Marine Steam Propulsion Turbines

Past, Present and Future -
A Personal Journey.

1

ss Vitrina – 9.69 MW Steam Turbine, 30,000 Ton Oil Tanker. H&W 1957.

2

Open Platform Engine Room Control Panel - 1950's Spec.

3

VLCC
ss Medora,

20.88 MW

Steam Propulsion
250,000 Ton VLCC
[Very Large Crude Carrier]

4

VLCC
ss LIMA

26.85MW

360,000T
Displacement

5

VLCC ss Mysia

Routine check of Hull Cathodic Protection System in Fosc'le Head.

6

VLCC
ss LIMA

Indian Ocean

7

G-Class Membrane type LNG Carrier.

Cargo: 75,000 m cubed of Cryogenic LNG at -163 ºC @AP

8

SHELL TANKER "GOULDIA" LNG CARRIER 75,000 m³ CAPACITY

9

Engine Control Room – 1970s Specification.

10

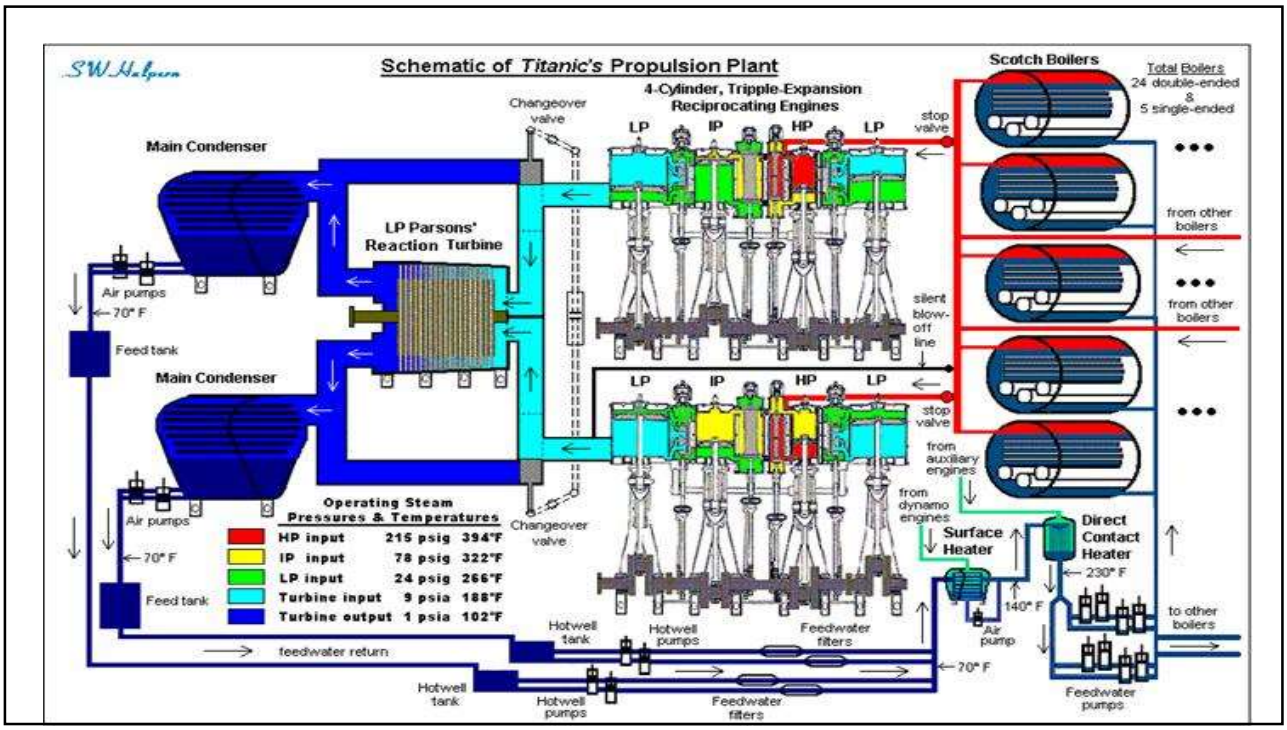
1912

11

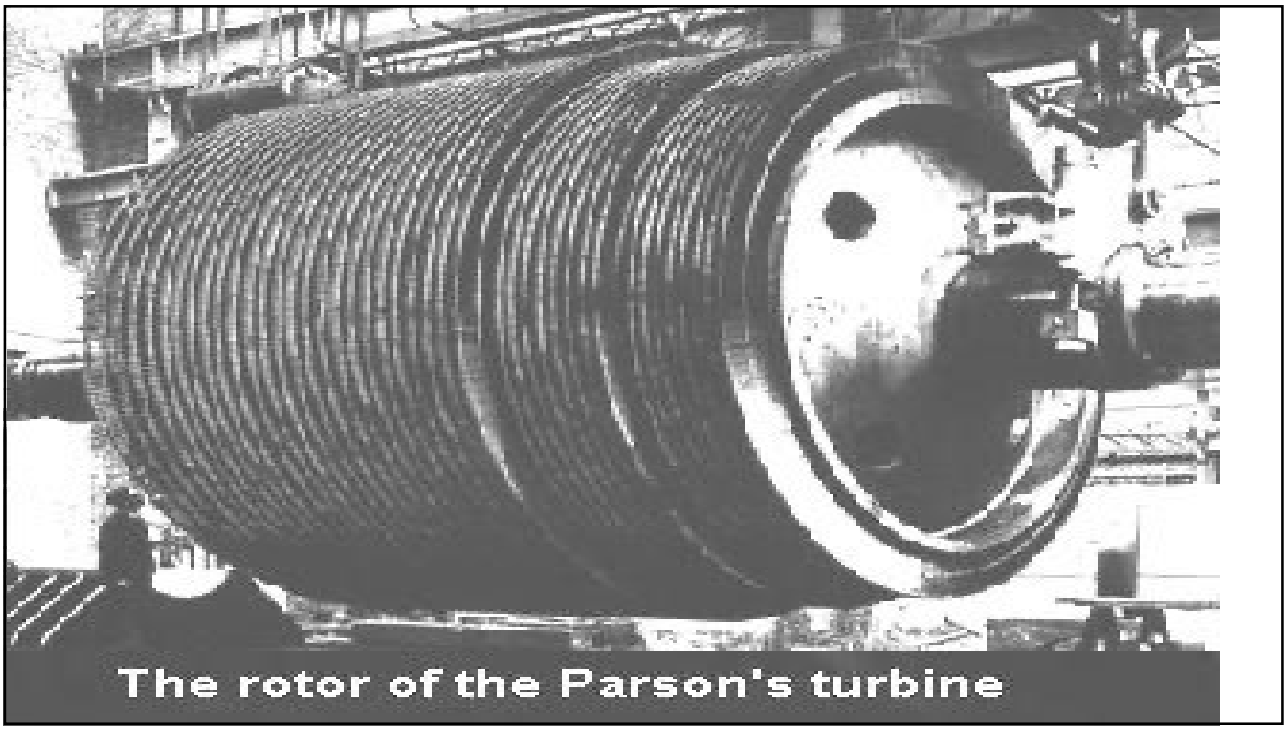
RMS TITANIC

- 46,328 GROSS TONS [Internal Volume]
- 50,000 shp [37.3 MW]
- 25 kn.

12


SW Halpern
Schematic of Titanic's Propulsion Plant
4-Cylinder, Tripple-Expansion Reciprocating Engines
Changeover valve
LP
IP
HP
LP
stop valve
Scotch Boilers
Total Boilers
24 double-ended
&
5 single-ended
Main Condenser
LP Parsons' Reaction Turbine
Air pumps
70° F
Feed tank
Main Condenser
from other boilers
from other boilers
silent blow-off line
from auxiliary engines
from dynamo engines
Surface Heater
Direct Contact Heater
230° F
140° F
Air pump
to other boilers
Operating Steam Pressures & Temperatures
HP input 215 psig 394°F
IP input 78 psig 322°F
LP input 24 psig 266°F
Turbine input 9 psia 188°F
Turbine output 1 psia 102°F
feedwater return
Hotwell tank
Hotwell pumps
Feedwater filters
Feedwater pumps

13


The rotor of the Parson's turbine

14

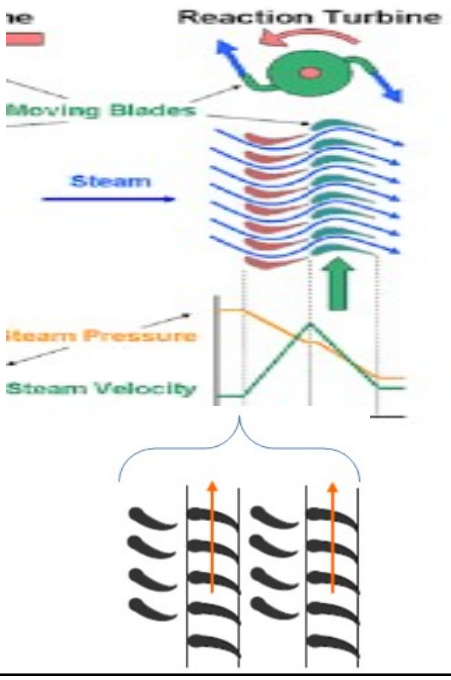
Parson's 1911 Reaction Turbine - Multi-Stage, Low Pressure Exhaust, Direct Coupled.

- Steam delivered to two Reciprocating Steam Engines at 14.6 bar / 201° C from 29 hand stoked coal boilers.
- Reciprocating Engines rotated at 78 rpm.
- Steam Exhausted from Engines to the Turbine at – 0.39 barg [0.61barA] / 86.7°C.
- Condenser vacuum at -0.93 barg [0.07barA] / 38.8°C.
- Turbine rotated at 165 rpm delivering 16,000 shp [11.93 MW].
- Turbine Blades were laced, 45.7cm to 64.8cm long on a rotor diameter of 3.7m.

