MOLD AREA PROTECTION IN THE PLASTICS INDUSTRY

Most molded products, whether injection molded, blow molded or vacuum formed (thermoformed) products are cooled by chilled water in mold cavities. The cooling time, which normally is the longest part of the total cycle time and the molding process, is an expensive and an important part of the manufacturing process. Lowering the chilled water temperature in the mold leads to a shorter cycle time.

It is suggested to use pure chilled water at a temperature not lower than 6ºC [43ºF]. Lower water temperatures require adding antifreeze to the water in the cooling circuit to avoid freezing in the heat exchanger (evaporator) of the chiller. Adding antifreeze to the chilled water to achieve a low temperature has its disadvantages. Antifreeze agents normally have low thermal conductivity which lowers the heat withdrawal from the product in the mold and the majority of them have high viscosity which lowers the water pump performance and reduces the water flow rates. The chilled water flow rates are recommended to be at a high rate to create turbulent water flow in the mold cooling channels.

Experiments on blow molded products showed a production increase of 1% when the chilled water temperature was lowered 1K [1.8ºF]. This fact was consistent until Glycol had to be added to the chilled water to avoid freezing in the heat exchanger of the water chiller. The water/Glycol mixture had to be cooled down to a temperature of -14ºC [7ºF] to get the same cycle time with pure water at 6ºC (43ºF) on a light weight product. The same product but 50% heavier needed a water / Glycol temperature of -20ºC [-4º F] to achieve the same cycle time as with pure water at a temperature of 6ºC [43ºF]. A similar experience was made in other molding processes.

Lowering the temperature under the dew point of the ambient air causes condensation on the mold surfaces adding challenges to the process.

In many manufacturing plants process engineers tend to increase the chilled water temperature in hot and humid climates to avoid mold sweat and this leads to some problems. Increasing the chilled water temperature extends the cooling time, slows the production and shrinks the profit. In many cases a longer cooling time increases the crystallization rates in the molded plastic resulting in inferior product quality.

Some manufacturing engineers assume that air conditioning systems can solve the mold sweat problem. Air conditioning the manufacturing plant helps, but it does not completely solve the problem.
One disadvantage is the high initial investment required to install a sufficient air conditioning system and the huge operating cost of the system, which becomes obvious when considering the energy household of a plastic processing plant. The total energy supplied to the plant is converted into heat. Some of the heat is transferred out of the plant through the mold water cooling system and other water cooling systems such as hydraulic fluid cooling. The remaining energy is transferred into heat in the air. The air conditioning system has to be capable of handling the heat radiated in the plant and the dehumidification of the air inside the manufacturing plant. Air conditioning systems may improve the working environments for the working force in the plant but the high operating cost shrinks the profit.
Another disadvantage is that the humidity is not absolutely controlled in an air conditioned plant. Ambient air mixes with the air in the plant whenever a gate or a door is opened. Moisture penetrates through the concrete floors and the walls of the plant, if the building is not designed with a sufficient moisture barrier. Exchanging molds in processing machines is accompanied by water leaks. Cleaning and washing the floors also results in additional moisture in the plant air.

The ideal and most profitable solution is the **M**old **A**rea **P**rotector (**MAP**). This should be combined with a good ventilation system in the plant to get rid of the excessive heat radiated from the machines in the plant.
The **MAP** is a simple air dehumidification unit with integrated chiller (condensation dryer). It filters the ambient air sucked into the unit through a washable and replaceable filter and then chills the air to a temperature of 3ºC [37ºF] in two steps before the air is being heated to a temperature of 25ºC [77ºF]. The first chilling step requires chilled water from the plant's chiller at the same temperature used in mold cooling. The second chilling step is done by the integrated chiller of the **MAP** unit. A lot of the moisture contained in the air is separated from the air due to condensation on the cold surfaces of the heat exchangers (pre-cooler and evaporator). The heat extracted from the air in the second chilling step is given back to the air after it has lost the moisture in the condenser of the chiller. A blower sucks the air through the unit and blows it in a duct work to the molding areas to be protected from sweating.
The mold area protection is a complete system in which the clamp and mold area of every machine is enshrouded and separated from the ambient air. Trained installation technicians install the custom made covers on the machines and connect the dry air duct work to every machine.

