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JAPANESE INDUSTRIAL STANDARD

Testing Methods for Load Carrying Capacity of Lubricating Oil

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Testing Methods for Load Carrying Capacity
of Lubricating Oil

K 2519-1987

1. Scope

This Japanese Industrial Standard specifies the testing methods for load carrying capacity mainly of extreme pressure lubricating oil.

Remark: In this Standard the units and numerical values given in { } are based on the traditional unit and are the Standard value, and those shown in (()) are the marking unit and numerical value in the testing machine, and are informative reference value.

2. General Matters

The rounding-off of numerical values shall be in accordance with JIS Z 8401.

3. Definitions

For the purpose of this Standard, following definitions apply:

- (1) load carrying capacity The maximum load or maximum pressure which is able to be supported by lubricating oil when a specified testing machine is operated under a definite wear condition without causing seizure and other damage on the sliding wear contact surface. It is expressed by acceptable limit load in SODA type four-ball method, and by OK value in Timken method.
- (2) wear The fact that the surface of steel ball for test or test block is damaged by mechanical or chemical action or complex of both.
- (3) wear trace The trace of damage caused by wear on the surface of steel ball for test or test block.
- (4) seizure The partial melting of metal at the frictional surface of test block with steel ball for test or test cup. Herein the seizure designates the case where melting on a part of frictional surface can be recognized visually before the frictional surface attains such remarkable state the frictional surface completely adheres.

In the SODA type four-ball method, the time when the run-out of torsion pointer has exceeded a definite value is called as seizure, the maximum oil pressure load causing no seizure, as acceptable limit load, and the minimum oil pressure load causing seizure, as the seizure limit load.

Applicable Standards: See page 32.

- (5) Scoring In Timken method, the states shown in Fig. 8 (m) to (q) are of various wear traces appearing on the surface of test block is called as scoring, the states shown in Fig. 8 (a) to (d), as without scoring, the maximum load (mass value of weight applied to load pan) generating no scoring, as OK value, and the minimum load causing scoring, as score value.

- Remarks 1. The state of the most general scoring is the state where such damage exists that indicates local metal melting on a part of comparatively normal wear trace as shown in Fig. 8 and usually melting appears with protruding from the width of wear trace. On the surface corresponding to test cup, usually not excessively remarkable streak trace appears.
2. In Timken method, during test generally it is able to know that the seizure is caused according to streak trace generated on the test cup surface, mixing-in of large amount of wear powder in oil, abnormal noise and vibration, etc., but in the case where the degree of seizure is small, it can be known at first by checking the frictional surface after stopping the rotation in some cases.

4. Classification of Testing Methods

The testing methods shall be classified into the following two styles.

- (1) SODA Type Four-Ball Method The method to test the load carrying capacity of lubricating oil according to SODA type four-ball wear testing machine.
- (2) Timken Method The method to test the load carrying capacity of lubricating oil according to Timken type extreme pressure testing machine.

5. SODA Type Four-Ball Method

5.1 Summary of Testing Method Fix the steel balls for test with sample container and vertical shaft, and fill the sample in the sample container. After applying test oil pressure without rotating the vertical shaft under standing still state, rotate at 750 revolutions per minute, examine the existence of seizure within the specified time. Repeat this operation with changing the steel balls and sample at each one time to obtain the acceptable limit load, and take it as the load carrying capacity.

Further, obtain the average diameter of wear traces at this time.

5.2 SODA Type Four-Ball Friction Testing Machine The testing machine having shape and dimensions shown in Fig. 1 and Fig. 2, consists of three parts of driving part, loading part and test part.

