Magnetic Contactor "FJ Series" and "SK Series" Line Expansion

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ABSTRACT

A magnetic contactor is a control device that mainly starts and stops motors, and demand for them is increasing in the Chinese and Southeast Asian markets. Fuji Electric has expanded the economical magnetic contactor "FJ Series" product line intended for the markets and the compact-sized magnetic contactor "SK Series" product line ideal for inverters and servo amplifiers. To the FJ Series, we have added products with 40 to 95 A ratings and optimized the support sliding-portion design to ensure a small size and high reliability. For the SK Series, we have developed 18 A and 22 A products, which are higher ratings than the existing 6 to 12 A, to successfully improve the limit performance of contact welding resistance for inrush current by 2.5 times that of the existing products.

1. Introduction

Magnetic contactors are switches for industrial use installed in control panels of production facilities and machinery mainly as control devices for starting and stopping motors. Their demand is increasing in the Southeast Asian and Chinese markets. In these markets, magnetic contactors that combine high durability and low prices achieved by limiting applications are desired. Meanwhile, as motor control in Japan and other advanced countries, high-efficiency/high-precision inverter/servo control is common in addition to motor direct starting. On the primary side of these drive control devices, magnetic contactors are often installed. As described above, magnetic contactors for different applications are desired that provide limited functions to meet requirements for the regions of use or particular usage.

Fuji Electric has continuously provided the market with magnetic contactors that match user needs including the standard type magnetic contactor "SC Series" while pursuing smaller size and higher efficiency as a pioneer of magnetic contactors.

This paper describes line expansion of the economical contactor "FJ Series" for emerging countries and compact magnetic contactors "SK Series" ideal for inverters/servo amplifiers.

2. Economical Magnetic Contactor for Emerging Countries "FJ Series"

There are two major needs concerning magnetic contactors used in Southeast Asia and China:

(a) For facilities focused on safety such as equipment for export and elevating machinery, products featuring high quality and high switching durability, as well as conformity with international standards such as IEC and UL are desired.

(b) For simple control devices and facilities such as air conditioners, products offering the necessary and sufficient durability with low prices are desired.

The FJ Series offers products that meet the needs described in (b) and the line has now been expanded up to 40 to 95 A products in addition to those with 6 to 32 A ratings released in 2011 (see Fig. 1).

2.1 Background to line expansion and product features

(1) Background to line expansion

For high-frequency switching and high-quality applications such as overseas machine tool and elevating machinery applications, we continue to offer the standard SC Series. We recommend economical types for general residential air conditioners and low-frequency switching applications because only products with up to 32 A ratings were available as economical types. Therefore standard types were used to accommodate the needs for higher rating uses. We have now added products with 40 to 95 A ratings, increasing options of economical types and expanding applications of magnetic contactors.

(2) Downsizing

We have achieved a volume reduction of 38% from the standard SC Series while ensuring the performance required for economical magnetic contactors (rated operational voltage, rated operational current and electrical durability) (see Fig. 2).

Product downsizing has been successfully achieved by providing a structure integrating 1A/1B auxiliary

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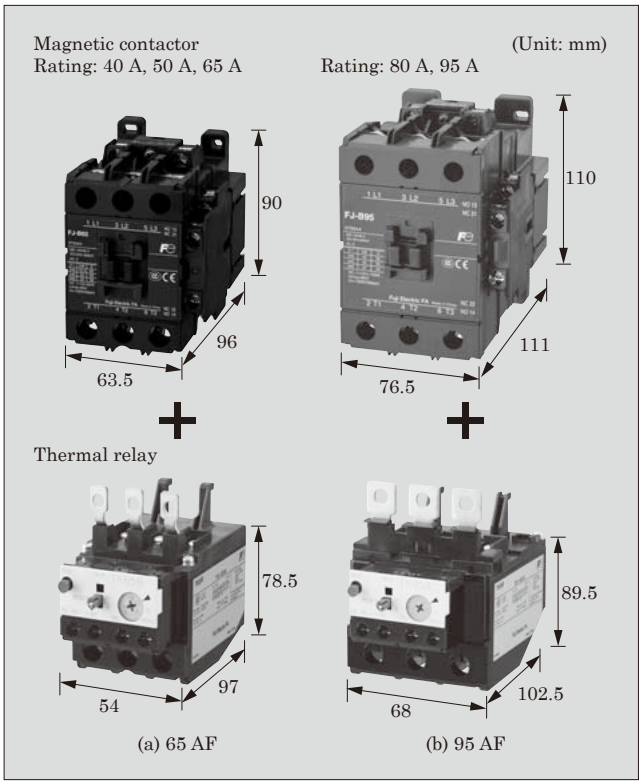


