Section_IIa.8.4

8.4. Discharging Gas-Filled Rigid Vessels (Fixed C.V.)

In the textbook, we have discussed the isentropic venting of rigid vessels filled with an ideal gas. Here we discuss a non-isentropic venting. See Section 8.5, in the textbook, for a more general case.

Again, the vessel constitutes the control volume. The mass flow rate leaving the vessel is a function of the vessel pressure. We may solve the problem for a variety of cases. For example, we may find the final pressure and temperature given the final mass of gas remaining in the vessel. For this purpose, we integrate Equations IIa.8.1 and IIa.8.3 from the initial (state 1) to the final (state 2). Substituting for the mass flow rate through the vent from Equation IIa.8.1 into Equation IIa.8.3, we get:

IIa.8.7

where he in Equation IIa.8.7 is the enthalpy of the gas leaving the rigid vessel. Since he is a function of the gas temperature in the vessel, for short periods of gas discharge with reasonable approximation, we may assume that

he = (h1 + h2)/2
IIa.8.8

where h1 and h2 are enthalpies at states 1 and 2, respectively. Applying the equation for volume constraint to states 1 and 2, we obtain:

m1v1 = m2v2 = Vvessel IIa.8.9

We solve Equations IIa.8.7, IIa.8.8, and IIa.8.9 to obtain:

IIa.8.10

Given the initial conditions (i.e., m1, u1, and h1) and the mass remained in the vessel after the closure of the vent, we can solve Equation IIa.8.10 for T2 (i.e., u2 and h2). On the other hand, if P2 is specified, Equation IIa.8.10 can be solved in conjunction with the Equation of state to find T2 and m2.

Example IIa.8.6. A tank is filled with 1 kg of air at 350 kPa and 1 C. A valve is opened to vent the tank. After the valve is closed 0.8 kg of air remains in the tank. Find the air pressure and temperature after the vent valve is closed. Assume equilibrium condition in the tank throughout the venting process.

Solution: We solve this problem by iteration. Treating air is an ideal gas, we assume T2 and find h2 = cpT2. Substituting h2 in Equation IIa.8.10, we solve for u2. We also obtain T2 from T2 = u2/cv and compare it with the assumed temperature. We repeat this process until the difference between the assumed and the calculated temperatures is exceedingly small.

If in the temperature range of interest, we assume cv and cp remain constant at cv = 1.209 kJ/kg•K and cp = 1.496 kJ/kg•K, using the above data we find T2 = –10 C (Try the following Options in ToolKit: a) Option 6 for FLUID FLOW, b) Option 2 for COMPRESSIBLE FLOW, and c) Option 4 for GAS FILLED VESSELS).