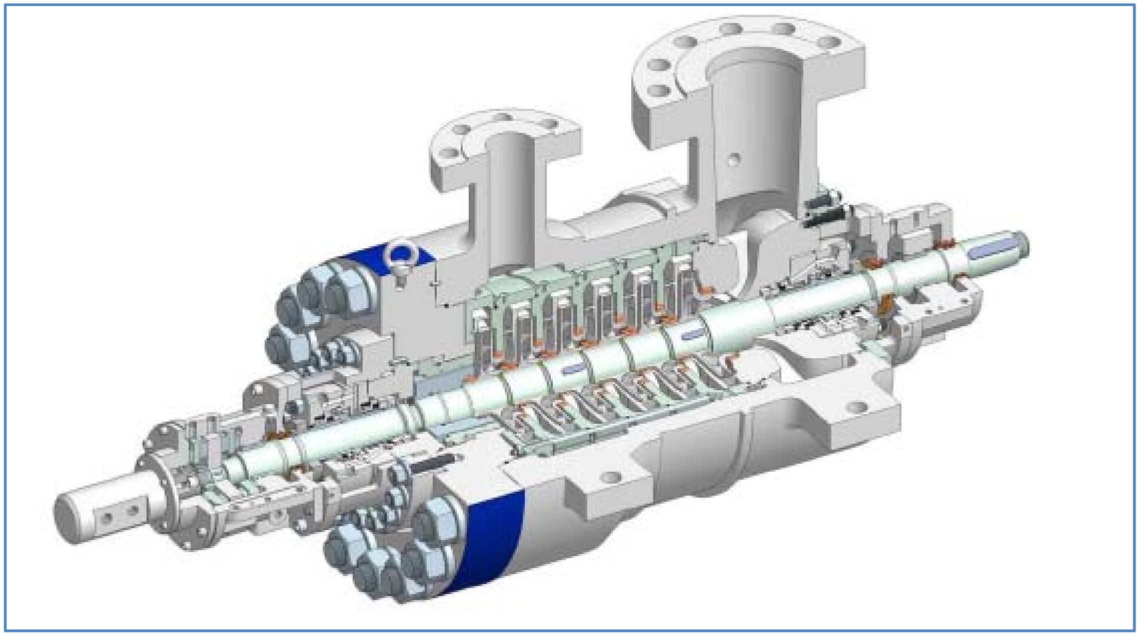
Boiler Feed Pump (BFP)– Review



Presentation By,
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Topics

- BFP – Introduction
- Cross Section of BFP (Typical)
- Typical Layout of BFP
- Water-Steam Cycle – Process Flow Diagram
- System Isometrci View of HP Feedwater (Typical)
- Pipe Isometric View of HP Feedwater (Typical)
- BFP Design Criteria
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- BFP – Transient Study
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BFP - Introduction

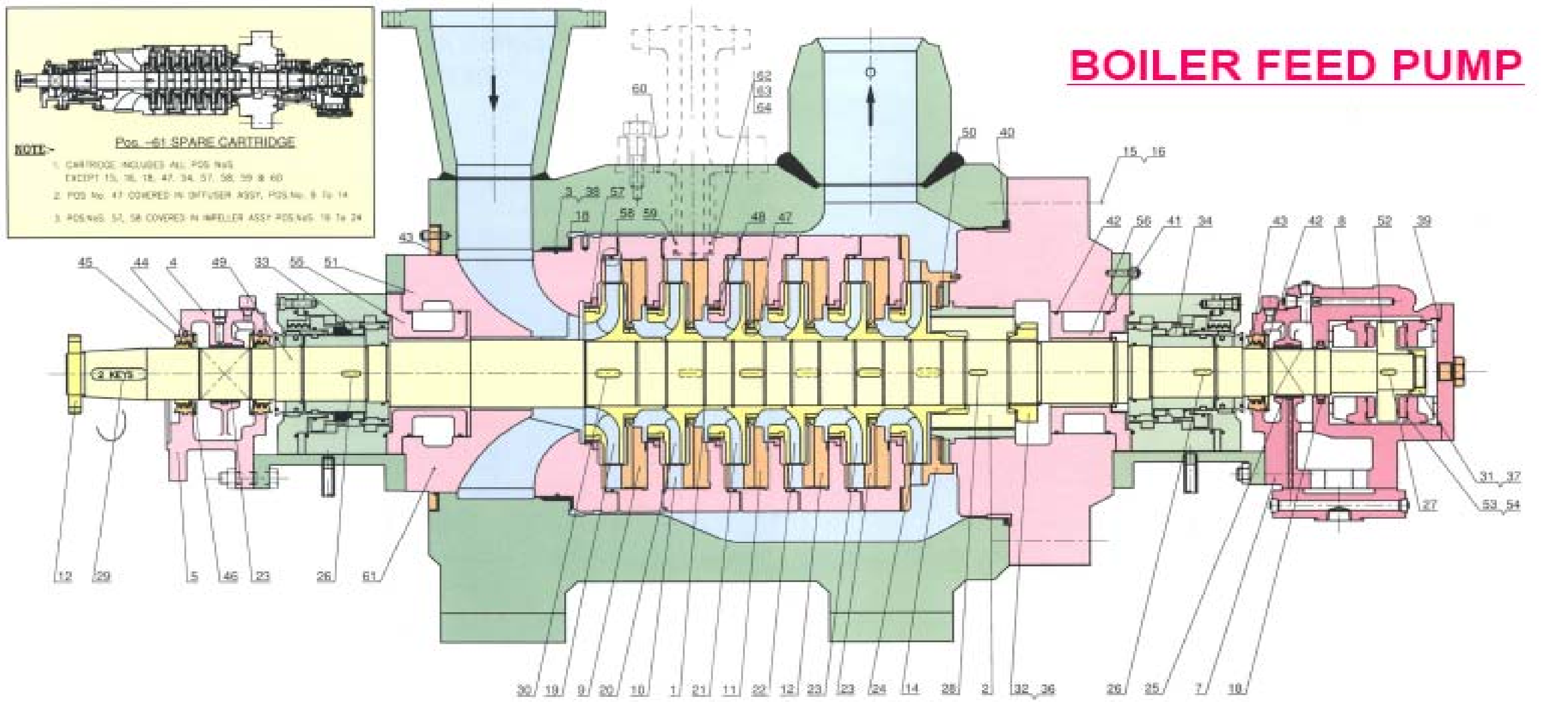
BFP is a multistage pump provided for pumping feed water to economiser.

- **Types of BFPs** –

  1. Ring section type: This is the pump for sending high pressure and high temperature fluid to the boiler. The types vary depending upon the pressure. The single casing type is used for the combined cycle, the subcritical steam power generation, etc.

  2. Barrel type: This is the multi-stage pump having the double casing, the inner casing contained in the outer casing. Among various boiler feed water pumps, this pump is adopted for high pressure and high temperature application as in the subcritial steam power generation. The double casing is also called "barrel type". As in the case of the single casing, there are differences in the way of splitting the inner casing, and special features are the same.

