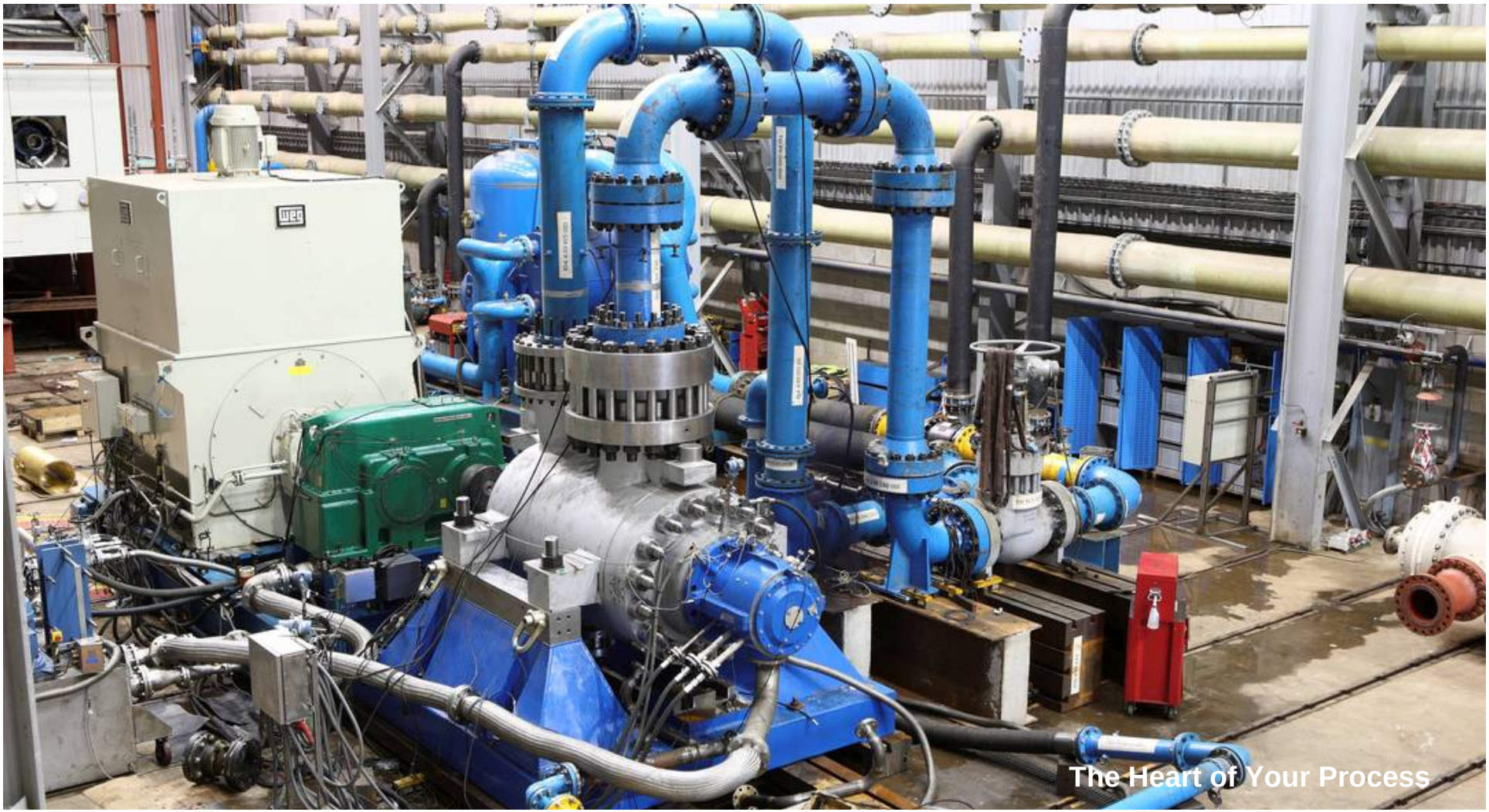
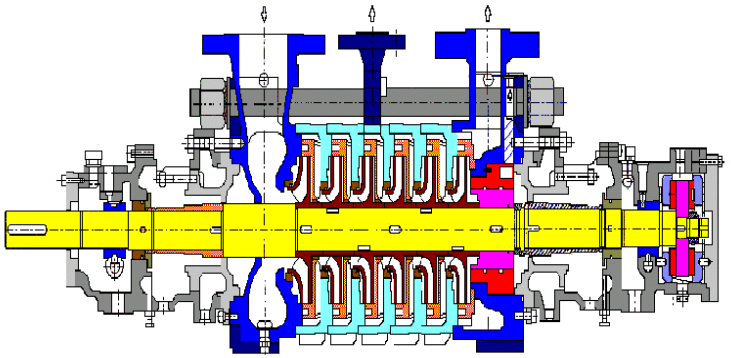
HPT High Speed Boiler Feedwater Pumps

Sulzer Pumps

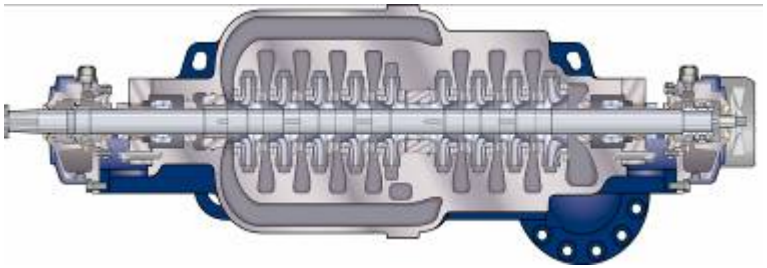


Types of Boiler Feedwater Pumps

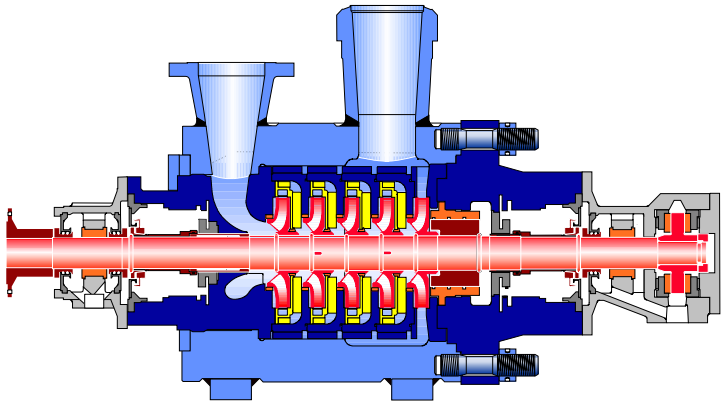
Diffuser Casing Segmental Ring



Volute Casing Horizontal Split



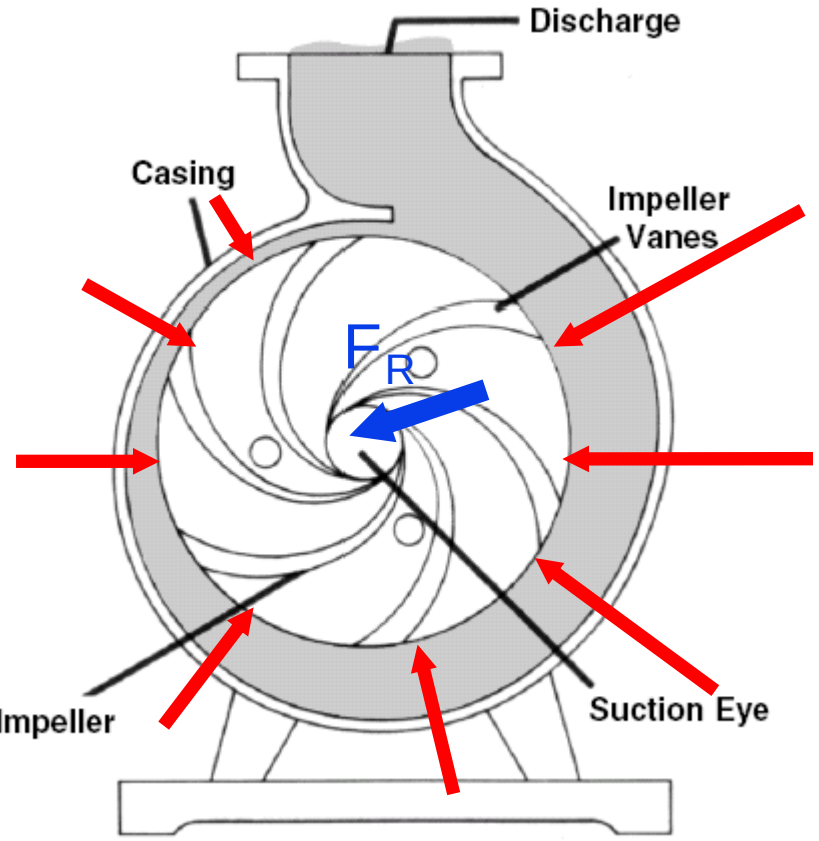
Diffuser Casing High Speed Barrel Casing



Volute vs. Diffuser Casings

Radial loads increase as the liquid flows through the volute and exits through the casing discharge. The result is an unbalanced radial load on the rotating element.

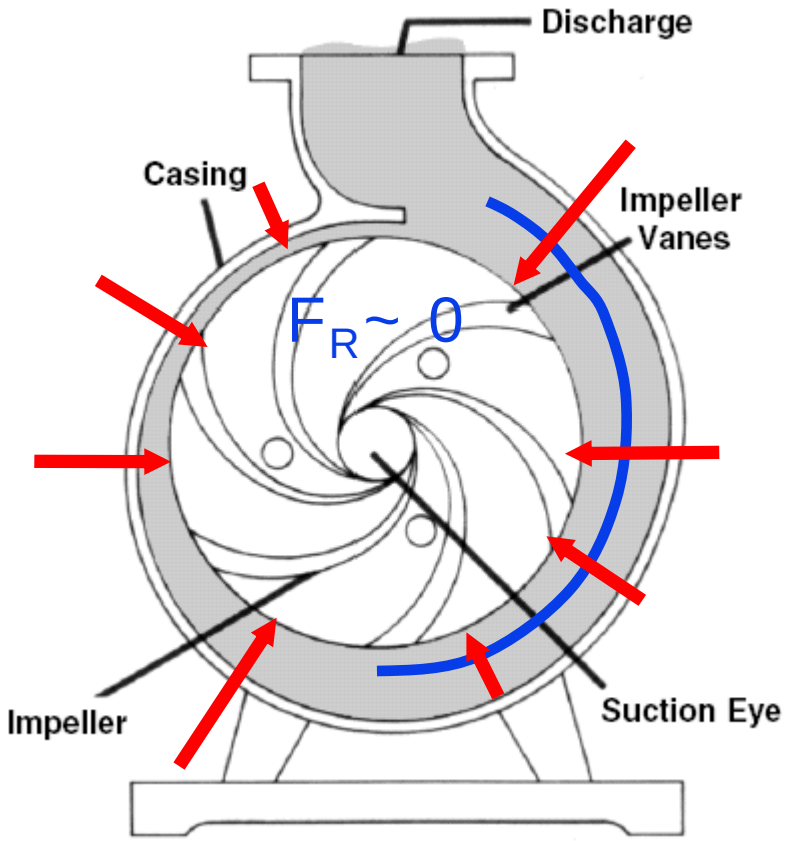
Single Volute Casing



Volute vs. Diffuser Casings

A dual volute casing will have an additional passage way 180º from the main volute which will almost balances the generated radial forces.

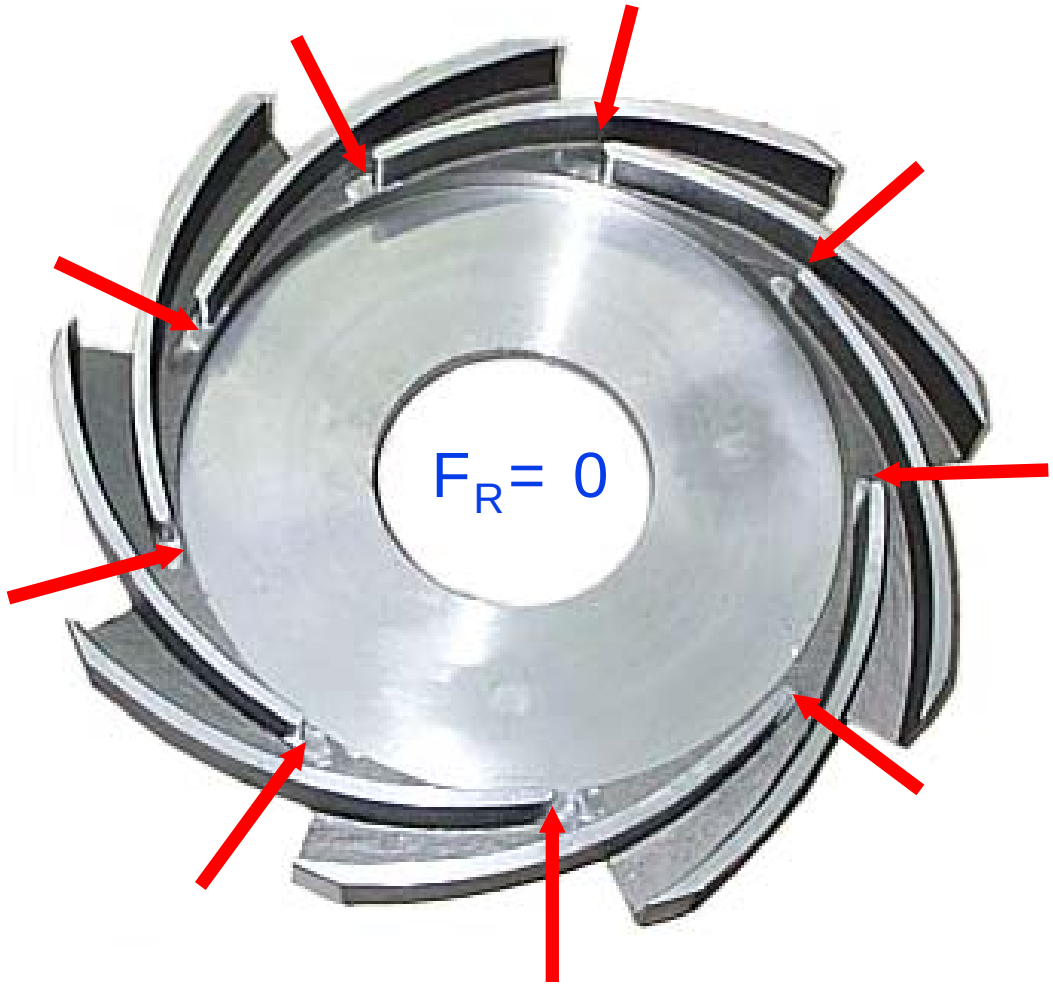
Dual Volute Casing



Volute vs. Diffuser Casings

A diffuser style casing has multiple discharge passage ways with equal area distributed throughout the circumference resulting in radially balanced rotating element.

