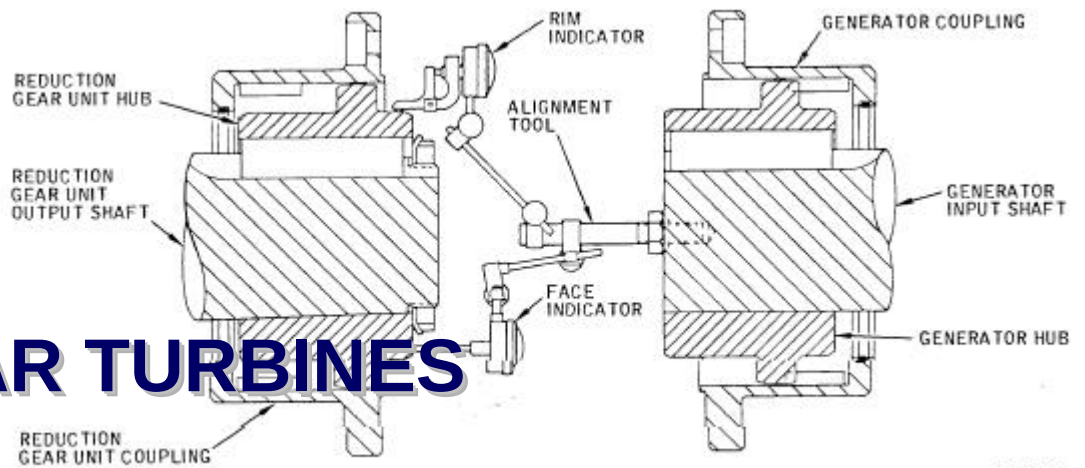
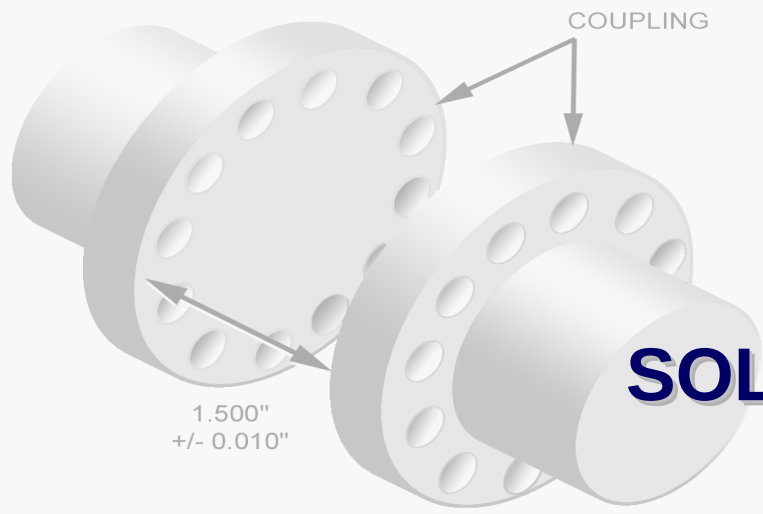
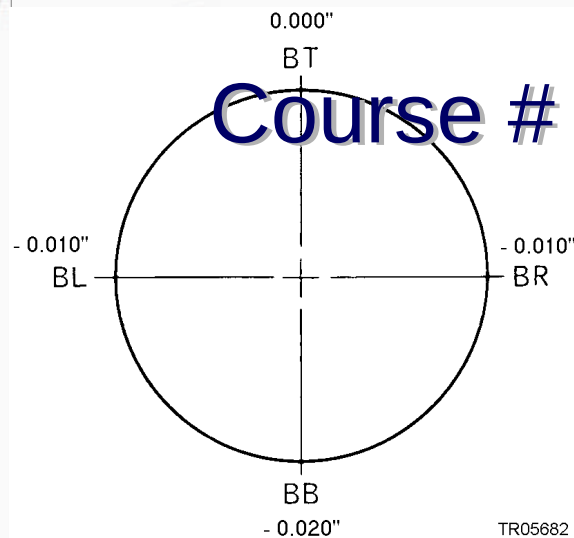




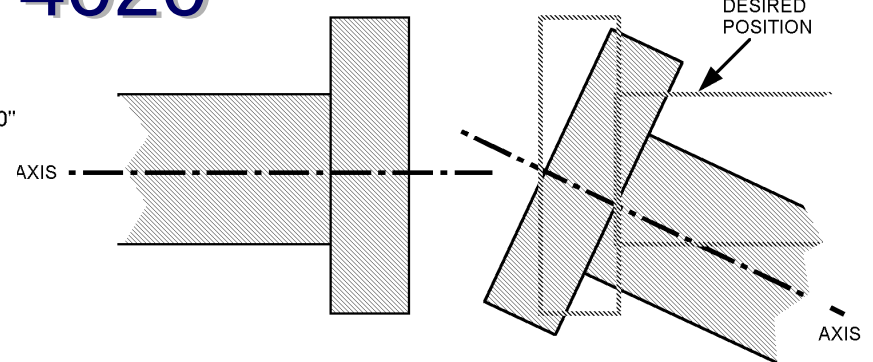
SOLAR TURBINES

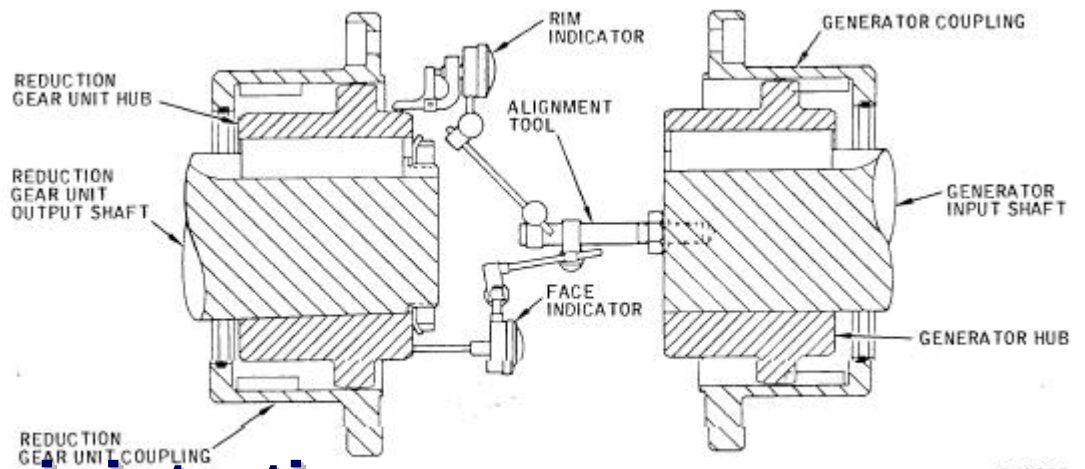
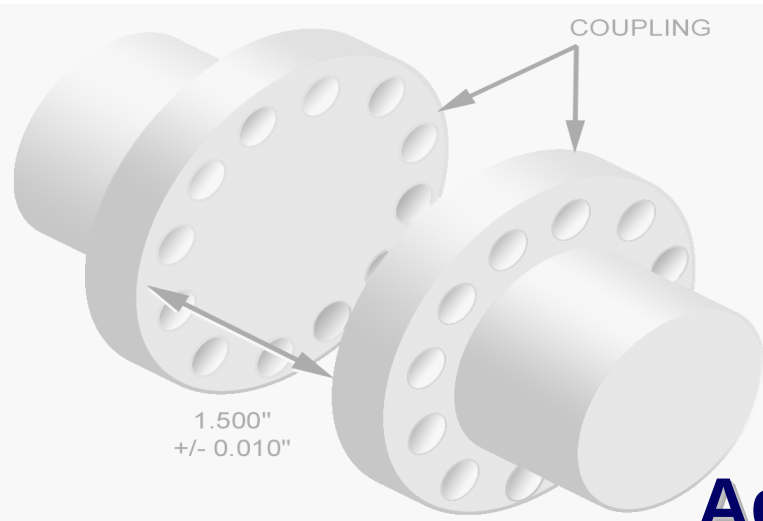
CUSTOMER SERVICES TECHNICAL TRAINING

PACKAGE LEVELING AND ALIGNMENT



Course # 4020





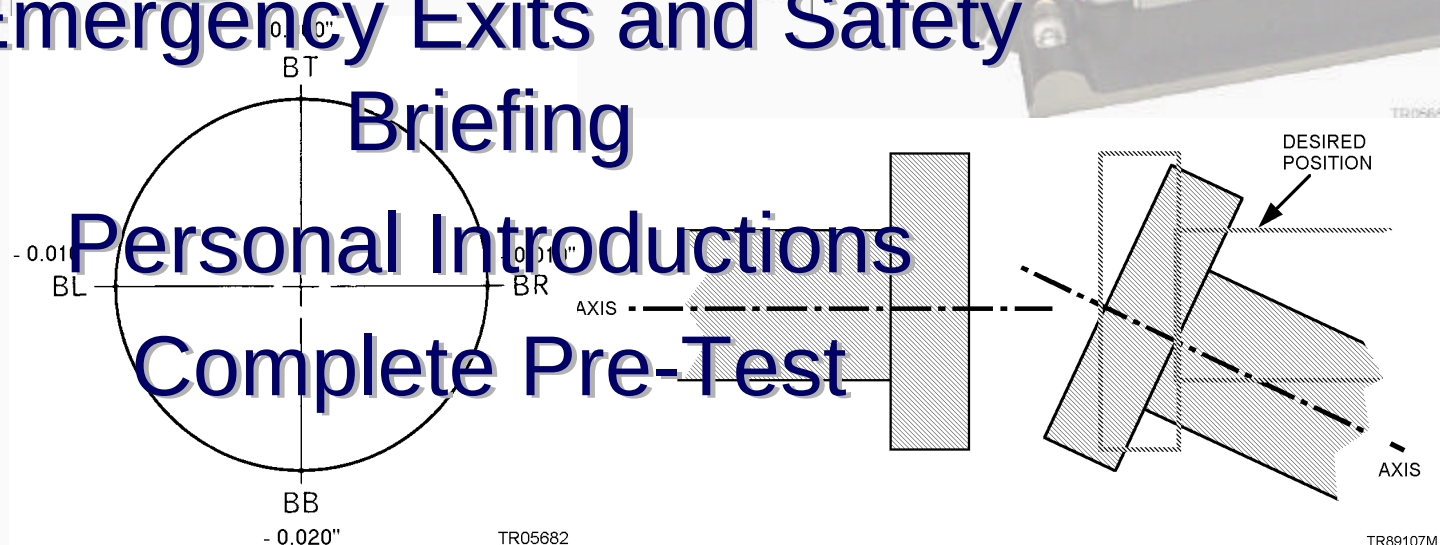
SA2203

Administration



Course Schedule
Emergency Exits and Safety
Briefing

Personal Introductions
Complete Pre-Test



TR89107M

Course Objectives

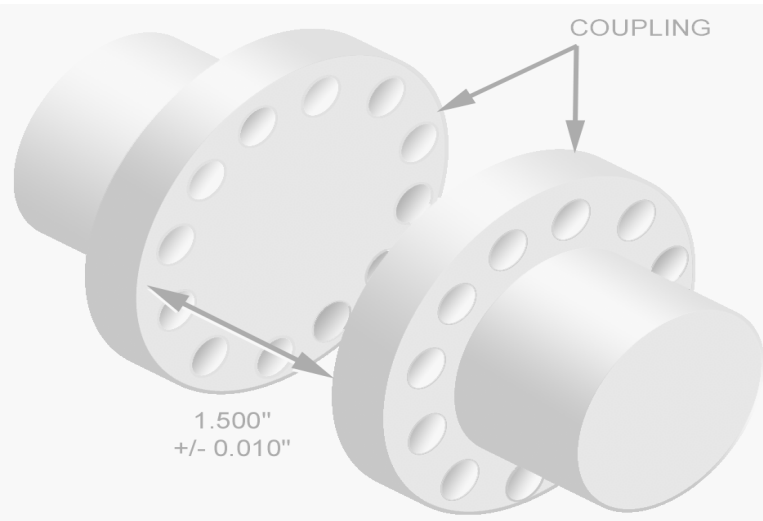
1. Describe the use of precision measuring equipment during package leveling and alignment checks
2. Have the necessary knowledge and skills to complete the leveling of a Solar package as part of the package commissioning activities
3. Describe the basic principles of machinery alignment
4. Locate and be able to apply sources of alignment information found on a Solar project
5. Complete practical exercises on test-rigs (shaft alignment simulators) to gain familiarity with alignment procedures and equipment
6. Complete practical exercises on actual turbine packages to align engines and driven equipment to within Solar specifications

List of Lessons and Appendices

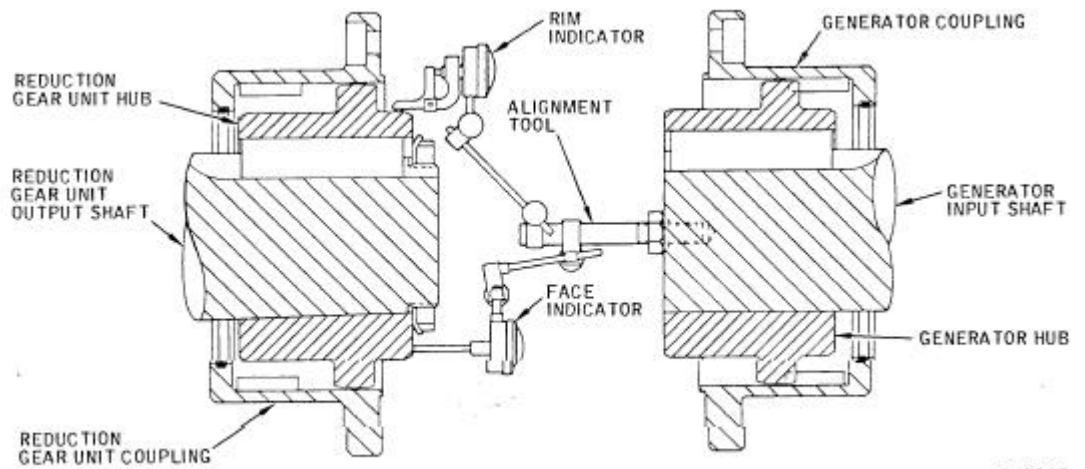
- LESSON 1 – Precision Measuring Equipment
- LESSON 2 – Package Leveling
- LESSON 3 – Principles Of Machinery Alignment
- LESSON 4 – Solar Alignment Information
- LESSON 5 – Solar Alignment Techniques
- LESSON 6 – Simulator Exercises
- LESSON 7 – Package Alignment Exercises
- APPENDIX A – Glossary of Terms
- APPENDIX B – Alignment Specifications and Readings for Lesson 6 Exercises
- APPENDIX C – Alignment Specifications and Readings for Lesson 7 Exercises

Safety

- Safety is our first consideration
- Before commencing any work in the lab, a Work Hazard Assessment and Task Risk Assessment will be completed



TR05650



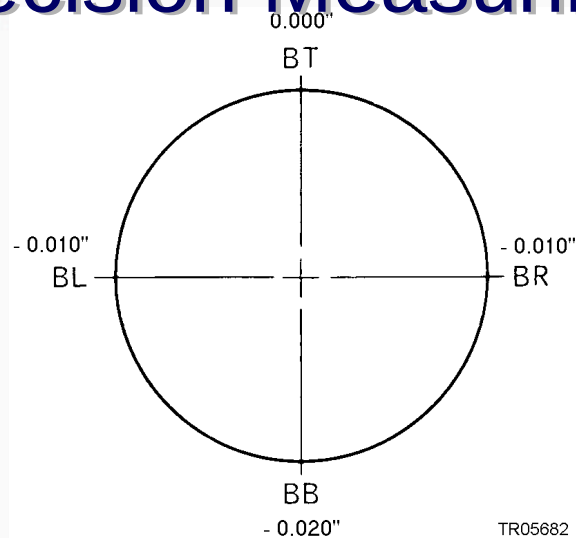
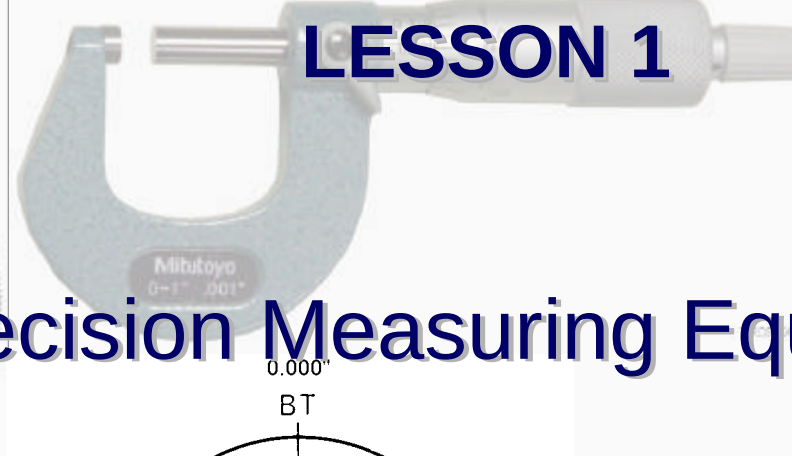
SA2203

LESSON 1

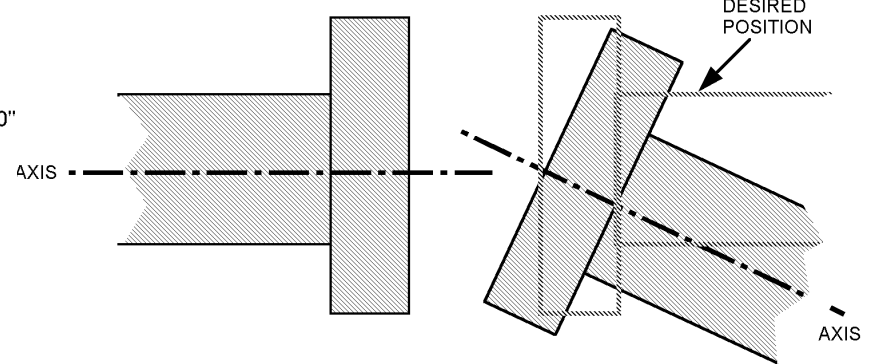
Precision Measuring Equipment



TR05600



TR05682



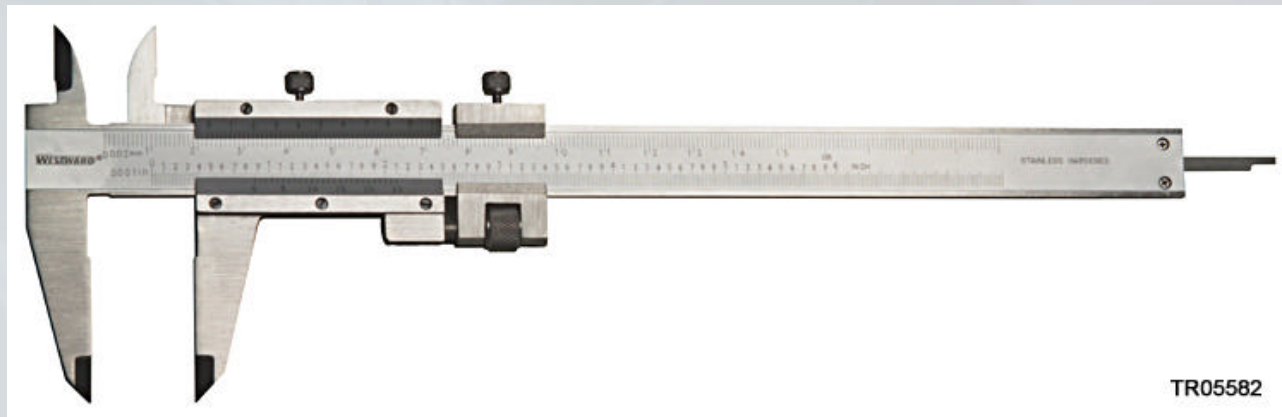
TR89107M

Objectives

1. Describe the basic principles of a Vernier Scale
2. Describe general procedures for taking measurements using:
 - Vernier Calipers
 - External Micrometers
 - Internal Micrometers
 - Dial Indicators
 - Go / No-Go Gages
 - Machinist's Level
 - Feeler Gages
3. Correctly measure the dimensions of selected test pieces

INTRODUCTION TO THE BASIC TOOLS

Vernier Calipers



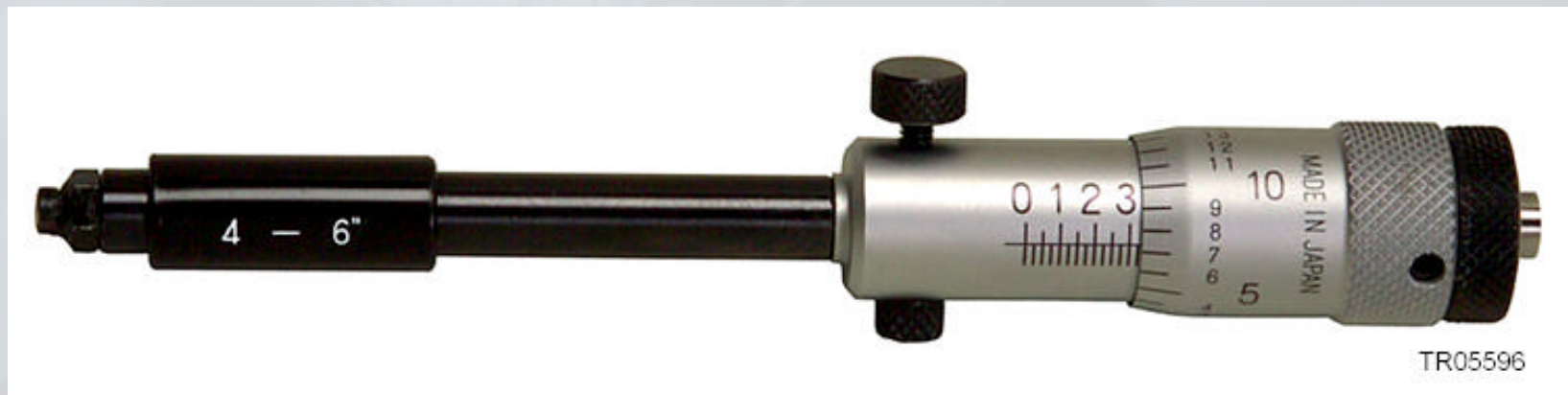
- Can be used to measure:
 - Shim thicknesses
 - Distance between shafts
 - Depth of blind holes
- Accurate to 0.001"
- Range of sizes available

External Micrometer



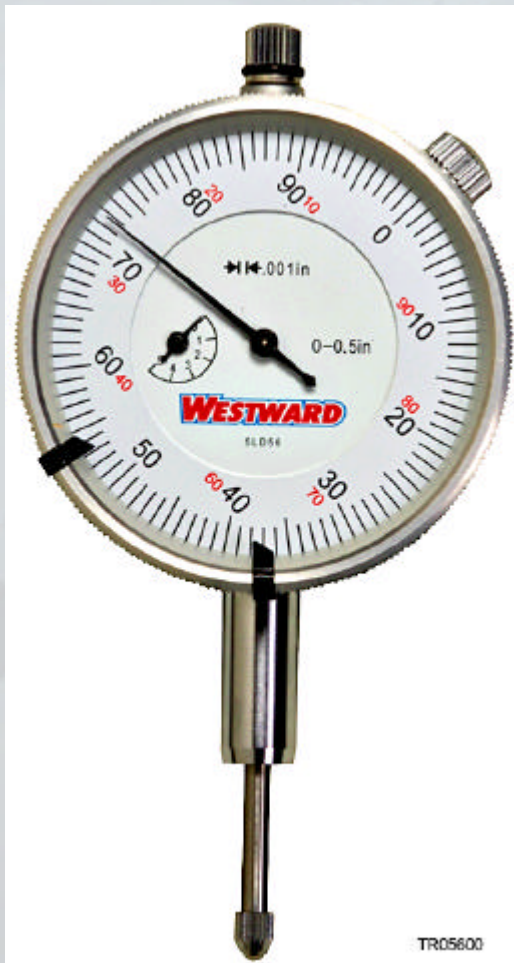
- Can be used to measure:
 - Shim thicknesses
- Accurate to 0.001"
- 0-1"
- Larger sizes available

Internal Micrometer



- Can be used to measure:
 - Internal dimensions from around 2" to a maximum dependent of the extension rods installed
- Accurate to 0.001"

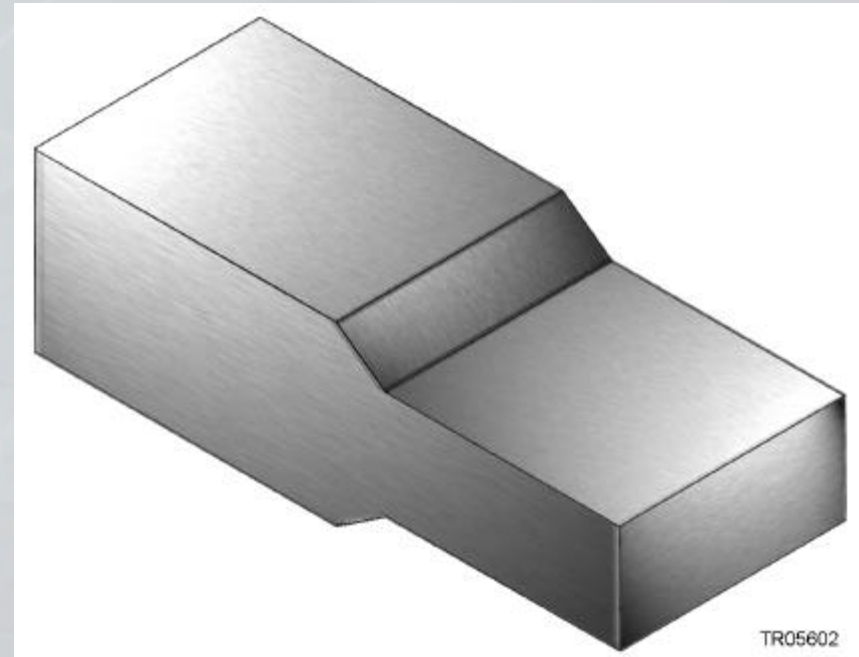
Dial Indicators



- Can be used to measure:
 - Alignment readings (“rim and face”)
 - Machinery movement using jacking bolts
- Spring loaded plunger
- Dial increments in 0.001”
- Different ranges available

Go / No-Go Gage

- Can be used to measure:
 - Small gaps between surfaces when other tools will not fit
- Manufactured from steel or other metal
- Different ends are machined to a specific sizes that correspond to the gap tolerance
 - One side should fit
 - Other side should not fit



Machinist's Level



TR05604

- Precision spirit level
- Mounted on machined surfaces to check package level

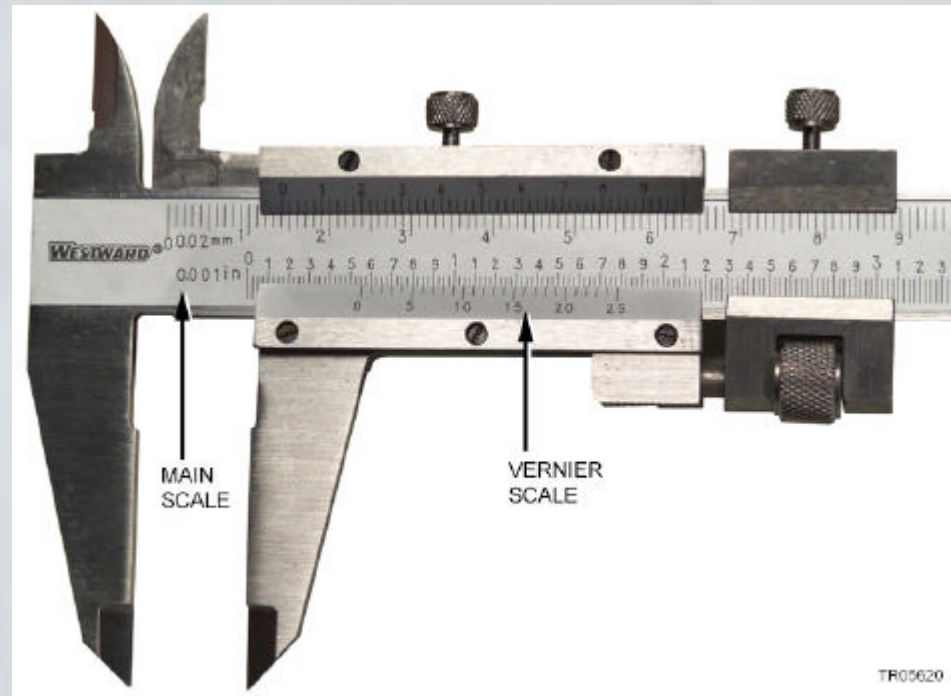
Feeler Gages



- Thin strips of steel of a known thickness
- Normally 0.001" increments
- Can be used with a machinist's level during package levelling checks

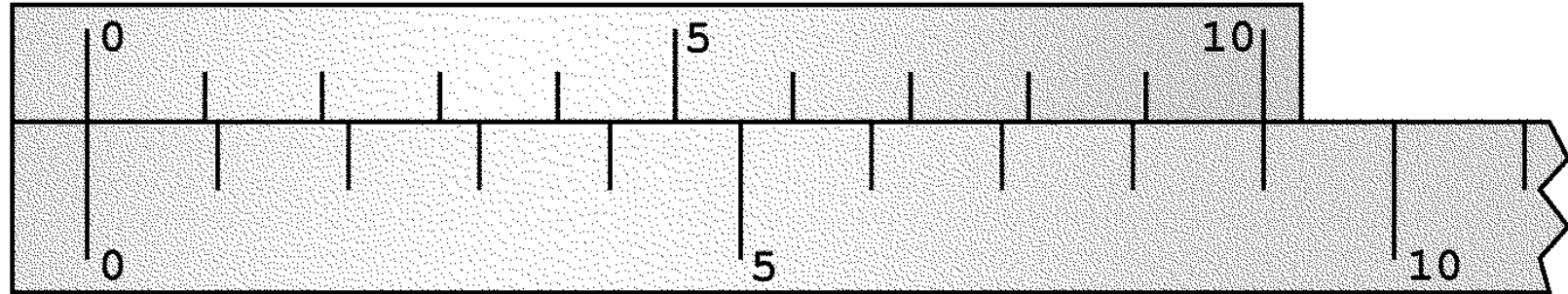
HOW TO USE THE TOOLS

Vernier Caliper Scales



- Vernier scales used in calipers and micrometers
- Allows reading of fractions of small divisions
- Principle involves two scales
 - Main Scale
 - Vernier Scale

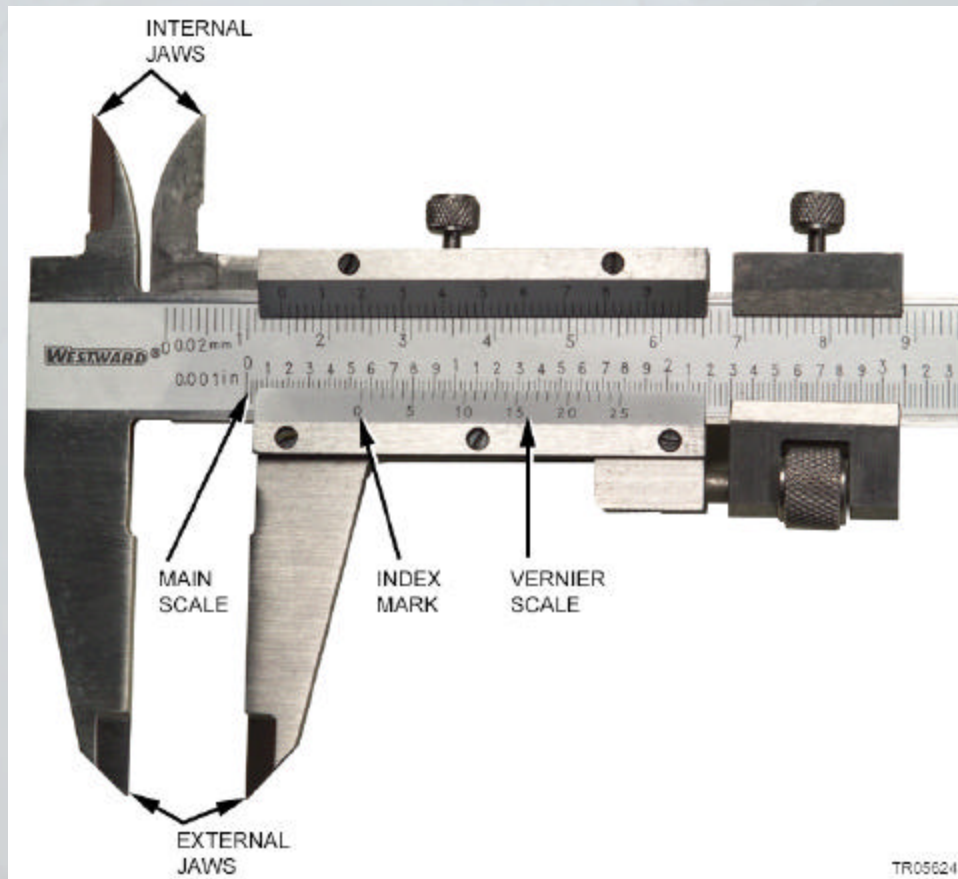
Vernier Scale Divisions



TR05622

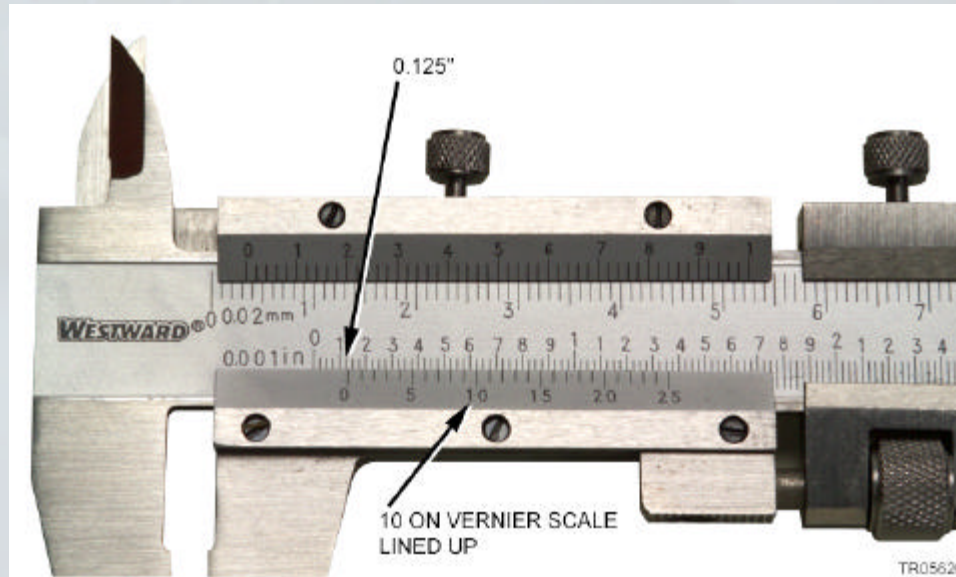
- Vernier Scale (top) has same number of divisions as Main Scale (bottom)
- However it takes up less length
- Mathematical principle is not important – we will concentrate on how to read the values

