

Technical Trends and International Standardization Activities in Electromagnetic Relays for Control Systems

Takeshi AOKI[†], Fellow, Kenjiro HAMADA^{††}, Nonmember, Kiyoshi YOSHIDA^{†††a)}, Senior Member, and Koichiro SAWA^{††††}, Fellow

SUMMARY Electromagnetic relays were developed in the first half of 19th century. At the beginning, they have been mainly used for telecommunication systems, afterwards, their uses were expanded, they have been applied to various systems such as industry products, traffic control equipment, household appliances and so on. During this time, international standardization on them became active, Japan took part in the auxiliary relay committee in the International Electrotechnical Commission (IEC). Recently, Japan is playing an important role in the committee activities. In this paper, transition and the present circumstance on technical trends of the electromagnetic relays and their activities on international standardization are described, talking about some future prospects.

key words: electromagnetic relays, contact failures, IEC/TC94, JIS C

1. Introduction

Electromagnetic relays (This term will hereafter be abbreviated “the relays”), which had been developed in USA in 1836, were used for magnetic type telephone exchange systems in 1878. After then, they continued to be applied to exchange systems such as the step by step (S × S) and the cross bar (XB), as key components in electric communication systems till 1960s~1970s.

Here, in the 1970s, when electronic technologies made remarkable progress and systematic compositions of semiconductors have advanced rapidly, these new technologies have enabled to make digital exchange systems. This introduction of digital systems made demand of electromagnetic relays to decrease rapidly in the electrical communication fields in 1980s. It feared at one time that the market of electromagnetic relays might be driven out by the digital components.

However, there were no signs of the market decrease. The markets stretched to extremely wide industry fields such as FA systems, OA equipment, electrical components for car, traffic control equipment, household/emergency apparatus and so on, making use of merits of electromagnetic components with high capacity load etc. (Table 1). Especially,

Table 1 Application examples of the electromagnetic relays

Fields	Examples of applied systems
Factory Automation	Manufacturer control apparatuses, Machine tool, Control apparatuses, Plants, Automatic doors, Programmable controller
Home applications	Microwave oven, Washing machine, Refrigerator, Refuel, TV, Air conditioner
Office automation	Copy machine, Printer, Scanner, Resister, Vending machine, Measuring instrument
Information communication	Telephone, FAX, Potable terminal, NW equipment
Automobile	Electric equipment, Safety equipment, Auto antenna
Transport system	Traffic signal, Elevator, Escalator, Electric train, Airplane
Disaster	Fire alarm, Gas leak detector, Antitheft device
Optics	Camera, Projector
Electric power	Smart grid, Solar power generation system, Solar battery panel

the following uses were remarkable: ON/OFF or switching of signal/test/power circuits, Transmission from detecting result by sensor or scanning switch to signal circuits, ON/OFF of output components such as motors and lamps by signal from control circuits.

It can be said that the main stream of relay market changed over from the relay for the electrical communication equipment to the relay for control systems from the time when relay market were expanded rapidly. Here, the relays for the electrical communication equipment are heading for miniaturization/high density, low consumption power for applied equipment and the reduction of labor in production process, trying to make coexist mounting with electric parts.

Recently, relays take role to secure reliability and safety of systems in extremely wide industry fields. Especially growth of relays for automobiles and the relays for printed boards, current capacity of which is more than 2A were remarkable. This is indicated also from market shares that electromagnetic relays are advantageous in higher capacity areas, compared with semiconductor relays.

On the other hand, standardization plays extremely important roles in progress of technologies and industries. Japan took part in the auxiliary relay committee in IEC in 1960s. At first, a lack of human resources delayed operations, however, they have been filled in order, Japanese members have moved to play an important role in the operations under the backgrounds of high production technolo-

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[†]The author is with NECA, Tokyo, 105-0013 Japan.

^{††}The author is with Bestact Solutions, Yukuhashi-shi, 824-8511 Japan.

^{†††}The author is with Nippon Institute of Technology, Saitama-ken, 345-8501 Japan.