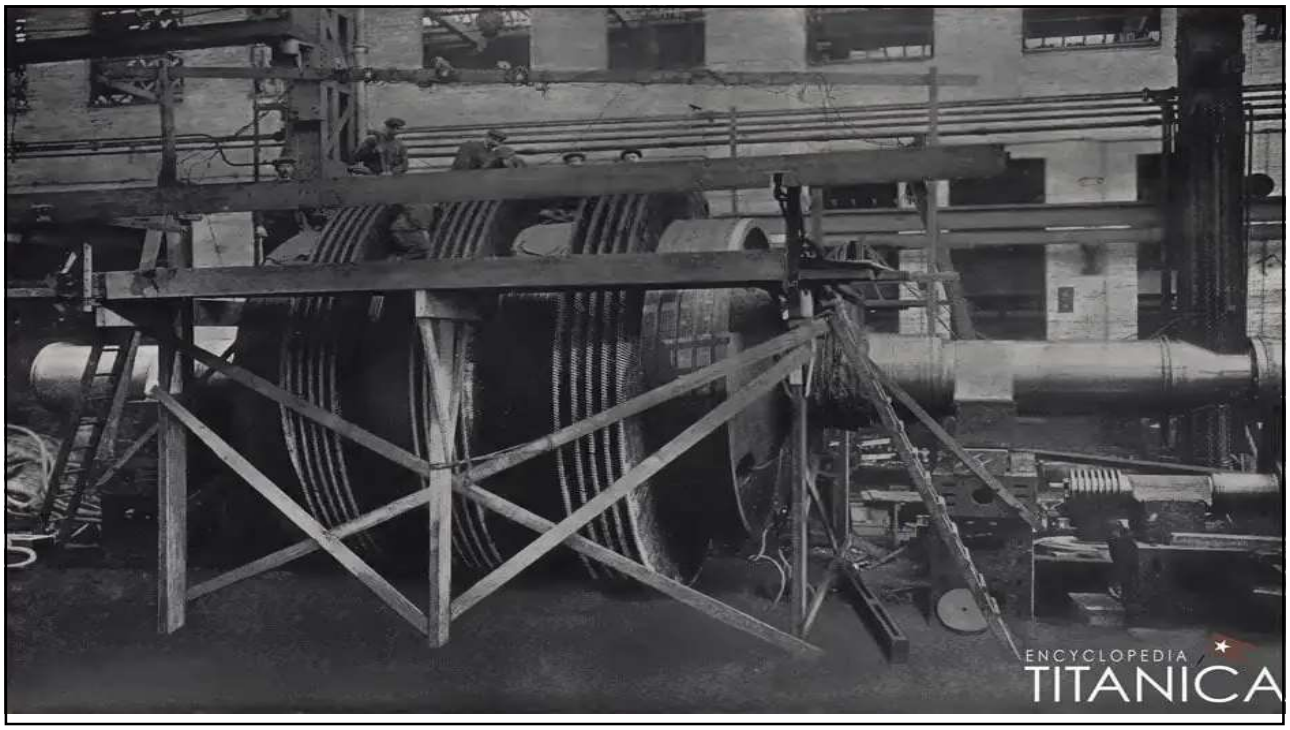
15

Reaction Turbine Blading Turning Forces

- Reaction force produced on the moving blades as the steam increases in velocity on exit from the converging nozzle shaped moving blade spaces.
- Reaction force is produced on the moving blades when the steam changes direction.
- The impulse force impinging on the moving blades on exit from the stationary blades [smallest effect].



16

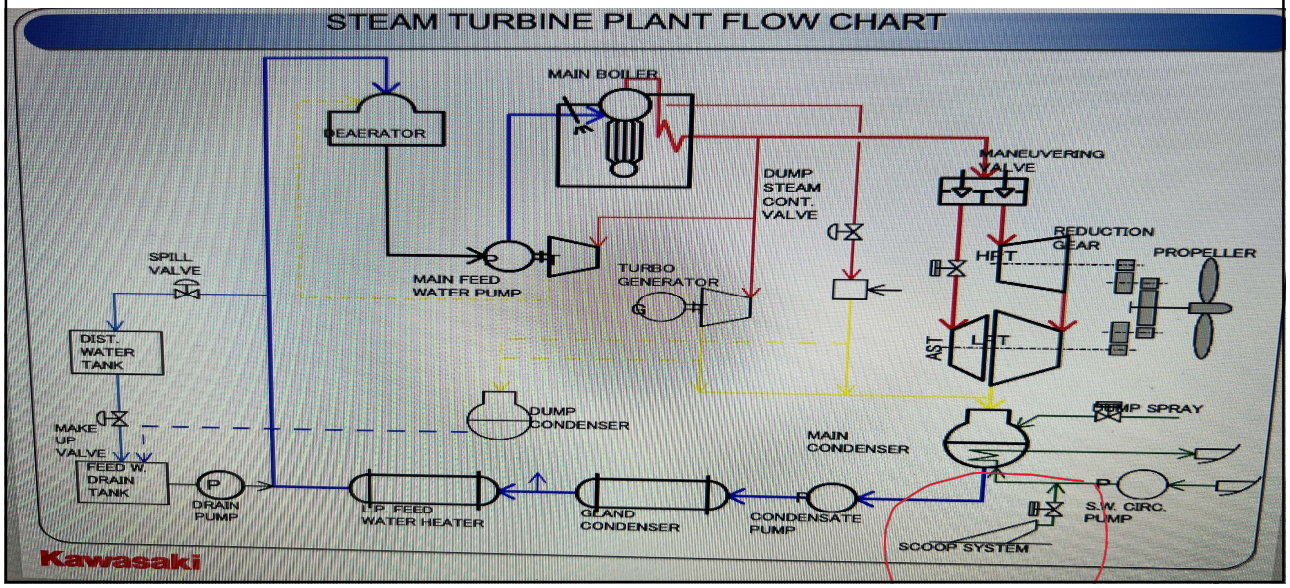


17

Conventional Marine Steam Turbine Propulsion.

18

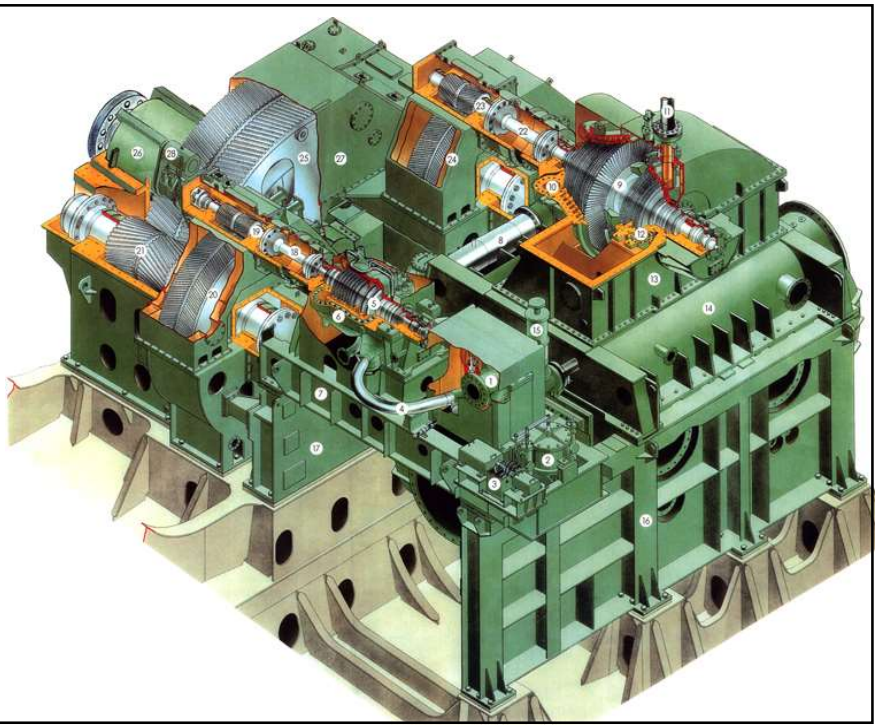
Closed Feed / Steam 60 Bar 515°C System



19

Kawasaki UA-TURBINE

1	Maneuvering Valve
2	Hydraulic Cylinder
3	Cam Gear
4	Main Steam Pipe
5	HP Turbine Rotor
6	HP Turbine Casing
7	HP Turbine Bed Frame
8	Cross Over Pipe
9	LP Turbine Rotor
10	LP Turbine Casing
11	Astern Steam Pipe
12	Astern Turbine Casing
13	LP Turbine Exhaust Casing
14	Main Condenser
15	Astern Guardian Valve
16	Fare Package Frame
17	AFT Package Frame
18	HP Flexible Coupling
19	HP 1st. Pinion
20	HP 1st. Wheel
21	HP 2nd. Pinion
22	LP Flexible Coupling
23	LP 1st. Pinion
24	LP 1st. Wheel
25	Main Gear
26	Main Thrust Bearing
27	Gear Casing
28	Turning Gear



