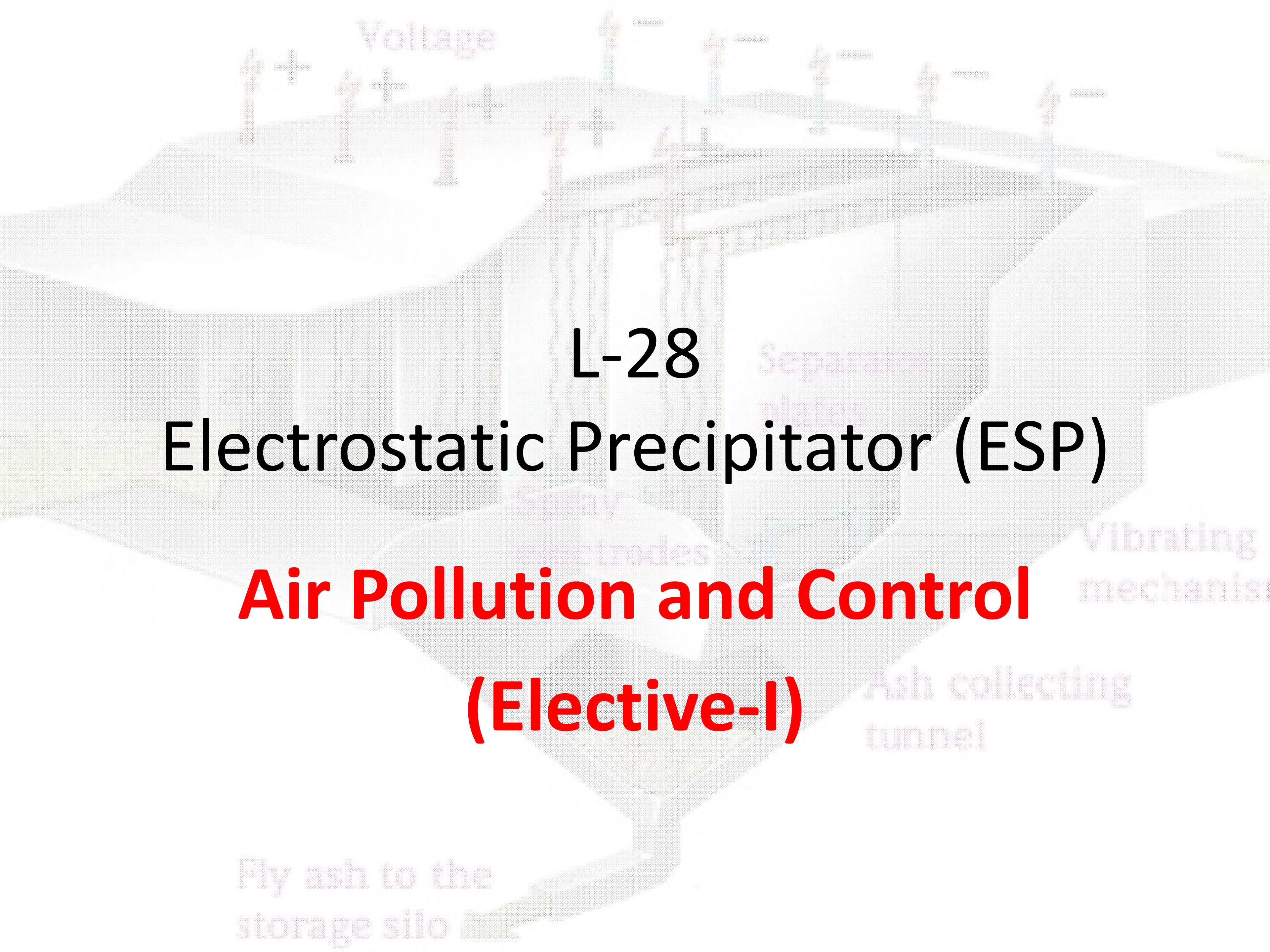


L-28
Electrostatic Precipitator (ESP)