^{††††}The author is with Keio University, Yokohama-shi, 223-8522 Japan.

a) E-mail: yoshida@nit.ac.jp

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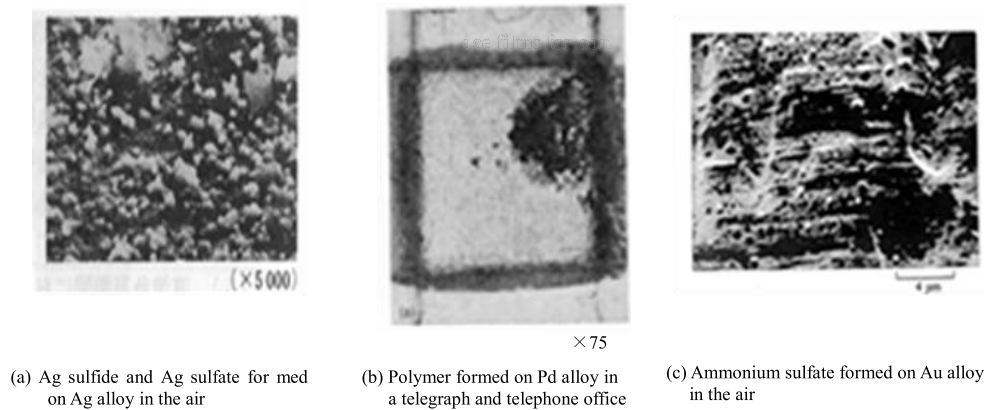


Fig. 1 Characteristic contact films formed on contact surfaces in the relays

Table 2 Transition of contact surface films in the telephone exchange systems in Japan

Surface films Speech Path Switch Contact materials		Films due to corrosion			Films due to catalyst	
		Oxides	Sulfides Sulfates	Chlorides	Polymers	Ammonium sulfate
Two motion (S×S, 1929)	Cu alloys	Many	Many	Middle	—	—
	Ag alloys	Middle	Many	Middle	—	—
Crossbar (XB, 1955)	Pd affiliate alloys	Small	Small	Middle	Many	—
XS (Electric, 1972)	Au affiliate alloys	—	—	—	—	Many

Inside of () is telephone exchange system and introduction year in Japan

gies, recently.

In this paper, transition and the present circumstance on technical trends of control relays like these and their activities on international standardization are described, talking about some future prospects [1], [2].

2. Technical Trends and a New Subject of Standards of Relays for Control Systems

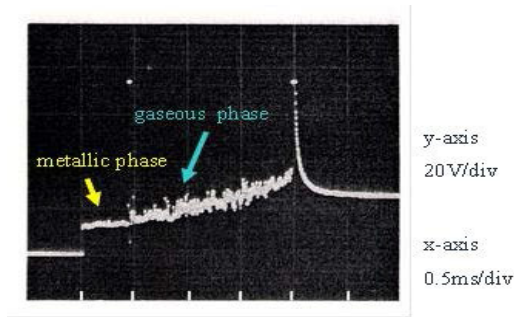
2.1 Failures and the Measures in Electromagnetic Relays

Failures are divided roughly into contact resistance failures and opening failures in the relays. In contact resistance failures, the contact surface films formed in lower capacity load area are the most dominant cause. And the formation mechanisms of contact films depend on largely contact materials. In telephone exchange systems, contacts silver/copper series, palladium series and gold series were used for the step by step systems (S × S), the crossbar systems (XB) and the electric exchange systems (EX) respectively [3]. Each system were renewed by the failures due to formation of the following contact films: 1) metal compounds of oxide, sulfide, sulfate and chloride and so on were synthesized due to reactions of contact metal and artificial air pollution gases in the air in S × S [4]. 2) organic films (polymer) were synthesized due to catalysis action of contact material in the air with organic gases in XB [5] and 3) ammonium sulfate ((NH₃)₂SO₄) were synthesized due to catalysis action in

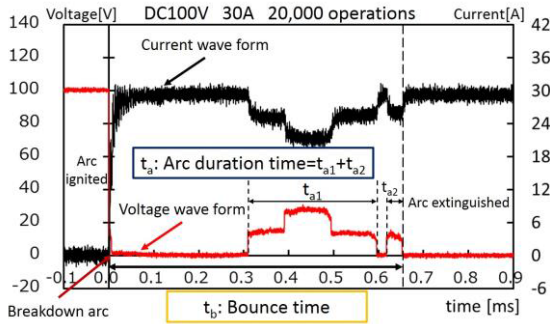
the air with ammonium gas from cable resins and air pollution gases in EX [6] (Fig. 1 and Table 2). A drastic measure for these contact resistance failures was enclosure by which contacts are blocked from the air. The examples are the Remreed (a kind of reed relay) used for the speech path switches in USA and the sealed multi-contact matrix switch used for the Electric exchange systems in Japan [7].

