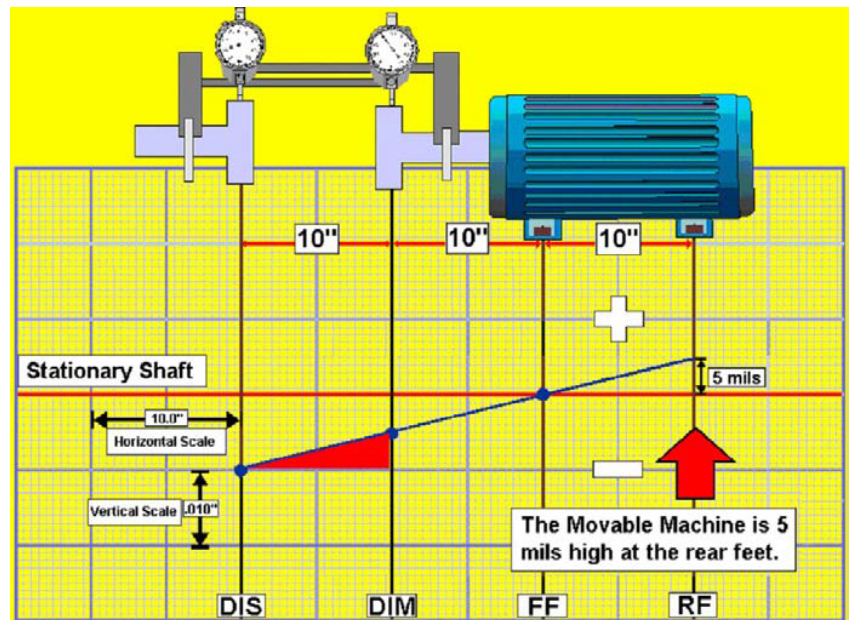


Shaft Alignment: Calculations for Horizontal Shaft Alignment

Summary

This article is the third in a series designed to provide maintenance personnel with the solid knowledge needed for equipment shaft alignment. This article explains in detail the method of calculation when performing shaft alignment. Specifically, the reader is provided step-by-step help in dial indicator alignment, rim-face alignment, reverse-rim alignment, graphing and correction techniques, and twin-laser alignment.



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Introduction

Shaft misalignment induces abnormal loads, which causes equipment to run improperly and eventually leads to a decreased life expectancy. An introduction into shaft alignment including the various methods is provided in the @ptitudeXchange article "Shaft Alignment: Introduction." In this article, the calculation method behind each technique is explained in detail.

Dial Indicator Alignment Method

Dial indicators are measuring devices designed to measure relative position. The primary parts of a dial indicator are the face or dial, the case, and the plunger. The plunger is a spring-loaded part that can be depressed into the case causing the dial to move clockwise.

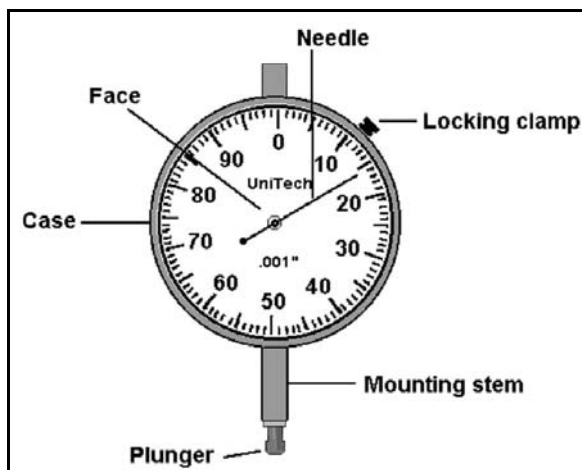


Figure 1. The dial indicator.

The plunger is fully extended out of the case if no pressure is applied to it. The total travel (all the way out to all the way in) varies depending on the particular indicator model. For shaft alignment, we typically use dial indicators with 0.250" - 0.300" total travel.

The plunger moves a needle clockwise when pushed in, and counter clockwise when let out. The face can be rotated so that the needle points to zero. A clamp holds the case and

holding rod, which are in turn held by a jig or magnetic base.

Dial Indicator Signs

With the plunger set to approximately mid-position, the face dial is set to read zero. From this zero reference point, two rules apply:

1. As the plunger moves out of the case, the needle travels counter-clockwise, giving a negative reading.
2. As the plunger moves into the case, the needle travels clockwise, giving a positive reading.

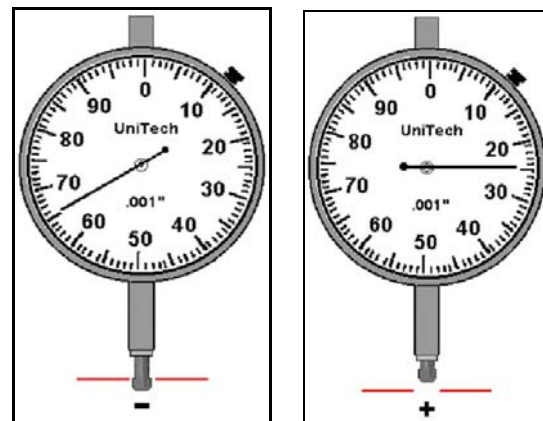


Figure 2. Positive readings when the plunger moves in to the case, negative when the plunger moves out.

Dial Indicator Bar Sag

The dial indicator bar sag describes a bending of the hardware used to support the dial indicator or other part that spans the coupling. The bending action occurs as a result of gravity and cannot be totally eliminated. Factors that influence how much bar sag exists include:

- Weight of the dial indicator and other parts that are overhung.
- Height of the supporting fixture required to clear the coupling.
- Span of the indicator bar(s).

- Stiffness of the fixture hardware materials.
 - Specific geometry of the hardware arrangement.
3. Position the indicator plunger(s) at the 12:00 position and set the dial(s) to zero.

In all cases of alignment, efforts should be made to minimize the amount of sag present. If it is not kept to a minimum, it is often not repeatable and, therefore, introduces different amounts of error. As long as the amount of bar sag is known and is consistent, it can be compensated for during the alignment process.

Indicator bar sag occurs for all types of alignment readings. However, sag affects only one particular type of reading in nearly all alignment tasks. That type of reading is the offset reading taken in the vertical plane. Except in rare situations, sag has negligible effect on offset readings taken in the horizontal plane and on conventional angularity type readings taken on the face of a coupling.

During each alignment task, after the indicator(s) have been set up on the machine, it is necessary to determine how much bar sag exists. To determine the amount of sag, the fixtures must be taken off the machine and remounted on a rigid mandrel, such as a piece of steel pipe. It is important to note that indicator bar sag can not be determined from a reading taken by rotating the shafts. The reason is that as the fixtures are rotated from 12:00 to 6:00 while mounted on the machine, the reading given includes a combination of sag and misalignment.

To determine sag, perform the steps below:

1. Mount the fixtures on the machine as they will be mounted during the alignment task. Verify fixture tightness, repeatability, etc.
2. Dismount the fixtures from the machine shafts and remount on a rigid mandrel.

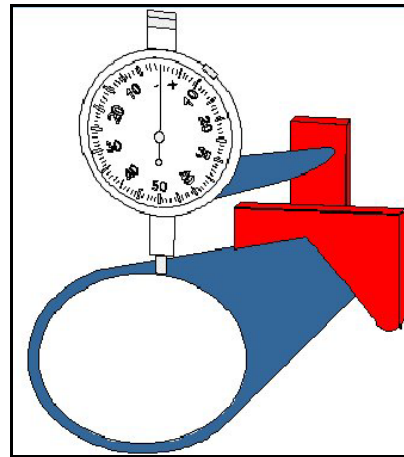


Figure 3. Determining bar sag, zero at 12:00.

4. Rotate the fixtures to the 6:00 position and read the amount of sag.

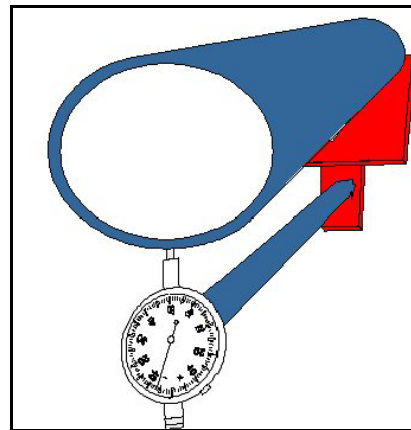


Figure 4. Determining bar sag, reading at 6 o'clock.

Once the amount of sag is determined, you must properly eliminate its adverse effects on all vertical offset readings. The simplest way to eliminate the effects of sag is to dial it into the readings at the initial measurement position.

For readings where the dial is normally zeroed at 12:00 and rotated to 6:00, set the dial to the positive value of sag at the 12:00 position.

For readings where the dial is normally zeroed at 6:00 and rotated to 12:00, set the dial to the negative value of sag at the 6:00 position.

Once sag is “dialed in” as described above, all values are correct; no further sag compensation means are required.

Measuring Offset Using Dial Indicators

To measure offset using dial indicators, a fixture bracket is attached to one shaft and the dial is setup to contact the other shaft. The dial is set to zero at position #1, for example 12:00.

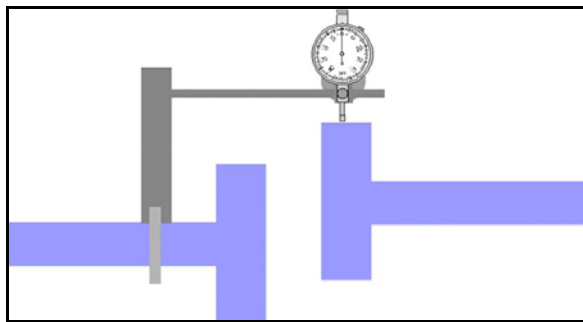


Figure 5. Measuring offset, position #1.

The dial is then rotated 180 degrees, for example, to the 6:00 position.

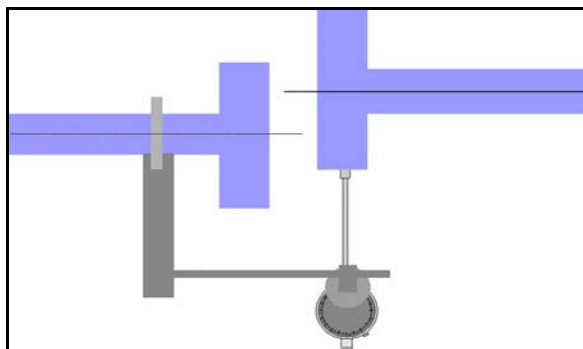


Figure 6. Measuring offset, position #2.

When shaft offset readings are obtained in this way, the Total Indicator Reading (TIR) is twice the amount of shaft-centerline offset. You must divide offset TIR by two to determine offset. Referring to the next illustration, notice that the offset between the

two shafts is 0.020” (0.508 mm), but the TIR is 0.040” (1.016 mm).

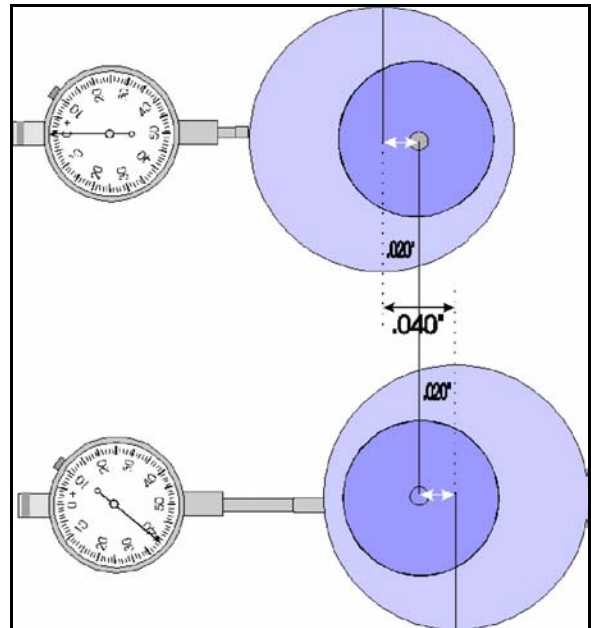


Figure 7. The offset is half the TIR (Total Indicator Reading).

Measuring Angularity with Face Dial Indicators

To measure angularity using dial indicators, a fixture bracket is attached to one shaft and the dial is setup to contact the face of the other coupling hub. The dial is set to zero at position #1, for example, 12:00.

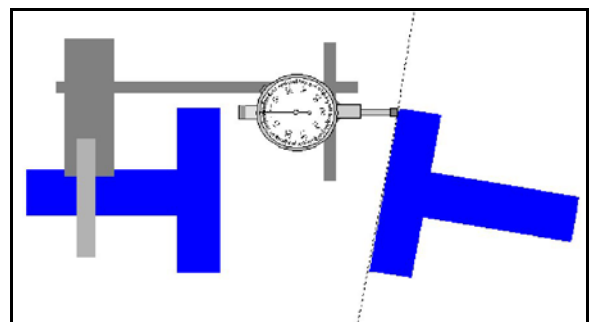


Figure 8. Measuring angularity, position #1.

The dial is then rotated 180 degrees, for example, to the 6:00 position.

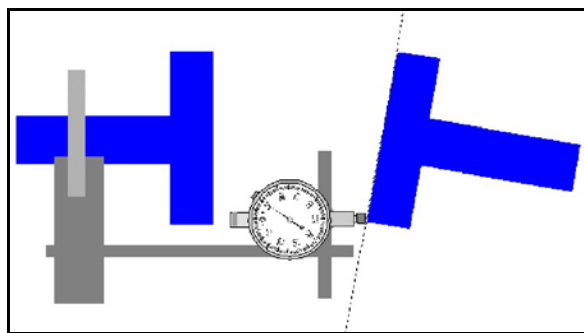


Figure 9. Measuring angularity, position #2.

When shaft angularity readings are obtained in this manner, the amount of angularity equals the Total Indicator Reading (TIR) divided by the indicator circle diameter. For example, if the 6:00 TIR is $+0.010''$ (0.254 mm) and the indicator circle diameter is 5'' (127 mm), the amount of angularity is $+0.002'' / ''$ (0.002 mm / mm).

