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FUJI ELECTRIC MOTOR DRIVE, TYPE RC915

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I. INTRODUCTION

With the modernization of various types of industries in recent years, there has been an increasing tendency to employ remote control systems for the various types of valves in industries where fluids are handled such as the steel, gas and chemical industries. In such cases, distribution piping with many complex branchings is operated remotely in a centralized location which saves labor. In addition, the automatic control due to the remote operation insures accurate operation. There are two main types of remote control systems: those which employ the pressure of fluids such as oil or air pressure and those which employ electromagnetic power or motors operated by electricity. Motor operated valves in the latter systems provide the following features:

1) The working fluids needed in oil and air pressure systems are not needed in the case of motor operated valves. Therefore, accessory equipment such as distribution pipes are not necessary.
2) If there is a power supply, it can be attached anywhere.
3) There is almost no limit on the operating stroke.
4) Strong operating power can be achieved.
5) Control response is rapid.

Because of these features, many of these valves are now in use. Using technology introduced from the Siemens Co., Fuji Electric has manufactured many electric motor drive systems for remote control which have the above features. They have been supplied as valves and gates in the steel, chemical, power related and water-works related industries and have proven their excellent performance. The RC915 type Electric Motor Drive described in this article is based on the RC910II type, which has been improved to form a new type which meets all the latest requirements.

II. OUTLINE AND FEATURES OF FUJI ELECTRIC MOTOR DRIVE, TYPE RC915

Fuji Electric Motor Drive, type RC915 operates valves by means of a reduction gear mechanism of spur and worm gears for the motor speed which reduces the speed to a value suitable for valve opening or closing and transmits this speed to the valve stem.

The features of the type RC915 are as follows:

1) Since the valves must have a maximum torque during stopping or starting for opening and closing, the motor is a torque motor with matching characteristics. The torque motor has an extremely small moment of inertia GD^2 for rapid control response. In addition, the motor is also designed to withstand a high frequency of operation. Because of this it is also possible to use this electric motor drive for control valves.
2) The type RC915 can be used with both manual and motor operation, although it is basically for motor operation. Therefore, it is necessary to use a changeover lever for manual operation but after the manual operation is completed, it is not necessary to use the changeover lever to return to motor operation. A self-changeover mechanism is provided which automatically converts back to motor operation once the motor is starting.
3) All operations can be performed on one surface since the manual operation handle and the manual/motor changeover lever are located on the same operation surface.
4) The switching mechanism contains a position limit switch and a torque limit switch. The position limit switch employs a counter system which allows highly accurate position control. The torque limit switch correctly detects any abnormal power applied because of some foreign matter in the valves and stops the motor, which protects both the valves and the operating devices. The torque limit switches are attached in both the opening and closing sides so that they form a double torque system.
5) An auxiliary terminal for operation is included so that optional selection between position control and torque control can be made. Either one can be set by a simple operation.
6) The position limit switch, the torque limit switch, the torque setting lever, the auxiliary

terminal for operation, the position transmitter and the position indicator are all contained in the same switching mechanism and can all be regulated within this mechanism.

7) Installation can be either vertical or horizontal.
8) Since a hammer-blow clutch system is used to transmit the rotational force, the maximum torque of the motor can be effectively utilized.
9) It is easy to set the output shaft torque.
10) Lubrication is by the bath system and the splash system.
11) Since weather-protected construction is used, sufficient protection is provided against humidity and rust.

