Mini Project 2.0

AIR POLLUTION CONTROL SYSTEM

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AIR POLLUTION CONTROL EQUIPMENT

The pollution control systems are a must at this time of era. Air contaminants are produced both from natural sources such as volcanic eruptions and wildfires and from sources created by humans which include mobile and stationary ones. Mobile refers to moving sources such as aircraft, trains, and vehicles, while stationary refers to fixed industrial sources such as power plants, factories, and other facilities. Contaminants emitted by either mobile or stationary sources at sufficiently high concentrations may cause adverse effects on the climate, the environment and human life, such as a rise in average global temperatures, a decrease in atmospheric visibility, a decrease in air quality and an impact on human health (Ronquillo, n.d.). The Environmental Quality (Clean Air) Regulations 2014 was enforced by the Department of Environment (DOE) under the Ministry of Environment and Water, which placed controls on all sources of air pollution to help minimize their effects on the atmosphere, the climate and human health

The DOE regulated categories of contaminants are classified into three classes, namely criteria air pollutants, air toxics, and greenhouse gases.

Criteria air pollutants are a group of six common air pollutants, i.e., particulate matter (PM), photochemical oxidants (e.g., ozone), carbon monoxide, sulphur oxide, nitrogen oxide, and lead, which can have a negative impact on public health and wellbeing, the environment, and surrounding structures.

The word 'air toxics' refers to a list of more than 180 air contaminants, e.g., organic chemicals, volatile organic compounds (VOCs), metals, and metal compounds, including oils, solvents, mercury, arsenic, asbestos, and benzene, which, even though present in trace amounts and emitted by fewer sources compared to criteria pollutants, cause dangerous health and environmental effects (Ronquillo, n.d.).

Greenhouse gases (GHGs) refer to gases that both influence human health, including carbon dioxide, chlorofluorocarbons (CFCs), methane and ozone, and lead to the escalation of the Earth's greenhouse effect and the resulting global climate effects.

All in all, the legislation affecting these various categories of air contaminants dictate some of the factors that companies must take into account in order to stay consistent with the DOE requirements, such as installing the required and effective air quality control equipment and systems and minimizing government repercussions.

This report discusses the different types of equipment available for air quality control to counter stationary causes of air emissions and describes their respective functions and mechanisms.

TYPES OF AIR POLLUTION CONTROL SYSTEMS AND EQUIPMENT

About any aspect of the industrial sector, including raw material sourcing, product manufacturing, maintenance and repair facilities, and delivery, produces air pollutants. As a result, many diverse types of air emission control equipment are available across a wide variety of industries for air emissions emitted by both mobile and stationary sources. However, this report focuses primarily on stationary-sourced air pollutant control devices, such as those generated during combustion processes (Ronquillo, n.d.).

Air pollution control equipment is an umbrella term in an industrial setting that refers to equipment and devices used to control and remove the discharge into the air, atmosphere, and surrounding environment of potentially dangerous pollutants, including particulate matter and gases, generated by production, processing systems, and testing applications. In a wide variety of industries, control equipment has applications that avoid the release of pollutants, vapours, and dust and clean and purify the air inside the work area. Fans or blowers usually direct industrial exhaust and emissions through air pollution control equipment and systems that, by using one or more of the following procedures, eliminate or mitigate air pollutants:

a) Combustion (i.e., destroying the pollutant)
b) Conversion (i.e., chemically changing the pollutant to a less harmful compound)
c) Collection (i.e., removing the pollutant from the waste air before its release into the environment and atmosphere)

Some types of air pollution control equipment applied to industrial applications that use one or more of the above listed methods of extracting or minimizing air pollutants include:

1) Scrubbers
2) Air Filters
3) Cyclones
4) Electrostatic Precipitators
5) Mist Collectors
6) Incinerators
7) Catalytic Reactors
8) Biofilters

1. Scrubbers

Scrubbers are one of the most commonly used air pollution control devices in manufacturing and processing facilities. Industrial air scrubbers use a physical method such as scrubbing, that extracts contaminants and gases from industrial pollutants before they are released into the atmosphere, such as smokestack exhaust (in the case of exhaust air scrubbers). There are two main categories of scrubbers which are dry scrubbers and wet scrubbers (Ronquillo, n.d.).

1.1. Dry Scrubbers

Dry scrubbers, also known as dry adsorption scrubbers, inject dry, neutralizing chemical agents into the emission stream, such as sodium bicarbonate, allowing the gaseous contaminants found inside to undergo a chemical reaction that either neutralizes or transforms the pollutants into harmless substances. Filters inside the scrubber chamber capture and remove the spent agents from the cleaned emission gas after the chemical reaction ends. In certain situations, for potential dry scrubbing processes, the collected agents can be washed and reused, however, if not feasible, the scrubbing waste must be disposed of by specialists. Dry scrubbers are commonly used to eliminate or counteract acid gas from industrial emissions. During the dry scrubbing process, the chemical reactions resulting from the addition of neutralizing agents help both reduce the acidity of the emissions and eliminate air pollutants (Ronquillo, n.d.).