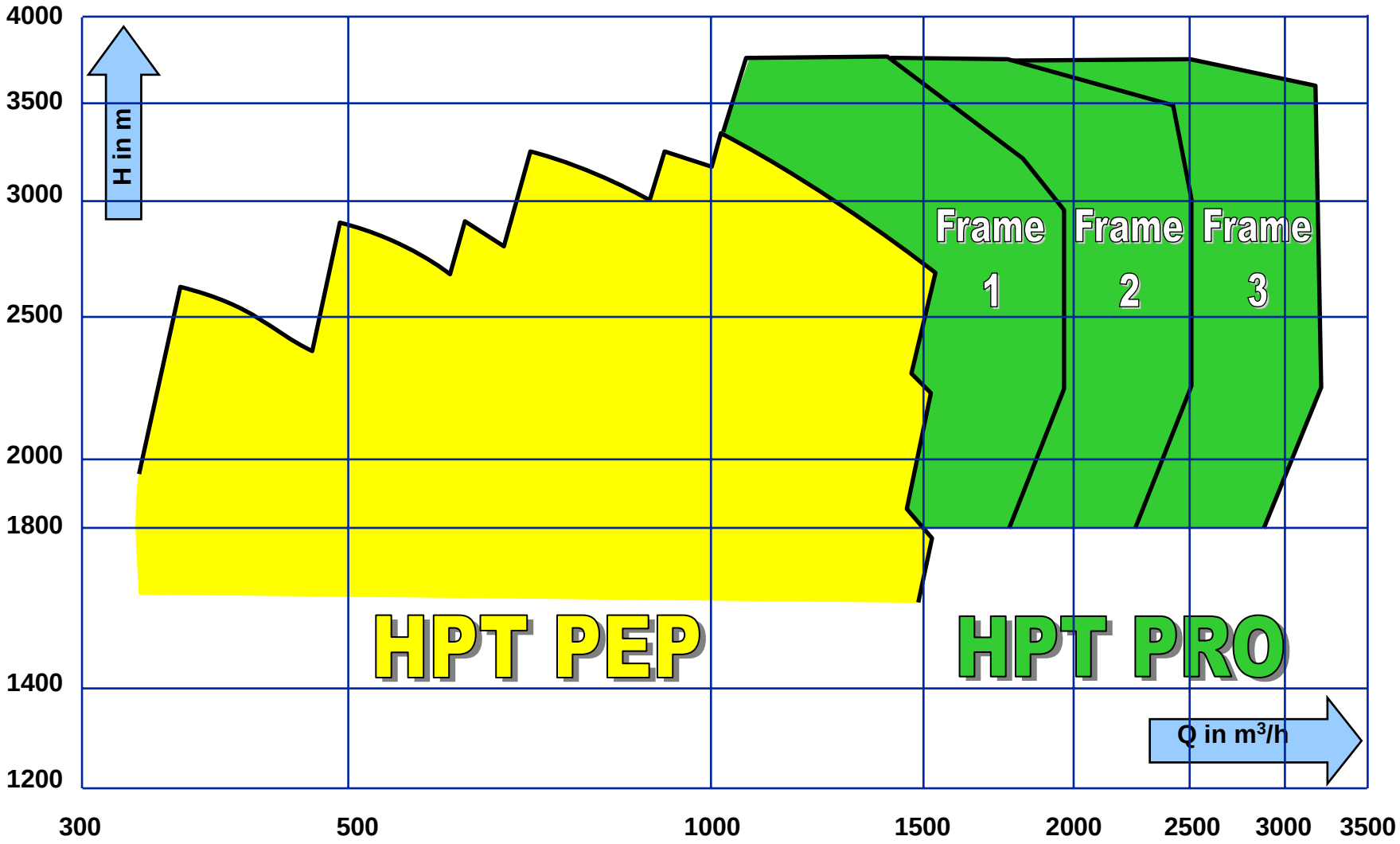
Diffuser Casing



HPT Boiler Feed Pumps
Range Chart

SULZER

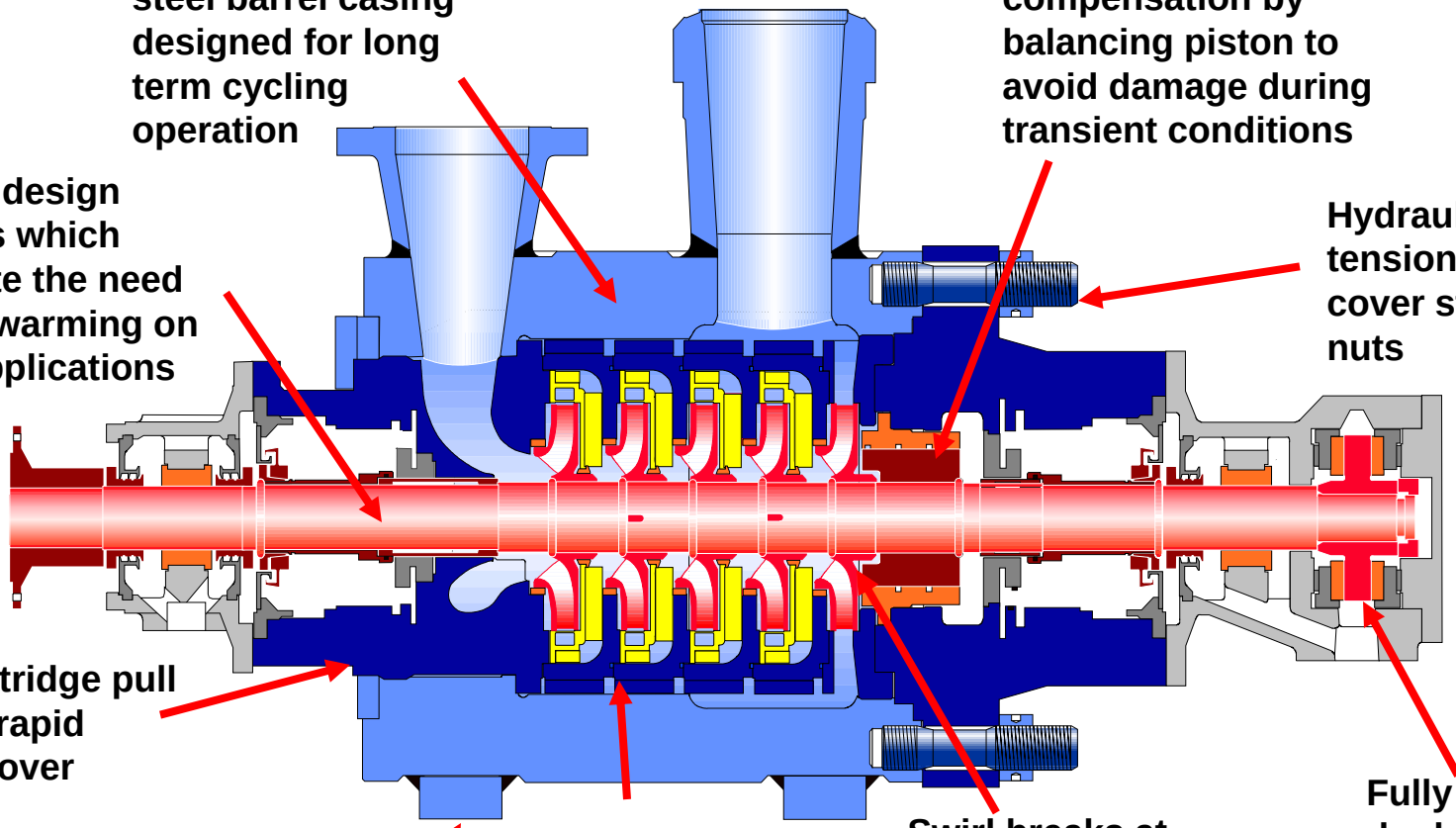
Sulzer Pumps



HPT Boiler Feed Pumps
Cross Section

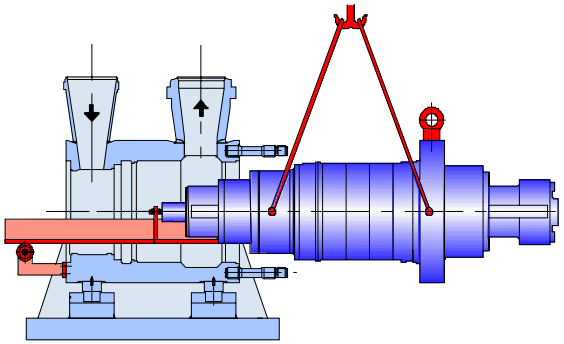
SULZER

Sulzer Pumps



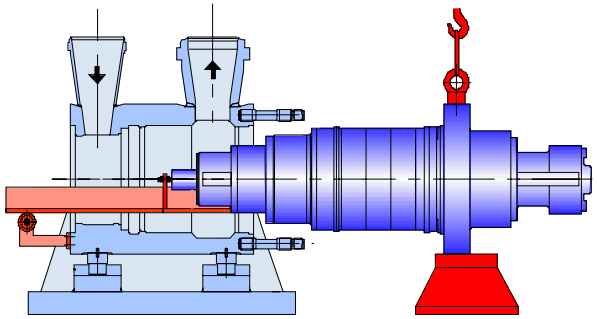
HPT Boiler Feed Pumps
Installation (Removal of Cartridge)

Advantage
Quick and safe cartridge change



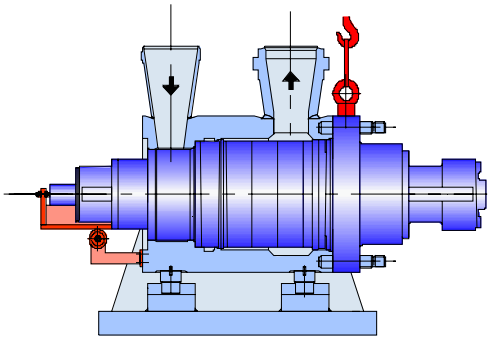
Step 1

Suspended and supported on rollers at DE



Step 2

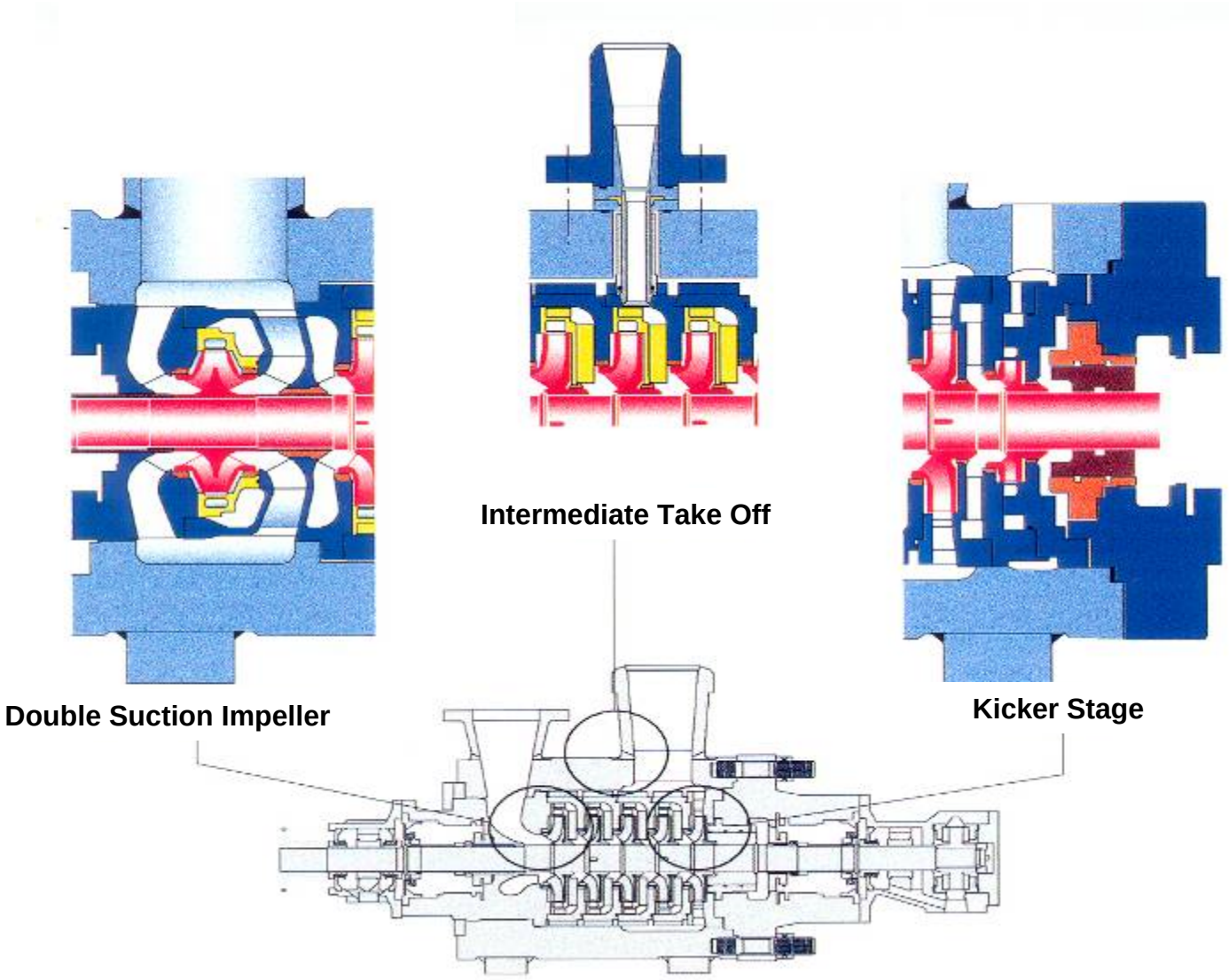
Supported for re-rigging



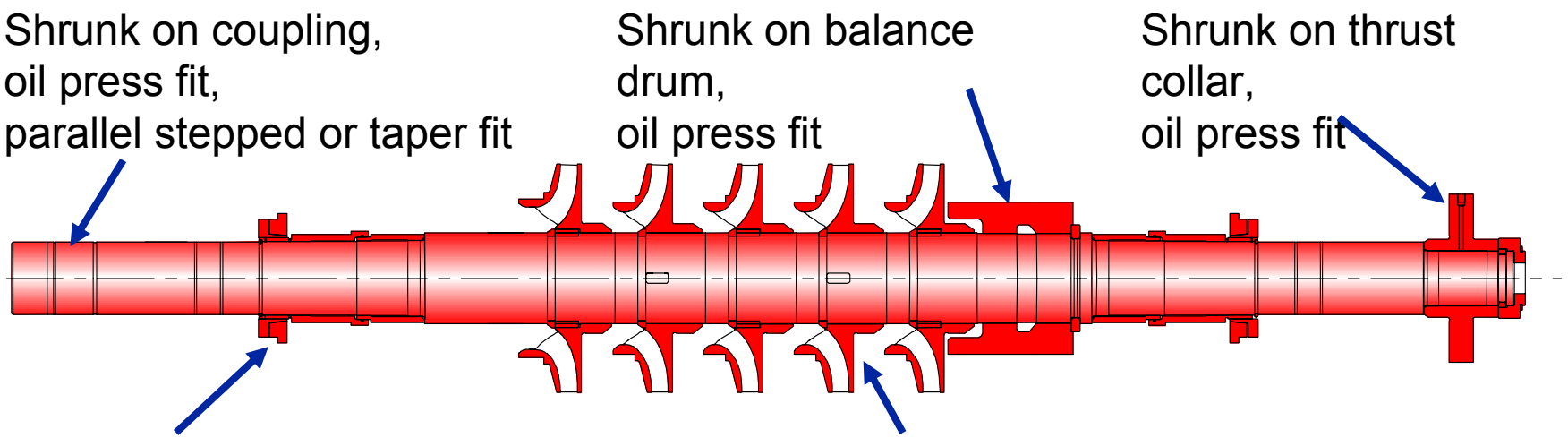
Step 3

Final installation

HPT Boiler Feed Pumps
Alternative Arrangements



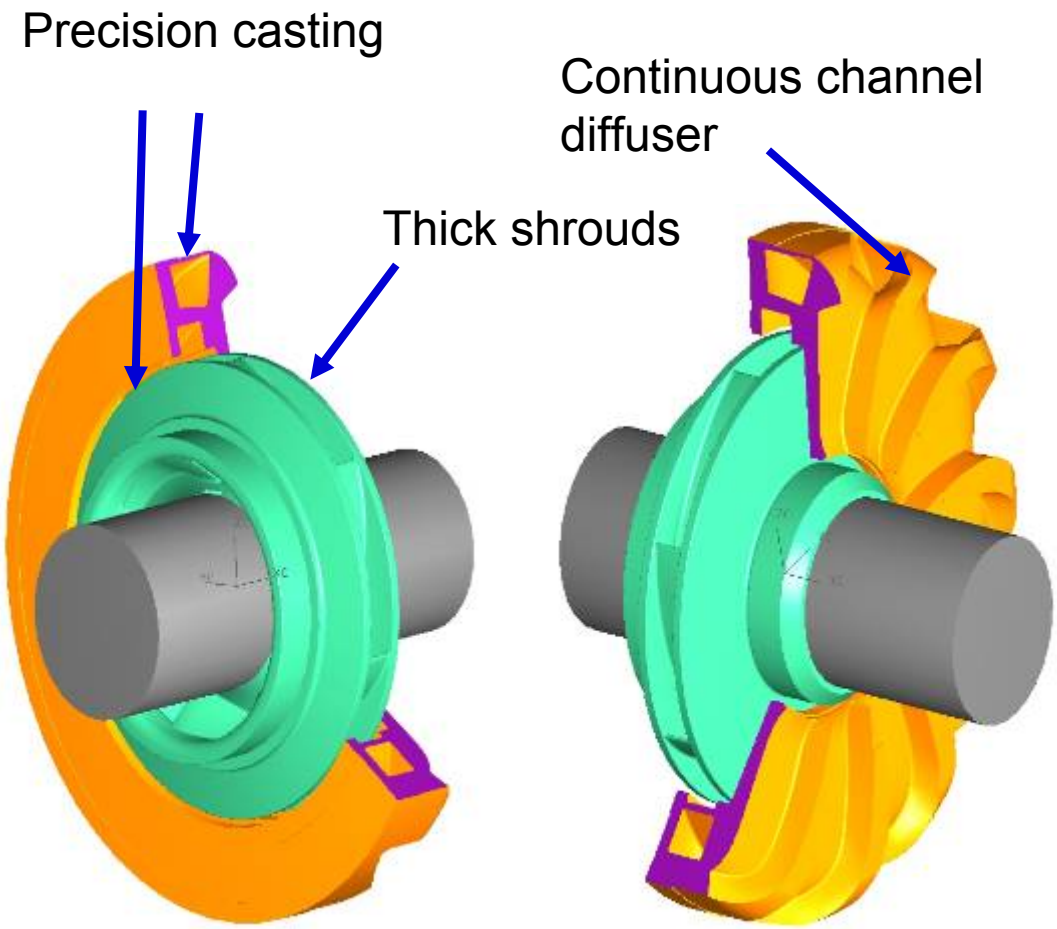
HPT Boiler Feed Pumps
Rotor Design



Advantages:

- Shrunk on parts allow for high rotor balancing quality
- Shrunk on parts avoid fretting corrosion and minimize stress concentrations
- Shrunk on parts avoid loose parts on shaft during operation and result in lower vibration

HPT Boiler Feed Pumps
Impeller and Diffuser Design



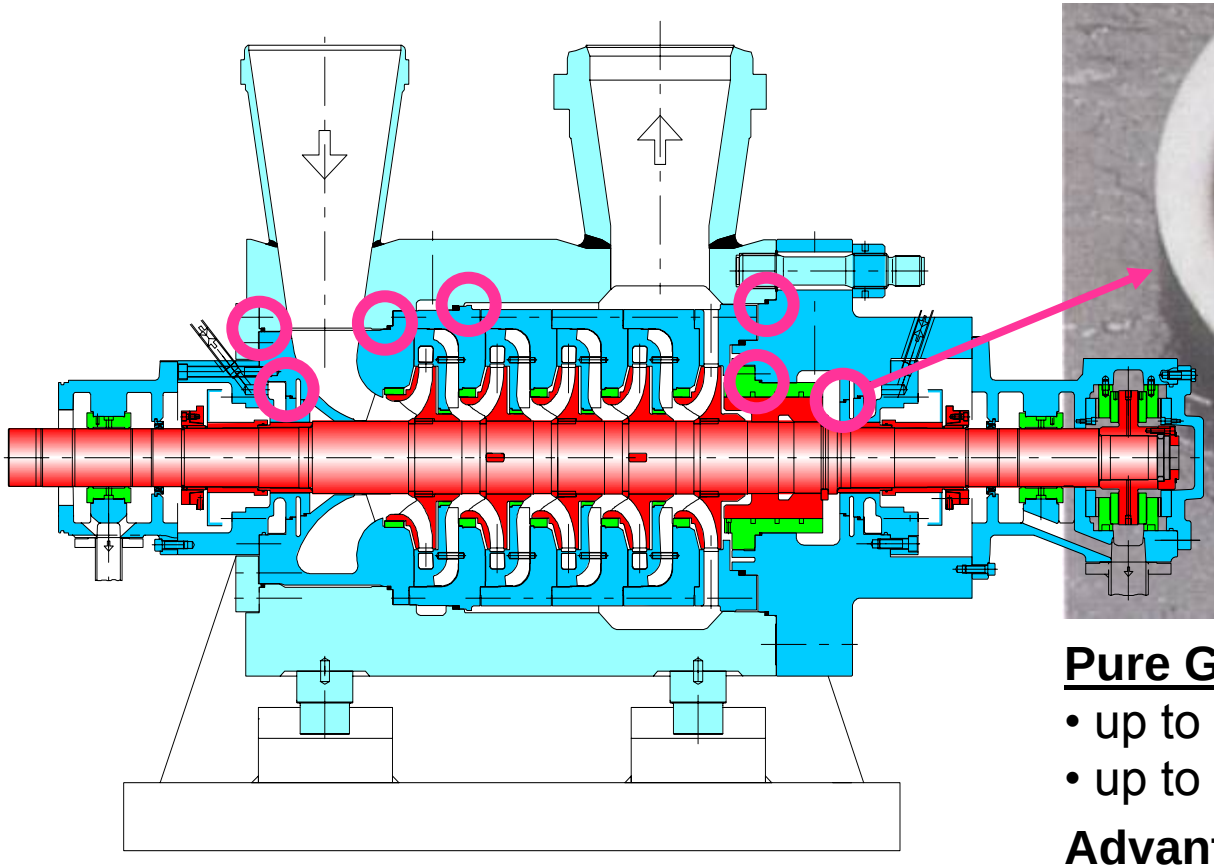
Advantages:

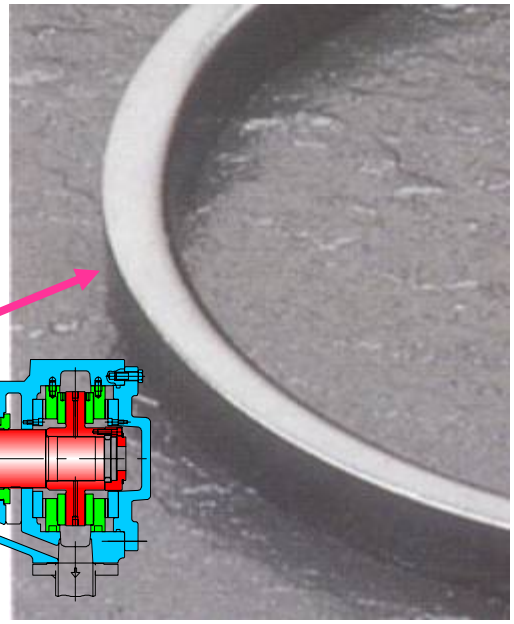
Precision castings
- high efficiency
- small hydraulic unbalance

Thick shrouds
- high strength for high head
- natural frequency away from resonance thus avoiding shroud breakage

Continuous channel diffuser
- high efficiency

HPT Boiler Feed Pumps
Static Seals





Pure Graphite Seal Rings

- up to 1000 bar
- up to 300 °C

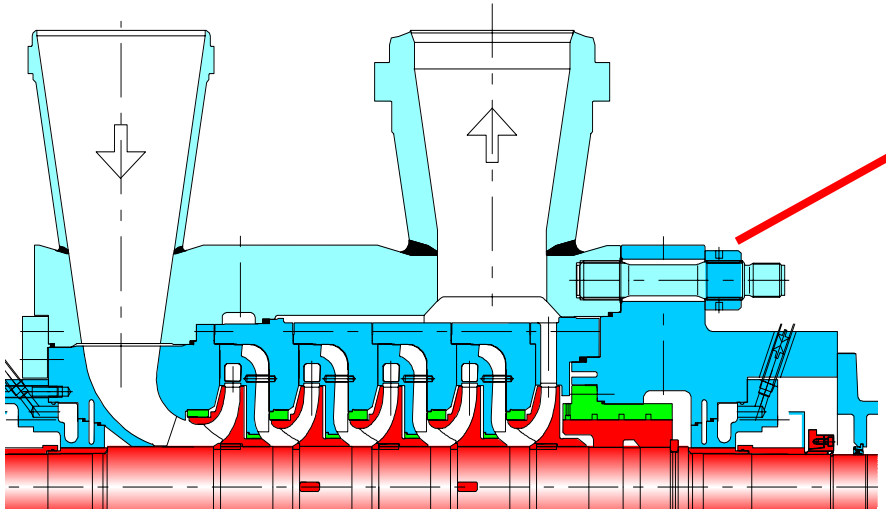
Advantages:

- low gasket seating load required
- fully confined gasket
- metal to metal face

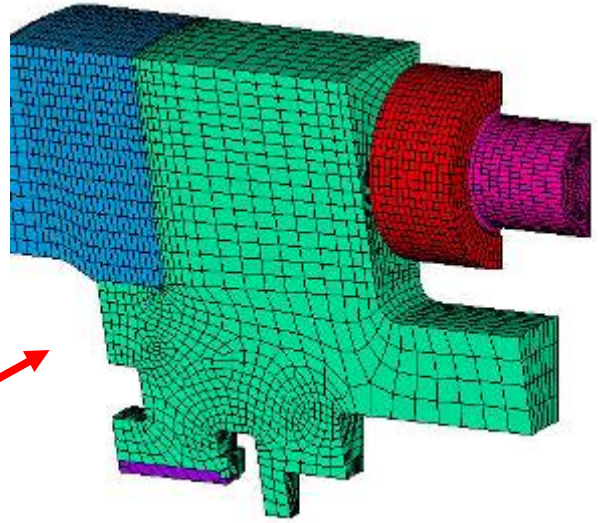
HPT Boiler Feed Pumps
Pressure Retaining Parts

Analyzed with proven codes:

- German vessel code AD, standard
- ASME section VIII, Division 1, option
- FE for selected cases



FE model



Advantages:

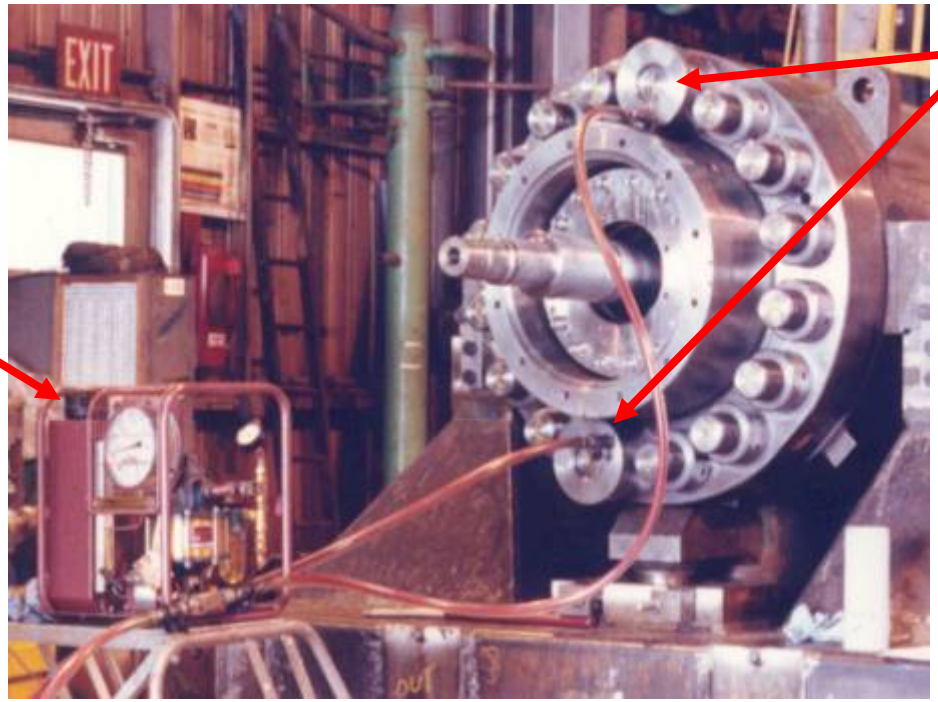
- proven codes provide high reliability
- hydro test (1.5 x or 1.3 x p_D) of each pressure casing provides high safety

HPT Boiler Feed Pumps
Tightening of Delivery Cover Studs

SULZER

Sulzer Pumps

Air operated hydraulic oil pump



Hydraulic jacks

Advantages:

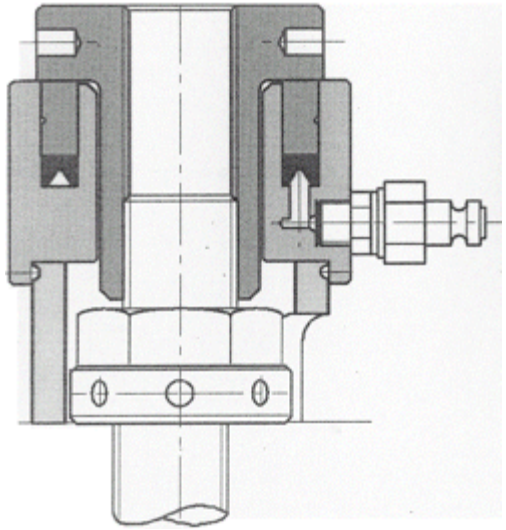
- accurate tensioning to required pre-load
- fast cartridge change

HPT Boiler Feed Pumps
Case Bolt Tensioning Tool

SULZER

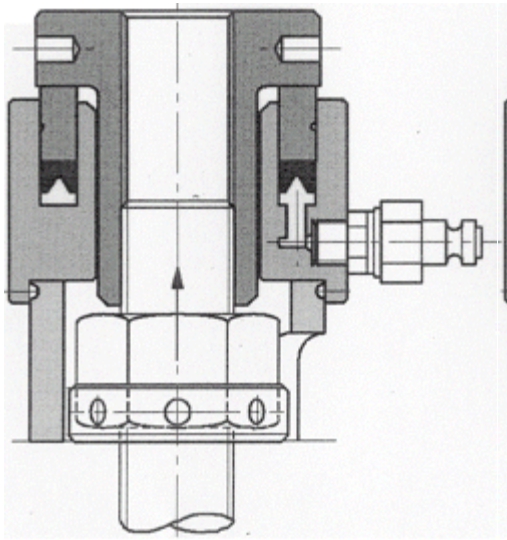
Sulzer Pumps

Stage 1



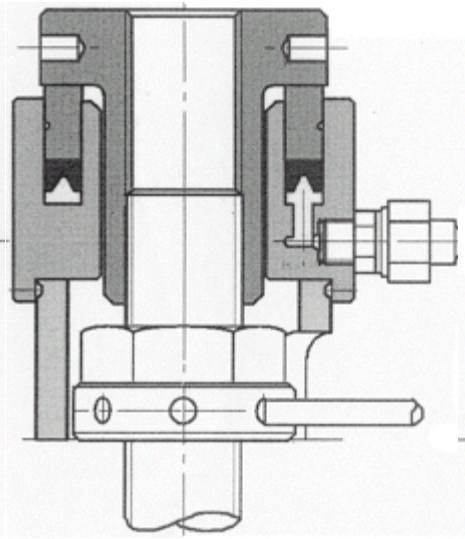
Set Up Tensioning Tool

Stage 2



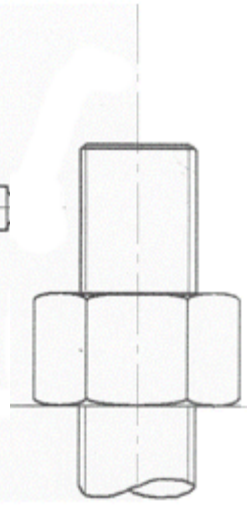
Tighten Stud Bolt

Stage 3



Turn Nut

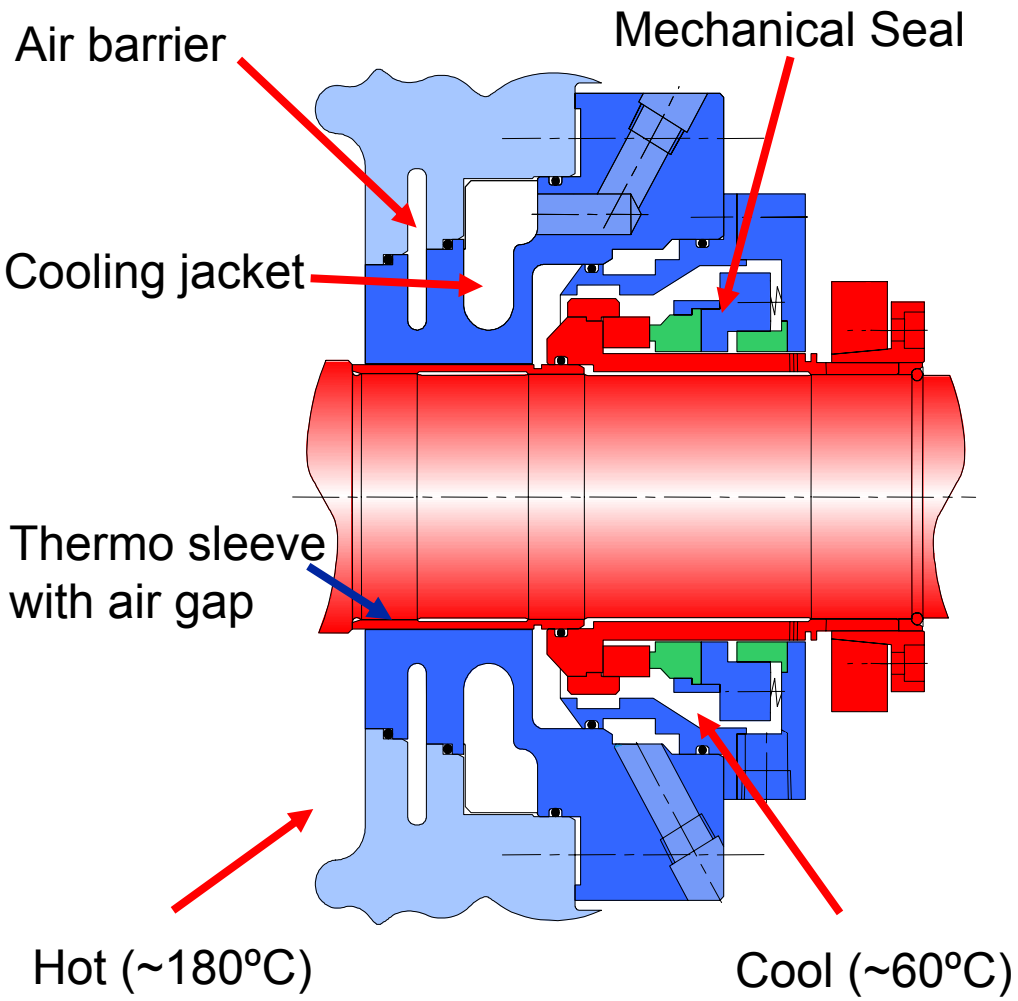
Stage 4



Release Tensioning Tool

HPT Boiler Feed Pumps
Mechanical Sealing

Shaft seal with single mechanical seal



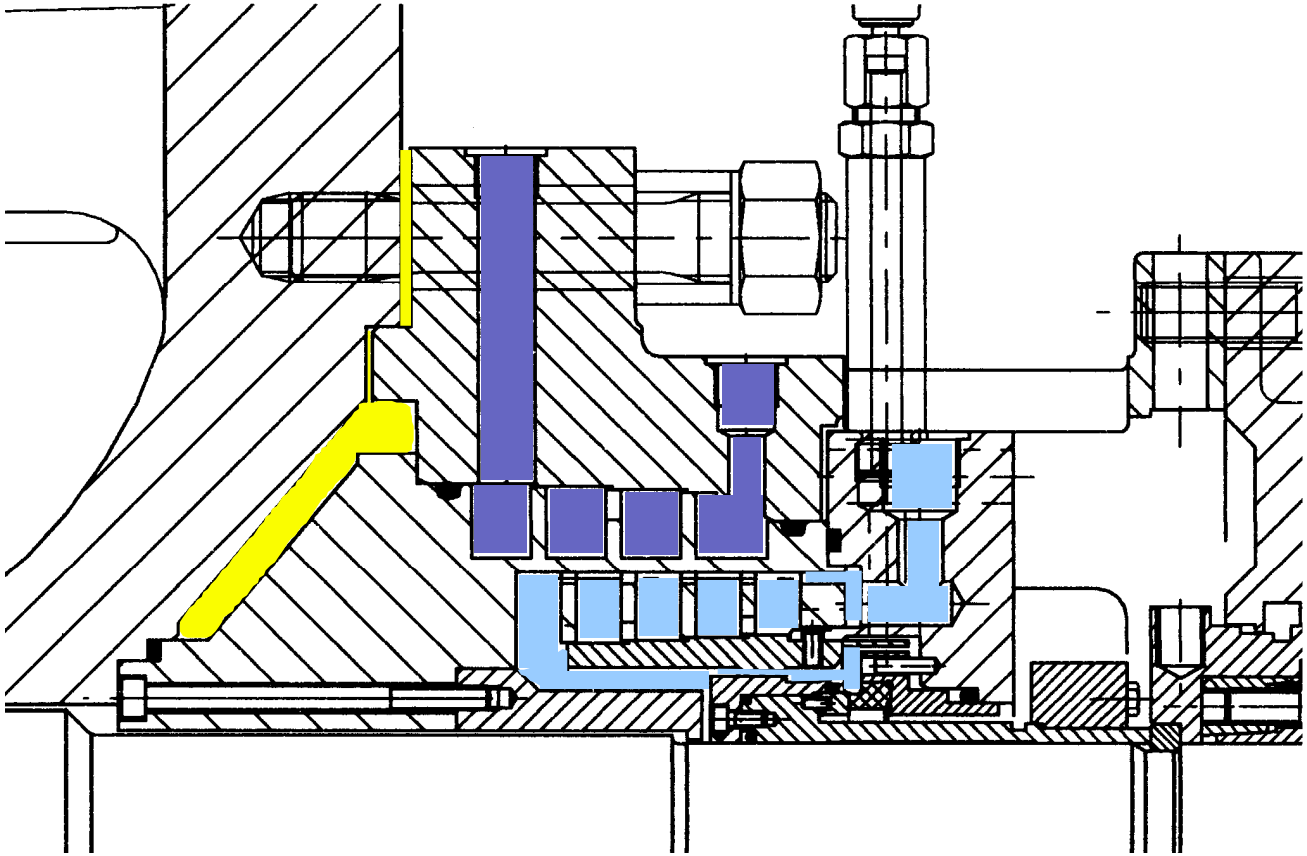
Advantages:

- High pump efficiency
- Air barrier and thermo sleeve insulates hot and cool area thus reduces thermal stratification. Avoids shaft bending due to thermal stratification
- Cooling jacket keeps elastomer seals cool during stand still

HPT Boiler Feed Pumps
Mechanical Sealing with Integral Cooler

SULZER

Sulzer Pumps



Air- filled gaps

Avoids the heat transfer coming from hydraulic pump parts to the sealing area

Cooling water

Decreases the temperature in the seal chamber.

