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PHARMACEUTICAL AIR-HANDLING SYSTEMS

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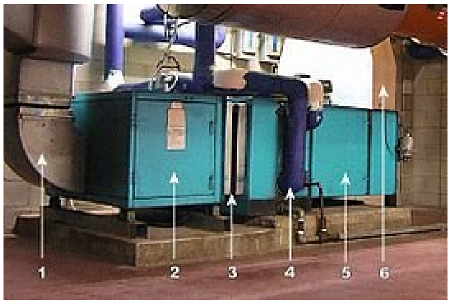
ABSTRACT

Air-handling system is a device used to condition and circulate air as a part of heating, ventilation and air conditioning (HVAC) system. It discusses about the construction of air-handling unit, humidity control, temperature control, air filtration and dust collectors of air-handling unit. In this article we are discussing about the air-handling system use in the pharmaceutical industries and their importance in the improvement of production quality.

KEYWORDS: Air-handling components, humidity control, dehumidifier, air filtration, dust collectors.

INTRODUCTION:

An air handler, or air handling unit, is a device used to condition and circulate air as part of a heating, ventilating, and air-conditioning (HVAC) system. An air handler is usually a large metal box containing a blower, heating or cooling elements filter racks or chambers, sound attenuators, and dampers. Air handlers usually connect to a duct work ventilation system that distributes the conditioned air through the building and returns it to the AHU. Sometimes AHUs discharge (supply) and admit (return) air directly to and from the space served without ductwork[1].Small air handlers, for local use, are called terminal units, and may only include an air filter, coil, and blower; these simple terminal units are called blower coils or fan coil units. A larger air handler that conditions 100% outside air, and no recirculated air, is known as a makeup air unit (MAU).



Air handling unit

RTU

Air flow is from the right to left in this case. Some AHU components shown are
1. Supply duct
2. Fan compartment
3. Vibration isolator ('flex joint')
4. Heating and/or cooling coil
5. Filter compartment
6. Mixed (Recirculated + outside) air duct

RTU:
An air handler designed for outdoor use, typically on roofs, is known as a packaged unit (PU) or rooftop unit (RTU).
Construction: The air handler is normally constructed around a framing system with metal infill panels as required to suit the configuration of the components. In its simplest form the frame may be made from metal channels or sections, with single skin metal infill panels. The metalwork is normally galvanized for long term protection. For outdoor units some form of weatherproof lid and additional sealing around joints is provided.

Larger air handlers will be manufactured from a square section steel framing system with double skinned and insulated infill panels. Such constructions reduce heat loss or heat gain from the air handler, as well as providing acoustic attenuation. Larger air handlers may be several meters long and are manufactured in a sectional manner and therefore, for strength and rigidity, steel section base rails are provided under the unit.

Air handler components:

The major types of components are described here in approximate order, from the return duct (input to the AHU), through the unit, to the supply duct (AHU output).

Filters:

Air filtration is almost always present in order to provide clean dust-free air to the building occupants. It may be via simple low-MERV pleated media, HEPA, electrostatic, or a combination of techniques. Gas-phase and ultraviolet air treatments may be employed as well.Filtration is typically placed first in the AHU in order to keep all the downstream components clean. Depending upon the grade of filtration required, typically filters will be arranged in two (or more) successive banks with a coarse-grade panel filter provided in front of a fine-grade bag filter, or other "final" filtration medium. The panel filter is cheaper to replace and maintain, and thus protects the more expensive bag filters. The life of a filter may be assessed by monitoring the pressure drop through the filter medium at design air volume flow rate. This may be done by means of a visual display using a pressure gauge, or by a pressure switch linked to an alarm point on the building control system. Failure to replace a filter may eventually lead to its collapse, as the forces exerted upon it by the fan overcome its inherent strength, resulting in collapse and downstream ductwork.

Heating or cooling elements:

Air handlers may need to provide heating, cooling, or both to change the supply air temperature, and humidity level depending on the location and the application. Such conditioning is provided by heat exchanger coil(s) within the air handling unit air stream; such coils may be direct or indirect in relation to the medium providing the heating or cooling effect. Direct heat exchangers include those for gas-fired fuel-burning heaters or a refrigeration evaporator, placed directly in the air stream. Electric resistance heaters and heat pumps can be used as well. Evaporative cooling is possible in dry climates. Indirect coils use hot water or steam for heating, and chilled water for cooling.Coils are typically manufactured from copper for the tubes, with copper or aluminium fins to aid heat transfer. Cooling coils will also employ eliminator plates to remove and drain condensate. The hot water or steam is provided by a central boiler, and the chilled water is provided by a central chiller. Downstream temperature sensors are typically used to monitor and control "off coil" temperatures, in conjunction with an appropriate motorized control valve prior to the coil.If dehumidification is required, then the cooling coil is employed to over-cool so that the dew point is reached and condensation occurs. A heater coil placed after the cooling coil re-heats the air (therefore known as a re-heat coil) to the desired supply temperature. This has the effect of reducing the relative humidity level of the supply air.In colder climates, where winter temperatures regularly drop below freezing, then frost coils or pre-heat coils are often employed as a first stage of air treatment to ensure that downstream filters or chilled water coils are protected against freezing. The control of the frost coil is such that if a certain off-coil air temperature is not reached then the entire air handler is shut down for protection.