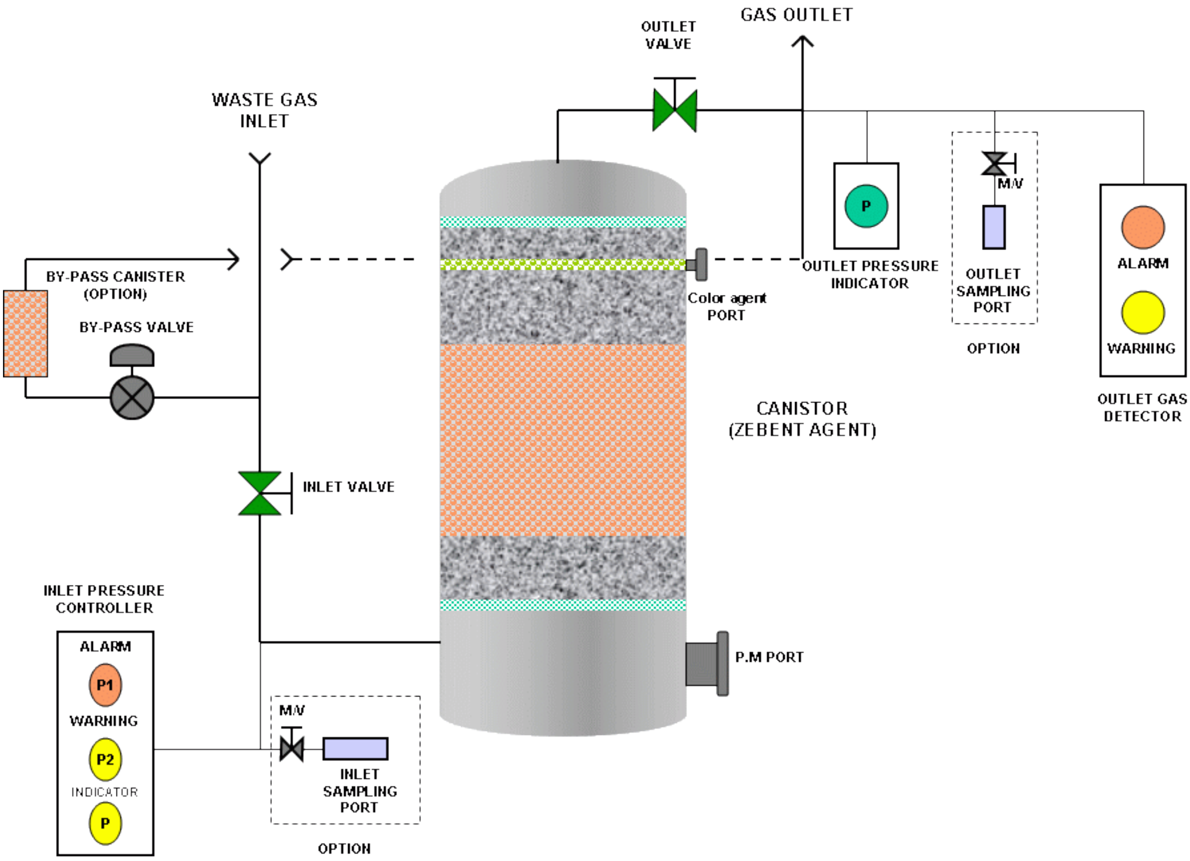

Figure 1: Dry exhaust gas scrubber (Luedicke, n.d.)

1.2. Wet Scrubbers

Wet scrubbers, also known as wet adsorption scrubbers or wet collectors, use liquid solutions for capturing and removing water-soluble gas and particulate contaminants from industrial pollution, usually water. The wet scrubbing process either passes a gas stream through a liquid solution or injects a liquid solution into a gas stream. The solution eliminates the contaminant by extracting it from the water as the gas stream comes into contact with the liquid. The available forms of wet scrubbing equipment include venturi, packed bed (or packed tower), and scrubbers for bubbling (Ronquillo, n.d.).

