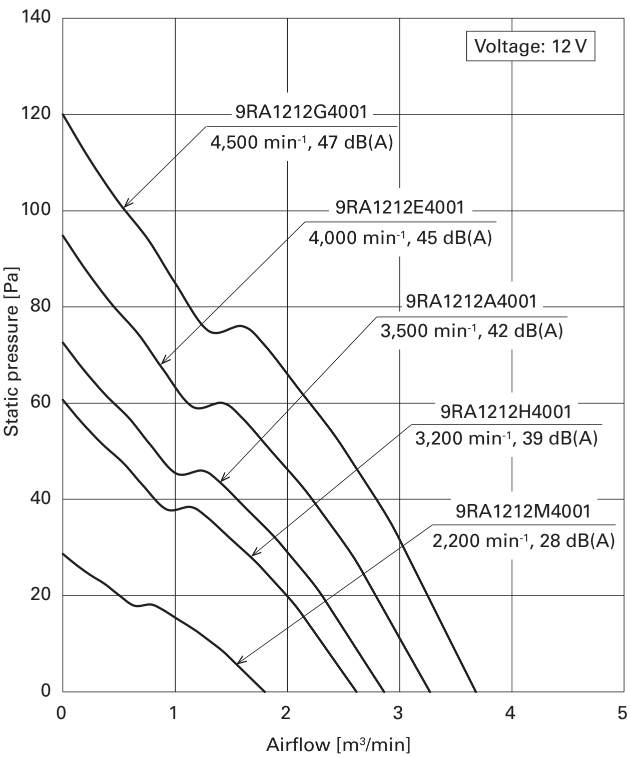

Fig. 12 Airflow vs. static pressure characteristics of the new *San Ace 120*

4. Key Points of Development

The new models, when compared to the current models, achieve lower noise, lower power consumption, and longer service life with cooling performance maintained.

The key points of development are explained below.

4.1 Motor and circuit

We used highly efficient compact motors for the new 60 × 60 mm and 120 × 120 mm models. We also designed a new circuit and changed the drive system for the new models including the 80 × 80 mm and 92 × 92 mm models, reducing the power consumption from the current models.

This drive system change also reduced the heat generation inside the fan by the motor and electronic components, which suppressed the temperature rise in bearings, resulting in longer fan service life compared with the current models.

4.2 Impeller and frame

Figure 13 compares the shape of fan impellers and frames of the current and new models, using the *San Ace 60* as an example.

We used compact motors in the new models to increase the design flexibility for the impeller. This allowed us to do simulations with increased the number of conditions, such as impeller shape and blade installation angle. We conducted simulations and actual evaluations combining various frame shapes and numbers of spokes so that we could determine the ideal shape.

Fig. 13 Shape comparison between the new and current *San Ace 60* models

5. Comparison of New and Current Models

5.1 Comparison of the airflow vs. static pressure characteristics and noise levels between new and current models

Figures 14 through 17 compare the airflow vs. static pressure vs. power consumption characteristics and the noise level characteristics of the fastest new and current models for each size. The figures show that the new models consume 26% to 44% less power while maintaining the airflow vs. static pressure characteristics compared to the current models. The figures also show significant noise reductions, a 3 dB (A) reduction for the 60 × 60 mm and 80 × 80 mm models and 4 dB(A) reduction for the 92 × 92 mm and 120 × 120 mm models. A 3 dB(A) difference in noise means that the noise level from two units of a new model in operation is equal to that from one unit of a current model in operation.

5.2 Comparison of expected life

The new models have an expected life of 60,000 hours at 60°C (survival rate of 90%, run continuously at rated voltage and normal humidity in free air). The expected life of the current models is from 30,000 to 40,000 hours, so the new models have 1.5 to 2 times longer expected lives.

