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RELIANCE ELECTRIC

Mechanical Installation of Electric Motors

I. Designing the base
II. Grouting soleplates
III. Aligning Techniques

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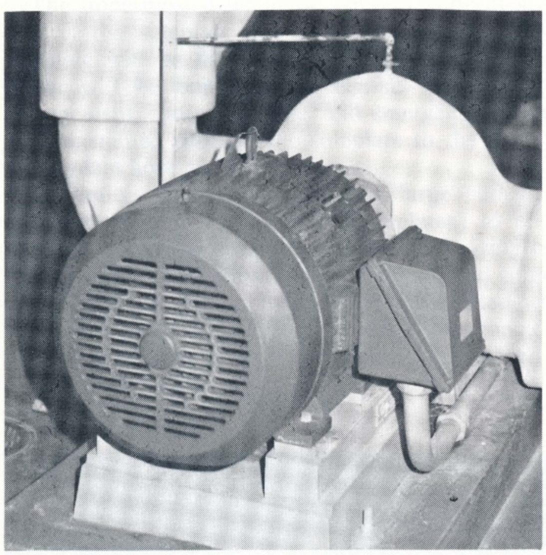

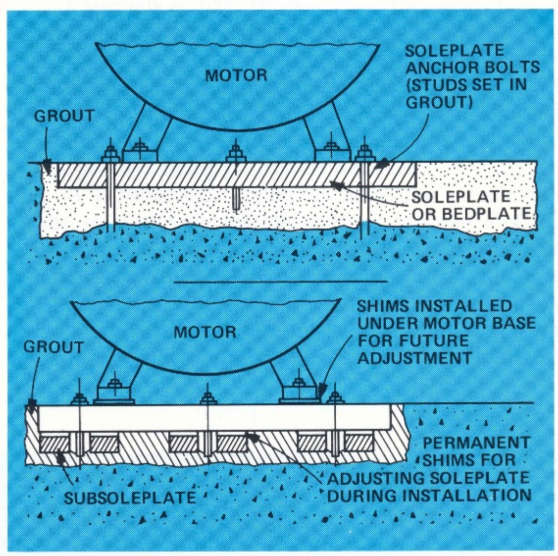

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Mechanical Installation of Electric Motors

I. Designing the base

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PROPER MECHANICAL INSTALLATION of an electric motor is essential to ensure reasonable bearing life and minimize vibration stresses that can damage rotor bars, the motor insulation system, the drive coupling, and the driven load. Proper alignment of the motor and the driven load is the prime consideration in a good mechanical installation, and alignment cannot be maintained without a good base, or supporting structure, for the motor. In fact, the mounting base should be considered to be an integral part of the motor drive system.

The uppermost element of a motor support structure is the soleplate (or bedplate). Typically, the soleplate will be flush with the plant floor, and the motor will be bolted to it, Fig. 1. With such an arrangement, static, dynamic, and emergency loadings are transmitted through the soleplate to the concrete of the plant floor and foundation.

Generally, the soleplate area is large enough to permit permanent supports (subsoleplates) to be inserted between the soleplate and the underlying concrete, Fig. 2. These subsoleplates position and support the soleplate and keep it from being distorted when anchor bolts are tightened. If the soleplate is too small to present enough support area, the resulting load on the underlying concrete is excessive. In these cases, the soleplate is placed on a bed of dry-pack grout. Secondary grout is then poured around the perimeter, Fig. 3.

The arrangement shown in Fig. 3 is widely used, even when the soleplate is large enough to provide an adequate support area. It is not generally recommended, though, because its stability depends entirely on the quality of the grout and placement of the soleplate, and good grout quality and accurate placement are difficult to achieve.

Experience has shown that the best results are obtained when subsoleplates are used with grouting. The subsoleplates become an integral part of the building's concrete structure as they are locked in place by the grout. During installation, supports are sometimes tack-welded to prevent movement while the grout is being poured or tamped.

A subsoleplate simplifies adjusting the elevation of the soleplate during the setting process, Fig. 4. The subsoleplate can be placed on the underlying concrete (the concrete must be ground flat), or it can be placed on a mound of plain portland cement dry-pack grout and tapped into place until it is firmly supported and properly positioned. Placing the subsoleplate on a

Fig. 1. Grout is used to secure the soleplate if the soleplate was not embedded in the floor during building construction, or in a new pedestal poured over an existing concrete floor.

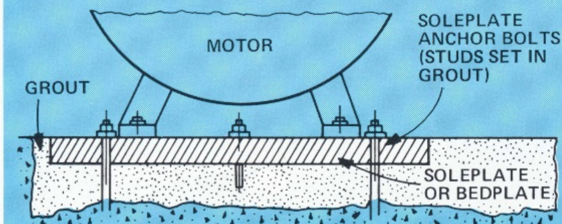
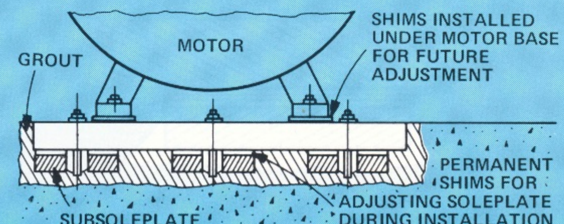


Fig. 2. Permanent supports (subsoleplates) are often used between the soleplate and the underlying concrete.