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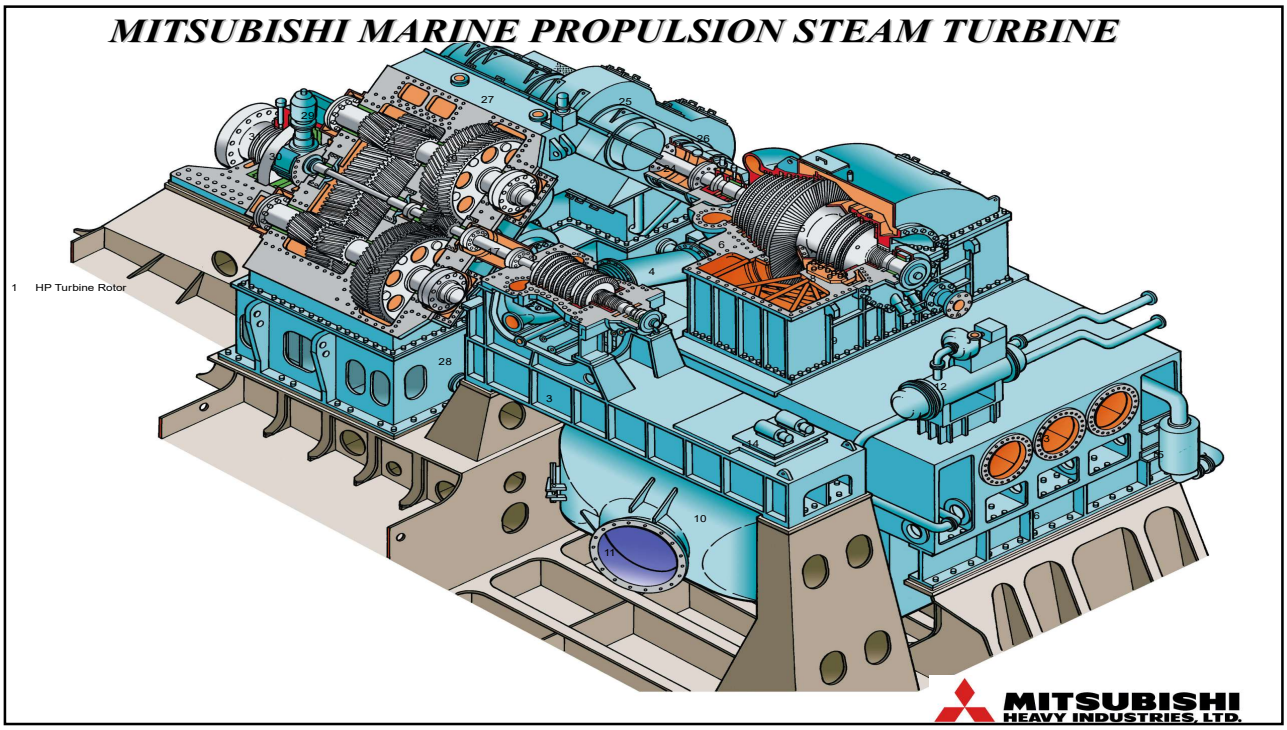
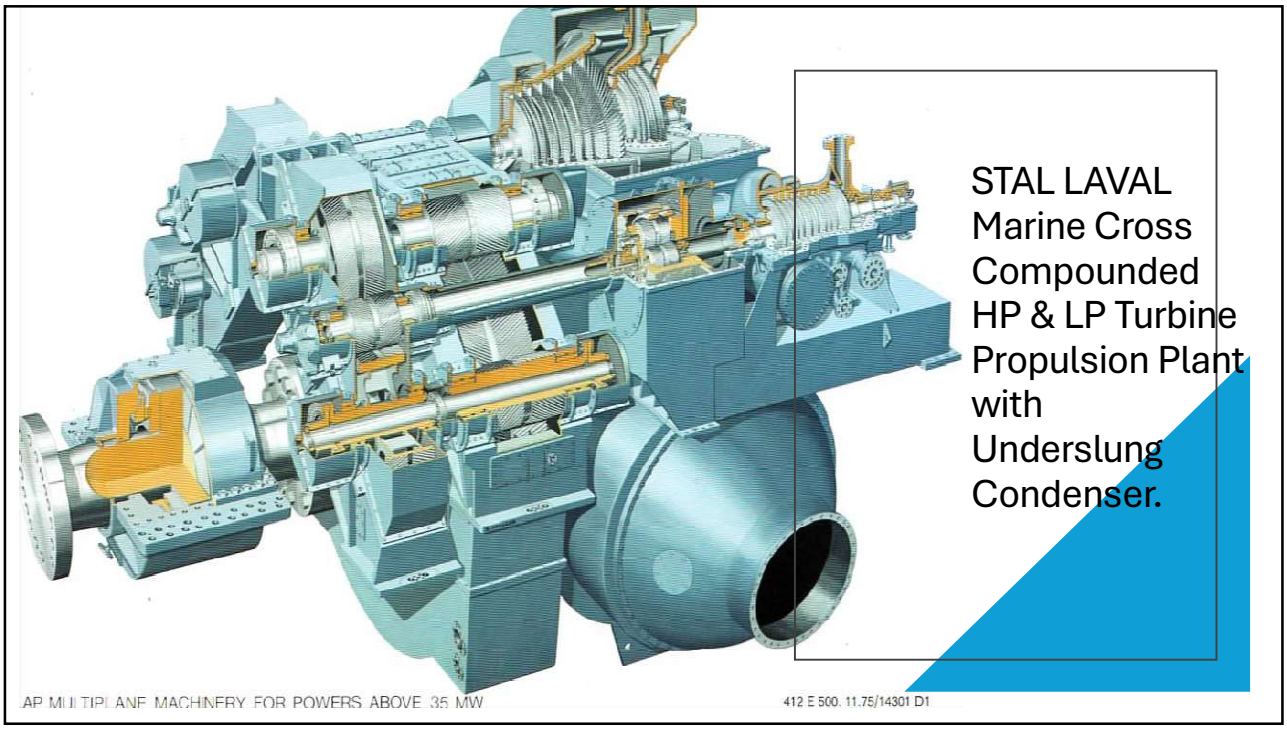
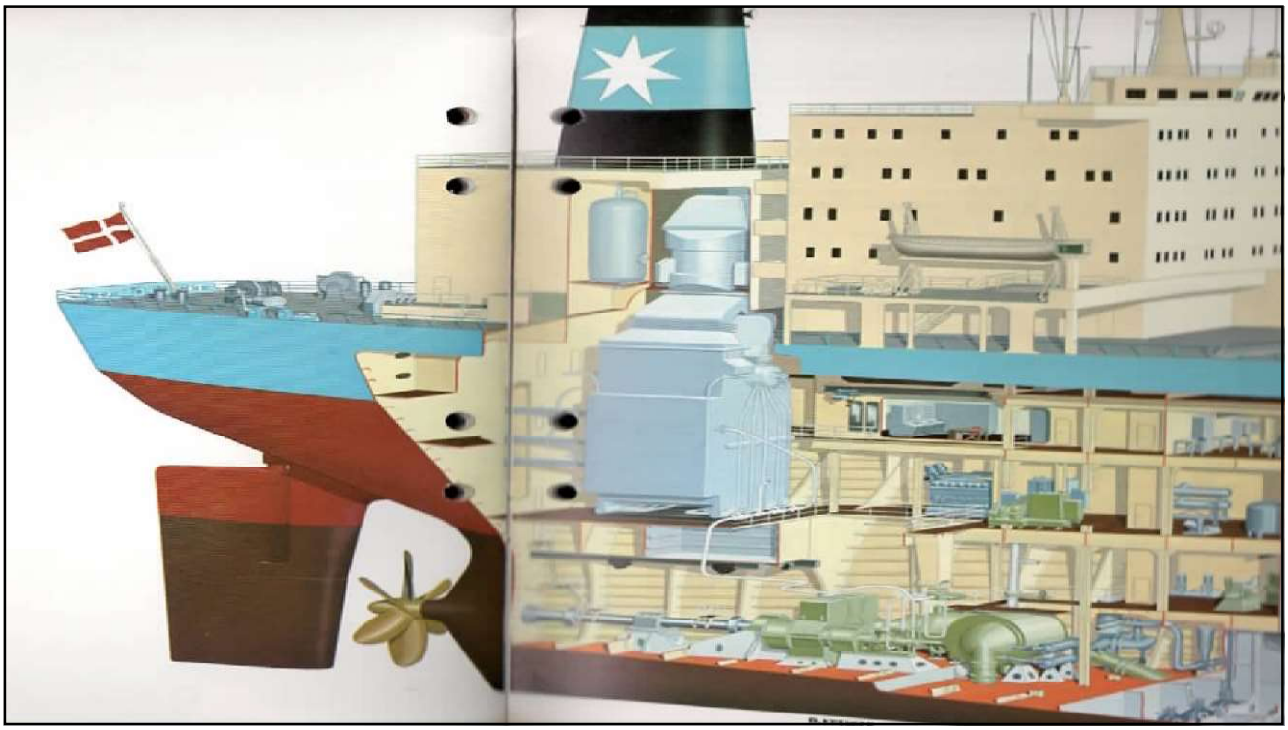

MITSUBISHI MARINE PROPULSION STEAM TURBINE
1 HP Turbine Rotor
MITSUBISHI
HEAVY INDUSTRIES, LTD.

21


STAL LAVAL
Marine Cross
Compounded
HP & LP Turbine
Propulsion Plant
with
Underslung
Condenser.
412 E 500. 11.75/14301 D1

22



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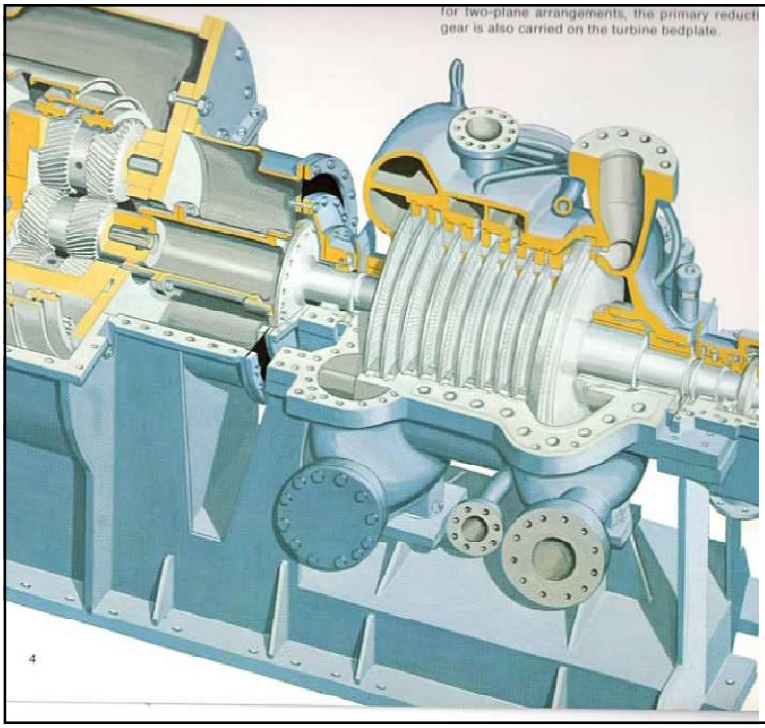


