



Sharing The Knowledge

Module 6

Drying Polymers



GE Plastics

Module 6

Drying Polymers

- Reasons for Drying
- Critical Aspects
 - Moisture
 - Drying Rates
 - Drying Efficiencies

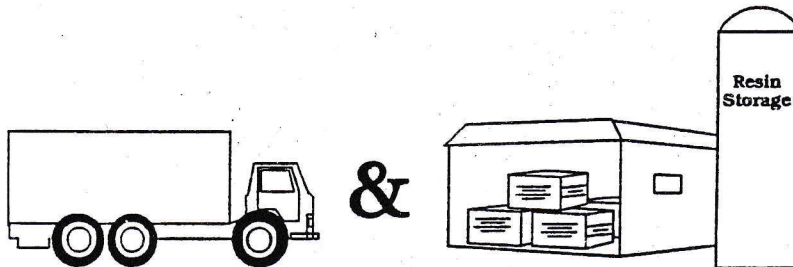
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Participant's Notes: _____



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Moisture in Thermoplastics



Engineering thermoplastic pellets collect moisture during manufacturing, transportation and storage.

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Participant's Notes: _____

Introduction

Drying Polymers

Sharing the Knowledge continually stresses the importance of using proper processing techniques to manufacture high performance thermoplastic parts. Drying is an integral part of this molding process. Thermoplastic pellets must be thoroughly dried before being processed. Improper drying techniques will result in insufficient drying, producing substandard parts. Module 6 explains the drying process and why it is so important. It then establishes proper drying procedures for thorough drying and higher quality part production.

STK 601

Objectives:

At the end of this module, participant should be able to:

- Describe the reasons for drying and the hazards of not drying.
- Identify three critical aspects of drying: moisture content, drying rates, drying efficiencies.
- Determine how to measure moisture content.
- Identify three types of hopper dryers (condensation, hot air and desiccant bed dryers).

Moisture in Engineering Thermoplastics

Thermoplastic pellets absorb moisture during manufacturing in the weeks of transportation and storage before processing. It must be assumed that every supply of resin potentially contains excessive moisture, regardless of the circumstance.

STK 602

Plastic pellets absorb water.



Must Remove Moisture

Pellets That Are Not Thoroughly Dried May:

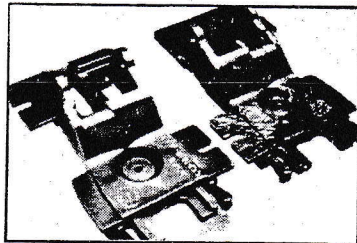
- Produce Parts That Are Substandard in Terms of **Surface Appearance** and **Property Performance**
- Cause Serious Inconsistency During Processing

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Participant's Notes: _____



Surface Appearance



A foamy or frothy melt and splay or silver streaking in a molded part are the result of moisture bubbles trapped in the resin.

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Participant's Notes: _____

Reasons for Drying

Moisture can negatively affect surface appearance and property performance in the molded part.

Must Remove Moisture

Moisture must therefore be removed from the pellets before processing. Excessive moisture can cause serious material inconsistency during processing. Excessive moisture in the resin can also result in substandard parts: substandard in terms of both surface appearance and property performance.

STK 603

Moisture bubbles in resin cause splay or silver streaking.

Surface Appearance

Moisture bubbles trapped in the resin can ruin a part's surface appearance by causing splay or silver streaking. Still worse are the potential hazards that aren't visible.

STK 604



Property Performance

Two Problems Can Be Caused by Insufficient Drying:



1. Voids in the Part Caused by Steam Bubbles



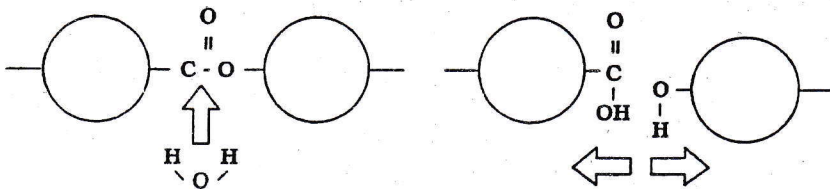
2. Loss of Molecular Weight Caused by Hydrolysis

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Participant's Notes: _____



Hydrolysis



Hydrolysis is the splitting of a molecule with the addition of water in the presence of heat & pressure, as in processing.

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Participant's Notes: _____

Insufficient drying can result in a loss of material properties.

Property Performance

Moisture can cause a loss in material properties. Trapped moisture bubbles can cause voids in the interior of the part as seen in this cutaway of an actual moisture damaged part. Moisture can also cause a loss in molecular weight due to hydrolysis. **STK 605**

Hydrolysis is the splitting of a molecule with the addition of water in the presence of heat and pressure, as in processing.

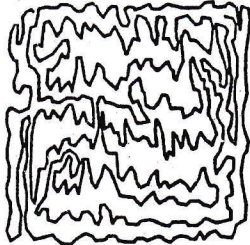
Hydrolysis

Hydrolysis is the chemical process of decomposition that occurs with the addition of water. During processing, the presence of heat and pressure allow the water molecule (H_2O) to split the polymer molecule. The polymer bond breaks and one end links with the OH^- and the other links with the H^- . In this particular example, the bond between the carbon and oxygen has broken and the C- has linked with OH^- , and the O- has linked with the H^- . This may occur at bonding points throughout the molecule thus severely shortening the molecular chains. **STK 606**



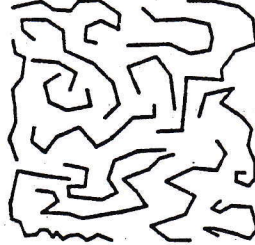
Property Loss

Long Chain Molecules

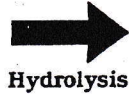


High Molecular Weight

Shorter Chain Molecules



Lower Molecular Weight



Hydrolysis

Since the polymer's properties depend on its high molecular weight, reducing that weight (shortening the molecules) can lower its properties.

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Participant's Notes: _____

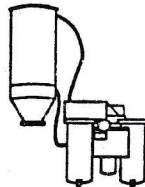
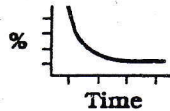


Drying Polymers

• Moisture Content

• Drying Rates

• Dryer Efficiencies



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Participant's Notes: _____

Hydrolysis causes property loss.

Property Loss

The molecular weight of a molecule is calculated as the sum of the atomic weights of its constituent atoms. Therefore a molecule that is comprised of many atoms tends to have a high molecular weight. Polymer molecules, for example, are very high in molecular weight because of their extreme length. Remember, polymers are made up of many long chainlike molecules. In fact, these molecules can have as many as 10,000 repeating structural units. And it is this extreme length/high molecular weight that gives the polymer material so many of its desirable properties. So if splitting the chains reduces the molecular weight, then it also degrades the polymer properties. Impact strength, for example, can be greatly reduced by the presence of moisture during processing.

