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

Hassan

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 :

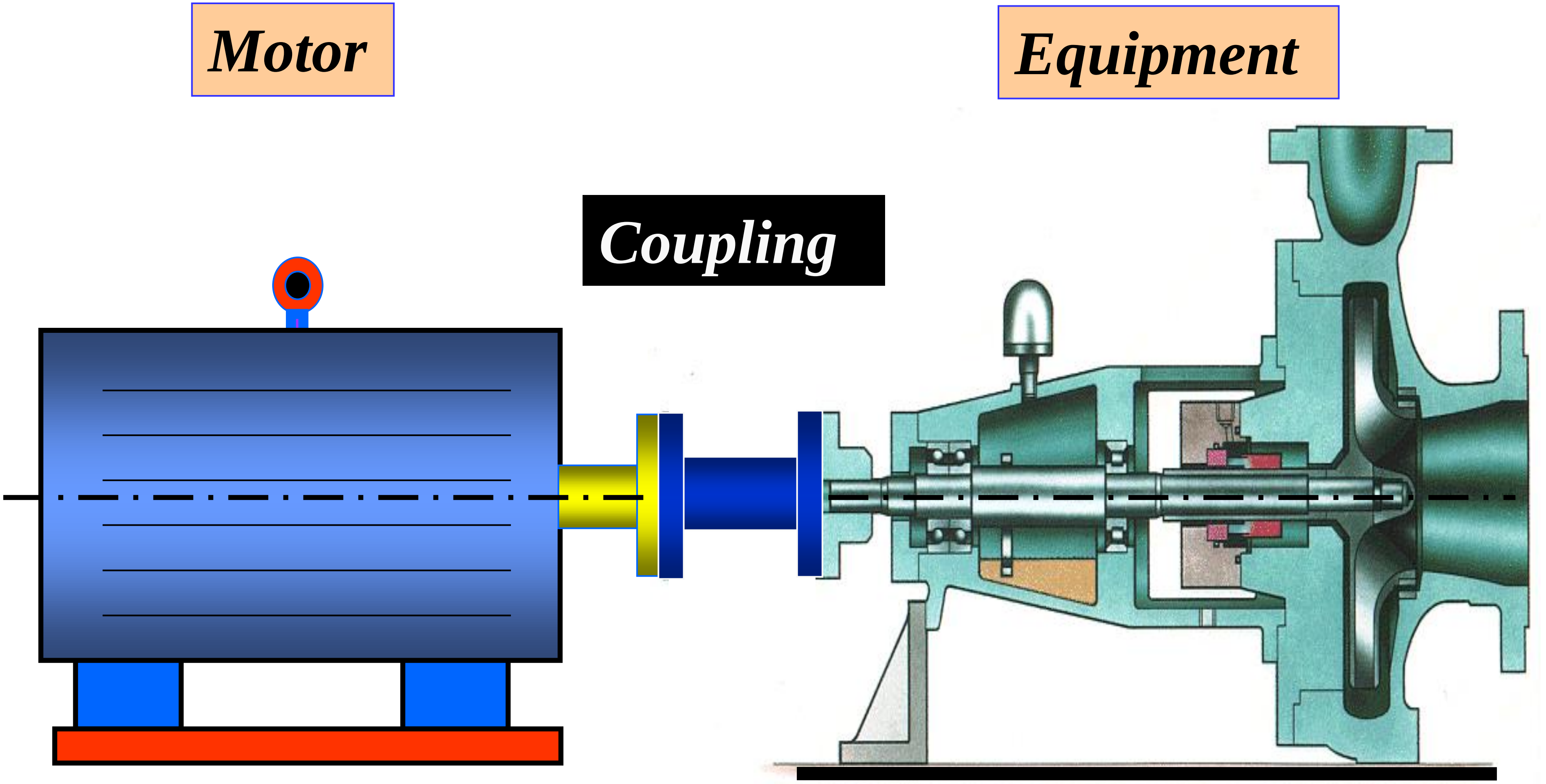
It is a metal to metal contact (%100 collinear)

2 -Flexible Couplings

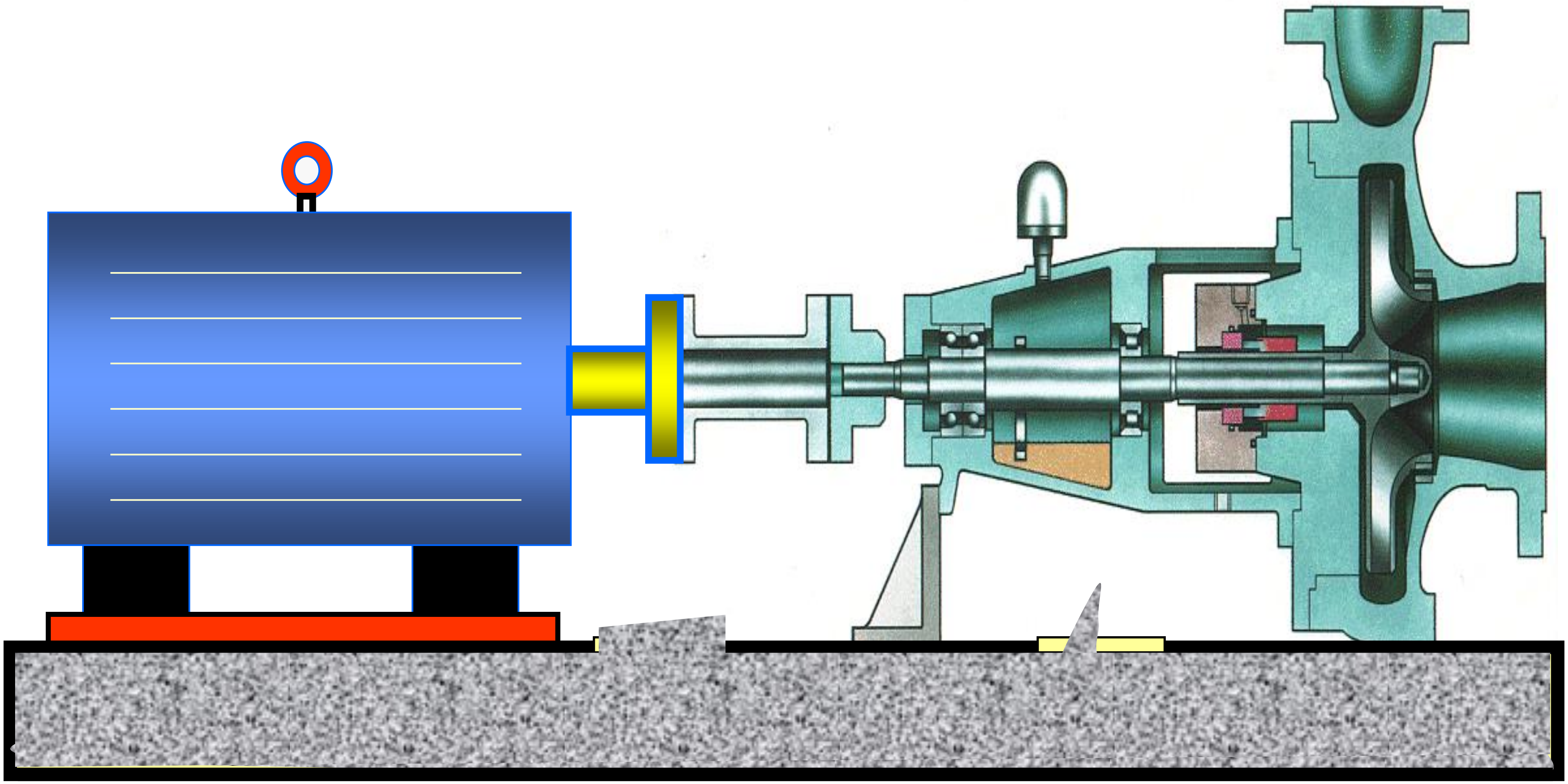
** Spacer with shims*
** Gear*
** Grid*
** Rubber*
** Others*
** Torque converter*

Alignment

It is collinear of two center lines

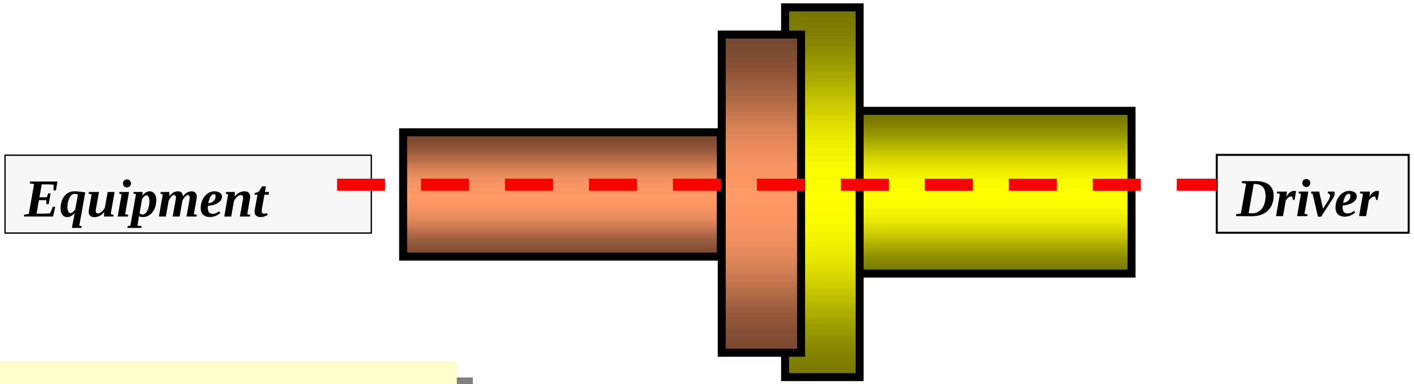


Pump Grouting



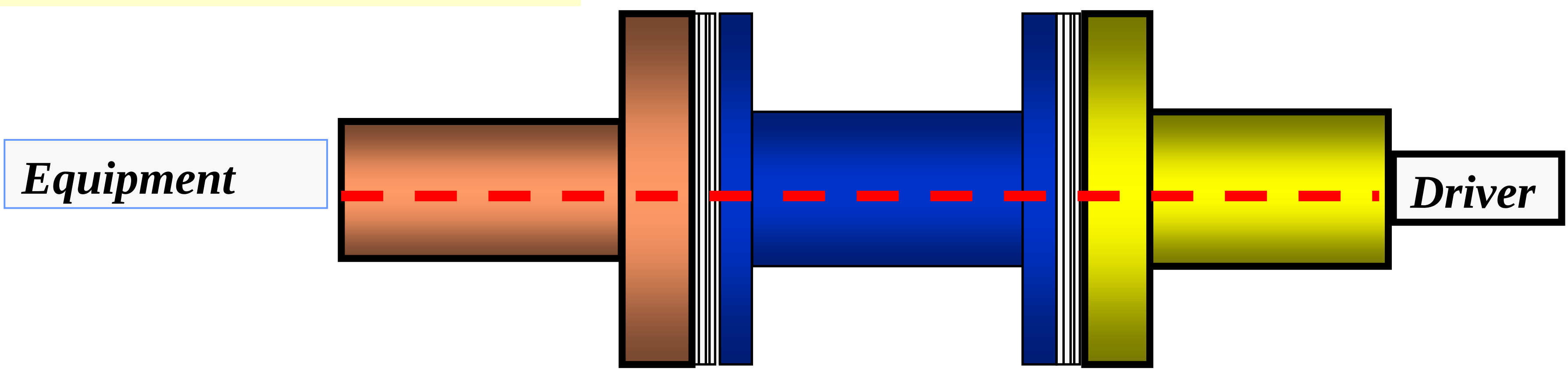
Special grouting concrete

1 -Rigid Couplings

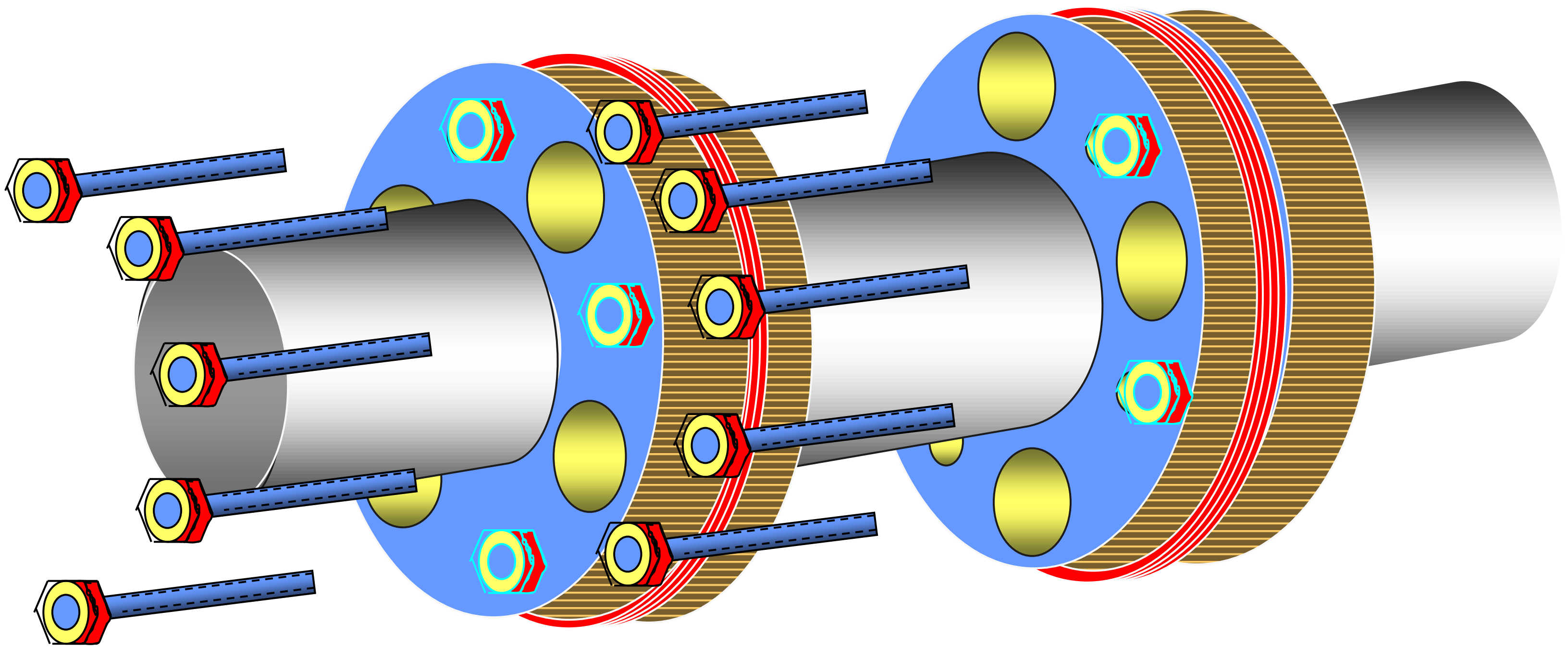


2 – Flexible Couplings

*Spacer with shims

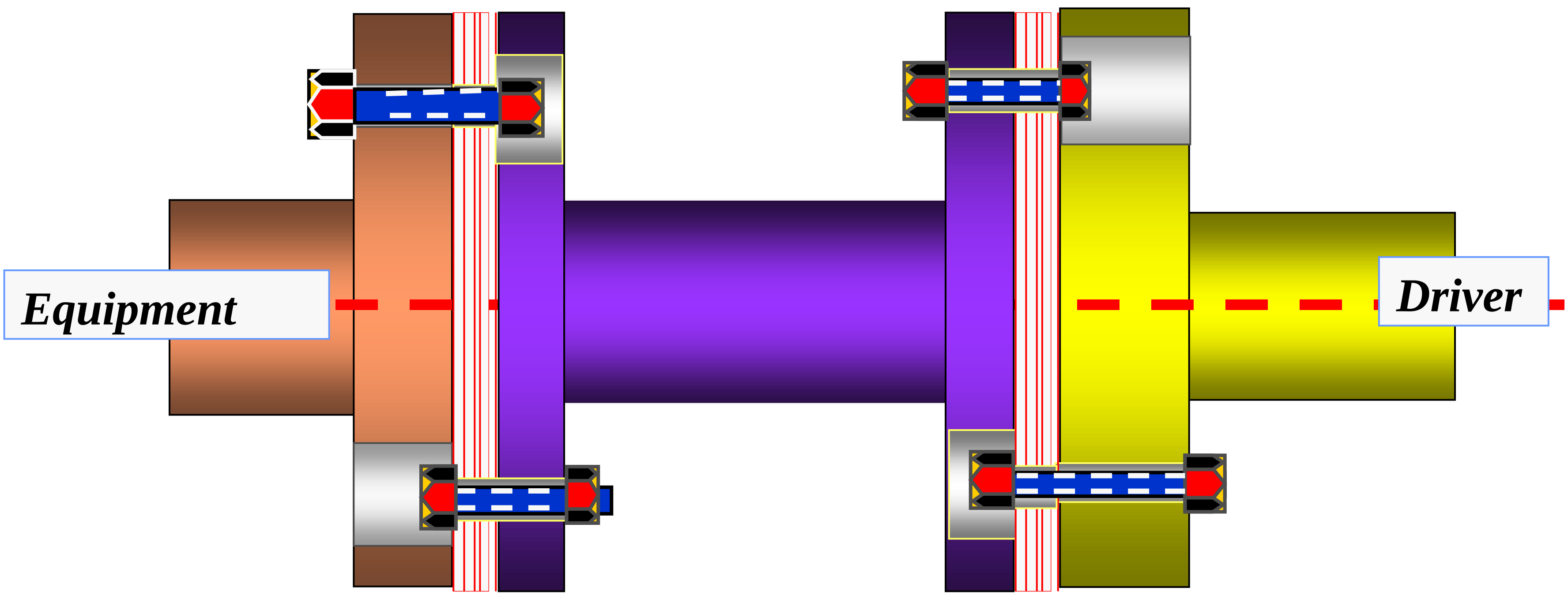


*Spacer with shims

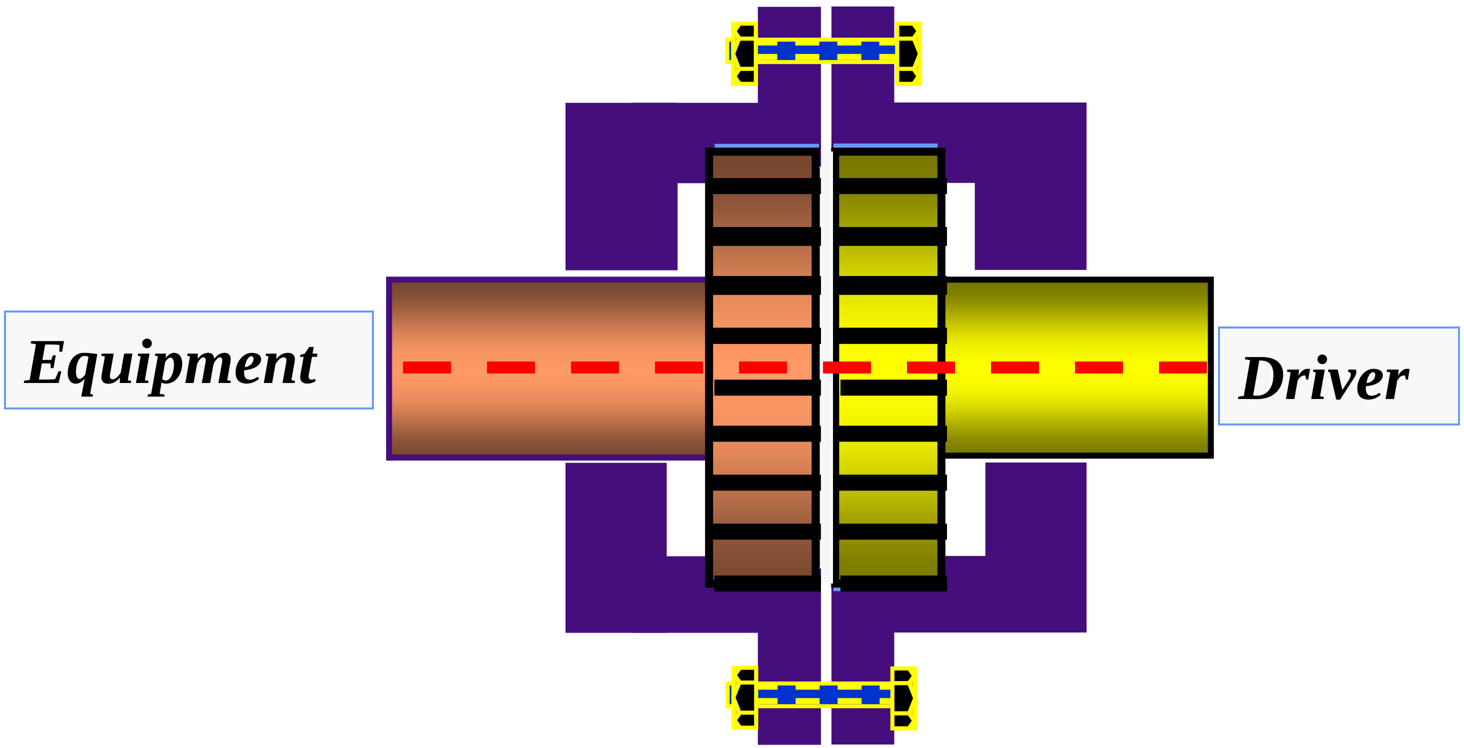


*Spacer with shims

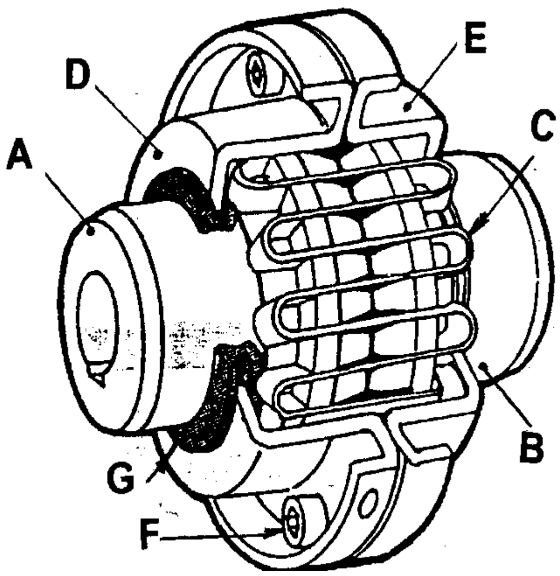
Spacer is not connected directly to both hubs, but through the shims

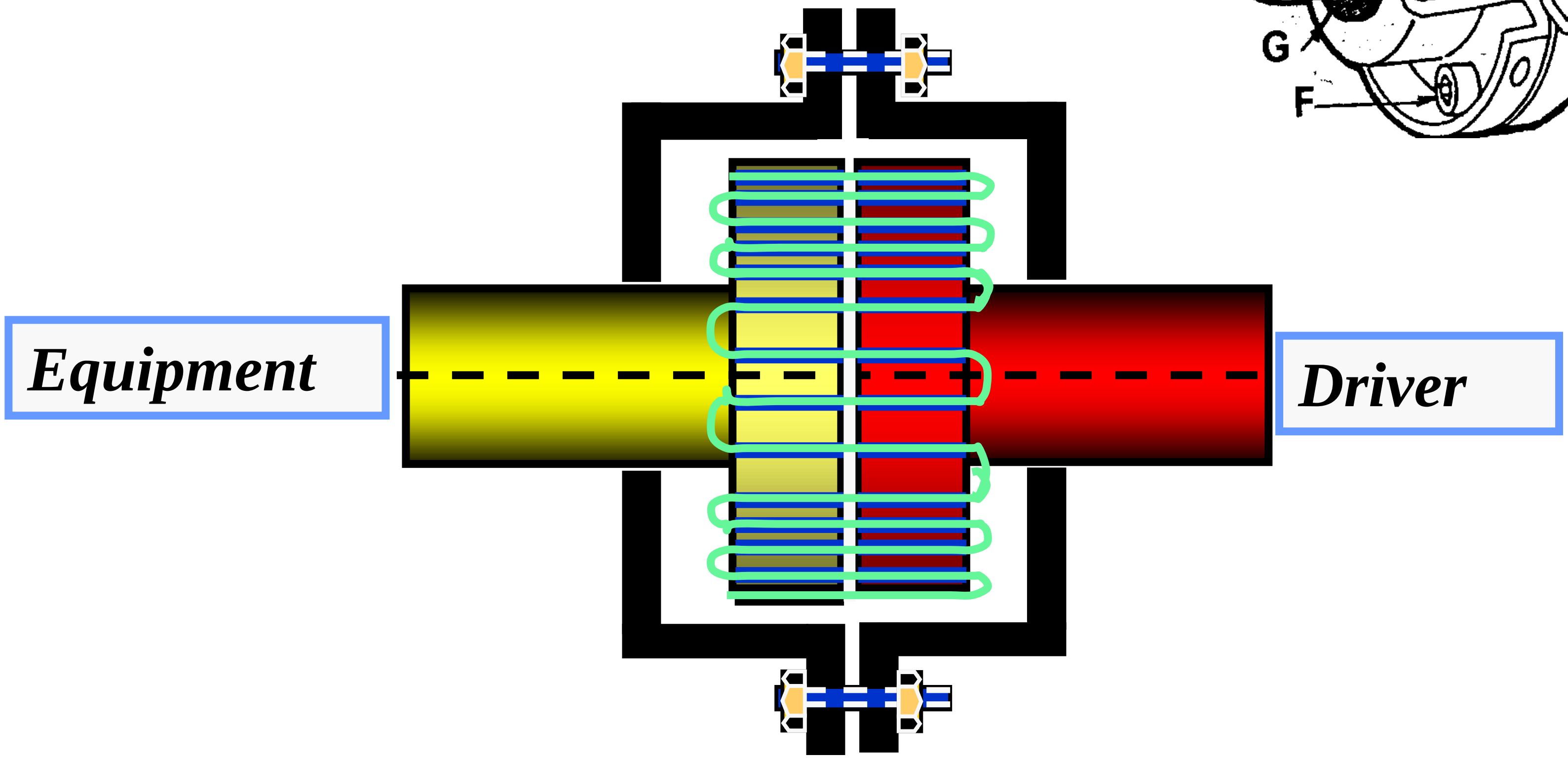


*Gear

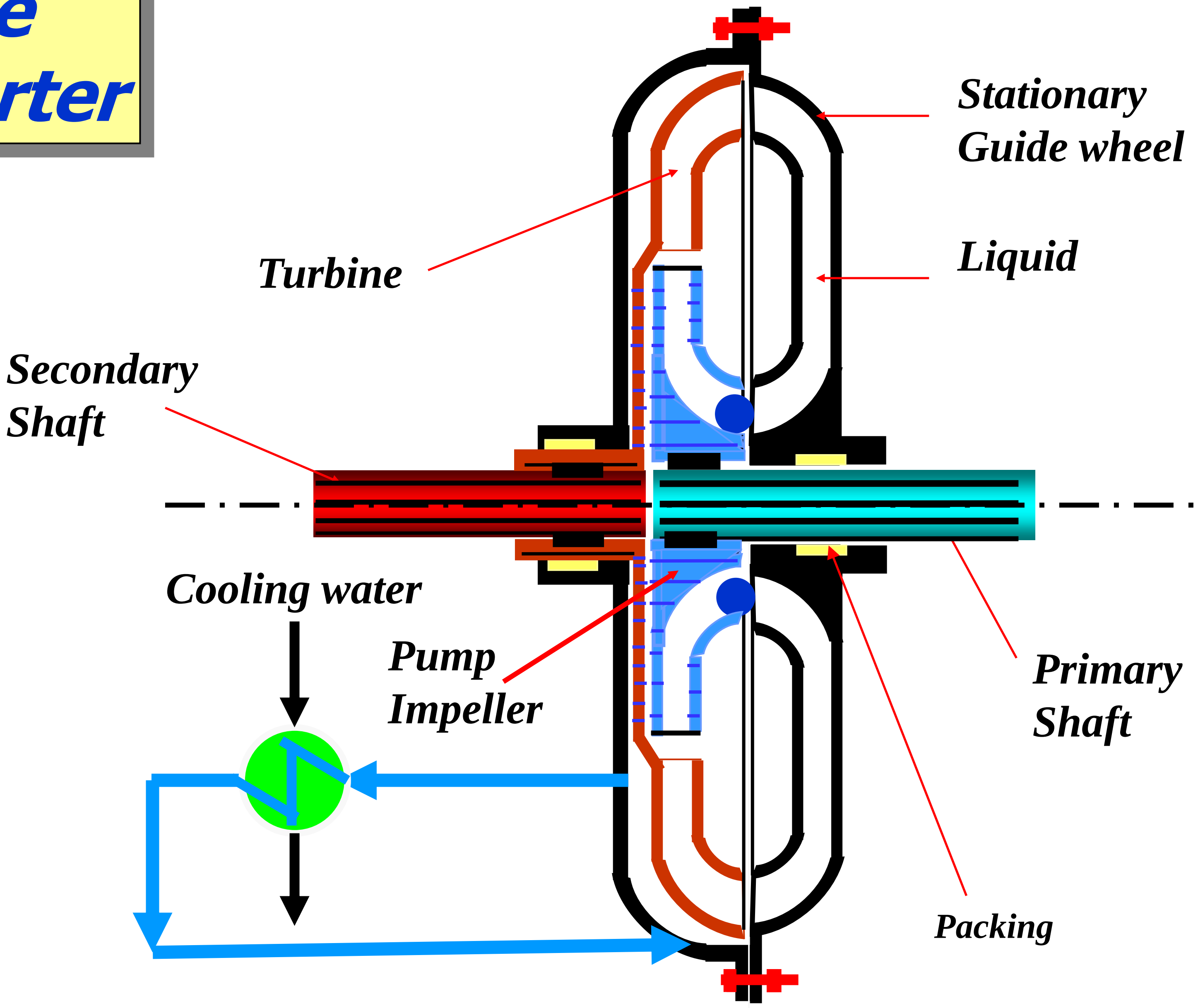


*Grid

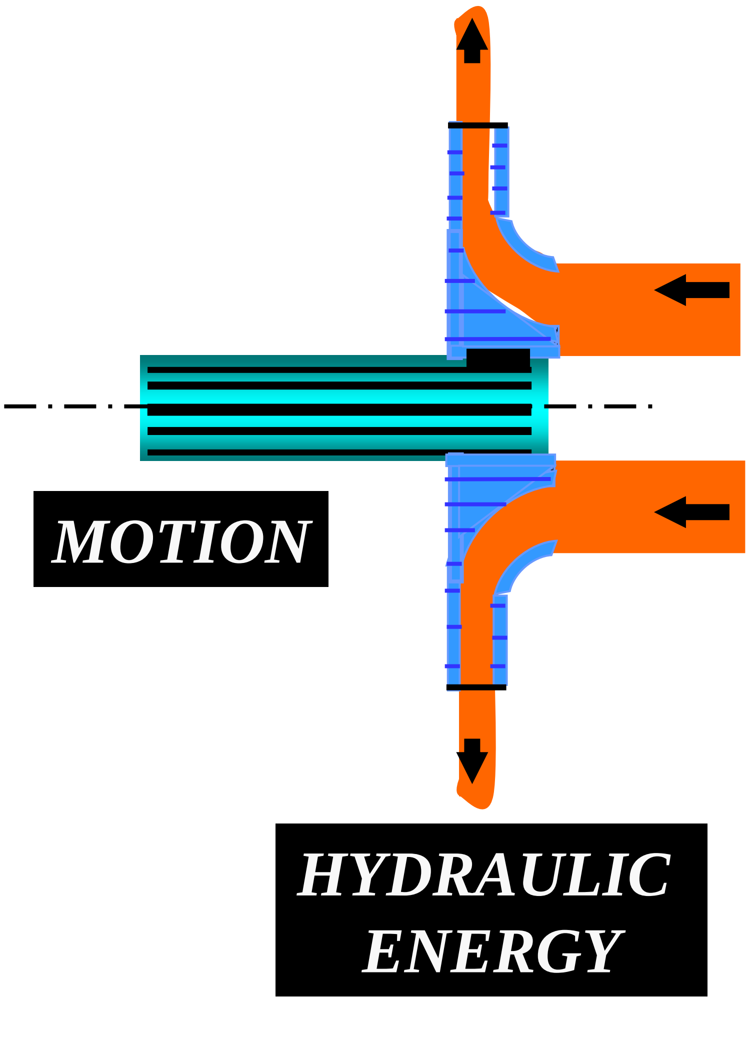




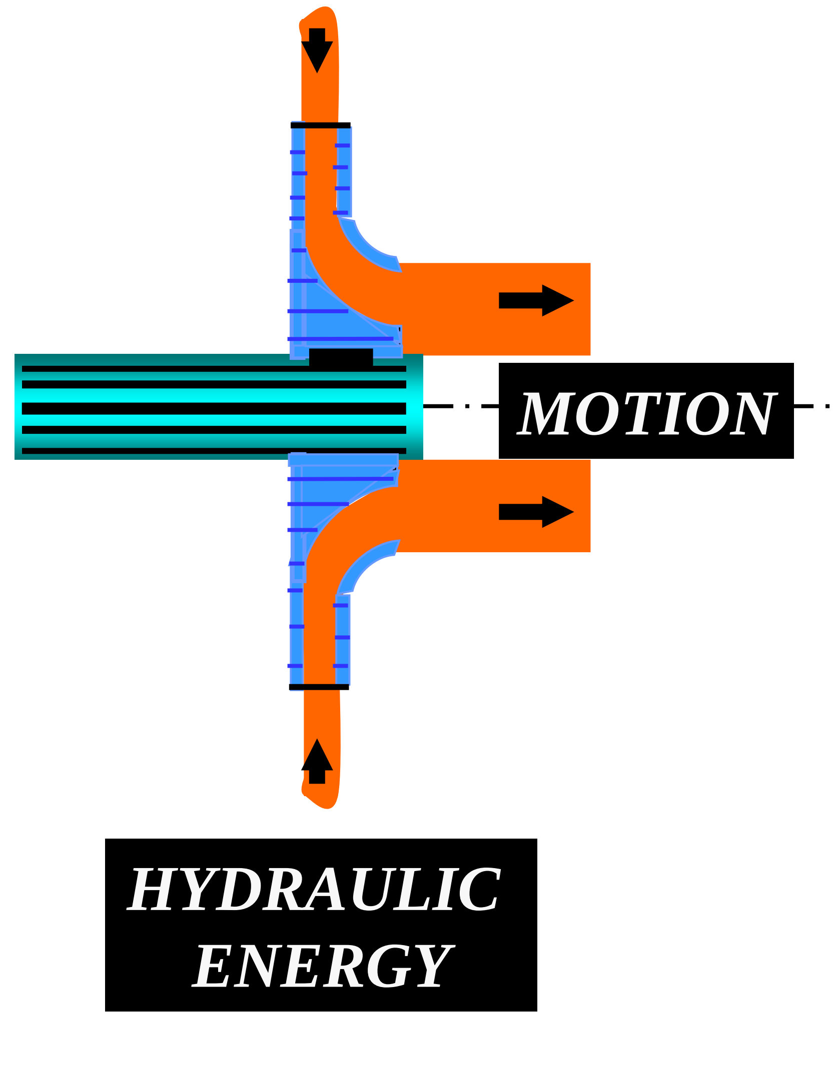
Torque converter

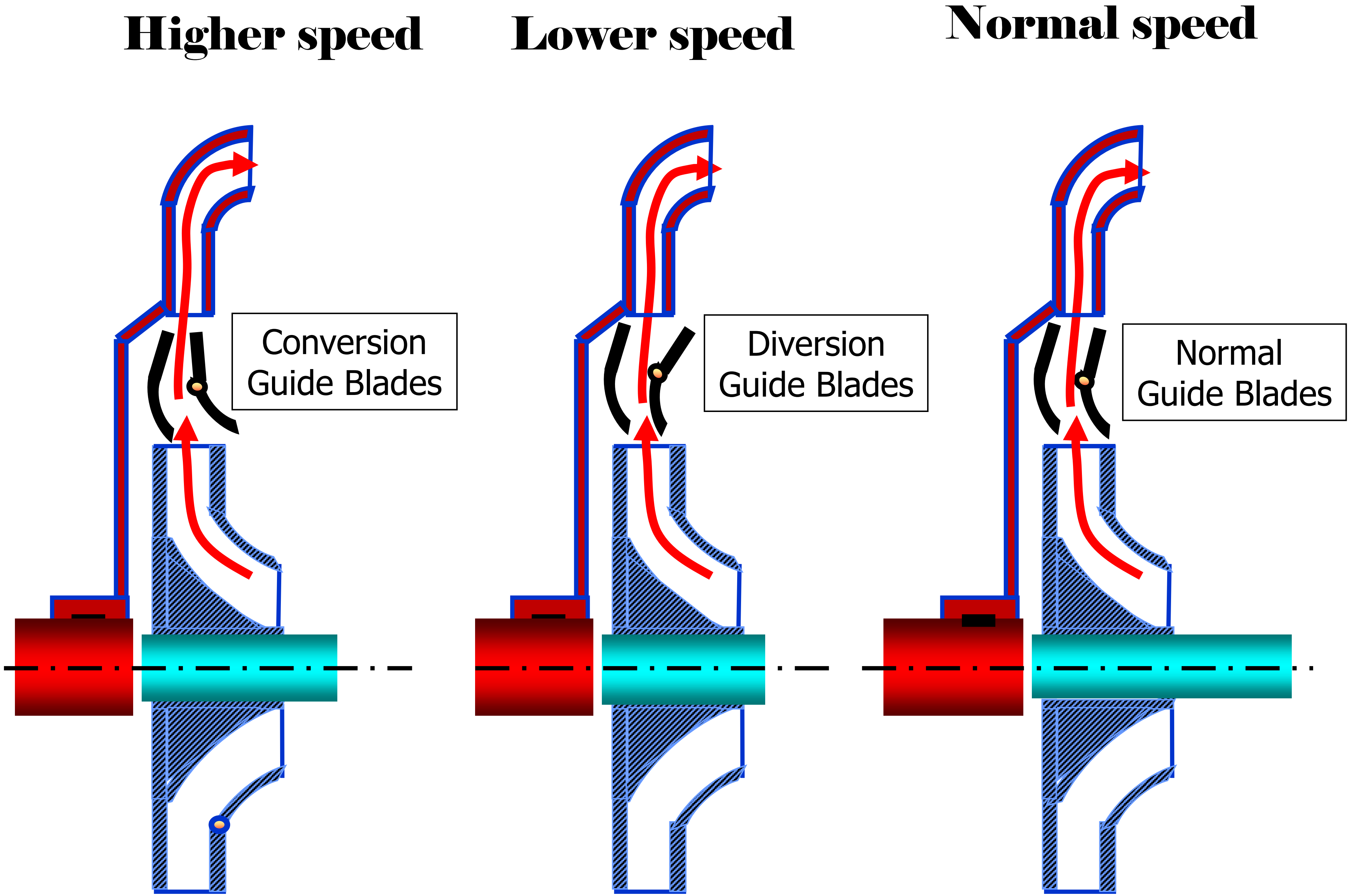


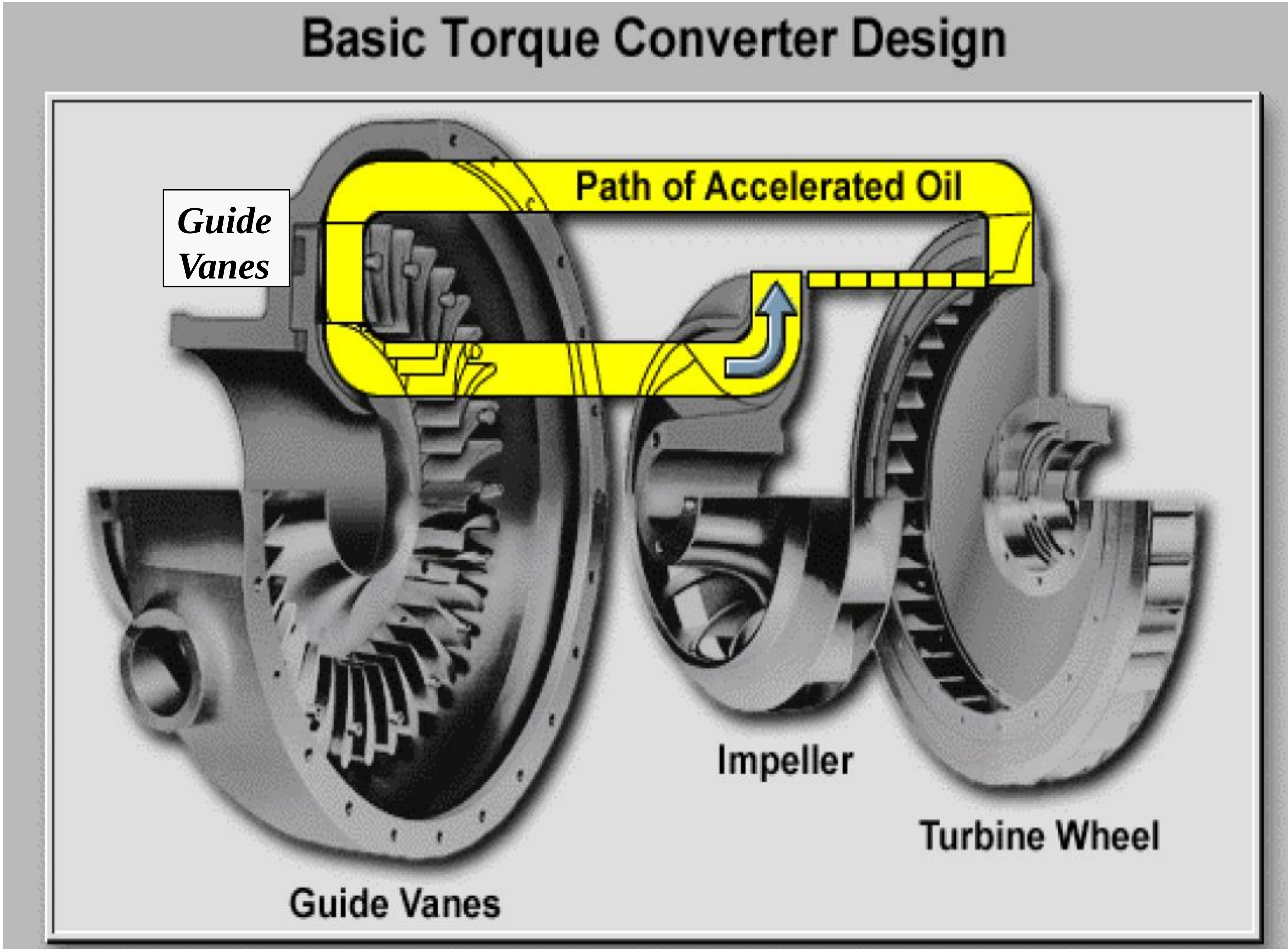
Pumps



Turbine




Higher speed
Lower speed
Normal speed
Conversion Guide Blades
Diversion Guide Blades
Normal Guide Blades


Basic Torque Converter Design
Path of Accelerated Oil
Guide Vanes
Impeller
Turbine Wheel
Guide Vanes

3- Alignment Preparation check list

Alignment Preparation check list

	Description	OK	N/A	Comments
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 →			

	Description	OK	N/A	Comments
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

	Handing over check list	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			

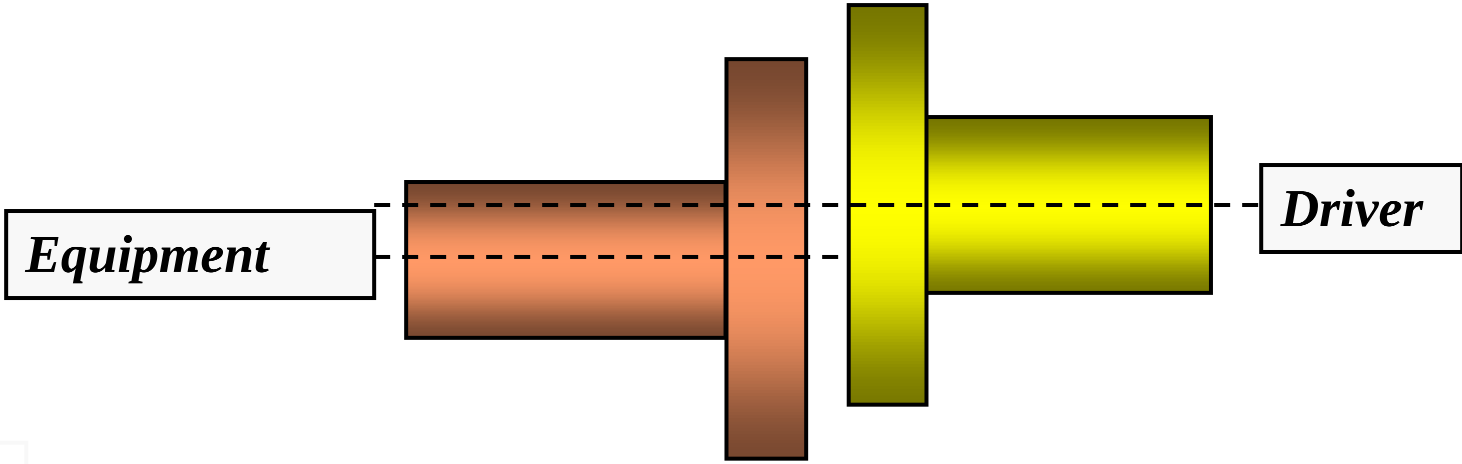
	Completed By	Inspected/Checked By	Quality Inspection	Completions Acceptance
Name and ID No				
Organization				
Sign				
Date				

