UDC 621.316.544.067.4

MAGNETIC MOTOR STARTER WITH SUPER MAGNET

Isao Murayama
Kazumi Uchida,
Minoru Ishikawa
Noriaki Kunii
Shigekazu Mitani

1. INTRODUCTION

The magnetic motor starter (hereinafter abbreviated "motor starter") is widely used as motor starting and stopping switch, being serialized from ones with small capacity up to large capacity, and various technological innovations as miniaturization, performance improvement and extension of its useful life have been introduced.

For this type of motor starter, studies on arc extinguishing principle, search for the limit for saving resourses and saving energy, and ease of mounting, wiring and maintenance as well as operational reliability for the motor starter in face of diversification of the system and enhancement of its functionality are vigorously demanded.

For responding these needs and for coping with electronification of facilities, we have developed New SC Series motor starter in search of higher functionality and higher reliability. For this, we have adopted electronically controlled super magnet (AC input DC exciting system) having IC's of exclusive use in its control circuit. By doing thus, we have succeeded in enhancing operational performance and operational reliability. The following introduces the outline of functioning and operation of the new products.

2. FEATURES AND CONSTRUCTION

2.1 Features

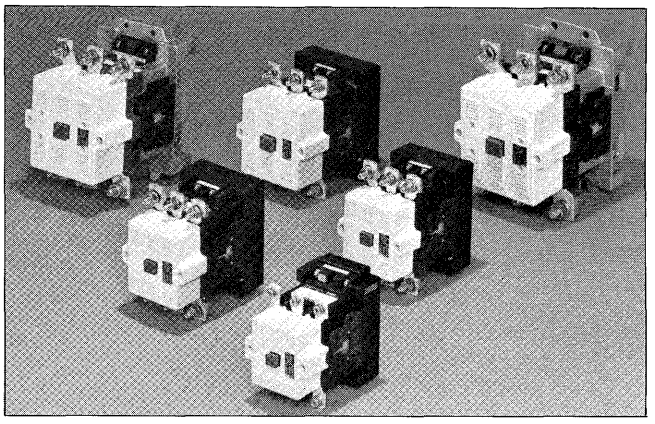
(1) Improvement of operational reliability

By mounting IC's of exclusive use, reliability in operations in a wide voltage range has been obtained. In particular, the new motor starter is so deviced that closing of the magnetic contactor at low voltage where there is danger of coil burnt out and chattering operation is avoided and when there is regular rated voltage at the time of making, it should operate normally even when the voltage may drop to 65% at the time of contact of main contacts. At the same time, overload and restrictive operations of motors due to starting with undervoltage can be avoided.

(2) Reduction in power consumption

By adopting AC input DC exciting magnet and power switching circuit, power consumption of the magnet and magnet capacity (VA) have been reduced in a large scale.

Fig. 1 New SC series magnet contactor with super magnet



S I 1207

Table 1 Expansion of coil rating range

Rated voltage (V)	Range of coil rating		
	AC (V),	(Hz)	DC (V)
24	24~ 25	50/60	24
48	48~ 50	50/60	48
100	100~127	50/60	100~110
200	200~250	50/60	200~120
300	265~347	50/60	–
400	380~440	50/60	–
500	460~575	50/60	–

(About 30% in power consumption and retaining VA, about 50% comparison with conventional type starter of our own make).

(3) Extension of coil rating range

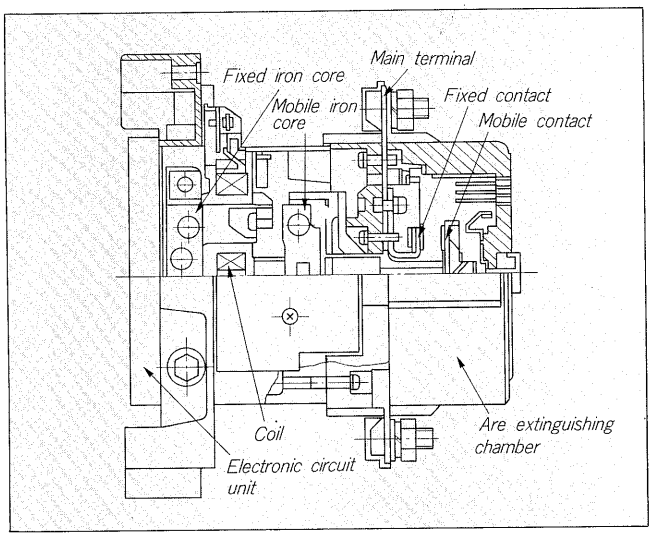
By adopting the super magnet, common use for AC and DC is realized. Furthermore, by suppressing the temperature rise of the coil through reduction of power consumption, the rated voltage range of the coil was expanded greatly. (See *Table 1*)

(4) Prevention of beating

Since exciting of the magnet is made by DC, no shading coils as in case of AC magnet are required so that no beating sound will be generated.

(5) Incorporation of surge absorbing function

Fig. 2 Structure of magnetic contactor



As super magnets incorporate surge absorbing function, no surge voltage will be generated at the time of closing and opening the magnetic coil.

2.2 Construction

Motor Starter is composed of magnetic contactor which opens and closes the load and thermal relay which protects the device from overload. For the magnetic contactor, a structure of direct coupling of contacts with magnet unit and the electronic circuit part is made to compose it with modules and placed on the bottom, is adopted. *Fig. 2* shows typical construction of magnetic contactor.

3. IMPROVEMENT OF OPERATIONAL RELIABILITY AGAINST VOLTAGE VARIATION

3.1 Behavior of magnetic contactor at the time of voltage variation

Together with improvement of quality of component parts and others, failures now emerging in the magnetic contactors are due, mainly, to the problem of selecting the right device and those due to abnormal use of the device as in the case of power supply voltage fluctuation. The New SC Series aim to improve the operational reliability by taking up measures against these failures that are supposed to emerge from the problem of using modality, not due to the defects of the component parts, and to minimize the failures.

Failures in the magnetic contactors are:

(1) Burning out of coils and beat,
(2) Welding falling off or abnormal wears of main contact,
(3) Contact failure of auxiliary contacts.

Main cause of the failures of coil burning out and main contact is due to imperfect closing of the magnetic contactor and chattering due to the voltage drop and voltage fluctuation at the time of starting the electric motor.

3.2 Principle of operation of super magnet

Fig. 3 shows the circuit composition of the super

Fig. 3 Circuit composition of super magnet

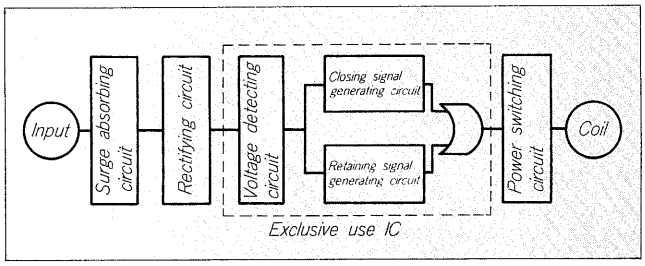
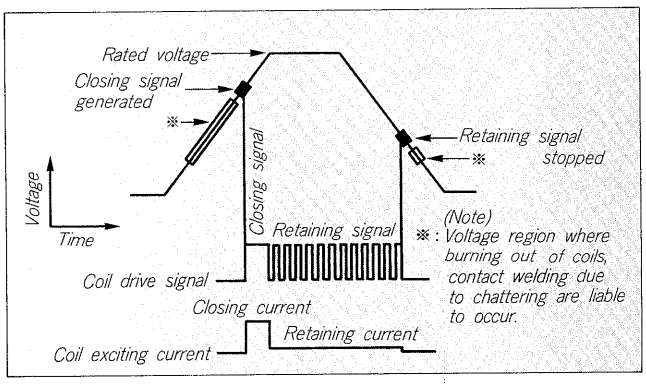


Fig. 4 Principle of operation of super magnet



magnet. When a voltage is applied to the control coil, a voltage detecting function incorporated into IC of exclusive use will confirm its value and only when it is judged that the voltage is not harmful for closing operation of the magnet, closing signal will be generated and this excites the coil through the power switching circuit.