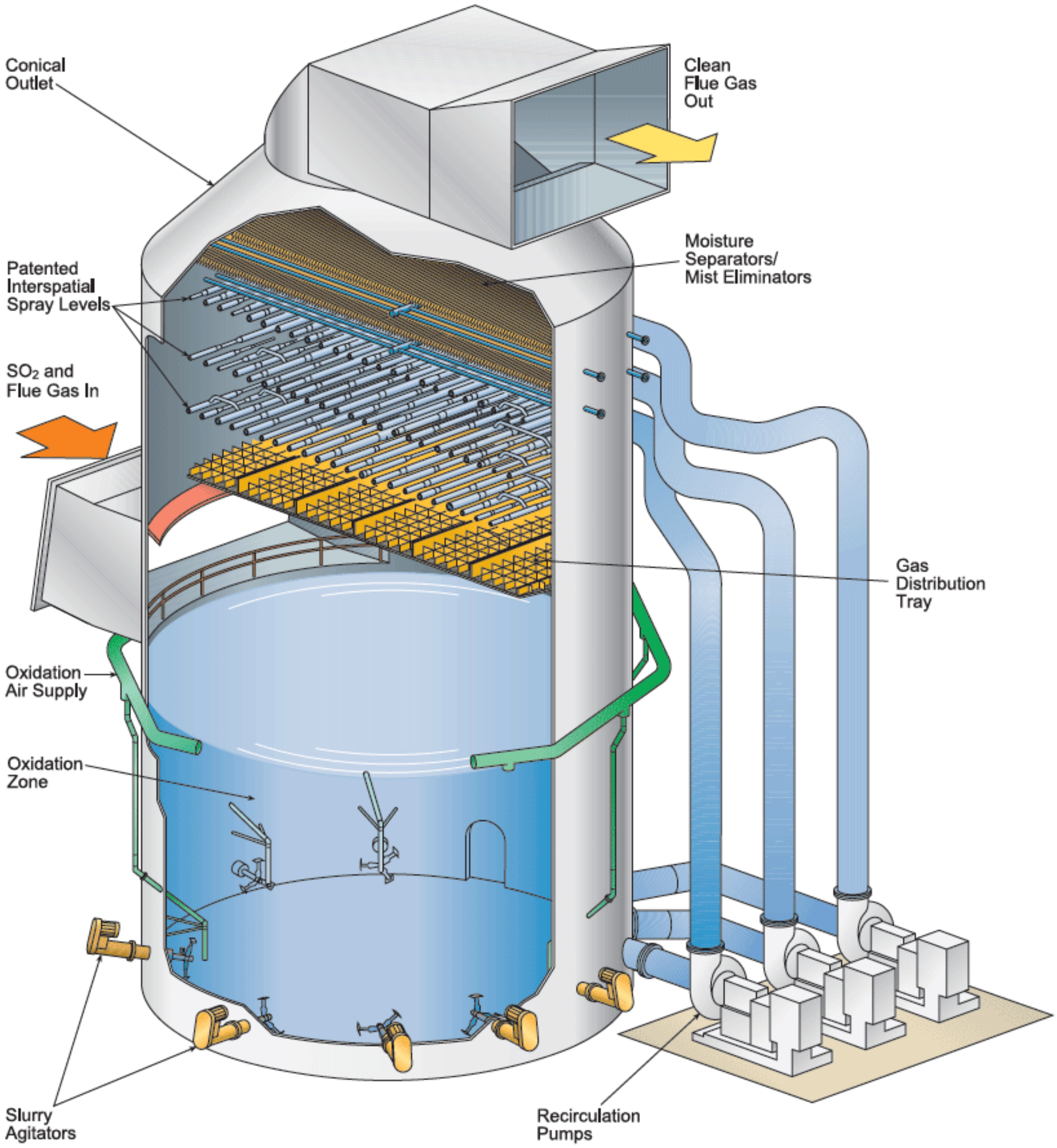

Figure 2: Wet Scrubber (Babcock & Wilcox, n.d.)

2. Air Filters

Air filters are instruments used to regulate air pollution that absorb and remove dry particles and contaminants, such as dust, pollen, bacteria, chemicals, etc., from air moving through them, using a particular form of filtration medium, such as cloth, sintered metal, ceramic, etc. These devices are used to eliminate contaminants from exhaust air and enhance air quality within the work environment in residential, commercial and industrial applications. There are many types of air filters, including HEPA filters, fabric filters, and cartridge dust collectors, available for industrial applications (Ronquillo, n.d.).

2.1 HEPA Filters

Industrial HEPA filters, also referred to as high-efficiency particulate air filters, are a type of air filters that use fibreglass filter mats to eliminate airborne particles from the work atmosphere mechanically, such as pollen, smoke, dust, and bio-contaminants. The fibreglass filter mats usually have fibres varying in size from 0.5 to 2 μm. Particulates bind to or become trapped within the fibres as the blower portion of the filtration device passes air through the HEPA filter. In addition, particles moving through the filter collide with the trapped gas, which slows their velocity and increases their probability of adhering to the filter or being lodged in it (Ronquillo, n.d.).

The filtration system must be configured to achieve a 99.97 percent efficiency for collecting and removing particulates greater than or equal to 0.3 μm in diameter in order to be rated as a HEPA filter. HEPA filters are usually used in combination with other filtration components and systems to filter and further purify the air, such as ultraviolet light, ionizers, and activated carbon air filters, despite their high efficiency.

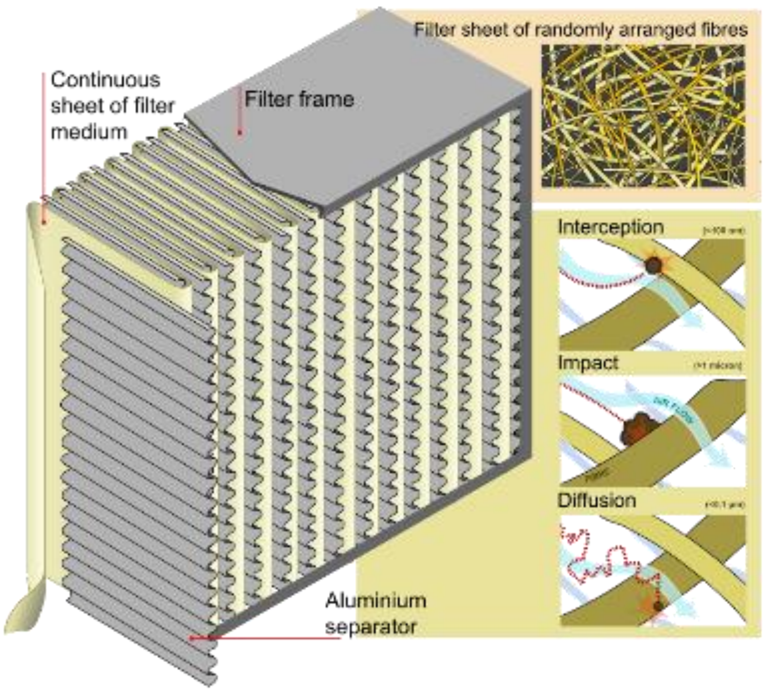

Figure 3: HEPA filter (Wikipedia, n.d.)