III. SPECIFICATIONS

Large operating torque is required at the moment when the valves are opened and at the moment when the valves are closed. When the valve is opened, torque to overcome contact friction and torque to overcome fluid pressure are required since they are suppressed by the power of the valve disk and valve seat when the valve is completely closed. Even when the valve is closed, a large operating torque is required since it is essential to suppress the valve disk and the valve seat with the contact pressure in the same way. In the valve intermediate position, a comparatively small operation torque is sufficient since it is necessary only to overcome the torque due to fluid pressure and the torque due to friction in the gland packing. Generally, it is rather difficult to estimate correctly the forces which act on the valves and there are times when some unexpected forces occur during opening and closing. For this reason it is necessary to provide sufficient margin in the torque characteristics of the motor. After operation of the position limit switch and the torque limit switch, there must be very little coasting so that the motor can be stopped accurately. Recently, there are many cases where valve opening and closing are repeated frequently because of the increasing variety of valve controls and therefore, it is essential to have motors which can withstand very frequent starting and stopping. Considering the above points, the motor used in this Electric Motor Drive is a specially designed torque motor which fulfills the above mentioned requirements. *Fig. 1* is an application chart of the Electric Motor Drive.

The following equation shows the relation between the motor output P (kW), the output shaft rotation speed N (rpm), the output torque T kg·m and the total motor operating efficiency η.

$$T=974\times\frac{P}{N}\eta$$

Fig. 1 shows graphically the results of calaculations of the above equation with the total motor operating efficiency $\eta=50\%$ and the motor output $P=200\%\times$ rated output. The relation between the output shaft torque and the motor speed is indicated with the motor output as parameter. Since the efficiency of the drive device is actually about 60% and, as will be described later, the maximum motor torque is more than 300%, the calculations show a sufficient margin.

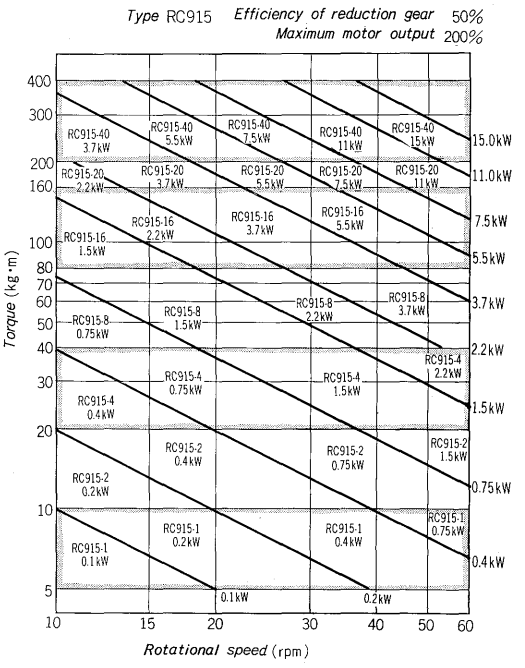


Fig. 1 Fuji Electric Motor Drive, type RC915 application chart

The position limit switch uses a counter system. From the time the valves are completely closed until they are completely opened, the rotational speed of the output shaft increases 3 to 6 times and this is transmitted to the counter. After the counter counts the required revolution, the microswitches are operated by means of cams. Since the revolution of the output shaft increases, correct position control can be achieved. This is the main feature of the counter switch. The torque limit switch employs the double torque system which operates from both the opening and closing directions. With such a system, the valves can be completely protected against the application of any abnormal torque. The position limit switch and the torque limit switch can be connected in series in the operating circuit to form a position switch-off system which breaks the circuit no matter which switch operates, or connected in parallel to form a torque switch-off system in which the circuit is broken by operation of the torque limit switch and a lamp inidication is given by operation of the position limit switch. These two systems can be selected optionally by means of the auxiliary terminal for operation. Changeover can be performed simply by shifting the connections.