Parallel misalignment

Vertical

OR

Horizontal

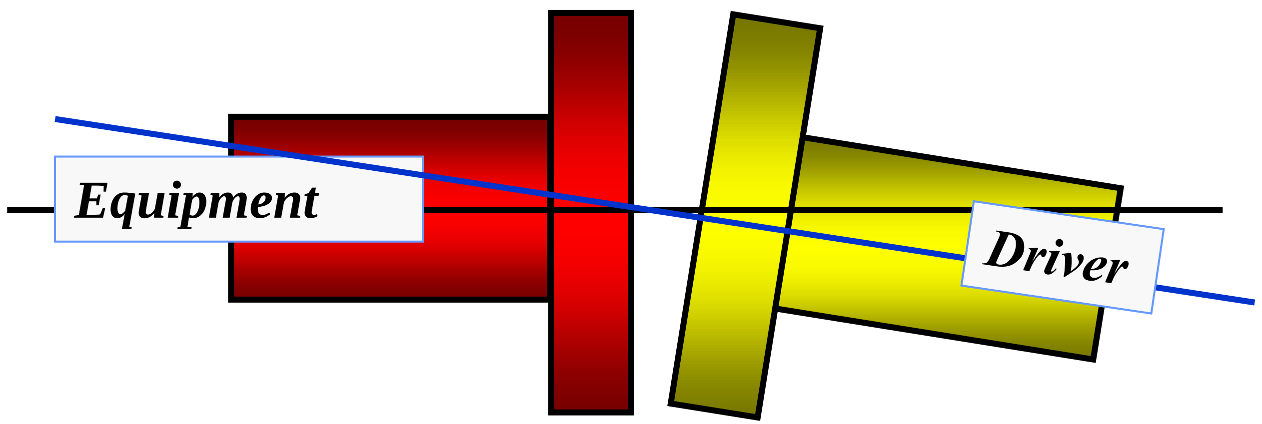


Angular Misalignment

Vertical

OR

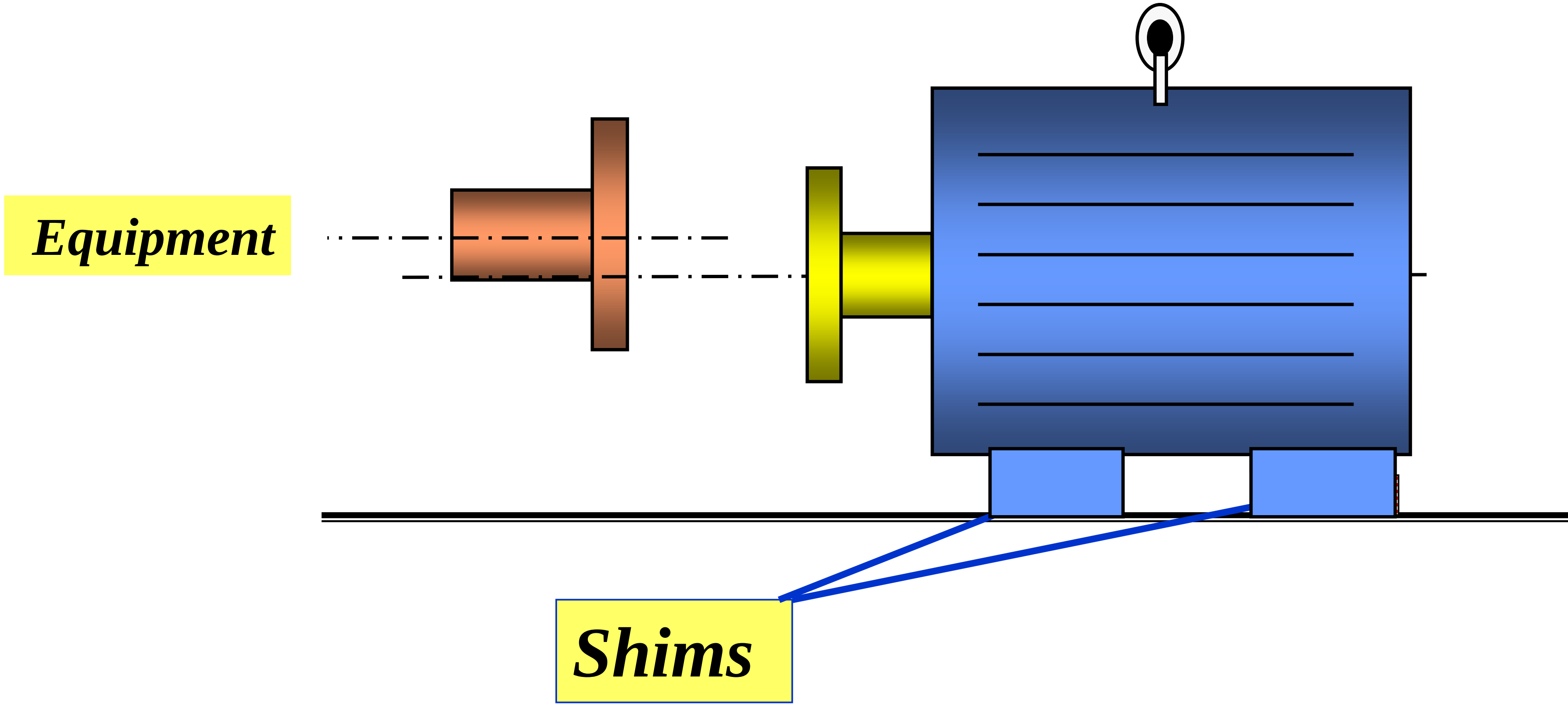
Horizontal



Correcting of Misalignment

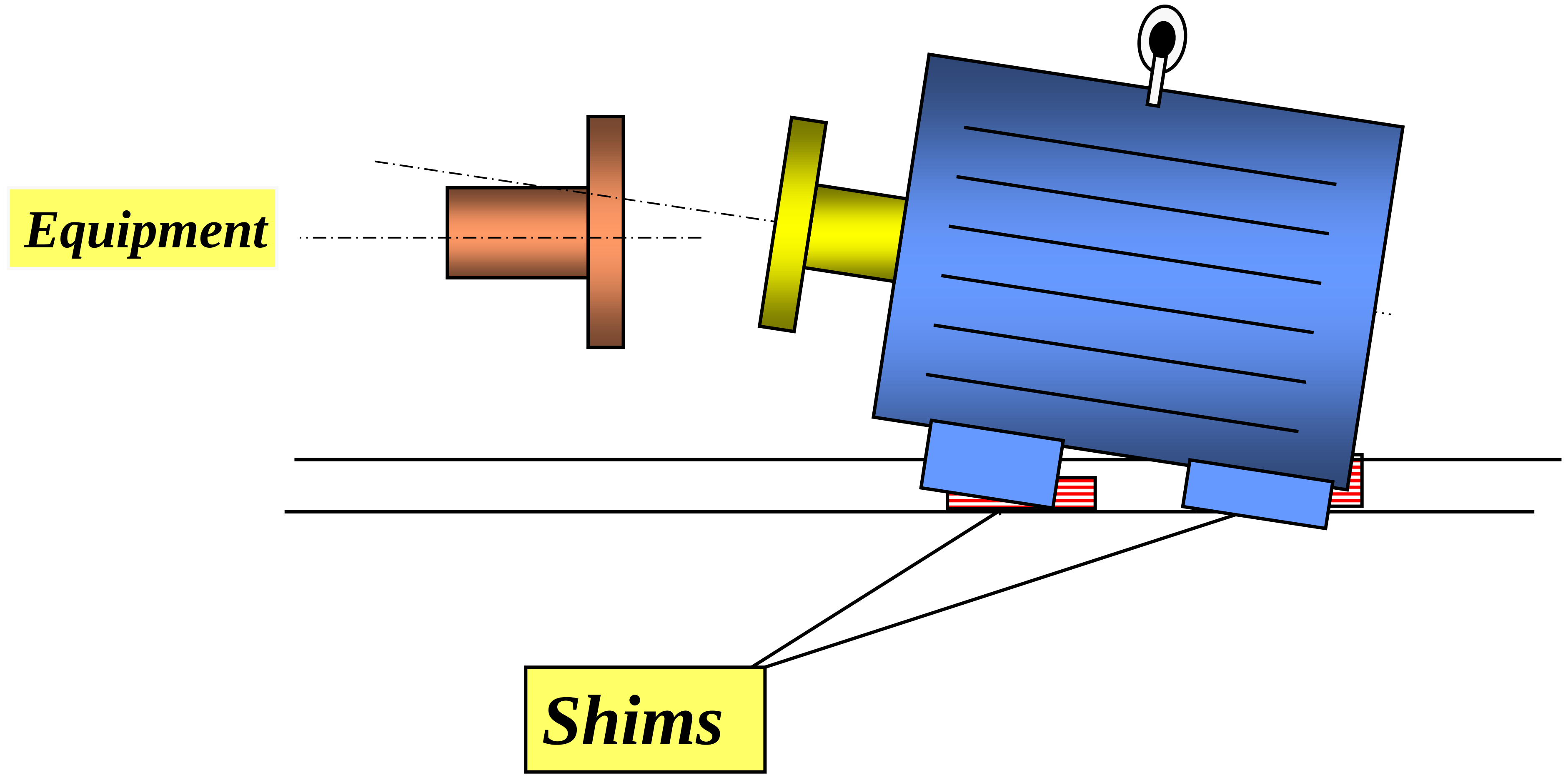
I- Vertical Plane

A- Parallel Misalignment



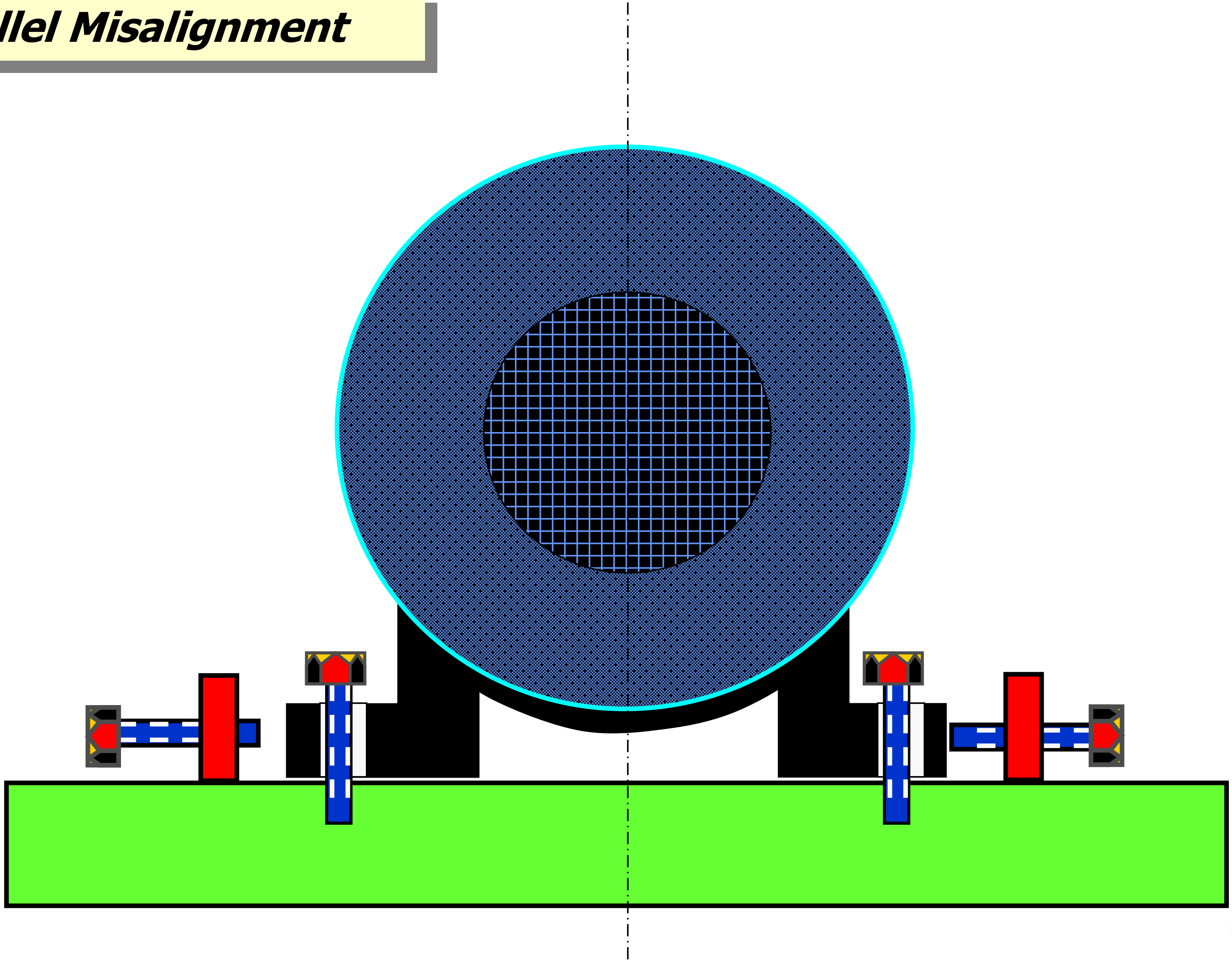
I- Vertical Plane

B- Angular Misalignment



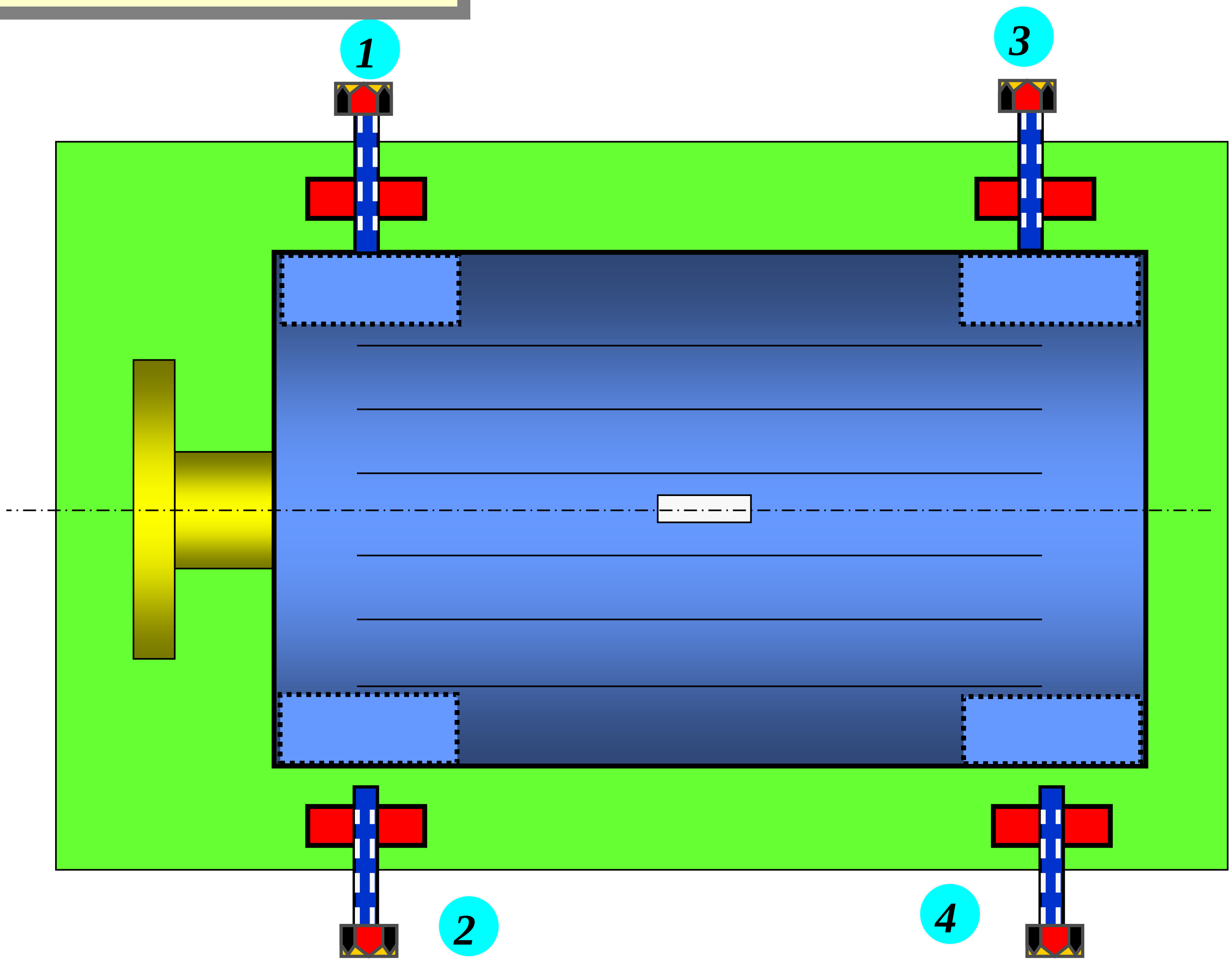
II- HORIZONTAL PLANE

A- Parallel Misalignment



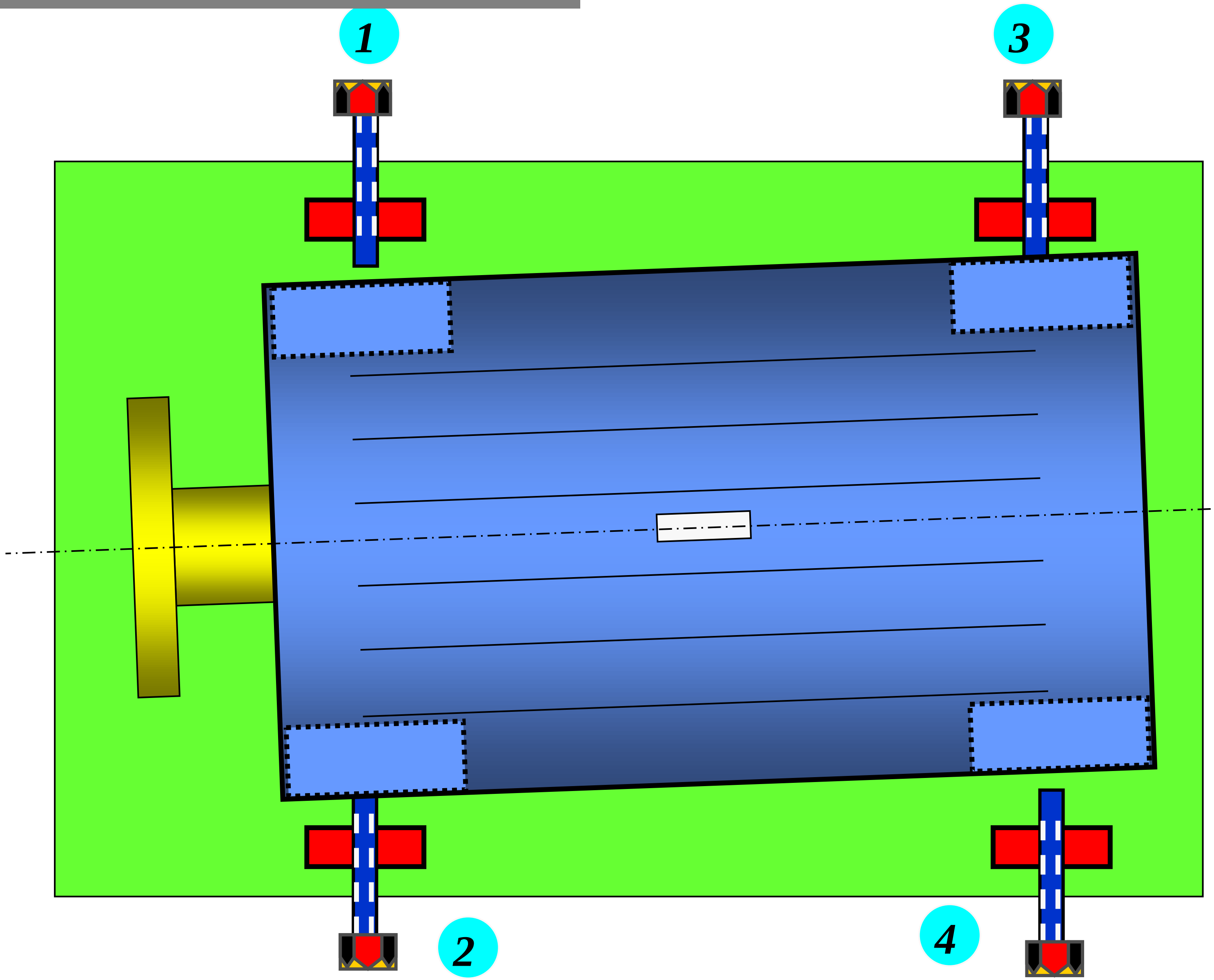
II- HORIZONTAL PLANE

A- Parallel Misalignment



II- HORIZONTAL PLANE

B- Angular Misalignment

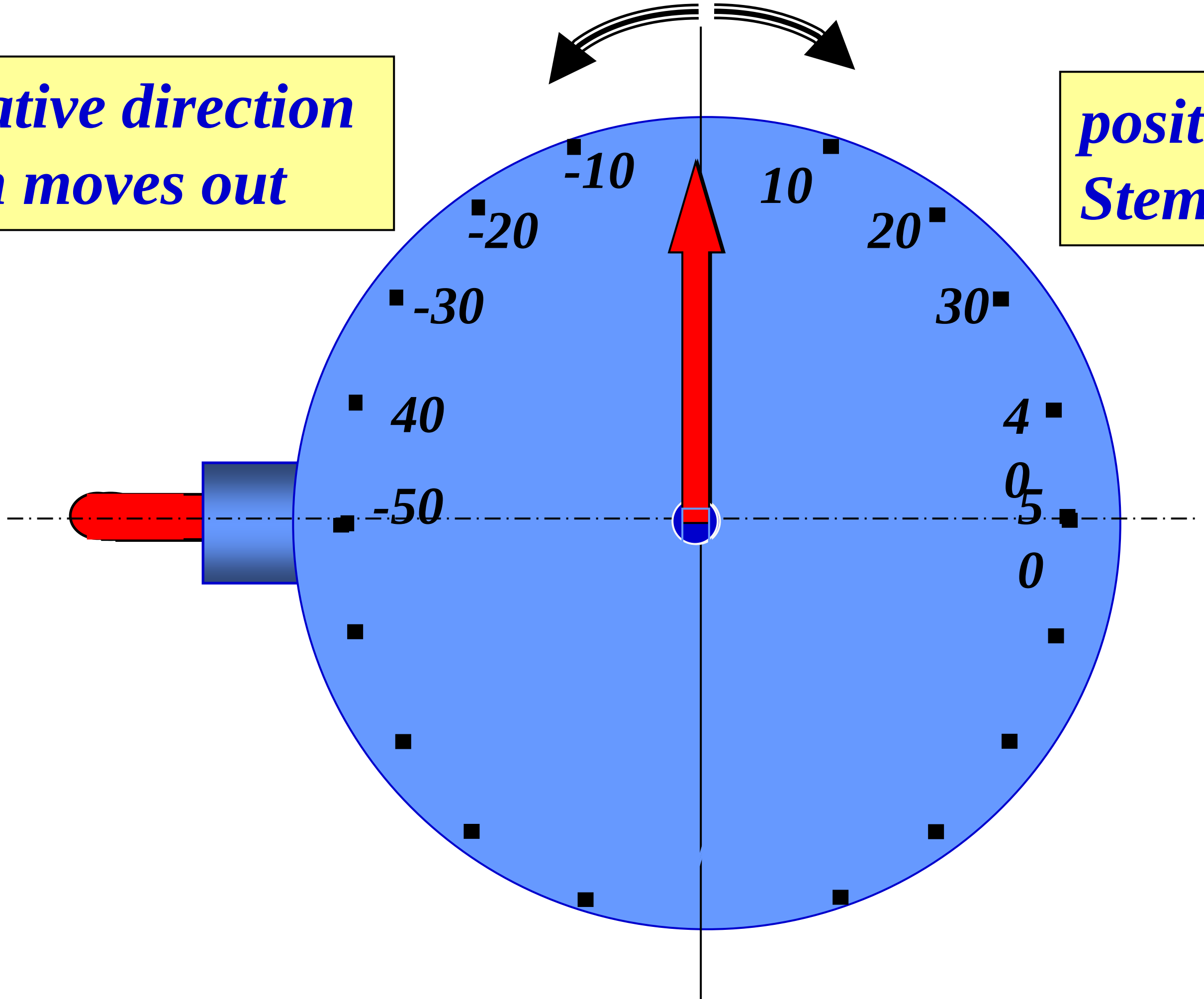


Dial indicators Types and Functions

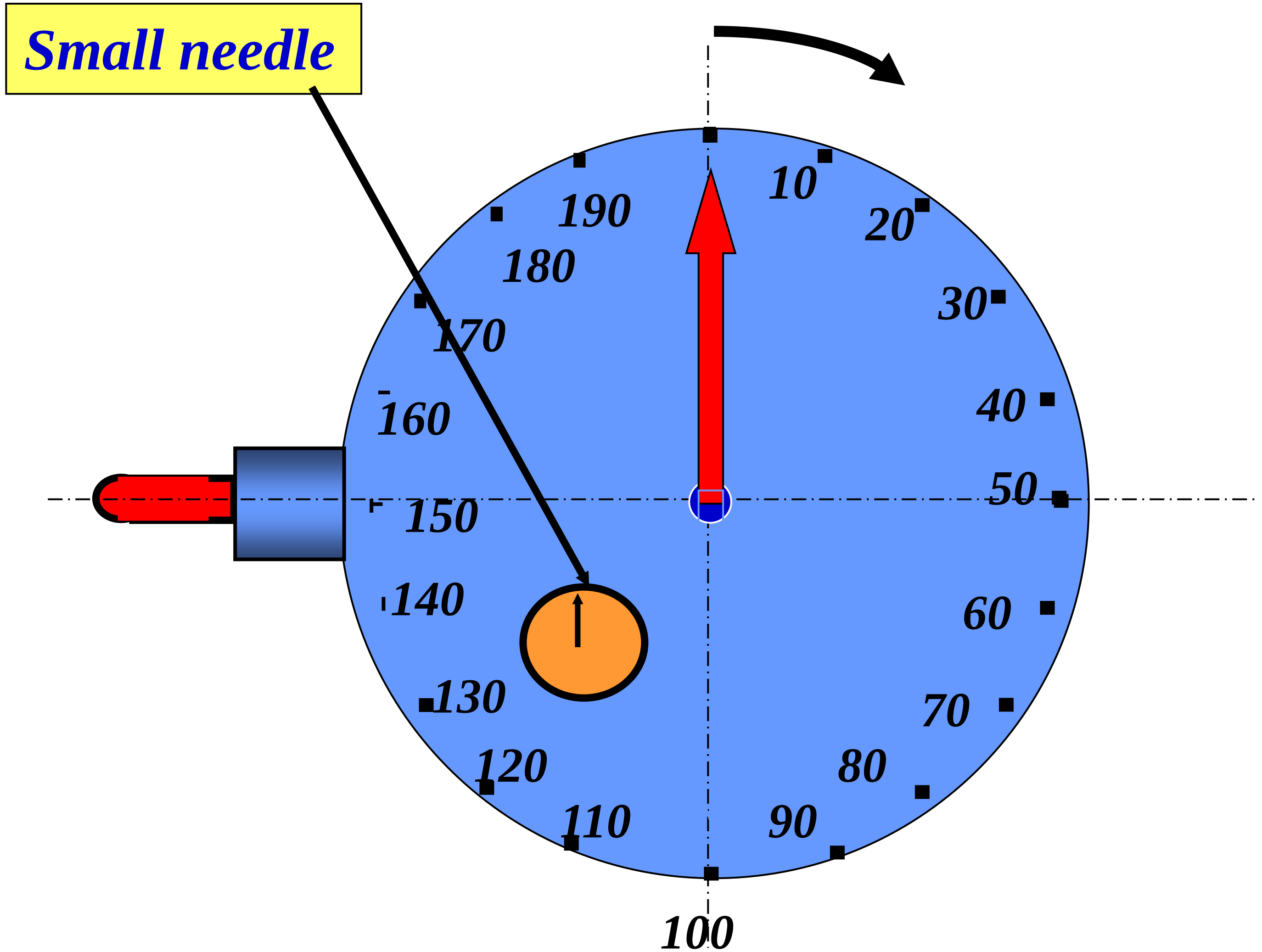
1- Balanced-Type

Negative direction
Stem moves out

positive direction
Stem moves in



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

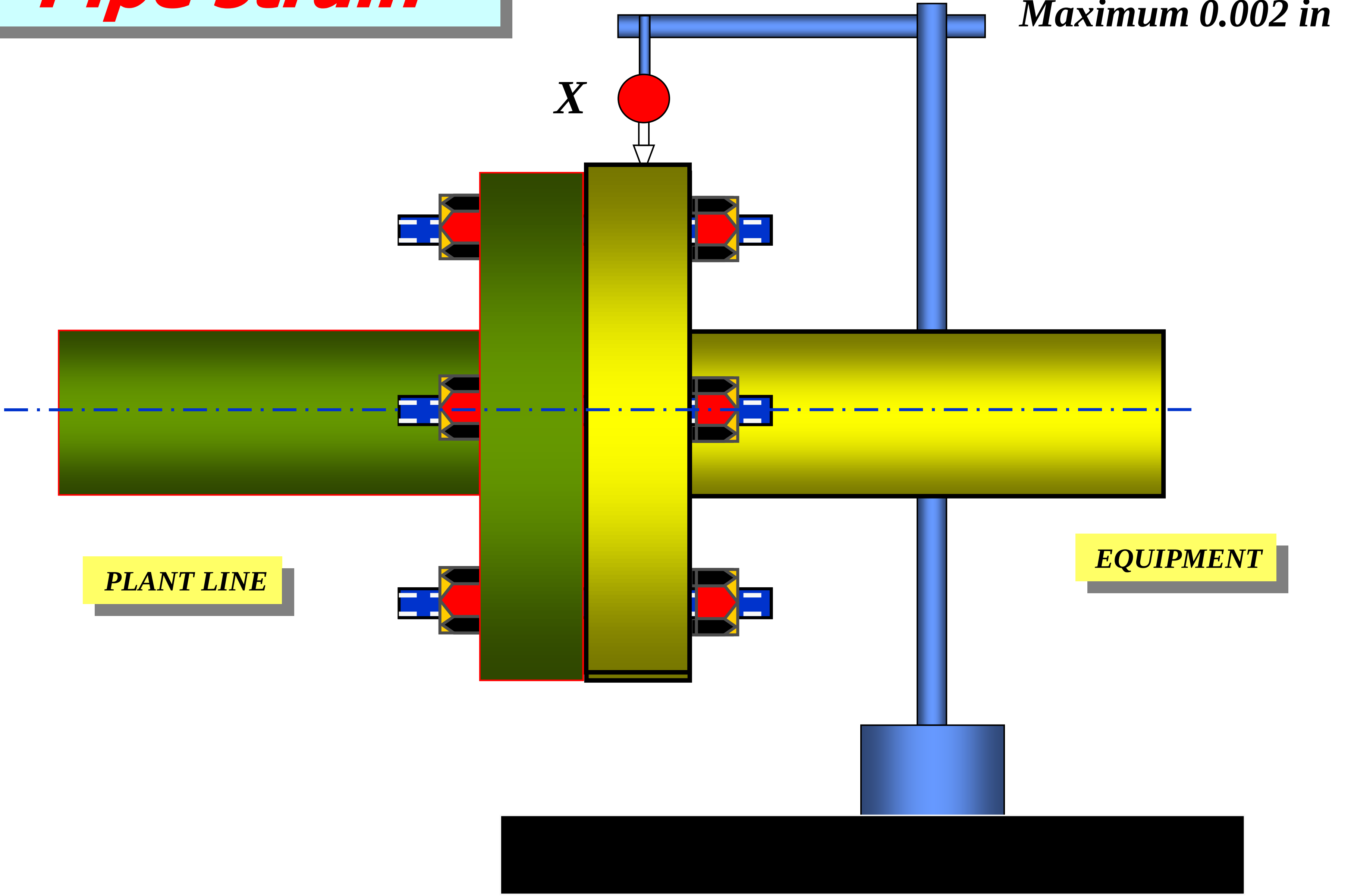
9. Position the stem of the dial indicator so that it is perpendicular to the surface and half travels..

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.

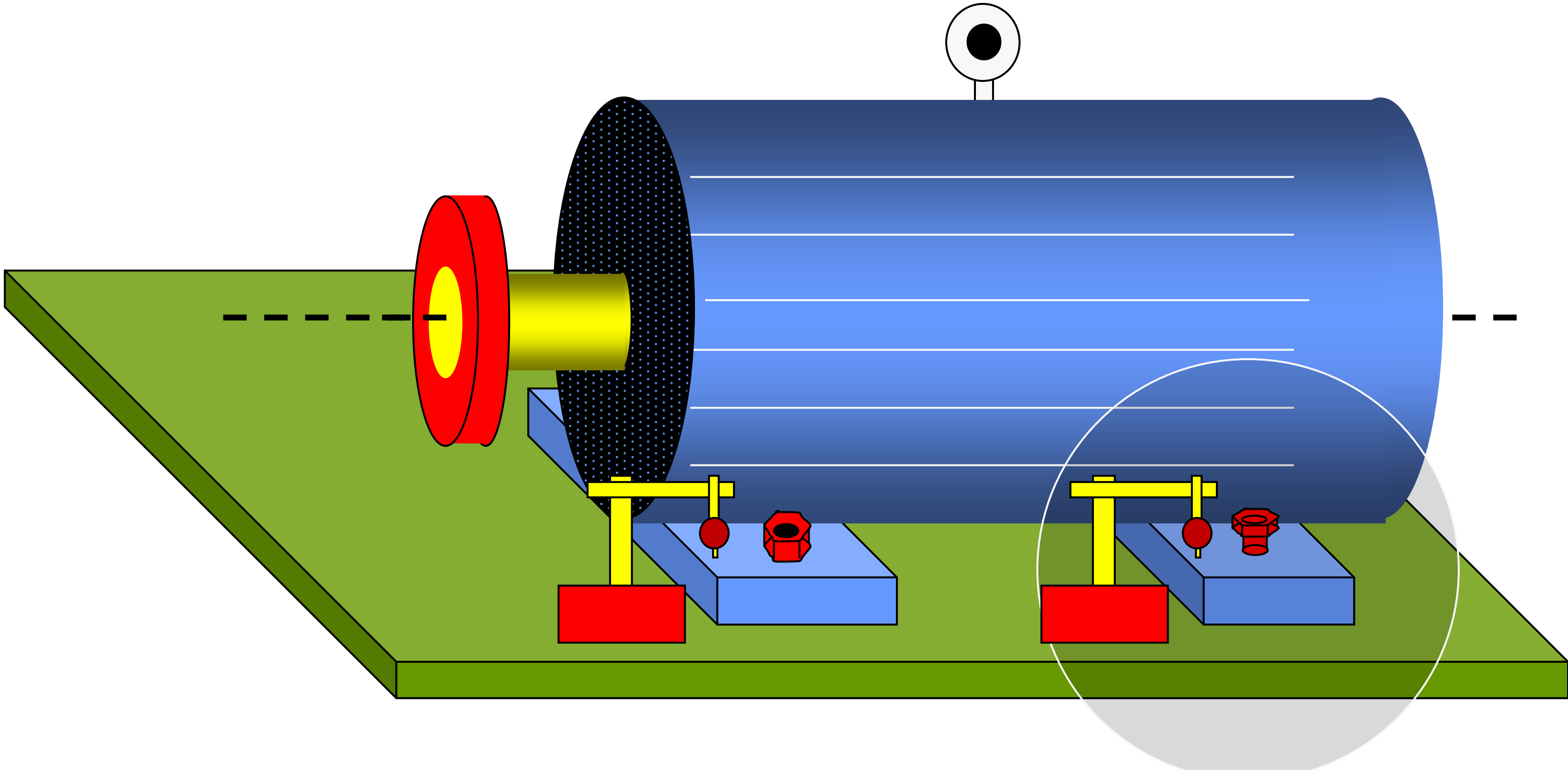
12. Use jacking bolts to adjust for horizontal offset and angular misalignment and to hold the prime mover in place while shimming

* 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).

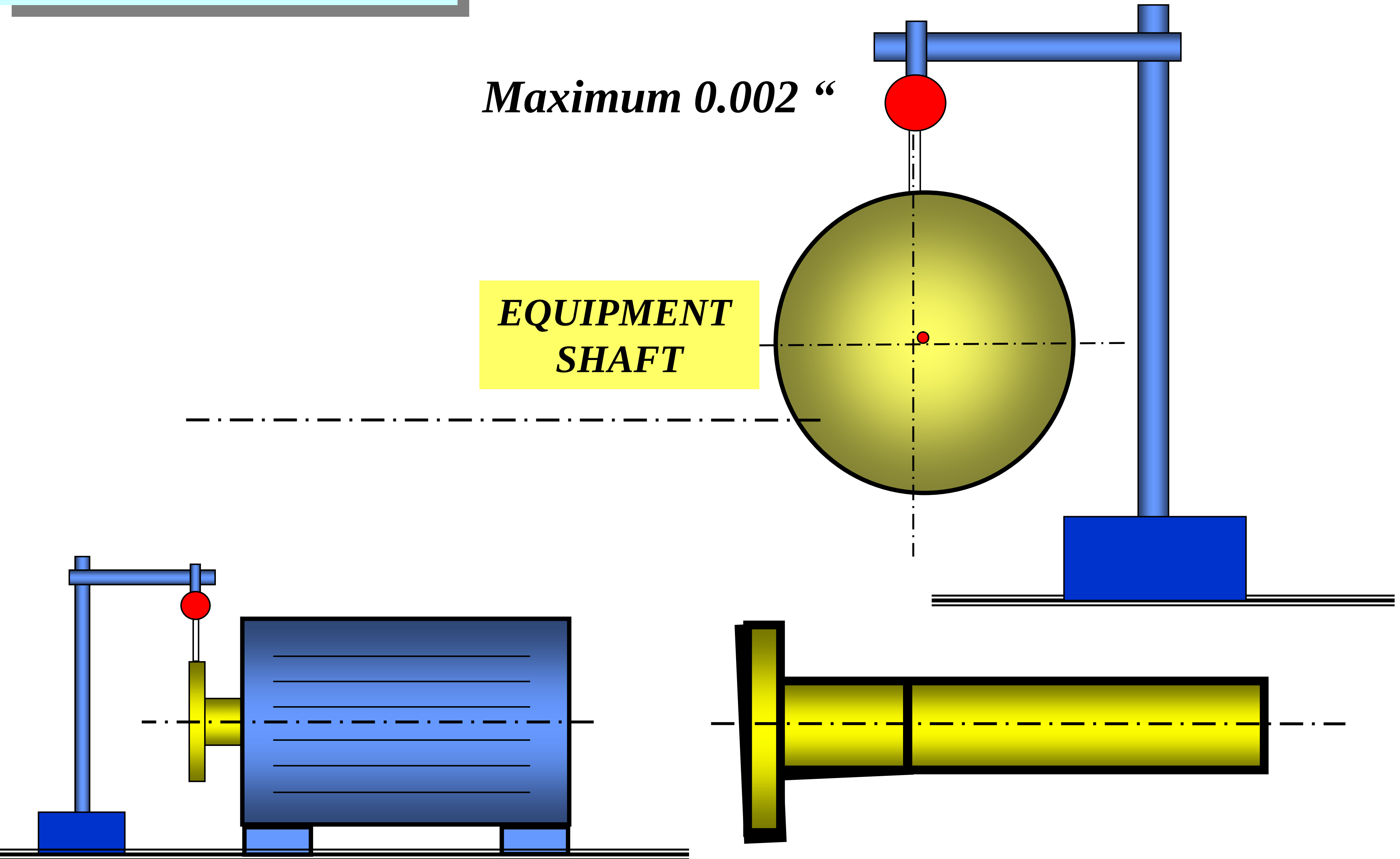
• Use a torque wrench to tighten all nuts with the same amount of torque.

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



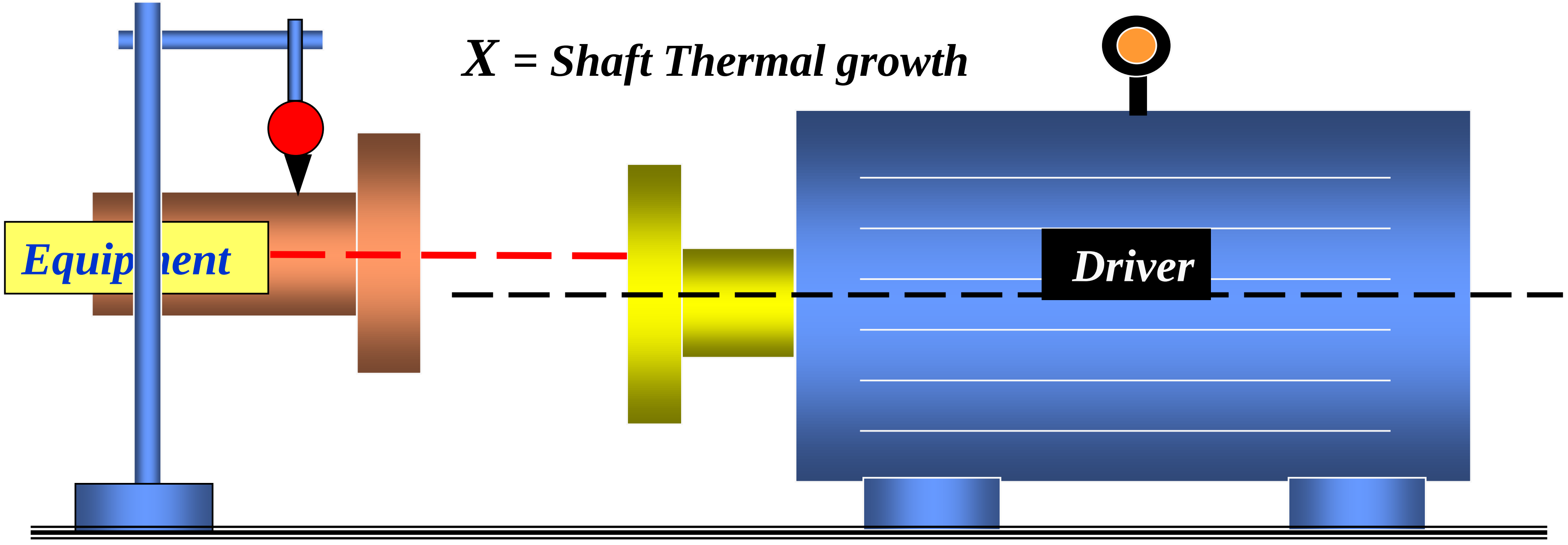
Growth factors (Expansion factor) (mil/in./F) for common materials are as follows:

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

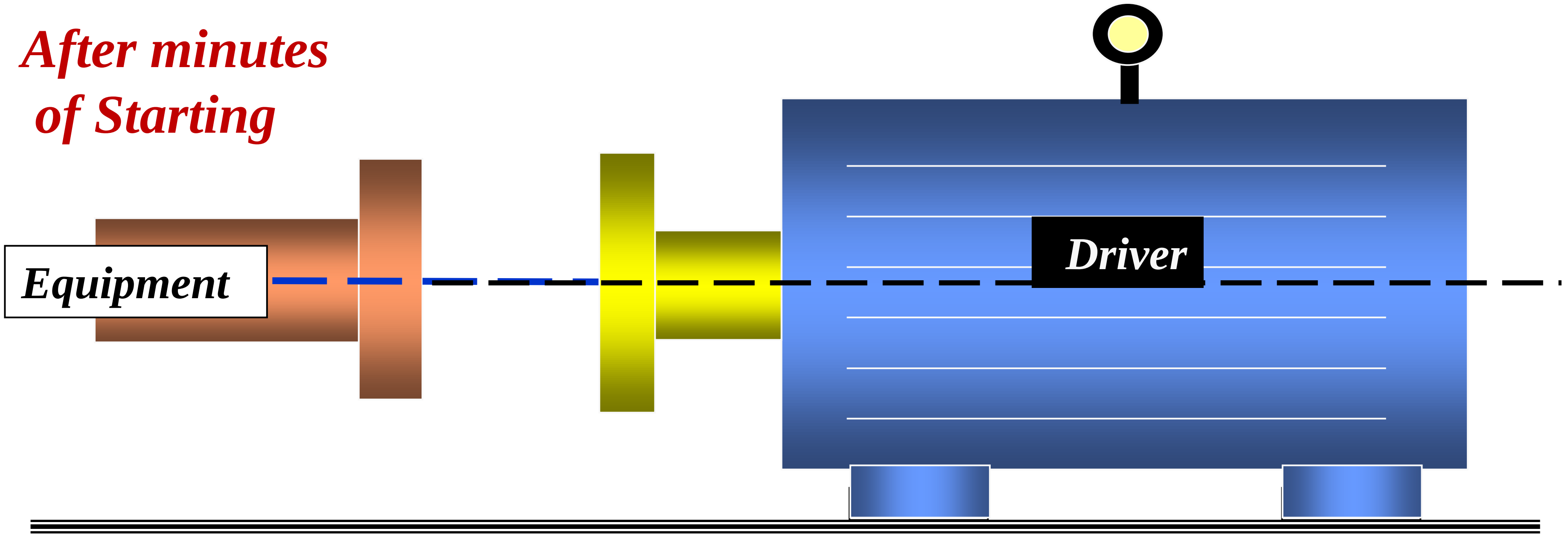
1- Apply the alignment procedure for the pump at ambient Temp.
2- Heat up the pump by opening the start up bypass for ½ hrs.
3- Put the dial indicator on the shaft and adjust to zero reading
4- close the bypass
5- Take the dial indicator reading after 24 hrs.
6- This reading is the shaft thermal growth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

