10 Reverse Indicator Method

The reverse indicator method is also often called the indicator reverse method or the double dial method and is shown in Figure 10.1. This method seems to have originated around the mid to late 1950s in the United States and it is not clear who first developed this technique. Clark brothers (now Dresser–Rand) adopted this technique for use in aligning their rotating machinery and Don Cutler (currently working for Thomas-Rexnord) developed the line-to-point graphing method while working for Clark.

The reverse indicator method can be used on 60%–70% of the rotating machinery in existence and is still one of the preferred dial indicator methods for measuring rotating machinery shafts. It is best suited for use when the distances between measuring points on each shaft range from 3 to 30 in. Although Figure 10.1 shows using two brackets and two dial indicators at the same time, there is no reason why one bracket and dial indicator setup could not be used where a set of readings are captured on one shaft first and then reversing the bracket and indicator to capture a set of readings on the other shaft. In fact, it may be wise to use just one bracket at a time to insure that readings are taken correctly and minimize the confusion that could result from trying to observe two indicators simultaneously as illustrated in Figure 10.2. Additionally, how much time does it take to setup two brackets and two indicators versus setting up one bracket and one indicator twice?

Advantages

- Typically more accurate than the face-rim method as the distance from the mounting point of the bracket to the point where the indicators capture the readings on the shafts is usually greater than the distance a face reading can be taken.
- If the machinery is supported in sliding type bearings and the shafts are floating back or forth axially when rotating the shaft-to-capture readings, there is virtually no effect on the accuracy of the readings.

Disadvantages

- Both shafts must be rotated.
- Difficult to visualize the positions of the shafts from the dial indicator readings.
- Bracket sag must be measured and compensated for.

10.1 BASIC MATHEMATICAL EQUATIONS FOR THE REVERSE INDICATOR METHOD

There is a mathematical relationship that exists between the size of the machinery (i.e., where the foot bolts are located), where the shaft position measurements are taken, and the shaft

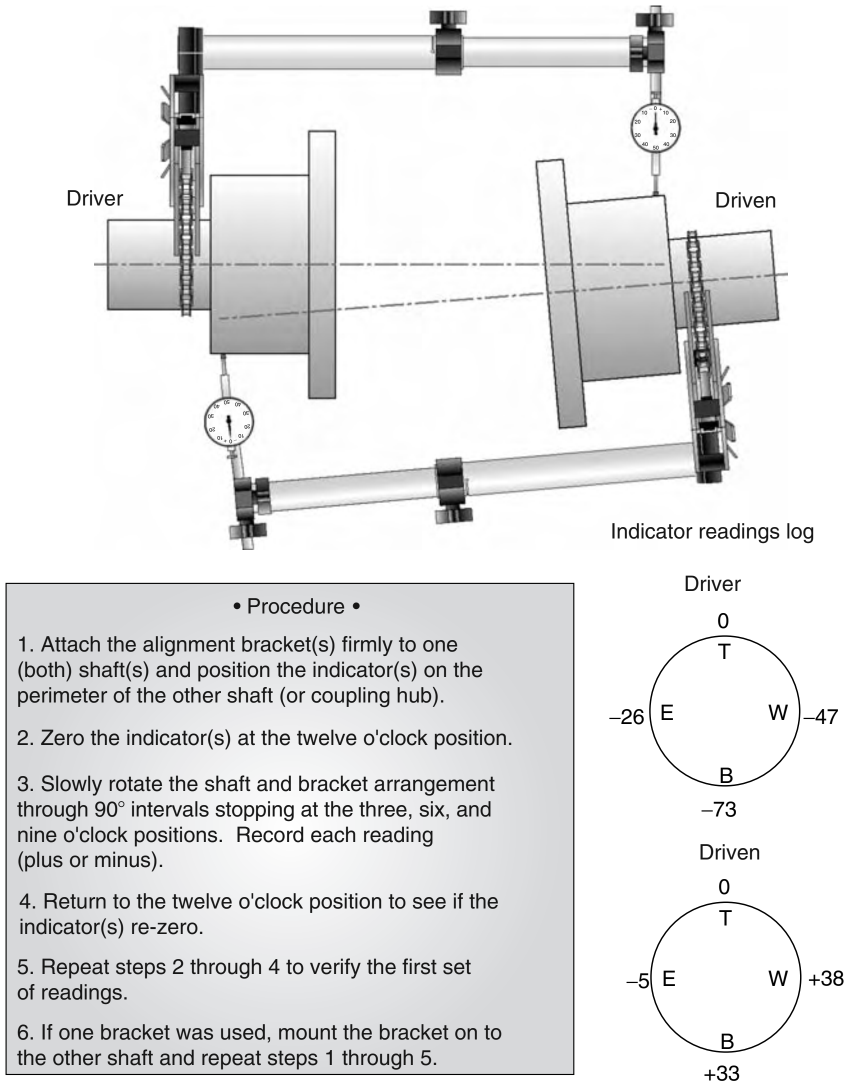


FIGURE 10.1 Reverse indicator method and procedure.

measurements themselves. Once all the measurements have been taken, and the shaft plotted onto the alignment model, the corrective movement solutions can be arrived at.

Figure 10.6 shows the mathematical relationship between the machinery dimensions and the dial indicator readings captured using the reverse indicator technique. The equations will solve for the moves that need to be made to correct the misalignment condition (i.e., bring the shafts into a collinear relationship when off-line) on one or the other machine case. It is an either/or condition. If you decide to keep the driver stationary, you solve for the moves on the driven machine or vice versa. This is often referred to as the ‘‘stationary-movable’’ alignment concept and is not recommended for reasons explained in Chapter 8. Alignment modeling methods and the ‘‘overlay line’’ concept have been in use since the late 1970s.