Humidifier:

Humidification is often necessary in colder climates where continuous heating will make the air drier, resulting in uncomfortable air quality and increased static electricity. Various types of humidification may be used:

- Evaporative: dry air blown over a reservoir will evaporate some of the water. The rate of evaporation can be increased by spraying the water onto baffles in the air stream.
- Vaporizer: steam or vapor from a boiler is blown directly into the air stream.
- Spray mist: water is diffused either by a nozzle or other mechanical means into fine droplets and carried by the air.
- Ultrasonic: A tray of fresh water in the airstream is excited by an ultrasonic device forming a fog or water mist.
- Wetted medium: A fine fibrous medium in the airstream is kept moist with fresh water from a header pipe with a series of small outlets. As the air passes through the medium it entrains the water in fine droplets. This type of humidifier can quickly clog if the primary air filtration is not maintained in good order.

Mixing chamber:

In order to maintain indoor air quality, air handlers commonly have provisions to allow the introduction of outside air into, and the exhausting of air from the building. In temperate climates, mixing the right amount of cooler outside air with warmer return air can be used to approach the desired supply air temperature. A mixing chamber is therefore used which has dampers controlling the ratio between the return, outside, and exhaust air.

Blower/fan:

Air handlers typically employ a large squirrel cage blower driven by an AC induction electric motor to move the air. The blower may operate at a single speed, offer a variety of set speeds, or be driven by a Variable Frequency Drive to allow a wide range of air flow rates. Flow rate may also be controlled by inlet vanes or outlet dampers on the fan. Some residential air handlers (central "furnaces" or "air conditioners") use a brushless DC electric motor that has variable speed capabilities.

Heat recovery device:

A heat recovery device heat exchanger of many types, may be fitted to the air handler between supply and extract air streams for energy savings and increasing capacity. These types more commonly include for:

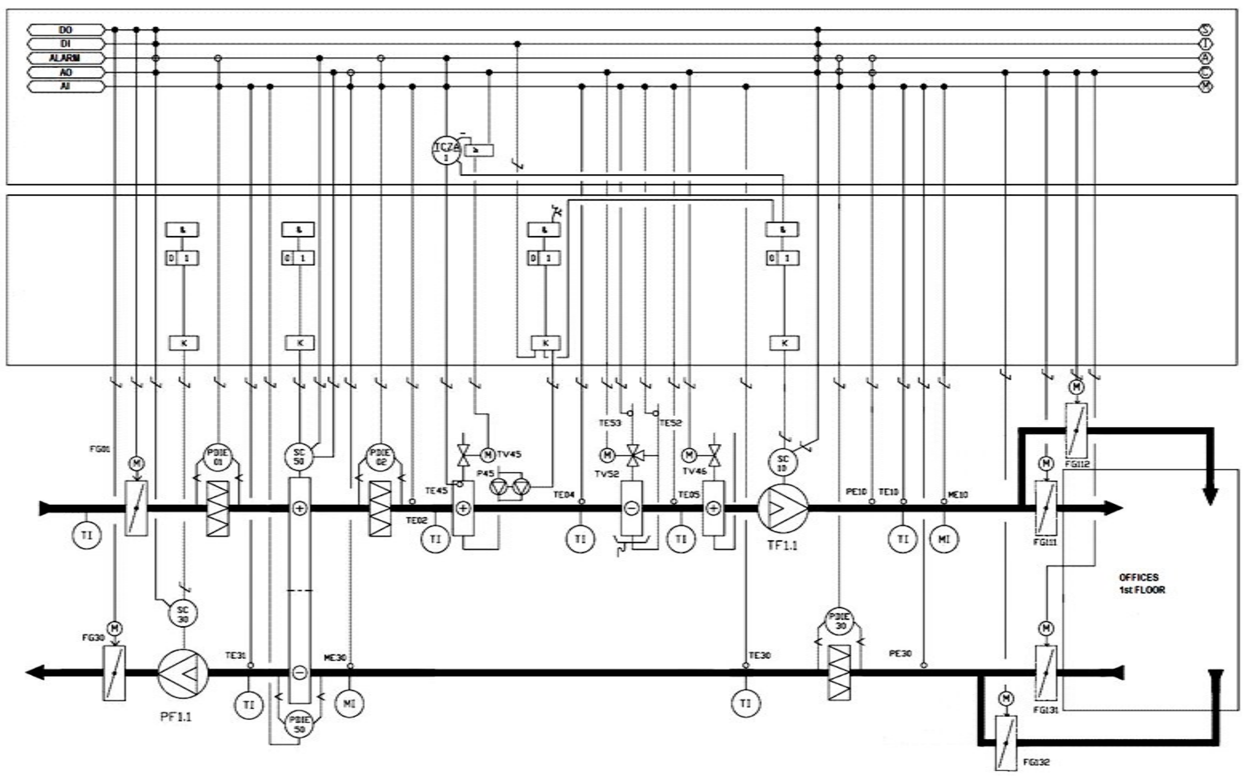
- Recuperator, or Plate Heat exchanger: A sandwich of plastic or metal plates with interlaced air paths. Heat is transferred between airstreams from one side of the plate to the other. The plates are typically spaced at 4 to 6mm apart. Can also be used to recover cloth. Heat recovery efficiency up to 70%.
- Thermal Wheel, or Rotary heat exchanger: A slowly rotating matrix of finely corrugated metal, operating in both opposing airstreams. When the air handling unit is in heating mode, heat is absorbed as air passes through the matrix in the exhaust airstream, during one half rotations, and released during the second half rotation into the supply air stream in a continuous process. When the air handling unit is in cooling mode, heat is released as air passes through the matrix in the exhaust air stream, during one half rotations, and absorbed during the second half rotation into the supply air stream. Heat recovery efficiency up to 85%. Wheels are also available with a hydroscopic coating to provide latent heat transfer and also the drying or humidification of airstreams
- Run around coil: Two air to liquid heat exchanger coils, in opposing air streams, piped together with a circulating pump and using water or a brine as the heat transfer medium. This device, although not very efficient, allows heat recovery between remote and sometimes multiple supply and exhaust airstreams. Heat recovery efficiency up to 50%.
- Heat Pipe: Operating in both opposing air paths, using a confined refrigerant as a heat transfer medium. The heat pipe uses multiple sealed pipes mounted in a coil configuration with fins to increase heat transfer. Heat is absorbed on one side of the pipe, by evaporation of the refrigerant, and released at the other side, by condensation of the refrigerant. Condensed refrigerant flows by gravity to the first side of the pipe to repeat the process. Heat recovery efficiency up to 65%.