Air Pollution and Control

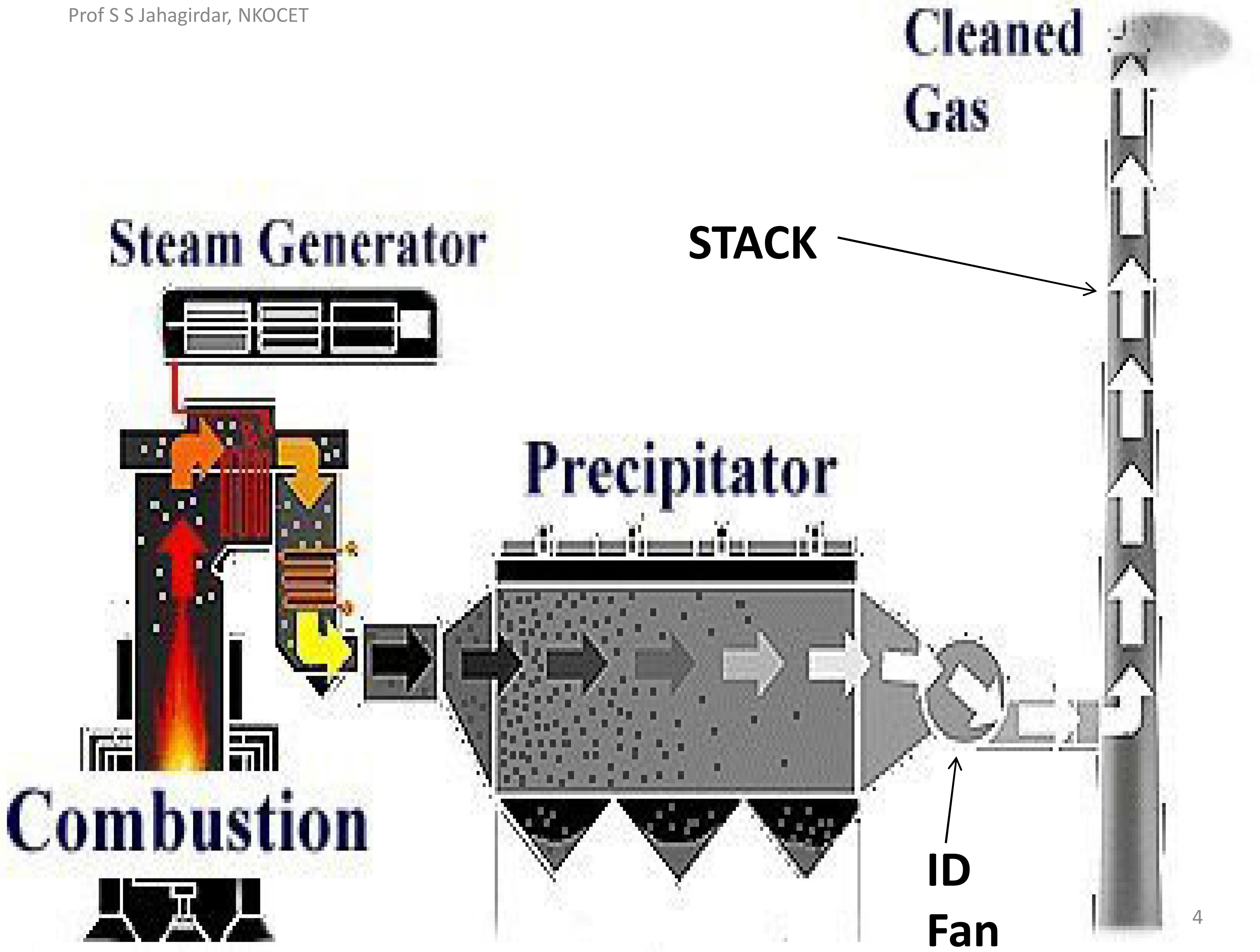
(Elective-I)

Electrostatic Precipitators

- Electrostatic precipitators (ESP) are particulate collection devices that use electrostatic force to remove the particles **less than 5 micron** in diameter.
- It is difficult to use gravity settlers and cyclones effectively for the said range of particles. **Particles as small as one-tenth of a micrometer can be removed** with almost 100% efficiency using electrostatic precipitators.

An electrostatic precipitator is a large, industrial emission-control unit. It is designed to trap and remove dust particles from the exhaust gas stream of an industrial process. Precipitators are used in these industries:

- Power/Electric
- Cement
- Chemicals
- Metals
- Paper


Cleaned
Gas
STACK
Steam Generator
Precipitator
Combustion
ID
Fan

Types of ESP

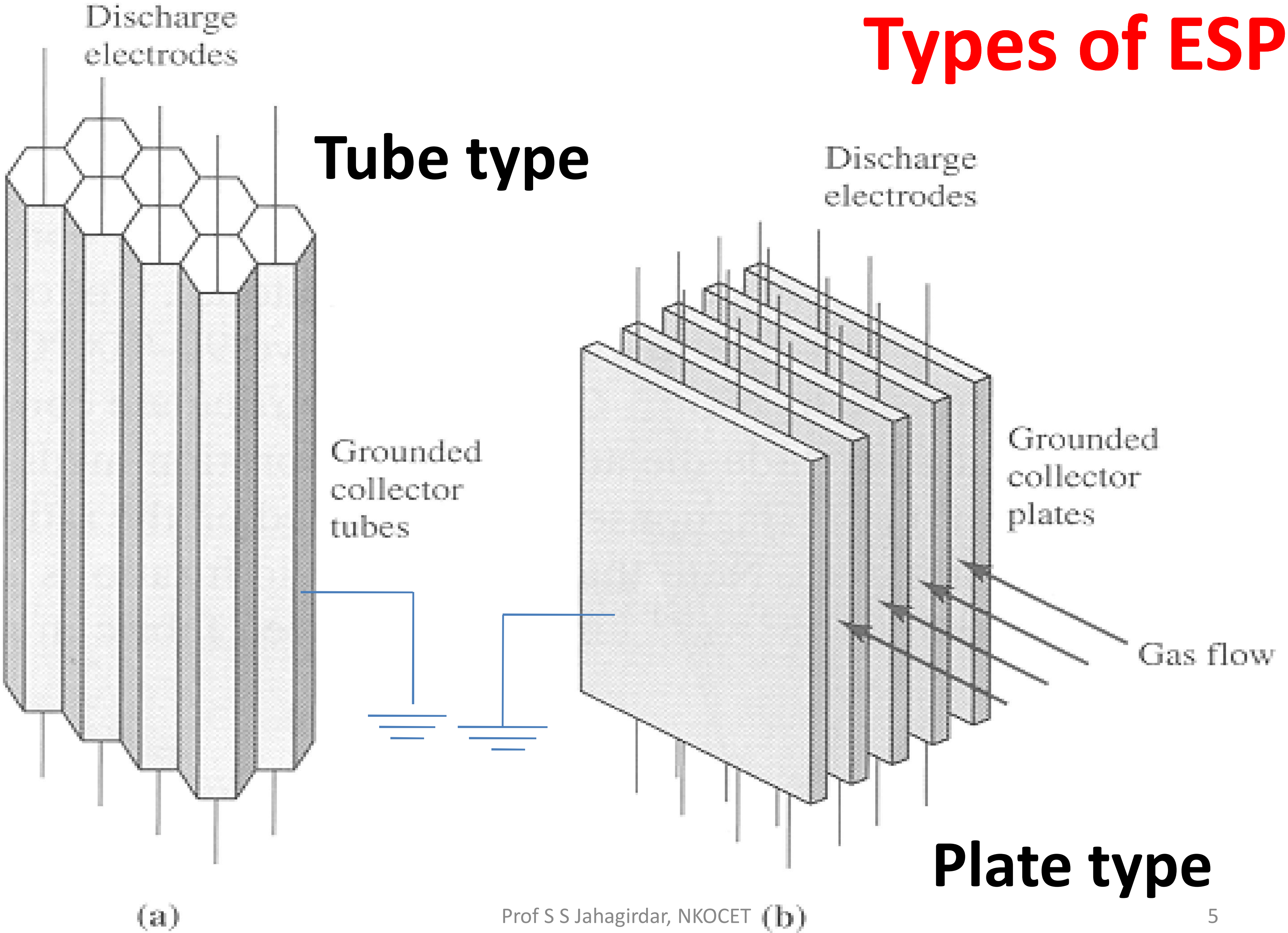
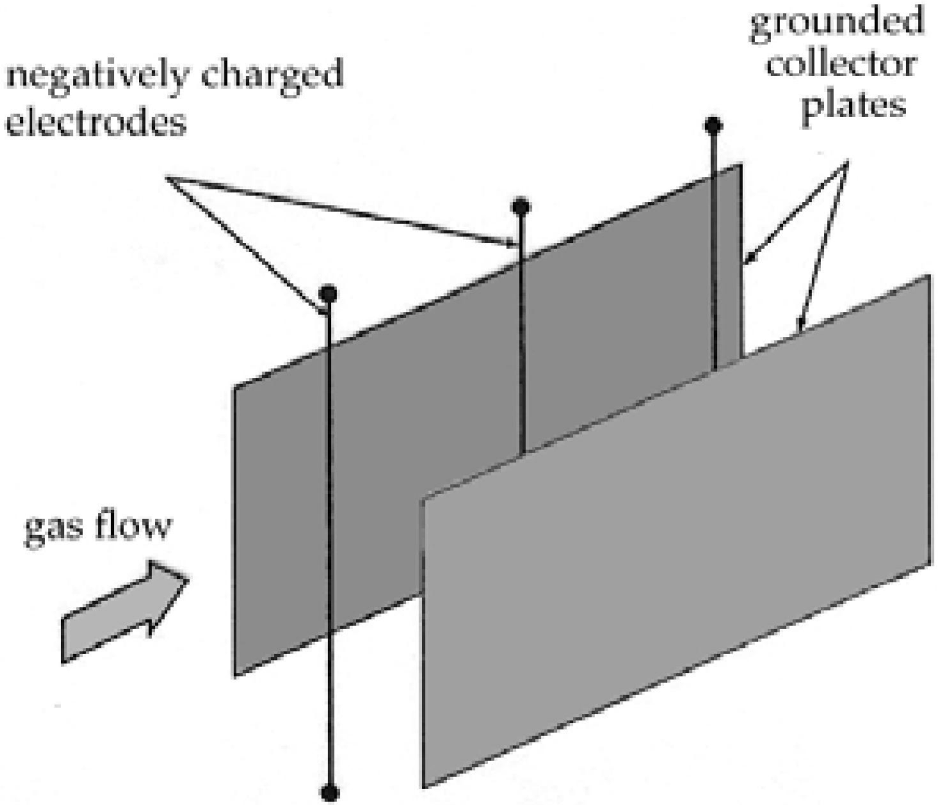

