Importance of

PROPER PLASTICS DRYING

IN PROCESSING OF ENGINEERING PLASTICS

by

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ABSTRACT

Drying is the necessary criteria for quality processing of plastics, particularly with the increased usage of thermoplastics / engineering polymers / resins

Engineering polymers / resins absorb moisture during manufacturing, transportation and when in storage prior to processing. It can be safely assumed that all batches of resins potentially contain surplus/excessive moisture, regardless of the circumstances.

Thus, the moisture must be removed from the resins prior to processing. Excessive moisture in the resin results in severe material inconsistency during processing. Apart from resulting in sub-standard product, both in terms of appearance and property, moisture trapped inside the resin can cause silver streaking or splay. More disastrous can be damages, which are not visible.

Plastics resins which are affected by moisture, can be classified as:

- *Non-Hygroscopic*
- *Hygroscopic*

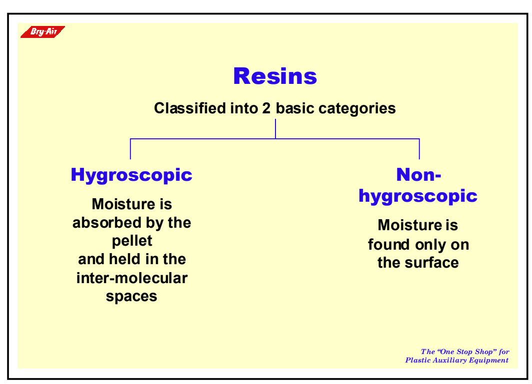
Non-Hygroscopic resins collect moisture only on the surface of the pallet. This surface moisture can be dried by exposing the resin to a continual blow of the hot air

Hygroscopic resins, collect moisture inside the core of the pallet and can be best dried by dehumidifying dryers.

Hygroscopic resins like PA, ABS, PET, PC, PS etc., which have a high affinity for moisture, need to be dried thoroughly and properly to ensure quality finish of final product. Improper and inadequate drying can result in loss of structural, impact strength and tensile strength, cosmetic defects and many other moisture related defects and deficiencies.

In this paper we will elaborate, the importance of proper drying of engineering plastic resins, to maximize quality of moulded parts and minimize possibilities of degradation. We will also be discussing various variables of drying and equipment / methods available for effective drying of engineering plastic.

WHY IS PLASTICS DRYING IMPORTANT?



One of the most important and universal advantages of engineering plastics is their virtual freedom from attack by ambient moisture or from surface attacks compared to the rusting of steel or the atmospheric corrosion of copper and aluminium.

However, **plastics** in the **resin state** may be **hygroscopic** (moisture penetrates the pellets) and **absorb moisture** from the **atmosphere** during **storage** or **before being processed**, which **adversely** affects the **final quality** of the moulded part.

Even **non-hygroscopic plastics** (moisture accumulates on the surface) are **susceptible** to **surface moisture** contamination that should be removed before processing.

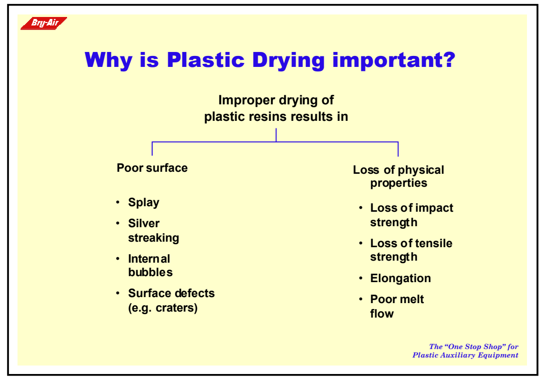
PROBLEMS DUE TO IMPROPER DRYING

Common problems of many resins like - *Nylon, ABS, Polythermide, Polysulphone, Polycarbonate* due to improper drying are -

1. **SURFACE APPEARANCE**

   Moisture bubbles trapped in the resin can ruin a part's surface appearance by causing:

   - Splay (splash type defects)
   - Silver streaking
   - Internal bubbles, and
   - Surface defects (e.g. craters etc.)



2. **PROPERTY PERFORMANCE**

   Moisture can cause a loss in material properties. Trapped moisture bubbles can cause voids in the interior of the part. Moisture can also cause a loss in molecular weight due to hydrolysis. (A chemical process of decomposition that occurs with the addition of water)

   Loss of Physical properties may result in -

   - Loss of impact strength
   - Loss of tensile strength
   - Elongation and
   - Poorer melt flow.

   For resins such as polycarbonate and polyester where impact strength is a critical property, dry resin is a must.

   Hence, *proper drying* of many *plastic resins* is the *first critical* step towards obtaining *optimum performance* of molded parts and minimizing possibilities of *degradation*. Without exception, the longer and hotter a given forming operation is, the drier the pellets must be.

PROBLEMS OF MOISTURE IN PLASTIC PELLETS

Resin's 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. Some polymers have a greater affinity to water than others and therefore will absorb moisture more readily. Not only does every resin family have its own moisture absorption characteristics, but each resin grade does as well. The weather conditions or the moisture content of the air as will as the temperature of the ambient air and the pellets also affect the resin's moisture content

Drying Variables

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

Proper Drying

Drying reverses the absorption process, removing moisture from the pellet to a very low level moisture content that is suitable for processing. Proper drying Improves processing consistency by removing moisture from the pellet prior to processing and preheating the material to predetermined temperature. 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.

