



RESIN DRYING IN THE PLASTICS INDUSTRY

Most plastic resins, such as PA (Nylon), PC and PET, are hygroscopic materials. They adsorb moisture from humid ambient air and give moisture back to dry air. Every type of resin can hold a specific amount of moisture between its molecular chains. Additional amounts of moisture can be condensed on the surface of the pellets (surface moisture). Non-hygroscopic resins, such as PE, PP and PVC, do not adsorb any moisture, but they still can have surface moisture.

Adsorbed moisture in hygroscopic resins and surface moisture in non-hygroscopic resins are known to cause defects in molded plastics and they might lead to a complete production stop.

Heating the resins, all the way through to the center of the pellets, to the highest possible temperature is very important to achieve good drying results.

The dew point of the air is the temperature at which the air would be saturated with moisture. Lowering the dew point of the air under -20°C [-4°F] in resin drying process is not necessary.

The standard compressed air quality has a dew point of 5°C [41°F] at a pressure of 7bar [100psi] which equals atmospheric air with a dew point of -20°C [-4°F] at sea level.

There are two ways to remove moisture from or reduce the amount of moisture in plastic resins:

- Increasing the pressure of the moisture inside the capillaries to drive the moisture out and then carry the moisture away by air (air drying) or
- Dragging the moisture out of the capillaries by setting the resin under low pressure (vacuum drying).

THE HOT AIR DRYER

Hot air dryers are very simple devices. The resin is loaded into a drying hopper where heated air is blown at the bottom of the hopper. The hot air rises between the resins heating the pellets and carrying the released moisture before it leaves the hopper at the top. The humidity of the ambient air used to dry the resin plays a big role in the drying results. The dryer performs better when the ambient air is dry but the ambient air humidity is never constant and very seldom low enough. The hot air dryer is not suitable for drying hygroscopic resins.

THE DESICCANT DRYER

The desiccant dryer is more complicated. The air is circulated between the drying hopper and a dryer in a closed loop to insure low air humidity at all times. The desiccant is regenerated periodically by hot air and the moisture is released from the dryer to ambient air. The moisture is removed from a hygroscopic material (the resin) and then deposited in a hygroscopic material (the desiccant) before it is released to the ambient air. This leads to many moving parts, high energy consumption, high maintenance and more floor space requirements.

THE COMPRESSED AIR RESIN DRYER

The compressed air dryer is the ideal continuous resin dryer. It combines the advantages of the hot air dryer and the desiccant dryer and avoids all the disadvantages of air dryers. The **Compressed Air Resin Dryer (CARD)** preheats the material with hot air and then uses a small amount of compressed air to remove the moisture from the resin. The compressed air is decompressed before it is heated and released at the bottom of the drying hopper. Standard quality of compressed air with a dew point of 5°C [41°F] or lower at 7bar [100psi] or higher is very sufficient for the job. The central air compressor in plastics processing facilities supplies air to multiple dryers saving expensive floor space in the manufacturing area and reducing the maintenance requirements. The energy consumption of the **CARD** is much lower than that of a desiccant dryer. In some applications, as in blow molding, the energy consumption can be reduced to nearly ZERO. The exhaust air from the process is used for drying and the heat can be recovered from the air compressor.

THE VACUUM DRYER

Vacuum drying is the best way to dry resins in a batch system but continuous vacuum dryers with multiple vacuum chambers in a carousel configuration were proven to be the wrong way to go. Too many moving parts with very high maintenance requirements are necessary to make the system operate in continuous mode. The chambers are difficult to clean when changing to a different type of resin or different color.

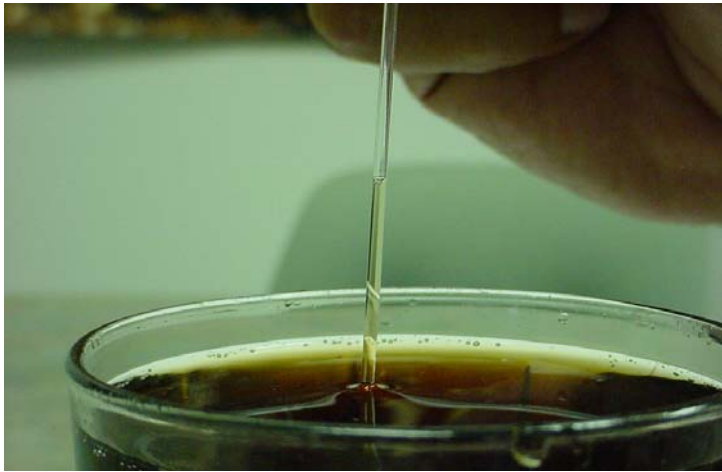
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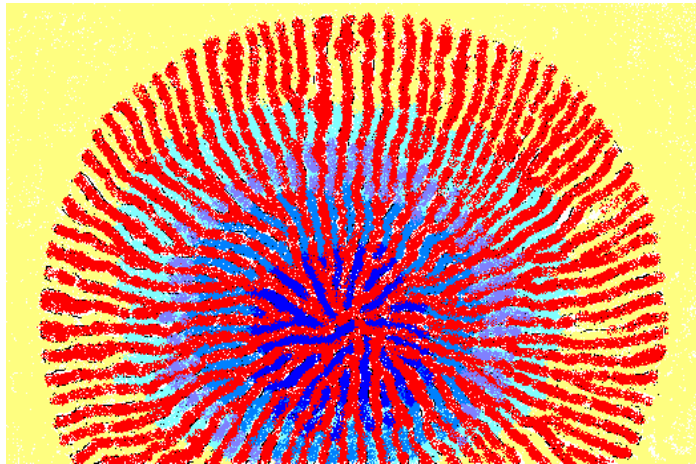
HYGROSCOPIC RESINS

The capillary phenomenon is known to most of us and can be demonstrated in a simple experiment: Inserting a long and very thin tube in a glass of colored water and holding the tube vertically will show that the water rises inside the tube above the water surface in the glass. Taking the tube out of the glass will show the water does not drop easily out of the tube. The capillary (the thin tube) would like to keep some water depending on its diameter. A thinner tube might show the water rising to a higher level and might keep more water after it was removed from the glass.

This experiment indicates that some of the moisture adsorbed by the capillaries of hygroscopic resins would stay inside the capillaries, even when the material had been stored in a very dry environment for a very long period of time.



Most plastic resins, such as PA (Nylon), PC and PET, are hygroscopic materials. They adsorb moisture from humid ambient air and give moisture back to dry air. Every type of resin can hold a specific amount of moisture between its molecular chains. Nylon, for example, can contain moisture up to 2% of its own weight. Additional amounts of moisture can be condensed on the surface of the pellets (surface moisture). Non-hygroscopic resins, such as PE, PP and PVC, do not adsorb any moisture, but they still can have surface moisture. The amount of moisture contained in the capillaries depends upon the type of material (the space between the molecules), the relative humidity of the air surrounding the pellets, the size of the pellets and the exposure time to the air.



Cutting a hygroscopic plastic pellet under a microscope will look like the graphic illustrated in the figure to the left. The plastic molecules are shown in red, moisture in blue and air in yellow.

Very tiny capillaries extending from the surface to the center of the pellet can be seen. Most of the moisture in the capillaries is concentrated in the center of the pellet. Surface moisture is not shown in this illustration.

The diameter of the capillaries in non-hygroscopic resins is smaller than the size of a water molecule and therefore such materials can not adsorb any moisture, but moisture might condensate on the surface of the pellets.

Adsorbed moisture and surface moisture are known to cause defects in molded plastics and they might lead to a complete production stop. Resin drying is a very important part of the molding process.



HEATING

Heating the resin will increase the pressure of the moisture inside the capillaries and it will set the water molecules in motion forcing more moisture to leave the capillaries. More moisture will leave the capillaries when the temperature is raised to a higher level. The velocity of the air on the surface of the pellets also plays a role in the drying process. A fast air stream causes a pressure drop on the surface of the pellets, which in turn helps drag the moisture out of the capillaries. The relative humidity of the surrounding air has much influence on the amount of moisture leaving the resin. Dry air is capable of carrying more moisture than moist air. A lower relative humidity will also accelerate the process to a certain extent. The exposure time to hot, dry and fast moving air is also an important factor. Longer exposure time will result in lower residual moisture in the capillaries of the resin.