STK 607

Critical Aspects of Drying Moisture Content

Three critical aspects of drying polymers.

Drying Polymers (Moisture Content)

It is extremely critical that thermoplastic pellets be dried before processing. This module covers the entire drying process: from defining moisture content, to explaining drying rates, to establishing dryer efficiencies. First let's define moisture content.

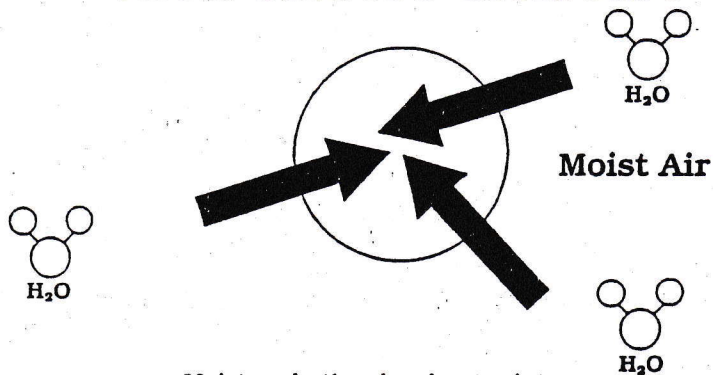
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STK 609

Pellets Absorb Moisture



Moisture in the air migrates into a thermoplastic pellet in the form of a gas.

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Participant's Notes: _____

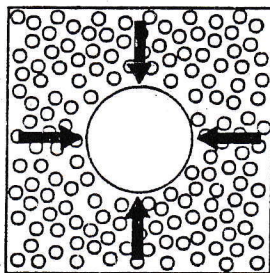


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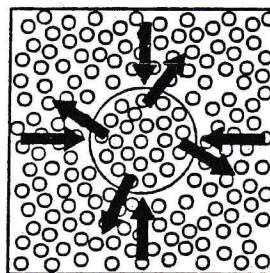
STK 610

Absorption till Equilibrium

Absorption



Equilibrium



The pellet will continue to absorb moisture till it reaches equilibrium with the air to which it is exposed.

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Participant's Notes: _____

**Moisture in the air
migrates into a
thermoplastic pellet.**

Pellets Absorb Moisture

Though you can't see it and usually can't feel it, there is moisture in the air. This moisture will migrate throughout a thermoplastic pellet.

STK 609

**A pellet will continue to
absorb moisture until it
reaches equilibrium.**

Absorption Till Equilibrium

The pellet will continue to absorb moisture until it reaches a point of equilibrium with the moisture content of the air. At this point, moisture is diffusing into and out of the pellet at an equal rate. Therefore the moisture level of the pellet remains constant.

The moisture absorption process can't be stopped. It is a function of the moisture present in the air. The only way to reduce the moisture content of the pellets is to reduce the moisture content of the air.

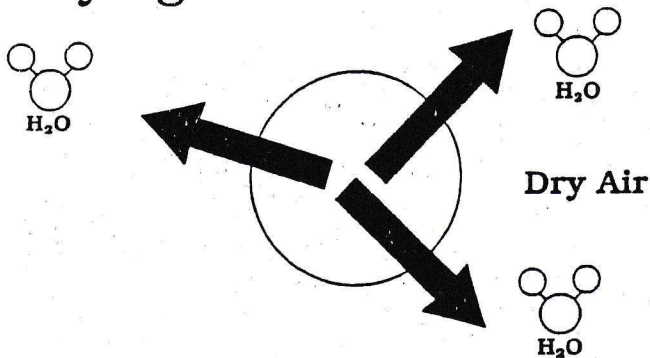
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STK 611

Drying Removes Moisture



Moisture in pellet will migrate out of the pellet when exposed to dry air.

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Participant's Notes: _____

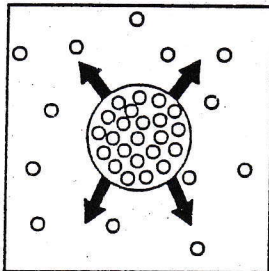


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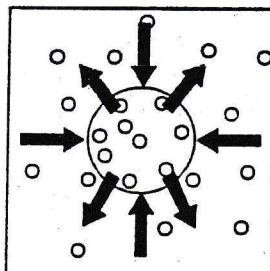
STK 612

Drying till Equilibrium

Drying / Removal



Equilibrium



The pellet will continue to release moisture until it reaches equilibrium with the air to which it is exposed.

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Participant's Notes: _____

Moisture will come out of the pellet when exposed to dry air.

Drying Removes Moisture

Reducing the moisture content of the air will upset the equilibrium that the pellet had established with the "moist" air. Because the equilibrium is upset, moisture will begin to migrate out of the pellet.

STK 611

The pellet will continue to release water until it reaches equilibrium with the air.

Drying Till Equilibrium

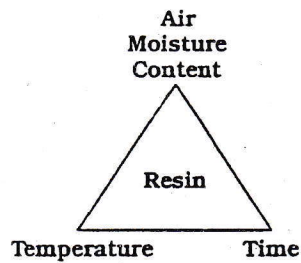
The pellet will continue to give up moisture until it reaches another point of equilibrium. At this point, moisture is diffusing into and out of the pellet at an equal rate. The moisture level of the pellet is, however, lower than before.

STK 612



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Defining Moisture Content



- Type of Resin
- Amount of Moisture in the Air
- Temperature of Air
- Time Exposed to Air

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Participant's Notes: _____



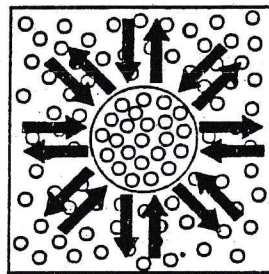
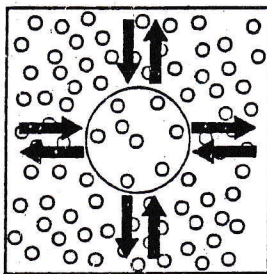
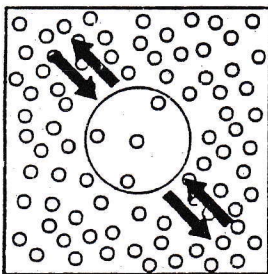
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Resin Moisture Capacity

Polyethylene

Polycarbonate

Nylon



Every resin has its own capacity to water meaning some will absorb water more readily than others.

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Participant's Notes: _____

Resin moisture content depends on the resin, moisture in the air, the temperature, and the time.

Defining Moisture Content

The amount of moisture a resin will absorb depends upon several key factors. Moisture content depends on the type of resin, for each resin has its own absorption characteristics. The weather conditions or the moisture content of the air will also affect the resin moisture content, as will the temperature of the ambient air and the pellets, and the time that the pellets are exposed to this moisture rich air. We'll explore each of these critical factors more closely. **STK 613**

Some resins absorb more water than others.

