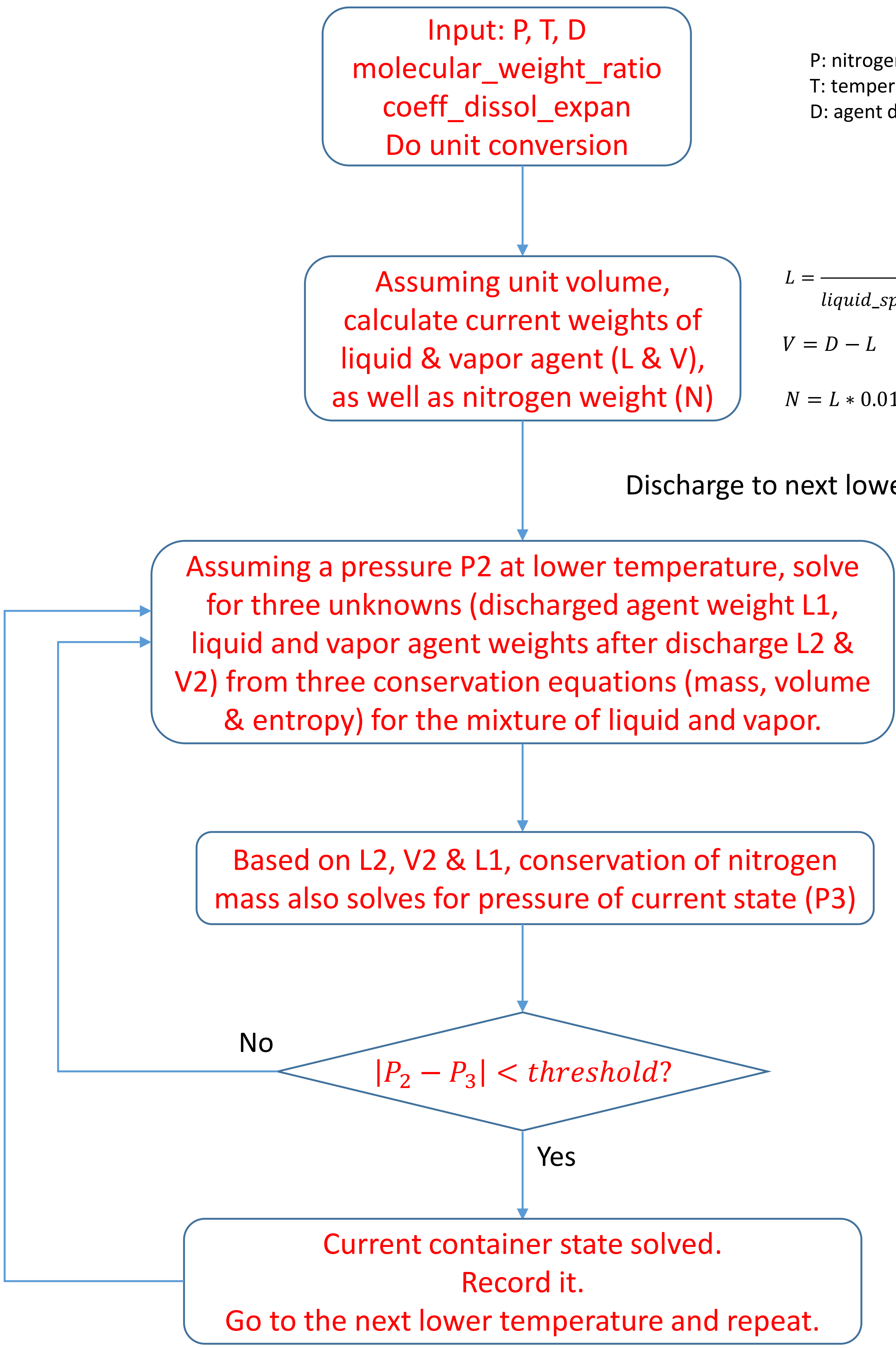
Williamson Method for Tank State during Discharge