Heating the resins, all the way through to the center of the pellets, to the highest possible temperature is very important to achieve good drying results.

HUMIDITY

Definitions such as DEW POINT and RELATIVE HUMIDITY are well explained in the MOLLIER DIAGRAM.

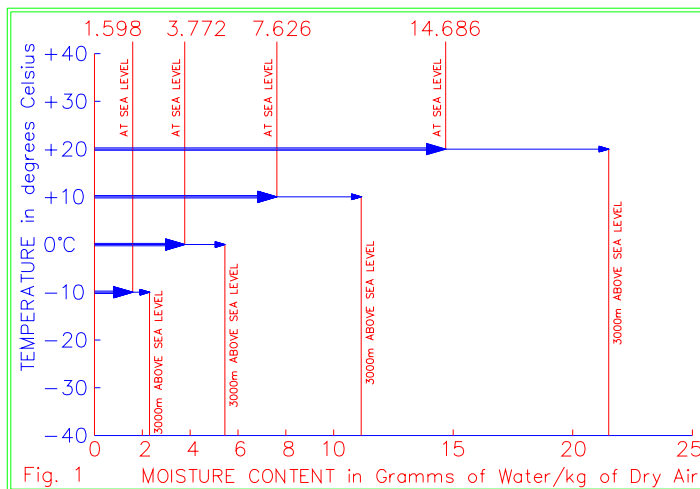


Fig. 1

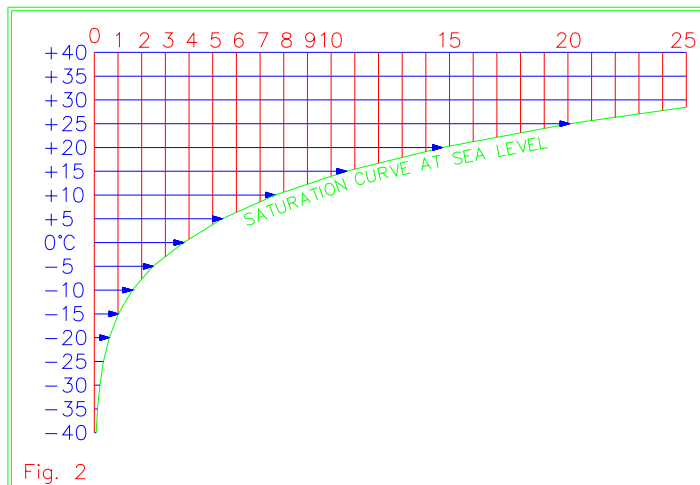


Fig. 2

Mollier (a Swiss scientist) found out that the air could carry a certain amount of vapor (invisible moisture) at a certain temperature and a certain pressure.

He created a diagram as shown in Fig. 1 and noted the amount of moisture, which 1kg [2.2lb] of dry air could carry and still be transparent. One kg of dry air at sea level and 10°C [50°F] can be saturated with 7.626g [117.68Grains] of moisture, as an example.

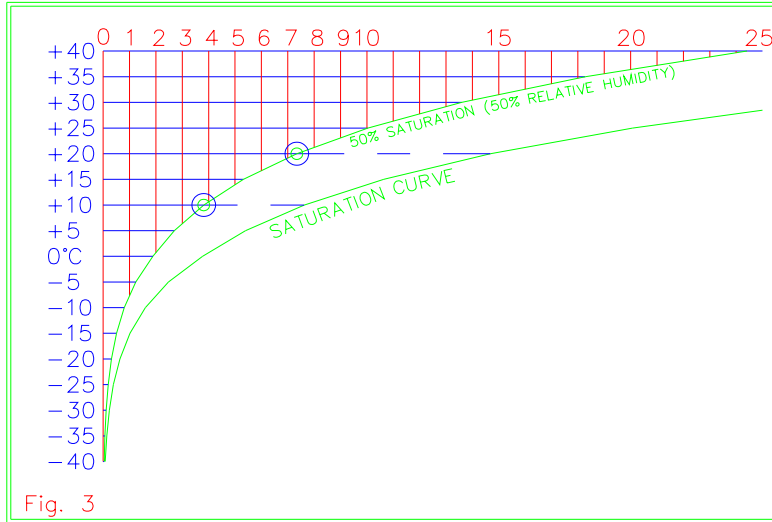
At the same temperature, but an altitude of 3000m [9843ft] above sea level, 1kg of dry air is able to carry more than 11g [170Grains] of invisible moisture.

Increasing the temperature of the air from 0°C [32°F] to 10°C [50°F] will cause an increase of the maximum moisture content (saturation) by 3.854g [59.5Grains] but increasing the temperature from 10°C [50°F] to 20°C [68°F] will allow a moisture increase of 7.060g [109Grains]. The temperature increase is equal in both cases but the maximum moisture content increase nearly doubled.

Connecting all moisture saturation values for 1kg of dry air at a certain pressure on a diagram (Fig.2) appears in a form of a curve, known as the saturation curve.

This illustration is valid for air ideal air pressure at sea level.

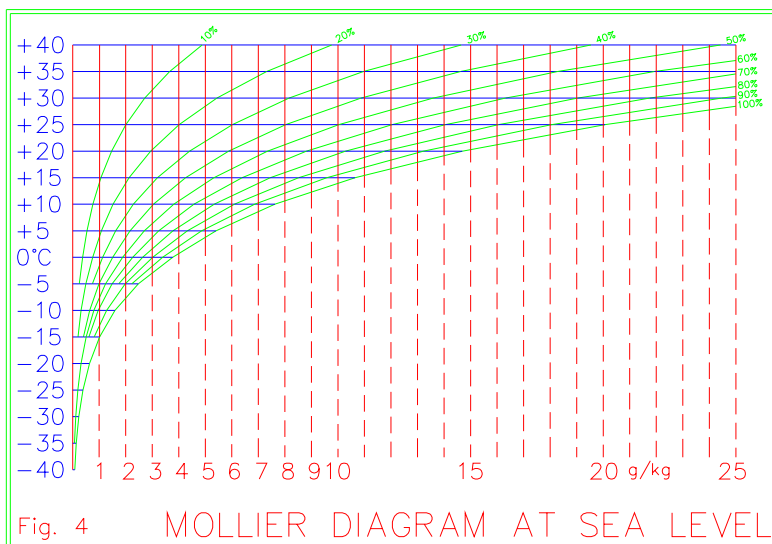
The fact that the result is a curve and not a straight line explains that the relation between temperature and maximum moisture content is not linear. The saturation curve starts at a temperature of -273°C [-459.4°F], which is known as Absolute Zero, with a maximum moisture content of Zero and reaches a maximum moisture content of 1g per kg of dry air [15.432Grains] at a temperature of -15°C [5°F]. In this range of the diagram we could easily consider the relation between maximum moisture content and temperature as a linear relation with ignorable moisture increase of 0.0037g for 1K [0.0033Grain for $^{\circ}\text{F}$]. A very clear curve appears in the temperature range from -15°C [5°F] to 30°C [86°F]. The saturation curve makes the dramatic increase of the saturation moisture, at higher temperatures very clear. Similar diagrams can be created for different altitudes or any different air pressure. Mollier diagrams are always valid for ONE kg of dry air.



In real life, the air we live in is not always saturated with moisture. If the air at a certain temperature and a certain pressure contains 50% of the moisture amount, which would saturate the air under the given conditions, the air is then 50% saturated (the relative humidity of the air in this case would be 50%).

Mollier connected the 50% saturation values in his diagram, which resulted in a curve (Fig.3).

Logically, the curve was called “THE 50% RELATIVE HUMIDITY CURVE”. The relative humidity of the air represents the amount of moisture contained in the air related to the amount of moisture, which would saturate the air at the given temperature and pressure.



The same procedure can be done with any percentage of moisture content relative to the maximum moisture value at the same temperature and the same pressure.