Vernier Caliper



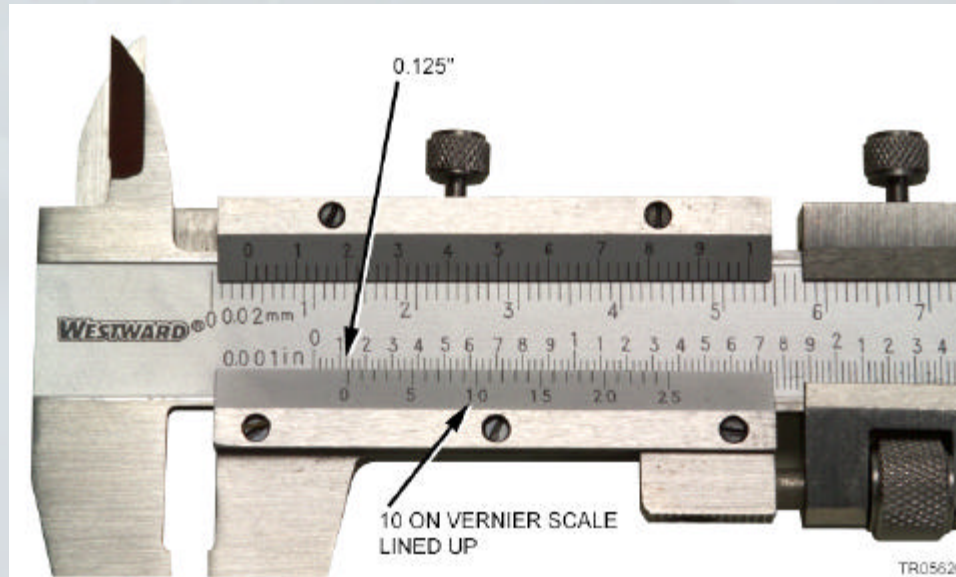
- Vernier calipers can measure internal or external dimensions
- Note the:
 - Main Scale
 - Vernier Scale
 - Index Mark
- Available in English or Metric
 - We will use English units

Example of Reading a Vernier Caliper



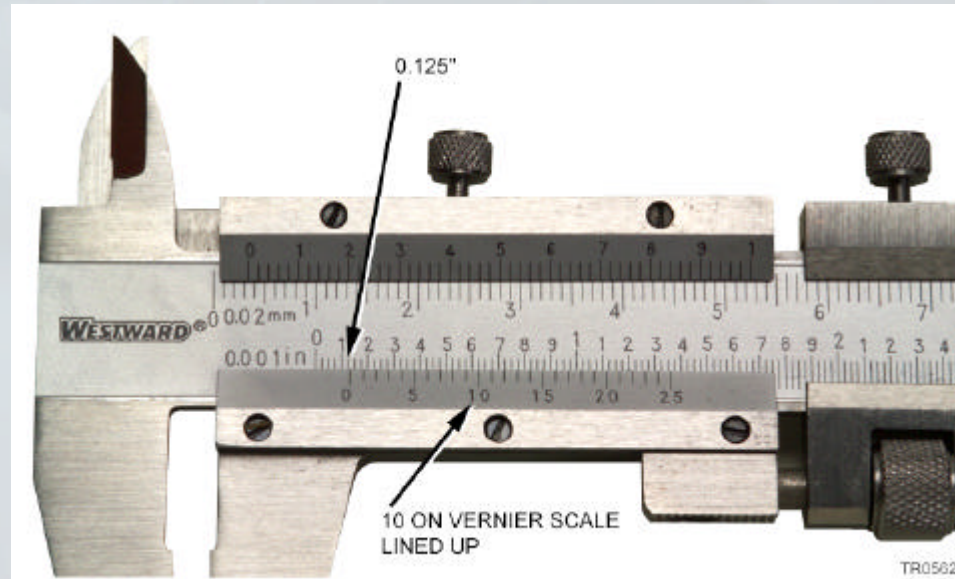
- Main Scale divided into 0.1" increments
- Further 0.025" sub-divisions
- Index Mark alone will indicate measured dimension to within 0.025"

Example of Reading a Vernier Caliper



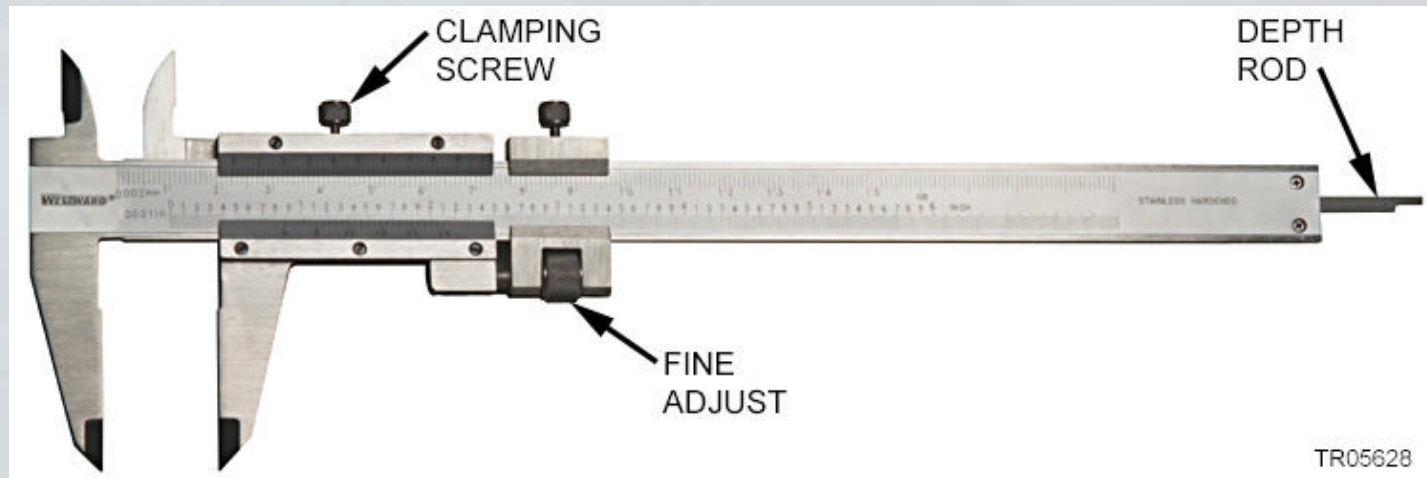
- Vernier Scale gives greater accuracy
- Subdivided into 25 increments
- Vernier Scale mark than lines up exactly with ANY Main Scale mark should be added to the previous reading

Example of Reading a Vernier Caliper



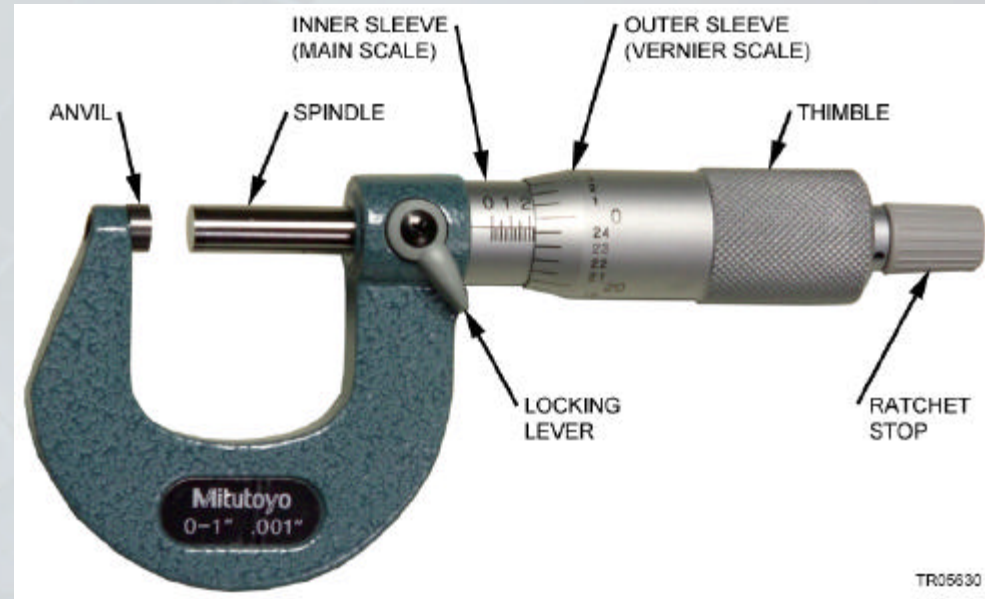
- Step 1 – Index mark just past 0.125"
- Step 2 – Vernier Scale mark 10 lines up exactly
- Step 3 – Total reading = 0.135"
- Accuracy to 0.001"

Other Vernier Caliper Features



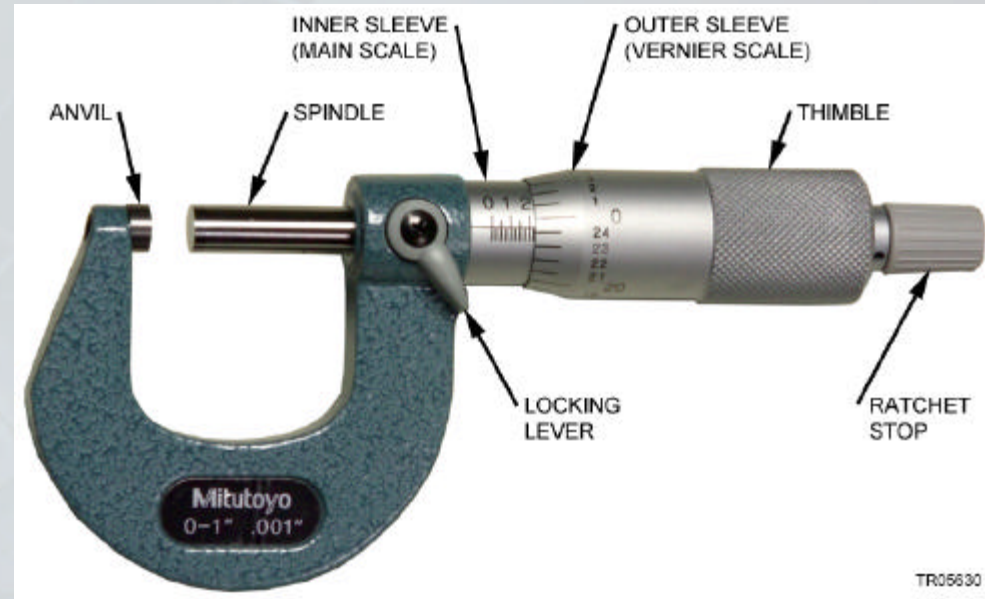
- Depth Rod can be used for blind holes
- Clamping Screw can be locked to prevent the reading being affected
- Fine Adjust (with it's own clamp screw) allows greater "feel"
- Zero check prior to use
 - Vernier Scale position may be adjusted

External Micrometer



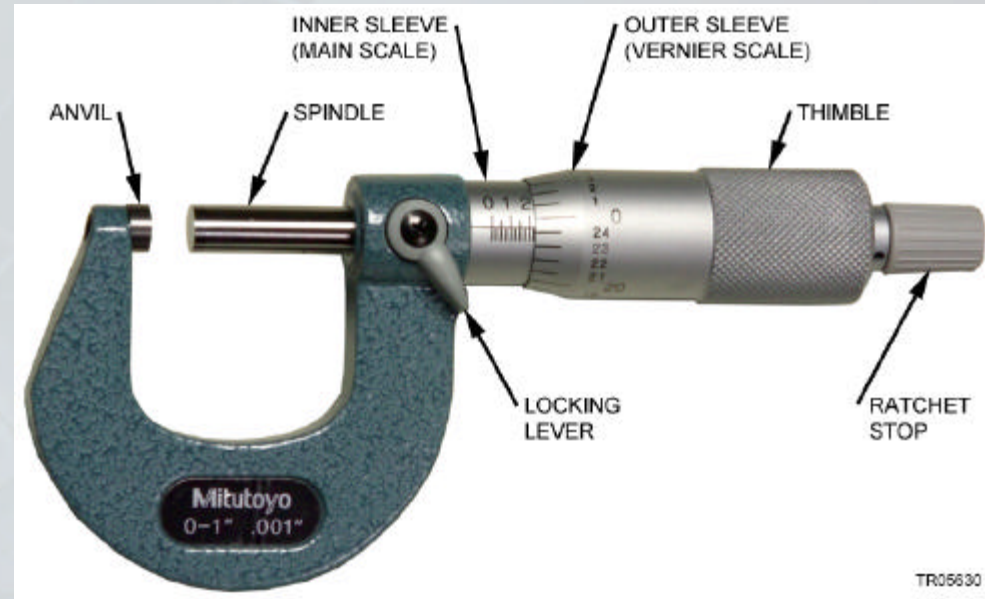
- Micrometers operates on same principle as Vernier calipers, except using screw-thread pitch
- Different types available:
 - External
 - Internal
 - Depth

External Micrometer



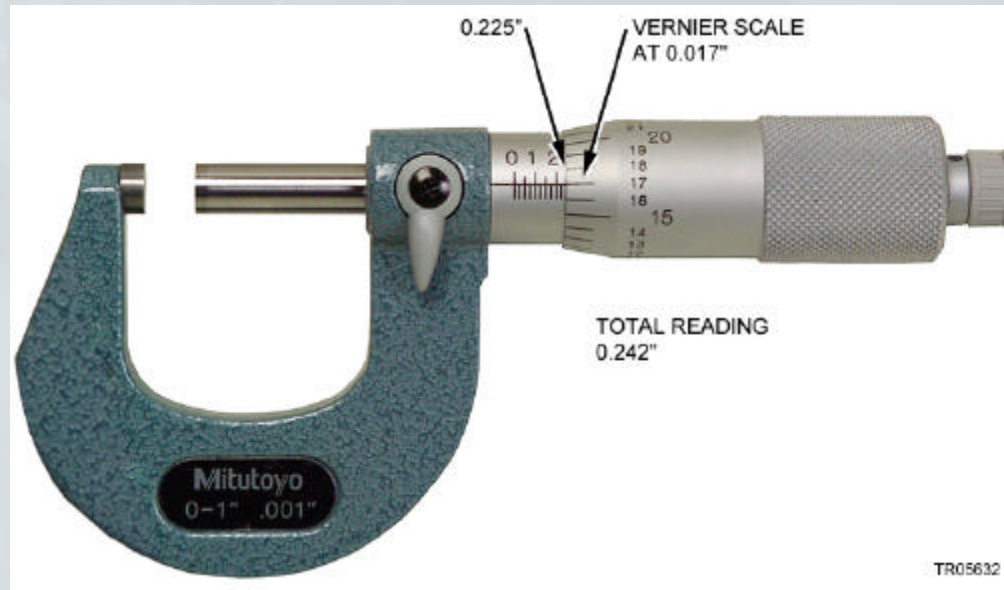
- Ratchet stop used to provide greater “feel”
- Locking lever to lock spindle in position
- Zero check prior to use
 - Tools provided to adjust position of outer sleeve

External Micrometer



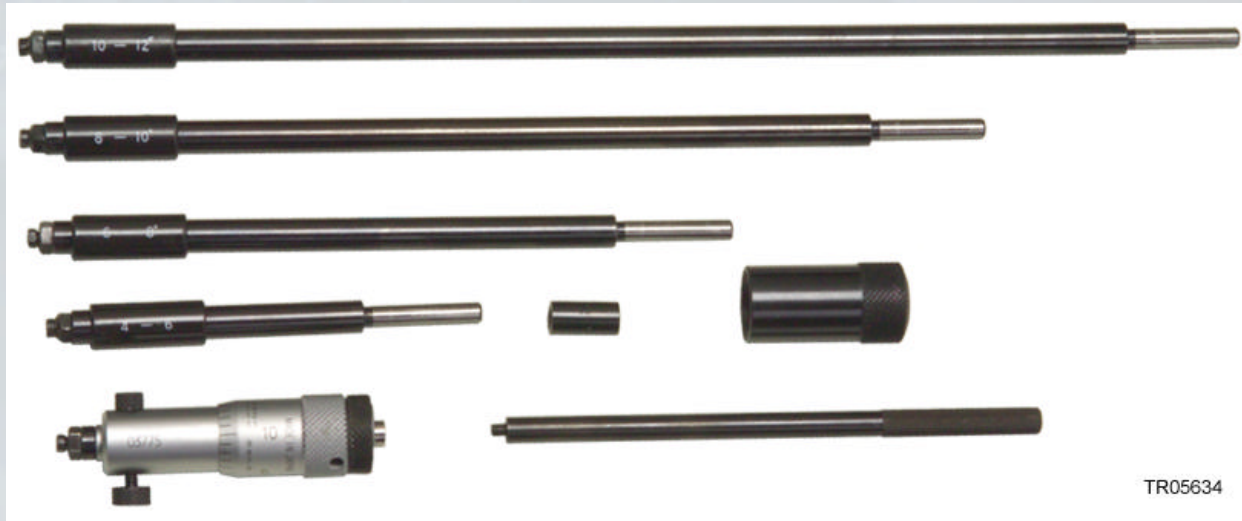
- Example is 0 – 1" External Micrometer
- Accurate to 0.001"
- Note:
 - Inner Sleeve with Main Scale
 - 0.1" divisions
 - 0.025" subdivisions
- Outer Sleeve with Vernier Scale
 - 25 x 0.001" divisions

Example of Reading a Vernier Micrometer



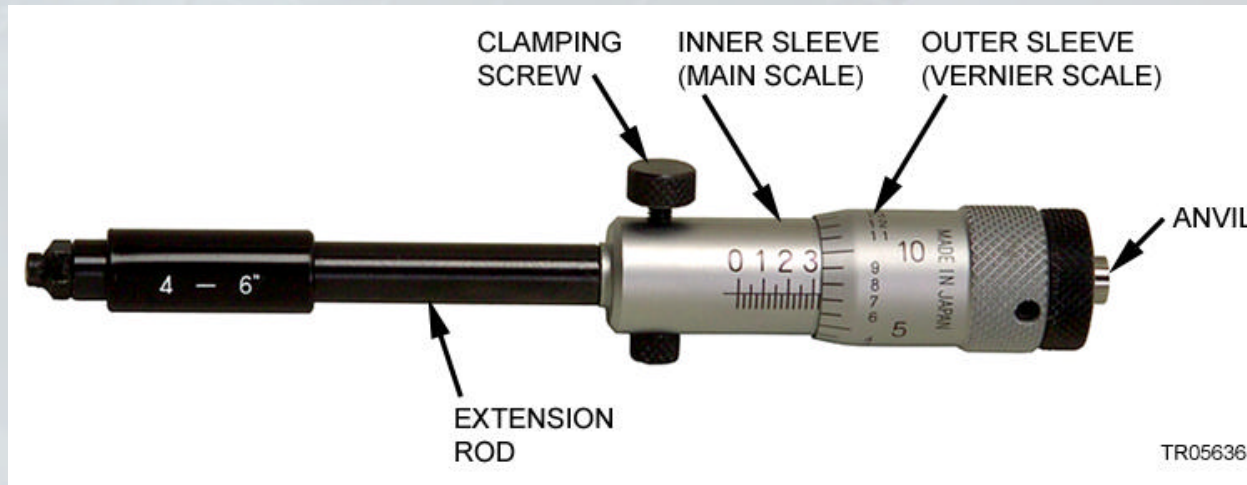
- Step 1 – end of outer sleeve aligned with 0.225" mark
- Step 2 – Vernier Scale mark 17 lined up with center-line
- Step 3 – Total reading = 0.242"

Internal Micrometer Kit



- Range dependent on extension rods
- Minimum length = 2" plus extension rod
- Accurate to 0.001"

Internal Micrometer Features



- Inner Sleeve
 - Main Scale
 - 0.1" divisions
 - 0.025" subdivisions
- Outer Sleeve
 - Vernier Scale
 - 25 x 0.001" divisions
- "Zero" check prior to use
 - Ensure when end of outer sleeve lines up with zero on Main Scale, the Vernier Scale zero is also lined up with the center-line
 - Tools provided for adjustment

Example of Internal Micrometer Reading



- Minimum length = 4.000"
- Position of inner sleeve = 0.325"
- Vernier Scale mark aligned = 0.007"
- Total Reading = 4.332"

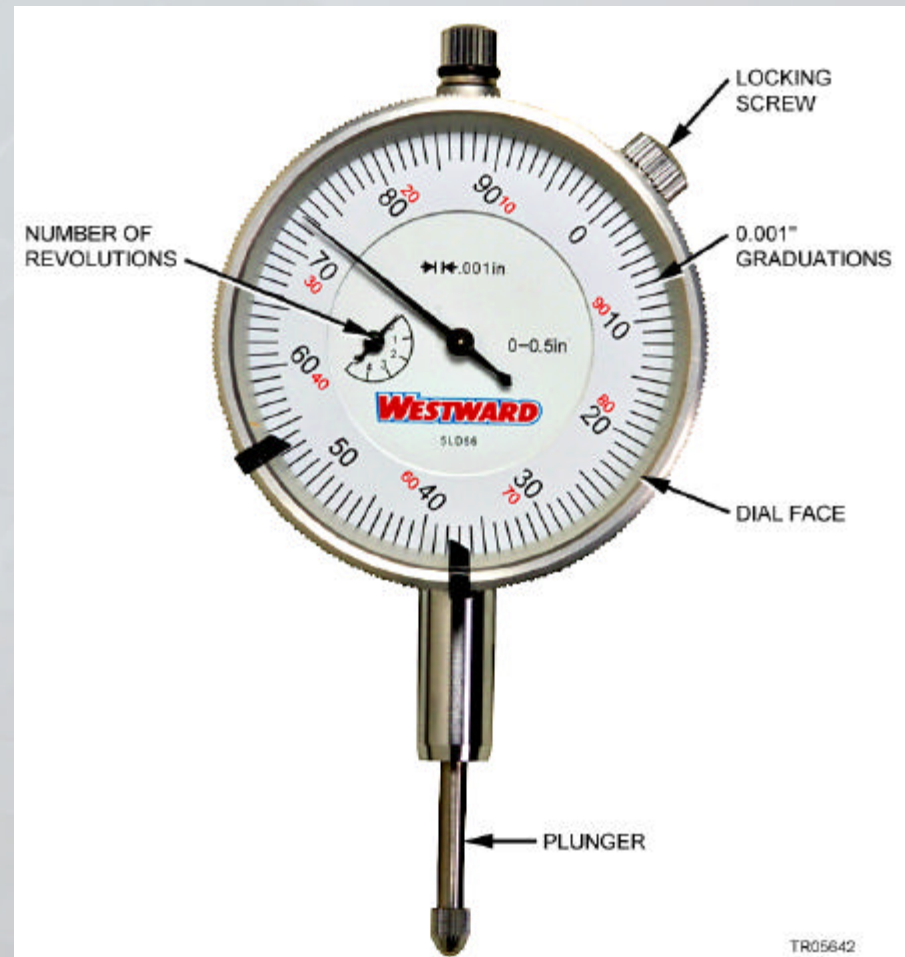
Internal Micrometer with Handle Attached



- Used when inserting into deep recesses

Dial Indicator

- Metric or English
- 0.001" graduations on main scale
- One revolution = 0.1"
- Number of revolutions up to 5
- Total range of this model = 0.5"



Dial Indicator Ready for Use

- Depress plunger to around 50% when setting up
- Then zero by rotating dial
- Note position of small needle (2)
- Depressing plunger = Positive / Clockwise
- Extending plunger = Negative / CCW



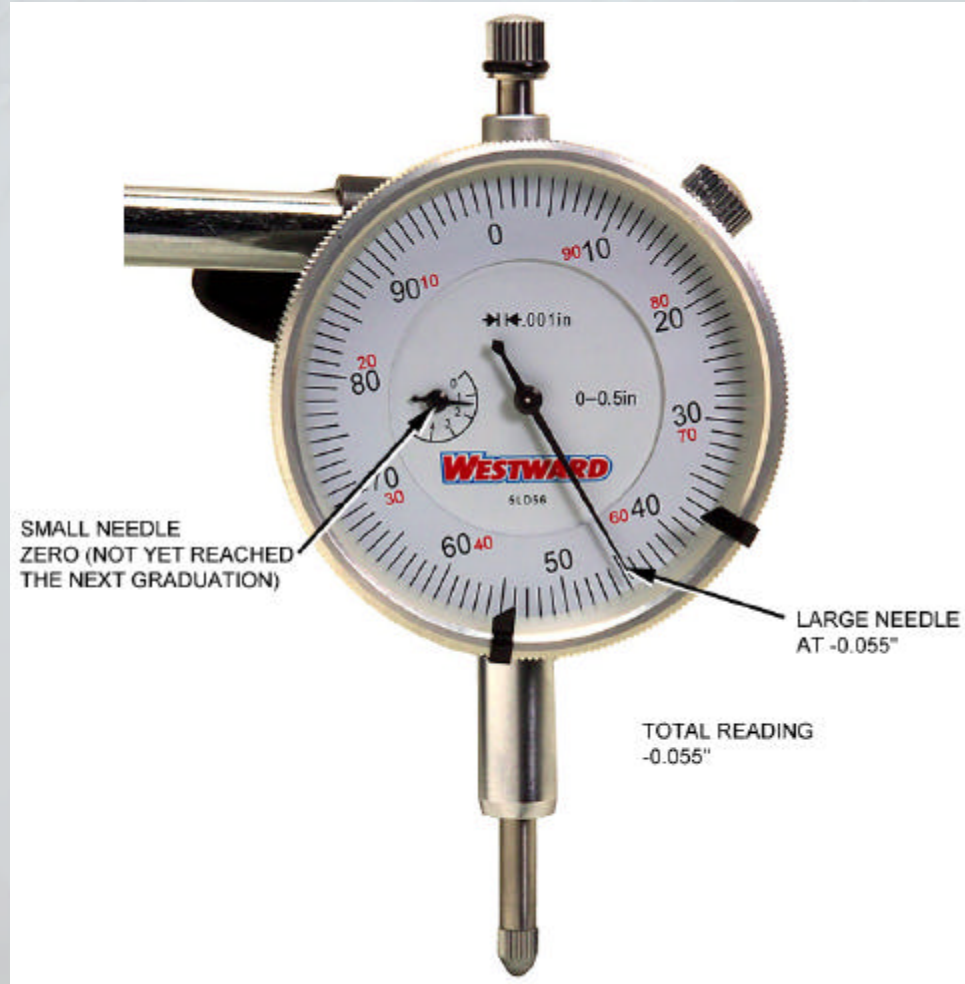
TR05644

Example of Dial Indicator Reading

- Large needle = 22
- Small needle = past 3 (must have moved one complete revolution)
- Direction = CW (positive)
- Total reading = +0.122"



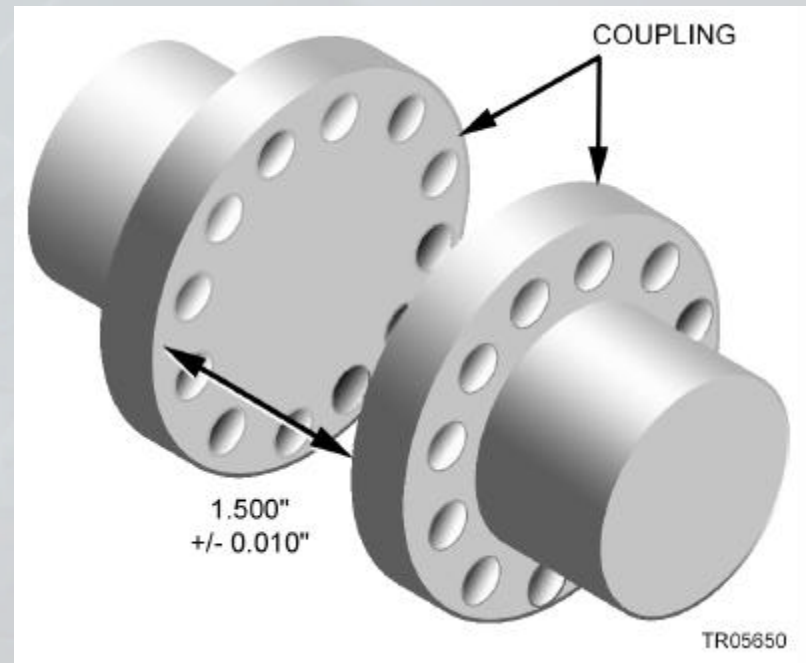
Example of Negative Dial Indicator Reading



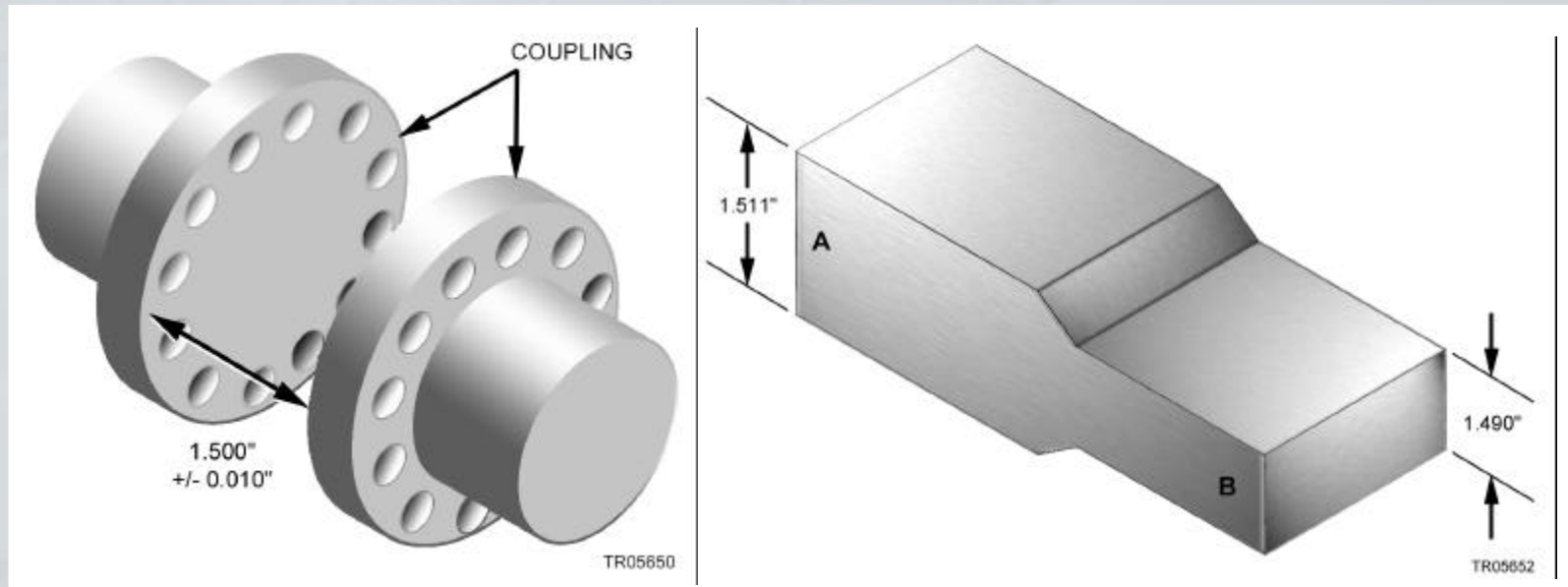
- Large needle = 45
- Small needle = less than 2
- Direction = CCW (negative)
- Total reading = -0.055"

Gap to be Tested

- Unable to use internal micrometer with small gaps
- Can use Go/No Go Gage



Go / No-Go Gage



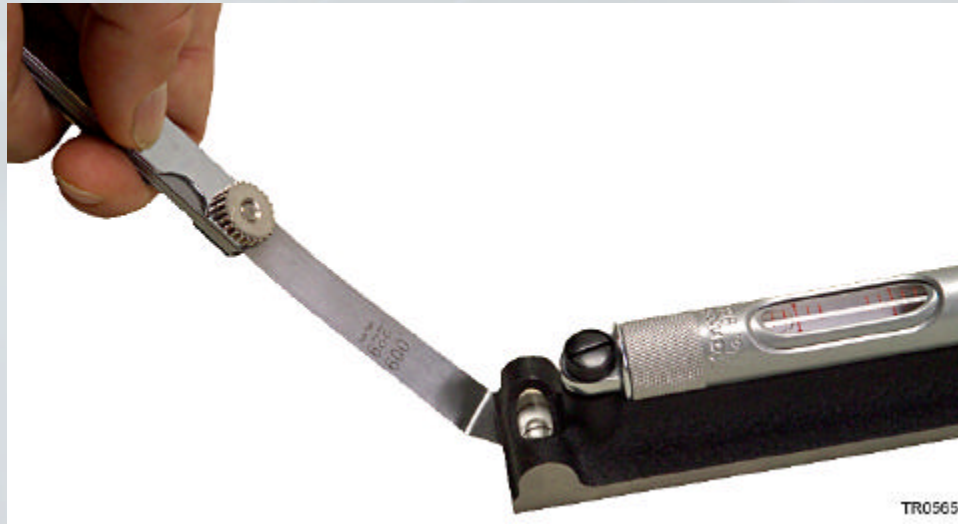
- Minimum gap = 1.490"
- Maximum gap = 1.510"
- If 1.490" gage fits, and 1.511" gage does not fit, then gap is within tolerance

Machinist's Level



- Simple method to level a package
- Precision spirit level placed on package machined surface
- Graduations represent deviation from level (0.001" increments)
- Example
 - If bubble is at 0.002" mark
 - Level = 6" long
 - Deviation = 0.004" per foot

Using Feeler Gages



- Alternative method is to use feeler gages under one end, until level

Machinist's Level



- Either method - then extrapolate distance to foundation pads to calculate shim requirements
- Example:
 - Deviation = 0.004" per foot
 - Distance to low foot = 10 feet
 - Insert 0.040" shim under that foot

QUESTIONS ON PRECISION MEASURING EQUIPMENT?

