

Course contents

1- What is shaft alignment

2- Types of Couplings

3- Alignment Preparation check list

4- Preparation on Alignment

5-How to Do Alignment

6- Reversal Alignment calculation Method

**7- Reversal Alignment Graphical Method
(complete with software)**

8- Case Studies For Alignment Failure

Reliability from different perspective

- Centrifugal Compressor Fail to start
- Centrifugal Compressor Alarm and shutdown

Actual Workshop Alignment procedure

1-What is shaft alignment

It is collinear of two center lines

1-Is the proper positioning of the shaft centerlines of the driver and driven components.

2-Alignment is accomplished either

A- Shimming

B- Moving a machine component.

Its objective is to obtain a common axis of rotation at operating equilibrium for two coupled shafts or a train of coupled shafts.

Why it is important to make shaft alignment?

Shafts must be aligned as perfectly as possible to maximize equipment reliability and life, particularly for high-speed

It is important because misalignment can introduce

1-High level of vibration

2-Cause bearings to run hot

Proper alignment

1-Reduces power consumption and noise level

2-Helps to achieve the design life of bearings, seals, and couplings.

2-Types Of Couplings

1 -Rigid Couplings :

It is a metal to metal contact (%100 collinear)

2 -Flexible Couplings

- * Spacer with shims*
- * Gear*
- * Grid*
- * Rubber*
- * Others*
- * Torque converter*

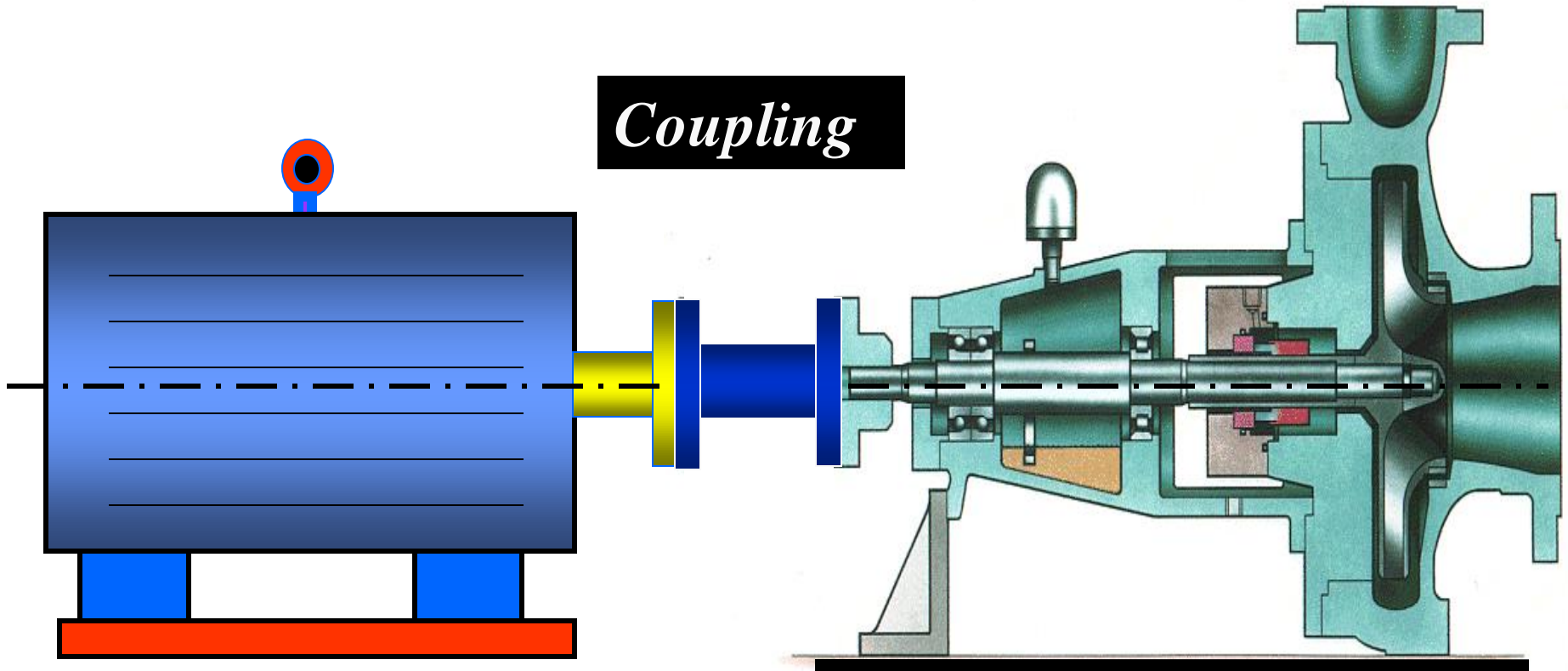
Alignment

It is collinear of two center lines

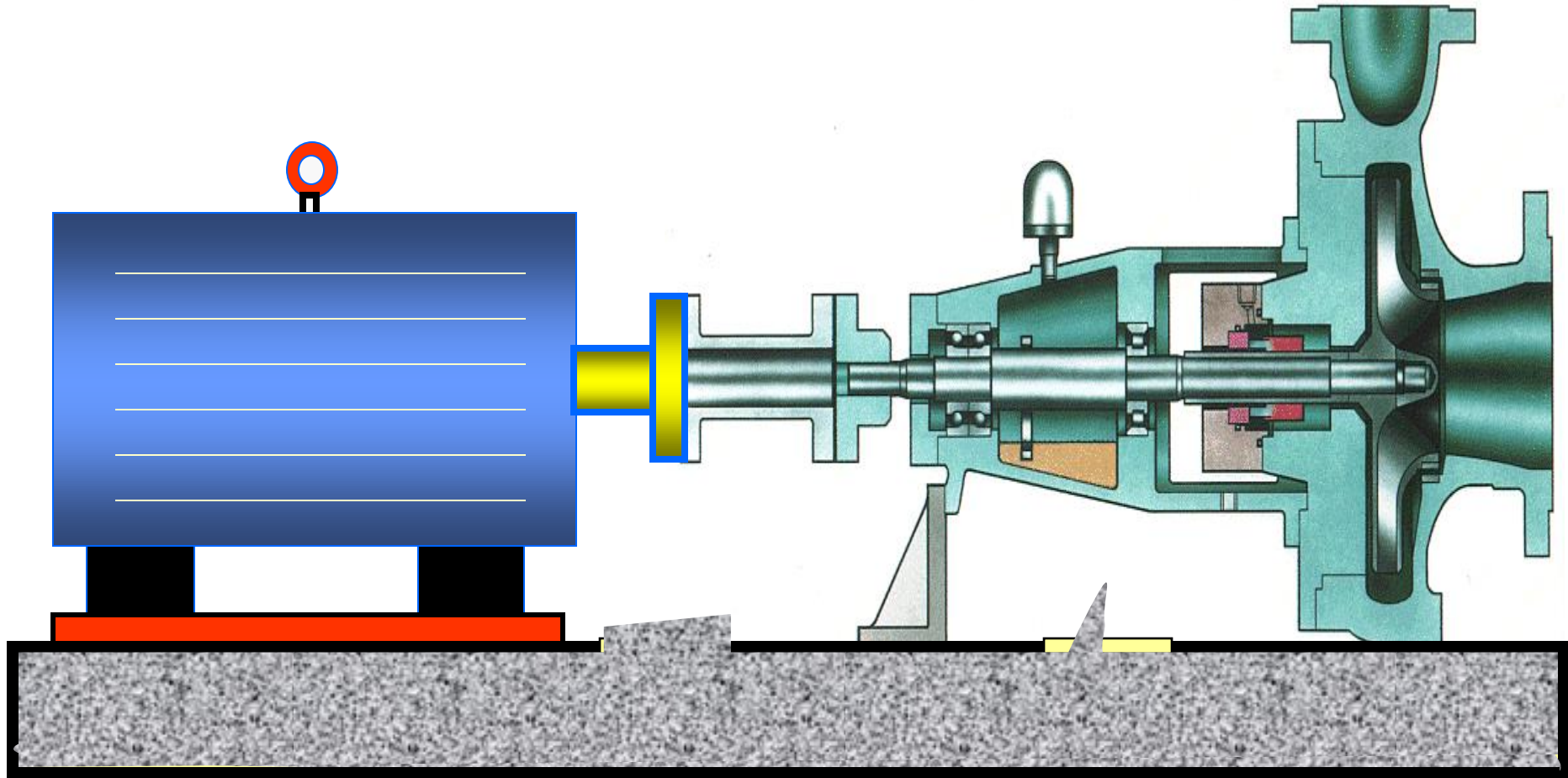
Motor

Equipment

Coupling

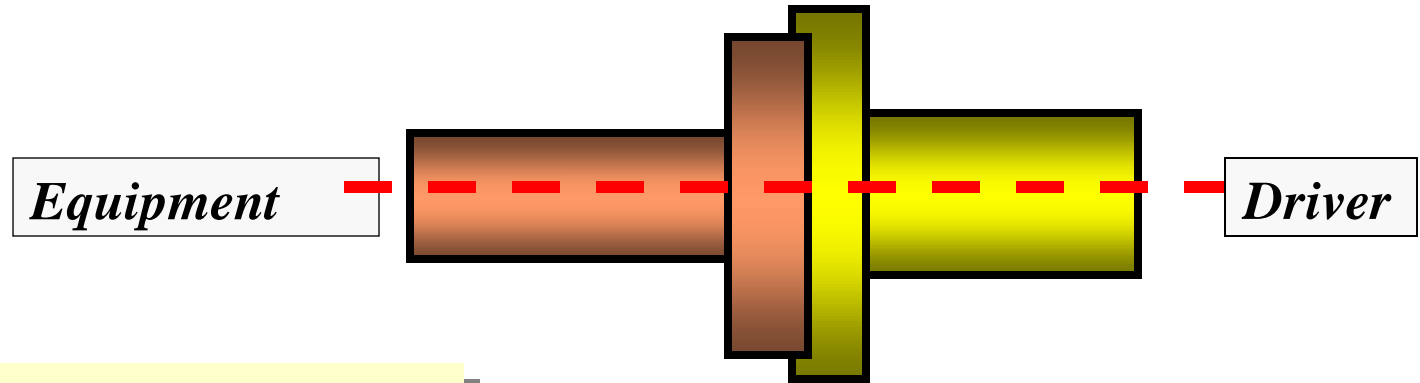


Pump Grouting



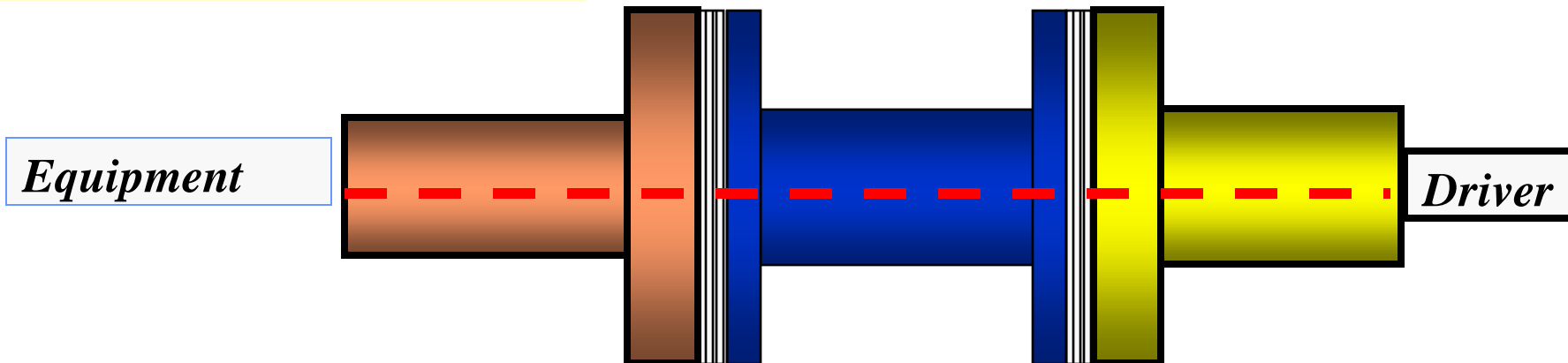
Special grouting concrete

1 -Rigid Couplings

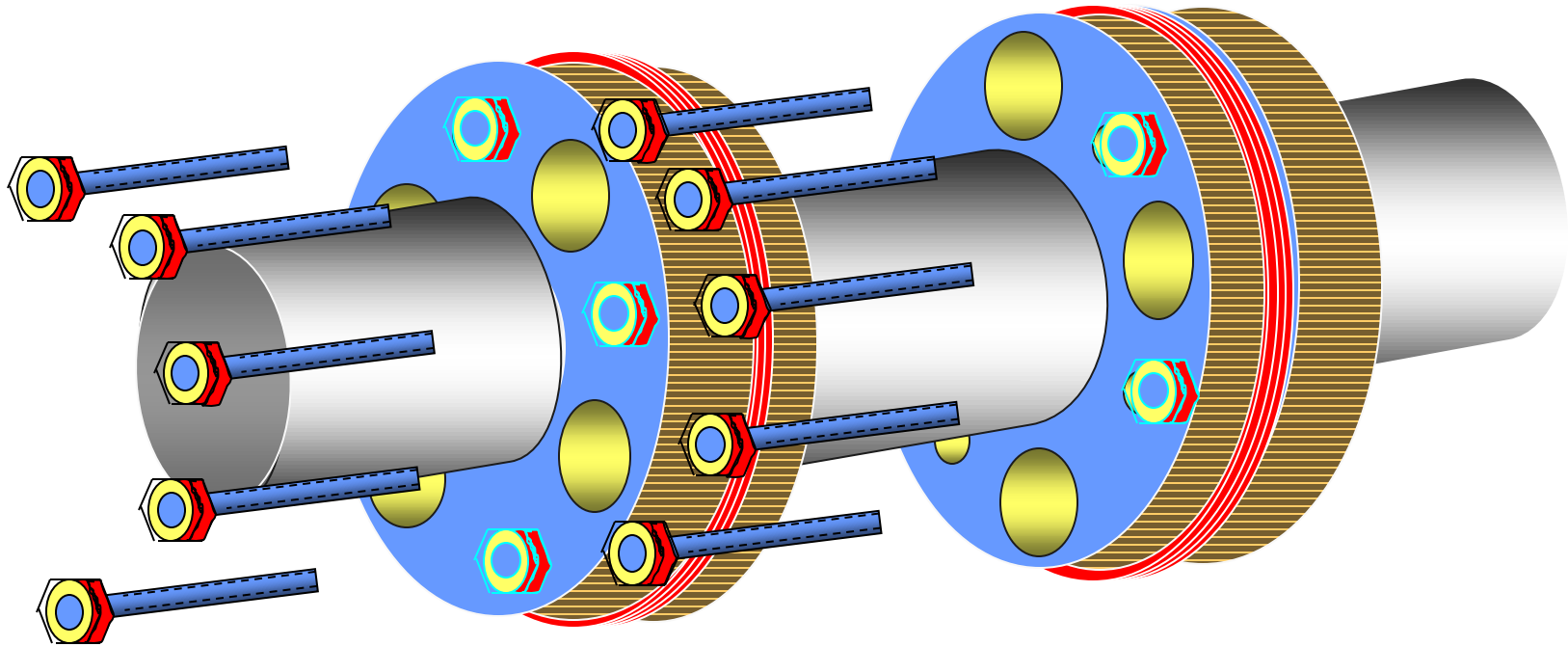


2 -Flexible Couplings

****Spacer with shims***

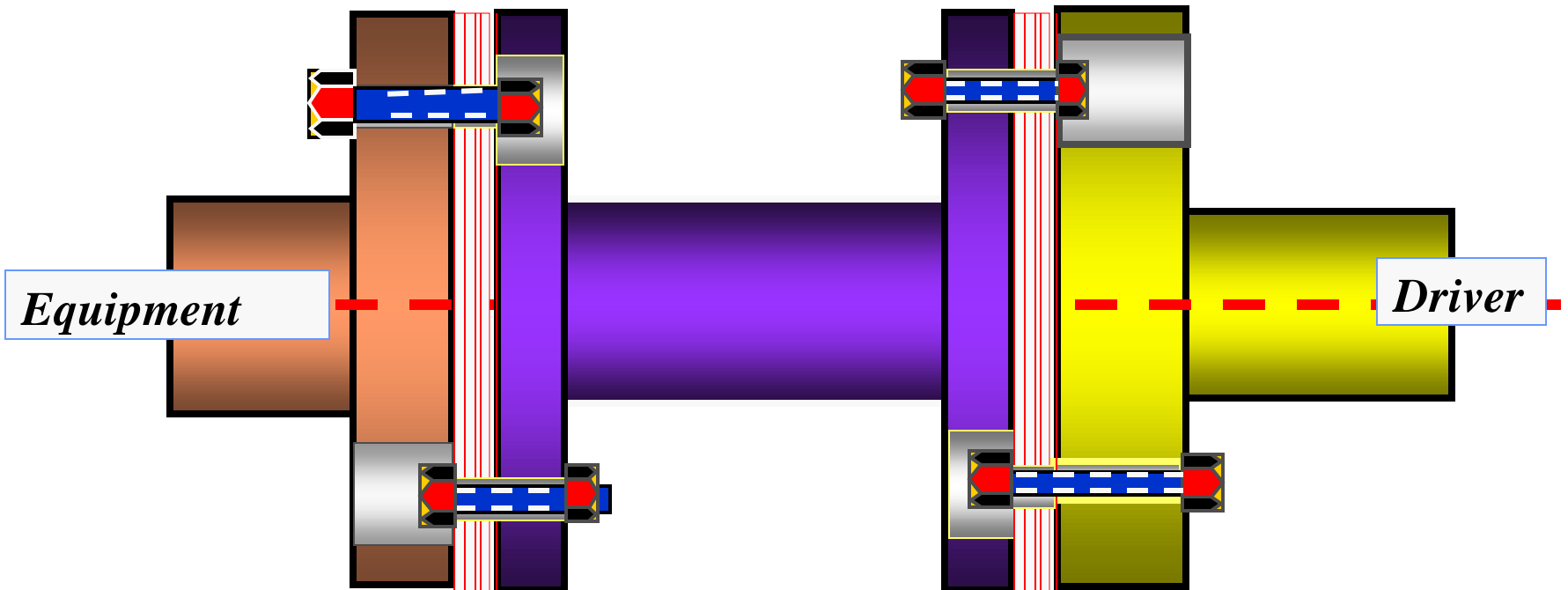


****Spacer with shims***

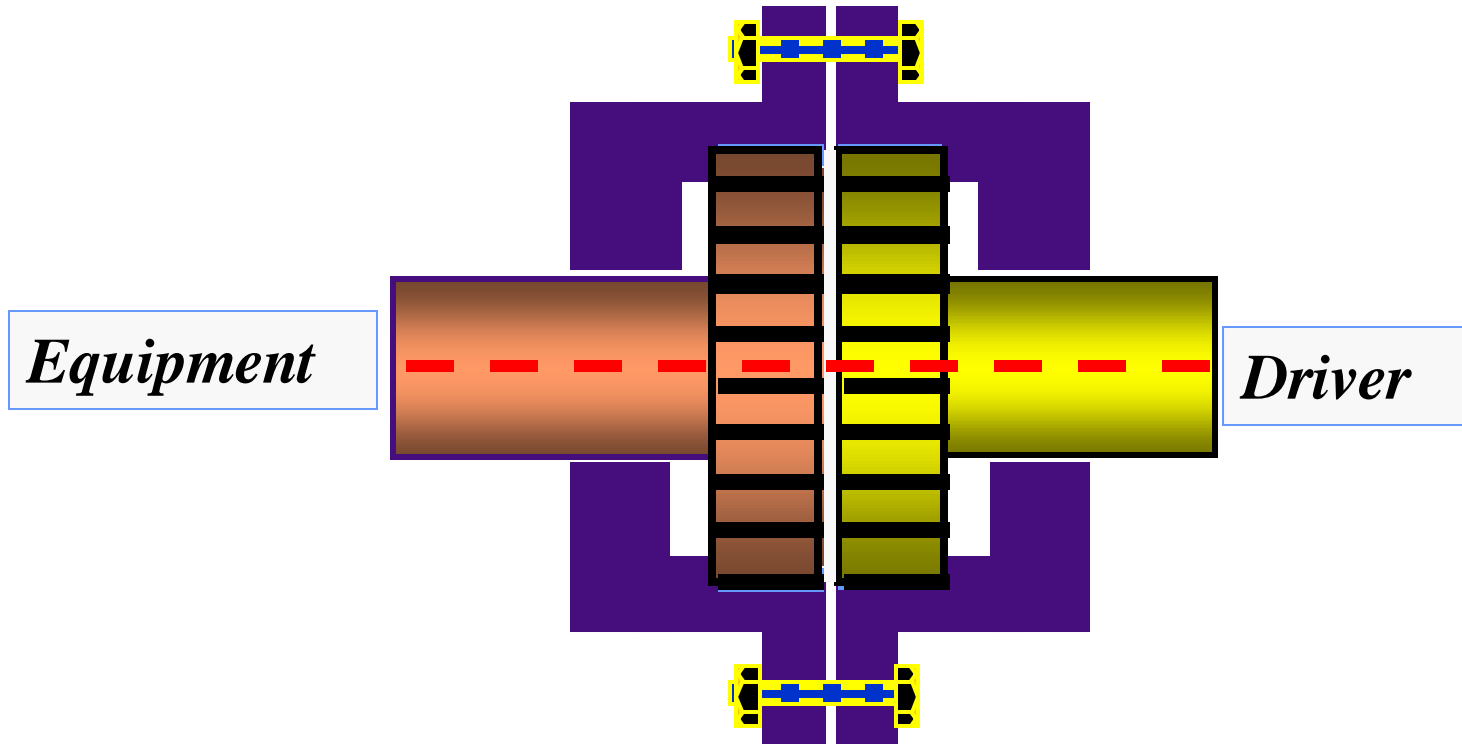


**Spacer with shims*

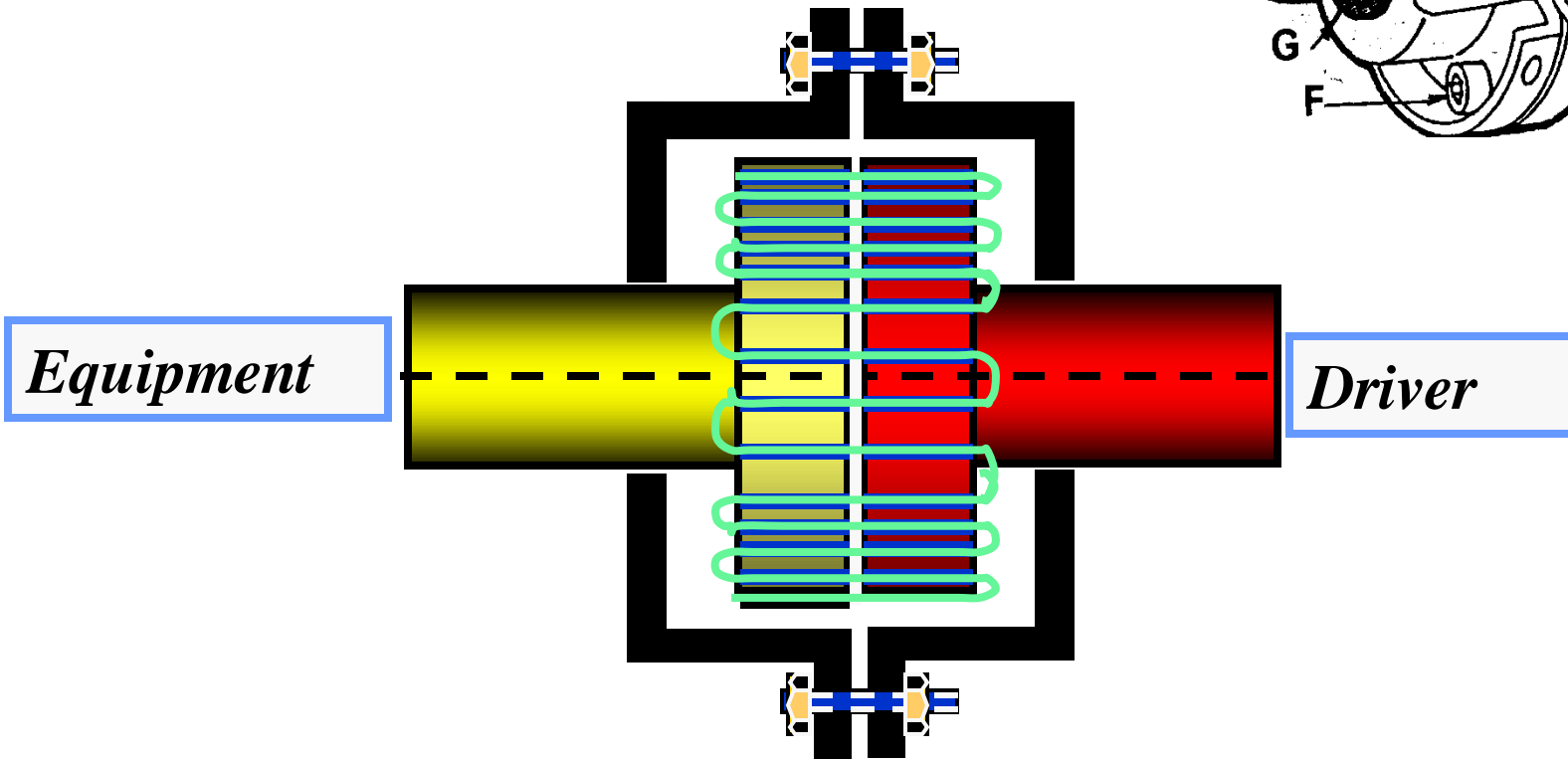
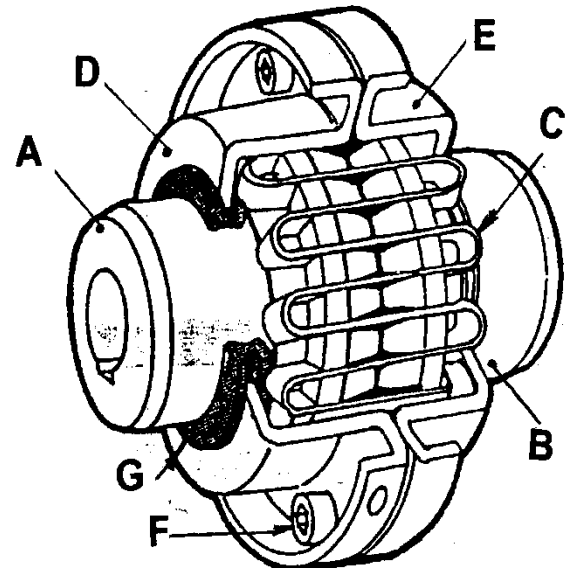
*Spacer is not connected directly to both hubs,
but through the shims*



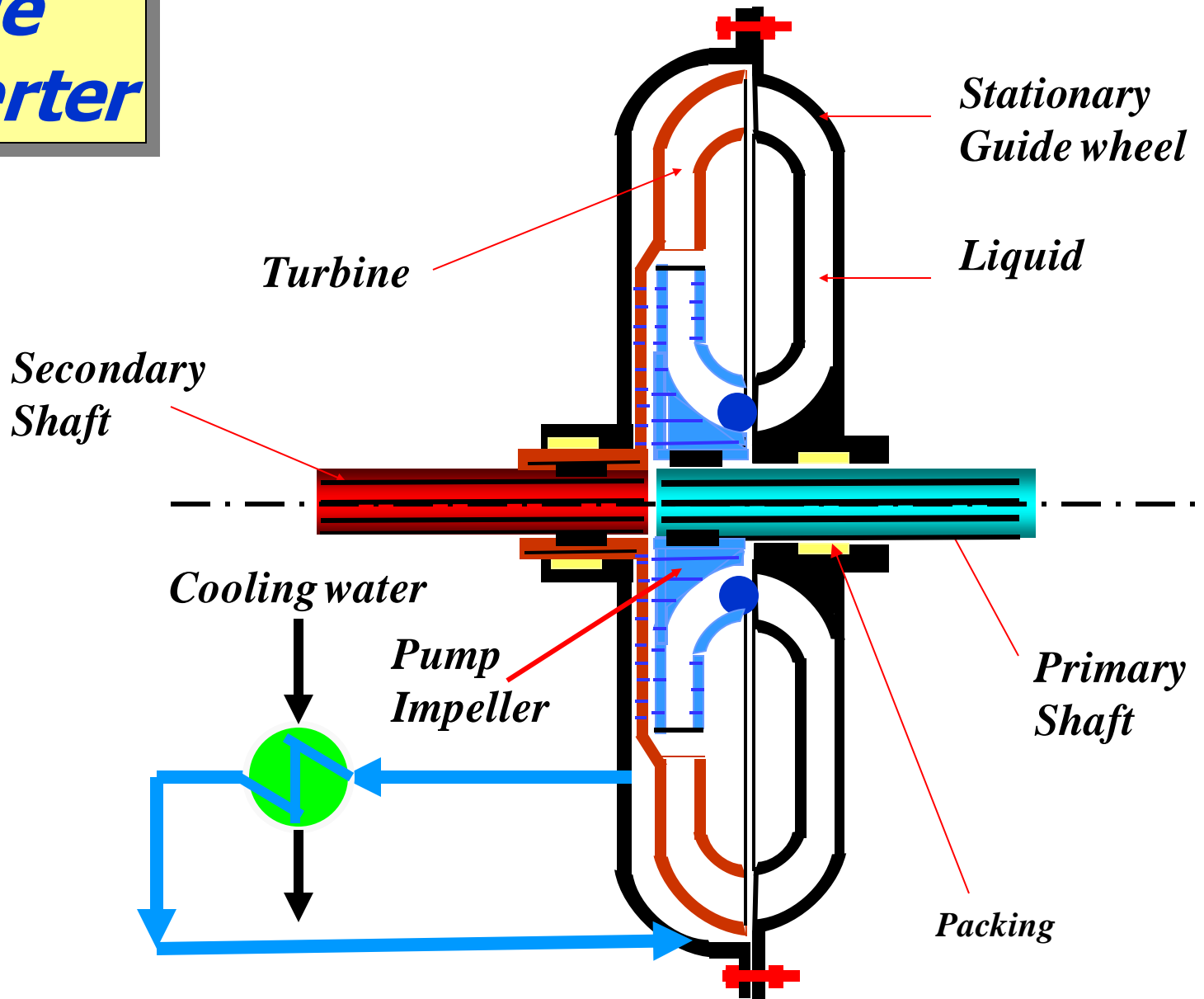
****Gear***



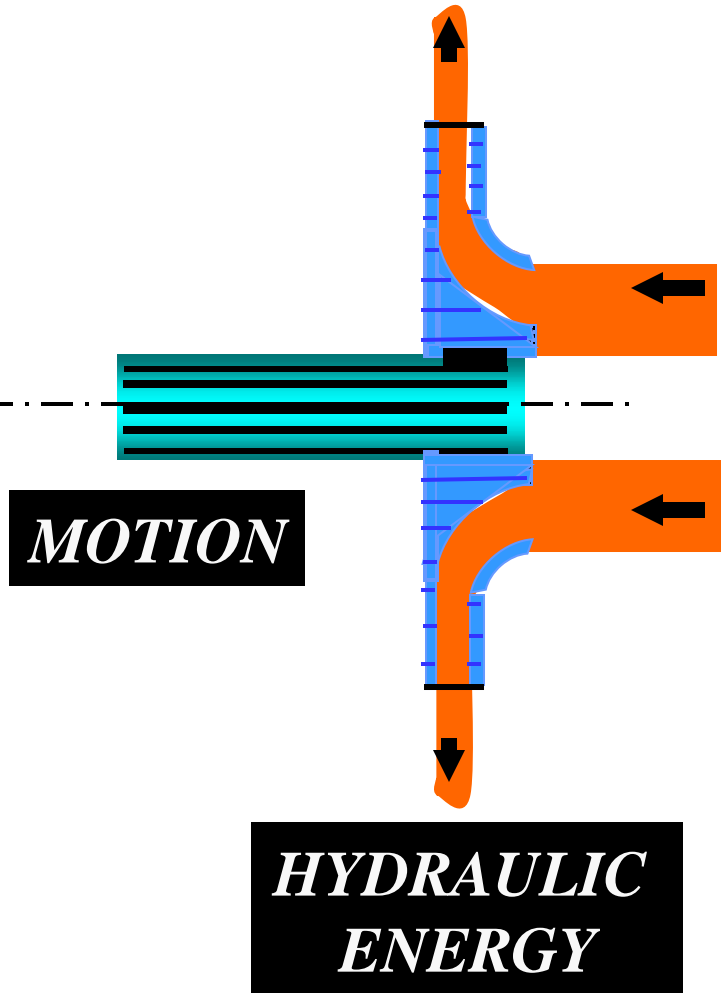
***Grid**



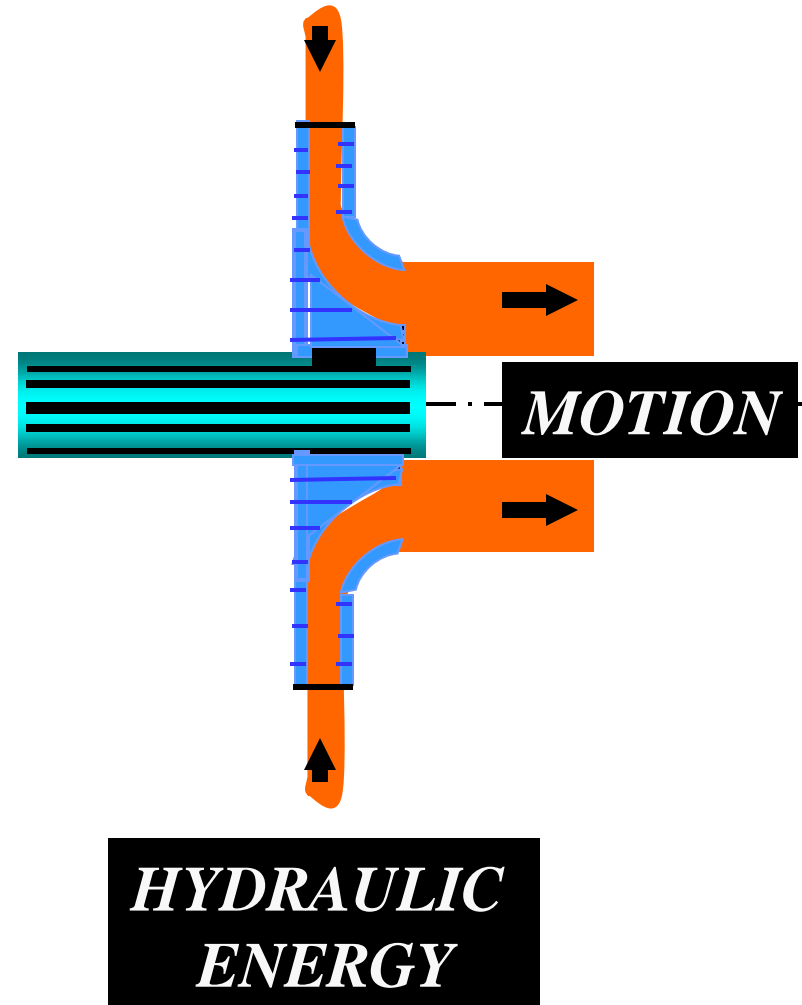
Torque converter



Pumps



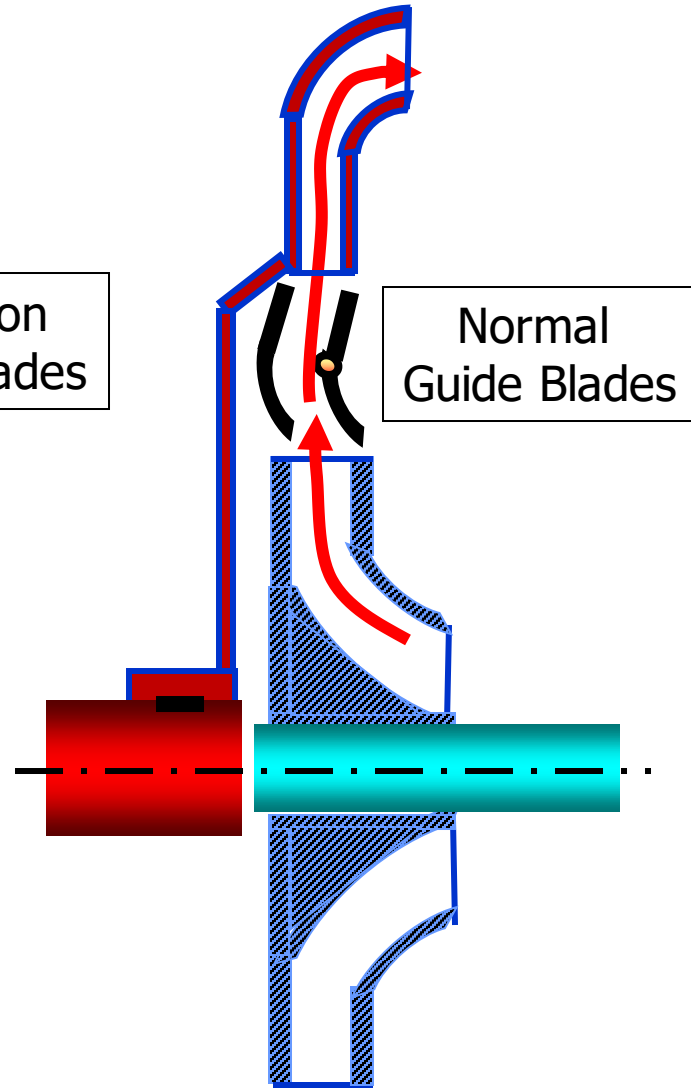
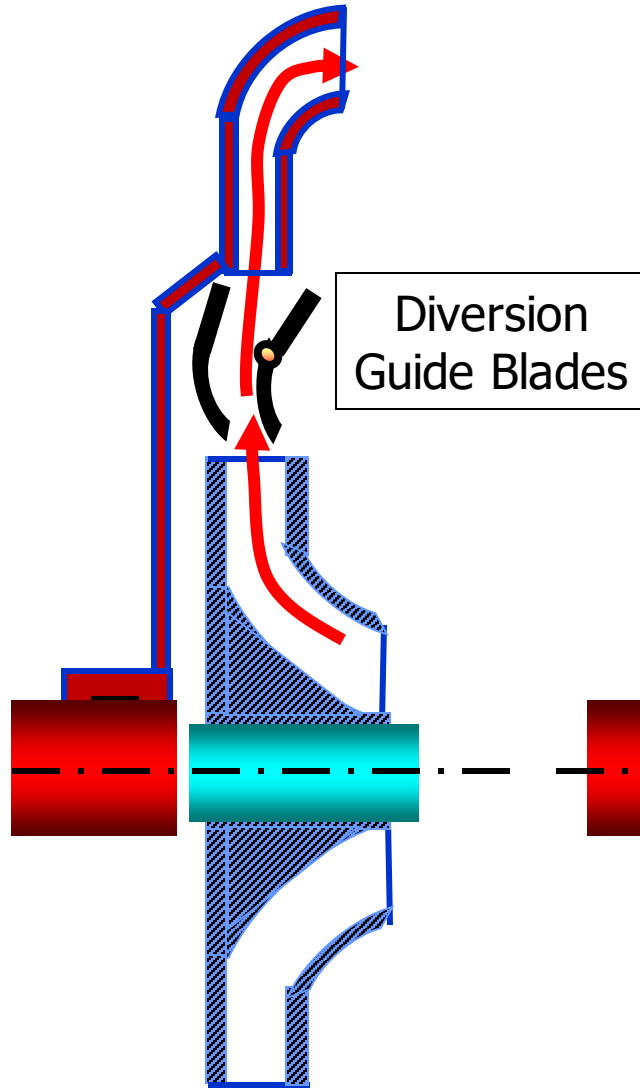
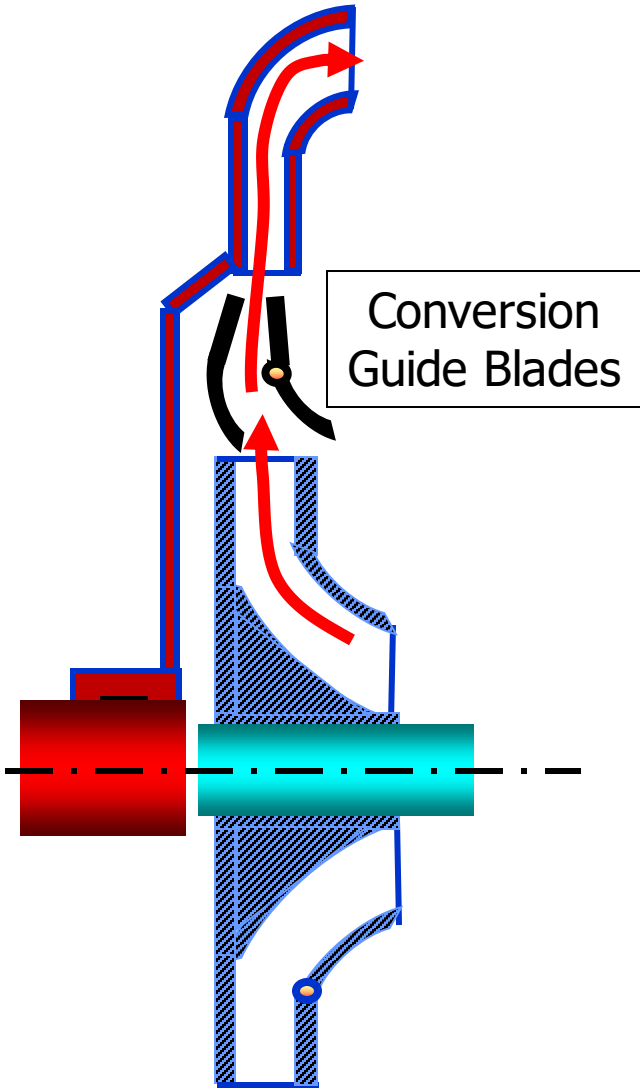
Turbine



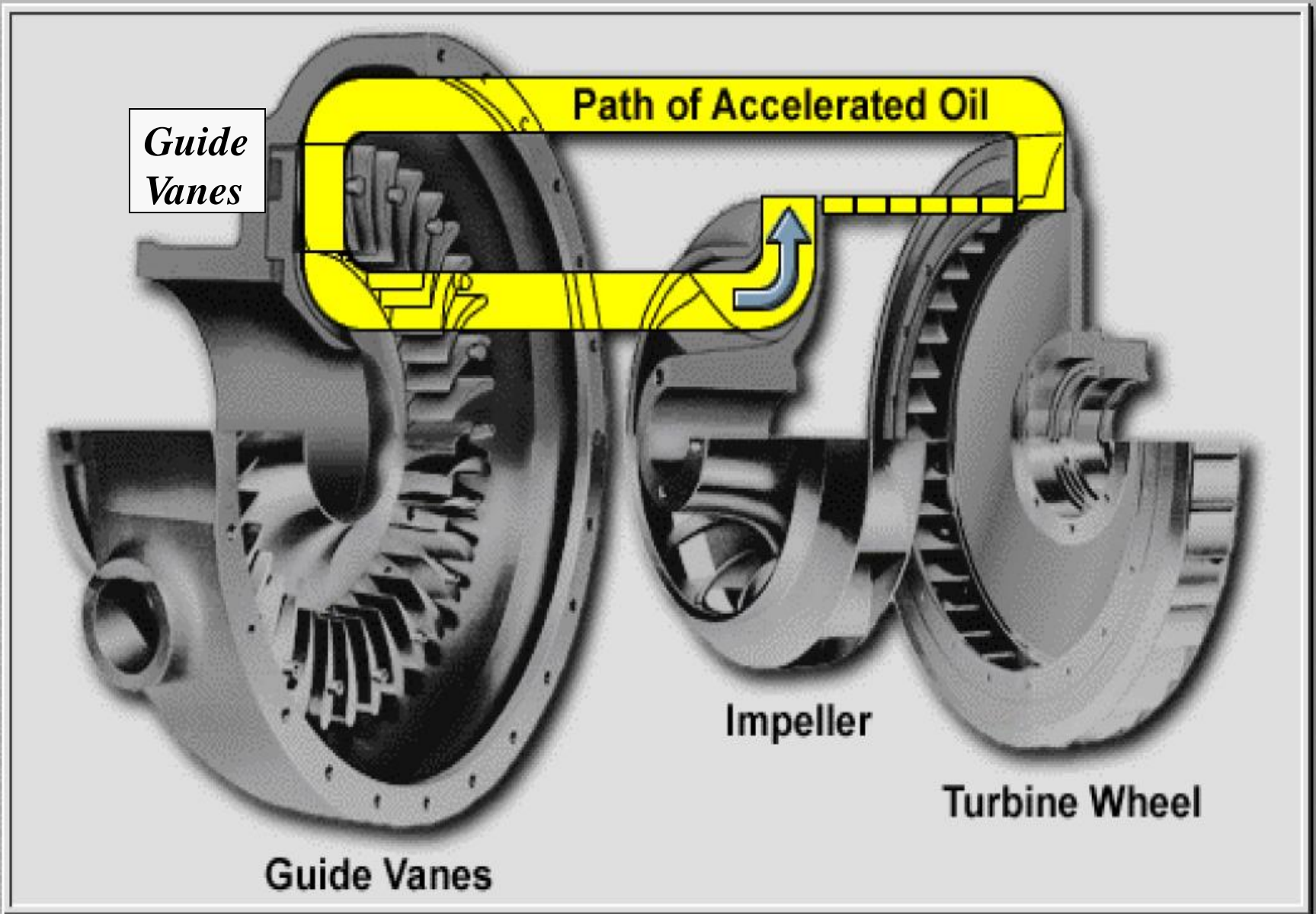
Higher speed

Lower speed

Normal speed



Basic Torque Converter Design



***3- Alignment
Preparation
check list***

Alignment Preparation check list

	<i>Description</i>	<i>OK</i>	<i>N/A</i>	<i>Comments</i>
1	Confirm that alignment procedures, dimensional offsets and tolerances are dictated by manufacturer and adhered to the standard			
2	Confirm the foundation grouting & anchor bolts are prepared correctly for specific equipment.			
3	Confirm soft foot under driver checked & corrected.			
4	Confirm coupling gap checked prior to final alignment			
5	Shaft & Coupling Run outs Complete. (refer to vendor manual for acceptable limits): Motor shaft run out → Pump shaft run out → Pump coupling hub run out → Pump coupling hub face run out →			

	<i>Description</i>	<i>OK</i>	<i>N/A</i>	<i>Comments</i>
6	Confirm the vendor thermal growth correctly for specific equipment (in case of hot fluid pumping)			
7	Determine the thermal growth if it is not allowable in the vendor document			
8	Determine mechanical centre			
9	Determine Magnetic centre.			
10	Confirm proper tight for the dial indicator holder and holding rods			
11	Confirm the dial indicator is rotated from the top position to the bottom position during the alignment procedure.			
12	Confirm the proper dial indicators position during the reversal alignment procedure .			

