COUPLING ALIGNMENT MADE EASY

- *REVERSE INDICATOR*
- *FACE/RIM*
- *ACROSS-THE-FLEX ELEMENT*

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9/90

COUPLING ALIGNMENT MADE EASY

By graphically plotting the shaft misalignment, the solution becomes apparent. A picture is worth a thousand words.

Correct alignment is mandatory for successful operation of rotating equipment. A flexible coupling is no excuse for misalignment.

HOW DO YOU EASILY DETERMINE THE RELATIONSHIP OF ONE SHAFT CENTER LINE RELATIVE TO THE OTHER? IT IS HARD SOMETIMES TO VISUALIZE THIS.

This is done by drawing a picture on a piece of graph paper to visually show where the equipment is and how far it needs to be shifted to get it into perfect alignment.

There is some confusion between shaft alignment and coupling alignment. We will restrict the comments to couplings using two flexing elements. The coupling flex element sees angular misalignment only. It is possible, as you can see in Figure 1, to have misalignment between two shafts yet one end of the coupling can still be in perfect alignment with its center member.

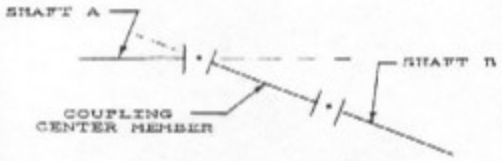


FIGURE 1

This could be the situation if all the problems are at one end of the coupling. In Figure 2, the two ends of the coupling share the misalignment equally.

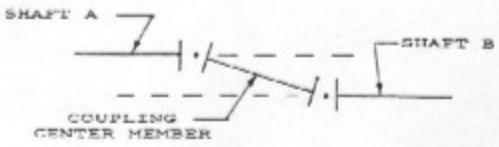


FIGURE 2

How do you go about correcting for shaft misalignment?

THESE INSTRUCTIONS WILL BE BROKEN DOWN INTO FOUR SECTIONS.

I. Items that must be considered before starting any of the alignment procedures.

II. Reverse indicator alignment graphical analysis.

III. Face and rim alignment graphical analysis.

IV. Across the flex element graphical analysis.

1. BEFORE STARTING

Before we get into the procedure itself, there are several items that must be considered before starting.

"SOFT FOOT"

"Soft foot" occurs when the equipment, let's say a motor, is not sitting flat on its base or it rocks. Now this rocking can be eliminated by tightening down all of the hold down bolts. What this does, however is to put the motor bearings under strain. This, in turn, can cause vibration. It also may give erroneous alignment readings. The "soft foot" must be corrected first. This is easily done by shimming under the motor foot until it no longer rocks.

INDICATOR SAG

Calibrate the dial indicator set-up sag. In other words, determine the difference in the dial indicator reading when it is on top of a shaft to when it is on the bottom. This is a gravitational effect. It is not necessary to eliminate sag but rather to know the amount of sag. The indicator set-up should be as rigid as practical, and then it should be calibrated. It is easily calibrated by mounting the set-up on a piece of pipe allowing the dial indicator to ride on the pipe itself. See Figure 3.

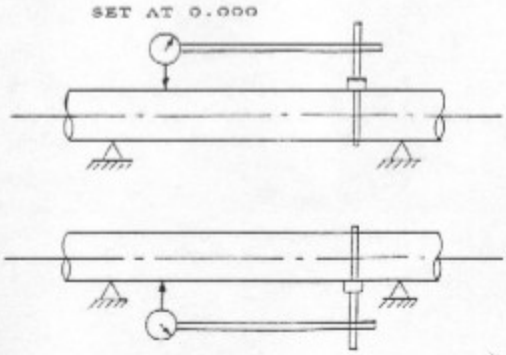


FIGURE 3

Set the indicator at "0" on top. Now roll the pipe over until the indicator is at the bottom of the pipe. The gravitational effect on the set-up can be determined by reading the indicator difference from top to bottom. This Delta reading can be algebraically subtracted from the alignment readings obtained at the bottom position.

In the example shown in Figure 3 the indicator set-up sag checked out to be −.005 inches. This reading will always be negative. The indicator set-up sag does not have to be considered for the horizontal or side-to-side reading.

ALIGNMENT READINGS

It is suggested that the dial indicator be zeroed at the top for convenience. The coupling hub should be marked at 0, 90, 180, and 270 degrees with a reference mark on the equipment so that the units can be turned through 90 degree increments. Both shafts should be turned together. This eliminates any runout that might exist between the point at which the indicator rides and the theoretical centerline of the shaft. Now rotate the coupling in 90 degree increments, recording all readings. It is important to keep the side-to-side readings straight. A suggestion is to refer to the sides of the unit as "near" and "far" ("near" being the side where you are standing). After making the four position check, return back to the top to make sure that the indicator returns to zero. If it does not, disregard the readings and repeat the above. It is a good practice to take several sets of readings to make sure they are consistent. It is a lot easier to take another set of readings than it is to move the units a second time.

THERMAL GROWTH

Now consider any thermal growth values for the equipment. For example, if the pump is pumping hot water, it will grow vertically from the ambient to the hot running condition. The whole objective is to have the equipment in good alignment when it is running under normal operating conditions. These predicted thermal movements can be obtained from the equipment manufacturer and should be taken into account before making the alignment changes.

SHAFT RELATIONSHIP

HOW DO YOU EASILY DETERMINE THE RELATIONSHIP OF ONE SHAFT CENTER LINE RELATIVE TO THE OTHER? IT IS HARD SOMETIMES TO VISUALIZE THIS. TO HELP, WHEN USING THE REVERSE INDICATOR METHOD, REFER TO FIGURE 4.

