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HIGH PRECISION AND ADVANCED FANCTIONS NEW SMALL THERMAL OVERLOAD RELAY TR SERIES

Katsumi Akiike
Toshikatsu Ohgami
Humio Chida

1. FOREWORD

Thermal type, magnetic type, induction type, static type, and various other types of overload relays are avaialble as low-voltage induction motor overload protection devices.

Of these, the thermal type overload relay (called thermal relay hereinafter) is not only more economical than the magnetic type, induction type, and static type, but since it also uses the generation of heat by current, it has operating characteristics which facilitate protection harmonizing with the thermal characteristics of the motor and because it is easy to handle, it is used widely in industrial facilities.

The thermal relay is used widely as a magnetic motor starter combined with a magnetic contactor, and is indispensable in automation and labor saving of various facilities. In recent years, production systems have become larger and more complex and the affect of failure of one motor on the entire system is becoming larger and the demand for improved protection reliability is becoming stronger.

The electronification of the control system of modern industrial facilities through the use of the programmable controller (PC) is advancing noticeably. Thermal relay auxiliary contacts must have an independent 1a1b configuration so that the a and b contacts can be used with different voltages. Improvement of contact reliability so that direct input to electronic devices is possible is also demanded.

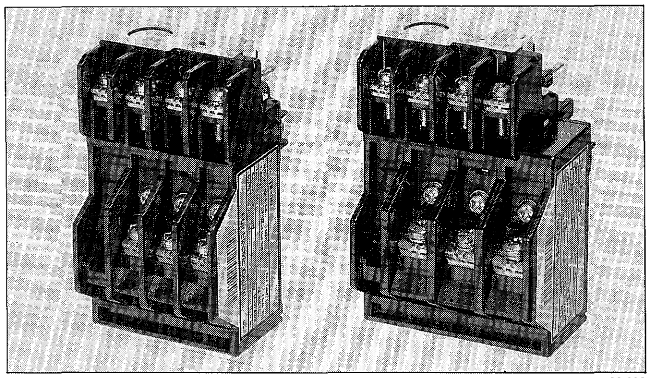
An outline and the features of the high precision and advanced functions new small thermal overload relay TR series developed on our many years of experience to meet such market needs are introduced. Exterior views of the new small thermal relay are shown in *Fig. 1*.

2. FEATURES AND CONSTRUCTION

2.1 Features

The new small thermal relay TR series are high precision and advanced functions thermal type protection relays that use the temperature rise bending characteristic of bimetal. Their main features are:

Fig. 1 Exterior view of new small thermal relay



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(1) Positive motor protection

Operating characteristics which meets IEC, JIS, JEM, and other standard values and excellent repetition stability. Motor burnout and overload constraint can be prevented safely and positively.

Relays with open phase protection (2E thermal relay; TK-□N type) which prevents motor burnout by open pahse operation can be manufactured in the same dimensions as the standard type (TR-□N type) to contend with diversification of protection.

(2) Dense mounting construction

The width of the thermal relay has been made smaller than that of the magnetic contactor for denser mounting. This also allows orderly arrangement inside the panel.

(3) Use of 1a1b high reliability auxiliary contacts.

The auxiliary contacts were made 1a1b contacts. Since there is ample isolation distance between the contacts, the a contacts and b contacts can use with different voltages.

Generation of an oxide film is prevented and contact reliability is improved by using gold-plated silver auxiliary contacts. The low level signal current (DC5V, 3 mA minimum) of PC and other electronic devices can be controlled directly.

(4) Easily mounts directly to contactor

Construction is such that a magnetic contactor mounting plate is unnecessary. Since all the coil terminals of the magnetic contactors are distributed to the power source side, connection points are reduced and one-touch mounting to a magnetic contactor is possible.

(5) Easy to see markings

The type designation, terminal numbers, and other markings have been made easier to see by mounting a markings cover to the front of the thermal relay. The dial scale has also been subdivided and made easier to read.

(6) Trip free mechanism

A safe trip free mechanism which operates when trouble occurs even when the reset button is pushed in mechanically by the connection wiring, etc. is used.

(7) Convertible manual or automatic reset operation

The reset system has been made the manual-automatic switching type so that circuit changes can be dealt with easily.

(8) Manual trip possible.

The thermal relay can be tripped easily by manual operation by pressing a trip button.