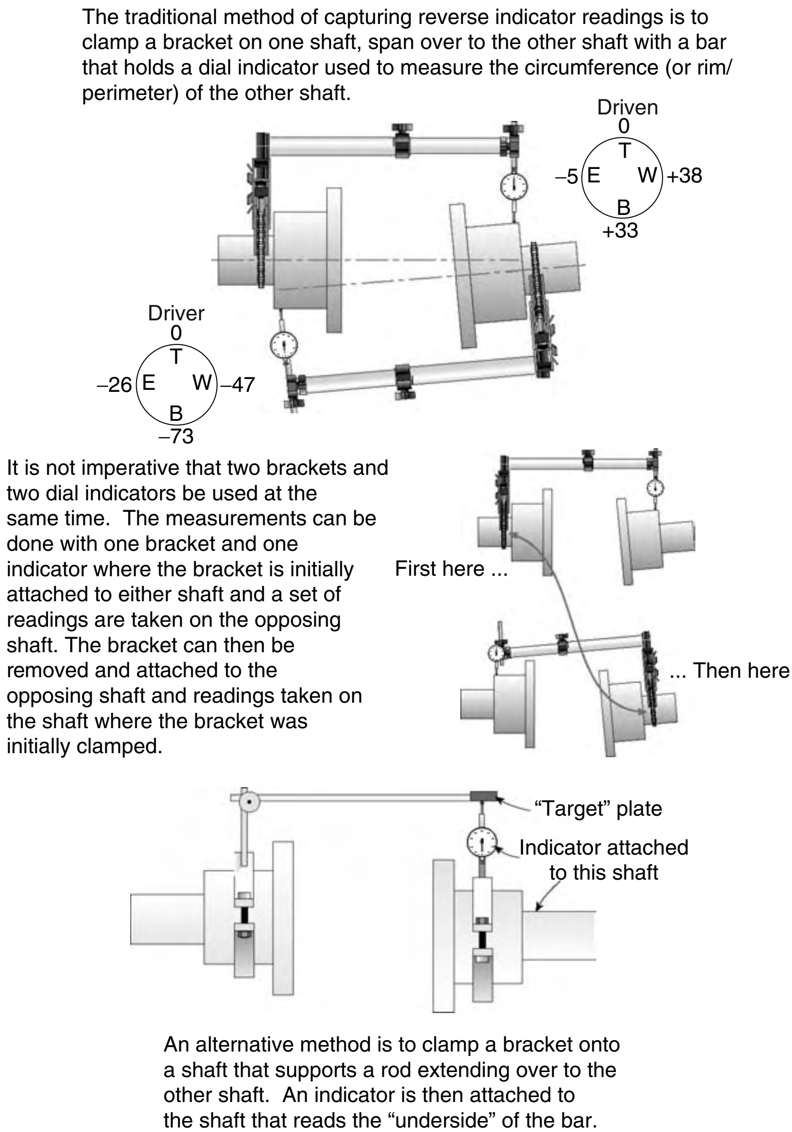


FIGURE 10.2 Reverse indicator setup variations.

10.2 MODELING REVERSE INDICATOR METHOD USING THE "POINT-TO-POINT" TECHNIQUE

Perhaps the easiest modeling technique to learn is the point-to-point reverse indicator modeling method and will therefore be the first one illustrated.

There are eight pieces of information that you need to properly construct the shaft positions using this technique:

1. The distance from the outboard-to-inboard feet (bolting planes) of the first machine.
2. The distance from the inboard bolting plane of the first machine to the point on the shaft where the bracket is being held in place.

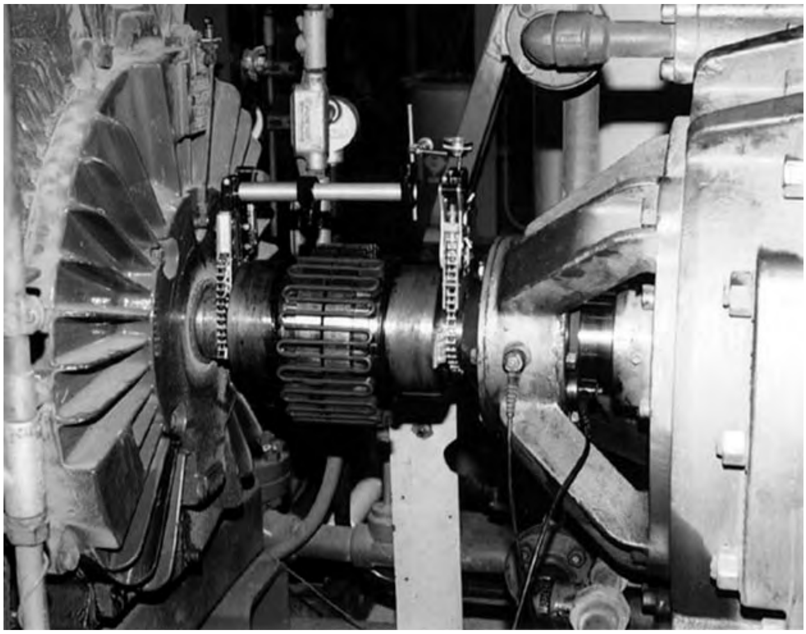


FIGURE 10.3 Reverse indicator technique employed across metal ribbon coupling.

3. The distance from where the bracket is being held in place to the point where the dial indicator is capturing the rim readings on the first machine. Note that this distance could be zero if you are using a symmetrical arrangement where you are clamping and reading at the same points on each shaft.