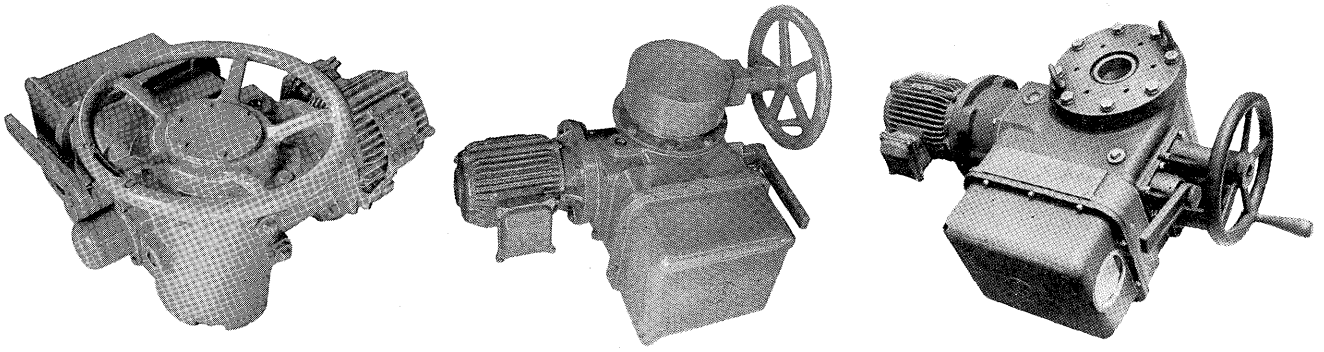
As was mentioned above, this motor drive can be used with either motor or manual operation, although motor operation is the general condition since it is

Table 1 **Specifications of type RC915**

Common specifications	Motor	Totally enclosed, self-cooling, weather-protected 4P $200/\frac{200}{220}$ V ~ $400/\frac{400}{440}$ V 50/60 Hz		
		Class E insulation torque motor		
		Starting torque, max. torque>300%		
	Output shaft speed	23.3/28 rpm 50/60Hz (10~50 rpm 50 Hz 12~60 rpm 60 Hz also posible)		
	Output shaft material	Sleeve material: HBs BE2 for double sleeve type S45C for inside screw type		
	Rotation direction	Output shaft	Closing by clockwise rotatiotn as seen from drive side	
		Manual handle	Closing by clockwise rotation	
		Position indicator	Closing by anti-clockwise rottaion	
	Limit switch	Position switch	Counter setting	Single pole, double throw
		Torque switch	Switching in both directions	Single pole double throw
	Torque switch setting range	More than 50% but less than 100% of output shaft torque		
	Position indicator	0° (completely closed)~265° (completely open), margin angle 8°		
	Position transmitter	Synchro-transmitter TS8N39, Slide resister CP6, up to 3 groups can be attached		
	Lub oil	Turbine oil #120~#200		
	Temperature available	−15°~40°C		
	Self-changeover mechanism	Motor→manual by changeover level, manual→motor by self-changeover		
	Exprosion proofing	Increased safety: eG3, flame-proof: d2G4		

Type	Motor output (kW)	Output torque (kg•m)	Max. permissible thrust (t)	Max. stem diameter		Weight※ (kg)
				Double sleeve type (mm)	Inside screw type (mm)	
RC915-1	0.4 (0.75) (1.5)	5~ 10	6.0	40 (46)	40	95
RC915-2	(0.4) 0.75 1.5	10~ 20	6.0	40 (46)	40	110
RC915-4	(0.4) (0.75) (1.5)	20~ 40	7.5	50 (60)	50	185
RC915-8	(1.5) 2.2 (3.7)	40~ 80	15.0	60 (70)	60	265
RC915-16[20]	(2.2) 3.7 (5.5)	80~160 [200]	25.0	70 (90)	75	465
RC915-40	(5.5) 7.5 (11)	200~400	45.0	95 (115)	120	1,100

Inside ( ) is special type
※ Weight with standard motor attached



(a) Type RC915-1 (b) Type RC915-2 (c) Type RC915-4, 8, 16, 20, 40

Fig. 2 Fuji Electric Motor Drive, type RC915

given priority. Changeover from motor to manual operation is performed by means of a changeover lever but the change from manual to motor operation is performed automatically when the motor is operated. Details of this system will be explained later. The gears are lubricated by oil equivalent to turbine oil #120 to #200. With the exception of the motor terminal box, all of the electrical parts are contained in the same switch box and they can be controlled centrally from that box. Increased safety and explosion-proof constructions can also be manufactured with the same specifications as the standard parts. *Table 1* gives the specifications of the RC915 type and *Fig. 2* shows an outer view.

