GEK-28075

INSTRUCTIONS

INDUCTOR DYNAMOMETERS
WATER COOLED

TH-300, FRAMES 311-382

GENERAL ELECTRIC

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INDUCTOR DYNAMOMETERS WATER COOLED

TH-300, FRAMES 311-382

INTRODUCTION

This instruction book covers the eddy-current inductor dynamometer line. The dynamometer is used for measuring torque and power. Power can only be absorbed and is dissipated as heat through cooling water. The dynamometer is an accurate instrument and is composed of four distinct components:

1. Rotating Eddy-current Machine
2. Cradle
3. Torque Measuring Equipment
4. Speed Measuring Equipment.

It is necessary to understand the function of each component to properly install, operate and maintain the dynamometer.

> **WARNING:** *HIGH VOLTAGE AND ROTATING PARTS CAN CAUSE SERIOUS OR FATAL INJURY. THE USE OF ELECTRIC MACHINERY, LIKE ALL OTHER UTILIZATION OF CONCENTRATED POWER AND ROTATING EQUIPMENT, CAN BE HAZARDOUS. INSTALLATION, OPERATION, AND MAINTENANCE OF ELECTRIC MACHINERY SHOULD BE PERFORMED BY QUALIFIED PERSONNEL. FAMILIARIZATION WITH NEMA SAFETY STANDARD FOR CONSTRUCTION AND GUIDE FOR SELECTION, INSTALLATION AND USE OF INTEGRAL HP MOTORS AND GENERATORS, NATIONAL ELECTRICAL CODE AND SOUND LOCAL PRACTICES IS RECOMMENDED.*

These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

This instruction book is organized into five major sections:

1. RECEIVING, HANDLING, AND STORAGE – Instructions regarding the receiving, inspection, storage and handling of an inductor dynamometer.
2. INSTALLATION – Alignment, mounting requirements, and other installation information.
3. OPERATION – Inspection procedures to be made prior to start-up, and checks prior to putting the dynamometer into service.
4. DYNAMOMETER FUNCTIONS – Instructions for operating and maintaining the four basic components of an inductor dynamometer.
5. MACHINE DISASSEMBLY AND ASSEMBLY – Instructions for disassembly and assembly of the eddy-current machine and cradle.

RECEIVING, HANDLING, AND STORAGE

RECEIVING

The equipment should be placed under adequate cover immediately upon receipt, as packing coverings are NOT suitable for out-of-doors or unprotected storage.

Each shipment should be carefully examined upon arrival. Any damage should be reported promptly to the carrier and to the nearest office of the General Electric Company.

HANDLING

The lifting holes in the base should be used to lift the entire machine. Chain spreaders or pads may be necessary to prevent scuffing or other damage to the unit. The lifting lugs on the stator frame can be used to lift the entire machine if the lifting holes in the base are inaccessible due to test cell configuration and/or accessory location. Caution must be taken to prevent damage to the trunnion bearings due to impact loads when lifting or setting down.

> **CAUTION:** *NEVER LIFT A DYNAMOMETER BY MEANS OF THE SHAFT EXTENSIONS. THIS PROCEDURE CAN PRODUCE EXCESSIVE BENDING STRESSES IN THE SHAFT.*

STORAGE

If a machine, or any part of a machine, is not to be installed immediately, it should be stored in a clean, dry place and protected from variations in temperature, high humidity, and dust. If possible, sudden changes in temperature and humidity should be avoided. If the temperature of the storage room varies to such an extent that the unit is exposed to sweating or freezing conditions, the machine should be protected by a safe, reliable heating system which will keep the temperature of the machine slightly above that of the storage room.

If the machine has been exposed to low temperatures for an extended period of time, it should not be unpacked until it has reached room temperature; otherwise it will sweat. The presence of moisture on the internal parts can cause electrical failure of insulated windings.

All exposed machined-steel parts are slushed with a rust preventive before shipment. These surfaces should be examined carefully for signs of rust and moisture, and reslushed if necessary. Once started, rust will continue if the surface is reslushed without first removing all rust and moisture. Rust may be removed by careful use of fine abrasive paper. Slushing compound can be removed by use of a suitable solvent such as mineral spirits.

WARNING: *MINERAL SPIRITS ARE FLAMMABLE AND MODERATELY TOXIC. THE USUAL PRECAUTIONS FOR HANDLING CHEMICALS OF THIS TYPE SHOULD BE OBSERVED. THESE INCLUDE:*

1. *AVOID EXCESSIVE CONTACT WITH SKIN.*
2. *USE IN WELL-VENTILATED AREAS.*
3. *TAKE NECESSARY PRECAUTIONS TO PREVENT FIRE OR EXPLOSION HAZARDS.*

Shaft journals and shaft extensions are precision ground and should be checked by experienced personnel. Care must be taken when cleaning to avoid damaging such surfaces. Extreme care must be exercised to prevent these parts from rusting since it is difficult, and sometimes impossible, to remove rust from these surfaces without damaging or deforming the surface. If burrs or bumps result from careless handling, carefully remove them by using a fine file or scraper. Machines in storage should be inspected, have the insulation resistance checked at frequent and regular intervals, and a log kept of pertinent data.

CAUTION: *WHEN STORED, THE ROTOR MUST BE ROTATED EVERY THREE MONTHS TO PREVENT LOSS OF LUBRICATION PROTECTION ON THE ROTOR BEARINGS. OIL-LUBRICATED MACHINES MUST HAVE THE PUMP OPERATING TO SUPPLY LUBRICANT TO THE BEARINGS. LUBRICATION PROTECTION ON THE TRUNNION BEARINGS IS ALSO SUGGESTED FOR MACHINES IN STORAGE. (REFER TO "CRADLE" ON PAGE 10 FOR INSTRUCTIONS FOR PROPER OPERATION AND LUBRICATION OF THE TRUNNION BEARINGS.)*

Storage After Operation

If the unit is placed in storage after being in operation, the same precautions should be followed. All water should be drained from the unit before placing it in storage. Water may be drained from dynamometers by tilting the unit and allowing the water to drain from the water outlet.

INSTALLATION

WARNING: *INSTALLATION SHOULD BE IN ACCORDANCE WITH THE NATIONAL ELECTRICAL CODE AND CONSISTENT WITH ALL LOCAL CODES. COUPLING, BELT AND CHAIN GUARDS SHOULD BE INSTALLED AS NEEDED TO PROTECT AGAINST ACCIDENTAL CONTACT WITH MOVING PARTS. SHAFT EXTENSIONS NOT BEING USED SHOULD BE GUARDED TO PROTECT AGAINST ACCIDENTAL CONTACT. MACHINES ACCESSIBLE TO THE PUBLIC SHOULD BE FURTHER GUARDED BY SCREENING, GUARD RAILS, ETC., TO PREVENT THE PUBLIC FROM COMING IN CONTACT WITH THE EQUIPMENT.*

LOCATION

Dynamometers should be installed where they will be readily accessible for inspection and maintenance. The area should be clean, dry, well ventilated, and free from oily, dirty atmospheres.

MOUNTING

The dynamometer base requires rigid support at each hold-down bolt. On concrete foundations, grouting between the foundation and base feet is desirable. When the dynamometer is mounted on a universal (engine) base the universal base should be well anchored to the foundation.

The dynamometer should be level for proper operation. Shims should be used at the hold-down bolt locations to level the base and to avoid base distortion when bolting down.

GROUTING

A rich, non-shrink grout should be used. High-grade grout mixtures are available commercially. If the grout is to be prepared at the site, a cement-sand ratio of 1:2 is recommended. Use only the amount of water necessary to produce a stiff mixture. The clean but rough surface of the foundation should be wet, and the grout rammed or puddled around the feet.

WATER DRAIN

Provision for a water drain in the floor near the dynamometer base should be made. The drain opening should not be above the bottom surface of the base. Back pressure at the dynamometer is not permissible. Where installation of a gravity drain is impossible or undesirable, a sump pump can be connected to the drain line. The base serves as a sump. The water may be pumped to any remote point within limitations of the pump.

WATER SUPPLY

A water-cooled, inductor-type dynamometer operates at a high rate of heat transfer between the heat-generating surface and the cooling water. Relatively small accumulations of such deposits as scale and corrosion considerably increase the temperature of the heat-generating surface.

Experience indicates that with tap water, which is relatively low in hardness (preferably below 100 parts per million), there will be no appreciable deposit of scale on the rotor. Excessive acidity, however, in the presence of certain chlorides and oxygen, may cause considerable corrosion. Different characteristics of various water supply sources make it impossible to specify more detailed limitations of the cooling water. This complicated problem is best solved by consulting a local chemist or water expert who knows the nature of water in that locality.

NOTE: *Because industrial water varies widely in impurity content, the General Electric Company cannot be responsible for excessive corrosion and/or scale build-up due to poor quality water. Where water quality is questionable, a closed system using a heat exchanger and treated water should be used.*

The water system must be able to deliver the required flow at a pressure of at least 30 pounds per square inch at the dynamometer inlet. Where a water regulating valve is used to conserve cooling water, the available water pressure should be at least 40 pounds per square inch. These pressure values are nominal figures and do not specify that rated water flow is exactly obtained with these pressures.