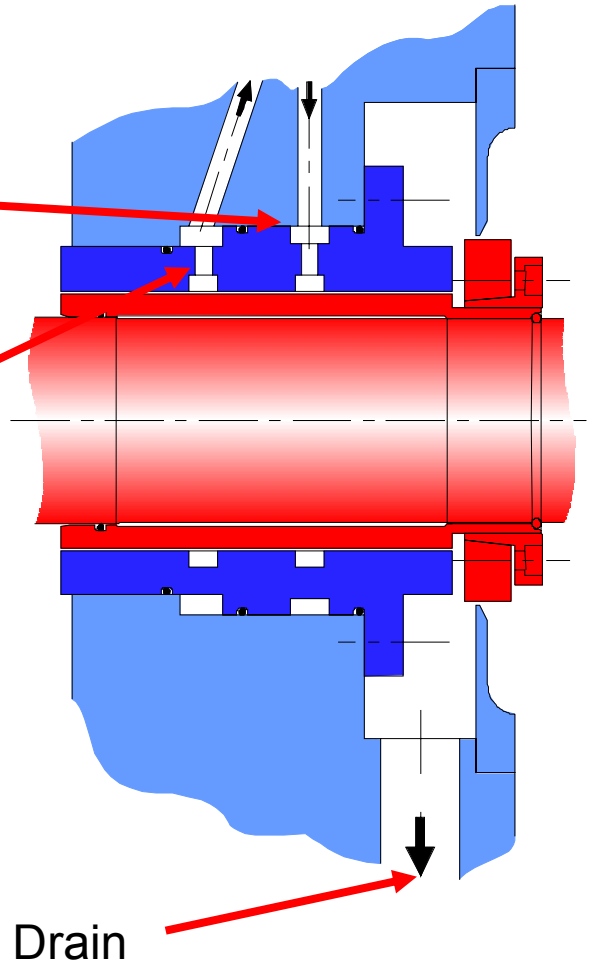
Hot seal water

Circulation produced by rotating part of the seal drives.

HPT Boiler Feed Pumps
Fixed Throttle Bushing

Cold condensate injection

Bleed-off for high suction pressures, without bleed-off for low suction pressures



Advantages:

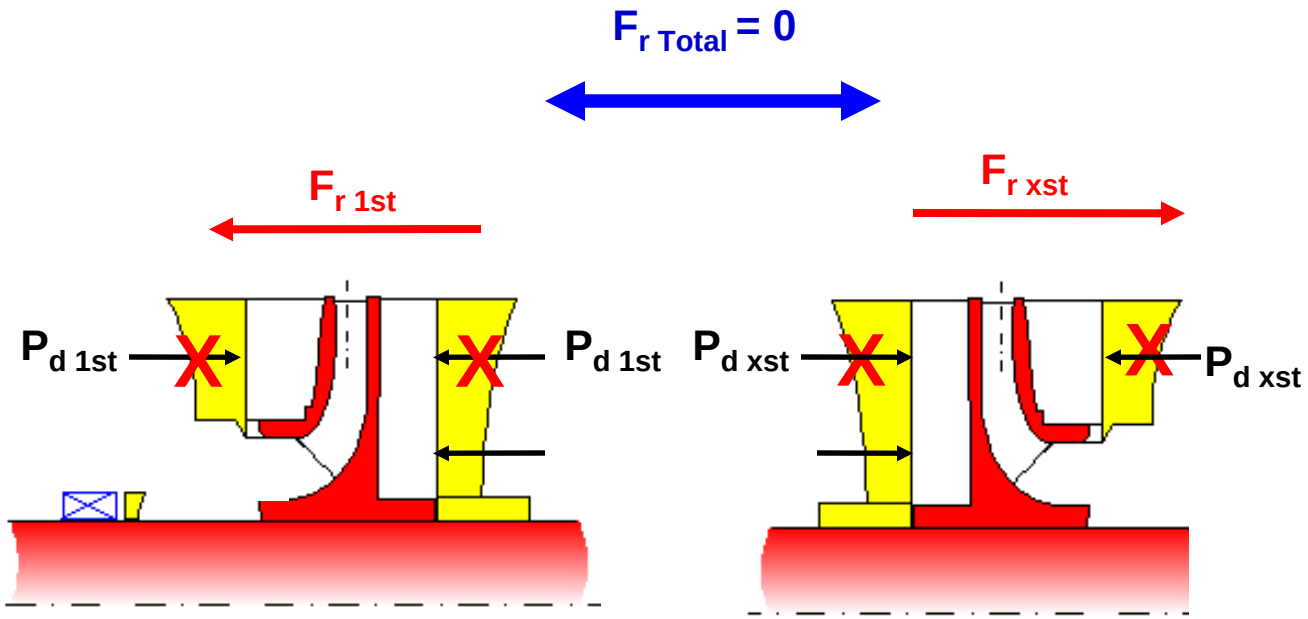
- simple design
- reliable
- temperature or differential temperature control avoids influx of cold water during stand still, hence avoiding thermally induced rotor bending

Disadvantages:

- lower efficiency (~2%)
- large leakage (50 gpm)
- risk of cold water entering pump (with pressure control)
- depends on CE availability
- auxiliary injection pump required during shutdown of CE pump

Axial Thrust Development

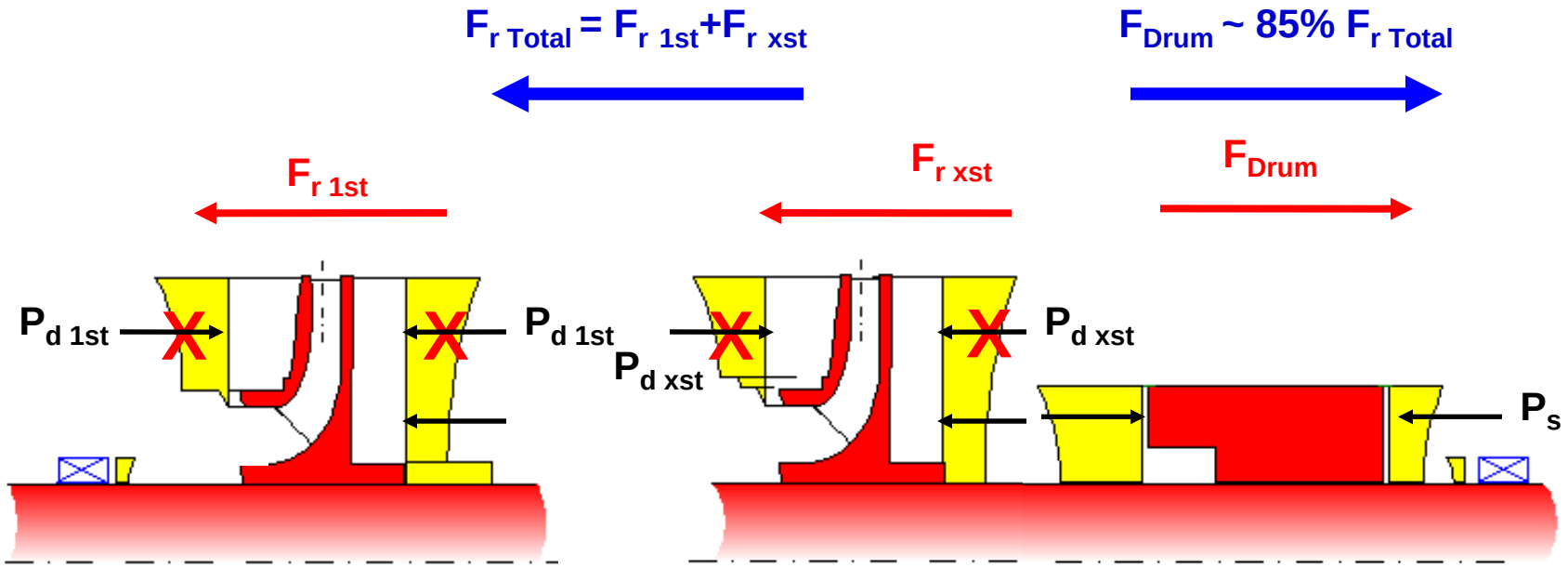
Opposed Impeller Design



- Unbalanced pressure distribution on impellers results in a force termed thrust in the direction of suction.
- Opposed impeller design offsets the unbalanced pressure distribution (thrust) effectively completely balancing axial thrust. Since axial thrust is not completely balanced or when there are odd number of stages residual thrust is handled by a thrust bearing.

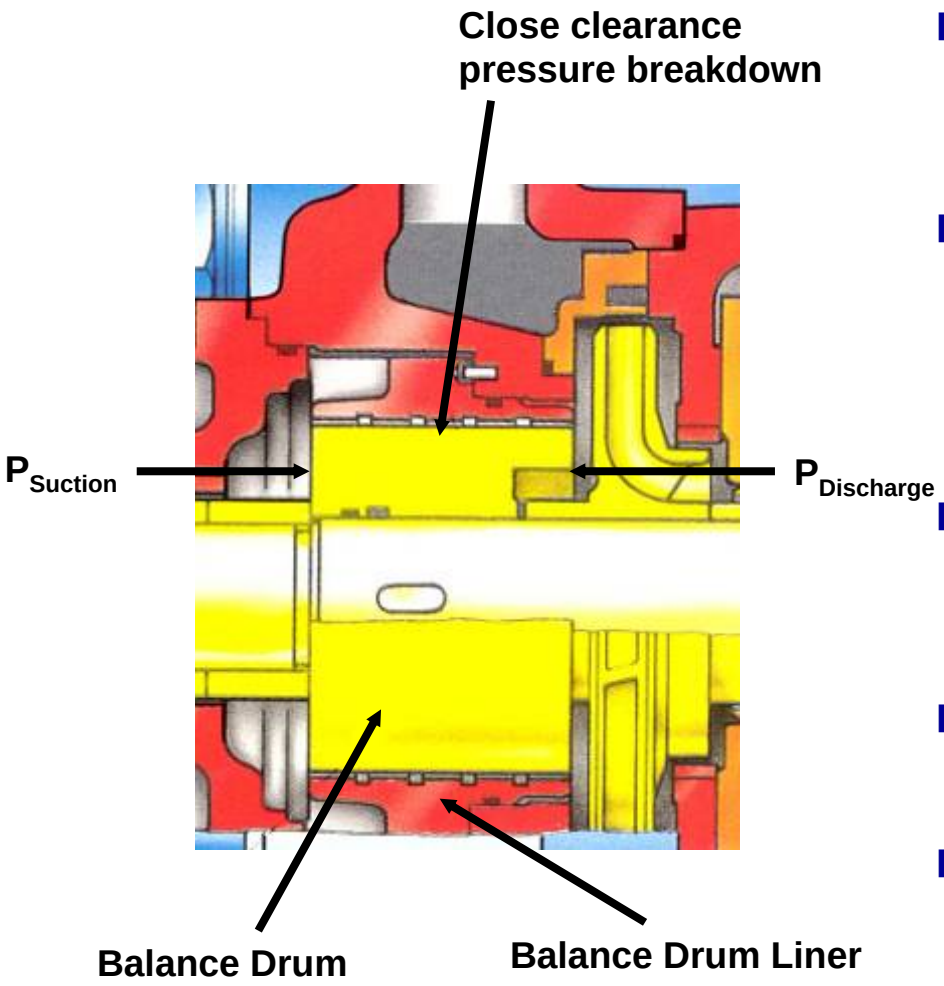
Axial Thrust Development

Stacked Impeller Design



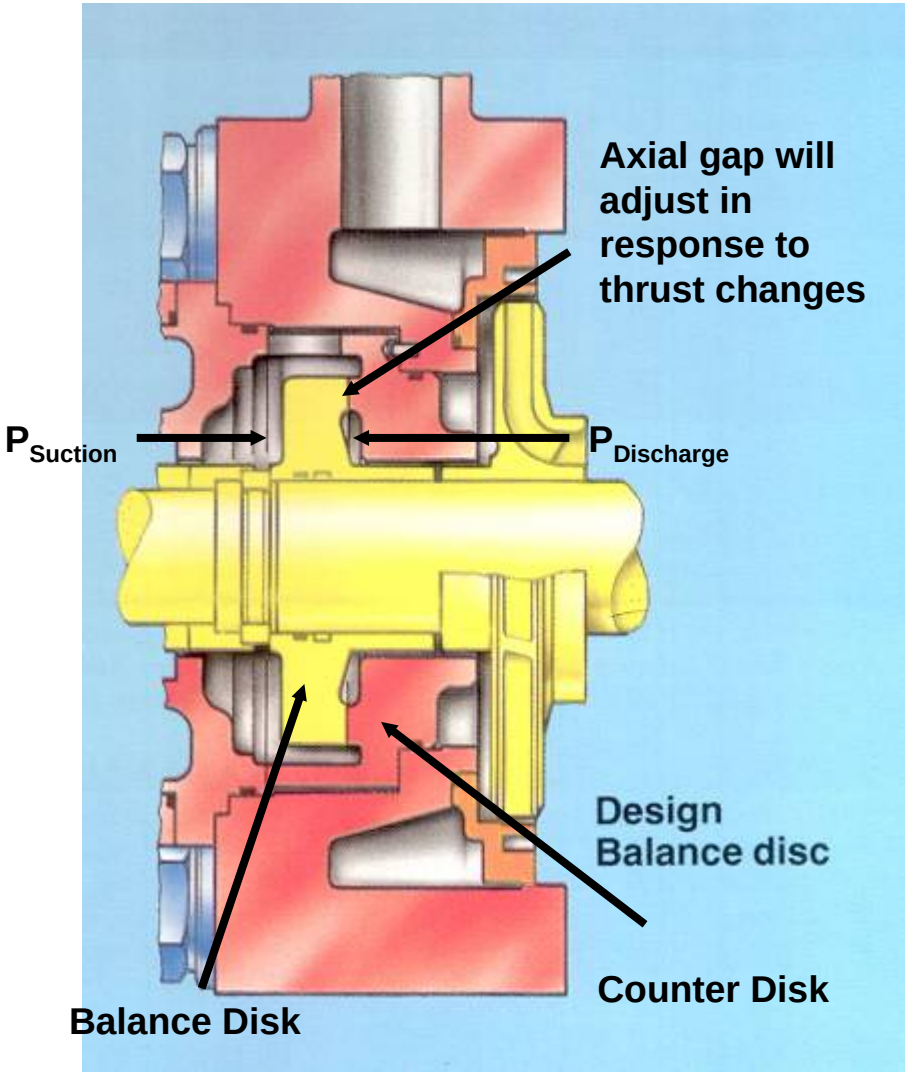
- Unbalanced pressure distribution on impellers results in a force termed thrust in the direction of suction.
- Stacked impeller design results in adding of (thrust) in the direction of suction.
- Developed thrust must be compensated by a hydraulic balancing device. Residual thrust is handled by a thrust bearing.

Axial Thrust Compensation – Balance Drum



- Balances 85 - 90% of generated thrust. Residual thrust handled by a thrust bearing.
- Most reliable design for transient conditions (start up and run down, quick temperature changes, daily starts and stops).
- Easy and safe axial rotor setting because of the radial gap as compared to axial sealing.
- Rotor is fixed in the axially position.
- Higher amount of leakage - less efficient.

Axial Thrust Compensation – Balance Disk



- Balances 100% of the generated thrust.
- No thrust bearing required.
- Rotor floats axially for proper operation.
- Least amount of leakage - higher efficiency.
- Disk lift off device required for frequent starts and stops

Product Description
Axial Thrust Compensation

SULZER

Sulzer Pumps

According to EPRI Statistics [1)] :

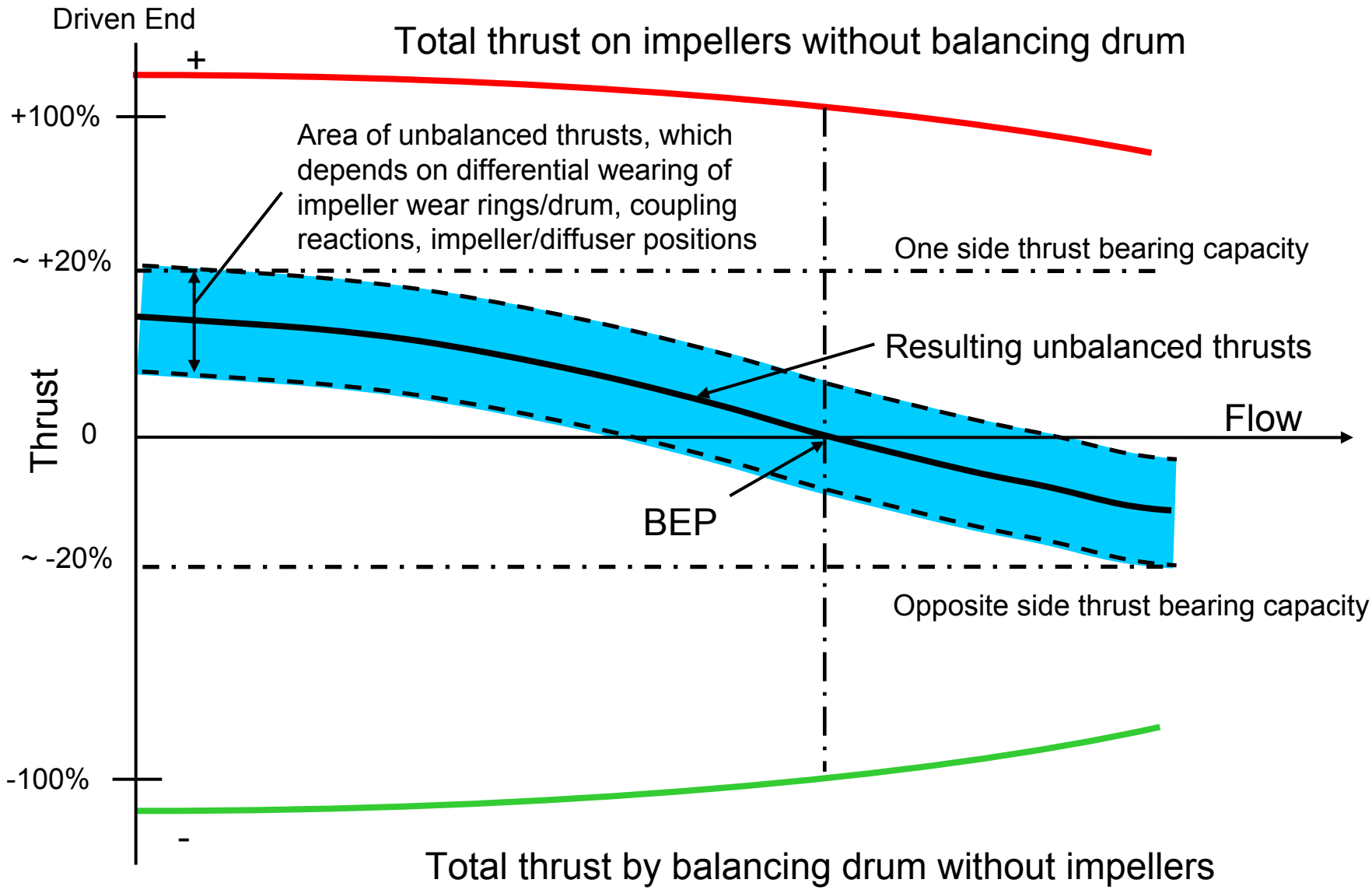
- **Out of 533 pumps balanced by disks, there were 310 failures (58%).**
- **Out of 511 pumps balanced by pistons, there were 27 failures. (5%)**
- **Balance disks are not suitable for DSS-operation. (daily start & stop)**