PUMP TO MOTOR ALIGNMENT GUIDE

THE PUMP IS FIXED IN PLACE AND THE MOTOR MOVABLE

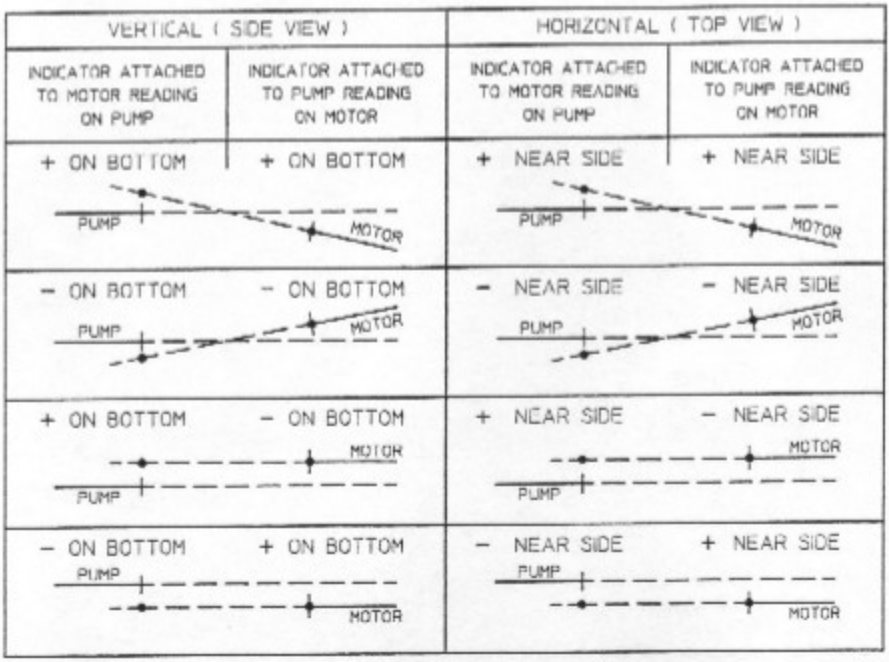


FIGURE 4

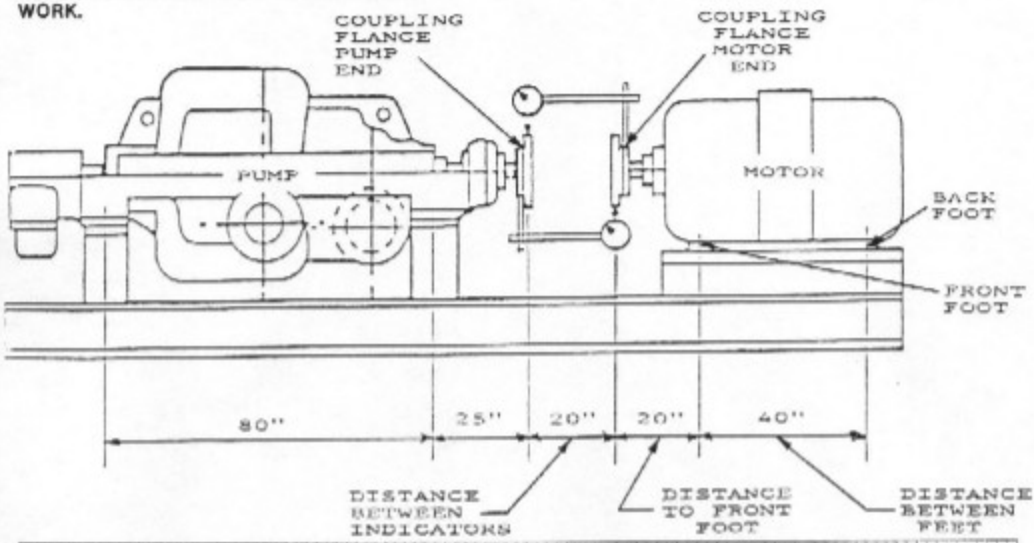
II. REVERSE INDICATOR

To explain the reverse indicator alignment procedure, a motor-to-pump example will be used. First correct the vertical misalignment by shimming, and then correct the horizontal misalignment by sliding the equipment from side-to-side. With proficiency these two steps can be done together.

REFER TO SECTION I FOR PRE-ALIGNMENT WORK.

Before starting the alignment work, determine which piece of equipment is easiest to move. This is not to eliminate the option of moving both units if a problem occurs. The pump, in this example, will be fixed. Therefore, the motor will be moved into alignment with the pump.

Now on a sheet of graph paper, lay out the equipment being aligned. See Figure 5.



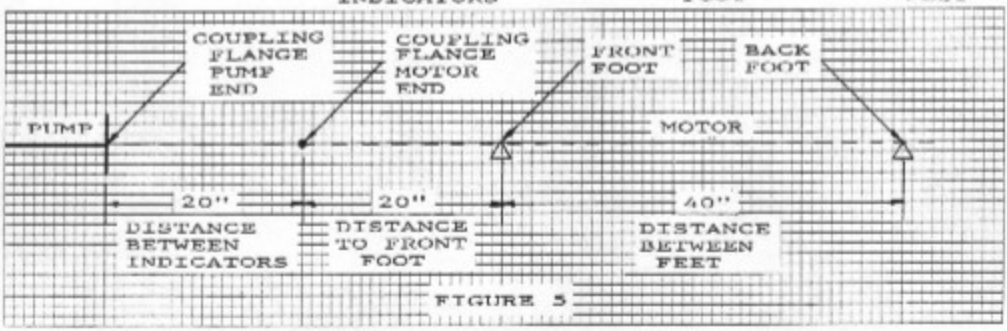


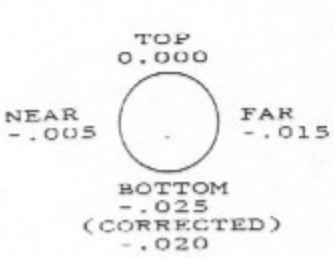
FIGURE 5

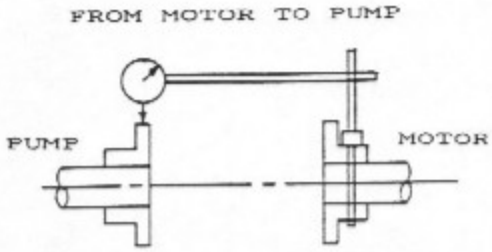
The horizontal scale on the graph used here is one small division equals one inch. The distances that are needed are:

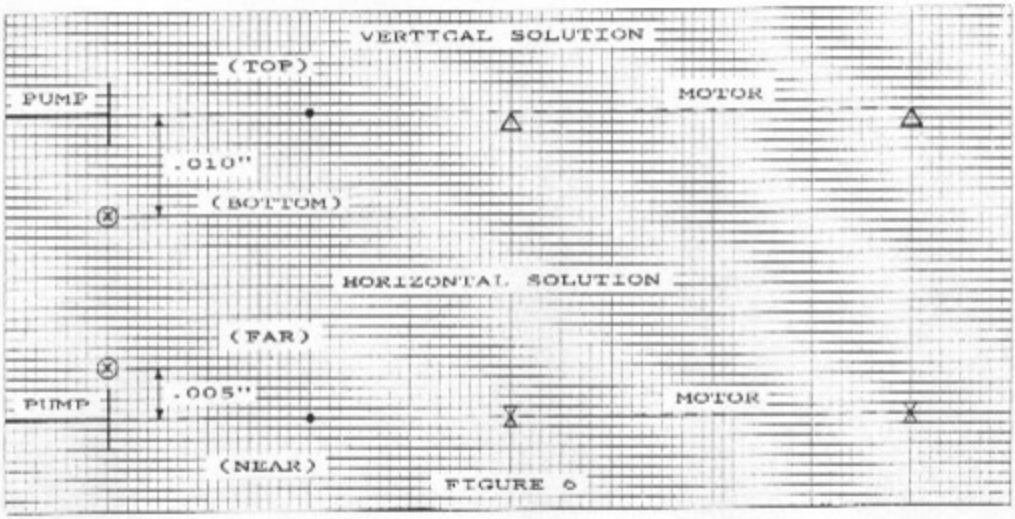
1. The distance from the first indicator riding on the pump hub to where the second indicator is riding on the motor hub. In the example, this is 20 inches.
2. The axial distance between the motor hub where the second indicator is riding and the center of the motor front foot. In the example, this is 20 inches.
3. The distance from the center of the front motor feet to the center of the back motor feet. In this example, this is 40 inches.