Complete Student Exercise

Student Exercise

1. List five items of measuring equipment commonly used during package leveling and machinery alignment
 - i. Vernier Calipers
 - ii. External Micrometers
 - iii. Internal Micrometers
 - iv. Dial Indicators
 - v. Go / No-Go Gages
 - vi. Machinist's Level
 - vii. Feeler Gages

>

Student Exercise

2. Depressing the plunger on a dial indicator will give a positive reading

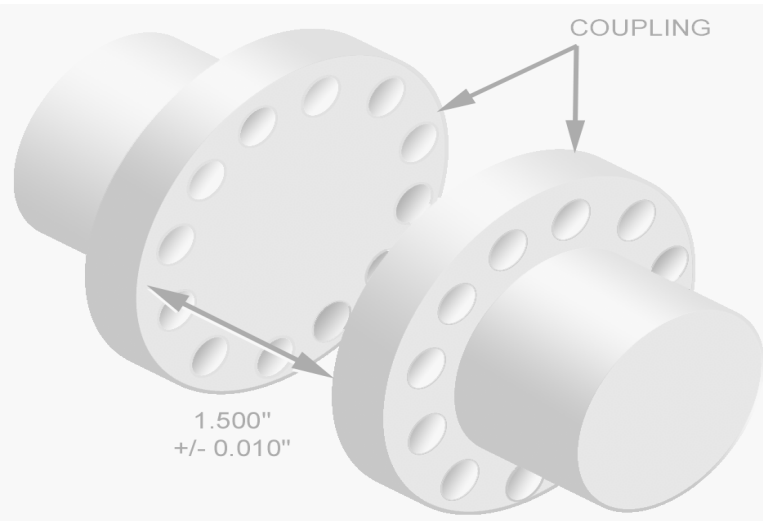
– TRUE / FALSE

Student Exercise

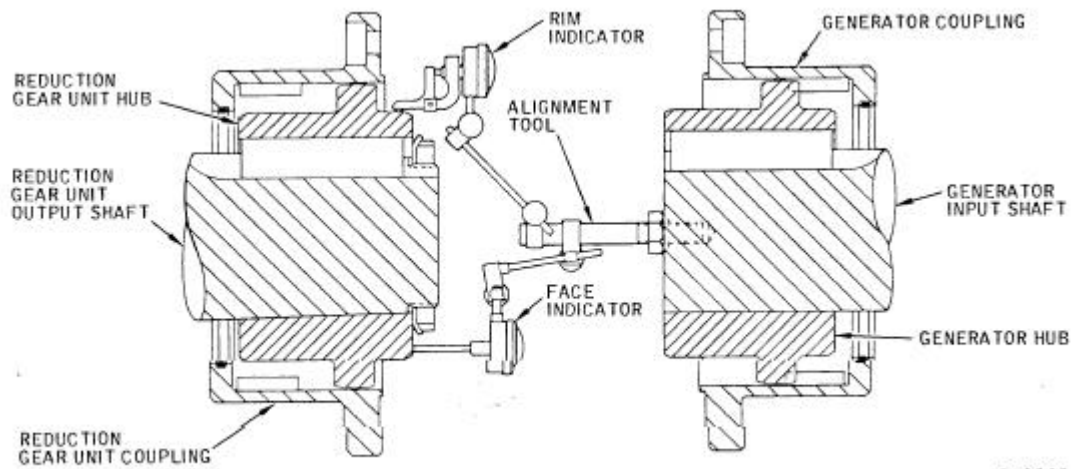
- Questions 3 – 5
- Instructor will pass round various objects to be measured
- Student will write the measurement in the table
- Instructor will confirm the measurement

Objectives - Recap

1. Describe the basic principles of a Vernier Scale
2. Describe general procedures for taking measurements using:
 - Vernier Calipers
 - External Micrometers
 - Internal Micrometers
 - Dial Indicators
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TR05650



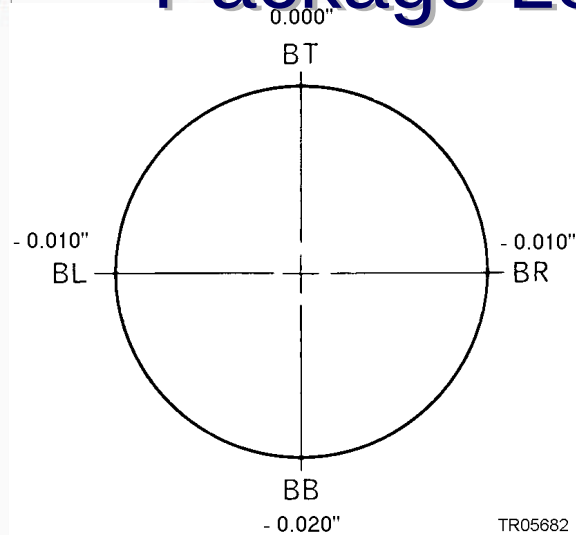
SA2203

LESSON 2

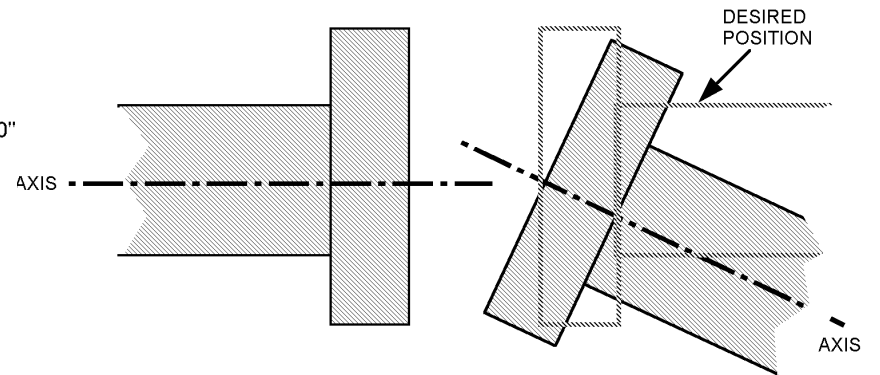
Package Leveling



TR05600



TR05682



TR89107M

Objectives

1. Describe the requirements for package leveling during installation and commissioning of a Solar package
2. List the available sources of information related to package leveling
3. Briefly describe the methods used to level a Solar package
4. Complete a practical exercise to check a Solar skid for level

Purpose of Package Leveling

- Ensures that:
- Machinery shafts are parallel
 - Prevents load of thrust bearings
- Machinery shafts are square in the bearings
 - Prevents sideways loading
- Fluid flow is not adversely affected
- Vertical height of package is also set, to allow external connections to be made

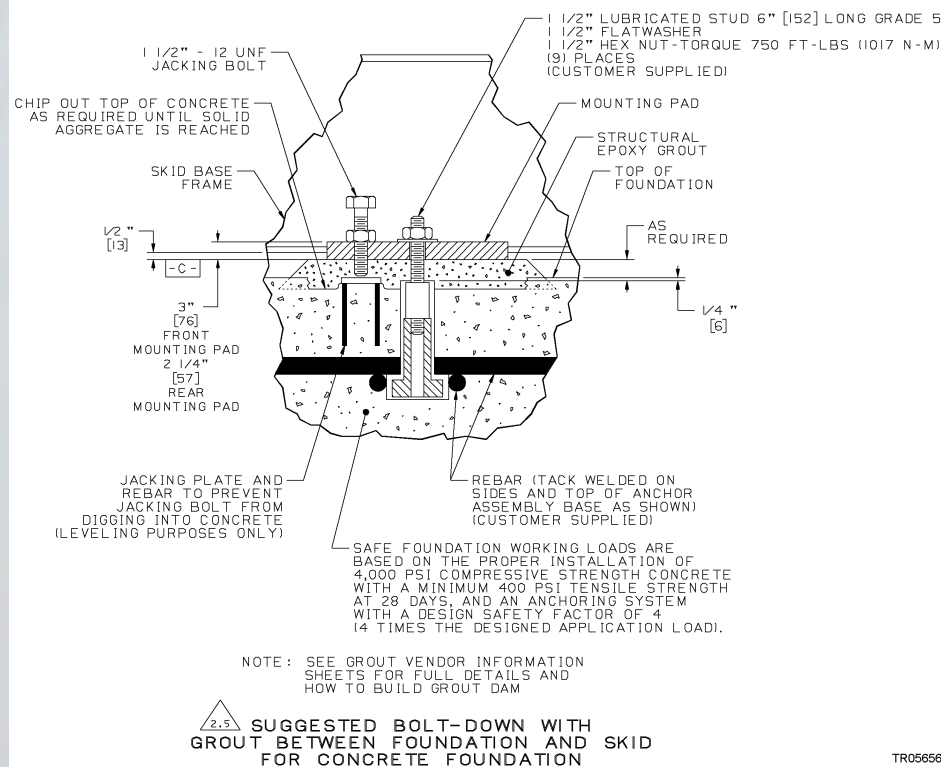
Available Information

- Mechanical Installation Drawings
 - Project specific information
- Engineering Specification 9-414
 - Generic information
- The following now be given as handouts
 - Drawing 72341-149606
 - ES 9-414

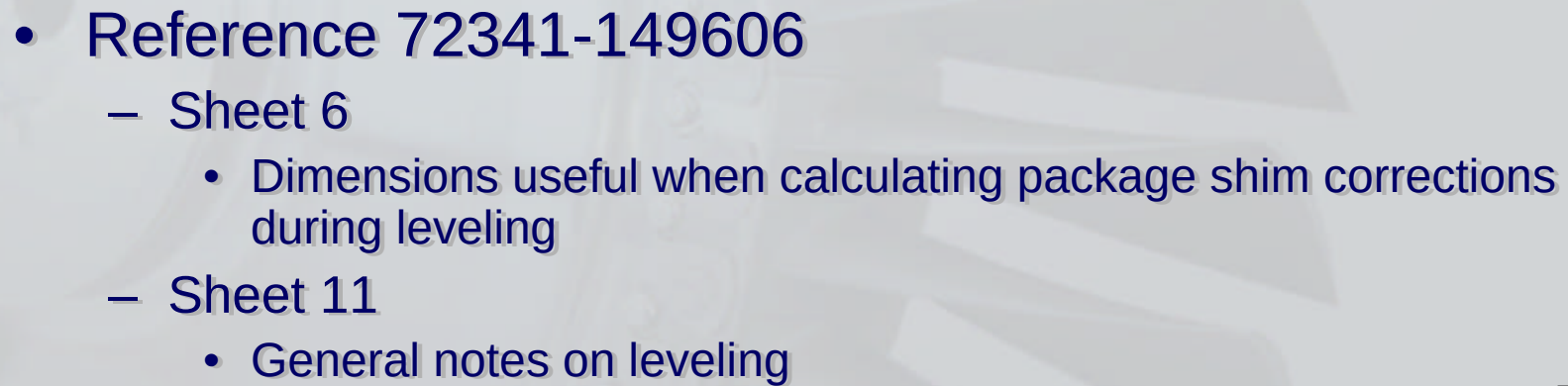
Mechanical Installation Drawings

- Reference 72341-149606
 - Sheet 1
 - Look at examples of notes
 - Torque requirements
 - Soft foot check, etc.

Skid Foundation Detail



- Reference 72341-149606
 - Sheet 6
 - Base mounting pad dimensions
 - Tie-down bolt details



Engineering Specification 9-414

- Covers multiple package configurations
 - Section 2.0B
 - Definitions of terminology
 - Identification of datum points

Engineering Specification 9-414

- Section 3.2A
 - Basic leveling procedure for one type of package configuration
 - Read through this section in ES 9-414, and then the summary in the SWB
- Section 4.0
 - Basic procedure for shimming and torquing
 - Read through this section in ES 9-414, and then the summary in the SWB
- **QUESTIONS?**

Leveling Methods

- Machined surfaces for levels
 - Preparation
- Equipment mounting pads to be level to within 0.005" per foot
 - If a 6 inch level is used, it should be level to 0.0025"
 - Use level graduations or feeler gages
- Extrapolation of feeler gage sizes can help determine shim corrections – see example in SWB

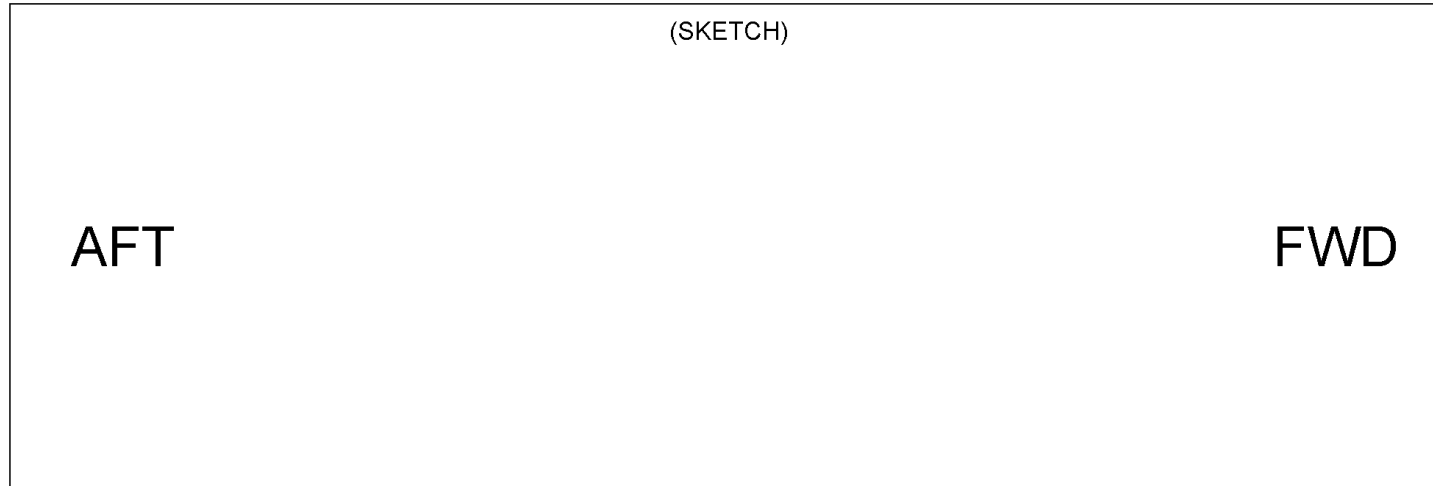
Objectives - Recap

1. Describe the requirements for package leveling during installation and commissioning of a Solar package
2. List the available sources of information related to package leveling
3. Briefly describe the methods used to level a Solar package
4. Complete a practical exercise to check a Solar skid for level

QUESTIONS ON PACKAGE LEVELING?

Complete Student Exercise

Student Exercise



TR05734

- Complete the graphic in the SWB with dimensions taken from the C40 skid (or other skid if this course is not in Mabank)
- Prepare the mounting pad surfaces for the level
- Calculate the package deviation from level
- Specify shimming corrections in the table in the SWB

(Calculations) AFT/FWD

(CALCULATIONS)

AFT

FWD

TR05736

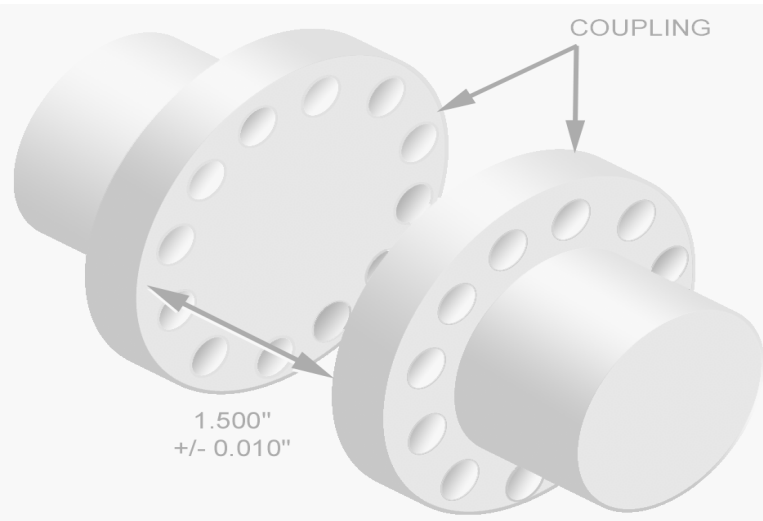
(Shim Correction Diagram) AFT/FWD

(SHIM CORRECTION DIAGRAM)

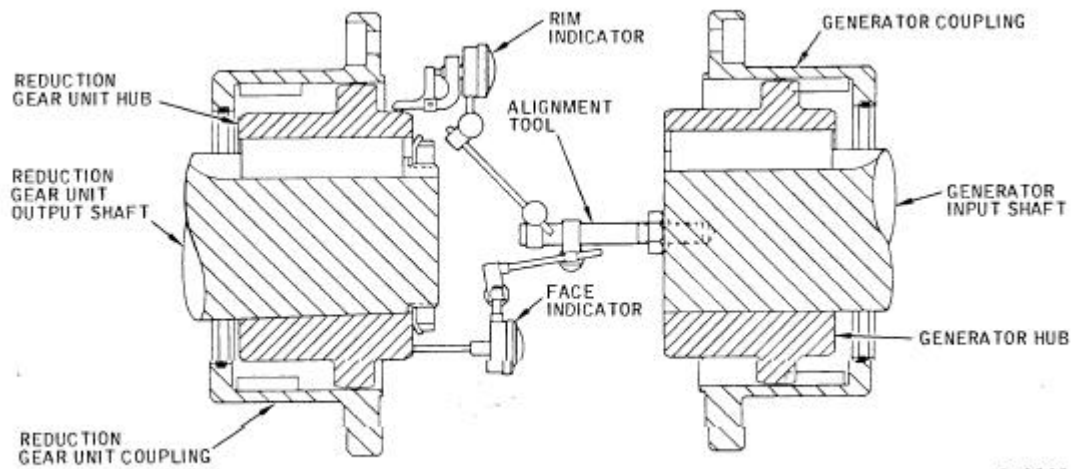
AFT

FWD

TR05738



TR05650



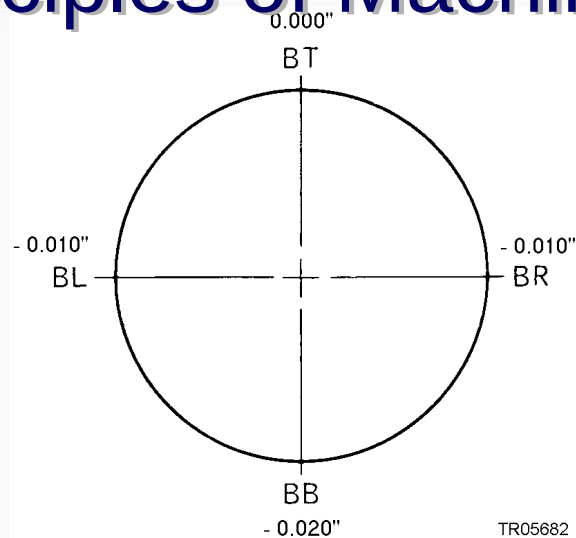
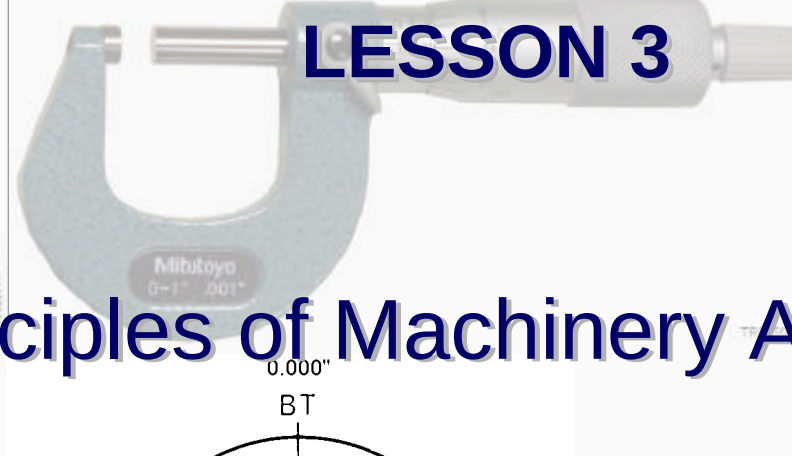
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LESSON 3

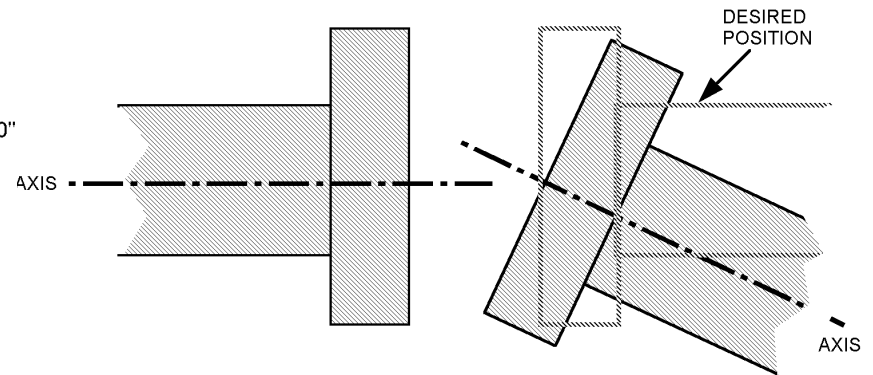
Principles of Machinery Alignment



TR05600



TR05682



TR89107M

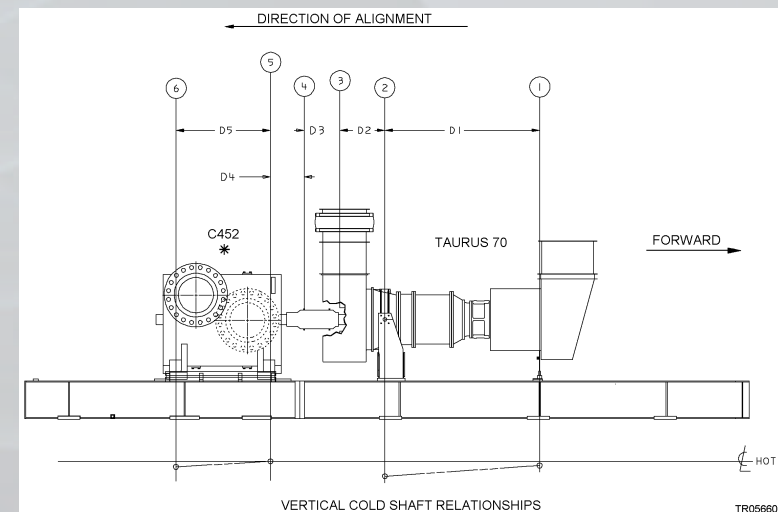
Objectives

1. Define the term “alignment”
2. Identify possible machinery problems that may be caused by poor alignment
3. List and describe the principles of different methods used in machinery alignment
4. Discuss negative influences that may affect final alignment accuracy

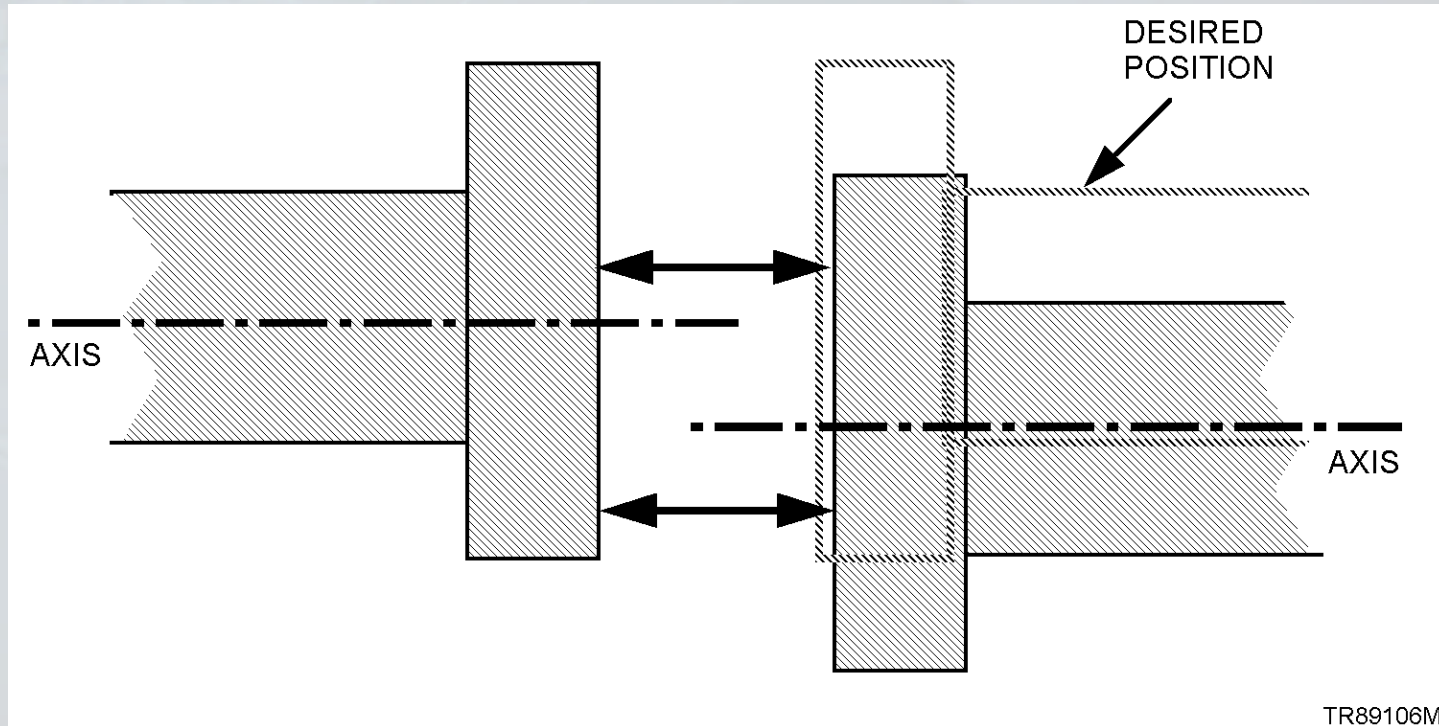
Basic Alignment Terms

Basic Alignment Terms

- When two machines are coupled together, the shaft center-lines should be concentric when the machinery is operating at normal temperatures
- Why?
- Abnormal loading
 - Reduced performance
 - High vibration
 - Premature failure

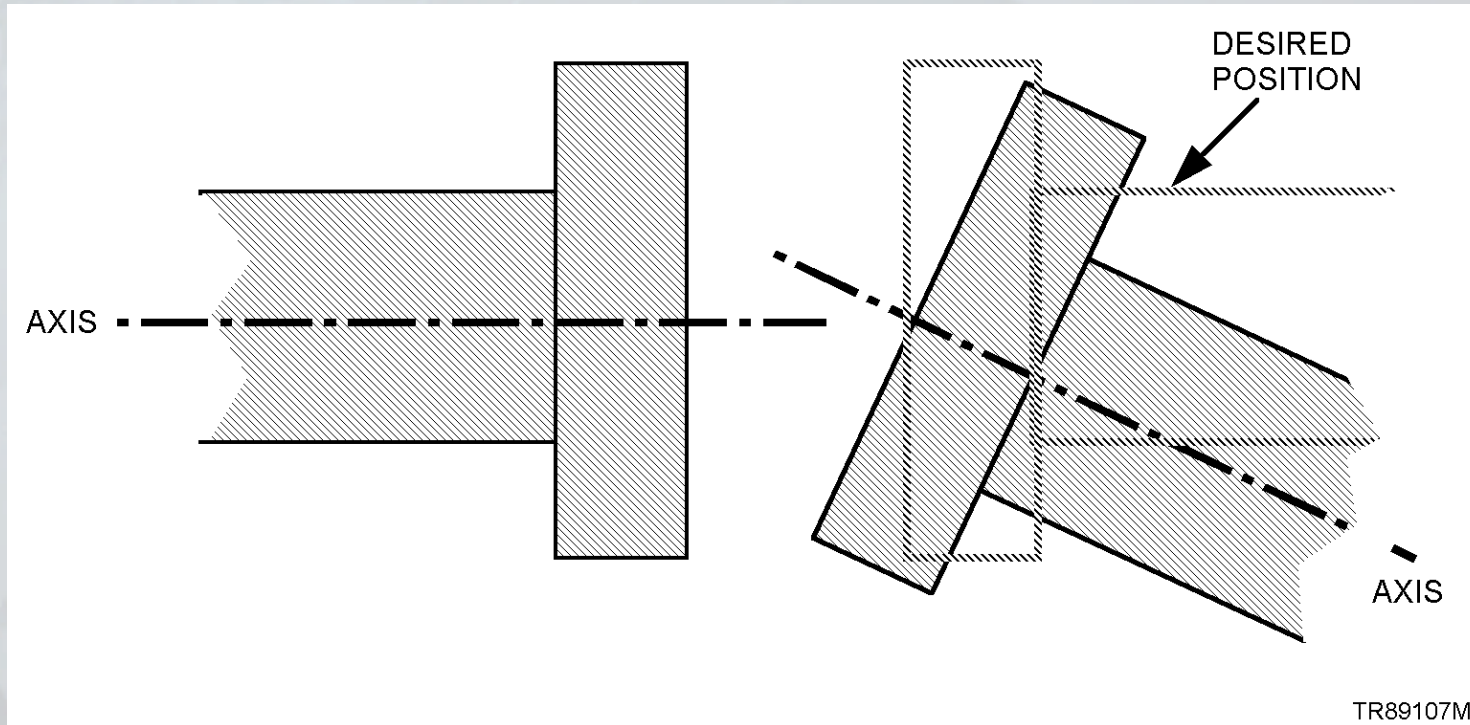


Parallel Misalignment



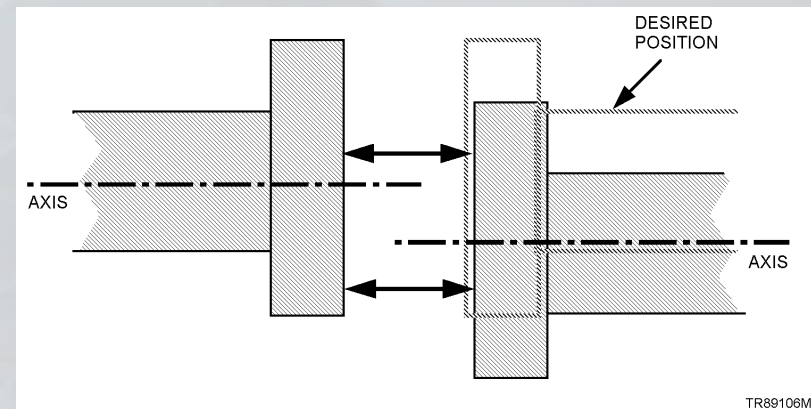
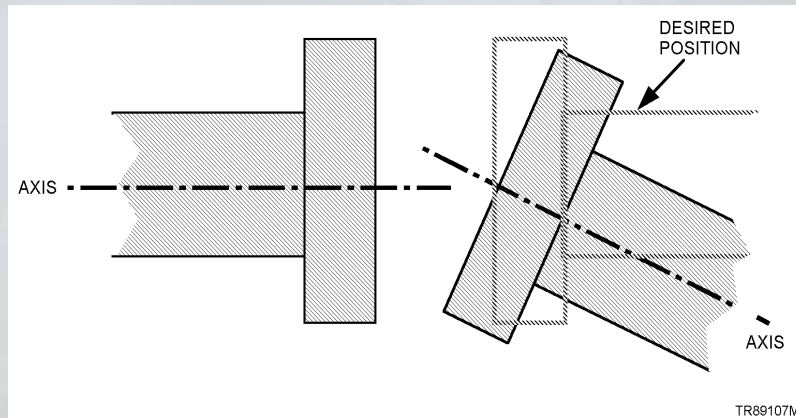
- Parallel Misalignment
 - Shafts centerlines are not co-linear
 - However shafts are parallel

Angular Misalignment



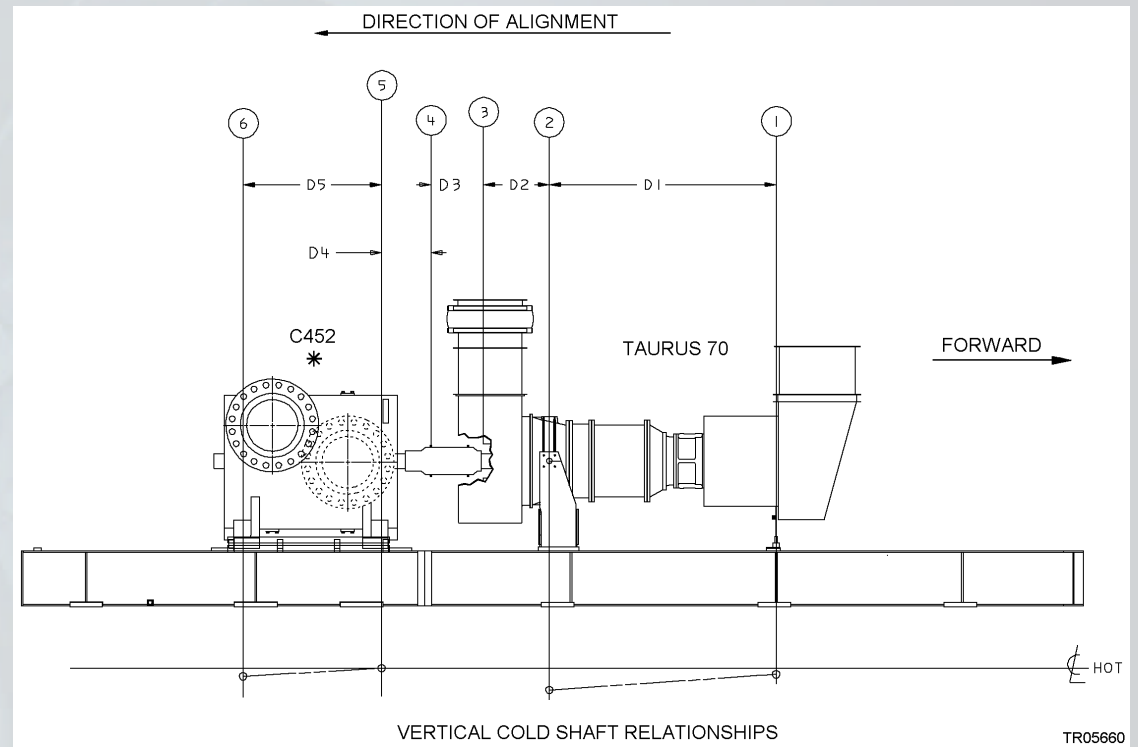
- Angular Misalignment
 - Shaft center-lines intersect at an angle