1) E. Makay, O.Szamody
Survey of Feed Pump Outages (EPRI FP-754)
Electric Research Institute, Palo Alto, California,
April 1978

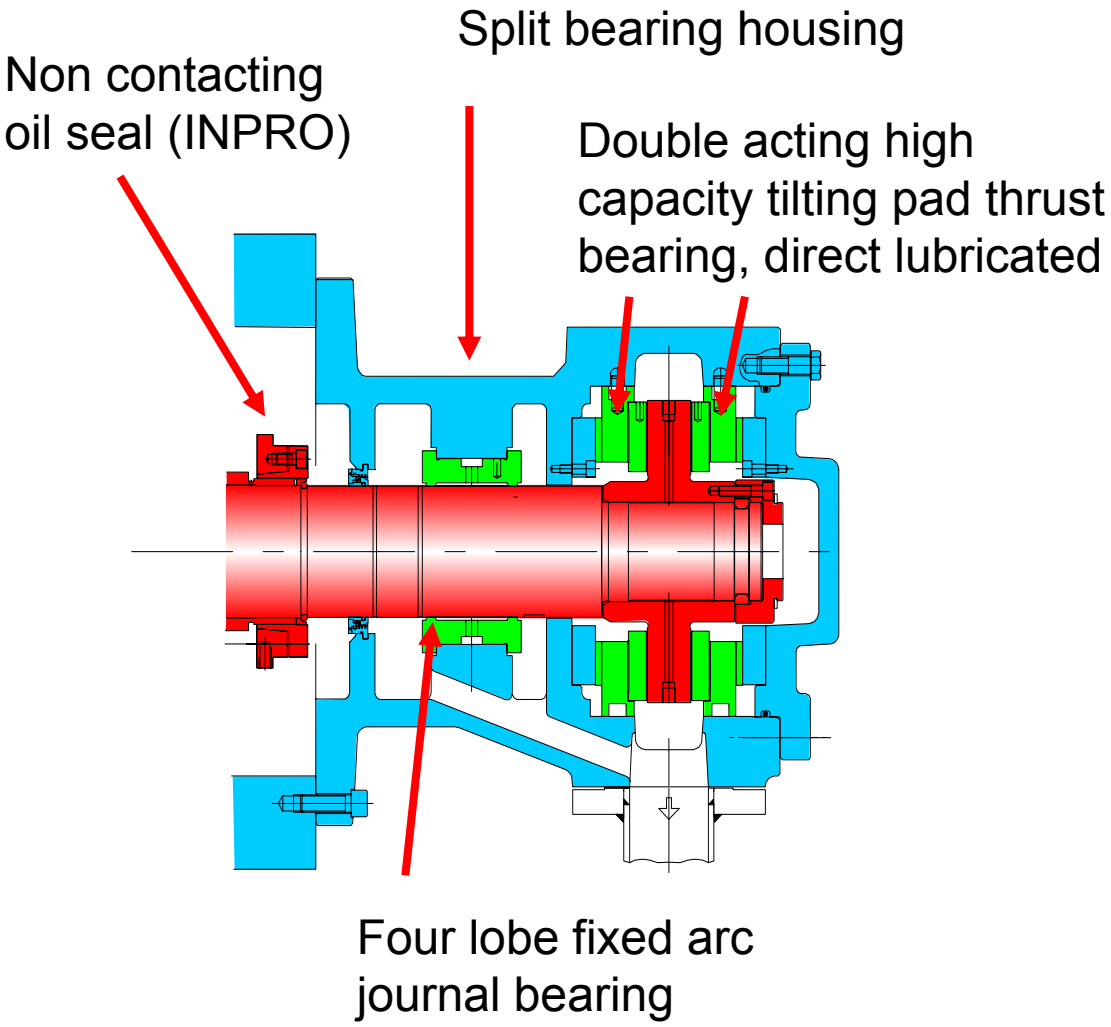
Product Description
Thrust Compensation Design

SULZER

Sulzer Pumps



HPT Boiler Feed Pumps
Journal and Thrust Bearing Arrangement



Advantages:

Thrust bearing
- low power loss
- high safety against overload

Journal bearing
- high damping
- good rotor stability

Oil seal
- provides positive oil seal to atmosphere

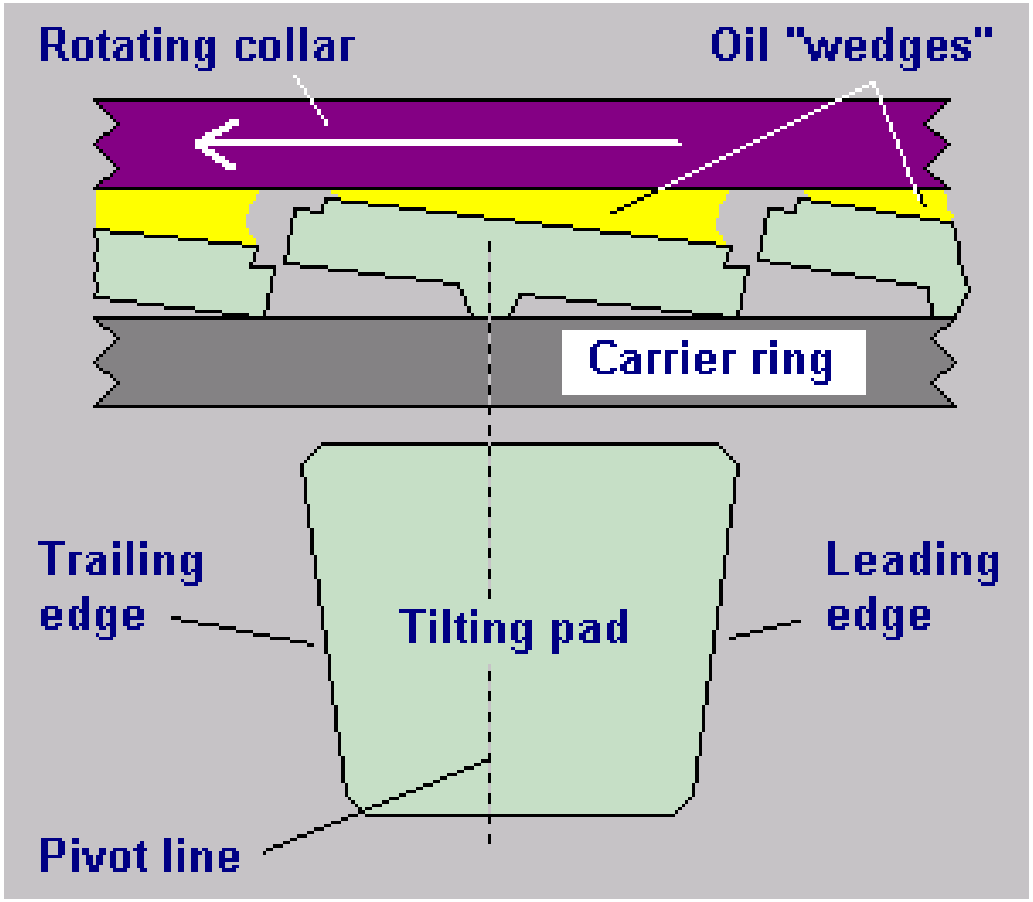
Split bearing housing
- allows bearing inspection without pump disassembly

Journal and Thrust Bearing Arrangement

Thrust Bearing Lubrication

A “wedge” of oil builds up between each stationary thrust pad and the rotating collar, and no metal-to-metal contact takes place during normal operation.

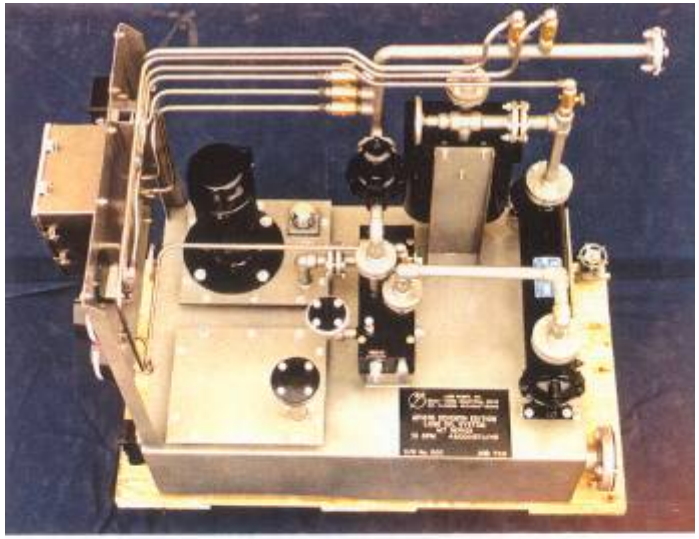
The white metal lining of the pads are designed to be tolerant of any minute particles of grit that may get through.

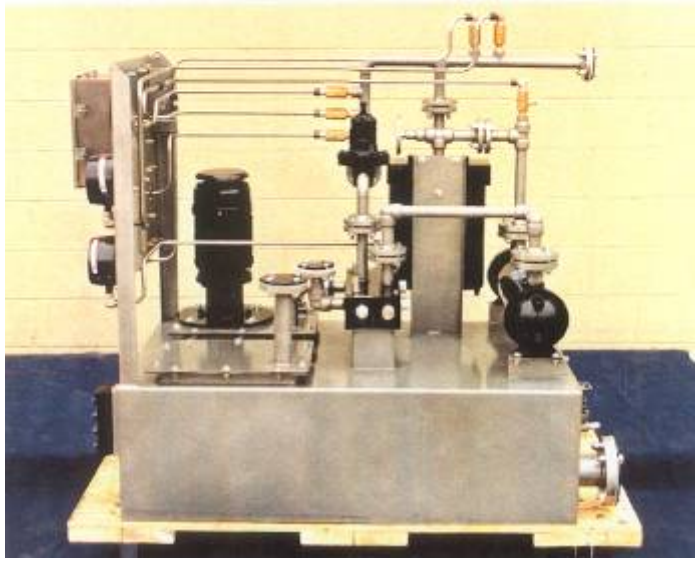


Journal and Thrust Bearing Arrangement

Double Acting Tilting Pad Thrust Bearing

Forced Oil Lube Systems

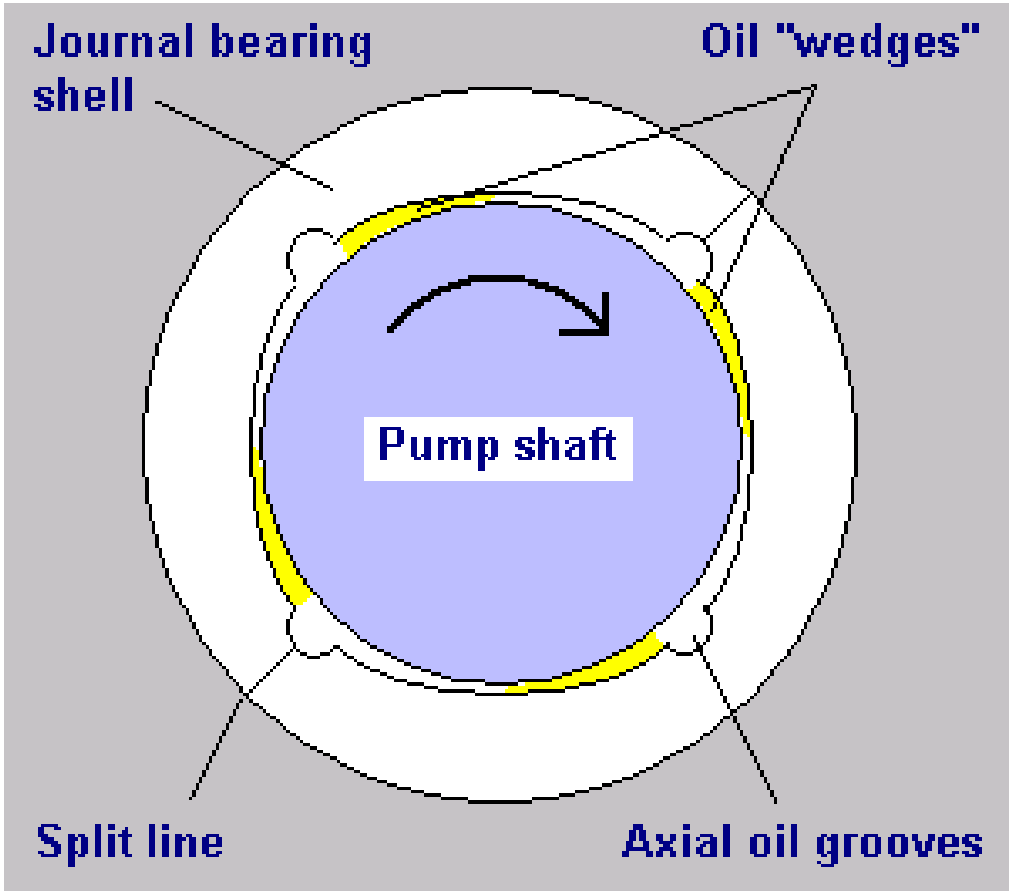




Journal and Thrust Bearing Arrangement

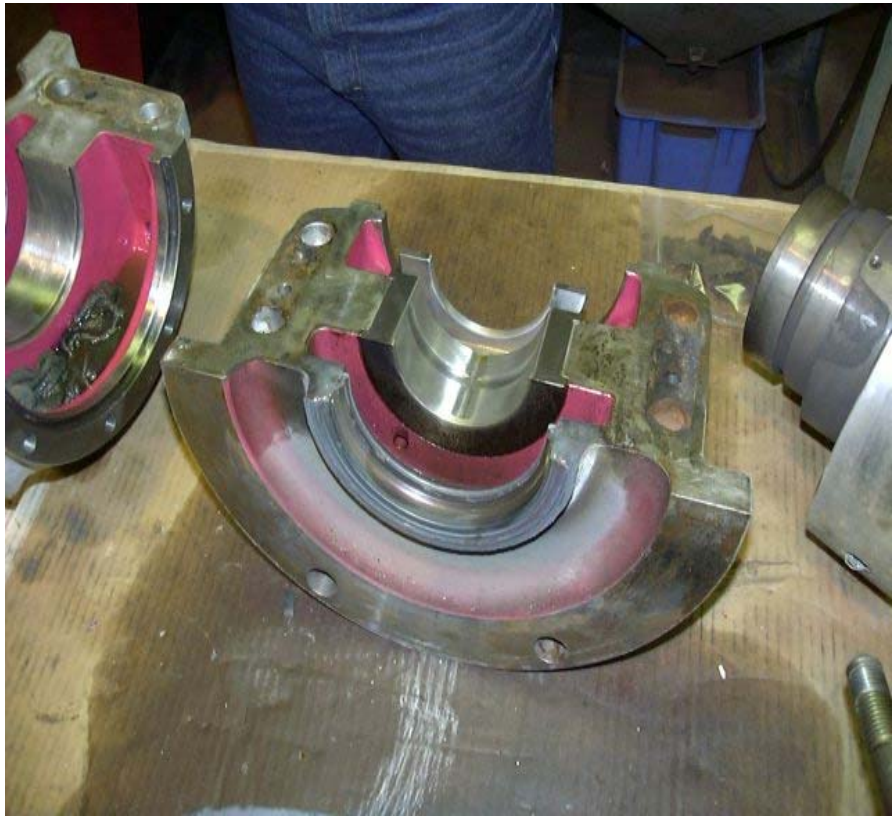
Journal or Radial Bearing Lubrication

During normal operation, “wedges” of oil build up between the shaft and the bearing surfaces, providing rotor dynamic stability, know as a hydrodynamic” effect.



