# Instruction Manual

## for

## Electro-Hydraulic Steering Gear

## (RE & FE Series)

①

Read and keep this Instruction Manual & Finished Plan.


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**(Drawing No. : 00905081F-1)**

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# SAFETY PRECAUTIONS

Before you use the product, you SHALL read this instruction manual and SHALL fully understand how to use the products. You SHALL also observe the related regulations and rules regarding safety. To use the product safely, you SHALL carefully read all Warnings and Cautions in this instruction manual.

 Danger : indicates an imminently hazardous situation which, if not avoided, will result in death, serious injury or serious accident.

 Warning : indicates a potentially hazardous situation which, if not avoided, could result in death, serious injury or serious accident.

 Caution : indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.

 Notice : signs used to indicate a statement of company policy directly or indirectly related to the safety of personnel or protection of property.

## [1] Warnings and Cautions related to operation

| | | |
|---|---|---|
|  | WARNING | ***This product(part) is designed and manufactured in accordance with the specifications of this ship, so it is impossible to change specification after delivered or to equip other ships.*** |
|  | WARNING | ***Never operate the product(part) after you have alcoholic drink or drug.*** |
|  | WARNING | ***Operate the hydraulic pump and valves in accordance with the instruction plate, otherwise the ship can lose the steering capability causing serious accident.*** |
|  | CAUTION | ***Do not step on the product(part), hit it, drop it, and give strong outside force to it, as one of these actions may cause the failure of work, damage, or oil leakage.*** |
|  | CAUTION | ***Use the safety equipment to avoid injury when you operate the product(part).*** |
|  | CAUTION | ***Pay enough attention on handling method to avoid pinching hands or back problems that may be caused by heavy weight of the product(part) or handling posture.*** |
|  | CAUTION | ***Wipe the oil on the floor off completely, as the oil creates slippery conditions that may result in injuring.*** |
|  | NOTICE | ***Keep the product(part) from dust and rust and pay the attention to the surrounding temperature and humidity when you transport or store the product(part).*** |
|  | NOTICE | ***Replacing the seals may be required if you use the product(part) after long time storage.*** |

## [2] Warnings and Cautions related to installation and removal of the product(part)

| | | |
|---|---|---|
|  | DANGER | ***Turn off the power before starting wiring or other works related to the electric power, otherwise you can be stuck by an electric shock.*** |
|  | WARNING | ***Installation, removal, piping and wiring shall be done by the certified person.*** |
|  | WARNING | ***Make it sure that the power of the hydraulic power unit is turned off and that the electric motor has completely stopped before starting installation or removal. You must also check the system pressure has dropped to zero.*** |
|  | CAUTION | ***Use the specified bolts and keep the specified tightening torque when you install the product(part). Usage of unauthorized bolts, lack of torque, or excess of torque may create problems such as failure of work, damage and oil leakage.*** |
|  | CAUTION | ***Clean the threads and mounting surface completely, otherwise you may experience damages or oil leakage caused by insufficient tightening torque, broken seal.*** |

## [3] Warnings and Cautions for operation

| | | |
|---|---|---|
|  | DANGER | ***Keep your body off the rotating or moving part such as electric motor, actuator or connecting rod, otherwise it may result in death or serious injury.*** |
|  | WARNING | ***Investigate the cause immediately if you find something wrong such as unusual noise, oil leakage and smoke, and fix it properly, otherwise you may encounter damage, fire, or injury.*** |
|  | WARNING | ***Use the proper working oil, and maintain the contamination, otherwise it may not work or be damaged.*** |
|  | WARNING | ***Use the product under the specification mentioned in the drawings and the specification sheet.*** |
|  | CAUTION | ***Make it sure that piping and wiring are correct and all the connection is tightened correctly before start operating, especially if it is the first run. Otherwise you may experience injury.*** |
|  | CAUTION | ***Keep your body off the product during the operations as it may become hot, in order to avoid a burn.*** |

## [4] Warnings related to maintenance

| | | |
|---|---|---|
|  | WARNING | ***Make it sure that the ship is safety condition such as at anchoring or at dock before starting maintenance, check or repair.*** |
|  | WARNING | ***Never modify the product.*** |
|  | WARNING | ***Do not disassemble and assemble without approval by FLUTEK. It may cause troubles and failure, or it may not work as specified. If it is necessary by all means to disassemble and assemble, it shall be done by an authorized person.*** |

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# 1. General

FLUTEK-Kawasaki Electrical Pump Control (Continuous Control) Steering Gear is of the “Rapson slide type” construction and consists mainly of tiller, ram and ram pin, hydraulic cylinder, valves and piping, FLUTEK-Kawasaki axial piston pump and pump control unit.

The hydraulic pump is tilted and discharges the oil, through the control box and the pump control unit according to the order signal of rudder angle from the steering stand.

The ram thrust produced by the pressure oil is transmitted to the tiller arm through the ram pin and the roller bearings and converted to the torque of the tiller keyed to the rudder stock and then the rudder is moved.

The signal of the actual rudder angle is directly feed-backed to the steering stand by means of the repeat back unit, and when it coincides with the signal of the order rudder angle, the rudder stops.

Thus, in the control system of the Electrical Pump Control (Continuous Control) Steering Gear, the actual rudder angle is directly compared with the order rudder angle and the deviation signal between order and actual rudder angles controls directly the tilting angle of the hydraulic pump.

Therefore the steering gear can obtain the very fast response and the accurate rudder angle, and the ship can keep her heading correctly with a less steering order.

This improves the propulsion efficiency remarkably and consequently can save fuel consumption of the main engine highly.

One or two sets of the hydraulic pump and electric motor are provided and have enough capacity to operate the rudder within the time required by the classification society.

For the specifications of the steering gear, refer to the PARTICULARS of the separate volume.

For the general arrangement and the hydraulic circuit, refer to the drawings of ARRANGEMENT and HYDRAULIC CIRCUIT of the separate volume.

# 2. Detailed description of main parts

## 2.1 Steering gear

2.1.1 Tiller : (Fig. 1)

The tiller made of cast steel, designed and manufactured according to the requirements of classification society is fixed to the rudder stock with the key. On the fork typed openings of the tiller, the hardened steel plates are bolted and they contact directly with the roller bearing of the ram. According as the roller bearing rotates on this surface, the linear movement of the ram is converted to the circular motion of the tiller.

2.1.2 Ram and hydraulic cylinder : (Fig. 1 & 2)

(1) The ram is made of carbon steel for mechanical structural use, and the hydraulic cylinder of nodular cast iron.

(2) The ram pin is incorporated into the center of the ram whose surface has been finished with high accuracy, and the rotatory roller bearings (1121) are fitted into the upper and lower parts of the ram pin and contact directly with the fork typed openings of the tiller arm. The ram thrust is transmitted to the tiller through the ram pin.
Therefore, the ram pin is subjected to a strong force, but this can be dealt with by employing the material of high tensile strength.
The oilless metal is fitted in the bore of the roller bearing and minimize the rotational friction between the ram pin and the roller bearing.
And also lubrication with oil on the bearing is unnecessary.

(3) Four (or two) hydraulic cylinders that move the two (or one) sets of ram are securely installed on the bed plate of the hull.
A pair of opposed hydraulic cylinders is connected with the ram guide bar (1222) and a pair of parallel hydraulic cylinders (in case of four cylinders) is connected with the connecting bracket (1231).
The hydraulic pump unit and the electric motor are installed on the hydraulic cylinders.
Inside of the each hydraulic cylinder, neck bushing (1205) is provided, supports the ram and withstands the perpendicular component force of the ram.
Five V-packings (1210) are also provided inside of the each hydraulic cylinder for

preventing oil leakage.

The packings are tightened by the adapters (1211,1212) and the packing gland (1206), and have superior sealing effect.

The rudder movement is indicated by the rudder angle indicator plate (4002) fitted between opposed hydraulic cylinders.

The max. turning angle is limited by the rudder angle limit switches at about 36.2 degrees although the max. working angle is 35 degrees.

And also the rudder movement is mechanically restricted by the stopper plug (1213) at the bottom of hydraulic cylinder (about 37 degrees).

2.1.3 Oil tank : (Fig. 3)

The oil tank is made of cast iron and mounted on the hydraulic cylinder.

Inside of the tank, the hydraulic pump, linkage necessary for tilting the pump cylinder and pipes are installed, and outside of the tank, pump control unit, servo pump unit and valve unit are mounted.

The oil filler with air breather, oil filter, oil level gauge, oil level switch, thermometer, drain plug etc. are also provided on the tank.

2.1.4 Oil block valve : (Fig. 4, 5 & 6)

(1) Function

Starting up one pump only provided that two or more pumps are installed and also piping connection is ready for parallel running of the pumps, delivered pressure oil from the running pump will not actuate ram, but merely drive the idle pumps in their reverse direction.

The oil block valve is a provision for preventing reverse driving of the idle pump.

The oil block valve consists mainly of main spool, spring and valve casing having ports AV, BV, AC, BC.

(2) Operation : (Fig. 5)

Right oil block valve :

As the solenoid control valve is energized, pressure oil delivered from running pump reaches the right end of main spool through a hole of valve casing, moves the main spool to the left against spring and pass AV/AC and BV/BC are opened. Then the pressure oil from pump is distributed to the hydraulic cylinders and actuates on the ram.

Left oil block valve :

As the solenoid control valve is de-energized, no pressure oil is supplied to the right end of main spool and valve is in the position where ports AV and BV are by-passed and AC and BC is closed as shown in the left figure.

So pressure oil from running pump as well as hydraulic cylinders is stopped at the valve and no pressure oil is applied on idling pump.

Idling pump, therefore, will not be driven in its reverse direction.

The solenoid control valve is energized after a few second later than the starting of electric motor (after the electric motor reaches the rated revolution) by means of timer. Therefore electric motor can be started under low load condition due to the pressure oil from cylinder being not applied on the pump.

Also the solenoid control valve has the following functions in the Electrical Pump Control (Continuous Control) Steering Gear :

① At the operation of rudder limiter, steering gear can be instantaneously stopped by being “OFF” condition.

② At the failure of control source, steering gear can be automatically stopped by being “OFF” condition.

As well as the main spool and spring, the safety valve, the spring loaded check valve for replenishing the hydraulic cylinder are integrally mounted on the valve casing and the OB valve is installed outside of oil tank as a part of valve unit.

## 2.2 Hydraulic pump

2.2.1 Construction and name of parts : (Fig. 8)

The hydraulic pump is a variable displacement axial piston type, available up to a high pressure of 39.2 MPa {400 kgf/cm$^2$}, compact and light, and shows high volumetric and mechanical efficiencies without influenced by pressure range.

The pump is installed inside of the oil tank by means of the bolted flange and direct-coupled through the flexible coupling to the electric motor outside of the oil tank.

The pump consists mainly of the cylinder (151) fitted in the cylinder casing (202), the seven piston sub (NO. 123-piston, NO. 121-connecting rod, etc.) being in reciprocating motion in seven bores of the cylinder, the driving shaft sub-group which transmits power to the pump, the bearings which support the driving shaft, the bearing casing (201), the front cover (251) in which oil seal (103) is provided, the valve cover sub-group.

The cylinder (151) is guided by the center rod (161) and rotated on the valve plate (171) fitted on the valve cover (253). As contact surfaces of the cylinder and the valve plate are of the spherical construction, self-centering can be obtained when the cylinder is rotated.

The driving shaft (101) is supported by the bearing casing (201) through the roller bearing (104) and tapered roller bearing (111).

The cylinder casing (202) is supported by the two needle roller bearings(205).

The cylinder casing (202) together with the cylinder (151), therefore, can be tilted around the axis of the needle roller bearings (205) by moving the pin of the cylinder casing by means of pump control unit.

Rotating motion of the driving shaft (101) actuated by an electric motor is transmitted to the cylinder (151) through the connecting rod (121), the cylinder (151) is accordingly rotated around its center in the synchronous speed of the driving shaft (101).

In the case the cylinder (151) is located in the oblique position against the driving shaft centre, the piston (123) reciprocates in the cylinder bore relatively to the cylinder.

The valve plate (171) having a suction-and a delivery-port to change over oil with the reciprocating motion of the piston is provided between the cylinder (151) and the valve cover (253). The valve plate (171) and the cylinder (151) are in optimum hydraulic balance during pump running.

Oil to be delivered from and sucked in the pump cylinder passes through the passages in the valve cover (253), the cylinder casing (202) and the pipe flange (254), then it is transferred to the pipe outside of the pump.

Suction valve unit (No.280-suction valve cover, No.281-poppet, No.283-spring etc) serves for replenishing oil automatically from the oil tank during pump running.

2.2.2 Principle of operation : (Fig. 9)

The driving shaft (101) of the pump is driven by the electric motor through the flexible coupling.

Rotating motion of the shaft is thereafter transmitted to the cylinder through the piston sub as described in foregoing sub-section.

Referring to the sectional views of the pump in Fig. 9, principle of pumping action is illustrated.

Middle and bottom of the right figures are the sections perpendicular to the left figure, and direction of rotation is assumed as clockwise viewed from the shaft end.

In the case that the tilting angle of the cylinder is equal to zero, i.e. the axis of the cylinder aligns with that of the driving shaft as shown in top and middle figures, any relative motion between the piston and the cylinder bore with pump rotation will not occur, no oil will consequently delivered. No delivery from the pump with its rotation as described above is called as neutral.

In the case that the cylinder is tilted around its tilting axis as shown in the bottom figure, the pistons below X-Y line are going to withdraw from the bottom of the cylinder bore with

their clockwise rotation and suck oil through the port “b” of the valve plate, and the pistons above X-Y line are going to approach to the bottom of the cylinder bore and discharge oil through the port “a” of the valve plate.

Displacement per revolution depends on the tilting angle of the cylinder from its neutral position and reaches its maximum value at the tilting angle of 27 degrees (the maximum tilting angle is adjusted according to the type of steering gear).

If the cylinder is tilted to the reverse direction of the bottom figure, the reverse action of the pistons relative to the cylinder bore will take place, accordingly the pistons below X-Y line will discharge oil through the port “b” and the pistons above X-Y line will suck oil through the port “a”. Such being the case, direction of flow can be changed without altering the direction of rotation of the driving shaft.

Relation of direction between oil flow and tilt of the cylinder is shown in the table.

The valve plate (171) in Fig. 8 having two ports “a” & “b” in Fig. 9 is of importance for changing over oil as well as preventing oil leakage through the cylinder end.

## 2.3 Continuous control system

### 2.3.1 Operation : (Fig. 11 & 12)

The signal of order rudder angle is compared with the feed-back signal of actual rudder angle at the steering stand and its deviation signal is transformed into the pump control signal in the control box.

By this signal, the torque motor is driven and the hydraulic pump is tilted through the hydraulic regulator. The oil is consequently discharged from the hydraulic pump and applied to the hydraulic cylinder, and the tiller will be rotated through the ram and the ram pin.

The torque motor is stopped when the pump tilting angle reaches that corresponding to the pump control signal because the electric signal of pump tilting angle is feed-backed to the control box by the differential transformer (LVDT) in the pump control unit.

In proportion as the actual rudder angle nears to the order angle, the hydraulic pump returns to neutral position due to the reverse rotation of torque motor and the tiller stops when the actual rudder angle coincides with order angle and oil is not discharged from the hydraulic pump because the electric signal of actual rudder angle is feed-backed to the steering stand by the repeat back unit.

2.3.2 Construction :

(1) Control box :

This box is supplied by the autopilot manufacturer in order to transform the deviation signal from the steering stand into the pump control signal and drive the torque motor. It also controls the solenoid control valve when the rudder angle limiter is operated.

(2) Pump control unit : (Fig. 13)

This unit consists of hydraulic regulator, torque motor and pump tilting angle indicator plate, differential transformer (LVDT).

The pump control signal from control box drives the torque motor and the hydraulic pump is continuously controlled through the hydraulic regulator.

The differential transformer (LVDT) is also provided in order to feed-back the electric signal of the pump tilting angle to the control box.

The pump control knob for local steering is usually mounted on the pump control unit and used when the autopilot system is failed or steering gear is adjusted.

(2.1) Hydraulic regulator : (Fig. 13)

The pilot spool (202) of the hydraulic regulator is moved by the torque motor (101). The servo piston (403) connected to the cylinder casing of hydraulic pump is also

moved by the help of pressure oil generated from the servo pump and the oil is discharged from the hydraulic pump.

Operation of regulator is explained by referring to Fig.12.

The rotor shaft of torque motor is connected to the pilot spool (202) and rotational movement is converted to the stroke of spool.

The servo piston (403) is also connected to the tilting pin of pump and the movement of piston is transmitted to the pump.

While, the servo piston (403) is connected to the feed-back sleeve (203) through feed-back lever (303) and the stroke of piston is feed-backed to the feed-back sleeve.

When the pilot spool (202) is controlled to “pushing in” direction (rightward in the figure), pressure oil from servo pump is lead into the chamber A (oil passage from “a” to “b” is closed). The chamber B is opened to the drain through oil passage “b” to “c”. Accordingly the servo piston (403) moves rightward and stops at the position where the feed-back sleeve (203) closes the oil passage “b” to the drain, that is, the servo piston stops at the position corresponding to the stroke of pilot spool (202).

Servo piston (403) tilts the pump in the same direction and by the same angle in accordance with the movement of pilot spool (202).

When the pilot spool (202) is controlled to “pulling out” direct-ion (leftward in the figure), pressure oil is lead into both chamber A and B. As pressure receiving area of chamber B is larger than that of A, servo piston (403) moves leftward and stops at the position where the pilot spool stops. At that position the oil passage from “c” to the drain opens to chamber B and the oil passage from “a” to “b” is closed.

Servo piston (403) tilts the pump in the same direction and by the same angle in accordance with the movement of pilot spool.

Also the spring (207 & 208) is provided in order to keep the pump at neutral position (Tilting angle 0 degree) when no force is given to the pilot spool (202). This spring

returns the pilot spool (202) to the neutral position when the control source of torque motor is failed and the pump also returns to neutral position.

Note : Neutral position has been adjusted and set the adjusting pin (302) before delivery. Do not attempt to adjust the regulator at field.

(2.2) Torque motor (Fig. 15)

Torque motor is provided in order to control the pilot spool and consists mainly of the frame (1) where the stator (11) is mounted, the rotor with the spider (13) and magnet (12) fixed to the rotor shaft, the stopper with lever (3) and bolt (7), the name plate (5) with pump tilting angle indicator etc. and installed on the casing of hydraulic regulator.

(2.3) Differential Transformer LVDT (Fig. 16)

LVDT is provided in order to detect the movement of pilot spool and feed-back the electric signal of the pump tilting angle to the control box.

LVDT consists of the case (2) with coil (9), the spindle (11) and core (10) connected to the pilot spool of regulator etc. and is mounted on the casing of regulator.

(3) Servo pump unit (Fig. 17)

Servo Pump Unit is provided in order to supply the pressure oil to hydraulic regulator and OB valve and mounted on the oil tank.

The servo pump is coupled to the electric motor through flexible coupling and started before main pump/motor.

(4) Relief valve for servo pump (Fig. 18)

Relief valve is mounted on the manifold of valve unit in order to adjust the servo pressure. Adjusting pressure is 1.8 - 2.0 MPa {18-20kgf/cm$^2$} and set before delivery.

(5) Line filter (Fig. 19)

The working oil flowed from the inlet of the filter by the servo pump is filtered while passing through the filter element from inside to outside and reaches the outlet, then

actuates the hydraulic regulator and OB valve.

The filter consists of the filter head (1) with an visual indicator (8) & by pass valve (relief valve) (11), filter case (2), filter element (5), etc.

(5.1) Indicator

During the filtration, the filtering surface is contaminated by the accumulated dirt in the oil and the differential pressure between the inlet and the outlet is increased, which causes a bad effect on the servo pump and hydraulic equipments. So the indicator is provided in order to know the degree of clogging condition (differential pressure) beforehand.

When the indicator ring (red) is floated up to the white level in the column (highest position), the differential pressure is 0.2 MPa {2kgf/cm$^2$}. In this case, the filter element (5) must be cleaned or replaced.

However it will be desirable to clean when the ring reaches the middle position in height (the differential pressure is 0.1 MPa {1kgf/cm$^2$}) since after then the ring will reach the top position comparatively in short time.

(5.2) By-pass valve (Relief valve)

When the filter element (5) is not cleaned although the indicator shows the clogging condition (highest position), the element (5) may be damaged since the pressure on element (5) is increased due to the less of allowable flow. The by-pass valve (11) is provided in order to prevent the damage of hydraulic equipments, and the valve is operated when the differential pressure is 0.29~0.31 MPa {3.0~3.2kgf/cm$^2$}, then a part of flow reaches the outlet directly without passing through the element (5).

(6) Repeat back unit

This unit is connected mechanically to the tiller in order to feed-back the electric signal

of actual rudder angle to the steering stand.

This unit is supplied by the autopilot manufacturer.

(7) Rudder angle limiter

Rudder angle limiter is provided in order to stop the movement of steering gear instantaneously by cancelling the electric signal to torque motor and de-energizing the solenoid valve consequently OB valve is unloaded when the steering gear will be moved by any reason over than the max. working angle (35 degrees on each side).

The limit switches are mounted between opposed hydraulic cylinders and operated by the movement of ram.

# 3. Instructions for installation

The steering gear will be shipped in sub-assembly groups.

In this case, special care should be taken to keep safe from injuring every parts, in particular the sliding surfaces of tiller, ram, ram pin, roller bearing and the gauges.

The tiller is usually installed on the rudder stock before launching. The hydraulic cylinders are then installed on the bed plate of the hull. The installation of the important components such as cylinder etc. should require centering adjustment and facing-up with the liner put on the bed plate.

For smooth operation and correct rudder angle, the installation should be strictly carried out in accordance with the relative positions and dimensions of each parts. For easy installation, the main component parts which go together are applied with match marks and knock-pin holes before being dismantled and despatched from our works.

The hydraulic cylinder is securely bolted to the bed plate and each cylinder foot is provided with the thrust receiver (stopper and cotter).

The hydraulic pipes are shipped after bending and cleaning (by pickling, flushing and corrosion preventing) of pipes are carried out and each flange is applied with blind plugs at our works.

Prior to filling with oil, check thoroughly the cleanliness inside the oil tank, hydraulic cylinder etc.

Until the basin trial of the steering gear, cover the surface of the ram with cloths for preventing the adhesion of slag and impurities.

Since the steering gear room is especially subjected to hard vibration, each bolt is applied with stoppers for preventing looseness and the hydraulic pipe is secured to the steering gear bed plate by pipe bands.

When the installed steering gear is painted aboard ship, care should be taken that machined sliding surfaces are not painted over but rather coated with lubricant or grease for preventing paint adhesion.

# 4. Instruction for adjustment

When satisfied that the tiller, ram, hydraulic cylinder, oil tank, electric motor, valves, pipes, repeat back unit etc. are correctly positioned, make operational preparation and adjustment in the following manners.

## 4.1 Preparation :

4.1.1 Wiring :

Connect the electrical parts of control box, steering gear terminal box to which torque motor and LVDT are connected, solenoid controlled valve, rudder angle limiter, repeat back unit etc. in accordance with the instruction manual of autopilot manufacturer.

4.1.2 Working oil and filling

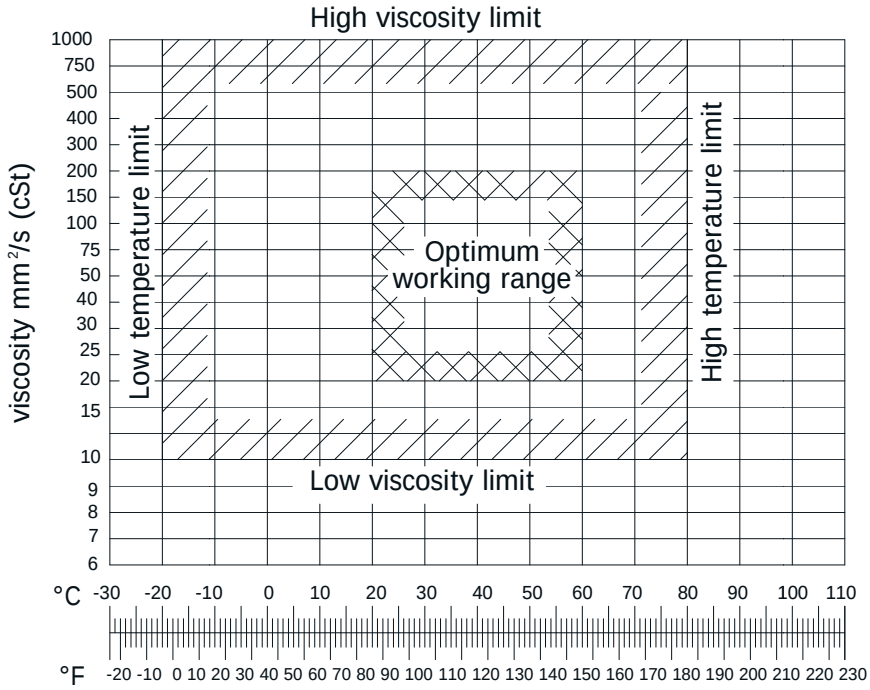
(1) Working oil :

The working oil applicable should be pure mineral oil. Use of vegetable oil is strictly prohibited because the pump function is spoiled due to deposits.

The highly viscous hydraulic oil which has additions of antifoaming agent, anticorrosive agent etc. is generally recommended for working oil.

The suitable range of viscosity is 10 cSt ~ 1000 cSt and the range of the operating temperature is limited to -20℃ ~ 80 ℃ due to oil seal, 0-ring etc. Further, as the deterioration of oil becomes excessive beyond 65 ℃, it is desirable not to exceed 60℃.

<suitable range of viscosity and temperature>




The hydraulic oil having the following properties has widely used for the steering gear and is recommendable for working oil.

| Grade (Viscosity grade) | Kinematic viscosity $mm^2/s$ {cSt} (at 40℃) | Viscosity index | Flash point ℃ | Pour Point ℃ |
|---|---|---|---|---|
| ISO VG68 | 61.2 to 74.8 incl. | Min. 95 | Min. 200 | Max. -20 |
| ISO VG56 | Over 50.6 to 61.2 excl. | | | |

Caution :

1. The oil must be dealt with carefully not to allow dust and other impurities to mix.
2. No oil mixture of different brands shall be allowed by any means.
3. The working oil for the use especially in cold regions shall be asked to the oil maker and our works.