Fig.1 Additions to "FJ Series" (40 to 95 A)

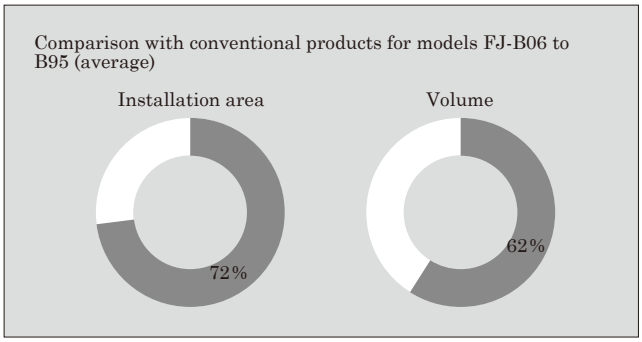


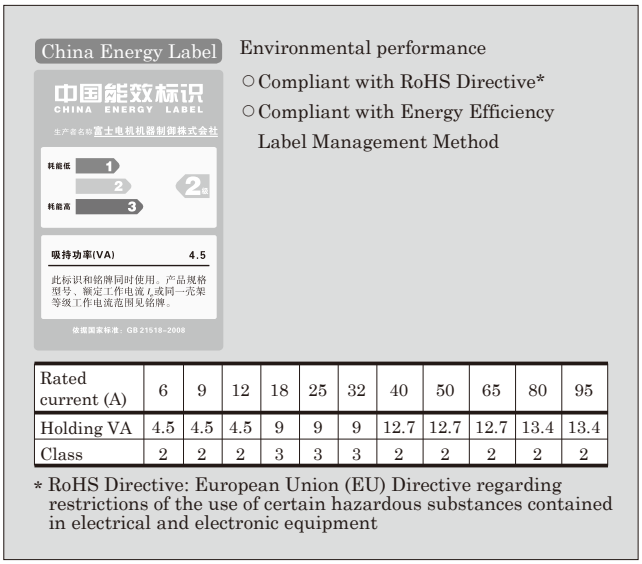
Fig.2 Downsizing of magnetic contactors

contacts for self-holding and interlocking of the control circuit into the main unit, in addition to limiting the variations such as reversing and mechanical latch types. If there are not enough contacts then they can be optionally added.

To reduce the size, the electromagnets that operate magnetic contactors have also been downsized. The electromagnet power consumption of the developed products with 40 to 95 A ratings satisfies the Class 2 requirements of the energy efficiency classification based on the Energy-Saving Law of China. Figure 3 shows the energy efficiency classes of the FJ Series.

(3) Ensuring safety

While low prices are required of economical types, considering possible electric accidents arising from misuse or at the end of product lifespan, their electric safety must be equivalent to that of the standard types. For the FJ Series, materials with high thermal



Rated current (A)	6	9	12	18	25	32	40	50	65	80	95
Holding VA	4.5	4.5	4.5	9	9	9	12.7	12.7	12.7	13.4	13.4
Class	2	2	2	3	3	3	2	2	2	2	2

* RoHS Directive: European Union (EU) Directive regarding restrictions of the use of certain hazardous substances contained in electrical and electronic equipment

Fig.3 Energy efficiency class (environmental protection performance)

tolerance equivalent to those of the standard types are used as contact supports, for which the highest thermal performance is required of all conductive part holding components. In this way, we have ensured a safety performance equivalent to that of the standard types including prevention of interphase short-circuit accidents due to excessive energization heating or prevention of electric shocks by providing terminal covers as standard equipment.

2.2 Stabilization of moving part behavior for downsizing

One product downsizing approach is to reduce the depth length, but this reduces the contact moving strokes. To address this problem, it is necessary to stabilize the behavior of the contacts (moving parts) upon making and release so as to suppress the amount of contact bounce upon making, and contact support bounce upon release. A contact support bounce upon release is a phenomenon that occurs when the control coil voltage is turned off, where the iron core is de-excitated and the contact support and moving core are pushed back in the direction of release by the back spring force, which causes the contact support to hit the upper frame and instantaneously bounce back (see Fig. 4).

In particular, as the rated capacity of a magnetic contactor increases to 40 to 95 A, the contact force of the contact inside also increases to cause a significant bounce upon release. To suppress contact bounces upon release for the developed products, structural analysis simulation has been used for evaluating the amount of contact bounce upon electromagnet release. In this way, we have identified the relationship between the component dimensions and amount of bounce.