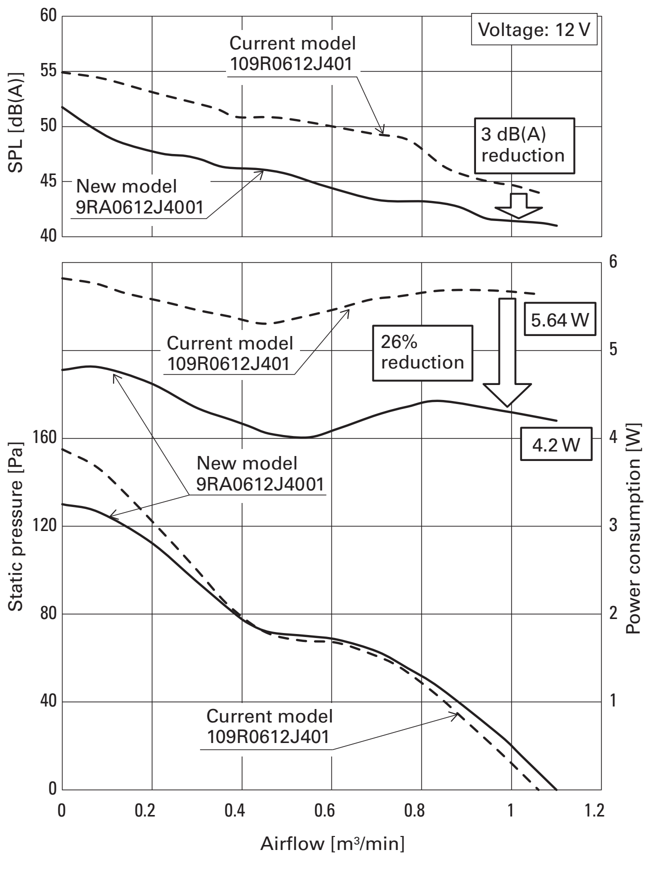

Fig. 14 Comparison of the new and current *San Ace 60* models

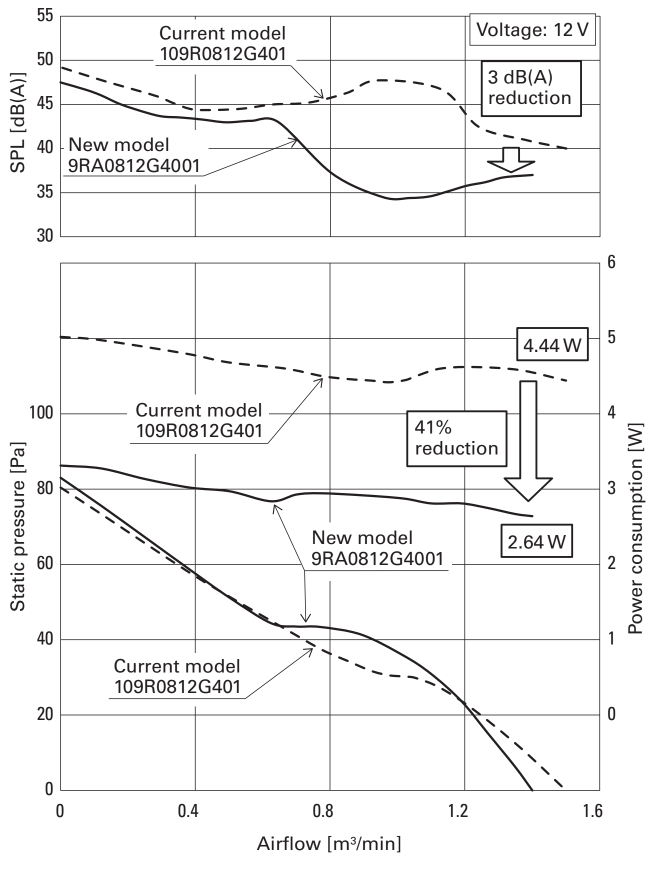

Fig. 15 Comparison of the new and current *San Ace 80* models

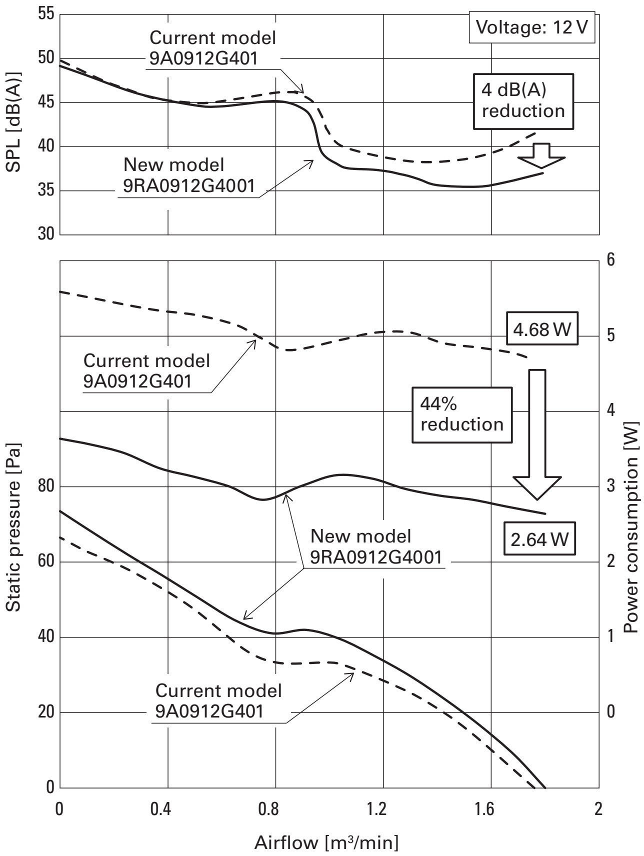

Fig. 16 Comparison of the new and current *San Ace 92* models

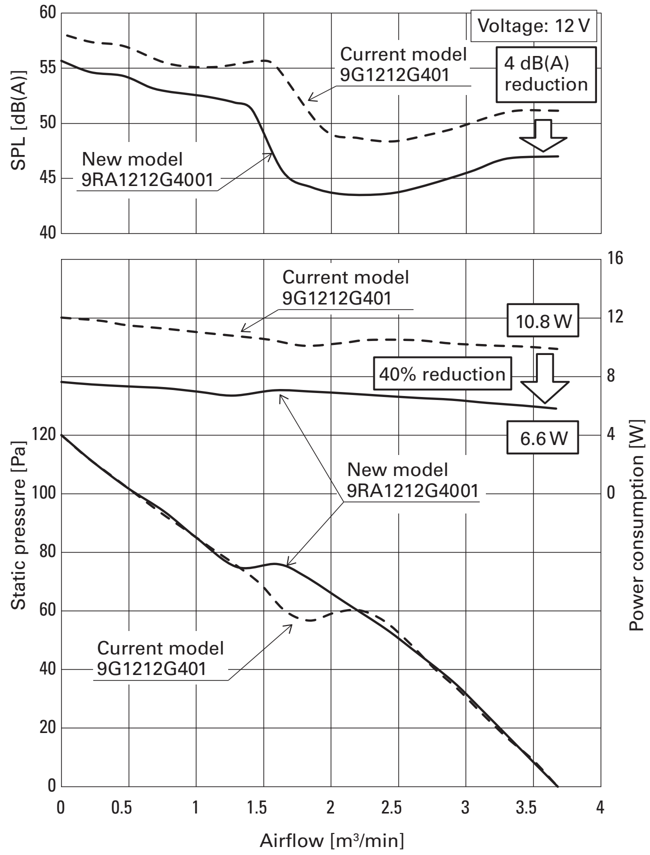

Fig. 17 Comparison of the new and current *San Ace 120* models

6. Conclusion

This article introduced the features and performance of the *San Ace 60*, *San Ace 80*, *San Ace 92*, and *San Ace 120* 9RA type Low Noise Fans.

The new models achieve lower noise and power consumption while maintaining the cooling performance compared to the current models. We believe that these fans will help reduce noise and save energy in measuring devices, amusement devices, medical equipment, and AV devices that are used nearby people.

The new models offer a longer expected life than the current models, and we believe that this will help increase the maintainability and extend the expected life of equipment.

We will continue developing products quickly responding to and meeting market needs to provide products that can help our customers create new value.

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Power Technology for Protecting People

Akira Miura

1. Introduction

There have been frequent natural disasters in recent years that threaten the safety of people. The frequency of these disasters is expected to increase in the furure. The major natural disasters that have occurred in Japan since 2018 are listed below. (1)

- 2018: Torrential rains in West Japan in July
- 2019: Typhoon No. 15 (Boso Peninsula)
- 2019: Typhoon No. 19 (East Japan)

The average annual temperature over land has been high over much of the world, and this is also true throughout Japan. The 2020 deviation from the reference value for average air temperature in Japan (30-year average from 1991 to 2020) was the highest since statistics began being recorded in 1898. Experts have indicated a strong link between the increase in natural disasters and global warming.

In October 2020, the Japanese government announced its goal of becoming "carbon neutral" by 2050, which means essentially zero emissions of greenhouse gases, setting a goal of increasing the use of renewable energy to around 50% to 60%.

This article introduces some of our Power Systems products: products that protect people from increasingly severe and frequent natural disasters, products that protect people during power outages caused by natural disasters, and products that promote carbon neutrality and protect people from global warming.

2. Outdoor UPS *SANUPS N11B-Li*

In December 2020, the Japanese government made a cabinet decision on the "Five-year Acceleration Plan to Prevent and Mitigate Disasters, and Improve National Resilience." Since then, the government has continued to accelerate plans and initiatives to enhance road network functionality and to increase emergency preparedness of vital infrastructure (such as railroads, harbors, and airports).

We have developed, based on the *SANUPS N11B-Li* UPS equipped with lithium-ion batteries for outdoor use, a custom UPS that can be used in Fundamental Plan for National Resilience projects with compliance with "Outdoor Uninterruptible Power Supply Device Specifications"(2) defined by Japan's Ministry of Land, Infrastructure, Transport and Tourism.

This product differs from our standard specifications in several points: we revised the storage battery layout and circuit so that power backup can be provided for the specified time in -20°C environments; the sheet metal material was changed from standard SUS430-KD to SUS304 to improve resistance to corrosion.

Operable in extreme environments, this product is now used as power backup for surveillance cameras and display devices that maintain infrastructure such as roads, rivers, ports, and water and sewerage systems.

This product contributes to enhancing the emergency preparedness of public infrastructure, keeping people safe from increasingly severe natural disasters.

Figure 1 shows the appearance of the *SANUPS N11B-Li*, while Table 1 provides its product specifications.

Fig. 1 *SANUPS N11B-Li*

Table 1 *SANUPS N11B-Li*'s ratings eligible for use in MLIT's "Fundamental Plan for National Resilience" projects

Model no.		N11BL152AK11TST44HP	N11BL102AK31TST44HP
Load		70 W	140 W
Backup time(1)		24 h	
Topology		Passive standby	
Transfer time		10 ms or less	
Efficiency (AC-AC)		95%	
AC input/output	**Rated frequency**	50/60 Hz (auto-sensing)	
	No. of phases/wires	Single-phase 2-wire	
	Rated voltage	100/110/120 V	
Load power factor		0.8 (lagging)	
Battery type		Lithium-ion battery	
Operating environment		Temperature: -20 to +50°C, humidity: 10 to 90% RH (non-condensing)	
Protection rating		IP44(2)	

(1) At a -20°C ambient temperature
(2) Standard models come with IP65 protection

2.1 Technology for use in extreme environments

(1) Use of LIB (lithium-ion batteries)

We used lithium-ion batteries (hereinafter, "LIB") so that the product could be used in extreme environments.

LIBs have high energy density and could cause smoke or fire if used improperly. We ensured the safety of the product with dual safety systems: the LIB's battery management system (hereinafter, "BMS") and the UPS's LIB status monitoring functionality.

- Protection by BMS
  The BMS monitors LIB current, cell voltage, and cell temperature, and turns the switch off to disconnect and protect the LIB if it detects an error.

- Protection by UPS
  The UPS communicates with the BMS and monitors LIB status during operation. If the UPS detects an error or can no longer communicate with the BMS, it stops charging/discharging to protect the LIB.

(2) High dust and water protection

To operate outdoors safely for a long period of time, the UPS housing has a sealed structure with IP65-rated dust and water protection (in the case of our standard products).

In designing the sealed housing, we used thermal fluid analysis to simulate the internal heat flow and optimized the structure and layout design to effectively circulate and discharge internal heat to the outside by using the entire housing.

This ensured IP65 dust and water protection, while also preventing internal heat from rising in concentrated areas, enabling us to develop a UPS that can be used outdoors safely without sacrificing performance or reliability.

3. Emergency Diesel Generator *SANUPS G53A*

The supply of quality power is crucial to keep electrical facilities running normally. The Japanese power grid is extremely stable and power outages are rare.

However, if a fire or large-scale natural disaster occurs and the power supply from the power company is interrupted, it could prevent emergency equipment from operating.

The *SANUPS G53A* generator is compliant with Japan's Fire Service Law, which is a mandatory requirement for building disaster management. With this compliance, it can be used as an emergency power source (for indoor firefighting equipment and sprinklers) defined in the law or as a backup power source (for emergency lighting and smoke ventilation equipment) defined by Japan's Building Standard Law.

If a fire or large-scale natural disaster occurs, the UPS protects people's livelihoods as a backup power source to allow work to continue and to maintain safety. It also keeps people safe by providing backup power for emergency equipment as an emergency power source as defined by the Fire Service Law or as a backup power source as defined by the Building Standard Law.

Figure 2 shows the appearance of the *SANUPS G53A*.

Fig. 2 *SANUPS G53A*

3.1 Technology to comply with Japan's Fire Service Law

Compared to a standard generator, the *SANUPS G53A* emergency diesel generator has the following additional features to comply with the Design Requirements for Emergency Use Engine-driven Power Generators (NEGA C 311 Standard) defined by the Nippon (Japan) Engine Generator Association.

- Earthquake-resistant structure for the engine and generator
- Cubicle materials and structure
- Charger compliant with Japan's Fire Service Law

We also used an engine from a new (to us) manufacturer and combined it with a newly designed generator.

In designing the engine and generator combination, we needed to satisfy standard requirements such as shaft strength versus torsional vibration and dynamic characteristics, while ensuring that the capacity of each would not be excessive.

In developing this product, we determined the engine and generator combination by using simulations to calculate the resonance points, stress on the shaft, and engine speed characteristics when an engine and generator are combined. We then checked the results of assessing this on actual equipment. This allowed us to optimize the combination selection quickly.