HP Impulse Bladed, Pressure Compounded Rateau Marine Steam Turbine

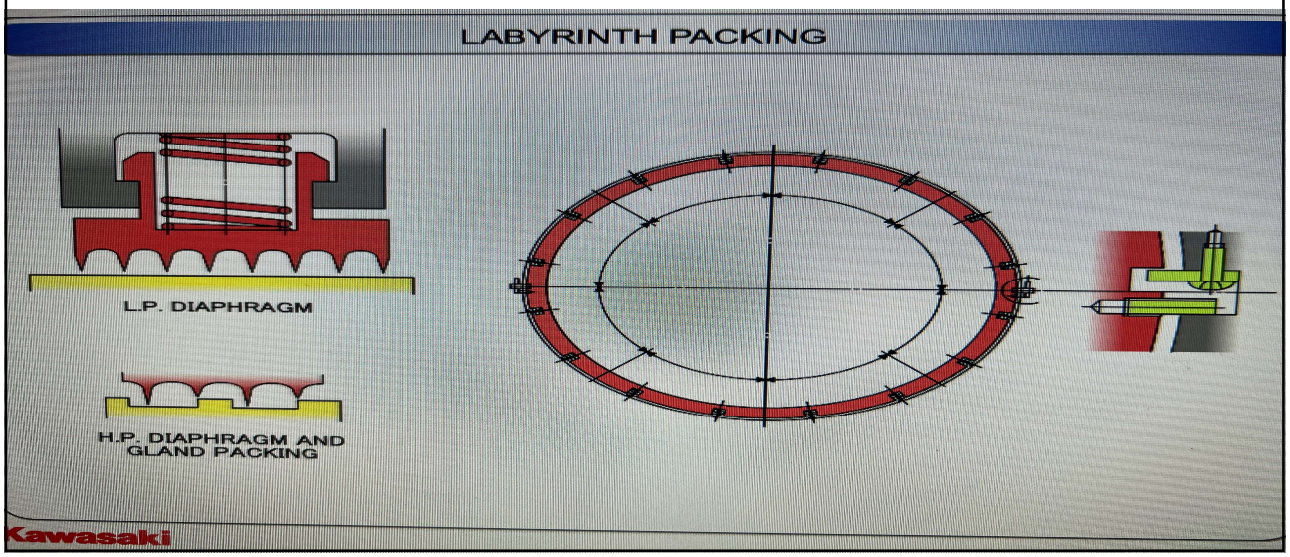
5000 rpm

24

HP TURBINE ROTOR

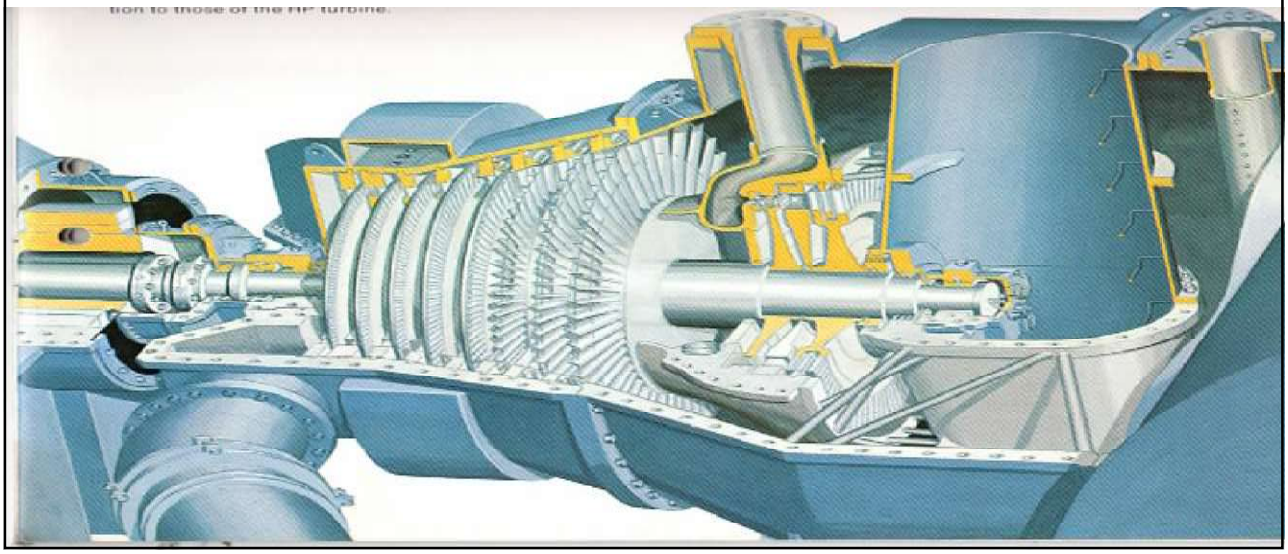
25

Diaphragm hung from HP & LP Turbine casing with stage labyrinth sealing.



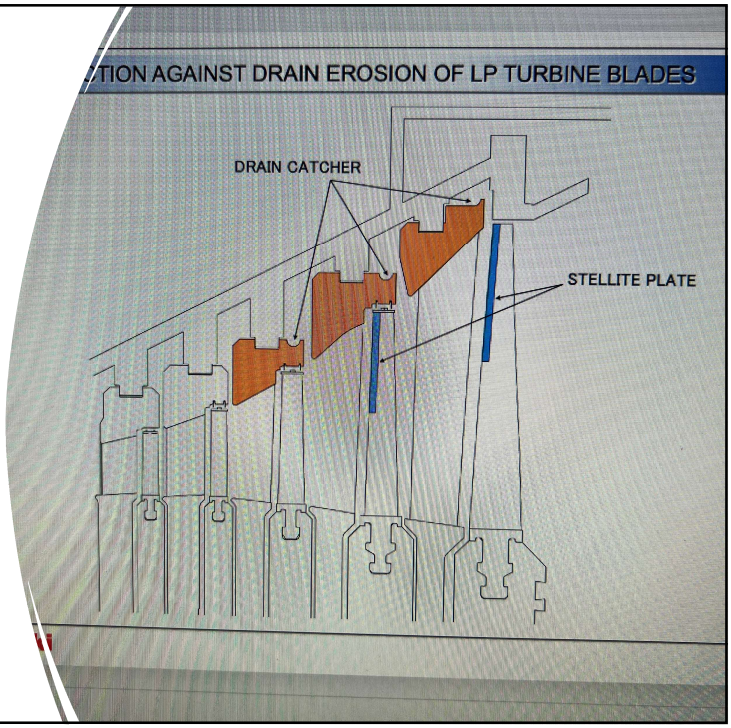
26

LP RATEAU TURBINE WITH CURTIS WHEEL ASTERN TURBINE [3000 rpm].



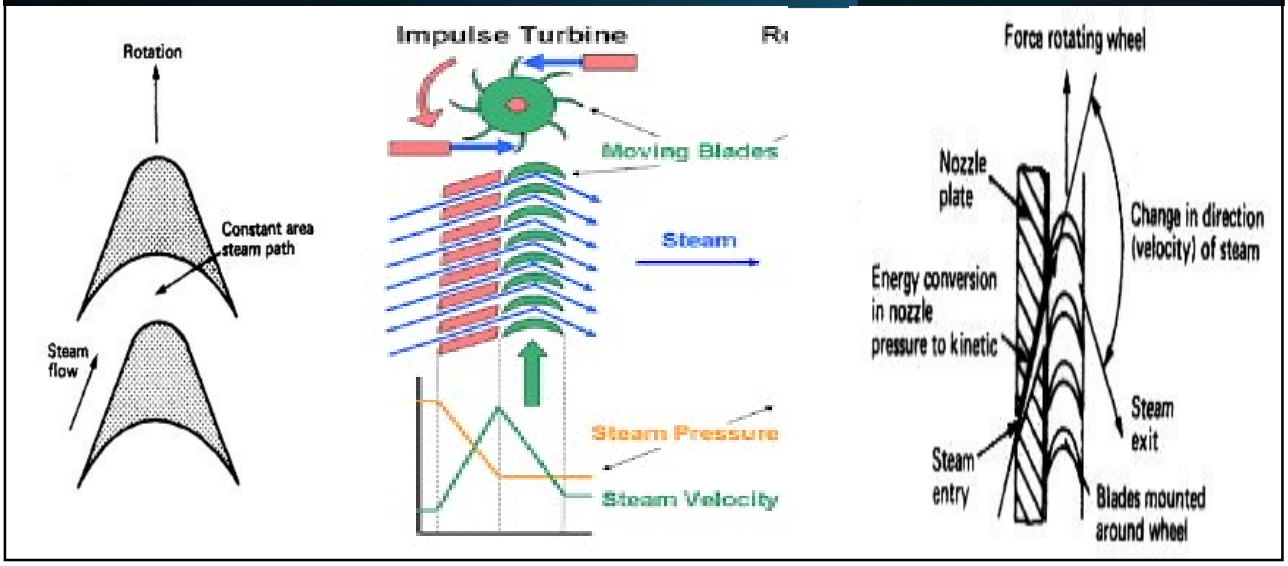
27

Hurricane Drainage and Erosion Protection Plates from wet steam



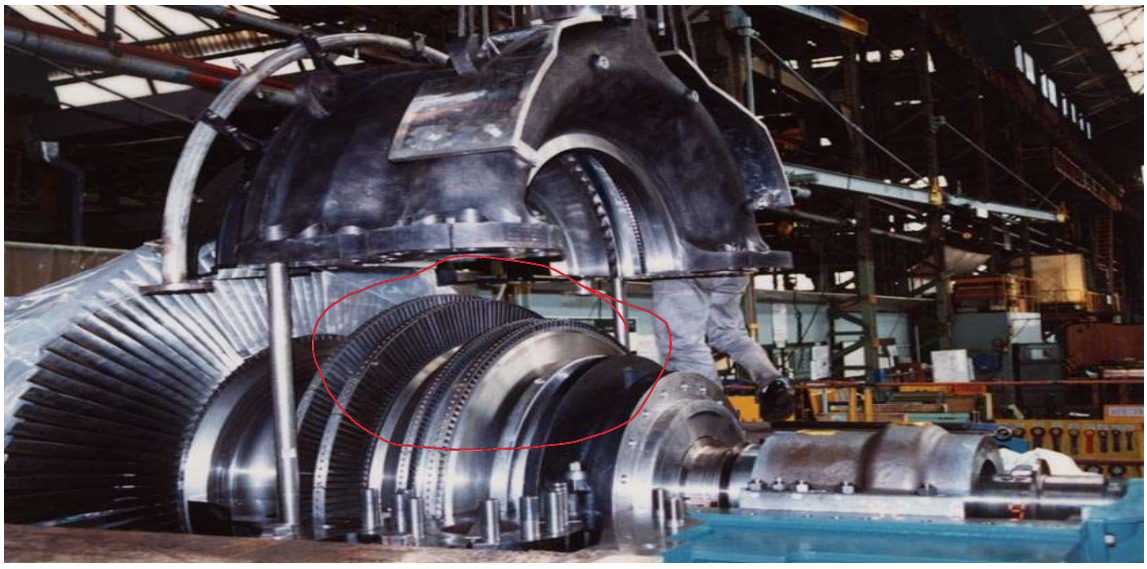
28

Impulse Blading.



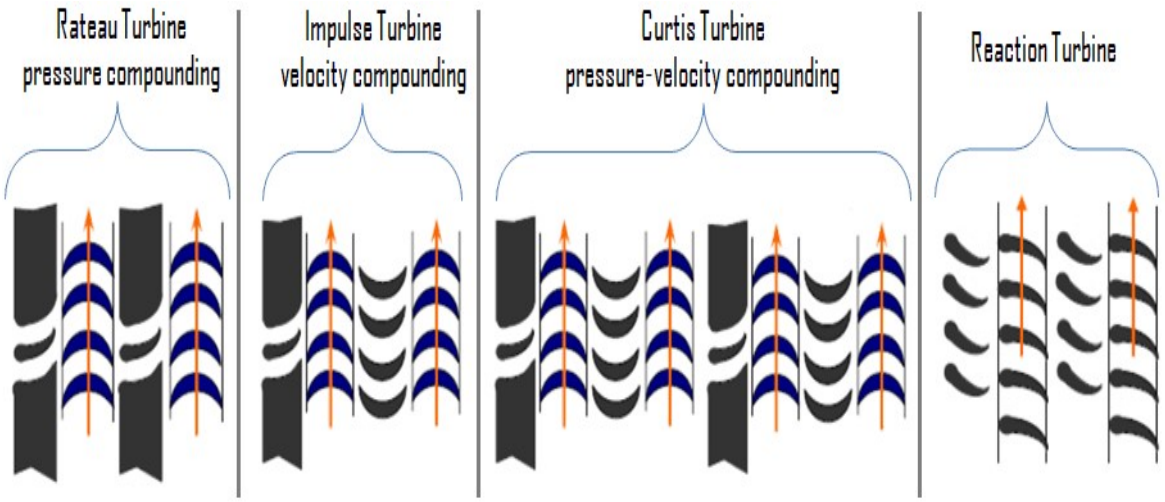
29

Astern Turbine Curtis Wheels.