IV. CONSTRUCTION AND OPERATION

1. Motor

As was mentioned above, the motor is a torque motor highly suitable for the opening and closing of various types of valves. The features of this motor are as follows:

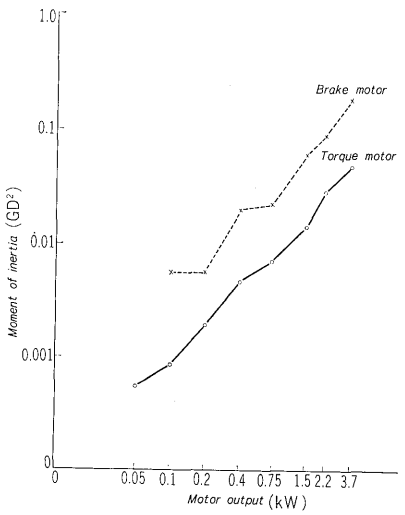


Fig. 3 Comparison of GD^2 between torque motor and brake motor

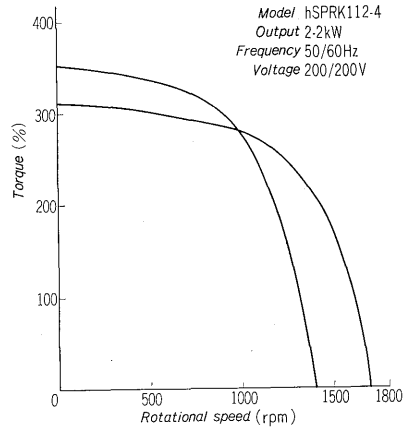


Fig. 4 Characteristics of motor torque

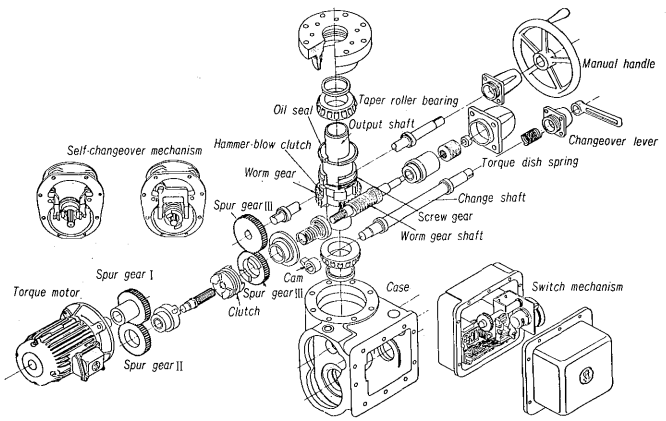


Fig. 5 Construction of type RC915-4, 8, 16, 20, 40

1) It can be employed with an IEC frame.
2) A CSA terminal box is used.
3) The moment of inertia is small.
4) The starting torque is more than 300%.
5) There are 9 terminals with switching from 200 to 400 V possible.
6) The permissible starting frequency is 360 switchings per hour (40% ED, 100% load)
7) It is a weather-protected type.
8) The ratings are for 15 minutes and the insulation is class E.
9) The amplitude of the motor vibration is less than 0.005 mm.

It is also possible to use a brake motor in accordance with customers' requirements. *Fig. 3* shows a comparison between the GD^2 of the torque motor and that of the brake motor, and *Fig. 4* shows the torque characteristics of the torque motor.

