Effects of Misalignment & The Benefits of Precision Shaft Alignment

DRAP 2007

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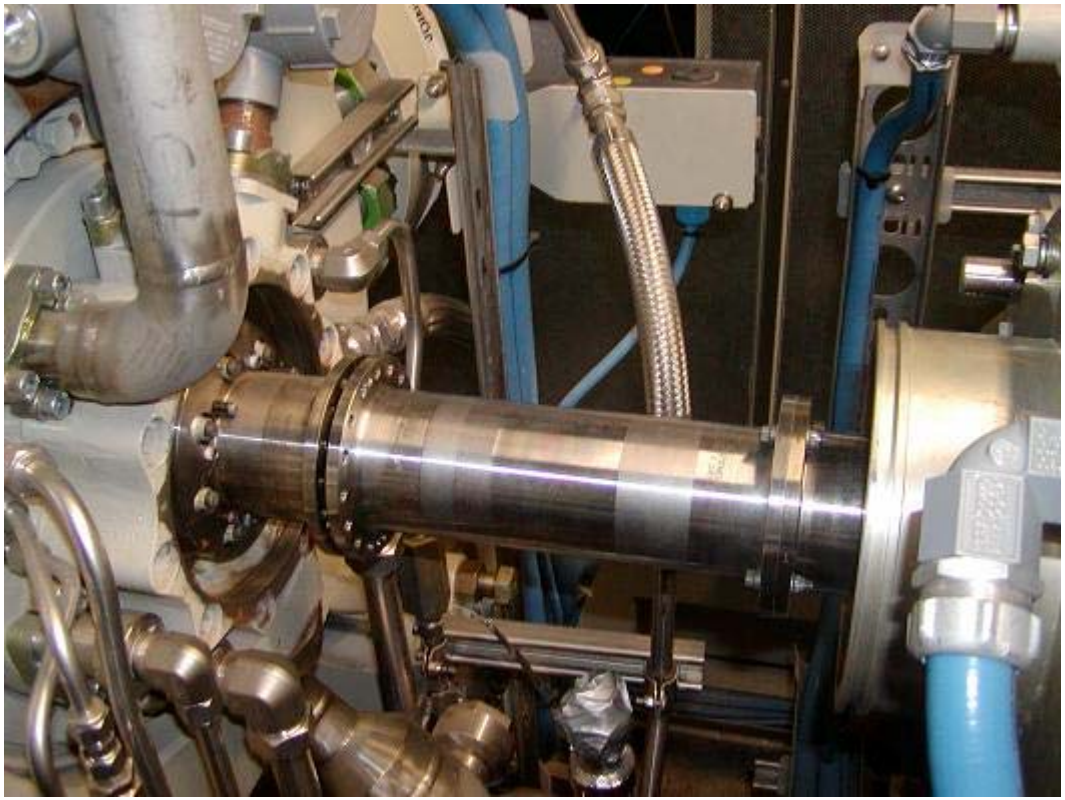
Alignment Definition

- The process of reducing the misalignment of two adjacent shafts connecte by a coupling so that the center of rotation for each shaft is as near as collinear as practical during normal operation.



Purpose of Shaft Alignment

- Good shaft-to-shaft alignment of rotating machinery is essential for long term operation.
- History has indicated that it is good practice to limit operating misalignment to low values.
- Good shaft alignment reduces forces acting on rotating shafts, bearings and other components.

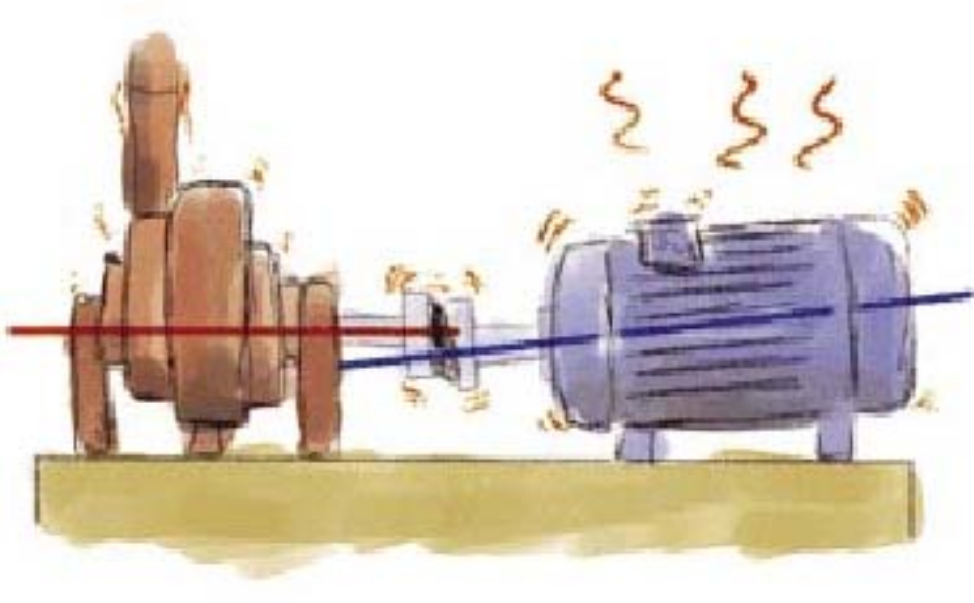
Benefits of Precision Alignment

- Reduced Vibration levels.
- Increased meantime between failures.
- Reduced maintenance costs.
- Reduced energy consumption.
- Increased production quantity and quality.

The Effects of Misalignment.

- Misaligned machines result in vibrations and premature wear of bearings, seals and couplings.

- Misalignment will lead to harmful forces, deteriorating the machines' performance.



Machinery Installation

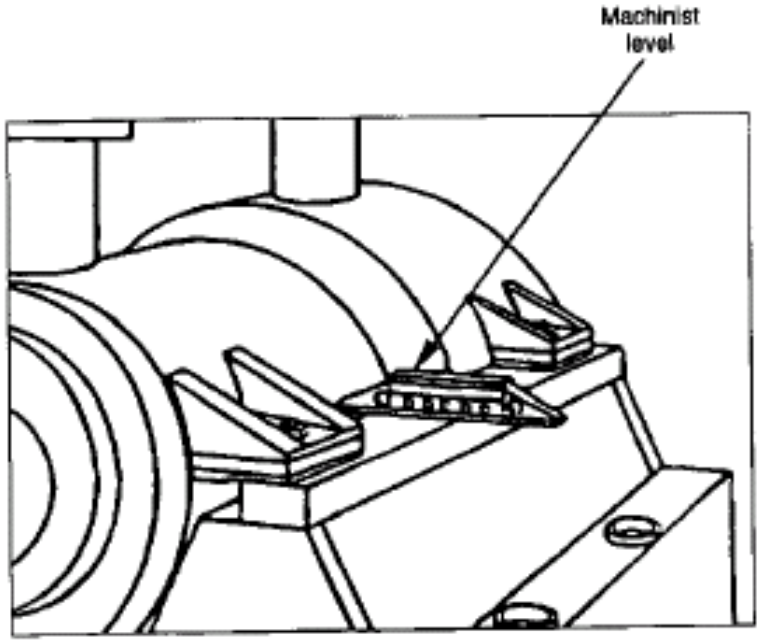
- Good practices during the machine installation and commissioning phase will likely result in good operational shaft alignment.

- Examples of this are: correct pipe-work procedures being followed, Base leveling & conditioning and thermal growth evaluations.

- Standards to refer to are API 686. **(Recommended Practices for Machinery Installation & Installation Design)**

Machinery Base and Foundations.

- Base should be level and flat and correctly pre-aligned before grouting.



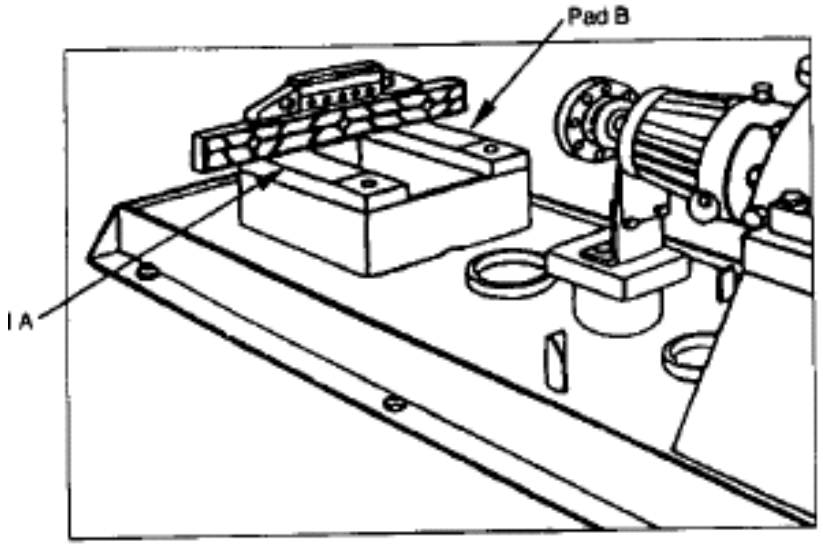
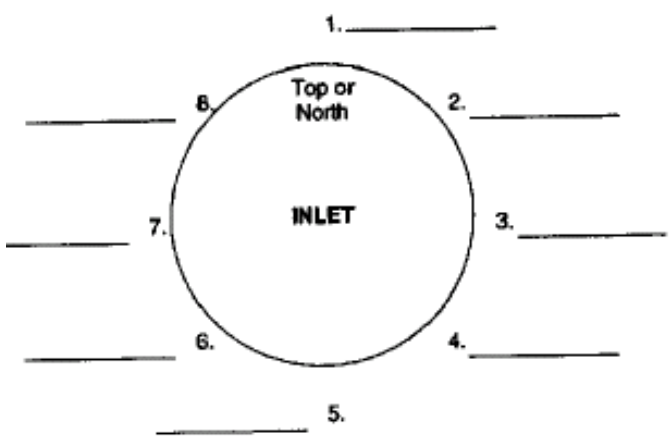
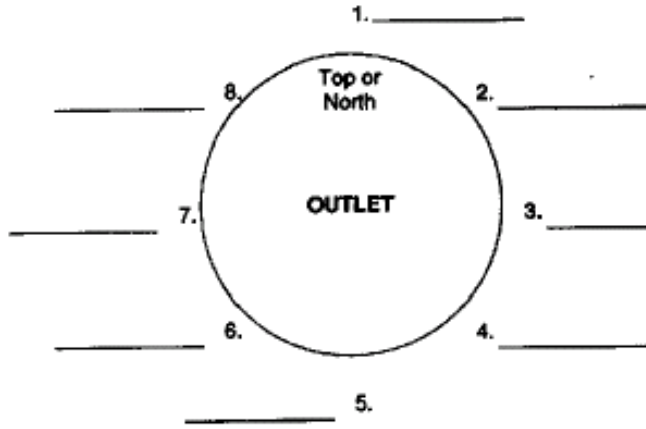


Figure D-3—Leveling Driver End Crosswise

Pipe-work Installation

- Flanges of connecting piping should not be sprung into place.
- Pipe flange bolt holes should be lined up to within 1.5mm (1/16”) without applying external force to the piping (API 686).
- Pipe flanges should be parallel to 0.001” per 1” of flange outside diameter.





