ME 201
Thermodynamics

Use of Compressible Substance Tables for the Evaluation of Incompressible Substance Properties Guide

When a substance that has been identified as an incompressible substance, say subcooled liquid water, has compressible substance property tables, it is possible to use these tables to evaluate the properties of the incompressible substance. We know that for an incompressible substance v, u, and s depend only on temperature, so that if we can find a value for these properties at the temperature of interest and any pressure (as long as we have the appropriate phase, liquid or solid), we will accomplish our task of evaluating the property. If we have compressible substance tables available for the substance of interest, then clearly the saturated liquid values and saturated solid values can be used. That is

For Incompressible Liquids	For Incompressible Solids
$v = v_f(\text{at } T_{given})$	$v = v_i(\text{at } T_{given})$
$u = u_f(\text{at } T_{given})$	$u = u_i(\text{at } T_{given})$
$s = s_f(\text{at } T_{given})$	$s = s_i(\text{at } T_{given})$

For example say we wish to know the entropy of Freon 12 at 0.1 MPa and -50°C. We can go to the saturation pressure table for Freon 12 and find that the boiling temperature at 0.1 MPa is -30.1°C, so our phase must be subcooled liquid. Since there are no compressed liquid tables for Freon 12, we will have to treat this subcooled liquid as an incompressible liquid. But we do have compressible subtance tables for Freon 12, so we can go to the saturated temperature table and read the entropy of saturated liquid (subscript f) at -50°C. Even though this the entropy of liquid Freon 12 at -50°C and 0.0391 MPa, we do not care that the pressure is incorrect because the entropy for this incompressible substance will depend only on the temperature. Hence

$$s = s_f(\text{at } -50°\text{C}) = -0.0384 \text{ kJ/(kg·K)}$$

For the enthalpy (h), we have a different story since we know that for an incompressible substance h depends on both temperature and pressure. This means that we can use h_f or h_i for our evaluation, but we will have to add in a pressure correction. We find the appropriate relation is

<u>For Incompressible Liquids</u>

$$h = h_f(\text{at } T_{given}) + v_f(\text{at } T_{given})[P_{given} - P_{sat}(\text{at } T_{given})]$$

<u>For Incompressible Solids</u>

$$h = h_i(\text{at } T_{given}) + v_i(\text{at } T_{given})[P_{given} - P_{sat,i}(\text{at } T_{given})]$$

As an example, if we now want the enthalpy of Freon 12 at 0.1 MPa and -50°C we go to the saturation temperature table and find at -50°C,

$$h_f = -8.772 \text{ kJ/kg},\ v_f = 0.000648 \text{ m}^3\text{/kg},\ P_{sat} = 0.0391 \text{ MPa} = 39.1 \text{ kPa}$$

and

$$h = h_f(\text{at } T_{given}) + v_f(\text{at } T_{given})[P_{given} - P_{sat}(\text{at } T_{given})]$$
$$= -8.772 + (0.000648)[100 - 39.1] = -8.733 \text{ kJ/kg}$$

Summary of Relationships for an Incompressible Substance

$$v = \text{fn}(T) \text{ only}$$

$$c_v = c_P$$

Assuming Constant Specific Heat

$$u_2 - u_1 = c_{P,avg}(T_2 - T_1)$$

$$h_2 - h_1 = c_{P,avg}(T_2 - T_1) + v_{avg}(P_2 - P_1)$$

$$s_2 - s_1 = c_{P,avg} \cdot \ln\left(\frac{T_2}{T_1}\right)$$

where

$$c_{P,avg} = c_P\left(@\frac{T_1 + T_2}{2}\right) \text{and}$$

$$v_{avg} = v\left(@\frac{T_1 + T_2}{2}\right)$$

Using compressible substance tables of the substance

$$v = v_f(\text{at } T_{given})$$

$$u = u_f(\text{at } T_{given})$$

$$s = s_f(\text{at } T_{given})$$

$$h = h_f(\text{at } T_{given}) + v_f(\text{at } T_{given})[P_{given} - P_{sat}(\text{at } T_{given})]$$

Always Work in Absolute Temperature for an Incompressible Substances