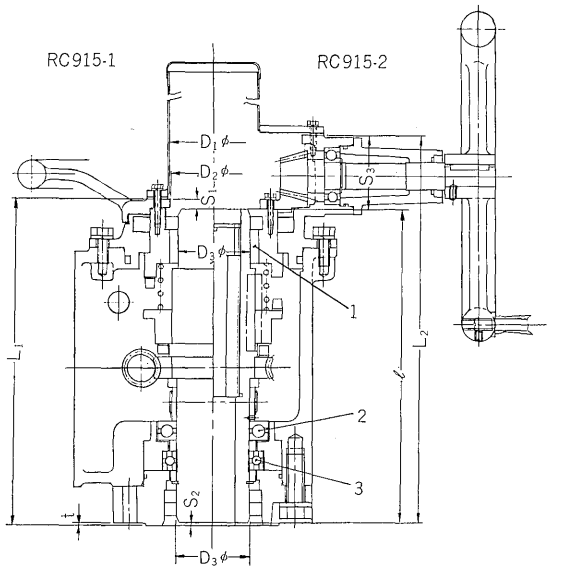
2. Reduction Gear Mechanism

The type RC915 can be classified into two groups of types depending on the construction of the manual operation mechanism and the self-changeover system. There are types RC915-1 and 2, and RC915-4, 8, 16, 20 and 40. *Fig. 5* shows the construction of the RC915-4, 8, 16, 20 and 40 types, and *Fig. 6* shows a sectional drawing of the RC915-1 and 2 types. The gear reduction mechanism is the same for all types and is explained with reference to *Fig. 5*.

The rotation of the torque motor is reduced one step by spur gears, worm shaft is speeded down considerably by the worm gear and transmitted to the output shaft. The output shaft connects with the valve stem and performs opening or closing of the valve. There are two types of output shaft: the double sleeve type and the inside screw type. The double sleeve type has a female screw in the sleeve attached inside the output shaft and is connected to a male screw on the valve stem.

The inside screw system has a screw mechanism inside the valve. The output shaft and the valve stem are connected by a key and only rotation is transmitted to the stem.

The worm gear rotates freely on the output shaft and the output shaft can not be rotated directly by the worm gear. However, the clutch directly above the worm gear is attached to the output shaft and by means of this clutch, the rotation of the worm gear can be transferred to the output shaft. There are two ends in the worm gears and the clutches. Their ends are geared so that the rotational force can be transmitted. Since the worm gear must rotate through some angle before the end of the clutch and the end of the worm gear are meshed, the motor is started initially with no load and at a certain inertia, both ends are meshed together by impact. This system is known as the hammer blow clutch.



Dimensions / Type	$D_1\phi$	$D_2\phi$	$D_3\phi$	L_1	L_2	ℓ	S_1	S_2	S_3	t	Bearing No. 1	2	3
RC915-1	80ϕ	80ϕ	65ϕ	295	—	290	2	3	—	3	Oilless bearing 65ϕ/85ϕ ×30	6013	51113
RC915-2	80ϕ	80ϕ	65ϕ	—	365	290	—	3	72	3			

Fig. 6 Sectional drawing of type RC915-1, 2

The worm shaft is rotated only while receiving a certain set pressure in the rotational direction from a dish spring. When the output shaft receives some pressure above the set pressure and rotation stops, the worm shaft slides to the left and right and the dish spring is compressed. Operation of the worm shaft is transmitted to the inside of the switching meachnaism by means of a lever, the torque limit switch is operated and the motor stops. In other words, when a very large torque is applied to the output shaft, the motor is automatically stopped.

The output shaft is rotated to the right for closing when viewed from the reverse operation side. The worm shaft is supported by 2 deep groove ball bearings and one oilless bearing. In the RC915-1 and 2 types, the output shaft is supported by thrust ball bearings and in the RC915-4, 8 and 16 types, by a tapered roller bearing. The thrust load applied to the output shaft is thus supported.

Lubrication of the worm shaft and the worm gear and lubrication of the bearings employ the bath system and the splash system respectively, and use the equivalent of ♯120 to ♯200 turbine oil. The parts where the shaft passes through are sealed by an oil seal with a dust lip and the tube joints are sealed by 0-rings, asbestos packing, rubber packing, etc. This prevents oil leaks, and the penetration of rain water, dust, etc.

3. Self-changeover Mechanism

1) RC915-4, 8, 16 and 40 Types

Changeover from manual to motor operation is performed by the clutch on the worm shaft. In other words, when the clutch is meshed with the clutch of spur gear II on the left side, motor operation is performed, and when meshed with spur gear IV on the right side, manual operation is performed. The clutch is pushed to the left by the coil spring between the clutch and spur gear IV under normal conditions, and when it is meshed with spur gear II, the equipment is in the motor operation state.