P: nitrogen partial pressure
T: temperature
D: agent density in tank

$$molecular\_weight\_ratio = \frac{molecular\_weight(N_2)}{molecular\_weight(agent)}$$

$coeff\_dissol\_expan$: The coefficient of liquid solution volume expansion due to dissolved nitrogen: 0.053 for Halon and 0.0429 for Novec according to Tom.

$$L = \frac{1 - D * vapor\_specific\_volume(T)}{liquid\_specific\_volume(T) * \left(1 + coeff\_dissol\_expan * \frac{P}{Henry's\_const(T)}\right) - vapor\_specific\_volume(T)}$$

$$V = D - L$$

$$N = L * 0.01 * \frac{P}{Henry's\_const(T)} + V * molecular\_weight\_ratio * \frac{P}{vapor\_pressure(T)}$$

Discharge to next lower temperature in sequence

Mass: $(L - L_1) = L_2R_2 + V_2R_3 - VR_1$

Volume: $V_2 = \frac{(1 - L_2E_5)}{vapor\_specific\_volume(T-1)}$

Entropy: $(L - L_1)E_1 + VE_2 = L_2E_3 + V_2E_4$

$$P_3 = \frac{N - L_1 * 0.01 * \frac{P}{Henry's\_const(T)}}{\frac{L_2 * 0.01}{Henry's\_const(T-1)} + \frac{V_2}{vapor\_pressure(T-1)} * molecular\_weight\_ratio}$$

0.01 in the expressions is to translate percentage to decimal, so it's a constant that stays for all agents.

Williamson Method for Pipeline Expansion due to Pressure Drop

Input: Pipeline starting P, T from one snapshot of tank discharge Pressure Recession Table

P: nitrogen partial pressure
T: temperature

$$molecular\_weight\_ratio = \frac{molecular\_weight(N_2)}{molecular\_weight(agent)}$$

$coeff\_dissol\_expan$: The coefficient of liquid solution volume expansion due to dissolved nitrogen: 0.053 for Halon and 0.0429 for Novec according to Tom.

↓

Starting from only liquid and assuming unit mass agent, calculate weight of nitrogen (N) that's dissolved in the discharged liquid agent, and the total density D of the liquid mixture of nitrogen and agent

$$L = 1 \qquad V = 0$$

$$N = L * 0.01 * \frac{P}{Henry's\_const(T)}$$

$$D = \frac{1 + N}{liquid\_specific\_volume(T) * \left(1 + coeff\_dissol\_expan * \frac{P}{Henry's\_const(T)}\right)}$$

↓

Proceed along the pipe to the next lower temperature.
Try to find the pressure and density drop.

Assuming a pressure P2 at the next lower temperature point, solve for two unknowns (liquid and vapor agent weights after expansion L2 & V2) from two conservation equations (mass & enthalpy) for the mixture of liquid and vapor.

Mass: $LE_6 + VE_7 = L_2E_8 + V_2E_9 \quad (L + V = L_2 + V_2 = 1)$

Enthalpy: $LE_1 + VE_2 = L_2E_3 + V_2E_4$

↓

(Conservations of mass for agent and nitrogen are two independent equations.)

Based on L2 & V2, conservation of nitrogen mass also solves for pressure of current state (P3)

$$P_3 = \frac{N}{\frac{L_2 * 0.01}{Henry's\_const(T-1)} + \frac{V_2}{vapor\_pressure(T-1)} * molecular\_weight\_ratio}$$

↓

$|P_2 - P_3| < threshold?$

No → return to "Assuming a pressure P2 at the next lower temperature point…"

Yes ↓

Pipe state at current temperature solved. Go to the next lower temperature and repeat. → return to "Assuming a pressure P2 at the next lower temperature point…"

$$D = \frac{1 + N}{liquid\_specific\_volume(T) * \left(1 + 0.053 * \frac{P}{Henry's\_const(T)}\right) * L_2 + vapor\_specific\_volume(T) * V_2}$$