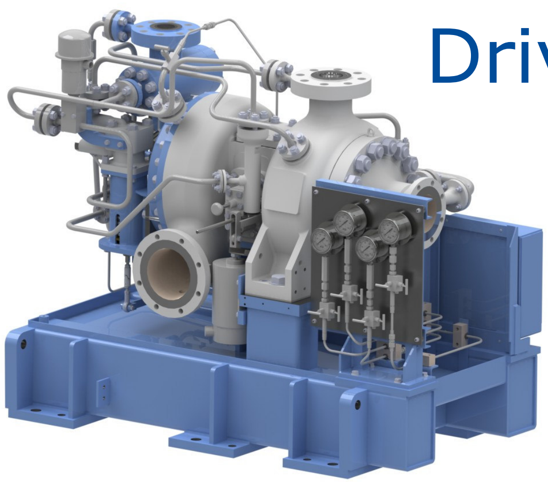
CLYDEUNION PUMPS

Nuclear Power

High Integrity Turbine Driven Pumping Solution



Ranald Patrick

9 November 2011

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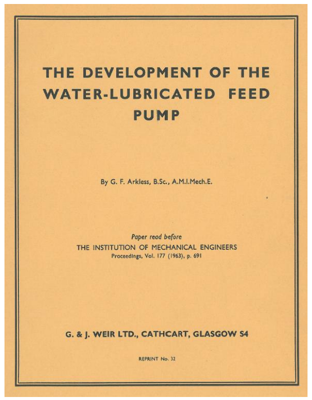
The TWL

- What is a "TWL"?

The TWL is a combined centrifugal pump and drive turbine on a single shaft in the one casing. It has product lubricated bearings and incorporates all the turbine governor/controls and overspeed trip mechanisms within the one package. It requires no external services to make it function such as lubricating oil, cooling water or electrical supplies.

In the 1960s the TWL concept was presented through the Institution of Mechanical Engineers. Originally featuring as a feed pump for naval applications, the TWL went through a number of design changes and enhancements and has been an excellent solution for turbine driven safety related duties in nuclear power plants over many years.


THE DEVELOPMENT OF THE WATER-LUBRICATED FEED PUMP

By G. F. Arkless, B.Sc., A.M.I.Mech.E.

Paper read before
THE INSTITUTION OF MECHANICAL ENGINEERS
Proceedings, Vol. 177 (1963), p. 691

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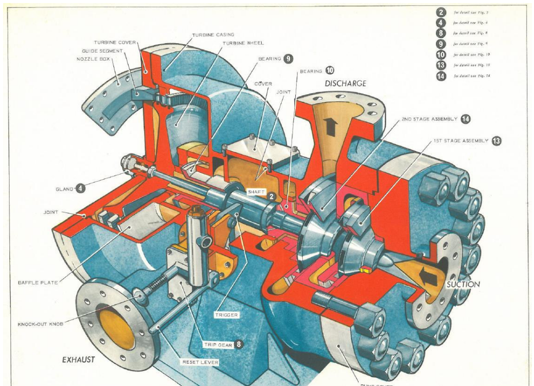


FIG 1. WATER LUBRICATED PUMP

- TWL Features

The TWL is unique and has a number of key features that make it an excellent choice for safety related applications:-

Single shaft in a monoblock casing –

No drive couplings and thus no alignment issues to accommodate between the driver and the driven unit. Rotor length is kept short.

No mechanical seals between the pump and driver. All self contained and thus no wearing seal components and potential leak paths (critical for contaminated water applications).

No external services required –

No electrical, pneumatic or other services are required to make the TWL function, only requires steam. The TWL functions with complete loss of AC and DC electrical power.

Overview and History

- TWL Features (continued)…

  Self contained governor –

  > Governor and controls are self contained on the unit and require no external services to make it function.

  Product lubricated bearings –

  > No oil required and thus no oil support system with complex logic needed to ensure lubrication of the bearings, bearing flushing system all self contained within the unit and skid.

  Capable of water slugs in the steam line –

  > Can accommodate water slugs in the steam line both at start up and running with no detrimental impact to the equipment and only momentary interruption on pump performance.

  Rapid start up –

  > Fast start up on application of steam with no overshoot on pump speed. Capable of repeated starting and stopping.

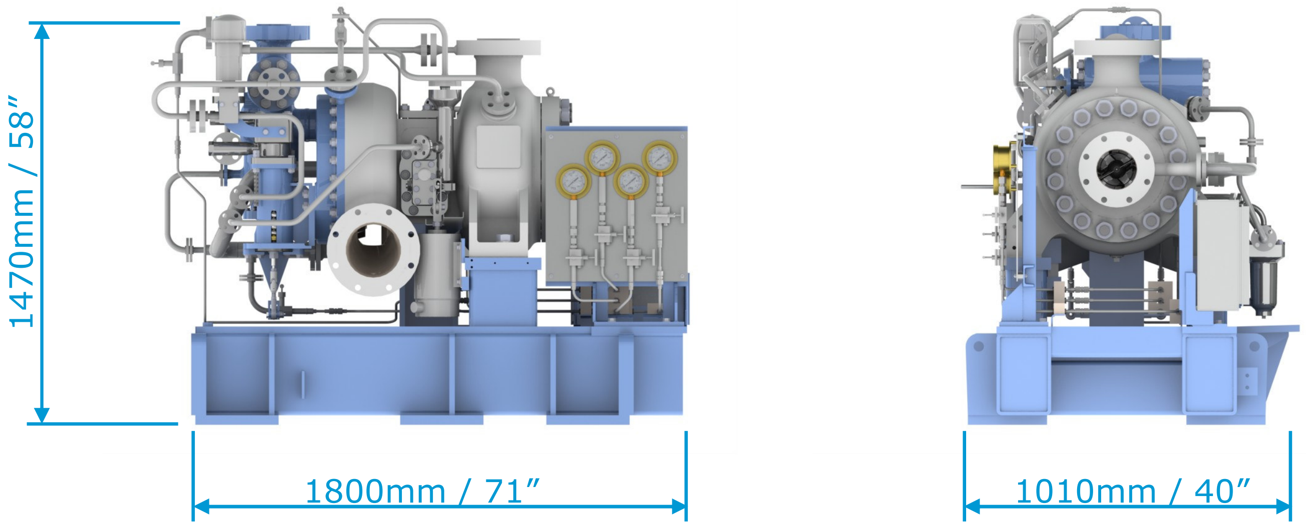
- TWL Features (continued)…

  Can accommodate a wide range of duties/steam conditions –

  The TWL can be designed to accommodate a variety of different conditions or special requirements since the turbine control and pump performance are managed in the one package.

  Small installed footprint –

  Complete unit considerably smaller than separate turbine drive and pump arrangement, significant space saving at site.



Main Feature Summary

AC power available

DC power available

→ TWL available/running and monitored

AC power lost

DC power available

→ TWL running and monitored

AC power lost

DC power lost

→ TWL continues to run…..

Total loss of electrical power does not affect the operation of the TWL

Support Services

- Supporting Services

  Although the TWL does not require any electrical supplies to function, there are attachments that enhance the TWL's features where an electrical supply is available.

  Monitoring Panel – this incorporates local and remote reporting on status of the TWL (tripped, ready to start etc.)

  Electronic Trip System – in addition to the mechanical trip system, handled by a speed monitor in the Panel.

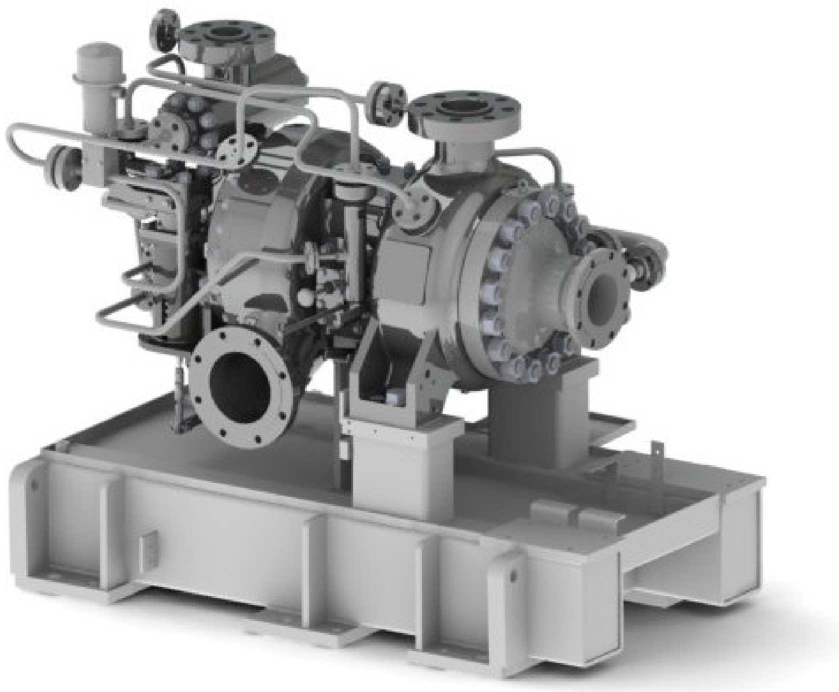
  Trip Reset facility – allows remote resetting of the TWL after tripping.

  Kickdown facility – solenoid operated control of the governor in addition to manual kickdown facility.

