Comment Response Sheet (CRS)

Project Title	Van Phong 1 BOT Thermal Power Plant Project				
Document Title	TM-02 Operation for Steam Turbine (incl. BFP-turbine) and Auxiliaries	**Document Type**	Training		
Document No	VP1-L2-Training-00003	**Returned Status**		**Prepared by**	Lot2
CRS No	VP1-L2-Training-00003-CRS	**CRS Issued Date**		**Engineer**	Mechanical

No.	Section/ Page	Owner's Comment	Response to Comment	Review Date	Status O/C *	Remarks
Comment from the owner before training						
1	22/95	(Operation) Please kindly explain in more detail about this advantages.	Since the deformation due to heat input during welding does not occur, there is no need for the post-welding throat adjustment and then dimensional control become easy. Welding nozzles are also adjusted and polished after welding, so the functions of welding nozzles and assembly nozzles are the same.	31 Aug 2022	O	
2	24/95	(Operation) Please kindly explain in more detail about the advantage and disadvantage of Impulse blade and Reaction blade.(In this project, what stages do we use impulse Design or Reaction Design?)	Impulse blade and reaction blade each have the following advantages and disadvantages. ✓ Impulse blade Advantage : The number of stages can be reduced because the heat drop per stage is large. Disadvantage : The turning angle is large, so the loss is large and the efficiency of the stage is worse. ✓ Reaction blade Advantage : Small turning angle reduces losses and improves stage efficiency Disadvantage : The number of stages increases because the heat drop per stage is small.	31 Aug 2022	O	

Comment Response Sheet (CRS)

3	27/95	(Operation) Please kindly explain this slide in detail to understand more.	Steam flow near the nozzle sidewalls is disrupted, causing losses and reducing turbine efficiency.	31 Aug 2022	O	
4	28/95	(Operation) Please kindly explain what is the secondary vortex? How it affect to the Turbine?	The flow turbulence near the sidewall of the nozzle, which is answered in No.3, is called "secondary vortex". Turbulence causes losses and reduces the efficiency of the turbine.	31 Aug 2022	O	
5	32/95	(Operation) Please kindly explain why we use different Snubber with each Turbine Section.	This turbine uses the snubber type at all stages. Straight fins are used for stage 26-28 due to the large differential expansion.	31 Aug 2022	O	
6	44/95	(Operation) Please kindly explain the working principal of Atmospheric Relief Diaphragm, Pressure Value inside of LP outer casing can break this Diaphragm?	It is designed so that the atmospheric relief diaphram breaks when the LP exhaust pressure exceeds 35kPag.	31 Aug 2022	O	
7	67/95	(Operation) Please kindly use the diagram which is the same with this project	Please let us keep this typical diagram because this is the material to explain about outline of monitoring items. For detail, please refer to VP1-C-L2-M-MAA-00009 Control Diagram for Steam Turbine.	31 Aug 2022	O	
8	71/95	(Operation) Please kindly explain: 1. What is HIP differential expansion? 2. What is LP Differential Expansion? 3. How to control these parameter in the range when startup turbine?	1. It means the difference in thermal expansion between stationary parts (casing and nozzle diaphragm, etc.) and rotating parts (HIP turbine rotor). 2. It means the difference in thermal expansion between stationary parts (casing and nozzle diaphragm, etc.) and rotating parts (LP turbine rotor). 3. When the turbine startup, the rotating part (rotor) thermally expands faster, so there is a differential expansion on the rotor long side. In order to reduce the differential expansion, it is necessary to sufficiently warm the stationary part, and it is necessary to use pre-warming, high-speed heat soak, load holding, etc. to sufficiently warm the stationary part and reduce the differential expansion.	31 Aug 2022	O	

Comment Response Sheet (CRS)

9	72/95	(Operation) Please kindly explain why we do not start Turbine in this case.	The rotating rotor shrinks axially due to centrifugal force. (Refer to answer No.11) The difference between the red band and the red mark (23.1-21.8=1.3mm) indicates the amount of the shrinkage of the rotor due to centrifugal force. If the differential expansion on the rotor short side exceeds the red mark (21.8 mm) before starting, the rotor will shrink by 1.3 mm as the rotation increases and the differential expansion on the rotor short side will increase and possibly enter the red band. Therefore, the turbine should not be started.	31 Aug 2022	O	
10	72/95	(Operation) Please kindly explain why we do not stop turbine in this case.	The rotating rotor shrinks axially due to centrifugal force. (Refer to answer No.11) The difference between the orange band and the red mark (3.2-1.9=1.3mm) indicates the amount of the shrinkage of the rotor due to centrifugal force. If the differential expansion on the rotor long side is less than the orange band (3.2 mm) during operation, the rotor will expand by 1.3 mm as the rotation decreases and the differential expansion on the rotor long side will increase and possibly enter the red band. Therefore, the turbine should not be stopped.	31 Aug 2022	O	
11	75/95	(Operation) Please kindly explain more detail about the affect of centrifugal force to rotor length.	As the rotating rotor expands radially due to centrifugal force, it shrinks axially due to the Poisson effect.	31 Aug 2022	O	
12	76/95	(Operation) Please kindly explain what is the difference to HP rotor.	The HIP rotor differential expansion detector is installed on the front standard, and the LP rotor differential expansion detector is installed between the No.6 bearing and the LPB-GEN coupling. Since the rotor thermally expands to the front and rear from the thrust bearing installed in the middle standard, the direction of rotor long and rotor short is opposite between the HIP rotor and the LP rotor. The means of green mark, red band, red mark and orange band is the same as HIP rotor.	31 Aug 2022	O	

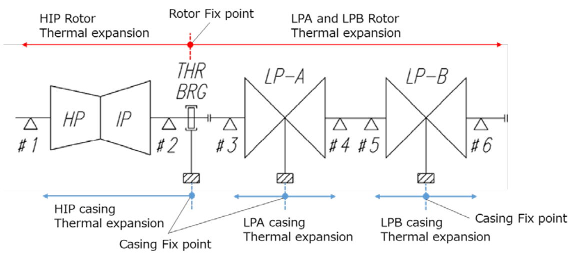
Comment Response Sheet (CRS)

13	86/95	(Operation) Please kindly explain this curve in more detail to understand more.	If the temperature change amount and temperature change rate of the rotor surface temperature are large, the rotor surface thermal stress will increase and the rotor life expenditure rate will increase. The rotor surface temperature is represented by the 1st stage shell inner surface temperature. In this curve, the horizontal axis indicates the temperature of the 1st stage shell inner surface, and the vertical axis indicates the rate of the temperature change of the 1st stage shell inner surface. This curve estimates the rotor life expenditure rate during operation with temperature changes such as at startup. For example, if the 1st stage shell inner surface temperature changes by 300 degC at a temperature change rate of 60 degC/hr, it is estimated that the rotor will consume 0.001% of its life. The "CORE LIMIT" curve shown by the dotted line is a curve that limits the stress generated in the center of the rotor to be less than the material strength, and it is necessary to avoid operation where the temperature change amount and the temperature change rate exceed this curve.	31 Aug 2022	O	
14	88/95	(Operation) Please kindly explain in more detail for this table: 1. The temperature belong to inner casing or outer casing? 2. Which equipment use to detect these temperature?	1. The maximum temperature of all metal temperatures for the inner and outer casing shall be used. 2. Normally, the maximum temperature is the 1st stage shell inner surface temperature or the reheat bowl inner surface temperature.	31 Aug 2022	O	

Comment from the owner after training

15	-	(Operation division) After the classroom training, we would like to have some questions below that needs the sufficient explanation for better understanding: 1.Please kindly provide related information about the key-phasor in shaft vibration monitoring. This question has been raised in the training, but the answer is not clear enough for us to understand. Please kindly provide clear answer.	A key phaser is an instrument for detecting the phase angle of the rotor. It is installed to detect in which angle direction of the rotor the peak of shaft vibration occurs.	07 Sep 2022	O	
16	-	(Operation division) 2.In the data log of steam turbine, the LSB is mentioned: - LP Turbine: 33.5” LSB - BFP Turbine: 14” LSB Please kindly explain the importance of this parameter (LSB) in the steam turbine. Please kindly provide the information about how much percentage of capacity for each blade stage in the LP Turbine.	LSB means "Last Stage Blade" and indicates the length of the last stage blade. The size of the turbine is simply expressed by the length of the last stage blade. The LP turbine contributes about 40% of the total output, of which the final stage blades contribute about 18%. In other words, the final stage blades contribute about 7% of the total output.	07 Sep 2022	O	
17	-	(Operation division) 3.In the Gland Seal Steam System, please kindly provide the instruction on how to keep the appropriate level of water in the Gland Steam Condenser.	The water level of Gland Steam Condenser is not required to be controlled since there is no drain water level in the shell. The drain is discharged by the balance between GSC inner pressure and Condenser pressure.	07 Sep 2022	O	

Comment Response Sheet (CRS)

18	-	(Turbine department) Please kindly provide the reference drawing(s) that shows the expansion of the casing and rotor.	Please refer to the figure below. The red arrow indicates the direction of thermal expansion of the rotor, and the blue arrow indicates the direction of thermal expansion of the casing. The axial position of the rotor is fixed by thrust bearing, and the casing is fixed by three keys. Each of them expands thermally in the axial direction starting from these fixed points. 	07 Sep 2022	O	
19	-	What is the function of RTRCL line?	RTRCL line is used in order to cool the IP turbine blades and wheels.	07 Sep 2022	O	
20	-	What is the function of HSL line?	HSL line is used in order to discharge the No.2 gland (between HP and IP steam path) leakage steam to condenser during pre-warming not to disengage turning gear. In addition, after the turbine trip, HSL valve is opened and No.2 gland steam is discharged to condenser and over speed is suppressed.	07 Sep 2022	O	
21	-	Selecting method of DTP and EL bearings	DTP is applied for light bearing load of HIP rotor. EL is applied for large bearing load of LP rotors.	07 Sep 2022	O	
22	-	Application of diaphragm coupling for BFPT-BFP	Diaphragm coupling is applied in order to absorb the radial misalignment and thermal expansion of rotor.	07 Sep 2022	O	

Additional Notes (if any)

* O - Open, C – Closed

Final

A2	08/Dec./2022	Final	K.Asai	K.Asai	M.Yamada
A1	29/Sep./2022	Final	K.Asai	K.Asai	M.Yamada
A	22/Aug./2022	First issue	K.Asai	K.Asai	M.Yamada
REV	DATE	DESCRIPTION	Approved	Checked	Prepared

OWNER

VAN PHONG POWER COMPANY LIMITED

PROJECT

Van Phong 1 BOT Thermal Power Plant Project

OWNER'S ENGINEER

AFRY Switzerland Ltd.

Status
☐Approved
☐Approved with Comment
☐Not Approved
☐Reviewed
☐Reviewed with Comment

EPC CONTRACTORS

IHI-TESSC-CTCI-DHI CONSORTIUM

PROJECT DOCUMENT No

VP1-L2-Training-00003

REV

A2

DOCUMENT TITLE

TM-02

Operation for Steam Turbine (incl. BFP-turbine) and Auxiliaries

EPC

Toshiba Energy Systems & Solutions Corporation

EPC DOCUMENT No.

VP1-L2-Training-00003

REV

A

TOSHIBA

Van Phong 1 Thermal Power Plant Project

Operation for Steam Turbine (incl. BFP-turbine) and Auxiliaries

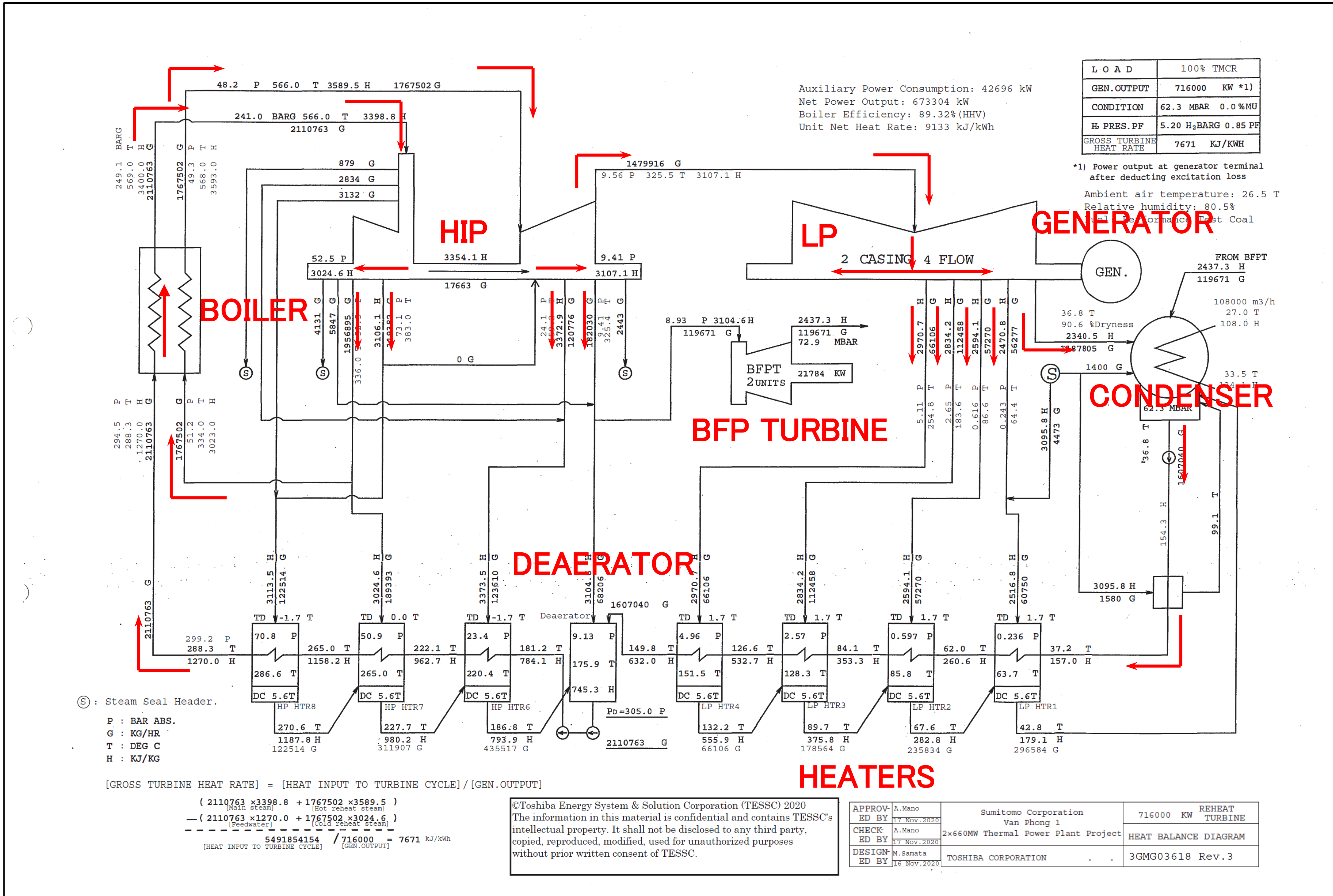
Toshiba Energy Systems & Solutions Corporation
2022.09

Contents

01

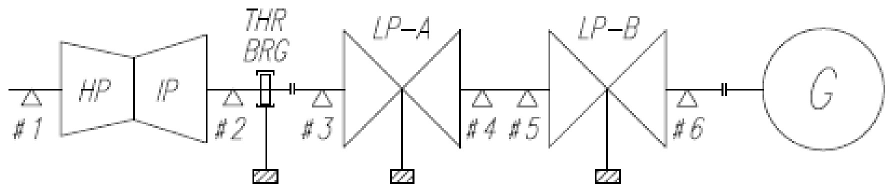
General

Heat Balance



Rating and Design Data

Turbine Type Tandem Compound, Four Flow Exhausts, Single Reheat, Condensing Turbine.



HIP Turbine HP and IP opposed Flow Type, Double Shell Construction

LP Turbine Double Shell and Four Flow Construction with 33.5" LSB

Steam Conditions (for Guarantee)

Main / Reheat Steam Temperature	566 deg.C / 566 deg.C
Main Steam Pressure	24.1 MPag (241.0 barg)
Exhaust Pressure	6.23 kPaa (62.3 mbar) at 100%TMCR

Stage No. HP 14 stages IP 8 stages LP 4×6 stages

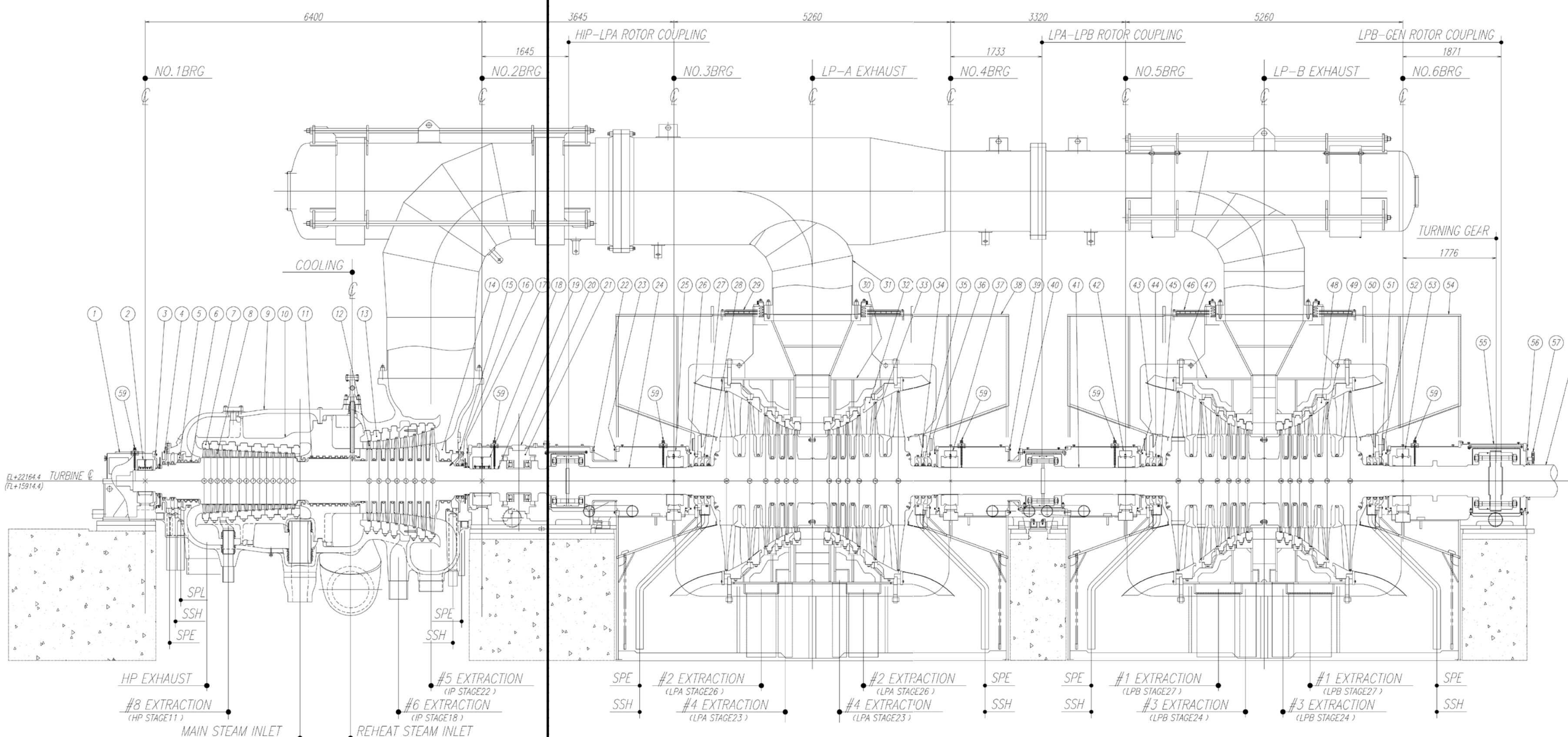
Extraction No. Eight(8) Extraction Lines for Regenerative Cycle

Overview of Turbine

Turbine Configuration TC4F-TN33.5”

