TRAINING MODULE

ON

ROTATING MACHINERY ALIGNMENT

TRAINING MODULE OBJECTIVE

This Training manual is intended to help engineers to understand the fundamentals of rotating machinery alignment. Thus, in this module, an effort has been made to provide, a much-needed source of information in the field of alignment fundamentals & it's execution.

To make the module easy to use, contents are divided into short sections like:

- Scope & Introduction to shaft alignment.
- Understanding alignment.
- Effect of misalignment..
- Types of misalignment.
- Summary of overall alignment job.
- Pre alignment checks.
- Alignment techniques & examples
- Cold Alignment & Hot Alignment.
- Interpretation of data & Calculation.
- Machine Movement.

It is hoped that users may suggest improvements in future editions, to make this module more useful.

CONFIDENTIALITY STATEMENT

TABLE OF CONTENTS

1. SCOPE:

Scope of this manual is limited to rotating machinery shaft alignment fundamentals, techniques & execution methods.

This excludes v-belt & pulley alignment.

2. INTRODUCTION:

For most of rotating machines used in process industries, the trend is toward higher speeds, higher horsepower per machine, and less sparing. The first of these factors increases the need for precise balancing & alignment. This is necessary to minimize vibration & premature wear of components like bearings, shaft seals & couplings etc.

Balancing deservedly has long received attention from machinery manufacturers & users as a way to minimize vibrations & wear. While alignment, which is equally important, has received proportionately less notice than its importance justifies.

As such alignment of rotating machinery is not a new subject. However till today as per statistics 20-30 % of total break down across the industry are caused by misalignment. It indicates the magnitude of attention and effort required to improve upon.

Accurate alignment & systematic approach to achieve this is a responsibility of all concerned i.e. technician, engineer & manager.
The alignment technology had been continuously upgraded since the age of straight edge & feeler gauge to the laser alignment which achieves higher accuracy in a much shorter time.

In following chapters, basics of alignment & systematic approach had been covered in details.

3. UNDERSTANDING ALIGNMENT:

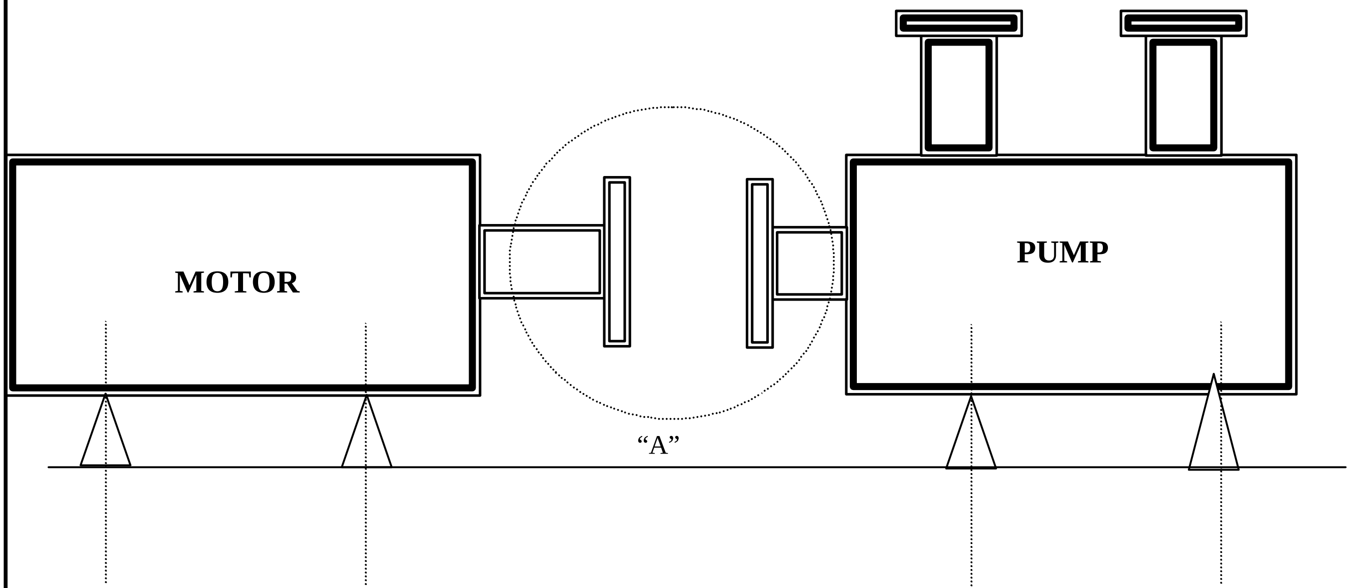
Alignment primarily for rotating machinery is the activity to check that centerlines of rotation of two shafts (Driver & Driven machine) are in line i.e. collinear with each other at operating conditions.

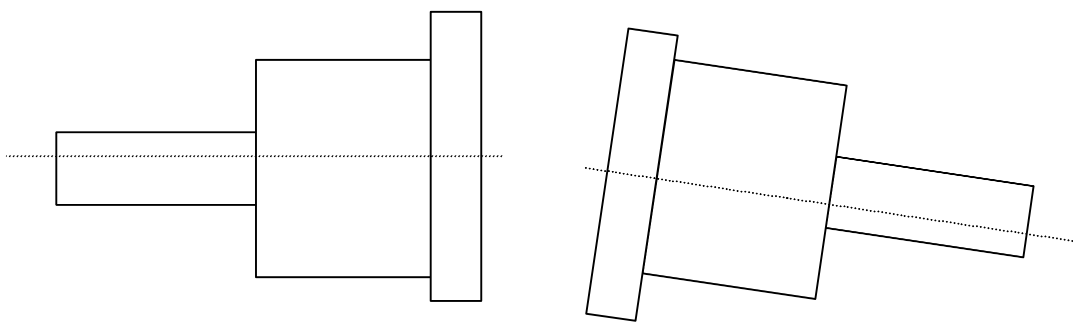
Definition of misalignment makes the term alignment easy to understand

More precisely shaft misalignment is the deviation of relative shaft position from a collinear axis of rotation measured at the points of power transmission when equipment is running at normal operating conditions.

To better understand above definition let's go word by word: collinear means in the same line or in the same axis. If two units are collinear then they are aligned. The deviation of relative shaft position accounts for the measured difference between the actual centerline of rotation of one shaft & projected centerline of rotation of the other shaft.
Attached fig.1 Shows typical misalignment situation on a motor and pump.

Most often words shaft alignment and coupling alignments are interchanged. It is necessary to understand that prime interest of alignment is to set the centerline of rotation of shaft for two or more pieces of rotating machinery collinear. However, in practice alignment check is performed on the coupling & it is assumed that coupling hub bore & shaft are concentric with each other. So it's necessary to ensure that coupling hub bores & shaft centerlines are concentric to each other.





Details at "A"

Misalignment is the deviation of relative shaft position from a collinear axis of rotation measured at the points of power transmission when equipment running at normal operating conditions.

Here it's worthwhile to note that the operating of two shafts in line with each other at operating condition is essential. However most of the alignment checks & corrections are performed when machine is at stand still, hence it is very much essential to know the movement of machine shaft from position of rest to the operating condition.

As the equipment begins to rotate, a wide variety of factors contribute to moving the shafts from the position of rest:

- Dynamic forces generated by fluid movement or gas compression.
- Differential heating up of various components when operating temperatures are higher.
- Piping force due to dynamic fluid reaction & thermal expansions.
- Foundation setting & movement.

The expected shaft position at operating condition is normally provided by the equipment vendor or can be calculated by the methods described later in this manual under hot alignment.

The difference between the shaft positions from the point of rest to operating conditions needs to be taken care of.

4. EFFECTS OF MISALIGNMENT

Misaligned rotating machinery have caused and is continuing to cause a tremendous financial loss to industry worldwide through consequential losses & effects, the most severe being the production loss on account of premature machinery failure & continued energy loss.

It has been universally accepted that good alignment is an essential pr-requisite for safe & smooth running of rotating equipment.

It is apparent that when two machines are misaligned, it creates undesirable reactionary forces on machine that adversely affect the shafts, the bearings, the seals and the couplings.

Failure to properly align rotating machinery can cause:

1) Increased vibrations subsequently leading to other problems.
2) Shaft seal failure.
3) Accelerated failure of close clearance machine parts.
4) Bearing overload/Failure.
5) Coupling failure.
6) Shaft fretting/failure.

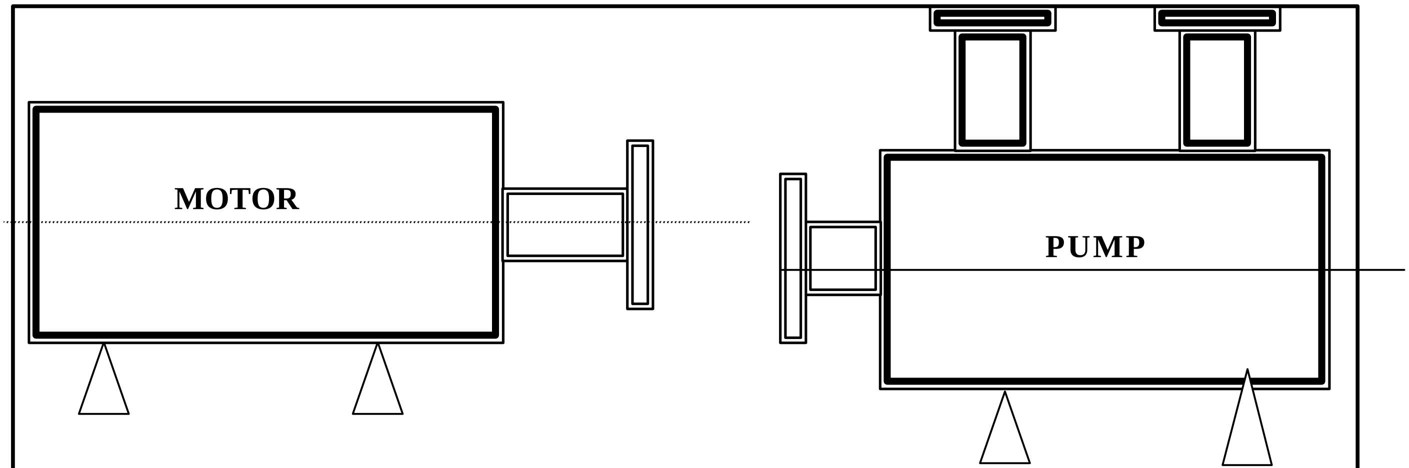
5. TYPES OF MISALIGNMENT:

Shaft misalignment can occur two basic ways: Parallel and angular. Actual field conditions usually have a combination of both parallel and angular misalignment.

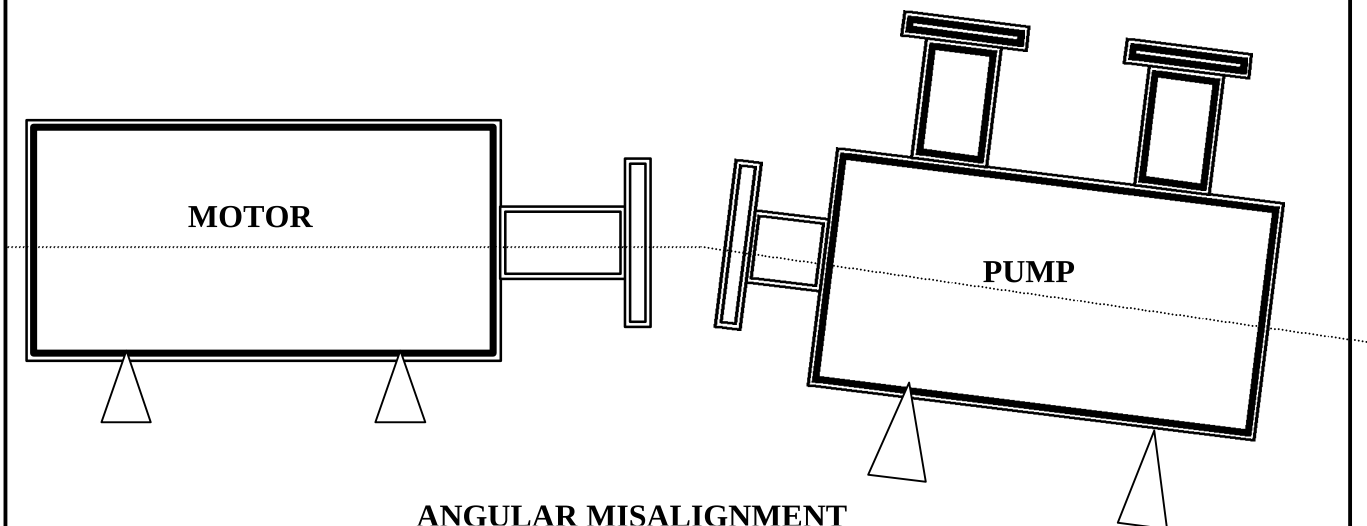
Parallel Misalignment: Parallel misalignment is a condition in which two shafts center lines are parallel but do not lie along the same line.
See fig.-2. This type of misalignment is also known as “Radial” or “Offset misalignment”.

Angular (Axial) Misalignment: Angular misalignment is a condition, which describes the angularity between the centerlines of two shafts. As shown in fig.-2.If misalignment is strictly angular can be corrected by rotating a shaft about the center of its coupling face.

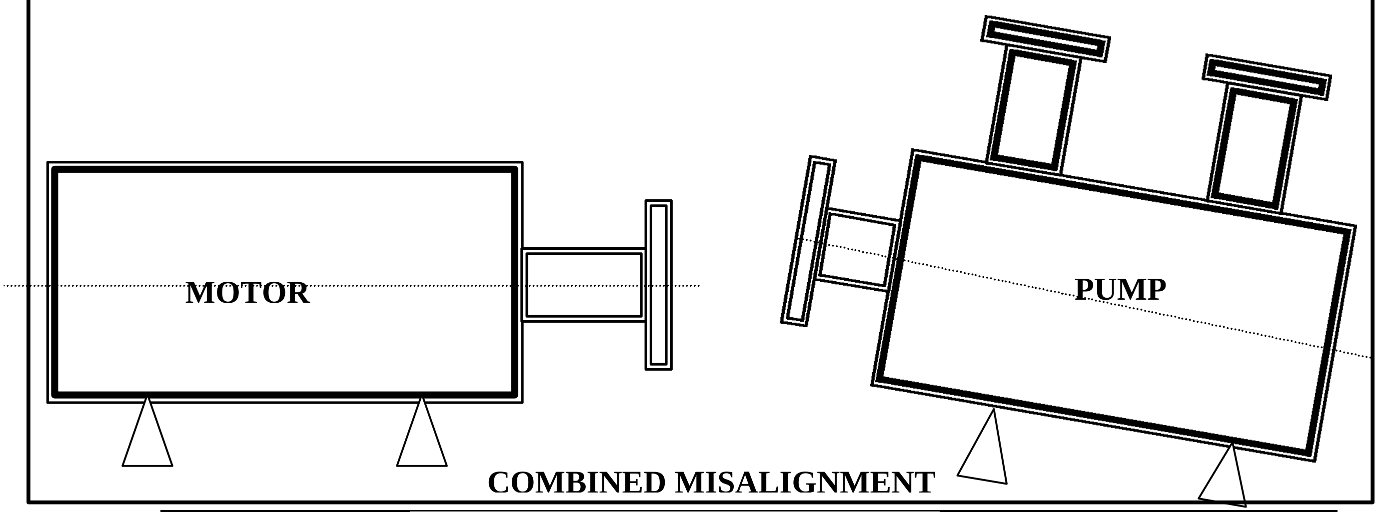
Combined angular & Parallel misalignment: Most often two shafts when are misaligned, the misalignment is both parallel & angular. This occurs when the centerlines of two shafts are not lying along the common centerline and the one coupling face is not parallel to other coupling face in any of the one plane horizontal or vertical. See fig.-2.



PARALLEL MISALIGNMENT



ANGULAR MISALIGNMENT



COMBINED MISALIGNMENT

6. SUMMARY OF OVERALL ALIGNMENT JOB:

There are basic eight steps involved in aligning rotating machinery.

1. Make the machine ready for alignment. Carry out pre-alignment checks i.e. ensure that no piping loads are coming on the machine, the machine is properly secured to foundation, no soft foot exists on the machine & no excessive run out conditions.