  It is important to remember that these are additional features that are not essential to the operation of the TWL, it will start and self govern without any electrical supply.

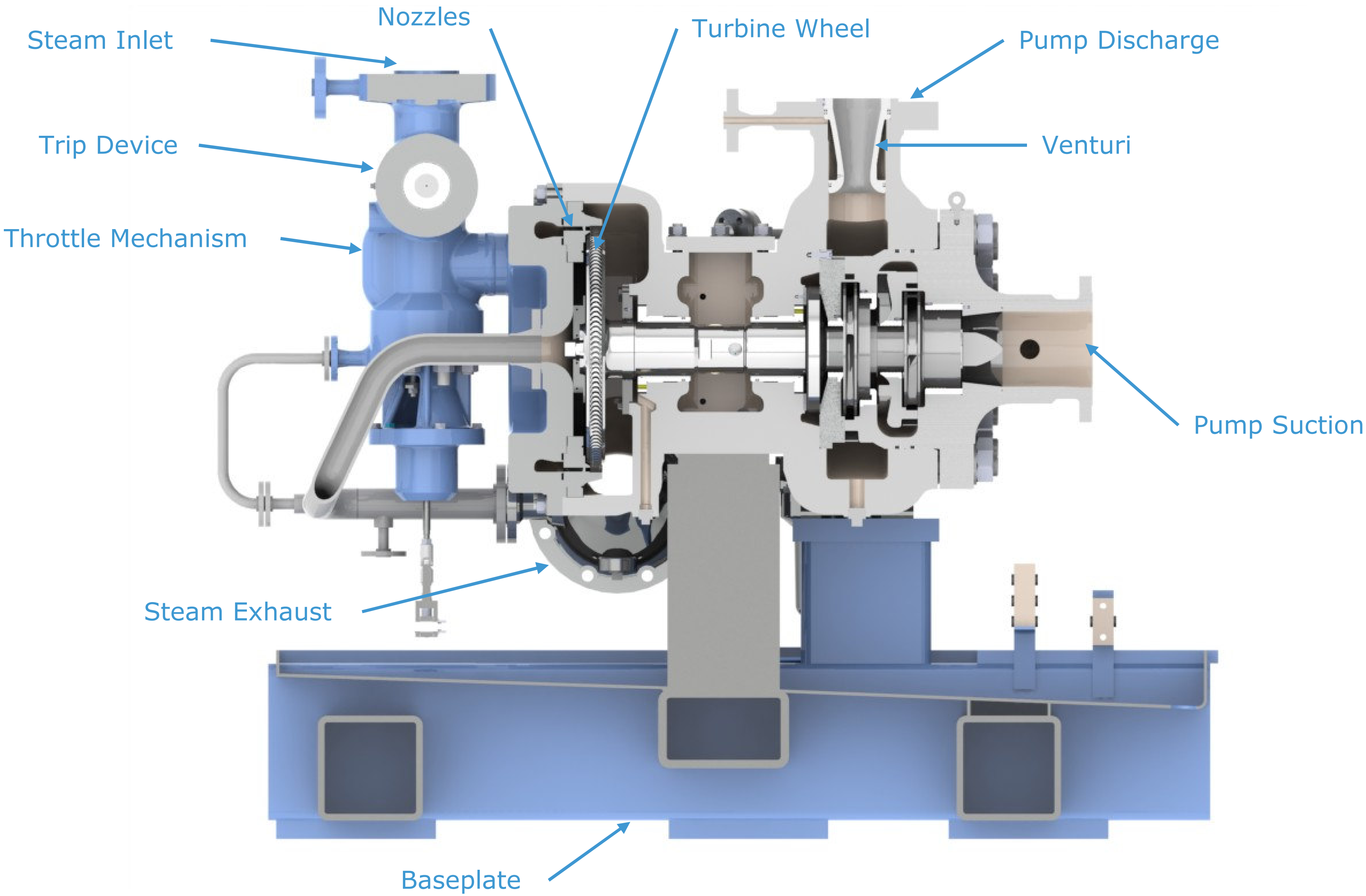
Capability

- TWL Capability – Overview



• Flow	up to 350 m^3/hr
	1550 usgpm
• Delivery Head	up to 1200m
	4000 ft
• Temperature	up to 120°C
	250 ℉
• Speeds	variable
	(~7500 rpm)

Key Components



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Principle of Operation

Principle of Operation

- Principle of Operation

Fundamental to the overall performance, operability and integrity of the TWL is how it operates in service. It is the compact governor and throttle mechanism that is the TWL's greatest asset.

The TWL has three main parts to the speed/flow control of the unit:-

The venturi, which provides a "signal" proportional to pump flow

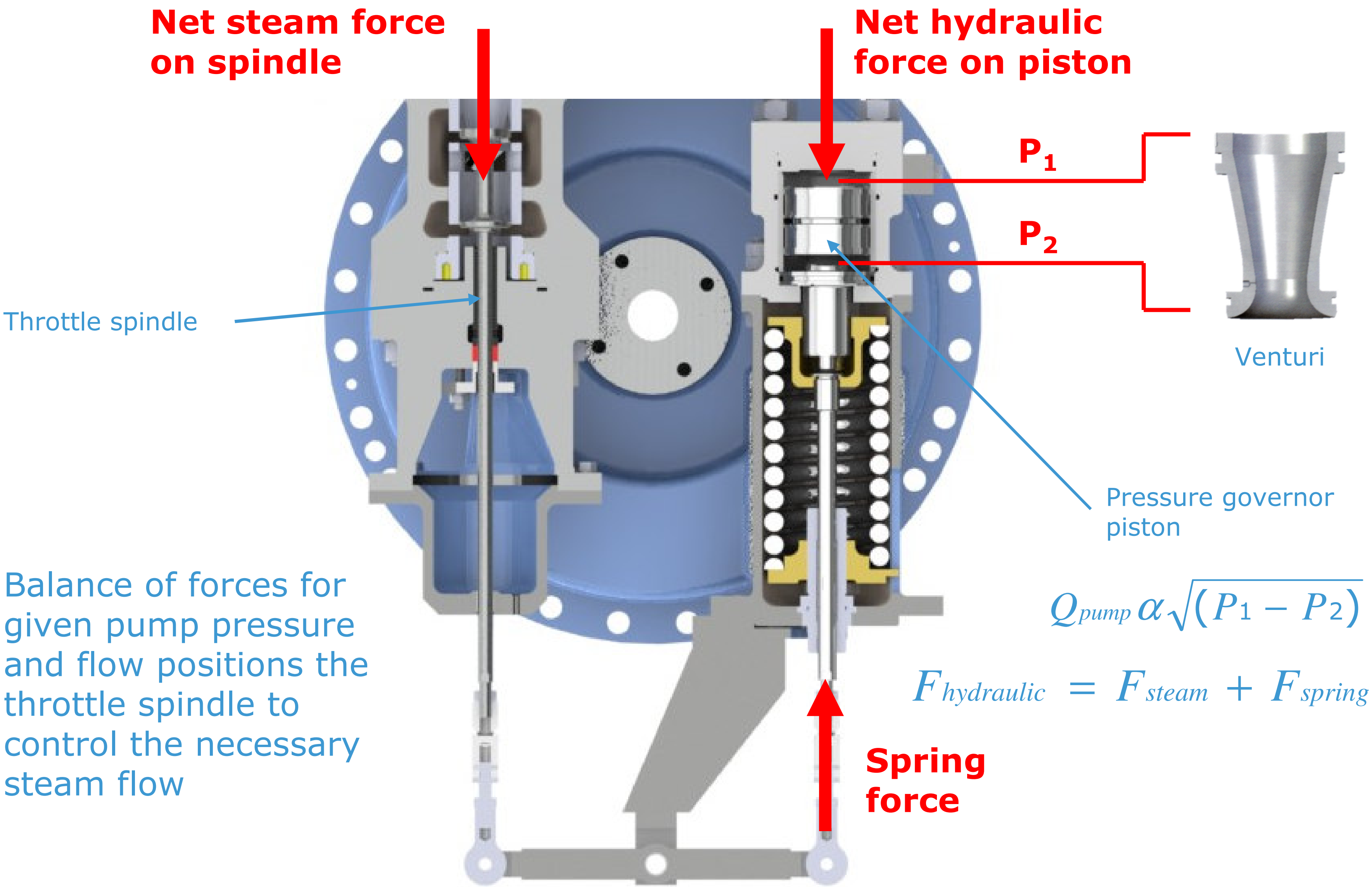
The pressure governor, that takes the "signal" from the venturi and converts this into mechanical action

The throttle mechanism, which takes this mechanical action to control the steam flow to the turbine

These three main components control the balance of steam flow and pump output across the operating range of the TWL.

So how does it work in practice?