Discharge
electrodes
Tube type
Grounded
collector
tubes
(a)
Discharge
electrodes
Grounded
collector
plates
Gas flow
Plate type
(b)

Plate Type



negatively charged electrodes
grounded collector plates
gas flow

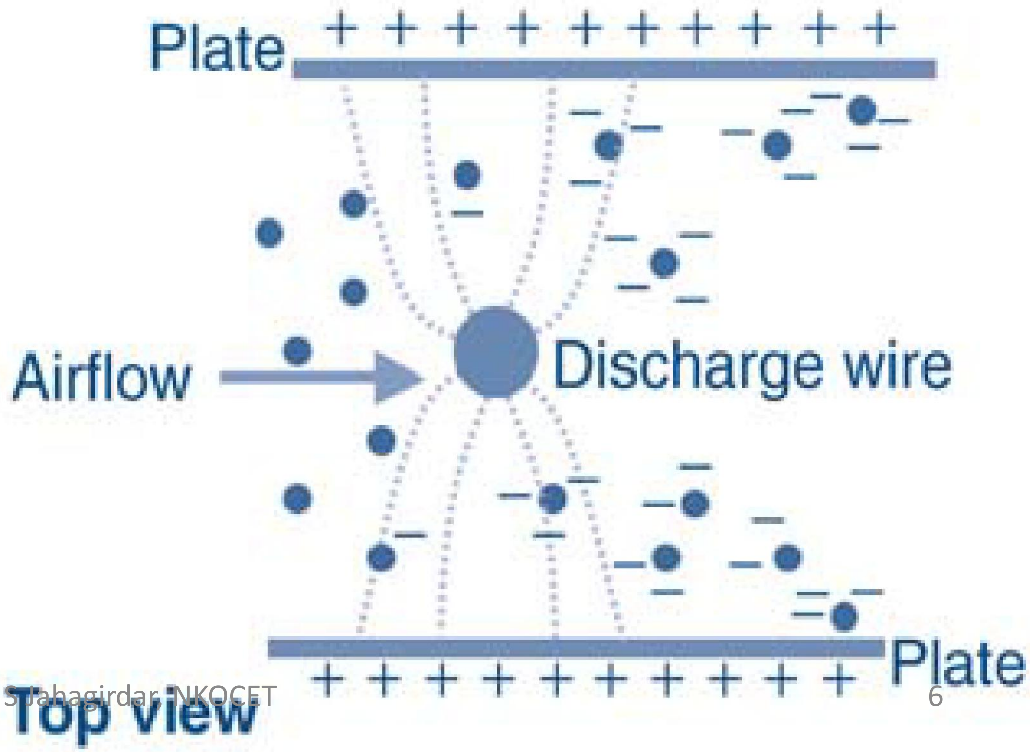


Plate
Airflow
Discharge wire
Plate
Top view

- **<u>Principle of working</u>**
- The **principle** behind all electrostatic precipitators is ***to give electrostatic charge to particles in a given gas stream and then pass the particles through an electrostatic field that drives them to a collecting electrode.***
- The electrostatic precipitators require maintenance of a high potential difference between the two electrodes, one is a discharging electrode and the other is a collecting electrode.