2. Purchase or fabricate the necessary alignment tools & measuring tools. Ensure that people involved in the job are adequately trained on alignment techniques.

3. Obtain necessary information on equipment being aligned i.e. are there any special tools needed to measure the alignment, is any data available on shaft movement from position of rest, tolerance on alignment. Determine final desired shaft positions with respect to each other or prepare the desired final reading set.

4. Inspect the coupling for any damage or worn out components, perform bearing clearance or looseness check, measure shaft or coupling hub run-out.

5. Choose right alignment technique, machine to be moved & prepare the data recording & machine movement calculation sheet.

6. Mount the alignment tools & measuring instruments, record one set of data & determine the shaft positions with respect to each other. Compare the shaft positions with desired shaft positions, if shaft positions are within tolerance no movement of machine is required. If it is not so calculate machine movement, before attempting machine movement, ensure the readings by one more set of measurement.

7. After carrying out the necessary machine movement, recheck the alignment & ensure that machine or shaft positions are as desired.

8. Couple the machine & run at operating conditions. After machine stabilization collect vibration data, bearing temperature data & ensure that machine is operating at desired values.

7. PRE-ALIGNMENT CHECKS:

Pre alignment checks are an important step in entire alignment procedure & perhaps the most over looked step. Ignorance of this step would largely nullify the benefits or prevent the attainment and retention of good alignment.

As mentioned earlier in alignment job summary preliamnry alignment checks are performed in these areas & any abnormalities shall be corrected prior to alignment.

- Foundation & grouting.
- Excessive run-out conditions i.e. Eccentric coupling bore, bent shaft.
- Machine to base plate interface problems i.e. soft foot.
- Excessive piping forces.

In following paragraphs all above checks are discussed in details:

7.1 Foundation & Grouting:

Adequate size and good condition of foundation is of utmost importance. As a rule of thumb concrete weight equal to three times machine weight for rotating machines and five times for reciprocating machines.

Ideal grout shall result in prefect bonding between base frame & foundation. There shall no voids or hollow spots in the grout. This can be detected by tapping with small hammer on grouted base areas. In case voids or hollow spots are large enough may call for regrouting, small voids & hollow spots can be corrected by epoxy injection or pressure grout injection.

7.2 Excessive run-out conditions: The term ‘run-out ‘ describes out of round or non-perpendicular conditions that exist on rotating machinery shafts and should be one of the first thing you should you check while attempting alignment.

Radial run-out quantifies the eccentricity of the outer surface of a component rigidly attached to shaft with respect to shaft centerline of rotation.

‘Face’ run-out quantifies the amount of non-perpendicularity that may exist at the end of component rigidly attached to shaft. As a general guide value less than 0.05mm can be accepted for face run-out in absence of any specific guide.

Run-out checks are normally performed with dial indicators as illustrated in fig.- 3.

In absence of any specific run-out acceptance values, a table attached below can be used as a guideline for radial run-out.

Recommended Runout Guidelines	
Machine Speed (RPM)	Maximum Allowable Total Indicated Runout (TIR)
0-1800	0.125 mm
1800-3600	0.05mm
3600 and up	Less than 0.05mm

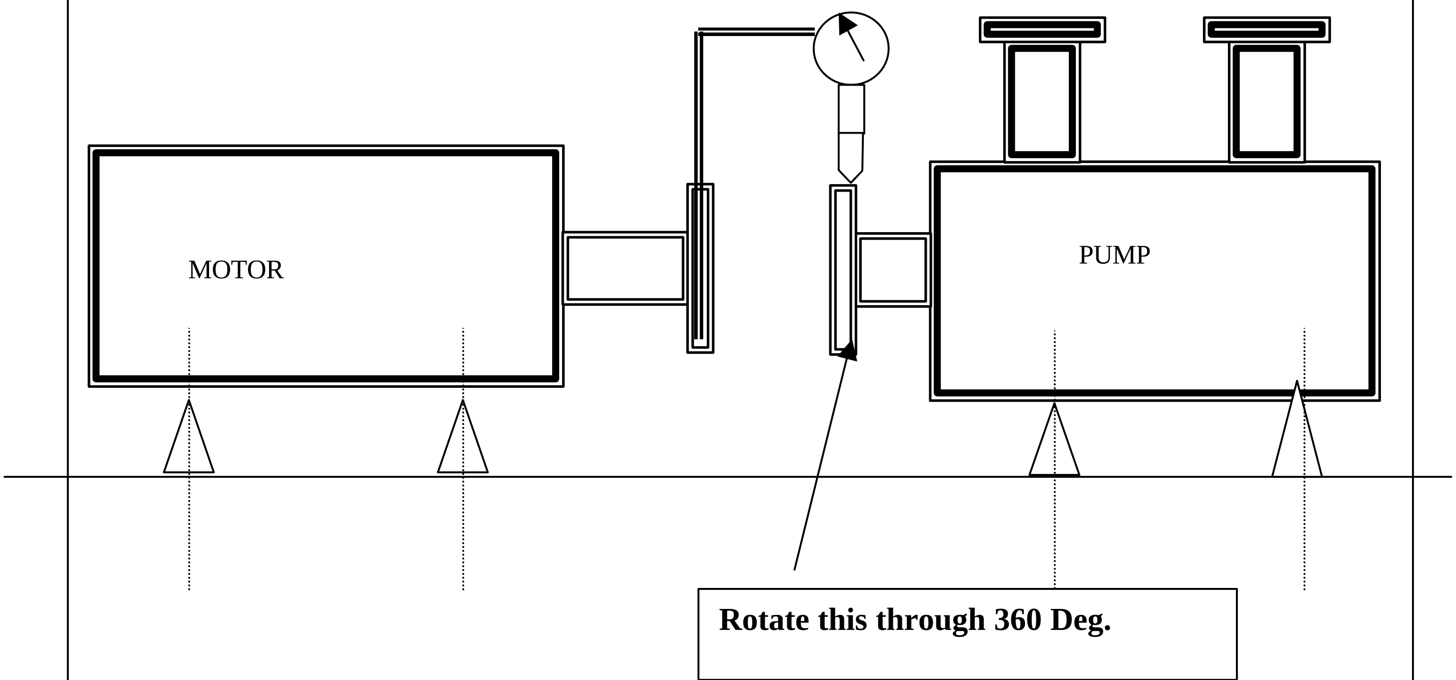


Fig.-3 One of the Set-up for run-out check of coupling.

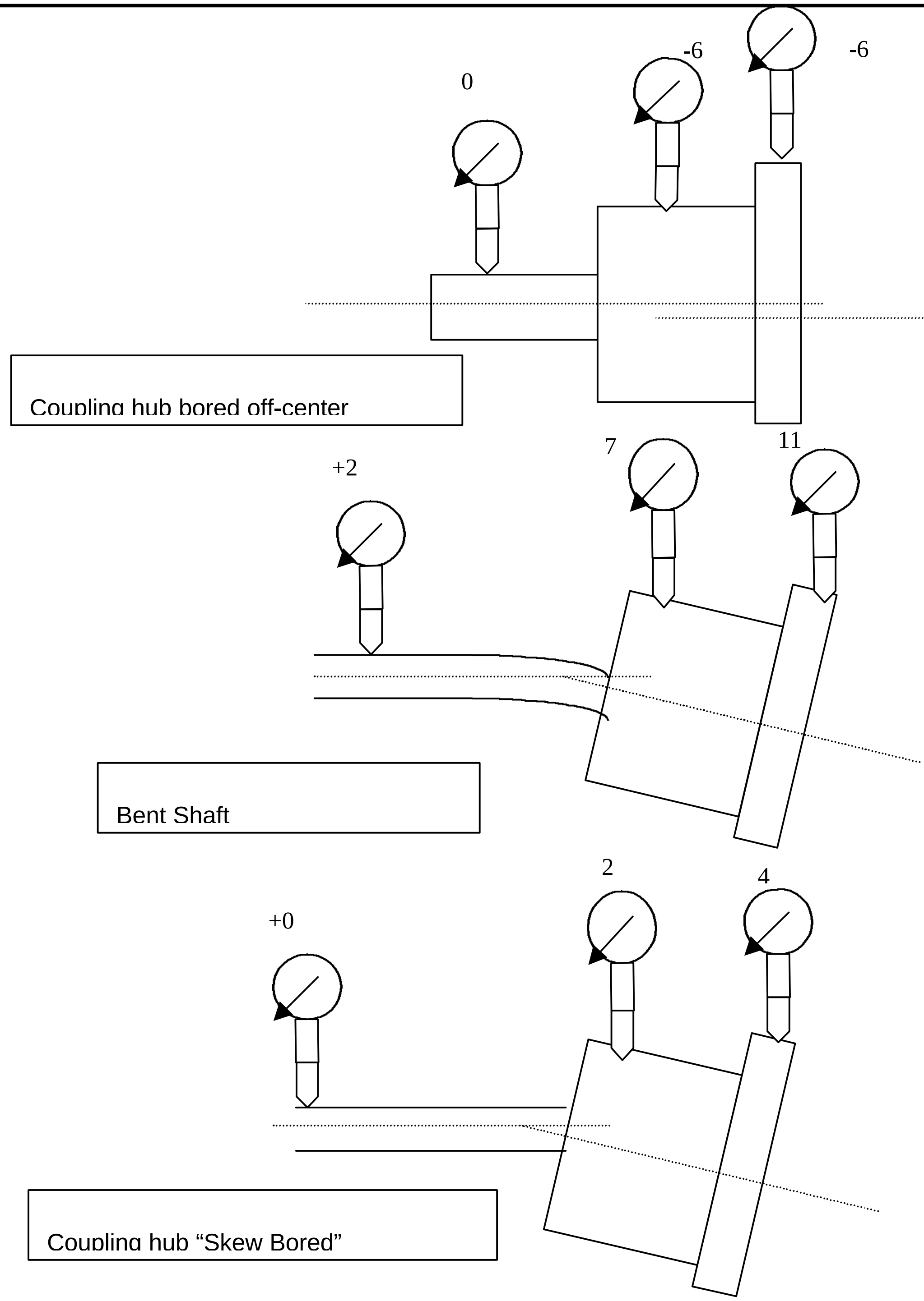


Fig.-4 Reasons for run-out problems

7.3 Machine casing to base plate interface problems (soft foot):

When rotating machinery is set in place on its base frame/ sole plate, one or more than one of the ‘feet’ may not make good contact at the ‘foot points’ on the frame. This can be attributed to bowed /warped frames, improper machining of feet etc.

The soft foot problem in the machine results in different alignment readings every time you open & tighten the machine mounting bolts. It will vary with bolt tightening sequence.

A soft foot primarily exist if all the foot of the machine are not in one plane i.e. one of the foot is short than the others, or if any individual feet is not flat enough to it’s mounting area or vice versa.

Follow the steps to detect & correct the soft foot problem.

1) For machine already in operation, it is necessary to ensure that cause of soft foot is not external i.e. Piping Load or Cable Pull. For new installation, it is recommended to check the soft foot before piping & cable connection.
2) Before machine installation on its base frame, ensure that all mounting pads on base frame are flat enough (Check with straight edge across the pads & no gap underside of the straight edge). If pad is not flat enough, correction can be done by machining the frame.
3) Clean the mounting area & install the machine on base frame.
4) Fully tighten all mounting bolts. Place dial indicator at one of the feet near the bolthole with stem resting on frame. Loosen all bolts one by one & observe the dial movement, if is not exceeding 0.05mm, no correction are required & no soft foot exists.
5) In case of higher movement, mark the feet, which had caused the movement. Check the gap between the feet & mounting pad, if gap exist & it’s uniform, install the shim of thickness equal to the gap. If gap is not uniform than preferably, it shall be corrected by correcting the machine feet flatness (Mounting pads flatness is

already ensured). If it is not feasible, can be corrected by taper shim or partial shim of "j", "L" shapes.

6) After correcting the soft foot, repeat the step-3 to verify that soft foot had been removed.

7.4 Piping forces:

It is shall be ensured that all piping connected to rotating equipment are well fitted, supported & sufficiently flexible, so that no more than 0.003" in vertical & horizontal movement occurs at the flexible coupling when the last pipe flanges are tightened.

The above-mentioned method may ensure safe piping load and parallelism of pipe flanges with machine flange in cold condition (ambient). However no direct checks are possible on the machine to ensure safe piping loads while machine is at operating temperature. Vibration analysis or some indirect measure like comparison of actual pipe support movement w.r.t. to calculated one etc. can be depended upon with necessary modifications.

Well designed piping shall restrict pipe loads coming on to the equipment below the limits set by relevant codes & keeping the alignment within the limits specified.

Normally pipe loads are exerted on equipment can be higher if pipe support systems are not sufficiently flexible or restricts the pipe thermal growth at operating temperature.

Normally to resolve piping related problems, Piping support & piping system modifications are called for.

8. COUPLINGS:

Coupling is an important component of drive system, which connects two rotating shafts together. Since it is nearly impossible to maintain perfectly collinear centerlines of rotation between two or more shafts, flexible couplings are designed to withstand certain degree of initial or running misalignment.

Couplings are broadly classified in two types, Flexible & Rigid Coupling.

Flexible coupling: As described above this type of couplings have in built ability to with stand certain degree of misalignment depending upon the type.
Following are some of the most commonly available flexible coupling types, each one of them are discussed in detail in following paragraphs.

1. Mechanically Flexible
2. Elastomeric
3. Metallic membrane/ disk

Rigid Couplings: Rigid couplings are the older type of couplings, before flexible coupling came in existence rigid couplings were used to connect two shafts. Unlike flexible coupling, they do not use any mechanism, which in addition to power transmission will allow misalignment. Hence rigid coupling will find its use only in the applications where there is no room for misalignment or very minor misalignment.

Typical application is vertical pumps where shaft of the drive has to support weight of driven shaft.

In selection of coupling other than power transmission capacity lot of other considerations like: Misalignment capability, Torsional flexibility, Temperature limits, Overhung weight limits, Axial spacing etc. plays vital role.
Following is a brief description of each flexible coupling along with its limitations. Depending upon the service requirement any one of these can be chosen with due considerations for it's limitations.

Note: Here values of allowable misalignment for each type are not given for two reasons 1) Manufacturer of similar couplings will never agree to same tolerance values.2) Manufacturer will never specify that misalignment values are combined or separate for angular & axial.

1.Mechanically Flexible coupling designs:

a) **Chain Couplings: The chain coupling is basically consists of two** identical gear sprocket with hardened sprocket teeth & connected by double width roller or silent type chain. Packaged grease lubrication is primarily used with this type of construction necessitating a sealed sprocket.

Capacity: to 1000hp @ 1800 rpm (roller), 3000hp @1800 rpm (silent)

Max. Speed: up to 5000 rpm.

Shaft Bores: up to 200mm.

Shaft Spacing: determined by chain width, generally 1/8" or ¼''.

Design considerations: Wear generally occurs in sprocket teeth due to excessive misalignment or lack of lubrication. Torsional flexibility limited by yielding of chain

Advantages:

- Easy to disassemble & assemble
- Fewer number of parts.

Disadvantages:

- Speed limitation due to difficulties in maintaining balancing.
- Require lubrication.
- Limited allowable axial displacement.

b) **Gear Coupling:** The gear coupling consists of two hubs with external gear teeth that are attached to the shafts. A hub cover or sleeve with internal gear teeth engage with the shaft hubs to provide the transmission of power. Gear tooth clearances and tooth profiles allow misalignment between shafts. Lubrication of gear teeth is necessary and various designs allow for grease or oil as the lubricant.

Capacity: up to 70,000hp

Max. Speed: up to 50,000rpm

Shaft Bores: up to 750mm

Shaft spacing: up to 5000mm.

Advantages:

- Allows freedom of axial movements

- Capable of high speeds
- Low overhung weights
- Good balance characteristic with proper fit & curved tooth profile.

Disadvantages:

- Requires lubrication
- Temperature limitation due to lubricant.

c) **<u>Metal Ribbon coupling</u>:** The metal ribbon coupling consist of two hubs with axial grooves on the outer diameter of the hub where a continuous shaped grid meshes in to the grooves. Misalignment and axial movement is achieved by flexing and sliding of the grid member on specially tapered hub 'teeth'.
Capacity: up to 70,000 hp/100 rpm
Max. Speed: to 6000 rpm
Shaft bores: to 500mm
Shaft spacing: to 300mm

Special design considerations: Grid fabricated from hardened, high strength steel. Close coupled hubs with removable spacer available.