Cross section of BFP (Typical)

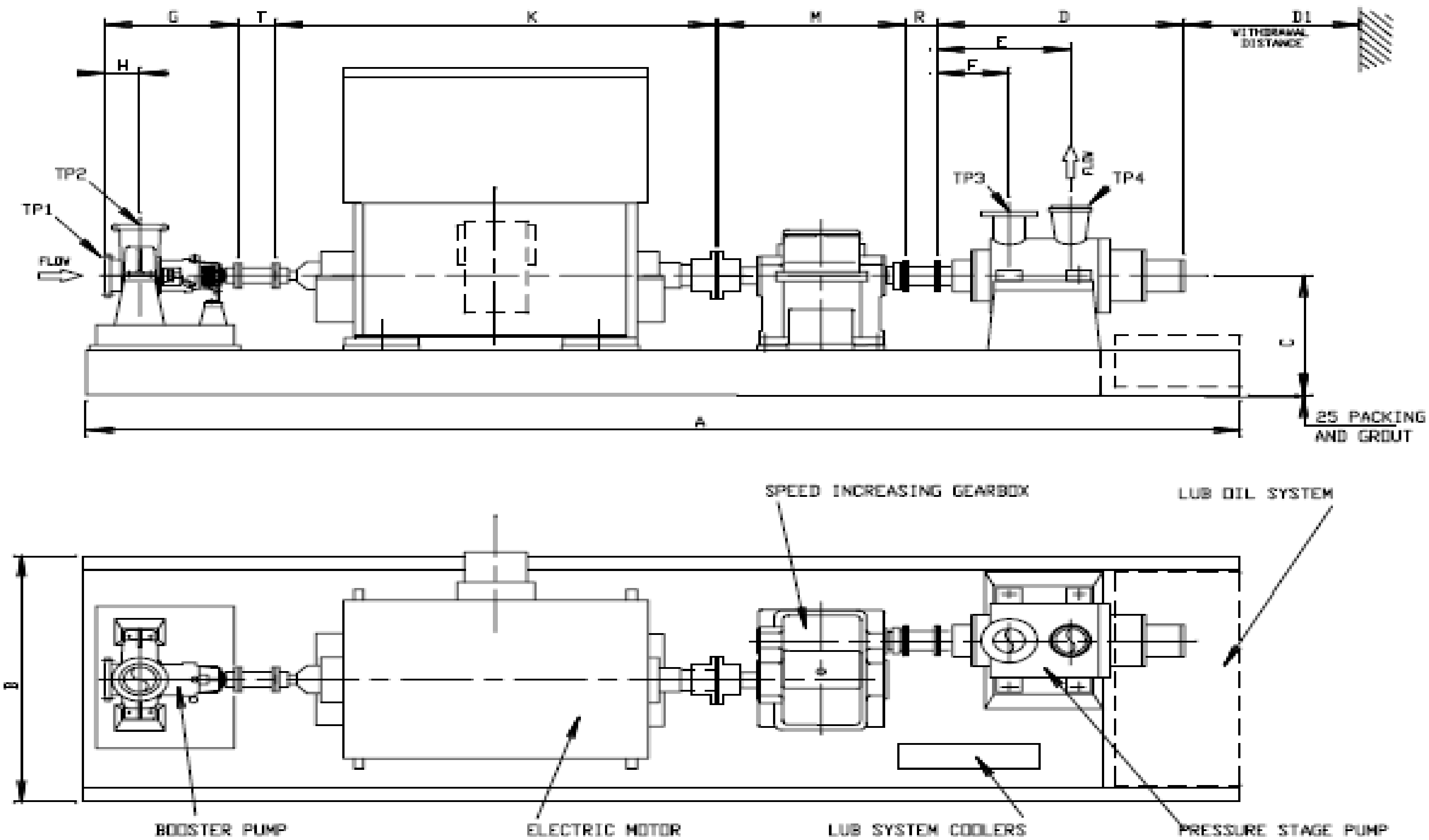


DRAWING NO : 01801154104

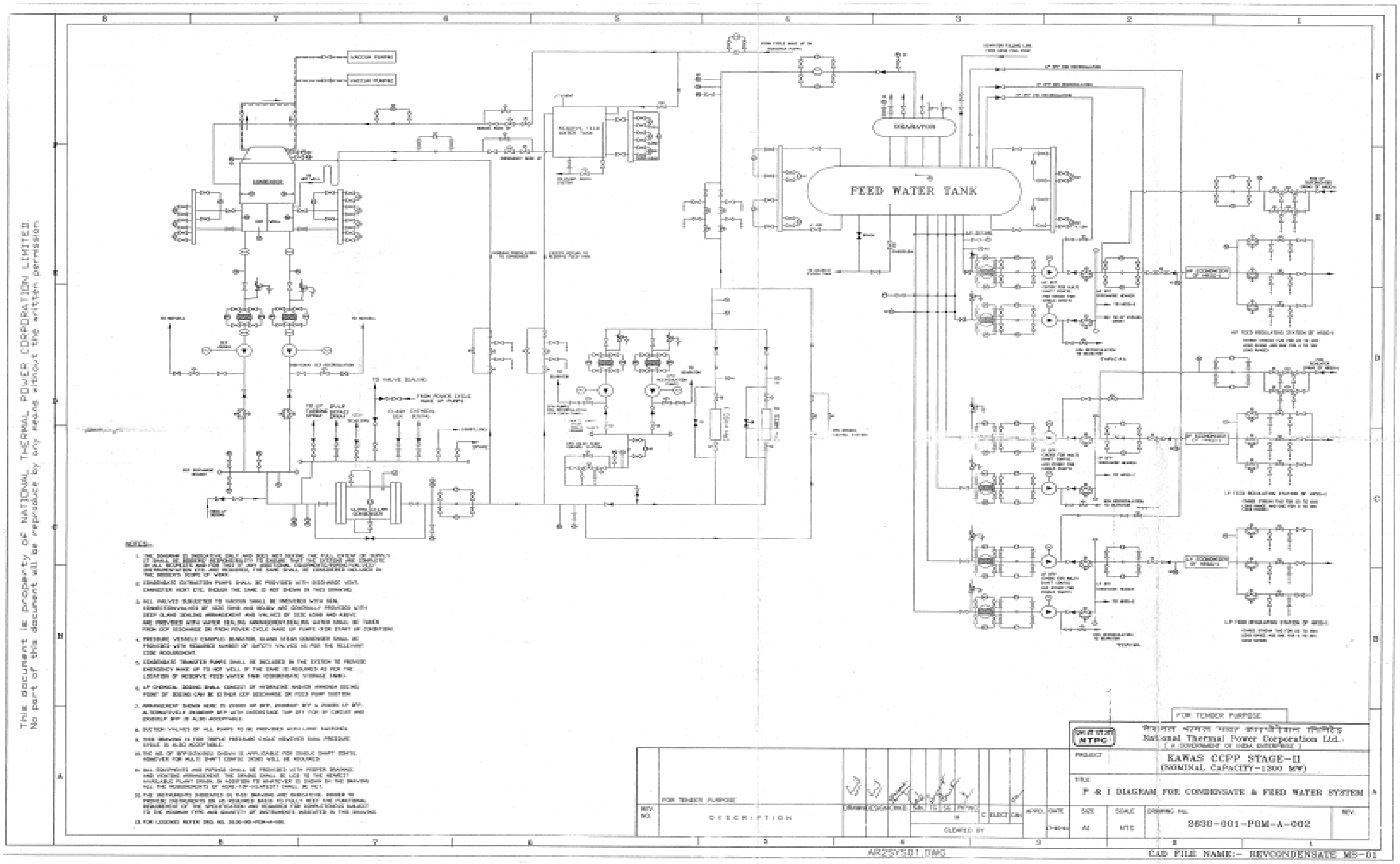
SL. NO.	ITEM DESCRIPTION
1.	ABUTMENT RING (IMPELLER)
2.	BALANCING DRUM
3.	BACK UP RING FOR 'O' RING
4.	BEARING HOUSING DE ASSY.
5.	BEARING HOUSING DE (INFORMATIVE ONLY)
6.	BEARING HOUSING NDE ASSY.
7.	BEARING HOUSING NDE (INFORMATIVE ONLY)
8.	BUSH (BALANCING DRUM)
9.	DIFFUSER 1ST ASSY.
10.	DIFFUSER 2ND ASSY.
11.	DIFFUSER 3RD ASSY.
12.	DIFFUSER 4TH ASSY.
13.	DIFFUSER 5TH ASSY.
14.	DIFFUSER LAST ASSY.
15.	DIS. COVER BOLTS
16.	DIS. COVER BOLT NUTS
17.	FLOATING SEAL
18.	GASKET (MS/CU)
19.	IMPELLER ASSY. 1 ^STG 1ST STAGE
20.	IMPELLER ASSY. 2ND STAGE
21.	IMPELLER ASSY. 3RD STAGE
22.	IMPELLER ASSY. 4TH STAGE
23.	IMPELLER ASSY. 5TH STAGE
24.	IMPELLER ASSY. LAST STAGE
25.	JOURNAL BEARING DE/NDE
26.	KEY (SHAFT SLEEVE)
27.	KEY (THRUST COLLAR)
28.	KEY (BALANCING DRUM)
29.	KEY (COUPLING)
30.	KEY (IMPELLER)
31.	LOCK WASHER (THRUST COLLAR NUT)
32.	LOCK WASHER (BALL DRUM NUT)
33.	MECHANICAL SEAL (DE)
34.	MECHANICAL SEAL (NDE)
35.	NUT (CPLG)
36.	NUT (BALANCING DRUM)
37.	NUT (THRUST COLLAR)
38.	O' RING (RING SECTIONS)
39.	O' RING (END COVERS)
40.	O' RING (CASING DISCOVER)
41.	O' RING (WATER JKT.)
42.	O' RING (WATER JKT.)
43.	O' RING (INSERT RING)
44.	OIL GUARD
45.	OIL THROWER (DE/NDE)
46.	'O' RING (OIL GUARD)
47.	PACKING RINGS FOR DIFFUSER (WEAR RINGS)
48.	PACKING RINGS FOR RING SECTION (WEAR RINGS)
49.	SHAFT
50.	SPRING DISC
51.	SUCTION GUIDE ASSY.
52.	THRUST COLLAR
53.	THRUST BEARING
54.	THRUST PADS SET
55.	WATER JACKET DE
56.	WATER JACKET NDE
57.	WEARING RINGS (IMP.EYE)
58.	WEARING RINGS (IMP.NECK)
*59.	PISTON RING SET
*60.	METAFLEX GASKET
61.	SPARE CARTRIDGE
*62.	METAFLEX GASKET
*63.	O-RING
*64.	BACK UP RING