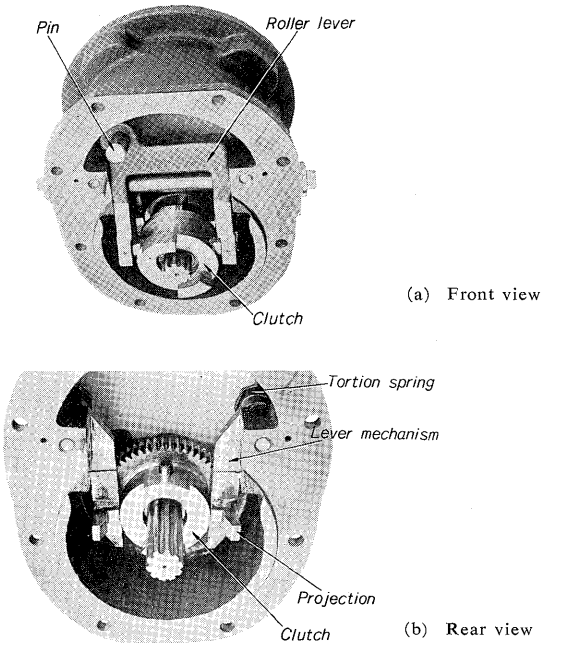


Fig. 7 Self-changeover mechanism of type RC915-4, 8, 16, 20, 40

As can be seen in *Fig. 7* (a), the clutch is meshed with the spur gears on either the left or the right by operation of the roller lever. The front side of the drawing shows the reduction gear mechanism. The motor is attached to the other side. When the changeover lever is pressed downwards, the cam at the front end of the changeover lever is pressed upwards and the roller lever is pulled toward the front. The clutch then meshes with spur gear IV and manual operation is possible. The lever mechanism seen in *Fig. 7* (b) is just behind the roller lever. The tops of two right and left levers are pushed toward the shaft side by the torsion springs located on the tops of the levers. As can be seen in *Fig. 7* (b) there are projections on the lower parts of the levers. During motor operation, the clutch is sandwiched between the projections and is meshed with the clutch of spur gear II. By operation of the changeover lever, the roller lever is pulled toward the front. At this time, the clutch is removed from between the projections, the projections change their position to the shaft side by means of the torsion spring force, and the roller lever is supported from the other end. In this way, manual operation is self-maintained.

The changeover lever which is pushed down is returned to its original position by movement of the

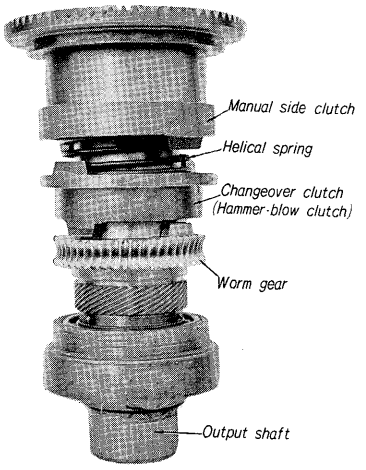
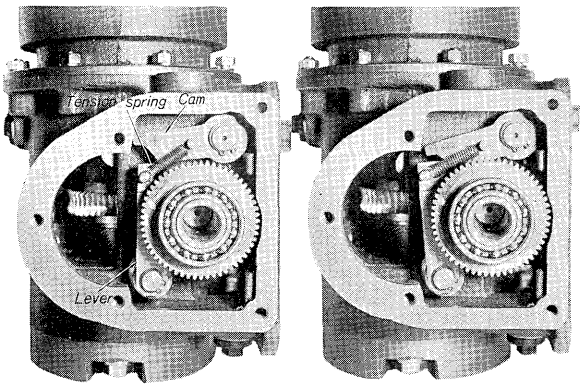


Fig. 8 Construction of drive shaft type RC915-1, 2



(a) Manual operation (b) Motor operation

Fig. 9 Self-changeover mechanism of type RC915-1, 2

torsion spring. When changing over to motor operation, if the motor is operated when the equipment is in the manual operation condition, the pin attached to clutch of spur gear II as shown is *Fig. 5* strikes the lever of the lever mechanism and the lever is pushed away. Then the roller lever shown in *Fig. 7* (a) drops down between the projections of the two levers and the equipment is in the motor operation state. Since the heights of the lever and the projections differ slighlty, there is an accurate changeover to motor operation no matter what condition the pins of the clutch of spur gesr II and the roller lever are in.