"Parallel wedges between the subsoleplate and soleplate provide a convenient means of elevation adjustment."

grout mound has the advantage of permitting easy adjustment for rough elevation and slope. The subsoleplate should be positioned so that it will be ⅛ in. below the bottom of the final elevation of the soleplate; tolerance should be $\pm 1/16$ in. Care should be taken to set the subsoleplate as parallel as possible to the final position of the soleplate.

If the subsoleplate is set on the building's concrete, it must have sufficient area to prevent exceeding the maximum loading pressure (300 psi) that can safely be imposed on concrete. On the other hand, if the area of the subsoleplate is more than 50 percent of the area of the soleplate, grout placement becomes difficult.

Although subsoleplates can be 20 in. or longer, using shorter segments will simplify changing shims and ensure good contact when the soleplate is set, even if the subsoleplate and soleplate are not parallel. The top surface of the subsoleplate should be flat to within a tolerance of ± 0.002 in. Usually, the top surface of the subsoleplate must be ground to achieve the necessary flatness. Also grinding the bottom surface will equalize stresses in the plate.

Because motor bases and soleplates have varying degrees of stiffness, all soleplates should be considered to be somewhat flexible. If the soleplate is exceptionally flexible, it might be necessary to use auxiliary supports. When anchor bolts have been tightened, auxiliary supports should be snug against the soleplate to eliminate the possibility of sagging that might occur after prolonged operation.

The best permanent type of support between the soleplate and the subsoleplate is a shim pack cut to the same size as the surface of the subsoleplate, Fig. 5. Shims should be at least 0.01 in. thick. Shims should be as thick as possible, because thin shims tend to be spongy. If thin shims must be used, they should be sandwiched between two shims that are 0.40 to 0.60 in. thick.

Parallel wedges between the subsoleplate and soleplate provide a convenient means of elevation adjustment, Fig. 6. When used as parallel pairs, wedges with

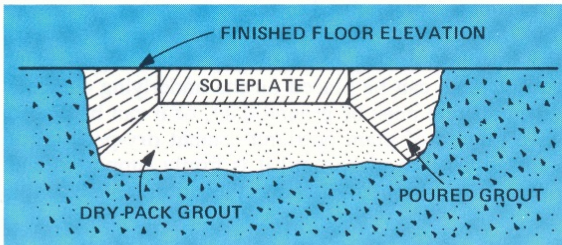


Fig. 3. Poured grout around the perimeter of the soleplate provides horizontal restraint and supplements the vertical support provided by dry-pack grout beneath the soleplate.

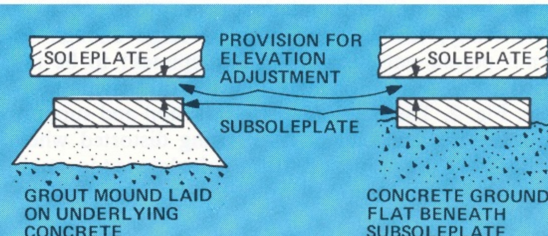


Fig. 4. Subsoleplate is set to leave about ⅛ in. of space for shims to permit final adjustment of the soleplate flush with the floor.

Fig. 5. Shims should be cut to full size of subsoleplate to provide solid support for soleplate.

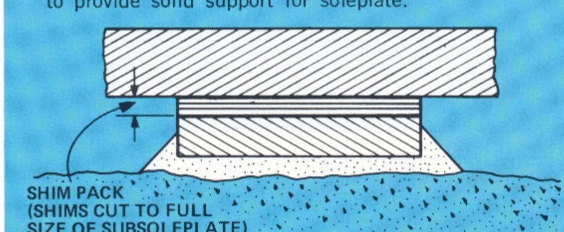
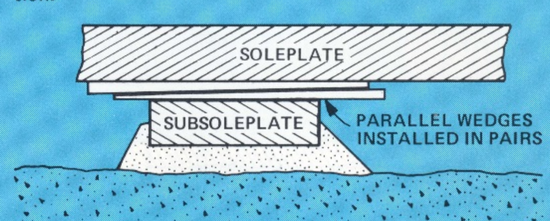


Fig. 6. Slow-taper wedges used in parallel pairs are a convenient method of adjusting the soleplate elevation.