Misalignment



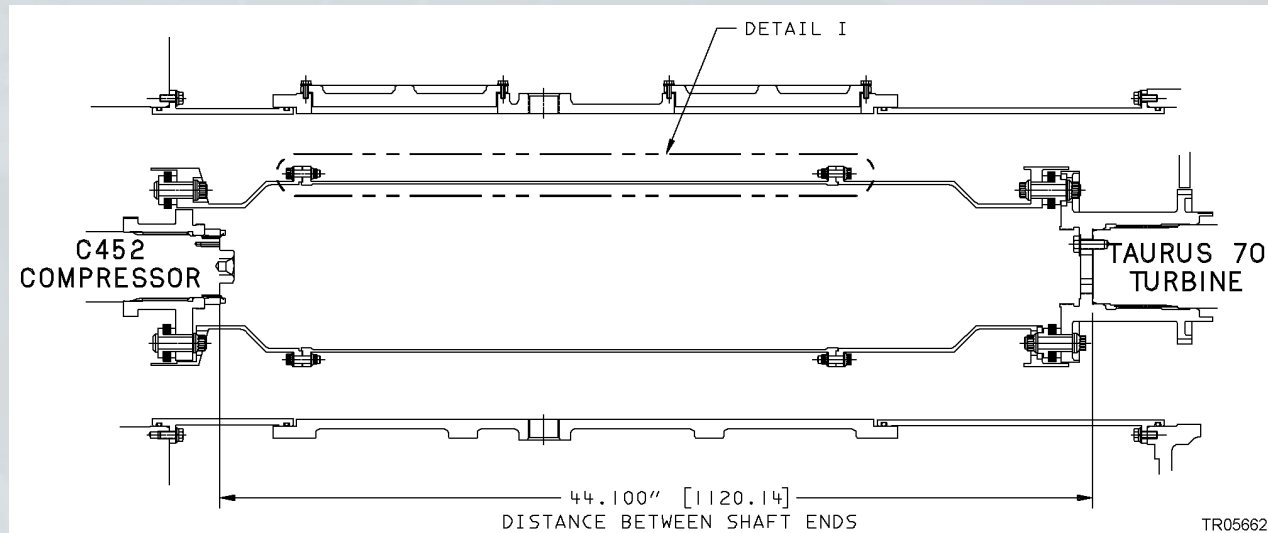
- In practice:
 - A combination of both normally exists in the COLD condition (cold offset)
 - At operating temperatures the shafts become aligned (thermal growth)

Illustration of Thermal Growth



- Different parts of the machinery experience different temperatures
- Hot “stations” will thermally grow more
 - Power Turbine (Station 2)
 - Discharge end of compressor (Station 6)
- Calculated thermal growth produces Cold Alignment specifications
- Hot alignment techniques are also available – will be discussed later

Illustration of DBSE



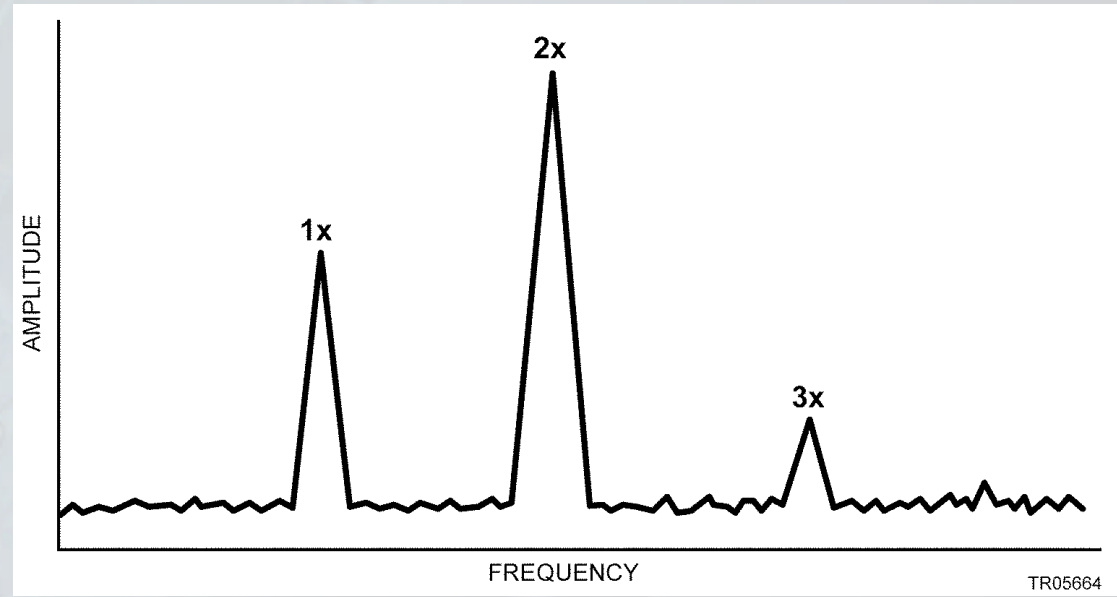
- Measuring points vary – but commonly called Distance Between Shaft Ends (DBSE)
 - Ensures adequate gap to install coupling
 - Prevents axial loading as machinery heats up

Problems Caused by Misalignment

- What problems can be caused by poor alignment?
- Limitation on operating range
- Higher operational costs
- Higher maintenance costs
- Seal failure
- Bearing failure
- Coupling failure

>

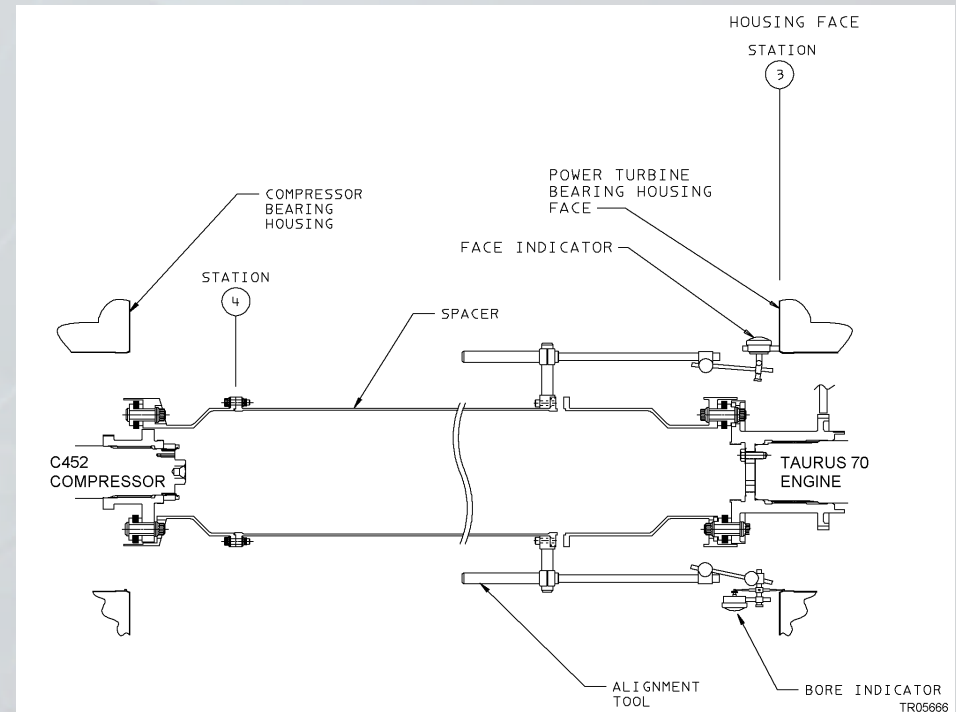
Typical Vibration Spectra Due to Misalignment



- High 1x RPM and 2x RPM components
- Can also be high axial vibration
- Can cause high bearing temps due to loading
- This can result in reduced efficiency or failure

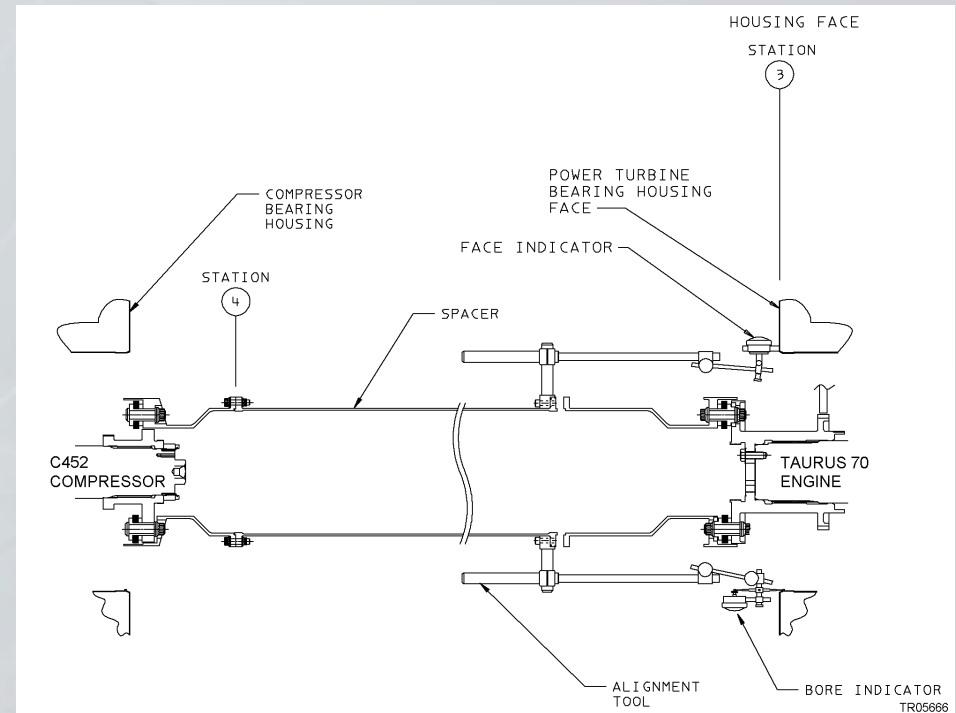
Methods of Performing Shaft Alignment Checks

Typical Rim-and-Face Setup



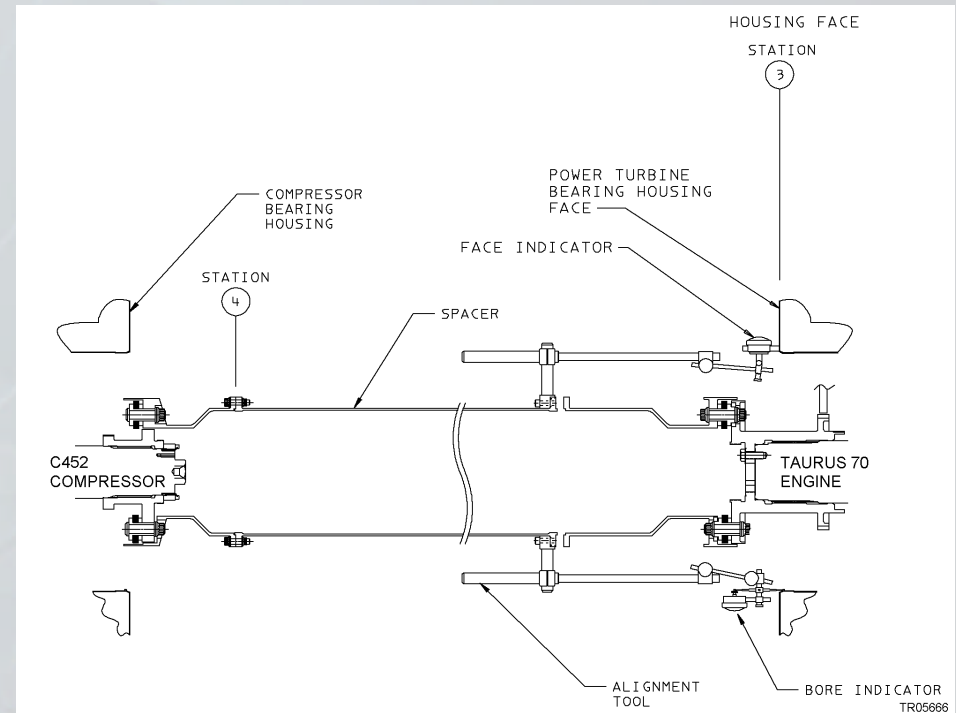
- Rim and Face
 - Uses two dial indicators
 - Mounted on one machine shaft
 - Target is shaft, coupling, or bearing housing on other machine

Typical Rim-and-Face Setup



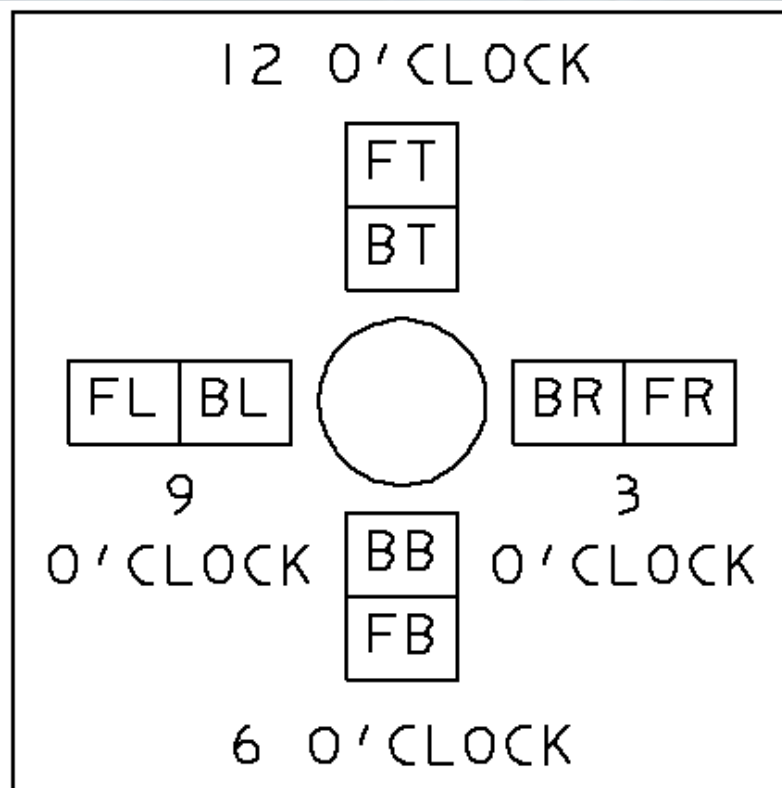
- Rim and Face
 - 360 degree sweep made
 - Readings taken at four clock positions
 - Interconnect shaft should be disconnected

Typical Rim-and-Face Setup



- Rim and Face
 - Face reading = angular misalignment
 - Rim or Bore reading = parallel misalignment

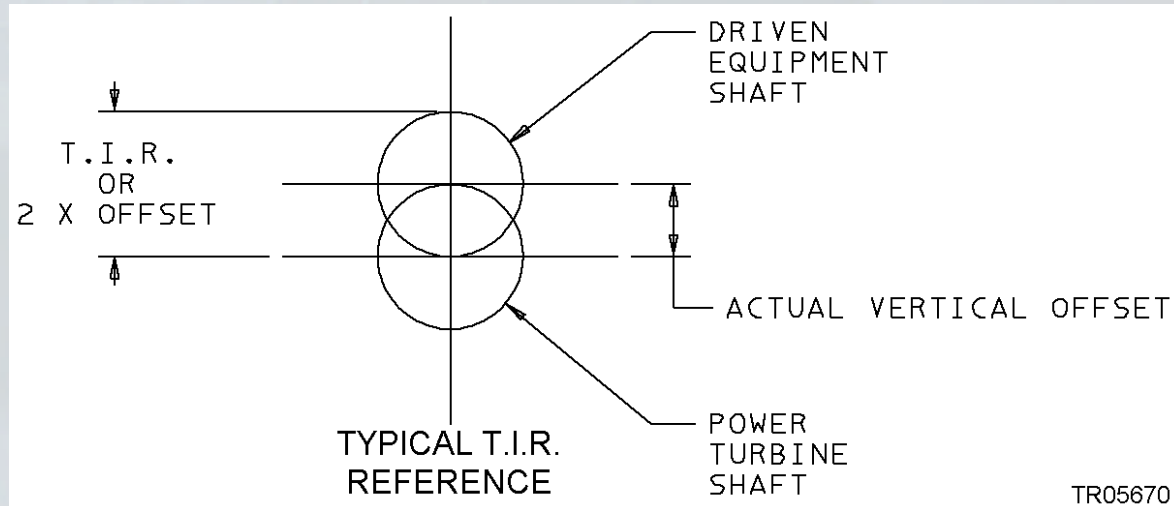
Dial Indicator Clock Positions



TR05668

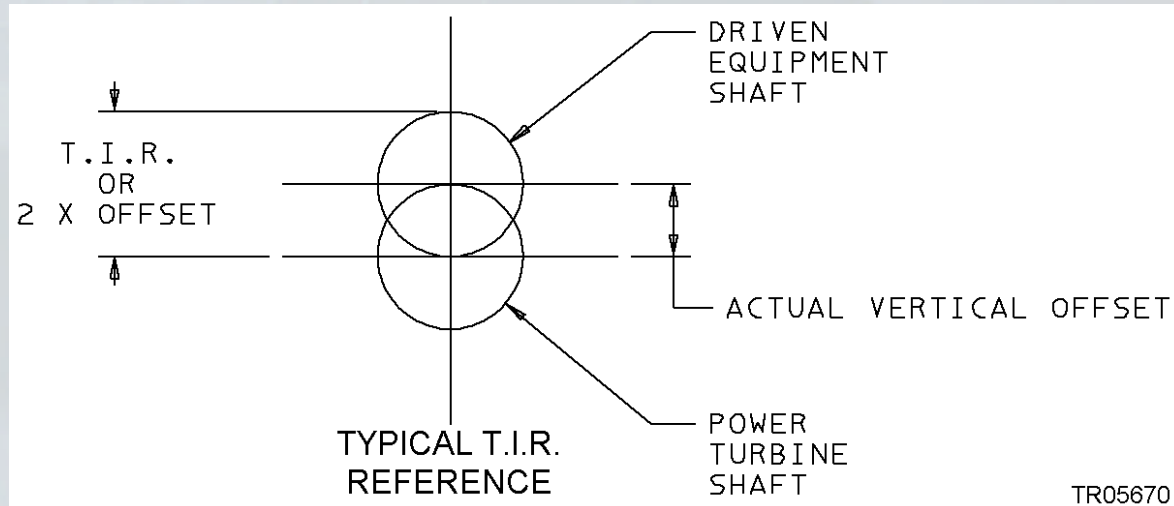
- 12 o'clock =
 - FT = Face Top
 - BT = Bore Top
- 6 o'clock =
 - FB = Face Bottom
 - BB = Bore Bottom
- etc.

TIR



- TIR = Total Indicator Reading
 - The actual reading on the dial gage
- $TIR = 2 \times \text{Actual Offset}$
- Solar specifications are normally TIR

TIR

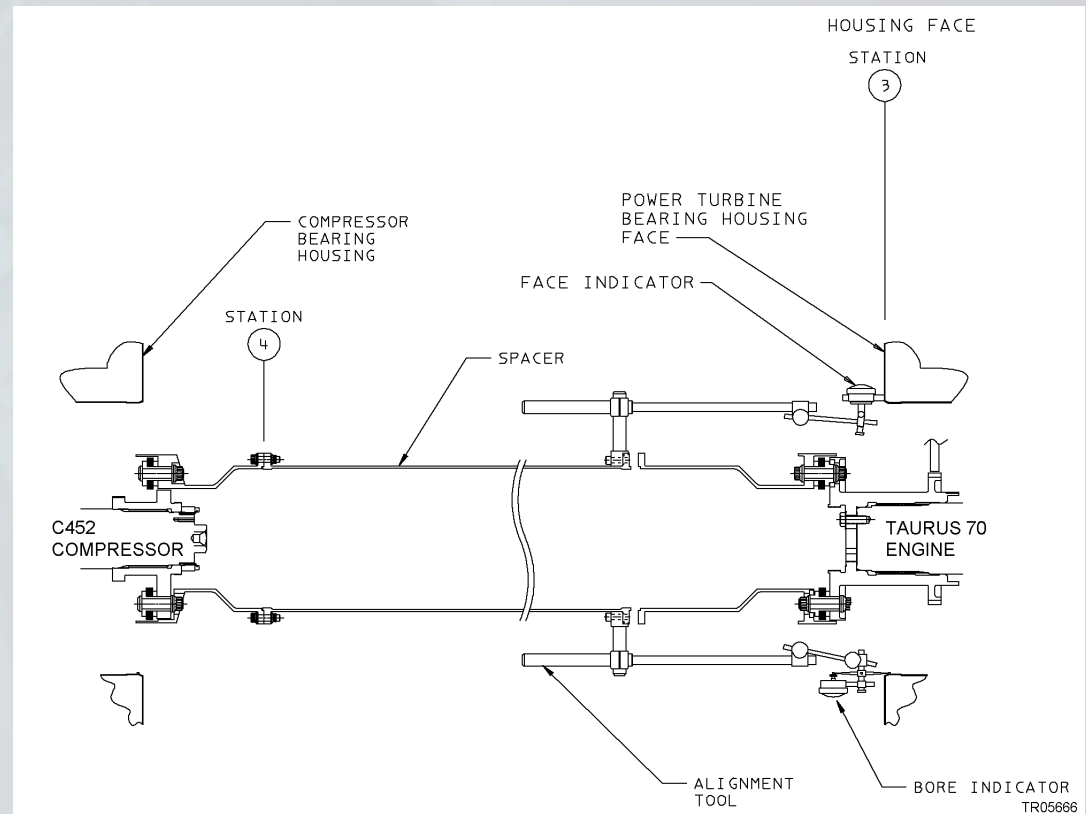


TR05670

- **Example:**
 - Actual BB = 0.060" (TIR)
 - Desired BB = 0.040"
 - Shim Correction = 0.010" (1/2 the difference)

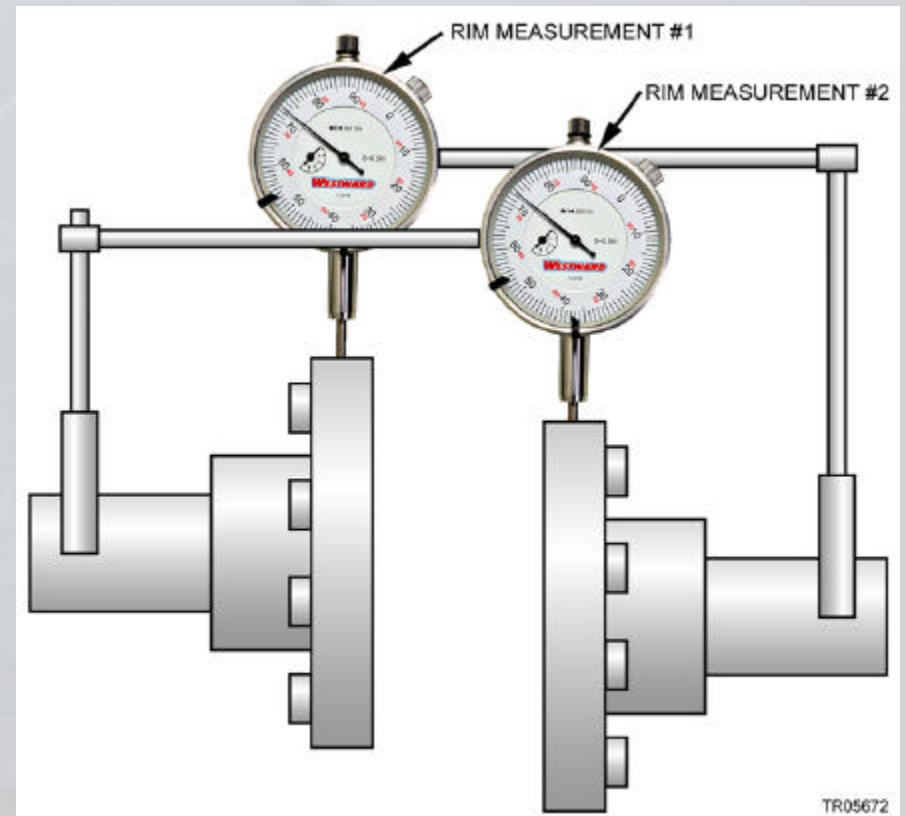
Rim-and-Face Advantages / Disadvantages

- Advantages
 - Simple
 - Easy access
- Disadvantages
 - Susceptible to Tool Sag and inconsistent readings
 - Face reading susceptible to axial motion of shafts
- Standard method used by Solar

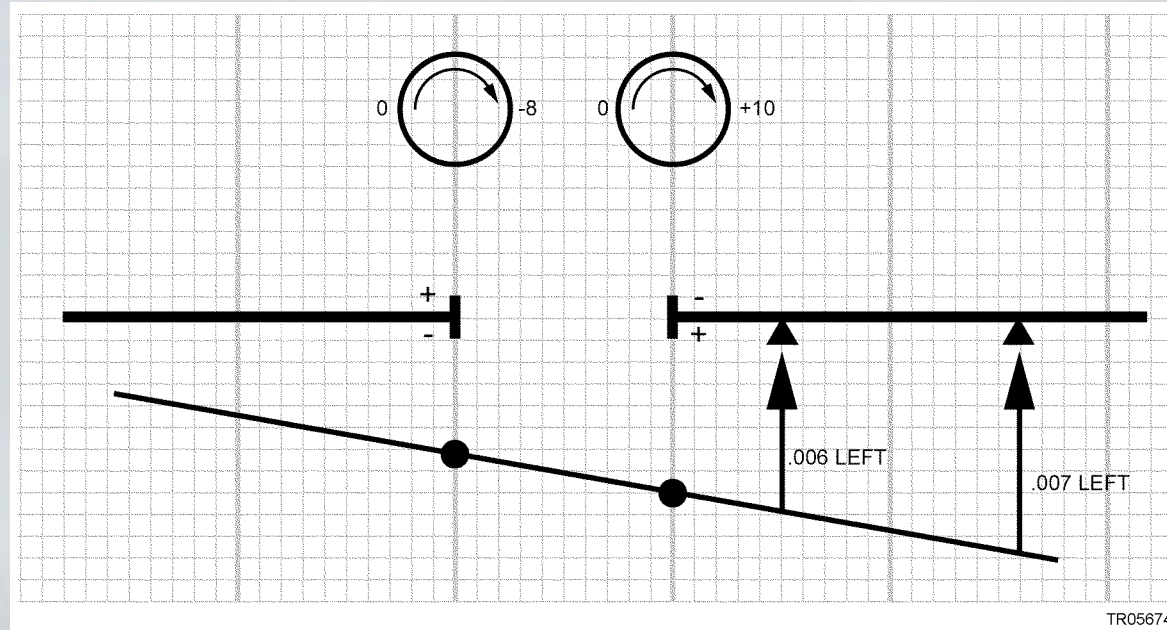


Reverse Alignment Tooling Setup

- Also uses dial gages
- One mounted on each shaft
- Both measure bore
- Shafts rotated together
- Readings taken at four clock positions



Reverse Dial Alignment Graph

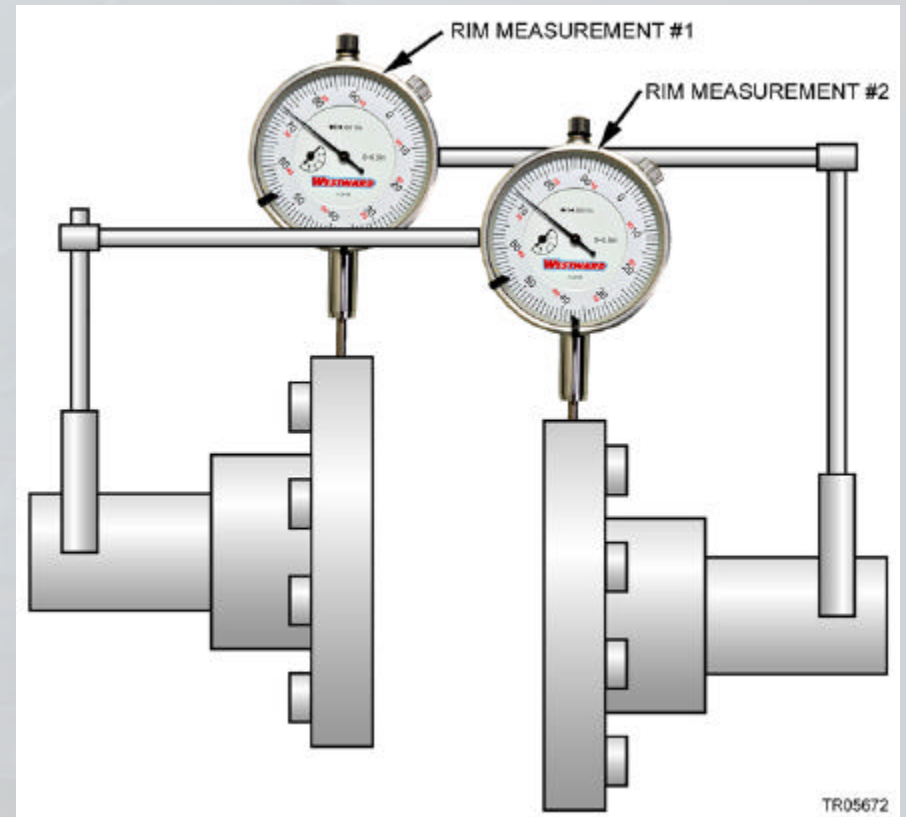


- Readings plotted on graph paper
- Machinery corrections are read from the scale on the graph paper

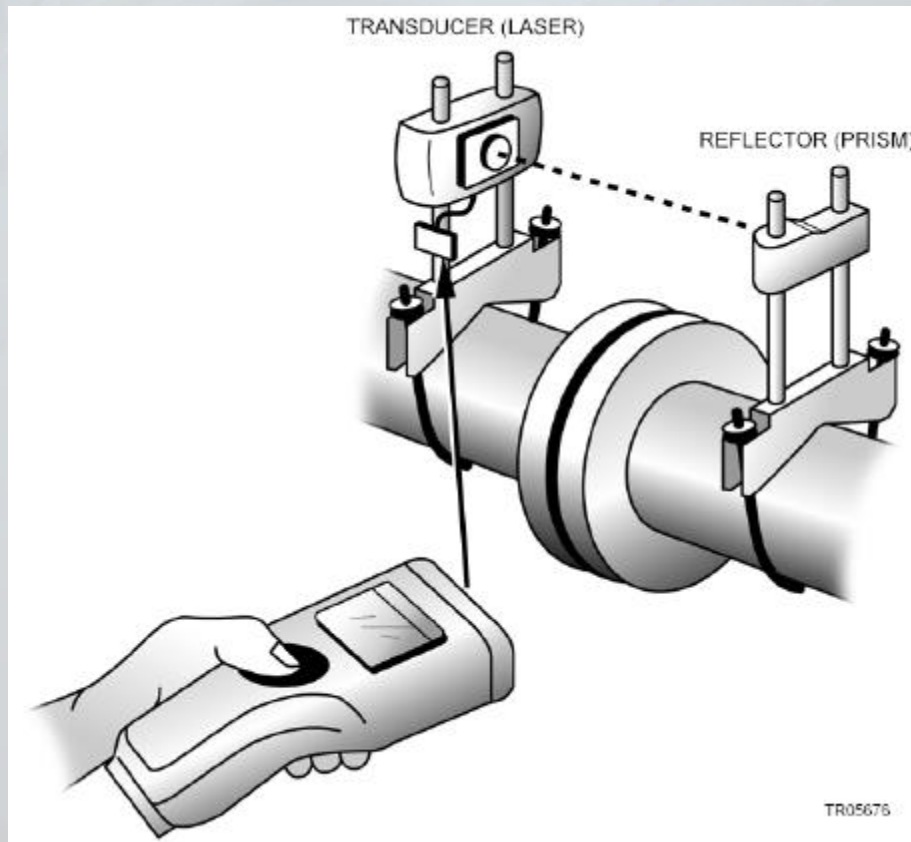
Reverse Alignment

Advantages / Disadvantages

- Advantages
 - No Face readings necessary
 - Not subject to axial shaft motion
 - Coupling can remain installed
- Disadvantages
 - Same problems with dial gages as rim and face method
 - Graph can be difficult to use
- Not normally used by Solar