Principle of Operation



Balance of forces for given pump pressure and flow positions the throttle spindle to control the necessary steam flow

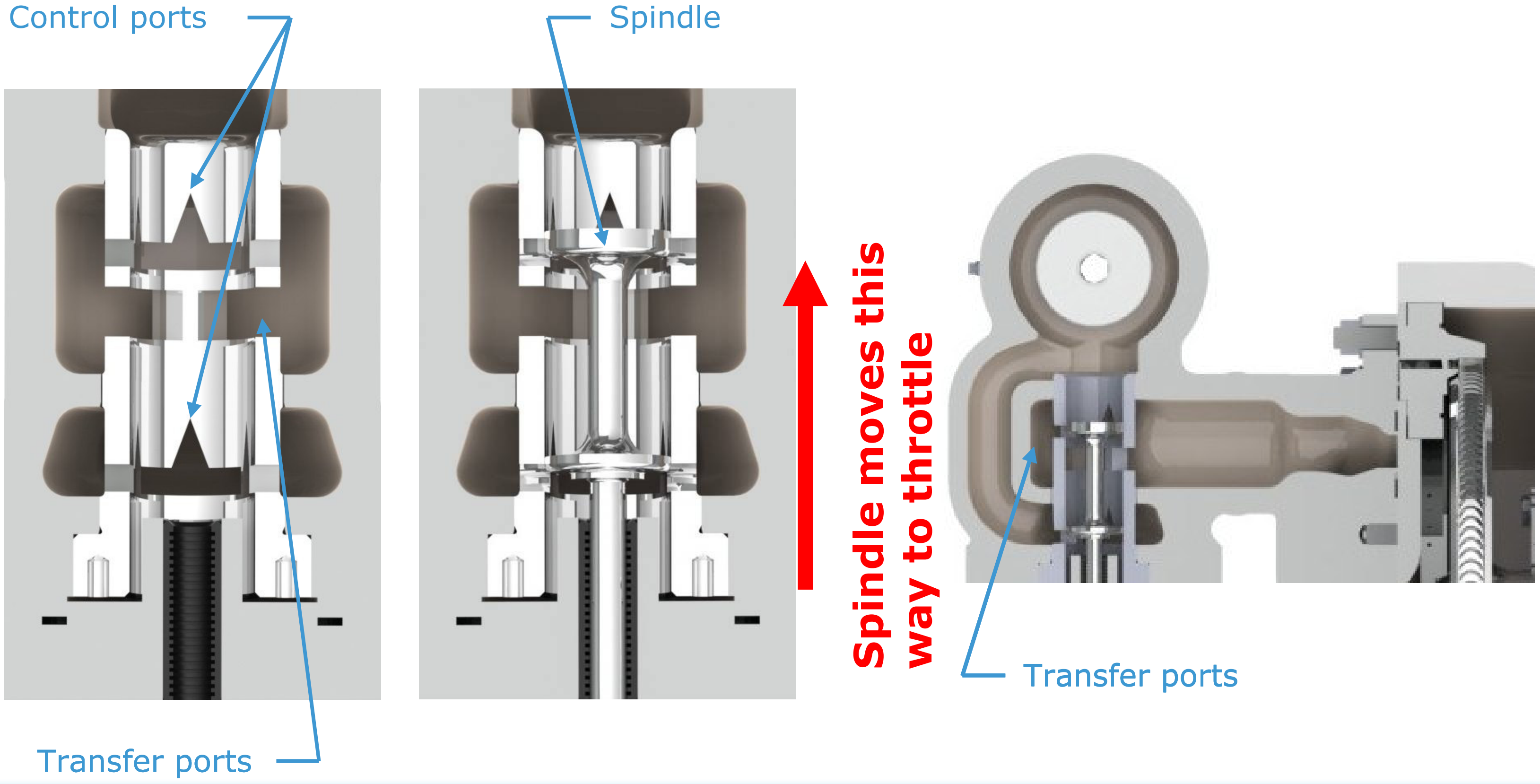
$$Q_{pump} \alpha \sqrt{(P_1 - P_2)}$$

$$F_{hydraulic} = F_{steam} + F_{spring}$$

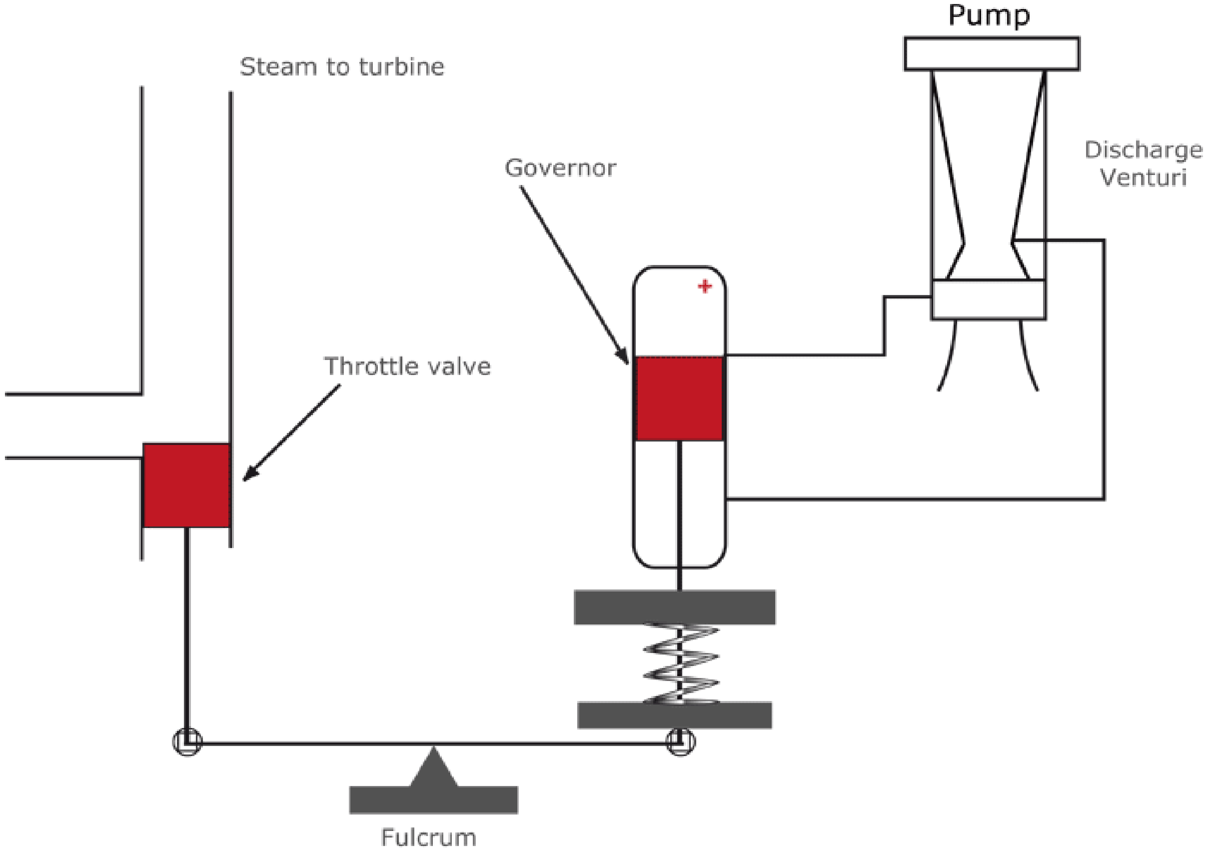
Principle of Operation

- Throttle Mechanism Ports

  The position of the throttle mechanism spindle exposes or covers the control ports that allow the steam to enter the nozzle box area.



Principle of Operation



- On pump start-up steam inlet port is fully open

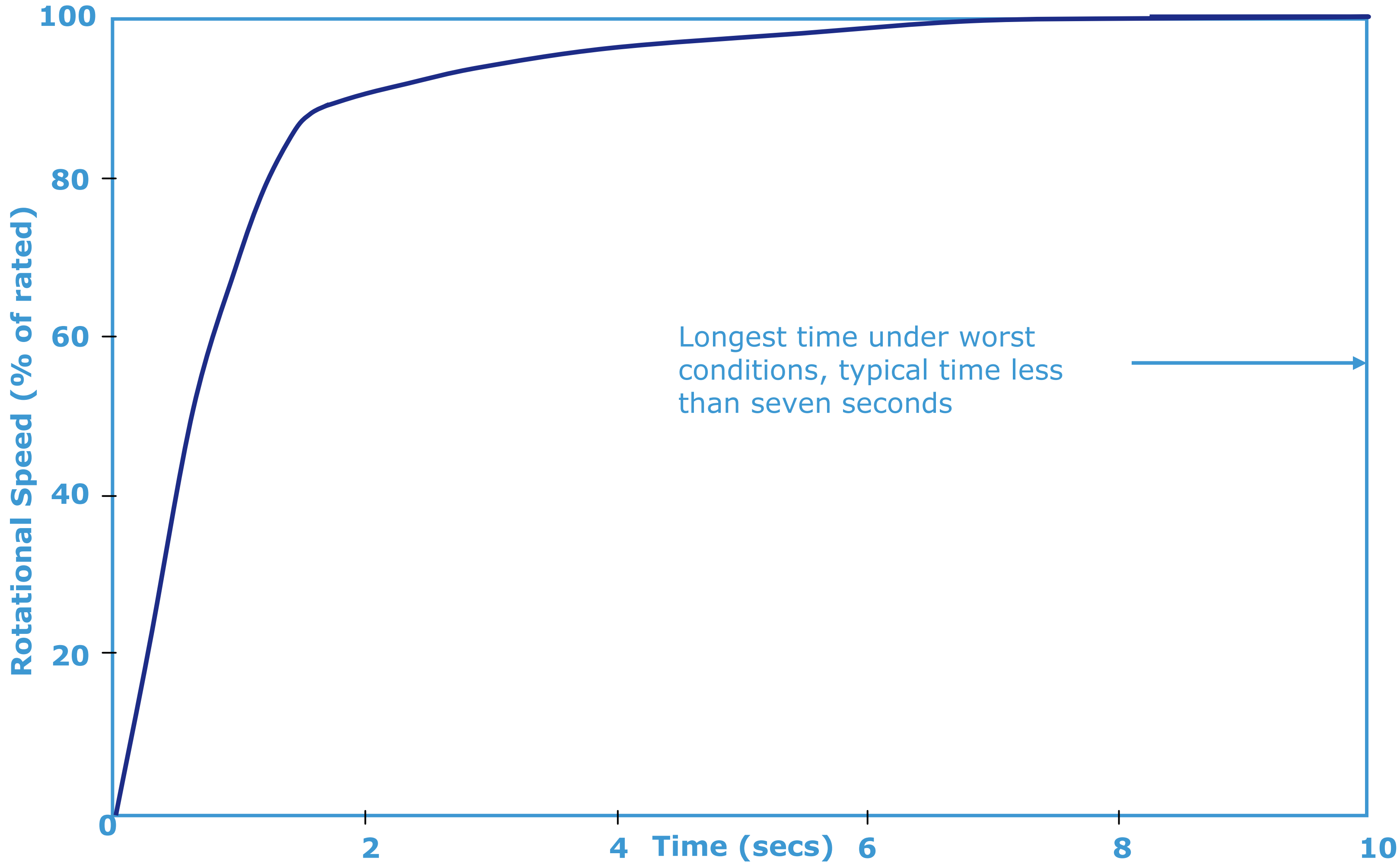
  The discharge pressure from the pump acts on the piston as well as a component relative to the pump flow