4. Power Conditioner (PV Inverter) with Peak Cut Function *SANUPS P73L*

The *SANUPS P73L* power conditioner is capable of charging and discharging LIBs.

The grid-connected isolated charging type can be used as a storage battery system. Thanks to the bi-directional converter installed in the storage battery input part, it can perform maximum power point tracking control (hereinafter, "MPPT control") even during the storage battery charge/discharge or isolated operation, making maximum use of PV-generated power. It promotes carbon neutrality and protects people from global warming by making effective use of PV-generated power.

Figure 3 shows the appearance of the grid-connected isolated charging type and the grid-connected isolated type, while Figure 4 shows the circuit block diagram for the grid-connected isolated charging type.

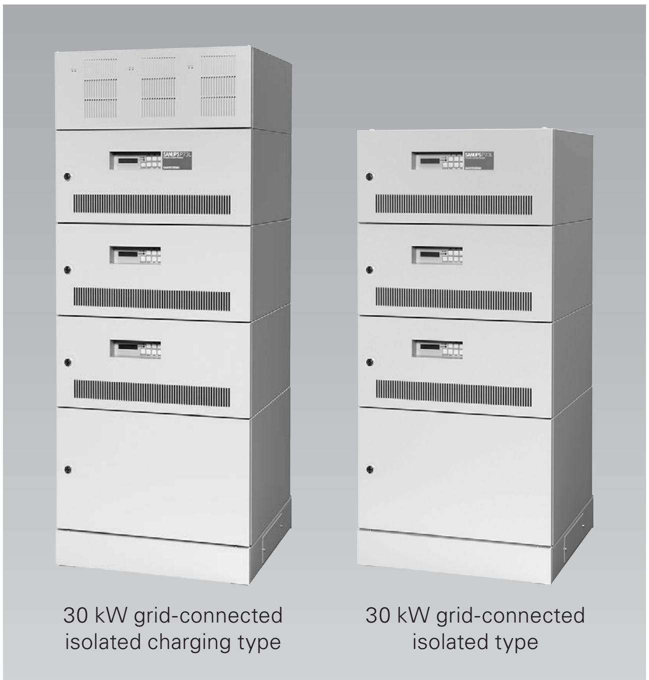

Fig. 3 *SANUPS P73L*

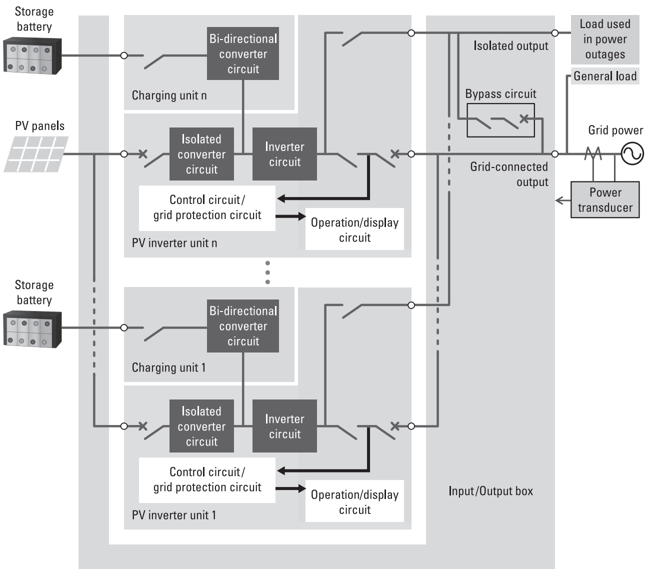

Fig. 4 Block diagram for grid-connected isolated charging type

4.1 Technology for making effective use of PV-generated power

MPPT control cannot be performed with power conditioners whose storage battery is directly connected to solar cells because the voltage of the solar cell is fixed to the voltage of the storage battery, preventing the full use of the PV-generated power.

The *SANUPS P73L* has a bi-directional converter installed in the storage battery input part, which allows it to manage the storage battery charge/discharge while continuing to perform MPPT control even during the storage battery charge/discharge. The maximum power of the solar cell can therefore always be output, resulting in a significant increase in power generated.

We also used a non-isolated buck-boost chopper in the bi-directional converter to support a wide range of storage battery voltages while maintaining high efficiency.

This made it possible to combine storage batteries and solar cells flexibly, which had conventionally been limited with PV inverters that are directly connected to solar cells, making system design easier.

5. Conclusion

This article introduced several products from Power Systems Division: products that protect people from increasingly severe and frequent natural disasters, products that protect people during power outages caused by natural disasters, and products that promote carbon neutrality and protect people from global warming.

We will continue to develop products that bring safety to people's lives.

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(1) National Resilience Promotion Office, Cabinet Secretariat: "Building National Resilience" pamphlet (version R3.3) https://www.cas.go.jp/jp/seisaku/kokudo_kyoujinka/pdf/kokudo_pamphlet_r3.pdf (April 1, 2021)

(2) Japan's Ministry of Land, Infrastructure, Transport and Tourism: "Outdoor Uninterruptible Power Supply Device Specifications" https://www.mlit.go.jp/tec/it/denki/kikisiyou/touitusiyou_17okugaimuteidenR0203.pdf (March 2020)

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Development of the Small-Capacity UPS *SANUPS E11B-Li* and *SANUPS A11M-Li* Series

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1. Introduction

In recent years, the demand for uninterruptible power supplies (hereinafter, "UPS") has been increasing throughout the world. One of the reasons for this is because the spread of mobile devices and IoT-ready equipment has required more robust power backup systems. As such, there is a demand for UPSs that can operate in regions inside and outside Japan with unstable power grids.

Also, UPSs are being used in increasingly diverse situations, including in extreme temperature environments. We see this as a market need to address. Conventional lead-acid batteries can be charged only within a limited temperature range, and this can be problematic. For example, in high-temperature environments, these batteries can be discharged but cannot be charged. Customers have requested less frequent battery replacement maintenance as much as possible and UPSs that are easier to handle during installation and transportation.

In response, we developed the *SANUPS E11B-Li* series and *SANUPS A11M-Li* series to resolve these issues and meet these demands. These products make use of lithium-ion batteries (hereinafter, "LIB"). This article will provide an overview of these products.

Fig. 1 *SANUPS E11B-Li* 1 kVA model

Fig. 2 *SANUPS A11M-Li* 8 kVA model (8 units in parallel)

2. Product Overview

The lineup of *SANUPS E11B-Li* series includes five models—1 kVA, 1.5 kVA, and 2 kVA for 100 V; 1 kVA and 2 kVA for 200 V—and the lineup of *SANUPS A11M-Li* series includes two models—for 100 V and 200 V. Figures 1 and 2 show the appearance of typical models of these series. Products in either series can be mounted in a 19-inch rack and horizontally or vertically on the floor.

3. Features

3.1 *SANUPS E11B-Li* series

This product uses a hybrid topology. The hybrid topology provides two operation modes: high-quality power mode (Double Conversion mode) and high-efficiency mode (Economy mode; standby topology). These modes can be used differently depending on the settings. When the setting is set to Double Conversion mode, the inverter always supplies high-quality power. When set to automatic, the UPS will switch between the Double Conversion mode and Economy mode depending on the state of the input power, achieving both high-quality power and energy savings.

(1) Double Conversion mode (High-quality power mode)

Figure 3 shows the power supply path for the Double Conversion mode. First, the grid power is rectified and converted to a DC voltage. This is then converted by the inverter to a sinusoidal voltage and output. Therefore, even when the grid power fluctuates, the fluctuation is absorbed by the rectifier and inverter, enabling the UPS to keep supplying high-quality power. The batteries are float-charged by the charger so that they stay charged and ready for a grid power failure such as a power outage or voltage dip. If the grid frequency is within the frequency synchronization range (within ±1% when set to the Double Conversion mode; when set to automatic, the range depends on the synchronization range setting), the UPS outputs a voltage with a frequency synchronized with the AC input frequency. If it is outside the range, it outputs a constant frequency of 50 Hz or 60 Hz and does not synchronize with the input voltage.

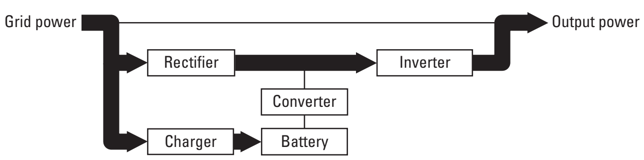

Fig. 3 The power supply path for the Double Conversion mode

(2) Economy mode (High-efficiency mode)

Figure 4 shows the power supply path for the Economy mode. When the grid power is stable, the inverter stops, allowing the grid power to be output as is. This eliminates the loss through the inverter and increases efficiency. The batteries are float-charged by the charger so that they stay charged and ready for a grid power failure such as a power outage or voltage dip. When the grid power becomes unstable, the UPS automatically transfers to the Double Conversion mode described in (1) above. This is done without interruption if the input frequency is within the synchronization range, or there will be an interruption within 8 ms if it is outside the range.

In the Economy mode, it is necessary to immediately detect abnormalities in the grid power. This is ensured by constantly monitoring the input voltage waveform.