* ONLY FOR INT STG. TAPOFF DESIGN

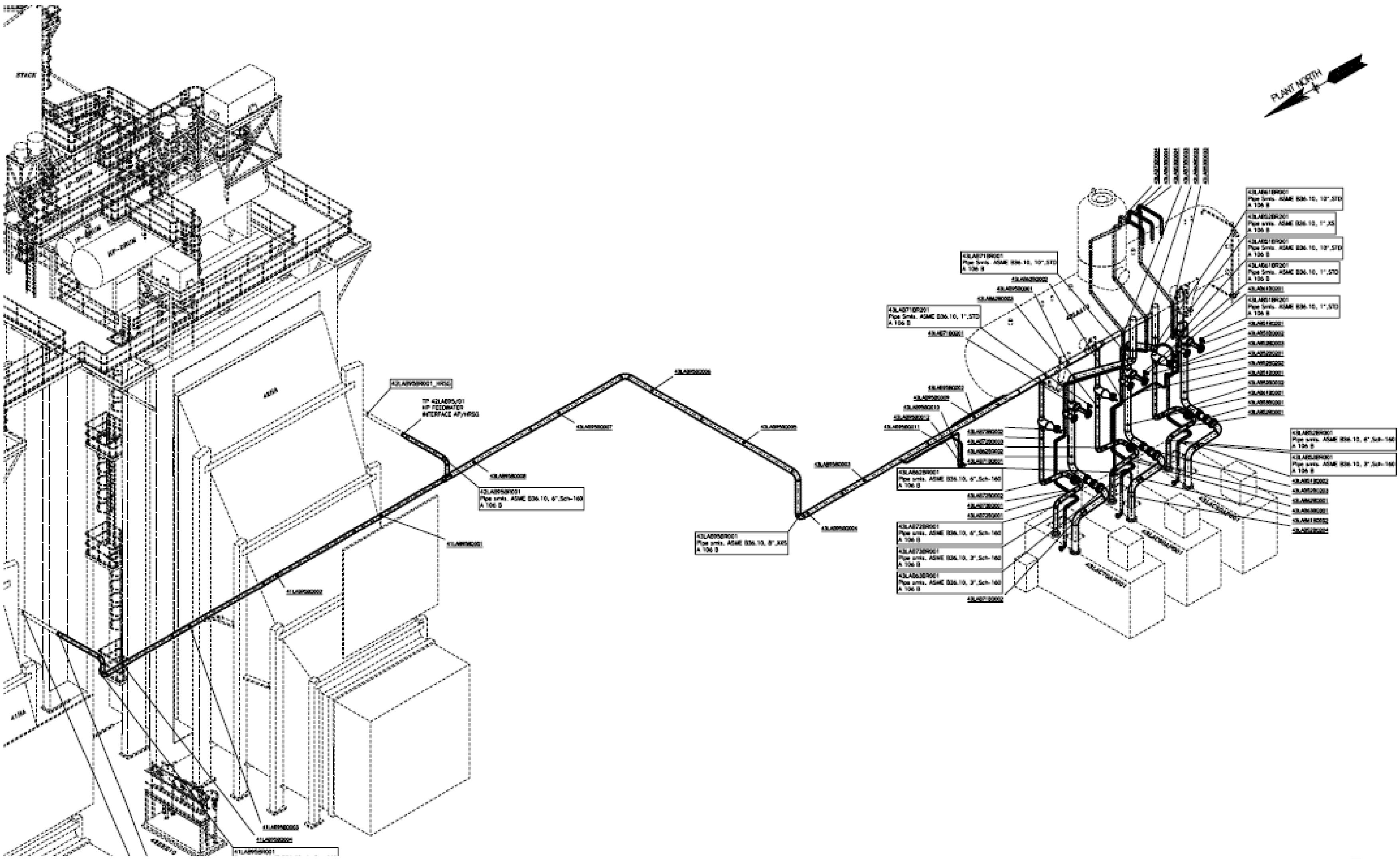
Typical Layout of BFP



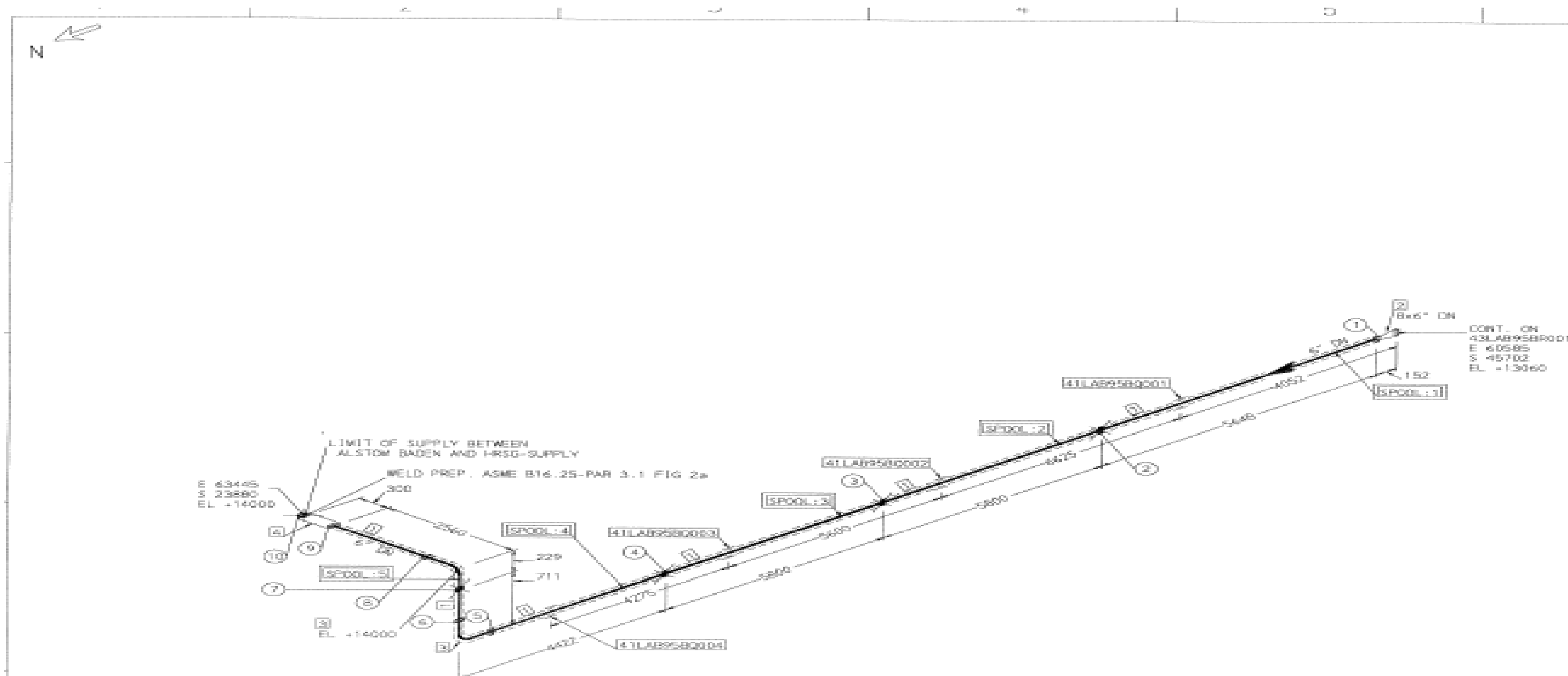
Water–Steam Cycle – Process Flow Diagram (Typical)



System Isometric View of HP Feedwater (Typical)



Pipe Isometric of HP Feedwater (Typical)



WELD NR	SHOP /FLD	DSP XR	DSP YR	U S	C T	H T	H D	FILM NO	WELDER NO	REPO NO
1	S									
2	F									
3	F									
4	F									
5	S									
6	S									
7	F									
8	S									
9	S									
10	F									

DS = RADIOGRAPHIC EXAMINATION
XR = X-RAY TEST
YR = Y-RAY TEST
US = ULTRASONIC TEST
CT = CRACK DETECTION TEST
HT = HARDNESS TEST
HD = HEAT TREATMENT DIAGRAMM

FF = FITTED FIELD WELD

BFP Design Criteria (Typical)

- **<u>Design Point</u>:** The design capacity of boiler feed water pump is specified by design capacity and head. The design capacity is based on plant's maximum steam flow requirements. For a large capacity power station, this would be the steam turbine throttle flow at valves-wide-open and 5% over pressure, plus steam or feedwater removed from and not returned to the flow path between boiler feed pump suction and turbine throttle. For example – steam supplied to process industries like sugar, textile etc.

  <u>Design Capacity</u>:

  The following are contributing factors generally considered in the determination of boiler feed pump design capacity

  - Turbine throttle steam flow typically at VWO and 5% overpressure conditions
  - Steam cycle make-up flow
  - Seam blowing steam flow, if applicable
  - Auxiliary steam flow, if applicable
