FANUC AC SPINDLE MOTOR

P series

DESCRIPTIONS

JR AUTOMATION TECHNOLOGIES INC*
JDOWLIN

B-65102E/01

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In this manual, we endeavor to include all pertinent matters.
There are, however, a very large number of operations that must not or cannot be performed, and if the manual contained them all, it would be enormous in volume.
It is, therefore, requested to assume that any operations that are not explicitly described as being possible are "not possible".

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I. AC SPINDLE MOTOR POWER-UP series (MODELS 8P, 15P, 22P, 40P)

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1. GENERAL

The AC spindle motor P series is suitable for structural rationalization by eliminating the machine spindle gear box.

2. FEATURES

1) As the rated output range is wide at 1:8, a gear box structure for speed change is not required, thereby allowing the structure of the machine to be simplified.
   Accordingly, vibration and noise caused by the gear box structure is also eliminated.
2) Improvement in efficiency of construction equipment
   In the conventional motor, it was necessary to stop the spindle when switching the gear to change the speed. However, the P series AC spindle motor reduces unnecessary use of time, other than that needed for machining, to a minimum by eliminating gear switching.
3) Despite a compact configuration, a large low-speed torque can be obtained.
4) Similar to the standard series, the method of fan exhaust can be selected from either a exhaust front type or exhaust rear type, thus preventing heat deformation of the machine.

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3. SPECIFICATIONS

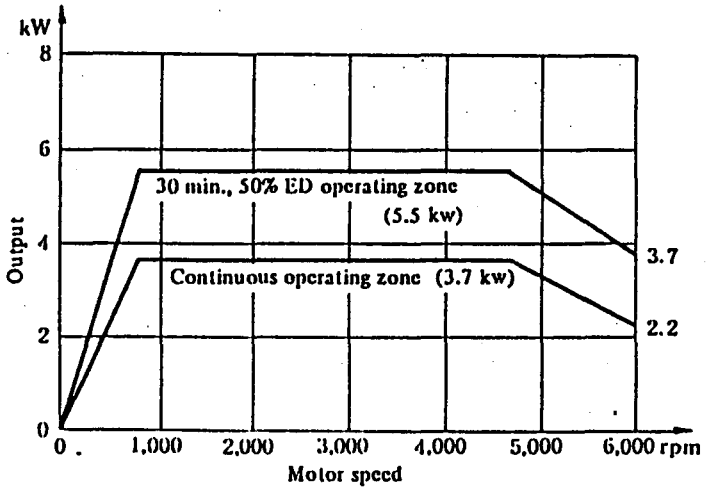
Items \ Models			8P	15P	22P	40P
Output power	Continuous rated output (*1)	kW (HP)	3.7 (5.0)	7.5 (10.0)	11 (14.7)	18.5 (24.8)
	30-minute rated output (*1)	kW (HP)	5.5 (7.4)	9 (12.0)	15 (20.1)	22 (29.5)
	50% ED rated output (*1,*2)	kW (HP)	5.5 (7.4)	9 (12.0)	15 (20.1)	22 (29.5)
Rotating speed	Base speed	rpm	750	750	750	575
	Maximum speed	rpm	6000	6000	6000	4500
Output torque (Continuous rated torque at constant torque range)		N·m (kg cm)	47.1 (480)	95.4 (974)	140 (1428)	307 (3133)
GD^2		$kg \cdot m^2$	0.11	0.36	0.51	1.18
Rotor inertia		$N \cdot m \cdot sec^2$ $(kg \cdot cm \cdot sec^2)$	0.027 (0.28)	0.091 (0.93)	0.126 (1.29)	0.29 (3.0)
Weight		kg	80	110	143	250
Cooling system			Totally enclosed fan cooled			
Cooling fan		W	56	68		84
Installation			The output shaft should be horizontal or vertically downward.			
Allowable overload capacity (1 min.)			120% of 30 minute-rating			
Insulation			Class F			
Ambient temperature			0 ~40℃			
Vibration			V5			
Noise			75 dB (A)			
Painting color			Munsell system N2.5			
Accessories			Pulse generator and thermostat			

(*1)The rated output is guaranteed at the rated input voltage (200V/220V/230V). If the input voltage fluctuates, it is possible that output cannot be obtained even when such fluctuations are within the allowable range.

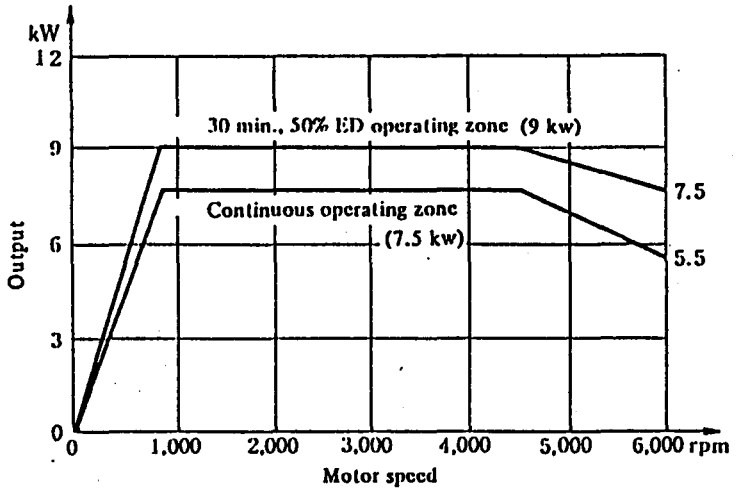
(*2)The cycle time is 10 minutes, 50% ED: ON 5 min, OFF 5 min.

4. OUTPUT CHARACTERISTICS

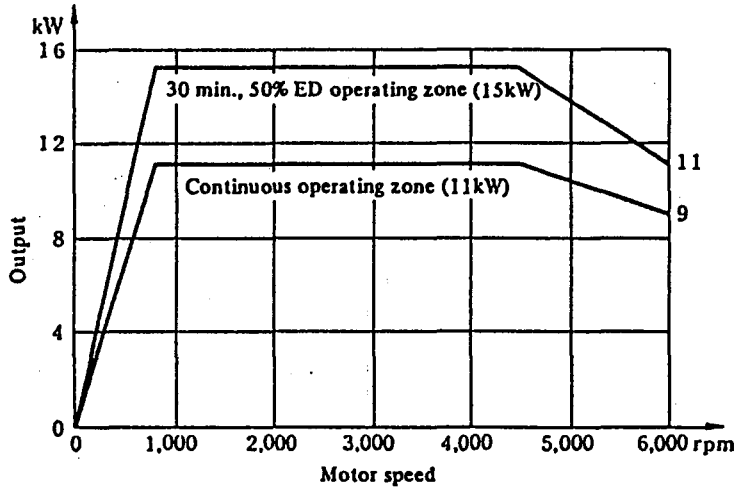
1) Model 8P



2) Model 15P



3) Model 22P



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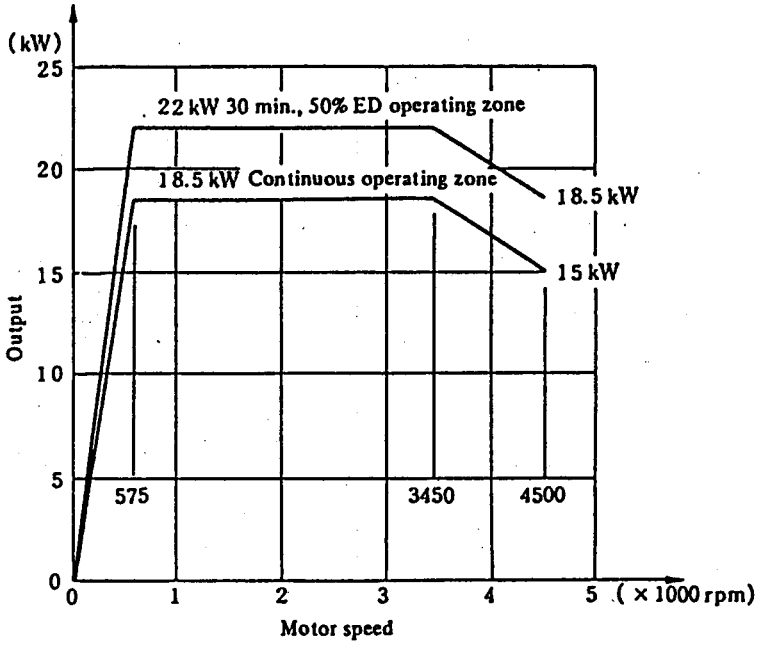
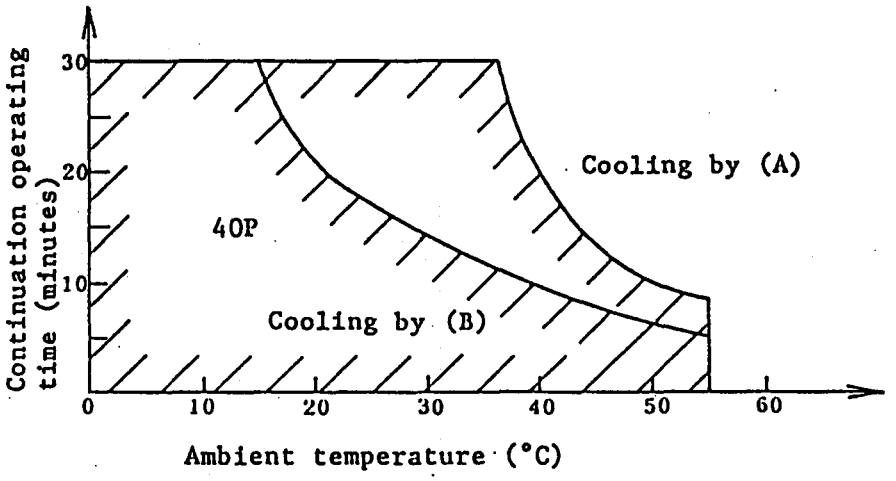
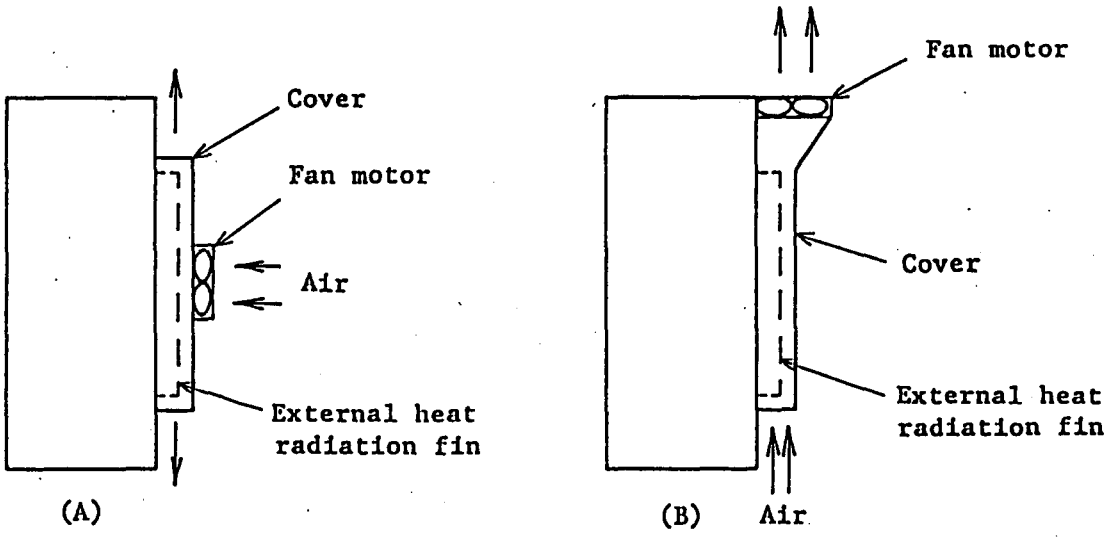
4) Model 40P


(kW)
25
20
15
10
5
0
Output
22 kW 30 min., 50% ED operating zone
18.5 kW Continuous operating zone
18.5 kW
15 kW
575
3450
4500
0
1
2
3
4
5
(× 1000 rpm)
Motor speed

Note) When ambient temperature is high in model 40P servo units, continuous usage time of a motor at 30 minutes rated output is shown below due to heat limitation of servo units.





External heat radiation fin cooling method

Note 1) In the case of internal ventilation, the extent of cooling is approximately the same as that by (B).

Note 2) Use the MINEBEA 5915PC-20W-B20-04 or its equivalents as a fan motor.

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5. ORDER SPECIFICATIONS

AC Spindle Motor

Name		Specification number	Description
Model 8P	Flange mounting	A06B-0725-B102	6000 rpm, has key, has oil seal, exhaust rear
		-B103	6000 rpm, has key, has oil seal, exhaust front
		-B302	6000 rpm, no key, has oil seal, exhaust rear
		-B303	6000 rpm, no key, has oil seal, exhaust front
	Foot mounting	A06B-0725-B202	6000 rpm, has key, no oil seal, exhaust rear
		-B203	6000 rpm, has key, no oil seal, exhaust front
		-B402	6000 rpm, no key, no oil seal, exhaust rear
		-B403	6000 rpm, no key, no oil seal, exhaust front
Model 15P	Flange mounting	A06B-0727-B102	6000 rpm, has key, has oil seal, exhaust rear
		-B103	6000 rpm, has key, has oil seal, exhaust front
		-B302	6000 rpm, no key, has oil seal, exhaust rear
		-B303	6000 rpm, no key, has oil seal, exhaust front
	Foot mounting	A06B-0727-B202	6000 rpm, has key, no oil seal, exhaust rear
		-B203	6000 rpm, has key, no oil seal, exhaust front
		-B402	6000 rpm, no key, no oil seal, exhaust rear
		-B403	6000 rpm, no key, no oil seal, exhaust front

Name		Specification number	Description
Model 22P	Flange mounting	A06B-0729-B102	6000 rpm, has key, has oil seal, exhaust rear
		-B103	6000 rpm, has key, has oil seal, exhaust front
		-B302	6000 rpm, no key, has oil seal, exhaust rear
		-B303	6000 rpm, no key, has oil seal, exhaust front
	Foot mounting	A06B-0729-B202	6000 rpm, has key, no oil seal, exhaust rear
		-B203	6000 rpm, has key, no oil seal, exhaust front
		-B402	6000 rpm, no key, no oil seal, exhaust rear
		-B403	6000 rpm, no key, no oil seal, exhaust front
Model 40P	Flange mounting	A06B-0731-B100	4500 rpm, has key, has oil seal, exhaust rear
		-B101	4500 rpm, has key, has oil seal, exhaust front
		-B300	4500 rpm, no key, has oil seal, exhaust rear
		-B301	4500 rpm, no key, has oil seal, exhaust front
	Foot mounting	A06B-0731-B200	4500 rpm, has key, no oil seal, exhaust rear
		-B201	4500 rpm, has key, no oil seal, exhaust front
		-B400	4500 rpm, no key, no oil seal, exhaust rear
		-B401	4500 rpm, no key, no oil seal, exhaust front

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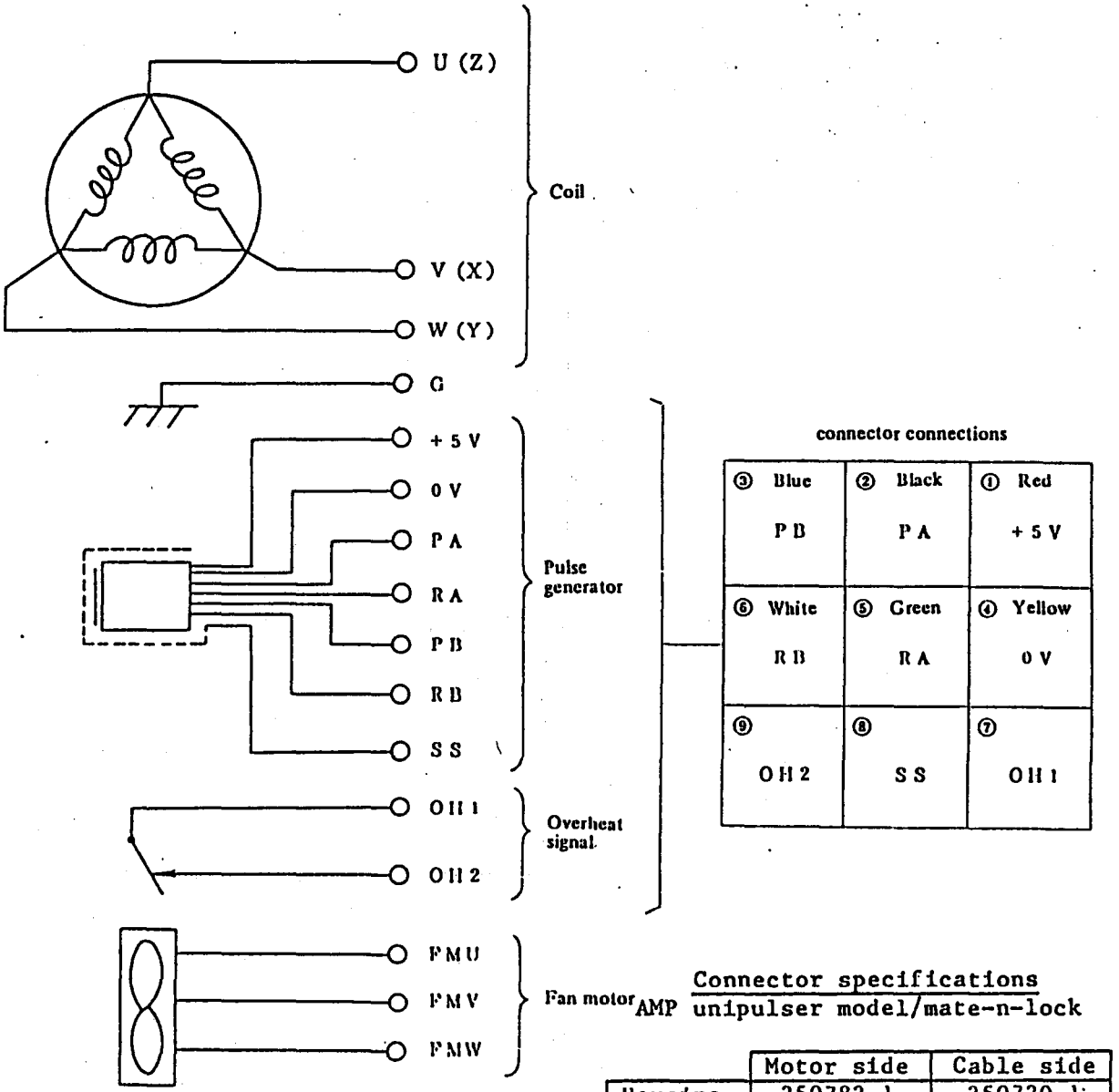
6. CONNECTIONS



AMP Connector specifications
unipulser model/mate-n-lock

	Motor side	Cable side
Housing	350782-1	350720-1
Contact	350706-7	350689-6

The pulse generator and overheat signals are connected to the AMP connector. The others are connected to the terminal block.

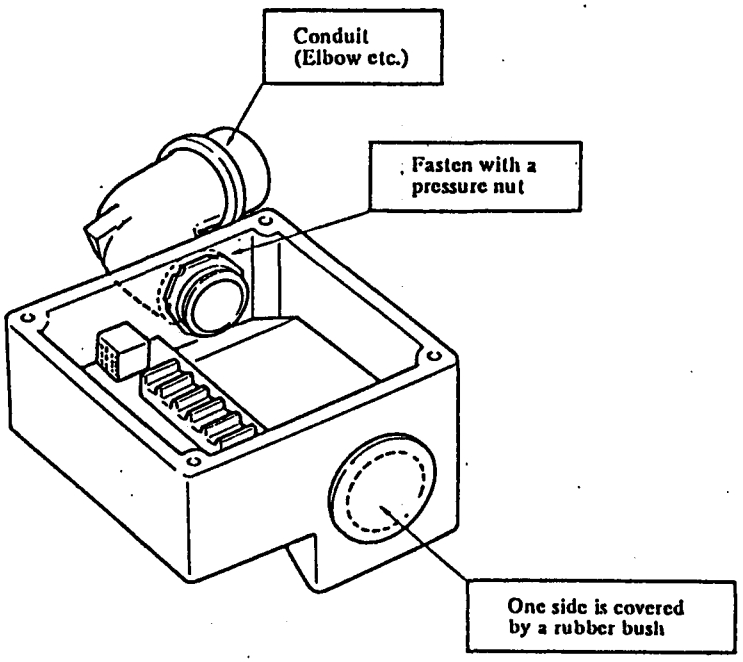
Terminal block screw dimensions

Terminal name / Model	U,V,W,G	FMU - FMW
8P - 22P	M5	M4
40P	M8	M4

7. PRECAUTIONS RELATED TO USE

1) Terminal box

The terminal box is made from plastic. Therefore, the metal plate that was attached to both side faces of the present terminal box have been discontinued. Mount the conduit by directly fastening with a nut, as shown in the diagram below.



2) Allowable radial load

Use the motor output shaft with allowable radial load shown in the below table or less.

Motor model	Allowable radial load	Output shaft bearing
Model 8P	300 kg	6210
Model 15P	300 kg	6312
Model 22P	450 kg	
Model 40P	550 kg	6314

Note) The above-listed allowable radial loads are values obtained when the load was applied to the end of the output shaft. In cases when the center of belt tension is beyond the end of the output shaft, the values for allowable load will be smaller than those given above.

When using belt to transmit power, adjust the tension so that it does not exceed the above allowable value. In case load is applied in the thrust direction by helical gears, the shaft will move in the thrust direction. Therefore, do not apply thrust load as a rule.

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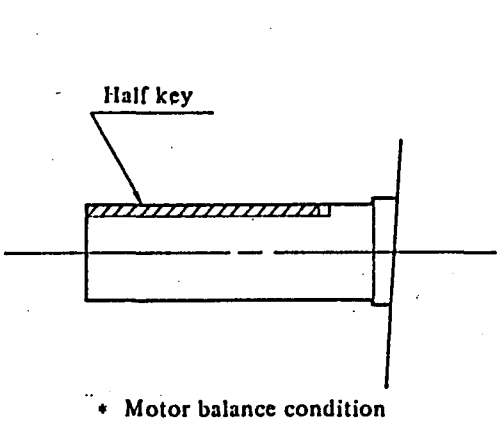
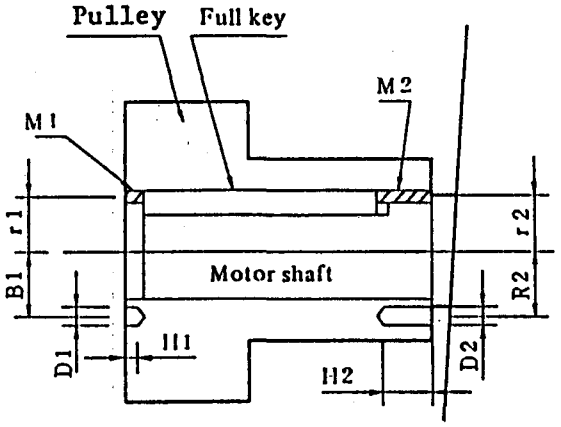
3) Mount the motor so that cutting oil or lubricating oil is not directly splashed to the motor main body.

4) Dynamic balance
The motor rotor is dynamically balanced with the balancing machine under the mounting condition of a half key (1/2 the key thickness shown in the outer dimensions drawing) keyed on the shaft.
Since the AC spindle motor is a high-speed rotating motor, its slightest unbalance causes noticeable vibrations. Pay particular attention to dynamic balance of motor shaft gears and pulleys as well as other high-speed rotating shafts.
For high-speed operation, use a keyless motor.



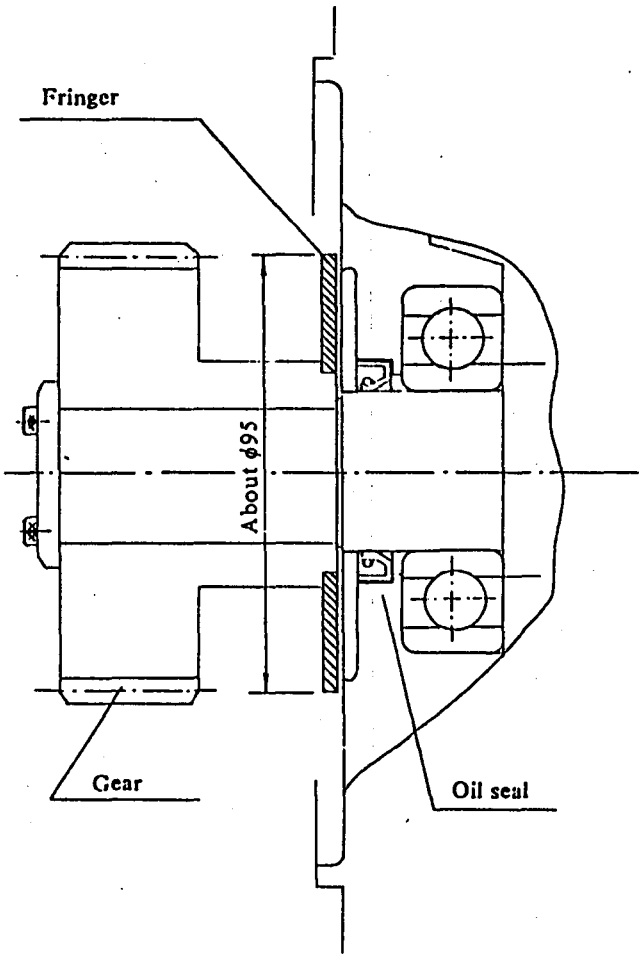


$\pi(D1/2)^2 H1 \cdot p \times R1 = M1 \times r1$ p; Density

$\pi(D2/2)^2 H2 \cdot p \times R2 = M2 \times r2$

* Balance correction

5) An oil seal is mounted to the flange type motor output shaft. Keep the lubricating oil level lower than the oil seal lip, so that lubricating oil will not spill straight on the lip.
Since the seal effect may be lost with lubricating oil spilled directly on the lip even in forced lubrication, mount a fringer as illustrated below.



Fringer mounting example

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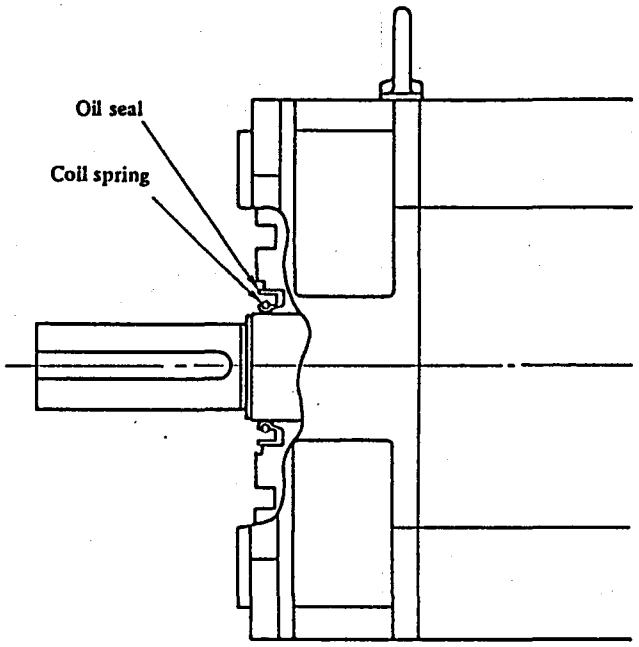
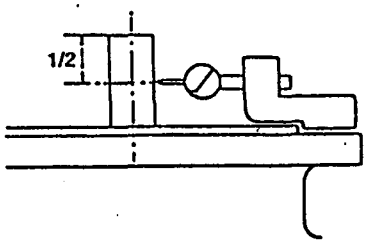
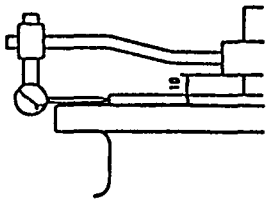
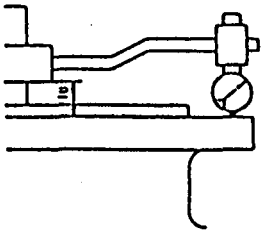
6) Points to be noted when the AC spindle motor is used in a dry environment
The seal effect, regarding the oil seal which is mounted in the front flange section of the flange type, is activated in the state where the lubricating oil is distributed on the flange surface in the same manner as inside an oil lubricated gear box. However, if it is rotated at high speed in the state where the lubricating oil has not been distributed by the belt drive, etc. (dry state), a shrill sound may be emitted from the contact section of the oil seal and the shaft. In this case, the lip section will be damaged, and the coil spring tightening the lip section will slacken off.
In order to prevent the above occurrence, when using the AC spindle motor in the dry state, detach the coil spring tightening the lip section and use in a state of reduced friction between the lip and the shaft. Even when the coil spring is detached, there will be no lessening of the dustproof effect for sludge, casting particles, etc.



7) Assembling Accuracy (T.I.R: Total Indicator Reading)

Item \ Model	22P or lower	40P	Measuring method
Vibration at the end of the output shaft	20μ or less		
Vibration of the faucet joint for mounting the flange against the core of the shaft	40μ or less	60μ or less	
Vibration of the flange mounting surface against the core of the shaft	80μ or less	100μ or less	

8) To ensure long-term reliability of each part of the motor, the acceleration of vibration in the areas where the motor is mounted must be 5G or less, even when the motor is used for cutting.

9) The strength of the motor's eyebolts is only suitable for lifting the motor itself (a gear and pulley can be used). Do not use the eyebolts for any other purposes.

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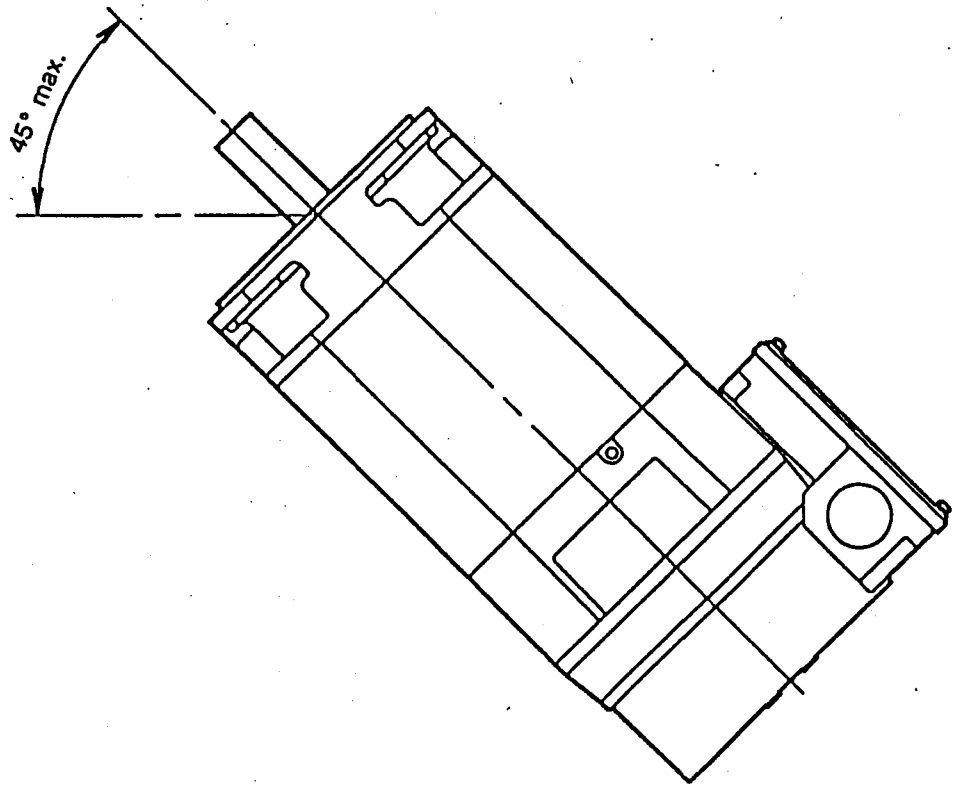
10) Installing a motor with the front upward

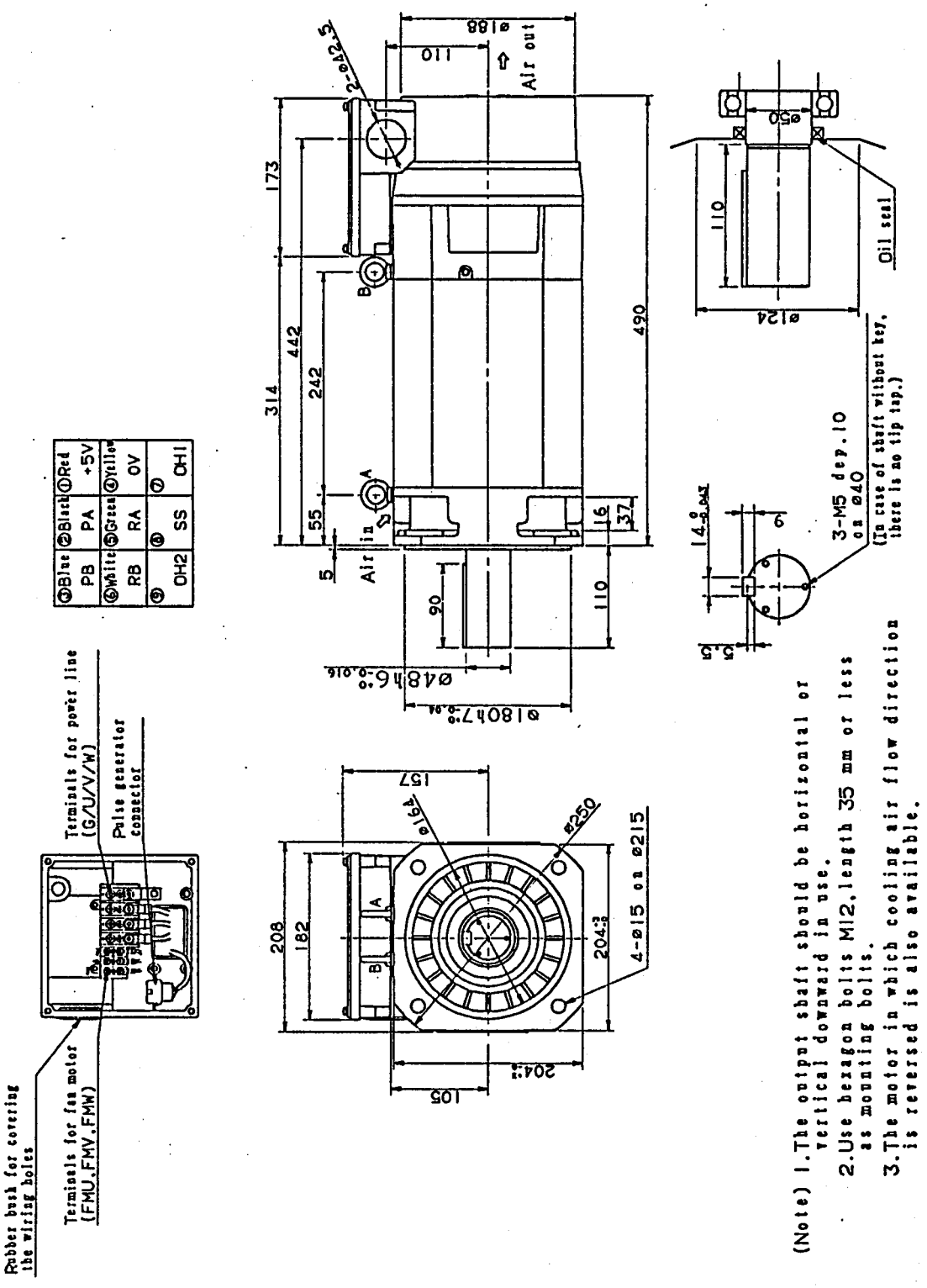
The motors described herein must be installed within 45° of the horizontal, as shown below. If it is necessary to install the motor sloping upward in oxcoss of 45°, please contact a FANUC sales section in charge.



8. EXTERNAL DIMENSIONS

8.1 AC Spindle Motor Model 8P

(a) Flange mounting type



(Note) 1.The output shaft should be horizontal or vertical downward in use.
2.Use hexagon bolts M12,length 35 mm or less as mounting bolts.
3.The motor in which cooling air flow direction is reversed is also available.

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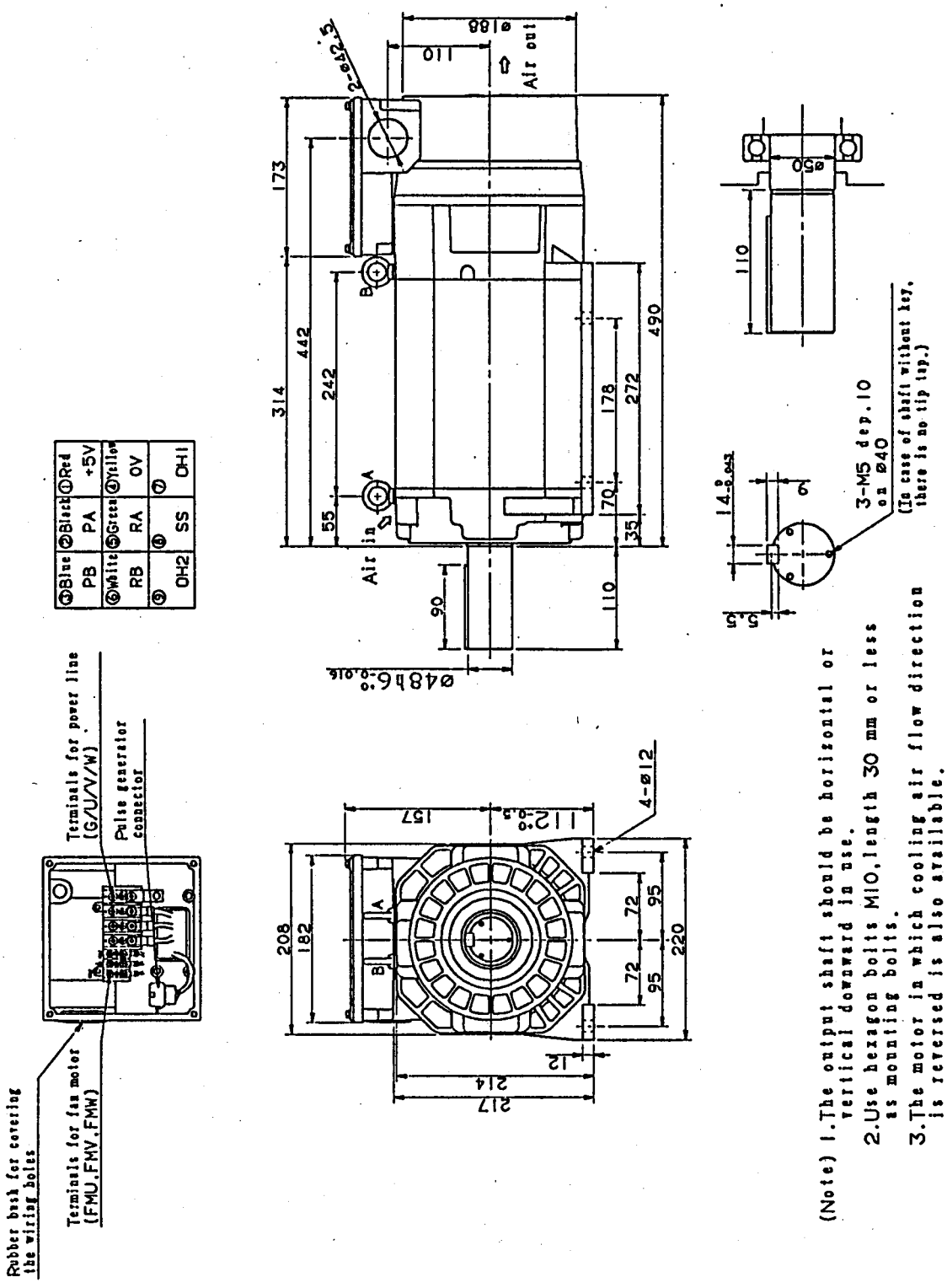
Model 8P

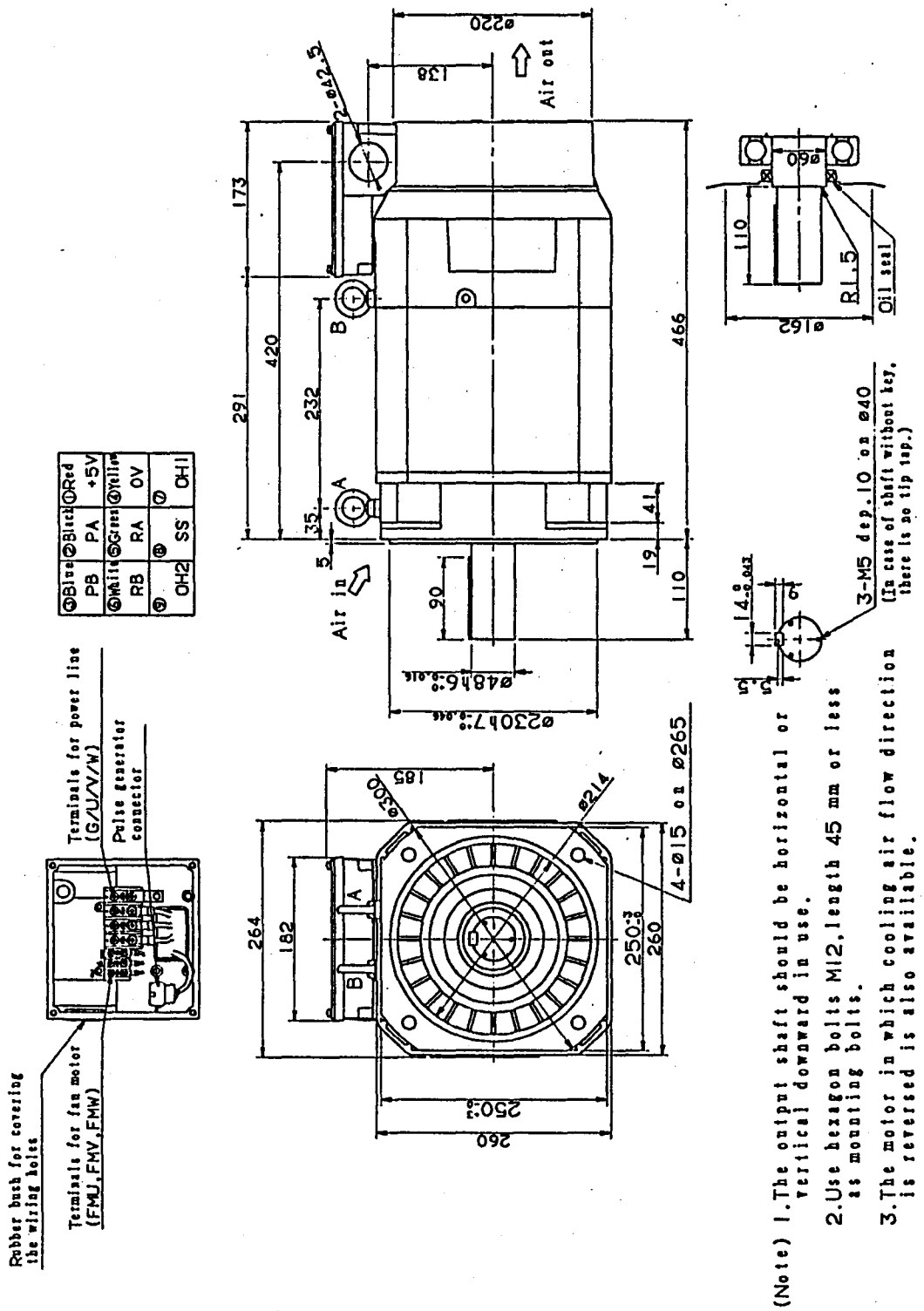
(b) Foot mounting type



(Note) 1.The output shaft should be horizontal or vertical downward in use.
2.Use hexagon bolts M10,length 30 mm or less as mounting bolts.
3.The motor in which cooling air flow direction is reversed is also available.

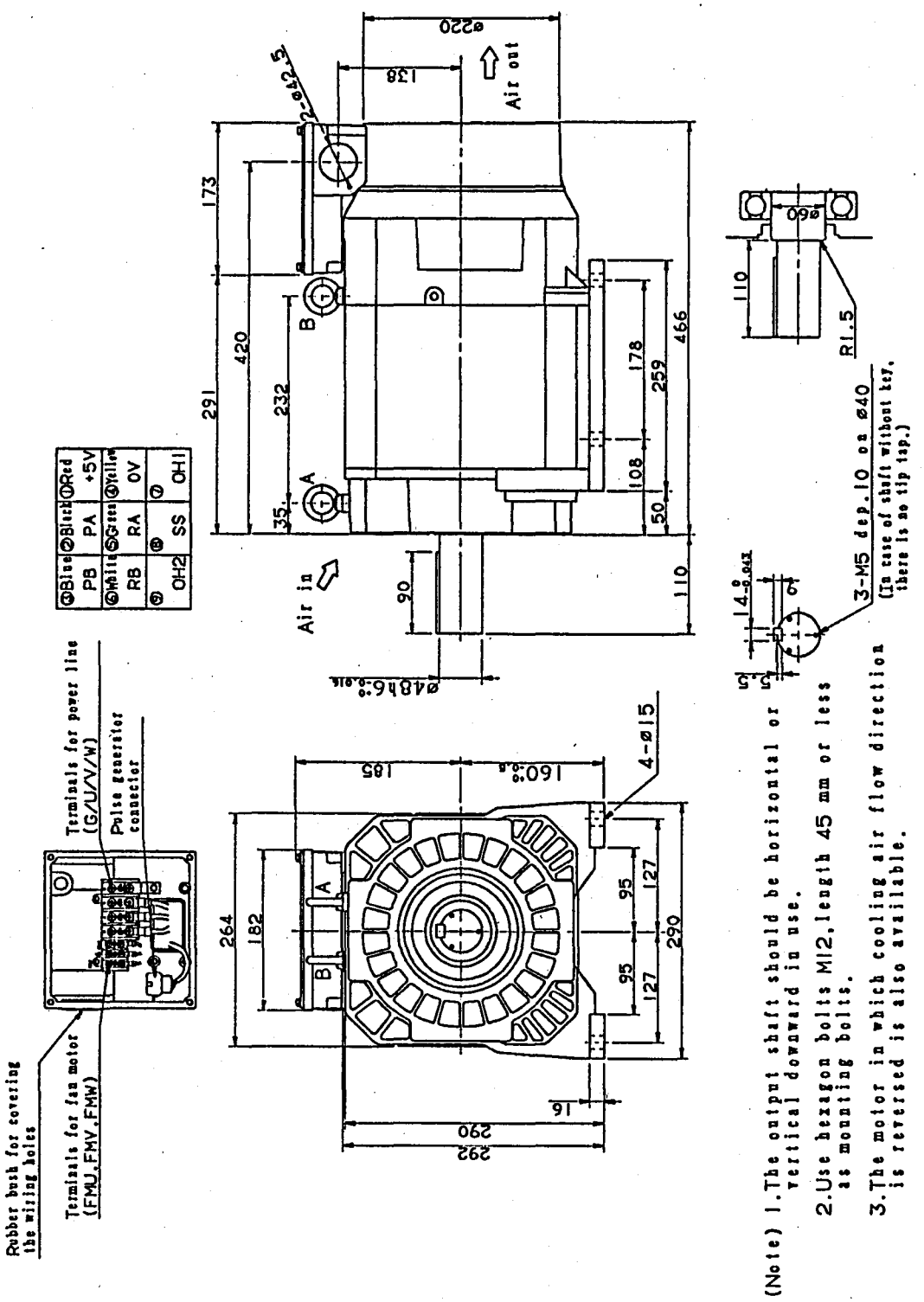
8.2 AC Spindle Motor Model 15P

(a) Flange mounting type



Model 15P

(b) Foot mounting type



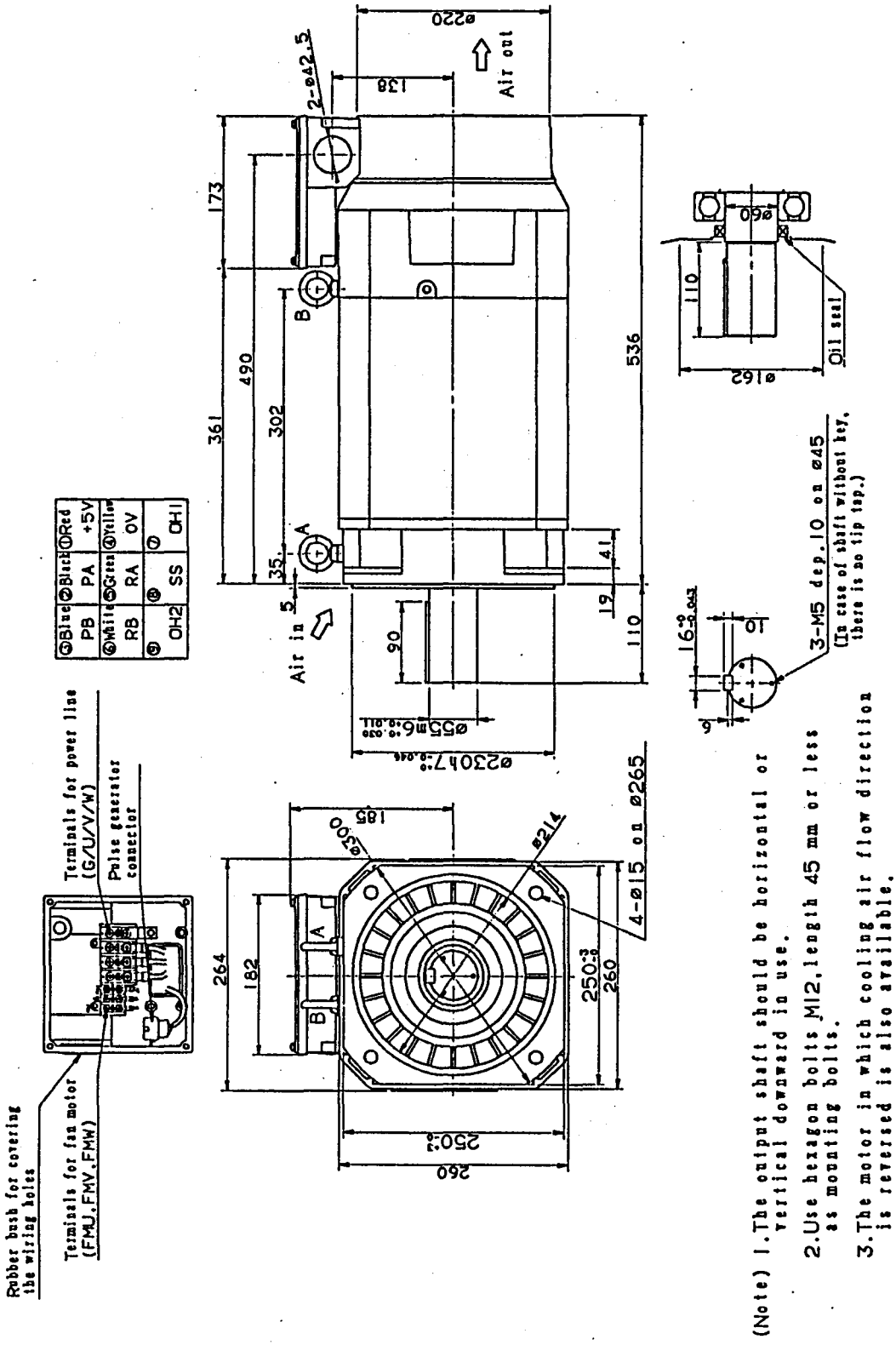
(Note) 1.The output shaft should be horizontal or vertical downward in use.

2.Use hexagon bolts M12,length 45 mm or less as mounting bolts.

3.The motor in which cooling air flow direction is reversed is also available.

8.3 AC Spindle Motor Model 22P

(a) Flange mounting type



(Note) 1. The output shaft should be horizontal or vertical downward in use.

2. Use hexagon bolts M12, length 45 mm or less as mounting bolts.

3. The motor in which cooling air flow direction is reversed is also available.

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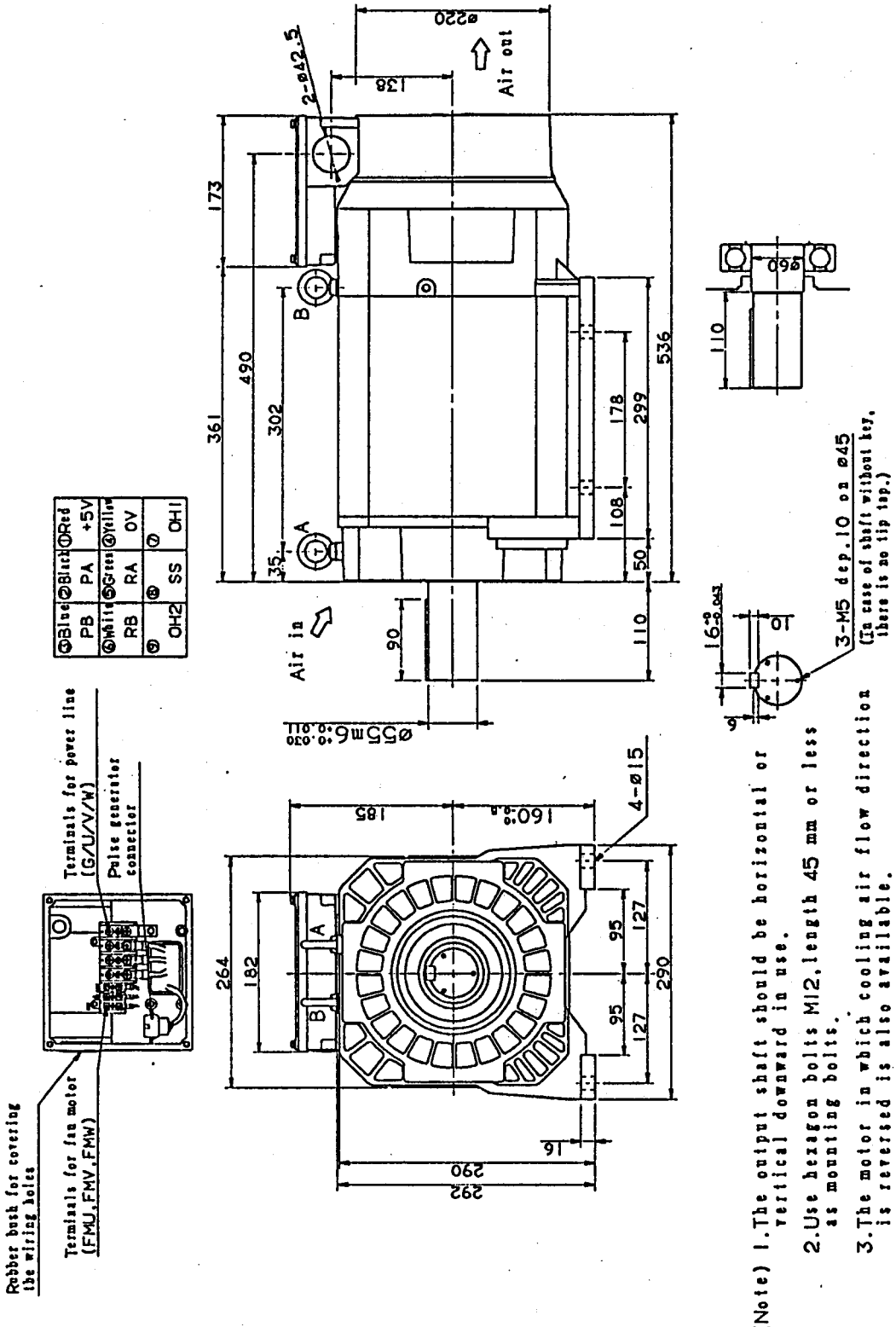
Model 22P

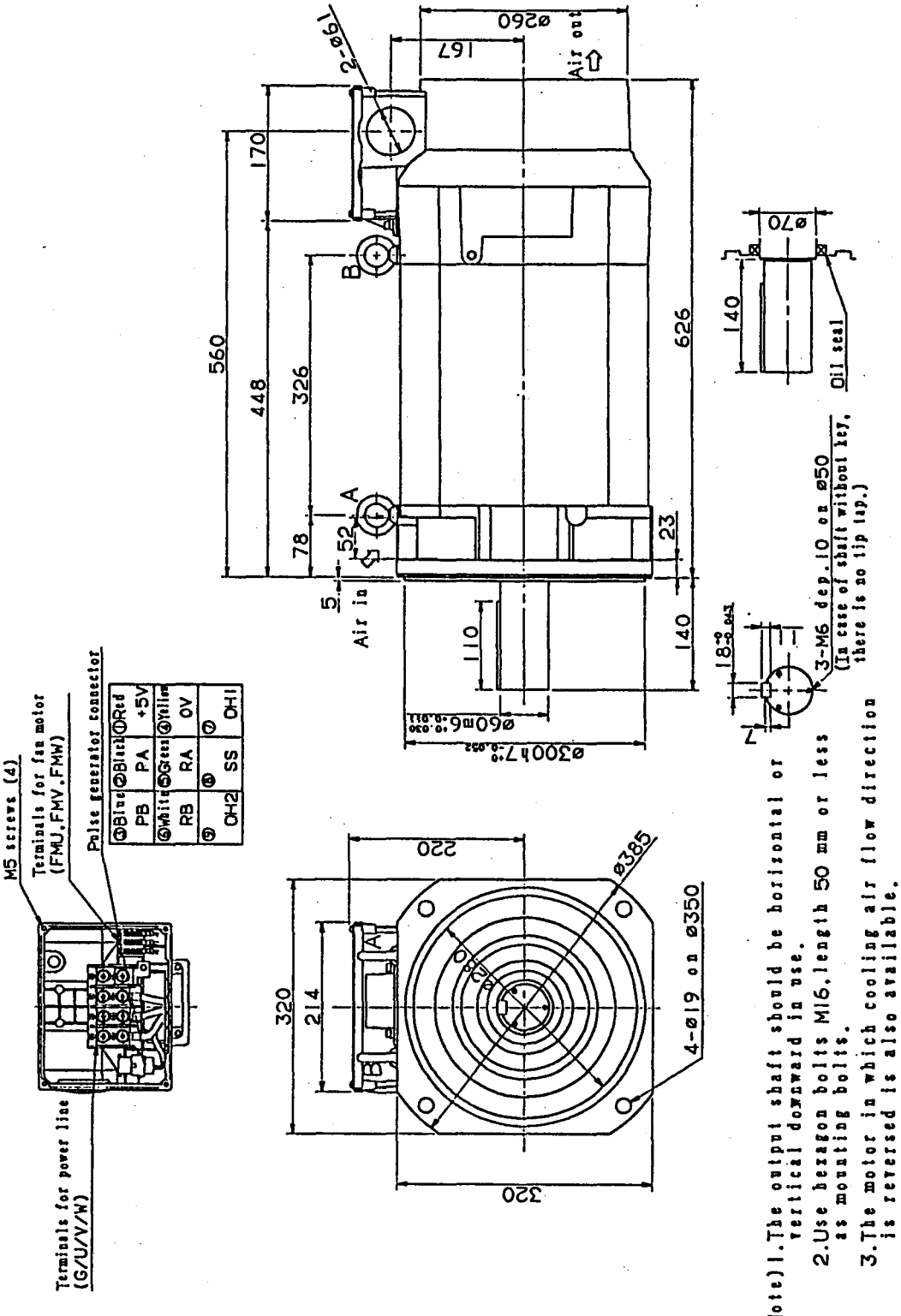
(b) Foot mounting type



(Note) 1. The output shaft should be horizontal or vertical downward in use.
2. Use hexagon bolts M12, length 45 mm or less as mounting bolts.
3. The motor in which cooling air flow direction is reversed is also available.