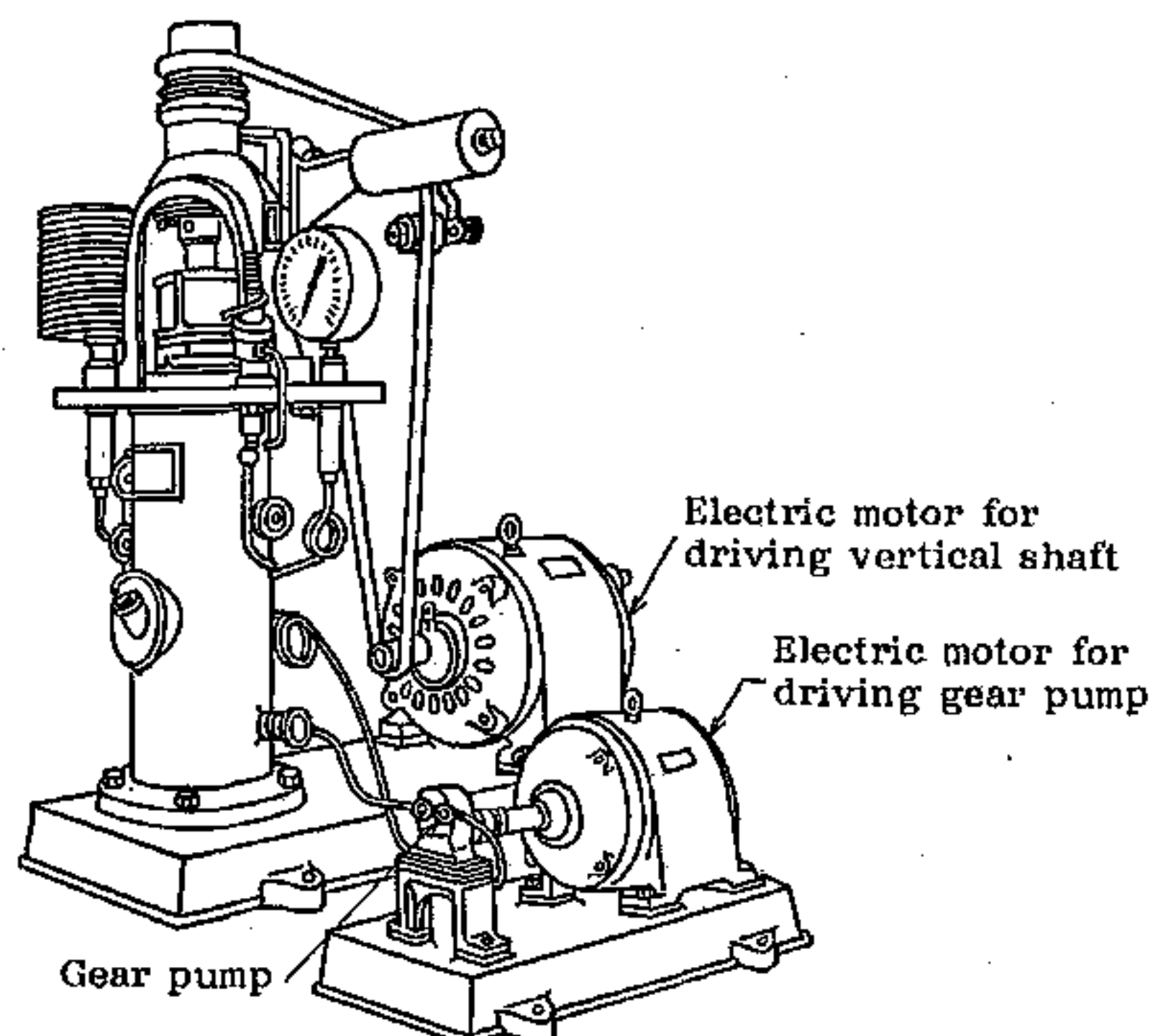
(1) Driving Part

- (a) The electric motor⁽¹⁾ for driving vertical shaft shall be three phase a.c. induction motor of not less than 1.5 kW and of which number of revolutions shall be 100 revolutions per minute for 50 Hz in frequency and 1200 revolutions per minute for 60 Hz. The outer diameter of belt pulley of this motor shall be 57.0 mm in the case of 50 Hz and 47.5 mm in the case of 60 Hz.

Note (¹) For the motor for driving, it is convenient to use the motor of varying speed type.

- (b) The electric motor for driving gear pump shall be three-phase a.c. induction motor of not less than 0.75 kW, its number of revolutions shall be 1500 revolutions per minute for 50 Hz in frequency and 1800 revolutions per minute for 60 Hz, and, directly connected with the gear pump.
- (c) The vertical-shaft outer cylinder shall be a rotating body attached to the thrust receiving stand by the radial ball bearing of upper part and the angular type radial ball bearing of under part as shown in Fig. 2, and, provided with a belt pulley of 75.0 mm in outer diameter at upper end. The vertical shaft shall a shaft capable of travelling vertically insides the vertical shaft outer cylinder, having about 23 mm in outer diameter, about 200 mm in length and two retaining holes, and fixed with vertical-shaft outer cylinder by either one of the hole and a set bolt.
- (d) The belt for driving shall be about 25 mm in width, and, hung on belt pulley for driving vertical shaft and belt pulley for vertical-shaft outer cylinder through two idle wheels.