VERTICAL ALIGNMENT SOLUTION

The alignment can be done either with the coupling totally installed, with the coupling hubs mounted, or with the coupling totally removed from the shafts. Find a spot to mount the dial indicator bracket. The shaft behind the hub or the hub itself is good. A chain clamp alignment bracket usually fits in well. With the indicator bracket attached to the motor hub and the dial indicator reading off the pump hub, rotate both units in 90 degree increments and take readings. These are shown in Figure 6.



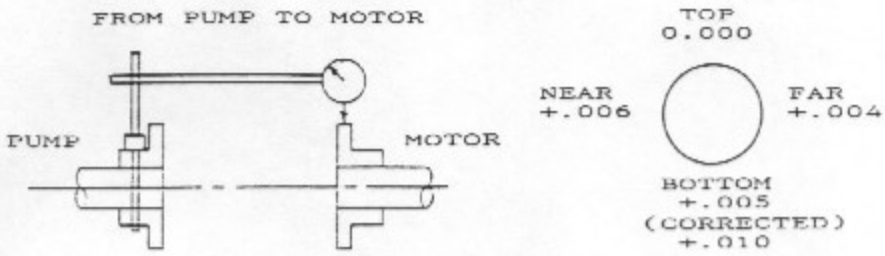


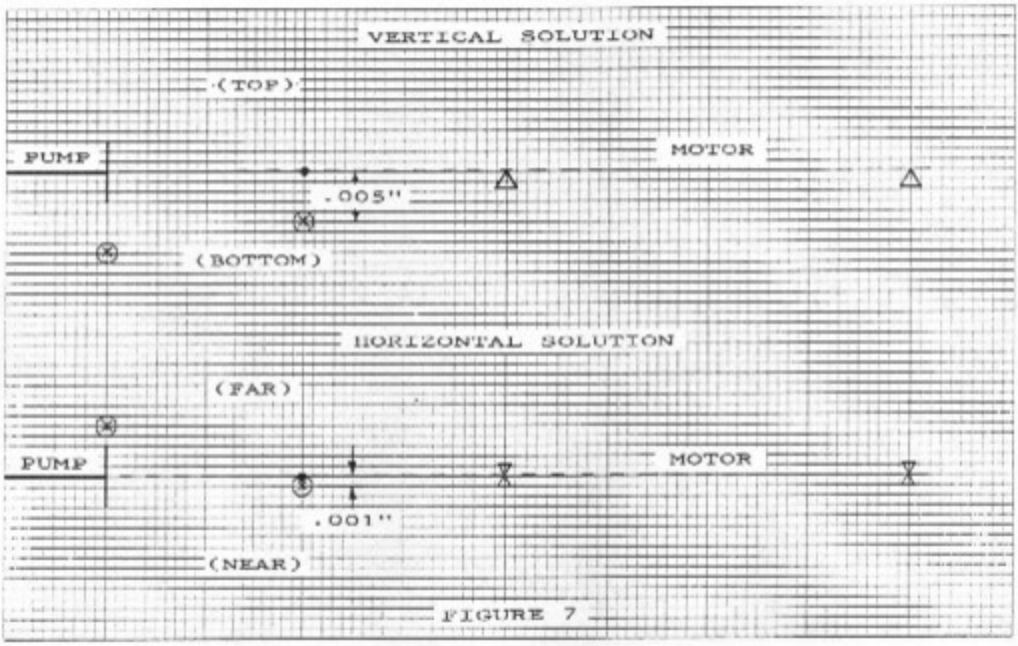


The bottom reading is then corrected for indicator set-up sag. The indicator set-up sag in this example was determined to be −.005 inches. A −.005 was subtracted algebraically from the −.025 indicator reading. Corrected reading is −.025 −(−.005) = −.020. The readings taken are total indicator readings (T.I.R.) which are two times the actual shaft-to-shaft relationship. This means that the readings taken must be divided by two. To solve for the vertical (up and down) part of the problem, take the corrected bottom reading of −.020 and divide it by two −.020 ÷ 2 = −.010. With a minus reading on the bottom of the pump flange, the motor center line extension must be lower than the center line of the pump. For further clarification, reference Figure 4.

Use a convenient scale in the vertical of .001 inches per small division. Plot this point as shown in Figure 6. Do nothing with the horizontal (near/far) readings at this time.

Reverse the bracket set-up by attaching it to the pump hub as shown in Figure 7 with the dial indicator reading off the motor hub.

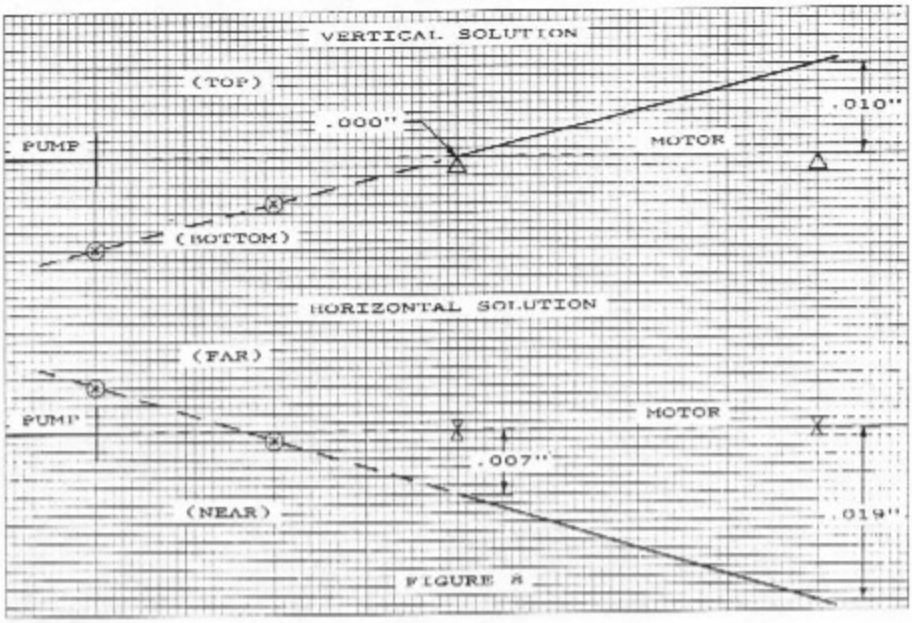




Take a set of alignment readings. In this case, the indicator shows a reading on the bottom of +.005 inches. Correcting for indicator sag by algebraically subtracting the −.005 indicator set-up from the +.005 which gives a +.010 corrected reading. Now divide this number by 2 as it is a total indicator reading. With a plus indicator reading on the bottom, the motor is low, relative to the theoretical center line of the pump. To help you to see the shaft to shaft relationship, refer again to Figure 4.