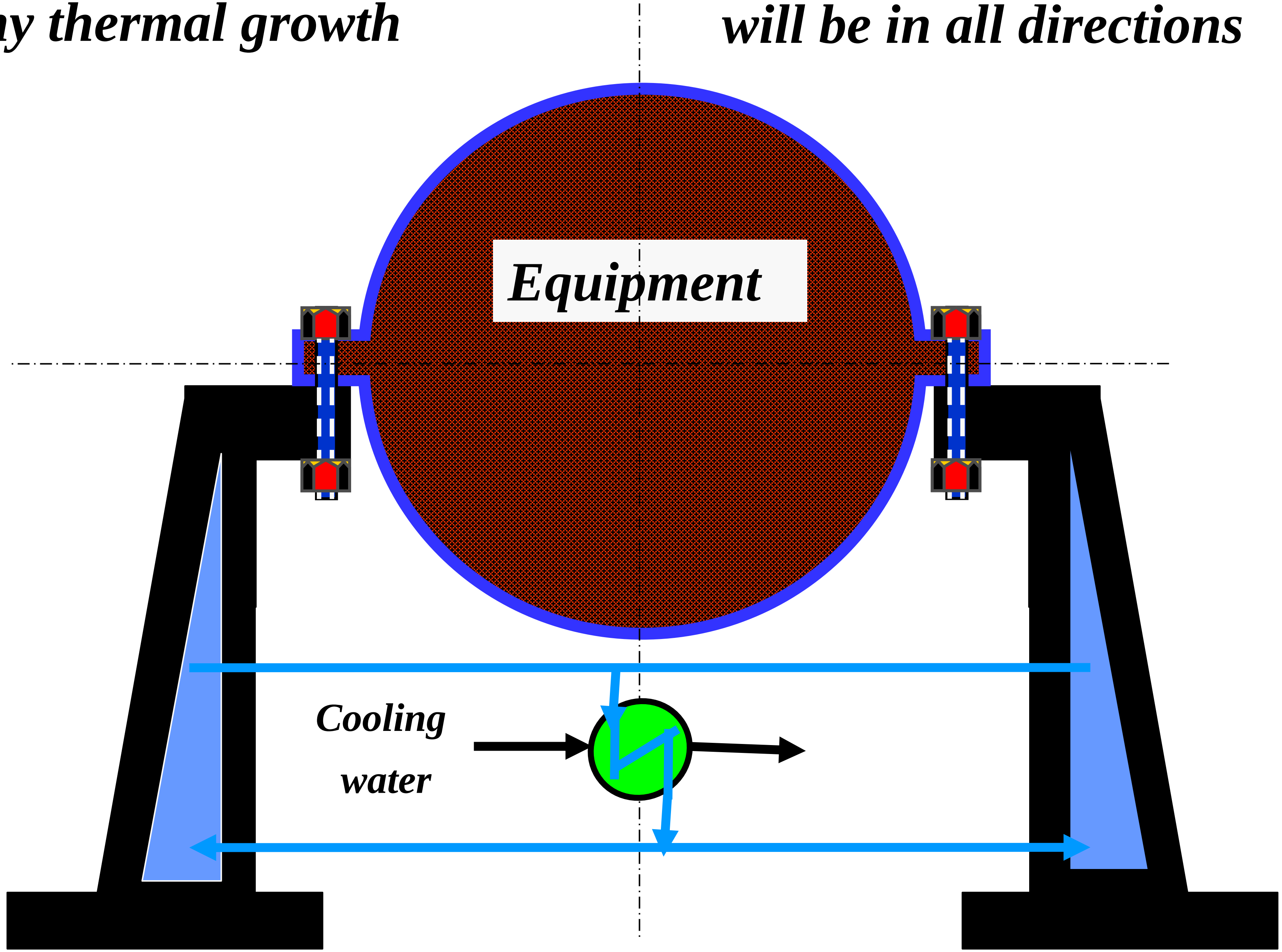
After minutes of Starting



X = The center line Thermal growth

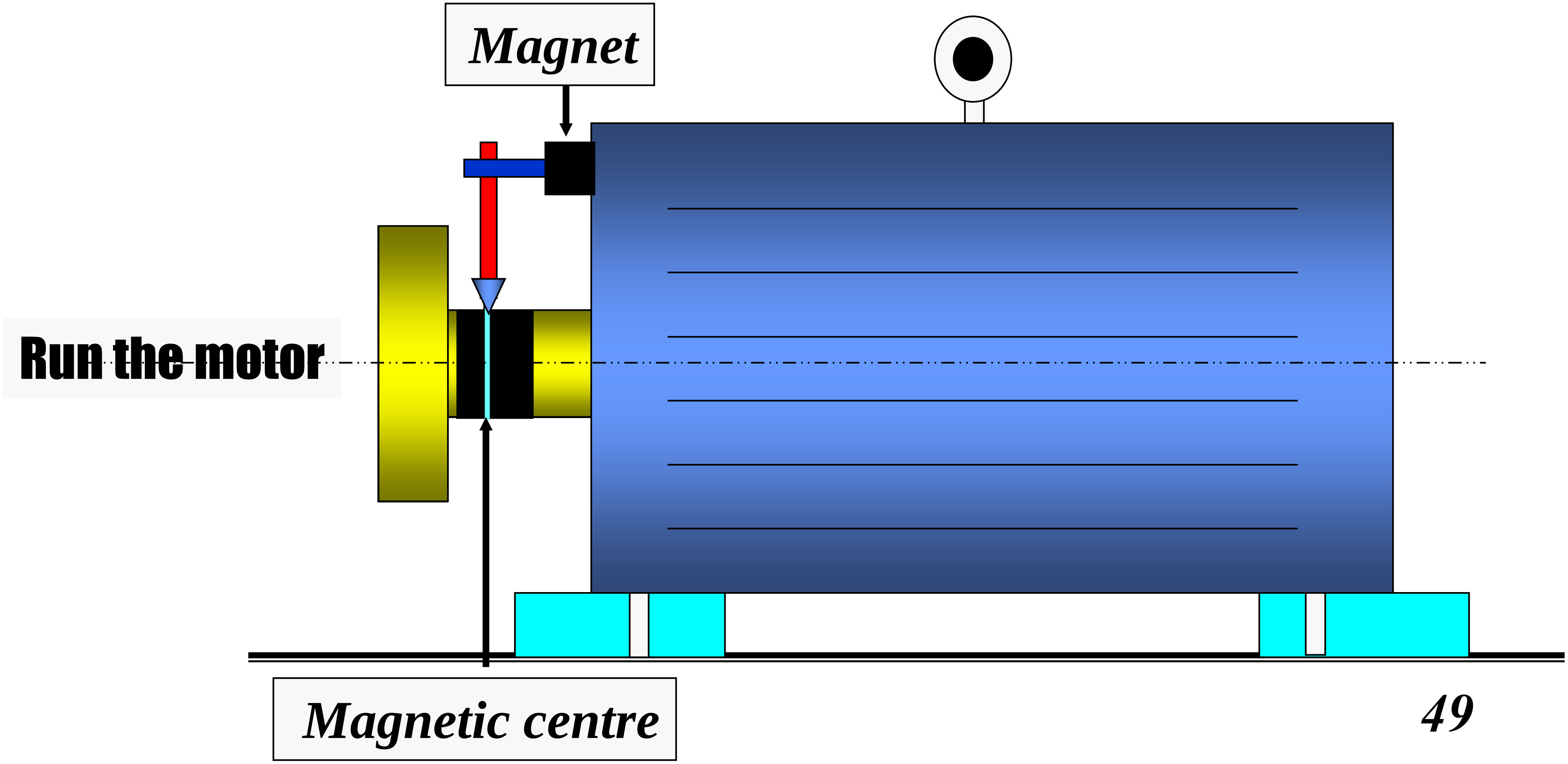
This design is to avoid any thermal growth

As thermal expansion will be in all directions

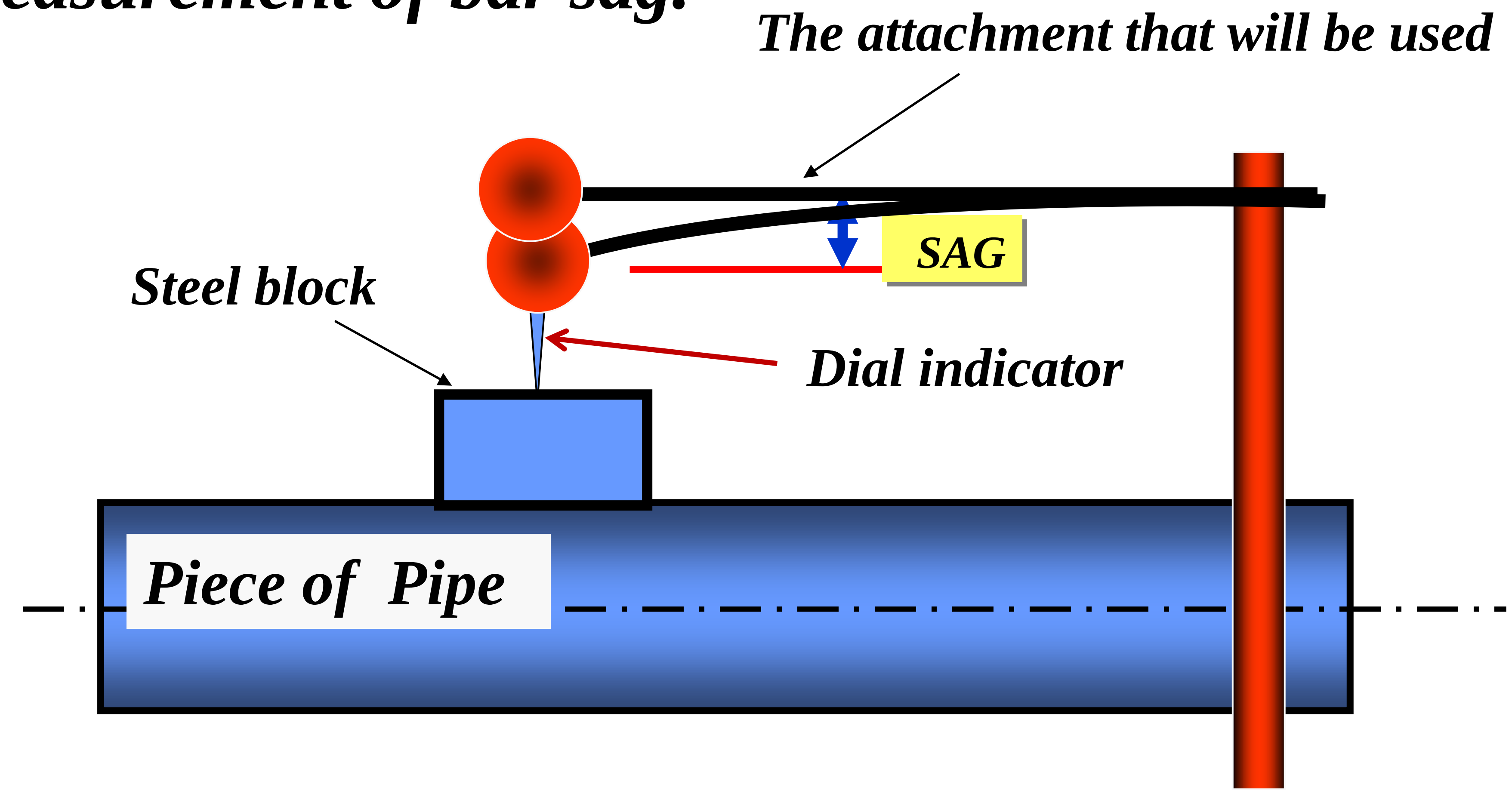


*Magnetic centre.

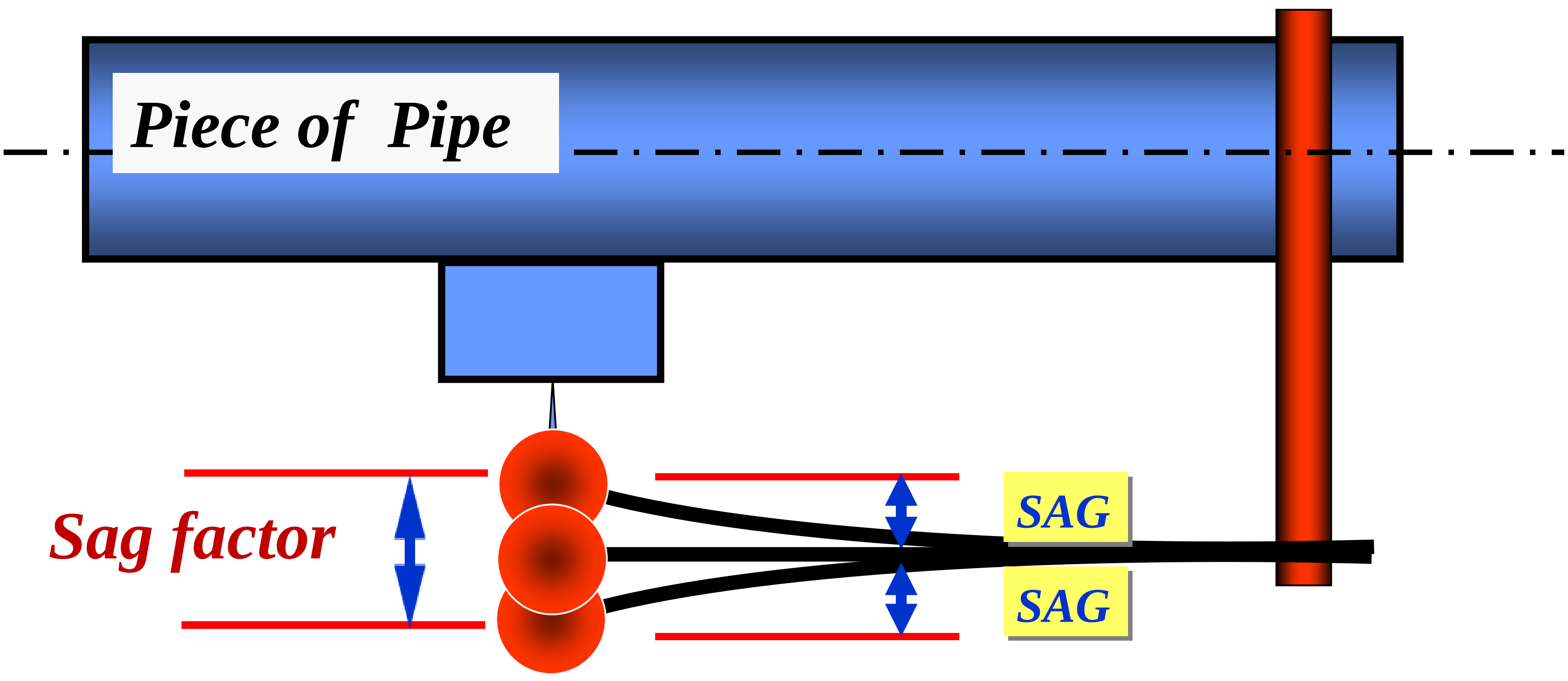
Electrical motors have no thrust bearings as they have instead a magnetic center



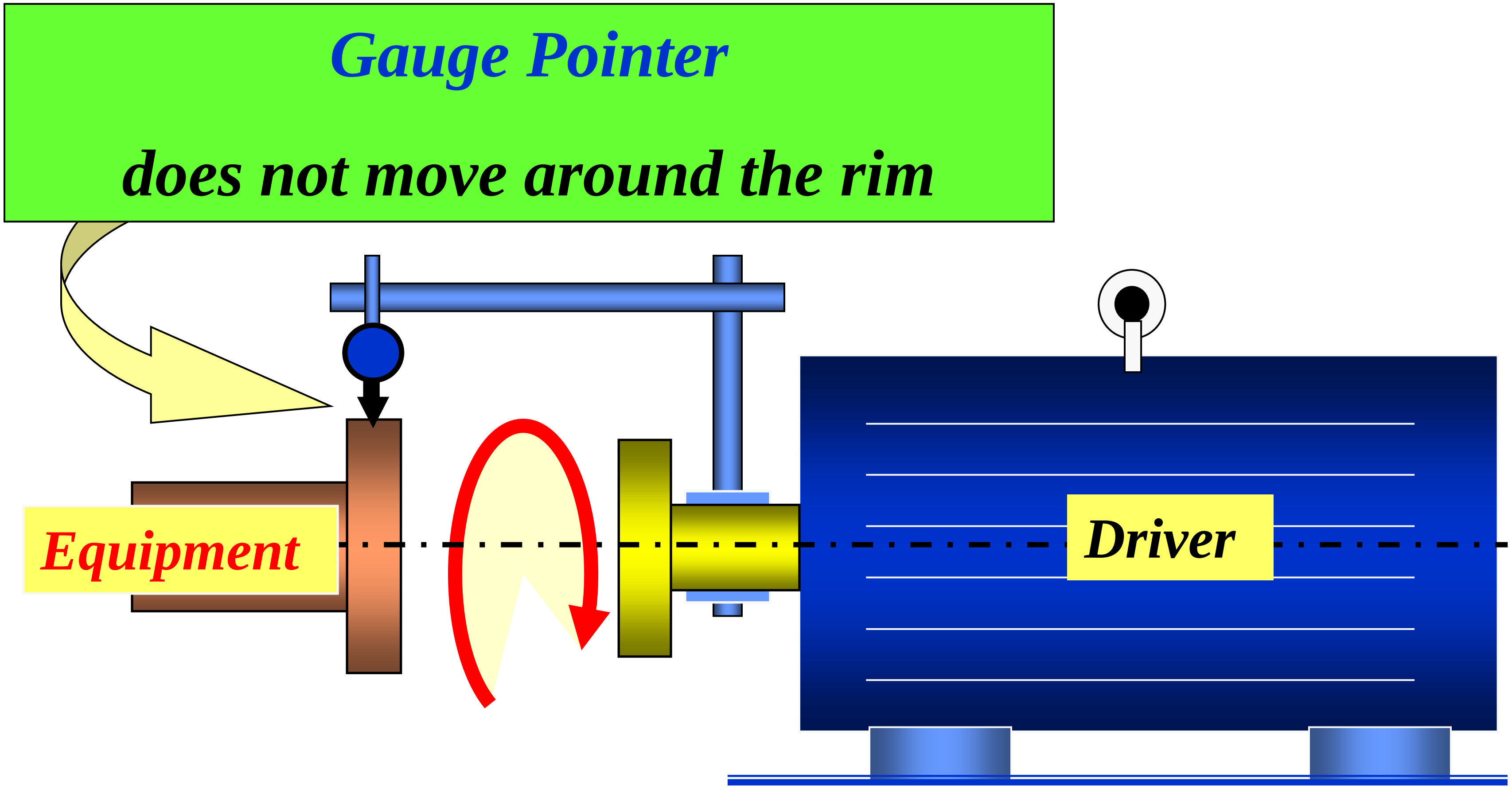
Measurement of bar sag.



Bar Sag on 12 O'clock Position

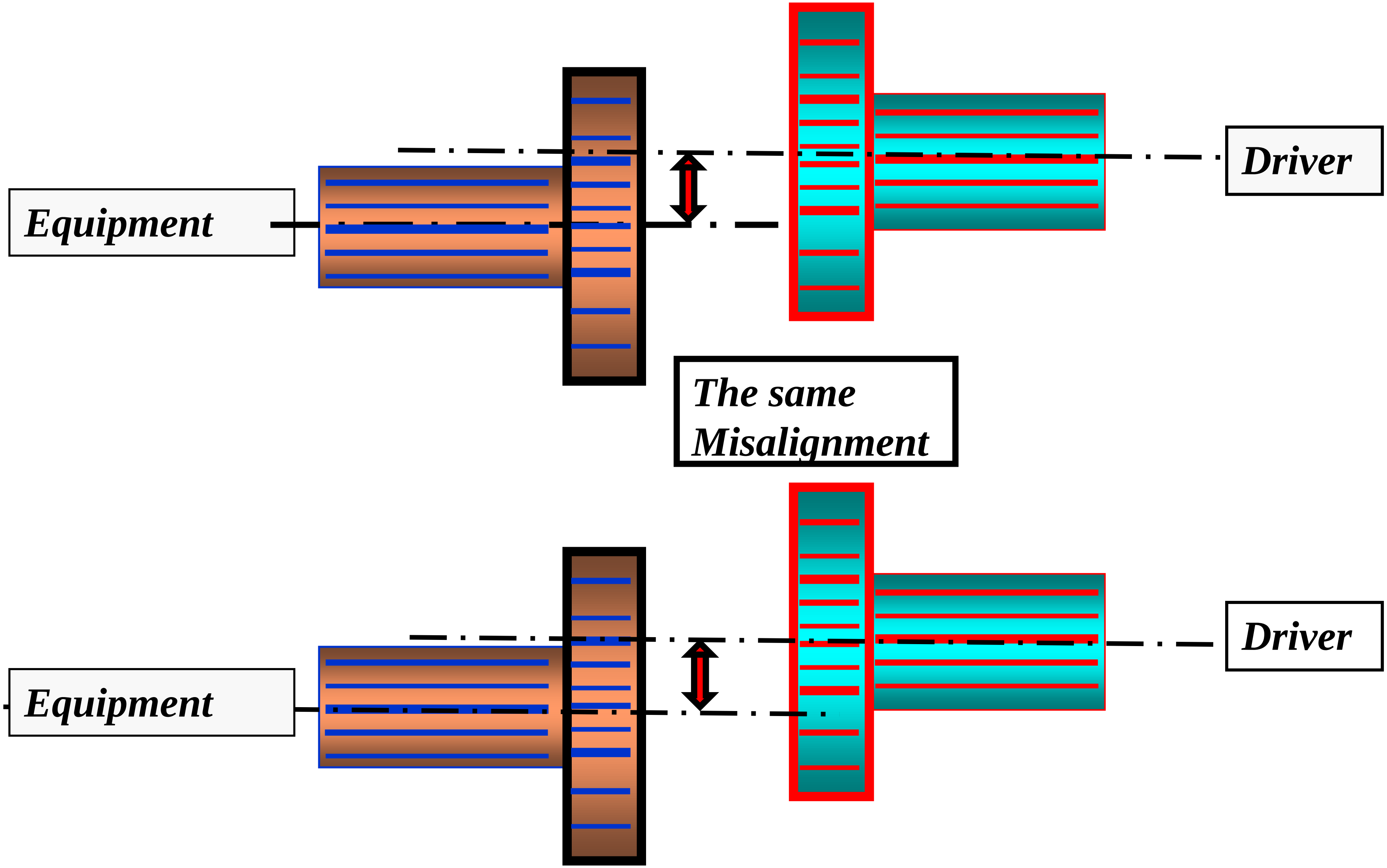

Piece of Pipe
Sag factor
SAG
SAG

How To Do Alignment

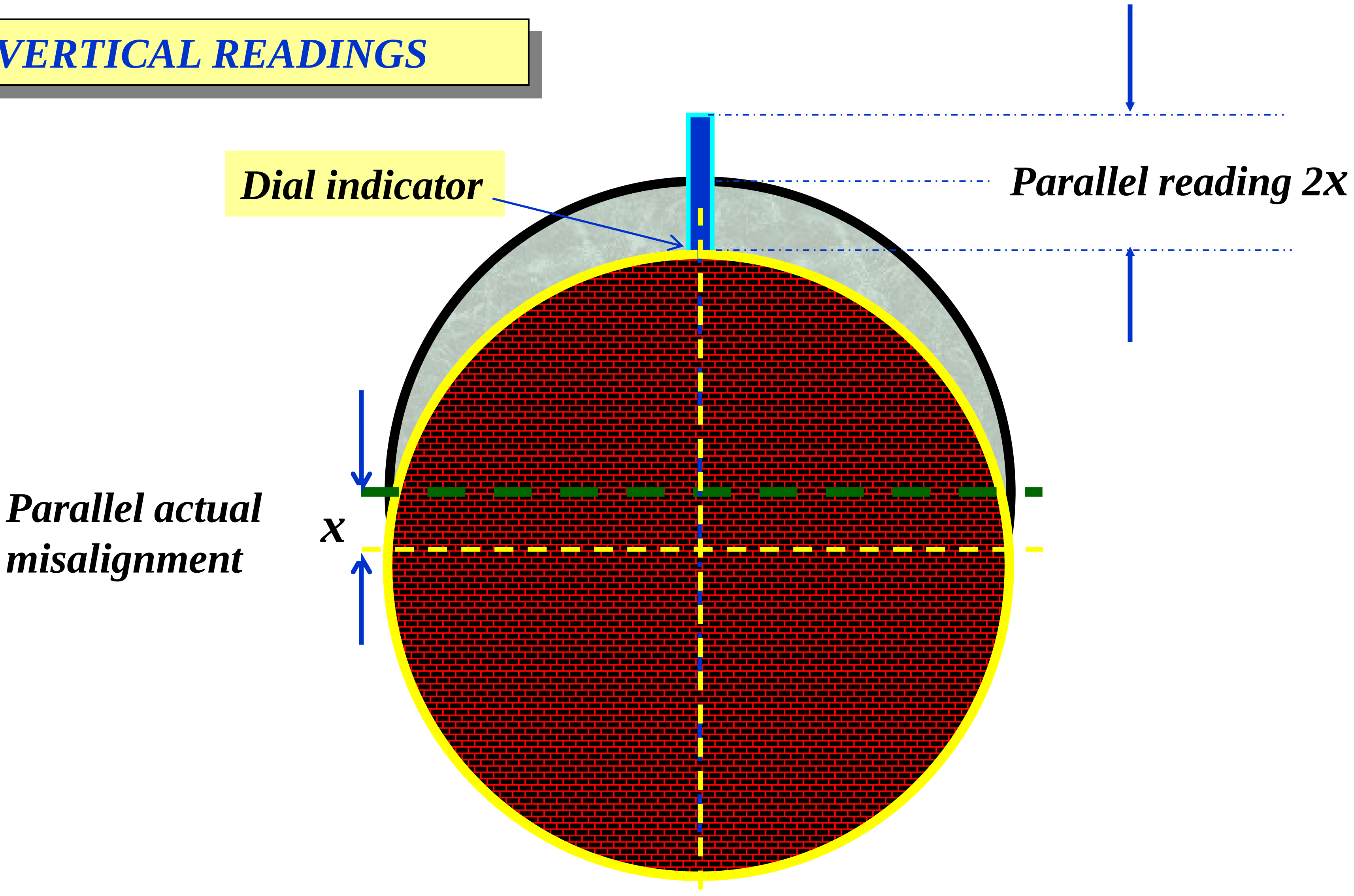


Motor and Equipment shaft

Rotate in the same time


Equipment
Driver
The same
Misalignment
Equipment
Driver

VERTICAL READINGS



HORIZONTAL READINGS

If :

- *Both shafts rotate*

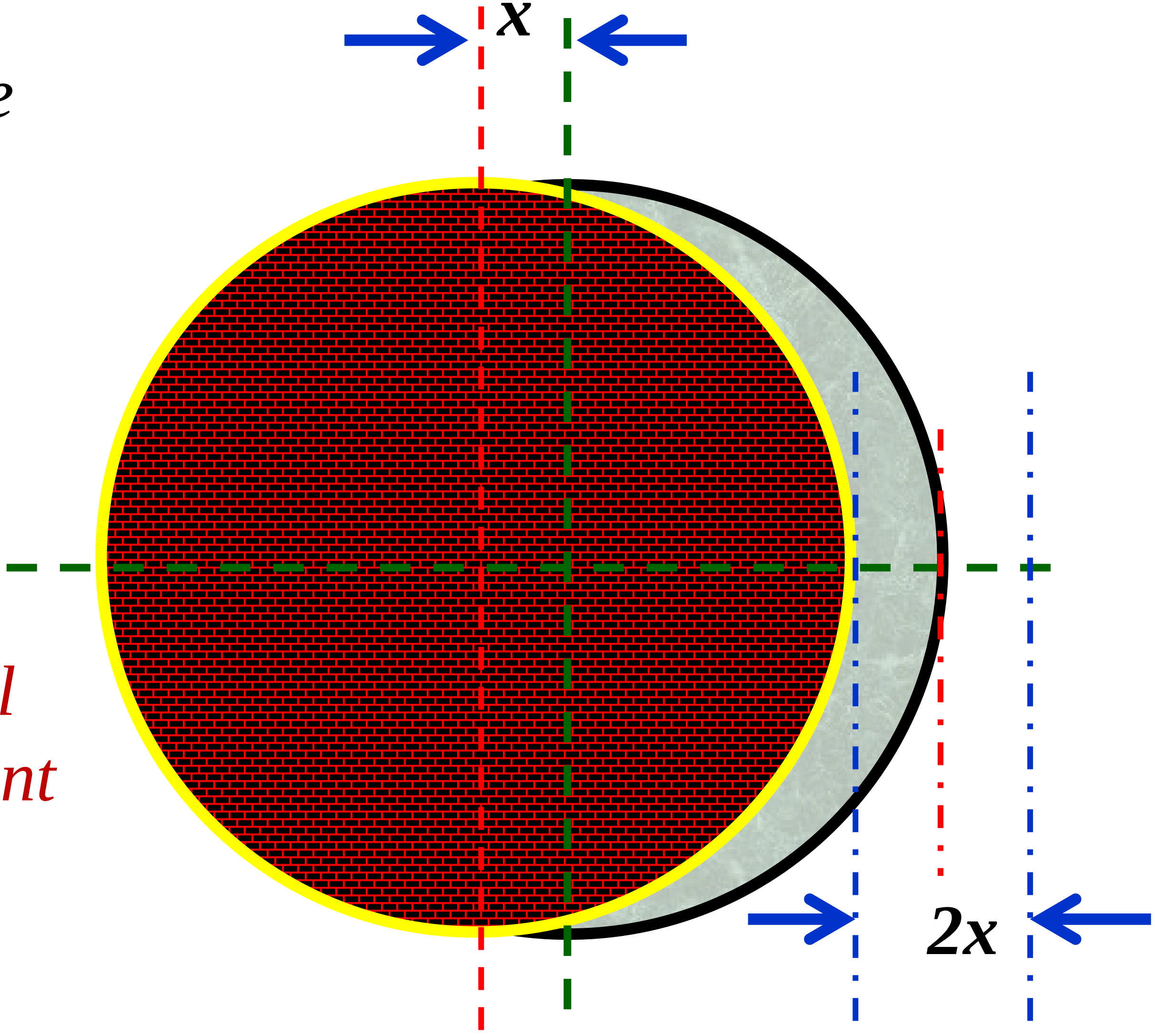
Or - *One shaft rotates*

The dial indicator reading is the same,

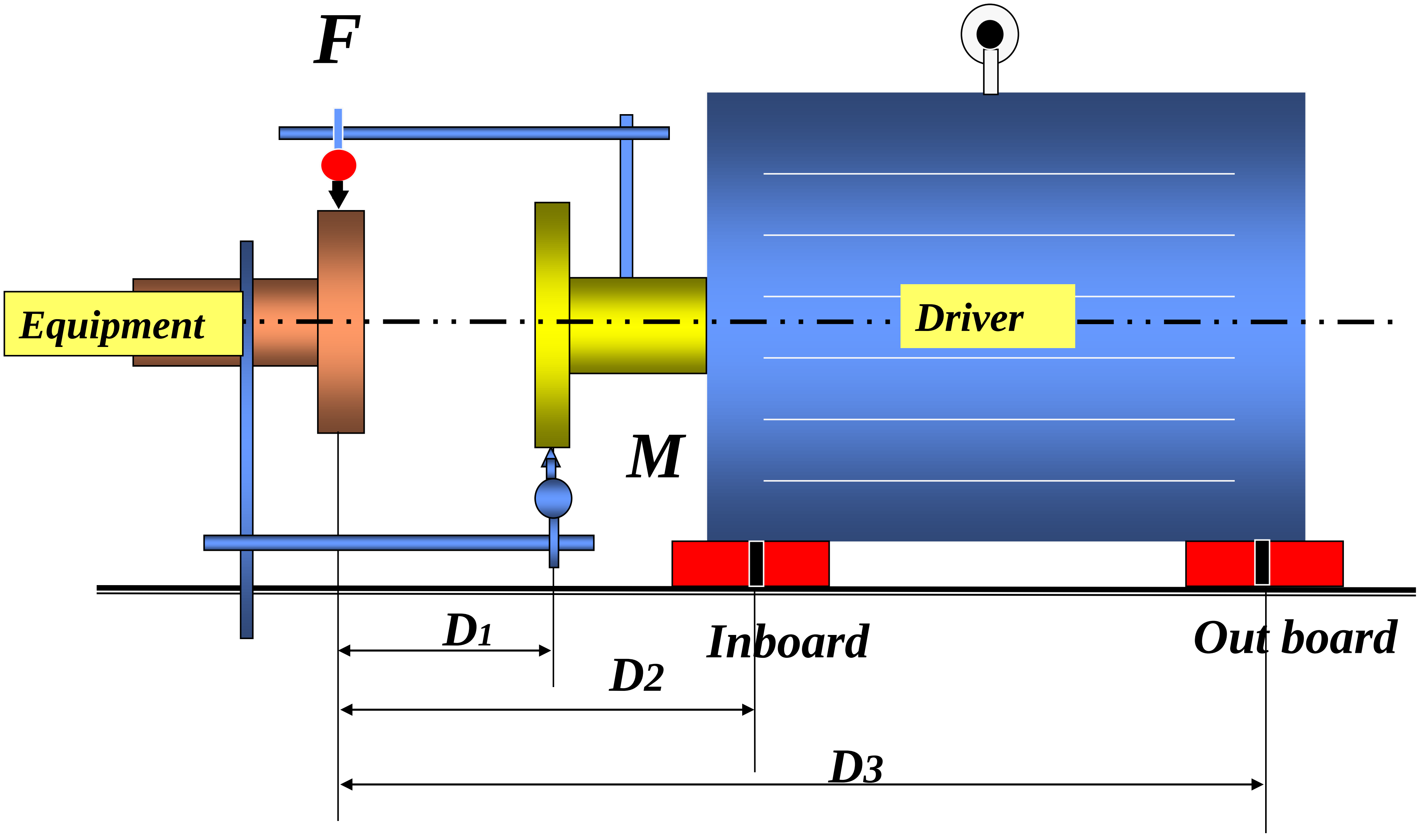
And equal to:

Double of the actual Misalignment amount

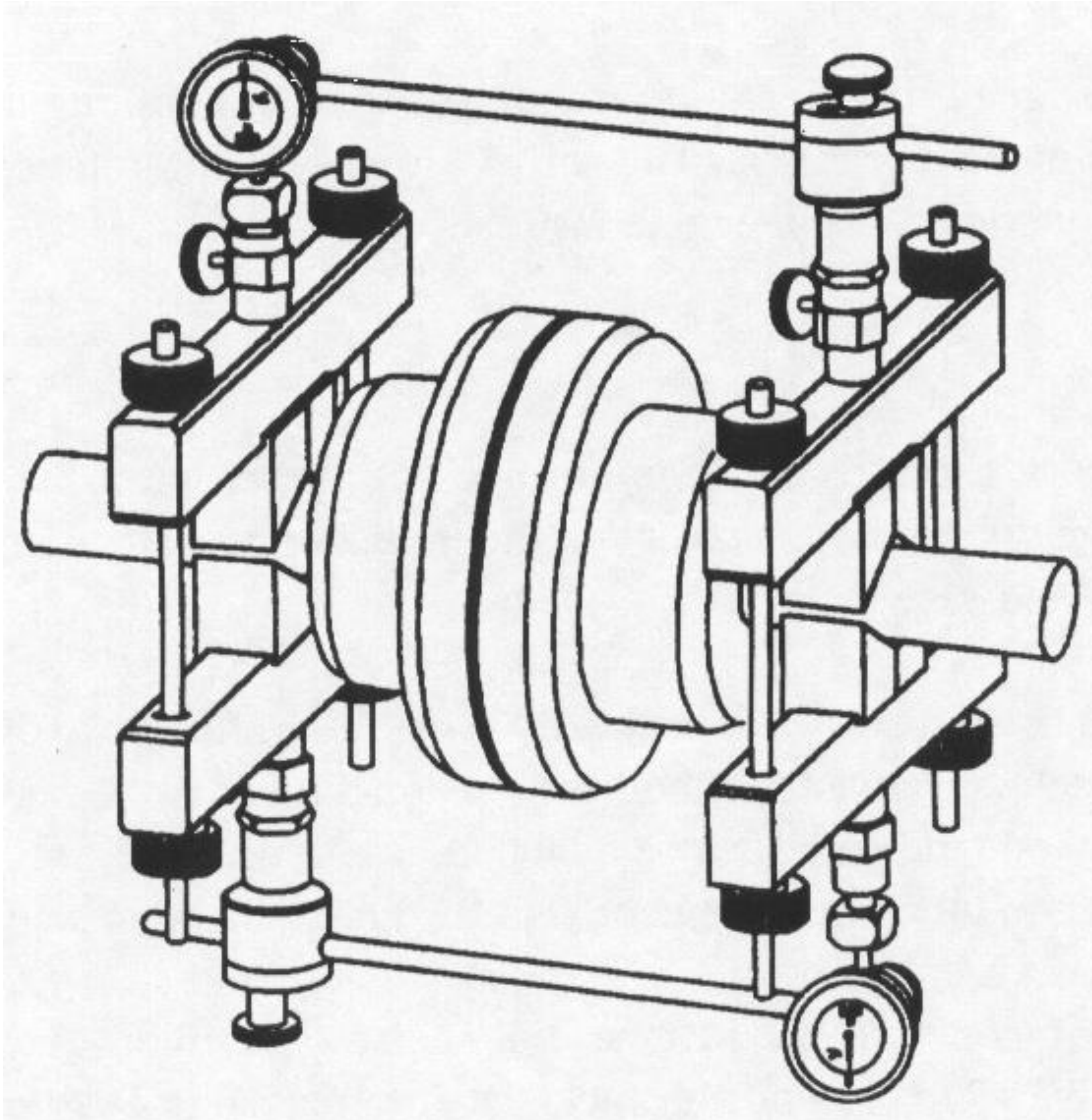
Parallel actual misalianment



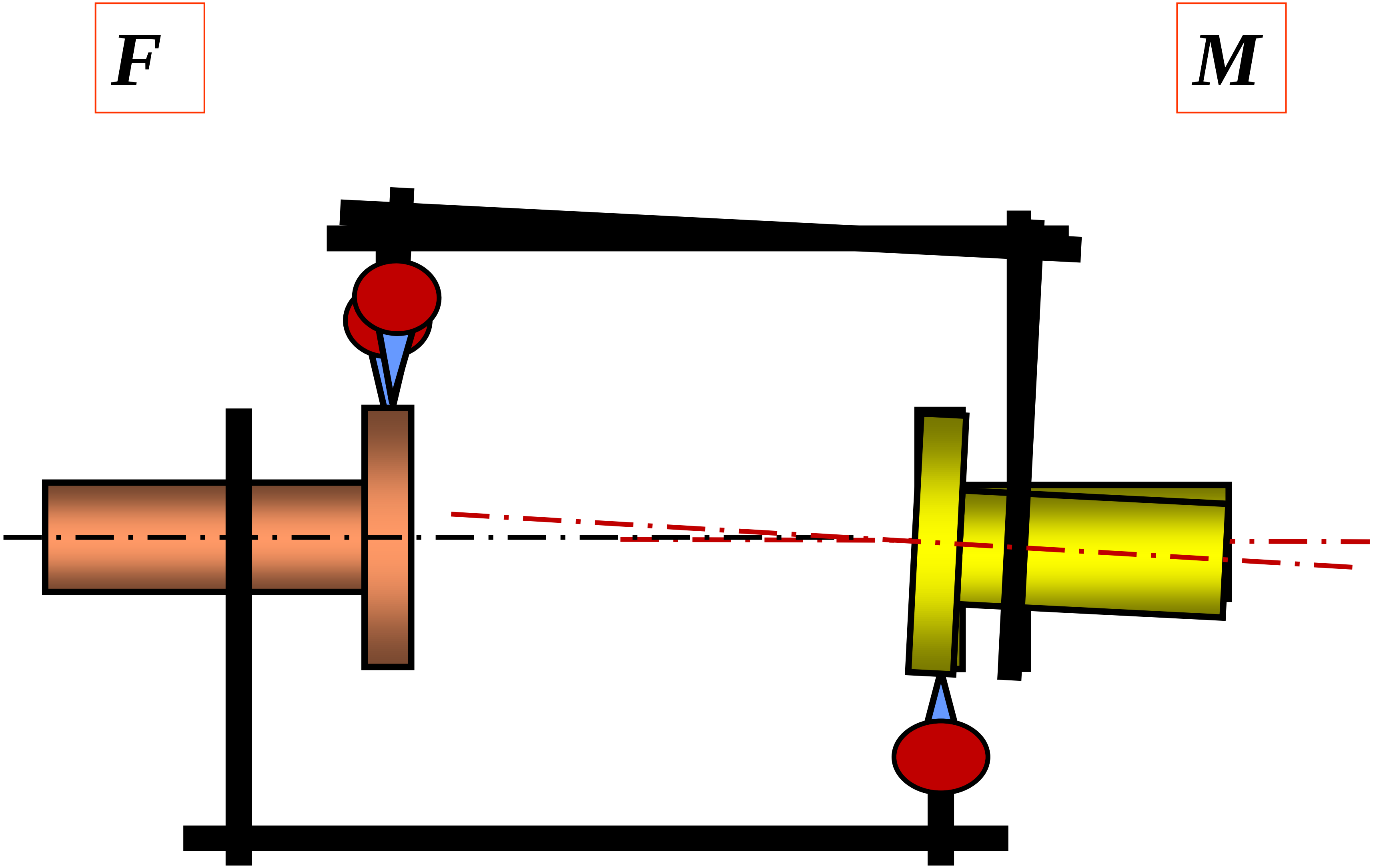
1-Reversal Alignment



F

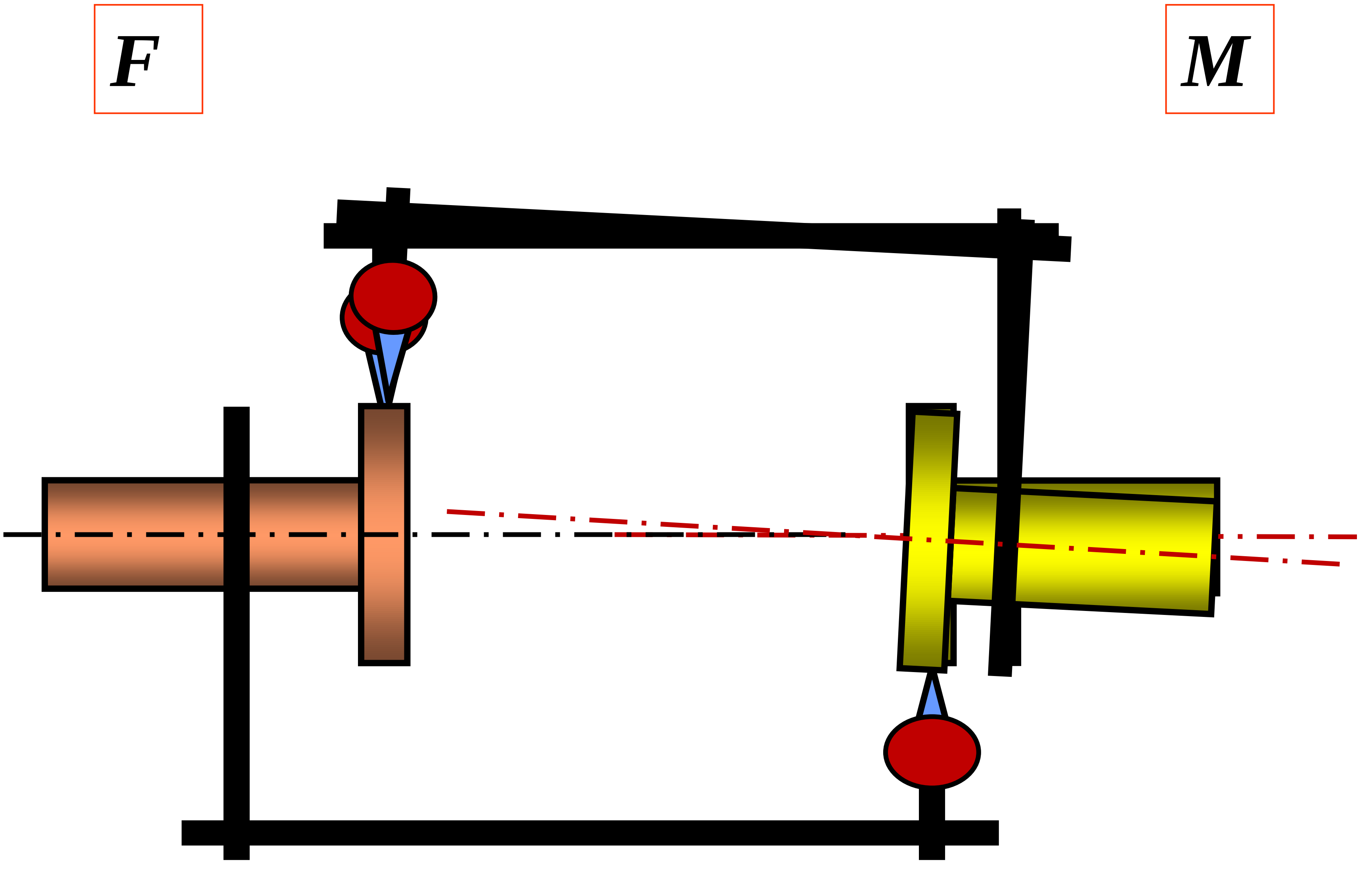


M



The Reversal alignment method,

eliminates the Angular misalignment due to prime mover axial movement


F
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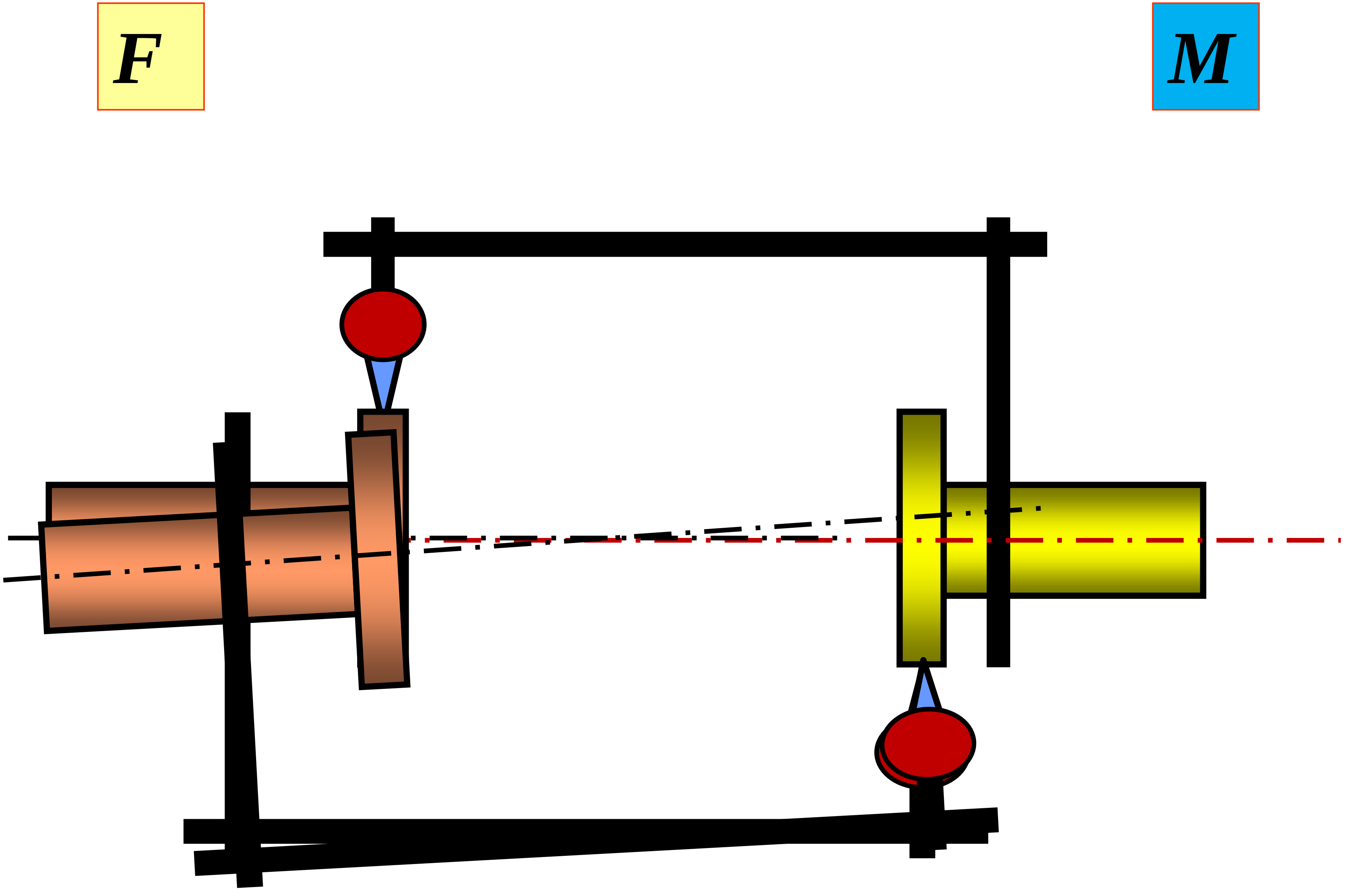
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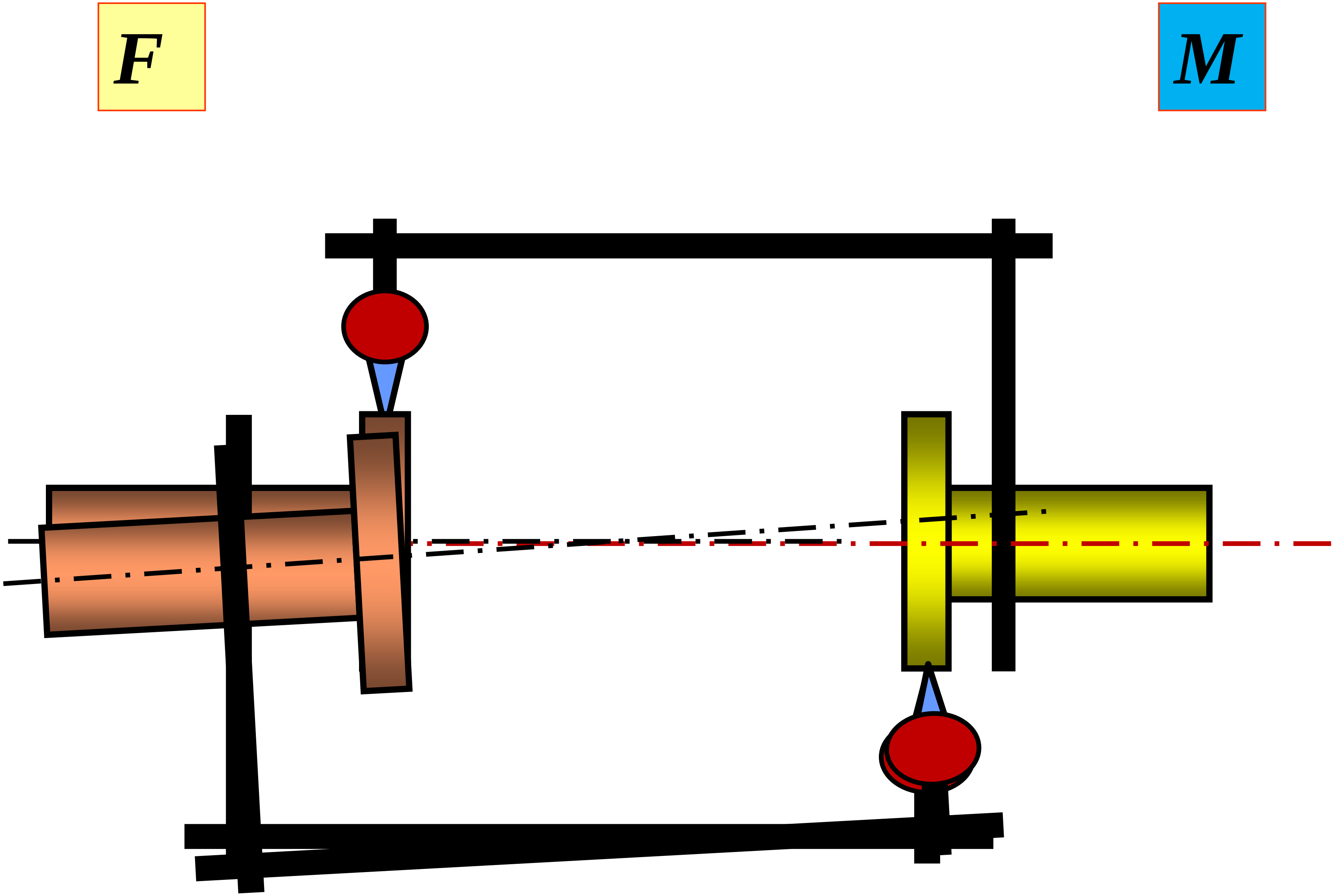
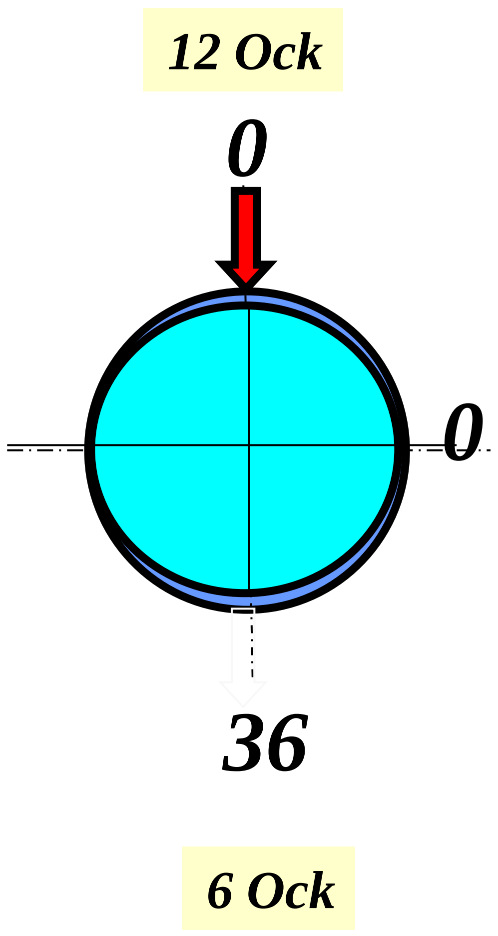
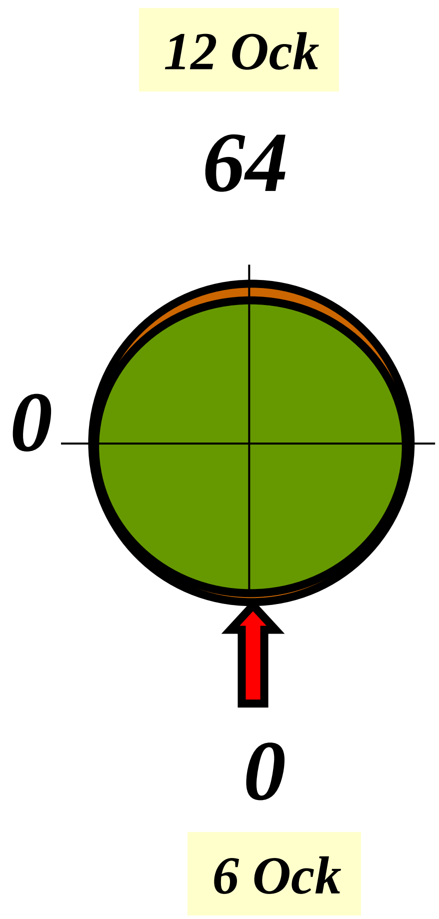