Necessary quantity of the oil is indicated in the drawing of ARRANGEMENT.

(2) Filling hydraulic system with working oil :

When working oil is filled in hydraulic system, a filter of 200 mesh or over should be applied for preventing foreign matters and dust.

* Fill the hydraulic cylinder with oil little by little through the oil filler at the upper part of hydraulic cylinder. In this case, air vent valve and cylinder stop valve should be thoroughly opened.
* Fill the oil tank with oil through the upper filler up to the visible upper limit of the oil level gauge.

4.1.3 Application of lubricating oil and grease :

Since the roller bearing and each joint portion of the steering gear are provided with oilless bearing and oil-impregnated metals respectively, it is not necessary to lubricate with oil or grease in normal cases.

However application of oil or grease is required at installation for rust prevention.

* Apply grease to the sliding parts of the lever.
* Fully apply working oil to the ram surface.
* Slightly apply grease for rust prevention to other machined surfaces (especially to the roller bearing, hardened steel plate and ram guide bar).

4.1.4 Centering of hydraulic pump and electric motor : (Fig. 20)

Poor centering will cause over-heating, wear, noises and vibration of the bearing of hydraulic pump and electric motor, oil leak from the oil seal, wear of the coupling etc. Correct centering should be checked in the following manners.

(1) Parallel error :

As shown in Fig. 20, keep a suitable clearance between the coupling faces, install a dial gauge on the coupling of the electric motor and let touch its pointer to the coupling of the pump.

(2) Inclination Error :

Measurement will be performed as mentioned above, however touch the dial gauge pointer to the point near the outer face of the coupling of the pump.

The permissible tolerances of the parallel error and inclination error shall be adjusted within the range shown in Fig. 20.

4.1.5 Inserting of ram V-packing : (Fig. 23)

The Ram V-packings are inserted at delivery from our works.

If not, it is necessary to insert them before the ram is moved.

After the confirmation that the ram and packing gland involve no dust and impurities, fit the packings.

The detailed inserting method is referred to item 6.4.

## 4.2 Adjustment :

After the preparation of each part has been finished, operation and adjustment will take place by means of the pump control knob in the steering gear room.

Clean each sliding surface carefully, open the stop valve and close the air vent valve.

4.2.1 Electric motor starting :

In the first place disconnect the control box from electrical power.

Before starting the electric motor, rotate the hydraulic pump by hand (5～10 turns) to circulate hydraulic oil in each part of the hydraulic pump.

After confirmation of the pump tilting angle being roughly in neutral by means of the tilting angle indicator plate of the pump control unit, start the electric motor.

Confirm the rotating direction of hydraulic pump and check for oil leakage from the front cover of pump and abnormal vibration.

(The rotating direction is indicated in the drawing of ARRANGEMENT and on the bodies of oil tank and electric motor.)

4.2.2 Adjustment of servo pressure : (Fig. 4 & 18)

The servo pressure supplying to the hydraulic regulator should be adjusted to 1.8 ~ 2.0 MPa {18~20 kgf/cm$^2$} (the green-colored range on the dial plate of the pressure gauge)

by the relief valve mounted on the manifold of valve unit.

However it is unnecessary to re-adjust the servo pressure onboard, since it has been adjusted at our works.

If the adjusted pressure should be the different value from the above at a daily check, adjust it according to the following procedure.

Remove the cap nut (3-10), loosen the lock nut (3-6), and adjust the pressure by turning the adjusting screw (3-2).

Turn the screw clockwise, and the pressure rises, and vice versa.

After the adjustment, tighten the lock nut securely. (For the sectional arrangement of the relief valve, refer to Fig. 4 & 18

4.2.3 Air release of Hydraulic regulator : (Fig. 13)

Residual air in the servo piston cylinder of the hydraulic regulator should be released through the air vent plug fitted on top of flange (409).

Open the air vent plug, and turn the pump control knob to the right and left alternately until the bubbles does not come out.

4.2.4 Adjustment of pump neutral position :

The pump neutral position is adjusted before delivery and it need not to be re-adjusted on board. However if necessary, the pump neutral position can be adjusted in accordance with the following procedure such as the pump, the regulator, the torque motor, the LVDT etc. are re-assembled by any reason.

(1) Hydraulic pump

1. Stroke fully the tilting lever (Fig.3-1681) together with the pump to the direction of hydraulic regulator.
2. After installing the power lock (Fig.3-1741) at the end of servo piston (Fig.13-403), push the piston into the tilting lever.

   Then connect the piston and the lever by tightening the power lock (Tightening torque is listed in Fig.3).

3. By measuring the length between the end of piston and the casing of hydraulic regulator, put the pump in neutral position.
   (The length is listed in Fig.13.)

(2) Hydraulic regulator

1. Disconnect the control box from electric power. Push the manual button of the solenoid valve for unloading device and lock it by means of lock nut.
2. Start the electric motor.
3. If the ram is moved large, grab the adjusting pin (Fig.13-302) with large monkey spanner (about 300 mm), and turn to the right or left slightly to find where the ram stops. Adjust it in order that the ram movement is less than about 0.5 degrees/min. at the rudder angle of zero degree.
   Don't loosen set bolts (Fig.13- 316) of the adjusting pin before the adjustment.
4. If set bolts of the adjusting pin are loosened, tighten the three set bolts to 6.9 N·m {70 kgf·cm} uniformly by using torque wrench, then turn the adjusting pin to adjust to zero position.
   (Note) Set bolts (Fig.13- 316) must NOT be tightened after the adjustment of adjusting pin.

(3) Torque motor

1. Insert the rotor (Fig.15-12 and -13) into the rotor shaft (Fig.13-103).
2. Install the frame (Fig.15-1) without the name plate (Fig.15-5) so that its receptacle (Fig.15-6) becomes in the direction of port or starboard side.
3. Insert the clamp element (Fig.15-2) and flange (Fig.15-10) into the rotor. (Direction of rotor is referred to Fig.13.)
4. Put the stopper lever (Fig.15-3) on the flange and lock it with flange by means of bolt (Fig.15-4).
5. Fit the name plate and knob. (The direction is shown in Fig.13.)

(4) Differential transformer (LVDT)

1. Adjust the length so that the distance between the end of pilot spool (Fig.13-202) and the edge of core (Fig.16-10) is 89±0.2mm.

4.2.5 Air release in hydraulic system : (Fig. 21)

It is not enough to fill the hydraulic system with hydraulic oil at preparation (When the pump is tilted after starting, its abnormal noises prove that a great amount of air is still left in the system.) In order to expel air in the system, push the manual button of the solenoid control valve and lock it by lock nut and operate the steering gear slowly with the pump control knob to “Port” and “Starboard” sides alternately (up to near 30 degrees in both directions) and open the air vent valve on the upper part of the hydraulic cylinder of the pressure side (ram-drawing side).

Keep on doing this work until the intermittent movement of ram is finished and smooth movement begins.

In this case the hydraulic pump will be started one by one.

Care should be taken to the oil level of oil tank and replenish the working oil if necessary.

Note : 1. Don't open the air vent valve on the cylinder where ram is pressed.
If it will be opened, the air that has tried to expel will be sucked in again.
2. Before expelling the air, don't run the hydraulic pump for hours.

4.2.6 Adjustment of control box :

Since the control box is supplied by the auto-pilot manufacturer, refer to its instruction manual for its detail. The adjusting items are as follows.

(1) Zero adjustment

(2) Adjustment of maximum tilting angle of hydraulic pump

(3) Adjustment of proportional band

(4) Adjustment of rudder angle

4.2.7 Adjustment of maximum pump stroke : (Fig. 13 & Fig. 15)

Having finished adjustment of item 4.2.6 “Adjustment of Control Box”, adjust the position of the mechanical tilting stopper of the pump control unit.

Loosen the lock nut, set the bolt (Fig. 15-7) to the position 2~3mm from the maximum tilting position of the stopper lever (Fig. 15-3), and then tighten the lock nut.

This adjustment serves to limit the maximum tilting angle during the local steering.

Note : In this adjustment, prevent the stopper lever (Fig. 15-3) from striking this bolt (Fig. 15-7) during the normal steering without fail.

Also, during the local steering, don't strike the bolt (Fig.15-7) hardly with the lever.

4.2.8 Adjustment of rudder angle limiter :

Set the limit switch position of the rudder angle limiter at 36.2degrees. Confirm that the OB valve becomes unloaded (solenoid valve is de-energized), the hydraulic pump returns to its neutral position and the steering gear stops, when the actual rudder angle reaches this limited angle. Then give an order of the opposite side to confirm that the OB valve becomes again onloaded (solenoid valve is energized), the hydraulic pump is tilted, and the steering gear is moved.

And also limit the max. order rudder angle of auto pilot so that the max. actual rudder angle is about 35.5degrees.

4.2.9 Measurement and adjustment of rudder turning speed :

(1) Normal steering :

* The steering gear is tested to be capable of putting the rudder over from 35 degrees on either side to 30 degrees on the way to 35 degrees on the other side in 28 seconds with the vessel running ahead at max. speed.
* Correct adjustment has been finished before delivery from our works.

  If something unsatisfied with the requirement of classification society will be found, adjust the max. pump tilting angle again.
* For special requirements, adjustment has been made to satisfy its specifications.

(2) Emergency steering (in case of two pumps parallel running) :

The steering gear is tested to be capable of putting the rudder over from 15 degrees on either side to 15 degrees on the other side in 60seconds with the vessel running ahead at half speed or 7 knots (or 8 knots), whichever is greater. One pump is used in emergency steering.

4.2.10 Adjusting test of safety valve : (Fig. 22)

The safety valve limits the max. pressure of the hydraulic system and releases abnormal high pressure produced in the hydraulic system to protect the system against abnormal load acting on the rudder.

The adjusting pressure has been set at the adjusting pressure shown in PARTICULARS before delivery from our works. Re-adjustment is not required accordingly.

However, it is necessary to confirm the operation on board together with the pressure test of the hydraulic pipes, gaskets etc., whose procedures are as follows :

(1) Preparation :

The safety valve test will be carried out by means of the pump control knob (Local steering).

* Disconnect the control box from electrical power.
* Push the manual button of the solenoid control valve and lock it by means of lock nut.

Depending on the safety valve subject to confirmation, the hydraulic pump and the isolating valve or stop valve shall be operated as shown in Fig. 22.

(2) Safety valve operation :

* Start the electric motor and hydraulic pump and operate the steering gear by the pump control knob.
* When the rudder angle is over 35 degrees, move the rudder slowly.

Since the ram reaches the stopper at the bottom of the cylinder, the pressure will

rise.

Turn the handle then until the pump tilting angle comes near 1/2 of the design max. pump tilting angle. Under this condition, confirm the adjusting pressure of the safety valve by observing the movement of the pointer of the pressure gauge. (The adjusting pressure is marked with red on the dial plate of the pressure gauge.)

* The operation of the safety valve shall not exceed 30 seconds at a time because the electric motor may cause burning.

(3) Adjustment of safety valve :

If the adjusting pressure of the safety valve is different from the designed one, adjust it in the following manners :

The assembly section is shown in Fig. 6.

* Remove the safety valve cap nut (3-10) and loosen the lock nut (3-6).

* Adjust the pressure by turning the adjusting screw (3-2).

Pressure will rise if screw is turned to right and pressure will drop if turned to left.

* After the adjustment, fix the lock nut and put the cap nut as original.

When confirming the safety valve, check for oil leakage and abnormality in each part of the steering gear.

After finish of the test, put the stop valve, isolating valve, solenoid control valve, pump control knob etc. to the original condition.

# 5. Steering method

The steering gear can be operated by the following methods assuring correct and easy handling and changing :

(1) Automatic steering by remote control system in wheelhouse

(2) Hand steering by remote control system in wheelhouse

(Follow up control / Non-follow up control)

(3) Local steering in steering gear room (by the pump control knob)

## 5.1 Normal steering :

The normal steering is made by the above-mentioned method, (1) or (2).

For details, refer to the Instruction Manual of the autopilot maker because the contents are different depending upon the remote control system in the wheelhouse (bridge).

The steering gear can be operated with all hydraulic cylinders and combinations of hydraulic pumps in order to meet with the requirements of classification society.

Also changing-over of the hydraulic pump can be done by the remote control of electric motor.

The rudder angle can be freely controlled by the order signal of the remote control system from 35 degrees on either side to 35 degrees on the other side.

Precautions :

1. Correctly operate the hydraulic pump and valves in accordance with the instruction plate.

## 5.2 Local steering :

In failure of the control system in the wheelhouse (bridge) or during the adjustment operation of the steering gear, the steering gear can be operated by the pump control knob of pump control unit mounted on the oil tank in the steering gear room.

The steering gear is controlled by the following procedure.

(1) Preparation

(1.1) Disconnect the control box from electric power.

(1.2) Push the manual button of the solenoid control valve for unloading device and lock it by means of lock nut.

(2) Operate the steering gear by turning the pump control knob by watching the pump tilting angle indicator plate and rudder angle indicator plate.

(3) When the steering gear reaches the desired angle, release the pump control knob. The knob and the hydraulic pump will return to the neutral position and steering gear will stop automatically.

Precautions :

1. Correctly operate the hydraulic pump and the valves in accordance with the instruction plate.
2. Don't operate the steering gear over max. working angle (35 degrees) because the rudder angle limiter is not actuated in local steering.
3. Reduce the ship's speed to half of the max. service speed or 7 knots (or 8 knots) whichever is greater in case of the failure of pipings, and so on.

# 6. Instructions for maintenance

In order to ensure good operation and long life of the steering gear, following maintenance and checks should be carried out.

## 6.1 General notes :

(1) Filling hydraulic system with working oil :

Apply good grade mineral hydraulic oil or equivalent, and keep the working oil fully supplied into the hydraulic cylinder, oil tank, and piping system.

Any air in the hydraulic system will produce abnormal noises from the hydraulic pump and cause not only unstable rudder angle but also other troubles. In case of replenishing the working oil, use the oil of same brand.

(2) Correct operation of stop valve :

Correctly open and close the stop valve and isolating valve in accordance with the instruction plate.

* Air vent valve :

Never open the valves during the steering gear is operated. If not, it will cause the failure of steering.

* Safety valve :

Never touch the safety valve unreasonably because it has been correctly adjusted.

(3) Lubrication and rust prevention of each part :

Properly apply the lubricant on the ram surfaces and sliding levers.

Apply the grease on the part where is afraid of rust due to the environment.

(4) Pump starting :

* Start the hydraulic pump in neutral position as far as possible.

Starting up under a big eccentricity will have the possibility of causing the excessive current of the electric motor.

* Pay attention especially when the hydraulic pump is started at low temperature such as winter season (below 10℃ approx.).

After ensuring the oil temperature rises by keeping small eccentricity and steering small rudder angles, start the normal steering.

(5) Pump stop :

Stop the hydraulic pump after ensuring that the rudder angle is in neutral(zero) position.

(6) Pump operation at zero tilting angle :

Long-time operation of hydraulic pump at zero tilting angle at anchor should be avoided as far as possible.

If unavoidable, it should be limited within 24 hours, because this will be undesirable for the lubrication between cylinder and valve plate of the hydraulic pump.

(7) Check items :

Checks shall be carried out surely by referring to item 6.2 and 6.3.

Special care should be taken to the oil level and temperature of the oil tank, operating conditions of hydraulic pump and steering gear, tightness of bolts, oil leakage etc.

## 6.2 Check items :

| Period | Check items | Period | Check items |
|---|---|---|---|
| Daily | A-1 Oil quantity<br>A-2 Oil temperature<br>A-3 Cylinder pressure<br>A-4 Abnormal noises<br>A-5 Oil leakage<br>A-6 Current of electric motor<br>A-7 Servo pump pressure<br>A-8 Torque motor temperature | Before Voyage check | (1) Oil quantity<br>(2) Valve positions<br>(3) Oil temperature<br>(4) Lubrication of sliding parts<br>(5) Ram surface<br>(6) Pump neutral position<br>(7) Operating condition<br>(8) Air release |
| Weekly | B-1 General operating condition<br>B-2 Lubrication of sliding parts<br>B-3 Cleanliness of machined parts | Periodical Checks (at dock Or basin) | (1) Safety valve<br>(2) Rudder turning speed<br>(3) Coupling<br>(4) Clearance between tiller and roller<br>(5) Pressure gauge and thermometer<br>(6) Bolt, nut, pin and turnbuckle<br>(7) Ram V-packing<br>(8) Oil seal of pump control unit<br>(9) O-ring of pipe joints<br>(10) Gasket packing<br>(11) Cylinder bottom packing<br>(12) Pump control unit<br>(13) Electric motor<br>(14) Working oil<br>(15) Tank cleaning<br>(16) Line filter cleaning<br>(17) Hydraulic pump<br>(18) Air release |
| Monthly | C-1 Ram V-packing<br>C-2 Air vent valve<br>C-3 Stop valve and isolating valve<br>C-4 Oil seal of pump control unit | | |
| Quarterly | D-1 Bolt, nut, pin<br>D-2 Turnbuckle<br>D-3 Coupling<br>D-4 Oil level switch<br>D-5 Line filter | | |
| Semi-yearly | E-1 Slide plate of ram guide bar<br>E-2 Working oil-visual check | | |
| Yearly | F-1 General function and appearance<br>F-2 Working oil-property inspection | | |

## 6.3 Detail of check items :

6.3.1 Normal checks :

Carry out the following checks whenever the ship is navigating or anchoring and take proper measures if necessary.

A) Daily checks :

A-1 Oil quantity in oil tank :

* Check the oil level in oil tank is within the visible range of the oil level gauge. If not, examine the cause, repair if necessary and refill oil tank with new clean oil.

A-2 Oil temperature in oil tank :

* Check the oil temperature in the oil tank by comparing with the normal data. Normally oil temperature will be within 30℃ plus room temperature. If it exceeds 80℃, stop the hydraulic pump and examine the cause.

A-3 Hydraulic cylinder pressure :

* Check the pressure of hydraulic cylinder by means of the pressure gauge by comparing with the normal data. If it is abnormally high, examine the cause.

A-4 Abnormal noises :

* Check its origin in the steering gear and examine the cause.

A-5 Oil leakage :

* Check for oil leakage from the oil tank, hydraulic cylinder, valves and pipe joints.

A-6 Current of electric motor :

* Check for excessive current of the electric motor.

A-7 Servo pump pressure

* Check the pressure of servo pump by means of the pressure gauge. Adjusting pressure is 1.8 ~ 2.0 MPa {18 ~ 20 kgf/cm$^2$}.

A-8 Torque motor temperature

* Check the temperature of torque motor, by comparing with the normal data. Normally temperature will be within 30℃ plus room temperature. If it exceeds

80℃, stop the torque motor and examine the cause.

B) Weekly checks :

B-1 General operating condition of steering gear :

* Check the steering gear is in normal operation. Expel air in its circuit, if necessary.

B-2 Lubrication of sliding parts :

* Lubricate the ram surface, tiller hardened steel plate, roller bearing and levers. Apply the ram surface with working oil and apply other surfaces with a light film of grease.

B-3 Cleanliness of machined parts :

* Make periodical cleaning and try to prevent rust by applying grease.

C) Monthly checks :

C-1 Ram V-packing :

* Check a light film of oil is produced on the ram surface.

Adjust the gap between packing gland and cylinder, if necessary.

C-2 Air vent valve :

* Check the valves are securely closed.

If not, tighten them hard up not to be loosened by vibration.

C-3 Isolating valve and stop valve :

* Check the valves are opened or closed correctly in accordance with the instruction plate. Tighten them hard up by means of lock nuts not to be loosened by vibration.

C-4 Oil seal of pump control unit :

* Check for oil leakage from the drain inspection ports provided at the foot of torque motor. Renew oil seal (Fig.13-109), if necessary.

D) Quarterly checks :

D-1 Bolt, nut and pin :

* Check the fixing condition of each bolt, nut, pin, pressure gauge and valves.

If loosen, tighten them evenly and hard up.

D-2 Turnbuckle :

* Check the nuts and lock washers for turnbuckle are tightened hard up.

D-3 Coupling :

* Exchange the grease in the chain coupling.

Turn off the power of electric motor and steering stand before starting the work.

First exchange : Within one month

Second exchange or more : Every three months

D-4 Oil level switch :

* Confirm that the alarm is given by pushing up the test bar of float switch mounted on the oil tank.

D-5 Line filter

* Check the clogging condition of filter by means of visual indicator. Wash the filter element, if necessary (Refer to item 6.5).

E) Semi-yearly checks :

E-1 Slide plate of ram guide Bar (white resin) :

* Check for any abnormal wear.

E-2 Working oil-visual check :

* Sample the working oil each from the hydraulic cylinder and oil tank. (Inspect it by visual check and if found abnormal, examine in detail.)

F) Yearly checks :

F-1 General function and appearance :

* Make a precision inspection if necessary, and repair or renew defective parts.

* Clean thoroughly.

F-2 Working oil-property inspection :

* Make a periodical property inspection of the working oil.

Sample about 1.0 lit. of working oil each from the hydraulic cylinder and the oil tank. Renew the working oil, if necessary. (Refer to item 6.3.4.)

6.3.2 Before voyage checks :

Check the followings before leaving the port.

(1) Oil quantity in oil tank :

* Check the oil level in oil tank is within the range of the oil level gauge.

(2) Valve positions :

* Check the valves are opened or closed correctly in accordance with the instruction plate.

(3) Oil temperature in oil tank :

* Check the thermometer is not damaged.

* Check the oil temperature is within proper range. (about 10℃ to 60℃).

(4) Lubrication of sliding parts :

* Check the lubricating condition of each sliding part. Check for any rust.

(5) Ram surface :

* Check for excessive leakage from the Ram V-packing.

The ram surface will be cleaned thoroughly.

(6) Pump neutral position :

* Start the hydraulic pump one by one and confirm that ram does not move large by non-follow up steering mode in no-load condition.

* If it moves 0.5 degrees/min. or more, adjust by referring to Item 4.2.4.

(7) Operating condition :

* Check the rudder moves correctly by the order signal from the wheelhouse (bridge) and the actual angle agrees with the order angle.

(8) Air release in hydraulic system :

* Expel air in the hydraulic system.

6.3.3 Periodical checks (at dock or basin) :

While the ship is at dock, periodical checks should be carried out where cannot be

examined fully at normal checks. Check in detail where found impropriety at normal check and repair if necessary.

(1) Safety valve :

* Check the safety valves are set at adjusting pressure. (The adjusting pressure is marked with red on the dial plate of the pressure gauge.)
* If not set, re-adjust it (Refer to item 4.2.10).
* When testing, check for oil leakage from the seal.

(2) Rudder turning speed :

* Examine the rudder turning speed at basin trial and confirm the rudder can be moves from 35 degrees on either side to 30 degrees on the other side within 28 seconds (except for special requirements).
* Check there is no large difference between the above data and the trial data.

(3) Coupling :

* Check the errors of centering are within the standard value by measuring the centering of couplings with the dial gauge (Refer to Fig. 20).
  If exceeding the standard value, re-adjust it by referring to item 4.1.4.

(4) Clearance between tiller and roller bearing :

* Check the clearance between hardened steel plate and roller bearing is within the permissible value.
  If not, adjust with the liner or replace the hardened steel plate.
* The permissible value of clearance : 0.5mm

(5) Pressure gauge and thermometer :

* Check for normality.
* Repair or replace if necessary.

(6) Bolt, nut, pin and turnbuckle :

* Check the tightness of all bolts, nuts, turnbuckles and also check for wear of the pins.

* Tighten additionally or repair if necessary.

(7) Ram V-packing :

* Replacement of packing is not required when there is no oil leakage from the packing gland under the condition that packing gland can be tightened and there is a light film on the ram surface.
* Even if oil leakage is not observed, it is desirable to renew it about every five years.

(8) Oil seal of pump control unit (Pump Regulator) :

* If oil leakage is observed from the drain inspection ports provided at the foot of torque motor, renew oil seal.
* Even if oil leakage is not observed, it is desirable to renew oil seal about every five years.

(9) O-ring of pipe joints :

* If oil leakage is observed, renew it.
* Even if oil leakage is not observed, it is desirable to renew it about every five years.
* If the back-up ring is not damaged, it can be further used as it is.

(10) Gasket packing :

* If oil leakage is observed, renew it.
* If sufficient thickness is kept and damage is not observed, the packing may be used as it is by tightening additionally.

(11) Cylinder-bottom packing : (Fig. 2)

* If oil leakage is observed, tighten the packing additionally.

  If oil leakage is not stopped, tighten it again by touching the ram to the plug and raising the pressure up to the adjusting pressure of the safety valve.

Caution :

This packing has been installed inside of the hydraulic cylinder. Therefore the packing cannot be renewed unless the ram is drawn out.

(12) Pump control unit :

* Check that the stopper is adjusted to the position of the max. pump tilting angle plus 2 ~ 3mm. Refer to Item 4.2.7.

(13) Electric Motor :

* Measure insulation resistance between stator coil and frame (more than 10 MΩ). If found faulty, repair or replace the electric motor.
* It is desirable to renew the bearing of the electric motor for servo pump about every three years.

(14) Working oil :

* Sample the oil each from the oil tank and the hydraulic cylinder and make a property analysis.
* Whenever the oil reaches the renewal standard, renew it with new one.

(15) Tank cleaning :

* Clean thoroughly the interior of the oil tank when the working oil is renewed or about every two years.

(16) Line filter cleaning :

* Even if the clogging condition is not observed by means of visual indicator, it is desirable to clean the filter when the working oil is renewed or about two years.

(17) Hydraulic pump :

* Care should be taken especially to worn-out parts, cylinder, valve plate and all bearings.
* For details, refer to item 6.6.

(18) Air release :

* Expel air after periodical checks.

6.3.4 Check of working oil :

As it is used long period the working oil will be mixed with foreign matters, deteriorated in the quality, and have the inconvenience to keep on the normal operation of the steering gear. To avoid this, the oil should be subjected to the periodical inspection.

