A. Bases Without Target Pads

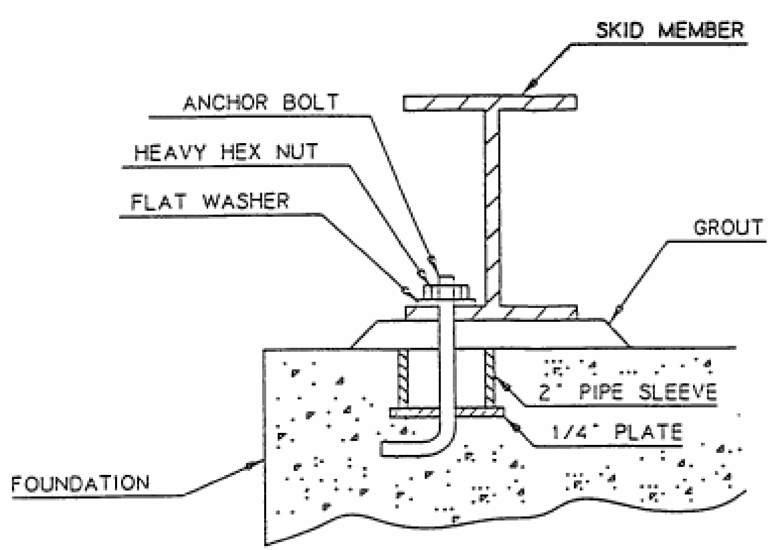
INSTALLING AND GROUTING PACKAGED SKIDS

The foundation pad for a process system package should be level, flat and clean. The pad thickness and design should take into consideration the nature of the sub-soils and the weight of the operating package. Base slabs laid on plastic or unstable subsoil may transmit vibration and / or settle in an unpredictable fashion. Provision for grounding, electrical conduits and other utilities that may be necessary that must penetrate the slab should be carefully laid out in advance.

The steel base should be bolted down to concrete substructure with anchor bolts at locations shown on the drawing. Sub-structure must be level, and it should be grouted to assure continuous contact with all accessible full depth members. This is essential on structural members supporting drivelines. It is recommended that the steel base to be filled with concrete to top of base in all pockets that are accessible and free of piping (allowing access for drain valves, etc.)

Anchor bolts should be positioned in ferrules fabricated from 2 IPS (50 DIN) pipe *(or* equivalent). The ferrule should be flush with the surface of the rough level. Soft wadding (or equivalent) should be used to center the bolt in the ferrule during placement of the package unit. This provides bolt flexibility to allow for final position and manufacturing tolerances. After final position has been obtained, the grout should flow into the ferrules and lock the anchor bolts into position.

No less than 1" (25 mm) of non-shrink epoxy base grout is recommended. The base may be leveled using conventional procedures and verified to be level side to side and corner to corner. Care should be taken to insure cross members are supported even if no measured deflection is observed.



Typical Installation

B. Bases With Target Pads

1.0 Purpose

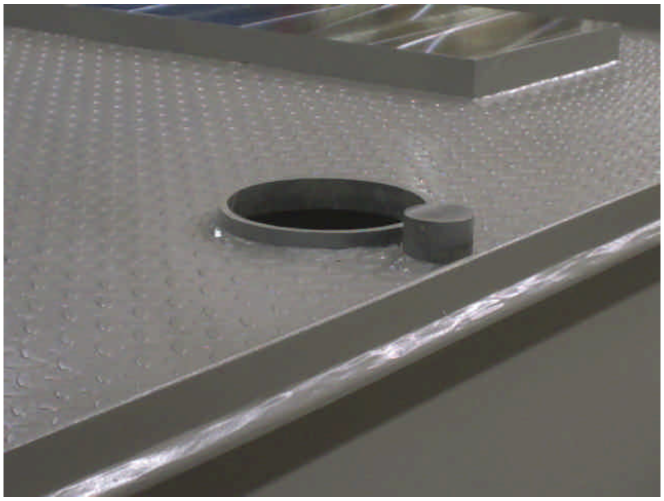
1.1 This guidance has been issued to ensure that Packages utilizing “Target Pads” for base setting are properly interpreted and applied when setting the package base. Proper utilization of the base targets will ensure the package is installed in the same plane as when fabricated. The purpose of this procedure is to eliminate problems associated with motor, gear, and/or compressor alignments and pipe strain resulting from deformation of the base during shipment, handling and setting.