Controls:

Controls are necessary to regulate every aspect of an air handler, such as: flow rate of air, supply air temperature, mixed air temperature, humidity, air quality.

Vibration isolators:

The blowers in an air handler can create substantial vibration and the large area of the duct system would transmit this noise and vibration to the occupants of the building. To avoid this, vibration isolators (flexible sections) are normally inserted into the duct immediately before and after the air handler and often also between the fan compartment and the rest of the AHU. The rubberized canvas-like material of these sections allows the air handler components to vibrate without transmitting this motion to the attached ducts.The fan compartment can be further isolated by placing it on a spring suspension, which will mitigate the transfer of vibration through the floor.



Control diagram of an advanced air handling unit

The air handling unit includes a heat recovery unit, pre- and post heaters and a cooling unit for temperature and humidity control.Supply air fan TF1.1 and exhaust air fan PF1.1 are controlled withvariable frequency drives SC10 and SC30. In addition, the system is equipped with several dampers,filters and a separate device TCZA1 for frost protection.

Functional description:

The air handling unit affects to the temperature and humidity inside the building. In this case the
Control is based on several principles. The supply air temperature should be kept constant to allow the adjustment of temperature in each room with separate thermostats or dampers. The supply air humidity (ME10) must not exceed a certain level. Also the circulation of air should always be sufficient.The temperature control can be roughly divided in to two scenarios.

When the outside temperature is lower than the indoor temperature, the sequence of operation is as follows: First the cooling valve TV52 is closed after which the speed of the heat recovery wheel SC50 is increased. If the set point temperature is not achieved with the HRW, then additional heating is acquired by opening the preheating valve TV45 and after that the post heating valve TV46.When the outside temperature is higher than the indoor temperature, the HRW should be always on.If the cooling power of the heat recovery wheel is insufficient additional cooling is acquired by opening the cooling valve TV52. In case the HRU starts to frost, its rotation speed is decreased according to a pressure difference measurement PDIE50.

The circulation of air is kept at an adequate level with the exhaust (PF1.1) and supply air (TF1.1) fans. Their run speeds are adjusted according to pressure measurements PE30 and PE10. When the supply air humidity exceeds a predefined level, it will be dried by adjusting the cooling coil valve TV52. When this happens, the supply air temperature is kept at the desired, constant level with the HRU and the pre and post heaters.Whenever an alarm that is severe enough is triggered, the system will be shut down. All three variable frequency drives (SC10, SC30, SC50) are set to zero speed and the exhaust and intake air dampers are closed.A separate frost protection device will prevent the preheating coil from freezing by over riding the control signal of the heating valve TV45 if the temperature TE45 of the heating coil is too low. Pressure difference measurements PDIE01, PDIE02 and PDIE30 will cause an alarm in case a filter gets too dirty and the pressure difference gets too big.

Temperature control

Temperature control is a process in which change of temperature as a space(and objects are collectively there within) is measured or otherwise detected,and the passage of heat energy into or out of the energy is adjusted to achieve a desired average temperature.

Control loops

A home thermostat is an example of a closed control loop: It constantly assesses the current room temperature and controls a heater and/or air conditioner to increase or decrease the temperature according to user-defined setting(s). A simple (low-cost, cheap) thermostat merely switches the heater or air conditioner either on or off, and temporary overshoot and undershoot of the desired average temperature must be expected. A more expensive thermostat varies the amount of heat or cooling provided by the heater or cooler, depending on the difference between the required temperature (the "setpoint") and the actual temperature. This minimizes over/undershoots. The process is called PID and is implemented using a PID Controller

Energy balance:

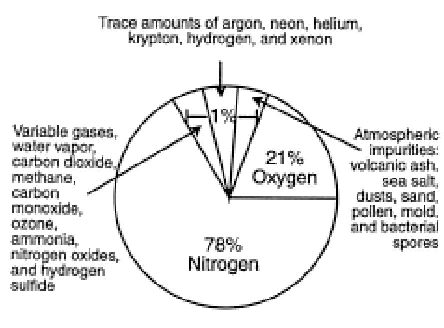
An object's or space's temperature increases when heat energy moves into it, increasing the average kinetic energy of its atoms, e.g., of things and air in a room. Heat energy leaving an object or space lowers its temperature. Heat flows from one place to another (always from a higher temperature to a lower one) by one or more of three processes: conduction, convection and radiat ion. In conduction, energy is passed from one atom to another by direct contact. In convection, heat energy moves by conduction into some movable fluid (such as air or water) and the fluid moves from one place to another, carrying the heat with it. At some point the heat energy in the fluid is usually transferred to some other object by means conduction again. The movement of the fluid can be driven by negative-buoyancy, as when cooler (and therefor denser) air drops and thus upwardly displaces warmer (less-dense) air (natural convection), or by fans or pumps (forced convection). In radiation, the heated atoms make electromagnetic emissions absorbed by remote other atoms, whether nearby or at astronomical distance. For example, the Sun radiates heat as both invisible and visible electromagnetic energy. What we know as "light" is but a narrow region of the electromagnetic spectrum.