8.4 AC Spindle Motor Model 40P

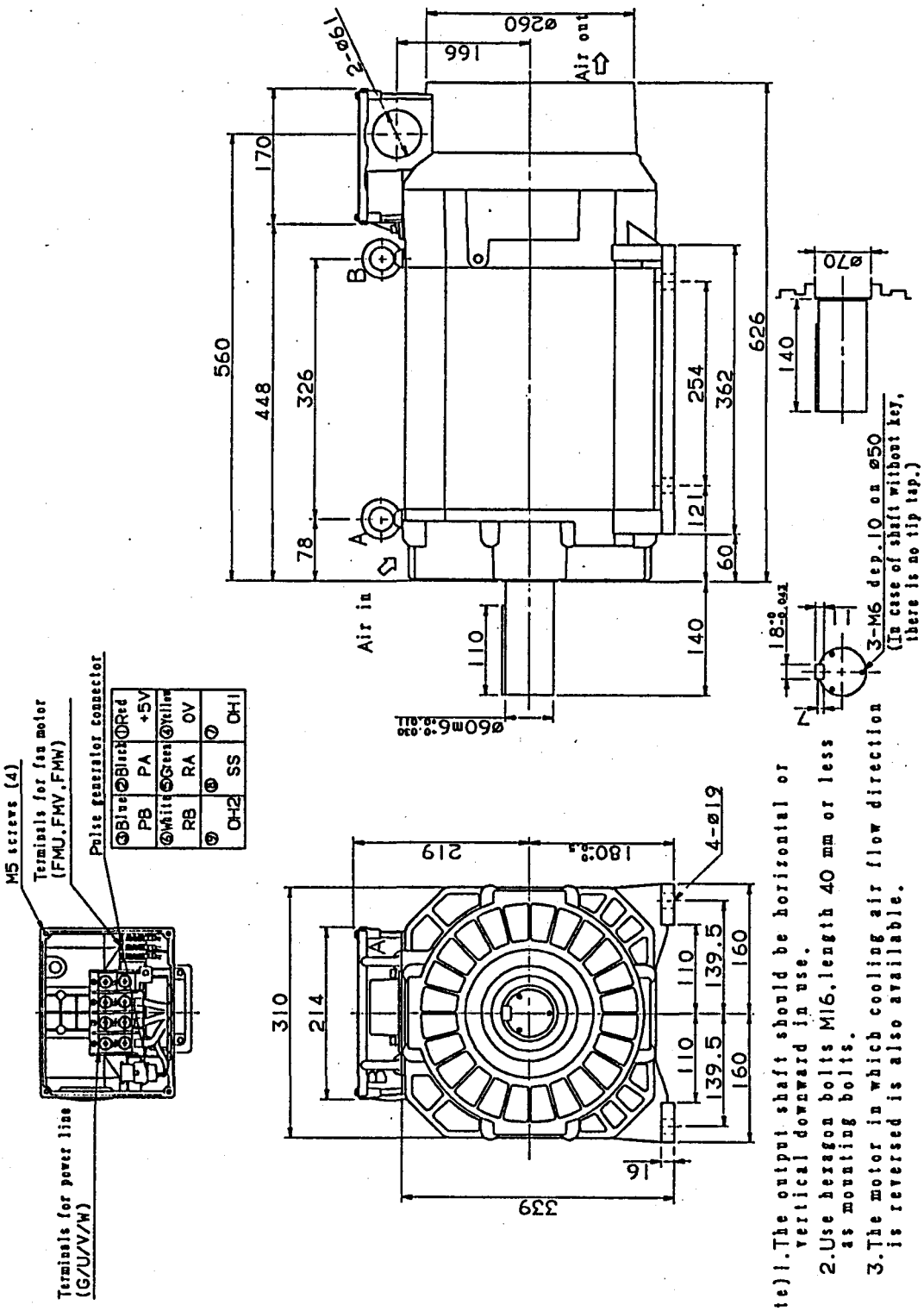
(a) Flange mounting type



(Note) 1. The output shaft should be horizontal or vertical downward in use.
2. Use hexagon bolts M16, length 50 mm or less as mounting bolts.
3. The motor in which cooling air flow direction is reversed is also available.

Model 40P

(b) Foot mounting type



① Blue	② Black	③ Red	+5V
PB	PA		
④ White	⑤ Green	⑥ Yellow	0V
RB	RA		
⑦	⑧	⑨	CH1
CH2	SS		

II. AC SPINDLE SERVO UNIT

1. GENERAL

The presents specification describe the AC SPINDLE SERVO UNITs for AC SPINDLE MOTOR MODELS 8P,15P,22P and 40P.

· Comfirming AC SPINDLE SERVO UNIT specification
The spindle servo unit is specified as follows.

Ex.) A06B-6055-H306 #H536
(A) (B)
(C)

(A) Power circuit and control PCB.
(B) Control ROM. ROM series is indicated on the ROM label. The lower two digits of ROM series show the lower two digits of (B).

Ex.) ROM label Spec. (B)

9636
002A

#H536

(C) Indicated on the label of the spindle servo unit.

AC SPINDLE SERVO UNIT		
TYPE	A06B-6055-H306#H536	⇐ Specification
NO.		⇐ Manufacturing No.
DATE		⇐ Manufacturing Date.
FANUC LTD.		

2. FEATURES

(1) Improvement of performance
(a) Responce characteristics have been improved for stable, high cutting performance.
(b) Improvement of tapping performance
Elongation of tapper can be shortened because of improvement of acceleration/deceleration performance in low speed range. It realizes the tap machininge of higher speed.
(c) Improvement of rigidity at orientation
Stable tool change can be made even though spindle speed is accelerated faster than motor speed.
(d) Reducing of adjustment process
Adjustment process can be reduced as measurement of spindle rotation number is made in digital method without using instruments.
(e) Improvement of linearity of loadometer
Load condition on the motor can be accurately checked with the loadometer.

(2) Improvement of flexibility
Easy chenge of maximum rotation(revolution) number and output limit value can be made with parameter setting system.

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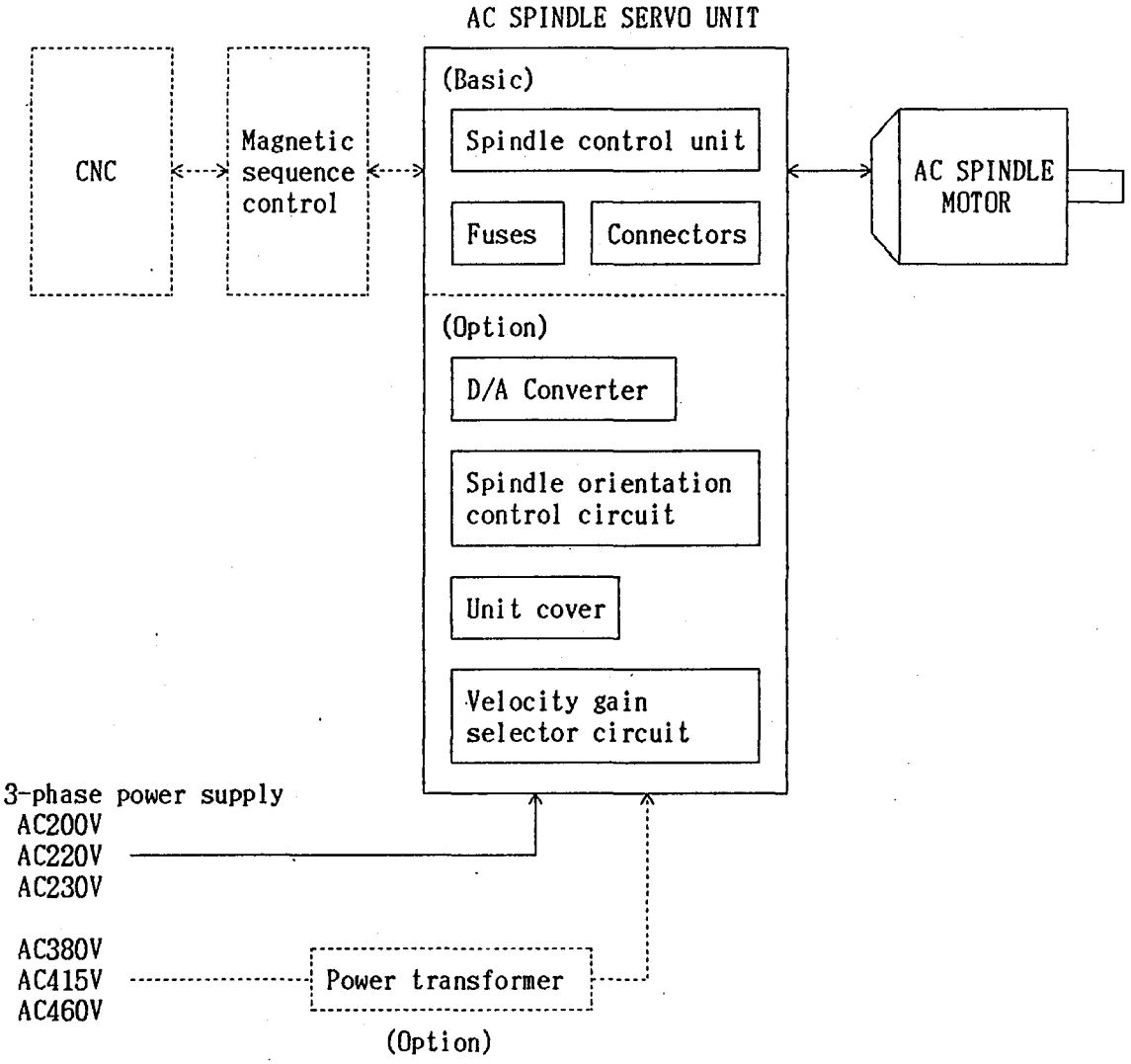
3. CONFIGURATION AND ORDER NUMBER

3.1 Configuration

AC SPINDLE SERVO UNIT consists of the following unit and parts.

(1)	Spindle control unit	(Basic)
(2)	Fuses	(Basic)
(3)	Connectors	(Basic)
(4)	D/A converter	(Option)
(5)	Power transformer	(Option)
(6)	Spindle orientation control circuit	(Option)
(7)	Unit cover	(Option for only MODEL 6S,8S)
(8)	Velocity gain selector circuit	(Option)



3.2 Types of units and combinations

Spindle servo unit model	Basic			Option					Remarks
	Spindle control unit	Connectors	Fuses	D/A converter	Spindle orientation control circuit	Velocity gain selector circuit	Power transformer	Unit cover	
Model 6S	○	○ 2 type	○	○ 2 type	○ 8 type	○	○	○	For Model 8P
Model 8S	○		○						For Model 15P
Model 15S	○		○				○	—	For Model 22P
Model 22S	○		○				○		For Model 40P

3.3 Order Number

Class	Name		Specifications	Remarks
Basic	AC spindle servo unit for Model 8P		A06B-6055-H306#H536	Internal ventilation (Model 6S unit is same)
	AC spindle servo unit for Model 15P		A06B-6055-H308#H531	Internal ventilation (Model 8S unit is same)
	AC spindle servo unit for Model 22P		A06B-6055-H315#H530	Internal ventilation (Model 15S unit is same)
	AC spindle servo unit for Model 40P		A06B-6055-H322#H540	Internal ventilation (Model 22S unit is same)
	Fuses	Model 8P	A06B-6055-K023	
		Model 15P	A06B-6055-K024	
		Model 22P	A06B-6055-K026	
		Model 40P	A06B-6055-K022	
	Connectors (Common to Model 8P 15P,22P and 40P)		A06B-6044-K009	Soldering
			A06B-6044-K034	Crimp style terminal
Option	D/A converter		A06B-6041-J031	BCD two digits
			A06B-6041-J032	Binary 12 bits
	Power transformer	Model 8P	A06B-6044-J006	Primary AC380/415/460V Secondary AC200V
		Model 15P		
		Model 22P	A06B-6044-J007	
		Model 40P	A06B-6044-J010	
	Unit cover		A06B-6044-K030	Special for Model 8P,15P

Spindle orientation control circuit : Refer to section Ⅲ.
Velocity gain selector : Refer to section Ⅳ.

4. SPECIFICATIONS

4.1 Spindle control unit

4.1.1 Specifications

Item	Motor model	8P	15P	22P	40P
	Unit model	6S	8S	15S	22S
30-min. rated power source capacity kVA		9	15	22	32
Power source (*1)		AC200/220/230V, +10%/-15%; 50/60Hz ± 1Hz			
Main circuit system		Transistor PWM inverter			
Feed back system		Speed feed back by pulse generator			
Braking system (Regenerative energy processing system)		Regenerative braking (Power source regeneration)			
Speed control range rpm (Speed ratio)		60-6000 (1:100)			45-4500 (1:100)
Speed variation		Less than 0.1% of the maximum speed (Load variation 10 - 100%)			
Ambient temperature (*2)		0 - 55℃			
Weight kg		27	34	43	57

(*1) If the power source voltage is other than specified herein, a transformer is needed.

(*2) In Model 40P, the continuous operating time of the motor at 30-min. rated output is determined as follows by the thermal limitation of the unit. (Refer to section 5.3)

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4.1.2 Functions

The spindle control unit rectifies three-phase AC inputs, and converts it into DC so as to perform the velocity control of the AC spindle motor through transistor PWM inverter.

The spindle control unit is provided with a protective and fault detection function as shown in (1) for the purpose of protecting machine, AC spindle motor, and AC spindle servo unit, if a trouble occurred. It also provides an auxiliary function as shown in (2) for monitoring the operating conditions of the spindle.

(1) Protective and fault detection functions

Item	Description	Display
Motor overheat detection	An alarm is issued, if the internal temperature of AC spindle motor increases.	Display of seven segments in five digits. (AL-01)
Excessive velocity deviation detection	An alarm is issued, if the AC spindle motor speed is largely deviated from the commanded speed due to an overload, etc.	Display of seven segments in five digits. (AL-02)
Main circuit input fuse blown out	If the main circuit input current is excessively high due to a ground fault, etc., the fuse is blown out to issue an alarm	Display of seven segments in five digits. (AL-04)
DC link fuse blown out	If the DC link current is excessively high due to a fault of the power circuit, etc., the fuse is blown out to issue an alarm.	Display of seven segments in five digits. (AL-03)
Over speed detection	If the AC spindle motor exceeds 100 to 115 % of the rated maximum speed, an alarm is issued.	Display of seven segments in five digits. (AL-06,07)
Over voltage detection	If the AC input power circuit voltage exceeds the rated voltage range, an alarm is issued.	Display of seven segments in five digits. (AL-08)
Main circuit overload detection	If the temperature at radiation of power circuit abnormally increases, an alarm is issued.	Display of seven segments in five digits. (AL-09)
Undervoltage detection	If the control power voltage abnormally lowers, an alarm is issued.	Display of seven segments in five digits. (AL-10)
DC link over voltage	If the DC link voltage abnormally increases, an alarm is issued.	Display of seven segments in five digits. (AL-11)

Item	Description	Display
Abnormal current detection	If an abnormally large current flows to the main circuit, an alarm is issued.	Display of seven segments in five digits. (AL-12)
Abnormal arithmetic circuit detection	An alarm is issued, if microprocessor or its pertipheral parts of arithmetic circuit is abnormal.	Display of seven segments in five digits. (AL-13)
Abnormal ROM detection	An alarm is issued, if ROM is in trouble.	Display of seven segments in five digits. (AL-14)

(2) Auxiliary functions
The AC spindle control unit provides the following auxiliary functions.

Item No.	Auxiliary function	Description
1	Loadometer output	The 10-V DC meter(one-sided deflection type) is connectable.
2	Speedometer outpur	The 10-V DC meter(one-sided deflection type) is connectable.
3	Zero-speed signal output	It is possible to verify that the spindle motor has stopped.
4	Speed arrival signal output	It is possible to verify that the speed of the spindle motor has reached the commanded speed.
5	Override	Override to the command speed (auto) is possible
6	Speed detection signal output	The clutch changeable speed and gear changeable speed can be confirmed to be lower than a certain speed.
7	Torque limit	The output torque of the spindle motor can be temporarily made small and ratated.
8	Motor speed display	The actual motor speed (rpm) can be displayed as 5-digit, 7-segment.
9	Selection of output limit pattern	Valious kinds of output limit patterns can be selected with setting of parameter. ・No output limit is made. ・Output limit is made only at acceleration /deceleration. ・Output limit is made only at normal rotation. ・Output limit is made for all functions. Divide the maximum output by 100 for setting.
10	Selection of rigid tapping mode	Necessary response characteristics for rigid tapping can be selected by setting of parameter and input of contact signal.

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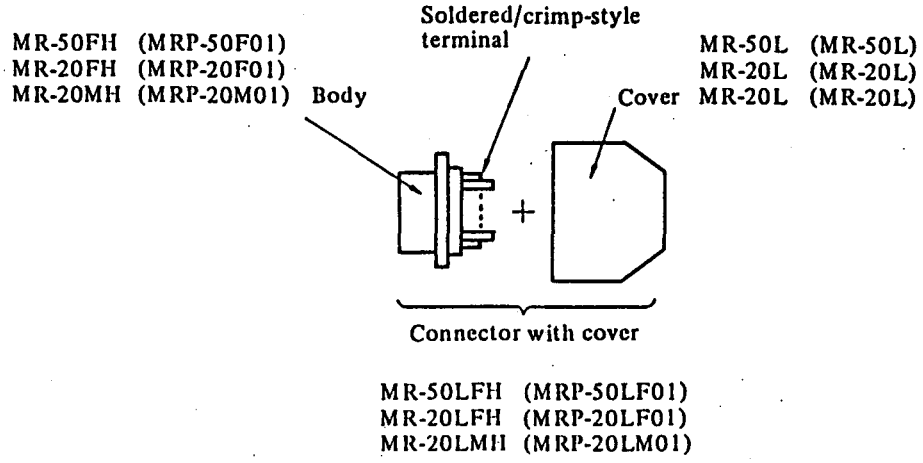
4.2 Connectors

The following specifications table specifies the counter-connectors for the connectors mounted on control PCB of basic of the AC spindle servo unit. The signal connectors of the motor side are attached to the motor.

1) Specifications

Use	Name	Specifications	Qty	FANUC's specifications	Remarks
For CN1	Connector with cover (50 pin)	MR -50LFH	1	A63L-0001-0134/01	Soldered
		MRP-50F01	1	A63L-0001-0134/21	Crimp style
For CN2	Connector with cover (20 pin)	MR -20LFH	1	A63L-0001-0134/02	Soldered
		MRP-20LF01	1	A63L-0001-0134/22	Crimp style
For CN3	Connector with cover (20 pin)	MR-20LMH	1	A63L-0001-0134/12	Soldered
		MRP-20LM01	1	A63L-0001-0134/32	Crimp style

2) Structure



Specifications shown in parentheses are for crimp-style terminal.

3) Pin array of terminal
Refer to Appendix 1 for the pin array of terminal.

4) Outer diameter of cable

Connector specifications	Outer diameter of cable
MR-50LFH	Max. ϕ16 mm
MR-20LFH MR-20LMH	Max. ϕ10 mm

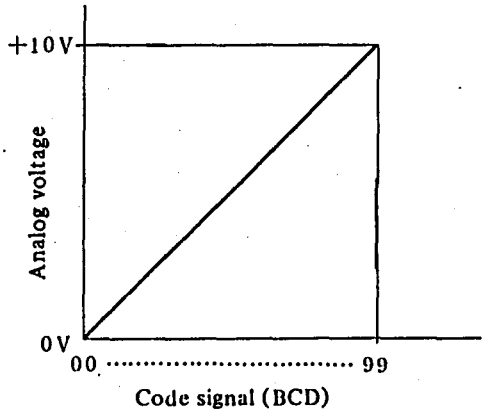
4.3 Fuses

Following table shows the spare fuses

Name / Spec. No.	Model 6S	Model 8S	Model 15S	Model 22S
	A06B-6055-K023	A06B-6055-K024	A06B-6055-K026	A06B-6055-K022
Fuse(75A) A60L-0001-0127/25FH75	4			
Fuse(100A) A60L-0001-0145(25SH100)		4		
Fuse(140A) A60L-0001-0149(25SH140)			4	
Fuse(150A) A60L-0001-0163(25SH150)				4
Fuse(20A) A60L-0001-0197/PC1F-20	2			
Fuse(30A) A60L-0001-0197/PC1F-30		2	2	
Fuse(50A) A60L-0001-0197/PC2F-50				2
Alarm fuse(3.2A) A60L-0001-0046/3.2	1	1	1	1
Fuse(5A) A60L-0001-0031/5A	5	5	5	2
Fuse(0.3A) A60L-0001-0175/0.3A	2	2	2	2
Fuse(1A) A60L-0001-0175/1.0A	1	1	1	1
Surge absorber A50L-2001-0062/441-12				
Surge absorber A50L-2001-0155/20D431	4	4	4	4
Remarks	For Model 8P	For Model 15P	For Model 22P	For Model 40P

4.4 D/A Converter(Option)
4.4.1 D/A Converter(BCD)

(1) This converter converts an 8-bit code signal into an analog voltage when the speed command is input by the BCD code (S 2-digit).



The relation between BCD codes and speed is as shown below.

BCD code	Analog output (V)	Motor speed (Max. 8000 rpm spec.)	Motor speed (Max. 6000 rpm spec.)	Motor speed (Max. 4500 rpm spec.)
00	0.0	0	0	0
01	0.101	80.8	60.6	45.5
02	0.202	161.6	121.2	90.9
⋮	⋮	⋮	⋮	⋮
98	9.899	7919.2	5939.4	4454.5
99	10.0	8000	6000	4500

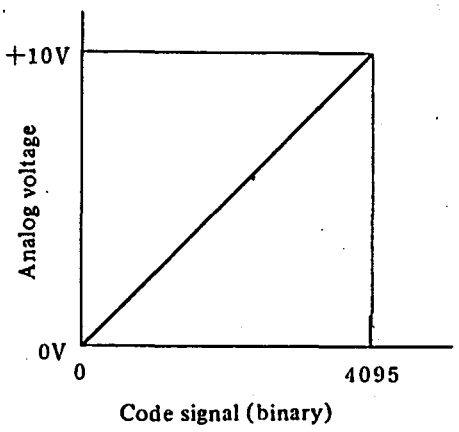
(2) The input terminals correspond to the BCD codes as shown below.

Input terminal	BCD	
R01	01	BCD unit digit (4 bitss)
R02	02	
R03	04	
R04	08	
R05	10	BCD tenth digit (4 bits)
R06	20	
R07	40	
R08	80	

* Input terminals R09 to R12 are irrespective of BCD codes.

4.4.2 D/A Converter(Binary)

(1) This converter converts a 12-bit code signal into an analog voltage when the velocity command is input as a binary code.



The relation between the binary code signals and speed is as shown below.

Binary number	Analog output	Motor speed (Max. 8000 rpm spec.)	Motor speed (Max. 6000 rpm spec.)	Motor speed (Max. 4500 rpm spec.)
000000000000	0.0	0	0	0
000000000001	0.002	1.95	1.47	1.09
000000000010	0.004	3.90	2.93	2.18
⋮	⋮	⋮	⋮	⋮
111111111110	9.99	7998.0	5998.5	4498.9
111111111111	10.0	8000	6000	4500

4.5 Spindle Orientation Circuit(Option)

Refer to section Ⅲ.

4.6 Velocity Gain Selector Circuit(Option)

Refer to section Ⅳ.

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4.7 Power Transformer(Option)

The FANUC AC spindle motor can be operated at 200 - 230VAC input without any transformer.

If AC input is other than specified above a power transformer is needed.

For preparing a power transformer by users, following specifications must be satisfied.

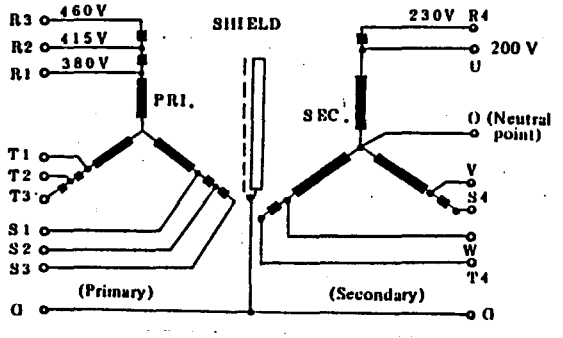
(1) Specifications

Item \ Motor models		8P	15P	22P	40P
Rated capacity (kVA)	30-min.	9	15	22	32
	Continuous	7	12	17	26
Secondary current(A) (30-min.)		26	43	74	110
Secondary tap output voltage		200V			
Secondary voltage regulation		5%			
Secondary voltage deviation		±3%			
Applivcabe unit model		6S	8S	15S	22S

(2) FANUC Power transformer specifications(option)

The following kinds of power transformers are available.

Select them according to the power capacity of AC spindle servo unit within the following rated capacity per 30 minutes.

Item \ Model		6S/8S (8P/15P)	15S (22P)	22S (40P)
Order specification		A06B-6044-J006	A06B-6044-J007	A06B-6044-J010
Entry drawing No.		A80L-0001-0313	A80L-0001-0314	A80L-0001-0352
Rated capacity	30 minutes	20kVA	30kVA	45kVA
	Continuous	15kVA	26kVA	40kVA
Rated primary voltage		380/415/460V +10%/-15%;50/60Hz±1Hz 230V +10%/-15%;50/60Hz±1Hz (Secondary side is used for auto transformer)		
Rated primary current (continuous)		23A (at 380V) 21A (at 415V) 19A (at 460V)	40A (at 380V) 36A (at 415V) 33A (at 460V)	61A (at 380V) 56A (at 415V) 51A (at 460V)
Rated secondary voltage		200V		
Rated secondary current (continuous)		43A	74A	115A
Secondary voltage regulation		5%		
Secondary voltage diviation		±3%		
Connection		Star-star connection		
Insulation		Class H(Max. temperature 180℃)		
Ambient temperature		0 - 45℃		
Allowable temperature rise of transformer		135 ℃		
Humidity		Max. 95%RH		
Type		All transformers are dry-type and self-cooling		
Dielectric voltage		2000VAC, 1 minute		
Weight		Max. 115kg	Max. 165kg	Max. 260kg
Outer dimensions		8.1.4(a)(b)	8.1.4(c)(d)	8.1.4(e)(f)
Connection diagram				

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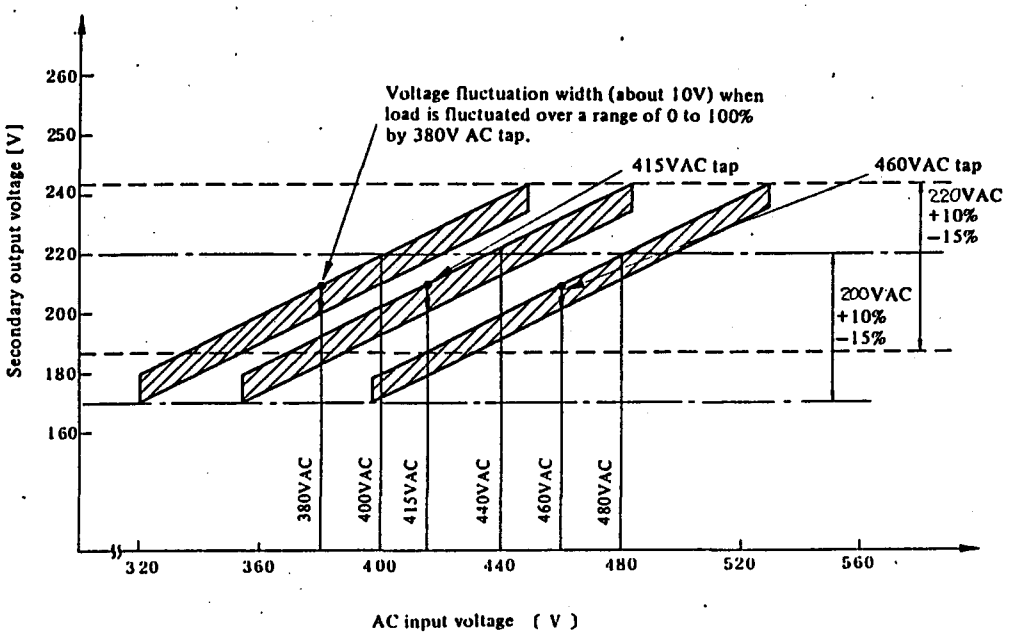
(3) Secondary output voltage



(4) Connection method of transformer

Connect the transformer to the taps given in the following table according to AC input voltages.

Connect and adjust the selector switch for the control power transformer inside the spindle servo unit according to the following table.

Nominal AC input voltage	Taps employed	Control power transformer voltage selector switch
380V +10% −15%	R1, S1, T1, G (380V)	(200V) side
400V +10% −15%	R1, S1, T1, G (380V)	(220V) side (upper)
415V +10% −15%	R2, S2, T2, G (415V)	(200V) side
440V +10% −15%	R2, S2, T2, G (415V)	(220V) side (upper)
460V +10% −15%	R3, S3, T3, G (460V)	(200V) side
480V +10% −15%	R3, S3, T3, G (460V)	(220V) side (upper)

(5) Cautions on use of transformer

(a) When mounting the transformer in a locker, separate it so as not to give a thermal effect to other unit.

(b) When mounting the transformer outside, be careful not to expose it to cutting chips and cutting oil slash directly.

(c) If the transformer may fall, fix it with bolts, etc.

4.8 Unit Cover(Option)

A cover may become necessary according to the mounting of the spidle servo unit for AC SPINDLE MOTOR MODEL 8P,15P on the machine magnetic cabinet.
The cover is used when it is necessary to protect the PCB.

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5. INSTALLATION

5.1 Environmental Conditions

Install the AC spindle servo unit in a place satisfying the following environmental conditions.

5.1.1 Ambient temperature

Ambient temperature of the unit : 0 to 55 ℃
Ambient temperature of the storage cabinet : 0 to 45 ℃

5.1.2 Humidity

Normally : 95% RH or less , and no dew.

5.1.3 Vibration

In operation : 0.5G or less.

5.1.4 Atmosphere

No corrosive or conductive mists or drops should deposit derectly on the electric circuit.

5.2 Input Power Supply and Grounding

(1) Input power supply

- Nominal rated voltage : 200/220/230VAC
- Allowable voltage diviation : -15% to +10%
- Power supply frequency : 50/60Hz
- Allowable frequency diviation : ±1Hz
- Power supply impedance : According to load (30 min. rating x 1.2),voltage fluctuation is 7% or less.
- Power supply unbalance : The range of voltage fluctuation between eact phase of a 3-phase power supply is the rated voltage ±5% or less.
- Mount the circuit breaker having enough capacity at the input side either of the AC spindle servo unit or machine tool.
- When the AC spindle motor provides most of the power for the entire machine, a low voltage phase advancing capacitor is not required at the input side of AC spindle servo unit.
- Alarm No.4 may occur at open-phase or temporary power failure.
- Leakage current when driving AC spindle motor
  Since the drive circuit employs the transistor-drive-pulse-width-modulation-control system, when the component of high-frequency leakage current flows to the earth through the spindle motor and connection cables.
  The 50/60Hz component of leakage current is equal to or less than the non-operating current(15mA) of the general high-sensitivity, high-speed earth leakage breaker for the cables of 50m or less.
- Radio noise
  Since the drive circuit employs the pulse-width-modulation control, a radio near AC spindle motor or drive circuit may be affected by noise due to high -frequency current when switching the transistor. The AM radio is interfered but TV or FM radio is not. To avoid a noise, mount the unit or install the machine tool using following notices.
  1) Mount the AC spindle servo unit in the metal cabinet.
  2) Cable connecting between the servo unit and AC spindle motor is routed through the metal duct and ground the duct.
  3) Connect the G terminals(ground) between the servo unit and AC spindle motor as specified.

(2) Grounding

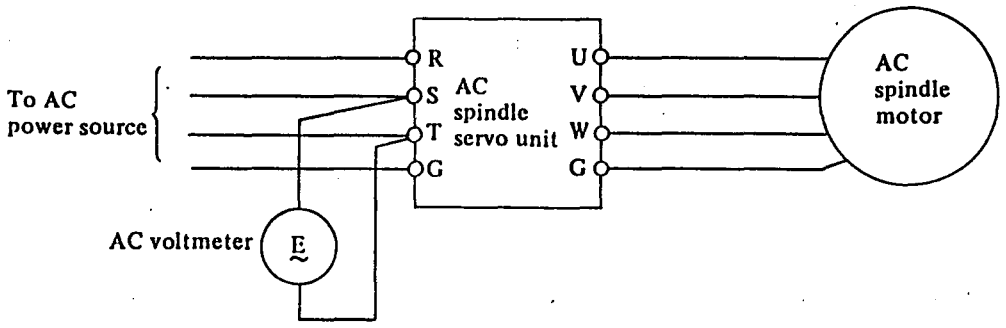
The following ground lines must always be connected.

- Input power supply grounding line.
- Motor grounding line.

Note) The rotation energy of the AC spindle motor is regenerated to the power source by using a thyristor inberter during the deceleration time. Accordingly, the following restirction and effect may be produsedd, if the power line impedance is high.
Particularly be careful with this caution when a power transformer having comparatively small capacity is used or a long power cable is used.
The power impedanse which may be almost free of the restriction in item(1) is within about 7% when the load is the maximum value of overload capacity (30 min. rating x 1.2).(*)

1) If the power line impedance (including the impedance of transformer) is high, it may be necessary to reduce the regenerative current and increase the deceleration time.(The AC spindle servo unit must be re-adjusted.)
2) It is possible that the power voltage waveform is disturbed by a commutation change of the thyristor inverter, and such a waveform distortion affects other units.

(*) Example of method of confirming the power impedance



$$\frac{E_0 - E_1}{E_0} \times 100\,(\%) < 7\,(\%)$$

E_0 : Voltage during motor stop

E_1 : Voltage during motor acceleration or just before the motor speed begins reducing with heavy load applied.

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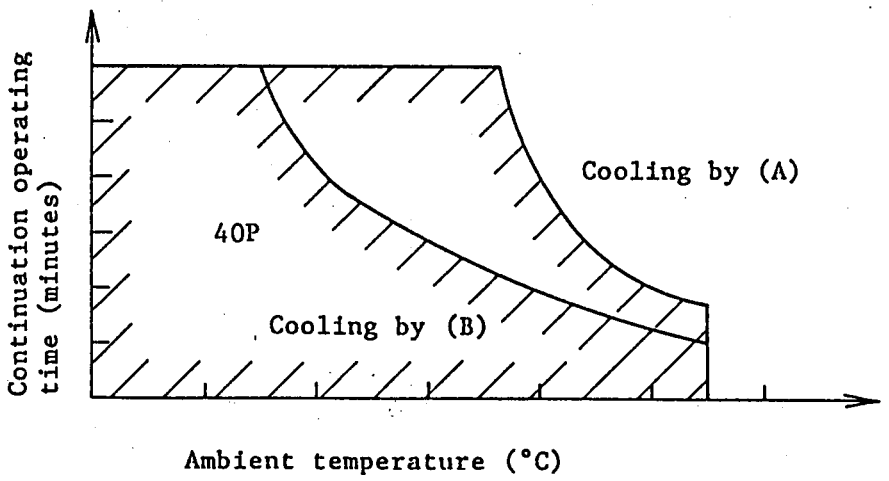
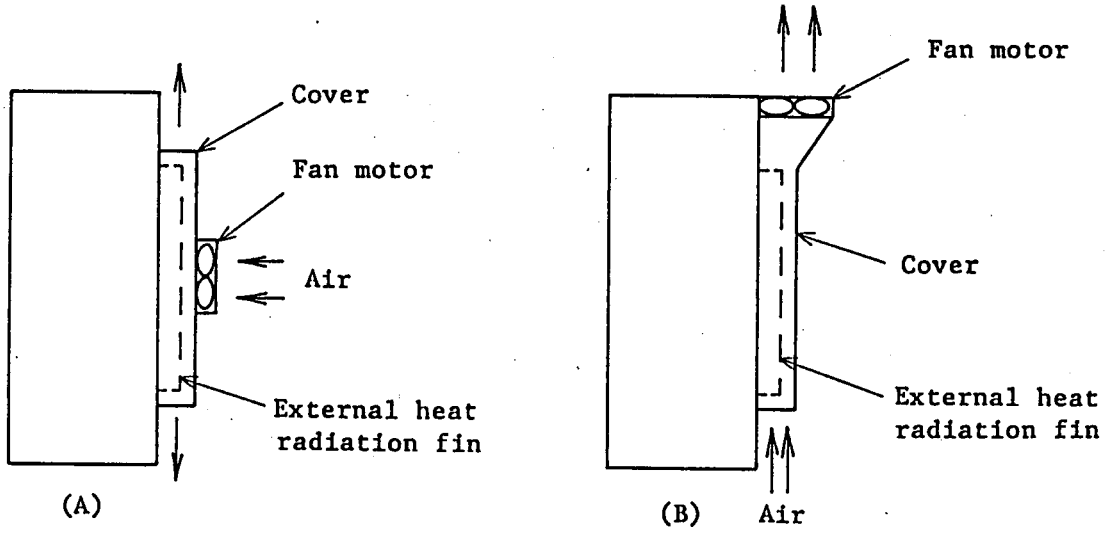
5.3 Caloric Value of Units

Motor model	8P	15P	22P	40P
Caloric value W at continuous rated output	420	500	840	1250
Applicable unit	6S	8S	15S	22S

For Model 40P, when the ambient temperature is high, continuous operating time at 30 min. rated value output is restricted as follows.





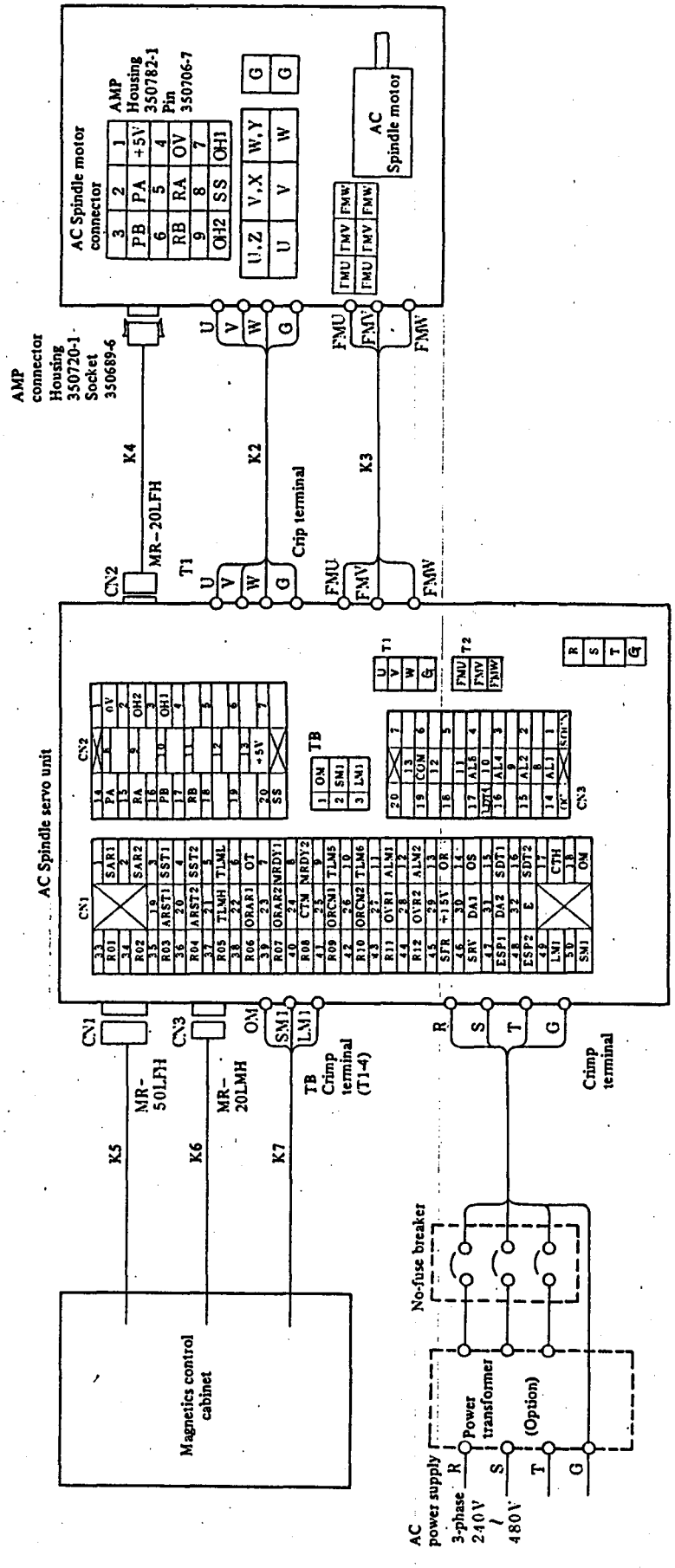
External heat radiation fin cooling method

Note 1) In the case of internal ventilation, the extent of cooling is approximately the same as that by (B).

Note 2) Use the MINEBEA 5915PC-20W-B20-04 or its equivalents as a fan motor.

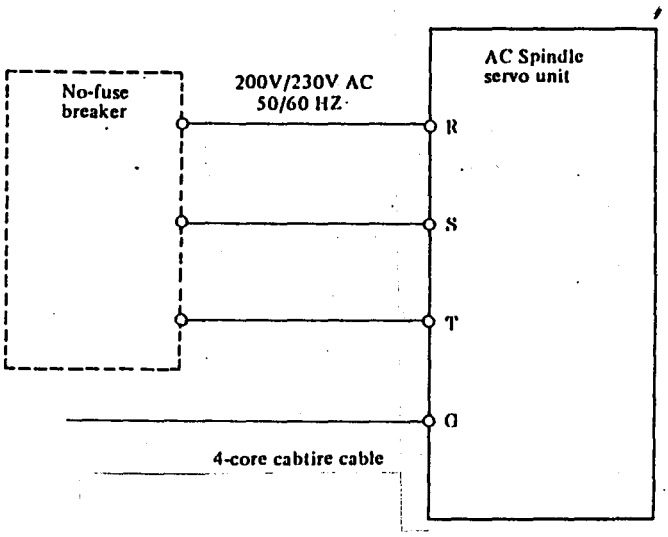
6. CONNECTIONS

6.1 Total Connection Diagram



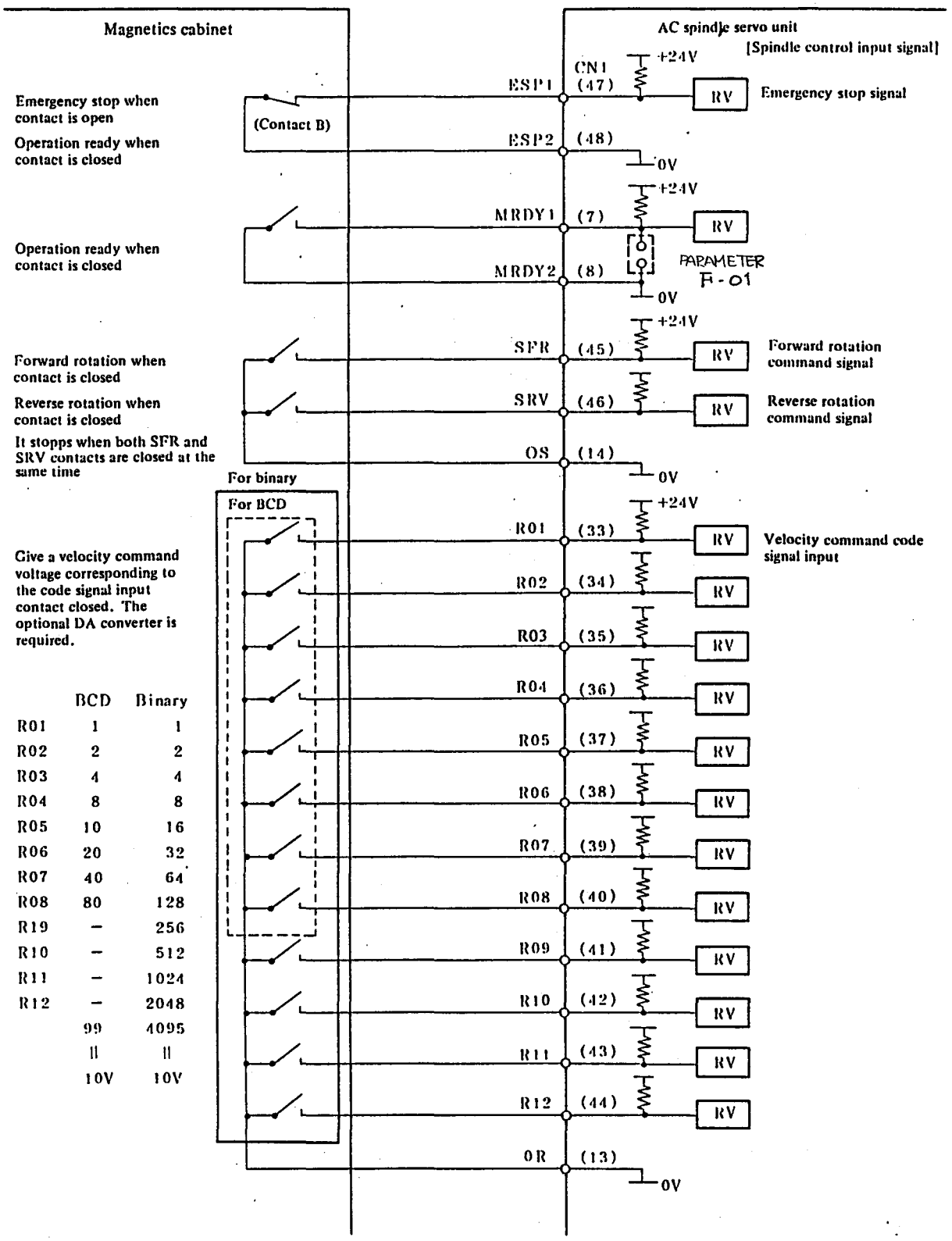
6.2 Detailed Connection Diagram

6.2.1 Connection diagram of the power supply



Unit type	Approved wire	Crimp terminal size		Applicable Motor model
		R,S,T terminal	G terminal	
Model 6S	8 mm² or more	M6	M5	Model 8P
Model 8S	14 mm² or more	M8	M6	Model 15P
Model 15S	22 mm² or more (Heat-proof type)	M8	M6	Model 22P
Model 22S	38 mm² or more (Heat-proof type)	M8	M6	Model 40P

6.2.2 Connection diagram of the AC spindle servo unit and the magnetics cabinet



	BCD	Binary
R01	1	1
R02	2	2
R03	4	4
R04	8	8
R05	10	16
R06	20	32
R07	40	64
R08	80	128
R19	—	256
R10	—	512
R11	—	1024
R12	—	2048
	99	4095
	〃	〃
	10V	10V

Fig. 6.2.2 (a) Connection diagram of the AC spindle servo unit and the magnetics cabinet

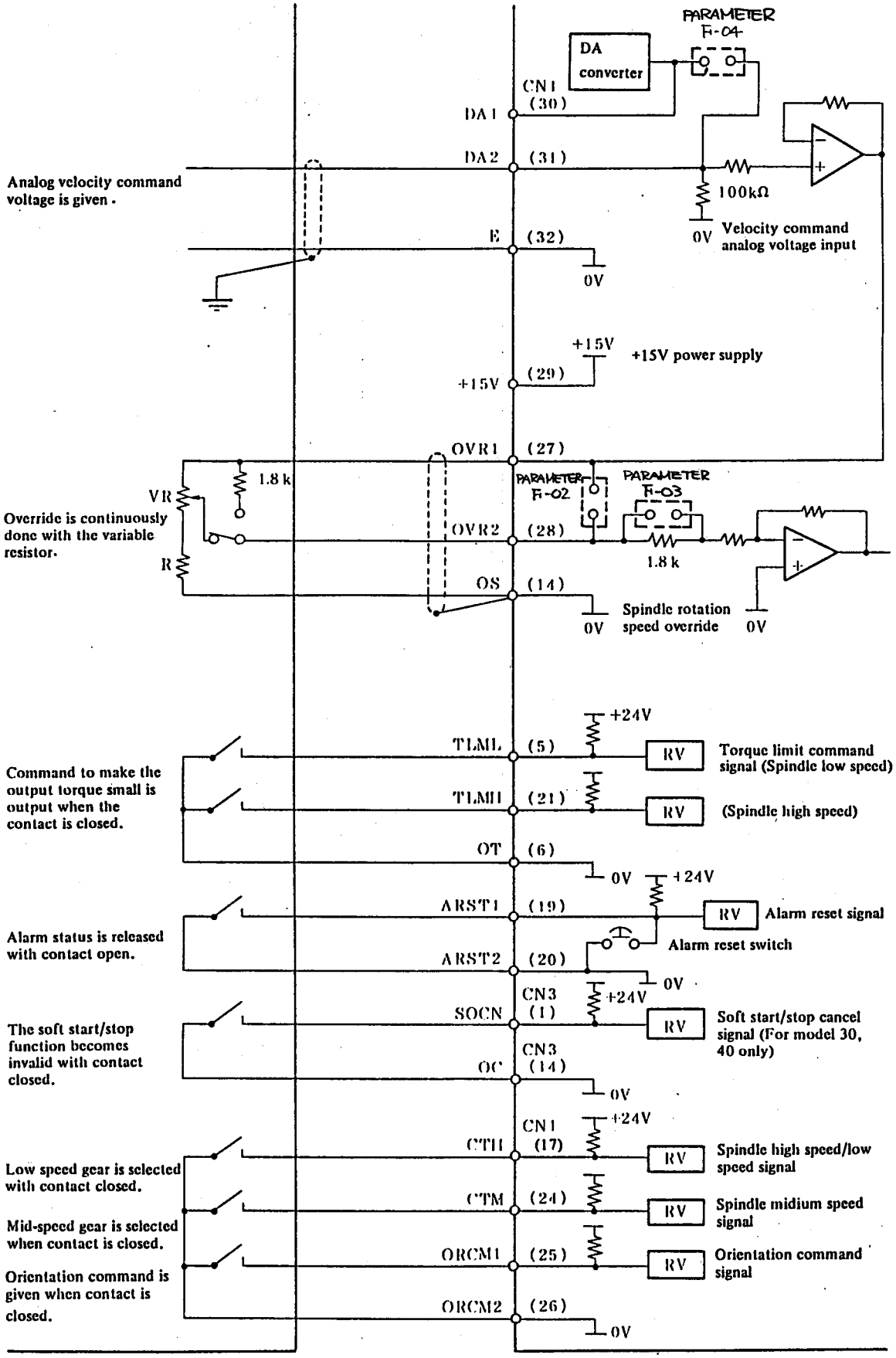


Fig. 6.2.2 (b) Connection diagram of the AC spindle servo unit and the magnetics cabinet

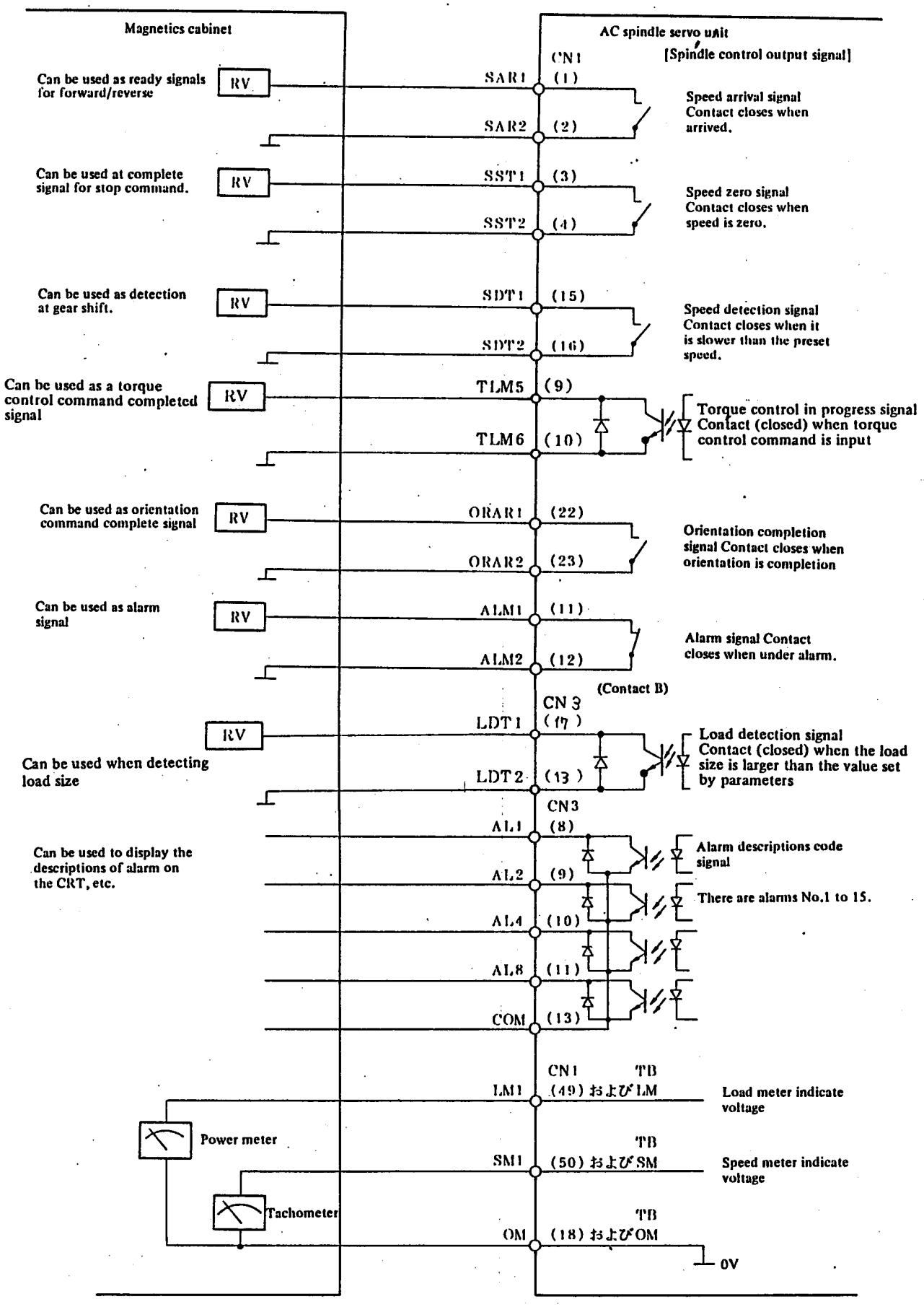
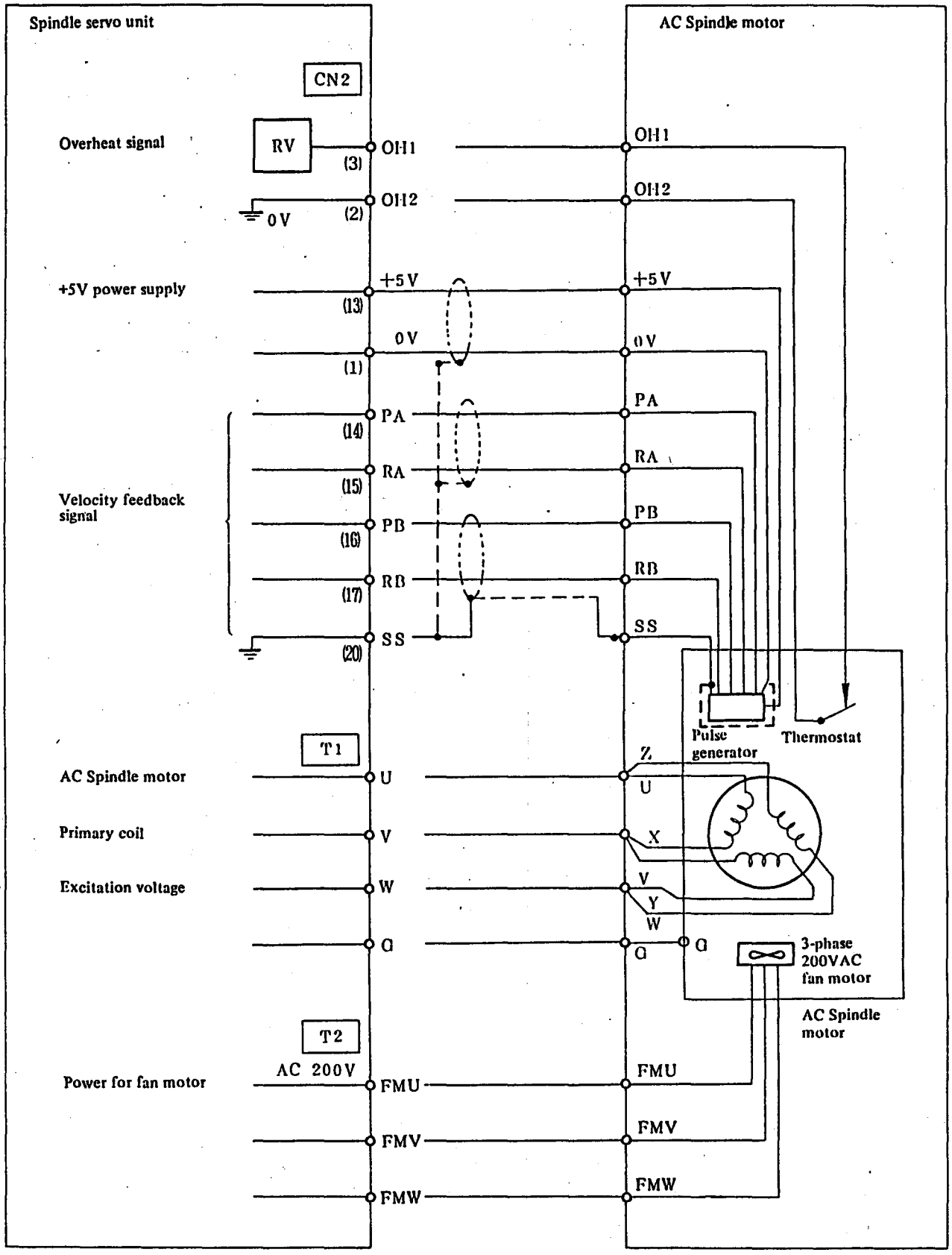


Fig. 6.2.2 (c) Connection diagram of the AC spindle servo unit and the magnetics cabinet

6.2.3 Connection diagram of the AC spindle servo unit and the AC spindle motor



Unit type	Unit U,V,W,G terminal			FMU,FMV,FMW terminal		Motor model
	Approved wire	Crimp terminal size		Approved wire	Crimp terminal size	
		U,V,W	G			
6S	8 mm² or more	M5	M5	2 mm²	M4	8P
8S	14 mm² or more	M5	M6			15P
15S	22 mm² or more (Heat-proof type)	M8	M6			22P
22S	38 mm² or more (Heat-proof type)	M8	M6			40P

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7. DESCRIPTIONS ON INTERFACE SIGNAL

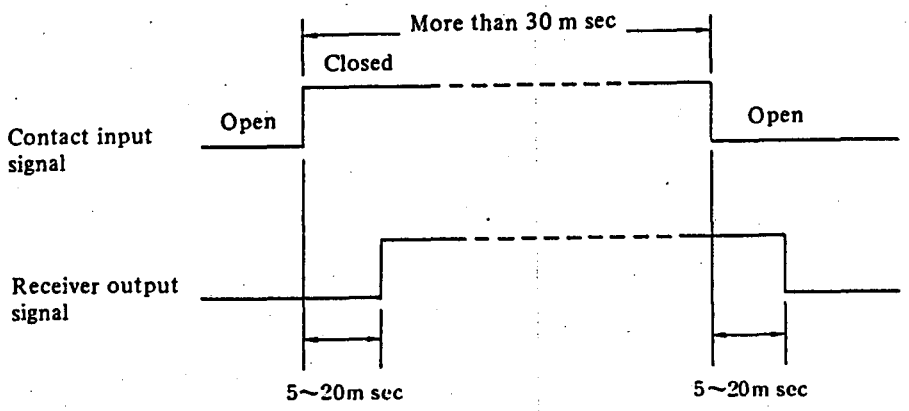
7.1 Interface Signal Standards

For signals to be transferred between the servo unit and the exterior, take the following input/output signal rating into due consideration.