HIP Turbine
22 stages

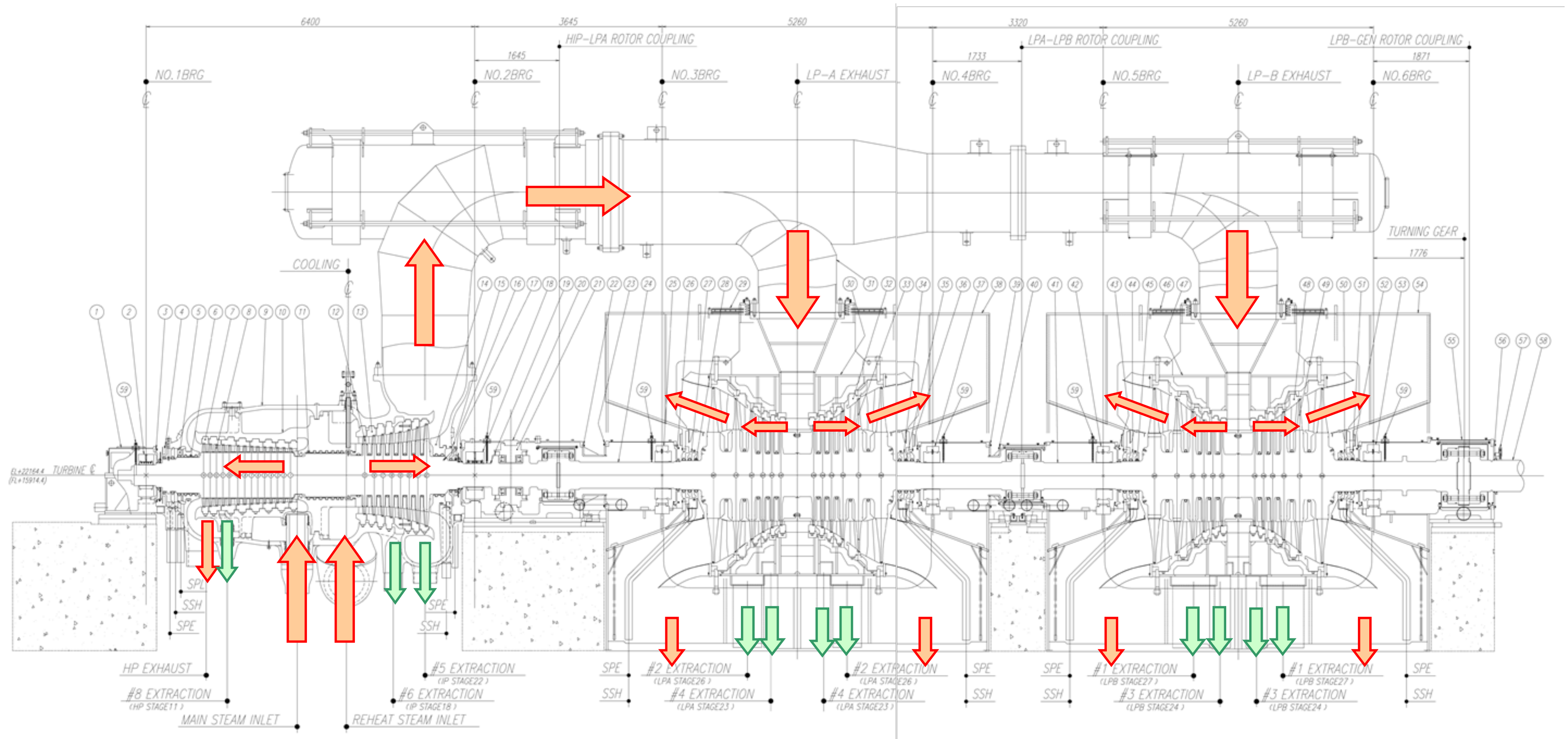
LP Turbine
Four Flow, 6 stages



HIP/LP Section of Turbine

Mainstream

Extraction



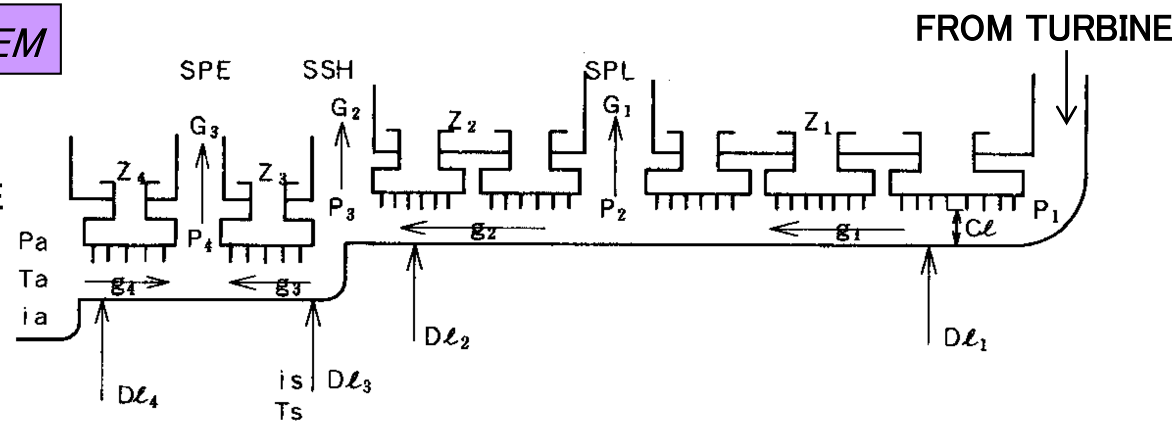
<u>HIP Section</u> <u>LP Section</u>

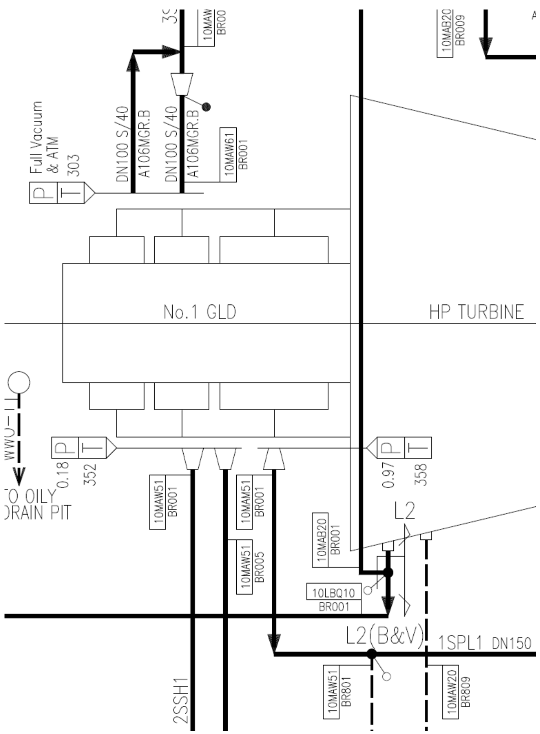
02

Gland Steam System

Turbine Gland Seal System

TURBINE GLAND SYSTEM





g: GLAND STEAM LEAK FLOW AND AIR

Z: NUMBER OF LABYRINTH PACKING

P: PRESSURE

T: TEMPERATURE

I: ENTHALPY

Cl: GLAND PACKING CLEARANCE

Dl: ROTOR DIAMETER

→

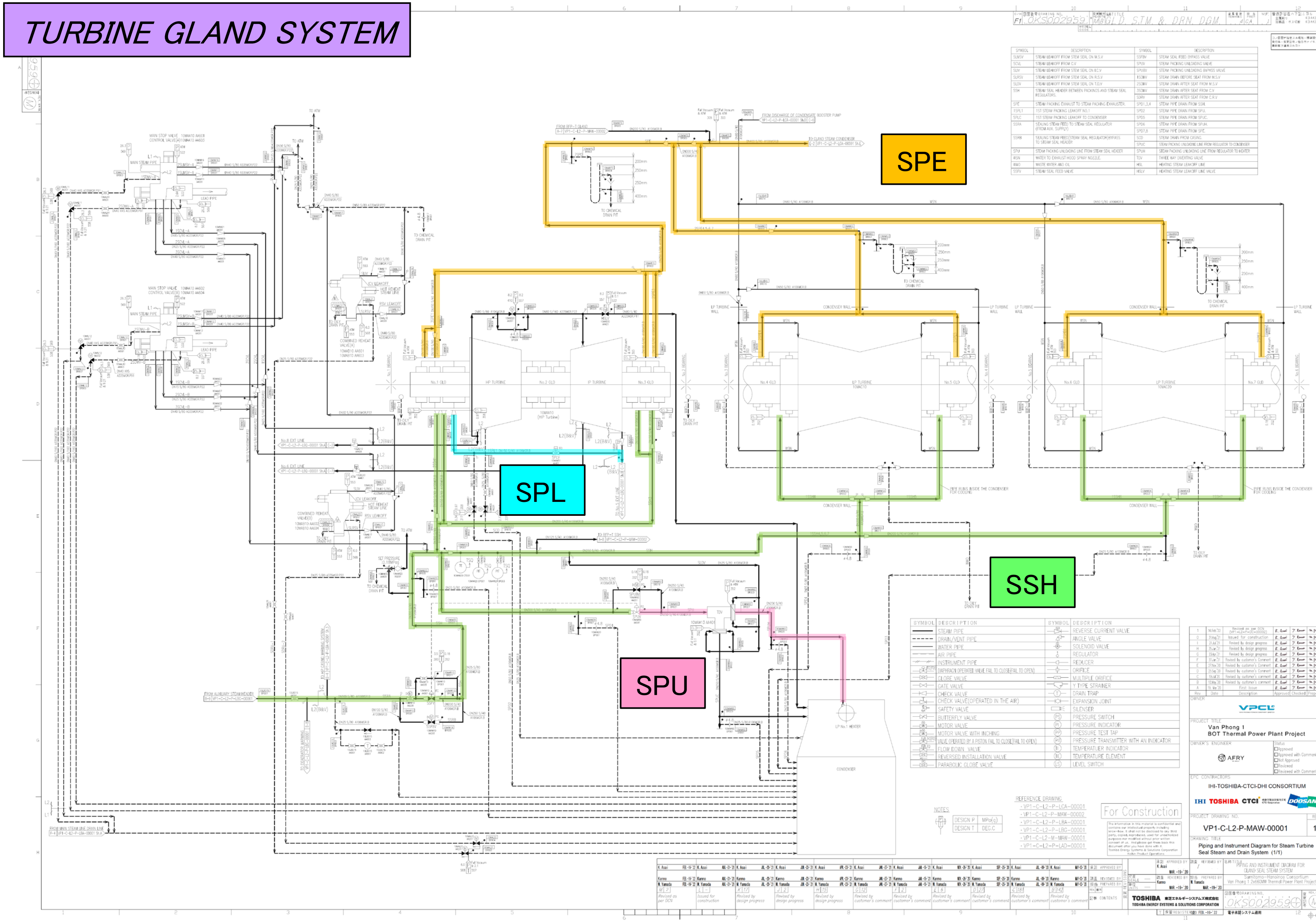
G1=g1－g2

G2=g2－g3

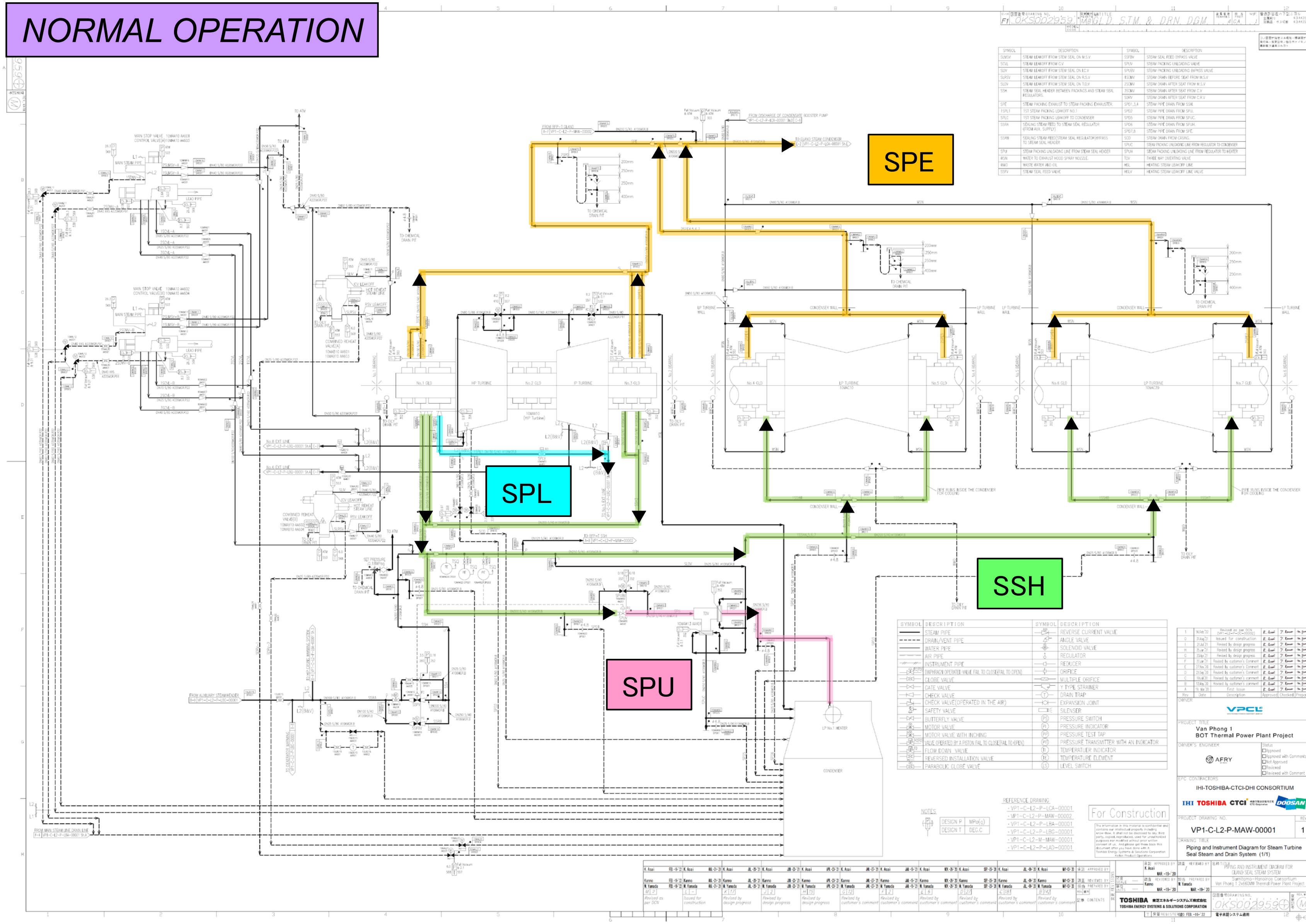
G3=g3＋g4

Typical

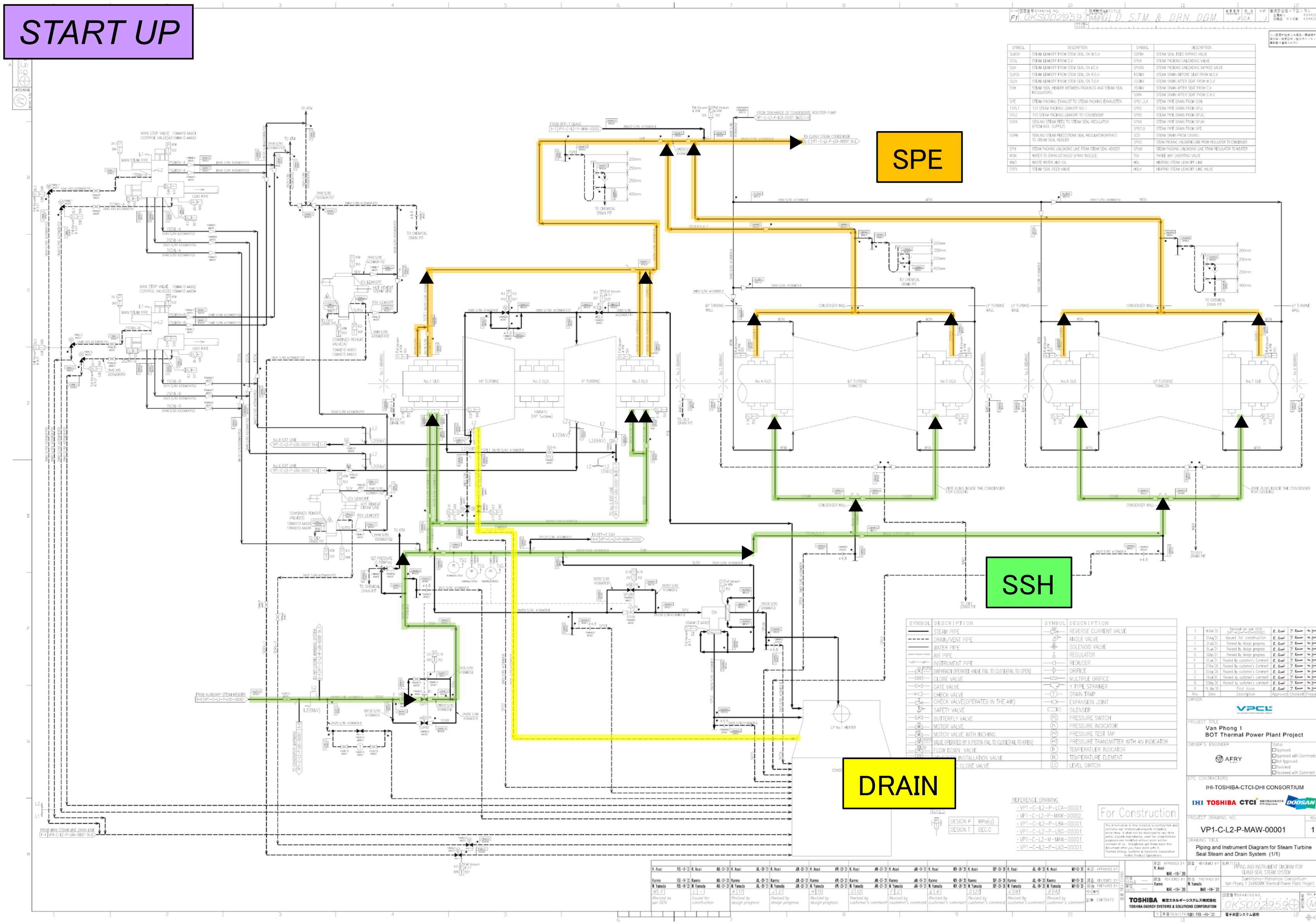
Turbine Gland Seal System



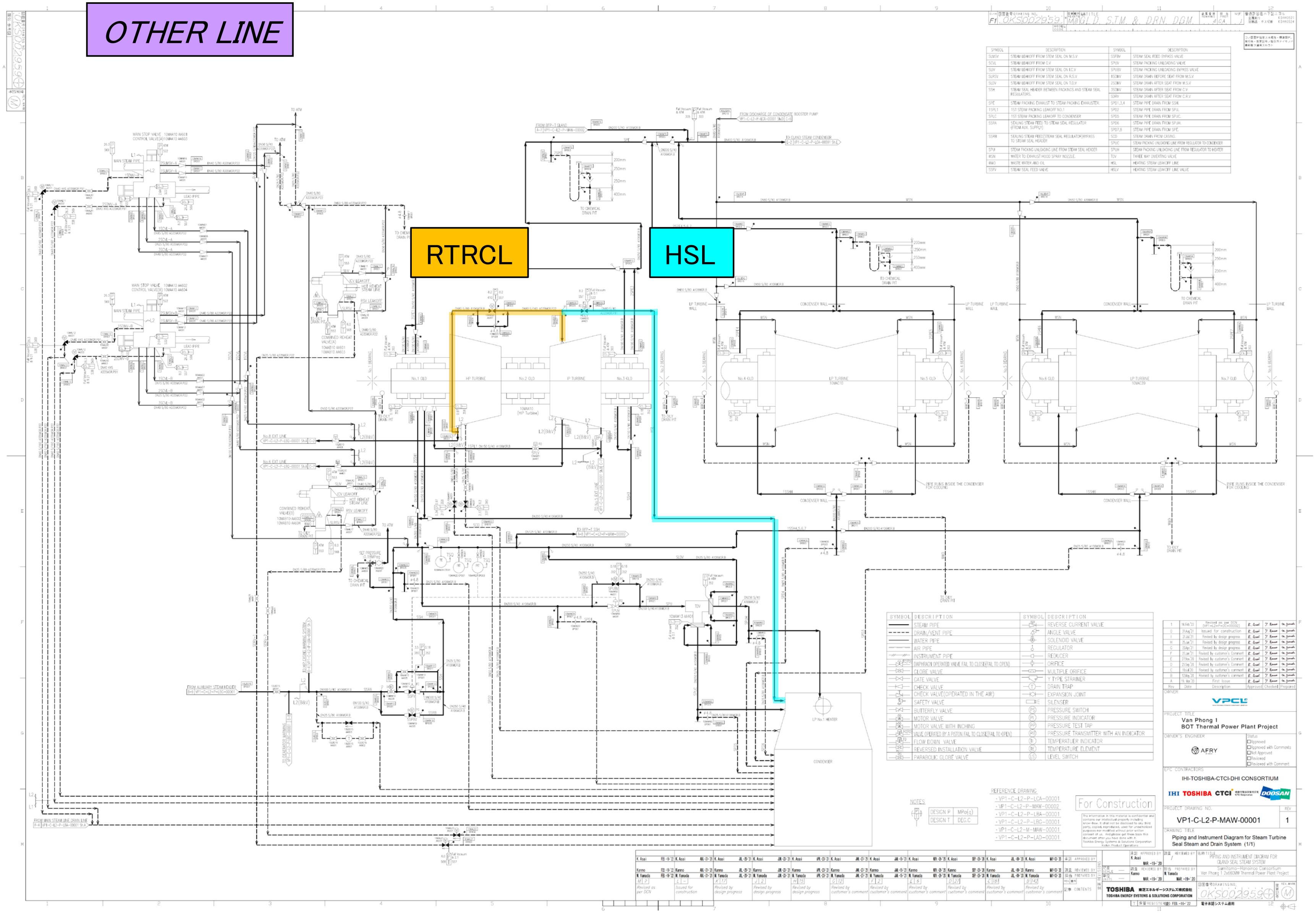
Turbine Gland Seal System



Turbine Gland Seal System

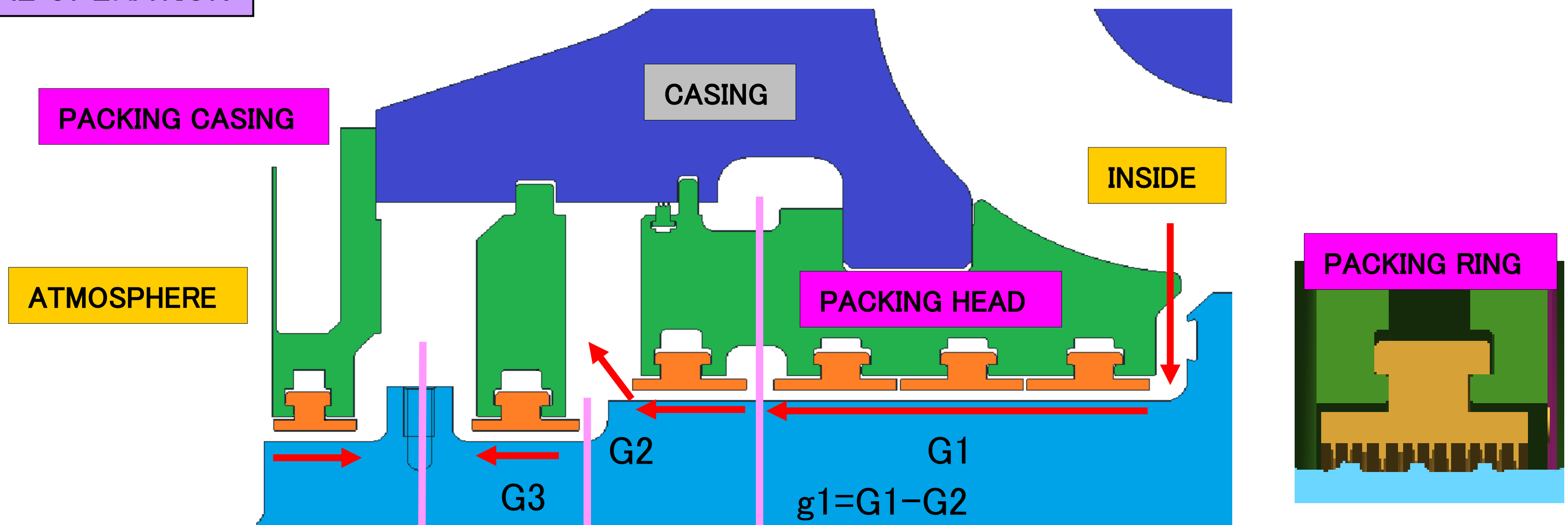


Turbine Gland Seal System



Gland Seal System – High Pressure Gland

NORMAL OPERATION



SPL (Steam Packing Leakoff)

This line is connected to deaerator extraction.

g2=G2−G3

SSH (Steam Seal Header) 0.28 bar gage

SPE (Steam Packing Exhaust) about −0.01 bar gage

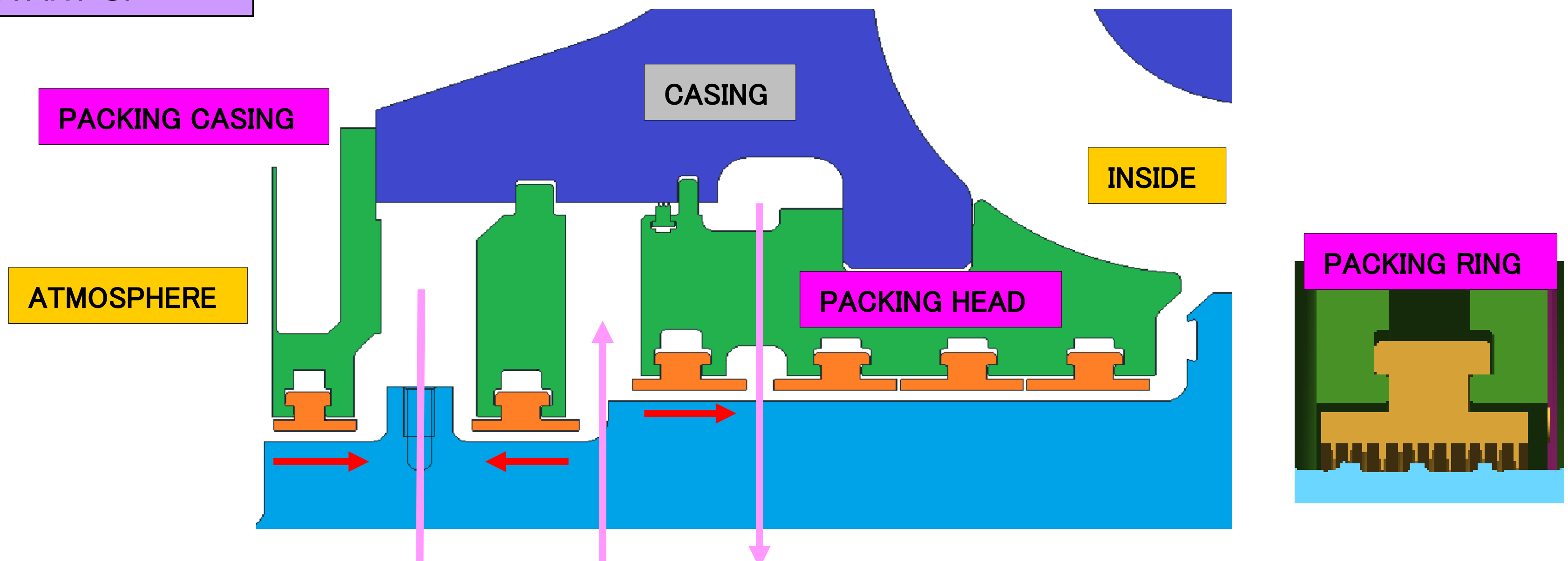
This line is connected to gland steam condenser

Prevention of steam leakage from HP/IP casing ends.

Typical

Gland Seal System – High Pressure Gland

START UP



SPL　(Steam Packing Leakoff)
Vacuum condition
This line is connected to condenser during start up condition.

SSH　(Steam Seal Header)　0.28 bar gage

SPE　(Steam Packing Exhaust)　about −0.01 bar gage

This line is connected to gland steam condenser

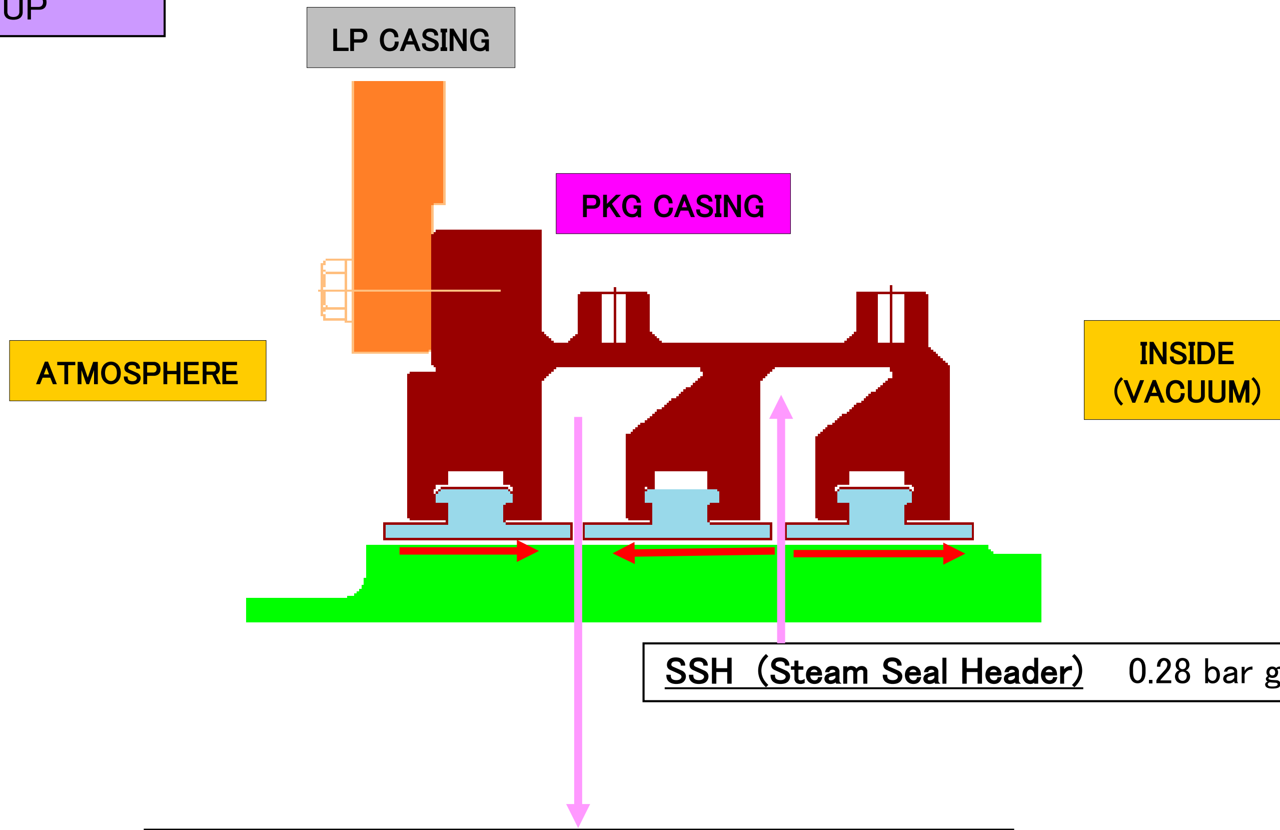
Prevention of air inleak into HP/IP casing ends.

Typical

Gland Seal System – Low Pressure Gland

NORMAL OPERATION

START UP



SSH (Steam Seal Header)　0.28 bar gage

SPE (Steam Packing Exhaust)　about −0.01 bar gage

Prevention of air inleak into LP casing ends.

Typical

03

Major Parts of the Steam Turbine

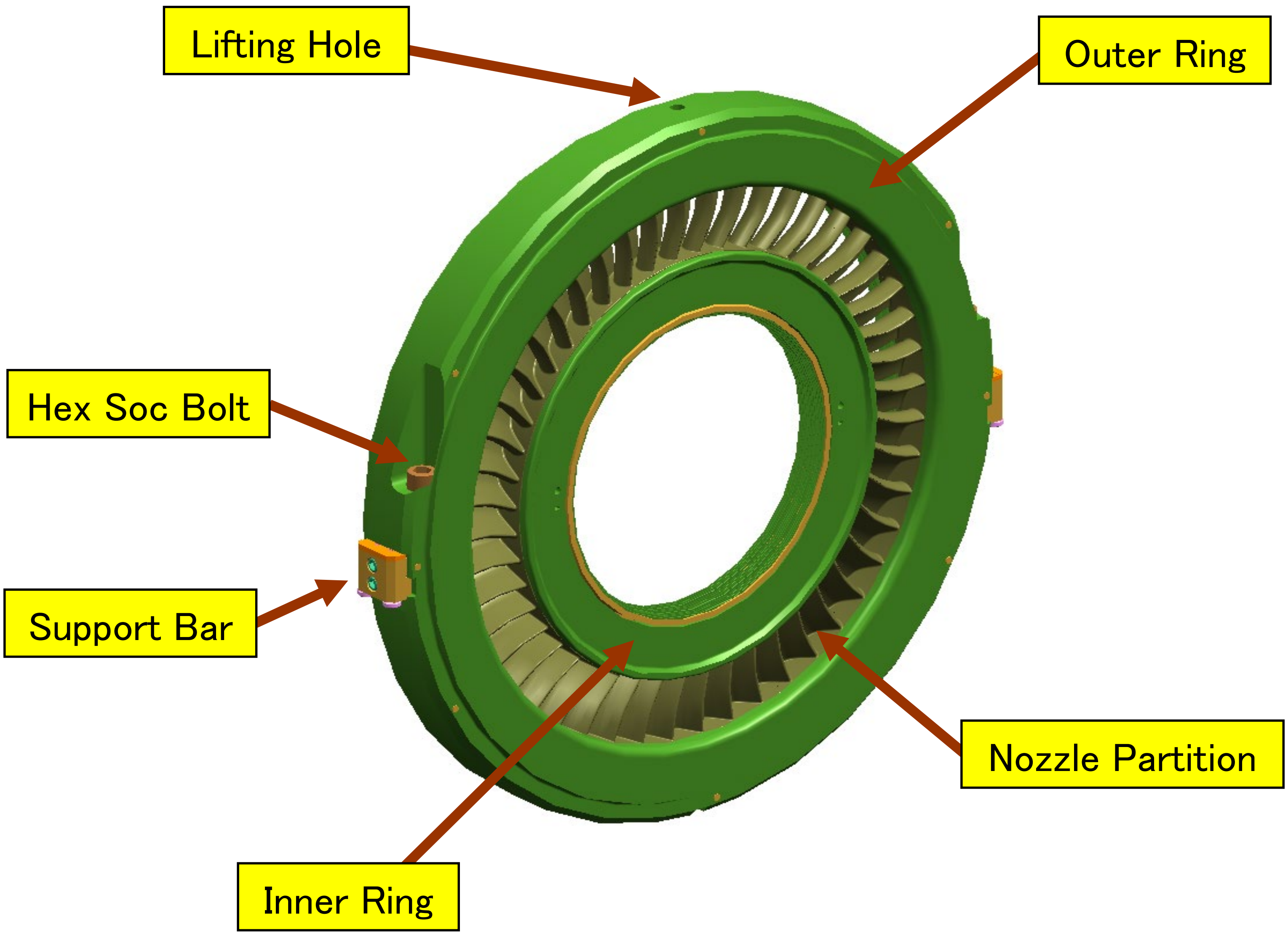
- Turbine Nozzle
- Turbine Blade
- Turbine Casing
- Turbine Rotor
- Bearing
- Turning Gear

03-1

Major Parts of the Steam Turbine

- Turbine Nozzle
- Turbine Blade
- Turbine Casing
- Turbine Rotor
- Bearing
- Turning Gear

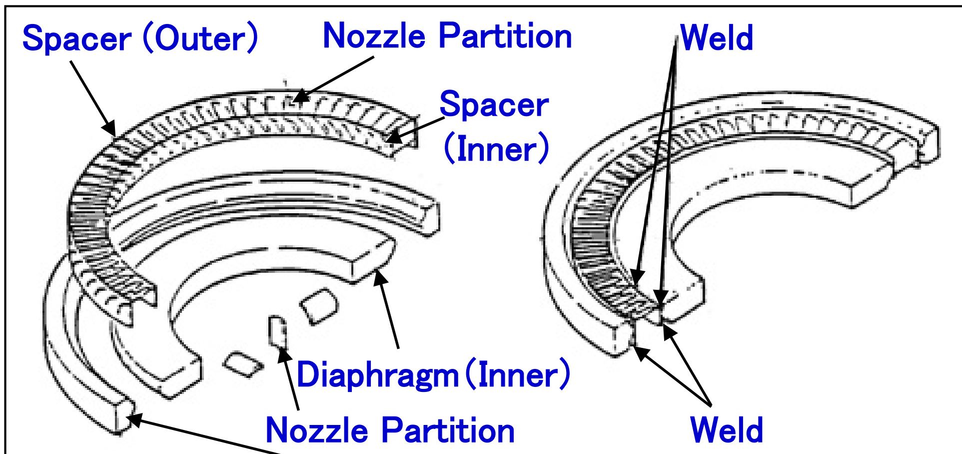
Nozzle Diaphragm Assembly



Typical

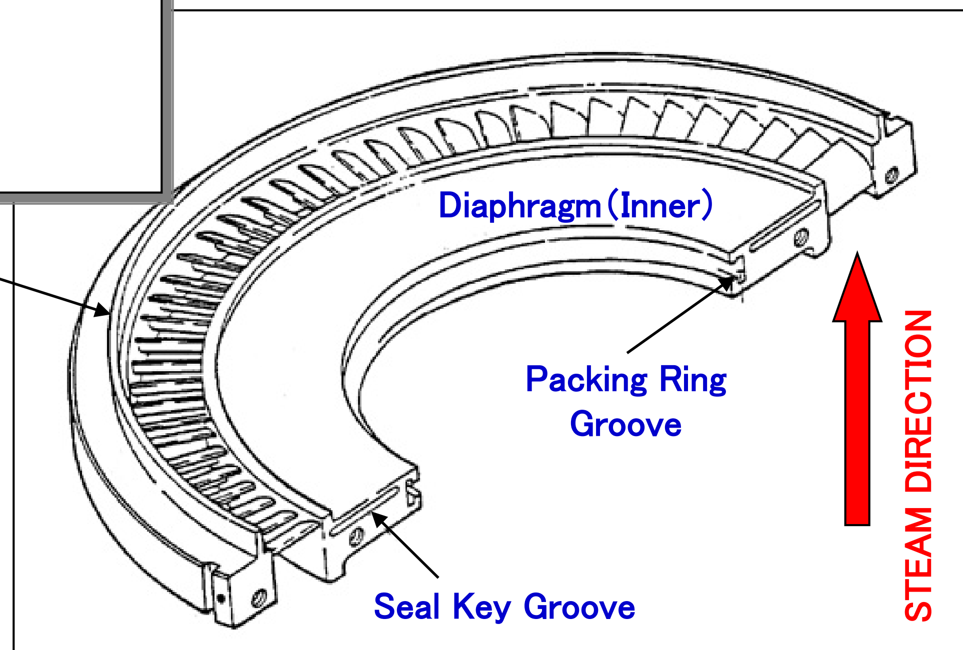
Weld Nozzle

Assembly → **Welded**



Diaphragm(Outer)

Finished Product



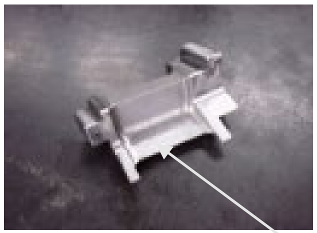
Typical

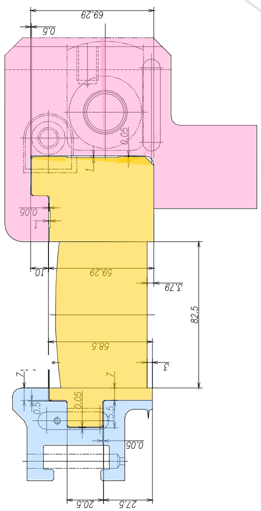
Assembly Nozzle

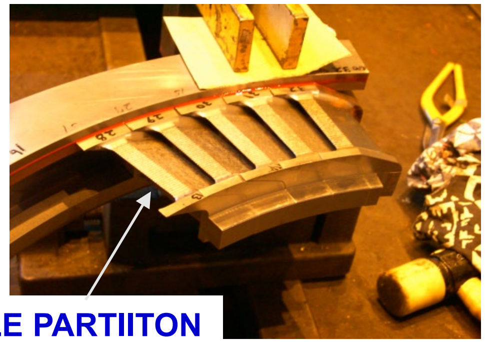
BUILT-UP STAGE NOZZLES

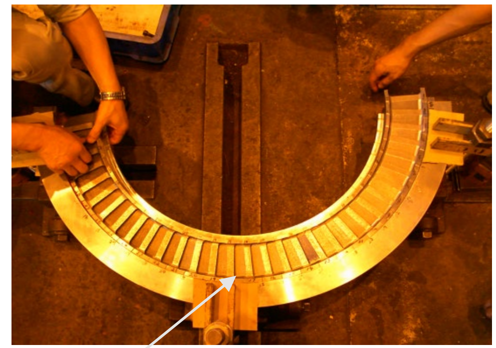
ASSEMBLY

ASEMBLE NOZ PARTITION INTO OUT NOZ DIAPHRAGM







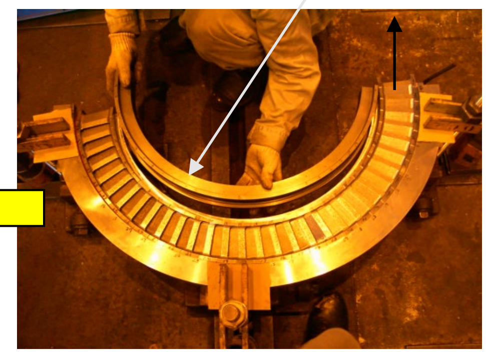


NOZZLE PARTIITON

DIAPHRAGM（OUTER）

DIAPHRAGM（INNER）

FINISHED PRODUCT

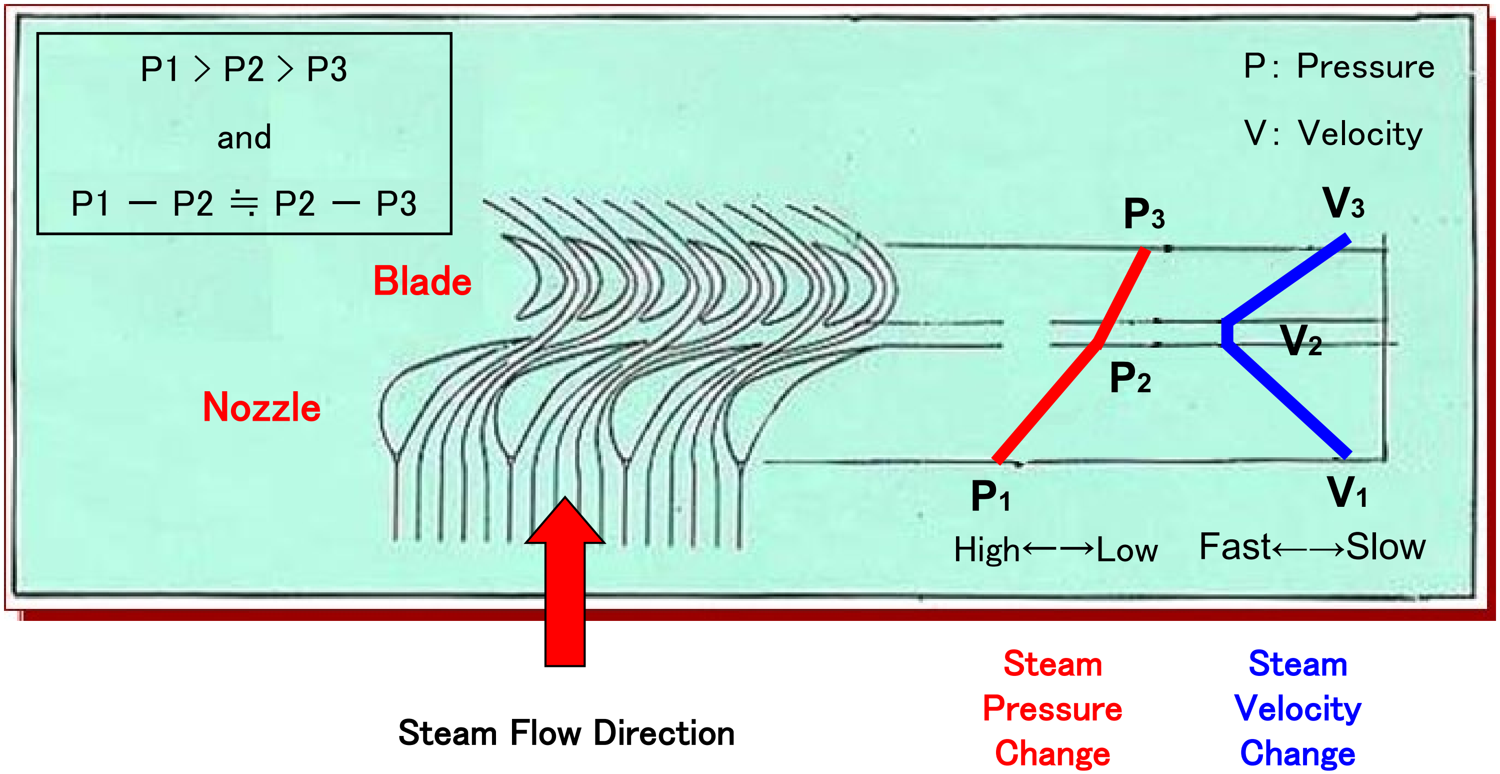


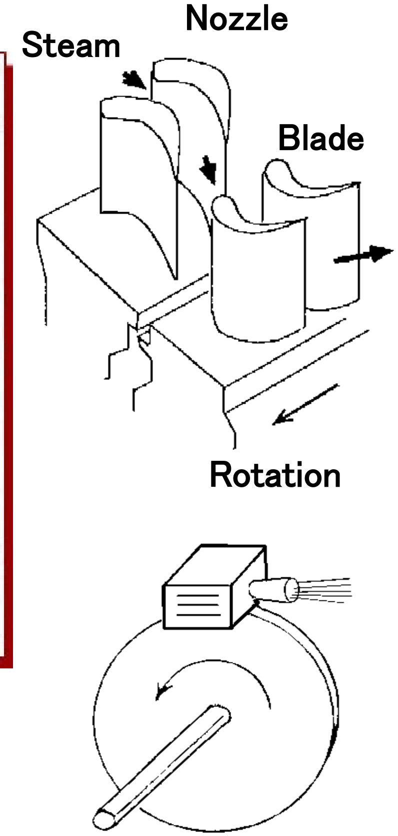
ASSEMBLE INNER NOZ DPH

Advantages
: High turbine performance
Improvement in dimensional control
(No welding distortion)
Smooth nozzle surface finish
(No roughness degradation)

Typical

Steam Path of "High-Efficiency Reaction Design"



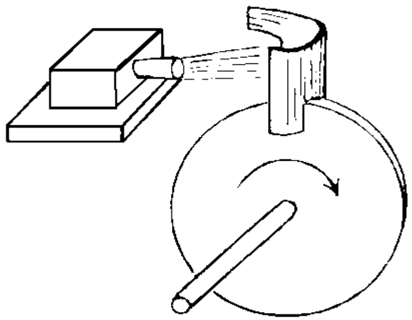


Reaction Design Model

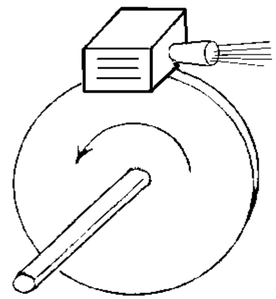
<u>Reaction-Type Steam Path – Blade Design</u>

Typical

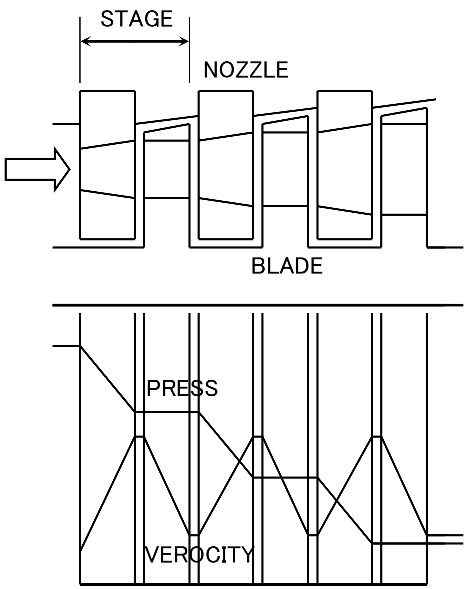
“Impulse Design” and “Reaction Design”