  - Reheat steam de-superheating flow, if applicable
  - Any other steam / feedwater requirement (ex. For Process application)

BFP Design Criteria (Typical)

Design Head :

The total developed head for boiler feed pump is calculated by determining the difference between the boiler feed pump discharge head and suction head as shown in table below.

Boiler Feed Pump Total Suction Head Determination

Item	Head	Comments
Deaerator pressure	a	Based on deaerator operating pressure @ max. turbine HBD conditions
Max.Static head between deaerator LL L and BFP impeller centreline	a	Based on low low water level in storage tank of deaerator.
Friction loss between deaerator and BFP suction line		This includes pipe friction loss, suction filter 50% clogged condition (-ve value)
Total Suction Head	a	Sum of above items

BFP Design Criteria (Typical)

Boiler Feed Pump Total Developed Head Determination

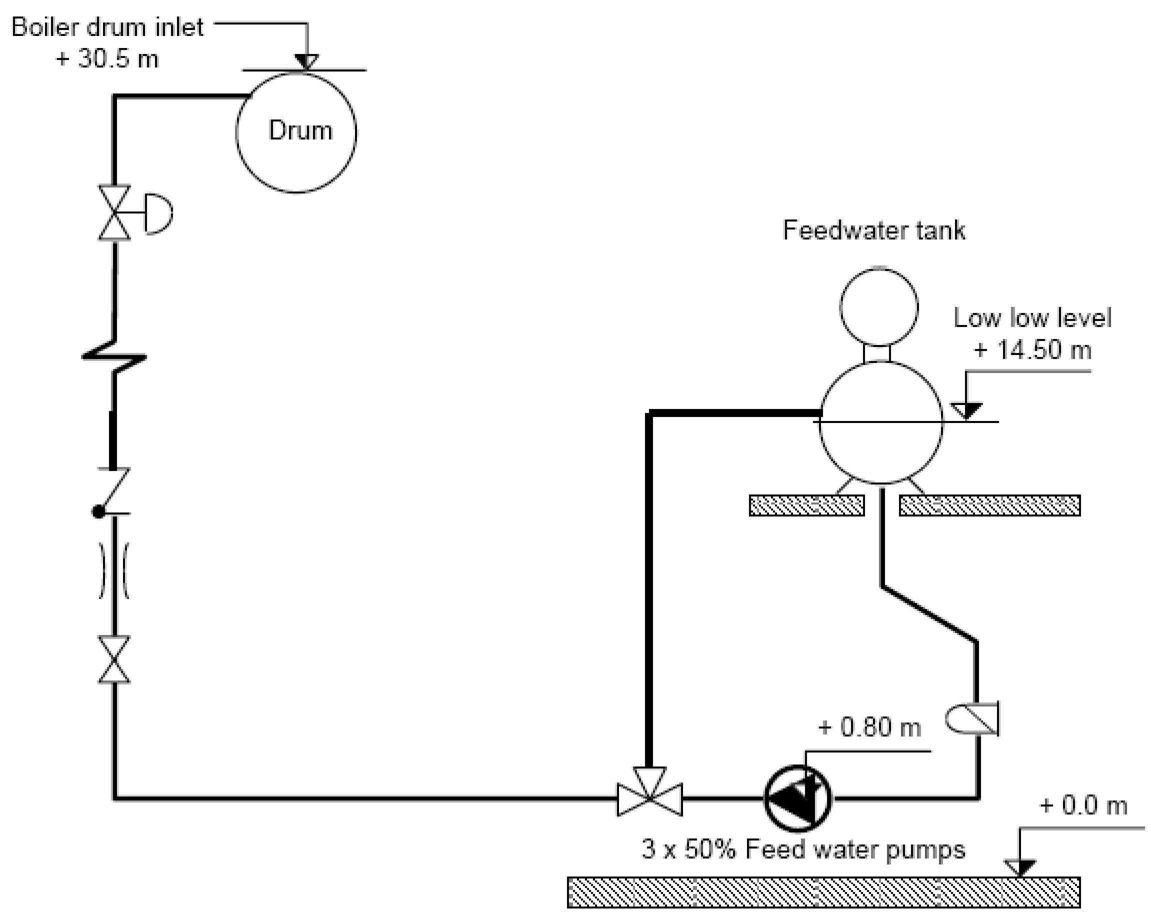
Item	Head	Comments
Turbine throttle pressure	a	Based on turbine throttle pressure at maximum turbine heat balance conditions
Main steam line friction loss	a	Based on maximum turbine heat balance conditions. Typically, main steam line economically sized to render a 100-200 psi pressure drop
Superheater friction loss	a	Determined by the steam generator manufacturer. Generally limited by the plant designer to an economically feasible value by specification
Economizer friction loss	a	Determined by the steam generator manufacturer and limited by specification
Static head between steam drum water level and economizer water inlet	a	Based on steam generator configuration