On the other hand, opening failures are caused by welding due to arc discharge, bridge and joule heat, and adhesion due to relative sliding motion. Arc discharge is the most dominant in causes of them, and occurs at opening contacts and at closing contacts. Typical voltage and current waveforms at opening and closing contacts are shown in Fig. 2 [8]. Arc discharge is a kind of plasma state, where contact erosion, transfer and oxidation etc. occur as the state is kept in high temperature [9].

Welding occurs at both making and opening contacts. At making contacts, arc discharge may occur by the breakdown of contact gap or re-breaking after the first touch of contacts or at contact bounce. During arcing, arc spots are melted and melted part may be solidified after they close again. If opening force is not strong enough to break the solidified part, the contacts cannot break and the welding occurs. The welding may occur even at the final stage of bounce. The contacts are going to re-open but the opening force is not enough to break contacts. Then, the contacts are partly melted by decreasing the contact force which causes the decrease of contact spot area to make the contact surface



(a) Voltage waveform of steady arc at break



(b) Voltage and current waveforms of bounce arcs.

Fig. 2 Typical waveforms of arc discharge at break and make contacts.

heated to melting point, and the contacts come back to be welded.

At breaking contacts, the contact part which is weakly welded at making contacts, would be pulled out by opening force, and cause oscillation of the contact spring. It might cause welding like contact bounce [10], [11].

Installation of contact protection methods (called spark killer or arc quenching), such as blowing out by magnet [12], suppression of arc discharge due to sealing in gas with high thermal conductivity [13] and spark quenching circuits [14], [15] is valid for prevention of arc discharge.

2.2 Technical Requirement for Control Relays

Now, the relays have had the following subjects required from applications:

The high capacity, miniaturization, high frequency and energy saving are required for control systems in order to deal with rapid increase of telephone demand and diversification of communication methods. Accompanied by them, high density-miniaturization and energy saving were required for relays also, on the assumption of assurance of high reliability, furthermore, technologies for accomplishment of the requirements have been created [1].

Besides, the high function and high performance were advanced in each system, the technologies for realization of them were required also for relays, since the control systems leaded relay markets in 1960s, Furthermore, weight saving, energy saving and high reliability were required in

the miniature relays. At the same time coexistence with electrical components were kept moving.

On the other hand, withstand voltage 1000V for automobile relays and withstand current, several hundred A level were required, in the relays for the middle and high voltage and current relays. Their markets were superior to the relays for printed boards. It is necessary to grasp accurately advanced technologies and to create technical bases for spread of the demands and assurance of market.

Recently, electrical and electronic programmable electric safety systems (E/E/PE) technologies are used in systems such as transportations, nuclear plants, process equipment and key industry systems, in which high safety are required, and guide of functional safety for safety assurance of the systems with E/E/PE technologies are specified in IEC (International Electro technical Commission), furthermore, Systematic Capability in Safety Integrity Level became to be required also for components such as relays. It must be paid attention to what functional safety specify is required in addition to technical requirements for multipurpose relays.

As permanent subjects of contact metals, the following big problems have been took up: 1) environmental issues due to RoHS Directive of specified hazardous chemical substances and usage restriction substances such as lead solder, Cd and Hg, 2) depletion of resources such as the precious metals, for a long time. Alternative materials have been developed hard for resolution of the problems, however complicated assignment on cost-effectiveness is left, these issues are important subjects which have to be continued also in the future.

2.3 Specification from International Standards (IEC & ISO)

Standards of national level were required to form basis of international standards for reduction of the technical trade barriers between IEC member nations in 1990s, as mentioned in detail in the clause 3.1. In Japan, JIS was specified in principle to be translated from the international standards (IEC & ISO) in future. It is important matter that consistency between JIS and IEC or ISO is checked considering of time lag in translation.