Fig. 1. SODA Type Four-Ball Friction Testing Machine (One Example)

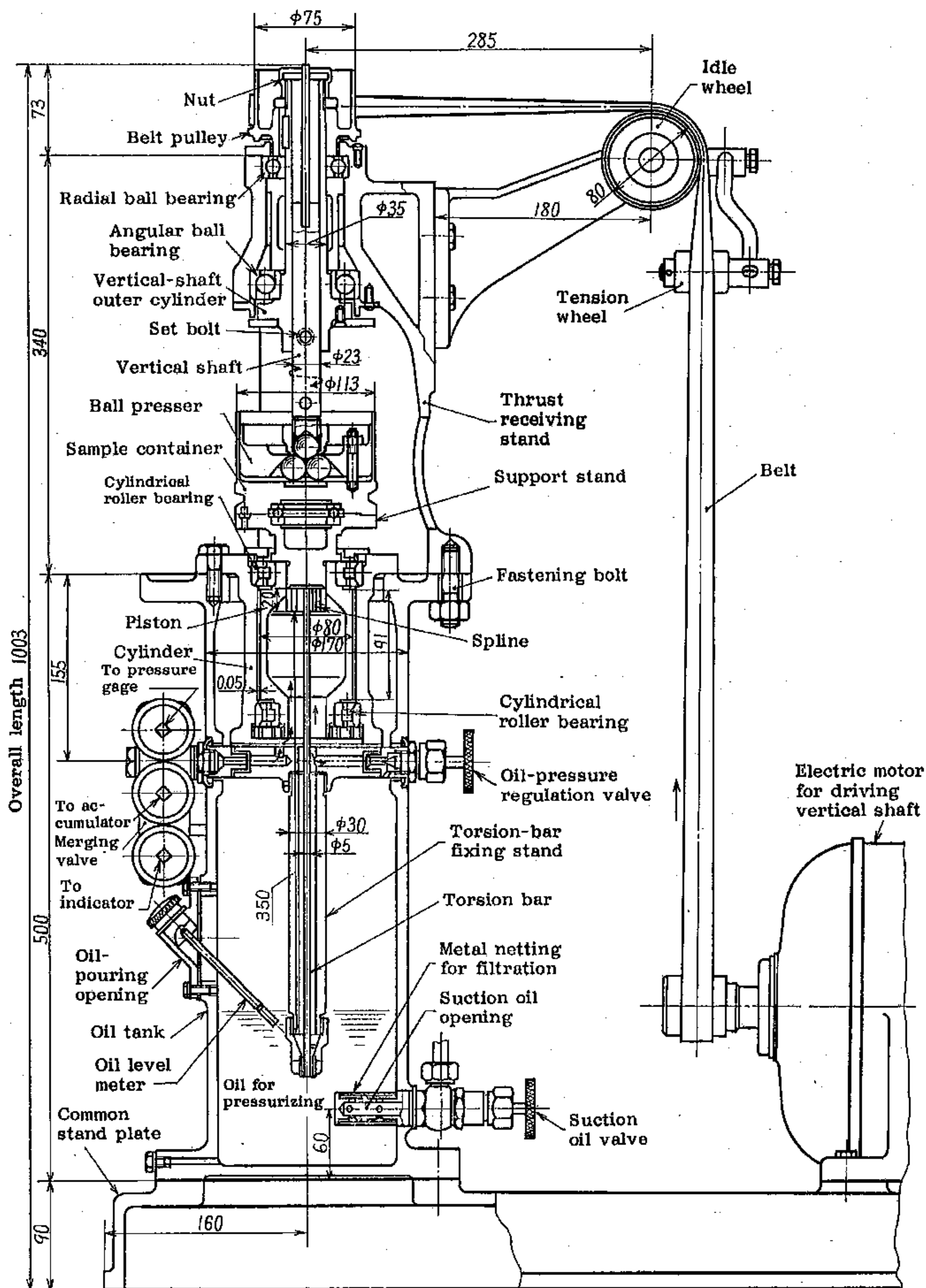


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Fig. 2. SODA Type Four-Ball Friction Testing Machine (One Example)