Sample the oil at least every half a year for visual check and every year for detailed property inspection and decide its suitability.

If the result exceeds the renewal standard, renew the working oil.

During the visual check (spot judgment), carefully observe the following points compared with the new oil :

a. Isn't the color turned from light yellow to dark brown ?

b. Isn't the smell producing an irritative smell ?

c. Isn't there any sign of foreign matter ?

d. Isn't it emulsified ?

| Working Oil Renewal Standards | | | |
|---|---|---|---|
| Item | Changes resulting from deterioration and pollution | Cause | Working limit (changing rate) |
| Specific gravity | Increase | Deterioration | 0.05 |
| Flash point | Decrease | Deterioration | 60℃ |
| Color | Darken | Oxidation, mixture of worn powder | (Union) 2 |
| Viscosity | Increase (decrease) | Deterioration | ±10% |
| Acid value | Increase | Oxidation | 0.4 mg KOH/g |
| Humidity | Increase | | 0.05 % |

### 6.4 Replacement of ram V-packing : (Fig. 23)

During the replacement work of the packing, care should be taken to avoid damaging the ram surface and seal surface of the cylinder.

Five packings are inserted in each hydraulic cylinder. To facilitate the work, oblique cut has previously been made in one portion.

(1) Drawing out of packing :

V-packings can be drawn out by making use of the friction with the ram.

a. Loosen the nut and lock nut of the packing gland by about 2mm.

b. Move the ram slowly by local steering. (The packing can be drawn out little by little along with the ram.)

c. The packing can be drawn out by repeating above works a and b.

If packing cannot be drawn out by above work, prepare a suitable tool and draw out the adapter and packing. (The screw holes has been machined on the female adapter for disassembling.)

(2) Inserting of packing :

a. Before inserting new packings, thoroughly remove dirt and impurities stuck on the interior of the stuffing box and the ram surface.

b. Insert the male adapter inward.

c. Wind the new packing to the ram. At the moment, confirm that the section is correctly met. (If the packing is hard, make it soft by hand rubbing.)

d. Insert the packing inward by fingers or a bamboo spatula to support the packing.

e. Follow the same manner subsequent to the second one. At the moment, the splits in the packing should be staggered around so that no two splits come together.

f. Insert the female adapter and tighten the packing gland.

Care should be taken then not to allow one-side tightening. The suitable clearance between the cylinder and the packing gland is shown in Fig. 23.

g. Operate the steering gear by the pump control knob and adjust the packing gland to form a light film of oil on the ram surface.

h. Check for excessive oil leakage by raising the pressure up to the adjusting pressure of safety valve.

Cautions :

1. Assembly of wrong inserting direction of ram V-packing will lead to failure in sealing.
2. Care should be taken to the packing since it tends to turn up itself when inserting.
3. New packing may occasionally cause oil leakage in the first condition. Tighten them additionally if necessary.

## 6.5 Dismantling and assembling of line filter : (Fig. 19)

When the indicator (8) of the filter shows the clogging condition (red indicator ring is floated up to the white level in the column), the line filter will be dismantled and the filter element (5) is changed to new one or cleaned in the following procedures. It will be desirable to clean when the ring reaches the middle position in height.

a) Stop the electric motor.

b) Loosen slightly the U-bolt and nuts for filter support.

c) Grab the hexagon plug on bottom of filter case (2) with large monkey spanner (about 300 mm), turn the left direction in order to loosen the filter case (2).

Caution :

During the removal of filter case (2), care should be taken not to spill the remaining oil inside of filter case.

d) After loosening the filter case (2), hold the filter case and filter element respectively with hands, and pull out the filter element downward with twisting slightly.

e) Wash the filter element (5) by shaking in the washing oil and clean its surface by using a soft cloth. It is desirable to blow from the outlet side with compressed air.

If filter element is damaged, renew the filter element.

f) Discharge the oil in filter case and clean the interior of filter case.

g) The assembly of the filter will be performed in reverse order to that of disassembly.

Caution :

1) Check the o-ring (3) & back-up ring (4) before assembly, which are inserted inside of filter head (1), for prevention of oil leak between filter case(2) & filter head(1).

2) Tightening torque of filter case (2) : 160 N·m (16 kg·m)

## 6.6 Dismantling and assembling of hydraulic pump : (Fig. 8 & 10)

The hydraulic pump will be dismantled and checked in the following procedures.

However, special attention and skill in dismantling and assembling of the pump are required, so it is recommendable that the work is performed by the specialist, if possible (Exploded view of axial piston pump in Fig. 8 & 10 is referred to).

(1) Preparatory items :

a. Tools necessary for dismantling and assembling of the pump (bar spanner M4 ~ M20, pliers, driver, hammer, monkey wrench, depth gauge)

b. Clean waste cloths and wooden pieces for bed seat

c. Washing oil (about 10 liters)

d. Chain block, 2 sets (0.5 ~ 1 ton capacity)

e. Spare parts of pump

(2) Procedures for Disassembly :

a. Discharge oil contained in the oil tank, disconnect the hydraulic regulator, hydraulic pipe, each valve, electric motor and the pump coupling, remove the pump from the oil tank and lift the pump by the chain block. Place the pump on a proper wooden piece.

Caution :

Disassemble at a clean place.

b. Remove the valve cover (253) from the cylinder casing (202).

Caution :

The copper packing (203) is used at the ports of valve cover.

Replace the copper packing at assembly.

c. Remove the suction valve cover (280) and the poppet (281).

d. Remove the valve plate (171) from the valve cover (253).

e. Pull out the cylinder (151) and the center rod (161).

Caution :

1) Care should be taken not to lose the cylinder spring (165) because it is come out together with cylinder.

2) Place the cylinder taking care not to damage the sliding surface (spherical part).

f. Remove the both pipe flanges (254).

Caution :

Shims (211) for adjustment (centering) of the cylinder casing (202) are inserted together with the thrust pad (210). Keep the top and the bottom shims separately to prevent mistakes in assembly.

g. Remove the both supporting axle (208) from the cylinder casing (202).

h. Remove the cylinder casing (202) from the bearing casing (201).

Caution :

Remove the cylinder casing by means of the chain block since the weight of casing is larger according to the size of pump.

i. Remove the key (102) and then the front cover (251).

Caution :

1) Remove the cover by using the drawing bolt holes without graver and driver.

2) Remove the front cover taking care not to damage the lip of the oil seal (103). If it is damaged, replace at assembly.

j. Remove the stop ring (105), the inner shim 2 (106) and the inner spacer (109) from the driving shaft (101). They will come out by striking the top of the shaft with a wooden hammer (Remove the stop ring by using a pliers).

k. Grip the piston sub (01) and pull out the driving shaft.

Caution :

1) Check that there is nothing wrong with the roller bearing (104) and the tapered roller bearing (111). If nothing, don't pull out them and leave inside of the bearing casing (201).

2) Don't remove the piston, connecting rod etc. from the driving shaft (101).

l. With the above, the disassembly is finished.

(3) Check and repairs :

After the disassembly is finished, check and repair each part.

① Worn components :

Care should be taken especially to the wears between the piston sub and the cylinder, the piston and the small spherical end of connecting rod, the large spherical end of connecting rod and the set ring, the center rod and the cylinder. If there is no abnormal increase in the clearance and remarkable visual damage, replacement of them will be unnecessary.

Standards for Replacement of Worn Parts (Unit: mm)

| Item \ Pump size | | 030 | 060 | 090 | 120 | 180 | 260 | 500 |
|---|---|---|---|---|---|---|---|---|
| Piston and Cylinder | Nominal size | 16 | 20 | 22 | 25 | 28 | 32 | 40 |
| | Standard clearance | 0.024 | 0.030 | 0.033 | 0.037 | 0.042 | 0.048 | 0.060 |
| | Recommended Replacement Clearance | 0.050 | 0.060 | 0.070 | 0.080 | 0.090 | 0.100 | 0.120 |
| Piston and Con-rod | Standard clearance | 0.15 | 0.15 | 0.15 | 0.15 | 0.20 | 0.20 | 0.25 |
| | Recommended Replacement Clearance | 0.50 | 0.50 | 0.50 | 0.50 | 0.55 | 0.55 | 0.60 |
| Con-rod and Set ring | Standard clearance | 0.09 | 0.09 | 0.10 | 0.11 | 0.14 | 0.17 | 0.19 |
| | Recommended Replacement Clearance | 0.20 | 0.20 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 |
| Center rod and Cylinder | Nominal size | 16 | 20 | 22 | 25 | 28 | 32 | 40 |
| | Standard clearance | 0.024 | 0.030 | 0.033 | 0.037 | 0.042 | 0.048 | 0.060 |
| | Recommended Replacement Clearance | 0.050 | 0.060 | 0.070 | 0.080 | 0.090 | 0.100 | 0.120 |

② Cylinder and valve plate :

If the sliding surfaces of the cylinder and the valve plate are roughened, replace them at the same time. And if the worn value of the valve plate is over although sliding surfaces are in normal condition, replace the cylinder and the valve plate at the same time.

The correction standards are as follows :

| Parts | Item | Standards for Correction |
|---|---|---|
| Cylinder Valve plate | Surface roughness requiring correction | 3.2-a Note 1) (approx.▽▽finish) |
| Valve plate | Recommended replacement hardness | Hs 84 |
| | Working limit (replacement) | Hs 82 and under |
| | Standard hardness | Hs 90 and over |

Note 1) 3.2-a indicates a state of roughened sliding surface which makes you feel a considerable scratching when you apply your nail to the sliding surface.

③ Bearing :

Check for flaws and peeling off on the surface of the bearing.

Caution :

When replacing the roller bearing, the tapered roller bearing and the needle roller bearing, consult with us for essential information.

(4) Procedures for assembly :

The assembly of the pump will be performed in reverse order to that of disassembly. However special attention should be paid on the followings :

① General cautions :

a. Repair the parts if damaged at disassembly work. Prepare the packings before assembly.

b. Wash each part thoroughly with the washing oil and dry it by blowing with compressed air. Use of waste cloth shall be avoided.

If waste cloth is used, take care that fiber scraps will never remain on the cleaned parts.

c. Apply clean working oil on the moving parts before assembly.

d. Tighten the bolts in symmetrical order little by little by referring the table.

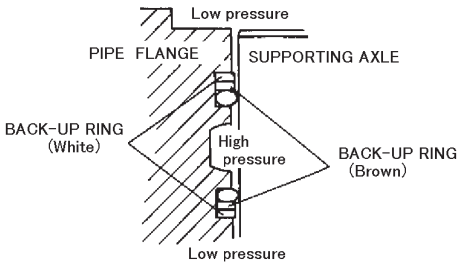
Tightening Torque

| Material | Item | Unit | Bolt size | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | M4 | M5 | M6 | M8 | M10 | M12 | M16 | M18 | M20 |
| SCM435 | Torque | kgf·cm | 35 | 70 | 120 | 300 | 580 | 1,000 | 2,400 | 3,400 | 4,400 |
| | | N·m | 3.4 | 6.9 | 11.8 | 29.4 | 56.9 | 97.1 | 235.4 | 333. | 431.5 |

② Cautionary Instructions in Assembly :

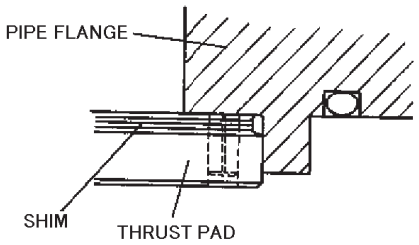
a. When installing the oil seal (103) to the front cover (251), carry out the hammering-in after applying the liquid packing to the periphery of the oil seal.

Fill the grease into the oil seal lip space and carefully install the front cover to the bearing casing (201).



b. When inserting the O-ring (260) and back-up ring (261 and 263) into the pipe flange (254), care should be taken in the direction of them.

c. When inserting the thrust pad (210) and the shim (211), care should be taken not to be wrongly inserted.




As the thrust pad and the shim may be fallen, prevent falling by applying the grease etc.

d. When installing the valve plate (171) to the valve cover (253), apply the grease etc. for preventing falling of the valve plate.

e. When installing the copper packing to the port of the valve cover (253), replace it for new one.

As the packing may be fallen at assembly, prevent falling from the port by applying the grease etc.

f. After the assembly is over, rotate the driving shaft (101) by hand and ensure there is no abnormality.

Then, install the pump inside of the oil tank and put it to the original condition.

## 6.7 Dismantling procedures for pintle bearing inspection :

When inspecting the pintle, the rudder plate must be jacked up 400 to 500mm.

However, it cannot be done as it is because the arms of fork-typed tiller have inserted the ram at upper and lower parts.

Therefore, dismantle the steering gear in the following procedures by referring to Fig. 1 & 24 :

a. Remove all connecting levers above the tiller.

b. Remove the stop ring for ram pin with a pliers and take off the upper and lower roller bearings.

Caution :

The lower roller bearing will drop if the stop ring is removed, so safety is especially given to the work.

c. Loosen the bolt and remove the guide bracket.

d. Loosen the ram pin set screw by around 20mm.

e. Jack up the ram pin from the lower part and pull out it completely upwards.

f. Carefully and slowly turn the tiller and rudder plate (rudder stock) by means of a winch at the dock up to the 90 degrees position as shown in Fig. 24.

Caution :

For the rudder plate not allowing the 90degrees turn due to the hull construction, remove the key, jack up only the tiller and turn it up to the 90degrees position.

g. Jack up the rudder plate (rudder stock) and the tiller in such condition, and inspect the pintle portion.

h. After the inspection, assemble the steering gear in reverse order to that of disassembly. At the moment, screw the set screw for ram pin and bolts for guide bracket without fail.

# 7. Trouble shooting guide

Flutek-Kawasaki Type Electro-Hydraulic Steering Gear has sufficient strength and durability. In the event of trouble, it is necessary to let us know exactly what has been observed and what measures have already been taken.

## 7.1 General notes :

(1) The Steering Gear System is considered to be classified into the auto-pilot system (including the repeat back unit and gyro compass) that outputs the rudder order angle in the wheel-house (bridge), the continuous control system such as the control box, the pump control unit etc, that controls the pump tilting angle in the steering gear room with the above order received, and the steering gear, such as the ram, the cylinders, the tiller etc.

Any poor rudder response from the wheel-house (bridge) should be always dealt with by separating the auto-pilot system and the continuous control system from the steering gear for earlier discovery of the cause.

(2) When an alarm is given for failure in any power unit, stop the power unit concerned (and then start another power unit). Then, investigate the defective part.

(3) When investigating the cause of the trouble, operate the steering gear by the pump control knob in the steering gear room (i.e. local steering). If the trouble continues, the cause will be in the steering gear and the detailed check of the steering gear should be carried out.

If the steering gear operates in order, the cause will be in the auto-pilot system or the continuous control system. Then proper remedies should be taken by referring to the Instruction Manuals of their systems.

(4) When carrying out investigation and remedy, take care to prevent the entry of dirt and dust, and handle the parts not to damage them.

(5) Take smooth procedures in the transportation and disassembly of heavy weights, and pay attention to safety.

(6) If the cause is not cleared ask our company.

## 7.2 Trouble shooting of steering gear :

Investigate the cause and take measures by referring to Fig. 25 Trouble Shooting Flow Chart.

(1) Steering Gear does not work :

a. External oil leakage :

* Check for oil leakage from the ram V-packing and connections.

  Tighten them additionally or replace the packing if necessary.

b. Electric motor does not rotate :

* Check that the starter is in normal operation.

* Disconnect the coupling with the hydraulic pump and investigate which is in trouble, the motor or the hydraulic pump.

c. Trouble or mis-operation of valves :

* Check that the stop valve and isolating valve are opened or closed as indicated on the instruction plate.

d. Investigate any obstacles around the tiller and ram.

e. Check that the safety valve is surely set.

f. Check that the air vent valve is closed.

g. Poor tilting of hydraulic pump :

* Check that the servo pump pressure is 1.8 ~ 2.0 MPa {18 ~ 20kgf/cm$^2$}.

* Check for abnormalities of the torque motor of the pump control unit.

* Check for normal operation of LVDT of the pump control unit (pump regulator).

h. OB valve does not change over to on-load condition :

* Check for correct change-over of the solenoid control valve for unloading device and check that the electric source is supplied.

* Check for burning of the solenoid and for sticking of the spool.

  If the spool sticks, remove it for lapping.

i. Trouble of Hydraulic Pump :

* Check for abnormal noise of running pump or the opening of the suction valve.

  If the pump seems to be found abnormal, disassemble and check the pump and make necessary remedies. (Refer to item 6.6)

(2) Rudder turning speed is slow :

The time of rudder turning speed is measured when the rudder moves from 35 degrees on either side to 30 degrees on the way to 35 degrees on the other side (excluding special requirements).

a. External oil leakage :

Check for oil leakage from the ram packing and connections.

Tighten additionally or replace the packing if necessary.

b. Trouble or mis-operation of valves :

Check that the stop valve and isolating valve are opened or closed as indicated on the instruction plate.

c. Investigate any obstacles around the tiller and ram.

d. Poor setting of safety valve :

Check that the adjusting pressure of the safety valve is not reduced.

e. Check that the air vent valve is closed.

f. The maximum tilting angle of the hydraulic pump is small :

Check the specified maximum tilting angle of the hydraulic pump.

If excessively small, re-adjust it with the control box.

g. OB valve does not change over to on-load condition :

Refer to item 7.2 (1) h.

h. Trouble of hydraulic pump :

Refer to item 7.2 (1) i.

(3) Steering Gear does not work smoothly :

a. Air contained in hydraulic circuit :

Air contained in the hydraulic circuits will cause the delayed response.

Expel air periodically without fail. (Refer to item 4.2.5)

b. Investigate any obstacles around the tiller and ram.

c. Over-tightening of ram V-packing :

The tightening value has roughly been set up depending upon the type of steering gears.

Over-tightening will cause oil shortage or intermittent movement of the ram.

(Refer to item 6.4)

d. The tilting angle of the hydraulic pump is changed :

Refer to item 7.2 (1) g.

e. Play between rudder stock and bearing :

Disassemble and repair it while the ship is at dock. (Consult with the shipyard.)

(4) Steering gear is unstable (Steering gear does not stand still) :

a. Poor neutral adjustment of hydraulic pump :

If the neutral position of the hydraulic pump shifts when the pump tilting angle order is zero, the steering gear will not stand still.

Adjust the pump neutral position as shown in item 4.2.4 and the zero adjustment of the control box as shown in item 4.2.6.

Don't leave it in non-follow up control for a long time because rudder may be moved slowly by external force as non-follow up steering mode is not fed back the actual rudder angle.

b. Poor setting of proportional band :

If the proportional band is adjusted too small in the control box, the steering gear will not stand still. Re-adjust the proportional band to 2degrees ~ 5degrees.

c. Excessive clearance of the pin of pump control unit :

If the clearance of the pin of pump control unit becomes abnormally great, following-up to the order from the control box becomes unstable and the steering gear will not stand still.

Repair it or replace its part if necessary.

d. Excessive clearances of pin for repeat back unit :

If the clearance of the pin for repeat back unit becomes abnormally great, actual rudder angle signal to the steering stand becomes unstable and the steering gear will not stand still. Repair it or replace its part if necessary.

e. Excessive clearance between tiller arm and roller bearing : (Fig. 1)

If the clearance between the hardened steel plate (1003) and the roller bearing (1121) becomes abnormally great, the steering gear will not stand still.

(Refer to item 6.3.3 (5)).

f. Poor shut of air vent valve :

Repair the sliding parts so that the valve can be surely closed.

g. Poor adjustment of control box :

Re-adjust it by referring to the instruction manual of the auto-pilot manufacturer.

(5) Abnormal Noises while ship is under voyage :

Abnormal noises can be dealt with by full confirmation of their origins.

a. Occurring whenever the rudder is worked :

Expel the air thoroughly because a great amount of air remains in the hydraulic circuits.

Check further for existence of place to allow air to enter. (Refer to item 4.2.5.)

b. Noises from ram V-packing :

This is caused by excessive tightening of the ram packing (Refer to item 6.4).

c. Noises from rudder carrier :

Ask the shipbuilder concerned. Check the lubricating condition thoroughly.

d. Abnormal noises from pump :

Immediately stop the operation for detailed check. Disassemble or repair the pump, if necessary.

(6) Abnormal pressure rise in all cylinders :

Confirm that the valve is operated in accordance with the instructions.

(7) Rudder moves while ship is at anchor :

If the ship is at anchor for long time, the rudder may move owing to the influence of the air in the cylinder and the oil leakage from valves. If this causes vibration of the hull, start the pump and fully expel the air. (Operate the steering gear at least every 24 hours.)

When the stop valves are provided on the hydraulic cylinders, closing of the valve will be effective. In this case, don't fail to open the stop valve before starting the pump.

## 7.3 Trouble Shooting of valve, pump and electric motor :

When the pump is found in failure and required disassembly for check, do it after full understanding of item 6.6.

(1) Stand-by pump rotates in reverse :

* If the stand-by pump rotates in reverse at high speed, it will cause steering failure. To prevent it, the oil block valve is provided.

  It is therefore necessary to disassemble the OB valve for detailed check. Special care should be taken to check that the spool is not sticky, damaged, abnormally worn out, the check valve is normal, or the casing is not damaged, deformed, etc. After the check, take necessary measures, such as lapping the spool, facing up the seat of the check valve, etc. If the reverse rotation influences upon the rudder turning speed in spite of the above remedies, replace the OB valve.

  In this case, ask our company immediately.

* For an emergency measure, it can be prevented by simultaneous operation of two pumps.

(2) Excessive temperature on pump bearing casing :

* The bearing casing temperature will become higher by 10 to 20℃ than the oil temperature. If this difference is abnormally large, stop the pump immediately for check.

a. Poor centering between pump and electric motor :

Re-adjust the centering by referring to item 4.1.4.

Investigate the cause of such poor centering.

b. Dust biting in bearing :

* Check that it is not abnormal by rotating the pump by hand.

c. Oil shortage in oil seal :

Oil shortage will cause high temperature in the oil seal.

Apply sufficient amount of grease.

(3) Excessive oil temperature in oil tank :

Depending upon the room temperature, while the pump is running the pump will be set approximately at the room temperature plus 30℃.

If the oil temperature rises above 80℃, stop the pump to investigate the cause.

a. Disassembling check of pump :

Refer to item 6.6.

b. Check of working oil :

Refer to item 6.3.4.

(4) Abnormal noise from pump :

a. Large amount of air in hydraulic system :

In this case, cavitation will generate and the rudder will not work smooth.

Expel the air thoroughly.

b. Poor condition inside pump :

Noise will be caused by the breakage of the piston, connecting rod or the abnormal condition of the bearing. Disassemble the pump for check and repair.

Foreign matters in the working oil may cause troubles, although it is not so often the case.

(5) Decrease of oil in oil tank in a short time :

* Since the hydraulic system of the steering gear comprises the closed circuit, large amount of oil decrease cannot be considered so far as no external oil leakage occurs. If such phenomenon is observed, immediately take proper measures.

(6) Electric motor can not start :

* In this case, burning of the electric motor, failure of the electric source and starter, and damage of pump can be considered.

Ensure that the coupling can be rotated by hand and take proper measures.

(7) Abnormal wear of coupling :

* Poor centering between pump and electric motor will cause the abnormal wear

(Refer to item 4.1.4.)