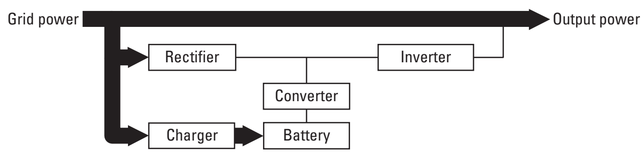

Fig. 4 The power supply path for the Economy mode

(3) In the event of a power grid failure

Figure 5 shows the power supply path during a power grid failure. If grid power causes an interruption or power outage, the rectifier and charger will be stopped, then the converter will operate to supply power from batteries. If a grid failure occurs during the Double Conversion mode, battery power will be supplied to the load without interruption. If a grid failure occurs during the Economy mode, there will be an interruption within 8 ms until battery power will be supplied.

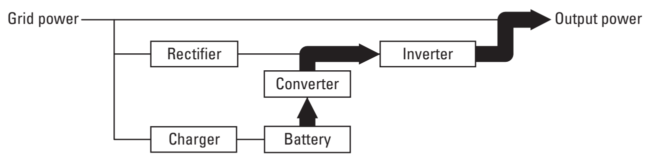

Fig. 5 The power supply path during a power grid failure

3.2 *SANUPS A11M-Li* series

(1) System diagram

Up to eight 1 kVA UPS units can be operated in parallel for increased reliability and expanded capacity. As shown in Figure 6, the product consists of up to eight UPS units and one power distribution unit.

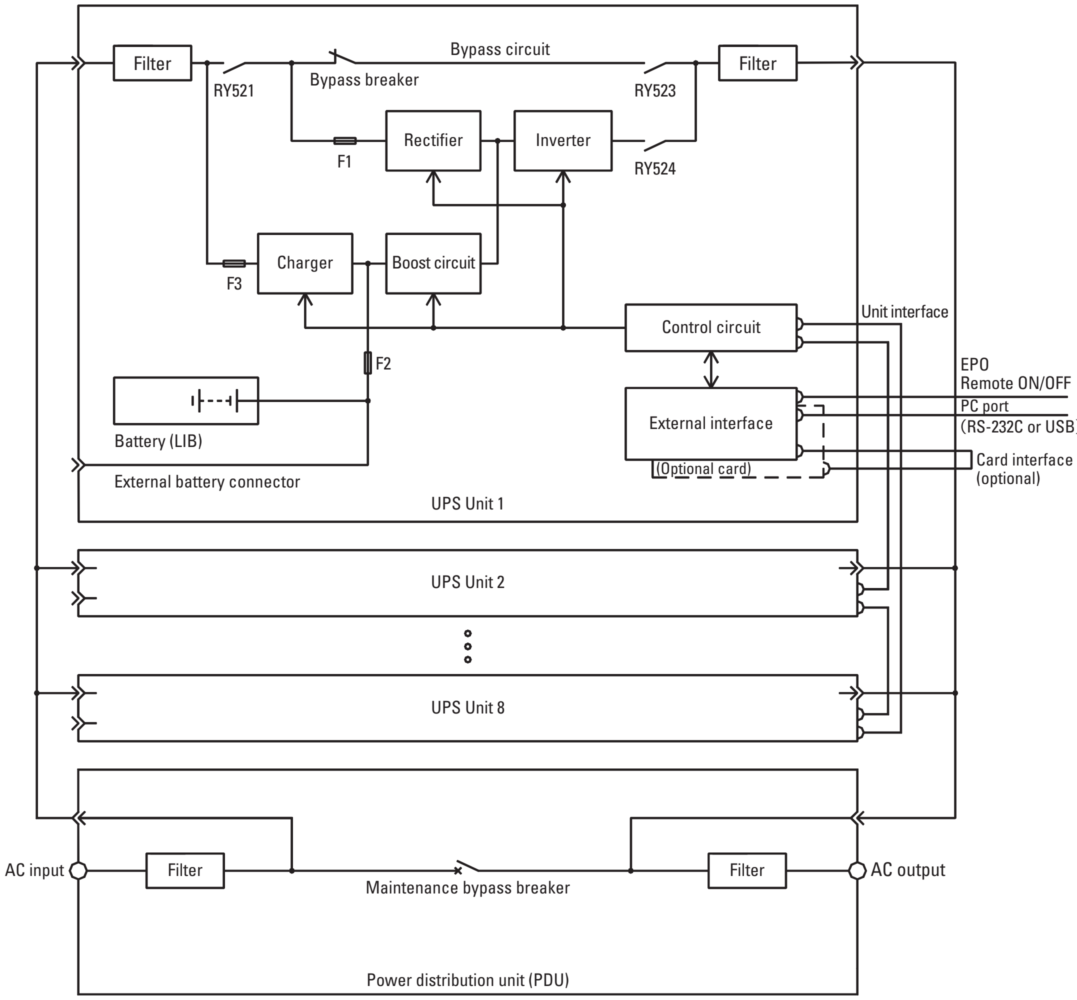

Fig. 6 A11M-Li system diagram

(2) Control method

The product uses the autonomous control method. Compared with the central control method and master/slave method, this method allows for independent control of each unit using each unit's control circuit doing control individually. This ensures high reliability and disconnectability of units if failure occurs. As shown in Figure 7, connecting eight units allows power to be supplied to a maximum load of 8 kVA. When the load capacity is 7 kVA or less, the UPS can have an extra capacity of one unit for redundancy to maintain operation even if one unit fails.

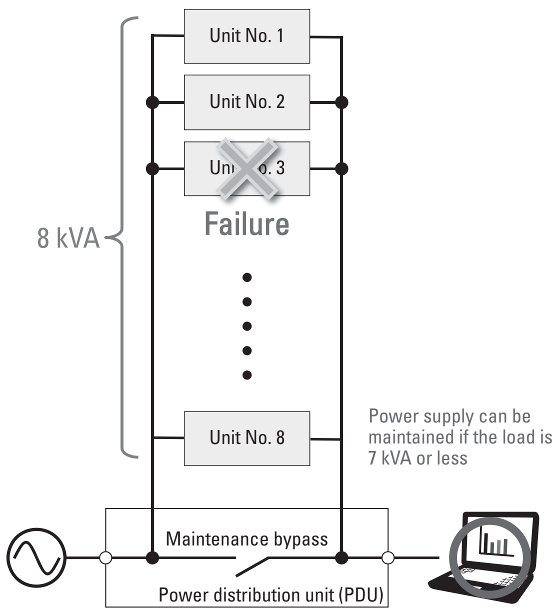

Fig. 7 Parallel redundant operation

3.3 Wide input ranges

We designed the *SANUPS E11B-Li* and *SANUPS A11M-Li* to have wide input voltage and frequency ranges. The voltage range is 55 to 150 V for 100 V models and 110 to 300 V for 200 V models, and the frequency range is 40 to 120 Hz. This can reduce the number of transfers to battery operation even in regions where input power is unstable and voltage and frequency fluctuate greatly. This means that stable power can be supplied to a load while battery wear is kept minimal.

3.4 Wide operating temperature range

In an ambient temperature of 40°C or higher, lead-acid batteries can be discharged but cannot be charged. LIBs can be both charged and discharged throughout a wide operating temperature range of -10°C to +55°C. They can be used in extremely hot and cold regions, or inside small unmanned buildings without air-conditioning.

3.5 Reduced maintenance

While our current UPSs that use lead-acid batteries require battery replacement about every five years, the UPSs with LIBs allow for operation for roughly ten years (at an ambient temperature of 30°C) without battery replacement. We revised the product service life based on the LIB's longer battery service life, increasing it from seven years of the current product to 10 years. This reduces maintenance work and battery replacement costs. Figure 8 shows the product's front panel and LIB.

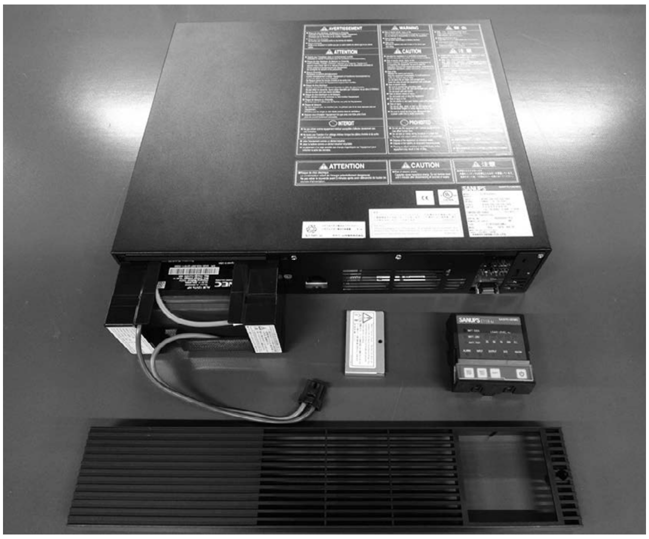

Fig. 8 Front panel and LIB

3.6 Reduced weight

LIBs weigh only one-third of lead-acid batteries, reducing the product weight significantly. This makes the handling of the product easier when the product is transported, installed, and mounted in a 19-inch rack.

3.7 LIB monitoring function

The LIB itself provides safety protection functions. When a protection function is activated, the LIB shuts down the LIB battery circuit. Connection then recovers automatically once the error is resolved. Following are the major protection functions.