Then, after the predetermined exciting time sufficient for completing the closing operation, the signal will be switched over to retaining signal, and the magnet will be retained by flowing the exciting current sufficient only to retain the magnet. During this retaining operation, the power switching circuit will try to reduce the power consumption by carrying out the switching operation. When the coil voltage is lowered, the voltage detecting circuit will judge the magnitude of the voltage as in the case of voltage being applied, and stop the retaining signal to release the coil.

The voltage detecting circuit, not only at the time of closing and releasing, but always supervises the coil input voltage during the operation, and functions in a way that a stable operation and functioning should be secured against any sort of voltage variation.

That is, for example, suppose the case as shown in *Fig. 4*, where the applied voltage is raised gradually, no closing signal will be generated in a range where the magnetic contactor may carry out an unstable operation (region marked by *), and only when the voltage comes to the range of stable operation, passing over this range, the closing signal will be generated and the coil will be excited. After supplying current in a lapse of time sufficient to the closing operation, the signal will be switched over to retaining signal and the coil current will be reduced to the retain-

ing current. Then, in case the voltage is lowered gradually, just as in the case of closing, the retaining signal will be cut out before entering the unstable region, and the magnetic contactor will be released.

Consequently, contact welding and falling down due to burning out of the coil and chattering operation can be avoided enen with the voltage application at the low voltage region that may bring out unstable operation due to the voltage variation and instantaneous voltage drops.

3.3 Concrete example of voltage variation

(1) Voltage drop due to simultaneous starting of motors

When a number of electric motors are started at the same time, for example, in a large factory at the beginning of the day's work, the line voltage will drop on account of starting current of the electric motors, and the voltage will recover gradually with the increase of turning speed of the motors. In order to secure a good efficiency of the installation, if the load is connected up to the limit of the power supply capacity, the voltage drop at the time of simultaneous starting will be remarkably large. (*Fig. 5*)

By time lag, when there is a motor that starts a little later (Mn of *Fig. 5*), the coil of the magnetic contactor that control this motor will be applied by the voltage that will increase gradually. The conventional type of magnetic contactor was liable to cause troubles as burning out of the coil, welding of the contact and damage to the device by the chattering operation due to the extent of the voltage drop.

In case of super magnet, even though an instruction to the effect of closing is given, when the voltage drop is large, thanks to the operation of the voltage detecting function, the closing signal is applied only when the power supply voltage is recovered to the value that permits a stable operation of the magnetic contactor, and the coil will be excited so that no chattering operation will be produced.

This has a merit, at the same time, of being able to start motor steadily because there will be no danger of starting with low voltage inutilely (overload or locked rotor operation due to lack of starting torque).

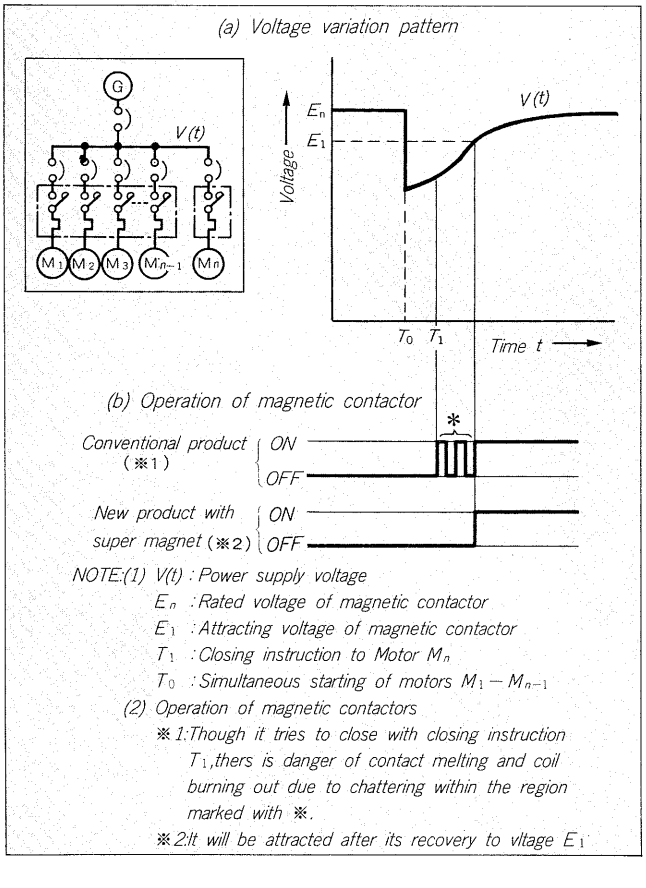
(2) Instantaneous voltage drop during operation.

In case there is any accident caused by lightning or short circuit in the power circuit, there will be momentaneous voltage drop or current interruption, until when the troubled parts should be disconnected or the trouble should be restored to normalcy.

In case the equipment is exposed to such instantaneous voltage drop or current interruption, the conventional magnetic contactors will be liable to burn out the coil or cause trouble to the contact when the equipment is placed to operation at the time of power recovery. (*Fig. 6*)

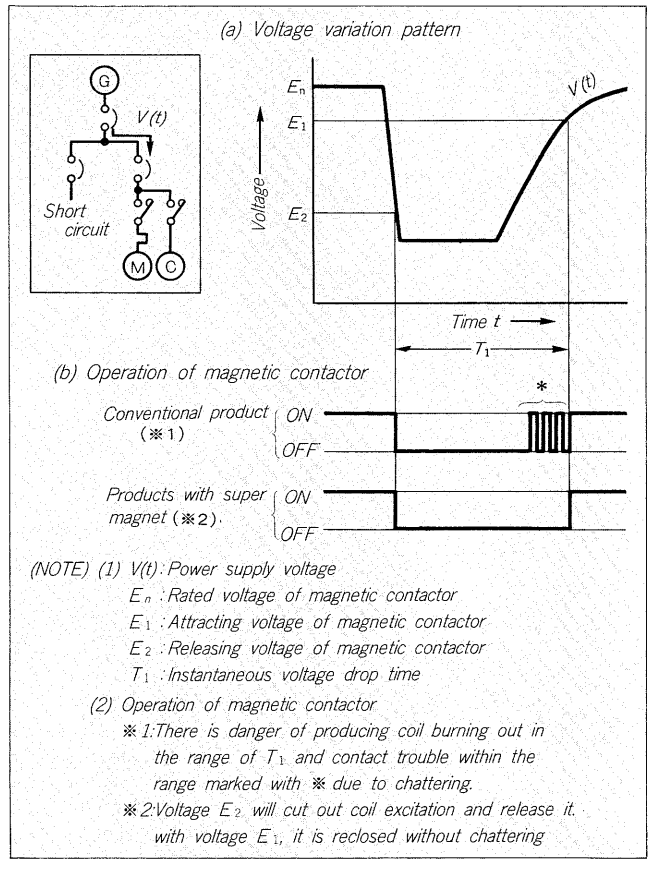
For super magnet, no troubles like coil burning out or contact welding since, when the voltage drop is excessive, coil excitation will be cut out by the operation of voltage