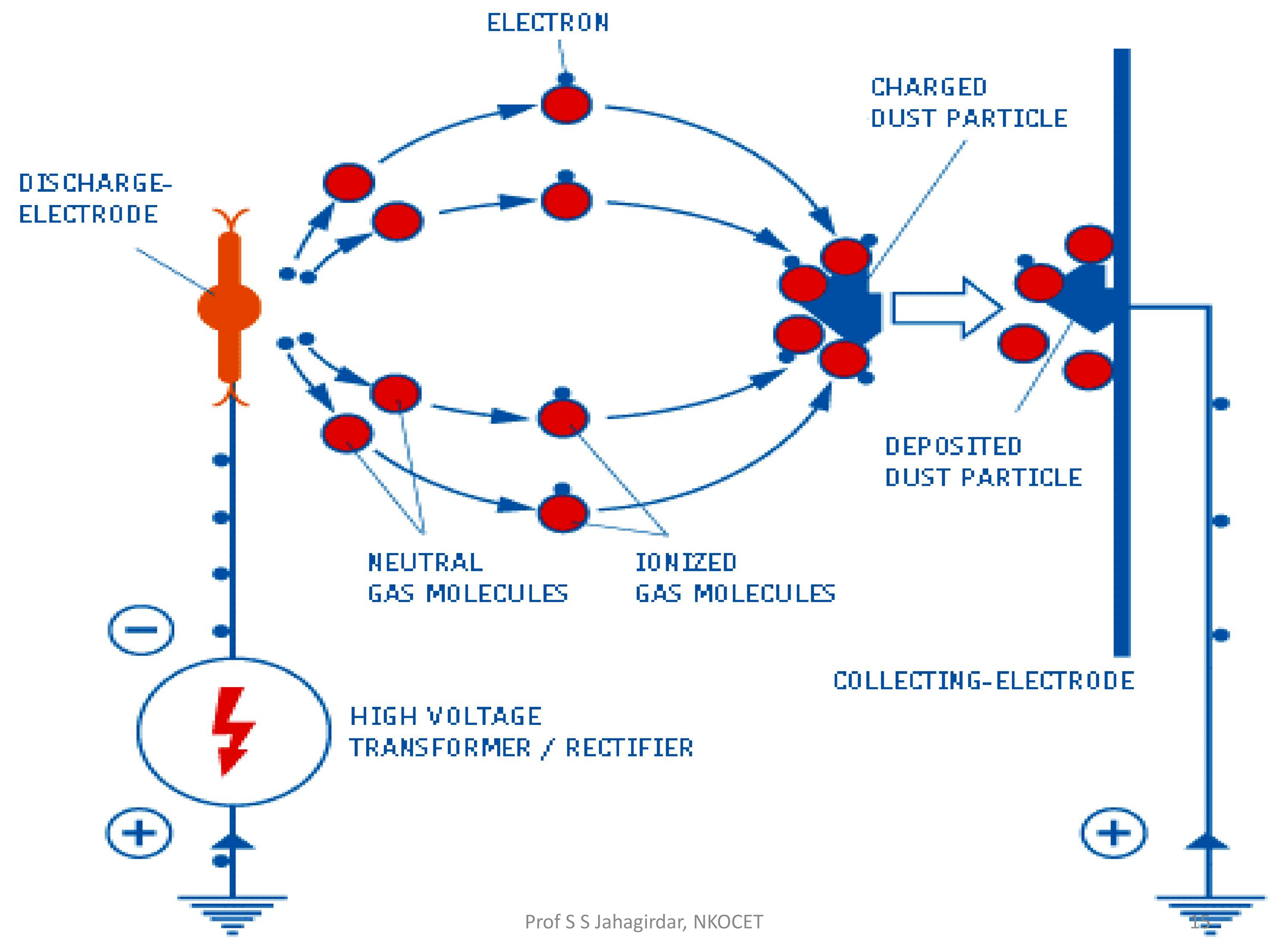
- Because of the high potential difference between the two electrodes, a powerful ionizing field is formed.
- Very high potentials – as high as 100 kV are used. The usual range is 40- 60 kV.
- The ionization creates an active glow zone (blue electric discharge) called the 'corona' or 'corona glow'. Gas ionization is the dissociation of gas molecules into free ions.

- As the particulate in the gas pass through the field, they get charged and migrate to the oppositely charged collecting electrode, lose their charge and are removed mechanically by rapping, vibration, or washing to a hopper below.