- As pump flow increases, steam inlet closes

  Since the discharge pressure is proportional to the square of the pump speed, control is quickly established as the pump rapidly accelerates to rated speed

Principle of Operation

- Rapid start-Up with no Overshoot



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Overspeed Trip System

Overspeed Trip System

- Overspeed Trip system

  Turbine drives require an overspeed trip system to ensure that during fault events that could cause the turbine to run beyond the rated speed, the system will trip and allow the turbine to coast down to a halt before any damage could occur.

  The TWL has three trip systems :–

  Mechanical system that utilizes a centrifugal bolt to push a lever once the trip speed has been met and the lever in turn trips the unit. Typically set at 115% of the maximum rotor speed.

  Where an electrical supply is available, an electrical trip system that energizes a solenoid valve in the trip system pipework during overspeed.

  Manual trip facility that can be activated at any time.

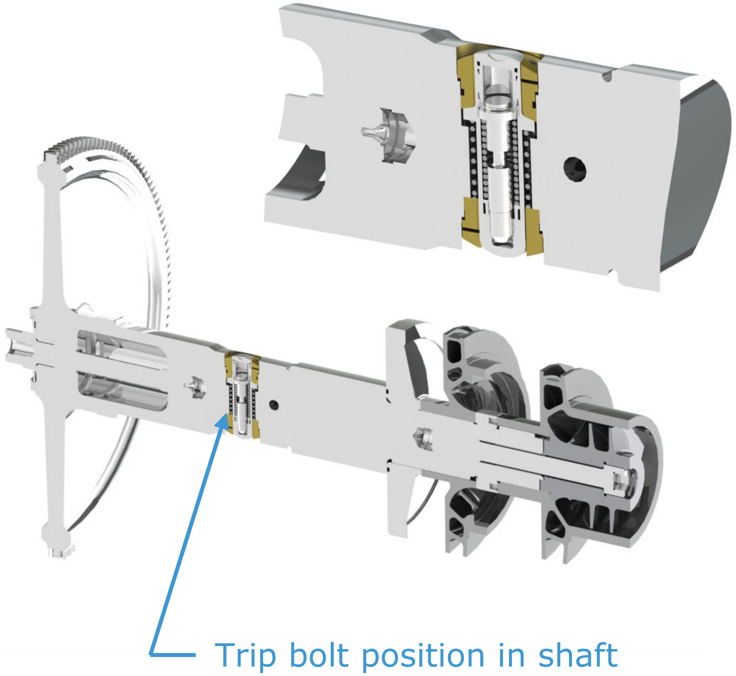
  The electrical trip system has a second level of trip above the mechanical trip setting as a safety when testing the mechanical trip system but also offers additional safety measure against failure of the other trip devices.

Overspeed Trip System

- Mechanical Trip system

Like many turbine designs, the mechanical trip system employs a centrifugal “bolt” that extends from the shaft during overspeed, hits a lever and activates the trip device actuator. The trip device actuator causes the pressure behind the trip device to fall forcing the trip device piston to close off the steam supply to the throttle mechanism which therefore brings the TWL to a halt.

However, unlike other turbines, the trip bolt in the TWL is in water as it is placed between the bearings that are product lubricated and this was shown to cause problems. The solution was a relay trip bolt designed to operate in high speeds and be insensitive to being completely immersed.



Trip bolt position in shaft

Overspeed Trip System

- Trip Bolt Design

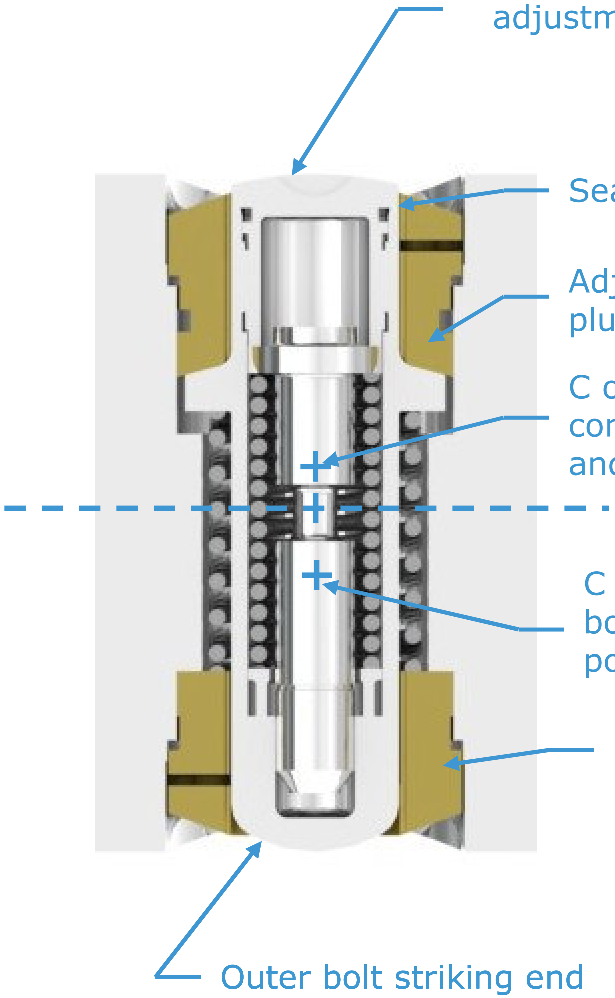
The relay trip bolt works like a centrifugal bolt inside another outer bolt. The unit is tested and sealed in the factory:-

Inner bolt factory set on test rig and electron beam welded in a vacuum chamber.

At normal speeds, both bolts are held in place by their springs.

Approaching trip speed, the inner bolt moves the combined Centre of Gravity across the shaft centre and the bolt moves out rapidly to strike the lever.

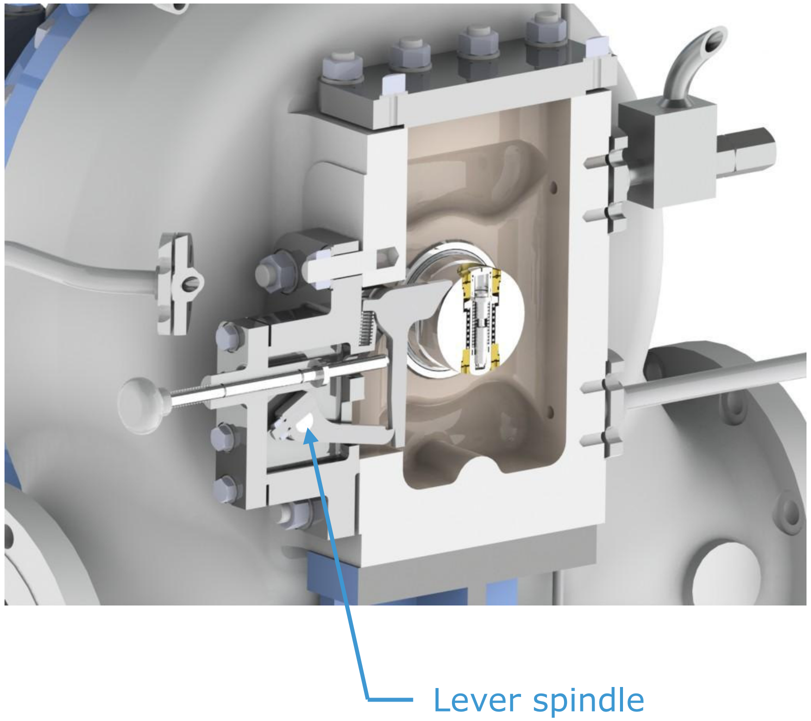
Very clever!

