

Enthalpy is a broader, more inclusive quantity to measure the energy in a system. Remember that in all your flows *material and energy are conserved*. There are many kinds of energy, including heat, chemical, and the energy required to maintain the physical state of a system. One way to visualize this is continually smaller components. For instance, in a gas you have lots of larger molecules bouncing against the walls (e.g. of a balloon), which is one kind of energy. We can also think of this energy as being related to the phase of a material. For a gas, this is represented in the expanding volume of a gas, but if that gas were to condense, the enthalpy from expanding the balloon would be stored in the latent heat of vaporization. That gas is likely made of molecules that have another form of energy in the bonds between atoms. Each of those molecules is also vibrating or moving at some frequency related to the temperature. All of these are different types of energy contained within the same system.

We represent enthalpy as H . We also consider it to be a function only of where the system is at two different points, so we use ΔH . For enthalpy, you can consider only the discrete initial and final values of interest, you do not need to integrate over all the states of the system in between. So if you had chemical reactions, or various rates of temperature change that were not the same between two systems, as long as the initial and final system states were the same, you don't need to know which system underwent which process. For our initial definition of enthalpy, which was introduced in chapter 2, we can define it simply as

$$\Delta H = C_p(T_b - T_a) \quad (1)$$

where C_p is the average specific heat of your gas between the two temperatures, and the two temperatures are just final and initial temperatures of the system. Since we aren't undergoing any chemical transformations here (same chemical composition at beginning and end) we can ignore those forms of energy. They still contribute to the enthalpy, but as we consider the difference between states, that value would cancel out.

Water Injection. As we discuss methods of cooling our exhaust (removing heat energy from the system) enthalpy becomes a useful measure to use in discussing our systems. Particularly in the case of water injection cooling, we need to describe how the heat is transferred from the exhaust gas mixture to water. The enthalpy of the overall system must remain constant, which means that the enthalpy lost from the exhaust gas must be gained by the water. We can represent this as

$$\dot{M}_a(h_{ai} - h_{af}) = \dot{M}_w(h_{wf} - h_{wi}) \quad (2)$$

air mass flow \times enthalpy change = water mass flow \times enthalpy change

where \dot{M} is dM/dt or mass flow. You can consider this to be similar to Q except instead of the volume flow per time it's the mass flow per time. The a and w subscripts refer to air and water and the f and i subscripts refer to the final and initial states. This is the basic balance for the water injection cooler, but how do you actually get those values?

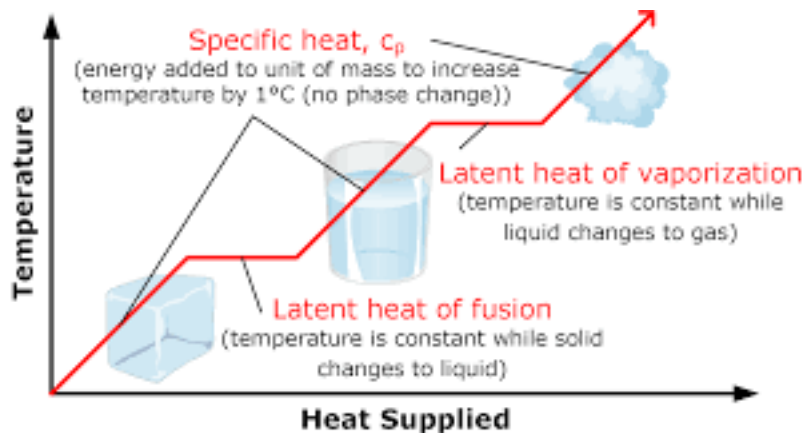
First, we can look at **table B.7** in your textbook. Notice that the footnote for that table indicates that the water values are only for water vapor, so if you start with liquid water, you will also need to include the latent heat of vaporization, because enthalpy accounts for not only temperature change but also phase change. As this is air pollution control, we may also have a complex air system. Let's say we are trying to control an exhaust flow composed of the following gases: N_2 , O_2 , and pollutants A and B. In that case, the left half of the previous equation would be:

$$\begin{aligned} \dot{M}_a(h_{ai} - h_{af}) &= \sum \dot{M}_n(h_{ni} - h_{nf}) \\ &= \dot{M}_{N_2}h_{N_2} + \dot{M}_{O_2}h_{O_2} + \dot{M}_A h_A + \dot{M}_B h_B \end{aligned} \quad (3)$$

There is also an equation in the book demonstrating how to deal with the phase change of the water, by including the latent heat of vaporization (ΔH_v) and the two stages of changing temperatures. If you remember from the diagrams in the recording (see figure below), you have two sloped energy changes and the horizontal line as you heat up a liquid, vaporize it, then heat up the vapor.

$$\dot{M}_a C_{pa}(T_a - T_f) = \dot{M}_w [\Delta H_v + C_{P_{wv}}(T_f - T_v) + C_{p_{wl}}(T_v - T_w)] \quad (4)$$

You could set any of the single sided forms in equations 2-4 equal as long as you are consistent about which mass and enthalpies must be equal. You can return to the discussion of system boundaries in chapter 2 if necessary. For instance if you have very simple water remaining liquid and cooling a complex gas system, you might want to use RHS of equation 2 and LHS defined in equation 3.



(Figure stolen from <https://guides.firedynamicstraining.ca/g/structural-firefighting-fundamentals-of-fire-and-combustion/116484> via google images)