(1) Contact input signal A
This is inputted from the exterior to the servo unit.

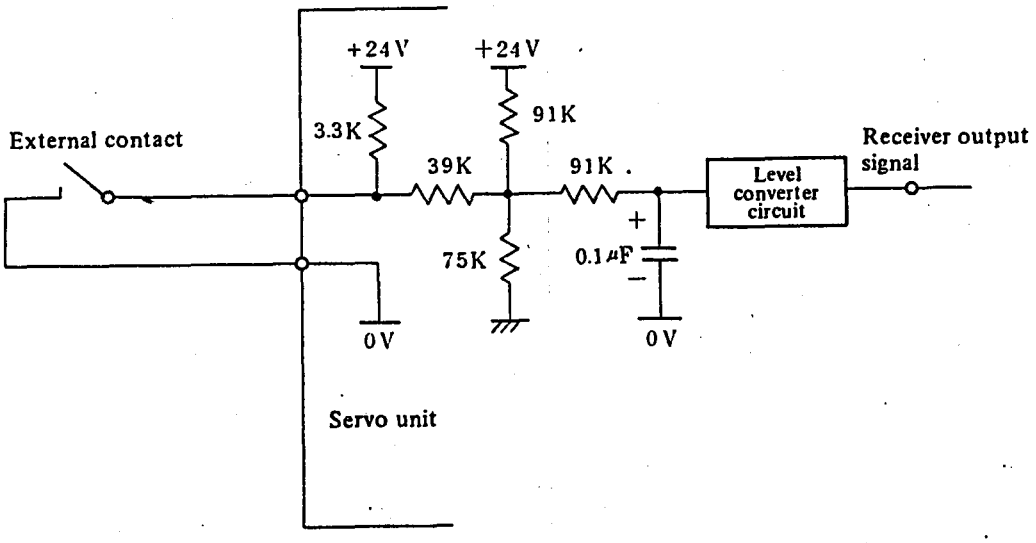
(a) External contact capacity required: Higher than 30V, higher than 16mA.

(b) The following figure indicates the delay time of the receiver output signal to the contact input signal.



Accordingly, the servo unit receives signals after 5 to 20ms delay when the contact input signal was turned on and off.

(c) For the receiver circuit on the servo unit side, refer to the following figure when using a no-contact input, etc.



Signification levels in case of no-contact (at input terminal voltage)

Low level logic "0" ..... Lower than 2V
High level logic "1" ..... Higher than 20V

(2) Contact output signal A1
This is output from the servo unit to the exterior.

(a) The AC spindle servo unit side employs a lead relay.
The contact rating is lower than 50V or lower than 500mA at 5VA or lower.
Use it at 24VDC, 200mA or lower, or 48VDC, 100mA or lower, accordingly.
The chattering time of contact is shorter than 1 msec.
The related signals are shown hereunder :

Model	Signal name	Symbol
6S 8S 15S 22S	Orientation completion signal	ORAR1,ORAR2

(b) If an external relay or another inductive load is connected, insert a surge absorber in the vicinity of the relay without fail. If a capacitive load is connected, insert a current limiting resistor in series, and set the power to be lower than 5VA including an instantaneous value.

(c) If an external lamp is connected, insert a protective resistor so that the current becomes lower than 500mA including an insatataneous value.

(3) Contact output signal A2
This is output from the servo unit to the exterior.

(a) The AC spindle servo unit side employs a transistor.
The output standard is as follows.
i . Output voltage : max. 48 V
ii . Output current : max. 200mA
The related signals are shown hereunder :

Model	Signal name	Symbol
6S 8S 15S 22S	Speed arrival signal	SAR1,SAR2
	Zero-speed signal	SST1,SST2
	Speed detecting signal	SDT1,SDT2
	Spindle alarm signal	ALM1,ALM2

(b) If an external relay or another inductive load is connected, insert a surge absorber in the vicinity of the relay without fail. If a capacitive load is connected, insert a current limiting resistor in series, and set the power to be within the output rating including an instantaneous value.

(c) If an external lamp is connected, insert a protective resistor so that the current becomes within the output current including an insatataneous value.

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(4) Contact output signal A3
This is output from the servo unit to the exterior.

(a) This signal is output by the open collector transistor(polarized) from the AC spindle servo unit.
The output standard is as follows.
i . Rated voltage : Less than 30VDC
ii . Output current : Less than 40mADC
iii . Saturated voltage : 1.5 or less(Ic=40mA)

(b) Signal polarity is as follows:

Model	Signal name	Polarity	
		Positive(+)	Negative(-)
6S 8S 15S 22S	Load detection signal	LDT1	LDT2
	Torque limit signal	TLM5	TLM6
	Alarm content signal	AL1 , AL2 AL4 , AL8	COM

7.2 Spindle Control Signals

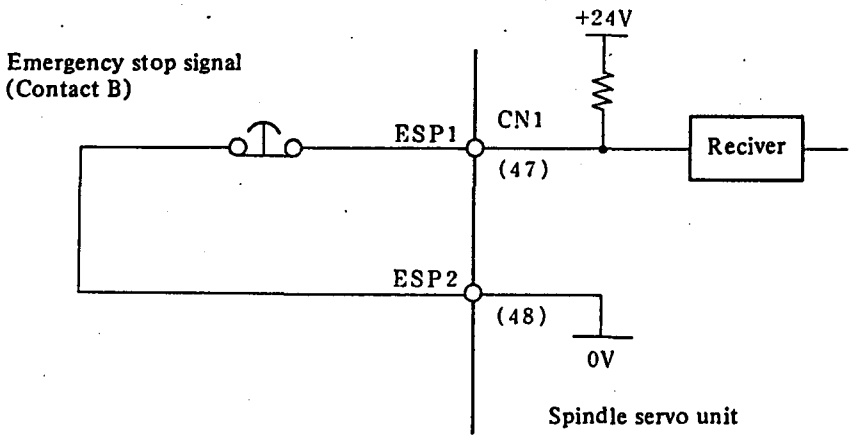
See 7.1 "Interface signal standards" for standards of the signals.

7.2.1 Emergency stop signal (ESP1, 2)

(1) When the contact is ON (closed), the spindle motor and the servo unit is ready for operation. When the contact is off (open), the magnetic contactor in the servo unit is OFF, and the spindle motor does not operate.

(2) When the contact becomes OFF (open) during rotation of the motor, the spindle motor will decelerate and stop at once. The magnetic contactor will also become OFF after the motor stops.

(3) When this contact is turned on (closed) again, the spindle motor is placed to be ready for rotation. It rotates immediately when the rotation command is given. Accordingly, reset the command signals (velocity command, forward rotation, reverse rotation commands) to the spindle servo unit simultaneously when the emergency stop signal was inputted.



7.2.2 Machine ready signal (MRDY 1, 2)

1) Mode set by parameters F-01 and F-09 is shown below.

Mode	Setting		Contents	
	F-01	F-09		
(A)	0	0 or 1	Machine ready signal is not used. Input of the emergency stop signal alone will make the spindle motor ready for operation.	
(B)	1	0	Machine ready signal is used to make an operation ready status by double signal.	When the contact is off the electro-magnetic contactor will come OFF to cut off the motor power.
(C)	1	1		Power is cut off by cutting the excitation signal of the transistor in inverter section when the contact is OFF the electro-magnetic contactor is still ON.

Note) Contact: Contact of MRDY signal.

The following 2) to 4) are how to use the machine ready signals in each of the above modes.

2) Mode (A)
Used to minimize the input signal points. It is not necessary to connect the signal line to the contact.

3) Mode (B) (Standard setting)
   ① Used to control an operation ready status by double signal. For example, when it is necessary to set two electro-magnetic contactor ON/OFF signal input terminals on machines where the worker must touch the spindle directly for loading and unloading workpieces or tools.
   ② When the contact is ON (closed), the electro-magnetic contactor turns ON, and the motor becomes ready for operation.
   ③ When the contact is OFF (open), the electro-magnetic contactor turns OFF, and the power to the motor is cut off.
   ④ If the contact is turned OFF (open) during the rotation of the motor, the spindle motor will decelerate to a stop at once, and the electro-magnetic contactor will also turn OFF after the motor stops.

⑤ Do not use the electro-magnetic contactor too frequently (some 100 times) in a single day, because it may shorten the electro-magnetic contactor's open/close life.

4) Mode (C)

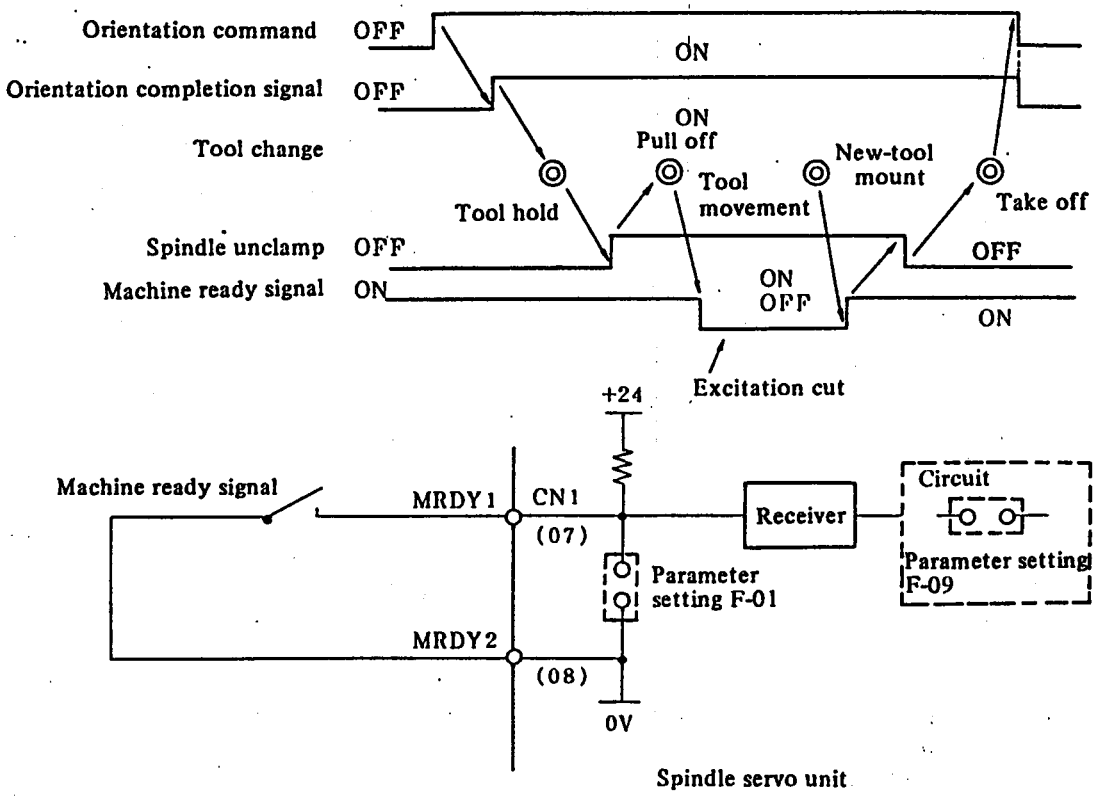
1 Used in case the open/close of the electro-magnetic contactor is assumed to be frequent.

② In machines in which a spindle motor is restricted by the tool unclamp signal during operation of the automatic tool change (ATC) orientation, the command of the load meter may become large or large motor current may flow because of a small shift from the orientation stop position. In this case, cancel an orientation status during tool unclamp by making OFF this signal. Orientation status can be made by making ON this signal without spindle rotation at tool unclamp ending.

③ If the contact of the orientation command signal is still ON (closed) in the above ②, the OFF/OF of the contact of the machine ready signal will only cause a small shift of the stop position; it is not necessary to perform orientation again with another rotation.

Timing chart

Condition) Parameter F-01:1 ..... Use machine ready signal.
Parameter F-09:1 ..... Cut the motor power using MRDY signal.



7.2.3 Forward rotation command signal (SFR)

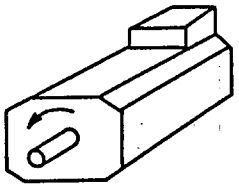
(1) The spindle motor will start forward rotation according to the velocity command (positive voltage) when the following three conditions are satisfied.

① The contact of emergency stop signal is ON (closed)

② The contact of machine ready signal is ON (closed)

③ The contact of forward rotation command signal is ON (closed).

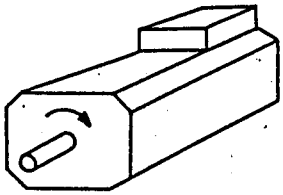
(2) During contact on (closed), the spindle motor rotates counterclockwise (CCW) as viewed from the shaft side according to the command speed.



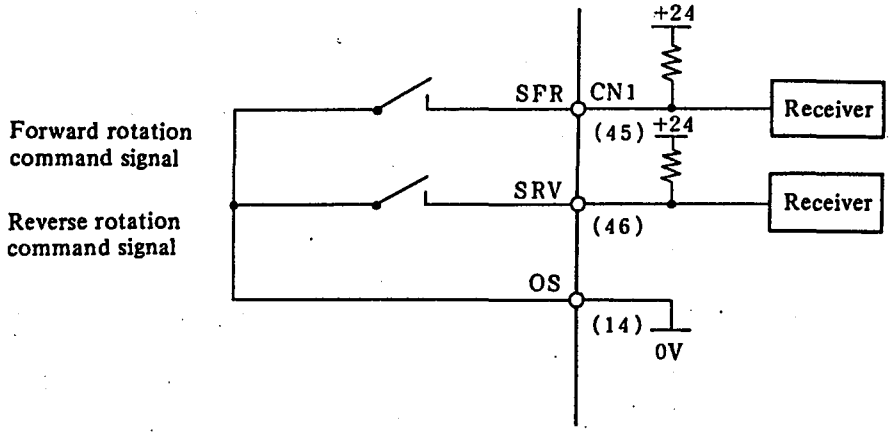
(3) When the contact turns off (open), the spindle motor is stopped by the regenerative braking. After stop, the base signal of transistor is turned off to interrupt the power to the spindle motor.

7.2.4 Reverse rotation command signal (SRV)

(1) During contact on (closed), the spindle motor turns clockwise as viewed from the shaft side according to the command speed.



(2) When the forward rotation command signal and reverse rotation command signal are turned on simultaneously, the spindle motor stops.



7.2.5 Code signal(option)

(1) The code signal has the following two types of inputs.
   ① BCD signal input
   ② Binary signal input

(2) A D/A converter(option) must be prepared for code signal input. Detailed explanation is given in section 4.4 "D/A Converter" When operating with code signal input only, set the parameter F-04 turned '1'.

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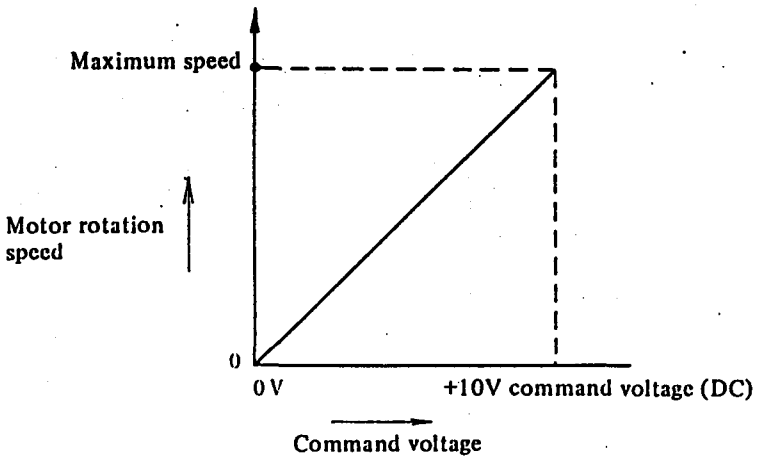
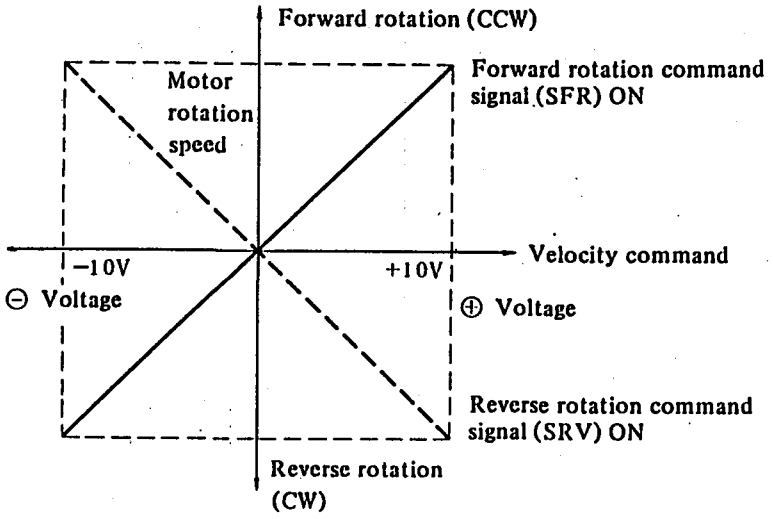
7.2.6 Analog voltage signal (DA2, E)

(1) The velocity command voltage and the motor rotation speed are in linear proportion as shown in the following graph.



(2) Normally, command + voltage (0 to +100VDC). Use the forward/reverse rotation command signals to destinguish the direction of rotation.

(3) The ⊕ ⊖ command voltages (0 to ±10VDC) results in the following figure.



Do not command the ⊕ ⊖ voltages in machines which tools and workpieces break or in machines which safety cannot be guaranteed if rotated reverse direction by a forward command.

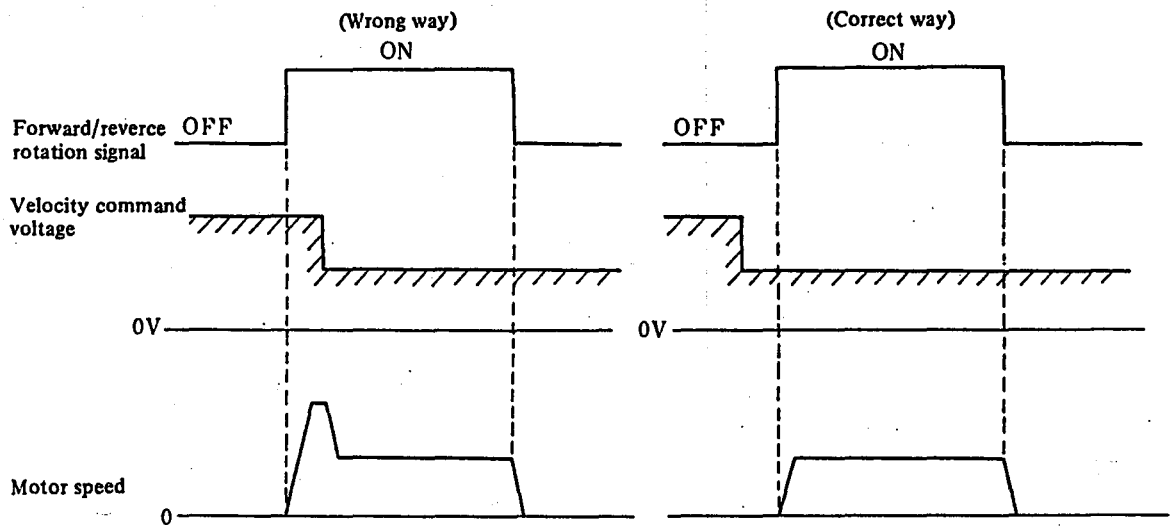
(4) Be careful with wiring so that the velocity command voltage line is not affected by external noises. Use a shielded wire without fail. Connect the shield earth to terminal E.

(5) Compose the velocity command voltage (DC 0 to +10V) circuit as shown in the next figure. In this circuit, the manual input (analog input) and automatic command (DA converted output) are selectable by relay. If the velocity command voltage exceeds +10V, it is automatically clamped to max. 10.7V internally. Be careful since the motor revolution reaches max. 107% of the rated value.

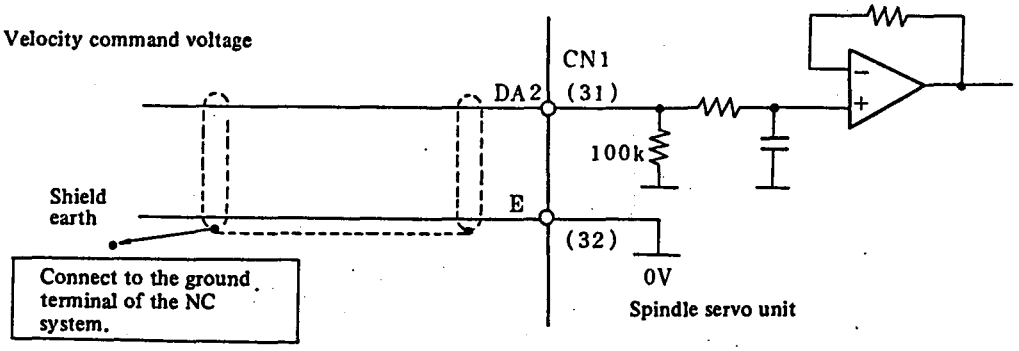
(6) The motor is not rotated when the velocity command voltage only is applied. It rotates when either forward or reverse rotation command was given.

(7) When the velocity command voltage became ±10V or more, it will automatically be internally clamped to maximum ±10.7V. However, the rotation speed of the motor may rise maximum 107% of the rated rotation.

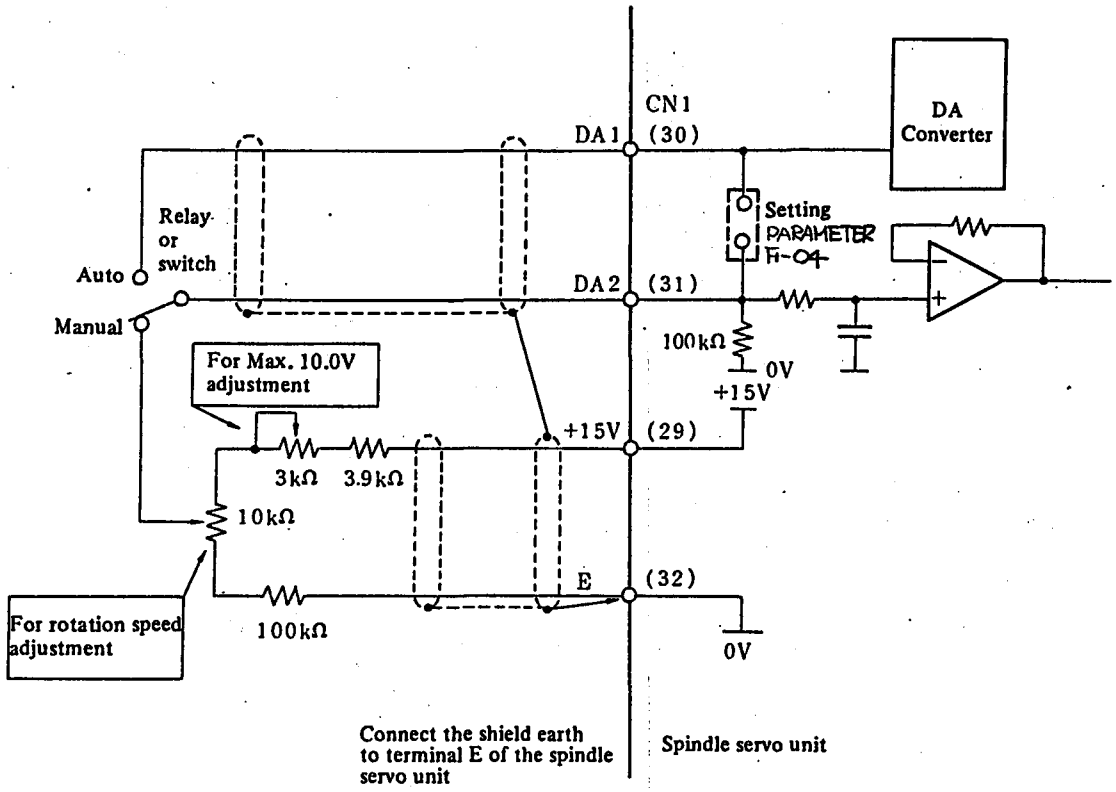
(8) The movement of the motor will differ according to the ways the velocity command voltage and the forward/reverse rotation command signals (SFR/SRV) are given. Change the velocity command voltage inputs as the following figure, and then set the forward/reverse rotation command signals ON (closed).



(9) Example of connection when using the analog output of the NC.



(10) Example of connection when switching from the automatic velocity command by code signal input to manual velocity command by variable register on the machine operator's panel.



(11) The input impedance of the velocity command voltage receiver circuit is 100kΩ.

7.2.7 +15V power supply (+15, E)

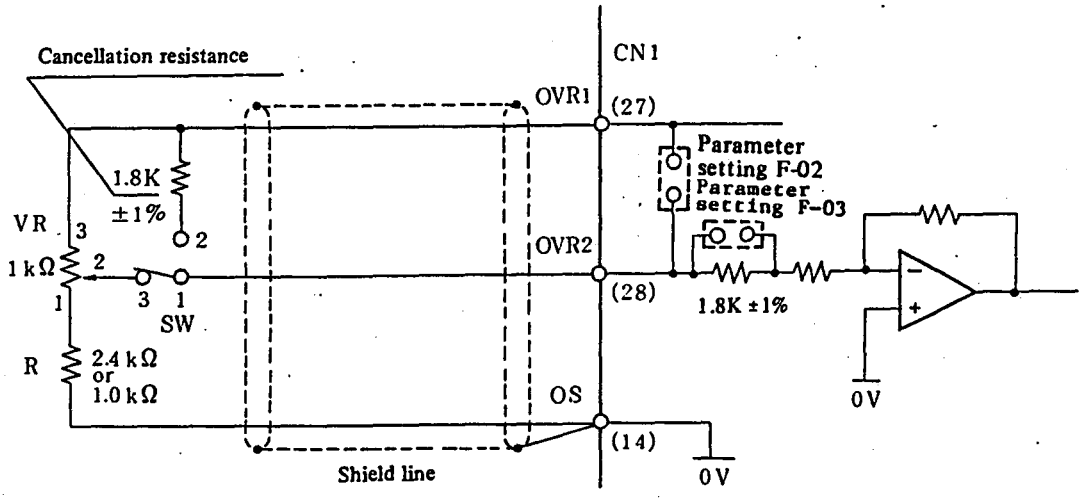
(1) This power supply is used to give analog velocity command using the variable register, from outside the unit in manual input.

(2) Maximum 30mA current can be used in this +15V power source.

7.2.8 Spindle rotation speed override (OVR1, OVR2)

(1) This signal is used to override the spindle rotation speed of the automatic velocity command, to gain the optimum cutting condition. The NC system also has the spindle speed override function. Use the function of the NC system normally.

(2) When using the speed override function of the spindle servo unit, connect the following circuit externally.



Override cancel (Short SW1-2)
Speed override (Short SW1-3)

AC Spindle servo unit

(3) When performing synchronous feed as thread cutting or other external manual velocity commands, the override must be cancelled. Switch the circuit (short SW1-2) and set the override precisely to 100%.

(4) Setting on the spindle servo unit for speed override function and range of override is as follows.

Function		Parameter	
		F-02	F-03
Speed override function not used		0	0
Speed override function used	Override range Up to 120% (upper limit)	1	1
	Up to 100% (upper limit)	1	0

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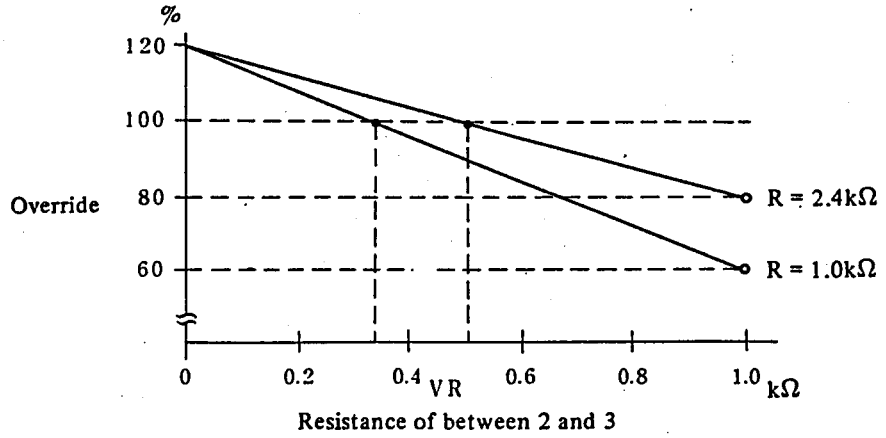
(5) The override range is determined by the resistance value of R in the figure.

When R = 1.0 KΩ : 60 to 120%
R = 2.4 KΩ : 80 to 120%



(6) If the override range upper limit is set to 100%, short cancel resistor 1.8 kΩ, since this resistor is not needed.

7.2.9 Torque limit command signals(TLMH, TLML, OT)

(1) The torque limit is used to temporarity reduce the output torque of the AC spindle motor during the AC spindle motor rotation in case of mechanical spindle orientation, gear shift, etc.

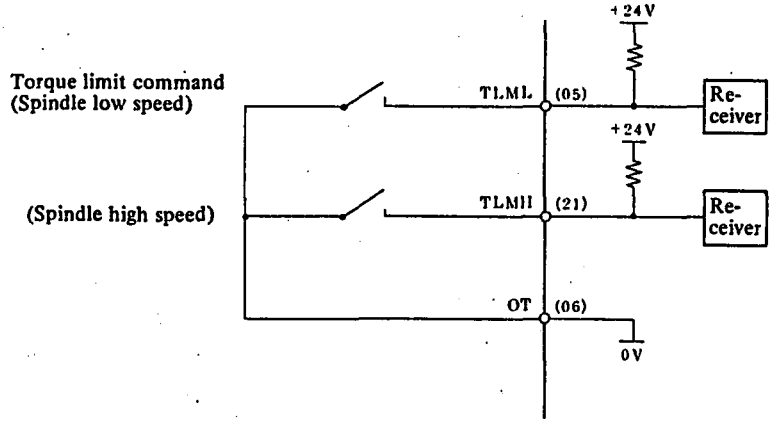
(2) The machine tool builder is requested to set the orientation output torque and the revolution at the orientation time for every model so as to reduce a shock when the machine stopper operates.

(3) Adjust the torque at the time of torque limit by parameter F-18. The torque limit value is ±(set value of F-18)% of the maximum torque when TLMH is ON. When TLML is ON, the torque is about 1/2 of the TLMH:ON.

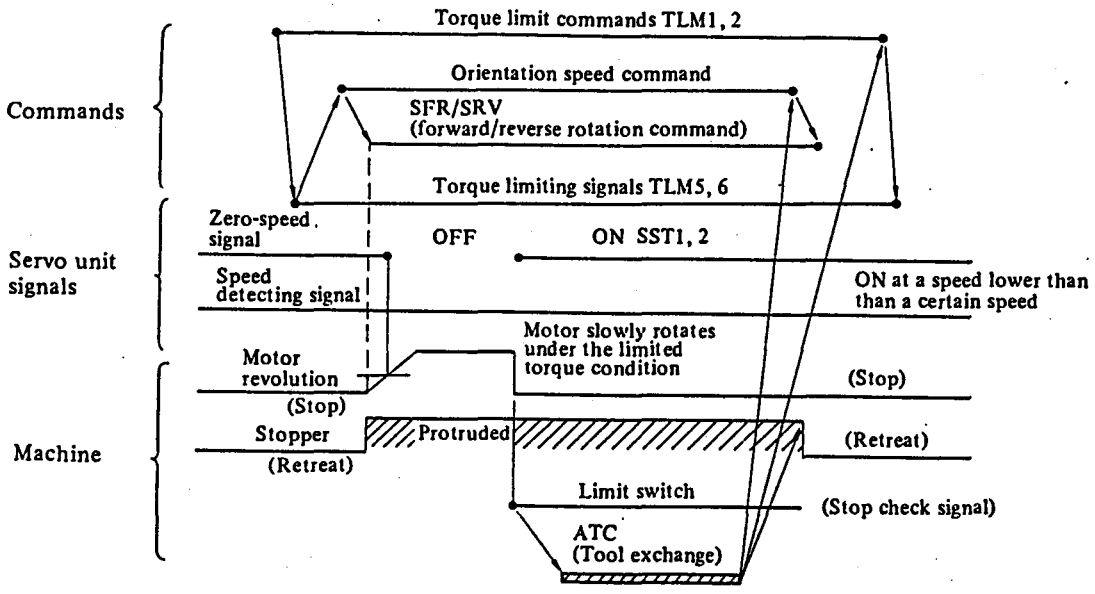
(4) When the torque limit command signal turns on(closed), the torque is limited.(This signal is effective at once, even if this torque limit command is given during the motor rotation.) The torque limiting signals (TLM5,TLM6) are sent outside, immediately when the torque is limited.

(5) For executing the mechanical orientation during ATC of a machining center, take the following items into consideration when designing the power magnetic sequence so as not to damage the stopper.

1) The output torque is suppressed during orientation so as not to allow it to be excessively large.
2) The revolution is suppressed during orientation so as not to allow it to be excessively high. If an excessively high revolution is detected by the speed detection signal, take the interlock not to operate the stopper.
3) The stopper should be securely retreated when the torque limit was released.



Example of mechanical orientation sequence



If the above conditions are difficult, adopt the electric spindle orientation (option) without stopper.

7.2.10 Alarm reset signal (ARST1, 2)

(1) After eliminating causes of alarms such as motor overheat, excessive speed deviation, circuit short-circuit, overspeed, overvoltage, overcurrent, overload, power drop, etc., input the alarm reset signal, and the alarm is released to place the unit to be ready for operation.

(2) This signal is ineffective, if it is inputted during the absence of alarm.

(3) The servo unit is also provided with a reset switch, which has the same function as this alarm reset signal.

7.3 Orientation Signal

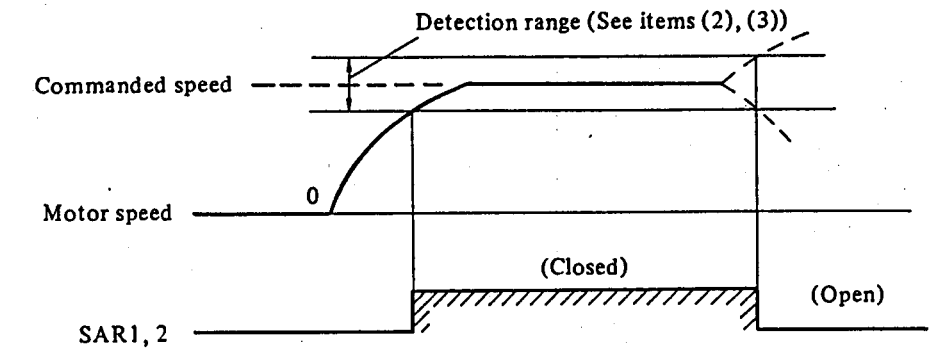
Connected when using the spindle orientation control circuit (option). Descriptions of the signal is mentioned in Ⅲ.

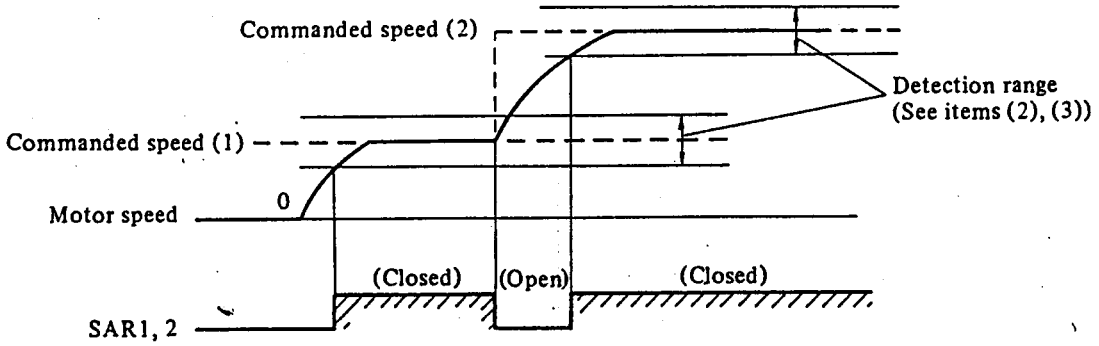
7.4 Spindle Control Output Signals

For the output signal rating, refer to Section 7.1.

7.4.1 Speed arrival signal (SAR1, 2)

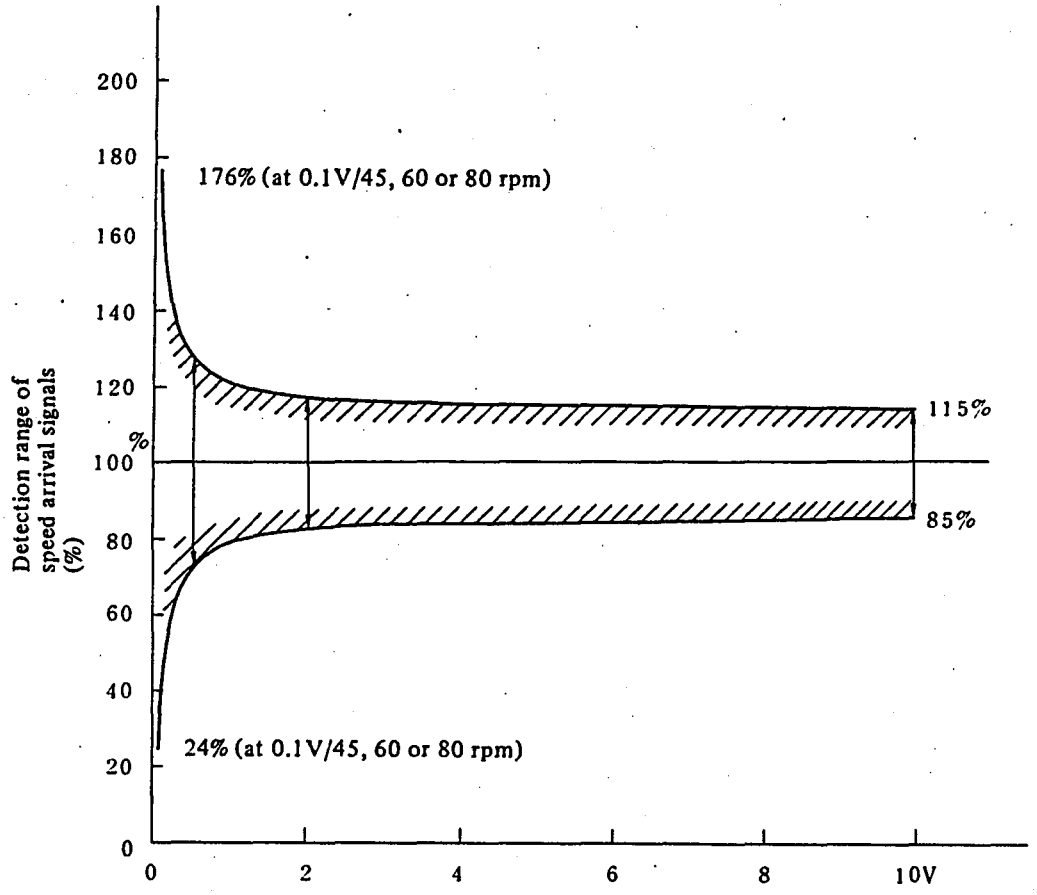
(1) The contact is turned on (closed) when the actual rotation speed of the spindle motor reaches a certain preset range with reference to the command speed.





(2) The preset range is adjustable within a range of ±10% to 50% of the command speed; provided that the detection range becomes wider than the present range, if the speed is lower than 10% of the maximum revolution speed.

(3) This detection range of the speed arrival signals is set to ±15% as the standard setting before shipment. However, it is expanded as illustrated below at low speed.



If a 45/60/80rpm velocity command is issued, the arrival signal is sent when actual motor revolution reaches 45/60/80rpm ±76%.

(4) This signal is not outputted, unless either SFR or SRV is turned on.

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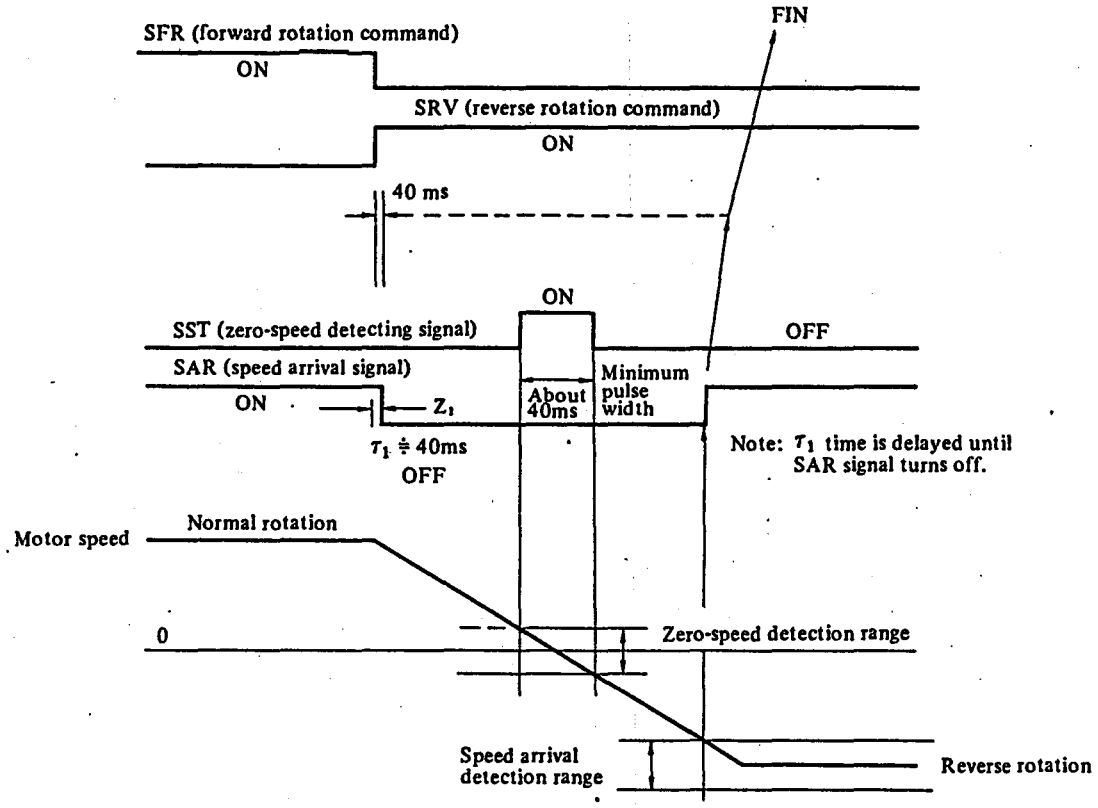
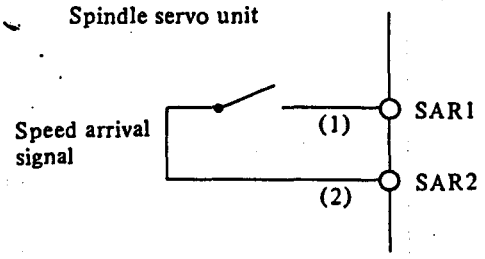
(5) The reverse rotation at the tapping cycle is controlled by using this signal as follows.



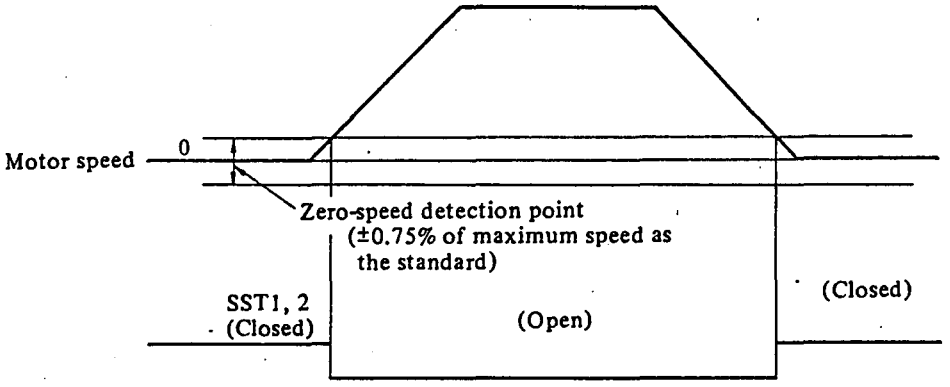
When the reverse rotation command is sent, the spindle motor starts deceleration, and the speed arrival signal turns off within 40ms. Then, the next turn-on of the speed arrival signal is detected as the reverse rotation command end.



(6) This signal is employed as the check signal (FIN signal) for forward rotation (M03) and reverse rotation (M04) command.

7.4.2 Zero-speed detecting signal (SST1, 2)

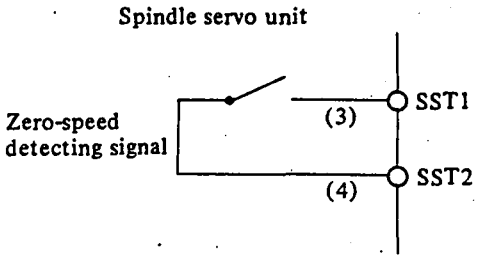
(1) If actual rotation speed of the spindle motor is reduced to be lower than the zero-speed detection point when the stop command was given, the contact is turned on (closed).



(2) The zero-speed detection point is fixed at 0.75% of the maximum speed as the standard.
In other words, the zero-speed detection signal turns on when the rotation speed is lower than about 33, 45 or 60 rpm.

(3) This signal is outputted when the above condition is satisfied, irrespective of rotation commands (SFR, SRV).

(4) The minimum pulse width value of this signal is about 40ms. (See item 7.4.1 (5))



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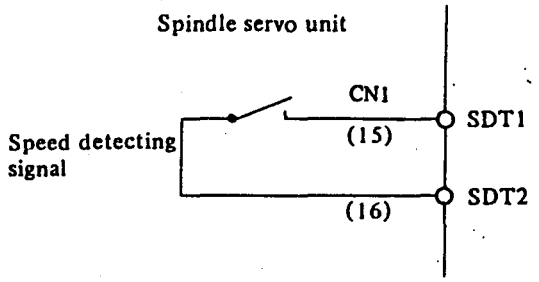
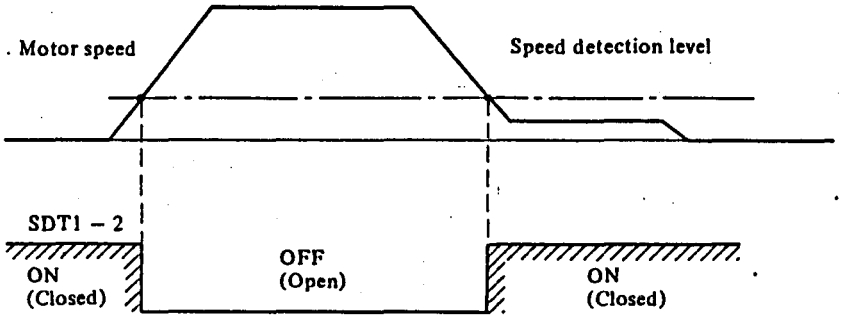
7.4.3 Speed detecting signal (SDT1, 2)

1) The contact is turned on (closed) when the actual motor speed is lower than the speed being set on Parameter F-17.
2) The detection point is fixed at the maximum speed x (set volume of F-17/1000)%.



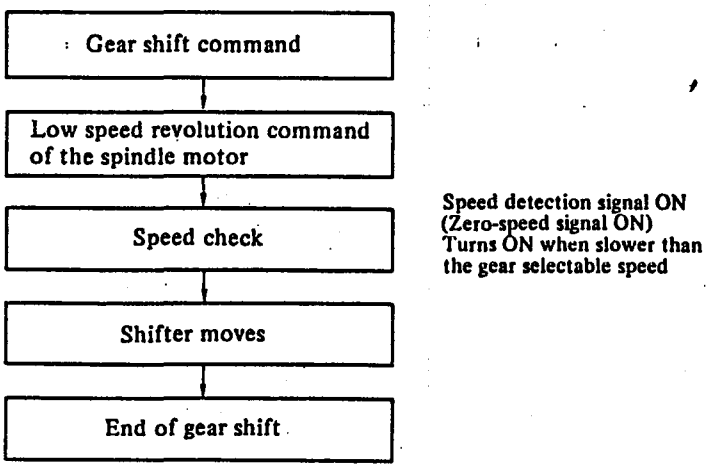
3) This signal is used to detect the rotation speed which becomes lower than a certain speed set such as clutch selectable speed or gear selectable speed. It is usually set to 3% of the maximum speed (standard setting) in case of gear change or 30% of the maximum speed in case of clutch change.
The machine tool builder is requested to set the check terminal voltage to a desired value by the variable resistor.



4) The signal contact is turned on (closed) when the absolute value of the motor speed is reduced to be lower than the preset detection level, irrespective of rotation commands (SFR, SRV).

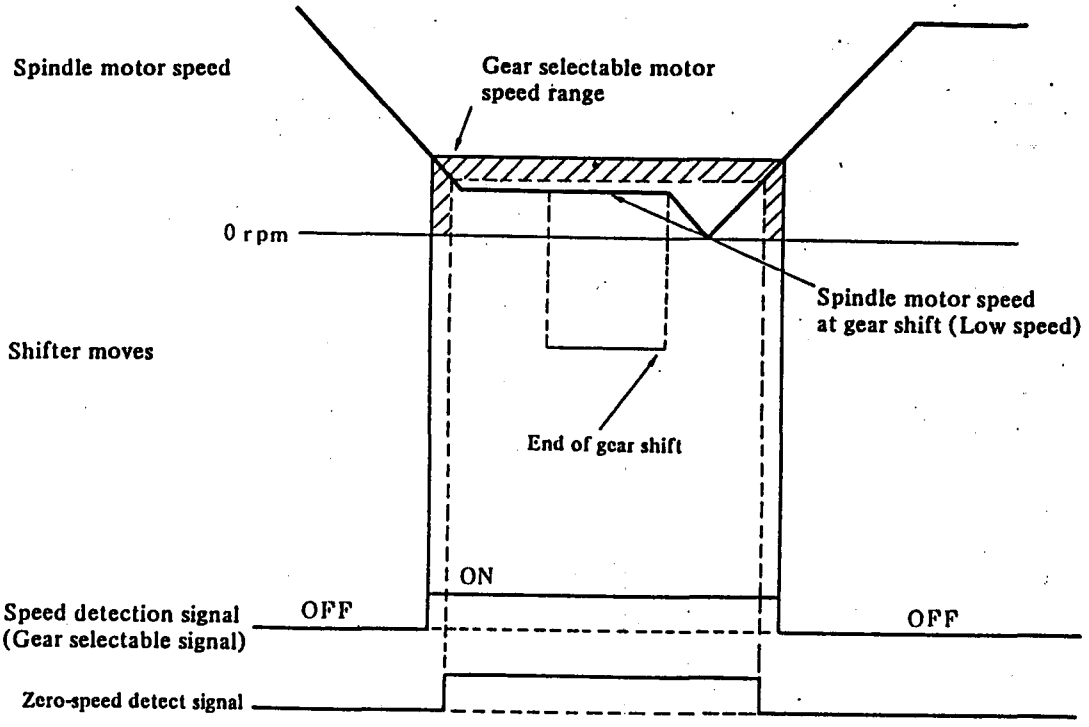
(Reference)
Sequence of the gear shift
The gear shift in the CNC machine tool is one of sequence controls. The electric circuit signal on the sequence is used to move the spindle gear, which is an important component of the machine. It is then necessary to check that the spindle motor revolution is in low speed to switch the gear safely.
The following is an example of sequence at gear shift, when the speed detection signal (gear selectable signal) was used. This example can be referred to when designing the magnetics sequencer.
An example of gear shift sequence using speed detection signal

(Sequence) (Check signal)



To change the gear safely, check that the spindle motor revolution is low enough before moving the shifter. If the zero-speed signal is also applied, the safety can be doubly checked.

If the shifter moves when the spindle motor is rotating in high speed, the gear will break.



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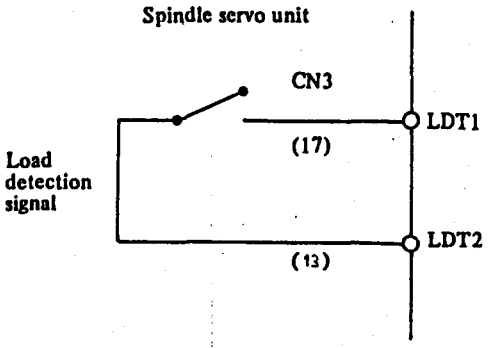
7.4.4 Load detection signal (LDT1, 2)

When the load becomes greater than the set value (%) against the maximum detection level (10 V) of the load meter, the contact is ON (closed).