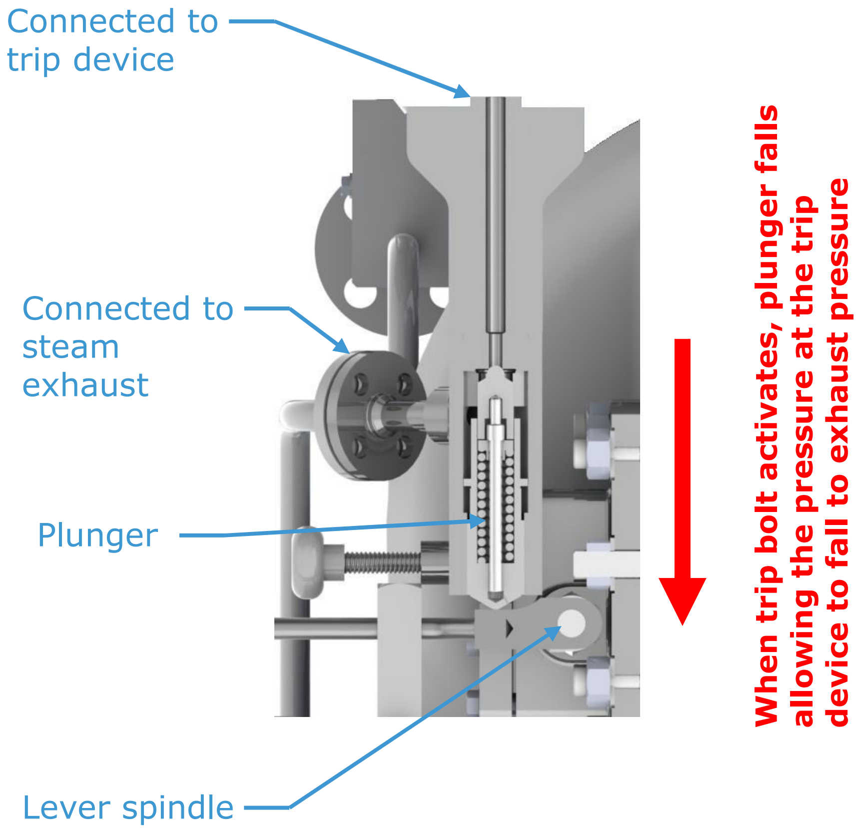


Overspeed Trip System

- Trip Lever Mechanism

The bolt strikes the lever which in turn activates the trip mechanism actuator……



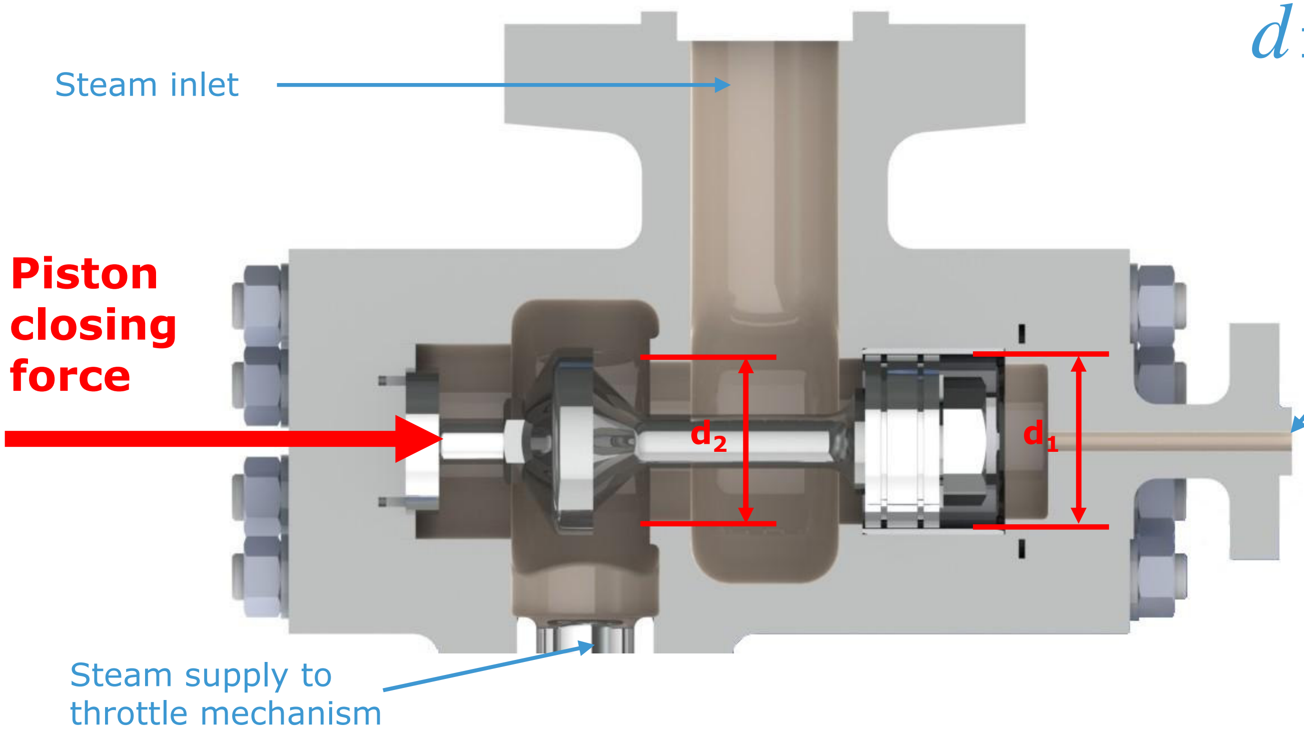


Overspeed Trip System

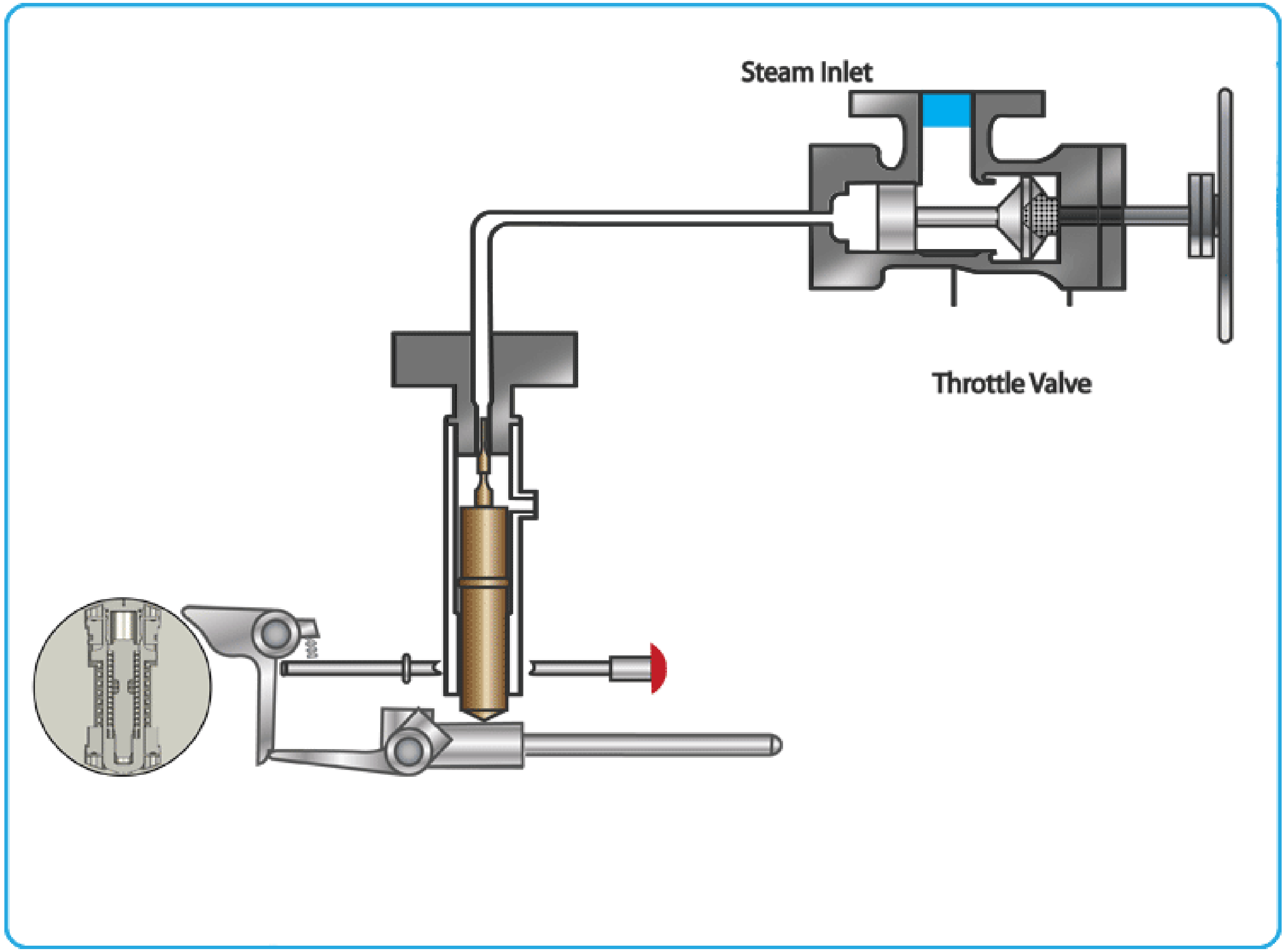
- Trip Device

  When the trip bolt hits the lever, the trip device actuator causes the pressure at the right (in this diagram) to fall to steam exhaust pressure. Since diameter d_1 of the piston is greater than d_2, the piston is forced to the right and closes off the steam supply to the throttle mechanism.

$$d_1 > d_2$$



- Overspeed Trip Operation



Bearing Lubrication System

Bearing Lubrication

- Bearing Lubrication System

  The TWL has product lubricated bearings which is one of the main features of the unit. The bearings need to be lubricated/flushed with clean water to ensure that they do not become damaged and the TWL has it's own system to carry out this function.