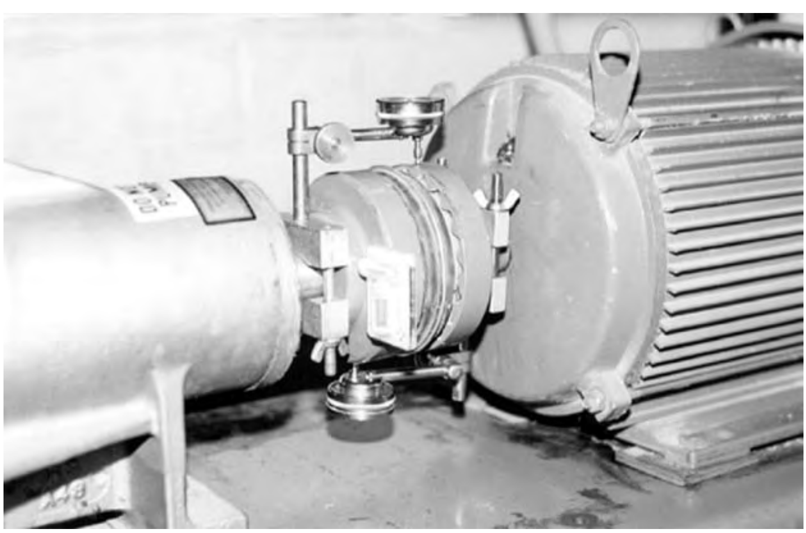


FIGURE 10.4 Reverse indicator technique employed across small motor and pump drive using miniature brackets.

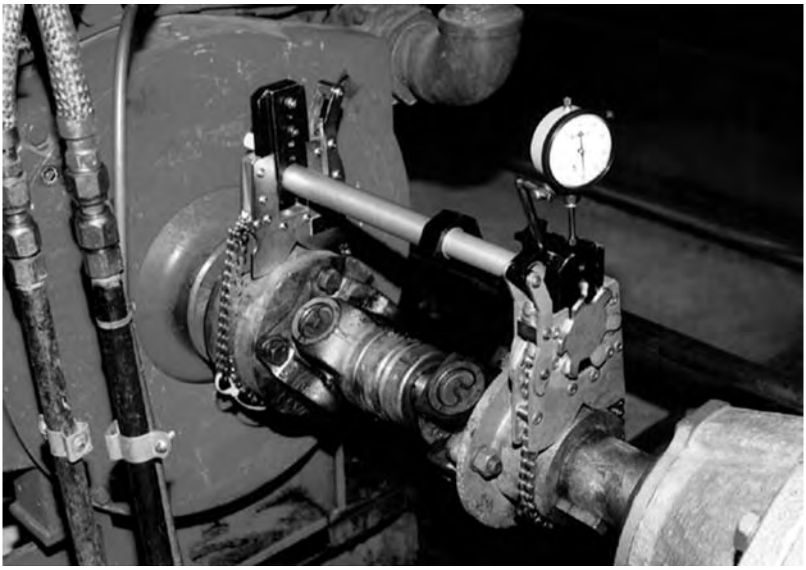


FIGURE 10.5 Reverse indicator technique employed across universal joint.

4. The distance from where the dial indicator is capturing the rim readings on the first machine to the point where the dial indicators are capturing the rim readings on the second machine.

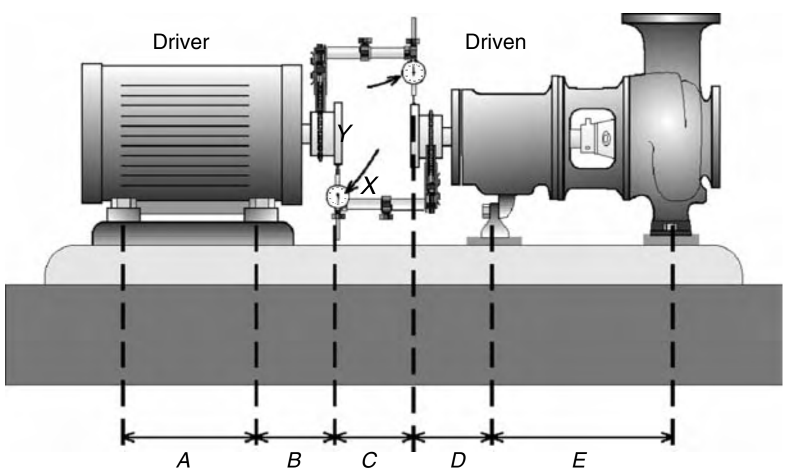
Reverse indicator method mathematics

where:

A, B, C, D, E = distances shown (in.)

X = one-half of the driver rim reading difference (from top to bottom or side to side in mils)

Y = one-half of the driven rim reading difference (from top to bottom or side to side in mils)



$$\text{Inboard feet of Driver} = \frac{(B+C)\,(X+Y)}{C} - (Y)$$

$$\text{Inboard feet of Driven} = \frac{(C+D)\,(X+Y)}{C} - (X)$$

$$\text{Outboard feet of Driver} = \frac{(A+B+C)\,(X+Y)}{C} - (Y)$$

$$\text{Outboard feet of Driven} = \frac{(C+D+E)\,(X+Y)}{C} - (X)$$

FIGURE 10.6 Reverse indicator mathematics for correcting moves on either machine case.

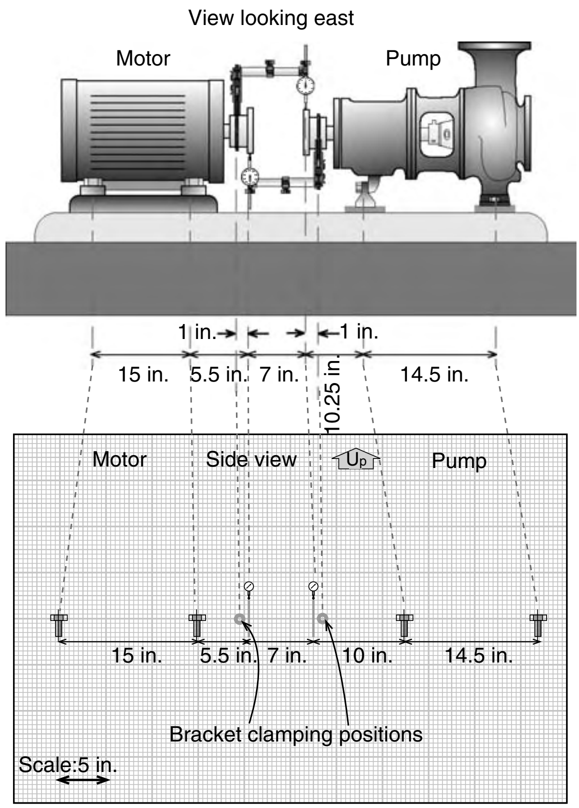


FIGURE 10.7 Dimensional information needed for plotting the reverse indicator readings using the point-to-point plotting method.