Maximum Allowable Tolerances: (difference between high & low readings)

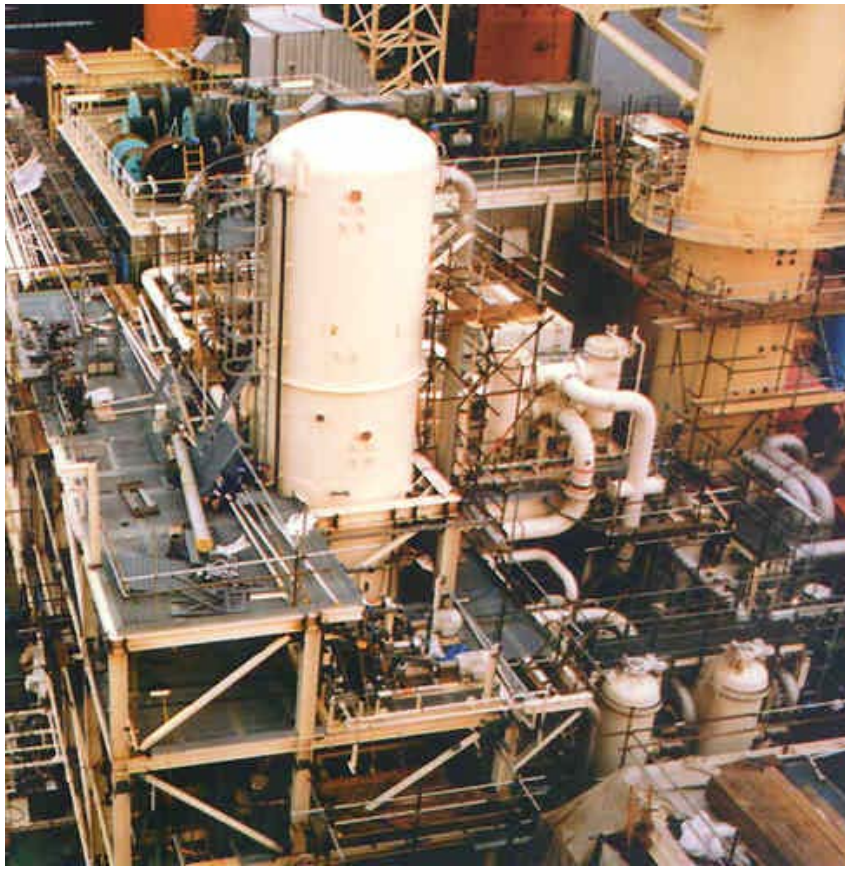
Measuring Pipe-strain

- An alignment bracket must be fitted to the machine being measured for pipe-strain.

- Indicators will be mounted on the coupling hub to measure horizontal and vertical movement on the opposite machine as the flange bolts are being tightened using a torque wrench.

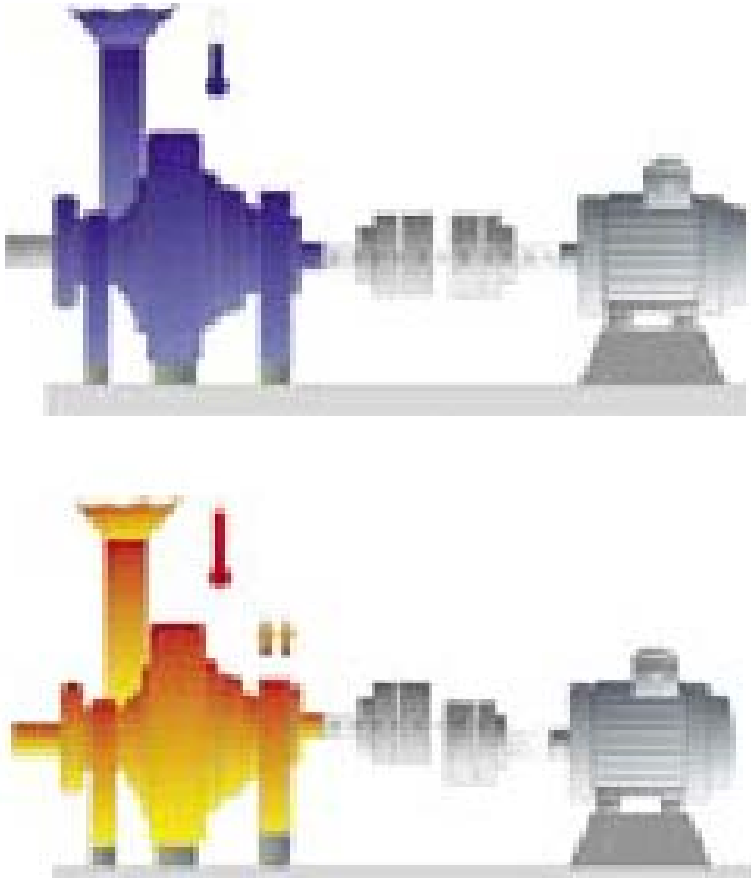
Measuring Pipe-strain

- Bolt up will start with the largest flange first.
- Bolts should be snug to 10% of total torque. Then tightened to 30% and then to 100% of total torque.
- The maximum shaft movement in either Horizontal or Vertical direction after tightening should not be more than 0.002”



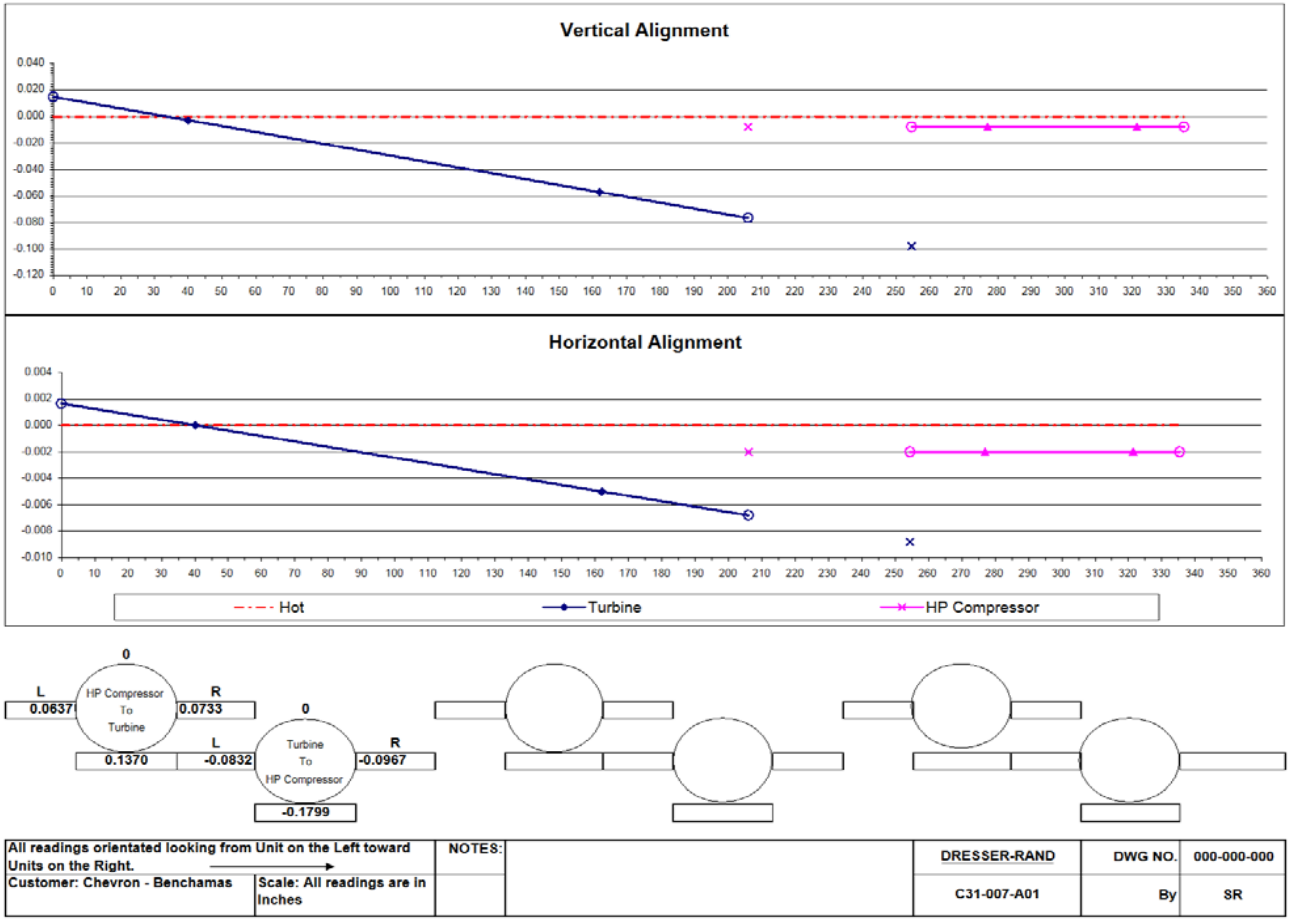
Thermal Growth Considerations.

- Machines move and grow from offline to running conditions.
- How much depends upon a number of different factors such as work load, machine casing material, pipe strain and more.