2.0 Application

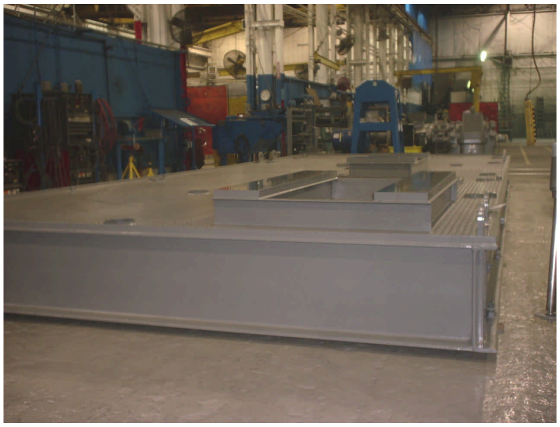
2.1 This guidance applies only to packages utilizing target pads. Target pads are typically used on large screw compressor packages with vertical oil separators or centrifugal drivelines. Targets are sometimes used on large packages that must be bolted together in the field. Refer to the project general arrangement drawings.

3.0 General

3.1 The package base has been designed with sufficient stiffness to prevent permanent deformation of the structure during normal handling. Because of size and weight limitations it is not possible to design a base that will not experience some deflection during handling and setting. However, if the base is installed in the same elevational relationship as it was manufactured, the components on the base should return close to their original relationship. In order to insure the package is restored to its “as built” condition a number of target posts have been installed on the base to permit measurement of the base’s elevation in several locations. During fabrication the pre-assembled base is set and steel plates are placed under each jack bolt. The base is then leveled using a transit. Readings are then taken from the top of each target and recorded on an inspection sheet. After the package has been completely assembled the elevation of all the targets are shot a second time and the deviation above and below the original zero lines are recorded. The measured deviations are then stamped on to the tops of the targets. If the base elevations are accurately re-established, less time and effort will be required to align the drive components.



Target near base fill hole.



Leveled base at factory.

4.0 TOOLS

4.1 A good quality accurate surveying Instrument (transit) or equivalent

4.2 Tripod

4.3 Sliding Scale – (story pole) – with minimum graduations of 0.12" (3mm).

4.4 Alignment indicators or laser alignment tools.

4.5 Wrenches for adjusting the jack bolts.

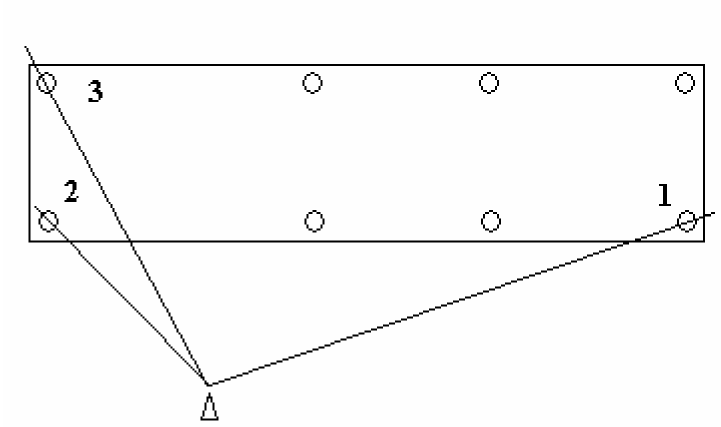
4.6 3” x 3” (75 x 75 mm) or equivalent ¼” to ½” (6-12 mm) thick steel plates to place under the base jack bolts.