2.2 Fabric Filters

Fabric filters are a category of air filters, also referred to as baghouses, that usually use cylindrical fabric bags to trap and remove airborne dust and other particles. The particulates gather and settle on the filter's surface as air passes through a baghouse. The accumulation increases the performance of the filter, allowing the aggregation of smaller particles and creating a pressure build-up in the filter fabric. Some baghouses, even for small particulate matter, are able to attain 99.9 percent efficiency. These filter types are ideal for the filtration of air contaminants in a wide range of industrial processes, including power plants, metal processing centres and foundries, as well as for multi-stage cleaning systems. The accumulation of particulates and the resultant difference in pressure cause the need for regular cleaning. To eliminate the accumulation from the filter bags, there are many methods used by baghouses, including:

- Shaking the filter bags
- Introducing an airflow into the filter bags in the opposite direction to the filtration process
- Pulsing compressed air into the filter bags in the opposite direction to the filtration process

For either of the removal methods described above, particulates fall into a collection hopper for subsequent processing and disposal from the filter fabric to the bottom of the baghouse enclosure.

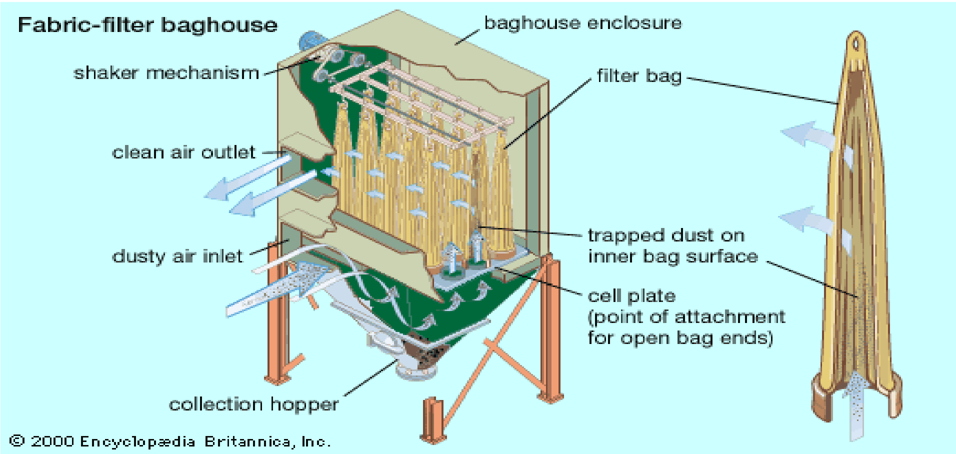

Figure 4: Baghouse filter (Encyclopædia Britannica, Inc., 2000)

2.3 Cartridge Dust Collectors

Cartridge dust collectors, similar to baghouses, are air filters that use cartridge filters to capture and extract airborne dust and other particulates, rather than filter bags. Periodic cleaning and removal are also required for the particulate accumulation on cartridge dust collectors. While, depending on the cartridge content, this type of dust collector can achieve greater efficiencies than a comparable baghouse, it can also be more susceptible to condensation.