(9) Easy trip verification

The trip state can be verified at a glance by trip button.

(10) Abundant option units

Option units can be added easily according to the application.

(a) Dial cover: Prevents unnecessary operation by the current setting value.

(b) Trip indicator: Facilitates verification of the trip operation.

(c) Reset release: Reset operation is performed from the front of the panel.

(d) Base unit for separate mounting: Unit which mounts the thermal relay only. Track mounting is also possible.

2.2 Construction

The thermal relay consists of a heating section, which bend displaces a bimetal by the heat generated by current flow, and an operation section, which switches the auxiliary contacts by the reversing operation when the displacement exceeds the prescribed value.

Of the features of the new small thermal relay described previously, the points given special consideration from the standpoint of construction are described below.

(1) Reduction of width dimension

This series consists of the TR-0N type for 200 V, 2.2 kW use and TR-5-1N type for 200 V, 3.7 kW use. The construction of the new small thermal relay is shown in *Fig. 2.*

To mount the relays closely, the TR-0N type must match the width dimensions of the magnetic contactor SC-0 type with which it is combined.

Therefore, the heating section and operation section have been made a two-stage construction and the auxiliary contacts, current setting dial, reset button, etc. are arranged at the top of the heating section. The leaf spring mechanism, which switches the auxiliary contacts by the tripping operation when the bending displacement of the bimetal exceeds the prescribed value, and the current adjusting link mechanism are provided at the side of the heating section. This has reduced the width dimension to 44 mm.

Fig. 2 Construction TR-0N

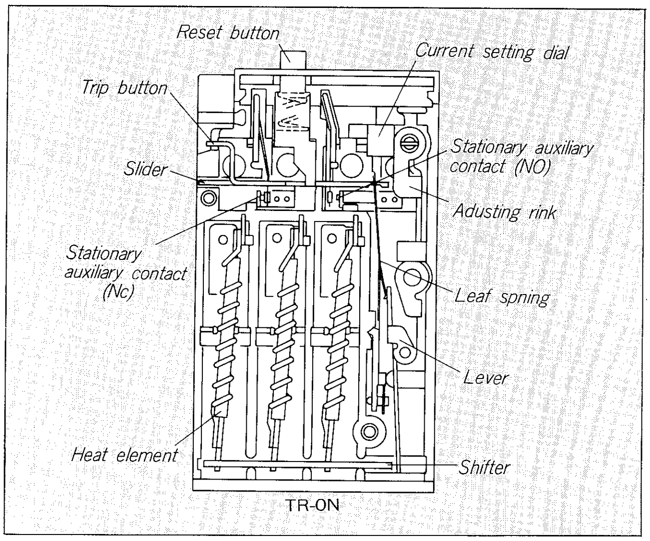
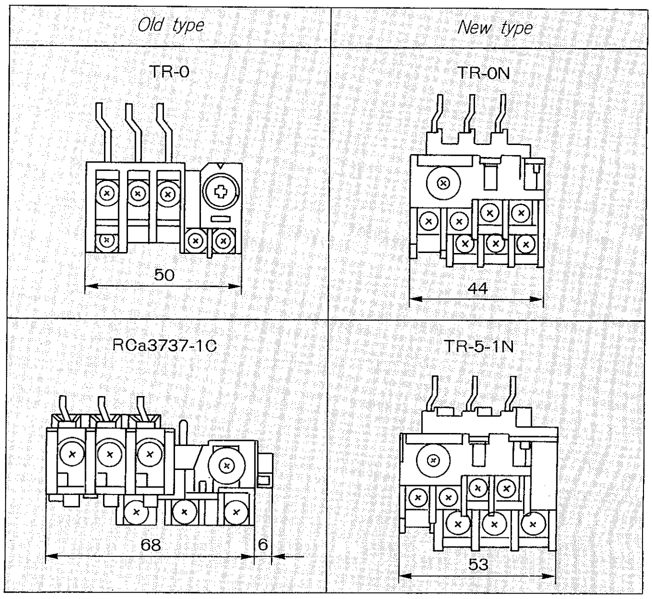


Fig. 3 Comparison of new and old width dimension



Since the maximum rated current of the TR-5-1N type is high and the main terminal screws are M4, the width of the heating section is large. The operation section parts have been made common with the TR-0N type.