3. Activities to International Standardization Commission

3.1 Transition of Activities in Japan

Standards are rated in the following priority orders in de jure standards (official standards), 1) international standards (IEC, ISO, ITU, etc.), 2) community standards (EN, SAE, etc.), 3) national standards (JIS, DIN, ANSI, etc.), 4) group standards (MIL, UL, etc.) and 5) brand standards (BELL, JRS etc.). Many of activities in them are turned to IEC and JIS, which are key standards and are used mostly in Japan.

Japanese technical committee on the relays participated internationally to IEC/TC41 (Electrical relays) in latter half

Table 3 IEC standards and JIS standards used now

Grouping		Items	Number of IEC standards (IS year)	Number of JIS standards (JIS year)
Product standards	Relay products	General and safety requirements	IEC 61810-1 Ed.4 (2015)	JIS C 4540-1 Ed.3 (2010)
		Relay with forcibly guided contacts	IEC 61810-3 Ed.1 (2015)	
		Reed relays	IEC 61810-4 Ed.1 ^{*1}	JIS C 61810-4 Ed.2 (2018)
		High capacity relays	IEC 61810-10 Ed.1 ^{*2}	
		Solid-state relays	IEC 62314 Ed.2 ^{*3}	
		Telecom elementary relays	IEC 61811-1 Ed.2 (2015)	
	Structure components	Reed switches (Generic specification)	IEC 62246-1 Ed.3 (2015)	JIS C 62246-1 Ed.1 (2016)
		" (Individual)	IEC 62246-1-1 Ed.2 (2018)	JIS C 62246-1-1 Ed.1 (2016)
		" (TR)	IEC TR 62246-3 Ed.1 (2018)	
	Applied systems	Time relays	IEC 61812-1 Ed.2 (2011)	JIS C 61812-1 Ed.1 (2014)
Performance/Test method standards		Reliability	IEC 61810-2 Ed.3 (2017)	
		Verification of B_{10} values	" -2-1 Ed.2 (2017)	
		Test and measurement procedures	" -7 Ed.2 (2006)	JIS C 5442 Ed.1 (1996)
Basic standards		Vocabularies	IEV 444 and 445	

^{*1} under deliberation, CD stage in 2018; ^{*2} under deliberation, CDV stage in 2018; ^{*3} under deliberation, CD stage in 2018.

of 1960s. Here, in Japan, standards on the lower level components like control relays were covered mainly at IEC/TC 48 domestic committee (Electromechanical components) in the Institute of Electronics, Information and Communication Engineers (IEICE).

So, a joint committee of the TC 48 and TC41 in the Institute of Electrical Engineers of Japan (IEEJ) was formed temporarily, the documents on control relays were deliberated domestically at the joint committee. Afterwards, in 1992, TC41 was separated to TC94 (All-or-nothing electrical relays) and TC95 (Measuring relays and protection equipment), the subjects of the relays have become to be able to be deliberated independently at TC 94, domestic technical committee which belongs to Nippon Electric Control Equipment Industries Association (NECA) [16].

The present subjects in IEC/TC94 are the following points: 1) developments standards on high voltage relay and reed relay, proposed from Japan 2) revisions of standards on characteristics and test methods. Especially, serious efforts have to be made for the former subjects proposed from Japan.

Here, JIS standards are managed by Japanese Industrial Standardization Committee (JISC) on the basis of the Japanese Industrial Standardization Act (established in 1949) and are established by duty ministers. Besides, in relays, practical works are carried by the technical committee on the relays, which is organized under the Standard Board, NECA usually designated from the JISC.

There were no special obligation till early half of 1990s, when JIS C 5442, 1966 [17], which is the oldest JIS in existing ones in TC94, was established.

However, it was obliged in 1995 that each member

country obey the following regulations: 1) the establishment of technical regulations and standards are based on the international standards, 2) conformity assessment procedures follow guides provided by international standards organizations. These obligations were provided in order to protect WTO/TBT agreements (the agreements on technical barriers to trades) [18].