Figure 5 illustrates the contact support bounce phenomenon that occurs when a contact support is released. When the contact support moves from the

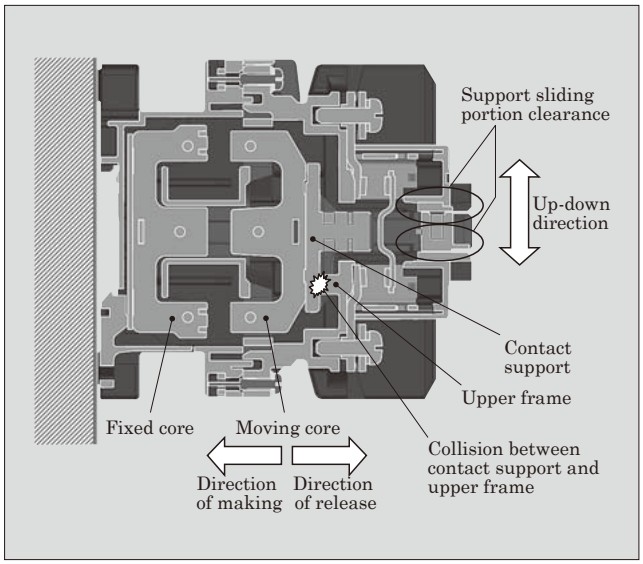


Fig.4 Structure of magnetic contactor

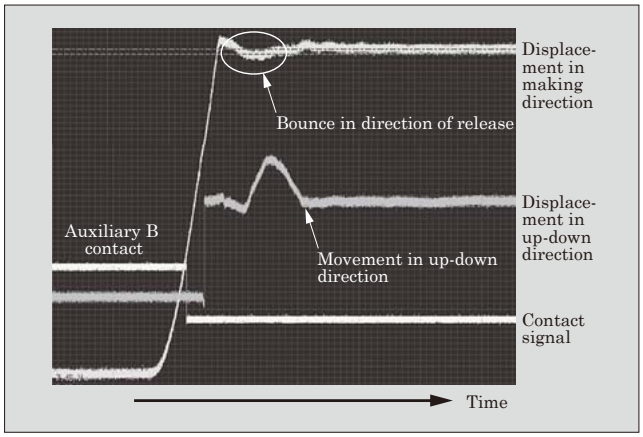


Fig.5 Contact support bounce upon release (observed displacement waveforms)

making position to the release position as the coil is turned off, a bounce in the opposite direction turned out to occur. Large bounces may cause the auxiliary B contact to turn on and off repeatedly a few times when released. In order to prevent this malfunction, the amount of bounce must be kept small by absorbing the collision energy of the contact support.

Structural analysis simulation has revealed that dispersing the collision energy generated upon release on the sliding surface that guides the contact support (see the up-down direction in Fig. 4) allows bouncing to be suppressed. Specifically, movement of the contact support in the up-down direction can be controlled by the support sliding portion clearance with which the support comes into contact, as shown in Fig. 4. We have evaluated and verified the relationship between the support sliding portion clearance and the amounts of bounce and wear, as shown in Fig. 6. This clearance also influences abrasion of the support sliding portion, and the optimum clearance dimensions (see the arrow in Fig. 6) that keep a balance between the amounts of

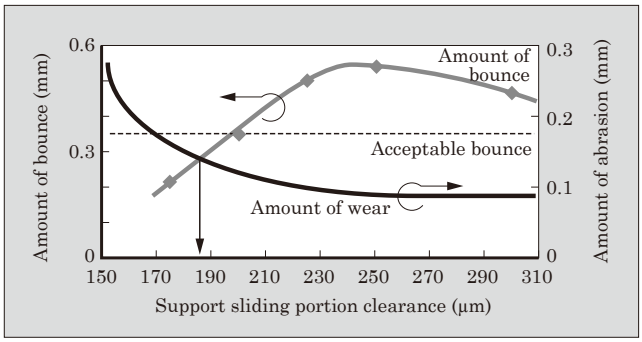


Fig.6 Support sliding portion clearance vs. amounts of bounce and wear

bounce and abrasion has been reflected in the product design.

For products with 40 to 95 A ratings, we have optimized the design of the support sliding portion clearance to achieve a small size and ensure high reliability.