Use the same scale of .001 inch per small division. Now plot the +.005 on the graph as shown in Figure 7.

The solution to the problem now becomes easy. Draw a line through the two points plotted and extend it beyond the plane of the motor feet as shown in Figure 8.



Then by counting the graph graduation in line with each of the motor feet, it can be seen that the motor must be lowered by .010 inches at the back foot and left alone at the front foot. By making this correction, the motor center line extension falls on top of the pump center line. This would solve the vertical alignment problem if there was no thermal correction to be made for either the pump or the motor.

NOTE: If the vertical scale chosen is too big, it may realize some minor shimming errors.

Let's say that the pump does grow .005 inches at both ends because it is handling a hot liquid. In order to compensate for this, add an additional .005 inches to each motor foot in order to have the motor in line with the pump when the pump is running under normal operating conditions. The total solution now is to add .005 inches of shims to the front motor feet and subtract .005 inches of shims from the back motor feet. The vertical alignment is now solved.

HORIZONTAL ALIGNMENT SOLUTION

In a similar manner, the side-to-side movements can be plotted. Refer back to Figure 6 and imagine looking straight down on the pump/motor combination. The alignment readings obtained were −.005 inches on the "near" side (this is the side you are standing on) and −.015 inches on the "far" side. By adding a value of .015 to each side, the "far" side becomes 0.000 and the "near" side becomes +.010 T.I.R. or +.010 ÷ 2 = +.005 inches actual. With a "+" on the "near" side, the motor center line extension falls on the "far" side of the pump center line. See Figure 4.

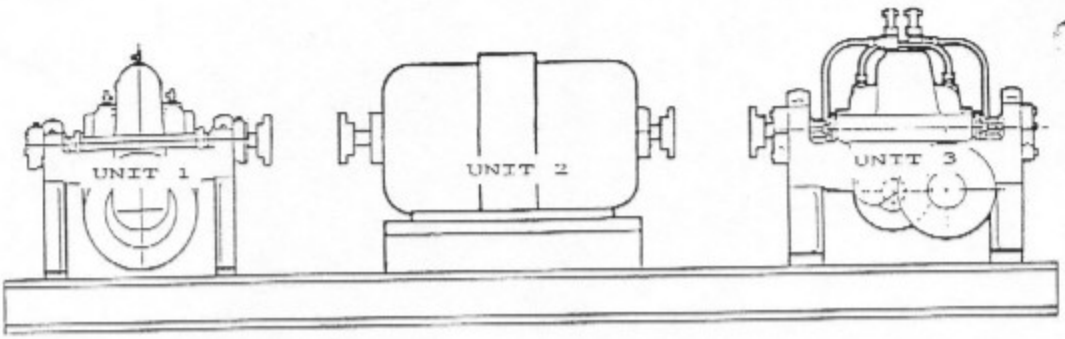
Now plot this point as shown in Figure 6.

Moving on to Figure 7, the side-to-side alignment readings obtained were +.006 inches on the "near" side and +.004 inches on the "far" side. By subtracting .004 from each side, the "far" side becomes 0.000 and the "near" side becomes +.002 T.I.R. or .002 ÷ 2 = .001 inches actual. With a "+" on the "near" side, the motor center line is on the "near" side of the pump center line extension. (See Figure 4.) Now plot this point as shown in Figure 7.

Now draw a line through the two plotted points, extending it past the front and back motor feet as shown in Figure 8.

As the graphical plot shows, the motor must be moved .007 inches towards the "far" side at the front foot and moved .019 inches towards the "far" side at the back foot. This solves the horizontal alignment provided there is no side-to-side movement caused by operating conditions.

Where this graphical procedure really has its greatest value is when there are more than two units in one train to be aligned. As shown in Figure 9, there are three pieces of equipment to be aligned.



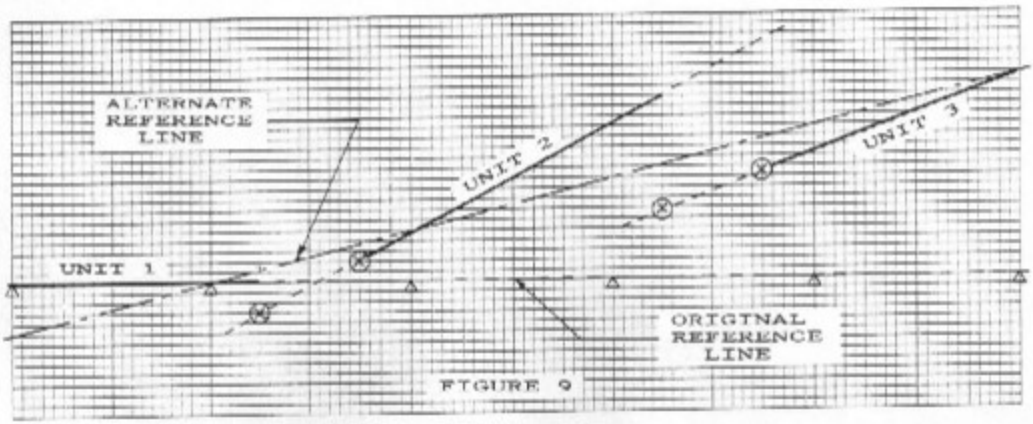


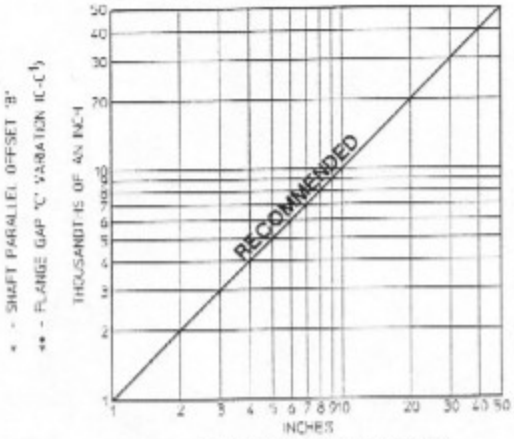
FIGURE 9

If you start by aligning the second unit to the first unit and then the third unit to the second unit, the third unit may have to be moved a considerable distance. In the actual installation, there may not be room to move that third piece of equipment the required amount. For example, there may not be enough shims under the third unit to lower it or there may not be clearance in the bolt holes in order to move it sideways. The approach that should be taken is shown in Figure 9. Plot all three units on one piece of graph paper after taking reverse indicator alignment readings across both couplings. As can be seen, the third unit is a long way off the original reference line. By drawing an alternate reference line close to the actual position of the three units, it can be seen that there is minimal movement required to get all the units in align with respect to the alternate reference line.

