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NEW TYPE FUJI HIGH POWER MERCURY RELAY

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I. INTRODUCTION

The contacts of the mercury contact switch (called mercury switch hereinafter), the output element of the mercury contact relay, are isolated from the outside air, and since it is highly reliable and contact chattering is eliminated by conduction through mercury, it is widely used in the low level circuit field. We developed the Fuji mercury relay with "c" contacts for general purpose use through independent techniques and placed them on the market the year before last. The superb characteristics and handling ease of these relays have been highly praised and they are being widely used in all fields. An example of a control panel using mercury relays is shown in *Fig. 1.*

In order to make them easier to use, we have now developed an "a" contact and "b" contact mercury switch to increase capacity and reduce costs, and have complete a series of mercury relays combining various contacts and mercury keep relays. The features and performances of these relays are described.

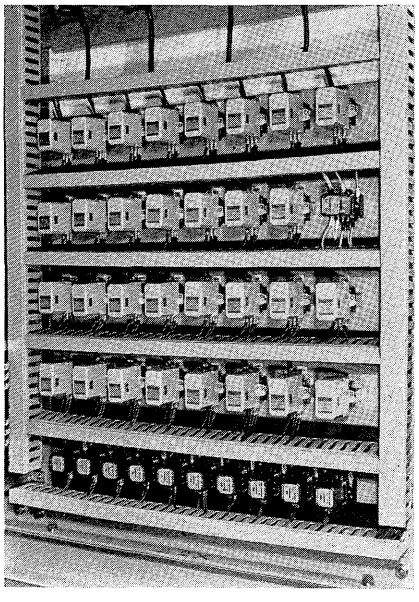


Fig. 1 Mercury relays mounting control panel

II. FEATURES OF THE FUJI HIGH POWER MERCURY RELAY

1. High Reliability

Since the contacts are perfectly isolated from the outside air, they are uneffected by dust, gas, water, and since the contact surfaces are covered with mercury and conduction is performed through this mercury, the contact state and contact resistance are stable. The usable level range is several μV$\sim$300 V and several μA$\sim$5 A and they are extremely reliable.

2. No Contact Chattering

Chattering when the contacts are opened and closed is eliminated by the damping action of the viscous mercury at the contact surfaces.

3. High Capacity, Long Life, High Withstand Voltage

Since they are specially designed for use in general purpose equipment having high power circuits, contact capacity is high. In addition, long life has been obtained through the use of a construction which makes replenishment of the mercury at the contacts easy. Moreover, they have a withstand voltage performance of AC 2000 V, 1 minute across each circuit.

4. Abundant Contact Combinations

Since the development of "a" contacts, "b" contacts, and "c" contacts has made various contact combinations of up to a total of 3 contacts possible in a single relay, a relay having the most economical contact configuration can be selected.

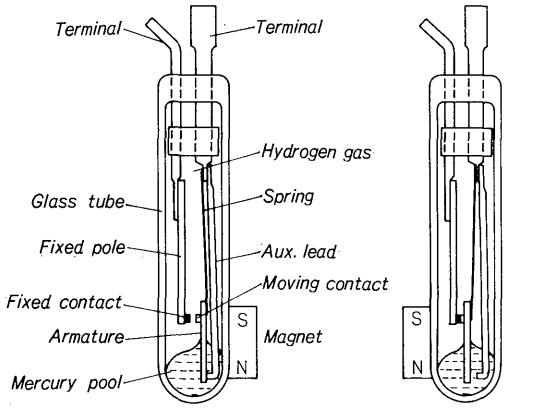
5. Abundant Types and Specifications

A plug-in type and a printed circuit board mounting type mercury relay is available. Operation of these relays is monostable. The mercury keep relay is a plug-in type and its operation is bistable. Since these types have various coil ratings and two plug-in types, a vertical panel mounting type and a horizontal panel mounting types, are available, they can be used in general purpose applications by combining the various contact combination specifications and coil ratings.