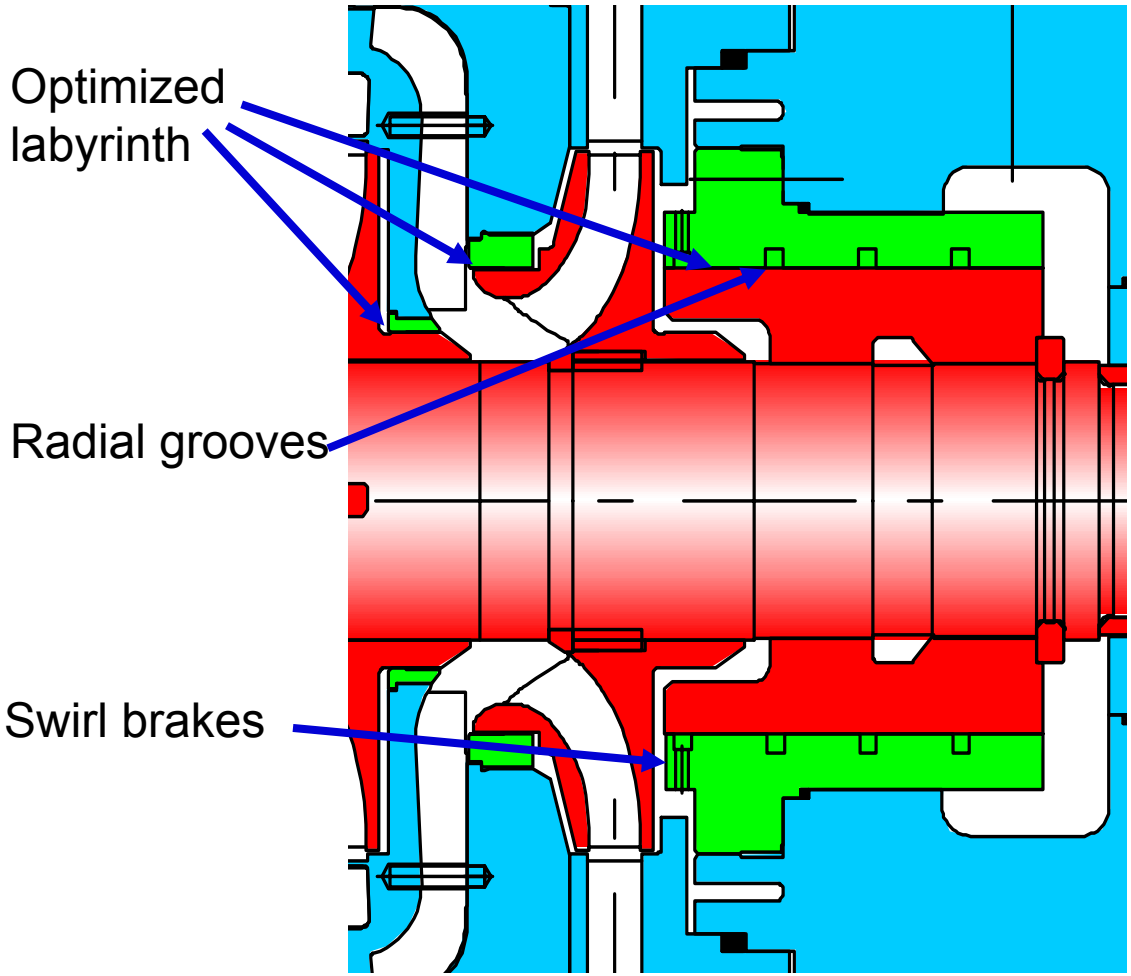
Journal and Thrust Bearing Arrangement

Sleeve Bearings



HPT Boiler Feed Pumps
Design of Close Running Clearances

Design of close running clearances



Advantages

Optimized labyrinth

- high efficiency
- good rotor dynamic behavior

Radial grooves

- increased radial stiffness
- reduced effect on rotor tilting
- good rotor dynamic behavior

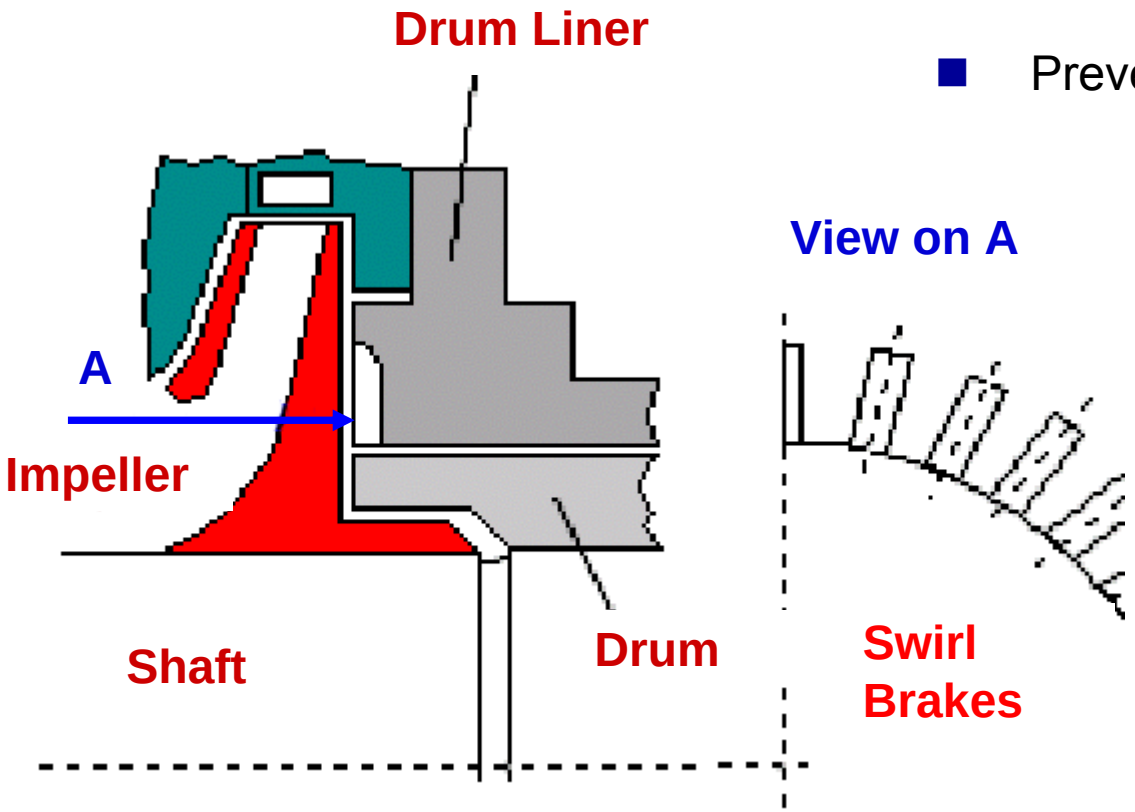
Swirl brakes

- high rotor stability even with worn clearances

HPT Boiler Feed Pumps
Swirl Breaks

Swirl Break Advantages:

- High rotor stability even with worn clearances
- Prevents pre-rotation of fluid



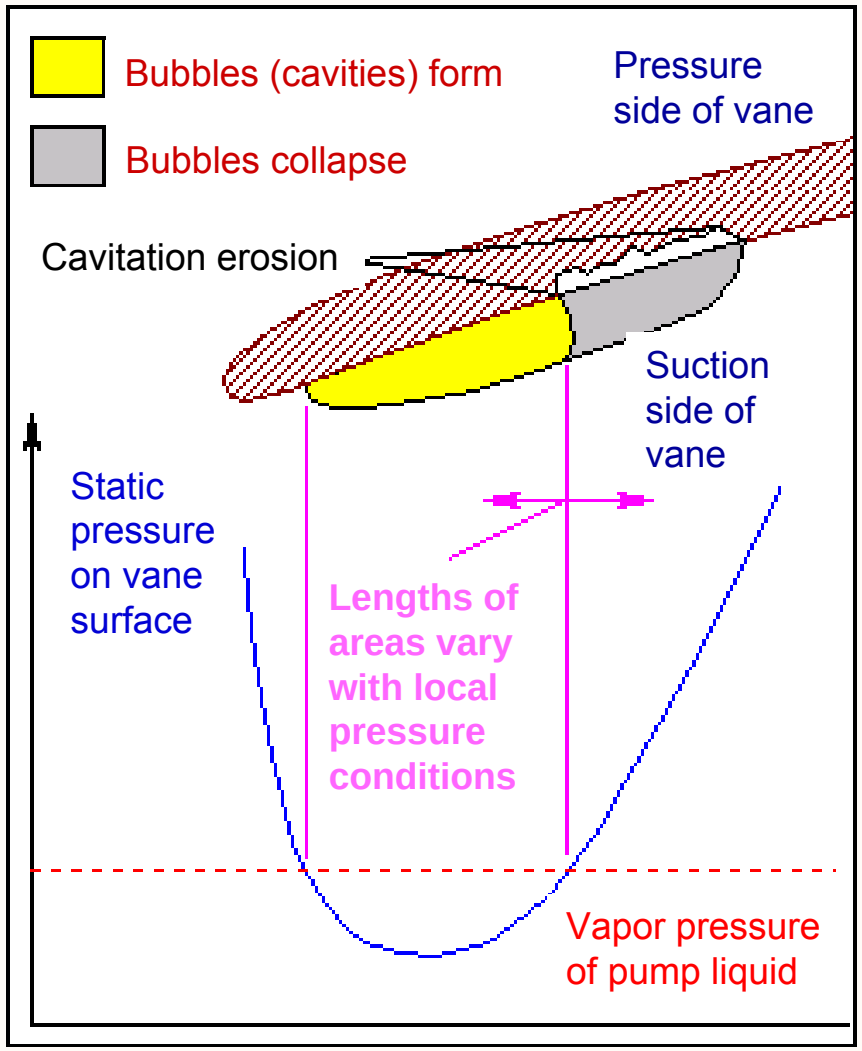
NPSH Considerations - Cavitation

The $NPSH_A$ must exceed the pump's $NPSH_R$ or the liquid will vaporize within the pump impeller. This vaporization of the liquid is called **cavitation**.

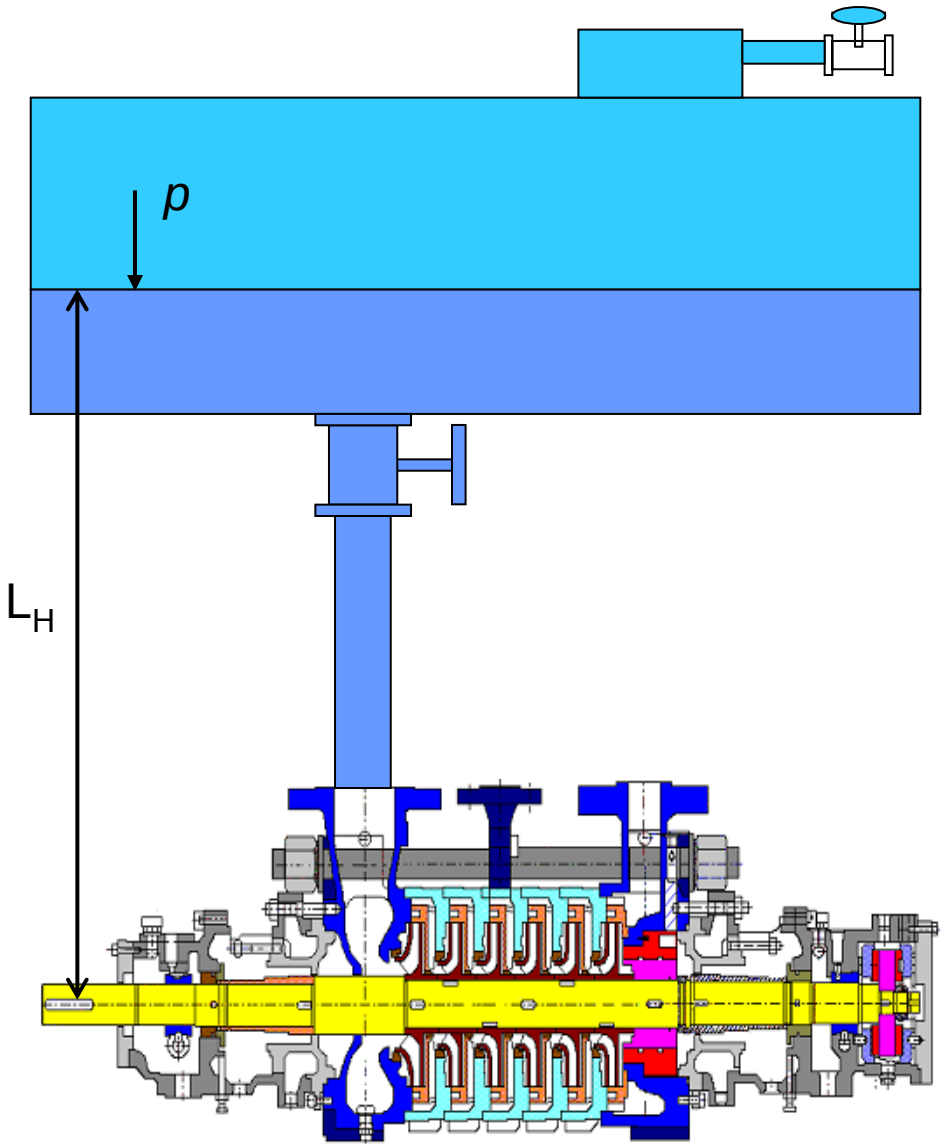
Cavitation can occur in many areas of the pump. The most common and significant is within the impeller.

In an area on the vane commencing a short distance form the vane tip, the static pressure can fall sharply, before rising again further along the vane.

If the local static pressure falls below the vapor pressure of the liquid being pumped, bubbles (cavities) form and travel along the vane. As soon as they reach an area of higher pressure, the bubbles collapse suddenly. **This is cavitation.**



NPSH Available – Closed Suction Supply with Head



NPSH available is a function of the system in which the pump operates. It is the excess pressure of the liquid over its vapor pressure as it arrives at the pump suction.

$$NPSH_A = p + L_H - (V_P + h_f)$$

Where:

p = pressure in suction vessel

L_H = static height of liquid in suction vessel to centerline pump

V_P = vapor pressure of liquid at pump suction

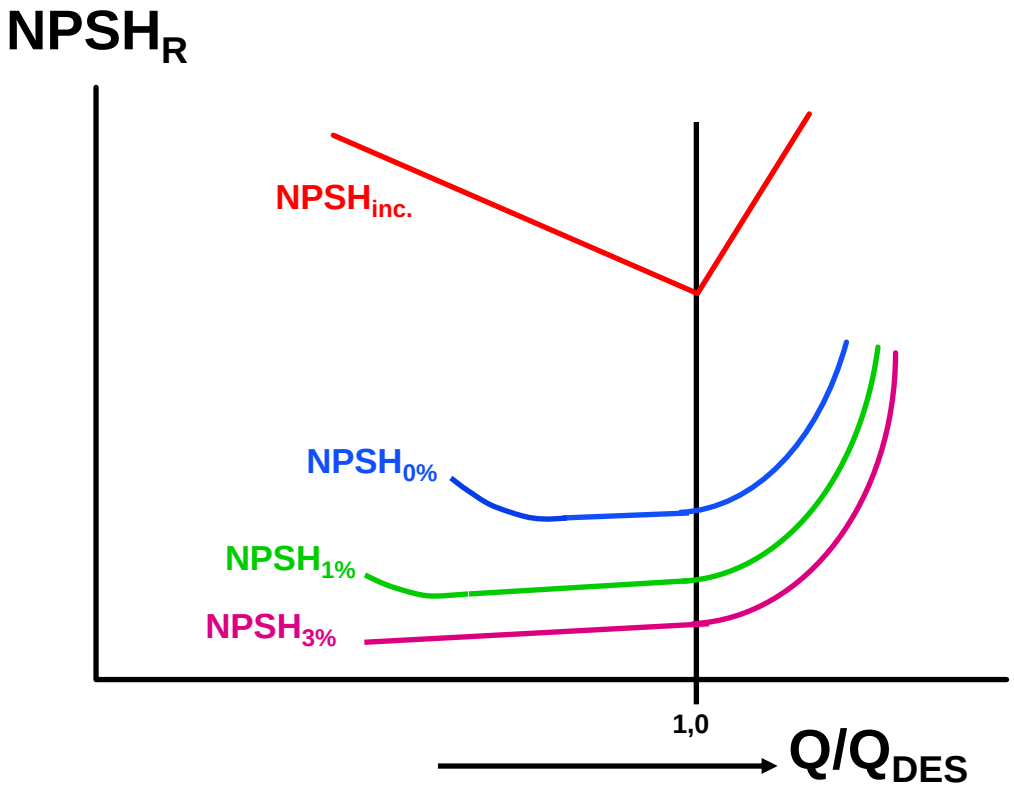
h_f = frictional losses of liquid in suction piping

NPSH Required

NPSH Required is physical design property of each pump. It is dependent on the design of the suction casing, impeller, capacities and speeds. In Boiler Feedwater applications the greater the margin between NPSH available to required the better the pump can handle suction transients occurances.

NPSH Required can be identified in various ways:

- Incipient cavitation
- Head decrease by a certain percentage (0%, 1%, 3%...)
- Efficiency loss by a certain amount
- Erosion of a specific material quantity in a unit of time
- Exceeding of a certain noise level
- Maintenance of a certain vibration level
- Collapse of the flow, i.e. total cavitation



NPSH Required

NPSH required is measured on the test stand by reducing the suction pressure and measuring discharge pressure.

Incipient values represent the very onslaught of bubble formation with no reduction in head.

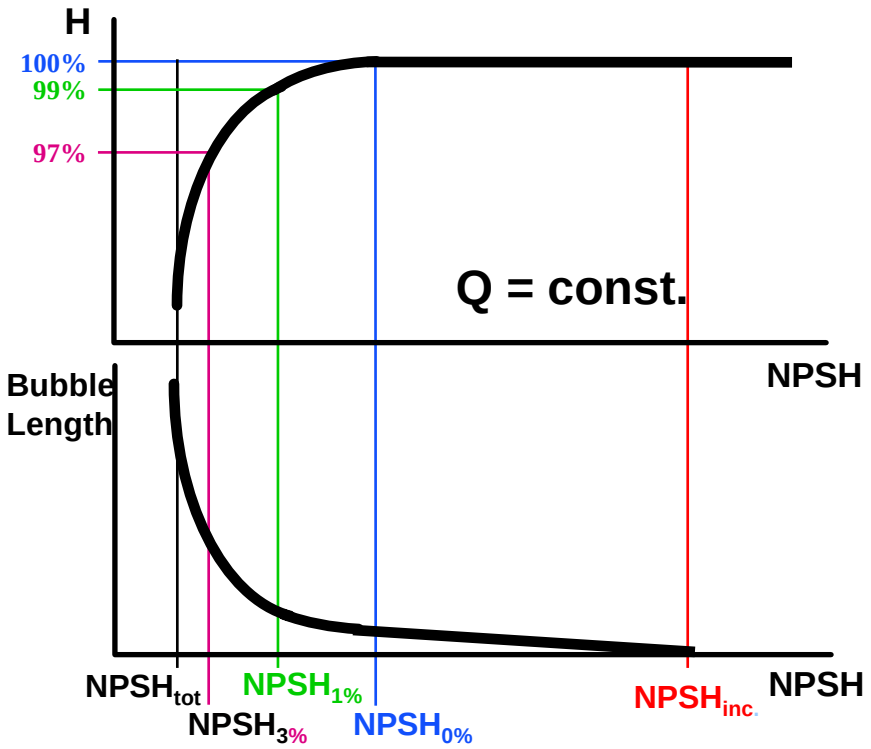
NPSH 0% values represent the beginning of bubble formation but with no reduction in head

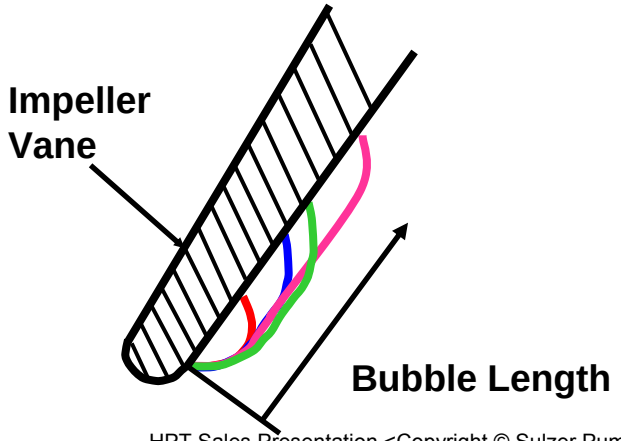
NPSH 1% values represent a larger and more bubbles with a reduction of discharge head of 1%.

