ESP Problems

5.1 An ESP must treat 500,000 acfm with 99% efficiency. Assuming an effective drift velocity of 0.4ft/sec, calculate the required plate area in ft^2, and the number of plates if each is 20 ft tall by 10 ft long, and there are 4 mechanical fields.

Solution

Total plate area: $\mathbf{A} = -\frac{Q}{w_e}\ln(1-\eta) = -\frac{500000}{60\times0.4}\ln(1-0.99) = 95941\ ft^2$

每块板的面积$A_S = 20 \times 10 = 200ft^2$,双面集尘时$A_P = 2 \times A_S = 400ft^2$

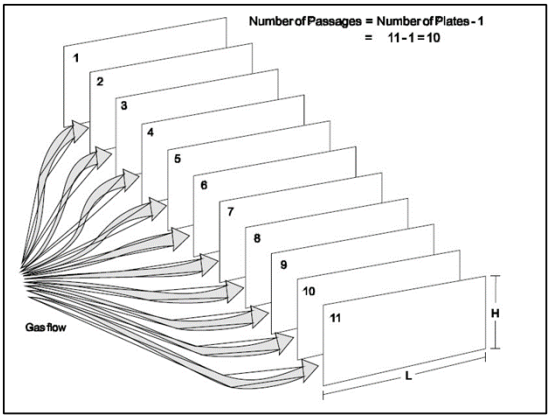
$\because A = A_P(N - N_S)$**(A 为集尘板总面积，$A_P$为集尘板双面面积，N为集尘板总数，$N_s$为电场数)**

$\therefore N = \frac{A}{A_P} + N_s = \frac{95941}{400} + 4 = 243.9$

取整（注意：只能向上取整，不能向下，因为向下取整，面积就达不到95941 ft^2），所以，集尘板数量 N=244 块，总集尘板面积$\mathbf{A} = (244-4) \times 400 = 96000ft^2$, 每个电场的集尘板数量= 61 块，其中，59 块双面集尘，2 块单面集尘【本题仅仅是作为习题，现实中，如此大的烟气量，500000 acfm，至少要分成两个室（two electrical sections）】。

注：

假设一台静电除尘器分成N_S个电场（mechanical fields），那么有$N_S \times 2$块板是单面集尘，其余板是双面集尘。



【图中为每个电场内集尘板的布置示意图，假设有 11 块板，则第 1 块板和第 11 块板是单面集尘，其它位于中间的 9 块板是双面集尘。也就是说每个电场必有 2 块板是单面集尘，其余板是双面集尘。从该图可看出，11 块板有 11-1=10 个通道，烟气就从这 10 个通道流过，在每个通道的正中央布有放电电极（这里没有画出），通电后，放电电极就与集尘极建立静电电场，含尘烟气通过时，尘粒在电场力作用下迁移到集尘极。】

令每块板的单面面积为A_S，双面面积自然为$A_P = 2 \times A_S$。假设整台除尘器有 N 块板，则单面集尘面积+双面集尘面积=集尘总面积，

所以：$A_S \times N_S \times 2 + A_P \times (N - N_S \times 2) = A \implies A_P \times (N - N_S) = A$

这也就是教材中的（5.13）式。

5.2 A coal-burning power plant has two options for fly-ash removal from its stack gases. In either case, a total efficiency of 99.5% must be achieved for a total flow rate of $1{,}000{,}000\text{acfm}$. The options are as follows:
Option A: Use only an ESP. Assume an effective precipitation velocity of 0.3ft/sec.
Option B: Use a multi-cyclone precleaner with an 85% efficiency, followed by an ESP with an effective drift velocity of 0.25ft/sec.
For each option specify, Collection area of the ESP.
Solution

Case A:

Total collection area: $\mathbf{A} = -\frac{Q}{w_e}\ln(1-\eta) = -\frac{1000000}{60\times0.3}\ln(1-0.995) = 294350\ ft^2$

Case B:

$\because\ \eta_T = 1-(1-\eta_{\text{旋风除尘器}})\times(1-\eta_{\text{静电除尘器}})$

$0.995 = 1-(1-0.85)\times(1-\eta_{\text{静电除尘器}})$

$\therefore\ \eta_{\text{静电除尘器}} = 1-\frac{1-0.995}{1-0.85} = 0.967$

Total collection area: $\mathbf{A} = -\frac{Q}{w_e}\ln(1-\eta) = -\frac{1000000}{60\times0.25}\ln(1-0.967) = 227417\ ft^2$

5.3 Design an ESP that is 98.5% efficient in treating $8050\ \text{m}^3/\text{min}$ of gas. Assume the plates are 6.1 m high and 4.1 m long. The effective drift velocity of the particles is $5.2\ \text{m/min}$. The design should include the plate design (total area, layout, number), channel width, gas velocity, number of ducts, aspect ratio, number of mechanical fields and number of electrical sections total, and actual area.

solution

(1)首先选取集尘板间距和烟气流经除尘器的断面风速

取板与板之间的间距（a single channel width 250～500mm）B=400mm（现在基本上建设宽距静电除尘器）

取烟气流经除尘器的断面风速（Gas velocity 0.5～2.5m/s）v=1.2m/s【具体取多少，可根据粒子性质和粒子驱进速度判断，驱进速度越小，风速也要小。本题处理的是 A coal-burning power plant 的烟尘，根据已有运行数据可取 1.2-2.5m/s（教材 table5.1），其它烟尘一般取的风速≤1.0m/s】

(2)计算除尘器的断面积 F（The across area of the ESP）和通道数 N_d

$F = \frac{Q}{v} = \frac{8050}{60\times1.2} = 111.8m^2$

$N_d = \frac{8050}{60\times1.2\times0.4\times6.1} = 45.8$（单个通道宽就是相邻两排集尘板间距 0.4m，高就是集尘板的高 6.1m）

取整，$N_d = 46$

由于烟气量8050 m^3/min较大，分成两个室，每个室的通道数=23.

（3）计算电场数（number of mechanical fields）

Total collection area: $\mathbf{A} = -\frac{Q}{w_e}\ln(1-\eta) = -\frac{8050}{5.2}\ln(1-0.985) = 6501.5\ m^2$

由于是两个室，每个室承担的集尘面积=$\frac{6501.5}{2} = 3250.75\ m^2$

每个室 23 个通道，就有 24 排集尘板，2 排单面集尘，22 排双面集尘，折算后，也就是 23 排双面集尘。

the area of each plate $\boldsymbol{A_P} = 6.1\times4.1\times2 = 50\ m^2$

单块集尘板长度达 4.1 m，这已经是一个电场长度了，所以，需要的电场数

number of mechanical fields $N_s = \frac{3250.75}{50\times23} = 2.8$

取整$N_s = 3$

至此，我们得到该静电除尘器为双室 3 电场，电场中集尘板间距为 400mm，单室 23 个通道（双室 46 个），据此，重新核算相关参数：

number of chambers =2

number of mechanical fields N_s=3

number of ducts N_d=46

channel width B=400mm

gas velocity=1.2m/s

actual collection area $\boldsymbol{A_a = 46\times50\times3 = 6900}m^2$

number of plates $N = \frac{A}{A_P} + N_s = \frac{6900}{50} + 3 = 141$(有 6 块板为单面集尘，135 块板双面集尘)