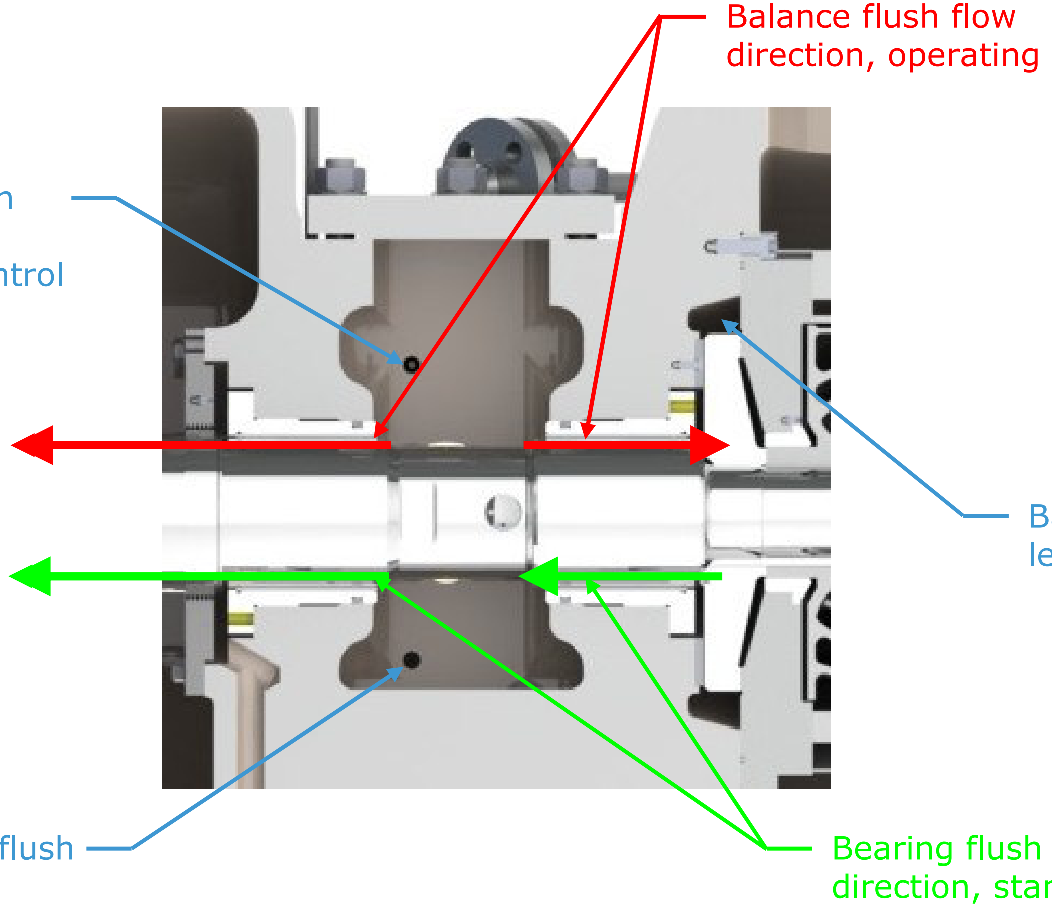
  Bearing flushing is achieved by taking product water from the first stage, reducing this pressure to an acceptable and manageable value, filtering and injecting into the bearing assembly.

  During operation, filtered water is injected into the bearing area and maintained at a pressure of around 3 barg (43.5 psig). Water flows from inside the bearing area through each bearing, passing into the balance chamber on the pump side and the steam exhaust on the turbine side.

  During standby condition, the bearings continue to be flushed, this time water flows from the suction side of the pump, through the pump end bearing and then through the exhaust to drain.

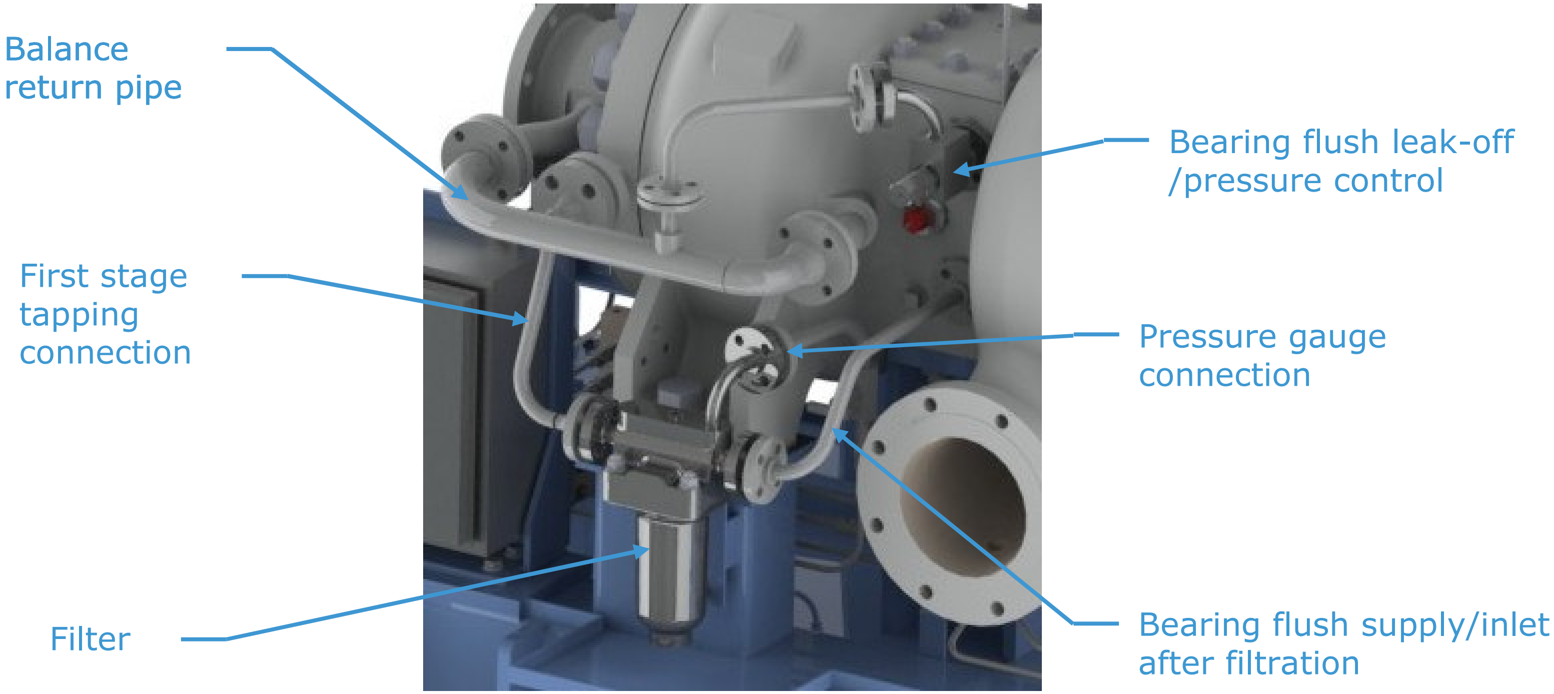
  Operation flow is around 1.6 m3/hr (7 usgpm) and standby flow is around 0.3–1.0 m3/hr (1.3-4.4 usgpm) depending on the suction pressure.

- Bearing Lubrication System (continued)