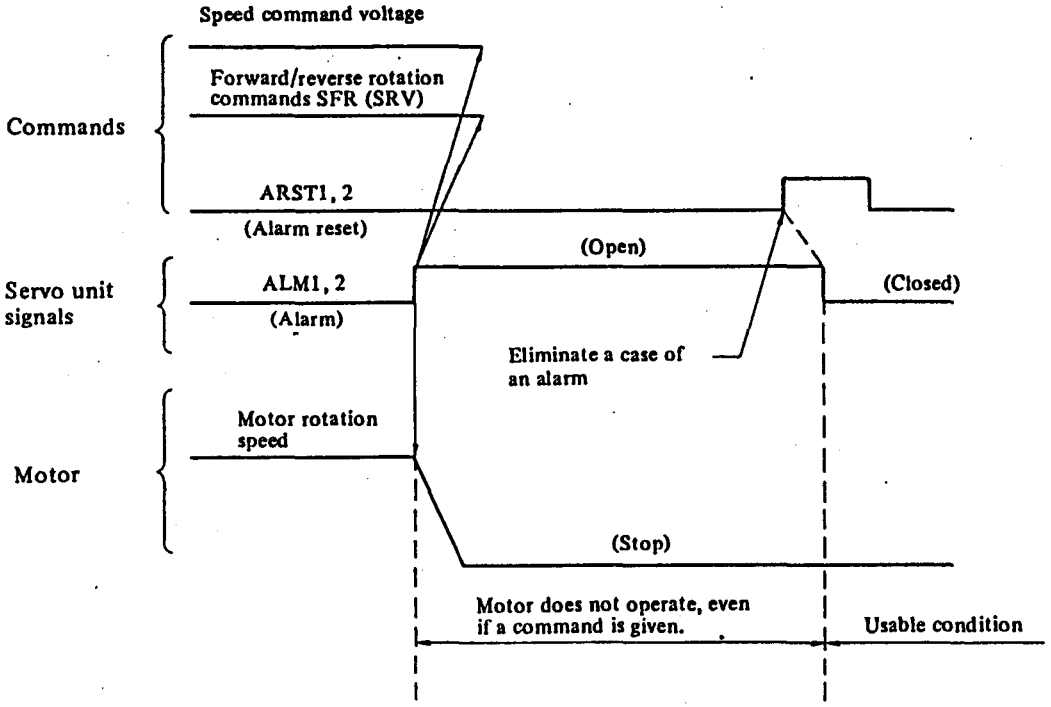


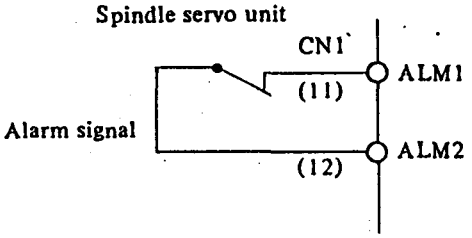
. Output by an open collector transistor (polarized).

7.4.5 Spindle alarm signal: (ALM1, 2)

1) If the spindle motor operation cannot be continued due to trouble, the spindle motor power is turned off to stop the spindle motor.
   An alarm signal is also sent to the exterior concurrently. (The output contact is open under an alarm condition.)
2) The alarm signals employ one contact only. For the alarm contents, refer to section 7.5 alarm contents signal.
3) Reset the command signals (speed command, forward rotation, reverse rotation commands, and torque limit command) to the spindle servo unit by using this alarm signal output without fail (clear all signals from PMC). Otherwise the spindle motor may rotate when the alarm of the spindle amplifier was released, and a dangerous accident may result.

4) Since the spindle motor is decelerated and stopped simultaneously when an alarm signal is outputted, it is necessary to set the emergency stop condition or feed hold condition on CNC or the power magnetics control panel side.
5) The contact is open under an alarm condition.
The spindle motor is being decelerated and stopped during alarm signal off (open contact), irrespective of external commands.
6) The relation between alarm signals and alarm reset signal is as illustrated below.

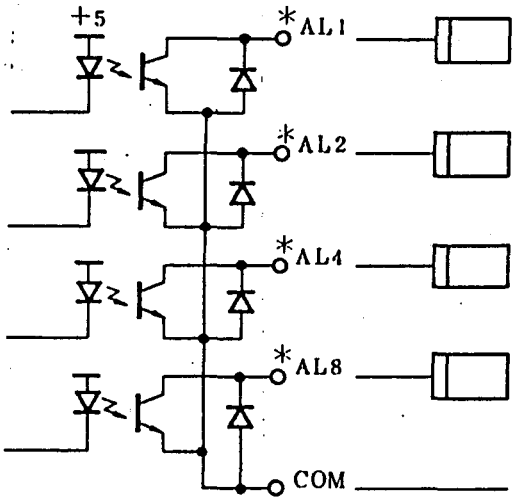




7.5 Alarm Content Signals(AL8, AL4, SL2, AL1)

(1) These signals are provided with the AC spindle servo unit.

(2) The alarm conditions of the AC spindle servo unit are indicated by seven segments five digits on PCB.
Alarm contents are sent to the exterior by code signals concurrently.



(3) The correspondence between LED display and alarm signals is as shown in the following table.

LED display	Alarm content signals			
	AL8	AL4	AL2	AL1
AL-01				o
AL-02			o	
AL-03			o	o
AL-04		o		
AL-05		o		o
AL-06		o	o	
AL-07		o	o	o
AL-08	o			
AL-09	o			o
AL-10	o		o	
AL-11	o		o	o
AL-12	o	o		
AL-13	o	o		o
AL-14	o	o	o	
AL-15	o	o	o	o

o: Contact ON (closed)

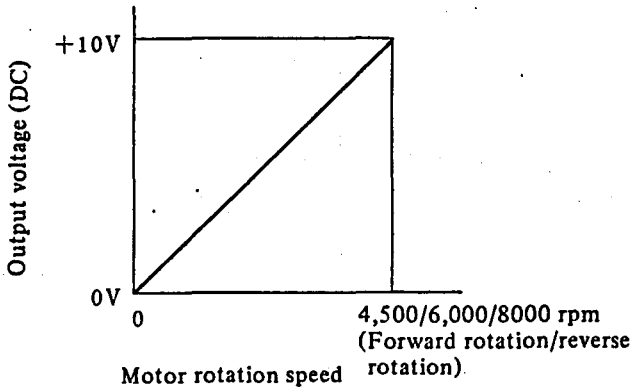
(4) Alarm signals can be received at magnetics sequencer and their signals can be displayed on the CRT of CNC. These signals can be used to design magnetics sequenceby the MTB.
Alarm contents are shown in the Table 7.5.

Alarm No.	Meanings	Contents
AL-01	Motor overheat	This alarm is issued when internal temperature of motor is higher than the specified value.
AL-02	Excessive deviation of speed	This alarm is issued when the motor speed is largely deviated from the command.
AL-03	Fuse in DC link is blown out	This alarm is issued when the fuse in DC power supply is blown out.
AL-04	AC input fuse is blown out	This alarm is issued when the fuse an AC input fuse is blown out. A phase of input power is open.
AL-05		
AL-06	Overspeed (Analog detection)	This alarm is issued when the motor speed exceeds 115% of the rated speed.
AL-07	Overspeed (Digital detection)	Same as described above.
AL-08	Overvoltage	This alarm is issued when voltage largely exceeds the rated working voltage range due to a tap selection failure, etc
AL-09	Overload in main circuit	This alarm is issued when temperature of the radiator for cooling semiconductor, etc. abnormally increases.
AL-10	+15V drop detection	This alarm is issued when the control power is lower than the rated range of +15V.
AL-11	Overvoltage in power circuit	This alarm is issued when the DC power voltage of the power supply is abnormally high.
AL-12	Abnormal current of DC link	This alarm is issued when the circuit current is excessive. Defective transistor.
AL-13	Defective arithmetic circuit	This alarm is issued when microprocessor or its peripheral parts of arithmetic circuit are abnormal.
AL-14	Defective ROM	This alarm is issued when ROM is abnormal.
AL-15	Defective option circuit	Detects defective optional circuit and erroneous connection to optional circuit.
AL-16～23	Defective peripheral parts of arithmetic circuit.	
A	Defective ROM	

Table 7.5 Description of Alarm

7.6 Speed Indication Voltage (SM1, OM)

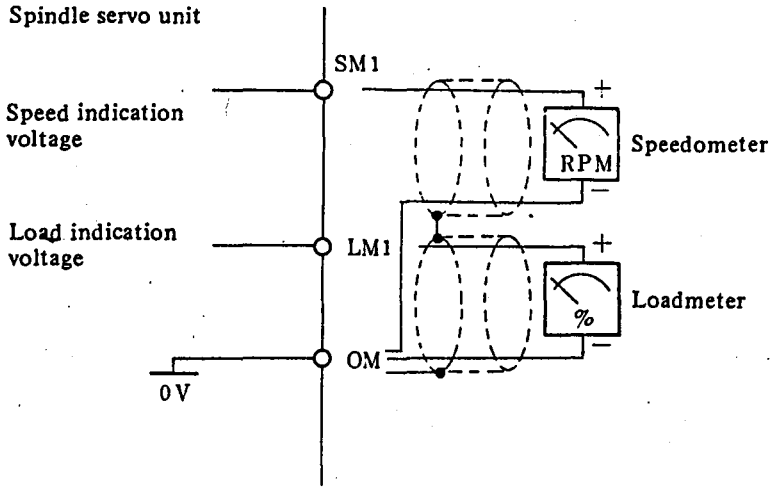
(1) The rotation speed of the spindle motor can be indicated by externally connecting a speedometer.



A voltage (DC) proportional to the rotation speed is outputted, irrespective of the forward or reverse rotation of the motor. A +10V is outputted at the maximum revolution 4,500/6,000/8,000 rpm.

(2) Use the following speedometer (DC voltmeter)
- o One-sided deflection DC voltmeter
- o DC voltage 10V full scale
- o Internal resistance higher than 10 kilo ohm

(3) The speed indication voltage is used for the speedometer, and the forward rotation/reverse rotation output voltages are not calibrated. The voltage accuracy is max. ±3%.

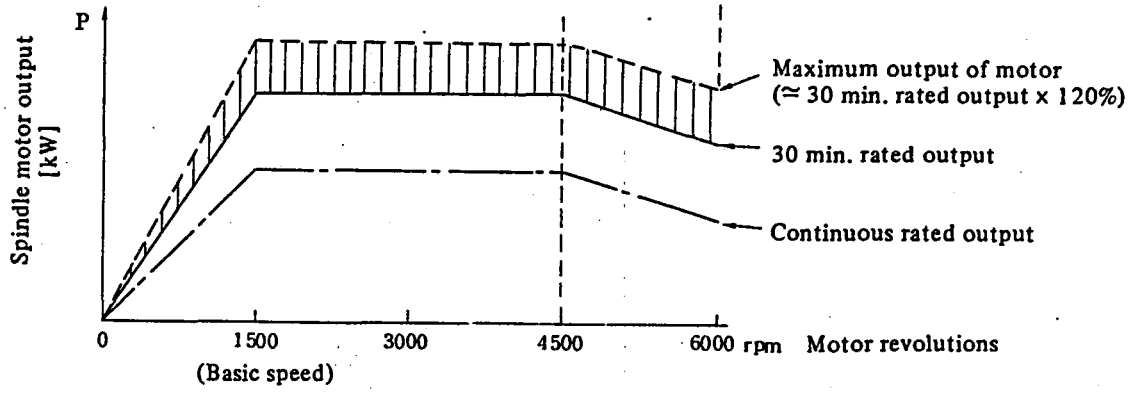


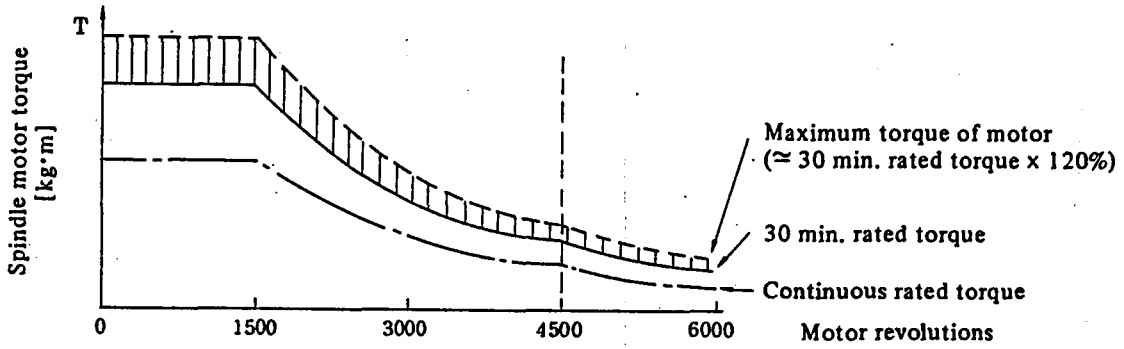
(4) SM1, LM1, and OM indication interface can be used from terminal board TB as well as connector CN1.
Use a 2-conductor shielded cable.

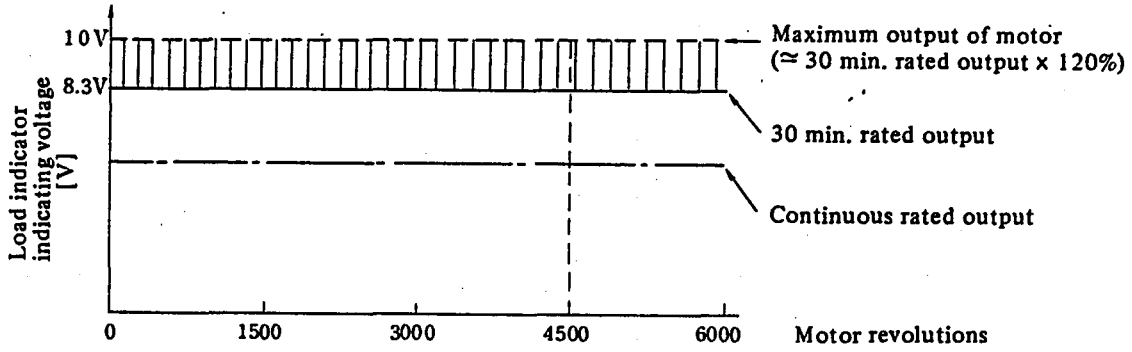
7.7 Load Indicator Voltage (LM1, OM)

(1) The load indicator indicates the load factor, which is the ratio of the load to the maximum output obtainable by the spindle motor at the input voltage and working revolutions when the machine tool spindle is rotating without load or when cutting is in progress.

(2) The revolutions-to-spindle motor output relation, revolutions-to-torque relation and revolutions-to-indicating voltage relation are as illustrated below approximately when the rated input voltage is applied.







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(3) The relation between each spindle motor output and the indicating voltage of the load indicator is as shown in Table 7.7(a), assuming that the continuous rated output of the spindle motor is 100%. ,

(4) Three types of indications of the load indicator may be considered approximately from Table 7.7(a). For the indication of the load indicator in this case, refer to examples shown in Table 7.7(b).

(5) Machine tool builders are requested to prepare a load indicator (DC voltmeter) which complies with the following specification.
- o One-side deflecting DC voltmeter
- o DC voltage 10V, full scale
- o Internal resistance 10 kilo ohm

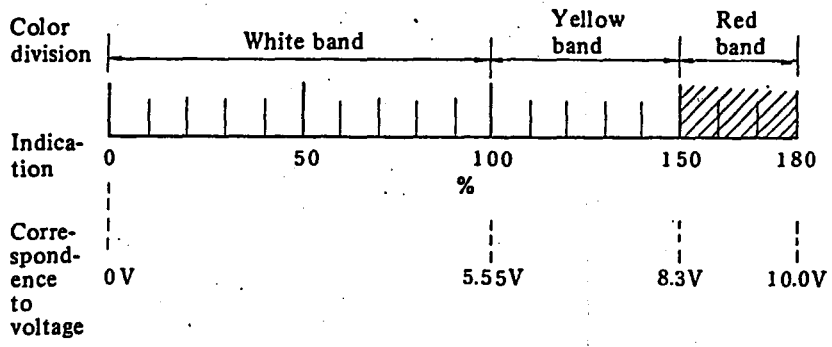
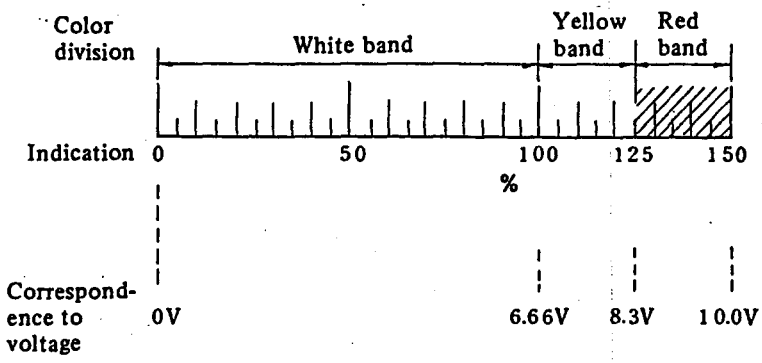
(Example) DC voltmeter LM-80 made by KUWANO DENKI

Table 7.7 (a) Relation between each spindle motor output and indicating voltage of load indicator.

Model	Output (kW)	Indicating voltage of load indicator (V) Note)	Ratio assuming that continuous rated is 100% (%)	Example of load indicator	
				Type of applicable load indicator	Ratio to full scale (%)
8P	3.7	5.6	100	A	101
	5.5	8.3	148		150
	6.6	10.0	178		180
15P	7.5	7.0	100	B	105
	9.0	8.3	118		125
	10.8	10.0	143		150
22P	11.0	6.1	100	A	110
	15.0	8.3	136		150
	18.0	10.0	164		180
40P	18.5	7.0	100	B	105
	22.0	8.3	118		125
	26.4	10.0	143		150

Note) Accuracy of the load indicator voltage depends upon the speed used or the input voltage. The maximum deviation is approximately ±15%.

Table 7.7 (b) Examples of types of load indicators

Type	Indication of load indicator	Remarks
A		For MODEL 8P,22P
B		For MODEL 15P,40P

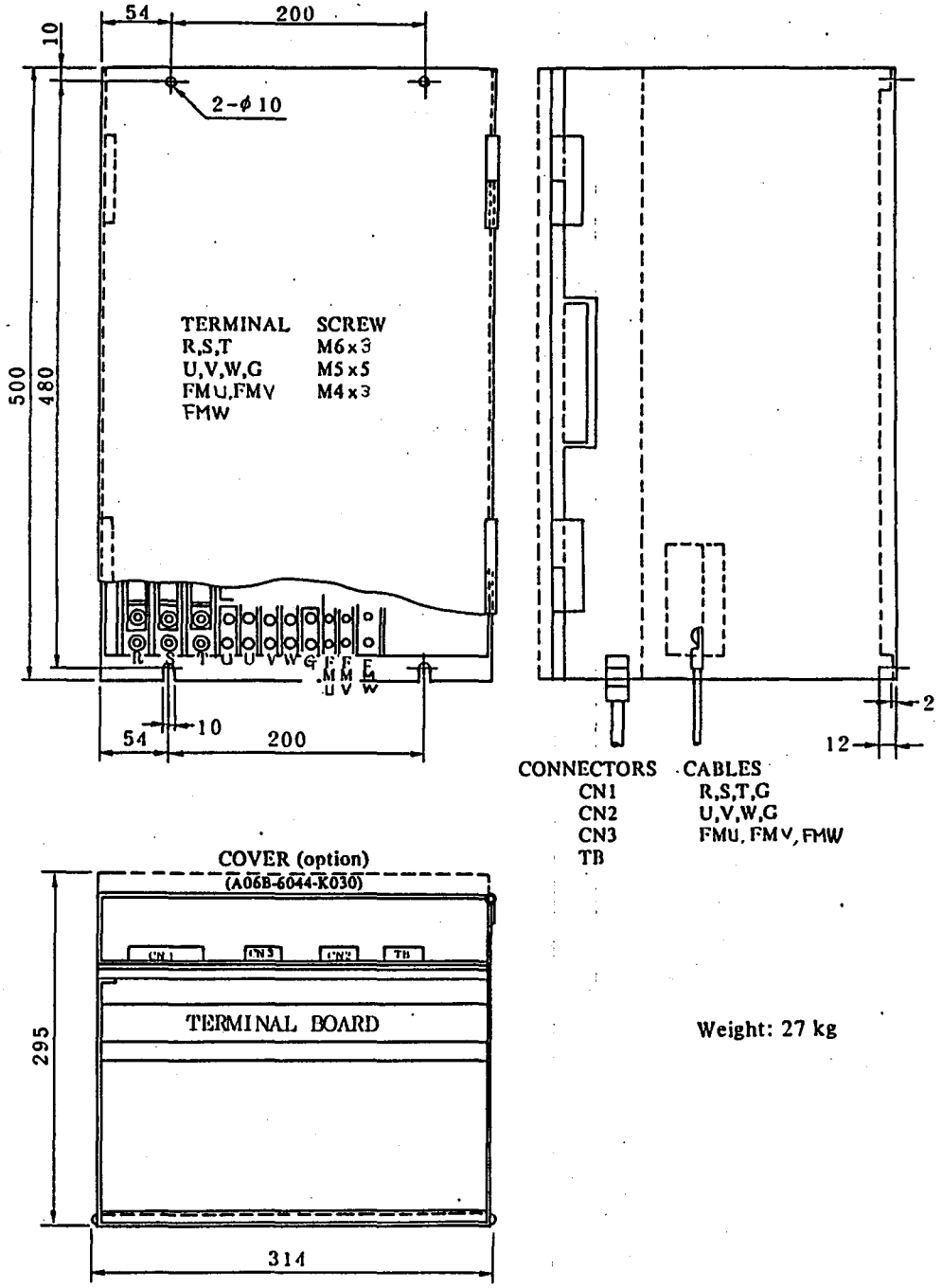


Fig. 8.1.1(a) Model 8P(A06B-6055-H306)(internal ventilation)

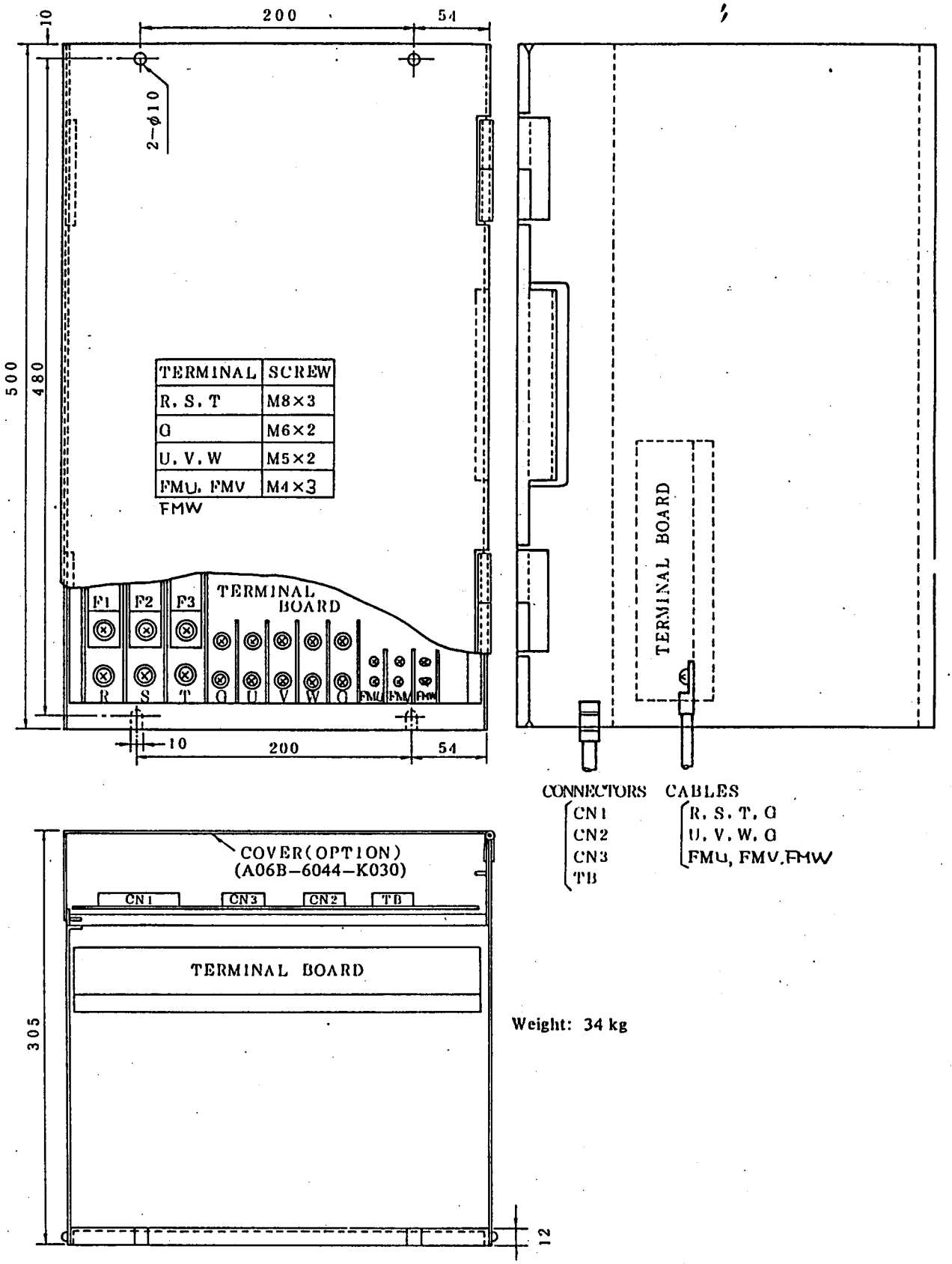


Fig. 8.1.1(b) Model 15P(A06B-6055-H308)(internal ventilation)

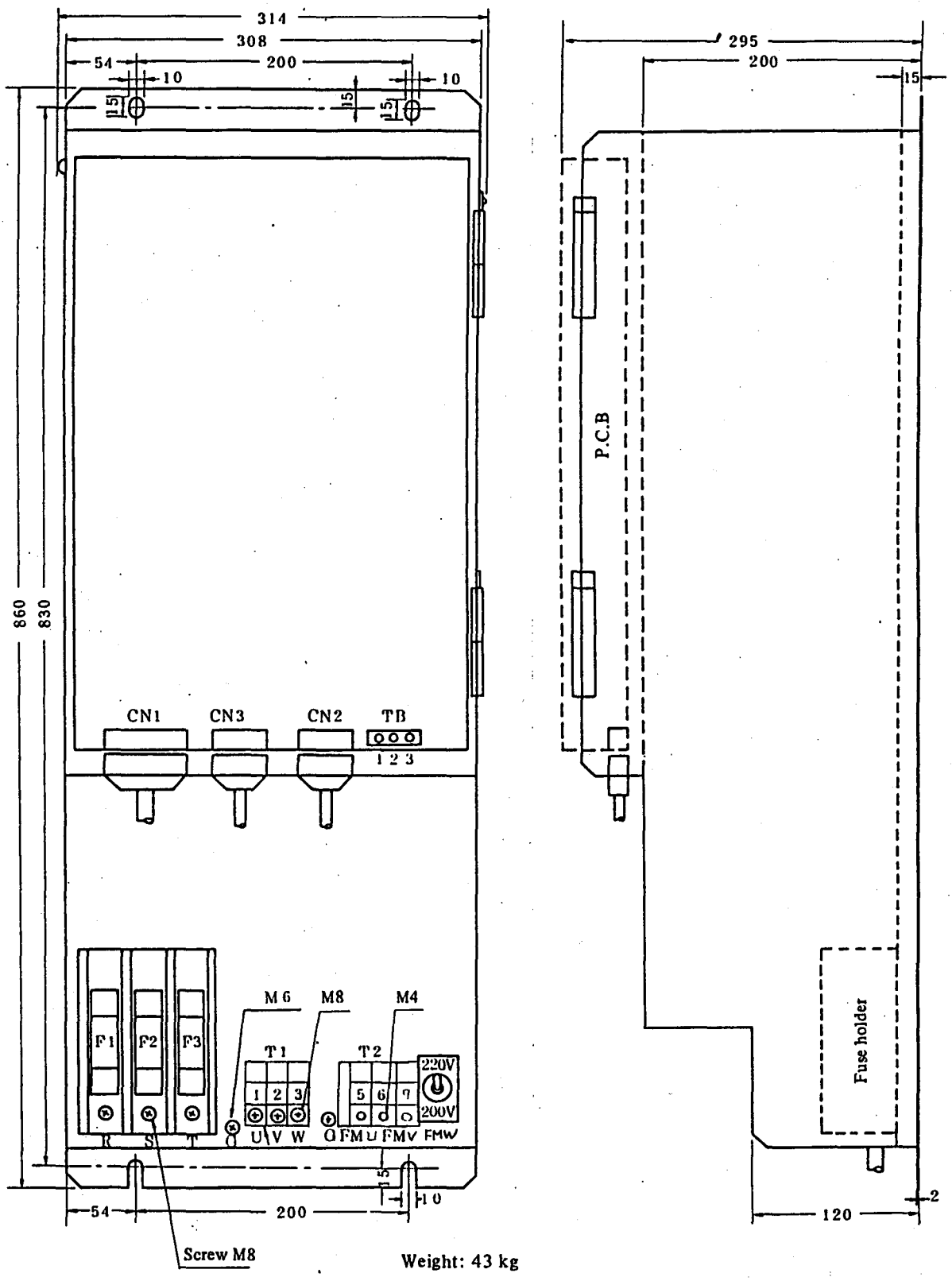


Fig. 8.1.1(c) Model 22P(A06B-6055-H315)(internal ventilation)

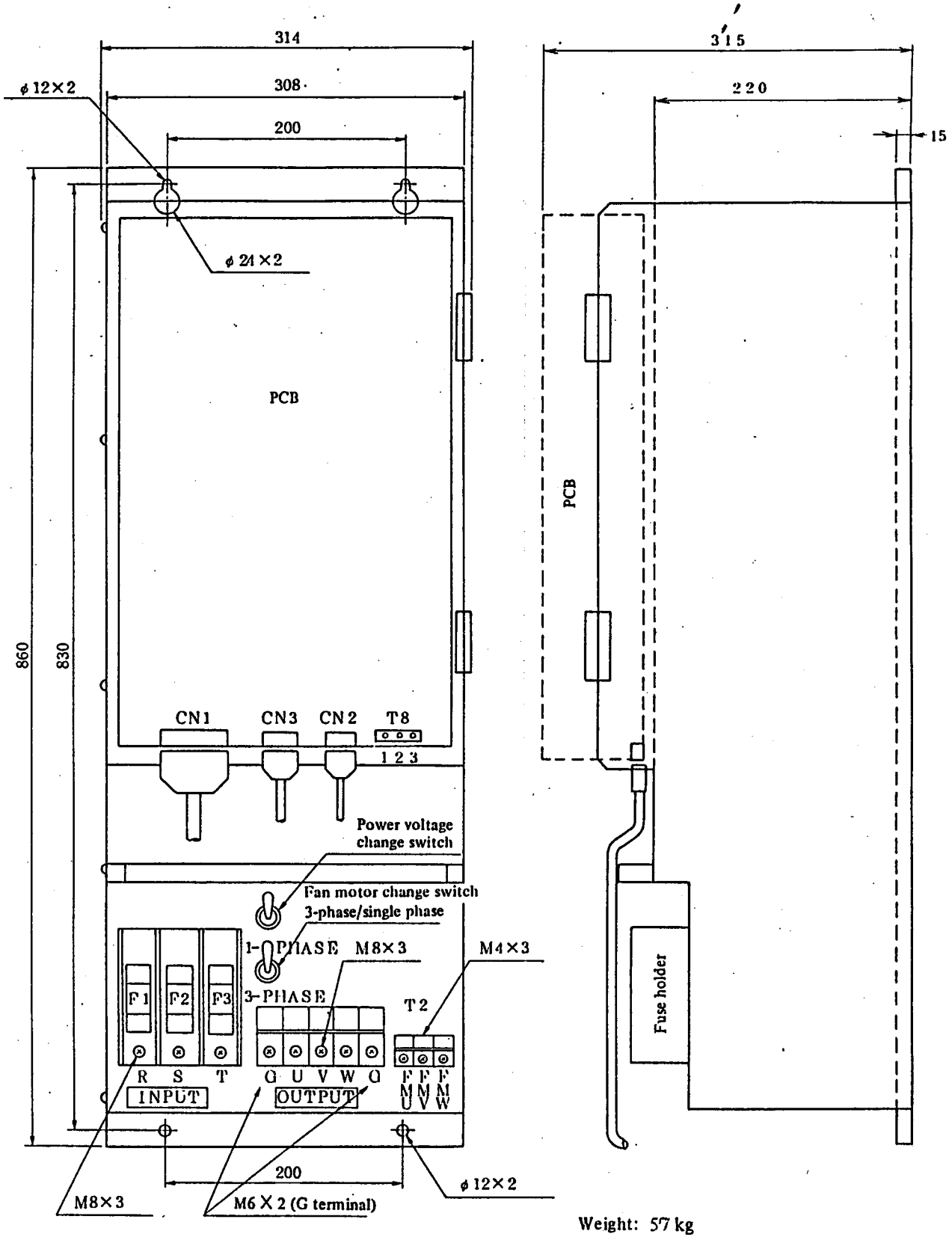
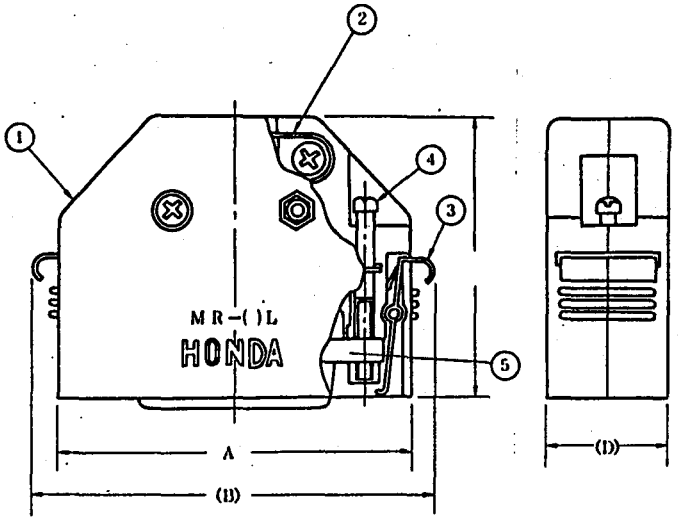


Fig. 8.1.1(d) Model 40P(A06B-6055-H322)(internal ventilation)

8.1.2 Connector



Specifications \ Symbol	A	(B)	C	(D)	No. of terminals
MR-50LFH	67.9	73.5	44.8	18	50
MR-20LFH MR-20LMH	39.3	44.9	39.8	17	20

Symbol	Name
1	Connector cover main body.
2	Cable clamp
3	Connector clamp spring.
4	Connector clamp screw.
5	Female connector.

Fig. 8.1.2 Connector

8.1.3 D/A Converter

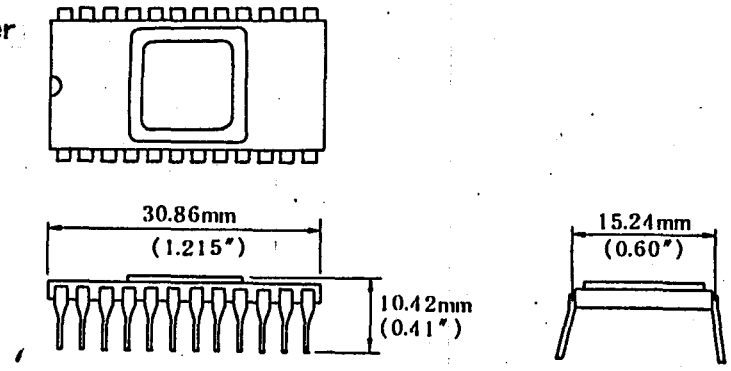


Fig. 8.1.3 D/A converter

8.1.4 Power Transformer

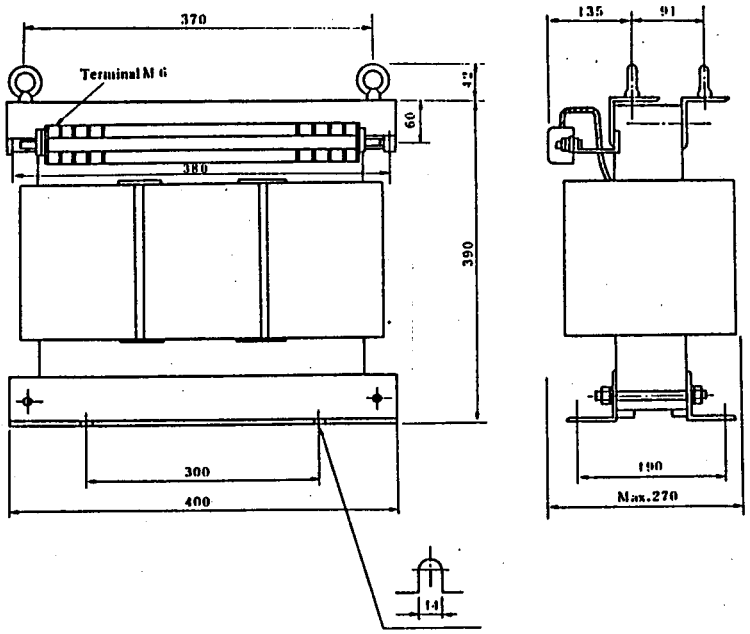
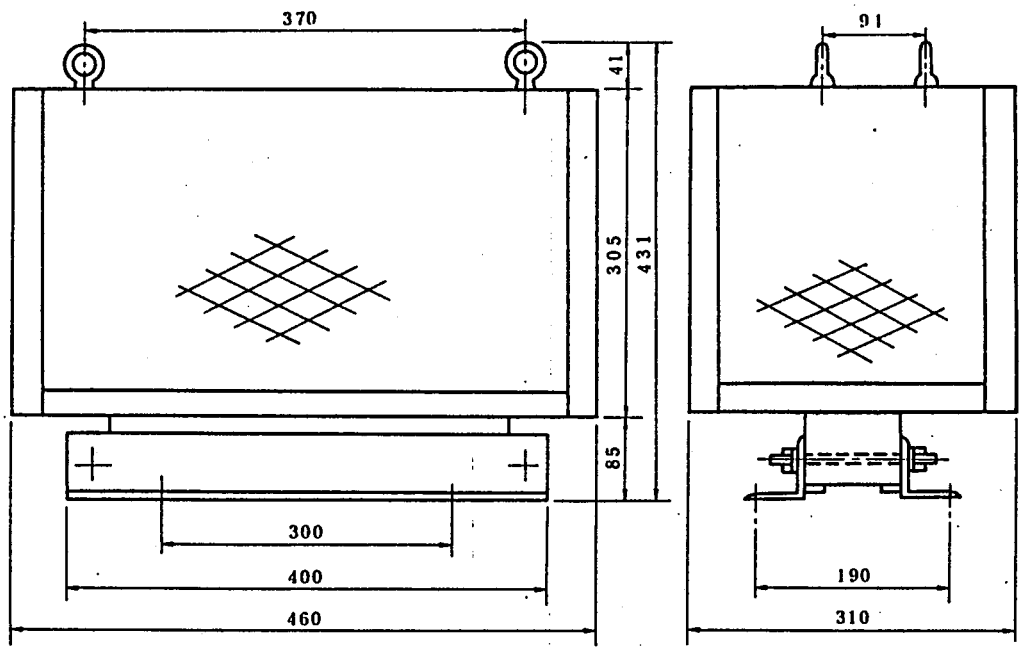


Fig. 8.1.4(a) For Model 8P, 15P(A06B-6044-J006)(Without cover)



Note: All the four side boards are nets, but the top is plate.

Fig. 8.1.4(b) For Model 8P, 15P(A06B-6044-J006)(With cover)

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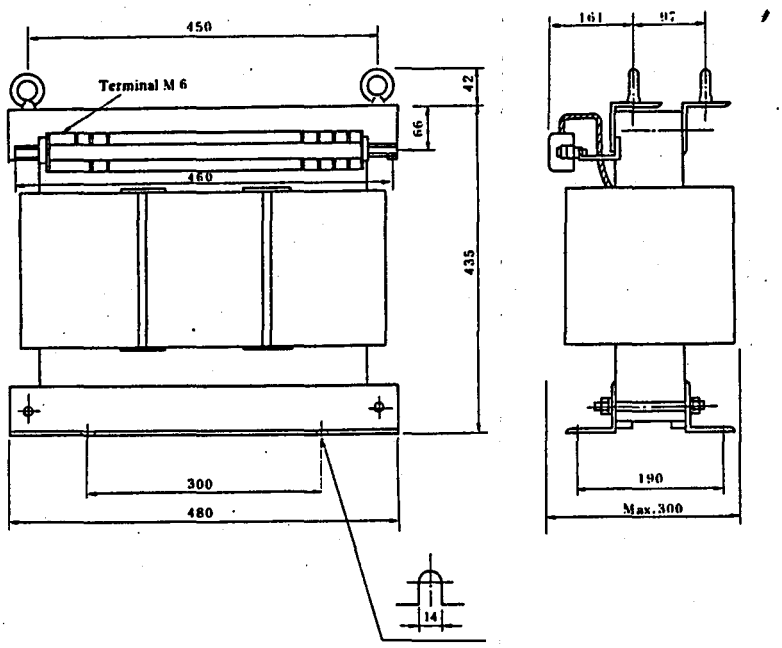
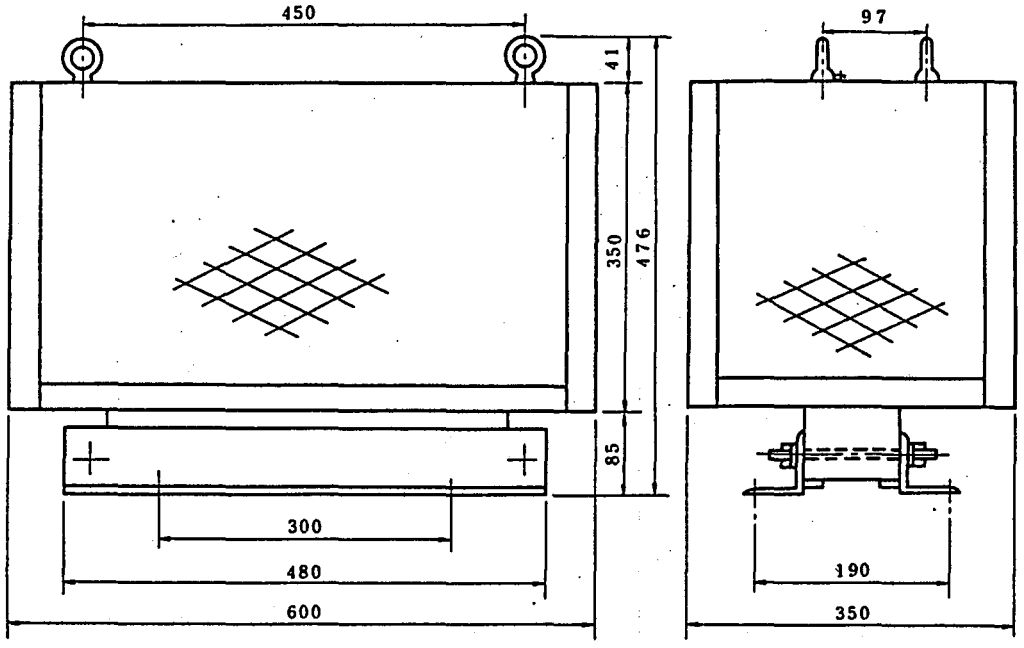


Fig. 8.1.4(c) For Model 22P(A06B-6044-J007)(Without cover)



Note: All the four side boards are nets, but the top is plate.

Fig. 8.1.4(d) For Model 22P(A06B-6044-J007)(With cover)

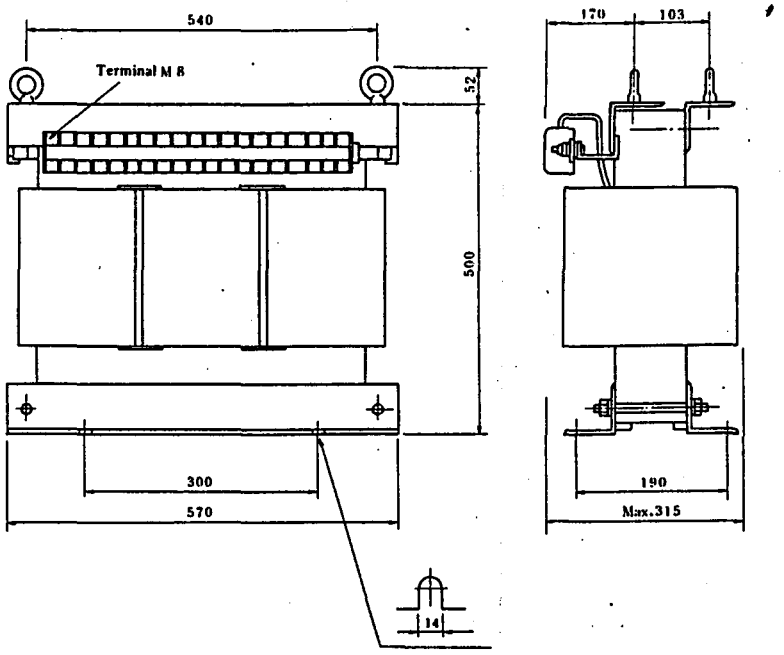
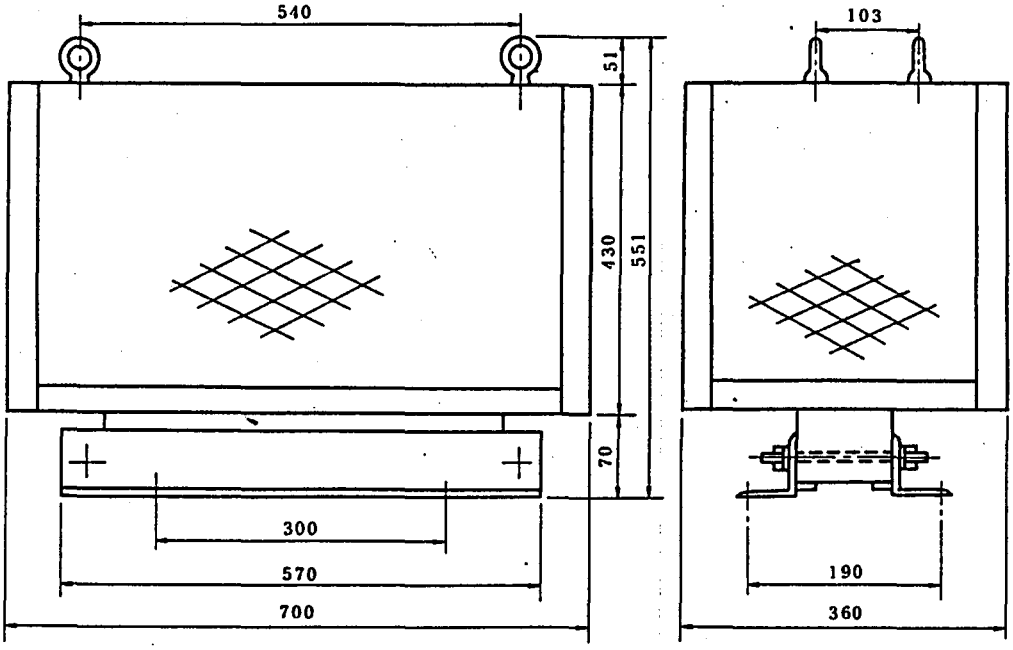


Fig. 8.1.4(e) For Model 40P(A06B-6044-J010)(Without cover)



Note All the four side boards are nets, but the top is plate.

Fig. 8.1.4(f) For Model 40P(A06B-6044-J010)(With cover)

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8.1.5 Unit Cover

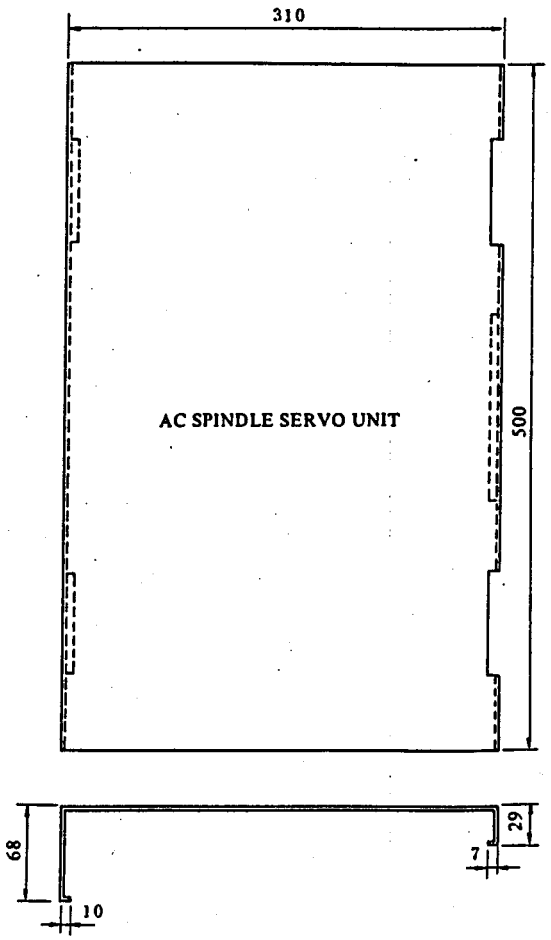
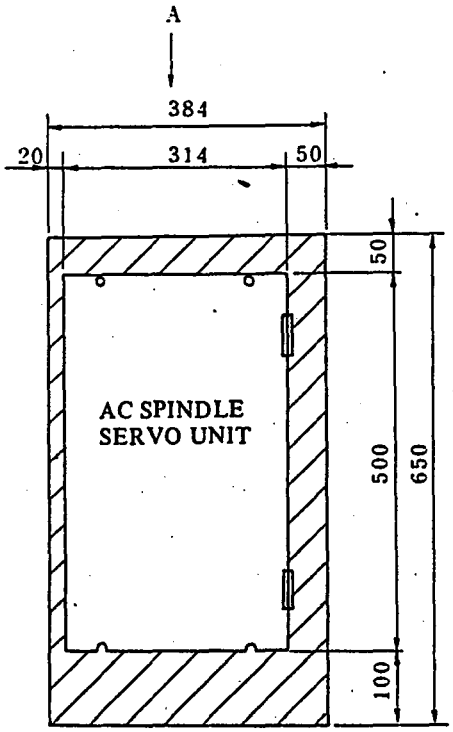


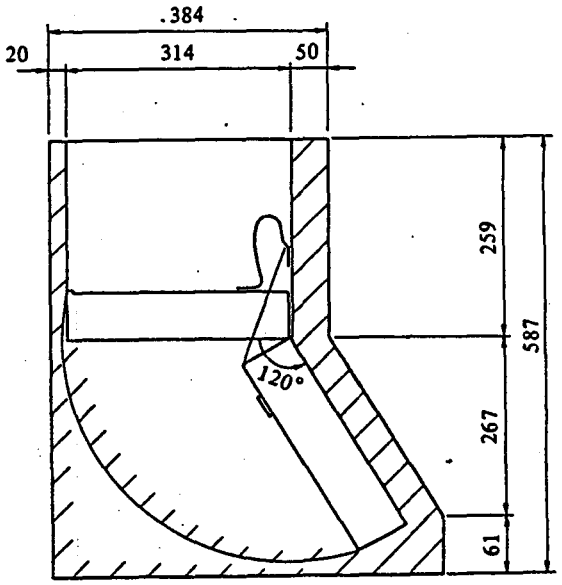
Fig. 8.1.5 Unit cover

8.2 Maintenance Area

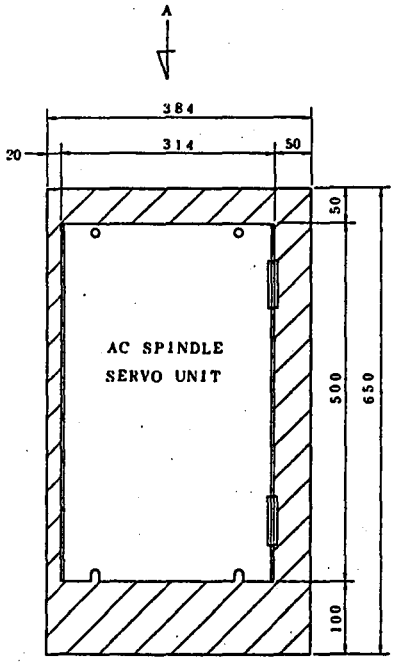
8.2.1 Model 8P(A06B-6055-H306)



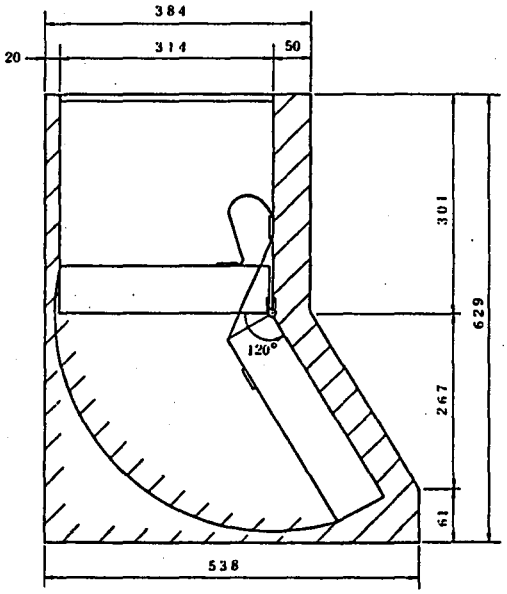
View from A



8.2.2 Model 15P(A06B-6055-H308)



View from A



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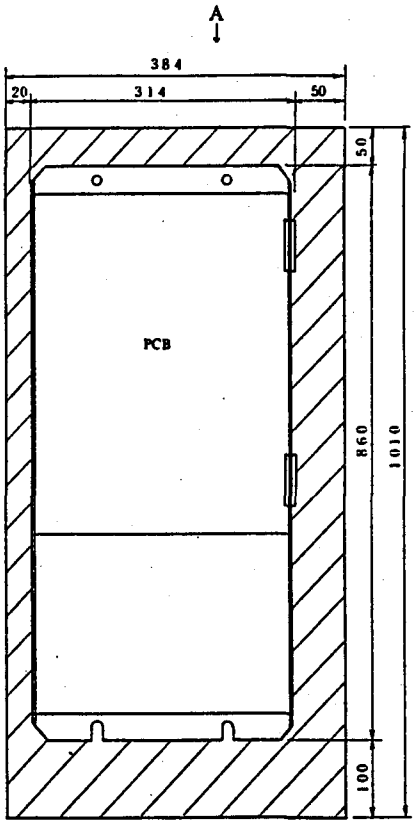
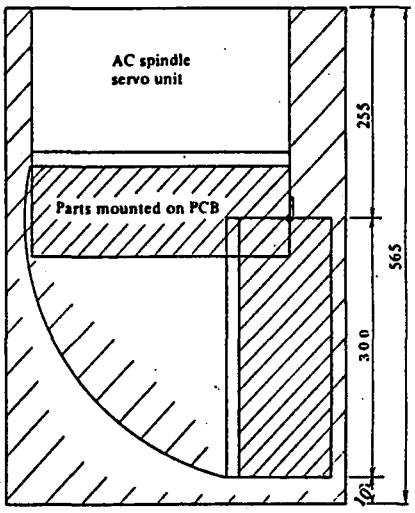
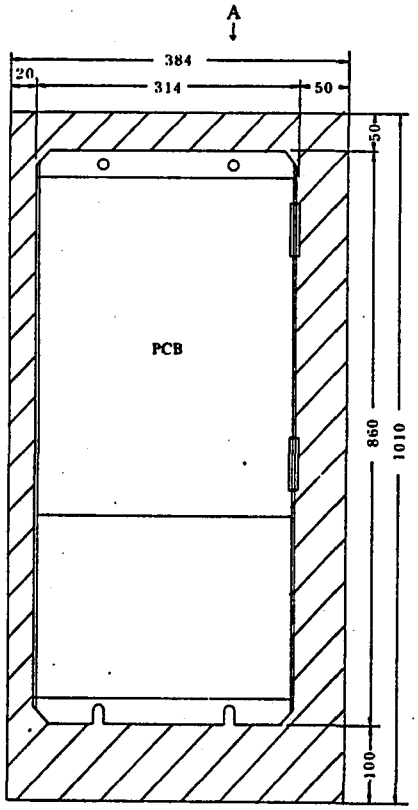
8.2.3 Model 22P(A06B-6055-H315)



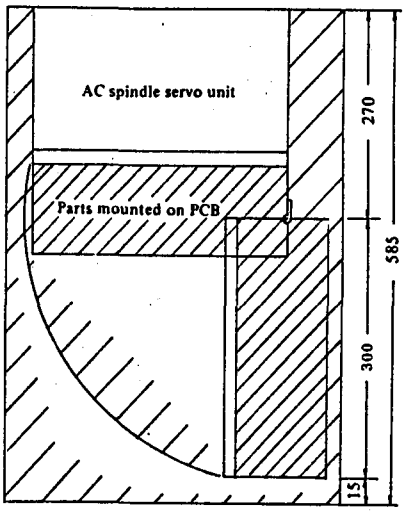
View from A



8.2.4 Model 40P(A06B-6055-H322)



View from A



9. RIGID TAPPING

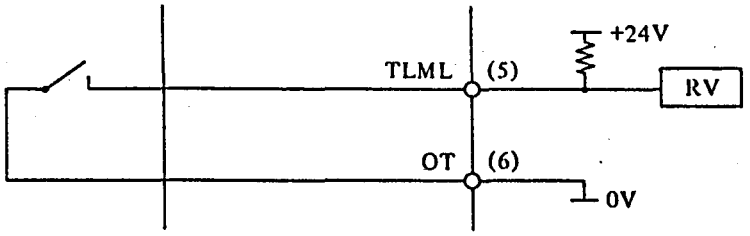
Response characteristics needed for the normal operation mode and the rigid tapping mode are different from each other when using AC spindle motor. Noise on the spindle may possibly get louder depending on machines when response characteristics are improved. Therefore, the parameter for selecting rigid tapping mode that improves response characteristics to the extent without such a trouble has been set for rigid tapping, according to the type of machine. Make setting and control specified as follow:

(1) Selection of rigid tapping mode

Select the mode number F-31 to set the display as 0001 at rigid tapping.