Ambient Offset

- Ambient Offset: The practice of misaligning two shaft centerlines at ambient conditions to account for the estimated relative changes in shaft centerlines from ambient temperatures



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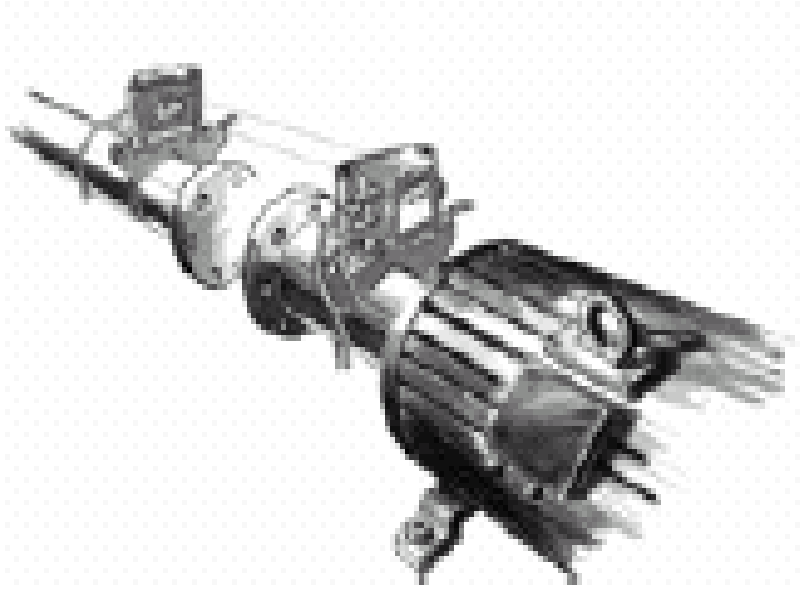
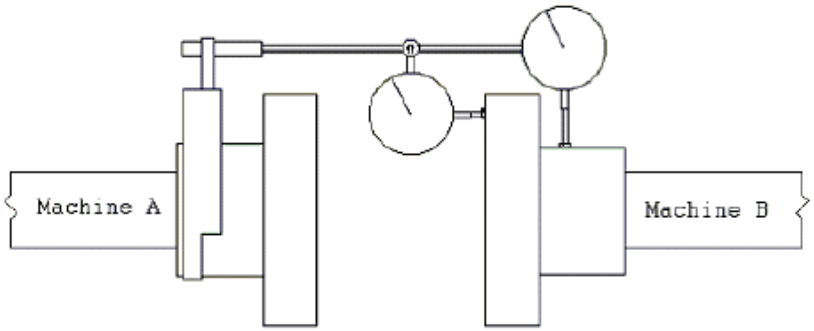
Alignment Methods

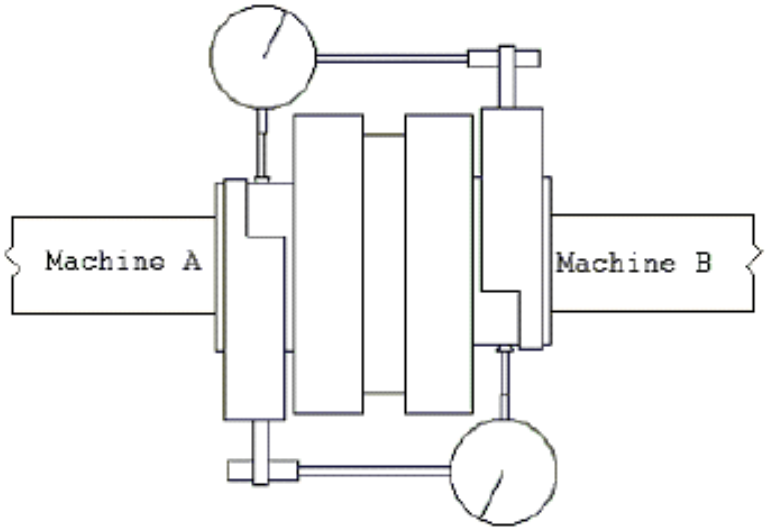


Laser Alignment

Rim & Face

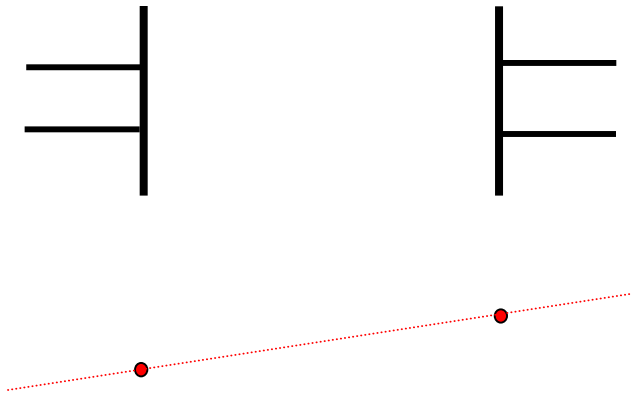


Reverse Dial

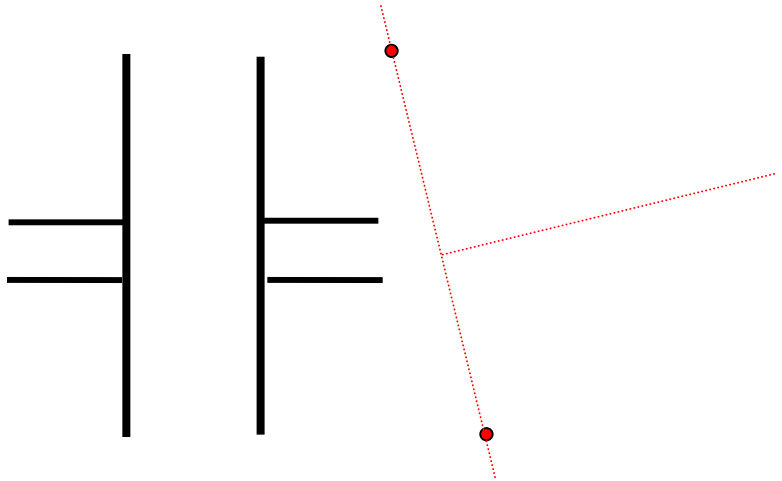


Alignment Methods - Considerations

Reverse Dial



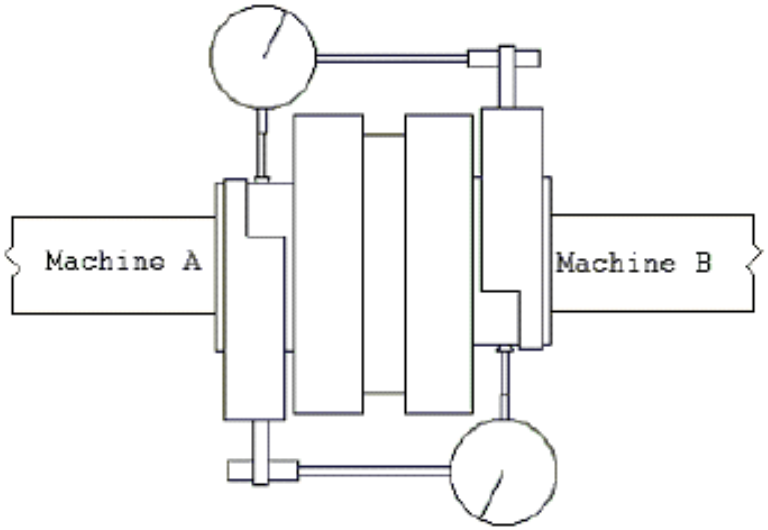
Rim & Face



Considerations of Reverse Dial Method

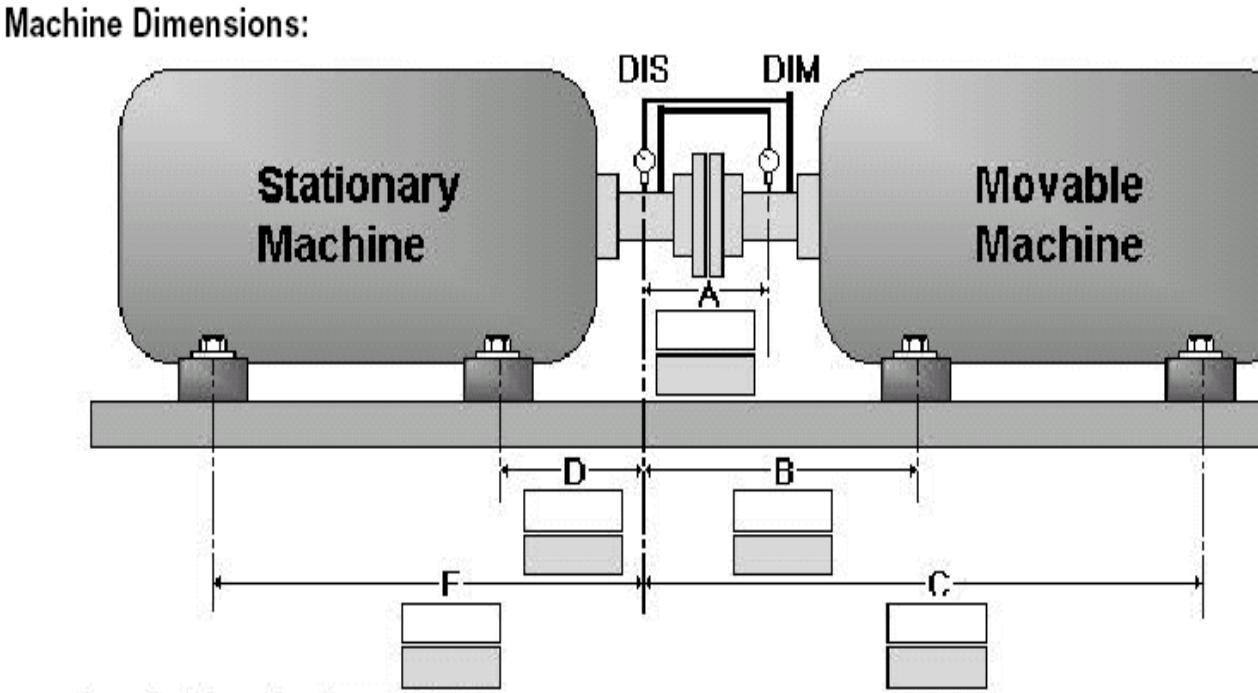
- Advantages of reverse dial method:
- Relatively inexpensive and has been carried out by tradesmen for years.
- Most plants have dial gauges at hand.

