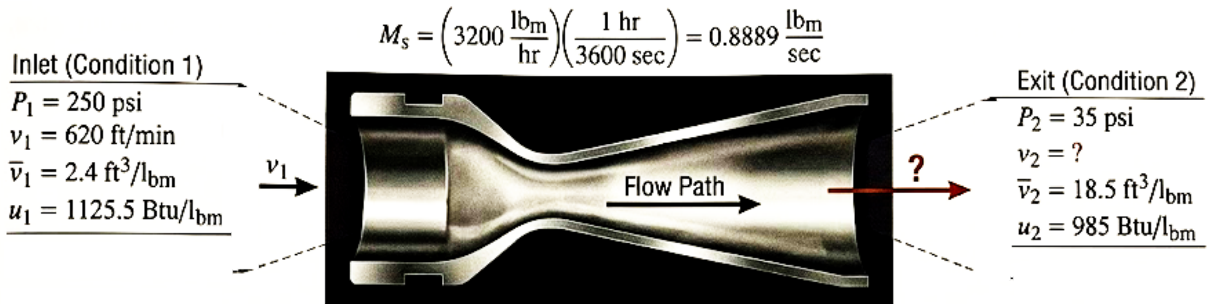
An engineering device designed to vary the velocity of a moving fluid by modifying its cross-sectional passage area is classified as a **Nozzle**.



In a fluid system running under stable operating parameters, a nozzle represents an **Open System** governed by **The First Law of Thermodynamics for Steady Flow**. Because a nozzle's primary task is to convert thermal energy directly into directed macroscopic movement, several unique operating parameters apply:

- **Adiabatic Operation (Q = 0):** The velocity of the fluid stream passing through a nozzle is so high that the substance spends a negligible fraction of a second inside the device. Consequently, there is virtually no time for heat to transfer across the solid perimeter walls to or from the external room environment (q = 0).
- **No Shaft Work Output (W_{sf} = 0):** Unlike a steam turbine or reciprocating piston assembly, a nozzle features absolutely no moving internal parts, rotating blades, or linkages. It cannot capture or generate mechanical shaft power (w_{sf} = 0).
- **Negligible Potential Energy Changes (ΔPE = 0):** The structural alignment of a standard nozzle is horizontal, and any small elevation differences between the inlet and outlet centerlines produce a mathematically insignificant hydrostatic impact.

Given these constraints, the standard **Steady-Flow Energy Equation (SFEE)** on a per-unit-mass basis (1 lb_m) simplifies to a strict balance between entering Enthalpy ($h_1 = u_1 + P_1V_1$) and Kinetic Energy (KE_1) versus exiting Enthalpy ($h_2 = u_2 + P_2V_2$) and Kinetic Energy (KE_2):

$$U_1 + P_1\overline{v_1} + \frac{v_1^{\,2}}{2g_c} = U_2 + P_2\overline{v_2} + \frac{v_2^{\,2}}{2g_c}$$

Rearranging this expression to solve for the structural change in kinetic energy yields:

$$\Delta KE = \frac{v_2^{\,2} - v_1^{\,2}}{2g_c} = -\left(U_2 - U_1\right) - \left(P_2\overline{v_2} - P_1 v_1\right)$$

Where $g_c = 32.2\frac{lb_m - ft}{lb_f - sec^2}$ is the universal gravitational proportional conversion factor for the United States Customary System (USCS), which is vital to balance mechanical force and thermal components safely.

Step 1: Extract and Standardize Input Data

- Mass Flow Rate (m) = 3200 lb_m/hr (This value is actually redundant since the calculation can be solved purely on a per-unit-mass basis)
- Inlet Pressure (P_1) = 250 psi = 250 lb_f/in^2
- Inlet Velocity (v_1) = 620 ft/min = $\frac{620}{60}\frac{ft}{sec}$ = 10.3333 ft/sec
- Inlet Specific Volume ($\overline{v_1}$) = 2.4 ft^3/lb_m
- Inlet Internal Energy (U_1) = 1125.5Btu/lb_m
- Outlet Pressure (P_2) = 35 psi = 35 lb_f/in^2
- Outlet Specific Volume ($\overline{v_2}$) = 18.5 ft^3/lb_m
- Outlet Internal Energy (U_2) = 985 Btu/lb_m

Step 2: Calculate Specific Internal Energy Change (ΔU)

$$\Delta U = (U_2 - U_1) = (985 - 1125.5) = -140.5\frac{Btu}{lb_m}$$

Step 3: Calculate Specific Flow Work Change (ΔW_f)

$$\Delta W_f = \left(P_2\overline{v_2} - P_1 v_1\right) = \left(35\ \frac{lb}{in^2}\right)\left(\frac{144\ in^2}{1\ ft^2}\right)\left(18.5\ \frac{ft^3}{lb_m}\right) - \left(250\ \frac{lb}{in^2}\right)\left(\frac{144\ in^2}{1\ ft^2}\right)\left(2.4\ \frac{ft^3}{lb_m}\right)$$

$$\Delta W_f = \left(6840\frac{lb_f - ft}{lb_m}\right)\left(\frac{1\ Btu}{778\ lb_f - ft}\right) = 8.7918\frac{Btu}{lb_m}$$

Step 4: Combine the Enthalpy Component Drop

Using the values derived above, find the total change in specific kinetic energy (ΔKE):

$$\Delta KE = -\Delta U - \Delta W_f = -\left(-140.5\ \frac{Btu}{lb_m}\right) - \left(8.7918\frac{Btu}{lb_m}\right) = 131.7101\frac{Btu}{lb_m}$$

$$\Delta KE = \left(131.7101\frac{Btu}{lb_m}\right)\left(\frac{778\ lb_f - ft}{1\ Btu}\right) = 102,492.684\ \frac{lb_f - ft}{lb_m}$$

Since $\Delta KE = \frac{{v_2}^2 - {v_1}^2}{2g_c}$,

$$102,492.684\ \frac{lb_f - ft}{lb_m} = \frac{{v_2}^2 - {v_1}^2}{2\left(\frac{lb_m - ft}{lb_f - sec^2}\right)}$$

$${v_2}^2 - {v_1}^2 = 6,595,093.243\ \frac{ft^2}{sec^2}$$

<u>Step 5:</u> Solve for Final Exit Velocity (v_2)

$$v_2^{\,2} - \left(10.3333\,\frac{ft}{sec}\right)^2 = 6,595,093.243\,\frac{ft^2}{sec^2}$$

$$v_2 = 2,568.11\,\frac{ft}{sec}$$

In power generation plants, this high-speed jet leaving a nozzle array is immediately slammed against the curved blades of a steam turbine rotor. The massive momentum change of the fluid jet creates a high hydrodynamic torque profile, spinning large electrical generators. Accurate nozzle calculations are mandatory to optimize kinetic transfer efficiency and protect turbine structural limits against supersonic shockwave erosion.