EVERYTHING YOU WANTED TO KNOW ABOUT DIRECT THERMAL DRYING BUT WERE AFRAID TO ASK

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ABSTRACT

Direct thermal drying is a relatively straightforward process that uses hot air to drive off the moisture in dewatered biosolids. The final dry product is a 1-4 mm, 95 percent dry pelletized material that meets the stringent Class "A" requirements under EPA 40 CFR Part 503. This paper explains the direct drying process in simple terms so that the reader can begin to develop an understanding of the major concepts.

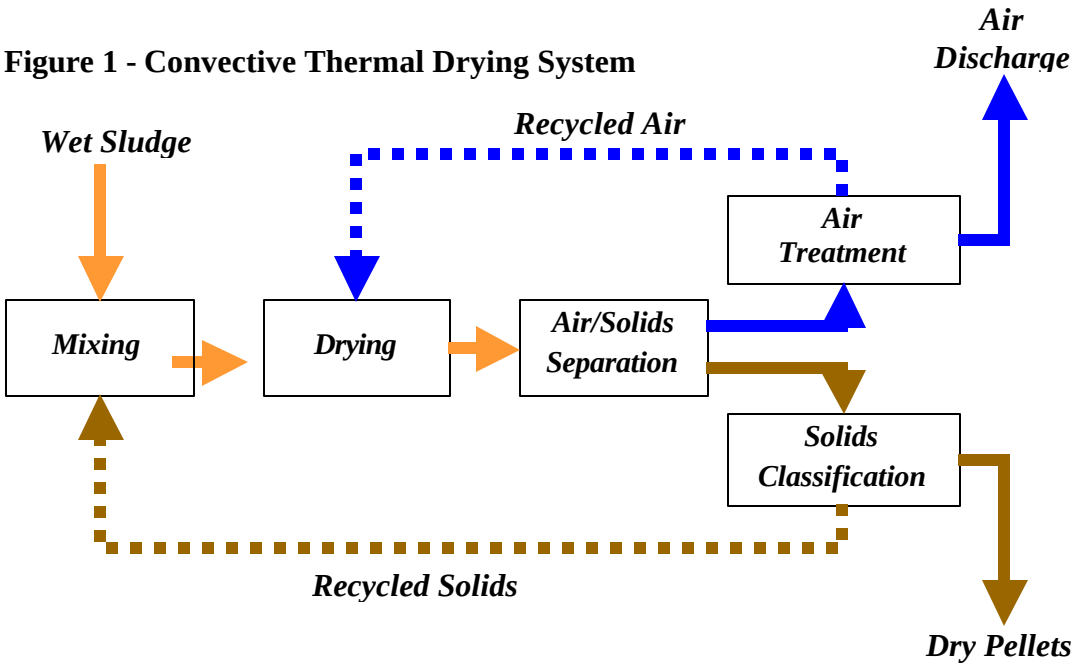
KEYWORDS

Biosolids, direct drying, pelletization, separation, condense, classify.

INTRODUCTION

The Direct Thermal Dryer (CTD) is a complete biosolids drying system that produces a 95 percent dry pelletized product and exceeds the Class "A" requirements under EPA 40 CFR Part 503. The system includes five main groups of equipment: mixing, drying, air/solids separation, air treatment, and solids classification. The following process flow diagram shows how each major equipment system interacts within the overall CTD drying system.

Figure 1 - Convective Thermal Drying System



- Mixing: Wet and recycled dry sludge are mixed to produce a 1 – 4 millimeter sphere that has a solid dry core surrounded by a thin wet film of sludge.
- Drying: The semi-dry mixed sludge is introduced into a stream of hot air produced by the furnace and pneumatically conveyed and dried through a rotary drum dryer constructed of three interconnected concentric cylinders.
- Air/Solids Separation: The saturated air and dry product produced by the drum are pneumatically conveyed to a preseparator to separate out the gross solids and then to a polycyclone to remove dust and fines from process air stream.
- Solids Classification: The solids are classified into fine, product size, and large size pellets using a vibrating screen. A trash screen is also incorporated to remove very large inorganic products. The product size (1-4 mm) pellets are pneumatically conveyed to a pellet cooler and final product storage bin. The large pellets are crushed and conveyed along with the fines to the recycle bin. The trash is removed and conveyed to a bin for disposal.
- Air Treatment: The saturated air is conveyed to a combined wet scrubber and saturator to cool and condense the moisture out of the air. Approximately 90% of the dry air is directed back to the burner and used as process air. The remaining 10% is treated with a Venturi and then discharged through a stack to the atmosphere.