Resin Moisture Capacity

First let's consider the resin. Some polymers have a greater affinity to water than others and therefore will absorb moisture more readily.

Nylon, for example, will absorb more moisture than polycarbonate, which will absorb more moisture than polyethylene, when each is exposed to the same sample of air. This is because nylon is said to be hygroscopic. The term hygroscopic means "readily absorbs moisture." So while nylon is said to be hygroscopic, polyethylene is said to be only slightly hygroscopic and therefore absorbs less moisture.

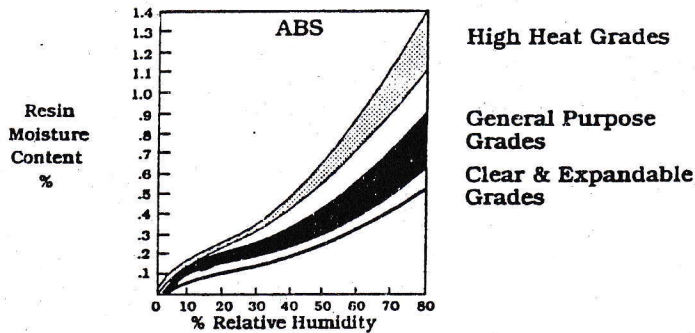
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STK 615

Resin Moisture Content



Resin moisture content is measured as a percentage by weight and varies depending on the resin grade and prevailing weather conditions.

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Participant's Notes: _____

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Weather Conditions (Ambient Air)

The amount of moisture in the air is defined by:

- Relative Humidity
- Dew Point

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Participant's Notes: _____

Different grades of resins absorb more moisture than others.

Resin Moisture Content

Not only does every resin family have its own moisture absorption characteristics, but each resin grade does as well. This graph depicts the rise in pellet moisture content as the moisture level of the air increases. The Y-axis indicates the pellet moisture as a percentage by weight. The X-axis indicates the relative humidity of the air. The difference in moisture absorption characteristics among the many grades of ABS is clearly illustrated by the range in moisture levels at 80% relative humidity. This graph brings up another important point for discussion: the effect of the moisture content of the ambient air on the amount of moisture absorbed by the pellets.

STK 615

Air moisture content can be defined by the relative humidity and the dew point.

Weather Conditions (Ambient Air)

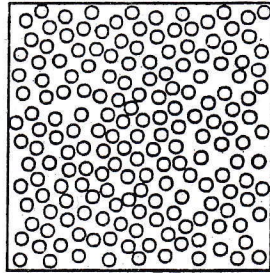
The next variable that affects pellet moisture content is the moisture content of the ambient air, that is the prevailing weather conditions. The moisture content of the ambient air is described by either relative humidity or dew point.

STK 616



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Humidity



Humidity is the moisture in the air.

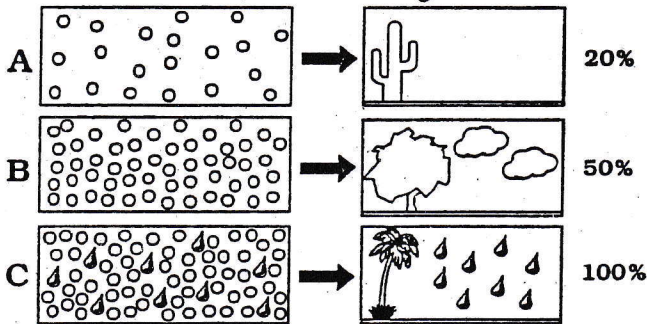
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Participant's Notes: _____



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Relative Humidity @ 75°F



Relative Humidity describes the percent of moisture present in the air relative to the greatest amount of moisture the air can hold at a given **temperature**.

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Participant's Notes: _____

Humidity is the moisture in the air.

Humidity

Humidity describes the dampness in the air due to its moisture content. On a dry day, when there is less moisture in the air the sweat on our skin evaporates thus cooling us in the process. On a humid day, however, the sweat on our bodies can't evaporate. There is too much moisture present in the air to allow it to do so. That's why we feel hotter and sweatier on a humid day. A door that sticks is another example of what happens on a humid day. The door absorbs moisture from the air and swells.

STK 617

Relative humidity describes the percent of moisture present in the air relative to the greatest amount of moisture the air can hold at a given temperature.

Relative Humidity @ 75°F

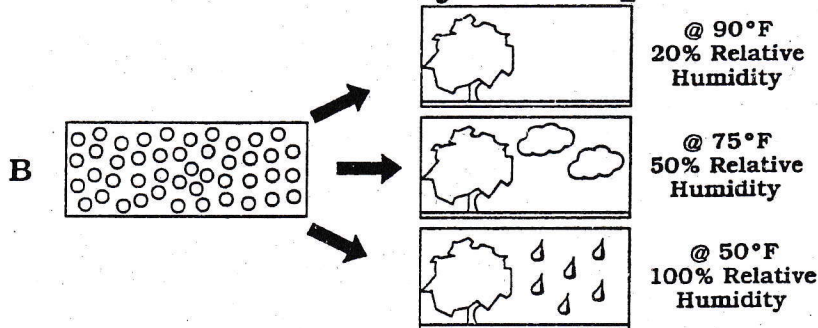
In order to understand drying we must first understand relative humidity. Relative humidity describes the moisture content of the air at a certain temperature. Here are three different air samples @ 75°F. Sample A contains only 20% of the maximum amount it could hold @ 75°F. Sample B contains 50% of its ultimate capacity @ 75°F. And sample C is at 100% capacity @ 75°F. Sample C is so saturated that it can't hold all the moisture present and therefore precipitates.

STK 618



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Relative Humidity / Temperature



Given the same sample of air, warm air can hold more moisture than cool air and therefore becomes saturated at a higher moisture content.

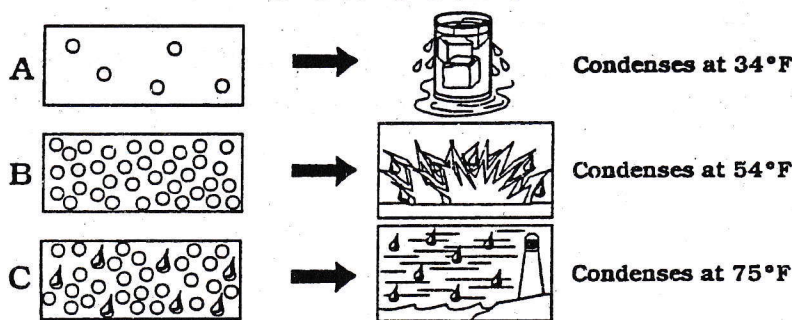
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Participant's Notes: _____



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Dew Point



Dew Point defines the amount of moisture in the air.
Dew point is the temperature at which moisture in the air begins to condense.