3. Compact Size Magnetic Contactor "SK Series[(1)]"

In 2011, we launched a range classified as miniature with a rating of 12 A or smaller by the AC-3 standard, which has been received favorably as the world's smallest low-power-consumption range of magnetic contactors. We now have developed products with larger ratings than 12 A, "SK18" of the 18 A and "SK22" of 22 A, to expand the line. Their appearance is shown in Fig. 7 and features in Fig. 8.

3.1 Background of development and product features

(1) Background of development

DC-operated products of the SK Series allow low-power-consumption driving and can also be directly driven by PLCs, which makes them a popular choice for the primary side of inverters and servo amplifiers. Many of these applications use products of 30 A or smaller and products with ratings of over 12 A have been in demand.

For SK18 and SK22, we have pursued user friend-

Fig. 7 "SK18" and "SK22"

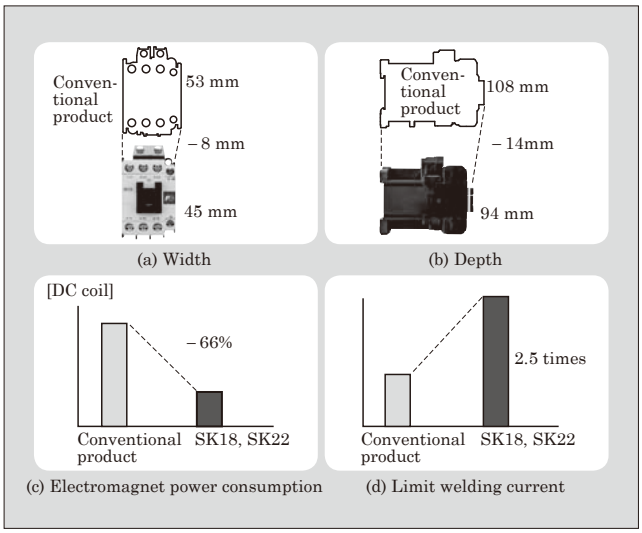


Fig. 8 Features of "SK18" and "SK22"

liness in applications used for inverters and servo amplifiers. For this reason, the SK Series offers products for specialized applications, a different line from the SC Series which provides standard magnetic contactors. Specifically, the limit performance of contact welding resistance has been improved to 2.5 times the conventional products.

Inverters and servo amplifiers has a built-in capacitor for rectifying and smoothing circuit, and an inrush current flows into the capacitor in a few ms when the contactor is closed. This inrush current may cause a risk of slight welding of the magnetic contactor. With the SK Series, the improved limit performance of contact welding resistance has reduced this risk. In view of inverter and servo amplifier applications and general market applications, the electric lifespan of AC-3, which relates to motor direct starting, has been specified to be the necessary and sufficient amount of 1 million switching actions.

(2) Improved limit performance of contact welding resistance

Limit performance of contact welding resistance for inrush current upon contact closing of a magnetic contactor is determined by factors including contact bounces upon closing and contact materials. For SK18 and SK22, bounces upon contact closing have been successfully reduced by optimizing the wipe amount of contact and pressure, and new environment-friendly Cd-free contacts providing improved contact welding resistance have been adopted. In this way, we have achieved a limit performance that withstands an inrush current 2.5 times larger than the conventional SC Series.

3.2 Downsizing technology

In order to fit three poles of the main circuit including one pole for the auxiliary contact into the product width of 45 mm, performance is required that allows turnon and cutoff of a current that is six times larger than the 22 A rating, which is in the AC-4 standard, with a main circuit pole pitch of 11.4 mm.

(1) Ensuring phase-to-phase insulation

Reducing the width from 53 to 45 mm means narrowing the pole pitch of the main circuit from 13 to 11.4 mm; this makes it essential to ensure electric insulation between phases. SK18 and SK22 are not only usable for making and breaking applications of inverters and servo amplifiers but also used in familiar motor direct starting (AC-3 standard) and drive systems capable of inching operation (AC-4 standard). For that reason, in inching (repeated small movements of motors) and plucking (antiphase braking), large arc energy causes wear to the partition walls intended for ensuring insulation between phases. Excessively increasing the thickness of partition walls in order to ensure electric make/break durability decreases the space for arc extinction and reduces the breaking performance. In addition, dimensional variation in manufacturing of partition walls themselves may increase, causing dimensional defects.

In the developed products, the parts of the partition walls that are worn by arcing, which were identified by actual machine verification and simulation, have been made locally thicker (see Fig. 9). Furthermore, the groove shape for retaining arc gas has increased the arc cooling effect upon breaking, which has improved durability.