EQUIPMENT SYSTEMS

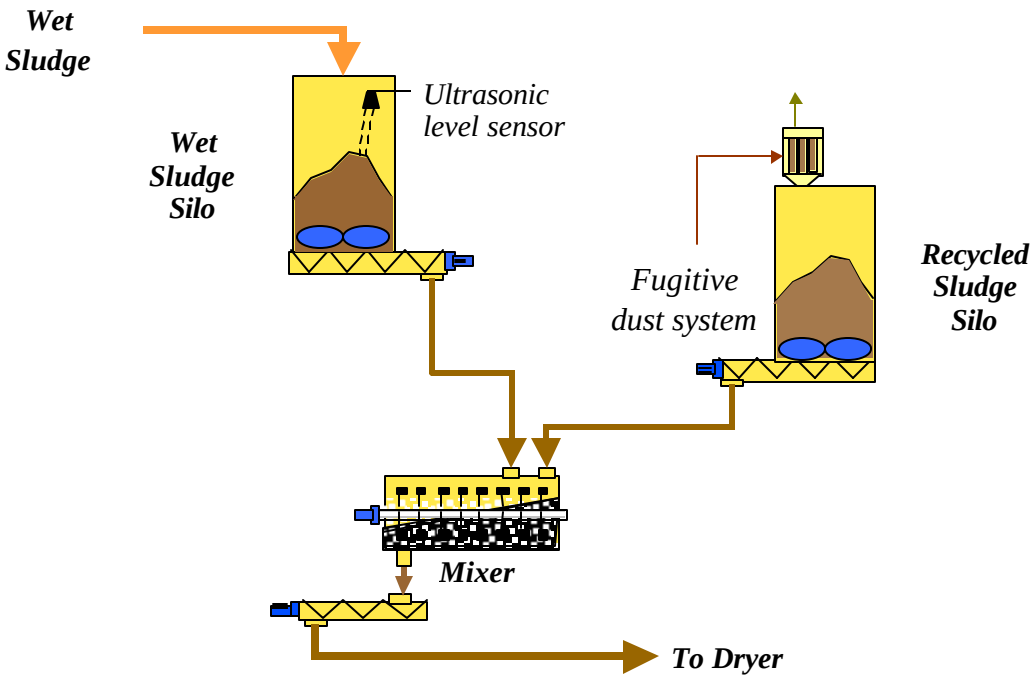
Mixing System

The mixing system is comprised of the following equipment:

- Wet Sludge Silo
- Recycled Sludge Silo
- Mixer

A schematic of the Mixing System Group is shown below:

Figure 2 - Mixing System Group



As shown in the Mixing System Schematic, Wet Product (15% solids – 70 lb/cu ft) is combined with dry recycled product in a plowshare mixer. During the mixing process, the wet product attaches to outside of the dry recycled product forming a thin layer of wet material over a dry core. The mixed product that is formed has a total solids concentration of about 70% and a bulk density of about 55-lb/cu. ft.

Wet Material Bin

The wet material bin stores dewatered material generated by the wastewater treatment plant. All parts that come in contact with wet material are constructed of 304L stainless steel. The bin walls have sufficient slope to create mass flow. A recycle bin discharge screw conveyor is fitted to the bottom of the bin activator.

The dosing screw conveyor speed is controlled by a variable frequency drive. The drive unit is located on the discharge end of the screw conveyor for maintenance access. The variable frequency drive unit is located remotely.

Recycle Bin

The recycle bin stores dried recycled pellets with sufficient capacity to enable startup of the dryer. The bin has a conical bottom with a vibrating bin activator that is connected to a screw conveyor. The bin is equipped with thermocouples for monitoring pellet temperature within the recycle bin.

A recycle bin dosing screw conveyor is fitted to the bottom of the bin by a flexible connection. The dosing screw conveyor speed is controlled by a variable frequency drive. The drive unit is located on the discharge end of the screw conveyor for maintenance access. The variable frequency drive unit is located remotely.