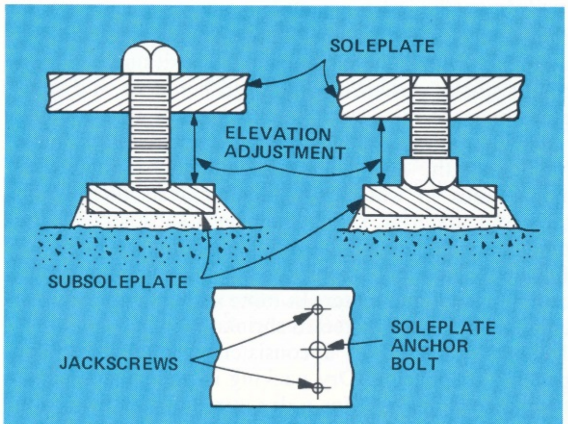


Fig. 7. Temporary jackscrews can be used for leveling the soleplate and adjusting its elevation. Ideal location of jackscrews is in line with the soleplate anchor bolts.

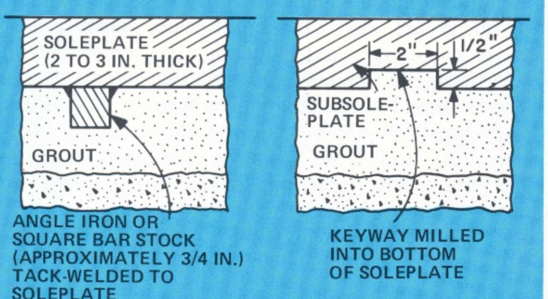
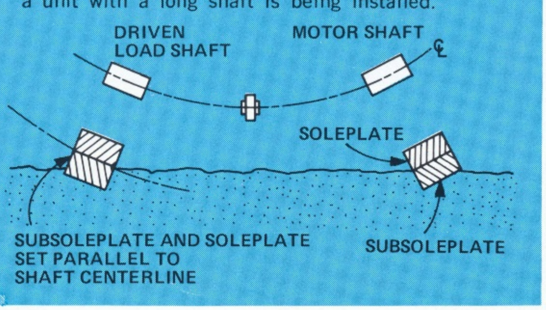


Fig. 8. Additional horizontal restraint can be provided by tack-welded key or keyway milled into bottom of soleplate.

Fig. 9. Shaft deflection must be considered when a unit with a long shaft is being installed.



a taper of about ⅛ in. per foot work exceptionally well. Wedges with a taper of ¾ in. per ft (or more) can be used if adjustment is not critical, but they should be welded into position. Wedges intended to be a permanent part of the installation should be used only in parallel pairs; single wedges should be used only for temporary support during rough-setting.

Jackscrews provide an especially convenient means of adjusting soleplate elevation during installation, Fig. 7, but they are rarely intended to provide permanent support and should be removed before grouting.

Normal machine loading is transmitted vertically to the underlying concrete, but horizontal forces must also be considered. If horizontal expansion of the support structure is ignored, thermal expansion can cause heaving of the soleplate and misalignment. Stresses caused by expansion can be minimized by using shorter soleplates with expansion joints in between. Anchors can also be used to restrain horizontal movement. They can consist of heavy angle iron tack-welded to the soleplate, or keyways milled into the bottom of the soleplate, Fig. 8. Soleplates with cast-in anchors can also be used to restrain horizontal movement.

Some motor and driven-load combinations must be mounted on a slope for proper operation (for example, some types of kilns that might require a slope of ⅜ in.). If the motor and load are connected by a long drive shaft, the motor and the load may have to be installed with opposing slopes to account for shaft deflection, Fig. 9. When shaft deflection must be accounted for, several soleplates are distributed along the support locations.

In a long-shaft installation, the center soleplates are set level and supports are placed on both sides of the anchor bolts to prevent bending of the soleplate. Outboard soleplates are sloped approximately parallel to the shaft. During installation, temporary supports are provided on 18 in. centers; ultimate location of the supports will be determined by loading conditions.

Mechanical Installation of Electric Motors

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PROPER MECHANICAL INSTALLATION of an electric motor begins with the design of a proper base structure to support the motor; the support structure should, in fact, be considered to be an integral component of the drive system.* The motor will, typically, be supported on a soleplate (bedplate) set flush with the plant floor. Preferably, the soleplate will be set on a subsoleplate to provide better support and make it easier to align the soleplate.

Grout is an essential element of the supporting structure; it is used to marry the soleplate (and subsoleplate) to the underlying and surrounding concrete of the plant floor. The grout is forced into the void between the soleplate and the concrete and, when properly applied, displaces air from the spaces beneath and around the soleplate, Fig. 1. If a subsoleplate is used, the anchor bolts that fasten it to the soleplate should be firmly tightened before the grout is applied.

If a subsoleplate is not used, steel posts should be used to provide additional support in the horizontal plane, Fig. 2. These posts, preferably, will have been set in place before the floor was poured. They must be grouted if they are installed after the floor is poured. If square steel bar stock is used for the posts, machined steel keys are used between the posts and the soleplate when the soleplate is positioned. When round stock is used, the void between post and soleplate must be filled with poured lead or type metal.