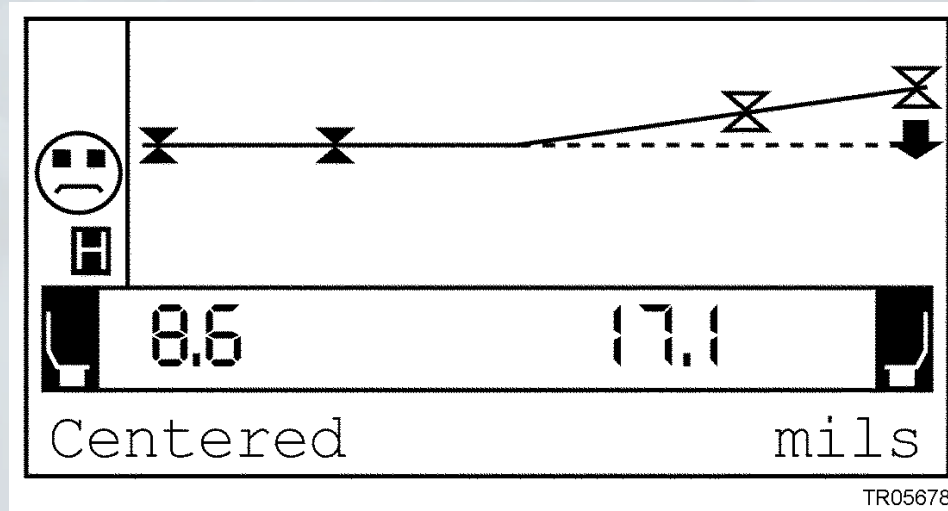


Typical Laser Alignment Setup



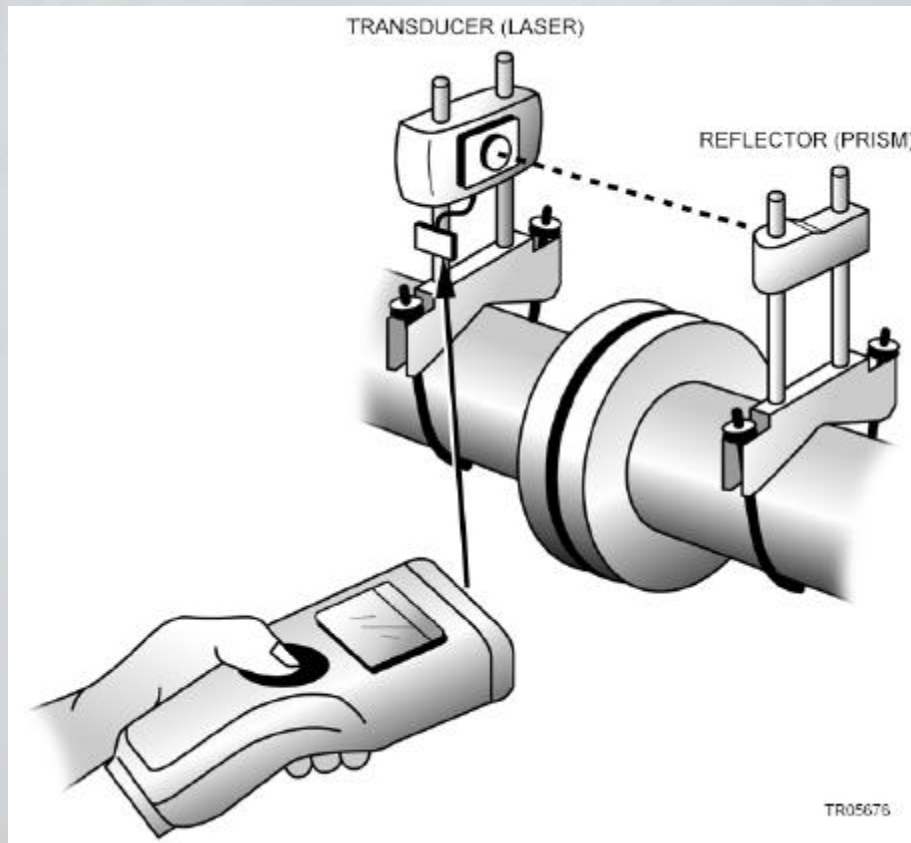
- Similar to reverse dial alignment, but uses laser
- Coupling remains installed

Sample Laser Alignment Readout



- “Graph” computed by the instrument
- Shows correction to be made
- Can be monitored live as the corrections are made

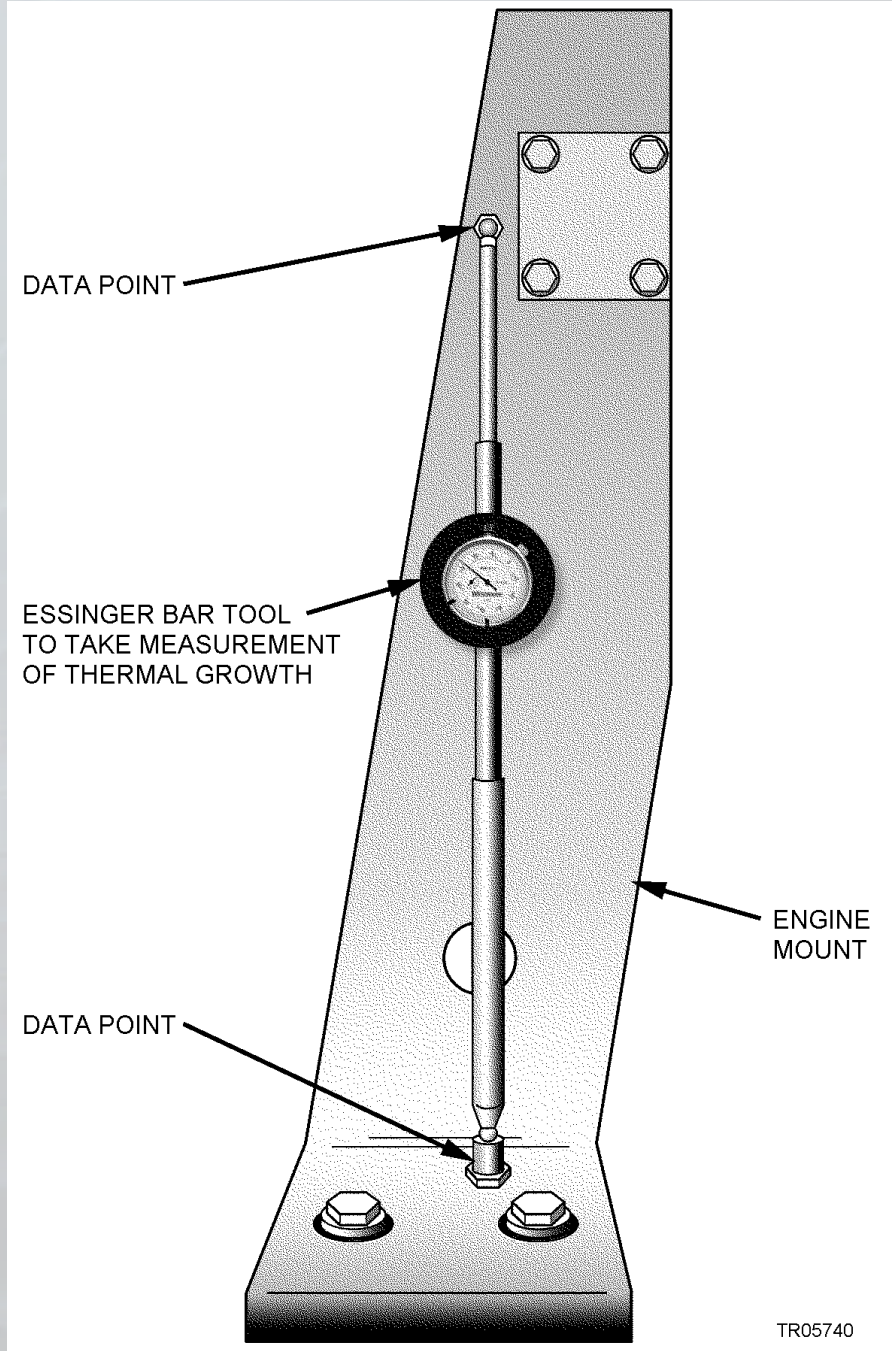
Laser Alignment Advantages / Disadvantages



- Advantages
 - Quick
 - Accurate
 - Limited Tool Sag
- Disadvantages
 - Cost
 - Cannot be used on all applications due to space
- Laser specifications are now included on Solar drawings

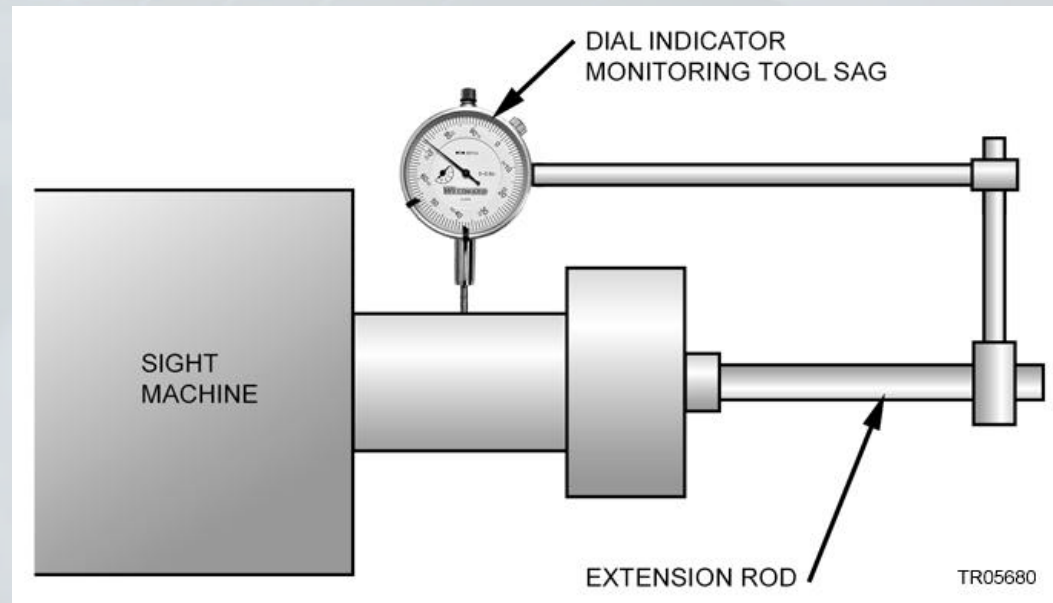
Example of Essinger Bar Installation

- Used for Hot Alignment checks
- Directly measure various data points on the package
- Not very common



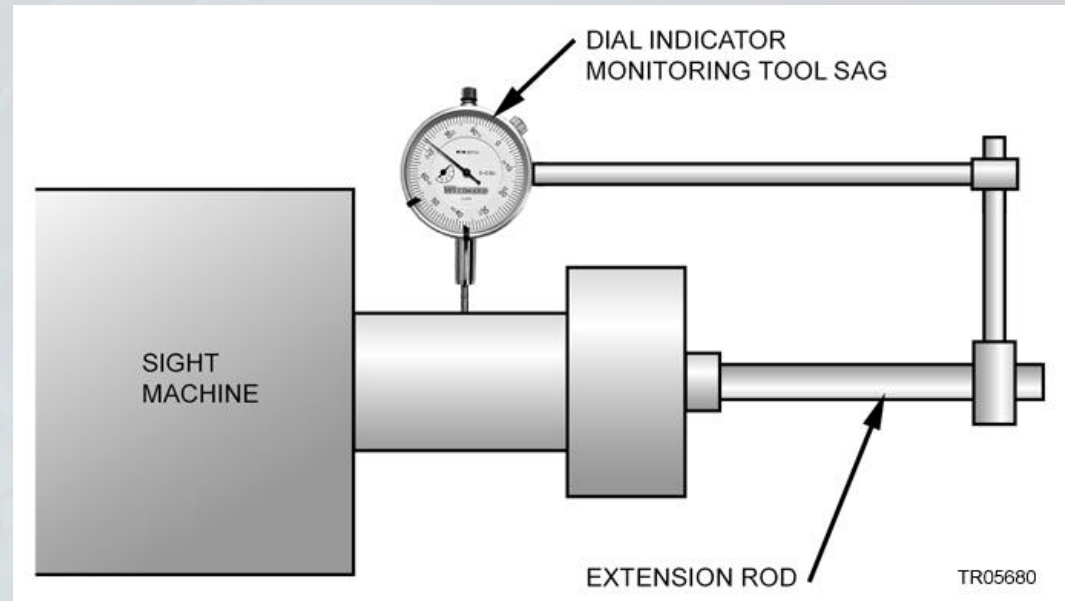
Abnormal Conditions That May Affect Alignment

Tool Sag Check Setup



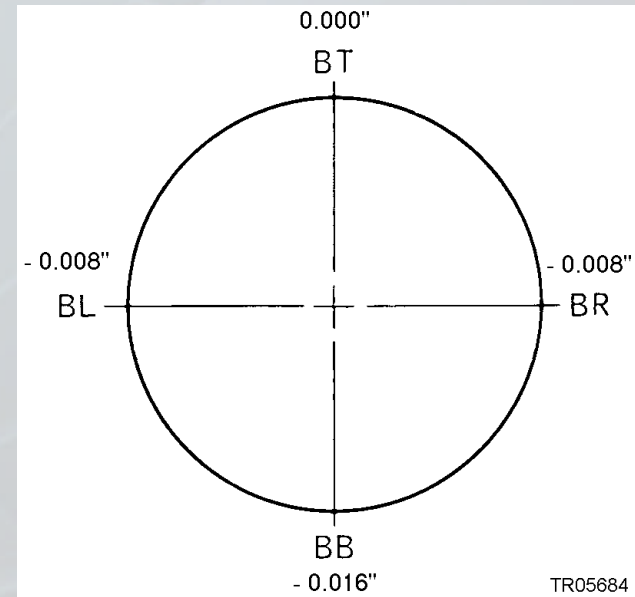
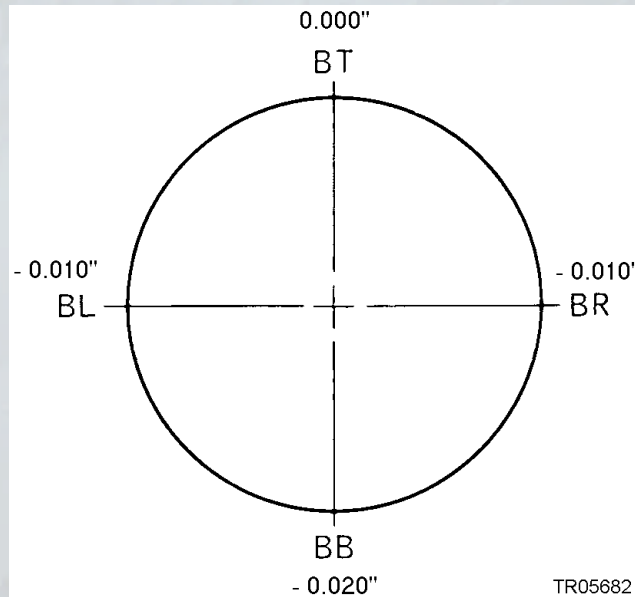
- Tool Sag caused by the weight of the tooling
- Causes erroneous readings
- Can be measured and corrected by biasing the readings

Tool Sag Check Setup



- Basic Procedure:
 - Install extension rod
 - Install alignment tooling with dial gage targeting the shaft of the same machine
 - Zero dial gage at 12 o'clock
 - Rotate shaft 180 degrees
 - Record reading – should always be a negative value
 - Subtract this value from all future BB readings
 - Subtract this value from all future BR and BL readings
 - If Tool Sag exceeds 0.010" – rectify tool setup

Tool Sag Example

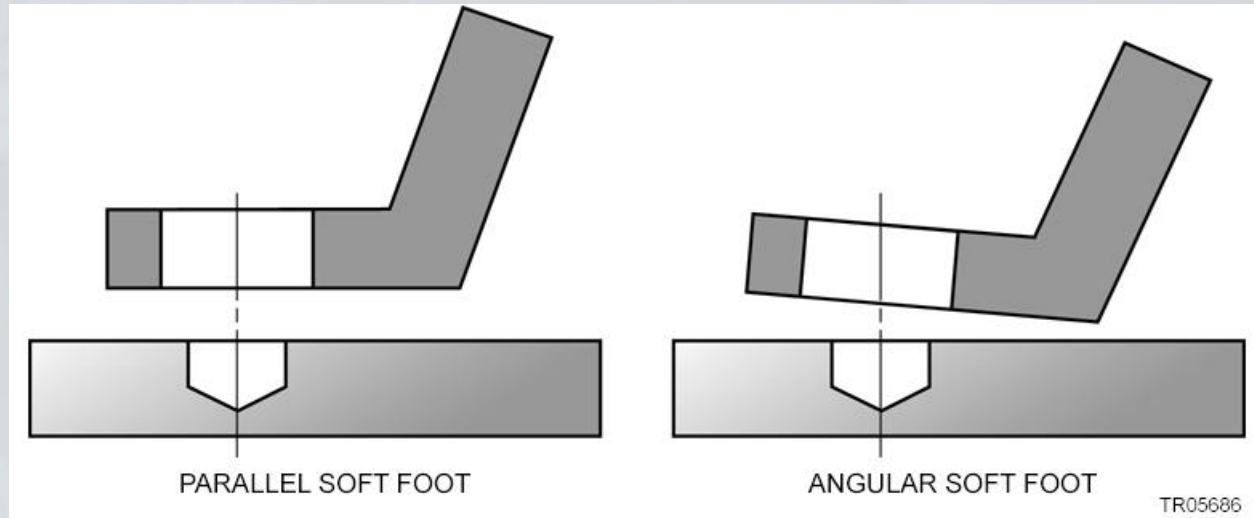


- Assuming tool sag of $-0.004"$
- Measured BB = $-0.020"$
- Corrected BB = $-0.020 - (-0.004) = -0.016"$

Other Causes of Poor Alignment

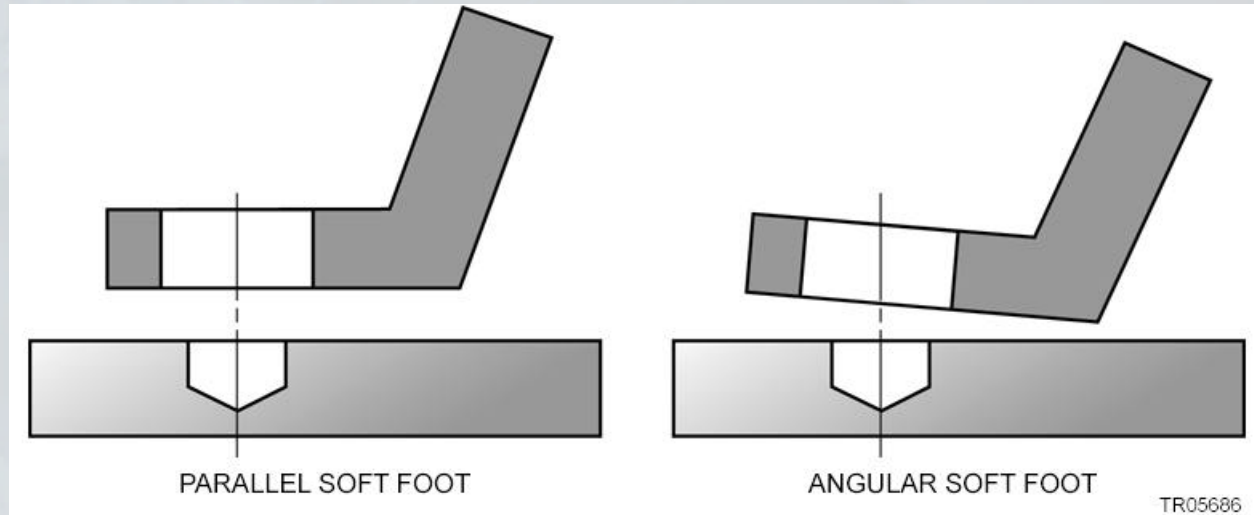
- Target Surfaces
 - Clean and even
 - True indication of the shaft position
 - Use bearing housing, not movable end cap
- If using coupling hub as target
 - Center the hub
 - Install dial gage on magnetic base, with the hub as the target
 - Runout <0.001"
- Bent shaft
 - Only a problem if this is the target surface
 - Should be evident during a runout check
 - Will not affect readings if it is the sight machine shaft (where the tools are mounted)
 - The tools will be at the same relative position as the bent shaft rotates

Angular and Parallel Soft Foot



- Soft foot causes problems in completing alignment checks
 - As bolts are tightened, the machines can “walk”
- Also causes machinery problems when operating
 - Stress on foundations and casings
- Angular soft foot
 - May need tapered or stepped shims
- Parallel soft foot
 - Need more shims under one foot

Angular and Parallel Soft Foot

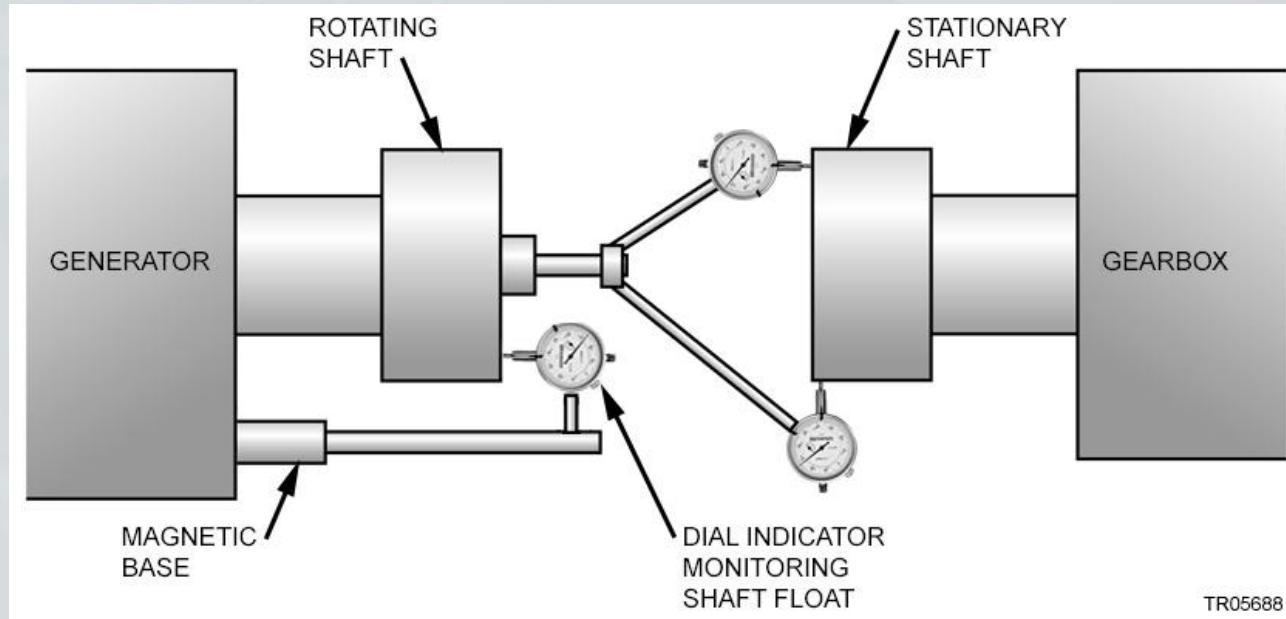


- Carry out soft foot check prior to starting alignment checks
- Basic Procedure:
 - Tighten hold down bolts
 - Install dial gage on a magnetic base on one foot
 - Loosen bolt on that foot
 - Record reading (should be $<0.002''$)
 - Check remaining feet

Other Causes of Poor Alignment

- Temperature Variations
 - Specifications are for Cold Alignment
 - Allow 24 – 36 hrs to cool
 - Ambient temperature variations can have a significant impact
- Generator Magnetic Center
 - DBSE readings on generators should be taken with the rotor at magnetic center
 - Often marked on the shaft

Monitoring Shaft Axial Float



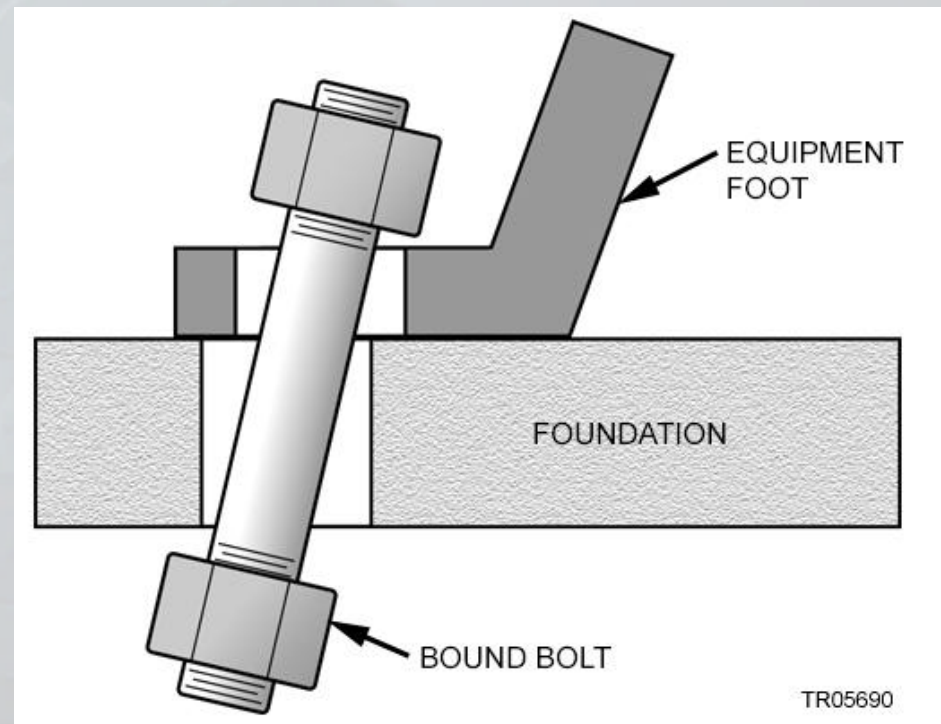
- Monitor shaft axial float when taking face readings
- Normally thrust collars should be against active thrust bearings
- If shaft is moving about – install a dial gage as shown to check and make necessary corrections

Other Causes of Poor Alignment

- Springy Shims
 - Where shims do not provide a firm support
 - Can cause vibration problems
- Shim Requirements
 - Clean, free from rust
 - Stainless steel
 - Recommend 3 shims max under each foot
 - Maximum 6 shims under each foot
 - Minimum thickness 0.010"
 - Minimum total 0.025"
 - Maximum total 1"
- Piping Strain
 - Piping or ducting can exert forces on the machinery – especially compressor header pipes
 - Piping should be self-supporting
 - Dial gages should be monitored during piping connection to check for abnormal loading
 - Maximum deviation 0.005"

Bound Bolts

- Can cause:
 - Lateral motion of the equipment when bolts are tightened
 - Difficulty in moving the equipment during alignment checks
- Solution
 - Increase foundation bolt-holes



TR05690

QUESTIONS ON ALIGNMENT PRINCIPLES?

Complete Student Exercise

Student Exercise

1. The fundamental principle of machinery alignment is:
 - a. Machinery shafts will be co-linear when the machines are not operating and cold.
 - b. Machinery shafts will be co-linear when the machines are not operating and hot.
 - c. Machinery shafts will be co-linear when the machines are operating and cold.
 - d. Machinery shafts will be co-linear when the machines are operating and hot.

Student Exercise

2. The three main considerations in machinery alignment are:

- a. Parallel misalignment; angular misalignment;
DBSE
- b. Parallel misalignment; vertical misalignment;
DBSE
- c. Angular misalignment; horizontal misalignment;
DBSE
- d. Horizontal misalignment; vertical misalignment;
DBSE

Student Exercise

3. The machine that the alignment tooling is located on is known as the _____ machine; the machine that the dial indicators are touching is known as the _____ machine.

- a. Target; Sight
- b. Target; Aiming
- c. Sight; Target
- d. View; Sight

Student Exercise

4. Which of the following would not normally be caused by poor alignment?
- a. High vibration
 - b. High bearing temperatures
 - c. Increased machinery performance or efficiency
 - d. Premature machinery failure

Student Exercise

5. The primary alignment method used by Solar is known as:

- a. Rim and Face
- b. Tool Sag and Soft Foot
- c. Reverse Dial Alignment

Student Exercise

6. If a dial indicator Bore Top reading is zero, and Bore Bottom reading is 0.050", what is the TIR and actual shaft Vertical Offset?
- a. TIR = 0.100"; Offset = 0.050"
 - b. TIR = 0.050"; Offset = 0.100"
 - c. TIR = 0.050"; Offset = 0.025"
 - d. TIR = 0.050"; Offset = 0.050"

Student Exercise

7. A condition where unequal shims may be required under machinery feet is known as:
- a. Tool sag
 - b. Soft foot
 - c. Thermal growth
 - d. Bent shaft

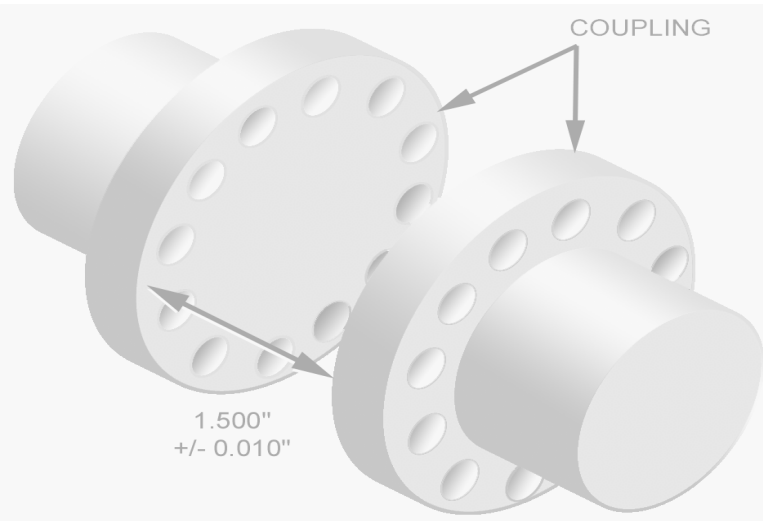
Student Exercise

8. If tool sag is measured as $-0.002''$, and the BB reading during an alignment check is $-0.018''$, what is the corrected BB reading?

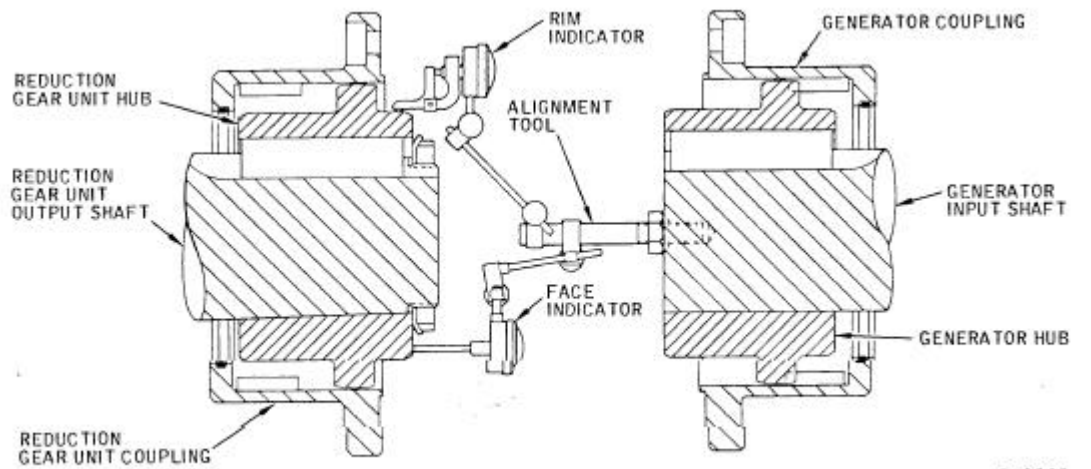
- a. $-0.016''$
- b. -0.018
- c. $-0.020''$

Objectives - Recap

1. Define the term “alignment”
2. Identify possible machinery problems that may be caused by poor alignment
3. List and describe the principles of different methods used in machinery alignment
4. Discuss negative influences that may affect final alignment accuracy



TR05650



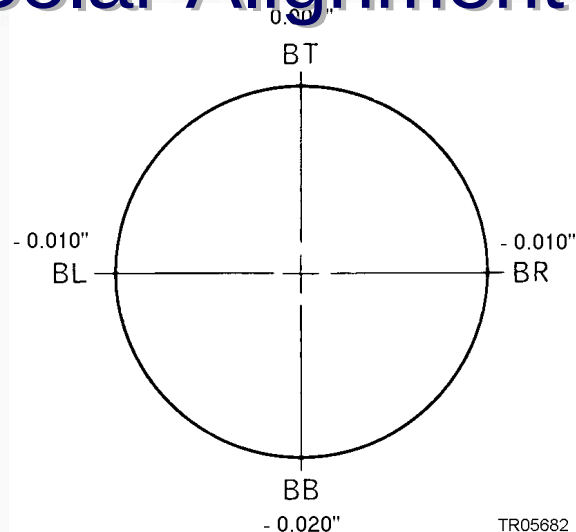
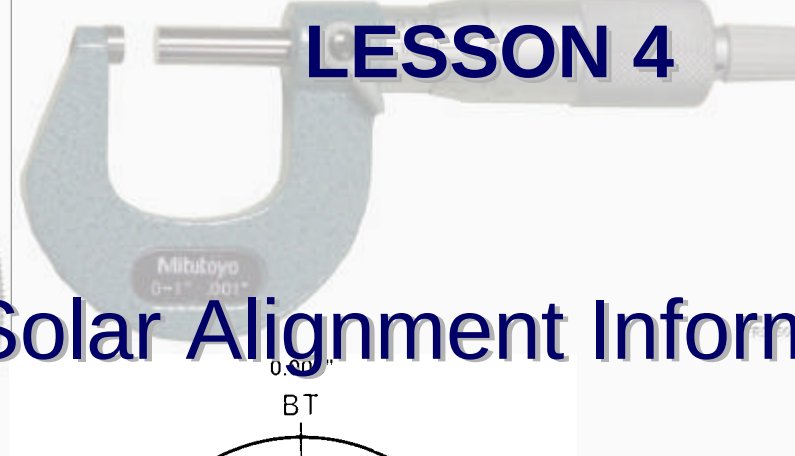
SA2203

LESSON 4

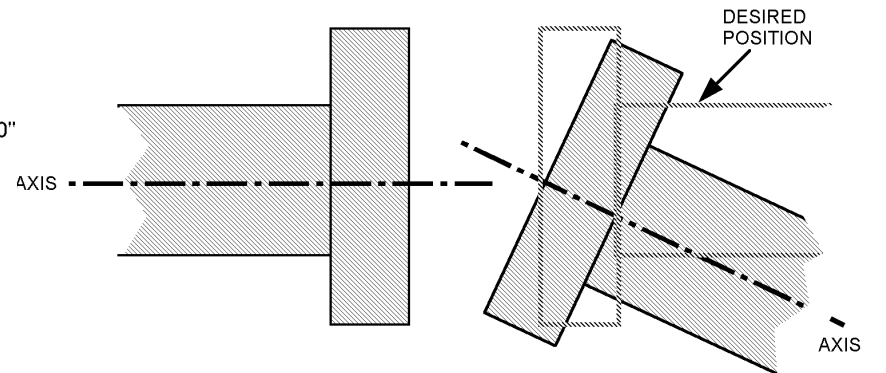
Solar Alignment Information



TR05600



TR05682



TR89107M

Objectives

1. List available sources of information related to alignment
2. Describe the responsibilities of Solar and other personnel in relation to machinery alignment under different project situations
3. Convert both Solar-supplied and vendor-supplied thermal growth figures to alignment specifications
4. Given example figures, use available formulae or software tools to identify machinery shimming requirements

Main Sources of Information

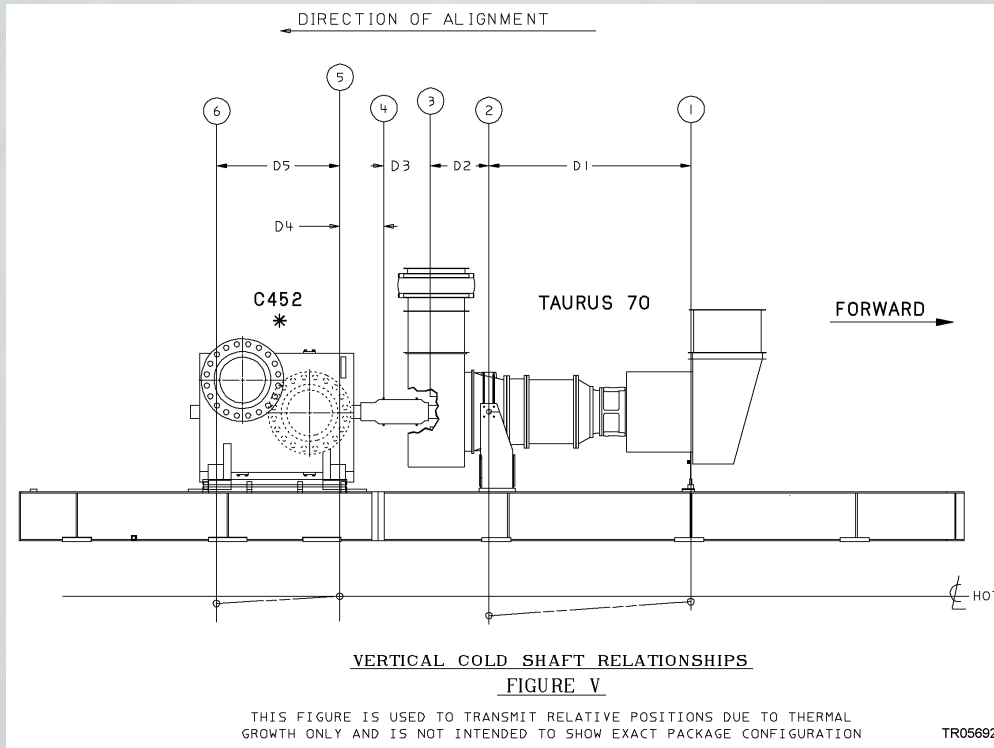
- Mechanical Installation Drawings
 - Using Taurus 70 CS PD72341
- Vendor information
 - When third party equipment is used
- Solar Align-It program
 - On CD
 - Demo, but not used
- Solar Alignment spreadsheet
 - On CD
 - Used for exercises this week

Mechanical Installation Drawing

- Reference 72341-149605 (Sheet 11)
 - Grid Reference H-118
- Look at general alignment notes
 - Shipping braces
 - Header pipes, etc.

