W06

You are an engineer working on the design of an insulated spherical gas storage tank. The tank is used to store pressurized gas, and maintaining the gas at a specific temperature range is crucial for its stability and performance. To achieve this, the tank is equipped with a multi-layer insulated spherical wall.

Figure 11: Spherical gas storage tank

This innovative design operates with four specialized layers. The gas resides within a spherical vessel of inner diameter d_i = 10 m. The innermost layer is stainless steel with thermal conductivity k_ss = 50 W/mK and thickness x_ss = 10 mm, ensuring core stability. Wrapped around it, a robust fiberglass composite layer, k_fc = 20 W/mK and x_fc = 30 mm thick, provides strength and insulation. The third layer is EPS with k_EPS = 0.03 W/mK and x_EPS = 20 mm thickness, buffering temperature for stability. The outermost layer features a precision-crafted aluminum sheet with thermal conductivity k_al = 237 W/mK, x_al = 5 mm thickness, and optical properties $\rho = 0.95$, $\tau = 0$ acting as a grey body, adding elegance.

The gas is being stored at a temperature of T_g = 750 $^\mathrm{o}$C with an inner convective coefficient of h_in = 150 W/m^{2}K. The tank loses heat ambient with a temperature of T_amb = 21 $^\mathrm{o}$C by convection and radiation.

a) Provide a diagram of the thermal network, incorporating all temperatures, resistances, and the direction of heat flow. Elaborate on each component's function.

b) Present a graphical representation of the temperature profile. The depicted range should encompass both the gas's internal temperature and the external ambient temperature.

c) Calculate the rate of heat loss from the tank, assuming steady-state operational conditions.

d) Maintaining a constant gas temperature costs approximately 1 € /kWh. Determine the potential annual savings if the insulating material's thickness is doubled. Reason whether this strategy is advisable.