After this change of regulation on national standards, JIS C 4540-1 (General and safety requirement), JIS C 61812-1 (Time relays) and JIS C 62246 series (Reed switches) in order.

3.2 Current Established and Deliberated Standards in IEC/TC94 and the Correspondent JIS

Standards discussed presently in IEC/TC94 and the correspondent JIS are shown in Table 3, The standards are separated are classified roughly into ones on products and ones on performance/Test method, as seen from the Table 3 [16].

The present subjects in IEC/TC94 are the following subjects: 1) developments of specifications on high voltage relay and reed relay, 2) revisions of specifications on characteristics and test methods of the relays. Especially, it is worthy of recognition that development subjects are both ones proposed from Japanese technical committee.

Tasks of JIS were apt to be behind, however, recently they are making active by supplement human resources from companies and spirit of members. Reliability and B_{10} value in the relays are urgent subjects in tasks of JIS.

Main working activities in IEC/TC94 domestic committee are described in the next clause.

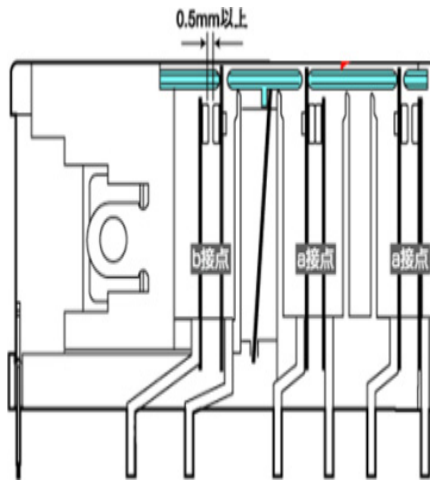


Fig. 3 A relay with forcibly guided contacts

3.3 Main Working Standards and the Future View

3.3.1 IEC 61810-1 Ed.4 (General and Safety Requirement)

This standard is applied to generic electromechanical elementary relays (non-specified time all-or-nothing relays), which specifies the basic functional and safety requirements and safety-related aspects for applications in electrical engineering or electronics, such as general industrial equipment, electrical facilities, information technology and business equipment, automotive equipment and business equipment, control equipment, vehicles, telecommunications and so on. The voltage ranges are spread up to 1000 V AC or 1500 V DC recently. Compliance with the requirements of this standard is verified by the type tests indicated. In case of the application, a relay determines additional requirements exceeding those specified in this standard, the relay should be assessed in line with this application in accordance with the relevant IEC standard(s).

This 4th edition includes the significant technical changes such as provisions for basic safety requirements, test procedure according to North American requirements and dedicated device application tests especially relevant for applications in the North American Market etc. [19].

3.3.2 IEC 61810-3 Ed.1 (Relays with Forcibly Guided Contact)

This standard applies to the relays in which special design and constructional measures are used to ensure that make (normally-open) contacts cannot assume the same state as break (normally-closed) contacts (Fig. 3).

This standard specifies special requirements and tests for the relays with forcibly guided contacts, also known as mechanically linked contacts [20]. These special requirements apply in addition to the general requirements of IEC 61810-1. The first version, which was proposed from the

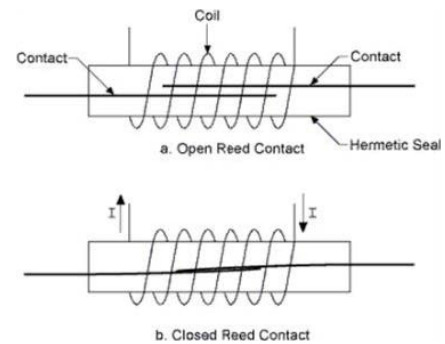


Fig. 4 Open and closed reed relays

international secretary in 2013, was published in 2015.

3.3.3 IEC 61810-4 Ed.1 (Reed Relays – General and Safety Requirements)

This document applies to the relays with reed switches as switching elements for general control circuits (Fig. 4) [21].