Ensuring Accuracy of Dial Indicator Readings

The importance of obtaining accurate dial indicator readings can not be overemphasized. Regardless of the efficiency of any alignment process, whether it involves graphing, calculations, or computers, the precision obtained is dependent on the indicator readings that are obtained. After fixtures have been properly set up, several precautions should be observed to ensure the accuracy of all dial readings. Among them are the following:

1. Take readings at the true clock positions: 12:00, 3:00, 6:00, and 9:00. Once these positions are determined, some mechanism (such as marks on the bearing housing or shaft) should be utilized to ensure all readings are taken at these points.
2. All readings should be checked for repeatability. This includes ensuring that the dial comes back to zero at the first measurement position, and double-checking all readings for consistency.
3. Watch indicators throughout the rotation of the shafts to ensure that the proper amount and sign of the reading is determined and documented.
4. Eliminate error due to coupling backlash. This can be achieved by holding opposing pressures on the shafts while they are rotated.
5. If error is suspected, check readings for mathematical validity. This is accomplished by adding the top and bottom readings and comparing the resulting sum to that of the side-to-side readings. For readings that are valid, these sums are equal.

Consider the following sets of offset readings:

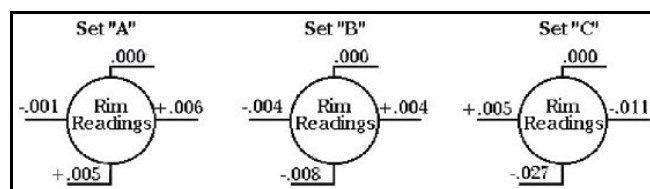


Figure 10. Validity rule. Top + bottom values equals left + right values.

Set "A"

Note that the sum of the top and bottom, $0.000 + (+0.005)$, is equal to 0.005, and the sum of the side-to-side readings, $-0.001 + (+0.006)$, is also equal to $+0.005$. Since these sums are equal, we can conclude that the readings are indeed valid.

Set "B"

The sum of the top and bottom value, $0.000 + (-0.008)$, is equal to -0.008 , and the sum of the side-to-side readings, $-0.004 + (+0.004)$, is equal to $+0.000$. Since these sums are not equal, we can conclude that the readings are not valid.

Set "C"

The sum of the top and bottom value, $0.000 + (-0.027)$, equals -0.027 , and the sum of the side-to-side readings, $+0.005 + (-0.011)$, is equal to -0.006 . Since these sums are not equal, we can conclude that the readings are not valid.

Rim-Face Alignment Method**Rim-Face Alignment Overview**

The rim-face method is recognized as the oldest method of shaft alignment. Many different variations of the rim-face method are used, including straight-edge and feeler-gauge methods, single-dial rim-face, two-dial rim-face, trial and error rim-face, etc. In this manual, we will focus on two-dial rim-face alignment and how to accurately determine shaft positions using calculation and graphing.

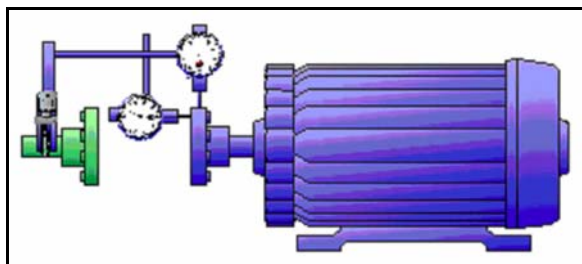


Figure 11. Two dial indicators are used to determine the relative position of the movable shaft with respect to the stationary shaft.

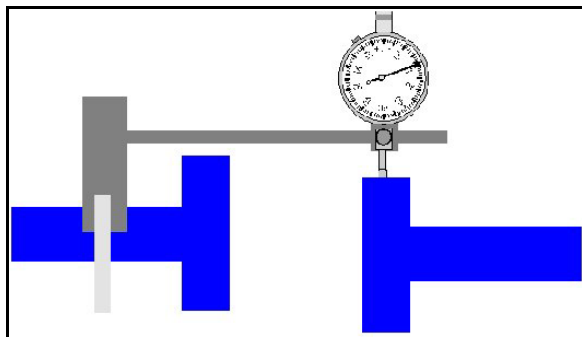


Figure 12. The rim dial is used to measure offset in one plane along the shaft lengths.

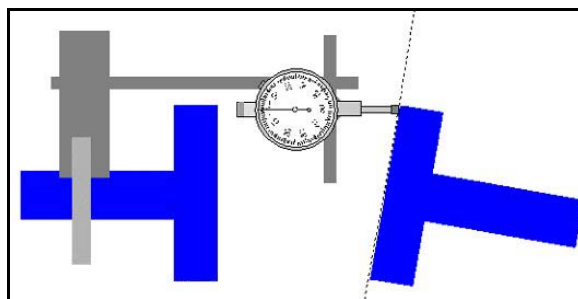


Figure 13. The face dial measures angularity or slope between the shafts.

Using the offset and angularity measurements along with fixture setup and machine dimensions, the relative position of the movable shaft is determined by performing calculations or by graphing/plotting.

Rim-Face Fixture

A variety of shaft alignment fixtures are available for performing a rim-face alignment. Selection and use of a commercial package designed to accommodate a variety of shaft diameters is recommended. The fixtures should include an assortment of rods to span various coupling lengths. These packages expedite the precision alignment process. In addition, sag values can be pre-determined for the standard rod assortment.

For machines with sufficient space between coupling halves, fixtures can be mounted such that the dial indicators are in direct contact with the coupling or the shaft. The alignment can be performed with the shafts uncoupled.

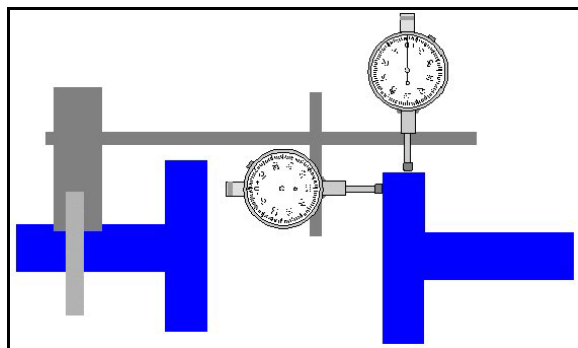


Figure 14. Uncoupled shafts.

When machines are close-coupled, there is generally NOT sufficient room to mount indicators to contact the coupling hub. In these cases, rim-face alignment can be performed with the shafts coupled. Indicators are often mounted to contact a bracket, similar to the illustrations below.

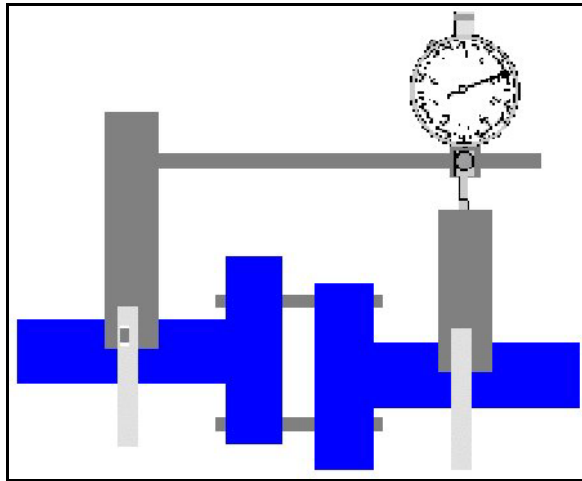


Figure 15. Coupled shafts, rim dial.

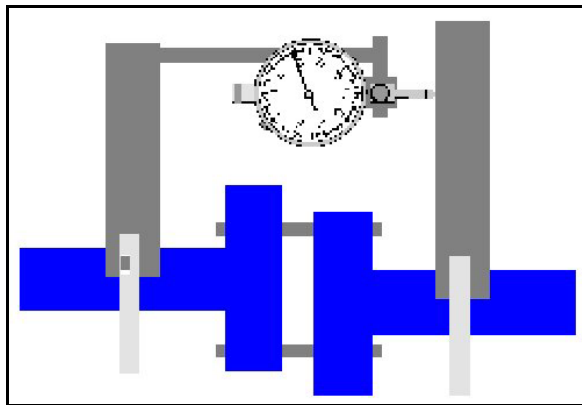


Figure 16. Coupled shafts, face dial.

Mounting Rim-Face Fixtures

Fixture mounting procedures are obviously dependent on the specific type of hardware being used. Generally, to mount the fixtures follow these steps:

1. With the coupling broken, mount a fixture bracket to the stationary shaft or coupling hub as illustrated in Figure 17.

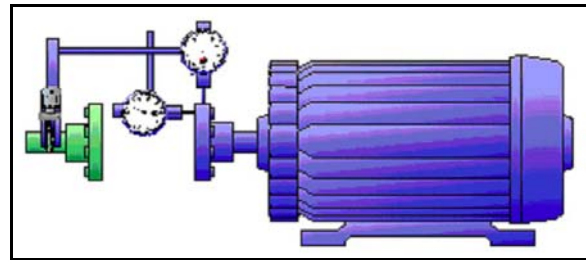


Figure 17. Mounting fixtures.

2. Span the coupling from the mounted bracket with an indicator support rod.
3. Rotate the fixture to 12:00.
4. Attach a face dial indicator with the plunger centered for equal positive and negative travel.
5. Attach a rim dial indicator with the plunger centered for equal positive and negative travel.

Fixture Mounting Precautions

Regardless of the specific hardware being used, the following precautions should be observed.

- Never attach the fixture to the flexible portion of the coupling.
- Maximize the sweep distance of the face dial indicator for the geometry of the machine being aligned. If the face dial contacts the coupling face directly, ensure that the plunger of the indicator contacts the coupling near its outer edge.
- Ensure fixtures are mounted at a position where rotation is possible. It is desirable to have 360 degrees of rotation.
- Before obtaining alignment measurements, determine dial indicator bar sag of the rim dial indicator and ensure that dial indicator readings are valid and repeatable.

Rim-Face Dimensions

To accurately determine the position of the movable shaft using rim-face calculations or graphing procedures, the diameter of face dial indicator travel and the relative position of the rim dial indicator and the front and rear feet of the movable machine must be determined.

These dimensions should be determined using a standard tape measure. Each dimension should be measured to the nearest 1/8".

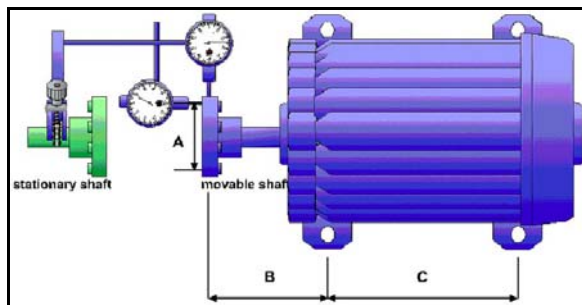


Figure 18. Rim-face dimensions.

The “A” Dimension

The “A” dimension is the diameter of the face dial indicator travel. When reading directly on the coupling face, the “A” dimension should be slightly less than the coupling diameter. This is the most critical dimension and should be measured very carefully. As mentioned earlier, when setting up fixtures for rim-face alignment, care should be exercised to maximize the circle diameter of the face dial travel based on the machine geometry and space available.

The “B” Dimension

The “B” dimension is the distance from the rim dial indicator to the front foot bolt center. This dimension is measured parallel to the shafts. Especially on larger machines, it is sometimes helpful to use a string or straight edge to transfer the position of the rim dial plunger to the machine base, before measuring this dimension.

The “C” Dimension

The “C” Dimension is the distance between front and rear foot bolt centers. This dimension is measured parallel to the shaft.

Rim-Face Alignment Procedure

Measurement Process Overview

The rim-face dial measurement process consists of the following procedures:

- Measuring and documenting as-found misalignment conditions.
- Measuring vertical misalignment conditions.
- Measuring horizontal misalignment conditions.

Obtaining a set of as-found readings is considered optional in some facilities, but is highly recommended here. For most alignment tasks, it is desirable to obtain and document a complete set of as-found readings along with the A, B, and C dimensions. The as-found readings are used for a variety of purposes:

- Documenting alignment conditions before removing equipment from service for repair.
- Determining whether suspected misalignment is realistic or not.
- Supporting and justifying actions taken to equipment suppliers, vendors, and manufacturers.
- Maintenance of equipment history files.
- Better communication between different personnel involved with the alignment task.

Obtaining As-found Readings

To obtain a complete set of as-found readings, perform the steps below:

1. Rotate the dial indicators to 12:00.
2. Set the rim dial indicator to the positive sag value.
3. Set the face dial indicator to zero.
4. Record the setting of both dials at 12:00.
5. Rotate the dial indicators to 3:00.
6. Determine and record the reading on both dials.
7. Rotate the dial indicators to 6:00.
8. Determine and record the reading on both dials.
9. Rotate the dial indicators to 9:00.
10. Determine and record the reading on both dials.
11. Rotate the dials to 12:00 and ensure that both dials return to their original setting.

To document as-found results, use a format similar to that shown below. Note that “DIF” stands for Dial Indicator on the Face and “DIR” stands for Dial Indicator on the Rim.



Figure 19. Documenting as found readings.

Measuring Vertical Misalignment

To measure vertical misalignment, perform the following steps:

1. Rotate the dial indicators to 6:00.

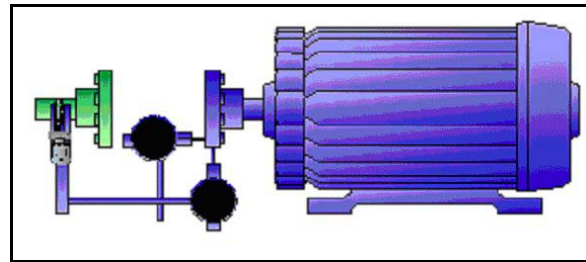


Figure 20. Measuring vertical misalignment, 6:00.

2. Measure vertical misalignment, 6:00.
3. Set the face dial indicator to read zero.
4. Set the rim dial indicator to the sag value. For example, if the amount of sag for the rim dial fixture is determined to be -9 mils, the dial would be set to read - 9 at the 6:00 position.