- **<u>step by step process of removing particles</u>**

1. **Ionization -** Charging of particles
2. **Migration -** Transporting the charged particles to the collecting surfaces
3. **Collection -** Precipitation of the charged particles onto the collecting surfaces

4. **Charge Dissipation -** Neutralizing the charged particles on the collecting surfaces
5. **Particle Dislodging -** Removing the particles from the collecting surface to the hopper
6. **Particle Removal -** Conveying the particles from the hopper to a disposal point


ELECTRON
CHARGED
DUST PARTICLE
DISCHARGE-
ELECTRODE
DEPOSITED
DUST PARTICLE
NEUTRAL
GAS MOLECULES
IONIZED
GAS MOLECULES
COLLECTING-ELECTRODE
HIGH VOLTAGE
TRANSFORMER / RECTIFIER

Design of Electrostatic Precipitators

- The efficiency of removal of particles by an Electrostatic Precipitator is given by Deutch-Anderson equation

$$\eta = 1 - e^{\left(-\frac{wA}{Q}\right)}$$

η = fractional collection efficiency

ω = drift velocity, m/sec.

A = available collection area, m^2

Q = volumetric flow rate m^3/sec

The particle size of the dust is also very important in the determination of the value of migration velocity for design purposes. The variations in migration velocity result largely from particle size variations. With improved particle sizing techniques, the Deutsch–Anderson equation may be modified as

$$\eta_i = 1 - \exp\left(-\frac{w_i A}{Q}\right) \tag{42}$$

where η_i is the fractional collection efficiency for the *i*th particle size, w_i is the migration velocity of the *i*th particle size, and the overall collection efficiency η is the summation of fractional collection efficiency η_i times mass fraction f_i:

$$\eta = \sum_{i=1}^{n} \eta_i f_{mi} \tag{43}$$

where f_{mi} is the mass fraction of the *i*th particle size.