It defines kinds of tests for the basic functional and safety requirements in all areas of electrical engineering or electronics in accordance with the parts of IEC 61810 series [19]. That is, it specifies type tests, routine tests and special tests such as reliability data tests used in functional safety applications, environmental tests to confirm the service conditions for applications. Besides, it provides technical changes/additions to the part 1 as safety requirements for reed relays. Here, reed relays have been used in wide fields such as transportation (e.g. railways) household and similar appliances, security control systems for appliances, measuring instruments, semiconductor and chip test equipment, information and communication equipment, power distribution facilities and transit vehicles, etc.

This document was proposed from Japan in 2018 and a member of Japan has been recommended for the project leader of this Ed.1. Besides, it is scheduled to be published in 2020.

3.3.4 IEC 61810-10 Ed1 (Relays for High Capacity Relays)

This document applies to electromechanical elementary relays with high capability requirements like breaking or short circuit capabilities and similar for incorporation (Fig. 5).

These relays may have a specific design to extinguish the electric arc between contacts (e.g. by magnetic blow-out) or use an insulation coordination not covered by IEC 61810-1 (e.g. for higher loads). It defines additional requirements for high-capacity relays with generic performance intended for use in applications in smart grids, electric vehicles and other applications where e.g. battery charge/discharge switching is used, such as: Electrical Energy Storage (EES) systems, solar photovoltaic energy systems, electric road vehicles (EV) and electric industrial trucks, power electronic systems and equipment, secondary

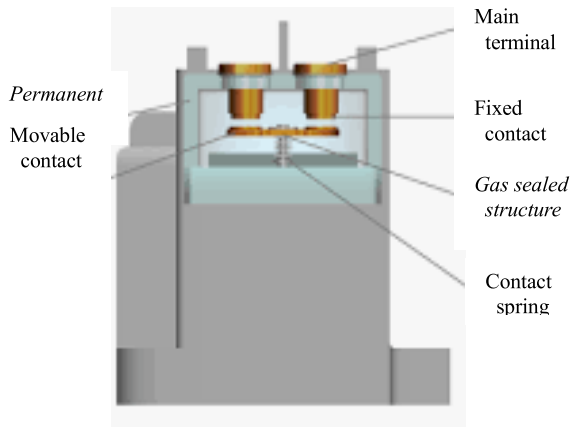


Fig. 5 A high capacity relay

cells and batteries, and road vehicles. Compliance with the requirements of this standard is verified by the type tests indicated [22].

This document was proposed from Japan in 2015 and a member of Japan has recommended for the sub-project leader. Besides, it is scheduled to be published in 2019.

3.3.5 IEC 62246-1-1 and IEC TR 62246-3 (Reed Switch Series)

IEC 62246-1-1 Ed.2 (Reed switches – Generic specification – blank detail specification) is a blank detail specification derived from requirements and tests in reed switches for general and industrial applications [23]. It is intended to be used in conjunction with IEC 62246-1:2015 and specific products standards applying as switching elements. Besides, it selects from IEC 62246-1:2015 and from other sources the appropriate test procedures to be used in detail specifications derived from this specification. Reed switch types are specified depending on characteristic values including functional ratings for safety and tests. This second edition cancels and replaces the first edition of IEC 62246-1-1 published in 2013.

IEC TR 62246-3 (Reed switches – Reliability data for reed switch - devices in typical safety application) is a Technical Report, provides basic technical background and experience about reliability data for reed switch-devices applied to machinery systems as well as E/E/PE safety-related control systems during the life cycle phases in general and industrial safety applications [24]. The first edition of this technical report published in 2018.

Here, IEC 62246-series (Standards on reed switches) have been arranged under the leadership of Japan. Convener of the project for these series was handed over recently to UK member, who has been one of influential member in the project.

3.3.6 The Other Standard Documents

There are standards on performance and test methods (IEC

61810-2, IEC 61810-2-1, IEC 61810-7) [25]–[27] respectively, telecom relays (IEC 61811-1) [28], time relays (IEC 61812-1) [29] and solid-state relays (IEC 62314) [30], except standards mentioned in the forward sections. Here, there is no definite plan of developments or revisions for the former two standards, however, review plans were made in the latter two ones. In addition, it was accepted at the TC 94 meeting in 2018 that Japanese members ran for each convener for the two committees. Successful fulfillment of roles two Japanese conveners is expected greatly.