CAUTION: *INSUFFICIENT OR EXCESSIVE WATER FLOW CAN CAUSE DAMAGE TO THE DYNAMOMETER. THE FLOW RATE SHOULD BE CHECKED DURING INSTALLATION. PROVIDE SOME MEANS OF MEASURING WATER FLOW. WATER PRESSURE ALONE IS NOT A MEANINGFUL INDICATION OF ADEQUATE COOLING.*

WATER FLOW RATE

The water flow required by the dynamometer is specified on the nameplate, and the maximum continuous water discharge temperature is 150 F. The temperature of the dynamometer is dependent upon the cooling water supply temperature and the actual power absorbed.

The water flow required by the machine, in gallons per minute, can be determined from the relationship:

$$\text{GPM} = \frac{5.12 \times \text{HP}}{\text{Degree of Fahrenheit Rise}}$$

Fahrenheit rise is the difference in temperature between the inlet and outlet water.

The standard water flow specified on the nameplate is calculated for the rated horsepower and 8 gpm per 100 horsepower. Thus, the calculated temperature rise is 64 degrees Fahrenheit. If the maximum discharge temperature is 150 F, then the maximum permissible water inlet temperature is 86 F.

It is preferable that the normal outlet temperature should not exceed 140 F. This value or lower values produce less deposition of scale or corrosion inside the dynamometer. The water supply quality and amount of running time at maximum water discharge temperature are basic factors affecting the amount of corrosion.

These factors plus water supply temperature, with seasonal variations, should be evaluated to provide assurance of low maintenance and non-interruption of testing. The dynamometer is furnished with two overtemperature devices set at 170 F.

Some installations may want to reduce water flow to conserve on the total capacity of the water system. This can be accomplished manually or with a temperature-sensitive control to adjust water flow.

CAUTION: *REDUCED RATE OF WATER FLOW MUST BE USED ONLY WHEN THE POWER DISSIPATION REQUIREMENTS ALLOW NORMAL MAXIMUM DISCHARGE WATER TEMPERATURE AT THE REDUCED RATE.*

The installation should be made so that load greater than the reduced dissipation capacity cannot occur. The dynamometer has a minimum water flow that is always required to provide proper cooling of the rotor and the field coil (see Table I).

TABLE I
MINIMUM STANDARD WATER FLOW RATES

(MAXIMUM REDUCED HORSEPOWER RATING IS BASED ON DISCHARGE WATER TEMPERATURE NOT EXCEEDING 150 F)

FRAME SIZE	STANDARD HORSEPOWER RATING	REDUCED MAXIMUM HP RATING	MINIMUM WATER FLOW (GPM)
311	80	20	1.6
311	63, 50, 40, 31.5, 25	15	1.2
312	160	40	3.2
312	125, 100, 80, 63, 50	31	2.5
322	250	62.5	5
322	200, 160, 125, 100	50	4
332	400	100	8
332	315, 250, 200, 160	81	6.4
342	630	156	12.5
342	500, 400, 315, 250, 200	125	10
352	1000	250	20
352	800, 630, 500, 400, 315	200	16
362	1600	400	32
362	1250, 1000, 800, 630, 500	312	25
372	2500	625	50
372	2000, 1600, 1250, 1000, 800	500	40
382	4000	1000	80
382	3150, 2500, 2000, 1600, 1250	800	64

ALIGNMENT

CAUTION: *CAREFULLY ALIGN, OR CHECK ALIGNMENT, BETWEEN THE DYNAMOMETER AND THE COUPLED MACHINE. MISALIGNMENT CAN CAUSE EXCESSIVE VIBRATION AND DAMAGING FORCES ON SHAFTS AND BEARINGS. TIME TAKEN TO ASSURE GOOD ALIGNMENT WILL BE RETURNED IN REDUCED DOWNTIME.*

COUPLING

Dynamometers are normally designed for direct connection through a flexible coupling to the prime mover. The coupling shouldbe dynamically balanced and as light weight as is practical. An overweight coupling can lower the shaft critical speed into the operating speed range and result in damaging vibrations.

The dynamometer shaft is normally required to support the combined weight of a hub and one-half of the connecting shaft or one-half of a flexible coupling. The maximum weight that the dynamometer shaft can support is shown in Table II.

TABLE II
SHAFT SUPPORT WEIGHTS

FRAME SIZE	MAXIMUM WEIGHT ON SHAFT EXTENSION (IN POUNDS)
311, 312	6.6
322	9.4
332	27
342	48
352	80
362	90
372	160
382	430

Since the factors which affect torsional vibration are contained principally in the design of the equipment to be tested rather than in the design of the dynamometer, the responsibility for avoiding torsional vibration trouble shall rest with the customer.

A shaft sketch, weight and WK^2 of the entire dynamometer rotating system is included on the outline drawing. The complete drive system can be checked, using this data and data of the connected equipment, for torsional vibration and stresses. Analysis of the complete system will show if it is necessary to use special couplings or flywheels, or if operation at specific speeds should be avoided.

PROTECTION

CAUTION: *THE FOLLOWING PROTECTIVE FUNCTIONS ARE THE MINIMUM WHICH SHOULD BE INCLUDED IN THE CONTROL SYSTEM. ADDITIONAL DEVICES AND CONTROL FUNCTIONS MAY BE REQUIRED TO FURTHER PROTECT THE DYNAMOMETER AND THE EQUIPMENT UNDER TEST.*

1. *WATER SUPPLY FAILURE - SHUT DOWN MACHINES IF THE WATER SUPPLY IS LOST.*

2. *WATER OVERTEMPERATURE - THE OVERTEMPERATURE DEVICE IS NORMALLY SET AT 170 F. SHUT DOWN MACHINES IF THE DISCHARGE WATER TEMPERATURE IS TOO HIGH.*

3. *OIL PUMP POWER SUPPLY FAILURE - SHUT DOWN MACHINES IF POWER SUPPLY IS LOST.*

4. *OVERSPEED - DO NOT OPERATE OVER TOP RATED SPEED. MAXIMUM MECHANICAL OVERSPEED CAPABILITY IS 125 PERCENT OF TOP RATED SPEED.*

OPERATION

WARNING: *HIGH VOLTAGE. ELECTRICAL SHOCK CAN CAUSE SERIOUS OR FATAL INJURY. DISCONNECT POWER BEFORE TOUCHING ANY INTERNAL PART. HIGH VOLTAGE MAY BE PRESENT EVEN WHEN THE MACHINE IS NOT ROTATING. IF USED WITH A RECTIFIER POWER SUPPLY, DISCONNECT ALL AC LINE CONNECTIONS TO POWER SUPPLY. WITH OTHER POWER SUPPLIES, DISCONNECT ALL DC LINE AND FIELD CONNECTIONS. ALSO DISCONNECT POWER FROM AUXILIARY DEVICES.*

WARNING: *GROUND THE MACHINE PROPERLY TO AVOID SERIOUS INJURY TO PERSONNEL. GROUNDING SHOULD BE IN ACCORDANCE WITH THE NATIONAL ELECTRICAL CODE AND CONSISTENT WITH SOUND LOCAL PRACTICES.*

INSPECTION BEFORE STARTING

NOTE: *The following inspection procedures should be followed before starting the machine for the first time, after an extended shut-down, or after a tear-down for extensive maintenance or repair.*

Cradle Shipment Protection

All dynamometers are protected against damage to the cradle system while being transported. The adjustable stator stops are positioned to lock the stator and must be turned to the proper open position. Dynamometers equipped with an oil-floated trunnion cradle have additional locking straps which must be removed.

Insulation

Check and record the one-minute insulation resistance of each machine. Keep a permanent record of this value and date that the data are taken. See Insulation portion of DYNAMOMETER FUNCTIONS Section.

Connections

All terminal connections should be checked against the connection diagrams to be sure that the polarity will be correct. See that bolted connections are tight and that adequate clearances exist between conductors of opposite polarity and between conductors and ground. Bolted connections of flexible cable should be insulated.

Rotor Bearings

Check to ensure that these bearings are properly lubricated and that the oil system is providing the required 15 to 40 drops per minute of oil flow.

General Mechanical Inspection

Check the machine for tools, metal chips or any other foreign material that may have accumulated during storage or installation. Make sure that all rotating parts have clearance from stationary parts. Turn the rotor over by hand, if possible, and check for scraping noises or any other sign of mechanical interference. Check tightness of all bolts.

The static balance, freedom of movement in the cradle, and speed measuring and torque measuring systems must be checked before starting the unit. See DYNAMOMETER FUNCTIONS for instructions.