PARALELL READINGS

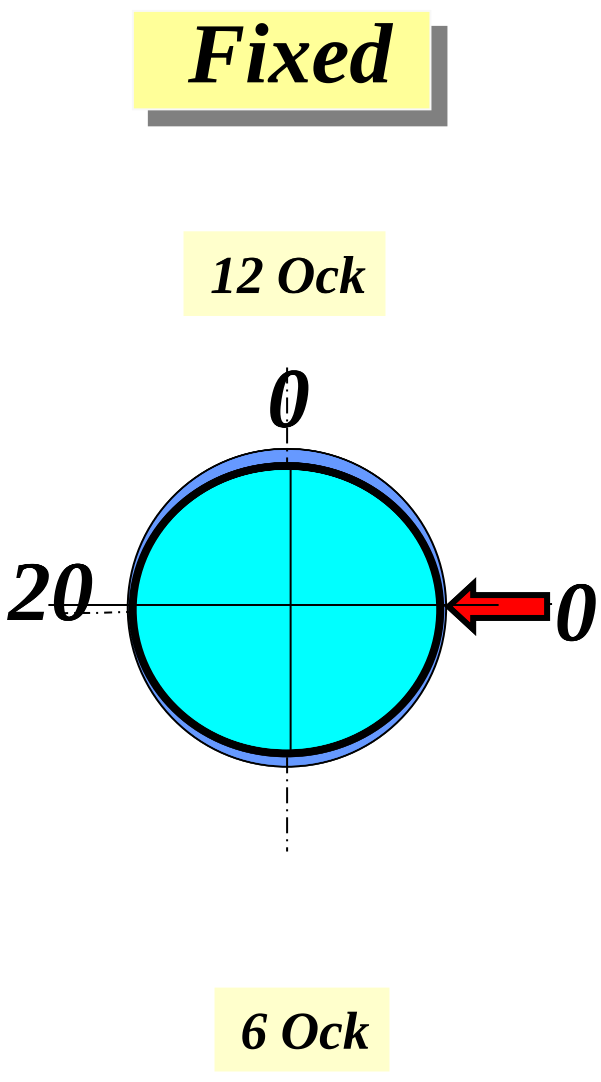
Fixed

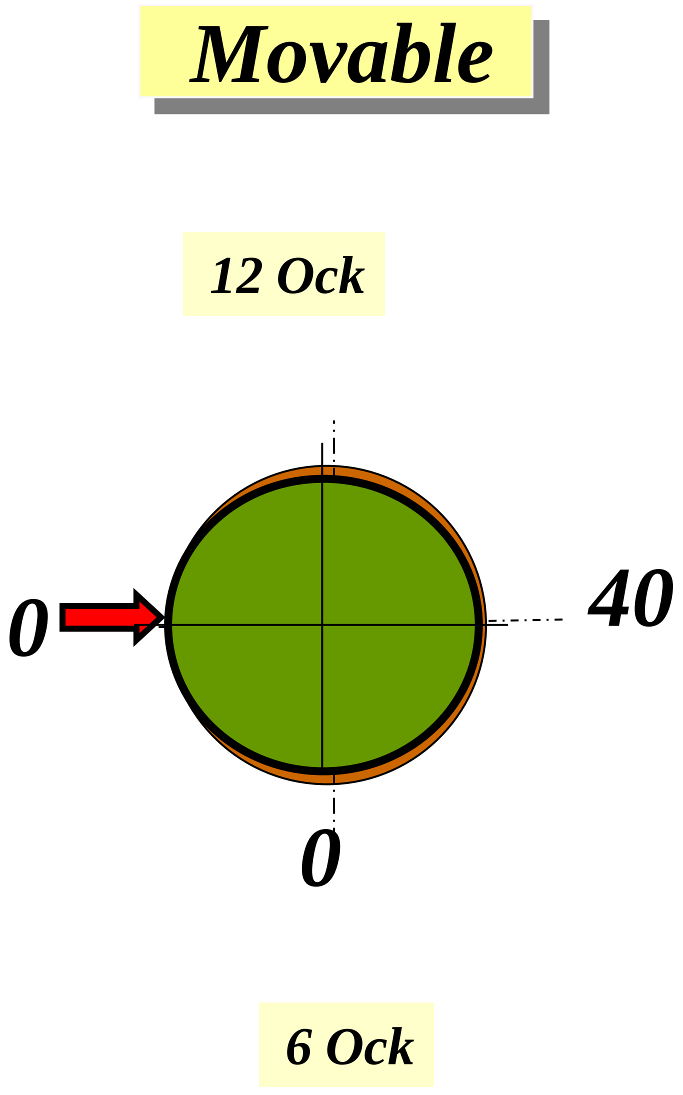
Movable





PARALELL READINGS





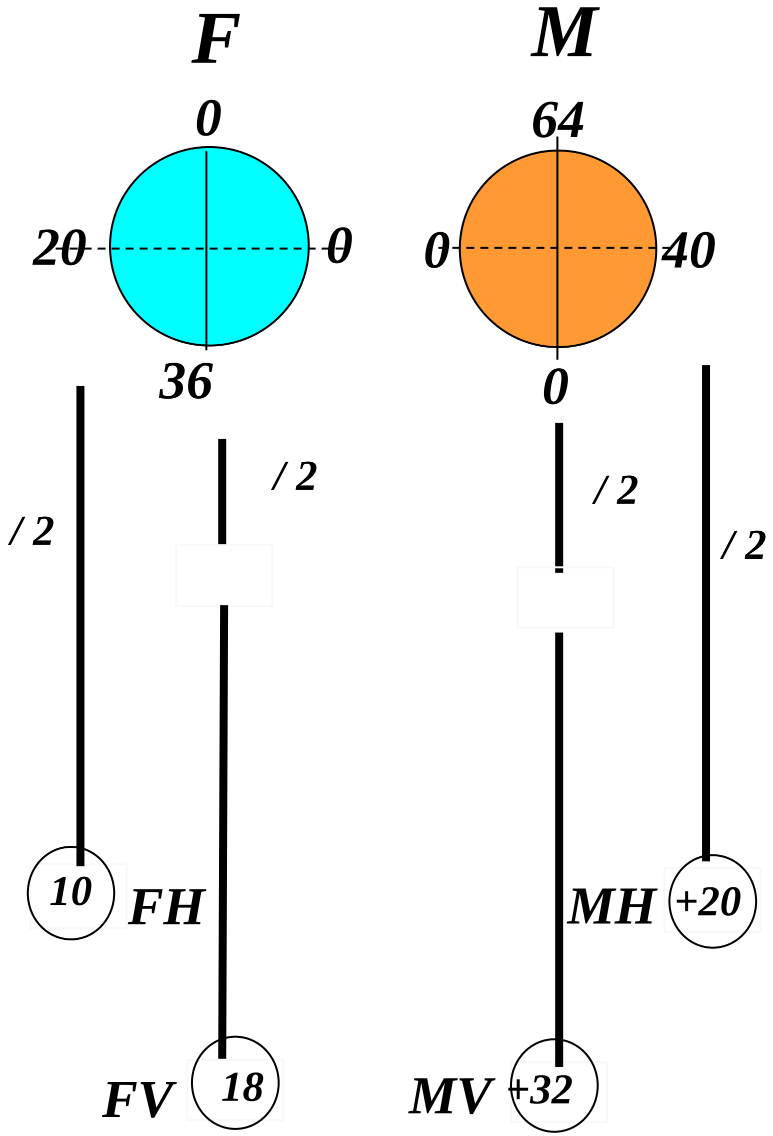
1-Reversal Alignment Calculation Method

D 1 =

D 2 =

D 3 =

Sag = (0)



VERTICALLY

$$\text{INBOARD} = \left\{ MV - FV \right\} \frac{D2}{D1} + FV$$

$$\text{OUTBOARD} = \left\{ MV - FV \right\} \frac{D3}{D1} + FV$$

HORIZONTALLY

$$\text{INBOARD} = \left\{ MH - FH \right\} \frac{D2}{D1} + FH$$

$$\text{OUTBOARD} = \left\{ MH - FH \right\} \frac{D3}{D1} + FH$$

Mils

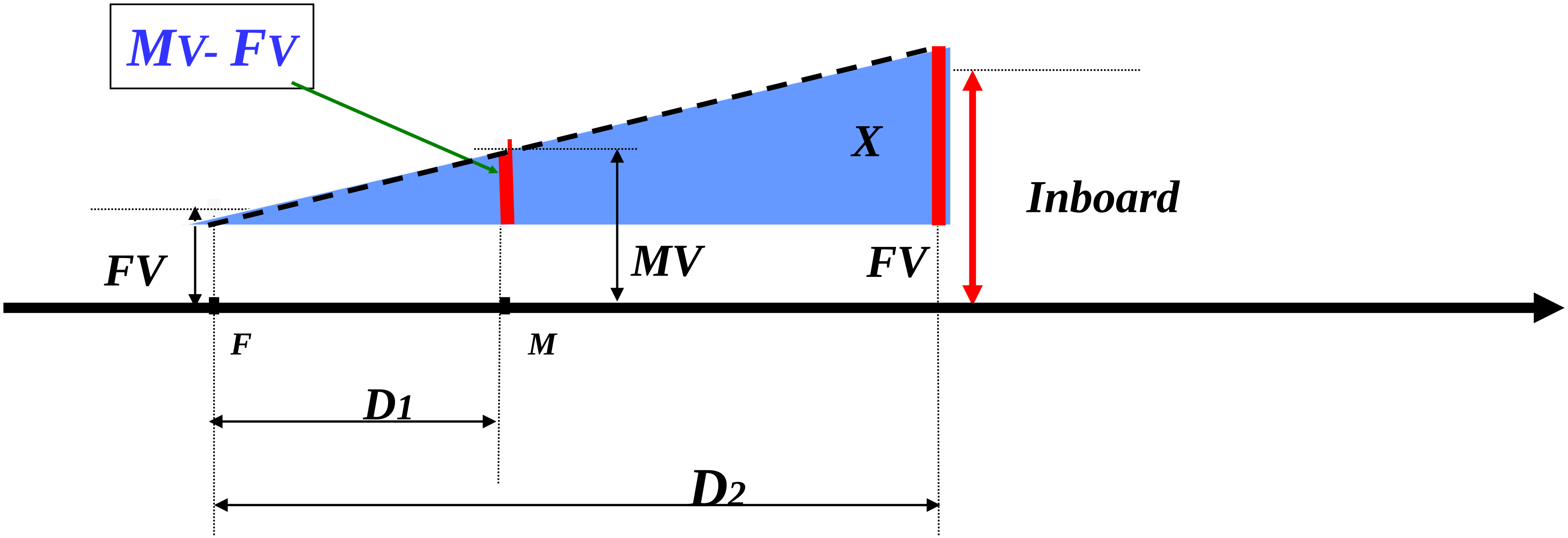
VERTICALLY

$$INBOARD = X + FV$$

$$\frac{X}{M_V - F_V} = \frac{D_2}{D_1}$$

$$INBOARD = \{ M_V - F_V \} \frac{D_2}{D_1} + FV$$

$$X = \{M_V - F_V\} \frac{D_2}{D_1}$$



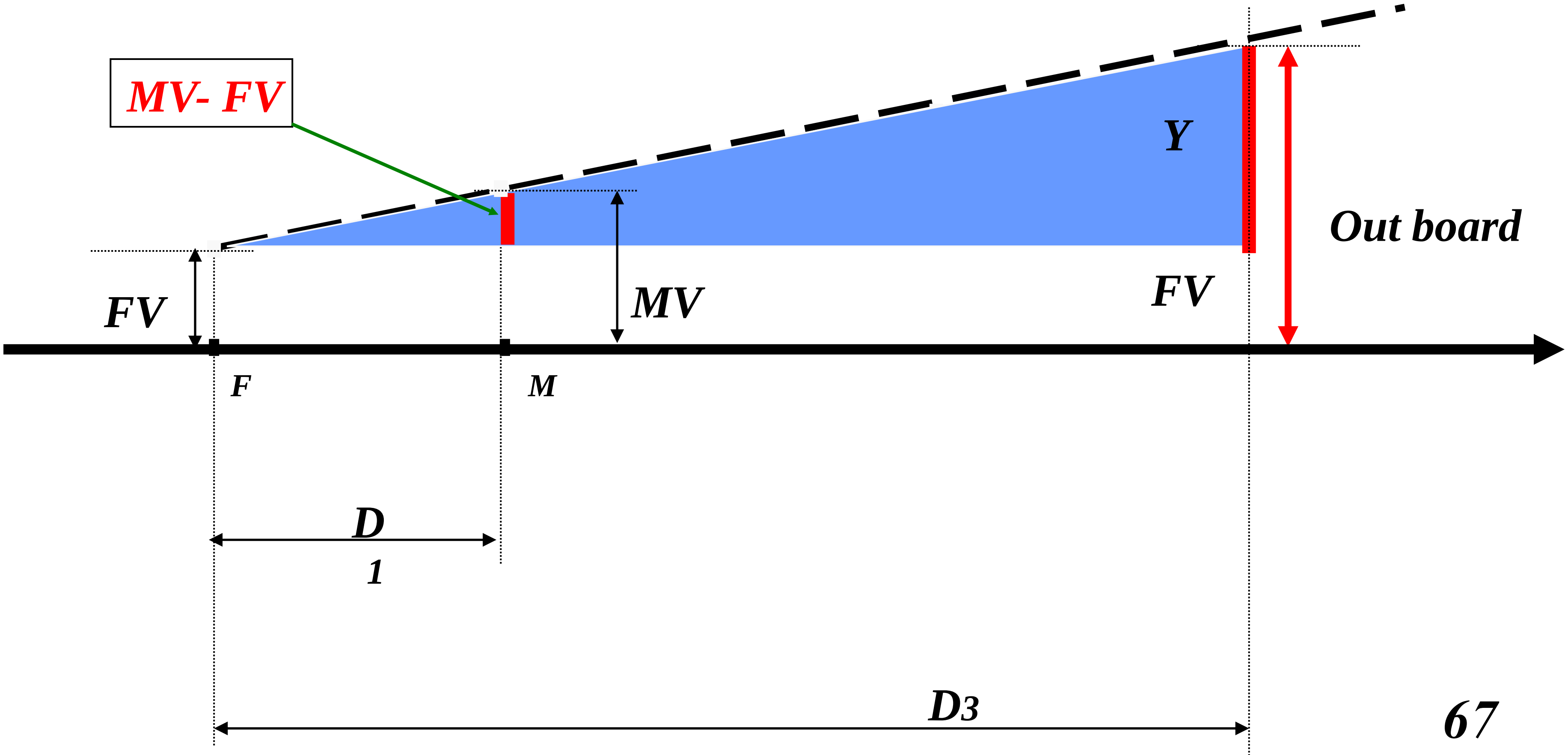
VERTICALLY

$$OUTBOARD = Y + FV$$

$$\frac{Y}{M_V - F_V} = \frac{D_3}{D_1}$$

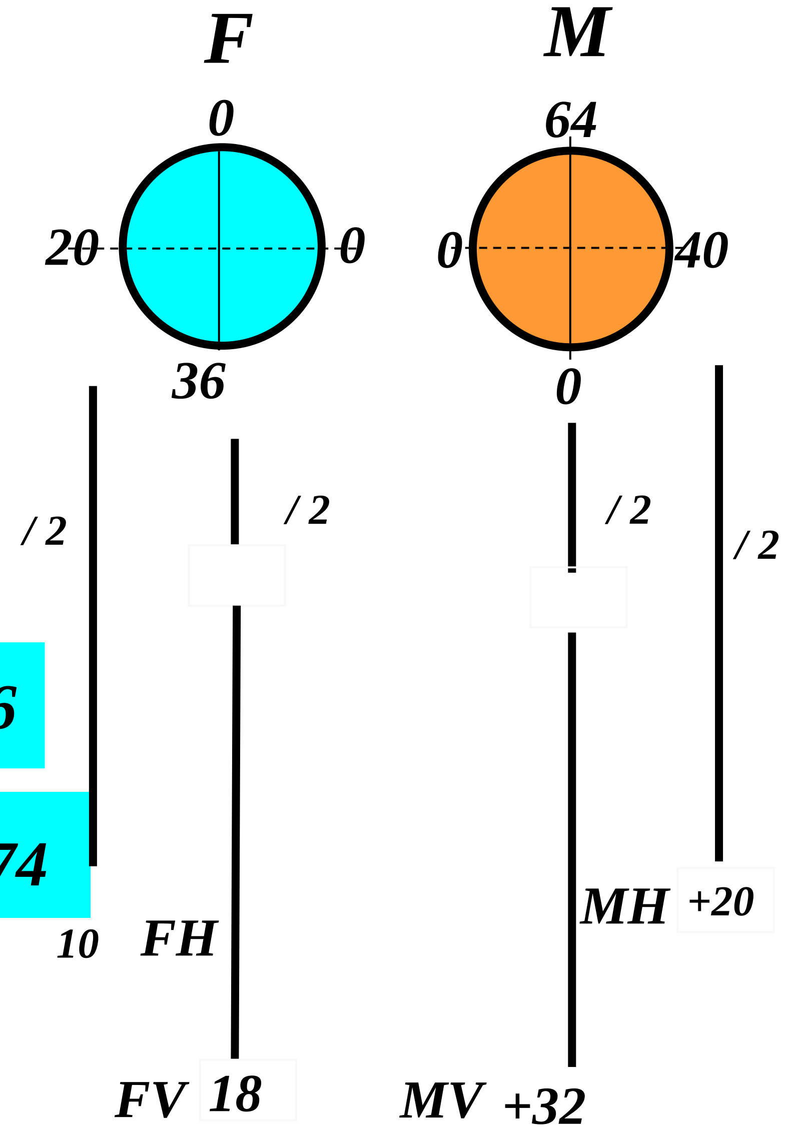
$$OUTBOARD = \{M_V - F_V\}\frac{D_3}{D_1} + FV$$

$$Y = \{M_V - F_V\}\frac{D_3}{D_1}$$



D1 = 4 in
D2 = 8 in
D3 = 16 in
Sag = (0)

F = 0
M = 0



VERTICALLY

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

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

HORIZONTALLY

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

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

Mils

D1 = 4 in
D2 = 8 in
D3 = 16 in
Sag = (1)

F = + 1

M = -1

VERTICALLY

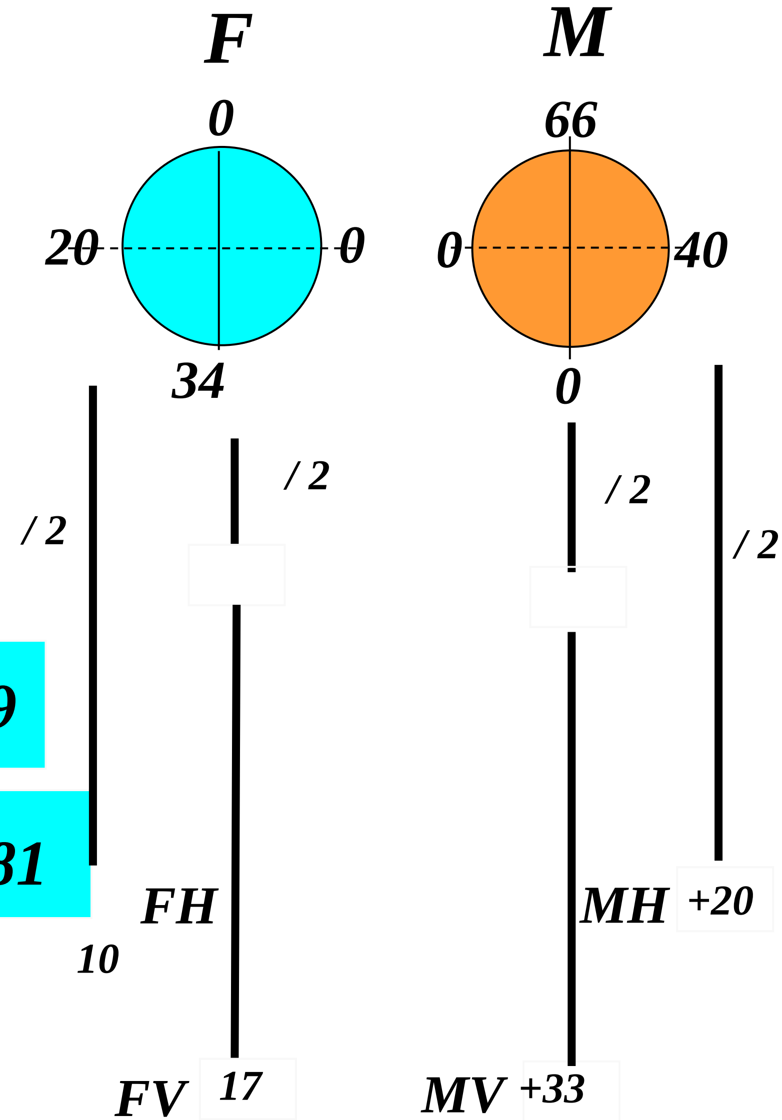
$$\text{INBOARD} = \{33 - 17\}\frac{8}{4} + 17 = +49$$

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

HORIZONTALLY

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

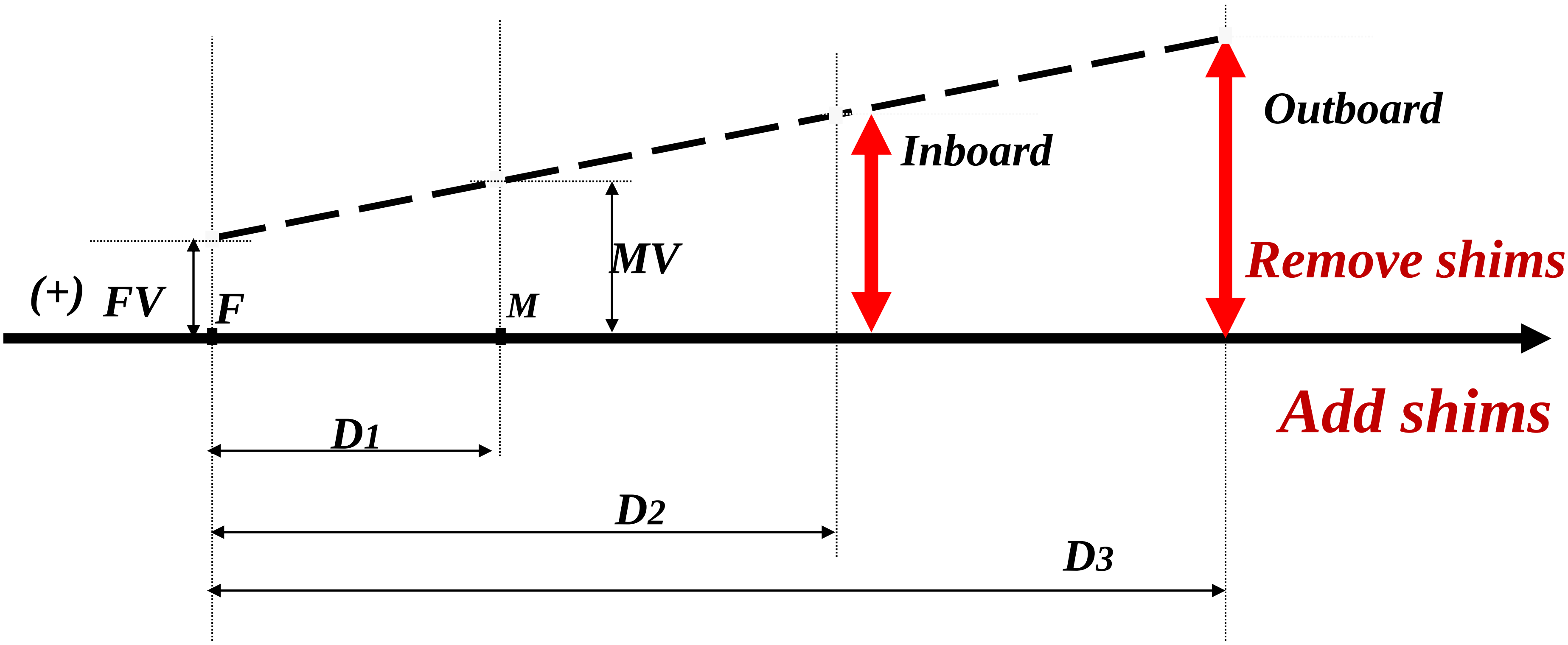
$$\text{OUTBOARD} = \{20 - 10\}\frac{16}{4} + 10 = +50$$



Mils

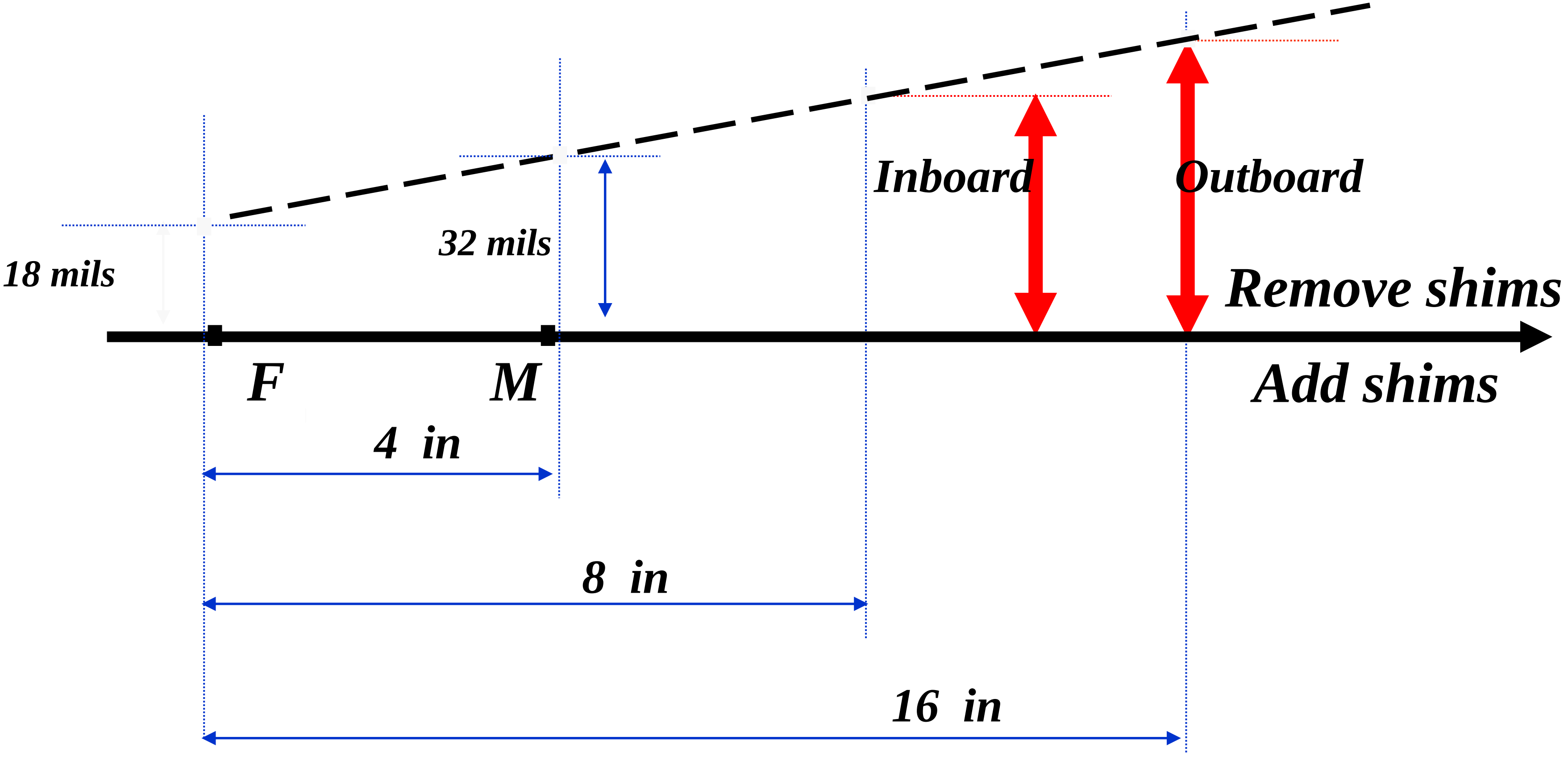
Reversal Alignment Graphical Method

Vertically

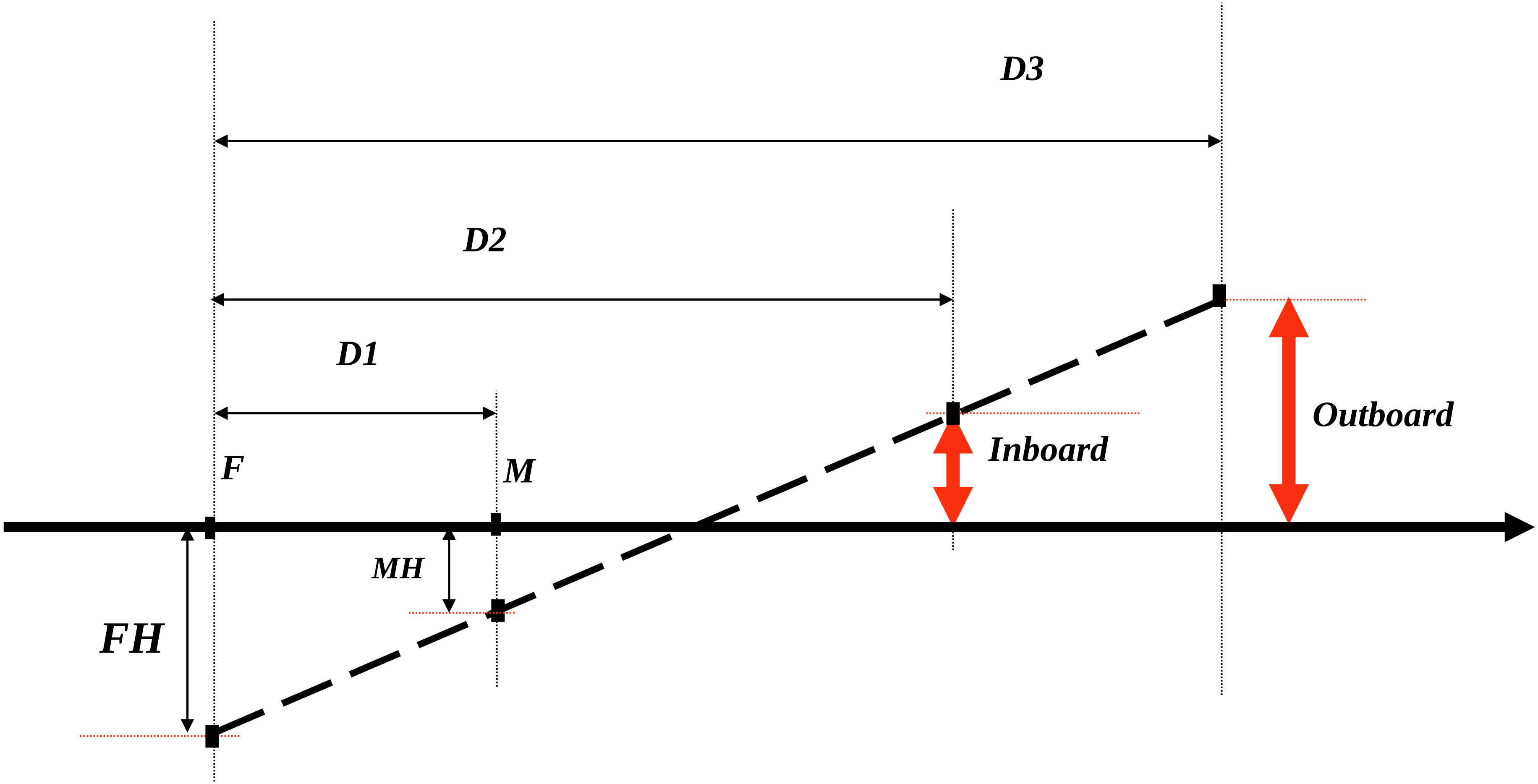


Vertically

FV = 18 mils
MV = 32 mils

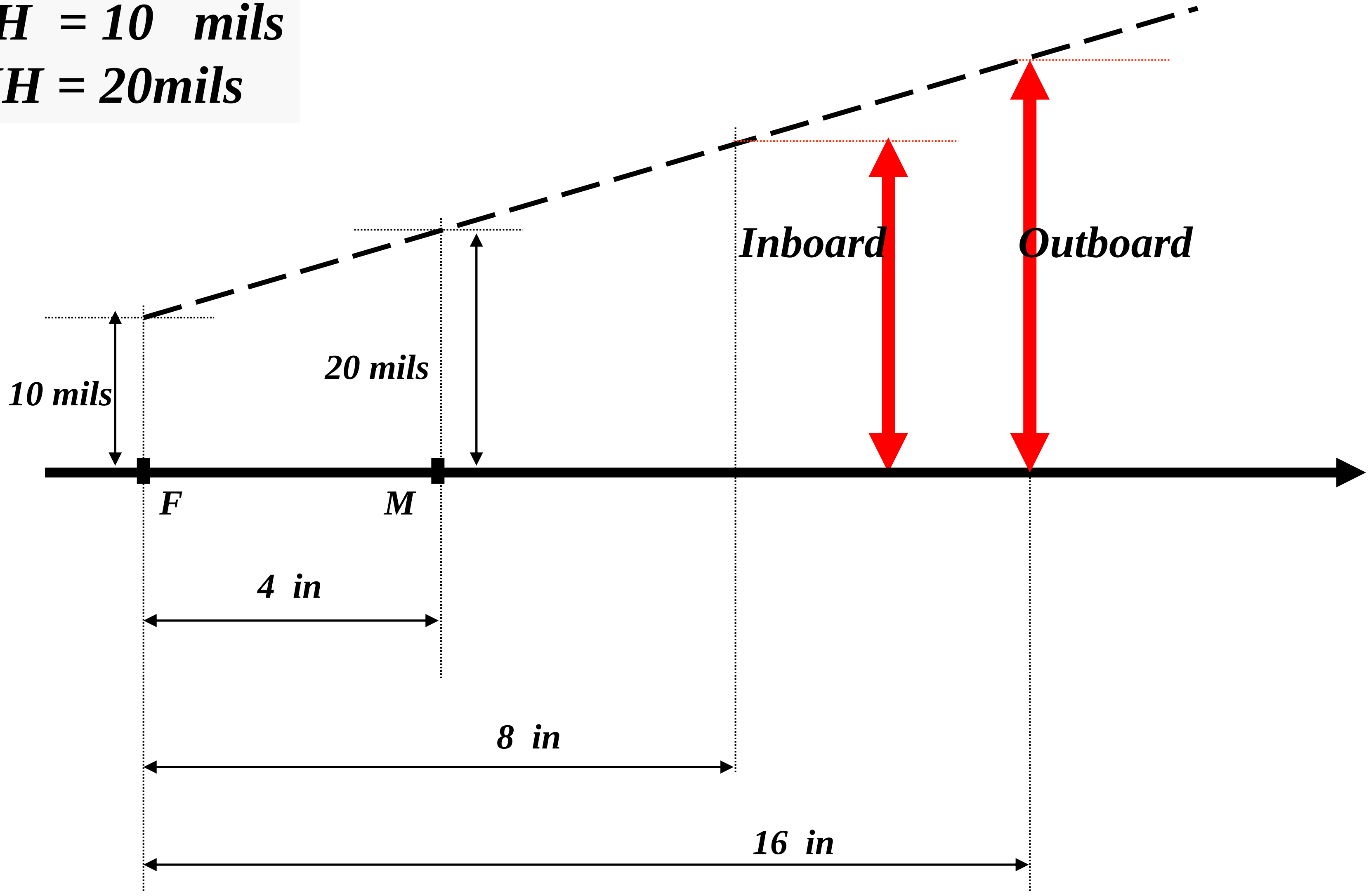


Horizontally



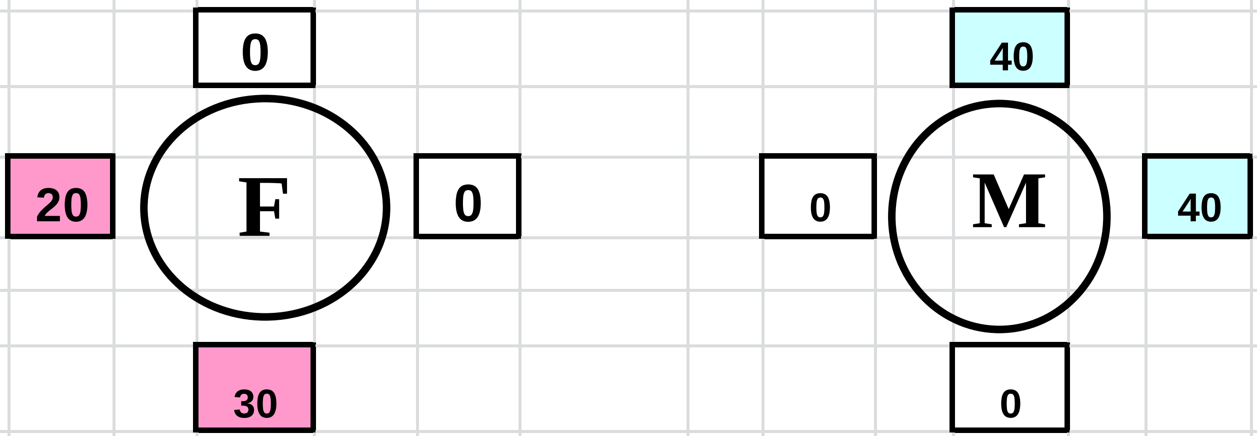
EXAMPLE

FH = 10 mils
MH = 20mils



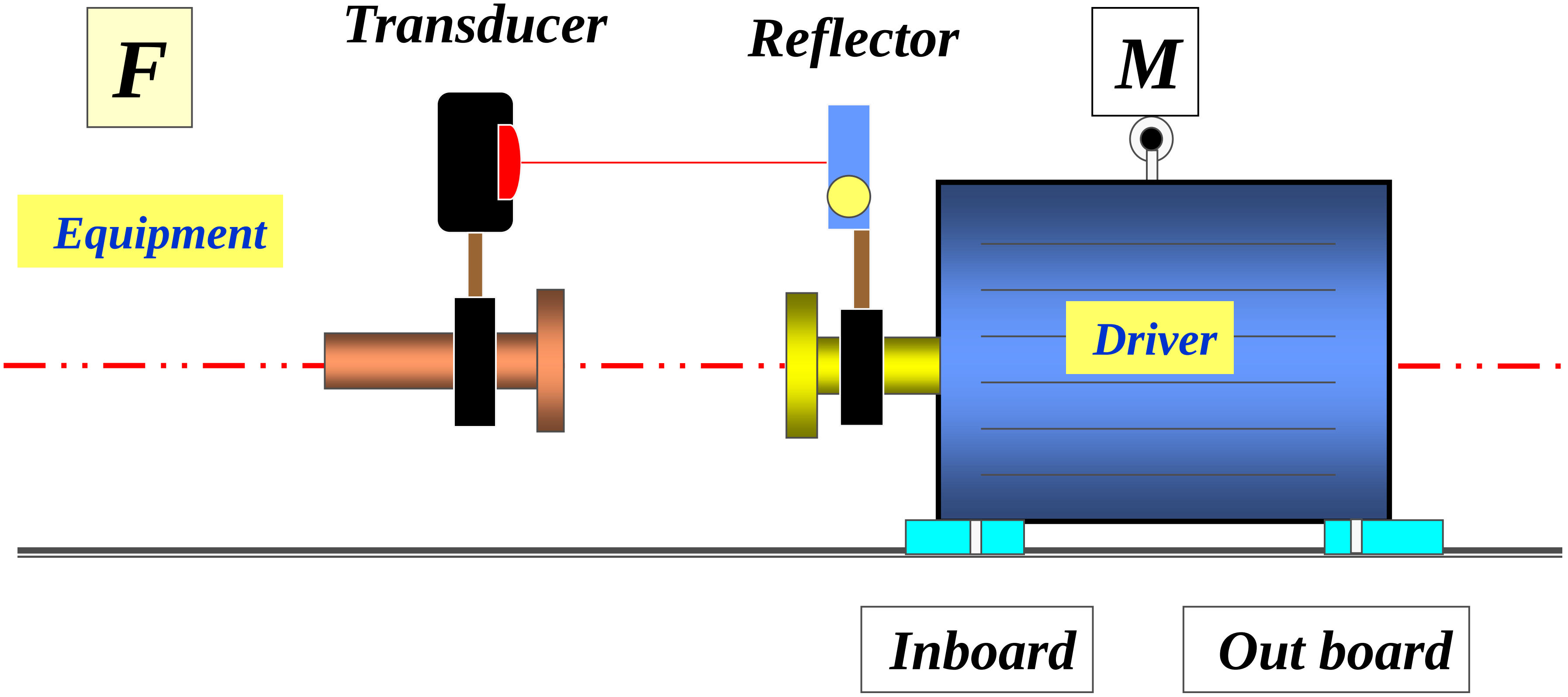
3-Reversal Alignment Software

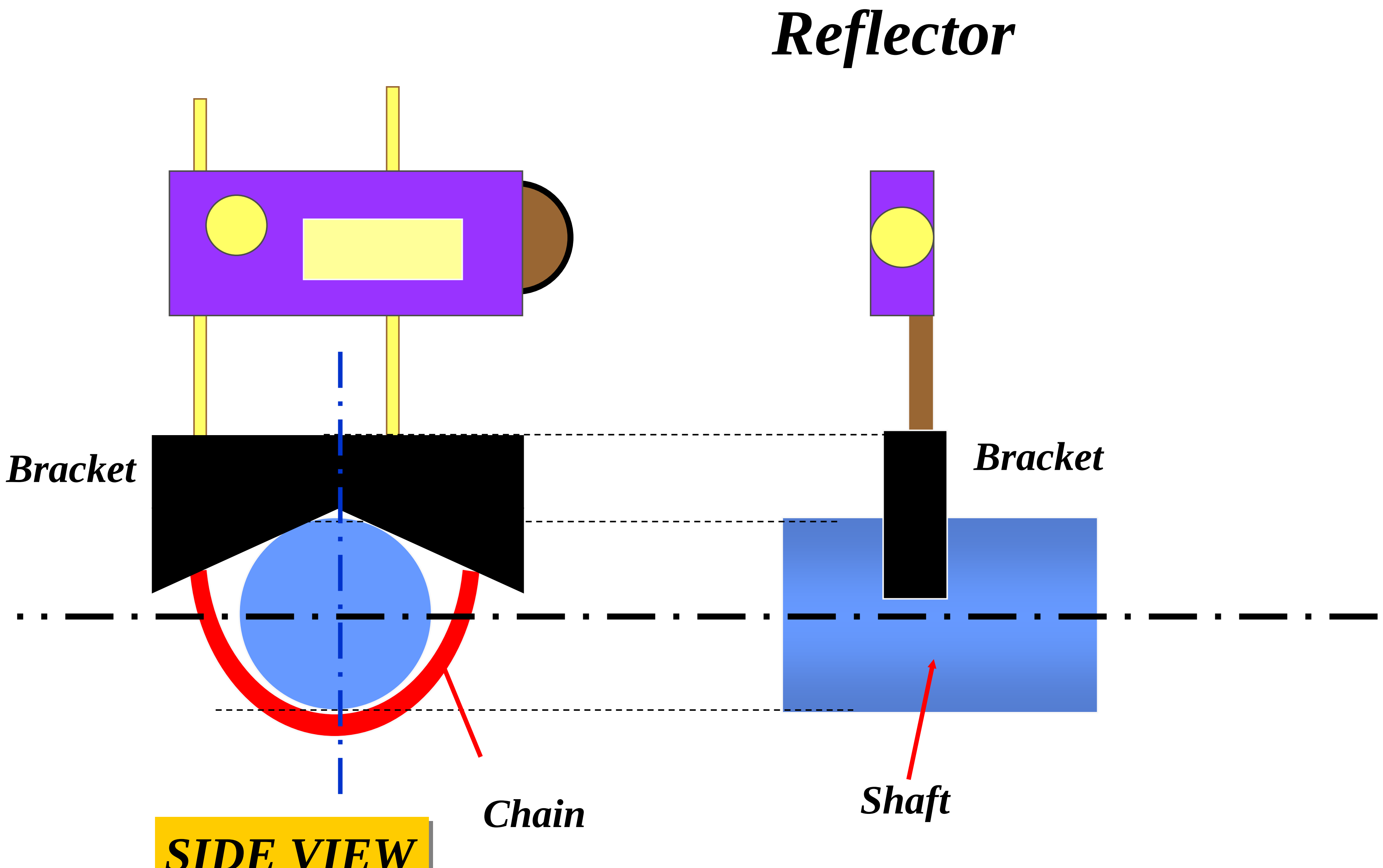
D1	D 2	D 3	Sag Factor(F)	Factor (M)
2	4	8	0	0