The new and old width dimensions are compared in *Fig. 3*. With the TR-0N type, the width dimension was reduced to 6 mm and with the TR-5-1N type, the width dimension was reduced to 21 mm.

(2) High reliability auxiliary contact mechanism

The contact mechanism section of the new small thermal relay is shown in *Fig. 4*.

This contact mechanism uses Fuji Electric's original lift off system (system by which the moving contacts spring provides contact force by its own force by a predetermined

Fig. 4 Contact mechanism

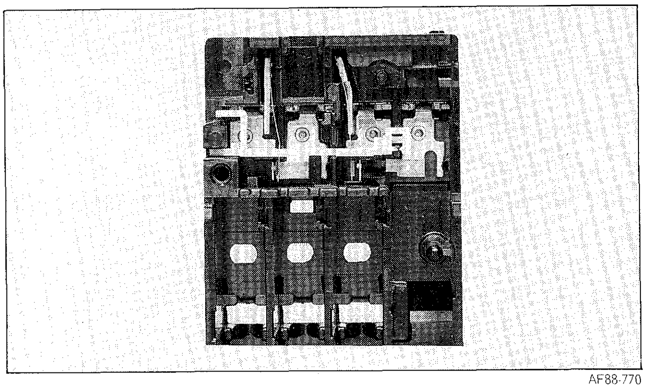


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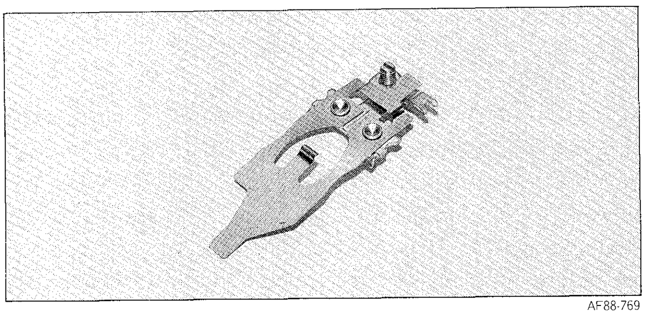
Fig. 5 Leaf spring construction



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bend and the contacts are opened by movement of the moving contacts spring through a link plate by the force of a reversing spring). Since the contacts are not affected even if the leaf spring and link plate bounce at operation or reset, a contact mechanism with a short bounce can be obtained. A large making capacity and breaking capacity is taken and the contact pressure drop due to contact wear is reduced, and contact performance with excellent vibration resistance is obtained.

The thermal relay output contacts operate only when overload, constraint, or other circuit abnormalities occur. For this reason, "b contacts closed a contacts open" is maintained in the normal usage state. Therefore, since there is no contact surface mechanical wear or change due to arcing, creation of an oxide film during operation, etc. may cause the contact resistance to increase. In the low level voltage and current range, this lowers the contact reliability. To prevent this, contact reliability has been improved by using gold-plated silver contacts and making the moving contacts and fixed contacts a cross contact system. This has made direct input to DC5V, 3 mA low-level voltage and current electronic control circuits possible.

(3) Use of thin plate leaf spring

The construction shown in *Fig. 5* is used as the leaf spring mechanism, which switches the auxiliary contacts by tripping operation when the bend displacement of the bimetal exceeds the prescribed value.

Since this leaf spring is made of a single thin plate fastened to a support, small size (especially reduction of the wide dimensions) and easy assembly by automatic machine could be realized.