If, in a place or thing, more energy is received than is lost, its temperature increases. If the amount of energy coming in and going out is exactly the same, the temperature stays constant—there is thermal balance, or thermal equilibrium

Humidity Control

When exterior hot, humid air is cooled its relative humidity is increased. If it is cooled sufficiently, condensation occurs. High relative humidities and condensation can lead to mold and other biological growth. Interior relative humidities at surfaces and within building cavities need to be controlled to prevent condensation and biological growth.An ideal approach to control indoor humidity and indoor air quality in the hot, humid south is to minimize the need for outside air. The air should be obtained in a controlled manner (mechanically with a fan). The air should be conditioned where it comes into the building. It should be dehumidified by cooling it below its dew point, and used to maintain the enclosure at a slight positive air pressure relative to the exterior. By doing so, it can be used to control the infiltration of exterior hot, humid air. Furthermore, the building envelope should be built in a manner those aides in the pressurization of the building. Tight construction is recommended. The building envelope should also exclude rain, control rain water absorption and control vapor diffusion. Vapor diffusion retarders should be installed on the exterior of building envelopes in the humid south as compared to the practices innorthern heating climates. Finally, the building envelope should be forgiving so that if it gets wet, it can dry to the interior. Interior vapor diffusion retarders such as impermeable wall covering should be avoided.

Dehumidifier

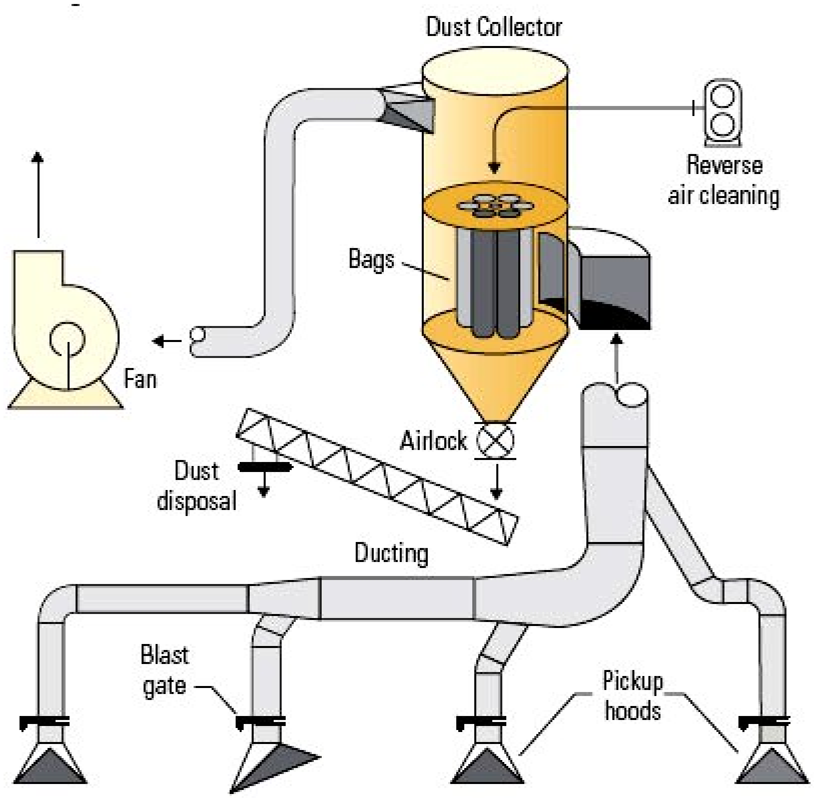


The Air We Breathe

A dehumidifier is typically a household appliance that reduces the level of humidity in the air usually for health reasons. Humid air can cause moldand mildew to grow inside homes, which pose various health risks. Very humid climates or air make some people extremely uncomfortable, causing excessive sweating that can't evaporate in the already-moisture-saturated air. It can also cause condensation that can disrupt sleeping, or prevent laundry from drying thoroughly enough to prevent mustiness. Higher humidity is also preferred by most pests, including clothes moths, fleas,cockroaches, woodlice and dust mites. Relative humidity in dwellings is preferably 30 to 50 percent.

By their operation, dehumidifiers produce an excess of water which has been removed from the conditioned air. This water, usually called condensate in its liquid form, must be collected and disposed of. Some dehumidifier designs dispose of excess water in a vapor, rather than liquid form. Energy efficiency of dehumidification processes can vary widely. Dehumidifiers are also used in industrial climatic chambers, to control relative humidity within certain rooms to stay at levels conducive to processing of products.

Air Filtration: Air filtration supplies the means to obtain the level of particulate cleanliness required by any definition of "air conditioning." It extends from the simple task of preventing lint and other debris from plugging heating/cooling coils to removing particles as small as 0.1 micron which could cause a short circuit on a microchip.