Grout material should be chemically inert, have high strength, and be nonshrinking. In noncritical applications in which the soleplate rests directly on the grout material, rather than on a subsoleplate, the grout may be 1 to 4 in. thick, depending on the load. In such cases, the grout can be a mix of portland cement, sand, and water. In more critical applications, an additive is used to retard shrinkage.

Grout is mixed to a consistency suitable for dry packing or pouring. Dry packing is preferred because shrinkage is minimal for a dry mix, but it is limited to use in installations in which the space below the soleplate is easily accessible. Poured grout must be used if working space beneath the soleplate is limited.

Surfaces of the soleplate and the concrete must be clean and rough to achieve a good grout bond. All dirt, oil, grease, rust flakes, mill scale, concrete dust, imperfect concrete, and paint must be removed from the surfaces of the concrete and the soleplate. The concrete should be cleaned with a fiber-bristled brush; a wire brush should be used on the metal surfaces. Heavy rust and scale must be removed from the metal, but a very light film of rust will improve the bond.

Fig. 1. Grout is used to fill all voids between the soleplate (and subsoleplate, if used) and the underlying and surrounding concrete of the plant floor. Soleplate anchor bolts can be poured into the floor at time of plant construction, set in drilled holes and individually grouted, or set in poured lead or type metal.

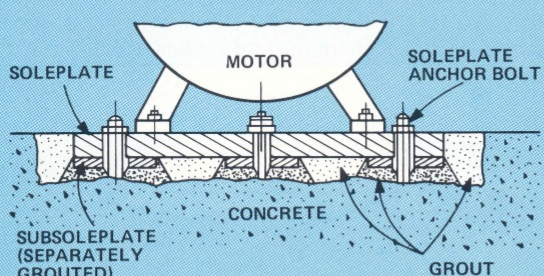
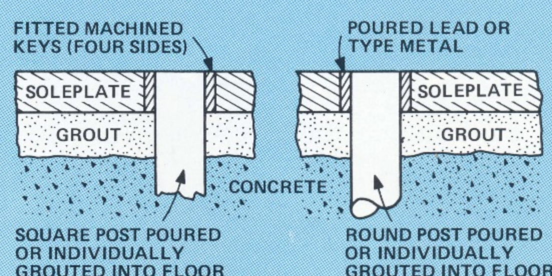


Fig. 2. Steel posts should be used to provide additional horizontal support for the soleplate if a subsoleplate is not used. The void between the post and soleplate is filled after soleplate is grouted in.



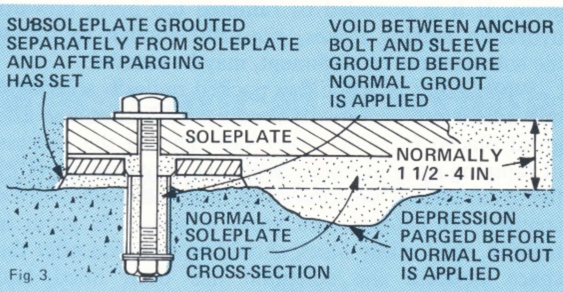


Fig. 3.

Fig. 3. Deep depressions in the concrete should be parged with grout before subsoleplate and soleplate are grouted. It is especially important to grout the void between anchor bolts and poured-in sleeves or surrounding concrete (for drilled-in holes) before grouting of subsoleplate and soleplate.

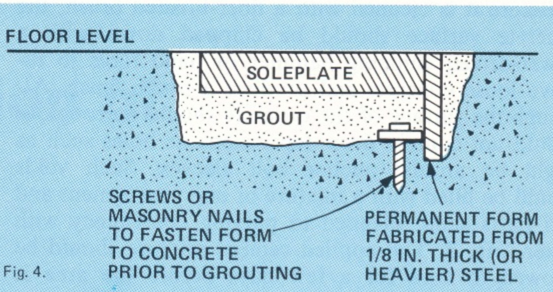


Fig. 4.

Fig. 4. If space limitations will prevent the removal of temporary forms after the grout has been placed, steel forms should be used. Forms should be fabricated in a manner that allows them to be firmly anchored with screws or masonry nails to the concrete to secure the forms in place solidly while the grout is being applied and set.

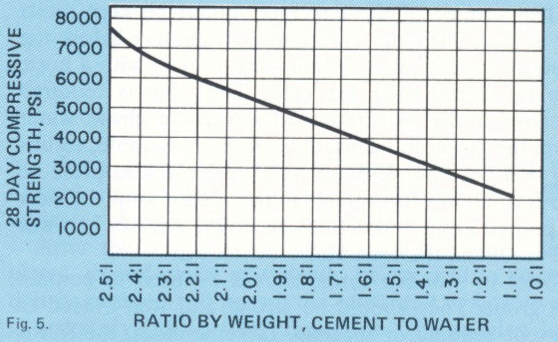


Fig. 5.

Fig. 5. Grout strength diminishes with the amount of water used in preparing the grout mixture. Mixtures for grouting soleplates and subsoleplates for motors should contain not less than two parts of cement to one part of water (by weight).