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Participant's Notes: _____

Relative Humidity/Temperature

Here is sample B at three different temperatures. As before, sample B is at 50% of its capacity @ 75°F. But notice the same sample is only at 20% of its capacity @ 90°F. This is because warm air has a greater capacity to hold moisture than cool air. The maximum amount of moisture air can hold @ 90°F is greater than the maximum amount it can hold @ 75°F.

Warm air holds more moisture than cool air.

So sample B is at 20% of its capacity @ 90°F, at 50% of its capacity @ 75°F, and at 100% of its capacity @ 50°F. Just as sample C was at full capacity at 75°F, sample B finally reaches full capacity at 50°F and the moisture begins to condense.

STK 619

Dew Point

The temperature at which the moisture in the air begins to condense is called the dew point. The dew point is a useful, quantitative means of describing the moisture content of a sample of air. For example, sample A has a dew point of 34°F. The moisture in the air sample will begin to condense on the glass of ice water if the air contacting the surface of the glass is at or below 34°F. Sample B has a dew point of 54°F. The moisture in the air sample will begin to condense on the grass if the air contacting the surface of the ground is at or below 54°F. Finally, sample C has a dew point of 75°F. The moisture in the air sample will begin to condense if the temperature drops to 75°F, causing it to rain. Any sample of air is saturated at its dew point.

Dew point is the temperature at which moisture in the air begins to condense.

STK 620

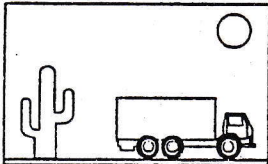


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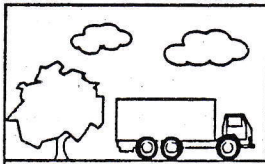
Pellet Moisture Absorption

The higher the dew point -
the more moisture in the air.

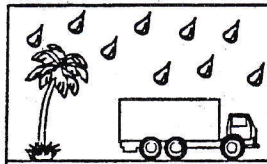
Dew Point of
34°F



Dew Point of
54°F



Dew Point of
75°F



The more moisture in the air - the more moisture
absorbed by the pellets.

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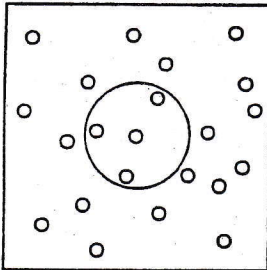
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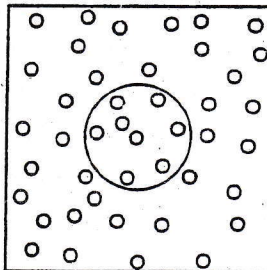
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Point of Equilibrium

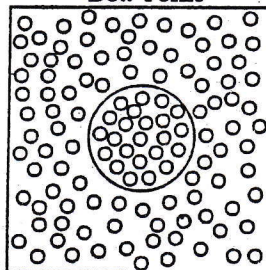
34°F
Dew Point



54°F
Dew Point



75°F
Dew Point



For a given resin, the point of equilibrium is the maximum
moisture level a resin will reach at a given dew point.

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Participant's Notes: _____

The higher the dew point, the more moisture in the air.

Pellet Moisture Absorption

Dew point defines the amount of moisture in the air: the higher the dew point, the higher the moisture content of the air; the lower the dew point, the lower the moisture content of the air.

Remember, the higher the moisture content of the air, the higher the dew point, and the more moisture available to be absorbed by the resin.

STK 621

The point of equilibrium for a given resin varies depending on the dew point.

Point of Equilibrium

At each dew point, a pellet for a given resin will reach a different point of equilibrium. A pellet that is exposed to air with a dew point of 75°F will reach a higher maximum moisture content than a pellet exposed to air with a dew point of 20°F.

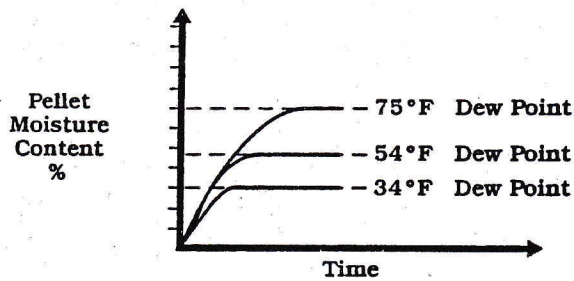
STK 622



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STK 623

Point of Equilibrium / Dew Point



The amount of moisture a resin will absorb depends on the dew point, however, the rate of absorption depends on the absorption characteristics of the resin and the temperature.

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Participant's Notes: _____



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STK 624

Temperature / Time

Temperature increases the rate at which the moisture will migrate into and out of the pellet.

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Participant's Notes: _____

The rate of absorption depends on the absorption characteristics of the resin and the temperature.

Point of Equilibrium/Dew Point

This graph depicts the rise in pellet moisture content over time at three separate dew points. As you can see, the higher the dew point, the higher the maximum moisture level of the pellet. Once the pellet reaches its point of equilibrium for a given dew point, it will absorb no more moisture.

STK 623

Temperature increases the rate at which the moisture will migrate into and out of the pellet.

Temperature/Time

The speed of absorption till equilibrium is affected by temperature. Higher temperatures tend to increase the absorption/removal process.

STK 624



Measuring Moisture Content

- Sticking to specified drying rates and recommended drying procedures should result in an acceptable resin moisture content after drying.
- There are several test methods to verify moisture content such as the Karl Fischer Titration Test and the Tomasetti Volatile Indicator (TVI).

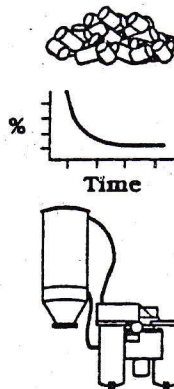
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Participant's Notes: _____



Drying Polymers

- Moisture Content
- Drying Rates
- Dryer Efficiencies



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Participant's Notes: _____

Sticking to specified drying rates and recommended drying procedures should result in an acceptable resin moisture content after drying.

Measuring Moisture Content

Pellet moisture content is impossible to determine visually. By understanding the variables that affect moisture absorption, adhering to the drying specifications outlined for each resin, and following proper drying procedure, you can be certain that the pellets will be dry enough for processing.

The Karl Fischer Titration Test and Tomasetti Volatile Indicator can be used to periodically test your procedure and equipment to make sure the pellets are being dried properly. The Karl Fischer Titration Test is a quantitative means of accurately determining the moisture level in the pellets as a percentage by weight. The Tomasetti Volatile Indicator (TVI) is a visual means of determining if a resin is simply "dry enough" for processing. It does not measure the moisture content in a quantitative fashion, but merely lets you know if the moisture level is sufficiently low, so as not to degrade the polymer during processing. Specific details of these two tests can be made available to converters interested in measuring moisture content in resin.