Dust collector

Air filters are used for a wide variety of purposes, some of which include:

- Protecting the general well-being of the occupants of a space
- Protecting the decor of occupied spaces by removing the staining portion of airborne dust
- Reducing maintenance of building interiors by reducing the frequency of washing such items as Venetian blinds and fluorescent bulbs
- Protecting the contents of occupied spaces including paintings, tapestries, and other items of historic or cultural value
- Elimination of fire hazards by removing lint and other materials which might accumulate in ductwork
- Extension of shelf life of perishable dairy products by removing airborne mold during processing operations
- Removing airborne bacteria from operating room air to help prevent postoperative infection

Air filter

A particulate air filter is a device composed of fibrous materials which removes solid particulates such as dust, pollen, mold, and bacteria from the air. A chemical air filter consists of an absorbent or catalyst for the removal of airborne molecular contaminants such as volatile organic compounds or ozone. Air filters[2] are used in applications where air quality is important, notably in building ventilation systems and in engines. Some buildings, as well as aircraft and other man-made environments (e.g., satellites and space shuttles) use foam, pleated paper, or spun fiberglass filter elements. Another method, air ionisers, use fibers or elements with a static electric charge, which attract dust particles. The air intakes of internal combustion engines and compressors tend to use either paper, foam, or cotton filters.

Dust collector

A dust collector is a system used to enhance the quality of air released from industrial and commercial processes by collecting dust and other impurities from air or gas. Designed to handle high-volume dust loads, a dust collector system consists of a blower, dust filter, a filter-cleaning system, and a dust receptacle or dust removal system. It is distinguished from air cleaners, which use disposable filters to remove dust. The father of the dust collector was Wilhelm Beth from Lübeck[3].

Types of dust collectors

Five principal types of industrial dust collectors are:

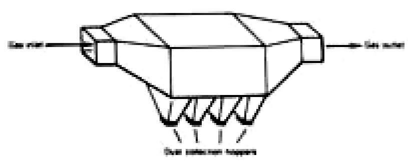
- Inertial separators
- Fabric filters
- Wet scrubbers
- Electrostatic precipitators
- Unit collectors

Inertial separators

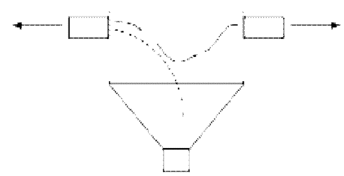
Inertial separators separate dust from gas streams using a combination of forces, such as centrifugal, gravitational, and inertial. These forces move the dust to an area where the forces exerted by the gas stream are minimal. The separated dust is moved by gravity into a hopper, where it is temporarily stored.

The three primary types of inertial separators are: Settling chambers, Baffle chambers, Centrifugal collectors.

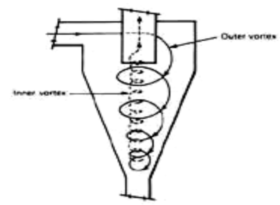
- **Settling chamber** **Baffle chamber** **Centrifugal collectors**



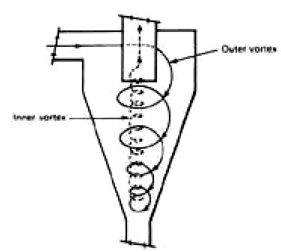
Settling Chamber



Baffle Chamber



Cyclone



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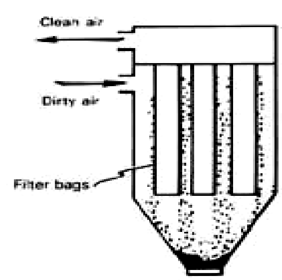
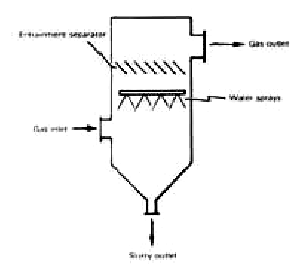


Baghouse



Wet Scrubber

Multiple-cyclone separators **Parts of Fabric filters** **Wet Scrubber**

A settling chamber consists of a large box installed in the ductwork. The sudden expansion of size at the chamber reduces the speed of the dust-filled airstream and heavier particles settle out.Settling chambers are simple in design and can be manufactured from almost any material. However, they are seldom used as primary dust collectors because of their large space requirements and low efficiency.

Baffle chambers use a fixed baffle plate that causes the conveying gas stream to make a sudden change of direction. Large-diameter particles do not follow the gas stream but continue into a dead air space and settle. Baffle chambers are used as precleaner.

Centrifugal collectors use cyclonic action to separate dust particles from the gas stream. In a typical cyclone, the dust gas stream enters at an angle and is spun rapidly. The centrifugal force created by the circular flow throws the dust particles toward the wall of the cyclone. After striking the wall, these particles fall into a hopper located underneath. The most common types of centrifugal, or inertial, collectors in use today are:

Single-cyclone separators

They create a dual vortex to separate coarse from fine dust. The main vortex spirals downward and carries most of the coarser dust particles. The inner vortex created near the bottom of the cyclone, spirals upward and carries finer dust particles.

Multiple-cyclone separators

Multiple-cyclone separators consist of a number of small-diameter cyclones, operating in parallel and having a common gas inlet and outlet, as shown in the figure. Multiple-cyclone separators operate on the same principle as cyclones—creating a main downward vortex and an ascending inner vortex.These separator are more efficient than single cyclones because they are longer and smaller in diameter. The longer length provides longer residence time while the smaller diameter creates greater centrifugal force. These two factors result in better separation of dust particulates. The pressure drop of Multiple-cyclone separators collectors is higher than that of single-cyclone separators.Multiple-cyclone separators dust collectors are found in all types of power and industrial applications, including pulp and paper plants, cement plants, steel mills, petroleum coke plants, metallurgical plants, saw mills and other kinds of facilities that process dust.