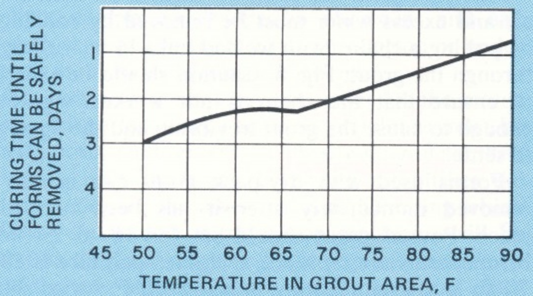


Fig. 6. Temperature in the grout area will determine the curing time required before forms can be safely removed. Temperature should be between 50 and 90 F when the grout is applied, and should be maintained at that point for as long as possible during the curing period.

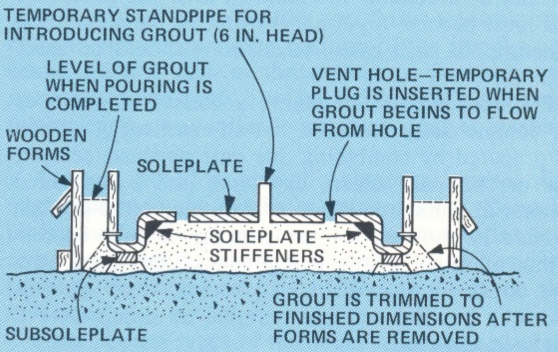


Fig. 7. Temporary forms for poured grout should be of double-walled construction. Grout should be introduced from one side of the form only and permitted to flow through to the other side; grout can also be introduced through a temporary standpipe and permitted to flow outward in all directions.

Fig. 8. After grout has been poured, temporary plugs are removed from vent holes and grout is rodded or a chain is repeatedly drawn through to settle the grout and eliminate any air pockets. The rod or chain passes between individual segments of the subsoleplate.

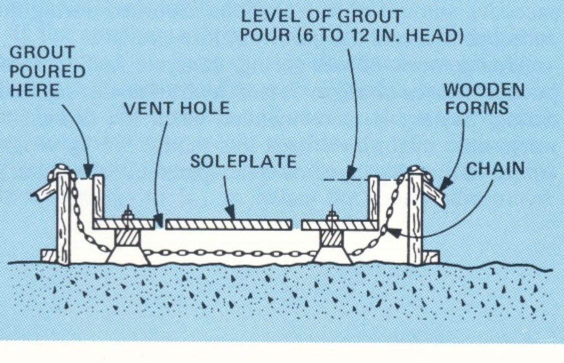
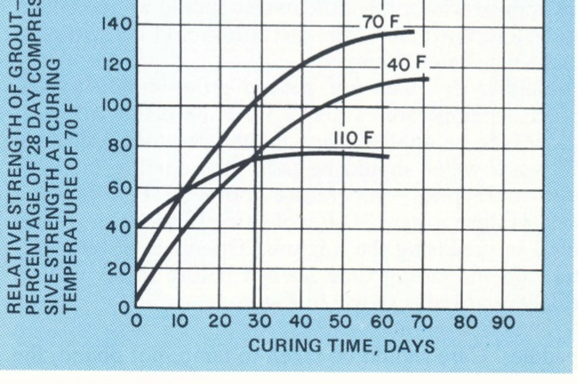


Fig. 9. Final strength of cured grout is a function of time and curing temperature; reasonable temperatures should be maintained during the curing period. Maximum strength is achieved in about 70 days at 70 F.



Before it is cleaned with a fiber-bristled brush, the concrete surface should be chipped down with a power-driven chipping hammer or hand tools to remove loose concrete and produce a rough finish. Although the surface of the concrete should be rough, it should not contain deep depressions or holes such as might be around anchor bolt sleeves. Such voids should be filled with a mixture of one part cement and two parts sand, blended to parging consistency with water, Fig. 3. The applied cement mixture should be allowed to cure for a few days before the area is grouted.

The surface of the concrete should be kept moist for at least 24 hours (preferably 48 hours) before the grout is applied. Wet burlap, kept soaked with a hose, can be placed over the area. This step is required because a dry concrete surface would draw water from the grout and cause its cement to hydrate, resulting in a poor bond. A dry surface could also promote the formation of grout plugs that could stop the flow of poured grout and could also create stresses between the grout and the concrete.

Steel or wooden forms should be used to contain the grout. They should be strong and well-braced to prevent bending or slipping. In some cases, the forms will not be accessible for removal after the grout sets and must become a permanent part of the supporting structure. In such cases, steel forms should be used, Fig. 4.

Premixed grouts containing a variety of additives are commercially available, but an excellent grout can be prepared by combining one part portland cement, one or two parts clean, dry sand, and a controlled amount of aluminum powder. If an aluminum-powder mixture is prepared for dry packing, it must be cast within 45 minutes after it is prepared. Dry-pack mixture consistency should be such that, after water is added, a handful will not crumble or slump after it has been squeezed.