III. CONSTRUCTION

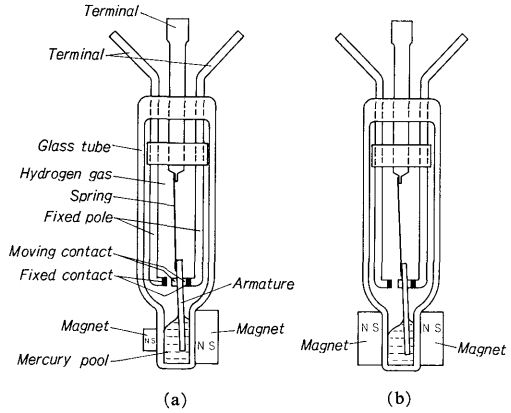
1. Construction

The construction of the " a " contact, " b " contact mercury switch is shown in *Fig. 2* and the construction of the " c " contact mercury switch is shown in *Fig. 3*. The Fuji mercury switch is constructed by collecting the two terminals in the same direction of the glass tube, and features ease of contact gap adjustment and sealing of the glass tube. The moving contacts are welded to an armature which is supported by a spring and are opposite the fixed contacts. The free end of the armature is immersed in a mercury pool. The mercury of the mercury pool is raised up



(a) " a " contact (b) " b " contact

Fig. 2 **Constructions of mercury switch**



(a) (b)

(a) Monostable operating characteristics type
(b) Bistable operating characteristics types (keep relay use)

Fig. 3 **Constructions of " c " contact mercury switch**

to the surface of the contacts by the armature by the capillarity and covers the surface of the contacts. When switching, conduction is performed through the mercury at the surface of the contacts and chattering is prevented by the viscosity of the mercury and the damping action on the armature immersed in the mercury pool.

The mercury splashed and evaporated by the arc during switching of the contacts is cooled and returned to the mercury pool and only the amount lost at the contacts is replenished with new mercury through the armature. The mercury is constantly circulated in this manner, and the life of the switch is determined by the ease or difficulty of this replenishment. The contacts and mercury pool of this mercury switch are close together and a special glass to which mercury will not cling and which facilitates replenishment of the mercury to the contacts is used to improve life and increase power.

1) " a " contact mercury switch

The mechanical construction consists of a fixed electrode with fixed contacts housed inside a tube made by molding the end of a glass pipe into a semispherical shape and an armature with moving contacts supported by a plate spring and an armature stopper which applies pretension by means of a plate spring and auxiliary lead which maintains the contact gap constant forms a construction in which mercury and high pressure hydrogen gas are sealed. When the switch is operated, current flows through the path :

Terminal → fixed contact → moving contact → armature → mercury → auxiliary lead → terminal

→ plate spring

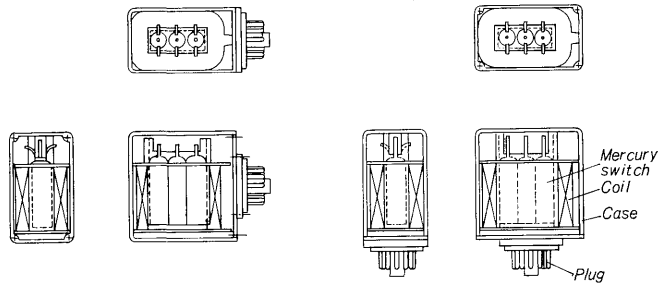
When there is no auxiliary lead, the cross sectional area of the plate spring is small and the current carrying capacity is limited to 3 A. However, when an auxiliary lead having a resistance lower than that of the plate spring is provided in parallel with the plate spring, almost all the current flows in the auxiliary lead and the current carrying capacity can be increased to 5 A.

2) " b " contact mercury switch

In the " b " contact mercury switch, the bias magnet of the " a " contact switch is installed at the opposite side and the contacts are made " b " contacts which are maintained in the closed circuit state when not excited.