Alignment

*Handing over
check list*

	<i>Handing over check list</i>	OK	N/A	Comments
13	Confirm driver has been installed and initial alignment completed and accepted.			
14	Confirm suction and discharge nozzles are installed as per design and alignment is correct and stress free. Confirm pipe strain checked and corrected.			
15	Confirm free rotation and correct direction is clearly marked.			
16	Confirm bearings and seals are clean and free from damage			
17	Confirm coupling hubs are clean damage free and match marked.			
18	Confirm that after final code alignment with pipe work is connected, the misalignment tolerance is maintained after releasing spring pipe supports .			
19	Ensure guards are fitted and in accordance with area design requirements			

	Completed By	Inspected/Checked By	Quality Inspection	Completions Acceptance
Name and ID No				
Organization				
Sign				
Date				

Parallel misalignment

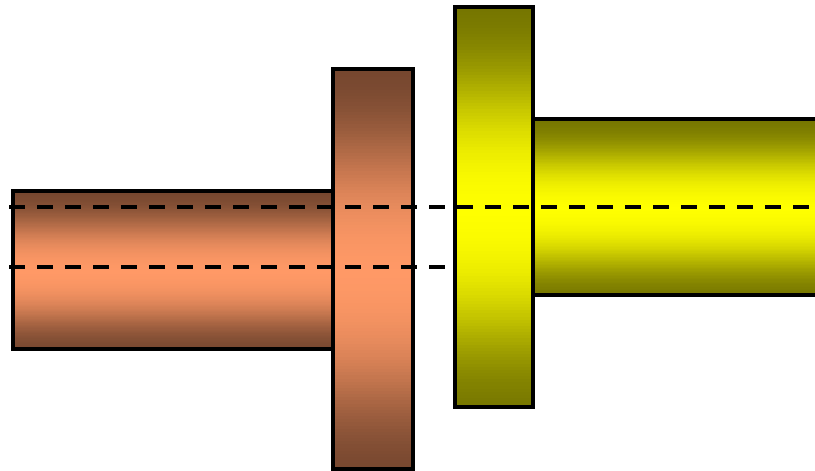
Vertical

OR

Equipment

Horizontal

Driver

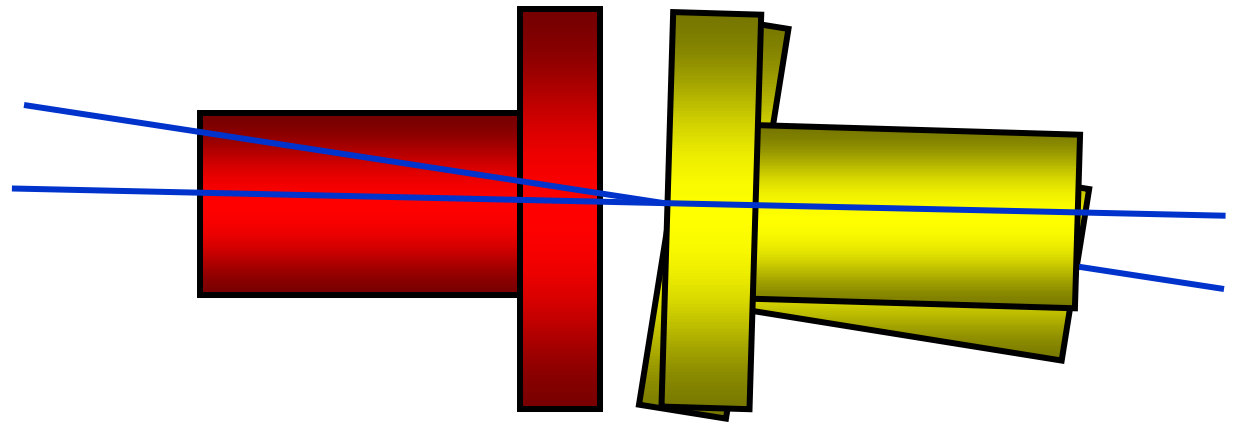


Angular Misalignment

Vertical

Equipment

Driver



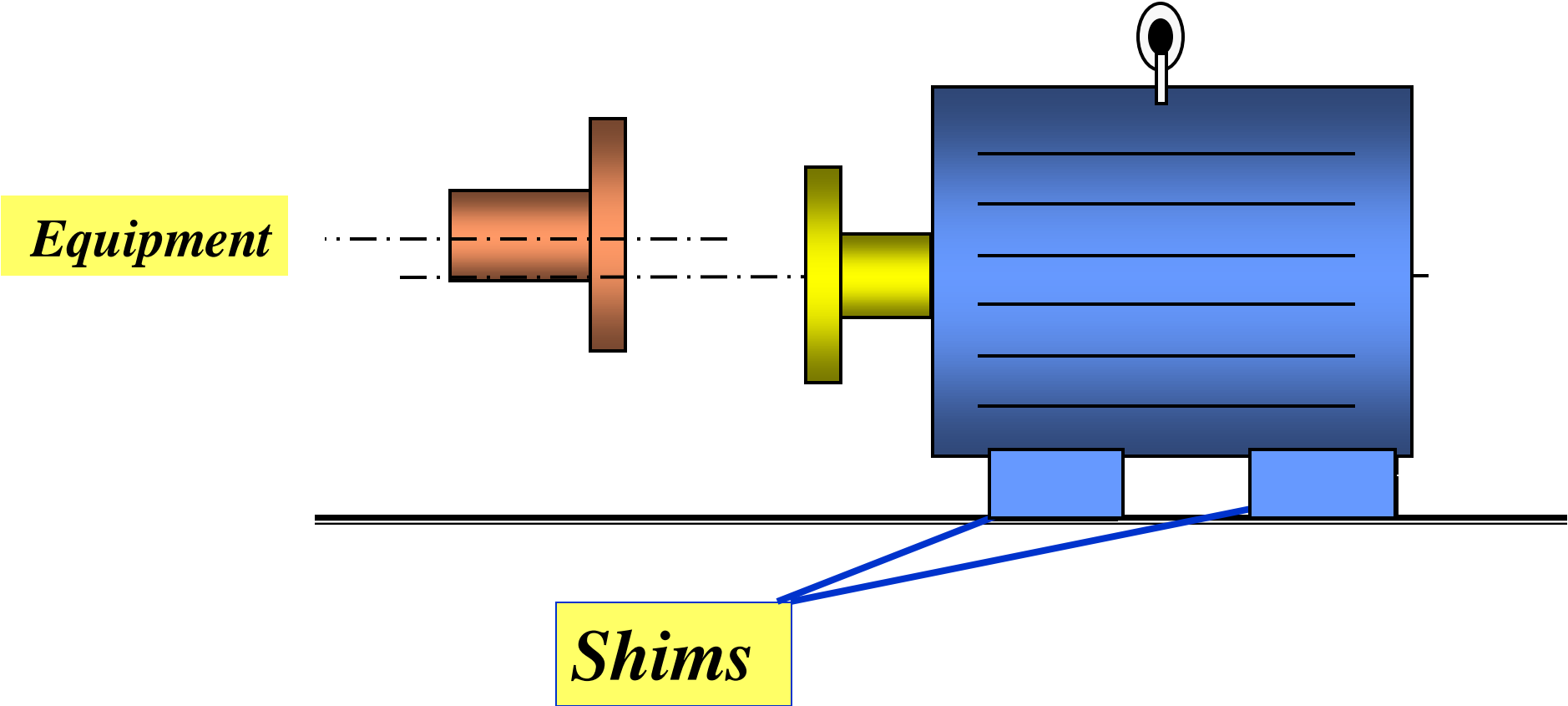
OR

Horizontal

CORRECTING OF MISALIGNMENT

I- VERTICAL PLANE

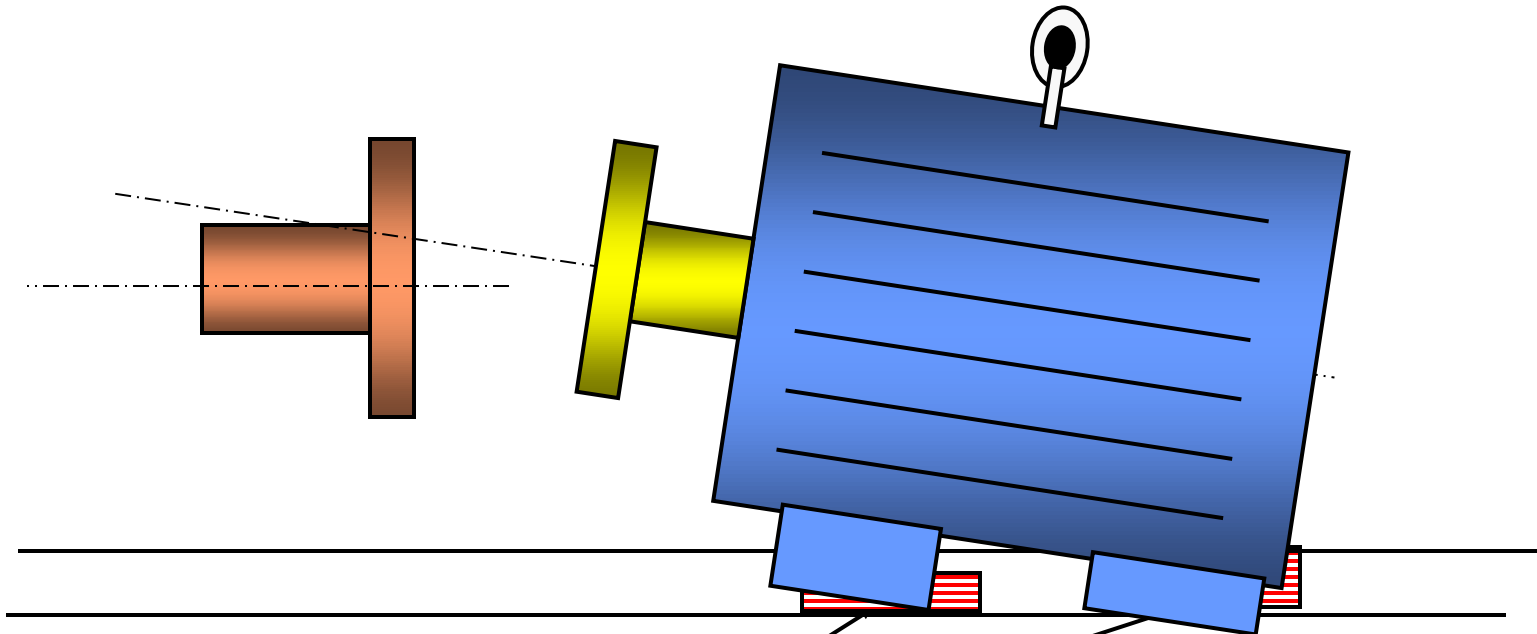
A- Parallel Misalignment



I- VERTICAL PLANE

B- Angular Misalignment

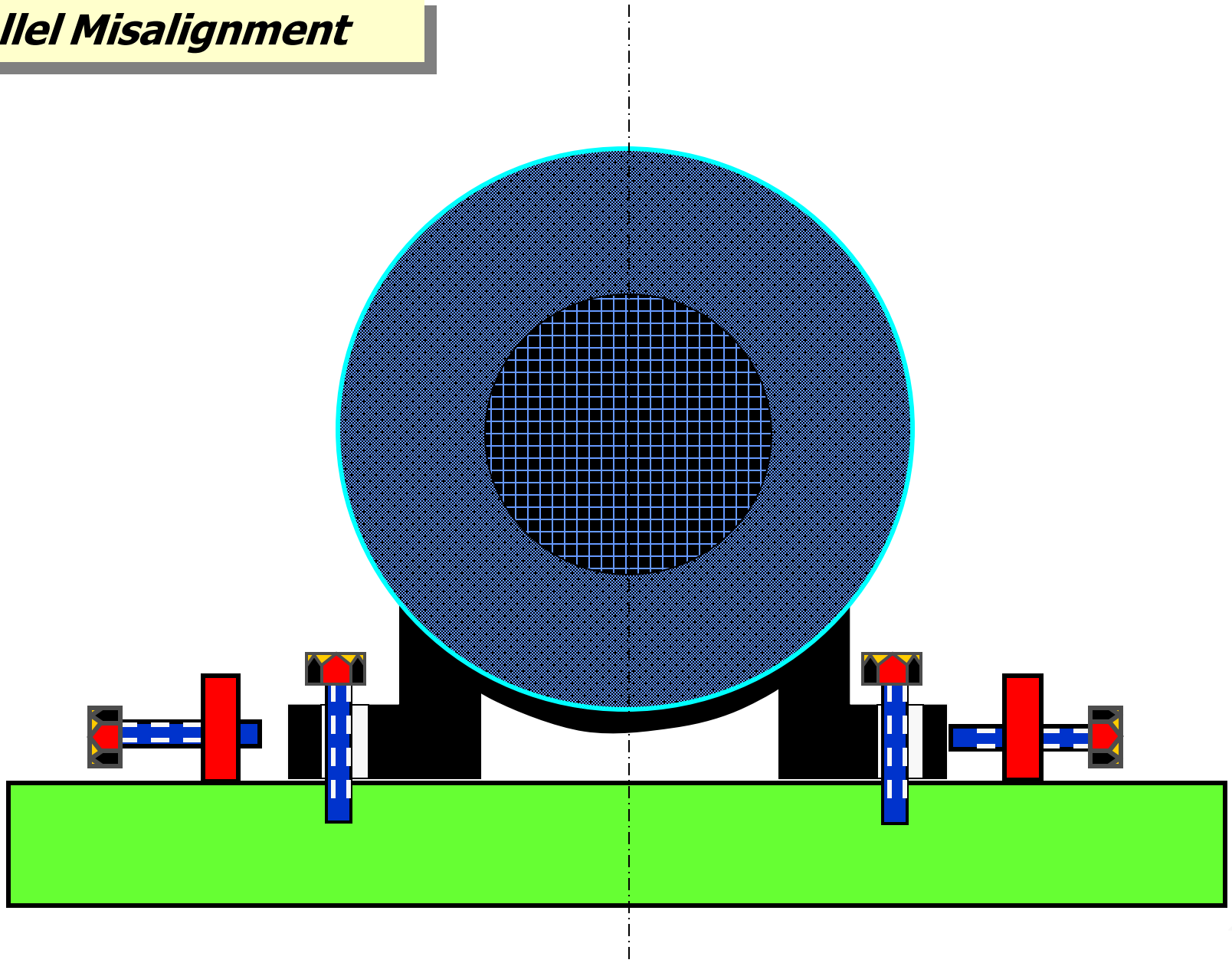
Equipment



Shims

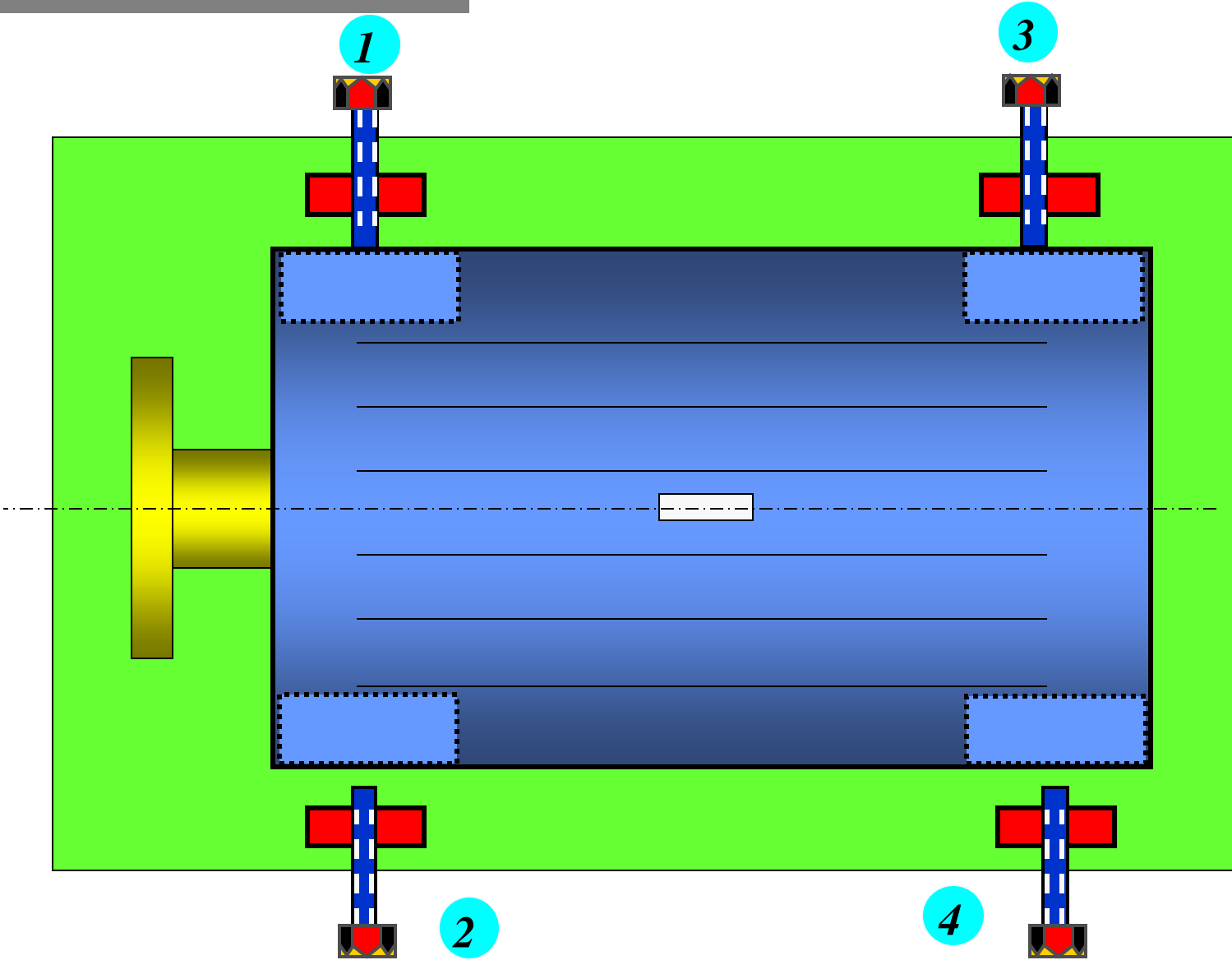
II- HORIZONTAL PLANE

A- Parallel Misalignment



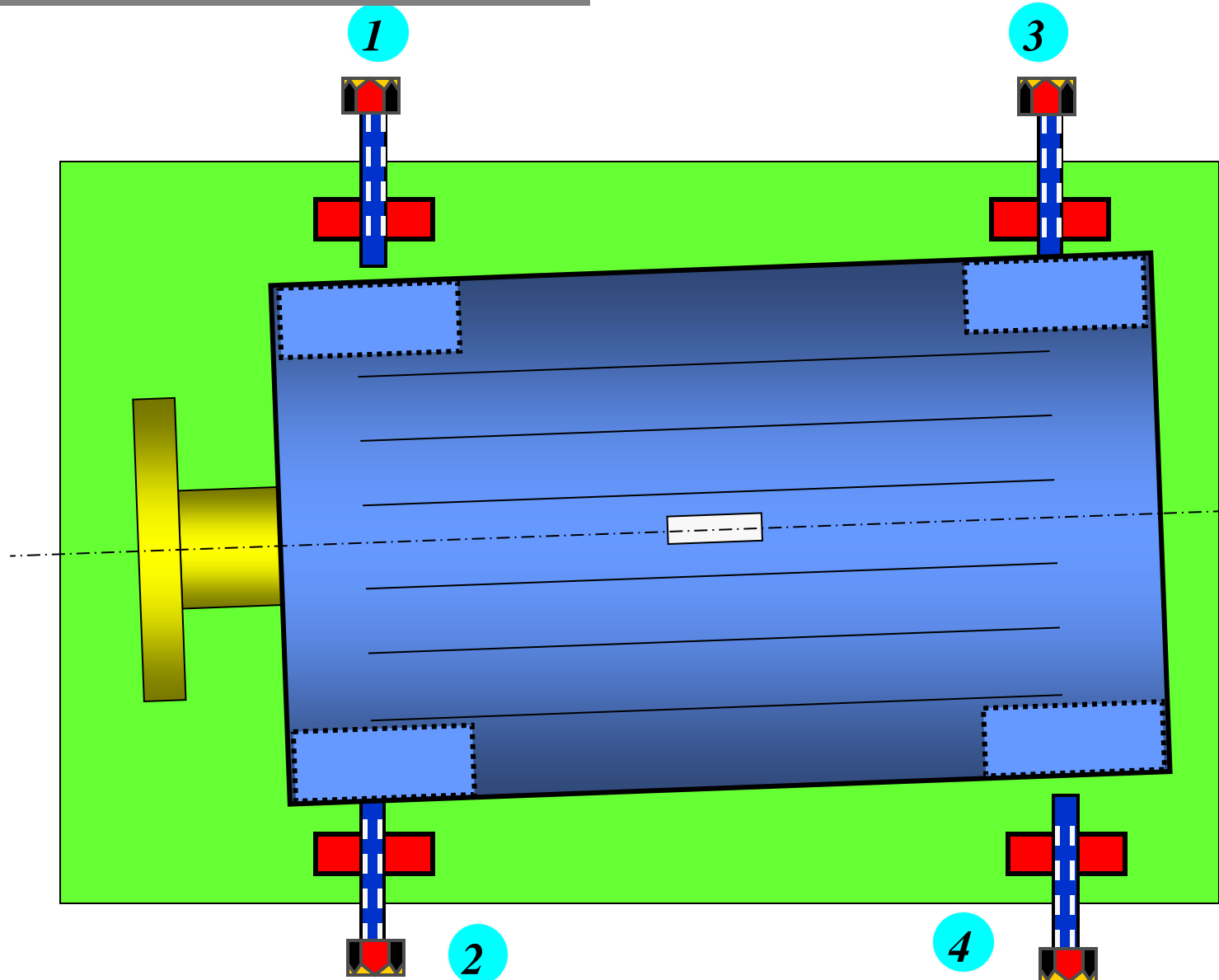
II- HORIZONTAL PLANE

A- Parallel Misalignment



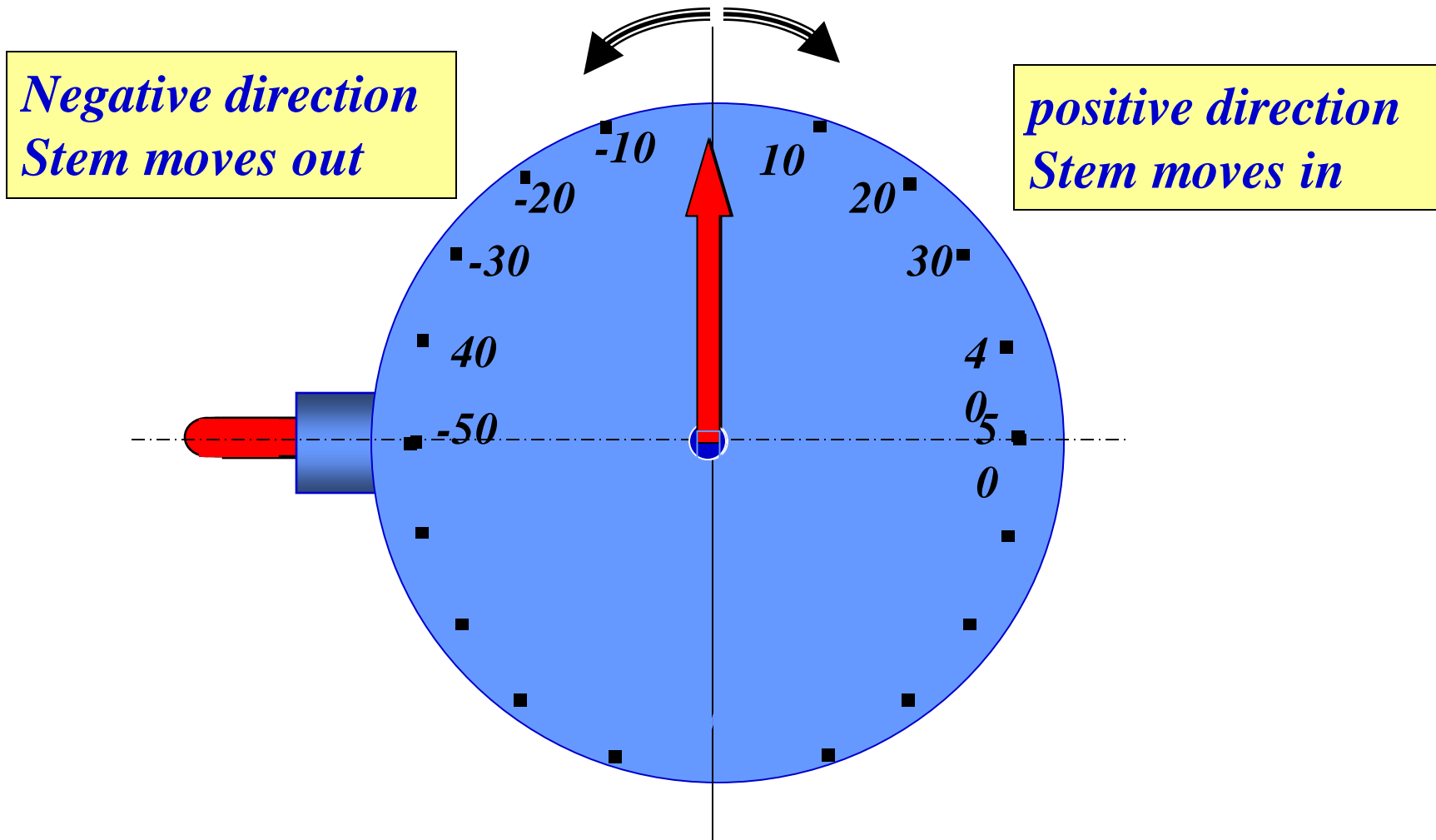
II- HORIZONTAL PLANE

B- Angular Misalignment

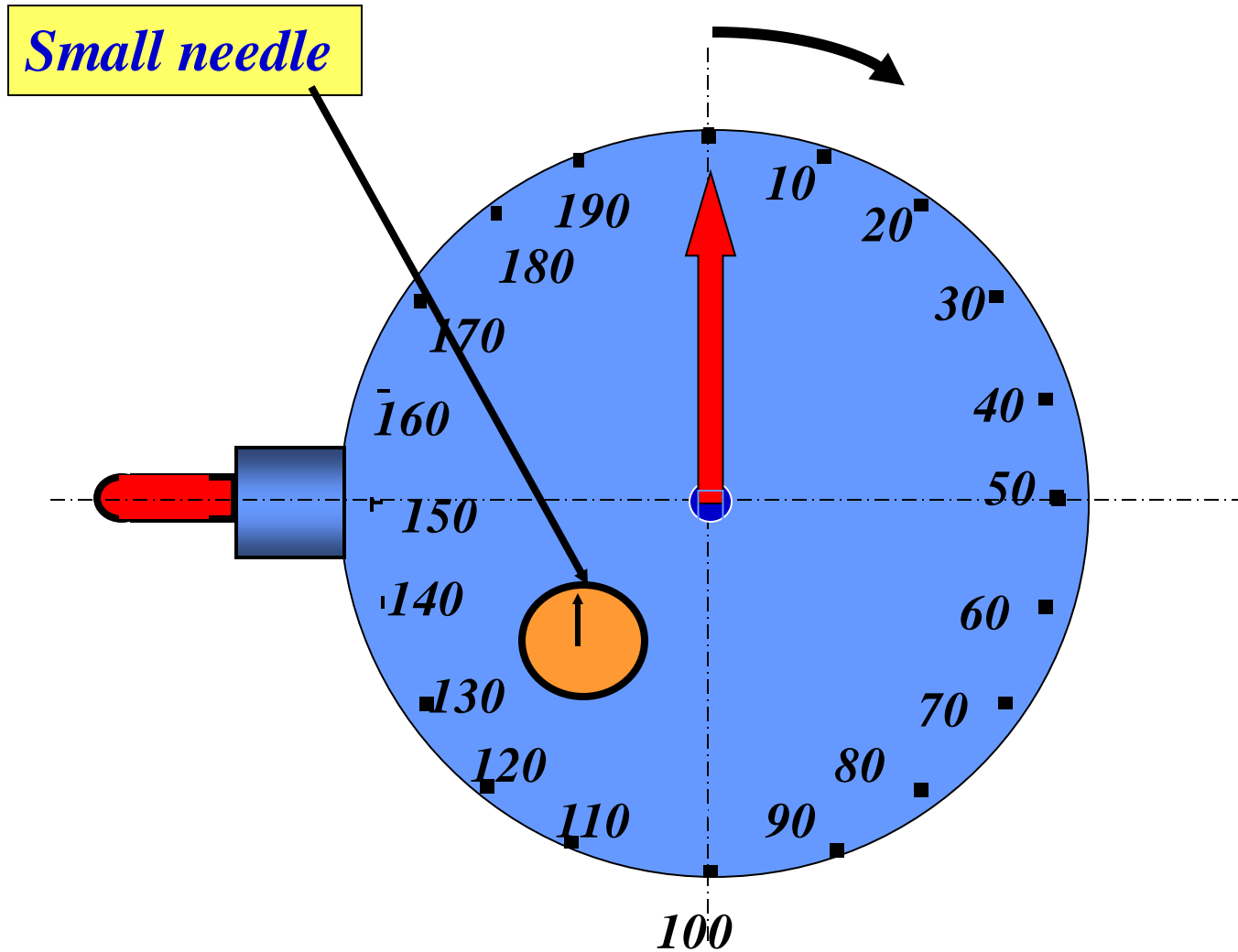


Dial indicators Types and Functions

1- Balanced-Type



- **2 - Continuous Type**



Preparation on Alignment

The following preparatory steps should be taken before attempting to align a machine train:

1. Before placing a machine on its base, make sure that both the base and the bottom of the machine are clean, rust free, and do not have any burrs. Use a wire brush or file on these areas if necessary.
2. Common practice is to position, level, and secure the driven unit at the required elevation prior to adjusting the driver to align with it. Set the driven unit's shaft centerline slightly higher than the driver.
3. Check the motor supports shims (2mm) under legs.

Preparation on Alignment

4. Use only clean shims that have not been "kinked" or that have burrs.
5. Make sure the shaft does not have run out.
6. Before starting the alignment procedure, check for "soft-foot" and correct the condition.
7. Always use the correct tightening sequence procedure on the hold-down nuts.
8. Determine the amount of indicator sag before starting the alignment procedure.

Preparation on Alignment

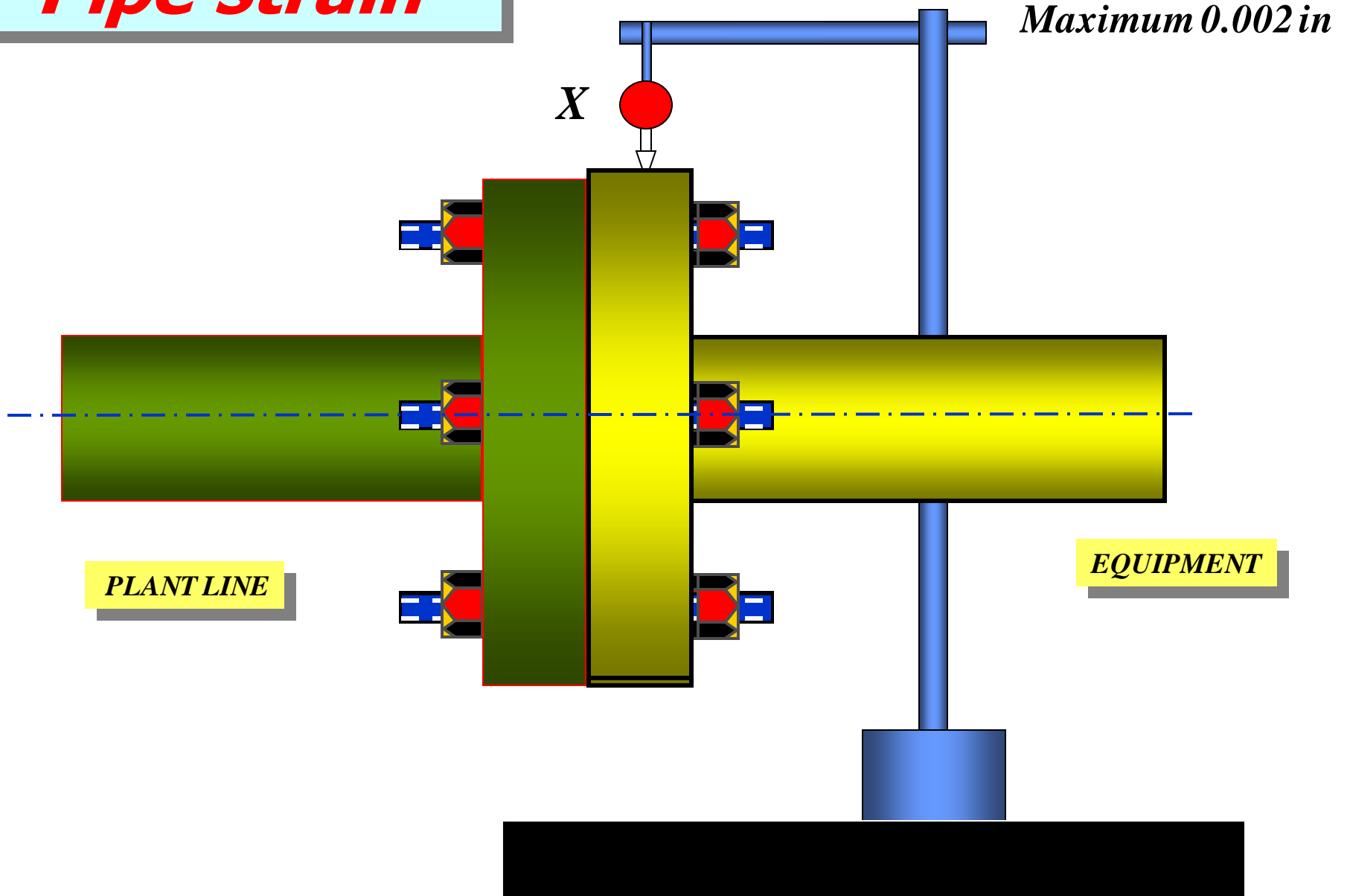
9. Position the stem of the dial indicator so that it is perpendicular to the surface and half travels..

10. Avoid lifting the prime mover more than is absolutely necessary to add or remove shims.

11. Jacking bolt assemblies should be welded onto the bases of all large the prime mover. add them before starting the alignment procedure.

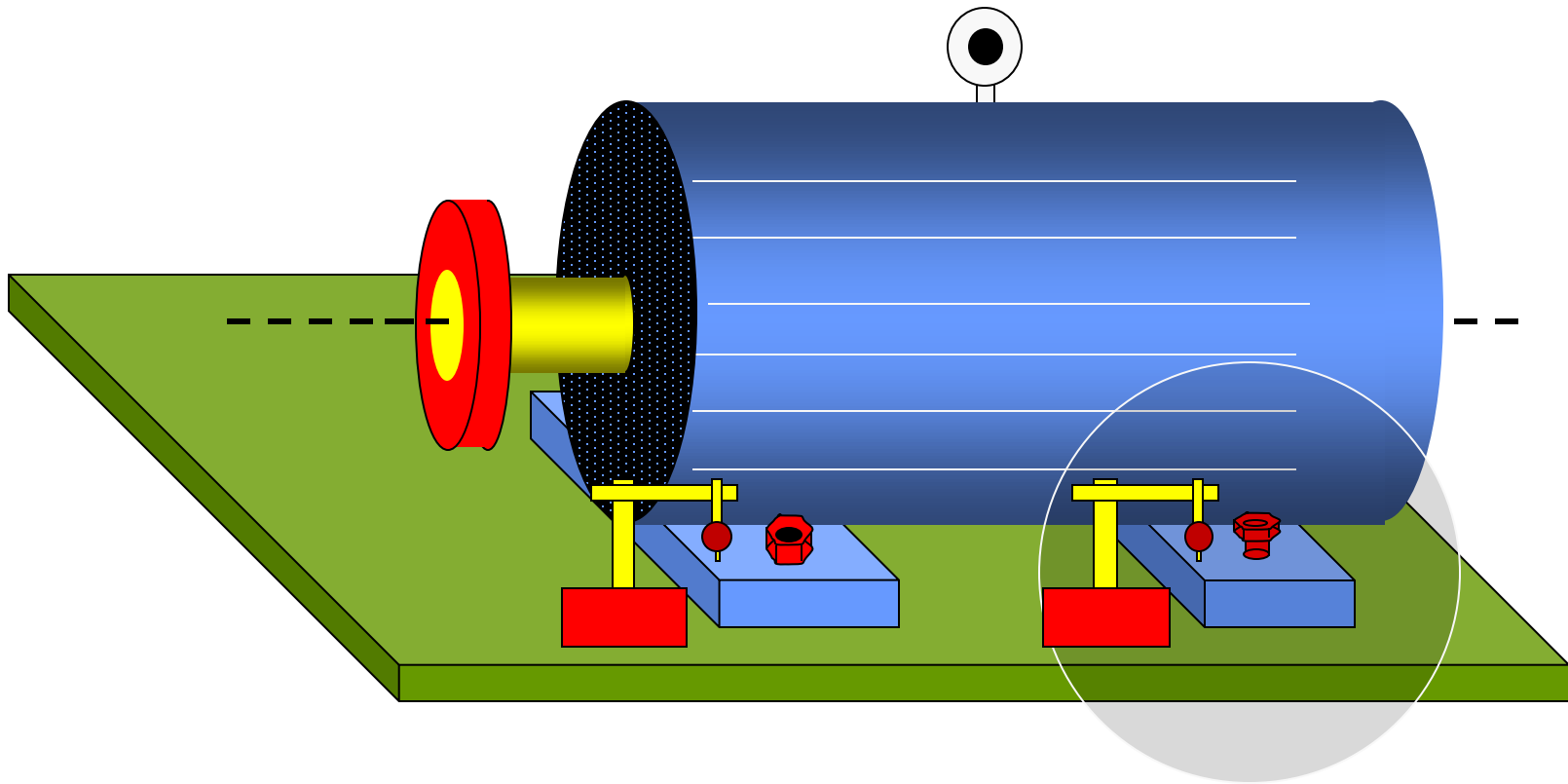
12. Use jacking bolts to adjust for horizontal offset and angular misalignment and to hold the prime mover in place while shimming

** Pipe strain*



*** *Soft foot***

One driver leg is not settled on the base



Maximum 0.002 “

Correcting for Soft-foot

- Soft-foot is the condition when all four of a machine's feet do not support the weight of the machine.
- It is important to determine if this condition is present prior to performing shaft alignment on a piece of machinery.
- As an example, consider a chair with one short leg. The chair will never be stable unless the other three legs are shortened or the short leg is shimmed.
- In this example, the level floor is the "plane" and the bottom tips of the legs are the "points" of the plane.
- Three of the four chair tips will always rest on the floor.

Consequences

Placing a piece of machinery in service with uncorrected soft-foot may result in the following:

- Dial-indicator readings taken as part of the alignment procedure can be different each time the hold-down nuts are tightened, loosened, and retightened. This can be extremely frustrating because each attempted correction can cause a soft-foot condition in another location.
- The nuts securing the feet to the base may loosen, resulting in either machine looseness and/or misalignment. Either of these conditions can cause vibration.

- If the nuts do not loosen, metal fatigue may occur at the source of Soft-foot. Cracks can develop in the support base/frame and, in extreme cases, the soft-foot may actually break off.
- Initial Soft-foot Correction the following steps should be taken to check for and correct soft-foot.
- Before setting the machine in place, remove all dirt, rust, and burrs from the bottom of the machine's feet, the shims to be used for leveling, and the base at the areas where the machine's feet will rest.
- Set the machine in place, but do not tighten the hold-down nuts.

Final Soft-foot Correction

- The following procedure describes the final soft-foot correction:
- Tighten all hold-down nuts on both the stationary machine and the machine to be shimmed
- Secure a dial indicator holder to the base of the stationary machine. The stem of the dial indicator should be in a vertical position above the foot to be checked. A magnetic-base indicator holder is most suitable for this purpose.
- Set the dial indicator to zero.
- Completely loosen the hold-down nut on the foot to be checked. Watch the dial indicator closely for foot movement during the loosening process.
- If the foot rises from the base when the hold-down nut is loosened, place beneath the foot an amount of shim stock equal to the amount of deflection shown on the dial indicator.

- Retighten the hold-down nut and repeat the entire process once again to ensure that no movement occurs.
- Move the dial indicator and holder to the next foot to be checked and repeat the process. Note: The nuts on all of the other feet must remain securely tightened when a foot is being checked for a soft-foot condition.
- Repeat the above process on all of the feet.
- Make a three-point check on each foot by placing a feeler gauge under each of the three exposed sides of the foot.
- Tightening Hold-Down Nuts Once the soft-foot is removed, Always tighten the nuts as though the final adjustment has been made, even if the first set of readings has not been taken

The following procedure should be followed:

After eliminating soft-foot, loosen all hold-down nuts.

- Number each machine foot in the sequence in which the hold-down nuts will be tightened during the alignment procedure. The numbers (1, 2, 3, and 4) should be permanently marked on, or near, the feet.
- It is considered a good idea to tighten the nuts in an X pattern
" Always tighten the nuts in the sequence in which the positions are numbered (1, 2, 3, and 4).
- Use a torque wrench to tighten all nuts with the same amount of torque.

Indicator Sag

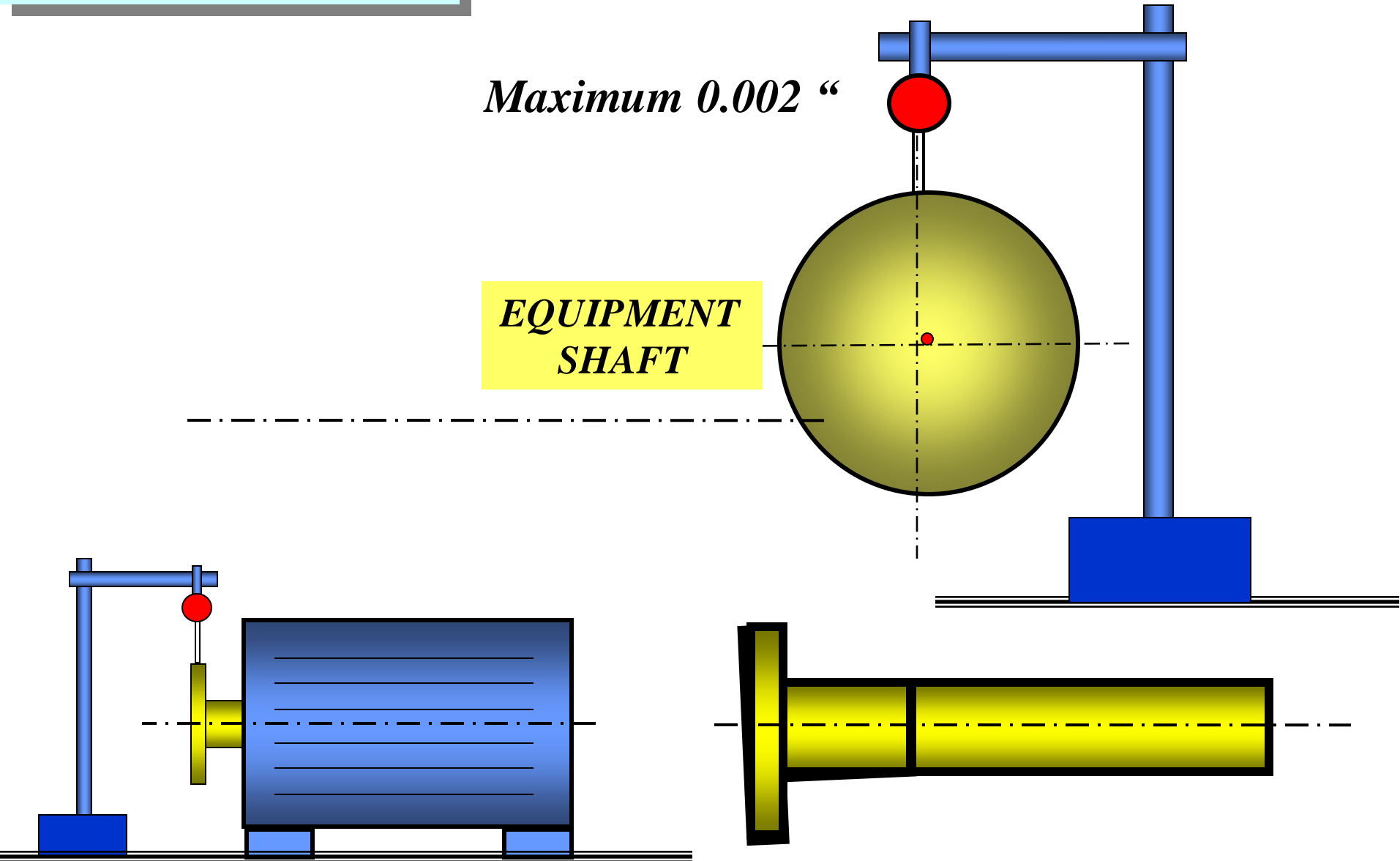
- Indicator sag is the term used to describe the bending of the mounting hardware as the dial indicator is rotated from the top position to the bottom position during the alignment procedure.
- Bending can cause significant errors in the indicator readings that are used to determine vertical misalignment, especially in rim-and-face.
- The degree to which the mounting hardware bends depends on the length and material strength of the hardware.
- To ensure that correct readings are obtained with the alignment apparatus, it is necessary to determine the amount of indicator sag present in the equipment and to correct the bottom or 6 o'clock readings before starting the alignment process.

- Indicator sag is best determined by mounting the dial indicator on a piece of straight pipe of the same length as in the actual application. Zero the dial indicator at the 12 o'clock, or upright, position and then rotate 180 degrees to the 6 o'clock position.
- The reading obtained, which will be a negative number, is the measure of the mounting-bracket indicator sag for 180 degrees of rotation and is called the sag factor.
- All bottom or 6 o'clock readings should be corrected by subtracting the sag factor.
- When two shafts are perfectly aligned, the mounting rod should be parallel to the axis of rotation of the shafts. However, the rod bends or sags by an amount usually measured in mils (thousandths of an inch)

*** Run out**

Maximum 0.002 "

**EQUIPMENT
SHAFT**



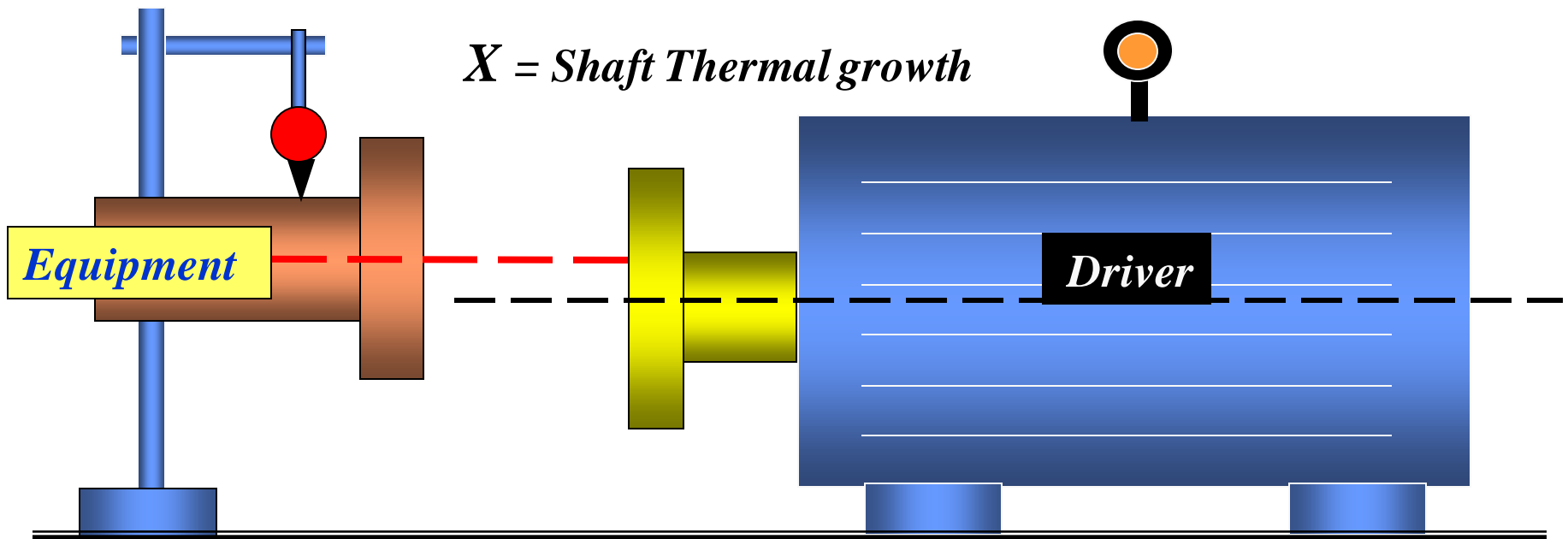
Growth factors (Expansion factor) (mil/in./F) for common materials are as follows:

Aluminum	0.0126
Bronze	0.0100
Cast iron, gray	0.0059
Stainless steel	0.0074
Mild steel, ductile iron	0.0063

- For vertical growth, L is usually taken as the vertical height from the bottom of the foot where shims touch the machine to the shaft centerline.
- In the case where the machine is mounted on a base that has significant temperature variations along its length, L is the vertical distance from the concrete or other constant temperature base line to the shaft centerline.