Advantages:

- Easy to assemble.
- Torsionally soft.

Disadvantages:

- Requires lubrication.
- Temperature limited.
- Speed Limited.

2. <u>Elastomeric Couplings:</u>

A wide variety of design employs an elastomeric medium to transmit torque and accommodate misalignment. Most of these couplings are torsionally 'soft' to absorb high starting torques or shock loads.

Capacity: up to 67,000 hp/100 rpm but varies widely with design.
Max. Speed: approx. 5000 rpm (vary widely with design).

Shaft bores: up to 750mm
Shaft spacing: up to 2500mm (varies widely).
Special Design Considerations: The elastomeric medium is generally natural or synthetic rubber, urethane, nylon, teflon or oil impregnated bronze. Since the elastomer is markedly softer than the hubs and solid driving elements (wedges, pins, jaws etc.), wear is minimal and replacement of the elastomer it self is all that needed for periodic servicing.

Advantages:

- Minimal wear in coupling.
- Acts as vibration damper and isolator.
- Acts as electrical shaft current insulator.
- Torsionally “soft”.
- Accepts axial movement and dampens axial vibration.
- No lubrication required.

Disadvantages:

- Speed limited due to distortion of elastomer from high centrifugal forces.
- Deterioration of elastomer from: Temperature, oxidation of rubber, corrosive attack from environment.
- Potential safety hazard if elastomeric element released from drive elements.

3.<u>Metallic membrane/ disk type coupling:</u>

a) Diaphragm Couplings:

Transmission of power occurs through two flexible metal diaphragms, each bolted to the outer rim of the shaft hubs and connected via spacer tube. Misalignment and axial displacement is accomplished by flexing of the diaphragm members.

Capacity: up to 30,000hp.
Max. Speed: up to 30,000 rpm.
Shaft Bores: up to 175mm.

Shaft spacing: 50 to 5000mm.

Special Design Considerations: Metal diaphragm couplings are a highly reliable drive component when operated within their rated conditions. Exceeding the maximum allowable angular and or parallel misalignment values or axial spacing will eventually result in a disc failure. Since diaphragm is in effect spring, considerations must be given to the axial spring rate & vibration characteristics to insure the diaphragm coupling natural frequency does not match rotating speed or harmonics in the drive system.

Advantages:

- Excellent balance characteristics.
- No lubrication required.
- Low coupling weight & bending forces on shafts when operated within alignment limits.
- Accepts high temperature environment.

Disadvantages:

Limited axial displacement and oscillation.

Proper shaft spacing requirements are more stringent.

c) Flexible disc couplings:

The flexible disc coupling is very similar in design & principal s to the diaphragm coupling with the exception that multiple, thinner discs or a non-circular flexing member is used as the flexible element instead of circular, contoured diaphragm elements.

Capacity: Up to 65,000/100 rpm.

Max.speed: up to 30,00 rpm.

Shaft Bores: 300mm.

Shaft spacing: 5000mm.

Special design considerations: it is important to note that two disc packs (or diaphragms) are needed to accommodate parallel misalignment whereas a single disc can only handle pure angular misalignment.

Advantages & disadvantages are same as diaphragm couplings.

9. ALIGNMENT TOLERANCES:

Before attempting any alignment job the person responsible shall know the accuracy of alignment required for that machine or alignment tolerances recommended for that machine.

It is very well accepted that perfect alignment i.e. 100% collinear shaft alignment is not possible because of so many reasons and even efforts made to achieve will not justify it. Hence, it is necessary to arrive at the values, which will achieve the objective of good alignment i.e. safe & smooth running of equipment without any premature failures of components.
Primarily the speed of the machine & distance between shaft ends determines the tolerances on alignment.

Various alignment tolerance charts are available, all the charts are based on the above criteria. Normally alignment tolerance recommended by equipment manufacture is to be followed in absence of any such values a fig.-5 given below can be used as a guide.

10. MEASUREMENT INSTRUMENTS & ALIGNMENT TOOLS:

To achieve the objective of shaft centerline measurement a below listed tools are primarily used:
1) Straight edge.
2) Feeler gauge.
3) Taper Gauges
4) Measuring tape & ruler.
5) Alignment bracket.
6) Vernier Caliper.
7) Dial indicators.

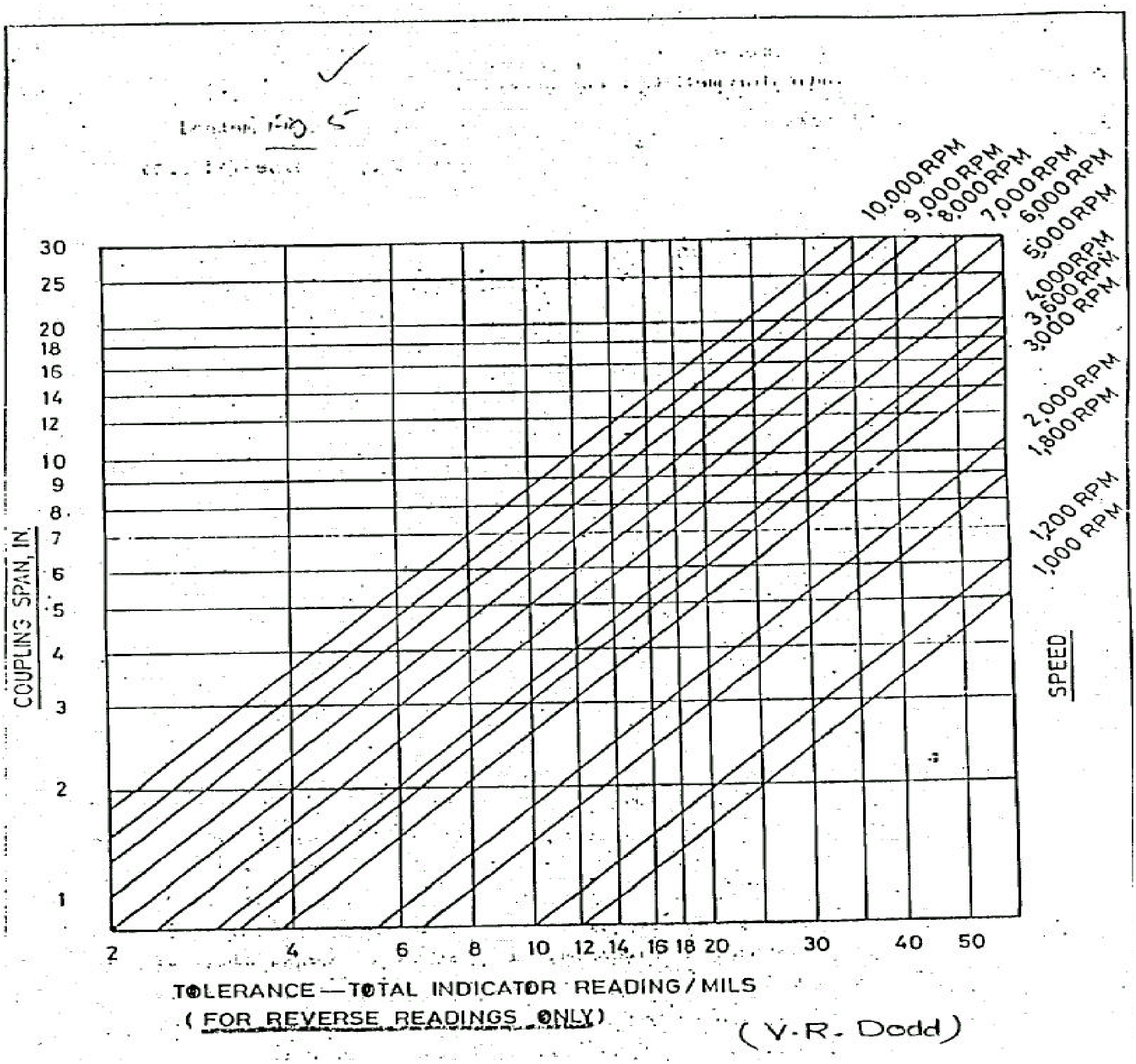


Fig.-5 ALIGNMENT TOLERANCES

1) **Straight edge:** Straight edge is a flat machined steel bar within an accuracy of micron per length. It is used to measure the flatness of a surface in combination of feeler gauge.
2) **Feeler Gauges**: Feeler gauges are simply strips of metal stock arranged in a ‘fold out fan’ type of package design. They are available in both Inch & mm graduations, they are used to measure the soft foot gap & end gap of closely coupled coupling to an accuracy of 0.05mm.
3) **Taper Gauge:** Taper gauges are precisely fabricated metal wedges having scribe marks along length indicating thickness at each particular scribe line. They are specifically used to measure the gap between closely spaced shaft ends where accuracy of +/- 0.2 mm is required.
4) **Measure tape & Ruler**: These are steel tape or normal measure tape with graduation up to 1mm.These tapes are used normally to measure the distance between machine feet & coupling dia., which requires accuracy up to +/- 1mm.
5) **Alignment brackets:** Alignment brackets are primarily the frameworks to hold the dial indicators in required position & measure the readings. The sturdy & well-machined brackets are must, this will minimize the bracket sag (Discussed in detail in another chapter later). Various forms of brackets are required depending upon the alignment technique or method selected.
6) **Vernier Caliper:** Vernier caliper is required for measurement, which requires accuracy in hundredth of mm. In alignment primarily they are used check shim thickness etc.
7) **Dial indicator & measurement methods:**
   The dial indicator is the measuring tool used to determine the physical relationships between shafts to be aligned. There are two basic types:

   Balanced Type: Having figures that read in both directions (+ or -) from zero. With face graduated in thousandths of an inch or millimeter, these are recommended for alignment work.

Continuous Reading Type: Having figures that read only clock-wise from zero.

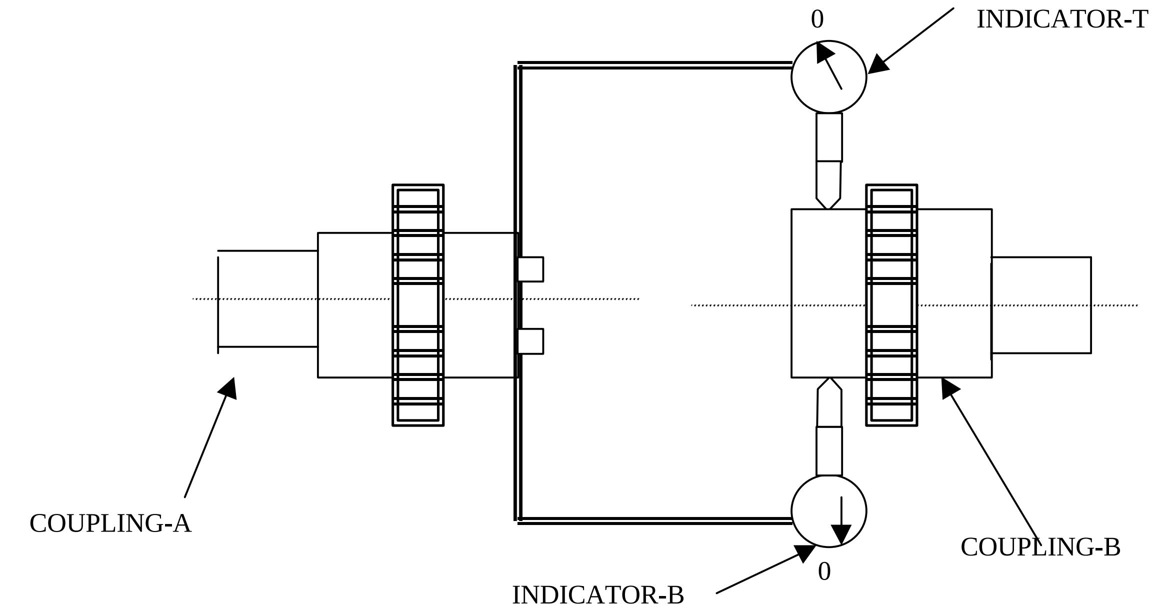
The dial indicator is operated by a plunger and convention, the inward movement of which moves the hand clock-wise or in plus (+) direction. Out ward movement of the plunger moves the hand counter clock-wise or in minus (-) direction. The face of the dial can be rotated for reading zero in any plunger position.

Vertical move: The attached fig. –6, Displays that how the vertical offset of 0.2mm of a shaft with respect to other shaft will be displayed.

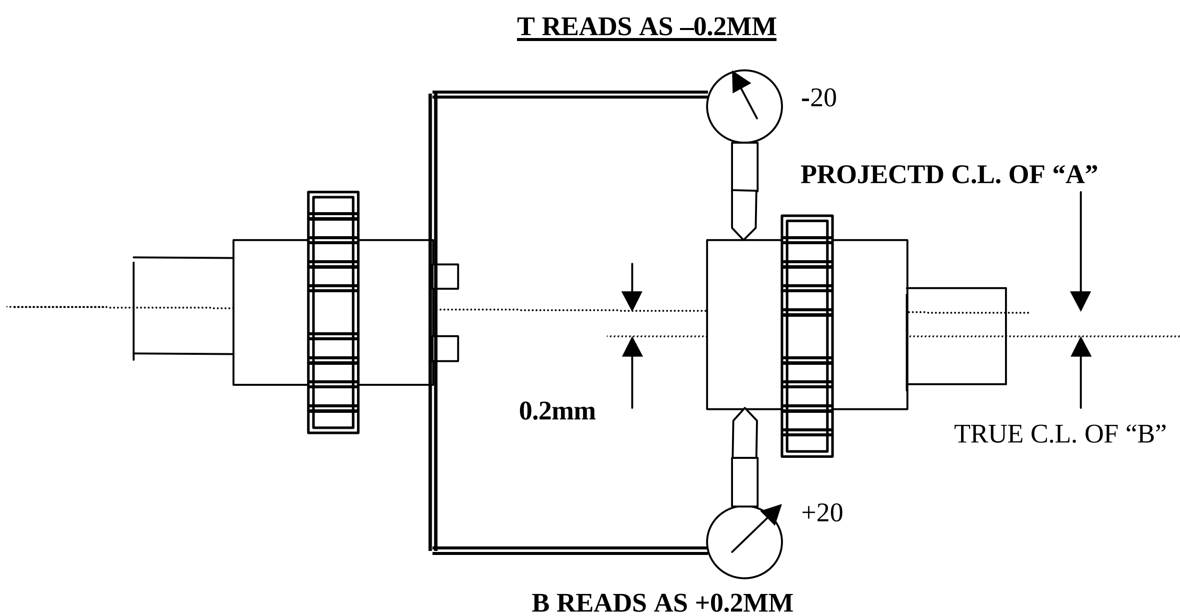
If indicator reading at top is zeroed than bottom will be double than actual offset. This is called “TIR” total indicated reading, which is normally double than actual offset.

S**weep readings**: To determine both vertical & horizontal offsets, it is necessary to obtain a complete set of “sweep readings”. Sweep readings are obtained by zeroing the dial indicator at the top position on the coupling to be indicated. Slowly rotate the shaft so that the dial indicator is rotated by 360 Deg. In 90 Deg. increments. Obtain reading at
Top (T), right (R), bottom (B) and left (L) fig.-7.

Horizontal move: The attached fig-7, displays that how the alignment readings of two shaft having 0.2mm vertical offset & 0.2mm horizontal offset will look like.