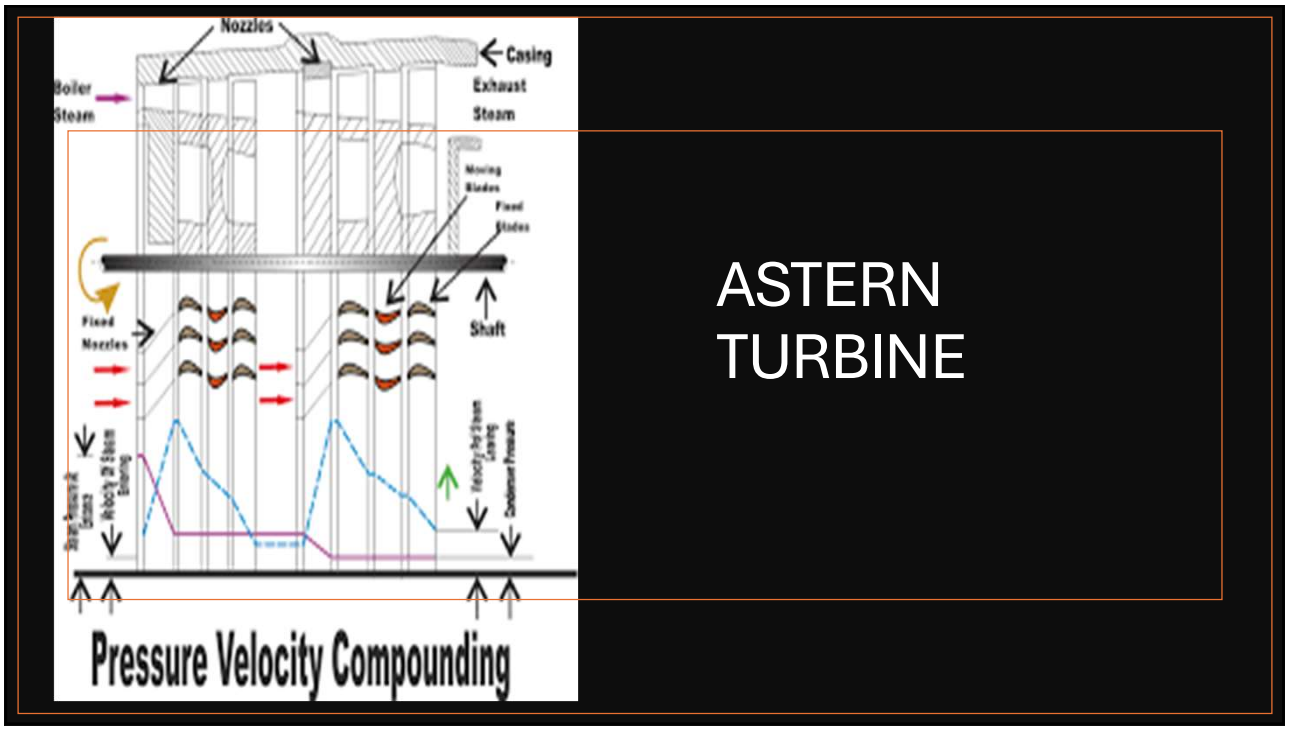


30

Common Compounding Types



31

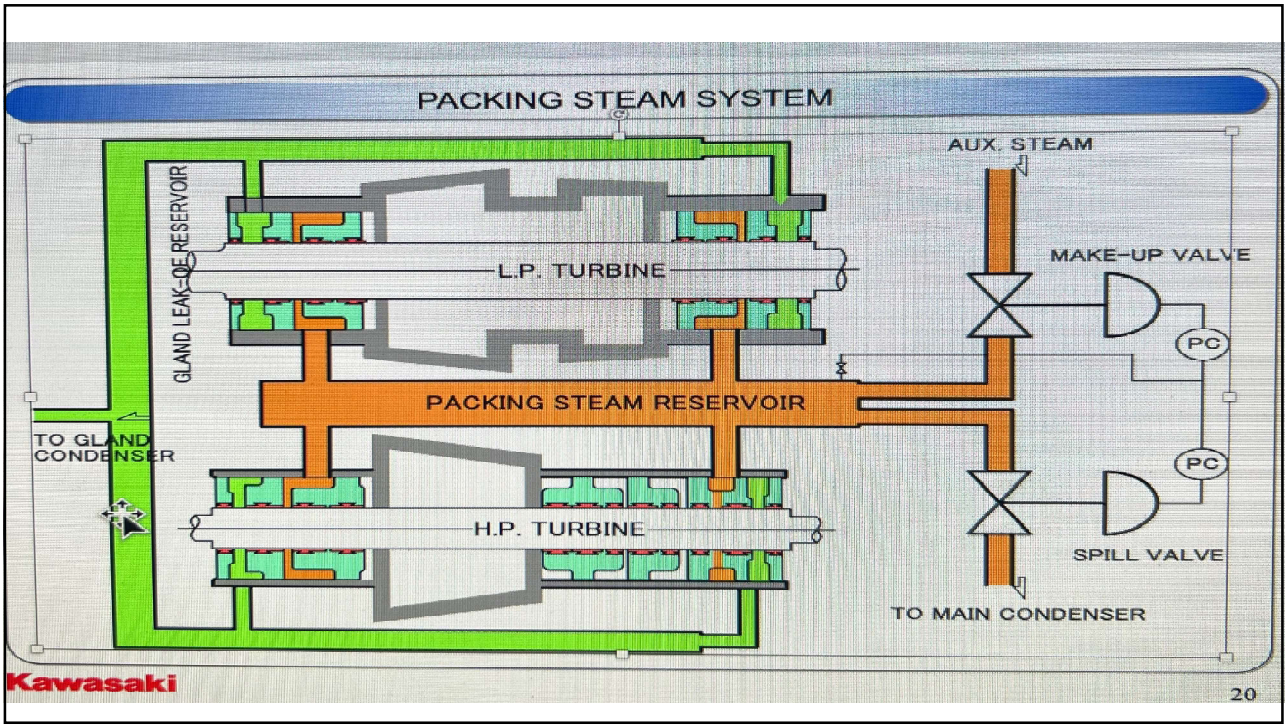


32

Comparison Between Velocity and Pressure Compounding Impulse Turbines

Velocity Compounding	Pressure Compounding
Not equal velocity drop for each stage	Equal velocity drop for each stage
No pressure drop per stage	Not equal pressure drop per stage
Non equal power per stage	Equal power per stage
High friction losses due to high velocities	Low friction losses due to reduced steam velocity
Not recommended for more than two stages	Recommended for multistage
No problem with steam leak	Larger steam leak
Suitable for small turbines as well as only for the first stage in large turbine	Suitable for large turbines

33



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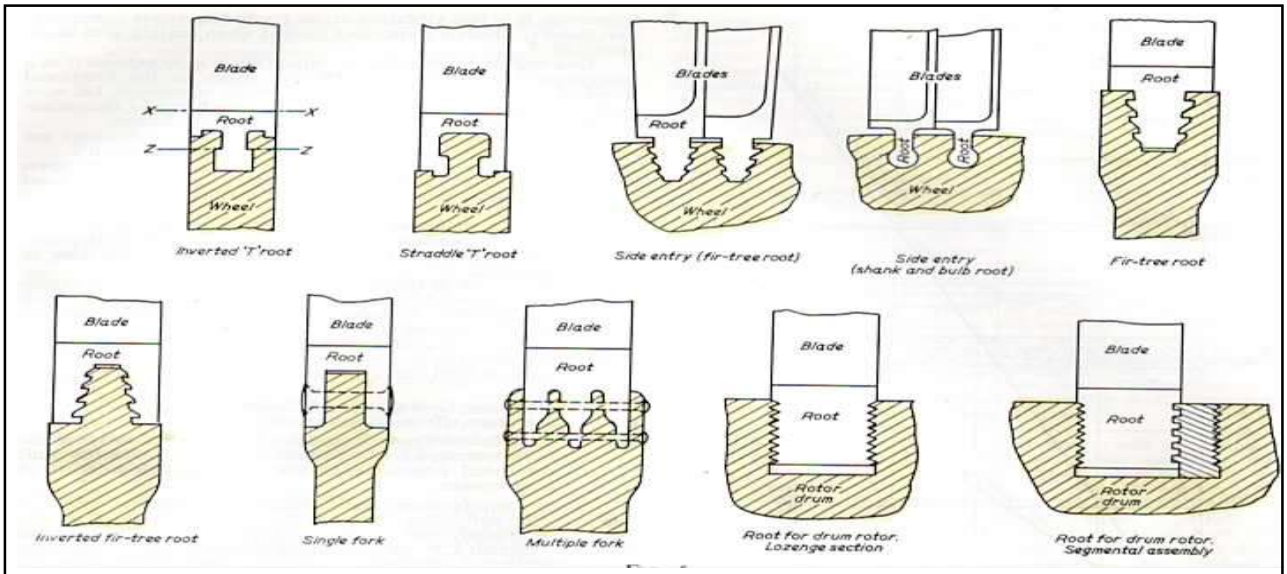


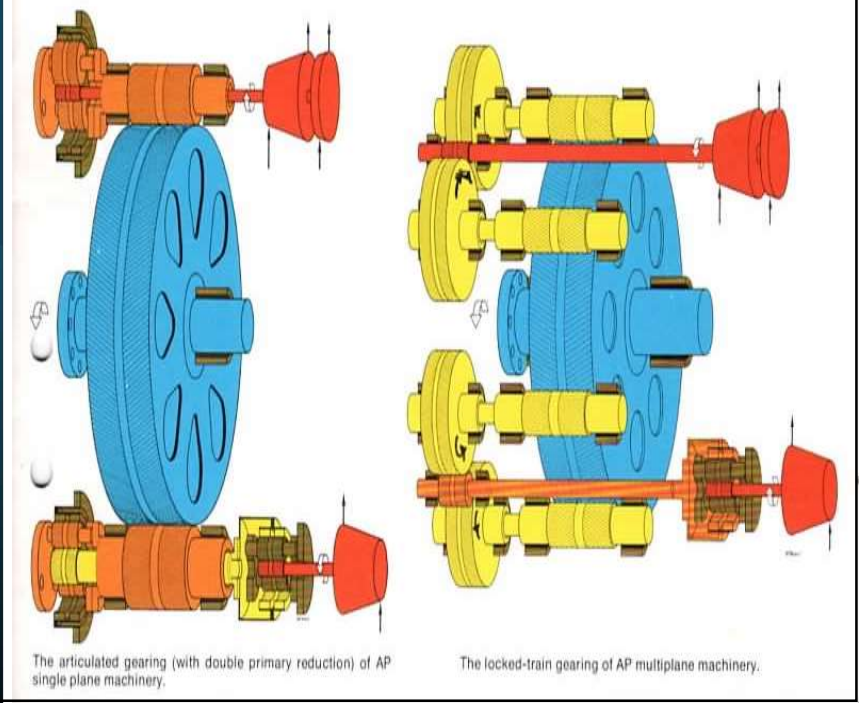
Typical Blade Root Fixings

35

Articulated, Double Helical Gearing:

Epicyclic lhs

Double Reduction rhs

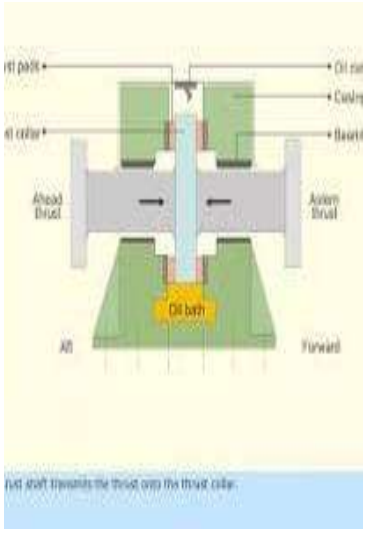


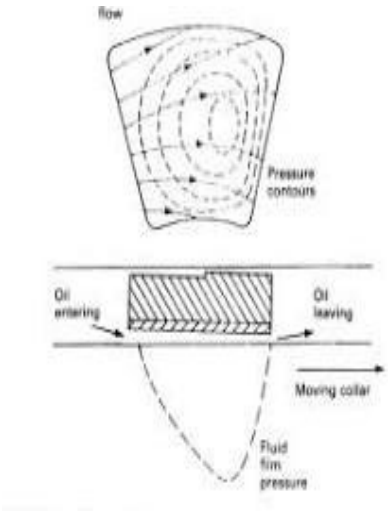
The articulated gearing (with double primary reduction) of AP single plane machinery.

The locked-train gearing of AP multiplane machinery.

36

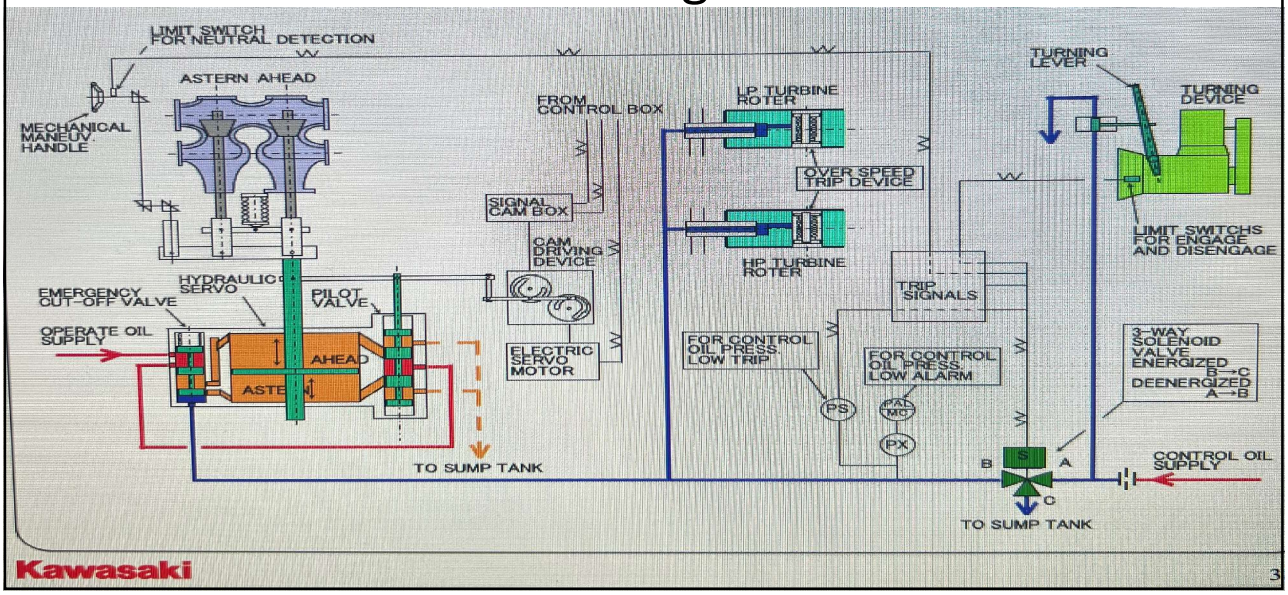
Michell Hydrodynamic Tilting Pad Thrust Block





37

Manoeuvering Control.



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The Critical Importance of Steam Purity

- Boiler water of evaporated sea water to a max of 5 ppm Ca_2CO_3.
- Oxygen elimination for boiler water corrosion control by mechanical deaeration, scavenging chemical injection [N_2H_4] and Pourbaix pH maintained from 9.5 to 10.5
- Boiler and turbine blade surfaces must be maintained scale free.
- Boiler water quality maintained to strict levels of TDS.
- No shoreside water permitted.

39

Turbine Trip Systems

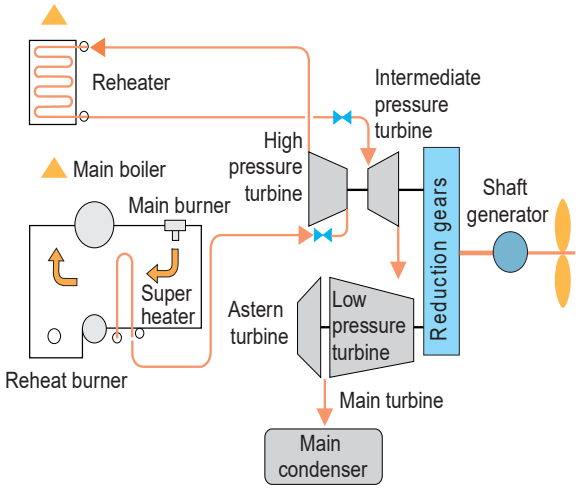
High steam drum water level.	Emergency stop.	Turning gear engaged.	High vibration LP turbine.	High vibration HP turbine.
Low condenser vacuum.	High condenser level.	Low lubricating oil pressure.	Axial displacement of propellor trust bearing.	Axial displacement of HP rotor.
	Axial displacement of LP rotor.	Overspeed of HP turbine.	Overspeed of LP turbine.	

40

Future Turbine Propulsion Possibilities.

41

Mitsubishi 100 Bar / 560°C Marine Reheat Steam Turbine System



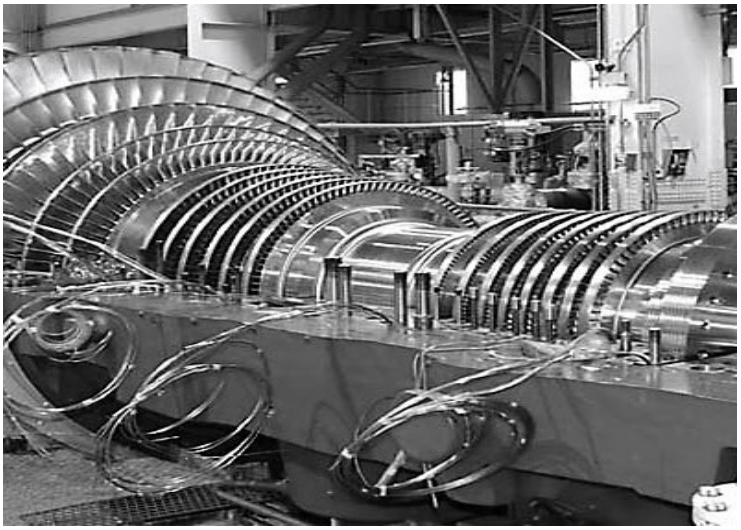
Development of High Efficiency Marine Propulsion Plant (Ultra Steam Turbine)

MAKOTO ITO*1
KAZUYOSHI HIRAOKA*1
SHOICHI MATSUMOTO*1
KENJI TSUMURA*1

42

Mitsubishi H I Development of a New High Efficiency Steam Turbine

By: EIICHIRO WATANABE,
TAKASHI NAKANO,
KEIZO TANAKA,
MASANORI TSUTSUMI,
YOSHINORI TANAKA,
HIROHARU OHYAMA,
TOSHIHIRO MIYAWAKI,
And TANEHIRO SHINOHARA



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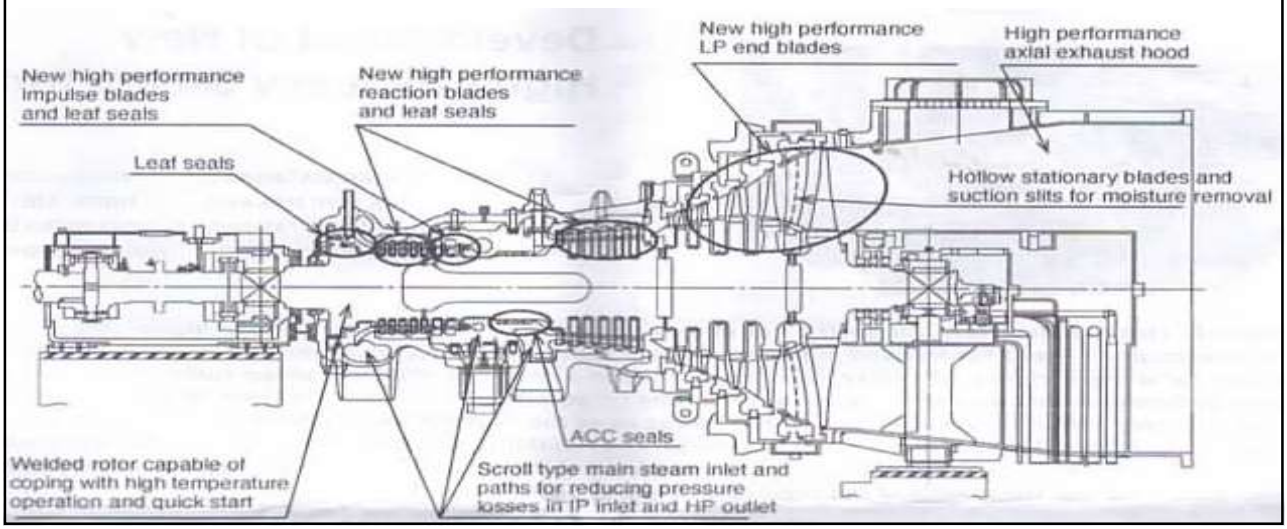
3 Stage, Single Casing, Higher Efficiency Modified Steam Turbine



44

Primary Modifications are:
CFD Generated Stationary Blade Profile

Fig. 2 Example of unsteady flow analysis

45

Modified Diaphragm Stage Seal

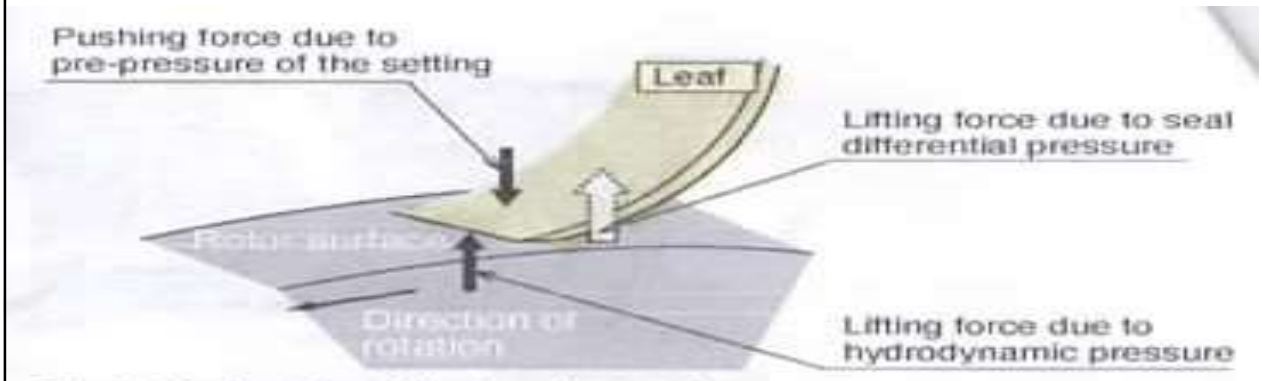


Fig. 7 Mechanism of leaf seal operation
The tip of the leaf is lifted-up by a balance of the pushing force due to pre-pressure of the setting, lifting force due to hydrodynamic pressure generated during rotation of the rotor, and lifting force due to the differential pressure of the seal.