PLEASE READ THE FOLLOWING PAGES FOR MORE DETAILS

MOLD SWEAT AND PROCESS CHALENGES

Most molded products, whether injection molded, blow molded or vacuum formed (thermoformed) products are very often cooled by chilled water in mold cavities. The cooling time, which normally is the longest part of the total cycle time and the molding process, is an expensive and an important part of the manufacturing process. Lowering the chilled water temperature in the mold leads to a shorter cycle time.
Lowering the temperature under the dew point of the ambient air causes condensation on the mold surfaces adding challenges to the process.

WHEN THIS HAPPENS ON CHILLED MOLDS

THE RESULTS ARE

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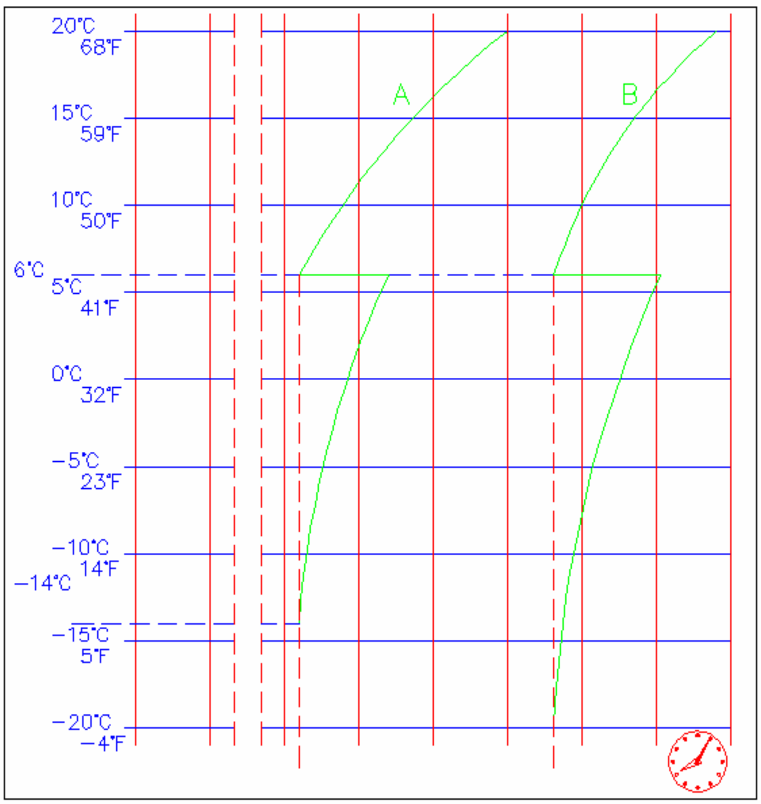

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Pure water at a temperature of 6ºC [43ºF] has achieved the best cooling results; however mold sweat was an unfortunate side effect when the water temperature was lower than the dew point of the ambient air. It gets even worse with temperatures below the freezing point. The result is a struggle against ice.

MOLD SWEAT

Definitions such as dew point and relative humidity are well explained in Mollier's diagram. Mollier found out that a certain amount of moisture will saturate a specific mass of air. The amount of moisture varies as the air temperature or the pressure changes. The air is capable of carrying larger amounts of invisible moisture at higher temperatures or lower pressures.