Fig. 5 Operation at the time of voltage drop due to simultaneous starting



NOTE:(1) V(t) : Power supply voltage
E_n : Rated voltage of magnetic contactor
E_1 : Attracting voltage of magnetic contactor
T_1 : Closing instruction to Motor M_n
T_0 : Simultaneous starting of motors $M_1 - M_{n-1}$
(2) Operation of magnetic contactors
※1:Though it tries to close with closing instruction T_1,thers is danger of contact melting and coil burning out due to chattering within the region marked with ※.
※2:It will be attracted after its recovery to vltage E_1

Fig. 6 Operation during instantaneous voltage drop



(NOTE) (1) V(t) : Power supply voltage
E_n : Rated voltage of magnetic contactor
E_1 : Attracting voltage of magnetic contactor
E_2 : Releasing voltage of magnetic contactor
T_1 : Instantaneous voltage drop time
(2) Operation of magnetic contactor
※1:There is danger of producing coil burning out in the range of T_1 and contact trouble within the range marked with ※ due to chattering.
※2:Voltage E_2 will cut out coil excitation and release it. with voltage E_1, it is reclosed without chattering

detecting function to release completely the magnetic contactor, and when the voltage is recovered, the equipment is placed to operation by generating the closing signal only after the power voltage is completely recovered.

(3) Sudden voltage drop during closing operation.

In case the power capacity is, for example, small, as in case of small factory, equipment used for agriculture, power facility for temporary works, etc. or when the line length of control circuit is extremely long, there occurs often a large voltage drop with the starting current at the time of motor starting.

As for the operation of magnetic contactor, all movable part including movable contact will start moving at the rated voltage and from the moment when the contact makes, the magnetic contactor may be attracted while making chattering operation by the sudden voltage drop produced by the starting current of the motor. (*Fig. 7*) If this chattering phenomenon persists at the contact, the contact may weld or drop out or cause deformation to surrounding insulating materials by the arc heat.

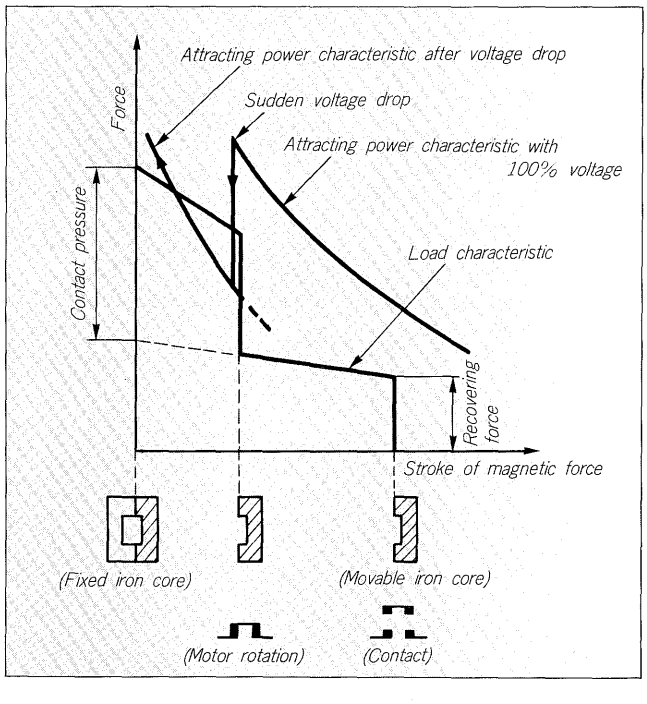
The super magnet has wider allowable voltage sudden drop range than that of conventional series products that used to have the voltage sudden drop characteristic of 75% of rated voltage, and no contact welding will take place even the voltage drops down to 65% of the rated voltage.

4. EVALUATION OF RELIABILITY

As we have come to describe the outline of the New SC Series, they are outstanding new products provided with many features that have been hard to find in conventional types of devices. Furthermore, in order to achieve these functions, and to prove in fact that these functions are realized in the practical works, we have carried out an assessment on basis of our vaste practical experience and accumulation of technologies of having produced more than hundred millions of magnetic contactors as well as development of new technology.

For assessment, we have taken into account of various standards of each country as commodities of international market, as well as various conditions for their practical applications, assessment on durability for their use for a long period until the analysis of failure mode for the time of failure. Thus, we have carried out type approval test taking into account of all cases of failure that could be presented during their practical use through analyzing the failures in the conventional market.

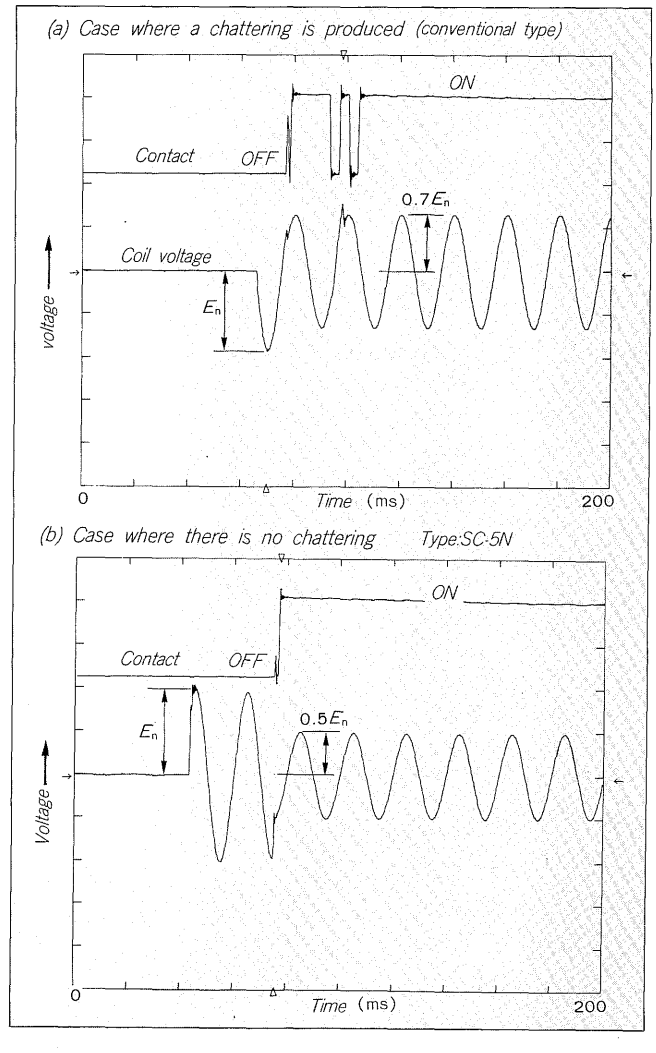
Fig. 7 Operation at the time of voltage suden drop during closing operation



4.1 Operational characteristic

Super magnet carries out voltage detection of the control circuit according to its theoretical function and exerts control on the excitation of the magnet in proportion of the detected voltage level. Therefore, there is no region of instable operation where the device carries of closing and

Fig. 8 Example of voltage sudden drop characteristic



opening of the current in high speed due to imperfect contact of the contactor.

As for contact behaviours during the test simulating various voltage conditions that could be emerged in the market, we have obtained the following.