Secondary Air Flow Separators

This type of cyclone uses a secondary air flow, injected into the cyclone to accomplish several things. The secondary air flow increases the speed of the cyclonic action making the separator more efficient; it intercepts the particulate before it reaches the interior walls of the unit; and it forces the separated particulate toward the collection area. The secondary air flow protects the separator from particulate abrasion and allows the separator to be installed horizontally because gravity is not depended upon to move the separated particulate downward.

Fabric filters

Commonly known as baghouses, fabric collectors use filtration to separate dust particulates from dusty gases. They are one of the most efficient and cost effective types of dust collectors available and can achieve a collection efficiency of more than 99% for very fine particulates Dust-laden gases enter the baghouse and pass through fabric bags that act as filters. The bags can be of woven or felted cotton, synthetic, or glass-fiber material in either a tube or envelope shape.

Types of Bag Cleaning

Baghouses are characterized by their cleaning method.[3]

Shaking

A rod connects to the bag is powered by a motor that provides motion to remove the caked on particles. The speed and motion of the shaking depends on the design of the bag and composition of the particulate matter. Though, generally shaking is horizontal. The top of the bag is closed and the bottom is open. When shaken the dust collected on the inside of the bag is set free. During the cleaning process, no dirty gas flows through a bag while the bag is being cleaned. This redirection of air flow illustrates why baghouses must be compartmentalized.

Reverse Air

Air flow gives the bag structure. Dirty air flows through the bag from the inside, allowing dust to collect on the interior surface. During cleaning, gas flow is restricted from a specific compartment. Without the flowing air, the bags relax. The cylindrical bag contains rings that prevent it from completely collapsing under the pressure of the air. A fan blows clean air in the reverse direction. The relaxation and reverse air flow cause the dust cake to crumble and release into the hopper. Upon the completion of the cleaning process, dirty air flow continues and the bag regains its shape.

Pulse Jet:

This type of baghouse cleaning (also known as pressure-jet cleaning) is the most common. A high pressure blast of air is used to remove dust from the bag. The blast enters the top of the bag tube, temporarily ceasing the flow of dirty air. The shock of air causes a wave of expansion to travel down the fabric. The flexing of the bag shatters and discharges the dust cake. The air burst is about 0.1 second and it takes about 0.5 seconds for the shock wave to travel down the length of the bag. Due to its rapid release, the blast of air does not interfere with contaminated gas flow. Therefore, pulse-jet baghouses can operate continuously and are not usually compartmentalized. The blast of compressed air must be powerful enough to ensure that the shock wave will travel the entire length of the bag and fracture the dust cake.

Sonic

The least common type of cleaning method is sonic. Shaking is achieved by sonic vibration. A sound generator produces a low frequency sound that causes the bags to vibrate. Sonic cleaning is commonly combined with another method of cleaning to ensure thorough cleaning. Fabric filters generally have the following parts are Clean plenum, Dusty plenum, Bag, cage, venturi assembly, Tubeplate, RAV/SCREW, Compressed air header, Blow pipe, Housing and hopper

Cartridge collectors

Cartridge collectors use perforated metal cartridges that contain a pleated, nonwoven filtering media, as opposed to woven or felt bags used in baghouses. The pleated design allows for a greater total filtering surface area than in a conventional bag of the same diameter, the greater filtering area results in a reduced air to media ratio, pressure drop, and overall collector size.Cartridge collectors are available in single use or continuous duty designs. In single-use collectors, the dirty cartridges are changed and collected dirt is removed while the collector is off. In the continuous duty design, the cartridges are cleaned by the conventional pulse-jet cleaning system.

Wet scrubbers

Dust collectors that use liquid are known as wet scrubbers. In these systems, the scrubbing liquid (usually water) comes into contact with a gas stream containing dust particles. Greater contact of the gas and liquid streams yields higher dust removal efficiency.

There is a large variety of wet scrubbers; however, all have one of three basic configurations:

1. Gas-humidification - The gas-humidification process agglomerates fine particles, increasing the bulk, making collection easier.

2. Gas-liquid contact - This is one of the most important factors affecting collection efficiency. The particle and droplet come into contact by four primary mechanisms:

a) Inertial impaction - When water droplets placed in the path of a dust-laden gas stream, the stream separates and flows around them. Due to inertia, the larger dust particles will continue on in a straight path, hit the droplets, and become encapsulated.

b) Interception - Finer particles moving within a gas stream do not hit droplets directly but brush against and adhere to them.

c) Diffusion - When liquid droplets are scattered among dust particles, the particles are deposited on the droplet surfaces by Brownian movement, or diffusion.

This is the principal mechanism in the collection of submicrometre dust particles.

d) Condensation nucleation - If a gas passing through a scrubber is cooled below the dewpoint, condensation of moisture occurs on the dust particles. This increase in particle size makes collection easier.

3. Gas-liquid separation - Regardless of the contact mechanism used, as much liquid and dust as possible must be removed. Once contact is made, dust particulates and water droplets combine to form agglomerates. As the agglomerates grow larger, they settle into a collector. The "cleaned" gases are normally passed through a mist eliminator (demister pads) to remove water droplets from the gas stream. The dirty water from the scrubber system is either cleaned and discharged or recycled to the scrubber. Dust is removed from the scrubber in a clarification unit or a drag chain tank. In both systems solid material settles on the bottom of the tank. A drag chain system removes the sludge and deposits in into a dumpster or stockpile.