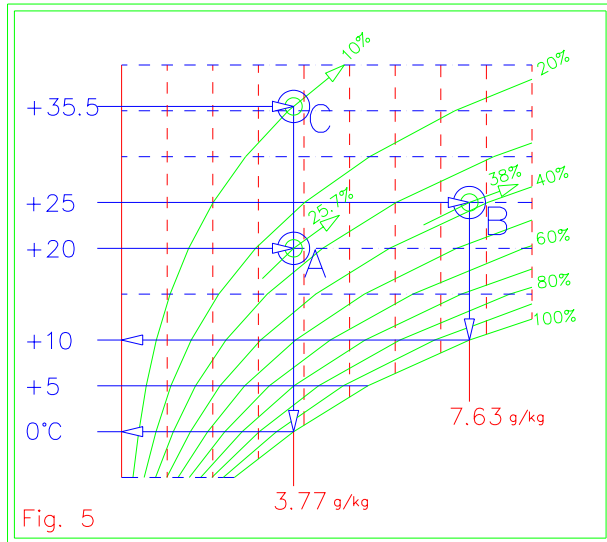
Psychometric charts and Mollier diagrams can be created for any temperature range containing as many relative humidity curves as required.

The Mollier diagram shown in Fig. 4 contains 10 curves for relative humidity from 10% to 100% (saturation curve).

A small amount of moisture might not saturate the air at higher temperatures and the relative humidity of the air would be low at the said temperature. If the air is cooled down to a lower temperature, the relative humidity of the air will increase as the temperature drops down, until the relative humidity reaches 100%. If the temperature continues to drop down, the air becomes over-saturated and the excessive amount of moisture, beyond the saturation value, will appear in the air in a form of fog, mist, clouds or dew.

The dew point of the air is the temperature at which the air would be saturated with moisture.

Lowering the dew point of the air under -20°C [-4°F] in a drying process is not necessary.



Point {A} in Fig. 5 represents air at a sea level with a temperature of 20°C [68°F], a moisture content of 3.77g/kg [58.17Grains] and a relative humidity of 25.7%. Cooling this air down to a temperature of 0°C [32°F] will raise its relative humidity to a value of 100% and the air would be saturated at this temperature. The air at point {A} has a DEW POINT of 0°C [32°F].

At point {C} the temperature is 35.5°C [96°F], the relative humidity is 10%. The air contains the same amount of moisture as in point {A} and point {C} also has a dew point of 0°C [32°F].

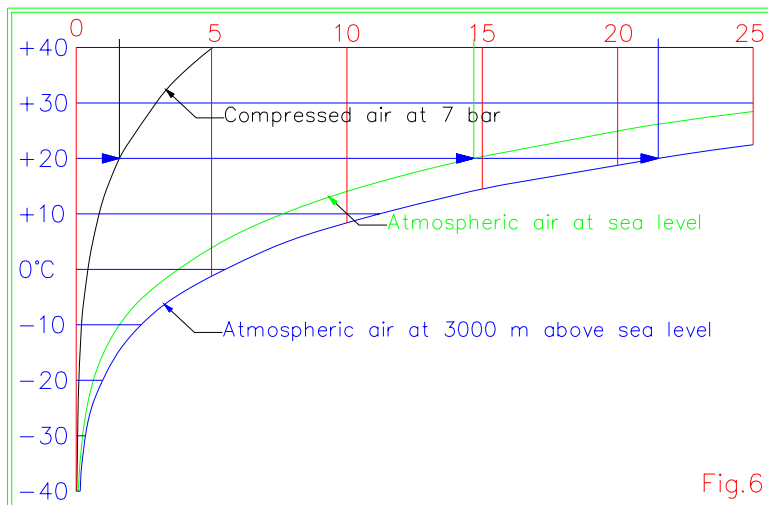
The temperature at point {B} is 25°C [77°F] and the relative humidity is 38%. The moisture content is 7.63g/kg [117.7Grains] and the dew point is 10°C [50°F].

From the examples shown in Fig.5, we can clearly see that the dew point of the air is directly related to the moisture content of the air. There is no direct relationship between dew point and temperature. There is no direct relationship between dew point and relative humidity.

The dew point is directly related to the moisture content and the saturation curve.

We can also see from the examples in Fig.5 that air at 35.5°C [96°F] and 10% relative humidity is more suitable for drying purposes than air at 20°C [68°F] and 25.7% relative humidity. The dew point in both cases is equal, but the air temperature is higher at point {C} and the relative humidity is also lower at point {C}.

The relative humidity of the air is more important than the dew point in the drying process.



The amount of moisture to saturate 1kg [2.2lb] of air at a certain temperature depends on the air pressure. In Fig.6 we can see that 1kg of air at sea level and a temperature of 20°C [68°F] can carry up to 14.686g [226.6Grains] of moisture.

At the same temperature, but an altitude of 3000m [9843ft] above sea level, 1kg of dry air is able to carry more than 21.5g [331.8Grains] of invisible moisture. The air pressure in this case is lower than the air pressure at sea level.

One kg of compressed air at a pressure of 7bar [100psi] can carry as little as 1.6g [24.69Grains] of moisture.

Ambient air becomes over-saturated with moisture when compressed to higher pressures. The excessive amounts of moisture in compressed air (liquid) can easily be separated from the air in standard equipment. Decompressing the air after separating the excessive moisture will result in very dry atmospheric air.



Compressed air at a pressure of 7bar [100psi] and a dew point of 5°C [41°F] will have a dew point of -20°C [-4°F], when decompressed to atmospheric air pressure at sea level. Compressed air at 30bar [435psi] and a dew point of 3°C [37°F] would have a dew point of -36°C [-33°F] at sea level.

Standard compressed air with a dew point of 5°C [41°F] at a pressure of 7bar [100psi] which equals atmospheric air with a dew point of -20°C [-4°F] at sea level.

There are two ways to remove moisture from or reduce the amount of moisture in plastic resins:

- Increasing the pressure of the moisture inside the capillaries to drive the moisture out and then carry the moisture away by air (air drying) or
- Dragging the moisture out of the capillaries by setting the resin under low pressure (vacuum drying). A combination of the two is also possible.

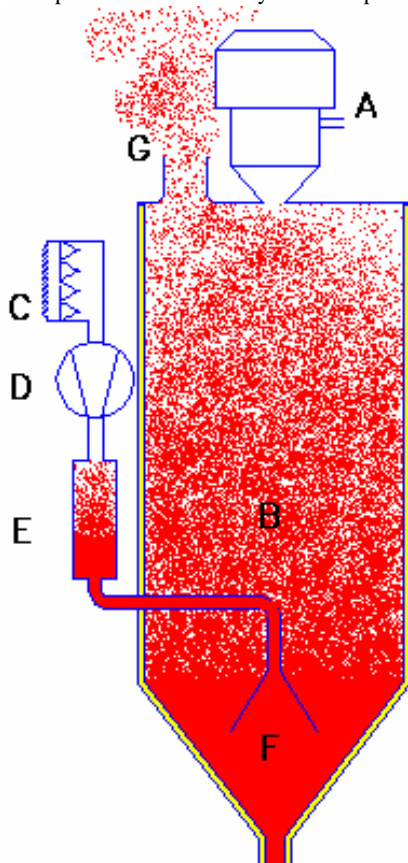
AIR DRYERS AND RESIN DRYING

We should note that water (moisture) turns into ice at a temperature of 0°C [32°F] under ideal atmospheric pressure at sea level. The lower the pressure gets, the higher is the freezing temperature. This fact leads to the necessity of heating the resin and its moisture content before applying low pressure in the vacuum drying method.

Heating is very important in drying plastic resins. Applying hot air to heat the resin in a drying hopper or container is the most common heating method. Other heating sources such as Microwave and Infrared are theoretically usable, but they are not very practical when used for heating resins in industrial scale.

A large amount of air is required to heat the resin to the required temperature, but once the resin is properly heated and the adsorbed moisture is driven to the surface of the pellets, a smaller amount of dry air is normally sufficient to carry the moisture out of the drying hopper.

The simplest form of resin dryers in the plastics industry is the HOT AIR DRYER.