46

Modified Dynamic Clearance Control

[Rotor Labyrinth Ring Between HP and IP turbine]

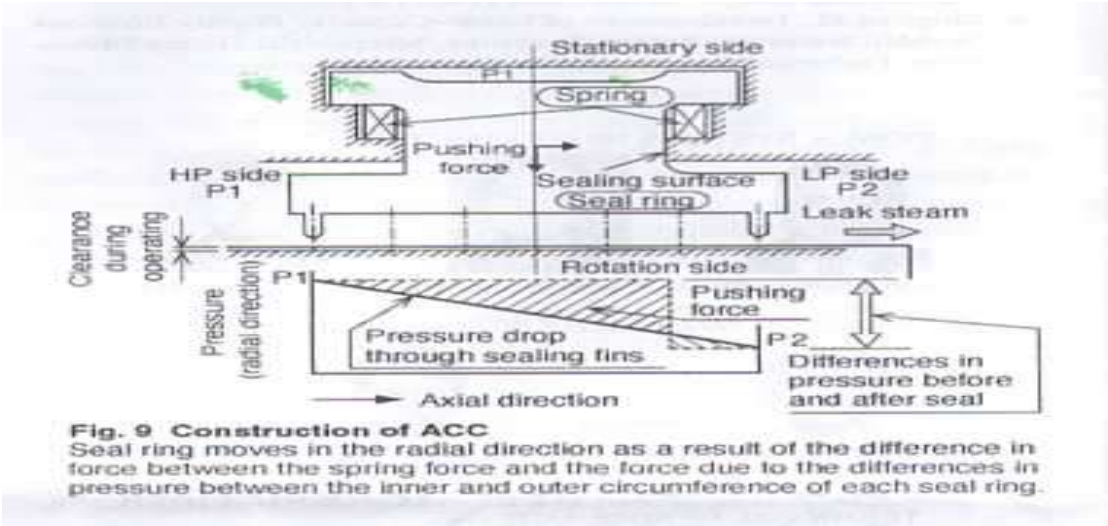


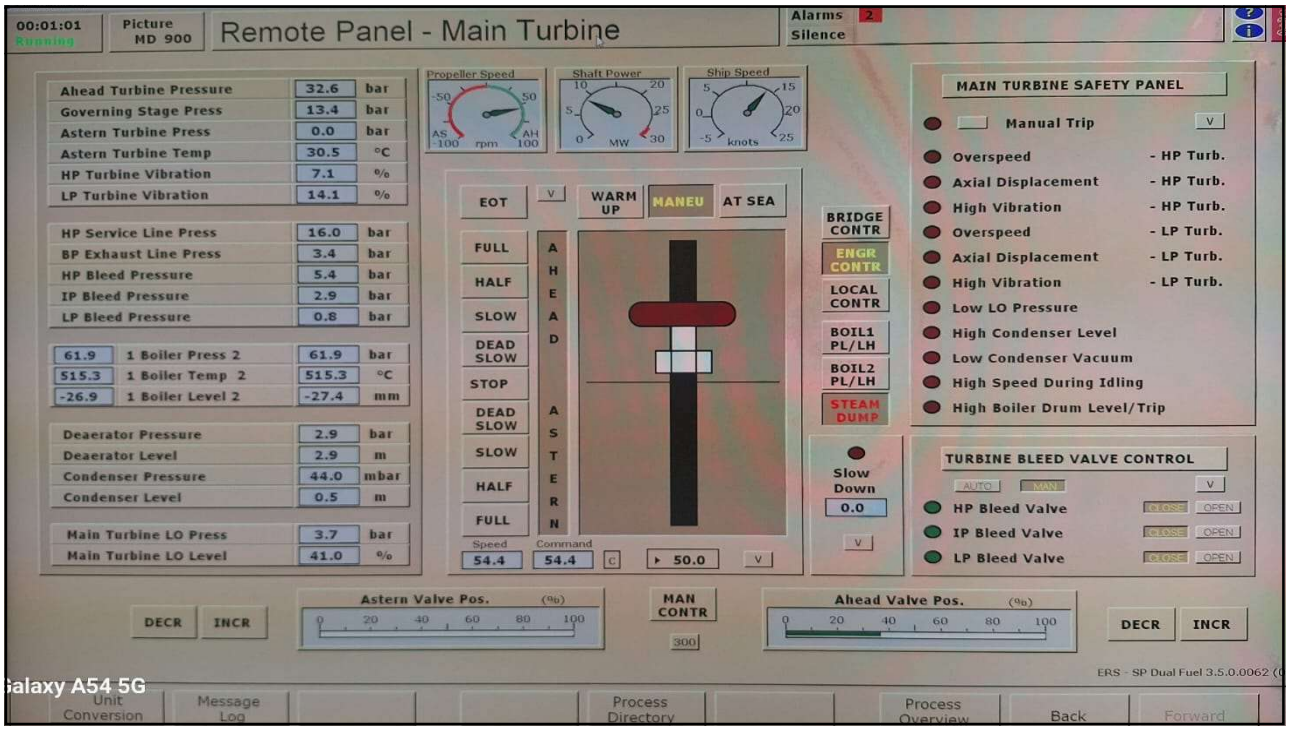
Fig. 9 Construction of ACC
Seal ring moves in the radial direction as a result of the difference in force between the spring force and the force due to the differences in pressure between the inner and outer circumference of each seal ring.

47

Contemporary Marine Control Systems

- Electronic computer touch screen control panels on two screens.
- Engine Room control panel now on the Navigation Bridge.
- Engineer Officer compliment 4 to 5 persons of varying nationalities and languages.
- A new Autonomous Shipping era is dawning.
- But.....

48


00:01:01
Running
Picture
MD 900
Remote Panel - Main Turbine
Alarms 2
Silence
Ahead Turbine Pressure 32.6 bar
Governing Stage Press 13.4 bar
Astern Turbine Press 0.0 bar
Astern Turbine Temp 30.5 °C
HP Turbine Vibration 7.1 %
LP Turbine Vibration 14.1 %
HP Service Line Press 16.0 bar
BP Exhaust Line Press 3.4 bar
HP Bleed Pressure 5.4 bar
IP Bleed Pressure 2.9 bar
LP Bleed Pressure 0.8 bar
61.9 1 Boiler Press 2 61.9 bar
515.3 1 Boiler Temp 2 515.3 °C
-26.9 1 Boiler Level 2 -27.4 mm
Deaerator Pressure 2.9 bar
Deaerator Level 2.9 m
Condenser Pressure 44.0 mbar
Condenser Level 0.5 m
Main Turbine LO Press 3.7 bar
Main Turbine LO Level 41.0 %
Propeller Speed
Shaft Power
Ship Speed
EOT
WARM UP
MANEU
AT SEA
FULL
HALF
SLOW
DEAD SLOW
STOP
AHEAD
ASTERN
Speed 54.4
Command 54.4
50.0
BRIDGE CONTR
ENGR CONTR
LOCAL CONTR
BOIL1 PL/LH
BOIL2 PL/LH
STEAM DUMP
MAIN TURBINE SAFETY PANEL
Manual Trip
Overspeed - HP Turb.
Axial Displacement - HP Turb.
High Vibration - HP Turb.
Overspeed - LP Turb.
Axial Displacement - LP Turb.
High Vibration - LP Turb.
Low LO Pressure
High Condenser Level
Low Condenser Vacuum
High Speed During Idling
High Boiler Drum Level/Trip
Slow Down 0.0
TURBINE BLEED VALVE CONTROL
HP Bleed Valve
IP Bleed Valve
LP Bleed Valve
Astern Valve Pos.
Ahead Valve Pos.
MAN CONTR
DECR
INCR
Galaxy A54 5G
Unit Conversion
Message Log
Process Directory
Process Overview
Back
Forward