(Detailed Drawing)

Unit: mm



(2) Loading Part

- (a) The gear pump for pressurizing shall be that of about 1.96 MPa {20 kgf/cm²} in maximum using pressure and about 7 l/min of maximum discharge amount in capacity.
- (b) The oil tank shall be of vertical circular cylindrical shape, provided with a pouring-oil opening with cover and oil level meter at its middle part, and with a suction oil opening attached with metallic netting for filtration⁽²⁾ at the lower part.

Further, at the outlet of suction oil opening a suction oil valve shall be attached.

Note ⁽²⁾ For metallic netting for filtration, the sieve of 425 μ m in aperture specified in JIS Z 8801 shall be used.

- (c) The cylinder shall be connected with the upper part of oil tank, having the inner diameter of 80.1 mm and inside it a piston for pressurizing, received.
- (d) The piston shall be a hollow cylinder shape of 80.0 mm in outer diameter, and at its upper end supported in the cylinder by the cylindrical roller bearing of upper part and that of lower part, the support stand to be placed-on with the sample container shall be provided.
- (e) The lower end of the support stand is made spline, and fitted with the spline attached to the torsion bar fixed at the inside of torsion bar fixing stand, and it shall be of such structure capable of sliding vertically.
- (f) The torsion bar shall be of piano wire of Class A or Class B of JIS G 3522 of 5 mm in diameter and about 350 mm in length, and when calibrated according to 5.4, the torsion scale (degrees) at 118 N {12 kgf} in load, be in the range of 25 to 29.
- (g) The pressure gage⁽³⁾ shall be of the highest scale of 1.47 MPa {15 kgf/cm²} and of the subdivision scale of 0.049 MPa {0.5 kgf/cm²}.

Note ⁽³⁾ The pressure gage generates errors easily, and therefore inspection shall be made at times.

- (h) For oil pressurizing, Class 2 (additive) of JIS K 2213 ISO VG 68 shall be used⁽⁴⁾ and, filled up to the specified oil surface in the oil tank.

Note ⁽⁴⁾ It shall be exchanged at least once in a year to be used.