3) " c " contact mercury switch

As shown in *Fig. 3*, construction consists of a tube made by molding the end of a glass pipe into a cylindrical shape, 2 fixed electrodes having fixed contacts, an armature with moving contacts supported by a spring, mercury, and hydrogen sealed in at high pressure. There are two types of operating characteristics depending on the bias magnet, mono-



(a) Vertical panel use (b) Horizontal panel use

Fig. 4 **Constructions of mercury relay and keep relay**

stable operating characteristics and bistable operating characteristics. Switching operation of the contacts is non bridging for both and is generally called the BBM type (Break Before Make). The changeover time (the time from the breaking of the " a " contacts to making of the " b " contacts or vice versa) is 0.1 ms or greater. The monostable type is used in the mercury keep relay.

IV. CONSTRUCTION, OPERATION, AND CHARACTERISTICS OF THE RELAY

1. Construction

The plug-in type relay is shown in *Fig. 4* and the printed circuit board mounted type relay is shown in *Fig. 5*. These relays consist of a coil and a switch assembled in the coil, a plug or terminal wired from the coil and switch, and a case which houses these parts. The coil and switch are fixed to the case by filling with wax after wiring, considering safety during use. Any desired combination of from 1 to 3 " a " contacts, " b " contacts, and monostable type " c " contacts can be housed in the plug-in type. The installation direction of the switch is restricted so that the mercury pool is always at the bottom. However, two plug-in types are available, one for vertical panel use and the other for horizontal panel use, to permit

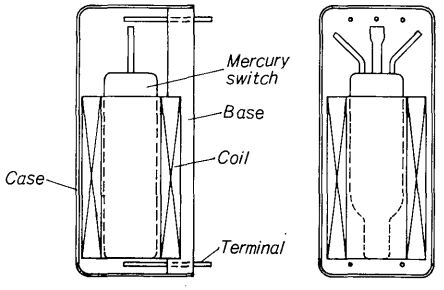


Fig. 5 Constructions of mercury relay for printed board

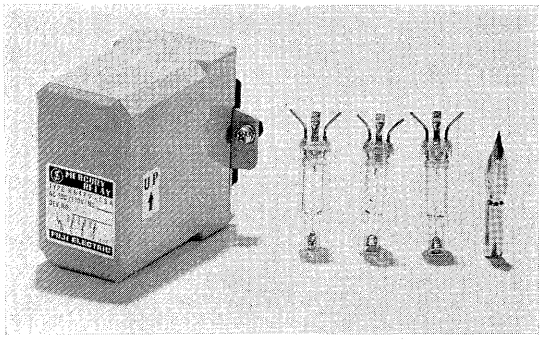


Fig. 6 Outerview of high power mercury relay

convenient installation. These are installed by changing the direction of the coil and switch 90° with respect to the case and have the same outside dimensions and internal connections. This relay can be used at an angle of ± 30° relative to the specified installation direction. The plug section can be either an octal base (8 pins) or submagnal base (11 pins) corresponding to the number of contacts. There are two kinds of sockets, a soldered connection buried type and a screw connection surface mounting type.

Since the relay is securely held by 2 screws after being plugged into the socket, the reliability of the plug contact section is assured even in the presence of vibration. An exterior view of the plug-in type relay is shown in *Fig. 6*.