BFP Design Criteria (Typical)

Item	Head	Comments
Static head between the economizer water inlet and the center line of the boiler feed pump impeller	a	Based on location of the economizer inlet elevation and the boiler feed pump Elevation
High-pressure feedwater heater pressure drop	a	Generally limited by feedwater heater design and specifications to 50 psi or less depending on the number of feedwater heaters
Friction drop between the boiler feed pump discharge connection and the economizer inlet	a	Based on the feedwater flow at maximum turbine heat balance conditions
Total discharge head	a	Sum of the above items
Total developed head	a	Total discharge head minus total suction head
Design margin		Typically 5% of the subtotal of total developed head above
Design total developed head	**A**	**Sum of the above items**

BFP Design Criteria (Typical)

Installation Data



Sample for BFP Sizing Criteria (Typical)…….conti

A. Flow calculations

	Description	Unit	Max. flow	Normal Flow	Under frequency	Transient Condition
1	Temperature of the feed water	ºC	105	105	105	105
2	Density of water	kg/m³	954.74	954.74	954.74	954.74
3	HRSG capacity (with super heater spray built in)	TPH	43.60	41.20	43.60	43.60
4	HRSG blow down (3% Con , 2% Intermittent)	TPH	2.18	0.82	2.18	2.18
5	Total feed water flow requirement(3+4)	TPH	45.78	42.02	45.78	45.78
5	Flow with margin due to low frequency	TPH	NA	NA	2.41	NA
6	Feed water flow with 20% margin during transient operation	TPH	NA	NA	NA	9.16
7	Capacity of each Pump	TPH	45.78	42.02	48.19	54.04
8	10% design margin on flow (allowance for ageing)	TPH	4.58	NA	NA	NA
9	Required flow from each pump	TPH	50.36	42.02	48.19	54.94
10	**SELECTED CAPACITY IN CMH**	m³/hr	**53.00**	**44.00**	**50.00**	**58.00**

Sample for BFP Sizing Criteria (Typical)…….conti

B. Discharge Head calculations

	Description	Unit	Max. flow	Normal Flow	Under frequency	TRANSIENT OPERATION
1	Highest safety valve set pressure	Kg/cm^2 (a)	91.63	NA	NA	NA
2	Drum Operating Pressure	Kg/cm^2 (a)	NA	81	81	81
3	Over Pressure (3 %)	Kg/cm^2	2.75	NA	NA	NA
4	Static pr. due to drum height (21.6 m) {height) x sp.gravity/10 }	Kg/cm^2	2.06	2.06	2.06	2.06
5	Pr. Drop in Economizer	Kg/cm^2	3.00	3.00	3.00	3.00
6	Pr. Drop in feed control station	Kg/cm^2	1.50	1.50	1.50	1.50
7	Pr. Drop in discharge piping including fittings, valves, etc.	Kg/cm^2	1.0	0.69	0.89	1.20
8	Pr. Drop in flow element	Kg/cm^2	0.30	0.21	0.27	0.36
9	Pr. Drop in ARC valve at discharge	Kg/cm^2	1.0	0.69	0.89	1.20
10	Total variable pressure drop (5+6+7+8+9)	Kg/cm^2	6.80	6.09	6.55	7.25
11	Margin on variable pr. drop (21%) (min. 1 kg/cm2)	Kg/cm^2	1.43	NA	NA	2.31
12	Pressure at discharge of Pump (1 + 2 + 3 + 4 + 10 + 11)	Kg/cm^2(a)	140.67	89.15	89.61	90.32 68

Sample for BFP Sizing Criteria (Typical)…….conti

C. Suction Head calculations

	Description	Unit	Max. flow	Normal Flow	Under fr	TRANSIENT OPERATION
1	Pressure of De-aerator	Kg/cm^2 (a)	1.23	1.23	1.23	1.23
2	Pr. due to Height of the De-aerator LWLL from BFP suction nozzle	Kg/cm^2 (a)	1.38	1.38	1.38	1.38
3	Total of above (1+2)	Kg/cm^2	2.61	2.61	2.61	2.61
4	Pr.drop in suction strainer-50% clogged (normal pr. drop approx. 0.1 Kg/cm^2)	Kg/cm^2	0.2	0.2	0.2	0.2
5	Pr. drop in suction piping, inclusive of fittings, valves, etc	Kg/cm^2	0.20	0.14	0.18	0.24
6	Pr. loss on suction side of BFP (4+5)	Kg/cm^2	0.40	0.34	0.38	0.44
7	Available pr. on pump section side (3 – 6)	Kg/cm^2	2.21	2.27	2.23	2.17
8	Available NPSH (7 – 1)	Kg/cm^2	0.98	1.04	1.00	0.94
		mwc	10.26	10.92	10.50	9085
9	Considering margin between NPSHA & NPSHR as minm. 2.5 m, the NPSHR of the pumps shall be limited to max. (50 % for rated flow)	Kg/cm^2	5.13	8.42	8.00	7.35

Sample for BFP Sizing Criteria (Typical)

D. Differential Head calculations						
	Description	**Unit**	**Max. flow**	**Normal Flow**	**Under frequency**	**Transient Condition**
	Net Differential head to be developed by pump	Kg/cm^2	102.46	86.88	87.38	88.15
	Margin due to change in frequency i.e. applying factor $\{(50/47.5)^2-1\}$	Kg/cm^2	NA	NA	9.44	NA
	Required differential pressure	Kg/cm^2	102.46	86.88	96.82	88.15
	Required differential pressure	mwc	1073.16	909.14	1014.07	923.25
	Final selected differential pressure	mwc	1074	910	1015	924
E. Final parameters						
	Capacity of each pump	m^3/hr	**53.00**	**44.00**	**50.00**	**58.00**
	Pump differential head required	mwc	**150**	**125**	**145**	**170**