* *Thermal growth for hot liquid pumps*

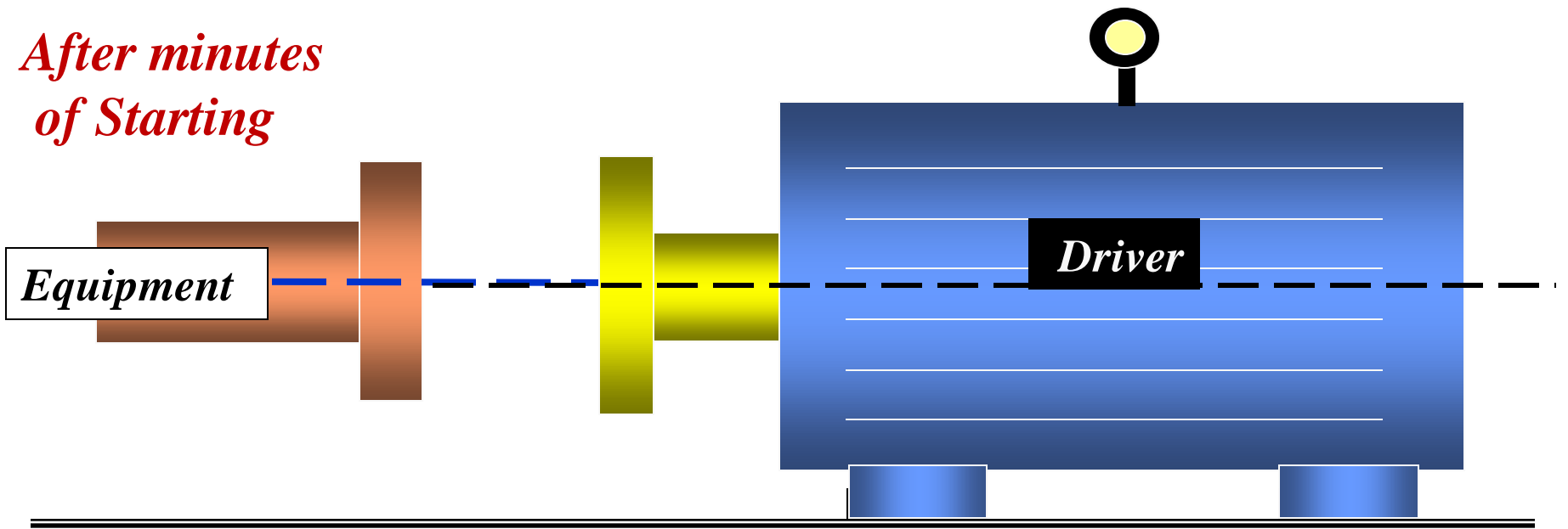
- 1- Apply the alignment procedure for the pump at ambient Temp.
- 2- Heat up the pump by opening the start up bypass for ½ hrs.
- 3- Put the dial indicator on the shaft and adjust to zero reading
- 4- close the bypass
- 5- Take the dial indicator reading after 24 hrs.
- 6- This reading is the shaft thermal growth
- 7- Add the center line thermal growth reading under the driver legs



** Thermal growth for Compressors*

- 1- Apply the alignment procedure for the compressor at ambient Temp.
 - 2- Go to catalogue and read the center line thermal growth amount.
 - 3- Add the center line thermal growth reading under the driver legs
 - 4- If the equipment manual gives the hale equipment thermal growth
- The center line thermal growth = The hale equipment thermal growth /2

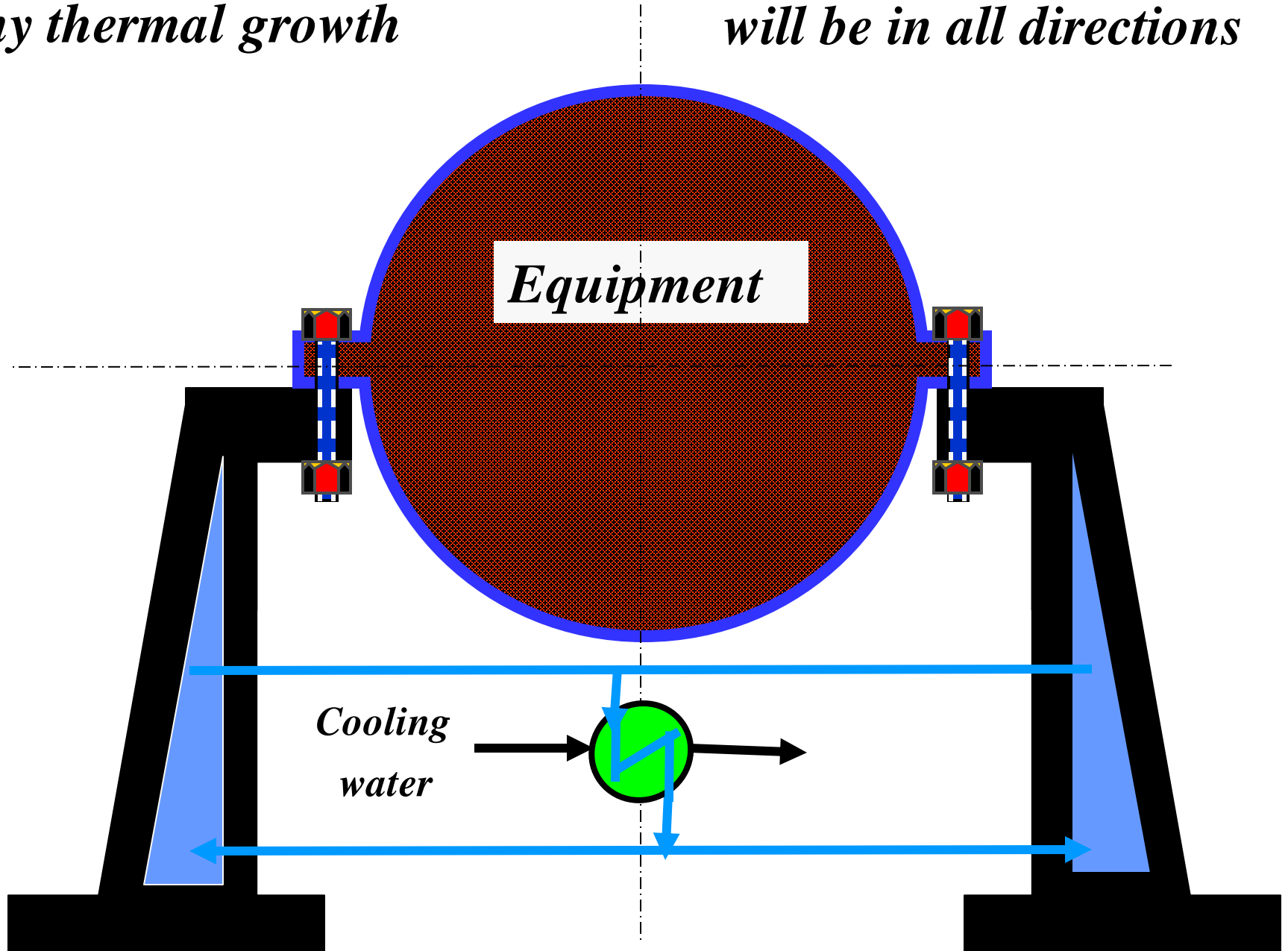
*After minutes
of Starting*



X = The center line Thermal growth

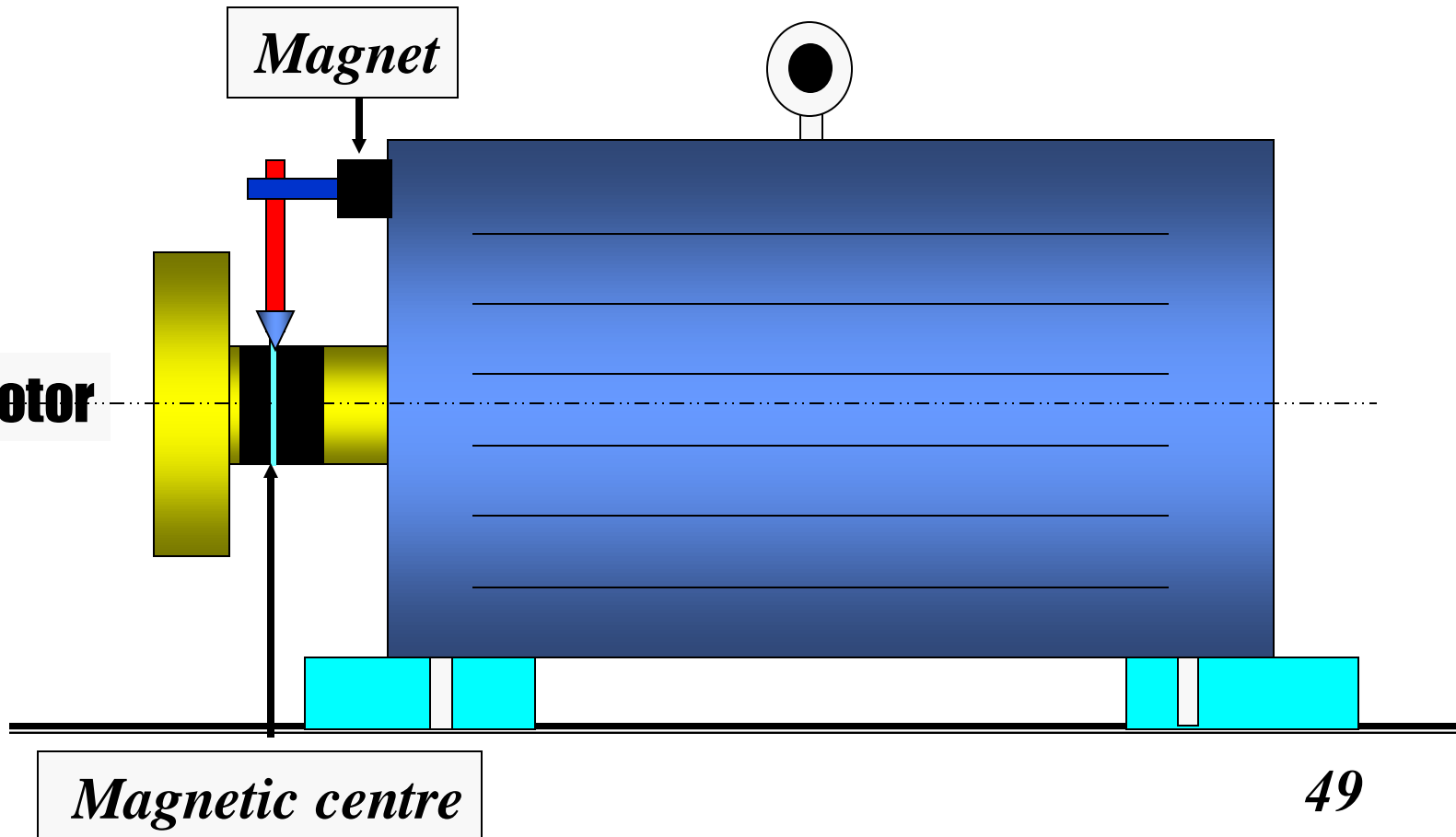
This design is to avoid any thermal growth

As thermal expansion will be in all directions

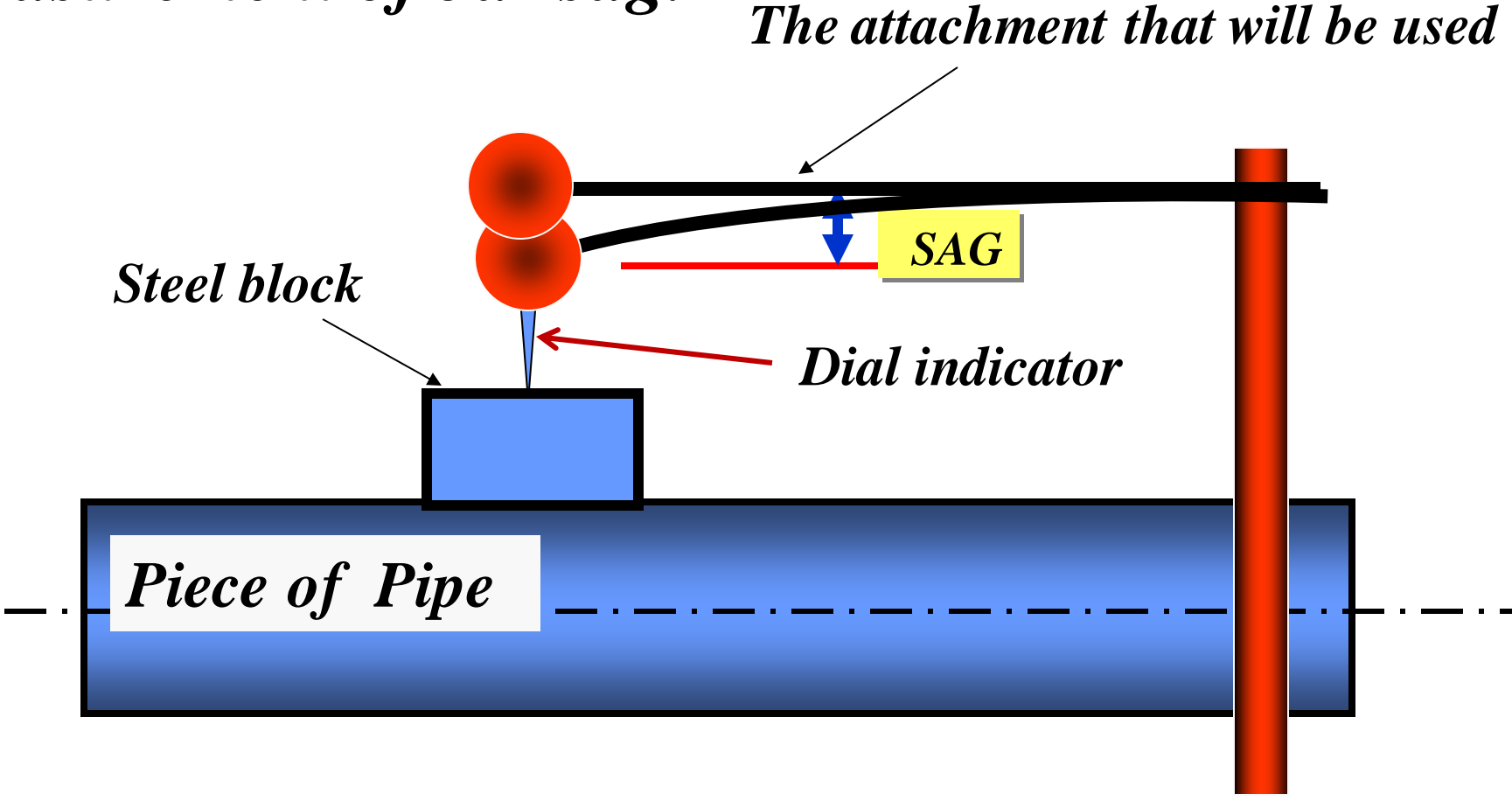


****Magnetic centre.***

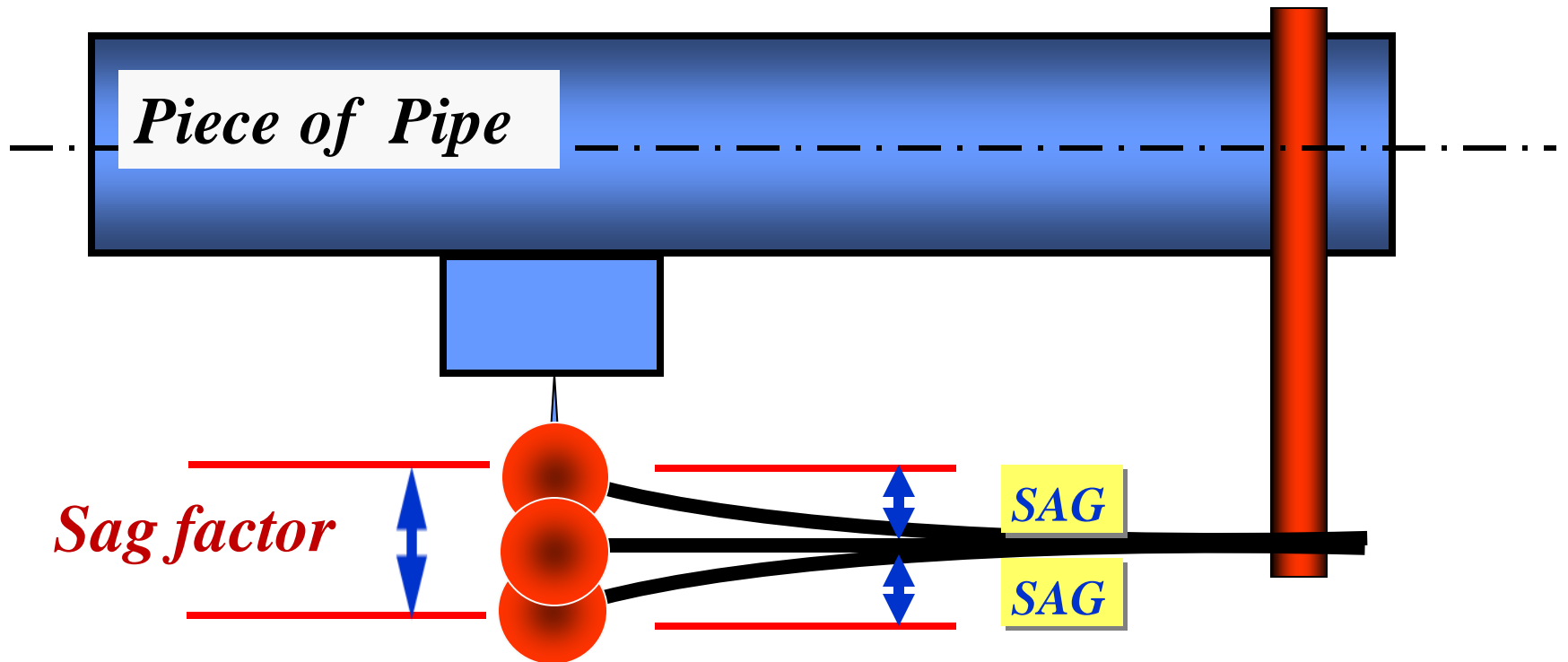
*Electrical motors have no thrust bearings
as they have instead a magnetic center*



Measurement of bar sag.



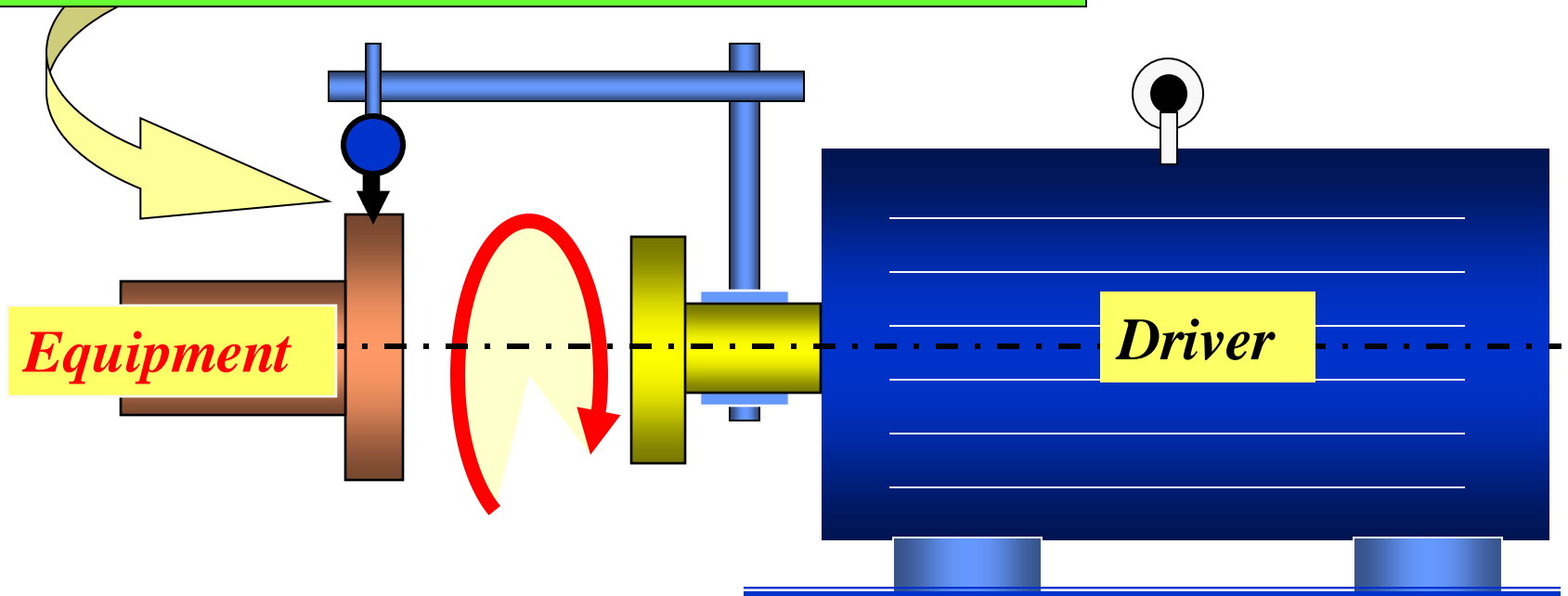
Bar Sag on 12 O'clock Position



How To Do Alignment

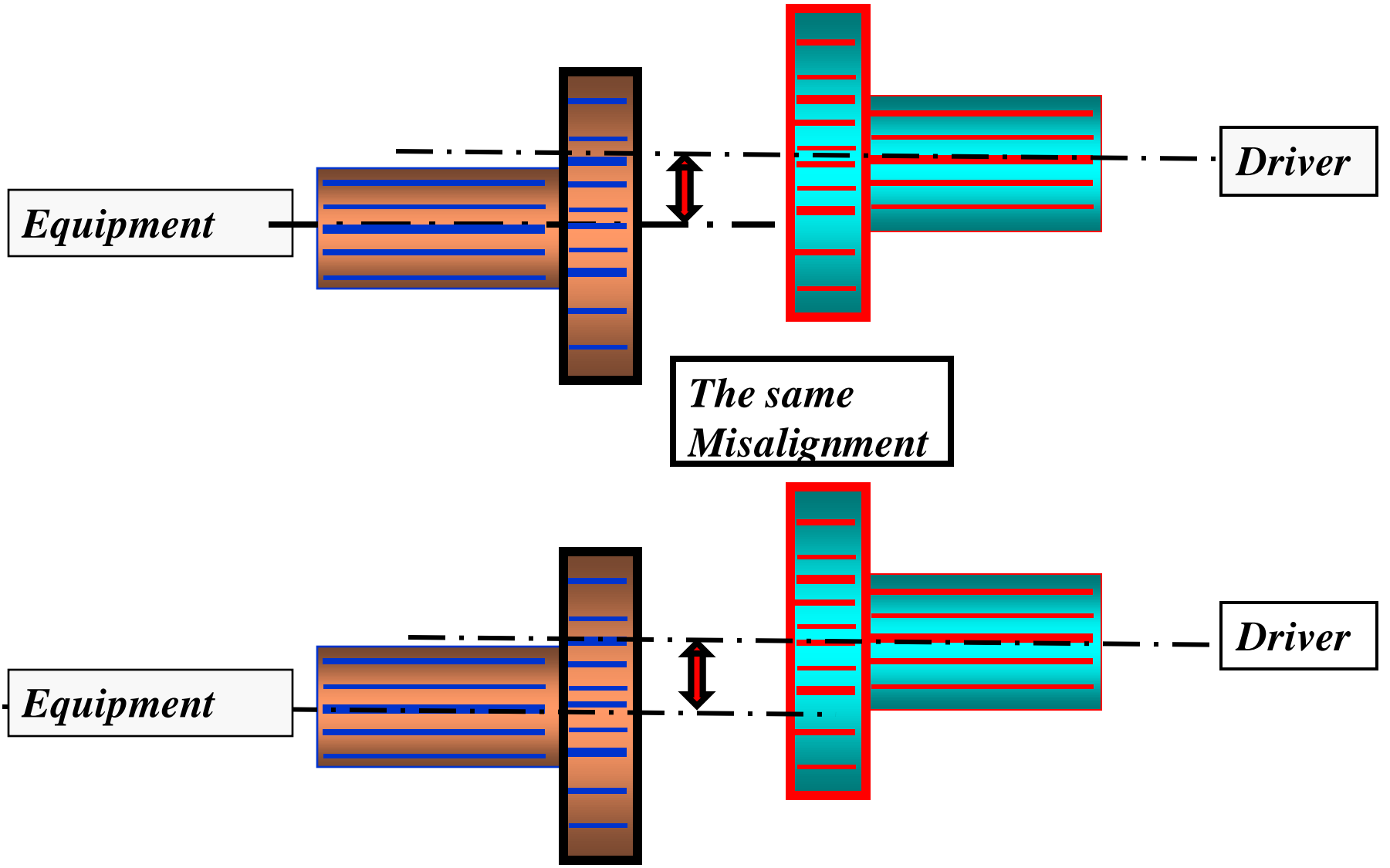
Gauge Pointer

does not move around the rim



Motor and Equipment shaft

Rotate in the same time



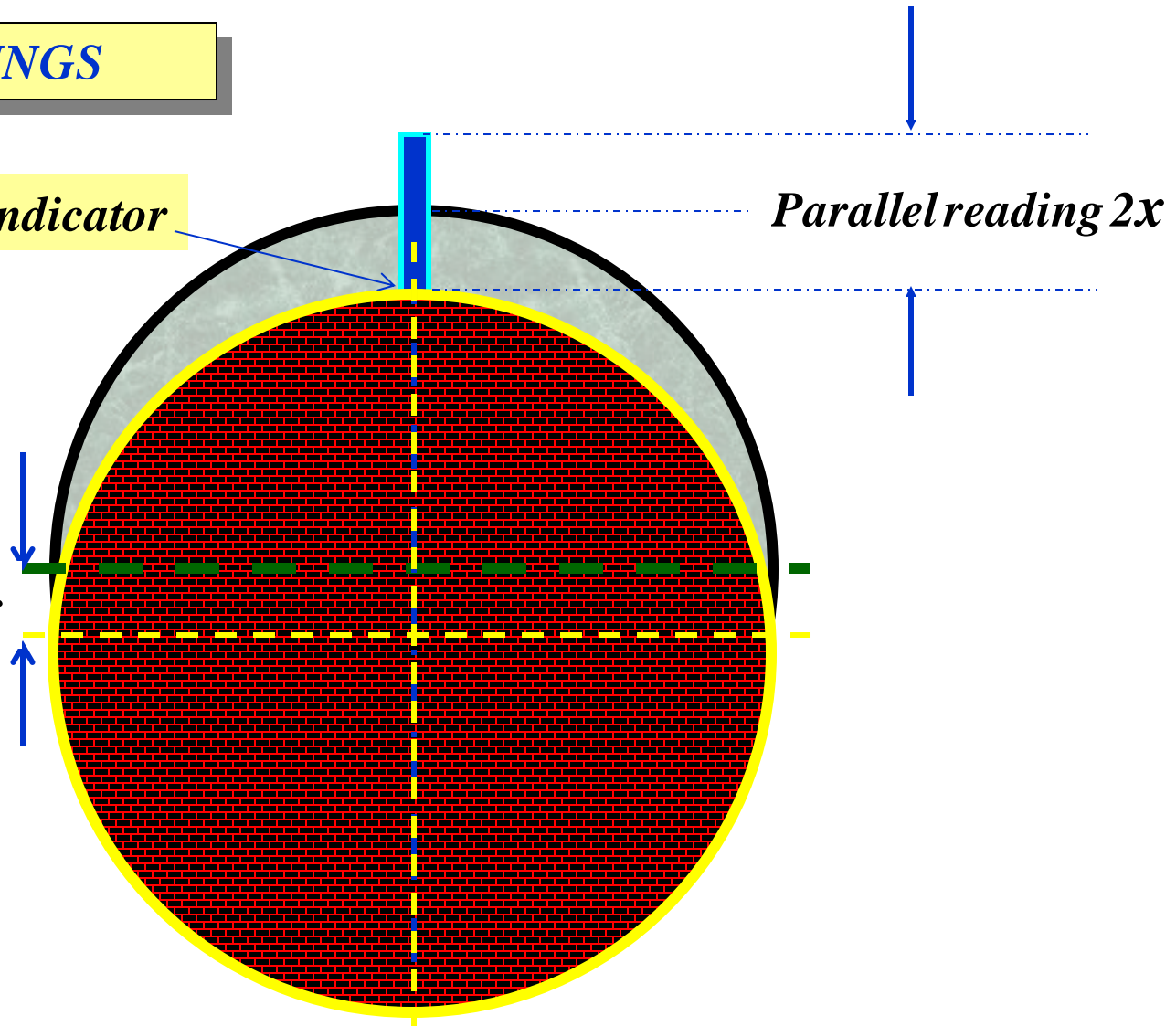
VERTICAL READINGS

Dial indicator

Parallel reading $2x$

Parallel actual misalignment x

x



HORIZONTAL READINGS

If:

- Both shafts rotate

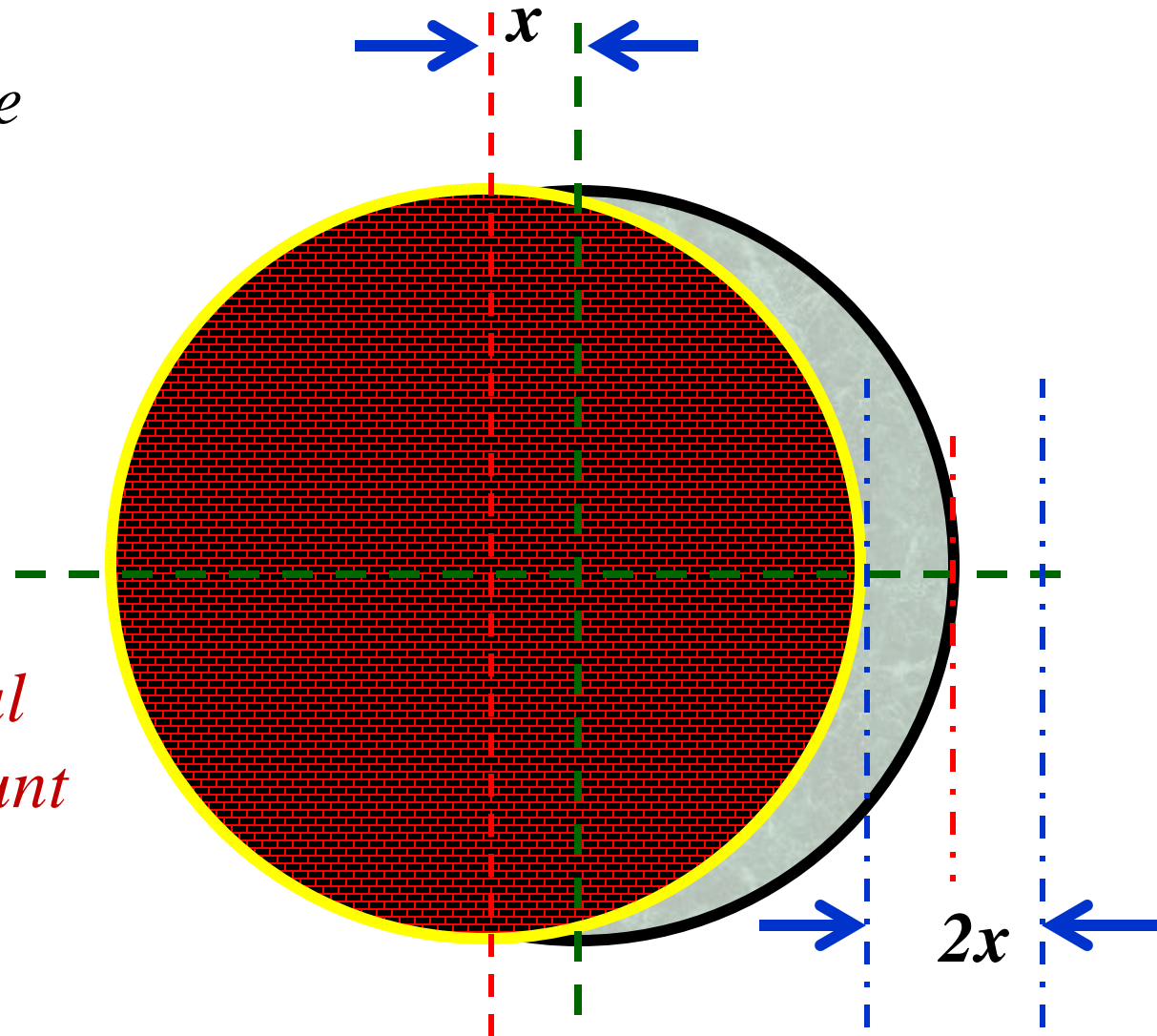
Or - One shaft rotates

The dial indicator reading is the same,

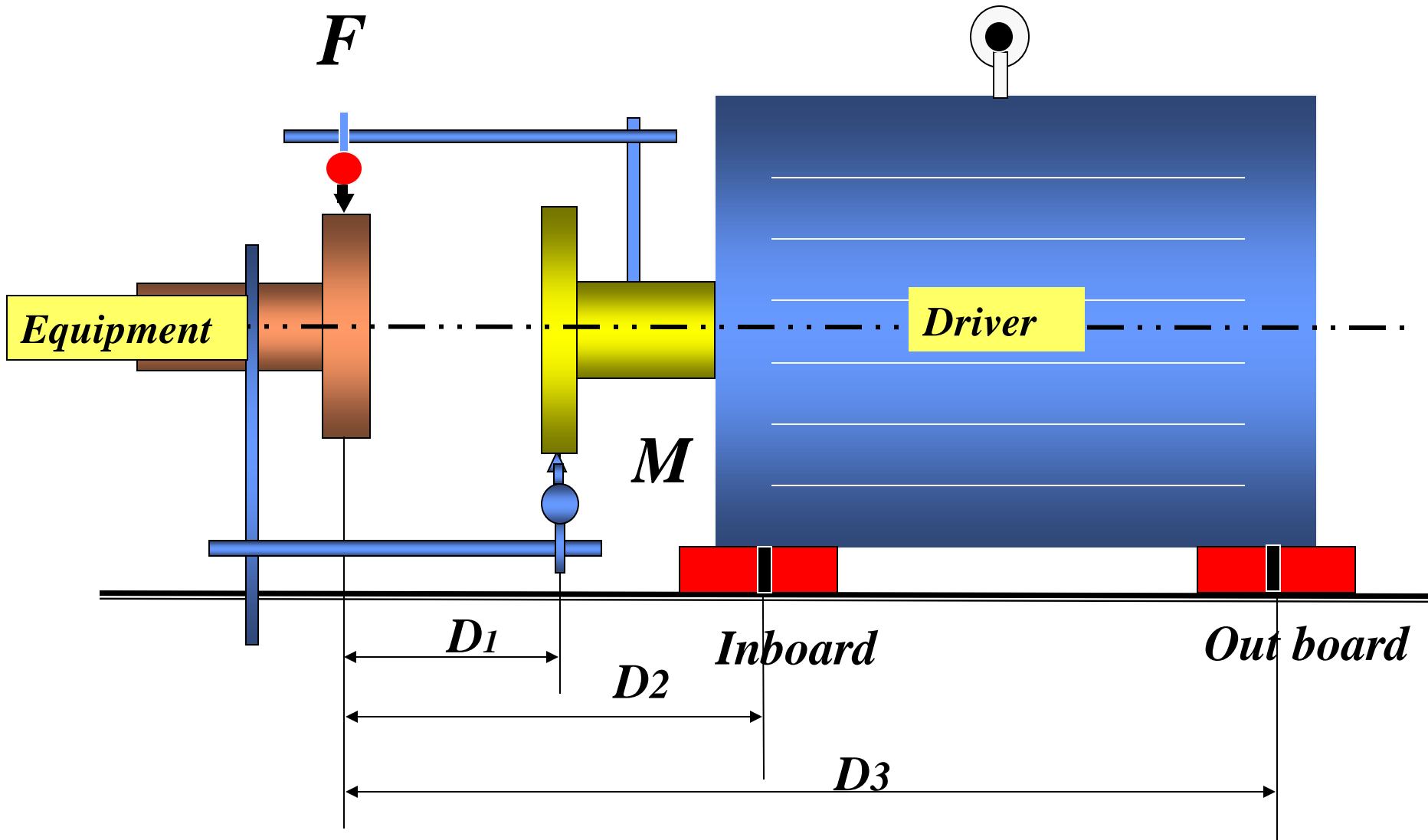
And equal to:

Double of the actual Misalignment amount

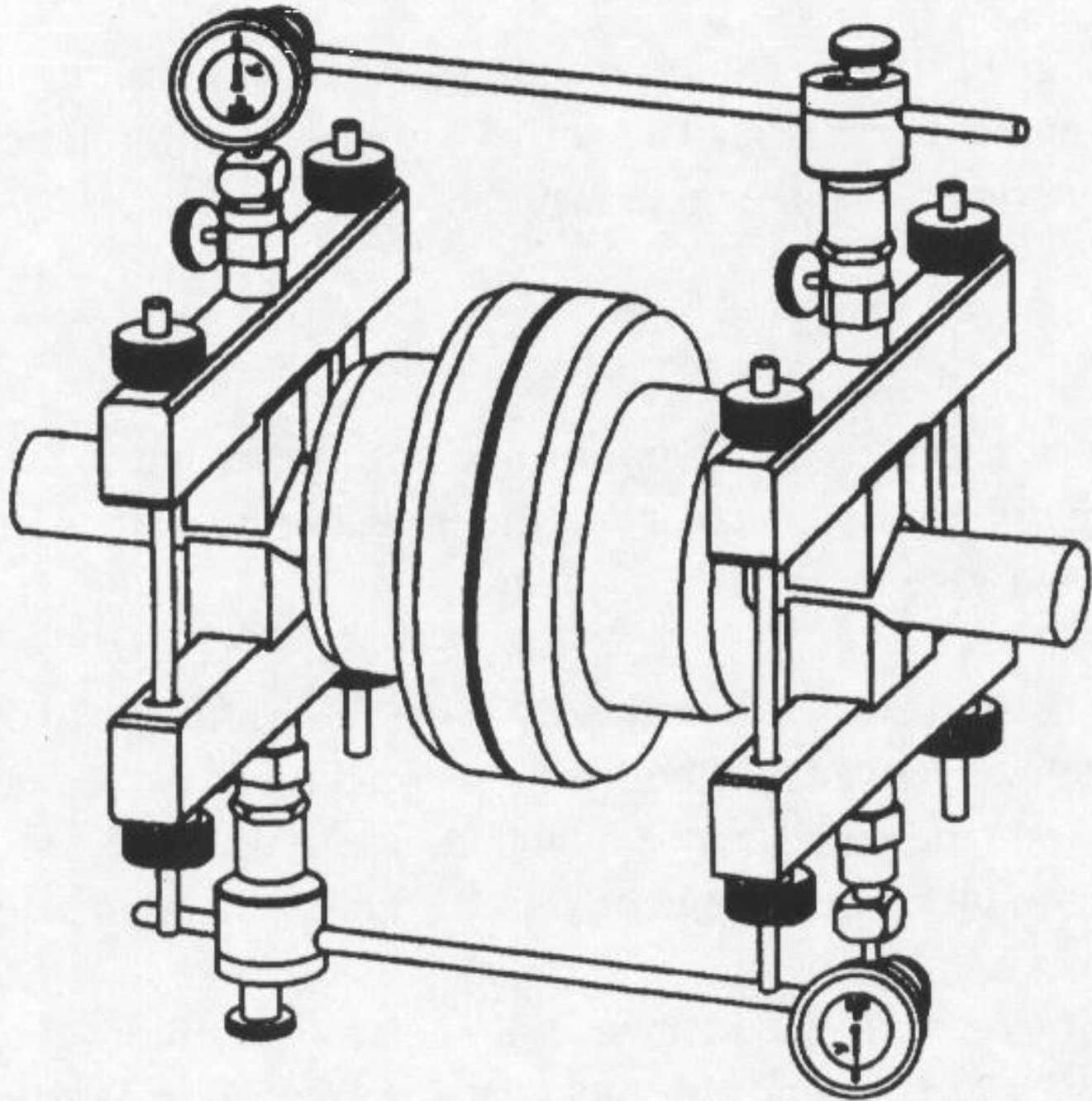
Parallel actual misalignment



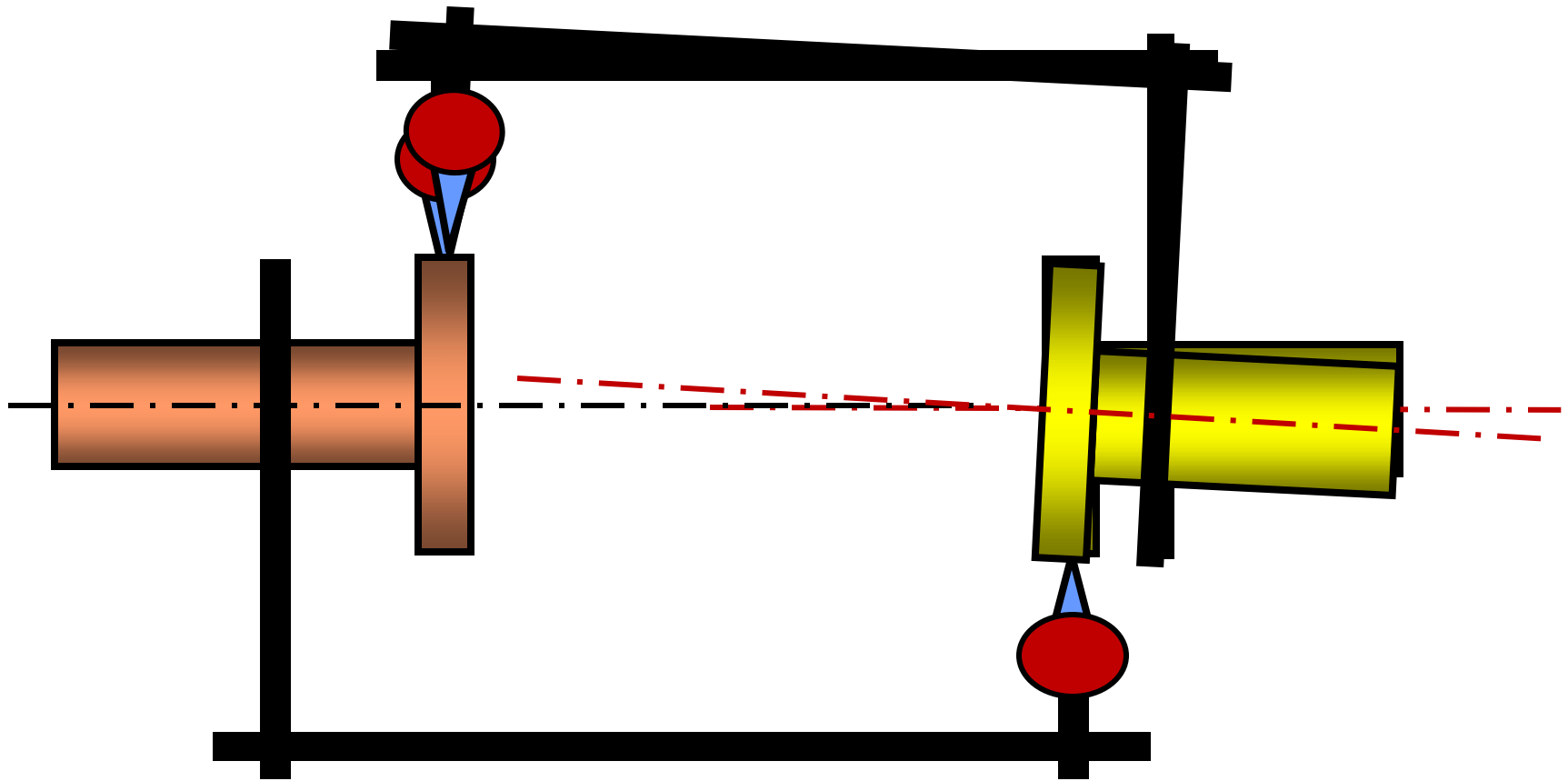
1-Reversal Alignment



F



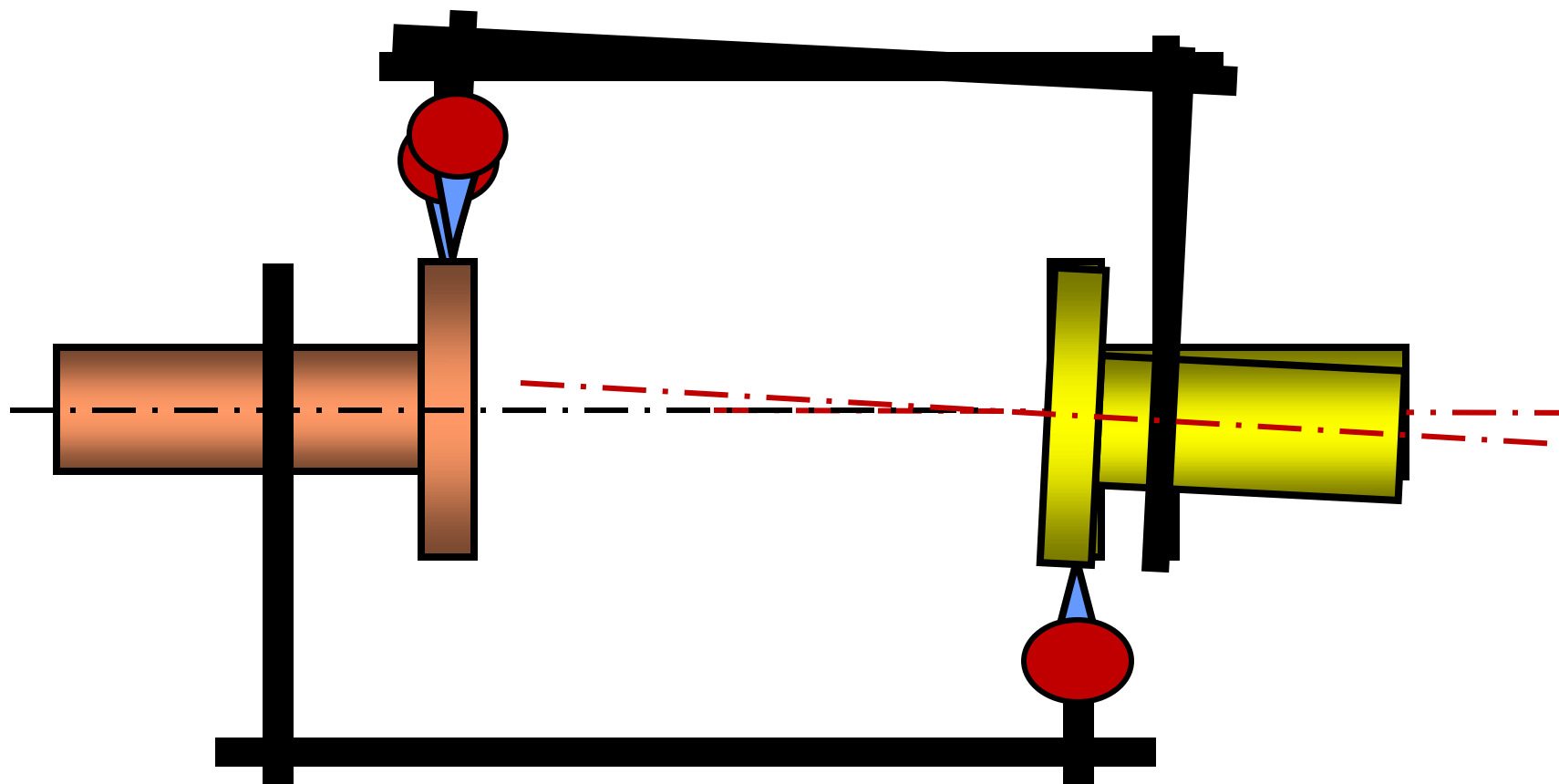
M

F M 

**The Reversal alignment method,
eliminates the Angular misalignment due to prime
mover axial movement**

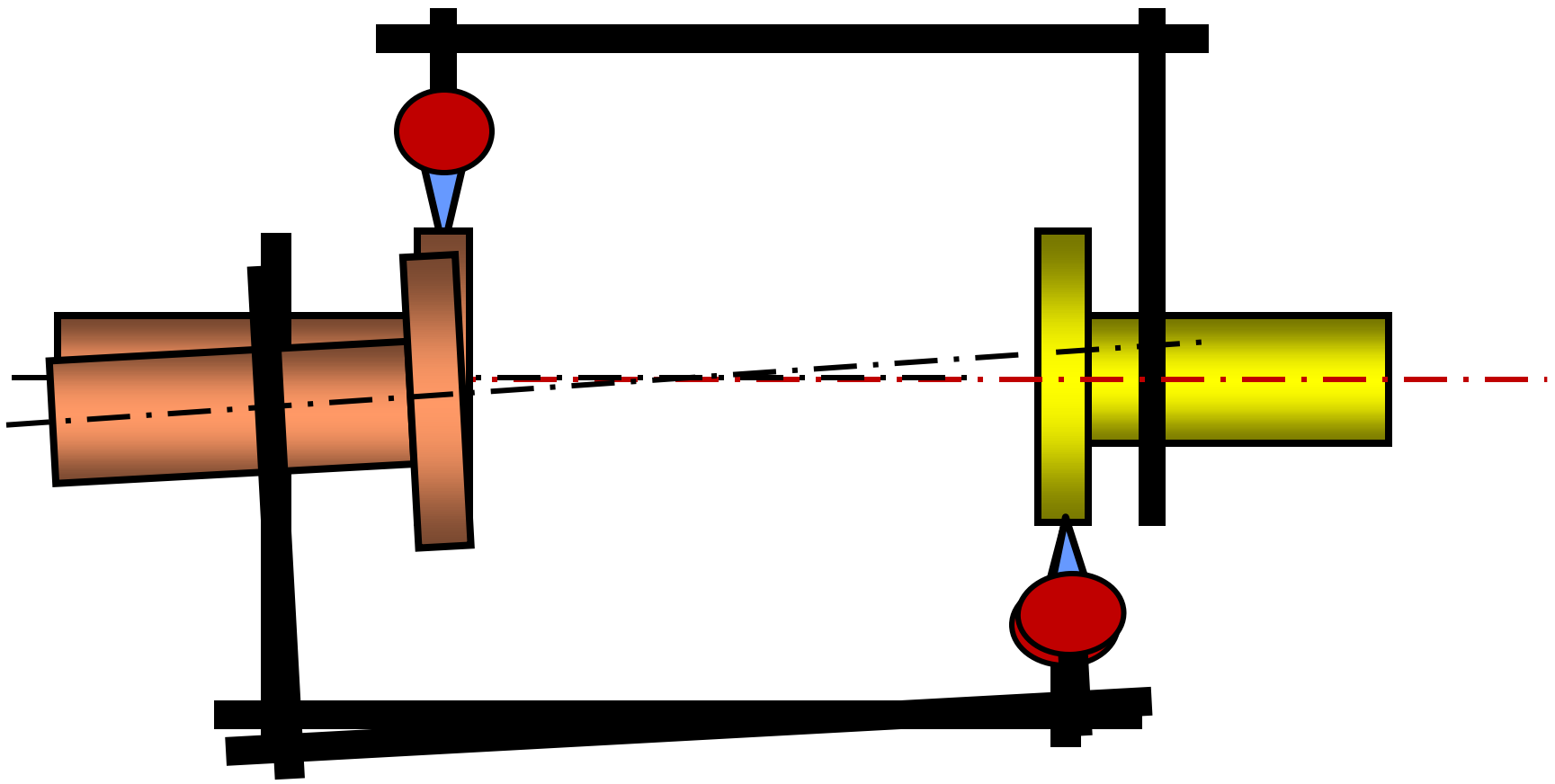
F

M



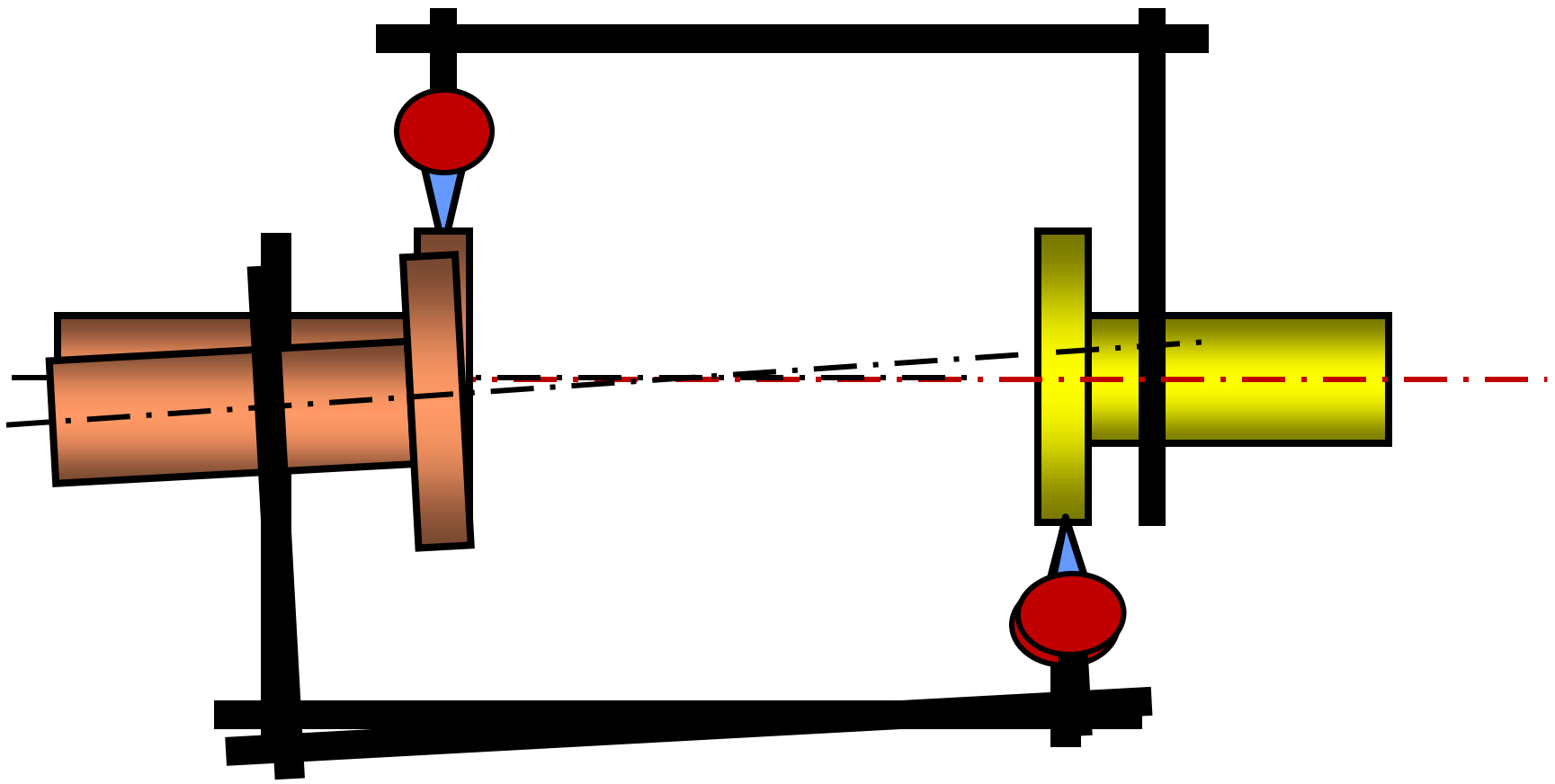
F

M



F

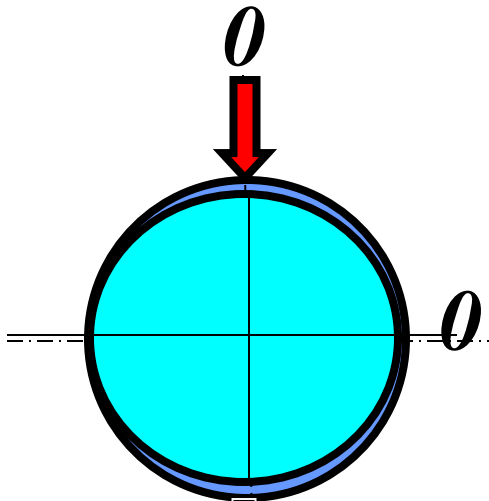
M



PARALELL READINGS

Fixed

12 Ock

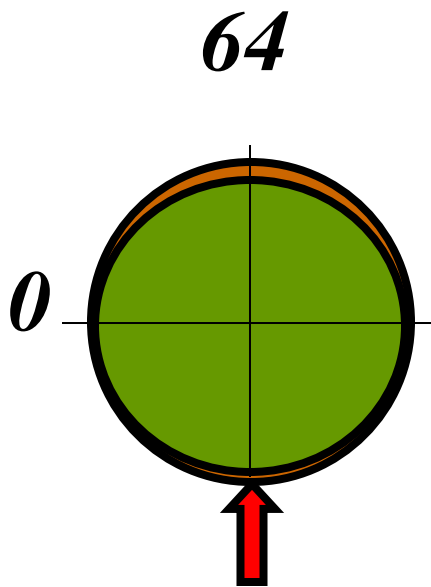


36

6 Ock

Movable

12 Ock



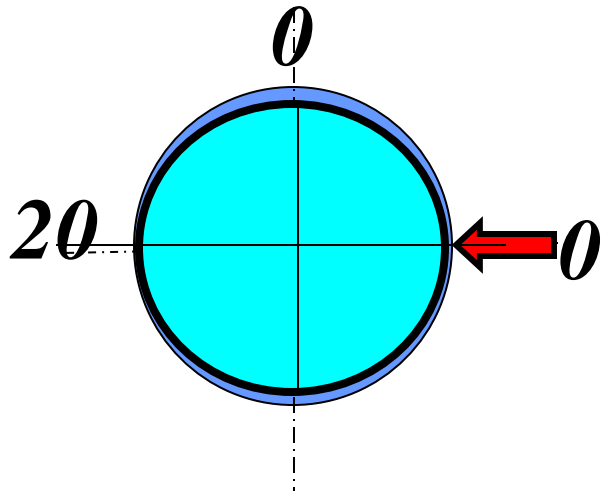
0

6 Ock

PARALELL READINGS

Fixed

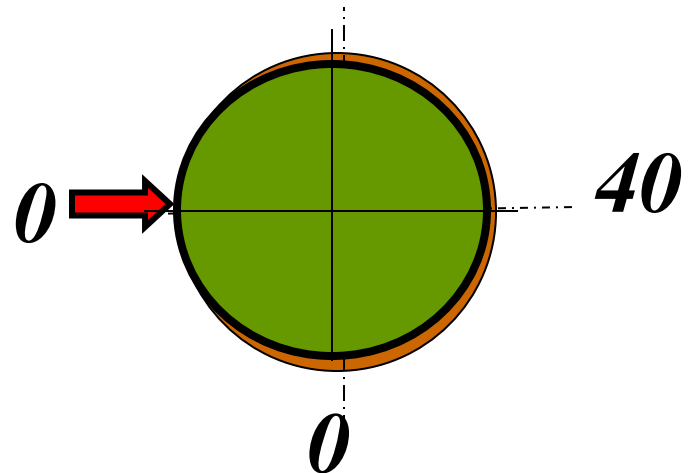
12 Ock



6 Ock

Movable

12 Ock



6 Ock

*1-Reversal
Alignment
Calculation
Method*

$$D 1 =$$

$$D 2 =$$

$$D 3 =$$

$$Sag = (0)$$

VERTICALLY

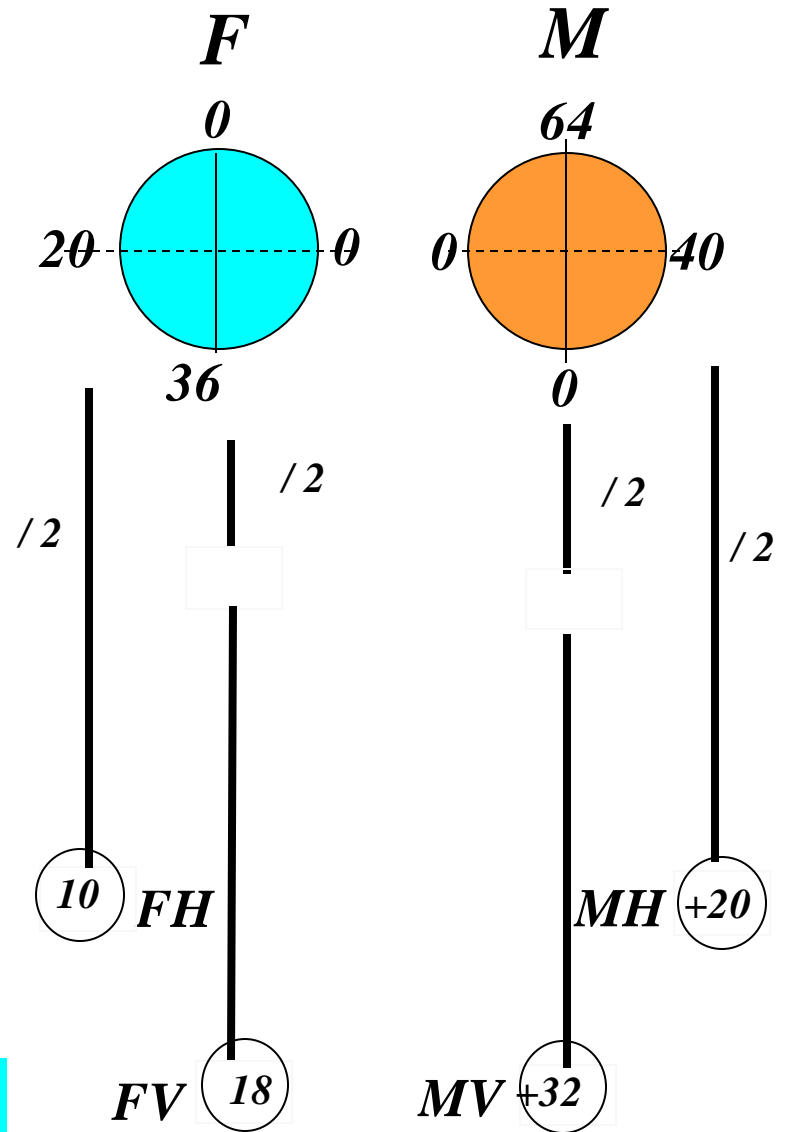
$$INBOARD = \{ MV - FV \} \frac{D 2}{D 1} + FV$$

$$OUTBOARD = \{ MV - FV \} \frac{D 3}{D 1} + FV$$

HORIZONTALLY

$$INBOARD = \{ MH - FH \} \frac{D 2}{D 1} + FH$$

$$OUTBOARD = \{ MH - FH \} \frac{D 3}{D 1} + FH$$



Mils

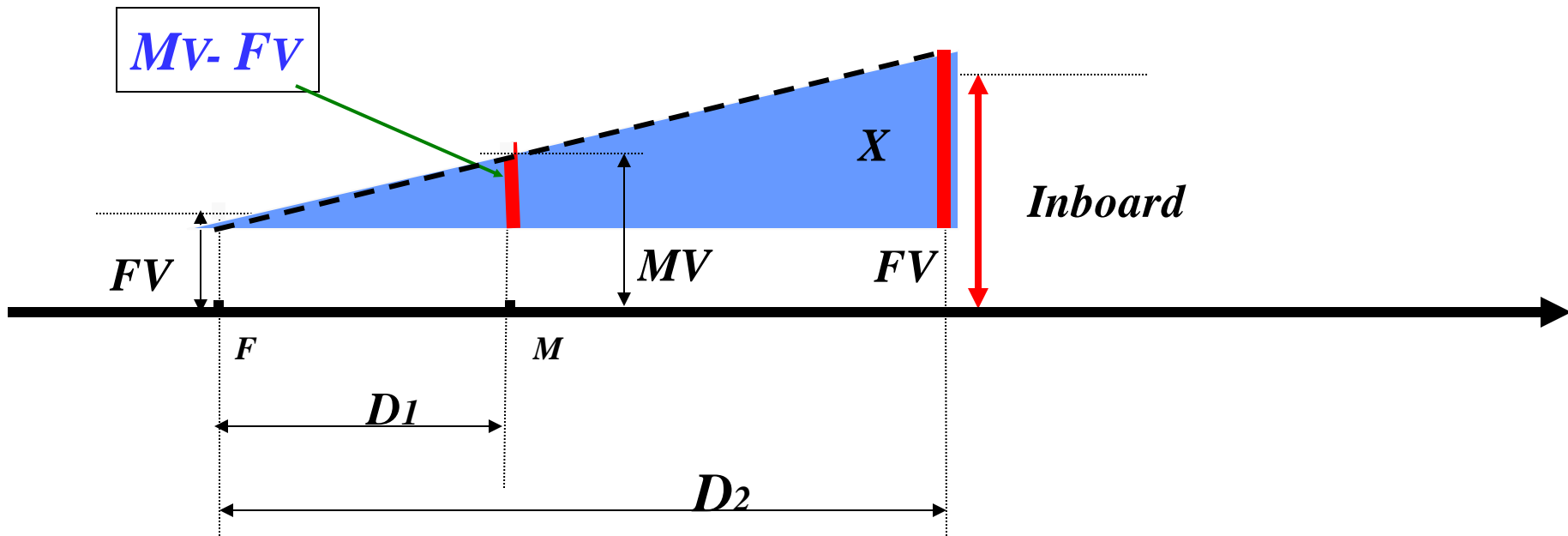
VERTICALLY

$$INBOARD = X + FV$$

$$\frac{X}{Mv - Fv} = \frac{D_2}{D_1}$$

$$INBOARD = \{ Mv - Fv \} \frac{D_2}{D_1} + FV$$

$$X = \{ Mv - Fv \} \frac{D_2}{D_1}$$



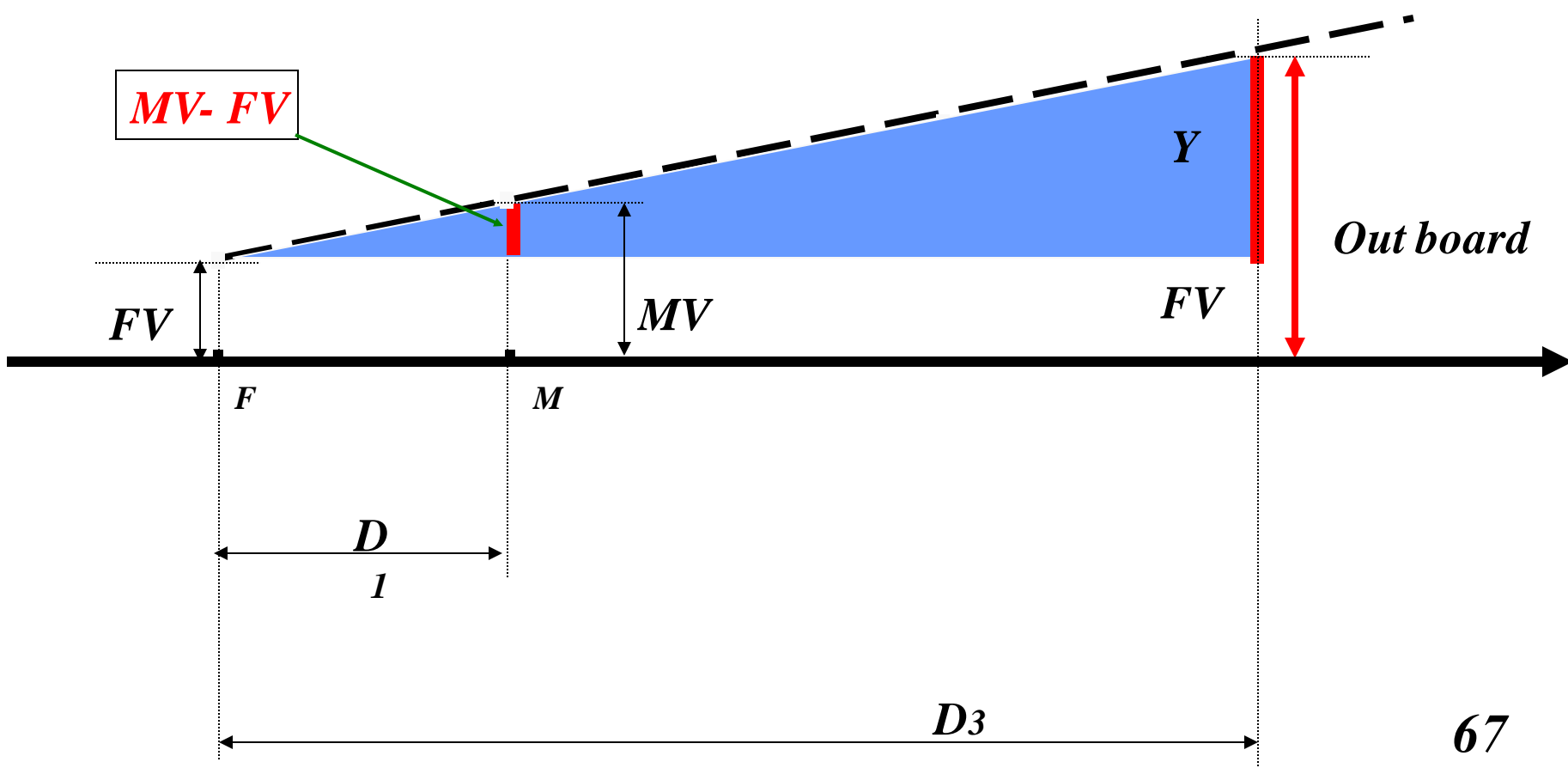
VERTICALLY

$$\text{OUTBOARD} = Y + FV$$

$$\frac{Y}{Mv - Fv} = \frac{D_3}{D_1}$$

$$\text{OUTBOARD} = \{ Mv - Fv \} \frac{D_3}{D_1} + FV$$

$$Y = \{ Mv - Fv \} \frac{D_3}{D_1}$$



$$D1 = 4 \text{ in}$$

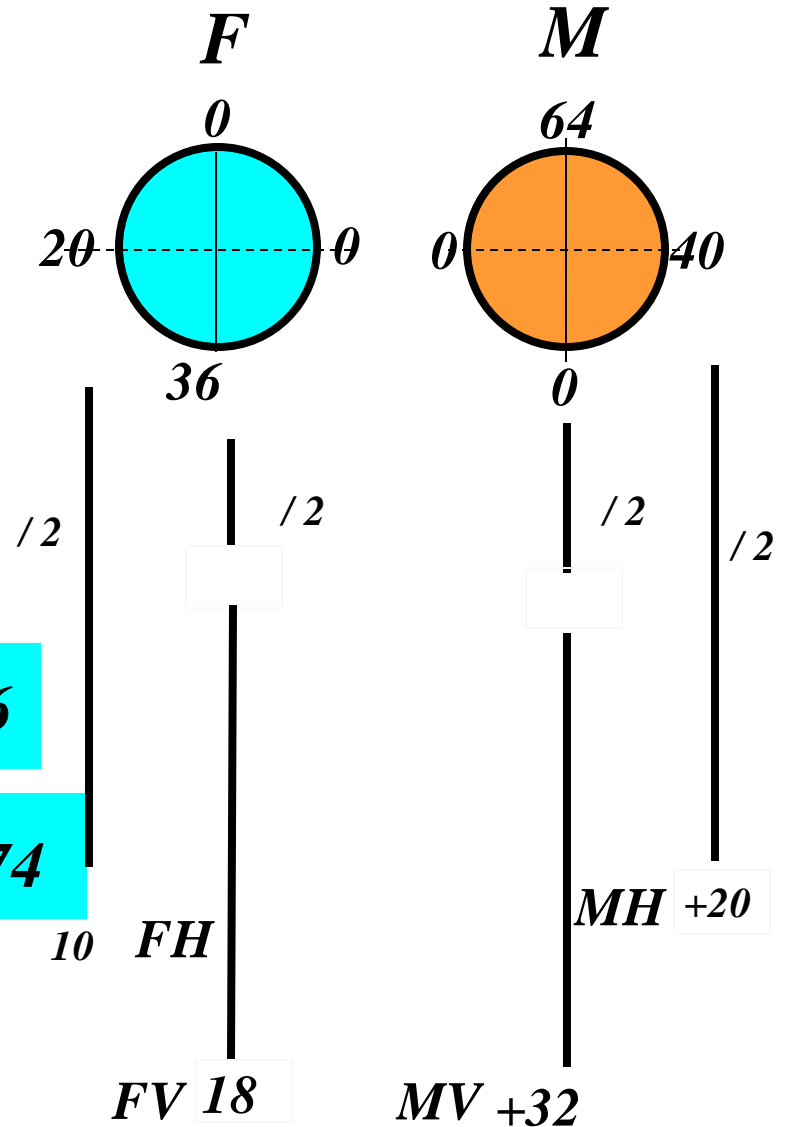
$$D2 = 8 \text{ in}$$

$$D3 = 16 \text{ in}$$

$$\text{Sag} = (0)$$

$$F = 0$$

$$M = 0$$



VERTICALLY

$$\text{INBOARD} = \{ 32 - 18 \} \frac{8}{4} + 18 = + 46$$

$$\text{OUTBOARD} = \{ 32 - 18 \} \frac{16}{4} + 18 = + 74$$

HORIZONTALLY

$$\text{INBOARD} = \{ 20 - 10 \} \frac{8}{4} + 10 = + 30$$

$$\text{OUTBOARD} = \{ 20 - 10 \} \frac{16}{4} + 10 = + 50$$

Mils

$D1 = 4 \text{ in}$
 $D2 = 8 \text{ in}$
 $D3 = 16 \text{ in}$
 $Sag = (1)$

$F = +1$

$M = -1$

VERTICALLY

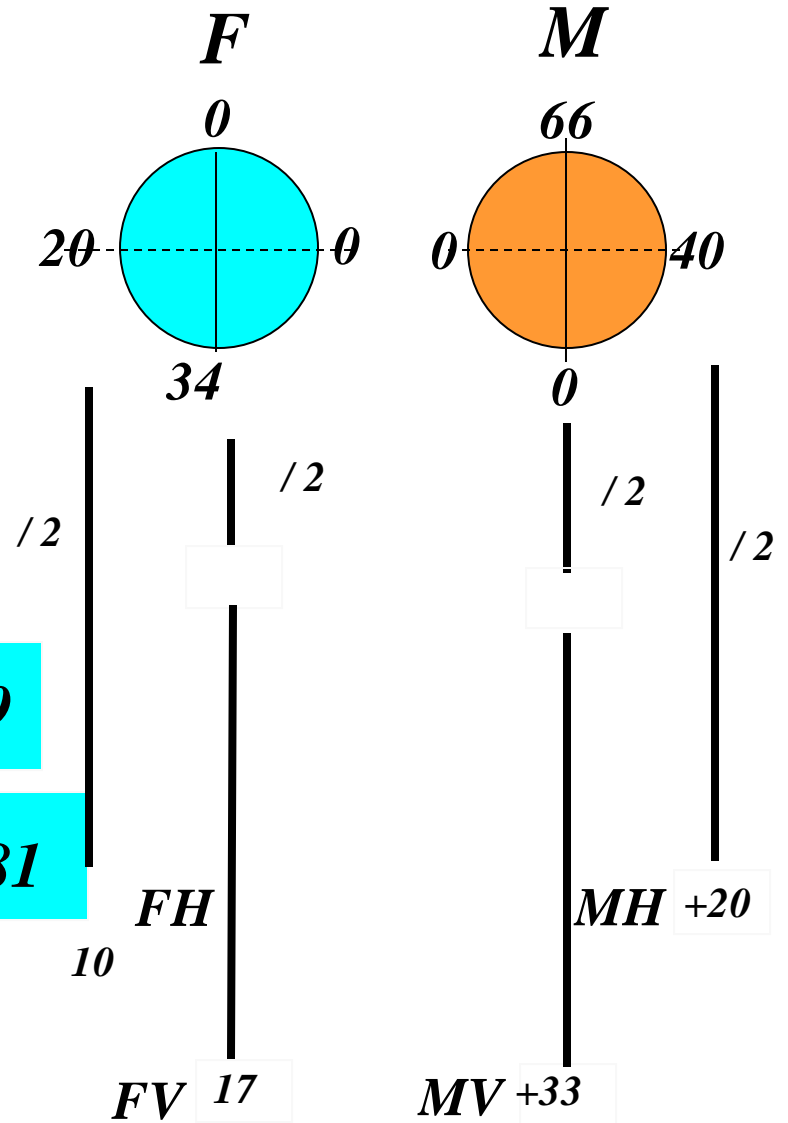
$$INBOARD = \{ 33 - 17 \} \frac{8}{4} + 17 = +49$$

$$OUTBOARD = \{ 33 - 17 \} \frac{16}{4} + 17 = +81$$

HORIZONTALLY

$$INBOARD = \{ 20 - 10 \} \frac{8}{4} + 10 = +30$$

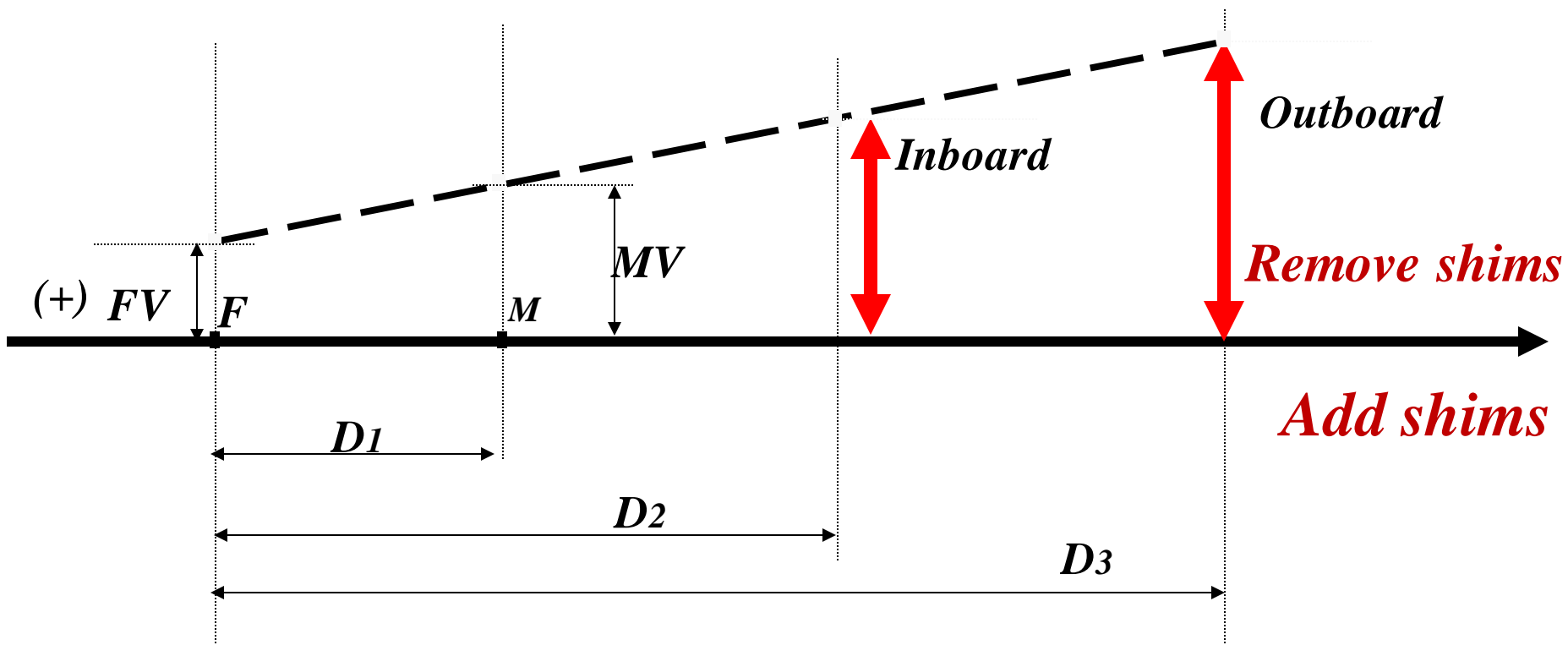
$$OUTBOARD = \{ 20 - 10 \} \frac{16}{4} + 10 = +50$$



Mils

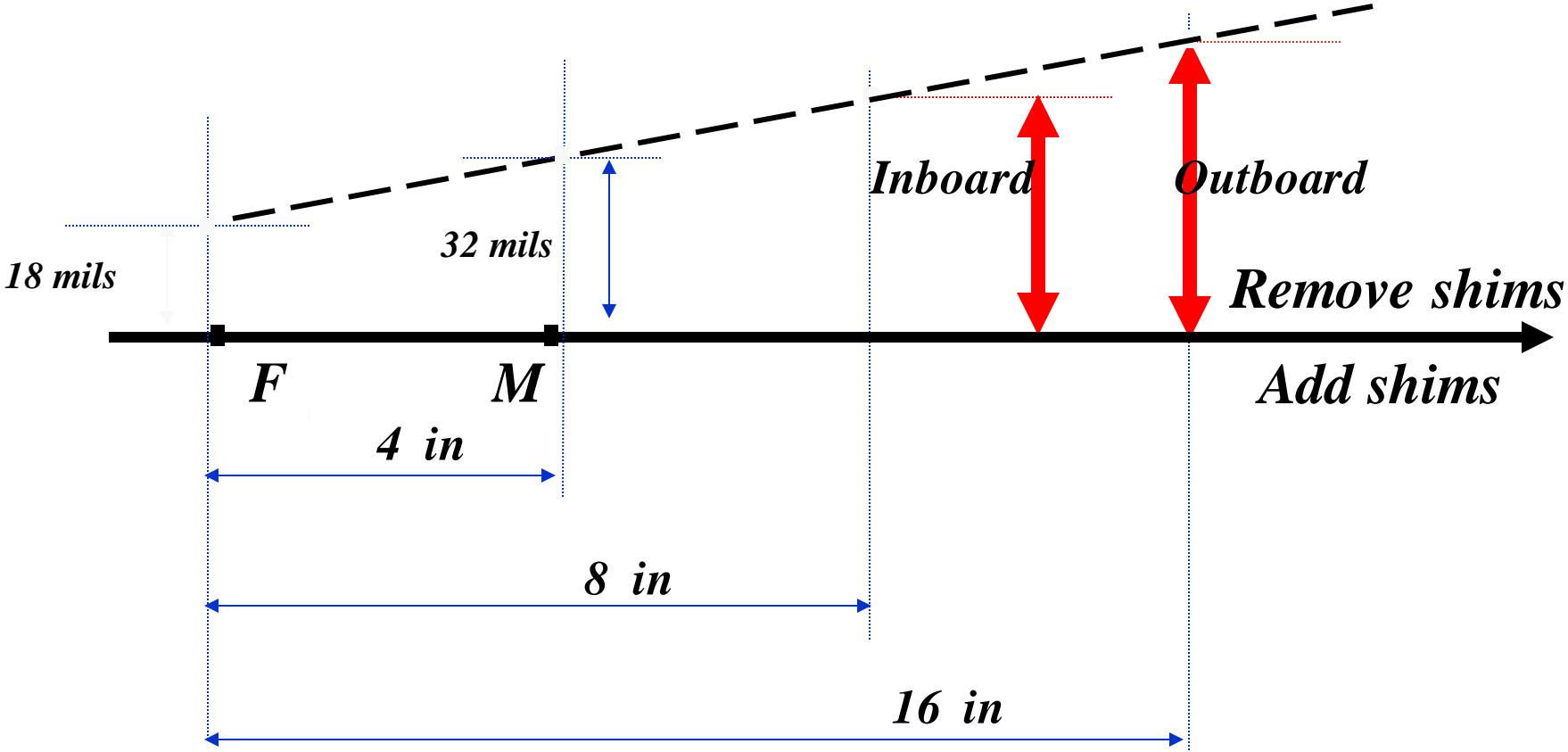
*Reversal
Alignment
Graphical Method*

Vertically

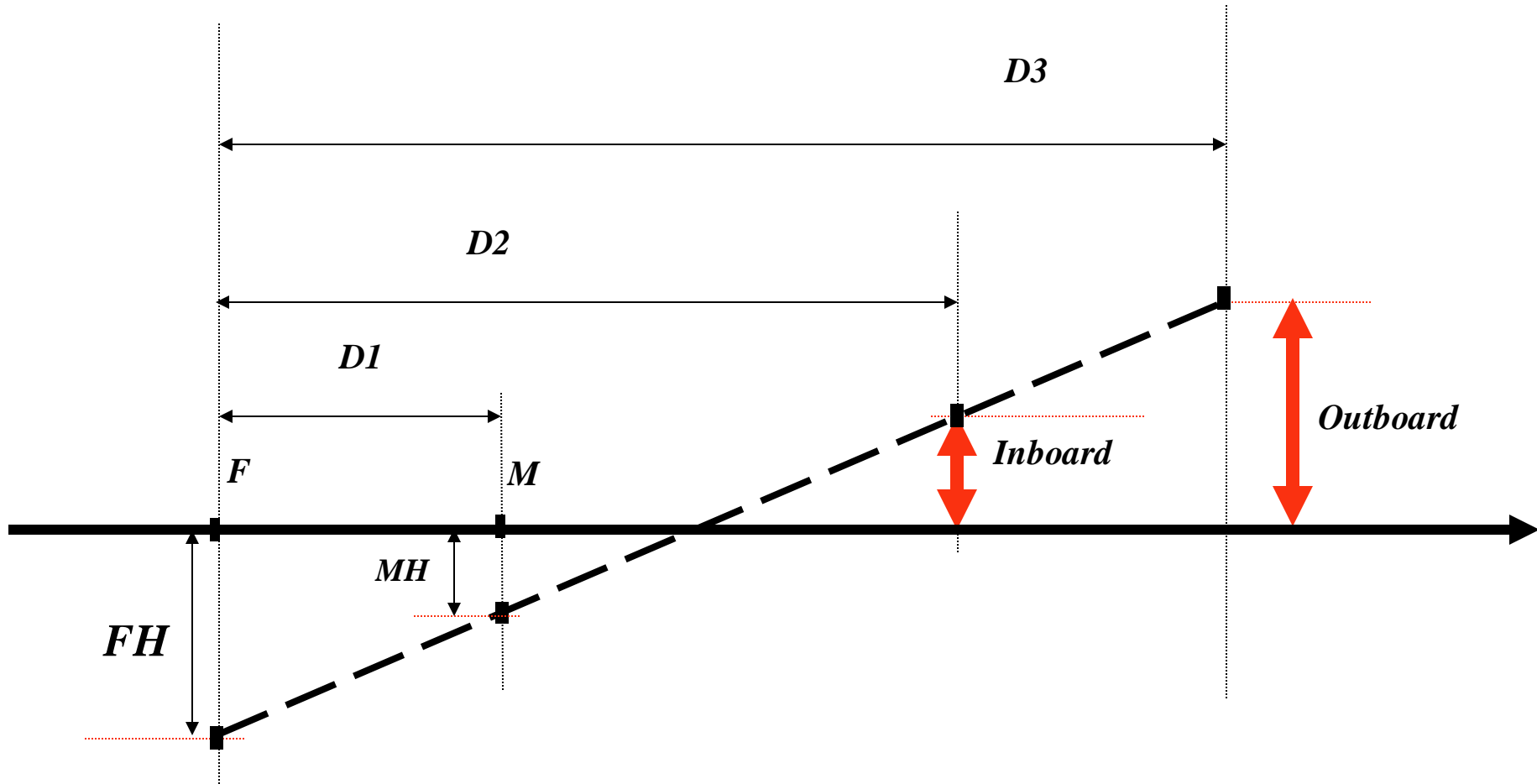


Vertically

$FV = 18 \text{ mils}$
 $MV = 32 \text{ mils}$



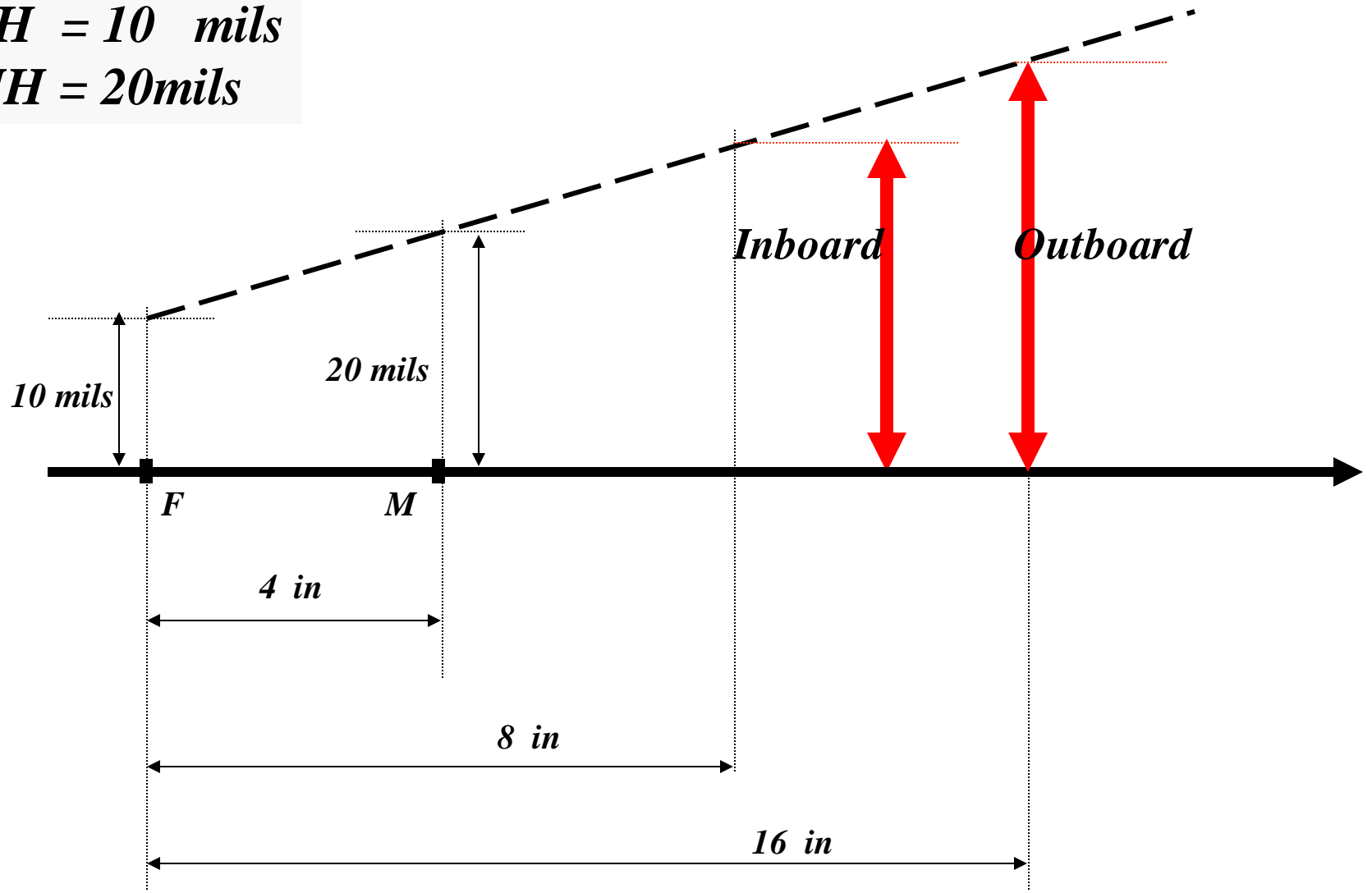
Horizontally



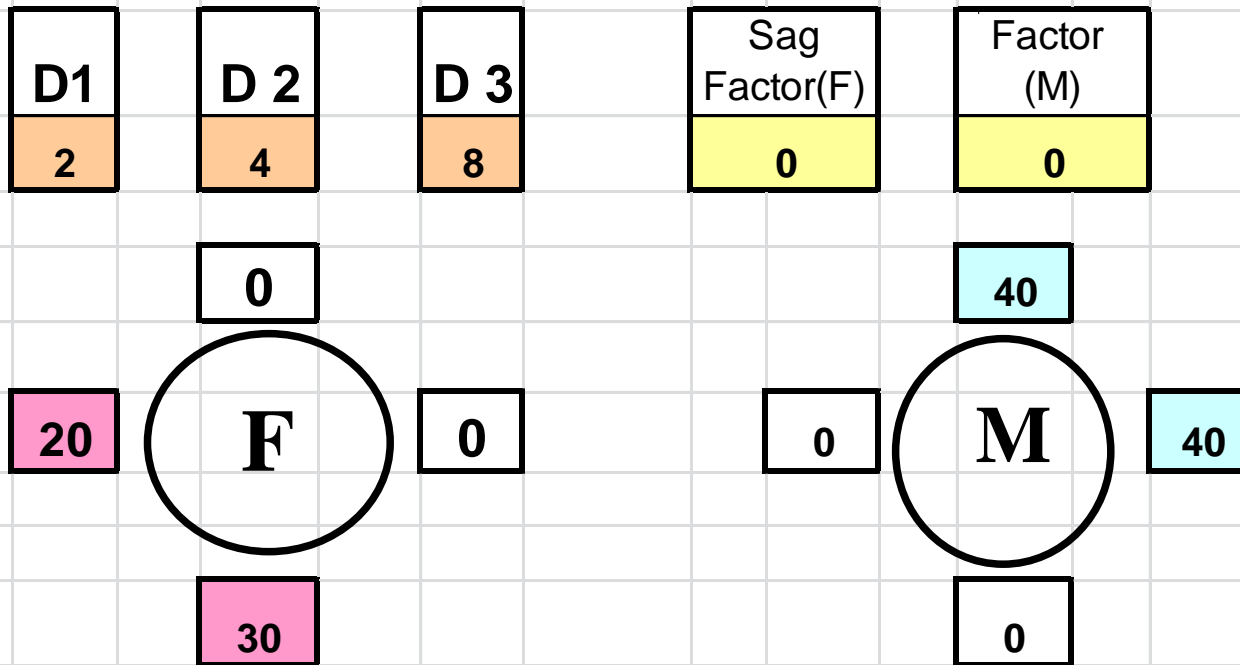
EXAMPLE

$FH = 10 \text{ mils}$

$MH = 20 \text{ mils}$

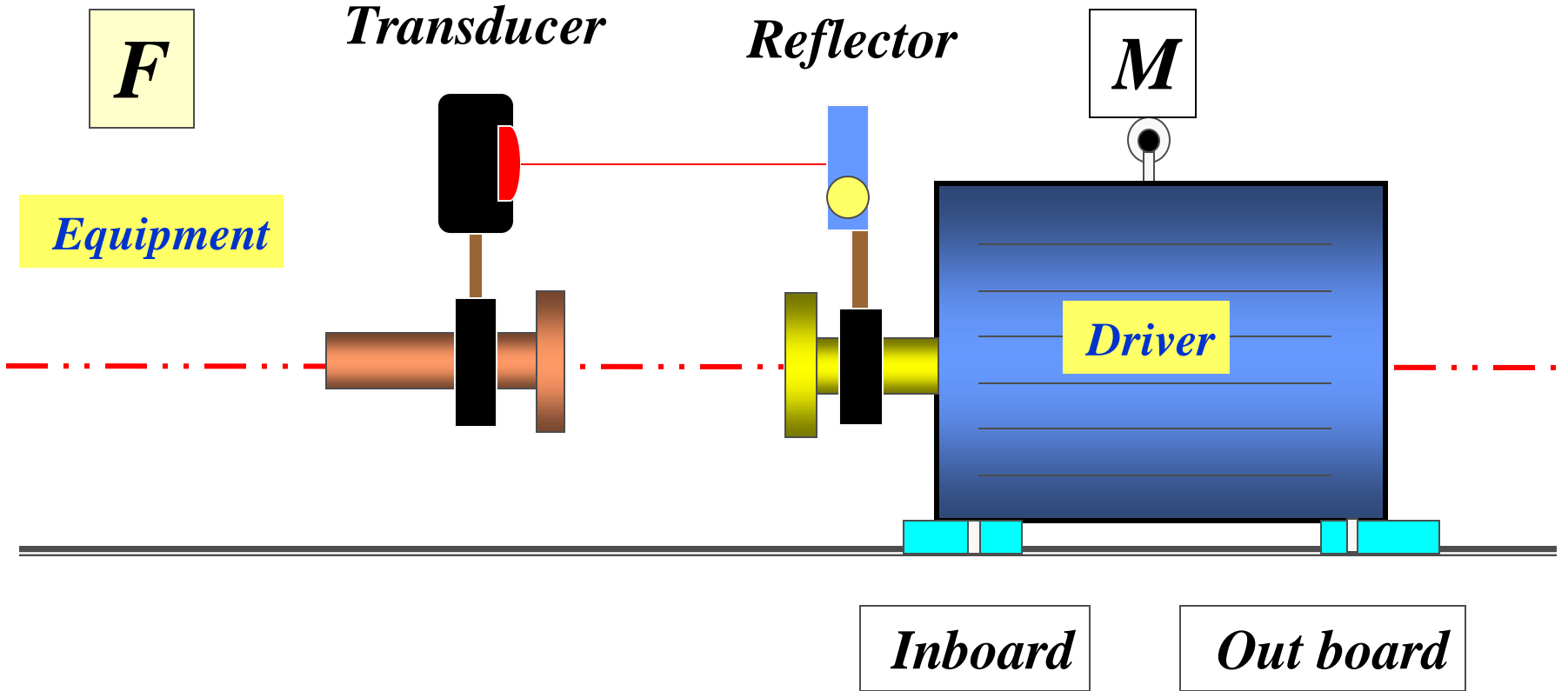


3-Reversal Alignment Software

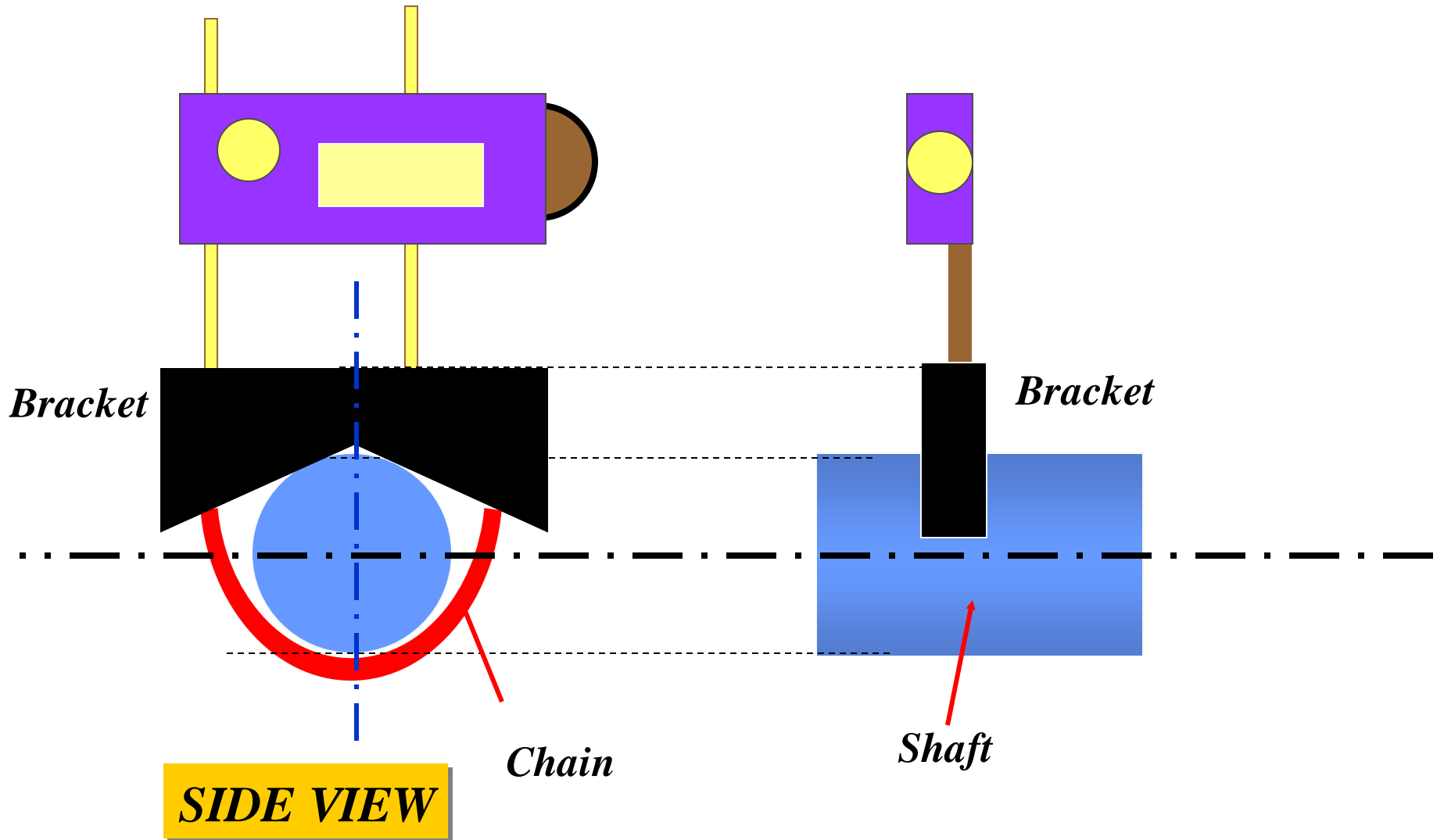


Inboard	(vertical)	25	→	0	REMOVE shims
Outboard	(vertical)	35	→	0	REMOVE shims
Inboard	(Horiz.)	30	→	0	Move towards 9
Outboard	(Horiz)	50	→	0	Move towards 9