- OCP (over-current protection)
- OTP (over-temperature protection)
- OVP (over-voltage protection)
- UVP (under-voltage protection)

The UPS checks the battery circuit for connection every 24 hours to confirm whether an LIB protection function is activated. If an error is confirmed, it outputs a minor failure alarm.

4. Specifications

(1) Table 1 shows the standard specifications of the *SANUPS E11B-Li* 1 kVA model.

(2) Table 2 shows the standard specifications of the *SANUPS A11M-Li*.

5. Conclusion

This article introduced the *SANUPS E11B-Li* and *SANUPS A11M-Li*.

The *SANUPS E11B-Li* can be used with peace of mind even in regions with unstable power grids and in harsh operating environments. It offers benefits such as a longer product life and lightweight thanks to the LIB's high energy density. It can therefore be proposed to customers all over the world.

The *SANUPS A11M-Li* offers the same benefits as the *SANUPS E11B-Li*, and is also capable of parallel redundant operation. It can be proposed to customers who require a small-capacity, high-reliability UPS.

We will continue to accurately identify the needs of our customers and quickly develop products that can meet these needs.

Table 1 Standard specifications of the *SANUPS E11B-Li* 1 kVA model

Items			Ratings and standards		Remarks	
Model			E11BL102 100 V class	E11BL102 200 V class		
Output capacity			1 kVA / 0.8 kW			
Topology			Hybrid		Interruption occurs when transferring to battery power from Economy mode	
Cooling method			Forced air cooling			
AC input	**Input plug**		IEC 60320-C14			
	Number of phases/wires		Single-phase 2-wire			
	Rated voltage		100/110/115/120 V	200/208/220/230/240 V		
	Voltage range		At load levels < 40%: 55 to 150 V At load levels < 70%: 68 to 144 V At load levels ≥ 70%: 80 to 144 V	At load levels < 40%: 110 to 300 V At load levels < 70%: 136 to 288 V At load levels ≥ 70%: 160 to 288 V	When in Double Conversion mode	
			Within ±8% of rated voltage		When in Economy mode	
	Rated frequency		50/60 Hz		(auto-sensing)	
	Frequency range		40 to 120 Hz			
	Required capacity		1.1 kVA or less		Max. capacity during battery recovery charging	
	Input power factor		0.95 or greater		In Double Conversion mode, at rated output	
AC output	**Output outlets**		NEMA 5-15R × 6	IEC 60320-C13 × 6		
	Number of phases/wires		Single-phase 2-wire			
	Rated voltage		100/110/115/120 V	200/208/220/230/240 V	User-selectable	
	Voltage regulation		Within ±2% of rated voltage		When in Double Conversion mode	
	Rated frequency		50/60 Hz		Same as the input frequency (auto-select)	
	Frequency regulation		Within ±1% of rated frequency		In fixed Double Conversion mode	During battery operation: Within ±0.5%
			Within ±1/3/5% of rated frequency		In "automatic" setting	
	Voltage waveform		Sinusoidal			
	Voltage harmonic distortion		At linear load: 3% or less At 100% rectifier load: 8% or less		At rated output	
	Transient voltage fluctuation	**For abrupt load change**	Within ±5% of rated voltage		0⇔100% load step changes at rated input	
		For loss/ return of input power			At rated output	
		For abrupt input voltage change			For ±10% changes When in Double Conversion mode	
	Response time		5 cycles or less			
	Load power factor		0.8 (lagging)		Variation range: 0.7 (lagging) to 1.0	
	Overcurrent protection		Automatic transfer to bypass circuit at 105% or more		With automatic retransfer function	
	Overload protection	**Inverter**	105%		200 ms	
		Bypass	15 A (current protector)	8 A (current protector)	200% for 30 s, 800% for 2 cycles (reference values)	
Battery	**Type**		Lithium-ion battery			
	No. of batteries		2		Serial connection	
	Capacity		40 Ah·cell			
	Backup time		4 min		At a 25°C ambient temperature, using new, fully charged batteries.	
Heat dissipation			25 W		When in Economy mode	
			130 W		When in Double Conversion mode and batteries fully charged	
Environment			Ambient temperature: -10 to +55°C Relative humidity: 20 to 90% (non-condensing)		Battery charging stops when outside the ambient temperature range	
Acoustic noise			41 dB or less		When in Economy mode	1 m from front of device, A-weighting
			51 dB or less		When in Double Conversion mode	

Table 2 Standard specifications of the *SANUPS A11M-Li*

Items			Ratings and standards		Remarks
Model			A11ML102 100 V class	A11ML102 200 V class	
Rated output capacity	N configuration		1.0 to 8.0 kVA / 0.8 to 6.4 kW		Depends on the no. of units in parallel
	N+1 configuration		1.0 to 7.0 kVA / 0.8 to 5.6 kW		
Topology			Double conversion online		
Cooling method			Forced air cooling		
AC input	Number of phases/wires		Single-phase 2-wire		
	Rated voltage		100/110/115/120 V	200/208/220/230/240 V	Depends on the output voltage settings
	Voltage range		At load levels < 40%: 55 to 150 V At load levels < 70%: 68 to 140 V At load levels ≥ 70%: 80 to 140 V	At load levels < 40%: 110 to 300 V At load levels < 70%: 136 to 280 V At load levels ≥ 70%: 160 to 280 V	
	Rated frequency		50/60 Hz		
	Frequency range		40 to 120 Hz		
	Required capacity	N configuration	1.1 to 8.2 kVA		Depends on the no. of units in parallel Max. capacity during battery recovery charging
		N+1 configuration	1.2 to 7.2 kVA		
	Input power factor		0.95 or greater		At rated output
AC output	Number of phases/wires		Single-phase 2-wire		
	Rated voltage		100/110/115/120 V	200/208/220/230/240 V	User-selectable
	Voltage regulation		Within ±2% of rated voltage		
	Rated frequency		50/60 Hz		Same as the input frequency (auto-select)
	Frequency regulation		Within ±1/3/5% of rated frequency		
	Voltage harmonic distortion		At linear load: 3% or less At 100% rectifier load: 8% or less		At rated output
	Transient voltage fluctuation	For abrupt load change	Within ±10% of rated voltage		0⇔100% load step changes at rated input
		For loss/return of input power			At rated output
		For abrupt input voltage change			For ±10% changes
	Response time		5 cycles or less		
	Load power factor		0.8 (lagging)		Variation range: 0.7 (lagging) to 1.0
	Overcurrent protection		Automatic transfer to bypass circuit at 105% or more		With automatic retransfer function
	Overload protection	Inverter	105%		200 ms
		Bypass	200% (for 30 s), 800% (for 2 cycles)		
Battery	Type		Lithium-ion battery		
	No. of batteries		2		Per unit. Serial connection
	Capacity		40 Ah·cell		Per unit
	Backup time		4 min		At a 25°C ambient temperature, using new, fully charged batteries, with N units used
Heat dissipation			130 to 1040 W		Depends on the no. of units in parallel When batteries are fully charged
Environment			Ambient temperature: -10 to +55°C Relative humidity: 20 to 90% (non-condensing)		Battery charging stops when outside the ambient temperature range
Acoustic noise			54 to 59 dB		Depends on the no. of units in parallel 1 m from front of device, A-weighting

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Servo Technology for Protecting People

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Shinichi Takeda Yuqi Tang Shogo Yoda

1. Introduction

Advances in servo systems have mainly done through contribution to *monozukuri* (manufacturing) such as for machine tools, injection molding machines, and semiconductor manufacturing equipment. Moreover, these systems are increasingly being used in medical and welfare equipment to maintain people's health. Servo systems are now expected to contribute toward manufacturing, maintaining people's health, and preserving the environment.(1)

In this article, we'll introduce our Servo Systems products used in medical devices to protect people's health. We'll then introduce our technology that protects people's safety, using our production line where this servo product is manufactured as an example.

First, we introduce a Servo Systems product used with medical analysis equipment. Next, we introduce an example of using a Servo Systems product with a cutting-edge remote pipette operation system for cell culturing. Finally, we introduce our servo technology that protects the safety of factory workers taking an example of a motor assembly process in which people work together with robots.

2. Use with Medical Analysis Equipment

The medical field is supported by a wide variety of medical devices. One example of such a device is medical analysis equipment, which is crucial in diagnosing illness and determining an individual's state of health.

There are various types of analysis equipment, such as genetic testing equipment, automatic biochemical analyzers, blood testing equipment, and urine testing equipment. Many stepping motors are used in these kinds of medical analysis equipment. This chapter introduces some of our products used in medical devices, taking an automatic biochemical analyzer as an example.

2.1 Equipment overview

Figure 1 shows the appearance of an automatic biochemical analyzer. An automatic biochemical analyzer uses blood or urine to induce a reaction with a reagent, to analyze the components of the sample such as sugars, proteins, and lipids.

Fig. 1 Automatic biochemical analyzer

2.2 Example of usage in equipment

With an automatic biochemical analyzer, the specimen sample and reagents are placed on a turntable. A pipette is used to dispense the specimen sample and reagents. This equipment uses many motors so that these processes are all performed automatically.