Alignment problems can be made easier. There are a lot of tools on the market to make the mathematics simple, however, a graphical picture shows the whole problem at a glance and makes the solution apparent.

Alignment Chart, Figure 10 may be helpful.

ALIGNMENT CHART



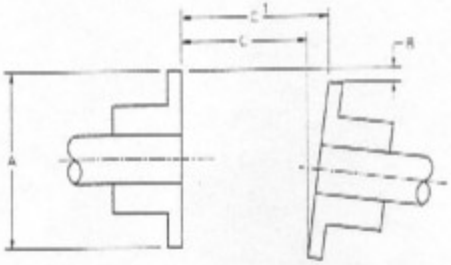


FIGURE 10

III. FACE/RIM

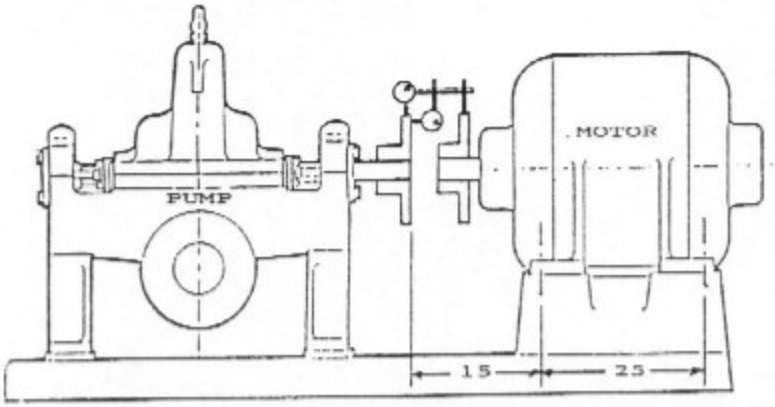
To explain the face/rim alignment procedure, a motor to pump example will be used. First, correct the vertical misalignment by shimming and then correct the horizontal misalignment by sliding the equipment from side-to-side. With proficiency, these two steps can be done together.

REFER TO SECTION I FOR PRE-ALIGNMENT WORK.

Before starting the alignment work, determine which piece of equipment is easiest to move. This is not to eliminate the option of moving both units if a problem occurs. The pump, in this example, will be fixed. The motor will be moved into alignment with the pump.

VERTICAL ALIGNMENT

Now on a sheet of graph paper, lay out the equipment being aligned. See Figure 11.



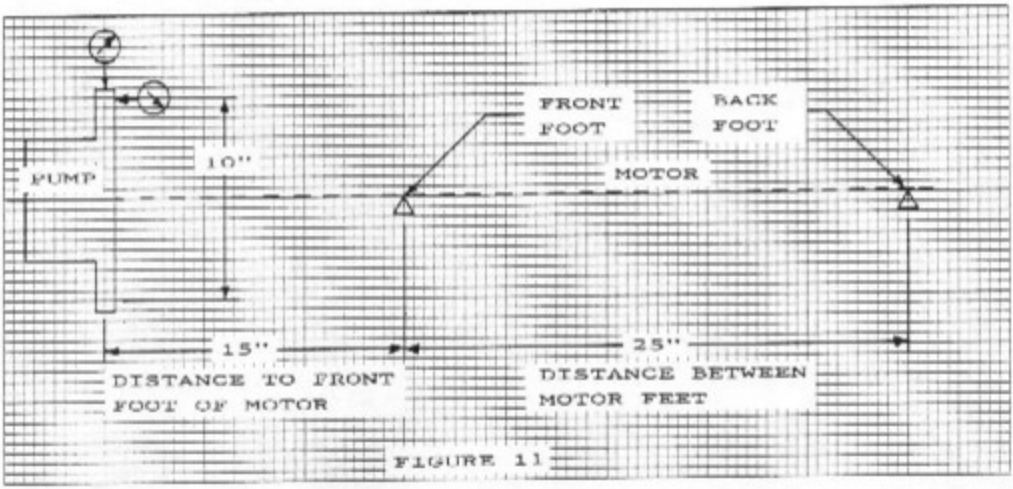


FIGURE 11

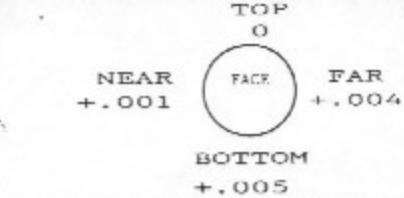
The horizontal scale on the graph used here is one small division equals one inch. The distances that are needed are:

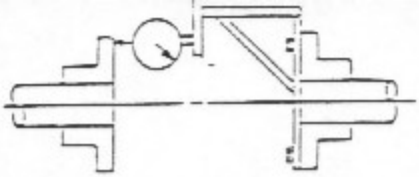
1. Distance from where the indicator rides radially on the pump hub, to the center of the motor front feet. In the example, this is 15 inches.
2. Diameter of the pump hub flange, at the location the face indicator rides. In the example, this is 10 inches.
3. Distance from the center of the motor front feet to the center of the motor back feet. In the example, this is 25 inches.

The alignment can be done either with the coupling totally installed, or with just the coupling hubs mounted. Find a spot to mount the dial indicator bracket. The shaft behind the hub or the hub itself is good. A chain clamp alignment bracket usually fits in well.

ANGULAR (FACE) SOLUTION

With the indicator bracket attached to the motor hub, reading off the pump hub face, rotate the shafts in 90° increments and take readings (See Figure 12). **NOTE:** Make sure that neither of the equipment shafts being aligned move axially as this will distort the face readings.