STK 625

Drying Rates

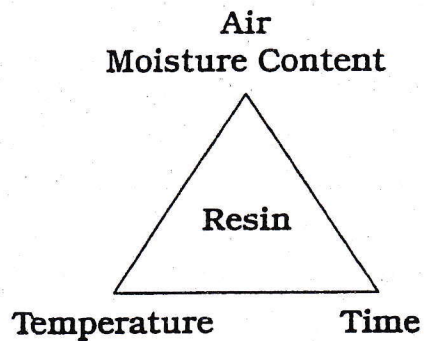
Drying Polymers (Drying Rates)

The drying rate refers to the time it will take to dry a resin under a very specific set of circumstances.

STK 626



Drying Variables

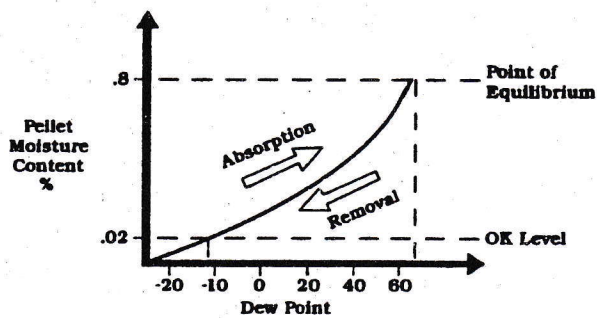


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Participant's Notes: _____



Absorption / Removal



To reverse the absorption process a resin must be exposed to dry air long enough to drop from its maximum moisture content to an "OK level."

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Participant's Notes: _____

**Drying variables:
moisture content of air,
temperature, and time.**

Drying Variables

Just as in moisture absorption, the variables that will affect moisture removal or drying are: the nature of the resin; the moisture content of the air; the temperature of the air and the pellets; and the time that the resin is exposed to the air.

STK 627

**The absorption process
is reversible.**

Absorption/Removal

Drying reverses the absorption process, removing moisture from a pellet to a very low level that is suitable for processing. This recommended level varies depending on the thermoplastic, so we'll just call it the "OK level."

STK 628



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"OK Level"

The "OK level" is the recommended moisture level to which a given resin must be dried before processing to produce parts with good surface appearance & property retention.

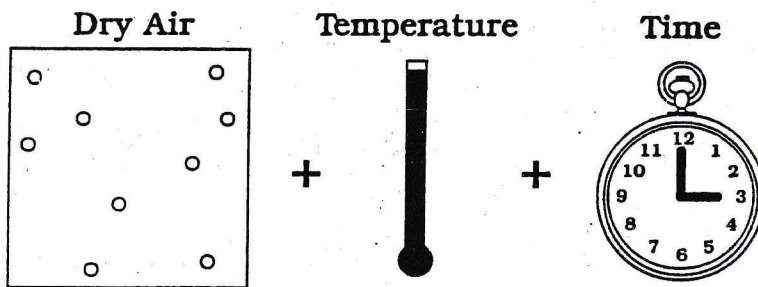
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Participant's Notes: _____



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Drying Specifications



The drying specifications establish to what temperature the air must be heated and the length of time the resin must be dried to reach an OK moisture level.

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Participant's Notes: _____

"OK Level"

The "OK level" is the recommended moisture level to which a given resin must be dried before processing.

Engineering thermoplastics generally have an "OK level" of .02% but may be as high as .08%.

STK 629

Drying Specifications

The drying specifications establish to what temperature the air must be heated and the length of time the resin must be dried to reach an OK moisture level.

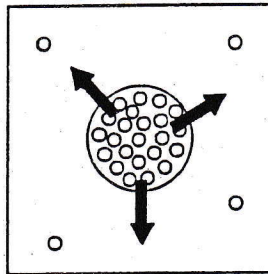
In order to achieve the "OK level," drying specifications must be strictly followed. The drying specifications outline three criteria: how "dry" the air must be; how high the air temperature must be; and how long the resin must be dried.

STK 630



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Dry Air

Dew Point of -20°F

A dew point of at least -20°F is required, to achieve the recommended OK level at the temperature and time specified.

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Participant's Notes: _____



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Sample Drying Specifications

<u>Resin</u>	<u>Drying Temperature</u>	<u>Drying Time</u>	<u>Air Dew Point</u>
PPO	210°F	1-2 Hours	-20°F
ABS	180°F	2-4 Hours	-20°F
Polycarbonate	250°F	3-4 Hours	-20°F
Polyetherimide	350°F	3-4 Hours	-20°F
PBT	250°F	2-4 Hours	-20°F

Note: Presence of regrind will necessitate longer drying time due to larger pellet size.

Each resin grade has its own recommended drying temperature and corresponding time specified on the processing data sheet.

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Participant's Notes: _____

To achieve the "OK level" a dew point of -20 degrees F is required.

Dry Air

The air used to dry the pellets must have a dew point of at least -20°F. Only if the air is this dry, can a pellet reach the point of equilibrium to maintain a moisture level of less than .05%. The drying temperatures and times specified assume that the air in the dryer will have a dew point of at least -20°F.

STK 631

The time and temperature for drying is different for each type of resin.

Sample Drying Specifications

Here are some drying specifications for some general resins. Before processing, you must check the drying specifications for the specific resin grade you are about to process. Remember that the drying temperature and time go together and both must be followed strictly to ensure proper drying. If you don't dry for the minimum required time at the specified temperature, the resin won't reach the "OK level." Also remember that the drying time for regrind and glass reinforced materials will be longer. Drying at temperatures below the specified level for longer times may cause incomplete moisture removal and inadequately prepare the resin for molding. Therefore it is very important that drying equipment be operating at the proper temperature.

The specified drying temperature and time optimize the drying process without degrading the resin. The drying temperature is the maximum possible temperature to dry the polymer as quickly as possible without degradation or fusing the pellets together. The drying times report the time the resin must be dried to reach the "OK level."

STK 632



GE Plastics

STK 633

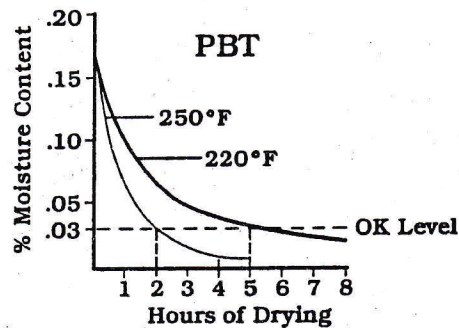
Drying Curves

Drying Specifications

Drying Temperature
250°F

Drying Time
2 - 4 Hours

Dew Point
-20°F



A drying curve clearly illustrates the need to follow the drying specifications exactly to achieve the necessary OK level.

6

Participant's Notes: _____



GE Plastics

STK 634

Drying Precautions

Temperature:

- Too Low - Resin May Not Be Dried
- Too High - Resin May Begin to Degradе or Soften / Melt & Stick Together

Time:

- Too Short - Resin May Not Be Dried
- Too Long - Resin May Degrade

6

Participant's Notes: _____

It is necessary to follow the drying specifications to reach the "OK level."