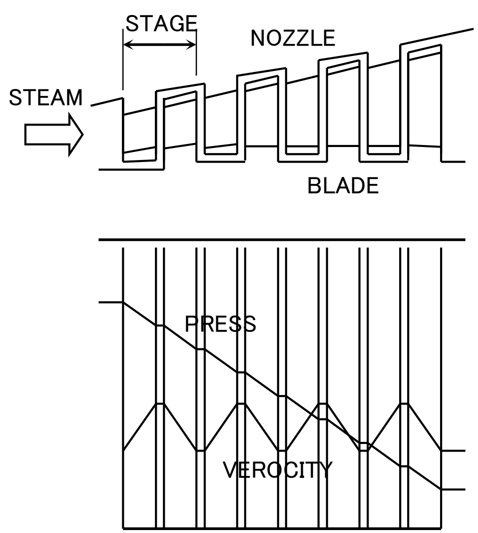


Impulse Design Model

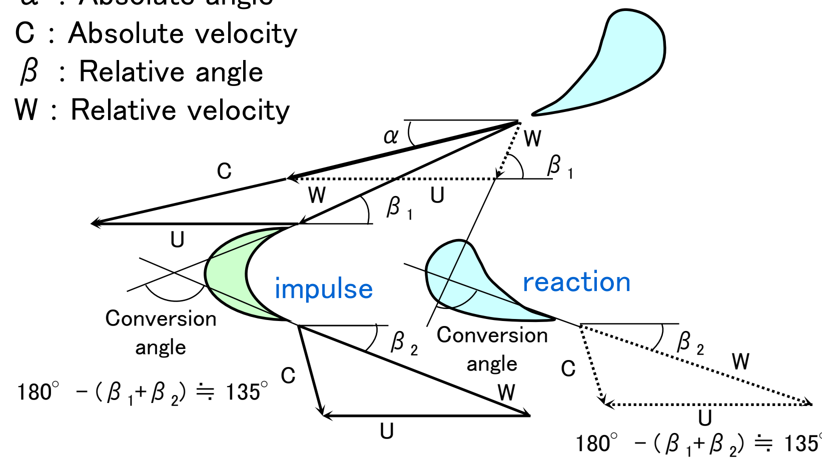


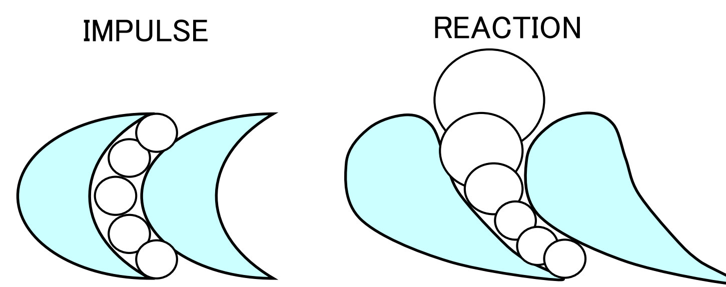
Reaction Design Model





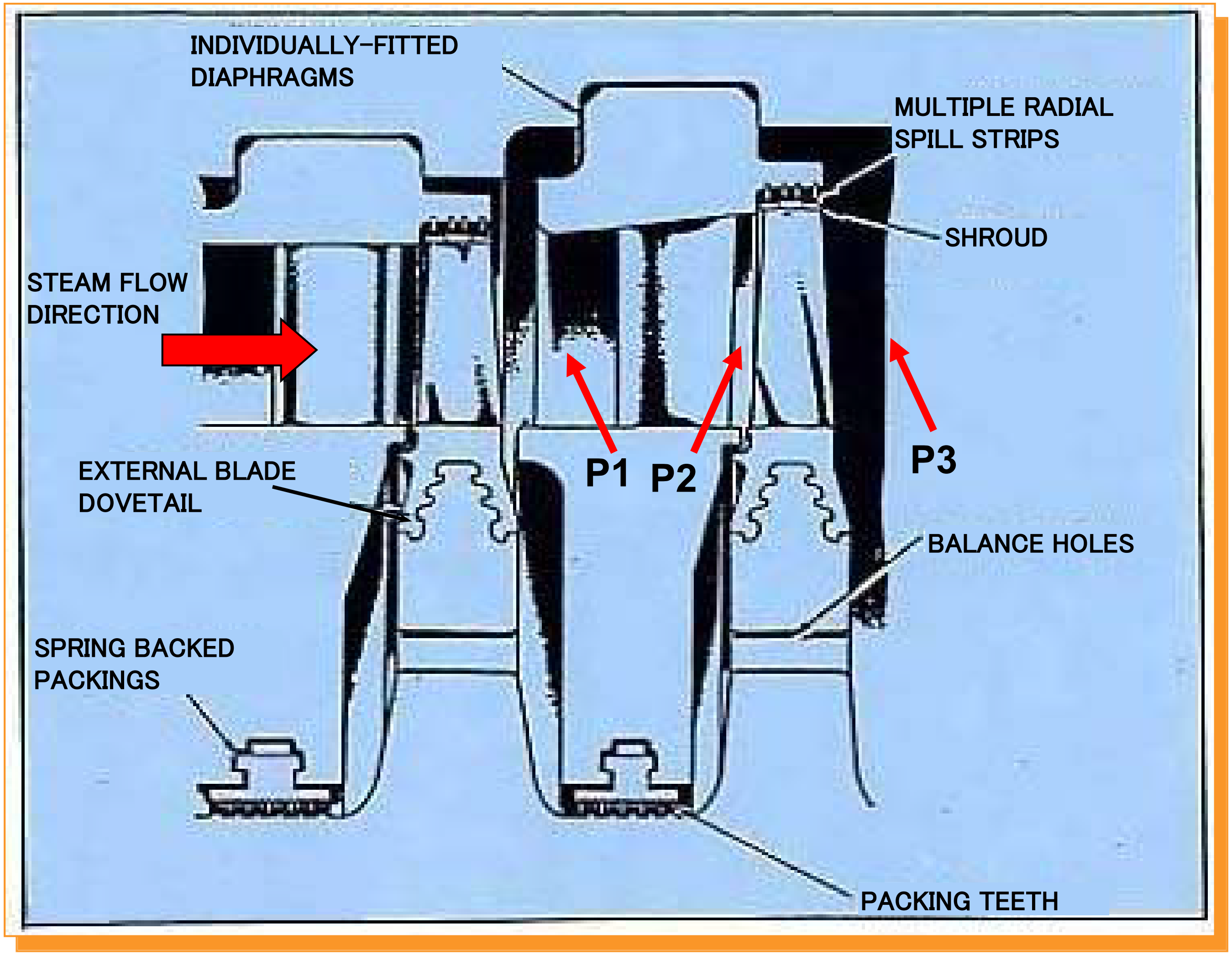
U : Blade velocity
α : Absolute angle
C : Absolute velocity
β : Relative angle
W : Relative velocity





Typical

Nozzle Diaphragm and Blade



Wheel and Diaphragm Construction

Reaction Design Feature

P1 ＞ P2 ＞ P3

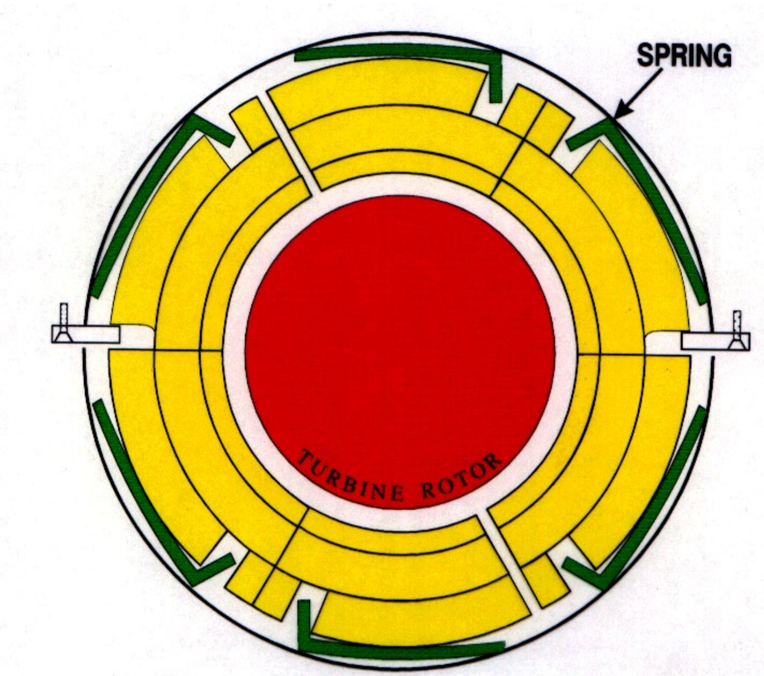
and

P1 − P2 ≒ P2 − P3

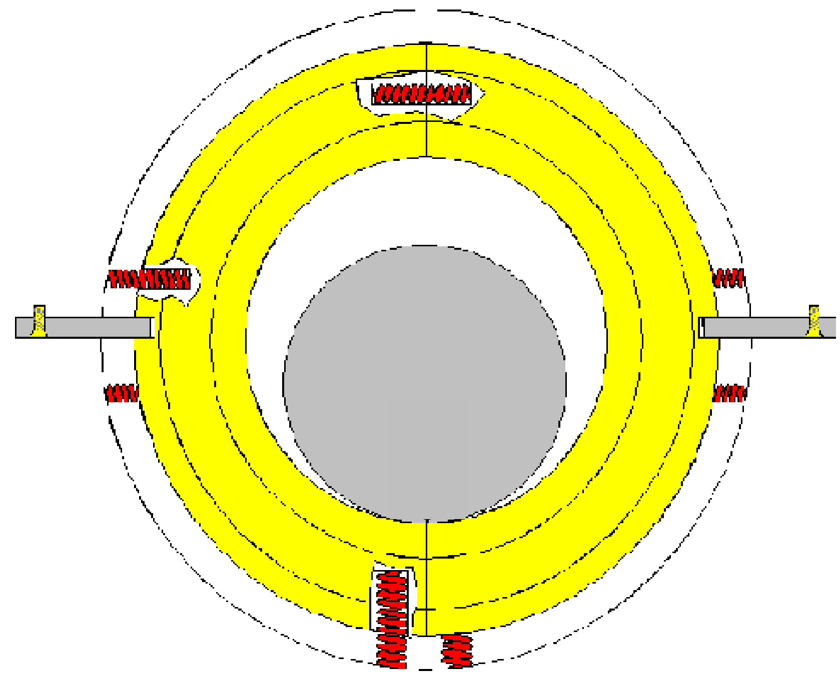
Typical

Packing Ring

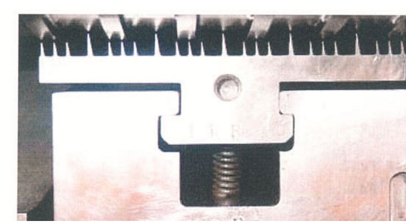
Plate type Packing



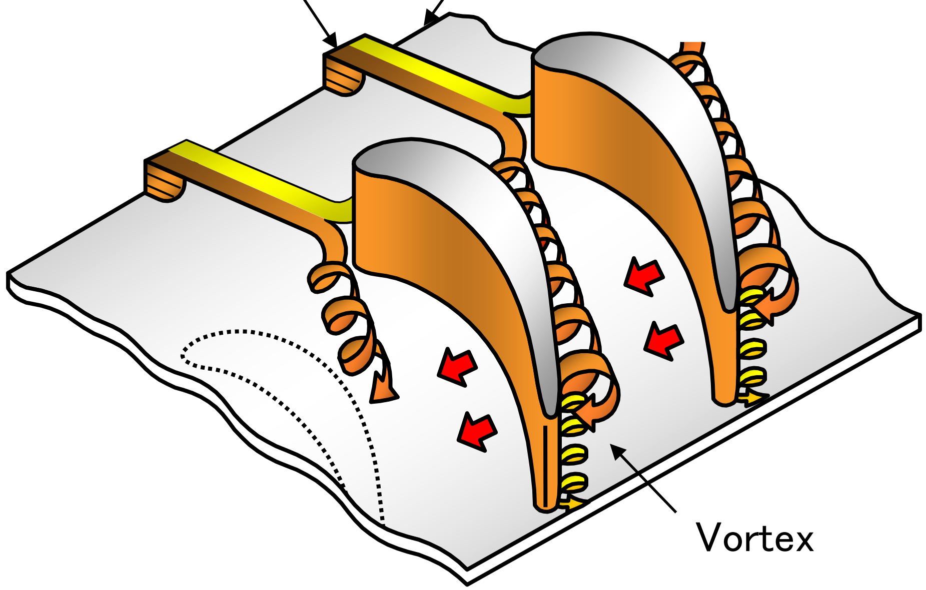
Sensitized Packing



Packing weight is balanced with spring force
Even if rubbing is occurs, heavy rubbing is avoided.



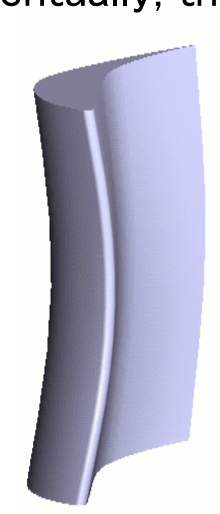
Steam Flow near Nozzle

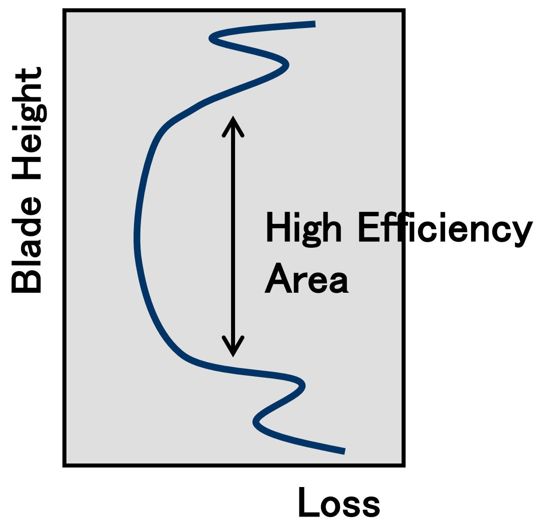


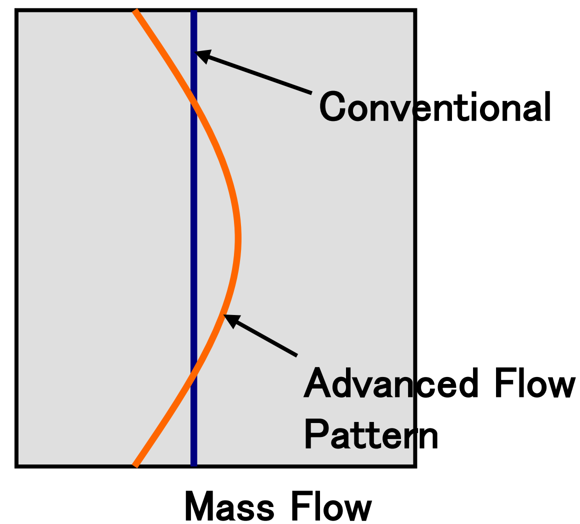
- Complicated three-dimensional flow
- Vortex is one of the factor of efficiency loss

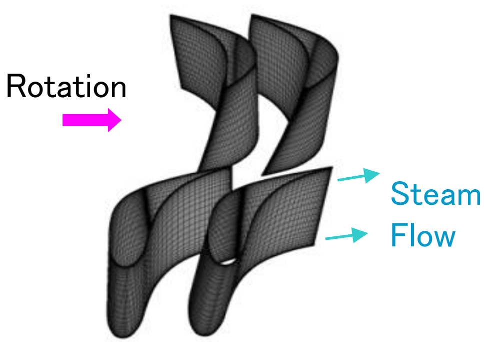
Advanced Flow Pattern

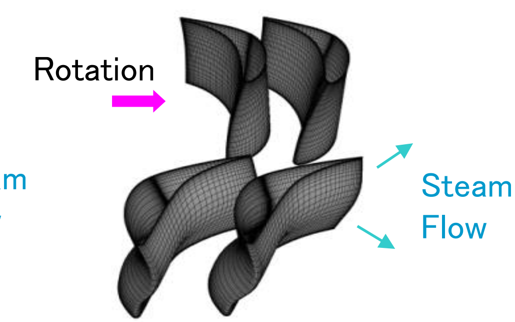
- Curved profile of nozzle makes steam flow toward nozzle end wall.
  It suppresses the secondary vortex.
- The larger efficient the mid-section of blades, the higher steam mass flow rate.
  Eventually, the overall stage efficiency can be improved.











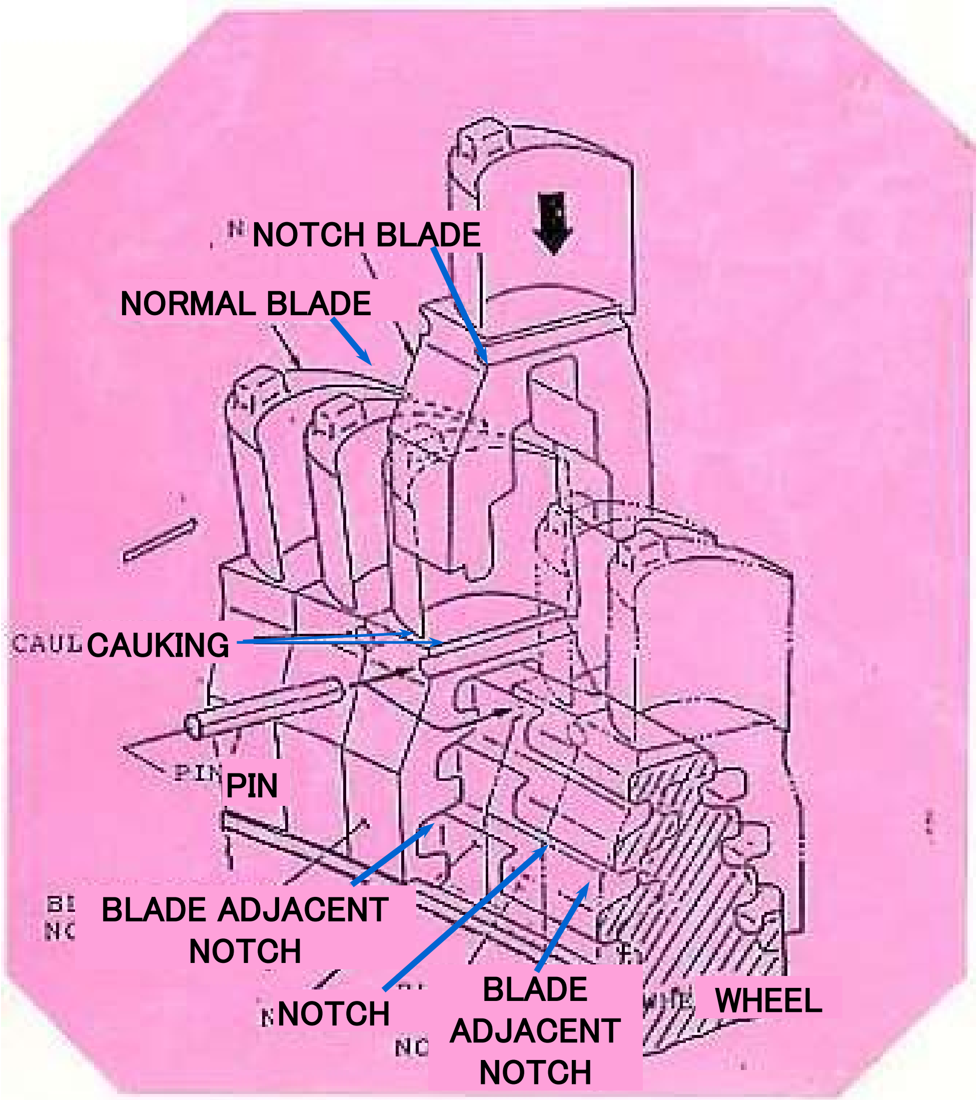
Typical

03-2

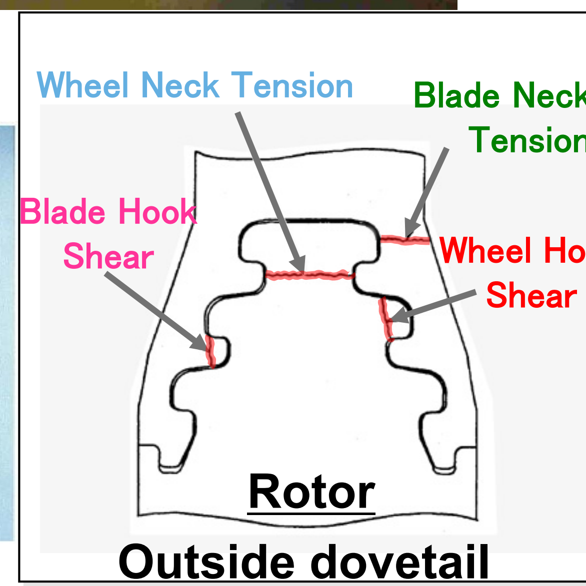
Major Parts of the Steam Turbine

- Turbine Nozzle
- Turbine Blade
- Turbine Casing
- Turbine Rotor
- Bearing
- Turning Gear

Stage Blades



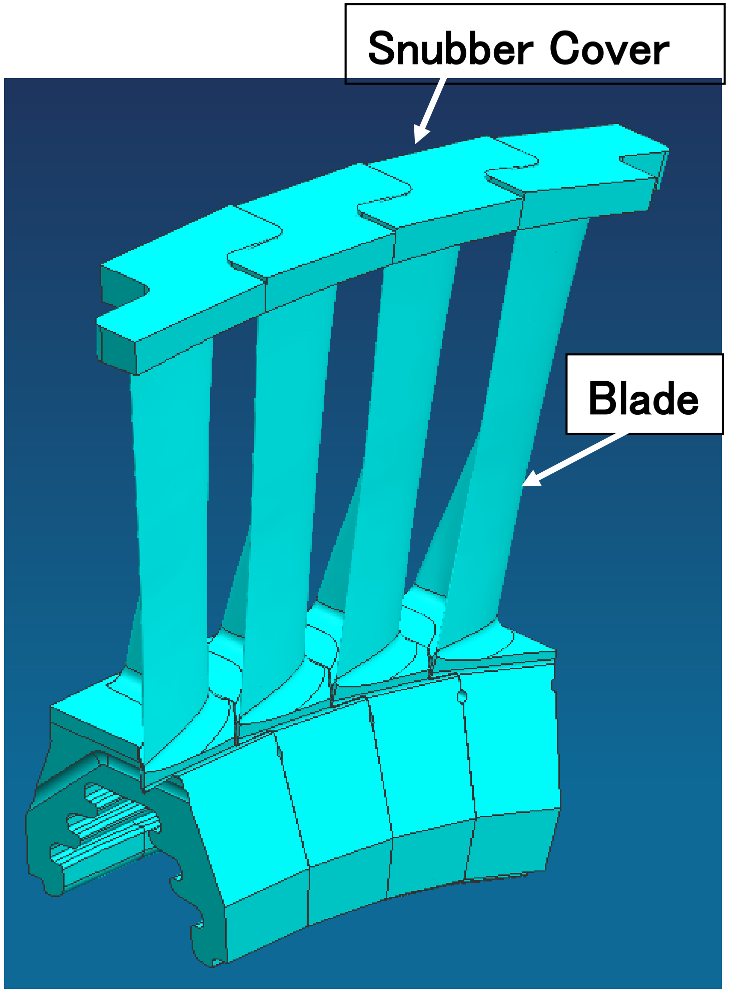
Typical



Snubber Type Blade

Blade and cover are integrally machined from a single forging :

- Continuous coupling 360 degrees
- Low vibration stresses
- Resistant to corrosion fatigue
- Improved tip sealing
- Easy to assemble and disassemble



Low Vibration Stresses

High Reliability

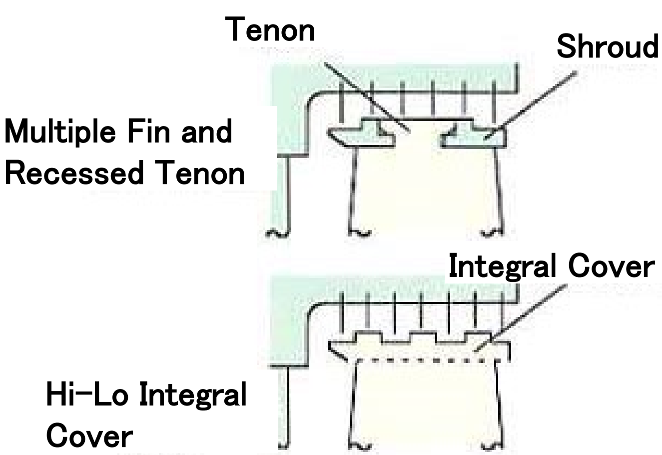
Typical

Snubber Type Blade

Recessed Tenon Type with Multiple Tip Fins and
Snubber Type Blade With Hi-Lo-Type Tip Fin

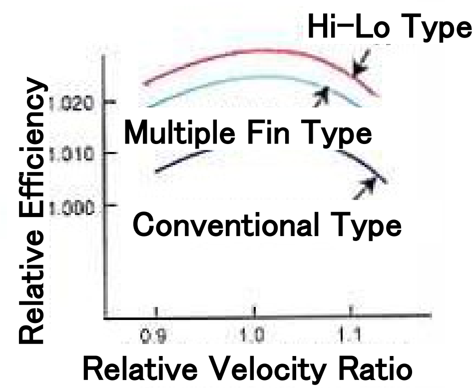
Stage No.	Blade / Tenon / Shroud Type
HP – 1 to 14	Snubber Type with Hi-Lo Fins
IP – 15 to 22	Snubber Type with Hi-Lo Fins
LP – 23 to 25	Snubber Type with Hi-Lo Fins
LP – 26,27	Snubber Type with Straight Fins
LP – 28 (L-0)	Snubber Type / Lug and Sleeve


Continuously Coupled
Snubber Type Blade



Comparison of Tip Fins


Recessed Tenons
and
Stepped Shrouds



Stage Efficiency

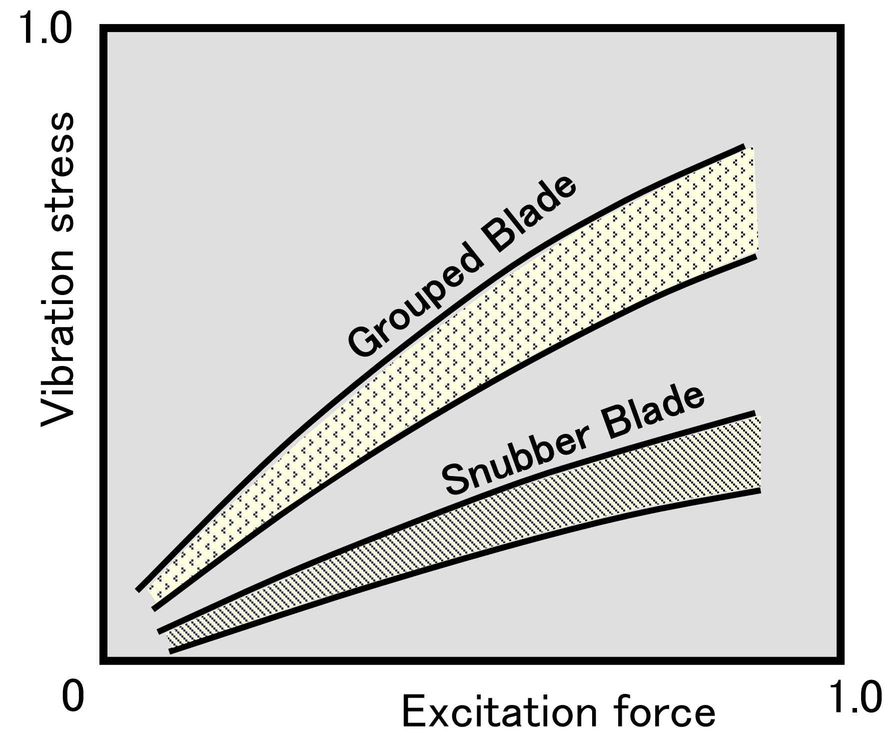
Typical

Snubber Type Blade

- Pressure-contact of the covers provides superior damping when excitation forces work

- Continuously coupling structure greatly reduces the dynamic response of the blades to harmonic stimulating forces

- Thus, the vibration stresses are much lower compared to the conventional tenon-and-shroud design



Comparison of Vibration Stresses

Low Vibration Stresses

High Reliability

Typical

Snubber Type Blade

- The continuously coupled integral covers provide an optimal interstage sealing with a minimum of leakage losses
- Multi tip fins machined on the snubber cover substantially reduce the tip leakage flow
- No gaps between the shroud bands, observed in the tenon-and-shroud type conventional blades

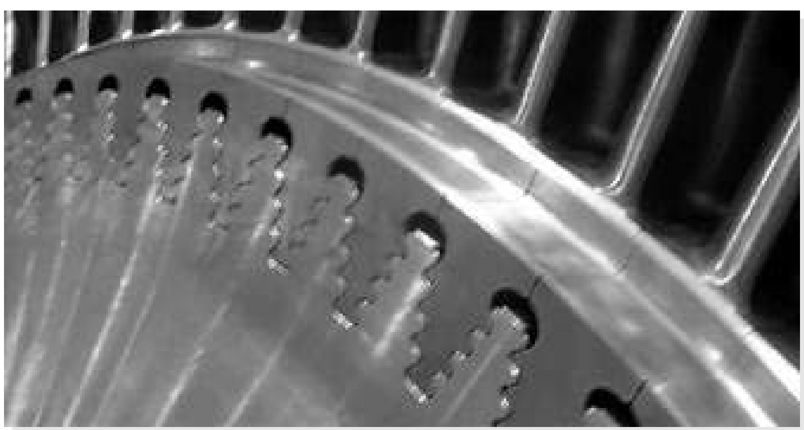
High Efficiency

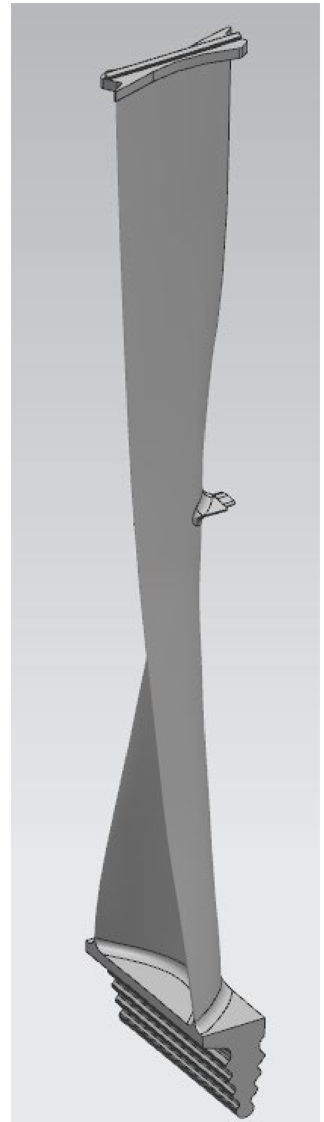
Multiple Fins

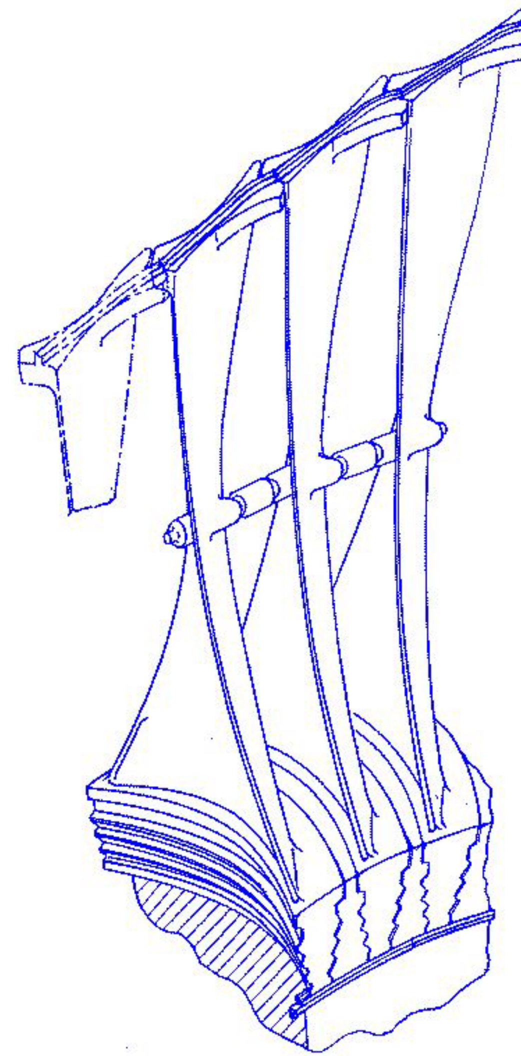
Typical

Last Stage Blade

- **Structural features**
  - 33.5 inch length
  - Axial Entry Dovetail
  - Lug and Sleeve at middle height
- **Continuously coupling effect**
  - Continuous connection at tip and middle height provide vibration damping.