PD72341 Package Stations

Grid Reference E-112



- Identifies stations (1 – 6)
- Identifies dimensions (D1 – D5)
- Important to follow station identification (some specs will reverse sign if opposite direction is used)

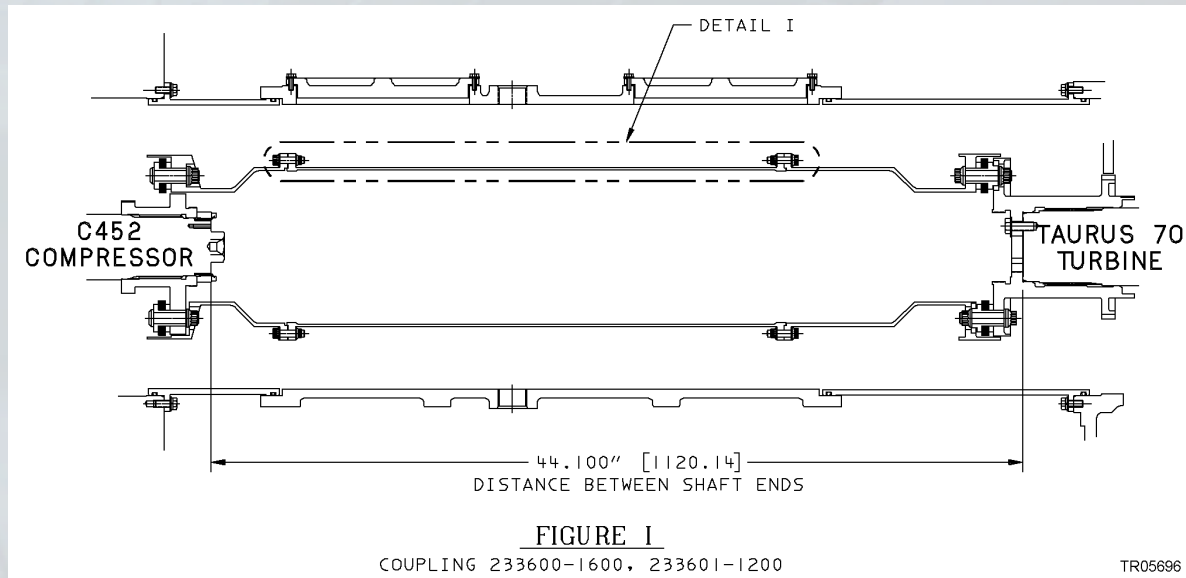
PD72341 Thermal Growth Figures and Package Dimensions

- Table shows:
 - Thermal growth figures for stations
 - Dimensions (useful for calculating shim corrections using formula or spreadsheet)

DISTANCE	DESCRIPTION	INCHES (mm)
D1	FEET DISTANCE T70 TURBINE	92.77 (2356)
D2	TRUNNION MOUNT TO P.T. BEARING HOUSING	29.48 (749)
D3	P.T. BEARING HOUSING FACE TO BEARING HUB FACE (TOOLING DISTANCE)	38.32 (973)
D4	BEARING HUB FACE TO C452 FORWARD FOOT	10.68 (271)
D5	FEET DISTANCE C452	65.9 (1674)
STATION	VERTICAL THERMAL GROWTH	INCHES (mm)
①	FORWARD MOUNT T70 TURBINE	+ .006 (+ .152)
②	TRUNNION MOUNT T70 TURBINE	+ .032 (+ 0.813)
⑤	FORWARD FOOT C452 COMPRESSOR (SUCTION END)	.000 (.000)
⑥	AFT FOOT C452 COMPRESSOR (DISCHARGE END)	+ .010 (+ .254)

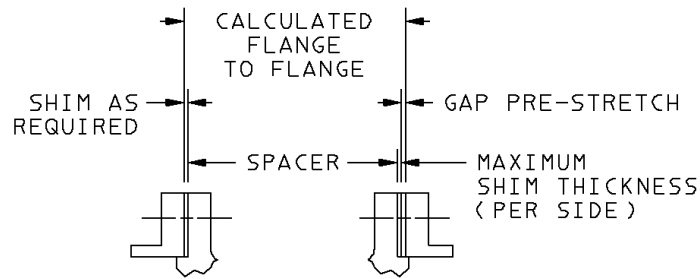
TR05694

PD72341 Distance Between Shafts Grid Reference H-115



- This project uses a Kopflex flexible diskpack type coupling
- DBSE shown (44.100")
- However in practice the distance between the coupling hubs will be used
- See next slide

PD72341 Coupling Shim Calculation



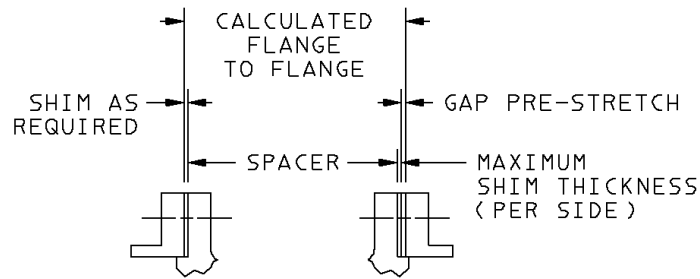
STATION LOCATION	SPACER LENGTH	CALCULATED FLANGE TO FLANGE	MAXIMUM SHIM THICKNESS (PER SIDE)	GAP PRE-STRETCH
3 TO 4	26.317" [668.5]	26.462 ±.010" [672.1 ±.254]	.060" [1.524]	.085" [2.159]

DETAIL I

TR05698

- When hubs are free (locking and collapsing screws removed) the distance should be 26.642" +/- 0.010"
- This includes the 0.085" pre-stretch gap (to allow thermal expansion) and assumes that one complete 0.060" shimpack is installed
- After measuring the actual gap – the complete shimpack may be removed OR one additional 0.060" shimpack may be installed
- Shims should be about equal on both sides of the coupling spacer
- Shims are normally in increments of 0.010"

PD72341 Coupling Shim Calculation



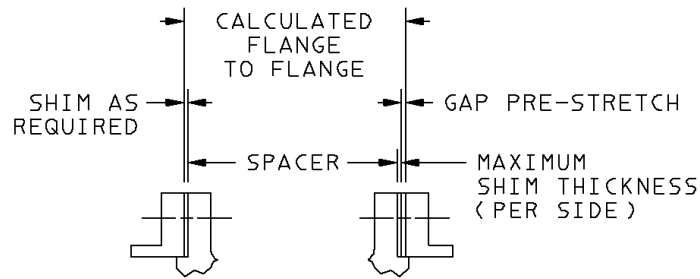
STATION LOCATION	SPACER LENGTH	CALCULATED FLANGE TO FLANGE	MAXIMUM SHIM THICKNESS (PER SIDE)	GAP PRE-STRETCH
3 TO 4	26.317" [668.5]	26.462 ±.010" [672.1 ±.254]	.060" [1.524]	.085" [2.159]

DETAIL I

TR05698

- Example 1:
 - Specified = 26.462" +/- 0.010"
 - Measured = 26.425"
 - Difference = 0.037" less gap than specified
 - Shim correction = remove 0.040" from original shimpack (leave 0.010" on either side)

PD72341 Coupling Shim Calculation



STATION LOCATION	SPACER LENGTH	CALCULATED FLANGE TO FLANGE	MAXIMUM SHIM THICKNESS (PER SIDE)	GAP PRE-STRETCH
3 TO 4	26.317" [668.5]	26.462 ±.010" [672.1 ±.254]	.060" [1.524]	.085" [2.159]

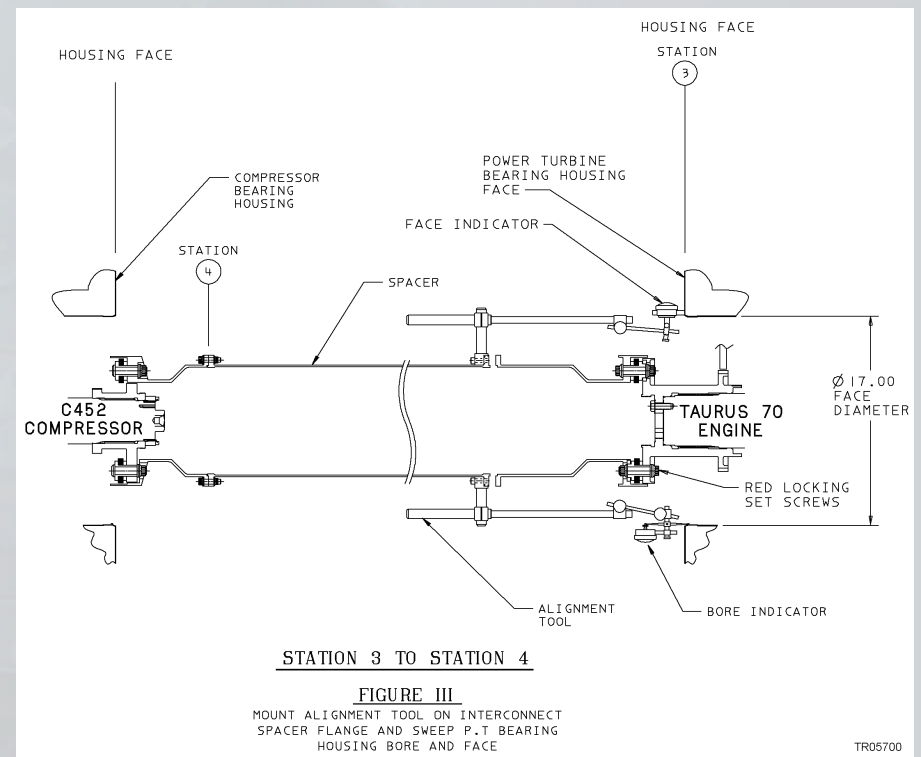
DETAIL 1

TR05698

- **Example 2:**
 - Specified = 26.462" +/- 0.010"
 - Measured = 26.482"
 - Difference = 0.020" more gap than specified
 - Shim correction = insert additional 0.020" shims (leave 0.040" on either side)

PD72341 Alignment Tool Installation Grid Reference D-115

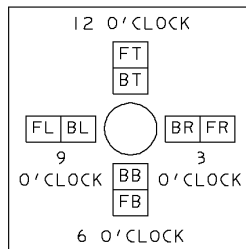
- Note direction of tooling
 - Station 4 to Station 3
 - Reverse sign of bore specs if opposite direction used
- Spacer used as tool extension, but disconnected at other end
- PT housing is target
 - No need to center either hub
- Note face diameter (17")
 - Recalculate face specs if this is significantly different
- Note bore internal sweep
 - Reverse sign of bore specs if outside sweep used



Other Alignment Information

- Reference 72341-149605 Sheet 12
- Equipment Alignment Notes
 - Grid Reference H-128
 - Read through all alignment notes
 - Specs in TIR
 - Bearing pre-lube required, etc.

Clock Positions and TIR Grid Reference G-125

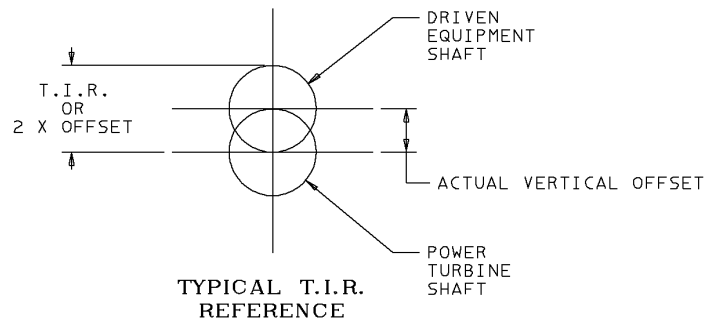


VIEW LOOKING BOTH FORWARD AND AFT

IMPORTANT: ACCURATELY LOCATE THE 90° CLOCKING POSITIONS

DIAL INDICATOR READINGS:

DIAL INDICATOR READINGS ARE ALWAYS "TOTAL INDICATOR READINGS" (T.I.R.).



TYPICAL T.I.R.
REFERENCE

TR05702

- Accurately locate clock positions
- All Solar specs in TIR

Dial Indicator Alignment Specifications

Grid Reference H-121

TABLE I - DIAL INDICATOR ALIGNMENT - BORE AND FACE OFFSETS

BORE OFFSET = T.I.R.	SIGHT "FROM"	TARGET "TO"	OFFSET (BORE OFFSET)				ANGULARITY (FACE OFFSET)				FACE DIAMETER	SHAFT RELATIONSHIPS
			BT	BL	BR	BB	FT	FL	FR	FB		
	④	③	00	-.048 (-1.21) INSIDE TIR	-.048 ±.002" (-1.21 ±.051) INSIDE TIR	-.095 ±.005" (-2.42 ±.127) INSIDE TIR	00	.001 (.028)	.001 ±.001 (.028 ±.025)	-.002 ±.002 (-.055±.051)	17.0 (.452) COMPRESSOR BEARING HOUSING	④ ③ — —

CAUTION: DIAL INDICATOR READINGS ABOVE ARE TOTAL INDICATOR READINGS (T.I.R.).

THE FACE DIAMETER IS DEFINED AS THAT DIAMETER ON THE SPECIFIC HOUSING FACE FOR WHICH THE FACE OFFSET IS GIVEN (SHOULD NOT BE AN INTERRUPTED SURFACE).

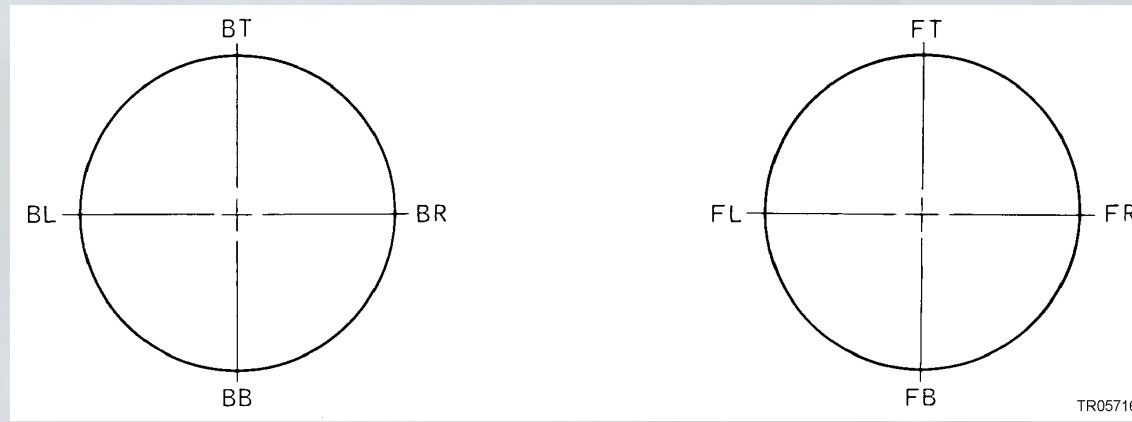
BORE LEFT (BL) READINGS AND FACE LEFT (FL) READINGS ARE RECORDED FROM EQUIPMENT DURING A 360° SWEEP.

BORE RIGHT (BR) READING AND FACE RIGHT (FR) READING MUST BE WITHIN THE TOLERANCE NOTED ABOVE.

TR05704

- BB = -0.095" (inside sweep)
- FB = -0.002"
- Allowable tolerances:
 - BB = 0.005"
 - BL / BR = 0.002"
 - FB = 0.002"
 - FL / FR = 0.001"
- Face readings only valid at specified diameter (17")
- Metric units also given
- Question – is the PT higher or lower than the Compressor?

Student Exercise



- Sketch the above
 - Left – bore readings
 - Right – face readings
- Use the table at H-121 to complete the sketch with the correct specifications

Laser Alignment Specifications

Grid reference E-121

TABLE I (CONTINUED) - LASER ALIGNMENT - BORE OFFSETS AND ANGULARITY (FACE OFFSETS)

LASER STATIONARY	DETECTOR MOVEABLE	COLD TARGET AT	COLD TARGET OFFSETS (BORE OFFSETS)			COLD TARGET ANGLES (FACE OFFSETS)			
			VO (BB)	HO (BL-BR)	TOLERANCE	VA (FB)	HA (FL-FR)	DIAMETER	TOLERANCE
C452	TURBINE	CPLG CENTER	-.051 (-.129)	.000	±.005" (.127)	-.001 (-.033)	.000	10"	±.002" (±.051)

TR05706

- Laser alignment specs approx ½ dial indicator specs
- Precise conversion can be made with the alignment spreadsheet

Torque Values

Grid reference C-123

TABLE II - TORQUE VALUES

THREAD SIZE	TIGHTENING TORQUE ENGLISH (FOOT-LBS)	TIGHTENING TORQUE METRIC (NEWTON-METERS)	GRADE
.75-10	211 (LUBRICATED)	286 (LUBRICATED)	B7
1.00-8	423 (LUBRICATED)	574 (LUBRICATED)	B7
1.12-7	806 (LUBRICATED)	1094 (LUBRICATED)	B7
1.50-6	1437 (LUBRICATED)	1950 (LUBRICATED)	B7
2.00-4 1/2	3408 (LUBRICATED)	4624 (LUBRICATED)	B7

FOR ADDITIONAL TORQUE VALUES REFERENCE SOLAR SPECIFICATION ES 9-54.
TR05708

- Standard torque values for various sizes of fastener
- Some packages use “super-bolts” for equipment hold-down bolts
 - Use multiple small allen-screws to stretch the main bolt

Alignment Tool FT Number Grid Reference B-123

TABLE III - TOOLING

FT67107-300	ALIGNMENT TOOL
FT67108	DIAL INDICATOR KIT

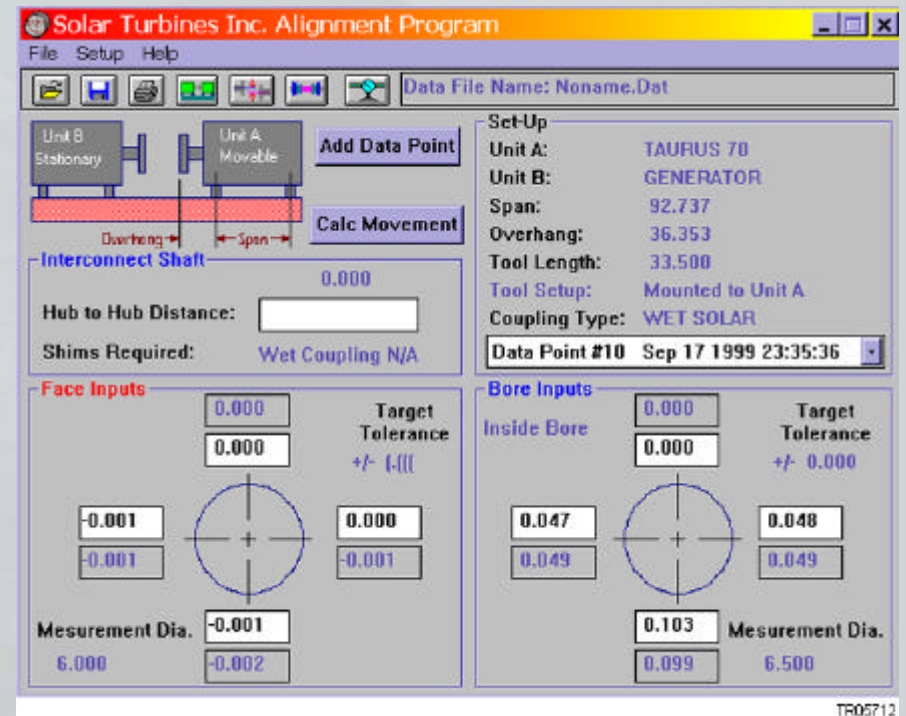
TR05710

Vendor Information

- If the driven equipment is supplied by a third-party (e.g. Dresser) then alignment information will have to be extracted from their data
 - May use laser or reverse-alignment
- Thermal growth figures and dimensions can be input to the alignment spreadsheet to produce rim-and face specs
 - This will be an exercise later

Solar Align-It Program

- Useful program for alignment
- Available on the CD, with the instruction manual
- Will use a simpler method during the exercises
 - Solar Align XL spreadsheet



TR05712

Alignment Spreadsheet

	A	B	C	D	E	F	G	H	I	
1	ALIGNMENT CALCULATIONS									
2										
3	REQUIRED INPUTS (FROM FIGURE I AND IV OF DRAWING)									
4	MACHINE NUMBER 1 ALL MEASUREMENTS ARE IN INCHES UNLESS OTHERWISE SPECIFIED									
5	ENTER									
7	DISTANCE BETWEEN FEET						7			
8	NEAR FOOT TO FACE						6			
9										
10	Enter thermal growths as (+) and thermal contractions as (-) in Column G.									
11	ENTER									
12	THERMAL GROWTH FAR FOOT						0.015	-0.015		
13	THERMAL GROWTH NEAR FOOT						0.010	-0.01		
14										
15	SHAFT TO SHAFT, COUPLING TO COUPLING OR CALCULATED FLANGE TO FLANGE DISTANCE									
16	ENTER									
17	DISTANCE BETWEEN MACHINE FACES:						9			
18										
19	MACHINE NUMBER 2									
20	ENTER									
21	NEAR FOOT TO FACE						6			
22	DISTANCE BETWEEN FEET						7			
23	Enter thermal growths as (+) and thermal contractions as (-) in Column G.									
24	ENTER									
25	THERMAL GROWTH OF NEAR FOOT						0.03	-0.03		
26	THERMAL GROWTH OF FAR FOOT						0.02	-0.02		
27										
28	FACE DIAMETER OF MACHINE #1						2.5			
29	FACE DIAMETER OF MACHINE #2						3			
30	Sheet1 / Sheet2 / Sheet3 /									

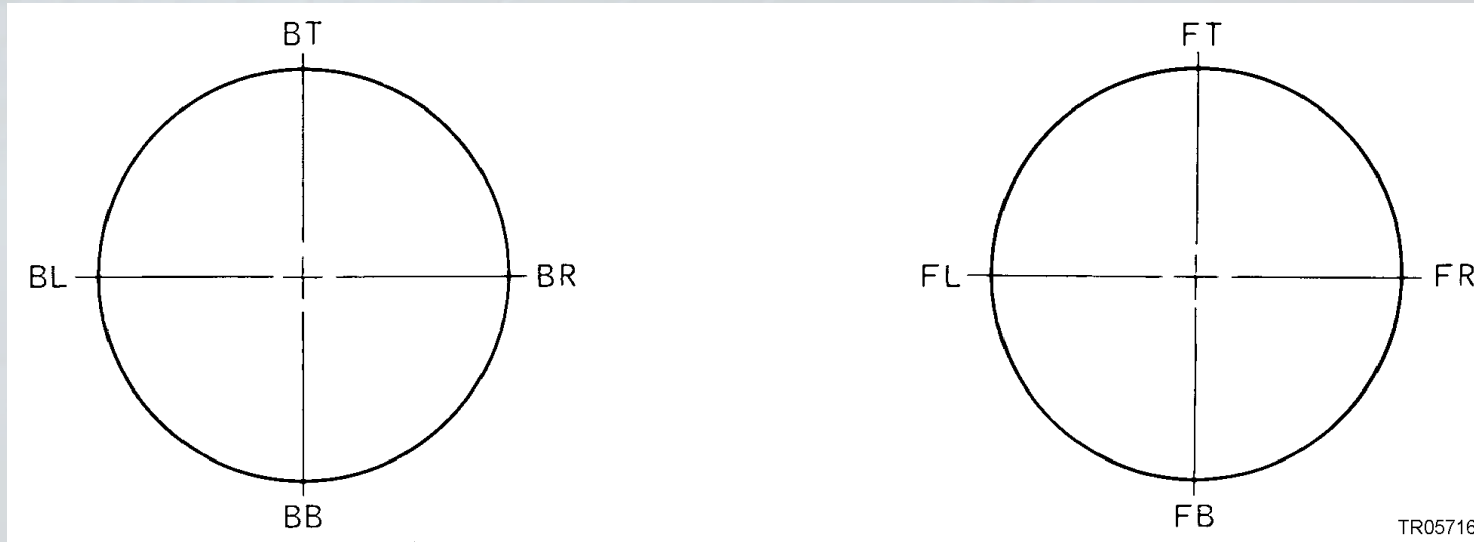
TR057.14

- Various versions available in the field
- Replicates the complex formula that was contained on older package drawings
- Also useful for other purposes
- Available on the CD

QUESTIONS ON SOURCES OF INFORMATION?

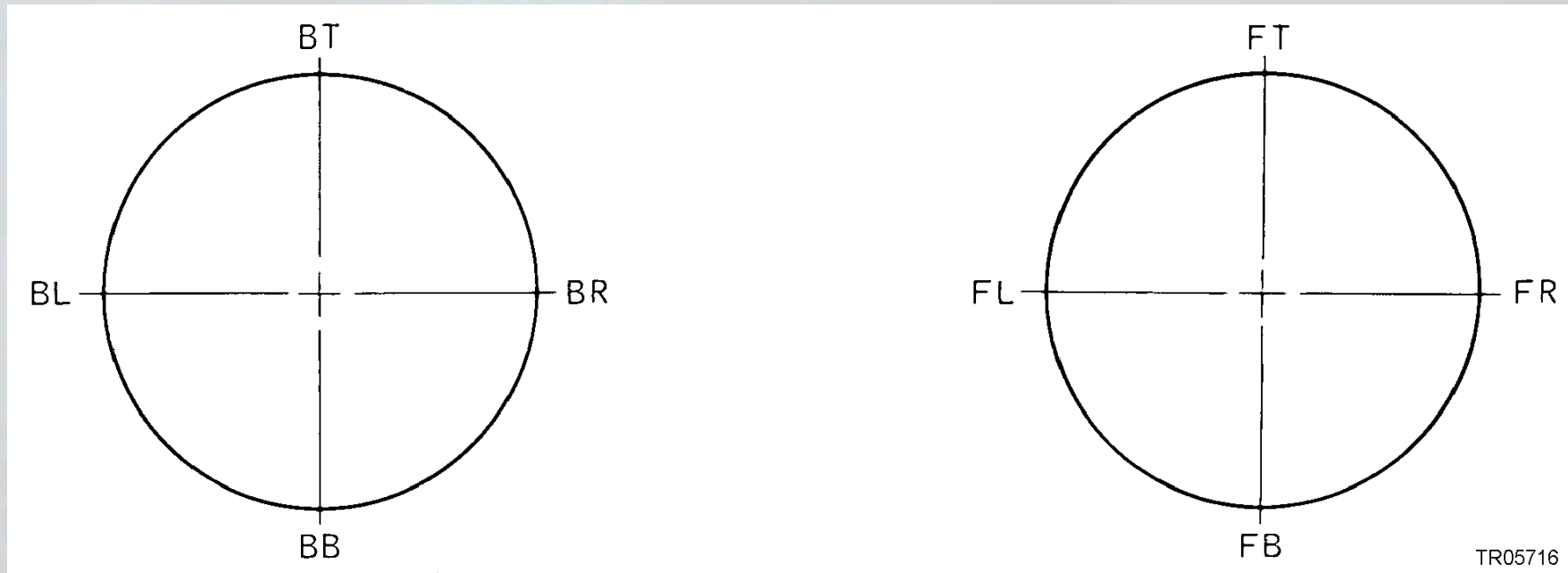
Complete Student Exercises

Student Exercise 1



- Use 72341-149605 and Align XL
- Open up the “Master” XL and save it under a new name
- Follow directions in Exercise 1 to compare specifications obtained from Align XL to specifications on the drawings
- **Instructor: “Answer” XL is on the CD**

Alignment Specifications From Drawing



TR05716

Student Exercise 2

- Use the XL spreadsheet produced in Exercise 1
- Follow the instructions in Exercise 2 to obtain shim correction values
- Compare the values to the answers in the table
- Instructor: “Answer” XL is on the CD (same XL as Exercise 1)

Personnel Responsibilities

Scenario 1

- All Solar equipment
 - Solar provide all data on drawings

Scenario 2

- Generator Package
 - Solar obtain growth figures from generator manufacturer, and provide all data on drawings

Scenario 3

- Third Party Driven Equipment
 - See SWB for options

QUESTIONS ON PERSONNEL RESPONSIBILITIES?