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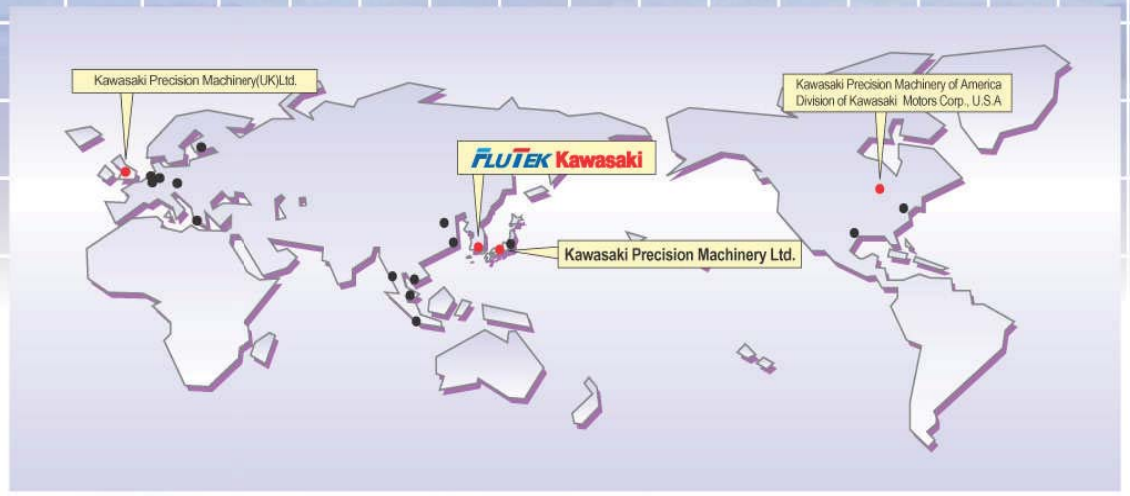


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Phone: 1-310-549-2550 Fax: 1-310-5491350

FIG.1 ASSEMBLY OF TILLER & RAM

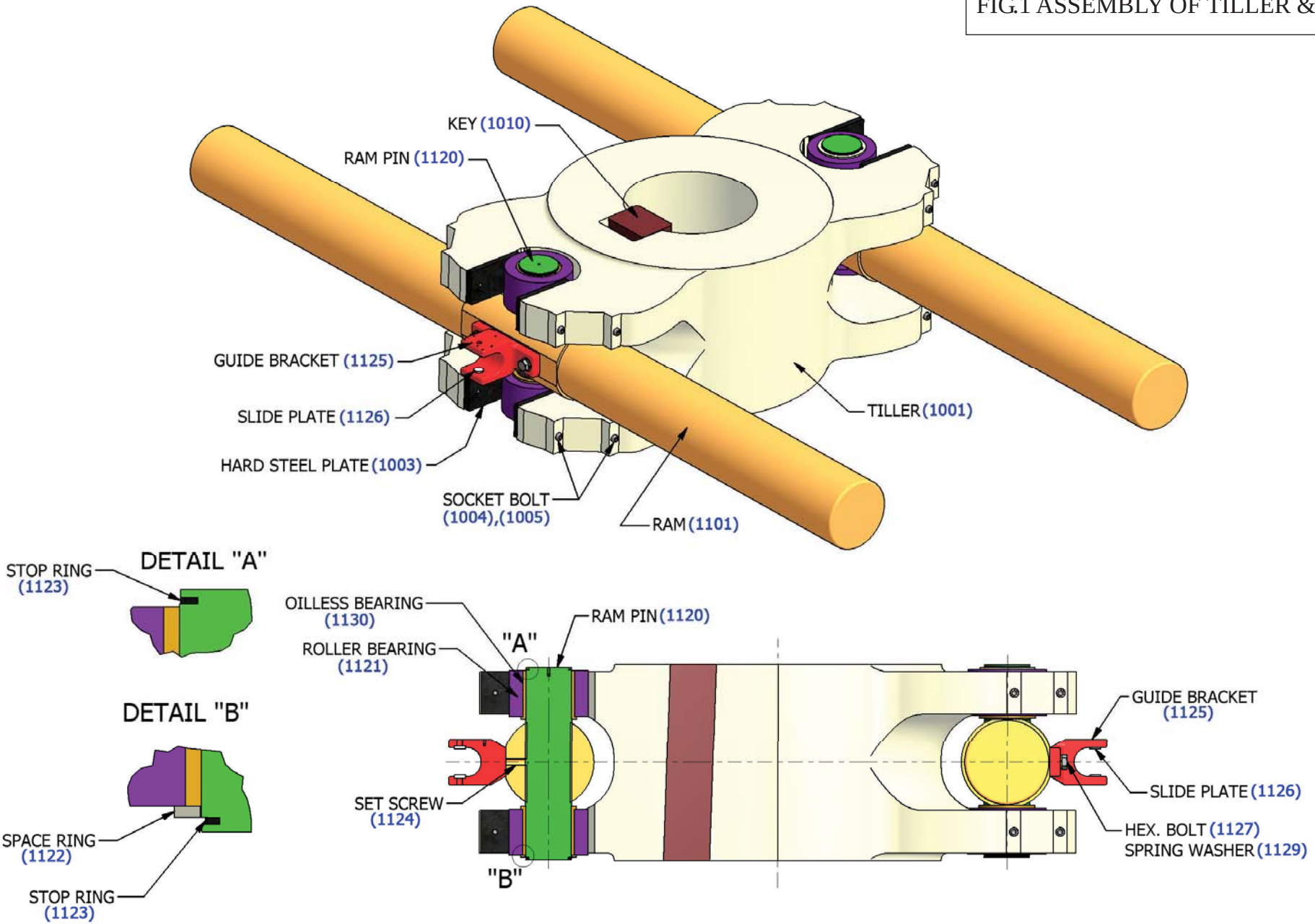


FIG.2 HYDRAULIC CYLINDER

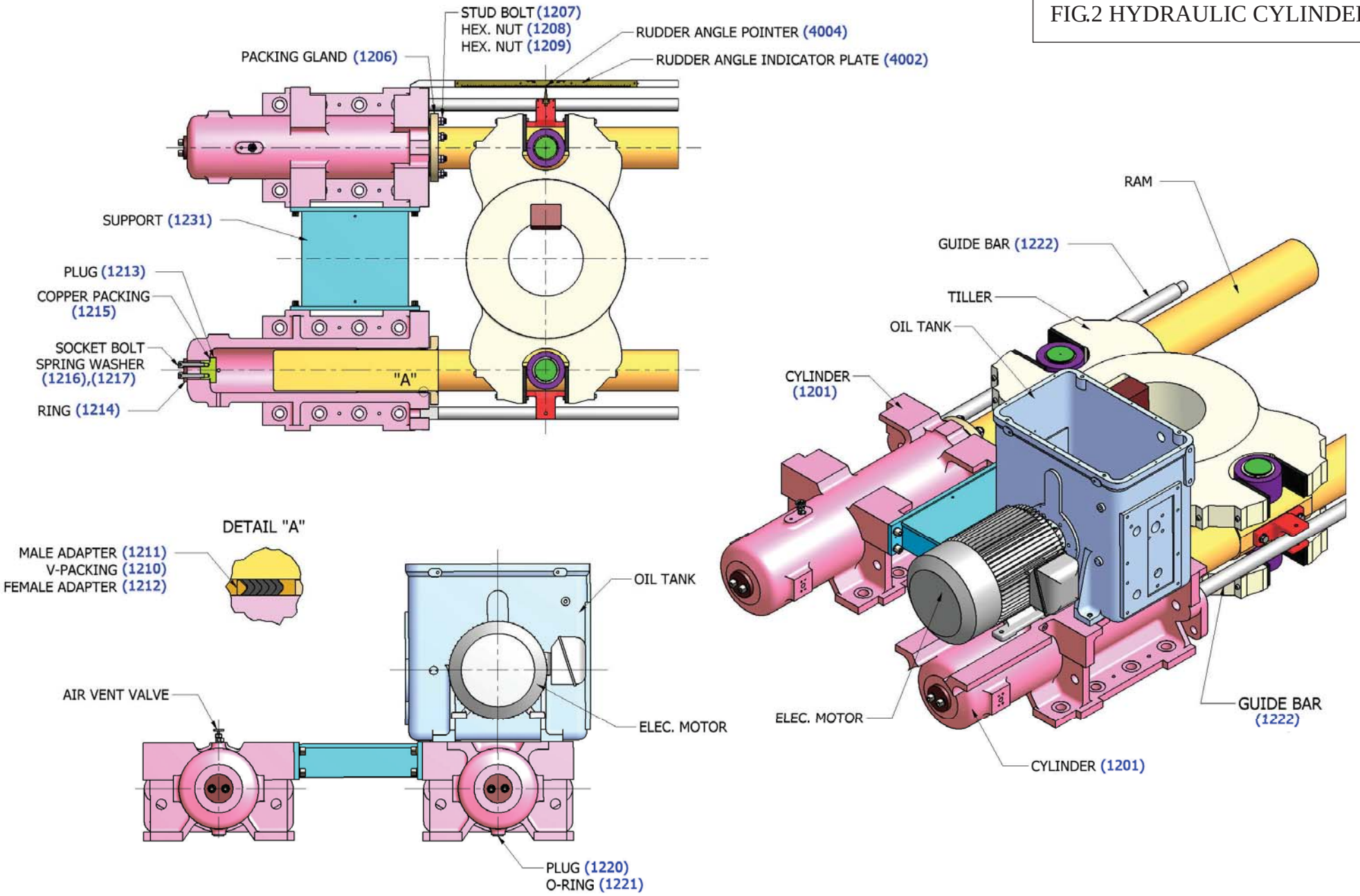
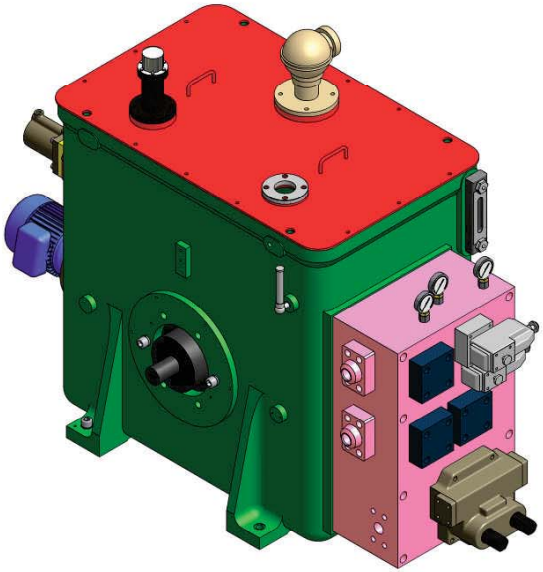
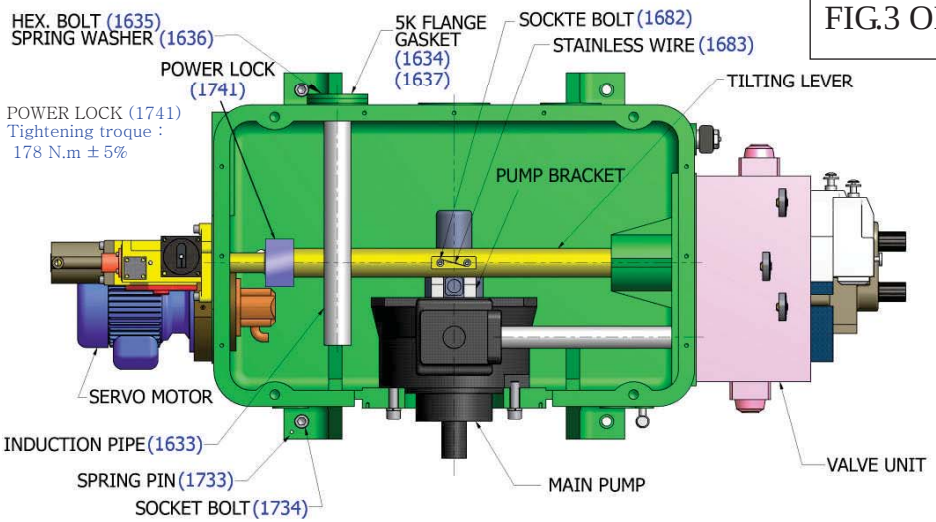
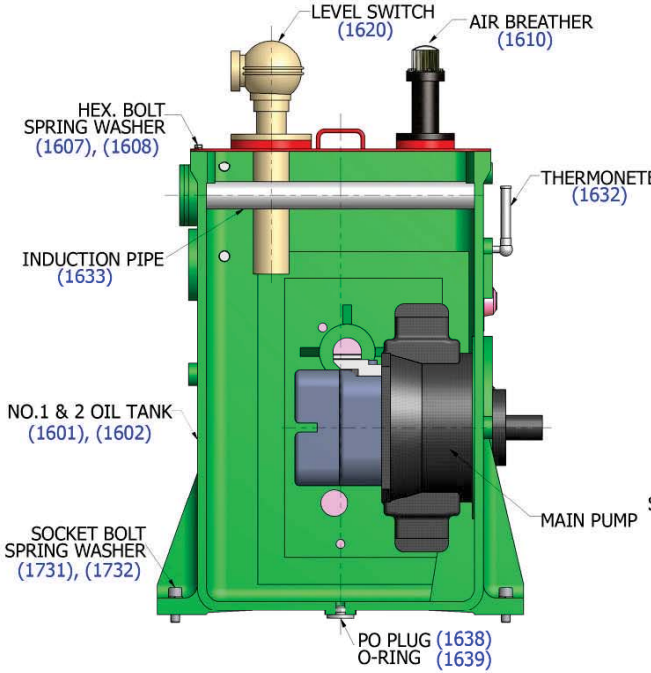
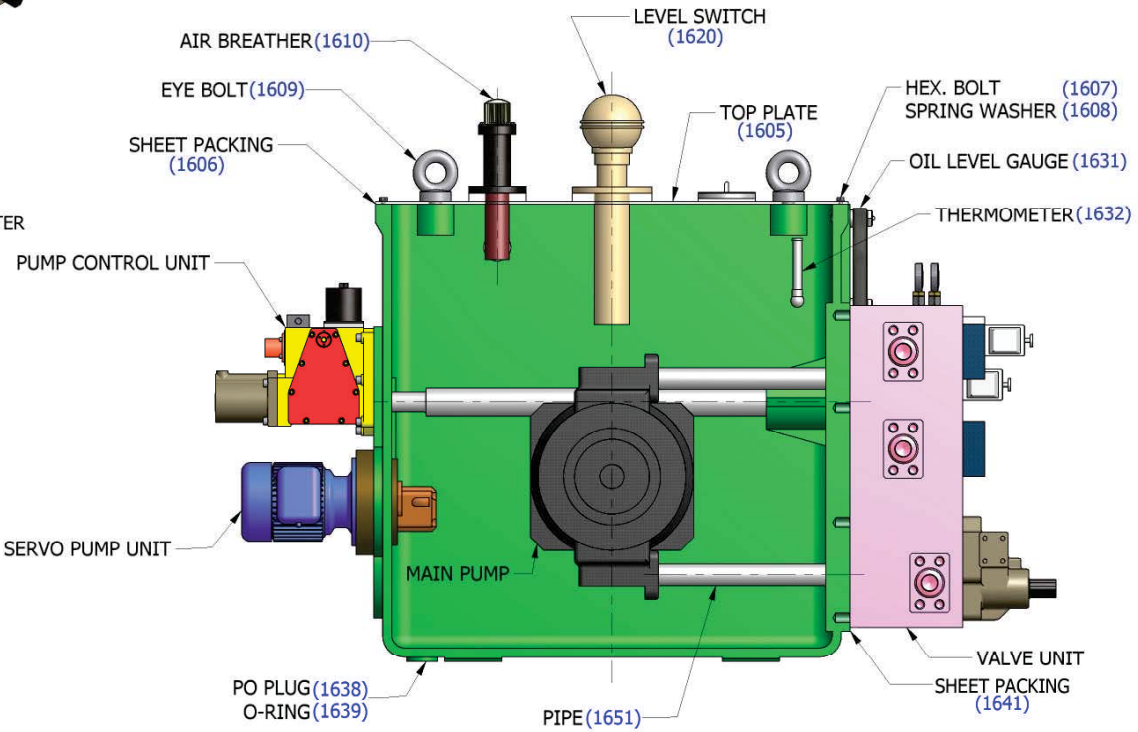


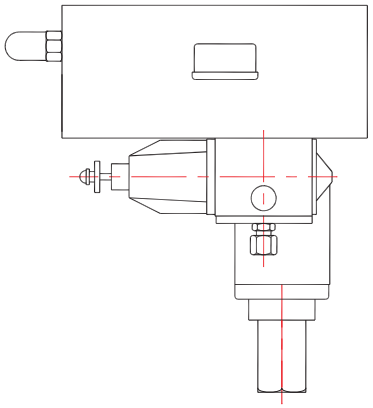
FIG.3 OIL TANK UNIT







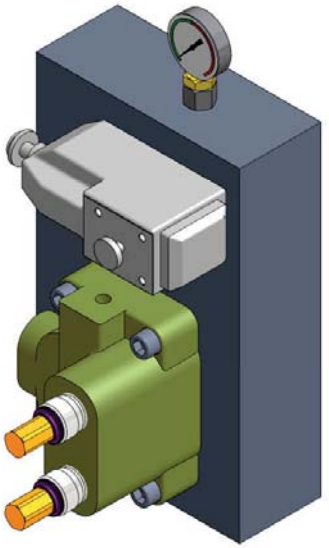
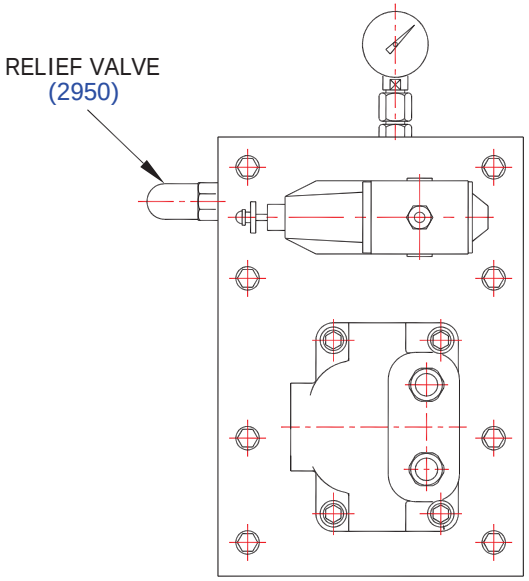


FIG.4 VALVE UNIT (RE SERIES)



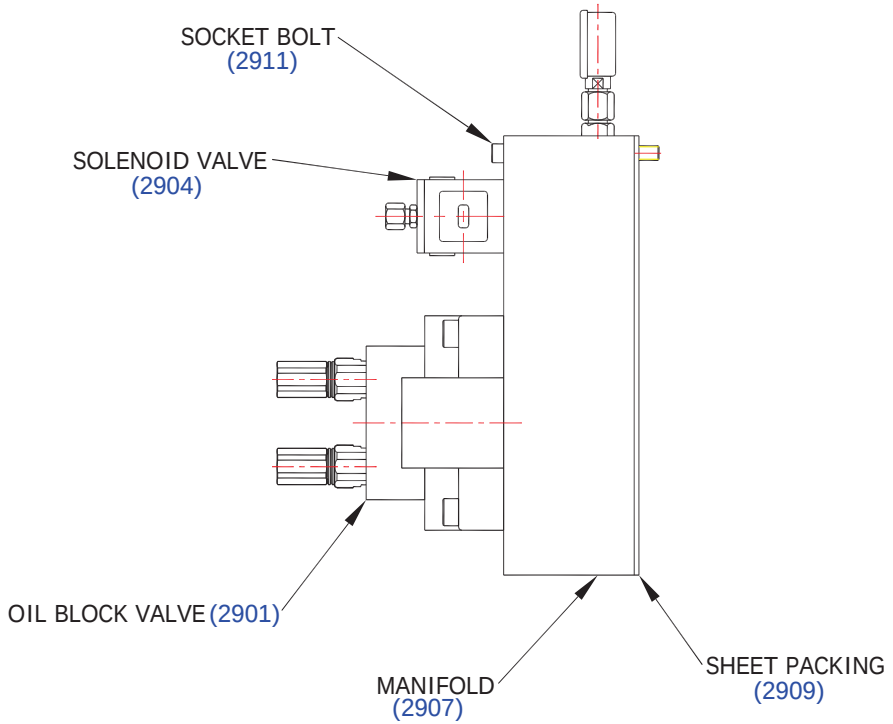
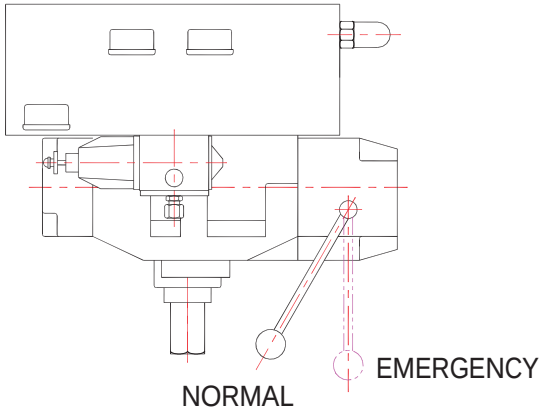
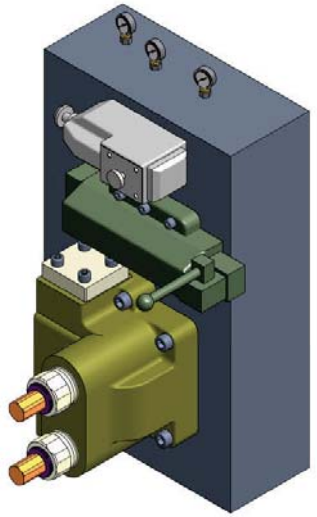
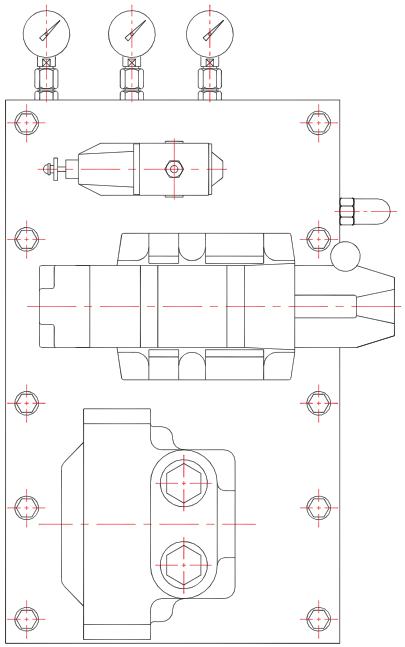



FIG.4 VALVE UNIT (FE SERIES)





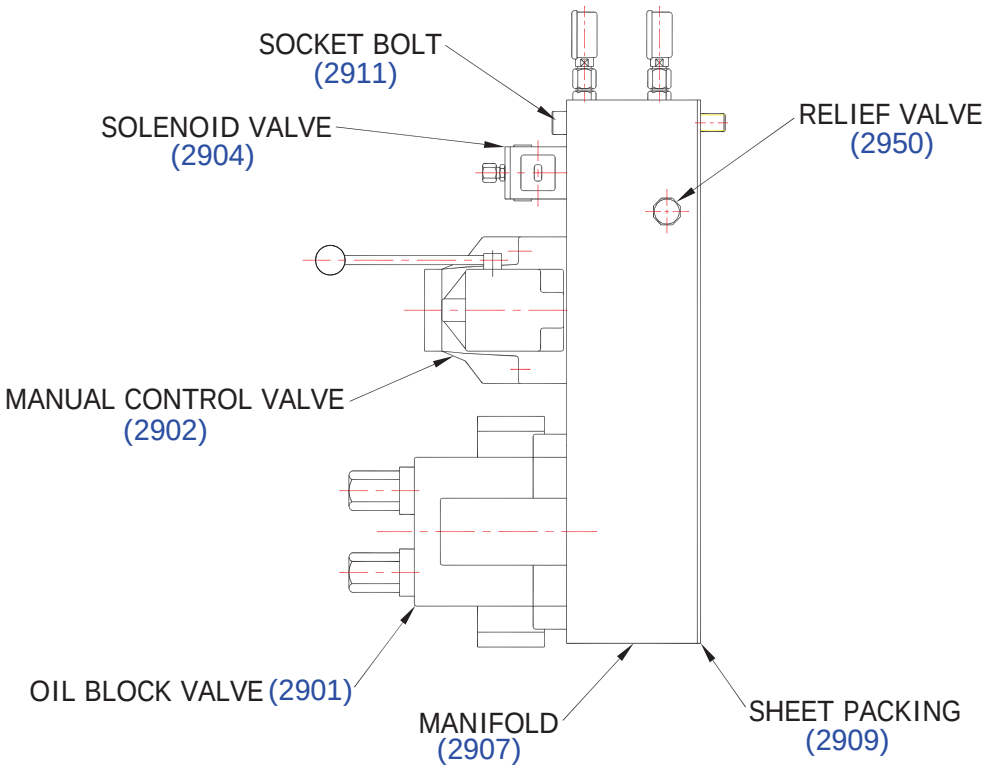


FIG.5 FUNCTION OF OB VALVE

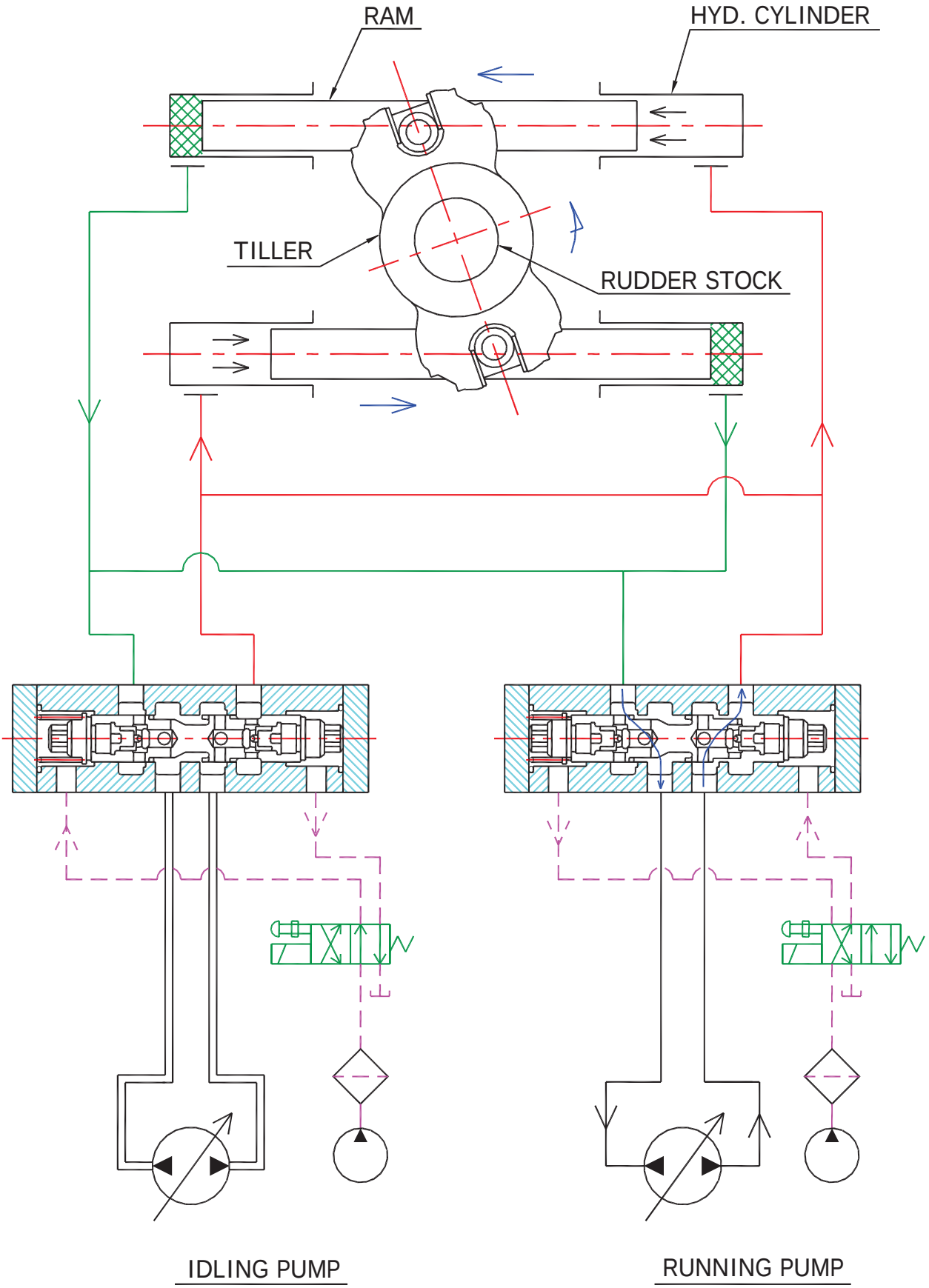
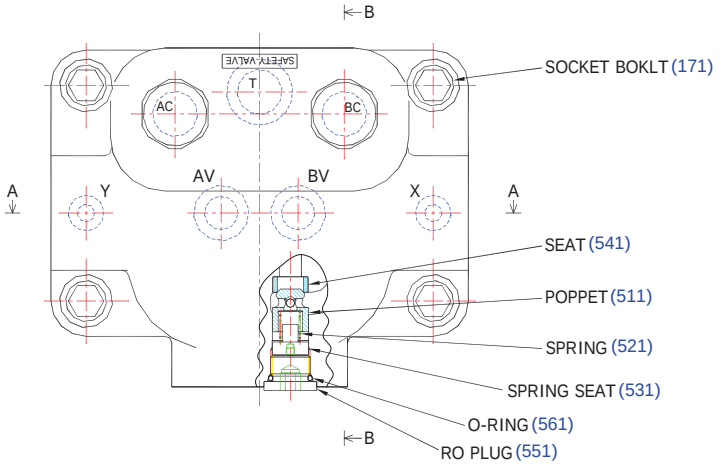
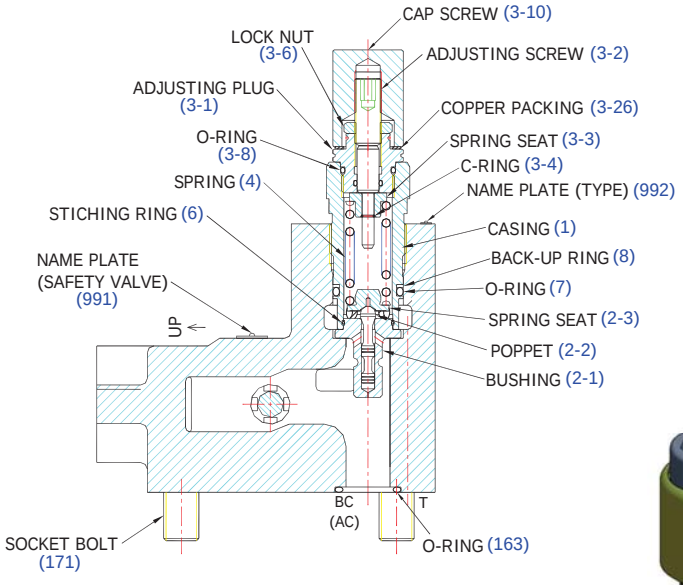
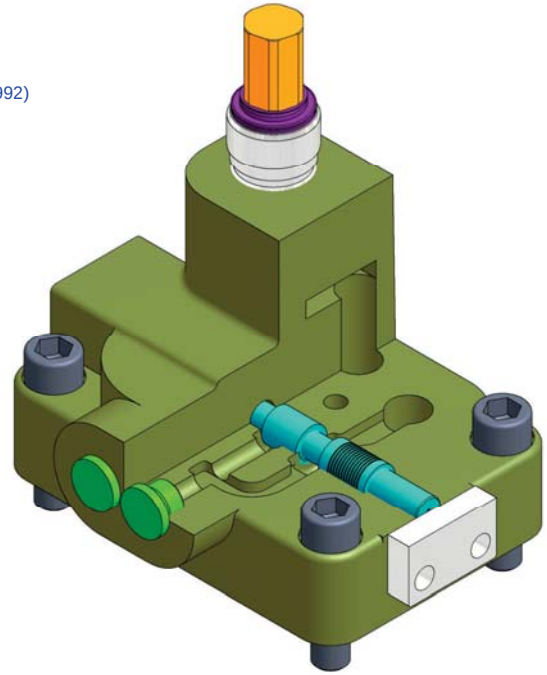