2. Characteristics

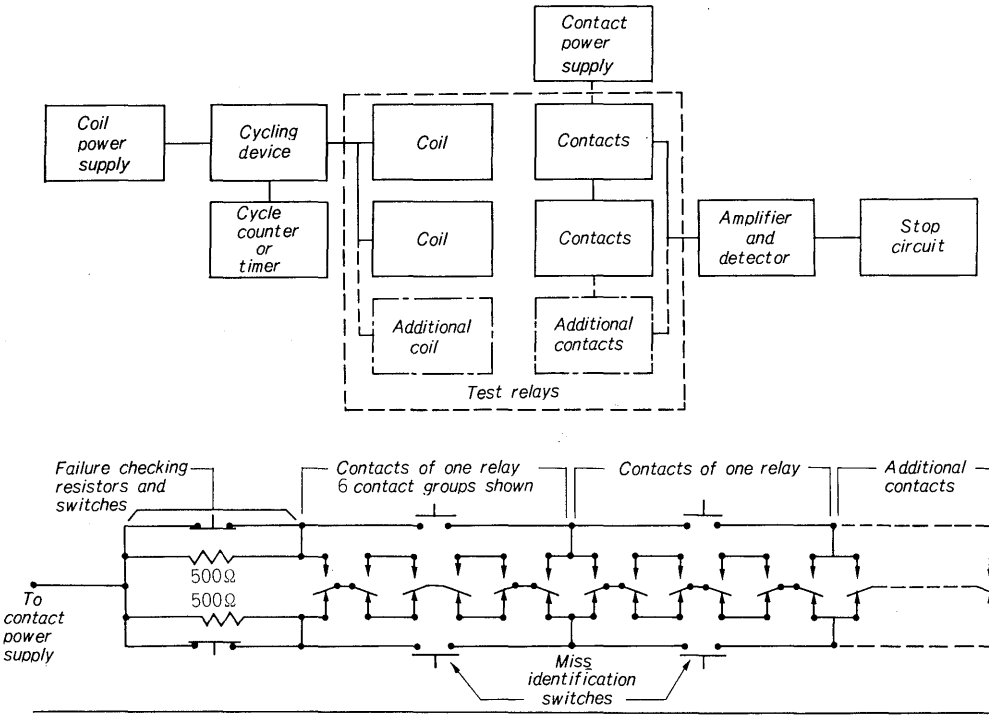
1) Contact reliability

The mercury relay is essentially extremely reliable. Contact reliability in dry contact relays generally poses a problem in the low level range. When switching current at a low level, arc start is difficult, the electrical cleaning action of the contact surface, the so-called, softening effect (according to NARM materials, there is no softening effect when switching below 80 mV, 100 mA), is small, and contact reliability conditions are severe. There are numerous methods of testing contact reliability, but we used the NARM method shown in *Fig. 7*. The relay is driven by turning the coil current ON-OFF. The sample contacts are connected in series and 50 mV, 10 μA is switched. The contact resistance is measured in synchronization with the coil power supply, and contact failure is judged when this value is over 500 Ω, that is 5 mV (10% of power supply voltage). At extremely low level conditions such as this, normal operation continues up to 2×10^8 contacts and it can be seen that reliability is high. Moreover, the test results with a DC 100 V, 27 mA load confirm that operation is normal even when switched up to 2×10^{10} contacts.

The moving parts of the mercury switch are only the spring and armature supported by the spring and the moving contacts welded to the armature, and there are no friction parts. Therefore, since there are no elements which change the characteristics due to mechanical wear, mechanical life is a long 5×10^8 operations or more. Typical characteristics of the operating voltage and resetting voltage and typical characteristics of the operating time and resetting time in the life test are given in *Fig. 8* and *Fig. 9* respectively.

3) Electrical life

The life of the mercury switch by current switching varies considerable with its current value and circuit voltage, whether the load is inductive or resistive, usage frequency. The mercury at the contact surface vaporized and splashed by the arc energy expended at the contacts when a current is interrupted is cooled and returned to the mercury pool, and in the circulating process which replenishes the contacts, the drop in the purity of the mercury becomes more pronounced as the arc energy increases, the replenishment efficiency drops due to the increase



(a) Block diagrams of low level test equipment for "Stop with each miss"

(b) Test relay contact chain circuit (typical)