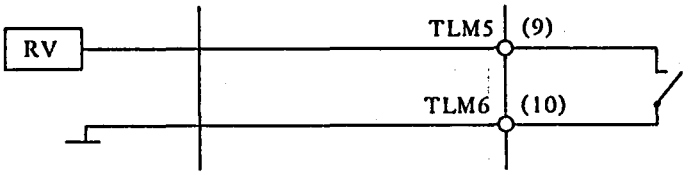
(2) Contact signal TLML-0T

Apply power sequence to close the contact signal TLML-0T when rigid tapping is made.



(3) Check of ready signal

Check the contact point of control output signal TLM5 and 6 is closed as ready signal, to start rigid tap machining.



(4) Improvement of response characteristics

Select the mode number F-34 to set the display as 0100 when rigid tapping is made.
Lower the setting from 0100, 0099, to 0050 to input proper data, when the spindle on the machine makes noise. Possible setting range:

Cautions on application: 0100 - 0010

Note that the torque limit command signal TLML can not be used when the above mode is selected.
Use the torque limit command signal TLMH when torque limit is necessary.

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III. SPINDLE ORIENTATION

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1. GENERAL

Unlike conventional mechanical spindle orientation using stoppers, etc., the electrical spindle orientation stops the spindle at a fixed position by directly feeding back position signals from the position coder or magnetic sensor directly connected to the machine spindle.

The electrical spindle orientation comprises the following eight types, which are selectable according to uses.

Type	Method	Explanation	Use
Orientation A	Position coder method. (Stop position internally specified.)	Stops at any spindle rotation point by the setting in the printed circuit board.	- Lathes For spindle positioning (Work- piece loading and unloading). - Machining centers For spindle orientation. - Applicable to the machine tool of up to 2-stage speed change system.
Orientation B	Position coder method. (Stop position externally specified.)	The stop position, which is set in advance in the P.C.B can be changed to any spindle rotation point by inputting a 12 bits signal.	- Lathes Used for spindle positioning (Used for spindle index at turning centers, provided that the spindle is mechanically locked for the cutting operation) Used for positioning to align loading/unloading direction of workpiece using the robot. - Applicable to the machine tool of up to 2-stage speed change system.
Orientation C	Magnetic sensor method. (Up to 2-stage speed change gear system)	Stops at a fixed position using a non-contacting position detector. The stop position is where the magnetizing element and the magnetic sensor face each other.	- Machining centers. For spindle orientation. - Applicable to the machine tools of up to 2-stage speed change system. - Applicable to the machine tool of which spindle speed is less than 8,000 rpm.

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Type	Method	Explanation	Use
Orientation D	Magnetic sensor method. (3-stage speed change gear system)	Same as the orientation D.	- Machining centers. For spindle orientation. - Applicable to the machine tools of 3-stage speed change system. - Applicable to the machine tool of which spindle speed is less than 8,000 rpm.
Orientation E	Position coder method. (Stop position internally specified.)	Stops at any spindle rotation point by the setting in the printed circuit board.	- Lathes For spindle positioning (Work- piece loading and unloading). - Machining centers For spindle orientation. - Applicable to the machine tool of up to 4-stage speed change system.
Orientation F	Position coder method. (Stop position externally specified.)	The stop position, which is set in advance in the P.C.B can be changed to any spindle rotation point by inputting a 12 bits signal.	- Lathes Used for spindle positioning (Used for spindle index at turning centers, provided that the spindle is mechanically locked for the cutting operation) Used for positioning to align loading/unloading direction of workpiece using the robot. - Applicable to the machine tool of up to 4-stage speed change system.
Orientation G	Magnetic sensor method. (Up to 2-stage speed change gear system)	Stops at a fixed position using a non-contacting position detector. The stop position is where the magnetizing element and the magnetic sensor face each other.	- Machining centers. For spindle orientation. - Applicable to the machine tools of up to 2-stage speed change system. - Applicable to the machine tool of which spindle speed is 6,000 to 12,000 rpm.
Orientation H	Magnetic sensor method. (up to 2-stage speed change gear system)	Same as the above.	- Machining centers. For spindle orientation. - Applicable to the machine tools of up to 2-stage speed change system. - Applicable to the machine tool of which spindle speed is 8,000 to 20,000 rpm.

2. FEATURES

(1) Mechanical parts are not required.
This orientation is accomplished simply by connecting the position coder or magnetic sensor to the spindle without any need of mechanical orientation mechanism (stoppers, pins, etc.) for spindle orientation.

(2) Reduction of orientation time
Since the spindle motor connected to the spindle is utilized and the orientation can be done directly from high-speed rotation, irrespective of gear shift, the orientation time is largely reduced.

(3) Simplified power magnetic sequence control
This sequence consists of the spindle orientation command, its completion signal, spindle high/low speed signal and spindle medium speed signal only without any need of other signals. Neither orientation speed command sequence nor torque limit command sequence is needed.

(4) Low price
This simplified orientation control circuit designed for the spindle orientation only is simplified and low-priced.

(5) High reliability
Electrical system assures improved reliability without any damage to the mechanical section against an external impact.

(6) High accuracy and rigidity
The spindle orientation accuracy and rigidity are enough to execute automatic tools exchange (ATC).

(7) Positioning of workpiece
Workpieces can be positioned to arrange their loading and unloading directions in lathe.

(8) Reduction of the number of processes in boring.
Since the spindle orientation can be done in the same direction as the rotating direction of the spindle when boring ends, workpieces will not be damaged by tool blades.
Since these tool blades can be mounted or dismounted in a fixed direction with reference to workpieces, programming is easy.

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3. SPECIFICATIONS

3.1 Position Coder Method

No.	Item	Explanation	
		Stop position internal setting	Stop position external setting
1	Position coder	Coupled to the spindle one to one ratio. 1024 pulses/rotation (A-phase and B-phase signals) 1 pulse/rotation (One pulse/rev. signal) Parallel transmission type for 4,000 rpm, 6,000 rpm or 8,000 rpm.	
2	Detection units	One spindle rotation (360°) is divided by 1024 x 4 (4096) pulses, i.e. 0.088° is made one pulse unit (detection unit). 360°/4096 pulses = 0.088°/pulse	
3	Stop position	The distance between the point indicated by the position coder one pulse/rev. signal and the actual stopping point is set for the number of pulse (N) using three digital switches of 4-bits each.	
4	Precision of repeated positionings	±0.2° (spindle angle) Machine error factors (for example, the backlash of the coupling between the spindle and position coder) are excluded. Depending on the fineness of the position gain adjustment, the spindle may move for one detection unit length (0.088°) after stopping at the oriented position.	
5	Stop position external setting	———	The stop position can be specified by the external 12 bits (4096) contact signal. (M pulses) The actual stopping point is the point which is M+N pulses from the position indicated by the position coder one pulse/rev. signal.
6	Operation	———	When orientation command is given, spindle rotates 1/2 to 2-1/2 turns after spindle speed spindle orientation speed, and stops at the specified stop position. No incremental positioning is possible.

3.2 Magnetic Sensor Method

No.	Item		Spped change gear system			
			Up to 2-stage speed			3-stage
1	Magnetic sensor		See item 5.3 of this chapter.			
2	Stop position		Stops when the center of the magnetizing element faces the center of the magnetizing element or the step position check scale. The stopping position can be adjusted to a fineness of ±1° by the circuit.			
3	Repeatability		±0.2° or less Excluding factors from the machine side errors, such as setting errors.			
4	Max. Hold torque at orientating		Continuous rated torque of AC spindle motor.			
5	Range where a spindle can be orientated		Orientation stop position ±240°.			
6			Circuit C	Circuit G	Circuit H	Circuit D
	Allowable range of max. spindle speed (Note 1)	High speed	2000 to 8000 rpm	6000 to 12000 rpm	8000 to 20000 rpm	4000 to 8000 rpm
		Medium speed	-	-	-	1000 to 2000 rpm
		Low speed	400 to 2000 rpm	1200 to 6000 rpm	1200 to 6000 rpm	250 to 667 rpm
7	Allowable range of gear ratio $\frac{\text{High speed}}{\text{Low speed}}$, $\frac{\text{High speed}}{\text{Medium speed}}$, $\frac{\text{Medium speed}}{\text{Low speed}}$		2 to 5	2 to 5	2 to 5	3 to 4

(Note 1) If the maximum revolution range of spindle is deviated from the above ranges in high speed, medium speed, and low speed gear stages, the spindle orientation time becomes longer, and a trouble may arise in practice. Observe the above revolution ranges, accordingly.

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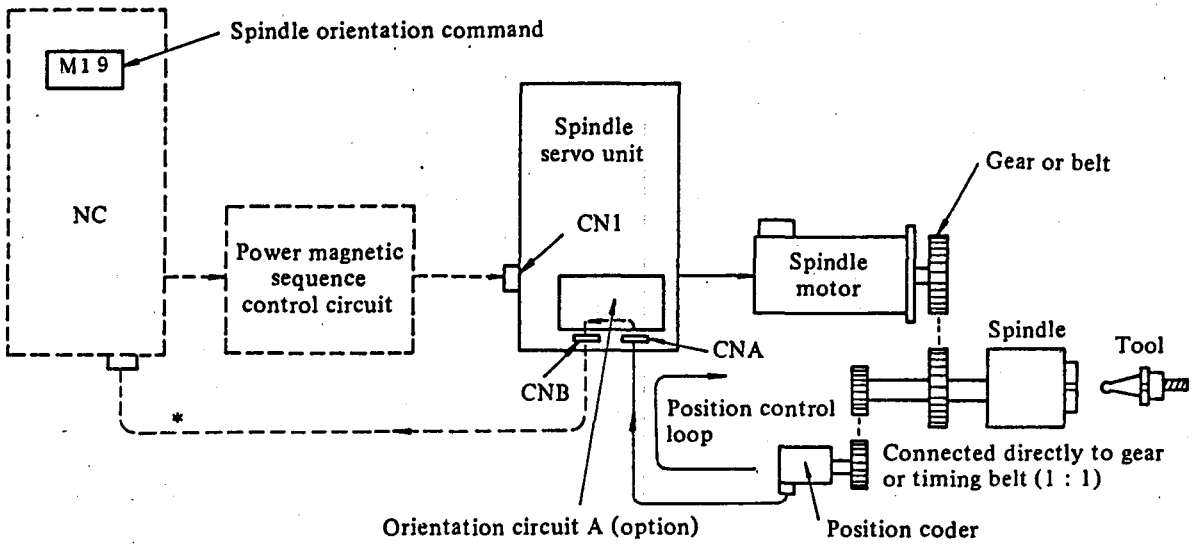
4. CONFIGURATION

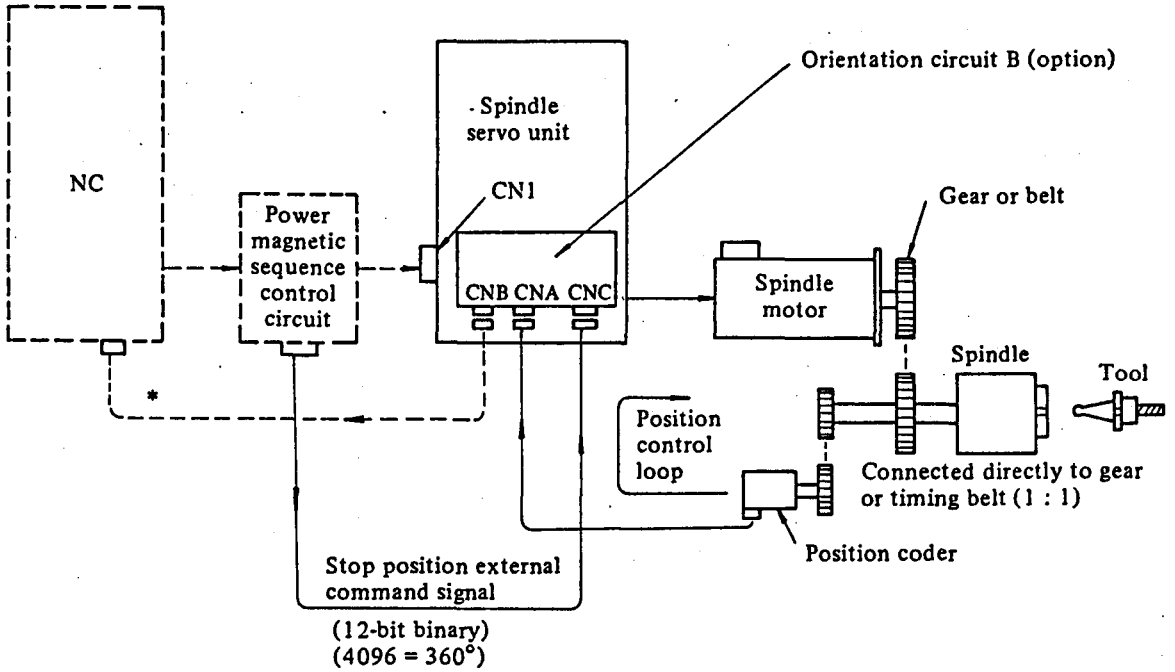
4.1 Position Coder Type (Stop position internal setting)



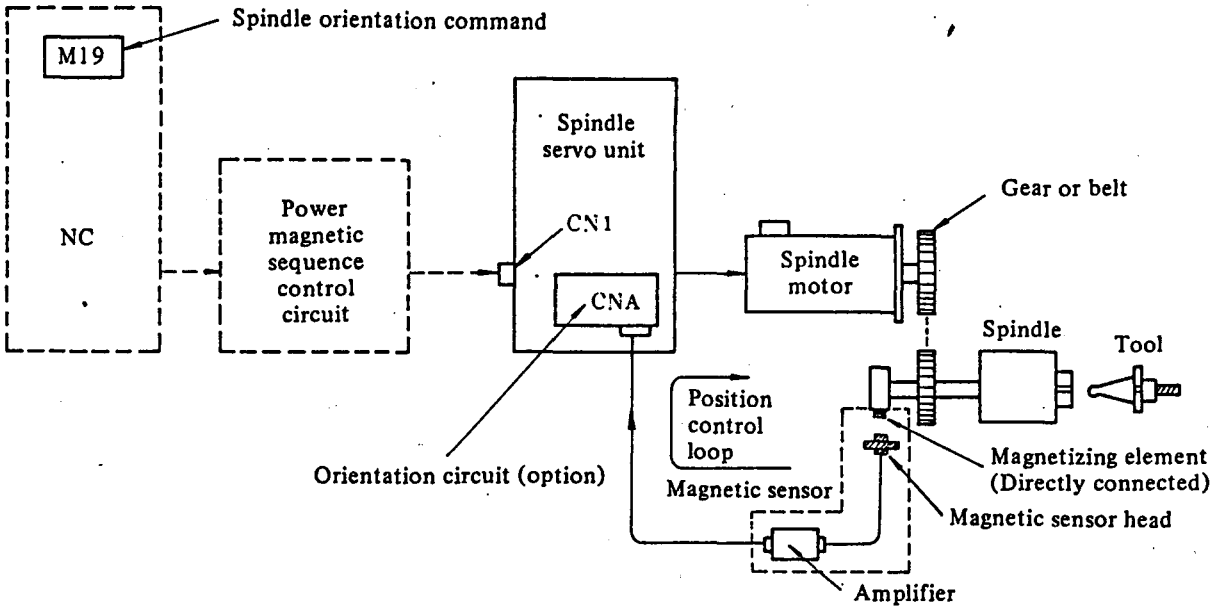
(Note 1) When a position coder is attached to lathe, etc., it can be used for this purpose.

(Note 2) The broken line marked with * is the cable route when the position coder attached to lathe or the position coder for the synchronous feed for machining center is used concurrently.

4.2 Position Coder Type (Stop position external setting)



4.3 Magnetic Sensor Type



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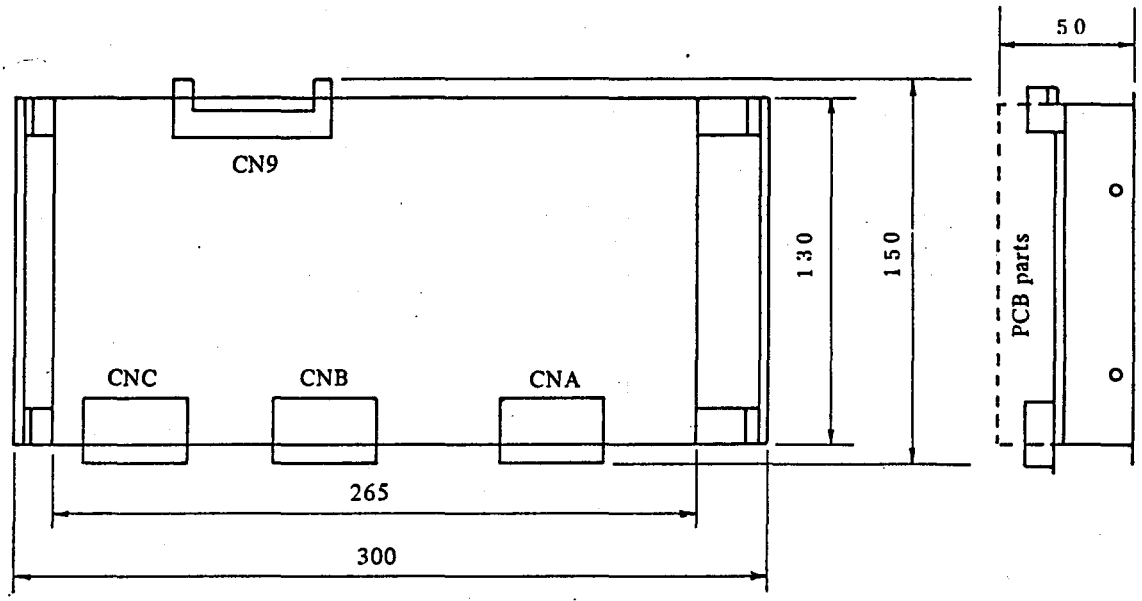
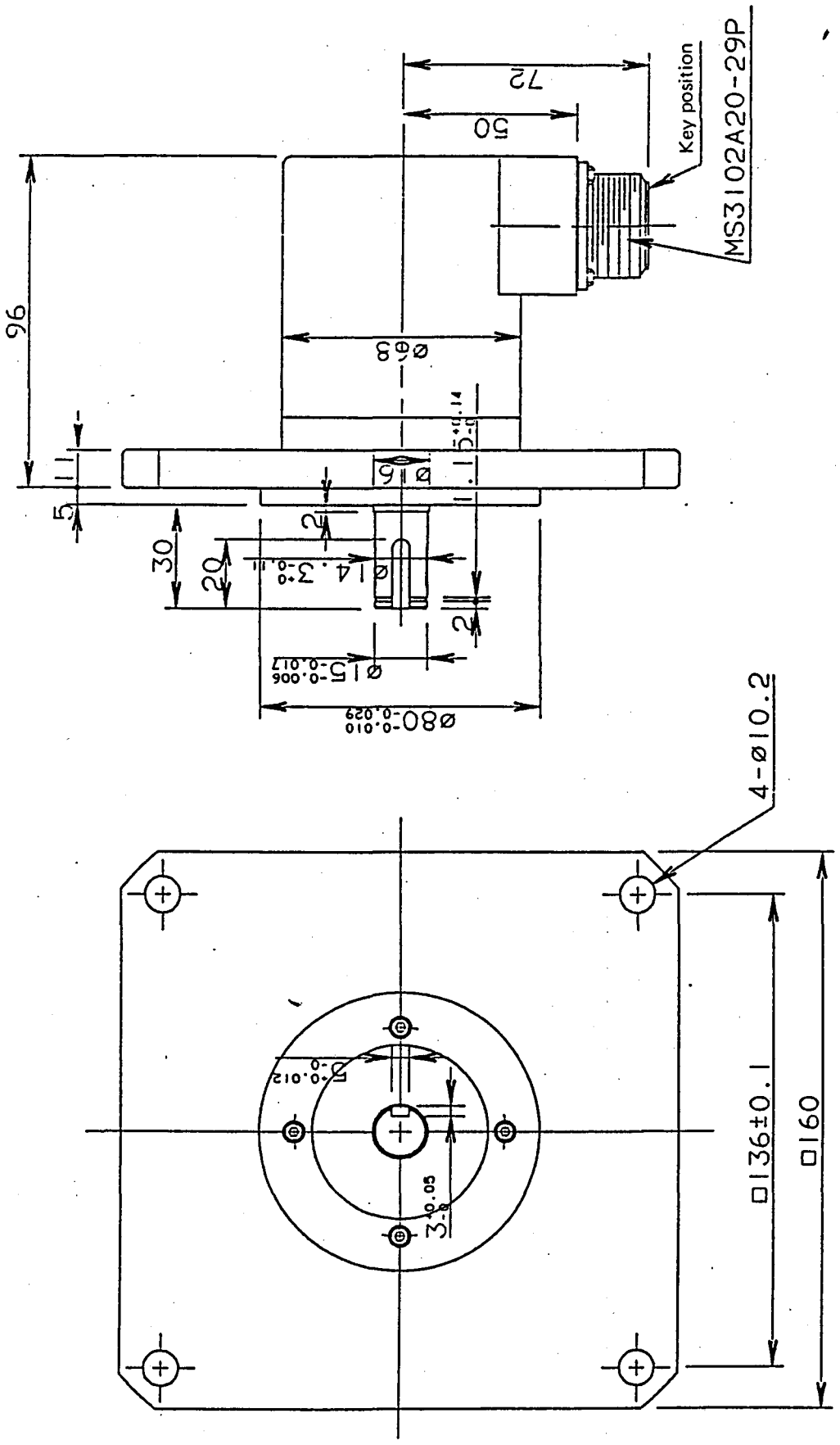
5. OUTER DIMENSIONS

5.1 Outer Dimensions of Option PCB



(1) PCB and fixtures have the same sizes in the position coder system and magnetic sensor system.
(2) Option PCB are mounted to the PCB of the spindle servo unit before shipment.

5.2 Outer Dimension of Position Coder

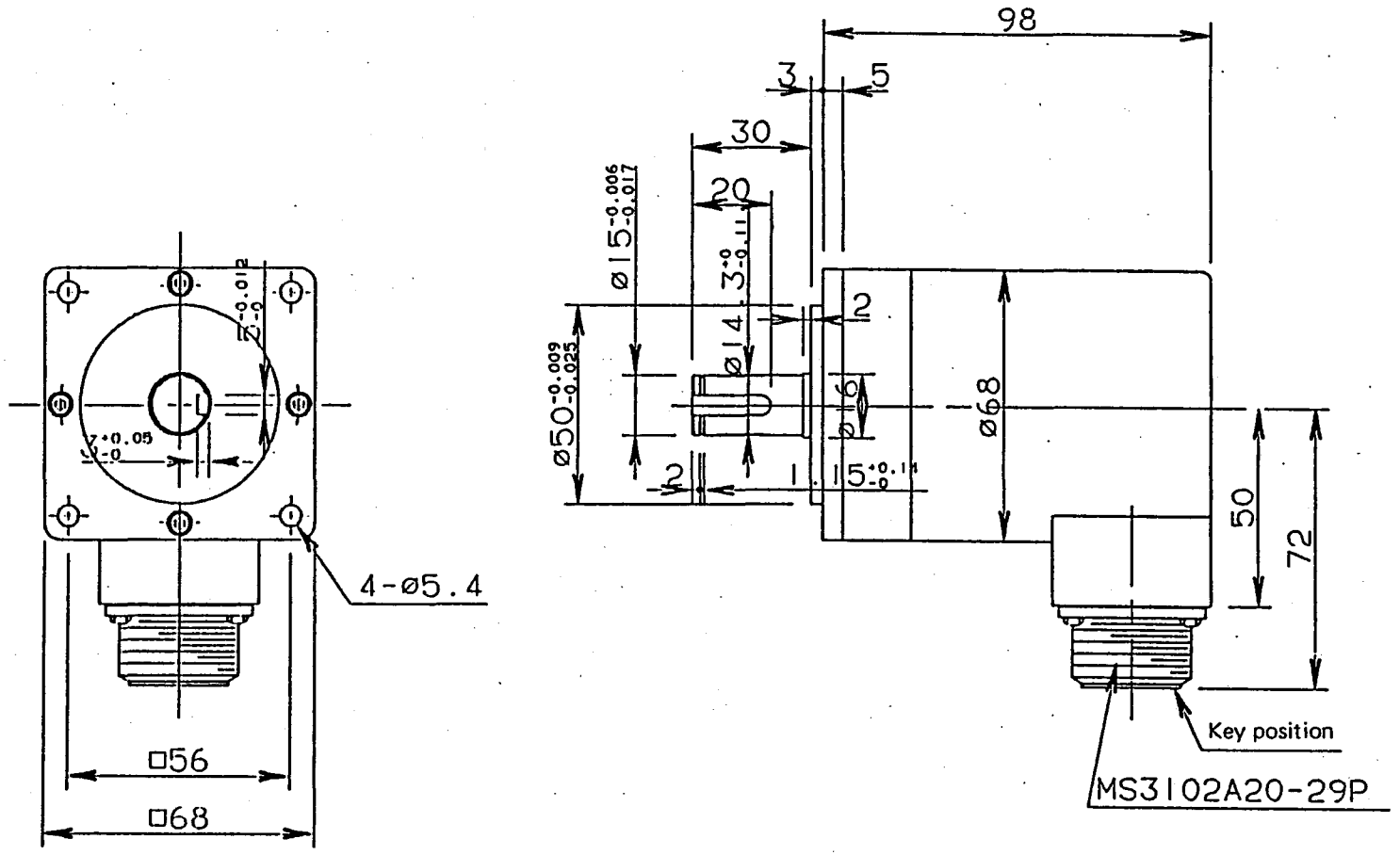


Cautions for mounting

(1) Since the position coder uses a glass board, do not apply a large mechanical shock.

(2) To prevent water or oil intrude from the cannon connector, mount the cannon connector downward.

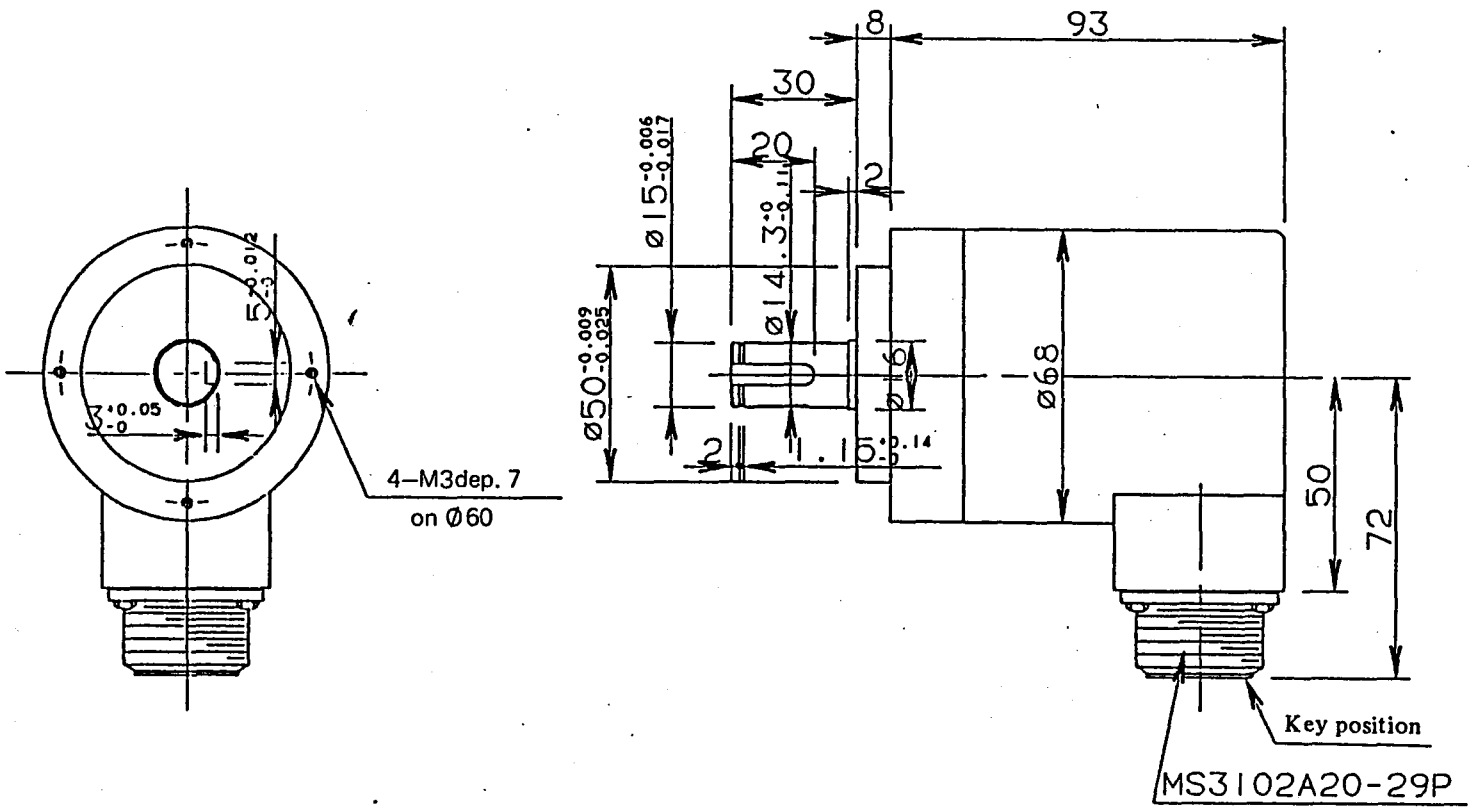
Figure 5.2 (a) Outer Dimensions of Position Coder A86L-0027-0001#□01 (with mounting plate □ 160)



Cautions for mounting

(1) Since the position coder uses a glass board, do not apply a large mechanical shock.
(2) To prevent water or oil intrude from the cannon connector, mount the cannon connector downwards.

Figure 5.2 (b) Outer Dimensions of Position Coder A86L-0027-0001#□02 (with mounting plate □ 68)



Cautions for mounting

(1) Since the position coder uses a glass board, do not apply a large mechanical shock.
(2) To prevent water or oil intrude from the cannon connector, mount the cannon connector downward.

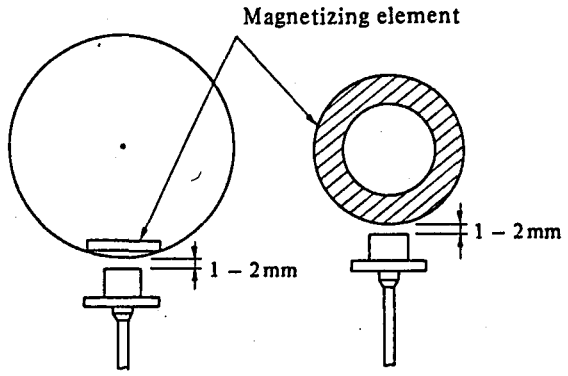
Figure 5.2 (c) Outer Dimensions of Position Coder A86L-0027-0001#□03 (with mounting plate)

5.3 Magnetic Sensor

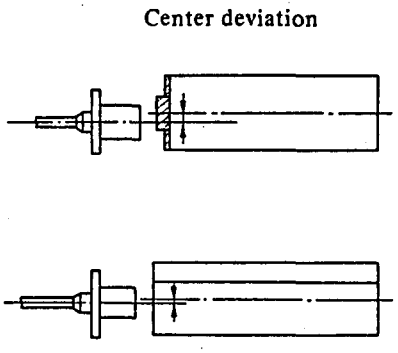
5.3.1 Magnetic sensor type

Items	Unit	Sensor N	Sensor P	Sensor Q	Sensor R	Sensor S	Sensor T
Maximum spindle speed	rpm	12,000 rpm		20,000 rpm		15,000 rpm	
Magnetizing element weight	g	33 ±1.5	14.8 ±0.7	315 ±10	460 ±10	770 ±15	1000 ±15
Allowable centrifugal force	kg	255 (Note3)	130 (Note3)	———			
Mounting radius from the spindle center to the magnetizing element	mm	40 to 110 (Note3)		20	25	30	35
Gap width from magnetizing element to sensor (Note 1)	mm	1.0 to 2.0					
Deviation between the magnetizing element center and the sensor center (Note 2)	mm	0 to ±2.0					
Working temperature range	°C	0 to +50					

(Note 1)



(Note 2)

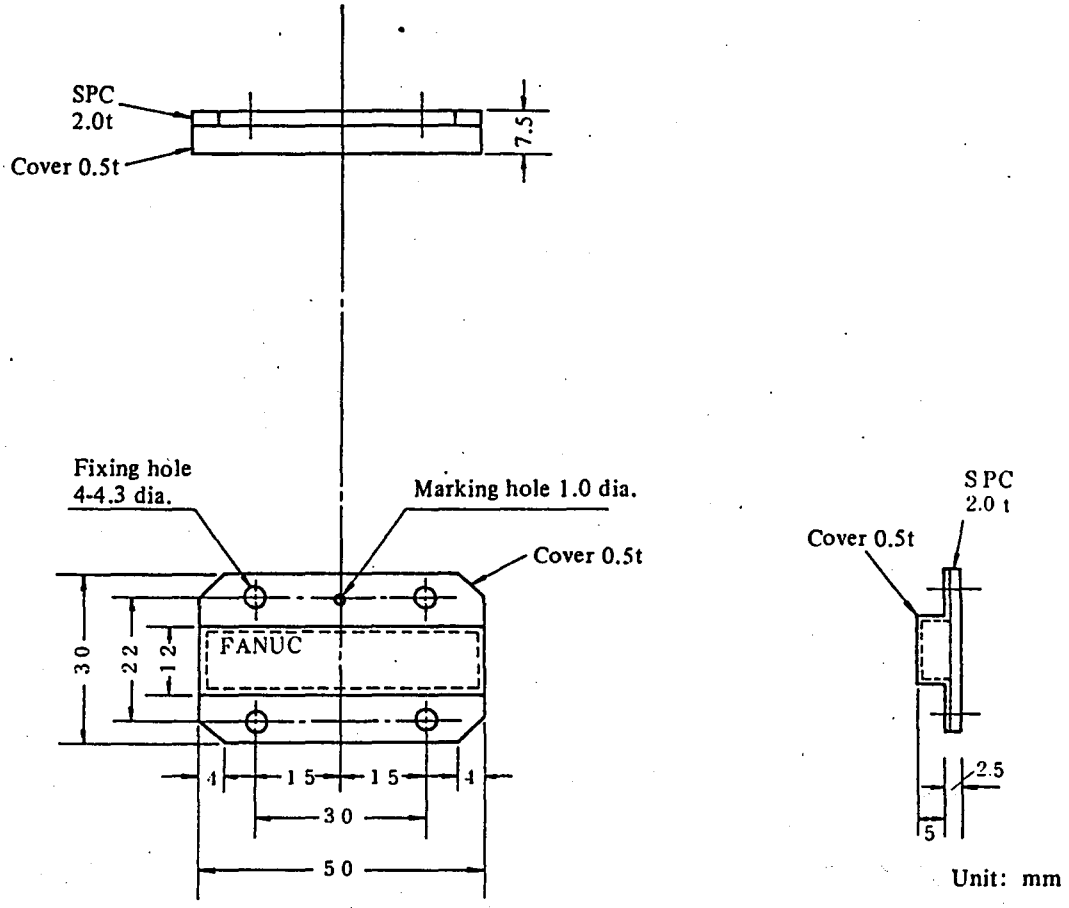


(Note 3) When the mounted radius to the magnetizing element is large, maximum revolution is restricted due to allowable centrifugal force.

(Note 4) It is recommended to mount the magnetizing element using high-strength bolt.

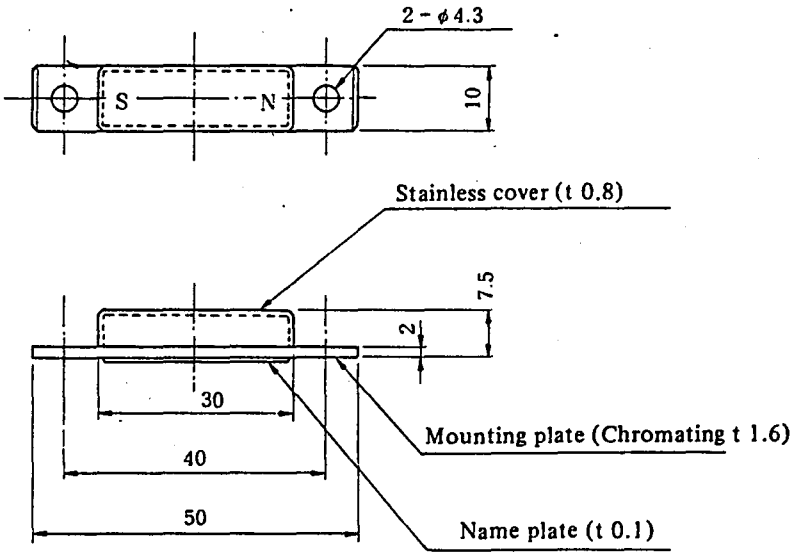
5.3.2 Magnetizing element outer dimensions

(1) Outer dimension of magnetizing element for magnetic sensor N



Weight: 33g ± 1.5g (Be careful with the balance of spindle)

(2) Outer dimension of magnetizing element for magnetic sensor P



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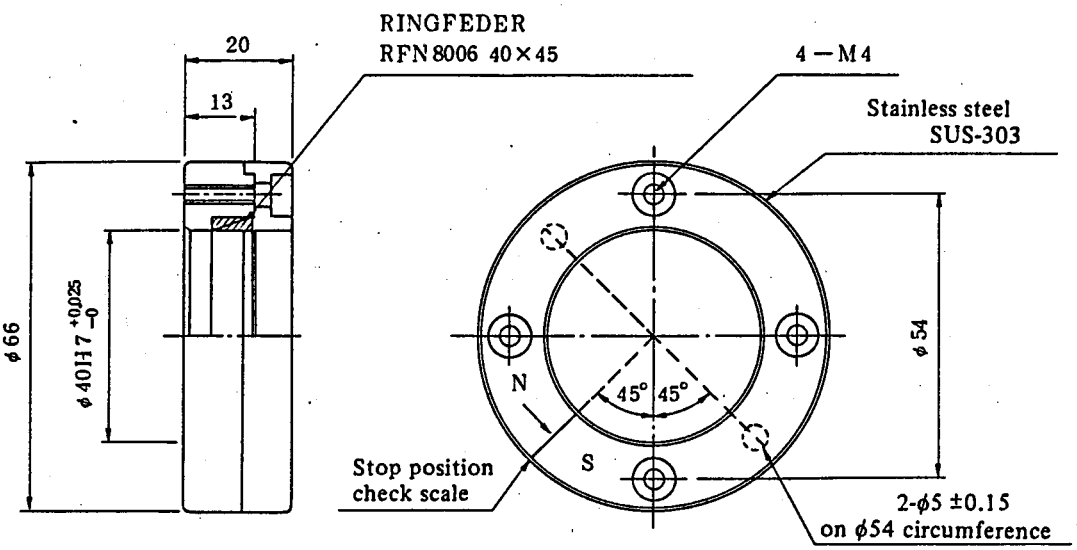
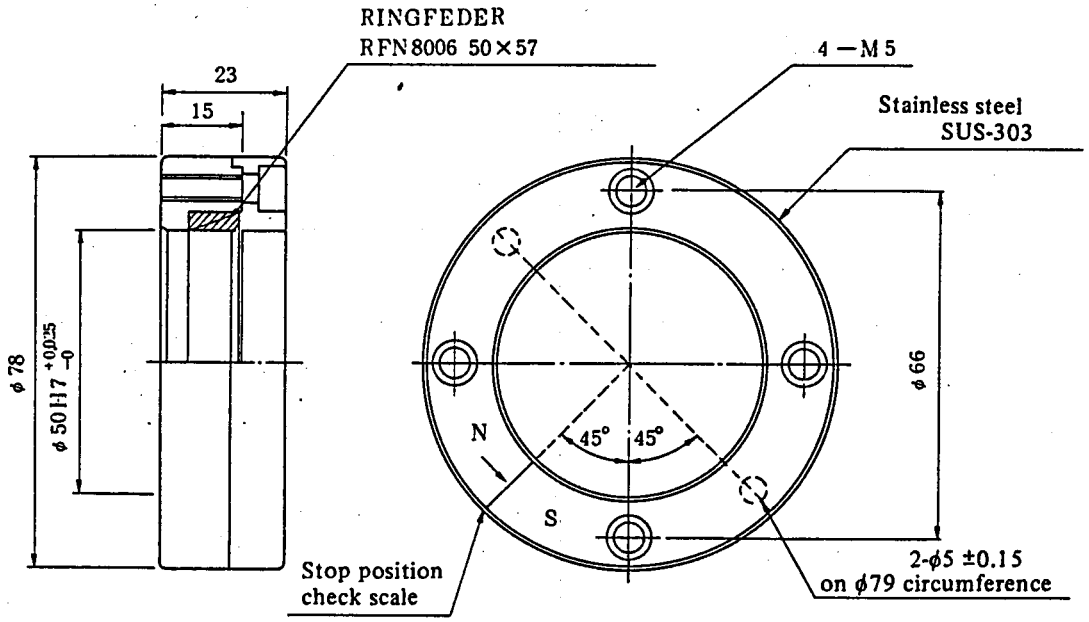
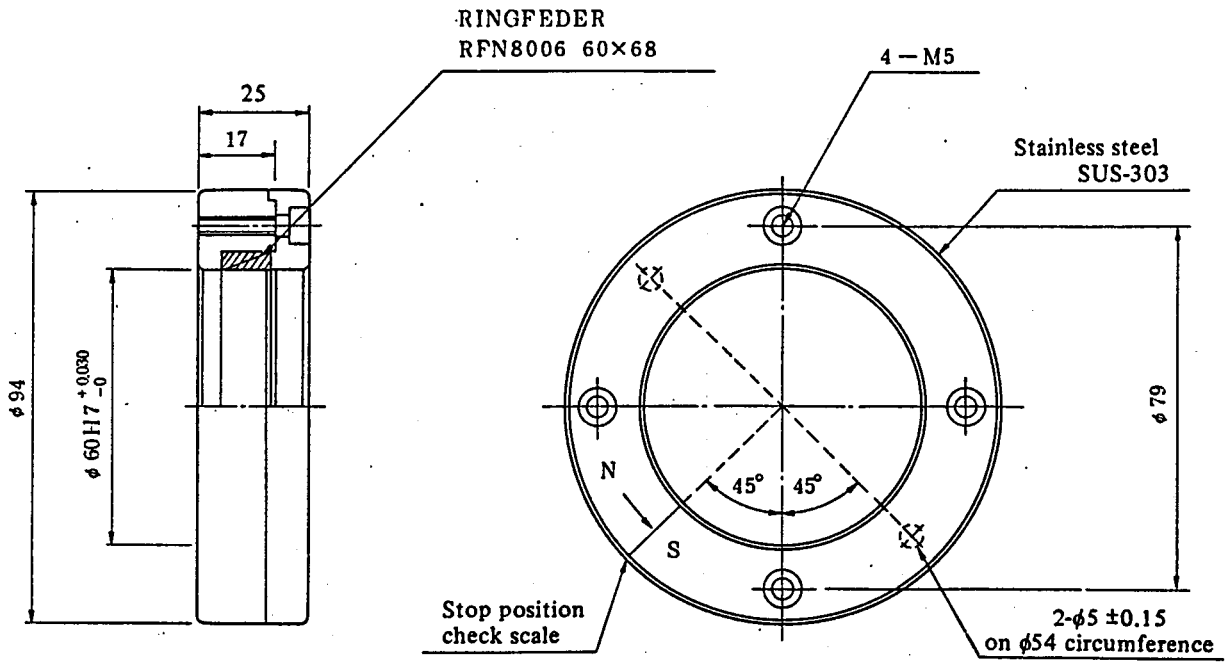
(3) Outer dimensions of magnetizing element for magnetic sensor Q



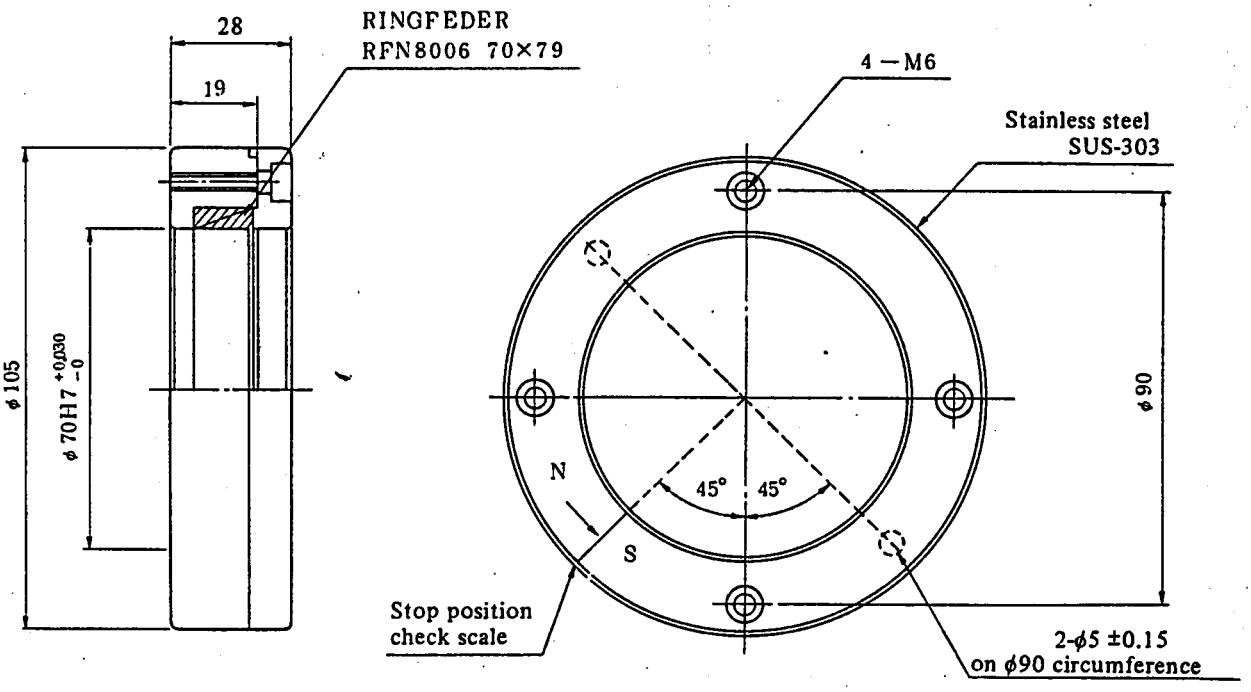
(4) Outer dimensions of magnetizing element for magnetic sensor R



(5) Outer dimensions of magnetizing element for magnetic sensor S



(6) Outer dimensions of magnetizing element for magnetic sensor T



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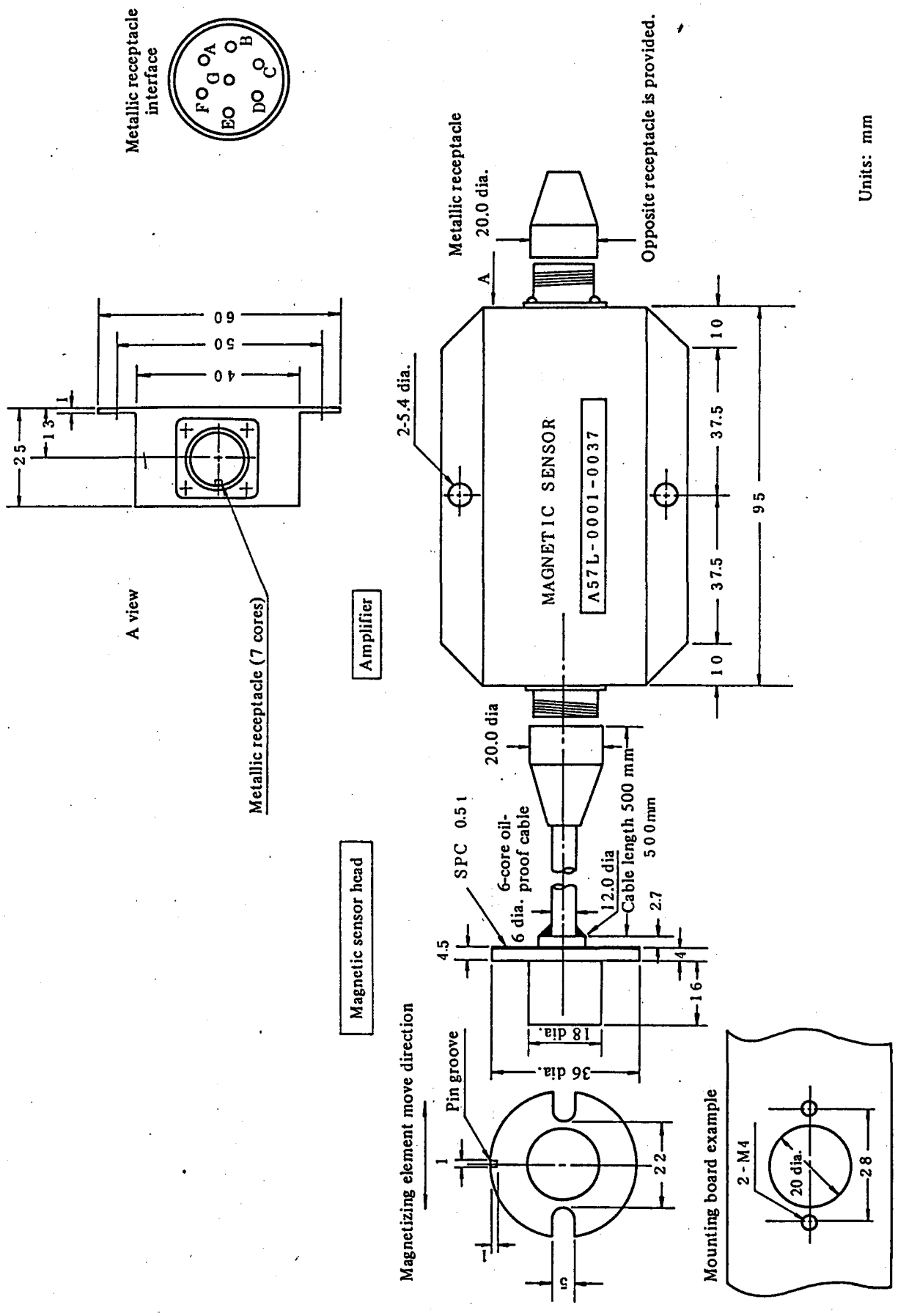
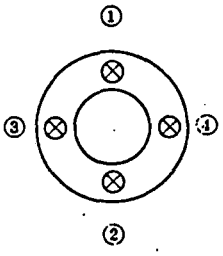
5.3.3 Magnetic sensor outer dimensions



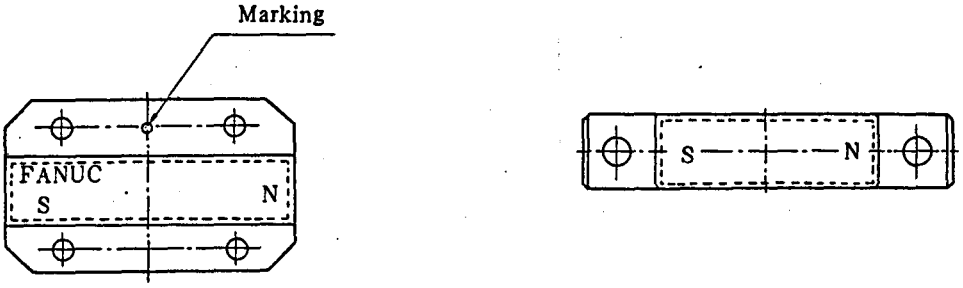
5.3.4 Cautions in use

(1) A ringfeder is used inside the magnetizing element. Tighten four bolts evenly and securely.



Tighten bolts gradually and repeatedly in the order of ① through ④.

(2) The relation between the decision standard hole and the magnetic polarity is as illustrated below.



(3) Utilize the screw fixing holes of magnetic sensors Q, R, S, T and two ø5.0 holes on the opposite side faces for the orientation positioning jig.