Plastic resins are fed by means of a hopper loader {A} to a drying hopper {B}. Ambient air is pulled through a filter {C} by a blower {D} and blown through a heater {E} and the distributor {F} inside the lower part of the hopper {B}. The heated air, with lower relative humidity, flows upwards between the pellets inside the hopper, thus raising the temperature of the resin, the moisture contained in the capillaries between the molecular chains inside the pellets and any condensed moisture on the surface of the pellets. The pressure of the moisture increases inside the capillaries of the resin. The hot air passing by the surface of the pellets is capable of carrying a certain amount of the released moisture before it leaves the hopper at the top {G}.

The higher the temperature of the hot air stream through the hopper, the lower is the relative humidity of the air. The drying results in a hot air drying system depend on the humidity of the ambient air as the process air temperature is limited and must be lower than the resin melting temperature. In some cases the temperature of the drying air stream is limited to a lower level because of other reasons such as oxidation.

The hot air dryer can be used as a continuous or a batch drying system.

It is widely used to dry surface moisture in non-hygroscopic materials.

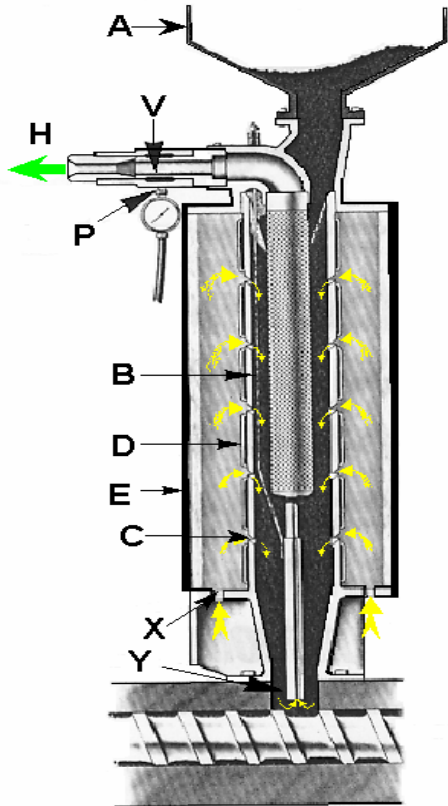
ADVANTAGES:

- Simple and compact system
- Low initial cost
- Low maintenance cost

DISADVANTAGES

- Not suitable for drying hygroscopic resins
- Instable drying (depending on ambient air conditions)
- Relatively high energy consumption

The hot air dryer has also appeared in other forms. The most primitive form is the hot air oven. Hot air is blown on shelves containing thin layers of resin inside a cabinet. The material is manually loaded on trays into the cabinet and the dried material is manually unloaded and stored in bins.



The most sophisticated form of hot air dryers is illustrated to the left. This type of dryer is an attempt to dry resins in a continuous drying system under low pressure effect to accelerate the moisture removal from the resin. It is normally used directly on the processing machine.

The loader {A} fills a cigar formed hopper {B} with resin. The hopper wall is surrounded by heater bands {D} and has many tiny holes {C} spaced between the heater bands.

Compressed air {P} is supplied to the venturi {V} to create a vacuum at the end of a suction tube {Y} inside the hopper. Ambient air enters the housing of the dryer {E} through halls {X} at the bottom. The air is heated by the heater bands before it enters the hopper through the tiny holes {C}. The hot air flows downward through the resin inside the hopper and enters the suction tube at a low pressure.

The use of a venturi to avoid moving parts (vacuum pump or blower) increases the operating cost.

ADVANTAGES:

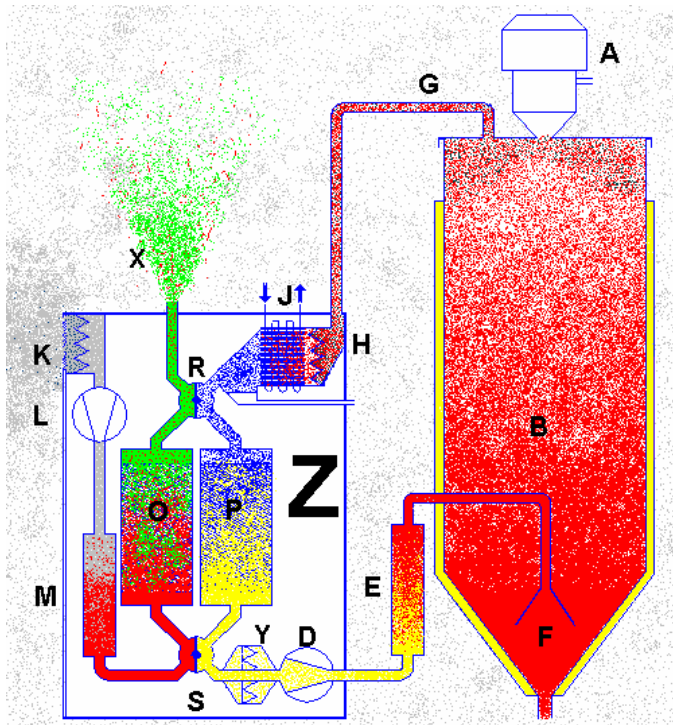
- Simple and compact system
- Low initial cost and low maintenance cost
- Better drying results than the classical hot air dryer

DISADVANTAGES

- Available for small material throughputs only
- Unstable drying (depending on ambient air conditions)
- Not easy to clean when changing material types or colors

The most common form of resin dryers in the plastics industry is the **DESICCANT DRYER**.

The desiccant dryer is an improved form of the hot air dryer. Instead of using ambient air, as in the hot air drying system, the desiccant dryer uses heated dry air to remove the moisture from the pellets in the hopper {B}. The process air in the desiccant drying system is circulated in a closed loop. The air {G} does not exit from the top of the hopper to the ambient air. It is returned back to a dryer {Z} to be dried before it is repeatedly used to remove moisture from the resin in the hopper. The process air is always circulated between the hopper {B} and the desiccant dryer {Z}.



The dried and heated process air released at the bottom of the drying hopper {F} in the desiccant drying system has a lower and much more stable dew point when compared to the ambient air used in hot air dryers. The results are shorter drying time and lower residual moisture content in the dried resin.

Air is sucked from the top of the hopper {G} to the dryer {Z} through the filter {H} and the cooling heat exchanger {J}. The distributors {R} and {S} guide the air through one of two containers filled with desiccant {O} or {P}. In our example the process air passes through the desiccant container {P}. The desiccant (very hygroscopic material) adsorbs the moisture from the process air. The dried air gets to the suction side of the blower {D} through the distributor {S}. The blower blows the dried air through the heater {E} and the distributor {F} at the bottom of the hopper {B}.

The amount of moisture adsorbed by the desiccant increases over time and the desiccant has to be regenerated. The desiccant in the container {O} is being regenerated, while the desiccant in the container {P} is adsorbing moisture from the process air. Ambient air is sucked by the blower {L} through the filter {K} for the regeneration process.

The heater {M} heats the regeneration air to high temperatures up to 300°C [600°F] before it is guided to the desiccant in the container {O} through the distributor {S}. The regeneration air removes the moisture contained in the desiccant and then gets released to the ambient air {X}. The heated desiccant is then cooled down by ambient air (the heater {M} is switched off) before it can be used for drying process air. The air distributors {R} and {S} switch over guiding the process air to the container {O} and the heated regeneration air to the container {P}. The regenerated desiccant in the container {P} now dries the process air while the saturated desiccant in the container {O} is being regenerated. Automatic timers or a dew point measuring instrument are used to control the regeneration cycle in desiccant dryers.

Not only energy loss is claimed in the regeneration process but stress is also caused by heating the desiccant (Molecular Sieve) to regeneration temperature level and then cooling it down to be ready for drying the process air. The desiccant pellets fracture and turn into powder losing absorption efficiency over time. Desiccant powder is then carried by the process air to the drying hopper. Some desiccant dryers include an air filter {Y} to avoid contaminating the plastic resins in the hopper. Some chemicals and additives are released from the resin during the drying process in the hopper. The process air carries the released chemicals from the hopper to the desiccant covering the surface of desiccant pellets and further reducing the efficiency over time. In fact, the desiccant starts losing efficiency from the first regeneration cycle and it has to be replaced when it is no longer capable to dry the process air to an acceptable dew point.