Figure 2 shows an example where stepping motors are used in an automatic biochemical analyzer. Stepping motors can be easily installed inside the equipment and are capable of performing highly accurate positioning control. This makes them very suitable for use in controlling the shaft of the turntable and the pivot shaft of the pipette.

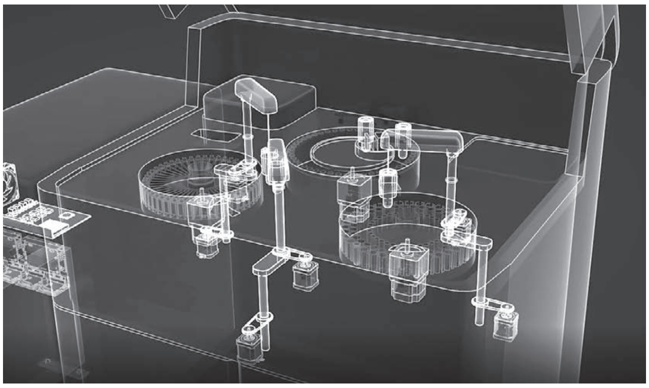

Fig. 2 Illustration of stepping motors in use

2.3 Product specifications (Stepping motors)

The *SANMOTION F* series 42 mm sq. 2-Phase 1.8° stepping motor[2] achieves low noise, high torque, and low energy consumption. It is often used in medical analysis equipment. Its increased torque improves the testing speed, and lower noise reduces the burden on the medical technician, and increased efficiency results in reduced heat generation and better energy savings, contributing to the medical field.

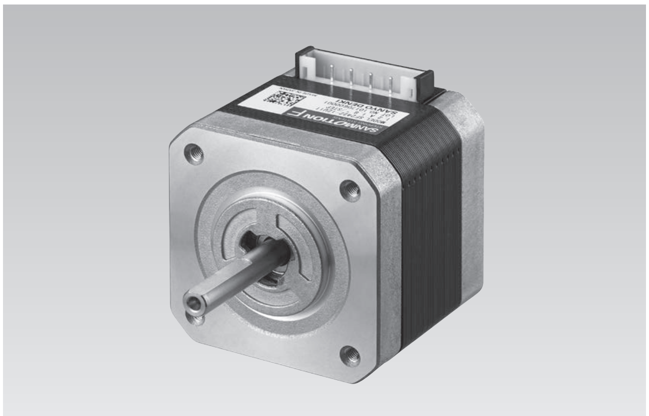

Fig. 3 Appearance of SF2422 type

3. Use with Remote Pipette Operation System for Cell Culturing

The field of regenerative medicine has made rapid advances in Japan, and this has significantly increased the demand for cell culturing. On the other hand, insufficient workplace safety and staffing shortages are two issues faced by individuals involved in cell culturing, and there is a pressing need to develop technology to resolve these issues.

In response, products are now being developed to allow pipette operation to be performed remotely that use a 5G mobile communications system and robot arms. This chapter introduces the *SANMOTION* compact cylinder linear servo motor[4] that is installed in the end effector of a remote robot arm of an advanced remote pipette operation system for cell culturing.

3.1 Equipment overview

Remote pipette operation using a 5G mobile communications system and robot arms is illustrated in Figure 4 (operator side) and Figure 5 (remote robot arm side).[3] A remote pipette operation system for cell culturing has two basic requirements. First, the operator must feel no delay. Second, the remote robot arm must accurately mimic the movement of the operator. The following two technologies are required to achieve these.

1) Technology to eliminate delay when transferring operator movement data
2) Pipette operation system that accurately mimics operator movements

The *SANMOTION* compact cylinder linear servo motor is used in the remote pipette operation system for cell culturing to operate the pipette in the remote robot arm's end effector. It is capable of accurately mimicking the movement of an expert operator as they move the pipette.

Fig. 4 Pipette operation (operator side)

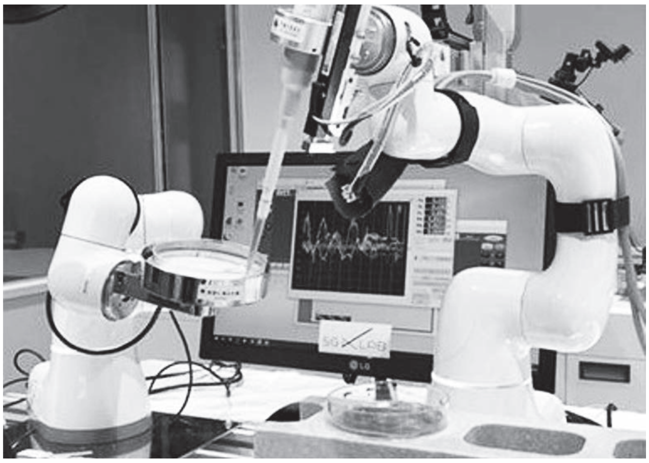

Fig. 5 Pipette operation (remote robot arm side)

3.2 Compact cylinder linear servo motor specifications and features

Figure 6 shows the appearance and structure of the *SANMOTION* compact cylinder linear servo motor. This compact linear servo motor has an all-in-one structure with a built-in linear encoder and linear guide, with a width of only 12 mm. The inside of the stainless steel pipe is composed of a mover with a built-in magnet and a stator with a stationary power supply cable, downsizing the motor and achieving ease of use.

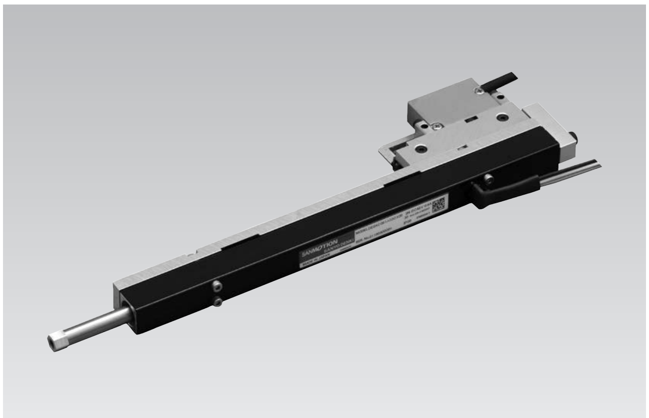

Fig. 6 *SANMOTION* compact cylinder linear motor

The motor has a maximum thrust of 16.5 N and a rated thrust of 5.1 N, achieving both increased thrust and downsizing. The maximum acceleration with no load is 37.4 G. This motor is expected to play an important role in a wide variety of fields thanks to its high-acceleration/deceleration operation and high-speed positioning.

The built-in linear encoder has a resolution of 1 µm, making it suitable for precision positioning operations. This allows for fine control when suctioning, dispensing, and measuring small amounts of liquids when using a pipette during the cell culturing process, without damaging cells.

The compact cylinder linear servo motor has a coreless linear structure with a back yoke. There is no fluctuation in thrust caused by magnetic fluctuation, and its operation is smooth and responsive. This allows an expert operator to control the pipette in real time with the robot arm end effector accurately mimicking their movements, making this motor ideal for driving the end effector of a robot arm.

The *SANMOTION* compact cylinder linear servo motor contributes toward the development of remote pipette operation systems for cell culturing that allow for fine operations to be performed remotely, as a technology for protecting people.

4. Motor Assembly Process Technology for People to Work Together with Robots

We use collaborative robots in processes for manufacturing the stepping motors used in medical devices so that workers can safely and reliably perform complicated tasks in limited spaces.

In this chapter, we introduce our specialty technology that protects the safety of workers that is used in a motor assembly process in which people work together with robots.

4.1 Assembly process in which people work together with robots

Figure 7 shows a stepping motor assembly line. This manufacturing line performs all tasks from assembly to checking for 56 mm sq. size[5] motors.

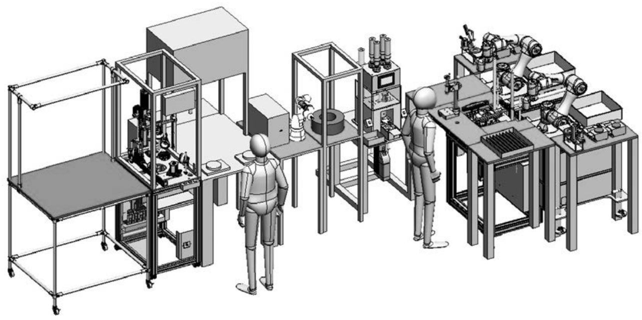

Fig. 7 56 mm sq. stepping motor assembly line

There are two collaborative robots placed at the head of the line. These supply parts to workers. Once a robot supplies a part, it then searches and picks next part while the worker is busy with assembly work. In this way, people and robots work together to establish a seamless assembly line. Figure 8 shows the collaborative robots installed when building the line.

Image recognition cameras are mounted on the end effector of robots. These are used to capture images of the parts being picked. This image data is used to recognize differences in height between parts as well as their locations, and to control the operation of the robots. This allows 3D gripping technology to be used, which means that randomly placed parts can be gripped.

Controlling the trajectory of movement at which the robot grips parts based on image data is our specialty technology.

