

Dryer Advancements - Introduction

By: Albert Brand, Henk Dijkman, Wilfred Roebersen

edited by: Tom Schroeder

A continuous fluid bed dryer/cooler is a machine in which a continuous flow of wet granular material is dried and subsequently cooled. Drying of the material occurs because of the direct contact between the material to be dried and the hot drying air that is blown through a layer of the product. The air velocity of the drying air is adjusted in such a way that the layer of product is maintained in a fluidized state. The same principle applies for cooling, only the cooling is with ambient air or with conditioned (cooled) air.

In the 1st stage of drying, the free water is removed from the product. All available energy, supplied as heat in the drying air, is used for evaporation. Both the gas flow and the product attain the adiabatic saturation temperature. The temperature of the drying air reduces while the air absorbs the moisture from the product up to its saturation point i.e. the gas sensible heat is converted in latent heat of evaporation.

In the 2nd stage of drying, when the free water is evaporated and the product is nearly dry, part of the available energy is used for the evaporation of the last moisture and part is used for heating up the product. There is a relation between the end temperature of the product and the moisture content after drying. If the product temperature at the required moisture content is known, this temperature will be used for controlling the dryer. If there is a change in the moisture content of the feed product or in the product rate, the drying air temperature is automatically adjusted to maintain the product temperature at the end of the dryer.

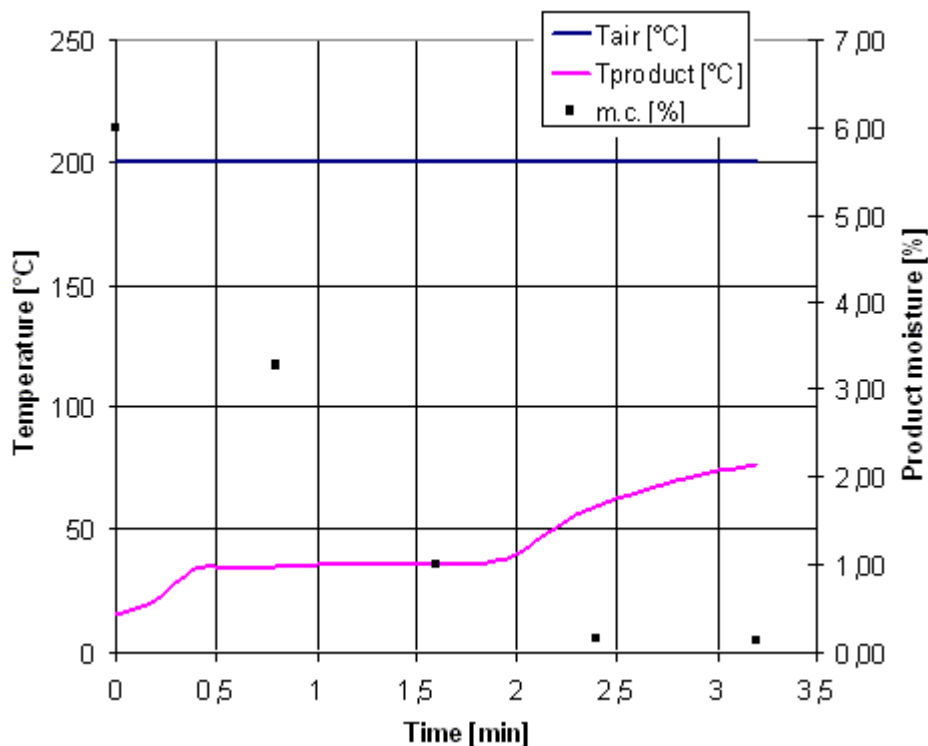


Figure 1: Typical drying curve

2. DRYER DRIVE UNIT

A special design feature of the VENTILEX fluid bed dryers is the shaking movement of the dryer that moves the product forwards, also with low air velocity (sub-fluidization). The shaking movement is a mechanical movement created by a crank-connection rod mechanism. The desired product velocity through the dryer can easily be adjusted by changing the shaking frequency, without changing the amplitude.

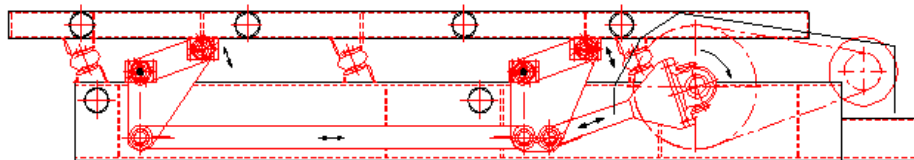


Figure 2: Principle drawing Dryer Drive Unit (Shaking Mechanism)

Compared to static dryers, the advantage of the shaking movement is that the fluidization is improved and the air load can be reduced. Because of the lower air load, the amount of fines to the filter will be reduced.

For products that need long resident times (mainly in the food industry), VENTILEX invented sub-fluid bed dryers. The layer thickness of the product with normal continuous fluid bed drying is about 10 - 15 cm [4 - 6 inches]. If the layer thickness is increased, the spread of product residence time is increased excessively due to axial mixing of the product during the drying process. With sub-fluid bed drying it is possible to run with thicker layers, up to 60 cm [24 inches]. The amount of air is kept to a minimum to keep the mixing to a minimum. Forward movement of the product through the dryer is created by the shaking mechanism. With sub-fluidization, the product outlet is equipped with a rotating weir that continuously controls the discharge of the dryer. Residence times up to 2 hours are possible without substantial mixing.

3. DE-DUSTING EXHAUST AIR

De-dusting of the exhaust air from the dryer/cooler can be done with filter installations, cyclones or wet scrubbers. In the sand drying industry VENTILEX uses VENTILEX Pulse-Jet Filter installations.

A VENTILEX dryer/cooler is a shaking fluid bed dryer with an expanded suction hood. The suction hood is expanded in order to reduce the velocity of the exhaust air in the hood. This will result in particles dropping back in the bed instead of going to the air filter.