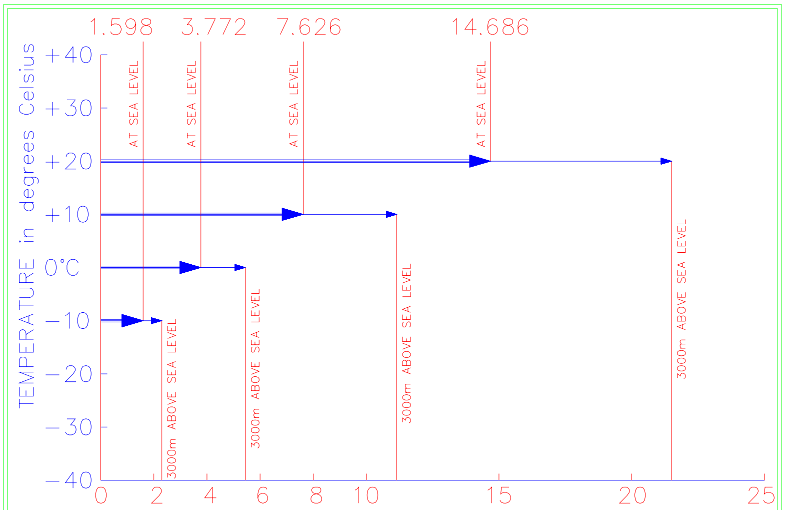

Fig. 1

One kg [2.2lb] of dry air at sea level and 10ºC [50ºF] can be saturated with 7.626g [117.68Grains] 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 11g [170Grains] of invisible moisture.

Increasing the temperature of the air from 0ºC [32ºF] to 10ºC [50ºF] allows an increase of the maximum moisture content (saturation) by 3.854g [59.5Grains] but increasing the temperature from 10ºC [50ºF] to 20ºC [68ºF] allows a moisture increase of 7.060g [109Grains]. The temperature increase is equal in both cases but the maximum moisture content increase nearly doubled (Fig. 1).

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. Similar diagrams can be created for different altitudes or any different air pressure.

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 air 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%). Connecting the 50% saturation values in the diagram appears in a form of a curve as well (Fig.3).

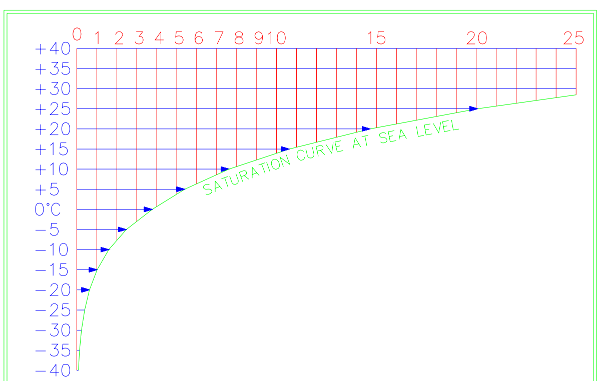

Fig. 2

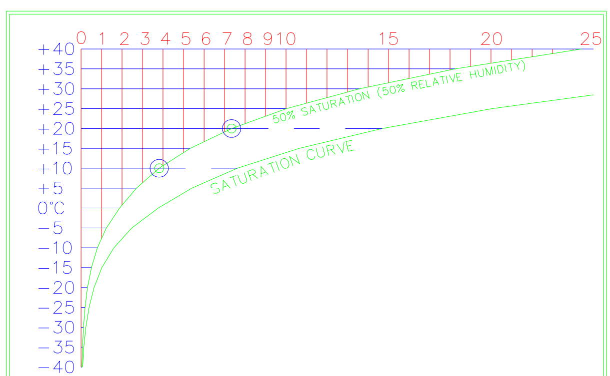

Fig. 3

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 (Fig. 4).

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.