03–3

Major Parts of the Steam Turbine

- Turbine Nozzle
- Turbine Blade
- Turbine Casing
- Turbine Rotor
- Bearing
- Turning Gear

HIP Casing Feature

- **Double Shell Construction**
  - ・Minimal possibility of steam leakage
  - ・Lower stress and temperature gradient

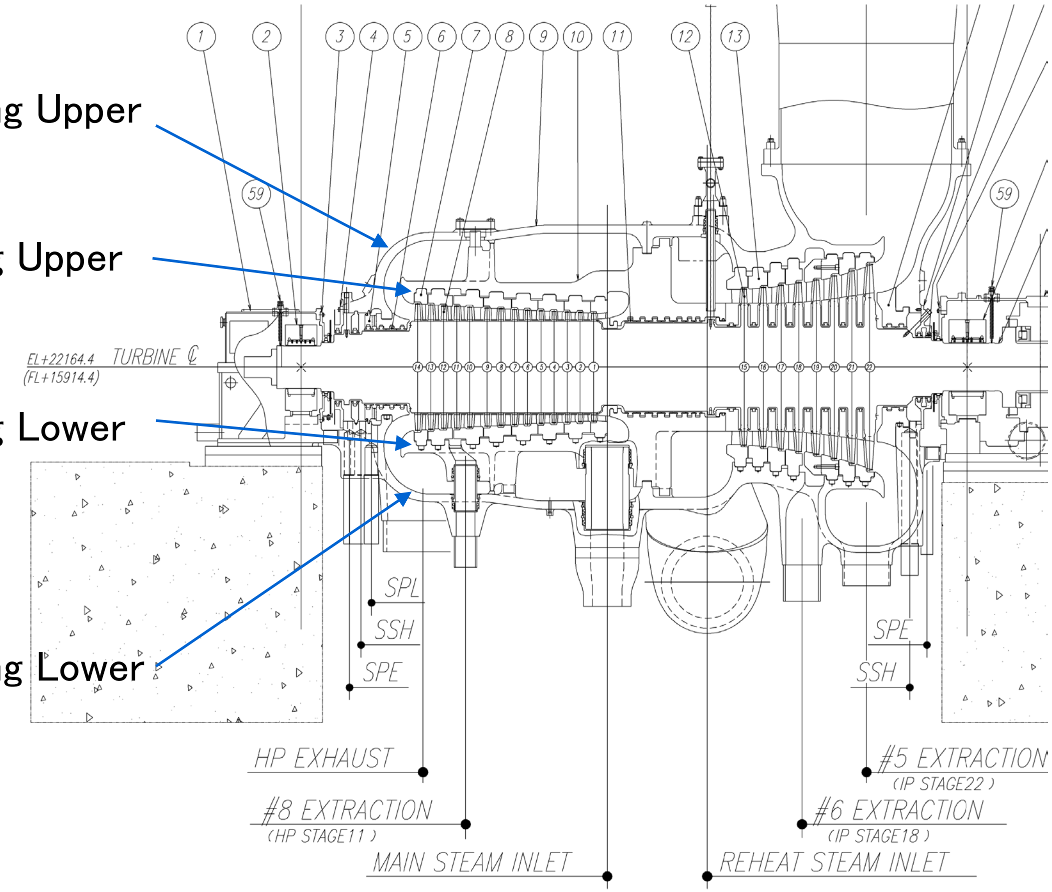
- **Centerline Support**
  - Easy Operation, Installation and Maintenance

HIP Outer Casing Upper

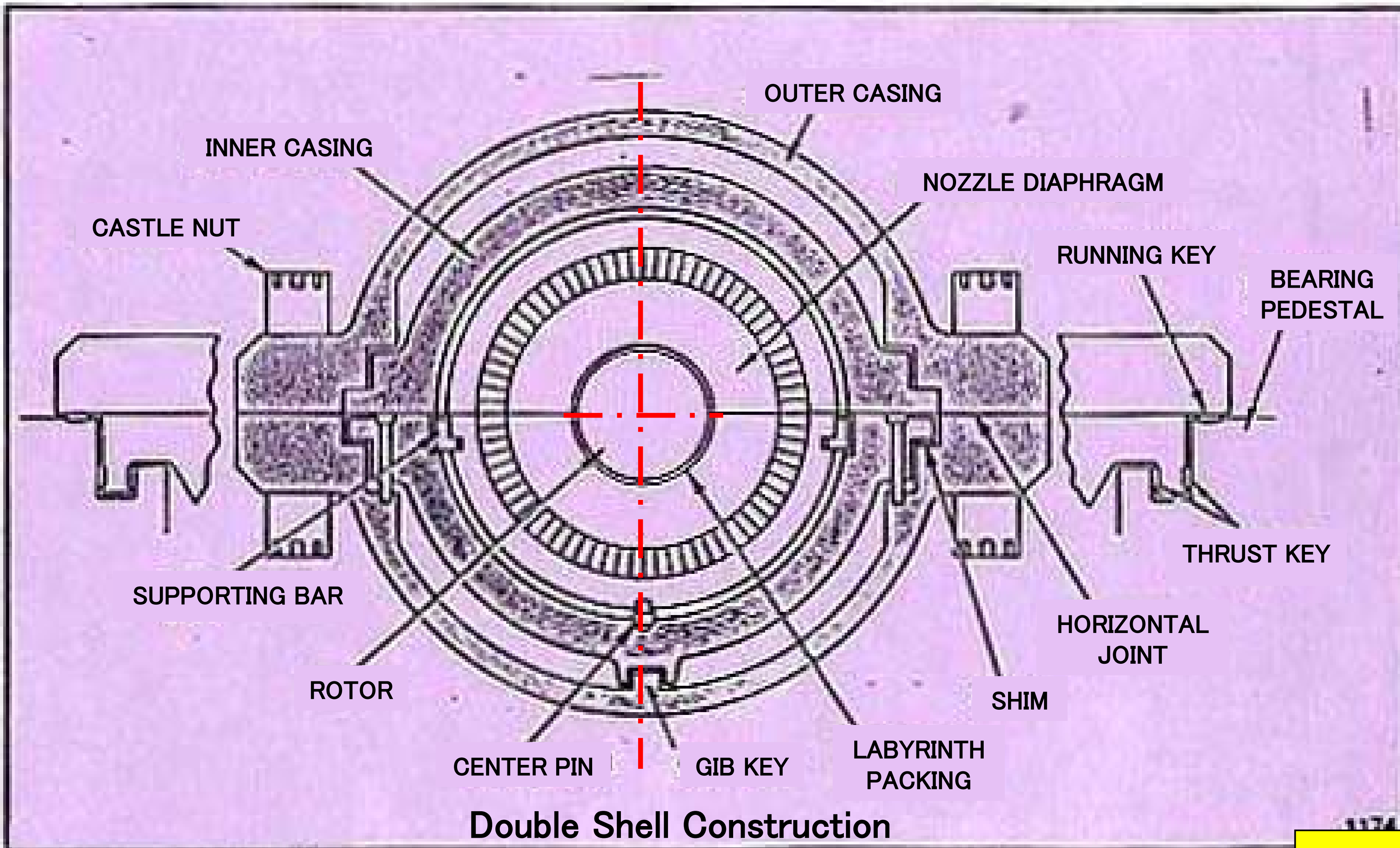
HP Inner Casing Upper

HP Inner Casing Lower

HIP Outer Casing Lower

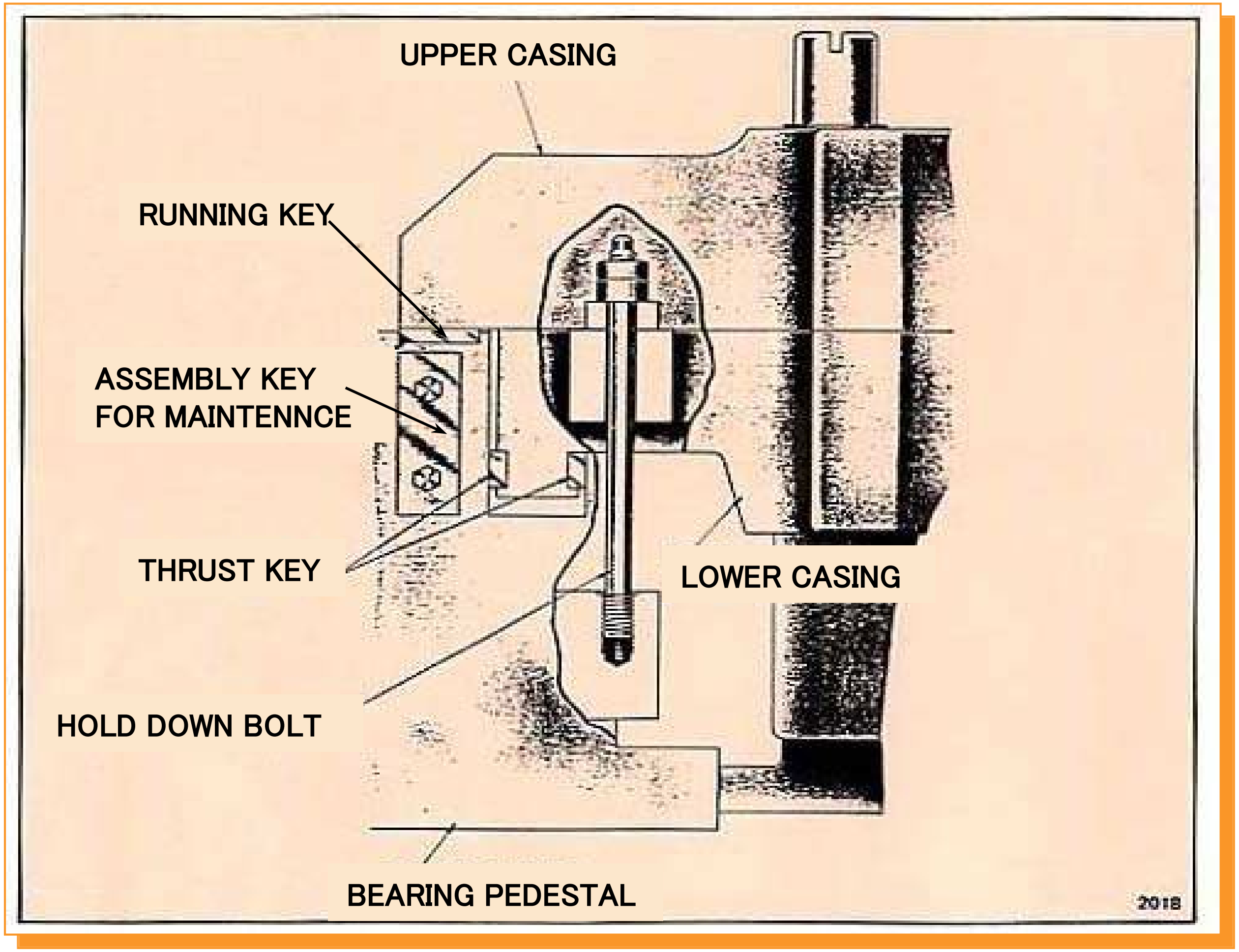


Centerline Support – Nozzle and Casing



Double Shell Construction

Centerline Support and Expansion Control

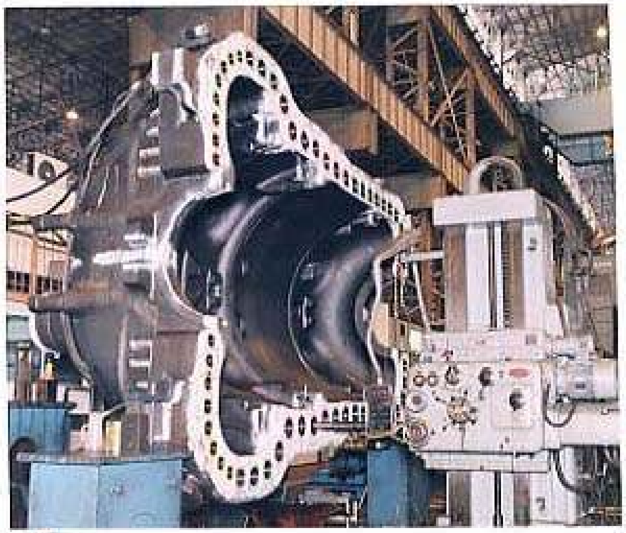


True Centerline Support

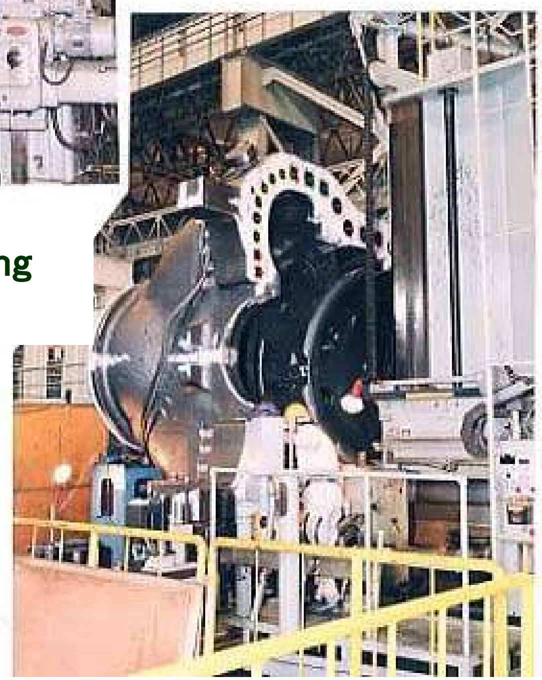
Typical

HIP Casing

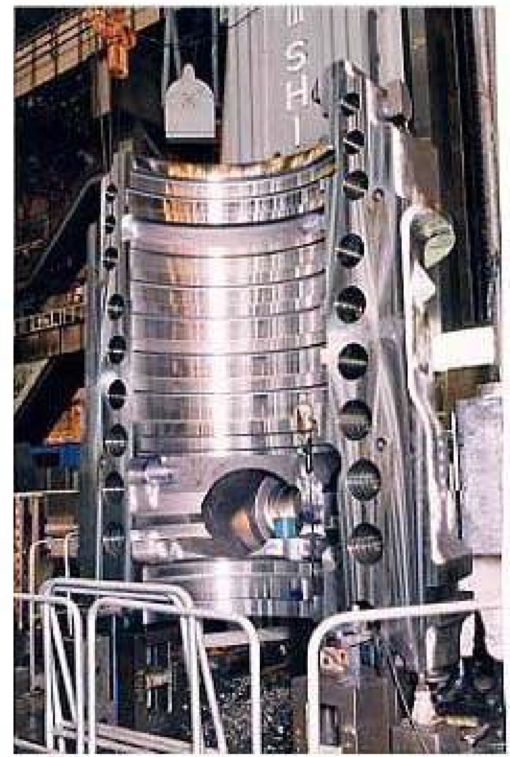
Photo Viewing of Steam Turbine Components under Manufacturing



HIP Outer Lower Casing under machining



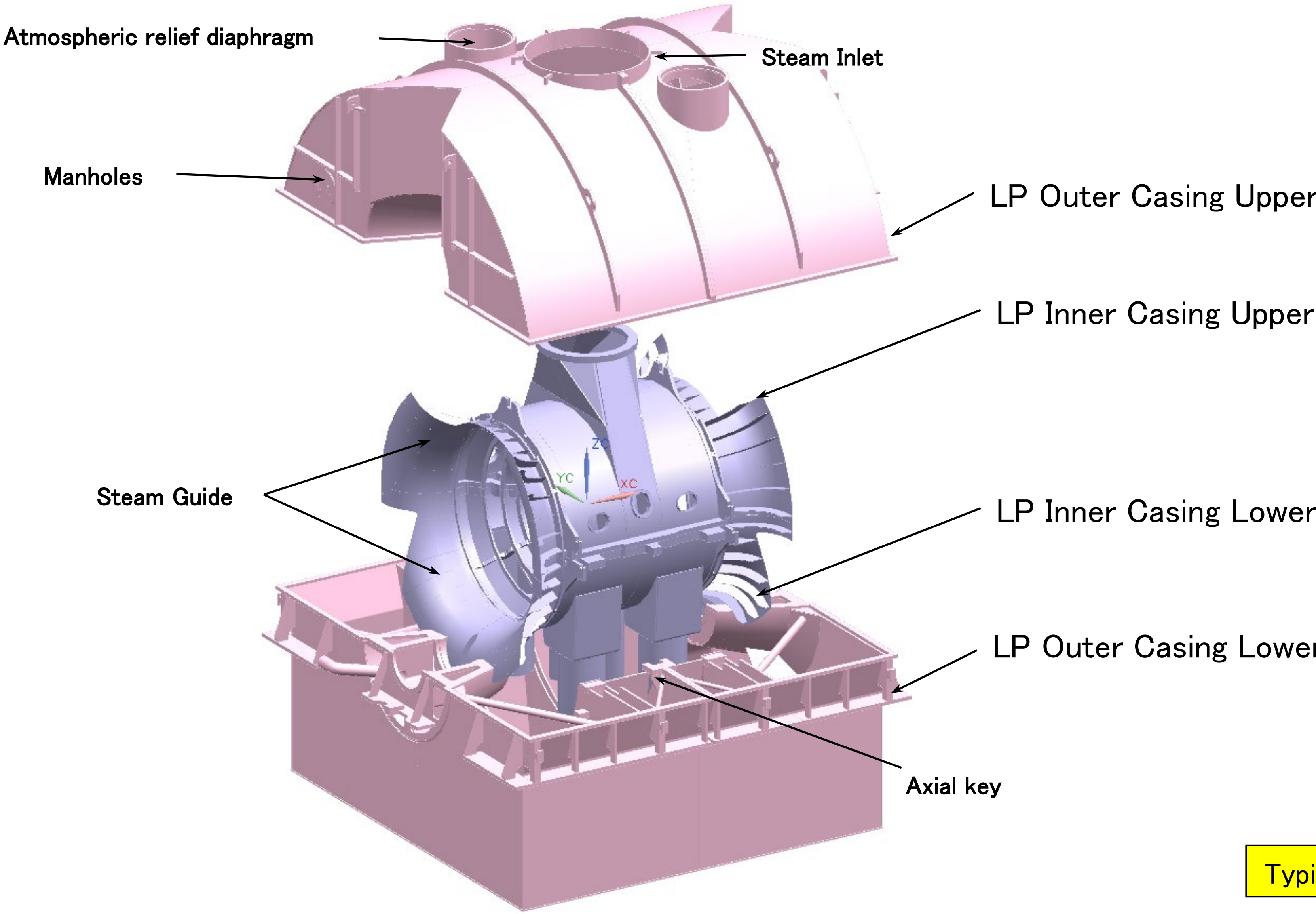
HIP Outer Upper Casing under machining



HIP Inner Upper Casing under machining

Typical

LP Casing



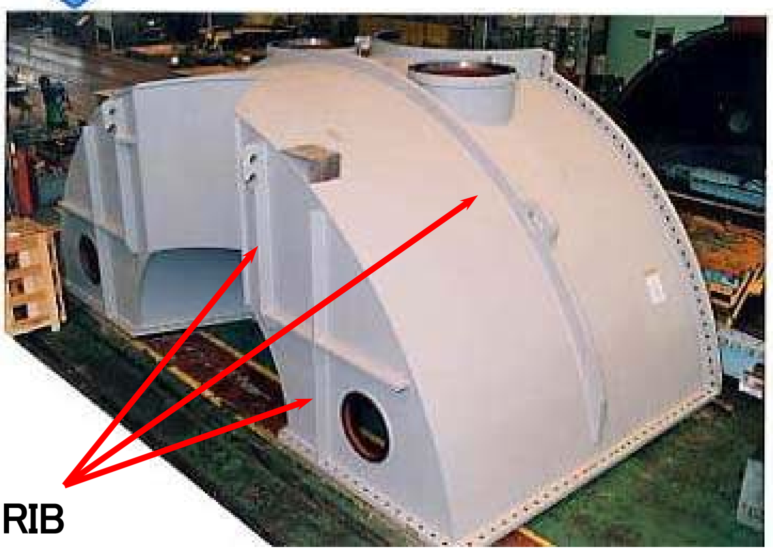
Typical

LP Casing

Photo Viewing of Steam Turbine Components under Manufacturing

LP Outer Upper Casing GEN/END

LP Outer Upper Casing TB/END



RIB

Typical

LP Casing

Photo Viewing of Steam Turbine Components under Manufacturing

LP Outer Lower Casing Middle Part

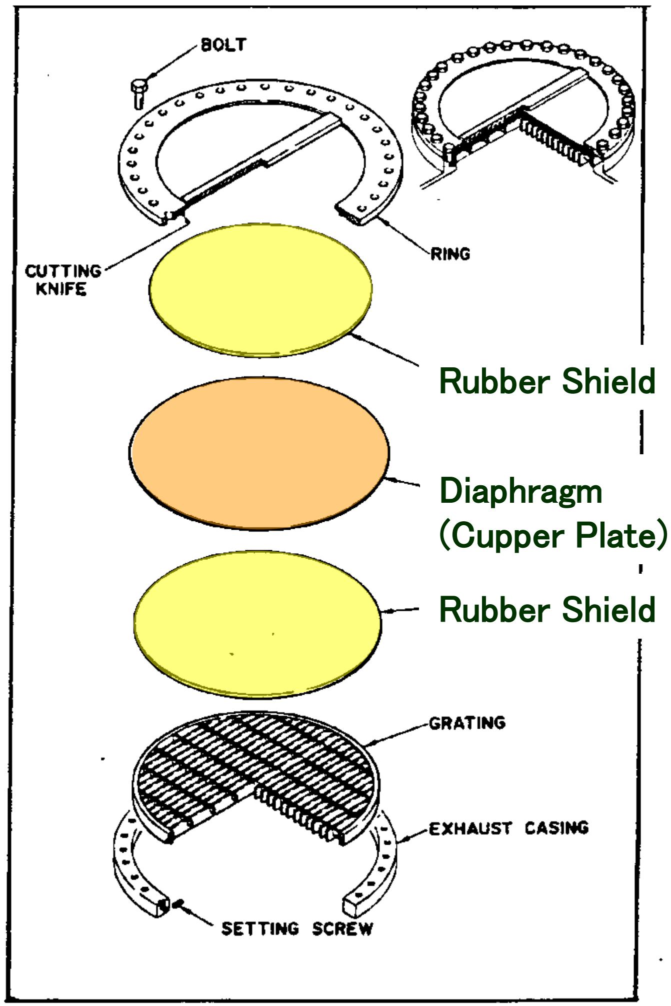
LP Outer Lower Casing GEN/END

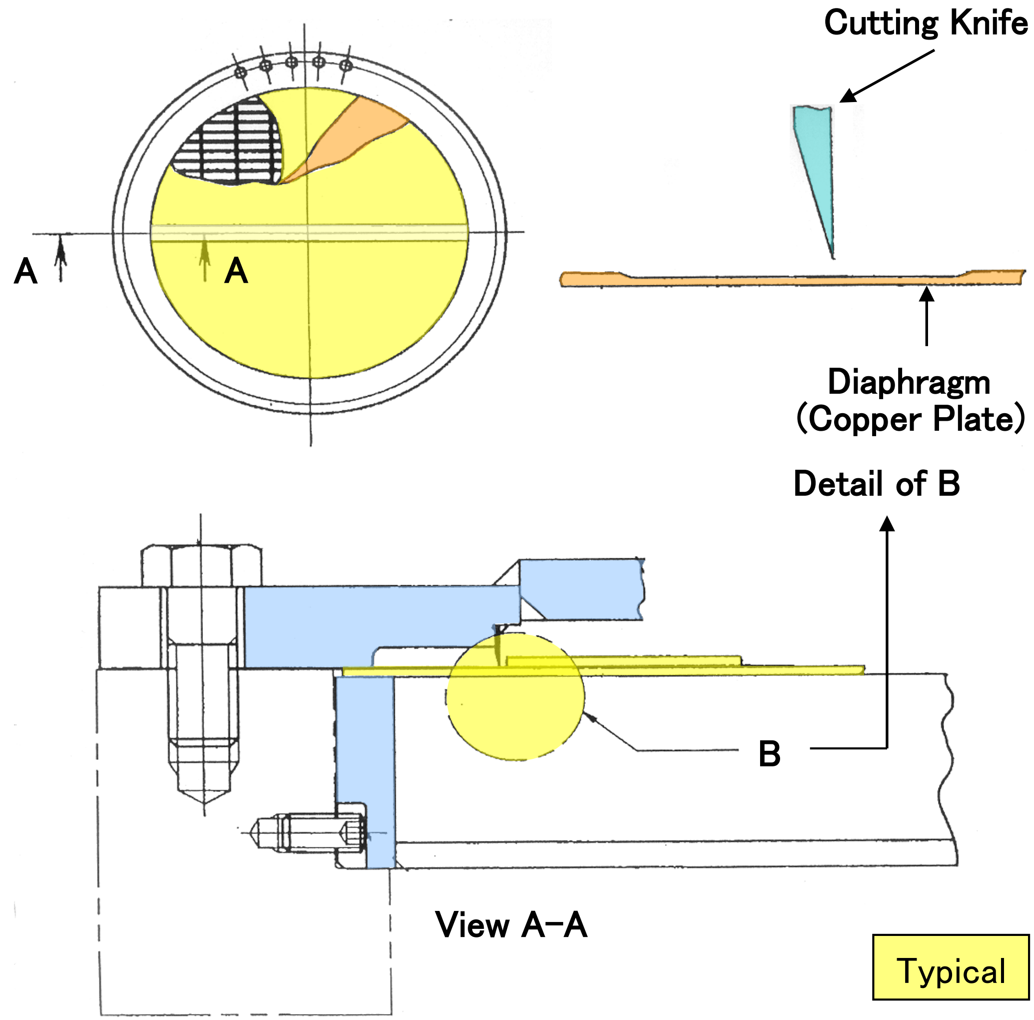
LP Outer Lower Casing TB/END under Machining

Typical

Atmospheric Relief Diaphragm

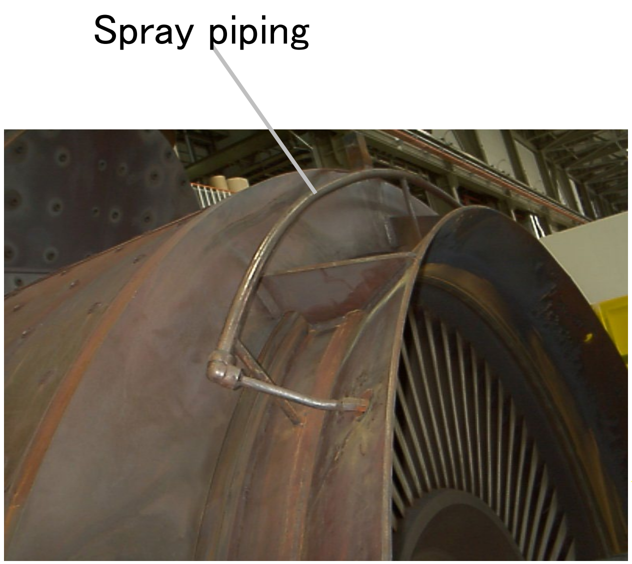
Protection from overpressure of LP outer casing inside.

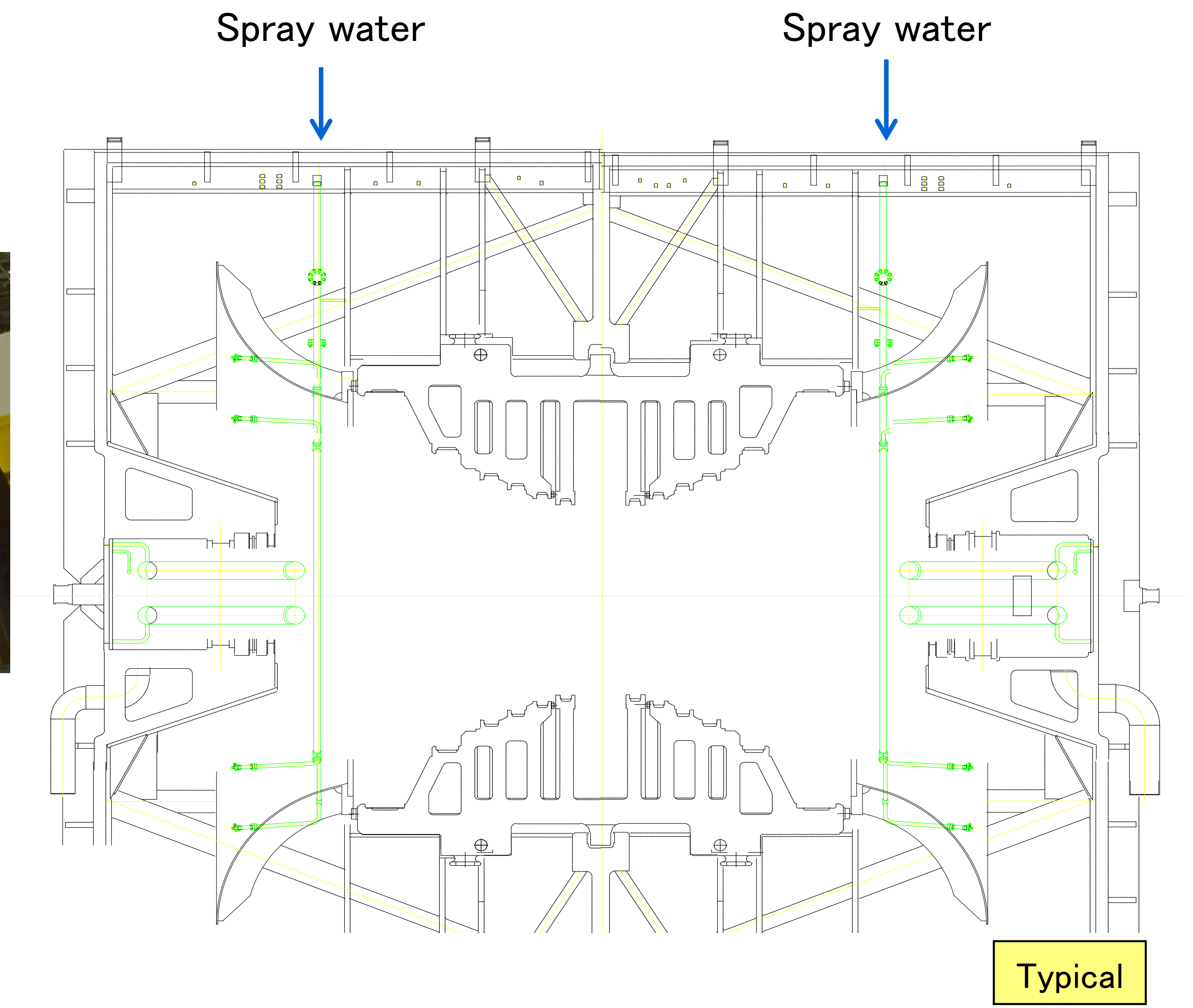




LP Casing Spray

When LP casing temperature rises over 65 deg.C, spray will cool down the casing



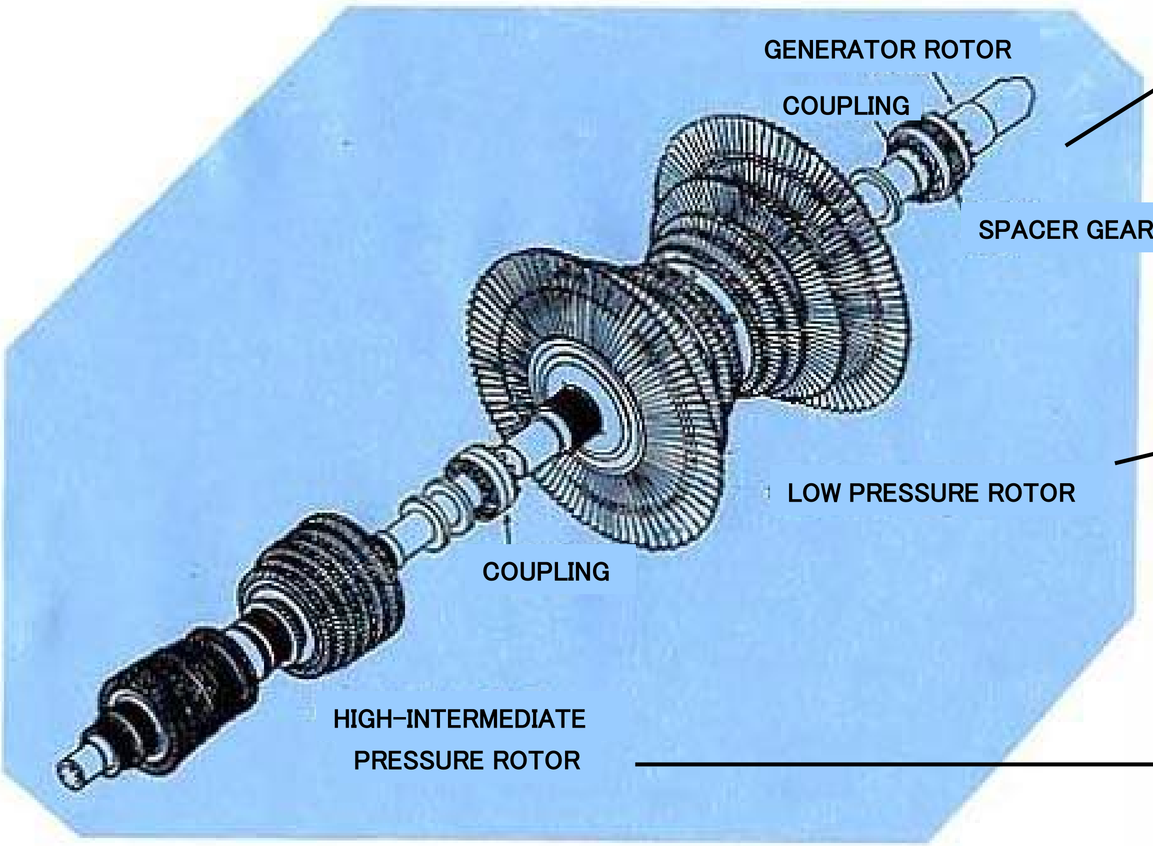


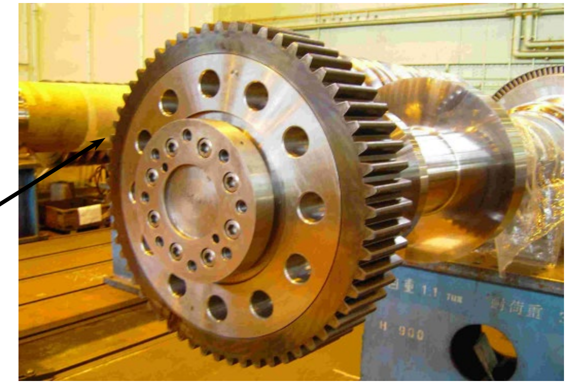
03-4

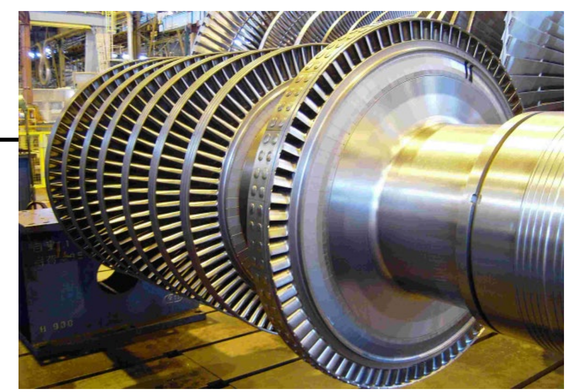
Major Parts of the Steam Turbine

- Turbine Nozzle
- Turbine Blade
- Turbine Casing
- Turbine Rotor
- Bearing
- Turning Gear

Turbine Rotor







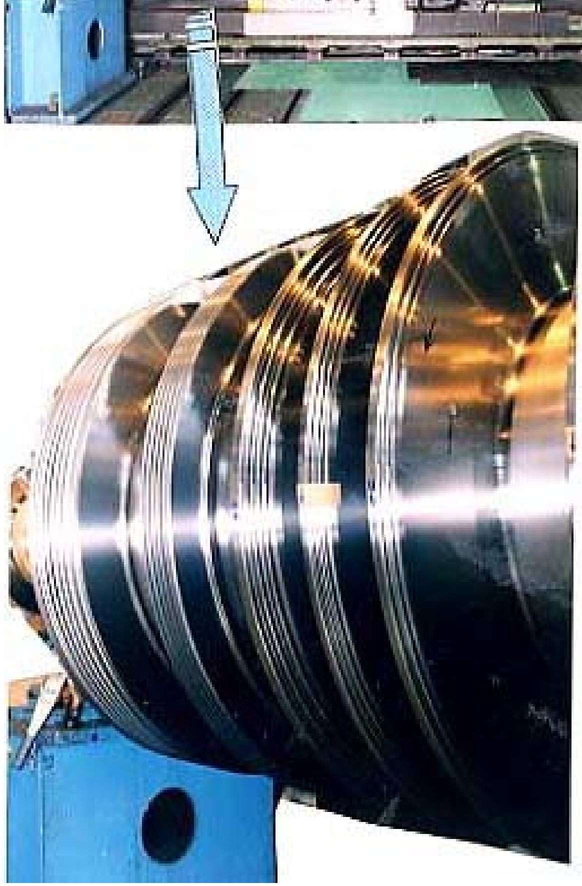
※After measuring of weight of each blade,

the arrangement of blade are decided.