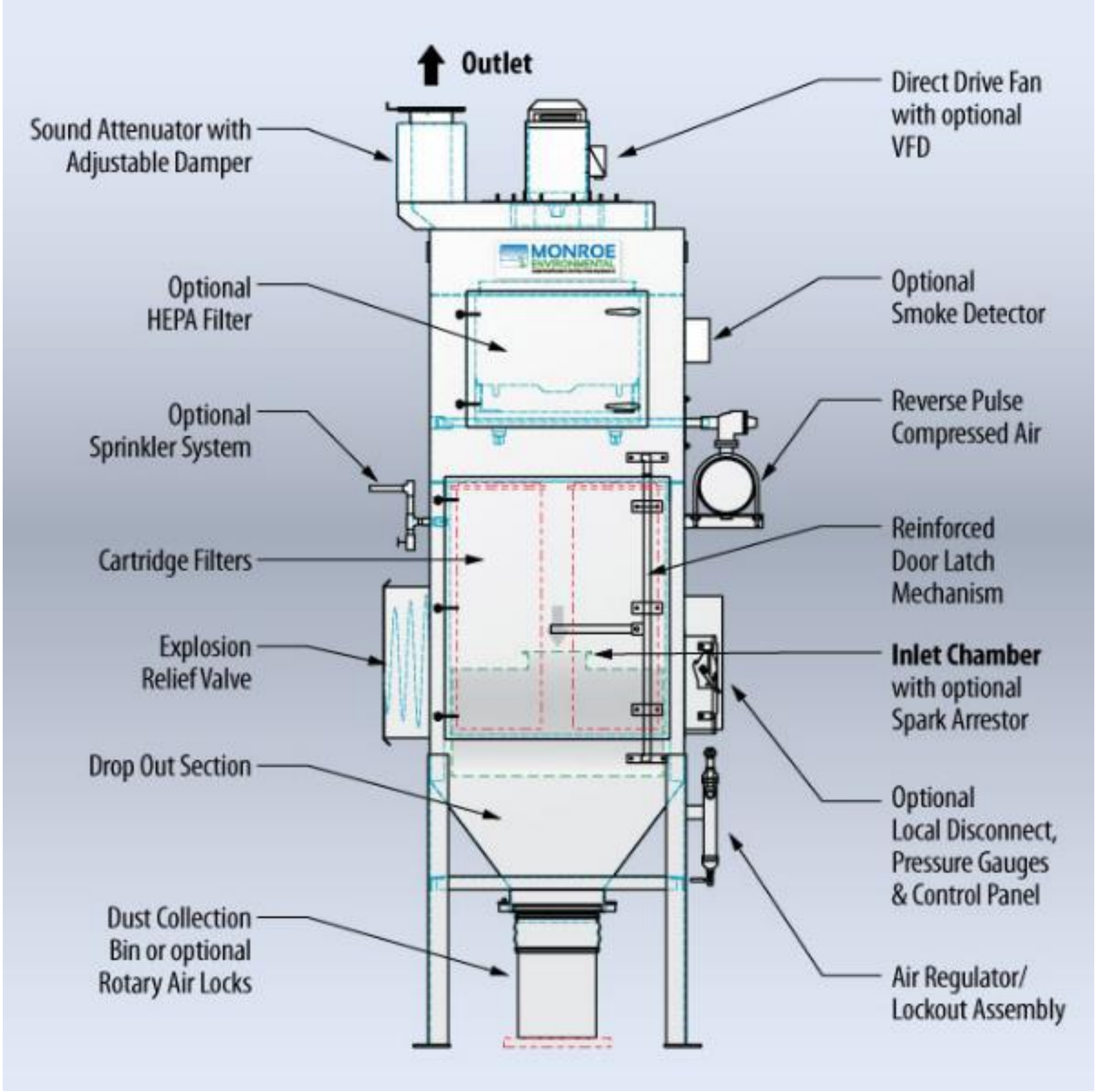

Figure 5: Catridge Dust Collector (Monroe Environmental, 2015)

3. Cyclones

Cyclones, also known as cyclone dust collectors, are instruments for air pollution control that distinguish dry particulate matter from gaseous emissions, similar to air filters. However, cyclones use centrifugal force to absorb and remove particulates rather than using filtration media. They flow along a spiral path inside the cylindrical chamber as gas streams join a cyclone. This spinning motion pushes large particles against the wall of the chamber, which slows their inertia, allowing them for further processing and disposal to drop into the collection hopper below. The gas streams that are washed continue upwards and out of the cyclone (Nathanson, 2019).

Although cyclones are usually used for particulate filtration applications of ≥ 50 µm in diameter, for particulates of ≥ 10-20 µm in diameter, some models are capable of greater than 90 percent effectiveness. Based on bigger or smaller particulate diameters, efficiency increases or decreases. Usually, following cyclones in an air pollution control system, additional filtration systems used to control air pollution, such as baghouses, are used to eliminate the smaller particles not previously isolated and gathered by the cyclones from the gas stream.

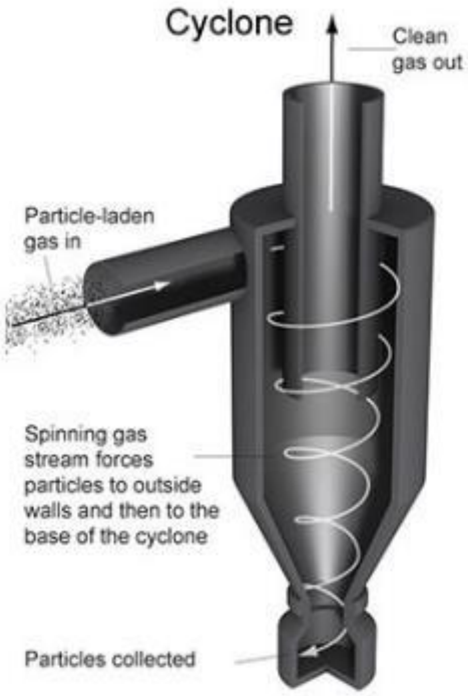

Figure 6: Cyclones (Queensland Government, 2013)

4. Electrostatic Precipitators

Electrostatic precipitators (ESPs) are air pollution control systems used to capture and remove particulate matter, such as dust, from industrial pollutants and exhaust, including air filters and cyclones. To create a high static electrical potential distinction between charging electrodes and collecting plates, ESPs employ transformers. An electrical charge is applied to the particulates when gas streams flow between the two elements, which draws the particulate matter to the collecting plates. PM accumulation is regularly collected from the collecting plates, equivalent to air filters, and deposited in a collection hopper below, either by manually dislodging the particles or by adding water to sweep the particles away. ESPs which use the latter method are referred to as wet ESPs. Since ESPs usually have several collection plates, their output often exceeds 99% (Ronquillo, n.d.).