Inspection Before Putting Machine Into Service

The dynamometer oil system should be run approximately 30 minutes prior to starting the unit. The following items should be checked after the dynamometer is running:

1. Rotor Bearings – Bearings should be rechecked to ensure that the proper oil flow is still being maintained.

2. Noise and Vibration – Check for unusual noise or vibration that might indicate rubbing or interference.

The vibration magnitude of a dynamometer should not exceed 0.002 inch at the bearing housings as measured by a General Electric light-beam vibration meter. This is a general means of measuring machine vibration. Actual energy must be measured for a factual representation of vibration effects. The limit is 0. 5 g's (acceleration). The most likely causes of excessive vibrations are improper installation, misalignment, oversize and/or unbalanced couplings, or damage during shipment or installation.

Run at light loads or at no load for a few hours to determine that no unusual bearing temperatures occur. Check for vibrations when a load is first applied.

Inspection After Short Time In Service

After a machine has been operating for a short time, an inspection should be made to ascertain that there have been no changes since installation. Check for increased vibration, signs of change in alignment or foundation settling, bolts that may have loosened, rubbing parts, loose connections, and take the proper steps to correct any deficiencies found.

DYNAMOMETER FUNCTIONS

INDUCTOR-TYPE ROTATING EQUIPMENT

A dynamometer has special features required for high-speed operation and highly sensitive cradling. An inductor dynamometer operates on the eddy-current brake principle. Field coils are energized by a direct-current power source, creating a magnetic field concentrated at the rotor by the stator teeth. The rotor, revolved by mechanical power from a prime mover, cuts through these concentrations of magnetic flux, producing eddy-current torque to load the prime mover. The eddy currents heat the rotor at a rate proportional to the prime mover shaft power and the heat is dissipated by the cooling water system. Torque developed is controlled by adjusting the d-c field current.

Insulation

The field coil insulation system is a vital part of the dynamometer. Failures are caused by moisture, contamination, or mechanical damage due to chafing resulting from vibration. The insulated field coils are completely enclosed by the dynamometer frame and sealed from the water internally. The main cause of failure would be improper assembly or loose bolts.

Insulation — Inspection and Testing

The insulated field coils are enclosed and visual inspection is not possible. The leads and connections are visible and should be inspected. The visible points are potential trouble areas and often the source of problems.

An excellent write-up covering insulation-resistance testing methods, values and interpretation is Report No. 43, "Recommended Guide for Testing Insulation Resistance of Rotating Machinery", published by the American Institute of Electrical Engineers, 345 East 47th Street, New York, N.Y. 10017.

AIEE Report No. 43 states that direct measurement of insulation resistance may be made with the following instruments:

1. Direct-indicating ohmmeter with self-contained hand- or power-driven generator.

2. Direct-indicating ohmmeter with self-contained battery.

3. Direct-indicating ohmmeter with self-contained rectifier using an external a-c supply.

4. Resistance bridge with self-contained galvanometer and batteries.

The same type of instrument should be used each time insulation resistance is checked.

Electrical tests of a particular insulation system are meaningful only when this system is isolated from other systems. Power input and control circuits should be opened and the unit tested separately.

Tests should be made when the unit is at room temperature. Best results are obtained when the unit is not operated for at least five hours. Readings of insulation resistance are taken after a test voltage application of one minute (no less). Since the value of insulation resistance changes with temperature, any reading obtained must be corrected to an equivalent value at 40 C. When the insulation resistance is obtained at a temperature other than 40 C, the insulation resistance at 40 C can be calculated as follows:

$$R_{40C} = \frac{R_t}{K_t}$$

R_t = insulation resistance measured at t degree C.

K_t = insulation resistance temperature coefficient (from Fig. 1) at t degree C.

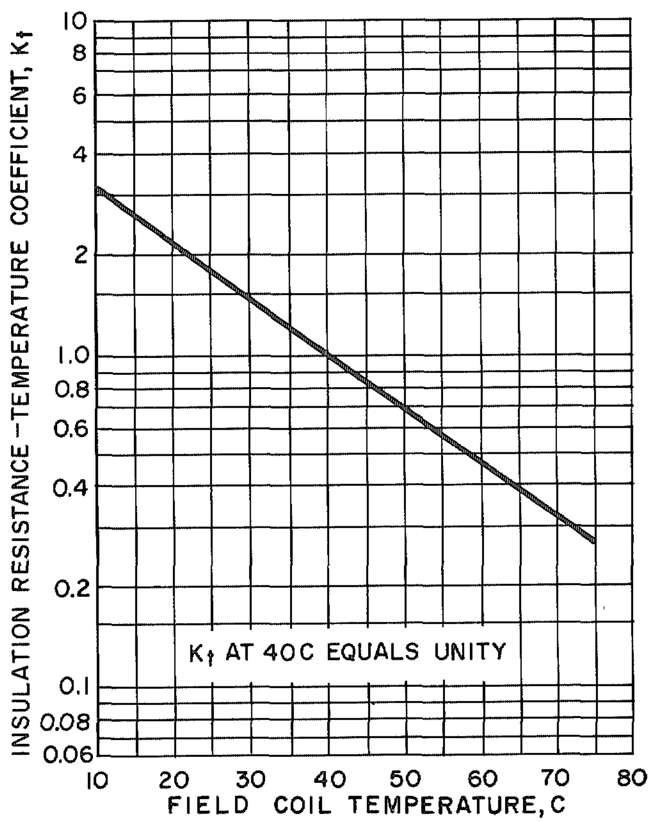


Fig. 1. Approximate insulation-temperature coefficient of inductor dynamometer field windings

The insulation resistance measurements are affected by surface condition (contaminants), moisture, temperature, magnitude of test voltage, and duration of application of test voltage. One-minute insulation resistance is useful for evaluating insulation condition where comparisons can be made with earlier data, similarly obtained.

Maintain a record of insulation resistance for each dynamometer. The recommended minimum insulation-resistance value is 1.0 megohm at 40 C.

This minimum value of insulation resistance is the lowest value recommended which the field coil should have prior to application of an overpotential test or if the machine is to be operated. It is impractical to specify a definite minimum value below which the machine cannot be operated.

Rotor Bearings

The inductor dynamometer line has precision anti-friction bearings which are necessary for the speeds at which the machines operate. The bearings are lubricated by a drip oil supply for reliability. The proper flow rate is 15 to 40 drops per minute per bearing.

> **NOTE:** *The bearings, in addition to being precision quality, are special designs for dynamometer service. It is recommended that replacement bearings be secured through General Electric or a bearing manufacturer that is knowledgeable of GE dynamometers.*

The oil supply is either from a low-pressure pump system furnished for the rotor bearings or from a high-pressure pump system furnished for the oil-floated trunnion cradle system. The flow is controlled by a metering unit above each bearing cavity. Incorporated with the metering unit is a sight glass for visual observation and a small filter to prevent clogging.

Low-pressure System

The low-pressure system has a ceramic filter in the oil return line and a felt filter on the pump inlet (in reservoir) to provide clean oil and to assure long life of the bearings:

1. Use light mineral oil with Saybolt Second Universal (SSU) viscosity of approximately 160 seconds at 100 F. An oil inhibited against rust and oxidation is recommended.

2. Run the oil system at least 30 minutes before initially starting the dynamometer or if the unit has been idle for over a week. It is desirable to run the oil system at least 15 minutes any time prior to starting the dynamometer.

3. Check the oil level, pressure and drops-per-minute daily to make certain that the rotor bearings are properly lubricated. If adjustment is necessary, remove the cover plate from the top of the pump and turn the bypass adjustment screw. Oil pressure is set at 15 to 20 psi at the factory.

4. Clean the felt filter in the pump every six months. The ceramic filter should be inspected periodically to determine when the filter should be cleaned or the oil should be changed.

High-pressure System

The high-pressure system is provided for a dynamometer with oil-floated trunnion bearings. See OIL-FLOATED TRUNNION BEARINGS for complete description of the oil system. The rotor bearing lubrication is obtained from a tap on the high-pressure line. It is necessary to run the system 30 minutes initially and at least 15 minutes any time prior to starting the dynamometer. Daily checks should be made to be certain that the rotor bearings are receiving the proper lubrication as detailed above.

SHAFT EXTENSIONS AND COUPLINGS

The smaller size dynamometers, frame sizes 311, 312 and 322, have straight shaft extensions with keyways for use with keyed couplings. Standard practices for coupling size and fits should be followed. All other dynamometers have straight shaft extensions without keyways but with a circumferential groove for hydraulically removing the couplings.

Coupling Hub (Hydraulic-Removable)

The coupling is made with a straight bore. Use an intereference fit sufficient to give adequate driving torque with reasonable safety factor. Request "Coupling Design Fundamental 36H925451AA" if help is necessary in designing a suitable coupling.

Assembly

The coupling is heated uniformly in an oil bath or controlled oven to a temperature of about 200 C and shrunk on the shaft extension. (HEATING WITH ANY KIND OF TORCH IS NOT RECOMMENDED.)