- Disadvantages are:
- Moves must be manually calculated
- Possibility of reading errors
- Coupling run out errors
- Bracket or bar sag



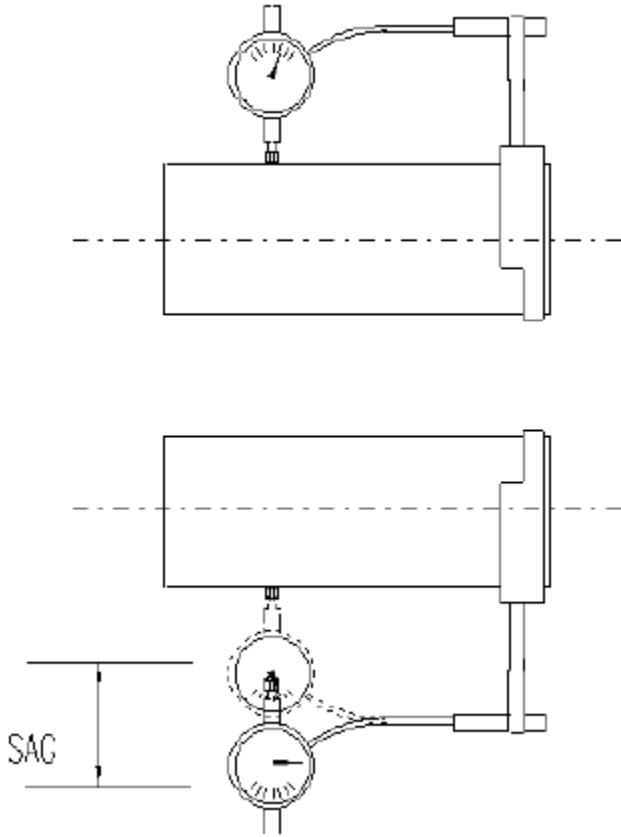
Reverse Dial Method

- Dial gauges mounted on each shaft.
- Machine dimensions are recorded.
- Machine moves are calculated mathematically or by scaling.



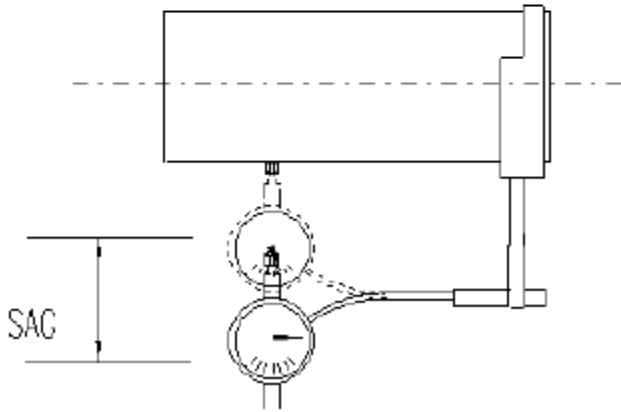
Bracket Sag

- If you have indicators attached to a bracket you have bracket sag.
- In order to properly correct misalignment, bracket sag must be measured and accounted for.
- Sag is caused by gravity working on the weight of the brackets and indicators.



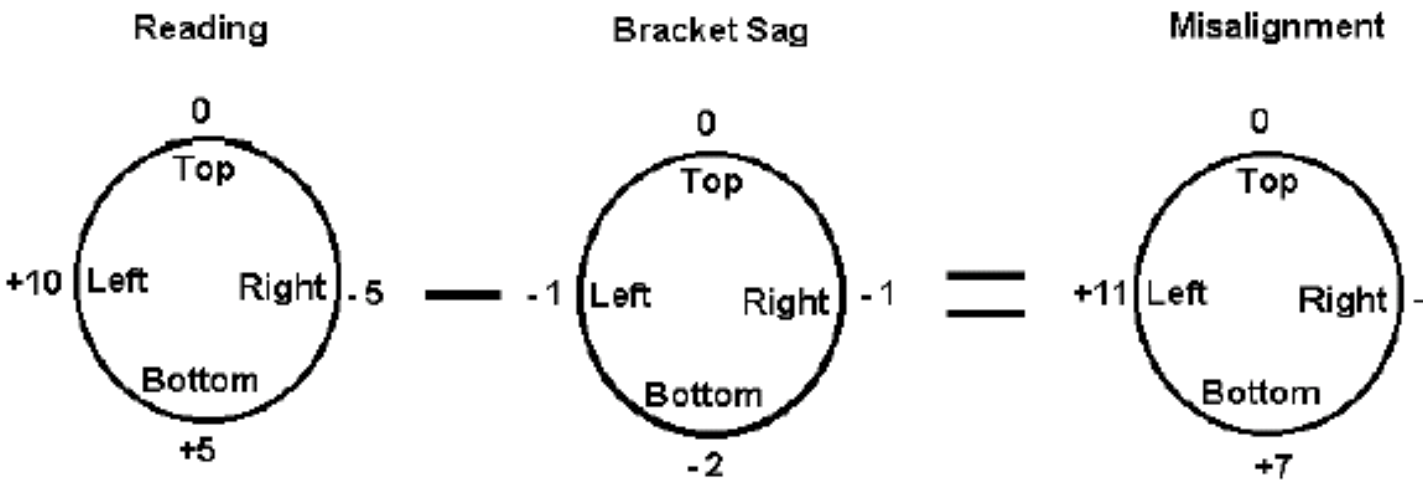
Measuring Bracket Sag

- Mount the indicators on pipe, bar stock etc as they are to be mounted on the machine. 0 at 1200.
- Rotate through 0300, 0600 and 0900 positions and record dial readings.
- Check the dial returns to 0 at 1200. Repeat the process and check for repeatability.
- Bar sag should always be (-).



Measuring Bracket Sag

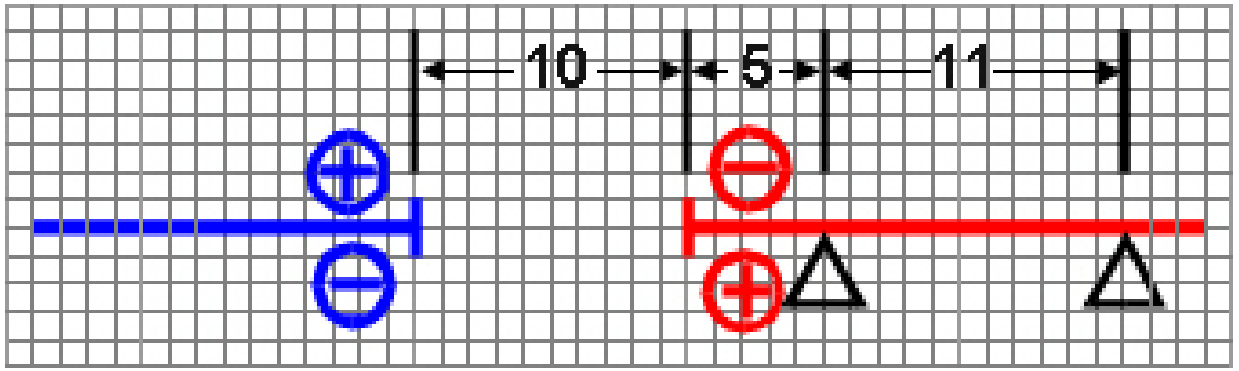
- When carrying out alignment on the machine, indicator readings are a sum of misalignment and bracket sag.
- Readings – Bracket sag = Misalignment
- Sag must be subtracted from the measured readings as follows.



Reverse Dial Graphical Method - E.g

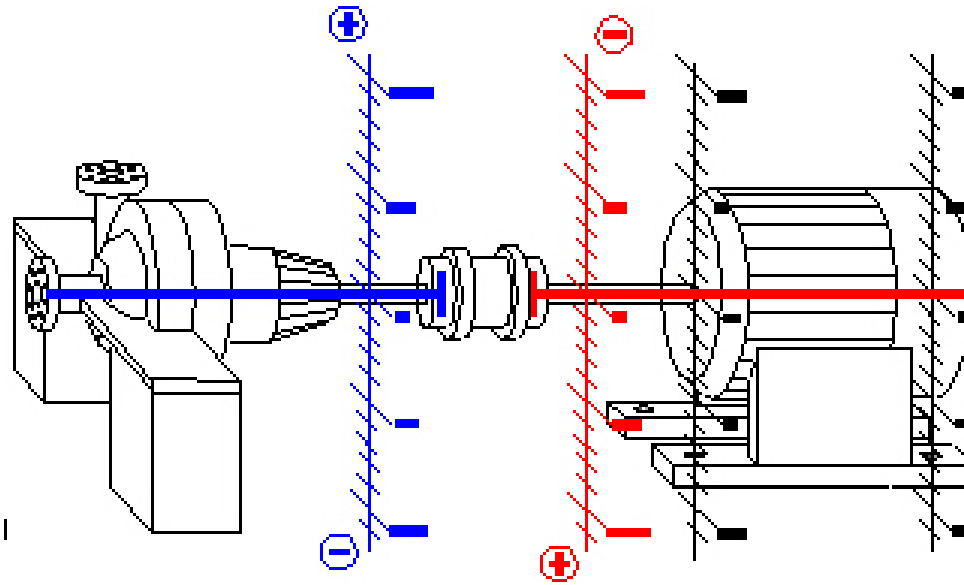
- Pick a suitable scale on the graph paper and plot similar as below.

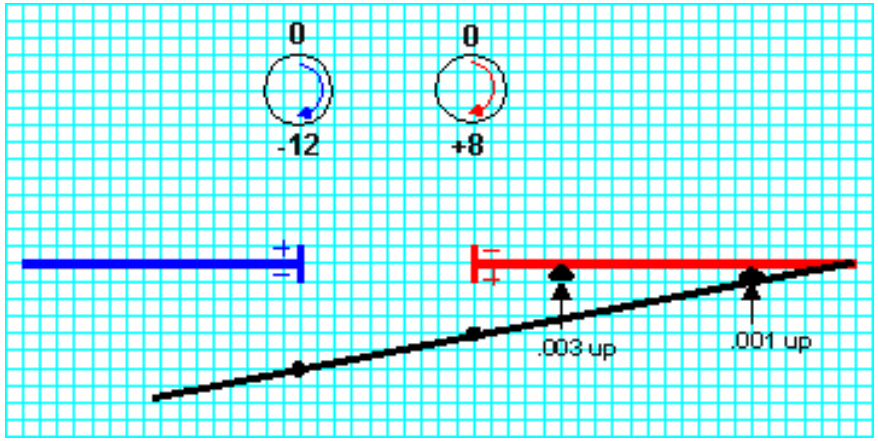
- The machine on the right hand side in red we will consider as our movable machine.