Optical Alignment



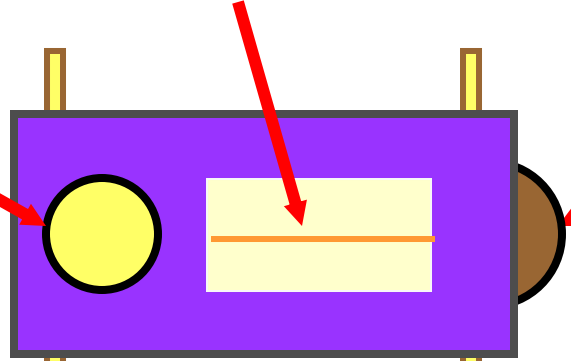
Reflector



***HRIZONTAL
ANGLE
ADJUSTTMENT***

90⁰ PRISM

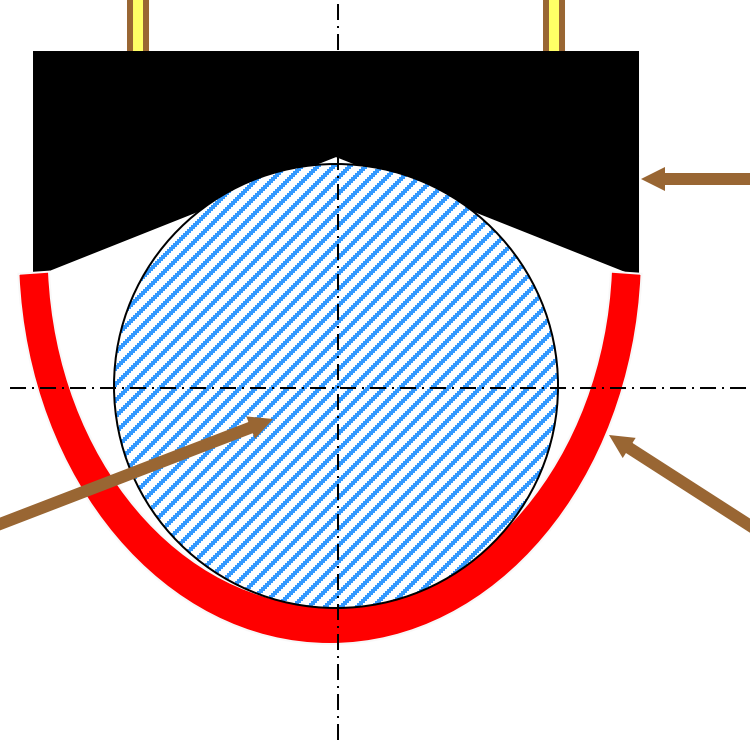
***VERTICAL
POSITION
ADJUSTTMENT***



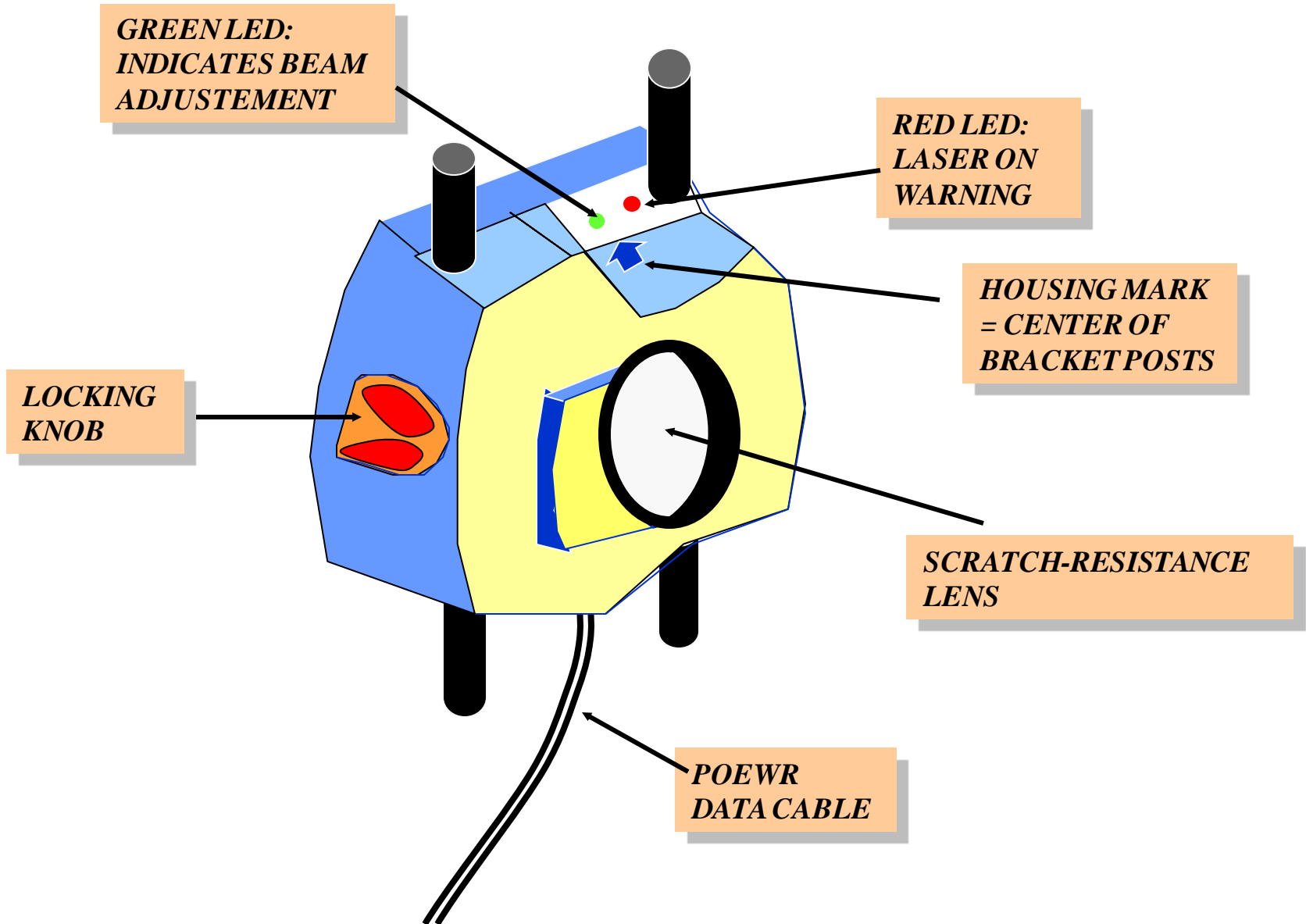
Bracket

Shaft


Chain



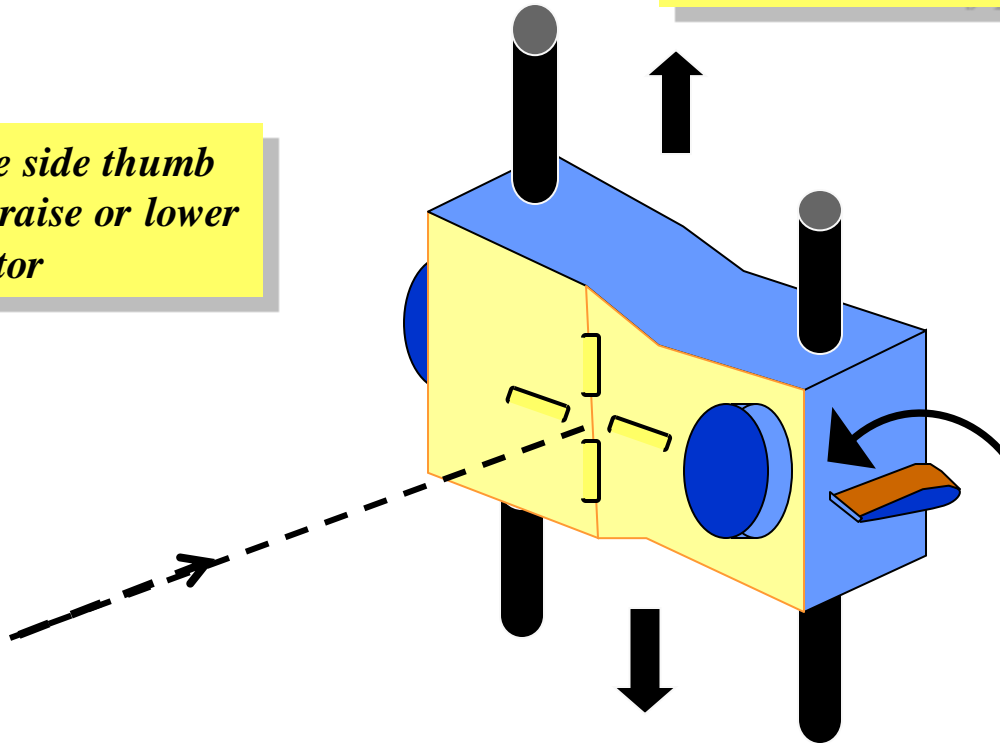
Transducer



REFLECTOR

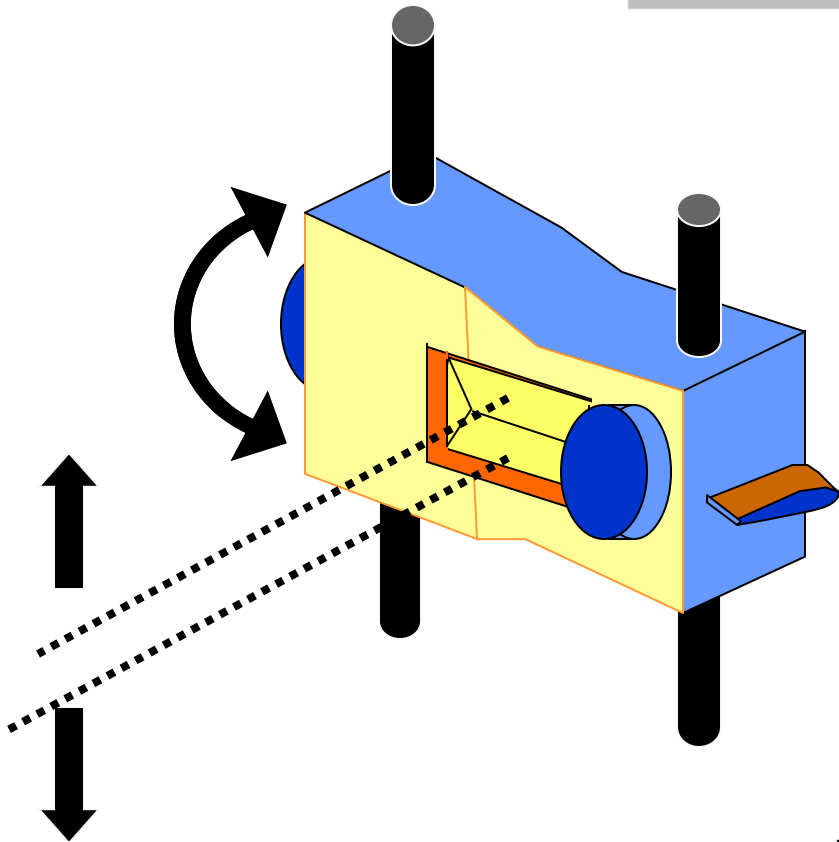
- 1- PRESS  and remove transducer cap.
- The laser beam now is on.
 - Leave the reflector cap on for now.
 - Beam strikes the cap, it should be visible.
 - Hold a sheet of paper to locate the beam

*Rotate the side thumb
Wheel to raise or lower
the reflector*



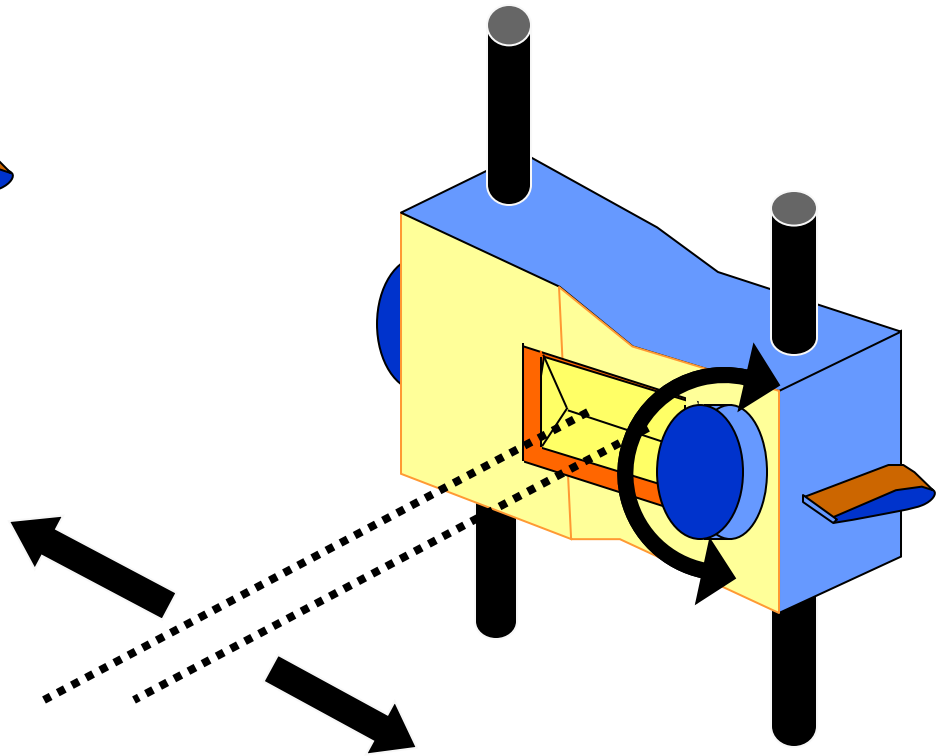
*This lever to lock
The reflector position*

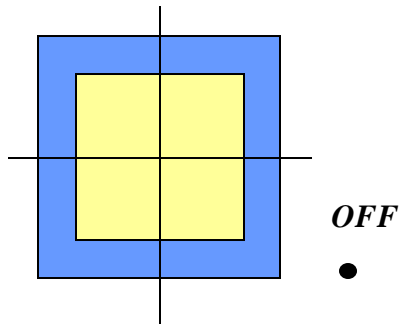
REFLECTOR



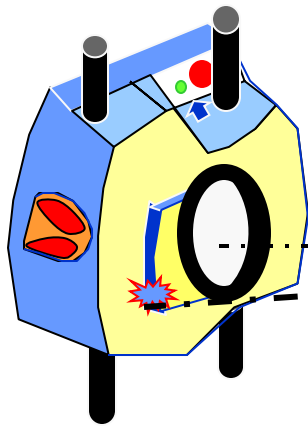
**VERTICAL
ADJUSTMENT**

**HORIZONTAL
ADJUSTMENT**

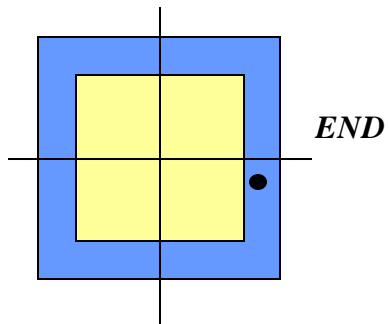
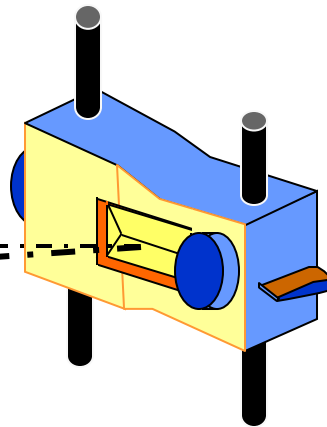




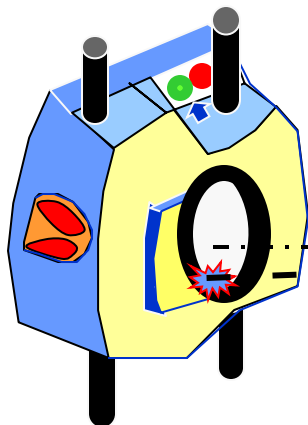
OFF



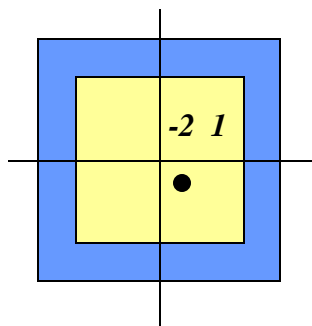
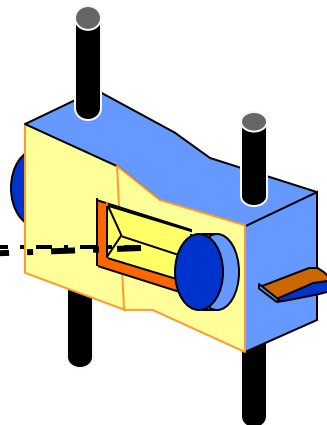
*OFF Beam misses detector
Red Blinks quickly
Green Is OFF*



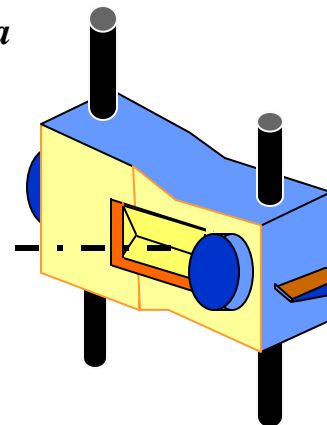
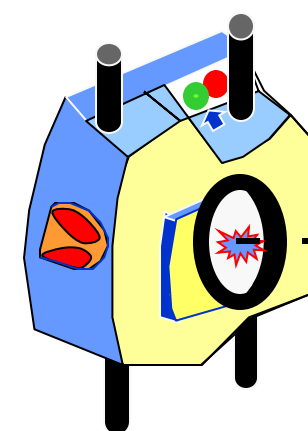
END



*END Beam hits non linearized
area of detector
Red & Green Blinks quickly
Alternatively*



*COORDINATES Beam hits area
of detector
Red & Green Blinks Slowly
Together*



1- PREPARING FOR ALIGNMENT PROCEDURE

a- Solid flat foundation

b- Machine mobility (2 mm higher & screw type positioning)

c- Soft foot (Must be checked immediately)

d- Thermal growth

HORIZONTAL MACHINE ALIGNMENT

Select

DIM

Cycle through with



and



1-Transducer to reflector

2-Transducer to coupling center

3-Coupling diameter

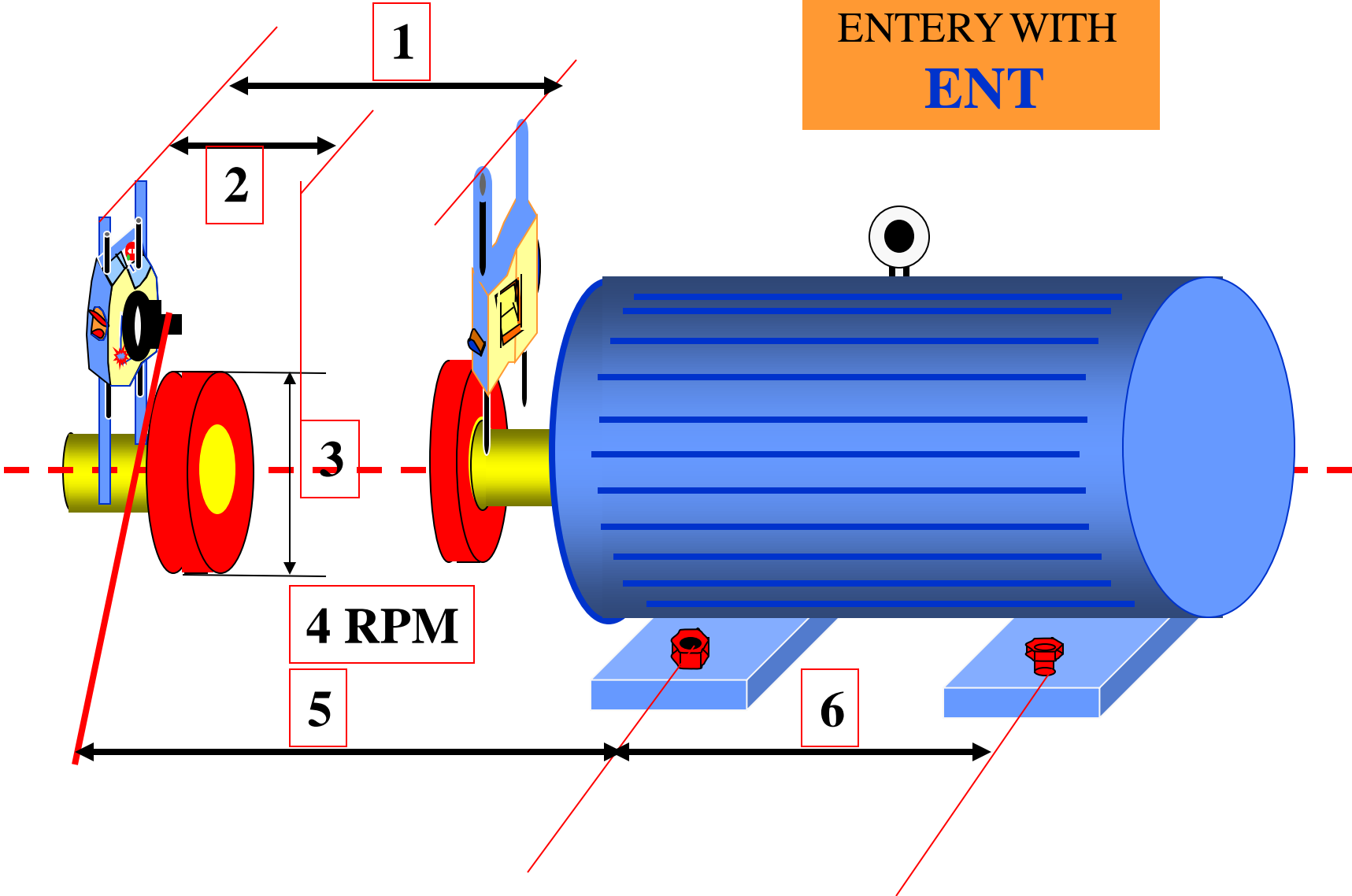
4-RPM

5-Transducer to front feet

6- Front feet to rear feet

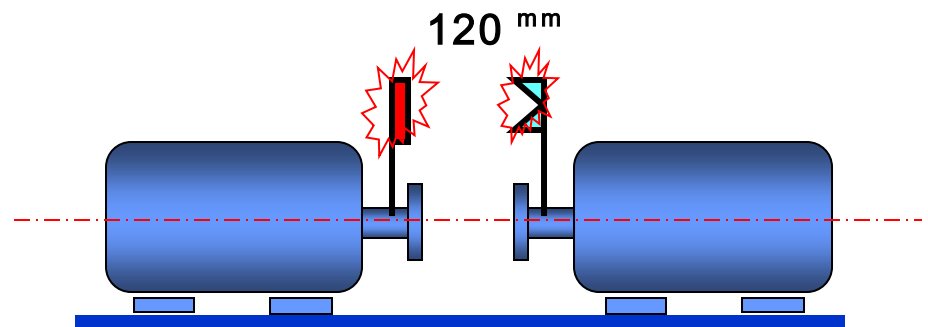
DIM

CONFIRM EACH
ENTRY WITH
ENT

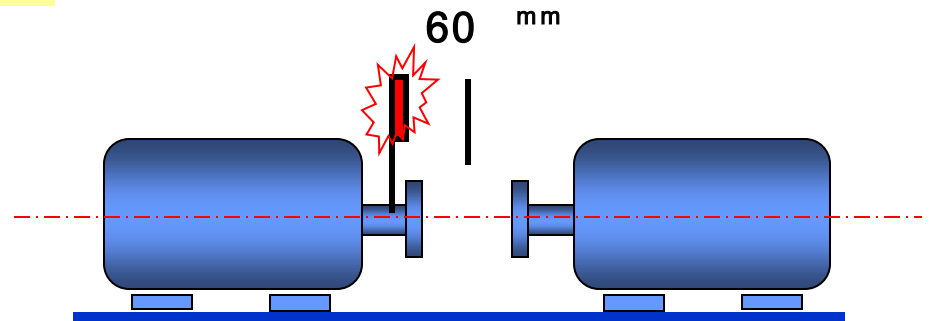


DIM

1-Transducer to reflector



2-Transducer to coupling center

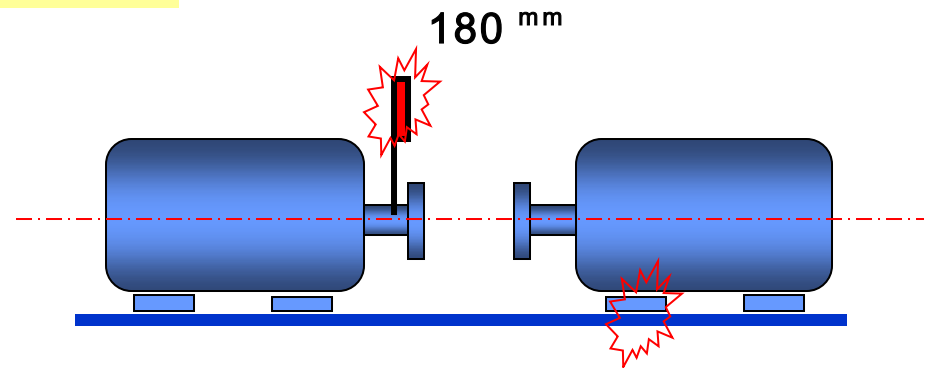


DIM

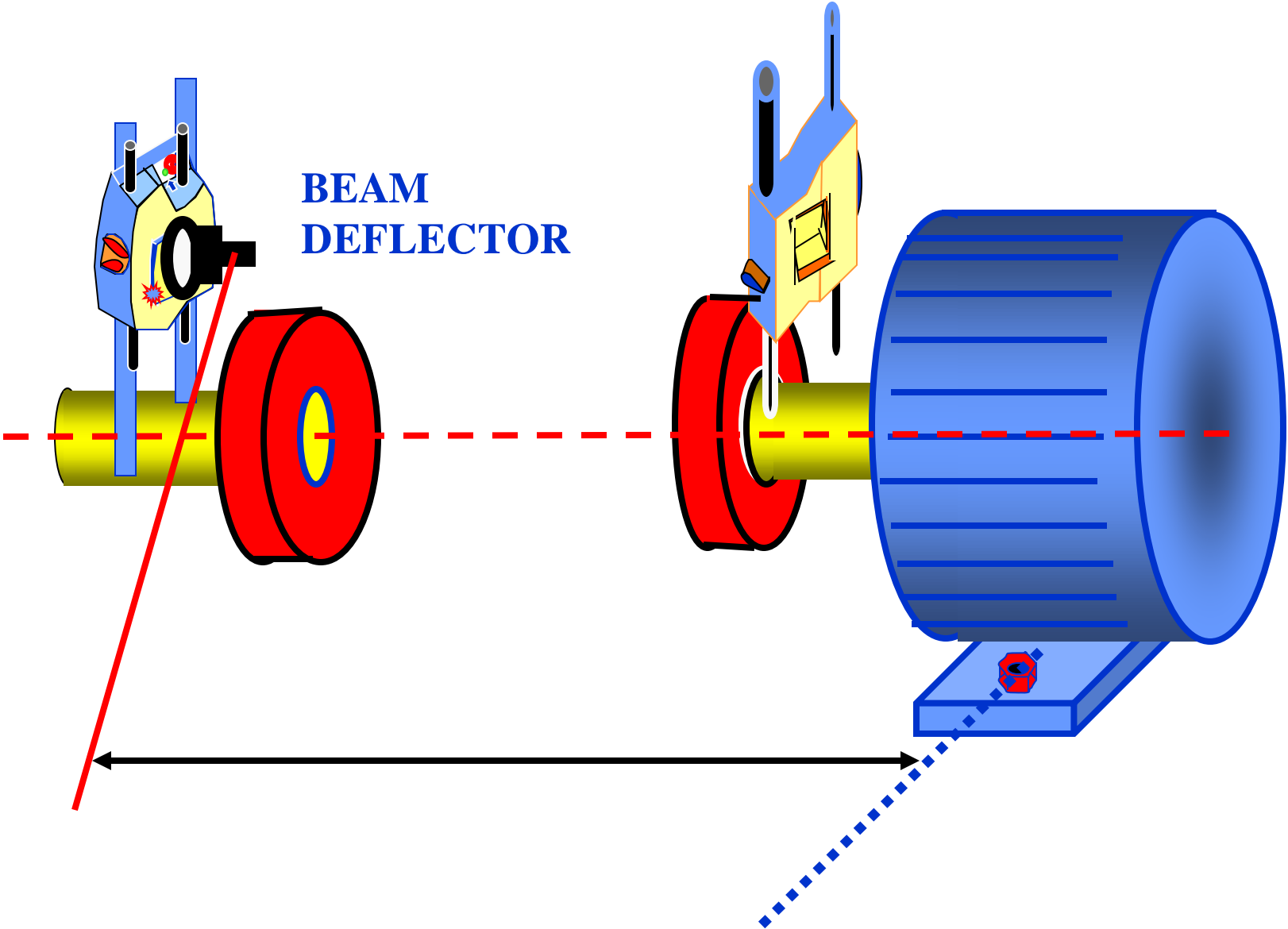
3- Coupling diameter

D

4- Transducer to front foot, right m/c

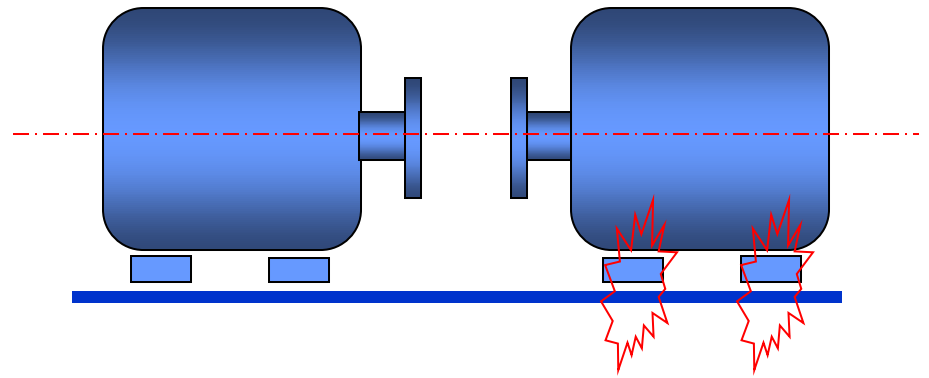


DIM




DIM

5-Front foot to back foot , right m/c

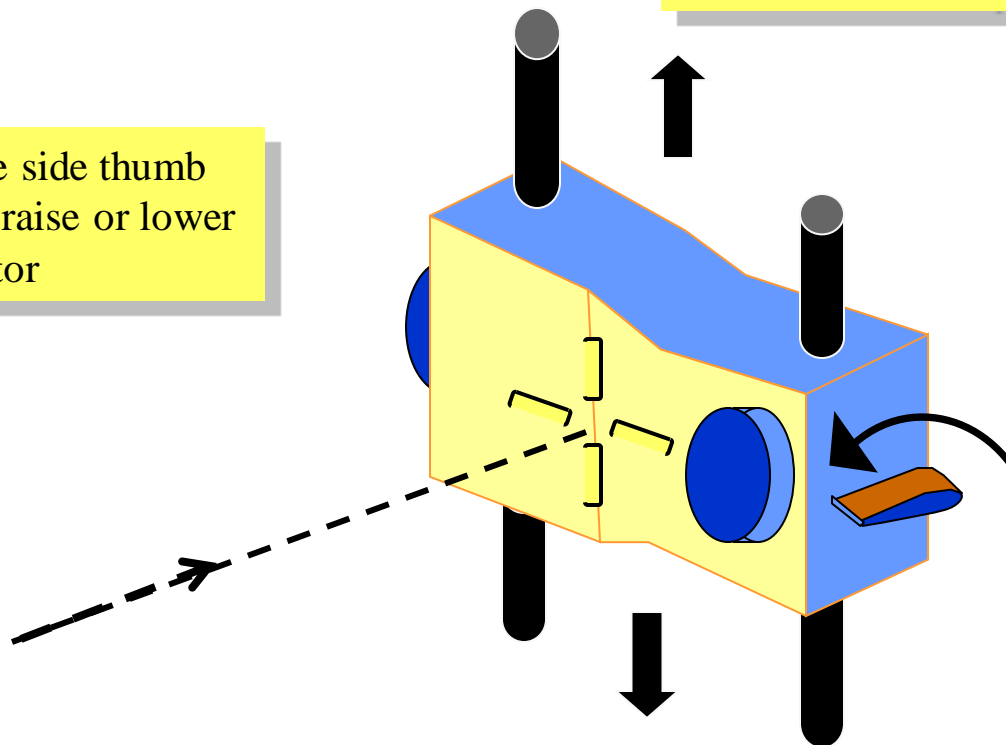




5-Laser beam adjusting

- 1- PRESS  and remove transducer cap.
- The laser beam now is on.
 - Leave the reflector cap on for now.
 - Beam strikes the cap, it should be visible.
 - Hold a sheet of paper to locate the beam