Removal

Figure 2 shows a typical cut-away section of a hydraulic coupling ready for removal. To remove the coupling, hydraulic pressure (approximately 25,000 psi) is applied to the circumferential groove (C) in the shaft extension (S). When this pressure exceeds the initial radial stress due to the interference fit, the coupling hub (H) expands a minute amount and allows oil to creep out into the fit in

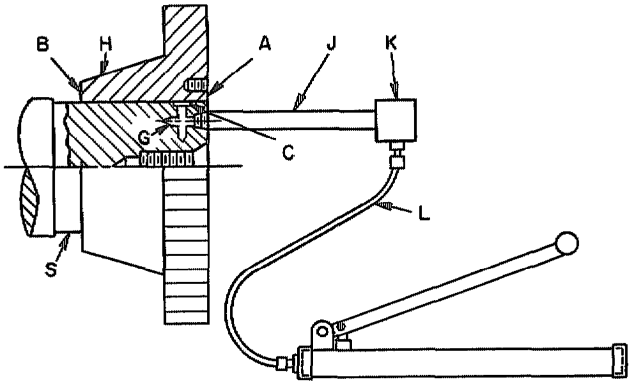


Fig. 2. Cut-away section of a hydraulically removable flexible coupling ready for removal

both directions from the groove (C). Although the distance from the groove (C) to the coupling face (A) is much less than that to the coupling face (B), the end effect at a corner effectively maintains the hydraulic pressure until the entire length of bore has expanded and oil appears at the face (B). When this condition is reached, some time after the pressure is initially applied, the coupling is floating on a high-pressure oil film and may be removed with a conventional puller.

When the coupling face (B) uncovers the groove (C), oil pressure is lost. The coupling will pull harder the rest of the way. The remaining area of contact is small, however, so that the job may be finished with the same puller and a little more force.

The shaft center must be protected from damage by a small brass or copper shim under the driving point of the puller. Some oil may leak out between the coupling hub and shaft and, if the leaks are small, no harm will result. If a large leak should occur so that pressure cannot be held, the leak may be stopped by carefully peening the coupling in the area of the leak to move metal into the opening. Do not peen any more than necessary because high areas may be created that can scratch the shaft or coupling bore.

Pressure Equipment

The hydraulic pressure is provided by a suitable pump, GE Catalog No. 8746652 part 1 (Power-Packer Hand Pump Model HP-9900-41-00 or equivalent), connected to groove (C) by flexible high-pressure tubing (L), a high-pressure elbow (K), and a high-pressure nipple (J) long enough for the hub to pull clear of the shaft extension without interfering with the elbow or tubing. The nipple also serves as a support for the coupling when it drops free. This nipple screws into a pipe tap in the end of the shaft which is connected to groove (C) by two intersecting drilled holes (G).

> **WARNING:** *RUPTURED PIPE CAN CAUSE SERIOUS OR FATAL INJURY. USE ONLY HIGH-PRESSURE PIPE AND FITTINGS, SINCE THE PRESSURE OF THE HYDRAULIC SYSTEM IS WELL ABOVE THE RUPTURE STRENGTH OF ORDINARY PIPE AND FITTINGS.*

Static Balance

For accurate indication of the torque to the measuring device, the complete inductor-type rotating machine plus all cradled accessories must be statically balanced. The dynamometer is statically balanced in the cradle at the factory. This static balance normally leaves a slight pendulum effect toward the bottom. The pendulum effect is desirable since it tends to provide a definite location of the torque arm at no load.

Before making balance adjustment, make sure that all cradled accessories are mounted on the dynamometer. Also, be sure that the parts of the torque-measuring device linkage, supported by the dynamometer, are in place. The dynamometer shaft must not be connected to any load. Check the balance by rotating the dynamometer frame slightly away from the horizontal. The unit is in balance if it remains in this position or returns to the horizontal position. Adjust the balance by adding or subtracting shot to shot-boxes (weight wells) fastened on the side of the frame. In this manner the conditions for achieving balance will be met when the torque arm is moved either direction away from the horizontal. The static balance should inherently remain in adjustment as long as no changes are made on the dynamometer, but it should be rechecked periodically in conjunction with the torque measuring equipment.

Torque Arm

The dynamometer has machined surfaces on each side of the frame for mounting torque and checking arms. This allows different torque arms and different torque measuring devices to be attached. The distance from the centerline of the dynamometer to the face of the machined surface is stamped on the surface face.

CRADLE

The cradle is the support of the rotating inductor-type machine and is designed to minimize friction so that accurate torque measurements can be made. Electrical, water and oil connections made from stationary parts to cradled parts are specially designed to minimize friction and torque error. All parts must be inspected and checked periodically to maintain the minimum friction of the complete cradled dynamometer.

The following cradles or trunnion bearings are used for dynamometers.

Hand-operated Trunnion Bearings

The hand-operated trunnion bearing permits hand turning of the outer race to obtain a new seat for the balls. Frames 311 through 362 have deep-groove radial ball bearings; Frames 372 and 382 have spherical-seat roller bearings for the trunnion bearings. The bearing outer race is supported through the adapter ring by the pedestals. See Fig. 3.

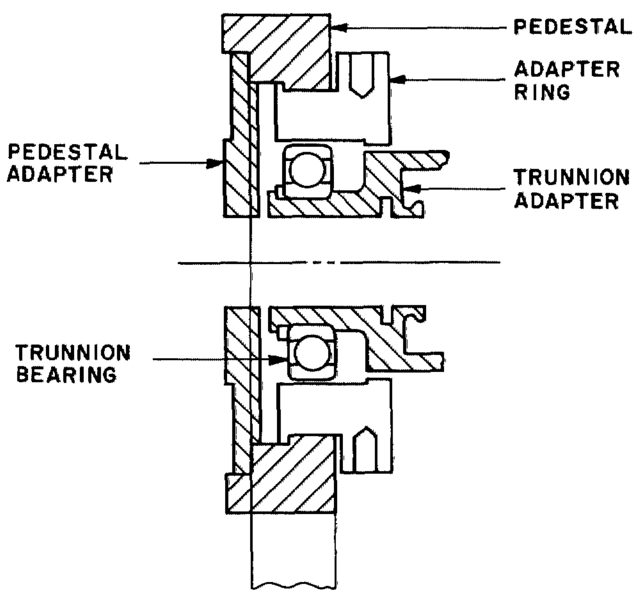


Fig. 3. Hand-operated trunnion bearing

The adapter ring fits closely in the horizontally split pedestal and may have a slight interference in the vertical direction. Clean all dirt from the pedestal and loosen or remove the bolts that hold the caps to the pedestals. Rotate the adapter ring (and bearing outer race) about 10 to 15 degrees, using the barring holes in the adapter ring. It is recommended that rotation always be in the same direction (CW). Trunnion bearings should be rotated at least every 2 to 6 months to provide long life.

Bearings are lightly greased with standard ball bearing grease or petroleum jelly to give corrosion protection. The bearings are essentially stationary so practically no lubrication is required.

The grease may tend to oxidize and harden after a lengthy time in service. Yearly visual inspection should be maintained. Lubricate if required. If the grease is hard, the bearing should be removed, cleaned and regreased lightly.

Oil-floated Trunnion Bearings

The oil-floated trunnion bearing is a sensitive cradle system, in which the cradled parts are supported by an oil film. See Fig. 4.

The bearing consists of three parts with a hydrostatic film between the inner and middle parts of the bearing. High-pressure oil is fed into recessed areas of the bearing and a regulated flow of oil supports the cradled parts. Thrust is provided in the locked bearing (locked between adapter ring and adapter trunnion) and positions the stator in the pedestals. The opposite end bearing (unlocked) has clearance for stator expansion, allowing the bearing position to move inside the pedestal. The lift (thickness of the oil film between the inner and middle parts of the bearing) of the cradled parts is set at the factory by flow adjustments, and will be approximately 0.0025 to 0.003 inch.

The oil system consists of a positive displacement pump, an adjustable bypass valve, low- and high-pressure gages, filters, junction block, strainer, and necessary piping. The junction block has capillary-type orifices, and their lengths are adjusted to provide proper flow to each recessed area. See Fig. 5.

Pump pressure is adjusted by means of the bypass valve and factory set. Usually about 300 psi is required at the gage.

Extensive filtering and straining prior to the pump and main filter in the junction block are used to provide sufficient capacity and redundancy. All particles greater than ten microns should be trapped. Clean or replace the main filter yearly or whenever oil appears dirty. Other filters should seldom require attention.

A low-pressure tap with valve and gage is in the bypass line to supply oil to the rotor bearings. Pressure should be set at about 15 to 20 psi. Rotor bearing flow is 15 to 40 drops per minute per bearing.