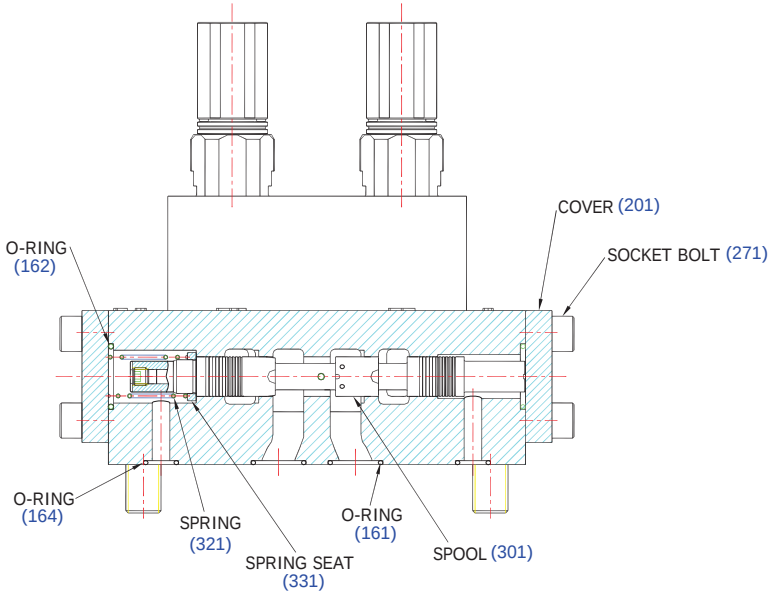
FIG.6 OB VALVE (OB15)



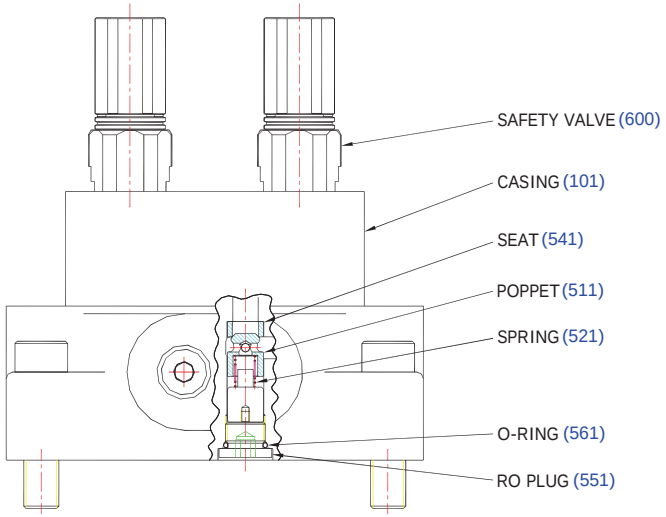



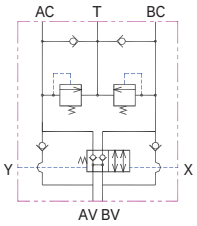

SECTION B-B





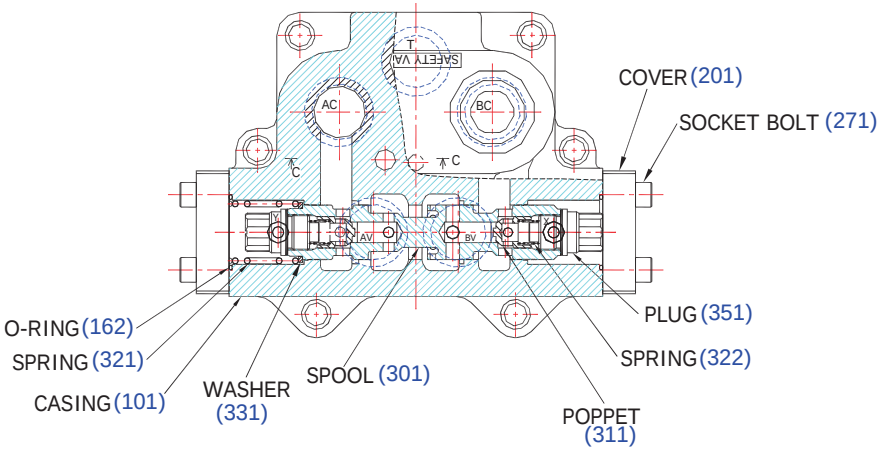

SECTION A-A



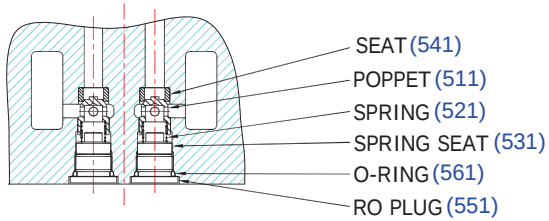




HYDRAULIC CIRCUIT

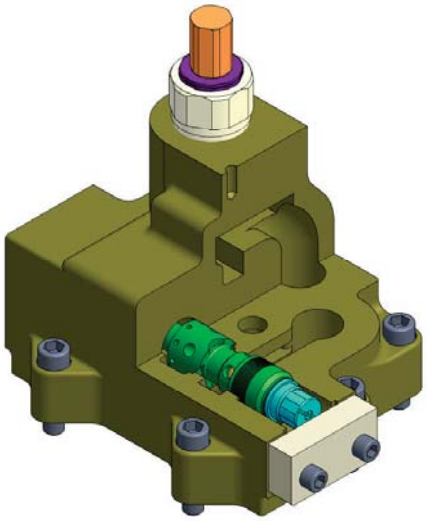
FIG.6 OB VALVE (OB20)

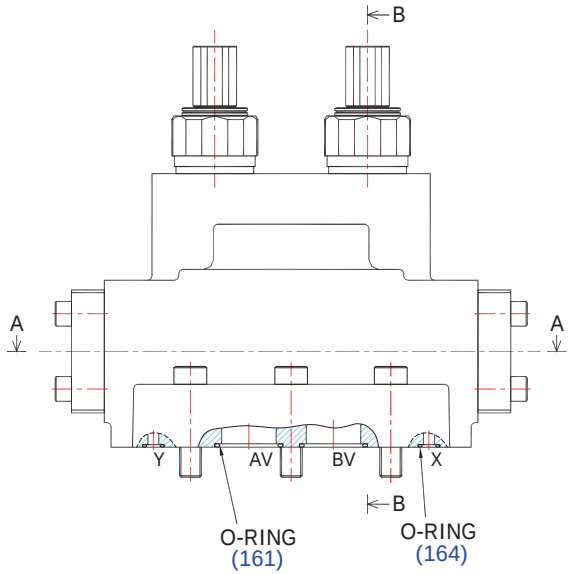


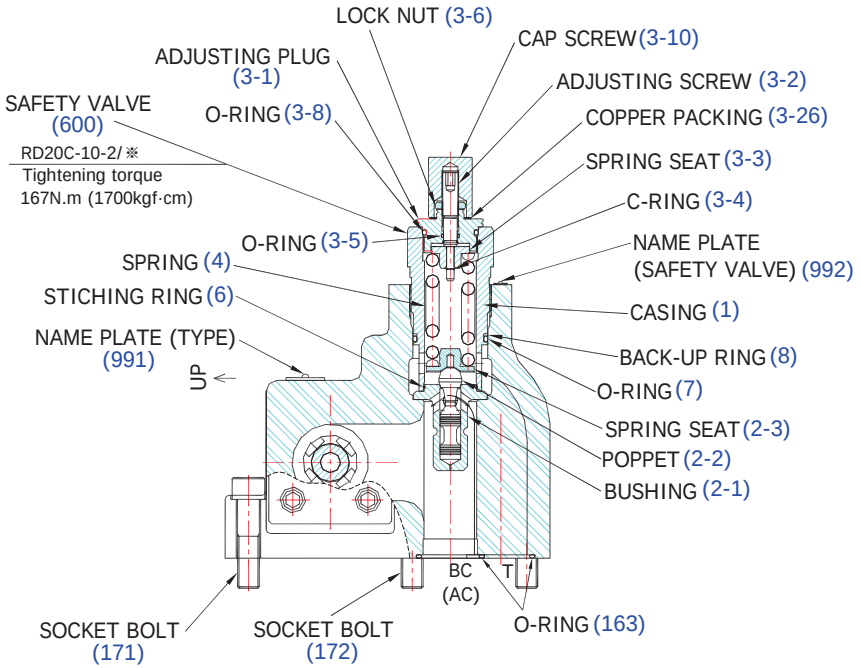

SECTION A-A



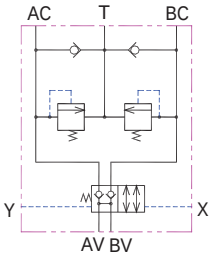

SECTION C-C






SECTION B-B



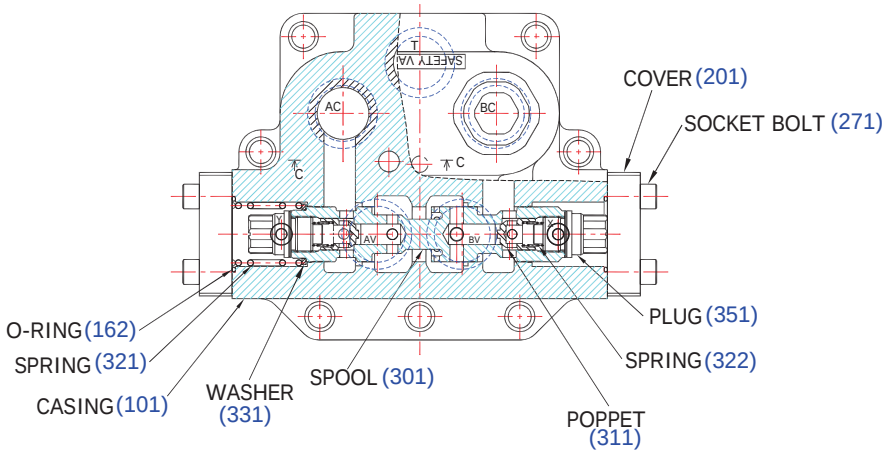

HYDRAULIC CIRCUIT

Tightening Torque

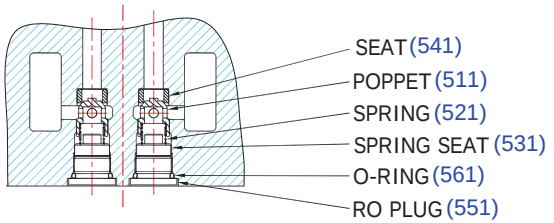
| NO. | SIZE | TIGHTENING TORQUE |
|---|---|---|
| 171 | M16 | 235 N.m (2400 kgf·cm) |
| 271 | M12 | 69 N.m (700 kgf·cm) |
| 551 | M27 | 176 N.m (1800 kgf·cm) |
| 600 | - | 294 N.m (3000 kgf·cm) |

※ : Setting pressure of relief valve

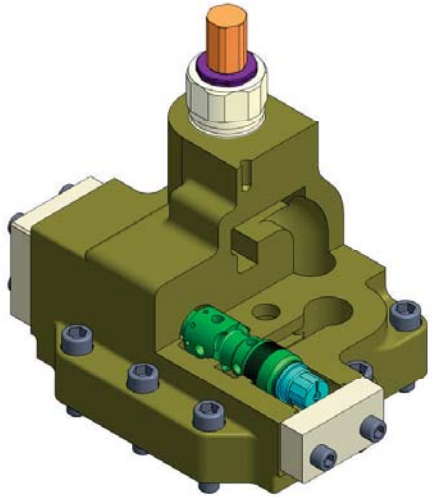
# FIG.6 OB VALVE (OB30)

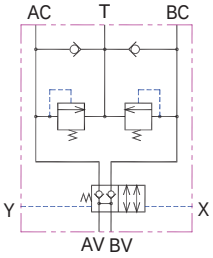



SECTION A-A

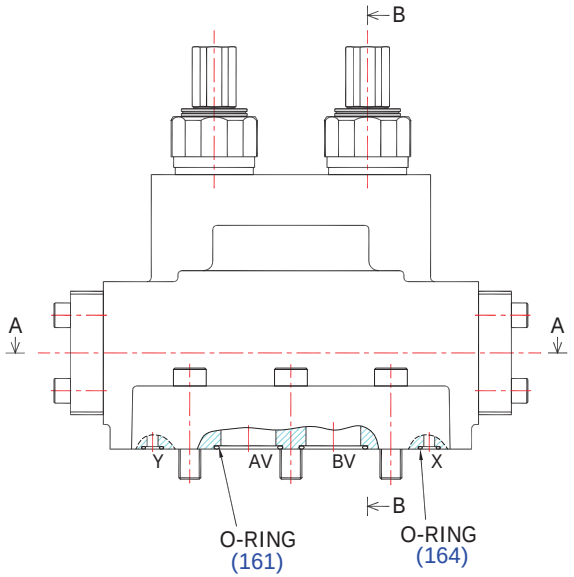


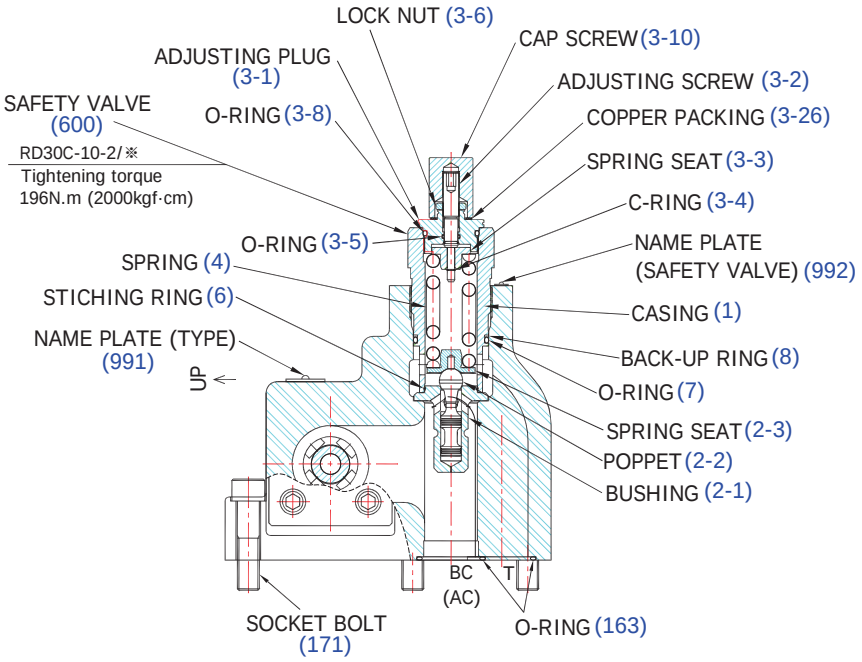

SECTION C-C






HYDRAULIC CIRCUIT



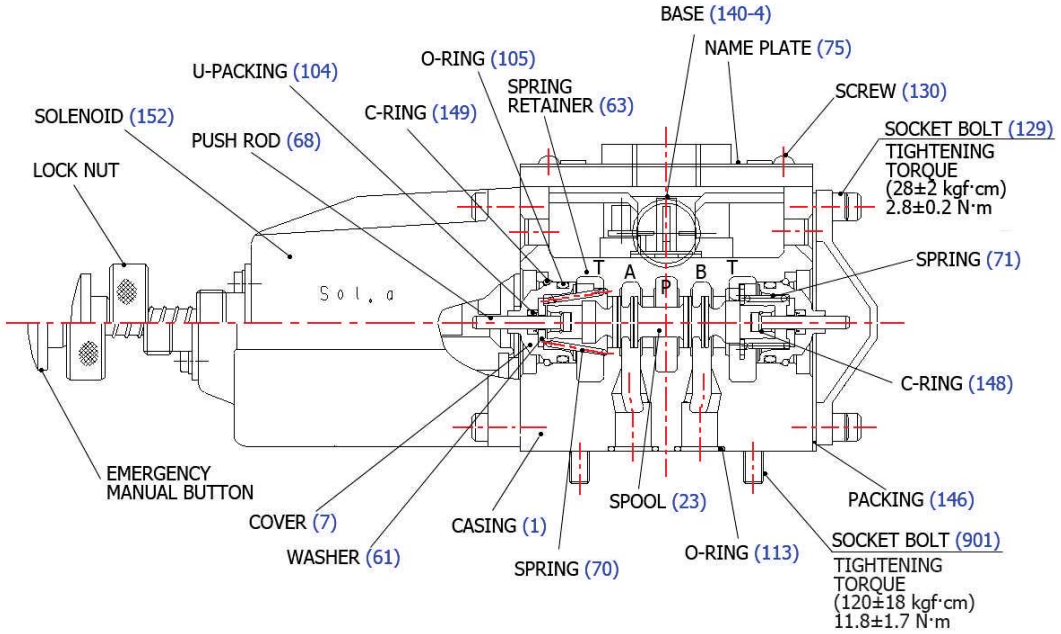

SECTION B-B

## Tightening Torque

| NO. | SIZE | TIGHTENING TORQUE |
|---|---|---|
| 171 | M16 | 235 N.m (2400 kgf·cm) |
| 271 | M12 | 69 N.m (700 kgf·cm) |
| 551 | M27 | 176 N.m (1800 kgf·cm) |
| 600 | - | 294 N.m (3000 kgf·cm) |

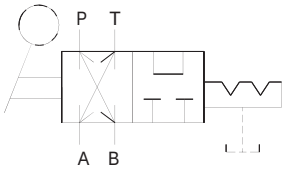
※ : Setting pressure of relief valve

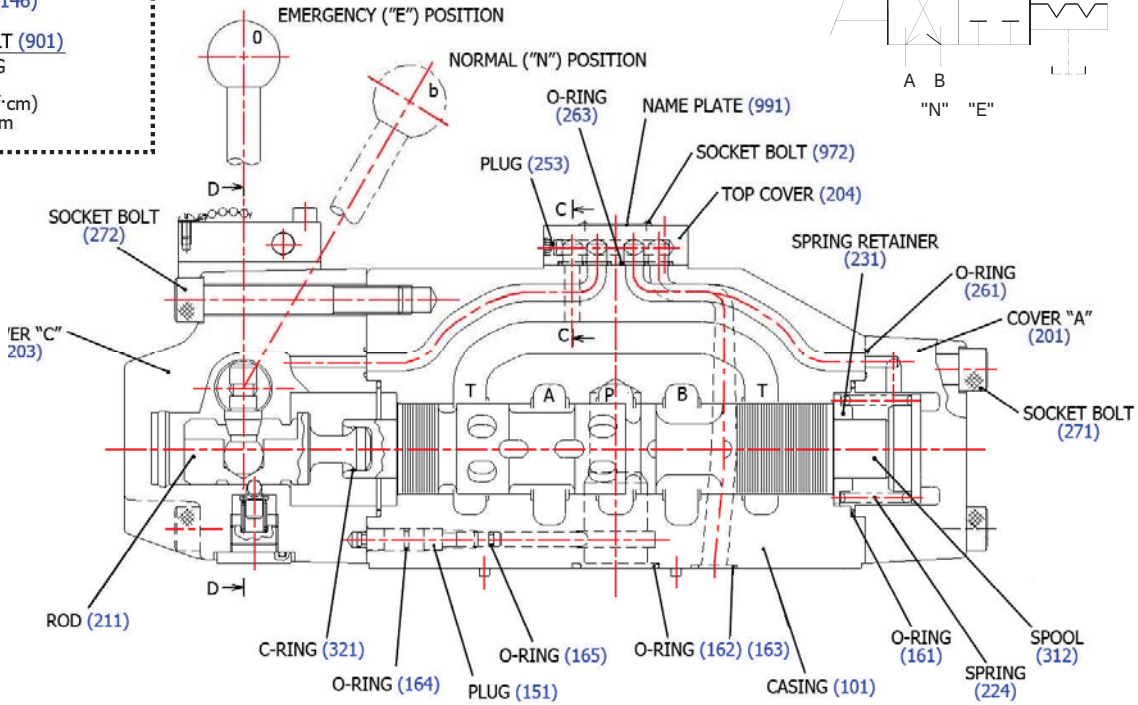
FIG.7 SOLENOID VALVE AND MANUAL ISOLATING VALVE

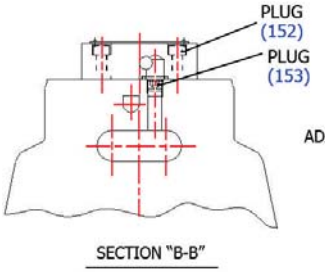



SPOOL (23)

* THIS DRAWING SHOW EMERGENCY POSITION.