5.0 BASE SETUP

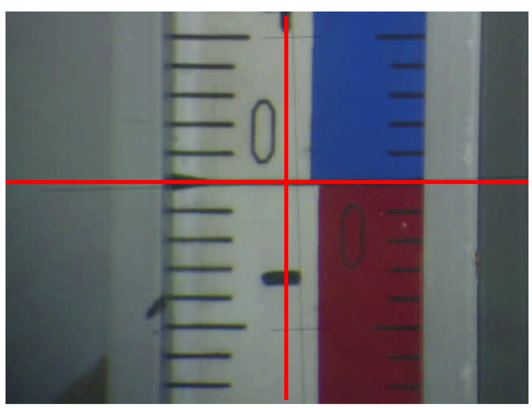
5.1 The foundation should be reasonably clean, level and flat. The package frame should be located in its final position and steel plates placed under each jack bolt prior to lowering the base. Jack bolts should turn freely and may be lubricated with anti-seize compound to prevent galling. The plates should be set flush with the edge of the base so as not to protrude after grouting. The jack bolts should all extend down at least ½” to ¾” inch (12 to 18 mm) below the base to allow for a minimum of 1” (25 mm) of grout under the frame after the base has been set.

Steel plates under jackbolts to prevent gouging pad.

5.2 Set the transit at a point approximately halfway between the targets to be measured and approximately three (3 to 5) feet (1 to 2 M) back from the base. A position that can effectively shoot two to three of the frame corners is desirable if it can be achieved. One or more corner target posts will have a zero stamped in the top and may be used as a starting point.



5.3 Verify your instrument has been properly leveled and elevated to allow comfortable viewing and that the focus is sharp and parallax free. Place the “story pole” on top of the starting target and adjust the sliding scale on the story pole until the crosshair is centered on zero. In the example above the target identified as "1" has a value of zero and could be used as a starting point.



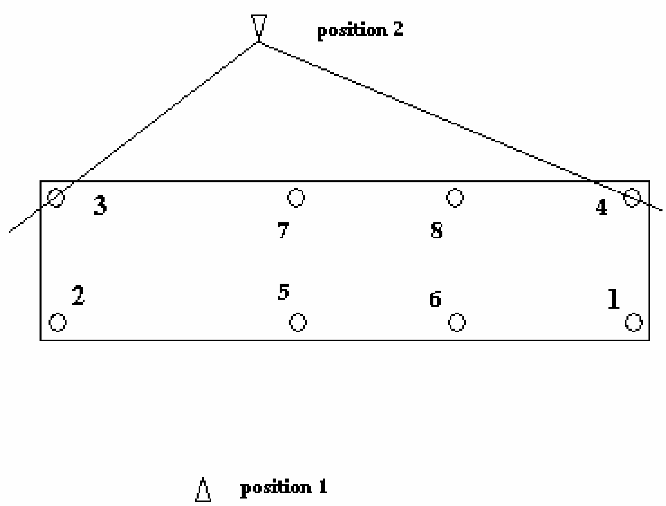
Instrument zeroed out on target #1.

Readings below the zero division are prefixed with a minus sign.

Readings above zero are positive. The accuracy of the factory readings is to one half of one division or .06" (1.5 mm) minimum.

Target values are clearly stamped on the target surface.

5.4 There are jacking bolts provided along the sides of the base for the purpose of adjusting elevation. On large packages, there may be jacking bolts along the centerline of the package as well. The four corners of the packaged should be leveled first and then the remaining targets on the perimeter. After adjusting targets 3 and 4 the elevation of targets 1 and 2 should be reconfirmed from position 1 before adjusting for targets 5 through 8.