Fig. 7 **Reliability test methods by NARM**

in viscosity, and the life becomes shorter. On the other hand, since high pressure hydrogen is sealed inside the switch and the current interrupting characteristics are superb, the counter emf generated when an inductive load current is interrupted differs with the current value and time constant of the counter emf and can reach 2,000~6,000 V in a DC 100 V circuit, for example. This high voltage has such undesirable effects as deterioration of the insulation around the contact circuit and other devices and damage to semiconductors and other circuit parts. Therefore, the contact life can be improved substantially by preventing the generation of counter emf by using a suitable method to absorb the energy stored in the inductive load so that an arc is not started at the contacts. Therefore, a contact protecting circuit must always be installed when switching an inductive load with this relay. There are various contact protecting circuits, and an example is shown in *Fig. 10*. The diode system is effective in the case of DC circuits and the varister system is generally effective with AC circuits. The relationship between the contact capacity and electrical life of this relay is shown in *Fig. 11*.

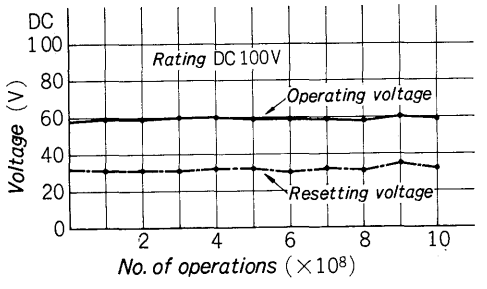


Fig. 8 **Operating characteristics by mechanical life test**

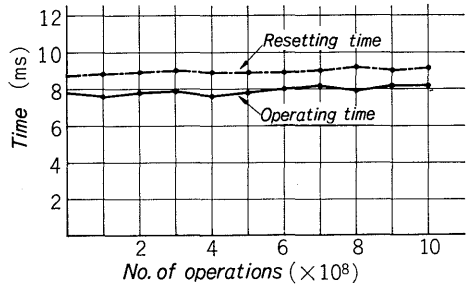


Fig. 9 **Dynamic characteristics by mechanical life test**

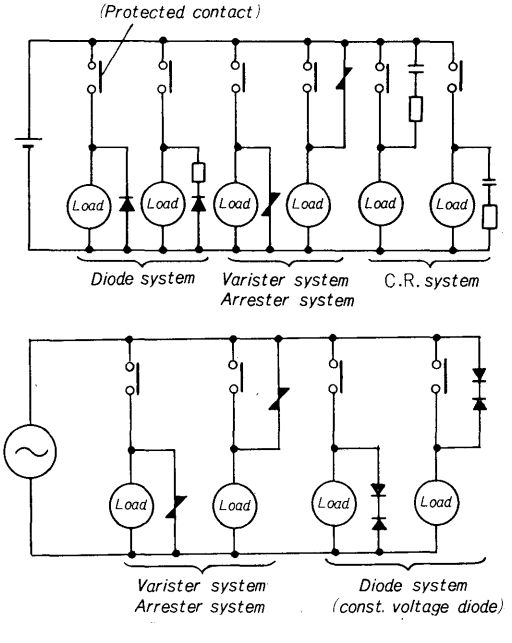


Fig. 10 **Contact protection circuits**

4) Dynamic characteristics

The distance between the contacts has been made large so that a withstand voltage between the contacts of the switch of AC 2000 V, 1 minute can be withstood. But the operating speed is 2～3 times that of the general auxiliary relay. The relationship between the input and the operating resetting time is shown in *Fig. 12*. The non bridging time of the "c" contacts is 0.1 ms or greater.

5) Withstand vibration

An example of the withstand vibration characteristics of this relay are shown in *Fig. 13*. The contact open state is weaker than the contact closed state because the mercury which is splashed by vibration contacts between the contacts and appears as miss operation.