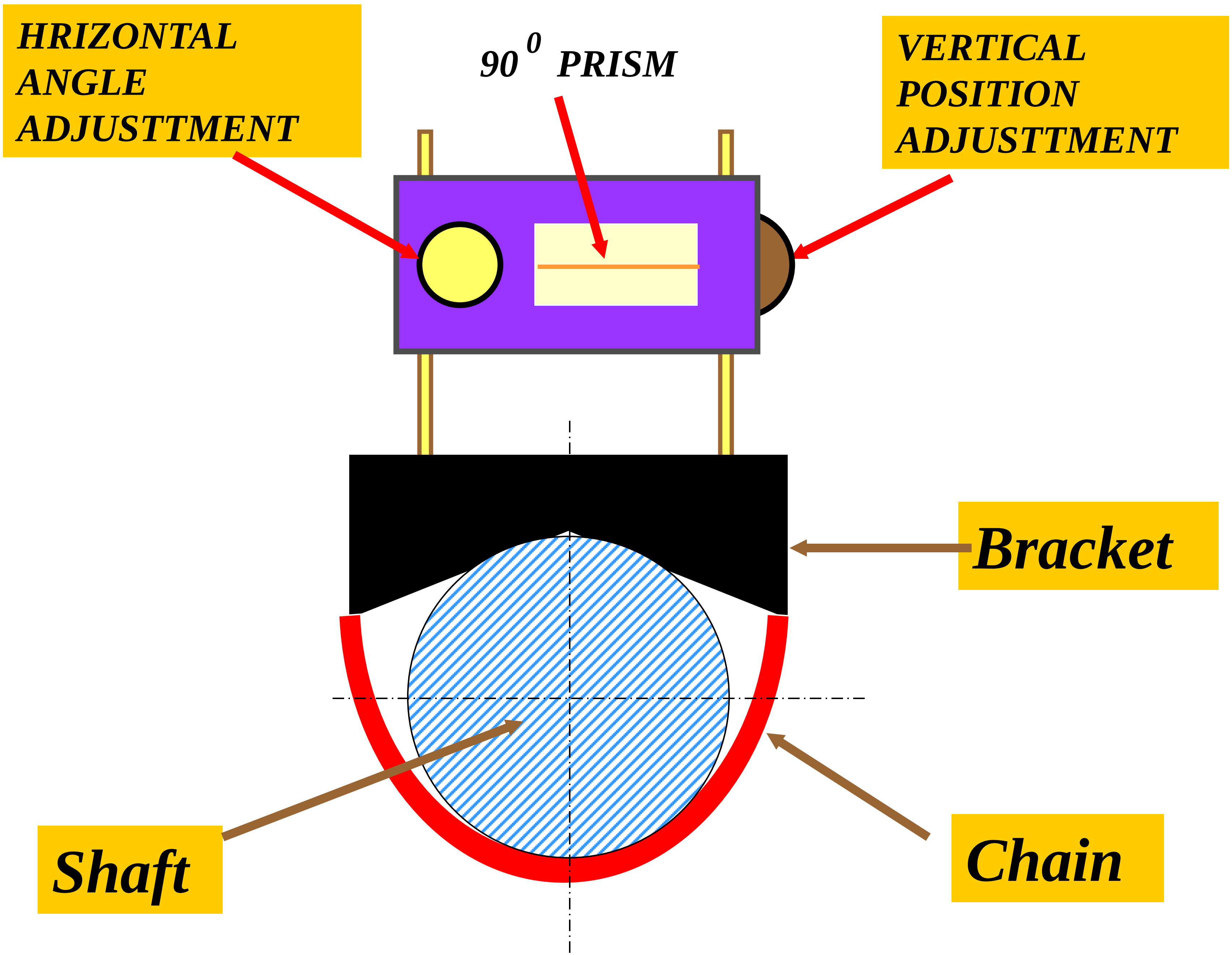
Inboard (vertical)	25	→	0	REMOVE shims
Outboard (vertical)	35		0	REMOVE shims
Inboard (Horiz.)	30	→	0	Move towards 9
Outboard (Horiz)	50		0	Move towards 9

Optical Alignment



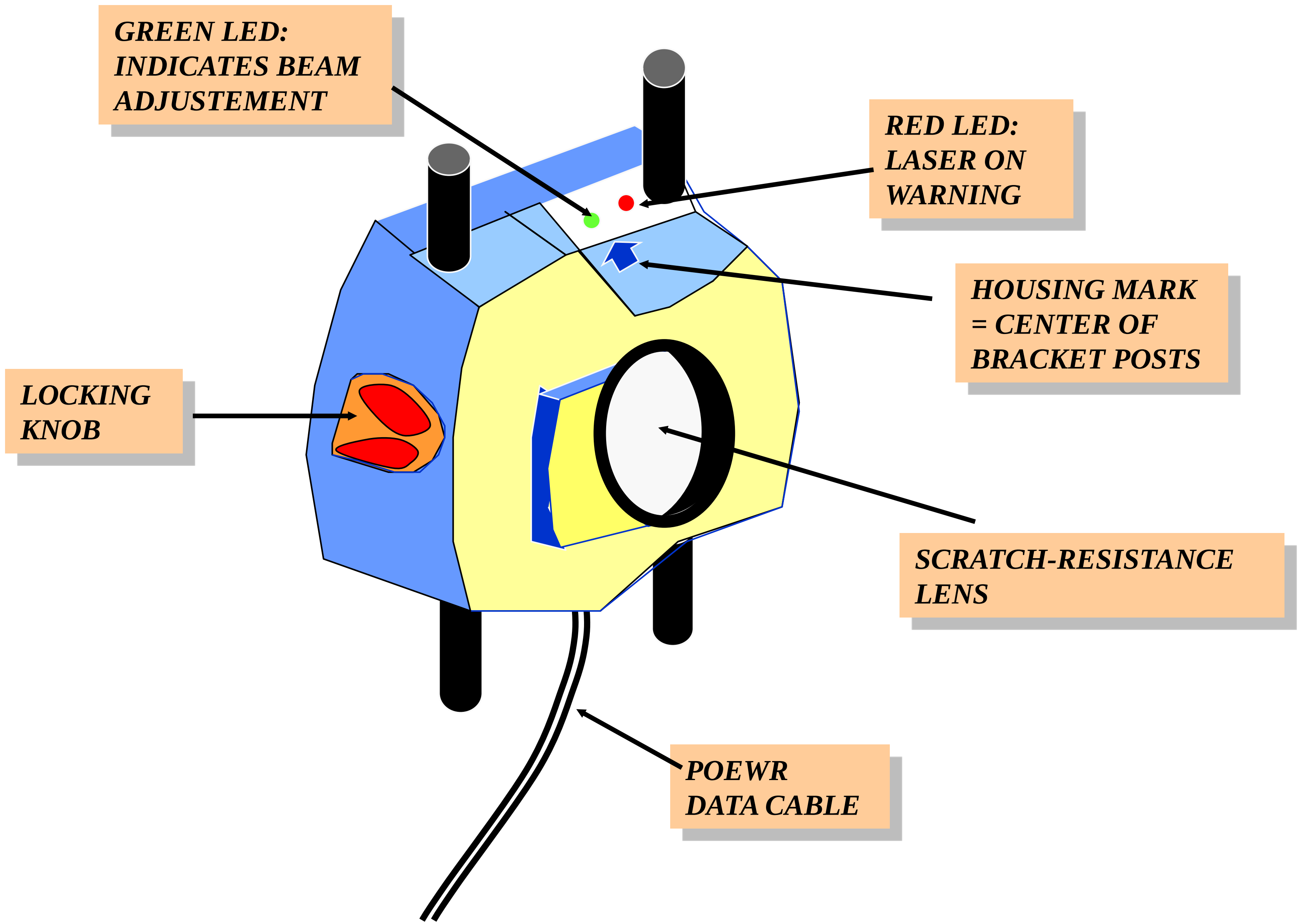


Reflector
Bracket
Bracket
Chain
Shaft
SIDE VIEW



HRIZONTAL ANGLE ADJUSTTMENT
90 0 PRISM
VERTICAL POSITION ADJUSTTMENT
Bracket
Shaft
Chain

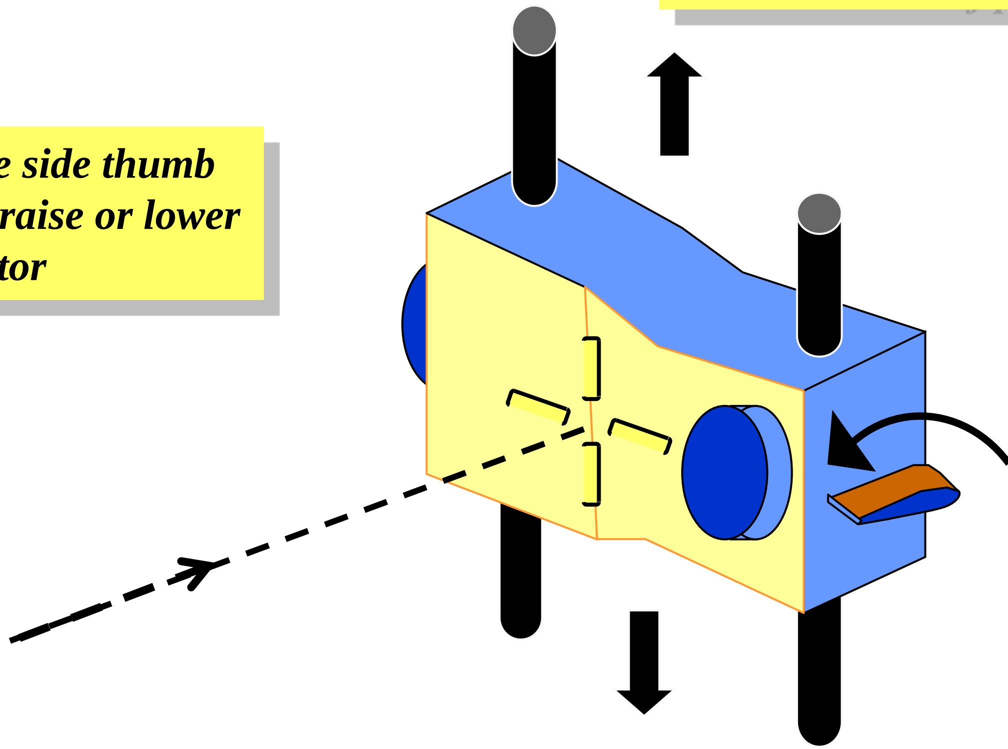
Transducer


GREEN LED: INDICATES BEAM ADJUSTEMENT
RED LED: LASER ON WARNING
HOUSING MARK = CENTER OF BRACKET POSTS
LOCKING KNOB
SCRATCH-RESISTANCE LENS
POEWR DATA CABLE

REFLECTOR

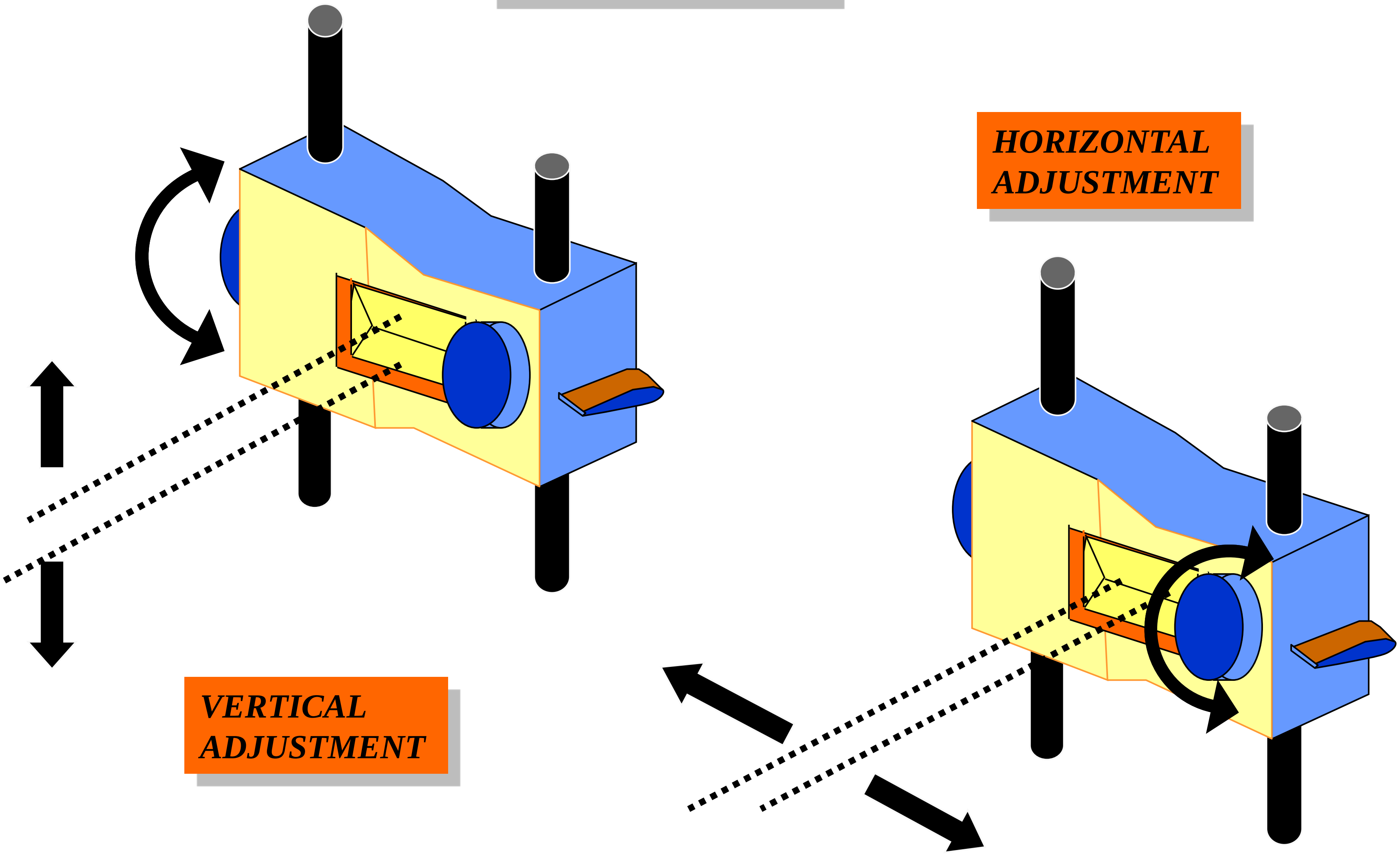
1- PRESS M and remove transducer cap.
-The laser beam now is on.
-Leave the reflector cap on for now.
-Beam strikes the cap, it should be visible.
- Hold a sheet of paper to locate the beam

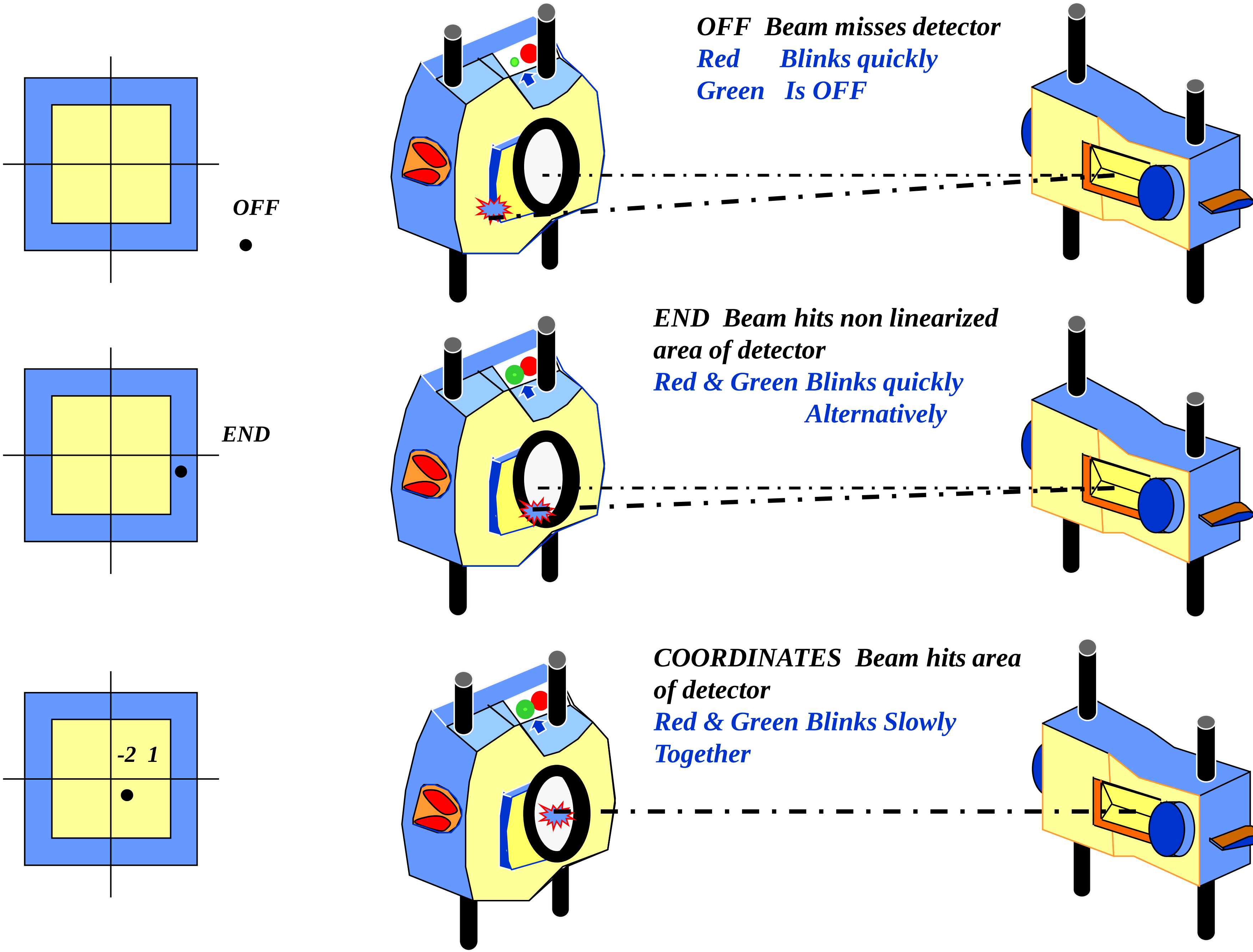
Rotate the side thumb
Wheel to raise or lower
the reflector



This lever to lock
The reflector position

REFLECTOR




OFF
END
-2 1
OFF Beam misses detector
Red Blinks quickly
Green Is OFF
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