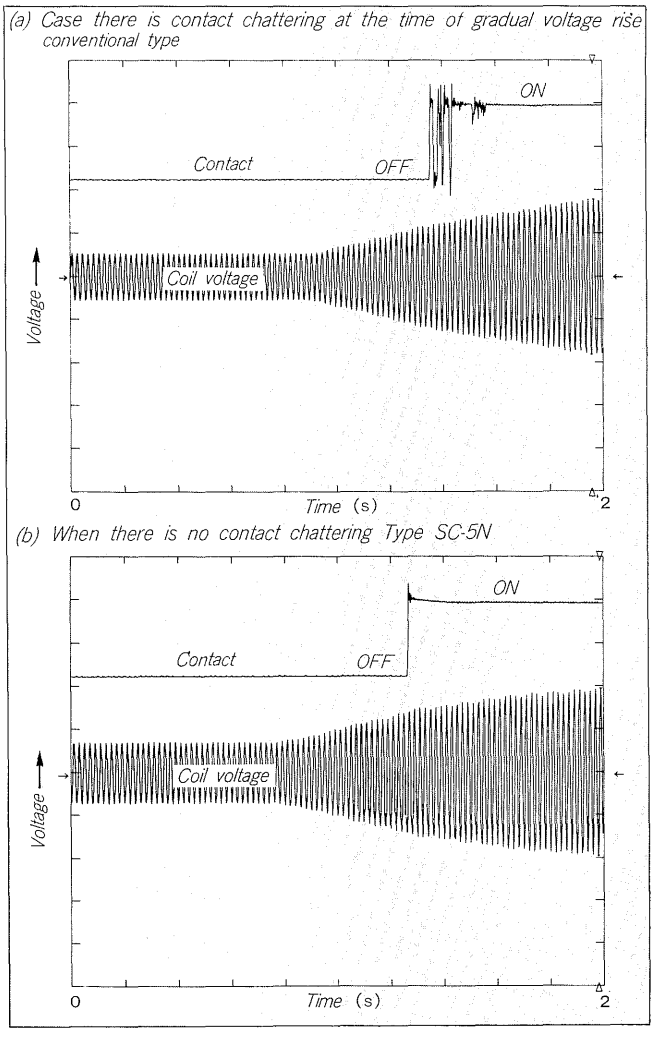
4.1.1 Voltage sudden drop characteristic

In case the power source capacity is small or the cable length of the circuit is long, as a large starting current may run when the contact makes during the motor starting, we have carried out the test taking into consideration of sudden drop of the control voltage and we have obtained the result mentioned in *Fig. 8*. No chattering was produced in the contact when we have reduced the voltage down to 65% of the rated voltage.

4.1.2 Voltage slow raising and lowering characteristics

The test was carried out by taking into account of simultaneous starting of various motors after recovering a current interruption, in such case, we can think of case in which the voltage would recover together with the increase of rotating speed of electric motor. However, even in such case, as shown in *Fig. 9*, the contact will open and close without producing any chattering with the voltage smaller than 85% of the rated voltage.

Fig. 9 Example of contact chattering during slow rising of voltage



Likewise, in case the voltage is lowered gradually, as shown in *Fig. 10*, no chattering of contact will be produced.

4.1.3 Instantaneous Current Interruption Characteristics

The behaviour of the magnetic contactor differs depending on the magnitude of residual voltage determined by the line conditions, when there emerges instantaneous current failure. As a rule, the following will occur:

(1) When the residual voltage is more than 50%, the circuit will not opened. *Fig. 11* shows this behaviour.

(2) When the residual voltage is less than 50% of the rated voltage:
   (a) If the instantaneous interruption is less than 20 ms, the circuit will not be opened.
   (b) When the instantaneous current interruption surpasses (a), the circuit will be opened once, then it will be closed again when the voltage is restored. *Fig. 12* shows this behaviour.

Fig. 10 Contact behaviour during slow lowering of voltage (Type: SC-5N)

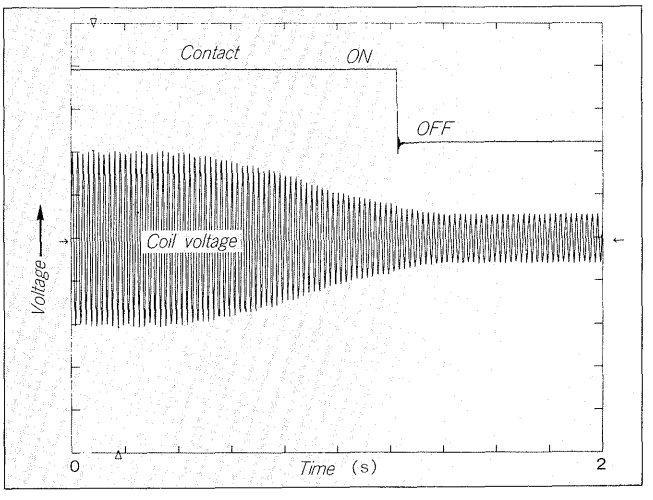


Fig. 11 Characteristics at the time of instantaneous current interruption (In case the residual voltage is more than 50% of rated voltage)

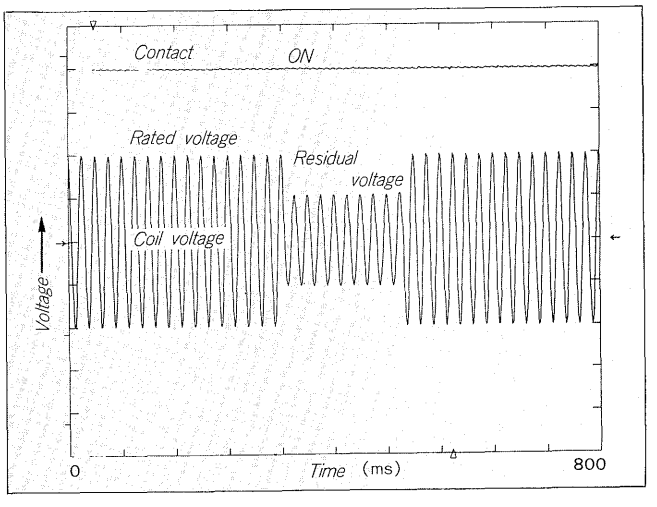
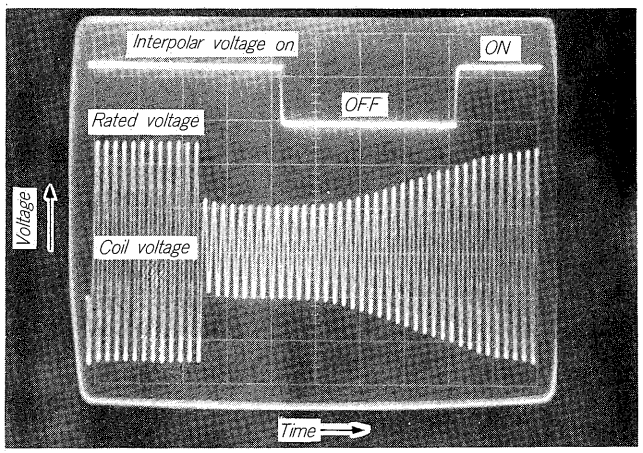


Fig. 12 Characteristics at the time of instantaneous current interruption (In case the residual voltage is less than 50% of rated voltage)



In case it is necessary to keep the circuit closed positively even when instantaneous current interruption occurs, use the motor starter of delayed release type or mechanical latch type.