Use light mineral oil with Saybolt Second Universal (SSU) viscosity of approximately 160 seconds at 100 F. An oil inhibited against rust and oxidation is recommended. The main points to observe in maintaining this oil system and trunnion bearings are:

1. Check and maintain oil level with the proper oil.

2. Keep foreign material out of the oil system. In the event that the system has to be opened, be

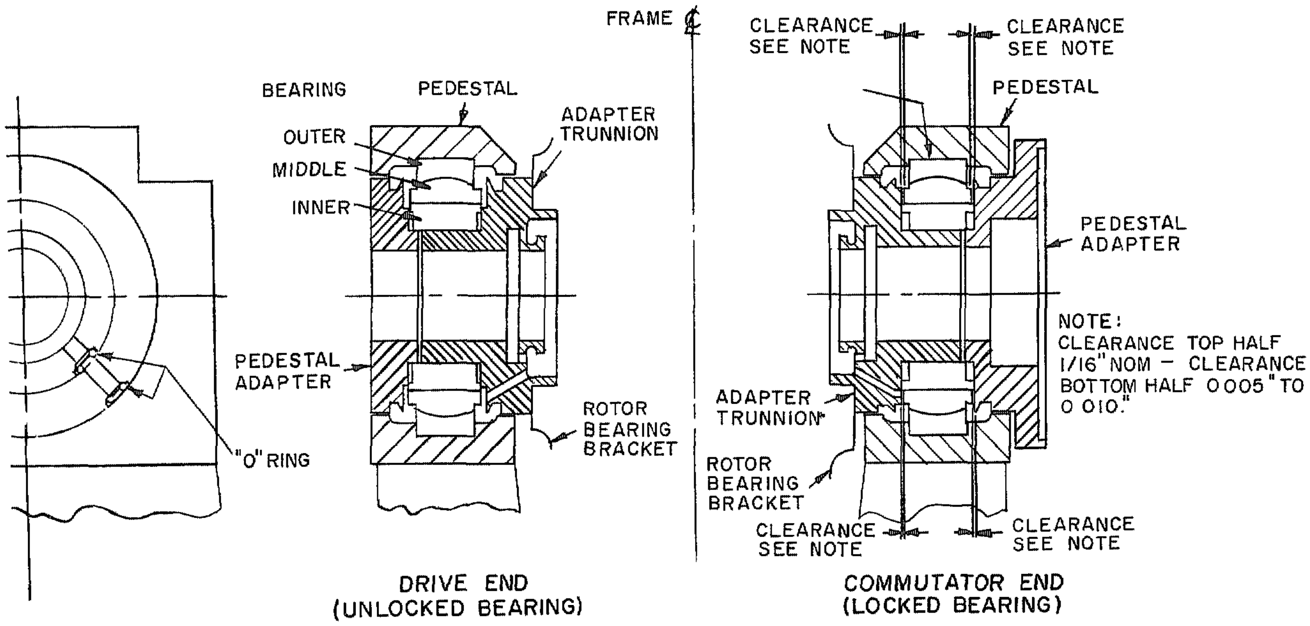


Fig. 4. Pedestal and bearing assembly, oil-floated trunnion bearing

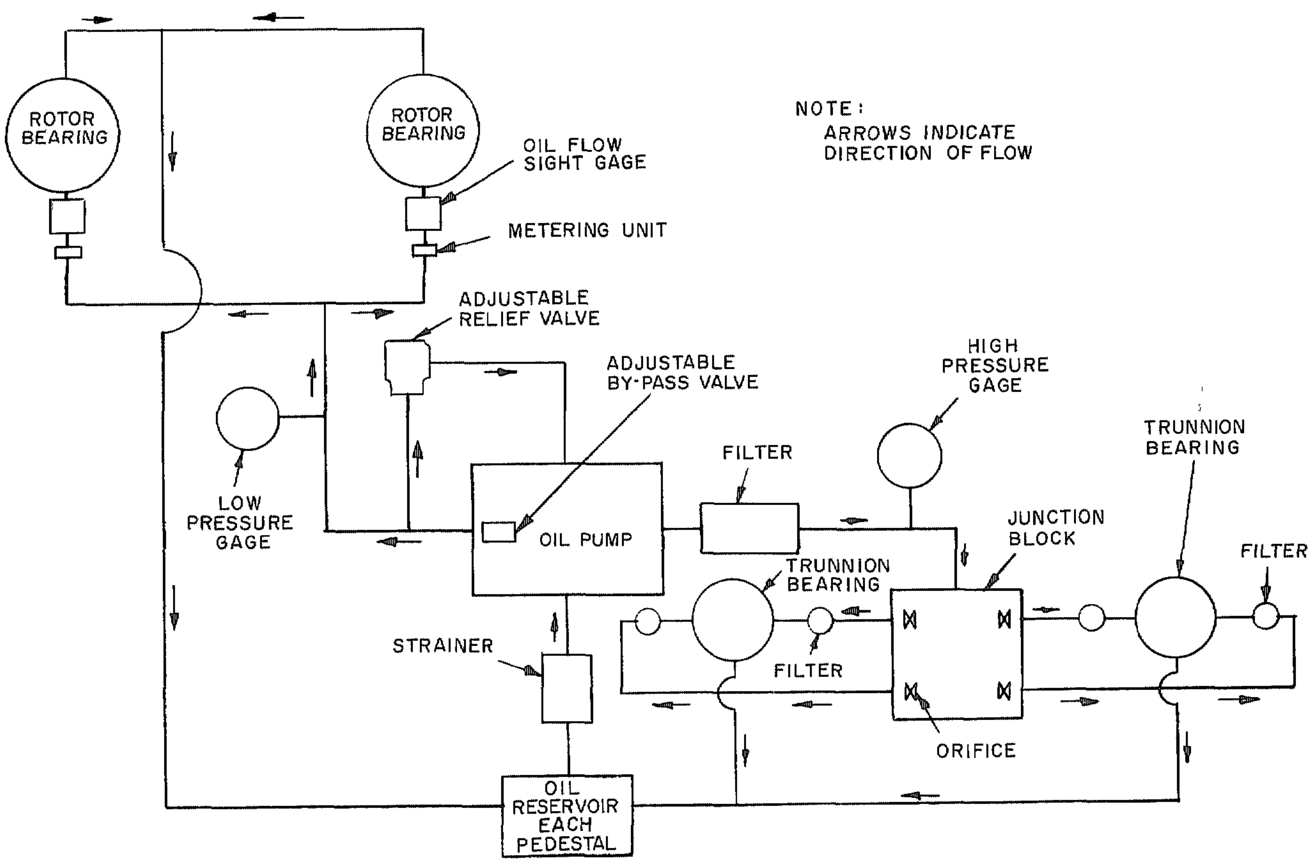


Fig. 5. Schematic of oiling of rotor bearing and oil-floated trunnion bearing

sure to cover all openings and be especially careful not to contaminate the oil.

3. Check cradle sensitivity as evidence of proper operation.

TORQUE MEASURING EQUIPMENT

The addition of a force-measuring device to a torque arm of an accurately cradled inductor-type machine gives an instrument capable of measuring torque. All of the shaft torque appears on the force-measuring device except for very small, uncorrectable system errors. There are no inherent corrections or additions required. Accuracy and sensitivity are part of the design, but careful adjustment and installation of the equipment is necessary to obtain the true capability of the equipment.

Minimized friction, precise plumb and level, proper balance, and correct calibration are necessary for successful operation. Give particular attention to all connections to the frame and the cradle.

For proper balance, both the dynamometer and any force-measuring device linkage mounted or hung on the dynamometer should be checked. The balance must be precise and done separately from adjusting the force-measuring device.

The force-measuring device should be plumb and level in order to ensure correct adjustment and calibration. The dynamometer shaft must not be connected to any load when checking balance and calibrating the force-measuring equipment.

Force-measuring equipment may be supplied by the General Electric Company or by the customer. The force-measuring devices are a complete product and can be purchased from one of several commercial firms. Local service availability varies with the vendor and with the product.

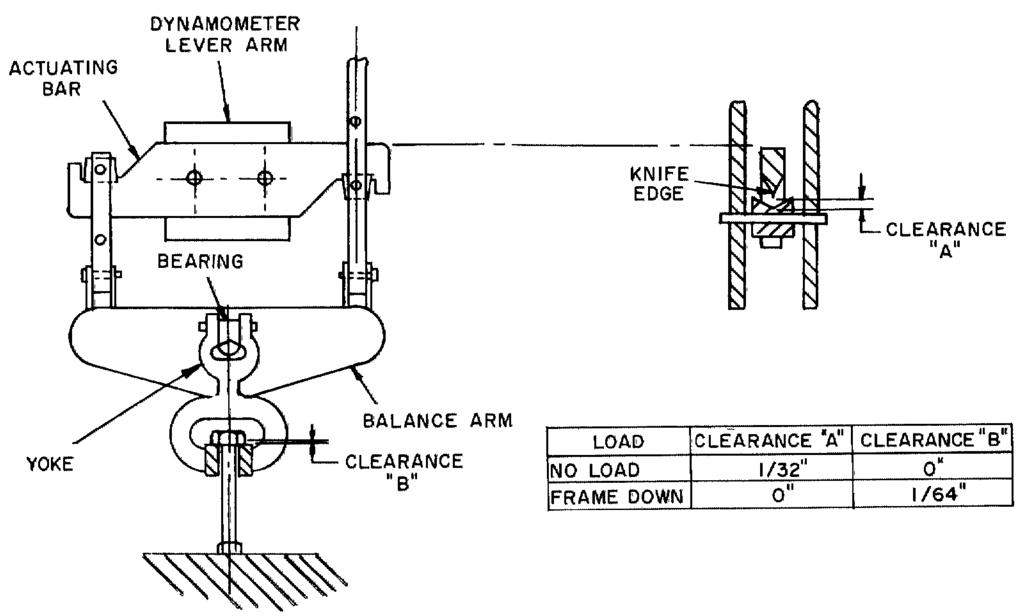
General

Each torque-measuring device has its own particular adjustments and characteristics. The information or local service received with the unit is normally sufficient to install and calibrate the device. If further information is required, contact the factory or the vendor directly.