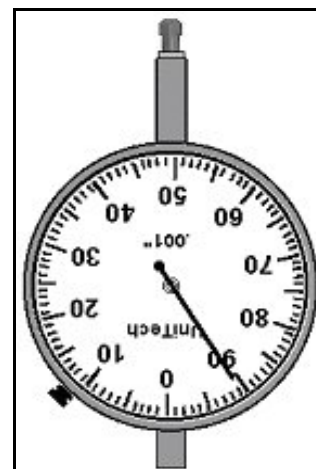


Figure 21. Setting the sag value.

5. Rotate both shafts (if possible) to 12:00.

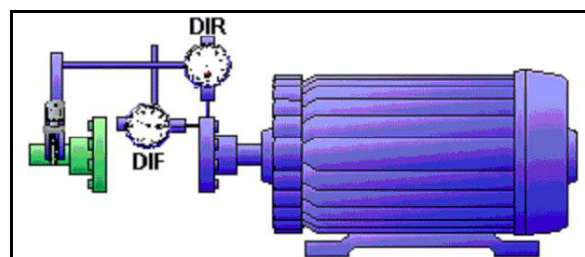


Figure 22. Measuring vertical misalignment, 12:00.

- Record the DIR and DIF dial indicator TIR values.

Interpreting Vertical Misalignment Data

To determine offset and angularity from the 12:00 TIR's, use the following rules:

$$\text{Coupling Offset} = \frac{\text{Rim Dial (DIR) TIR}}{2}$$

$$\text{Shaft Angularity} = \frac{\text{Face Dial (DIF) TIR}}{A}$$

Example: Consider the following rim-face 12:00 total indicator readings (TIR's).

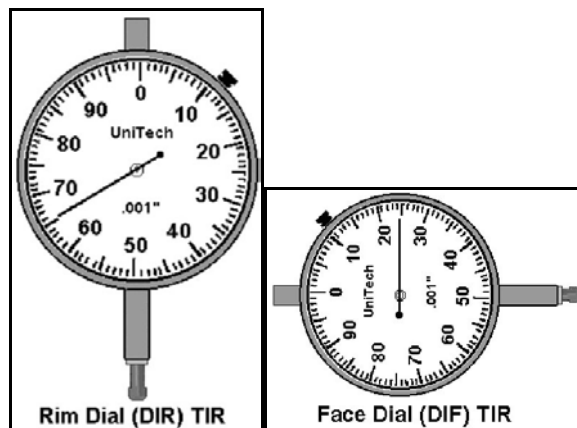


Figure 23. Example, TIR readings.

- The rim dial TIR is -34 mils (-0.864 mm). The shaft coupling offset is -17 mils (-0.432 mm), or 17 mils low.
- The face dial TIR is +24 mils (+0.610 mm). Given the A dimension of 4 inches (101.6 mm), the vertical angularity would be +24 mils / 4" (0.006 mm / mm) = 6.0 mils per inch (0.6 mm / 100 mm).

Measuring Horizontal Misalignment

A major precaution for measurement and interpretation of horizontal misalignment data is the establishment of the direction of view. For this training, all clock positions are referenced from the viewpoint shown below,

standing behind the movable machine facing the stationary machine.

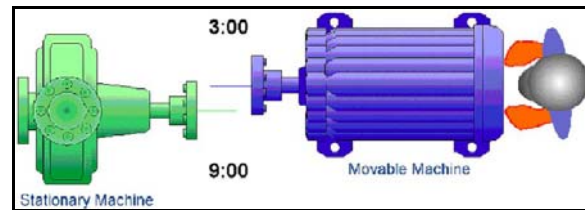


Figure 24. Measuring horizontal misalignment.

To measure horizontal misalignment, perform the following steps:

- Rotate the dial indicators to 9:00.

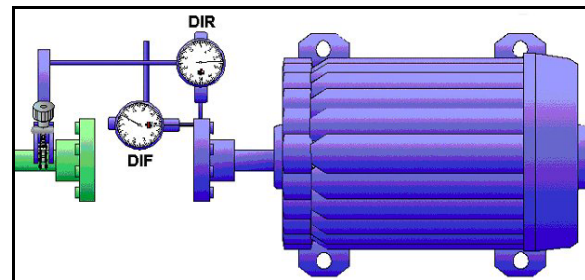


Figure 25. Measuring horizontal misalignment, 9 o'clock.

- Set both dial indicators to zero.
- Rotate both shafts to 3:00.

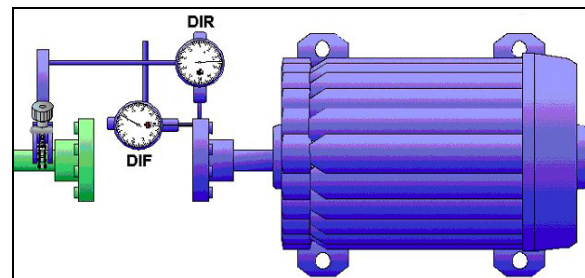


Figure 26. Measuring horizontal misalignment, 3 o'clock.

- Record the DIF and DIR dial indicator TIR values.

Interpreting Horizontal Misalignment Data

To determine offset and angularity from the 3:00 TIR's, use the following rules:

$$\text{Coupling Offset} = \frac{\text{Rim Dial (DIR) TIR}}{2}$$

$$\text{Shaft Angularity} = \frac{\text{Face Dial (DIF) TIR}}{A}$$

Example: Consider the following rim-face 3:00 total indicator readings (TIR's).

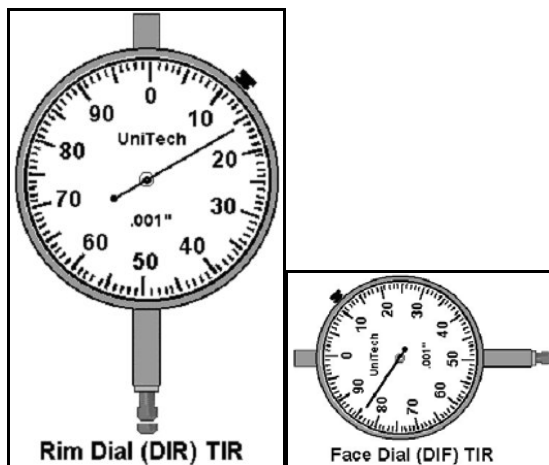


Figure 27. Example, horizontal TIR readings.

1. The rim dial TIR is +16 mils (+0.406 mm). The coupling offset is +8 mils (+0.203 mm), or 8 mils to the right.
2. The face dial TIR is -16 mils (-0.406 mm). Given an A dimension of 4 inches (101.6 mm), the horizontal angularity would be -16 mils / 4" (-0.004 mm / mm) = -4.0 mils per inch (-0.4 mm / 100mm).

Rim-Face Calculations

Many different equations may be used for various rim-face calculations. The information presented here applies to a rim-face dial setup. The equations presented are used to calculate the position of the movable machine's front and rear feet from DIR offset value, and the

shaft angularity as determined from the face dial indicator (DIF).

Calculations apply to both the vertical and horizontal planes of misalignment. However, they are typically applied primarily to the vertical plane. Correcting misalignment in the horizontal plane may be accomplished without calculating or graphing the exact front and rear feet positions.

Calculating the Front Feet and Rear Feet Positions

The position of the movable machine's front feet is determined using the equation:

$$\left(\frac{\text{Face TIR}}{A} \times B \right) + 1/2 \text{ Rim TIR}$$

The position of the movable machine's rear feet is determined using the equation:

$$\left(\frac{\text{Face TIR}}{A} \times (B + C) \right) + 1/2 \text{ Rim TIR}$$

Where:

- Face TIR = Total Indicator Reading from the face dial
- Rim TIR = Total Indicator Reading from the rim dial
- A = the diameter of the face dial indicator
- B = the distance from the rim dial indicator plunger to the movable machine's front feet bolt center
- C = the distance between the movable machine's front and rear feet bolt centers

Positive values mean the foot is too high (vertical) or too far to the right (horizontal)

Negative values mean the foot is too low (vertical) or too far to the left (horizontal)

Rim-Face Calculation Examples

Assume the vertical misalignment data:

- The rim dial (DIR) 12:00 TIR is +24 mils (+0.610 mm).
- The face dial (DIF) 12:00 TIR is +12 mils (+0.305 mm).
- A = 6 inches (152.4 mm)
- B = 7 inches (177.8 mm)
- C = 24 inches (609.6 mm)

Front foot position calculation:

$$\left(\frac{\text{Face TIR}}{A} \times B \right) + 1/2 \text{ Rim TIR}$$

$$\left(\frac{+12 \text{ mils}}{6''} \times 7'' \right) + 1/2(+24 \text{ mils}) = +26 \text{ mils}$$

$$\left(\frac{0.305 \text{ mm}}{152.4 \text{ mm}} \times 177.8 \text{ mm} \right) + \frac{1}{2} (+0.610 \text{ mm}) = 0.66 \text{ mm}$$

The front feet are 26 mils (0.66 mm) too high; shims need to be removed.

Rear foot position calculation:

$$\left(\frac{\text{Face TIR}}{A} \times (B + C) \right) + 1/2 \text{ Rim TIR}$$

$$\left(\frac{+12 \text{ mils}}{6''} \times (7'' + 24'') \right) + 1/2(+24 \text{ mils}) = +74 \text{ mils}$$

$$\left(\frac{0.305 \text{ mm}}{152.4 \text{ mm}} \times (177.8 + 609.6) \text{ mm} \right) + \frac{1}{2} (+0.610 \text{ mm}) = 1.88 \text{ mm}$$

The rear feet are 74.0 mils (1.88 mm) too high; shims need to be removed.

Rim-Face Calculation Precautions

1. Ensure that the rim and face dial indicator TIR's are properly determined from the dials before performing calculations.
2. Be careful NOT to make mathematical errors when subtracting signed numbers.
3. Observe parentheses in the equations. Perform operations inside parenthesis first.
4. Do NOT make human errors substituting real values into the equations.
5. Ensure that the A, B, and C dimensions are accurate and are properly entered into the equations.

Rim-Face Graphing

One way to determine the position of the movable machine's front and rear feet from DIR and DIF TIR values is to perform rim-face calculations. Another way is to construct a scaled graph. The main advantage of graphing methods is that the shaft centerlines and misalignment conditions are represented visually. The information presented here applies to a rim-face dial setup where both dial indicators are attached at the same location around the circumference.

Graphing procedures may be applied to both the vertical and horizontal planes of misalignment. However, they are typically applied primarily to the vertical plane. Misalignment determination in the horizontal plane may be accomplished without calculating or graphing the exact front and rear feet positions.

Setting Up the Graph

To construct a scaled rim-face graph, perform the following steps:

1. Obtain graph paper with 10 divisions between bold lines.
2. Turn the graph paper so that the long side is horizontal.
3. Draw a horizontal line at the center of the page. This line represents the stationary shaft center. It is helpful if this line is on top of one of the bold lines.
4. Determine the horizontal plotting scale. Always use the largest scale possible. Measure the distance from the stationary

- indicator plunger to the centerline of the rear feet of the movable machine. Standard graph paper is about 10 inches across. The largest horizontal scale will be the machine distance divided by the page width. Note your horizontal scale.
5. Make a vertical line on the extreme left of the movable machine. This mark represents the point where the rim dial indicator contacts the shaft or coupling hub and is labeled: DIR.
 6. Make a second vertical line representing the point along the shaft length of the front feet of the movable machine (FF).
 7. Make a third vertical line representing the point along the shaft length of the rear feet of the movable machine (RF).
- Upon completion of the steps above, the graph looks similar to the one shown below. For this example, the B and C dimensions both equal 10 inches.

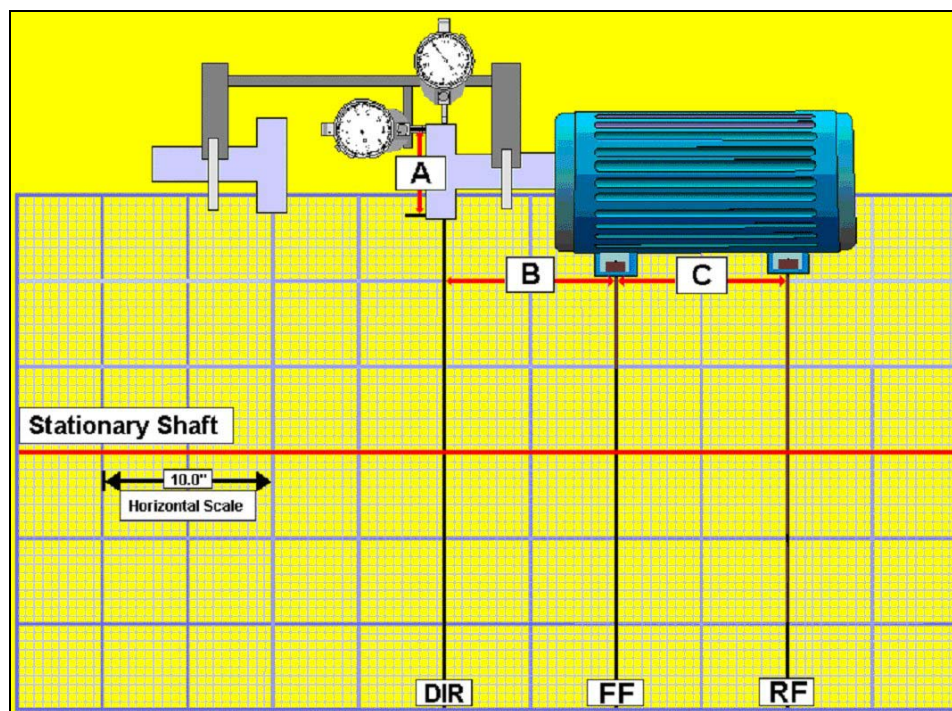


Figure 28. Setting up the graph.

Plotting Offsets

After setting up the graph, the next step is to plot two offset points. One is the offset measured in the plane of the rim dial indicator (DIR). The other offset point is derived from the face dial indicator (DIF) reading and the “A” dimension. To plot the offsets, perform the following steps:

- Determine the vertical scale. The vertical scale is typically 1 mil (0.001”) per division. In cases of gross misalignment

where the offsets will not fit on the page, a larger scale, such as 2-3 mils per division, is sometimes required.