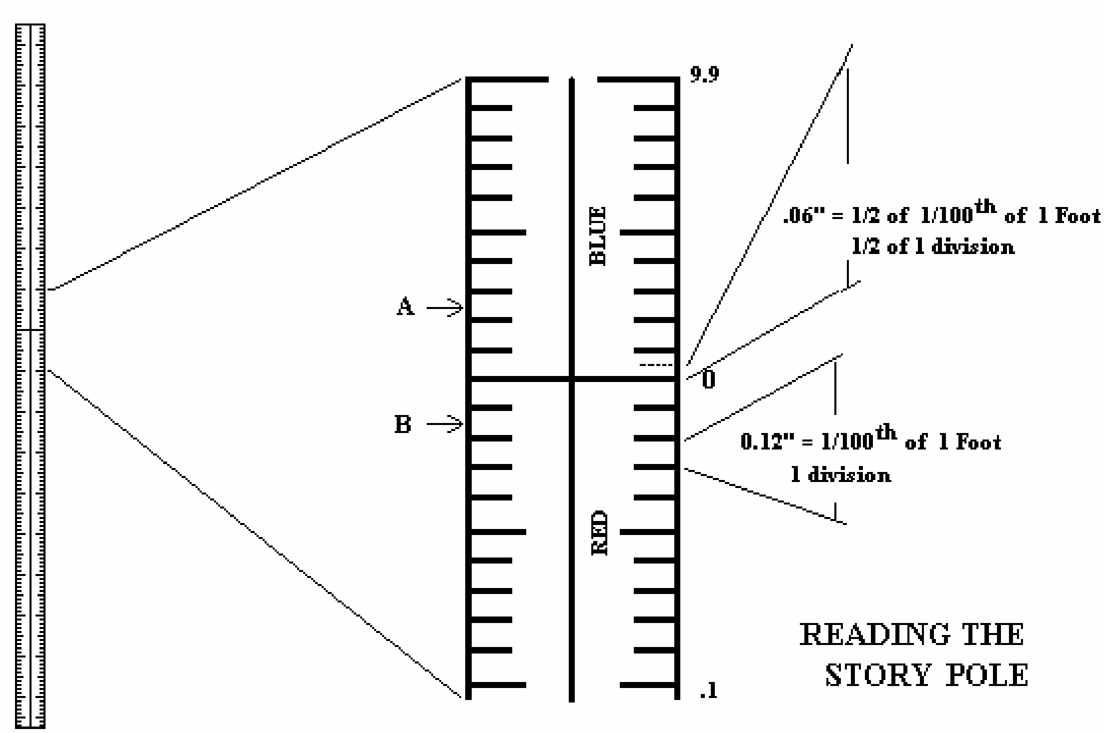
5.5 The jackbolts between the corners may be adjusted after the four corners have been established. After adjusting one side of the skid the opposite side should be reconfirmed. After all the perimeter jackbolts have been adjusted satisfactorily, any jackbolts near the center of the skid may be adjusted. Again, after any adjustment of a jackbolt the elevations of the other targets should be reconfirmed.

5.6 On centrifugal drivelines and packages with large motors or gearboxes, the coupling alignment should be rechecked prior to grouting in the skid. The alignment of the components should closely approach the factory alignment if the base has been restored to the plane defined by the deviations noted on the targets. If the alignment of the components is off more than .040" to .050" (1.0 to 1.2 mm) TIR in either angular or parallel alignment recheck the targets. Also make sure that all jackbolts are in contact with the floor.

5.7 If the package has been accurately leveled and the driveline components are within reasonable rough alignment the skid can be grouted in place. In order to help avoid pipe strain issues later it is suggested that the driveline be aligned prior to the installation of any interconnecting piping to the components.

ADDENDUM A

READING THE STORY POLE



Readings below the 0 line are negative. Readings above the 0 line are positive. Reading A for example would be a positive .30 (.12+.12+.06). Reading B would be -.18 (-.12+ -.06).

Abstract

Base Fabrication Practice

Packaging has emerged as one of the prominent methods of constructing rotating equipment drive trains. This practice simplifies procurement, allows greater control of construction methods and environment, and speeds the installation process at the job site. Packaging has gained wide acceptance, especially in the process chemical and petroleum industries.

Packaging, as the term implies, is the prefabrication of equipment assemblies, usually on base weldments, fabricated from structure steel components. The base, sometimes referred to as the skid, is

usually a frame that consists of steel channel or wide-flange beam members coped and fillet welded together at the various intersections. The beam size is selected using empirical or analytical methods in order to optimize base rigidity and cost. It is important to note that the base rigidity is optimized, not maximized. Some flexibility is permitted and expected. Some deflection of the base is observed, especially along the longitudinal members.

Bases fabricated for drivetrains (rotating equipment), usually include pieces of steel plate welded to the top of the frame assembly and milled or planed to a smooth finish. These mounting pads are positioned in the same location as the mounting feet of the rotating equipment. The pads are drilled and tapped for the hold-down bolts.