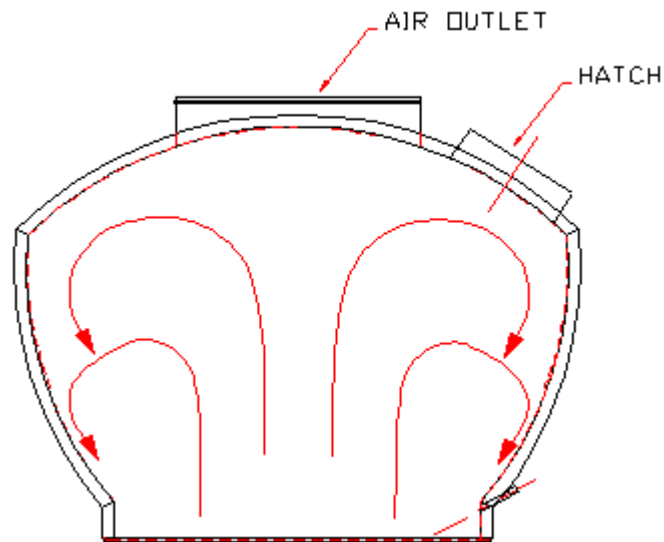


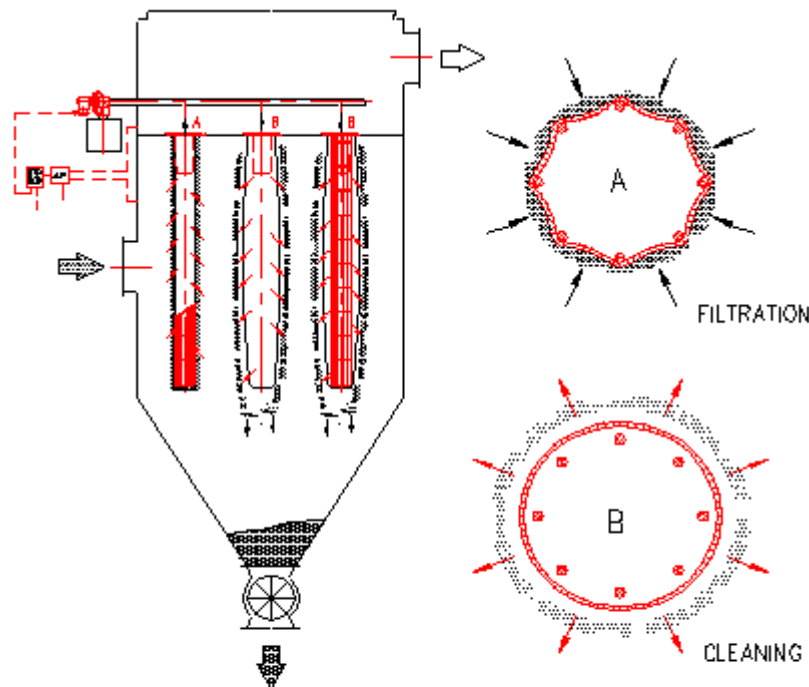
Figure 3: Cross section Expanded Suction Hood

Depending of the local situation, a VENTILEX filter installation can be mounted in the roof or in a steel structure next to the fluid bed dryer. The filter is a so called sub-atmospheric pressure bag filter. The dusty air is conducted into the filter area through a part that spreads the air over the whole filter cloth area, there is no airflow direct on the filter material.

The cleaning of dusty air is achieved on the outside of the filter material. Filter bags are supported by wire cages and are mounted in a top plate, which separates the bag house from the top section.

Normally the dust from the filter is dry and therefore it can be transported with a screw conveyer to the product outlet of the dryer/cooler and mixed with the end product.

The filter is equipped with compressed air tanks that are connected to electro-pneumatic air valves. The control of the air valves runs simultaneously with the cleaning of one series of bags. This is a fully automatic process, which suits the needs of the installation. The electronic filter control is fitted in a case, pulsation and frequency can accurately be adjusted in such a way that the pressure drop remains constant.



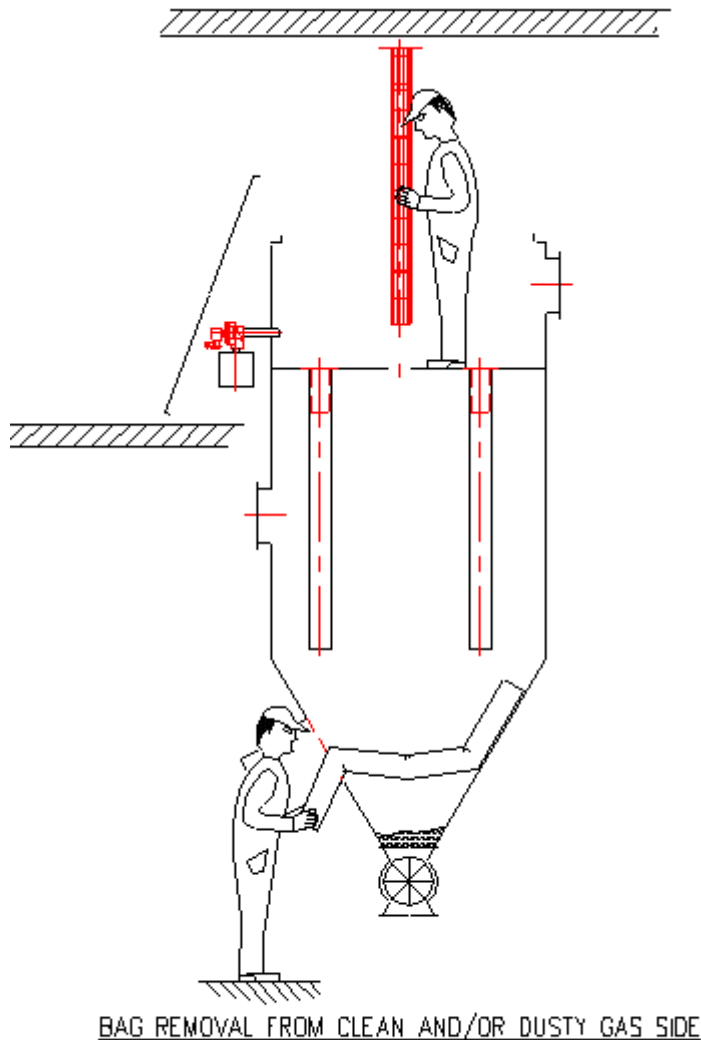
BAG CLEANING

ACCUMULATED DUST ON THE EXTERIOR OF A BAG IS PERIODICALLY REMOVED BY INDUCING A SHORT PULSE OF COMPRESSED AIR DOWN THE INSIDE OF THE BAG

Figure 4: Filter bag Cleaning

The collected dust is carried off by means of a flap valve or a rotary valve. Depending on the size, the filter installation is equipped with a screw conveyor in the filter cone to carry off the dust to the dust outlet.