- Plot the offset from the rim dial indicator on line DIR.
- Use the horizontal line representing the stationary shaft centerline as the reference. All points above this horizontal line are positive (+) and all points below the line are negative (-).

- Ensure you divide the rim dial TIR by two to obtain an offset value.
- Plot the second offset point using the shaft slope (Face TIR / “A” dimension).
- Plot this point counting from the DIR offset point!

In the example below, the DIR offset is -10 mils and the shaft slope is +4 mils over an A dimension of 5”.

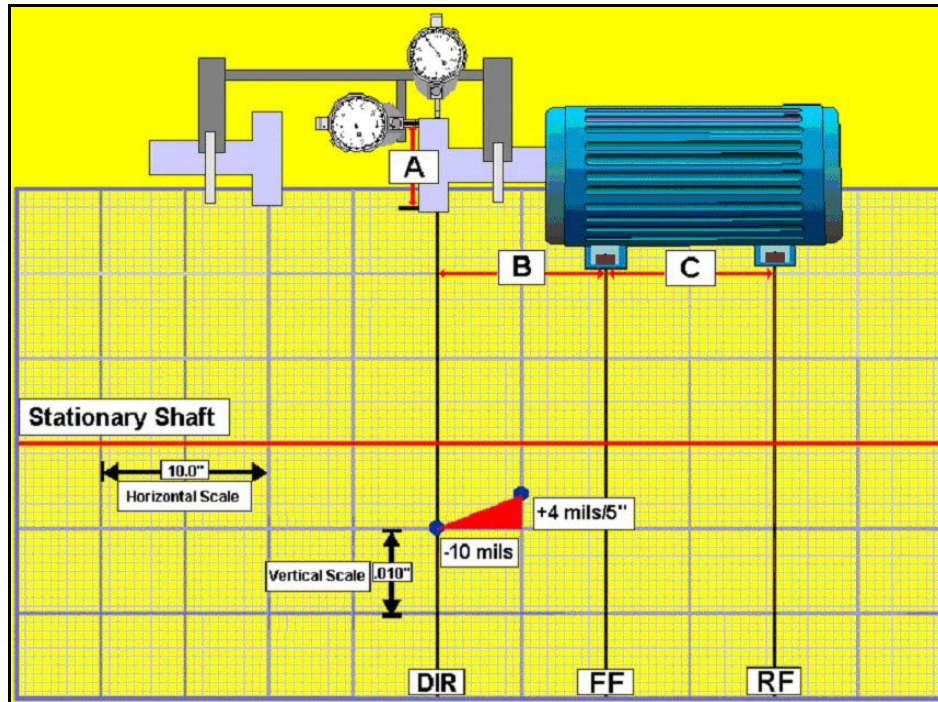


Figure 29. Plotting.

Determining Movable Shaft Position

After plotting the two points, to determine the movable shaft position perform the following steps:

1. Using a ruler or straightedge, draw a line through the two offset points that extends to the rear feet of the movable machine.

2. Count the number of squares in the plane of the front and rear feet to determine the position and corrections needed.

In the example below, the front feet of the machine are 2 mils low; shims need to be added. The rear feet are positioned 6 mils too high; shims need to be removed from both rear feet.

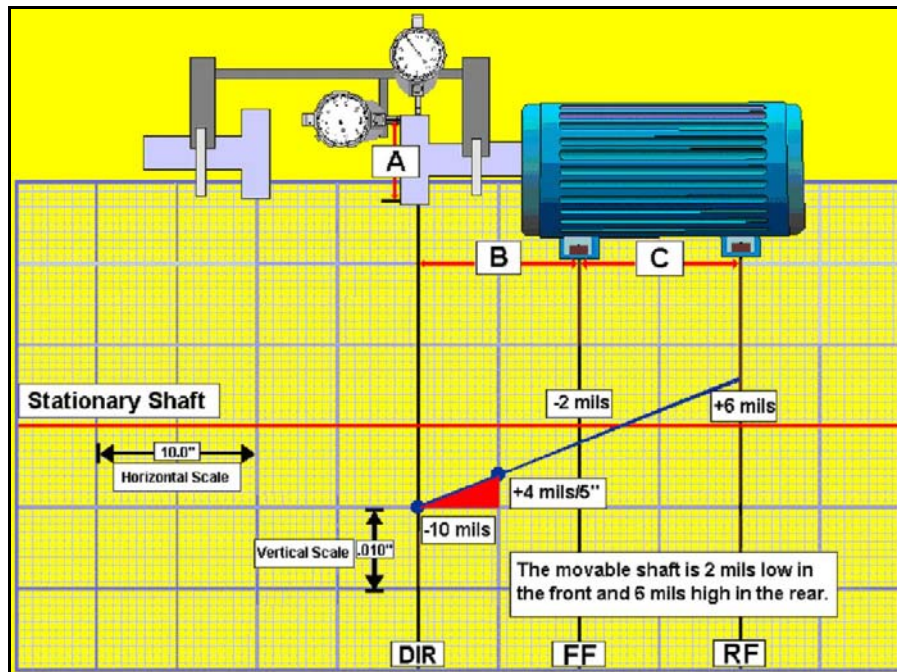


Figure 30. Graph, feet positions.

Rim-Face Graphing Precautions

1. Ensure that proper horizontal and vertical scaling techniques are consistently used.
2. Always double-check the position of vertical lines drawn to represent the DIR, FF, and RF.
3. Ensure that the two plot points are properly determined from TIR's.
4. Ensure that positive offsets are plotted above the horizontal reference line and negative offsets are plotted below the line.
5. When interpreting the graph to determine the movable shaft's front and rear feet positions in the vertical plane, observe the following rules:
 - If the movable shaft is above the horizontal stationary shaft reference line, the shaft is too high.
6. When interpreting the graph to determine the movable shaft's front and rear feet positions in the horizontal plane, view the graph the way you view the machine, that is, standing behind the movable machine facing the stationary machine. Observe the following rules:
 - If the movable shaft is above the horizontal stationary shaft reference line, the shaft is positioned to the right.
 - If the movable shaft is below the horizontal stationary shaft reference line, the shaft is positioned to the left.

Rim-Face Corrections

Correction Process Overview

To correct misalignment involves a number of different procedures. The sequence of steps in a correction process varies slightly

according to the specific alignment conditions of the machine. Before correcting misalignment, the following procedures are to be performed:

- Perform pre-alignment checks and corrections.
- Setup the rim-face fixtures.
- Correct soft foot.
- Measure misalignment.
- Determine alignment tolerances.
- Compare alignment conditions to specified tolerances.

After correcting misalignment, the following procedures are to be performed.

- Re-measure alignment conditions.
- Compare alignment conditions to specified tolerances.

- Document final results.

When it comes to actually moving the machine, that is, *solving the problem*, several questions are often asked:

- Do I start with the vertical or horizontal plane?
- What about use of precut shims?
- Should I take a new set of readings after moving vertically or horizontally?
- Do I need to use dial indicators to monitor the horizontal moves?

The Sequence of Corrections

Correcting misalignment involves initial and final corrections. Initial corrections are made to minimize the amounts of misalignment and improve the accuracy of alignment measurements. Before making any moves, look at the horizontal and vertical positions of the movable machine. In general, you will start the correction process by making initial corrections in the plane where the misalignment is worse.

Making Corrections	If	Then
Both vertical and horizontal front and rear feet	Misalignment is 0.025" or less	• Make final vertical corrections. • Make final horizontal corrections.
Both vertical and horizontal front and rear feet	Misalignment is greater than 0.025"	• Make initial vertical and horizontal corrections. • Make final vertical corrections. • Make final horizontal corrections.
Either vertical or horizontal front and rear feet	Misalignment is greater than 0.025"	• Make initial vertical or horizontal corrections. • Make final vertical corrections. • Make final horizontal corrections.

Consider the following sets of data:

- Front feet vertical position: +8 mils
- Rear feet vertical position: +24 mils
- Front feet horizontal position: -15 mils
- Rear feet horizontal position: -52 mils

In this example, the horizontal misalignment is over twice the vertical misalignment. Therefore, an initial horizontal adjustment will be made, then, final vertical and horizontal corrections will be made.

Making Vertical Corrections

Determine the vertical position of the movable machine using calculation and/or graphing techniques.

Positive values at the feet mean that the movable machine is too high; you should remove shims.

Negative values mean that the movable machine is low, so shims should be added.

Vertical correction tips:

1. Make shim changes to both front feet and both rear feet as needed.
2. Always check shim thickness with an outside micrometer. Precut shims are not always what they are marked; many shim manufacturers designate shims with the “nominal” thickness.
3. Use consistent and correct torquing procedures.
4. As shim changes are made, check for and take precautions to avoid creating soft foot conditions.

Making Horizontal Corrections

When using the rim-face method, two different procedures are commonly used for horizontal corrections:

1. Determining the corrections using calculation or graphing techniques, followed by monitoring movement, using dial indicators positioned at the machine’s feet.
2. Monitoring movement, using dial indicators mounted at the coupling.

Dial indicators at the machine’s feet

To correct horizontal misalignment by monitoring movement at the movable machine’s feet, perform the following steps:

1. Measure horizontal misalignment.
2. Determine the horizontal position of the movable machine using calculation or graphing.
3. Ensure that you are standing with the movable machine on your right and the stationary machine on your left. Positive values at the feet mean that the movable machine is away from you; it should be moved towards yourself. Negative values at the feet mean that the movable machine is towards you; it should be moved away from yourself.
4. Position dial indicators at the front and rear feet.
5. Move front and rear feet the amounts needed while watching the dial indicators.

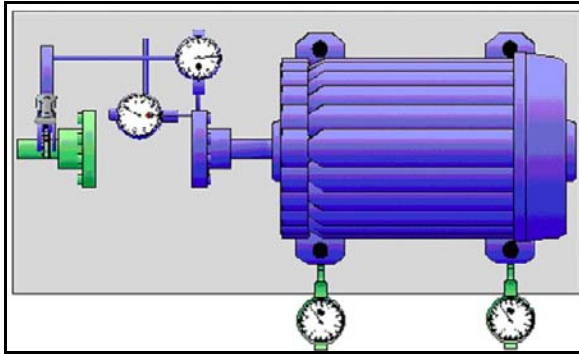


Figure 31. Horizontal corrections. Dial indicator at the feet.

Dial indicators at the coupling

To correct horizontal misalignment by using dial indicators mounted at the coupling, perform the following steps:

1. Rotate the dial indicators to 9:00 and zero them.
2. Rotate shafts to 3:00.
3. Adjust the dial indicators to one-half their values.
4. Move the front feet of the movable machine as you watch the rim dial indicator move to zero.
5. Move the rear feet of the movable machine as you watch the face dial indicator move to zero.
6. Repeat steps 4 & 5 until both dial indicators read zero.

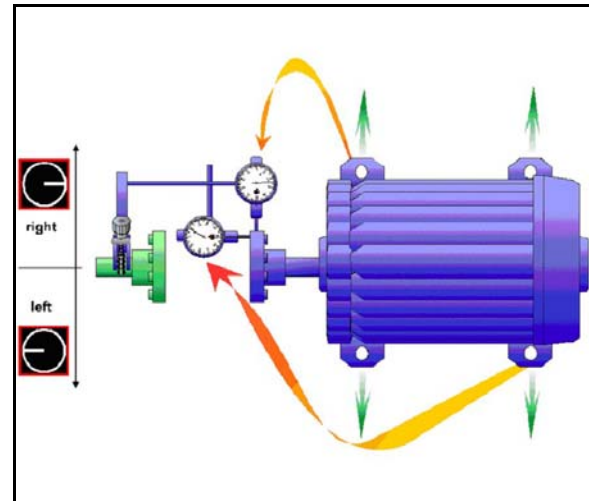


Figure 32. Horizontal corrections. Monitoring dial indicators mounted at the coupling.

Horizontal correction tips:

1. Start making moves at the feet where the misalignment is greatest.
2. If not already present, install jack bolts wherever possible.
3. Bring the front and rear feet into alignment together; they are a team.
4. When the feet are within 2 mils, start torquing and watch the dial indicators. Use the proper criss-cross torquing sequence.

After Making Vertical and Horizontal Corrections

After making final vertical and horizontal corrections, you should:

1. Obtain new measurements.
2. Compare results to specified tolerances.
3. Repeat corrections until results are within tolerances.
4. Obtain and document a final set of measurements.

5. Restore equipment in accordance with procedures at your facility.

Reverse-Rim Alignment Method

Reverse-Rim Alignment Overview

The reverse-rim method is widely acknowledged as the “preferred method” of shaft alignment.

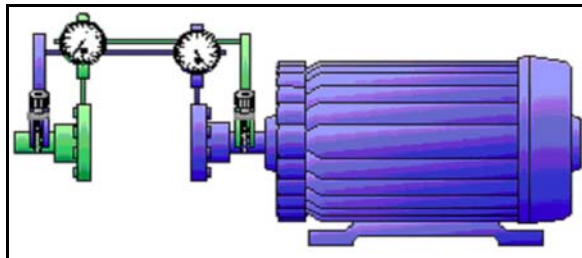


Figure 33. Reverse-rim alignment method.

Two rim dial indicators are used to measure the relative position of the movable shaft with respect to the stationary shaft at two planes along their length.

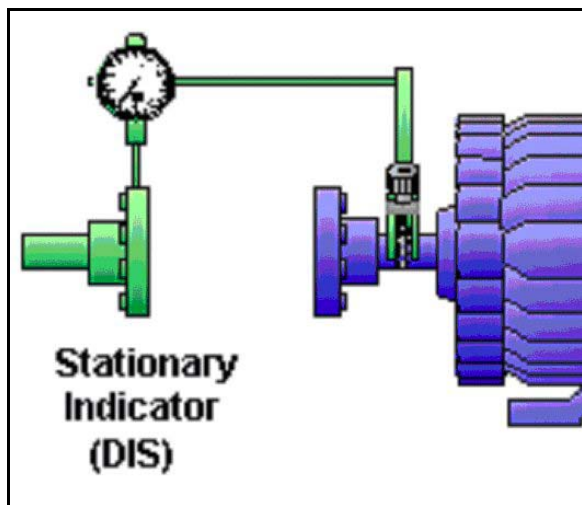


Figure 34. The stationary indicator (DIS) measures offset in a plane along the stationary shaft or hub.