Drying Curves

Drying curves track the drop in a resin's moisture content with regard to time. Here's a sample drying curve for a grade of PBT. It's already a given that the dryer air has a dew point of at least -20°F. The drying temperature has been specified as 250°F and the time as 2-4 hours. The lower curve illustrates the drop in moisture under specified drying conditions. The curve clearly illustrates that if the resin isn't dried long enough, it won't reach the "OK level." After 1 hour @ 250°F, the moisture content is still almost .10%. The upper curve indicates that if the temperature drops below the specified drying temperature, the resin won't reach the "OK level" in the minimum drying time. After 4 hours @ 220°F, the moisture content is still above .03%. Ultimately, so long as the dryer air has a dew point of at least -20°F, then drying is a function of time.

STK 633

Follow drying precautions.

Drying Precautions

Many part deficiencies can be traced back to inadequate or improper drying rates and temperatures, or they can be attributed to inefficient drying equipment.

STK 634



GE Plastics

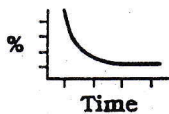
STK 635

Drying Polymers

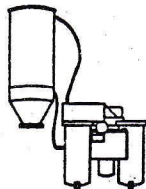
- Moisture Content



- Drying Rates



- Dryer Efficiencies



6

Participant's Notes: _____



GE Plastics

STK 636

Proper Drying Improves Processing Consistency

- Removes Moisture from Pellet Prior to Processing
- Preheats Material to a Predetermined Temperature

6

Participant's Notes: _____

Drying Efficiencies

Dryer efficiencies.

Drying Polymers (Dryer Efficiencies)

There are several different types of dryers designed to dry thermoplastic pellets; some are more efficient than others. **STK 635**

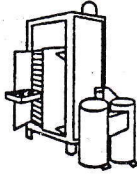
**Drying improves
processing consistency.**

Proper Drying

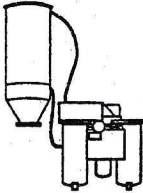
Proper drying improves processing consistency by removing moisture from the pellet prior to processing and preheating the material to a predetermined temperature. **STK 636**



Methods of Drying



Oven Dryer with Trays
Effective for Small Batches



Hopper Dryer
Preferable for Longer Runs

6

Participant's Notes: _____



Hopper Dryers

- Hot Air
- Condensation / Refrigerant
- Desiccant Bed Dehumidifying

6

Participant's Notes: _____

Methods of Drying

Oven and hopper dryers.

There are two methods of drying: oven dryers and hopper dryers. When using an oven dryer, the pellets should be dried in shallow trays at a depth of 1 to 2 inches. The pellets must be transported from the oven after drying and placed in the hopper. Care must be taken to make sure this transport is done as quickly as possible, and to make sure the hopper lid is shut so as not to expose the pellets to moisture in the ambient air. The oven dryer is effective for short batches but becomes too labor intensive for long runs. The hopper dryer, on the other hand, allows for continuous drying in the hopper and is preferable for long runs. We will concentrate on the hopper method of drying in the following discussion.

STK 637

Hopper Dryers

Hopper dryers.

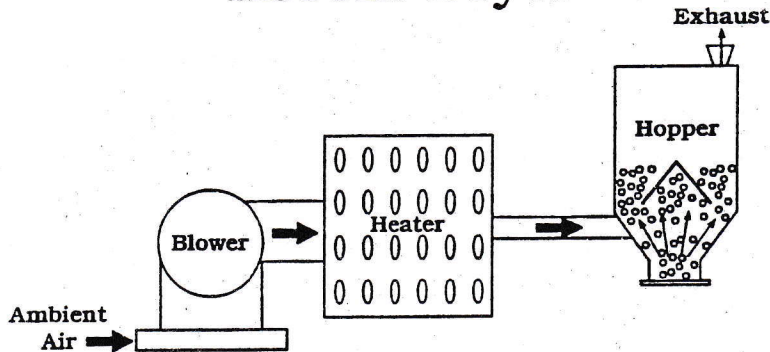
We're going to discuss three types of hopper dryers: the hot air dryer, the refrigerant or condensation hot air dryer, and the desiccant bed dehumidifying hot air dryer.

STK 638



GE Plastics

Hot Air Dryer



The Hot Air Dryer decreases the relative humidity of the air by heating but doesn't lower the dew point.

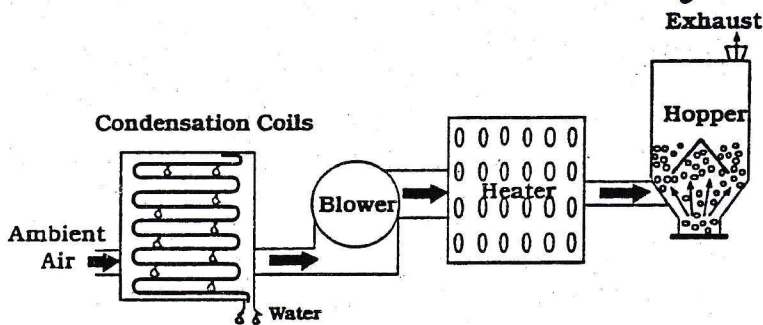
6

Participant's Notes: _____



GE Plastics

Condensation Hot Air Dryer



Condensation Hot Air Dryers condense moisture out of the air but the dew point is still limited by the temperature of the condensation coils.

6

Participant's Notes: _____

Hot air dryers decrease the relative humidity of the air by heating but don't lower the dew point.

Hot Air Dryer

Hot air dryers heat the air, thus decreasing the relative humidity. Remember warm air holds more moisture than cool air. So heating the air upsets the equilibrium, causing the moisture to migrate out of the pellets until they reach a new point of equilibrium and consequently a lower moisture level. Still, the dew point of the air depends on the ambient relative humidity, typically no lower than 50% @ room temperature. That's a dew point of 54°F. But the recommended dew point for dryer air is at least -20°F. **STK 639**

The dew point is still limited by the temperature of the condensation coils.

Condensation Hot Air Dryer

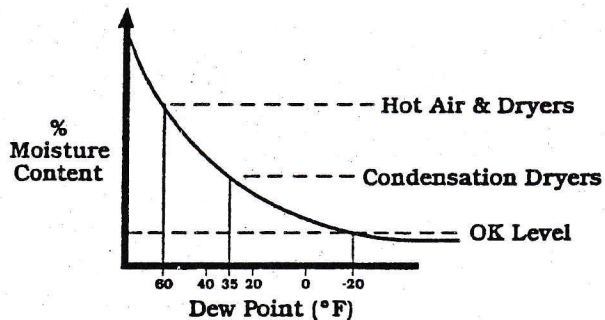
Condensation hot air dryers condense moisture out of the air to lower its dew point. If the condensation coils are, for example, 34°F, then enough moisture will condense to leave the air with a dew point of 34°F. but that's probably the lowest dew point the dryer can achieve without freezing its cooling coils. A dew point of -20°F is therefore impossible to achieve. **STK 640**



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STK 641

Pellet Moisture Level vs. Dryer Air



The "OK level" that can be achieved by the pellets depends on the dew point of the air inside the dryer.