Bearing Lubrication

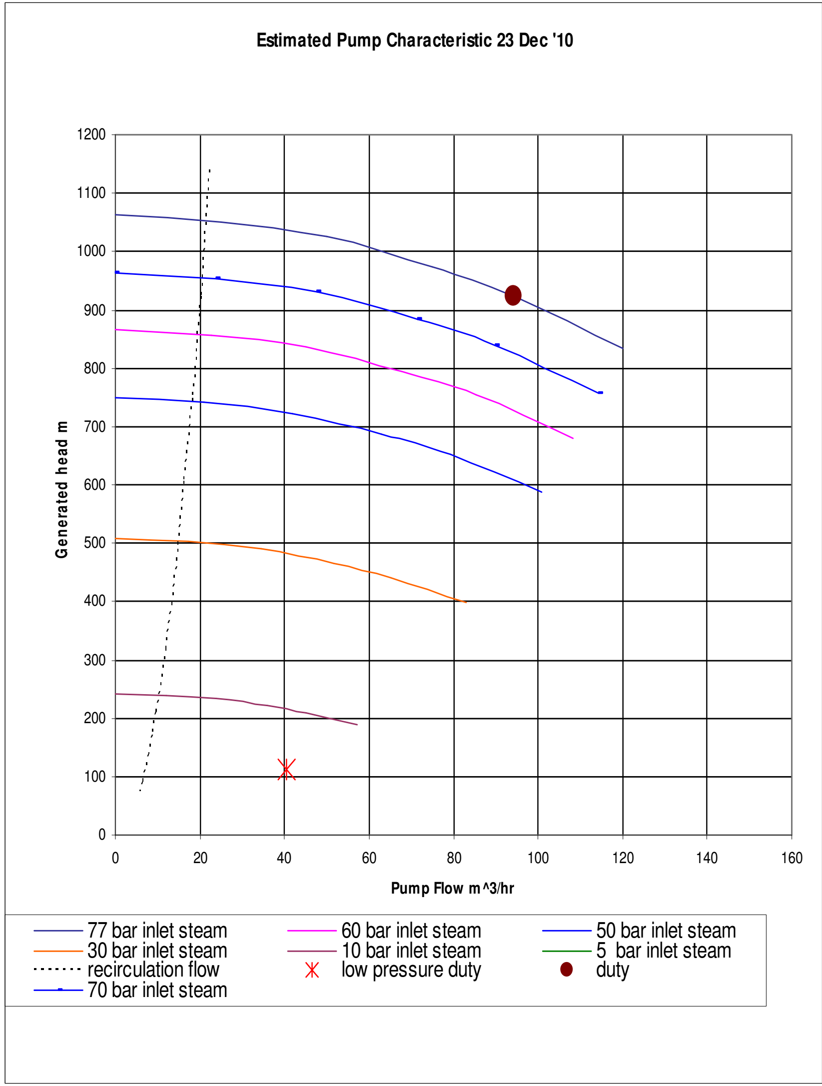
- Bearing Lubrication System (continued)

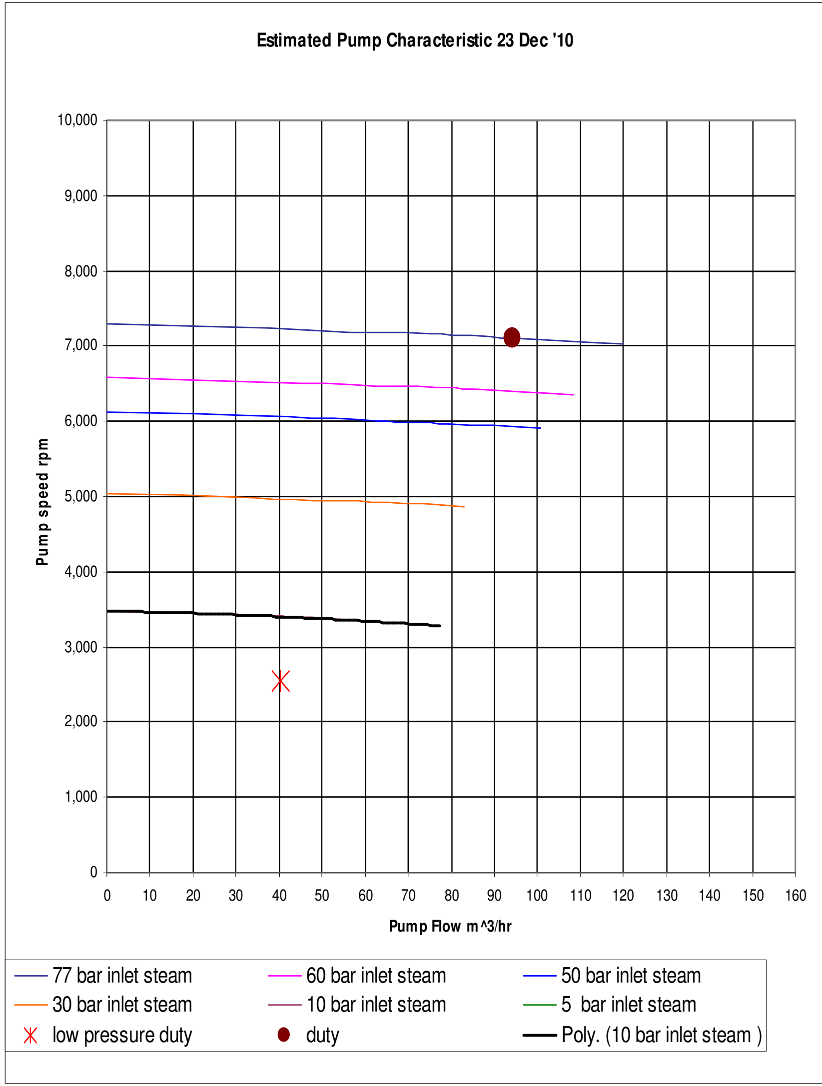


Typical Curves and Supporting Information

TWL Presentation

Performance Curves





Safety Impact for Installing a TWL

Topic	Separate pump and turbine	CLYDEUNION TWL
Configuration	Separate driver and driven machine Shafts extends through casings, seals and drive coupling required Field alignment required Lubrication system needed	No field alignment needed No mechanical seals No drive coupling Less potential for vibration issues More reliable thus improves safety case
Control	Performed externally Flow is measured and electronically sent to a governor controller Electro-hydraulic control valve actuator to signal servo adjustment Control valve then throttles steam therefore speed History of governor electrical & hydraulic problems	Control completely internal within pump & turbine No electrical connections needed No flow measurement needed No external control need to provide safety function More reliable thus improves safety case
Starting	Governor reaction time slow Started gradually for 10 sec System stability required before opening main steam valve	Direct mechanical actuation Up to speed within 3 <10 sec depending on steam pressures No over speed on start up More reliable thus improves safety case
Control of flow	Requires dedicated electricity supply Potential for local adjustment Slow reaction time to system transients Spurious cold start-up trips issues	Rapid start up under all steam conditions Automatically matches flow & pressure requirements No electrical requirements or operator influence Pump can be started and stopped as often as needed Kick down flow control can be offered More reliable thus improves safety case
Gland Sealing System	Pump mechanical seals each end Double seals on steam turbine Piped to barometric condenser	Leakage contained within pump set via turbine exhaust Leakage on standby can be stopped by fitting stand still seals Less system equipment needed More reliable thus improves safety case
Lubrication	Both pump and turbine are oil lubricated Cooling/filtration systems required to prevent oil degradation Possible oil contamination from steam/water Risk of fire	Product lubricated bearings Simplification of maintenance and increased reliability More reliable thus improves safety case
Barometric condenser system	Barometric condenser fitted to collect seal leakage Vacuum pump fitted for sub-atmospheric condenser Both pump and turbine are oil lubricated	Condenser not needed Vacuum pump not needed This system not needed thus improves safety case
Services	Water required for cooling purposes Electricity required for control	No cooling water required No electricity required (for operation) Less dependency thus improves safety case

Installation List

Site	Year of manufacture	Frame	No Off	Head m (ft)	Flow m3/hr (usgpm)	Steam Mpa (psig)	Speed rpm	Power kW (hp)
Ringhals II	1971	TWL35S	1	832 (2730)	154 (2981)	7.8/0.76 (1131/110)	8100	557/73 (747/98)
Ko-Ri I	1973	TWL20HS	2	930 (3051)	93 (1800)	6.9/0.83 (1000/120)	7400	556/95 (745/127)
Ringhals III	1974	TWL45HS	1	945 (3100)	173 (3348)	8.35/1.3 (1211/189)	7100	683/51 (916/68)
Ringhals IV	1974	TWL45HS	1	945 (3100)	173 (3348)	8.35/1.3 (1211/189)	7100	683/51 (916/68)
Sizewell B	1987	TWL45S	2	1004 (3294)	219 (4239)	7.50/0.6 (1088/87)	7800	928/22 (1244/30)
Ulchin 3&4	1993	TWL45S	4	1097 (3599)	125 (2419)	8.9/0.49 (1291/71)	7870	812/247 (1089/331)
Qinshan II	1995	TWL45S	4	1062 (3484)	116 (2245)	7.5/0.53 (1088/77)	7750	730/55 (979/74)
Yongg 5&6	1996	TWL45S	4	1097 (3599)	125 (2419)	8.9/0.49 (1291/71)	7870	812/247 (1089/331)
Lungmen 4	1997	TWL45S	2	991 (3521)	195 (3774)	8.38/1.0 (1215/145)	6000	813/152 (1090/204)
Ulchin 5&6	1999	TWL45S	4	1097 (3599)	125 (2419)	8.9/0.49 (1291/71)	7870	812/247 (1089/331)
Shin Kori 1&2	2003	TWL45S	4	1137 (3730)	82 (1587)	8.6/0.41 (1247/60)	7850	471/195 (630/262)
Qinshan II Ext	2005	TWL45S	4	1062 (3484)	116 (2245)	7.5/0.53 (1088/77)	7750	730/55 (979/74)