Fig. 6 Contact load force and leaf spring contact drive

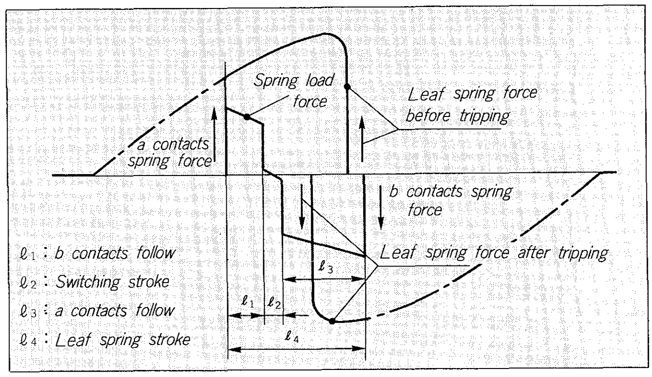


Fig. 7 Thin plate leaf spring stress distribution

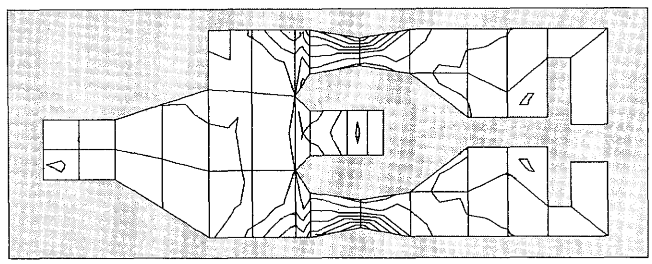
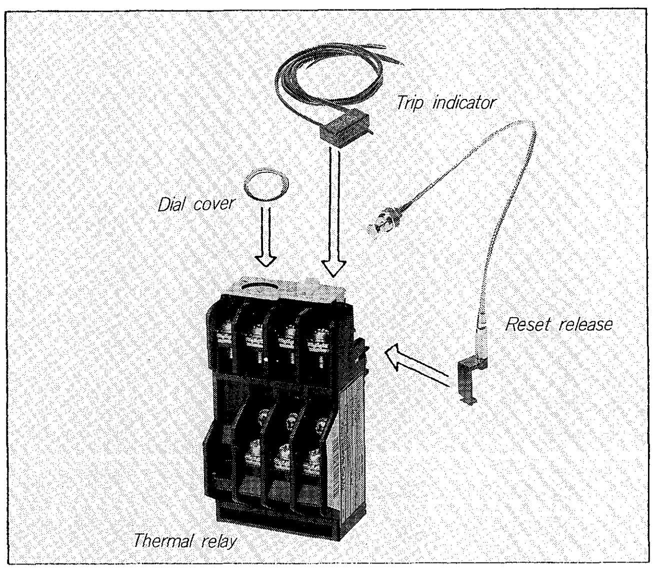


Fig. 8 Mounting of option units



During the development of this leaf spring, the shape, plate thickness, deformation amount, reversing load, and contact drive force relationship was analyzed by the finite element method (FEM) and optimum design was performed.

The relationship between contact load force and leaf spring contact drive force at the contact driven position is shown in *Fig. 6*.

The stress scatter chart of the maximum stress generated at tripping is shown in *Fig. 7*.

(4) Mounting of option units

Abundant option units are available so that they can be added according to the application. The (1) dial cover, (2) trip indicator, and (3) reset release mounting is shown in *Fig. 8*. All these units can be mounted and dismounted with one touch.

3. RATINGS AND PERFORMANCE

3.1 Ratings

(1) Heat element ratings

The kinds of heat element ratings of the new small thermal relay and the standard application of the heat element ratings for Fuji Electric standard motor output are shown in *Table 1*.

(2) Auxiliary contacts ratings

The auxiliary contacts of a thermal relay generally break the exciting current of the operating coil of a magnetic contactor, make and break alarm circuits, etc. The auxiliary contacts ratings of the new small thermal relay are shown in *Table 2*.

Table 1 Kinds of heat element ratings

Fuji Electric motor full load current (reference)				Standard type thermal relay type designation and heat element rating	
4P 400V 50Hz		4P 200V 50Hz			
				TR-0N TR-0NH	TR-5-1N TR-5-1NH
Output (kW)	I_L (A)	Output (kW)	I_L (A)	Combined magnetic contactor: SW-03 SW-0 SW-05	SW-4-0 SW-4-1 SW-5-1
				0.1~0.15A	0.1~0.15A
				0.15~0.24A	0.15~0.24A
0.1	0.36			0.24~0.36A	0.24~0.36A
				0.36~0.54A	0.36~0.54A
0.2	0.7	0.1	0.71	0.48~0.72A	0.48~0.72A
				0.64~0.96A	0.64~0.96A
0.4	1.2			0.8~1.2A	0.8~1.2A
		0.2	1.4	0.95~1.45A	0.95~1.45A
0.75	1.8			1.4~2.2A	1.4~2.2A
		0.4	2.3	1.7~2.6A	1.7~2.6A
				2.2~3.4A	2.2~3.4A
1.5	3.3	0.75	3.6	2.8~4.2A	2.8~4.2A
2.2	4.6			4~6A	4~6A
		1.5	6.5	5~8A	5~8A
3.7	7.5			6~9A	6~9A
		2.2	9.2	7~11A	7~11A
5.5	11			9~13A	9~13A
7.5	15	3.7	15		12~18A

Table 2 Contact ratings

Type designation	Rated thermal current (A)	Rated voltage (V)	Rated operating current (A)	
			AC11	DC12
TR-0N TR-5-1N	3	24	3 (0.3)*	1.1 (0.3)*
		110	2.5 (0.3)*	0.28 (0.28)*
		220	2 (0.3)*	0.14 (0.14)*
		440	1 (0.3)*	–
		550	1 (0.3)*	–

<Note> Values in * ( ) are the contact ratings for automatic reset type.