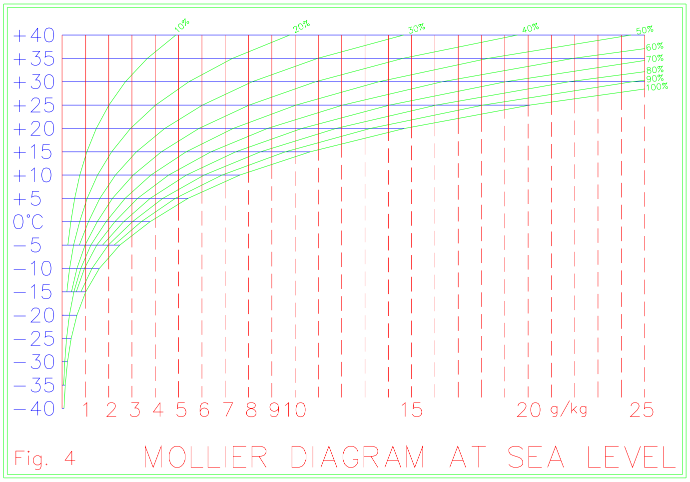

Fig. 4 MOLLIER DIAGRAM AT SEA LEVEL

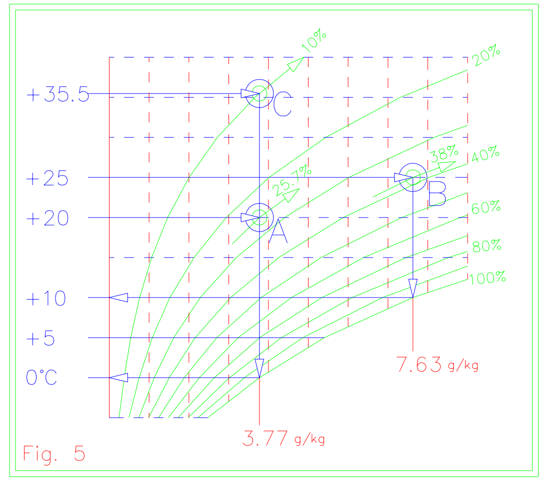

Fig. 5

Point {A} in Fig. 5 represents air at a sea level with a temperature of 20ºC [68ºF], a moisture content of 3.77g/kg [58.17Grains] and a relative humidity of 25.7%. Cooling this air down to a temperature of 0ºC [32ºF] 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 0ºC [32ºF].
At point {C} the temperature is 35.5ºC [96ºF], 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 0ºC [32ºF].
The temperature at point {B} is 25ºC [77ºF] and the relative humidity is 38%. The moisture content is 7.63g/kg [117.7Grains] and the dew point is 10ºC [50ºF].
Some manufacturing engineers assume that air conditioning systems can solve the mold sweat problem. Air conditioning the manufacturing plant helps, but it does not completely solve the problem.
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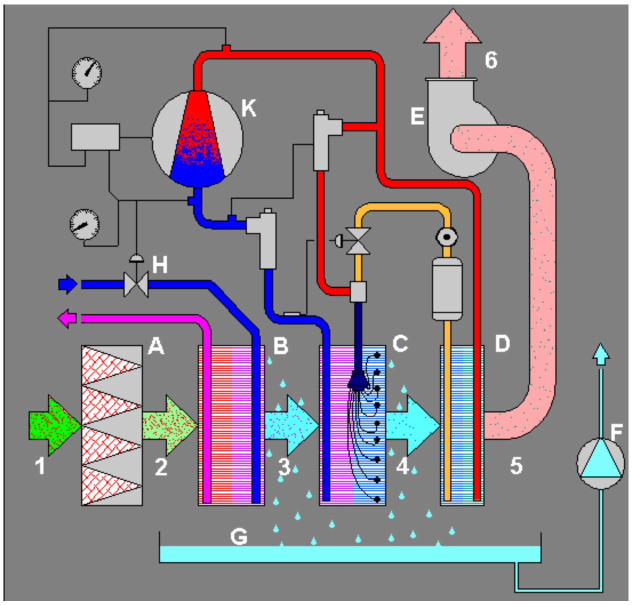
The ideal and most profitable solution is the **M**old **A**rea **P**rotector (**MAP**). This should be combined with a good ventilation system in the plant to get rid of the excessive heat radiated from the machines in the plant.
Mold dehumidification systems are very useful in molding applications. The molding area of the molding machine will be isolated from the ambient air and fed with filtered dry air from a dehumidification unit (**MAP**). This allows the use of chilled water temperature at 6ºC [41ºF] at all times even under tropical weather conditions with no mold sweat.