The finish on the mounting pads is typically 250 μ inch (6.4 microns) or better. The base weldment is usually positioned in free form, shimmed and secured for machining. The base is not forcefully straightened or deformed since doing so would result in residual stresses in the base. Such stresses would adversely affect the parallelism of the machined surfaces later when the base is unrestrained. The machining process utilizes indexing and milling or planing techniques that permit normal machined surface tolerances. Once the base is removed from the machine, the flatness and parallelism are altered because of the flexibility and deflection inherent in the frame.

Customer Expectations

Many contractors and millwrights are accustomed to installation practices using soleplates or the use of local machining techniques to mount rotating equipment. Soleplates embedded in aggregate (or epoxy) permit relatively precise cold misalignment[1] prior to permanent setting of the soleplates. Local machining practices allow contractors to match the mounting surface to the component foot plane. Both practices make it possible to: 1) avoid the use of tapered or stepped shims and 2) use as few as two shims to achieve the final hot alignment[2]. Both practices are labor intensive during installation at the jobsite.

This type of expectation sometimes encourages users and/or contractors to write specifications requiring tight tolerances on the flatness and parallelism of the machined component mounting surfaces on fabricated steel bases. The intention is to reproduce the condition that results using soleplates or local machining, thus avoiding the need for tapered or stepped shims or machining at the jobsite. Some procurement specifications now refer to *leveling*, *flatness*, and *parallelism* limits. One requires mounting pads to be machined *flat* and *parallel* to within 0.002" per foot (0.17 mm per meter). Another requires the mounting surface and components to be *level* to within 0.002" per foot (0.17 mm per meter) of length and width of the mounting plates. This can be achieved on the machine tool. It cannot be retained because of base flexibility.

Definitions

[1] *Cold misalignment* is the phrase describing the use of intentional parallel and angular offsets in the alignment of components to compensate for expected shaft movement. These movements are caused by operating loads and thermal growth as the equipment reaches operating temperature.

[2] Hot alignment is the condition of alignment concurrent with full load, full temperature operation.

Level: describes to the deviation of the plane described by the mean of a surface profile relative to the plane described normal to the vector direction of gravitational acceleration in distance per length of surface (inch/foot).

Flatness: describes the deviation of any point on a surface from the plane described by the mean of the surface profile in distance (inches).

Parallelism: describes the deviation of the plane described by the mean of one surface profile relative to a parallel reference plane, usually the plane described by the mean of another surface profile, in distance per length of surface (inches).

Objectives

These are the primary goals of setting rotating equipment.

Alignment

Alignment of the rotating equipment must be achieved within the operating tolerances of the couplings, seals and bearing systems. If these tolerances are not met, the reliability of the rotating system is in jeopardy. High vibration, serious equipment damage, and hazard to personnel can result from hot misalignment.

Foot Plane

The feet of rotating equipment components are machined to the same plane within the tolerances of the manufacturer's machine tool and assembly process. The mounting surface is usually a machined surface with one or more shims made to achieve shaft alignment.[3] When the component is placed on the mounting surface, there is a gap that results between one or more of the feet and the corresponding mounting surface. If the gap is relatively large, and is not properly adjusted for using shims, a condition called *soft foot* results. This condition imposes stresses in the component casing that can cause misalignment of bearings, seals and rotating components. The reliability of the operating component can be severely reduced if the condition is bad enough. For this reason, *foot plane* or *soft foot* is checked and limited to manageable values.

[3] Some mounting surfaces are made by locating the component feet using jackscrews and then pouring an epoxy compound between the foundation surface and the feet. This technique is usually used on small equipment where adjustments are unnecessary. Some mounting surfaces are made using plates that more or less match the component foot dimensions and can be jacked into location using permanent fine thread screw fixtures. This type of mounting is rare on large rotating equipment.

Maintenance

Maintenance becomes a consideration if a component must be moved and then realigned. For this reason, end users usually limit the number, type and material of shims used. It is also desirable to eliminate tapered or stepped shims since they must be reinstalled in the precise orientation necessary to compensate for the existing angular gap between the foot and the mounting surface.