Number of Passages = number of Plates - 1

=11-1=10

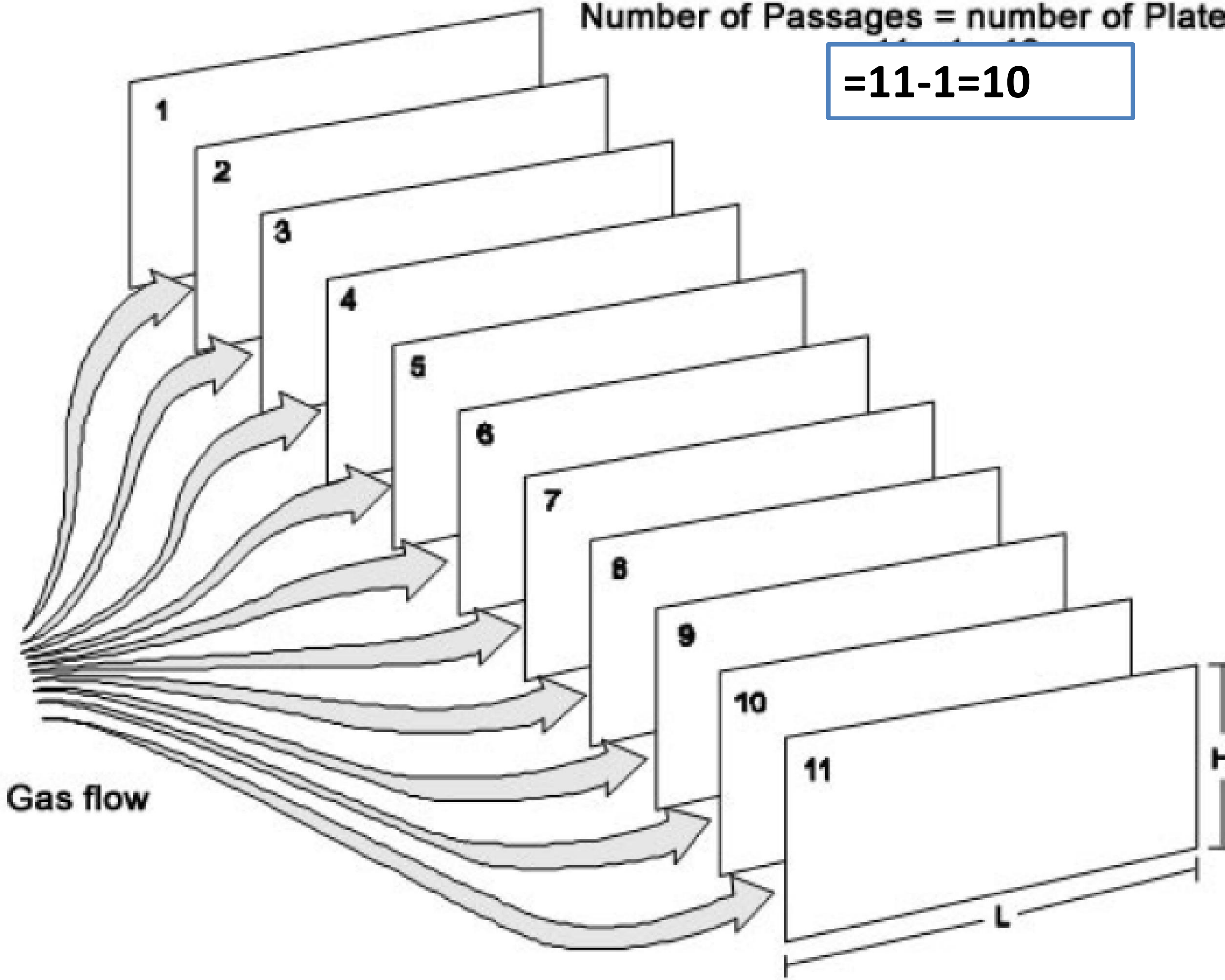


Figure 9-26. Collection plate area calculation

The collection plate area is calculated based on the dimensions of the plate. Since dust collects on both sides of the collection plates in the passages, the collection plate area is calculated using Equation

$$A_i = 2\,(n-1)\,(H)\,(L)$$

Where:

A_i = collection plate area in field i (m^2)

n = number of collection plates across unit

H = height of collection plates (m)

L = length of collection plate in direction of gas flow (m)

Find the collection efficiency of a horizontal-flow, single-stage electrostatic precipitator consisting of two sections formed by plates 4.0 m wide and 6.0 m high on 25-cm centers, handling a gas flow of 2.5 m^3/s. Assume that the migration velocity is 12 cm/s.

Solution

Given: The plate area of each section $A = 4 \times 6 \times 2 = 48\ m^2$

The average flow rate per section $Q = 2.5/2 = 1.25\ m^3/s$

The migration velocity $w = 12$ cm/s = 0.12m/s

For uniform gas velocity,

$$\eta = 1 - \exp(-wA/Q) = 1 - \exp[-(0.12)(48.0)/1.25] = 99\%$$

Find the migration velocity for an existing electrostatic precipitator, which the collection plate area is 110 m^2, gas flow rate is 2.5 m^3/s, and collection efficiency is 99.5%.

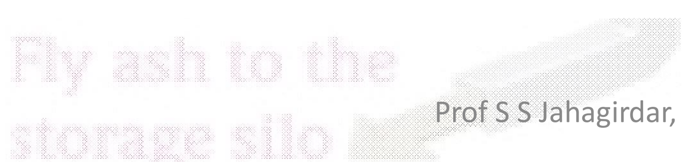
Solution

Given: $\eta = 99.5\%$, $Q = 2.5$ m^3/s, and $A = 110$ m^2

$$\eta = 1 - \exp(-wA/Q)$$

$$0.995 = 1 - \exp[-w(100)/2.5]$$

$$w = \ln(1 - 0.995)(2.5)/(110) = 0.12 \text{ m/s (or 12 cm/s)}$$



Advantages

i) High collection efficiency.
ii) Particles as small as **0.1 micron** can be removed.
iii) Low maintenance and operating cost.
iv) Low pressure drop (0.25-1.25 cm of water).
v) Satisfactory handling of a large volume of high temperature gas.
vi) Treatment time is negligible (0.1-10s).
vii) Cleaning is easy by removing the units of precipitator from operation.
viii) There is no limit to solid, liquid or corrosive chemical usage.

Disadvantages

i) High initial cost.