2) RC915-1 and 2 Types

In the RC915-1 and 2 types, the self-changeover mechanism and the manual operating mechanism differ slightly from those of the RC915-4, 8, 16, 20 and 40 types because the former have a smaller output and are more compact.

The manual handle is on the top of the output shaft. In the RC915-1 type, it directly rotates the output shaft and in the RC915-2 type, it rotates the output shaft via a bevel gear (see *Fig. 6*). The clutch for changeover between manual and motor operation is on the output shaft in the RC915-1 and 2 types (*Fig. 8*). The changeover clutch is also used as the hammer blow clutch and can be meshed with the clutch on the manual side by operation of the changeover lever.

The changeover clutch, i.e. the hammer blow clutch, is pressed by the coil spring on the upper part and is normally meshed with the worm gear clutch so that the operating device is in the motor operation condition. When the changeover lever is pushed downwards, the hammer blow clutch is pulled upwards and meshes with the manual side clutch. At this time, the cam connected to the changeover lever moves upwards, the lever of the lever mechanism is inserted under the cam by the force on the tension spring, and the lever is then supported from under the cam (*Fig. 9* (a) and (b)). Since the movement of the cam and the hammer blow clutch is exactly the same, manual operation is self-maintained in this condition. When changing over to motor operation, the same thing happens as in the RC915-4, 8, 16, 20 and 40 types, i.e., if the motor is operated, the levers of the lever mechanism are flipped out by the pin and changeover occurs when the cam is returned downwards to the original condition. Two levers are attached one on top of the other and when the two levers are flipped, the pins are separated from each other by 180°. Therefore, even if one pin stops with one lever in the flipped condition, manual operation is self-maintained by the other lever. Therefore, conversion to manual operation is possible in any stopping condition.

4. Switch Mechanism

1) Position limit switch

This switch controls the completely open and completely closed positions of the valves. It increases the revolution of the output shaft and transmits it to the counter. The counter can be easily set optionally to any number of rotations between 0 and 1,000 and two rotational numbers can be set with one counter. Every RC915 type has 2 counters and therefore, this is very convenient when intermediate positions are required in addition to complete opening and complete closing.

2) Torque limit switch

When the output shaft is stopped by an extra large torque, the worm shaft slides in the shaft direction due to contraction of the dish spring. This movement is detected by the torque lever, the lever in the switch mechanism moves and the microswitch is operated. Torque adjustment which determines the operating position is easy to perform by shifting the torque adjustment lever in the switch mechanism in accordance with the scale.

3) Position indication

The rotational speed of the output shaft is increased or reduced by the screw gears, worm gears and spur gears and indicated on the scale. The standard scale angle is 265° for complete closing to complete opening of the valves.