Rotate the side thumb
Wheel to raise or lower
the reflector



This lever to lock
The reflector position

CHAPTER 7

- *Case Studies
For Alignment Failure*

A- Bearings Failure

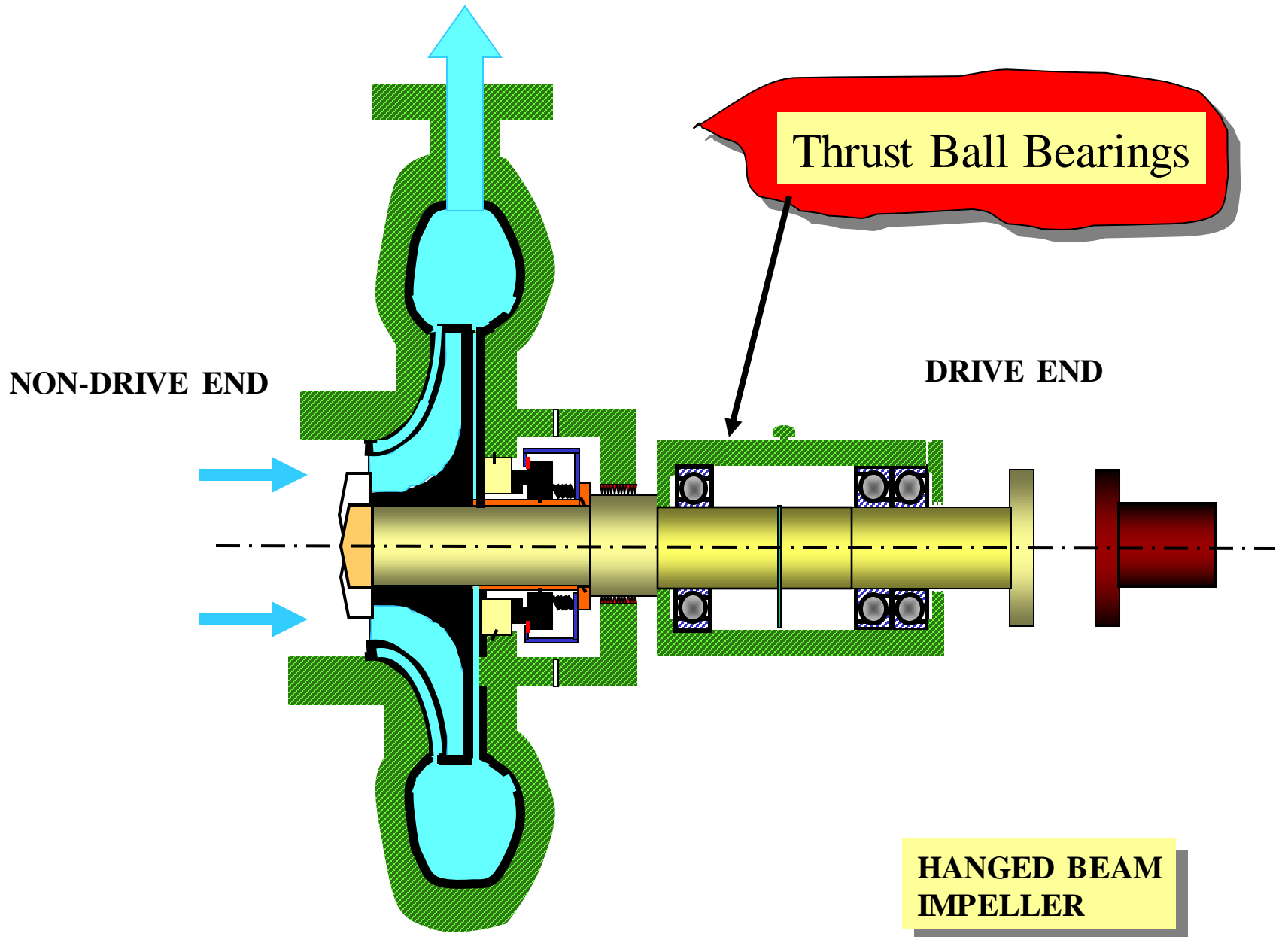
RADIAL BEARING

THRUST BEARING

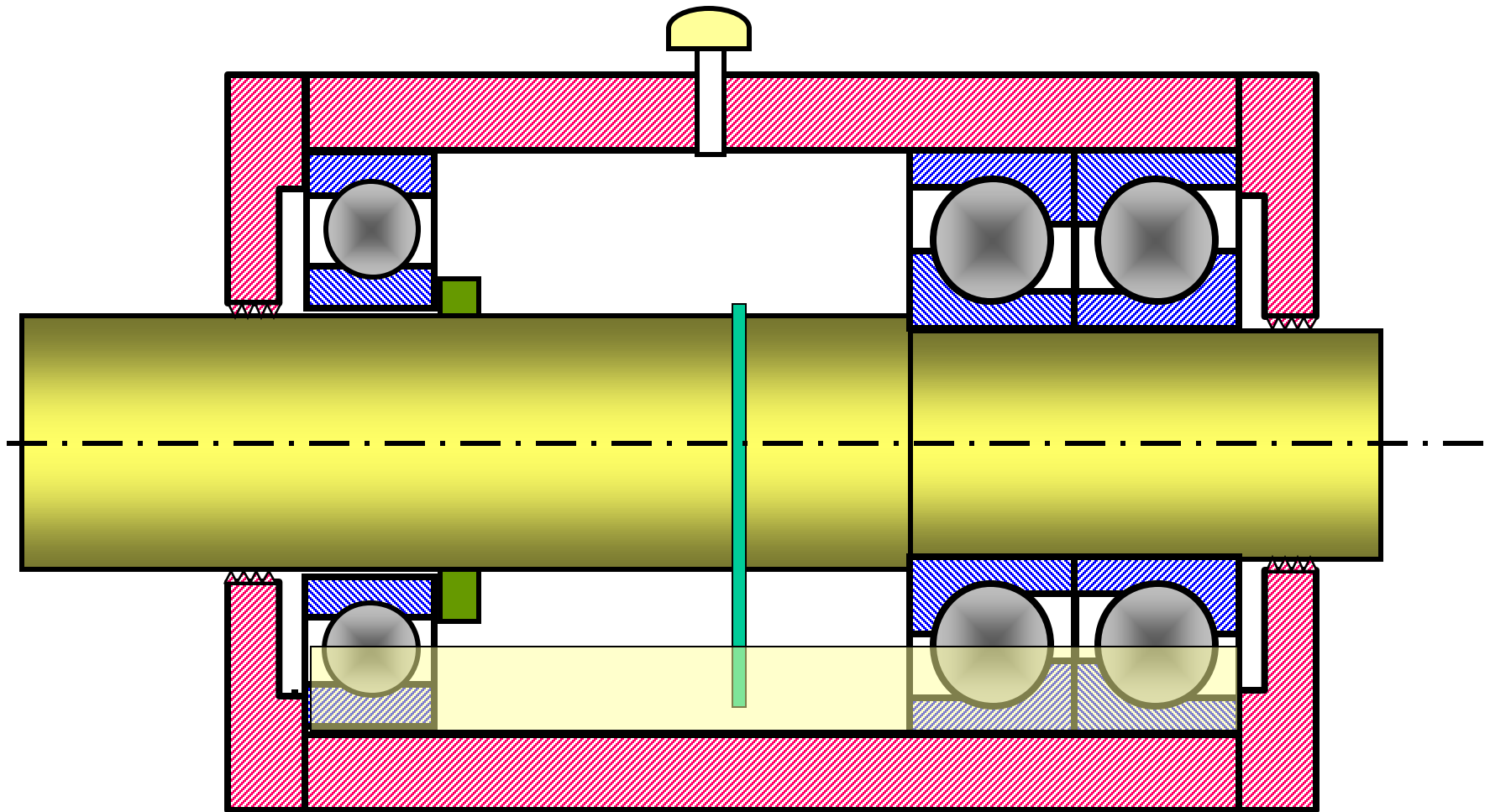
ball Bearings

roller Bearings

Tilting pad Bearings



Thrust Ball Bearings

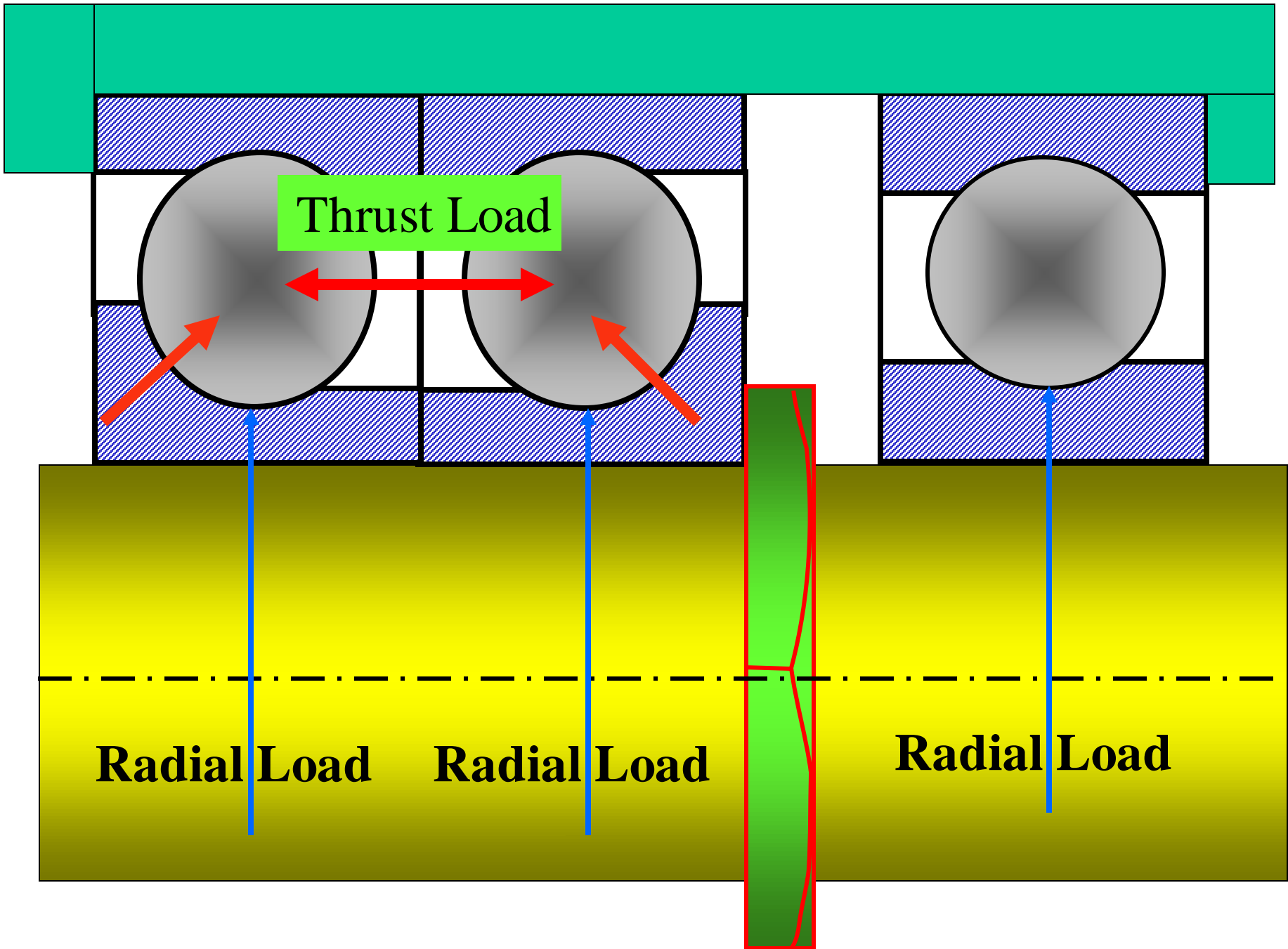


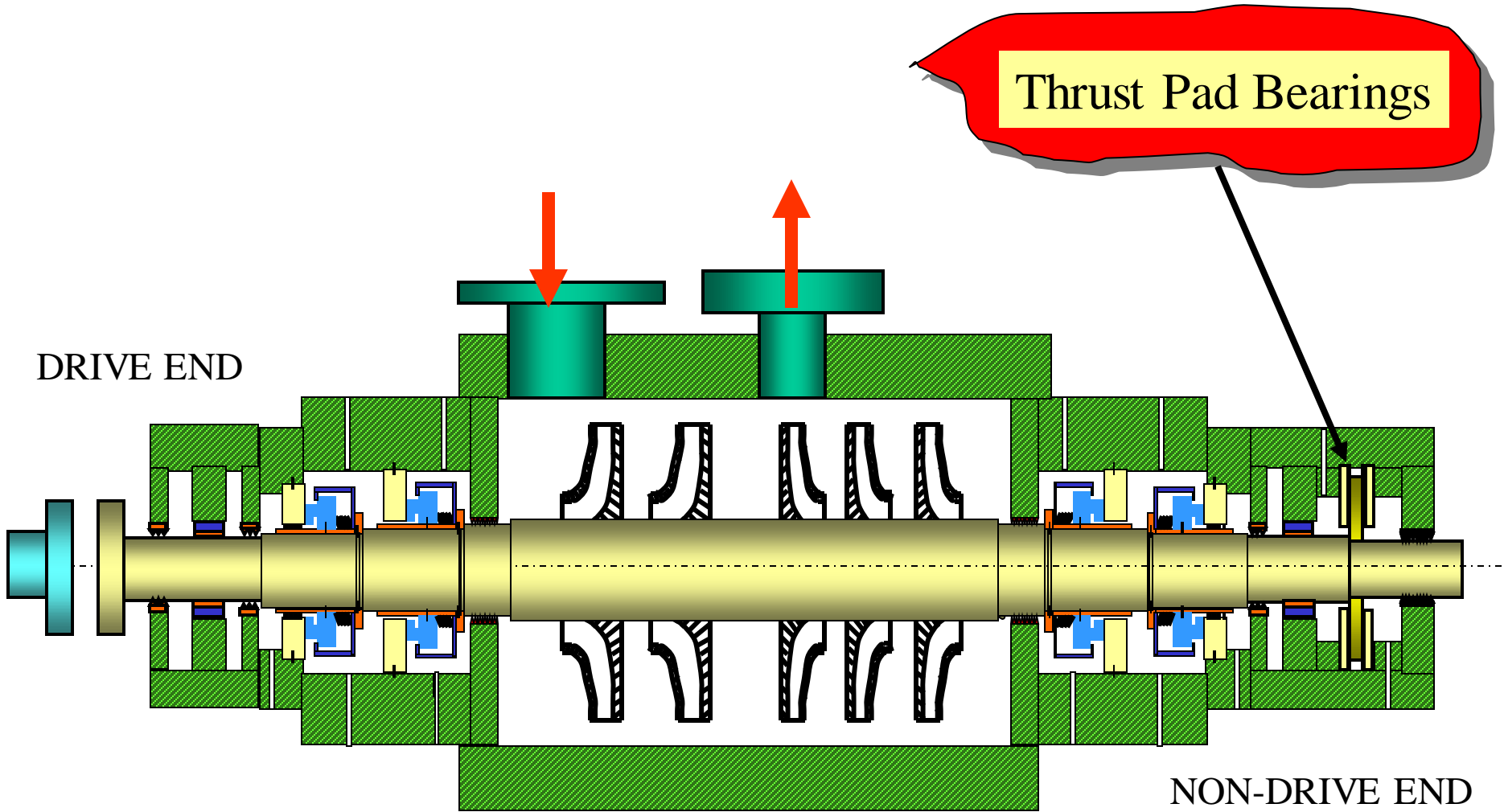


MECHANICAL SEAL

A detailed cross-sectional diagram of a pump assembly. The main body is a light blue color. A central shaft is shown in a dark grey color. On the left, there is a large, dark grey, curved component, likely a pump impeller. The shaft passes through a mechanical seal assembly, which is highlighted by a yellow callout box. The shaft then passes through a bearing housing, which is highlighted by a blue callout box. The bearing housing contains two bearings, one on each side of the shaft. The shaft is supported by a base on the right side. The diagram shows the internal components and their relative positions within the pump housing.

BEARING HOUSING





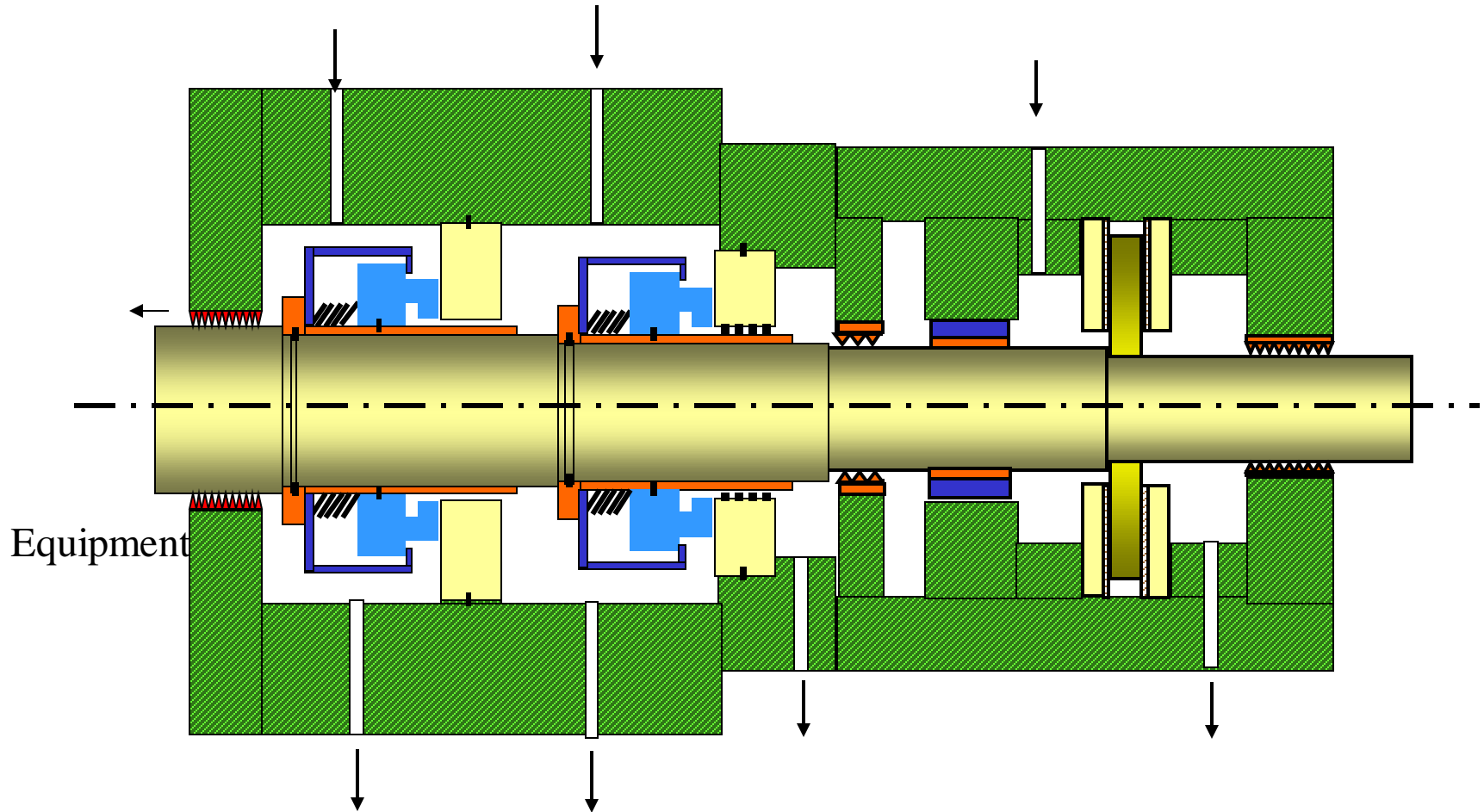
Thrust Pad Bearings

DRIVE END

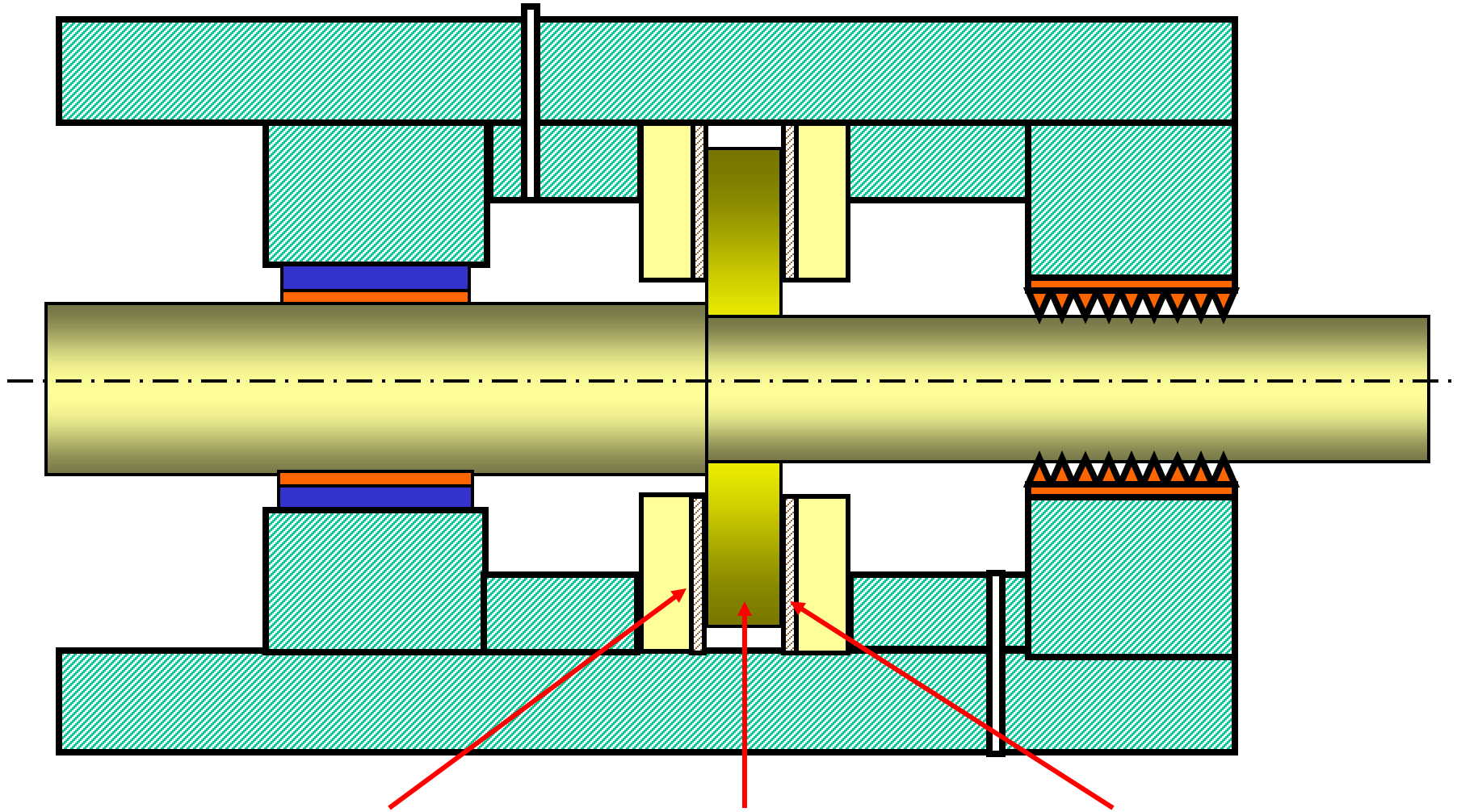
NON-DRIVE END

IN-BETWEEN TWO BEARINGS IMPELLER

Mechanical seal and bearings arrangement



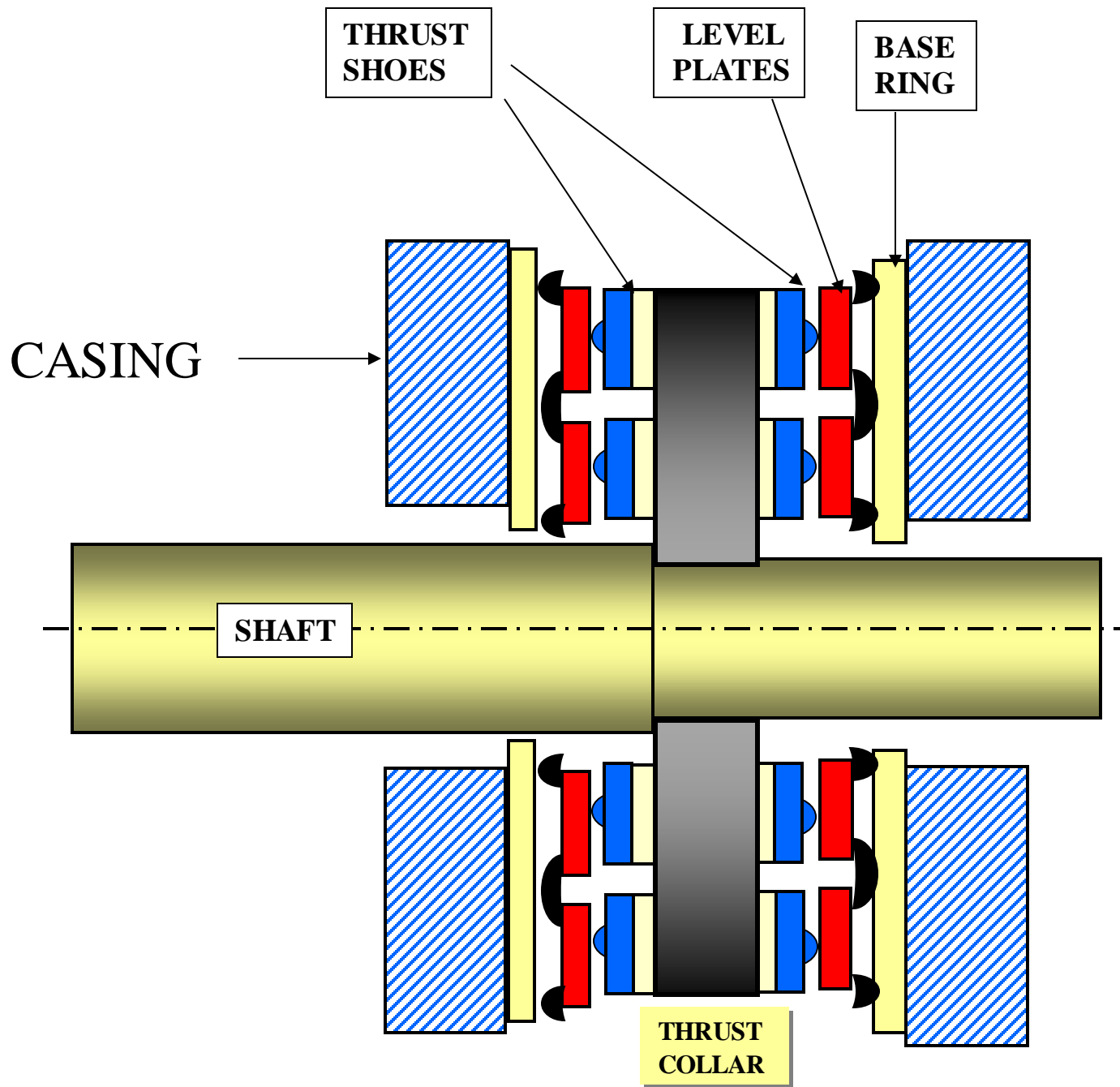
THRUST PAD BEARING



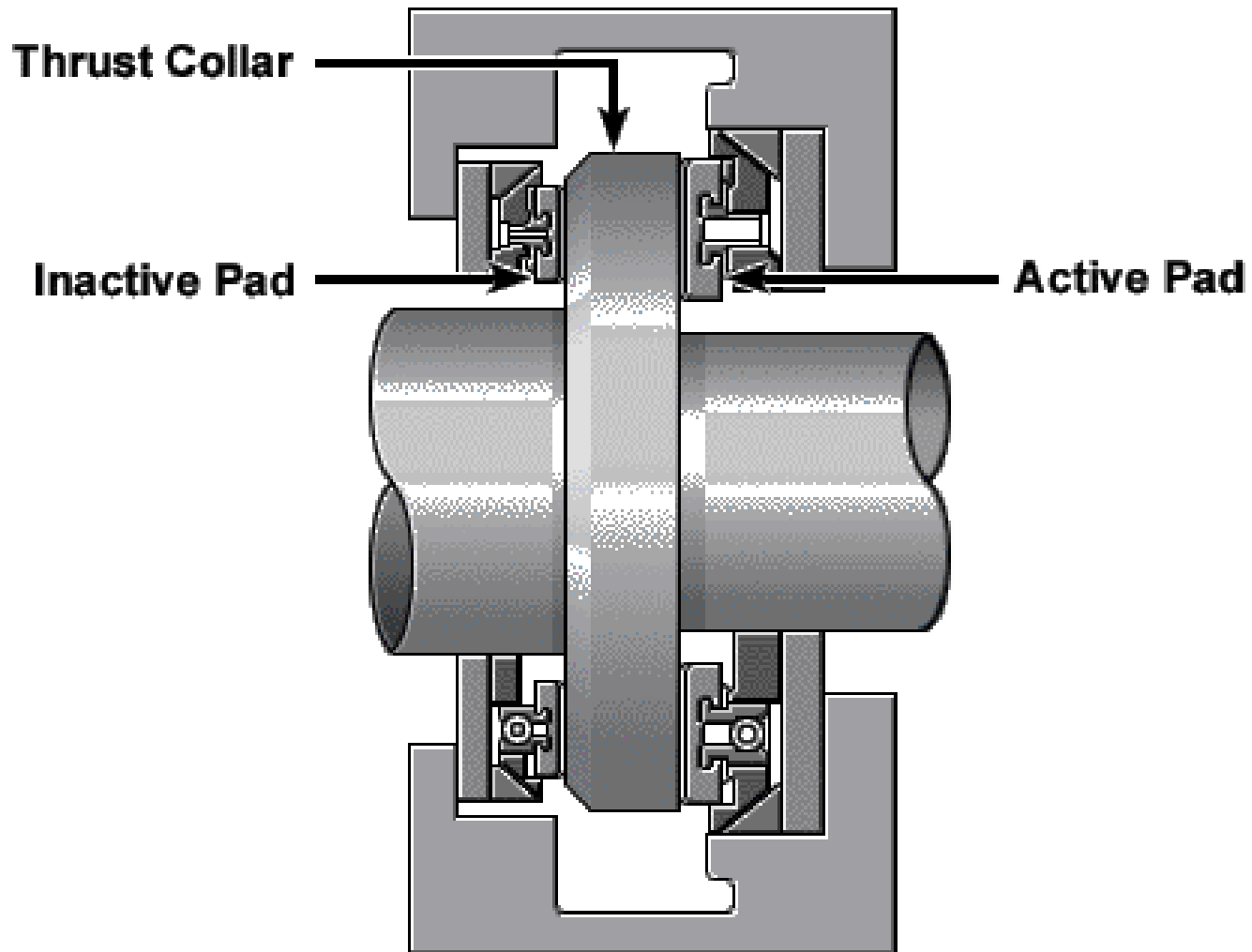
THRUST SHOES

THRUST COLLAR

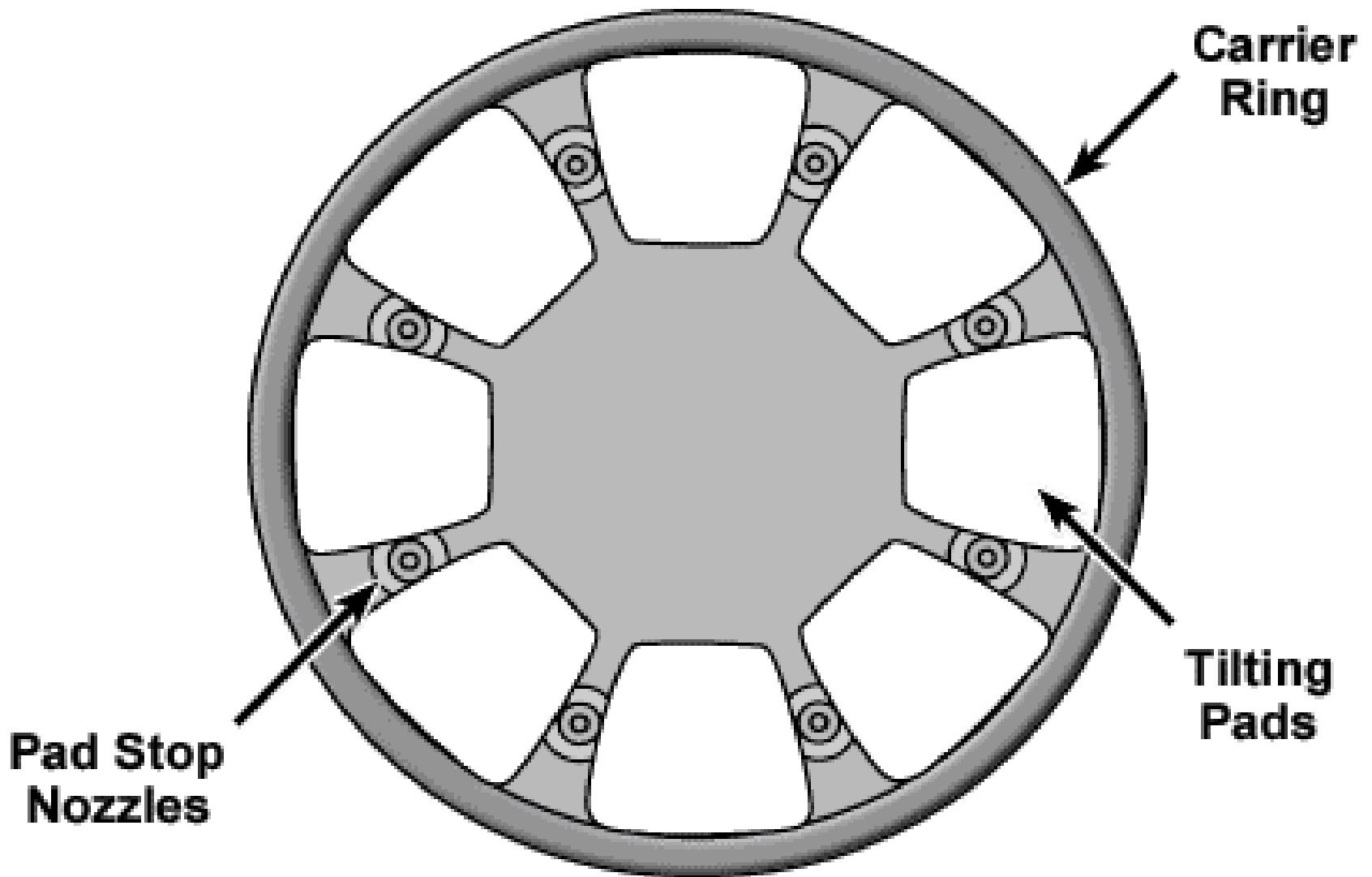
THRUST SHOES



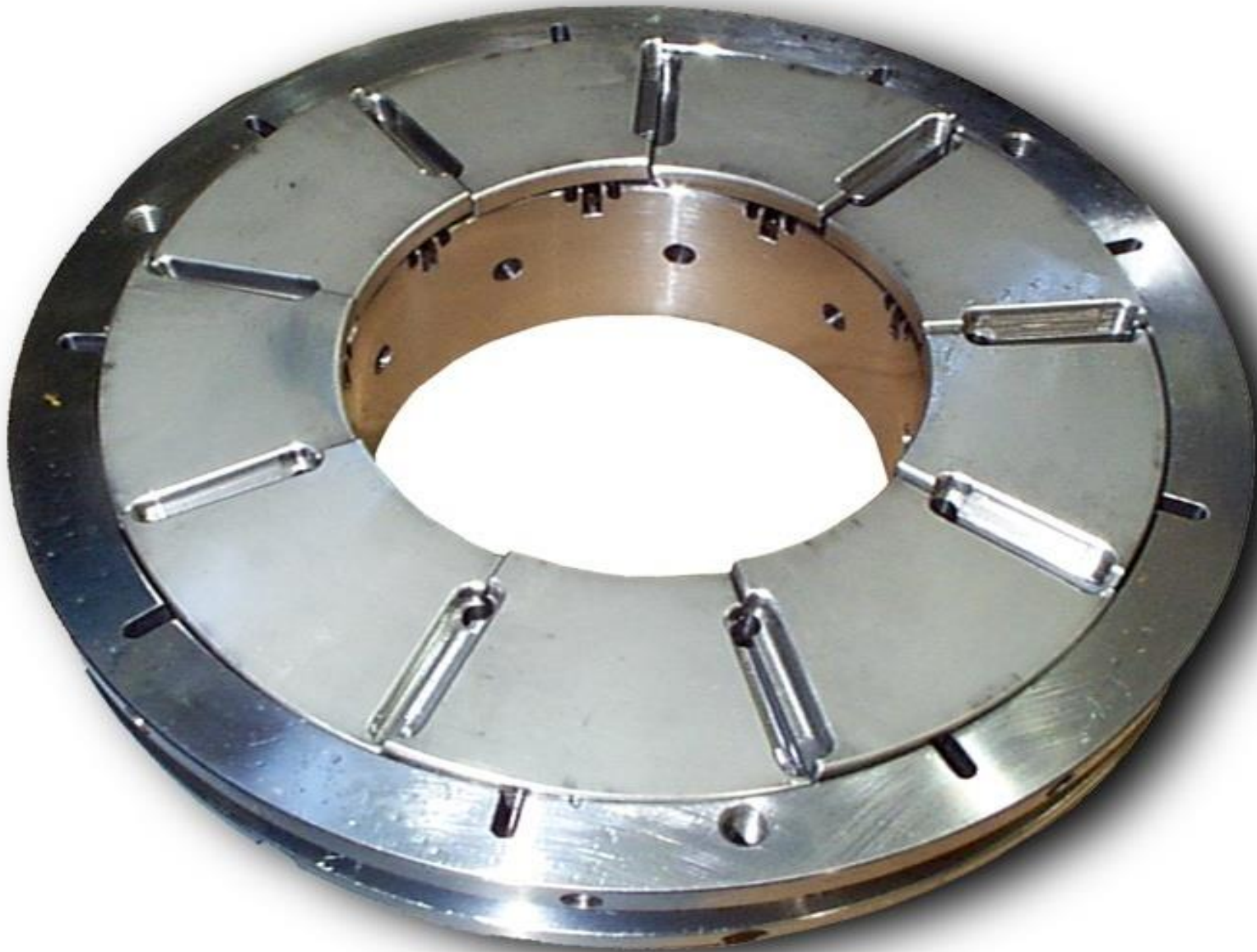
Thrust Bearing



Thrust Bearing Details



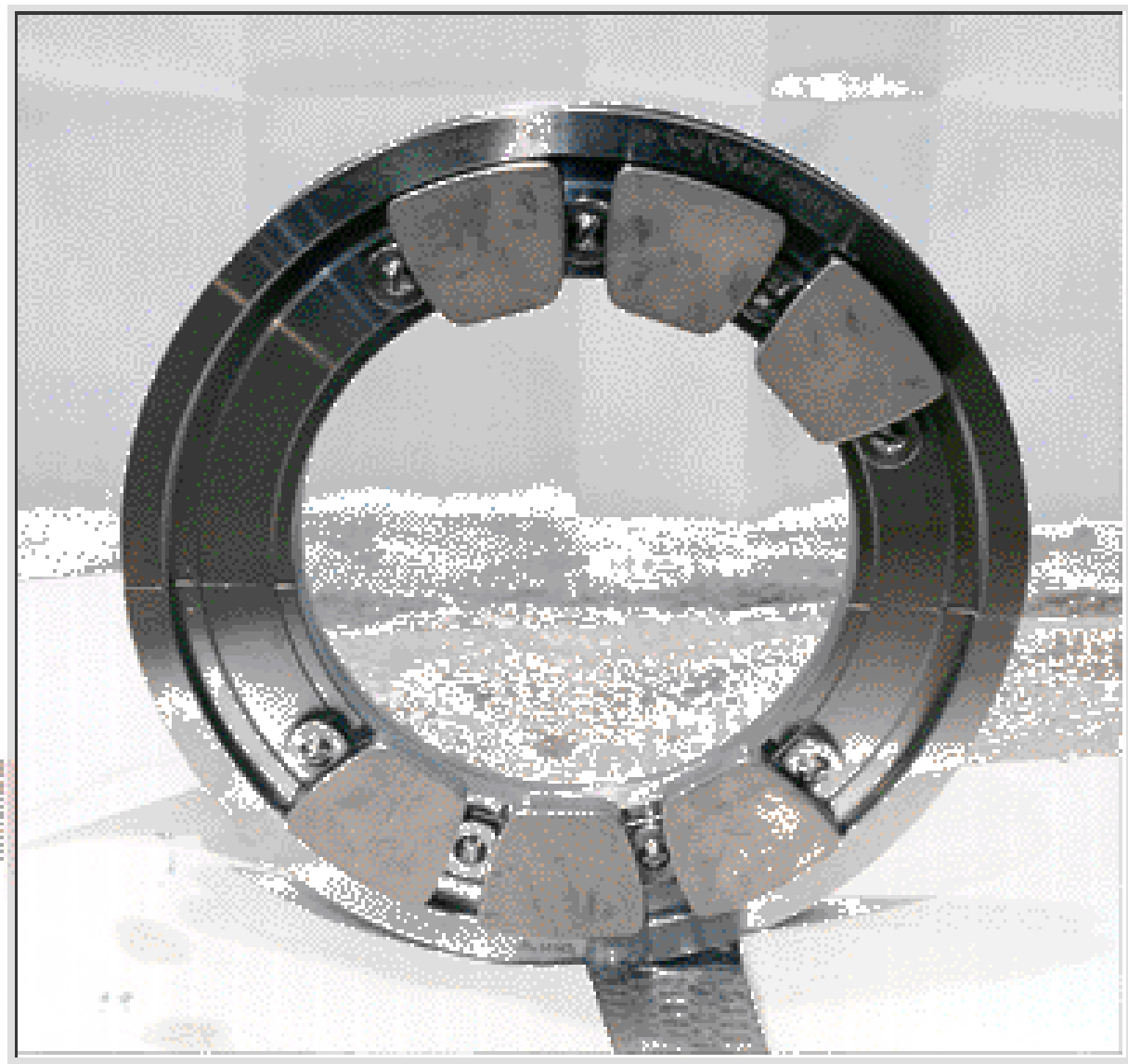
Titan 130 Thrust Bearing



Active Thrust Bearing

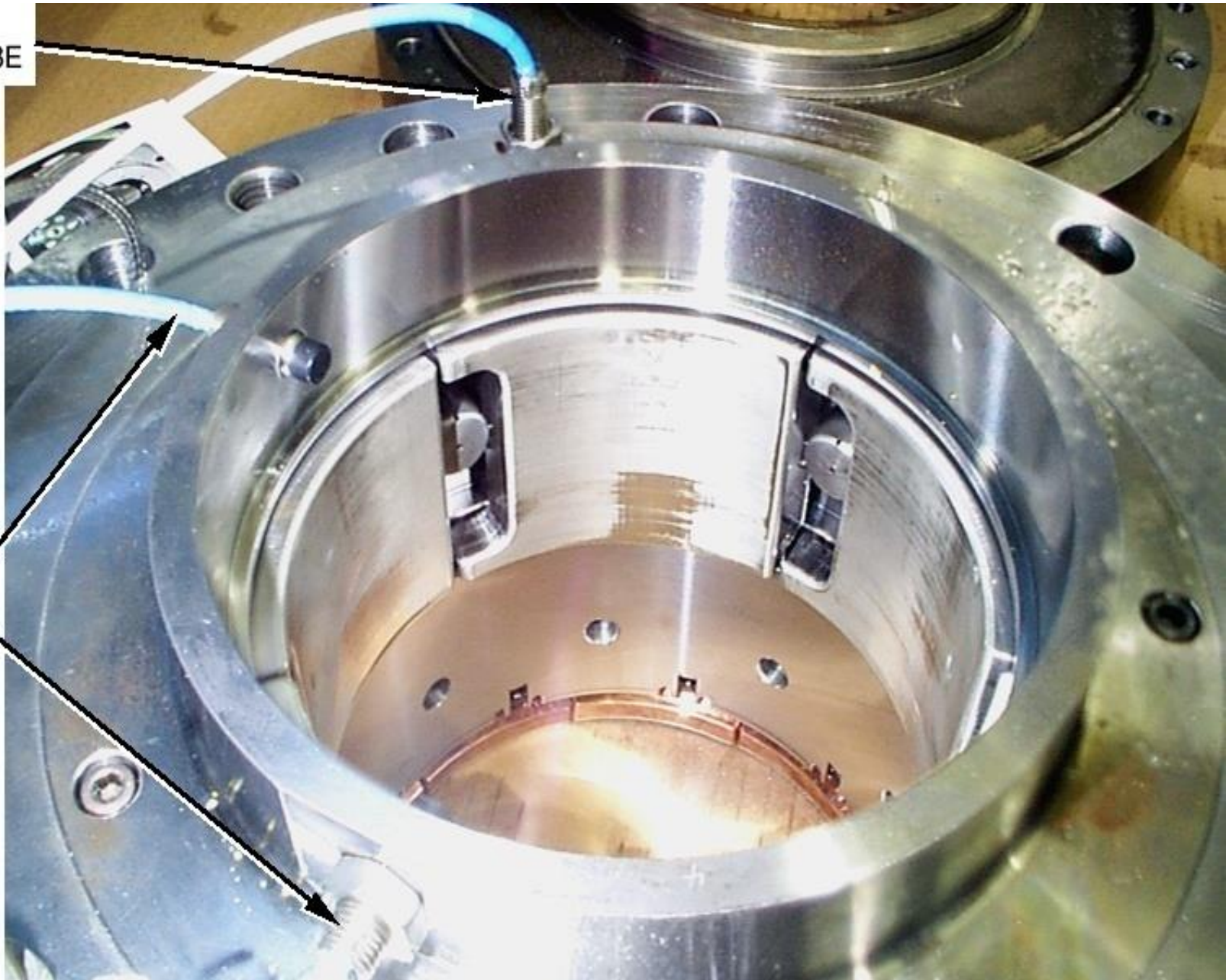


Inactive Thrust Bearing



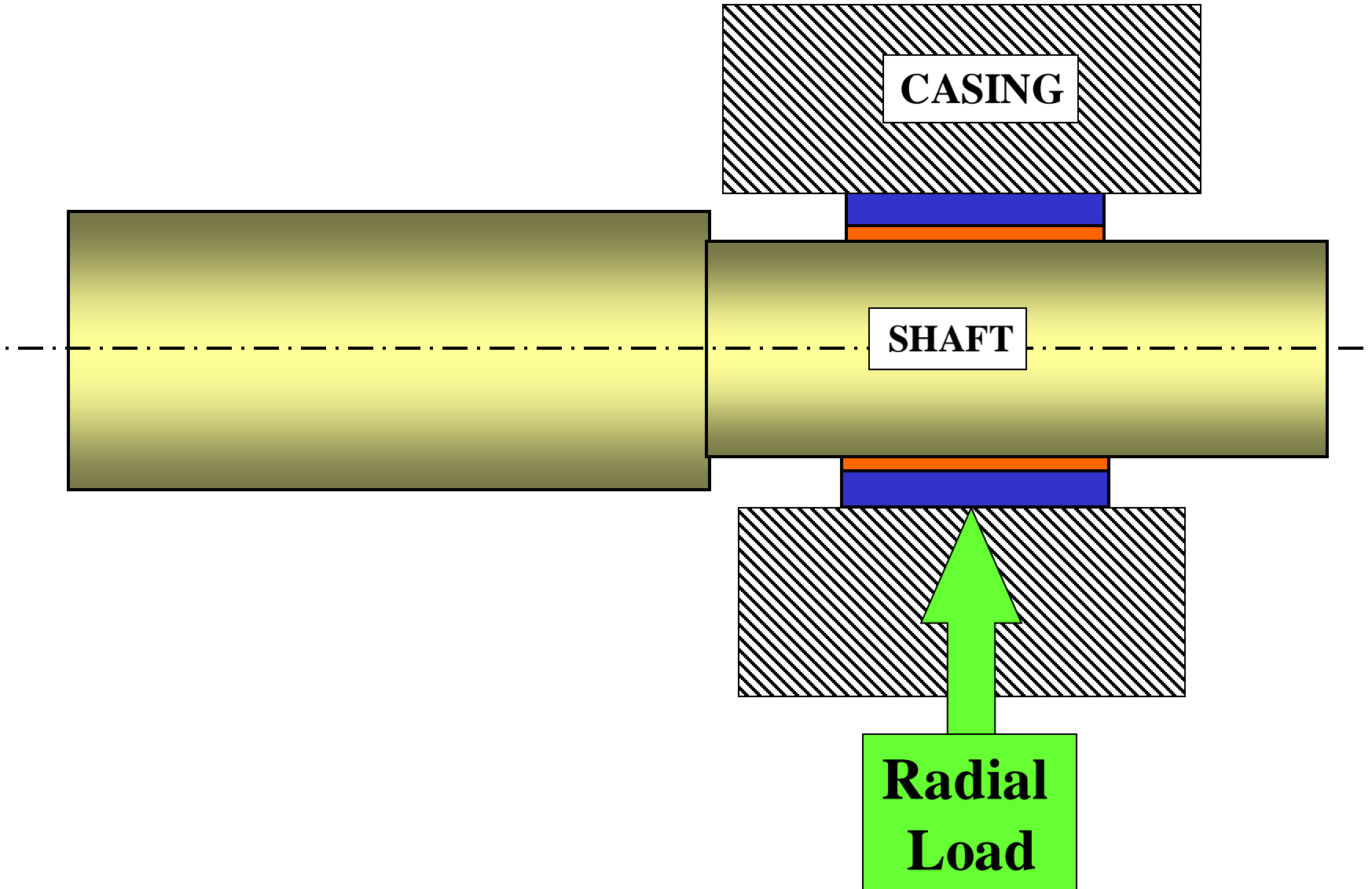
Radial Tilt-Pad Bearing

AXIAL POSITION
PROXIMITY PROBE



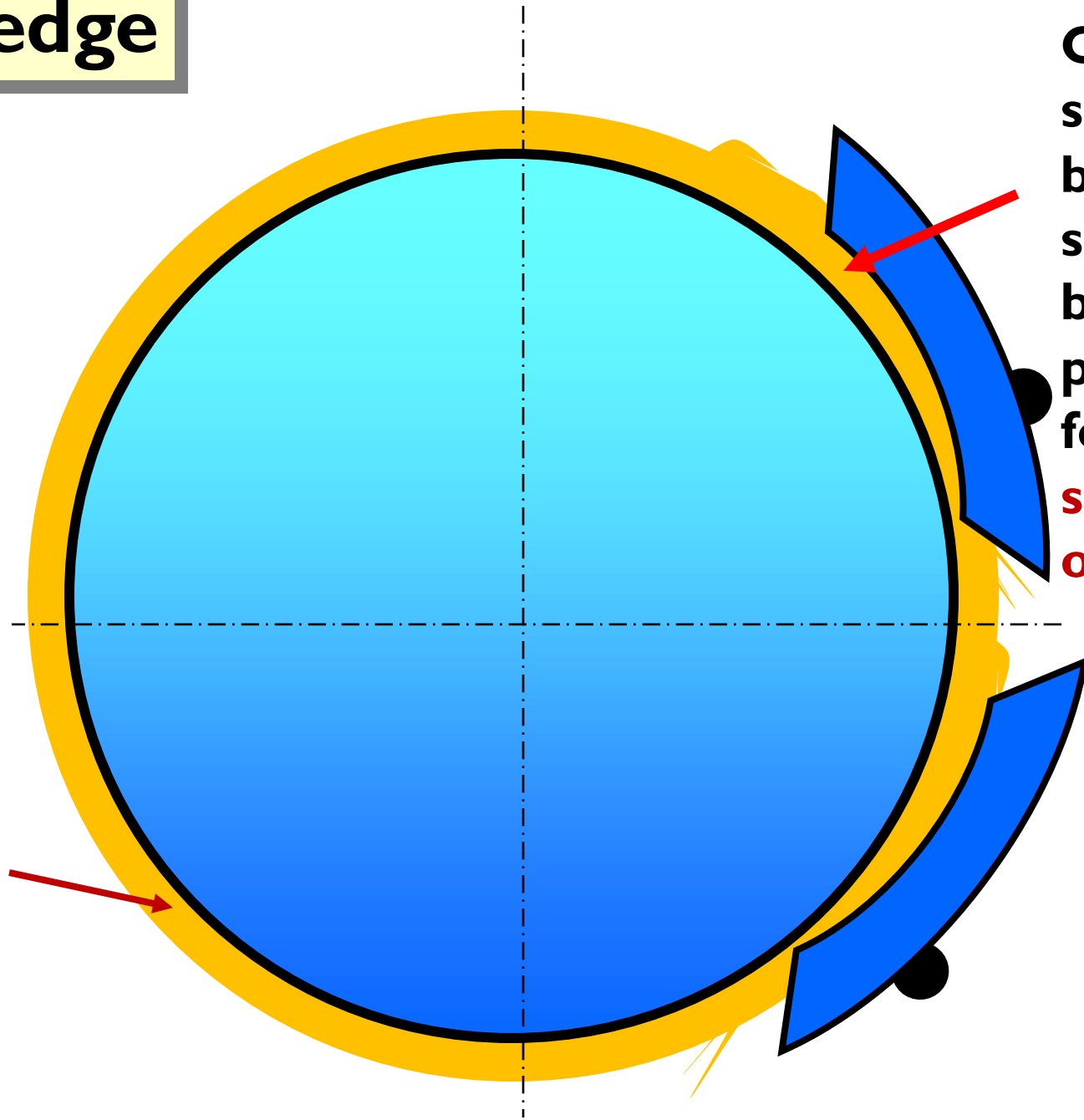
RADIAL
VIBRATION
PROBES

RADIAL TILTING PAD BEARING



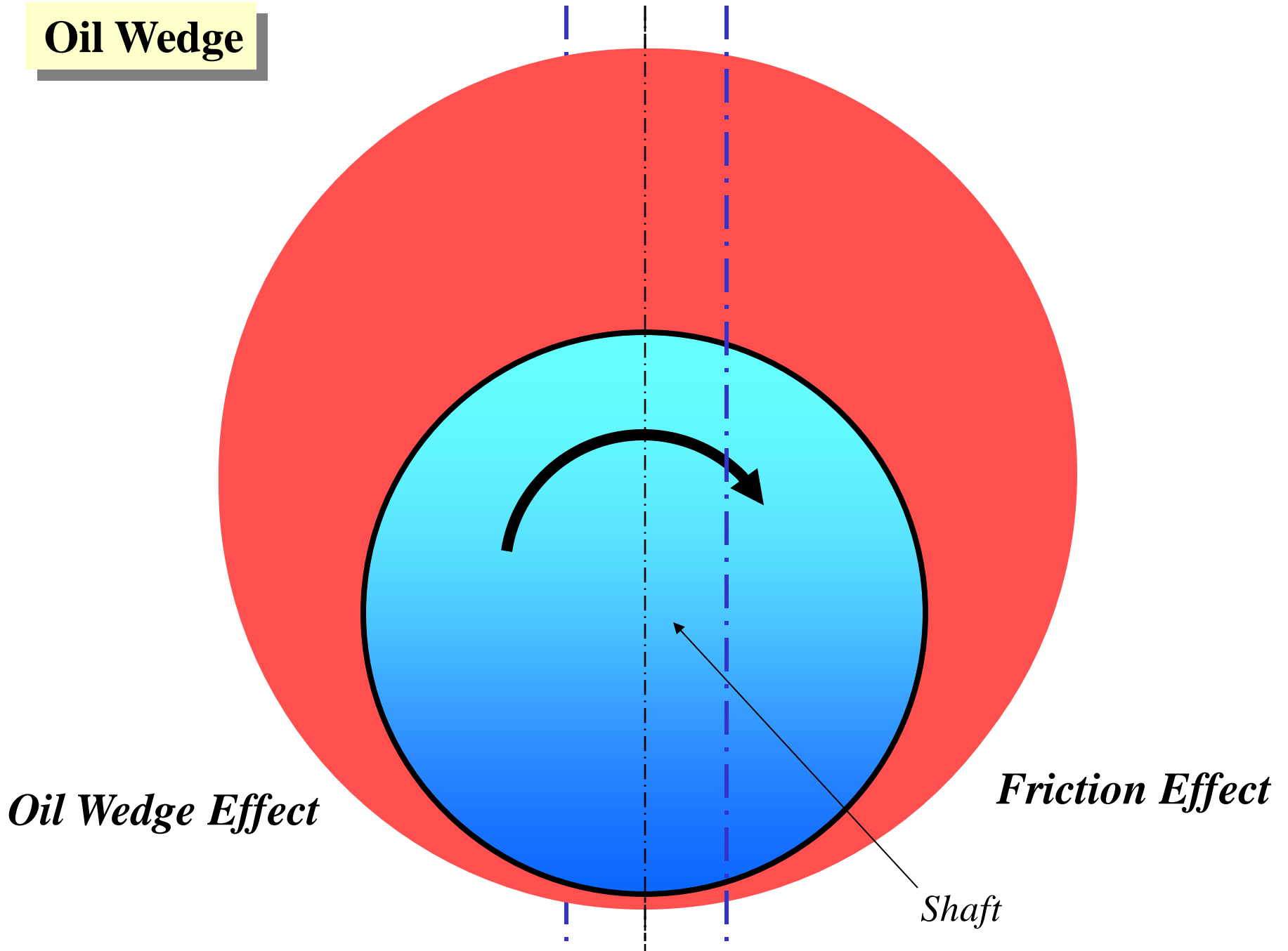
Oil Wedge

Due to **Oil Surface Tension**, And high speed, The Oil adhere to the shaft Forming an **Oil Ring**