3.2 Performance

(1) Operating characteristics

The thermal relay operating characteristics (rated value) specified by IEC, JIS, and JEM are shown in *Table 3*. The new small thermal relay has operating characteristics which satisfy these rated values. The limit of operation at a balanced circuit is 105% I_n non-operation, 105-120% I_n within 2 hours. At 600% I_n, the operating characteristics satisfy class 10 (operation within 10 seconds at 600% I_n current setting) specified in UL standards.

The operating characteristic curves are shown in *Fig. 9*.

(a) shows the cold start characteristics and

(b) shows the hot start characteristics.

(2) Overload resistance

JEM1365 specifies that "there must be no mechanical or electrical abnormalities after energized 8 times current setting (maximum value) untill tripping, and repeat 3 times. However, Fuji Electric performs an overload resistance test at 10 times the current setting and confirms that the characteristics change is small and that there are no practical problems. The overload resistance test results are shown in *Table 4*.

It is confirmed that the heat element and other main circuit live parts are not melted before the auxiliary contacts operate when 13 times the current setting (maximum value) was energized.

(3) Durability

A thermal relay should operate only when there is an overload, and its number of operations should be very small. Frequent operation means that trouble has occurred somewhere in the circuit, or that there was a election error. JEM1356 specifies that "unhindered operation shall be possible after 1000 switchings". However, Fuji Electric performs a durability test up to 5000 operations and confirms that there are no practical problems. The durability test results are shown in *Fig. 10*. The main circuit operating

Fig. 9 Operating characteristics curves

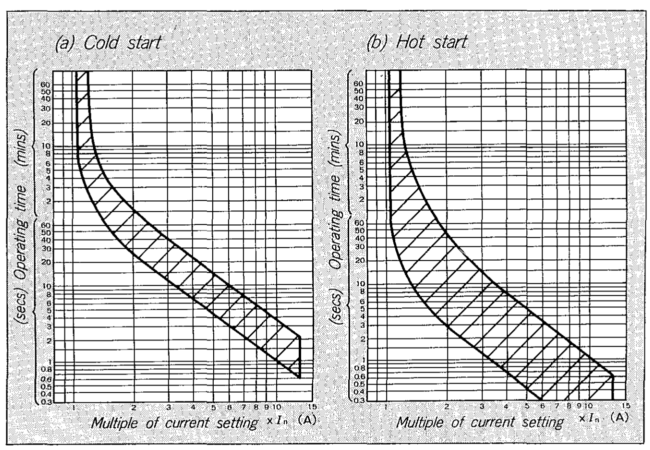


Table 3 Operating characteristics (rated value)

I_n: Current setting

Rating		Operation at balanced circuit: Limit of operation: No operation	Operation at balanced circuit: Limit of operation: Operation	Operation at balanced circuit: Operation at overload (hot start)			Operation at balanced circuit: Operation at constraint (cold start)			Operation at unbalanced circuit: No operation	Operation at unbalanced circuit: Operation (hot start)	Reference ambient temperature
JIS (C8325)		100%I_n	125%I_n Within 2 hours	200%I_n Within 4 minutes			600%I_n 2 to 30 seconds			–	–	40°C
				Standard type	Quick operating type	Long-time operating type	Standard type	Quick operating type	Long-time operating type			
JEM (1356)	Not phase loss sensitive	100%I_n	120%I_n Within 2 hours	200%I_n Within 2 minutes	200%I_n Within 1 minute	200%I_n Within 4 minutes	600%I_n 2 to 30 seconds	600%I_n Within 20 seconds	Value indicated by the manufacturer	100%I_n	2 poles: 132%I_n 1 pole: 0%I_n (Within 2 hours) 1 pole: 144%I_n 2 poles: 0%I_n (Within 2 hours)	20°C
	Phase loss sensitive									2 poles: 100%I_n 1 pole: 90%I_n	2 poles: 115%I_n 1 pole: 0%I_n (Within 2 hours)	
IEC (292-1)	Not phase loss sensitive	105%I_n	120%I_n Within 2 hours	–			–			105%I_n	2 poles: 132%I_n 1 pole: 0%I_n (Within 2 hours)	20°C
	Phase loss sensitive									2 poles: 100%I_n 1 pole: 90%I_n	2 poles: 115%I_n 1 pole: 0%I_n (Within 2 hours)	