Depending on the type of resin being dried, the drying temperature might be set to a temperature in the range between 70°C [158°F] and 200°C [392°F]. The temperature of the return air {G} is normally high when air temperature above 110°C [230°F] is used to dry the resin but the desiccant does not adsorb moisture from hot air. In such cases the return air {G} must be cooled down by chilled air in the heat exchanger {J} before it is led to the desiccant in the process air circuit. There is a waste of energy if the air is to be cooled down in the heat exchanger {J} and then has to be heated up in the heater {E} to the required drying temperature.

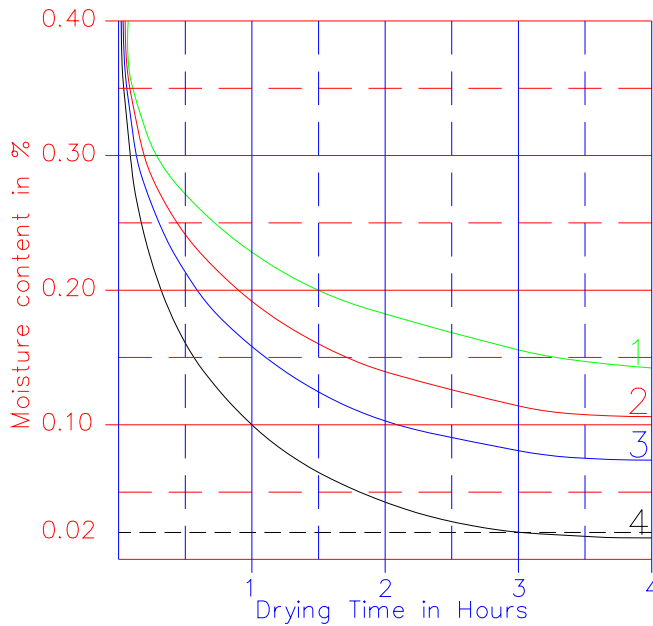
Very powerful process air blowers are necessary to move the process air through the resin in the hopper {B}, the air filters {H and Y}, the distributors {R and S} and the desiccant {P or O}.



Dust from the resin in the drying hopper and from the desiccant is separated from the process air in the filters {H} and {Y}. The air filters have to be cleaned or exchanged when necessary. Clogged filters will reduce the air flow and the drying efficiency.

The air distributors {R} and {S} are moving parts prone to much wear and tear. Leakage in the air distributors will cause an undesired mixture of process and regeneration air streams.

The sudden change from one container to the other one after the regeneration process will cause sudden changes in the process air temperature. The temperature of the process air can involuntarily exceed the limits. When this happens, the surface of the pellets at the lower part of the hopper might suffer from high temperature. Many users tend to set the process air temperature to a lower level to avoid temperature spikes. Lower efficiency and longer drying time are the results of lowering the process air temperature.



Many studies have shown that drying with dry and hot air is the most feasible method. Heating air to lower the relative humidity has limitations, when used in drying resins. A maximum temperature of 80°C [176°F] is allowed in drying Nylon because higher temperatures would cause oxidation when Oxygen is present in the drying hopper.

The difference between hot air drying and desiccant drying is illustrated in the diagram to the left.

Curves 1, 2 and 3 are drying results with a hot air dryer under various weather conditions.

- 1- 20°C [68°F], 80% relative humidity: The dew point is 16°C [61°F]. After 4h of drying time residual moisture of 0.14% was reached.
- 2- 15°C [59°F], 70% relative humidity: The dew point is 9.5°C [49°F]. Residual moisture of 0.11% was reached in 4 hours.

3- 0°C [32°F], 70% relative humidity: The dew point is -4°C [25°F]. Moisture content was measured at 0.1% after 2 hours and it was measured at 0.07% after 4 hours.

4- Dry air with a dew point of -20°C [-4°F] was able to drop the moisture content to 0.1% in 1 hour and 0.02% within 3 hours.

The diagram shows clearly that both dryer types can dry Nylon with high moisture content (up to 2%) to 0.35% equally fast. The drying results in a desiccant drying system are indeed better than the drying results in a hot air drying system, but the classical desiccant dryer has many problems.

ADVANTAGES:

- Controlled (low) humidity of the process air
- Suitable for drying hygroscopic resins

DISADVANTAGES

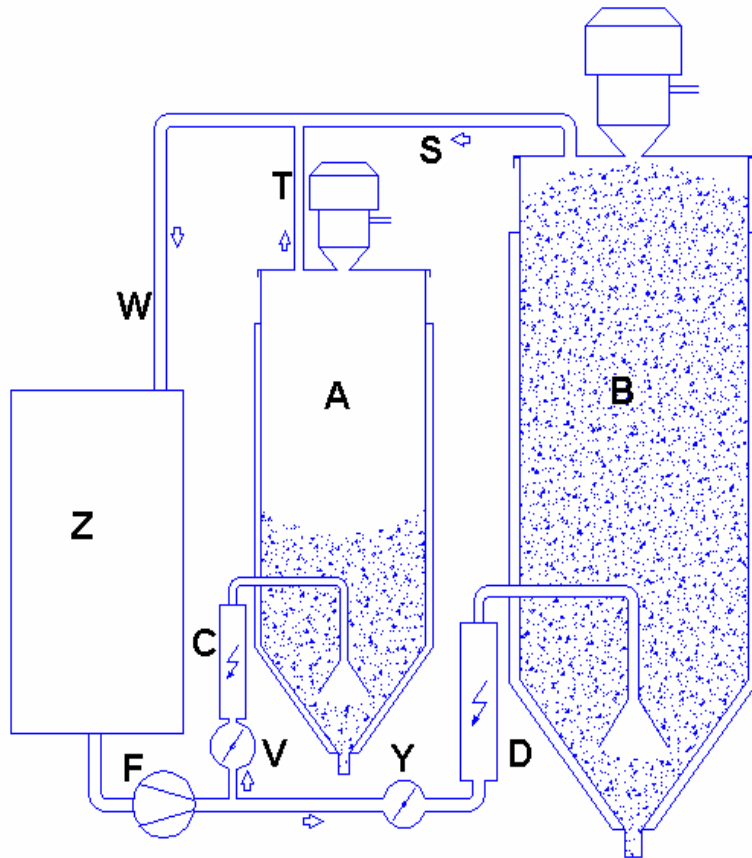
- Decreasing efficiency over time (Filters, desiccant and distributors)
- Requires intensive maintenance
- High energy consumption
- Requires chilled water cooling when used to dry at higher temperatures
- Large floor space requirements

There were many attempts to improve the desiccant drying systems, but none was successful in eliminating the major disadvantages of the system.

Some desiccant dryer manufacturers applied very large desiccant containers to allow for longer time between the desiccant changes. More energy was needed to regenerate the excessive amounts of desiccant and more floor space was needed for the large dryer size. The initial cost of the dryer also increased accordingly.

Other manufacturers applied more than two desiccant containers in a rotating carousel. The air distributors became very complicated and the rate of wear and tear was much higher. The initial cost increased as well.

Some dryer manufacturers offer a **CENTRAL DESICCANT DRYER** to reduce the initial cost and the floor space requirements. The central system consists of one desiccant dryer to supply dry air to multiple hoppers in different sizes. Each hopper includes a process air heater so that different types of material can be dried in different hoppers with different material flow rates.



The blower {F} sucks dried air from the desiccant dryer {Z} and blows it into ductwork with branches to supply the air to multiple hoppers. Our example shows two hoppers of different sizes {A} and {B}. One of the supply air branches supplies dry air to hopper {A} through a throttle valve {V} and a heater {C}. The other branch supplies air to hopper {B} through the valve {Y} and the heater {D}.

The process air temperature is individually adjusted to suit different types of resins to be dried in each hopper. The throttle valves {V} and {Y} are adjustable, but normally fixed in a certain position to adjust the air flow rates based on the size of each hopper assuming that both hoppers are full of resin with a specific calculated bulk density.

The return air from each hopper {T} and {S} is collected in a central ductwork {W} leading to the desiccant dryer {Z}.

The return air contains undesired moisture but it also carries some additives and chemicals from the resins in each hopper. The moisture will be separated from the process air in the dryer, but the additives will be mixed together and returned to both hoppers.