The filter bags have steel wire cages. The bags are provided with a stainless steel band, which is incorporated in the filter material. The mounting and changing can be done from the top without special tools. The filter installation is amply supplied with inspection hatches.



THE BAG CAGE IS TAKEN OUT FROM THE TOP AND THE BAG ITSELF IS DROPPED INTO THE HOPPER FROM WHERE IT CAN BE REMOVED. THE NEW BAG IS ALWAYS INSERTED FROM THE TOP.



Figure 5: Changing of Filter bags

4. BURNERS

In order to reduce the size of the dryer, the drying air temperature should be as high a possible (higher temperature = more energy input). Common drying air temperature for sand drying is 450 - 600 °C [840-1112 °F]. For the heating of the process air for drying, VENTILEX uses direct burners. This can be a burner fired by natural gas, light fuel oil, propane or heavy fuel oil. Also dual fuel burners can be supplied by VENTILEX. Most used are the gas burners and the light fuel oil burners.

For light fuel oil a separate combustion air fan is required. The amount of combustion air is controlled with the same ratio as the oil ratio. This is done automatically with a micro ratio control valve that is mounted in the oil supply pipe.

Because of the special design that is required at the high temperatures, the burner housing is manufactured in the VENTILEX workshop. The actual burner itself is supplied by worldwide well known suppliers.

Figure 6 shows a picture of a gas burner built in a duct as utilized in VENTILEX sand drying installations.

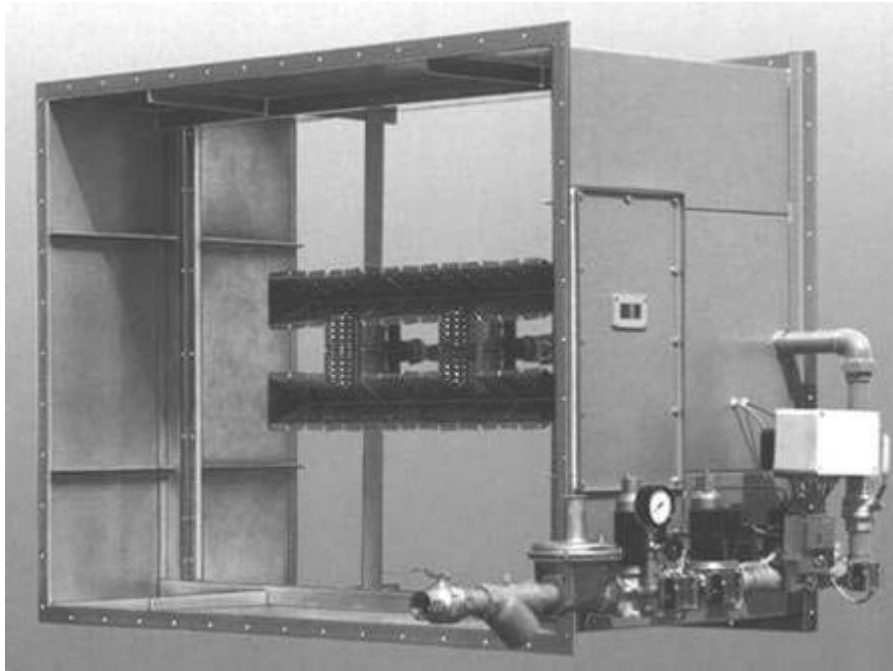


Figure 6: Gas burner

5. HIGH TEMPERATURE DRYERS

The last few years, the maximum drying air temperature used for the VENTILEX fluid bed dryers for sand has increased from 450 - 600 °C [840-1112 °F]. This results in more evaporation per m² and thus less energy usage (electrical) per Ton dried sand. Also with higher temperatures the energy efficiency is better.

The burner housing and the undercase of the dryer are built in high temperature resistant steel instead of stainless steel. Also the construction is different than in the past, to avoid problems due to size changes when the temperature of the material changes.

Some construction details are the following:

- Hatches are round to avoid cracks
- The bedplate is mounted in such a way that the plate can move freely.
- The undercase is mounted with a slide construction to the frame.
- No sharp corners and edges.
- Strengthening stripping are mounted in such way that it can expand.