NPSH 3% values represent increasing bubble size and amount with a reduction of discharge head of 3%.

NPSH tot represents a pump in full cavitation with a significant reduction in discharge head, heavy vibration and noise.

The point to note is that you do not want to operate a pump at or near the reported NPSH required value since this already represents a pump which is cavitating.



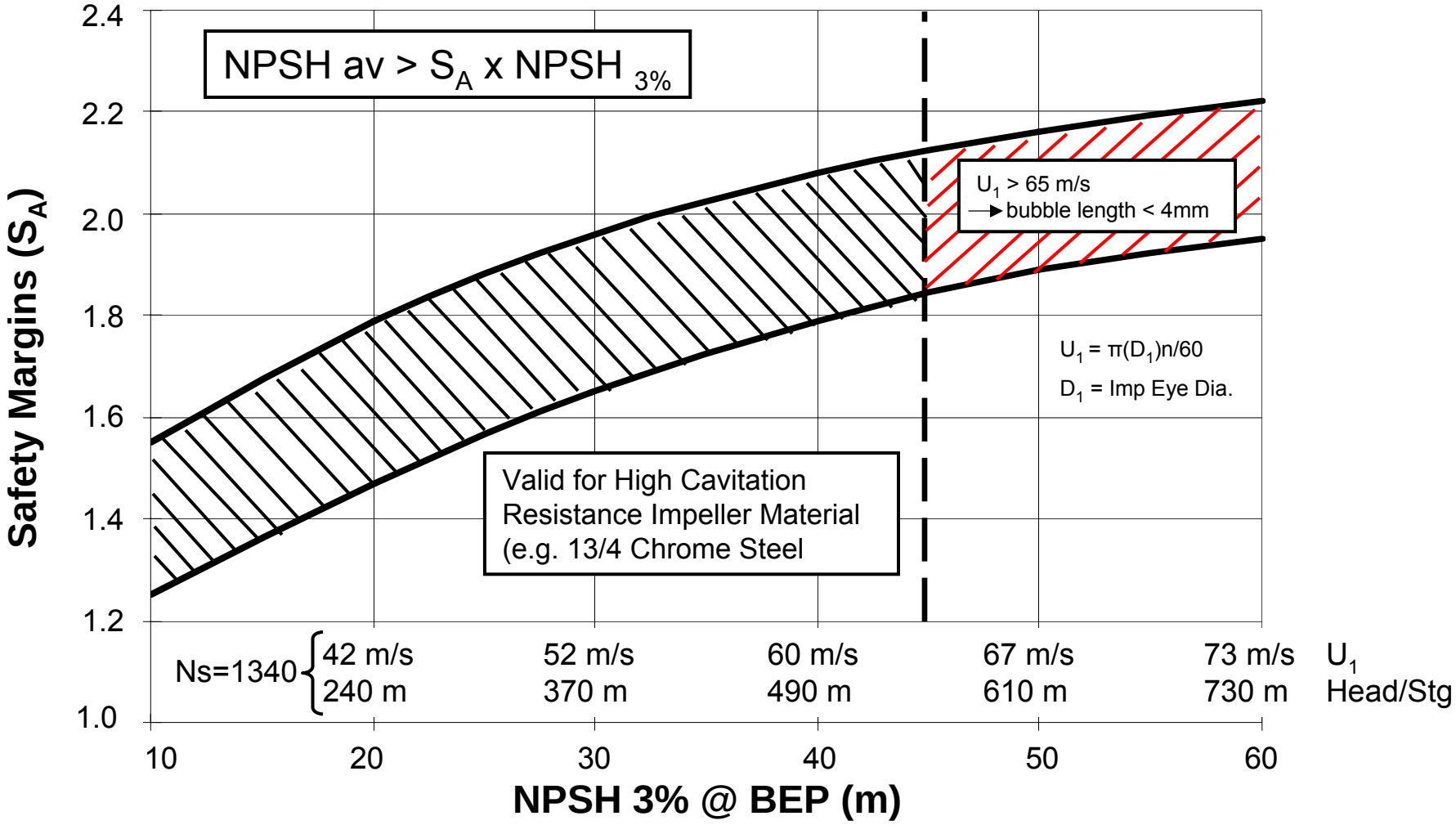


HPT Boiler Feed Pumps
NPSH Considerations

SULZER

Sulzer Pumps

Approximate Safety Margins for the Determination of NPSH Available (t = 170ºC – 190ºC)



HPT Boiler Feed Pumps
NPSH Considerations

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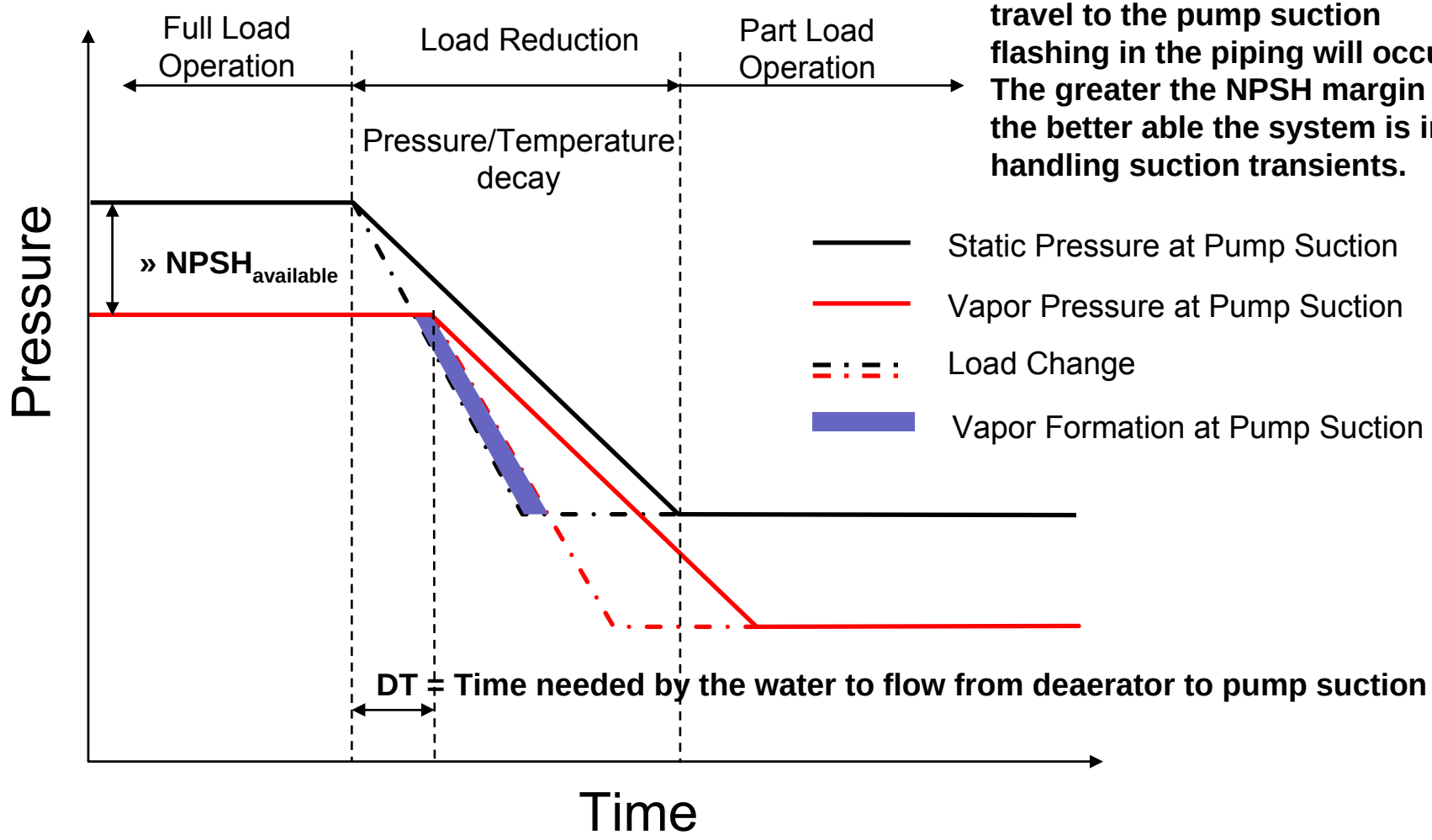
Sulzer Pumps

Common Transient Condition

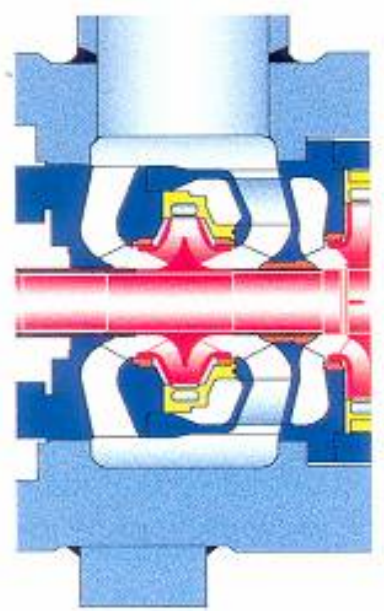


If the load reduction > NPSH margin and occurs in a time frame which is shorter than the time required for the liquid to travel to the pump suction flashing in the piping will occur. The greater the NPSH margin the better able the system is in handling suction transients.

HPT Boiler Feed Pumps
NPSH Considerations

Because of the high operating speeds the required NPSH is high and requires either a double suction first stage as a minimum or a separate booster pump.

A separate booster pump provides the ability to provide a high margin between available and required NPSH which helps during certain suction transient conditions.



Double suction impeller

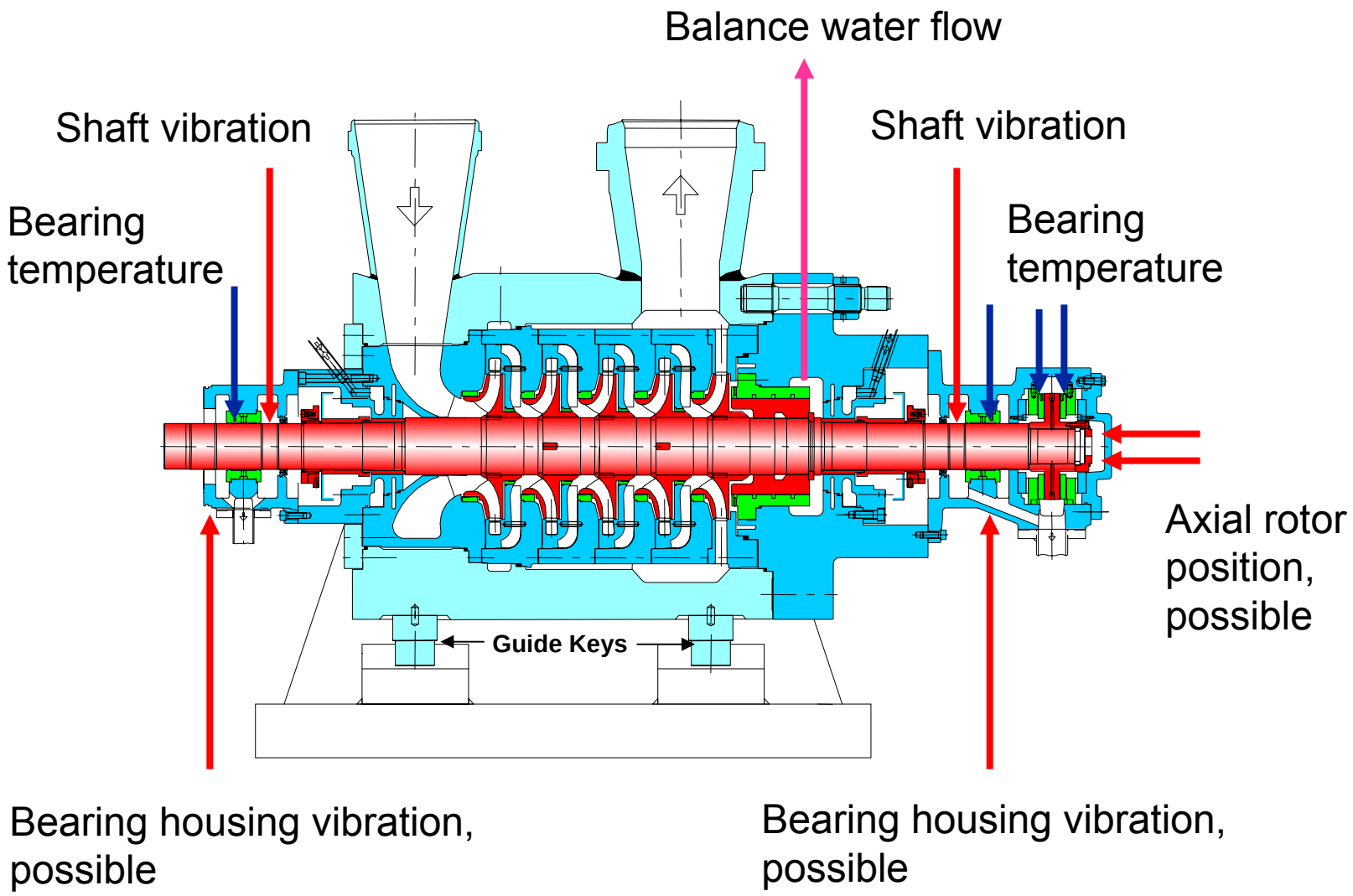
HPT Boiler Feed Pumps
Typical Materials

SULZER

Sulzer Pumps

Part	Material	Advantage
Barrel casing Delivery cover	10 Cr Mo 9 10, forged (A182 Gr F22)	■ high erosion resistance ■ good thermal transient properties
Impeller Diffuser Stage casing Suction casing	G - X 5 Cr Ni 13 4 (A743, Gr .CA-6MN)	■ high erosion resistance ■ good cavitation resistance
Shaft	X 4 Cr Ni 13 4 (A182 Gr F6MN)	■ high strength
Balance drum	X 20 Cr Ni 17 2 (A276 Type 431)	■ at least 50 HB hardness difference ■ high erosion resistance
Stationary wear parts	X 20 Cr Ni 17 2 (A276 Type 431)	
Stud	34 Cr Ni Mo 6 (A322 Gr 4340)	■ high strength
Static seals	Pure graphite	■ good pressure / thermal resilience

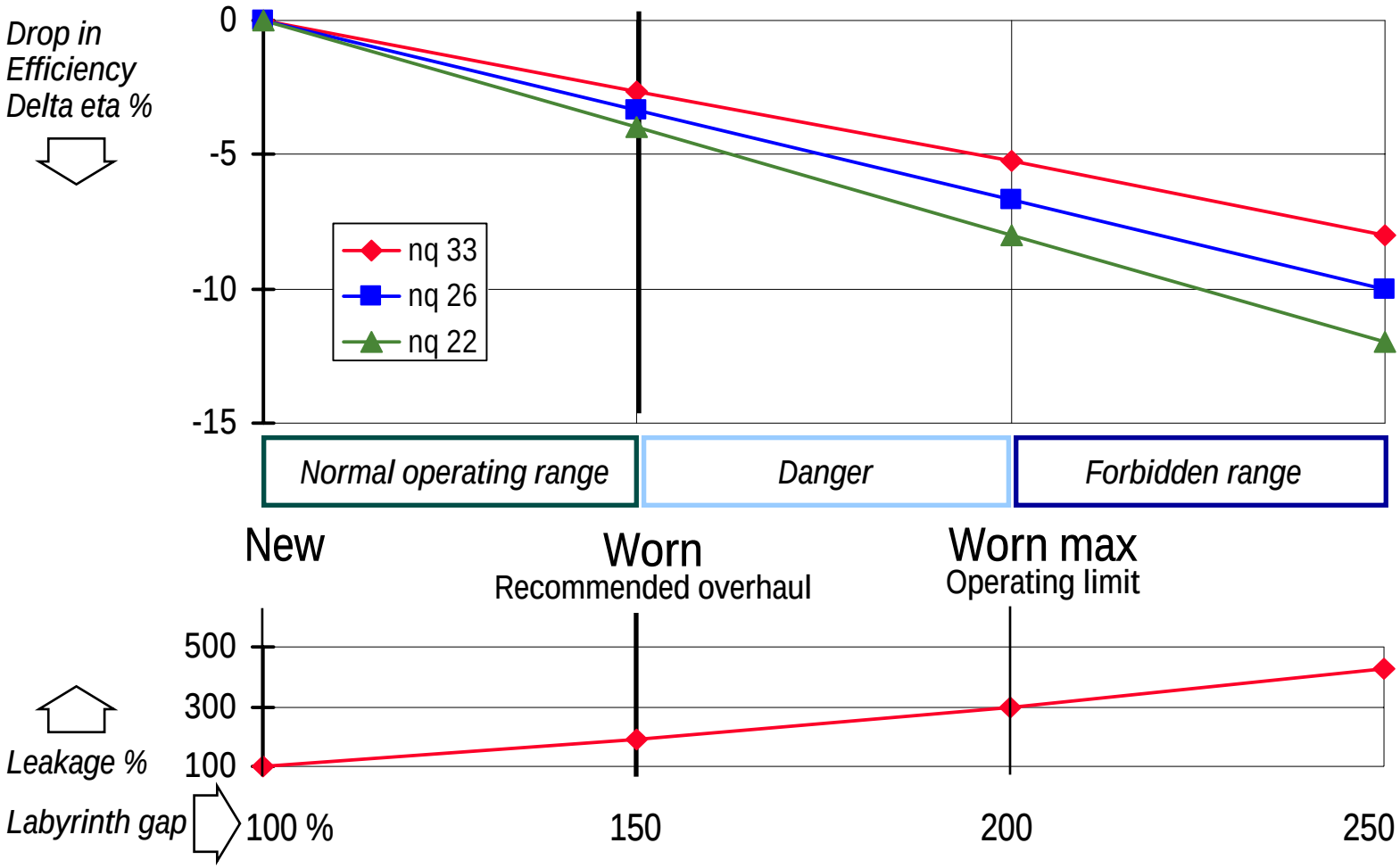
HPT Boiler Feed Pumps
Recommended Instrumentation