(3) Test Part

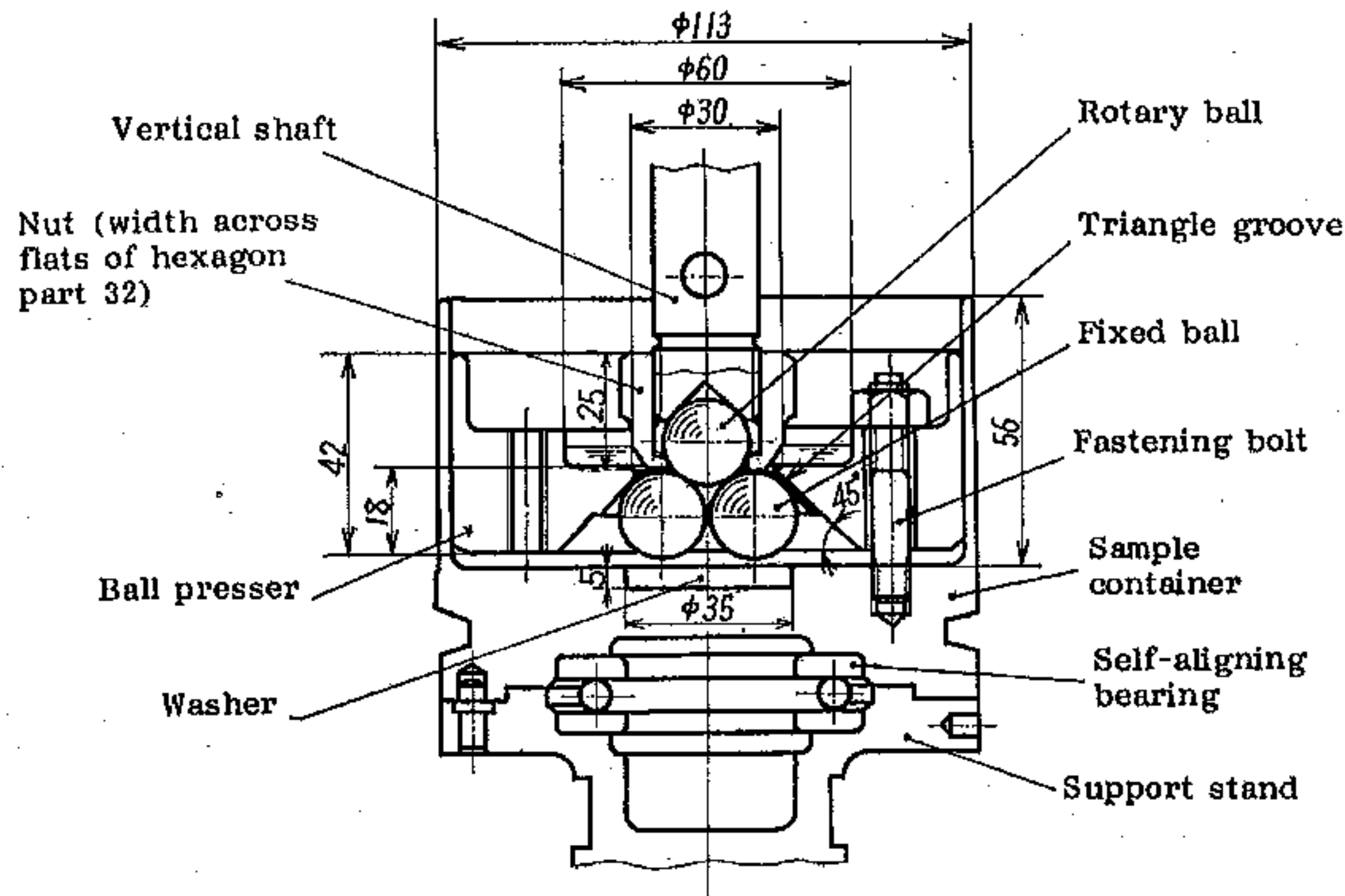
- (a) The sample container shall be of shape and dimensions shown in Fig. 3.

Further, inside the sample container, three steel balls for test shall be able to be fixed by ball presser.

- (b) Steel balls for test shall be of high grade 3/4 of JIS B 1501 (basic diameter 19.05 mm).

Fig. 3. Assembly Drawing of Test Part

Unit: mm



(4) Appliances

- (a) Microscope The microscope capable of measuring wear trace of steel ball for test to the nearest 0.01 mm.

Remark: The microscope having microscale in the visual field is convenient.

- (b) Watch The stopwatch capable of measuring the time to the nearest one second.
- (c) Thermometer COC 32 specified in JIS B 7410.
- (d) Torque Wrench The torque wrench of preset type of designation 120 specified in JIS B 4650.

5.3 Solvents for Washing

- (1) Gasoline for Industrial Purpose Class No. 1 specified in JIS K 2201.
- (2) Acetone The acetone specified in JIS K 1503.

5.4 Calibration Method of Torsion Bar In the main test the torsion moment due to friction is balanced with the moment of torsion bar, and when the torsion scale has exceeded a definite value for each load it is taken as seizure, and therefore the torsion bar to be used shall be calibrated in each one year or when considered that abnormalities are generated by miss operation.