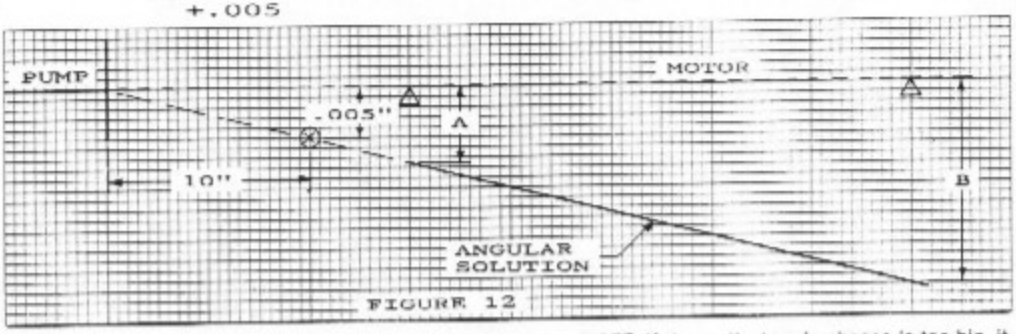


FIGURE 12

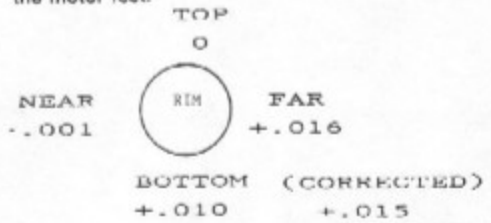
Reading on the face at a 10 inch diameter and getting +.005 at the bottom, we know the motor shaft is off .005 inch for every 10 inches in length. The plus reading at the bottom means the indicator was compressed. This can only happen when the motor shaft is low compared to the pump centerline extension. This can be shown graphically: Use the pump flange center as a pivot point. Extend the 10 inch (diameter of hub flange) along graph (pump centerline). Using a vertical scale of one small division on the graph equals .001 inch, plot the .005 inch as shown in the example. See Figure 12. Draw a line from the center of the pump flange face through the .005 inch point and extend it past the motor feet.

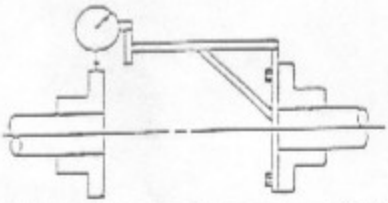
NOTE: If the vertical scale chosen is too big, it may realize some minor shimming errors.

The (face) angular vertical misalignment could now be corrected. From the graph, the solution is to add .0075 inch shims to the front foot (A) and add .020 inch shims to the back foot (B). **As it is easier to make one shim change instead of two, solve the parallel offset (rim) before shimming. Then add the two results together and make one move.**

PARALLEL OFFSET (RIM) SOLUTION

Now with the indicator bracket attached to the motor hub, reading off the pump hub outside diameter, rotate unit in 90° increments and take readings. See Figure 13.





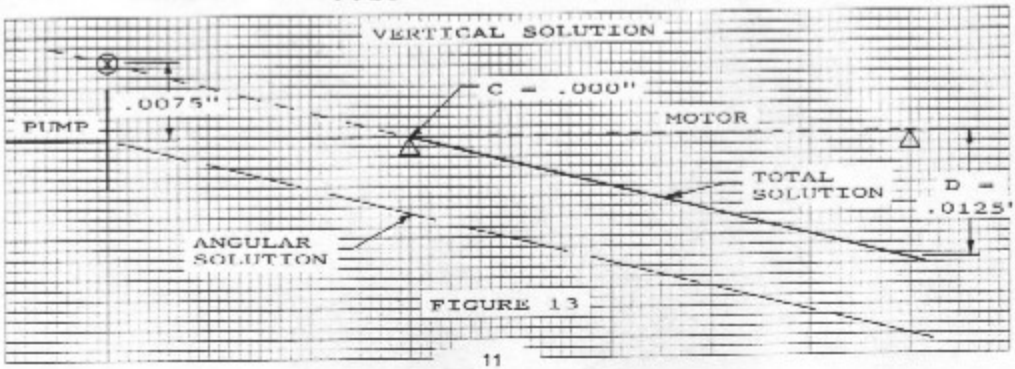


FIGURE 13

Bottom reading is then corrected for indicator sag. Indicator sag in the example was determined to be −.005. The −.005 was subtracted from the +.010 indicator reading to give an actual +.015 reading or +.010 − (−.005) = +.015.

As this is a T.I.R. (Total Indicator Reading) it is two times the actual shaft to shaft relation. +.015 ÷ 2 or +.0075 is used to show where the motor centerline extension is, relative to the pump shaft centerline at the pump hub. With a plus reading at the bottom it indicates motor shaft is high compared to the pump. Using a scale of one small division on the graph equals .001 inch, plot this point as shown in the example. The parallel offset (rim) misalignment alone could be corrected by removing .0075 inch of shims from under both front and back feet.

TOTAL VERTICAL ALIGNMENT SOLUTION

By drawing a line parallel to the angular (face) solution and thru the parallel offset (rim) point the total solution can be read off the graph at "C" and "D". In this example C = 0 and D = .0125 inches. Add .0125 inch shims to back foot. See Figure 13.

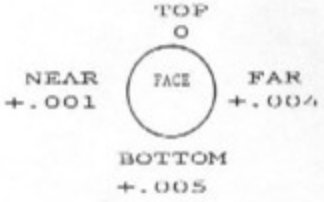
If there are any thermal growth considerations, they should be added or subtracted to the results before shim change. In the example, there are none.

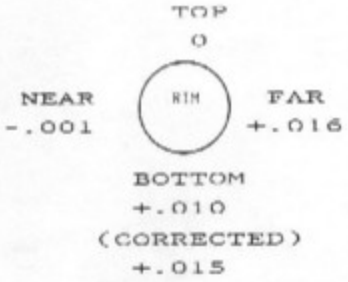
TOTAL HORIZONTAL ALIGNMENT SOLUTION

For the horizontal (side-to-side) results, the same procedure is used. Algebraically subtract the side-to-side readings. Indicator sag can be ignored as it cancels out. Plot these readings and the results can be read off the graph. See Figure 14.

The solution for this example is: At the front motor feet, push the motor away from you by .004 inches and at the back motor feet pull the motor towards you by .0035 inches.

Alignment Chart, Figure 10, may be helpful.