6) Ambient temperature characteristics

The melting point of mercury is −38.87°C, and to guarantee stable operation, the usage temperature range is made −30°C or higher. The upper limit is made 50°C considering the temperature rise of the coil and contacts. The operating resetting time temperature characteristic is shown in *Fig. 14* and the operating resetting voltage temperature characteristic is shown in *Fig. 15*. The resetting time is effected by changes in the viscosity of the mercury, but the increase of AT by the decrease in the coil resistance covers the effect of viscosity. The operating resetting voltage are directly effected by the temperature coefficient of the coil copper.

V. TYPES, SPECIFICATIONS, AND PERFORMANCES OF RELAYS

The types and specifications of this relay are given in *Table 1*, and performances are given in *Table 2*.

VI. APPLICATIONS

The high power mercury relay is used in numerous applications by utilizing its features and examples are given below.

(1) Control of low level circuits
Switching of thermocouple

(2) Semiconductor circuit output relay
Performance matching as to circuit insulation, reliability and life

***Table 1* Specifications**

Name	Mounting and connection	Type *	Contact		Drive coil			Time characteristics		Remarks
			Configuration	Current capacity	Rated voltage (V)	Resistance (Ω)	Power consumption VA	Operating time	Resetting time	
High power mercury relay	Vertical panel, plug-in system	AAQ1 EPVS	1a	a contact / b contact 5A	DC 6	ca 15	ca 2.7 W	5～10 ms Change-over time of "c" contact: More than 0.1 ms	5～10 ms Change-over time of "c" contact: More than 0.1 ms	*(Paren the sized): former type
		AAQ1 GPVS	3a		12	60				
		AAQ1 JPVS	1b		24	250				
		AAQ1 TPVS	2a+1b		48	960				
		AAQ1 APVS = (HA4PV-ASA)	1c		60	1,510				
		AAQ1 SPVS	2a+1c		100/110	3,800				
		AAQ1 CPVS = (HA4PV-CSA)	3c		200/220	15,400				
	Horizontal panel plug-in system	AAQ1 EPWS	1a	c contact 3A						
		AAQ1 GPWS	3a							
		AAQ1 JPWS	1b							
		AAQ1 TPWS	2a+1b							
		AAQ1 APWS = (HA4PW-ASA)	1c		AC 100/110	ca 3,800	ca 2.7 VA	5～12 ms Change-over time of "c" contact: More than 0.1 ms	Less than 30 ms Change-over time of "c" contact: More than 0.1 ms	
		AAQ1 SPWS	2a+1c		200/220	15,400				
		AAQ1 CPWS = (HA4PW-CSA)	3a							
	Vertical printed board, soldering system	AAQ3 ASVS	1c	3A	DC 6	ca 25	ca 1.4 W	5～10 ms Change-over time: More than 0.1 ms	5～10 ms Change-over time: More than 0.1 ms	
					12	100				
					24	470				
					48	1,900				
					100/110	7,200				
High power mercury keep relay	Vertical panel, plug-in system	AAQ5 BPVS	2c	3A	DC 6	15	ca 2.7 W	Change-over time: More than 0.1 ms	Change-over time: More than 0.1 ms	
	Horizontal panel, plug-in system	AAQ5 BPWS			12	60				
					24	250				
					48	960				
					60	1,510				
					100/110	3,800				
					200/220	15,400				

(3) Control circuit in gas, dust, wet, and other adverse environments
(4) Pulse generation circuits: Chattering-less
(5) Memory circuit: Mercury keep relay
(6) Relay circuit requiring high speed operating time