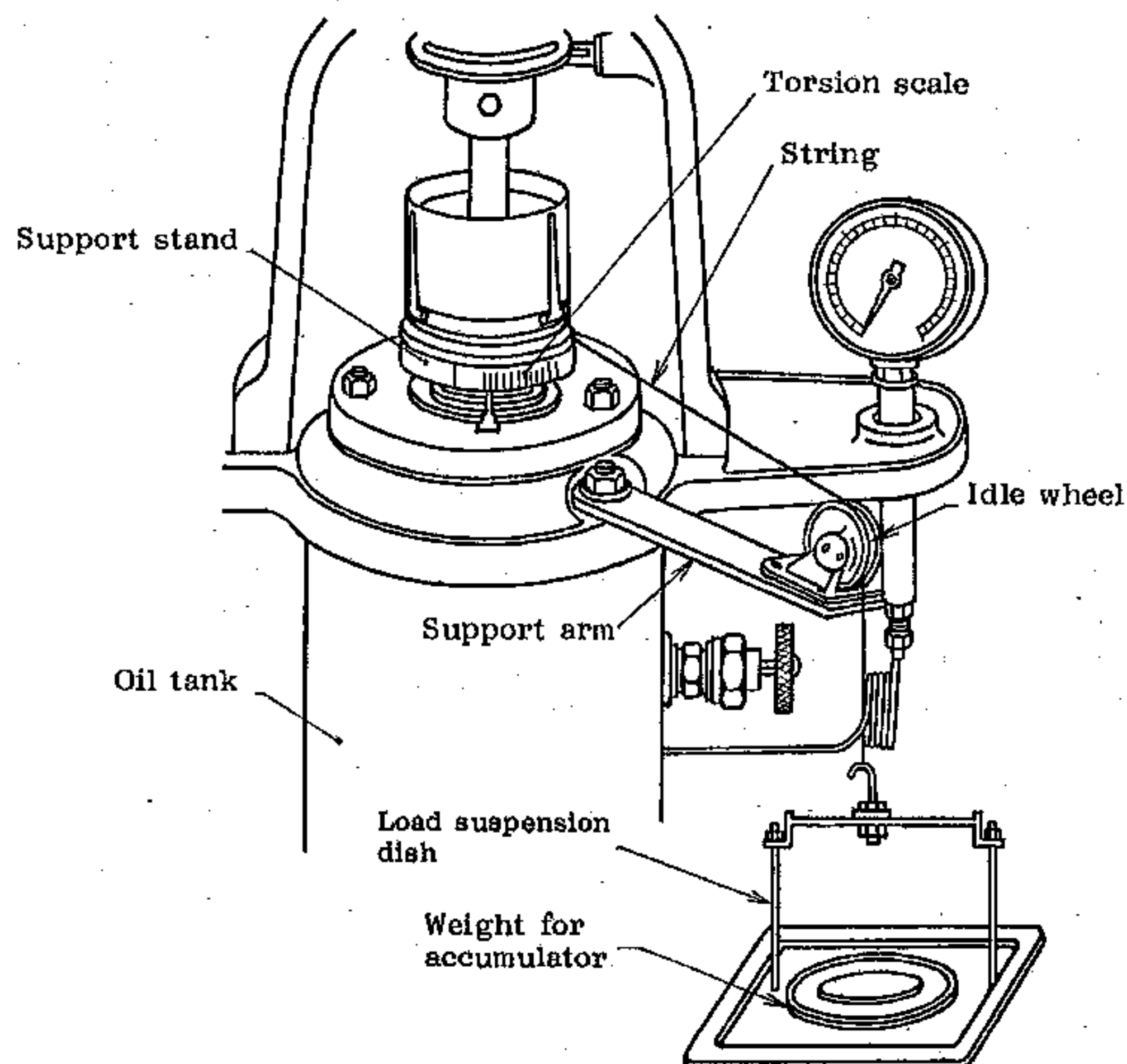
- (1) As shown in Fig. 4 detach the indicator attached at upper surface of oil tank, and instead of it attach a support arm. To this support arm, an idle wheel built in with roller bearing is attached. Hang a string capable of withstanding the load of 294 N {30 kgf} on the pin of back face of support stand, draw out to this side along the outer periphery (radius 57 mm) of support stand and bind to load suspension dish through the idle wheel. Regulate the load suspension dish at the load of 4.9 N {0.5 kgf}. For a weight, use the weight for accumulator (mass of one sheet 500 ± 2 g attached to the testing machine).
- (2) Fix three steel balls to the sample container, and also fix one steel ball to the vertical shaft. Lower the vertical shaft to fix with set bolt. Then detach the belt for driving vertical shaft, fully open the oil pressure regulating valve and suction oil valve, and close the cock (or valve) for indicator. Start to move the electric motor for driving gear pump, while taking care to motion of sample container, throttle the oil pressure regulating valve and then the support stand floats up. Adjust the oil pressure regulating valve so that the three steel balls of sample container contact slightly with one steel ball of vertical shaft. Hang up the load suspension dish to make no load, and read out the 0 point of torsion bar by scale board. At this time, after shaking slightly the support stand in right and left, preferably read the scale of stopping point.