Complete Student Activity

Student Activity

1. Use the following flange-to-flange measurements to specify the coupling shim corrections:

- Specified flange-to-flange = 26.462" +/- 0.010"
- Measured flange-to-flange = 26.418

– Required correction =

**REMOVE 0.040" FROM
ORIGINAL SHIMPACK**

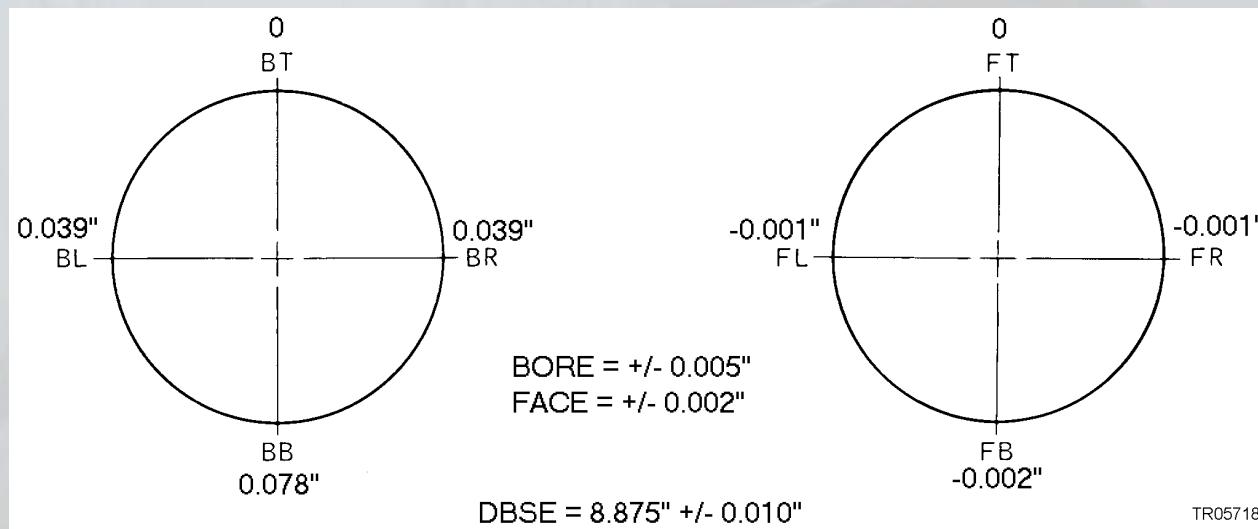
Student Activity

2. List three package conditions required prior to commencing alignment checks

Package to be level and secured
Shipping braces to be removed
Machinery must be cool (24 – 36 hrs after running)
Oil tank to be filled
All manifolds above the level of the oil to be loose
Compressor header pipes to be disconnected
Air inlet and exhaust ducts to be disconnected

Student Activity

3. Use the Alignment XL “Master” to create a spreadsheet that will be used later for the test-rig exercises



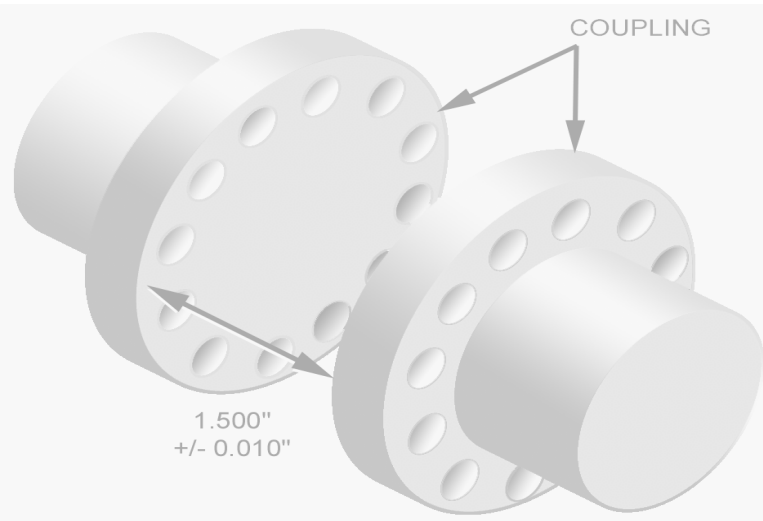
Student Activity

4. Use the spreadsheet just created to calculate shimming corrections

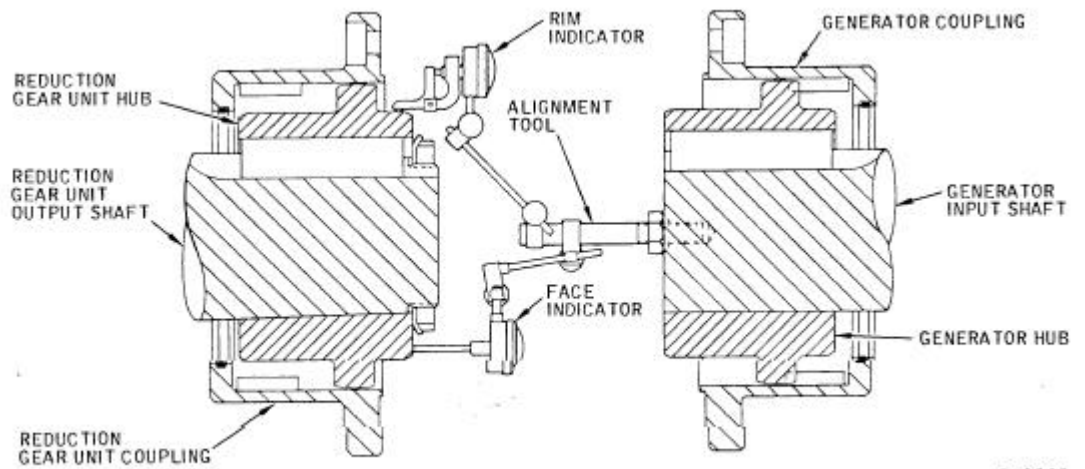
Shimming Corrections	
Near Foot Correction	0.027"
Far Foot Correction	0.024"

Objectives - Recap

1. List available sources of information related to alignment
2. Describe the responsibilities of Solar and other personnel in relation to machinery alignment under different project situations
3. Convert both Solar-supplied and vendor-supplied thermal growth figures to alignment specifications
4. Given example figures, use available formulae or software tools to identify machinery shimming requirements



TR05650



SA2203

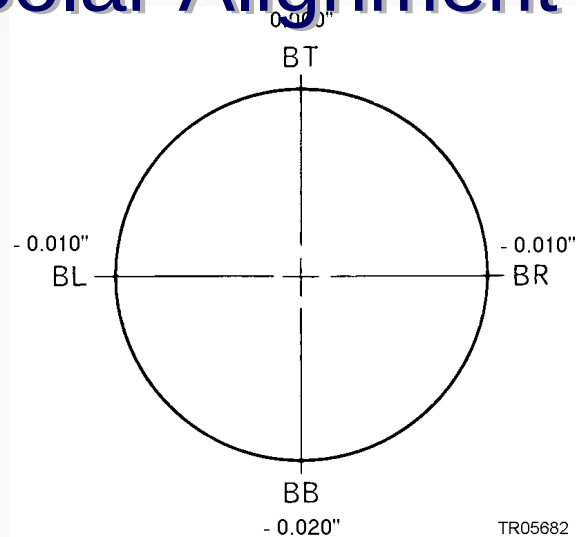
LESSON 5



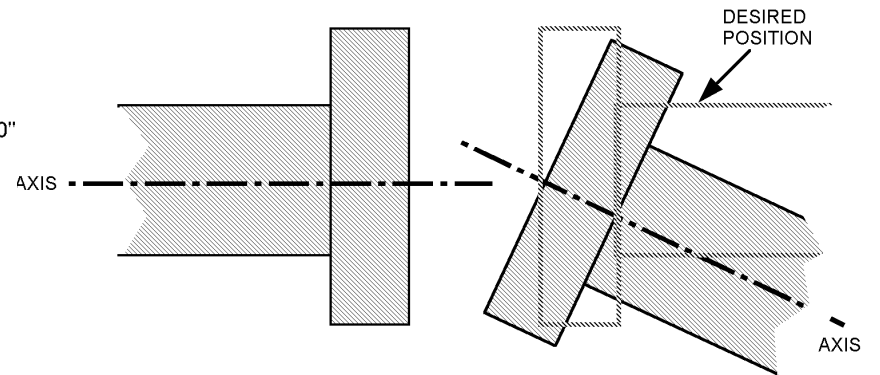
TR05600



Solar Alignment Techniques



TR05682



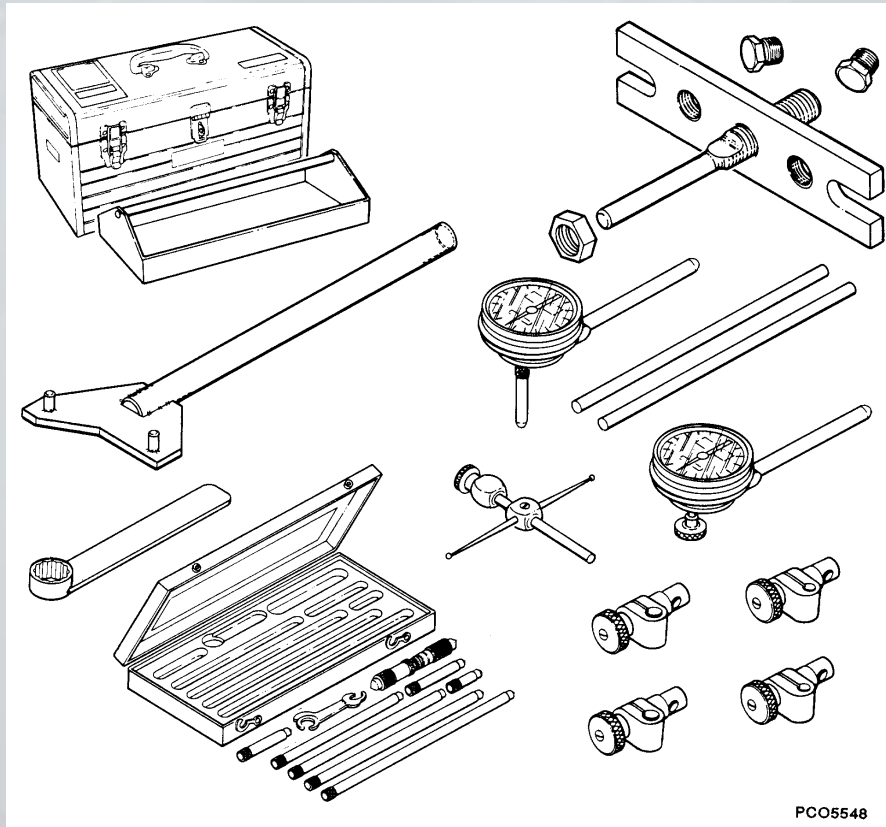
TR89107M

Objectives

1. Describe the installation requirements for alignment tooling on a range of Solar equipment
2. Describe the different types on interconnect shafts used on Solar packages, and the general alignment procedures associated with each type
3. Define package requirements to be established prior to commencing alignment

ALIGNMENT TOOLING

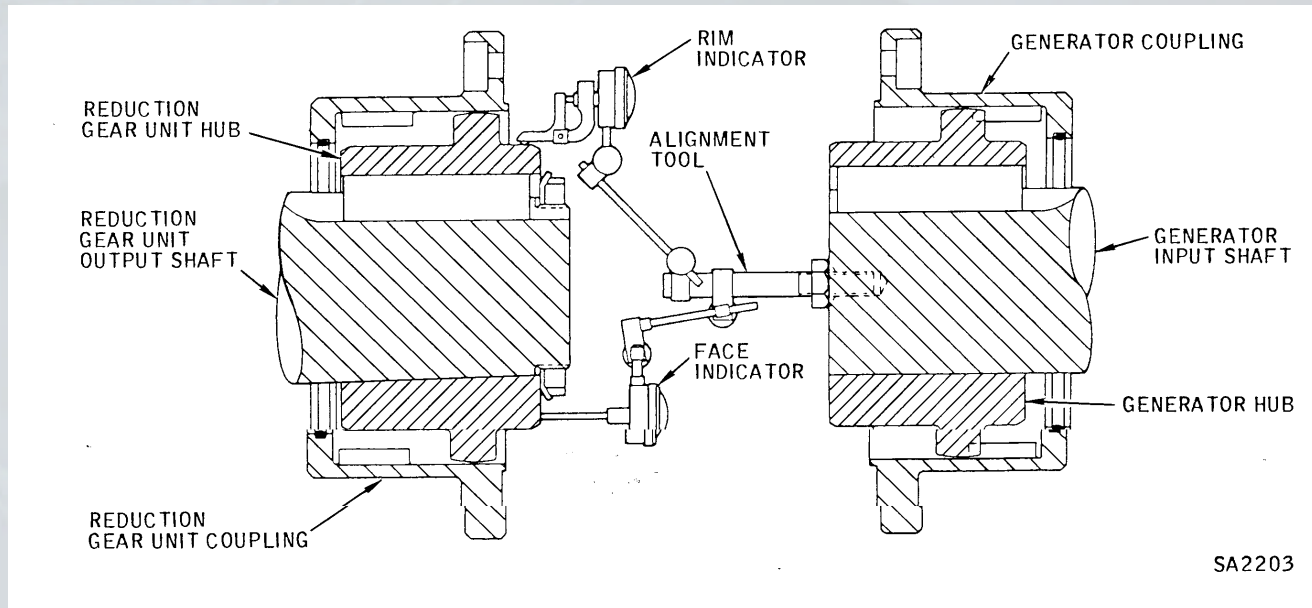
Alignment Tooling Example 1



PCO5548

- Typical tooling for a generator package
 - Mounting Tool
 - Dial Gages
 - Internal Micrometer
 - Shaft Rotation Tool

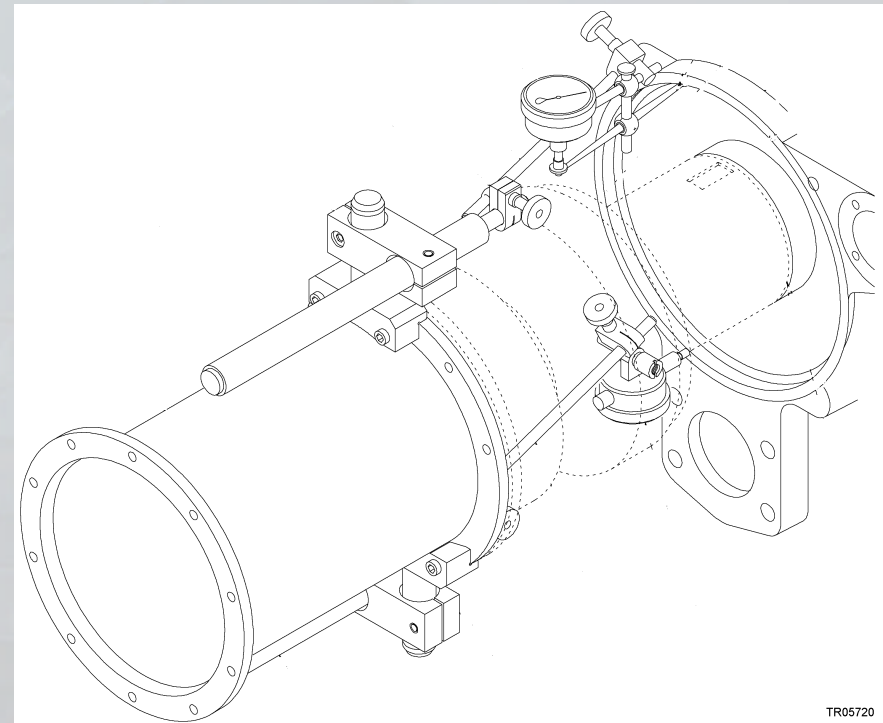
Alignment Tooling Example 2



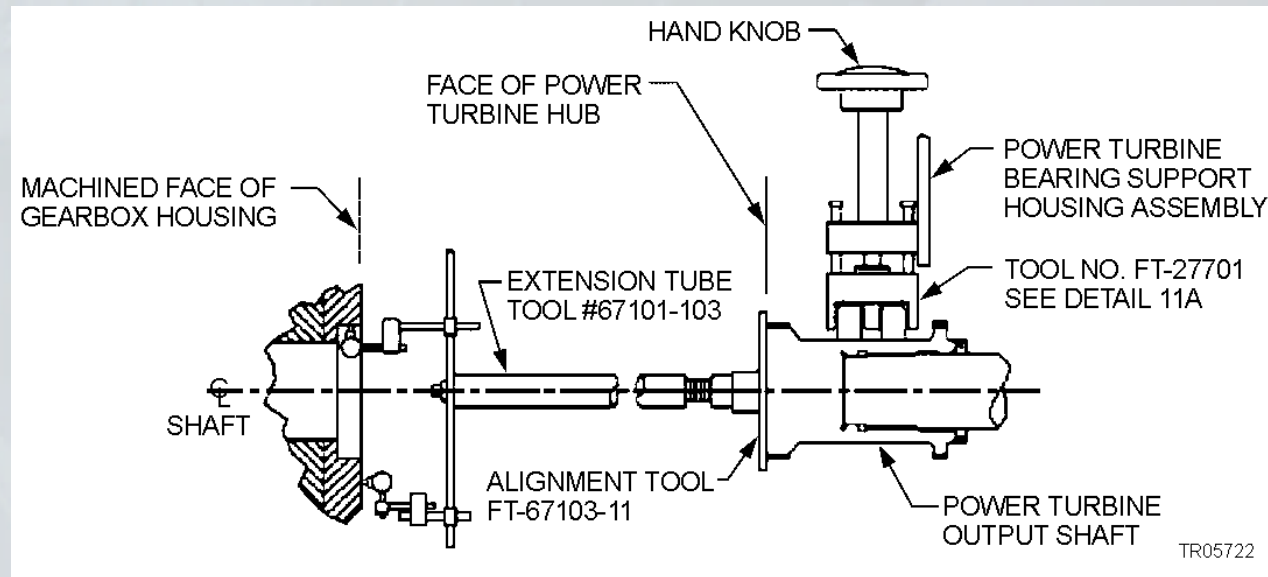
- Similar tooling to previous example
 - Mounting tool screws into generator shaft
 - Target is coupling hub on gearbox (generator usually easier to rotate)
 - Rotating tool (not shown) uses bolt holes in generator coupling half

Alignment Tooling Example 3

- Typical tooling on two-shaft machine
 - Uses coupling spacer as tool extension
 - Dial gage clamps bolt to spacer flange

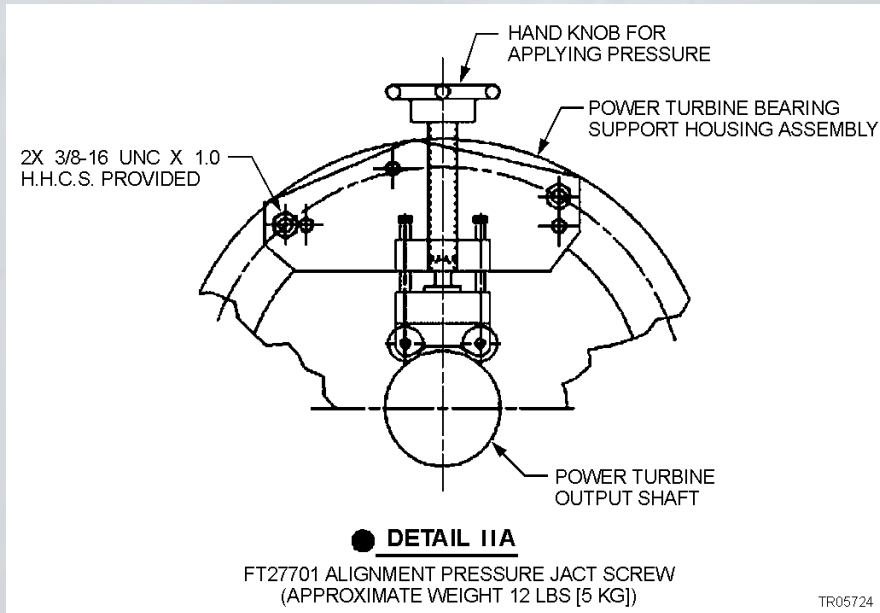


Alignment Tooling Example 4



- Solar PT's are supported by two bearings
 - PT disk will overhang, and droop
- PT shaft should be leveled
 - When using the shaft as a mount for the dial indicators, or
 - When using the shaft or hub as a target surface
- Tooling is supplied for this purpose

Alignment Tooling Example 5



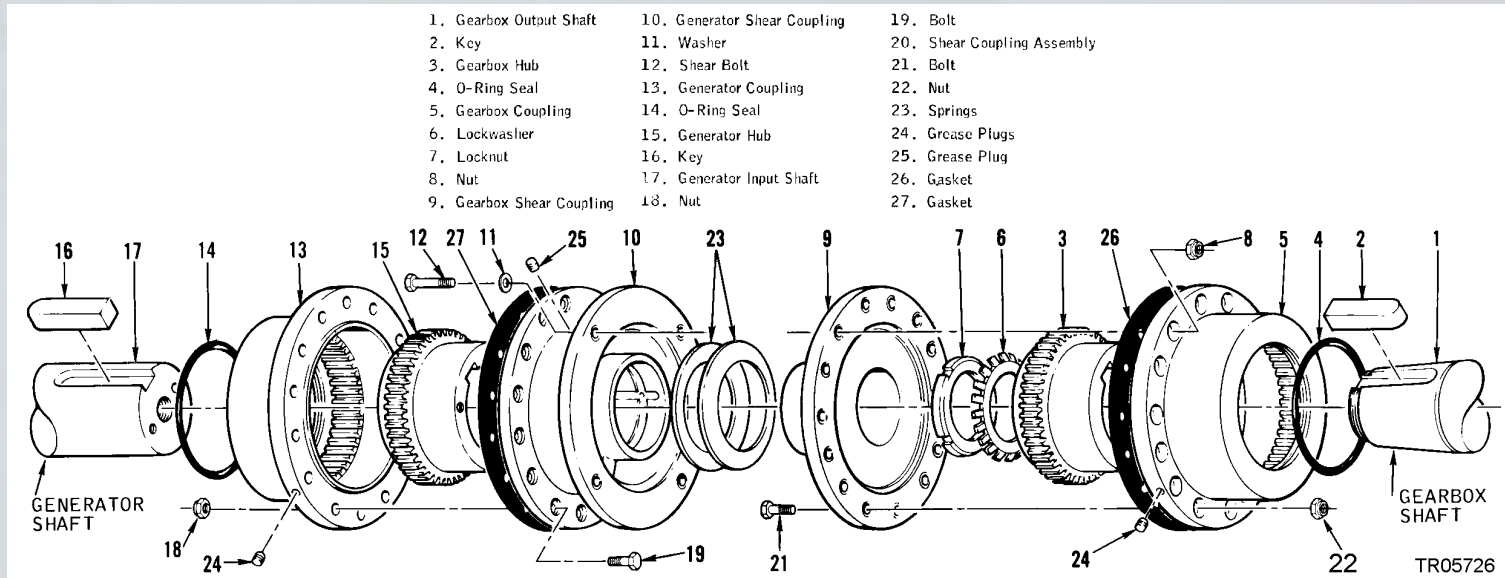
- Tool bolted to PT housing
- Rollers contact PT shaft
- Hand knob is tightened a prescribed number of turns

Other Considerations

- Rotation of shafts
- Adequate lubrication
 - Try and operate pump before rotation
 - Minimum is to pour oil into the bearing before rotation, and at regular intervals
- Rotate in normal direction only

TYPES OF COUPLING

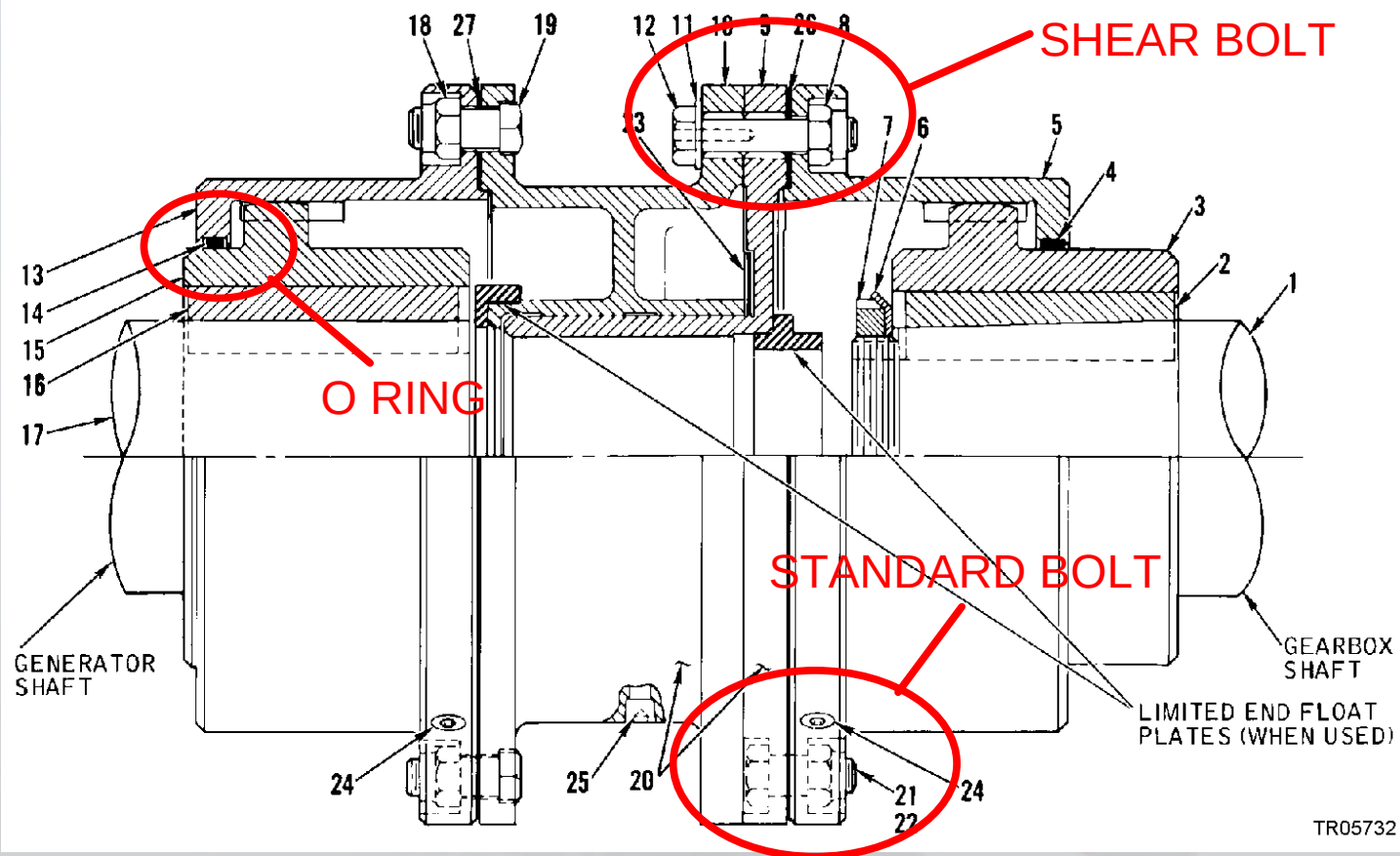
Gear Type / Wet Coupling



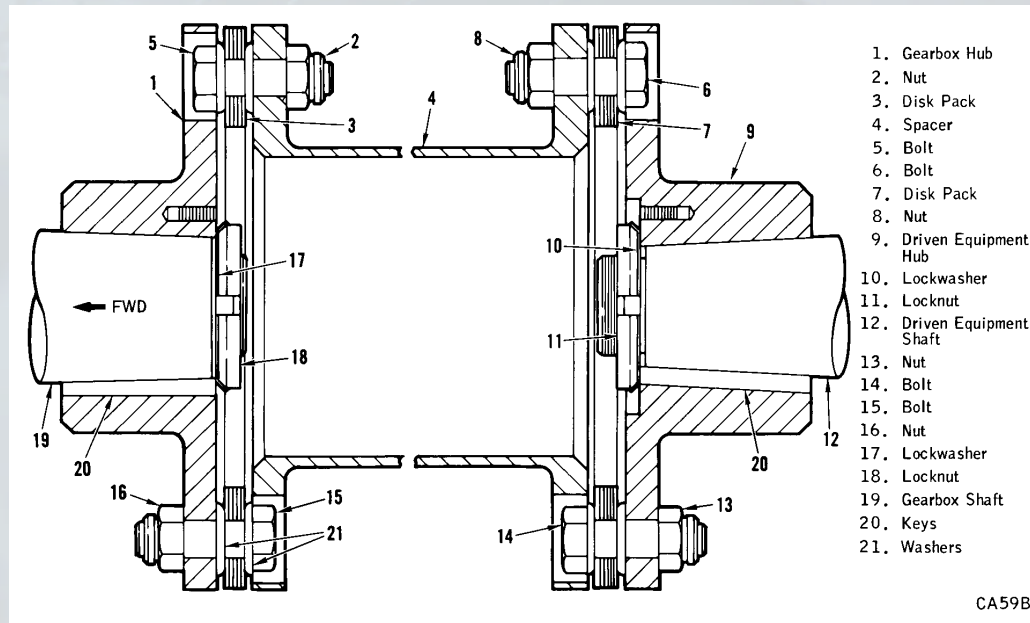
- Older design – requires grease
- Generator application illustrated
- Splined hub on each shaft (3 and 15)
- Secured by locknut/washer and key
- Splined coupling (5 and 13)
- Connected through shear coupling assembly (9 and 10)
- Slight misalignment absorbed by splines

Gear Type / Wet Coupling Assembled

- | | | |
|---------------------------|------------------------------|-----------------------------|
| 1. Gearbox Output Shaft | 10. Generator Shear Coupling | 19. Bolt |
| 2. Key | 11. Washer | 20. Shear Coupling Assembly |
| 3. Gearbox Hub | 12. Shear Bolt | 21. Bolt |
| 4. O-Ring Seal | 13. Generator Coupling | 22. Nut |
| 5. Gearbox Coupling | 14. O-Ring Seal | 23. Springs |
| 6. Lockwasher | 15. Generator Hub | 24. Grease Plugs |
| 7. Locknut | 16. Key | 25. Grease Plug |
| 8. Nut | 17. Generator Input Shaft | 26. Gasket |
| 9. Gearbox Shear Coupling | 18. Nut | 27. Gasket |

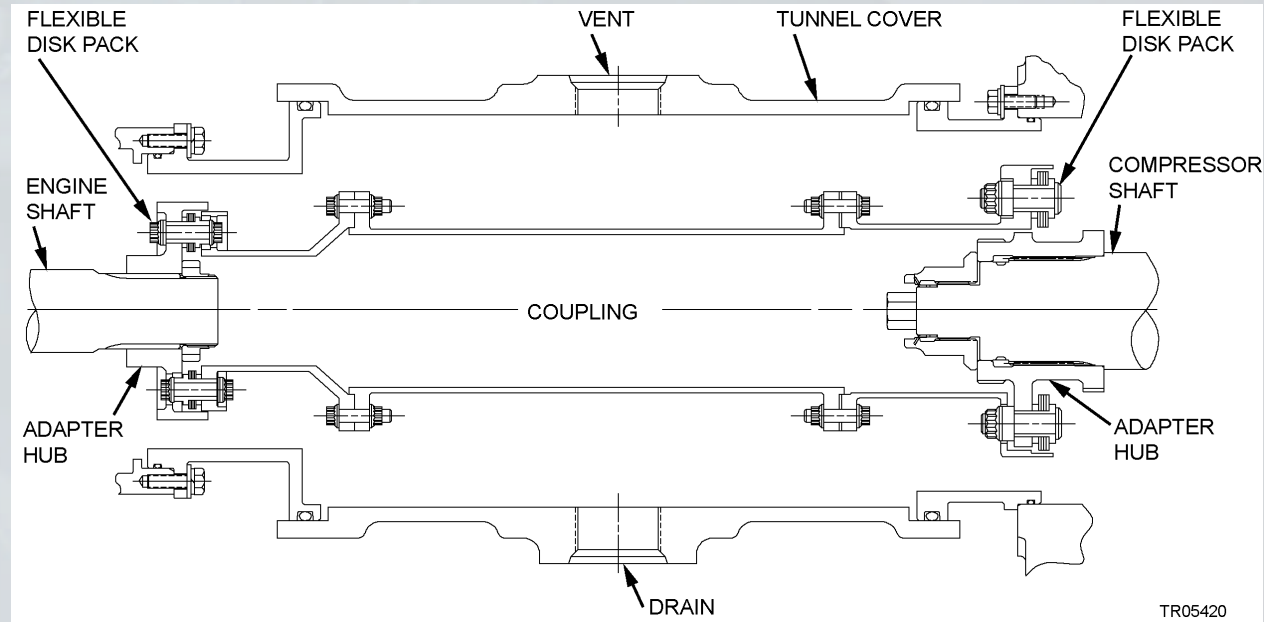


Dry Type Coupling Hubs



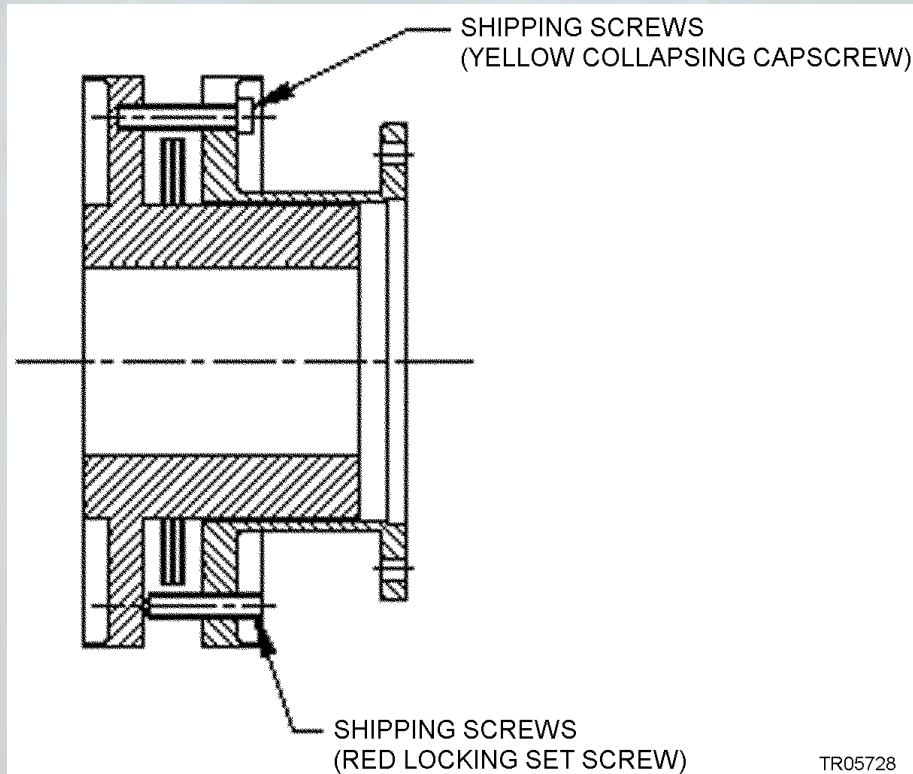
- Newer design – no lubrication
- Flanged hub on each shaft
- Secured by locknut/washer and key
- Flexible diskpacks absorb misalignment
- Spacer (may be shear coupling) – not shown

Dry Type Coupling With Spacer



- Shown for two-shaft application
 - No shear coupling
- Axial motion (thermal growth) absorbed by pre-stretch
 - Correct shim installation important

Kopflex Coupling Shipping Screws



- Kopflex coupling use red and yellow locking and collapsing crews for maintenance
- Should be removed prior to operating the equipment
- Kopflex data is available in the OMI manual (Supp Data section)

Package Requirements for Alignment

- Reference 72341-149605 Sheet 6
- Review the pre-alignment requirements
 - Skids joined and level
 - Machinery cold
 - Shipping braces removed, etc

QUESTIONS ON ALIGNMENT TECHNIQUES?