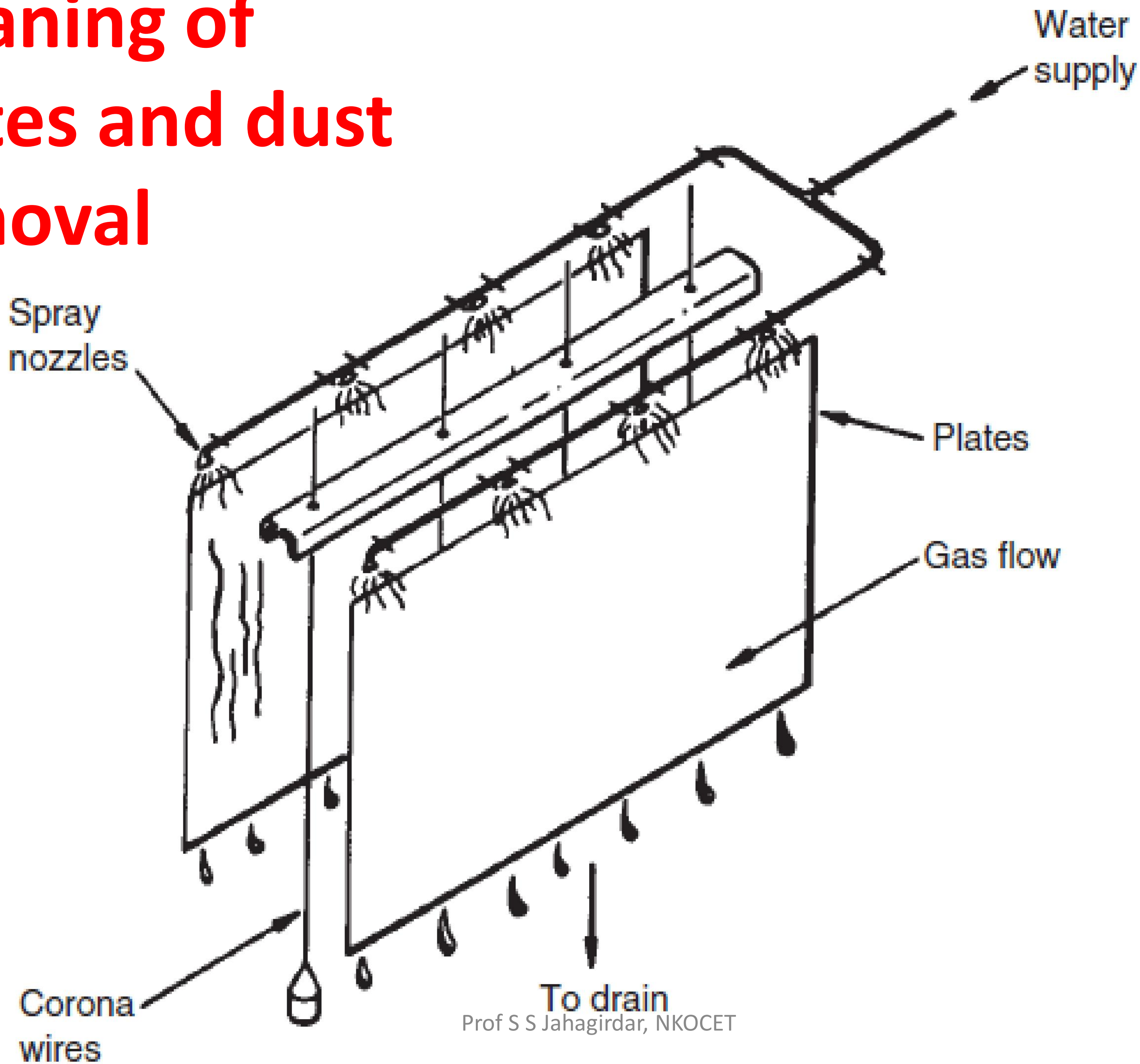
ii) Space requirement is more because of the large size of the equipment.

iii) Possible explosion hazards during collection of combustible gases or particulate.

iv) Precautions are necessary to maintain safety during operation. Proper gas flow distribution, particulate conductivity and corona spark over rate must be carefully maintained.

v) The negatively charged electrodes during gas ionization produce the ozone.

Cleaning of plates and dust removal



Applications of ESPs

i) Cement factories:

a) Cleaning the flue gas from the cement kiln.

b) Recovery of cement dust from kilns.

ii) Pulp and paper mills:

a) Soda-fume recovery in the Kraft pulp mills.

iii) Steel Plants:

a) Cleaning blast furnace gas to use it as a fuel.

b) Removing tars from coke oven gases.

c) Cleaning open hearth and electric furnace gases.

iv) Non-ferrous metals industry:

a) Recovering valuable material from the flue gases.

b) Collecting acid mist.

v) Chemical Industry:

a) Collection of sulfuric and phosphoric acid mist.

b) Cleaning various types of gas, such as hydrogen, CO_2, and SO_2.

c) Removing the dust from elemental phosphorous in the vapor state.

vi) Petroleum Industry:

a) Recovery of catalytic dust.

vii) Carbon Black industry:

a) Agglomeration and collection of carbon black.

viii) Electric Power Industry:

a) Collecting fly ash form coal-fired boilers.

Objective Questions

Q1. Deutch-Anderson equation is given by __________.

Q2. Efficiency of ESP can be above ___%.

Q3. ___________________ force is used to separate particles from gas stream in ESP.

Q4. ______________________ is the first step in removal of particles in ESP.

Q5. As compared to other equipments, _______ is most effective in removing fine particles with more than 99% efficiency.

Theory Questions

- Q1. Explain working of ESP with neat sketch. Discuss advantages and disadvantages.
- Q2. Write equations used in design of ESP. write meanings of each and every term