When grout for pouring is being prepared, care must be taken to use no more water than the minimum that will assure proper flowability, because the strength of the grout diminishes with the amount of water used in preparing the mixture, Fig. 5. Regardless of the batch size, the ratio (by weight) of portland cement to water should be not less than 2:1. In addition to curing with higher strength, a drier mixture has minimum shrinkage.

For best results, poured grout should also be applied within 45 minutes after it is mixed. If it cannot be applied within this time, water should not be added to restore flowability; the mixture should be discarded and a new batch prepared.

Neither dry-pack nor poured grout should be applied at temperatures above 90 F or below 50 F. If grout is to be applied when the temperature is near 50 F, warm water should be used in preparing the mixture to keep its temperature above 50 F. When the temperature is near 90 F, cold (iced) water should be used in preparing the mixture. The effect of temperature on the curing time needed before forms can be safely removed is shown in Fig. 6.

Dry-pack grout is tamped into place with wooden paddles. Care should be taken to tamp, not pound, the grout. If it is pounded or rammed too hard, upward hydraulic jacking forces, powerful enough to throw the soleplate out of alignment, may be created.

When grout is to be dry packed under a soleplate, one side of the soleplate should be blocked and the grout placed from the other side. During the process of tamping or pouring, excess water that drains out of the grout should be allowed to drain off or should be sponged off before more grout is added. If grout is tamped, the backup block should be removed after the space beneath the soleplate has been filled and tamped. The freshly exposed grout should then be firmly tamped down.

If grout is poured or pumped into place, double-walled forms high enough to contain the grout in the desired area should be built around the perimeter of the soleplate, Fig. 7. Holes should be provided in the soleplate to vent any natural air pockets and permit the grout to make full contact with the soleplate.

Formation of air pockets will be minimized by pouring the grout from one side of the soleplate only, so that it will flow through to the other side. An alternative method is to introduce the grout through a temporary standpipe in the center of the soleplate, and permit the grout to flow outward in all directions. Grout should be poured so that it rises in the forms to a level above the soleplate, thus creating a pressure head.

After the grout has settled for about 30 minutes, all air and excess water must be removed by rodding or by pulling a chain (with welded links ½ in. or larger) through the grout, Fig. 8. Caution should be exercised to ensure that the chain is not worked vigorously enough to cause the grout to vibrate and the aggregate to settle.

Forms used with dry-pack grout can usually be removed immediately after it has been tamped in place. Poured grout should set for 18 to 24 hours before forms are removed, if the temperature is above 70 F. If the temperature is below 70 F, forms should remain in place longer, as indicated in Fig. 6. After the forms are removed, the grout should be finished and pointed.

When the grout is set and the forms are removed, the grout must be permitted to cure and gain strength before a load is applied to the base. Figure 9 shows the relationship between grout strength and curing time and temperature. The grout should be kept covered with wet burlap for at least the first 7 days of the curing period, and temperature should be kept between 50 and 90 F. If the temperature is over 90 F, an excessive amount of water will be absorbed during the curing period, and the grout will lose strength.

After a week of wet curing, concrete sealing compounds can be used to retard hydration during final curing. Sealing is recommended when the cement to water ratio might have been less than 2.5:1 by weight (more than 4.5 gallons of water per sack of cement).

Mechanical Installation of Electric Motors

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EFFICIENT, quiet, troublefree service can be obtained from horizontal motor-driven machine sets only if the motor/load combination is properly aligned and the components are set on a proper, firm base that will permit alignment to be maintained. Permanent misalignment will create a number of problems—most notably, a reduction in bearing life.

There is a common misconception that flexible couplings can be used to compensate for poor alignment. But permanent misalignment cannot be relieved by flexible couplings. Their function is to compensate for slight, temporary changes in alignment and end play such as might be expected during startup or under unusual, momentary loading conditions.

After proper bedplates have been set for the motor and the driven machine, one of the machines must be properly positioned on its base. Positioning of the first machine is very important, because it establishes the fixed reference for the other machine. Deciding which machine—the motor or the driven machine—will be set first as the fixed reference unit requires consideration of the type of unit (its size, weight, function, etc.) and local conditions and free work place. Usually, the unit to be positioned first will be the one that is largest and heaviest, and, consequently, the most difficult to reposition.

The machine selected as the reference unit should be positioned on its bedplate with tie-down bolts aligned with their respective mounting holes. It is a good idea to set the unit on shims, retaining the option of adjusting the unit downward or upward if necessary. The reference machine should then be firmly anchored to its soleplate, and the second machine installed with alignment shims on its soleplate.

