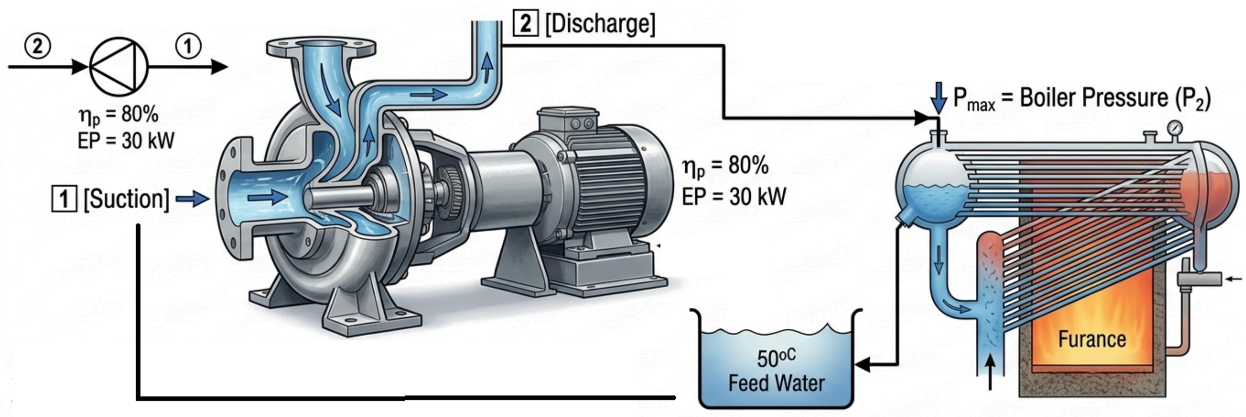
In a steam power plant operating on a modern Rankine cycle, the boiler feed pump (BFP) acts as the work-input mechanism that pressurizes subcooled or saturated liquid water exiting the condenser up to the operating pressure of the steam generator (boiler).



Thermodynamically, liquid water is assumed to be an incompressible fluid. Because its specific volume (v) remains virtually constant despite extreme changes in pressure, the ideal, reversible steady-flow work done by the pump can be derived from the general open-system energy equation $\Delta W = vdP$. Integrating this expression yields the fundamental formula for fluid or water power WP):

$$\text{WP} = mv_f\left(P_2 - P_1\right)$$

Where:

- WP = Water power (fluid power successfully added to the water column), in kW
- m = Mass flow rate of the feedwater, in kg/s
- v_f = Specific volume of the saturated liquid at the suction temperature, in m^3/kg
- P_1 = Suction pressure at the pump inlet (typically taken as the saturation pressure P_{sat} to avoid cavitation), in kPa
- P_2 = Discharge pressure delivered by the pump (representing the maximum pressure the boiler can attain), in kPa

Real-world mechanical components cannot execute perfectly reversible processes due to internal fluid friction, turbulence, and mechanical shear. The ratio between the actual power required to drive the fluid and the total electrical or mechanical power supplied to the pump motor is quantified by the pump efficiency (η_p). The relationship dictates that the actual input motor power BP or EP) will always be greater than the fluid water power (WP):

$$\eta_p = \frac{WP}{Motor\ Power}\ x\ 100\%$$

By applying this mechanical efficiency relationship, the true net power acting directly on the fluid volume can be isolated, which allows the analytical calculation of the absolute discharge pressure (P_2).

<u>Step 1:</u> Calculate the Fluid Water Power (WP)

To isolate the true thermodynamic work acting on the fluid stream, we must transform the gross mechanical power delivered by the motor using the known efficiency of the pump system.

$$\eta_P = \frac{WP}{Motor\ Power}\ x\ 100\%$$

Substituting the problem values (30 kW motor power at 80% mechanical efficiency):

$$0.80 = \frac{WP}{30\ kW}\ x\ 100\%$$

WP = 24 kW

<u>Step 2:</u> Formulate the Steady-Flow Incompressible Fluid Relationship

Using the fluid water power derived in the previous step, we apply the incompressible open-system flow equation to solve for the discharge boundary pressure (P_2).

WP = $mv_f\left(P_2 - P_1\right)$

Substituting the known parameters (m = 2.3 kg/s, v_f = 0.001012m^3/kg, andP_1 = 12.349 kPa):

24 KW = $\left(2.3\frac{kg}{s}\right)\left(0.001012\frac{m^3}{kg}\right)\left(P_2 - 12.349\ kPa\right)$

P_2 = 10,322.381 kPa

The calculated discharge pressure (P_2 = 10,322.381 kPa) indicates that this system is operating within a high-pressure utility power cycle. In actual engineering practice, the magnitude of this discharge pressure dictates the wall thickness and material constraints of the downstream piping networks, check valves, and the boiler drums themselves. It highlights how a relatively compact mechanical input (30 kW) can generate immense hydraulic pressure against a liquid column because liquids do not waste energy via volumetric compression.

Notice that the suction pressure P_1 is explicitly equal to the saturation pressure of water at 50◦C (12.349 kPa). In a practical power plant, running a pump right at P_{sat} is highly dangerous. If the local pressure inside the pump impellers drops even slightly below this value due to local velocity spikes, the water will instantly flash into vapor bubbles. When these bubbles move into higher-pressure zones, they collapse violently. This phenomenon, known as cavitation, erodes metal components and destroys pump impellers. Engineers must ensure the actual suction head includes a safety margin above this saturation value, a parameter known as the Net Positive Suction Head Available (NPSHA).