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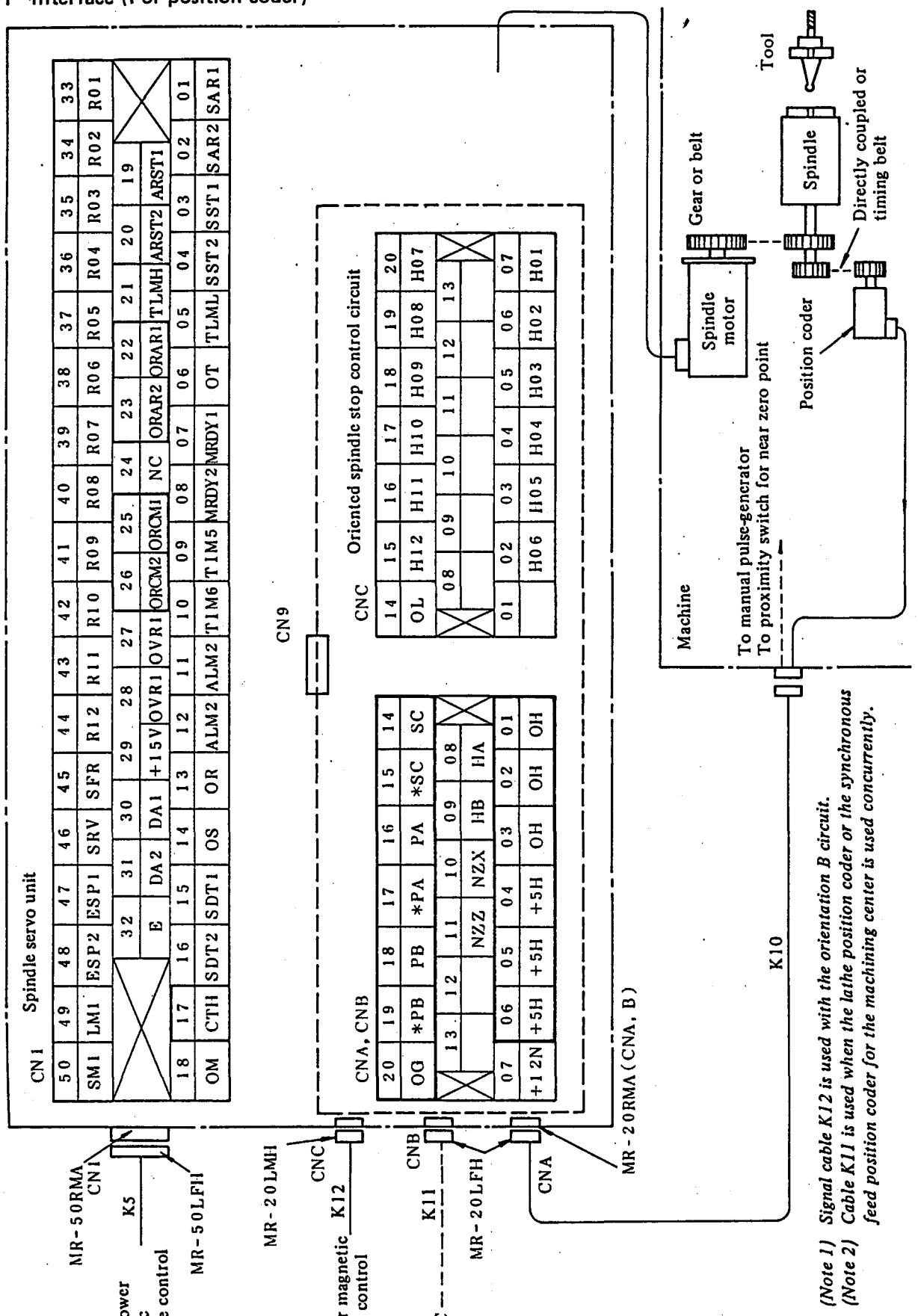
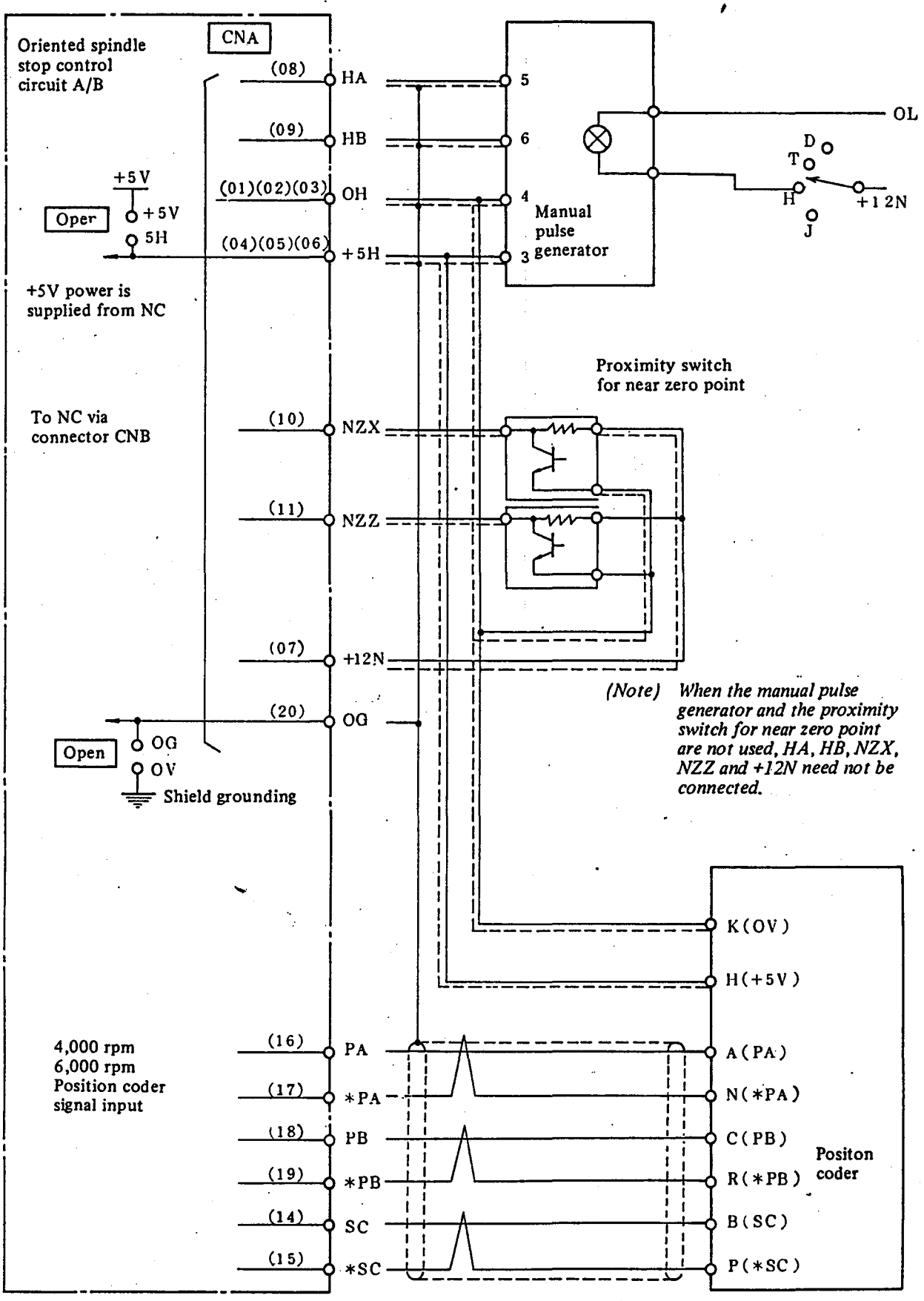
6. CONNECTION DIAGRAM

6.1 Interface (For position coder)

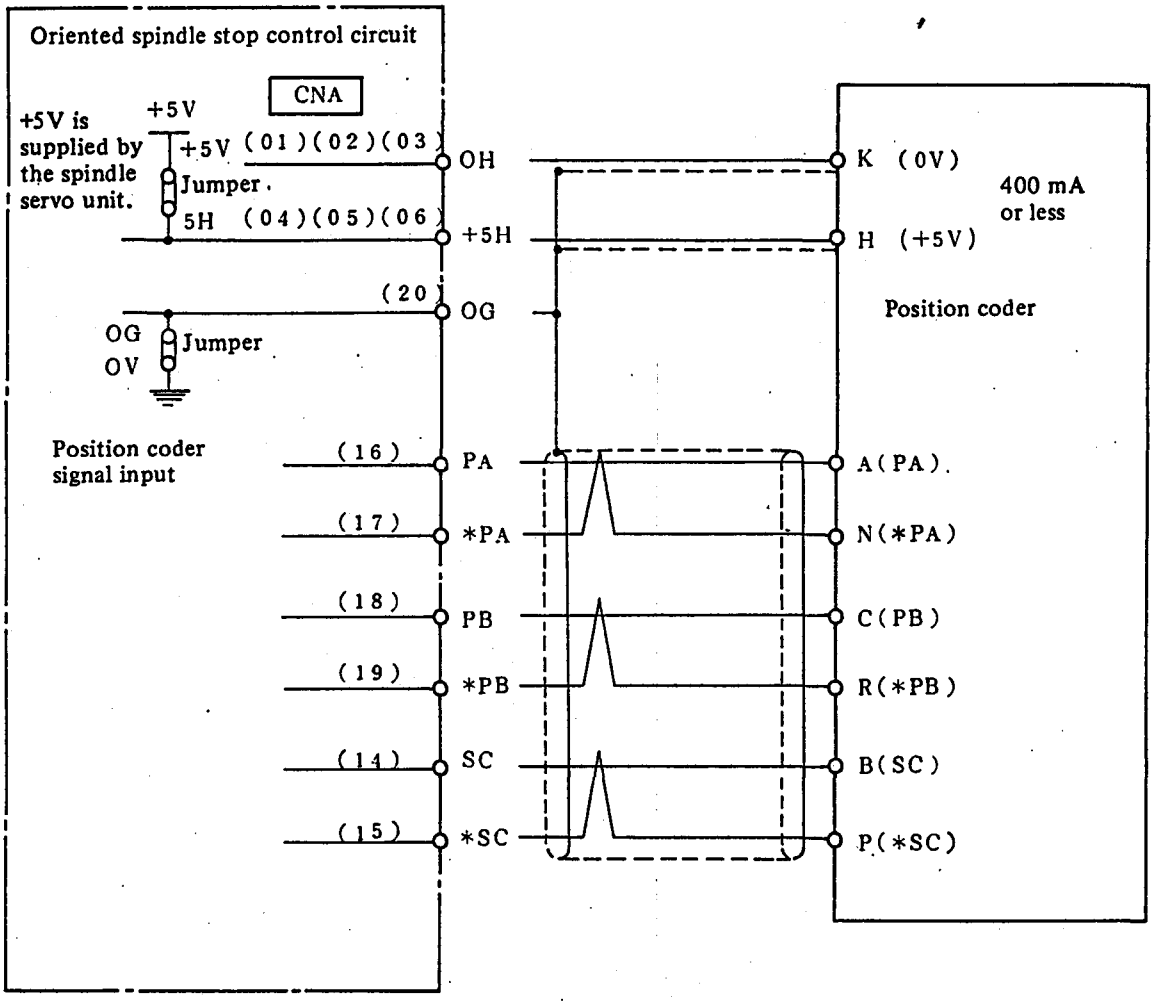


(Note 1) Signal cable K12 is used with the orientation B circuit.
(Note 2) Cable K11 is used when the lathe position coder or the synchronous feed position coder for the machining center is used concurrently.

6.1.1 Connection when synchronous feed position coder is concurrently used for lathes and machining centers

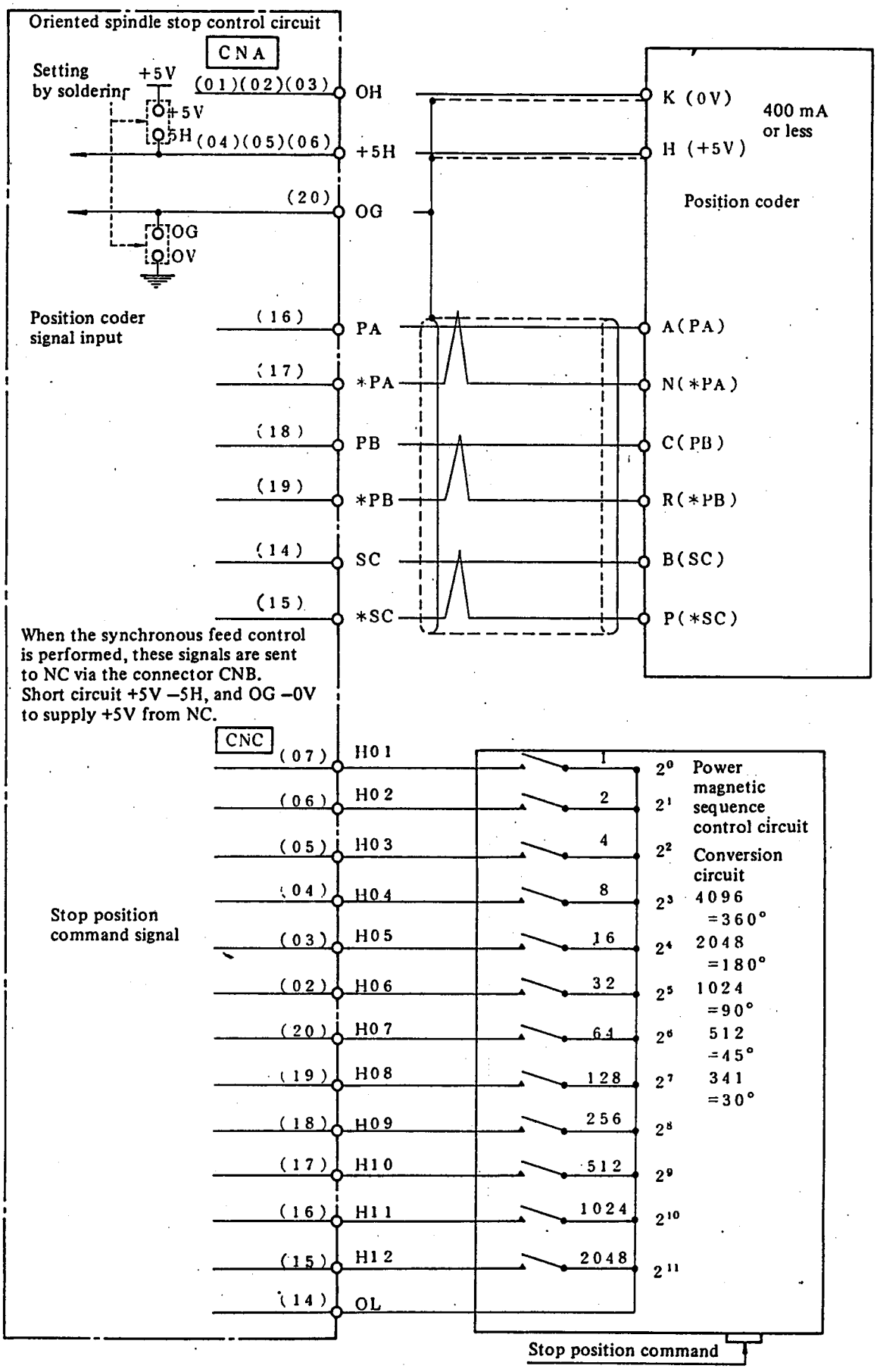


6.1.2 Connection for machining center spindle orientation only

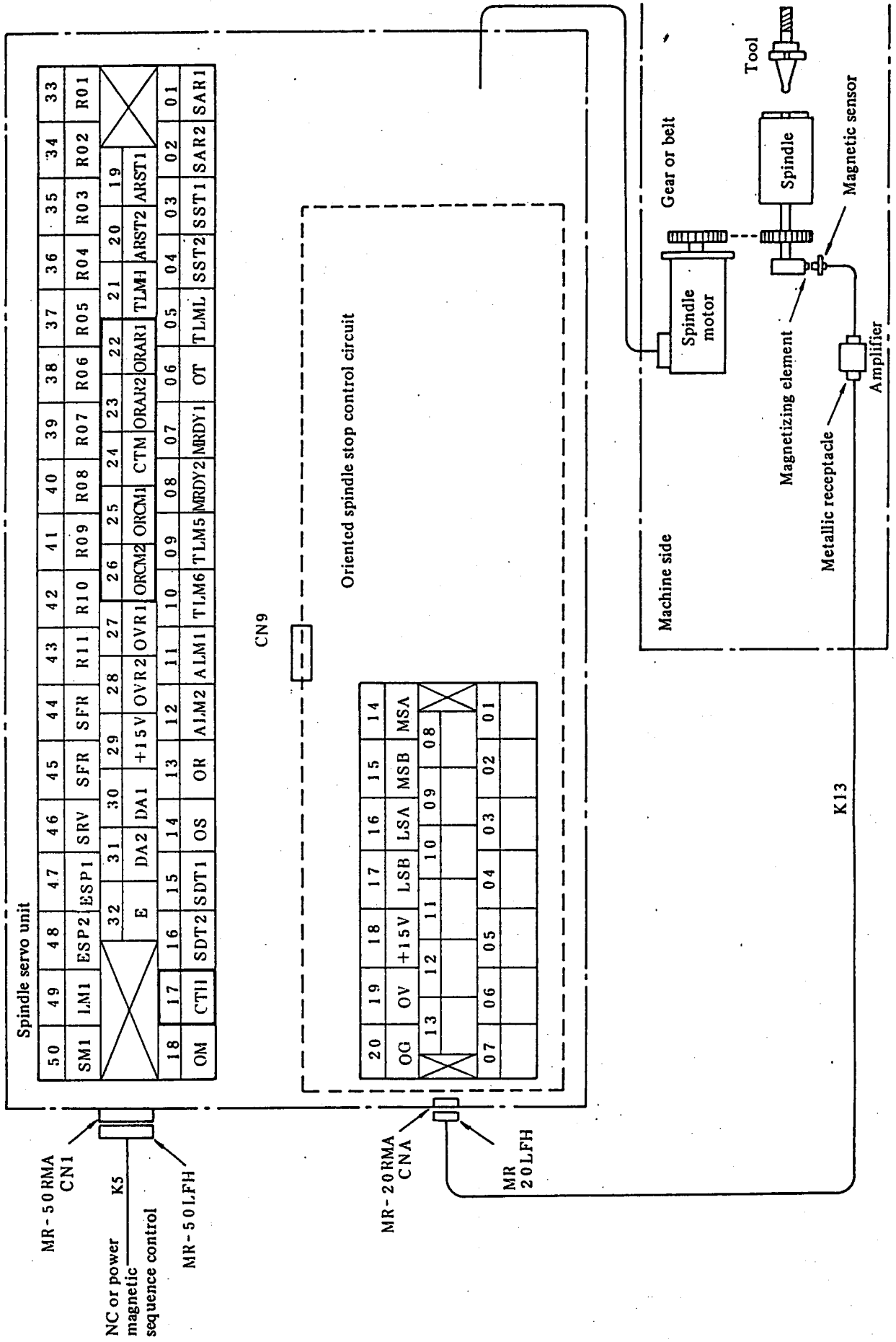


(Note) The cable between the servo unit and the position coder must not exceed 20 meters.

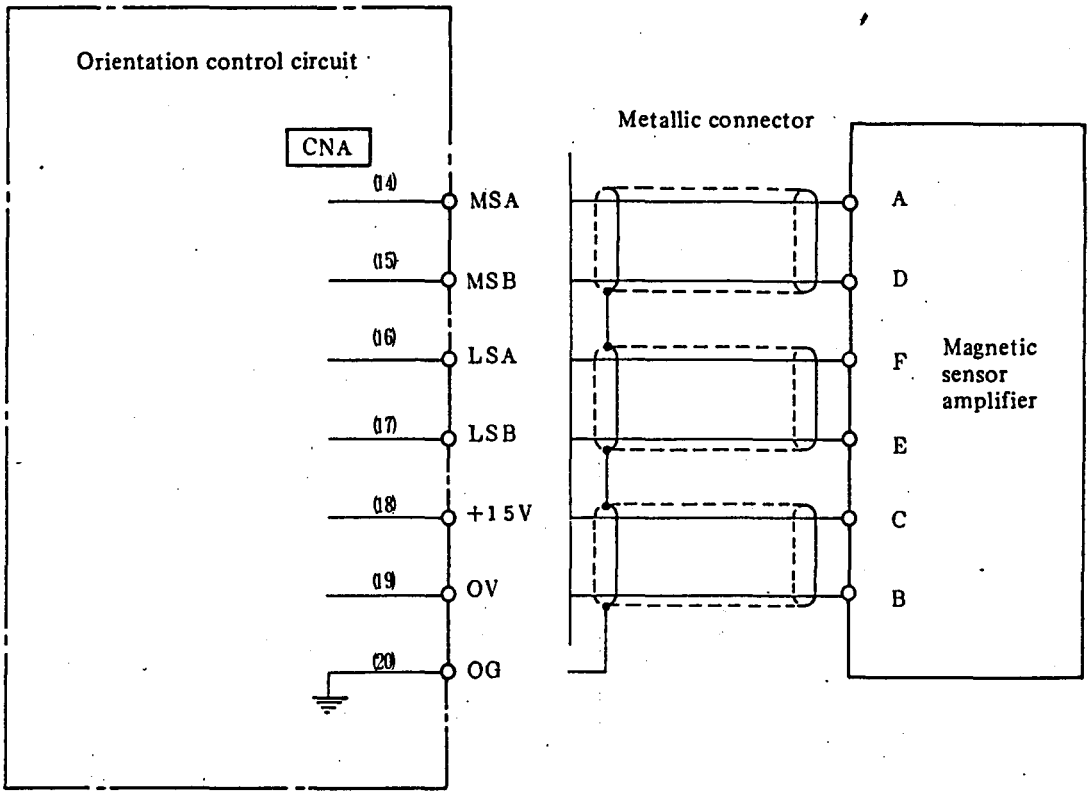
6.1.3 Stop position external setting connection



6.2 Interface (For magnetic sensor)



6.2.1 Magnetic sensor connection



(1) The cable between the servo unit and the magnetic sensor amplifier must not exceed 20 meters.

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7. SIGNALS

7.1 Description of Signals (In case of up to 2-stage speed change gear spindle)

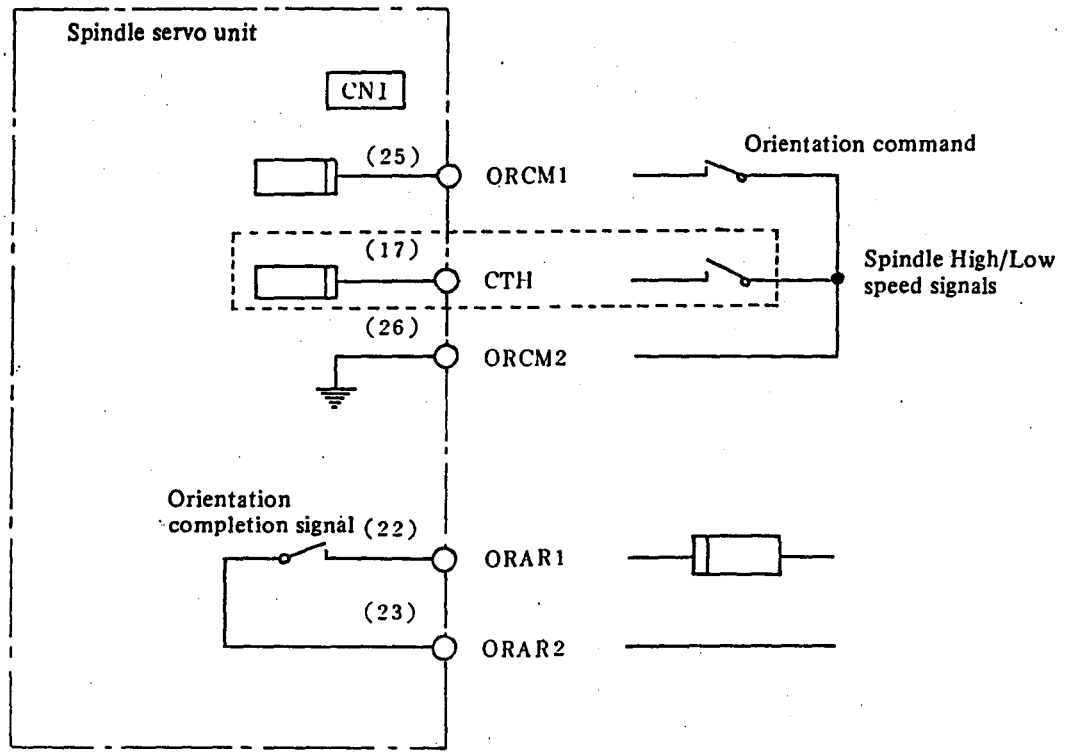


Fig. 7.1 Signals passed between the magnetic cabinet or NC and the spindle servo unit

7.1.1 Orientation command signal (ORCM1, 2)

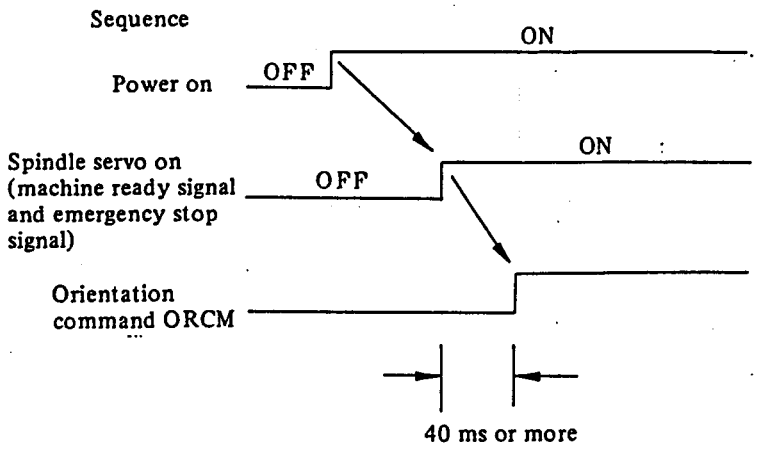
(1) This command signal is used to stop spindle movement to the preset position to allow tool change and workpiece loading/unloading.

(2) When this signal is input while the spindle is rotating, the rotation decelerates immediately and the spindle moves to the preset position.

(3) When the ORCM command is issued, turn off the spindle forward/reverse rotation command (SFR, SRV) for safety. In this status, the spindle will not rotate if ORCM1, 2 contact is opened during orientation.

(4) Turn off this signal by the tool change completion signal or workpiece loading/unloading completion signal.

(5) Always set the orientation command signal to OFF when turning on power.



(6) When an emergency stop occurs during orientation, the orientation command signal must be reset. Return the ATC arm to safe position so that it will not be damaged if the spindle or tool rotates when the power is turned on.

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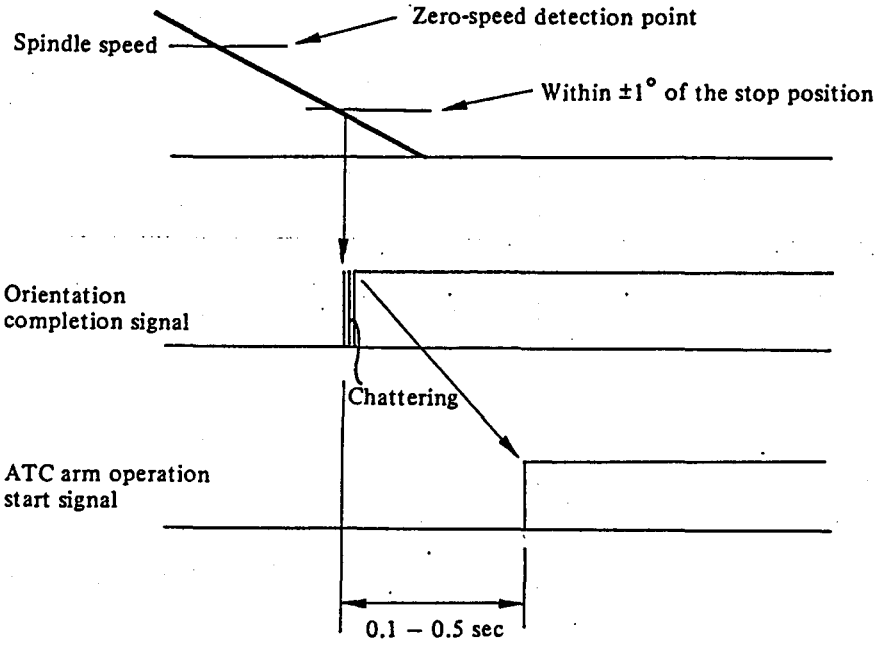
7.1.2 Orientation completion signal (ORAR1, 2)

(1) This signal is issued when the spindle moves within about ±1° of the preset position and stops. That is, this signal turns on under the following three conditions;
   (a) Signal ORCM is ON
   (b) Zero speed signal is ON
   (c) The spindle is in the vicinity of the preset position.

(2) If the orientation completion signal is not issued within a set period of time after the orientation command signal is input or if the orientation completion signal is issued when the orientation command signal has not been input, it is considered to be abnormal. So it should be detected by power magnetic sequence and an orientation alarm should be issued.

(3) Tool change or workpiece loading/unloading operations can be started only after the completion signal is on.

(4) The spindle orientation completion signal is issued when the spindle is within ±1° of the preset position. So it does not always indicate that the spindle has stopped completely. Some machine allow a very short operation time for the ATC arm to grip the spindle tool. In this case, start the ATC arm operation after 0.1 to 0.5 sec so that the arm will grip the tool when the spindle has stopped completely.



(5) This signal will turn off during a tool change if the spindle is pushed away from the preset position by an external force.
Design a power magnetic sequence so that the tool change operation is interrupted.
However, don't release orientation command, and if orientation completion signal is issued again, perform tool change.

(6) If the automatic tool change (ATC) structure is such that it may cause serious damage if a malfunction occurs, install a proximity switch to generate a verification signal when the ATC enters an area in which automatic tool change operation can be performed. In addition to this the power magnetic sequence should be designed to avoid such damage.

7.1.3 Spindle high/low speed signal (CTH)

(1) This signal is used to reduce the orientation time when two gears are used between the spindle and the spindle control.

(2) Increase the spindle motor speed in the low-speed gear by the high/low ratio so that the spindle orientation time is approximately the same for both gears.

(3) The contact is open when the high-speed gear has been selected, and closed when the low gear is in use.

(4) Both position coder and magnetic sensor methods are used for the machine with spindle change of 2-stage or less.

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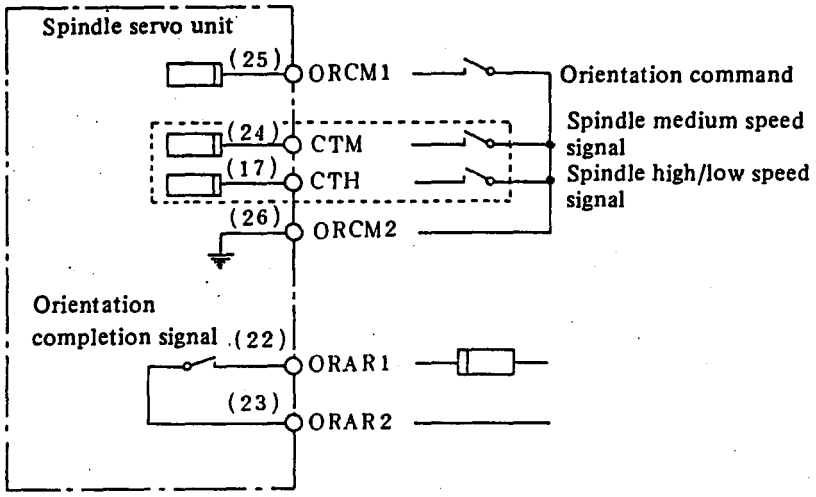
7.2 Description of Signals (In case of 3-stage speed change gear spindle)

The magnetic sensor system spindle orientation (A06B-6041-J121) comprises the following spindle medium speed signal.



Signals between power magnetic control (or NC) and spindle servo unit

7.2.1 Spindle medium speed signal (CTM)

(1) This signal is combined with spindle high speed/low speed signal (CTH) to reduce the spindle orientation time when the speed change gear stages between the spindle and the motor consist of 3 stages; high, medium, and low stages.

(2) Assume the following machine as an example.

Speed change gear	Spindle speed	Motor speed	Gear ratio
High gear	4500 rpm	4500 rpm	1
Medium gear	1500 rpm	4500 rpm	1/3
Low gear	500 rpm	4500 rpm	1/9

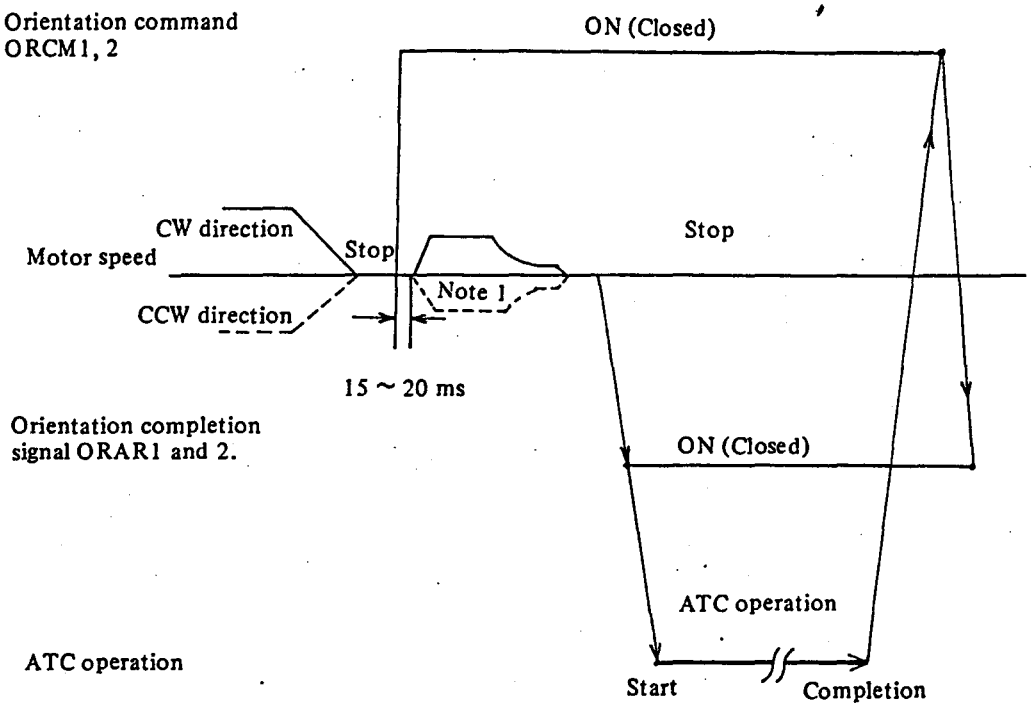
When the orientation command is given, the motor revolutions are set to 3 times in the medium gear and 9 times in the low gear during spindle orientation, if the motor revolutions are assumed as 1 in the high gear stage. In other words, the operation time is kept almost constant, irrespective of each speed gear stage, by keeping the spindle revolutions constant.

(3) Control the contact signals according to each speed change gear stage as follows.

Selection of spindle speed change gear stage	CTH signal contact	CTM signal contact
High speed gear stage	OFF (open)	OFF (open)
Medium speed gear stage	OFF (open)	ON (closed)
Low speed gear stage	ON (closed)	OFF (open)

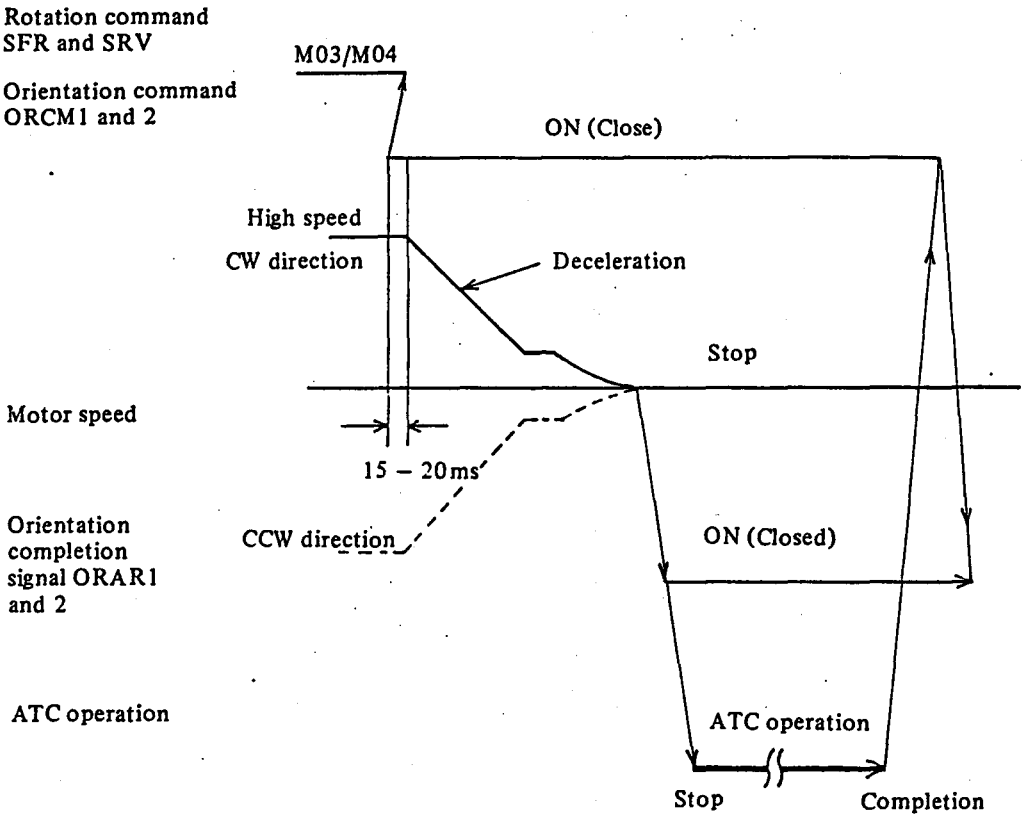
7.3 Sequences

7.3.1 Orientation command issued while stopping



Note 1: The spindle motor rotation direction can be changed by setting. In standard setting, the spindle motor will rotate in the direction the spindle motor was rotating before this orientation command signal was generated.

7.3.2 Orientation command issued during high-speed rotation



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7.4 Description of Signals (In case of stop position external setting type, position coder system) (In case of A06B-6041-J111)

7.4.1 Orientation command signals (H01 to H12-OL)

(1) These 12-bit contact signals are used to control the stop position.

(2) When these signals are all OFF (open), the spindle is stopped at the reference stop position (0°).
This reference stop position can be set by using 3 digital switches on PCB.

(3) Stop position command
The following stop positions (X°) are designated according to ON/OFF conditions of H01 to H12 contact signals with reference to the reference stop position (0°).

$$X(\text{degree}) = \frac{360}{4095}\left[\underset{(H01)}{1}+\underset{(H02)}{2}+\underset{(H03)}{4}+\underset{(H04)}{8}+\underset{(H05)}{16}+\underset{(H06)}{32}+\underset{(H07)}{64}\right.$$

$$\left.+\underset{(H08)}{128}+\underset{(H09)}{256}+\underset{(H10)}{512}+\underset{(H11)}{1024}+\underset{(H12)}{2048}\right]$$

The numbers corresponding to H01 to H12 become effective when contacts are turned on and those corresponding to H01 to H12 become zero when contacts are turned off.

(Example) H10 contact only is turned on.
360/4095 x 512 = 45°

In this case, the spindle stops at the position where it is turned clockwise by 45° as viewed from the reference stop position.

(4) The minimum shift unit is 360°/4095 = 0.088°.

(5) Positioning time
The positioning time is usually 1.4 to 20 sec when the speed change gear stages are 2 or less.
It becomes longer as the spindle inertia increases.

(6) Setting error
Since the position is set to integer times of the minimum shift unit (0.088°) in case of 30° indexing, 10° indexing, and 1° indexing, a setting error is produced.

Setting error Max. ±0.044°

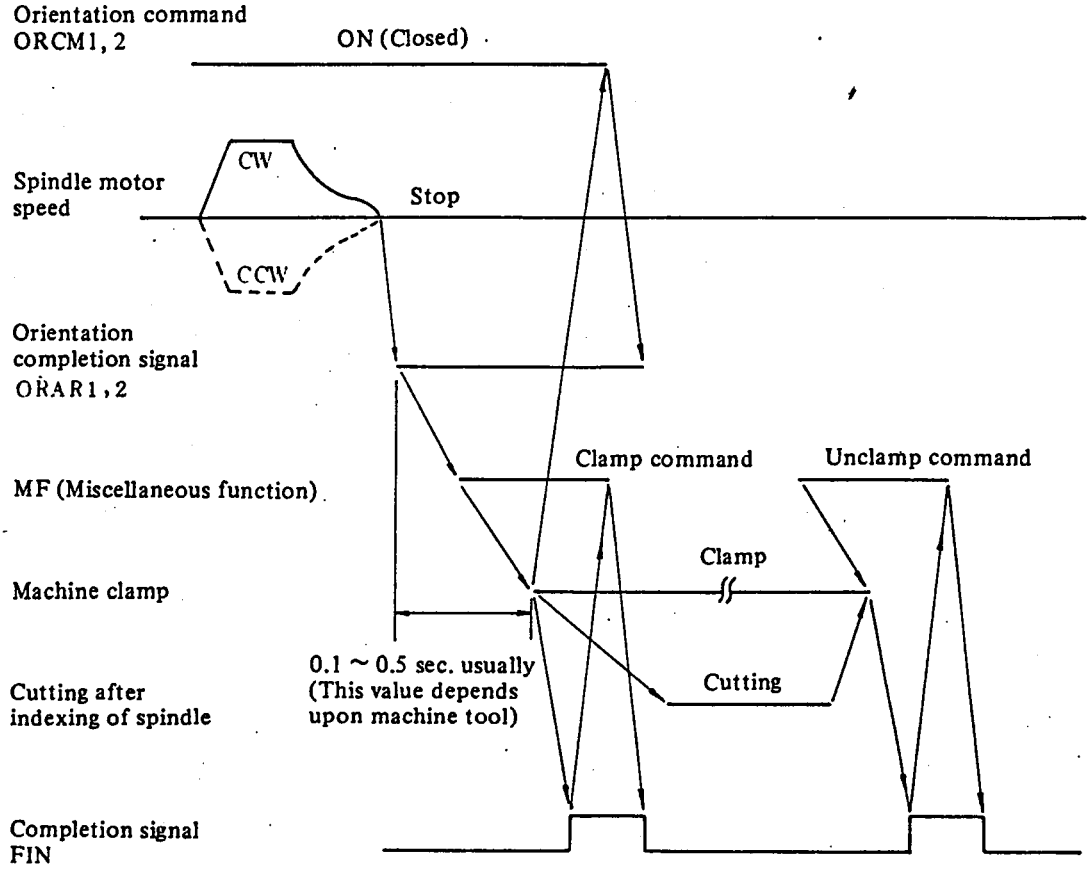
(Example)

30° indexing command	(Min.shift unit) x 341 = 29.974°	(Error - 0.026°)
10° indexing command	(Min.shift unit) x 114 = 10.020°	(Error + 0.020°)
1° indexing command	(Min.shift unit) x 11 = 0.967°	(Error - 0.033°)

To determine actual accuracy, a setting error is added to the repetition positioning accuracy (±0.2°)

(7) Necessity of mechanical clamp
A mechanical clamp is required for indexing of the spindle for cutting using this system.
Since the motor is displaced when load fluctuates during cutting, the spindle must be mechanically fixed, if cutting is made after indexing.

(8) Mechanical clamp timing



8. DETECTOR SPECIFICATIONS

8.1 Position Coder

Position coder signals PA, PB

The position coder emits square wave voltage signals in numbers proportionate to the spindle rotation angle, and must be attached to the spindle one to one gear ratio for fixed position stop usage.

(1) Kind and specification

A86L-0027-0001#□0□

- Mounting plate
  - 1: With mounting plate □160
  - 2: With mounting plate □68
  - 3: Without mounting plate
- Max. speed
  - 1: 4000 rpm
  - 0: 6000 rpm
  - 2: 8000 rpm

The following lists the position coder electrical and mechanical specifications.

(2) Electrical specifications

(a) Number of square waves/rotation

Channel	Signal
1 ch	1,024 pulses/rotation (A, B phase)
2 ch	1 pulse/rotation (C phase)

(b) Power supply

Voltage	Current
+5V, + 5%, -10%	400 mA or less

(c) Working ambient temperature range
0 to 50°C

(d) Output terminal
. Cannon connector MS3102A20-29P} Position coder side
. Cannon connector MS3106B20-29S} Cable side
. Cable damp MS3057-12A
The cable side cannon connector and the cable clamp are provided with the position coder.

(3) Mechanical specifications

(a) Input axis inertia : 1×10^{-3} kg.cm.s^2 or less

(b) Input axis torque at start : 1,000 g.cm or less

(c) Input axis load tolerance

	When stopped	During operation
Thrust load	10 kg or less	5 kg or less
Radial load	20 kg or less	10 kg or less

(d) Structure
Dust-proof and oil-proof structure. (IP43)

(e) Weight : About 1 kg (Without mounting plate)

(4) Storage
Store the position coder at a place free from moisture.
Also when transferring the product, always put it in a package and do not drop or throw down it.

(5) Notes on installation

(a) If there is baacklash in the interface between the position coder and the spindle, the stop position will vary. Therefore, the position coder should be linked to the spindle so as to eliminate backlash. If the position coder is installed with a timing belt or a gear, check periodically for backlash due to mechanical wear.

(b) Deviation of the center of axis between the body of position coder and the shaft shall be 0.02 mm or less.

(c) Since the position coder uses a glass plate, do not apply a large mechanical shock.
Also, to prevent water or oil intrude from the cannon connector, mount the cannon connector downward.

(d) The position coder shall be apart from the magnetic cabinet more than 50 cm.
Apart from a cable in which a large instantaneous current flows when the motor turns ON and OFF more than 30 cm.
Especially, when a machine such as electric discharge machine, electric welding machine which generates a radiation noise is near the position coder, make an electric shelding.

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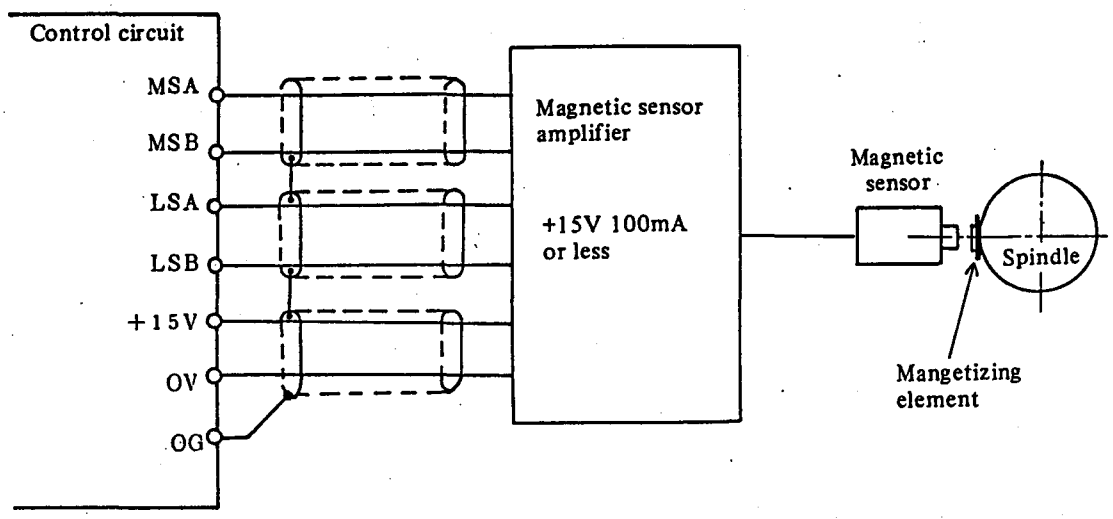
8.2 Magnetic Sensor

The magnetic sensor makes sure that the spindle stops at the specified position by attaching a magnetizing element to the spindle rotation part and installing a magnetic sensor at the stop position.

The magnetic sensor emits analog signals corresponding to the position of the magnetizing element attached to the spindle.



A shielded wire should be used. Shield insulation must be connected to OG. The following shows the magnetic sensor electrical specifications and how to attach the sensor.

(1) Electrical specifications

(a) Number of waves per rotation

Channel	Number of waves per rotation
1 ch	1/rotation (MSA-MSB)
2 ch	1/rotation (LSA-LSB)

(b) Power supply

+15V, +10%, -10%, 100mA or less

(c) Maximum number of rotation (Magnetizing element) : 8,000 rpm

(d) Working ambient temperature range (Magnetic sensor) : 0 to 50°C

(e) Output terminal
Metallic receptacle type. Receptacles for the cable of the magnetic sensor amplifier are provided.

(f) Output terminal layout (Magnetic sensor amplifier)

Terminal	Contents
A	MSA
B	0V
C	+15V
D	MSB
E	LSB
F	LSA

(g) Weight of magnetizing element : 33 g $\pm$ 1.5 g

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(2) Magnetic sensor mounting method

The followings show magnetic sensor mounting examples.

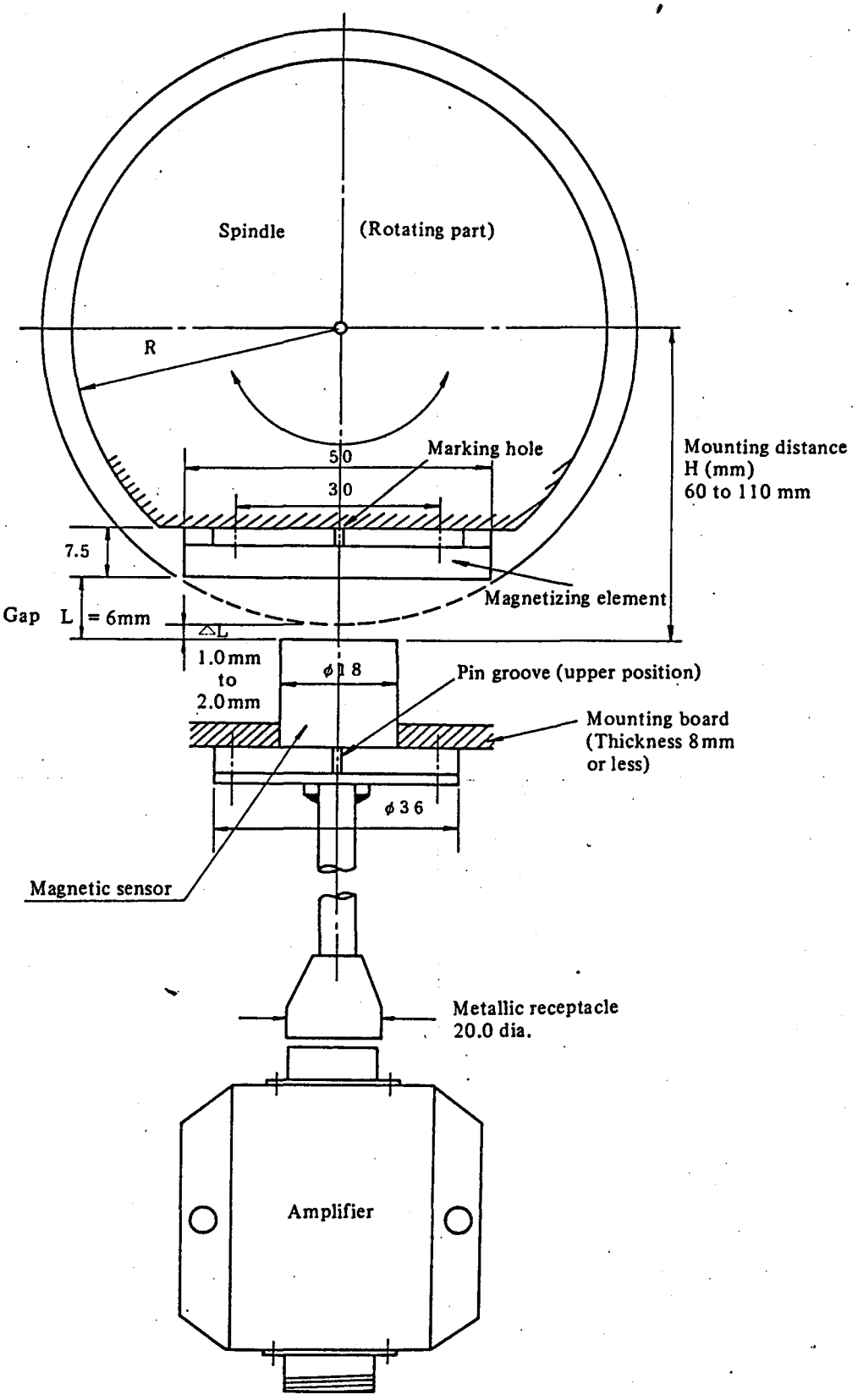
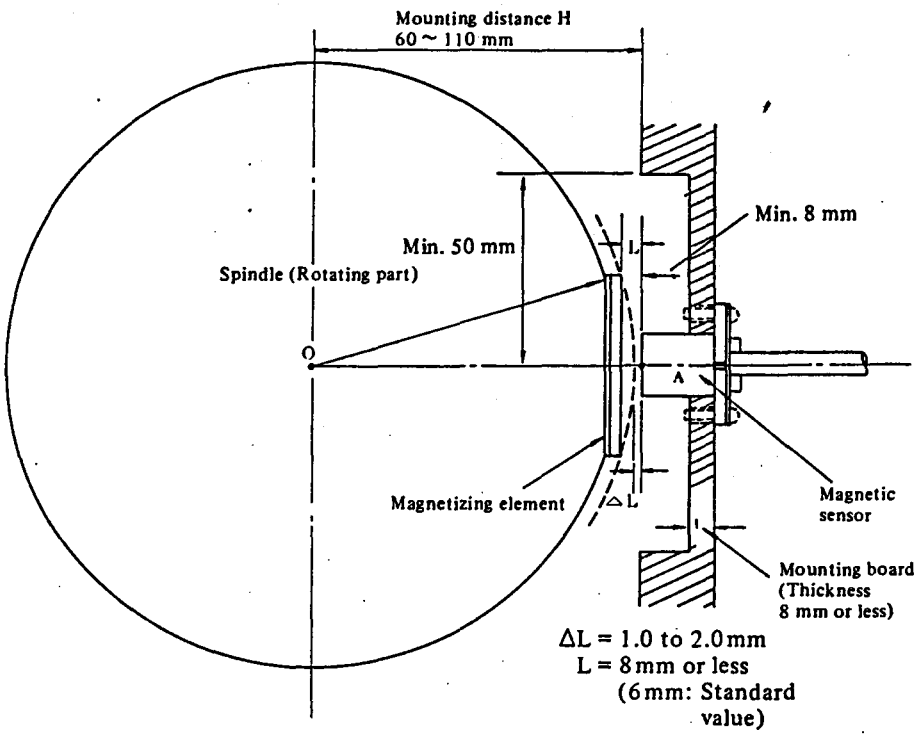


Fig. 8.2 (a) Magnetic sensor mounting example (1)



Note) Gap between mounting board and magnetizing element is 8 mm or more.

Fig. 8.2 (b) Magnetic sensor mounting example (2) (When mounted on cylinder)

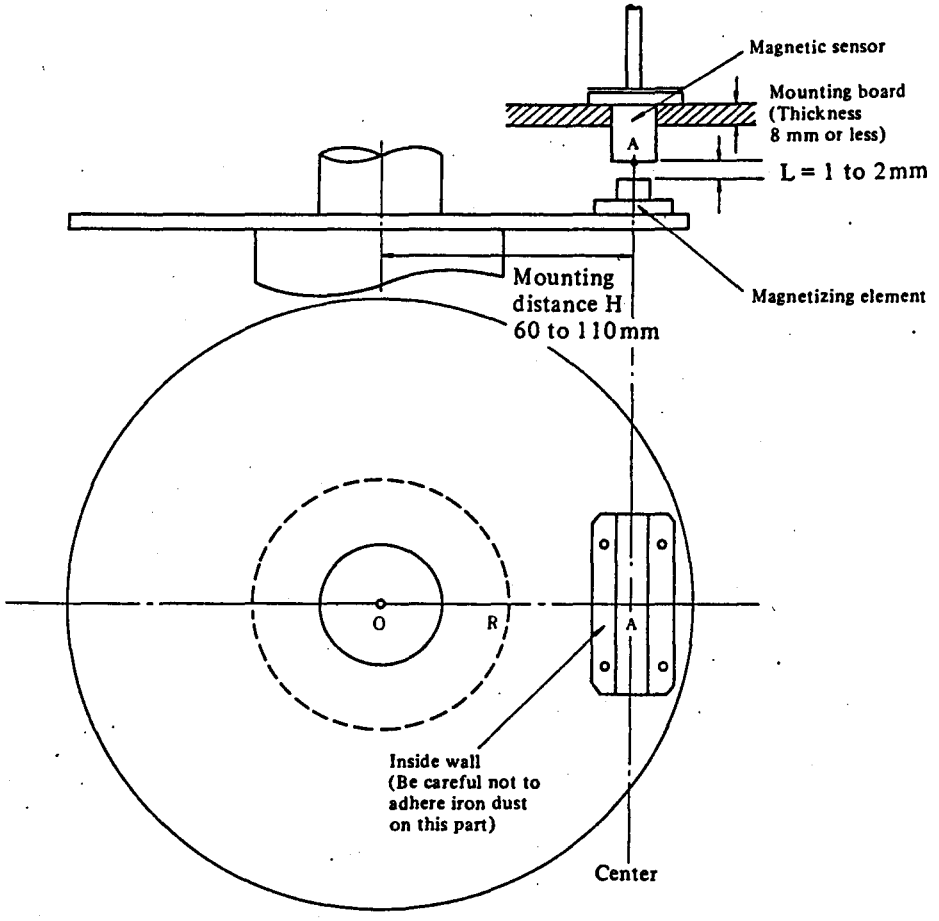


Fig. 8.2 (c) Magnetic sensor mounting example (3) (When mounted on disk)

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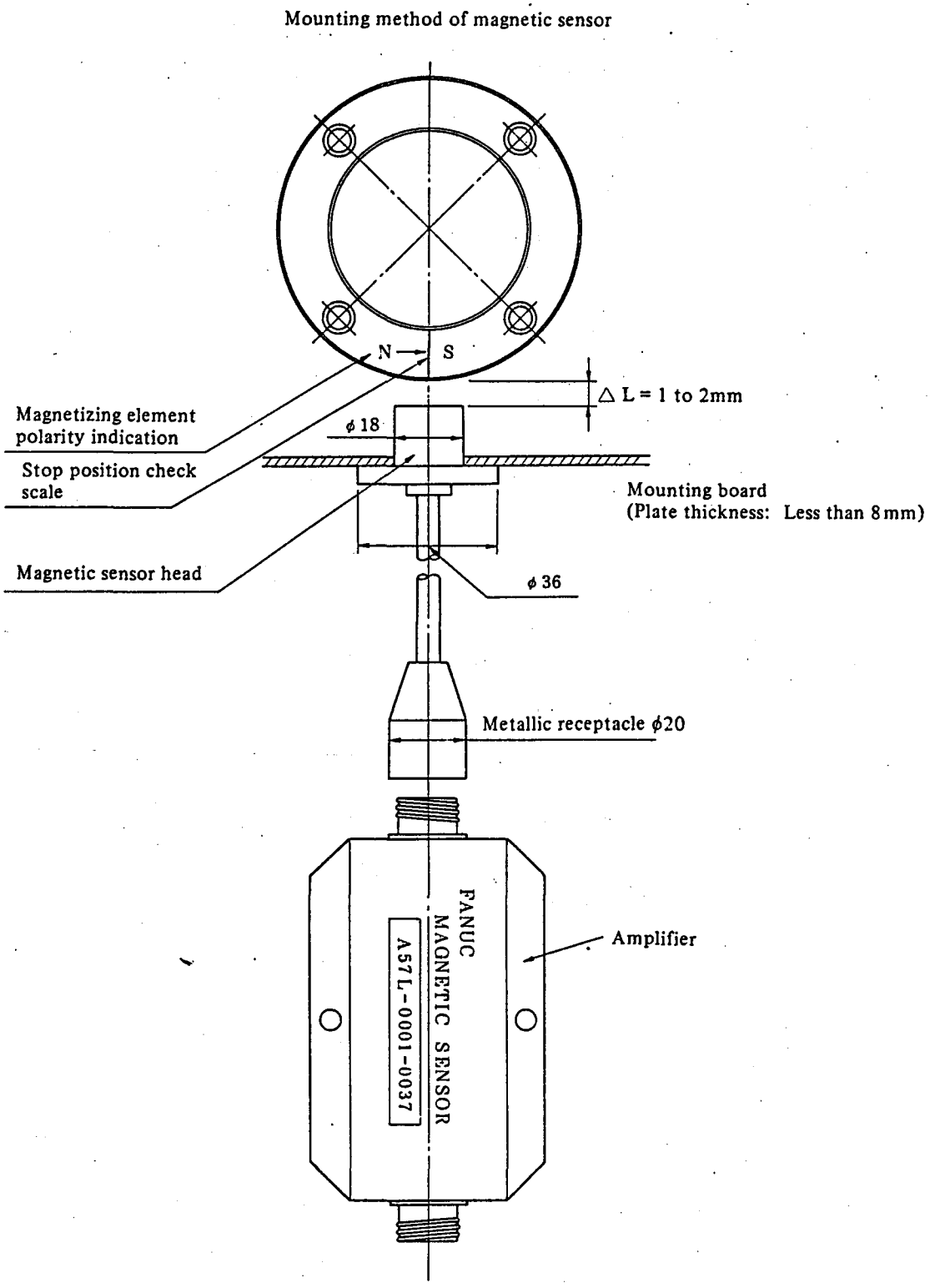


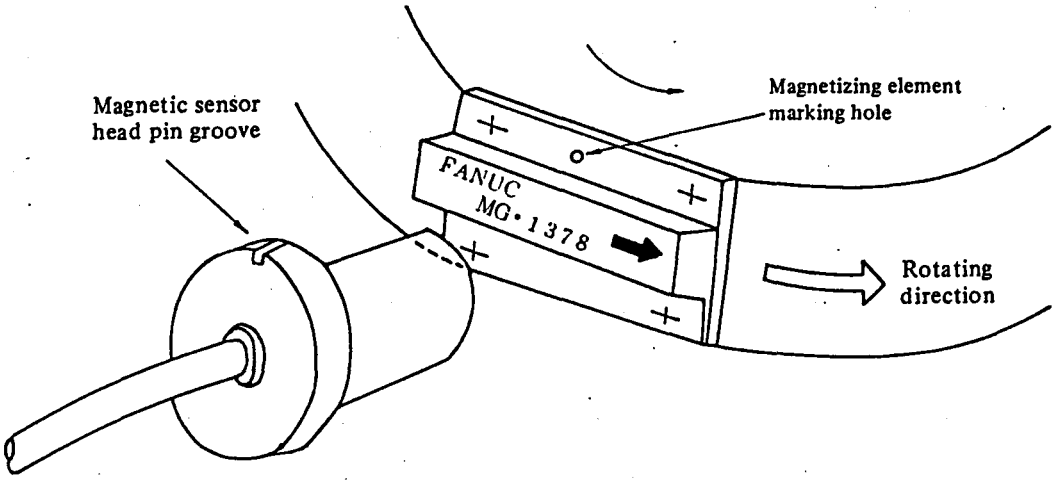
Fig. 8.2 (d) Magnetic sensor Q, R, S and T mounting example (4)

(a) Magnetic sensor head pin groove

When a magnetizing element is mounted to the spindle of a machine tool, the polarity is produced between the magnetic element and the magnetic sensor, and the mounting direction differs according to the composition of the spindle (belt transmission, gear coupling, etc.)