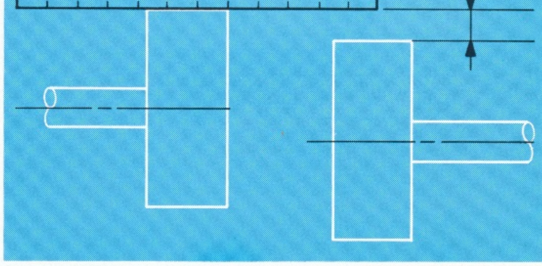
If the coupling halves on the drive unit and driven machine have the same outside diameters, rough alignment is initiated by using a straightedge, as shown in Fig. 1, and adjusting the unit as required in the vertical and horizontal planes. A machinist's rule is used to adjust the coupling gap so that the distances F1 and F2 are within $\frac{1}{32}$ to $\frac{1}{64}$ in. When the rough adjustment has been completed, the coupling rims should be aligned closely enough to permit the use of a dial indicator or micrometer for final adjustment.

After the rough, initial adjustment has been completed, the reference unit should be checked to ensure that its position will permit the other unit to be moved if necessary during final alignment. The spacing left between coupling halves should consider the type of coupling used (free-floating or thrust-transmitting) and the desired operating position of the free-floating shafts. Factors such as thrust-force transmission and parts expansion must also be considered; axial positioning can be very critical with some types of machine sets.

A check should be made for abnormal stresses that might act upon the machines being aligned. Conduit, piping, and ancillary equipment connected to the machine are potential sources of stress; they should be properly supported to prevent placing strain on the machine.

Some special types of machines require a specified, measured amount of loading on each foot, but most need only normal, equal loading on each foot. The units should be checked to ensure that their weight is properly distributed on all four feet. If one leg or

Fig. 1. Machinist's rule is used to closely approximate the correct positions of the machines in the rough alignment stage.



"Temporary support can be applied to good advantage."

support is even slightly out of the "foot plane," internal parts will tend to distort when anchor bolts are tightened. Even minor distortion can cause noise and vibration and parts damage.

Small units usually have especially rigid frames. When such equipment is being set, special care should be taken to ensure that each foot conforms to its support, and that weight is properly distributed over the foot area. When the unit is being checked for equal support, all hold-down bolts are first tightened solidly. They are then loosened one at a time and a dial indicator or feeler gauge is used to see if the foot rises from its support as the bolt is loosened. On a four-footed machine, only two adjacent feet need to be checked.

On many types of machines, temporary support can be applied to good advantage to equalize foot loading. With the unit resting on two feet at one end, a jack, hoist, or block-and-wedge combination is applied to the machine casing at the center of the free end. The free end is then raised until the two loose feet are clear of their supports by a few thousandths of an inch. The relative air gaps between the two feet and their respective supports are measured, and shims are inserted to equalize the spacing. Loading will then be the same on each support. The procedure is then repeated at the other end of the machine.

Before final alignment is begun, dial indicators and micrometers should be checked for accuracy; final positioning and alignment of the shafts must be accurate to within a thousandth of an inch.

Final alignment must consider the difference in positions of the two machines and their shafts under hot and cold running conditions. Shafts that were in near-

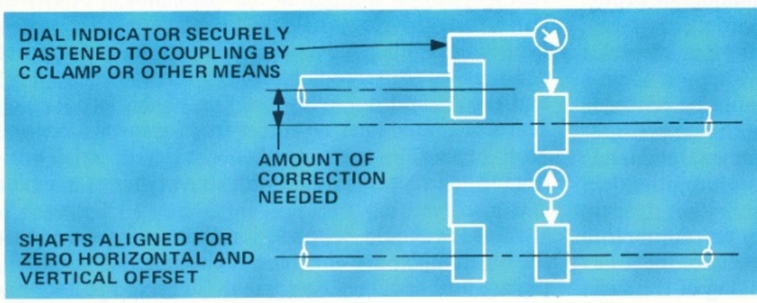


Fig. 2. A dial indicator is used in the rim check to determine the amount of offset between the two shafts.

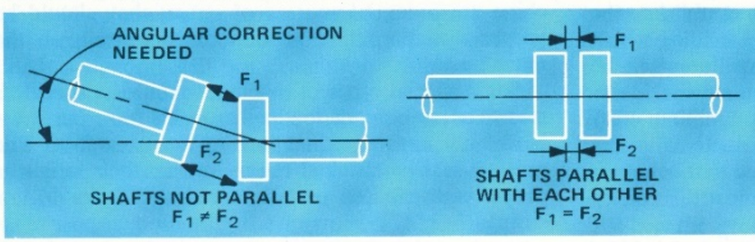


Fig. 3. The face-alignment check (also called the coupling-gap or face check) reveals the angular correction needed to make the shafts parallel to each other.