4.2 Magnetic noise

Conventionally, for the magnetic contactor of AC exciting type, smoothening of attractive force is effectuated by shading coil in order to prevent beating generated by the AC pulsating attractive force. However, by this method, waste wire material left over at the time of manufacture and chips would intrude into the magnetic contactor, and in case these are caught between magnets and rusted on their contact surface due to condensation, a considerable noise has been produced.

For the super magnet system, it has adopted fundamentally DC exciting system, there is no need of providing shading coils, and no noise would be generated even in the case mentioned above.

It has a dust-proof construction that prevents intrusion of foreign materials into the magnet parts, so that no foreign materials would penetrate into the interior and, at the same time, rusting can also be avoided.

In order to prove the efficiency of these systems, we have conducted accelerated tests on the device by setting it under a severe operating condition. The result is as indicated in the following. And as it is known from the result, the device is highly acceptable for practical use.

(1) Chip test

Though the magnet unit is of dust-proof structure we have made sure that no minute chips had penetrated into the device during panel manufacturing process. A magnetic contactor is mounted on the steel sheet of 3.2 mm in thickness under the normal operating conditions and in the position of 30 cm right above the magnetic contactor installed on the steel sheet, two holes of 5 mm in diameter were opened by a drill and dropped chips produced upon the magnetic contactor. Under this condition, the magnetic contactor was opened and closed for 100 times and checked if it has produced any beating. Also, after the test, the device was opened to see if there is any harmful intrusion of chips into the magnet unit.

The noise characteristics after the test was 30 dB, and the test result was considered to be good.

(2) Humidity test

In order to test the device on the noise characteristic when the pole surface of the magnet is rusted, the device was exposed to the environment of 40°C in temperature, 90 to 95% in relative humidity during 1,000 hours. As the result, rust was observed on all the pole surface, there was no abnormal sound.

(3) Salt-water splash test

Under the conditions established by BV Standards which are very severe for marine products, the test was conducted as follows:

35°C, pH 7.0, concentration 5%,

volume of salt water per hour for 80 cm^2 : 1.3 cm^3

Splashing time: 48 hours

After the test, no abnormal noise characteristics have been recognized.

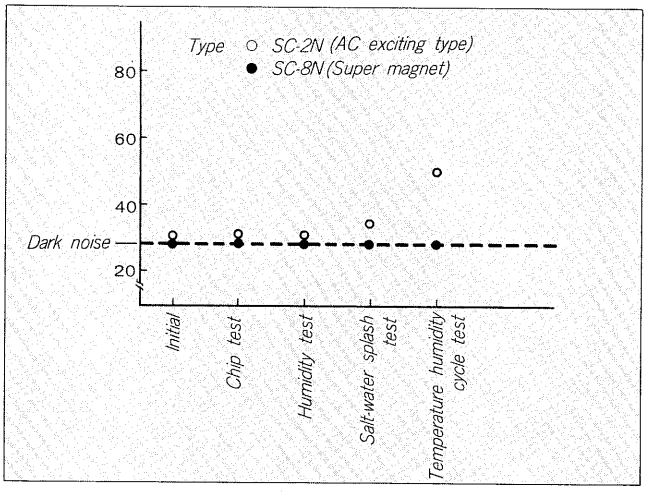
(4) Temperature-humidity cycle test

In order to check the behaviour of the device when the pole surface was abnormally rusted surpassing the normal limit of use, drying and dew formation were repeated on the pole surface. The test conditions being: Temperature, 40°C; Humidity, 90 to 96% for 12 hours then temperature of 25°C, humidity of 95 to 100% were applied for next 12 hours, and this cycle of drying and dew formation was repeated for 20 cycles. In general practice, for example for the marine products, 2 cycles are established for judging the resistance. As the result of this test on our device, rust was observed to form on the pole surface with a thickness of about 0.4 mm all over the surface, but the device with super magnet did not show any abnormal operation.

4.3 Assessment of reliability of electronic circuit

For super magnet system, its functionality is enhanced

Fig. 13 Noise characteristic before and after various environmental tests



by adding an electronic circuit to conventional manget. This electronic circuit withstands shocks of opening and closing of the magnet of many times and should be of equal strength in withstanding adverse environments such as thermal cycles ambient conditions to that of conventional products or more. For this, structure-wise, electronic parts would not receive any adverse effect from the shock and thanks to improvement of resistance to ambient conditions and humidity, by adopting special resine to protect printed circuit boards on which electronic parts are mounted. These structures are proved to be suitable for the correct functioning of the device working under conditions required by the market and to withstand any and even more severe conditions than those withstood by the conventional products.

From the point of view of assessment of the reliability, for proving the conditions of use established for this super magnet, as the ambient conditions to be met in particular, the following tests have been conducted on the device: resistance to repeated shocks, anti-humidity characteristics, anti-thermal characteristics, repeated thermal cycles, anti-noise characteristics in electronic circuits.

4.3.1 Mechanical life test

In order to prove the resistance to repeated shocks due to opening and closing of the circuit and that of electronic itself, tests were conducted on the test panel on which several devices are mounted under the condition of the devices being exposed to repeated opening and closing shocks and under those receiving opening and closing shocks from other magnetic contactors. Further, for these tests, repetition of thermal stress when strongly excited, and surge voltage (maximum of 2,000 to 3,000 V) generated when other devices open and close, are superposed.

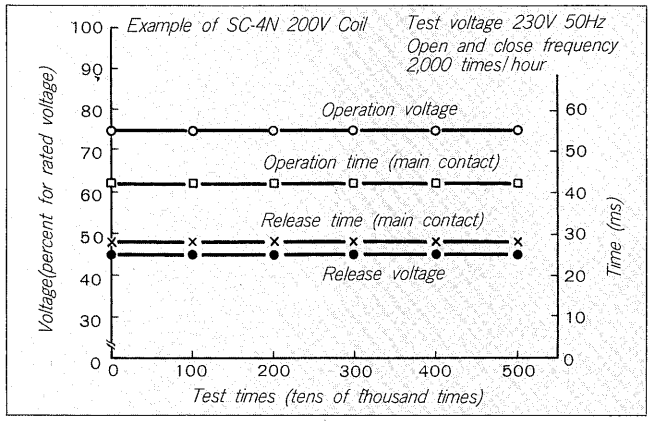
Under these conditions, opening and closing are made more than 5 millions of times and it was confirmed that there were no mechanical damage nor anomalies in operational characteristics.

4.3.2 Thermal limit test (Step stress test)

The aim of the test is to know the limit temperature in which the product will break down when it is exposed, and to know the failure point and mode. The test was conducted by raising 10°C every time from the ambient temperature of 80°C and the product was exposed to each degree of that temperature for two hours.

Then the result obtained has been that the device operated normally until 130°C and at 140°C, a varistor turned into a failure mode from short circuit to open circuit. However, no failure spreading to peripheries has been observed.

Fig. 14 Example of results of mechanical life test



4.3.3 High-temperature continuous exciting test.

The device was excited continuously with 130% of rated voltage in the ambient temperature of 80°C. After passing 7,200 hours, we have confirmed that there was no abnormality in the operation of the device. This equals to 230,000 hours in 40°C, by Arenius' law.

4.3.4 High temperature ON/OFF test

The device was made ON and OFF with an ambient temperature of 80°C, excitation of 130% of rated voltage, with a frequency of 1,200 times/hour for more than 5 millions of times. No anomalies were found in the electronic circuit functioning.