Air is provided from the fugitive dust system to the recycle bin for the purpose of cooling the material in the bin and preventing condensation on the top and sides of the bin on system shutdown. An operator adjustable timer is provided to allow the operator to adjust the length of time the air system is on.

Mixer

The mixer is a horizontal, continuous flow unit designed to homogeneously combine dewatered residuals from the wet material bin with dried residuals from the recycle bin. The single-shaft enclosed plowshare mixer is constructed of abrasion resistant steel. Plows are lined with wear resistant material to prevent erosion and are capable of being replaced without replacing the entire shaft.

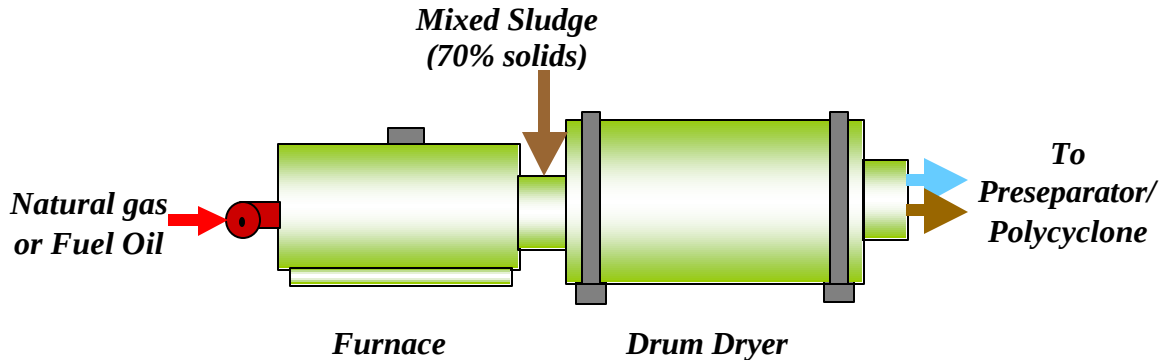
Drying System

The Drying System is comprised of the following equipment:

- Furnace with Burner
- Blower
- Drum Dryer

A schematic of the Drying System Group is shown below:

Figure 3 – Drying System Group

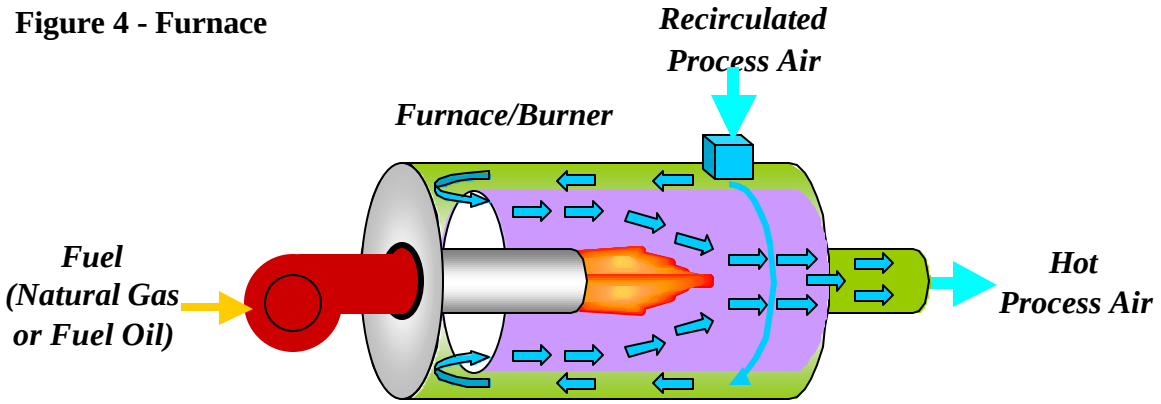


As shown in the Drying System Schematic, digester or natural gas is fed to the furnace that combusts the gas and generates hot air. A blower conveys the hot air to the drum dryer where the mixed sludge product is introduced. The hot dry air comes in direct contact with the mixed sludge in the triple pass drum and evaporates off the moisture. By the end of the drying process, the water evaporated in the process is contained in the now saturated air while the mixed sludge has essentially been converted to a 95 percent dry sludge product. The saturated air and dry sludge mixture are conveyed to a preseparator for gross separation and then a polycyclone to separate out the fines.