For the connection shown in the magnetic sensor interface, arrange the relative positions of the magnetizing element marking hole and pin groove of the magnetic sensor as illustrated below.

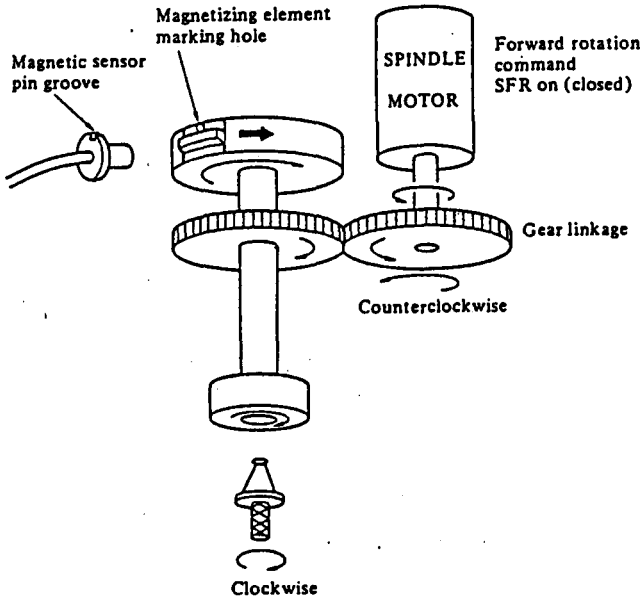
If this mounting is wrong, the spindle motor will repeatedly turn in the forward and reverse directions without being stopped.



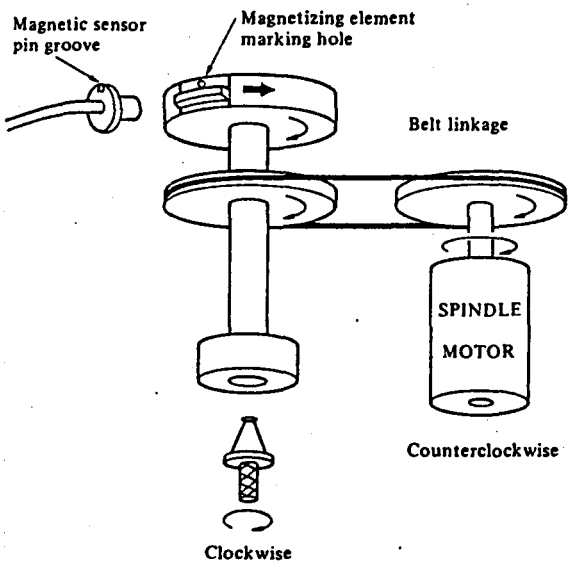
The spindle motor rotates counterclockwise (CCW) as viewed from the motor shaft by forward rotation command (signal SFR contact ON (closed), speed command VCMD (positive voltage).

Arrange the magnetizing element marking hole and the magnetic sensor pin hole face to face, so that the spindle motor rotates in the rotating direction specified in the figure.

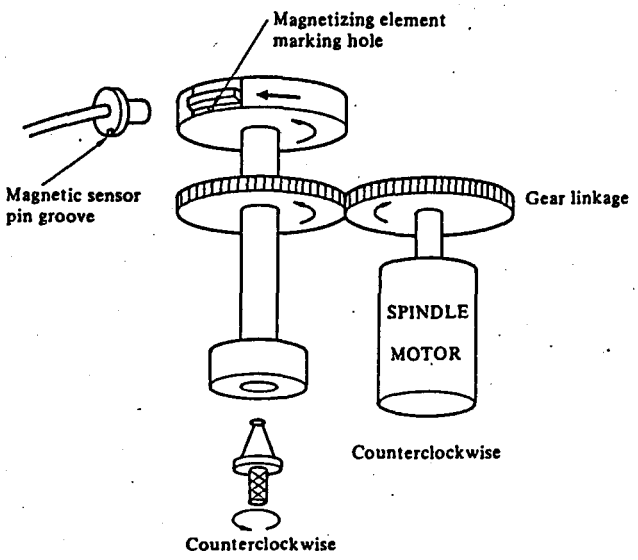
(Installation example 1)



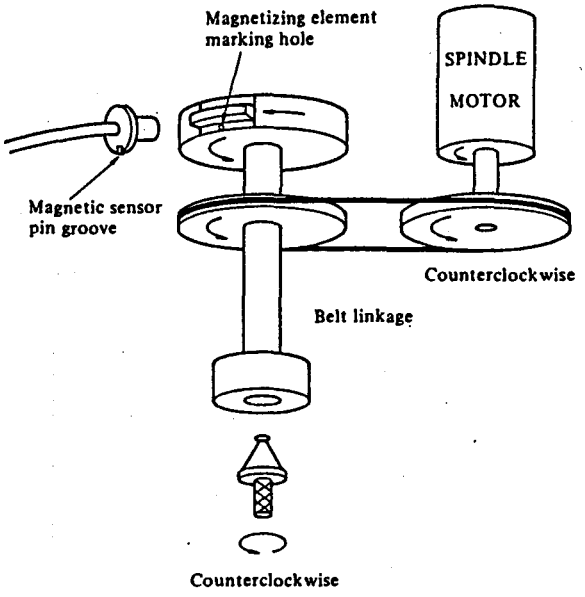
(Installation example 2)



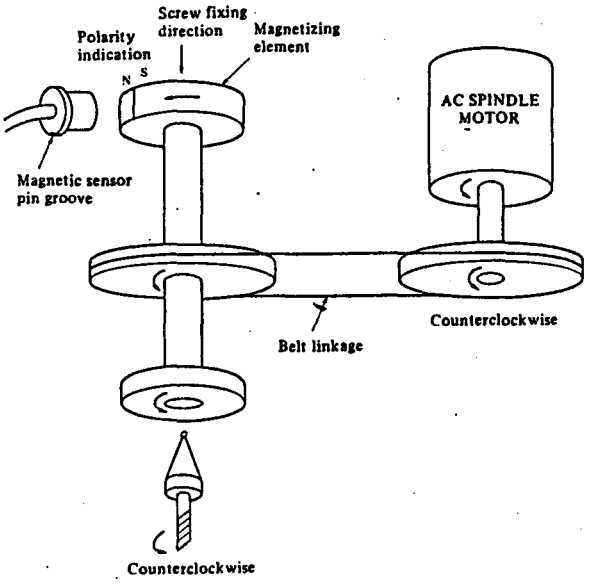
(Installation example 3)



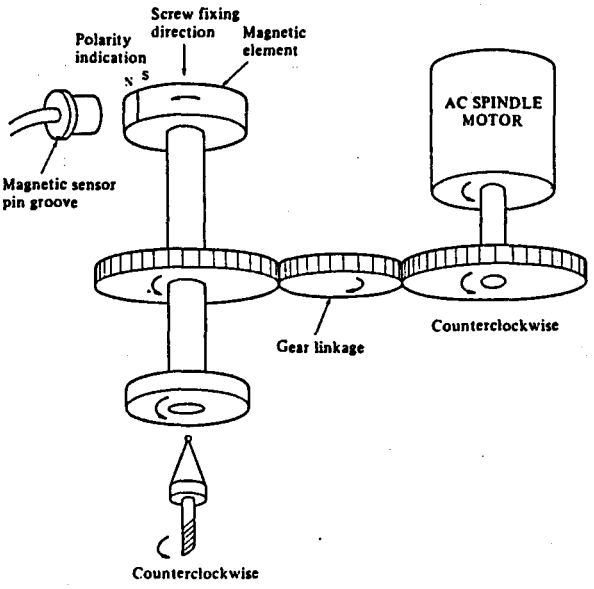
(Installation example 4)



(Installation example 5)



(Installation example 6)



(3) Cautions on installation

(a) Since the magnetizing element is mounted onto the rotating body of the spindle, be careful not to allow the magnetizing element to be detached by means of centrifugal force.
Limit the circumferential speed of the magnetizing element to lower than 3770 m/min.
(Take the depth of the screw holes of M4 x 4 into consideration)

(b) Mount the sensor amplifier as close to the sensor as possible (cable length 500 mm)

(c) Don't allow a magnetic field producing substance to be close to the magnetic sensor, otherwise the orientation accuracy fluctuates. Don't arrange any solenoid in the vicinity of the magnetizing element, in particular.

(d) Be careful not to attach iron powder and other substances sensible to the magnetism to the magnetizing element.

(e) If the spindle is provided with a built-in electromagnetic clutch for HIGH/LOW selection and other parts which may compose a magnetic loop, mount the magnetizing element on a non-magnetic substance (aluminum, etc.) without fail.
The magnetic flux of the magnetizing element is zero at the stop position. However, if it is affected by a magnetic loop of the electromagnetic clutch, the magnetic flux is added normally when the magnetic clutch is turned on. It should be carefully noted that if the clutch is turned on and off during the stop at the fixed position, the stop position changes due to a change of the steady-state magnetic flux.

(f) Don't contaminate the magnetic sensor cable, sensor amplifier, and connecting cables with lubrication oil and cutting oil.

(g) Mount the magnetizing element of the magnetic sensor onto the spindle directly.
If the magnetizing element is mounted by gear coupling or spindle coupling, the repetition orientation accuracy may fluctuate by a backlash quantity between the spindle and the magnetizing element.
Examine this accuracy by taking a change due to a secular change caused by mechanical abrasion, etc. into consideration.

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9. ORDER SPECIFICATION

(1) Orientation circuit

Name	Specification No.	Remarks (PCB No.)
Orientation A (Position coder type, 2-stage speed change gear spindle)	A06B-6041-J110	A20B-0008-0240
Orientation B (Position coder type, 2-stage speed change gear spindle)	A06B-6041-J111	A20B-0008-0241
Orientation C (Magnetic sensor type, 2-stage speed change gear spindle spindle speed: less than 8,000rpm)	A06B-6041-J120	A20B-0008-0030
Orientation D (Magnetic sensor type, 3-stage speed change gear spindle spindle speed: less than 8,000rpm)	A06B-6041-J121	A20B-0009-0520
Orientation E (Position coder type, 4-stage speed change gear spindle)	A06B-6041-J130	A20B-1000-0460
Orientation F (Position coder type, 4-stage speed change gear spindle)	A06B-6041-J131	A20B-1000-0461
Orientation G (Magnetic sensor type, 2-stage speed change gear spindle spindle speed: less than 12,000 rpm)	A06B-6041-J122	A20B-0008-0031
Orientation H (Magnetic sensor type, 2-stage speed change gear spindle spindle speed: less than 20,000rpm)	A06B-6041-J123	A20B-0008-0031 +A06B-6044-J948

(2) Magnetic sensor

Name	Specification No.	Remarks
Magnetic sensor N Spindle revolutions 12,000rpm or lower	A57L-0001-0037/N	This specification No. is also applicable when /N is not specified.
Magnetic sensor P Spindle revolutions 12,000rpm or lower	A57L-0001-0037/P	Compact type
Magnetic sensor Q Spindle revolutions 20,000rpm or lower	A57L-0001-0037/Q	ϕ40 ID cylindrical high-speed type
Magnetic sensor R Spindle revolutions 20,000rpm or lower	A57L-0001-0037/R	ϕ50 ID cylindrical high-speed type
Magnetic sensor S Spindle revolutions 15,000rpm or lower	A57L-0001-0037/S	ϕ60 ID cylindrical high-speed type
Magnetic sensor T Spindle revolutions 15,000rpm or lower	A57L-0001-0037/T	ϕ70 ID cylindrical high-speed type

(3) Position coder

Name	Specification No.	Remarks
Position coder C (4,000 rpm)	A86L-0027-0001#101	Parallel transimission type with 160 flange
Position coder D (6,000 rpm)	A86L-0027-0001#001	Parallel transimission type with 160 flange
Position coder E (4,000 rpm)	A86L-0027-0001#103	Parallel transmission type without frange
Position coder F (6,000 rpm)	A86L-0027-0001#003	Parallel transmission type without frange

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IV. VELOCITY GAIN SELECTOR CIRCUIT

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1. GENERAL

The velocity gain selector circuit (option) controls the velocity loop gain inside the AC spindle servo unit by selecting the gain according to an external signal.

For the purpose of improving the accuracy and stability in orienting the spindle with enhanced velocity loop gain of the AC spindle servo and also reducing the orientation time according to contact signals, this option circuit is employed when the orientation control of the spindle is executed using the position control circuit other than that of the AC spindle servo unit, while receiving a position feedback signal from the position coder directly coupled to the spindle of an NC machine tool.

This circuit is available for spindle position control at NC control circuit

2. FEATURES

(1) Stable control
The spindle orientation control is stable with reduced orientation time and higher orientation accuracy, even if the position control circuit other than the AC spindle servo unit option is used.

(2) Simple control
The spindle orientation is easily controllable using a contact signal only.

3. CONFIGURATION

The velocity gain selector circuit option is composed as shown in the following figure.

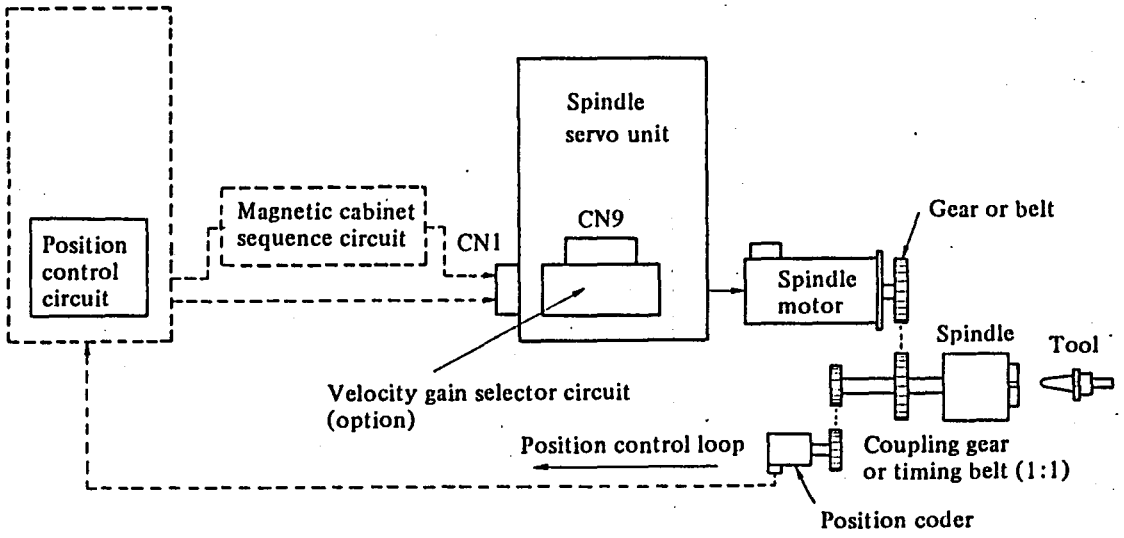
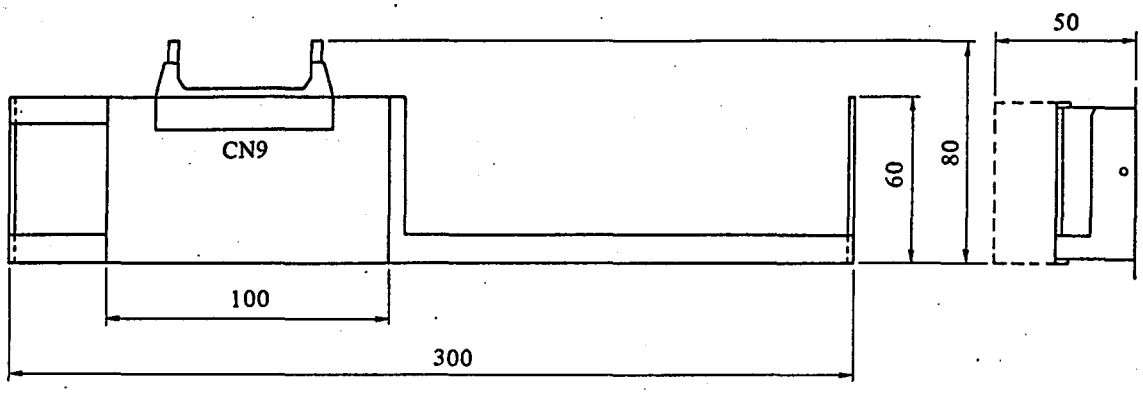


Fig. 3.1

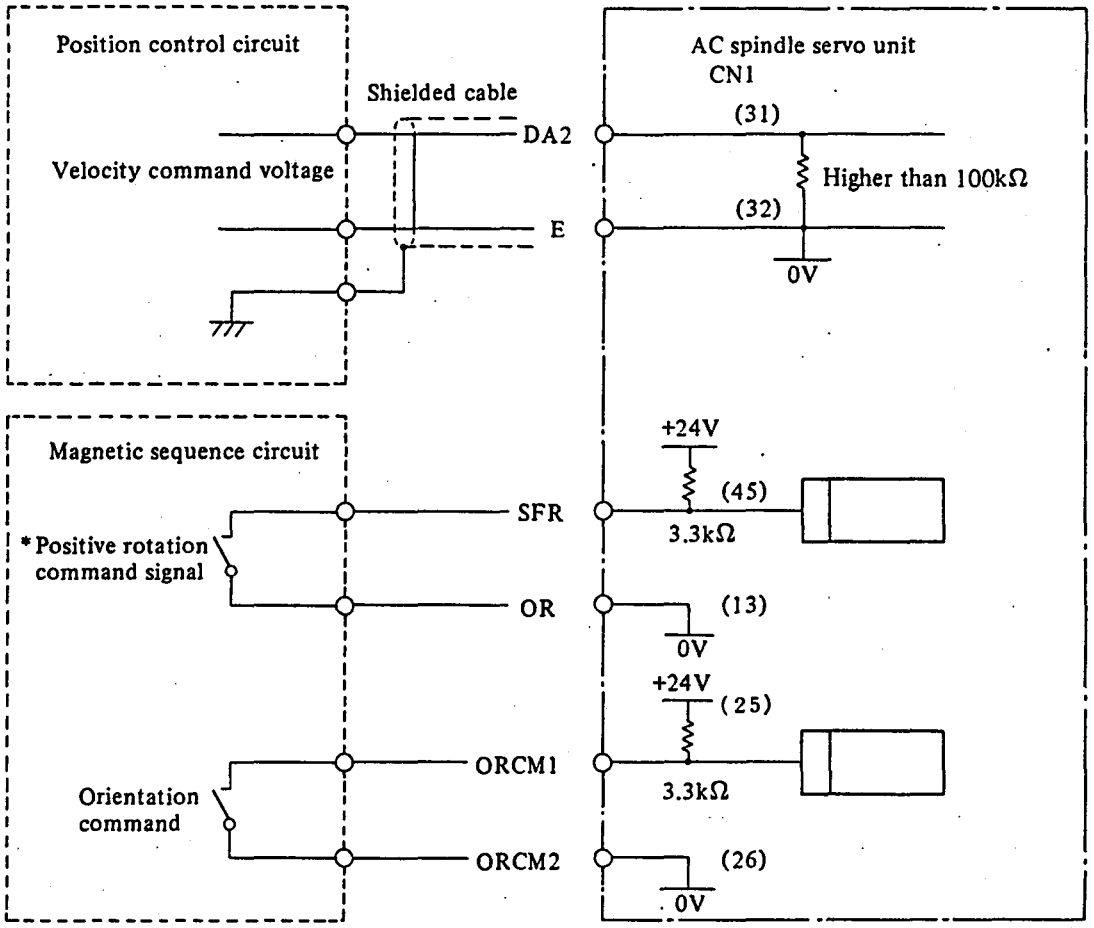
4. EXTERNAL VIEWS

4.1 External View of Velocity Gain Selector Circuit

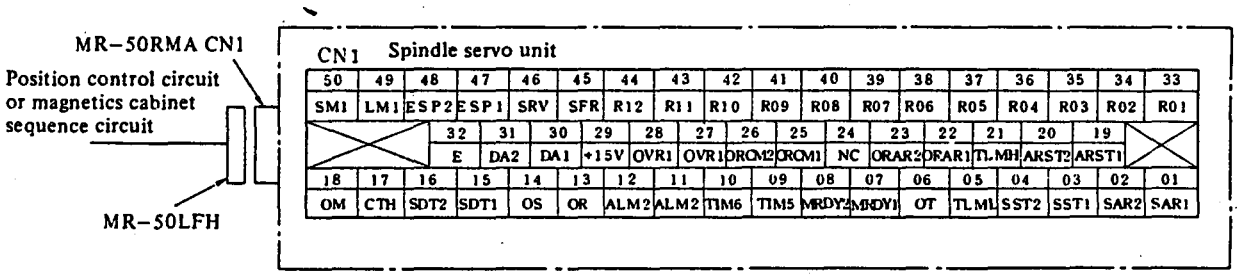


5. INTERFACE

The functions of these three signals differ from those described in section II-7. For details, see "6. Details of signals".



* Negative rotation command signal is not used.



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6. DETAILS OF SIGNALS

No.	Signal name	Signal contents	Type	Significant level	Send direction	Details of contents
1	DA2-E	Velocity command voltage	Analog voltage	0 to ±10V	Position control circuit → Spindle	(1) Either + or - analog velocity command voltage is externally inputtable. (2) ±10V correspond to the maximum velocity of the spindle motor. The relation between the specified voltage and the rotation speed is as shown in Fig. 6.1. (3) The input impedance is higher than 100kΩ.
2	SFR-OS	Positive rotation command signal	Contact	ON (closed)	Magnetics cabinet sequence circuit → Spindle	(1) The spindle motor rotates counterclockwise (CCW) as viewed from the shaft side when the velocity command voltage is positive (+) with the contact turned on (closed). The spindle motor rotates clockwise (CW) when the velocity command voltage is negative (-).
3	ORCM1-ORCM2	Orientation command	Contact	ON (closed)	Magnetics cabinet sequence circuit → Spindle	(1) This signal does not function as the spindle orientation function, but it is used when selectively enhancing the velocity loop gain inside the AC spindle servo from the external unit. (2) When this signal is applied, the velocity command voltage becomes effective, and the motor becomes controllable. (3) When this signal is applied, the positive rotation command signal becomes ineffective. (4) Turn off (open) the positive rotation command signal for a safety purpose when this signal is being applied. By this operation, the spindle does not start rotating, even if the ORCM1, 2 contacts should have been turned off (open) during orientation or the orientation is cancelled. (5) The velocity loop gain is selected when this signal is turned on (closed), and the motor revolutions have been reduced to less than about 1/100 of the maximum revolutions. (6) When this signal is applied, the light-emitting diode (LED) lights.

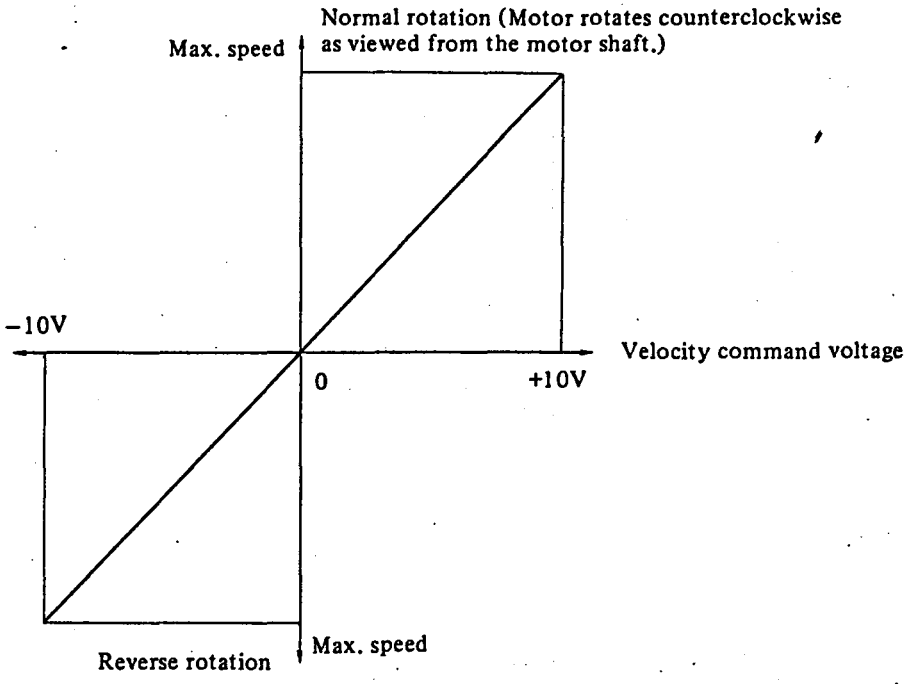

Fig. 6 Relation between Command Voltage and Speed

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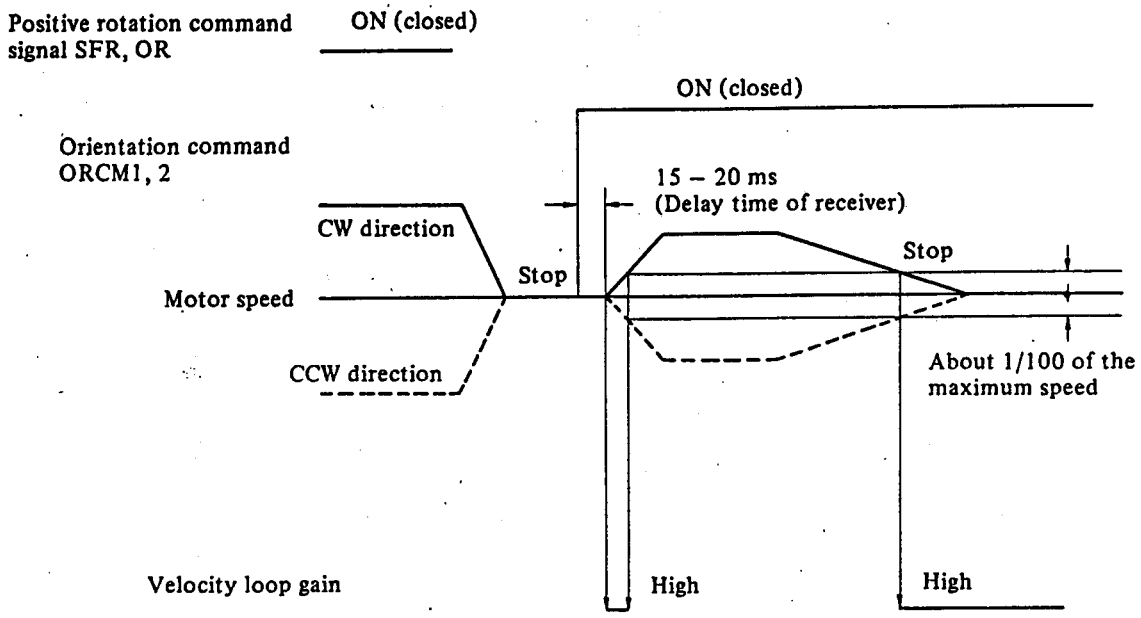
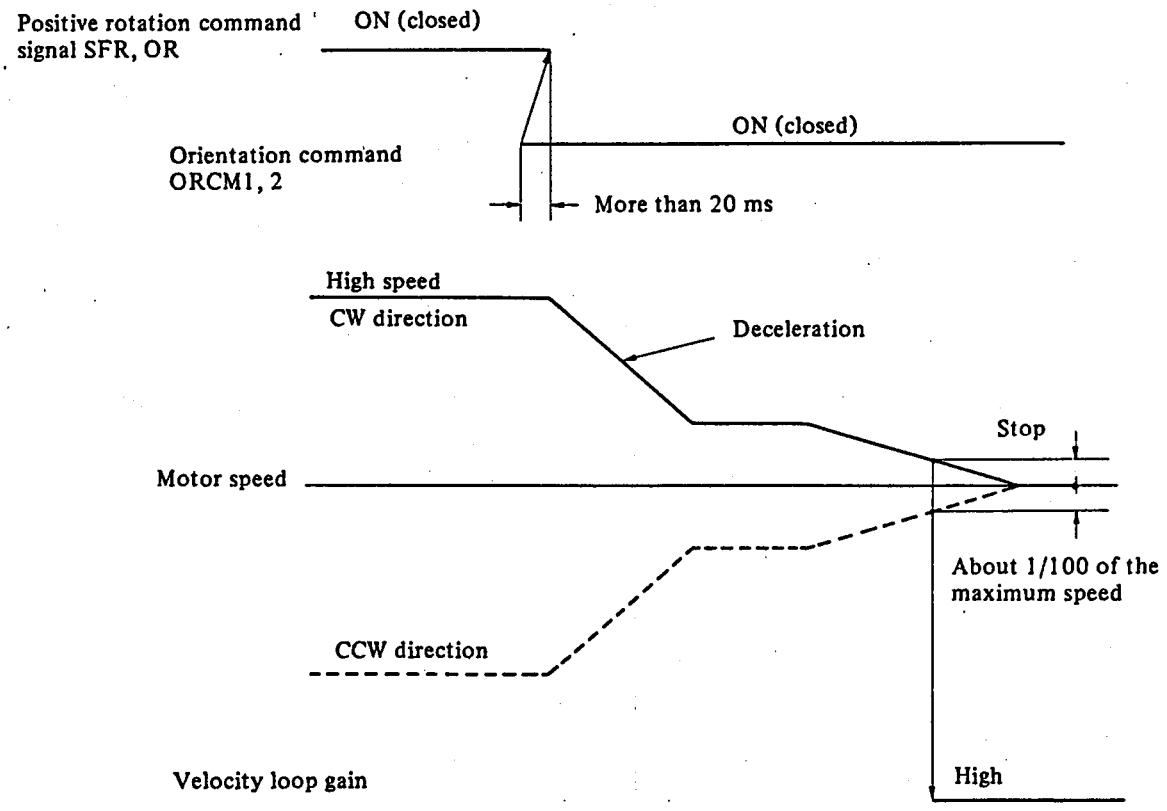
7. SEQUENCE

7.1 Sequence During Stop



7.2 Sequence During High Speed Rotation



8. ORDER SPECIFICATION

This option comprises the following type according to the AC spindle servo unit.

Name	Specification number
Velocity gain selector circuit	A06B-6044-J701

This option is mounted on the AC spindle servo unit PCB.

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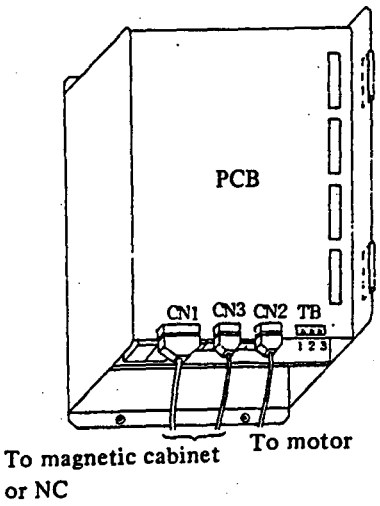
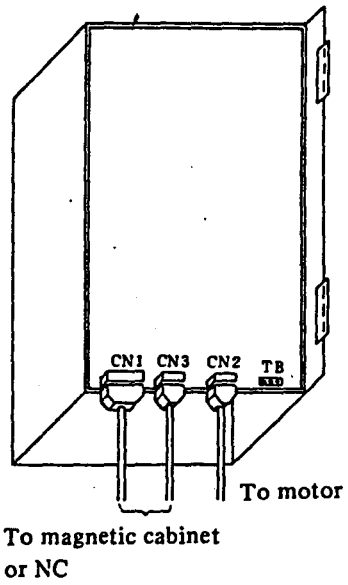
APPENDIX

APPENDIX 1 CABLE ROUTING

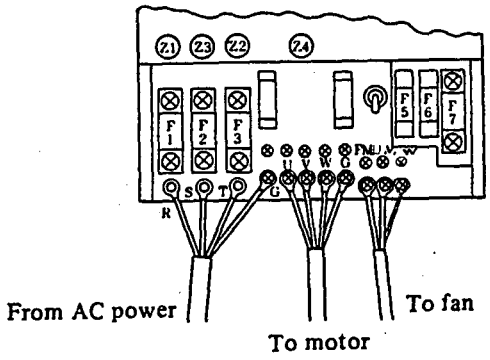
(1-1) Model 8P (A06B-6055-H306)



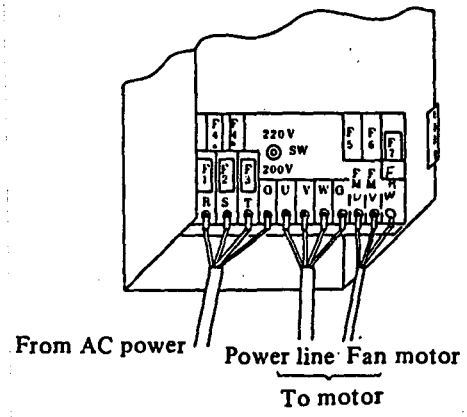
(2-1) Model 15P (A06B-6055-H308)



(1-2) PCB mount plate is open.



(2-2) PCB mount plate is open.



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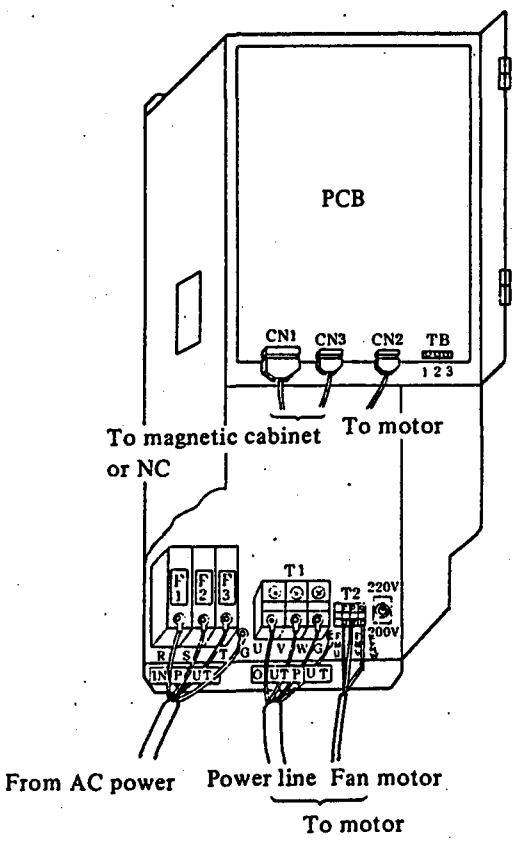
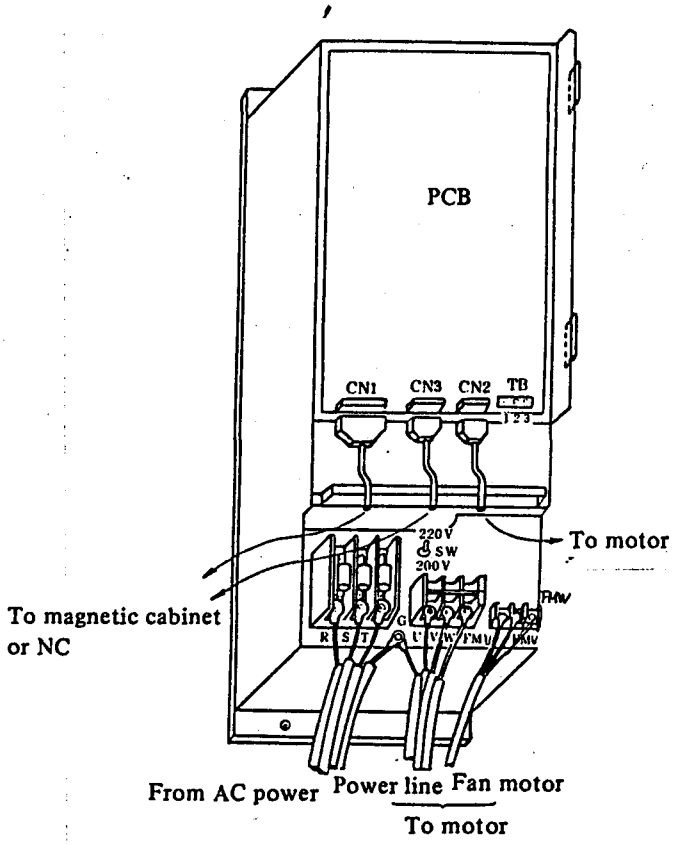
(3-1) Model 22P (A06B-6055-H315)



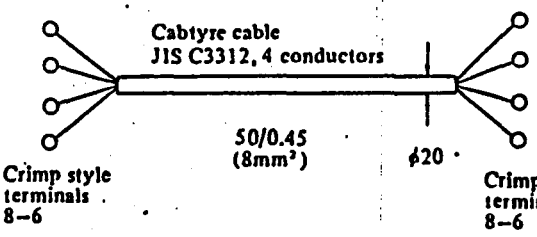
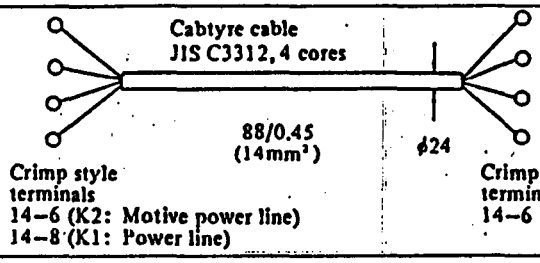
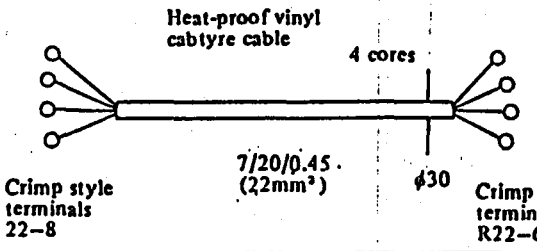
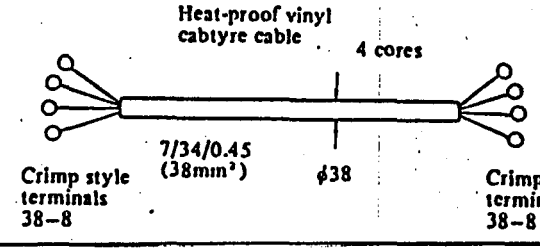
(4-1) Model 40P (A06B-6055-H322)



APPENDIX 2 CABLE SPECIFICATIONS

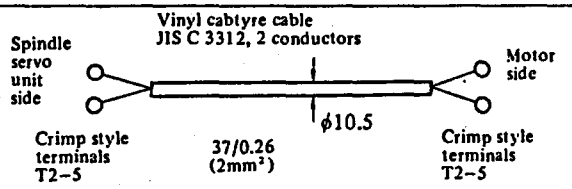
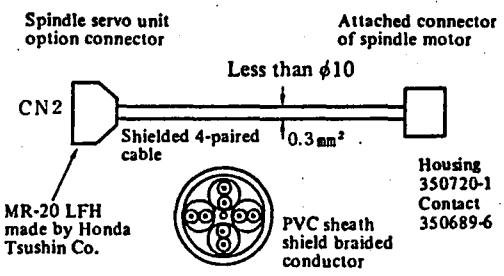
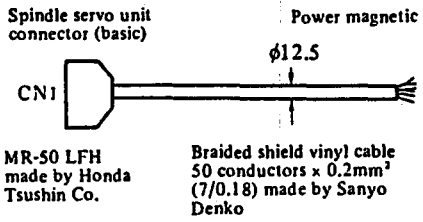
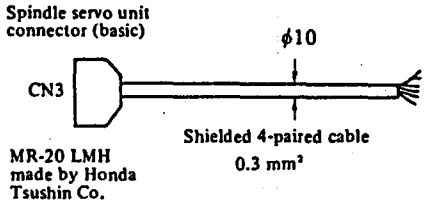
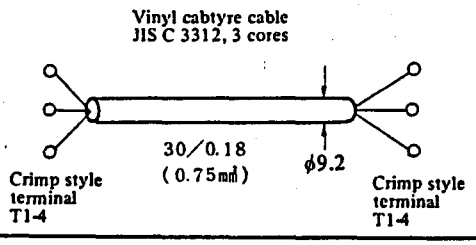
The cable specifications are as shown below.
Prepare cables by users.

1) Power line and motive power line for respective motor models

Use	Symbol	Specifications	FANUC specification No.
For MODEL 8P (Lower than 16kVA)	K1 K2		A02B-0008-K854 7m long
For MODEL 15P (Lower than 25kVA)	K1		A06B-6044-K017 7m long
	K2		A06B-6044-K018 7m long
For MODEL 22P (Lower than 30kVA)	K1 K2		A06B-6044-K019 7m long
For MODEL 40P (Lower than 45kVA)	K1 K2		A06B-6044-K021 7m long

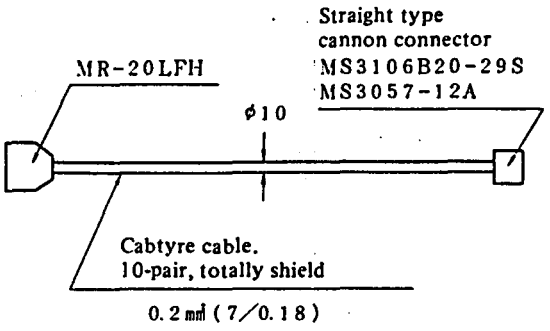
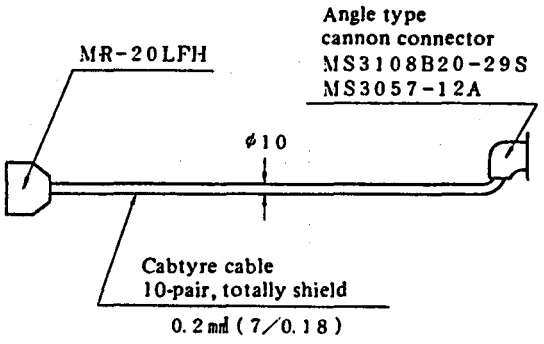
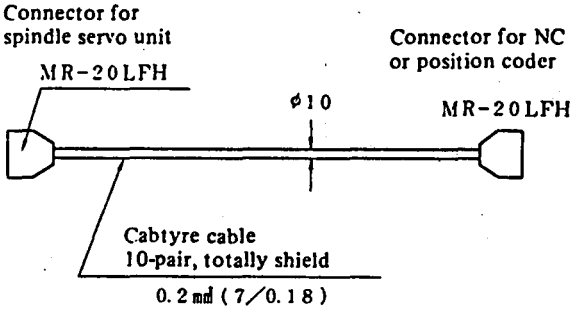
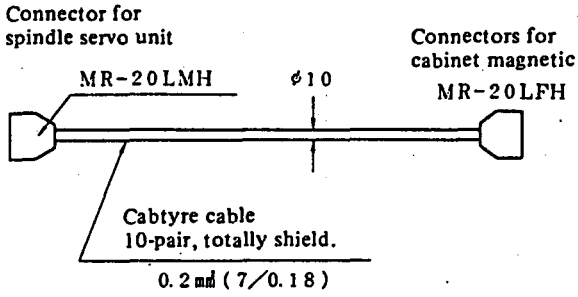
2) Common line

The following cables are common to each model.

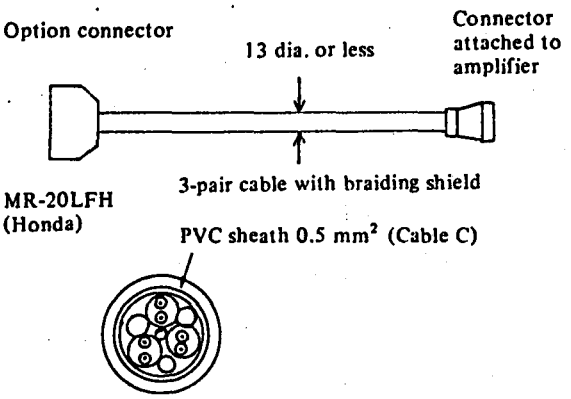
Use	Symbol	Specifications	FANUC specification No.
Spindle servo unit ↕ AC spindle motor (Cooling fan)	K3 K10 (for motor MODEL 30,40)		A06B-6044-K022 7m long
Spindle servo unit ↕ AC spindle motor (for signal)	K4		A06B-6044-K200 7m long
Spindle servo unit ↕ Power magnetic control (for signal)	K5		A06B-6044-K023 7m long
Spindle servo unit ↕ Power magnetic control (for signal)	K6		A06B-6044-K024 7m long
Speedometer load meter ↕ AC spindle servo unit (for meter)	K7		A06B-6044-K201 7m long

3) For spindle orientation

a) For position coder

Use	Name	Specification	FANUC specification No.
Spindle servo unit ↕ Position coder	K10		A06B-6041-K201 7m long
Spindle servo unit ↕ Position coder	K10		A06B-6041-K204 7m long
Spindle servo unit ↕ NC or position coder	K11		A06B-6041-K202 7m long
Spindle servo unit ↕ Magnetic cabinet	K12		A06B-6041-K205 Shield line is connected to 14 pin of magnetic cabinet connector.

b) For magnetic sensor

Use	Name	Specification	FANUC Specification No.
Spindle servo unit ↕ Magnetic sensor	K13		A06B-6041-K203 7m long

< Reference >

Detail of Cable specification

Name	Conductor		Sheath thickness	Finished outer diameter	Electrical characteristics		Specification (Note)
	Diameter	Configuration			Conductor resistance	Current tolerance	
Cable A (10-pair)	1.05 mm	7/0.18	1.4 mm	10.0 mm	110 Ω/km	1.6A	A66L-0001-0041
Cable B (50-core)	1.05 mm	7/0.18	1.5 mm	12.5 mm	106 Ω/km	1.6A	A66L-0001-0042
Cable C (3-pair)	0.93 mm	45/0.12	1.0 mm	10.8 mm	38.7Ω/km	1.6A	A66L-0001-0108

(Note) Cable length should be specified separately.

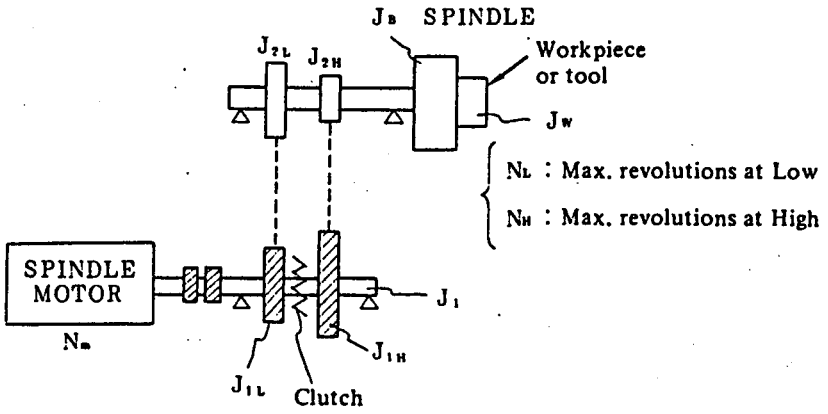
1. HOW TO OBTAIN LOAD INERTIA REFLECTED TO MOTOR SHAFT,

To obtain the load inertia reflected to motor shaft when the spindle holds the maximum tool or maximum work, full the procedure described below.

Spindle speed change gear stage	Inertia reflected to motor shaft
High J_H	——— kg.cm.s^2
Low J_L	——— kg.cm.s^2

Select the load inertia reflected to motor shaft so that it is less than 3 times the inertia of the spindle motor employed.
As the load inertia is larger, the acceleration/deceleration time becomes longer.

1) Calculation method of load inertia reflected to motor shaft (Example)



Nm: Maximum speed of motor (rpm)

N_L: Maximum speed when speed change gear stage is low (rpm)

N_H: Maximum speed when speed change gear stage is high (rpm)

Ra: Speed ratio between speed change stages N_H/N_L

G_L: Ratio of motor revolutions to revolutions when speed change gear stage is low N_L/N_m

G_H: Ratio of motor revolutions to revolutions when speed change gear stage is high N_H/N_m

J_1: Inertia of shaft directly coupled to motor (kg.cm.s^2)

J_{1L}: Inertia of gear or pulley when the motor side speed change gear stage is low (kg/cm.s^2)

J_{1H}: Inertia of gear or pulley when the motor side speed change gear stage is high (kg/cm.s^2)

J_{2L}: Inertia of gear or pulley when the spindle side speed change gear stage is low (kg/cm.s^2)

J_{2H}: Inertia of gear or pulley when the spindle side speed change gear stage is high (kg/cm.s^2)

J_B: Inertia of spindle (kg.cm.s^2)

J_W: Inertia of work (kg.cm.s^2)

① Calculation formulas when low and high speed change gear stages are switched by clutch

Inertia reflected to motor shaft when the speed change gear stage is low. J_L (kg.cm.s^2)

$$J_L = J_1 + J_{1L} + \left(\frac{1}{Ra}\right)^2 \times J_{1H} + G_L^2 \times (J_{2L} + J_{2H} + J_B + J_W) \quad .. \quad (1\text{-}1)$$

Inertia reflected to motor shaft when the speed change gear stage is high. J_H (kg.cm.s^2)

$$J_H = J_1 + Ra^2 \times J_{1L} + J_{1H} + G_H^2 \ (J_{2L} + J_{2H} + J_B + J_W) \quad ..... \quad (1\text{-}2)$$

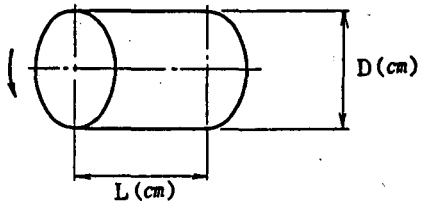
② Calculation formula when low and high speed change gear stages are switched by gear shift.

$$J_L = J_1 + J_{1L} + J_{1H} + G_L^2 \ (J_{2L} + J_{2H} + J_B + J_W) \quad ..... \quad (1\text{-}3)$$

$$J_H = J_1 + J_{1L} + J_{1H} + G_H^2 \ (J_{2L} + J_{2H} + J_B + J_W) \quad ..... \quad (1\text{-}4)$$

The calculation formulas of respective inertia are given below.

① Inertia of cylindrical body



The inertia produced when a cylindrical body rotates around its center shaft is calculated by the following formula. Calculate ball screws, gears, etc. by approximating this formula for cylindrical body.

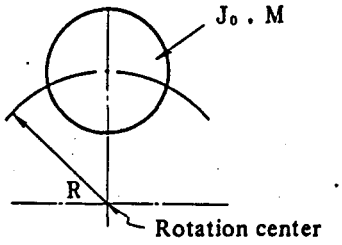
$$J = \frac{\pi\gamma}{32 \times 980} D^4 L \ (kg.cm.s^2) \quad ..... \quad (1\text{-}5)$$

This can be approximated in case of steel ($\gamma = 7.8 \times 10^{-3}$ kg/cm^3) as follows.

$$J = 0.78 \times 10^{-6} D^4 L \ (kg.cm.s^2) \quad ..... \quad (1\text{-}6)$$

Where, J: Inertia (kg.cm.s^2)
γ: Weight per unit volume (kg/cm^3)
D: Diameter of cylindrical body (cm)
L: Length of cylindrical body (cm)

② Inertia of cylindrical body having a deviated rotation center

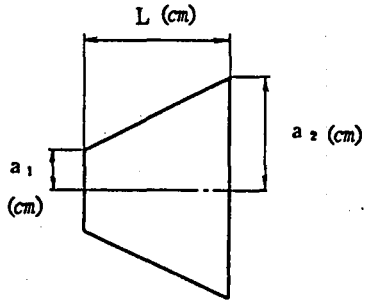


$$J = J_o + \frac{M}{980} R^2 \ (kg.cm.s^2) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1\text{-}7)$$

Where, Jo: Inertia around the center of cylindrical body ($kg.cm.s^2$)
M: Weight of cylindrical body (kg)
R: Rotation radius (cm)

The above formula applies to calculations of the inertia of large diameter gears when lightening holes were made for reducing their weight.

③ Inertia of tapered cylindrical body



$$J = \frac{\pi\gamma}{10 \times 980} \times \frac{(a_2^5 - a_1^5)}{(a_2 - a_1)} \times L \ (kg.cm.s^2) \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1\text{-}8)$$

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2. HOW TO FIND THE ACCELERATION TIME

Find the spindle acceleration time in the following manner.

1) Calculate the load inertia for the motor shaft.

2) Find the value required for calculation based on the spindle motor characteristic table.

3) Find the acceleration time according to the calculation expression.

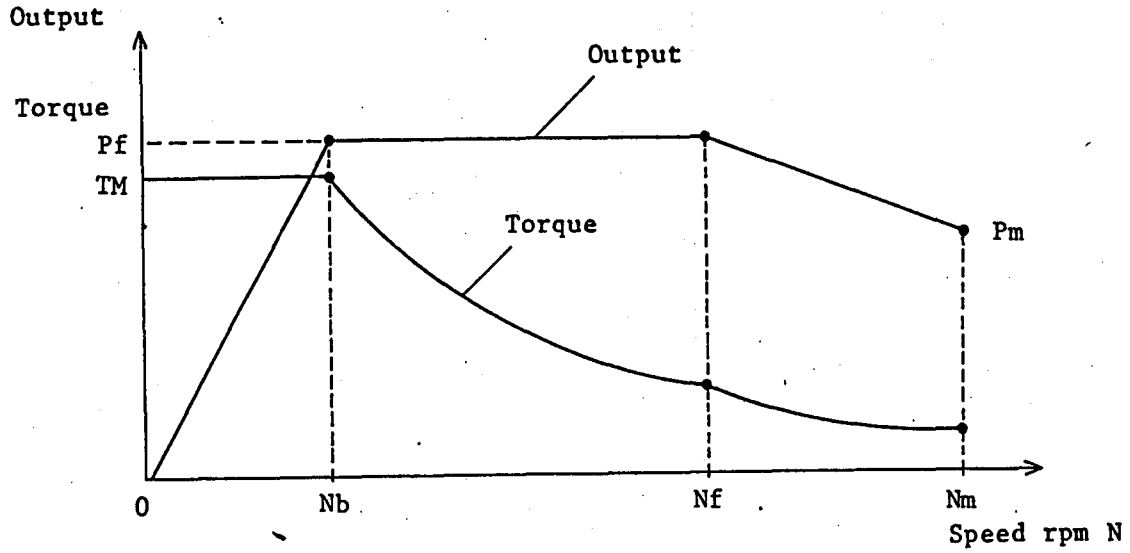
1) Motor shaft conversion load inertia

According to para. 1 above, find the load inertia. When GD^2 $(kg.m^2)$ is found, convert the unit system according to the following equation.

$$J_L\ (kg.m.s^2) = \frac{GD^2\ (kg.m^2)}{4g\ (m/s^2)} \quad \text{..... (4-1)}$$

Therefore, 1 $kg.m^2$ = 0.0255 $kg.m.s^2$

2) Spindle motor characteristic table



The following relation exists among output P, torque T and speed rpm N.