PERFECTLY ALIGNED SHAFTS



MACHINE 'B' LOWERED 0.2 MM IN RESPECT TO MACHINE'A'

Fig.-6

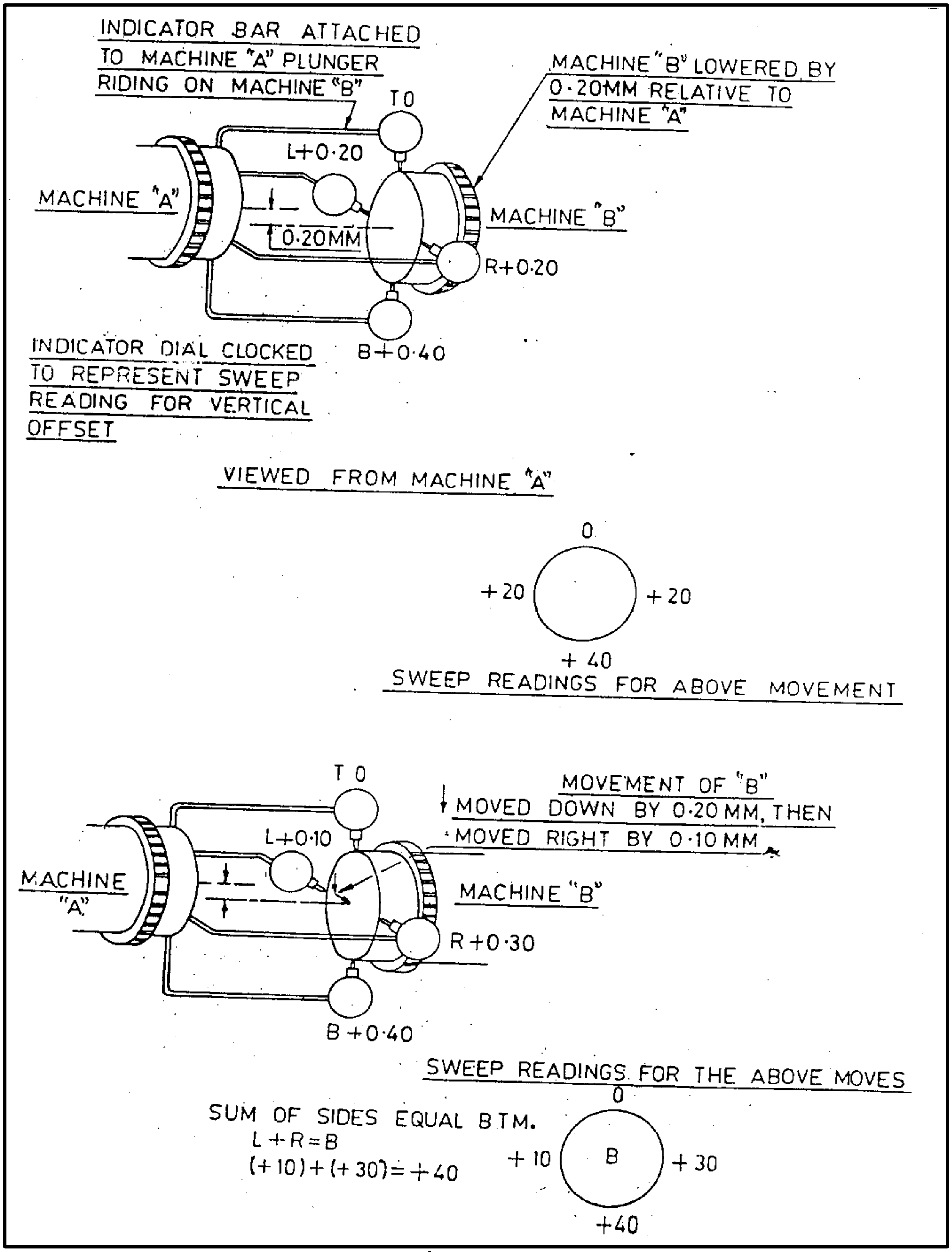

INDICATOR BAR ATTACHED TO MACHINE "A" PLUNGER RIDING ON MACHINE "B"
T 0
MACHINE "B" LOWERED BY 0·20MM RELATIVE TO MACHINE "A"
L+0·20
MACHINE "A"
0·20MM
MACHINE "B"
R+0·20
INDICATOR DIAL CLOCKED TO REPRESENT SWEEP READING FOR VERTICAL OFFSET
B+0·40
VIEWED FROM MACHINE "A"
0
+20
+20
+40
SWEEP READINGS FOR ABOVE MOVEMENT
T 0
MOVEMENT OF "B"
MOVED DOWN BY 0·20 MM, THEN
MOVED RIGHT BY 0·10 MM
L+0·10
MACHINE "A"
MACHINE "B"
R +0·30
B +0·40
SWEEP READINGS FOR THE ABOVE MOVES
SUM OF SIDES EQUAL BTM.
L + R = B
(+10) + (+30) = +40
0
+10
B
+30
+40

Fig. -7

11. SELECTING THE MACHINE TO BE ADJUSTED:

To determine the machine(s) to be moved in train, consider the type of machine and how it is mounted. Gearboxes sometimes to be shimmed unevenly to obtain optimum tooth contact and once set, should not be moved unless absolutely necessary. If it is necessary to move a gearbox tooth contact must be checked after movement has been completed.

Once set, steam turbines are generally not moved. Centerline mounted machines where the shim packs are readily accessible are the easiest to move and should be moved before foot mounted machines.

In summary fro selecting the machine to be moved following points shall be considered.

The machine which are easy to move & can be moved in least time with minimum effort are preferred for movement i.e.

- For Pump & Motor train, motor shall be preferred for movement.
- For pump & turbine train, pump shall be preferred for movement.
- For compressor, G.box & Turbine train, first fixing the G.box & carrying out adjustment on turbine& compressor shall be preferred.

12. ALIGNMENT TECHNIQUES:

To measure the centerline of rotation of one shaft with respect to each other various alignment techniques employing various tools are available.

The each one of them has it's own advantages & disadvantages. Depending upon the accuracy required, time & money to be spent, user can select best suited method for their use.

This section discuss in detail the merit & demerits of all most widely used methods.

12.1 Straight edge & feeler gauge.

12.2 Shaft alignment using dial indicators :

a) Face-Rim method

ii) Two indicator method.

ii) Three indicator method.

b) Reverse indicator method

c) Face-Face-Distance method.

12.3 Laser alignment method.

12.1 <u>Straight edge & Feeler gauge method:</u>

This is the oldest of all alignment technique & simplest one. It employs the straight edge & feeler gauge / taper gauge to measure the offset & face gap readings.

Advantages:
1) Simplest & cheapest of all methods.
2) Does not require too many tools.
3) Does not require specialized skills.

Disadvantages:
1) Least accurate of all methods.
2) Too much Scope for human errors.

Application is limited to low RPM & non-critical machines. This can be used to carry out rough alignment on critical machines to reduce the time for precise alignment.

12.2 <u>Alignment using Dial indicator methods:</u>

a) Face-OD method:

i) Two Indicator Method: Fig.-8, Illustrates the most widely used of the traditional alignment methods. A bracket is attached to one of shaft and extends near the coupling hub on other shaft. Dial indicators are attached to the brackets as shown, with the stem of one indicator resting on OD or rim of opposite coupling hub & other stem resting on face of same coupling hub. Offset of the shaft or parallel misalignment is determined by the OD readings, whereas angularity is determined by "Face" readings. Normally both the shafts are rotated together to eliminate errors due to face and rim irregularities. However, if one of the shafts cannot be turned, then these deviations ought to be determined & incorporated in the final readings.

The method has and continues to serve well in the vast majority of industrial alignment problems. Indeed, it is the specific method outlined in virtually every maintenance manual for industrial rotating equipment.

For high speed, high-HP turbo machinery, where requirements for precise alignment are more stringent, the shortcomings of this method become increasingly important. Consider the following points:

- The indicator readings taken during this method does not include only misalignment of two shafts, it also picks-up inaccuracies in geometry of the coupling hub upon which dial rest. These errors can be eliminated, by incorporating the allowance for geometry or by rotating both the shafts together.

- This method incorporate the errors caused by axial movement of shafts during alignment check. This is of little concern where shafts are fixed axially by the ball bearings. It becomes a problem, however on machine equipped with hydrodynamic thrust bearings.

- Graphing the results of Face-OD measurements is more complex than reverse –indicator method.

- In this method the angularity readings are measured on the hub face, which are relatively small on high-speed machines. For example, a reading of 0.05mm on the face of 100mm dia. Coupling hub represents an angularity of 0.5mm per meter or an error of o.5 m at the opposite end of a machine 1 meter long. This is most instances may not be a catastrophic but it is an error.

- This method requires removal of spacer for measurements. This may results in additional effort & additional wear & tears for coupling fasteners.

This method can be used effectively for equipment having anti-friction bearing & where no axial movement of coupling or shaft is expected during reading measurement.

ii) **Three- Indicator face –OD method:** This is an improvement over the two-indicator method, here adverse effect of machine axial shift is eliminated while taking the readings. The axial error introduced in indicator “T” while travelling to the bottom get introduced in indicator “B” that goes to top. While subtracting the two face readings for finding the face gap difference, this error is, there for automatically cancelled.

This set up would thus be useful for equipment having sleeve bearings that are prone to axial shift while turning.

b) **Reverse Indicator method:** In contrast to face method, indicator readings can be taken by the reverse indicator method on the OD of the coupling hub (or shaft only). Two brackets are used simultaneously, which is normally preferred (Fig.-8). Advantages of this method over “Face-OD“ method are:

i) By proper design of the alignment brackets, the need for removal of coupling spacer is eliminated in most cases. This feature provides three distinct advantages:
- Wear and tear on the coupling is reduced.
- Since both shafts turn as a unit with the spacer installed, errors caused by coupling hub run-out are entirely eliminated. This also reduces chances for lubricant contamination in case of gear couplings.
- By spanning the coupling, angular misalignment is greatly magnified and more precisely diagnosed.

ii) With this method, we need to mount only one indicator per bracket, thus reducing sag as compared to Face-OD method, which use two indicators.

This method can be used for all high horse power & high RPM machines. This method offers more accuracy for long coupling span machine over other methods.

c) Face –Face –Distance method: This set-up shown in fig.-8, is usable on long spans, such as cooling tower drives without elaborate long span brackets and consideration of bracket sag.

It is obvious that this method cannot be used where no coupling spacer is present.

12.3 Laser alignment method: As name implies this method uses LASER technology to measure the shaft alignment & software program to calculate corrective movements. As shown in fig.-9, system uses semiconductor laser emitting a bean with infrared range (wavelength 820mm), along with a beam finder incorporating an infrared detector. The laser beam is refracted through a prism and is caught by a receiver/detector. These lightweight, non-bulky devices are mounted on the equipment shafts, and only cordconnected microcomputer module is external to the beam emission and receiver /detector devices.

The prism redirects the beam and allows measurement of parallel offset in one plane and angularity in another, thus simultaneously controlling both. In one 360Deg. Rotation of the shafts all four directional alignment corrections are determined.

The receiver is bi-axial analog photoelectric semiconductor position detector, yielding mathematical results to within one micron. Data for computation are entered automatically through a cable direct from the receiver/detector. The only information still to be entered manually is relative position, 4 times at 0, 90, 180 and 270 Deg.

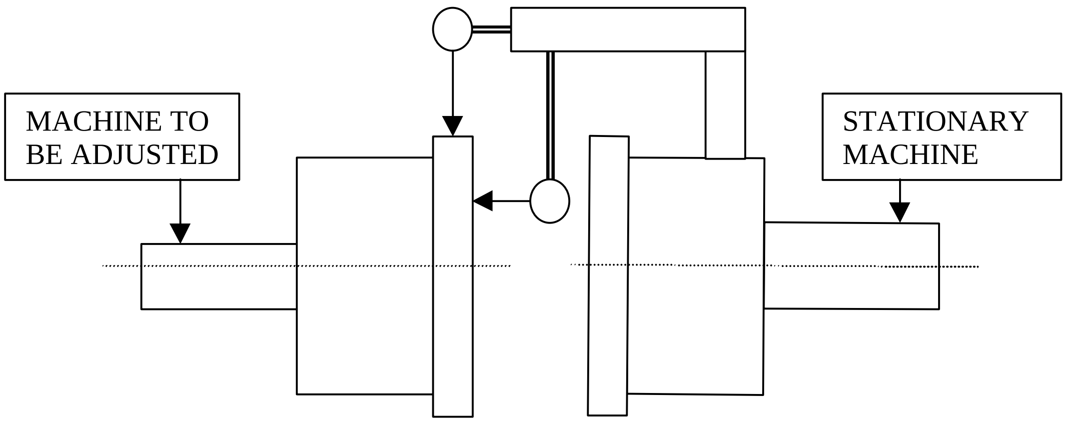
With the data automatically obtained from receiver/detectors, the microcomputer instantaneously yields the horizontal & vertical movement as well as shimming.

Some of the distinct advantages of the method over other s are:

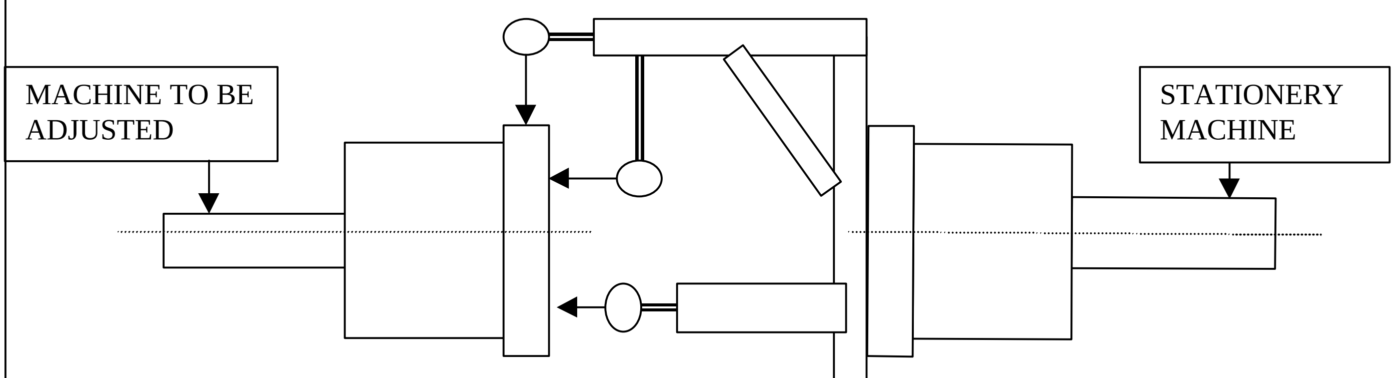
- Higher accuracy than any other method.
- Least time consuming as no manual calculation required.
- Eliminates all possible human errors of other method.
- Online monitoring of corrections being made.

Disadvantages:

- Higher capital cost than other methods.
- Specialised skills or training required.

