REVERSE-INDICATOR ALIGNMENT AND RELATED SUBJECTS

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This paper is a discussion of reverse-indicator measurement and other alignment subjects. The basic steps in doing an alignment job and some of the tooling that can be used will be described. The basic steps in alignment are as follows:

1. Do preliminaries such as piping connection without excessive strain, check and elimination of soft foot conditions, and check of coupling for axial spacing.
2. Do cold measurement, including bracket sag correction and data recording.
3. Do calculation of corrective moves, including any applicable thermal offsets such as could be obtained by using one of the growth measurement methods.
4. Make the corrective moves.
5. Repeat cold measurement and compare with desired figures. If not within required tolerance, run through another calculation-move-measurement cycle.

Various methods for measuring machinery thermal growth are available. This paper will describe the remainder of the alignment process. A reverse-indicator measurement setup takes "rim" measurements in two planes along the shaft axes. This is the best alignment measurement method for most situations, being easiest to apply and most accurate. With this arrangement, it is unnecessary to disconnect the coupling, and shaft axial float in sleeve bearings does not cause error. Other setups are the face-and-rim and the face-face-distance. Face-and-rim is useful when only one shaft can be turned, or when the coupling diameter greatly exceeds the axial span between flexure planes. Face-face-distance is used mainly with cooling tower drives, since it can handle unlimited axial spans without bracket sag problems.

Having taken and systematically recorded the measurements, it is now desirable to calculate the required corrective moves, plus any thermal offsets to be included. The objective is to achieve relative positions of adjacent machine elements such that at stabilized hot running conditions the extensions of their shaft centerlines coincide, or nearly so. How important this is, i.e., allowable tolerance or deviation from the ideal, depends on such factors as machine temperatures, speed, type of bearings and coupling, coupling spacer length, vibration and failure history, and economic and safety consequences of premature failure. Some machines can get along all right with just a cold straightedge alignment. For others, a cold dial indicator alignment will suffice, with no thermal growth correction. For hot pumps and most large or high speed turbomachinery, though, it is advisable to do a careful job, using dial indicators, and thermal offsets based on accurate growth measurements. For actual running misalignment tolerances, 1/4 to 1/8 thousandth maximum centerline offset deviation per inch of axial distance between coupling flexure planes has been recommended.

Getting back to the calculations, some people do not calculate, but rely on "feel", "instinct", or trial-and-error. This is likely to be time-consuming, and the calculations are not really that difficult, especially if the data are recorded on a well prepared form. The calculations can be done mathematically by longhand, graphically on paper or a plotting board, or electronically on a portable minicomputer or a remote central computer. For many alignment jobs, including two-element trains or multi-element trains done piece by piece, the plotting board will suffice. This is a compact, portable, two piece, graphical calculator which will handle both reverse-indicator and face-and-rim data, and easily converts from one to the other. Used properly, this device gives an accurate solution in about one minute.

Having done the calculations and determined the required moves, we are now faced with the task of making them. Several methods exist for doing this, as follows:

1. Hammers. Steel is bad, and can cause machine damage. Lead is all right, but not very durable. Plastic-faced hollow-head shot-loaded "dead blow" hammers are the most practical.
2. Jackscrews. Jackscrews should be rigidly supported to avoid stick-slip problems. They can sometimes be clamped on, but are usually better if installed permanently. They are often hard to retrofit in the field if hot work is not permitted.
3. Portable positioners. There are two types — screw lift and hydraulic lift. These devices use planar ball bearings and are especially advantageous for moving large electric motors. They permit making vertical, horizontal, and axial moves all in one overall movement, so the vertical correction does not upset the previous horizontal correction. They are used in pairs, and are limited to six tons per pair for the screw lift, and 20 tons per pair for the hydraulic lift. They move heavy machines accurately with an input force from two fingers of one hand, and are a real time saver.
4. Other movement devices which are sometimes useful include prybars, mechanical and hydraulic jacks, rams, wedges, comealongs, and cranes.
A word of caution on using commercially available pre-cut shims. Measure the thickness to be sure — sometimes markings are not accurate. Unrecognized, this can cause a soft foot condition and necessity for repeated corrections.

There are several types of "universal" clamp-on jigs available for sag calibration by zeroing indicators and rolling the object top to bottom. Graphite fiber epoxy composite tubing is often used and has the advantage of a high stiffness-to-weight ratio. Its disadvantages are high cost and a requirement for careful handling to avoid cracking. It has been found to be quite practical, though, and is preferred for longer spans. These longer spans need to be equipped with a sag remover. This system uses a counterweight to take out arm sag, which would otherwise be about 0.062 in on 180° rotation, or 0.031 in net.

The dial indicators used for most setups have a range of 0.200 in. (which can be doubled with an accessory), and has the advantage of compactness and light weight. Other high quality dial indicators can also be used. These can be modified a bit further by removing the main spring and adding an external counterweight. This helps to minimize the error introduced by the indicator spring force causing jig deflection. As it happens, this error is small enough to be neglected in most instances.

Many jigs manufactured are "universal" and can be varied in their dimensions to fit a variety of machine configurations. The other way of handling the situation is to make up custom brackets for each machine. Such brackets may have an advantage in their rigidity, but can be awkward to keep track of and to calibrate for sag. They also usually require face mounting, necessitating coupling spacer removal, rather than clamping onto the shaft with spacer remaining installed. An inclinometer is used for accurate top dead center finding and quadrant rotation, and is a little tool which is useful for installing smooth vertical surfaces at machine feet, for accurate indicator move monitoring.

REFERENCES
2. Murray, M. G., "All the Facts About Machinery Alignment." Hydrocarbon Processing, Vol. 53, No. 10 (October 1974), pp. 139-145. This includes an extensive bibliography of alignment writings by authorities such as Dodd, Essinger, Jackson, and others.