Additives and chemicals carried away from the resin in hopper {B} might be harmful to the resin in hopper {A}. The fact that one of the hoppers might not be completely full of resin or even empty leads to bad air distribution between the drying hoppers. Automatic dampers can be installed instead of the fixed throttle valves to insure the calculated air flow required for each hopper size, but this adds to the list of wear and tear and increases the initial cost of the system.

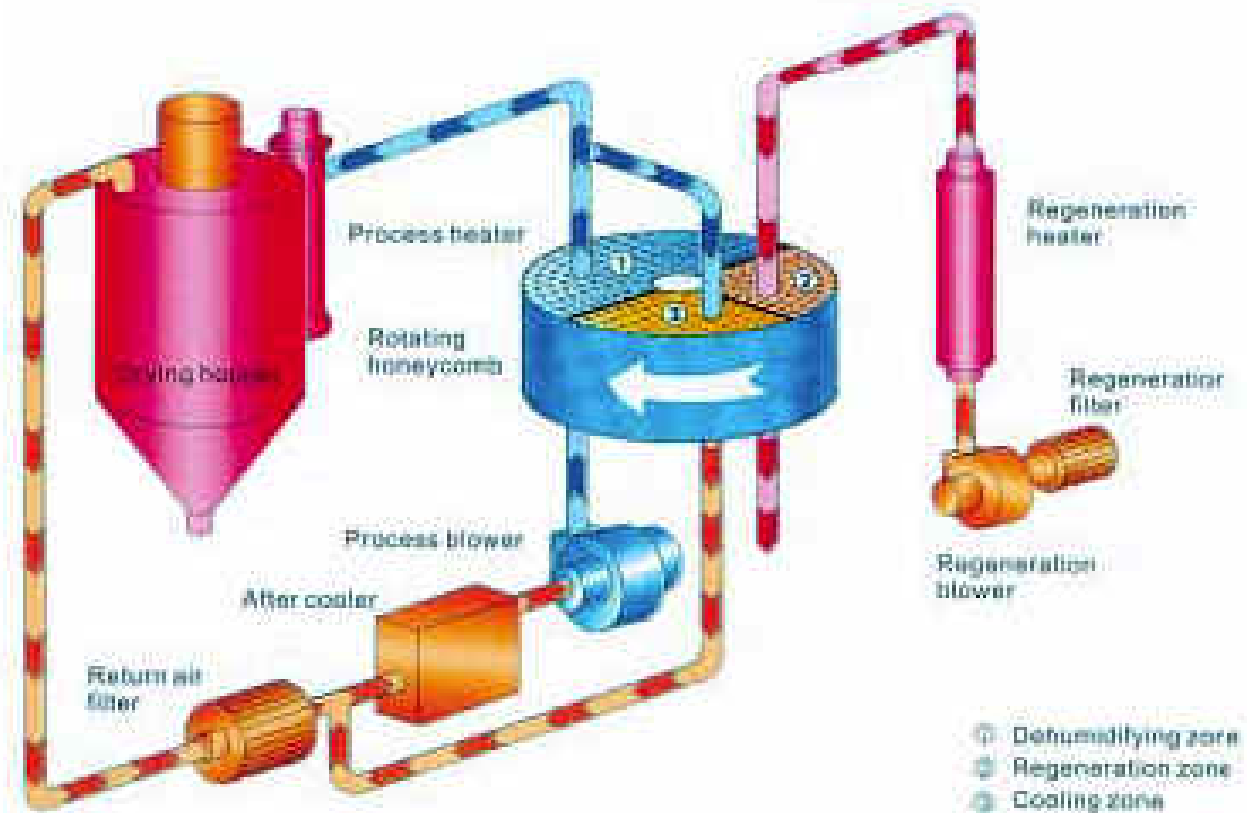
ADVANTAGES:

- Low initial cost
- Smaller floor space requirements
- Lower maintenance cost (one dryer)

DISADVANTAGES:

- Unstable process air flow rate and unstable drying
- Contaminants intermix between hoppers
- Higher energy consumption

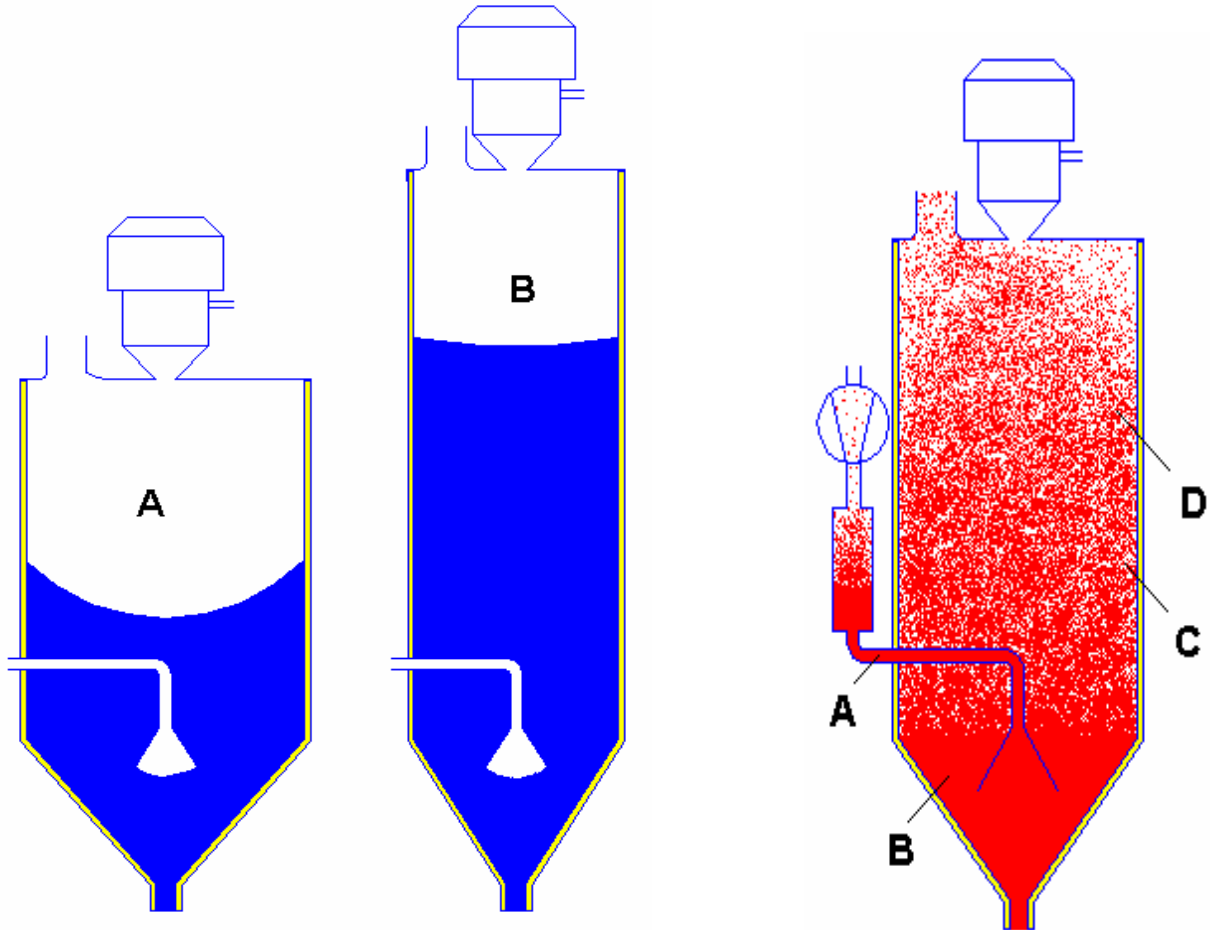
One of the remarkable improvements on the desiccant drying system was the invention of the desiccant rotor. It solved many of the desiccant problems found in the classical desiccant drying systems. The rotor is continuously rotating. It avoids temperature spikes when switching between two desiccant towers. The rotor is cooled down by cool, dry air before it reaches the process air section improving the efficiency of the desiccant. The rotor life time is still depending on contamination, even if it lasts longer than the desiccant in other dryers.



The main disadvantage of all desiccant drying systems is the fact that the moisture is removed from a hygroscopic material (the resin) and then deposited in a hygroscopic material (the desiccant) before it is released to the ambient air. This leads to many moving parts, high energy consumption, high maintenance and more floor space requirements.