Reverse Dial Graphical Method - E.g

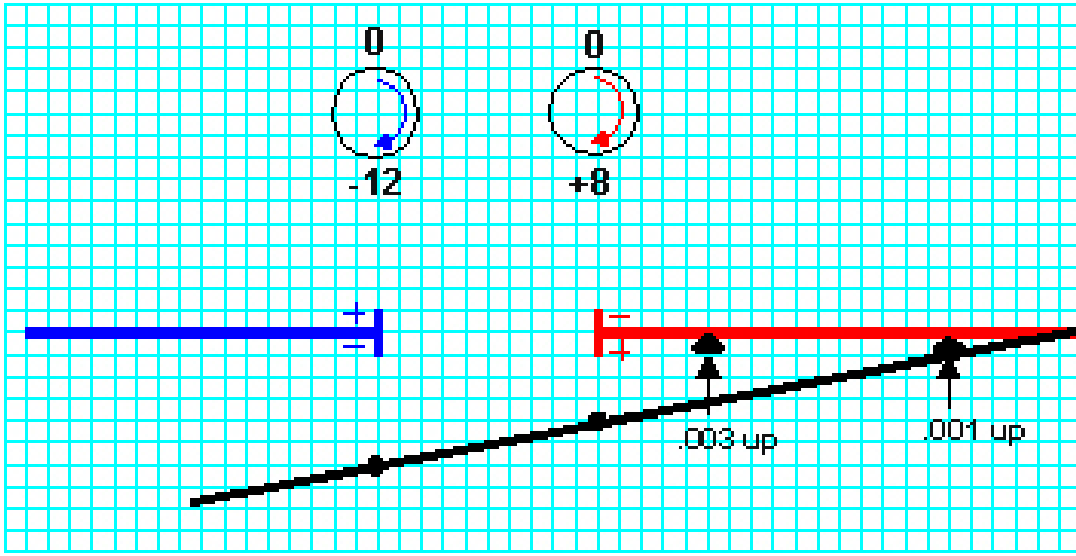
- In alignment it is easiest to solve the misalignment in the vertical plane first.
- Assume we attach our indicators and after sag is accounted for we get the following readings:
- Plot the readings on your graph. Remember, dial readings are TIR and actual misalignment is half of TIR.





Reverse Dial Graphical Method - E.g

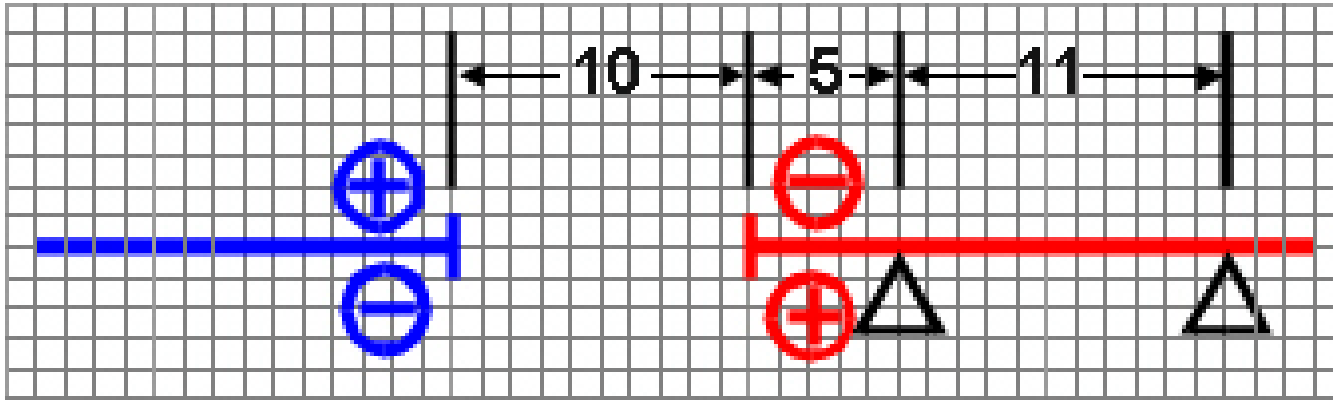
- After plotting, we can see the shimming that is required to bring the machine into alignment.
- 0.003” in at the front and 0.001 in at the back.



Reverse Dial Graphical Method - E.g

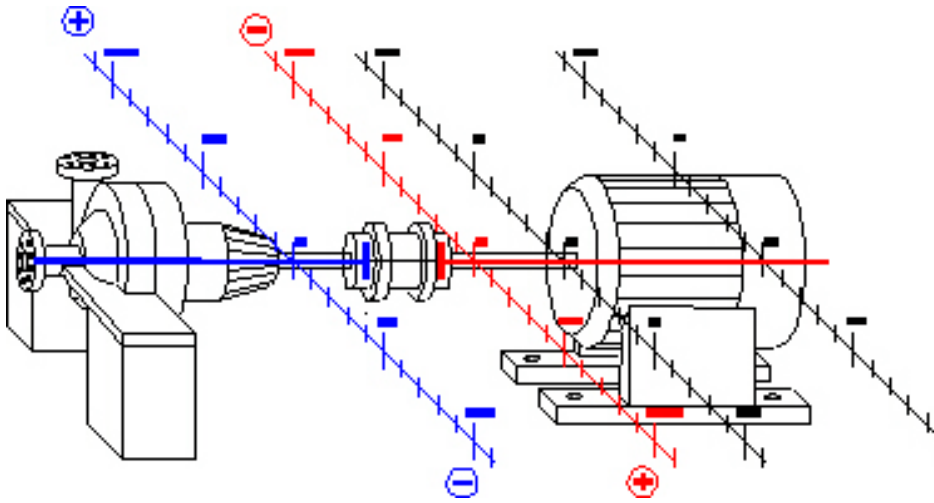
- We still have to solve the Horizontal misalignment.

- Scale another diagram the same as we did for the Vertical plane

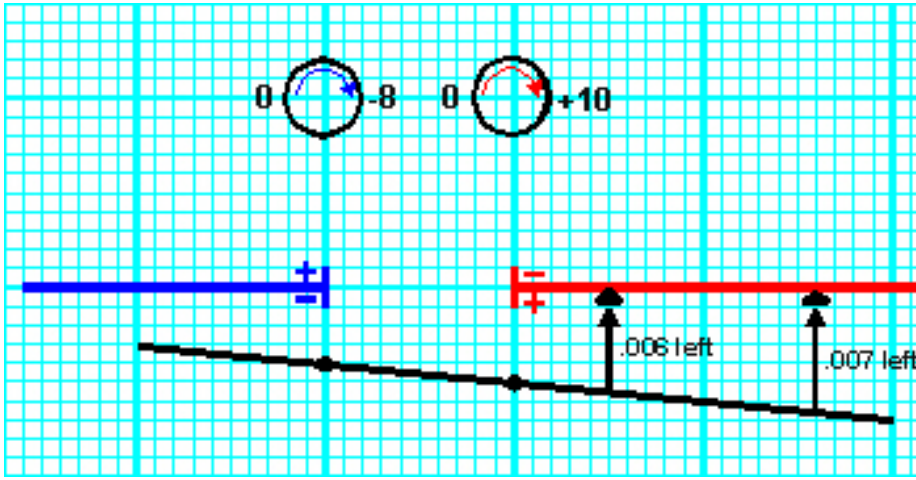


Reverse Dial Graphical Method - E.g

- After attaching our indicators, measuring and accounting for sag, we get the following readings:

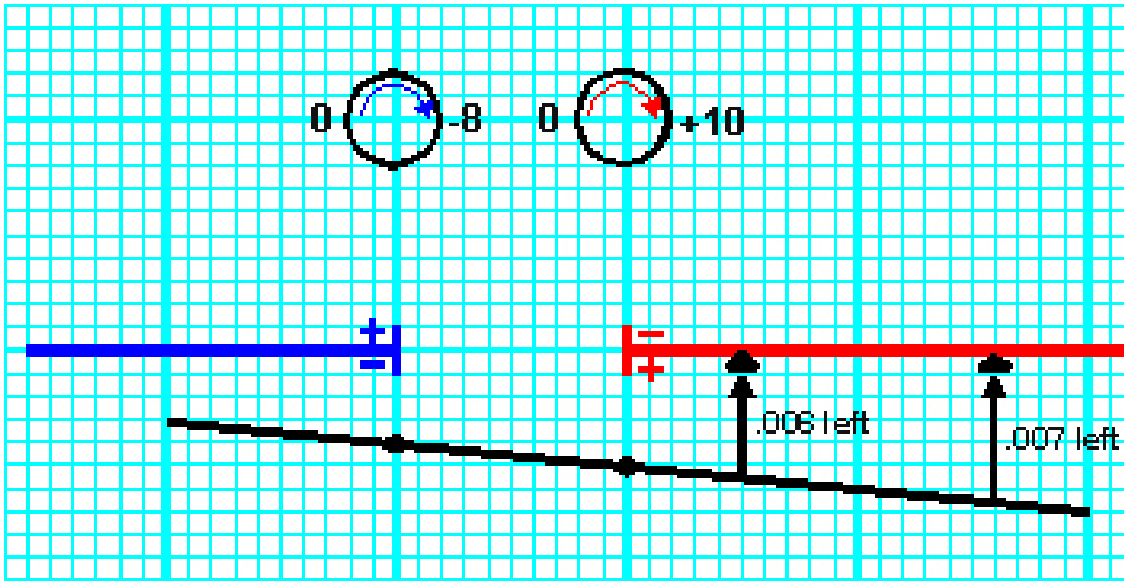


- Plot the readings on your graph. Remember, dial readings are TIR and actual misalignment is half of TIR.