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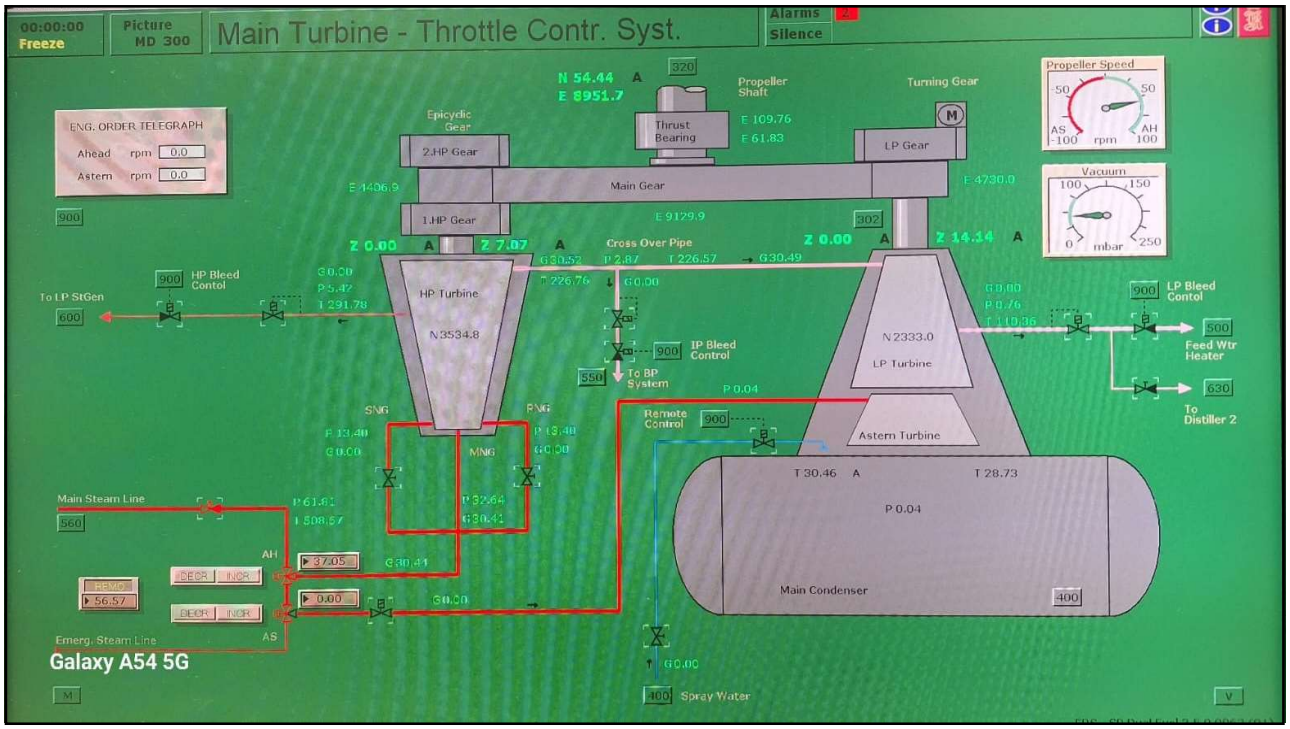
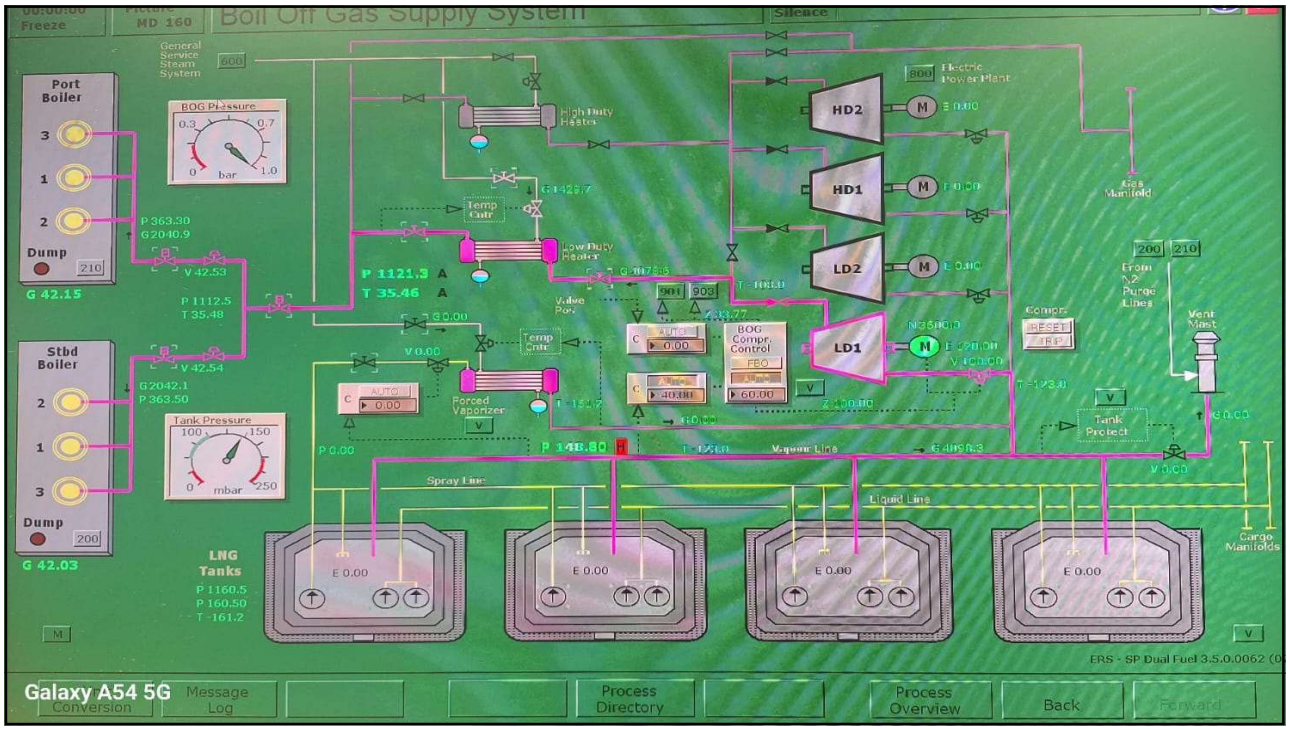
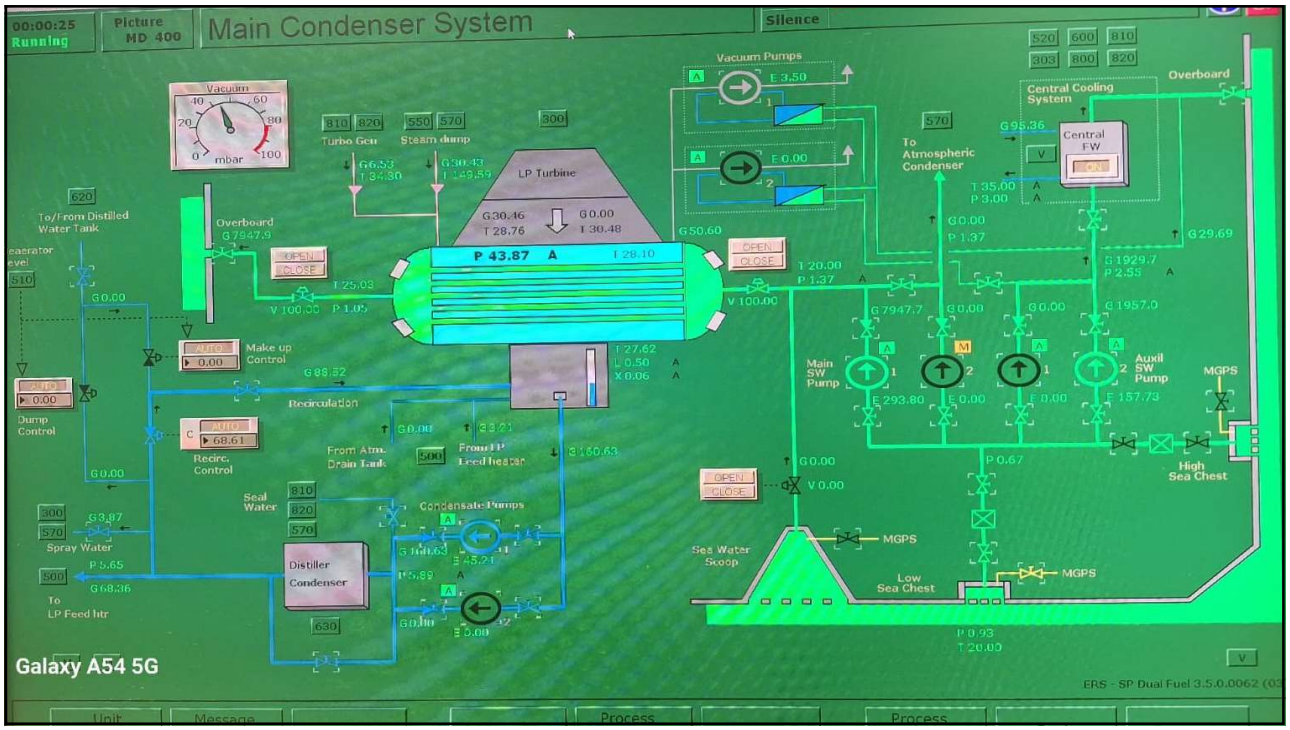

00:00:00
Freeze
Picture
MD 300
Main Turbine - Throttle Contr. Syst.
Alarms 2
Silence
ENG. ORDER TELEGRAPH
Ahead rpm 0.0
Astern rpm 0.0
N 54.44 A
E 8951.7
Propeller Shaft
Turning Gear
Epicyclic Gear
2.HP Gear
1.HP Gear
Main Gear
Thrust Bearing
LP Gear
E 109.76
E 61.83
E 1406.9
E 9129.9
E 4730.0
Propeller Speed
Vacuum
Z 0.00 A
Z 7.07 A
Cross Over Pipe
Z 0.00 A
Z 14.14 A
HP Bleed Contol
To LP StGen
HP Turbine
N 3534.8
IP Bleed Control
To BP System
N 2333.0
LP Turbine
LP Bleed Contol
Feed Wtr Heater
To Distiller 2
Remote Control
Astern Turbine
SNG
MNG
RNG
Main Steam Line
Emerg. Steam Line
T 30.46 A
T 28.73
P 0.04
Main Condenser
Spray Water
Galaxy A54 5G

50


Boil Off Gas Supply System
Silence
Port Boiler
Stbd Boiler
Dump
BOG Pressure
Tank Pressure
High Duty Heater
Low Duty Heater
Forced Vaporizer
HD2
HD1
LD2
LD1
BOG Compr. Control
Gas Manifold
From N2 Purge Lines
Vent Mast
Tank Protect
Spray Line
Liquid Line
Vapour Line
LNG Tanks
Cargo Manifolds
Electric Power Plant
Galaxy A54 5G
Message Log
Process Directory
Process Overview
Back
Forward

51


Main Condenser System
Silence
Vacuum
Turbo Gen
Steam dump
LP Turbine
Vacuum Pumps
Central Cooling System
Overboard
To Atmospheric Condenser
Central FW
To/From Distilled Water Tank
Make up Control
Recirculation
Dump Control
Recirc. Control
From Atm. Drain Tank
From FP Feed heater
Seal Water
Condensate Pumps
Spray Water
Distiller Condenser
To LP Feed htr
Main SW Pump
Auxil SW Pump
MGPS
High Sea Chest
Low Sea Chest
Sea Water Scoop
Galaxy A54 5G

52

Major Stressors for the Marine Engineer

T I D B B I T S P R F Cx7

53

The Competition.

A virtual trip:

- into the MAN 18V48/60B Medium Speed, 4–stroke, Multi-fuel type Marine Diesel Engine.

- Into the Wartsila Slow Speed RT Flex Marine Diesel-Engine.

The Modern Marine Slow Speed, 2 Stroke, Direct Drive, Multi Fuel Type Diesel Engine is 15 – 20% more efficient than a comparable Steam Turbine with up to 10,000 shp per cylinder and no gearbox required.

54

STS Westward – Last Trip as C/E

55

For the non-mariners present:

The Final Marine Riddle

What runs from forw'd to aft,
from aft to forw'd, and
from Port to Starboard
but not from Starboard to Port,
on every ship?
Thank You.

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