5. The distance from where dial indicator is capturing the rim readings on the second machine to the point where the bracket is being held in place. Note that this distance could be zero if you are using a symmetrical arrangement where you are clamping and reading at the same points on each shaft.
6. The distance from where the bracket is being held in place to the inboard bolting plane of the second machine.
7. The distance from the inboard-to-outboard feet (bolting planes) of the second machine.
8. The eight dial indicator readings taken at the top, bottom, and both sides on both shafts after compensating for sag (i.e., what a perfect, "no sag" bracket system would have measured).

From the standpoint of geometry, the reverse indicator method measures shaft centerline deviations at two "slices" in space at a known distance apart. Figure 10.7 illustrates the core modeling points that we will construct. Accurately scale the distances along the length of the drive train onto the graph centerline as shown in Figure 10.8.

10.3 RIM READINGS ARE ALWAYS TWICE THE OFFSET AMOUNT

Remember, anytime a rim or circumferential reading is taken, the amount measured from one side to the other side of the shaft (180° of rotation) is twice the amount of the actual distance

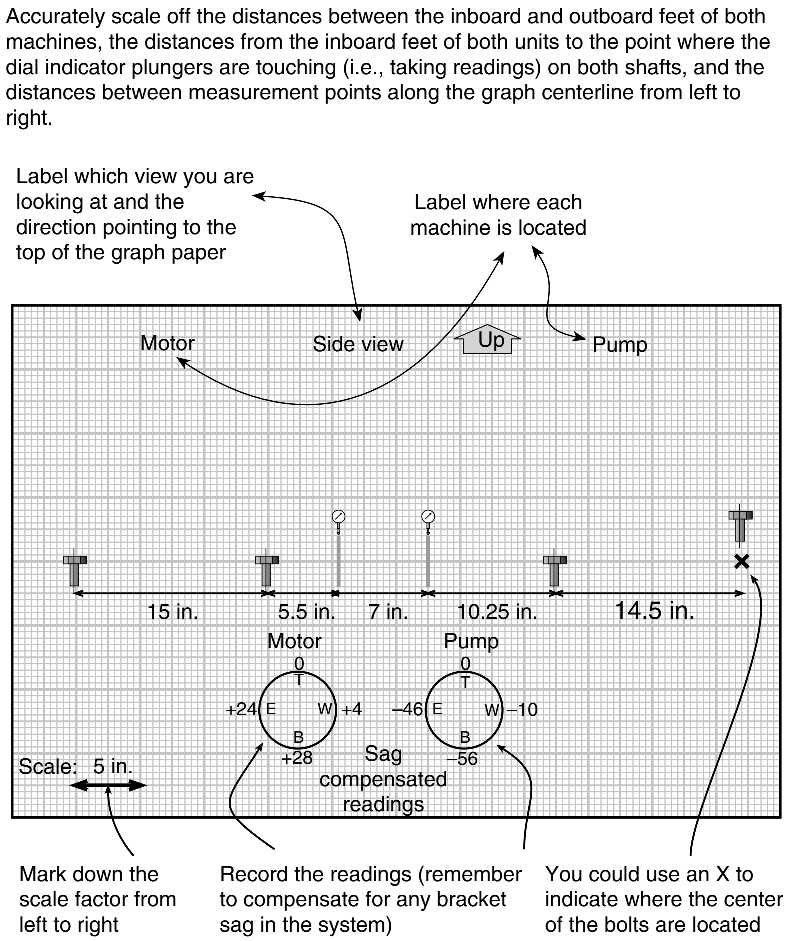


FIGURE 10.8 Scaling the dimensions of the drive system onto the graph.

between the centerlines of rotation at that point. Refer to Figure 6.44 and Figure 6.45 to understand why this happens.

The procedure for plotting the point-to-point reverse indicator technique is as follows:

1. Start with the top to bottom or side-to-side dial indicator readings on the shaft where the largest top to bottom or side-to-side reading occurred (this will help you pick the best scaling factor for the entire graph).
2. At the intersection of the graph centerline and the point where the dial indicator has captured the largest reading, plot a point above or below this intersection one-half of the top to bottom or side-to-side dial indicator reading. If the bottom (or side) reading was negative, place a point half of the bottom (or side) reading from the graph centerline toward the top of the graph. If the bottom (or side) reading was positive, place a point half of the bottom (or side) readings from the graph centerline toward the bottom of the graph (the same as in the point-to-point modeling techniques). Lay a straightedge from the point on the graph centerline where the bracket was held through the point on the graph where the dial indicator captured the