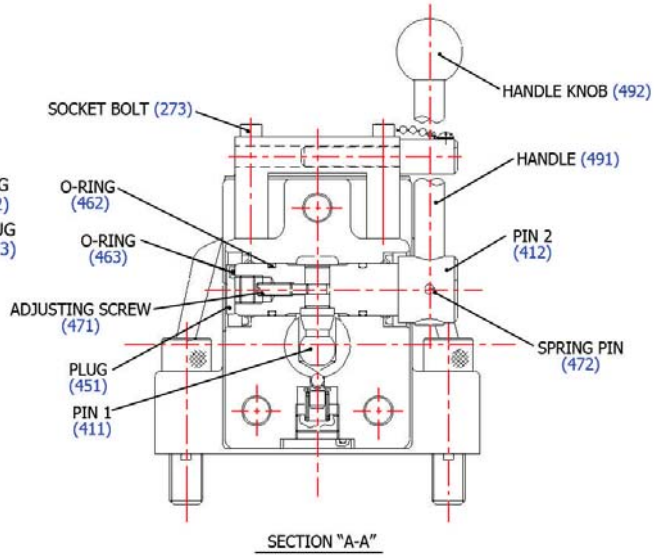



FIG.8 AXIAL PISTON PUMP

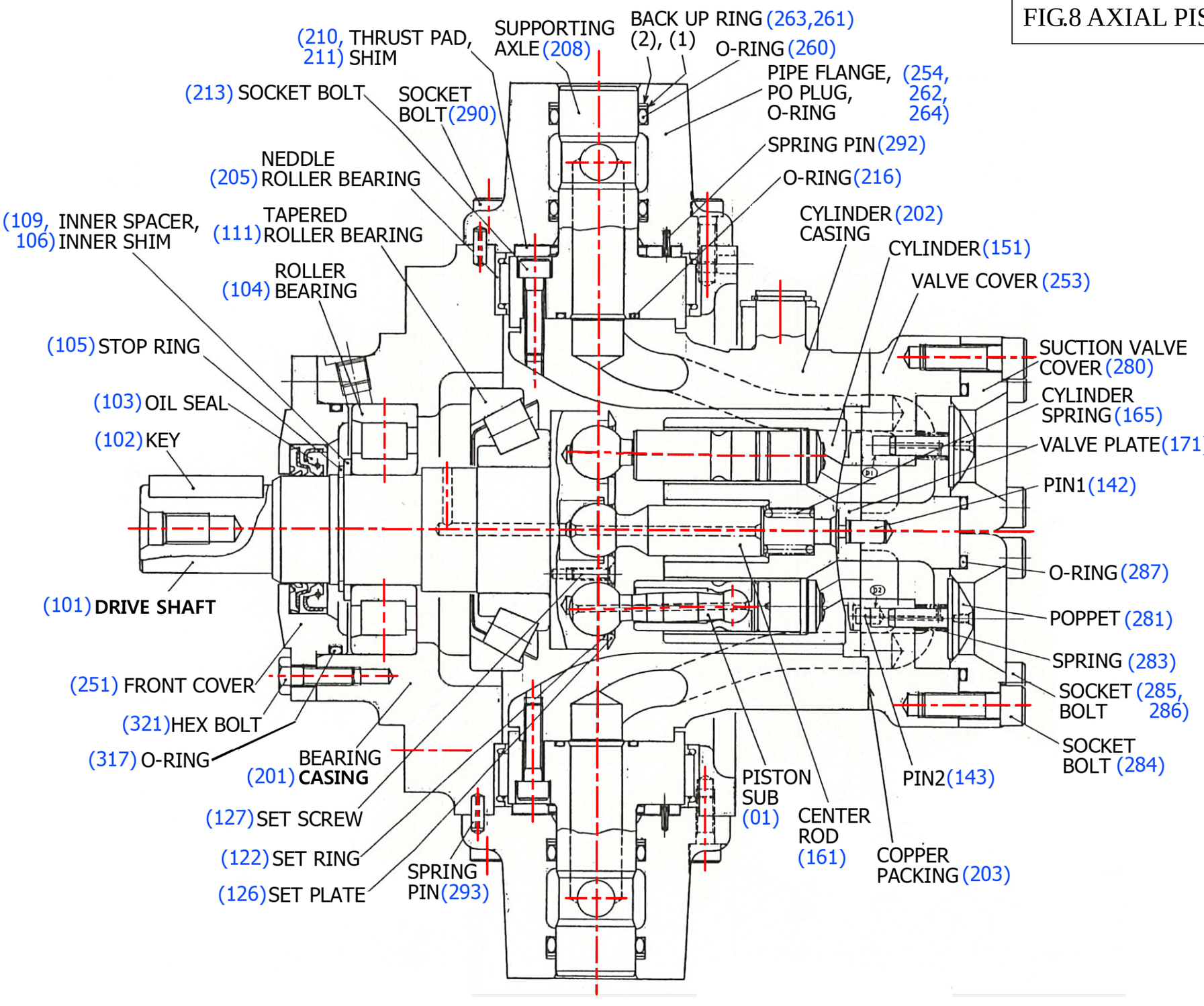
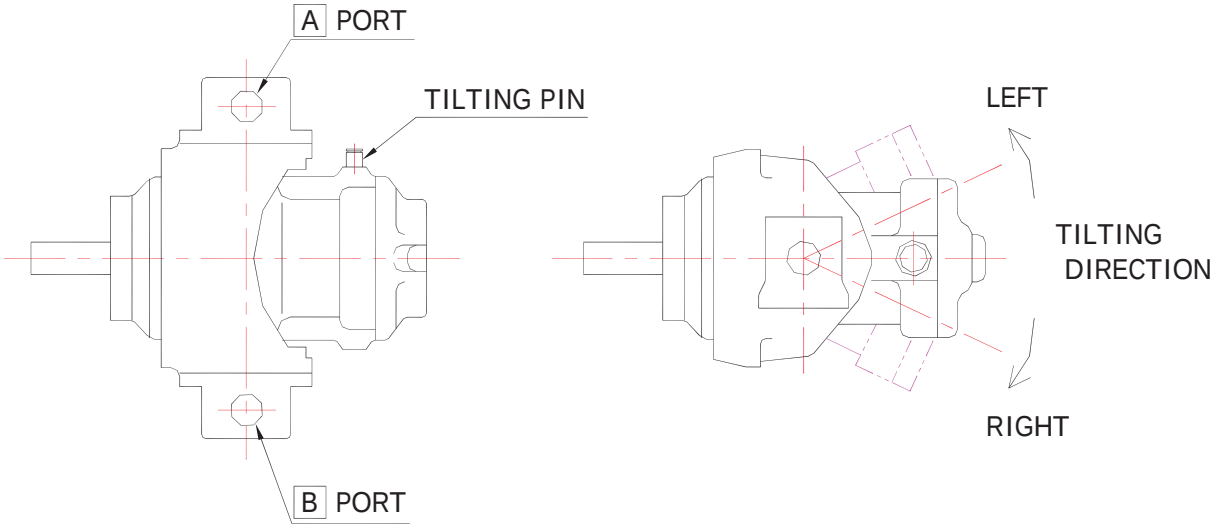
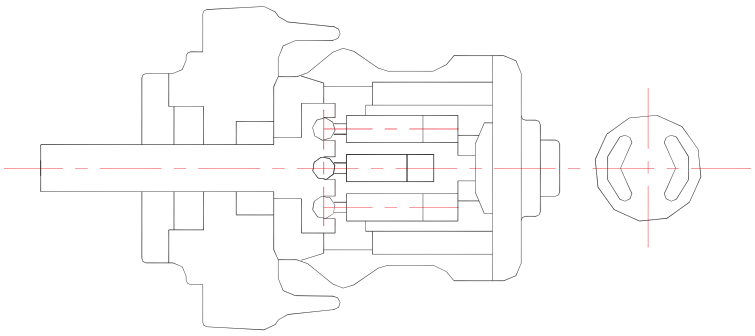
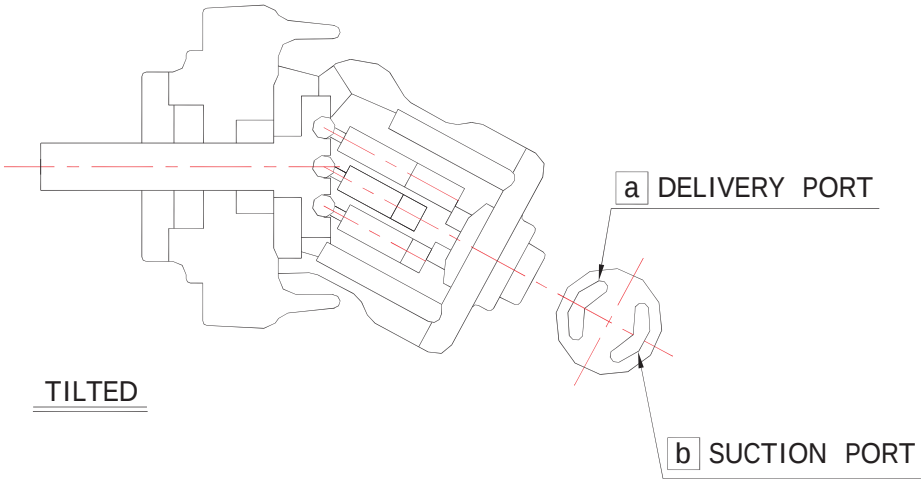


FIG.9 PRINCIPLE OF PUMP WORKING



NEUTRAL




TILTED

| TILTING DIRECTION | RIGHT | LEFT |
|---|---|---|
| DELIVERY PORT | A | B |
| SUCTION PORT | B | A |

FIG.10 EXPLODED VIEW OF AXIAL PISTON PUMP

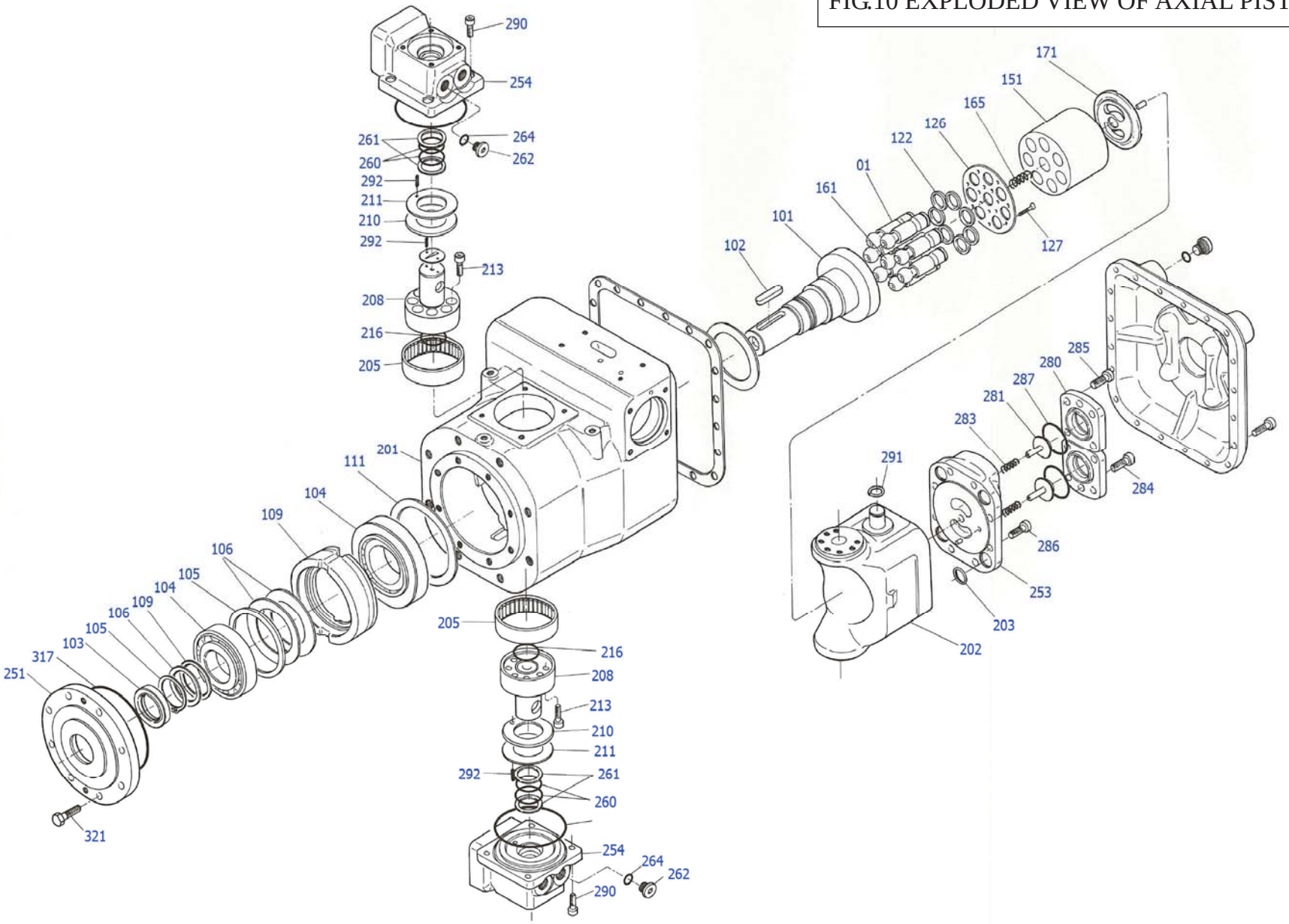


FIG.11 STEERING SYSTEM BLOCK DIAGRAM

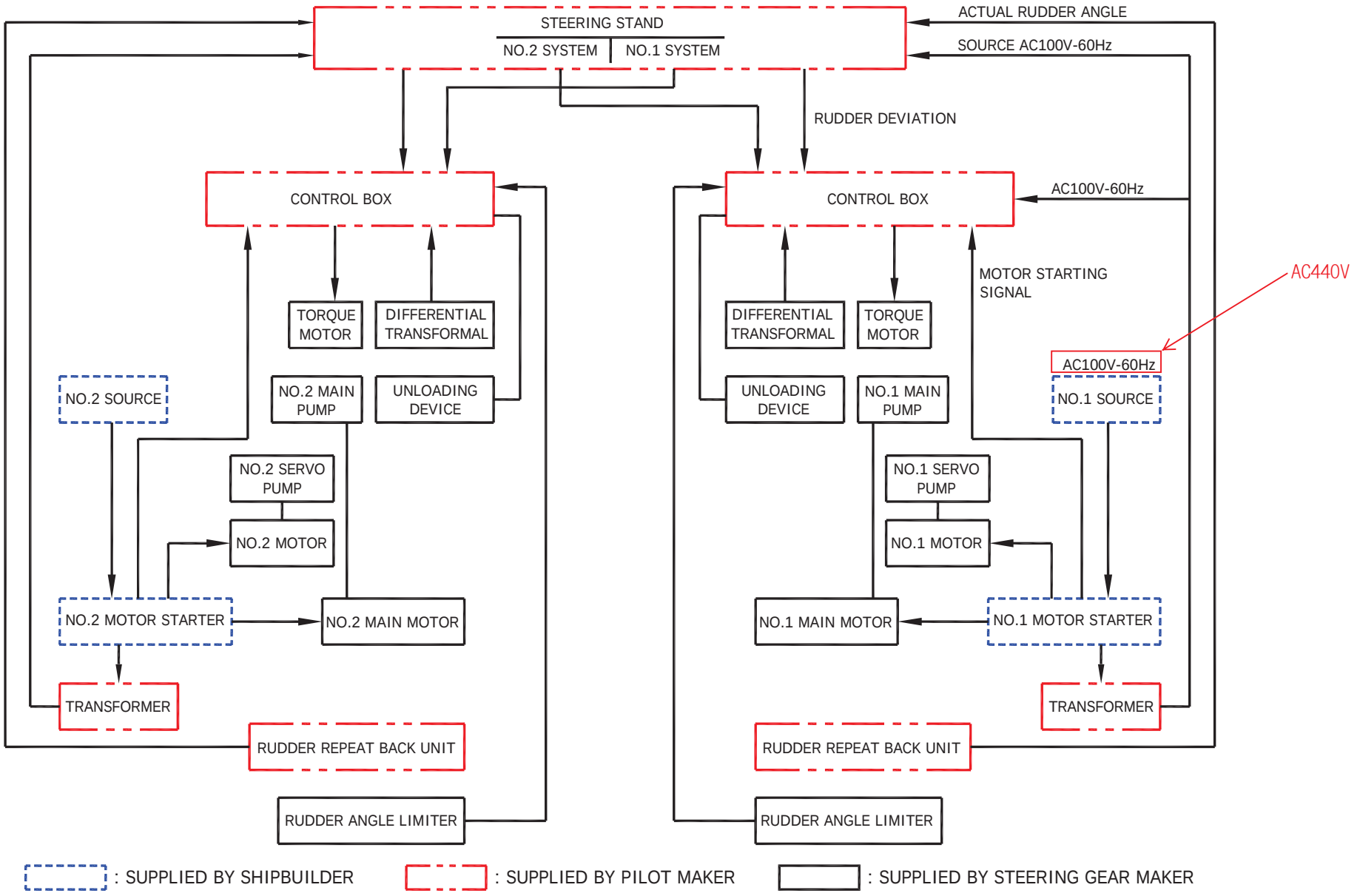
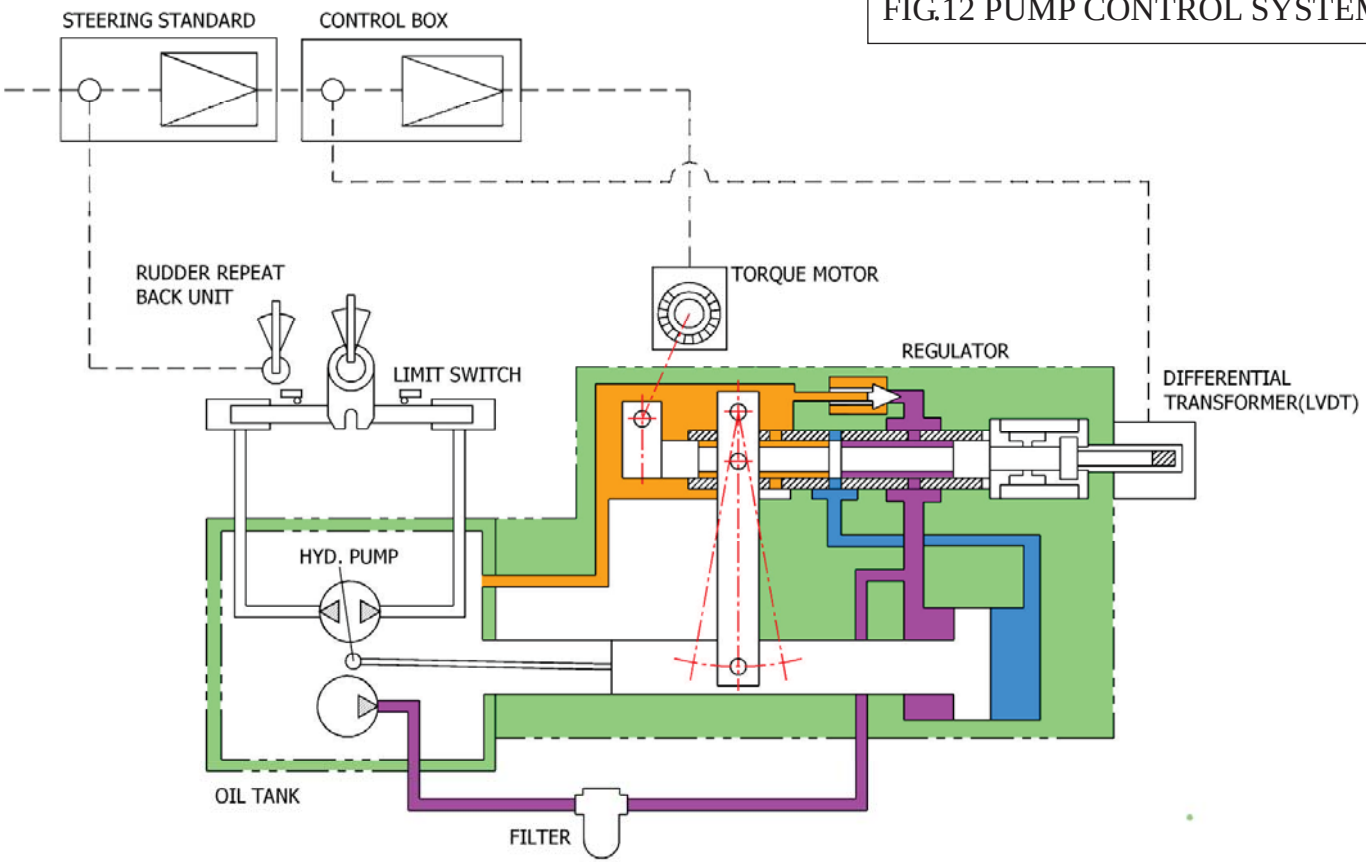
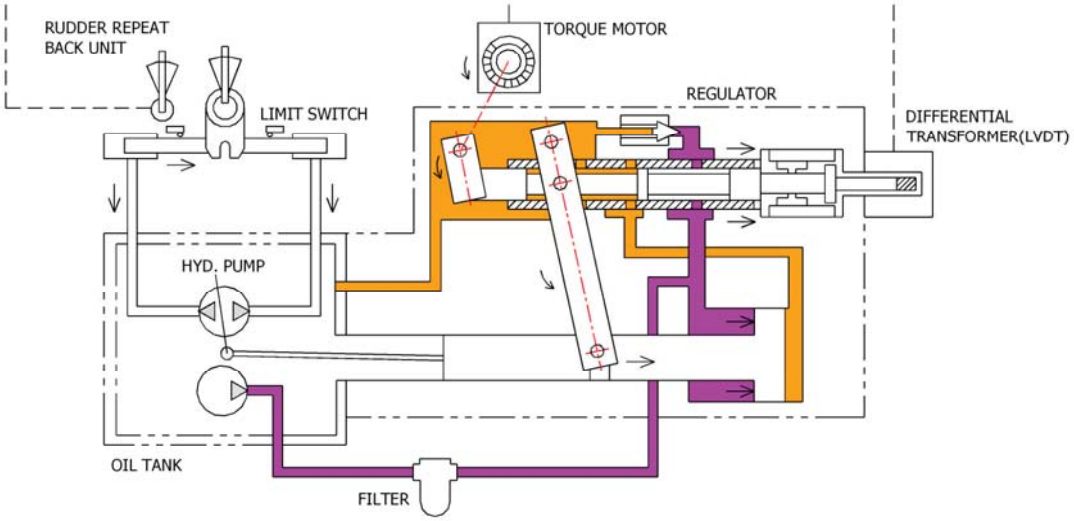
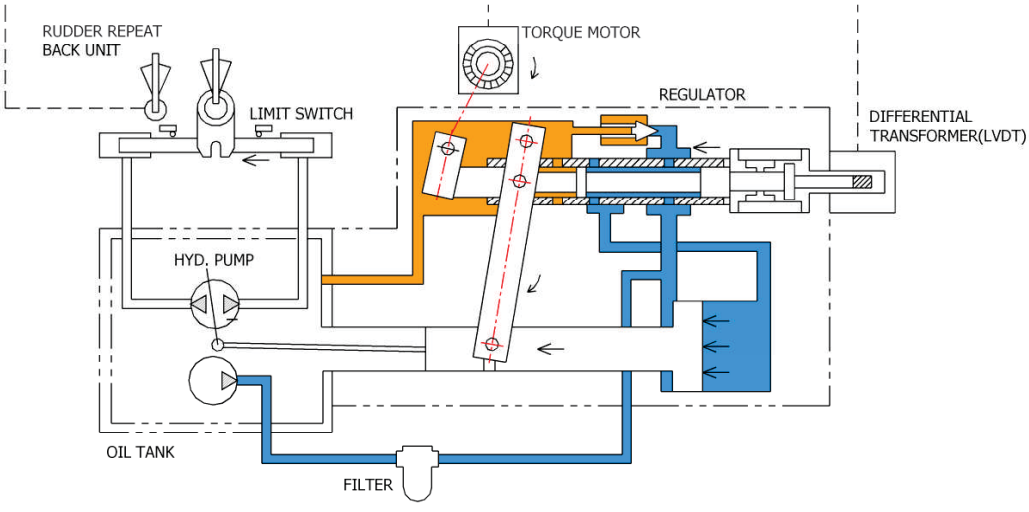