Reverse Dial Graphical Method - E.g

- After plotting, we can see the movement that is required to bring the machine into alignment.
- 0.006” at the front and 0.007” at the back.
- Alignment complete. Readings can be verified again.



Laser Alignment Systems

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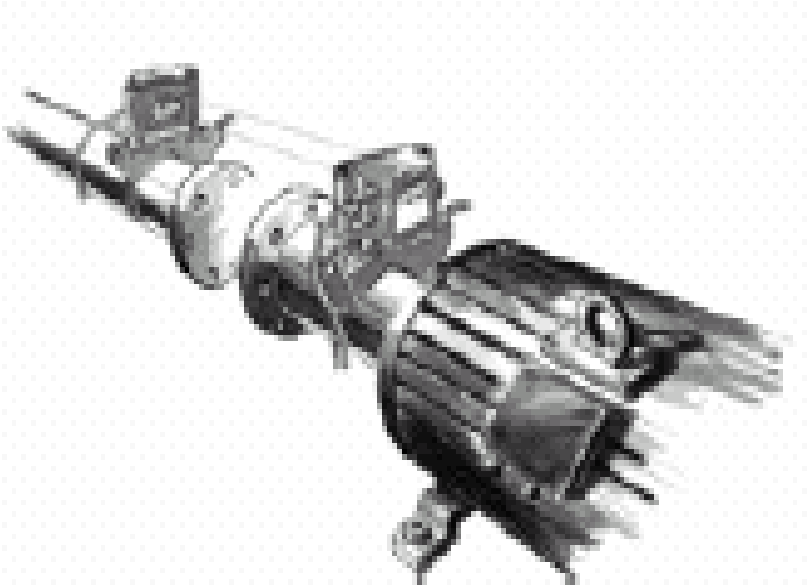
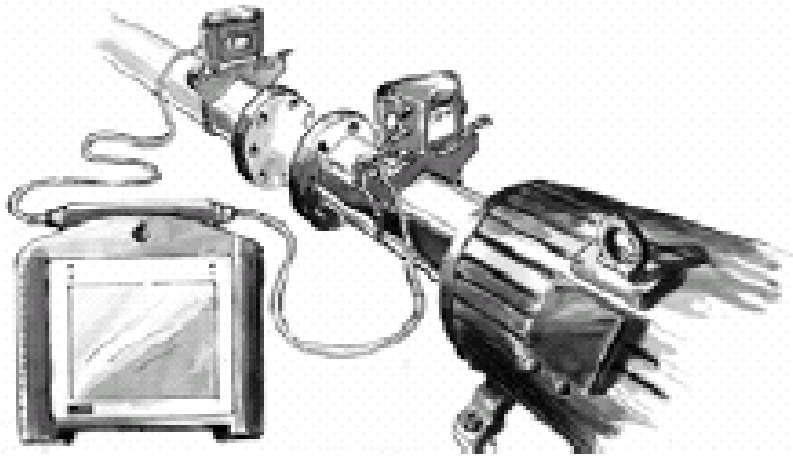
Some Modern Laser Kits are based on the principal of reverse dial method.



- Using laser beams instead of bars eliminates the possibility of sag.
- Machine moves are computer calculated.

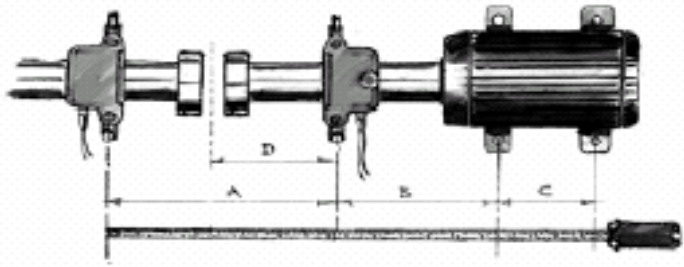
Mounting of Laser Fixtures

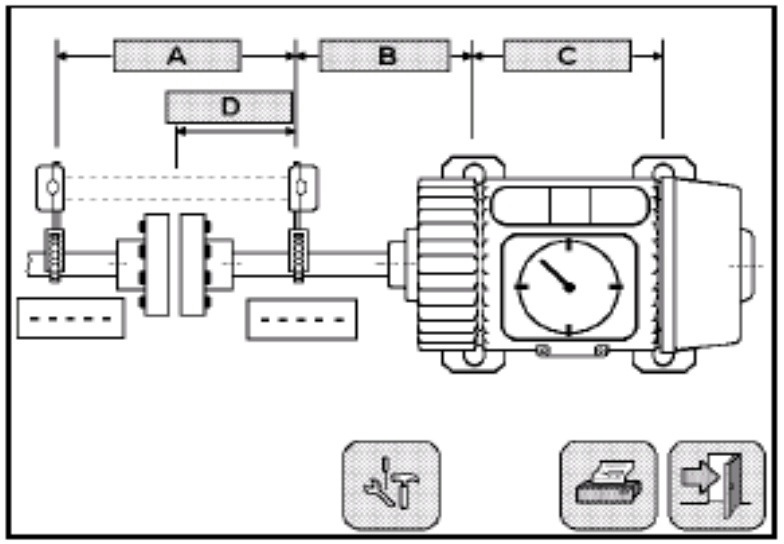
- Lasers are mounted on shafts using V-blocks (additional fixtures are available such as magnetic bases if v-blocks are not practical).
- Laser beams are adjusted so they project their beam to the opposite target.
- Lasers are cabled back to hand held computer.



Dimensions are Entered

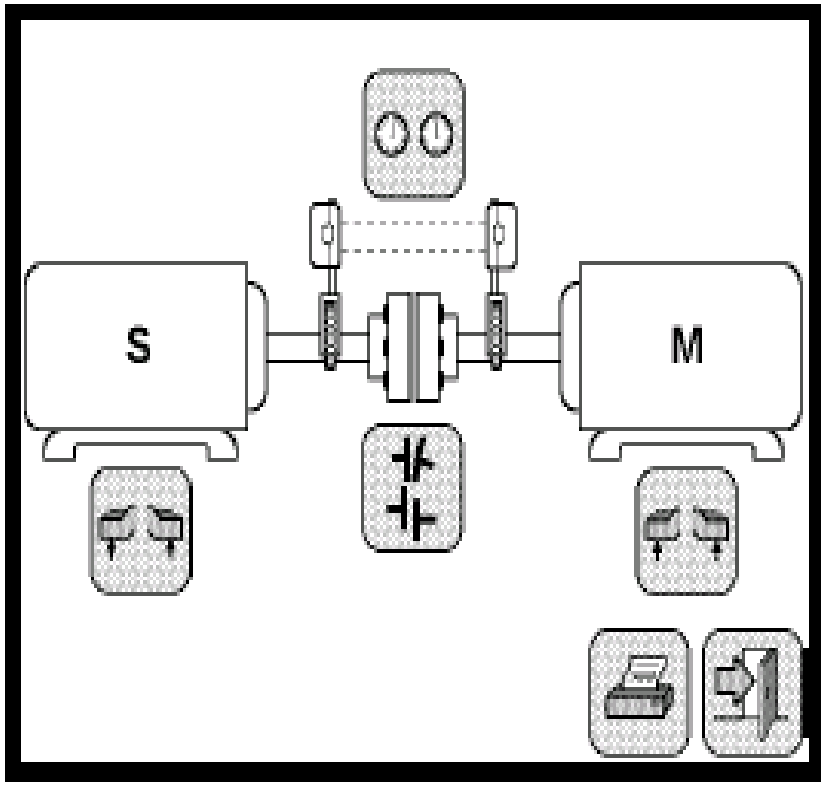
- Dimensions between lasers and between machine feet are entered.
- This is needed so machine moves can be calculated.





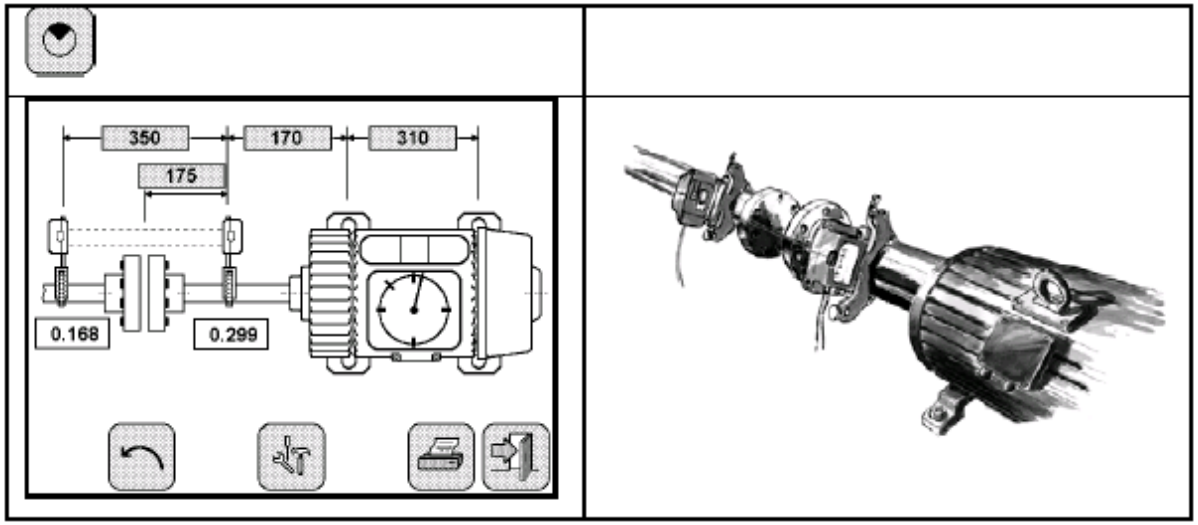
Thermal Growth

- Before starting the alignment there is the option to compensate for any thermal growth.
- We will discuss this later in the OL2R section, but any OEM specs can be entered here.