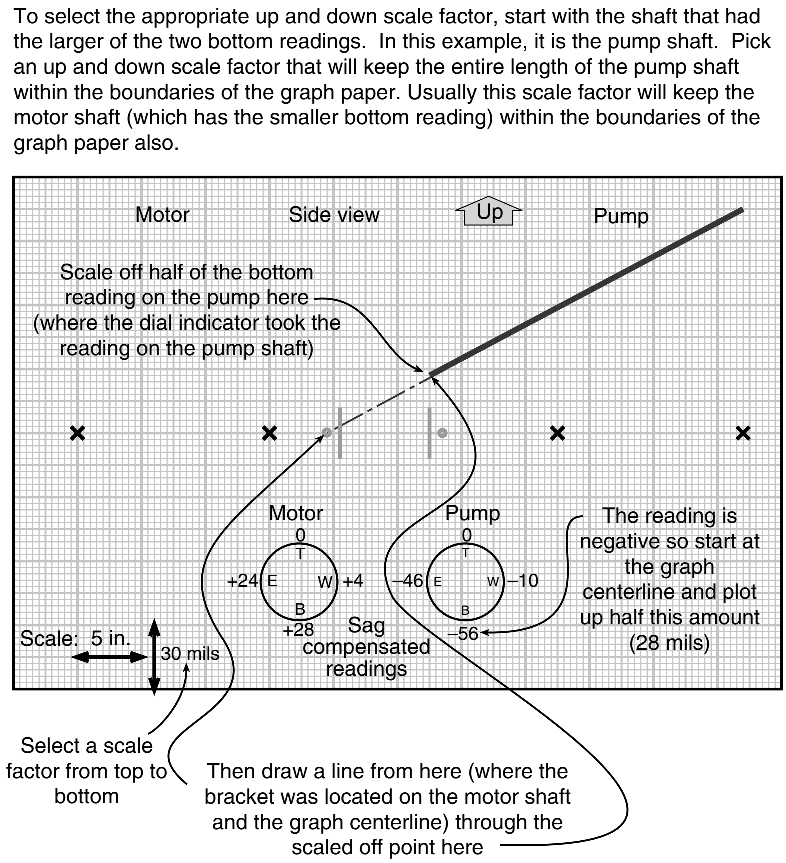


FIGURE 10.9 Plotting a pump shaft onto the side view alignment model.

reading. Draw a line from the point on the graph where the dial indicator captured the reading to the outboard end of that shaft. Remember, whatever shaft the dial indicator has captured the readings on, that is the shaft that will be drawn on the graph paper. Figure 10.9 shows an example of plotting a pump shaft onto the side view alignment model.

3. Next, at the intersection of the graph centerline and the point where the dial indicator has captured the smallest reading, plot a point above or below this intersection one-half of the top to bottom or side-to-side dial indicator reading. If the bottom (or side) reading was negative, place a point half of the bottom (or side) reading from the graph centerline toward the top of the graph. If the bottom (or side) reading was positive, place a point half of the bottom (or side) readings from the graph centerline toward the bottom of the graph (the same as in the point to point modeling techniques). Lay a straightedge from the point on the graph centerline where the bracket was held through the point on the graph where the dial indicator captured the reading. Draw a line from the point on the graph where the dial indicator captured the reading to the outboard end of that shaft. Figure 10.10 shows an example of plotting a motor shaft onto the side view alignment model.

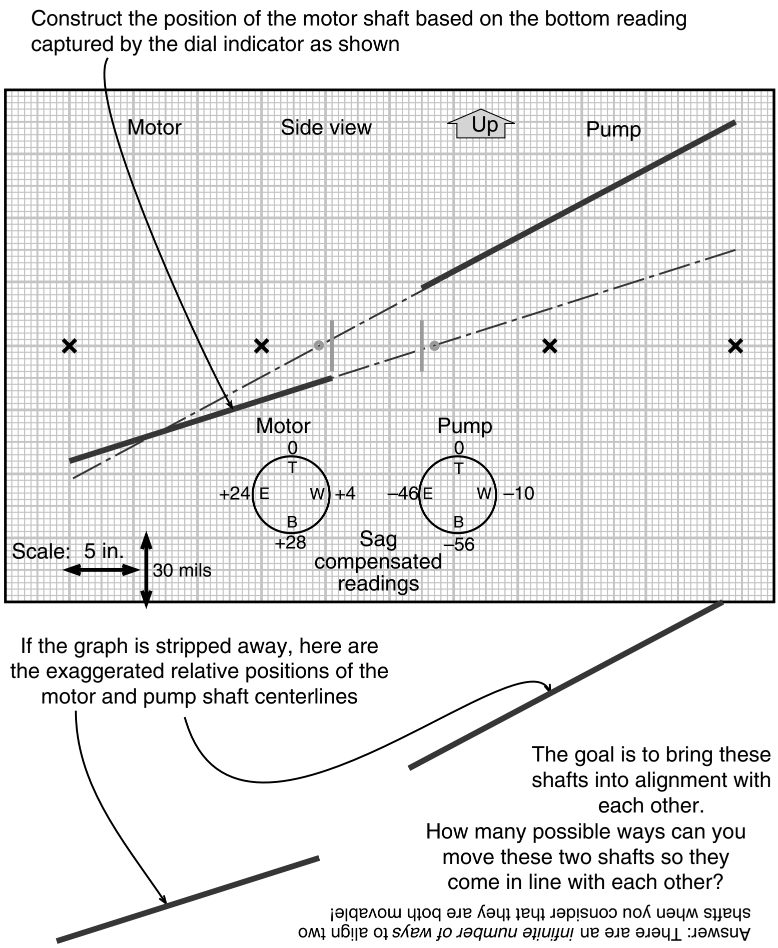


FIGURE 10.10 Plotting a motor shaft onto the side view alignment model.

Notice that there is a consistency to this plotting technique. If the top to bottom or side-to-side dial indicator reading is negative, plot half of the reading toward the top of the graph paper, for either shaft. If the top to bottom or side-to-side dial indicator reading is positive, plot half of the reading toward the bottom of the graph paper, for either shaft.

The process for plotting the shaft in the top view is the same as it is in the side view. As discussed in Chapter 8, one of the cardinal alignment modeling rules is to zero the indicator on the side that is pointing to the top of your graph paper. Refer to Figure 10.7 where it states "view looking east." Therefore, when looking at our drive system from above (i.e., the top view), the direction pointing to the top of the graph paper must be east. Figure 10.11 shows how the pump shaft is plotted in the top view and how the east side readings were zeroed to extract the west side readings on each shaft from the complete set of reverse indicator measurements. Figure 10.12 shows how the motor shaft is plotted in the top view.