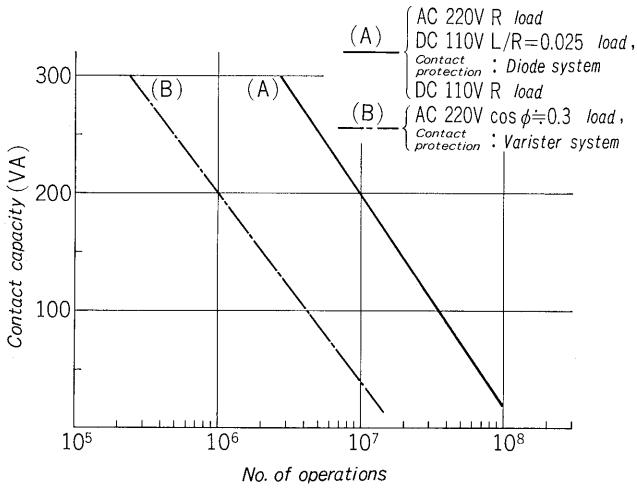


Fig. 11 Electrical life characteristics

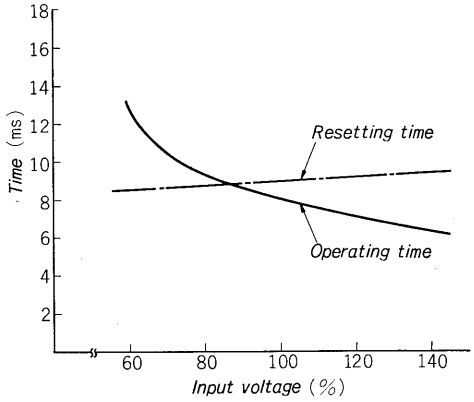


Fig. 12 Dynamic characteristics

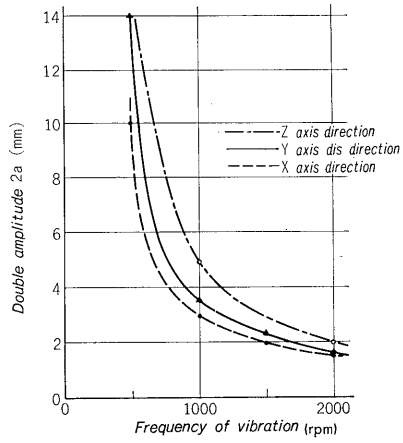


Fig. 13 Withstand vibration characteristics

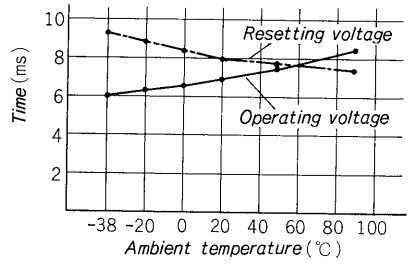


Fig. 14 Dynamic characteristics

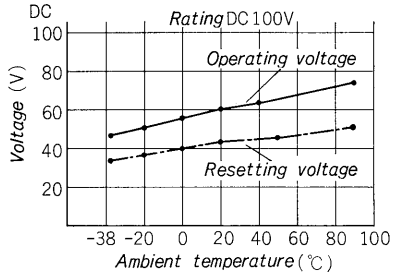


Fig. 15 Operating characteristics

Table 2 Performances

Item	Performances
Mechanical life	More than 500×10^6 times
Electrical life	DC/AC 200 VA 10×10^6 times 20 VA 10×10^7 times
Current closing capacity	"a" "b" contact 10 A DC/AC "c" contact 5 A DC/AC
Allowance of input voltage	80~130% of rating
Allowance of ambient temp.	−30~+50°C
Allowance of humidity	Less than 85%
Allowance mounting angle	Within ±30° of designated direction
Operation frequency	7,200 times/h
Withstand voltage	Between contacts Between contact and coil Between circuit and earth wire } AC 2,000 V 1/min
Insulation resistance	Between contacts Between contact and coil Between circuit and earth wire } DC 500 V, more than 50 MΩ
Withstand vibration	Double amplitude X, Y, Z axis direction 2 mm, 1,000 Hz

The new series of high power mercury relays utilizing the newly developed mercury switch have been described. Various control equipment are becoming increasingly sophisticated in the deteriorating environmental conditions and would be happy if we contribute to improved reliability of equipment at the present time when high reliability is desired.