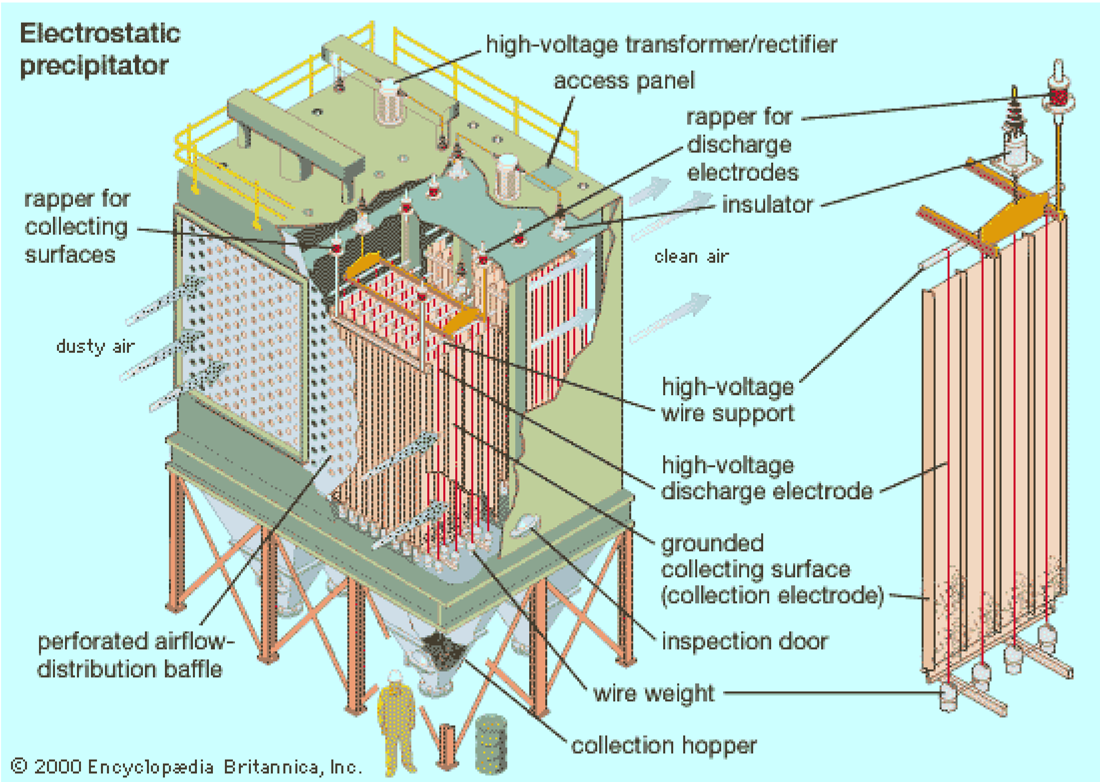

Figure 7: Electrostatic Precipitator (Hosansky, 2011)

5. Mist Collectors

Mist collectors, also known as mist or moisture eliminator filters, are devices for air pollution control that extracts moisture and vapour from gas streams, such as smoke, oil, mist, etc. In order to extract liquid droplets from the gas and collect them into a separate chamber for further processing and, theoretically, recovery and reuse, these devices use fine mesh-like filters.

For submicron liquid particles, mist collectors maintain high filtration efficiencies, with some models providing 99.9 percent efficiency for particles ≥ 0.3 µm in diameter. Though mist collectors are capable of handling acidic and corrosive gas streams, they are unable to handle large particulate gas streams as they can create an obstruction within the filter of the collector. They are often not used in applications with temperatures greater than 120 °F (Ronquillo, n.d.).

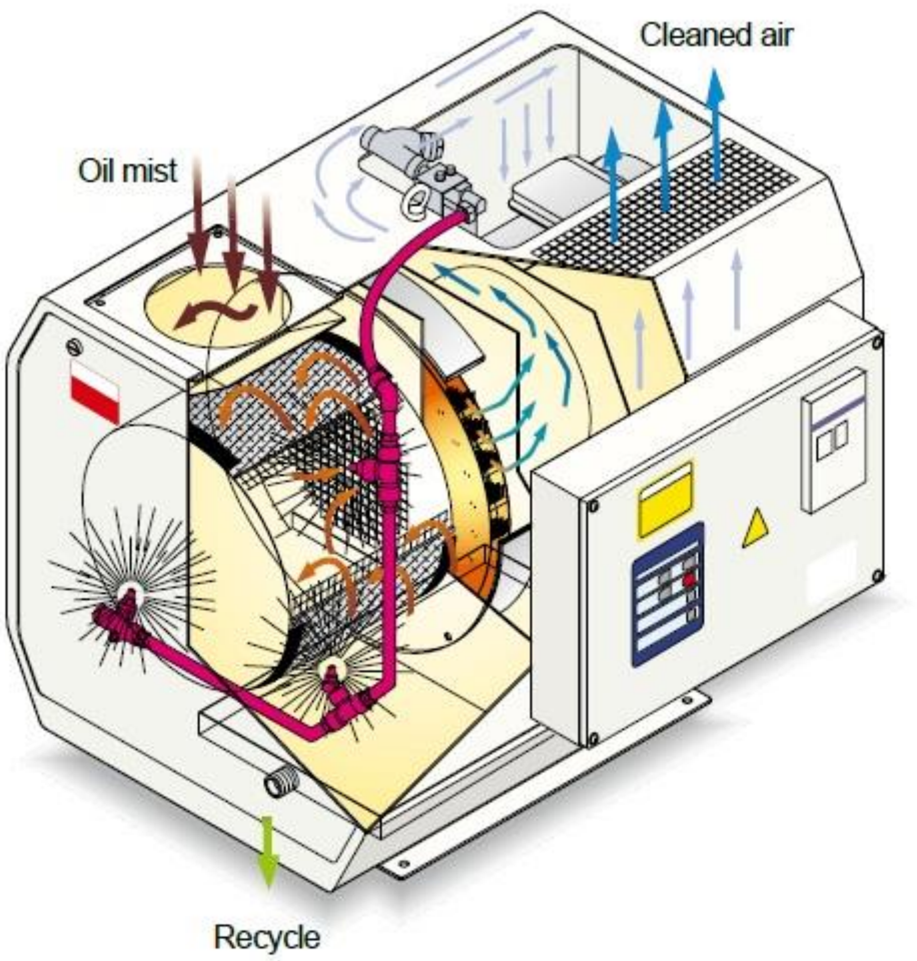

Figure 8: Mist Collector (Engineering360, n.d.)

6. Incinerators

Incinerators are machines that use methods of combustion to break down contaminants into non-toxic by-products. Although these machines may be used to incinerate solid, liquid, and gaseous waste, they are commonly used in a variety of industrial applications by transforming VOCs, hydrocarbons, and other harmful air pollutants (HAP) into harmless compounds, such as carbon dioxide, nitrogen, and oxygen, to preserve air quality and monitor gas emissions. Incinerators in an air pollution control system are usually replaced by scrubbers, as the scrubbing process eliminates any additional compounds produced by the combustion process.