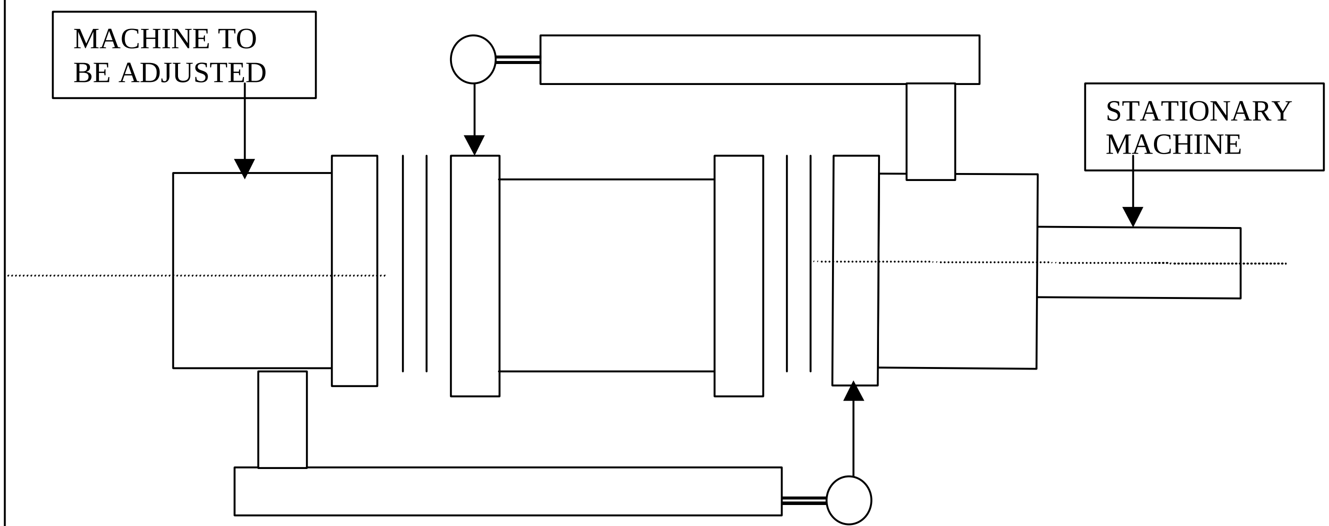


SET-UP FOR TWO INDICATORS (FACE-OD METHOD)

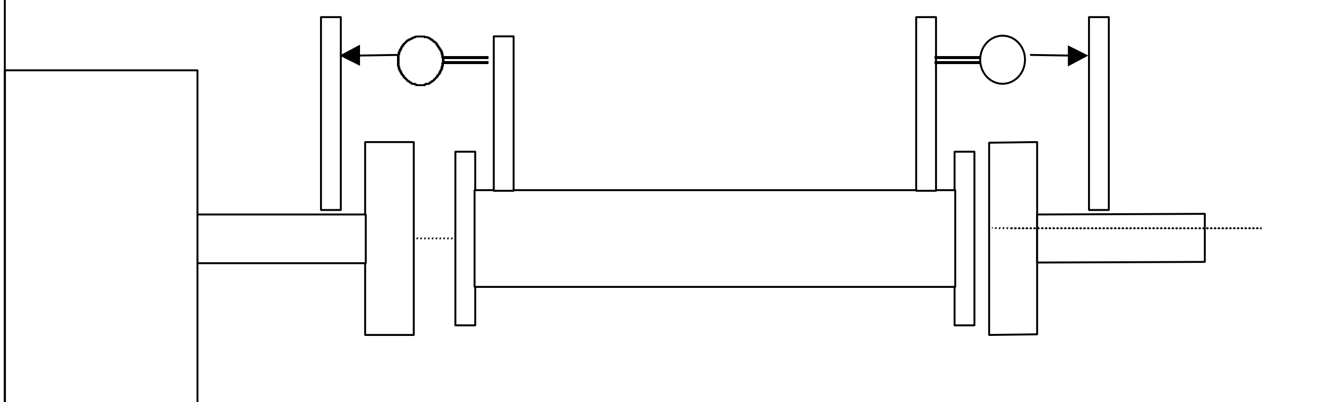


THREE INDICATORS (FACE-RIM METHOD)

FIG.-8/1



REVERSE INDICATOR METHOD



TWO INDICATOR FACE-FACE DISTANCE METHOD

FIG.-8/2

Alignment tool Kit

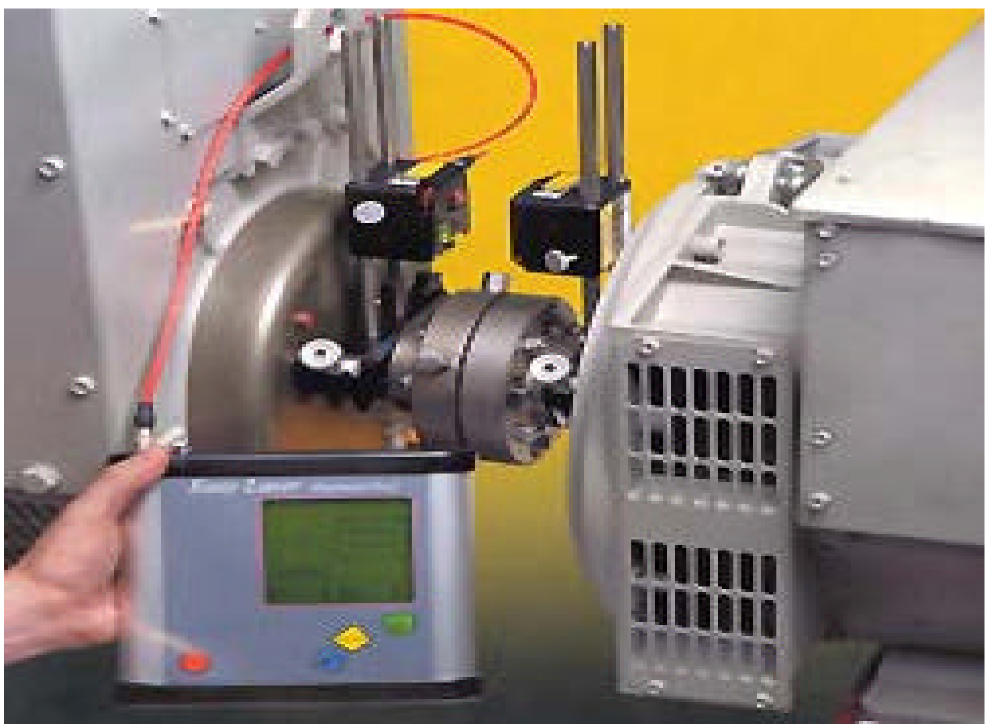


Fig.-9

13. BRACKET SAG OR INDICATOR SAG:

Indicator mounting brackets must be fabricated and securely fastened to the coupling hub or shaft in such a manner that indicator bracket ‘sag’ ill be eliminated. However before we proceed to take alignment readings and if the sag cannot be eliminated, it must be determined & accounted for. Generally, sag should be checked when using clamp-on jigs for spans greater than 6 inches, as well as when stiffness is in doubt.

Various ways are there to determine the bracket sag, the widely accepted & accurate method is described here.

Indicator bar sag can be determined by holding a bar-stock of appropriate size in n lathe between centers and then turning it to the proper diameter to accept the alignment bracket. Without removing the bar-stock from the lathe, alignment bracket is attached. With the bracket on top of the bar stock, the indicator is set to zero. Rotate the assembly by 180 Deg. so that the indicator now reads directly on the bottom of the bar stock (Fig.-10).

$$\text{Sag} = \text{TIR}/2$$

Correction of “Sag”: To correct the sweep readings for sag, add twice the amount of true sag to the bottom reading (B) and correct the side readings (R & L) by adding the sag amount.

In case of reverse indicator method the indicator that is zeroed at bottom shall be corrected for sag by subtracting the double the sag value from “ Top” reading.

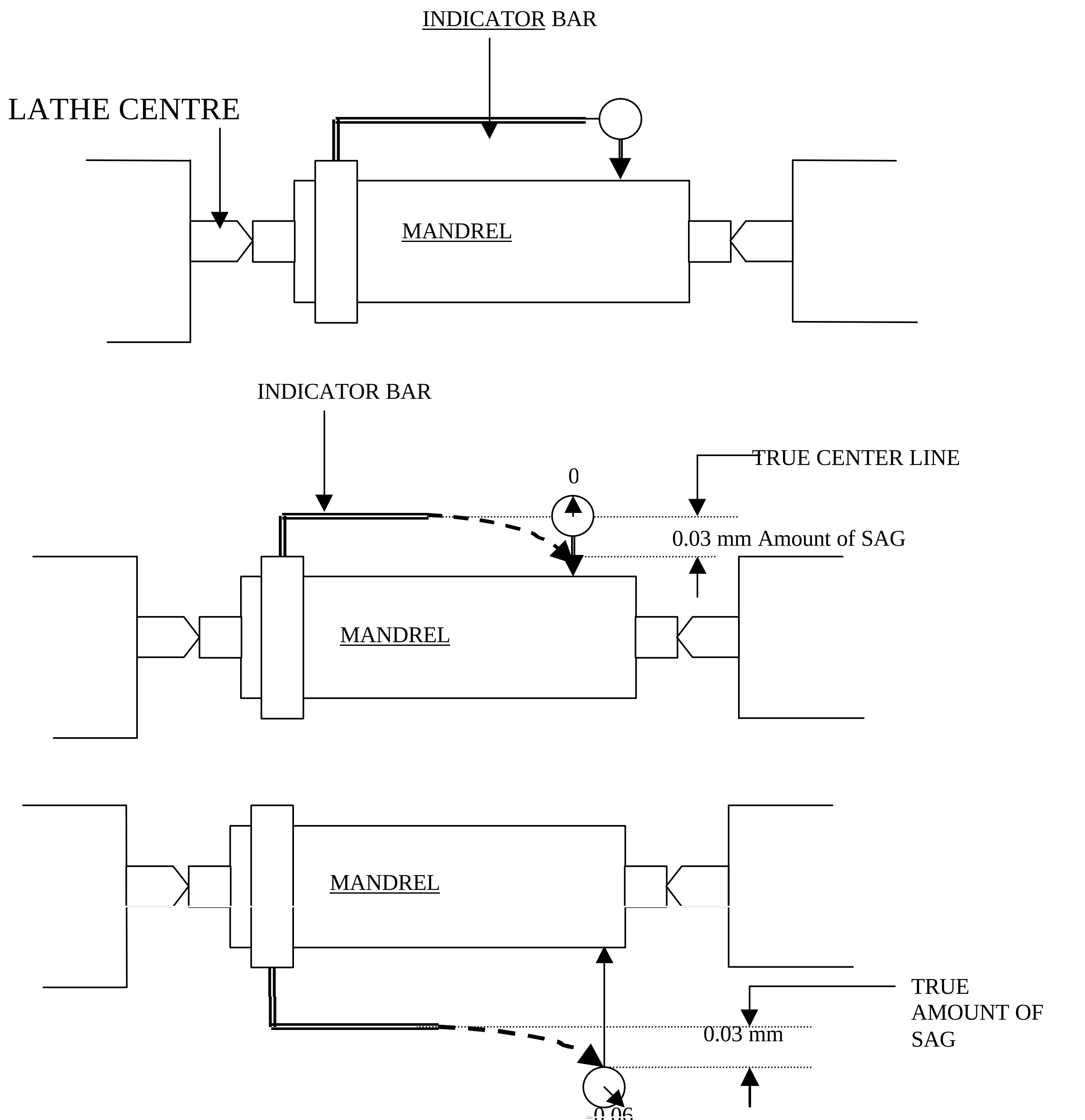


FIG.10 CHECKING INDICATOR BAR FOR SAG

14. DATARECORDING, INTERPRETATION AND CALCULATION:

The importance of systematic data recording cannot be over emphasized. The systematic data recording will eliminate many human errors & will be easy to understand. The figs.-11,12,13,14 Attached are sample for various set-ups.

14.1 Data Recording: The steps involved in Data recording will be clearer by following example. (Fig.15)

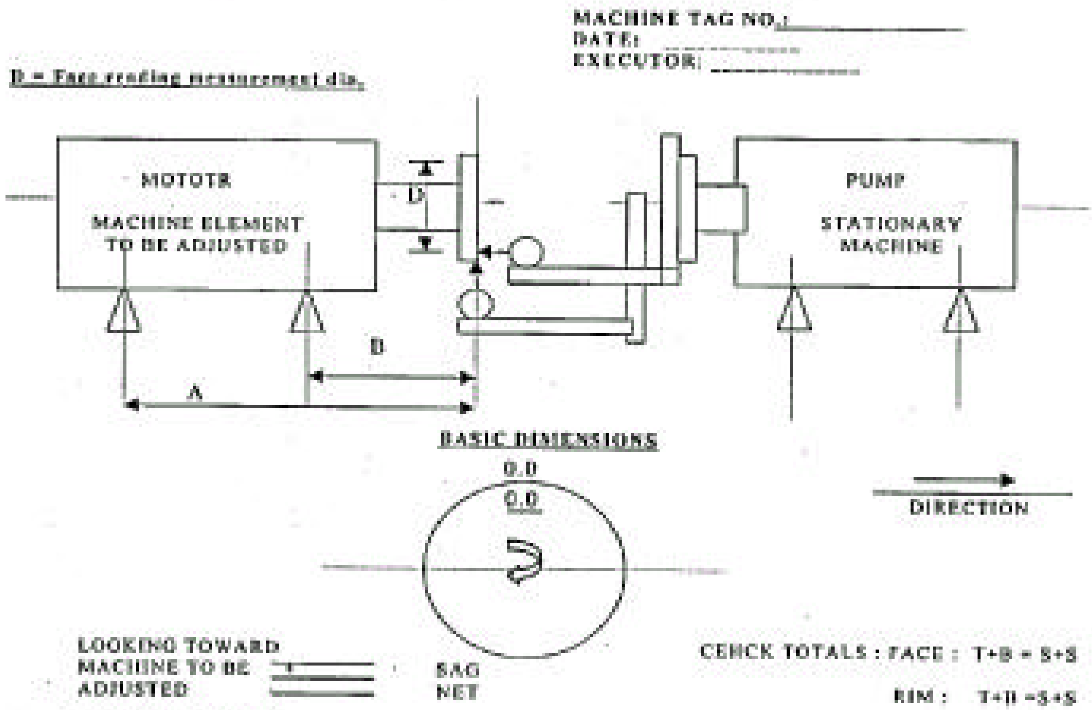
Take the appropriate data recording sheet for Face-OD method. Enter the machine diagram, date & machine no. & name of the person doing the job. Define the fix & machine to be moved. Enter the basic dimensions like distance of moveable machine first & second feet distance from coupling hub etc. Mount the bracket & dial indicators. Before taking reading meet all pre requisites. Take all rim & face readings, record the rim readings out side the circle & face readings inside the circle. Perform the check of correctness of readings by repeating the reading & checking the T + B = S + S. Add double the known sag to bottom readings & sag to side readings. This completes the data recording.

14.2 Data interpretation: Next step in alignment procedure is the data interpretation. Data interpretation or visualization of machine position is very important for calculating & carrying out correct machine movement.

Refer fig.-15 for reading set.

Calculate the half of vertical rim reading: -0.11/2 = -0.05 mm

This will give the centerline offset at the plane of measurement. The (-) sign indicates that machine to be adjusted is higher than the stationery machine. Similarly we see that the bottom face distance is 0.07mm wider than the top face distance.



INTERPRETATION:

MACHINE ELEMENT TO BE ADJUSTED IS ----------------------(HIGHER)(LOWER) THAN STATIONARY ELEMENT AT PLANE OF MEASUREMENT.

(TOP) (BOTTOM) FACE DISTANCE IS--------------- WIDER.

MACHINELEMENT OT ADJUSTED IS----------(NORTH) (SOUTH) (EAST) (WEST) OF STATIONARYELEMENT, AT PLANE OF MEASURMENT.

(NORTH) (SOUTH) (EAST) (WEST) FACE DISTANCE IS____________WIDER.

CORRECTIVE MOVEMENTS FROM GRAPH:

(RAISE) (LOWER) INBOARD FEET ------------------------------------.

(RAISE) (LOWER) OUTBOARD FEET ------------------------------------.

MOVE INBOARD FEET (NORTH) (SOUTH) (EAST) (WEST) ------------------------.
MOVE INBOARD FEET (NORTH) (SOUTH) (EAST) (WEST) ------------------------.

Fig.-11 Data Recording sheet Two Indicator Face-OD method.