Complete Student Activity

Student Activity

1. The gear type coupling does not require lubrication with grease
TRUE / FALSE
2. Shear couplings are normally installed on generator applications
TRUE / FALSE
3. Shear couplings are only available with gear type couplings
TRUE / FALSE
4. The red and yellow shipping screws should be removed from a Kopflex coupling prior to operating the equipment
TRUE / FALSE
5. During alignment of a compressor to an engine or gearbox, the header pipes should remain connected to the compressor
TRUE / FALSE

Objectives – Recap

1. Describe the installation requirements for alignment tooling on a range of Solar equipment
2. Describe the different types on interconnect shafts used on Solar packages, and the general alignment procedures associated with each type
3. Define package requirements to be established prior to commencing alignment

LESSON 6

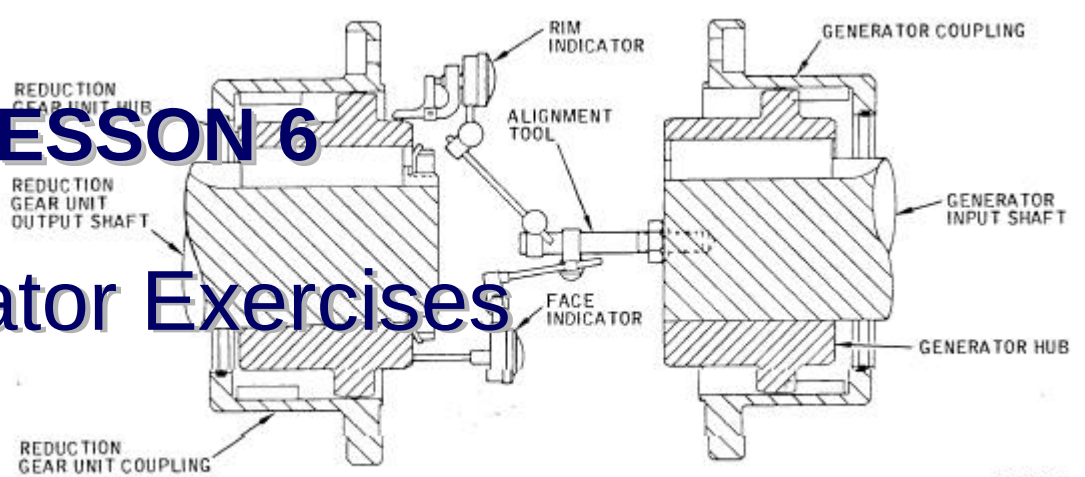
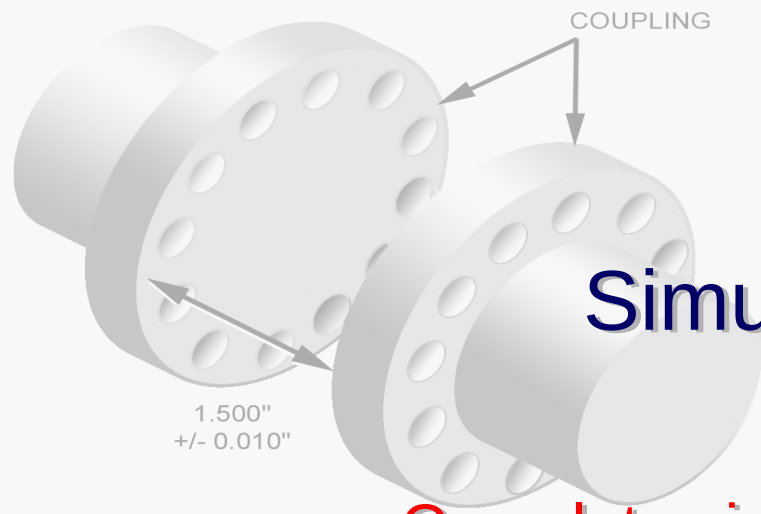
Simulator Exercises

Complete simulator exercise detailed in
Lesson 6

Use the table as a general guide, and to sign
off the steps

Instructor will also sign off on the main steps

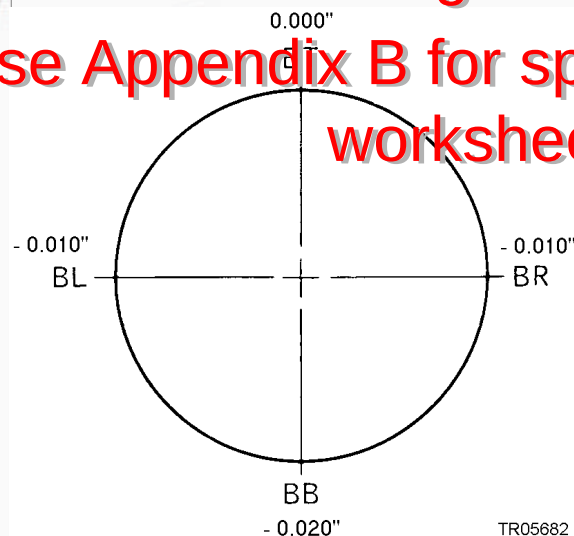
Use Appendix B for specifications and
worksheets



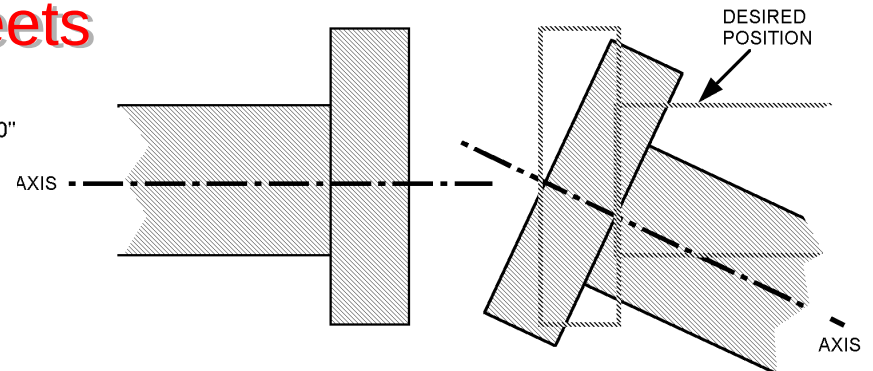
SA2203



TR05600

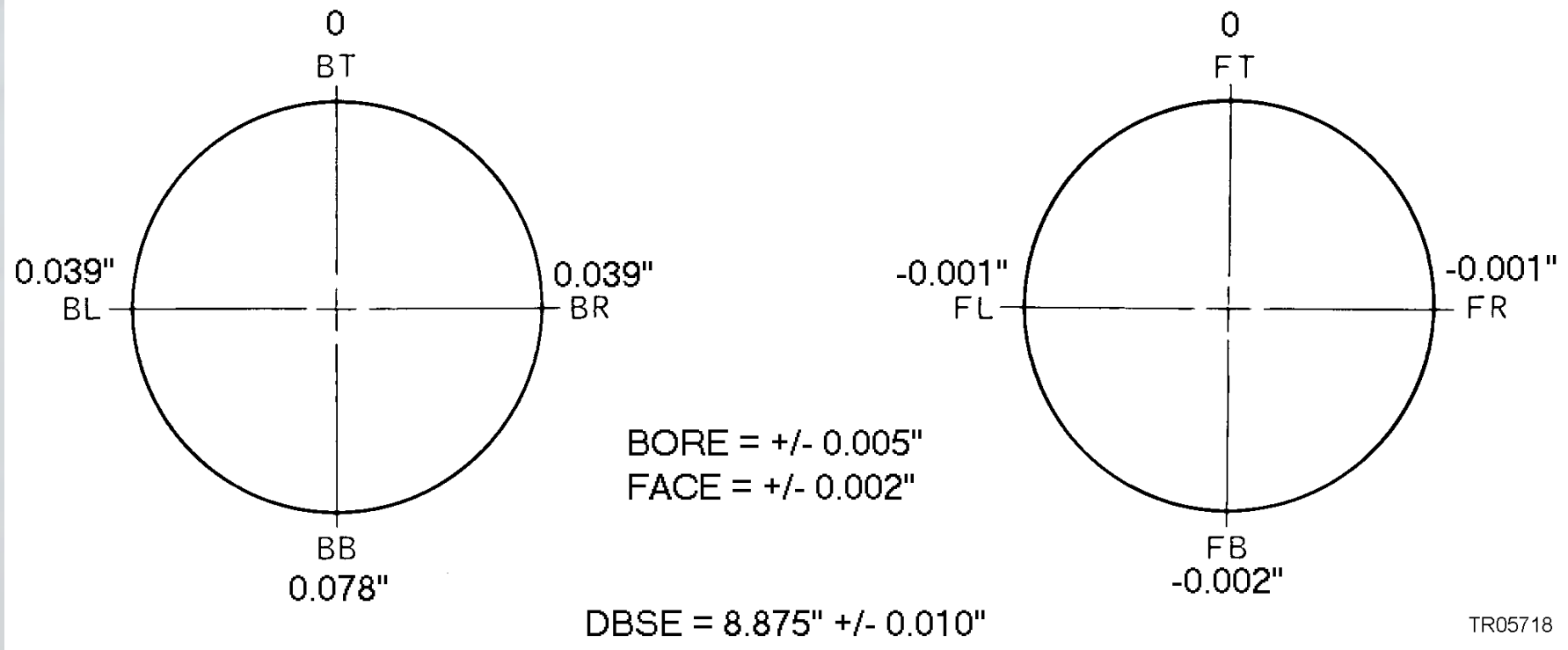


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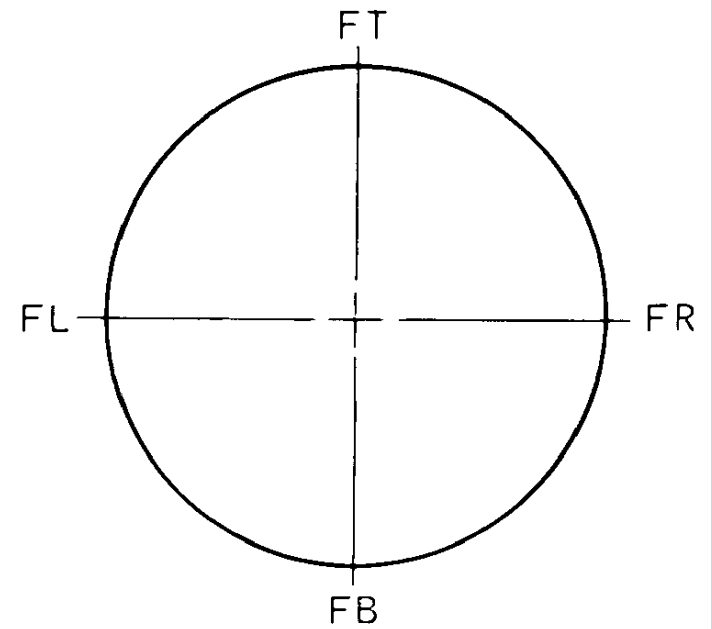
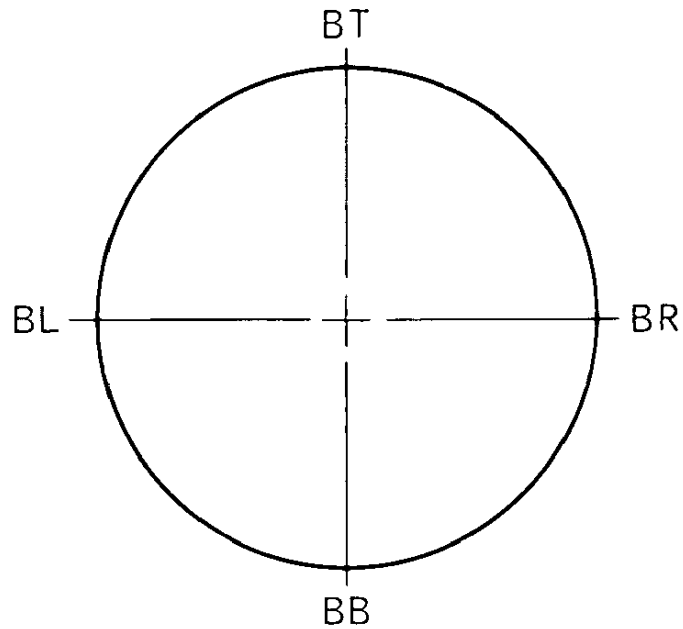


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Appendix B1 Exercise Alignment Specifications



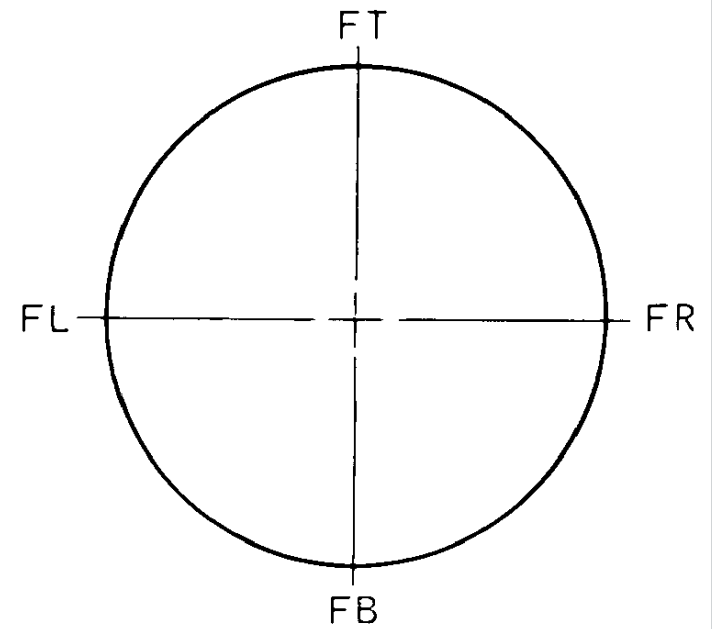
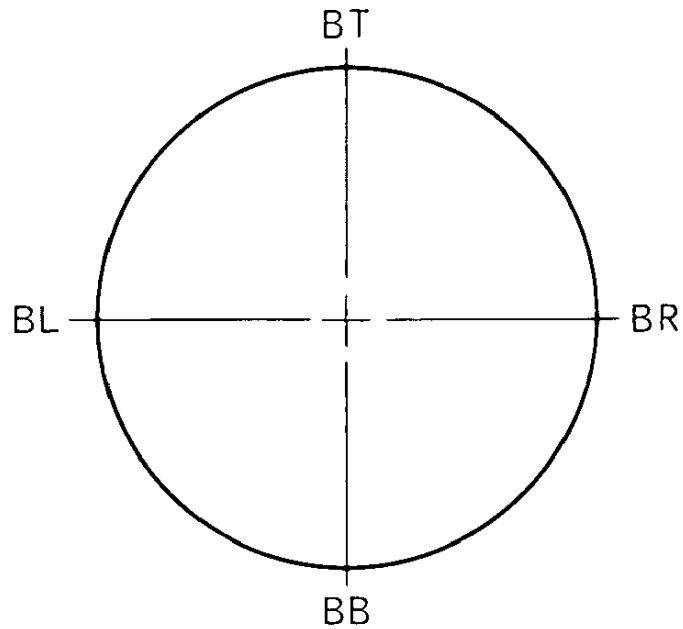
Appendix B2 Initial Alignment Readings



DBSE =

TR05730

Appendix B3 Final Alignment Readings

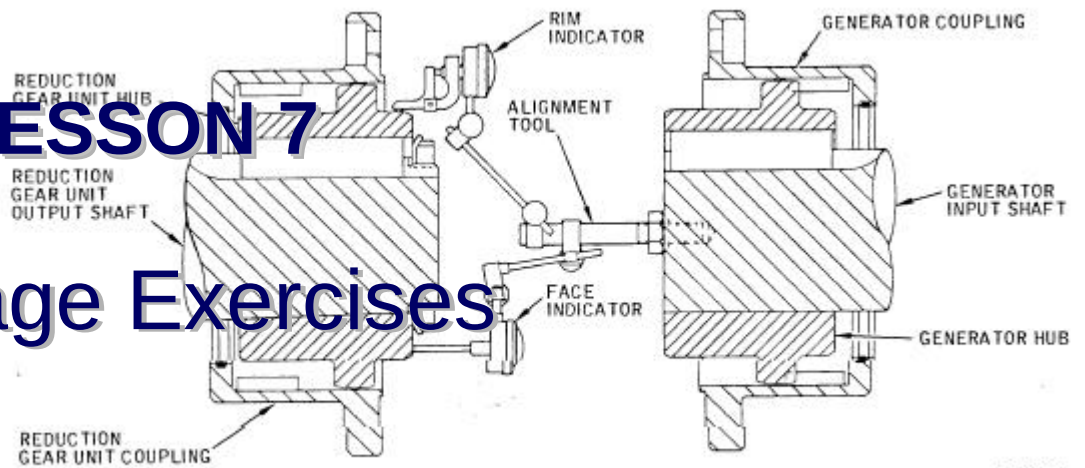
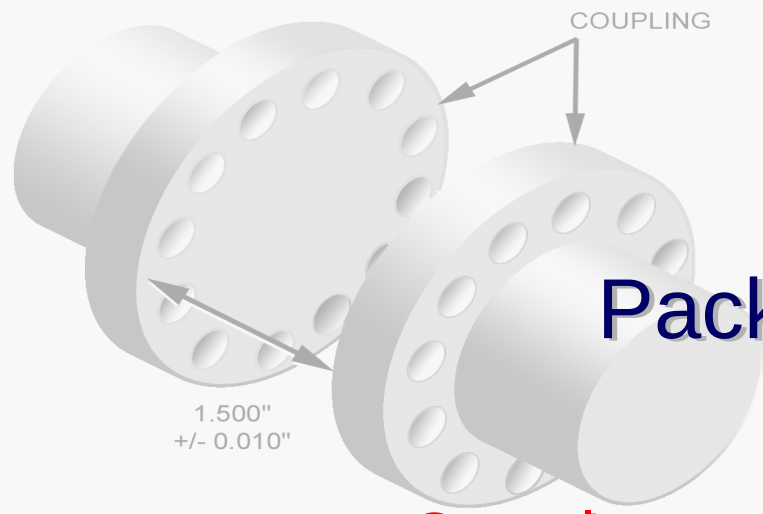


DBSE =

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LESSON 7

Package Exercises



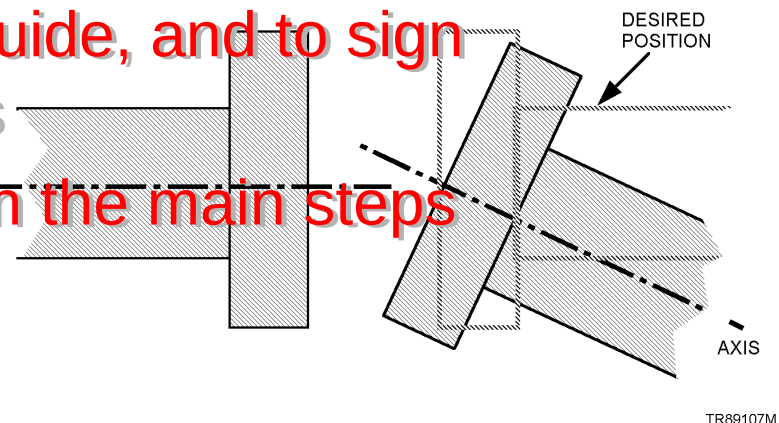
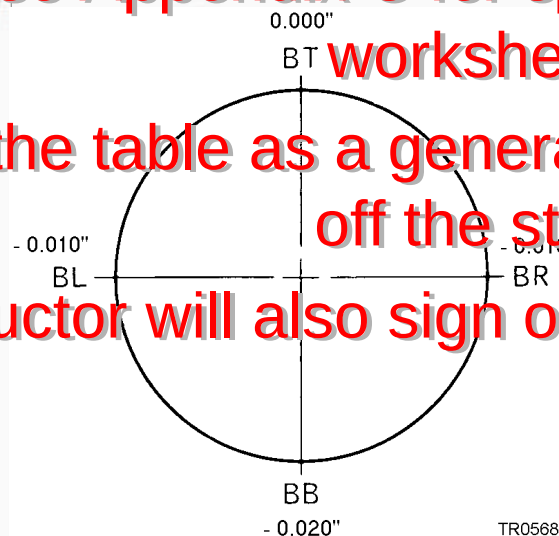
Complete package exercise detailed in Lesson 7

Instructor will provide either a drawing or just alignment specifications

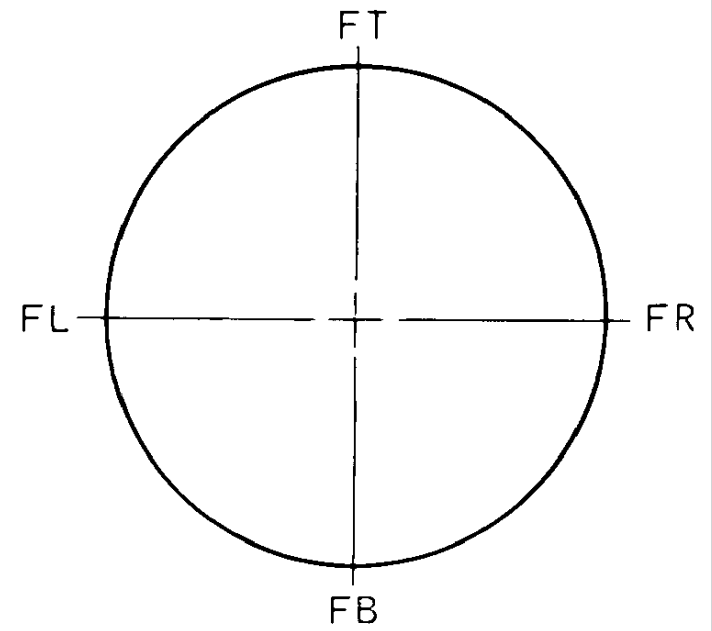
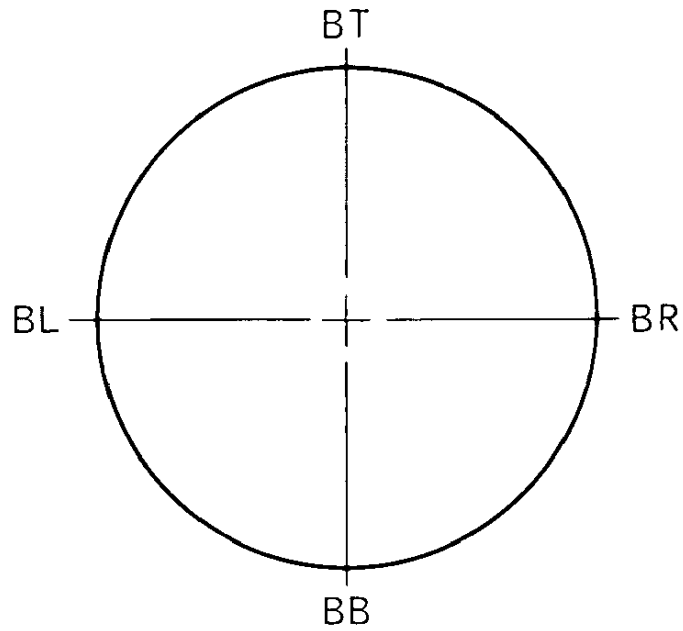
Use Appendix C for specifications and worksheets

Use the table as a general guide, and to sign off the steps

Instructor will also sign off on the main steps



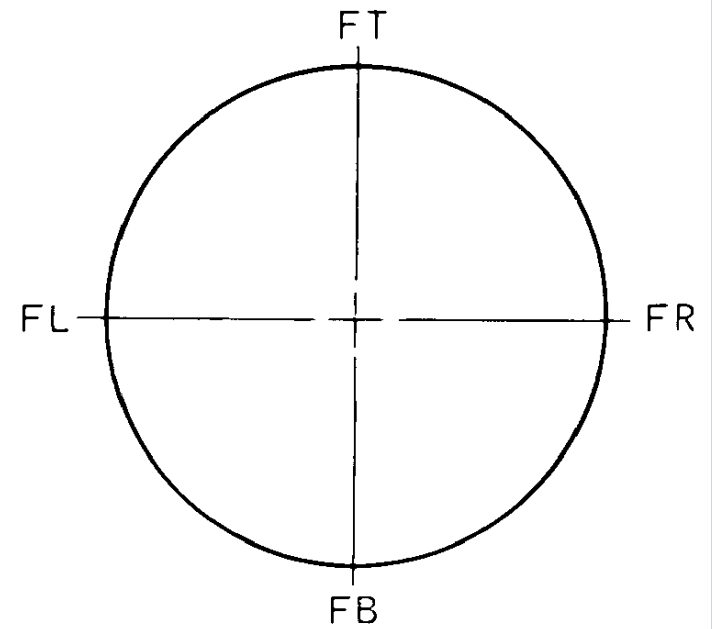
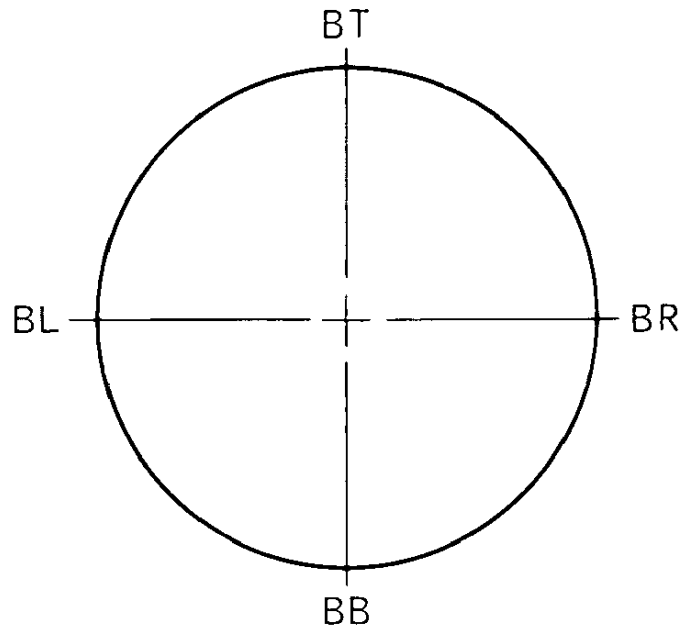
Appendix C1 Alignment Specifications



DBSE =

TR05730

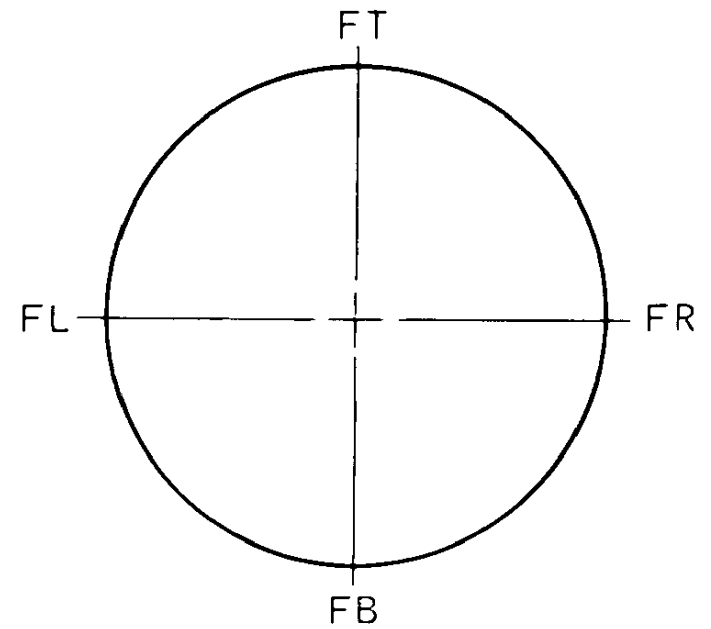
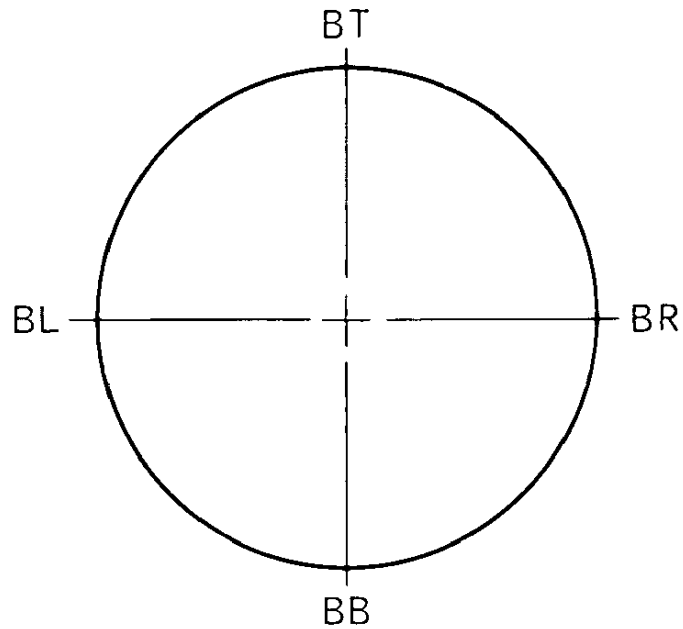
Appendix C2 Initial Alignment Readings



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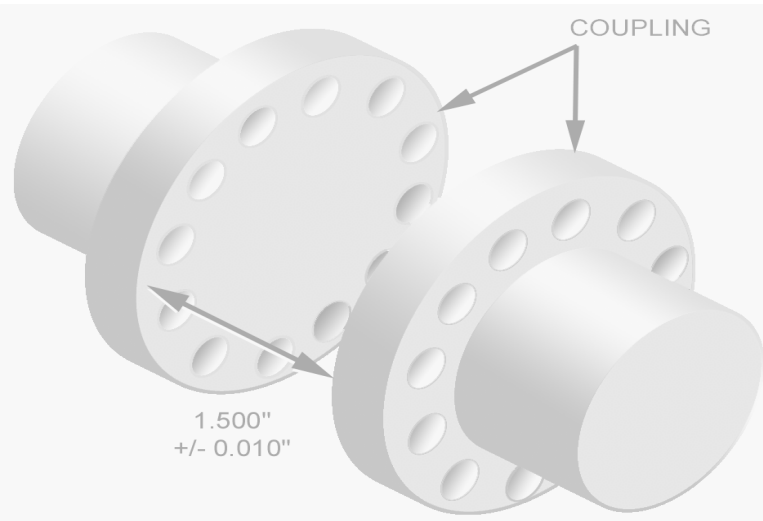
TR05730

Appendix C3 Final Alignment Readings

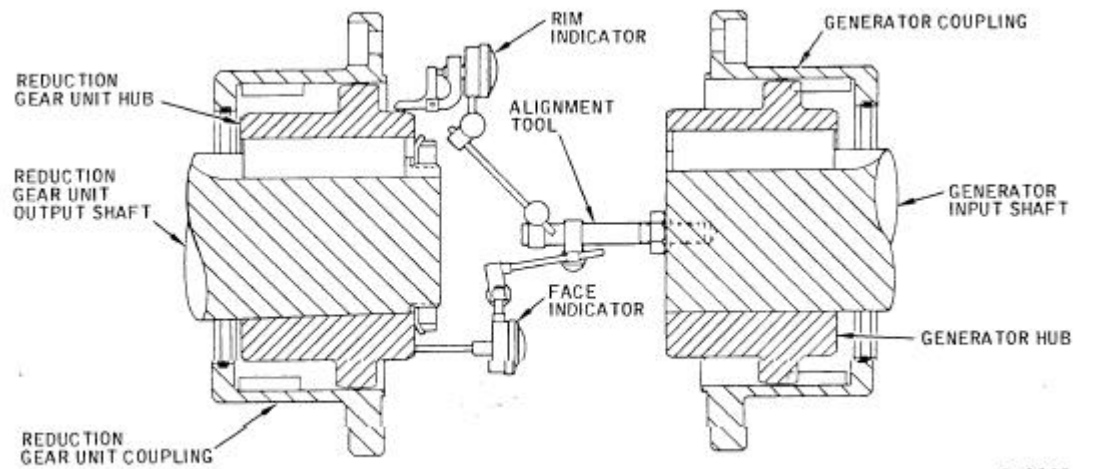


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TR05650



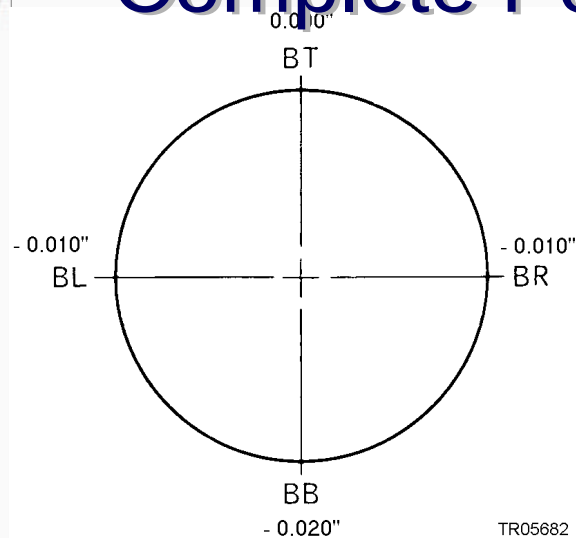
SA2203



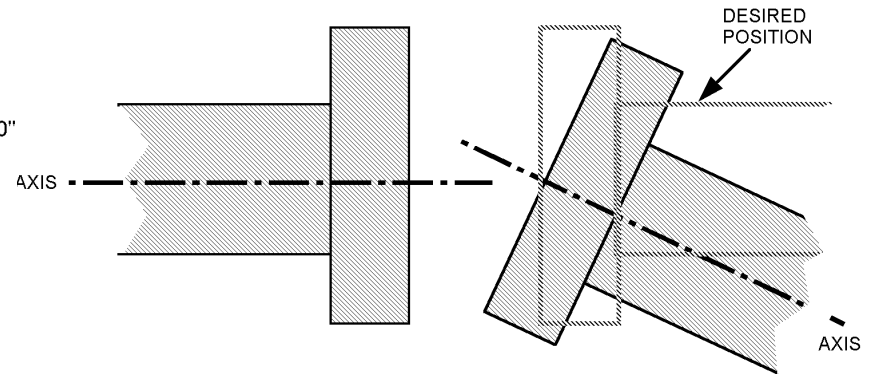
TR05600



Complete Post-Test



TR05682



TR89107M