FIG.12 PUMP CONTROL SYSTEM



| TYPE | L |
|---|---|
| REG090 | 54 |
| REG260 | 71 |
| REG500 | 89 |

FIG.13 PUMP CONTROL UNIT

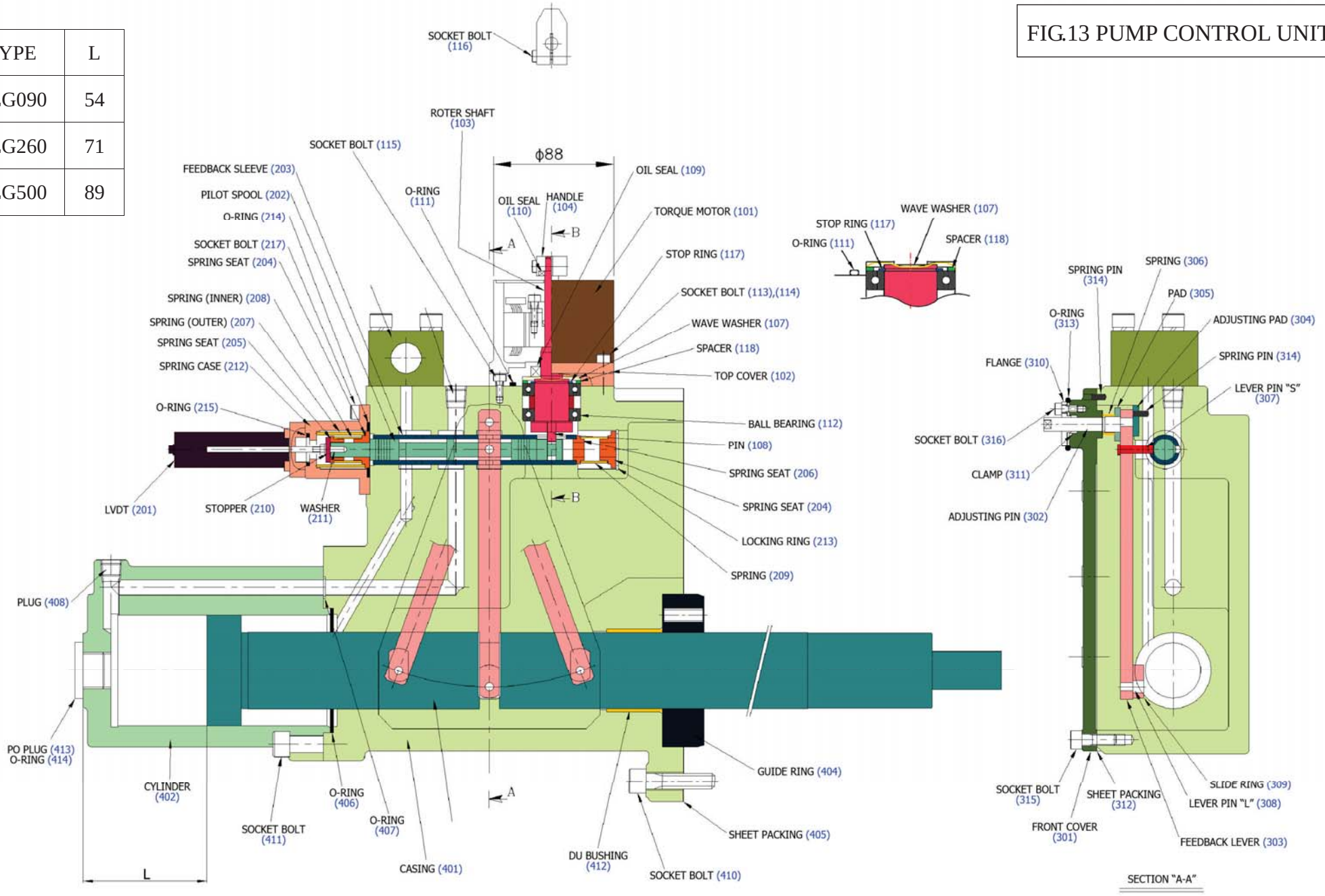


FIG.14 CONNECTING DIAGRAM OF PUMP CNTROL UNIT

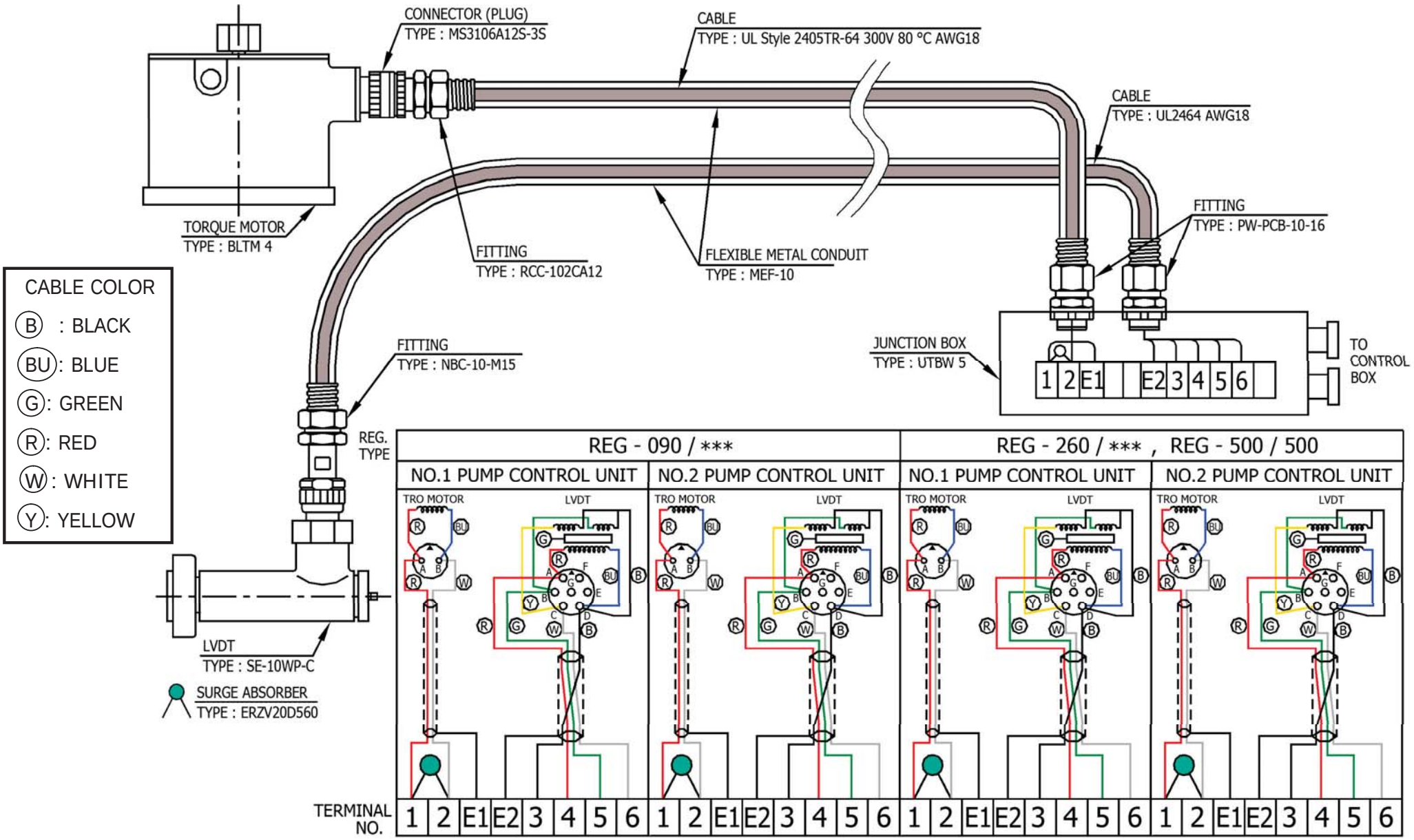
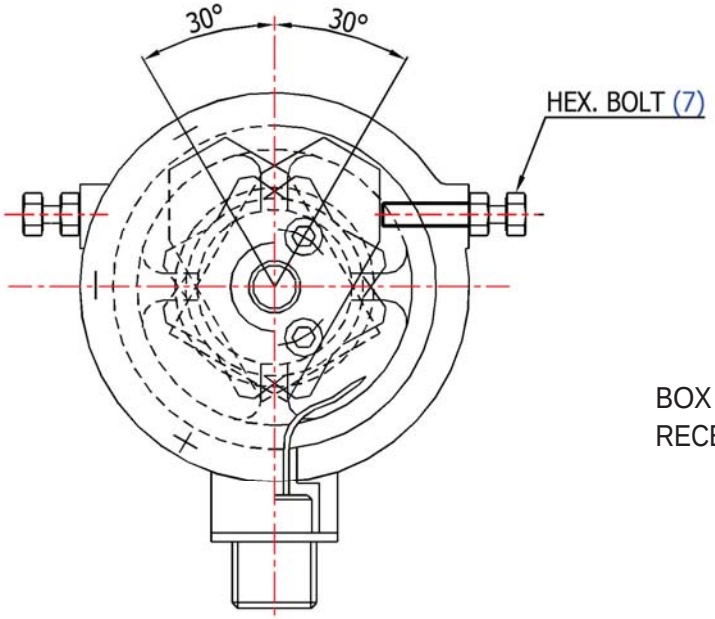
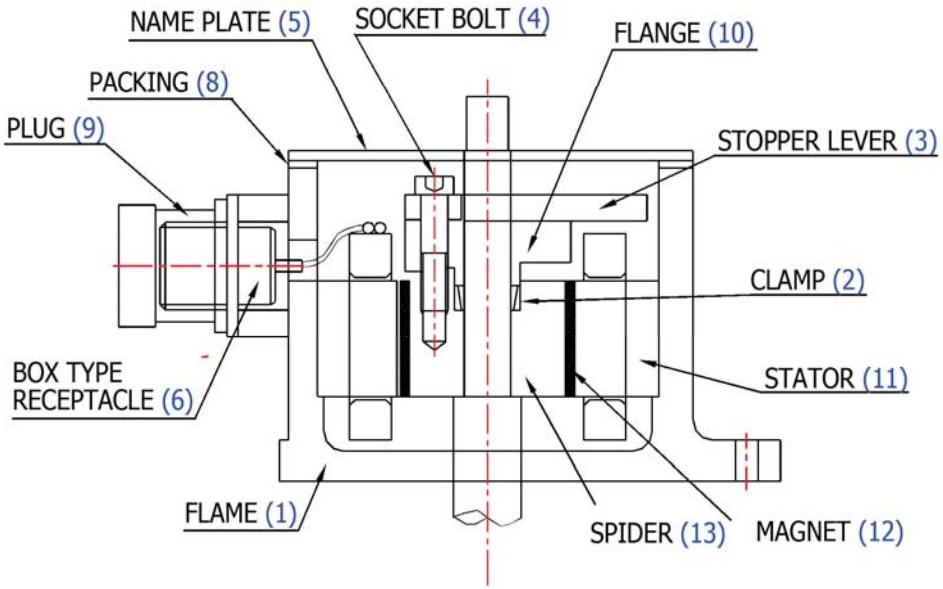


FIG.15 TORQUE MOTOR



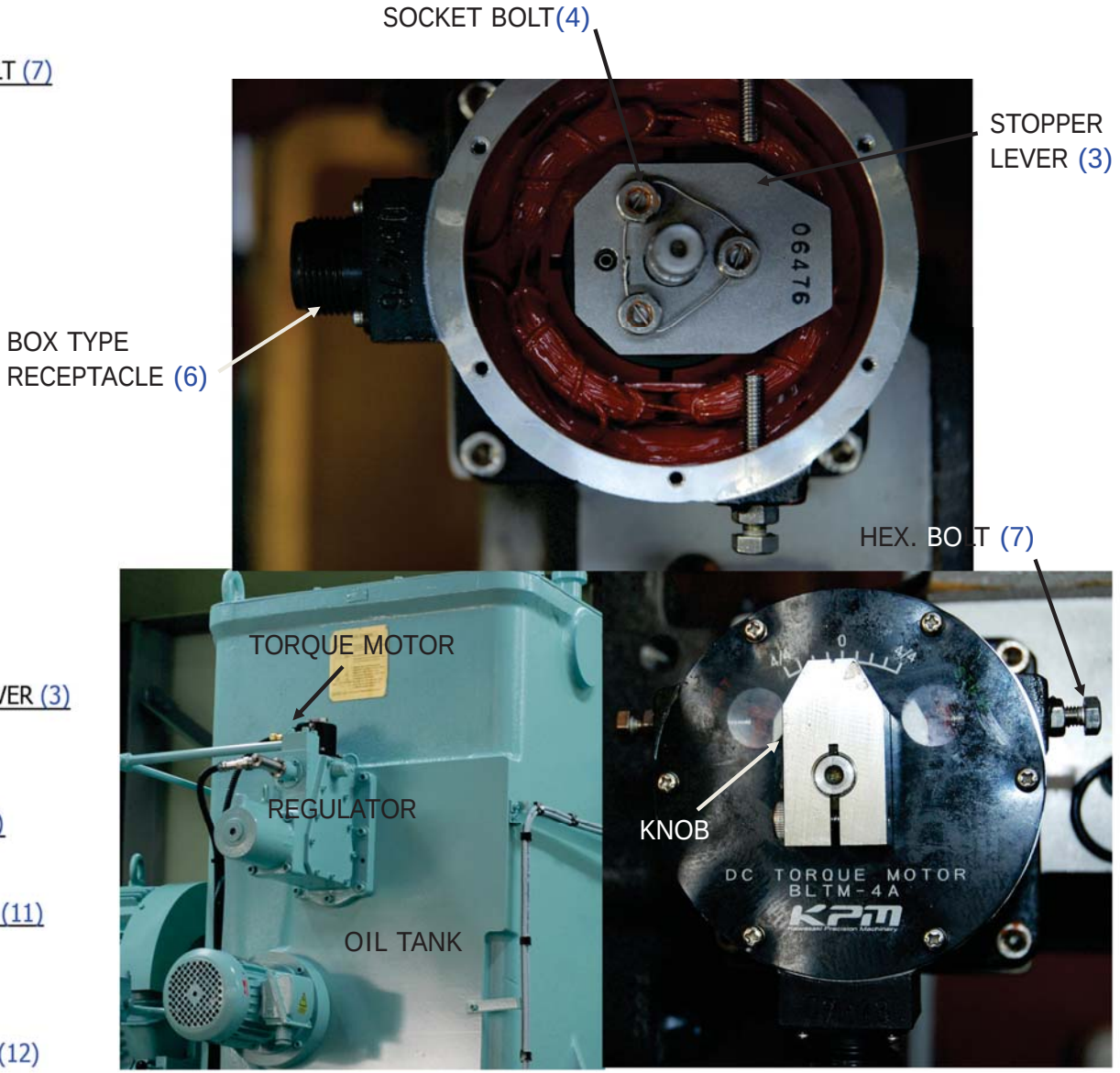



FIG.16 DIFFERENTIAL TRANSFORMER

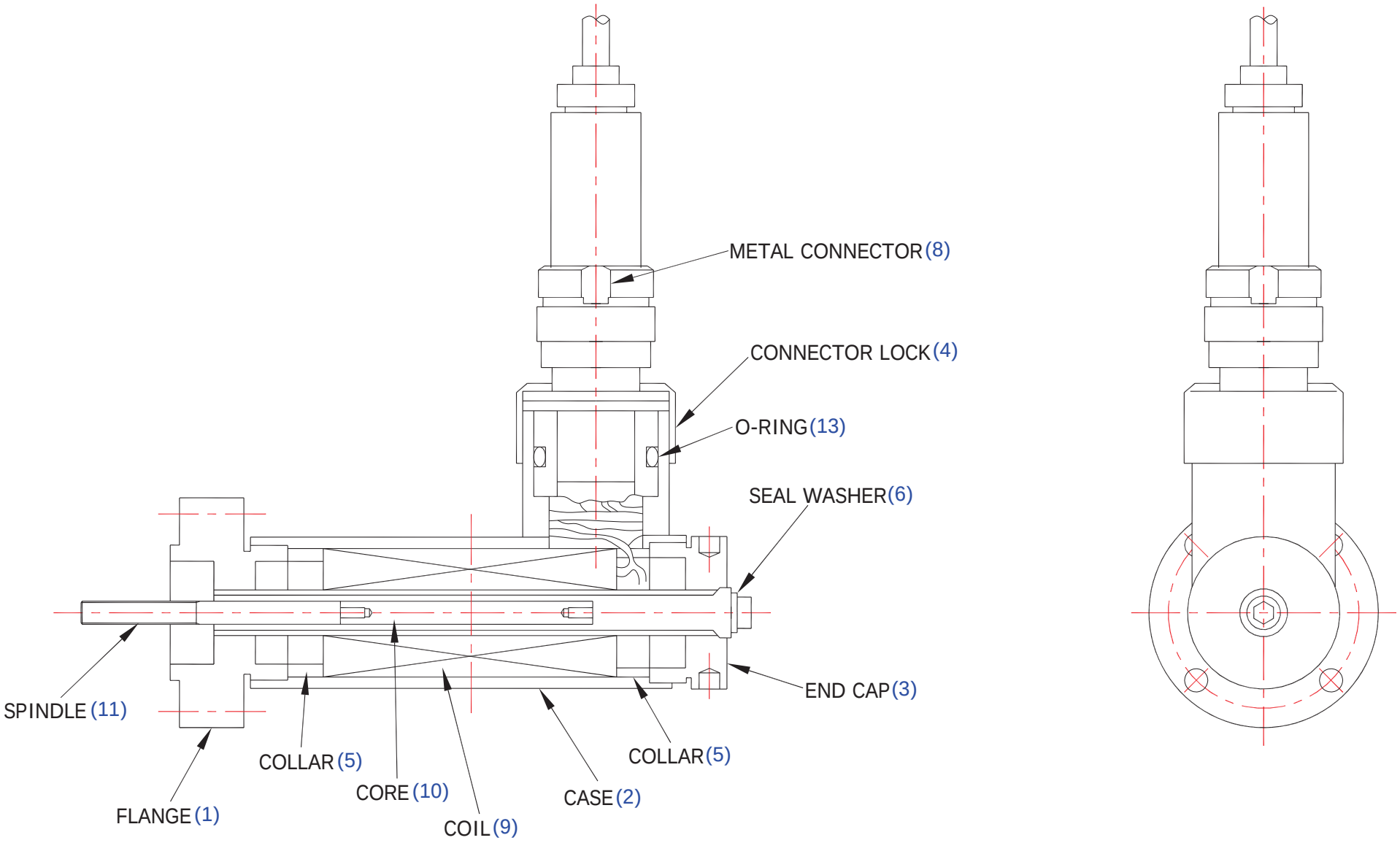
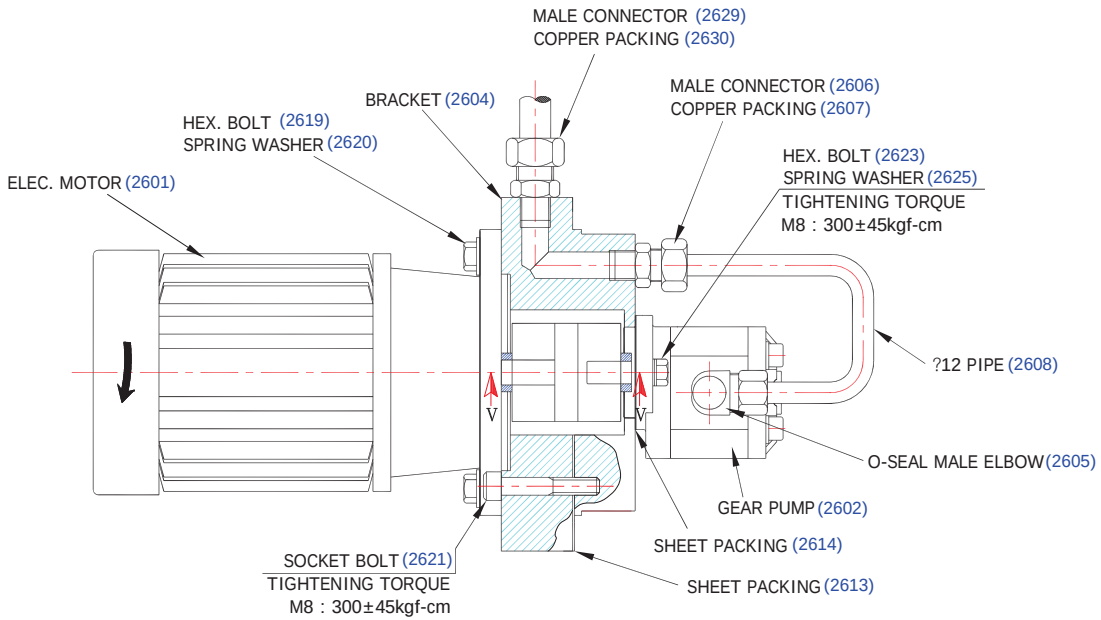
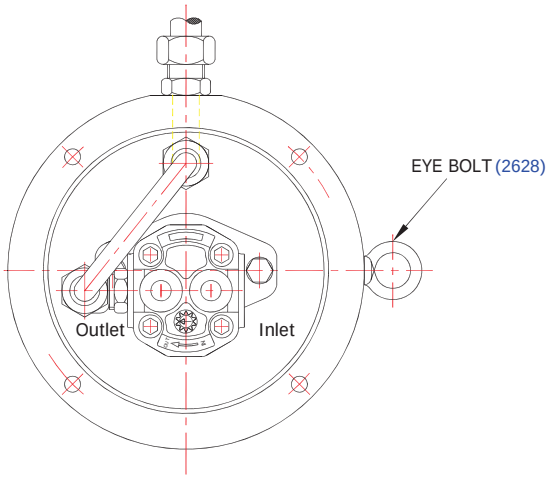
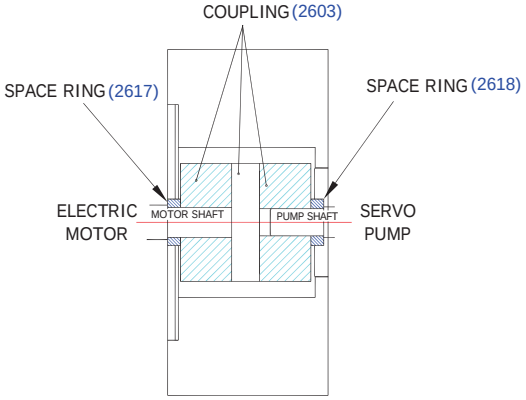


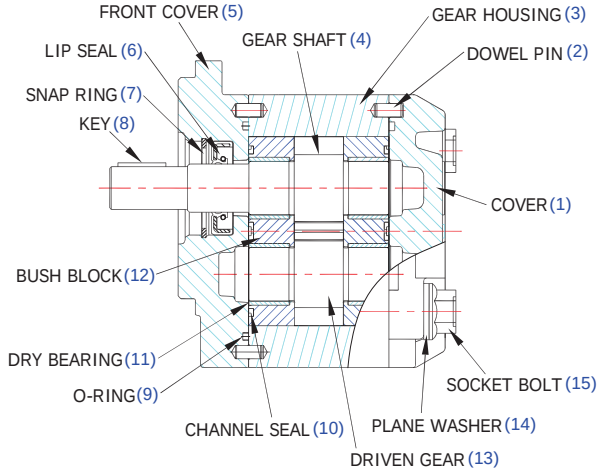
FIG.17 SERVO PUMP UNIT (0.4kW - 3.0cc / REV)



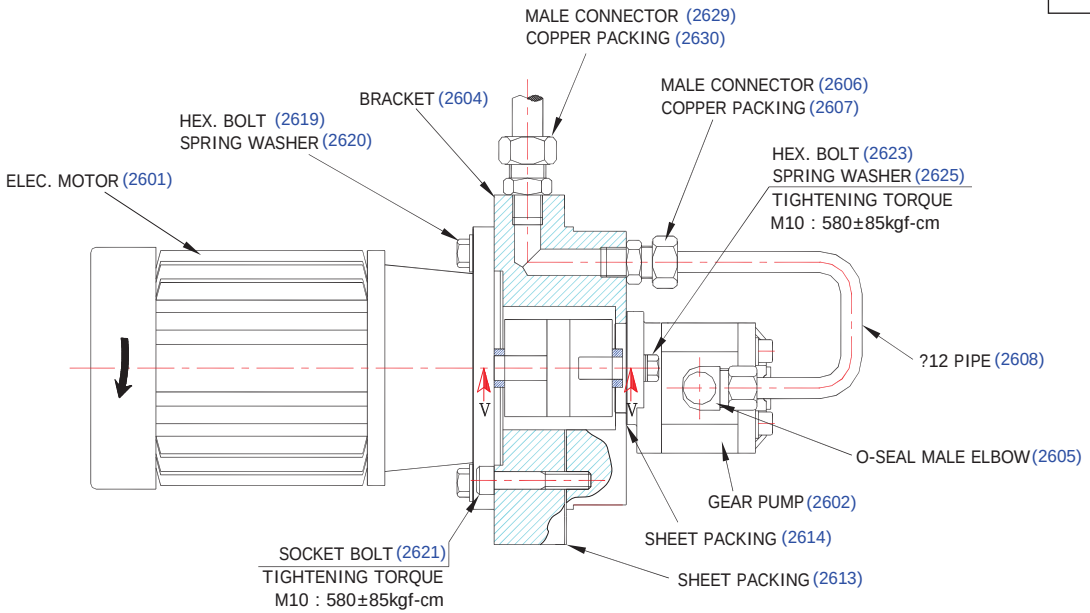



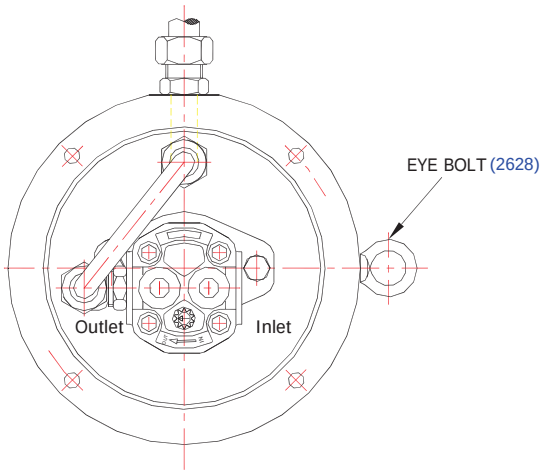

SECTION "V-V"

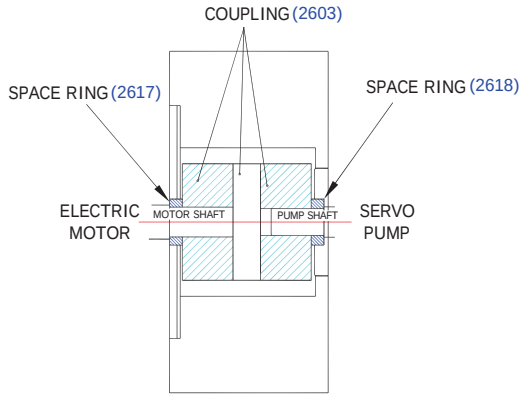



GEAR PUMP ASS'Y SECTION

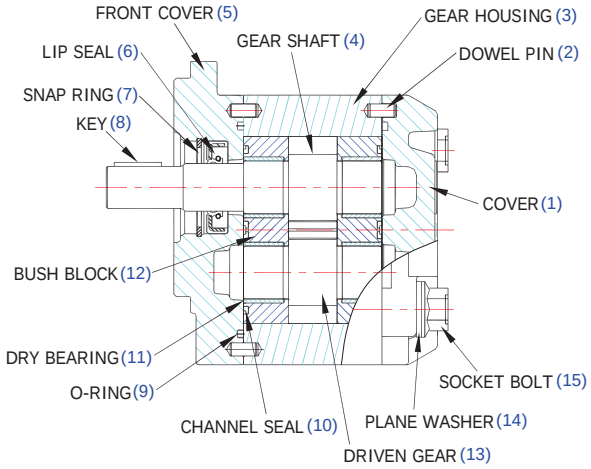
FIG.17 SERVO PUMP UNIT (0.75/1.5kW – 6.5cc/12.0cc- REV)




SECTION "V-V"