Installation List

Site	Year of manufacture	Frame	No Off	Head m (ft)	Flow m3/hr (usgpm)	Steam Mpa (psig)	Speed rpm	Power kW (hp)
Ling Ao II	2006	TWL45S	4	1125 (3691)	126 (2439)	7.5/0.53 (1088/77)	8000	795/51 (1066/68)
Hongyanhe 1&2	2007	TWL45S	4	1125 (3691)	126 (2439)	7.5/0.53 (1088/77)	8000	795/51 (1066/68)
Ning De 1&2	2007	TWL45S	4	1125 (3691)	126 (2439)	7.5/0.53 (1088/77)	8000	795/51 (1066/68)
Yangjiang 1 to 4	2008	TWL45S	4	1125 (3691)	126 (2439)	7.5/0.53 (1088/77)	8000	795/51 (1066/68)
Hongyanhe 3&4	2008	TWL45S	4	1125 (3691)	126 (2439)	7.5/0.53 (1088/77)	8000	795/51 (1066/68)
Fuqing 1&2	2009	TWL45S	4	1125 (3691)	126 (2439)	7.5/0.53 (1088/77)	8000	795/51 (1066/68)
Fangjiashan 1&2	2009	TWL45S	4	1125 (3691)	126 (2439)	7.5/0.53 (1088/77)	8000	795/51 (1066/68)
Ning De 3&4	2009	TWL45S	4	1125 (3691)	126 (2439)	7.5/0.53 (1088/77)	8000	795/51 (1066/68)
Hainan 1&2	2009	TWL45S	4	1062 (3691)	116 (2245)	7.5/0.53 (1088/77)	7750	730/55 (979/68)
Fangchengang 1&2	2010	TWL45S	4	1125 (3691)	126 (2439)	7.5/0.53 (1088/77)	8000	795/51 (1066/68)
Ringhalls	2011	TWL45S	2	924 (3032)	94 (1819)	7.6/0.5 (1100/75)	7110	409/248 (548/332)
Fort Calhoun	2011	TWL45S	1	914 (2999)	88 (1703)	7.0/TBC (1015/TBC)	7050	378/TBC (506/TBC)

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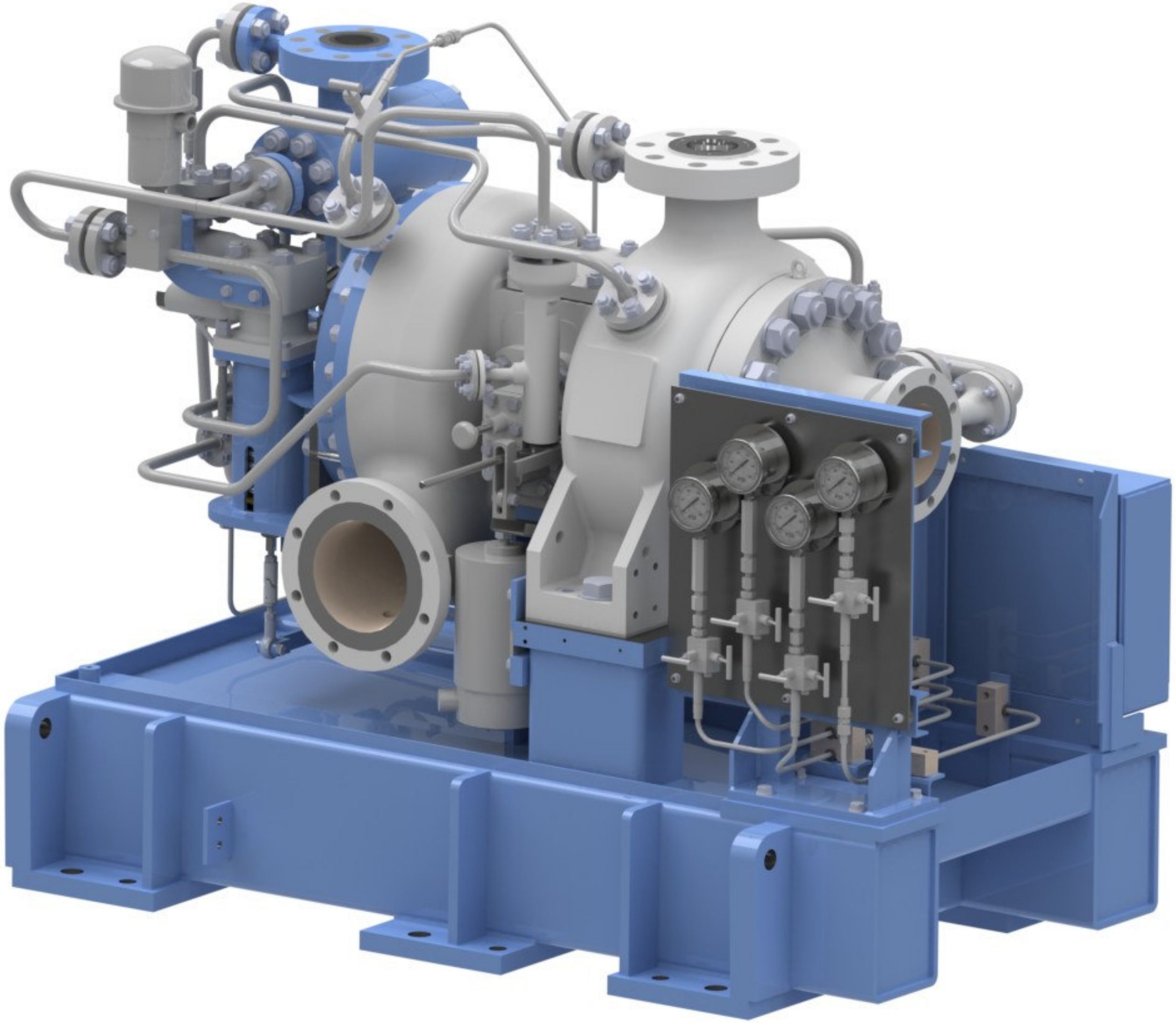
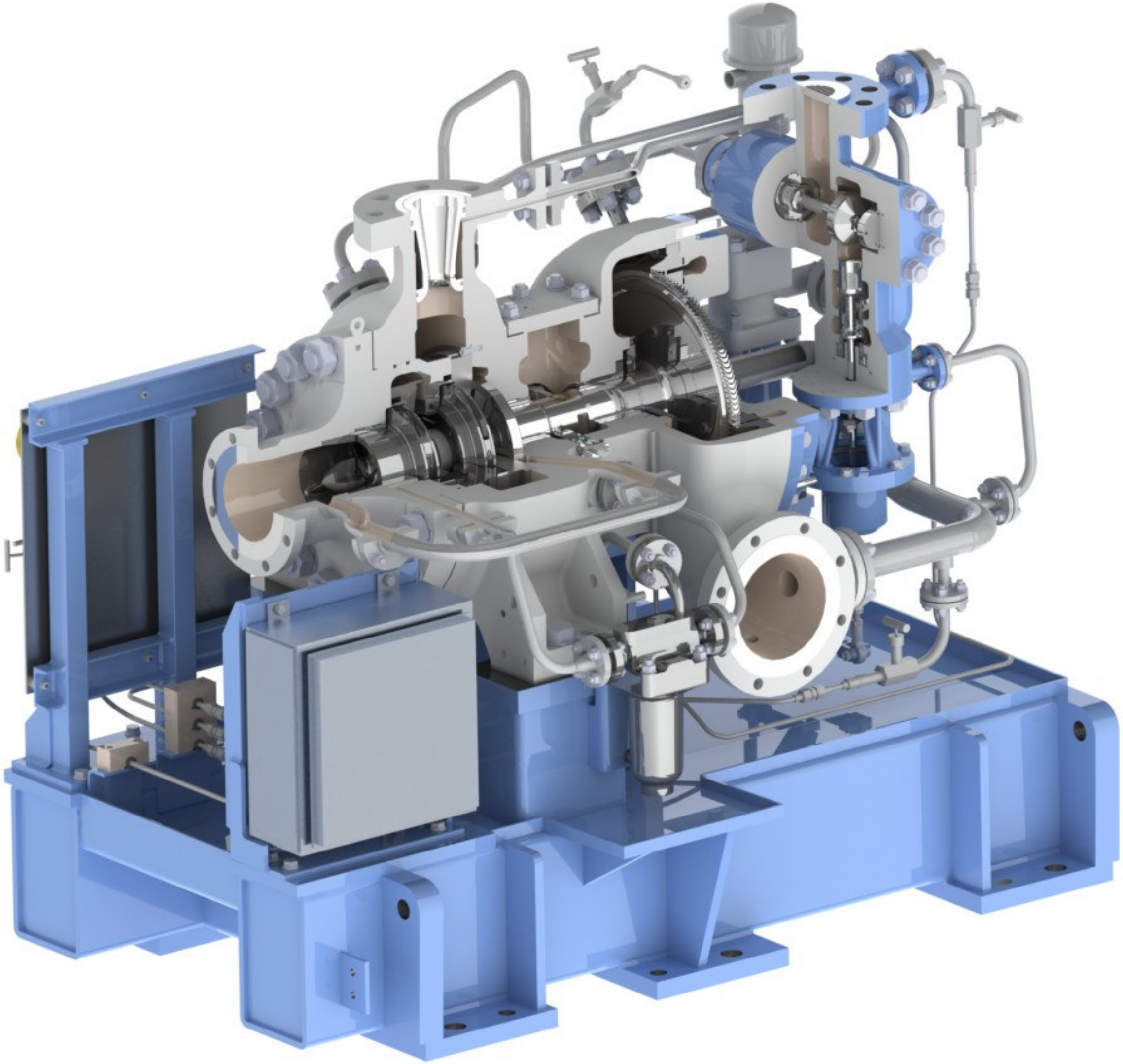
TWL Images

Images



Images



Images


2ASG141LP
NOZZLE BOX PRESSURE
2ASG142LP
BRG. LUBG. WATER SUPPLY PRESSURE
2ASG004LP
STEAM EXHAUST PRESSURE

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Questions and Discussion