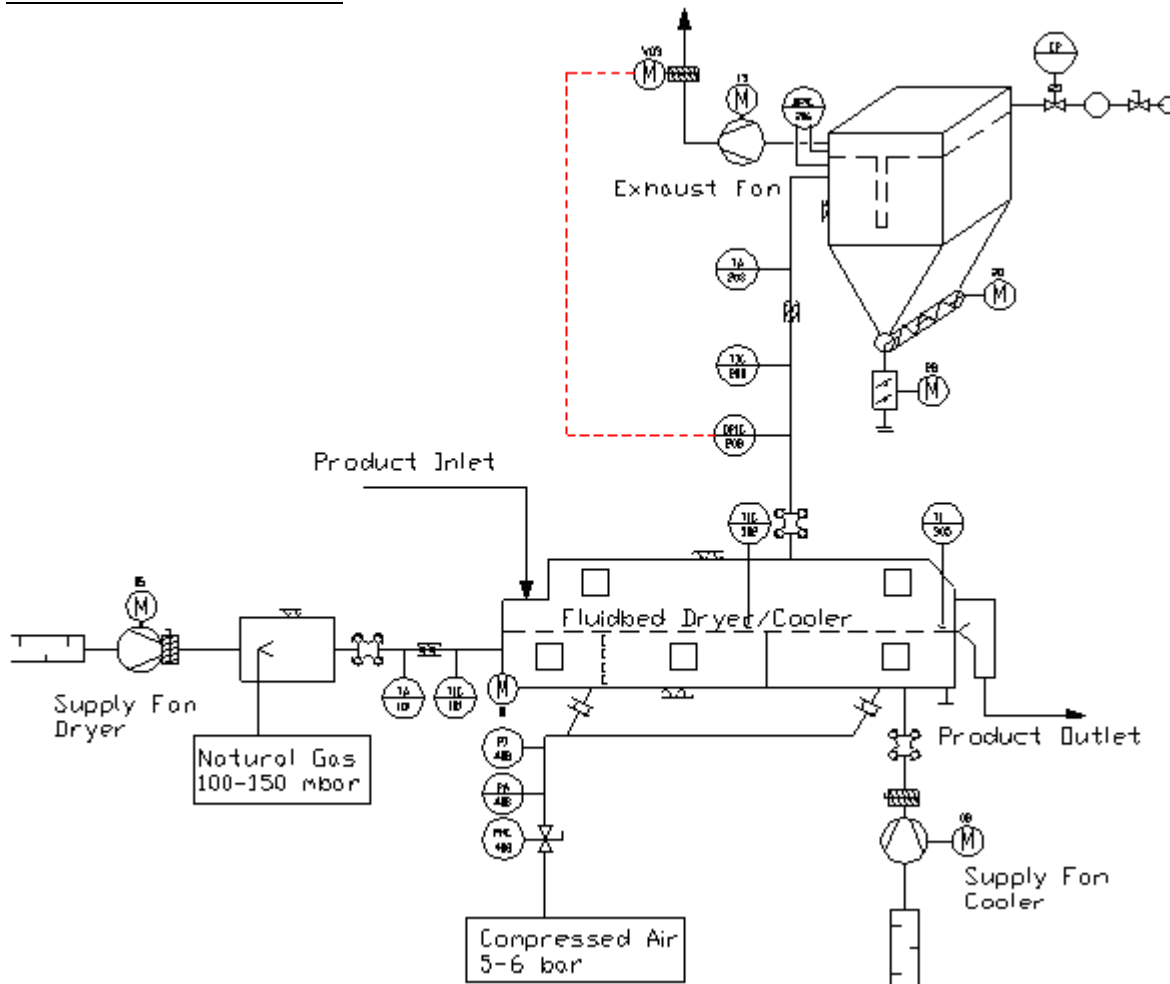
6. ENERGY SAVINGS


Figure 7: Flow sheet Sand dryer/cooler, without recirculation

An example of a flow sheet of a sand dryer is given in figure 7. The drying air is heated with natural gas. Another option of heating the drying air is by means of light fuel oil or LPG. The exhaust air from the dryer and from the cooler is combined and exhausted as one air stream.

Returning the exhaust gas from the cooler back to the air inlet from the dryer can save energy. Because the product is cooled, the cooler exhaust air will be $\pm 50 - 60 \text{ }^\circ\text{C}$ [$122-140 \text{ }^\circ\text{F}$]. The amount of energy that is saved by recirculating the cooling air is $\pm 15 \%$. Below in figure 8 you can see the flow sheet for a system with recirculation.

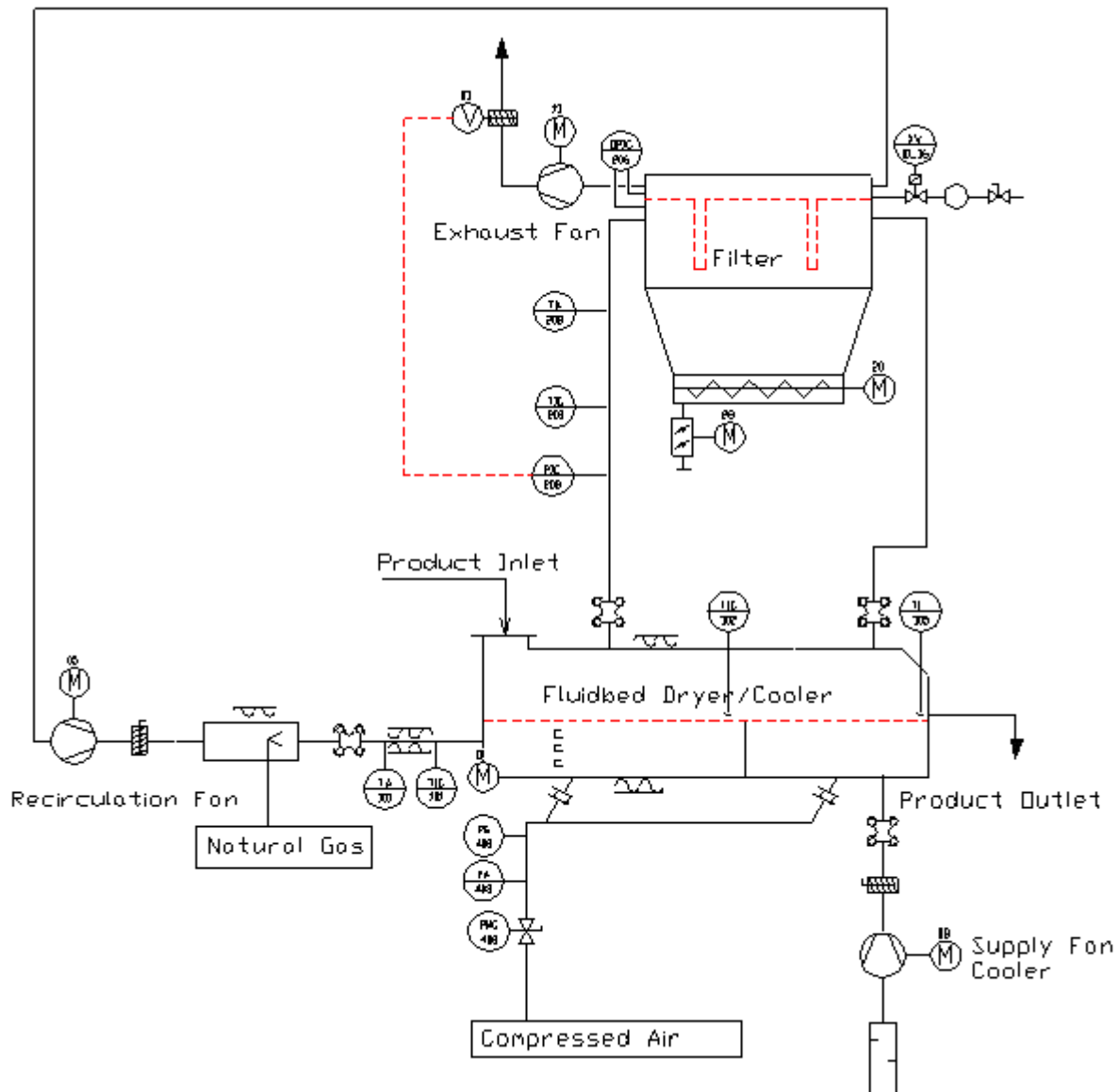


Figure 8: Flow sheet Sand dryer/cooler, with recirculation of exhaust air from the cooling section

Evaporative cooling

Some sand products can be dried using evaporative cooling. Evaporative cooling means that the last part of the moisture is evaporated in the cooler, instead of in the dryer. The product is not completely dried to $< 0.5\%$ m.c. Instead of this, it is dried to $\pm 1\%$. The rest of the moisture is dried of in the cooler.