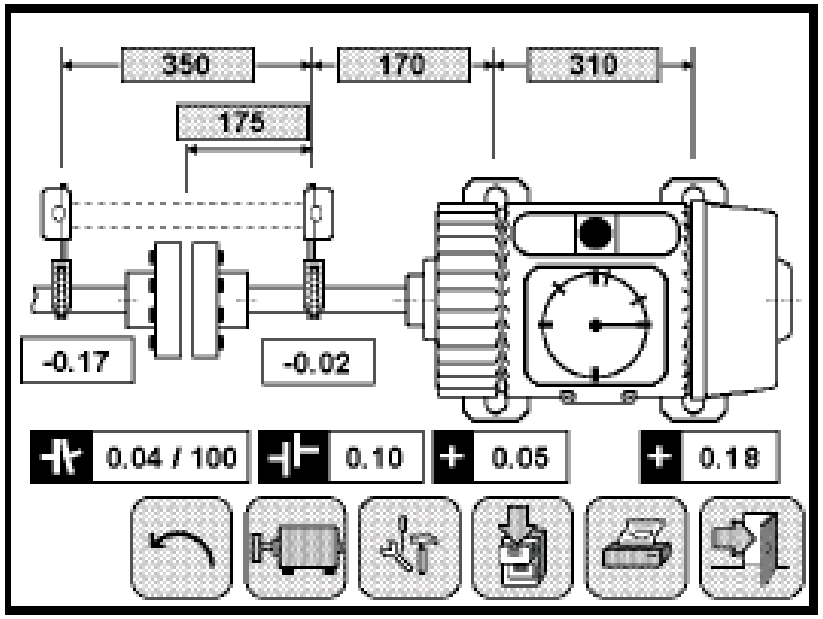


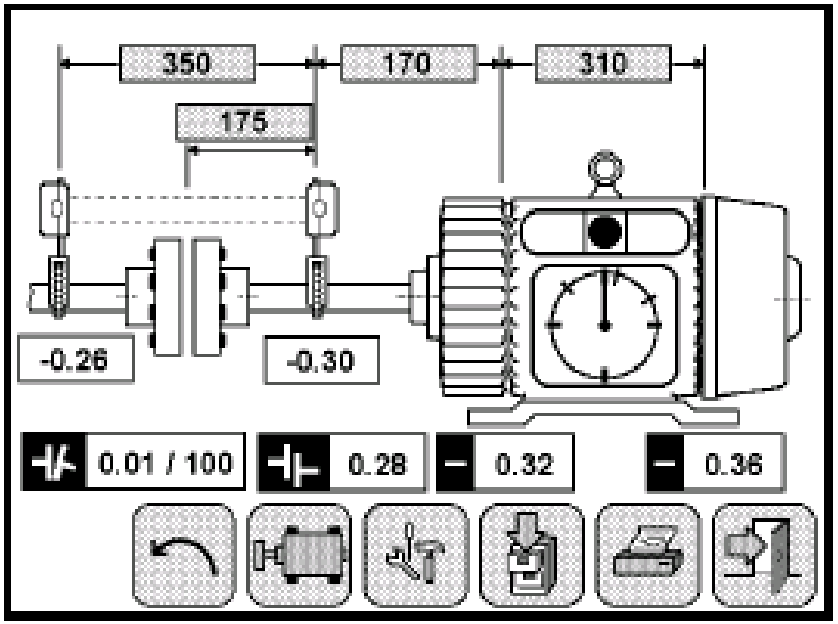
Ready to Measure - Rotate the shafts

- Shafts are ready to be rotated.
- 3 measurements must be taken at 3 separate shaft positions
- First measurement can be taken in the current shaft position



Alignment Measurement Complete

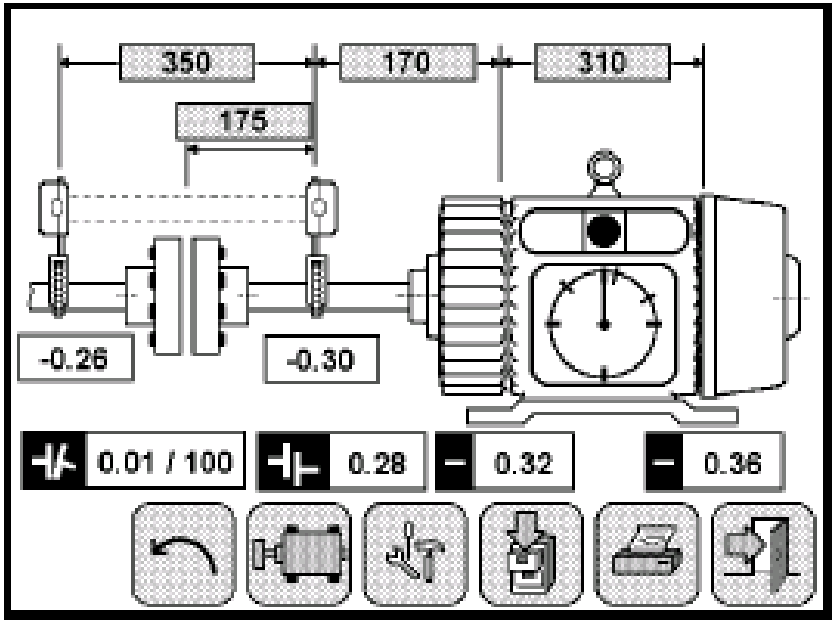




- Alignment measurement is complete and results in the Horizontal and Vertical planes are displayed.
- The feet values display the corrections required.

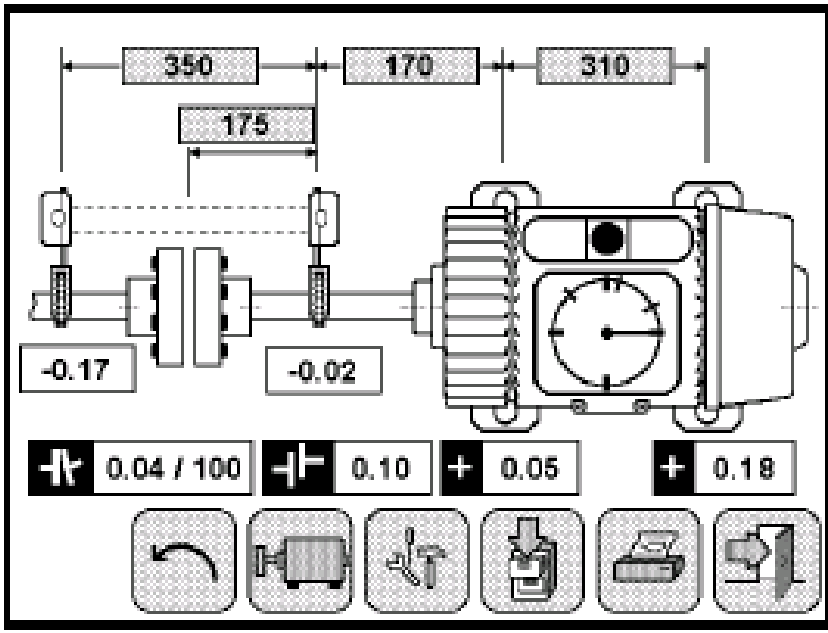
Adjust The Machine Vertically

- With the shafts in the 1200 position, the machine can be adjusted vertically until the desired alignment is reached.
- This is done in “LIVE” mode and this is a huge benefit compared to dial gauge as there is no need re-measure after every adjustment.



Adjust The machine Horizontally

- With the shafts in the 0300 position, the machine can be adjusted horizontally until the desired alignment is reached.
- This is done in “LIVE” mode and this is a huge benefit compared to dial gauge as there is no need re-measure after every adjustment.



Laser Alignment Considerations

- Faster and easier to install and measure than dial gauges.
- No need for manual calculations as machine movements are calculated by the computer.
- Generally more accurate as the effect of bar sag and coupling run out is eliminated.
- Live mode adjustments so there is no need to keep on re-measuring after every slight adjustment.
- Computer can take into account of thermal growth, either through manually entered values or those measured in the OL2R measurement.

Thermal Growth
&
Offline to Running (OL2R) Considerations

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Offline to Running Condition

- Machine alignment has to be accomplished when machine is shut-off.
- When performing alignment you have to consider running conditions such as thermal growth.
- Dresser-Rand spec considers this growth, however this is may often not be enough to ensure an aligned machine in running mode.

Offline to Running (OL2R)

- The *Fixturlaser* OL2R fixture mounted on a motor and pump.
- Performing two measurements, one in offline mode and one in running mode, will give you the correction values for a precision alignment.
- The machine will be perfectly aligned considering all forces and movements from offline to running condition.

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The OL2R fixtures are mounted either side of the coupling.

- The OL2R fixtures mounted on a Dresser-Rand Compressor and Lufkin Gearbox.

- The OL2R system can measure the difference in shaft position **while the machine is running.**

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OL2R Fixtures are mounted either side of the coupling

OL2R - What is it all about?

- Idea is to achieve desirable shaft alignment when machine is running at normal operating conditions.
- Thermal Growth and pipe strains on machines can effect the shaft alignment.
- By measuring the “real” growth of a machine once it reaches its normal operating condition we know how to offset machines in the alignment process to compensate for this growth.
- Most thermal growths are calculated & predicted by machine designers.
- “Real” thermal growth measurement is a relatively new technology.