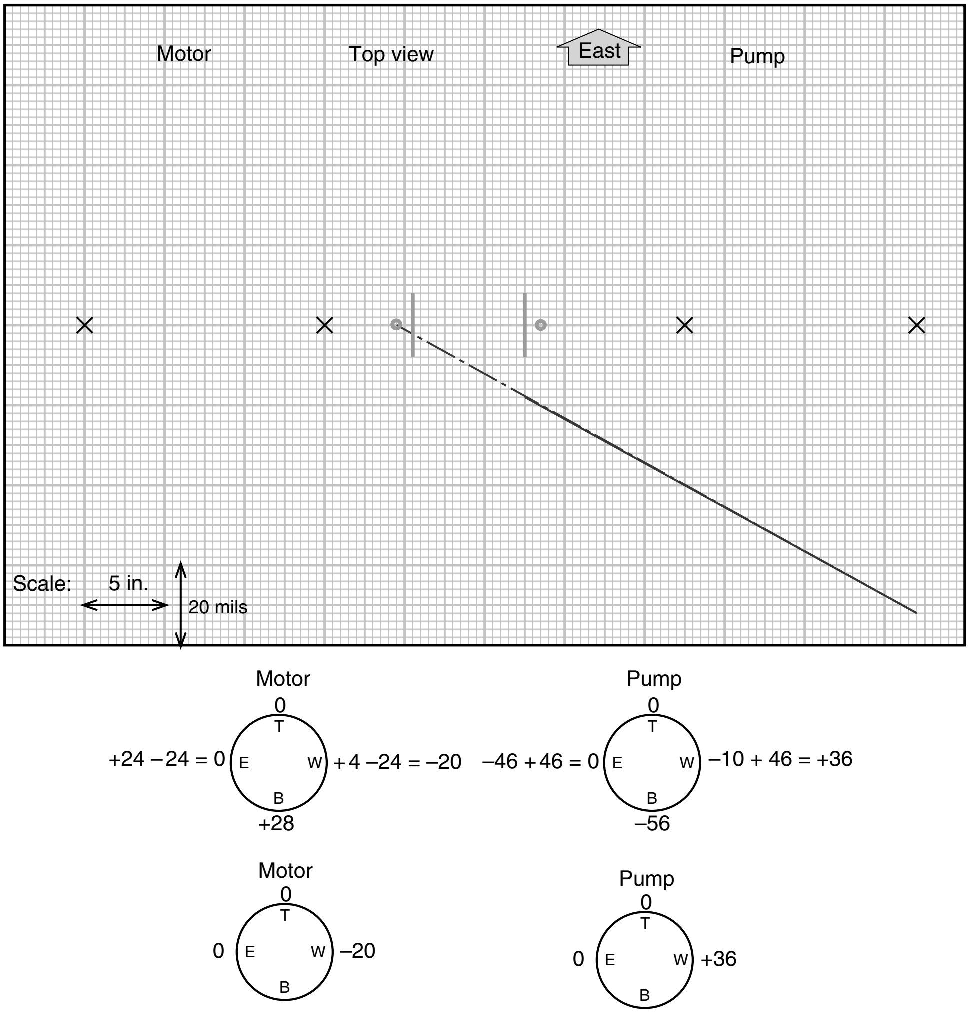


FIGURE 10.11 Plotting a pump shaft onto the top view alignment model.

10.4 MODELING THE REVERSE INDICATOR METHOD USING THE LINE-TO-POINT TECHNIQUE

There is an alternative method to graphing or modeling reverse indicator readings. There are two advantages of this technique as opposed to the point-to-point method:

- Somewhat easier to model multiple element drive trains where reverse indicator readings were captured at two or more flexible couplings.
- Regardless of whether you have an asymmetrical or symmetrical bracket arrangement, the points where the brackets are being clamped to the shaft are not relevant, only the points where the dial indicator readings are being captured are required.

There are six pieces of information that you need to properly construct the shaft positions using this technique.

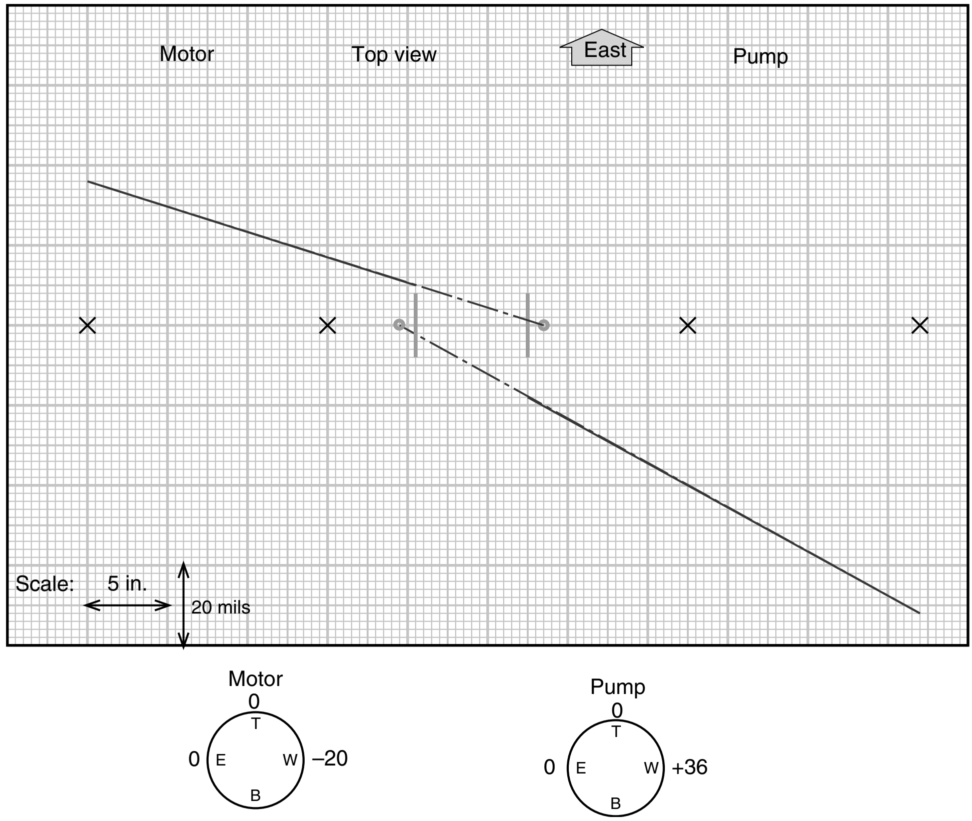


FIGURE 10.12 Plotting a motor shaft onto the top view alignment model.