4.3.5 Low temperature ON/OFF test

ON/OFF operations were made continuously with an ambient temperature of −25°C for 125,000 times, and no anomalies were found out in the operation.

4.3.6 Thermal shock test

Inferring the temperature to which the product will be exposed during its transport and in storage, a test in 10 cycles of −40°C for two hours and 100°C for the next two hours was conducted, and no operational anomalies were observed.

4.3.7 Humidity resisting test

In order to prove that the device is suitable for working for a long time under the high temperature and high humidity, the following two tests were carried out and found out that there was no abnormality in the device.

(1) Humidity test

40°C, 95% RH, 1,000 hours.

A voltage was applied to the parts where there is danger of silver transfer and electrolytic corrosion.

(2) Temperature and humidity cycle test

Device was exposed to a condition of 40°C, 90~96% RH and 25°C, 95~100% RH, twelve hours each, and dew formation and drying were repeated for twenty times.

4.3.8 Heat cycle test

Magnetic contactor is exposed to repetition of various sorts of temperature change due to repetition of current running and seasonal factors. Under such condtions, in order to confirm that there would be no functional deterioration due to repeated temperature change and metal fatigue, we have carried out endurance test against repeated temperature change, and we have obtained the results showing that there is no notice operational anomaly.

As amplitude of temperature change, we have presumed that of diurnal temperature change, seasonal temperature change and that due to current, and as the accelerating factor, we have adopted the value of $\Delta T = 105°C$ surpassing the endurance for more than 500 times.

4.3.9 Anti-noise test

In due consideration of the electro-magnetic environ-

ment to which the magnetic contactor will be thrown, various sorts of noise tests have been conducted, whose results are summarized as follows:

(1) Noise simulator 2,000 V No anomaly
(2) Contactor ON/OFF noise No anomaly

This test includes in addition to those of high-frequency tester of square-wave type (including triangle waves) commercially available in the market, high-frequency noise and ringing surge. The test features in larger pulse width and quicker rise time. Further it is provided with randomness of phase, its noise peak value is random, discrete saw-tooth wave (burst noise, showering arc noise) and such composite characteristics, and tough it has some difficulty in quantative assessment and reproductivity, it is a simulation of practical conditions in severe form, and it has a record of many applications as extremely effective test method. *Fig. 15* shows an example of noise waveforms.

Fig. 15 Example of contactor ON/OFF noise

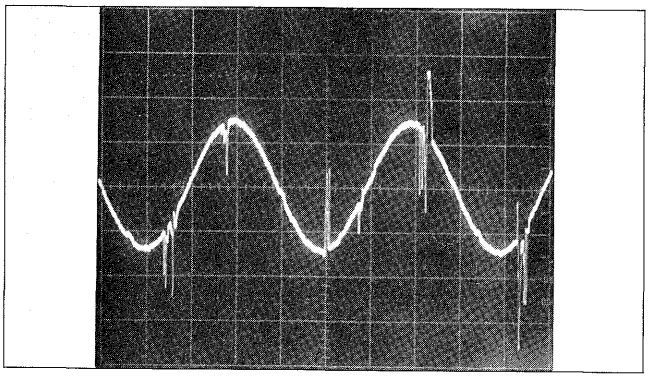
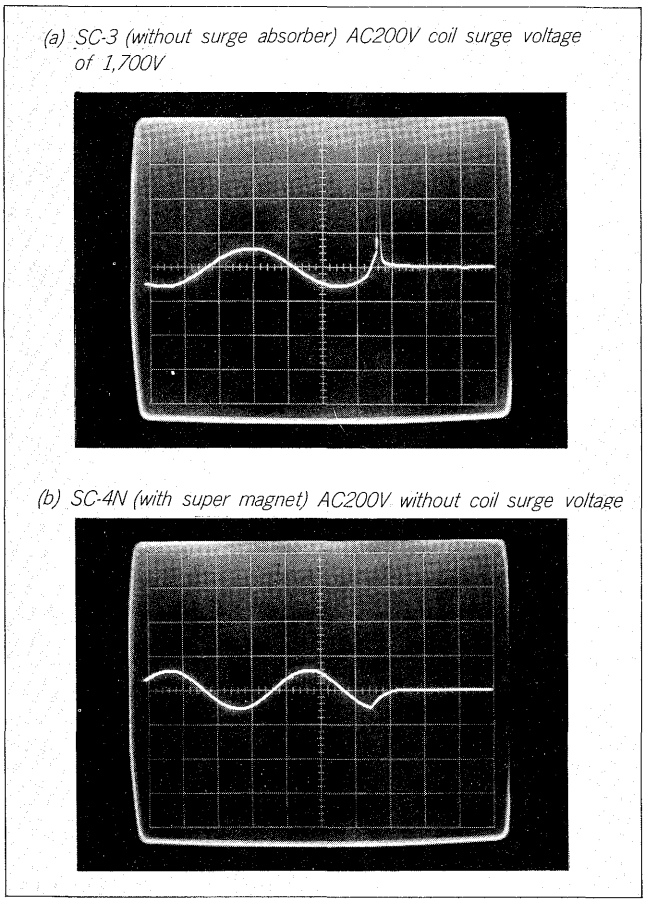


Fig. 16 Example of coil surge waveform



(3) Anti-magnetic field

Check was made as to find out if, when an overcurrent flows on the main circuit, the circuit would receive any influence from the magnetic field generated by the current, by taking the following procedure:

(a) Flow current equal to 13 times more of the rated current to main circuit.
(b) Flow I_p = 200 kA in parallel with the tested machine.

By the above tests, no anomaly has been found.

(4) Transceiver noise 10 W No anomaly
(5) Parallel cable test

For proving the influence of stray capacity between cables of control circuit, we have carried out tests in the permissible cable length in consideration of voltage drop, and found out that there was no anomaly at all. An example of the test was that it was made on SC-4N (200 V coil), and no anomaly was found out up to the length of 1 km.

4.3.10 Coil ON/OFF

For super magnet system, a surge absorber is incorporated so that, the surge voltage at the time of interrupting the coil current will not appear at the control circuit *Fig. 16* shows the voltage at the time of coil current interruption.

This has been the principal of the results of reliability assessment. For New SC Series, standard working temperature of −5 to 40°C as the general is adopted, and the in-panel temperature is fixed as 50°C. And it was proved from the results of tests mentioned above that the new Series machines operate without anomalies under these environmental conditions just as in case of conventional products.

The MTBF of this electronic circuit is calculated to be about 2,000,000 hours and as mentioned before, in the development stage, various reliability assessments have been conducted and, at the same time, in the mass production stage, all electronic parts that are used for the products are those that have passed a rigorous type test, and all the circuit units underwent whole number screening, circuit check by in-circuit tester and other severe quality control and functional tests in order that we may have perfect products. Furthermore, by periodical sampling test, check was made against lowering of the reliability.

Also in the practical operating stage, not only the test in the laboratory as mentioned above, we are constantly checking on the products reliability by installing them actually in the sites presumed to be severe working site for this product as water purifying plants (environment of chlorine), galvanizing plants (corrosive and humid environment), brazing plants (high-frequency noise), ceramic plants (dust), kitchen (high temperature and high humidity), etc. and checks are made periodically under the acutal working

conditions to confirm that there is no anomaly in their function.

5 OTHER FEATURES OF NEW SC SERIES MOTOR STARTER

Motor Starter is used for opening and closing of various loads as the last stage of control, and recently it is used more often in combination with electronic control devices that are gaining more and more popularity recently as the main control device, and it is more and more demanded to have a function with which signals can be received directly from the electronic equipment.