Furnace

The direct, horizontal end-fired furnace is equipped with a combustion air blower and forced draft burner that provides heat input into the drying system by discharging combusted natural gas or fuel oil from the burner into the furnace chamber and mixing it with secondary air before entering the rotary drum dryer. An annular ring is provided in the furnace to allow preheating of the secondary air before mixing with the burner flue gas in the interior combustion chamber. The rotary drum is coupled to the furnace through a rotating seal.

Figure 4 - Furnace



Safety controls include ultraviolet flame failure detector, combustion air blower pressure detector, main fan draft detector, high outlet temperature detector, drum motion switch, high and low fuel pressure and temperature switches as required.

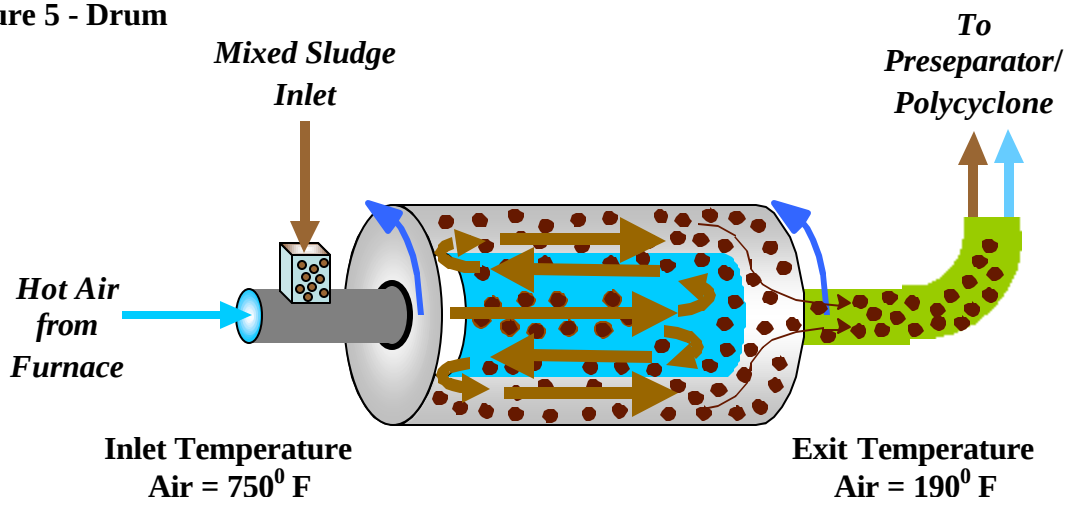
Blower

The blower is a heavy-duty industrial, belt driven, radial blade induced draft blower. It is a single width, single inlet arrangement. The blower wheel, shaft, and blades are constructed of steel, all capable of operation with gas temperatures up to 300°F.

Drum

The drying drum is a triple pass direct heat rotary drum with a horizontal concurrent residuals and gas stream flow pattern. The rotary drum is designed to meet specified evaporation rates while maintaining a drum outlet temperature of 190°F or less under all conditions. The dried solids emerging from the drum consist primarily of 1 – 4 millimeter, 95% dry spherical shaped pellets.

Figure 5 - Drum



The triple-pass drum consists of three concentric cylinders that are supported from the heads on either end in a manner that allows them to expand at different rates relative to each other. Each concentric cylinder of the triple-pass drum is equipped with heavy-duty flights for raising the material and showering it through the drying gas stream as the drum is rotated.

The triple-pass drum is equipped with three (3) temperature sensors at the drum outlet. The temperature sensors are interlocked with the burner controls. A drum inlet water spray extinguishing system is also interlocked with the sensors. An exit gas stream temperature in excess of 240°F activates the inlet water spray extinguishing system. The drum inlet is also equipped with a temperature sensor. The inlet is interlocked with the burner management panel to shutdown the burner if the inlet temperature exceeds 1600°F.