Then, lower the load suspension dish, place-on a sheet of weight to make the load 9.8 N {1 kgf} and read the torsion scale. Also at this time, after shaking up and down the load suspension dish, preferably read the scale at stopping position. Further add each two sheets of weight, and read the scale according to the same operation. In such way, read the scale at each 9.8 N {1 kgf} from 0 N {0 kgf}, 9.8 N {1 kgf}, 19.6 {2 kgf} ... until the maximum becomes 147 N {15 kgf}. When having attained at 147 N {15 kgf}, reversely to the before reduce the load by each 9.8 N {1 kgf} and read the scale until 0 N {0 kgf} in the similar operation. Repeat this three times. For reading of scale, read to one place of decimal.

- (3) Arithmetically average six values measured for each load, and round off to one place of decimal.

Take the load (N {kgf}) on ordinate of section paper and torsion scale (degree) on abscissa, draw a diagram of load-torsion scale and take it as the calibration diagram.

Fig. 4. Torsion Bar Calibration Apparatus



5.5 Preparation for Test

The preparation for test shall be as follows:

- (1) Wash the steel balls for test, sample container, nuts, ball presser, and lower end periphery of vertical shaft with gasoline for industrial purpose and further wash with a small amount of acetone to dry.

Remark: For handling of parts giving influence on the load carrying capacity such as steel balls for test, inside wall of sample container, etc., care shall be taken, and don't touch with fingers and the like, nor adhere oil other than sample.

- (2) Prior to test, fully open the oil pressure regulating valve, suction oil valve, accumulator valve, indicator valve and pressure-gage valve.
- (3) Confirm that the number of revolutions of vertical shaft is 750 ± 30 revolutions per minute.
- (4) Fix on steel ball for test at the bottom of vertical shaft, hereinafter referred to as the "rotary ball". Put three steel balls for test, hereinafter referred to as the "fixed balls", in the sample container, press these by triangular groove parts of ball presser, fix with bolts and attach the sample container on the support stand.

At this time, align the marks described on sample container and ball presser, and fasten bolts uniformly⁽⁵⁾ so that three fixed balls are fixed uniformly.

Note (⁵) For fastening of bolts, it is convenient preliminarily to set the torque wrench at about 9.8 Nm {about 100 kgf·cm}.

- (5) Lower the vertical shaft to contact the rotary ball with three fixed balls, and examine(⁶) the state of contact point.

Note (⁶) For this, it is preferable to examine struck mark (trace) on the tracing paper by inserting a flating tracing paper between rotary ball, and by slightly tapping the upper end of vertical shaft.

At this time, regulate the fixed balls by the degree fastening the bolts so that the sizes of three struck marks become approximately uniform.

- (6) Put the sample until the upper end of fixed balls are immersed (about 70 ml), and make the oil temperature at primary measurement $25 \pm 5^\circ\text{C}$.
- (7) Lower the vertical shaft and fix it securely with the vertical shaft outer cylinder by retaining hole of upper part.

5.6 Procedures of Testing The procedures of testing shall be as follows:

- (1) Start motion of electric motor for driving gear pump.
- (2) Preliminarily estimate the acceptable limit load of sample, and start the test from the oil pressure load corresponding thereto.
- (3) Place a weight (containing the load of plunger) corresponding to the test oil pressure load on the plunger(⁷) for accumulator, throttle the oil-pressure regulating valve with viewing the pressure gage, and raise the oil pressure(⁸) until test oil-pressure load. At this time, maintain the equilibrium of pressure with so slightly rotating the weight that the plunger for accumulator does not contact the plunger retainer.

Notes (⁷) The load of plunger is 4.9 N {0.5 kgf}, and corresponds to 0.049 MPa {0.5 kgf/cm²} in oil pressure.

(⁸) Within 30 sec, raise up to test oil-pressure load, and thereafter within 5 sec start.

- (4) Start the motion of electric motor for driving vertical shaft, at the same time start the motion of stopwatch, and when no seizure is recognized(⁹) with carefully viewing the moving of torsion pointer, maintain for 60 to 63 sec.

Note (⁹) For measurement of run-out of torsion pointer, it is more accurate to measure by a torsion scale recorder than by visual viewing.

- (5) When the run-out of torsion pointer during testing has exceeded the graduation shown in Table 1 relative to respective test oil pressures, it shall be taken as seizure.

Table 1 indicates the torsion graduation of seizure at each test oil pressure relative to the various torsion bars of individual test machine.