Dryer Energy Rate/ Humidity Ratio Correlation

Optimizing air flow as a function of the exhaust gas humidity is useful in optimizing energy in convection drying applications. There is an ideal humidity ratio / air flow correlation which helps optimize energy without affecting the evaporation rate. If the humidity ratio is too high, the evaporation rate can be reduced. If it is too low, energy is wasted and over drying can occur. Below are steps to follow to help calculate energy / humidity ratio correlations for any generic dryer.

1) Calculate enthalpy (kJ/kg) of ambient air, h_a. ($C_pT + r_ih_{wt}$) where T is temperature, r_i is humidity ratio (kg h2O/ kg dry air) and h_{wt} is enthalpy of saturated vapor at given T. C_p is specific heat of dry air.
2) Calculate the enthalpy of gas at inlet to dryer (after being heated) to a temperature T_i, h_i. Follow same steps as step 1 and humidity ratio will stay the same as step 1
3) Calculate the delta enthalpy, h_d: $h_i - h_a$
4) Calculate mass flow rate (kg/hr), m_f: Multiply gas density (kg/m3) x gas flow rate (m3/hr). Note: make sure you calculate the density of the mixed gas (air and water)
5) Multiply delta enthalpy by mass flow rate (kg/hr) to determine energy required to heat air per hour (kJ/hr), E_i: $Ei = h_d \times m_f$
6) Calculate evaporation rate (kg/hr) across dryer, m_e (inlet feed moisture less outlet product moisture)
7) Calculate minimum energy for evaporation rate (MJ), E_m. 2.3 MJ/kg (constant) times evaporation rate: $E_m = m_e \times 2.3MJ/kg$
8) Calculate exhaust gas humidity ratio r_e: $m_e/m_f + r_i$
9) Calculate dryer efficiency, n: $E_m/ E_i * 100$, see Table 1 below on typical industrial dryer efficiencies
10) Vary mass flow rate (m_f) to calculate the dryer energy rate (E_i), corresponding exhaust humidity ratio (r_e) and dryer efficiency.

Table 1: Dryer performance in selected industrial sectors

Industrial sector	Average drying plant efficiency, %	Total drying energy, PJ
Paper and board	50.0	91.8
Ceramics and building materials	69.3	79.0
Food and agriculture	47.1	123.0
Plaster and plasterboard	60.0	2.5
Textiles	57.3	38.7
Timber	55.0	9.6
Chemicals	58.0	3.3
Pharmaceuticals	70.0	0.02
Laundry	53.0	0.7

Gilmour et al. cited previously published values for different industry sectors in the United Kingdom