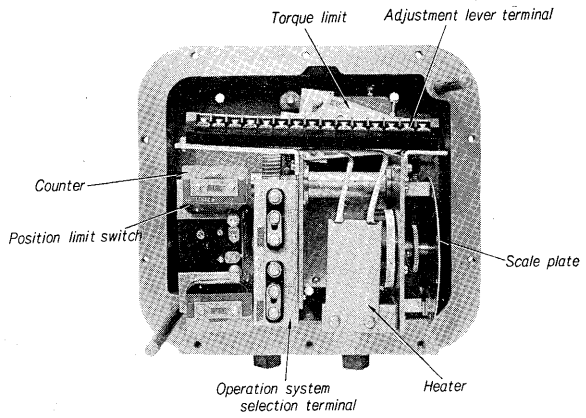
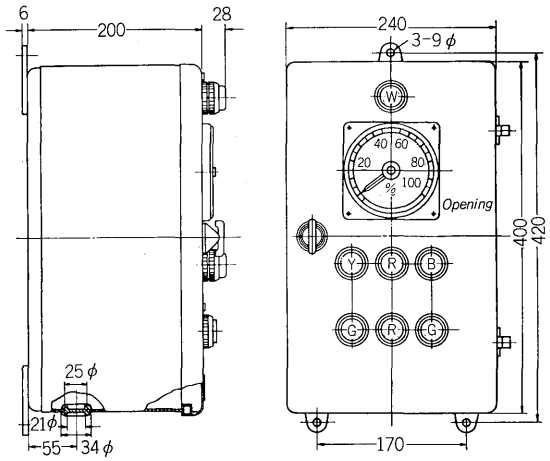


Fig. 10 Switching mechanism



Motor output (kW)	Thermal relay (A)	Fuse (A)	Wire size (mm^2)
0.4	1.6~3.3	10	>1.25
0.75	2.8~5.6	20	>1.25
1.5	4~8	40	>2.0
2.2	8~16	60	>3.5
3.7	12~18	75	>5.5

Note Control wire size: more than 1.25 mm^2
Ground wire: less than 300 V more than 2.0 mm^2
more than 300 V more than 5.5 mm^2

Fig. 11 Outside dimensions of operating box

In accordance with customers' requirements, it is possible to install synchro-transmitters and slide resistors. *Fig. 10* shows an inner view of the switching mechanism.

5. Operation Distribution Panel

When the valves are opened or closed by simple motor operation, the operating box of the equipment is used. *Fig. 11* shows the standard boxes used in each type. The operating boxes contain power source

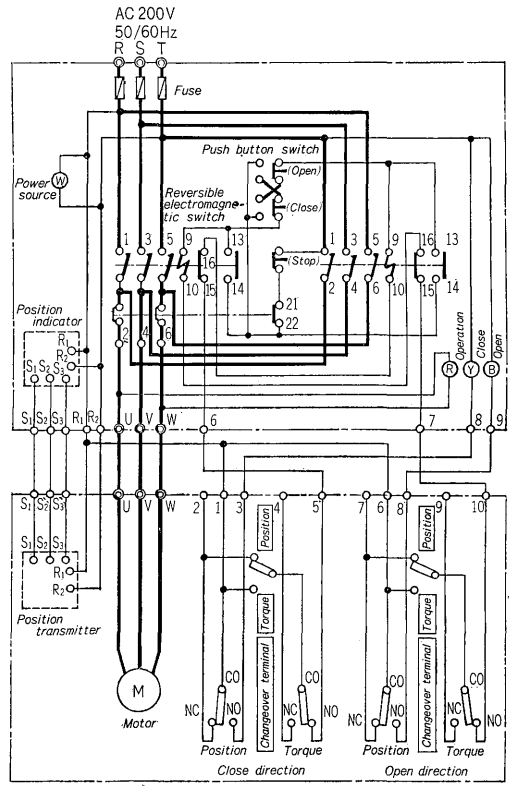


Fig. 12 Example of operating circuit

indication lamps, remote position indicators, lamps indicating complete closing, complete opening and operation, and push buttons for closing, opening and stopping. The operating device contains the reversible electromagnetic, open/close switch, the auto-breaker and various terminals. *Fig. 12* shows the standard circuitry used in this operating box.

V. CONCLUSION

Thi article has given a general outline of the new RC915 series of electric motor drives. Fuji Electric is now manufacturing an RC915K series which differs from the RC915 series, as well as applied products to meet various users' requirements such as double head motor drives and double shaft motor drives. In the future, more efforts will be made and we hope that industrial rationalization will be aided by the remote control operation of various valves.

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(2) Takao, Norimatsu, Aoki: RC910 Type Motor Drives, Fuji Electric Journal 37 No. 2 (1964)