Typical

Turbine Rotor

HIP Rotor on
Horizontal Lathe



LP Rotor on
Stand

Typical

03–5

Major Parts of the Steam Turbine

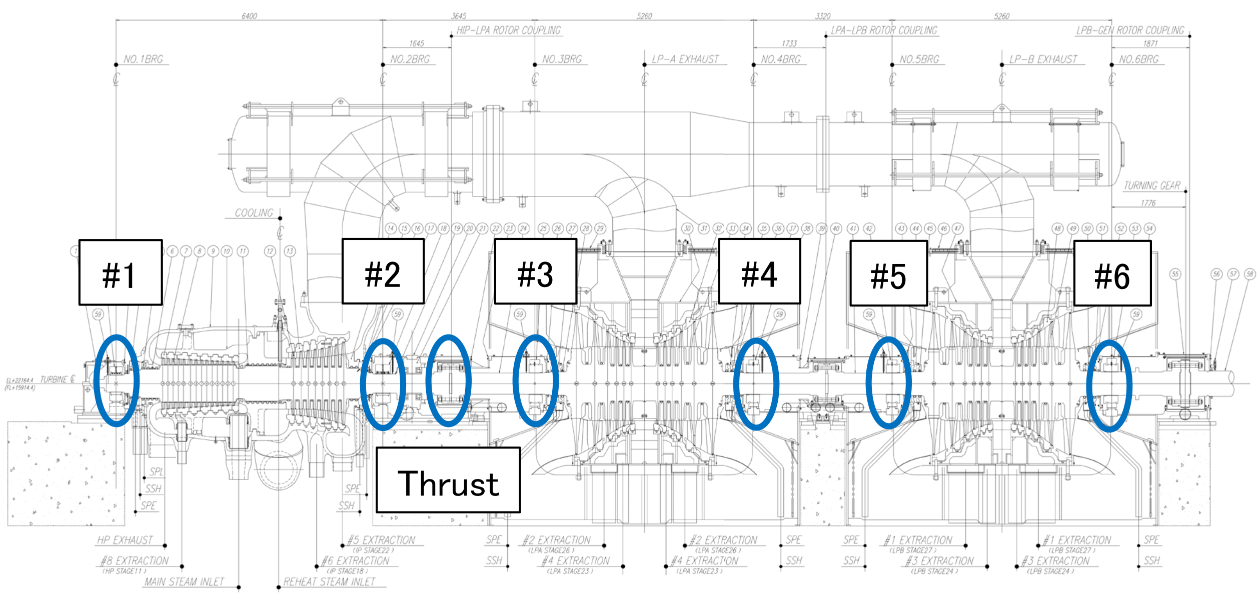
- Turbine Nozzle
- Turbine Blade
- Turbine Casing
- Turbine Rotor
- Bearing
- Turning Gear

Turbine Bearings

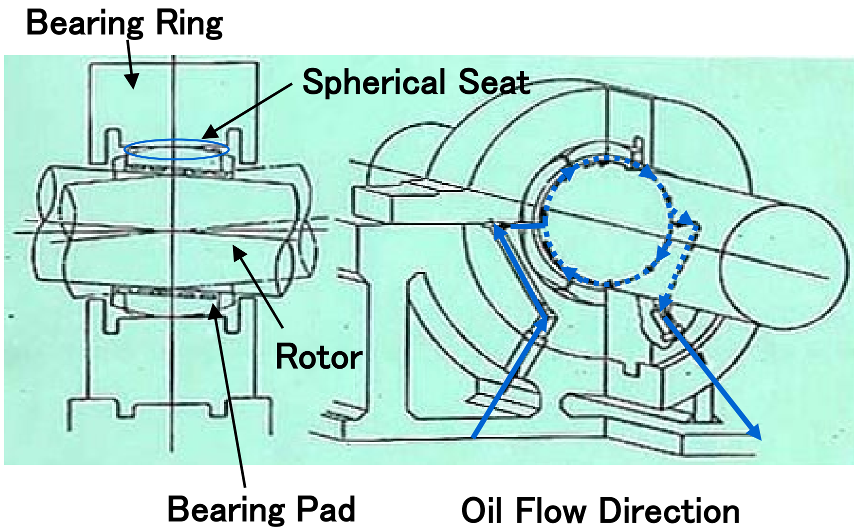
Arrangement of Bearings and Design Specifications

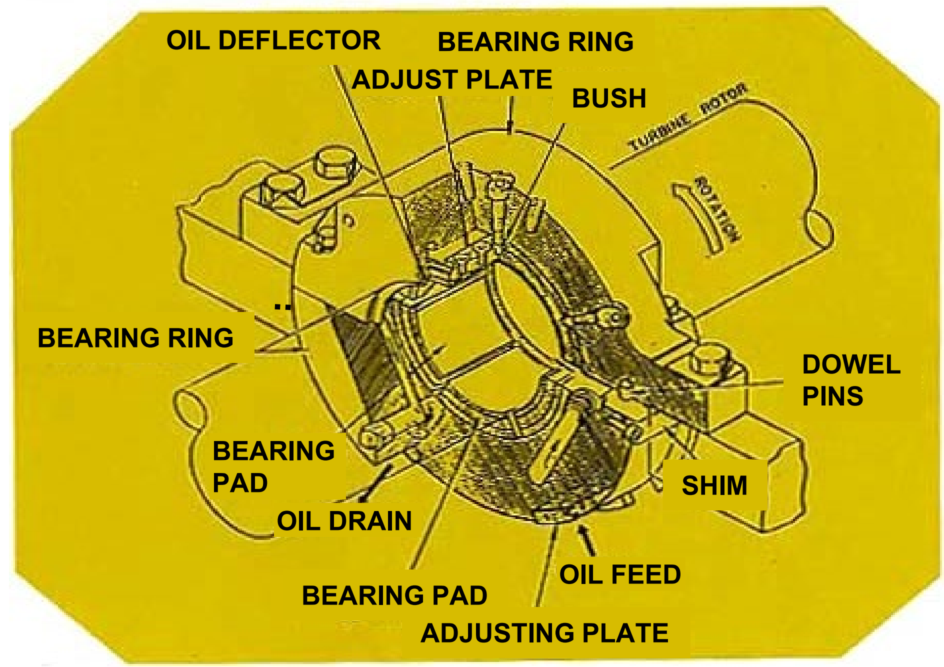
	HIP			LP			
	#1BRG	#2BRG	Thrust	#3BRG	#4BRG	#5BRG	#6BRG
Type	DTP	DTP	PAD Type	EL	EL	EL	EL
Size	16"x10"	18"x12"	OD:30" ID:18"	20"x11"	20"x11"	20"x11"	22"x12"
Mounted on	Front Stand	Middle Stand	Middle Stand	LP Casing Cone	LP Casing Cone	LP Casing Cone	LP Casing Cone

– DTP: Double Tilting Pad → good stability under light bearing pressure
– EL: Elliptical Type → support large bearing loads



Turbine Bearings – Pad Bearing (HIP Section)



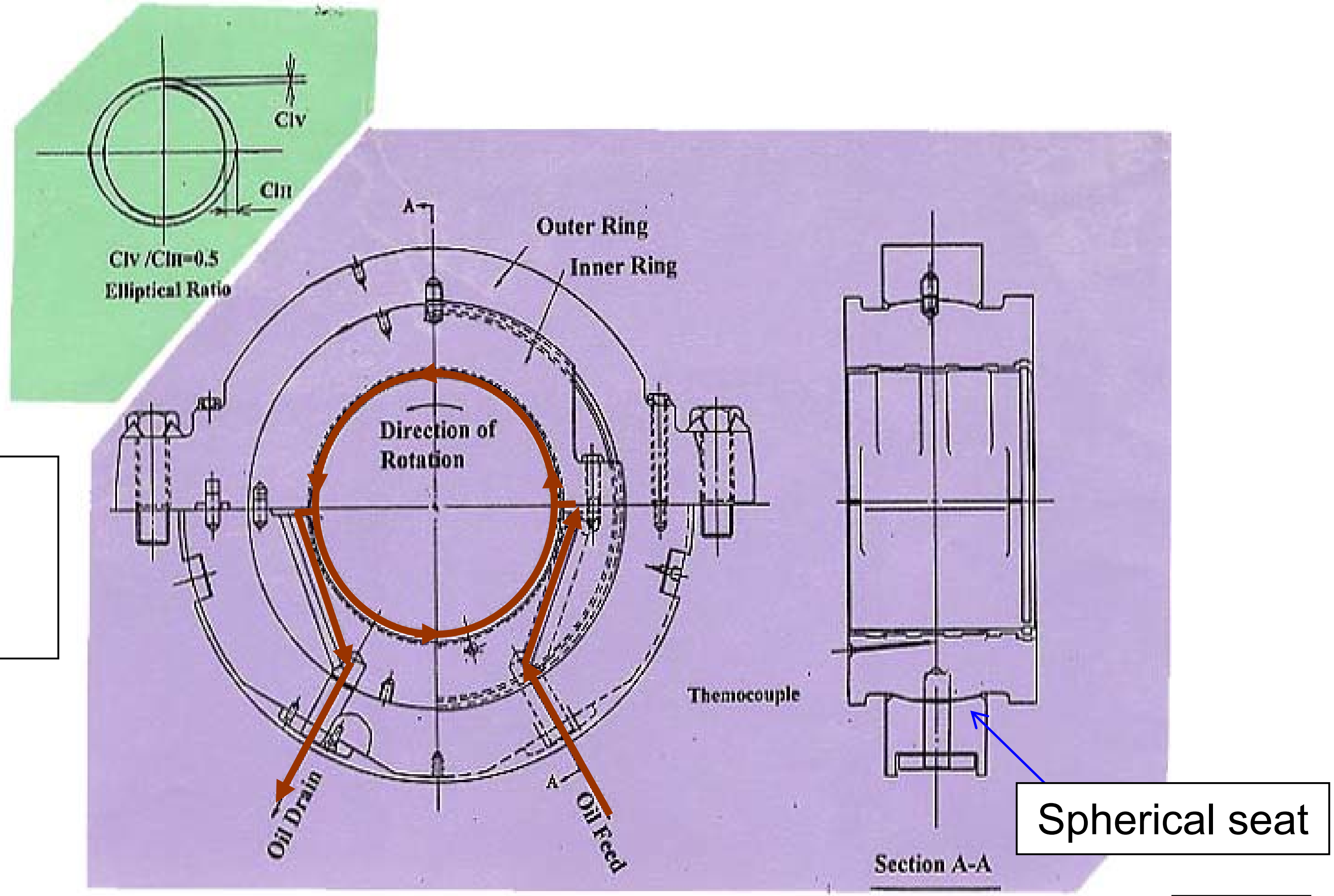


Each pad can move smoothly and align with rotor journal.

Typical

Turbine Bearings – Elliptical Bearing (LP Section)

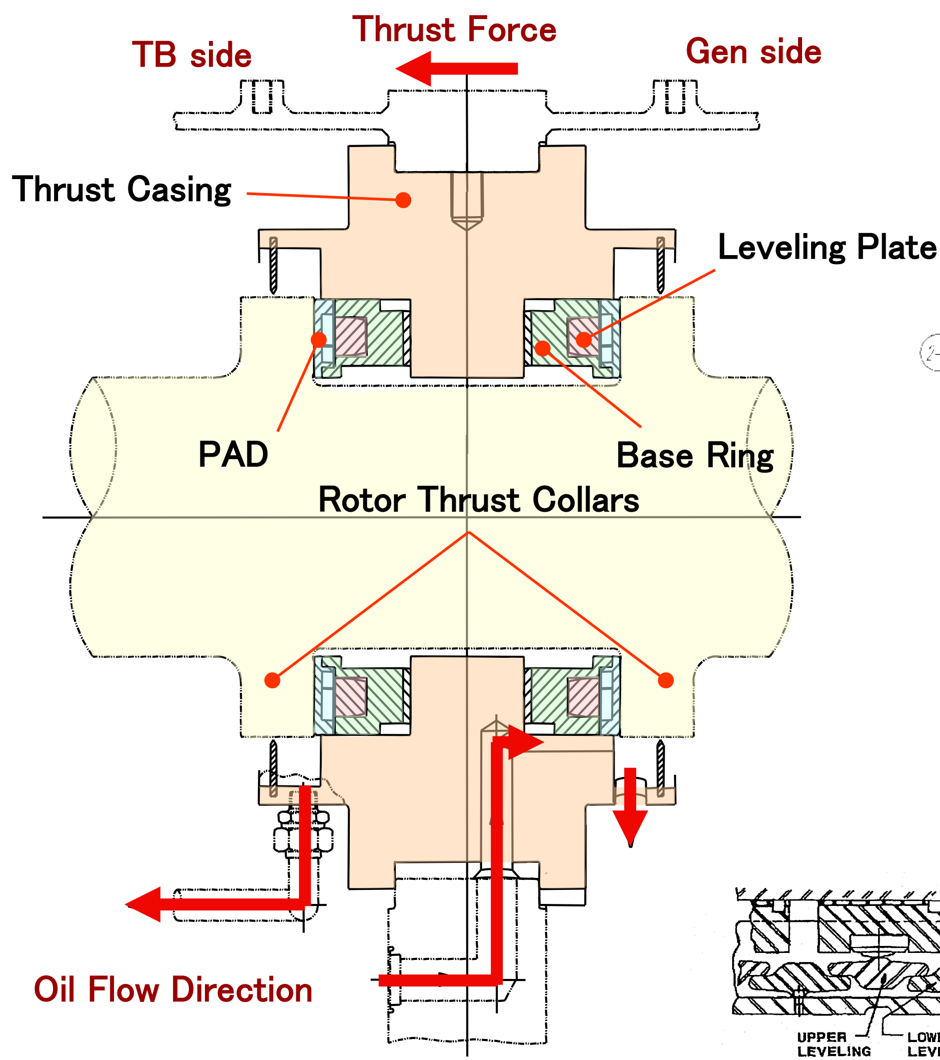
- Self align
- Suitable for LP Turbine

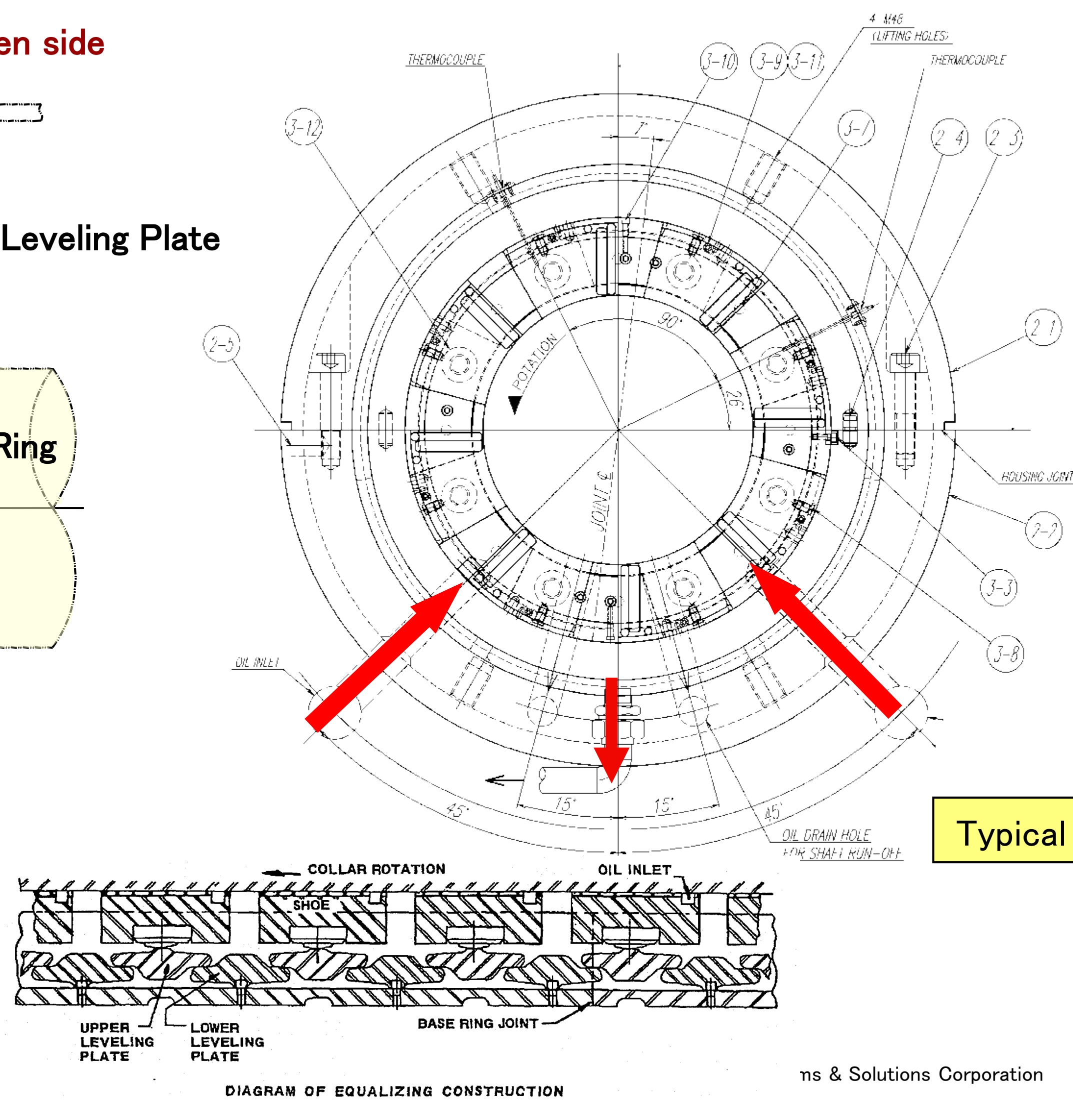


Typical

Turbine Bearings – Thrust Bearing

- Rotor thrust force is supported by the thrust bearing.
- Each pad can move smoothly and align with rotor collar.





Typical

03–6

Major Parts of the Steam Turbine

- Turbine Nozzle
- Turbine Blade
- Turbine Casing
- Turbine Rotor
- Bearing
- Turning Gear

Turning Device

Function

- Turning the rotor at about 6.20 rpm
- Jogging the rotor a small amount for inspection and installation of balance weight.

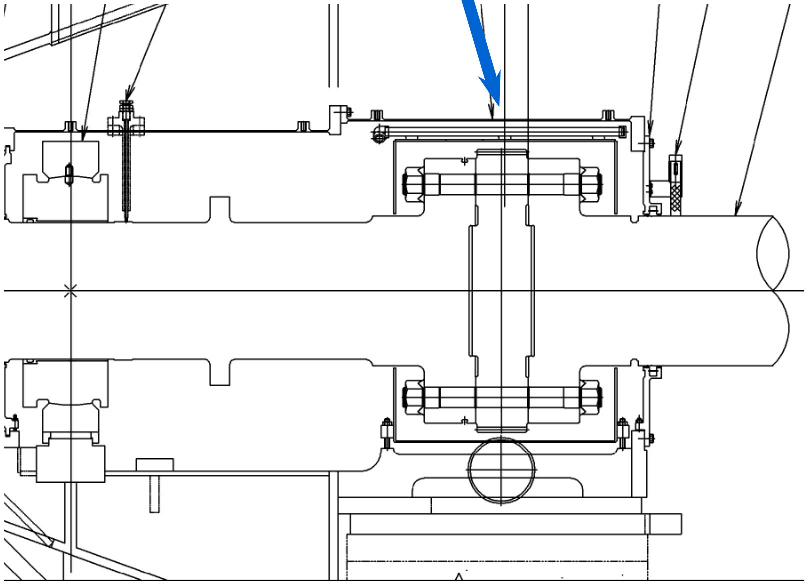
Location

The cap mount type turning device is located between LP turbine and generator pedestal.

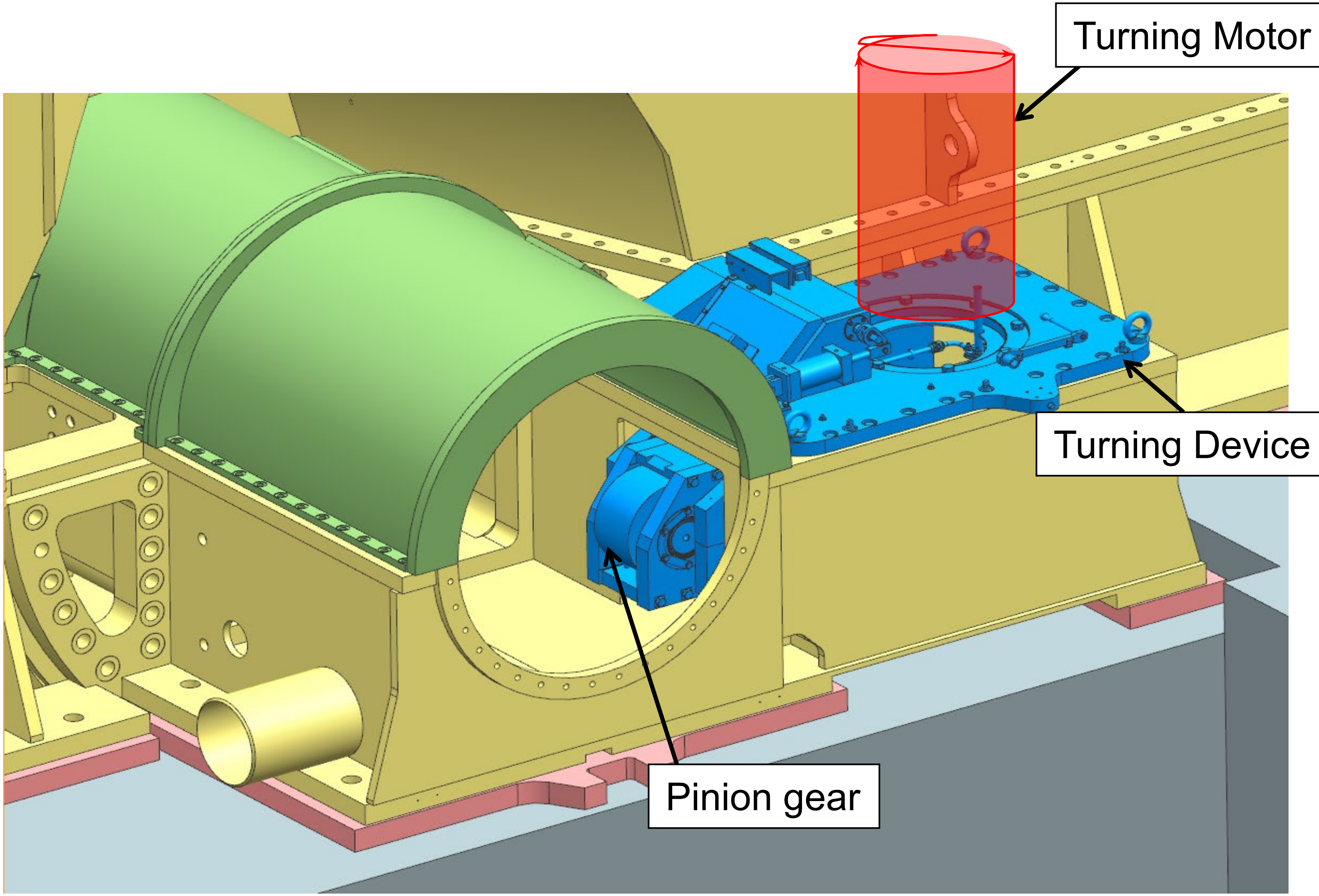
– A required driving force can be minimized because of the maximum spacer gear diameter at the ST/GEN coupling.

– The space around the ST/GEN coupling is more stable as a turning gear location because it will be the coldest end and the rotor alignment change is relatively smaller than other spaces.

Typical



Turning Gear Assembly



Typical

04

BFP Turbine

Rating and Design Data

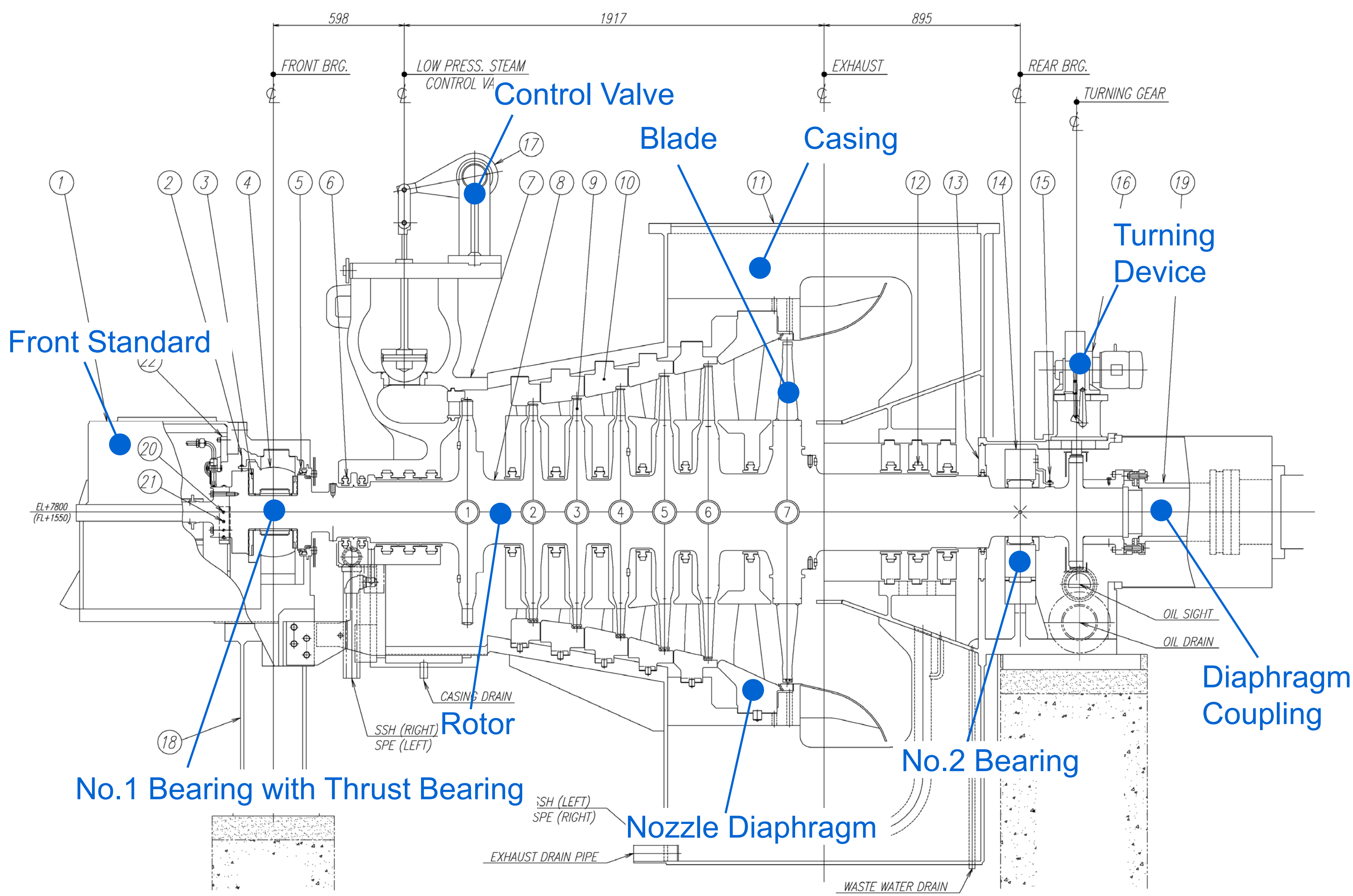
Turbine Type	Single Cylinder Single Flow type Condensing Turbine
Rated Speed	6,000 rpm
Rated Output	14000 kW

Rated Steam Conditions

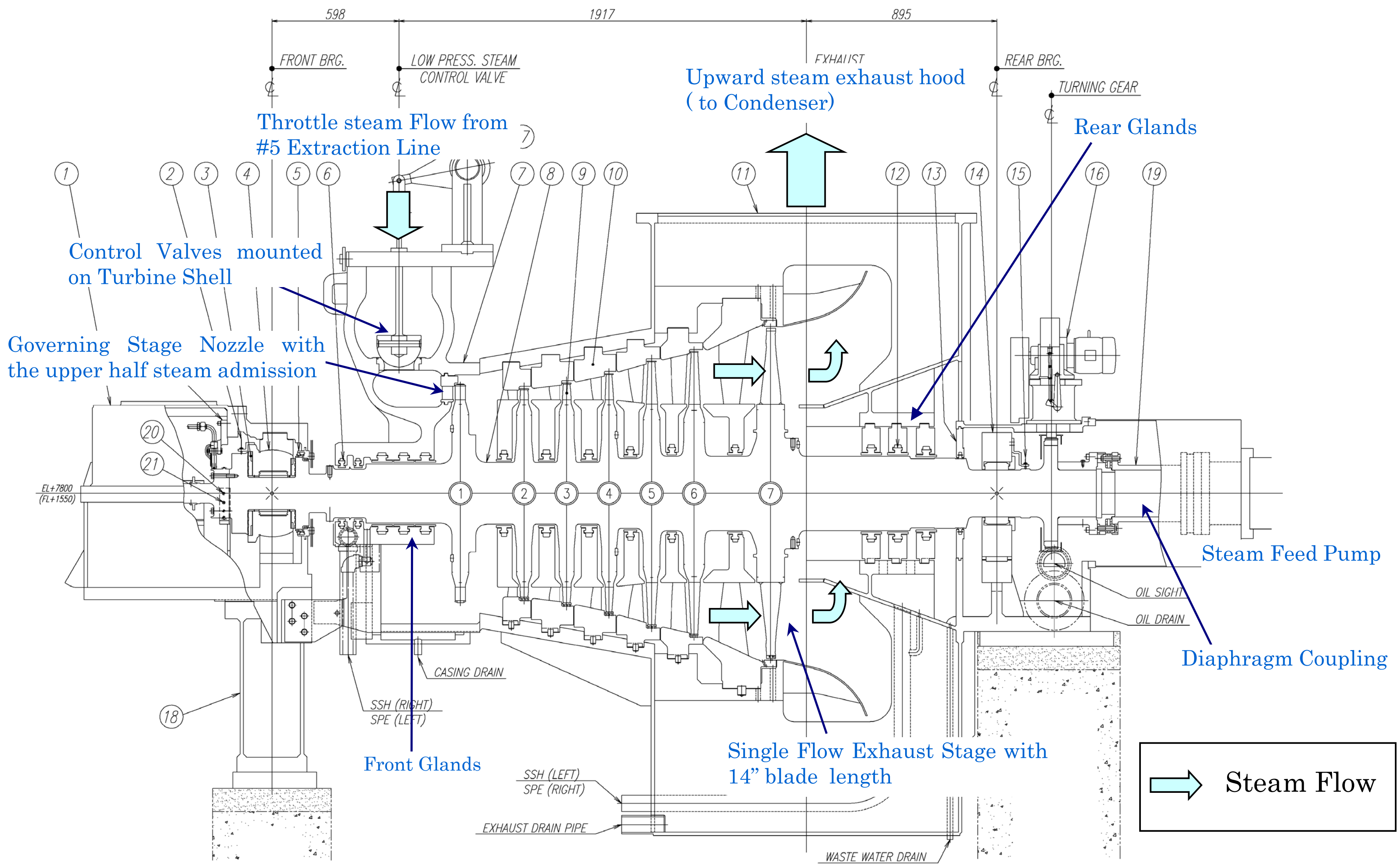
Main Steam Source	Main Turbine #5 Extraction Steam
Main Steam Temperature	324 deg.C
Main Steam Pressure	0.89 MPa abs.
Exhaust Pressure	7.29 kPa abs.

Stage No.	7 stages with 14” last stage blade length
Exhaust Hood	Upward steam exhaust hood
Application	Boiler Feedwater Pump Driven