The incineration process may be either self-sustaining, depending on the composition of the waste product, or requires supplementary fuel to ensure full combustion of the waste compounds. In addition, with regenerative and recupe ratory capacities, some incinerator models are available and are suitable for both continuous and batch applications. Several types of incinerators, including thermal oxidizers and catalytic oxidizers, are available (Nathanson, 2019).

6.1. Thermal Oxidizers

Thermal oxidizers, also known as thermal incinerators, are incineration machines that use a combustion process to transform particulate matter and gaseous contaminants into water vapour, carbon dioxide (CO2), and waste heat, such as VOCs, hydrocarbon compounds, and odorous fumes. At 99.99 percent effectiveness, certain forms of thermal oxidizers are able to incinerate air contaminants.

Direct fired thermal oxidizers (also referred to as afterburners), regenerative thermal oxidizers (RTOs), and recuperative thermal oxidizers are among the types of thermal oxidizers accessible. The suitability of each form of thermal oxidizer for an application for incineration depends on the application specifications. Afterburners, for instance, are ideally suited for applications with high VOC concentrations and require low capital expenditure, but do not have heat recovery options. RTOs, on the other hand, though more costly than afterburners, deliver 97 percent heat recovery efficiency capabilities that make them more suitable for low VOC concentrations and continuous incineration activities (Nathanson, 2019).

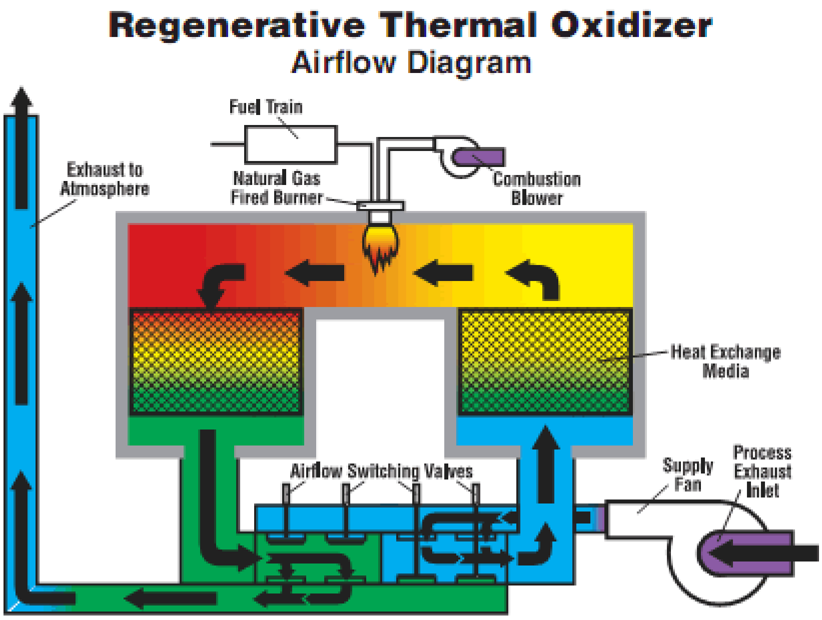

Figure 9: Thermal Oxidizer (The CMM Group, 2015)

6.2. Catalytic Oxidizers

Incinerators that use catalyst beds to assist the incineration process for gaseous pollutants and particulate matter are catalytic oxidizers. The catalyst bed, made of precious or base metal, lowers the temperatures needed to start oxidation, speeds up the process and decreases the amount of combustible compounds required to achieve combustion efficiencies comparable to those of thermal oxidizers. Catalytic oxidizers, like thermal oxidizers, are used to break down VOCs, hydrocarbon compounds and odorous gases in industrial applications. Some catalytic oxidizers are not ideal for incinerating gas and PM-containing emissions because the particles can cover the catalyst bed surface, preventing and disrupting the oxidation process, and newer catalysts allow most gas and PM compounds to be handled by catalytic oxidizers (Nathanson, 2019).

Regenerative catalytic oxidizers (RCO) and recuperative catalytic oxidizers are among the forms of catalytic oxidizers available.

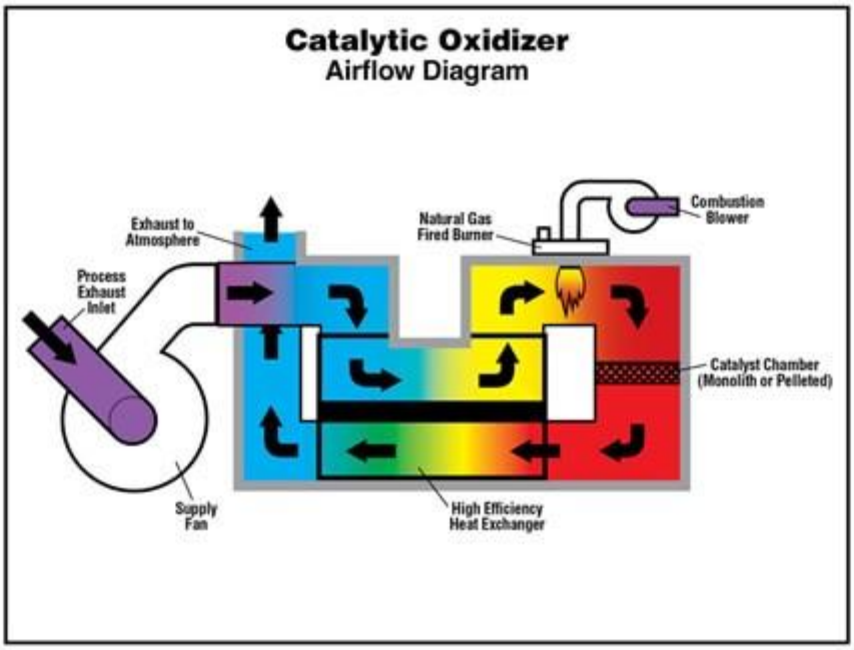

Figure 10: Catalytic Oxidizer (The CMM Group, 2015)