Tests have shown that evaporative cooling works well with temperatures of $\pm 45\text{ }^{\circ}\text{C}$ [$113\text{ }^{\circ}\text{F}$]. When the cooling air temperatures are too low, the air is not able to evaporate the moisture.

To have efficient evaporative cooling, we include two heat exchangers in the supply of the drying installation. The 1st heat exchanger is placed in the exhaust air duct. With this heat exchanger, the latent heat from the exhaust air is used to warm up water to a certain temperature. With a second heat exchanger, the warm water is used for heating the cooling air. The cooling air temperature is controlled at $\pm 45\text{ }^{\circ}\text{C}$ [$113\text{ }^{\circ}\text{F}$].

The residual moisture in the product is evaporated with the heat in the product. Evaporating the residual moisture in the cooler, with $\pm 45\text{ }^{\circ}\text{C}$ [$113\text{ }^{\circ}\text{F}$] air temperature means that the product temperature fast drops to the wet bulb temperature. This means that the sand is cooled quicker then normal. Examples of tests are shown in the next figure.

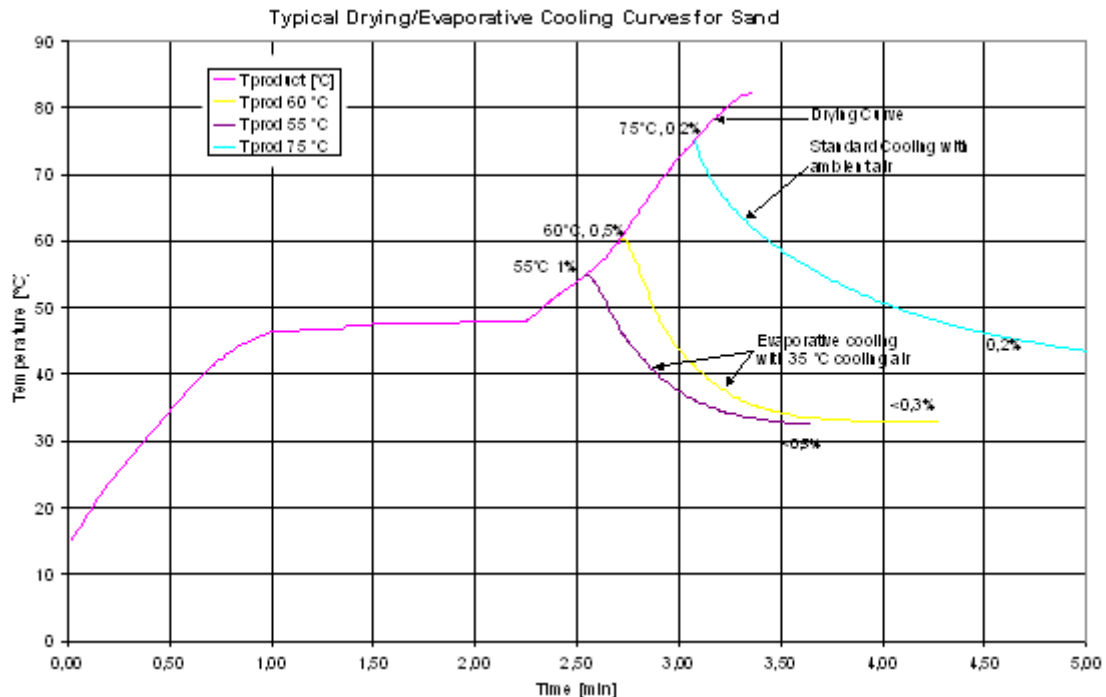


Fig.9: Evaporative cooling curves of sand after leaving the dryer at different temperature/moisture content
The system with evaporative cooling has the following advantages:

- The sand is not completely dried in the dryer, so the drying capacity per m^2 [ft^2] is increased.
- The temperature of the sand is not too high when entering the cooler. Also the evaporation of water takes the heat out of the sand. This means that the sand is colder after cooling than when it is complete dry before cooling, so the cooling capacity per m^2 [ft^2] is increased.
- Additional advantage is that the system is not influenced by the ambient (summer or winter) conditions. Cooling is always with $45\text{ }^{\circ}\text{C}$ [$113\text{ }^{\circ}\text{F}$] air temperature.

An example of a flow sheet is shown in the next figure.