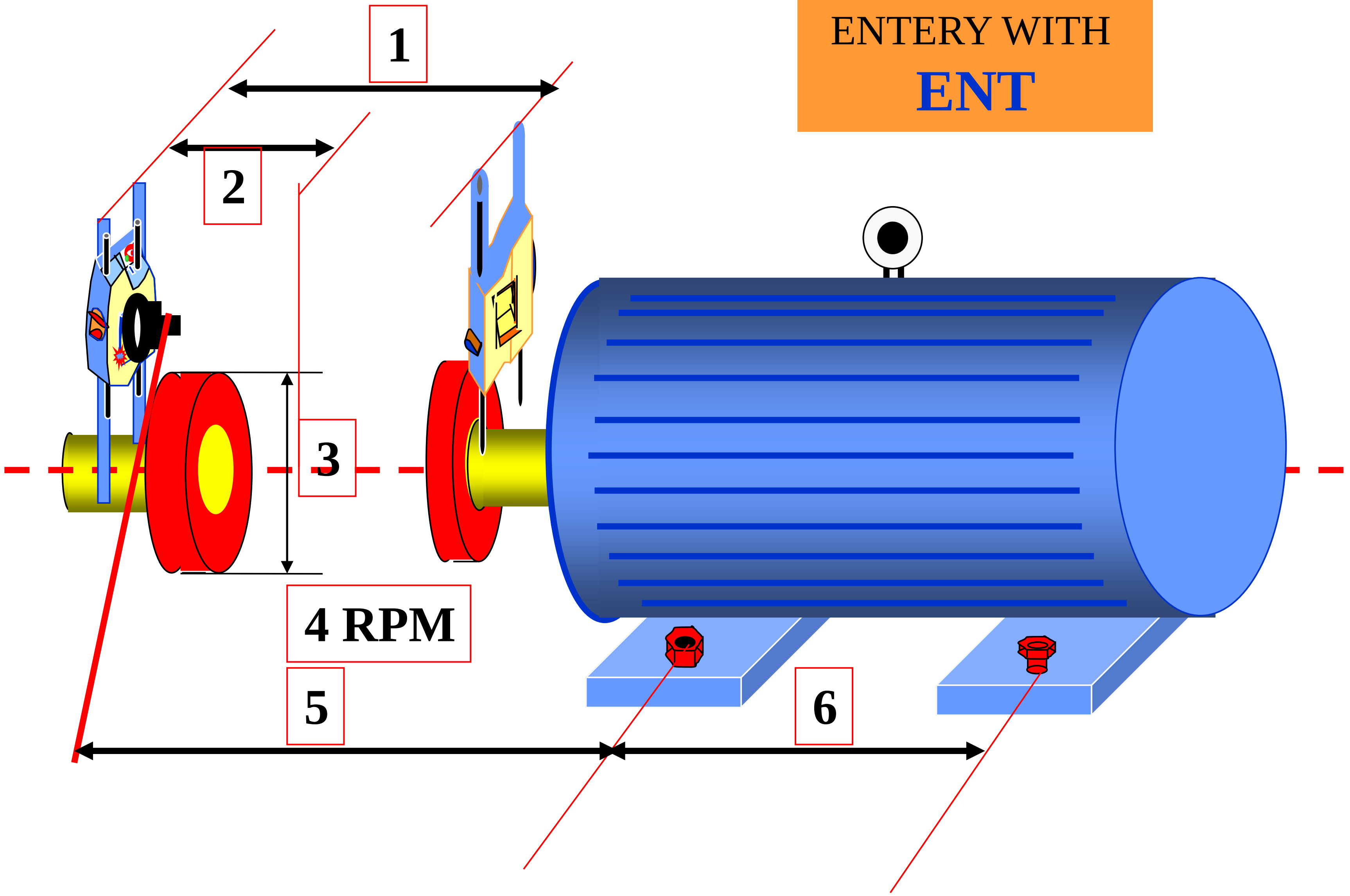
3-Coupling diameter

4-RPM

5-Transducer to front feet

6- Front feet to rear feet

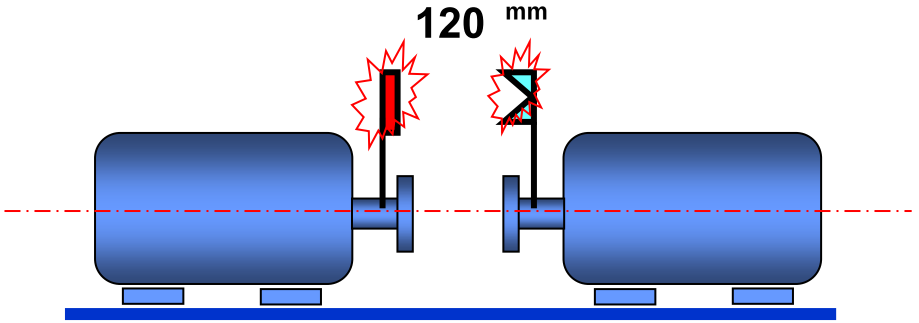
DIM



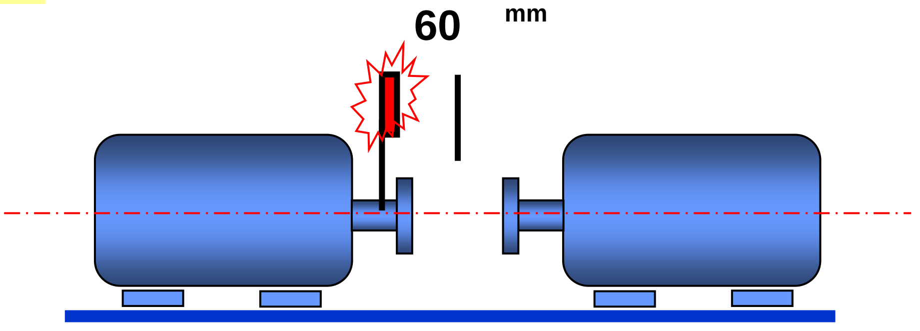
CONFIRM EACH ENTERY WITH **ENT**

DIM

1-Transducer to reflector



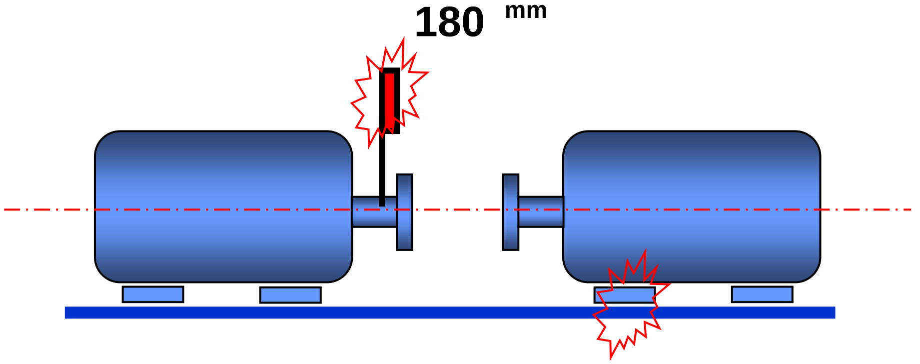
2-Transducer to coupling center



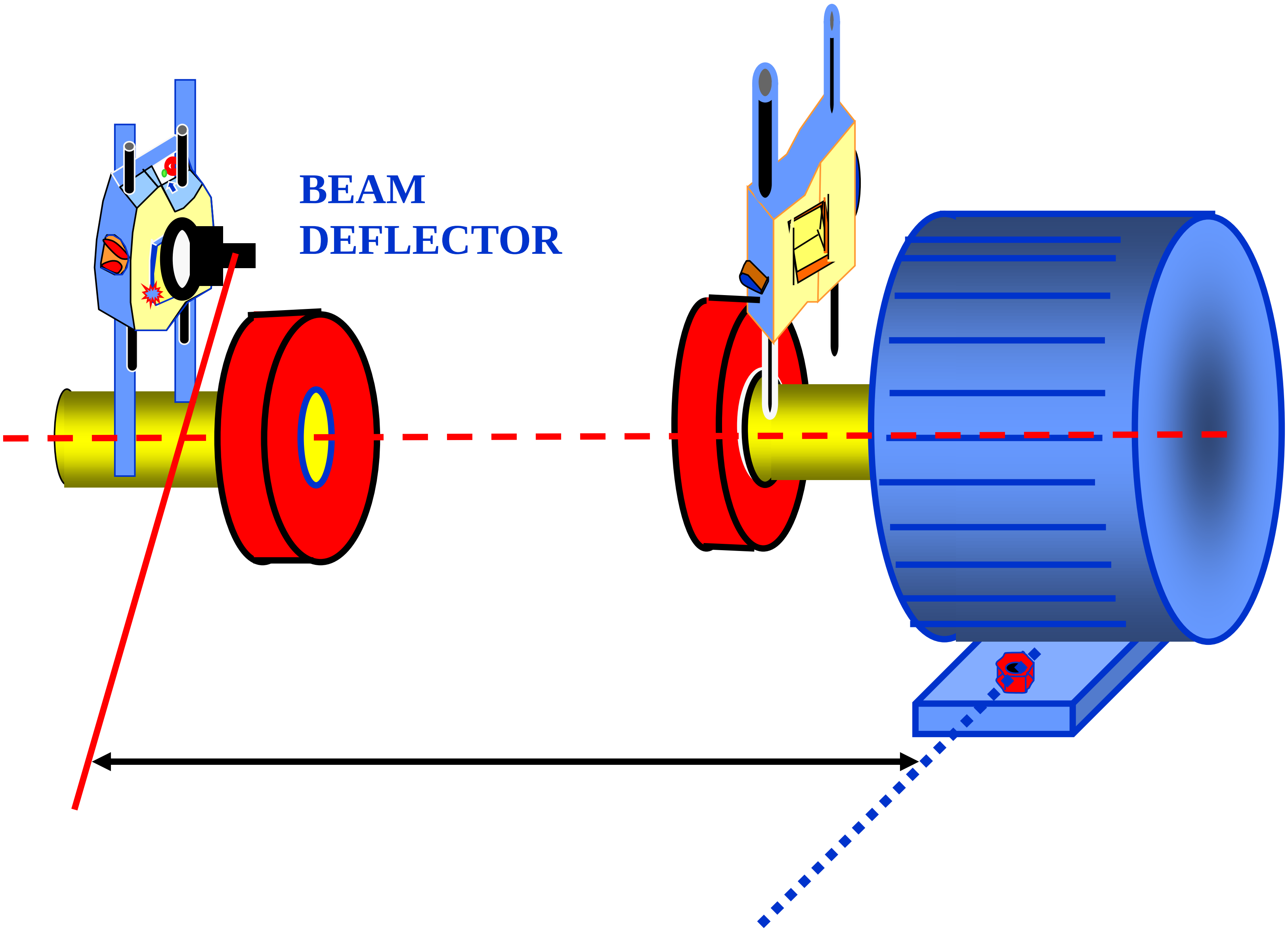
DIM

3- Coupling diameter D

4-Transducer to front foot, right m/c

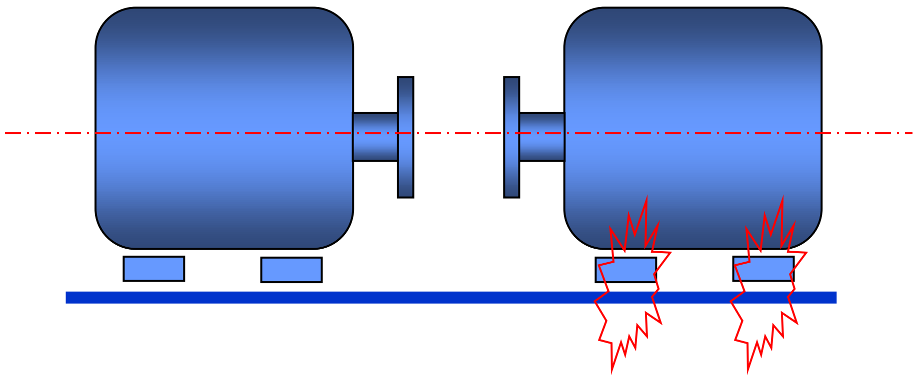


DIM



DIM

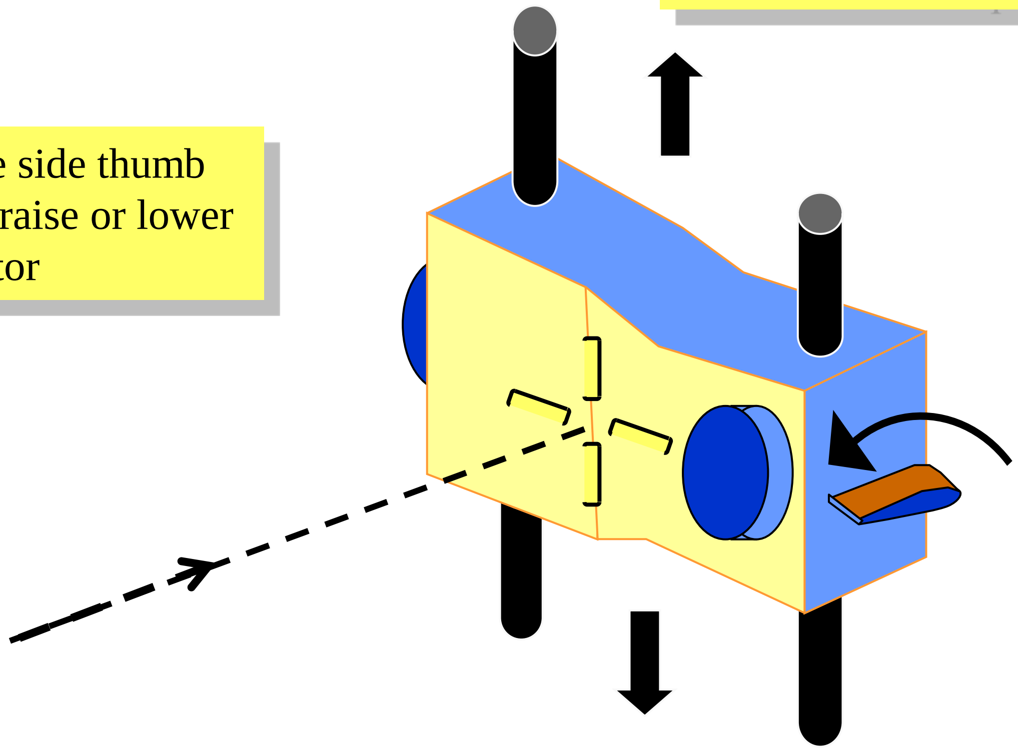
5-Front foot to back foot , right m/c



5-Laser beam adjusting

1- PRESS (M) 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

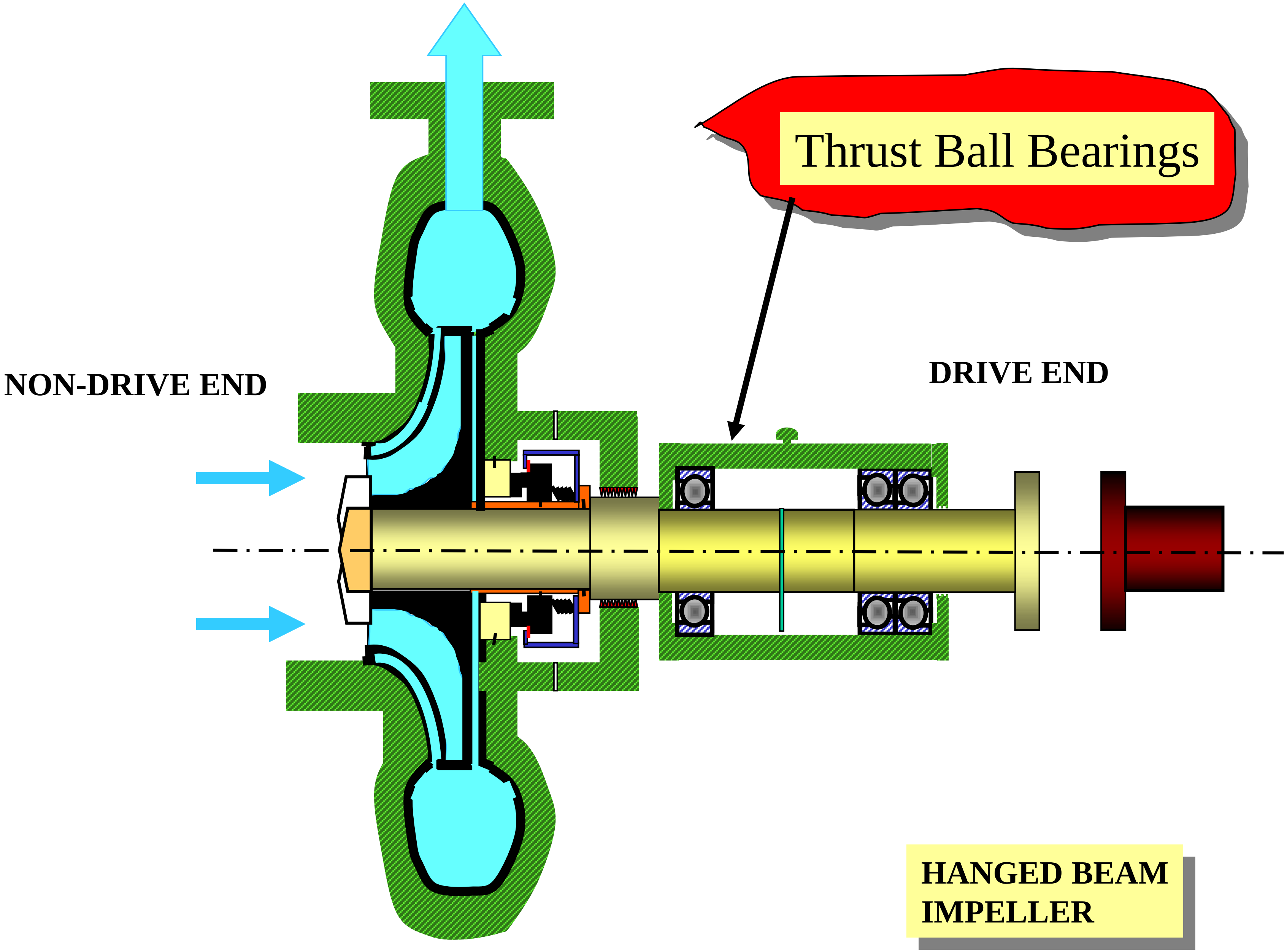
RADIAL BEARING

THRUST BEARING

ball Bearings

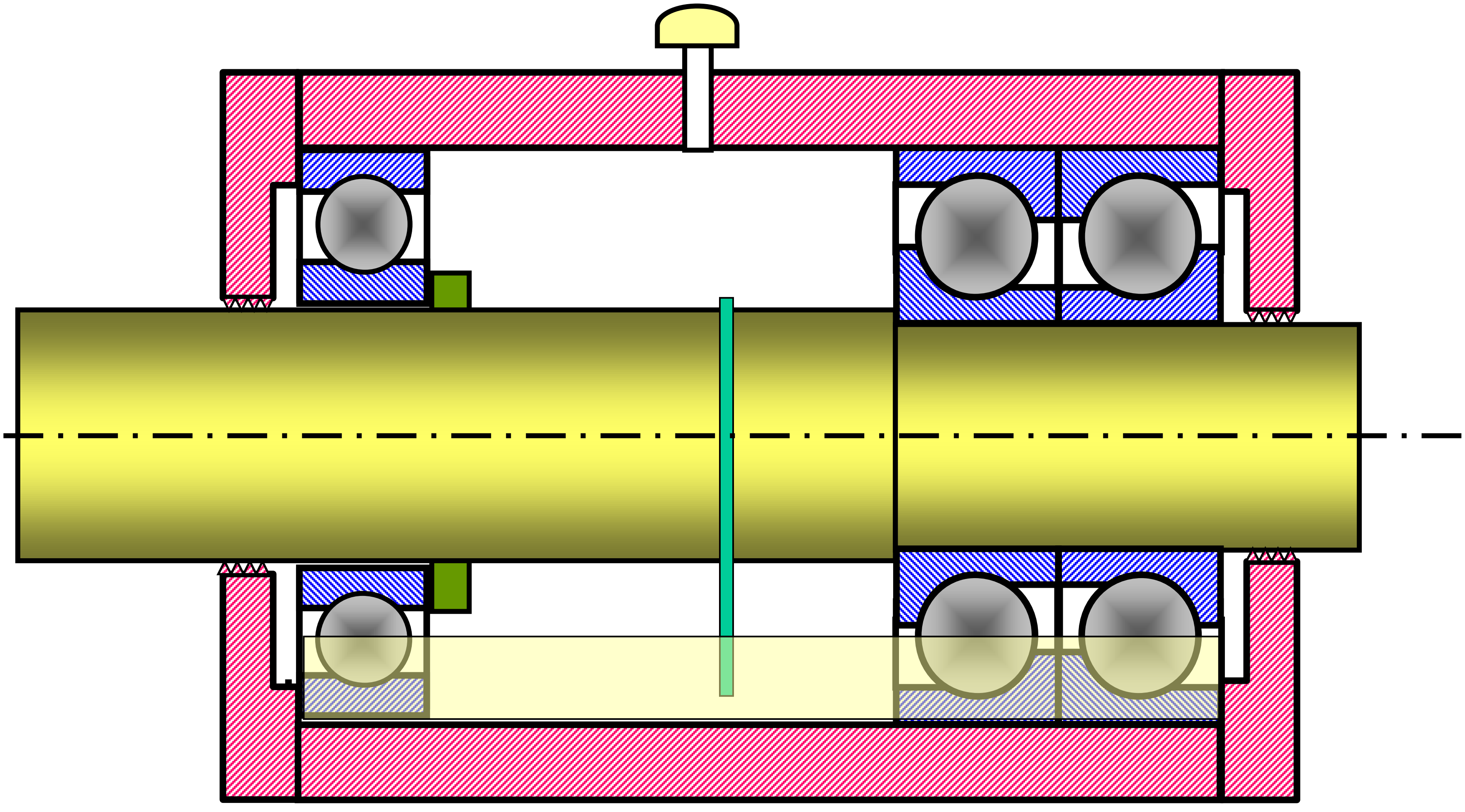
roller Bearings

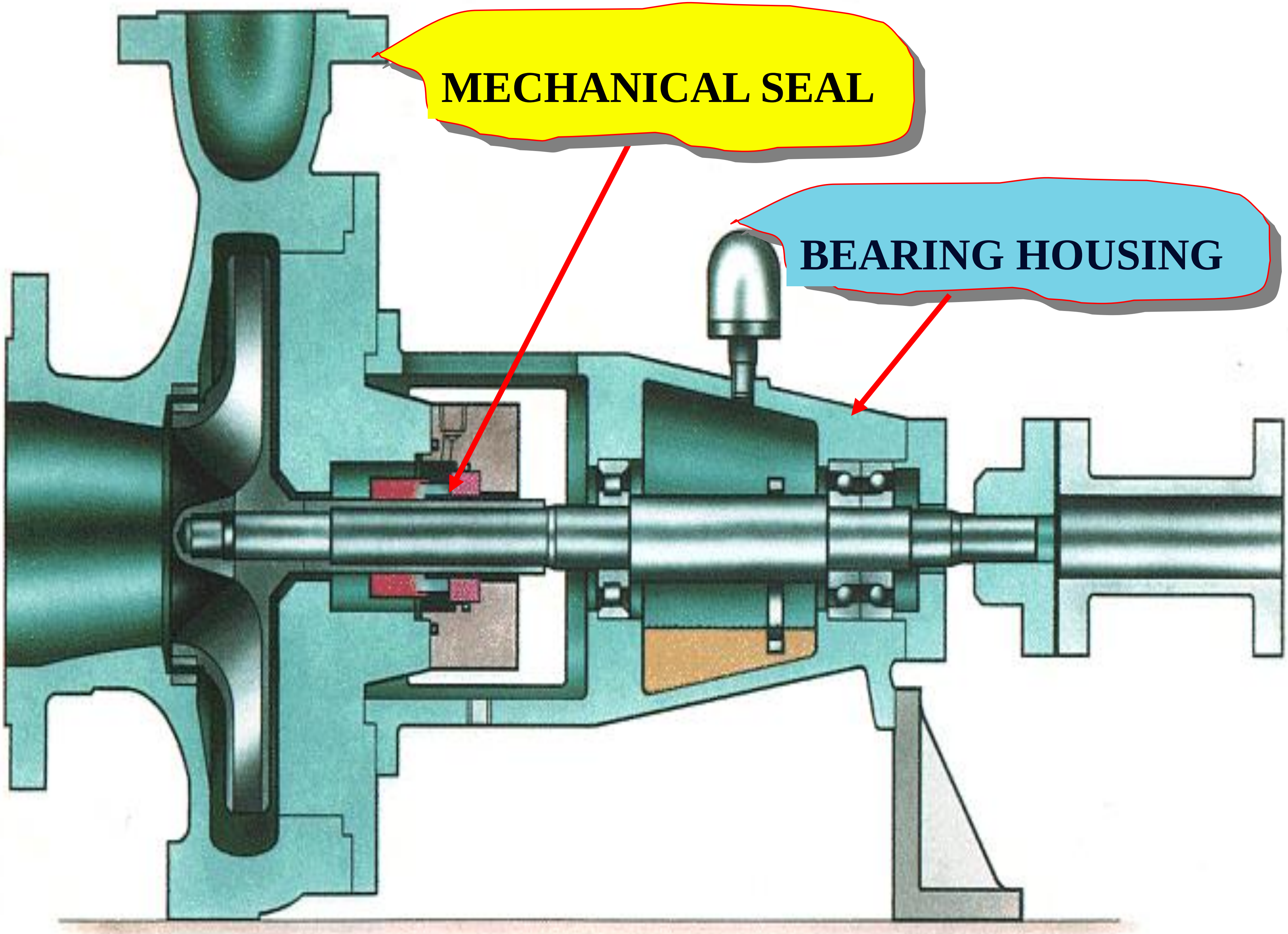
Tilting pad Bearings

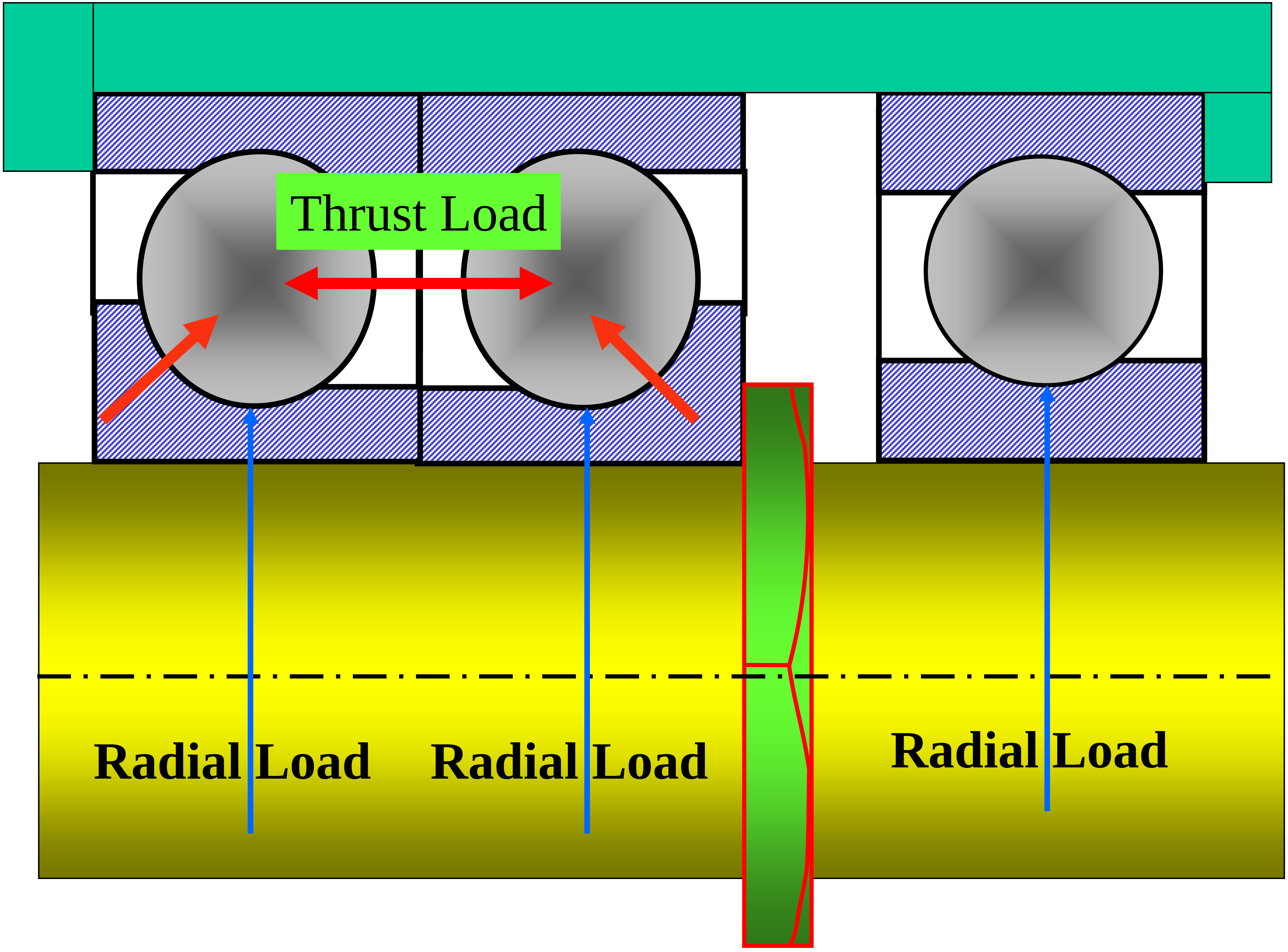


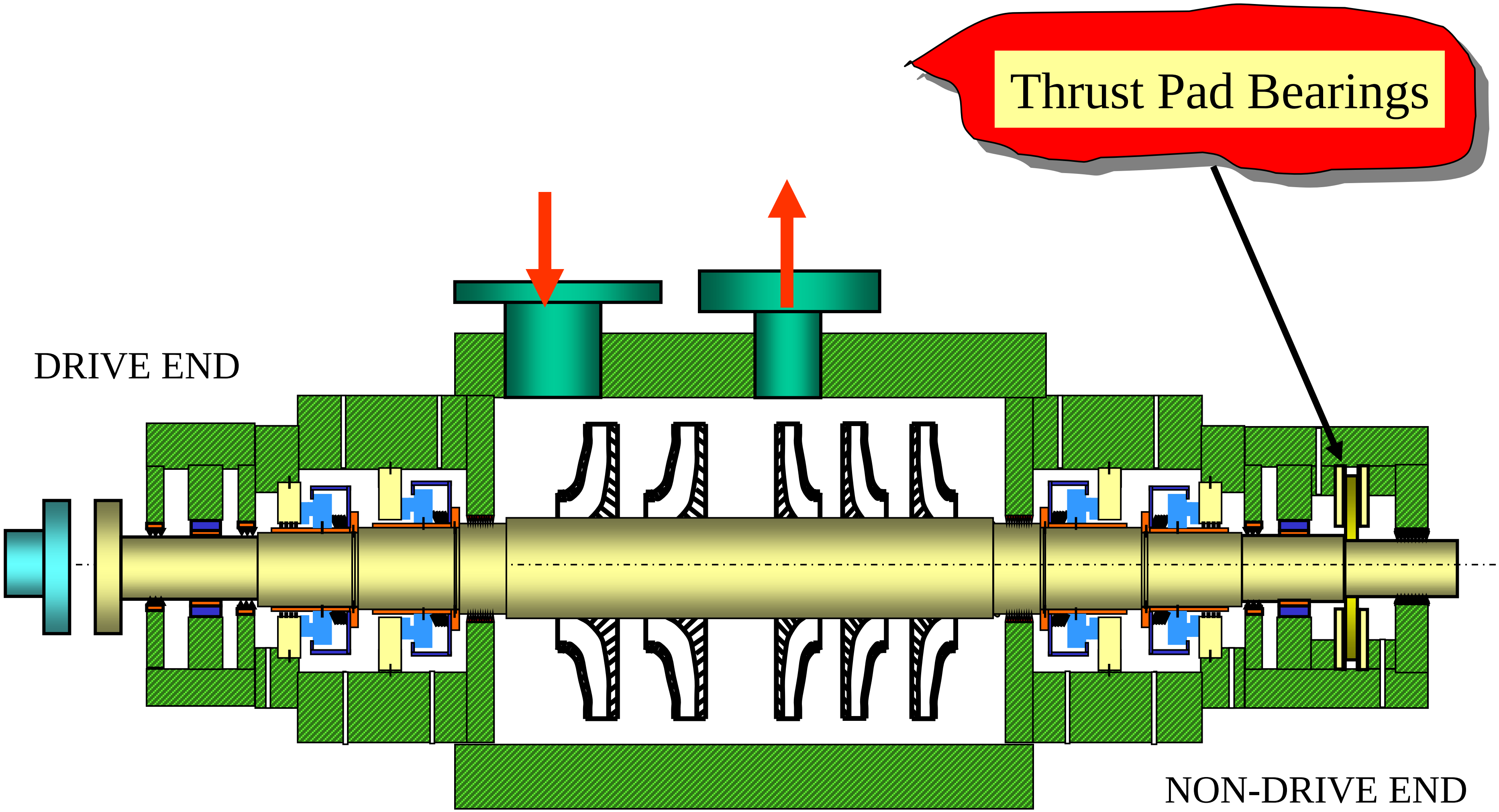
Thrust Ball Bearings
NON-DRIVE END
DRIVE END
HANGED BEAM
IMPELLER