THE MOLD AREA PROTECTOR

The **MAP** is a simple air dehumidification unit with integrated chiller (condensation dryer).



The illustration to the left explains the how **MAP** works.
Ambient air {1} is sucked into the unit through a filter {A} and the filtered air {2} is chilled in to steps. The 1st step takes place in the chilled water heat exchanger {B} and the pre-cooled air {3} then enters the heat exchanger of the integrated refrigeration circuit (evaporator) {C} to be cooled down to a temperature of 3ºC [37ºF] {4}.
A large amount of the moisture contained in the air is separated in both coolers due to condensation and is collected in a tray {G}. The water is then pumped out of the unit by the pump {F}.
The compressor {K} takes the heat from the evaporator {C} and pumps it in the condenser {D} at high temperature. The chilled air now passes through the condenser and warms up to a temperature of 25ºC [77ºF] {5} before it leaves the unit {6} to a dry air duct work through the centrifugal blower {E}. The filtered dry air is distributed inside an isolated cabin containing the molds of the processing machine.

MAP units are designed to deliver filtered dry air with a dew point of 3ºC [37ºF] to the enshrouded machine. The air escapes out of the isolated area through gaps and openings designed for the product to be removed from the production machine. Different sizes of **MAP** units are available to serve individual machines or to be applied in a central system serving multiple machines.
Simple filter media, washable and easy exchangeable, are used in all **MAP** units. A pressure switch measures the pressure drop across the filter and alerts the operator when the filter needs to be cleaned. This is all the maintenance required for **MAP** units.

Rainer Farrag designed the first mold dehumidification units in 80s and continued to improve the design to perfection. The first units were designed with a desiccant dryer with a dew point of -15ºC [5ºF] but soon it was clear that the desiccant dryer is not the right type for the application.

A very low dew point was not necessary, when ideal water temperature at 6ºC [41ºF] is used and the high maintenance requirement of the desiccant dryer was a disadvantage. The descending performance of the desiccant dryer did not help achieving the desired reliability either.

In 1991 the system was redesigned using a simple refrigeration system with much lower energy consumption and virtually no maintenance requirements.

THE MACHINE ENSCHROUDING

The design of the enshrouding used to isolate the molding machines from the environment has also improved over the years and installation technicians were trained to tailor make the enshrouding allowing an easy mold change and access to all machine parts for inspection, adjustment or repairs.

This is one of many professional installations on an injection molding machine using Aluminum profiles and Polycarbonate sheets to isolate the molding area from the ambient air in the production facility.

The covers on the top are mounted on slides easy to open for quick mold changes and easy access to the clamp area behind the mold.

Flexible hose is used to connect the enshrouding with the mold dehumidification unit (not shown).

The illustration to the left shows the top cover pushed opened to allow for easy mold change from the top.

The Aluminum profiles are powder coated in the same color of the machine and a spiral duct work is used to supply filtered dry air from the unit to the enshrouding for both the machine and the water cooled take off robot installed beside the molding machine.

The back part of the top cover slides under the front part to allow for easy access to the clamp area.

The bottom of the machine is also covered with suitable materials.