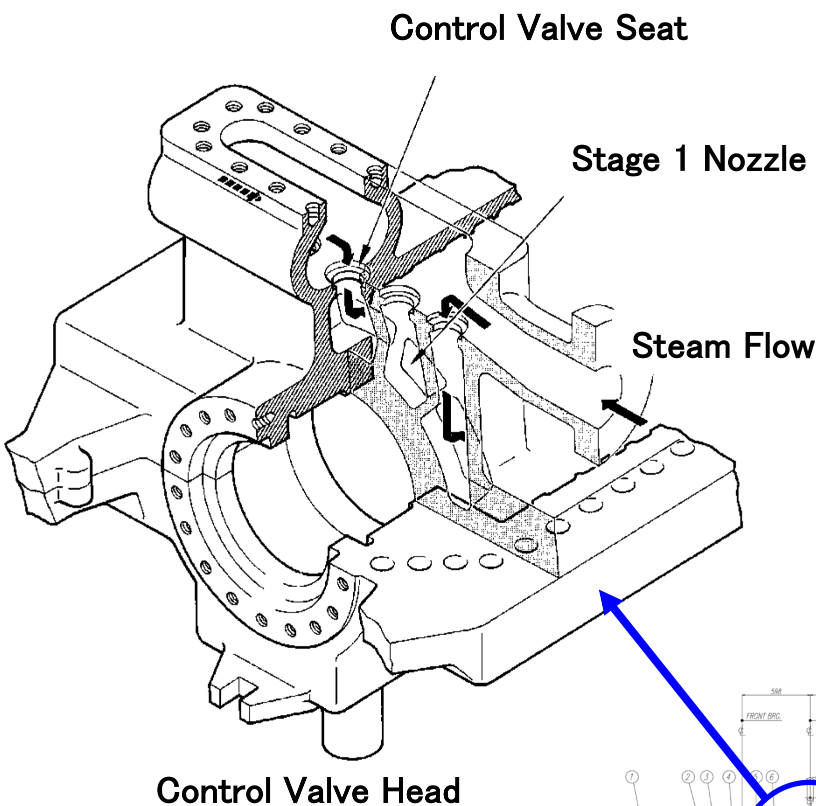
Cross Section of BFP Turbine

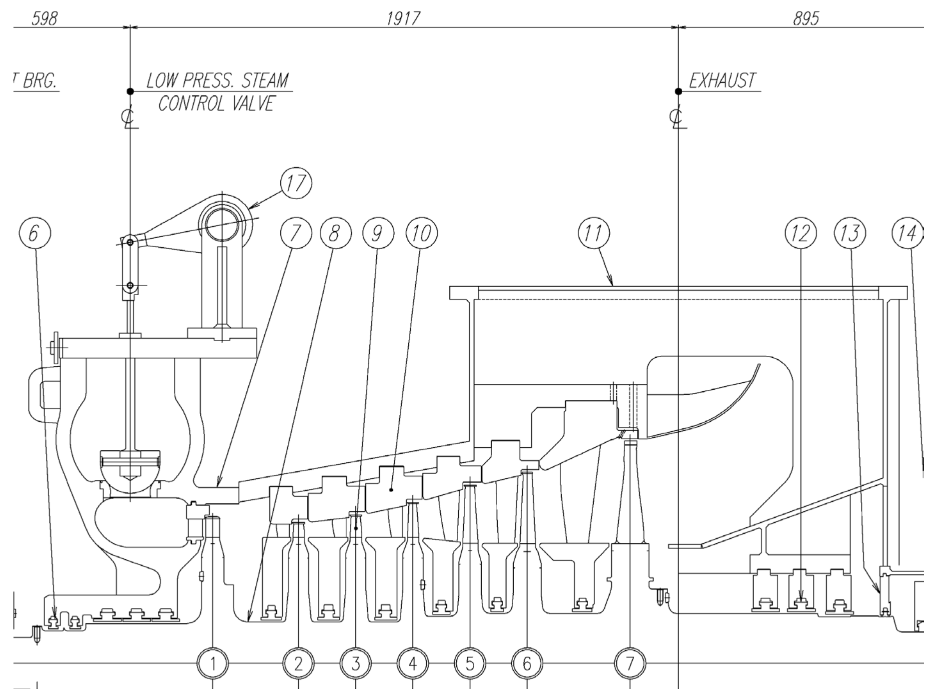


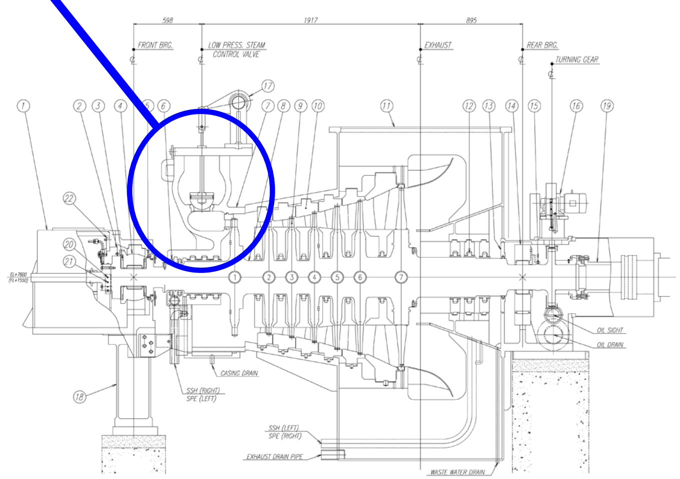
Cross Section of BFP Turbine



BFP Turbine Casing

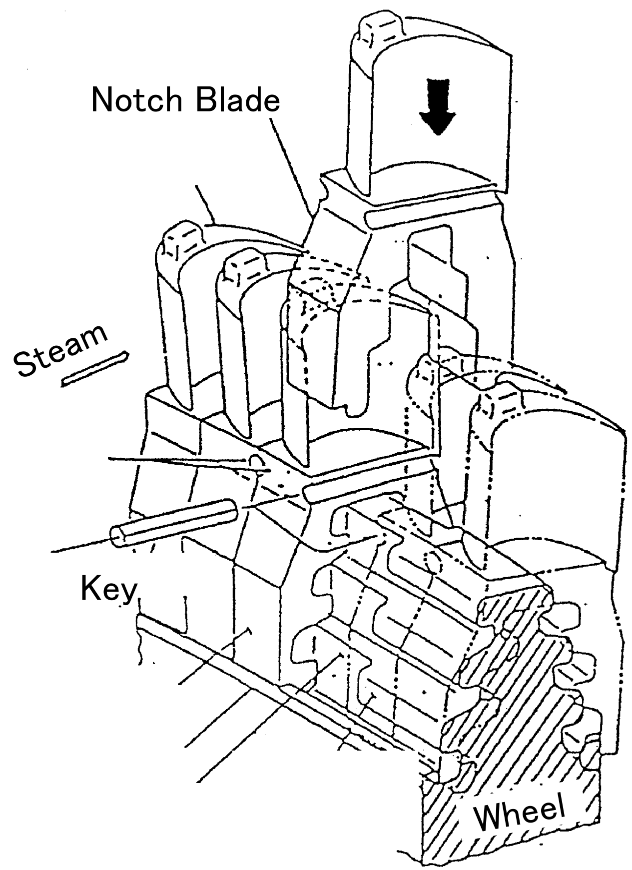






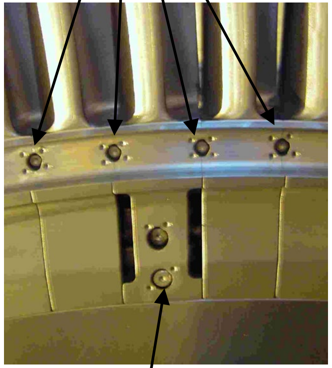
Typical

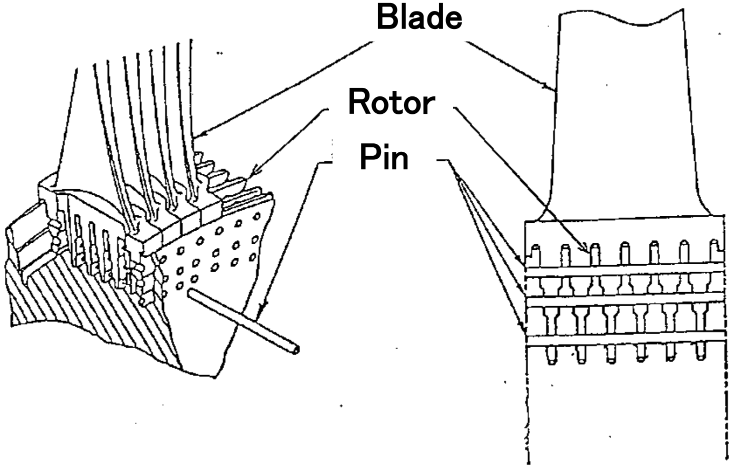
BFP Turbine Blade Dovetail



Stage 1～6

Outside Dovetail



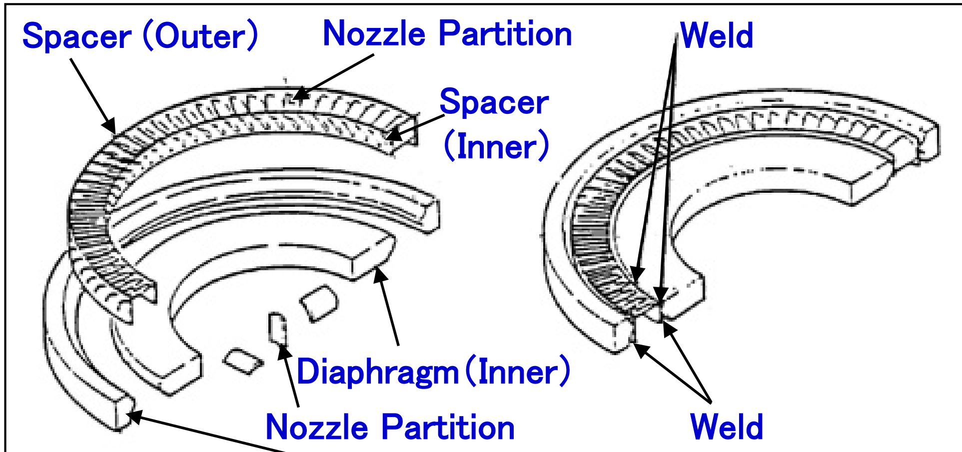


Stage 7

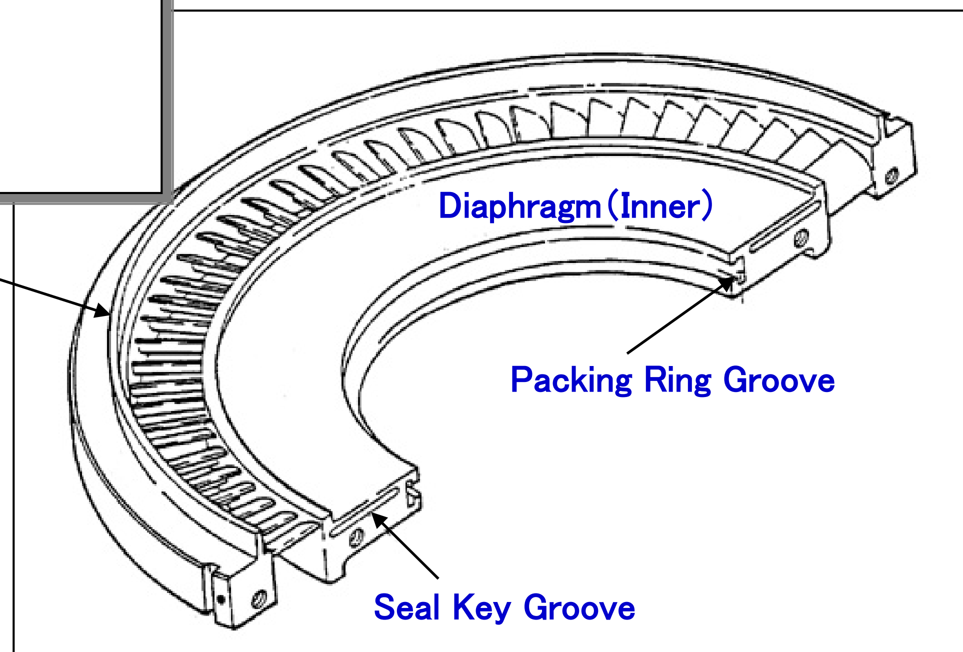
Fork Type Dovetail

Typical

BFP Turbine Nozzle Diaphragm

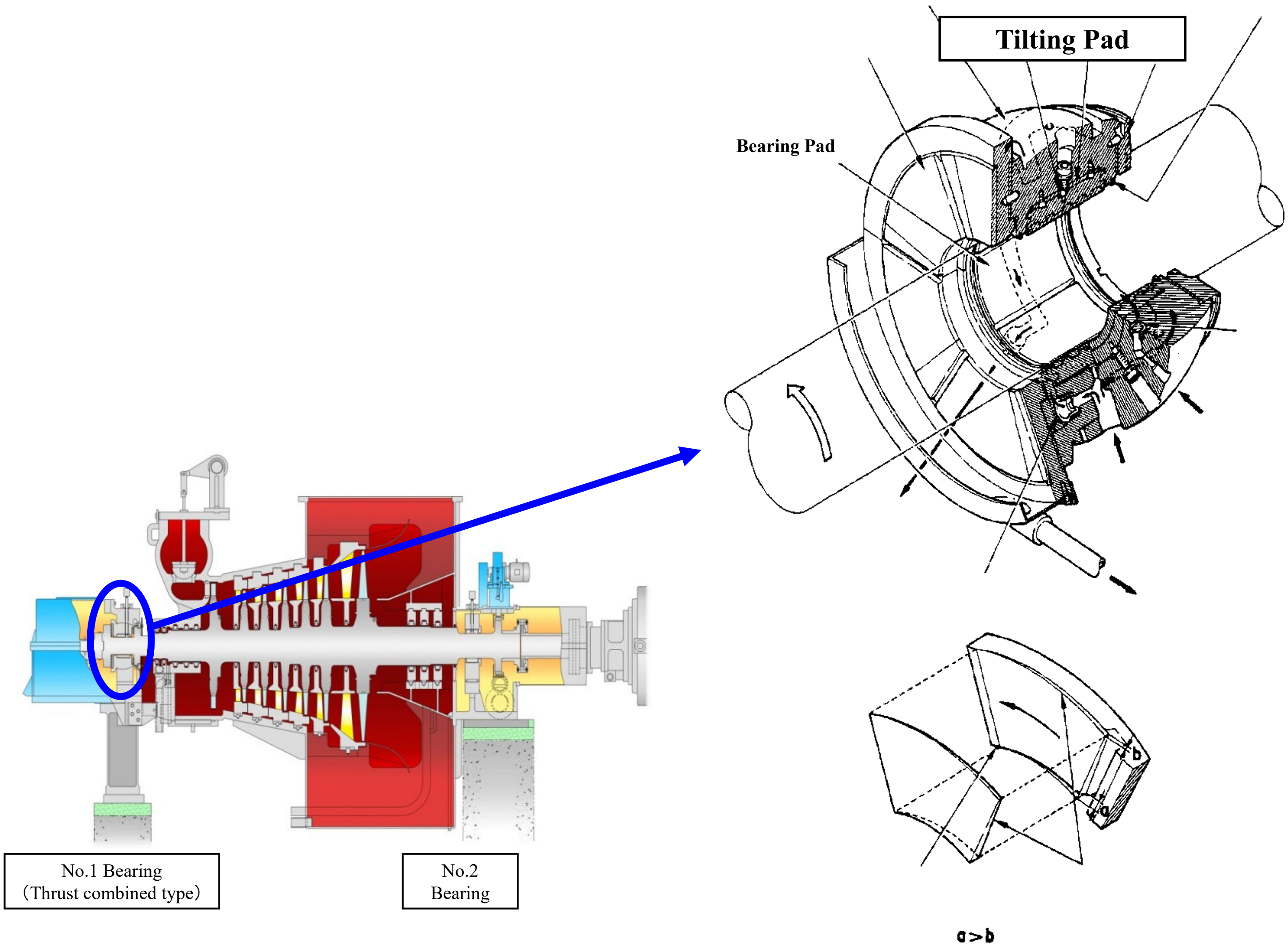


Diaphragm(Outer)

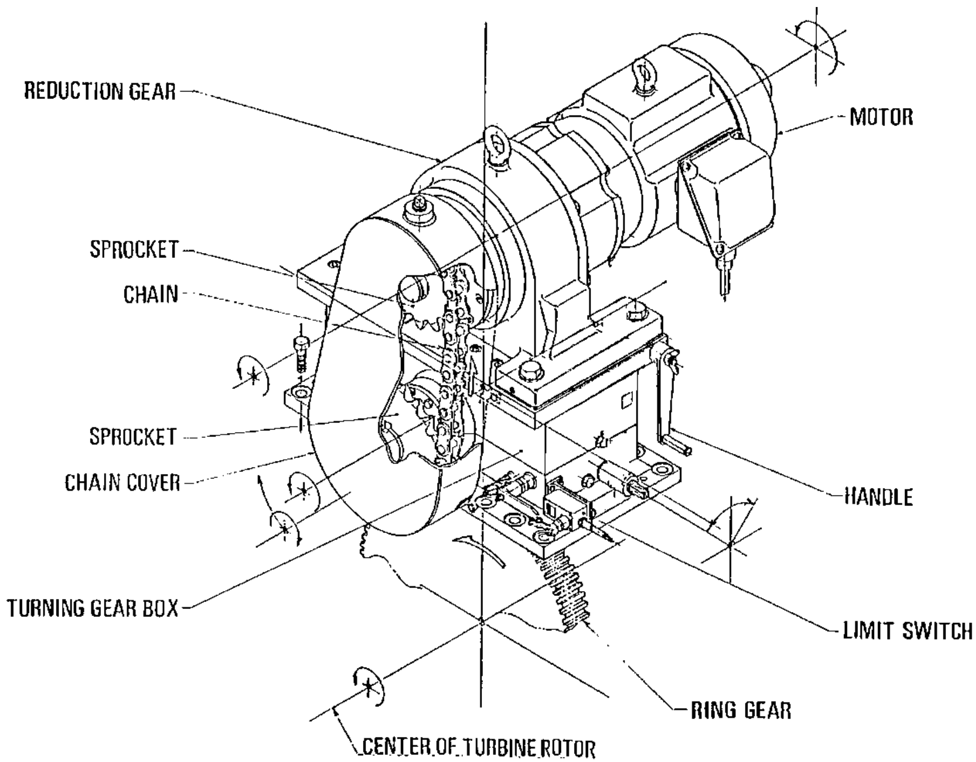


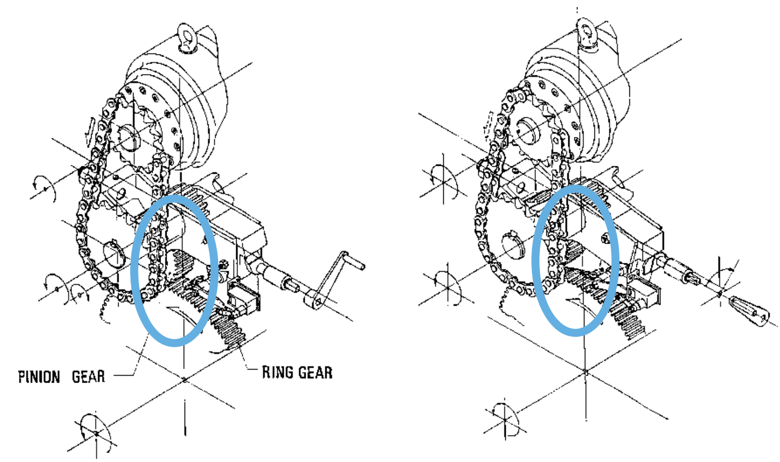
Typical

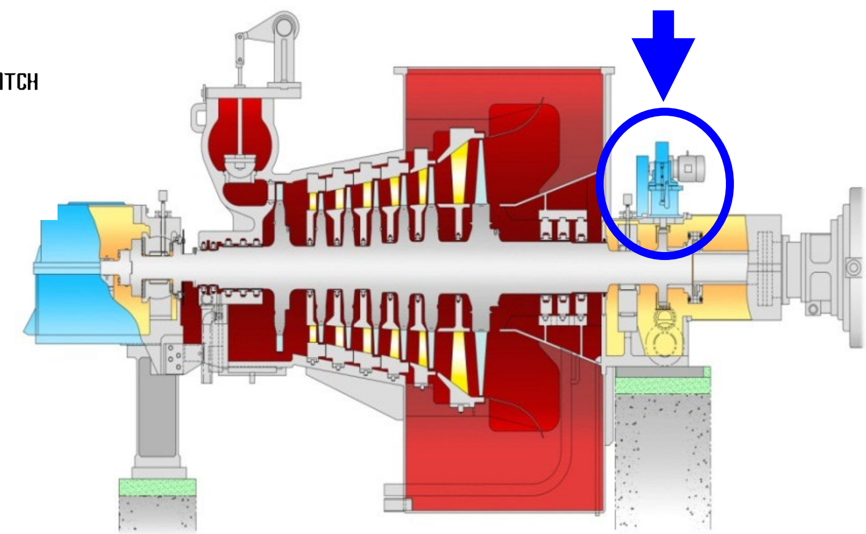
BFP Turbine Bearing



BFP Turbine Turning Device



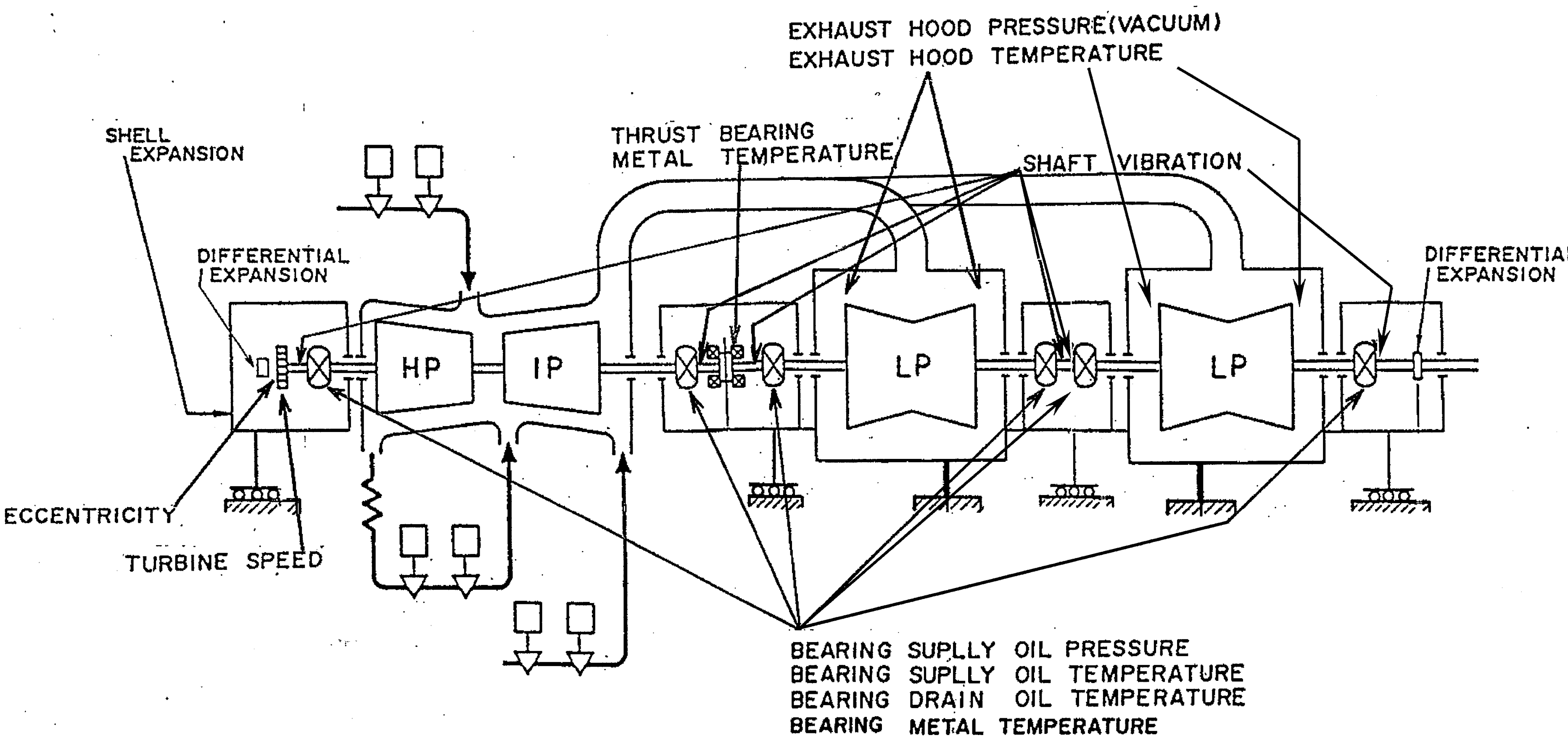




05

General Operation

Turbine Supervisory & Monitoring Item



Typical

Typical Turbine Rotating Speed Specification

Rotor First Critical Speed

Generator Rotor	980 rpm
HIP Turbine Rotor	1,680 rpm
LPA Turbine Rotor	1,720 rpm
LPB Turbine Rotor	1,700 rpm

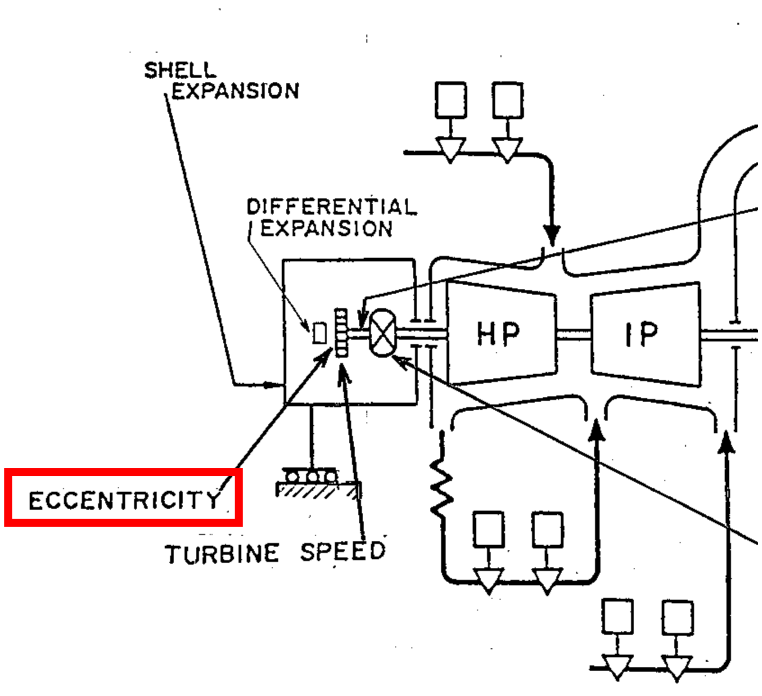
Heat Soak Speed

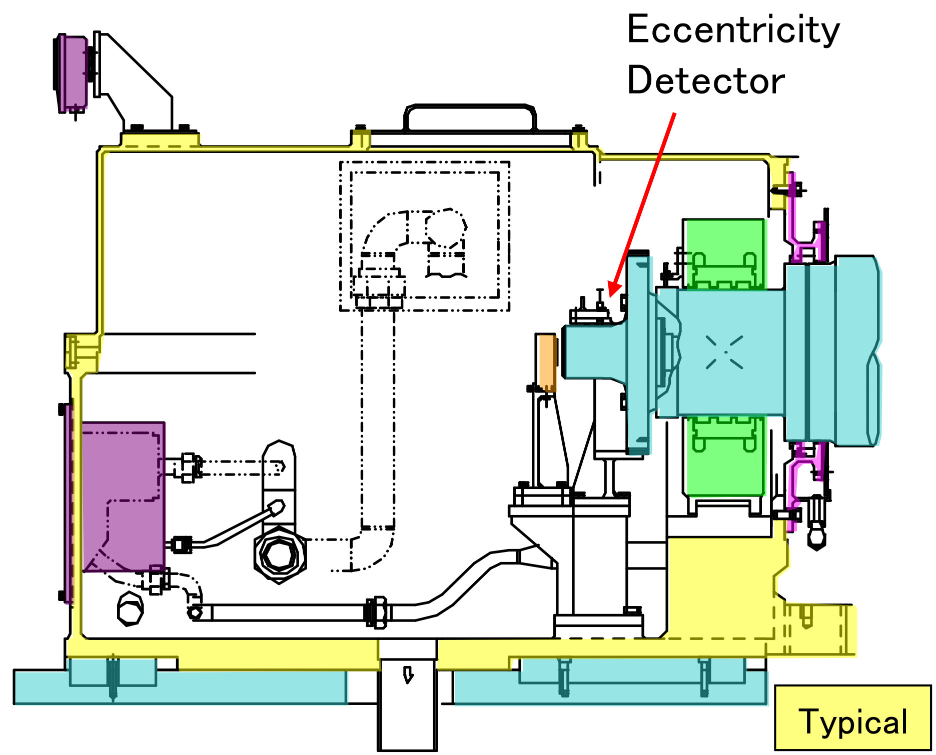
Low Speed Heat Soak	800 rpm
High Speed Heat Soak	3,000 rpm

＊ Rotating speed must not be held between 900 rpm and 2,700 rpm

Shaft Eccentricity

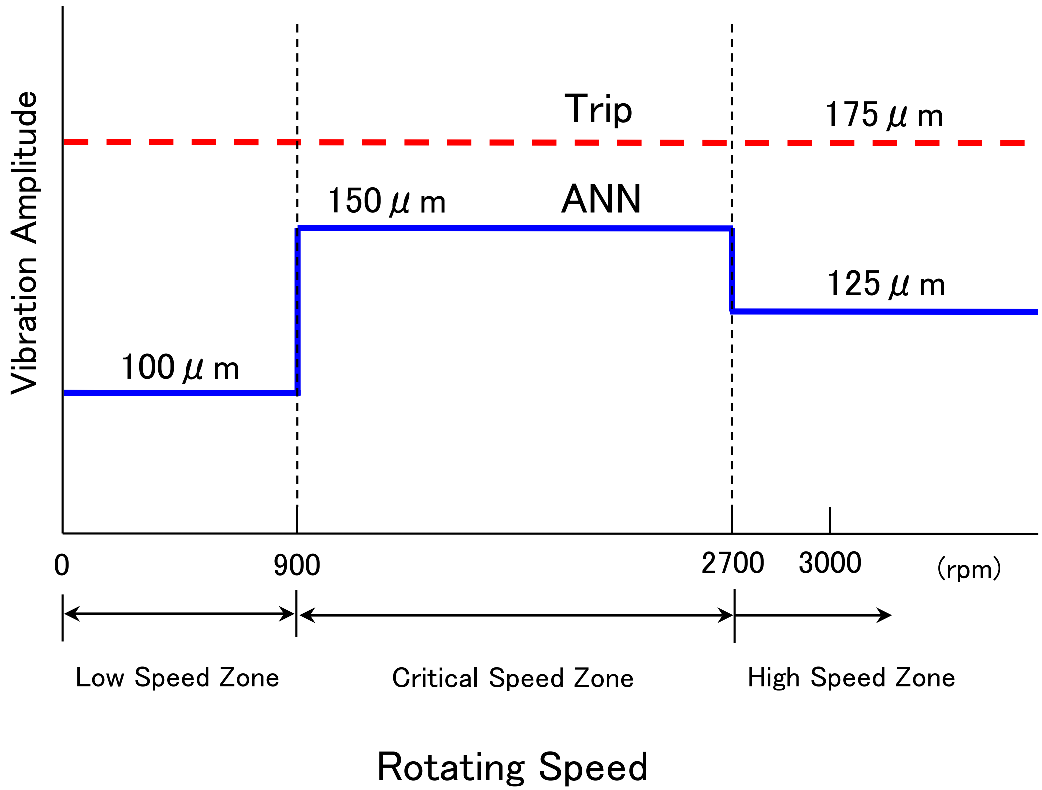
Operational Stage	Permissible Range	Note
At turning operation	Within 110% of normal value	Normal value should be determined during the initial turning operation after 5 hour turning

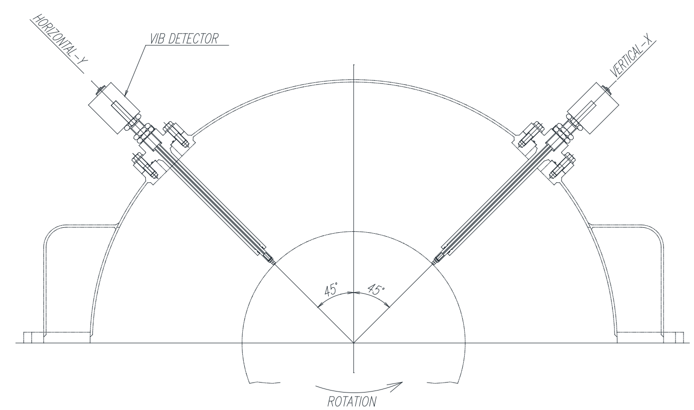




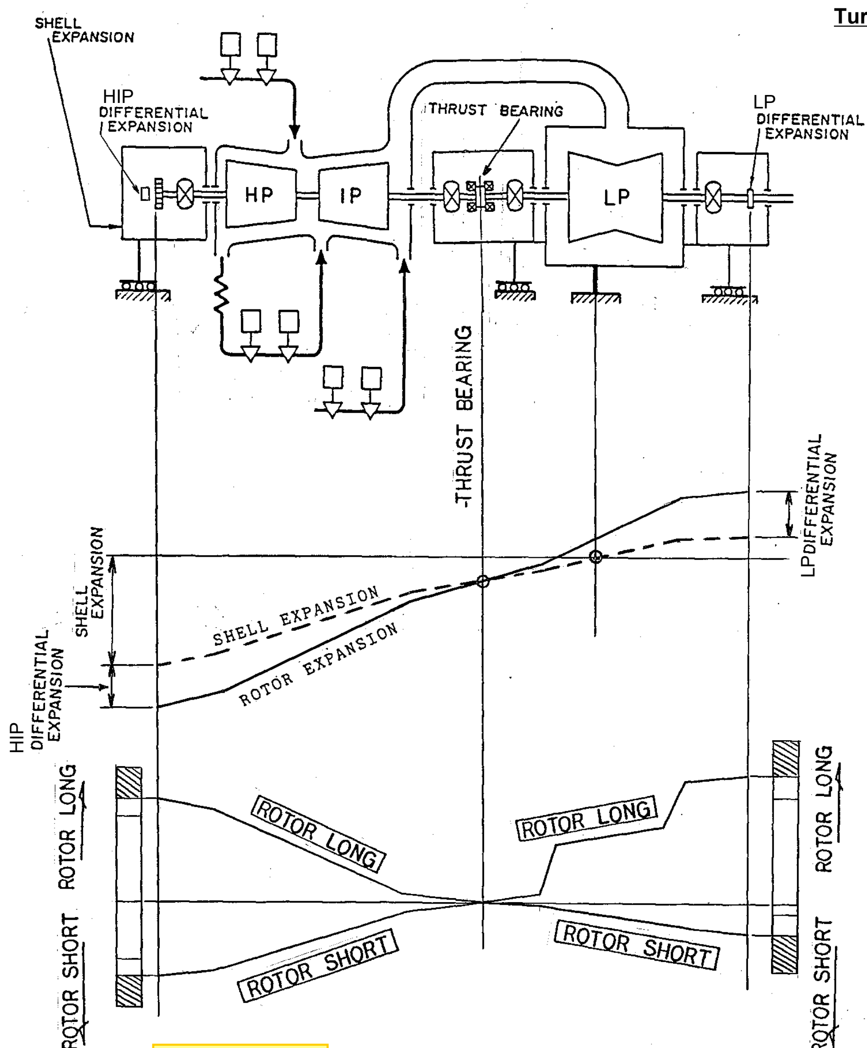
Shaft Vibration

Limits of Vibration Amplitude for Various Operating Zones

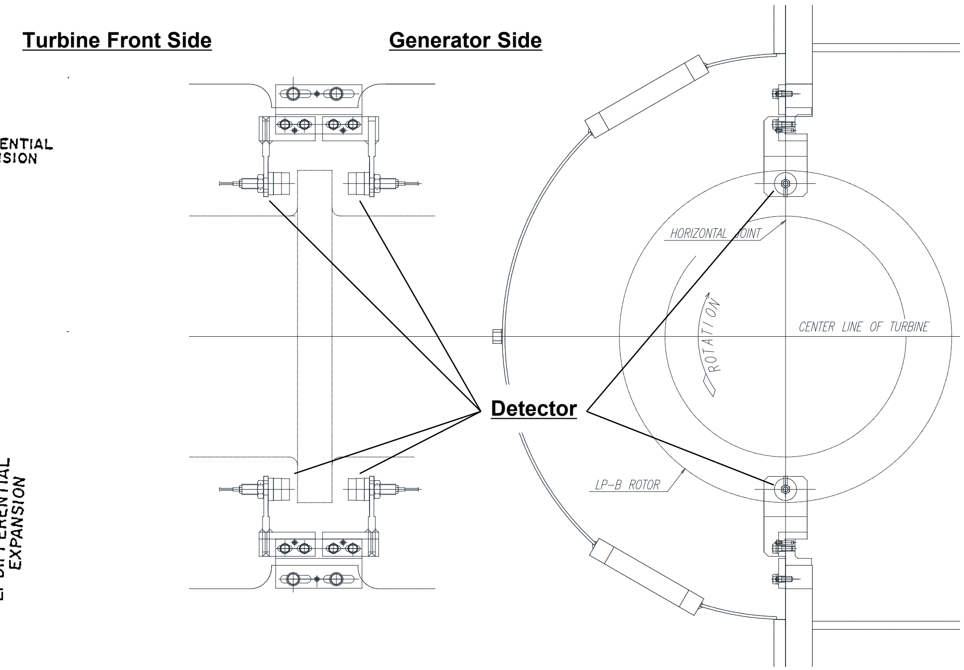




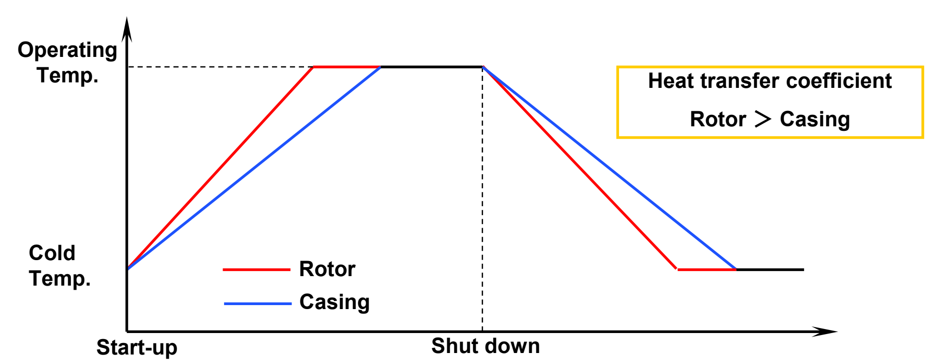
Shell & Differential Expansion



Typical

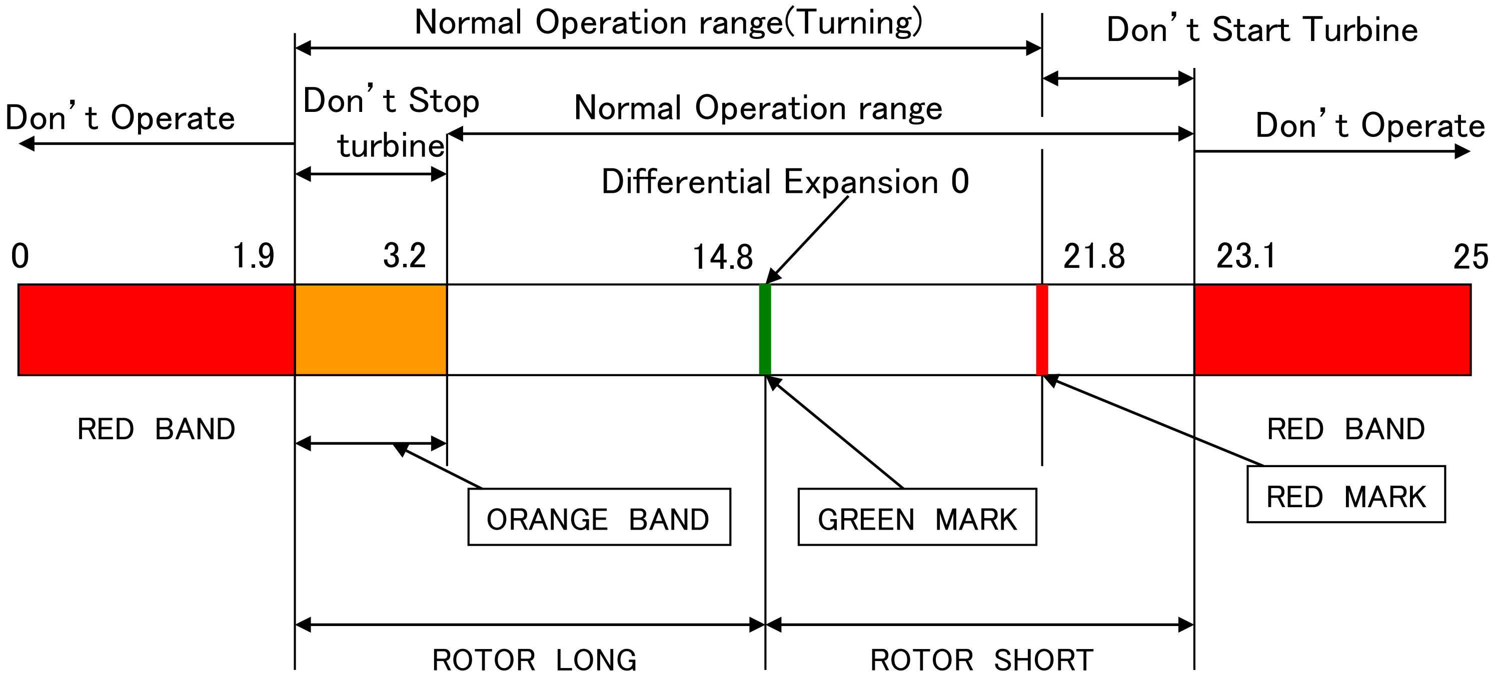


LP Differential Expansion Detector



Shell & Differential Expansion

(1) HP Rotor

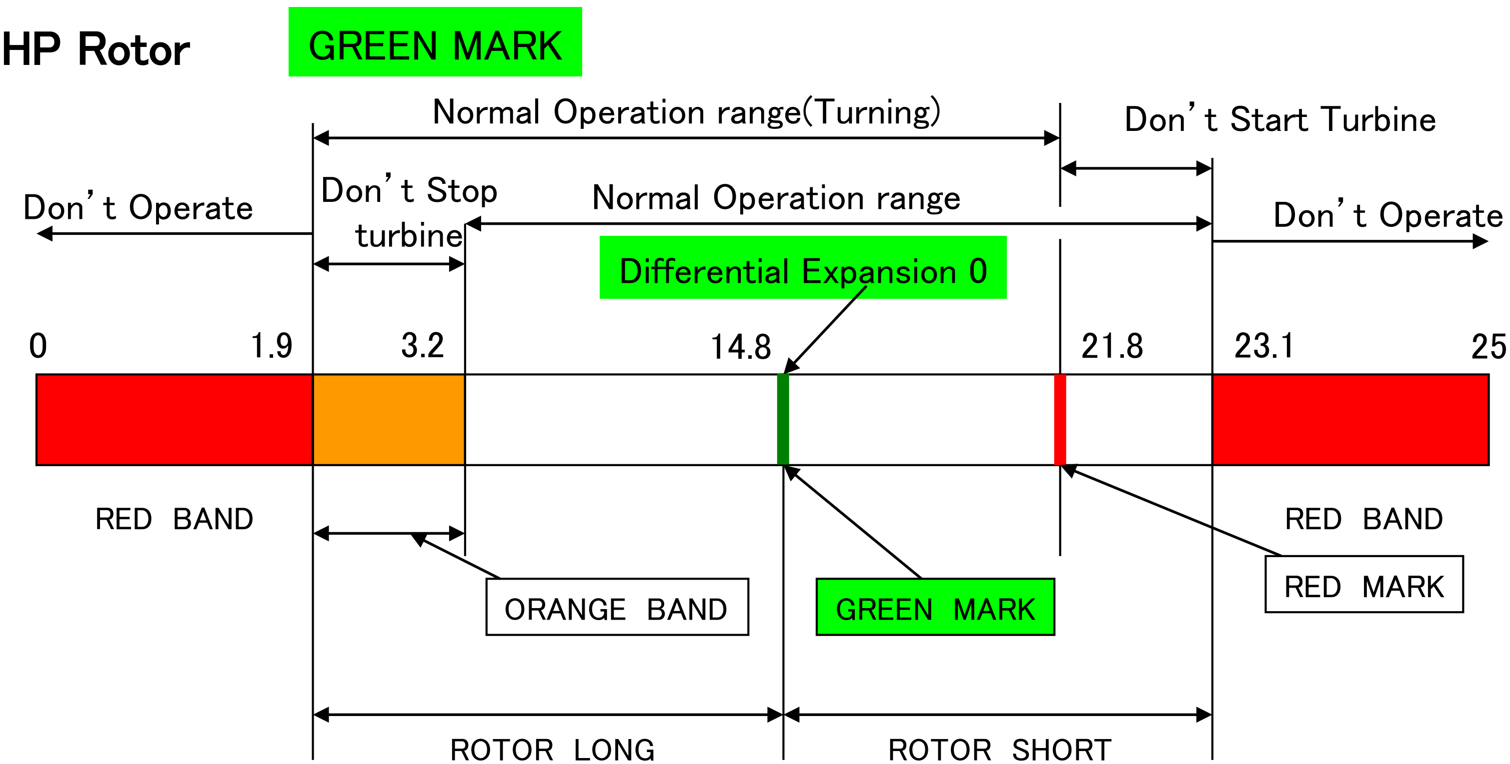


Rotor long means the expansion of the rotor is relatively longer than the casing.