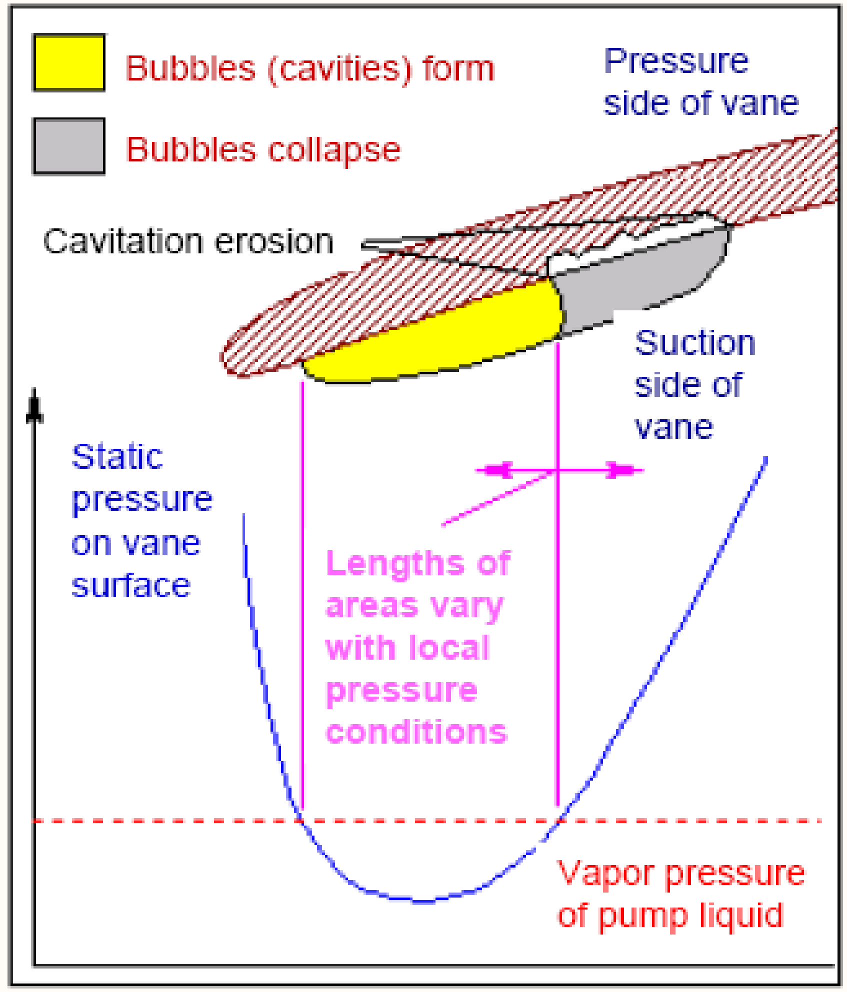
NPSH Considerations - Cavitation

The NPSHA must exceed the pump's NPSHR 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.

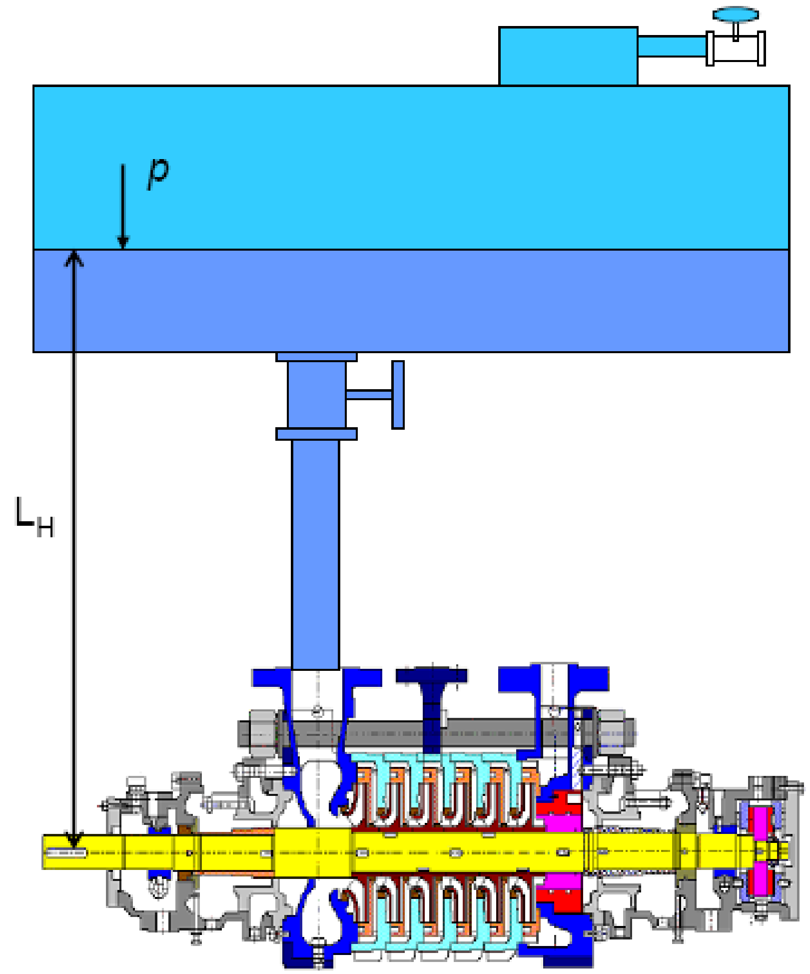
In an area on the vane commencing a short distance form the vane tip, the static pressure can fall sharply, before rising again further along the vane. If the local static pressure falls below

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.



NPSHA = p + LH – (VP + hf)

Where:

p = pressure in suction vessel

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

VP = vapor pressure of liquid at pump suction

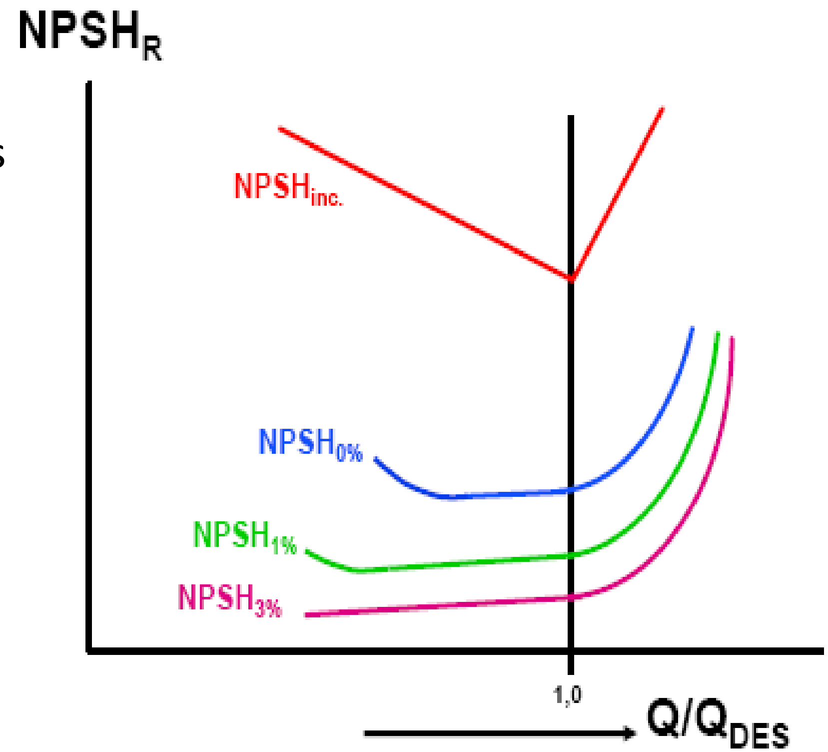
hf = frictional losses of liquid in suction piping

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
- 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