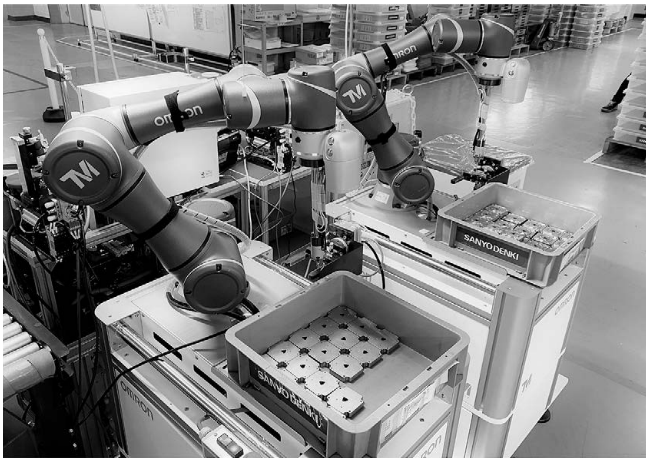

Fig. 8 Collaborative robot

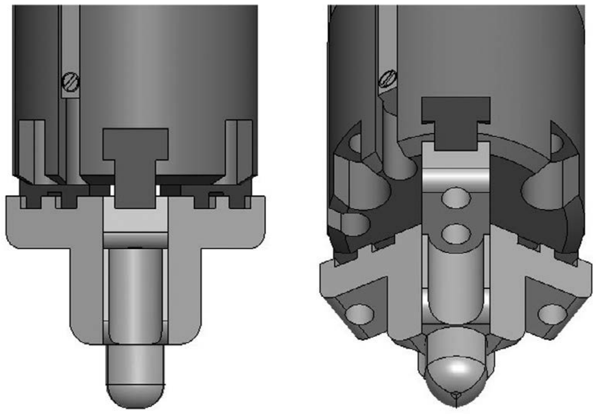

Fig. 9 Robot gripper finger
(Example of inherently safer design)

4.2 Safe manufacturing with robots

When building a production line that includes collaborative robots, it is important to ensure the safety of workers. We repeatedly conducted risk assessments and implemented countermeasures to assess and respond to possible risks that could occur at the manufacturing site, based on various safety standards including ISO/TS 15066 (an international safety standard for collaborative robots) and ISO 12100 (a basic safety standard). In this way, we were able to install collaborative robots, while ensuring worker safety.

We implemented several safety measures. Contact between robots and people is classified into two categories as defined in ISO/TS 15066: transient contact and quasi-static contact. These categories define how robots and people come into contact. Momentary contact (such as impact) is classified as transient contact, while clamping is classified as quasi-static contact.

The collaborative robots used here were configured to stop immediately if any transient contact is made. This is done by lowering the torque limit (tolerance) on any axes that experience a high external reactive force when impact occurs.

Quasi-static contact (clamping) would mainly occur with the worker’s hands or fingers during parts gripping. We set a torque limit during the downward motion of axes to ensure safety when the robot is operating. When designing the robot gripper finger, we gave it a rounded shape and made use of an inherently safer design to reduce the risk of injury to workers.

Figure 9 shows the robot gripper finger we designed, as an example of an inherently safer design.

Through making use of collaborative robots and carefully designing the robot gripper, we ensured the safety of the stepping motor assembly line when workers and robots make contact.

5. Conclusion

In this article, we introduced some examples of using servo technology in medical analysis equipment and a remote pipette operation system for cell culturing. These examples show how our Servo Systems products can be used in medical devices that protect people’s health. We also introduced an example of technology for safely manufacturing these servo products.

The motor technology used in medical analysis equipment achieves lower noise, higher torque, and lower energy consumption. This helps improve testing speed and reduce equipment noise. Reducing the noise of medical devices can help reduce the burden on medical technicians and patients.

We used a compact cylinder linear servo motor with large thrust and high response in the remote pipette operation system for cell culturing. This allows an expert operator to control a remote pipette in real time, with the robot arm accurately mimicking their movements.

We also introduced our specialty technology that protects people’s safety using an example of a motor assembly process in which people work together with robots, where contact between people and robots was carefully designed for safety.

Expectations for our Servo Systems technology will continue to grow for use as technology for protecting people’s health and safety, and as technology for protecting the global environment. We are committed to developing servo systems that will continue to meet these expectations and provide new value.

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Development of the *SANMOTION F* Series 56 mm sq. 2-Phase 1.8° Stepping Motors

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Takayoshi Seki Ryo Matsuo Fumiharu Yamazoe

1. Introduction

Stepping motors help simplify systems because they feature open loop control that can perform highly accurate positioning and speed control even without any position or speed sensors. They are used in a wide variety of fields, including office automation equipment and general industrial machinery. Demand for these products has been growing in recent years, and especially for use in semiconductor manufacturing equipment and medical devices. Products in these fields are required to have high torque, low noise, and low energy consumption. We released the *SANMOTION F* 42 mm sq. 2-Phase 1.8° stepping motors(1) in 2017 to great acclaim.

Against such a backdrop, we expanded the lineup with a newly developed *SANMOTION F* 56 mm sq. 2-Phase 1.8° stepping motors.

Our goal was to increase torque approximately 40% compared to our current model, as well as reduce noise and increase efficiency. We also enriched the lineup of options.

This article begins by showing the new models' appearance, lineup, and specifications. We then discuss the design concept we applied for the new models to increase torque, reduce noise, and reduce power consumption. This is followed by an explanation of how this was accomplished, along with a comparison with the current model. Finally, we discuss customizability and the lineup of options.

2. Specifications

2.1 Appearance

Figure 1 shows the appearance of the new model. Regarding the connection, although all of the current models (103H712 series) were lead types, the new models are connector types as standard. The advantage of a connector type is that you can connect a harness after mounting the motor to equipment. This makes handling of leads and mounting the motor to equipment easier. Also, harness customization had resulted in a number of different models for the current model, and it was difficult for customers to manage parts. For the new model, harness customization is handled using a relay harness, and the standardized motor makes it easier to manage parts.

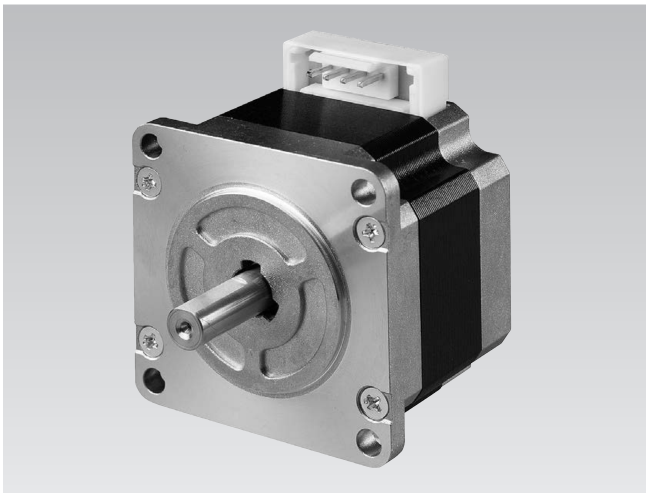

Fig. 1 Appearance of the new model (SM2562 type, bipolar)

2.2 External dimensions

Figure 2 provides the major dimensions of the new model. For mounting compatibility with the current models, the new models' flange size is 56 mm sq., with the same mounting pitch and fitting part dimensions as the current models. With this, replacement of the current models with new models is easy without requiring customers to change their equipment mounting specifications. We also used a standard shaft diameter of ø8 mm with increased shaft strength to handle the increased torque.

As with the current models, shaft specifications can be customized tailor to customer requests.

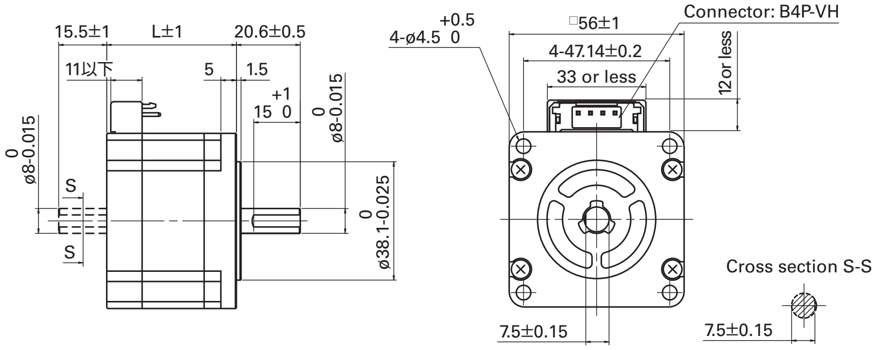

Fig. 2 Dimensions of the new model

Table 1 Unipolar motor lineup and main specifications

Model no.		Holding torque at 2-phase excitation	Rated current	Winding inductance	Rotor inertia	Mass	Motor length (L)
Single shaft	Dual shaft	N m or more	A/phase	mH	$\times10^{-4}$kg m^2	kg	mm
SM2561C10U41	SM2561C10U11	0.53	1	6.8	0.14	0.49	41.8
SM2561C20U41	SM2561C20U11	0.53	2	1.8	0.14	0.49	41.8
SM2561C30U41	SM2561C30U11	0.53	3	0.77	0.14	0.49	41.8
SM2562C10U41	SM2562C10U11	1.1	1	12.6	0.28	0.69	53.8
SM2562C20U41	SM2562C20U11	1.1	2	3.3	0.28	0.69	53.8
SM2562C30U41	SM2562C30U11	1.1	3	1.37	0.28	0.69	53.8
SM2563C10U41	SM2563C10U11	1.7	1	17	0.5	1.1	75.8
SM2563C20U41	SM2563C20U11	1.7	2	4.2	0.5	1.1	75.8
SM2563C30U41	SM2563C30U11	1.7	3	1.75	0.5	1.1	75.8
SM2564C10U41	SM2564C10U11	1.75	1	22	0.6	1.27	85.8
SM2564C20U41	SM2564C20U11	1.75	2	5.4	0.6	1.27	85.8
SM2564C30U41	SM2564C30U11	1.75	3	2.2	0.6	1.27	85.8