OL2R - How the measurement is done

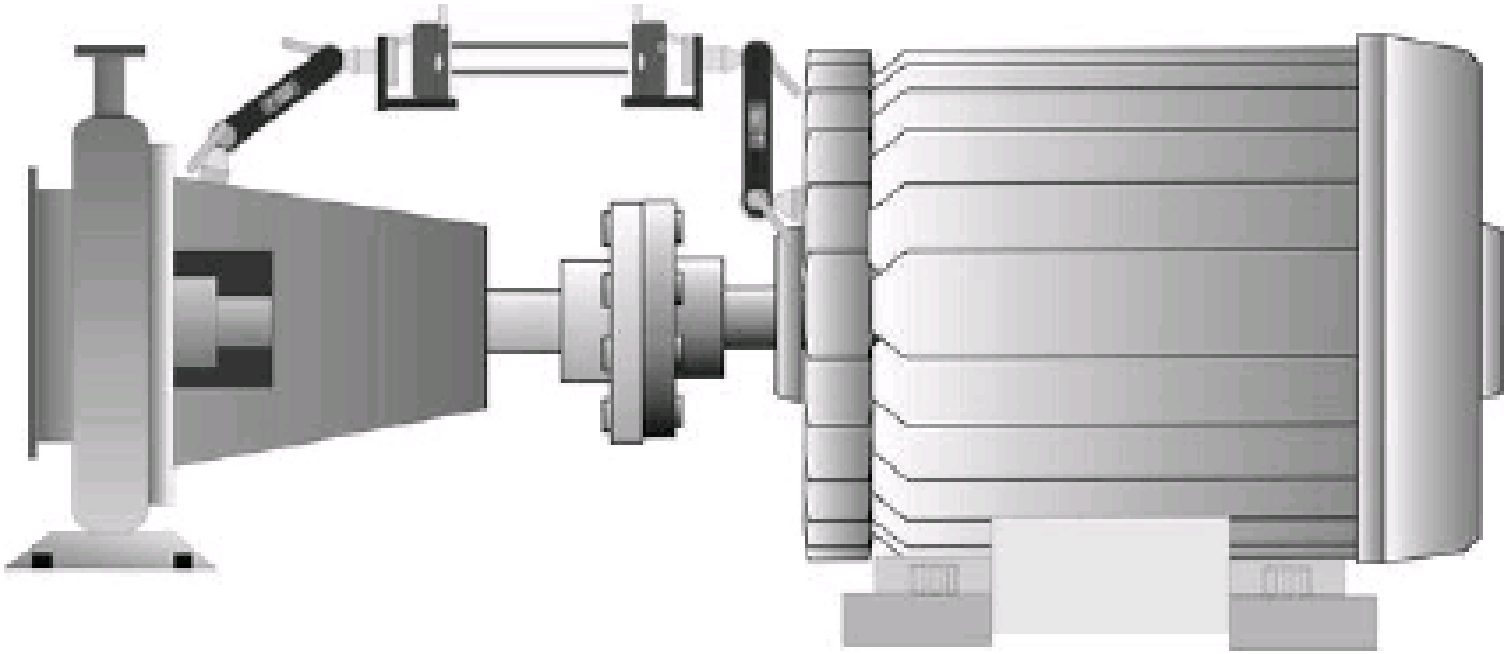
- Brackets mounted either side of coupling.
- Lasers mounted on each bracket and adjusted so each laser beam hits the target on the opposite laser head.
- With machine in Hot or cold condition, perform reference measurement by turning lasers through 0900, 0300 and 1200.
- Once machine has reached hot or cold condition, perform the measurement again. The difference between the two readings is the growth or expansion due to operation.
- The measured growth can now be compensated for in the shaft alignment process.

OL2R- Brackets.

- M6 hole is drilled and tapped in machine casing either side of the coupling.
- Brackets are locked in position using handles.

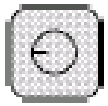
OL2R - Setting up the laser heads

- Laser units are mounted on brackets and are set so that beams hit the targets on the opposite laser head.

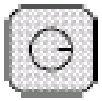


First condition is measured

- With machine in hot or cold condition, (which ever one you decide to measure first) measurements are taken by rotating the brackets through: -
- 0900



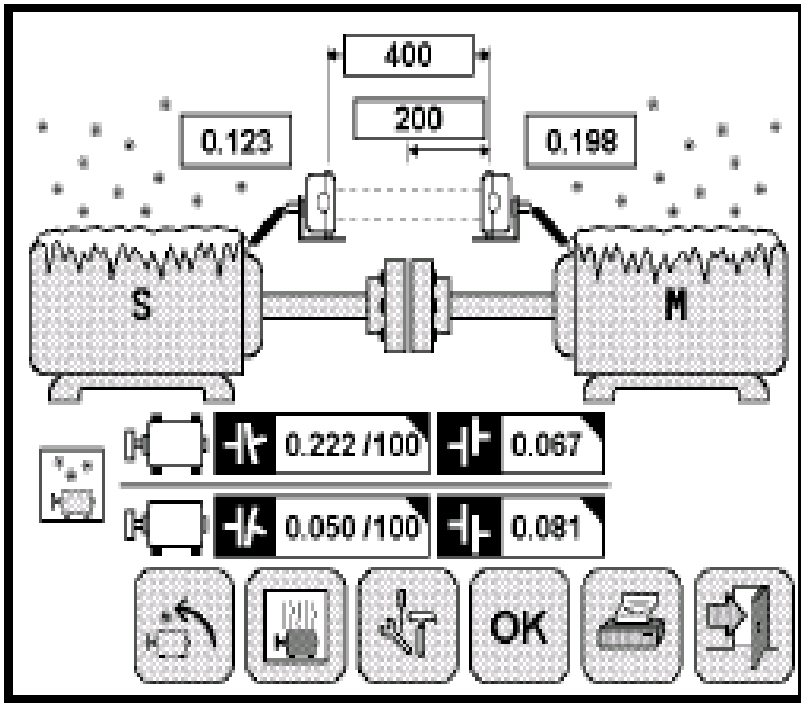
- 0300



- 1200

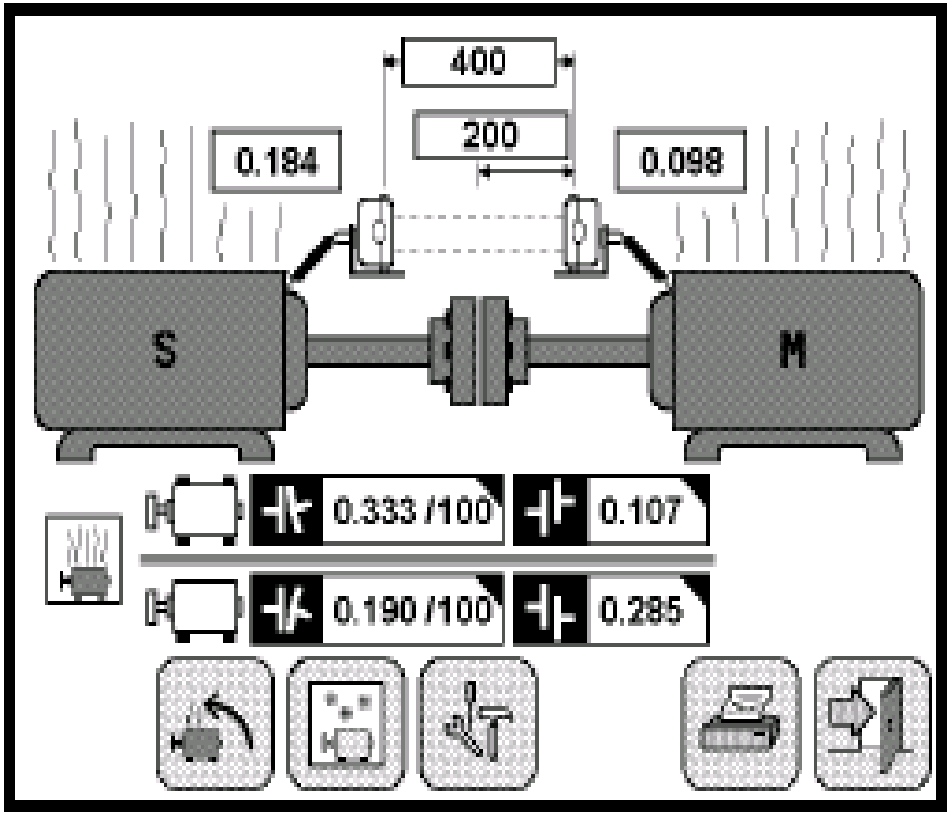
Cold Condition

- Results for cold condition are shown.
- This is considered reference position and it is the change from this condition once the machine reaches normal operating condition that we are interested in.
- The same procedure will now be used to measure hot condition (You must give the machine enough time to reach normal operating condition and temperature).



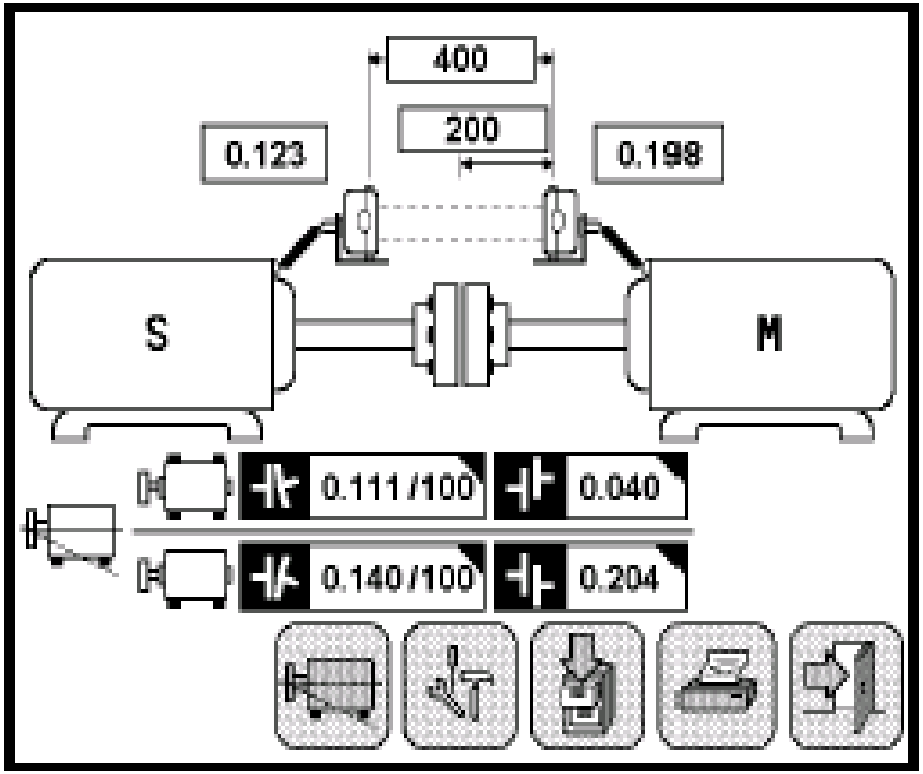
Hot Condition

- Hot condition is shown.
- The deviation between the cold and hot measurements is the growth we have measured.
- We must now compensate for this in the shaft alignment process.



The Measured Growth

- When both hot and cold conditions are measured the difference between hot and cold condition is shown.
- It is now possible to do a shaft alignment using these target values.



OL2R - Some considerations

- Measurement can only tell you difference between two conditions Hot/cold or Cold/hot.
- It can not tell you which part is moving. For this you will need to measure again from a single reference point.
- The OL2R brackets - Once set in position, they CAN NOT be touched, bumped or knocked by anyone other than the operator as this will cause error in the measurement. You must inform everyone in the area to stay away and don't touch.

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