(2) Adoption of thermoplastic resin for contact supports

To provide environmentally friendly products, we have adopted a reusable thermoplastic material for

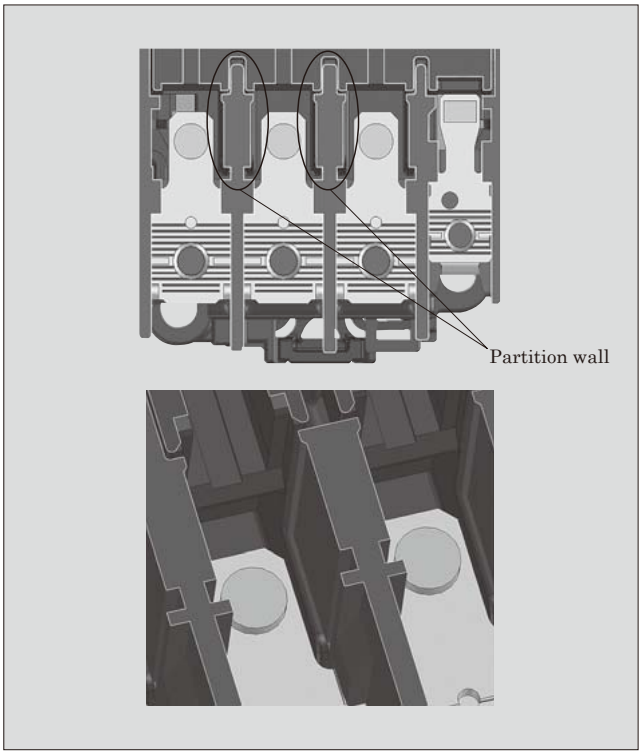


Fig. 9 Cross section of partition wall between phases

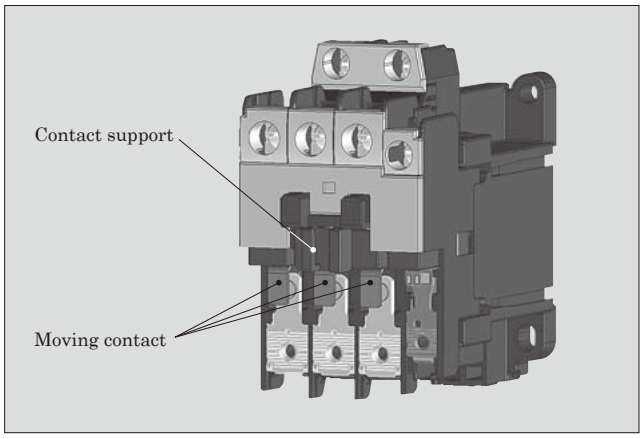


Fig. 10 Contact support structure

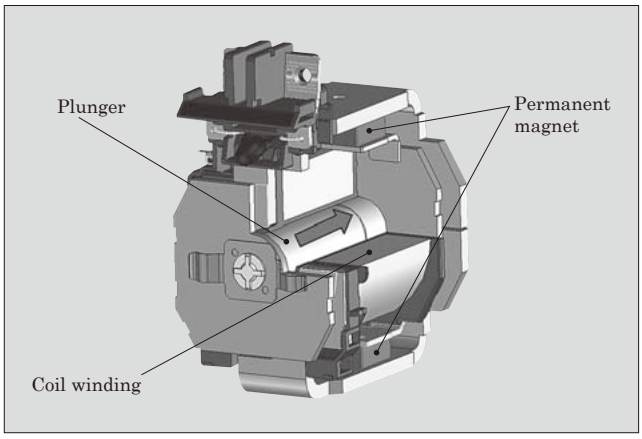


Fig. 11 DC electromagnet

contact supports. Contact supports hold moving contacts which are energized parts, and make sliding movements when switching of a magnetic contactor (see Fig. 10). Accordingly, they are required to have high heat resistance and abrasion resistance, which is why thermosetting resins including phenol resin have been used up to now. However, phenol resin has a problem in terms of its recyclability and cannot be readily molded into thin parts, which has posed obstacles to product downsizing.

The developed products have been provided with a structure having contact supports that use thermoplastic resin, which characteristically melts by heat, and high-strength polyamide resin, a type of thermoplastic resin that can undergo thin-wall molding, has been applied. By making use of the high melting point of this material that exceeds 300 °C and optimizing the cross-section area of the conductive part for improving the thermal characteristics, the temperature rise has been successfully limited to 250 °C or below.