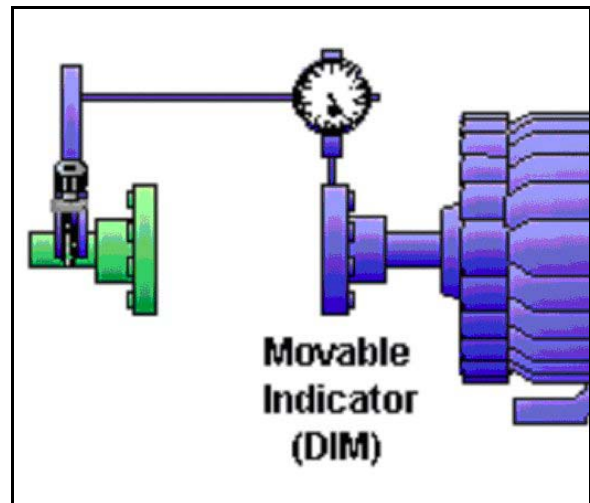


Figure 35. The movable indicator (DIM) measures offset in a plane along the movable shaft or hub.

Using two offset readings along with fixture setup and machine dimensions, the relative position of the movable shaft is determined by performing calculations or by graphing.

Comparison Rim-Face Dial Method

When the rim-face method is used on machines which shafts have axial end float greater than about 0.001”, and especially on machines with plain bearings, errors are introduced into the face reading. Since the reverse-rim method requires no face readings, measurement errors that occur when using a rim-face setup due to shaft end float are eliminated.

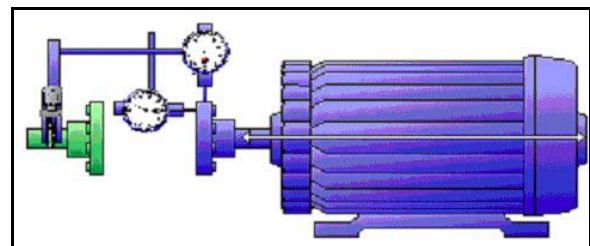


Figure 36. Comparison to rim-face method; errors due to shaft end float are eliminated.

Reverse-Rim Fixture

A variety of shaft alignment fixtures are available for performing reverse-rim alignment. Selection and use of a commercial package designed to accommodate a variety of shaft diameters is recommended. The fixtures should include an assortment of rods to span various coupling lengths. These packages expedite the precision alignment process. In addition, sag values can be pre-determined for the standard rod assortment.

While some fixtures are designed to permit reverse-rim alignment with the shafts uncoupled, others require that the shafts be coupled during the alignment process.

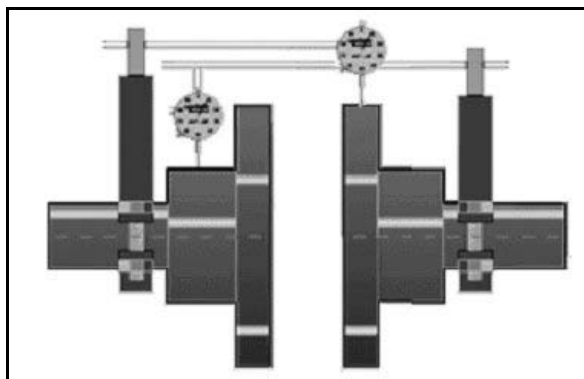


Figure 37. Fixtures, uncoupled shafts.

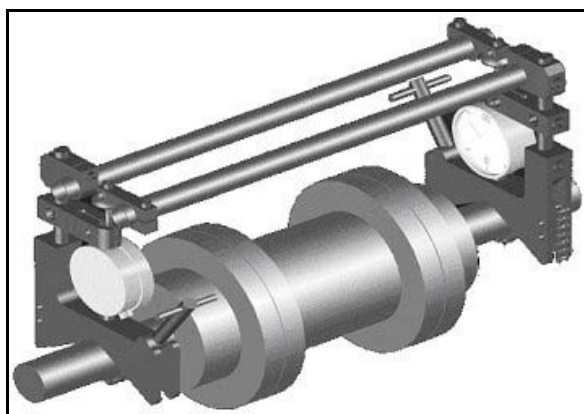


Figure 38. Fixtures, coupled shafts.

Many fixtures accommodate reverse-rim alignment with the indicators mounted either

at the same location along the shaft circumference (as shown above), or 180 degrees opposite one another, that is, in a cross dial arrangement.

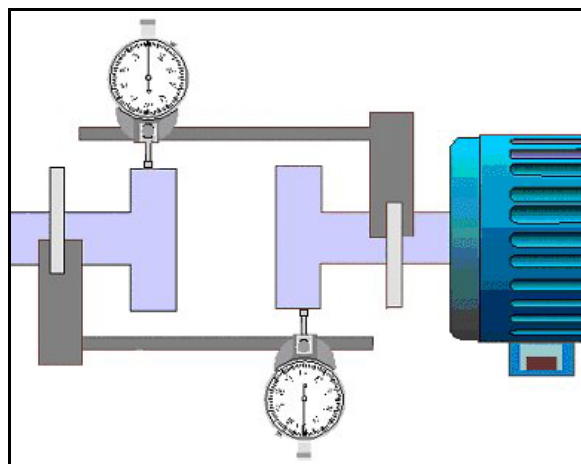


Figure 39. Fixtures mounted opposite one another.

Mounting Reverse-Rim Fixtures

Fixture mounting procedures are obviously dependent on the specific type of hardware being used.

To mount the fixtures follow these steps:

1. With the coupling assembled, mount the brackets to the shafts or coupling hubs as illustrated below.

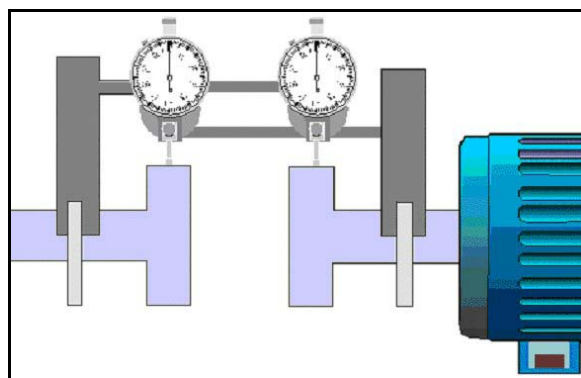


Figure 40. Fixture mounting.

2. Span the coupling from each bracket with rods.

3. Rotate the brackets to 12:00.
4. Attach the dial indicators with the plungers centered for equal positive and negative travel.

Regardless of the specific hardware being used, the following precautions should be observed.

- Never attach the fixture to the flexible portion of the coupling.
- Maximize the distance between the dial indicators for the geometry of the machine being aligned. As a general rule, the plungers should be positioned at least 4" apart.
- Ensure that fixtures are mounted at a position where rotation is possible. It is desirable to have 360 degrees of rotation.
- Before obtaining alignment measurements, determine dial indicator bar sag and ensure that dial indicator readings are valid and repeatable.

Reverse-Rim Dimensions

To accurately determine the position of the movable shaft using reverse-rim calculations or graphing procedures, the relative position of the dial indicators and the front and rear feet of the movable machine must be determined.

These dimensions should be determined using a standard tape measure. Each dimension should be measured to the nearest 1/8".

The "A" Dimension

The "A" dimension is the distance between indicator plungers. The "A" dimension is measured parallel to the shafts. This is the most critical dimension and should be measured very carefully. As mentioned

earlier, when setting up fixtures for reverse-rim alignment, care should be exercised to maximize the distance between the indicator plungers based on the machine geometry and space available.

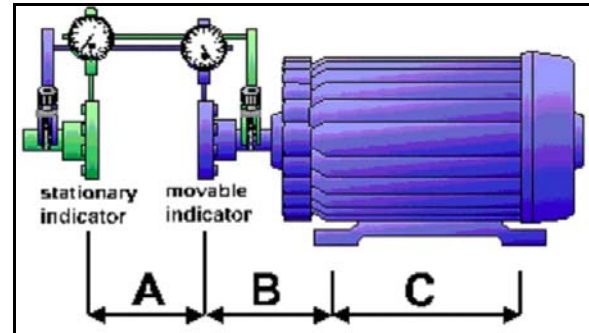


Figure 41. Reverse-rim dimensions.

The "B" Dimension

The "B" dimension is the distance from the movable side indicator to the front foot bolt center. This dimension is measured parallel to the shafts. Especially on larger machines, it is sometimes helpful to use a string or straight edge to transfer the position of the movable dial plunger to the machine base before measuring this dimension.

The "C" Dimension

The "C" dimension is the distance between front and rear foot bolt centers. This dimension is measured parallel to the shaft.

Reverse-Rim Signs

When doing a reverse-rim measurement, it is important to know that different setups affect the sign of the readings differently. This effect is caused by the fact that both dial indicators have the same plus/minus direction and are mounted, as the name of the method indicates, in reverse.

The effects of different set ups are:

- The setup does not affect the sign of the dial indicator readings (horizontally and vertically).

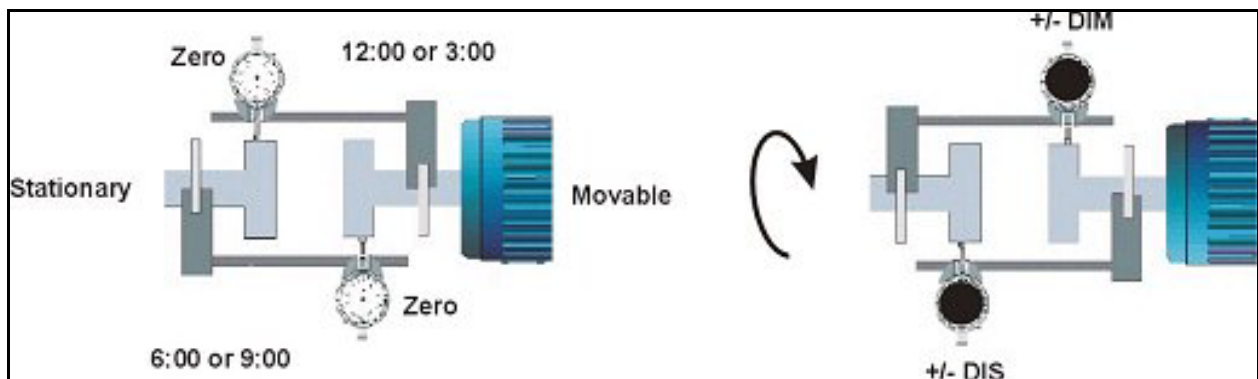


Figure 42. No effect on the signs.

- When using the setup in the next figure and zeroing at 12:00 or 3:00 the sign of the movable dial indicator value DIM has to be reversed.
- When using the same setup but instead zeroing at 6:00 or 9:00 the sign of the stationary dial indicator value (DIS) has to be reversed.

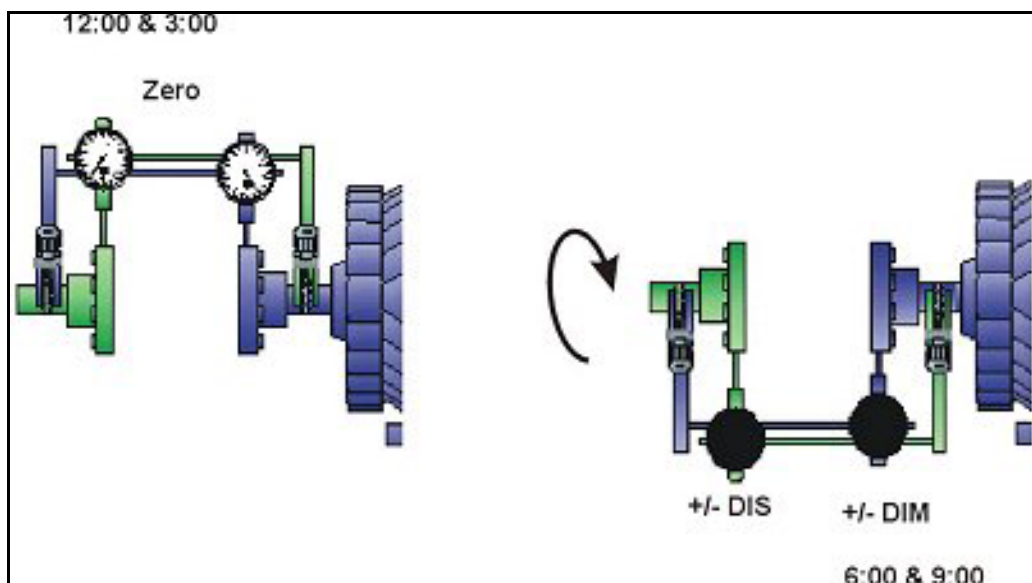


Figure 43. Zeroing at 12:00 or 3:00, change the sign of DIM. Zeroing at 6:00 or 9:00, change the sign of DIS.

The following measuring procedures describe both situations in the setup shown in Figure 43.

Reverse-Rim Alignment Procedure

Measurement Process Overview

The reverse-rim dial measurement process consists of the following steps:

- Measuring and documenting as-found misalignment conditions.
- Measuring vertical and horizontal misalignment conditions.

Obtaining a set of as-found readings is considered optional in some facilities, but is highly recommended here. For most alignment tasks, it is desirable to obtain and document a complete set of as-found readings along with the A, B, and C

dimensions. As-found readings are used for a variety of purposes:

- Documenting alignment conditions before removing equipment from service for repair.
- Determining whether suspected misalignment is realistic or not.
- Supporting and justifying actions taken to equipment suppliers, vendors, and manufacturers.
- Maintenance of equipment history files.
- Better communication between different personnel involved with the alignment task.

Obtaining As-found Readings

To obtain a complete set of as-found readings, perform the steps below:

1. Rotate the dial indicators to 12:00.
2. Set both dials to the positive sag value.
3. Record the setting of both dials at 12:00.
4. Rotate the dial indicators to 3:00.
5. Determine and record the reading on both dials.
6. Rotate the dial indicators to 6:00.
7. Determine and record the reading on both dials.
8. Rotate the dial indicators to 9:00.
9. Determine and record the reading on both dials.
10. Rotate the dials to 12:00 and ensure that both dials return to their original settings.