Rotor short means the expansion of the rotor is relatively shorter than the casing.

Shell & Differential Expansion

(1) HP Rotor

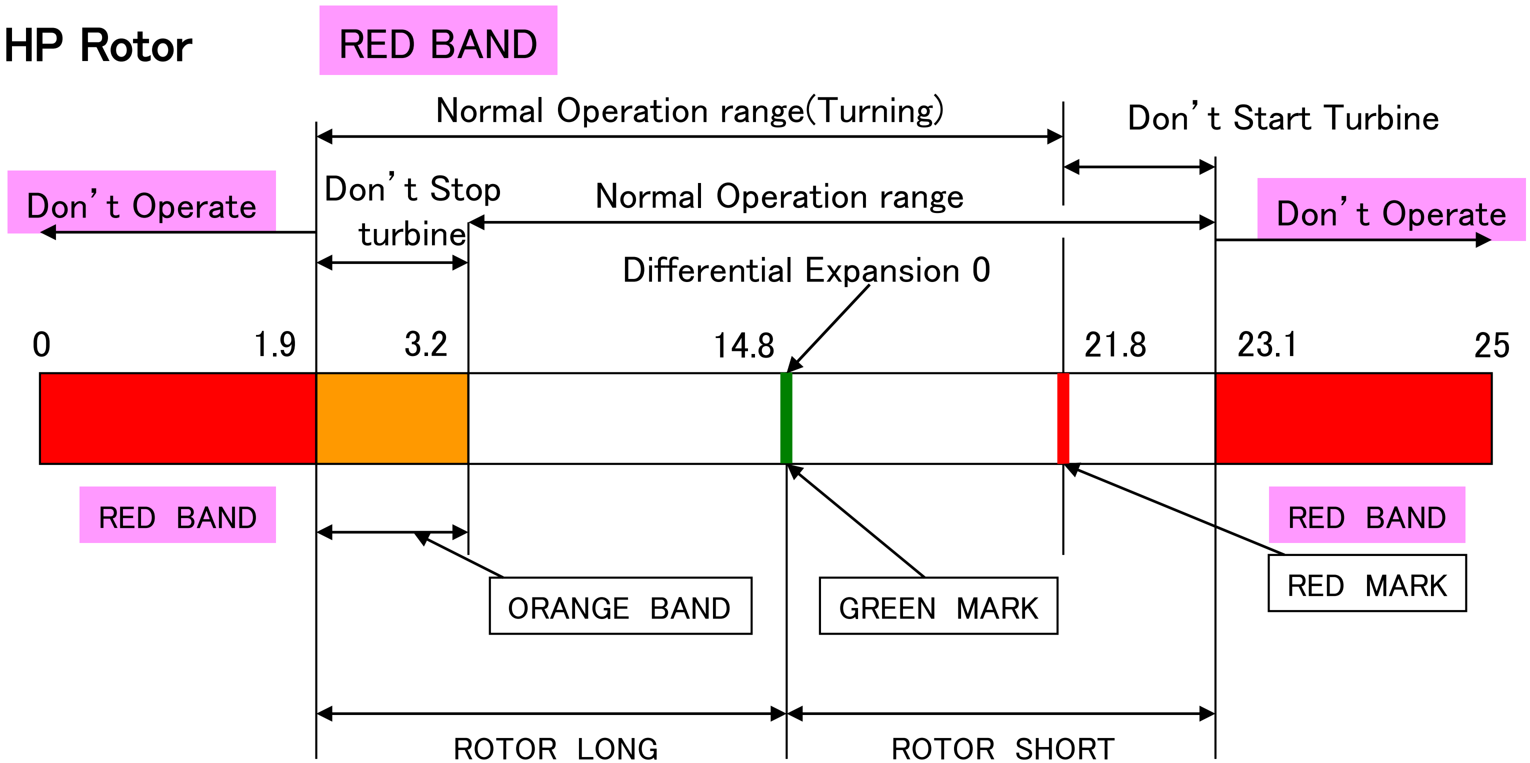


The base point of the differential expansion

The differential expansion meter should be set at cold condition.

Shell & Differential Expansion

(1) HP Rotor

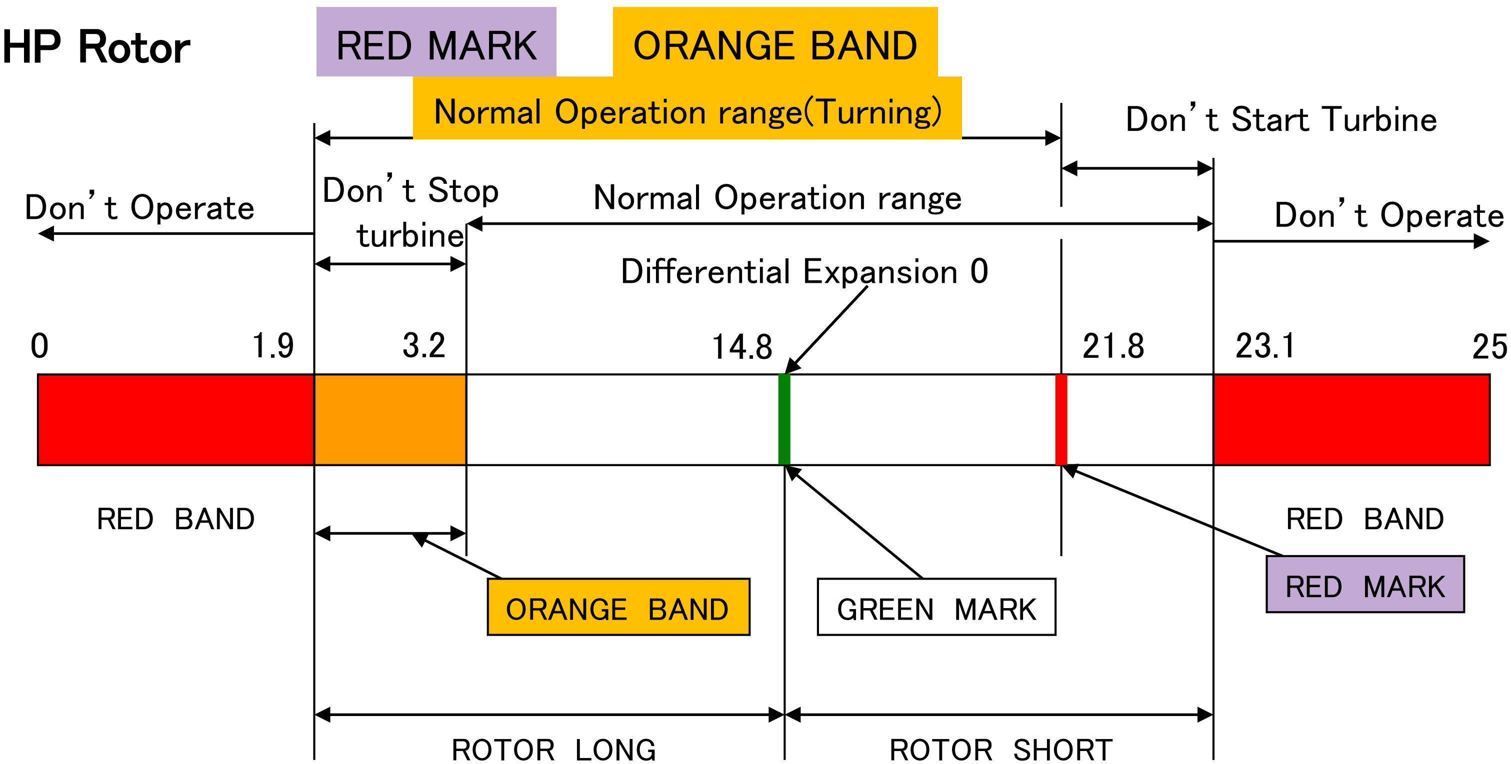


The possibility of axial contact between rotating and stationary parts in the turbine .

The limits of contact are the positions at maximum rotor short and rotor long.

Shell & Differential Expansion

(1) HP Rotor

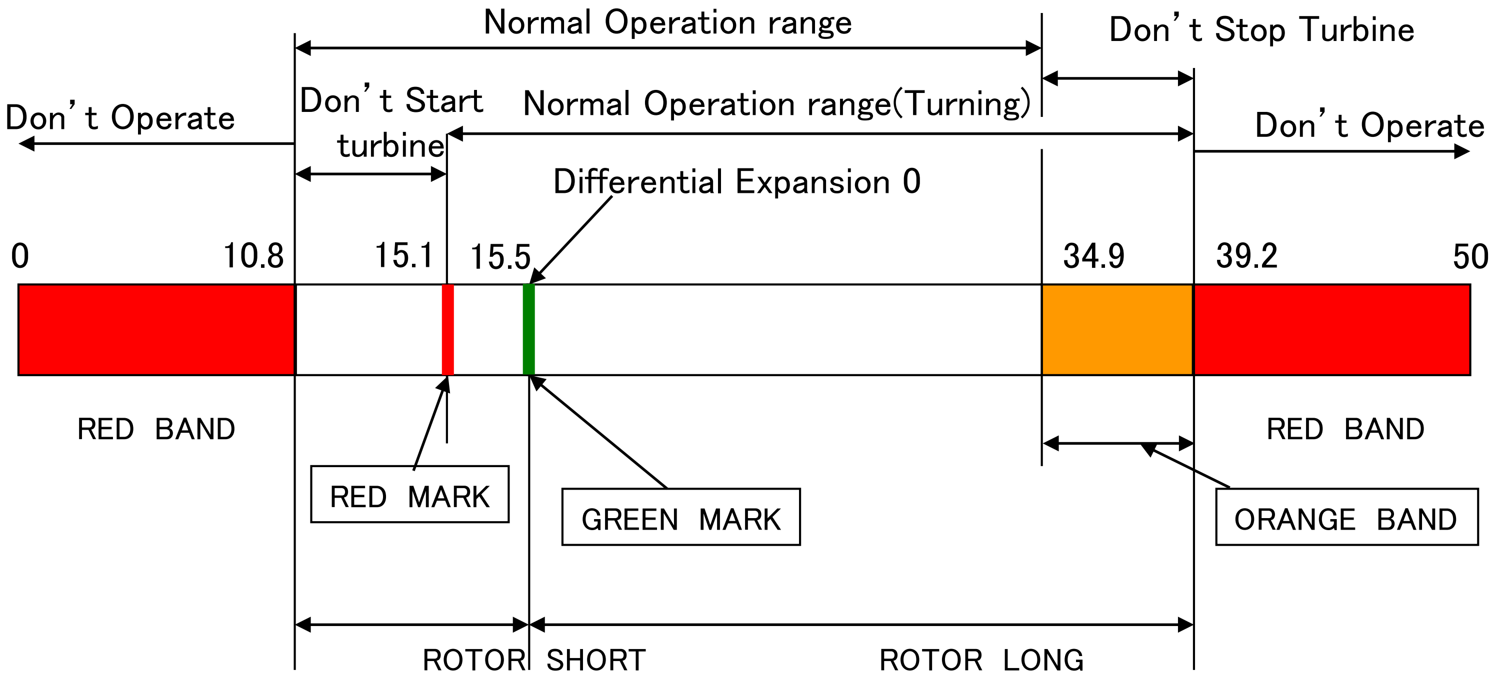


The distance between the red band and the red mark indicates that the rotor length is reduced as a result of the centrifugal force.

The orange band indicates the degree of rotor expansion caused by release or decrease of the centrifugal force.

Shell & Differential Expansion

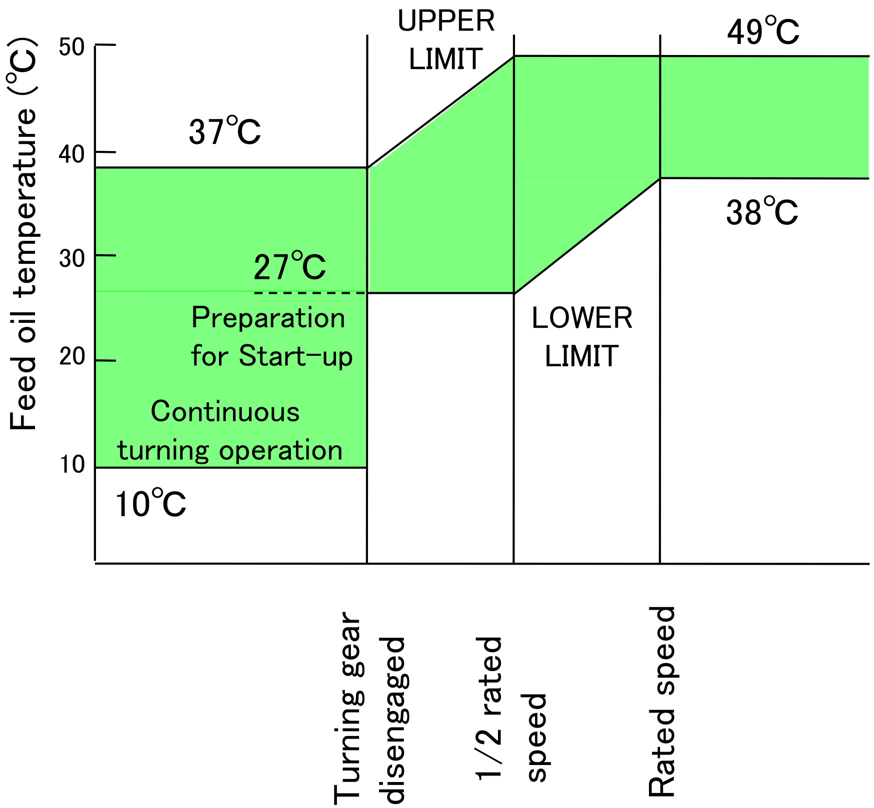
(2) LP Rotor



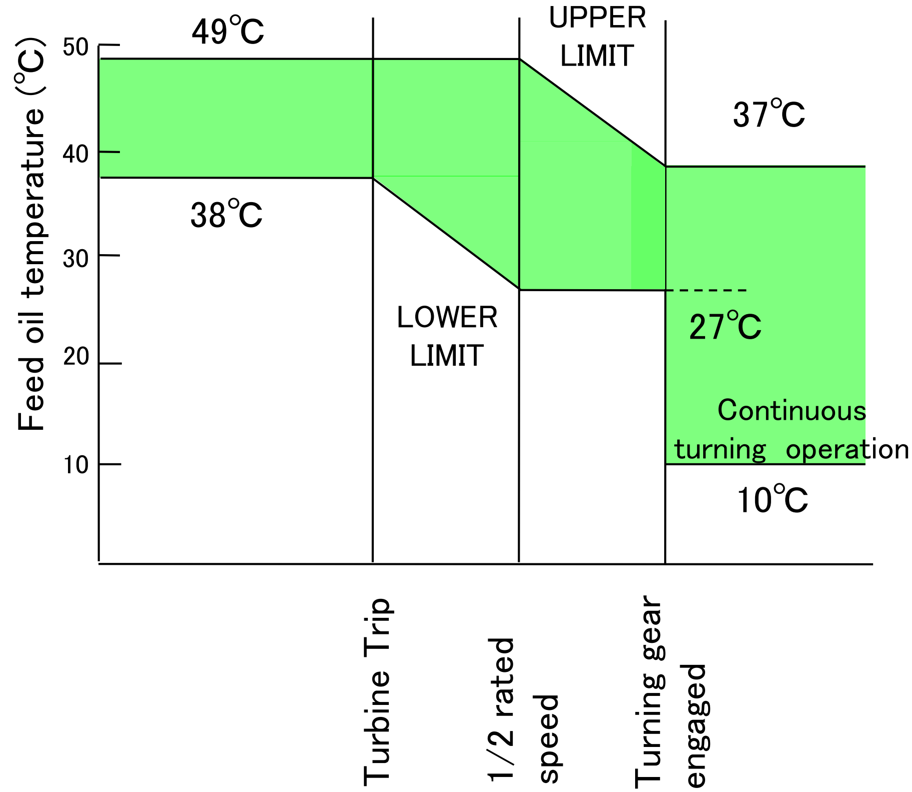
Lubricating Oil System

(a) Feed Oil Temperature

Start up



Shut down



Lubricating Oil System

(b) Bearing Oil Drain and Bearing Metal Temperature

Bearing Oil Drain Temperature

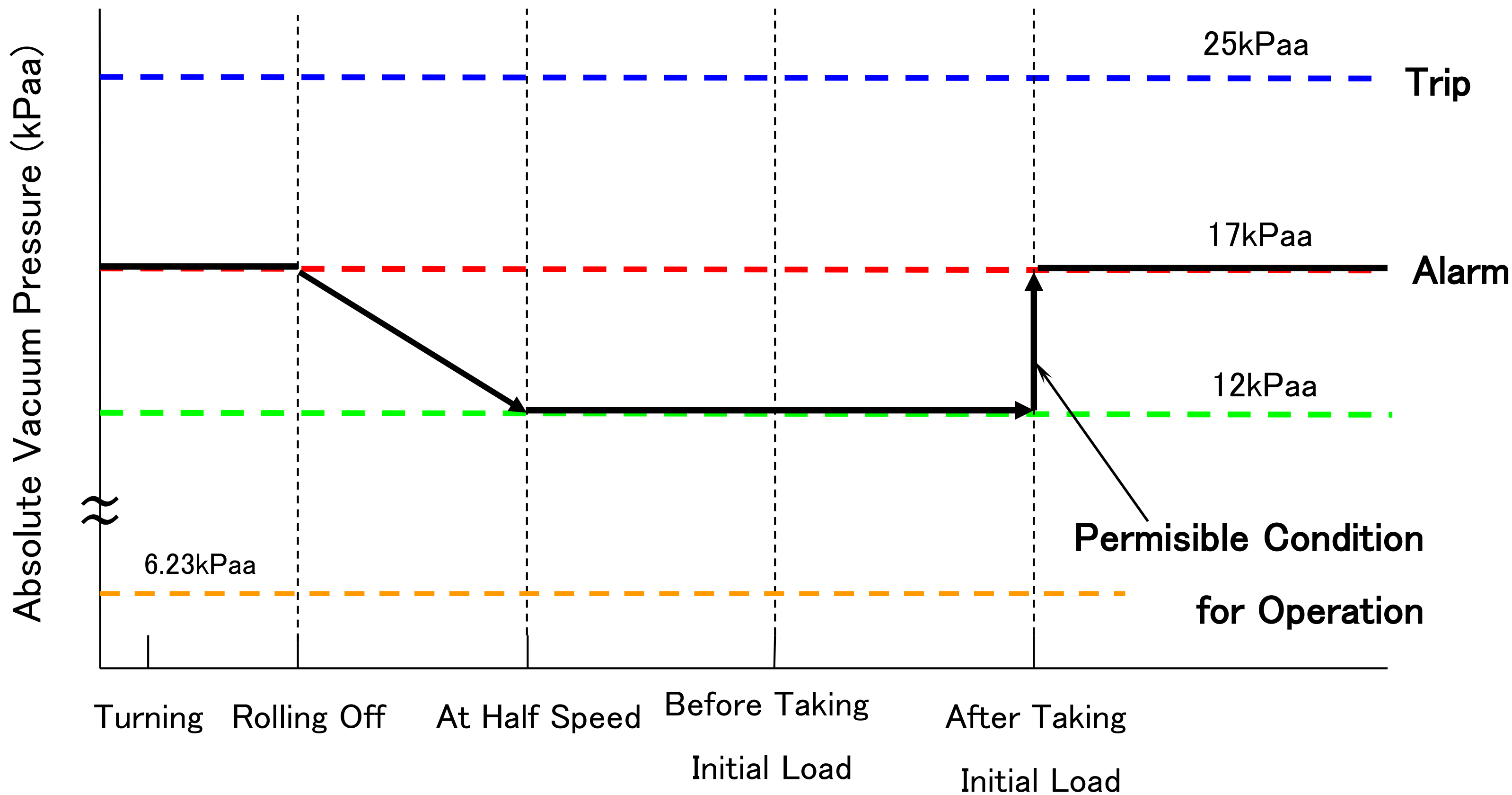
Parameter		Maximum
Normal Operation	Journal Bearing	79℃
	Thrust Bearing	82℃
Difference between Feed and Drain		28℃
Transient Change in Drain Temperature		3℃/min

Bearing Metal Temperature

Item		Alarm	Limit
Thrust Bearing	Active side	98℃	105℃
	Inactive side		
Journal Bearing	Elliptical type	107℃	121℃
	Pad Type	115℃	121℃
Transient Change in Metal Temperature		–	5.5℃/min

LP Turbine Exhaust Hood

(a) Vacuum



LP Turbine Exhaust Hood

(b) Temperature

Operating Condition	Set Point	Notes
Continuous Operation	80℃	High temperature Alarm
	107℃	High temperature Trip

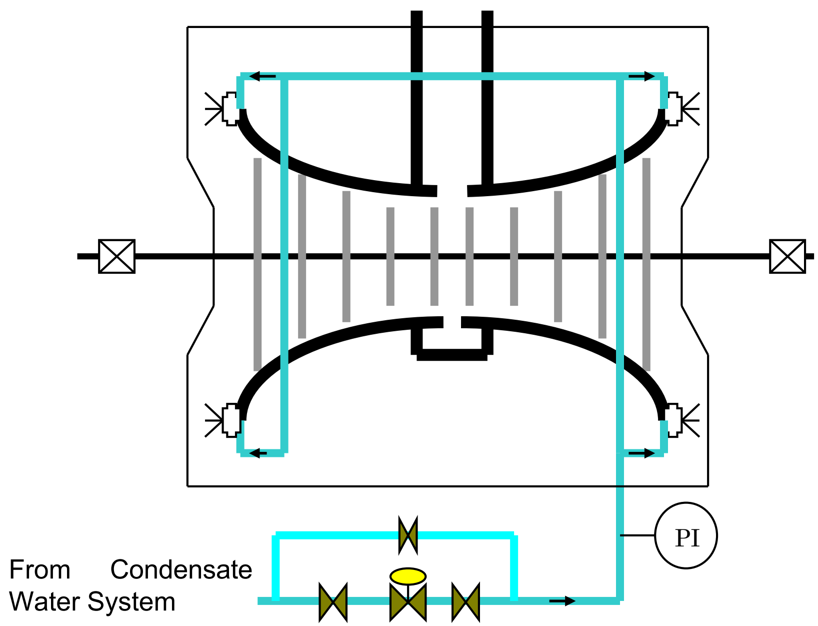
These values are related to overheating in the exhaust hood.

In general, such temperature increases are caused by decrease in condenser vacuum.

LP Turbine Exhaust Hood

(c) Exhaust Hood Spray

Operating Condition	Set Point	Notes
From Rolling off to Taking 10% Load	–	With Exhaust Hood Spray, always "ON"
Over 10% Load	>65℃	With Exhaust Hood Spray, Compulsory
	<52℃	Without Exhaust Hood Spray, after cool down

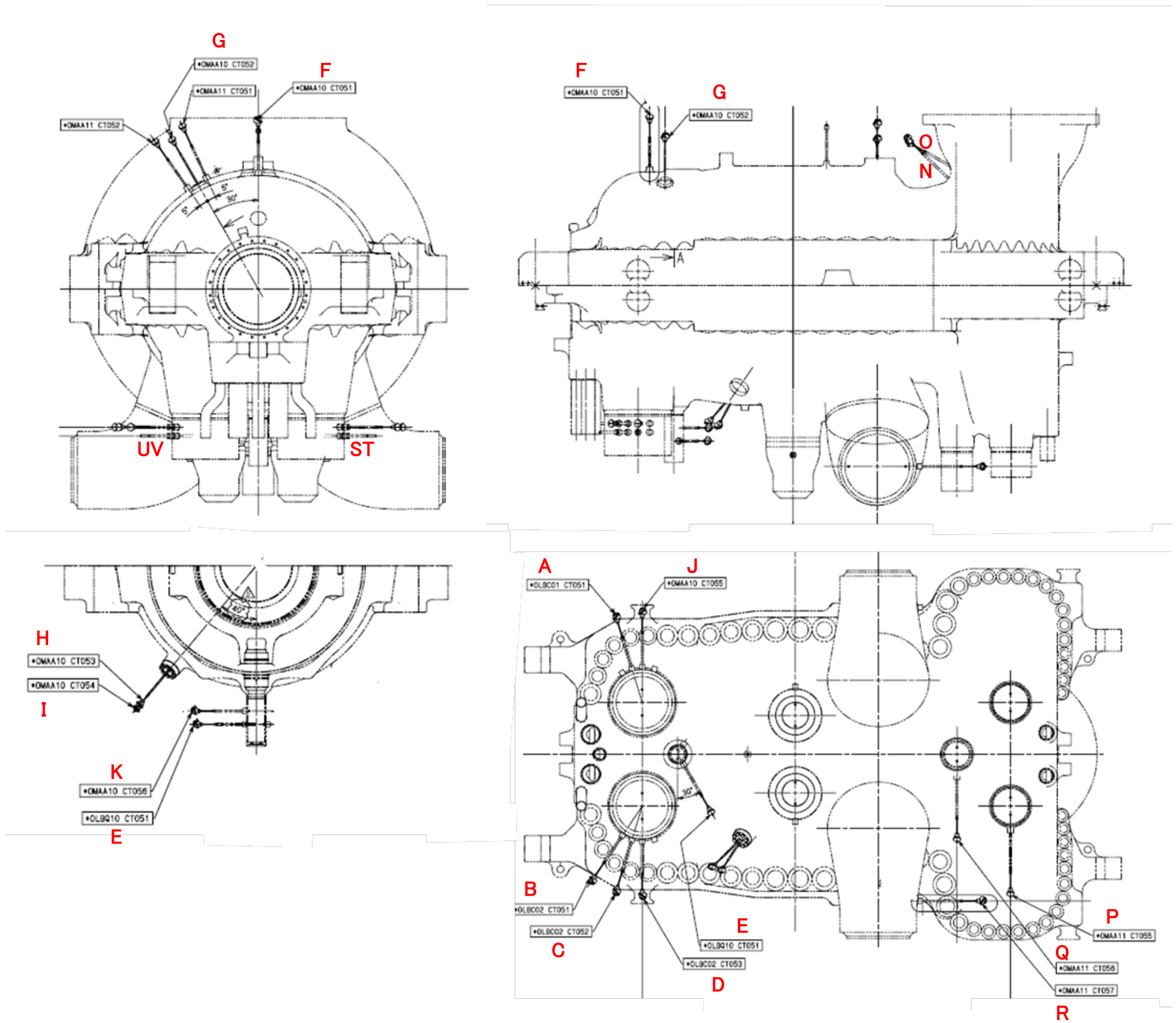


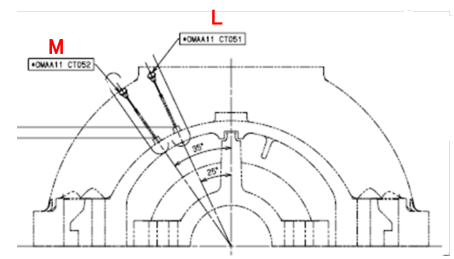
Spray Nozzle	
Normal	343 kPag
Maximum	490 kPag
Minimum	206 kPag

Temperature Difference between Upper & Lower Casing

(a) Location of Thermocouples on Turbine Casing

HIP Turbine



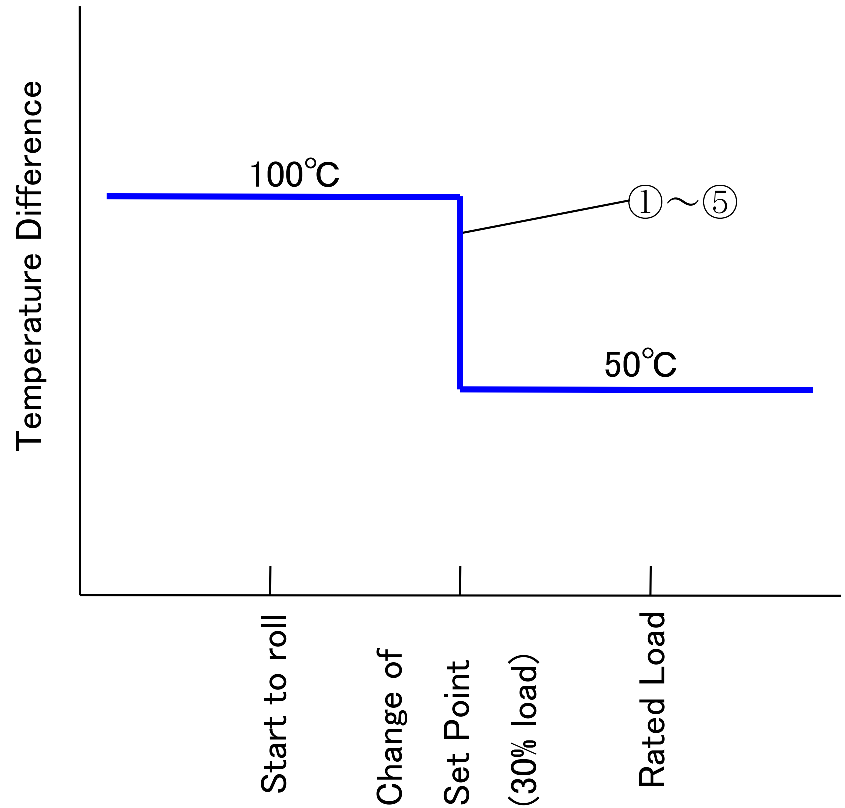


	THERMOCOUPLES	
	INSTRUMENT NUMBER	INSTRUMENT NAME & LOCATION
A	•OLBC01 CT051	HPT EXHAUST STEAM A TEMPERATURE
B	•OLBC02 CT051	HPT EXHAUST STEAM B TEMPERATURE A
C	•OLBC02 CT052	HPT EXHAUST STEAM B TEMPERATURE B
D	•OLBC02 CT053	HPT EXHAUST STEAM B TEMPERATURE C
E	•OLBQ10 CT051	HIP TURBINE NO.8 EXTRACTION STEAM TEMPERATURE
F	•OMAA10 CT051	HP UPPER CASING INNER METAL TEMPERATURE AT EXHAUST
G	•OMAA10 CT052	HP UPPER CASING INNER METAL TEMPERATURE AT EXTRACTION
H	•OMAA10 CT053	TURBINE 1ST STAGE INNER METAL TEMPERATURE
I	•OMAA10 CT054	TURBINE 1ST STAGE OUTER METAL TEMPERATURE
J	•OMAA10 CT055	HP LOWER CASING INNER METAL TEMPERATURE AT EXHAUST
K	•OMAA10 CT056	HP LOWER CASING INNER METAL TEMPERATURE AT EXTRACTION
L	•OMAA11 CT051	REHEAT BOWL UPPER INNER METAL TEMPERATURE
M	•OMAA11 CT052	REHEAT BOWL UPPER OUTER METAL TEMPERATURE
N	•OMAA11 CT053	IP UPPER CASING INNER METAL TEMPERATURE AT EXTRACTION
O	•OMAA11 CT054	IP UPPER CASING INNER METAL TEMPERATURE AT EXHAUST
P	•OMAA11 CT055	IP LOWER CASING INNER METAL TEMPERATURE AT EXHAUST
Q	•OMAA11 CT056	IP LOWER CASING INNER METAL TEMPERATURE AT EXTRACTION
R	•OMAA11 CT057	REHEAT BOWL LOWER INNER METAL TEMPERATURE
S	•OLBC01 CT201	HPT EXHAUST STEAM A TEMPERATURE A
T	•OLBC01 CT202	HPT EXHAUST STEAM A TEMPERATURE B
U	•OLBC02 CT201	HPT EXHAUST STEAM B TEMPERATURE A
V	•OLBC02 CT202	HPT EXHAUST STEAM B TEMPERATURE B

Temperature Difference between Upper & Lower Casing

(b) Allowable Temperature Difference between Upper and Lower Casing During Start-up

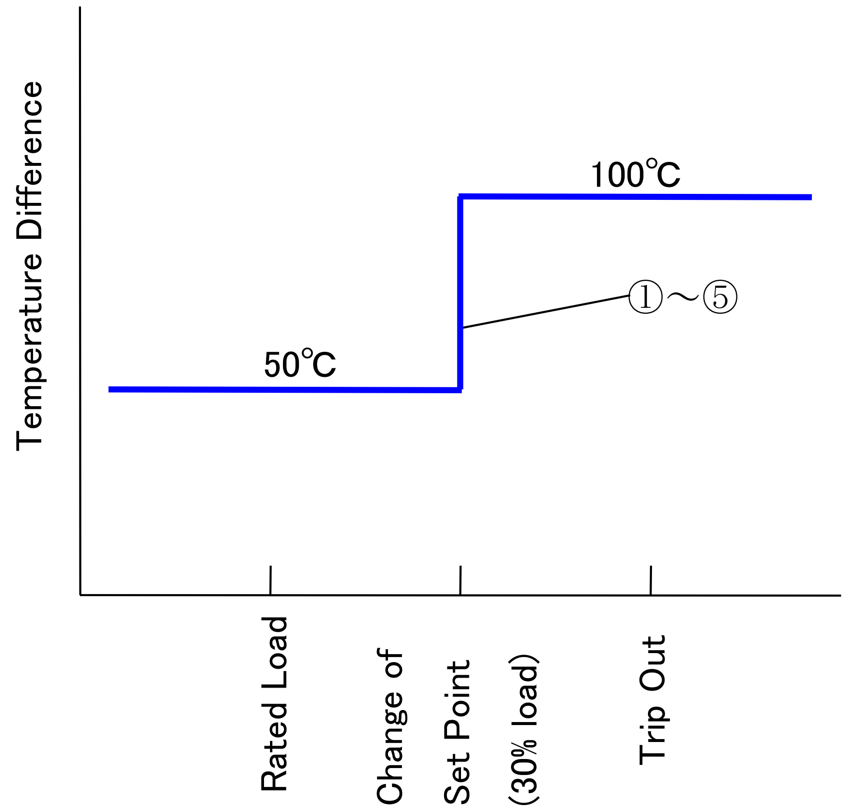
① HP Heater8 Extraction
② HP Exhaust Chamber
③ Reheat Bowl
④ IP Heater6 Extraction
⑤ IP Exhaust Chamber