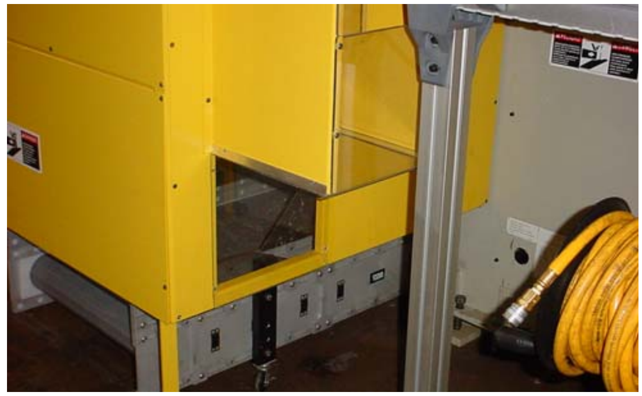
The illustrations to the left and below show a central system. One **MAP** unit supplies filtered dry air to 12 injection molding machines through a central air duct.

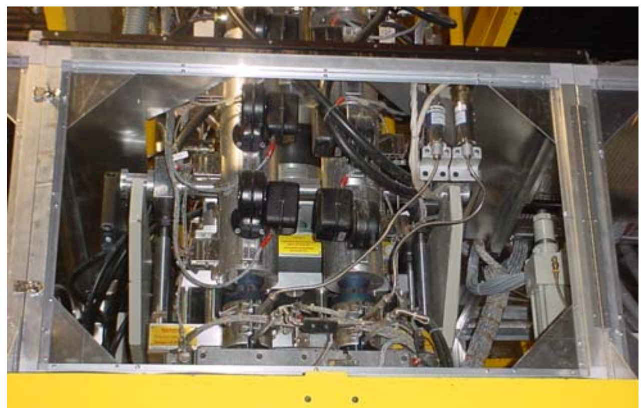
The flexible ducts at the end of every branch are necessary to enable sliding the top covers for mold changes.

The plant is air conditioned but the system could not maintain the required dew point. Mold area protection was added and the capacity of the air conditioning system was reduced to 40% for the comfort of the working force in the plant.

This example shows an injection stretch blow molding machine well covered by the machine manufacturer but there were many small openings to be covered.
The **MAP** unit is installed behind the machine with a simple air duct between the unit and the cabin.
The illustration below shows a flexible cover on the product outlet opening.

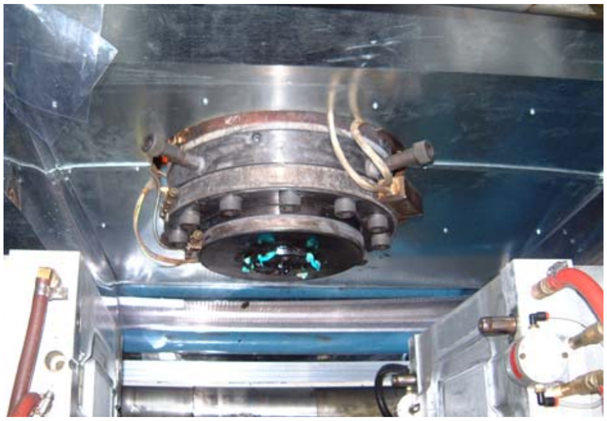
A mold area protection installation on a large size extrusion blow molding machine is shown in the illustration above. Note the brushes used on all gaps around the doors of the molding cabin.
The illustrations below show some details of the enshrouding. Access to all parts of the machine is guaranteed without the need to remove any part of the covers. Twin sheets are used on the top and the back side of the molding cabin. The brushes covering some gaps are also clearly shown in a couple of these illustrations.





This example shows a blow molding machine before and after the installation of the enshrouding.

Two central systems are protecting 12 machines in this facility with chilled water running through the molds at a temperature of 8ºC [46ºF] around the year in tropical conditions.
No mold sweat, high production rates and best quality.



An example of mold area protection for a large size industrial blow molding machine is shown. It is one of 6 machines supplied with filtered dry air in a central system.
Note the size of the enshrouding on one side of the machine (upper illustration) and also note the use of Aluminum sheet metal around the accumulator head on top of the mold (left).

The maintenance cost was noticeably reduced as no mold sweat was observed after the installation of the system. Mold sweat was causing corrosion in moving parts of some molds and machine parts.