6

Participant's Notes: _____



GE Plastics

STK 642

Desiccant Bed Dehumidifying Dryer

- Dries Air to the Required Dew Point
- Heats Air to the Specified Temperature
- Provides the Necessary Airflow in a Closed-loop System

6

Participant's Notes: _____

The "OK level" that can be achieved by the pellets depends on the dew point of the air inside the dryer.

Pellet Moisture Level vs. Dryer Air

Since the final pellet moisture level after drying depends on the dew point of the air inside the dryer, then neither the hot air dryer (capable of attaining a dew point of about 54°F) nor the condensation hot air dryer (capable of attaining a dew point of about 34°F) will allow the pellets to achieve the "OK level." The "OK level" is only achievable if the dryer air has a dew point of -20°F or less.

STK 641

Only desiccant bed dehumidifying dryers produce the -20 degrees F necessary to reach "OK level."

Desiccant Bed Dehumidifying Dryer

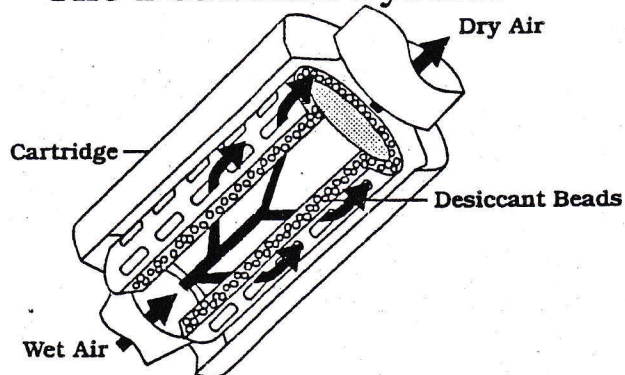
Only the desiccant bed dehumidifying dryer is capable of maintaining a dew point as low as -20°F. Like the other dryers, it also heats the air to the specified drying temperature; however, the air is circulated in a closed-loop system.

STK 642



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The Desiccant System



Incoming air is first dehumidified in a desiccant cartridge containing moisture absorbing desiccant beads.

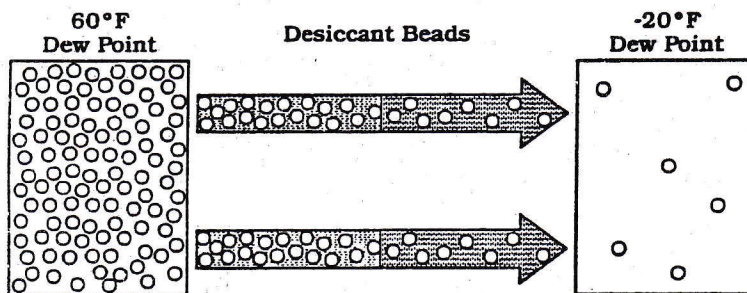
6

Participant's Notes: _____



GE Plastics

Desiccant Beads



The ceramic desiccant beads have such a strong affinity to water that they will absorb enough moisture from the air to achieve a dew point of at least -20°F.

6

Participant's Notes: _____

**Dehumidifying desiccant
dryers use a desiccant
system to dry the
incoming air.**

The Desiccant System

Incoming air is dehumidified in a cartridge containing a moisture-
absorbing desiccant bed. **STK 643**

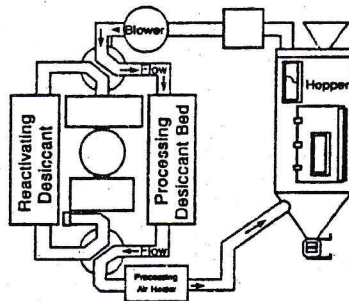
**Desiccant beads absorb
moisture.**

Desiccant Beads

The desiccant bed is made up of many tiny desiccant ceramic beads
that absorb most of the moisture from the air, reducing its dew point
to as low as -20°F. **STK 644**



The Drying System



A blower forces the air through the desiccant bed to lower its dew point, through the heater to raise its temperature, and into the hopper to dry the pellets.

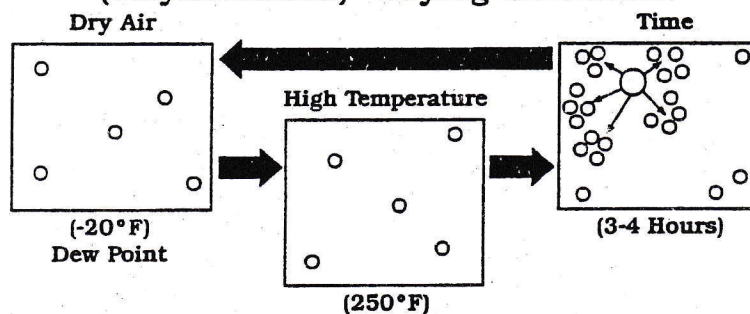
6

Participant's Notes: _____



The Drying Process

(Polycarbonate) - Drying Conditions



As this hot dry air circulates through the hopper, the moisture migrates out of the pellets.

6

Participant's Notes: _____

The routing of air in the desiccant system.

The Drying System

Here is a schematic drawing of the desiccant dryer system. A blower forces "wet" air through the desiccant cartridge, the "dry" air through the heater, and the "hot, dry" air into the hopper. **STK 645**

Moisture migrates out of the pellets.

The Drying Process

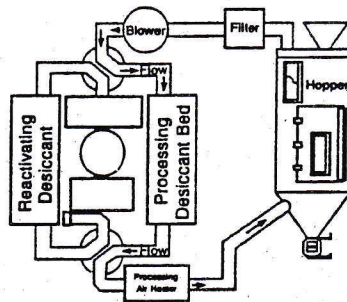
This "hot, dry" air circulates through the hopper. As it does, the moisture in the pellets migrates out into the air to establish equilibrium. The air is dried in the desiccant bed, heated in the processing air heater, passed over the pellets in the hopper, picks up moisture and cycles back through the desiccant bed, etc. **STK 646**



GE Plastics

STK 647

Closed-loop System



The return air is passed back through a filter to remove fines and dried in the desiccant bed to continue a closed-loop cycle.

6

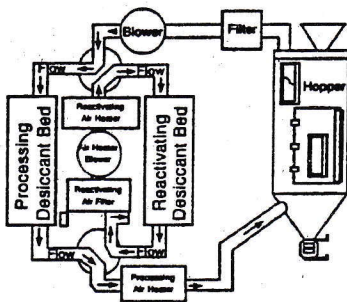
Participant's Notes: _____



GE Plastics

STK 648

Reactivating Desiccant Beads



Just as pellets can become saturated, the desiccant beads can become saturated and therefore have to be periodically reactivated.

6

Participant's Notes: _____

The desiccant bed is a closed loop system.