To document as-found results, use a format similar as the one shown below.



Figure 44. Documenting as-found readings.

Measuring Vertical Misalignment

To measure vertical misalignment, perform the following steps:

- Rotate the dial indicators to 12:00.

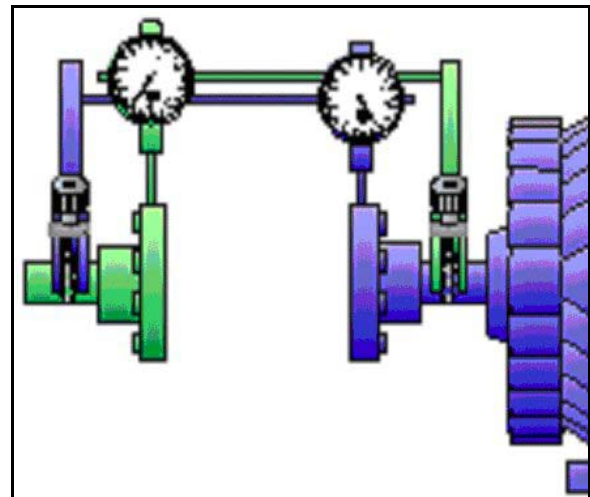


Figure 45. Rotate the dial indicators to 12:00.

- Set both dial indicators to the positive sag value. For example, if the amount of sag for a fixture is determined to be -10 mils (-0.254 mm), the dial would be set to read +10 mils (+0.254 mm) at the 12:00 position.

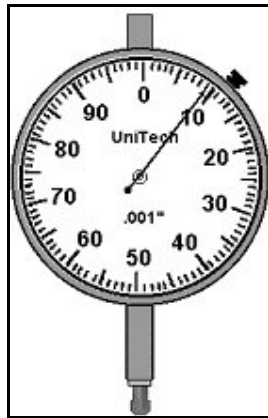


Figure 46. Set dial indicator to positive sag value.

- Rotate both shafts (if possible) to 6:00.

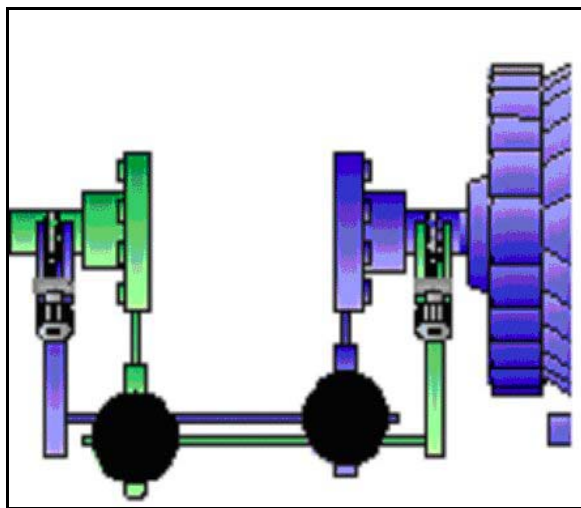


Figure 47. Rotate both shafts to 6:00.

- Record the DIS and DIM dial indicator TIR values.

Interpreting Vertical Misalignment Data

To determine vertical offset from 6:00 TIR's, use the following rules:

- Stationary side offset = DIS TIR / 2
- Movable side offset = DIM TIR / 2 and reverse the sign (+ to -) or (- to +)
- Coupling centerline offset = (stationary side offset + movable side offset) / 2

To determine vertical angularity from the two reverse-rim offsets, use the rule:

$$\text{Shaft Angularity} = \frac{(\text{Movable Side Offset} - \text{Stationary Side Offset})}{A \text{ Dimension}}$$

Example. Consider the following reverse-rim 6:00 total indicator readings (TIR's).

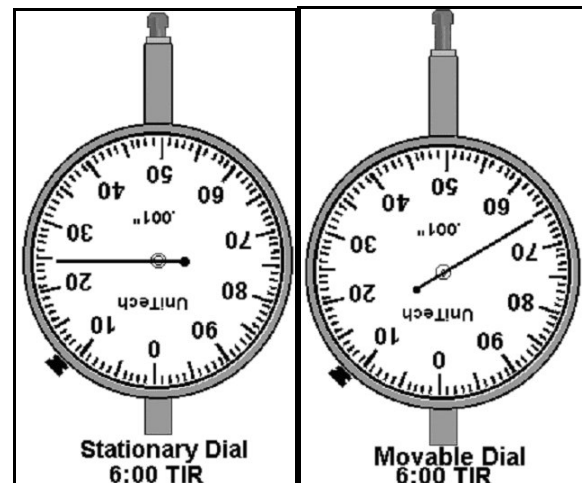


Figure 48. Example dial indicators.

1. The stationary dial TIR is +24 mils (0.610 mm). The stationary side offset is +12 mils, or 12 mils high (0.305 mm).
2. The movable dial TIR is -35 mils (-0.889 mm). The stationary offset is +17.5 mils, or 17.5 mils high (0.444 mm). (Remember, you have to change the sign of the DIM reading to determine offset.)
3. Vertical offset at the coupling centerline is $(+12 + 17.5) / 2 = +14.75$ mils, or 14.75 mils high (0.375 mm).
4. Given an A dimension of 8 inches (203.2 mm), the vertical angularity would be $(17.5 - 12) / 8 = +0.69$ mils per inch $((0.444 - 0.305) / 203.2 = 0.00069$ mm / 100 mm).

Measuring Horizontal Misalignment

A major precaution for the measurement and interpretation of horizontal misalignment data is the establishment of the direction of view. All clock positions are referenced from the viewpoint shown below; standing behind the movable machine facing the stationary machine.

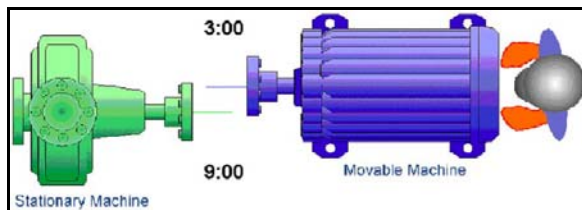


Figure 49. Measuring horizontal misalignment

To measure horizontal misalignment, perform the following steps:

1. Rotate the dial indicators to 9:00.

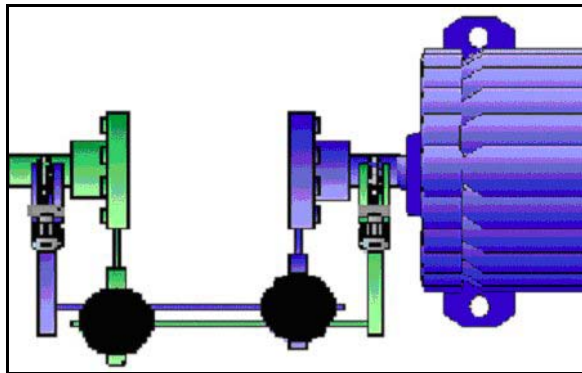


Figure 50. Rotate dial indicators to 9:00.

2. Set both dial indicators to zero.
3. Rotate both shafts to 3:00.
4. Record the DIS and DIM dial indicator TIR values.

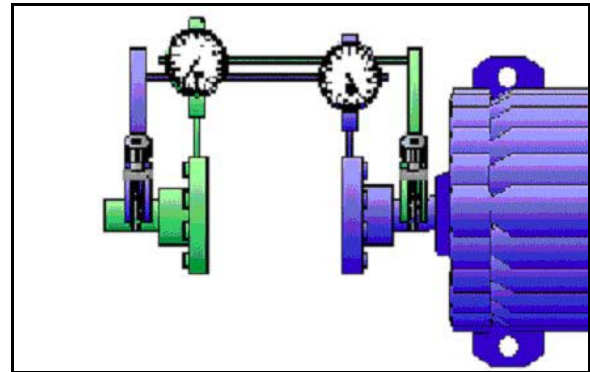


Figure 51. Rotate both shafts to 3:00.

Interpreting Horizontal Misalignment Data

To determine horizontal offset from 3:00 TIR's, use the following rules:

- Stationary side offset = DIS TIR / 2 and reverse the sign (+ to -) or (- to +)
- Movable side offset = DIM TIR / 2
- Coupling centerline offset = (stationary side offset + movable side offset) / 2.

To determine horizontal angularity from the two reverse-rim offsets, use the rule:

$$\text{Shaft Angularity} = \frac{(\text{Movable Side Offset} - \text{Stationary Side Offset})}{A \text{ Dimension}}$$

Example. Consider the following reverse-rim 3:00 total indicator readings (TIR's).

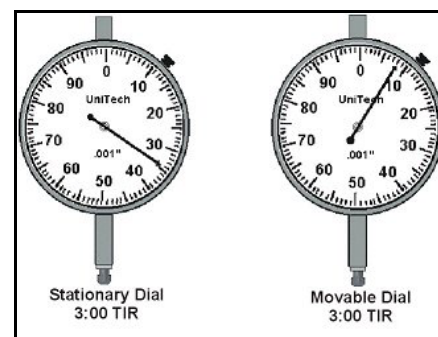


Figure 52. Clock readings at 3:00.

1. The stationary dial TIR is +34 mils. The stationary side offset is -17 mils, or 17 mils to the left. (Remember, you have to change the sign of the DIS reading to determine offset).
2. The movable dial TIR is +8 mils. The movable side offset is +4 mils, or 4 mils to the right.
3. Vertical offset at the coupling centerline is $(-7 + -4) / 2 = -6.5$ mils, or 6.5 mils to the left.
4. Given an A dimension of 8 inches, the horizontal angularity is $(4 - (-17)) / 8 = 2.63$ mils per inch.

Reverse-Rim Calculations

Many different equations may be used for various reverse-rim calculations. The information presented here applies to a reverse-rim dial setup such as that shown in Figure 53. The equations presented are used to calculate the position of the movable machine's front and rear feet from DIS and DIM offset values.

Calculations apply to both the vertical and horizontal planes of misalignment. However, they are typically applied primarily to the vertical plane. As presented earlier, misalignment determination in the horizontal plane may be accomplished without calculating or graphing the exact front and rear feet positions.

Calculating the Front Feet and Rear Feet Positions

The following setup, dimensions, and offset designations apply as in Figure 53.

The position of the movable machine's front feet is determined by:

$$\left(\frac{(M - S)}{A} (B) \right) + M$$

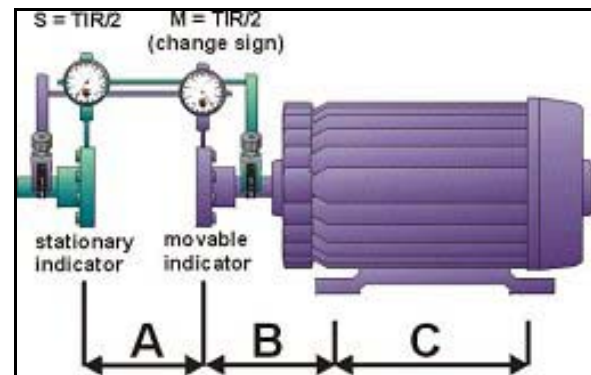


Figure 53. Setup, dimensions, and offset designations.

The position of the movable machine's rear feet is determined by:

$$\left(\frac{(M - S)}{A} (B + C) \right) + M$$

With:

- M = the offset in the plane of the movable indicator.
- S = the offset in the plane of the stationary indicator.
- A = the distance between the stationary and movable dial indicator plungers.
- B = the distance from the movable dial indicator plunger to the movable machine's front feet bolt center.
- C = the distance between the movable machine's front and rear feet bolt centers.
- Positive results mean the foot is high (vertical) or to the right (horizontal.)
- Negative results mean the foot is low (vertical) or to the left (horizontal.)

Reverse-Rim Calculation Examples

Consider the vertical misalignment data:

- The stationary side offset (S) is +12 mils (0.305 mm), or 12 mils high.
- The movable side offset (M) is +17.5 mils (0.444 mm), or 17.5 mils high.
- A = 5 inches (127 mm), B = 7 inches (177.8 mm), C = 24 inches (609.6 mm)

Front foot position calculation:

$$\left(\frac{(M - S)}{A} (B) \right) + M$$

$$\left(\frac{(17.5 - 12)}{5} (7) \right) + 17.5 = 25.2 \text{ Mils}$$

$$\left(\frac{(0.444 - 0.305)}{127} \times 177.8 \right) + 0.444 = 0.64 \text{ mm}$$

The front feet are 25.2 mils (0.64 mm) too high; shims need to be removed.

Rear foot position calculation:

$$\left(\frac{(M - S)}{A} (B + C) \right) + M$$

$$\left(\frac{(17.5 - 12)}{5} (7 + 24) \right) + 17.5 = 51.6$$

$$\left(\frac{(0.444 - 0.305)}{127} \times (177.8 + 609.6) \right) + 0.444 = 1.31 \text{ mm}$$

The rear feet are 51.6 mils (1.31 mm) too high; shims need to be removed

Reverse-Rim Calculation Precautions

1. Ensure that offsets for the stationary and movable indicators are properly determined from TIR's before performing calculations.
2. Be careful *not* to make mathematical errors when subtracting signed numbers.
3. Observe parentheses in the equations. Perform operations inside parenthesis first.
4. Do *not* make human errors substituting real values into the equations.

Reverse-Rim Graphing

As discussed earlier, one way to determine the position of the movable machine's front and rear feet from DIS and DIM offset values is to perform reverse-rim calculations. Another way is to construct a scaled graph. A main advantage of graphing methods is that the shaft centerlines and misalignment conditions are represented visually.

The information presented here applies to a reverse-rim dial setup where both dial indicators are attached at the same location around the circumference.

Graphing procedures may be applied to both the vertical and horizontal planes of misalignment. However, they are typically applied primarily to the vertical plane. As presented earlier, misalignment determination in the horizontal plane may be accomplished without calculating or graphing the exact front and rear feet positions.