Types of scrubbers

Spray-tower scrubber wet scrubbers may be categorized by pressure drop as follows:

- Low-energy scrubbers (0.5 to 2.5 inches water gauge - 124.4 to 621.9 Pa)
- Low- to medium-energy scrubbers (2.5 to 6 inches water gauge - 0.622 to 1.493 kPa)
- Medium- to high-energy scrubbers (6 to 15 inches water gauge - 1.493 to 3.731 kPa)
- High-energy scrubbers (greater than 15 inches water gauge - greater than 3.731 kPa)

Low-energy scrubbers:

In the simple, gravity-spray-tower scrubber, liquid droplets formed by liquid atomized in spray nozzles fall through rising exhaust gases. Dirty water is drained at the bottom.These scrubbers operated at pressure drops of 1 to 2 in. water gauge (¼ to ½ kPa) and are approximately 70% efficient on 10 µm particles. Their efficiency is poor below 10 µm. However, they are capable of treating relatively high dust concentrations without becoming plugged.

Low- to medium-energy scrubbers

Wet cyclones use centrifugal force to spin the dust particles (similar to a cyclone), and throw the particulates upon the collector's wetted walls. The wetted walls also prevent dust reentrainment.Pressure drops for these collectors range from 2 to 8 in. water (½ to 2 kPa), and the collection efficiency is good for 5 µm particles and above.

Medium- to high-energy scrubbers co-current-flow scrubber

Packed-bed scrubbers consist of beds of packing elements, such as coke, broken rock, rings, saddles, or other manufactured elements. The packing breaks down the liquid flow into a high-surface-area film so that the dusty gas streams passing through the bed achieve maximum contact with the liquid film and become deposited on the surfaces of the packing elements. These scrubbers have good collection efficiency for respirable dust.

Three types of packed-bed scrubbers are-

- Cross-flow scrubbers
- Co-current flow scrubbers
- Counter-current flow scrubbers

High-energy scrubbers

Venturi scrubbers consist of a venturi-shaped inlet and separator. The dust-laden gases venturi scrubbers enter through the venturi and are accelerated to speeds between 12,000 and 36,000 ft/min (60.97-182.83 m/s). These high-gas velocities immediately atomize the coarse water spray, which is injected radially into the venturi throat, into fine droplets. High energy and extreme turbulence promote collision between water droplets and dust particulates in the throat. The agglomeration process between particle and droplet continues in the diverging section of the venturi. The large agglomerates formed in the venturi are then removed by an inertial separator.Venturi scrubbers achieve very high collection efficiencies for respirable dust

Electrostatic precipitators (ESP)

Electrostatic precipitators use electrostatic forces to separate dust particles from exhaust gases. A number of high-voltage, direct-current discharge electrodes are placed between grounded collecting electrodes. The contaminated gases flow through the passage formed by the discharge and collecting electrodes.The airborne particles receive a negative charge as they pass through the ionized field between the electrodes. These charged particles are then attracted to a grounded or positively charged electrode and adhere to it.The collected material on the electrodes is removed by rapping or vibrating the collecting electrodes either continuously or at a predetermined interval. Cleaning a precipitator can usually be done without interrupting the airflow.

The four main components of all electrostatic precipitators are-

- Power supply unit, to provide high-voltage DC power
- Ionizing section, to impart a charge to particulates in the gas stream
- A means of removing the collected particulates
- A housing to enclose the precipitator zone

The following factors affect the efficiency of electrostatic precipitators:

- Larger collection-surface areas and lower gas-flow rates increase efficiency because of the increased time available for electrical activity to treat the dust particles.
- An increase in the dust-particle migration velocity to the collecting electrodes increases efficiency. The migration velocity can be increased by
    - Decreasing the gas viscosity
    - Increasing the gas temperature
    - Increasing the voltage field

Types of precipitators

There are two main types of precipitators:

- High-voltage, single-stage - Single-stage precipitators combine an ionization and a collection step. They are commonly referred to as Cottrell precipitators.
- Low-voltage, two-stage - Two-stage precipitators use a similar principle; however, the ionizing section is followed by collection plates.

Plate precipitators

The majority of electrostatic precipitators installed are the plate type. Particles are collected on flat, parallel surfaces that are 8 to 12 in. (20 to 30 cm) apart, with a series of discharge electrodes spaced along the centerline of two adjacent plates. The contaminated gases pass through the passage between the plates, and the particles become charged and adhere to the collection plates. Collected particles are usually removed by rapping the plates and deposited in bins or hoppers at the base of the precipitator.

Tubular precipitators

Tubular precipitators consist of cylindrical collection electrodes with discharge electrodes located on the axis of the cylinder. The contaminated gases flow around the discharge electrode and up through the inside of the cylinders. The charged particles are collected on the grounded walls of the cylinder. The collected dust is removed from the bottom of the cylinder.Tubular precipitators are often used for mist or fog collection or for adhesive, sticky, radioactive, or extremely toxic materials.

Unit collectors

Unlike central collectors, unit collectors control contamination at its source. They are small and self-contained, consisting of a fan and some form of dust collector. They are suitable for isolated, portable, or frequently moved dust-producing operations, such as bins and silos or remote belt-conveyor transfer points. Advantages of unit collectors include small space requirements, the return of collected dust to main material flow, and low initial cost. However, their dust-holding and storage capacities, servicing facilities, and maintenance periods have been sacrificed.A numbers of designs are available, with capacities ranging from 200 to 2,000 ft^3/min (90 to 900 L/s). There are two main types of unit collectors:

- Fabric collectors, with manual shaking or pulse-jet cleaning - normally used for fine dust
- Cyclone collectors - normally used for coarse dust

Fabric collectors are frequently used in minerals processing operations because they provide high collection efficiency and uninterrupted exhaust airflow between cleaning cycles. Cyclone collectors are used when coarser dust is generated, as in woodworking, metal grinding, or machining.