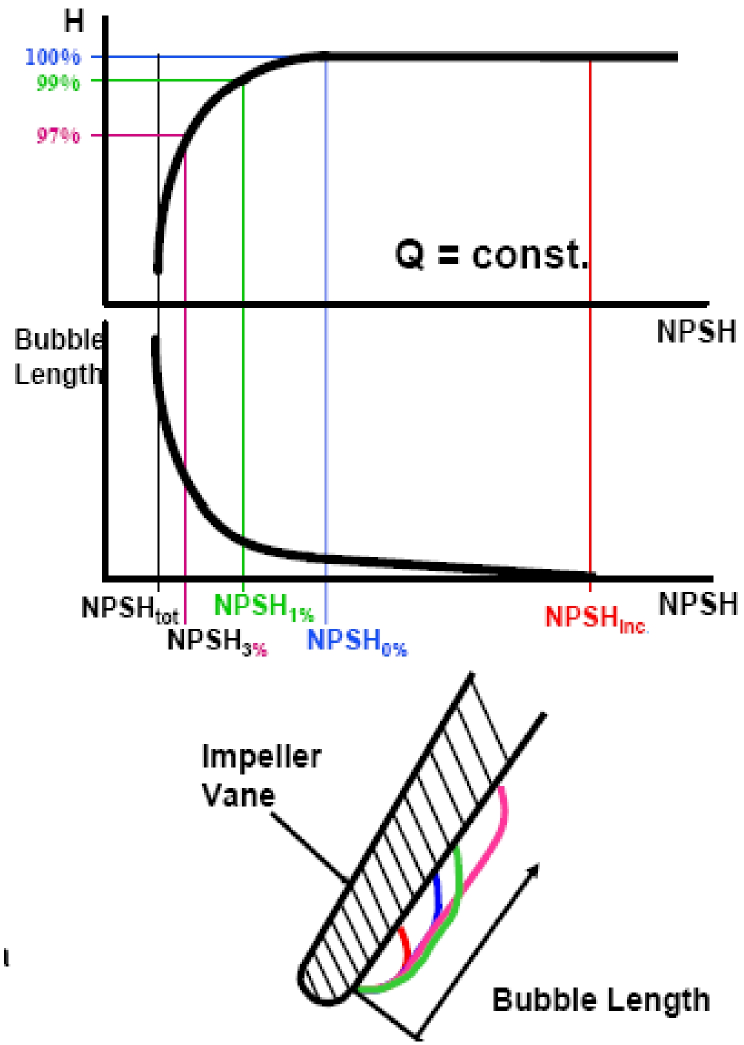
NPSH 1% values represent a larger and more bubbles with a reduction of discharge head of 1%.

NPSH 3% values represent increasing

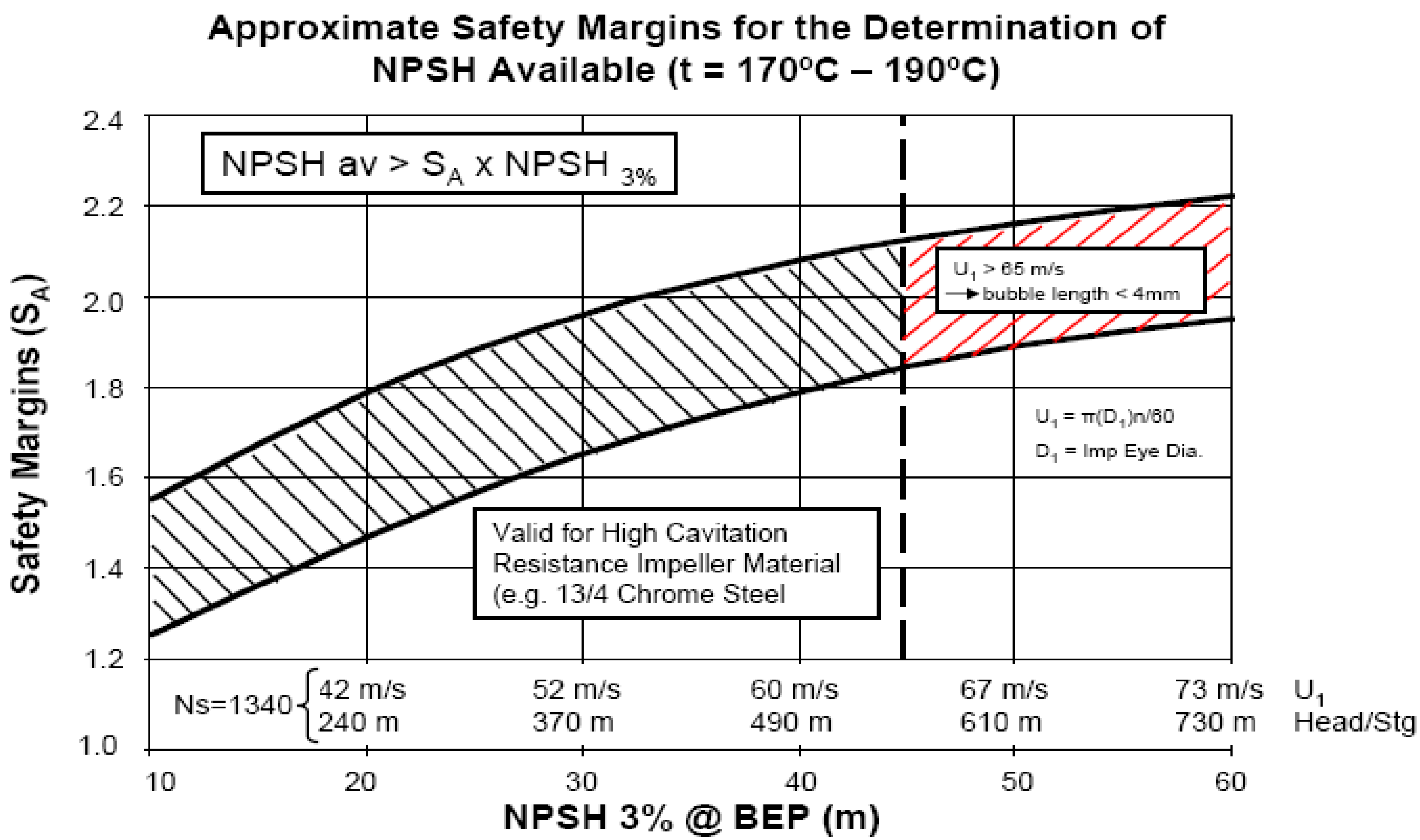
bubble size and amount with a reduction

of discharge head of 3%.