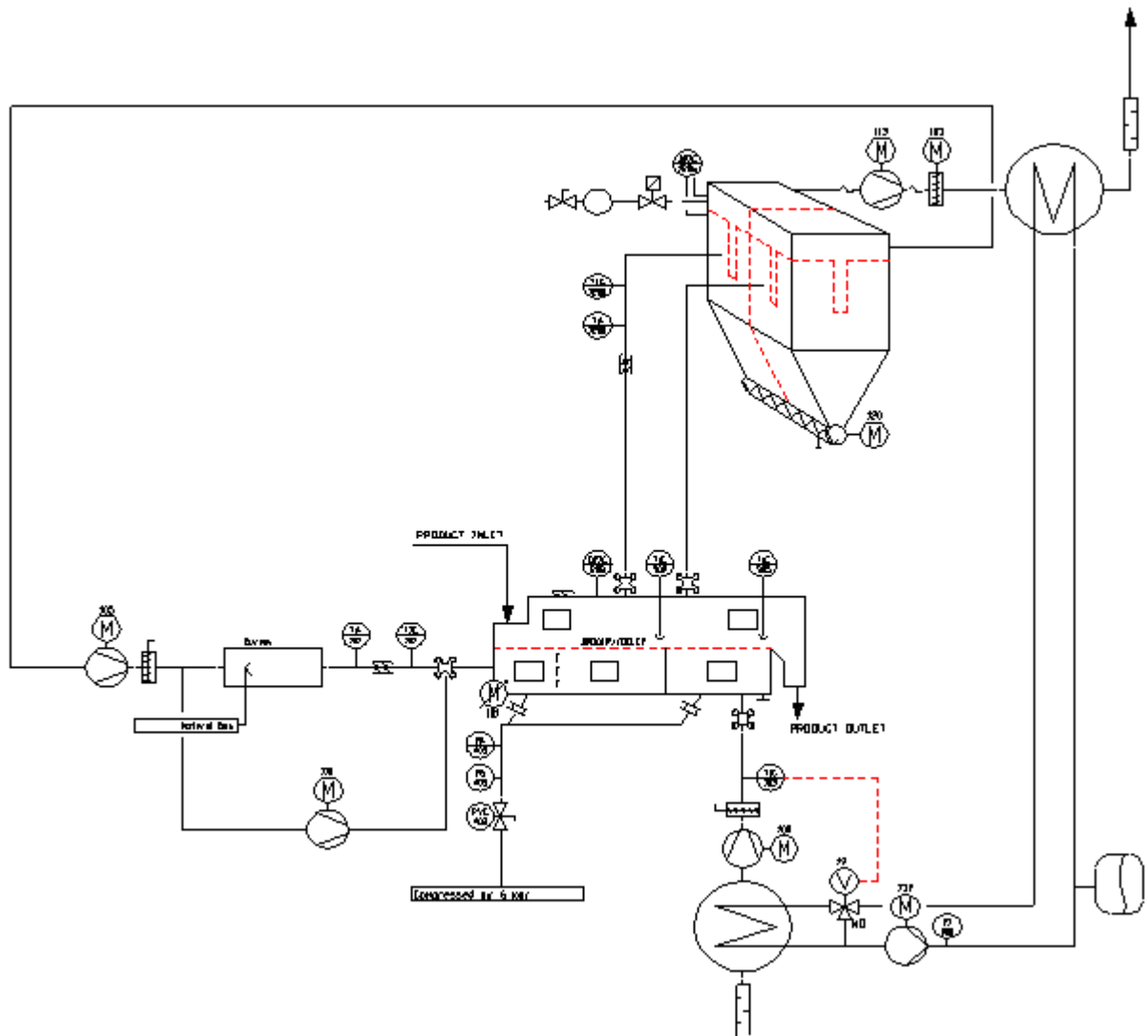


Figure 10 - Flow sheet dryer/cooler with evaporative cooling

7. LAY-OUT

The lay-out of the drying installations is kept as simple as possible in order to reduce the amount of space required. Normally the filter installation is placed next to the dryer. It is also possible to put the filter on a higher level or in the next room, then air extra ducting will be necessary. The next two drawings show possible layouts for a system without as well with air recirculation.

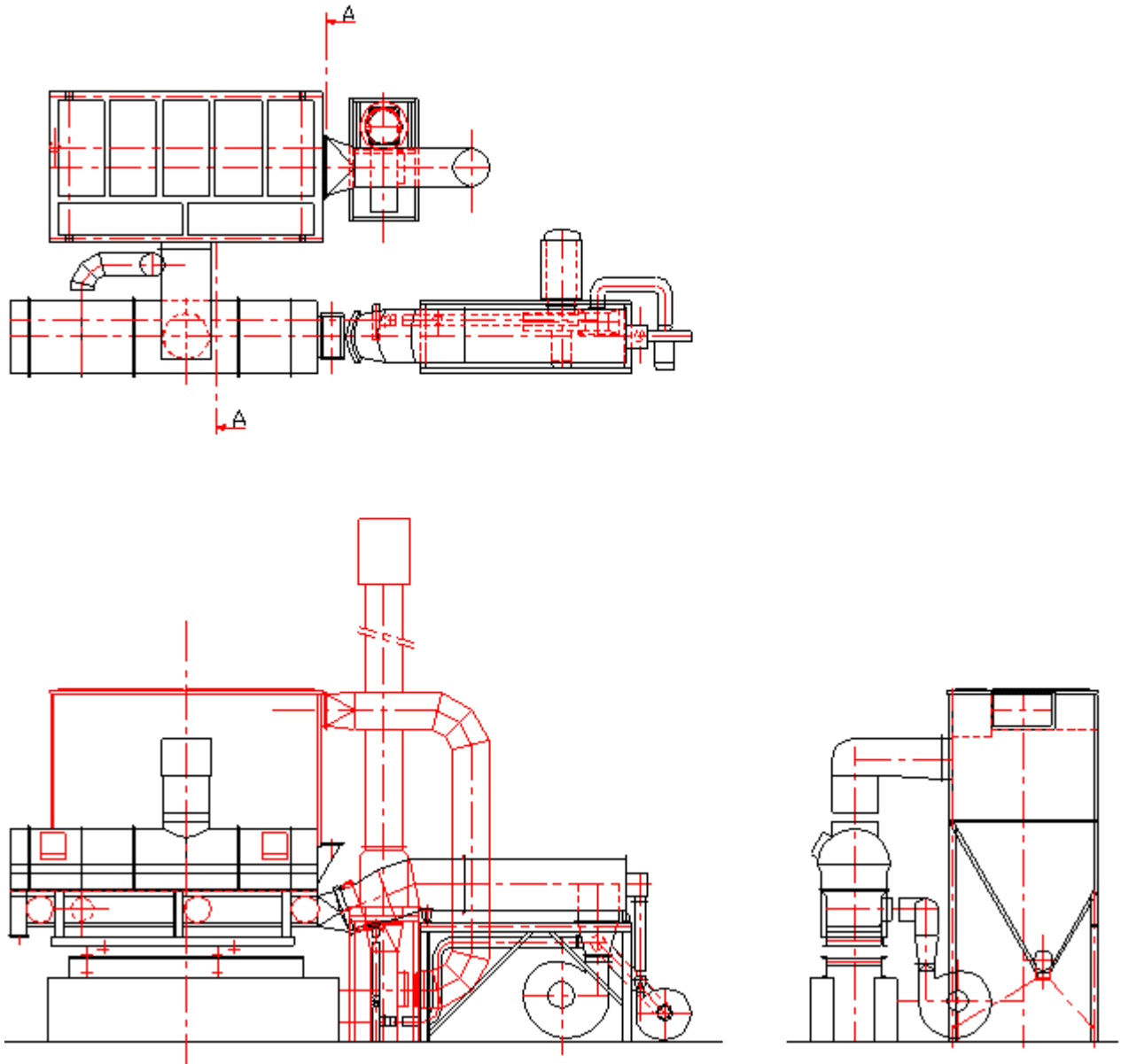


Figure 11: Layout of a dryer/cooler for sand without recirculation of cooler exhaust air.

