ME 201
Thermodynamics

First Law for Control Volume Systems Guide

Recall that for a control volume system there is no accumulation or depletion of mass so that the mass inflow must equal the mass outflow or

$$\sum_{\text{inflows}} \dot{m}_{in} = \sum_{\text{outflows}} \dot{m}_{out}$$

Also in a control volume system there is no boundary work. We can re-write our 1st law equation as

$$\sum_{\text{outflows}} (\dot{m}_{out} \cdot e_{out}) - \sum_{\text{inflows}} (\dot{m}_{in} \cdot e_{in}) = \dot{Q} - \dot{W}_{sh}$$

where $\dot{Q}$ now represents the net heat transfer rate into the control volume system (so it is positive for energy added by heat transfer and negative for energy removed by heat transfer) and $\dot{W}_{sh}$ represents the net shaft power out of the control volume system (so it is positive for energy removed by shaft work and negative for energy added by shaft work).

Some guidelines for solving control volume system energy problems are:

No Boundary Work
Use enthalpy, h, NOT internal energy, u
Either $\dot{Q}$ =0 or $\dot{W}_{sh}$ = 0
Results will either be shaft power/heat transfer rate or specific work/specific heat transfer
Ideal Gas Law is NOT Very Useful

There are three types of control volume systems:

Work Devices: Such as turbines, pumps, and compressors.
$\dot{Q}$ = 0 and Δs = 0 (ideal)

Heat Devices: Such as boilers, intercoolers, and heat exchangers.
$\dot{W}_{sh}$ = 0 and ΔP = 0 (ideal).
For those with multiple inflows and outflows, $\dot{Q}$ = 0.

Flow Devices: Such as nozzles, diffusers, valves, and pipes.
$\dot{W}_{sh} = 0$ and $\dot{Q} = 0$.
Ideal process depends on device.
$\Sigma(\dot{m}_{out} h_{out}) = \Sigma(\dot{m}_{in} h_{in})$

Ideal Thermodynamic Control Volume Devices

Work Devices

Device	Purpose	Process	Work	Heat
Turbine	Purpose is to produce work through the expansion of a high temperature, high pressure fluid.	$\Delta s=0$	$w_{sh} = h_{in} - h_{out}$	$q = 0$
Pump	Purpose is to the boost the pressure of a liquid by applying work on it.	$\Delta s=0$	$w_{sh} = h_{in} - h_{out}$	$q = 0$
Compressor	Purpose is to the boost the pressure of a gas by applying work on it.	$\Delta s=0$	$w_{sh} = h_{in} - h_{out}$	$q = 0$
Fan	Purpose is to the boost the pressure of a gas by applying work on it.	$\Delta s=0$	$w_{sh} = h_{in} - h_{out}$	$q = 0$
Blower	Purpose is to the boost the pressure of a gas by applying work on it.	$\Delta s=0$	$w_{sh} = h_{in} - h_{out}$	$q = 0$

Heat Devices: One Inflow, One Outflow

Device	Purpose	Process	Work	Heat
Boiler	Purpose is to convert liquid to vapor by adding heat.	$\Delta P=0$	$w_{sh}=0$	$q=h_{out}-h_{in}$
Condenser	Purpose is to convert vapor or two phase mixture to liquid by removing heat.	$\Delta P=0$	$w_{sh}=0$	$q=h_{out}-h_{in}$
Burner	Purpose is to raise temperature of gas by adding heat.	$\Delta P=0$	$w_{sh}=0$	$q=h_{out}-h_{in}$
Evaporator	This is a heat exchanger which uses ambient air to convert a liquid to a vapor.	$\Delta P=0$	$w_{sh}=0$	$q=h_{out}-h_{in}$
Reheater	Purpose is to increase temperature of fluid by adding heat just after one turbine and just before another turbine.	$\Delta P=0$	$w_{sh}=0$	$q=h_{out}-h_{in}$
Intercooler	Purpose is to decrease temperature of fluid by removing heat just after one compressor and just before another compressor.	$\Delta P=0$	$w_{sh}=0$	$q=h_{out}-h_{in}$
Afterburner	Purpose is to increase temperature of fluid just prior to expansion in nozzle	$\Delta P=0$	$w_{sh}=0$	$q=h_{out}-h_{in}$

Heat Devices: Multiple Inflows and Outflows

Device	Purpose	Process	Work	Heat
Regenerator	Purpose is to increase temperature of one fluid stream by extracting waste heat from a second fluid stream.	$\Delta P=0$ $\sum \dot{m}_{in} h_{in} = \sum \dot{m}_{out} h_{out}$	$w_{sh}=0$	$q=0$
Heat Exchanger	Purpose is to increase temperature of one fluid stream by extracting heat from a second fluid stream.	$\Delta P=0$ $\sum \dot{m}_{in} h_{in} = \sum \dot{m}_{out} h_{out}$	$w_{sh}=0$	$q=0$
Open Feed Water Heater	Purpose is to heat a subcooled liquid up to saturation by adding a hot fluid.	$\Delta P=0$ $\sum \dot{m}_{in} h_{in} = \dot{m}_{out} h_{out}$	$w_{sh}=0$	$q=0$

Flow Devices

Device	Purpose	Process	Work	Heat
Pipe	Purpose is to convey fluid	$\Delta P=0$ $\Delta h=0$ If PE and KE are negligible	$w_{sh}=0$	$q=0$
Valve	Purpose is to decrease pressure of a fluid	$\Delta h=0$	$w_{sh}=0$	$q=0$
Nozzle	Purpose is to take a high temperature, high pressure gas and produce a high velocity gas stream.	$\Delta s=0$ KE must be included	$w_{sh}=0$	$q=0$
Diffuser	Purpose is to take a high velocity gas stream and reduce it to a low or zero velocity gas stream.	$\Delta s=0$ KE must be included	$w_{sh}=0$	$q=0$