Thrust Ball Bearings



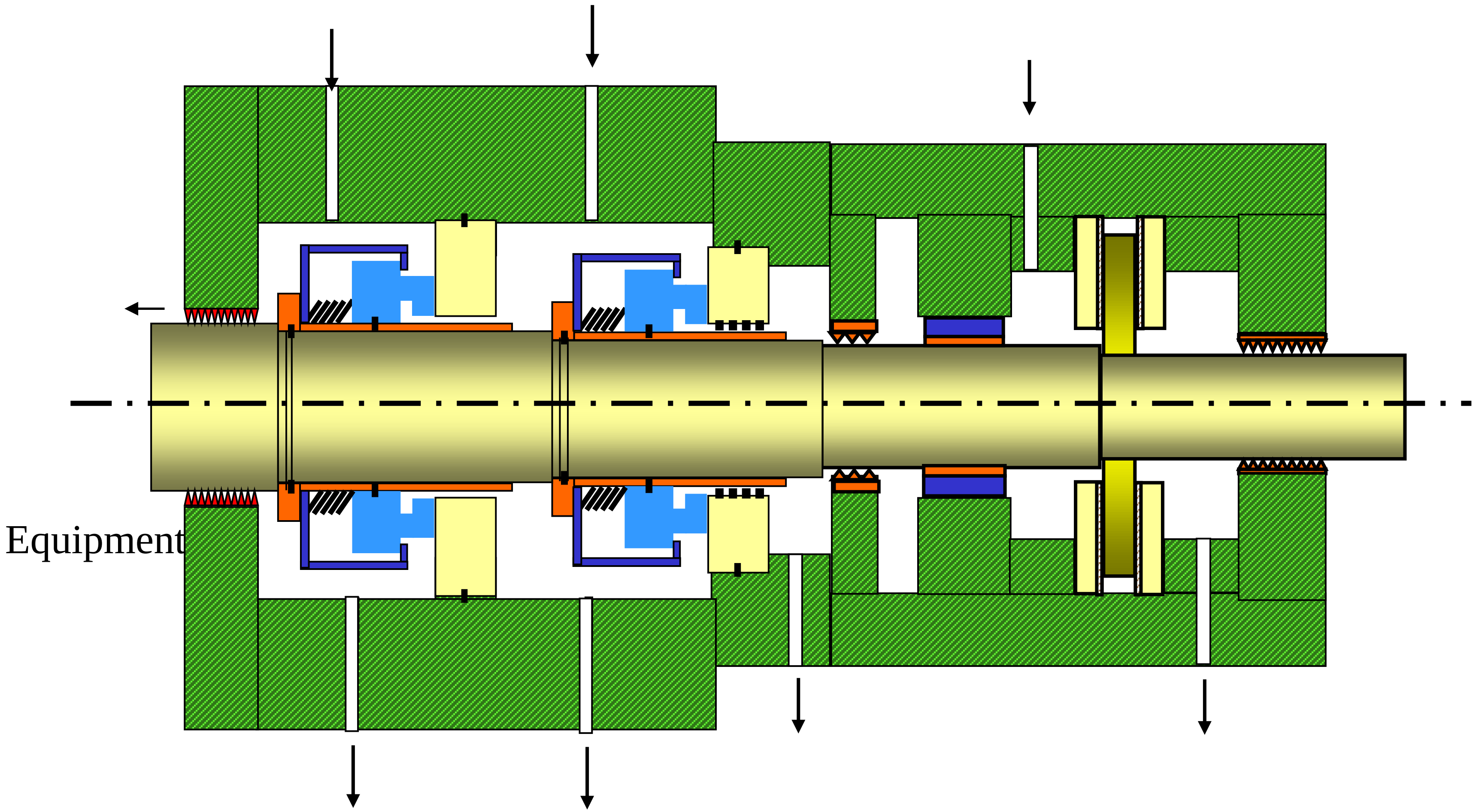

MECHANICAL SEAL
BEARING HOUSING


Thrust Load
Radial Load
Radial Load
Radial Load

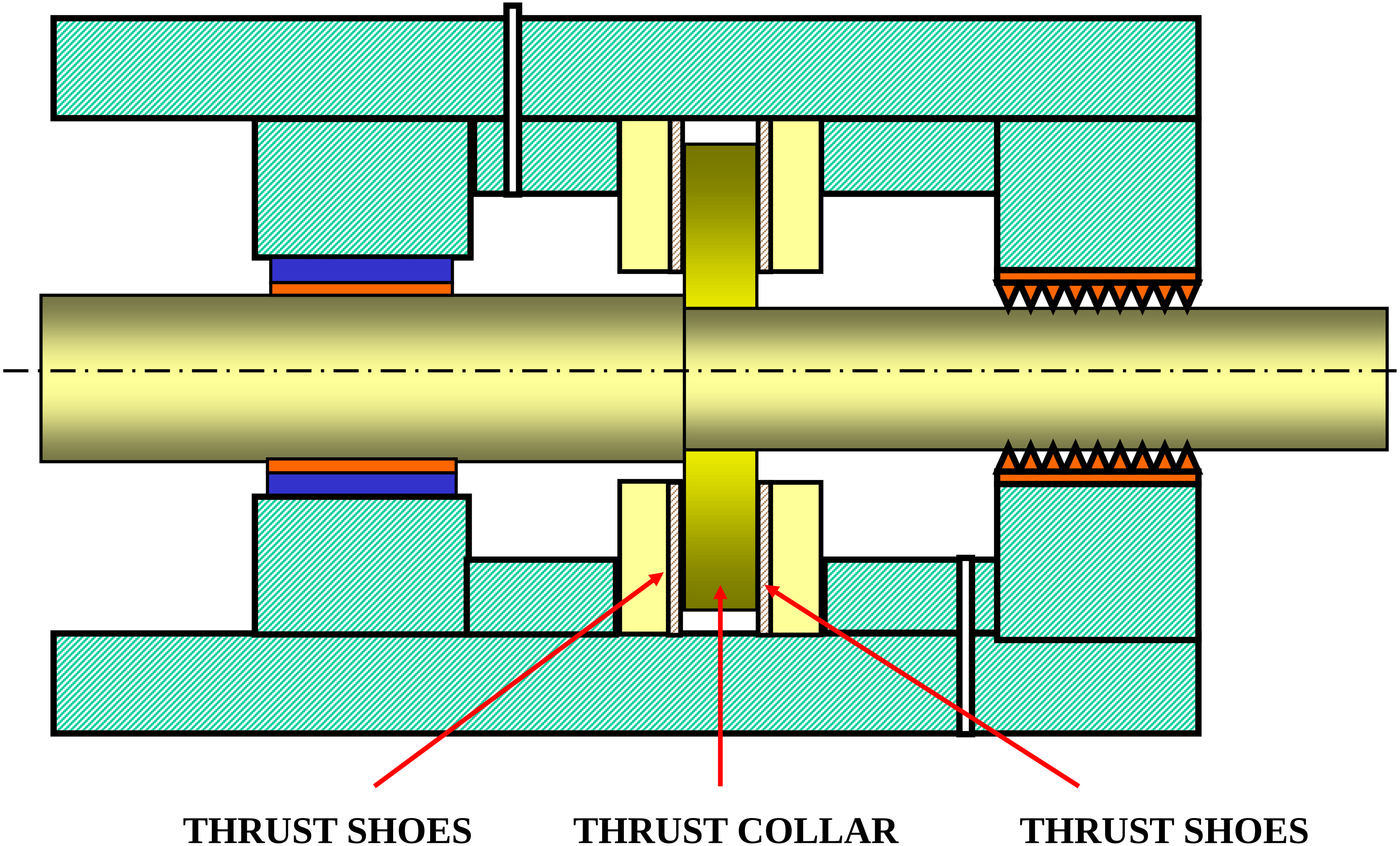


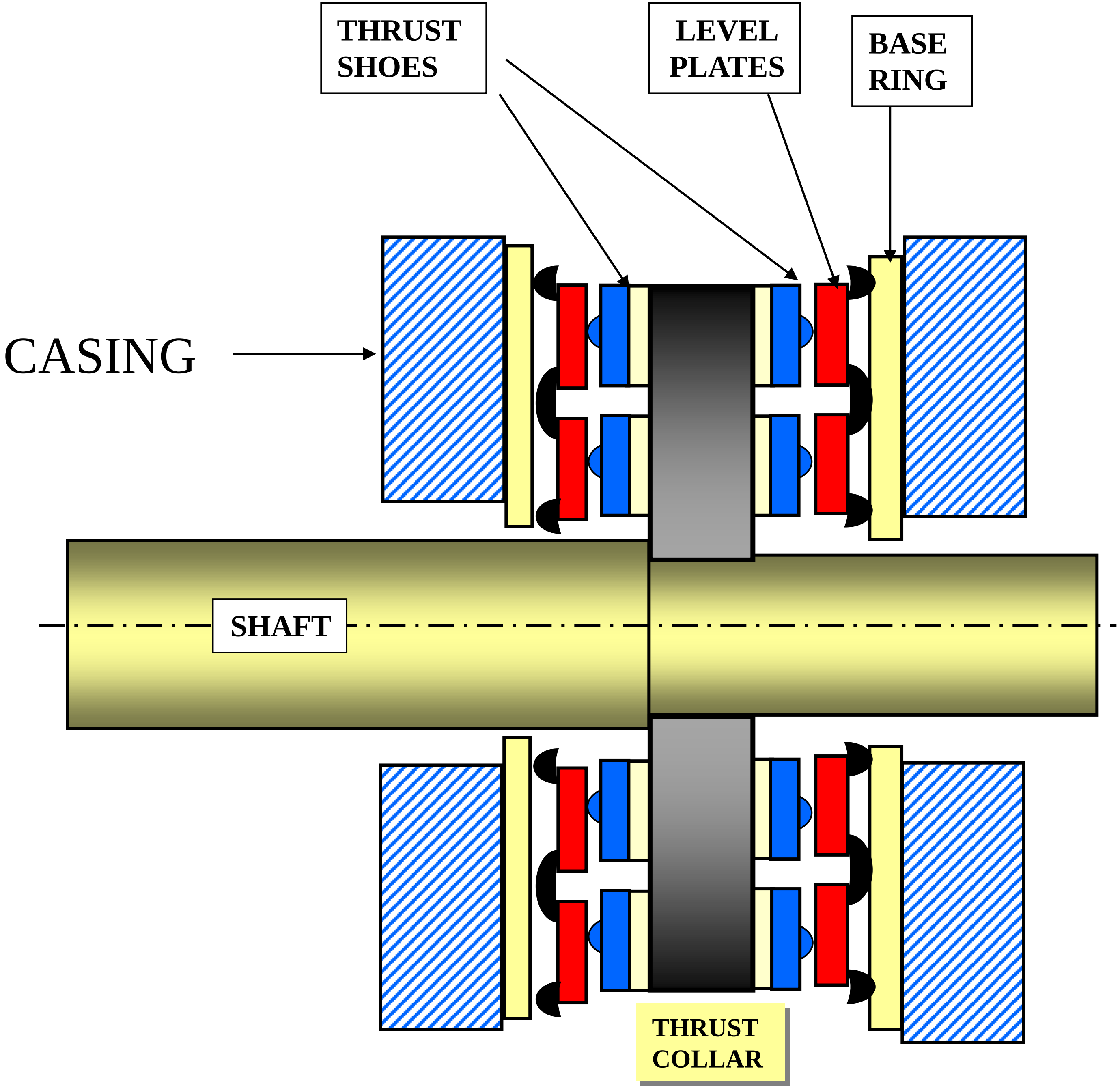
IN-BETWEEN TWO BEARINGS IMPELLER

Mechanical seal and bearings arrangement

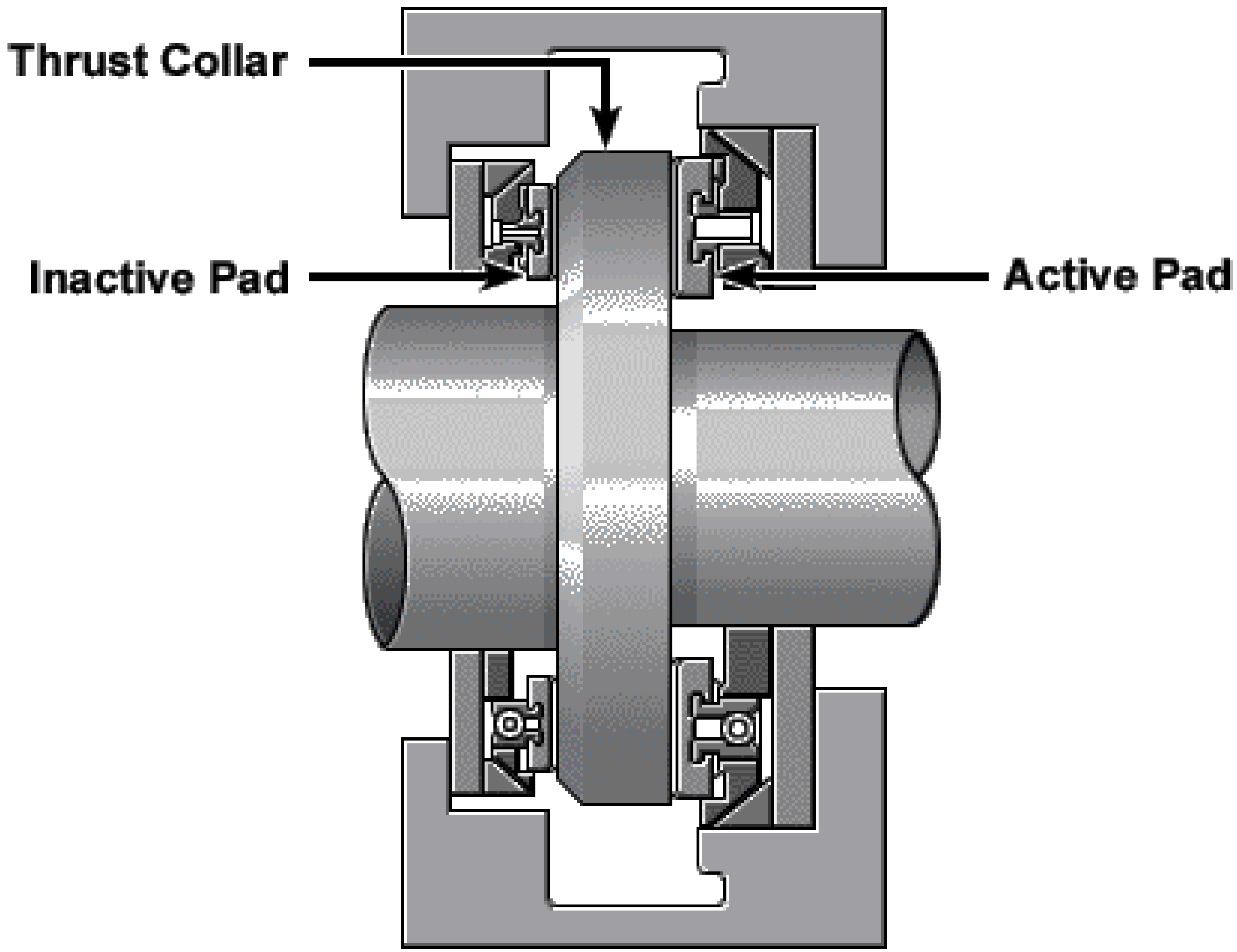


THRUST PAD BEARING

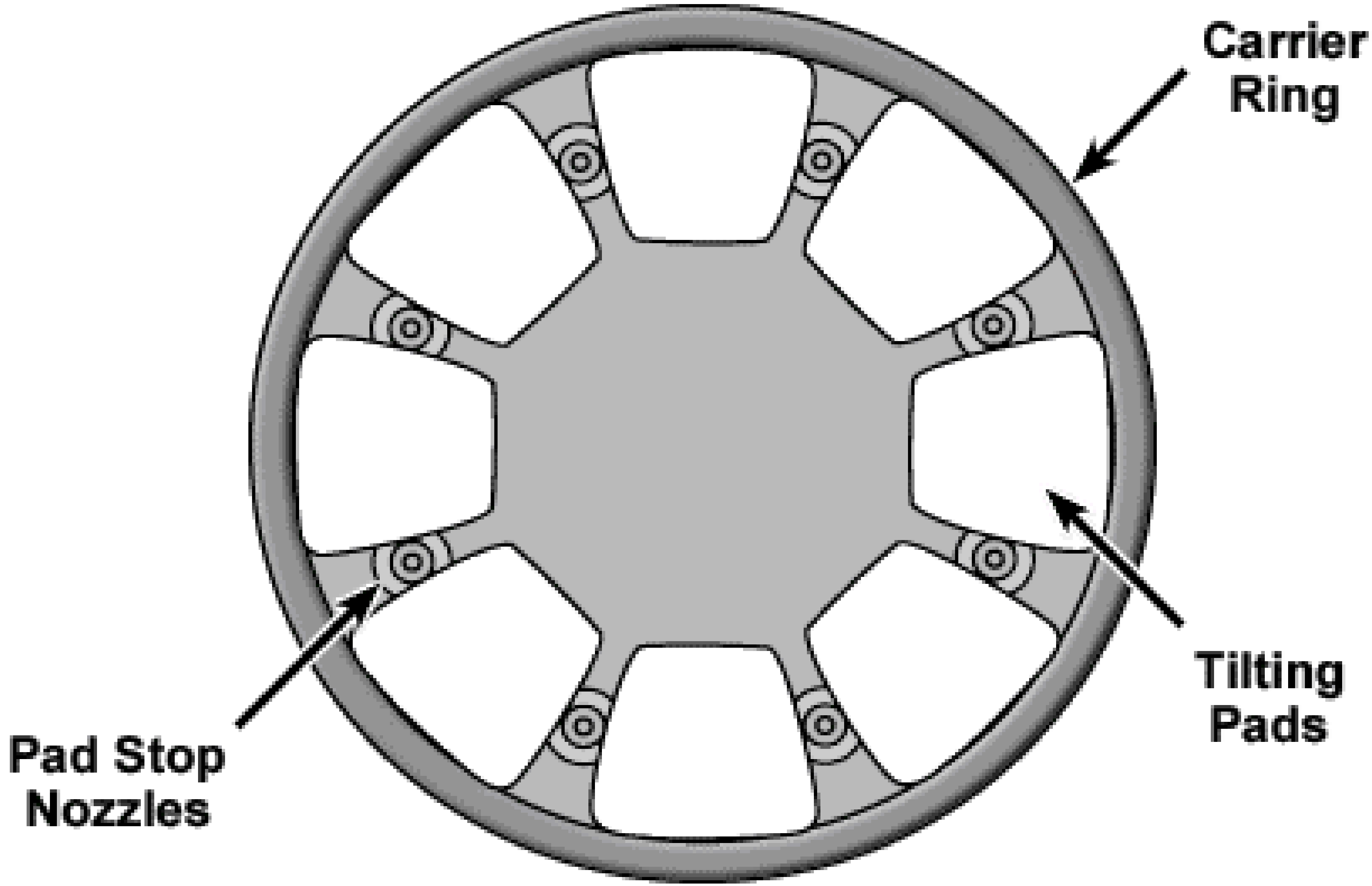



THRUST SHOES
LEVEL PLATES
BASE RING
CASING
SHAFT
THRUST COLLAR

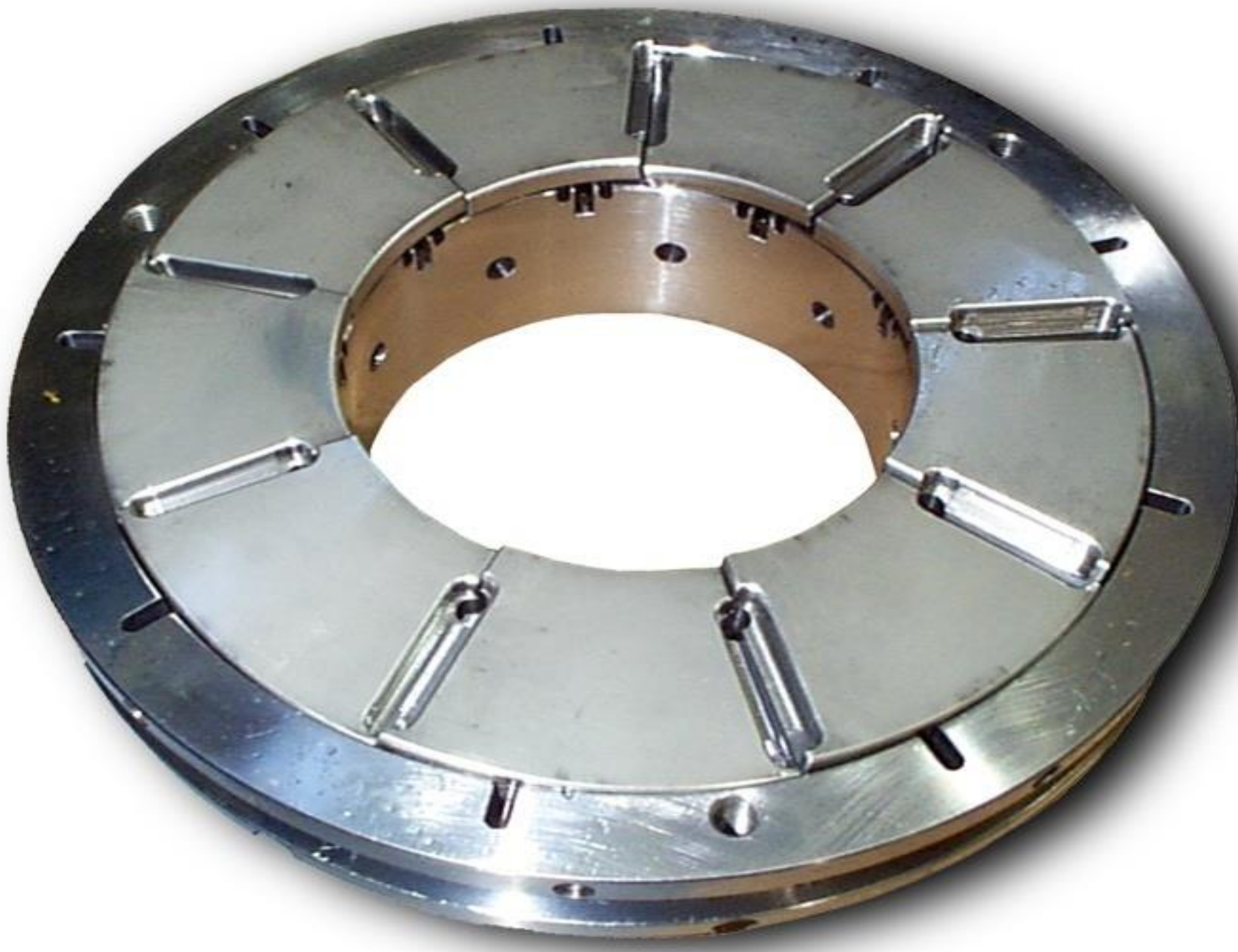
Thrust Bearing



Thrust Bearing Details



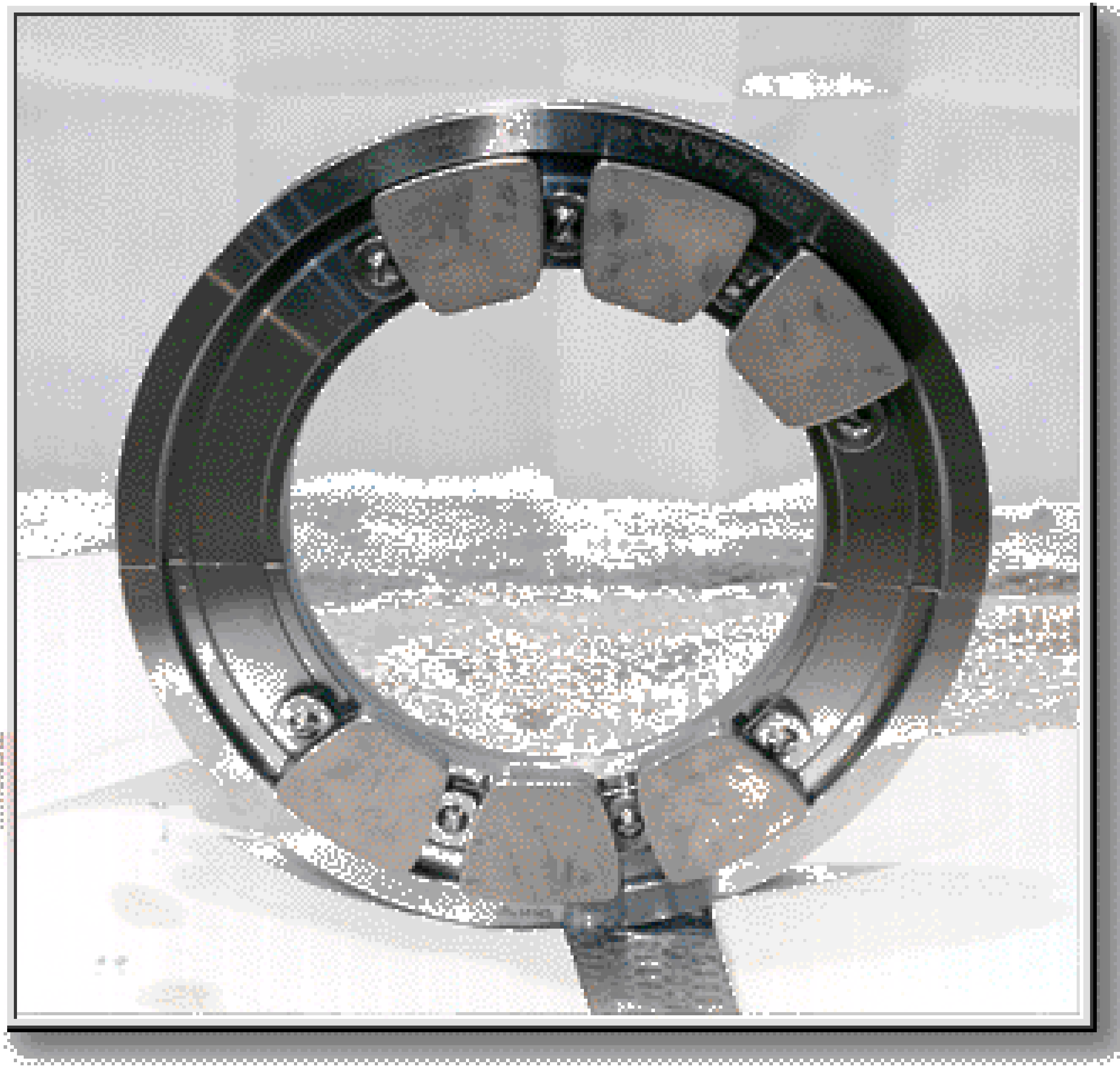
Titan 130 Thrust Bearing



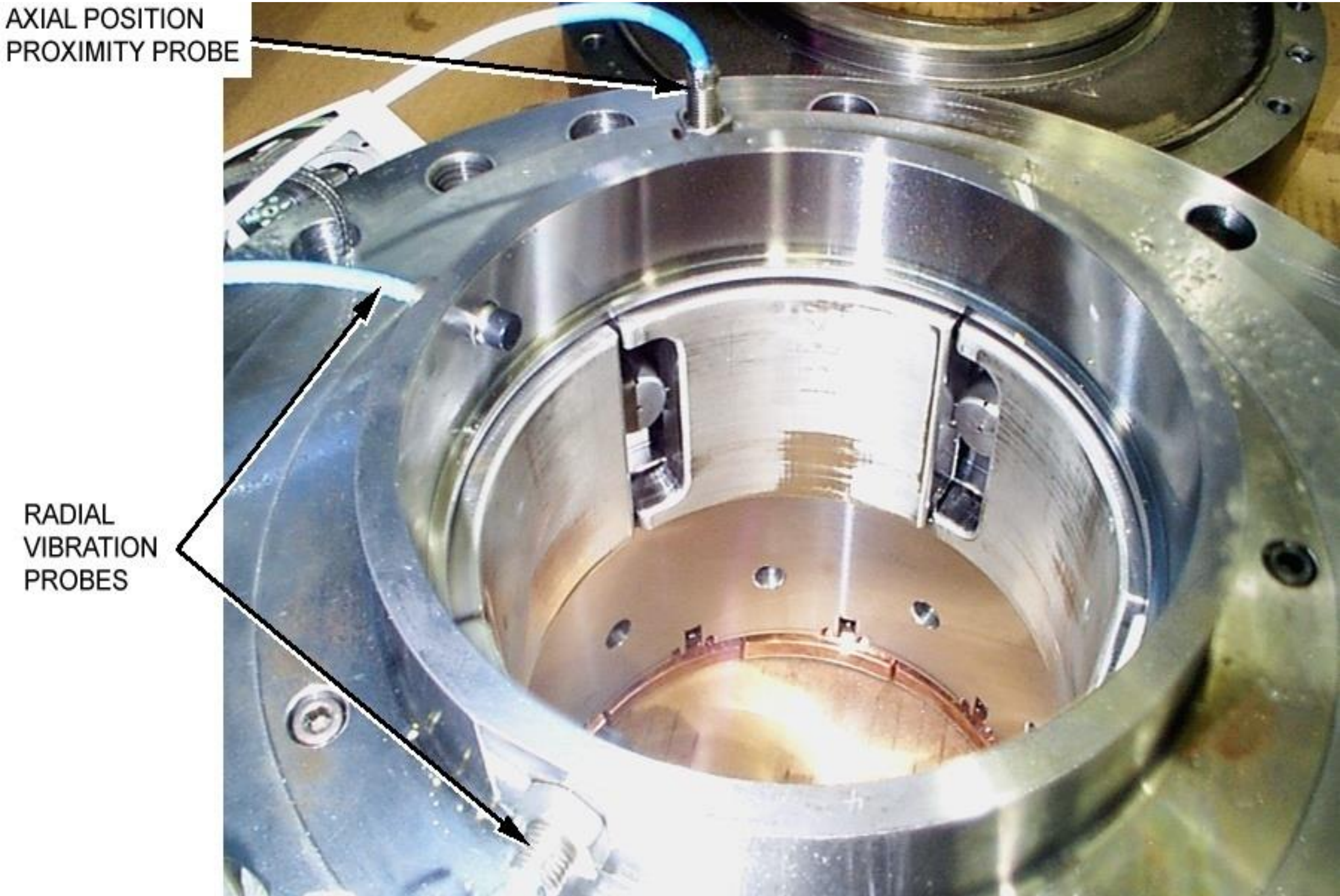
TR98285

Active Thrust Bearing

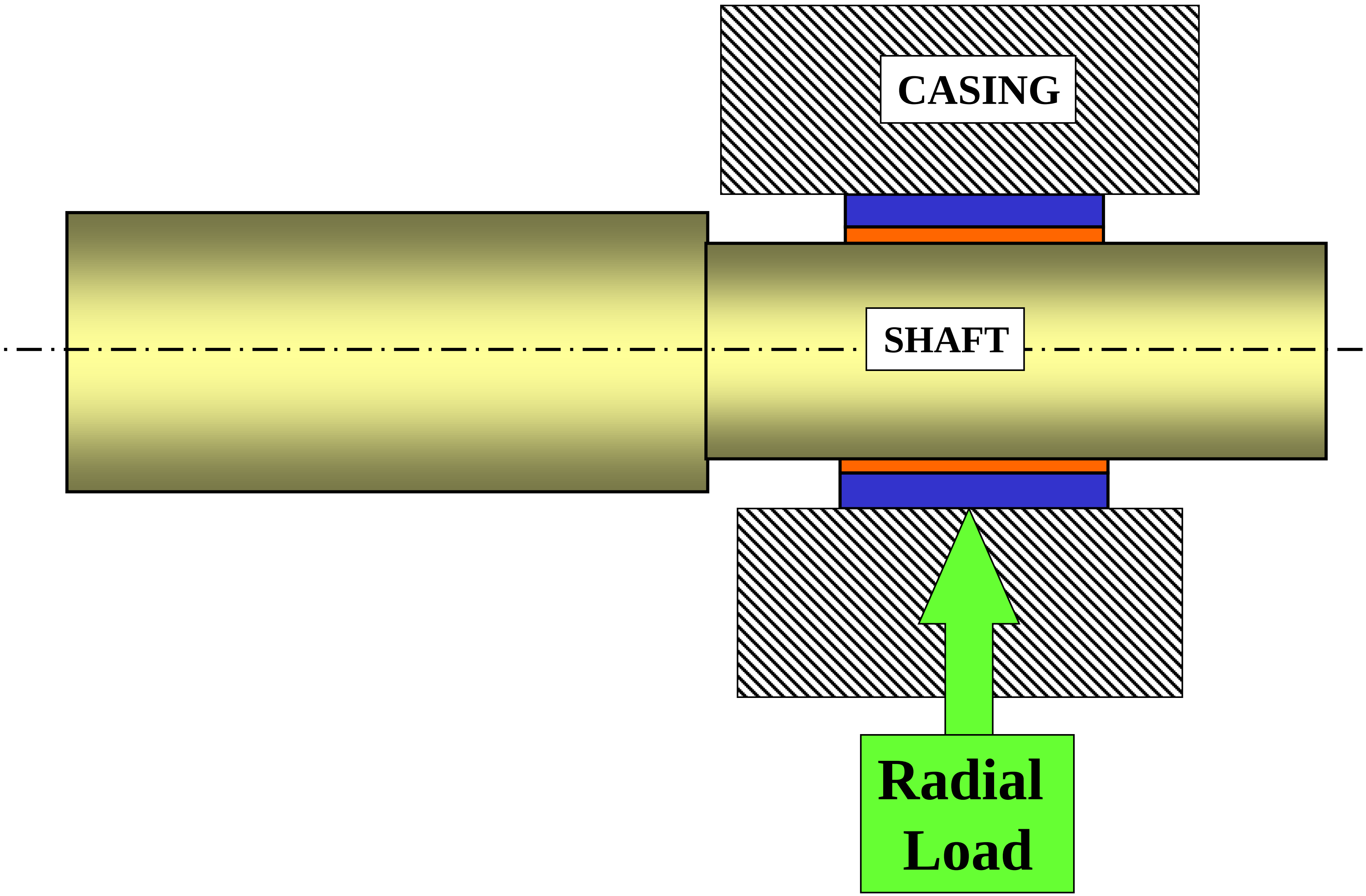
Inactive Thrust Bearing



Radial Tilt-Pad Bearing

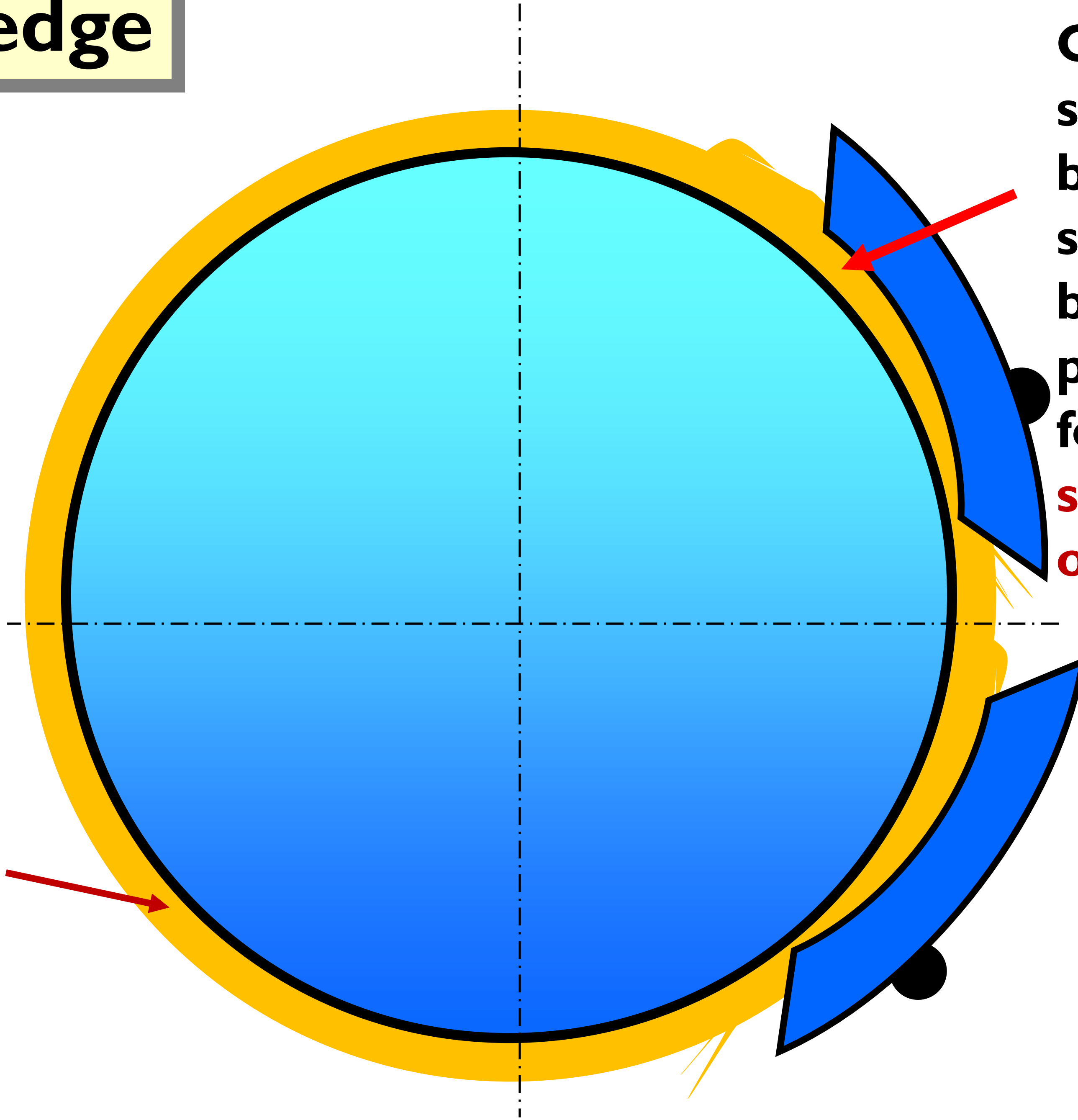


RADIAL TILTING PAD BEARING



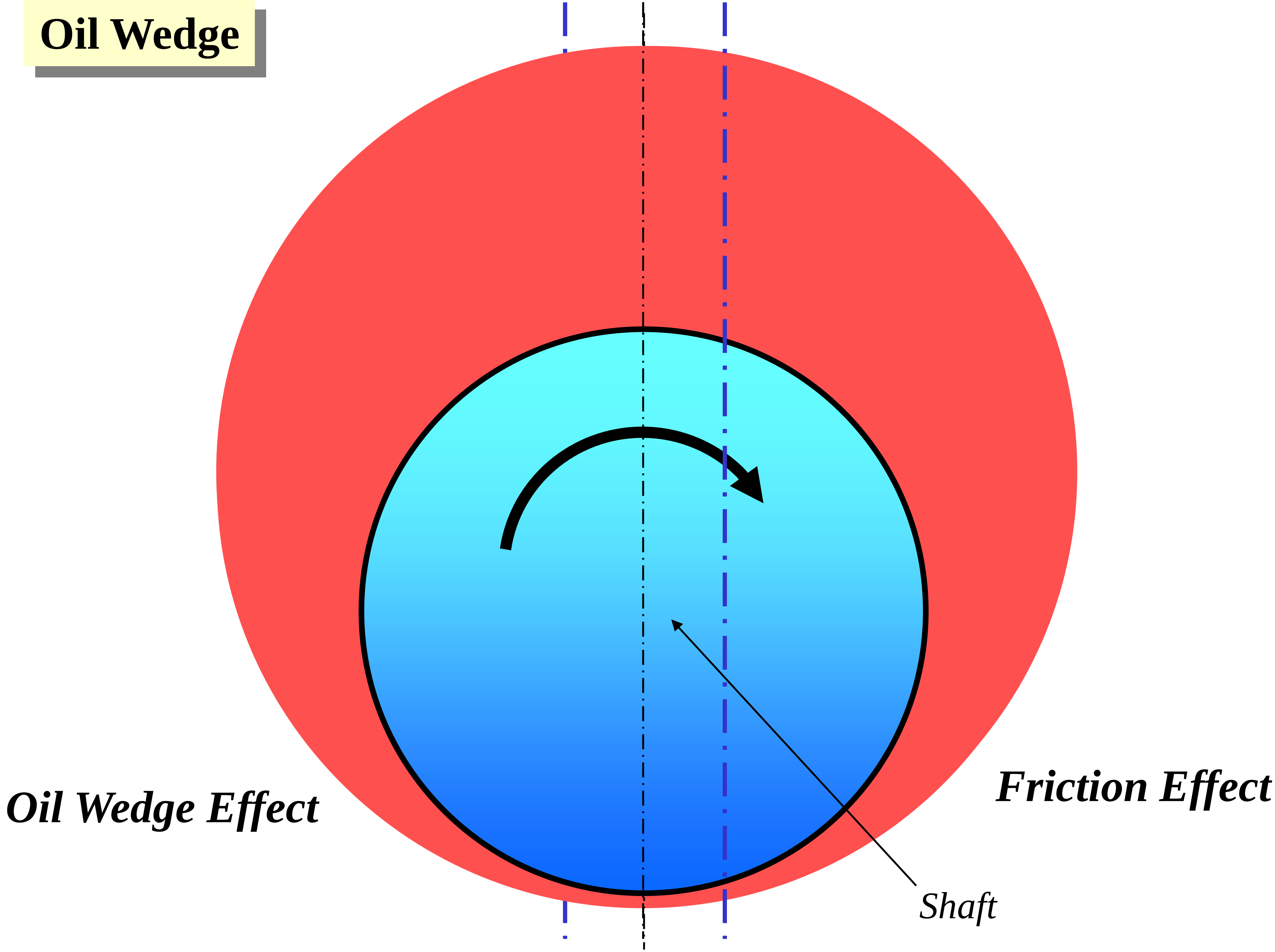
Oil Wedge

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

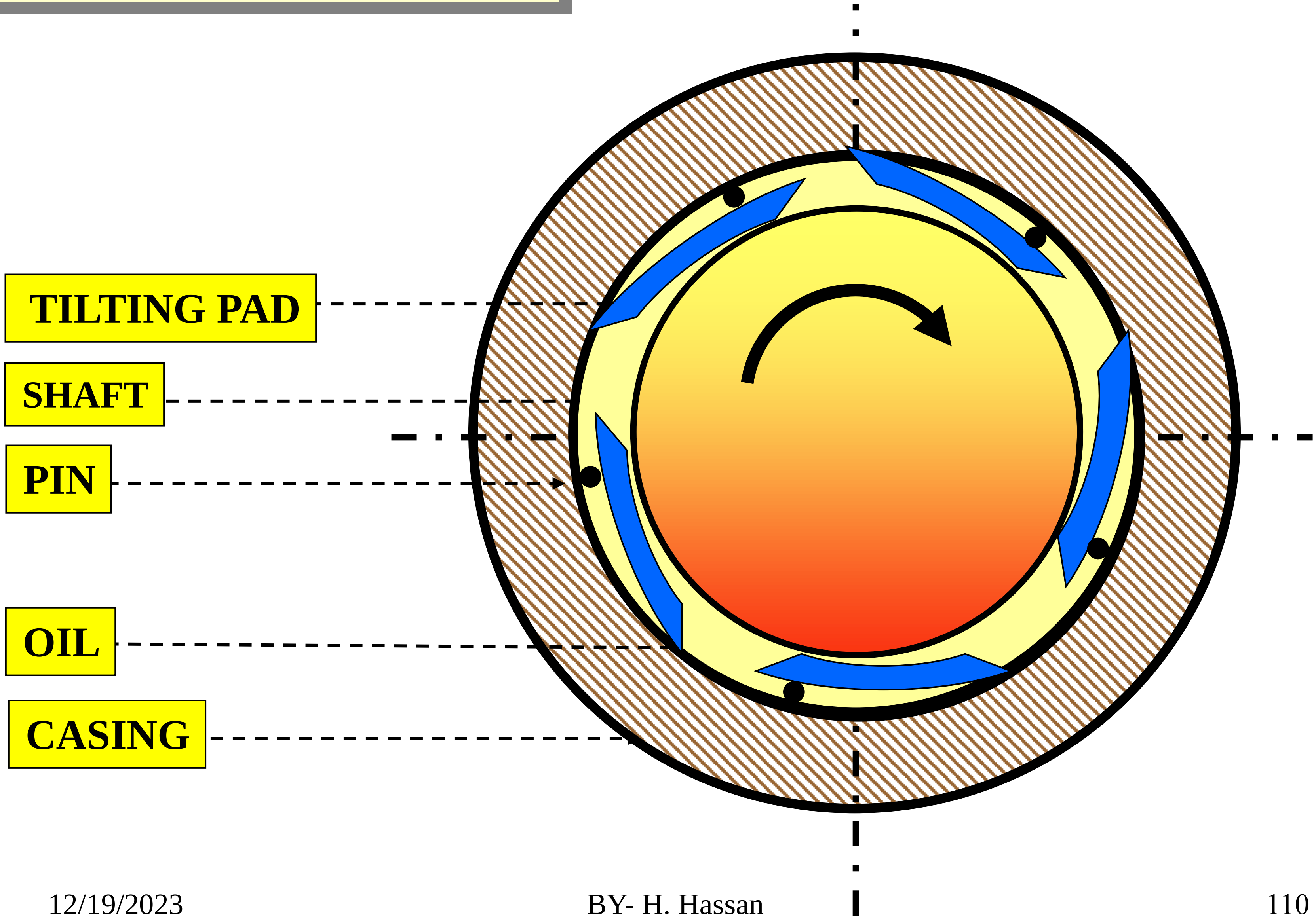


Oil squeeze between shaft and bearing pad forming a **solid oil wedge**

Oil Wedge



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

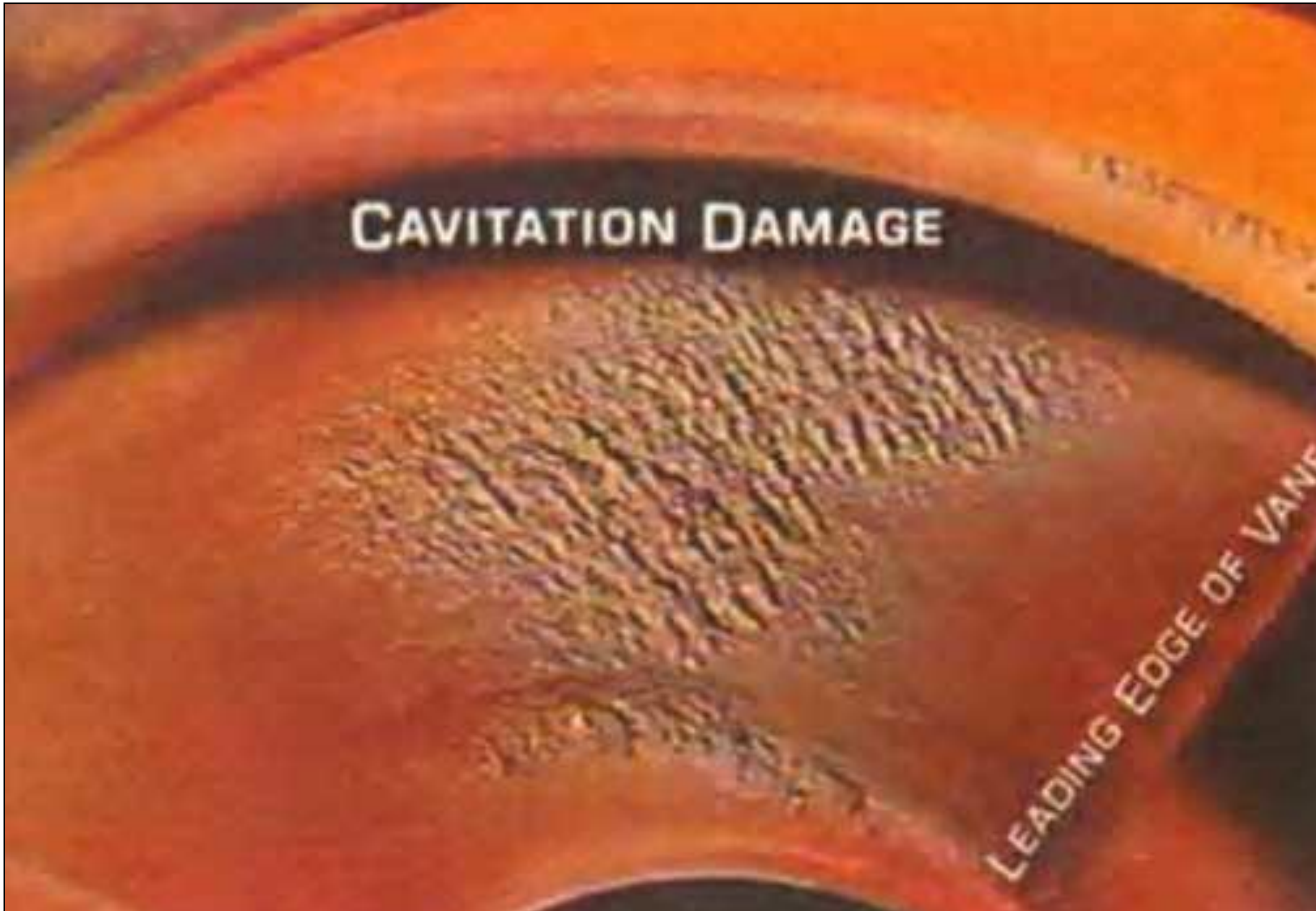
AND

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.

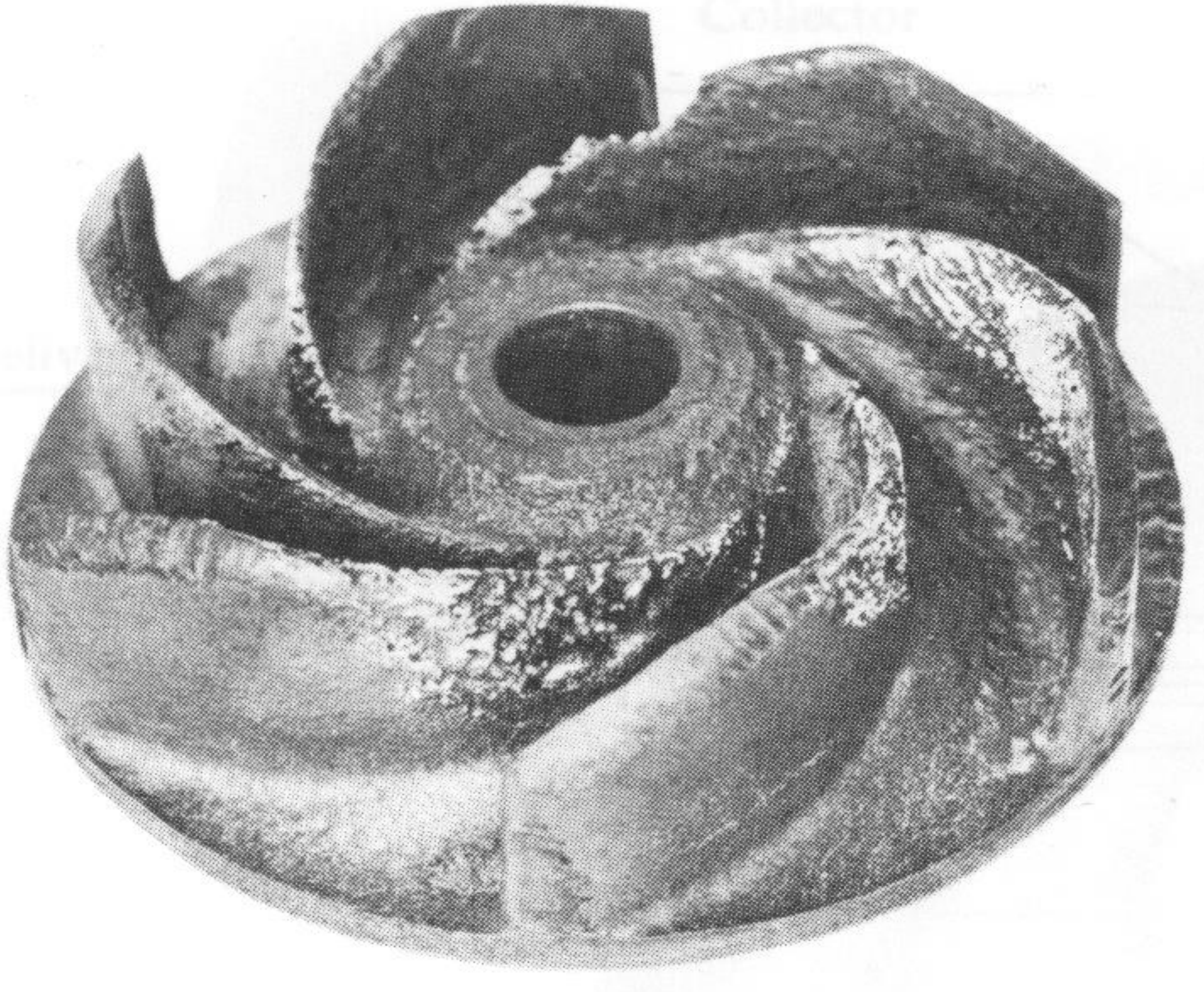
Failure Modes



Cavitation on Pump Impeller

Cavitation

Cavitation

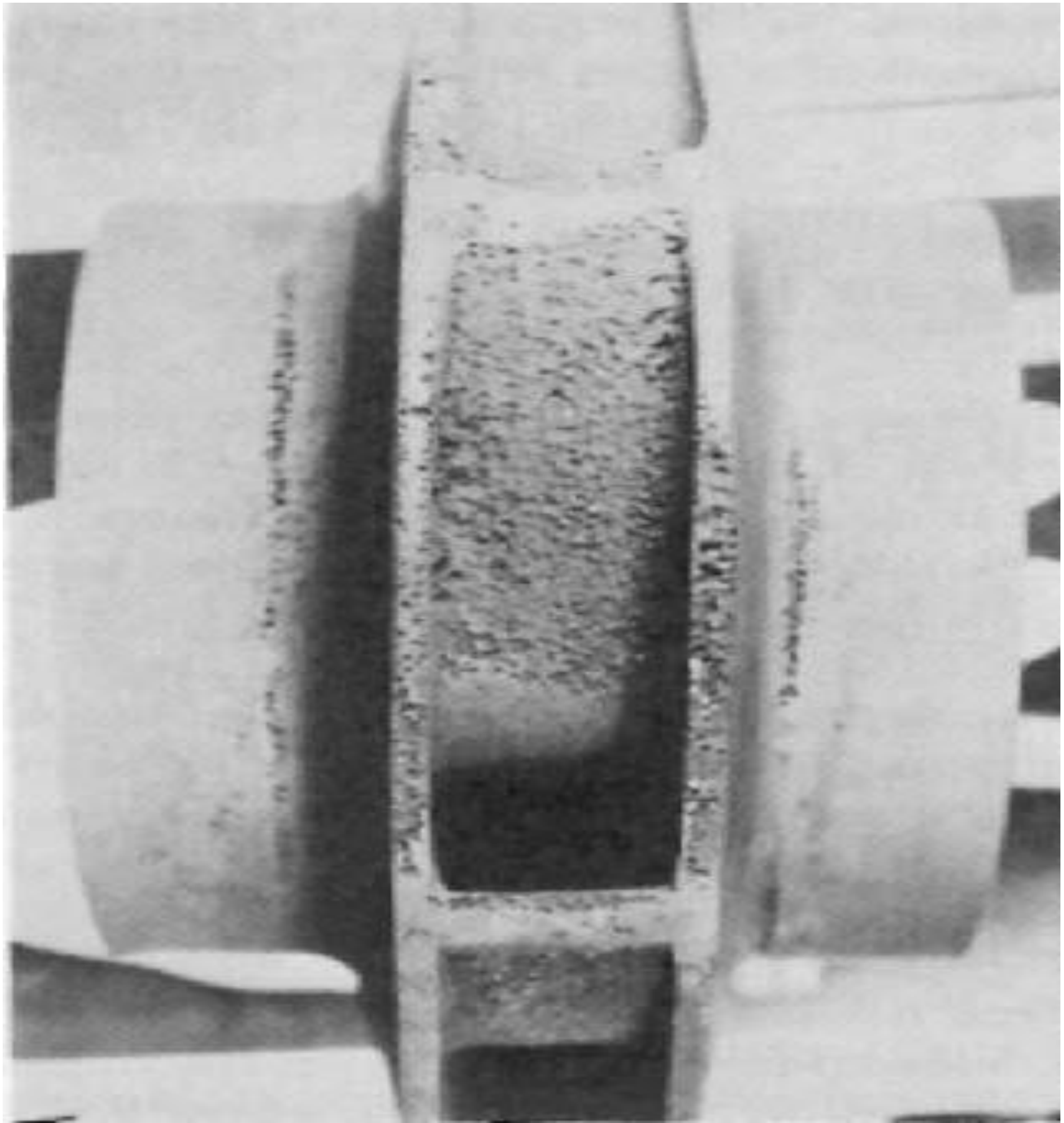



Cavitation
Damage

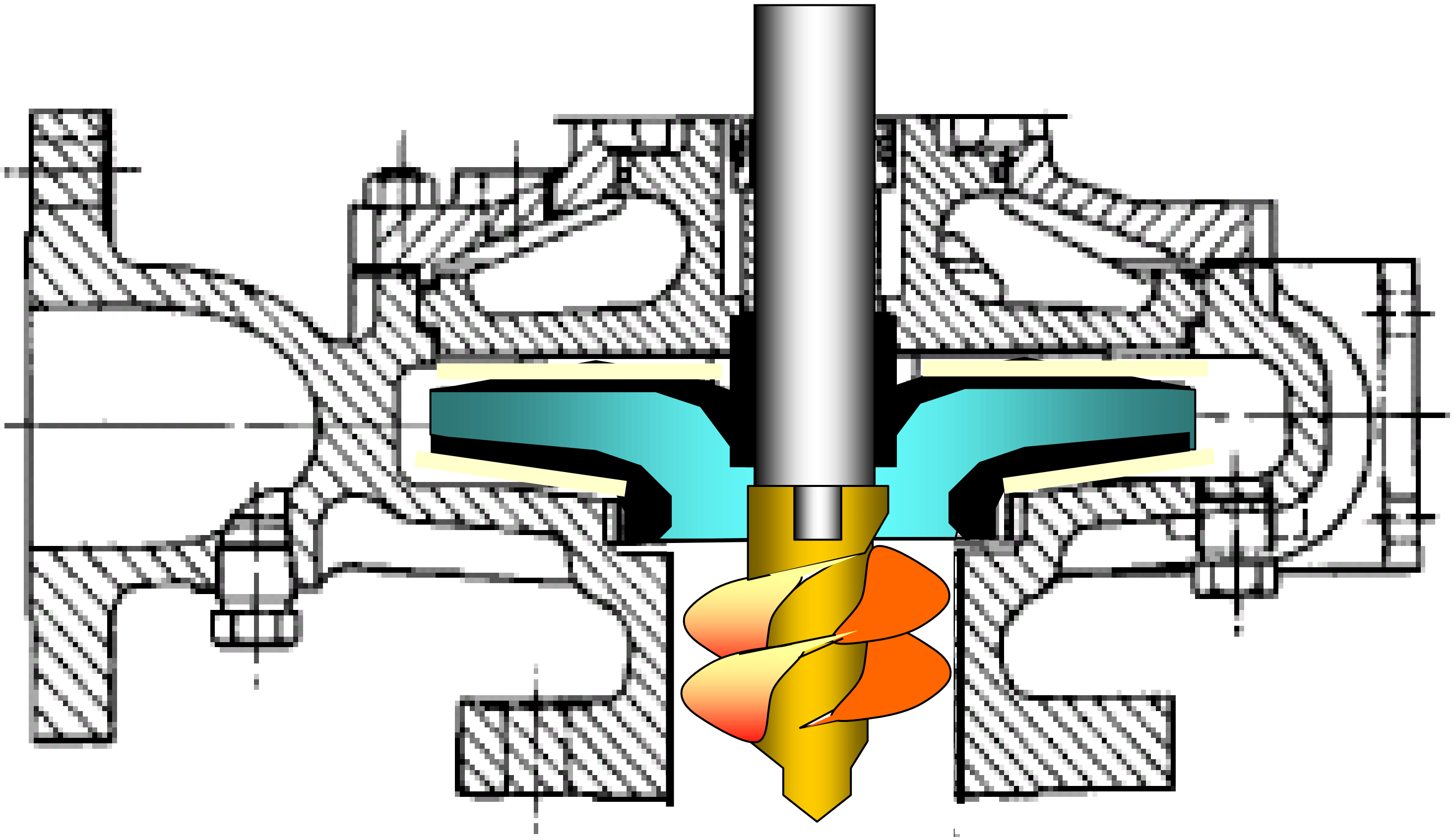
Cavitation Damage

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

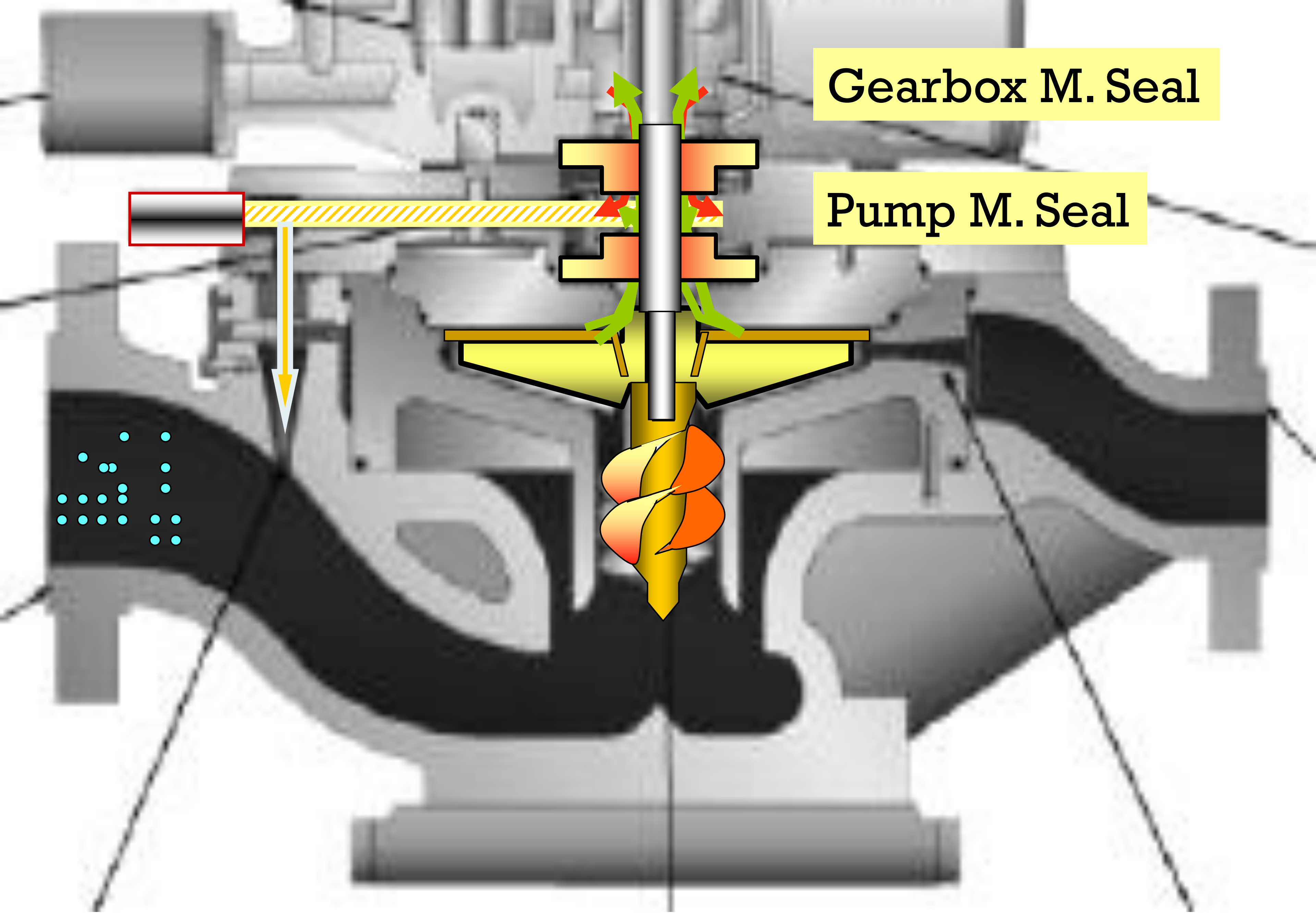
Damage to the pressure side of the vane from discharge recirculation



NPSHA < NPSHR



INDUCER


Gearbox M. Seal
Pump M. Seal

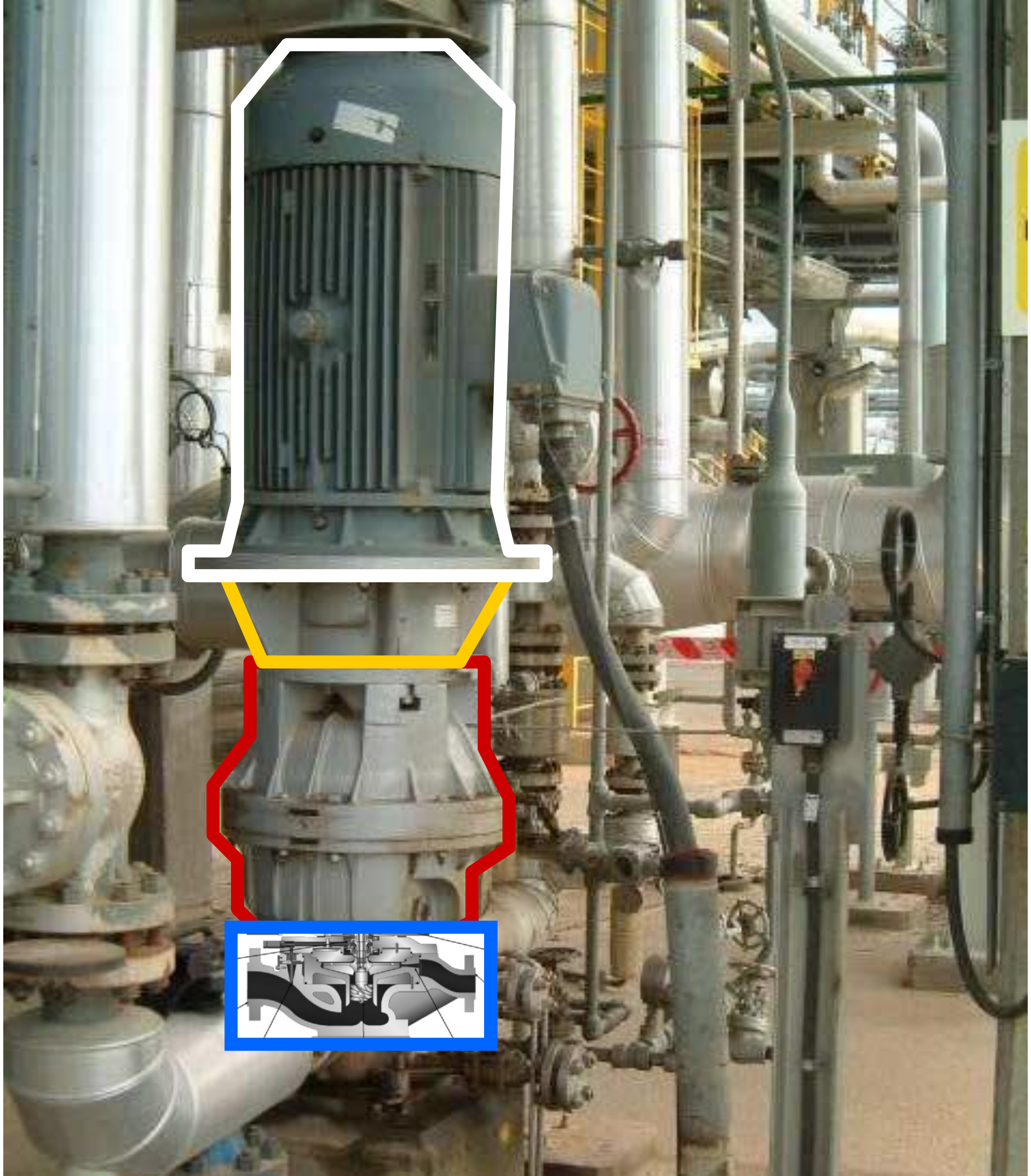
Vertical Inline Centrifugal Pumps

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:

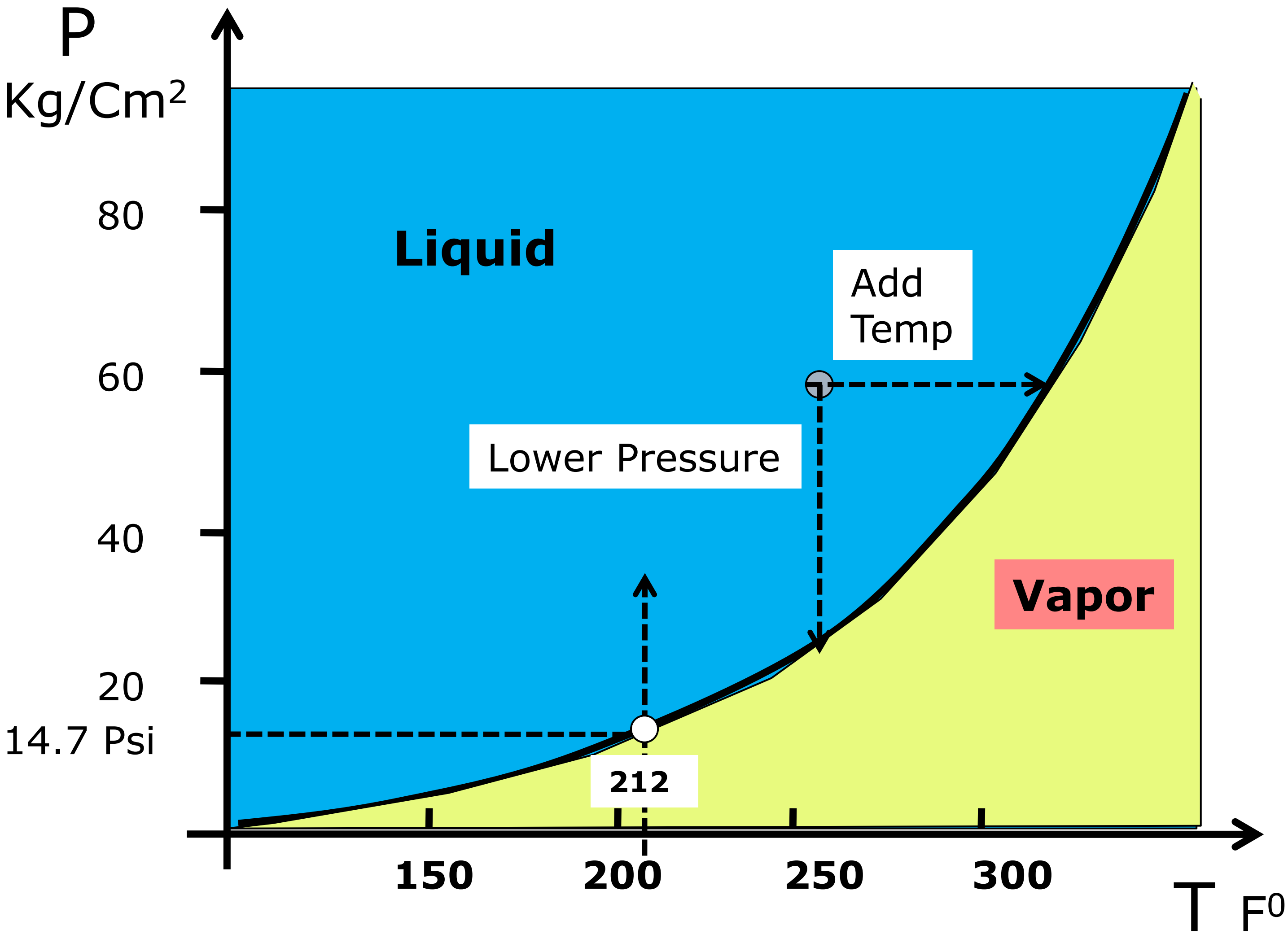
loss of the weakest component element of suction parts material *due to* bubble explosion on the surface of suction parts causing cavities .

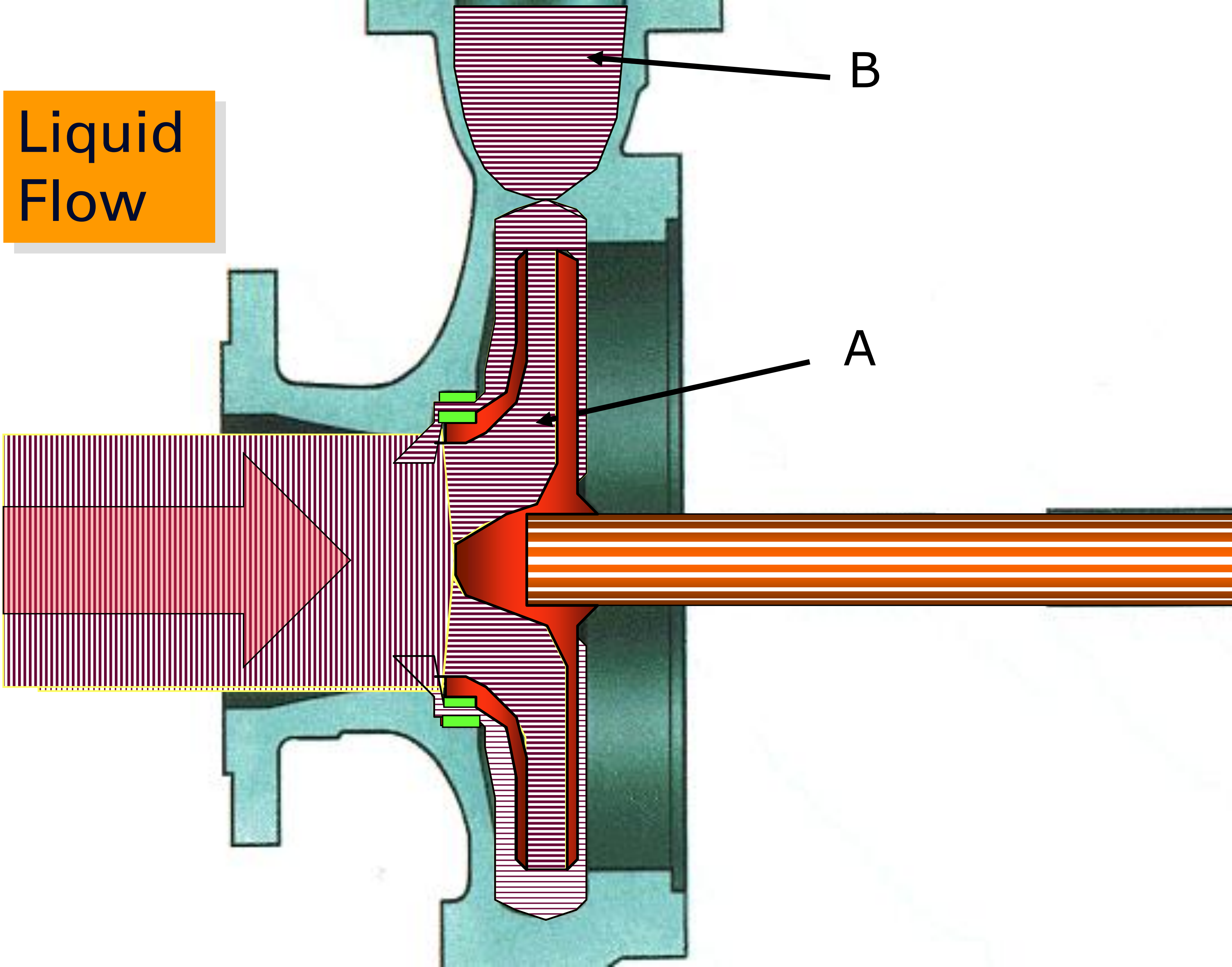
Vapor bubble explosion on

the parts surface could be

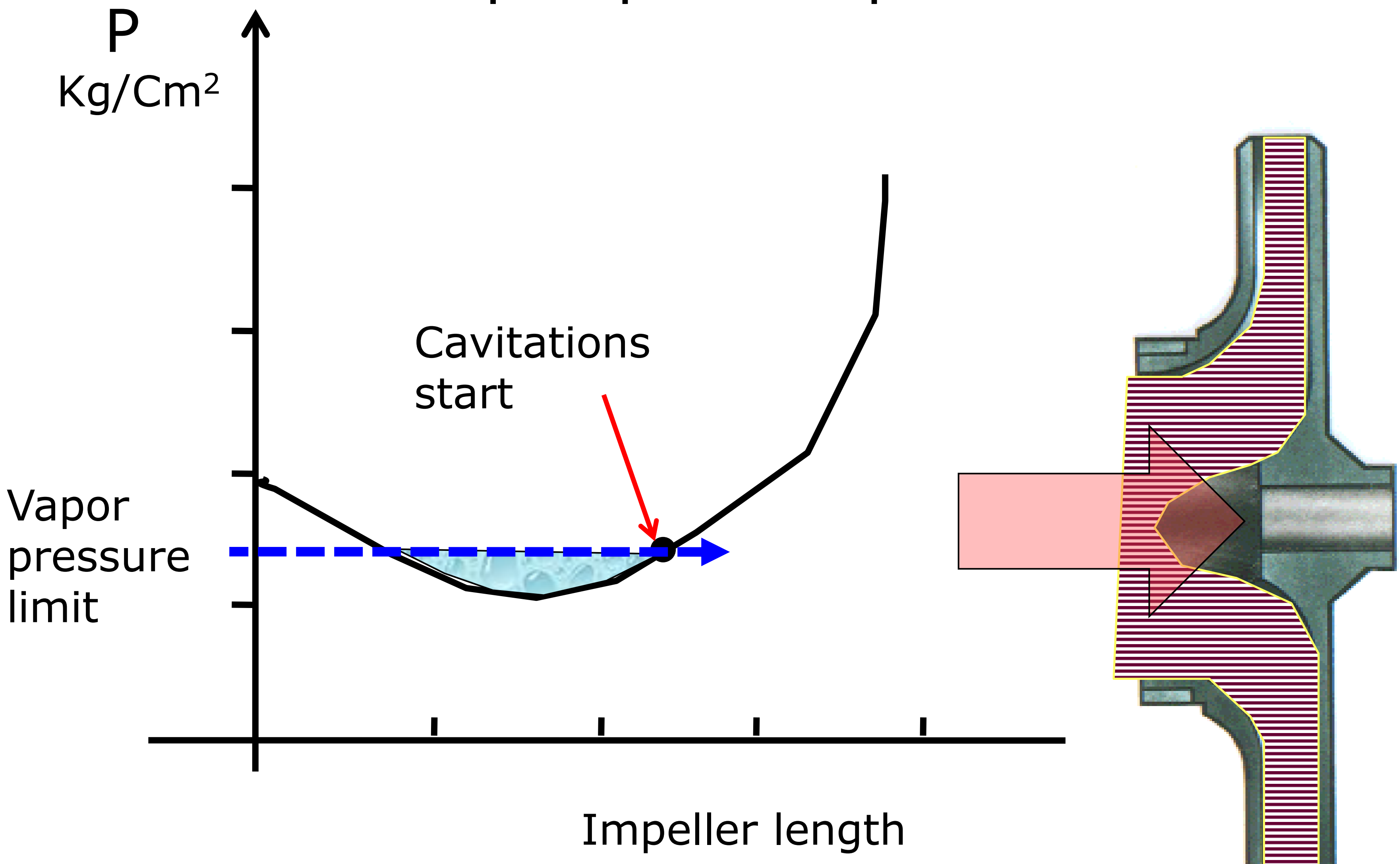
60,000 psi.