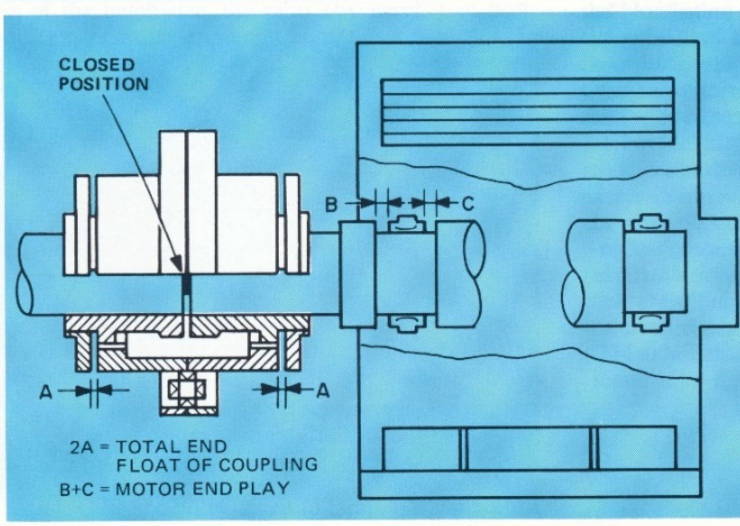


Fig. 4. The possibility of thrust-force damage can be minimized by use of a limited-end-float coupling.

perfect "zero" alignment when the unit was cold can develop considerable, damaging misalignment after the unit has been run for a while and heated up. The following factors can cause misalignment under running conditions:

- Dimension changes in the machine and its foundation resulting from thermal expansion. Considerable differential expansion can be expected between the two machines if one runs much hotter than the other (for example a motor driving a hot-air fan).
- Changes caused by radial shaft loading, shaft speed, and vector forces developed during operation.
- Coupling geometry and tolerances, and the behavior of the coupling during operation.

There is no easy or precise way to predict and compensate for the difference in alignment between cold and hot operation, and the procedure outlined here can be tried:

- Bring the machine set into zero alignment with the unit cold.
- Run the machine for an hour or so (or as long as is needed to bring the unit up to normal operating temperature).
- Stop the unit and bring it back into zero alignment while it is still relatively hot.
- Start the unit and check for quiet, vibration-free operation. Alternately starting and stopping the set, insert or remove shims until the machine set runs as smoothly and quietly as possible.
- Stop the unit when it is running as quietly as possible and let it cool. Take readings of the offset and angular displacement between shafts when they are cold. Record the readings for future reference.

For final alignment, ensuring that the two shaft axes coincide at the coupling point requires two checks—the rim alignment check (rim check) and the face-alignment (coupling-gap) check. In the rim check, the outer surface of the coupling rim is used as a reference to reveal how much the axis of one shaft is offset in relation to the axis of the other, Fig. 2.

The dial indicator must be solidly secured and mounted absolutely radial to the shafts. It should then be checked for secure mounting and proper operation. This check is made by sliding a feeler gauge or piece of shim stock under the dial indicator; the dial pointer should return to the same point after each try. The dial-indicator button must rest on a clean, smooth surface during this check.

Final readings obtained in the rim check should be logged for future reference; these readings will be useful when the unit is serviced or replaced. Each reading should be referred to the right or left side of the unit (when viewed from the drive end).

The coupling-gap check is made by using a micrometer to measure the distances between coupling faces in the vertical and horizontal planes. Fig. 3. The coupling-gap check will reveal any angular displacement and indicate how much adjustment is needed to bring the two shafts in parallel to each other.

It is important to remember that neither the rim check nor the coupling-gap check alone will bring a machine set into zero alignment. The rim check determines any offset between the two shafts, and the coupling-gap check determines the amount of angular displacement between the two shafts. In each case, readings must be taken in both the horizontal and vertical planes.

Thrust forces must also be considered in the mechanical installation of machine sets. Sleeve-bearing horizontal motors are normally designed with a predetermined amount of free rotor float or available axial rotor movement. The amount of float is controlled by shaft shoulders at the ends of the shaft journals and by axial bearing surfaces at the ends of the bearing bushings. Depending on the motor design, one or both of the bearings can be used to control the shaft float.

The normal axial running position of the rotor with respect to its total available float will be at or near the midpoint. While the motor is running, this position (usually referred to as the motor's "magnetic center") is maintained by electromagnetic forces.

The need for axial restraint of the rotor is, therefore, confined to restraining momentary thrust loading during startup (while the motor rotor is seeking its magnetic center), or to those periods when the motor is de-energized and coasting to a stop. The axial bearing surfaces are more than adequate for providing the required restraint for these situations—in fact, in many drive applications, the axial bearing surfaces can withstand continuous, moderate loading imposed by the drive system. Nevertheless, the drive system should be designed and installed in a manner that will prevent axial loading from being imposed on the motor bearings.

Because the forces acting to center the rotor are relatively weak, they can be easily overcome by externally imposed thrust forces, causing damage to the motor bearings. Such forces can be imposed unexpectedly and are of unpredictable magnitude. One cause of unpredictable thrust loading is coupling misalignment that causes the coupling halves to either close up or pull apart.

Thrust damage can be prevented by using a limited-end-float coupling, such as that shown in Fig. 4. Such couplings permit the two machines to be positioned so that the motor rotor is held at the midpoint of its end float while running, with allowance for thermal expansion. The axial position of the motor rotor is, thereby, determined by the thrust bearing of the driven machine.