7. Catalytic Reactors

Air pollution control devices typically used to reduce nitrogen oxide (NOx) emissions generated by the burning of fossil fuels in industrial applications are catalytic reactors, often referred to as selective catalytic reduction (SCR) systems. These devices first inject ammonia into the industrial exhaust and pollutants that create nitrogen and oxygen reacting with the NOx compounds. These machines also employ other catalysts, similar to incinerators, allowing some of the remaining gaseous contaminants to undergo combustion for further processing and reduction. In modern vehicles, one typical use of catalytic reactors is to use a three-way catalytic converter in the exhaust system of a vehicle to reduce the quantities of NOx, CO and other VOCs in the engine emissions (Nathanson, 2019).

Although SCR systems can achieve more than 90 per cent efficiencies for NOx reduction and elimination, these machines can achieve 99.99 percent efficiencies for other gaseous emissions with lower energy requirements compared to incinerators. SCR systems are not suitable for all gaseous pollutant reduction applications, despite the high efficiencies available, as the large quantities of catalyst needed are expensive and the systems do not process particulate matter containing pollutants and exhaust.

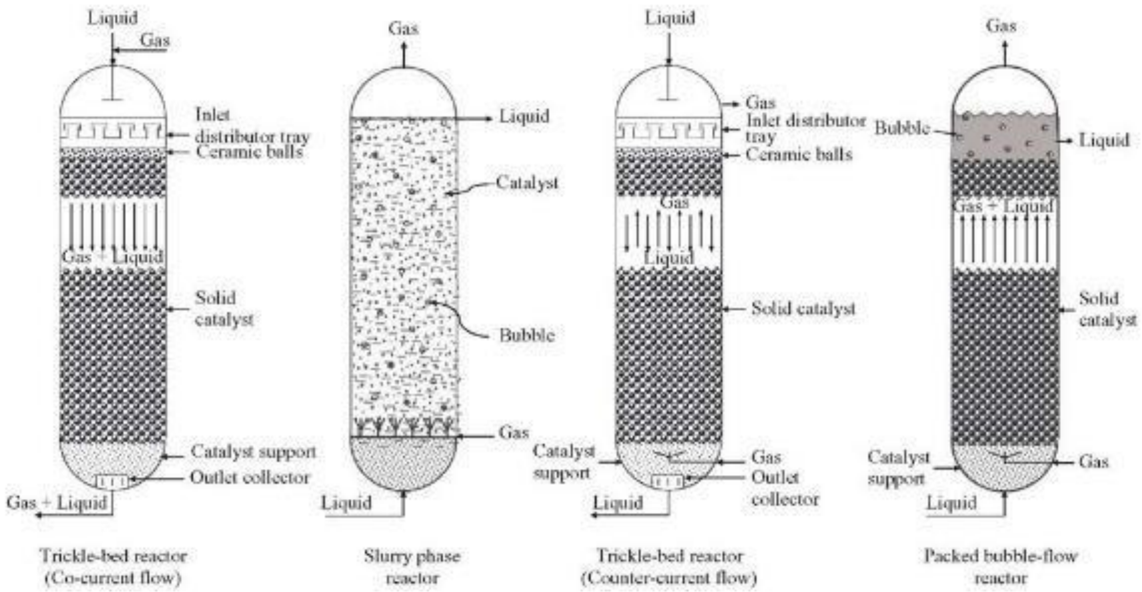

Figure 11: Catalytic reactor (What-When-How: In Depth Tutorials and Information, n.d.)

8. Biofilters

Biofilters are instruments for air pollution control that employ microorganisms to degrade and extract water-soluble materials, such as bacteria and fungi. Biofilters, similar to incineration systems, destroy contaminants in order to minimize the volume of industrial waste and exhaust. However, gaseous contaminants, such as VOCs and organic HAP, are ingested and metabolized by microorganisms in biofilters without producing by-products normally generated by combustion, such as NOx and CO. These instruments are capable of achieving efficiencies of over 98 percent.

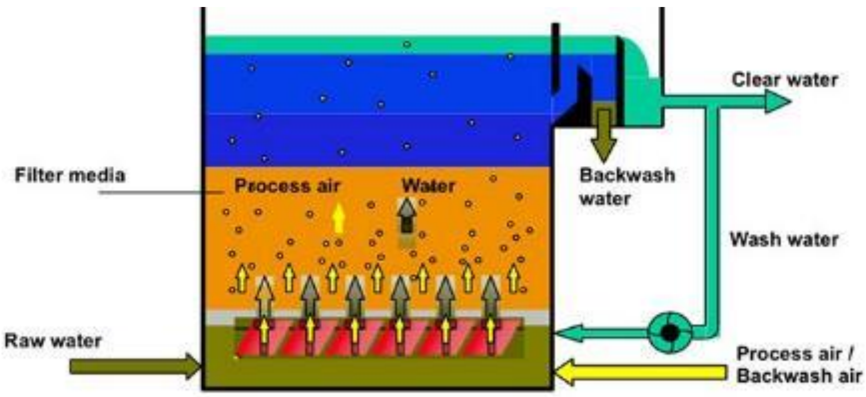

Figure 12: Biofiltration (AquaBiotech, n.d.)

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