5.1 Improvement of contact reliability of auxiliary contacts

The auxiliary contact of motor starter is used, conventionally in the lamp's display circuit, self-retaining circuit and interlock circuit, etc. and its voltage is generally 100V or 200V. However, recently, it is used in combination with electronic equipment represented by sequencers, and the lamps are now LED's, and the auxiliary contacts are often used directly for input of these electronic circuits. That is, the contact reliability must be sufficient for level of input (DC 24V, 10 mA) to typical sequencers.

We can cite dust coming from outside, friction powder produced within and chemical formation of the contact surface as the cause of contact failure. Taking the measures against these, conventionally, we have adopted a system eliminating positively the foreign matters from the contact surface as spits slide mechanism or double contact system that reduces the causing of failures in a probability-wise way, as well as use of gold contact that is highly anticorrosive metal. However, as the auxiliary contact of the motor starter is used for the load of very wide range of current from 10 mA to 10A, from the point of view of useful life, double-contact system and gold contact have come to be used exclusively for low level loads and they constituted articles of special order.

For New SC Series, by developing the conventional spits slide mechanism and aiming at reduction of early phase failure and stabilization of long-term contact, we have adopted the forced slide system as shown in *Fig. 17*. The sliding of contact is made mechanically by making the contact support in a form of "〈" and for reducing the early-phase failures, the contact surface was made in rasp form, and we have adopted structure and materials that has small friction for the sliding parts. Also, dust-proof construction is adopted for main body of the magnetic contactor avoiding adherence of dust on the contact surface, thus obtaining the stability of contact. *Fig. 18* and *Fig. 19* show the difference between the new products and the conventional ones in contact resistance and contact reliability, and from the figure, it is obvious that the forced slide mechanism is far better than conventional spits slide mechanism.

5.2 IC input/output interface unit

For New SC Series Motor Starter, many devices are

Fig. 17 Forced slide mechanism

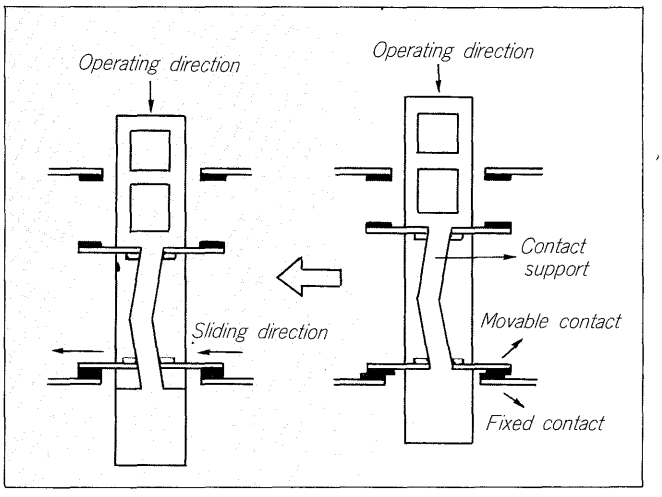


Fig. 18 Result of continuous measuring test of contact resistance

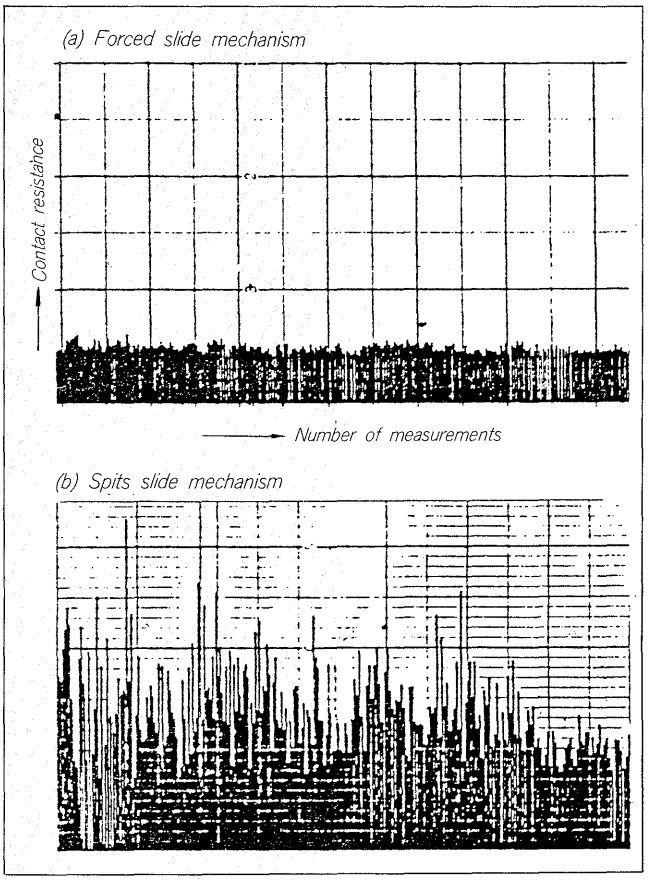


Fig. 19 Result of tests on contact reliability

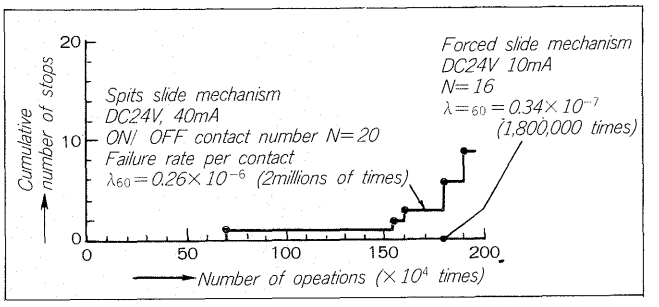


Fig. 20 IC Input/output interface unit

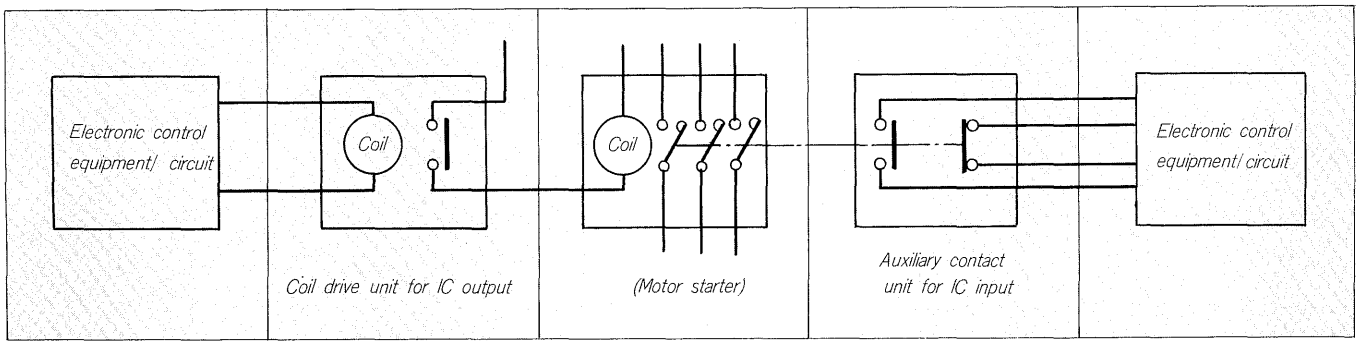
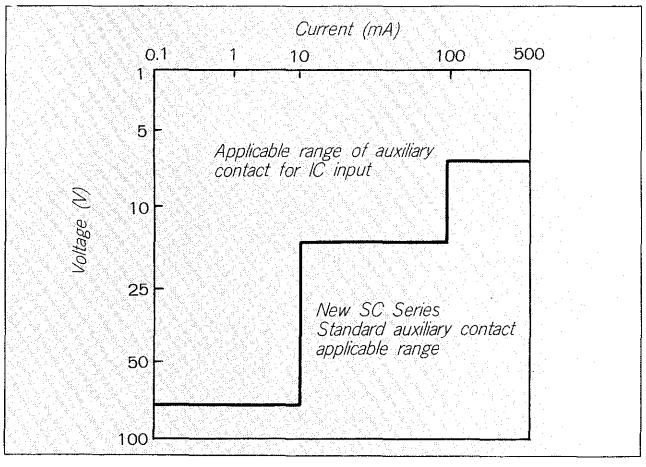