GEAR PUMP ASS'Y SECTION

FIG.18. RELIEF VALVE FOR SEVO PUMP

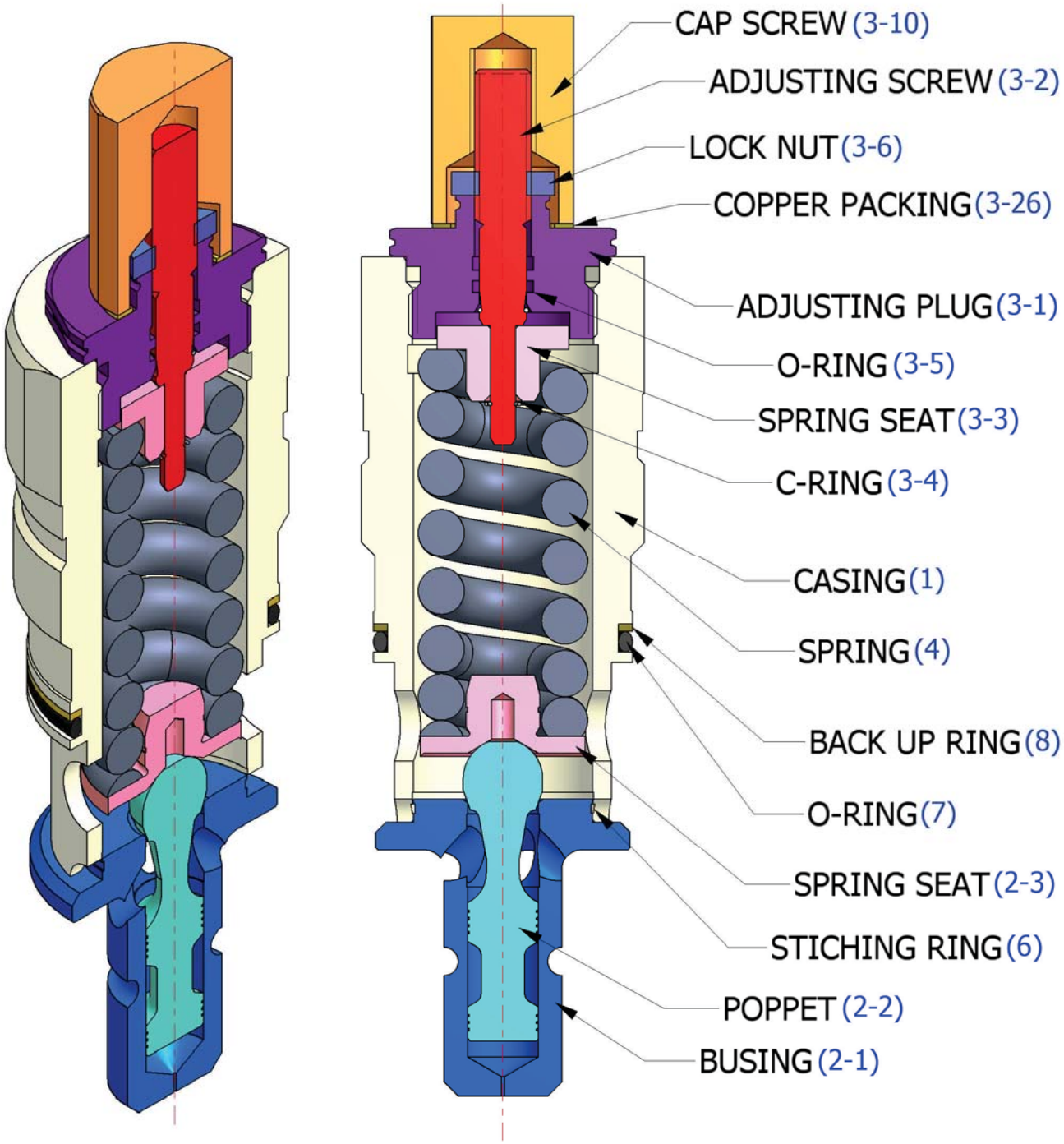
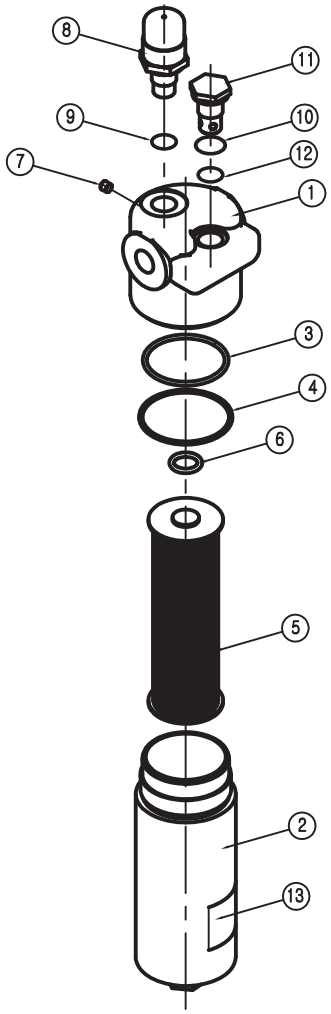
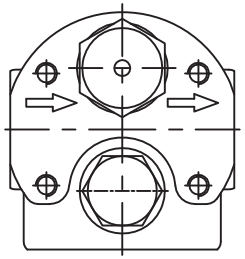
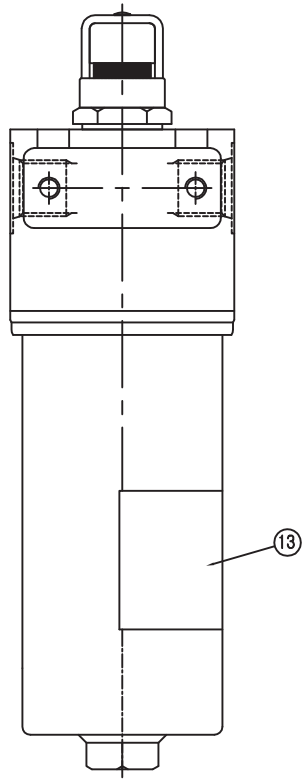


FIG.19 LINE FILTER

| | NAME OF PART |
|---|---|
| 1 | FILTER HEAD |
| 2 | FILTER CASE |
| 3 | O-RING |
| 4 | BACK UP RING |
| 5 | FILTER ELEMENT |
| 6 | O-RING |
| 7 | PT PLUG |
| 8 | VISUAL INDICATOR |
| 9 | PACKING |
| 10 | O-RING |
| 11 | BY PASS VALVE |
| 12 | O-RING |
| 13 | NOTICE PLATE |





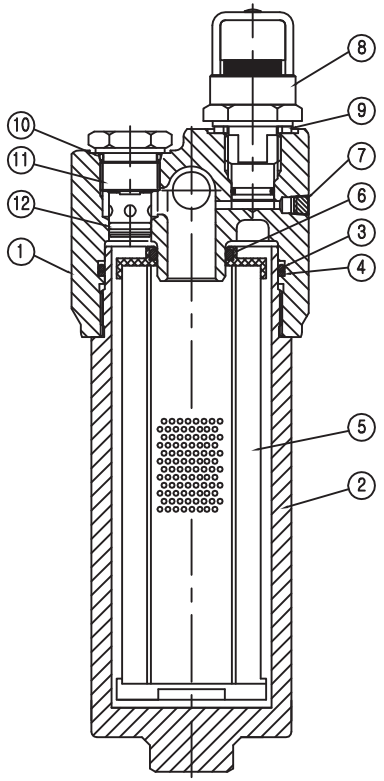
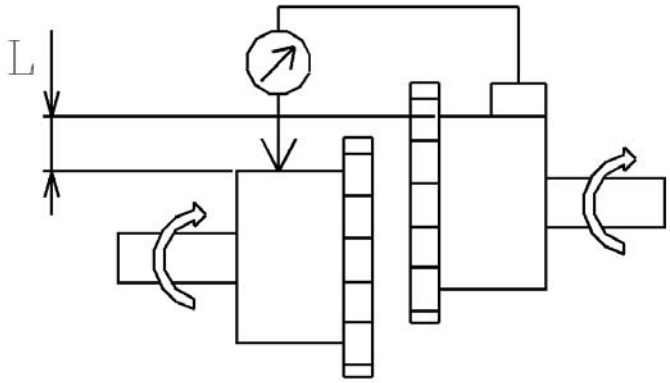
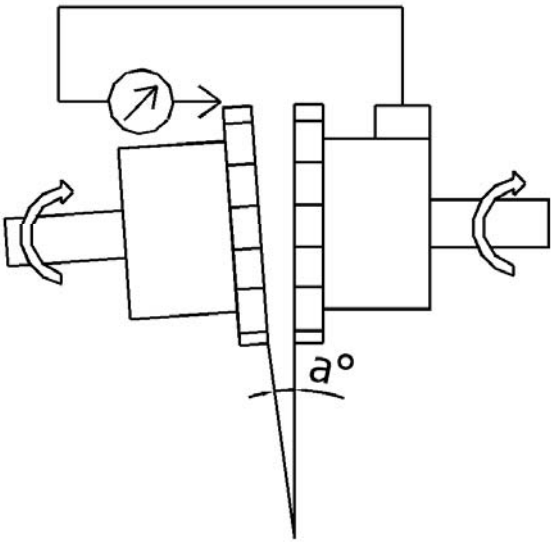



FIG.20 CENTERING OF HYDRAULIC PUMP AND ELECTRIC MOTOR

PARALLEL ERROR



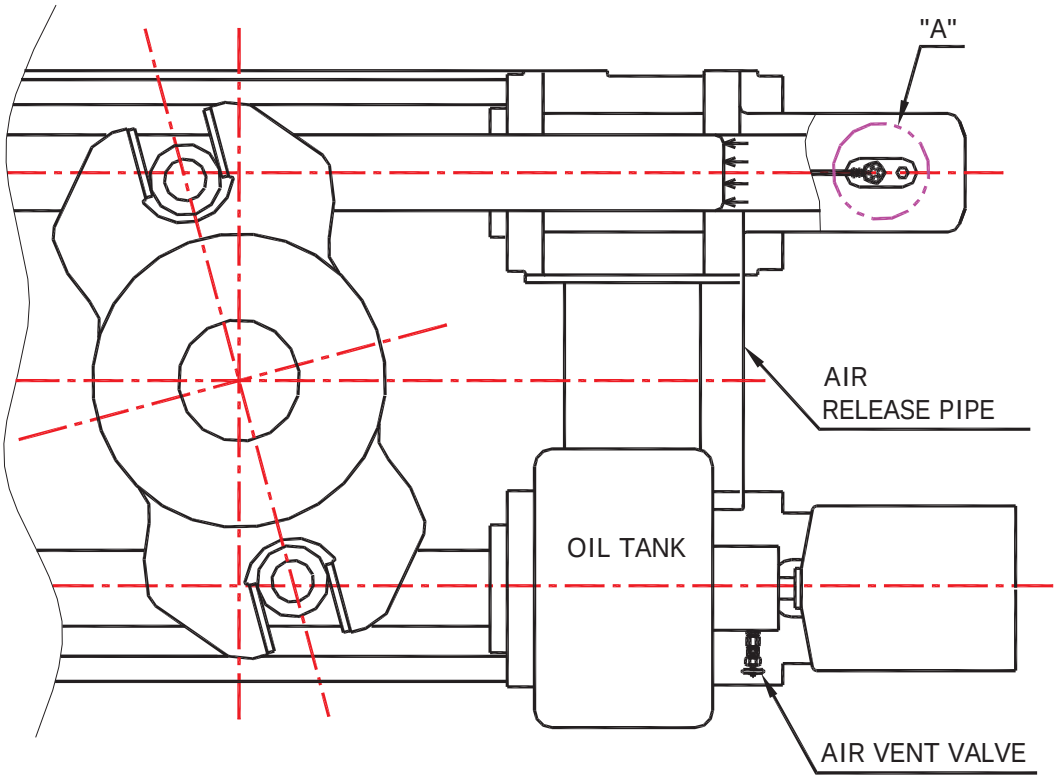

INCLINATION ERROR

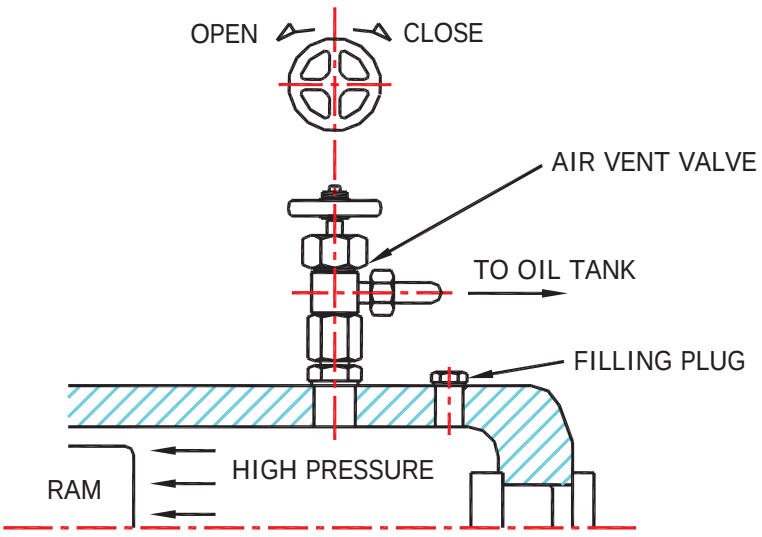



LIST OF ALLOWABLE ERROR

| | PARALLEL ERROR (L) | INCLINATION ERROR (a) |
|---|---|---|
| 허용 오차 | 0.15mm AND BELOW | 0.5° AND BELOW |

FIG.21 AIR RELEASING METHOD



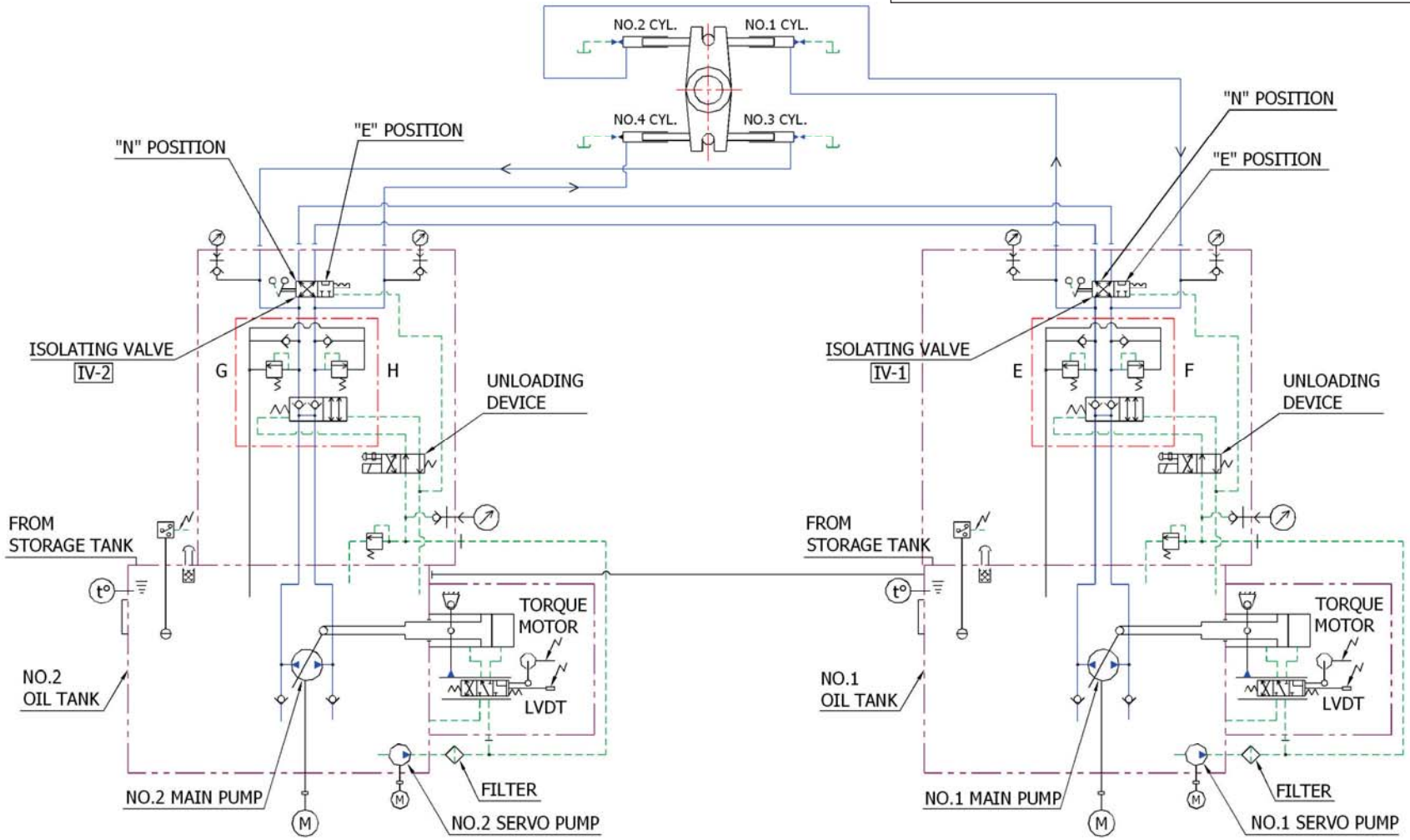




DETAIL "A"

## Caution

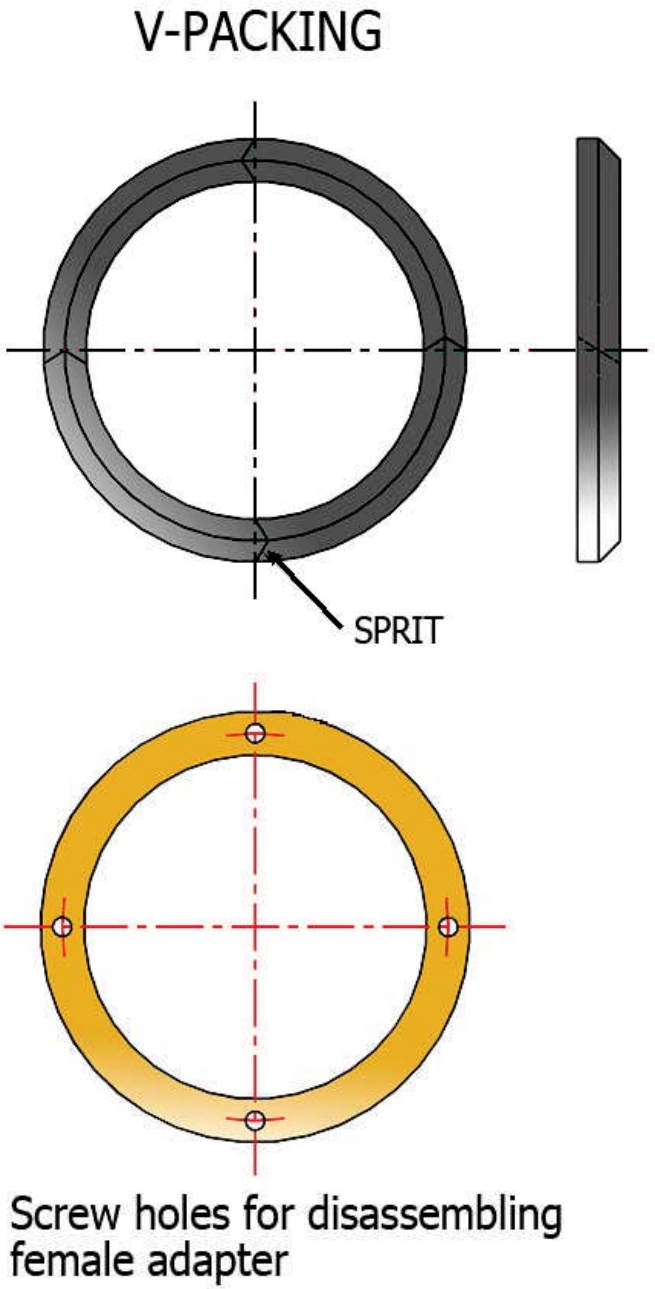
- Open the air vent valve attached on the cylinder where the ram is drawn (high pressure. Side) and release the air.

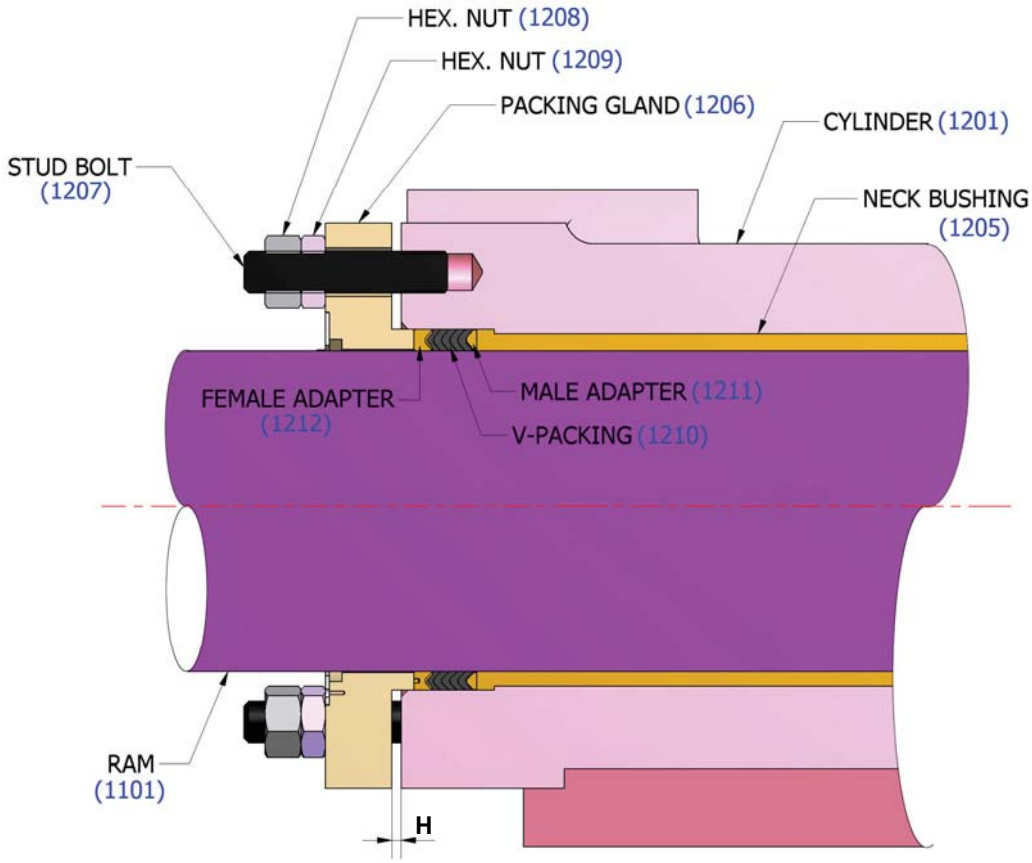
FIG.22 ADJUSTING PROCEDURE OF SAFETY VALVE




| SAFETY VALVE | PUMP | OPERATION OF CONTROL KNOB | ISOLATING VALVE | | PRESS. GAUGE |
|---|---|---|---|---|---|
| | | | IV-1 | IV-2 | |
| E | NO.1 | STB'D | "E" POSITION | "N" POSITION | NO.1 CYL. |
| F | | PORT | | | NO.2 CYL. |
| G | NO.2 | STB'D | "N" POSITION | "E" POSITION | NO.4 CYL. |
| H | | PORT | | | NO.3 CYL. |

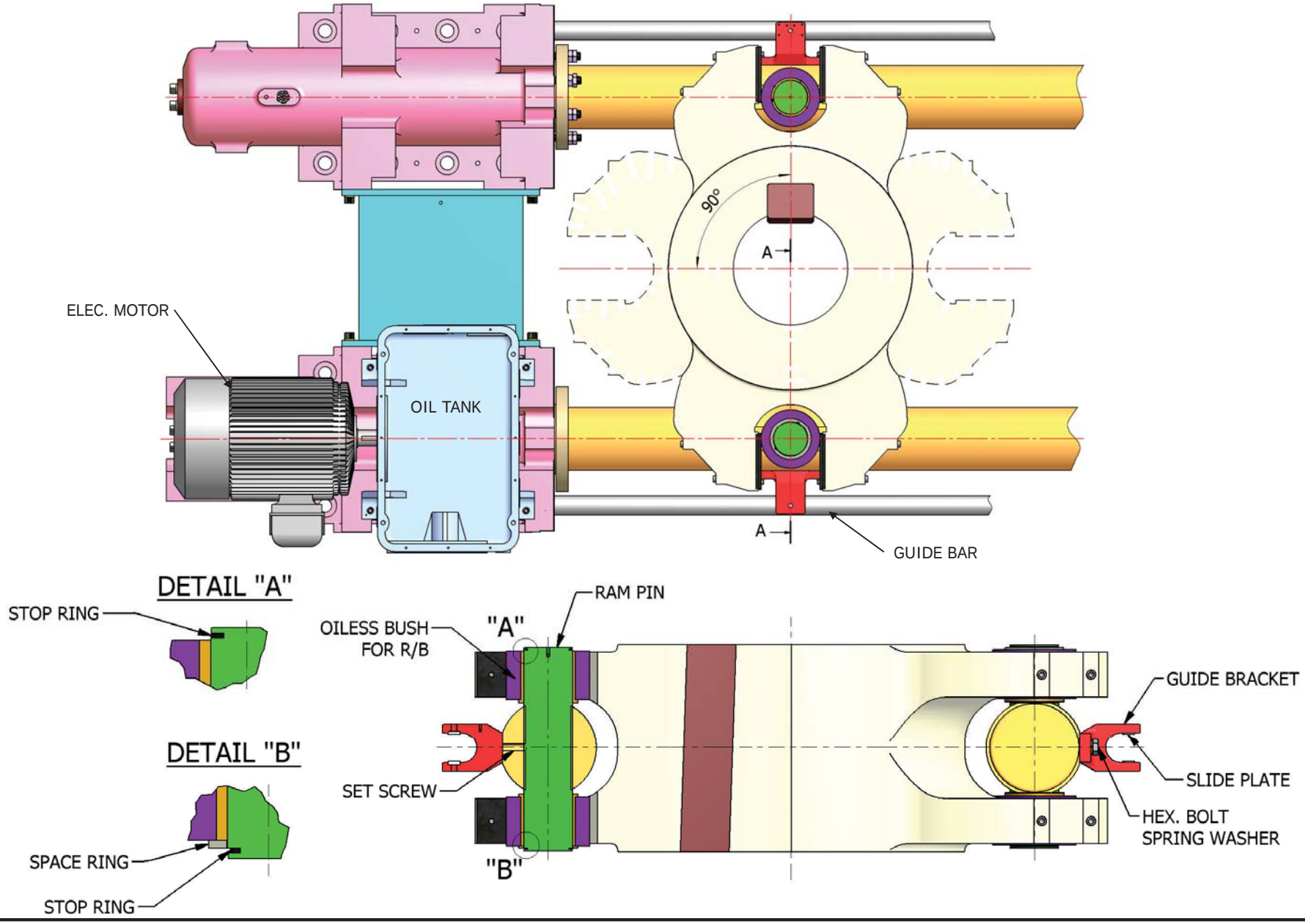
FIG.23 ASSEMBLY OF RAM V PACKING




| RAM DIA. (ΦD) | H (mm) |
|---|---|
| 170~250 | 2~6 |
| 265~425 | 4~8 |

FIG.24 DISMANTLING PROCEDURE FOR PINTLE BEARING INSPECTION



# FIG.25 TROBLE SHOOTING FLOW CHART (STEERING GEAR)