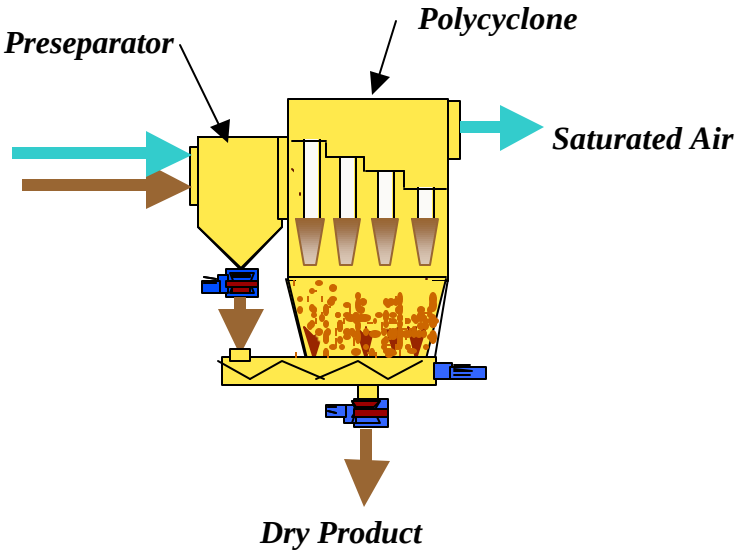
Air/Solids Separation System

The Air/Solids Separation System is comprised of the following equipment:

- Preseparator
- Polycylone

A schematic of the Separation System is shown below:

Figure 6 - Separation System



The preseparator is essentially a baffle that changes the direction of the combined air and solids stream and allows the heavier solids to fall out by gravity. The polycyclone further separates the solids from the air through a tube type settler. Solids and air enter the side of the tube and are directed into a downward spiral. Centrifugal action forces the solids to collide with the walls of the tube where they drop out and are collected in a closed hopper. The clean air is directed up the tube and conveyed to the air process train for further treatment.

Preseparator

The preseparator uses a baffle to reduce the velocity of the air and solids mixture causing the solids to drop to the bottom of the unit while the air is allowed to exit from the top of the unit. The preseparator has a sloped bottom hopper that directs the solids towards a central solids outlet. The solids outlet is equipped with a rotary airlock valve.

Polycyclone

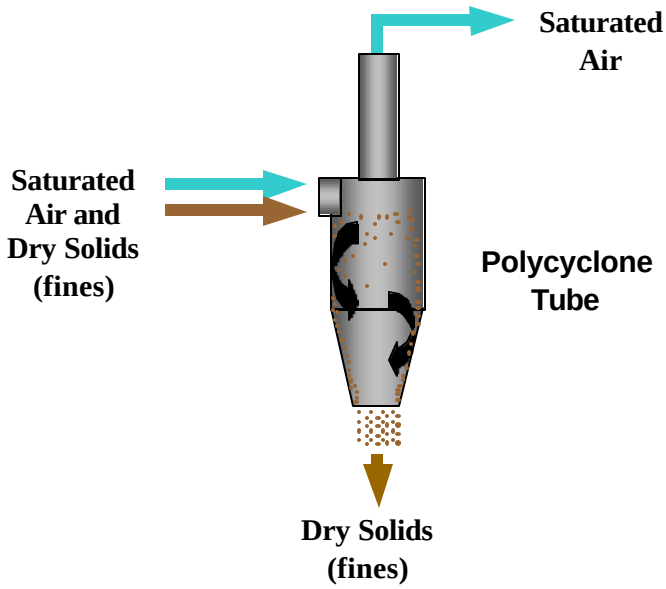
After the preseparator, fine dry particles are removed in the saturated process air in the polycyclone. The removal efficiency of the polycyclone is as follows:

Particle Size (micron)	Removal
0-10	70%
10-20	92%
20-40	98%
>40	99%

The polycyclone is a cluster of several vertical tubes with inlet vanes and is equipped with a common collection hopper. The tubes are designed to cause a centrifugal effect that separates the fines from the saturated air. The fines fall by gravity to a collection hopper while the air escapes through the top of the tube. The outlet of the common hopper is equipped with a rotary screw conveyor and a rotary airlock valve.

The polycyclone inlet and outlet is flanged and the connection to the process gas stream system ductwork is bolted and gasketed in a manner suitable to maintain negative pressure and temperature of the cyclone at design conditions. The exterior surface of the polycyclone is insulated.