In addition, the mechanical durability of 5 million switching actions has been ensured by optimizing the sliding portion, sliding area and clearance.

(3) DC electromagnet

To downsize products and reduce their power consumption, we have developed a new DC electromagnet. DC electromagnets are characterized by gradual increase of current in the closing operation because of the inductance of the coil winding. This has made it necessary to increase the coil AT (current × number of windings) in order to obtain the necessary attraction force. For this reason, it has been difficult to downsize the electromagnet portion and reduce its power consumption.

For the developed products, a polarized electromagnet that uses permanent magnets has been adopted (see Fig. 11). With a polarized magnet, however, the counter electromotive force that is generated when the plunger operates decreases the coil current and causes unstable operation, which posed a major challenge.

It has been found that unstable operation due to a current drop is caused by operation of the plunger that starts when the coil current rises after voltage is applied to the coil. This makes the operation force lower than the spring force of the contact pressure, which constructs the load. We have met this challenge by optimizing the amount of magnetic flux of the permanent magnets so that the plunger starts operating when the coil current has sufficiently risen in order to increase the retaining force between the permanent magnets and plunger immediately before the making operation.

3.3 Product structure enabling short delivery times

SK18 and SK22 have been designed to provide a "pile-up structure," which allows them to be assembled by gradually building up parts starting from those in the lowest level. With the structure of the conventional products, the upper and lower level parts of the product required separate assembly, which necessitated a batch production process as shown in Fig. 12. For this reason, intermediate inventory of upper level assemblies was required, hindering the flow production.

Figure 13 shows an illustrated breakdown of the parts of the pile-up structure. The numbers show the order of assembly. It allows a chain of assembly from (a) the process of assembling the lower frame and slid-

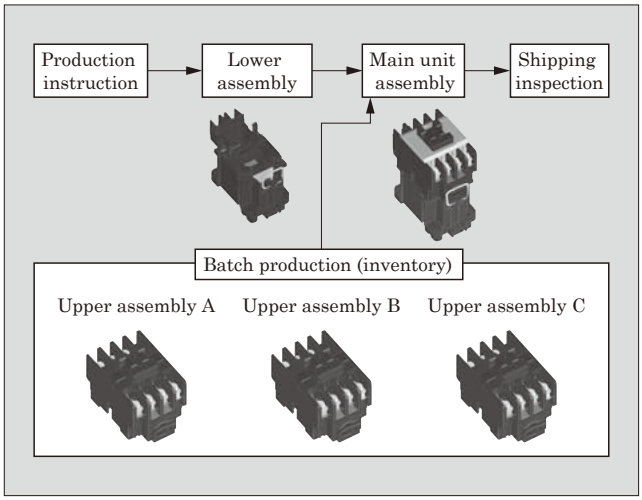


Fig. 12 Conventional order of assembly

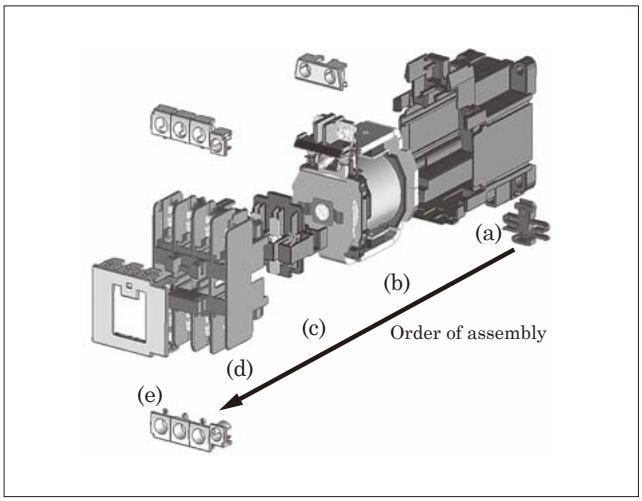


Fig.13 Illustrated breakdown of parts of pile-up structure.

er to (e) the final process of assembling the terminal cover. This has eliminated the need to have an inventory of various assemblies, which was necessary in the past, and made it possible to supply products in short delivery times.

4. Postscript

This paper has described the line expansion of the "FJ Series" and "SK Series" of magnetic contactors.

In the future, we intend to continue developing magnetic contactor technologies that match the market needs, and thereby further enhance products and contribute to increase market demand and improve customer satisfaction.

References

(1) Okubo, K. et al. "SK Series" of Miniature Contactor. FUJI ELECTRIC REVIEW. 2012, vol.58, no.3, p.98-103.