Types

1. Scale

A scale is a weighing system consisting of a counterbalance device and a means to indicate the weight or force applied. The most popular type is one with a double pendulum counterbalance. Another type is made of a beam with slide weight counterbalance. Both these types use a reverse-force linkage to give only one direction of force on the scale while the dynamometer is capable of two directions of force. Figure 6 shows the reverse-torque linkage



LOAD	CLEARANCE "A"	CLEARANCE "B"
NO LOAD	1/32"	0"
FRAME DOWN	0"	1/64"

Fig. 6. Reverse force linkage

normally used and its adjustment. Note that part of the linkage is hanging on the dynamometer cradle and is a portion of the static balance of the cradled parts.

2. Load Cell

A load cell is a device which transduces a force (weight) into another form which can be calibrated and indicated on a chart (dial) or with digital display. The three types are:

a. Electric Strain Gage – A load cell which translates a force change into a voltage change. The read-out instrument gives the indication of the resultant voltage change.

b. Hydraulic – This load cell changes the force into a hydraulic pressure which indicates the force with a properly graduated pressure gage.

c. Pneumatic – The same principle as a hydraulic type except that air pressure is the signal.

Figure 7 shows a typical linkage for connecting the dynamometer to the load cell. Cells can be two-direction (compression and tension) or single-direction as required. Note that the linkage plus some weight of the cell is attached to the dynamometer so this weight must be accounted for in the static balance.

SPEED-MEASURING EQUIPMENT

Speed-measuring equipment is used for speed indication, setting speed, obtaining data, and speed-feedback signal for the control circuit for such functions as speed regulation, overspeed, windage simulation and inertia simulation.

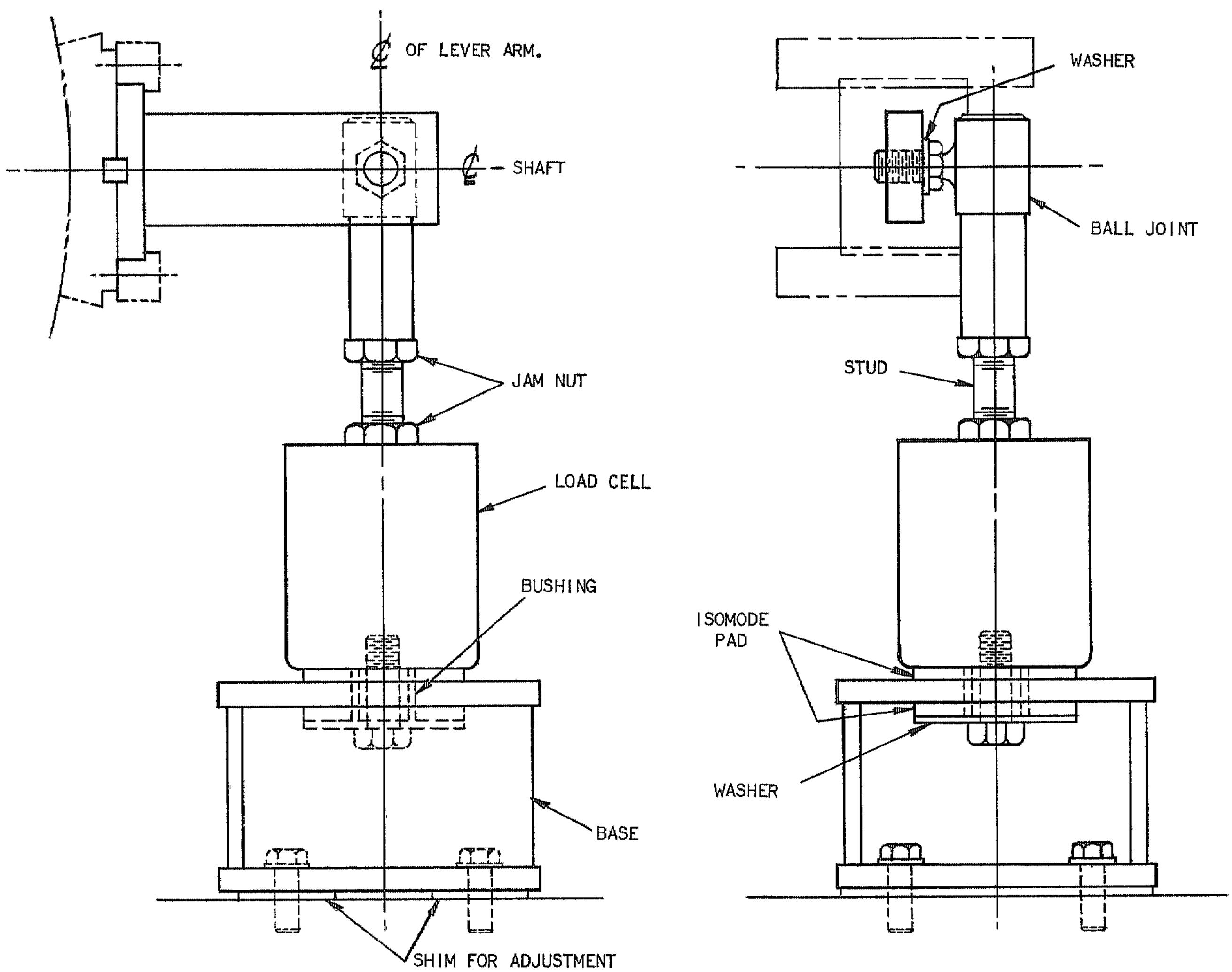


Fig. 7. Scale linkage, load cell type

Electric Pulse Generator

An electric pulse generator consists of a toothed wheel mounted on the dynamometer shaft and a housing with a magnetic pick-up. The output signal with a suitable control system is generally used for speed feedback. Sixty pulses per revolution is the most common wheel, as this can be readily used with an electronic digital counter for speed indication. Other wheels with more or less pulses per revolution use the same basic construction.

See Fig. 8 for adjustment of air gap of the pick-up unit. A greater air gap than specified is set at the factory to avoid damage during shipment. Adjust properly before operating and check periodically to maintain a proper signal. Pulse wheels with greater than 90 teeth may have a special-shaped pick-up probe to obtain successful operation. In this case, care must be taken to maintain the line-up of the probe axis parallel to the gear teeth in addition to maintaining the proper air gap.

DC Tachometer

A d-c tachometer, Type BC46, can be used for speed feedback. The tach is belted so that both shaft extensions of the dynamometer are available for customer use. The belt tension, vibration, and the commutator appearance of d-c tachometers should be periodically checked. The commutator may be wiped with a clean, dry cloth. Ball bearings are factory-greased for five years of normal operation. Severe operation (24 hours per day) requires regreasing every two years. Clean and repack about one-third full with General Electric ball bearing grease, Specification D6A2C5.

Proper belt tension, checking of alignment and vibration, and generator maintenance improve system performance and increase the accuracy of resulting data.

Chrono-tachometer

A chrono-tachometer is a complete speed-measuring system consisting of a signal generator and the required instrument.

The signal generator is driven by gear take-off from the dynamometer shaft. The output is three-phase, low-voltage a-c power. The main requirements for proper operation are maintaining oil level in the gear take-off and proper gear mesh.

The instrument is basically an indicating tachometer. A precision timer and revolution counter can be added to give more precise speed data. The maintenance required is specified by the equipment manufacturer.

