ABSTRACT FOR ELECTROSTATIC PRECIPITATOR (ESP)

Description: This code assumes that mass fraction of particulate matter of given diameter is distributed in the same way as overall in feed.

This code uses Matts-Ohnfeldt relationship to calculate the efficiency of particulate matter removal in ESP. Matts Ohnfeldt relationship:

$$\eta = 1\text{-}\exp(-\,(w_e\, A/Q)^k)$$

(Note: A different formula is given in the reference provided, which is probably misprint since it does results in dimension mismatch for k values other than 1. Also, the formula mentioned above is present in the reference [2] mentioned below.)

where η is the collection efficiency, w_e is the average migration velocity, A is the collection area, Q is the volume flow rate of gas and k is the correction factor (usually between 0.4 and 0.6).

Collection efficiency is defined as the ratio of number of particles removed to the number of particles entering ESP.

User can either provide the migration velocity or provide the data to calculate migration velocity. Migration velocity is found using the formula: $w_e = d_p E_o E_p / 4\pi\mu$

where d_p is the particle diameter, E_o is strength of field in which particles are charged (represented by peak voltage), E_p is strength of field in which particles are collected (normally the field close to the collecting plates) and μ is the gas viscosity.

If the user provides a range of diameters, then the code finds migration velocity for range of diameter and finds the corresponding efficiency using total gas flowrate and total collection area.

User has to provide the electric field strength at collection and discharging electrode of all individual ESP's.

Reference: https://ppcair.com/pdf/EPA%20Lesson%20Lesson%203%20-%20ESP%20Parameters%20and%20Efficiency.pdf

Examples:

Q1)
Assume a combination of 2 rows of ESP each equipped with 3 ESP's indiviually, making a total of 6 ESP's. Assume viscosity of air to be 1.5 x 10^{-4} Kg/ms. Range of diameter of particle are (in µm): (2,3), (3,4), (4,5) with corresponding mass fractions to be 0.3, 0.4, 0.3. Assume migration velocity to be 5m/s for each ESP. The inlet air stream is equally divided between 2 parallel ESP arrangement. Assume area of collection of each electrode to be 5m^2. Collection Field Strength (E_p) for the electrode of one row is 1V/m and other electrode is 2V/m. Charging Field Strength (E_o) for the electrode of one row is 1V/m and other electrode is 2V/m. Evaluate the efficiency of each particle size and also the final mass in product stream. Assume dynamic viscosity of feed to be: 1.679 x 10^{-5} Pa.s. The flowrate (Q) of feed is 3.47 m^3/s. Feed mass flowrate (F) is 7.833 Kg/s.
Feed: Air 63.69 mole/s; Bromine: 24.986 mole/s; Chlorine: 54.136 mole/s

A1)
The vector containing average diameters is: dp = [2.5 3.5 4.5] µm

The flowrate entering parallel sections of ESP would be Q/2 = 1.5105 m^3/s
Mass flowrate in this section is F/2 = 3.9165 Kg/s
Vector of moles of particles present wrt with their diameter: [11.869 15.823 11.869] mole/s

For row of ESP's with $E_o = E_p$ = 1V/m, the migration velocity vector for particles of different diameters calculated by the above given formula is as follows:
w_e = [0.0118 0.0166 0.0213] m/s
The corresponding efficiencies calculated from Matts-Ohnfeldt relationship with k=0.5 will be:
η = [0.18 0.21 0.23]
Vector giving removed mass with particle diameter after first ESP is: [2.136 3.323 2.73] mole/s
Vector giving mass transported to 2nd ESP is: [9.733 12.5 9.139] mol/s
Vector giving removed mass with particle diameter after second ESP is: [1.752 2.25 1.645] mole/s
Vector giving mass transported to 3rd ESP is: [7.98 10.25 7.494] mole/s
Vector giving removed mass with particle diameter after third ESP is: [1.437 1.845 1.349] mole/s
Vector exiting 3rd ESP is: [6.544 8.405 6.145] mole/s
Vector giving total removed mass in this 3-ESP system: [5.325 7.418 5.724] mole/s

For row of ESP's with $E_o = E_p$ = 2V/m, the migration velocity vector for particles of different diameters calculated by the above given formula is as follows:
w_e = [0.0474 0.0664 0.0852] m/s
The corresponding efficiencies calculated from Matts-Ohnfeldt relationship with k=0.5 will be:
η = [0.327 0.374 0.412]
Vector giving removed mass with particle diameter after first ESP is: [3.881 5.918 4.89] mole/s
Vector giving mass transported to 2nd ESP is: [7.988 9.905 6.979] mol/s
Vector giving removed mass with particle diameter after second ESP is: [2.612 3.239 2.282] mole/s
Vector giving mass transported to 3rd ESP is: [5.376 6.666 4.697] mole/s
Vector giving removed mass with particle diameter after third ESP is: [1.758 2.18 1.536] mole/s
Vector exiting 3rd ESP is: [3.618 4.486 3.161] mole/s
Vector giving total removed mass in this 3-ESP system: [8.251 11.337 8.708] mole/s

Vector giving total moles removed for given diameter: [13.576 18.755 14.433] mole/s

Total moles removed: 46.764 mole/s

Assuming mole fraction of Bromine and Chlorine is same wrt size distribution as in feed.
Thus, Molar rate of Bromine removal: 14.765 mole/s
Molar rate of Chlorine removal: 31.999 mole/s

The corresponding values obtained in DWSIM Custom model is:
Molar rate of Bromine removal: 15.247 mole/s
Molar rate of Chlorine removal: 33.035 mole/s

The errors are most probably introduced due to rounded values used in manual calculation.