Setting Up the Graph

To construct a scaled reverse-rim graph, perform the following steps:

1. Obtain graph paper with 10 divisions between bold lines.
2. Turn the graph paper so that the long side is horizontal.
3. Draw a horizontal line at the center of the page. This line represents the stationary shaft center and is drawn across the page midway down the graph dividing the page. It is helpful if this line is on top of one of the bold lines.
4. Determine the horizontal plotting scale. Always use the largest scale possible. Measure the distance from the stationary indicator plunger to the centerline of the

rear feet of the movable machine.

Standard graph paper is about 10 inches across (254 mm). The largest horizontal scale will be the machine distance divided by the page width. Note your horizontal scale.

5. Make a small vertical line on the left of the horizontal line. This mark represents the point along the length of the stationary indicator plunger and is labeled DIS.
6. Using the proper scale, make a second vertical line to the right of the first on the horizontal line. This line represents the point along the length of the movable indicator plunger and is labeled DIM.

7. Make a third small vertical line representing the point along the length of the front feet of the movable machine (FF).
8. Make the fourth vertical line representing the point along the length of the rear feet of the movable machine (RF).

Upon completion of the steps above, the graph will look similar to the one shown below. For this example, the A, B, and C dimensions all equal 10 inches.

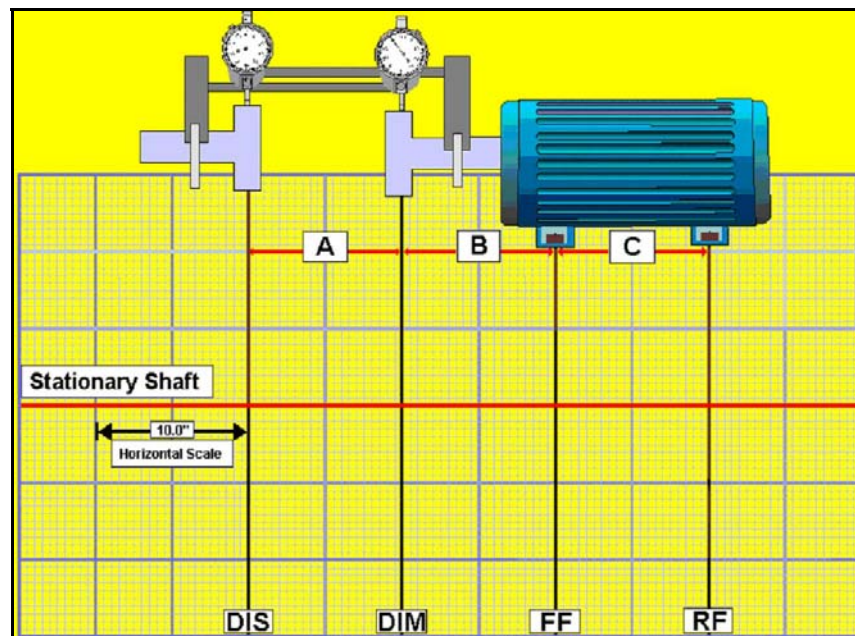


Figure 54. Setting up the graph.

Plotting Offsets

After setting up the graph, the next step is to plot the offsets in the planes of the dial indicators on the stationary side (DIS) and movable side (DIM). To plot the offsets, perform the following steps:

1. Determine the vertical scale. The vertical scale is typically 1 mil (0.001") per division. In cases of gross misalignment where the offsets will not fit on the page, a larger scale, such as 2-3 mils per division, is sometimes required.

2. Plot the offset from the stationary side on line DIS.
 3. Use the horizontal line representing the stationary shaft centerline as the reference. All points above this horizontal line are positive (+) and all points below the line are negative (-).
 4. Plot the offset from the movable side on line DIM.
- In the example below, the DIS offset is -10 mils and the DIM offset is -5 mils.

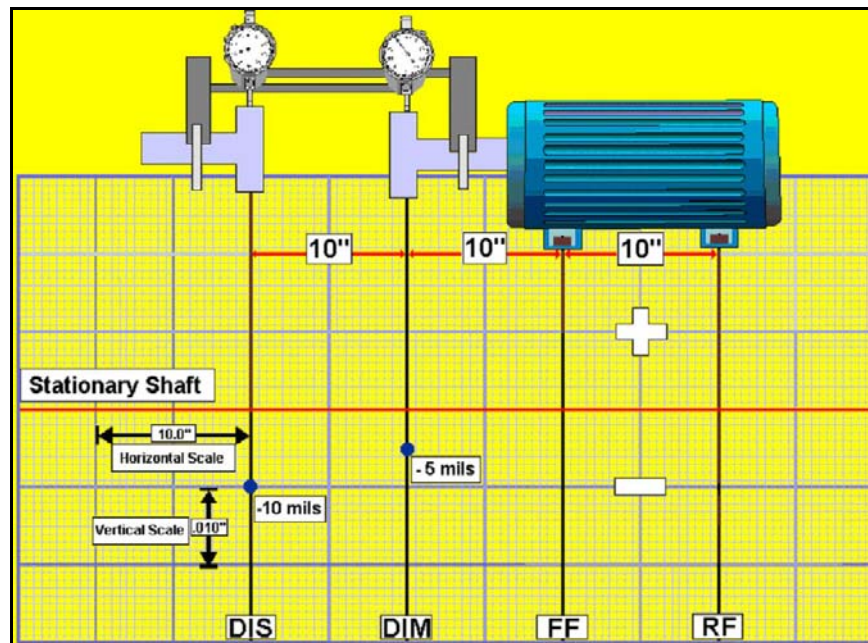


Figure 55. Plotting offset.

Determining Movable Shaft Position

After plotting the stationary and movable shaft offsets, to determine the movable shaft position perform the following steps:

1. Using a ruler or straightedge, draw a line through the two offset points that extends to the rear feet of the movable machine.
2. Count the number of squares in the plane of the front and rear feet to determine the position and corrections needed.

In the example below, the front feet of the machine are properly aligned; no shim changes are required. The rear feet are positioned 5 mils too high; shims need to be removed from both rear feet.

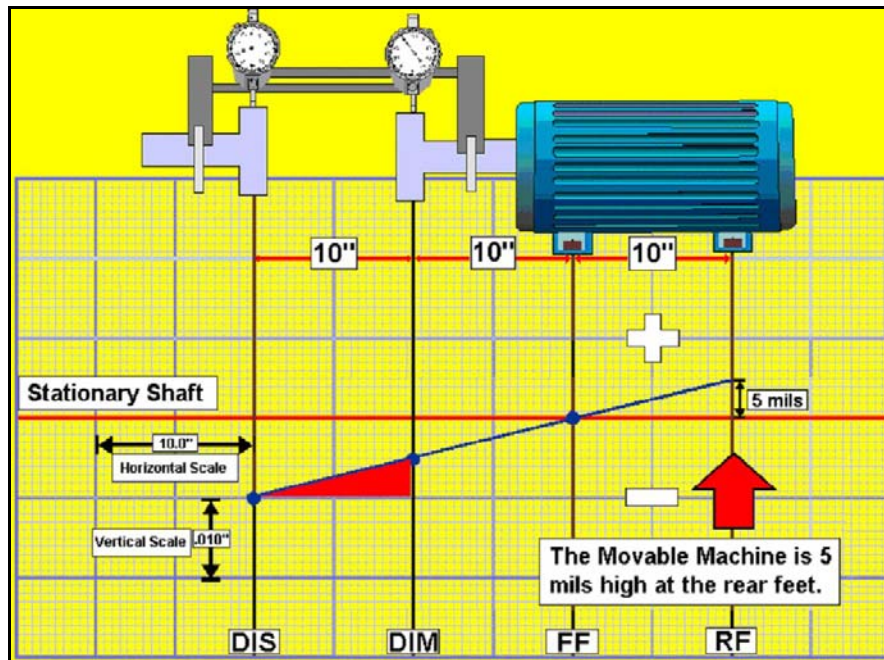


Figure 56. Determining movable shafts position.

Reverse-Rim Graphing Precautions

1. Ensure that proper horizontal and vertical scaling techniques are consistently used.
2. Always double-check the position of vertical lines drawn to represent the DIS, DIM, FF, and RF.
3. Ensure that offsets for the stationary and movable indicators are properly determined from TIR's before plotting points on the graph.
4. Ensure that positive offsets are plotted above the horizontal reference line and negative offsets are plotted below the line.
5. When interpreting the graph to determine the movable shaft's front and rear feet positions in the vertical plane, observe the following rules:
 - If the movable shaft is above the horizontal stationary shaft reference line, the shaft is too high.
 - If the movable shaft is below the horizontal stationary shaft reference line, the shaft is too low.
6. When interpreting the graph to determine the movable shaft's front and rear feet positions in the horizontal plane, view the graph the way you view the machine, that is, standing behind the movable machine facing the stationary machine. Observe the following rules:
 - If the movable shaft is above the horizontal stationary shaft reference line, the shaft is positioned to the right.
 - If the movable shaft is below the horizontal stationary shaft reference line, the shaft is positioned to the left.

Reverse-Rim Corrections

Correction Process Overview

To correct misalignment involves a number of procedures that are similar to the ones listed under the Rim-Face Method. A few details are different, as described below.

Making Vertical Corrections

Determine the vertical position of the movable machine using calculation and/or graphing techniques, see Figure 56.

Vertical correction tips:

1. Make shim changes to both front feet and both rear feet as needed.
2. Always check shim thickness with an outside micrometer. Precut shims are not always what they are marked; many shim manufacturers designate shims with the “nominal” thickness.
3. Use consistent and correct torquing procedures.
4. As shim changes are made, check for and take precautions to avoid creating soft foot conditions.

Horizontal Correction Process

When using the reverse-rim method, two different procedures are commonly used for horizontal corrections:

1. Determining the corrections using calculation or graphing techniques, followed by monitoring movement using dial indicators positioned at the machine’s feet.
2. Monitoring movement, using dial indicators mounted at the coupling.

Dial indicators at the machine’s feet

To correct horizontal misalignment by monitoring movement at the movable machine’s feet, perform the following steps:

1. Measure horizontal misalignment.
2. Determine the horizontal position of the movable machine using calculation or graphing procedures.
3. Ensure that you are standing with the movable machine on your right and the stationary machine on your left. Positive values at the feet mean that the movable machine is away from you; it should be moved towards you. Negative values at the feet mean that the movable machine is towards you; it should be moved away from you.
5. Position dial indicators at the front and rear feet.
6. Move front and rear feet the amounts needed while watching the dial indicators.

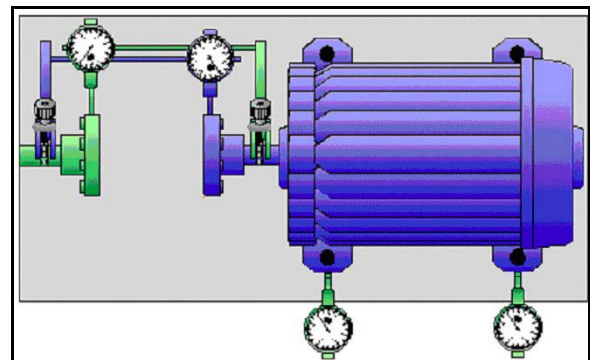


Figure 57. Monitoring movement using dial indicators at the feet.

Dial indicators at the coupling

To correct horizontal misalignment by monitoring using dial indicators mounted at the coupling, perform the following steps:

1. Rotate the dial indicators to 9:00 and zero them.
2. Rotate shafts to 3:00.
3. Adjust the dial indicators to one-half their values.
4. Move the front feet of the movable machine as you watch the movable indicator move to zero.
5. Move the rear feet of the movable machine as you watch the stationary indicator move to zero.
6. Repeat steps 4 & 5 until both dial indicators read zero.

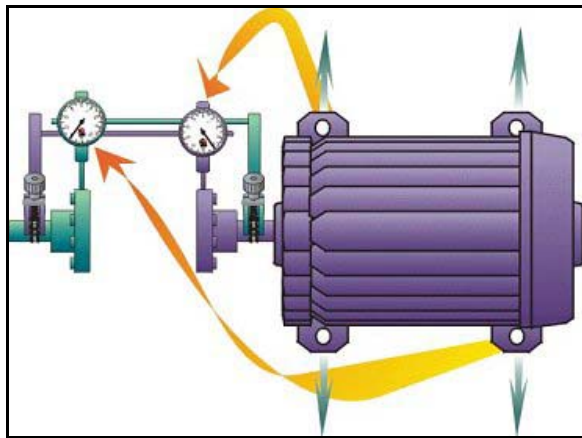


Figure 58. Monitoring movements using dial indicators in the coupling.

Horizontal correction tips:

1. Start making moves at the feet where the misalignment is greatest.
2. If not already present, install jack-bolts wherever possible.
3. Bring the front and rear feet into alignment together; they are a team.
4. When the feet are within 2 mils or so, start torquing and watch the dial

indicators. Use the proper criss-cross torquing sequence.

After Making Vertical and Horizontal Corrections

After making final vertical and horizontal corrections, you should:

1. Obtain new measurements.
2. Compare results to specified tolerances.
3. Repeat corrections until results are within tolerances.
4. Obtain and document a final set of measurements.
5. Restore equipment in accordance with procedures at your facility.

Twin Laser Alignment Method

Coning

As mentioned in the first sections, shaft alignment is all about making two rotating shafts co-linear. To achieve this, different kinds of methods are used to determine the axis of rotation of one unit and compare it to another one. When using the twin laser method a special method is used called “coning” to project the axis of rotation. The fact that light from the laser creates a perfectly straight line with no sag makes it possible to project the axis of rotation of any rotating object even over very long distances. By attaching a laser to the rotating object, the laser beam will describe a cone. When the “cone” is projected in one plane the beam will describe a circle and its center is the center of rotation in that particular plane. The direction of the axis of rotation is determined by projecting the center of rotation in two planes.

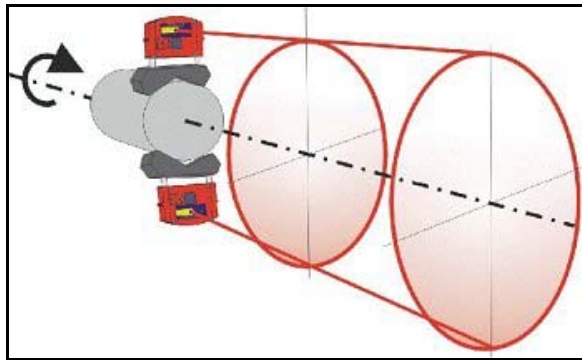


Figure 59. Coning principle 1. The center of the circle is the rotational center of the shaft.