Oil squeeze between shaft and bearing pad forming a **solid oil wedge**

Oil Wedge

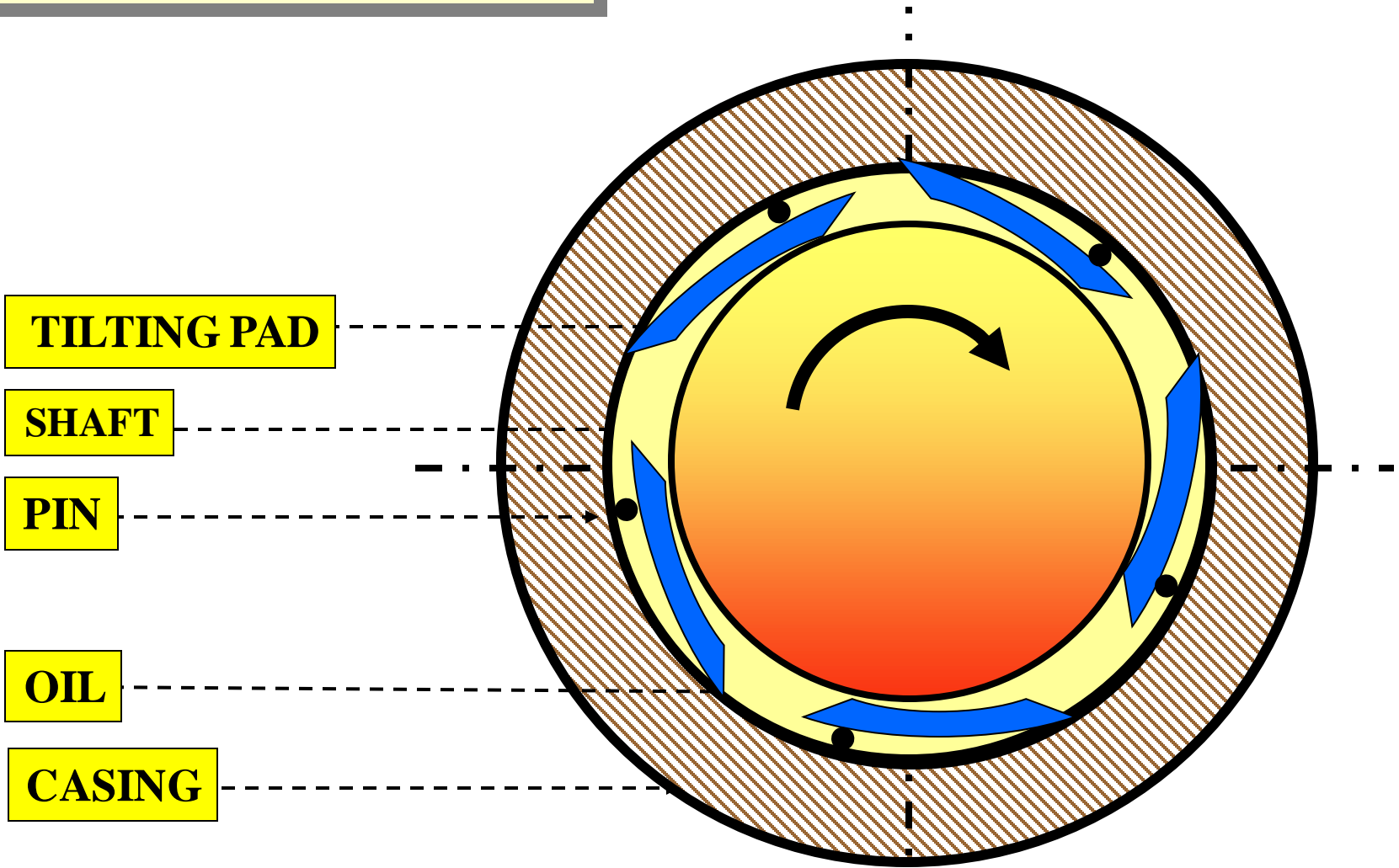


Oil Wedge Effect

Friction Effect

Shaft

RADIAL TILTING PAD BEARING



B- Pumps Cavitation Failure

**CAVITATION
OCCURS**

**AT THE MOMENT OF SUDDEN
CHANGE OF FLUID VAPOR
PHASE TO THE LIQUID PHASE .**

CAVITATION CAN OCCUR

in

***CENTRIFUGAL
PUMPS***

AND

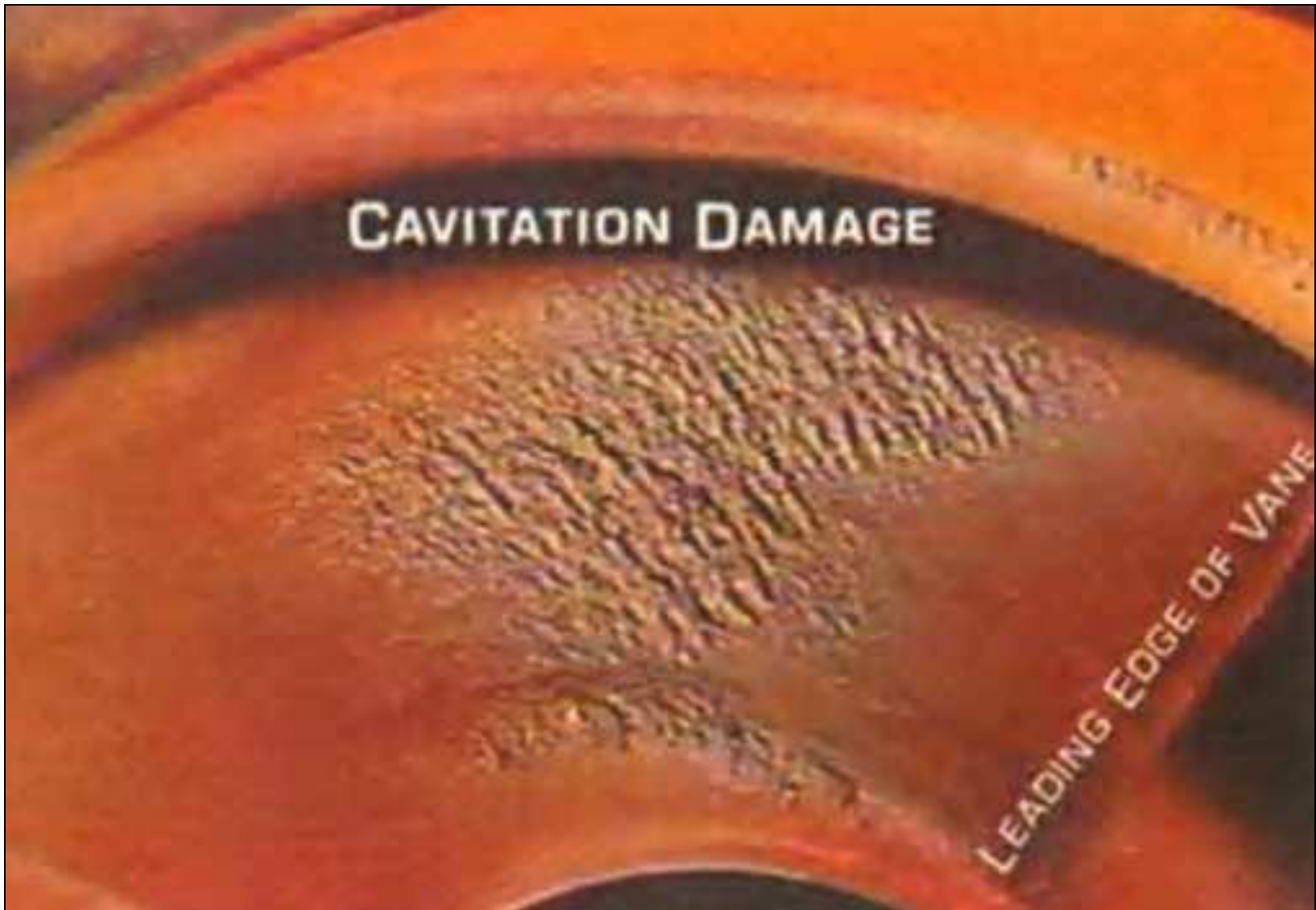
POSITIVE DISPLACEMENT PUMPS

Examples of Cavitation Damage

- Increase of noise and vibration, resulting in shorter seal and bearing life.
- Erosion of surfaces, especially when pumping water-based liquids.



Failure Modes

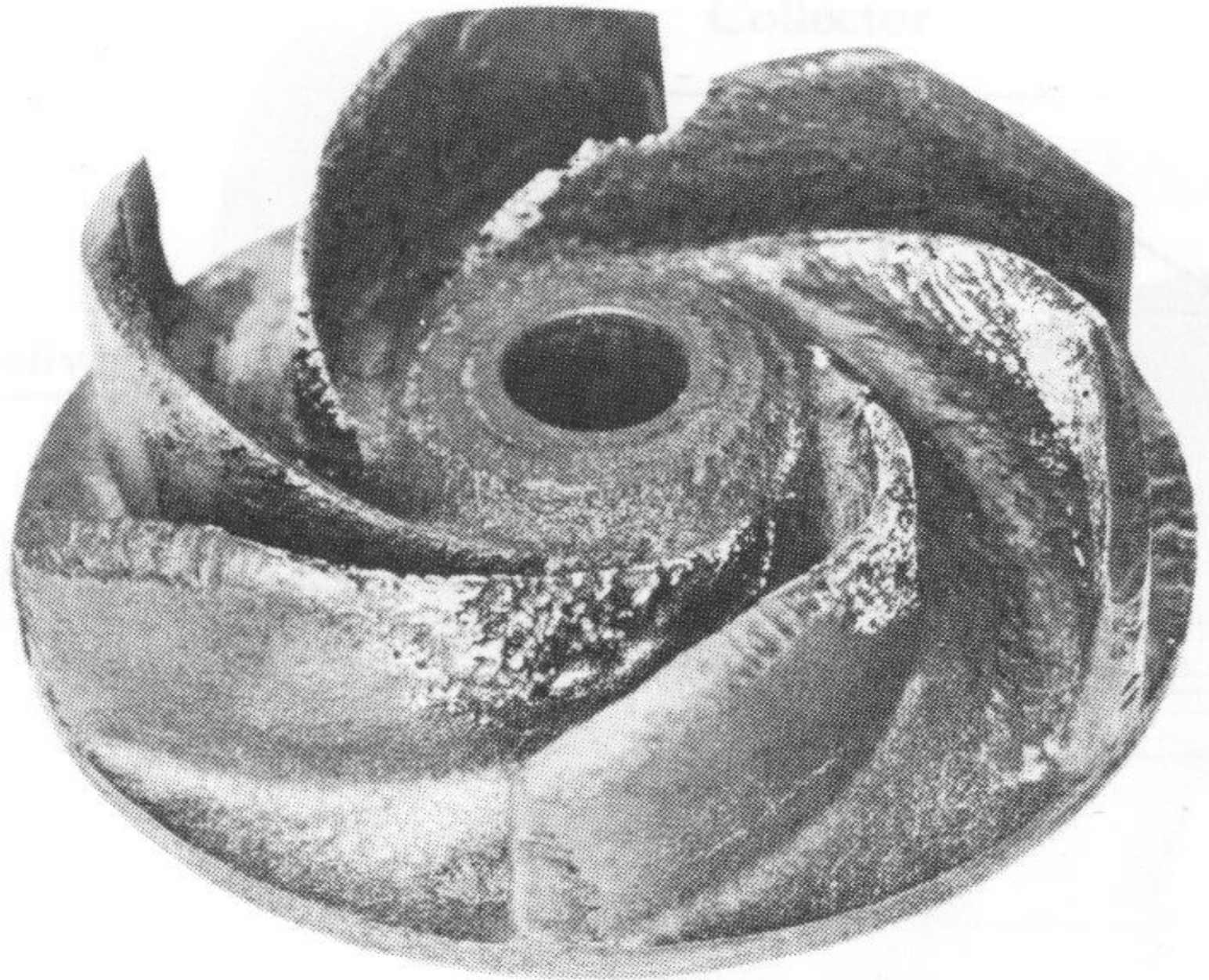


Cavitation on Pump Impeller

Cavitation



Cavitation



Cavitation Damage



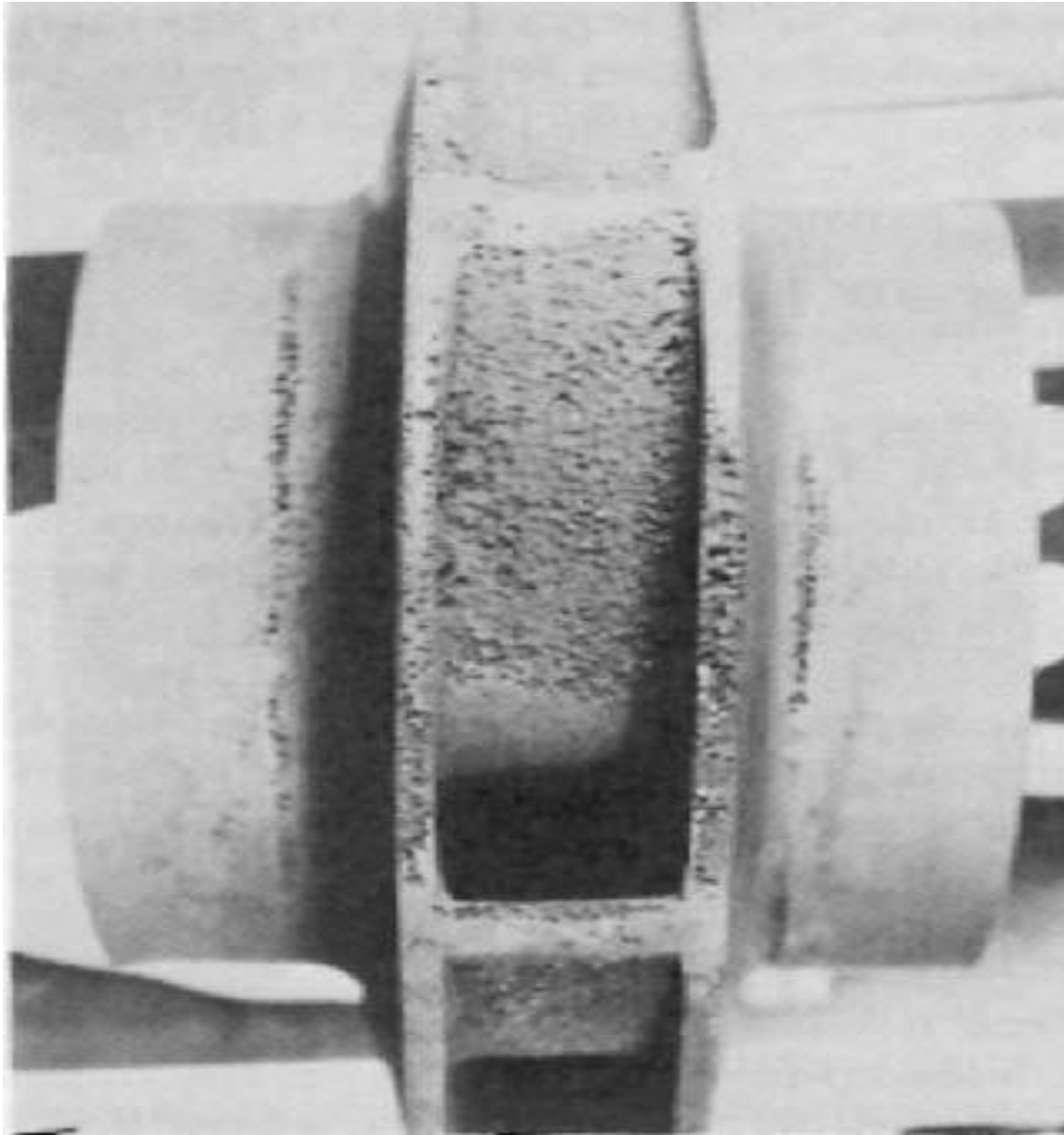
Cavitation Damage



Cavitations effect on an impeller, indicated by the cavities appearance of cavitated regions on the surface

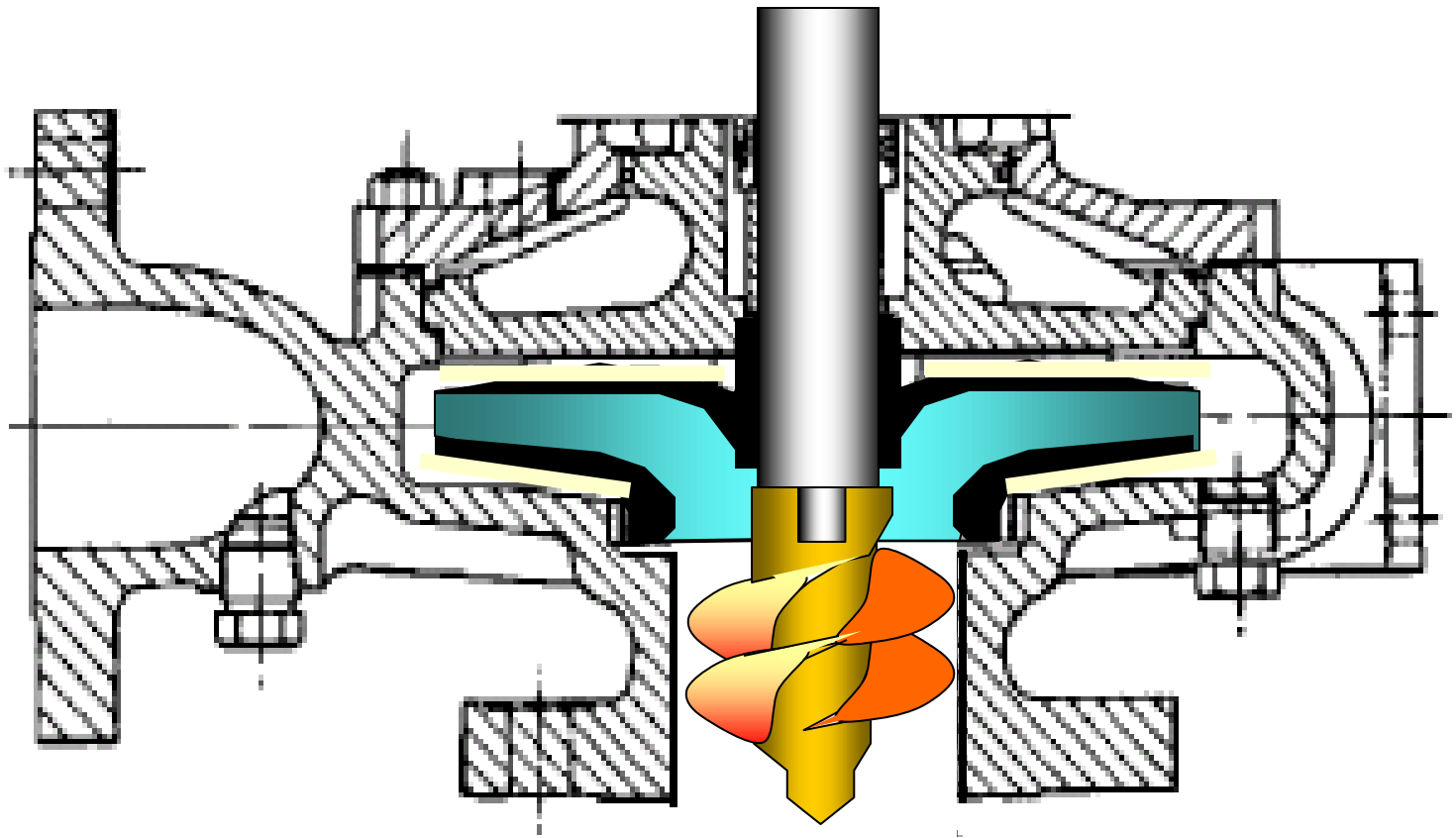


Damage to the pressure side of the vane from discharge recirculation



NPSHA < NPSHR

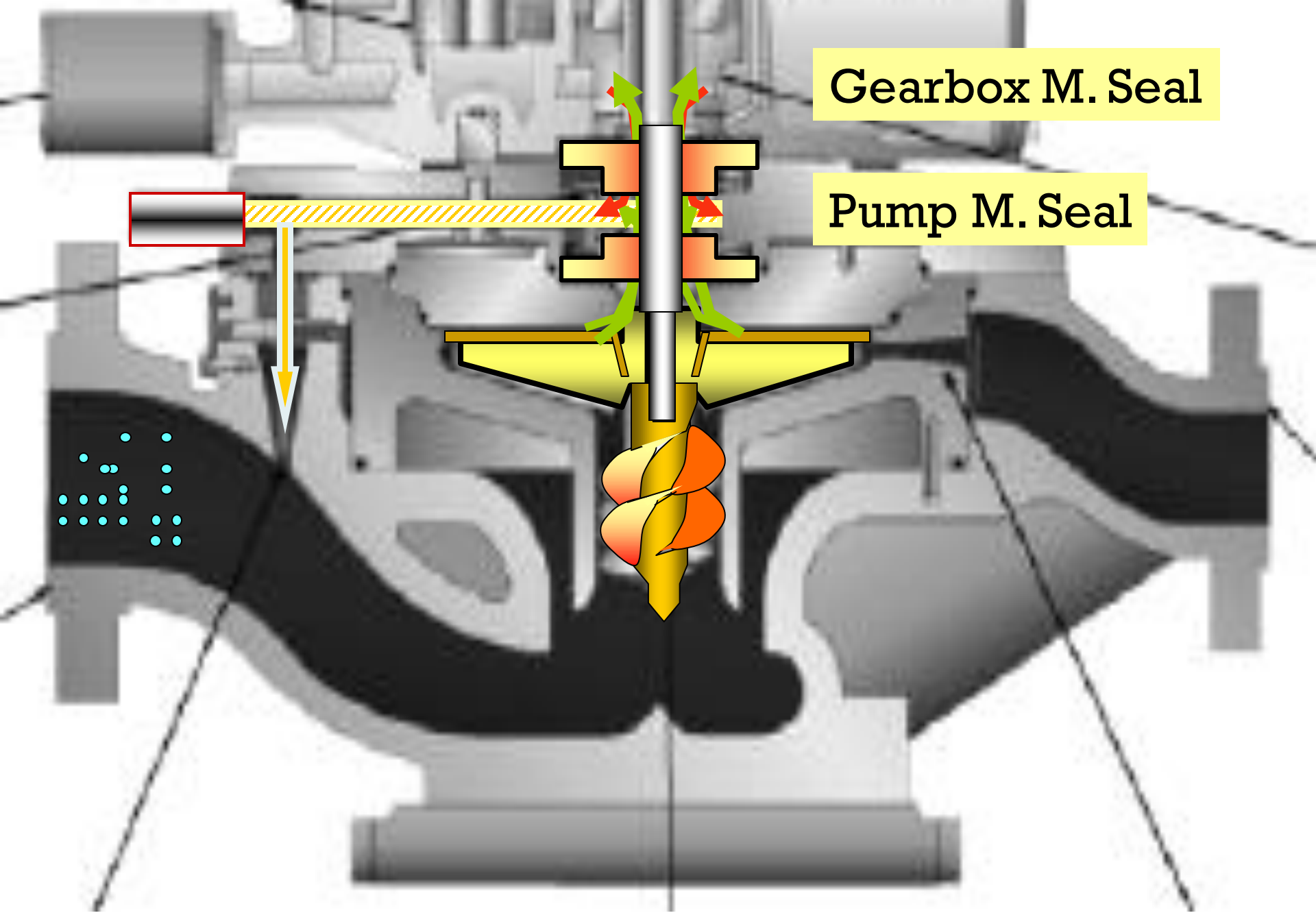




INDUCER

Gearbox M. Seal

Pump M. Seal



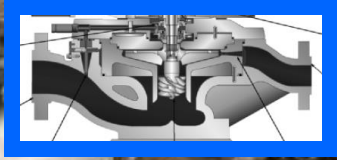
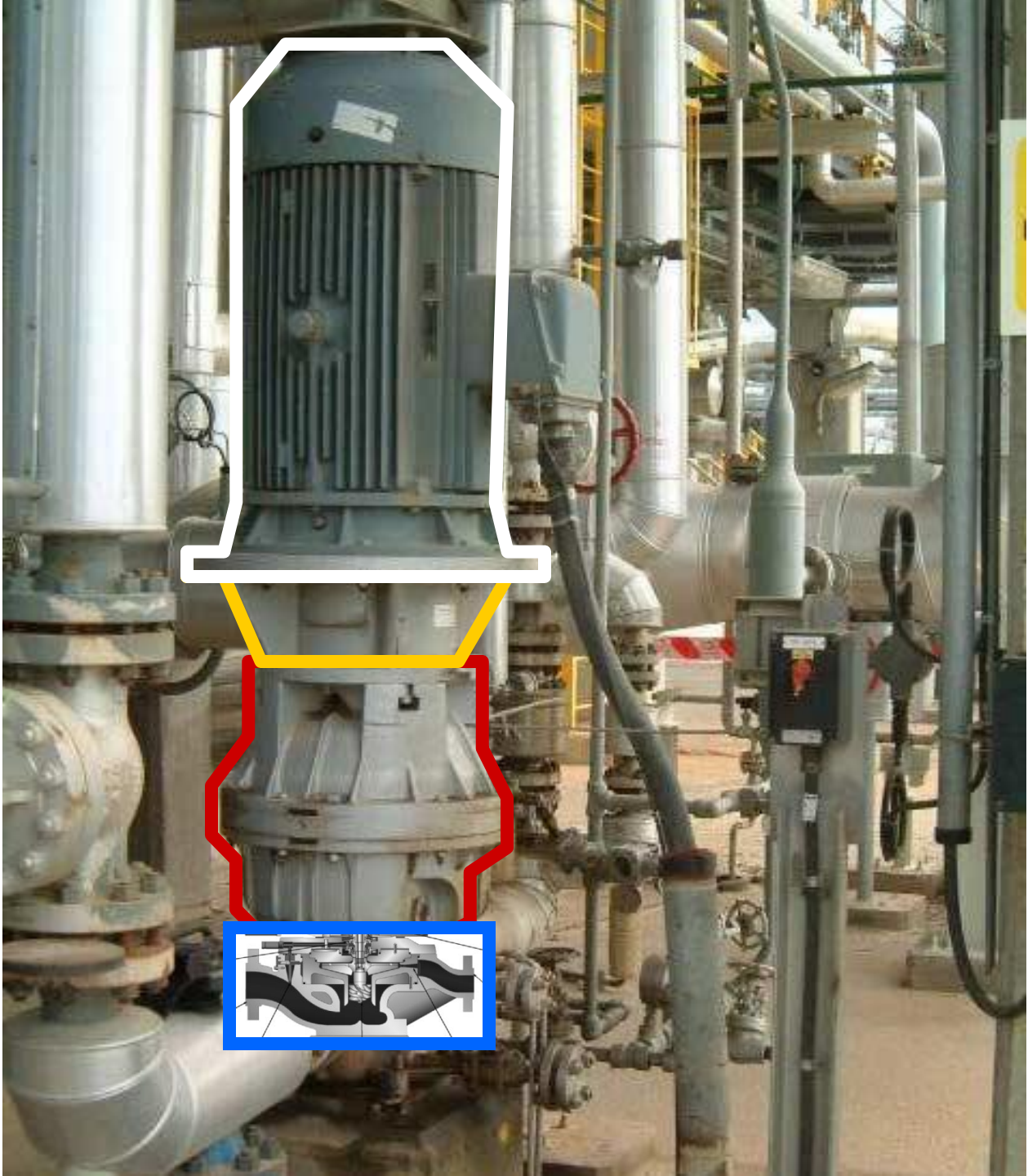
Vertical Inline Centrifugal Pumps

Driver

Coupling

Gearbox

Pump



WHAT IS CAVITATIONS PHENOMENON

It is an action of fluid vapor attack on the parts of equipment which produce:

Suction pressure less than

Vapor pressure of the pumped fluid.

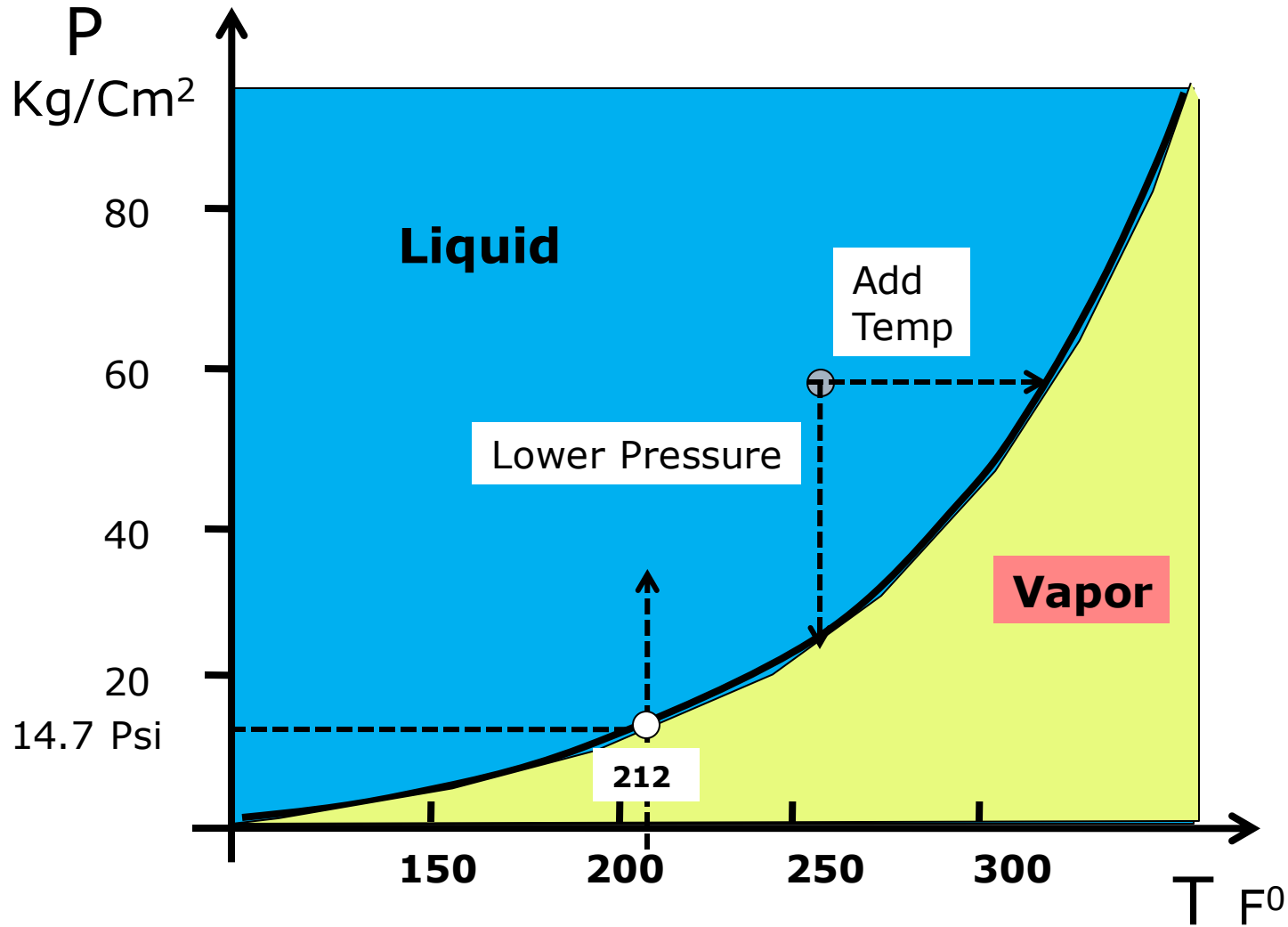
This action will cause:

loss of the weakest component element of suction parts material due to bubble explosion on the surface of suction parts causing cavities .

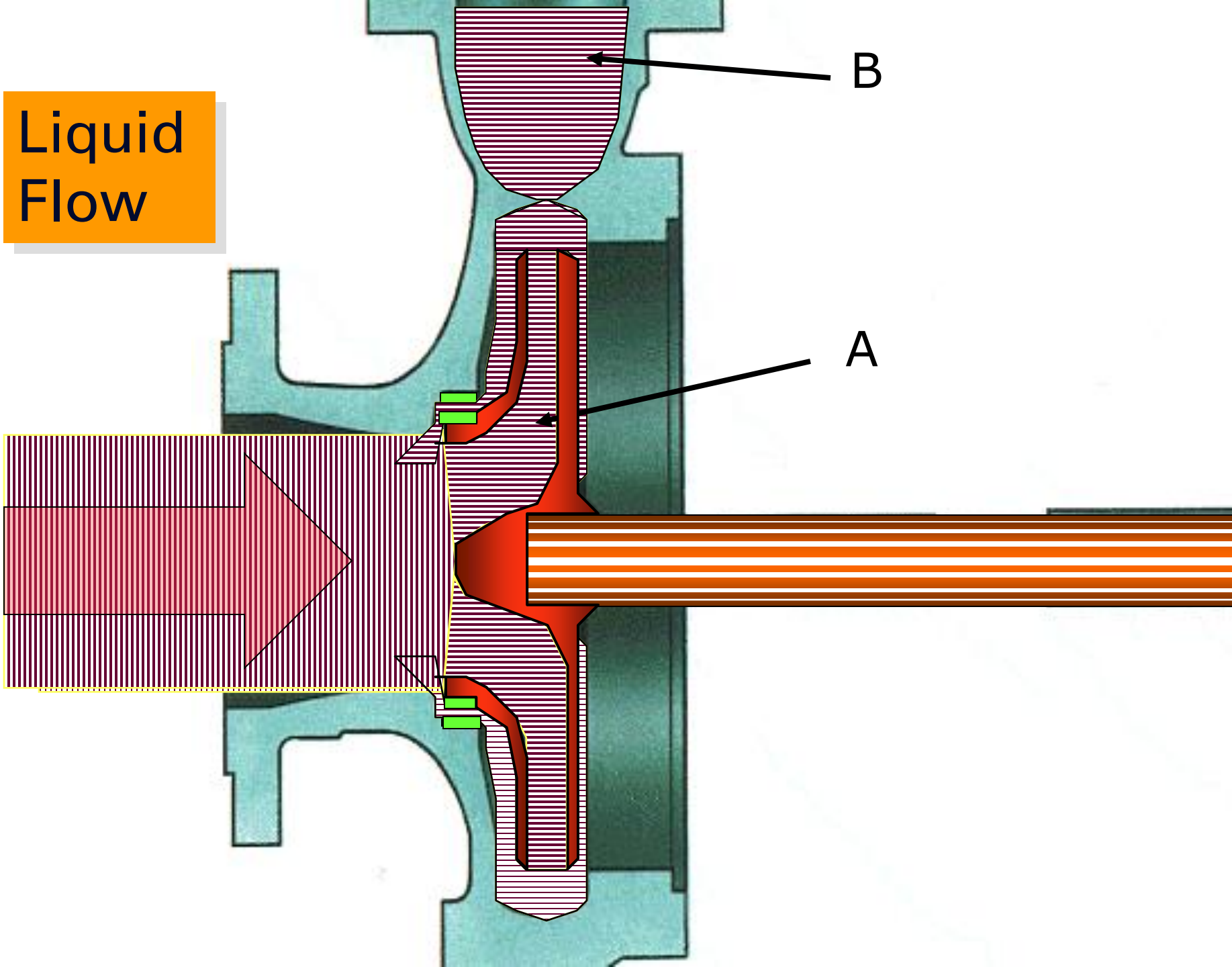
**Vapor bubble explosion on
the parts surface could be**

60,000 psi.

Water Vapor Pressure Graph



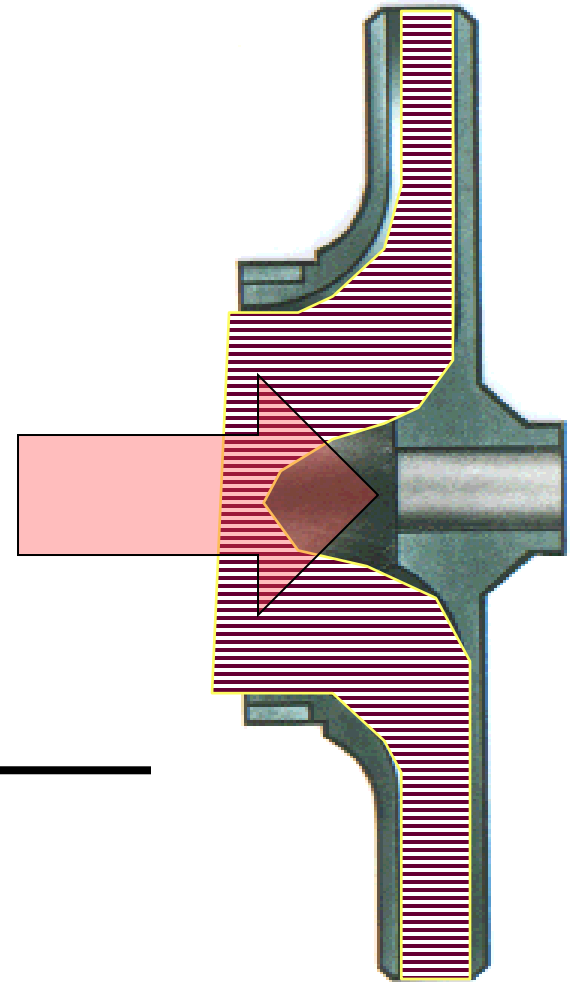
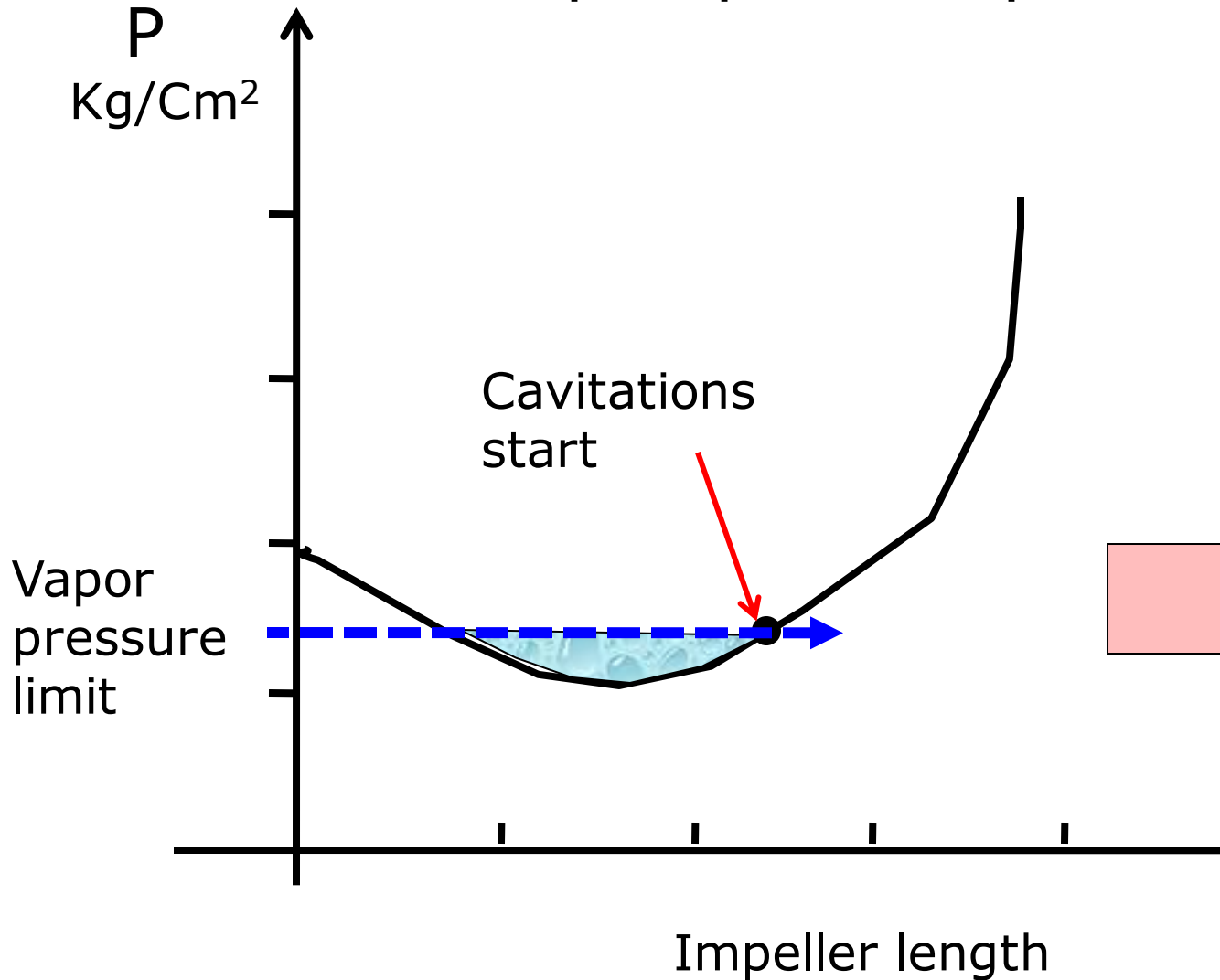
Liquid
Flow

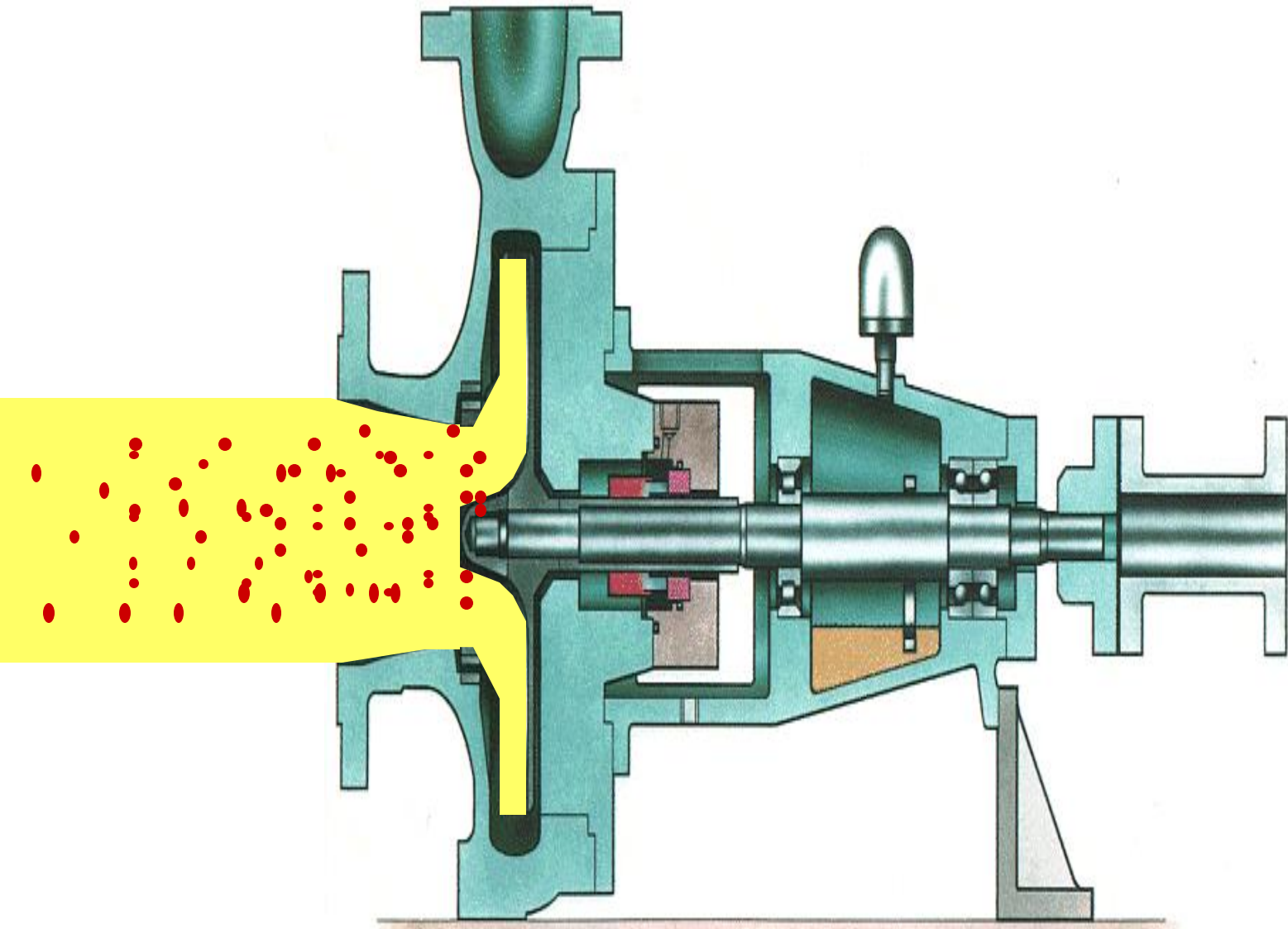


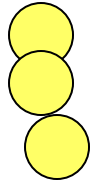
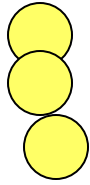
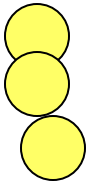
B

A

Vapor Pressure Graph through pump the impeller







FLUID VAPOR
BUBBLES



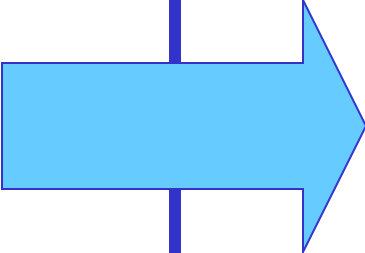
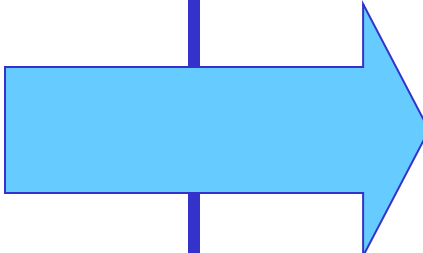
Pump suction parts

cavities



Pump suction parts
After attack

LOST ELEMENTS IN SUCTION PARTS

SUCTION PARTS MATERIAL	THE WEAKEST ELEMENT (LOST ELEMENT)
CARBON STEEL CAST IRON STIANLESS STEEL	 CARBON
BRONZ BRASS	 ZINC