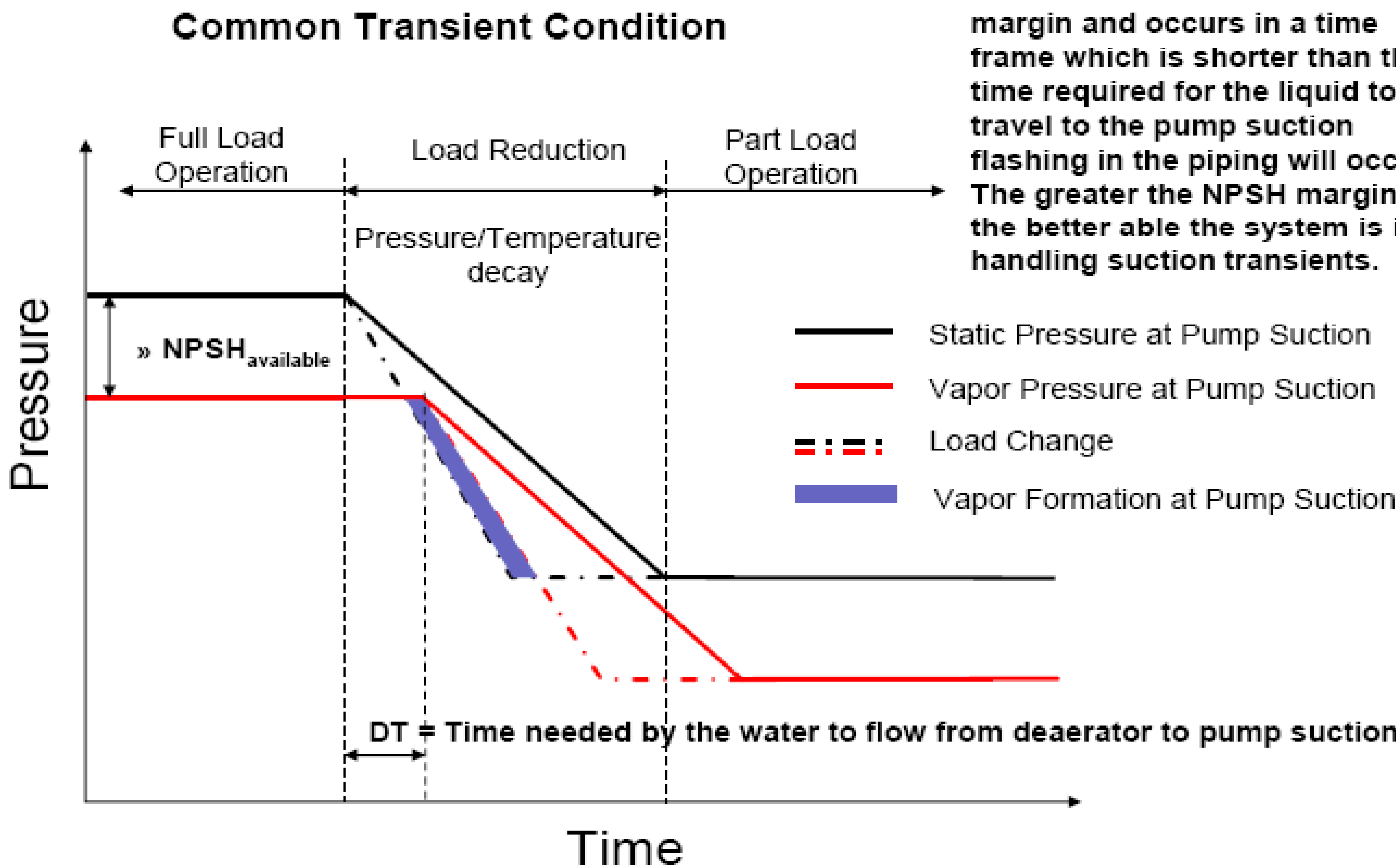
NPSH tot represents a pump in full cavitation with a significant reduction in discharge head, heavy vibration and noise.



NPSH Consideration



BFP Transient Study

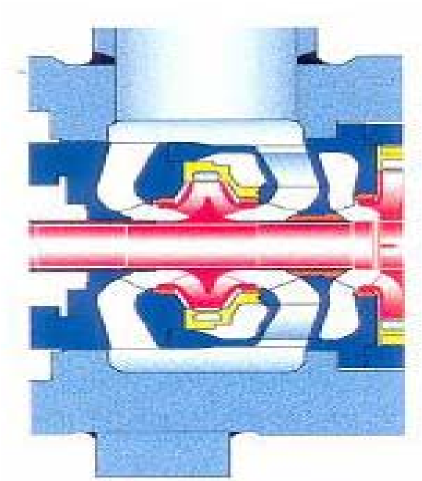


If the load reduction > NPSH margin and occurs in a time frame which is shorter than the time required for the liquid to travel to the pump suction flashing in the piping will occur. The greater the NPSH margin the better able the system is in handling suction transients.

BFP Transient Study

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.

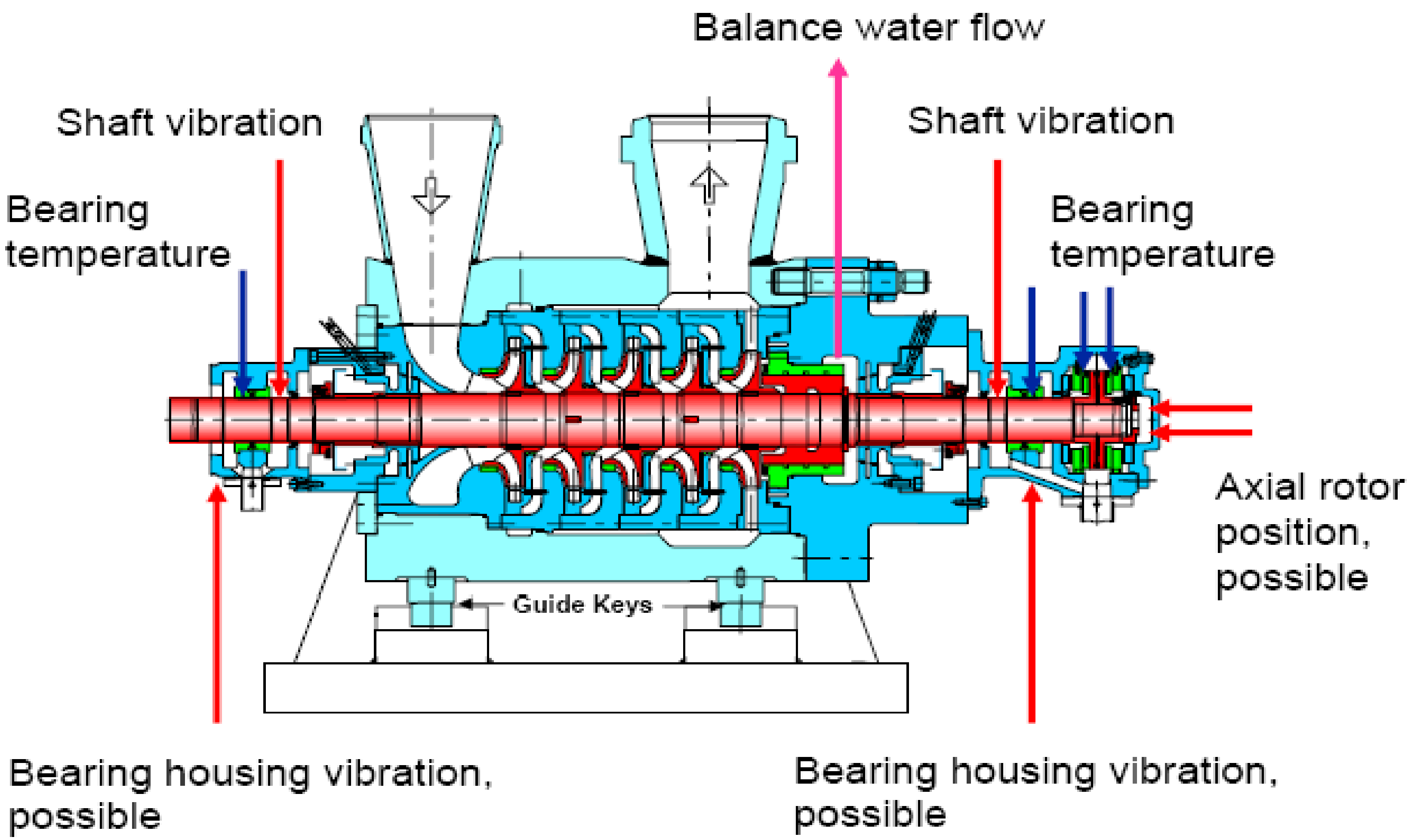
A separate booster pump provides the ability to provide a high margin between available and required NPSH which helps during certain suction transient conditions.


Double suction impeller

Typical Materials

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

Recommended Instruments



References

- National Power Training Institute (NPTI) manual for – “Boiler Feed Pump”.
- Power Plant Engineering by Black & Veatch.
- SULZER Multistage Barrel Casing – Boiler feed pump brochure.

Any Questions please

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Thank You All