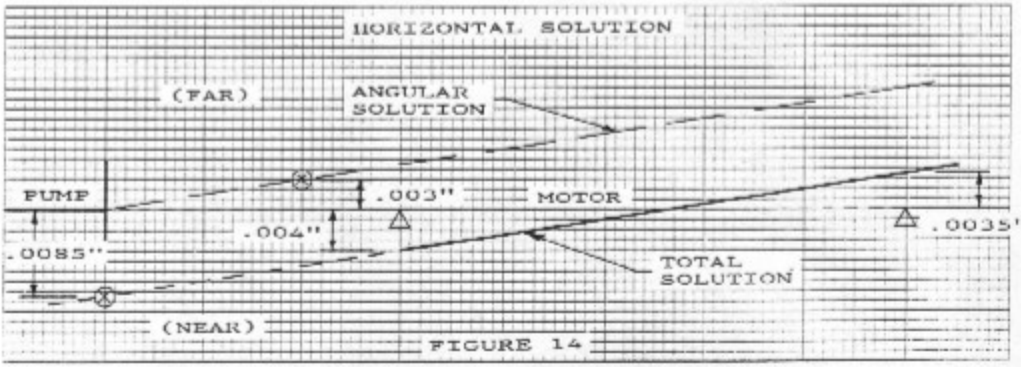


FIGURE 14

IV. ACROSS-THE-FLEX ELEMENT

When the distance between the disc packs is long and where it is not practical to try to span the distance with indicator bracketry, the "across-the-flex element method" can be used.

To explain the across-the-flex element alignment procedure, a motor to a right angle gear example will be used. First, correct the vertical misalignment by shimming and then correct the horizontal misalignment by sliding the equipment from side-to-side. With proficiency these two steps can be done together.

REFER TO SECTION 1 FOR PRE-ALIGNMENT WORK.

Before starting the alignment, determine which piece of equipment is easiest to move. This is not to eliminate the option of moving both units if a problem occurs. The gear box, in this example, will be fixed. The motor will be moved into alignment with the gear box.

VERTICAL ALIGNMENT SOLUTION

Now on a sheet of graph paper, lay out the equipment being aligned. See Figure 15.

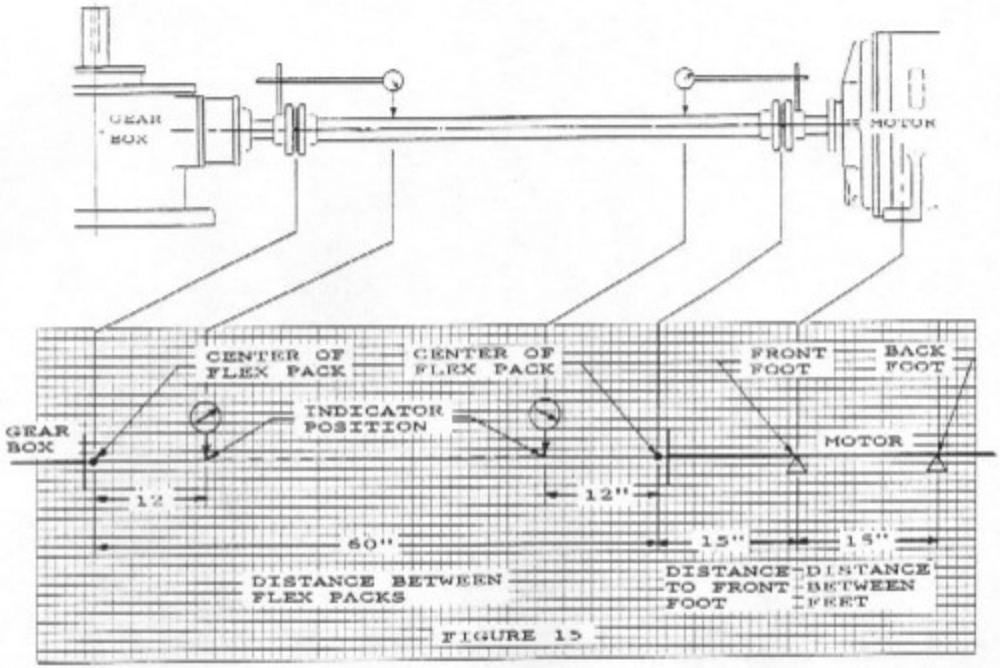


FIGURE 15

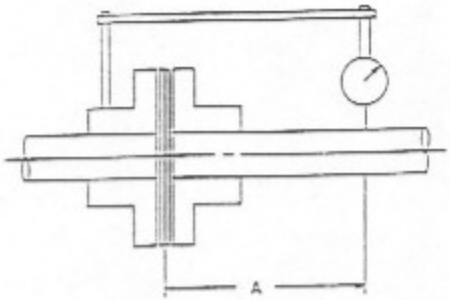
You should use a scale that is convenient to the size of the graph paper. The horizontal scale on the graph used here is one small division equals one inch. The distances that are needed are:

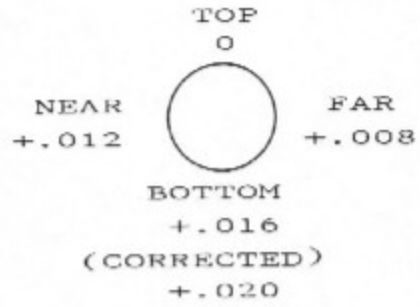
You should use a scale that is convenient to the size of the graph paper. The distances that are critical are:

1. Distance from center line of one flex pack to the center line of the other flex pack. In the example, it is 60 inches.
2. Distance from center line of motor flex pack to center of front motor foot. In this example, it is 15 inches.
3. Distance from the center of the motor front feet to the center of the motor back feet. In this example, it is 15 inches.
4. Distance from flex pack to dial indicator on center member. In this example, the distance is 12 inches.

The alignment can be done only with the coupling totally installed. Find a spot to mount the dial indicator bracket. The shaft behind the hub or the hub itself is good. A chain clamp alignment bracket usually fits in well.

With the indicator bracket attached to the gear box hub, reading out on the center member a convenient distance, (in this example 12 inches was used) rotate the unit in 90° increments and take readings. See Figure 16.