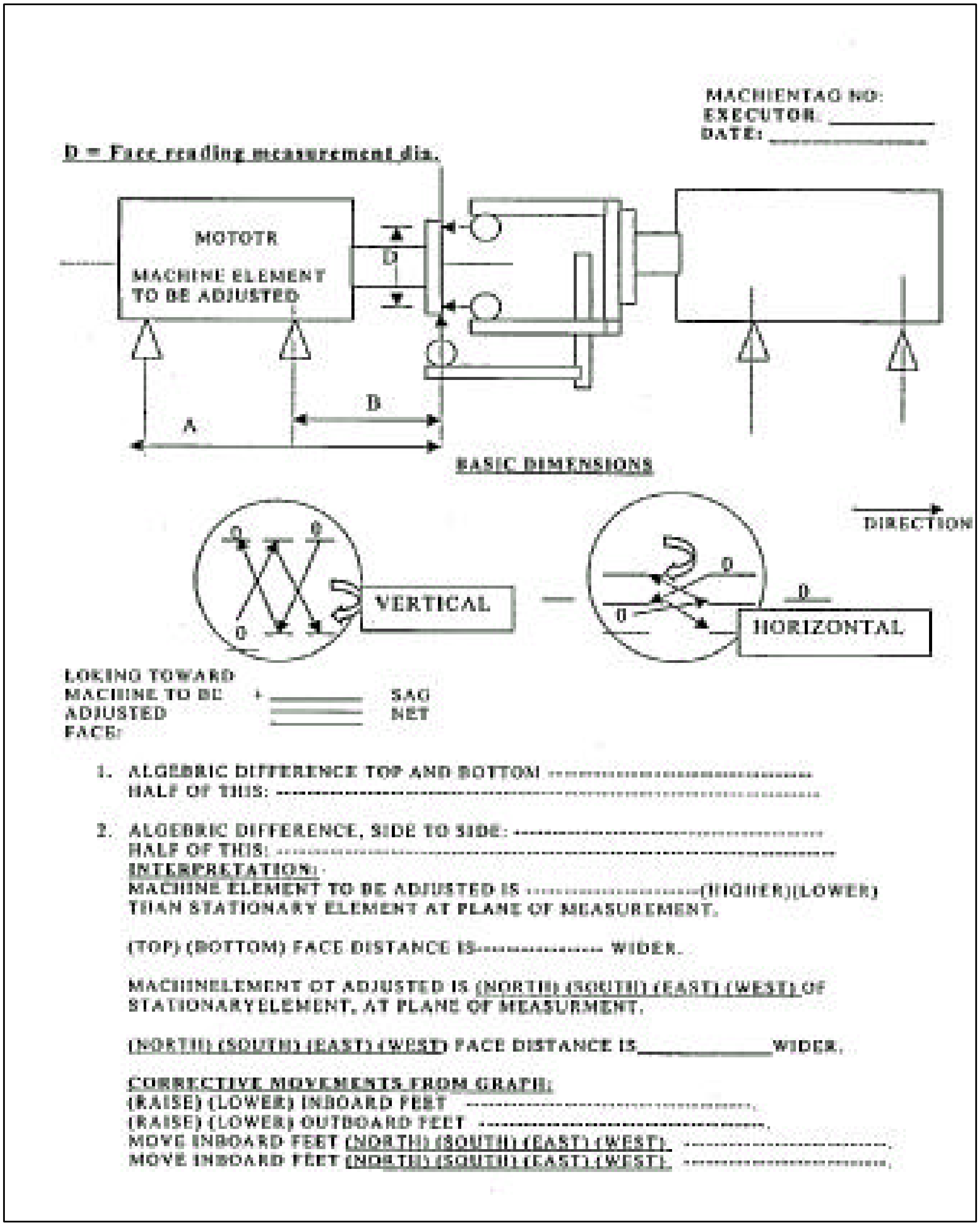
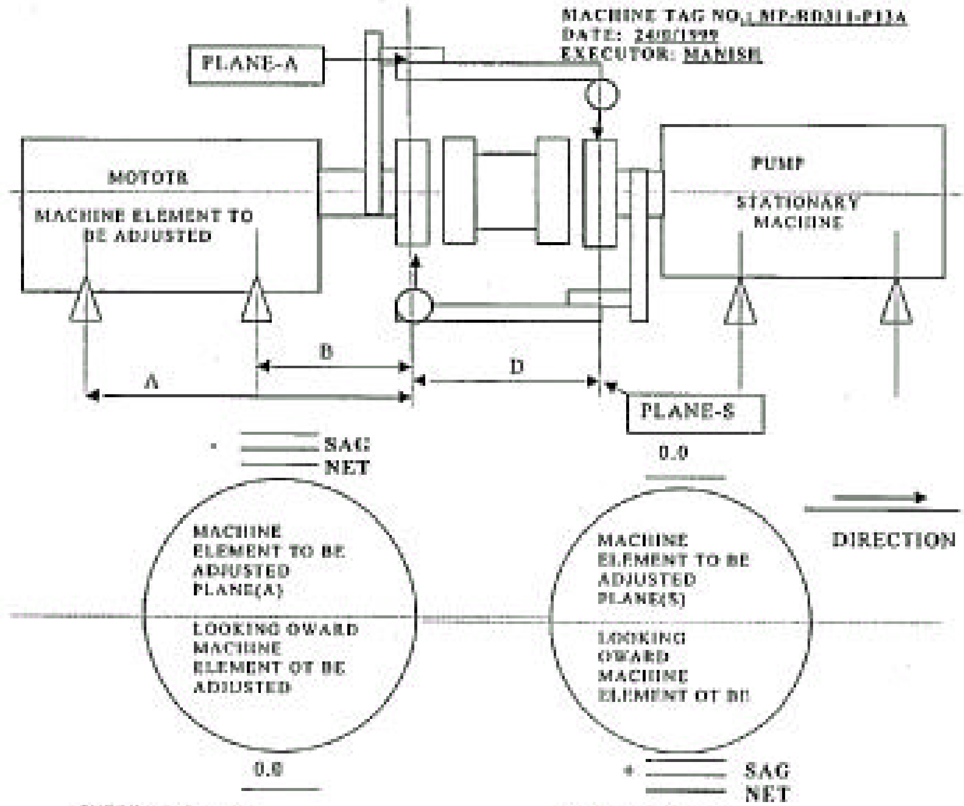


Fig-12 Data Recording Sheet for Three Indicator Face-OD method



CHECK: T+B = S+S

CHECK: T+B = S+S

INTERPRETATION:

EXTENSION OF MACHINE ELEMENT TO BE ADJUSTED IS ---------(HIGHER)(LOWER) AT PLANE (S).

MACHINELEMENT TO BE ADJUSTED IS---------- -(HIGHER) (LOWER) AT PLANE (A)

EXTENSION OF MACHINE ELEMENT TO BE ADJUSTED IS --------(NORTH)(SOUTH)(EAST)(WEST)OF STATIONARY MACHINE AT PLANE (S).

MACHINE ELEMENT TO BE ADJUSTED IS ----------(NORTH)(SOUTH)(EAST)(WEST) OF STATIONARY MACHINE AT PLANE (A).

CORRECTIVE MOVEMENTS FROM GRAPH:

(RAISE) (LOWER) INBOARD FEET --.

(RAISE) (LOWER) OUTBOARD FEET --.

MOVE INBOARD FEET (NORTH) (SOUTH) (EAST) (WEST) --,

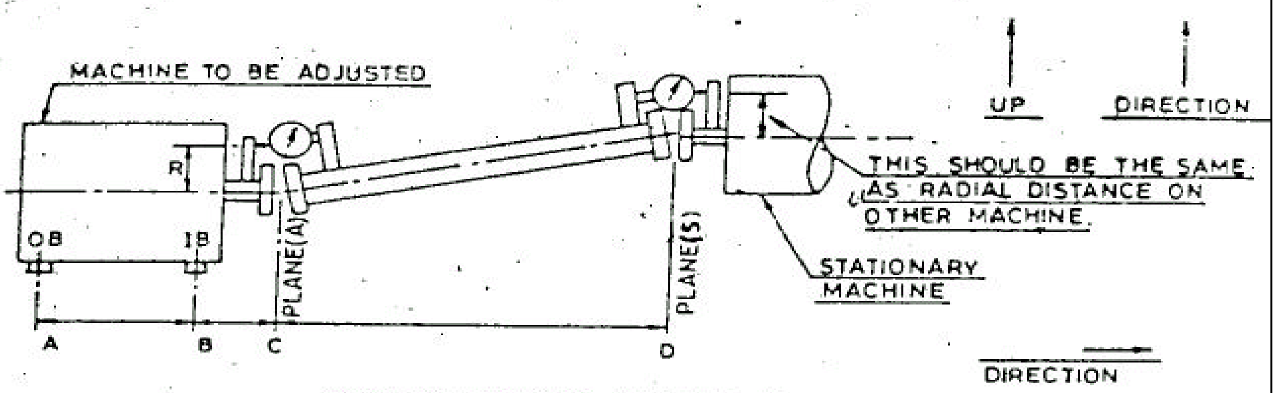
MOVE INBOARD FEET (NORTH) (SOUTH) (EAST) (WEST) --,

SETUP-D
FACE-FACE DISTANCE

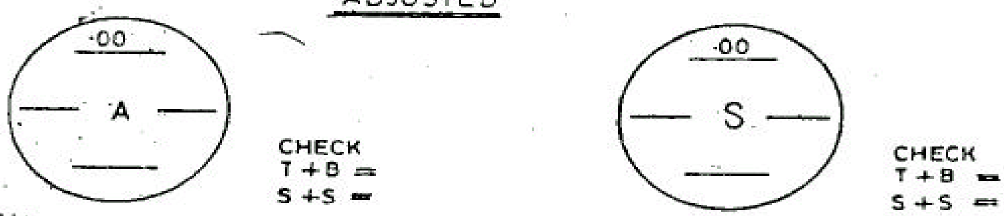
LOCATION ____________________

DATE ____________________

NAME (s) OF ALIGNER (s) ____________________



LOOKING TOWARD MACHINE TO BE ADJUSTED



INTERPRETATION:

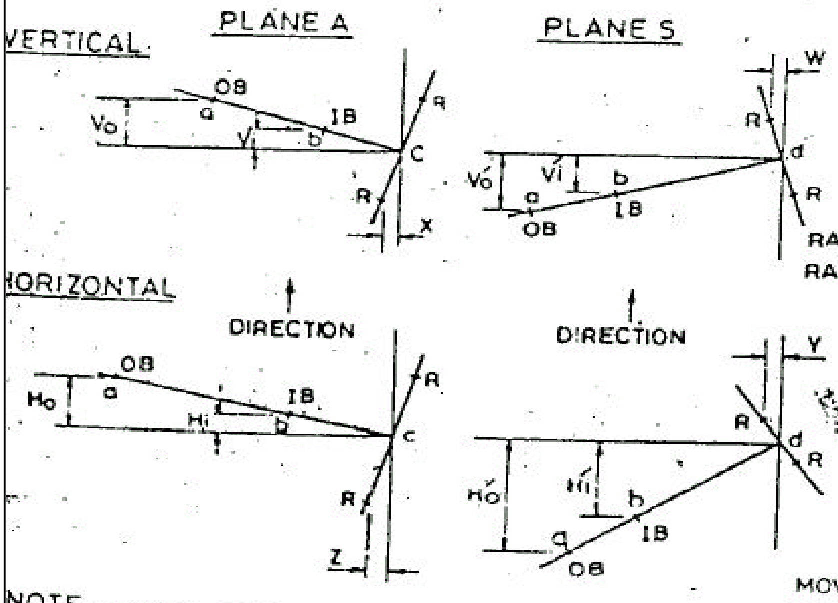
FACE GAP AT PLANE(S) IS ____________________ (W) WIDER AT (TOP) (BOTTOM).

FACE GAP AT PLANE(A) IS ____________________ (X) WIDER AT (TOP) (BOTTOM).

FACE GAP AT PLANE(S) IS (NORTH) (SOUTH) (EAST) (WEST) ____________________ (Y) WIDER AT

FACE GAP AT PLANE(A) IS ____________________ (Z) WIDER AT (NORTH) (SOUTH) (EAST) (WEST).

VERTICAL:



ALGEBRAICALLY COMBINING VERTICALS:

________ Vi	________ Vo
________ Ví	________ Vó
________	________
= ________ V(IB)	= ________ V(OB)

RAISE/LOWER IB : ____________ V(IB)

RAISE/LOWER OB : ____________ V(OB)

ALGEBRAICALLY COMBINING HORIZONTALS:

________ Hi	________ Ho
________ Hí	________ Hó
________	________
= ________ H(IB)	= ________ H(OB)

MOVE IB(NSEW) ____________ H(IB)

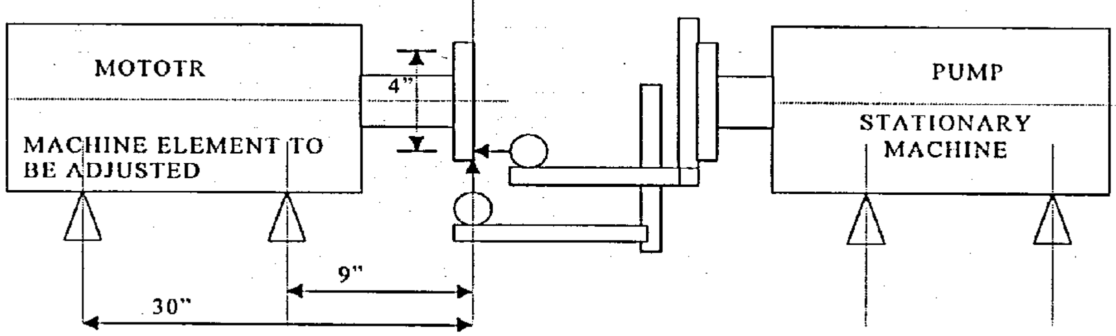
MOVE OB(NSEW) ____________ H(OB)

NOTE: ABOVE GRAPHS ARE ONLY ILLUSTRATIVE AND THIS SPACE SHOULD BE BLANK ON THE FORMAT.

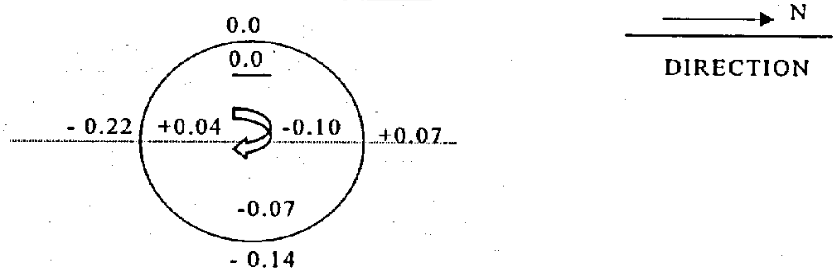
MACHINE TAG NO.: MP-RD311-P13A
DATE: 24/05/1999

PLANT: CRUDE-1
EXECUTOR: MANISH

D = Face reading measurement dia.=4"



BASIC DIMENSIONS



LOKING TOWARD MACHINE TO BE ADJUSTED

+0.03 SAG
- 0.11 NET

CEHCK TOTALS: FACE: T+B = -0.07 , S+S = -0.06 (O.K.)
RIM: T+B = -0.14, S+S = - 0.15 (O.K)

INTERPRETATION:

MACHINE ELEMENT TO BE ADJUSTED IS 0.055 mm (HIGHER) ~~(LOWER)~~ THAN STATIONARY ELEMENT AT PLANE OF MEASUREMENT.

~~(TOP)~~ (BOTTOM) FACE DISTANCE IS 0.07 mm WIDER.

MACHINELEMENT OT ADJUSTED IS 0.145 (NORTH) ~~(SOUTH) (EAST) (WEST)~~ OF STATIONARY ELEMENT, AT PLANE OF MEASURMENT.

(NORTH) ~~(SOUTH) (EAST) (WEST)~~ FACE DISTANCE IS 0.14 mm WIDER.

CORRECTIVE MOVEMENTS FROM GRAPH:

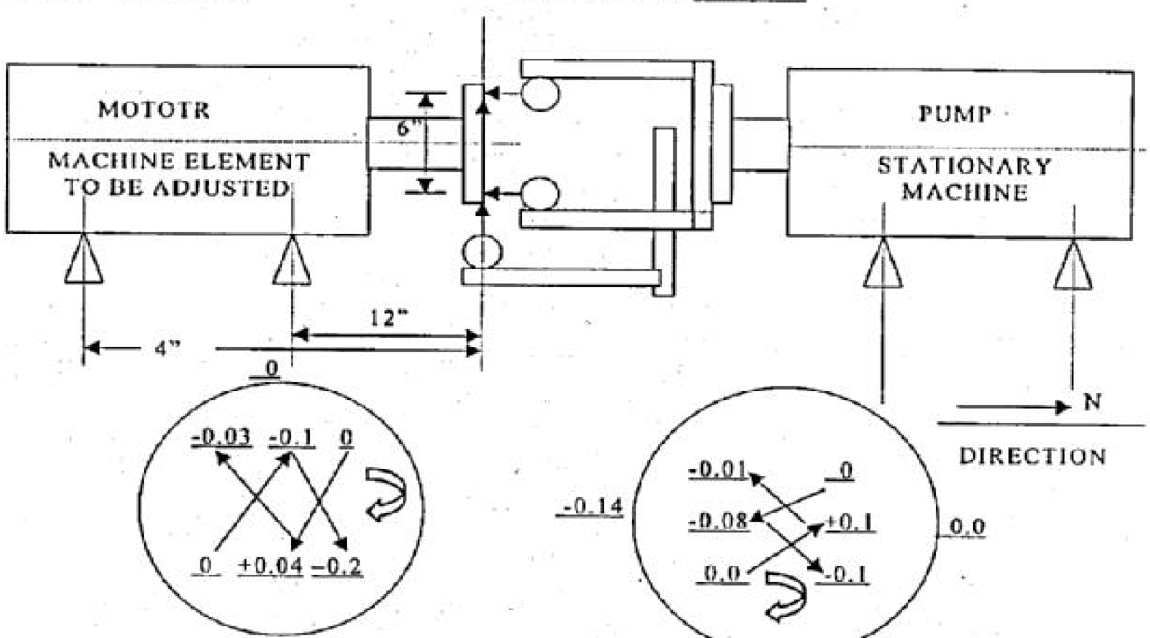
~~(RAISE)~~ (LOWER) INBOARD FEET 0.22 mm .
~~(RAISE)~~ (LOWER) OUTBOARD FEET 0.76 mm.

