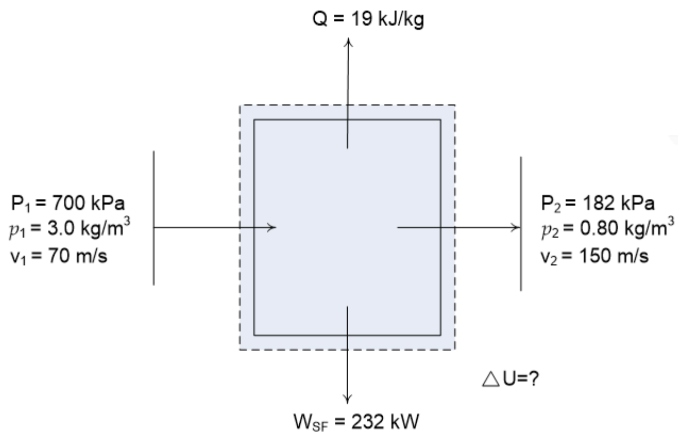
In engineering thermodynamics, a device that continuously processes a continuous stream of moving substance is classified as an **Open System** or a **Steady-Flow System**. Unlike closed systems where mass is trapped inside stationary boundaries, a steady-flow system experiences a continuous, uninterrupted mass flow rate (m) crossing its control surface boundaries. To evaluate the energy transformations taking place within such equipment (such as turbines, compressors, nozzles, or pumps), we must apply **The First Law of Thermodynamics for Steady Flow**, which states that the total energy entering the system must exactly equal the total energy leaving it plus any structural losses.



The comprehensive energy balance account tracks multiple distinct energy forms carried by the fluid:

- **Internal Energy (U):** The microscopic energy stored within the molecular structure of the substance, governed primarily by temperature.
- **Kinetic Energy (KE):** The macroscopic energy possessed by the fluid due to its bulk translation velocity (v).
- **Flow Work (W_f):** The mechanical energy required to push the fluid into and out of the control volume under the influence of its static pressure (P). It is expressed as PV or on a per-unit-mass basis as Pv, where v is the specific volume $\left(v = \frac{1}{\rho}\right)$.
- **Enthalpy (H):** A combined thermodynamic property representing the total thermal and flow energy of the fluid, explicitly defined as H = U + W_f.
- **Shaft Work (W_s):** The mechanical work exported to or imported from the surroundings via moving components like rotating shafts or pistons.
- **Heat (Q):** Thermal energy crossing the boundaries due to a temperature gradient.

For a system where elevation changes are insignificant, the change in potential energy (ΔPE) is treated as zero. Expressing the First Law on a **per-unit-mass baseline (kJ/kg)** yields the classical Steady-Flow Energy Equation (SFEE):

To determine change in internal energy (ΔU) in this problem, we can apply the First Law of Thermodynamics for open or steady-flow systems.

$$\left[E_{in} = E_{out}\right]$$

$$PE_1 + KE_1 + U_1 + W_{f1} = W_{SF} + Q + PE_2 + KE_2 + U_2 + W_{f2}$$

$$-\ Q = W_{SF} + \Delta PE + \Delta KE + \Delta U + \Delta W_f$$

For change in kinetic energy, ΔKE:

$$\frac{\Delta KE}{m} = \frac{1}{2g_C}\left({v_2}^2 - {v_1}^2\right) = \frac{1}{2\left(1\,\frac{kg-m}{N-s^2}\right)\left(\frac{1000\ N}{1\ kN}\right)}\left(150^2 - 70^2\right)\frac{m^2}{sec^2} = 8.8\,\frac{kJ}{kg}$$

For change in work flow, ΔW_f:

$$\frac{\Delta W_f}{m} = \left(P_2 v_2 - P_1 v_1\right) = \left[\left(182\,\frac{kN}{m^2}\right)\frac{1}{18\,\frac{kg}{m^3}} - \left(700\,\frac{kN}{m^2}\right)\frac{1}{3\,\frac{kg}{m^3}}\right] = -\ 5.8333\,\frac{kJ}{kg}$$

Substitute values:

$$-\ 19\,\frac{kJ}{kg} = \left(232\,\frac{kJ}{s}\right)\left(\frac{1}{4\,\frac{kg}{s}}\right) + 8.8\,\frac{kJ}{kg} + \Delta U - 5.8333\,\frac{kJ}{kg}$$

$$\Delta U = -\ 79.9667\,\frac{kJ}{kg}$$

There is a decrease in internal energy

In this open device, the fluid produces 58 kJ/kg of shaft work and simultaneously drops 19 kJ/kg of heat to the outside atmosphere. Where did all this energy come from? The kinetic energy actually *increased* by 8.8 kJ/kg, meaning the fluid accelerated, which consumes energy rather than yielding it. The small drop in flow work (5.83 kJ/kg) released a tiny bit of boundary energy. Therefore, the primary driver for both the shaft work output and the thermal heat loss is the **fluid's internal energy drop**. The fluid essentially burns up its own internal thermal reserves to power the device.