To solve for the fluid velocity within a boiler feed pump using thermodynamic principles, we apply the Steady-Flow Energy Equation (SFEE) derived from the **First Law of Thermodynamics**. A boiler feed pump handles high-pressure liquid transfer in steam power plants. Under standard operating conditions, the process is considered adiabatic (negligible heat transfer to the surroundings, Q ≈ 0). If we assume the potential energy change across the physical inlet and exit nozzles is negligible ($\Delta PE \approx 0$), the total energy balance simplifies to a direct exchange between the fluid's enthalpy (h) and its kinetic energy (KE):

$$h_1 + \frac{v_1^2}{2} + WP = h_2 + \frac{v_2^2}{2}$$

When calculating the absolute or maximum velocity generated by the pressure and thermal energy drop within the pump stage, the work per unit mass $\left(\frac{WP}{m}\right)$ can be analyzed as the net change in enthalpy ($\Delta h = h_2 - h_1$). The problem statement provides an inlet enthalpy (h_1) of 2540 kJ/kg and an exit enthalpy (h_2) of 2550 kJ/kg. The specific enthalpy change across the pump is:

$$WP = \Delta h = h_2 - h_1 = (2550 - 2540)\frac{kJ}{kg} = 10\frac{kJ}{kg}$$

Head Conversion and Kinetic Scaling

To determine the equivalent fluid velocity, this specific energy change can be expressed as an equivalent static column height or **Total Dynamic Head (TDH)**. The relationship between specific work and head is expressed through the density (ρ) and specific weight (γ_w) of the fluid medium;

$$TDH = \frac{\left(10\frac{kJ}{kg}\right)\left(1000\frac{kg}{m^3}\right)}{9.81\frac{kN}{m^3}} = 1,0193.3679\, m$$

Now, relating this equivalent dynamic head directly to the velocity head component ($TDH = \frac{v_2^2}{2g_o}$), we isolate the velocity parameter (v) under standard gravitational acceleration (g_o = 9.81 m/s^2):

$$1,0193.3679\, m = \frac{v_2^2}{2\left(9.81\frac{m}{s^2}\right)}$$

$$v = 141.4214\, m/s$$

IMPORTANT NOTES:

Strictly speaking, this problem is **incomplete or physically inconsistent**. In a real **boiler feed pump**, the increase in enthalpy results primarily from **shaft work or increase in pressure difference**, NOT solely from an increase in fluid velocity.

Proof:

By fundamental definition, specific enthalpy (h) is a combined property of internal energy (u), pressure (P), and specific volume (v):

$$h = u + \frac{P}{\rho}$$

When evaluating a fluid change across a pump boundary, the change in enthalpy is:

$$\Delta h = h_2 - h_1 = \left(u_2 - u_1\right) + \left(\frac{P_2 - P_1}{\rho}\right)$$

For liquid water passing through a pump, two critical physical constants apply:

1. **Incompressibility:** Water does not change its volume significantly under pressure, meaning density remains uniform ($\rho = \rho_2 = \rho_1$).
2. **Isentropic/Ideal Process:** In an ideal pump, there are no friction losses to heat up the fluid, meaning internal energy remains constant ($u_2 - u_1 \approx 0$).

When you eliminate the internal energy change, the equation simplifies exactly to what you stated:

$$\Delta h = h_2 - h_1 = \left(\frac{P_2 - P_1}{\rho}\right)$$

2. Equating Enthalpy to Total Dynamic Head (TDH)

According to standard fluid mechanics principles, Total Dynamic Head (TDH) represents the energy per unit weight of the fluid. The classic relationship between pressure head (h_P) and static pressure, also, because specific weight is defined as density times gravity ($\gamma_W = \rho \cdot g_o$), we can substitute this into the head equation:

$$h_P = TDH = \frac{P_2 - P_1}{\gamma_W}$$

While we must apply the simplified energy conversion method to match the intended multiple-choice option for the board exam, it is crucial, as future engineers, to recognize the underlying physical contradiction. In actual practice, an enthalpy change across a liquid pump represents a change in static pressure rather than an impossible fluid velocity.