By adjusting the angle of the out-coming laser beam on the transmitter, the diameter of the projected circle decreases until the beam eventually creates a spot. The coning technique can be used to create “points” at different distances from the rotational object to project the axis of rotation.

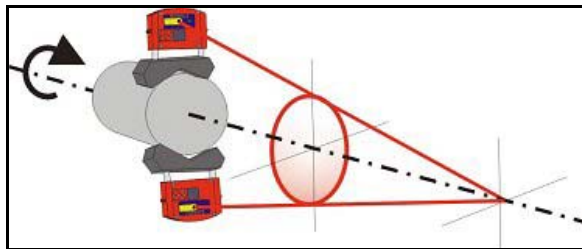


Figure 60. Coning principle 2. The axis of rotation is made into a single point at a distance from the shaft end.

Comparison to Dial Indicator Methods

By using the coning technique (principle 1), the twin laser based alignment instruments basically use the same method as alignment with dial indicators. In fact, the reversed dial indicator method uses exactly the same principle to determine the position of a rotating axis by defining the offset in two planes. While a dial indicator measures the offset by needle and plunger, the laser transmitter/detector (TD) unit measures the offset by detecting the movement of a laser beam on a single axis detector. The text below describes the relationship between the reversed dial method and the method used with twin lasers.

Figures 61 and 62 compare the two methods when measuring the offset in the plane of the stationary side of the coupling DIS or TD-S. The pictures are exaggerated to show the principle of how readings are taken. In the example, the rotational center of the movable shaft is +2.5 above the stationary shaft. The offset is +2.5 in the plane of the stationary coupling (DIS / TD-S).

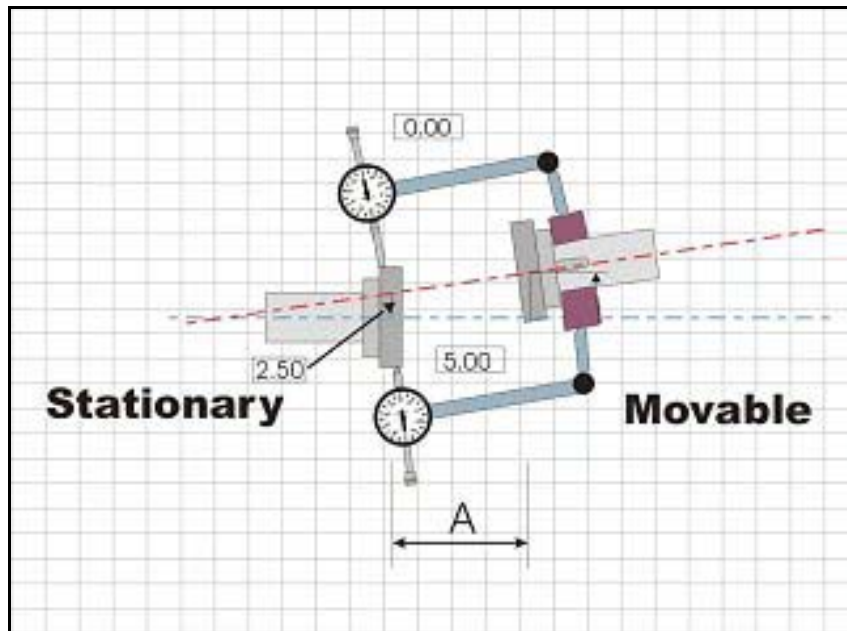


Figure 61. Reverse-rim dial indicator method. Measurement of stationary side offset, DIS.

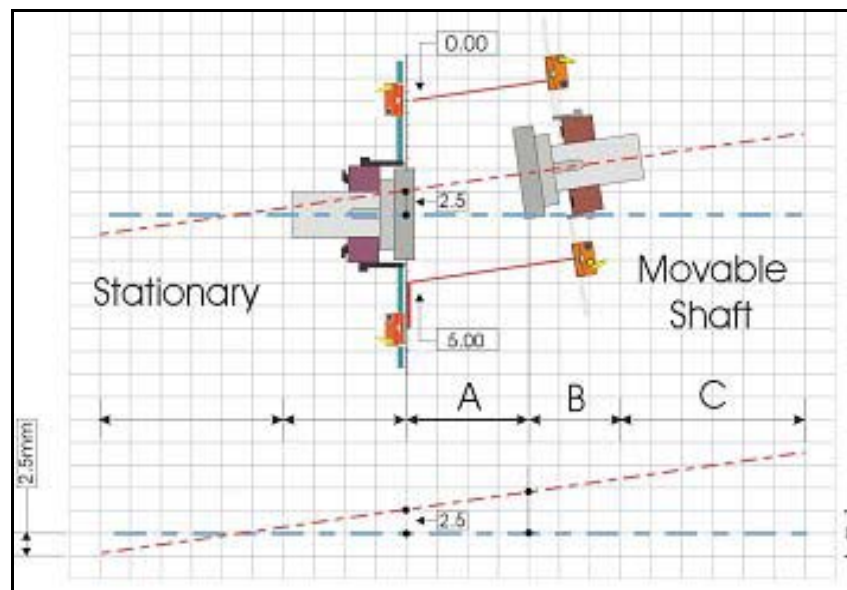


Figure 62. Twin laser method. Measurement of stationary side offset, TD-S.

In a twin laser system, the same type of measurement is simultaneously performed in the second plane. Sign changes are not necessary as the plus/minus direction is

reversed in the TD-M unit. In the figures below the distance (offset) between both axes of rotation in the second plane is +4.80.

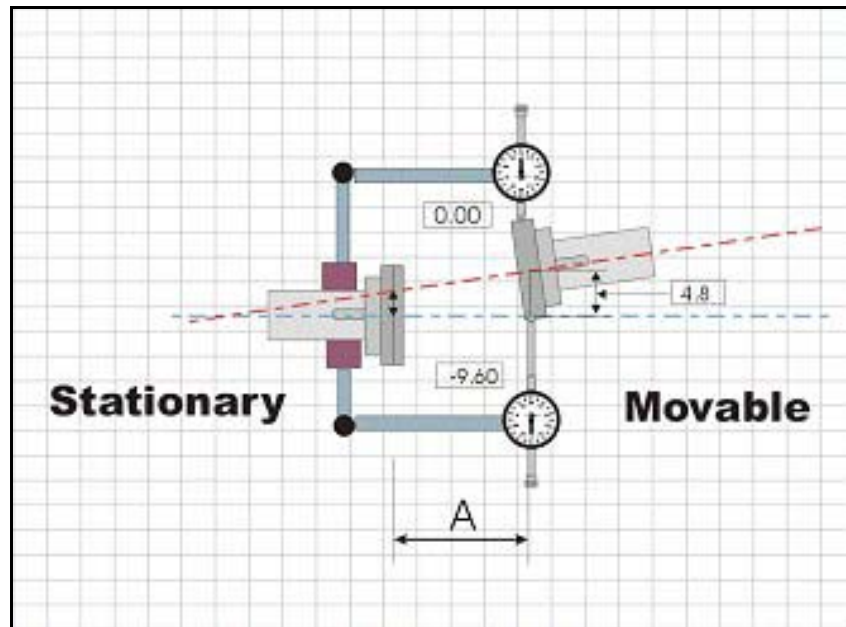


Figure 63. Reverse-rim method. Measurement of movable side offset, DIM.

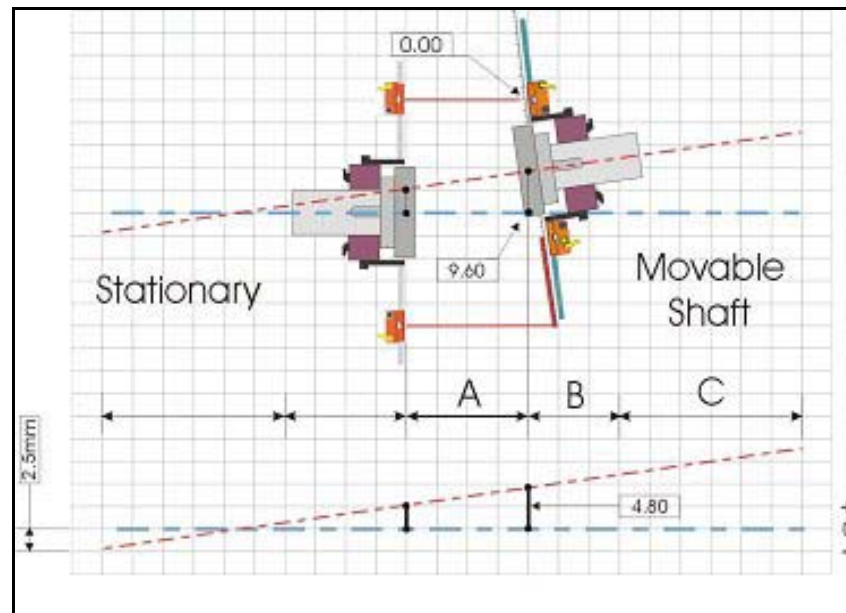


Figure 64. Twin laser method. Measurement of movable side offset, TD-M.

When having the two offset values in two planes it is now possible to determine the position of the axis of rotation for the movable machine. By adding the values for distance B and C, we can use the same calculation that is used in the reversed-dial indicator method to determine the feet

correction values. In laser alignment, these calculations are made quickly and continuously in the display unit making it possible to update adjustments to the machine while they are being made (real time).

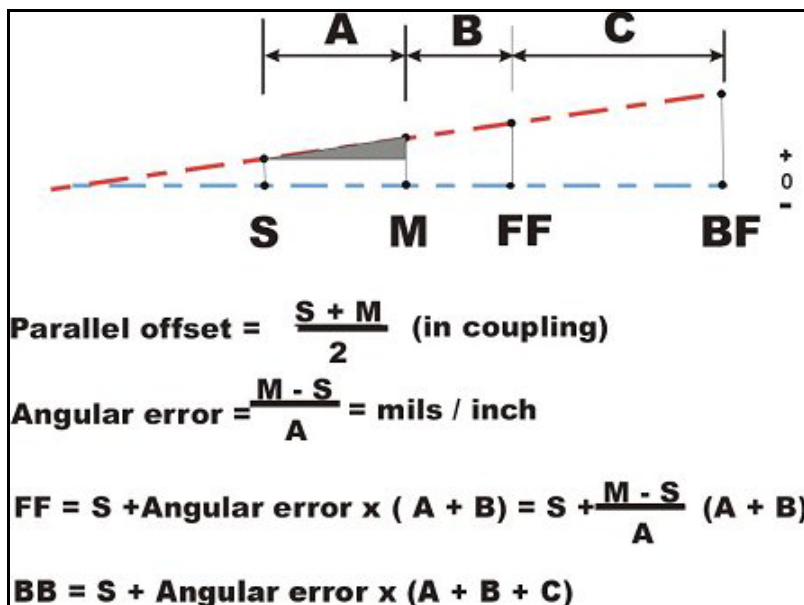


Figure 65. Equations for twin laser alignment.

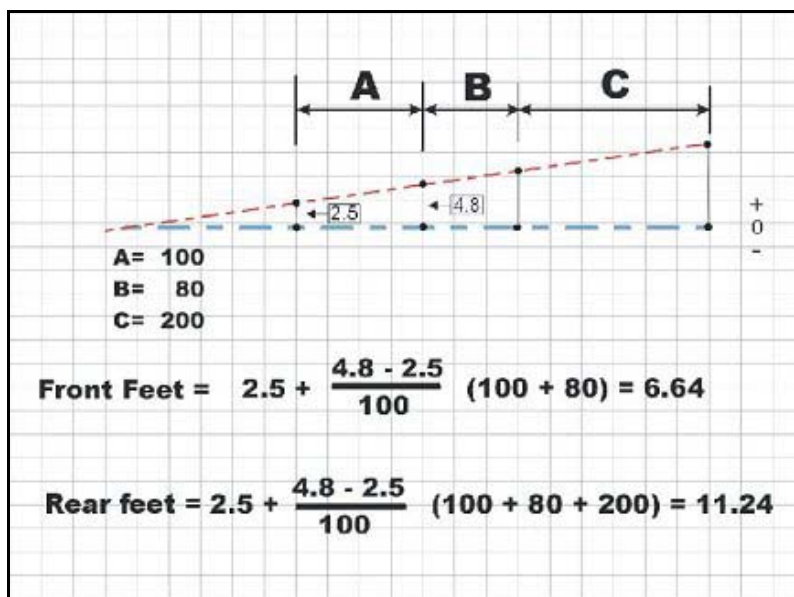


Figure 66. Example twin laser alignment feet calculation.

Further Reading

Consult www.aptitudexchange.com for detailed articles, covering topics such as:

- "Couplings"
- "Shaft Alignment: Introduction"
- "Benefits to Shaft Alignment"
- "Pre-Alignment"
- "Rough Alignment"
- "Horizontal Shaft Alignment"
- "Vertical Shaft Alignment"
- "Alignment of Offset Drives"

- “Machine Train Alignment”
- “Straightness”

SKF Maintenance Products
Kelvinbaan 16
NL-3439 MT Nieuwegein, The Netherlands

Piotrowski, J., *Shaft Alignment Handbook*.
Marcel Dekker, April 1986.

Internet: <http://mapro.skf.com>

Additional Resources

Fixturlaser AB -Fixturlaser AB develops, manufactures, and markets laser based alignment systems globally in a 70+ countries. Fixturlaser was founded in 1980 and the first laser alignment system developed in 1984. Since then the technology has been accepted in mostly every industry. Their mission is to become the leading provider of easy solutions, including equipment and application knowledge for measurement and alignment of machinery in any industry.

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Machine Support BV - The comprehensive capabilities of Machine Support include the highest proficiency in the installation support of diesel engines, turbines, and the alignment to generators, pumps, compressors, and shaft lines. Machine Support also specializes in geometric alignments such as measuring the line bore of diesel engines and measuring the straightness of stern tubes onboard marine vessels.

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