The following points should be considered when selecting a unit collector:

- Cleaning efficiency must comply with all applicable regulations.
- The unit maintains its rated capacity while accumulating large amounts of dust between cleanings.
- Simple cleaning operations do not increase the surrounding dust concentration.

- Has the ability to operate unattended for extended periods of time (for example, 8 hours).
- Automatic discharge or sufficient dust storage space to hold at least one week's accumulation.
- If renewable filters are used, they should not have to be replaced more than once a month.
- Durable.
- Quiet.

Fan and motor

The fan and motor system supplies mechanical energy to move contaminated air from the dust-producing source to a dust collector.

Types of fans

There are two main kinds of industrial fans:

- Centrifugal fans
- Axial-flow fans

Centrifugal fans

Centrifugal fans consist of a wheel or a rotor mounted on a shaft that rotates in a scroll-shaped housing. Air enters at the eye of the rotor, makes a right-angle turn, and is forced through the blades of the rotor by centrifugal force into the scroll-shaped housing. The centrifugal force imparts static pressure to the air. The diverging shape of the scroll also converts a portion of the velocity pressure into static pressure.

There are three main types of centrifugal fans:

- Radial-blade fans - Radial-blade fans are used for heavy dust loads. Their straight, radial blades do not get clogged with material, and they withstand considerable abrasion. These fans have medium tip speeds and medium noise factors.

- Backward-blade fans - Backward-blade fans operate at higher tip speeds and thus are more efficient. Since material may build up on the blades, these fans should be used after a dust collector. Although they are noisier than radial-blade fans, backward-blade fans are commonly used for large-volume dust collection systems because of their higher efficiency.

- Forward-curved-blade fans - These fans have curved blades that are tipped in the direction of rotation. They have low space requirements, low tip speeds, and a low noise factor. They are usually used against low to moderate static pressures.

Axial-flow fans

Axial-flow fans are used in systems that have low resistance levels. These fans move the air parallel to the fan's axis of rotation. The screw-like action of the propellers moves the air in a straight-through parallel path, causing a helical flow pattern.

The three main kinds of axial fans are-

- Propeller fans - These fans are used to move large quantities of air against very low static pressures. They are usually used for general ventilation or dilution ventilation and are good in developing up to 0.5 in. wg (124.4 Pa).

- Tube-axial fans - Tube-axial fans are similar to propeller fans except they are mounted in a tube or cylinder. Therefore, they are more efficient than propeller fans and can develop up to 3 to 4 in. wg (743.3 to 995 Pa). They are best suited for moving air containing substances such as condensible fumes or pigments.

- Vane-axial fans - Vane-axial fans are similar to tube-axial fans except air-straightening vanes are installed on the suction or discharge side of the rotor. They are easily adapted to multistaging and can develop static pressures as high as 14 to 16 in. wg (3.483 to 3.98 kPa). They are normally used for clean air only.

Electric motors

Electric motors are used to supply the necessary energy to drive the fan.Integral-horsepower electric motors are normally three-phase, alternating-current motors. Fractional-horsepower electric motors are normally single-phase, alternating-current motors and are used when less than 1 hp (0.75 kW) is required. Since most dust collection systems require motors with more than 1 hp (0.75 kW), only integral-horsepower motors are discussed here.

The two most common types of integral-horsepower motors used in dust collection systems are-

- Squirrel-cage motors - These motors have a constant speed and are of a nonsynchronous, induction type.
- Wound-rotor motors - These motors are also known as slip-ring motors. They are general-purpose or continuous-rated motors and are chiefly used when an adjustable-speed motor is desired.

Squirrel-cage and wound-rotor motors are further classified according to the type of enclosure they use to protect their interior windings. These enclosures fall into two broad categories:

- Open
- Totally enclosed

Drip-proof and splash-proof motors are open motors. They provide varying degrees of protection; however, they should not be used where the air contains substances that might be harmful to the interior of the motor.Totally enclosed motors are weather-protected with the windings enclosed. These enclosures prevent free exchange of air between the inside and the outside, but they are not airtight.Totally enclosed, fan-cooled (TEFC) motors are another kind of totally enclosed motor. These motors are the most commonly used motors in dust collection systems. They have an integral-cooling fan outside the enclosure, but within the protective shield, that directs air over the enclosure.Both open and totally-enclosed motors are available in explosion-proof and dust-ignition-proof models to protect against explosion and fire in hazardous environments.Motors are selected to provide sufficient power to operate fans over the full range of process conditions (temperature and flow rate)

Uses

Dust collectors are used in many processes to either recover valuable granular solid or powder from process streams, or to remove granular solid pollutants from exhaust gases prior to venting to the atmosphere. Dust collection is an online process for collecting any process-generated dust from the source point on a continuous basis. Dust collectors may be of single unit construction, or a collection of devices used to separate particulate matter from the process air. They are often used as an air pollution control device to maintain or improve air quality.

Mist collectors remove particulate matter in the form of fine liquid droplets from the air. They are often used for the collection of metal working fluids, and coolant or oil mists. Mist collectors are often used to improve or maintain the quality of air in the workplace environment.Fume and smoke collectors are used to remove sub micrometre size particulate from the air. They effectively reduce or eliminate particulate matter and gas streams from many industrial processes such as welding, rubber and plastic processing, high speed machining with coolants, tempering, and quenching.

CONCLUSION:

In this article we are discussed about the various air-handling unit based areas in pharmaceutical industries. There is a need of vast improvements in this system to develop the production quality and minimize the production cost while preparing pharmaceuticals**.**

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