1. The distance from the outboard-to-inboard feet (bolting planes) of the first machine.
2. The distance from the inboard bolting plane of the first machine to the point on the shaft where the dial indicator is capturing the rim readings on the first machine.
3. The distance from where the dial indicator is capturing the rim readings on the first machine to the point where the dial indicators are capturing the rim readings on the second machine.
4. The distance from where the dial indicator is capturing the rim readings on the second machine to the inboard bolting plane of the second machine.
5. The distance from the inboard-to-outboard feet (bolting planes) of the second machine.
6. The eight dial indicator readings taken at the top, bottom, and both sides on both shafts after compensating for sag (i.e., what a perfect, ‘‘no sag’’ bracket system would have measured).

Accurately scale the distances along the length of the drive train onto the graph centerline as shown in Figure 10.13.

The procedure for plotting the line-to-point reverse indicator technique is as follows:

1. Select one of the two machinery shafts and draw one of those shafts on top of the graph centerline. Figure 10.14 shows an example where the motor shaft was initially placed on

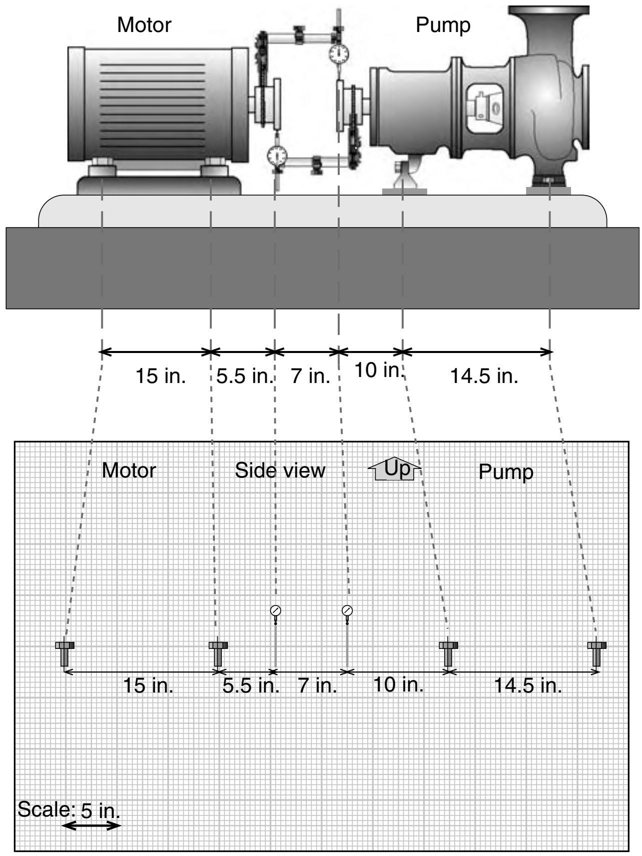


FIGURE 10.13 Dimensional information needed for plotting reverse indicator readings using the line-to-point plotting method.

the graph paper centerline and the pump shaft position was plotted from the reverse indicator measurements. Figure 10.15 shows an example where the pump shaft was initially placed on the graph paper centerline and the motor shaft position was plotted from the same reverse indicator measurements.

2. Start with the top to bottom or side-to-side dial indicator readings on the other shaft (i.e., the one you did not draw on the graph centerline).
3. Plot the other shaft centerline position by starting at the intersection of the graph centerline and the point where the dial indicator was capturing the readings on the other shaft. If the bottom (or side) reading was negative, place a point half of the bottom (or side) readings from the graph centerline toward the top of the graph. If the bottom (or side) reading was positive, place a point half of the bottom (or side) readings from the graph centerline toward the bottom of the graph (the same as in the point-to-point modeling techniques). Do not draw any lines yet!
4. Next, start at the intersection of the graph centerline and the point where the dial indicator was capturing the readings on the shaft that was drawn on top of the graph centerline. If the bottom (or side) reading was negative, place a point half of the bottom (or side) readings from the graph centerline toward the bottom of the graph. If the bottom (or side) reading was positive, place a point half of the bottom (or side) readings

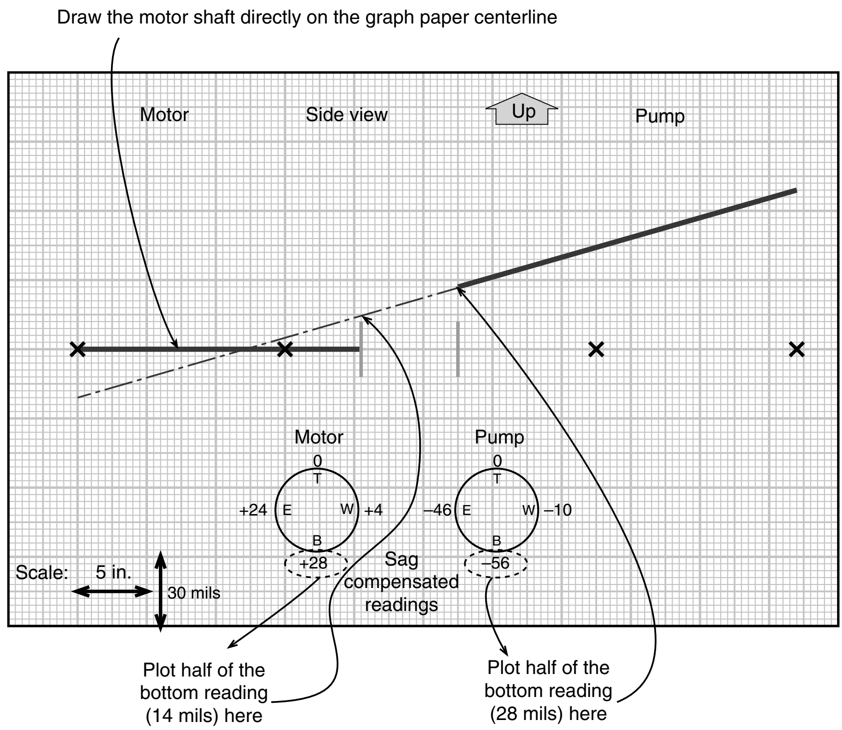


FIGURE 10.14 Side view example where the motor shaft was initially placed on the graph paper centerline and the pump shaft position was then plotted.