Table 4 Overload resistance test result

Sample		Conditions		Test result: Minimum operating current			Operating time: 200%I_n operating time		
Type designation	Heat element rating (A)	Current setting (A)	Operating current (A)	Before test (%I_n)	After three times operation (%I_n)	Rate of change (%)	Before test (secs)	After three times operation (secs)	Rate of change (%)
TR-0N	9~13	13	130	115	117.5	2.5	55	57	3.6
TR-5-1N	12~18	18	180	117.5	120	2.5	50	52	4.0

<Note 1> Test conditions and method conform to JEM1356.
<Note 2> 200%I_n operating time was measured at cold start.

Table 5 Applicable models

Name	With 3-heater element	Long-time operating type	Quick operating type	2E thermal relay
Application	Perfect for more positive overload protection, open phase protection of small motors, export devices and equipment, etc.	Perfect for blower, fan, and centrifugal separator motors with high inertia and long starting time.	Perfect for overload and constraint protection of compressor motor, submersible pump motor, etc.	Perfect for protection of motors against burnout by overload and open phase.
Type designation example	TR-0N/3	TR-0NL	TR-0NQ	TK-0N
	TR-5-1N/3	TR-5-1NL	TR-5-1NQ	TK-5-1N

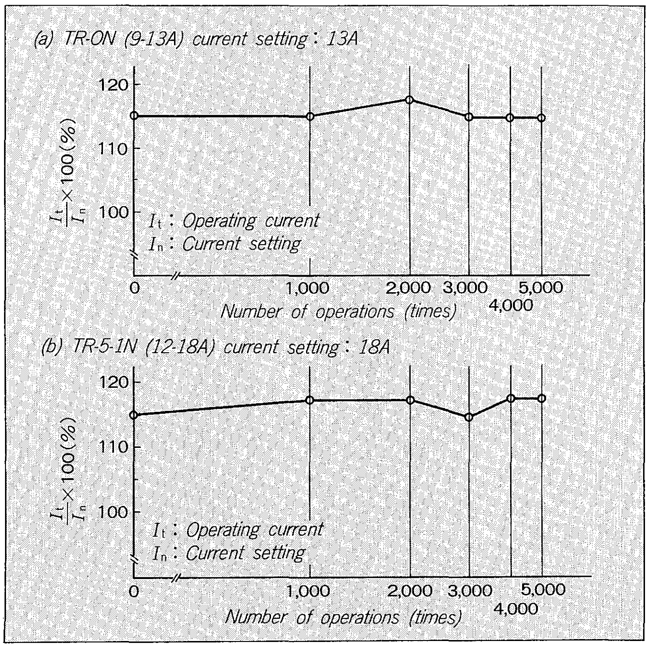
current was made six times the current setting and energized until the auxiliary contacts operate and the operating current was checked each 1000 times.

The auxiliary contacts circuit load conditions were:

- Circuit voltage: 50 Hz 220 V.
- Making current/breaking current: $10 I_e$ (power factor 0.65)/I_e (power factor 0.35)
- I_e: Rated operational current

The other test conditions and method conform to JEM1356.

Fig. 10 Durability characteristic test result



4. APPLICABLE MODELS

The thermal relay is used widely as a low-voltage induction motor overload protection device. The applicable model must be considered according to the starting time, thermal characteristics, and protection level (overload, constraint, open phase, etc.) of the motor to be protected. The applicable models other than the standard type (with 2-heater element) and their application examples are shown in *Table 5*.

5. CONCLUSION

The features, construction, ratings, and performance of the high precision and advanced functions new small thermal overload relay TR series were outlined above. The TR series reflect the many years of experience and accumulated technology of Fuji Electric. We are confident that it is a product matched to the needs of the market. Farther improvements are planned for the future and the guidance of users is requested.