Closed-Loop System

The return air has picked up a lot of moisture from the pellets. It is then passed through a filter to remove any fines or contaminants that it may have picked up in the hopper, then forced by a blower back through the desiccant bed for drying. The filter protects both the desiccant bed and the resin from any contaminants. It is a closed-loop system.

STK 647

How the dryer reactivates the beads.

Reactivating Desiccant Beads

The desiccant beads must also be periodically reactivated for optimum results. Like the air and the pellets, they too can become saturated and moisture must be removed. Most systems contain more than one cartridge so that one cartridge can continue to dry the air in the dryer while another can be reactivated.

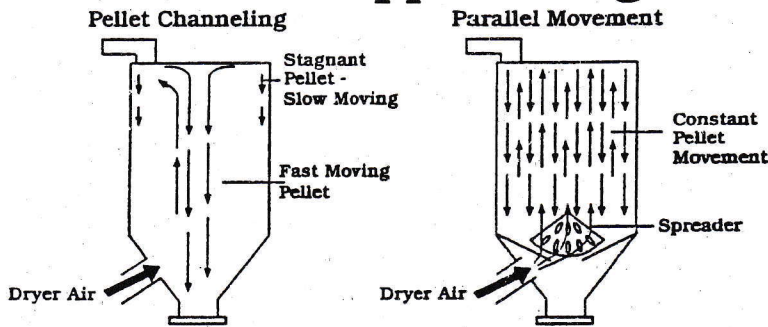
STK 648



GE Plastics

STK 649

Preferred Hopper Design



- Hoppers that are twice as high as they are wide (aspect ratio of 2:1) improve dryer efficiency.
- A spreader will prevent channeling and aid air flow.

6

Participant's Notes: _____



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STK 650

Dryer Recommendations

- Check dew point and temperature of air entering hopper.
- Check temperature of return air.
- Maintain proper air flow - approximately 1 CFM per (lbs / hour).
- If using regrind, increase drying time by 1 - 2 hours due to the larger pellet size.
- Make sure Desiccant Beds are being reactivated.

6

Participant's Notes: _____

Preferred Hopper Design

Finally, let's discuss the importance of proper hopper design to efficient drying. The hopper should have an aspect ratio of 2:1; that is, it should be twice as high as it is wide and be equipped with a spreader.

Preferred hopper design includes an aspect ratio of 2:1 and a spreader.

The 2:1 design with spreader will allow the pellets to move consistently and prevent channeling. The drawing on the left shows what happens when the pellets begin to channel. The inside pellets move too swiftly and won't be adequately dried before processing, while the outside pellets are stagnant and will be dried too long and possibly begin to degrade.

Consistent pellet movement is necessary to ensure adequate residence time for all the pellets and therefore proper drying. And in order to maintain adequate air flow, the hopper should be equipped with a spreader. The dryer air enters the hopper, passes through the spreader, and is spread throughout the pellets. **STK 649**

Dryer Recommendations

You should periodically check the dew point and temperature of the air entering the hopper. Check the temperature of the return air to monitor the air flow. The return air is the air entering the desiccant bed and should be less than 160°F. A proper air flow of approximately 1 cubic foot minute (CFM) per pound per hour through the hopper should be consistently maintained. As stated earlier, the desiccant beds should be periodically reactivated. **STK 650**

There are several checks that should be made when monitoring the drying process.



GE Plastics

STK 651

Hopper Size

- Shot Weight x Cycle Time = Throughput
ie: 1 Lb Part x 30 Sec Cycle = 2 Lb / Minute or
120 Lbs / Hour
- Throughput x Drying Time = Recommended
Hopper Size
ie: 120 Lbs / Hour x 4 Hours = 480 Lb Hopper

Hopper should be sized large enough to provide
adequate resin residence time.

6

Participant's Notes: _____



GE Plastics

STK 652

Understanding Polymer Drying

6

Participant's Notes: _____

Hopper size calculations.

Hopper Size

The size of the hopper should be calculated according to the resin throughput of the run to ensure adequate residence time. Throughput is calculated by multiplying the shot weight by the cycle time. For example, a part with a shot weight of 1 pound and a cycle time of 30 seconds will have a throughput of 2 pounds per minute or 120 pounds per hour. The recommended hopper size is then calculated by multiplying this throughput by the drying time. So if the throughput were 120 pounds per hour, and the drying time were 4 hours, then the recommended hopper size would be 480 pounds.

STK 651

Summary and Performance Feedback

Understanding Polymer Drying

As you've seen, pellet moisture content is impossible to determine visually. But an understanding of the variables that affect moisture absorption will help you understand how the process can be reversed. Only by adhering to the drying specifications outlined for each resin and by following proper drying procedure, can you be certain that the pellets will be dry enough for processing.

STK 652



GE Plastics

STK 653

What are the hazards of not properly drying the resin?

6

Participant's Notes: _____



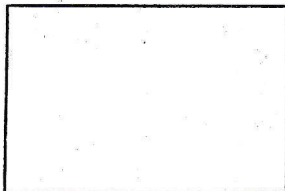
GE Plastics

STK 654

Hazards of Excessive Moisture

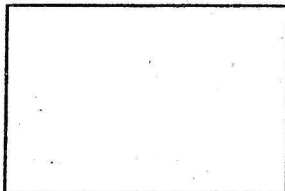
Imperfect Surface Appearance

- Streaks
- Splay



Decreased Property Performance

- Voids
- Lower Molecular Weight



6

Participant's Notes: _____



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What are the three most important variables in the drying process?

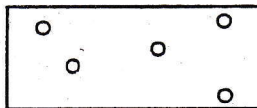
6

Participant's Notes: _____



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Proper Drying Variables



Dew Point of Air in
in the Dryer (-20°F)



Specified Resin
Drying Temperature

Specified Resin
Drying Time

6

Participant's Notes: _____



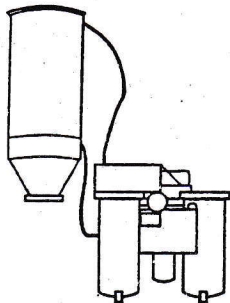
What is the most effective type of dryer and why?

6

Participant's Notes: _____



Desiccant Bed Dehumidifying Dryer



- Dries Air to Required Dew Point
- Heats Air to Specified Temperature
- Provides the Necessary Airflow in a Closed-loop System

6

Participant's Notes: _____



Module 7

Heating, Softening, and Melting Polymers

- Transition Temperatures
- Temperature Range for Processing
- Amount of Heat Necessary
for Processing
- Plastic Part Production
 - Heating
 - Controlling Heat Energy

6

Participant's Notes: _____



Module 6

Performance Feedback

1. What are the reasons for drying?
2. What are the hazards of not drying?
3. How are drying rates measured?
4. Identify the types of driers and the efficiencies of each. What type does your plant have?
5. Identify one drying problem you have encountered and describe how it could have been addressed.