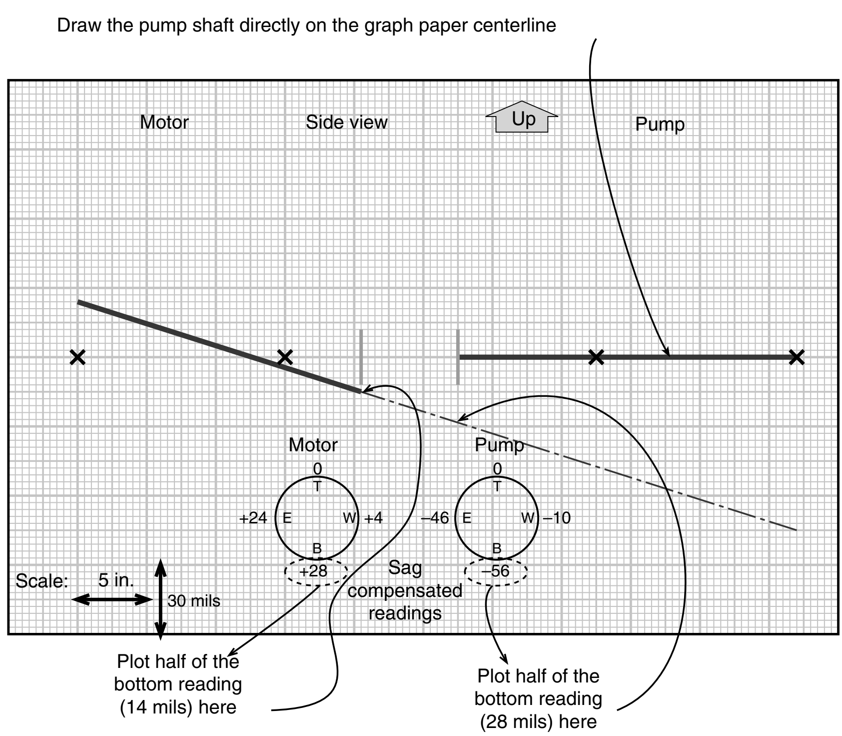


FIGURE 10.15 Side view example where the pump shaft was initially placed on the graph paper centerline and the motor shaft position was then plotted.

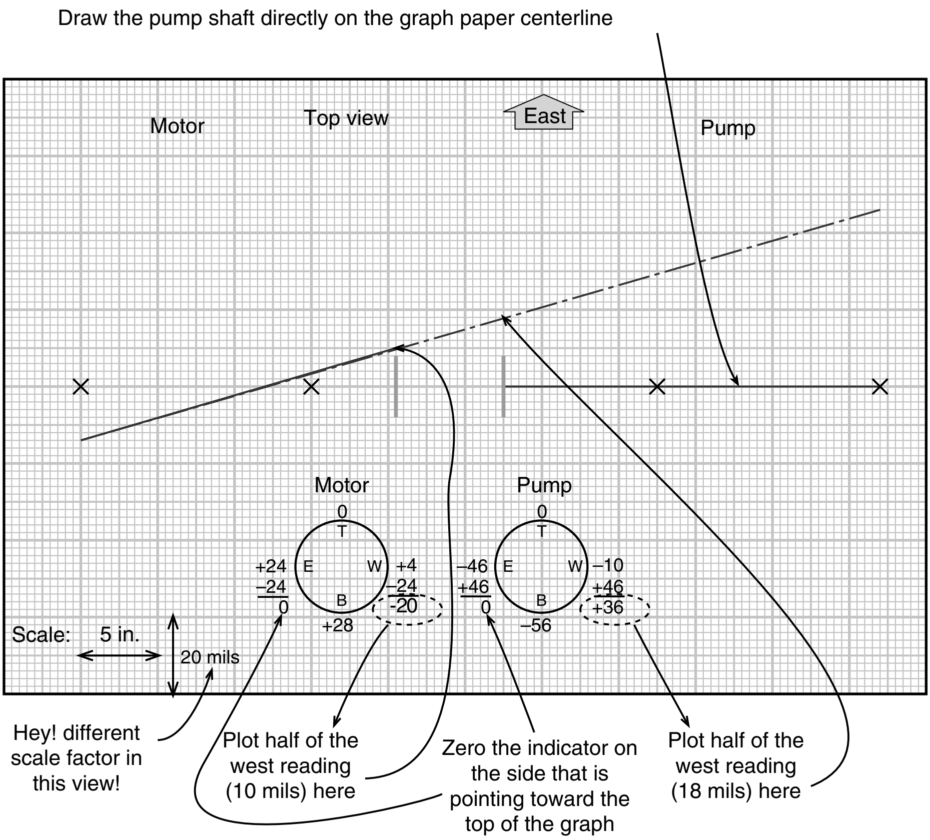


FIGURE 10.16 Top view example where the pump shaft was initially placed on the graph paper centerline and the motor shaft position was then plotted.

from the graph centerline toward the top of the graph (opposite of the point-to-point modeling technique).

5. These two points marked on the graph at the dial indicator reading points define the line of sight (i.e., the centerline of rotation) of the other shaft. Draw a straight line through these two points from the coupling end to the outboard end of the other shaft.

To make your alignment corrections, refer to the Section 8.4.6 and Section 8.4.7.

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