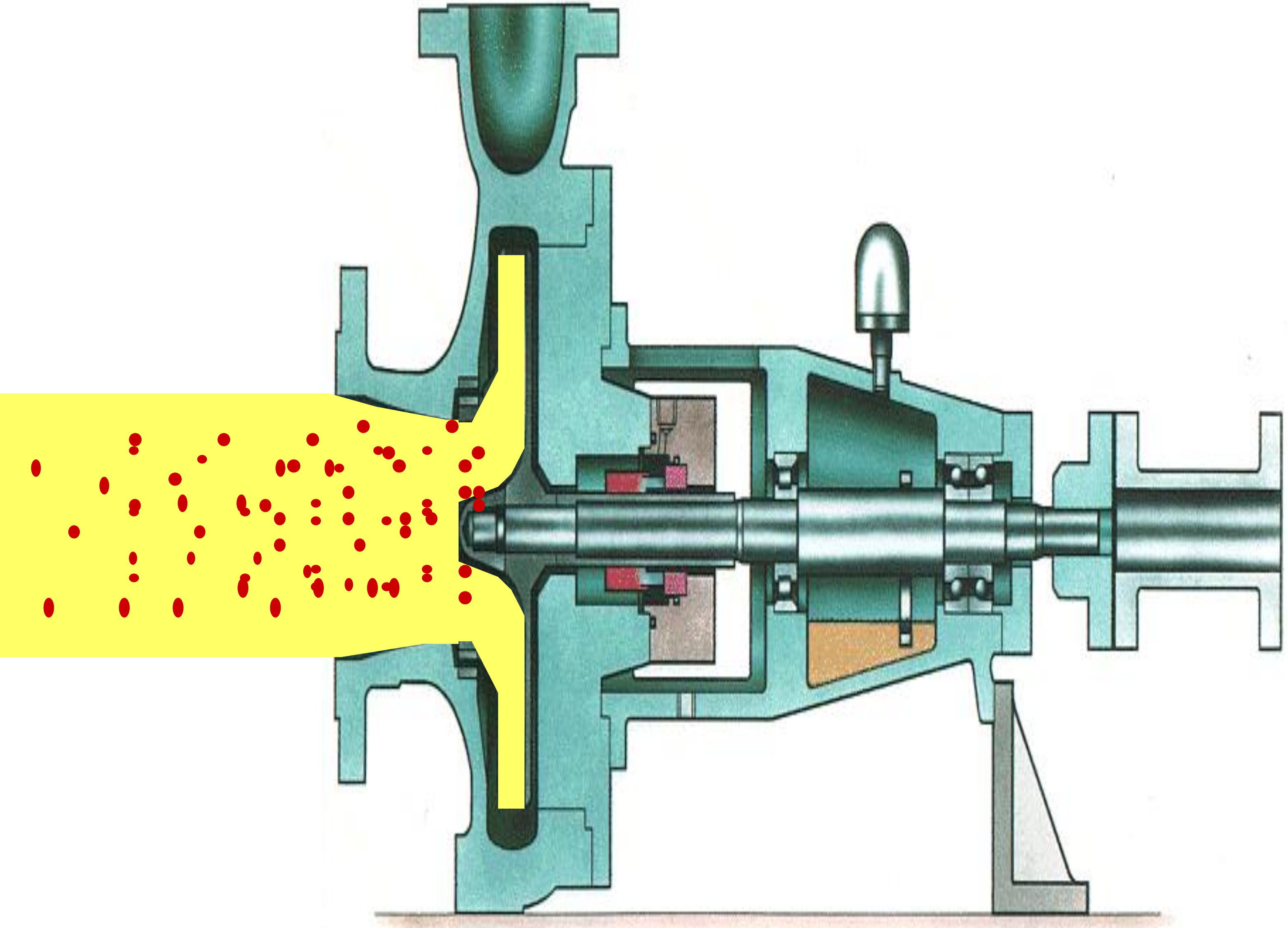
Water Vapor Pressure Graph

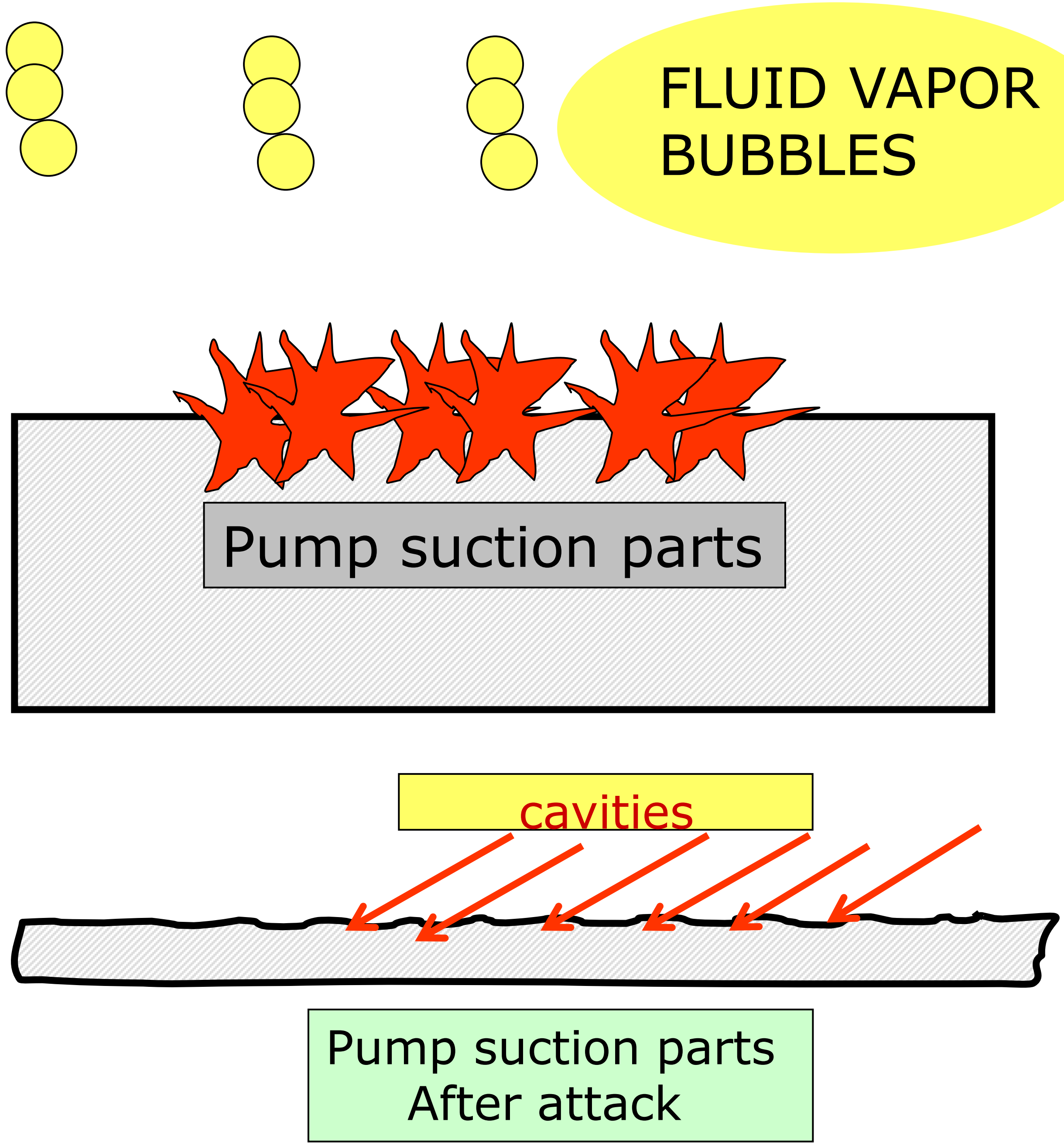



Liquid Flow
B
A

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

NPSHA > NPSHR

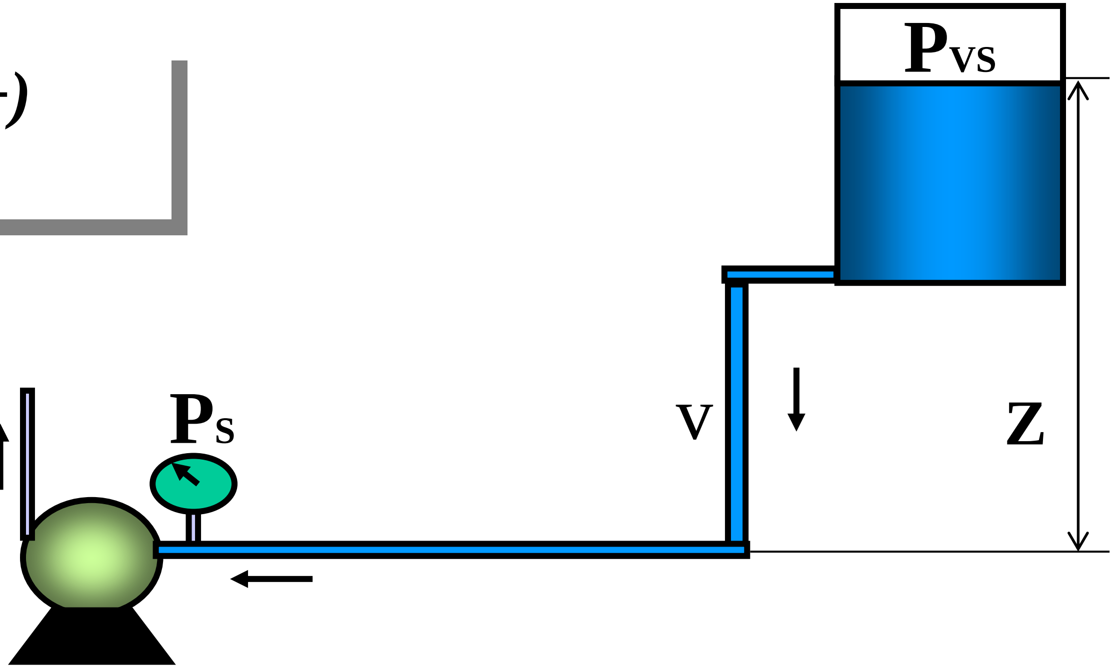
What is the parameters affecting NPSHA

- 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

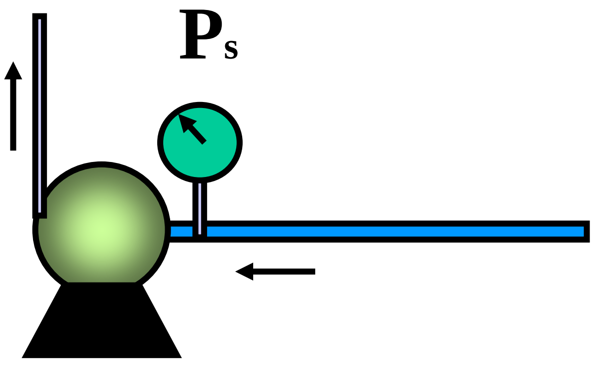
NET POSITIVE (+) SUCTION HEAD



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

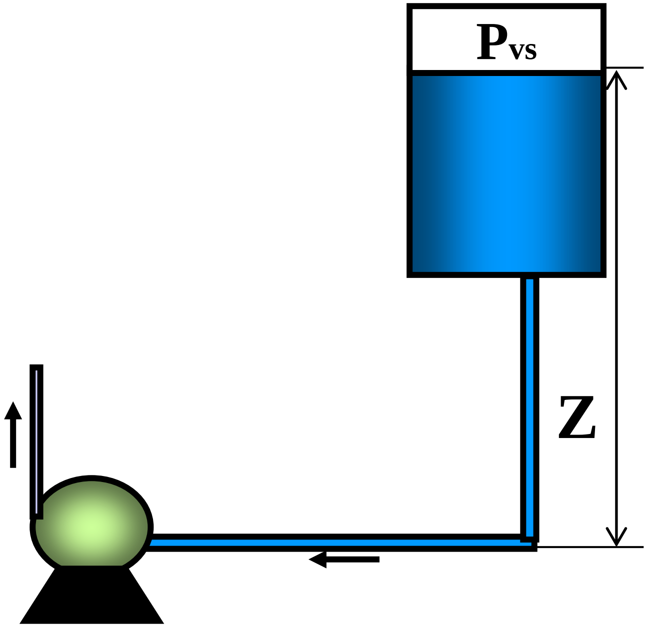
NPSHA **Is** **Not**

The suction Gauge pressure



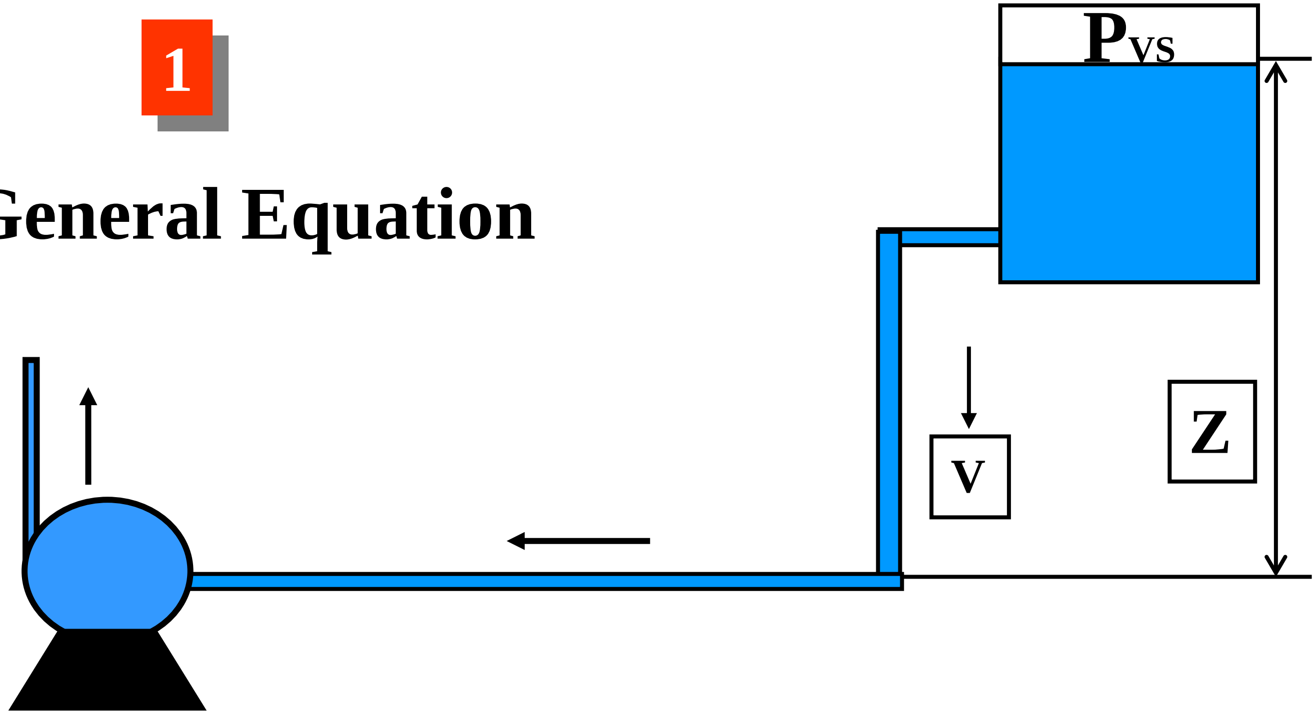
Or

Liquid level in The suction vessel



1

General Equation



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

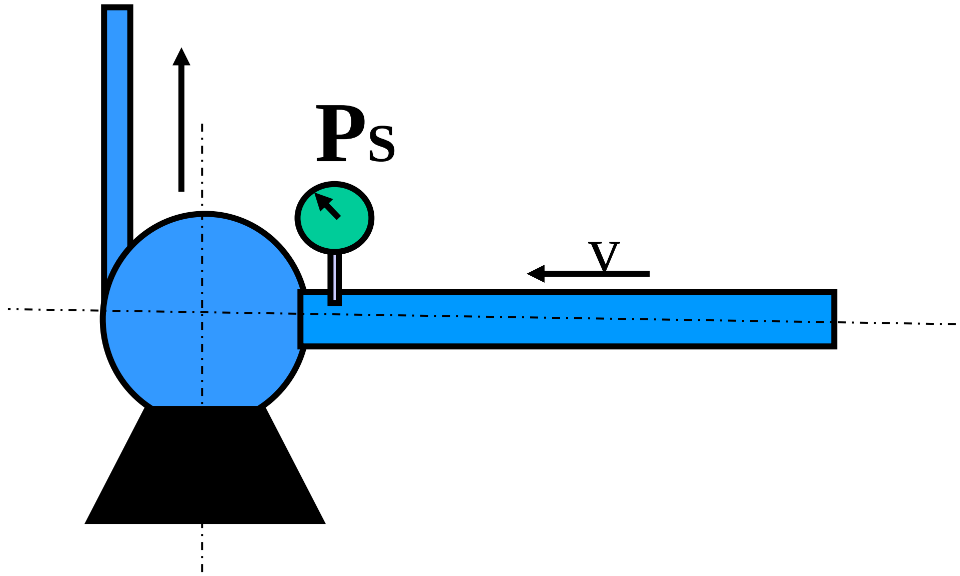
IF
The Suction pressure is known

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

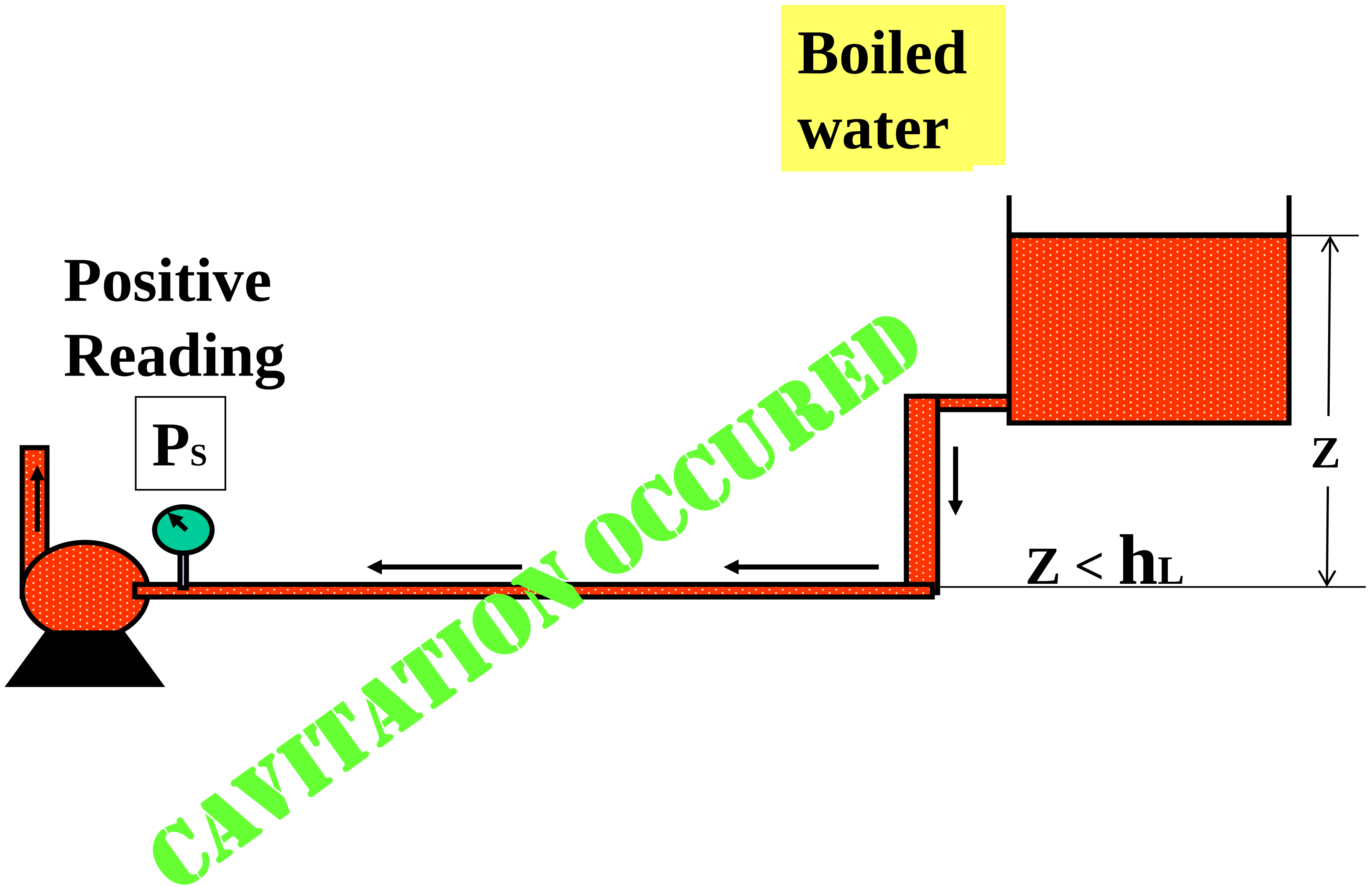
$$\textbf{NPSHA} = Z + \frac{V^2}{2g} + \frac{\{P_{sva} - V_p\}\,2.31}{Sp.gr} - h_L$$

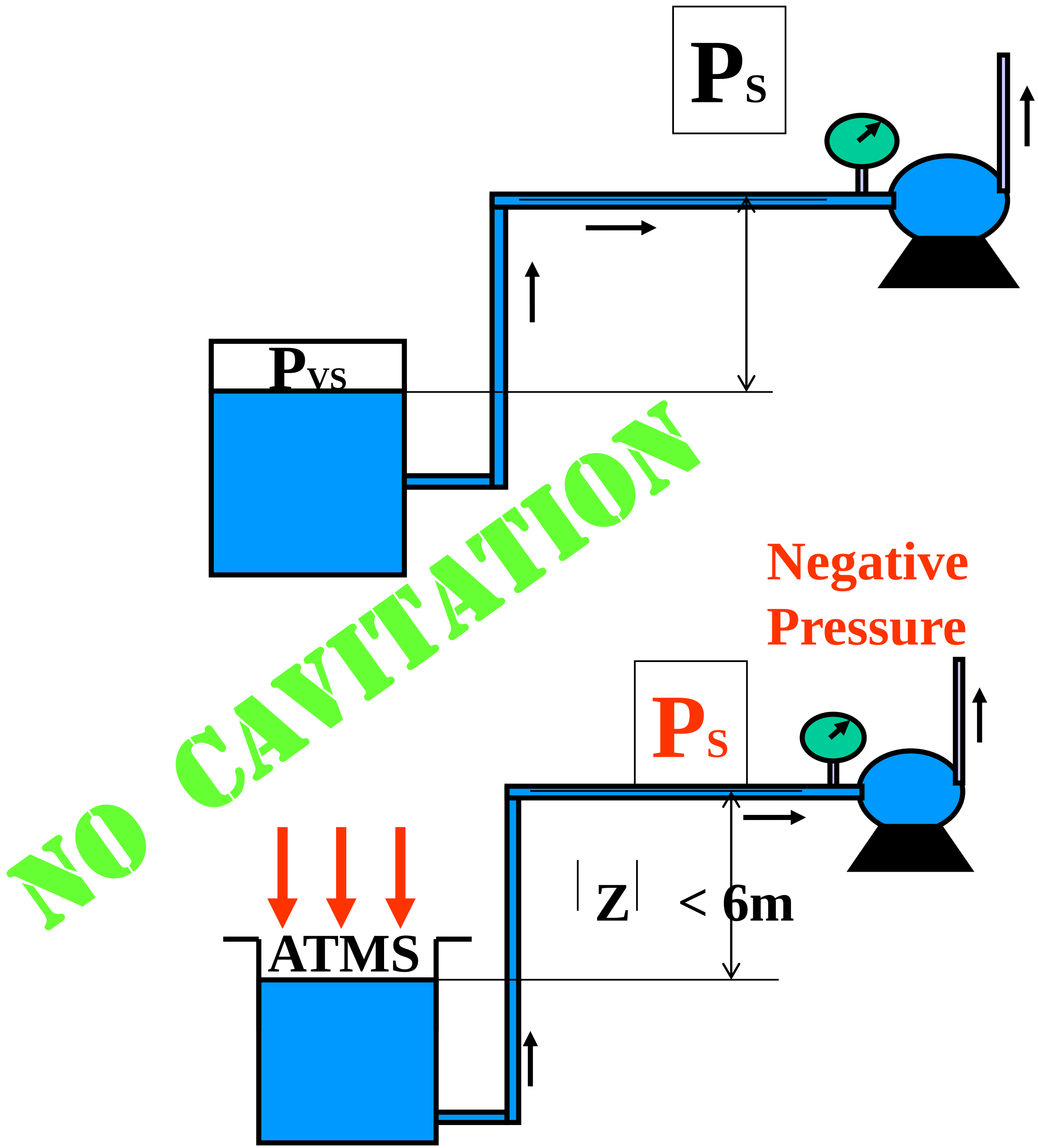
2

If The Suction pressure is known



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

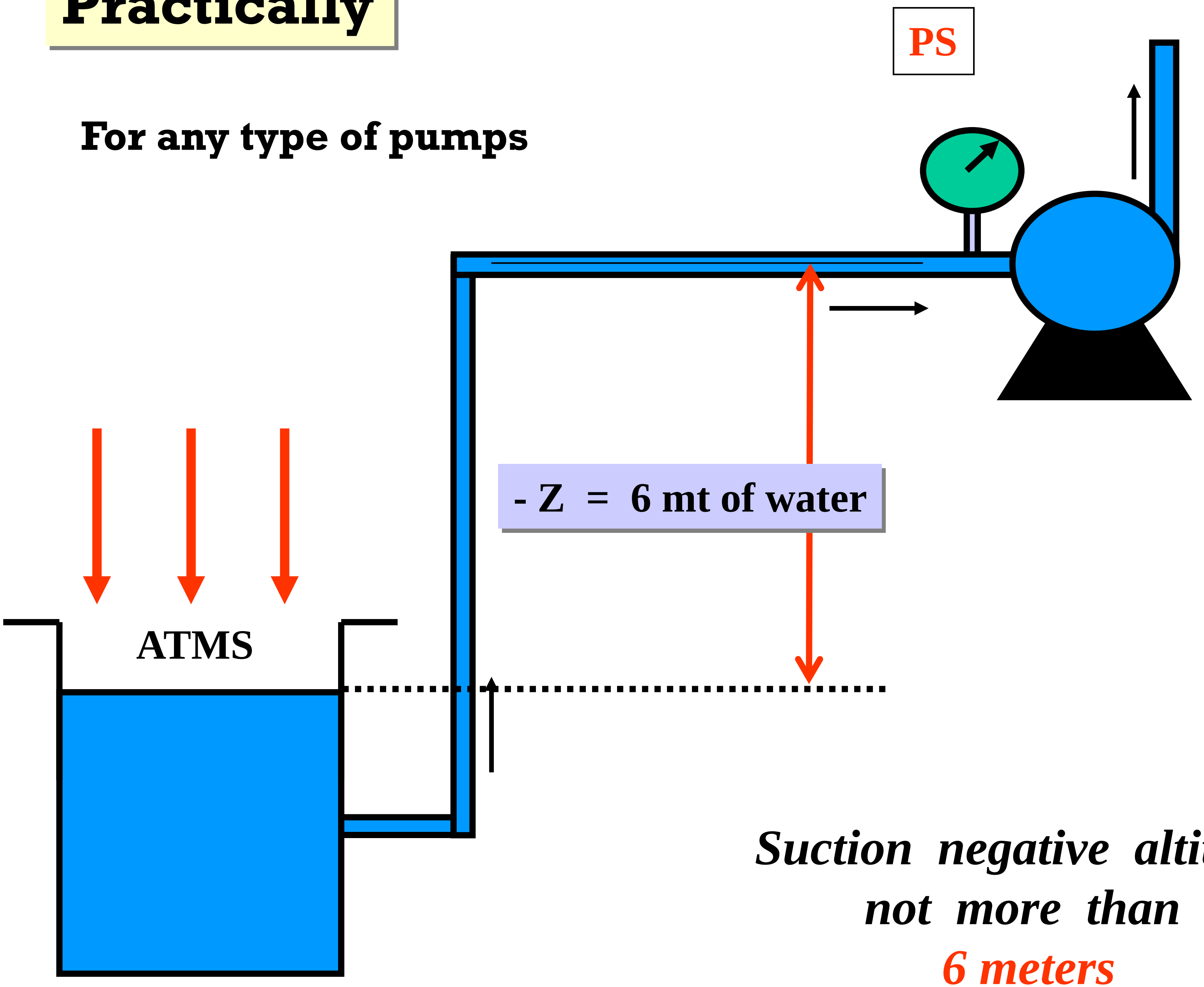

Boiled
water
Positive
Reading
Ps
Z
Z < hL
CAVITATION OCCURED



Ps
Pvs
NO CAVITATION
Negative Pressure
Ps
|Z| < 6m
ATMS

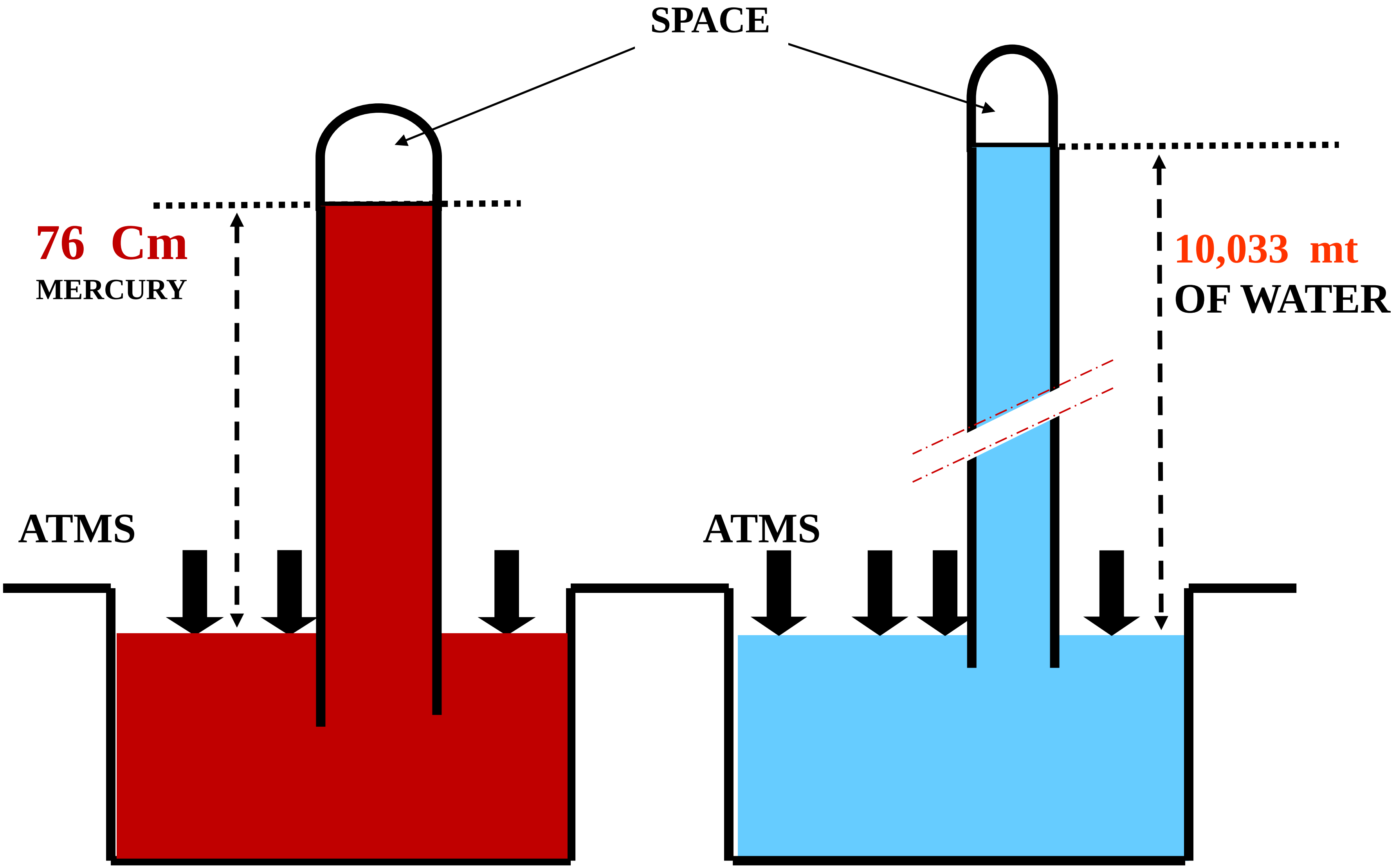
Practically

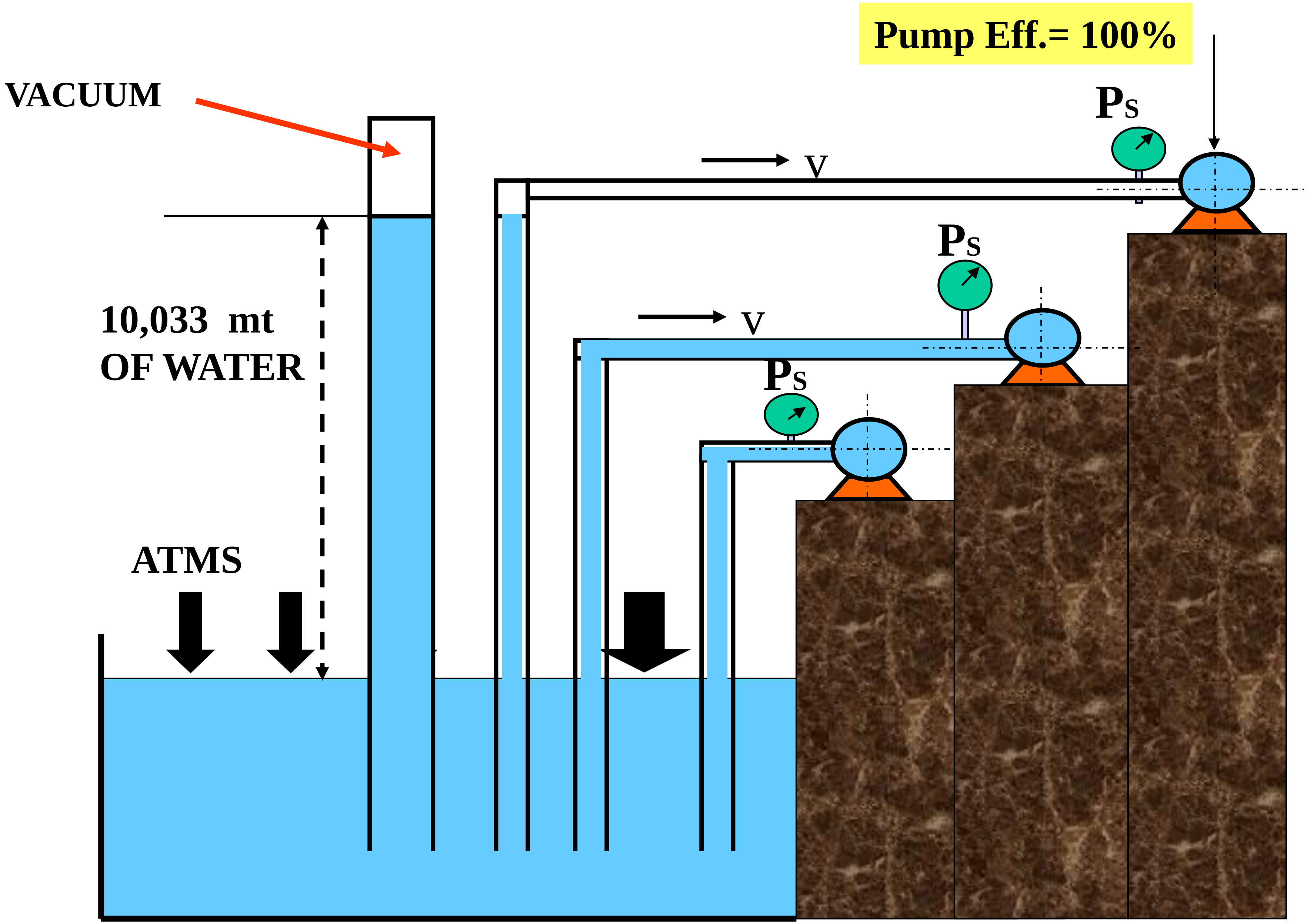
For any type of pumps



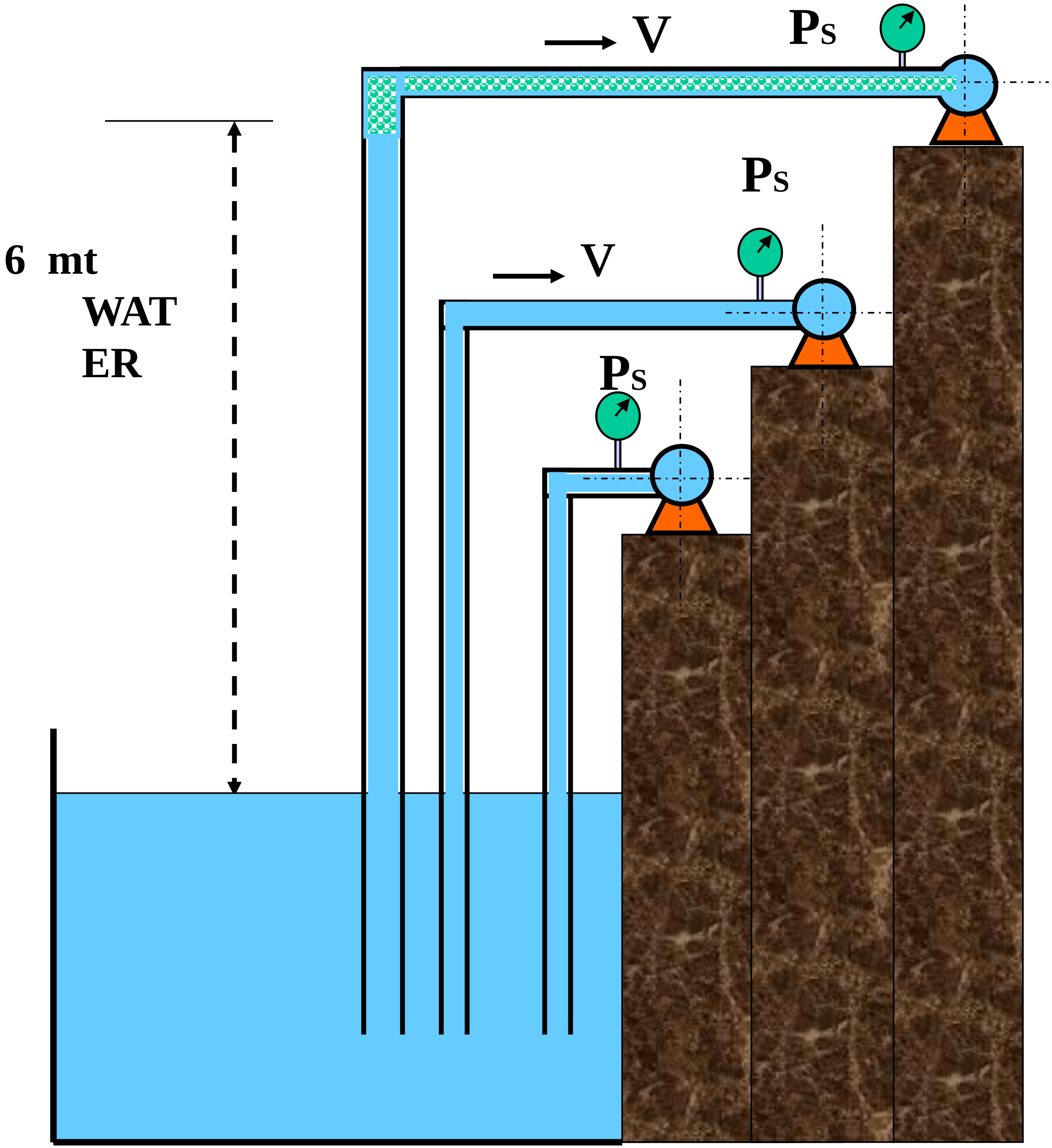
Suction negative altitude not more than 6 meters

ATMOSPHERIC PRESSURE



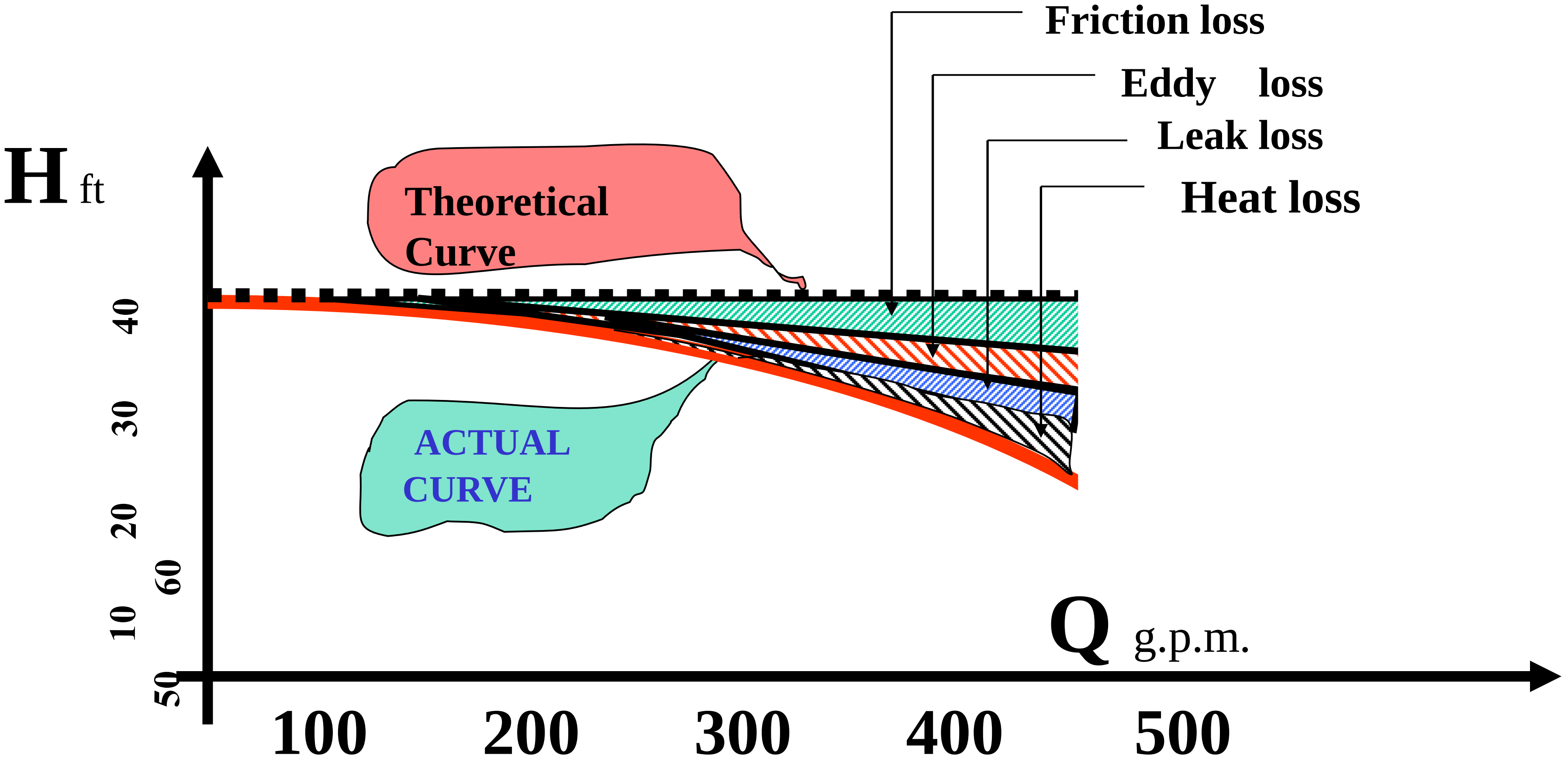


Pump Eff.= 100%
VACUUM
Ps
V
Ps
10,033 mt
OF WATER
V
Ps
ATMS



V
PS
PS
V
6 mt
WAT
ER
PS

Centrifugal
Pumps losses



VAPOR PRESSURE

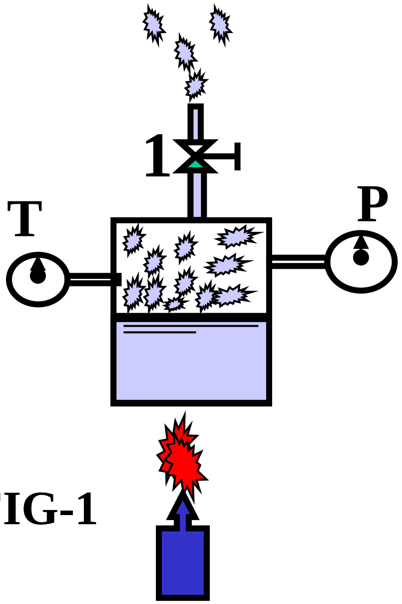


FIG-1

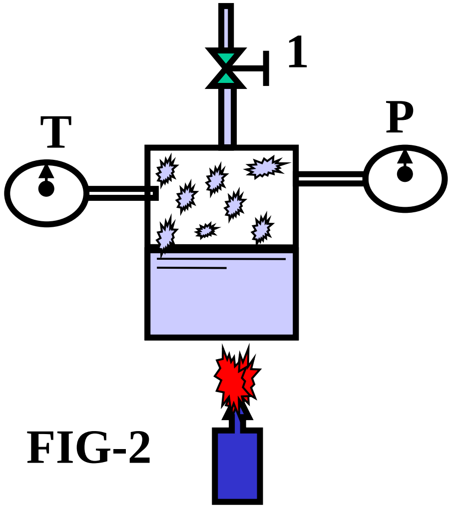
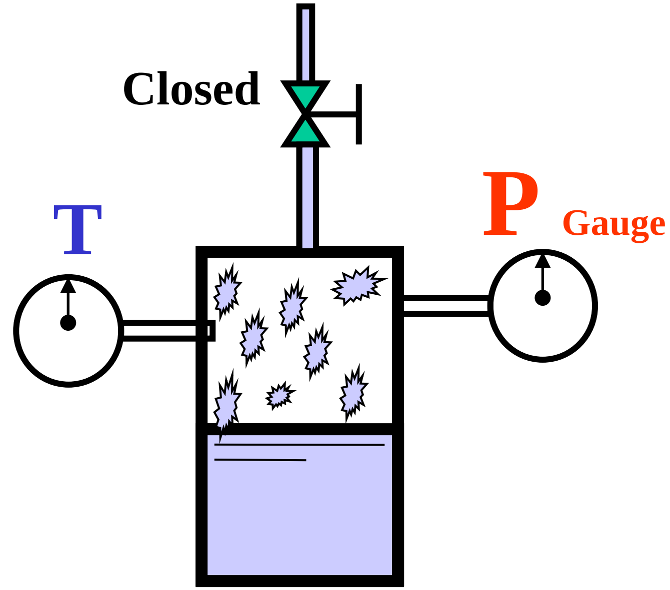


FIG-2

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 .

$$P_{Absolute} = P_{gauge} + 1$$

(bar)

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

(bar) absolute

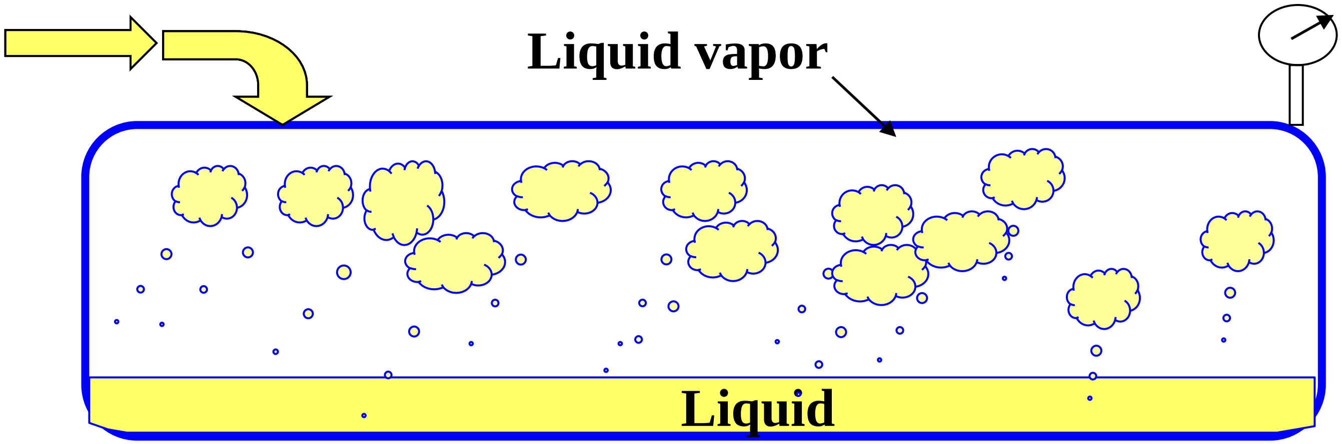
5- **Record the Absolute Liquid vapor pressure.**

Temp C	100	95	90	80	70	15
P_{Gauge}	0	- 0.1	- 0.3	- 0.5	- 0.7	- 0.98
$V_{apor} P_{ressure}$	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 = 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

Atmospheric pressure is 14.7 psia

(Neglect velocity head)

Solution

$$NPSHA = Z + \frac{\{ (P_{sv} + P_a) - Vp \} 2.31}{Sp.gr} - h_L$$

$$= 8 + \frac{\{ (0 + 14.7) - 4 \} \; 2.31}{0.8} - 12$$

$$= 8 + 31 - 12$$

$$= + 27 \quad (ft)$$

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

$$NPSHA = Z + \frac{\{ (Psv + Pa) - Vp \} 2.31}{Sp.gr} - h_L$$

$$= 8 + \frac{\{ (0 + 14.7) - 14 \} 2.31}{0.85} - 2$$

$$= 8 + 2 - 2$$

$$= +8 \quad (ft)$$

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

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

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

$$= +\ 12.8 \quad (ft)$$

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

$$\text{NPSHA} = \frac{\{ (P_s + P_a) - V_p \}\, 2.31}{\text{Sp.gr}} \quad (\text{ft})$$

$$= \frac{\{ ((0 + 14.7) - 5)) - 4 \}\, 2.31}{0.8} \quad (\text{ft})$$

$$= + \quad 16.46 \quad (\text{ft})$$

Compare with NPSHR

If the liquid is butane and level is **Z = - 8 ft**
System pressure is 60 psia.

Temperature is 90 F

Vp = 44 psia at 90 F, butane sp.gr is 0.58

Friction loss : 12 ft of liquid,

(Neglect velocity head)

FIND NPSHA

Solution

NPSHA

$$= Z + \frac{(Psva - Vp)\,2.31}{Sp\ gr} - h_L \quad (ft)$$

$$= -8 + \frac{(60 - 44)\,2.31}{0:58} - h_L \quad (ft)$$

$$= +\ 43.7 \quad ft$$

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

$$\text{NPSHA} = \frac{\{\text{Psa} - \text{Vp}\}\,2.31}{\text{Sp.gr}} \quad (\text{ft})$$

$$= \frac{\{(1 + 14.7) - 13\}\,2.31}{0.85} \quad (\text{ft})$$

$$= +7.33 \quad (\text{ft})$$

Compare with NPSHR