The design of the drying hopper in any air drying system is very important. The drying results do not only depend on the dew point and the temperature of the process air. The resin residence time in a high temperature range, the air distribution inside the hopper and the material flow through the drying hopper are also very important factors.



Funnel flow occurs when the resin flows faster through the center of the hopper than it does along the side wall. A slim and tall hopper helps avoid the funnel flow and insures a faster air flow and equal process air distribution through the resin. The drying results in hopper {B} are better than the drying results in hopper {A}.

The air temperature is set to 120°C [250°F] at point {A} when drying PC. The temperature drop in a classic hopper with a classic air distributor was measured just below the set temperature at point {B} but the temperature was much lower at point {C} and reached 75°C [167°F] at point {D}. The residence time of the resin in a high temperature range was very short.

The resin is not heated all the way through to the center of the pellets to the set temperature.

Increasing the air flow raises the set temperature to higher levels inside the hopper and improves the drying results but the energy consumption increases as the air flow rates increase.

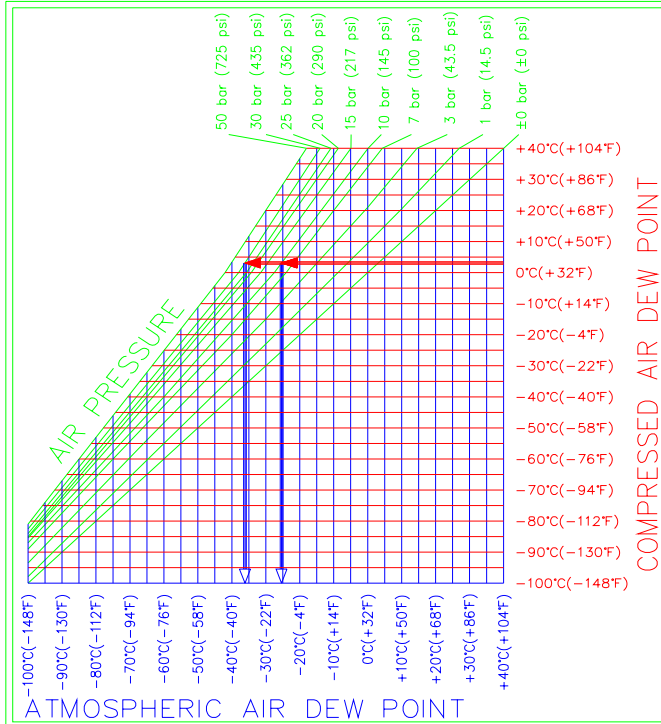
THE COMPRESSED AIR RESIN DRYER

A different approach was attempted by Rainer Farrag, who is also the inventor of the continuous vacuum drying system, to avoid all the disadvantages of the desiccant drying system. The new invention was born in 1991.

The compressed air dryer uses dry air to remove the harmful moisture from hygroscopic plastic resins in a hopper, but it uses dry compressed air instead of air dried by desiccant.



Ambient air becomes over-saturated with moisture when compressed to higher pressures. The excessive amounts of moisture in compressed air (liquid) can easily be separated from the air in standard equipment.



Decompressing the air after separating the excessive moisture will result in very dry atmospheric air. The illustration on the left side is a dew point conversion chart.

At 10bar [145psi] and a dew point of 3°C [37°F] the equivalent atmospheric air dew point is -26°C [-15°F]. Compressed air at 30bar [435psi] and a dew point of 3°C [37°F] would have a dew point of -36°C [-33°F] at sea level.

The standard compressed air dew point in plastic processing factories is 5°C [41°F] at 7bar [100psi]. When the air is decompressed to atmospheric pressure the dew point drops down to -20°C [-4°F]. These air conditions are very sufficient for resin drying purposes.

Once the resin is heated to the highest possible temperature, a small amount of dry air is capable of drying the resin.

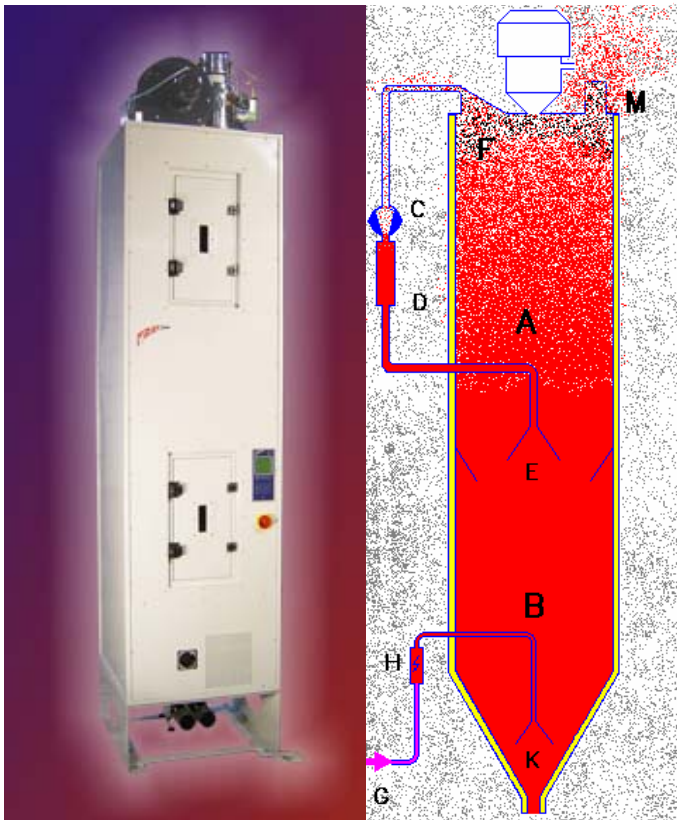
These are the two facts on which the compressed air resin dryer was based. The system uses two hoppers on top of each other. The resin is heated in the upper hopper by circulating hot air through the resin to increase the moisture pressure and drive the moisture out of the capillaries.

A much smaller amount of heated dry air is used in the lower hopper to drag more moisture out of the resin and carry it out of the hopper through a filter built on the lid of the upper hopper.

The Blower (C) pushes air through the heater (D) to the air distributor (E). The heated air rises through the resin in the upper part of the hopper (A) and heats the pellets raising the pressure of the moisture inside the capillaries and returns back to the blower at the very top of the hopper (F).

A small amount of dry and filtered compressed air (G) is decompressed to atmospheric pressure and enters the heater (H) on its way to the distributor (K) at the very bottom of the drying hopper. The dew point of the pre-dried air drops down due to the decompression and becomes sufficient for removing the moisture from the pellets while passing through the pre-heated resin in the lower part of the drying hopper (B).

The drying air continues rising through the upper part of the hopper (A) to carry any released moisture and leaves the hopper through the filter (M) on top of the hopper's lid.





The **Compressed Air Resin Dryer (CARD)** has proven reliability and very low maintenance requirements due to the use of compressed air instead of desiccant dryer.

The **CARD** does not lose efficiency over time, as desiccant dryers are known to, and it maintains excellent drying results as long as a standard quality of compressed air is provided. Wear and tear is limited to the small blower, which circulates the hot air in the upper hopper. The tall and slim hopper form insures excellent material and air flow. The resin is exposed to maximum air temperature for sufficient time allowing the pellets to be heated all the way through to the center.