3.4 Activities of Our Country for IEC/TC94

The IEC/TC94 is made up by 11 participating countries and 21 observing countries and is managed by Germany (a chair) and Austria (a secretary).

Japan supports it by assumption as conveners, project leaders and sub project leader in three projects. Besides, new subjects in the various projects are proposed from Japan. In the sense, it can be said that Japan plays presently an extremely important roles in the IEC/TC94.

Recently, China and the Republic of Korea have begun to participate also in IEC/TC94 [7]. Japan welcomes these movements, imaging that Sub-committee of Electrotechnical Standard, which can compete with the CENELEC (European Committee for Electrotechnical Standard), may be united in APEC (Asia-Pacific Economic Cooperation) in future.

4. Afterwords

Transition and the present circumstance on technical trends of electromagnetic relays and activities of international standardization in IEC/TC94 are described as above. They suggest that subjects for future relays are estimated as follows:

- 1) Growth of high capacity relays; Shares of high capacity electro mechanical relays are moving upward. Requirement of international standards on this high capacity relays will increase, accompanied by this trend.
- 2) Growth of relays with functional safety and mechanical safety; Requirement of application to protection circuits is on the rise. For the time being, item on functional safety was entered in a standard of the reed relays. As this will be also required for the most part of the higher capacity relays, this item deserves to be installed in part 1 in the future.
- 3) Maintenance of documents on performance and test specifications; As reliability and B_{10} value are urgent problems in electromechanical relays, it is necessary to be up-date for newly requirement.
- 4) Appropriate supplements and maintenance of JIS are needed. More care of spirit must be taken for activities to JIS in the future.

The relays were applied to electro communication field at the beginning, afterwards have expanded to the wide fields

such as control systems in industry world and transportations and so on. During this time, Japan took part in the auxiliary relay committee in International Electrotechnical Commission (IEC), began activities on international standardization. And now, Japan has moved to play an important role in the standardizations.

In this paper, transition and the present circumstance on technical trends of control relays of electromagnetic type and their activities on international standardization are described, talking about some future prospects.

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Now he is an expert in the IEC/TC94.

Takeshi Aoki received the B.S. degree in physics from Hokkaido University, Japan in 1966. Since then, he joined in Electrical communication laboratory, the former NTT till 1993. Afterwards, he moved to Tanaka precious metal co. During this time, he had been mainly engaged in R&D of relay contacts and had also participated in standardization activities in IEC/TC94 (Electrical relays). He received METI Minister Award from the METI in 1999 and 1906 AWARD from the IEC in 2007.



Chairman of Japan National Committee for IEC/TC94. He is now an Expert of IEC 61810 and 62246 series standards for reed switches and reed relays. He now with BESTACT SOLUTIONS INC., Fukuoka Japan.

Kenjiro Hamada graduated from the Electrical Engineering Department, National Institute of Technology, Ube College, Yamaguchi in 1974. He joined YASKAWA Electric Corporation in 1974. Since then he has been mainly engaged in quality control, research and development on reed switches-devices. He received IEC 1906 Award from IEC in 2010 and METI Minister's Award at METI's Industrial Standardization Awards in fiscal 2017. During this time, he was the Convenor of IEC/TC94/MT6 and the



Kiyoshi Yoshida received the B.E., M.E. and Ph.D. degrees in Electrical Engineering from Nippon Institute of Technology (NIT), in 1981, 1984 and 1995, respectively. He is now associate professor in the Department of electrical, Electronics and Communication Engineering at NIT. He has been engaged in research on arcing phenomena with relay or contactor contacts. He is a member of IEEE, IEE of Japan and IEICE of Japan.



Koichiro Sawa received the B.E., M.E. and Ph.D. degrees in Electrical Engineering from Keio University, Japan, in 1964, 1966 and 1982, respectively. He was a Professor in Department of System Design Engineering, Keio University until March, 2007. Now he is a Professor Emeritus of Keio university and a Guest Researcher of Nippon Institute of Technology. He has been involved in the field of electrical contact reliability and electrical machines for about 40 years. He also has been working in numerical analysis of

magnetic field by Finite Element Method and Boundary Element Method for about 20 years. He is a member of IEEE, IEE of Japan and IEICE of Japan.