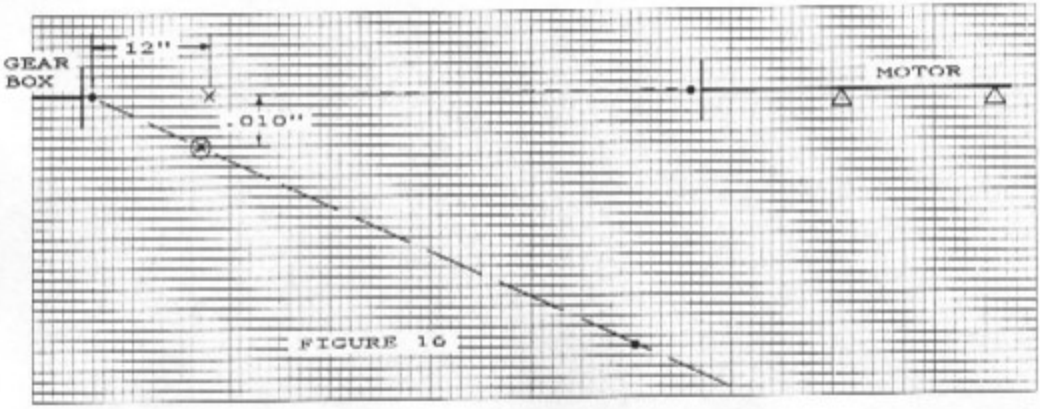


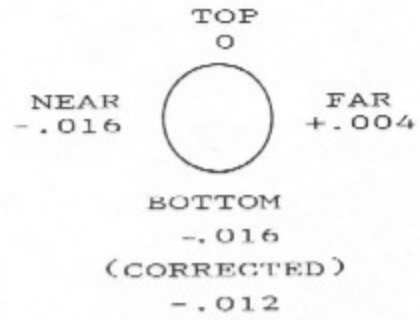
FIGURE 16

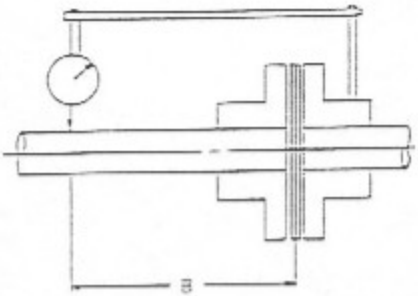
Bottom reading is then corrected for indicator sag. The indicator sag in the example was determined to be −.004 inches. The −.004 was subtracted from +.016 indicator reading to give an actual of +.020 reading or +.016 − (−.004) = +.020.

As this is a T.I.R. (Total Indicator Reading) it is two times the actual center member center line location relative to the pump shaft extension or +.020 ÷ 2 = +.010. (What we are trying to do here is to determine the angle the center member makes with respect ot the gear box shaft).

A plus reading at the bottom indicates that the center member tips down as it extends away from the gear box. Using a scale of one small division on the graph equals .002 inches, plot the .010 as shown in the example. See Figure 15.

Now with the indicator bracket attached to the motor hub reading out on the center member, rotate the unit in 90° increments and take readings. See Figure 17.





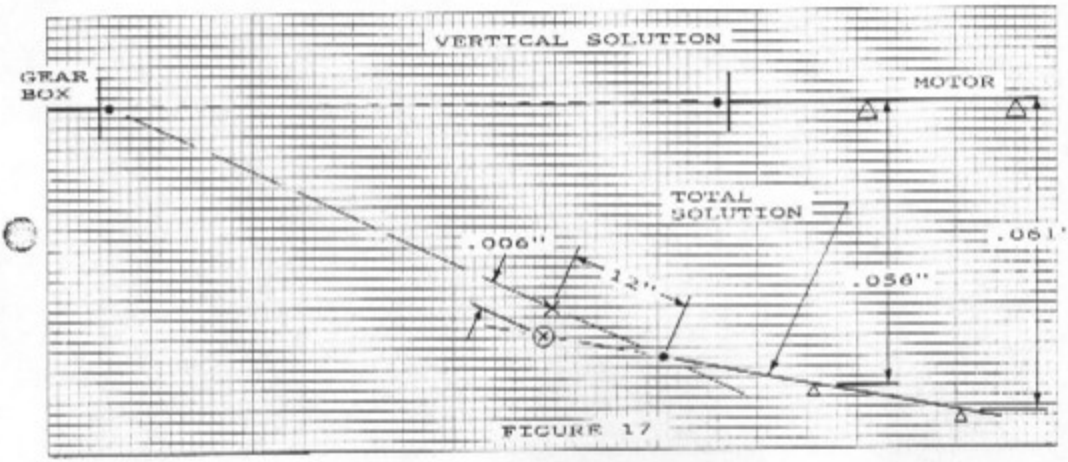


FIGURE 17

Bottom reading is corrected for indicator sag: $-.016 - (-.004) = -.012$. This is T.I.R. so actual is $+.006$. (What we are trying to do here is determine the angle the center member makes with respect to the motor shaft).

The minus reading on the bottom indicates that the center member tips up as it extends away from the motor. Using a scale of one small division on the graph equals .002 inches, plot the .006 inches as shown on the example.

The motor shaft can now be drawn in because two points along it have been defined: 1. Center of the flex element. 2. The point just plotted .006 inches below center member. The shimming requirements can now be read off the plot where the motor shaft intersects the planes of the motor feet.

NOTE: If the vertical scale chosen is too big, it may realize some minor shimming errors.

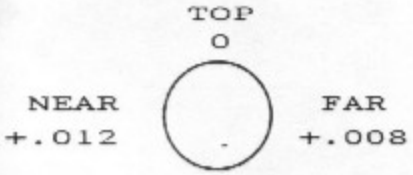
In this example the motor should be shimmed up .056 inches under front feet and shimmed up .061 inches under back feet.

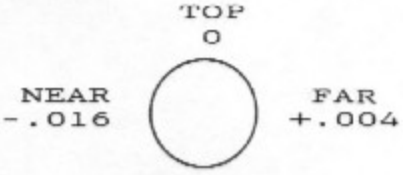
HORIZONTAL ALIGNMENT SOLUTION

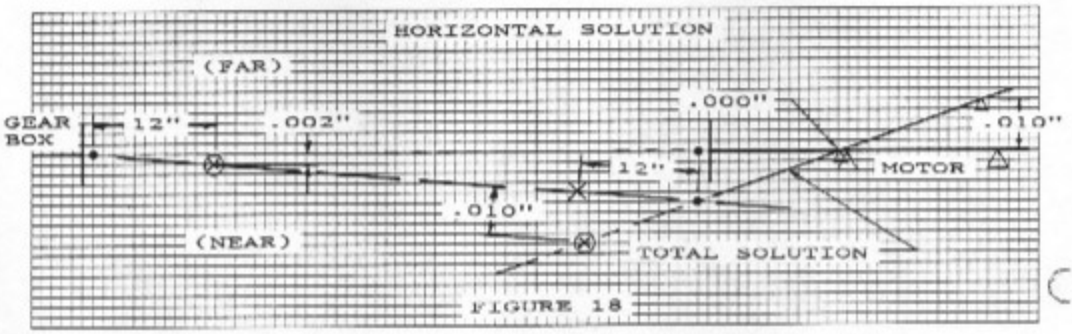
For the horizontal (side-to-side) results, the same procedure is used. Algebraically subtract the side-to-side readings. Indicator sag can be ignored as it cancels out. Plot these readings and the results can be read off the graph. See Figure 18.

The solution for this example is: At the front motor feet, do not move the motor and at the back motor feet, pull the motor towards you by .010 inches. See Figure 18.

The Alignment Chart, Figure 10, may be helpful.







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