Table 2 Input current of various digital ICs and their application

Digital IC			Whether auxiliary contact unit for IC input can be applied or not.	Remarks
Type		Input current		
T T L	Standard TTL	1.6mA	○	
	H-TTL	2 mA	○	High-speed type Tendency is not to use it.
	L-TTL	0.2mA	○	Low power consumption type Tendency is not to use it.
	LS-TTL	0.4mA	○	Mainstream in actual TTL-IC, and low power consumption and high-speed type
	S-TTL	2 mA	○	Super-high speed type and shot key type
	ALS-TTL	0.2mA	○	Product improved from LS-TTL, aiming at lower power consumption and higher speed
	AS-TTL	0.2mA	○	Improvement of S-TTL
C-MOS		μA order	×	

Fig. 21 Applicable voltage and current range of auxiliary contact unit for IC input



made for matching with input and output circuits of electronized equipment, however, in order to further improve the functionality, "auxiliary contact unit for IC input" and "coil drive unit for IC output" as shown in *Fig. 20* are available.

Table 3 Specification of coil drive unit for IC output

Control unit	Rated voltage	DC 24V
	Pick-up voltage	Less than 70% of rated voltage (at 20°C)
	Drop-out voltage	More than 10% of rated voltage (at 20°C)
	Maximum allowable voltage	Less than 130% of rated voltage
	Rated power consumption (operating current)	0.2W (8.3 mA)
Contact unit	Maximum open/close voltage	AC 380V DC 125V
Operating ambient temperature (inside the panel)		−5 ~ 50°C

Table 3 Applicable magnetic contactor for coil drive unit for IC output

Type (in abbreviated form) / Operating coil voltage	1N	2N	2SN	3N	4N	5N	6N	7N	8N	10N	11N	12N	14N
DC 24V	○	○	○	○	○	○	○	–	–	–	–	–	–
DC 48V	○	○	○	○	○	○	○	○	○	○	–	–	–
AC100V	○	○	○	○	○	○	○	○	○	○	○	○	○
AC200V	○	○	○	○	○	○	○	○	○	○	○	○	○

○: Applicable contactor type

The auxiliary contact unit for IC input, by incorporating a reed switch, is an auxiliary contact unit with super high reliability that made direct input to electronic control circuit possible. This is applicable even to the application that may not be made by a standard auxiliary contact adopting the slide mechanism of, for example, adverse condition as to the place where there is corrosive gas is abundant, and is optimum for inputting into electronic circuit of low level (5V, 2 ~ 3 mA) as micro-computers. *Fig. 5* and *Table 2* show the voltage and current range and the range of input current of various types of digital IC and their applications.

On the other hand, the coil drive unit for IC output is an interface unit that enabled direct driving of motor starter with its low level output (24V 10 mA) without providing a driver circuit of exclusive use on the electronic control equipment composed of micro-computer and IC's through

Table 5 Motor starters directly drivable with output cards of FUJI PC

	Type of output cards		Relay			Triac							
	Output circuit voltage		DC24V	AC100V	AC200V	AC100V				AC200V			
	Rated current		2A			2A	1.5A	1A	0.5A	2A	1.5A	1A	0.5A
Programmable controler (PC)	Series	μTmicro		●		–	●	–	–	–	●	–	–
		μTmini, μYmini, μKmini		●		●	–	–	–	●	–	–	–
		μT, μY		●		●	–	●	–	●	–	●	–
		μH		●		●	–	●	●	●	–	●	●
		μK		–		–	–	●	–	–	–	–	–
		B		●		●	–	–	–	●	–	–	–
Magnetic contactor	SC–1N		○	○	○	○	○	○	○	○	○	○	○
	SC–2N		○	○	○	○	○	○	○	○	○	○	○
	SC–2 SN		○	○	○	○	○	○	○	○	○	○	○
	SC–3N		○	○	○	○	○	○	○	○	○	○	○
	SC–4N		○	○	○	○	○	○	○	○	○	○	○
	SC–5N		○	○	○	○	○	○	○	○	○	○	○
	SC–6N		○	○	○	○	○	○	○	○	○	○	○
	SC–7N		○	○	○	○	○	○	○	○	○	○	○
	SC–8N		○	○	○	○	○	○	×	○	○	○	○
	SC–10N		○	○	○	○	○	○	×	○	○	○	○
	SC–11N		–	○	○	○	○	○	×	○	○	○	○
	SC–12N		–	○	○	○	○	×	×	○	○	○	×
	SC–14N		–	○	○	○	○	×	×	○	○	○	×

(NOTE) (1) ● denotes type of output cards available for FUJI PC.
(2) ○ denotes magnetic contactors that can be directly driven by output cards of FUJI PC.
(3) The conditions of choice mentioned in this table are for ambient temperature less than 40°C, ON/OFF frequency less than 600 (times/hour), and work factor less than 50%. In case the machine is required to work beyond these conditions, check the working condition by referring to each PC's Users' Manual and/or other documents.

incorporating small powered relays. This unit will become more effective in case it is desired to use the transistor output that can provide more number of outputs than triac outputs or relay outputs, or in case motor starter is desired to be driven directly from the electronic control equipment composed of IC's and micro-computers. *Table 3* and *Table 4* show the specifications of this unit and applicable motor starters, respectively.

These input/output interface units take advantage of the auxiliary contact unit of motor starter and for that reason, it is easy to mount and dismount this device to the main body of the motor starter.

The capacity of control magnet for this New SC Series motor starter is reduced in a lage scale due to adoption of super magnet and as shown in *Table 5*, it is possible to drive directly by programmable controller relay and triac output.

5.3 "INO INC" auxiliary contact of thermal relay

Conventionally the auxiliary contact of the thermal relay is often "1c" contact structured, and for tripping the motor starter coil "NC" contact is sued and "NO" contact is used for lighting alarm lamp with the same potential to that of coil. However, due to the rapid diffusion of sequencers, there are many increased cases in which contacts "NO" and "NC" are used independently as the case of inputting alarm signal to sequencer. For this in this new series, contacts of the thermal relays have been now structured as "INO INC" and that made the use of the equipment easier.

6 SUMMARY

Outlines of the new products with their contents, performance and reliability are described in this report. We have a firm conviction that the New SC Series are the epoch making motor starter raising the operational reliability through adoption of IC mounted super magnet on basis of experience and vast accumulation of technology of long standing of FUJI Electric. We would like to have comments on the products from our clients and like to use them for reference for future innovations if there may to manufacture better and impeccable products. We cordially invite your constructive comment and request your kind cooperation.