Figure 7 - Polycyclone



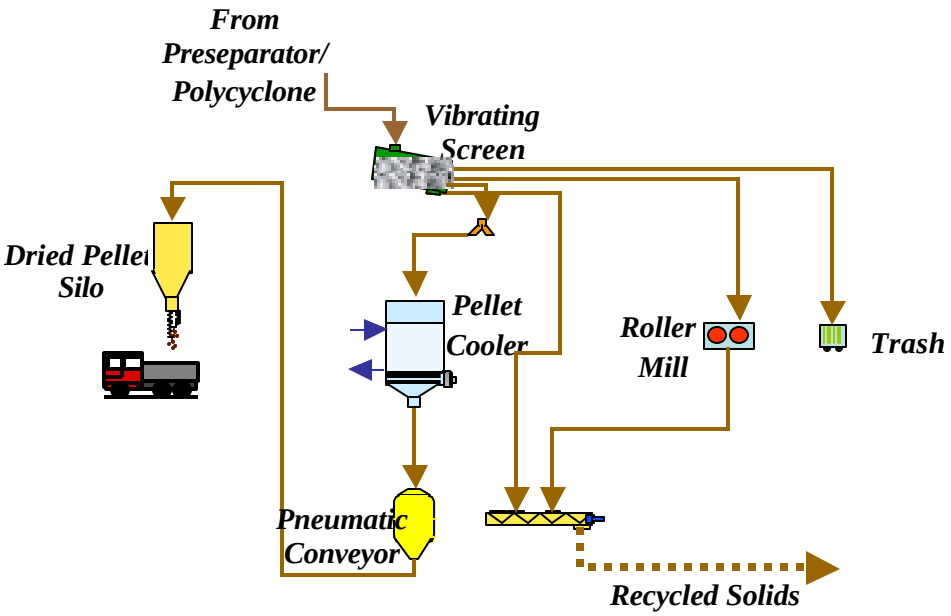
Solids Classificaton and Storage System

The Solids Classification System is comprised of the following equipment:

- Vibrating Screen
- Crusher
- Pellet Cooler
- Pneumatic Conveyor
- Dried Pellet Silo

A schematic of the Solids Classification and Storage System is shown below:

Figure 8 - Solids Classification and Storage System



As shown above, the dry product removed in the preseparator and polycyclone, is conveyed to a vibrating screen for classification. Three screens classify the dry pellets into trash, large, medium, and fine sizes. The trash is conveyed to a bin and disposed of. The large material is transferred to a roller mill for size reduction and conveyed back to the recycled bin along with the fines. The medium (1 – 4 mm) or final product is cooled in a pellet cooler and conveyed pneumatically to the dry product/truck-loading bin.

Vibrating Screen

The dry solids from the preseparator and polycyclone are conveyed to a vibrating screen to classify the dried pellets according to size. The unit is equipped with three screens for the classification of trash, oversized pellets, and product-sized pellets. Fines (undersized pellets) pass through the product-sized screen. Screen openings are as follows:

Description	Size
Trash (Top)	10 mm
Oversize (Middle)	4 mm
Product (Bottom)	1 mm

Roller Mill

The roller mill is used to crush oversized dried pellets that will be recycled back to the front of the dryer. It is constructed of heavy-duty, fabricated steel with seals on the housing, at the shafts and gasket seals, and at all joints to provide a dust-proof enclosure.

Pellet Cooler

The Pellet Cooler provides single stage pellet cooling for product-sized pellets only from the vibrating screen. The pellet cooler consists of a vertical bank of 316L stainless steel water-

cooled plates that cool the pellets by direct contact under mass flow conditions. The discharge hopper consists of a mass flow-vibrating feeder with variable speed drive to regulate solids flow rate through the cooler. Level control is used to control the feed rate and ensure that the plate bank is fully covered.

Pneumatic Conveyor

A dense phase pneumatic conveyance system is used to transport cooled, product size pellets to the final product storage silos. The conveyance system is sized to deliver dried pellets at design loading conditions.