Table 2 Bipolar motor lineup and main specifications

Model no.		Holding torque at 2-phase excitation	Rated current	Winding inductance	Rotor inertia	Mass	Motor length (L)
Single shaft	Dual shaft	N m or more	A/phase	mH	$\times10^{-4}$kg m^2	kg	mm
SM2561C10B41	SM2561C10B11	0.75	1	13.5	0.14	0.49	41.8
SM2561C20B41	SM2561C20B11	0.75	2	3.5	0.14	0.49	41.8
SM2561C30B41	SM2561C30B11	0.75	3	1.5	0.14	0.49	41.8
SM2561C40B41	SM2561C40B11	0.75	4	0.85	0.14	0.49	41.8
SM2561C60B41	SM2561C60B11	0.75	6	0.38	0.14	0.49	41.8
SM2562C10B41	SM2562C10B11	1.4	1	25.5	0.28	0.69	53.8
SM2562C20B41	SM2562C20B11	1.4	2	6.5	0.28	0.69	53.8
SM2562C30B41	SM2562C30B11	1.4	3	2.9	0.28	0.69	53.8
SM2562C40B41	SM2562C40B11	1.4	4	1.5	0.28	0.69	53.8
SM2562C60B41	SM2562C60B11	1.4	6	0.72	0.28	0.69	53.8
SM2563C10B41	SM2563C10B11	2.35	1	36	0.5	1.1	75.8
SM2563C20B41	SM2563C20B11	2.35	2	9.5	0.5	1.1	75.8
SM2563C30B41	SM2563C30B11	2.35	3	4.2	0.5	1.1	75.8
SM2563C40B41	SM2563C40B11	2.35	4	2.4	0.5	1.1	75.8
SM2563C60B41	SM2563C60B11	2.35	6	1.05	0.5	1.1	75.8
SM2564C10B41	SM2564C10B11	2.5	1	41	0.6	1.27	85.8
SM2564C20B41	SM2564C20B11	2.5	2	11	0.6	1.27	85.8
SM2564C30B41	SM2564C30B11	2.5	3	4.9	0.6	1.27	85.8
SM2564C40B41	SM2564C40B11	2.5	4	2.8	0.6	1.27	85.8
SM2564C60B41	SM2564C60B11	2.5	6	1.15	0.6	1.27	85.8

2.3 Lineup and main specifications

Table 1 and Table 2 show the lineup and main specifications for unipolar and bipolar type stepping motors, respectively. The new models are available in four motor lengths—41.8 mm, 53.8 mm, 75.8 mm, and 85.8 mm. 12 unipolar models and 20 bipolar models are available with single shaft and dual shaft models, for a total of 64 standard models. The motor length of the new models is the same as or shorter than the current models, making replacement with the same size easy and even downsizing is possible.

The new models also conform to the UL and cUL safety standards as standard.

3. Product Features

3.1 High torque

The new models provide approximately 40% higher torque in the operating speed range compared with the current models. Figure 3 shows a comparison of the rotational speed vs. torque characteristics of the new and current models. Stepping motors have an extremely narrow gap between the stator and rotor, and the amount of magnetic flux in the gap has a significant effect on torque. We decided to use a magnet with high residual magnetic flux density for the new models. We also improved the machining accuracy of parts such as the stator and rotor, and carefully designed our assembly processes and facilities. We increased both machining accuracy and assembly accuracy, and were able to reduce the gap length by 28% while maintaining the same productivity and quality. We used a design with a higher amount of magnetic flux in the gap and increased torque even at high speeds, helping customer equipment operate faster.

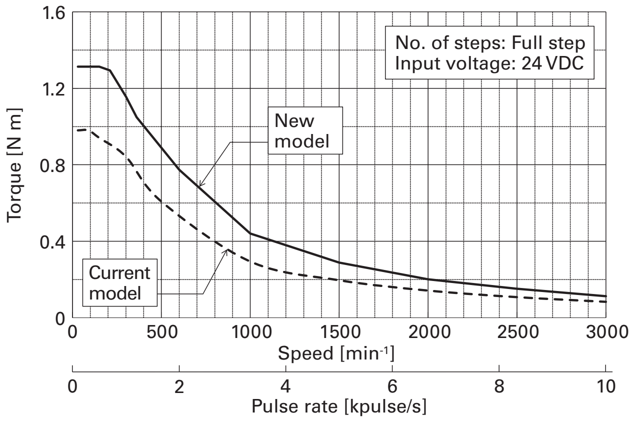

Fig. 3 Rotational speed vs. torque characteristics (SM2562C30B41)

3.2 Low noise

Compared with the current models, the noise level of the new models in their operating speed range has been reduced by 3 dB. This is equivalent to reducing acoustic energy by half. Stepping motors are often used in medical devices, and equipment is often used near medical personnel and patients. So, this equipment is required to operate quietly. To achieve low noise, we incorporated the following innovative ideas.

(1) High-rigidity stator core

We analyzed the structure of the stator core, and determined the back yoke and pole shapes to increase the rigidity of the stator structure.

(2) High-rigidity motor

We designed the new models so that the bracket and stator fitting parts would be easier to assemble while maintaining high motor rigidity. We optimized the tightening allowance and engagement length.

By designing the stator structure and motor with higher rigidity, we were able to optimally distribute the fixed vibration value and reduce noise.

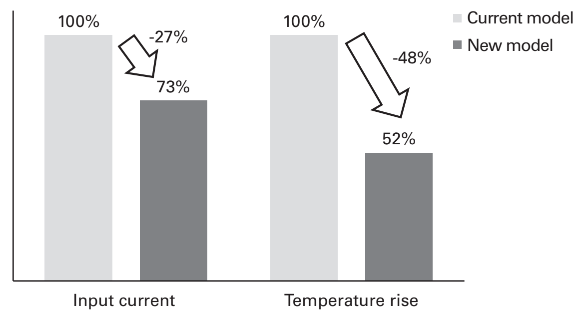

Fig. 4 Comparison of input current and temperature rise (SM2562C30B41)

3.3 Reduced power consumption through increased motor efficiency

Compared to the current model, the new model is approximately 3% more efficient. We increased the winding fill factor in the slot, reduced copper loss, and made use of the optimal core design to reduce iron loss. This allowed us to reduce overall loss. The reduction of these losses together with the increased torque discussed above made it possible to achieve equivalent torque to the current models with less input current.

Figure 4 shows an example comparing the input current and motor temperature increase for SM2562C30B41. When the torque is the same as the current models, the input current of the new models can be reduced 27%. This results in a 48% reduction in the temperature increase of the motor.

This reduces heat generation in equipment and contributes to energy savings.

3.4 Customizability and a wide lineup of options

As with the current models, we designed the new models so that it can be easily customized. It can be customized as required by the customer. For example, the axial shape could be changed, or a tap hole on a bracket could be added. We also added more options and designed a lineup of standard options, including models with gears and models with encoders. Table 3 shows the lineup of options. We prepared a lineup of models with gears, consisting of six low-backlash gear models with different speed-reduction rates, and two harmonic gear models. We prepared a lineup of models with encoders, consisting of three models with different step numbers. We also offer a lineup of models with electromagnetic brakes. With this, customers can easily customize products to suit their equipment, and can select from a wide lineup of options for greater flexibility in designing equipment.

Table 3 Lineup of options

Low-backlash gear	Gear ratio	1:3.6, 1:7.2, 1:10, 1:20, 1:30, 1:36
	Backlash	0.55° or less
Harmonic gear	Gear ratio	1:50, 1:100
Encoder	Microsteps	1000, 2000, 4000 P/R
	Number of channels	3
	Output circuit	Line driver
	Input voltage	5 VDC ±5%
Electromagnetic brake	Input voltage	24 VDC ±5%
	Static friction torque	0.8 N m or more

4. Conclusion

In this article, we introduced the lineup, specifications, and features of the *SANMOTION F* 56 mm sq. 2-Phase 1.8° stepping motor.

For the new models, we increased torque approximately 40%, reduced noise 3 dB, and increased efficiency approximately 3% compared with the current models. We switched to using a connector type so we could use the same motor for harness customization. The new models can easily replace the current models thanks to the mounting and size compatibility. We also enhanced the lineup of options.

The new stepping motors are easy to use and can contribute toward creating new value when used in customer equipment. We will continue our efforts to further improve stepping motor performance and functionality, and to develop products that will satisfy even more customers.

References

(1) Koji Nakatake and 6 others: Development of the *SANMOTION F* Series 42 mm sq. 2-Phase 1.8° Stepping Motor
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