<u>Constraints</u>

Base Flexibility

As mentioned above, structural steel base beam size is selected using empirical or analytical methods in order to optimize base rigidity and cost. The base rigidity is optimized, not maximized. Some flexibility is permitted and expected. Some deflection of the base is observed, especially along the longitudinal members. This flexibility occurs in the elastic region of the stress-strain curve and is manifest when lifting and rigging of packaged units. The deflection toward the midpoint of the longitudinal span can be anywhere from a small fraction of an inch to a few inches depending on the package design and dimensions. Even if the surfaces meet requirements at the time of machining, any deflection that is imposed, after the base is machined, will affect the flatness and parallelism of the surfaces. *Figure 1* illustrates the affect of even a very small deflection on the mounting surface flatness and parallelism. For example, if a deflection δ_1 of 0.125" (3.2 mm) is permitted over a length of 10 feet (3 M), the other deflections, δ_2 and δ_3, are on the order of .010" to .050" (0.3 to 1.3 mm). These deflections could be considered unacceptable given the stringent criteria of flatness and parallelism imposed in some specifications. In order to reproduce the "as machined" flatness and parallelism, the flatness of the base as it was set on the machine tool must be reproduced at the jobsite, within ten-thousandths of an inch! This is an insurmountable barrier in most field erection scenarios because of the

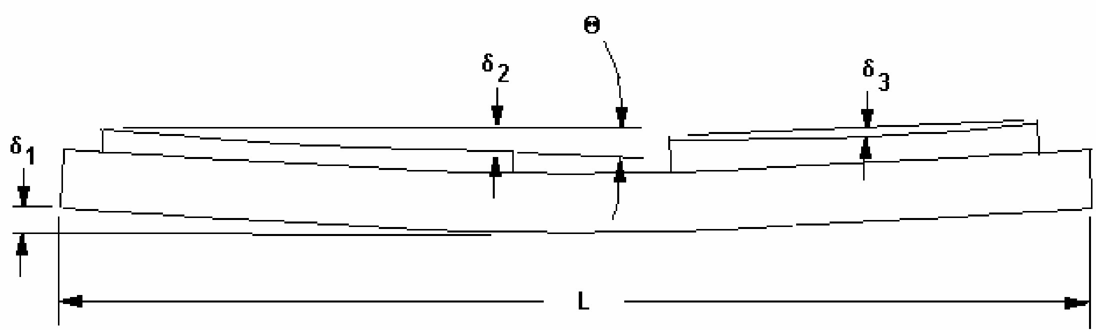


Figure 1

available instrumentation.

Component Assembly and Machining Limitations

Vertically split compressor casings provide another obstacle to very tight flatness tolerances. In many cases, the casings are machined separately prior assembly. Assembly objectives focus on bearing, shaft, rotor and bore concentricities so the foot plane becomes a secondary consideration. Combined parallel and angular offsets can result in measurement of one foot out of plane from another by .010" to .015" (0.25 to 0.38 mm), and still be within manufacturing tolerance. Manufacturers are reluctant to machine compressor casings once they have been assembled for fear of damaging the assembled machine.

Furthermore, some components, such as large motors, carry a manufacturing tolerance that permits one foot to be out of the plane of another by .005" to .010" (0.13 to 0.25 mm).

Although these issues do not affect the flatness and parallelism of the base, they do speak to the rationale of exhausting valuable resources to level the structural base mounting surfaces in such cases.

Intentional Cold Angular Misalignment

In refrigeration, it is common to impose an intentional angular cold misalignment to compensate for uneven vertical thermal growth along the length of the compressor. In the case of one five stage 55" (1400 mm) centrifugal compressor used for booster duty, an angular cold misalignment of 0.005" per foot (0.4 mm per meter) was needed to compensate for thermal growth. This results in a .005" (0.4 mm per meter) per foot taper under the feet. The typical limit imposed on *softfoot* at the foot of a component is 0.002" (0.05 mm) springback. It is often impossible to correct this *softfoot* indication without the use of tapered or stepped shims.

Again, this issue speaks to the rationale of exhausting valuable resources to level the structural base mounting surfaces.

Summary

Alignment and foot plane procedures take time to accomplish. Because it is not feasible to reproduce the "as machined" flatness of a large base within ten thousandths of an inch, it should be recognized that the time will be needed to accomplish a proper alignment at the jobsite. Up to a week may be needed in some cases. Stepped or tapered shims may be needed to compensate for any alignment or *softfoot* problems resulting from base flexibility, component foot plane variations or an intentional angular cold misalignment.