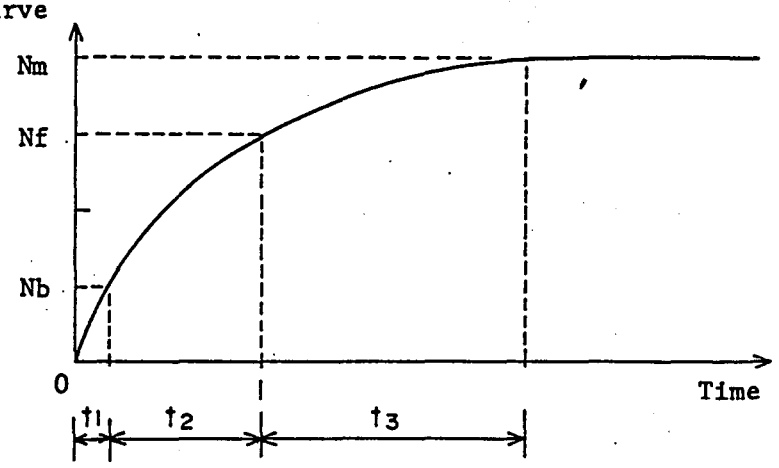
$$P\ (kW) = 1.0269 \times N \times T/1000 \quad \text{..... (4-2)}$$

Characteristics of each model at 30-minutes rating output

Model	J_M kg·m·s²	T_M kg·m	N_b rpm	N_f rpm	N_m rpm	P_f kW	P_m kW
8P	0.0028	7.14	750	4500	6000	5.5	3.7
15P	0.0093	11.69	750	4500	6000	9	7.5
22P	0.0129	19.47	750	4500	6000	15	11
40P	0.03	37.25	575	3450	4500	22	18.5

3) Calculation of acceleration time

Acceleration curve



Acceleration time

1) Speed rpm 0 to N_b (rpm)

$$t_1 = \frac{J_L + J_M}{T_M} \times \frac{2\pi N_b}{60} \text{ (sec)} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (4\text{-}3)$$

2) Speed rpm N_b to N_f

$$t_2 = \frac{J_L + J_M}{T_M} \times \frac{2\pi}{60} \times \frac{(N_f^2 - N_b^2)}{2N_b} \text{ (sec)} \quad \cdots\cdots\cdots\cdots\cdots \quad (4\text{-}4)$$

3) Speed rpm N_f to N_m

$$t_3 = (J_L + J_M) \times \frac{2\pi}{60} \times \frac{(N_m - N_f)^2}{(P_f - P_m)^2}$$

$$\times \left\{ - (P_f - P_m) + \frac{(P_f N_m - P_m N_f)}{(N_m - N_f)} \times \ell n \left| \frac{P_f}{P_m} \right| \right\} \cdots\cdots\cdots \quad (4\text{-}5)$$

Note 1) ℓn: Natural logarithm

Acceleration time t_a

$$t_a = t_1 + t_2 + t_3 \text{ (sec)} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (4\text{-}6)$$

By controlling the deceleration time to nearly the same time as the acceleration time, the elongation of the tap during tapping processing can be reduced.

JR

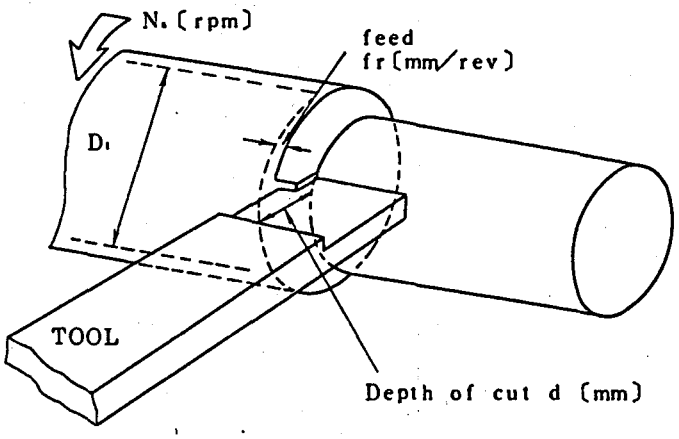
3. CUTTING AMOUNT OF MACHINE

The spindle motor output (HP or KW) of machine tools is specified to indicate their cutting amount, in general.

Regarding the lathing, milling, and drilling, the relation between the rate of metal removal and output power will be described by quoting it from the following references.

References: MACHINING DATA HANDBOOK AIR FORCE MATERIAL LABORATORY
(a) Lathe turning
(b) Machining center, milling using milling machine
(c) Machining center, drilling using drilling machine

(a) Turning



(Cutting conditions)

(1)	Spindle revolutions	Ns (rpm)
(2)	Workpiece diameter	Dt (mm)
(3)	Feed	fr (mm/rev)
(4)	Depth of cut	d (mm)

(Cutting formulas)

(1) Cutting speed $Vc = \pi \times Dt \times Ns$ (mm/min)

(2) Feed rate $fm = fr \times Ns$ (mm/min)

(3) Rate of metal removal $Q = d \times fr \times Vc/1000$ (cm^3/min)

$= d \times fr \times \pi \times Dt \times Ns/1000$ (cc/min)

$$\boxed{Q = \pi \times Dt \times d \times fm/1000 \text{ (cc/min)}}$$

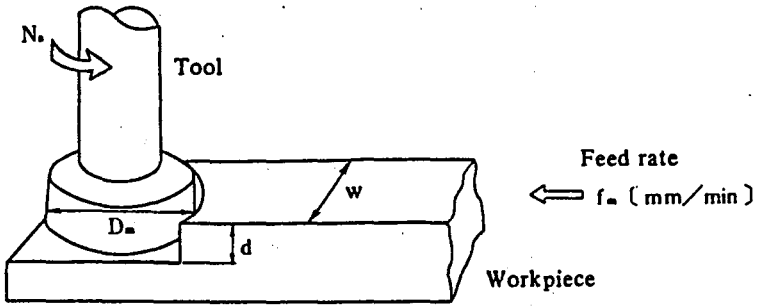
(4) Power required at spindle $PS = Q/MRt$ (kW)

Where, MRt: Rate of metal removal per kW (cc/min/kW)

(5) Power required at spindle motor $PM = \frac{1}{\eta} \times Q/MRt$

Where, η: Drive efficiency of spindle (%)

(b) Milling



(Cutting conditions)

(1)	Spindle revolutions	Ns (rpm)
(2)	Diameter of milling cutter	Dm (mm)
(3)	Width of cut	w (mm)
(4)	Depth of cut	d (mm)
(5)	Number of teeth in cutter	n (pieces)
(6)	Feed	ft (mm/tooth)

(Cutting formulas)

(1) Cutting speed $Vc = \pi \times Dm \times Ns$ (mm/min)

(2) Feed rate $fm = ft \times n \times Ns$ (mm/min)

(3) Rate of metal removal $Q = w \times d \times ft \times n \times Ns/1000$ (cm^3/min)

$$\boxed{Q = w \times d \times fm/1000 \text{ (cc/min)}}$$

(4) Power required at spindle $PS = Q/MRm$ (kW)

Where, MRm: Rate of metal removal per kW (cc/min/kW)

(5) Power required at spindle motor $PM = \frac{1}{\eta} \times Q/MRm$ (kW)

Where, η: Drive efficiency of spindle (%)

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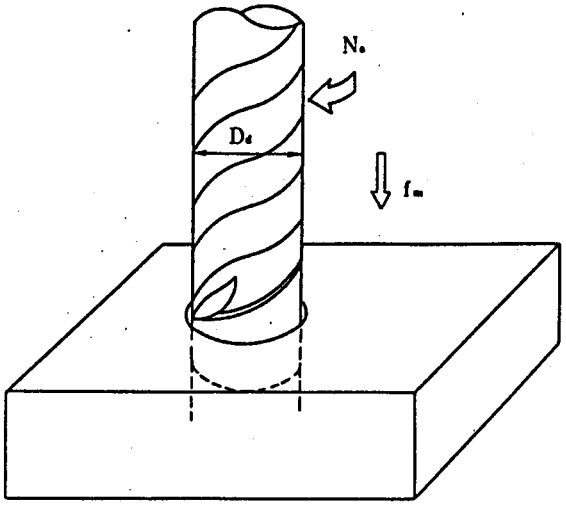
(c) Drilling



(Cutting conditions)

(1)	Spindle revolutions	Ns (rpm)
(2)	Drill diameter	Dd (mm)
(3)	Feed	fr (mm/rev)

(Cutting formulas)

(1)	Cutting speed	$Vc = \pi \times Dd \times Ns$ (mm/min)
(2)	Feed rate	$fm = fr \times Ns$ (mm/min)
(3)	Rate of metal removal	$Q = \frac{\pi}{4} \times Dd^2 \times fr \times Ns/1000$ (cm^3/min)
		$\boxed{Q = \frac{\pi}{4} \times Dd^2 \times fm/1000 \text{ (cc/min)}}$
(4)	Power required at spindle	$PS = Q/MRd$ (kW)

Where, MRd: Rate of metal removal per kW (cc/min/kW)

(5) Power required at spindle motor $PM = \frac{1}{\eta} \times Q/MRd$ (kW)

Where, η: Drive efficiency of spindle (%)

Rate of metal removal per kW (cc/min/kW) (average values)
(when the drive efficiency of spindle is 80%)

MATERIAL	HARDNESS (*1) Brinell hardness	MR: Rate of metal removal per kW (cc/min/kW)					
		TURNING MRt HSS AND CARBIDE TOOLS feed 0.127-0.381 mm/rev		MILLING MRm CARBIDE TOOLS feed 0.127 - 0.305 mm/tooth		DRILLING MRd HSS DRILLS feed 0.05 - 0.203 mm/rev	
		SHARP TOOL	DULL TOOL	SHARP TOOL	DULL TOOL	SHARP TOOL	DULL TOOL
STEEL-WROUGHT AND CAST Plain Carbon Alloy Steels Tool Steels	85-200(*4)	20	15.7	20	15.7	21.9	16.8
	35-40Rc(*2)	15.7	12.9	14.6	11.5	15.7	12.9
	40-50Rc	14.6	11.5	12.2	10	12.9	10.4
	50-55Rc	10.9	8.7	10.4	8.4	10.4	8.4
	55-58Rc	6.4	5.2	8.4	6.8	8.4	6.8 (*5)
CAST IRONS Gray, Ductile and Malleable	110-190	31.3	24.4	36.6	27.4	21.9	18.3
	190-320	15.7	12.9	20	15.7	13.7	10.9
STAINLESS STEELS Ferritic, Austenitic and Martensitic	135-275	16.8	13.7	15.7	12.9	20	15.7
	30-45Rc	15.7	12.9	14.6	11.5	18.3	14.6
PRECIPITATION HARDENINGS STAINLESS STEELS	150-450	15.7	12.9	14.6	11.5	18.3	14.6
TITANIUM	250-375	18.3	14.6	20	15.7	20	15.7
HIGH TEMPERATURE ALLOYS Nickel and Cobalt Base	200-360	8.7	7.0	10.9	8.7	10.9	8.7
Iron Base	180-320	13.7	10.9	13.7	10.9	18.3	14.6
REFRACTORY ALLOYS ... Tungsten	321	7.8	6.2	7.5	6.1	8.4	6.6 (*5)
Molybdenum	229	10.9	8.7	13.7	10.9	13.7	10.9
Columbium	217	12.9	10.4	14.6	11.5	15.7	12.9
Tantalum	210	7.8	6.2	10.9	8.7	10.4	8.4
NICKEL ALLOYS	80-360	10.9	8.7	11.5	9.1	12.2	10
ALUMINUM ALLOYS	30-150 500 kg	87.8	73.2	68.6	54.9	137.2	109.8

MATERIAL	HARDNESS (*1) Brinell hardness	MR: Rate of metal removal per kW (cc/min/kW)					
		TURNING MRt HSS AND CARBIDE TOOLS feed 0.127-0.381 mm/rev		MILLING MRm CARBIDE TOOLS feed 0.127 - 0.305 mm/tooth		DRILLING MRd HSS DRILLS feed 0.05 - 0.203 mm/rev	
		SHARP TOOL	DULL TOOL	SHARP TOOL	DULL TOOL	SHARP TOOL	DULL TOOL
MAGNESIUM ALLOYS	40-90 500 kg	137.2	109.8	137.2	109.8	137.2	109.8
COPPER	80R_B (*3)	21.9	18.3	21.9	18.3	24.4	20
COPPER ALLOYS	10-80R_B	34.3	27.4	34.3	27.4	45.7	36.6
	80-100R_B	21.9	18.3	21.9	18.3	27.4	21.9

Notes: (*1) Brinell hardness, Standard testing method, Steel ball diameter 10 mm , Load: 3000 kg, Maximum value about 450

(*2) Rc: Rockwell hardness, C scale, Measurement of hardness of comparatively hard metals

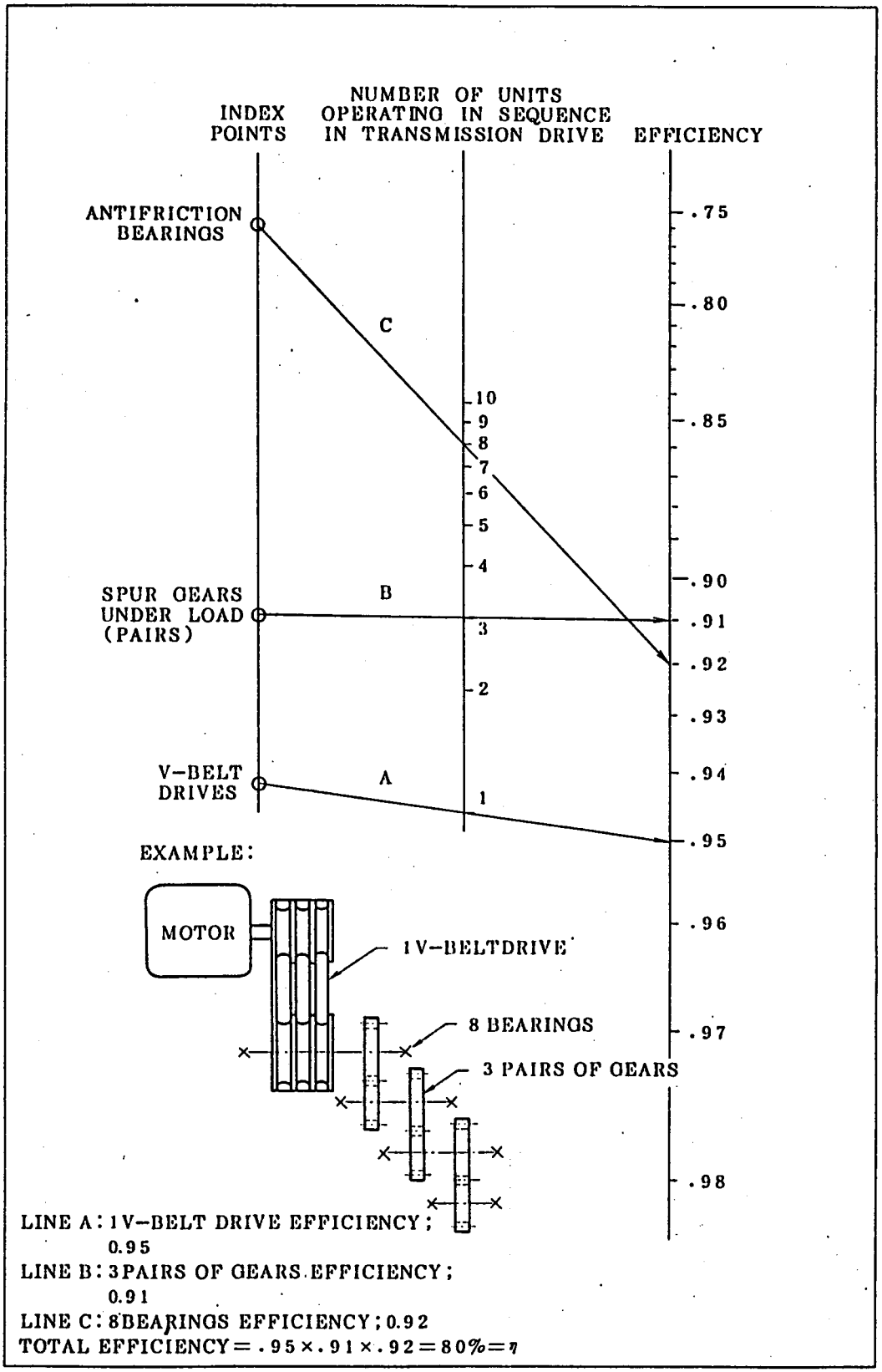
(*3) R_B: Rockwell hardness, B scale, Measurement of hardness of soft metals

(*4) Corresponds to hardness of general stell S45C

(*5) Carbide

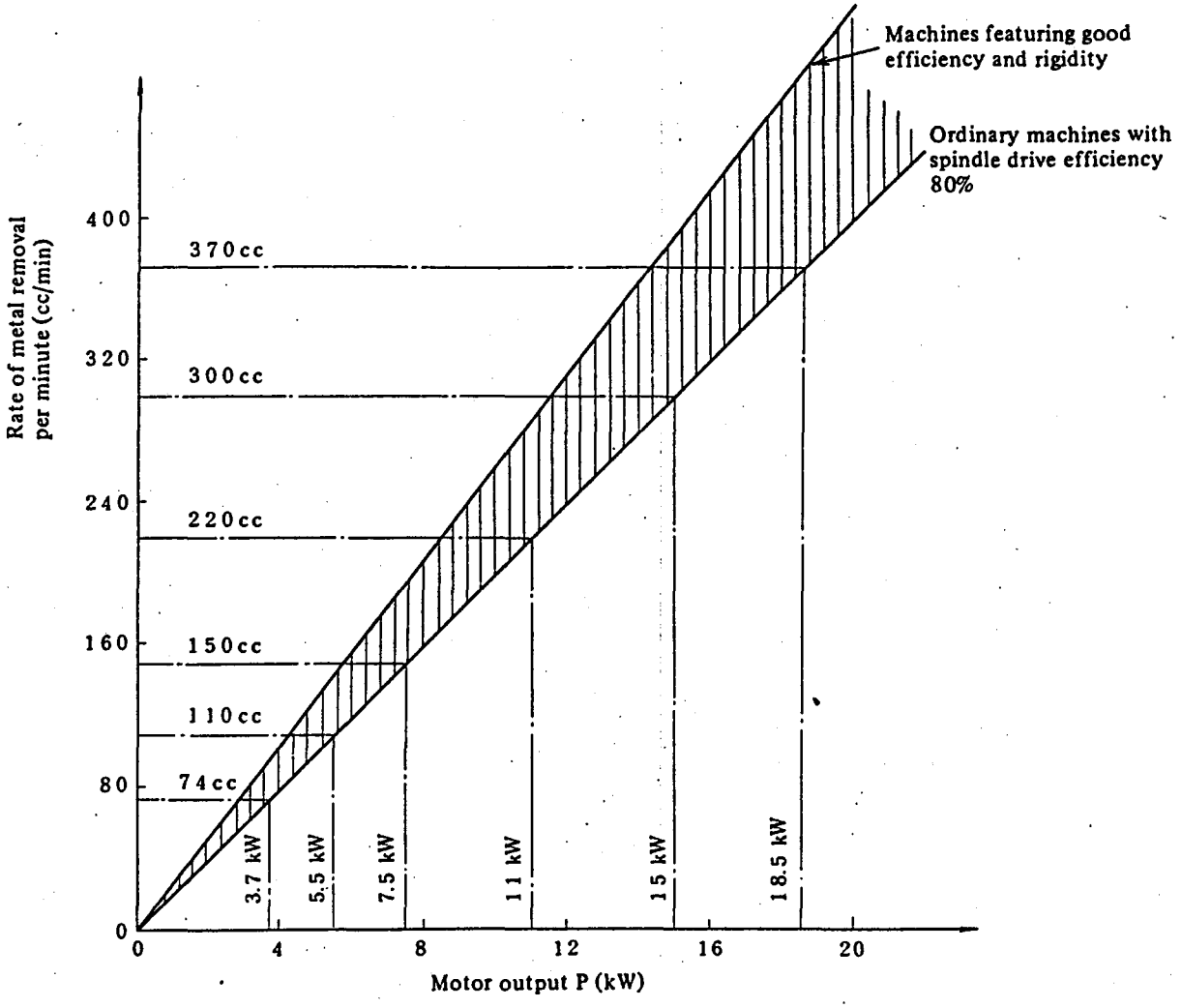
Efficiency of spindle drive system

The efficiency of spindle system can be obtained from the following diagram according to the V belt, number of gear stages, and number of bearings.



Data on rate of metal removal

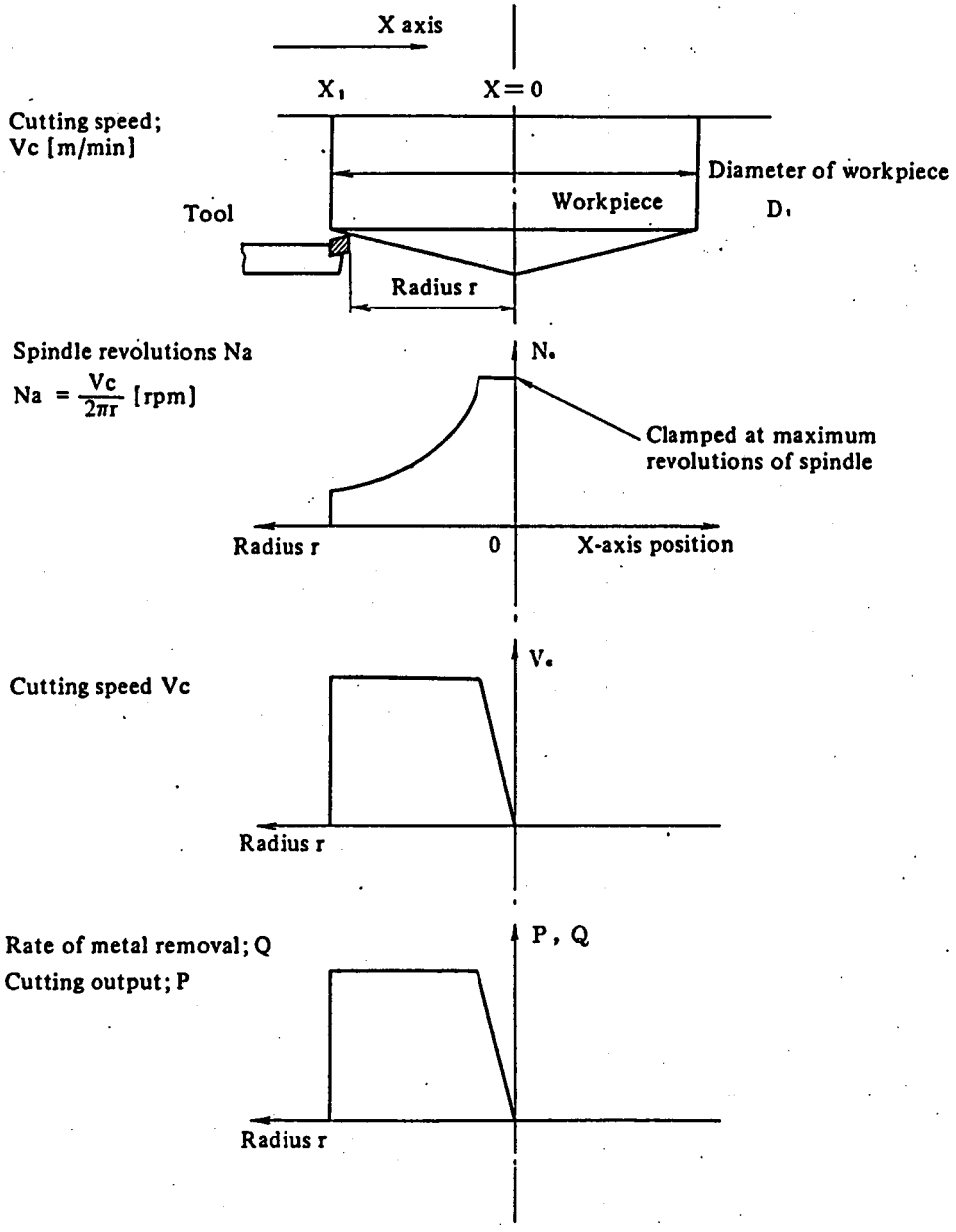
The rate of metal removal per minute when steel S45C is cut using a new tool on a lathe or machining center is obtained within the shadowed range in the following figure approximately; provided that noload torque such as friction torque, etc. are negligible.



4. CONSTANT SURFACE SPEED CONTROL

- Purpose of constant surface speed control in lathe
  (1) Good finish surface
  (2) Reduction of lathing time
  (3) Constant rate of metal removal
  (4) Prolonged lives of tools by setting the surface speed to a suitable value

- Constant surface speed control operation



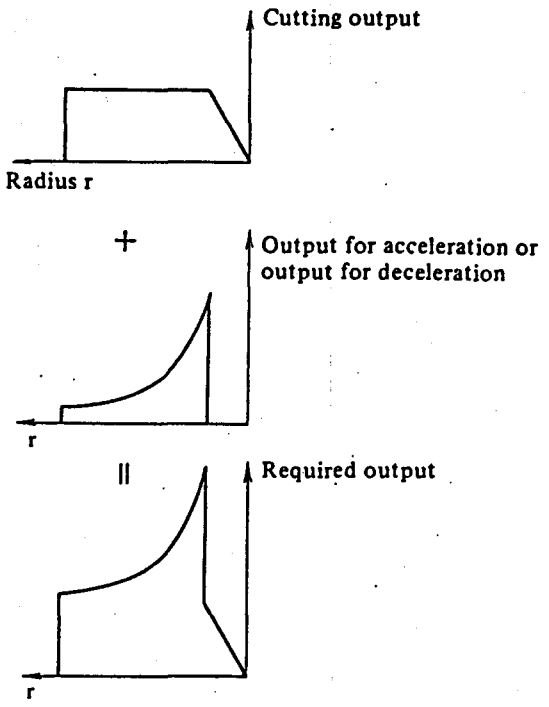
- The cutting output during constant surface speed control, or, the output required for cutting a metal during constant surface speed control under a certain condition is obtained by the following formula;

$$Po = \frac{1}{MRt} \times d \times fr \times Vc \quad (kW) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6\text{-}1)$$

Where, Po: Cutting output (kW)
MRt: Rate of metal removal per kW (20 usually) (cc/min/kW)
d: Depth of cut (mm)
fr: Feed rate (mm/rev)
Vc: Cutting speed (m/min)

- Motor output required for constant surface speed control

Both required cutting output and the output for acceleration (or deceleration) for increasing (or decreasing) the spindle revolutions are required, and the maximum output is required in the vicinity of the maximum revolutions of the motor.



Since cutting speed Vc is kept constant under the constant surface speed control, the tool position (radius r) on a workpiece is inversely proportional to spindle revolutions Ns.
Thus, the feed rate per minute fm (mm/min) becomes faster, as the tool advances toward the innermost of diameter.
Assume that the tool is displaced by $-\Delta X$ in the X-axis direction during Δt time, and a change rate

$-\frac{\Delta X}{\Delta t}$ represents the feed rate given by the following formula.

$$-\frac{dX}{dt} = fm = \frac{fr \times Vc}{2\pi X} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6\text{-}2)$$

From the above formula, the time required for the tool to be displaced from radius $X_1 > r_1$ to $X_2 = r_2$ is obtained by;

$$\boxed{ta = \frac{\pi}{fr \times Vc} |r_1^2 - r_2^2|} \quad \text{(sec)} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (6\text{-}3)$$

(where, $r_1 > r_2$)

This is the formula for obtaining the machining time under the constant surface speed control.

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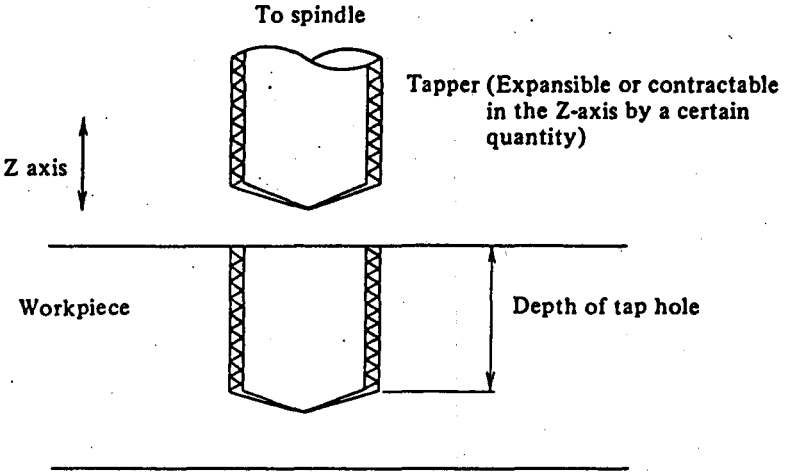
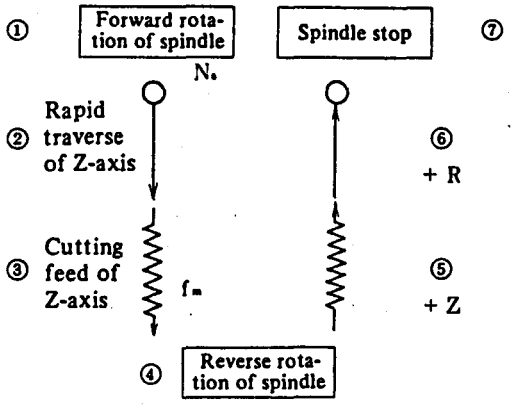
5. TAPPING

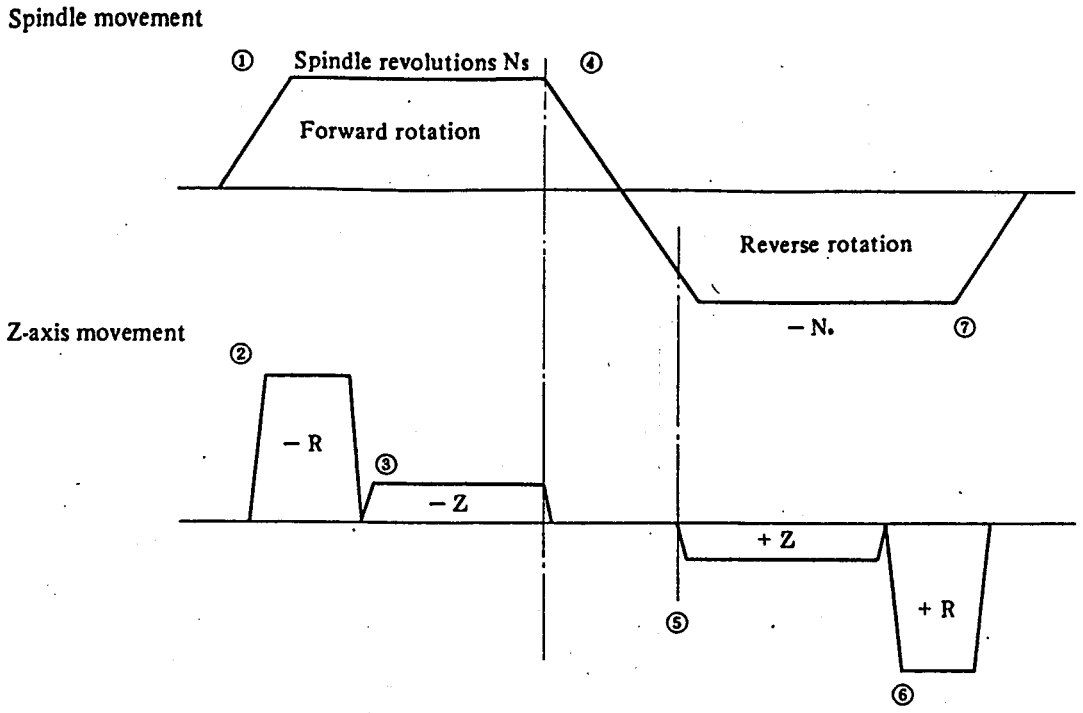
(1) Tapping operation

The tapping means a work of threading a female screw on a workpiece in machining center.



Tapping is made by controlling the spindle and Z-axis movement as follows.





Examine the following items for tapping.

(a) Depth of tap hole ..... Check if the depth is finished as specified.

(b) Expansion or contraction of tapper .... This will affect the threading accuracy.

(2) Tapping and cutting speed

In tapping work, the cutting speed is generally limited according to the kinds of workpieces and tools.

$$Vc = \pi \times d \times Ns/1000 \quad (m/min) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7\text{-}1)$$

Where, d: Tap diameter (mm)
Ns: Spindle revolutions (rpm)

Example of tapping conditions

- When a steel casting workpiece is tapped by an ordinary tapper; ..... Lower than 8 m/min
- When a light alloy workpiece is tapped by an ordinary tapper or when a cemented carbide tapper is employed; ..... Lower than 25 m/min

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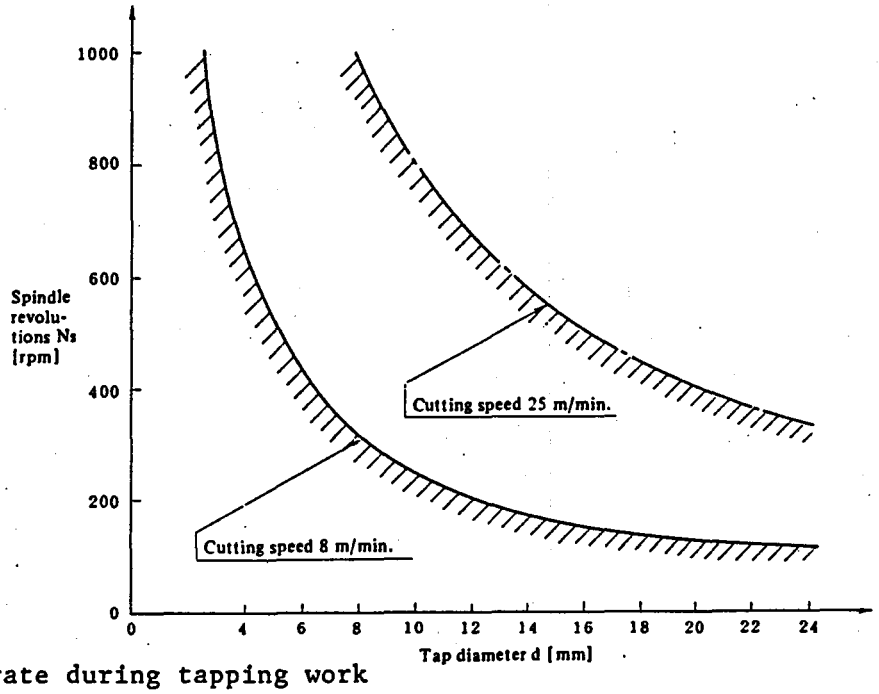
The relation between the tap diameter and spindle revolutions is as illustrated below.



(3) Feedrate during tapping work

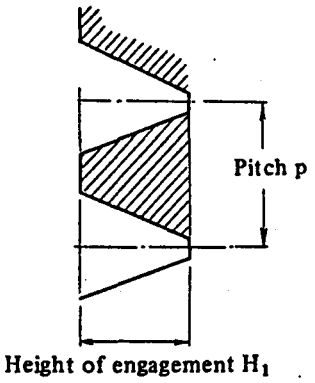
Set the cutting feed rate fm (mm/min) during tapping as follows.

$$fm = Ns \times p \quad (mm/min) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (7\text{-}2)$$

Where, p: Pitch of screw

The relation between the tap diameter (nominal diameter of screw) and pitch is as shown below.

Normal diameter of screw (d)	Pitch (p)	Height of engagement (H_1)
M 2	0.4 mm	0.217 mm
M 2.6	0.45	0.244
M 3	0.5	0.271
M 4	0.7	0.379
M 5	0.8	0.433
M 6	1.0	0.541
M 8	1.25	0.677
M10	1.5	0.812
M12	1.75	0.947
M16	2	1.083
M20	2.5	1.353
M24	3	1.624
M30	3.5	1.894
M36	4	2.165

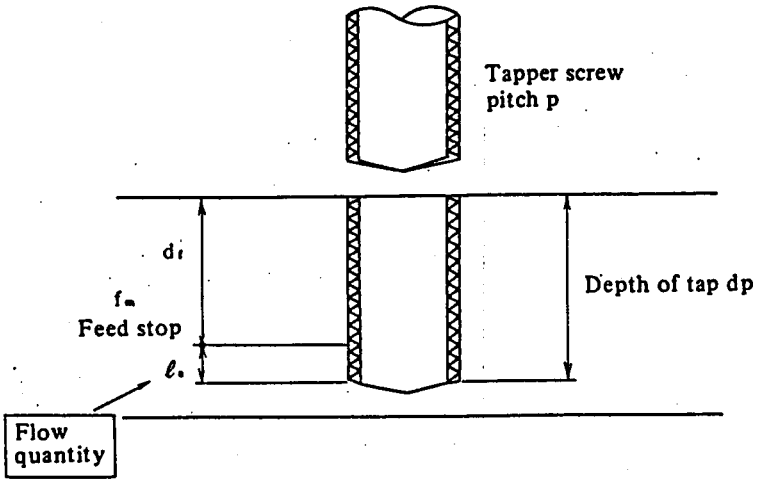


(4) Tap hole depth control

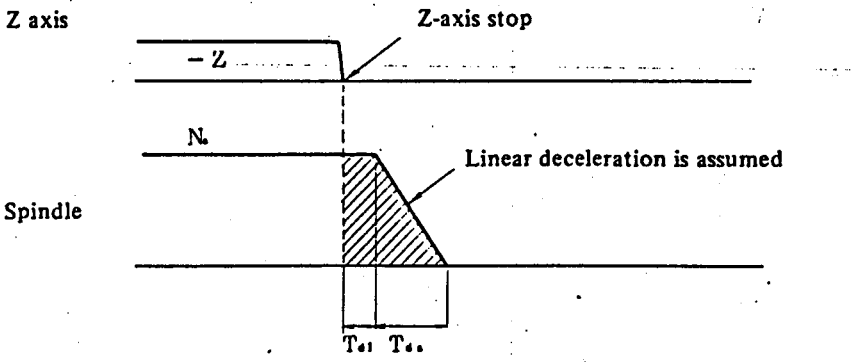
The hole depth dp (mm) is given by the following formula.

$$dp = df + \ell a \quad (mm) \quad \cdots\cdots (7\text{-}3)$$

Where, df: Moving distance commanded from a workpiece surface to Z-axis
ℓa: Machining distance of tapper by means of self-propulsion until the spindle is stopped after being decelerated (This is called flow quantity)



How to obtain flow quantity ℓa



Td_1: Operation delay time by the time the spindle starts deceleration (sec)

Tds: Deceleration time of spindle (sec)

$$\ell a = \left(Td_1 + \frac{1}{2} Tds\right) \times \frac{Ns}{60} \times p \quad (mm) \quad \cdots\cdots (7\text{-}4)$$

To decrease the flow quantity, the operation delay time and deceleration time must be reduced. This flow quantity corresponds to the expansion of the tapper. It must be controlled to obtain the depth of holes accurately.

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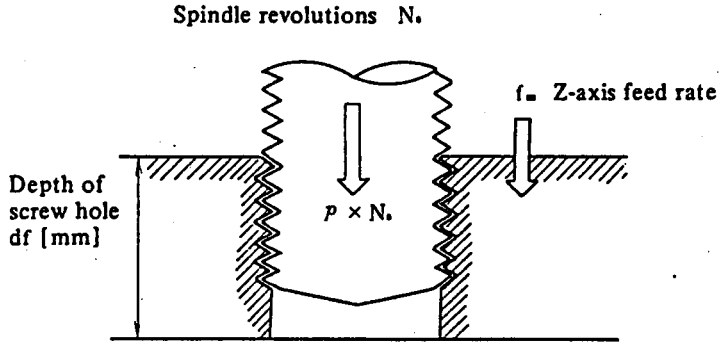
(5) Expansion and contraction of tapper

For the expansion and contraction of tapper, refer to tools maker's catalogues. Contraction is generally less than expansion, and the spring pressure increases during contraction.
Accordingly, the finish accuracy of screws is said to be better when threading is made in the expansion direction of the tapper rather than in the contraction direction.
The causes of expansion and contraction of the tapper are as described below.
Please examine the motor selection and power magnetic sequence design, so that tapping can be done with minimized expansion and contraction.

(a) Expansion and contraction caused by the difference between the feed rate and actual spindle revolutions Ns
Expansion and contraction quantity ε_1 of tapper caused by asynchronism between the feed rate and spindle revolutions



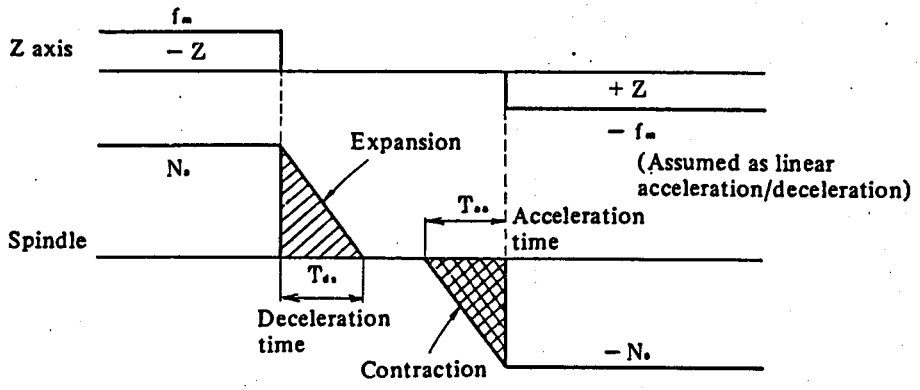
pNs - fm = positive (expansion of tapper)
pNs - fm = negative (contraction of tapper)

$$\varepsilon_1 = \frac{pNs - fm}{fm} \times df \quad (mm) \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (7\text{-}5)$$

The above relation is contrary when the tapper is lifted.
Particularly be careful with this relation when a hole is deep.

(b) Expansion and contraction ε_2 caused by the forward/reverse rotation of spindle and Z-axis feed timing

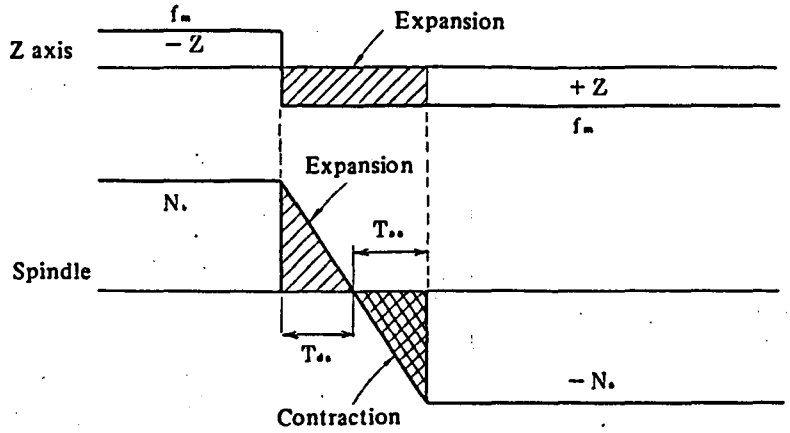
① Pattern A



$$\varepsilon_{2a} = \frac{1}{2} \times \frac{Ns}{60} \times p \times (Tds - Tas) \quad (mm) \quad \ldots\ldots\ldots\ldots\ldots (7\text{-}6)$$

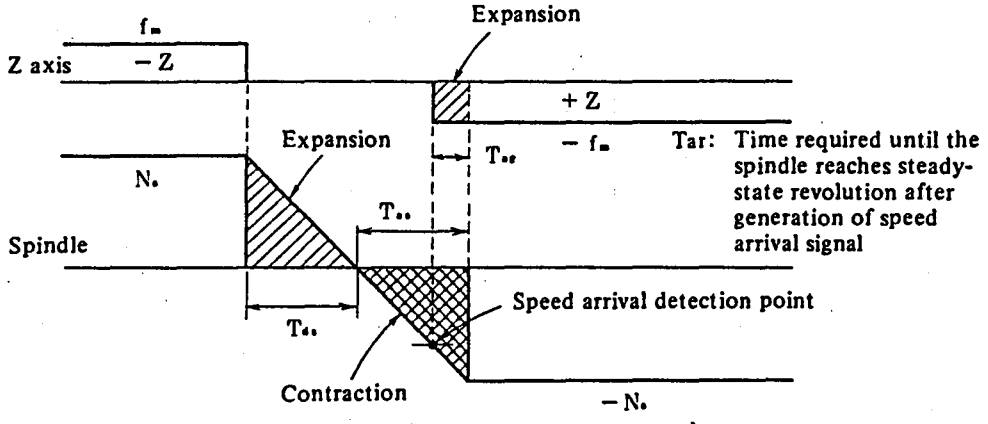
Tds ≦ Tas usually.

② Pattern B (Z-axis instantaneous reverse rotation)



$$\varepsilon_{2b} = \frac{1}{2} \times \frac{Ns}{60} \times p \times (Tds - Tas) + \frac{fm}{60} \times (Tds + Tas) \quad (mm) \quad \ldots (7\text{-}7)$$

③ Pattern C



$$\varepsilon_{2c} = \frac{1}{2} \times \frac{Ns}{60} \times p \times (Tds - Tas) + \frac{fm}{60} \times Tar \quad \ldots\ldots\ldots\ldots (7\text{-}8)$$

(6) Examination to minimize the expansion and contraction of tapper

① Synchronize the commanded spindle speed with actual spindle speed.

② Control the reverse rotation start time of the Z-axis feed motor as shown in pattern C until expansion/contraction $\varepsilon_{2c} \fallingdotseq 0$.
Adjust the detection level of the speed arrival signal from the spindle servo unit as a method.

③ Shorten the acceleration and deceleration time of spindle.
Switch gears from low gear to high gear at revolutions lower than normal gear switching point for the purpose of shortening the acceleration and deceleration time of the spindle during tapping work only.

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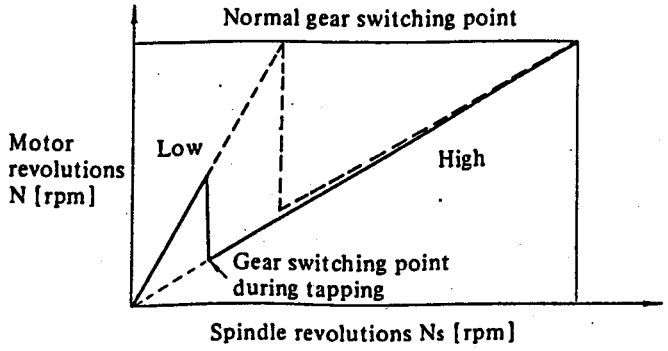
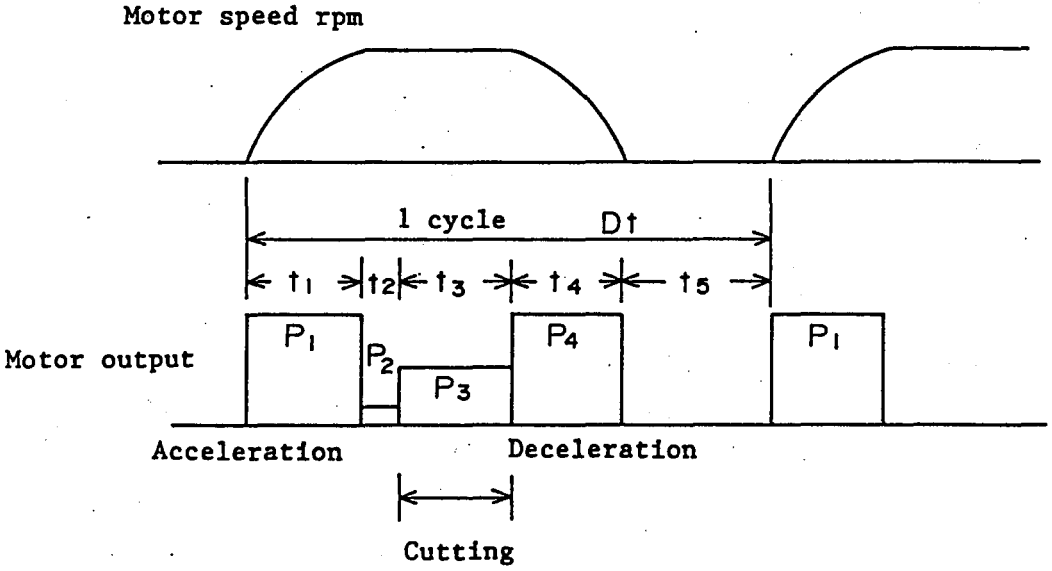

Normal gear switching point
Motor revolutions N [rpm]
Low
High
Gear switching point during tapping
Spindle revolutions Ns [rpm]

6. HOW TO FIND ALLOWABLE DUTY CYCLE

When the spindle accelerates and decelerates frequently for machining, the motor should be used so that the average output value of one cycle of operation does not exceed the continuous rated output.

Following is the description of the method of calculating its allowable duty cycle for a typical AC spindle motor.

1) Duty cycle and average output



P1, P4: Output at acceleration and deceleration (kW) = 30-minute rated output x 1.2
P2 : Output at no-load rotation (P2 ≃ 0)
P3 : Output during cutting (kW)

$$\text{Average output } Pav = \sqrt{\frac{P_1^2 t_1 + P_2^2 t_2 + P_3^2 t_3 + P_4^2 t_4}{D_t}} \quad \ldots (8\text{-}1)$$

Note) As to output P3 during cutting at motor speed N which is less than base speed Nb, assuming actual cutting output to be Pc (kW), the value is obtained by the following equation.

$$P3 \simeq \frac{Nb}{N} \times Pc \text{ (kW)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8\text{-}2)$$

2) How to find allowable duty cycle time Dt:
From eq. (8-1) above, Dt is determined by:

$$D_t = \frac{1}{Pav^2} \times (P_1^2 t_1 + P_2^2 t_2 + P_3^2 t_3 + P_4^2 t_4) \quad \ldots\ldots\ldots\ldots\ldots \quad (8\text{-}3)$$

Substitute the continuous rated output value of AC spindle motor used for Pav (kW).

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Ex: Find the allowable duty cycle time when acceleration and deceleration are repeated at no load ($P_2 \approx P_3 \approx 0$) for model 3.

o Continuous rated output: $P_{av} = P_{cont} = 3.7$ kW

o Output at acceleration/deceleration:
$P_1 = P_4 = 5.5 \text{ kW} \times 1.2 = 6.6$ kW

o Acceleration time $t_1 = 3$ sec

Deceleration time $t_4 = 3$ sec

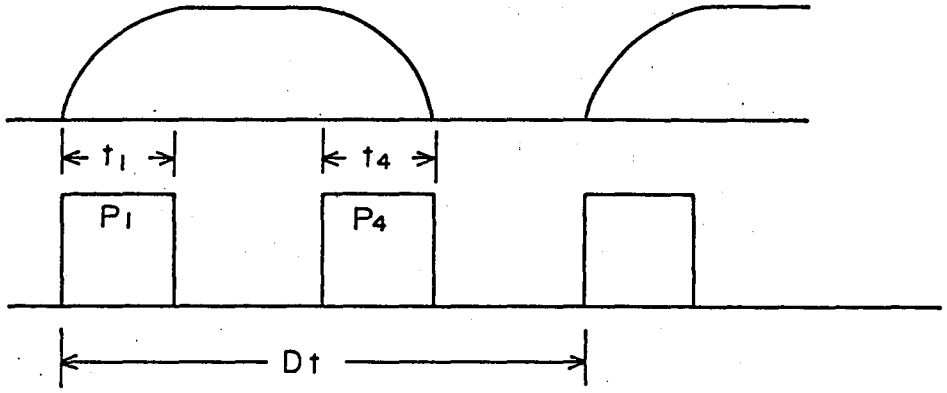
Under the aforementioned conditions, Dt is found as follows.

$$D_t = \frac{1}{3.7^2} \times (6.6^2 \times 3 + 6.6^2 \times 3)$$

$$= \frac{6.6^2}{3.7^2} \times (2 \times 3) = 19.08 \text{ seconds}$$

In other words, the allowable duty time when acceleration and deceleration are repeated at no load for model 3 corresponds to 3.18 times the summation of the acceleration and deceleration times.

3) Allowable duty cycle time D_t for repeated acceleration and deceleration



$$D_t = \frac{1}{P_{cont}^{1-2}} \left\{ P_{30min}^2 \times 1.2^2 \times (t_1 + t_4) \right\} \quad \ldots\ldots\ldots\ldots \quad (8\text{-}3)$$

where: P_{cont} = Continuous rated output

P_{30min} = 30-minute rated output

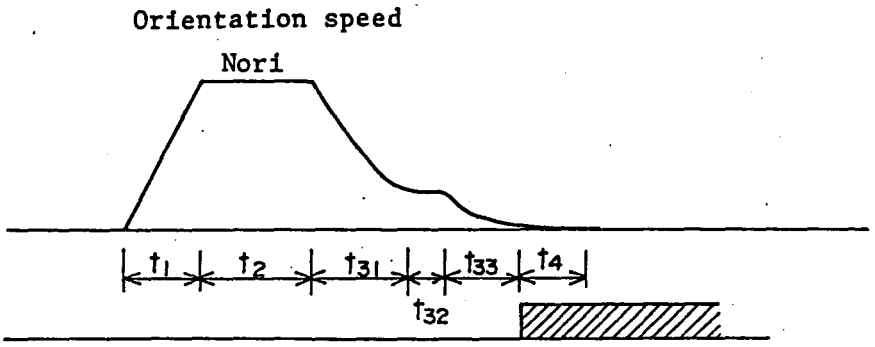
$t_1 + t_4$ = Summation of acceleration time and deceleration time

$$D_t = \left(\frac{P_{30min} \times 1.2}{P_{cont}} \right)^2 \times (t_1 + t_4) \text{ (seconds)} \quad \ldots\ldots\ldots \quad (8\text{-}4)$$

7. HOW TO FIND THE ORIENTATION TIME

The spindle orientation operation has two systems: the magnetic sensor system and position coder system. Find the orientation time from a stop for each system.

1) Magnetic sensor system



a) t_1

$$t_1 = \frac{J_L + J_M}{T_M} \times \frac{2\pi}{60} \text{Nori (sec)} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (10\text{-}1)$$

where: $\text{Nori} \leq N_b$ (= 1500 rpm)

b) t_2

$$t_{2max} = \frac{1}{\frac{\text{Nori}}{60}} \text{ (sec)} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (10\text{-}2)$$

In this period, the spindle rotates a maximum of one revolution.

$$\text{Nori} = 55 \times K_p \text{ (rpm)} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (10\text{-}3)$$

Where, position gain K_p is nearly 5 to 30 for the spindle. For a machine with compact models 1, 2, approx. 30 may be available for K_p; however, K_p is normally 5 to 15.

c) $t_{31} + t_{33}$

$$t_{31} + t_{33} \simeq \frac{3}{K_p} \text{ (sec)} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (10\text{-}4)$$

d) t_{32}

For stable control, set this time as follows.

$$t_{32max} = 0.2 \text{ (sec)} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (10\text{-}5)$$

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e) t_4

The motor operates for nearly the following time before it nearly stops after the orientation end signal is given.

$$t_4 = \frac{2}{K_p} \text{ (sec)} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(10-6)}$$

Ex: When position gain $K_p = 5$, the orientation time t_{ori} is as follows at load inertia $J_L = 0.0022$ kg.m.s^2 for model 3.

1) $t_1 = \frac{J_L + J_M}{T_M} = \frac{0.0022 + 0.0022}{0.71} \times \frac{2\pi}{60} \times 55 \times 5 = 0.18$ sec

2) $t_{2max} = \frac{1}{\frac{Nori}{60}} = \frac{60}{55 \times 5} = 0.22$ sec

3) $t_{31} + t_{33} = 0.6$ sec

4) $t_{32} = 0.2$ sec

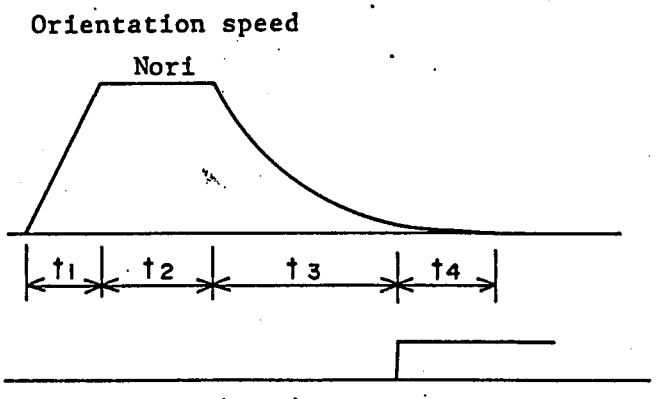
5) $t_4 = 0.4$ sec

$t_{ori} = t_1 + t_{2max} + t_{31} + t_{33} + t_{32} + t_4 = 1.6$ sec

The time when the orientation end signal is issued is $t_{ori} = 1.2$ sec.

Also, the orientation time during rotation is the deceleration time plus $(t_{2max} + t_{31} + t_{33} + t_{32} + t_4)$.

2) Position coder system



Orientation end signal (ORAR)

1) t_1

$$t_1 = \frac{J_L + J_M}{T_M} \times \frac{2\pi}{60} \times \text{Nori (sec)} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \text{(10-7)}$$

2) t_2

$$t_{2max} = \frac{2}{\frac{Nori}{60}}$$

Note) The motor gives 2 turns maximum.

$$Nori = 30 \times K_p$$

Position gain K_p is 5 to 30, and normally 5 to 15.

3) t_3

$$t_3 = \frac{3}{K_p} \text{ (sec)}$$

4) t_4

$$t_4 = \frac{2}{K_p} \text{ (sec)}$$

$$t_{ori} = t_1 + t_{2max} + t_3 + t_4$$

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