The pneumatic conveyor includes transporter, discharge line, pressure booster ports, diversion valves, instrumentation and controls, and other accessories as necessary for a comp lete pneumatic conveyance system. Compressed air is provided to the transporter for product conveyance.

Dried Pellet Silo

The final product storage silo is provided to store dried, 1-4 mm pellets from the drying system. The system includes a silo, bin activator, isolation gate, load-out chute, nozzle, instrumentation and other accessories. The silo is dust-tight and ventilated. A fugitive dust duct is provided for connection to the silo fugitive dust fan and bag house. A pressure and vacuum relief valve is provided to allow supply air into the bin for dust collection.

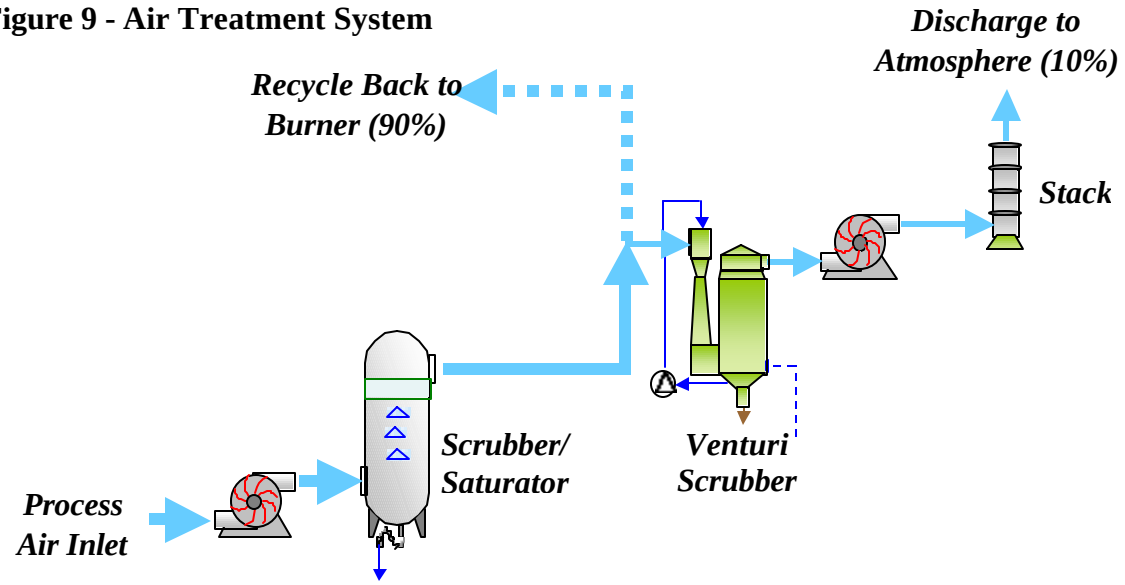
Air Treatment System

The Air Treatment System is comprised of the following equipment:

- Venturi Scrubber
- Scrubber/Saturator

A schematic of the Air Treatment System is shown below:

Figure 9 - Air Treatment System



Scrubber/Saturator

The scrubber/saturator removes particulate from the air stream and cools and condenses the air prior to recycling it back to the burner. This is accomplished by routing the air to an expansion chamber cooled by up to three water sprays. The drop in pressure combined with the cold water condenses the steam in the air and converts it to water. The spray also helps remove fine particulate matter from the air stream. The majority of the clean air (about 90 percent by volume) is recycled back to burner and used as process air.

Venturi Scrubber

The Venturi Scrubber further removes particulate matter from the process air stream by increasing the velocity of the air and forcing collisions with water droplets. This is accomplished by routing the air through a narrow throat and introducing a fine spray of water. The small dust particles attach to the water droplets and fall by gravity to a collection well at the base of the scrubber unit. The particulate laden water is routed back to the wastewater treatment plant for processing and the remaining air discharging the exhaust into the atmosphere.

The venturi throat section is constructed of 304 stainless steel and is fixed and pressure drop adjustable via the supplied water pump. The venturi shall have a minimum particulate removal efficiency of 90 percent.

Stack

As described above, about 90 percent of the process air is recycled back to the front of the plant and reused. The remaining 10 percent can be further treated in a Regenerative Thermal Oxidizer to remove volatile organic compounds or can be discharged directly though a stack.