HPT Boiler Feed Pumps
Recommended Instrumentation

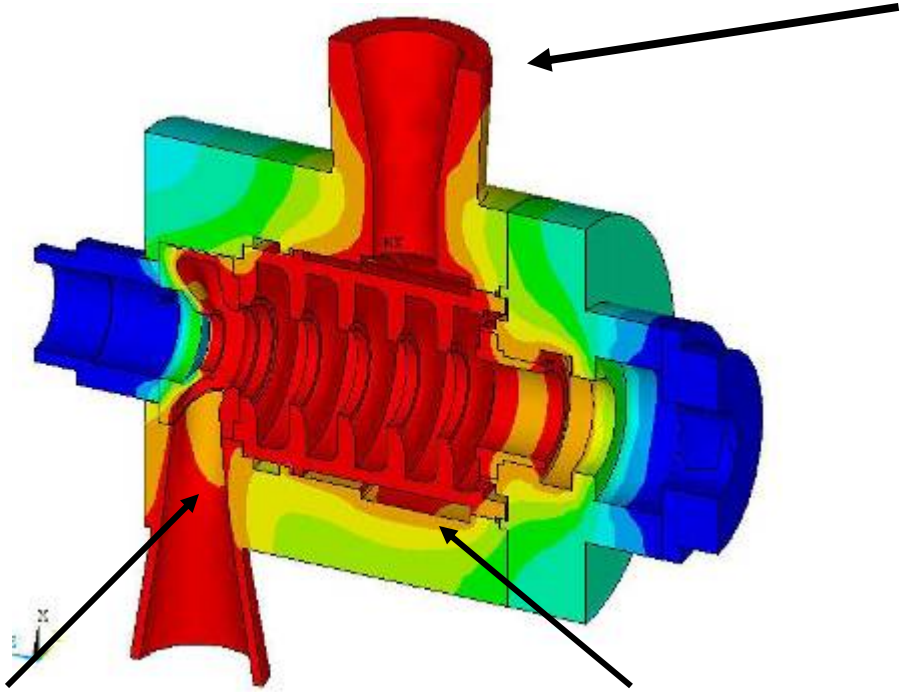
Drop in efficiency

Function of increased labyrinth gaps for different specific speed



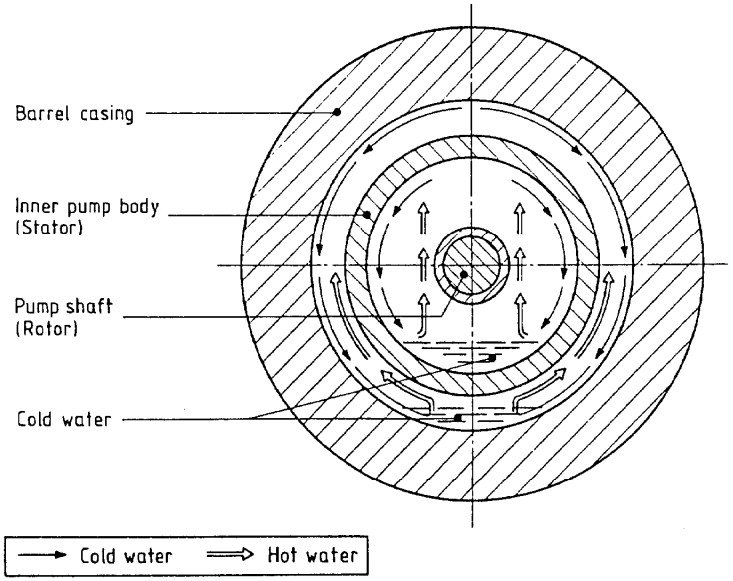
HPT Boiler Feed Pumps
Pre-Warming

Most Sulzer Diffuser Style Barrel Pumps do not require warm-up. On the very largest sizes, the warm-up flow back into the discharge surrounds the inner case, making warm-up faster and more uniform.

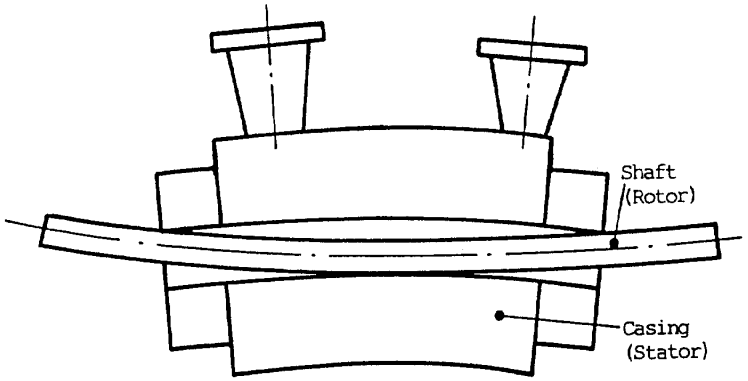


On some of those very largest sizes, additional warm-up flow is injected into the bottom of the suction chamber and barrel drain, as well as the discharge.

Typical Thermal Deformations

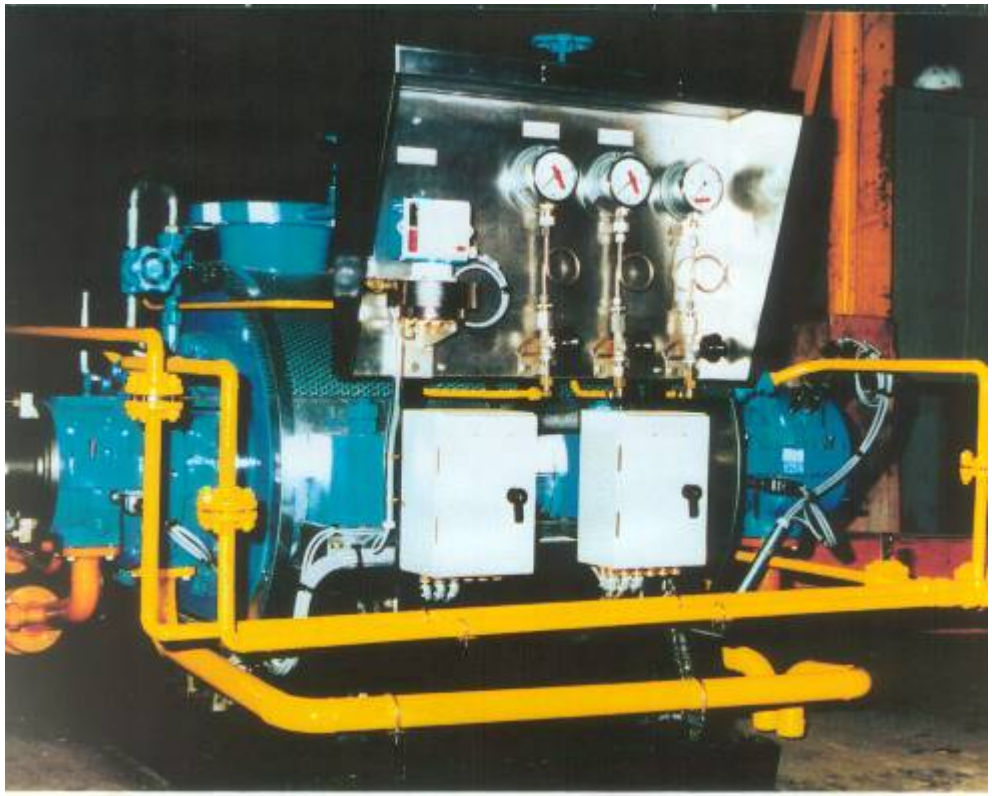


Section through a barrel type feedpump with thermally driven flows after shut-down



Thermal deformations of shaft and casing after shut-down (shaft is shown turned by half a revolution)

HPT Boiler Feed Pumps
Pre-Warming



Asymmetrical Casing Insulation

Sulzer standard casing design provides insulation on the bottom half to retain heat. The top half casing has perforated metal cover but no insulation to let heat escape. The result is a more uniform temperature throughout the top and bottom of the casing which minimizes the thermal deformations.

HPT Boiler Feed Pumps
Speed Control

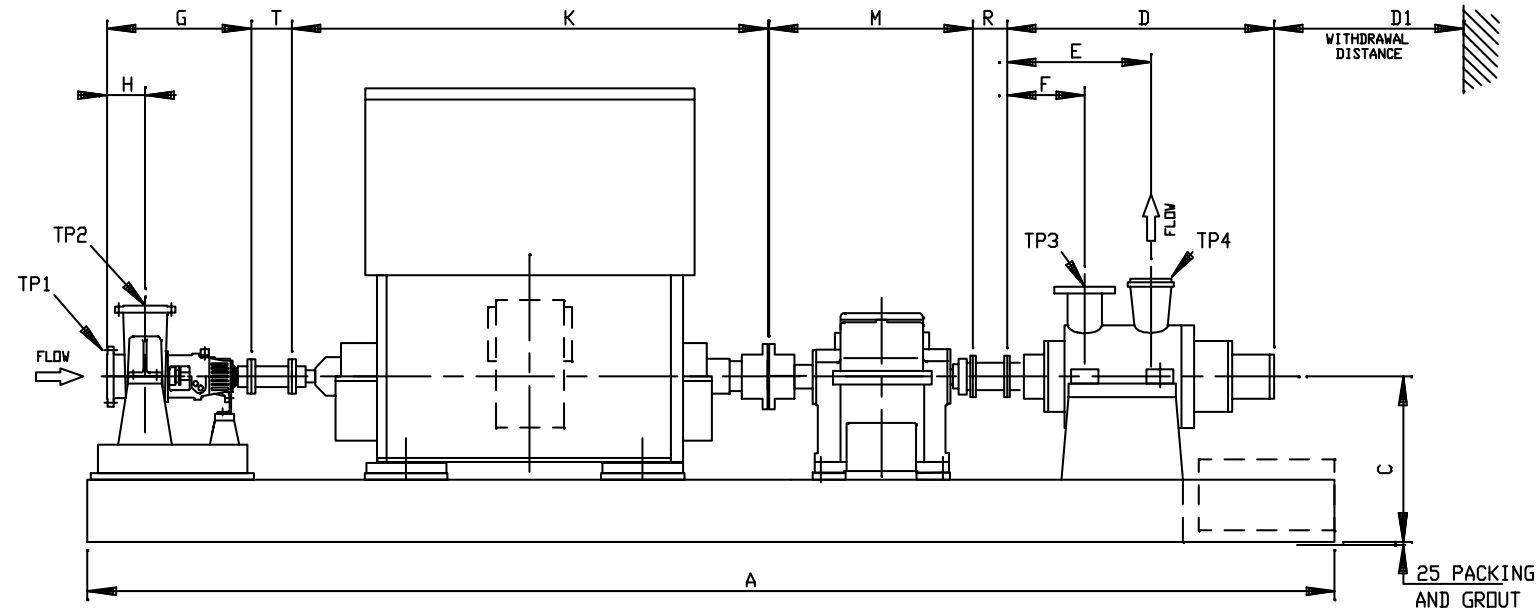
This type of pump is designed to operate at speeds above standard 2 pole motor speeds, typically 6000 rpm.

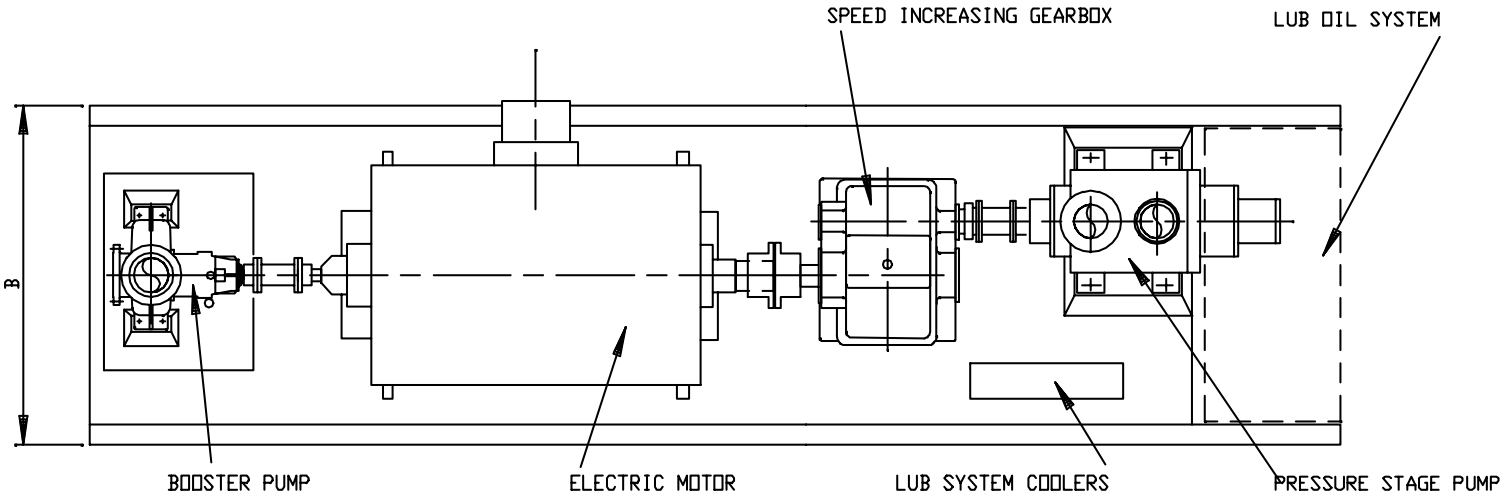
Typical speed control devices are:

- **Geared Fluid Coupling**
- **Fixed Speed Coupling**
- **Variable Frequency Drives (VFD)**
- **Steam Turbine**

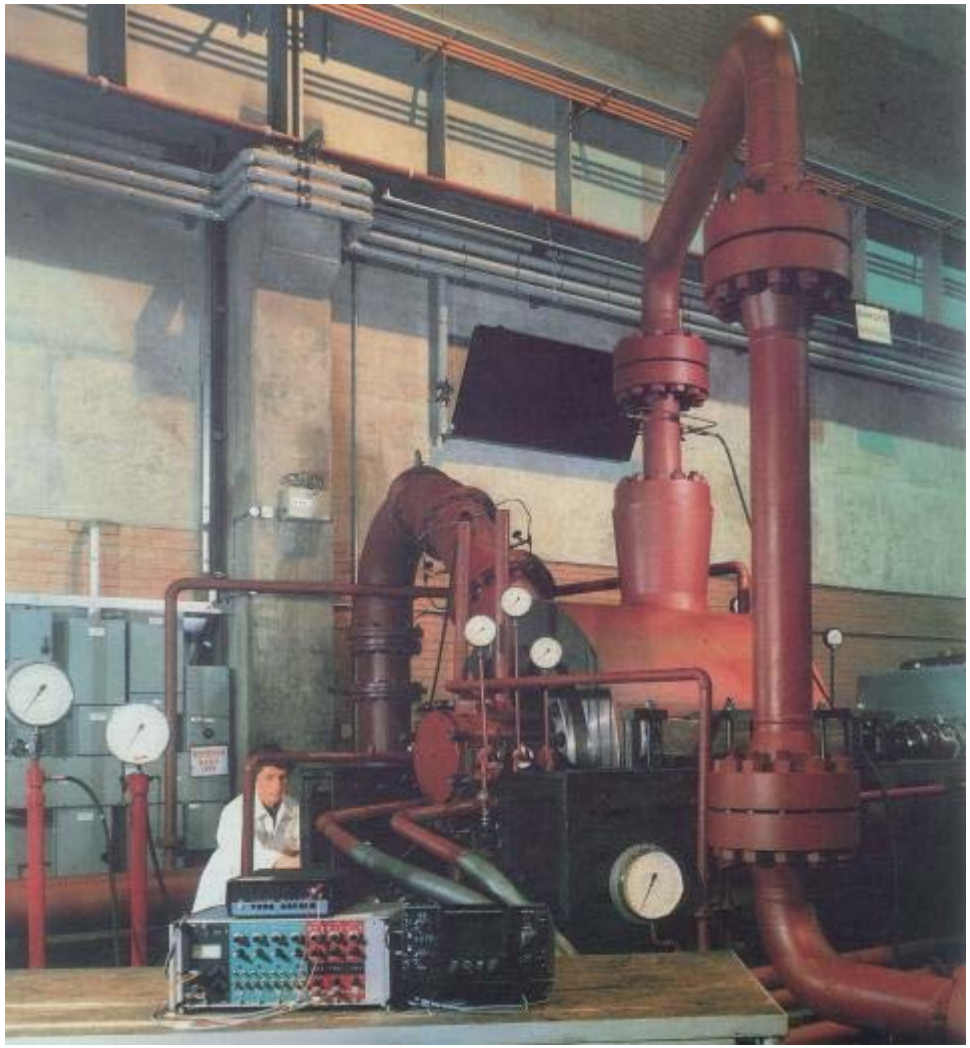
HPT Boiler Feed Pumps
Typical Layout

Sulzer Pumps





HPT Boiler Feed Pumps
Factory Acceptance Testing



Sulzer Leeds, UK Test Facility

- 10 MW Electric Motor at Full Speed
- Electric Capacity to 16 MW
- Speed Increasing Gearbox with Multiple Ratios
- 30 MW Gas Turbine Drive
- 365,000 Gallon Wet Sump, 30 Feet Deep
- 50 Ton Crane Capacity
- NPSH Testing
- Hot or Cold Testing

HPT Boiler Feed Pumps
Maintenance Inspection Frequency

SULZER

Sulzer Pumps

Typical HPT Maintenance Inspection Frequency

Operating Time		MEASUREMENTS							REPLACEMENTS				
		Without Disassembling				With Disassembling							
Hours	Years	Oil	Mech. Seal	Balance Line	Vibrations	Alignment	Bearings	Mech. Seal	Oil	Bearings	Mech. Seal	Balance Line	Wear Rings
2500		Analyze	Leakage	Leakage	Level								
5000	1		Leakage	Leakage	Level				18 months				
7500		Analyze	Leakage	Leakage	Level								
10000			Leakage	Leakage	Level								
12500	2	Analyze	Leakage	Leakage	Level				18 months				
15000				Leakage	Diagnostic	Check					Replace Faces		
17500		Analyze	Leakage	Leakage	Level								
20000	3		Leakage	Leakage	Level				18 months				
22500		Analyze	Leakage	Leakage	Level								
25000			Leakage	Leakage	Level								
27500	4	Analyze	Leakage	Leakage	Level				18 months				
30000				Leakage	Diagnostic	Check				Sleeve Bearings	Replace Faces		
32500		Analyze	Leakage	Leakage	Level								
35000	5		Leakage	Leakage	Level				18 months				
37500		Analyze	Leakage	Leakage	Level								
40000			Leakage	Leakage	Level								
42500	6	Analyze	Leakage	Leakage	Level				18 months				
45000					Diagnostic	Check	Check			Complete Cartridge Overhaul			