MOVE INBOARD FEET (NORTH) ~~(SOUTH) (EAST) (WEST)~~ 0.16 mm
MOVE INBOARD FEET (NORTH) ~~(SOUTH) (EAST) (WEST)~~ 1.2 mm

Fig.15 Reading set for Two Indicator Face-OD method

PLANT: CRUDE-I
DATE: 24/05/1999

MACHINE TAG NO.: MP-RD311-P04A
EXECUTOR: MANISH



LOKING TOWARD -0.08
MACHINE TO BE + 0.02 SAG
ADJUSTED -0.06 NET

FACE:

1. ALGEBRIC DIFFERENCE TOP AND BOTTOM: (-0.1) – (+0.04) = -.014mm
   HALF OF THIS: -0.07mm

2. ALGEBRIC DIFFERENCE, SIDE TO SIDE: (-0.08) – (+0.10) = -0.18mm
   HALF OF THIS: -0.09mm

INTERPRETATION:

MACHINE ELEMENT TO BE ADJUSTED IS 0.03mm (HIGHER) ~~(LOWER)~~ THAN STATIONARY ELEMENT AT PLANE OF MEASUREMENT.

(TOP) ~~(BOTTOM)~~ FACE DISTANCE IS 0.07mm WIDER.

MACHINELEMENT TO ADJUSTED IS 0.07 mm (NORTH) ~~(SOUTH) (EAST) (WEST)~~ OF STATIONARY ELEMENT, AT PLANE OF MEASURMENT.

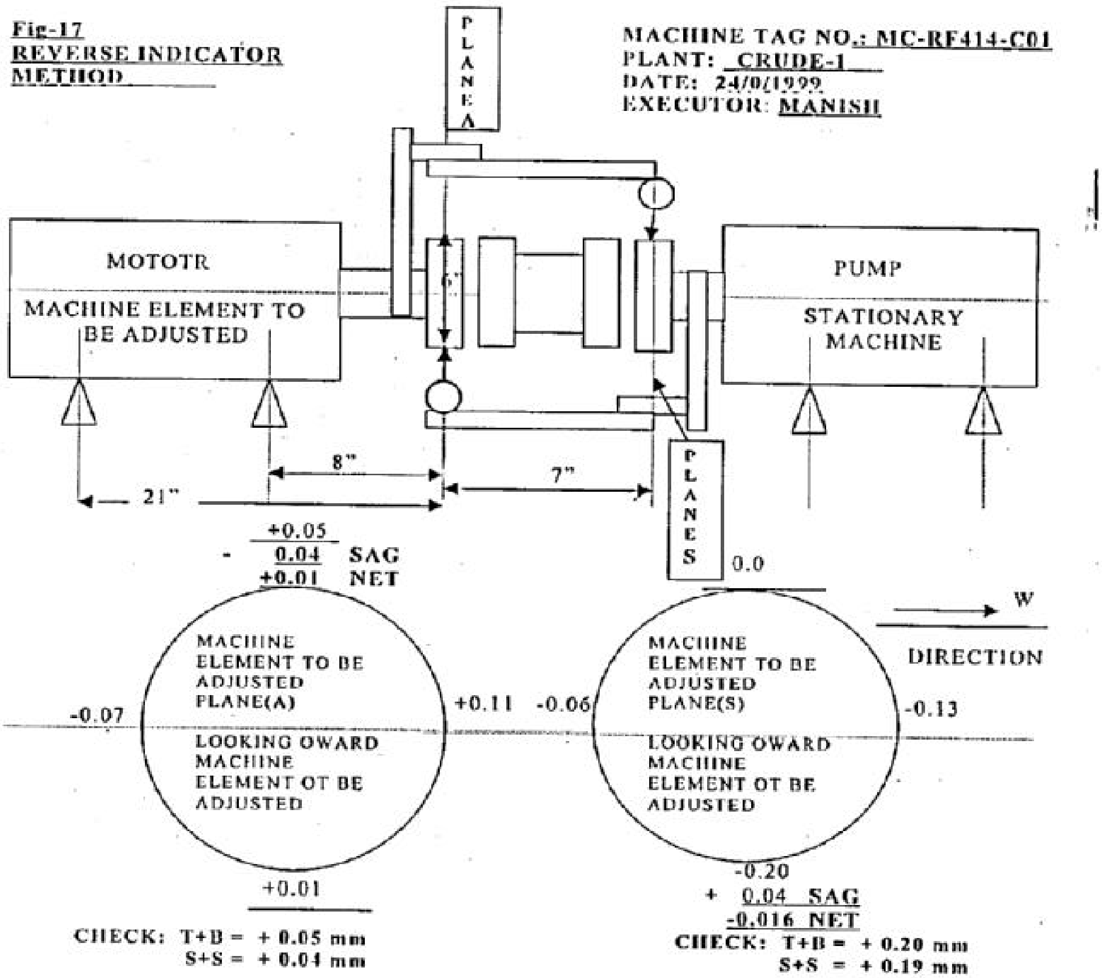
~~(NORTH)~~ (SOUTH) ~~(EAST) (WEST)~~ FACE DISTANCE IS 0.09mm WIDER.

CORRECTIVE MOVEMENTS FROM GRAPH:

(RAISE) ~~(LOWER)~~ INBOARD FEET 0.11mm
(RAISE) ~~(LOWER)~~ OUTBOARD FEET 0.59mm

MOVE INBOARD FEET ~~(NORTH)~~ (SOUTH) ~~(EAST) (WEST)~~ 0.26 mm
MOVE INBOARD FEET ~~(NORTH)~~ (SOUTH) ~~(EAST) (WEST)~~ 0.90 mm

Fig.-16 Reading set for Three Indicator Face-OD method



INTERPRETATION:

EXTENSION OF MACHINE ELEMENT TO BE ADJUSTED IS 0.08 mm ~~(HIGHER)~~(LOWER) AT PLANE (S).

MACHINELEMENT TO BE ADJUSTED IS 0.00 mm (HIGHER) (LOWER) AT PLANE (A)

EXTENSION OF MACHINE ELEMENT TO BE ADJUSTED IS 0.035 mm ~~(NORTH)(SOUTH)(EAST)~~(WEST) OF STATIONARY MACHINE AT PLANE (S).

MACHINE ELEMENT TO BE ADJUSTED IS 0.09 mm ~~(NORTH)(SOUTH)(EAST)~~ (WEST) OF STATIONARY MACHINE AT PLANE (A).

CORRECTIVE MOVEMENTS FROM GRAPH:

~~(RAISE)~~ (LOWER) INBOARD FEET: 0.1 mm
~~(RAISE)~~ (LOWER) OUTBOARD FEET: 0.36 mm

MOVE INBOARD FEET ~~(NORTH) (SOUTH)~~ (EAST) ~~(WEST)~~: 0.15 mm
MOVE INBOARD FEET ~~(NORTH) (SOUTH)~~ (EAST) ~~(WEST)~~: 0.32 mm

Fig.-17 Reading set for Reverse Indicator method

(For side readings make one side reading zero for better understanding by adding the amount equal to one side reading and reverse sign to both the side readings)

In similar way we can calculate horizontal offset & horizontal face gap.

Horizontal Offset is: -

-0.22mm
- 0.07 mm (Change sign)

-0.29mm /2

Horizontal gap difference is: +0.04 mm
+0.10 mm (Change sign)
+ 0.14mm wide at north

14.3 Calculation of corrective moves: After interpretation of data the next step is calculation of corrective moves. Most of the time when job alignment is left to technicians this movements are done by their own judgement, which is essentially a trial & error method. This method sometimes may take a days together to arrive at correct alignment.

Various scientific methods are there to accurately calculate these movements.

- The programmable mini calculators in which data entered in a prescribed manner give the desired results. However they are costly in comparison to other methods & unsuitable for adverse and hazardous field conditions.

- Manual calculation methods involving mathematical formulae. This has advantage of low investment (Paper, Pencil, Calculator). They have the disadvantage, in some view points, of being tedious to be done at site, difficult for the technician to comprehend, and requiring more thinking than the programmed electronic solutions, particularly to choose plus or minus signs correctly.

- The graphical methods, which have the advantage of aiding visualization and avoiding confusion, by showing the relationship of adjacent shaft centerlines to scale. Investment is low, speed is high once proficiency is attained.

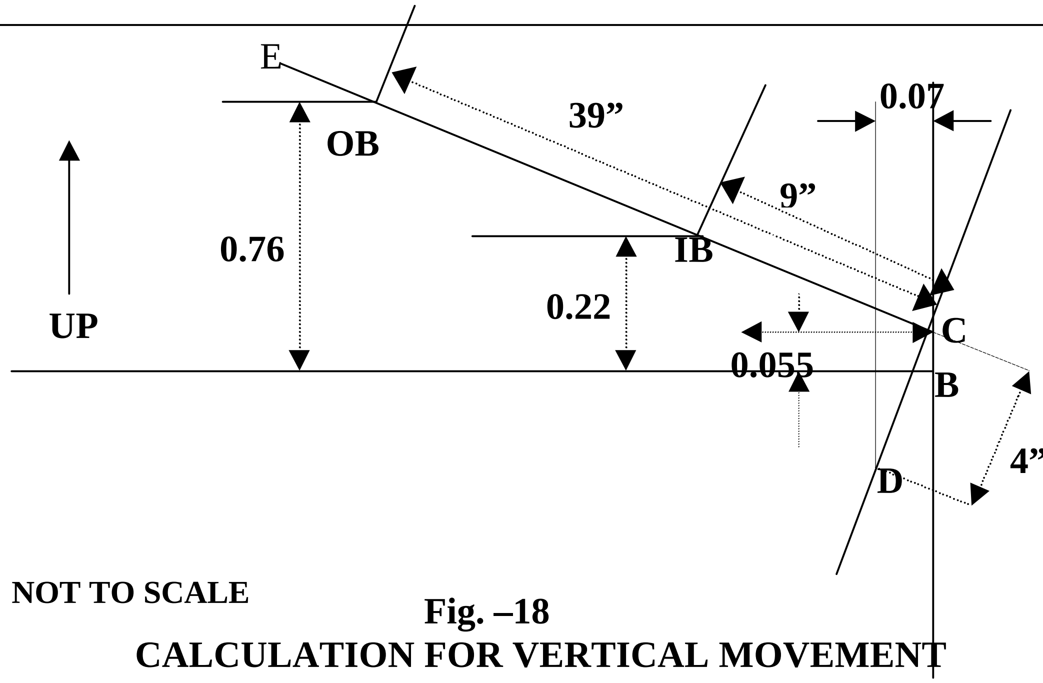
a) <u>Graphical Method:</u>

i) Face-OD method (Two indicators Method):

This follows the examples of graphical method for face & rim method (Two indicator method). This refers the Readings of fig.-15,for calculation.

Take vertical alignment first

Draw a horizontal line AB (representing the stationary machine center line) and a vertical line at B. Mark off the parallel offset C above (+) or below (-) B to scale depending on whether the machine to be adjusted is higher or lower than the stationary machine (in this case +0.055mm). Draw a vertical line parallel to and away from CB by the amount of face gap difference (0.07mm). With C as center, and radius as the face measurement dia., draw an arc to cut this line at D above or below C on depending on whether the face gap is wider at the top or bottom (4'' Diameter & 0.07mm wider at bottom in this case). Join CD, draw a line CE perpendicular to it which represents the centerline elevation of the machine to be adjusted. From C mark IB & OB supports on this line using the same scale as for coupling measurement dia.CD. The vertical distances of these points from the horizontal line represent the amount of shims to be removed from underside of the IB & OB supports to bring the machine to be adjusted in alignment with the other machine.



NOT TO SCALE

Fig. –18

CALCULATION FOR VERTICAL MOVEMENT

A similar graph can be drawn for horizontal alignment as follows. Mark off the parallel offset C towards north by 0.145mm. Draw a line parallel to and at a distance of 0.14mm from CB (by which amount the north face distance is wider). With C as center and 4” radius, mark off D at this line towards north as shown. Draw CE perpendicular to CD and mark off IB & OB points. The vertical distances of these points from AB indicate the amount by which the IB and OB supports of the machine to be adjusted would have to be shifted north to make it co linear with the stationery machine in the horizontal plane.

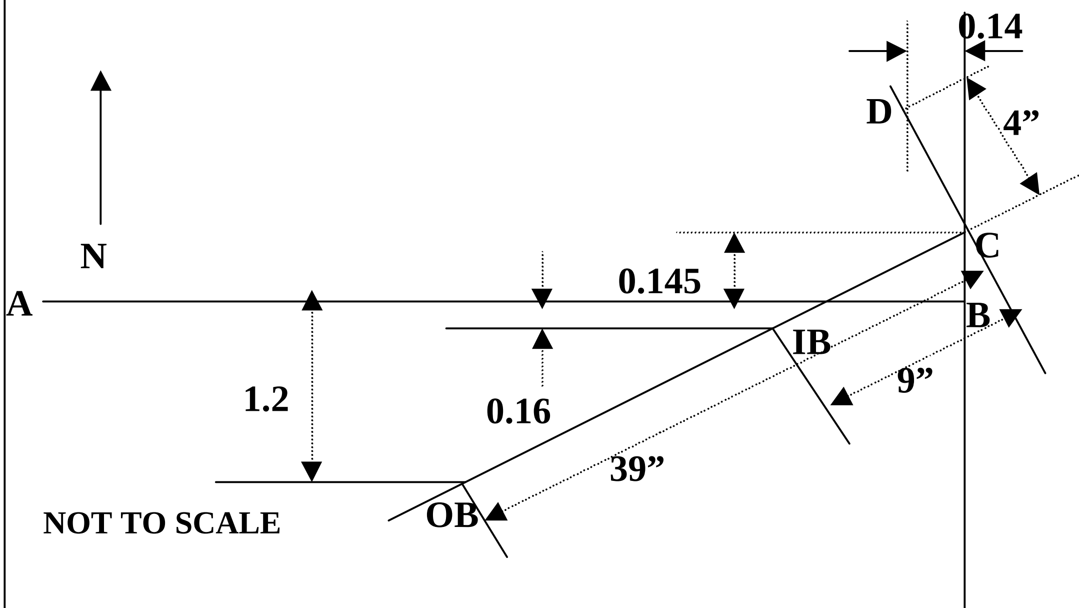
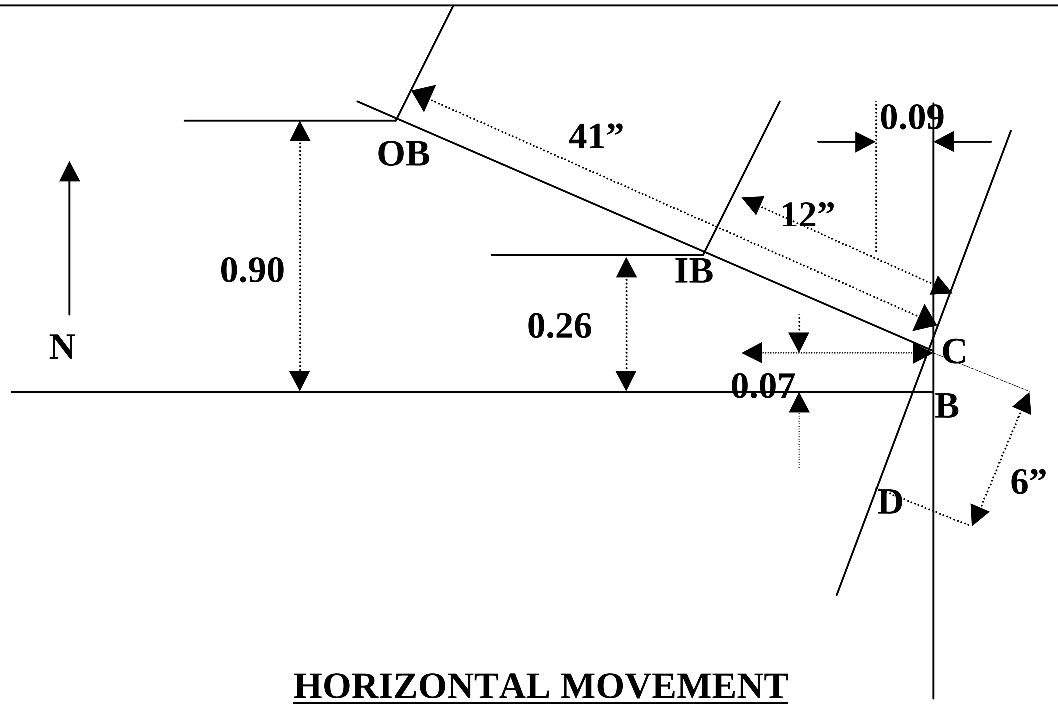
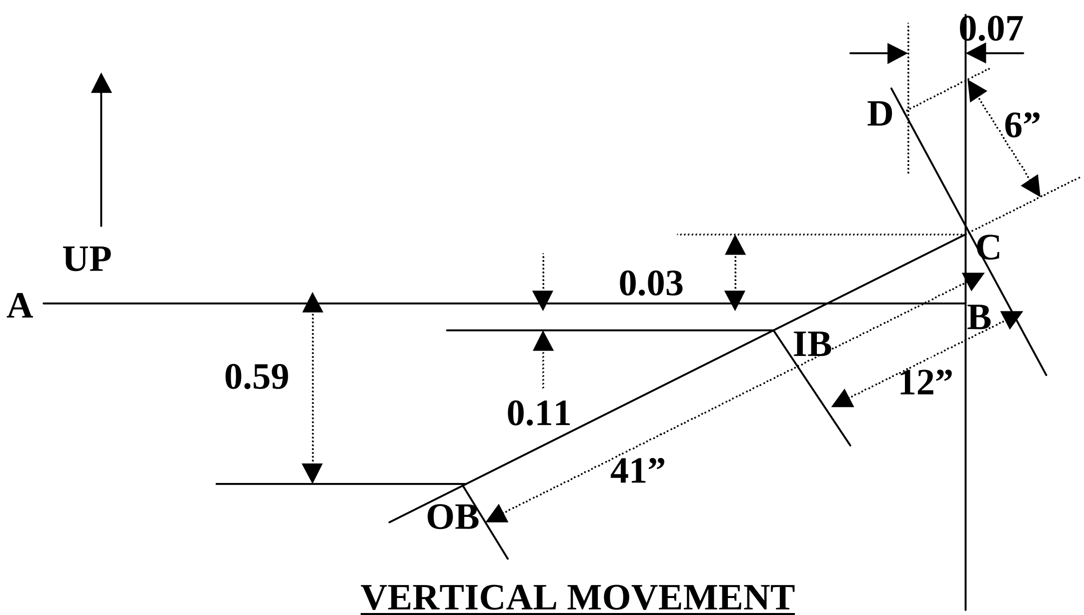