Temperature Difference between Upper & Lower Casing

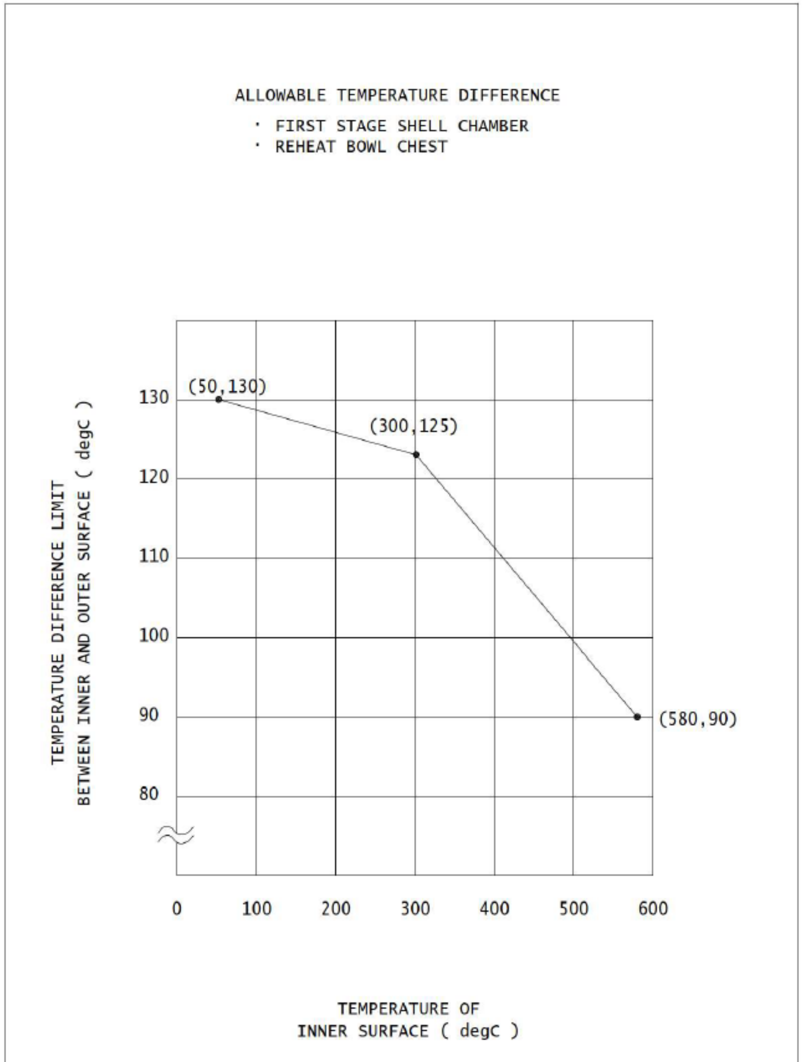
(b) Allowable Temperature Difference between Upper and Lower Casing During Shut-down

① HP Heater8 Extraction
② HP Exhaust Chamber
③ Reheat Bowl
④ IP Heater6 Extraction
⑤ IP Exhaust Chamber

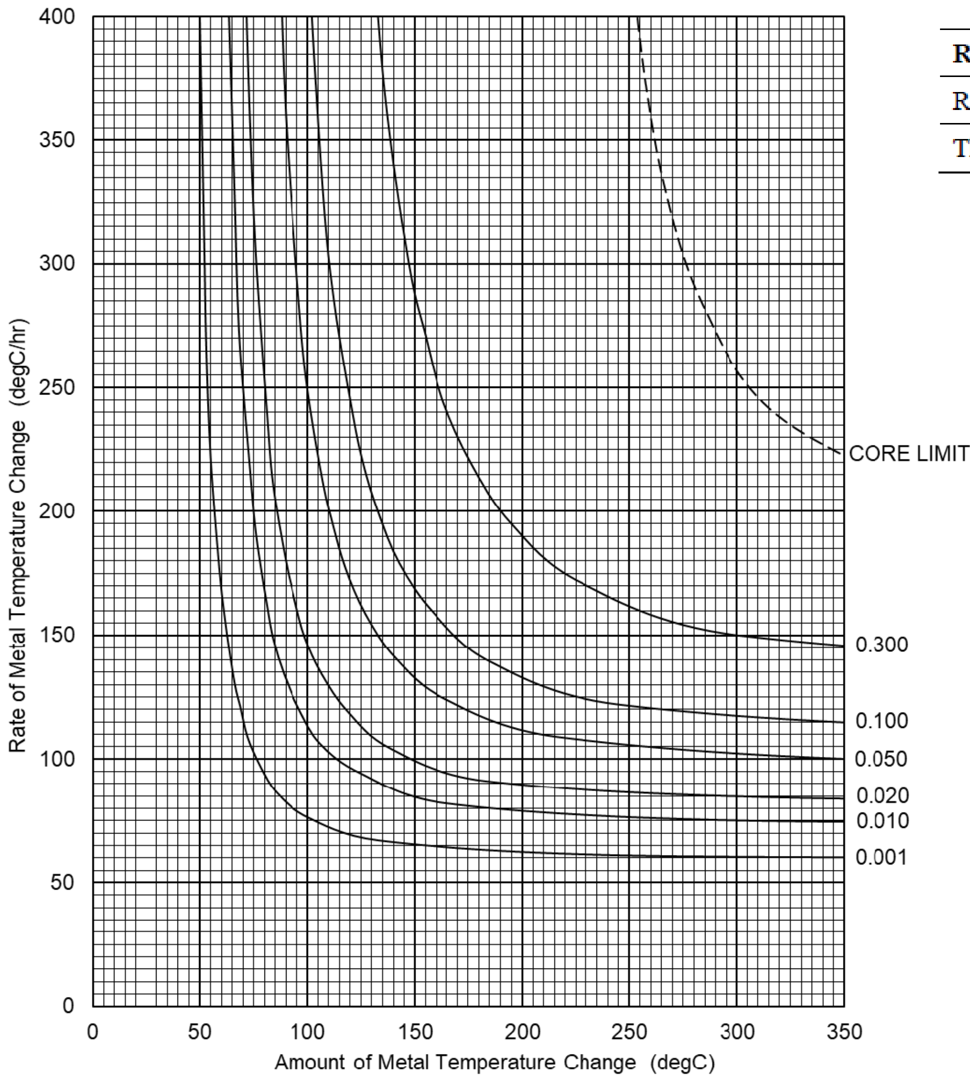


Temperature of First-Stage Shell & Reheat Bowl Chest

Allowable Temperature Difference in First-Stage Shell Chamber and Reheat Bowl Chest



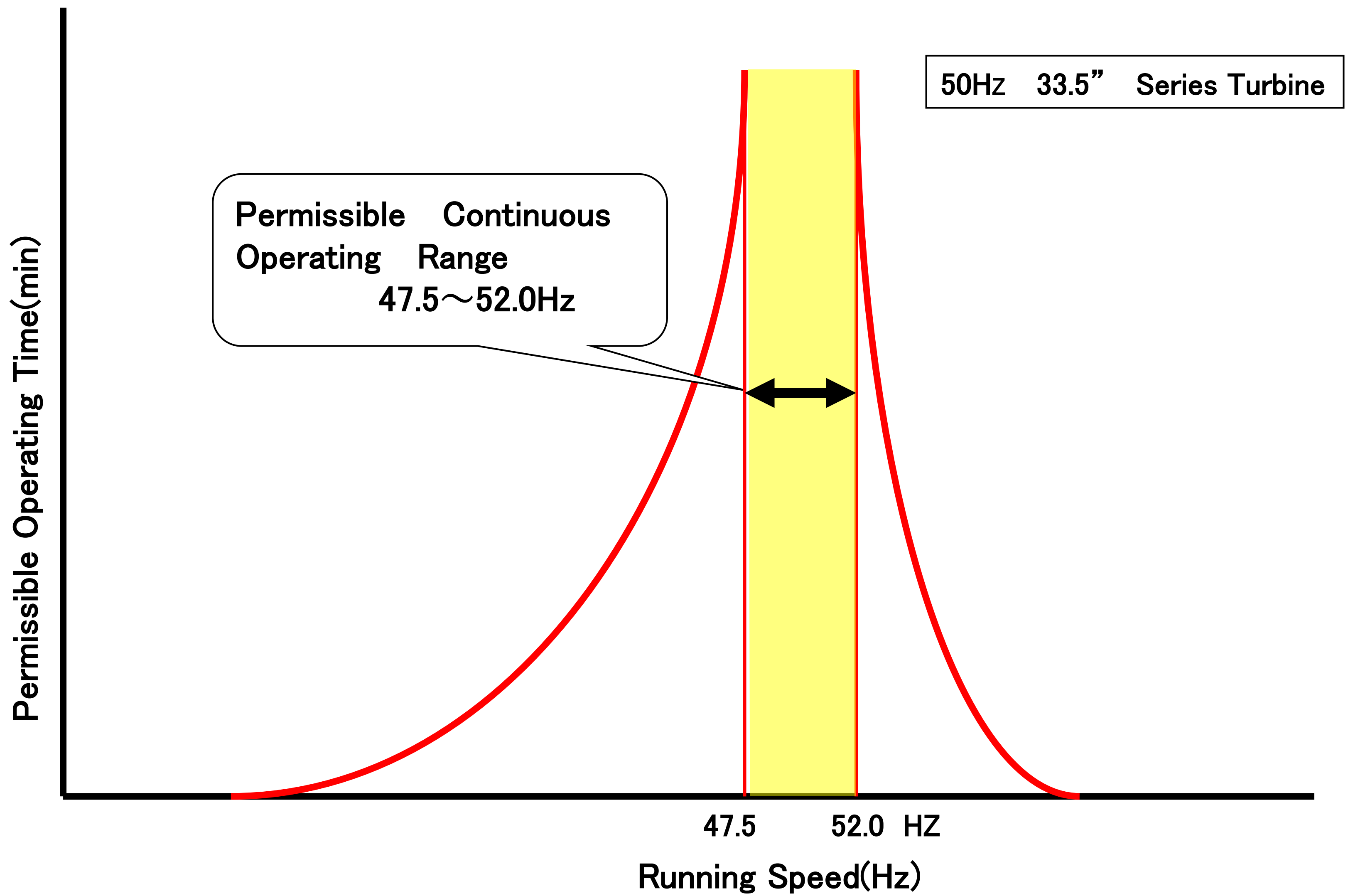
Cyclic Damage Curve of Rotor



Rotor section	High pressure section
Rotor nominal diameter	736.6 mm (29")
Thermocouple location	First stage shell inner

Notes : (1) Values on right hand vertical axis are life expenditure in percent per cycle.

Permissible Range for Off-Frequency Operation



Turning Operation

Maximum Temperature of Casing	Recommended Operating Time
Below 180℃	8 Hour
Above 180℃ , Below 350℃	6 Hour
Above 350℃	4 Hour

The maximum temperature of casing means the maximum temperature in each casing corresponding to the rotor system.

Normally, this is the temperature of the first-stage shell and reheat bowl inner surface.

Mismatch chart

Turbine Mismatch Chart

・The object to use mismatch chart

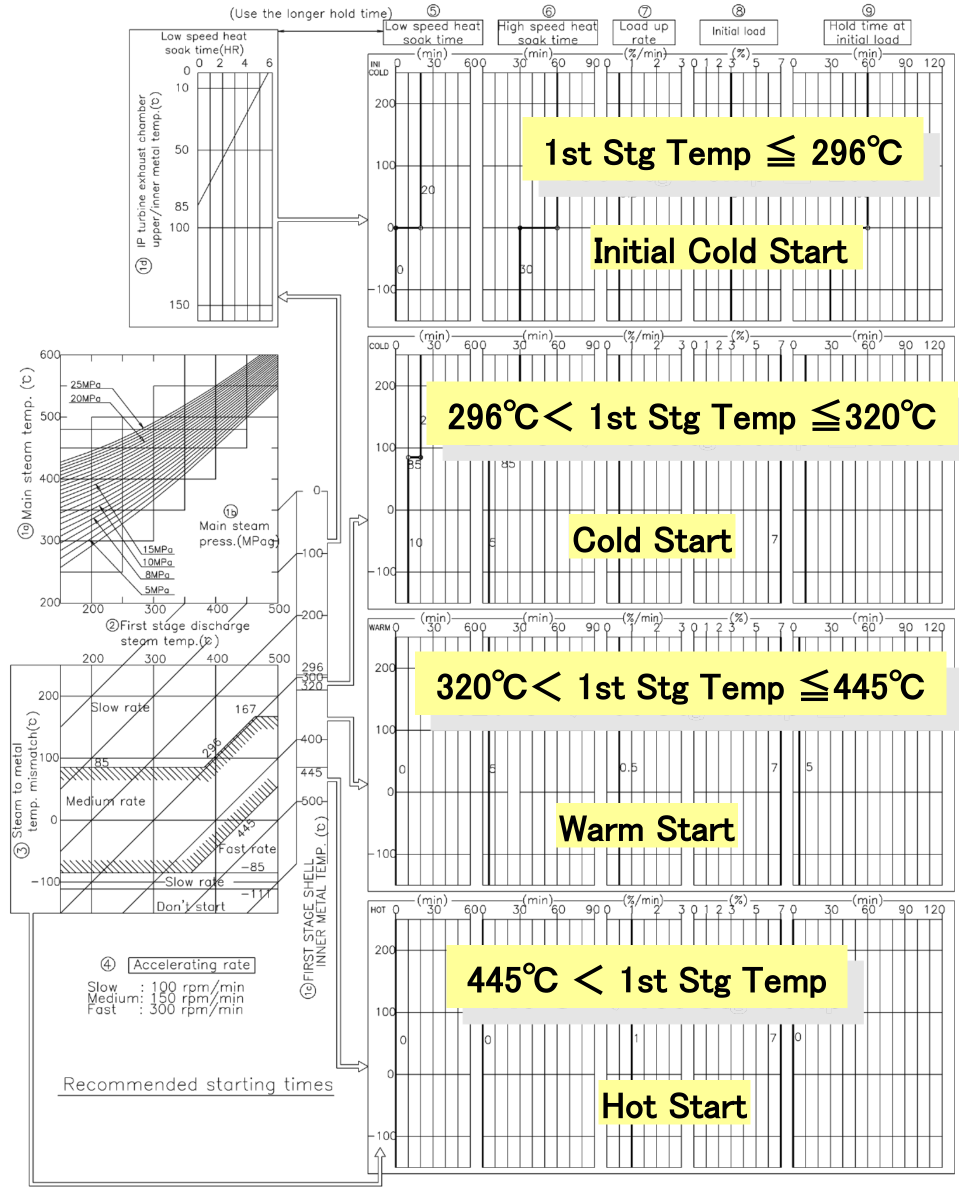
→Select the start up mode

→Smooth warm up steam turbine

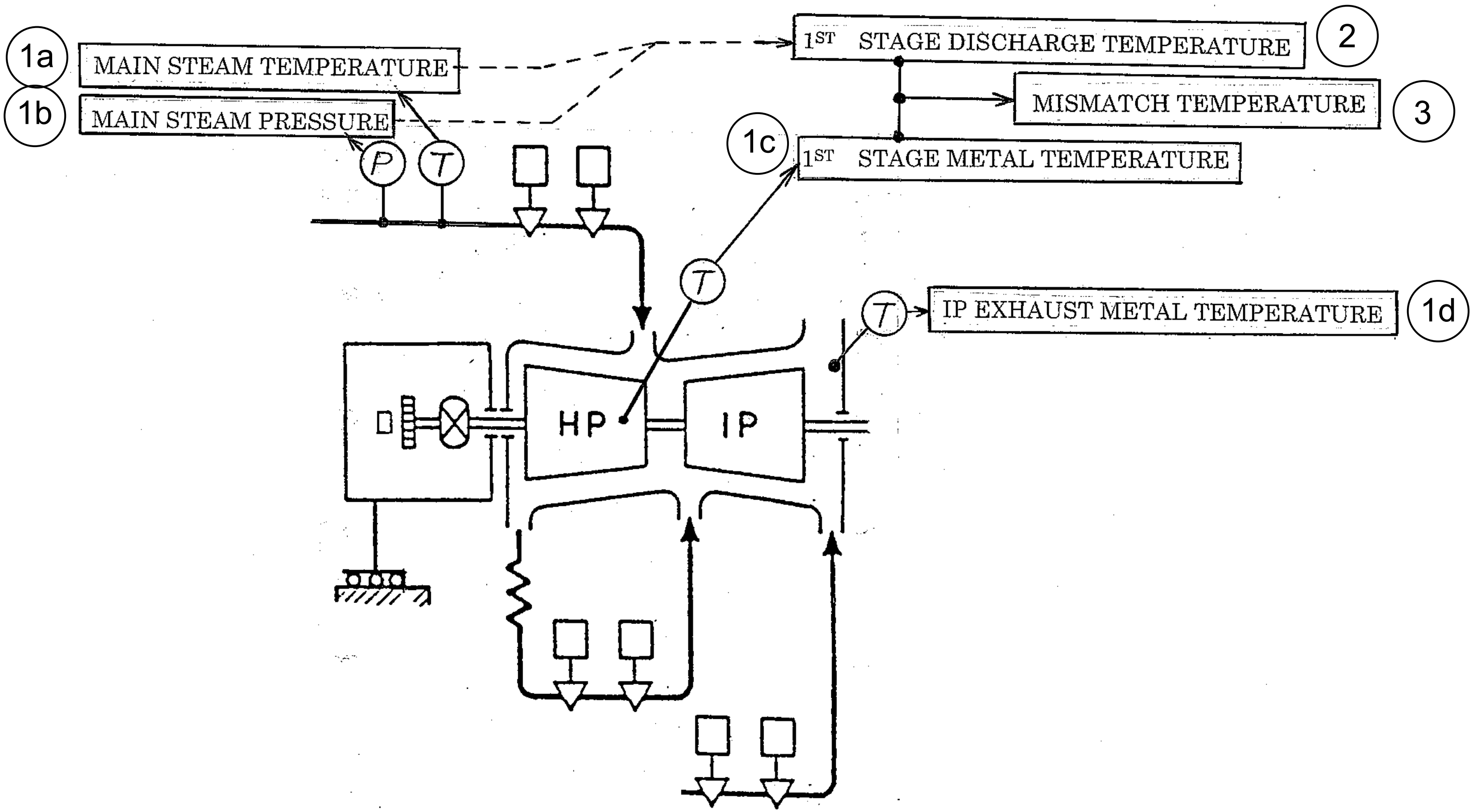
・Mismatch Temperature

1st stage discharge steam temperature

—1st stage shell metal temperature



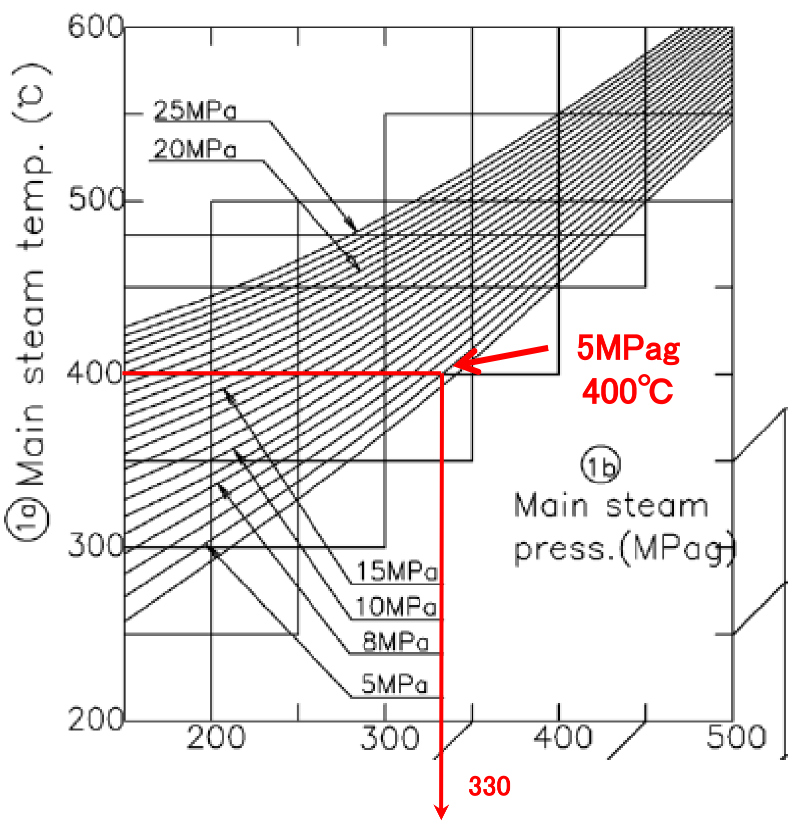
MISMATCH TEMPERATURE

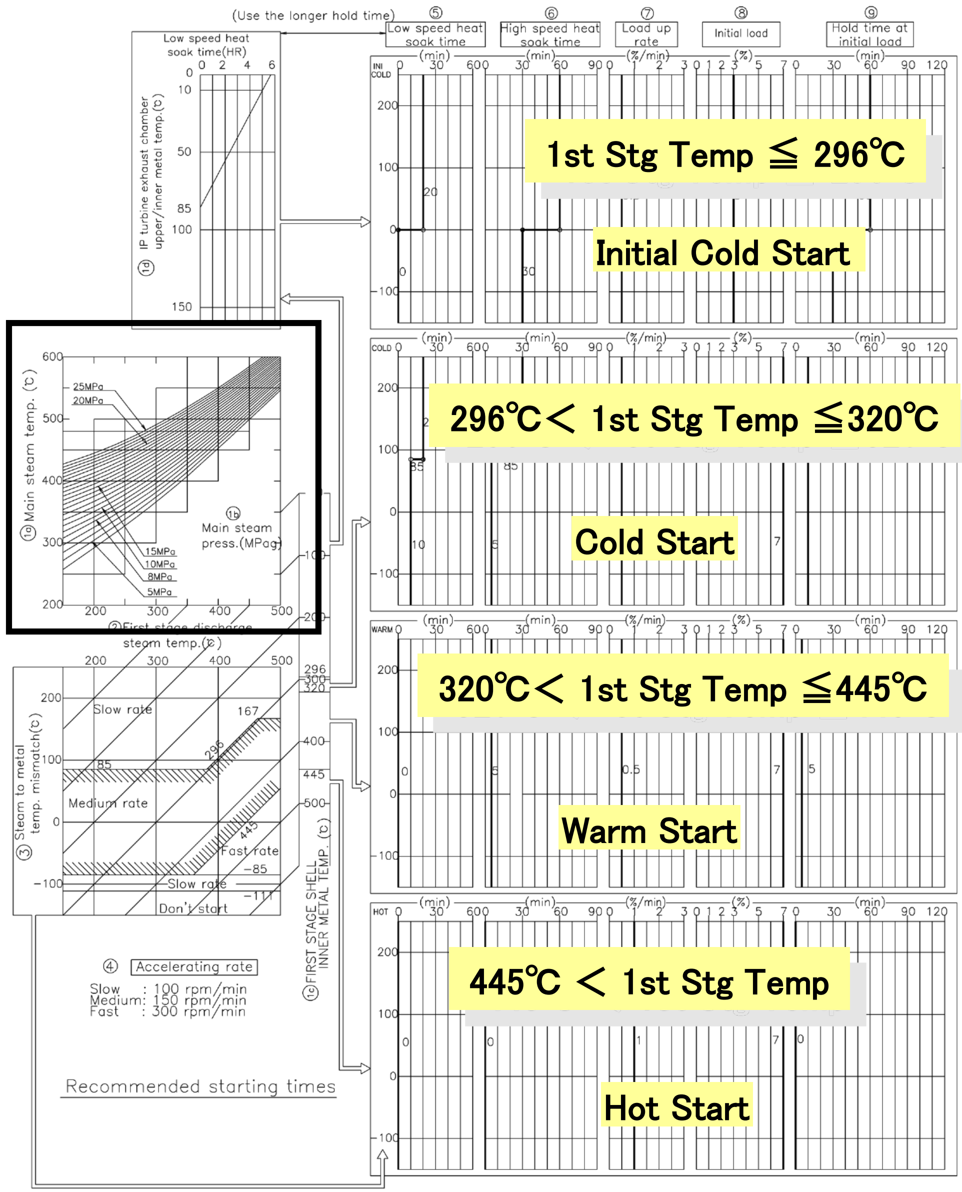


Mismatch chart

Turbine Mismatch Chart

For Example
Main Steam Temp. 400℃
Main Steam Press. 5MPag

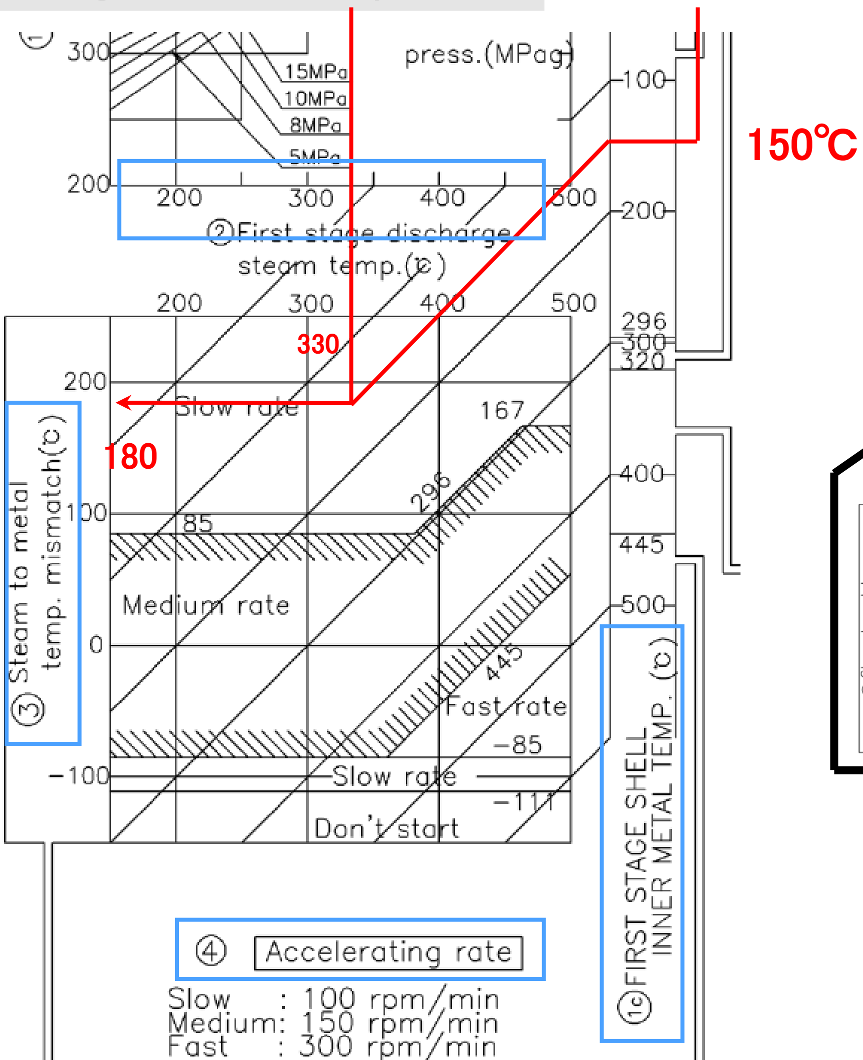


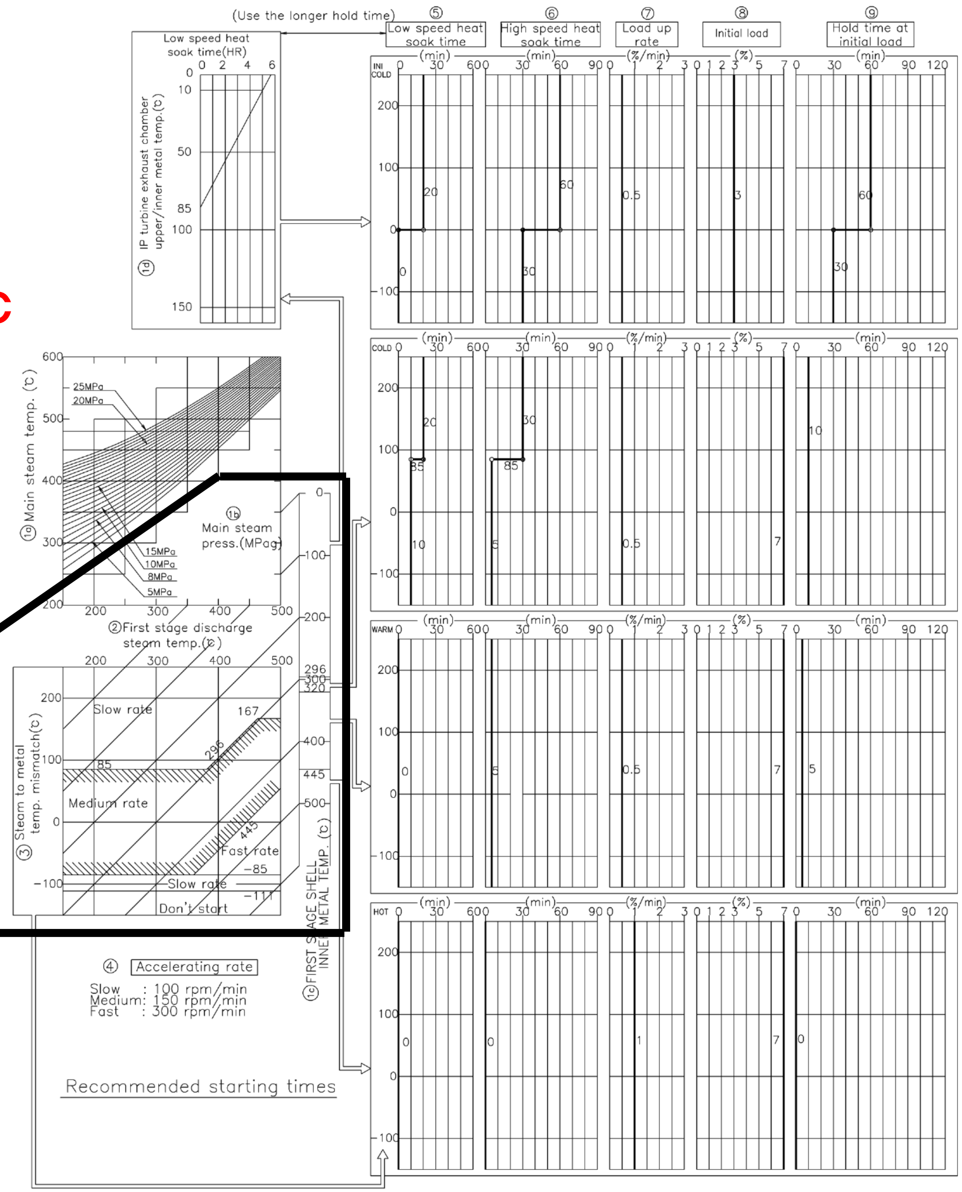


Mismatch chart

Turbine Mismatch Chart

For Example
1st Stg Inner Metal Temp. 150℃

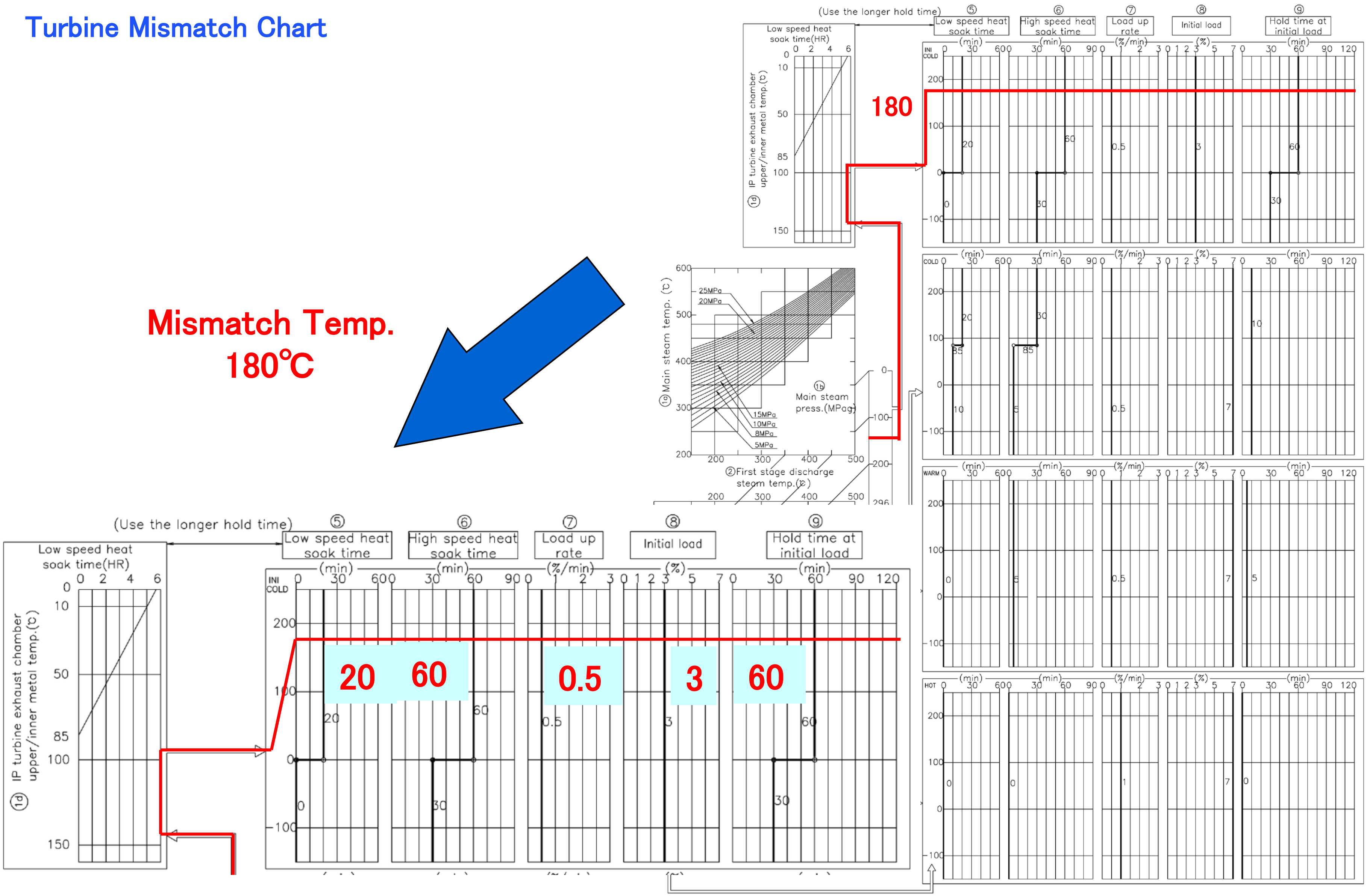




Mismatch chart

Turbine Mismatch Chart

Mismatch Temp.
180℃



TOSHIBA

Reference document

Document No.	Document Name
VP1-C-L2-M-MAA-00004	Section Drawing for Steam Turbine
VP1-C-L2-M-MAA-00001	Outline Drawing for Steam Turbine
VP1-C-L2-P-MAW-00001	Piping and Instrument Diagram for Steam Turbine Seal Steam and Drain System
VP1-C-L2-M-MAW-00001	System Design Description for Gland Steam Sealing System
02.02.02.004.	O&M Manual – Turbine Operation
02.02.02.006.	O&M Manual – Turbine Operating Limits