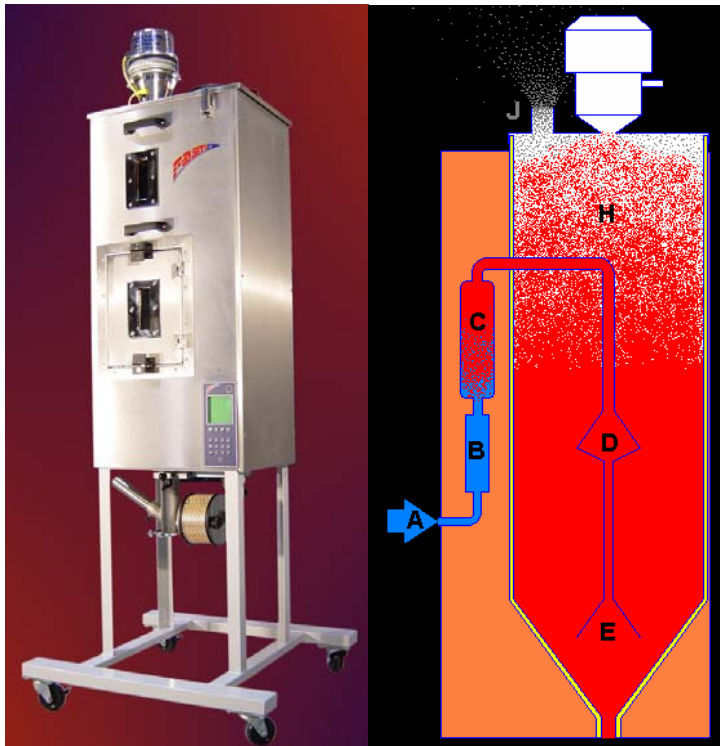
The featured **CARD** can be equipped to receive compressed air exhausted from the plastic processing machine and / or heat recovery from the air compressor, thus saving more energy. Drying resins for the blow molding process can be done very efficiently with air and heat recovery from the process reducing the energy cost of drying close to **ZERO**.

Using a central air compressor in the plant room saves expensive floor space in the molding area. The system can also be used as a central drying system with multiple drying hoppers without the disadvantages of a central desiccant drying system.

ADVANTAGES OF THE COMPRESSED AIR RESIN DRYER (CARD):

- Low initial cost
- Energy savings between 25% and 99% when compared with desiccant dryers
- Excellent and constant drying results with no losses in efficiency over time
- Very compact dryer with little space requirements
- Virtually no maintenance requirements

The **SCARD** is a simpler form of the compressed air dryer for small resin throughputs with no moving parts. Virtually no maintenance is required.



A small amount of compressed air {A} is taken from a central compressor to the **SCARD** to pass through a group of valves {B} and an electric heater {C} before it enters the drying hopper {H} through the air distributor. The compressed air is decompressed to atmospheric pressure before it enters the heater {C} and the dew point drops down. The air distributor releases the heated air through outlets {D} and {E} in different levels in the drying hopper insuring that the residence time of the resin in maximum temperature is sufficient to heat the pellets all the way through to the center.

The compressed air flow rate is variable based on the resin flow rate and the hopper is of a slim and tall design to avoid funnel flow.

The **SCARD** series are suitable for installation directly on the extruder of a plastic processing machine or for floor mounted installation with suction box to load the dried resin to a storage bin mounted on the extruder.

The **SCARD** does not lose drying efficiency over time and the drying results are excellent as long as a standard quality of air is provided.

ADVANTAGES OF THE SMALL COMPRESSED AIR RESIN DRYER (SCARD):

- Low initial cost
- Energy savings between 22% and 60% when compared with desiccant dryers
- Excellent and constant drying results with no losses in efficiency over time
- Very compact dryer with little space requirements or direct installation on extruders
- Virtually no maintenance requirements



VACUUM DRYERS AND RESIN DRYING

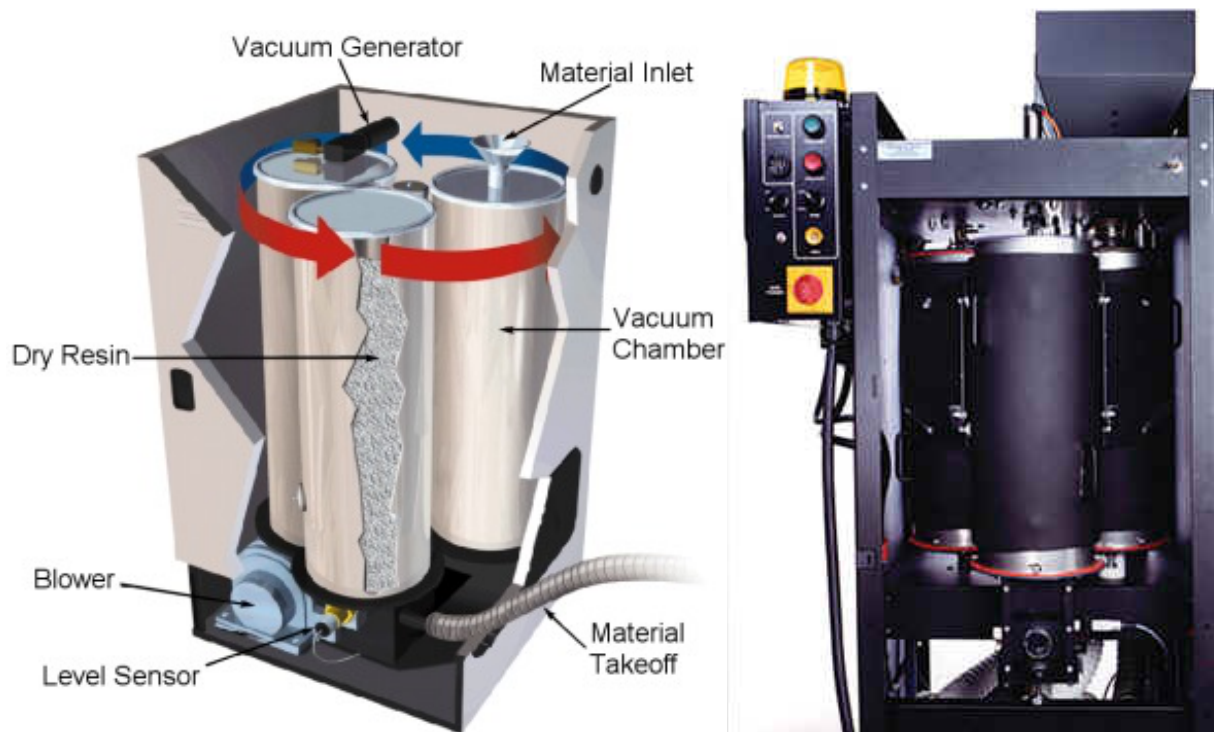
Vacuum dryers are known as a batch drying system for many decades. They are simple, fast and very efficient. Batch vacuum dryers are not widely used in the plastics industry because of the fact that they can only dry one batch of resin at a time and plastics processing machines have a need for continuous supply of dried resins. The resin is loaded into a vacuum chamber, heated and then set under low pressure to drag the moisture out of the pellets. The dried resin is then evacuated and stored in storage bins. Heating the resin all the way through to the center of the pellets is also very important in vacuum dryers.

Rainer Farrag, the inventor of the compressed air resin drying system, has also invented the continuous vacuum drying system and applied for patents in 1993. The system promised a lot when it was tested under lab conditions, but the real disadvantages of the system were discovered when the system was offered to the plastics market. The continuous vacuum drying system was too complicated with many moving parts. The dryer consisted of multiple containers in a carousel configuration. The resin is loaded in one of the chambers and heated by hot air. The carousel is then rotated and the chamber including the heated resin is set under vacuum while the next chamber is being filled and heated. The carousel is rotated again and the dried resin is evacuated from the chamber while the next chamber is set under vacuum to dry the heated resin. The rotation of the carousel continues and the dryer is continuously supplying dried resin to the process. Pellets, parts of pellets or dust of the dried resin gets between the moving parts of the carousel and the gaskets of the chambers while the carousel is rotating and the desired vacuum level is no longer achievable. The drying process fails and the dryer has to be cleaned to achieve the required vacuum level.

Cleaning the chambers is a painful job when changing from one type of resin to another or when different color is desired. The chambers have to be disconnected from the carousel and cleaned outside of the dryer.

Many moving parts are used in the system. Wear and tear is a problem when constant vacuum level is to be maintained.

Rainer Farrag recognized that the continuous vacuum drying system with the drying carousel was a failure and he concentrated his efforts on developing and improving the compressed air resin dryer in Europe. Many years later the continuous vacuum dryer with multiple vacuum chambers and a carousel was reinvented in the United States.



ADVANTAGES:

- Smaller floor space requirements
- Low operating cost
- Short drying time

DISADVANTAGES:

- Unstable drying
- Very high maintenance requirements
- Not easy to clean when changing materials or colors
- Not practical to use on top of a processing extruder