Fig. –19
CALCULATION FOR HORIZONTAL MOVEMENT

ii) Face-OD method (Three indicator method): Primarily the procedure for plotting the readings for three indicator method is same as two indicator method. Here for face readings two dial indicators are used to over come the axial float error of the machine. As shown in attached reading set, first readings as recorded in two-indicator method will be achieved by subtracting each face reading from opposite side dial reading & dividing by two. Further procedure remains same. A detailed example is illustrated in attached fig.- 20, this refers to the reading set recorded in fig.-16.



HORIZONTAL MOVEMENT



VERTICAL MOVEMENT

Fig.20

GRAPHICAL SOLUTION FOR THREE INDICATOR FACE-OD

iii) Reverse Indicator Method:

For better understanding, a data set in attached fig.-17 is referred here.

Followings are the detailed steps for constructing the plot to calculate the movements:

i) Mark 'up' and directions. Take and record data. Check T +B equals S+S.

ii) Correct the readings for sag & divide net vertical reading by 2.

iii) Enter the resulting figures in to the first and second lines under 'Interpretation ' without (+) or (-) signs.

iv) Look at the drawing and decide whether higher or lower at plane S and mark the interpretation accordingly.

v) Ditto at plane A, except that the sag is now subtracted from the top reading to get the new value.

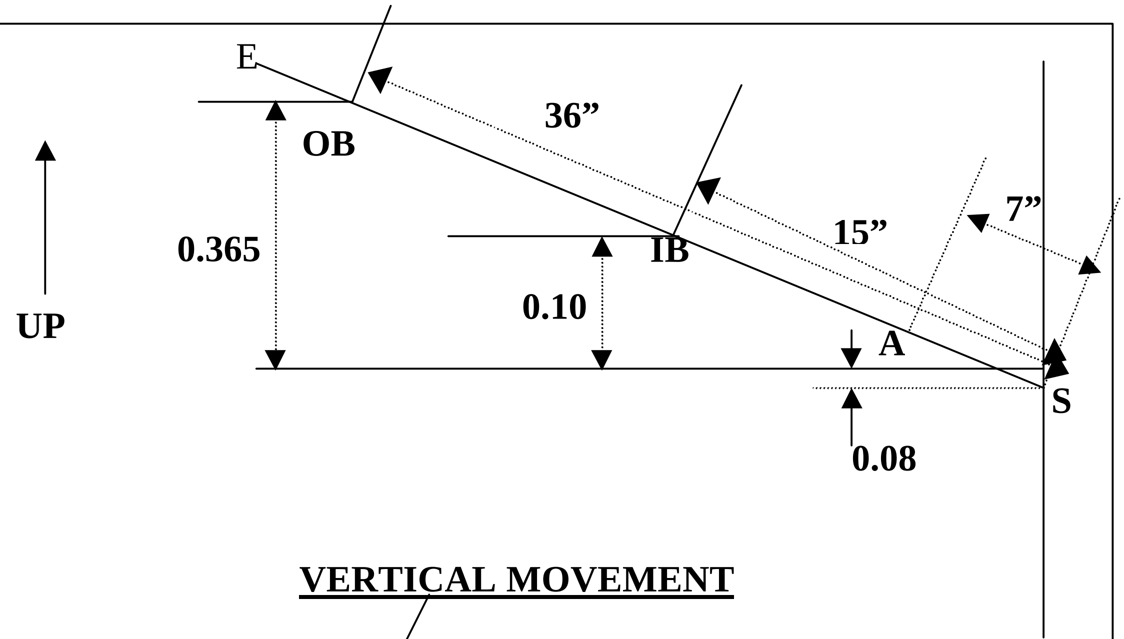
vi) Manipulate the side readings to get zero on one side as shown on the data-sheet. Divide the difference by 2. Do this for planes A & S.

vii) Enter the resulting figures in to the third and fourth lines under 'Interpretation' without (+) or (-) signs.

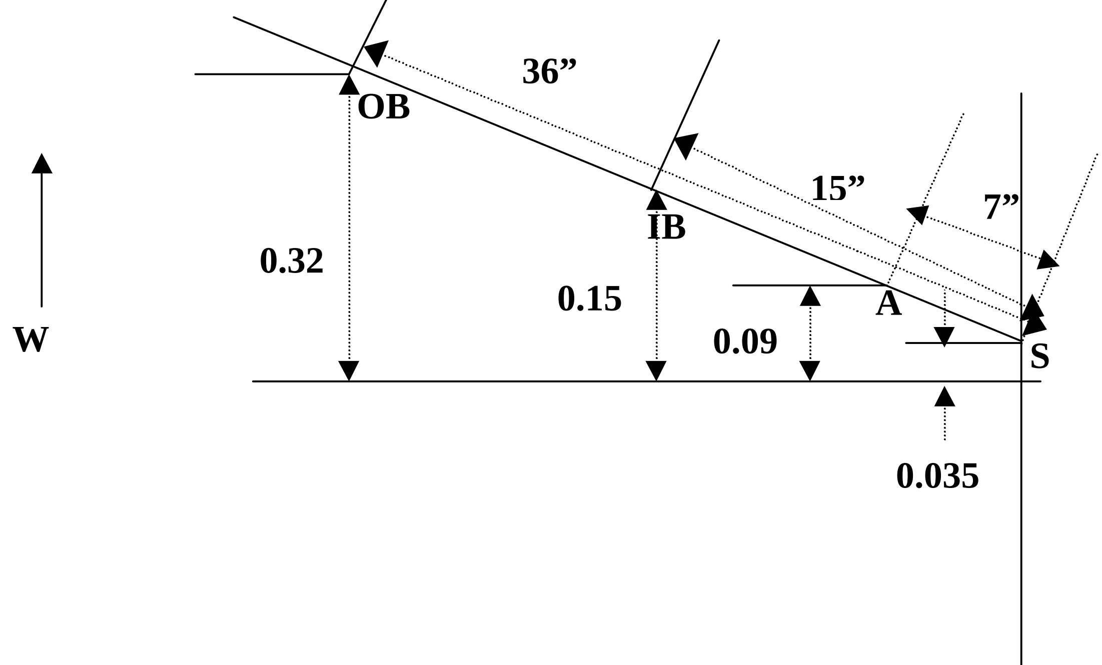
viii) Look at the drawing and decide whether north, south, east or west at planes 'S' and mark the interpretation accordingly. Ditto for plane 'A' in the fourth line.

ix) Proceed for graphical solution as shown on attached fig.22, mark 'up' and direction. Draw the horizontal and vertical axes as for the earlier setups. Mark the vertical centerline differences at planes 'S' & 'A' parallel to and above or below the horizontal, as the case may be. With a suitable scale for coupling length and spanning the total centerline difference, draw a line through S and extend it to show plane A, IB & OB supports. The vertical distances from these to the horizontal denote the vertical movements desired.

x) Proceed similarly for horizontal movement.



VERTICAL MOVEMENT



HORIZONTAL MOVEMENT

GRAPHICAL SOLUTION FOR REVERSE INDICATOR METHOD

Fig.-21

b) Calculation of corrective movement by formula:

Primarily the correction calculation method for Face-OD method with either two or three indicator dial method remains same. In the later one basically readings are reduce to readings in format of two indicator method.
The calculation of corrective move by formula method is generally not promoted for reverse indicator method, because there are plenty of scope for error while graphical method are quite easy to visualize.

Here example of Face-OD method with two indicator method is discussed for better understanding. (Fig.-15 & attached fig.-20)

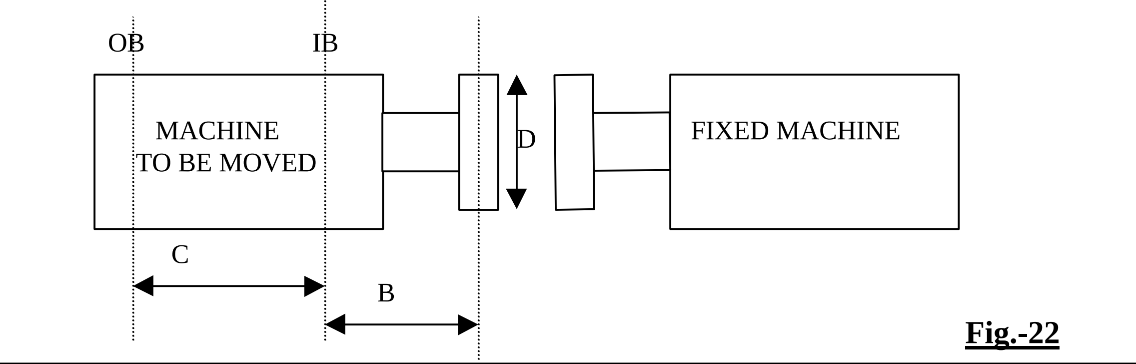


Fig.-22

Following formulas are derived to calculate the movement using trigonometry.

For shimming or vertical move:
Correction at IB = ± (Face gap Difference)* (B/D)± Net offset

Correction at OB = ± (Face gap Difference)* (B+C/ D)± Net offset

For given example:

Vertical Movement:

At IB = -(0.07)*(9/4)- (0.11/2) = -0.157 –0.055 = - 0.22 say lower by 0.22

At OB=-(0.07)*(39/4)- (0.11/2)= -0.683 –0.055 = -0.74 say lower by 0.74

Horizontal Movement:

At IB = (0.14)*(9/4) N ± (0.29/2) S = 0.316N –0.14 = - 0.17N, say move IB by 0.17 by north

At OB= (0.14)*(39/4) N ± (0.29/2) S= 1.37N –0.145 S = 1.24N, say move OB by 1.24 north.

In this method also interpretation of data or visualization of machine positions is important to assign (+) or (-) sings in the calculation.

15. **MOVING MACHINERY IN THE FIELD**:

The important step of the alignment procedure after collecting the alignment data, interpreting it & deciding the necessary movement, is to make actual movement in the field.

It is needless to mention here that like other steps of alignment, machinery movement in the field also if executed systematically will consume the least time.

From the calculations or graphical presentation it can be seen that two ways machinery movement would be required i.e. Horizontal & Vertical movement.

Following are some guidelines to accomplish the job of required machinery movement.

- Roughly adjust the axial position of the machinery within the tolerance of +/- of 1.2mm.

- Loosen the holding down bolts one by one & insert or remove the necessary shims to make vertical adjustment, to facilitate shim insertion use vertical jack screws. Before inserting shims, clean all feet & mounting area thoroughly.

- After making vertical adjustment carryout necessary horizontal movement with side jackscrews. To ensure the required movement at individual feet, make sure that holding bolts at other feet is tight enough. To monitor the movement on-line (if space permits) position the bracket in side reading position & check movement on dial gauge while moving the machine sidewise.
- Ensure that all holding down bolts are tight enough before checking the final readings.
- Finally, check the readings for both horizontal & vertical readings, if fine adjustments are required follow the same steps.

16. HOT ALIGNMENT:

Thermal growth of machines may or may not be significant for alignment purposes. In addition, movement due to pipe effects, hydraulic forces and torque reactions may enter the picture. Relative growth of the two or more elements is of concern.

Normally in absence of any specific data about expected movement of machine centerlines it is a good practice to start with zero-zero alignment at ambient conditions.

Machine performance at operating condition i.e. if vibration data indicates the misalignment than only any of the following methods can be used to estimate thermal growth.

i) Guess work based on experience: Although not reliable, if a certain thermal growth corrections have been found satisfactory for a given machine, often the same correction will work for a similar service.

ii) Manufacturer's Recommendations: If recommendations are specific to the machine considering all other factors like climate, piping etc. than it works well most of the time.

iii) Calculations based on Assumed metal temperatures, Machine Dimensions and Coefficient of thermal expansion: results are variable. This method ignores the effect of piping forces, torque reactions etc.

iv) Make mechanical measurements of machine housing growth during operation, referenced to base plate or foundation, or between machine elements.

v) Shut Down and measure before machine cooling: This method is questionable, since during the time necessary for de-coupling, indicator set-up etc., and most thermal growth would have vanished. This method also does not take in to account other parameters like hydraulic forces, piping load etc.

17 Do's:

- Always use calibrated dial gauges & calibrated instruments.
- Adjust the plunger of the dial gauges so that they are pressed half ways i.e. the small dial (hour dial) of the dial gauges should read 4 to 5.
- Ensure that dial gauge plunger is square to the coupling surface.
- As far as possible, mount the bracket on fixed machine & dial riding on moving machine. No hard & fast rule but this will ease out interpretation.
- Ensure that uniform conventions i.e. top, bottom, north & south is followed throughout the procedure.
- Measure all the readings facing the same direction.
- Follow uniform practice for dial readings i.e. divisions or mm.

- Before rotating the machine, ensure that bearings are lubricated.

- Always use pre-cut SS shims.

- Ensure the correctness of readings by taking at least two set of readings.

- As far as possible, rotate both the shafts together.

- Check the surfaces where measurements are to be made are free from burrs or marks.

18. Don’ts:

- While measuring the readings if you have passed the 90 Deg. mark never rotate back, complete the whole revolution.

- Do not hammer the machine feet directly for side movement. Use side jackscrews for movement.

- Do not use poorly fabricated or rough alignment brackets. Use properly machined & sturdy brackets.

- Never use magnetic dial stand for alignment.

- Don’t use trial error method for corrective movements.

- Don’t grind shank of the holding down bolts if restricting the movement, enlarge the holes.

- Avoid using too many shims.

19. REFERENCES:

1. Shaft Alignment Hand book- John Piotrowski.

2. Practical Machinery Management for process plants –Vol.-3 by Heinz P. Bloch and Fred K Geitner.

3. Manual on Rotating Machinery Alignment –IOC.

4. Steam turbine Inspection Program –Shaft Alignment by General Electric.