shown with Light fuel oil burner

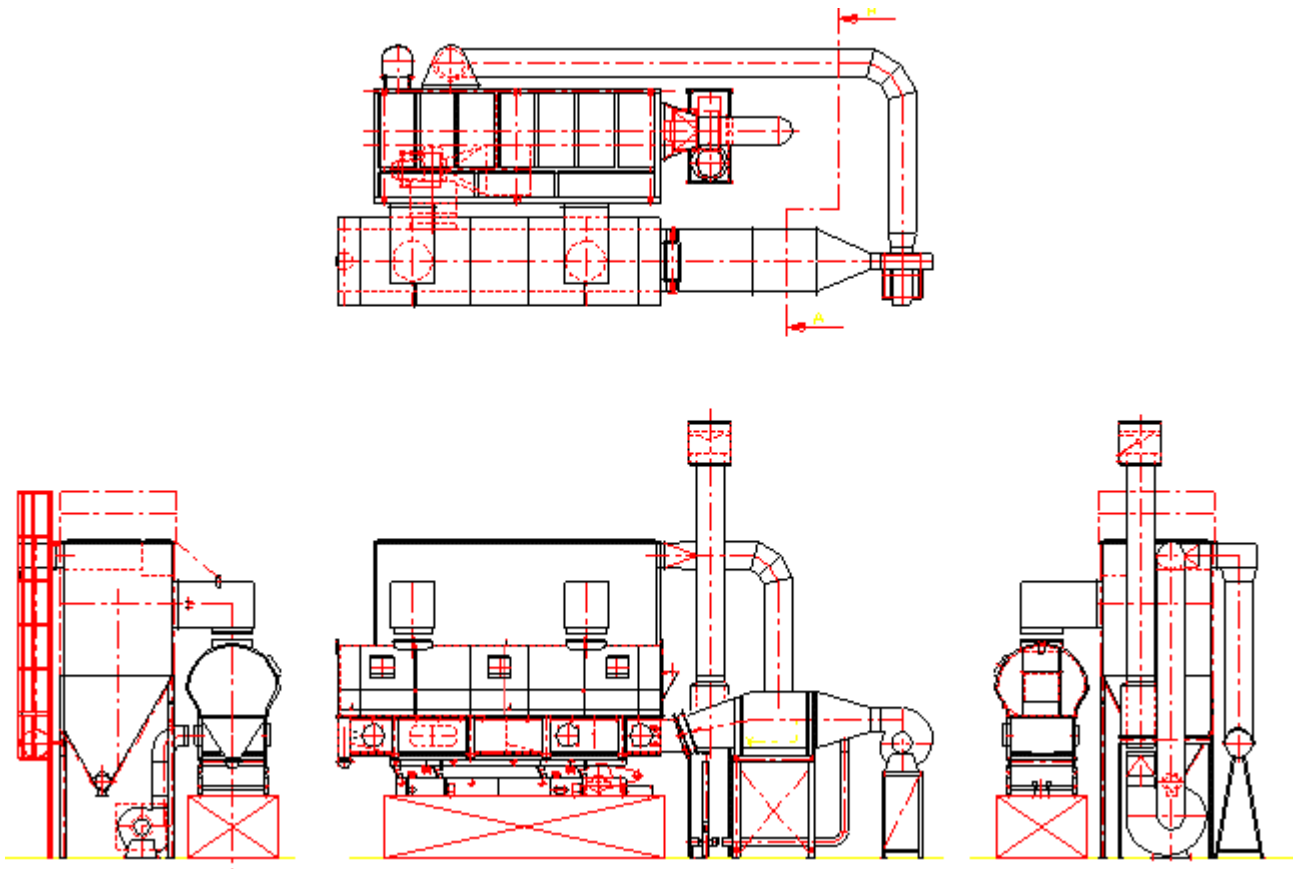


Figure 12: Layout of a dryer/cooler for sand without recirculation of cooler exhaust air.

Shown with Natural or LPG Gas burner

8. CONTROL SYSTEM OF A VENTILEX FLUID BED DRYER/COOLER

The fluid bed drying cooling system is supplied with a PLC based control system. In the VENTILEX control system the following controllers are integrated:

- Sub-pressure controller (pressure in the suction hood, controlled by valve on exhaust fan)
- Product temperature
- Exhaust air temperature
- Supply air temperature
- Product supply control

Sub-pressure control

The amount of exhaust air must be the same amount as the fresh air that is supplied plus the evaporation. A little extra bleed air is exhausted to maintain a sub-pressure.

The sub-pressure in the hood is measured with a Δp - measurement. The set-point of the pressure in the suction hood will be set just below the ambient pressure (± -0.5 mbar) [0.2 inches H₂O]. When the exhaust air temperature changes or the amount of cooling air is changed, the electric actuated throttle valve behind the exhaust fan will be opened or closed to maintain the sub-pressure.

Temperature controllers

For the temperature controllers we have integrated 5 PID controllers in the control system, complete with some extra functions. The control of the VENTILEX dryer/cooler is based on a 'standard' control system in which the supply air temperature and the exhaust air temperature are controlled (Cascade control). For sand dryers, we have extended the control system with a controller for the product temperature. This is very important for minimizing energy use and not over drying the sand or aggregate.

Standard control system

With a standard VENTILEX control system, the gas (or oil) valve (and accordingly the drying air temperature) is controlled on the exhaust air temperature. The product temperature after drying (and thus the final moisture content) is related to the exhaust air temperature. For drying of sand, lab testing of the product is important to determine the exact temperature and where it corresponds to % moisture of the product.

At the start-up of the drying installation, first the fans and then the burner will be started. When the required exhaust air temperature is reached, the product supply system will be started at $\pm 25 - 30$ % of the capacity. Then the controller for the product supply quantity will increase the capacity up to the maximum.

During the increase of the product rate, the supply air temperature will automatically be increased to maintain the exhaust air temperature at a constant level, because more energy is required for the evaporation. The maximum is reached when the gas supply valve (or the oil pump) of the burner is 100 % open.

When the installation is running at the maximum capacity and sand is supplied with a higher moisture content, the product temperature after drying will drop and the moisture content will be too high. If this situation is maintained, the exhaust air temperature will drop. At this point, the exhaust air temperature controller will reduce the capacity of the product supply system in order to maintain the exhaust air temperature at its set-point.

Despite the drying air temperature of 450 - 600 °C [840-1112 °F], the product temperature is not increasing while there is still some moisture on the surface of the product that evaporates. This temperature is what we call the 'wet bulb' or 'saturation' temperature. When the product is almost dry, the product temperature will start to increase. In case of variations in the ambient air temperature or at variations in the moisture content in the feed product, the product temperature will change in the case that the exhaust air is controlled at a constant temperature.

