Properties of Pure fluids: Incompressible & Ideal

Last time you were given states of a fluid & had to look up property information using tables in the back of your book & sketch a T-v plot. Lets do your homework with software like EES.

$T_1 = 200°C$, $x_1 = 0$, $P_2 = 0.5\,bar$ $x_2 = 1$, $P_3 = 0.75\,bar$ $v_3 = 0.1\,m^3/kg$, $T_4 = 400°C$, $u_4 = 2850\,kJ/kg$

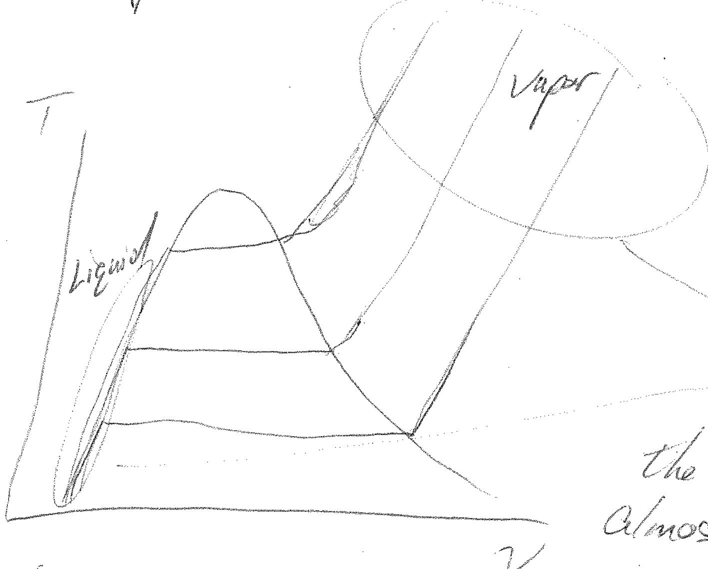
$T_5 = 100°C$, $P_5 = 100\,bar$

Show with Arrays & make a property plot in EES.

→ How are these tables & property plots made? → show fluid info for water

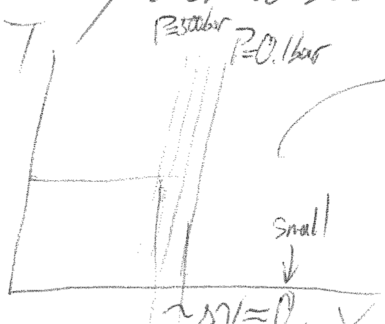
→ Some EOS have over 50 terms!!! In some situations it can become computationally taxing to use this complicated equation on a simple problem

→ Lets look at the plot we just made to see if there are any fluid "simplifications" we can make!



In these to regions the isobars become almost straight!

→ Early scientists & engineers noticed relatively simple areas of fluid EOS.



→ very little change in volume for a huge change in pressure.

Incompressible Substance

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Parts for Incompressible Substance model for Solids & liquids far from vapordome:

1) v = constant = ρ

2) internal energy → before it was tabulated or from software, now we can express it as only a function of temperature.

→ We defined internal energy as the energy stored by molecules.

→ What property is probably closely related to this? → heat capacity

→ The heat capacity of an incompressible substance is defined as

(difference between c_v & c_p is small, so just use C)

$$C = \frac{du}{dT} \Rightarrow du = C\,dT \Rightarrow \int_{u_1}^{u_2} du = \int_{T_1}^{T_2} C\,dT \Rightarrow u_2 - u_1 = \int_{T_1}^{T_2} C\,dT$$

→ C varies with temperature!! However it is usually a small change so in this class we'll generally assume it's constant.

For incompressible substance: $u_2 - u_1 = C(T_2 - T_1)$

→ Far away from the vapordome in the gas region the isobars are almost linear! $Pv = RT$

Ideal Gas

These lines are linear because the molecules are not interacting sticking etc. with one another.

Parts to Ideal Gas model for gases far away from vapor dome:

1) Ideal Gas Law: $Pv = RT$ → $R = \frac{R_{universal}}{\text{molecular weight}}$ (Gas Constant) ← Values tabulated in Appendix A-2 of book

2) $u = u(T)$ → internal energy is only a function of temperature

→ here, unlike the incompressible substance model, differences are computed using the specific heat capacity @ constant volume: C_v

$$C_v = \left(\frac{\partial u}{\partial T}\right)_v \Rightarrow C_v = \frac{du}{dT} \Rightarrow du = C_v dT \Rightarrow \int_{u_1}^{u_2} du = \int_{T_1}^{T_2} C_v dT \Rightarrow$$

$$\Rightarrow u_2 - u_1 = \int_{T_1}^{T_2} C_v dT$$

C_v is a function of temperature

Sometimes we will assume C_v is constant over small ΔT

then $u_2 - u_1 = C_v(T_2 - T_1)$ for ideal gas

If C_v is not constant we have 3 options:

1) Solve Integral of nasty function (We won't do this), 2) Ideal Gas tables in book (show), 3) Ideal gas function in software

Example of different methods in EES: CO_2 @ $T_2 = 200°C$, $P_2 = 1atm$, $T_1 = 100°C$, $P_1 = 1atm$

1) real fluid: Δu_{real} = intenergy(Carbondioxide, $T=T_2$, $P=P_2$) − intenergy(Carbondioxide, $T=T_1$, ...)

2) ideal fluid: Δu_{ideal} = intenergy(CO_2, $T=T_2$) − intenergy(CO_2, $T=T_1$) ← .03% error

Chemical Symbols in EES are only used for ideal gas functions

No function for this in EES

3) ideal fluid Constant C_v: $\Delta u_{c,const} = C_v(T_2 - T_1)$ (C_v = 706 J/kg·K) ← 8.3% error

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Important Notes for ~~these~~ Selecting a fluid Model

1) Pick a model & stick with it for the problem → be consistent (if you switch you may destroy energy.)

2) Don't worry about the absolute value of u! the values are way different

u_2 = intenergy (carbondioxide, $T=T_2$, $P=P_2$), u_{2ideal} = intenergy (CO_2, $T=T_2$)

Why? How? $u=0$ is defined relative to a reference state

it doesn't matter because you will always compute Δu's.

3) I will generally tell you in problems ~~which~~ if you can use incompressible substance or ideal gas.

4) You will have to use your engineering judgement to pick models