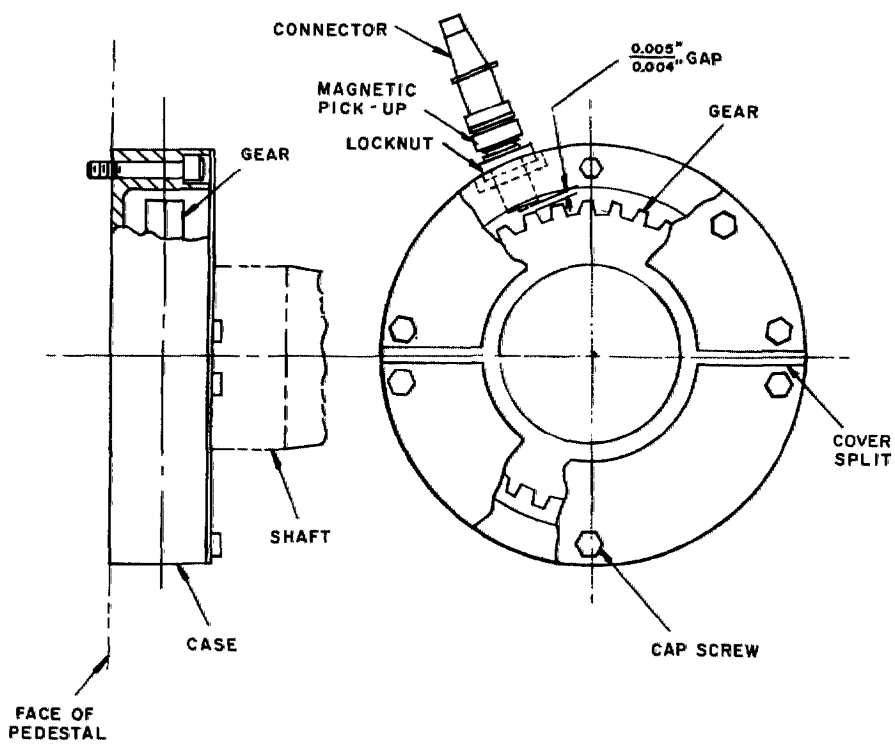


Fig. 8. Magnetic pick-up, adjustment of air gap

MACHINE DISASSEMBLY AND ASSEMBLY

The inductor dynamometer assembly and disassembly are designed for simplicity and ease of maintenance. Figure 9 is a sectional assembly that represents frames 312 through 382. The 311 frame is the same except that it has only one coil and one disk.

WARNING: *SAFE PRACTICES FOR LIFTING AND HANDLING EQUIPMENT SHOULD BE USED. HOISTS AND SLINGS OR CHAINS OF ADEQUATE CAPACITY IN GOOD REPAIR SHOULD BE USED.*

The maximum cradled weight for each frame size is shown in Table III.

TABLE III
CRADLED WEIGHTS

FRAME	MAXIMUM WEIGHT (POUNDS)
311	280
312	580
322	800
332	1150
342	2150
352	3800
362	6500
372	12800
382	19800

REMOVAL FROM CRADLE

The inductor dynamometer can be removed from the cradle by removing the following parts (if supplied):

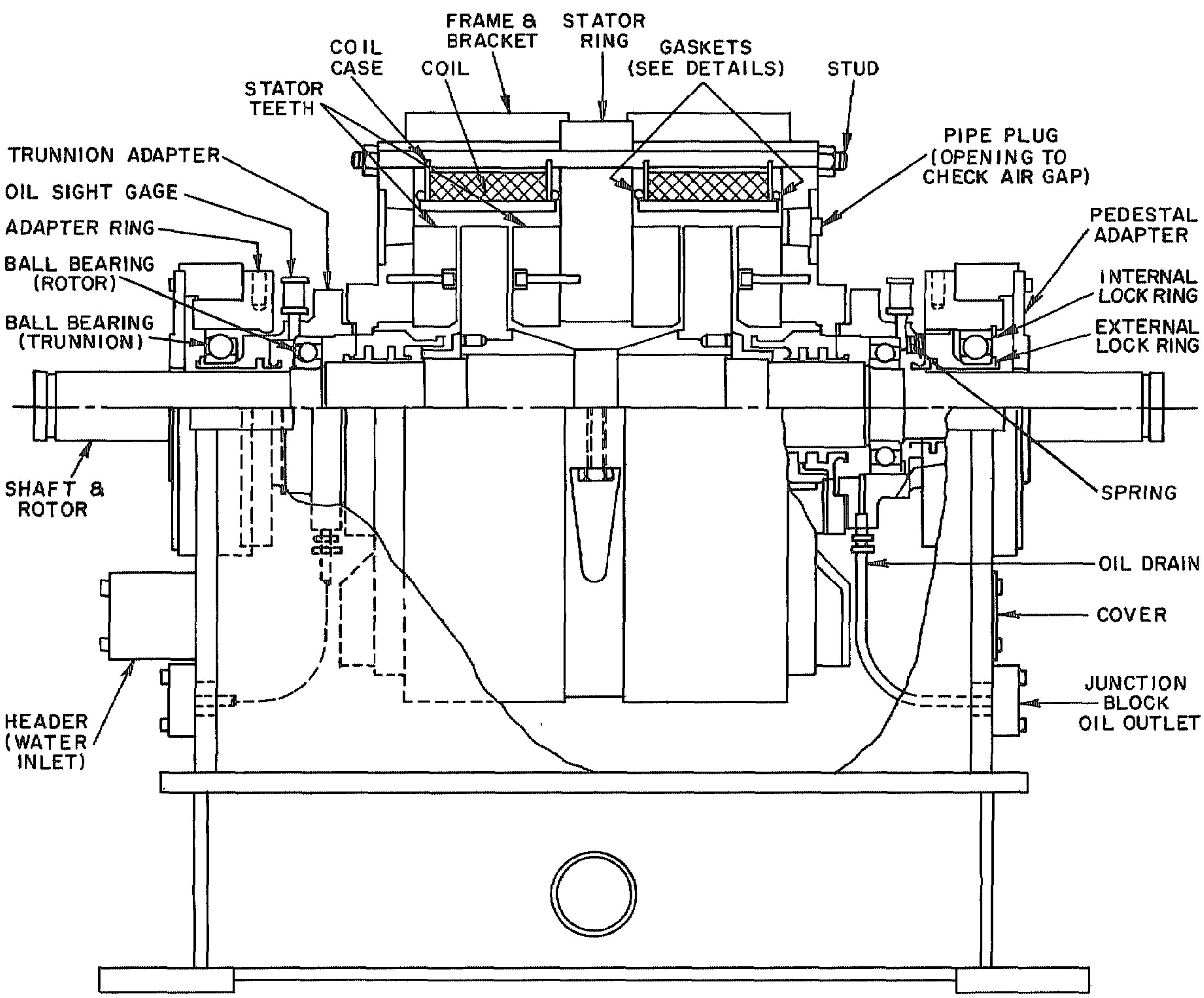


Fig. 9. Sectional assembly

1. Remove or disconnect the torque measuring system.

2. Remove hubs or couplings.

3. Remove the speed-measurement equipment.

4. Remove the pedestal adapters.

> **NOTE:** *It is sometimes possible to leave hubs and speed-measurement equipment in place at this time, but the pedestal adapters must be disconnected from the pedestals. The sequence of operation may be determined by equipment availability and convenience.*

5. Disconnect oil inlet line. Protect the fittings from damage and contamination.

6. Disconnect the two oil outlets by removing the junction block oil outlets and disconnecting the oil hoses. Protect the fittings.

7. Disconnect the water inlet. See Fig. 10. The junction block can be removed from the water inlet header or the hoses can be disconnected from the fittings.

8. Disconnect the field leads and the cable from the base.

9. Remove the top half of each pedestal.

10. Lift the dynamometer from the cradle, being sure that all connections are loose and have adequate clearance.

DISASSEMBLY

The disassembly of the cradled parts (rotor and stator) is accomplished with sub-assemblies. The reason for disassembly will determine if any sub-assemblies require further effort. See Fig. 9 and Fig. 11 for visual representation of parts noted in the following information. Disassembly may be performed with the shaft horizontal or vertical depending upon the size of the dynamometer and the facilities available.

1. The trunnion adapter, trunnion bearing, adapter ring sub-assembly is obtained by removing the bolts – trunnion adapter to frame and bracket. Disconnect the oil inlet line. Take care to keep shims and gaskets in good condition and associated with the correct sub-assembly. The bearing and the oil inlet should be protected. The opposite trunnion adapter (spring type) has a bearing ring and bearing preload springs as loose pieces of the sub-assembly.

2. Remove the screws – inner bearing cap to frame and bracket. Remove the studs – frame and bracket, stator ring, frame and bracket assembly. The frame and bracket, stator teeth sub-assembly can now be removed. The coils can also be removed.

3. The rotor bearings and inner bearing caps are still assembled on the shaft-disk assembly. Remove if required or protect these items.

4. The stator ring, stator teeth sub-assembly between the two disks can be removed by splitting into top and bottom halves (remove two bolts).

The reason for disassembly should be reviewed prior to starting. It is best to do the minimum work required. Note that trunnion bearings and rotor bearings can be left assembled. This may eliminate the cause for replacement.