The minimum set-point of the exhaust air, to ensure that the product is dried according the specification, is to be determined during the commissioning period of the installation. During this period, it is determined what the minimum product temperature should be, while the product still is sufficiently dried. With a standard control system, the set-point of the exhaust air will be chosen so that the minimum product temperature is guaranteed under all conditions. That means in most circumstances that the product temperature will be higher then necessary and consequently a loss of energy.

Extension product temperature control system (For sand dryers)

By controlling energy input to the dryer by controlling the product temperature, the energy usage will be kept at a minimum at all conditions, in contrast with the standard control system where only the exhaust air temperature is controlled as described above.

The product temperature control system makes use of the point where product temperature rises quickly when it almost dry. The set-point of the controller is just above this temperature. This maximizes the throughput and always delivers the correct discharged moisture of the sand or aggregate.

The product temperature controller is made in such a way that when the actual product temperature has a certain deviation of the set-point, the set-point of the exhaust air temperature is increased or decreased and in this way the product temperature is controlled back to the set-point. This is all controlled automatically, the actual value of the product temperature will always be at or just above the set-point. This is a very important part of controlling the system and minimizing energy use, while maximizing the product throughput.

The PID controller of the product temperature has three set-points:

- Set-point product temperature for the PID controller.
- Low temperature. This is a set-point with a signal for possible actions by the operator.
- Low/low temperature (this is the temperature when the product is just dry). When the product temperature gets lower then the low/low set-point, the dryer will be shut-off to avoid wet sand going to the screen or to the silo's.

Set-points that can be adjusted by the client are:

- Maximum operation capacity of the product supply system
- Maximum supply air temperature
- Product temperature (this corresponds to % moisture of discharged product)

The set-point of the exhaust air temperature is automatically controlled by the PLC.

To keep all process parameters under control, we have added some extra functions to the PLC-control system. An example is the fixed set-point of the exhaust air temperature during the increasing of the feed rate at the start-up of the installation.

Advantages product temperature control system:

With the product temperature control system, the exhaust air temperature in the drying section of the machine is always controlled at a value as low as possible. At this temperature, the exhaust air is, when it leaves the dryer, completely saturated with moisture. Also the product will not be heated more then necessary for the drying requirements (energy savings).

Since the product temperature controller is combined with the product feed rate controller, a low product temperature and a low exhaust air temperature are combined with a result of maximum production capacity. In this way, if required, the VENTILEX fluid bed dryer/cooler installation will always run at the maximum capacity of the installation, independent of the moisture content of the supply product. This means no operator involvement -- the VENTILEX control system makes all the adjustments necessary.

9. ADVANTAGES OF THE VENTILEX FLUID BED DRYERS

Comparison with a rotary dryer:

- In a fluid bed dryer, the drying air is more evenly distributed over the product than in a rotary dryer. The result of this is that the temperature of the dried product can be maintained constant in a fluid bed dryer. In the fluid bed dryer, there is a better control of the drying air temperature and the product temperature, also during fluctuations in the amount of product supply and in the moisture of the product supply.
- Due to the better controls, the exhaust air temperature can be kept low, so the energy costs are lower than in a rotary dryer.
- The cooler area normally represents approximately half the size of the unit, for the dry mortar industry cooling usually is required. A rotary drum dryer will need a separate cooler for the product, increasing the cost by 50 % – 60 %.
- The energy consumption for a fluid bed dryer is much lower than for a rotary drum dryer. The reason for this is that in a fluid bed we have a far better control over the product final temperature and the air is in cross flow with the product instead of co-current flow. The exhaust from the cooler area can be recycled to the dryer area, so that all energy in the product is recuperated, what means additional reduction of energy consumption.
- A fluid bed can handle a wider variety of grain [product] sizes and moisture content than in a rotary.
- All newly built dry mortar plants in Europe use fluid bed units; replacing of rotary drum dryers at 10 - 15 year old mortar plants is common practice.
- Less maintenance and low consumption of wear parts.
- Intelligent controls make sure that the product temperature is not higher than necessary, so the cooling section can also be small.

Comparison with a static fluid bed dryer:

- A static fluid bed dryer is a well mixed fluidized bed. This means that the exhaust air temperature of the bed will be higher than on a plug flow VENTILEX dryer. Typical exhaust temperature with a static dryer will be 90 °C – 100 °C [194-212 °F]. The product will be dry at approx 20 °C – 30 °C [68-86 °F] above wet bulb. The VENTILEX shaking fluid bed dryer has an exhaust temperature of ± 60 °C [140 °F]. The temperature of the product is 75 – 80 °C [167-176 °F]. The exhaust air temperature in a VENTILEX system can be lower because of the plug flow.
- A VENTILEX fluid bed dryer/cooler has a better thermal efficiency because of the plug-flow system than a static well mixed system. Another problem that can occur with a static dryer is that, because of high supply air temperatures, the lumps (accumulated clay) can bake and melt on the bottom of the fluid bed.
- Another advantage of the shaking movement of a VENTILEX fluid bed dryer is that stones and other lumps will also be moved forward and transported out of the dryer. The lumps that may contain more moisture stay longer in the unit because they do not fluidize. Because of the longer residence time, lumps will also be dry. In a static dryer, lumps will not be moved, these have to be taken out at regular interval by hand.
- Intelligent controls makes sure that the product temperature is not higher then necessary, so the cooling section can also be small.
- The shaking fluid bed dryer allows for automatic emptying of the dryer, both above as well as underneath the perforated bedplate.

Comparison with competition vibrating fluid bed dryers

- VENTILEX dryers uses higher drying air temperatures, 450 - 600 °C [840-1112 °F] instead of 350 - 400 °C [662 - 752 °F]. The temperature difference between the supply air temperature and the exhaust air temperature is higher so the drying is more efficient and also the amount of drying air can be less. This has advantages in the size of the fans, electricity consumption, size of the filter etc.
- Less maintenance and low consumption of wear parts.
- Intelligent controls makes sure that the product temperature is not higher then necessary, so the cooling section can also be small.
- Automatic emptying of the dryer, also underneath bedplate.
- 3 – 5 mm plate thickness of the distribution plate. No blockage of the holes.



So the benefits of the VENTILEX system are:

- Lower energy usage (heat/gas/oil/steam as well as electricity)
- Cooler incorporated in machine - allows for recovery of energy also.
- Lower investment costs because of combined machine.
- The lowest production costs per Ton of dried product.
- Automatic removal of stones (transport of oversized material)
- Better fines removal
- Sturdier, better constructed machinery

© 2004 VENTILEX USA Inc. – All rights reserved
No part of this document may be reproduced or used without the author's consent