What is cavitations effect

1- centrifugal pumps

- Impeller deterioration
- Decrease discharge pressure
- Decrease pump flow rate
- Increase vibration level
- Bearings & M/S failure

2- reciprocating pumps

- **Suction valve**
- **Spring Rupture**
- **Decrease discharge**
- **Decrease pump flow**
- **Cylinder Head**
- **Damage**
Piston Damage

NPSH

1- net positive suction head Required

You can get from pump manual

2- net positive suction head Available

You can calculate from pump site

To avoid suction cavitation and for safe operation

$$\text{NPSHA} > \text{NPSHR}$$

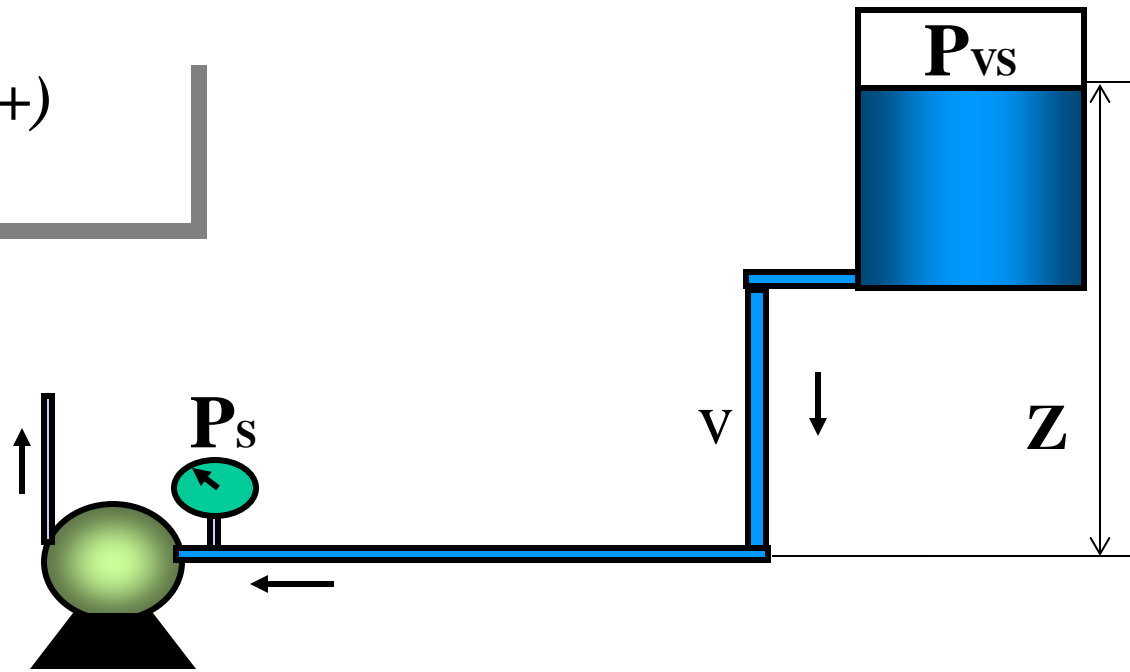
What is the parameters affecting **NPSHA**

- Suction pipe length
- Suction pipe diameter
- Liquid specific gravity
- Internal surface of suction pipe
- Liquid surface altitude
- Vapor contamination
- Suction pipe leaks
- Suction pressure
- Liquid temperature
- Liquid viscosity
- Liquid vapor pressure
- Atmospheric pressure

How to improve **NPSHA**

- Shorten the suction pipe
- ~~length~~ Increase suction
- ~~pipe size~~ Decrease suction liquid
- ~~temp.~~ Decrease suction negative
- ~~altitude~~ Increase suction positive
- ~~altitude~~ Stop the piping suction
- ~~leaks~~ Renew the suction pipe

***NET POSITIVE (+)
SUCTION HEAD***



Z	liquid surface height	ft
P_{sv}	Vessel pressure	psig
P_s	Pump suction pressure	psig
V	liquid velocity	ft/sec
P_f	Friction Pressure drop	psi
P_a	Atm. Pressure	psi
V_p	Vapor pressure	psia
$S_{p.gr}$	liquid specific gravity	
h_L	Suction head loss	ft
g	32.2	ft/sec.sec

NPSHA

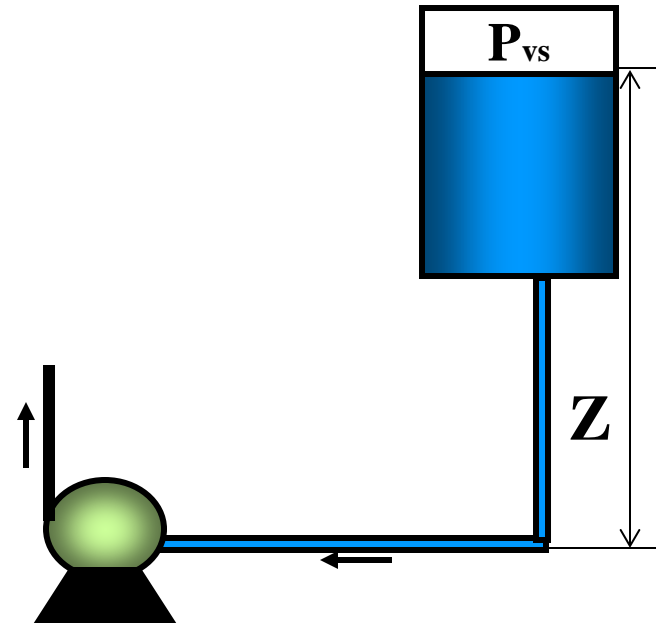
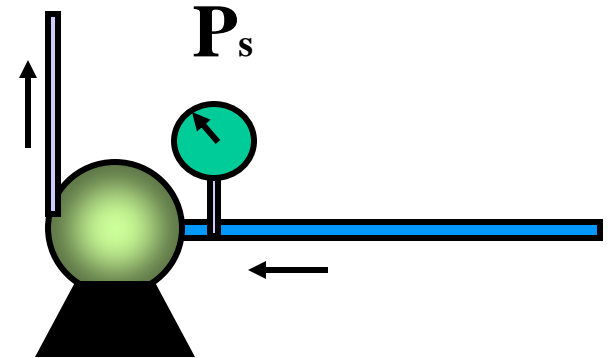
Is

Not

**The suction
Gauge pressure**

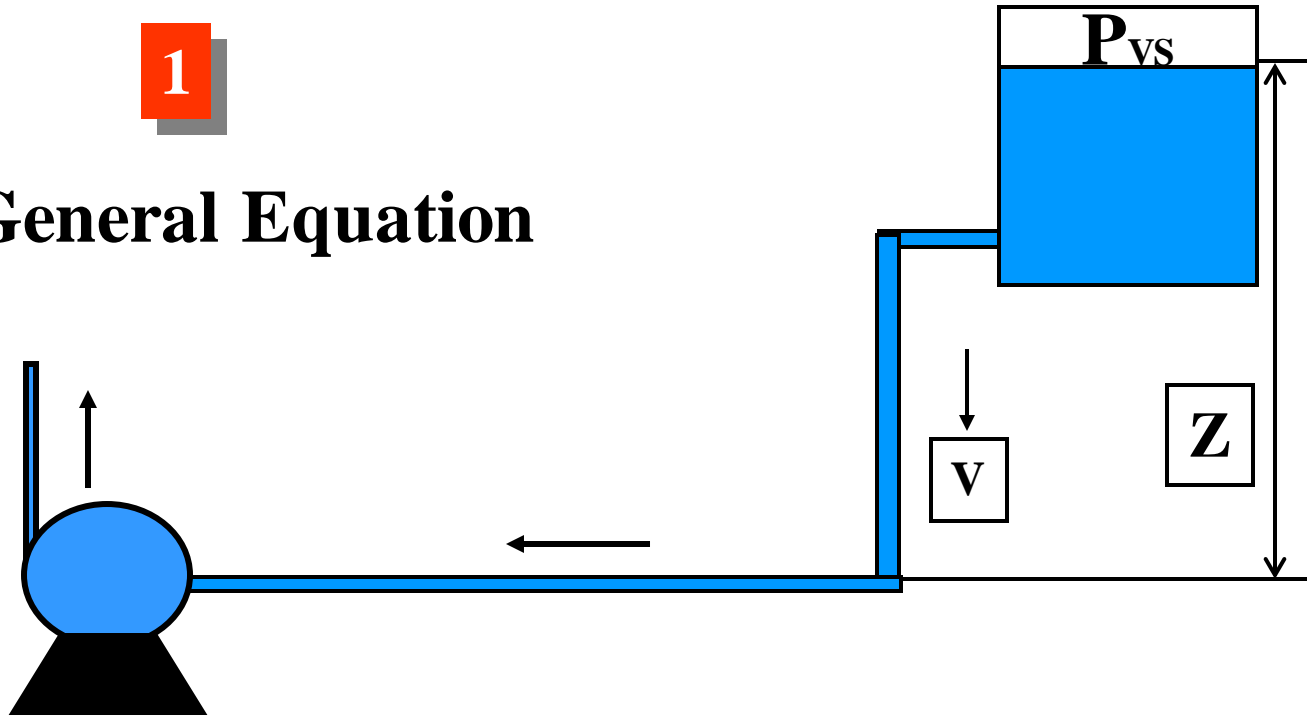
Or

**Liquid level in
The suction vessel**



1

General Equation



$$\text{NPSHA} = Z + \frac{v^2}{2g} + \frac{\{ (P_{vs} + P_a) - P_p \} 2.31}{\text{Sp.gr}} - h_L$$

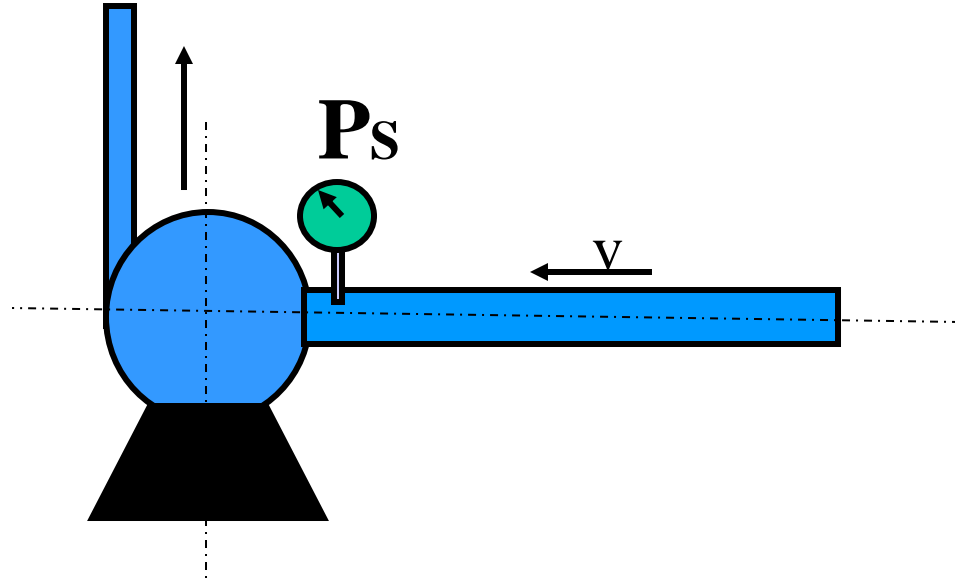
IF
The Suction
pressure is
known

$$\frac{P_s}{\text{Sp.gr}} = \frac{P_{\text{sva}}}{\text{Sp.gr}} + Z - h_L$$

$$\text{NPSHA} = Z + \frac{V^2}{2g} + \frac{\{ P_{\text{sva}} - V_p \} 2.31}{\text{Sp.gr}} - h_L$$

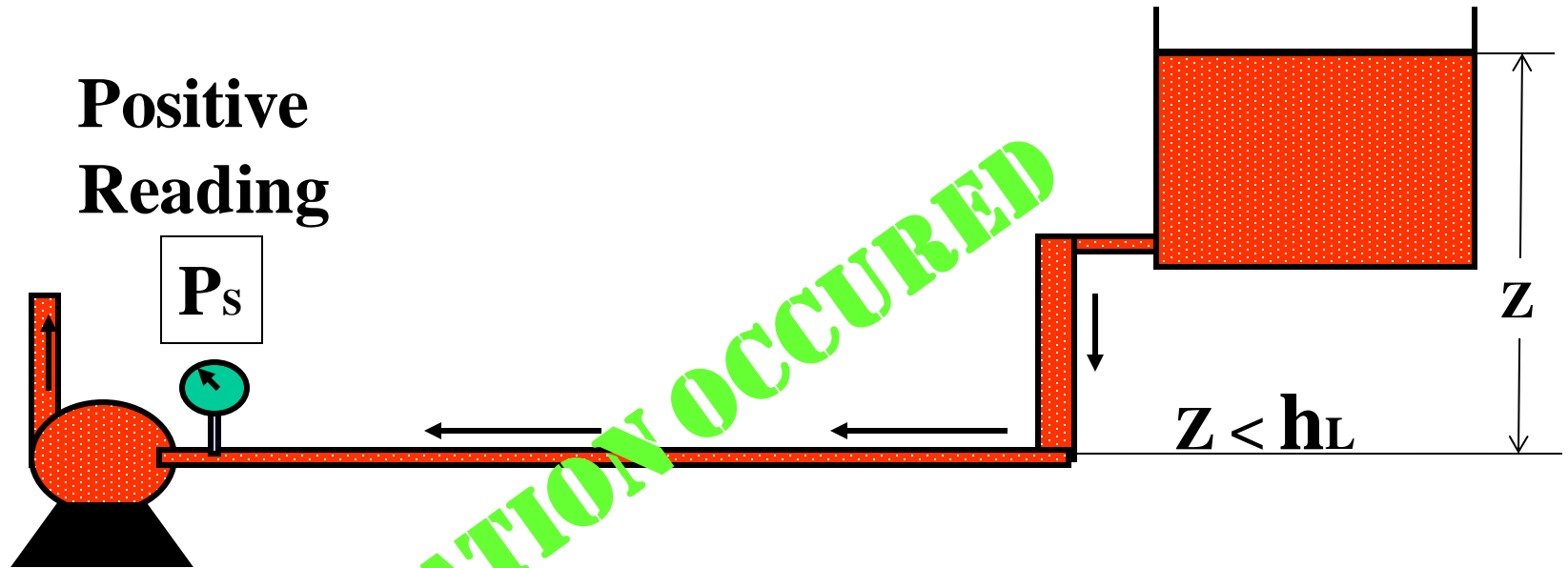
2

If The Suction pressure is known

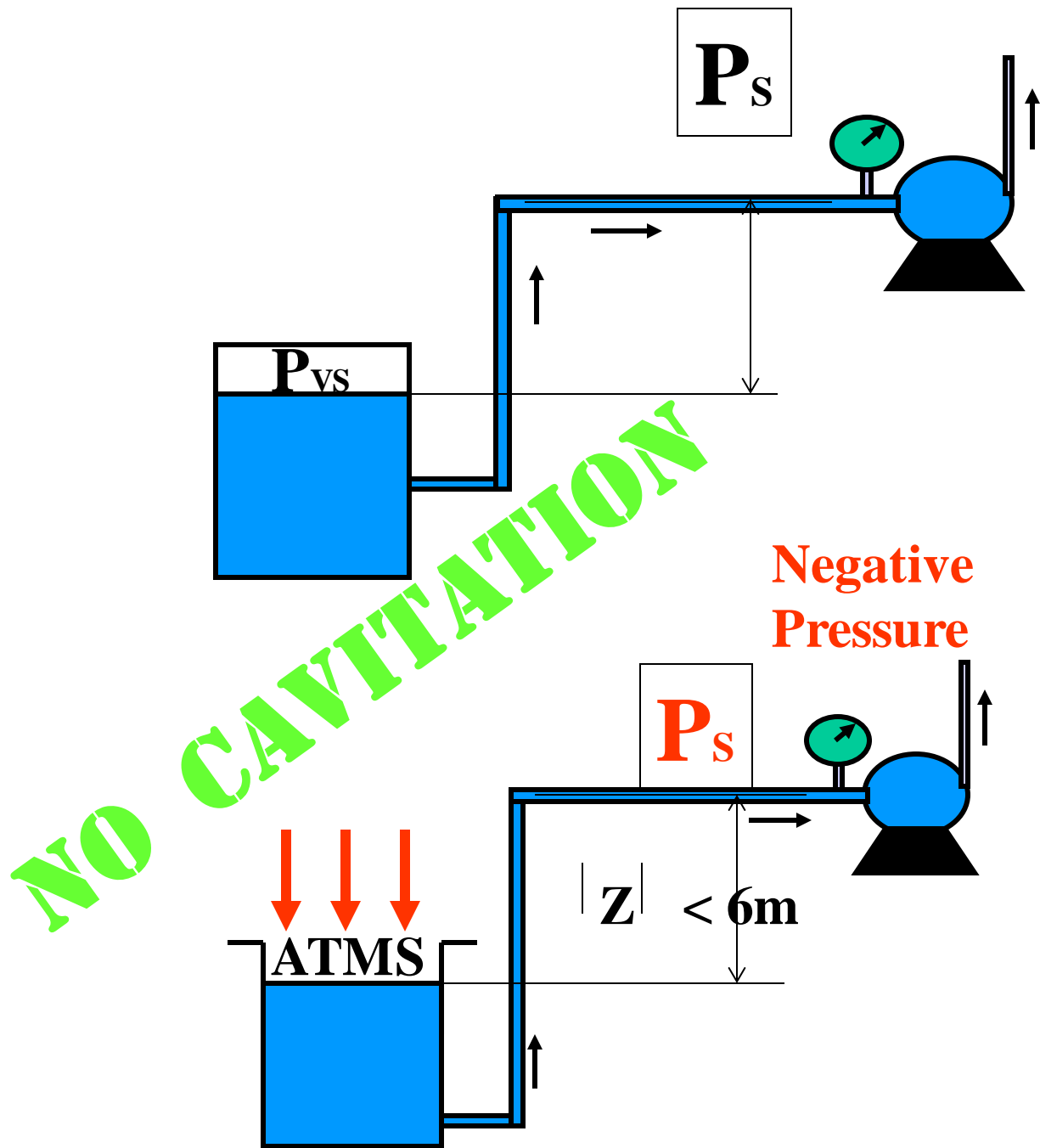


$$\text{NPSHA} = \frac{v^2}{2g} + \frac{\{ P_{sa} - V_p \} 2.31}{\text{Sp.gr}} \quad (\text{ft})$$

**Boiled
water**

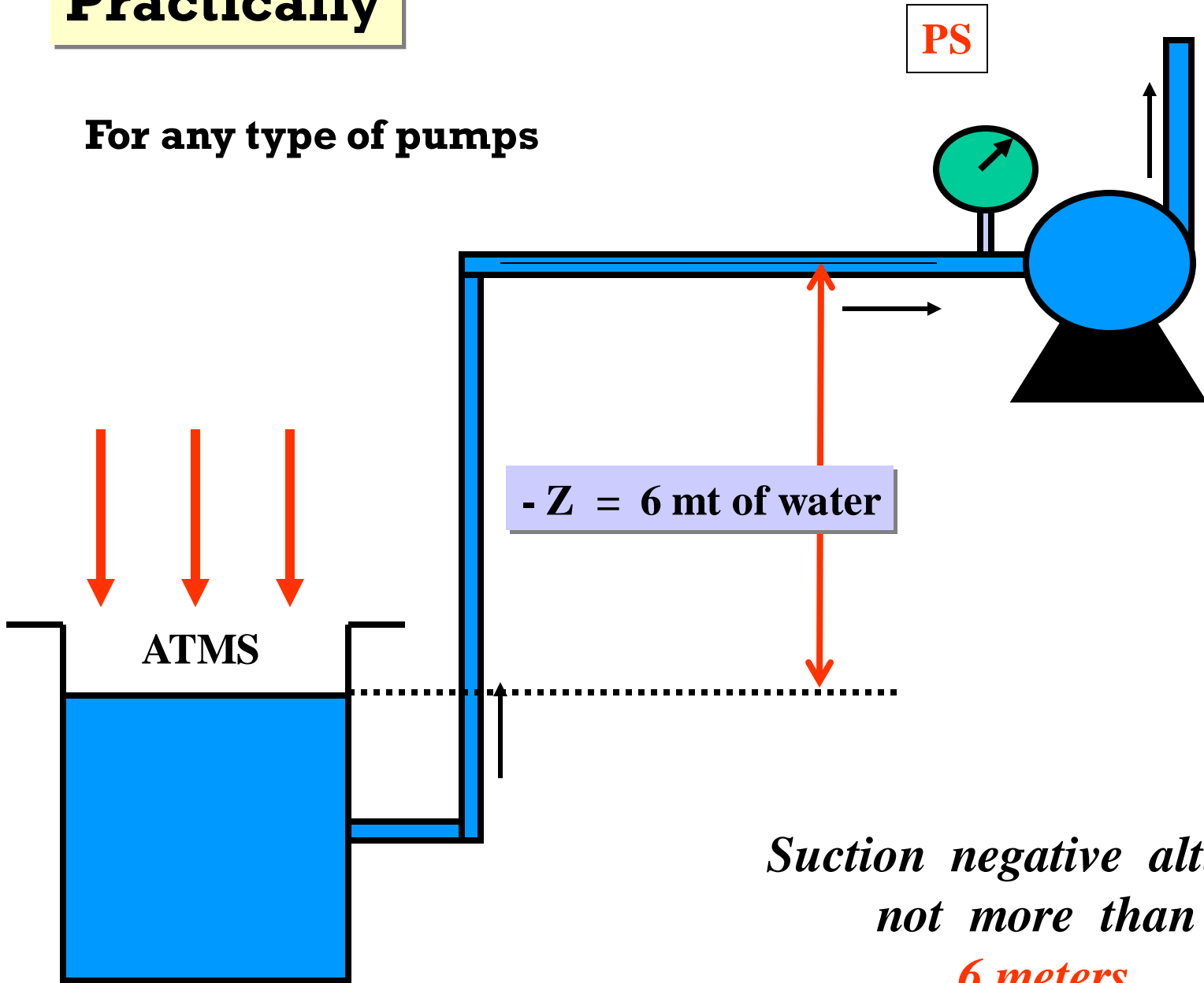


CAVITATION OCCURRED



Practically

For any type of pumps



*Suction negative altitude
not more than
6 meters*

ATMOSPHERIC
PRESSURE

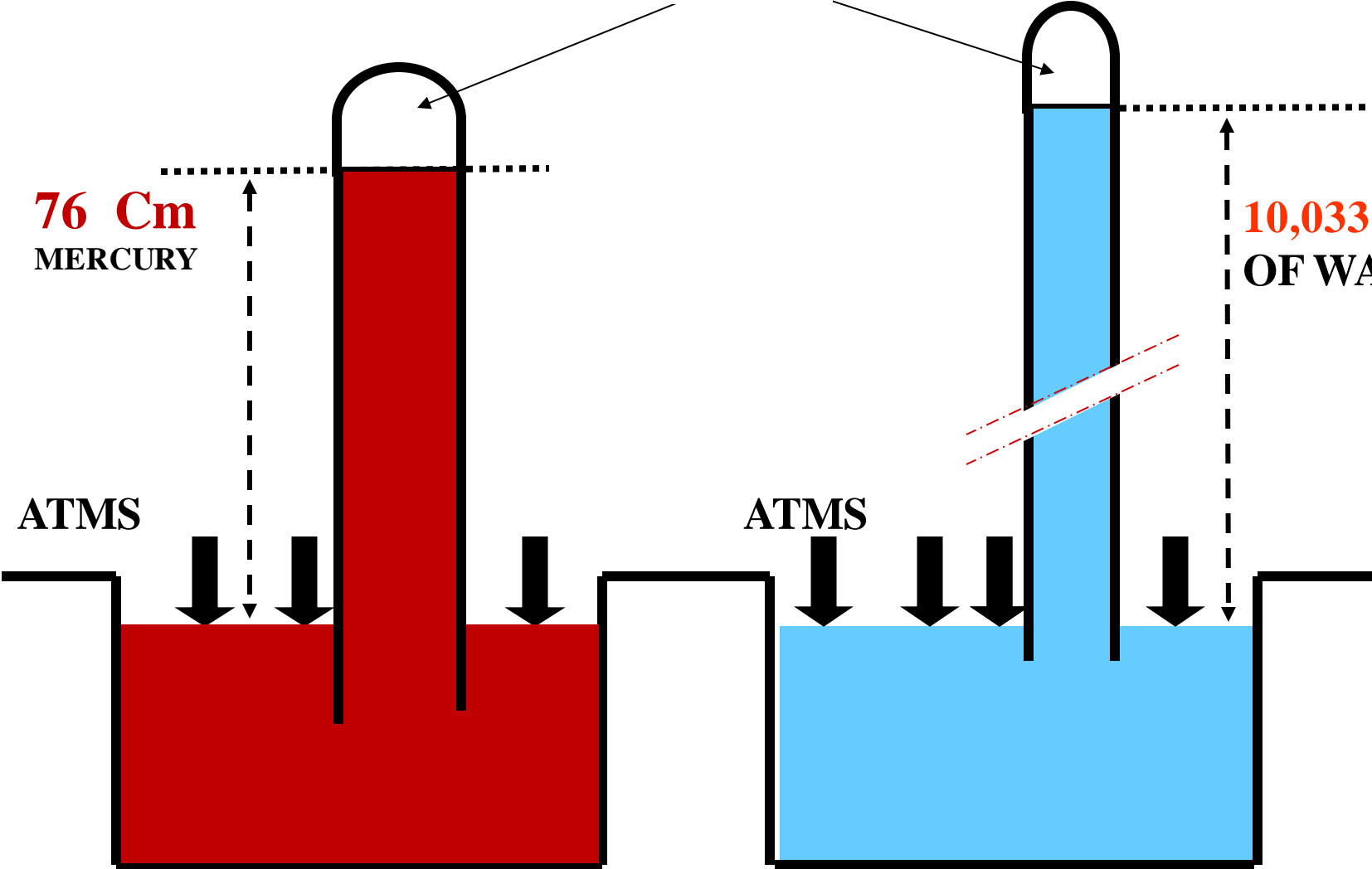
SPACE

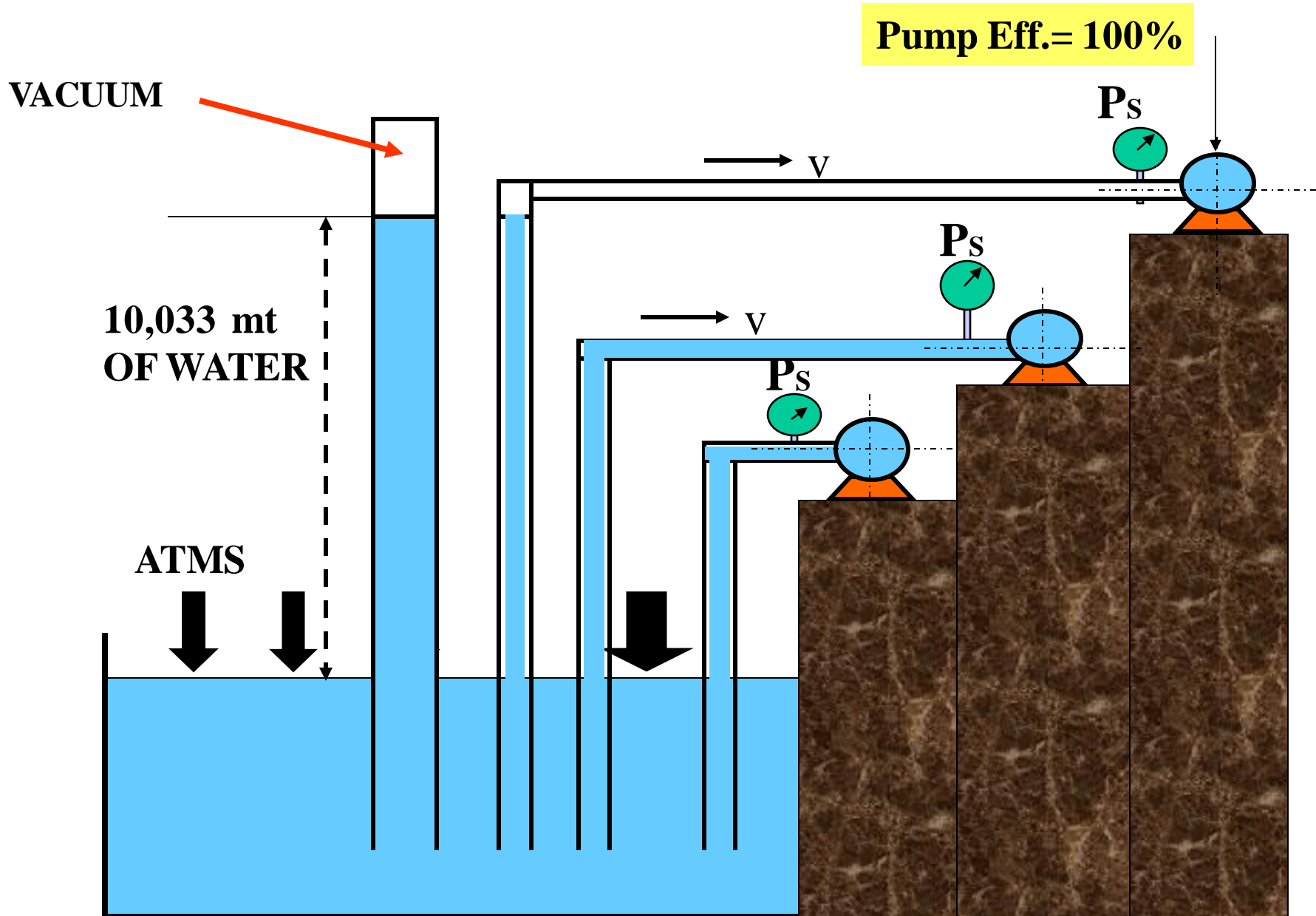
76 Cm
MERCURY

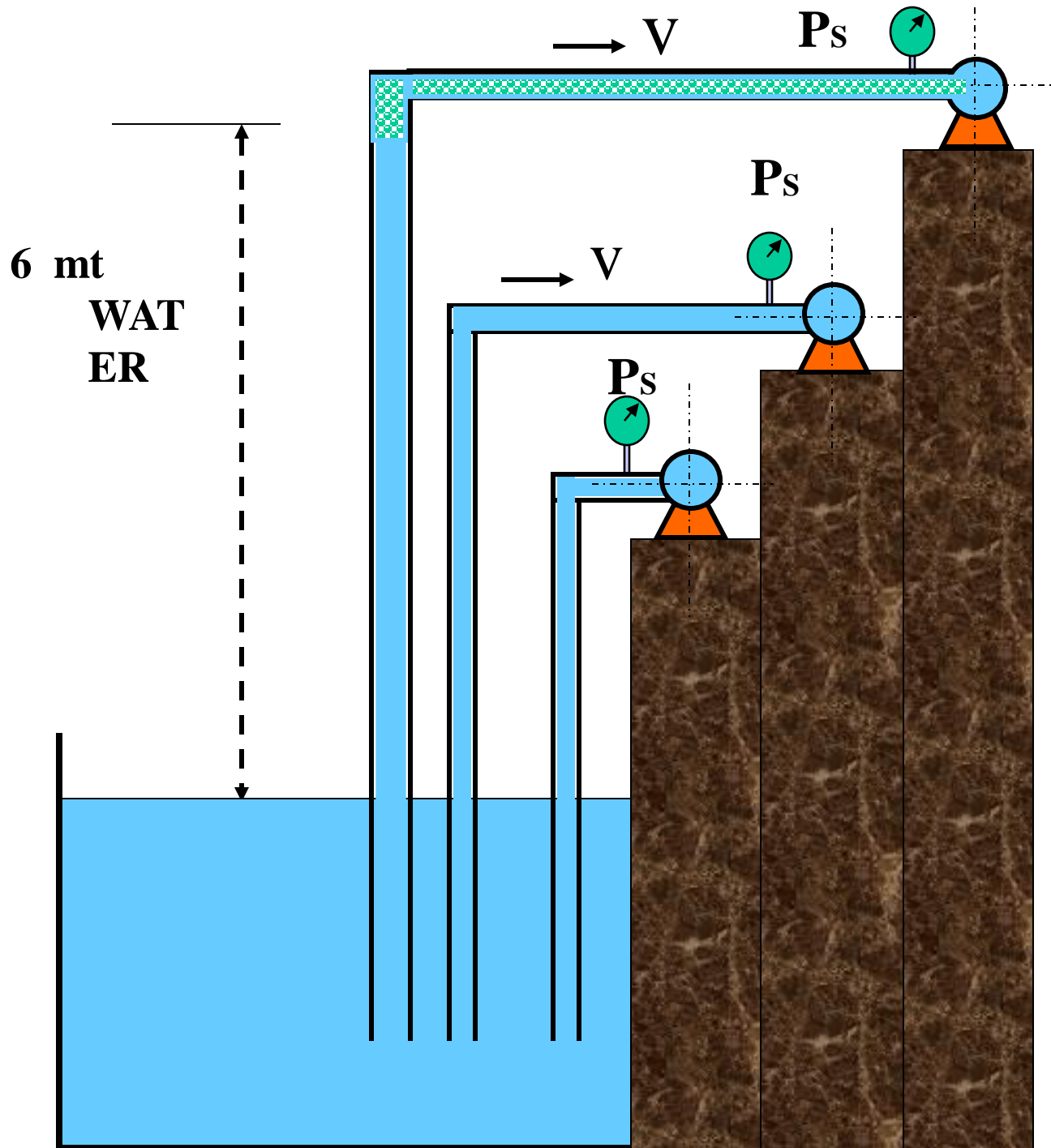
10,033 mt
OF WATER

ATMS

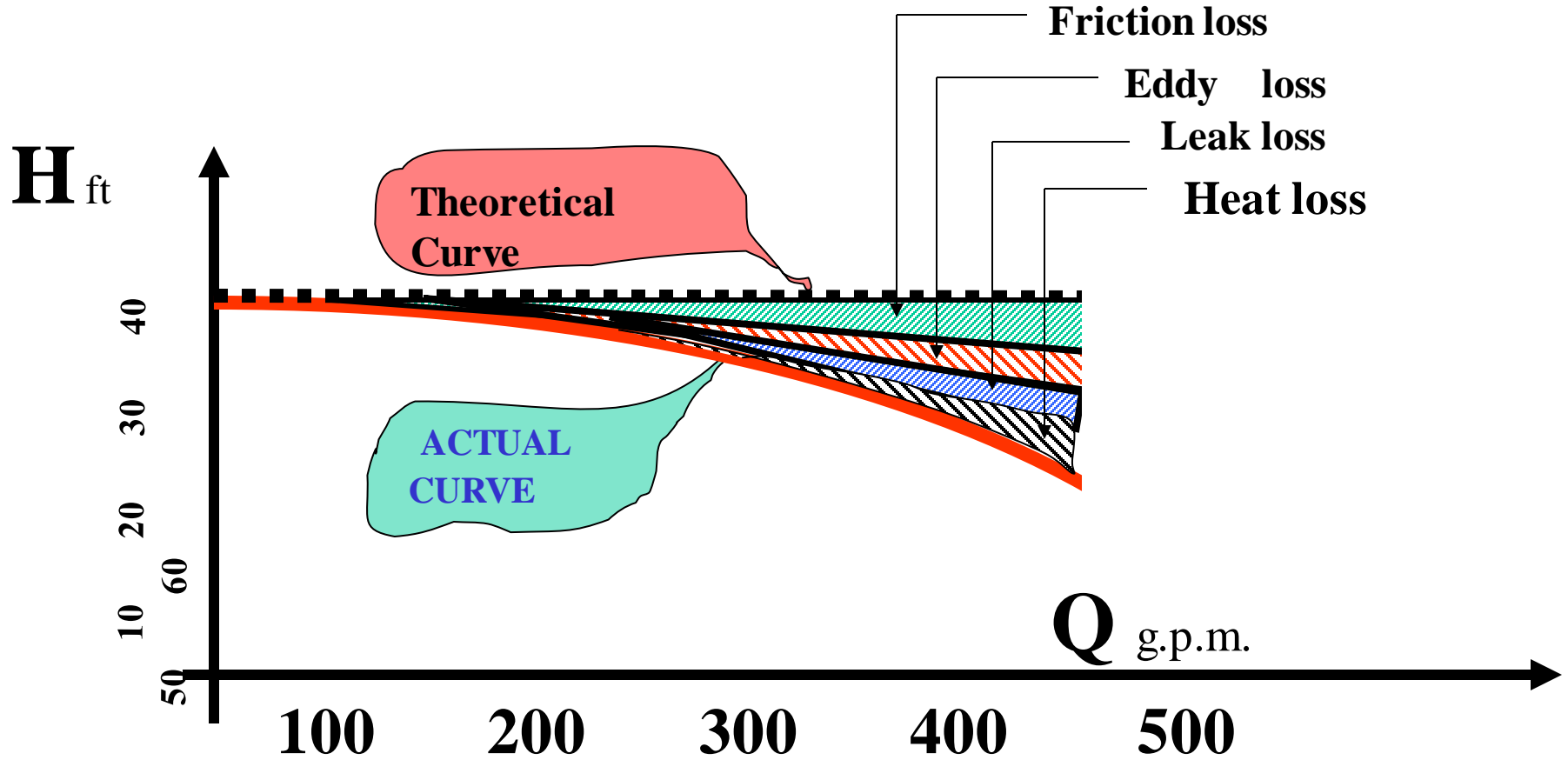
ATMS



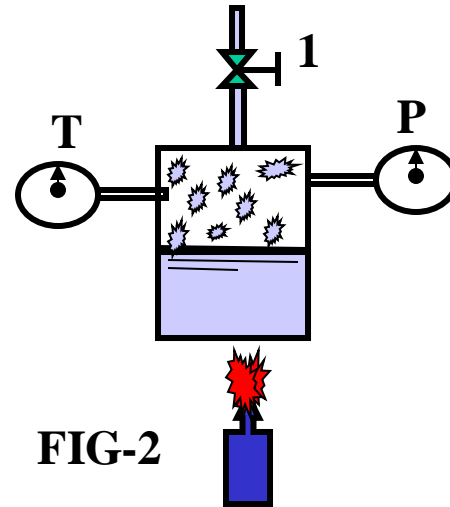
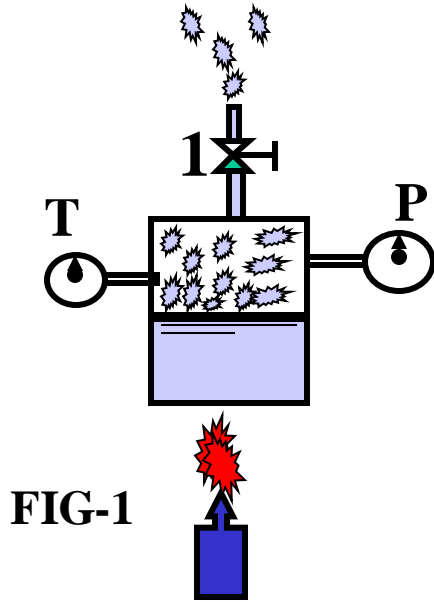




Centrifugal Pumps losses

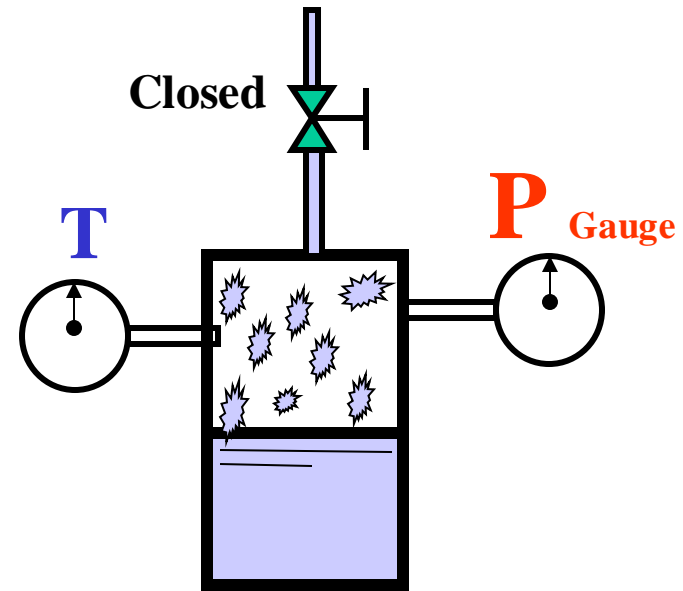
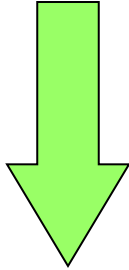


VAPOR PRESSURE



- 1- Heat up a little of water in a pot up to boiling point 100 C (valve 1 is opened)**
- 2- Take off the heating source, simultaneously close valve 1.**

Cool Down



3- During cooling down, Start to record the **P Gauge** relevant to **Temp.**

4- Apply Absolute pressure Equation .

$$\mathbf{P}_{\text{Absolute}} = \mathbf{P}_{\text{gauge}} + 1$$

(bar)

$$V_{\text{apor}} P_{\text{ressure}} = P_{\text{Gauge}} + 1$$

(bar) absolute

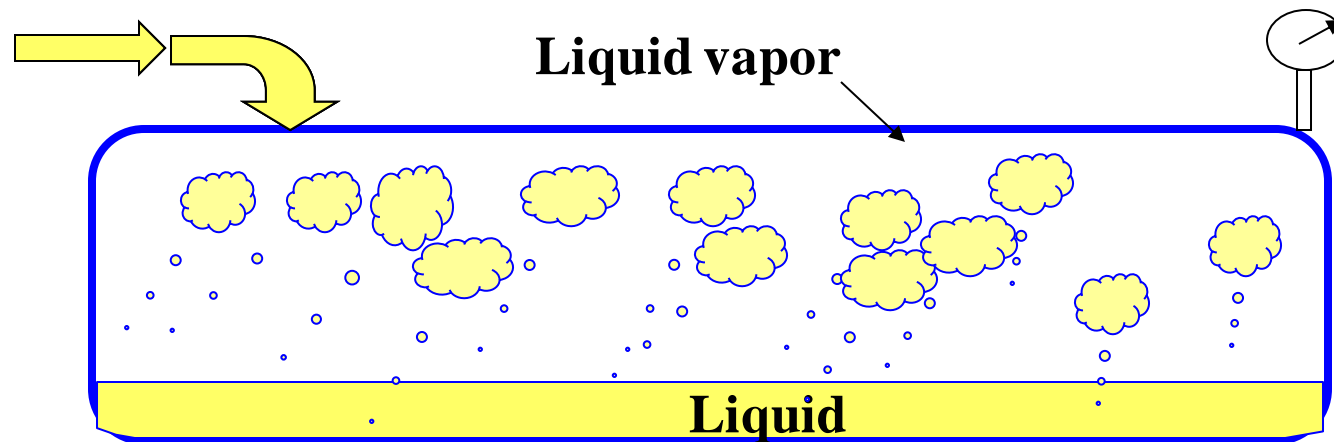
5- Record the Absolute Liquid vapor pressure.

Temp C	100	95	90	80	70	15
P Gauge	0	- 0.1	- 0.3	- 0.5	- 0.7	- 0.98
Vapor Pressure	1	0.9	0.7	0.5	0.3	0.02

Vapor Pressure

The **absolute** pressure exerted by the equilibrium vapor of a liquid when confined in a closed **Previously evacuated tank**

GPSA 1-7



$T = \text{CONSTANT}$

Examples

Crude oil level is **8 feet** above center line

of a pump , Vessel pressure is **Atmospheric**

Vp is **4 psia**

Sp gr. is **0.8**

Friction loss : **12 ft** of liquid

(Neglect velocity head)

Atmospheric pressure is **14.7 psia**

Solution

$$\begin{aligned} \text{NPSHA} &= Z + \frac{\{ (P_{sv} + P_a) - V_p \} 2.31}{\text{Sp.gr}} - h_L \\ &= 8 + \frac{\{ (0 + 14.7) - 4 \} 2.31}{0.8} - 12 \\ &= 8 + 31 - 12 \\ &= + 27 \quad (\text{ft}) \end{aligned}$$

Compare with NPSHR

Crude oil level is **8 feet** above center line of a pump ,

Vessel pressure is **Atmospheric**

Vp is **14 psia**

Sp gr. is **0.85**

Friction loss : **2 ft** of liquid

Atmospheric pressure is **14.7 psia** (Neglect velocity head)

Solution

$$\begin{aligned} \text{NPSHA} &= Z + \frac{\{ (P_{sv} + P_a) - V_p \} 2.31}{\text{Sp.gr}} - h_L \\ &= 8 + \frac{\{ (0 + 14.7) - 14 \} 2.31}{0.85} - 2 \\ &= 8 + 2 - 2 \\ &= + 8 \quad (\text{ft}) \end{aligned}$$

Compare with NPSHR

negative

If the liquid level $Z = -12$ ft

Friction loss is 1 ft of liquid

Atmospheric pressure is 14.7 Psia. at 150 F

water sp gr. is 0.982 (Neglect velocity head)

$V_p = 3.7$ psia

FIND NPSHA

Solution

NPSHA

$$= Z + \frac{(P_a - V_p) 2.31}{Sp\ gr} - h_L \quad (\text{ft})$$

$$= -12 + \frac{((0 + 14.7) - 3.7) 2.31}{0.982} - 1 \quad (\text{ft})$$

$$= + 12.8 \quad (\text{ft})$$

Compare with NPSHR

Crude pump

Suction pressure is **-5 psig**

Vp. is **4 psia**

(Neglect velocity head)

Sp gr. is **0.8**,

Atmospheric pressure is **14.7 psia.**

FIND NPSHA

Solution

$$\begin{aligned} \text{NPSHA} &= \frac{ \{ (P_s + P_a) - V_p \} 2.31 }{ \text{Sp.gr} } \quad (\text{ft}) \\ &= \frac{ \{ ((0 + 14.7) - 5) - 4 \} 2.31 }{ 0.8 } \quad (\text{ft}) \\ &= \quad + \quad 16.46 \quad (\text{ft}) \end{aligned}$$

Compare with NPSHR

If the liquid is butane and level is $Z = - 8 \text{ ft}$
System pressure is **60 psia.**

Temperature is 90 F

$V_p = 44 \text{ psia}$ at 90 F, butane sp.gr is **0.58** (Neglect velocity head)

Friction loss : **12 ft** of liquid,

FIND NPSHA

Solution

NPSHA

$$= Z + \frac{(P_{sva} - V_p) 2.31}{\text{Sp gr}} - h_L \quad (\text{ft})$$

$$= -8 + \frac{(60 - 44) 2.31}{0.58} - h_L \quad (\text{ft})$$

$$= + 43.7 \text{ ft}$$

Compare with NPSHR

Examples

If crude pump

suction pressure is **+1 psig**

(Neglect velocity head)

Vp. is **13 psia**

Sp gr. is **0.85**, Atmospheric pressure is **14.7 psia.** **FIND NPSHA**

Solution

$$\begin{aligned} \text{NPSHA} &= \frac{\{ P_{sa} - V_p \} 2.31}{\text{Sp.gr}} && (\text{ft}) \\ &= \frac{\{ (1 + 14.7) - 13 \} 2.31}{0.85} && (\text{ft}) \\ &= + 7.33 && (\text{ft}) \end{aligned}$$

Compare with NPSHR