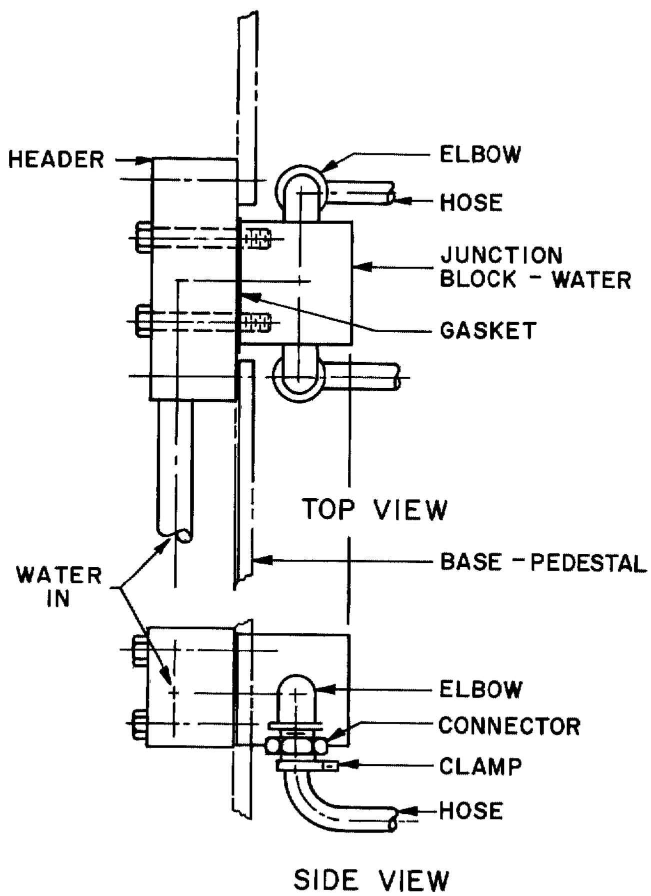
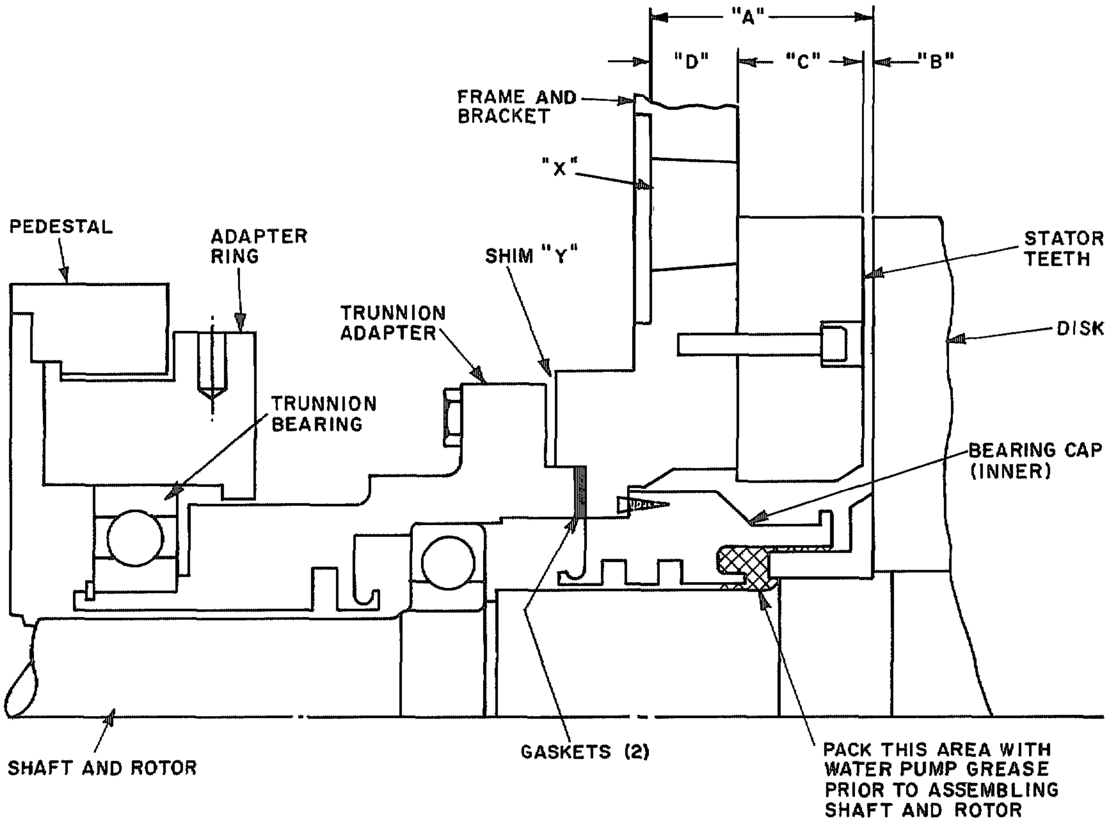
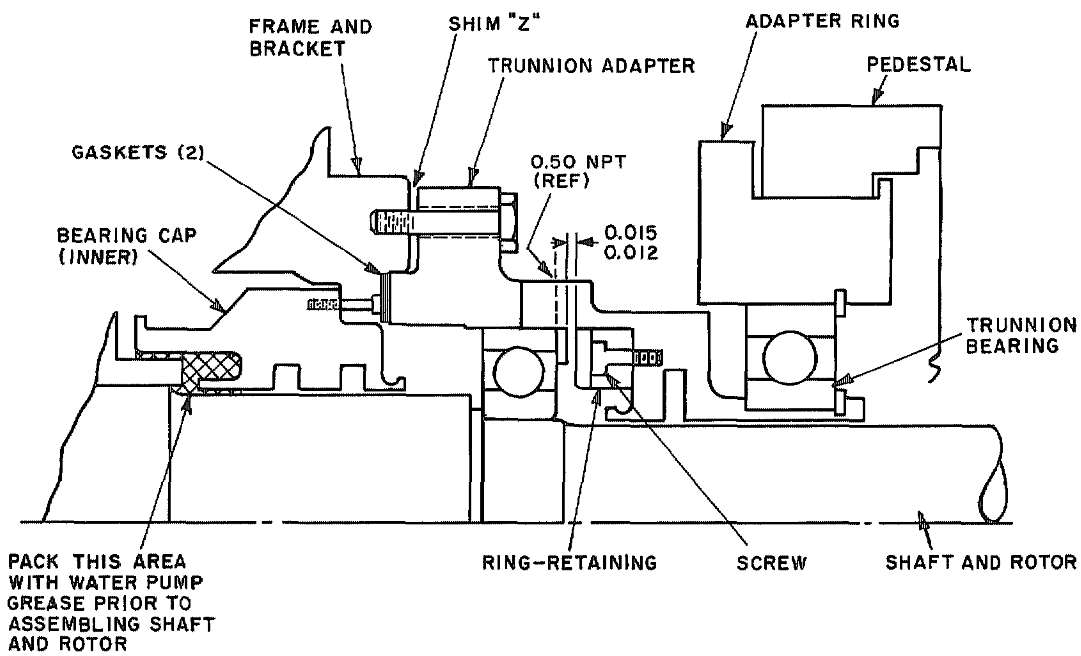


Fig. 10. Water inlet details



NON-SPRING END



SPRING END

Fig. 11. Enlarged section, bearings and gaps

ASSEMBLY

The assembly of the cradled parts is accomplished in the reverse order of disassembly. See Fig. 9 for the details of the gasket joint. Figure 11 has a notation for water pump grease packing for the inner-bearing caps. The salient points are: careful installation of gaskets and shims and mating parts together, as opposed to forcing assemblies by brute bolt forces. Make sure all bolted joints are tight.

The correct air gaps are an important part of a correctly assembled machine for proper operation. Table IV provides the tabulated dimensions required for the correct air gap. See Fig. 11 for definition of these dimensions.

TABLE IV

AIR GAP DIMENSIONS

FRAME	DIMENSIONS (Inches)			
	"A"	"B"	"C"	"D"
311	B+C+D	.040	1.001	Stamped
312	B+C+D	.040	1.001	on
322	B+C+D	.050	1.251	Face
332	B+C+D	.063	1.601	of
342	B+C+D	.080	2.001	End
352	B+C+D	.080	2.001	Bracket
362	B+C+D	.080	2.001	
372	B+C+D	.100	2.001	
382	B+C+D	.100	2.001	

Obtain the proper air gap by proceeding as follows:

1. Assemble the entire stator frame with its end brackets, coils, middle ring and rotor. Assemble the rotor bearing to the shaft.

2. Assemble the non-spring type trunnion adapter with a 0.060-inch shim between it and the end bracket. Draw the bolts up tight.

3. Assemble the opposite trunnion adapter (spring type) with bearing ring, springs, and retainer ring, omitting shims. Draw up the bolts only enough to compress the springs and assure that the bearing in the non-spring type adapter is properly seated. (These bolts must be drawn up evenly and with approximately the same amount of pressure to avoid cocking the bearing.)

4. At each end, measure the distance "A" between the counterbored surface ("X") on the end bracket and the rotor disk. Next, obtain dimension "C" from Table IV and add it to dimension "D", which is stamped on the face of the end brackets. This must be done for both ends. Subtract the sum (C+D) for each end from the dimension "A" for that end to obtain the air gap for each end. Equalize the gaps at both ends within 0.004 inch by adding or subtracting shims at "Y". Dimension "B" is the normal gap dimension and is listed for reference.

5. At "spring end", measure the gap between the bearing ring and spring retaining ring. This measurement must be made through the large pipe-tap hole in the trunnion adapter. Adjust this gap by drawing up on the bolts until a 0.012-inch to 0.015-inch gap is obtained. Measure the amount of shim "Z" that is required to obtain this gap. Remove this trunnion adapter and reassemble with measured thickness of shim at "Z".

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