Dry Air

The air used to dry the pellets must have a dew point of at least – 40° F/ °C Only if the air is this dry, can a pellet reach the point of equilibrium to maintain a moisture level $\geq$0.05%. The drying temperatures and times specified assume that the air in the dryer will have a dew point of at least – 40° F/° C or lower.

Methods of Drying

There are three methods of resin drying;

- Manual Drying
- Hot air or Hopper Drying
- Dehumidifying Drying

Manual Drying

Manual drying is an outdated, labour intensive process, with high probability of spoilage of pallets because of improper control of temperature.

Hot Air or Hopper Drying

The hopper (Hot air) drying, on the other hand, allows for continuous drying in the hopper and is preferable for long runs but only for non-hygroscopic resins i.e where moisture is only on the surface of pallets.

Dehumidifying Drying

Hopper (Hot Air) Dryer

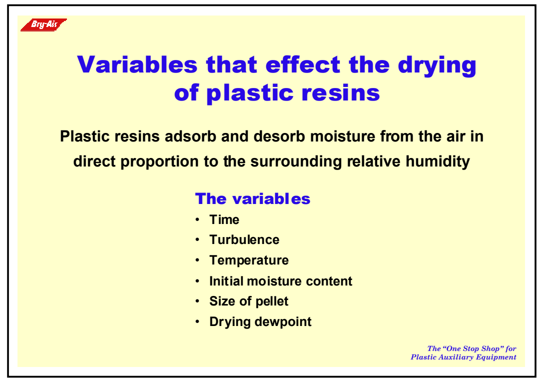
For hygroscopic resins i.e where moisture is inside the core of the pallet, dehumidifying drying is the only solution

VARIABLE THAT AFFECT THE DRYING OF RESINS

Effects of Air Temperature (Hot Air Drying)

The rate of moisture gain or loss along the solubility curve is quite dependent upon the temperature because of the strong effect on the diffusion rate of water molecules through the pellets.

Higher temperatures provide a lower RH, and hence the rate of drying is faster. However, with heating, the dewpoint and moisture content remains unchanged. As a result, there is no positive removal of moisture from the environment. The moisture equilibrium content of the plastic pellet can be limited. Thus, the degree of dryness will also be limited. This is particularly true for all hygroscopic plastic resins. Hot air drying is recommended for non-hygroscopic resins where the moisture is present on the surface.



Effects of Initial Moisture Content

As mentioned earlier, pellets come to equilibrium with the surrounding environment. Since the environment cannot always be controlled during shipment and storage, the initial moisture content before drying will vary. The drying time should be adjusted upward as the initial moisture content increases. E.g a rule of thumb for ABS is if the moisture content is increased by a factor of two, the drying time should be doubled as will.

Effect of Pellet Size

Basically, smaller pellets dry faster than larger pellets because the average diffusion path (heat flow inward and moisture outward) is shorter.

Effect of Dew point

The drying rate is greatly affected by differences in dewpoint. Lower dew points allow pellets to approach a lower equilibrium state of dryness. The extra degree of dryness is essential for producing quality parts. Furthermore, the lower the dewpoint, the less time it takes to reach a particular final moisture content.

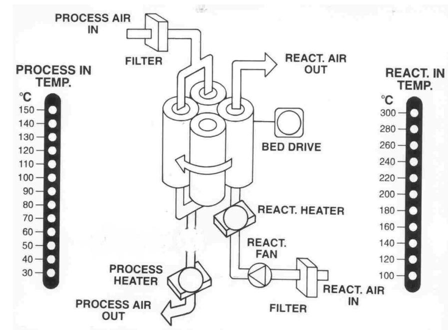
THE DESICCANT DEHUMIDIFICATION PROCESS

A desiccant bed is composed of desiccant enclosed by two solid

Resin Drying Temperatures

Material	Temp. (°F)	Time (Hr.)	Bulk Dens. (lb / ft^3)
ABS	190°	3-4	42
Acetal (Homopolymer)	200°	1-2	40
Acetal (Copolymer)	210°	1-2	40
Acrylic	180°	2-3	42
Cellulose Butyrate	170°	2-3	39
Cellulose Acetate	170°	2-3	38
Cellulose Propionate	170°	2-3	40
lonomer (Surlyn)	160°	7-8	44
LCP (Xydar)	300°	3-4	50
Nylon	180°	4-5	41
Polycarbonate	250°	3-4	40
P Carb/Pbt/Elast (Xenoy)	260°	3-4	42
Peek	310°	3-4	52
Pet-Bottle (Eastapak 9921)	340°	5-6	52
Polyester (Rynite)	275°	3-4	54
Pet(Thermx EGOOI)	265°	4	42
P'Ester (PBT/Pet Valox 815)	360°	4-5	48
Polyester (Pbt-Valox 420)	260°	2-3	48
Polyester (Pet-Valox 700)	320°	4-5	48
Petg (Easter Gnxxx)	155°	6	46
Pctg (Easter Dnxxx)	165°	6	45
Pctg/P'Carb (Eastalloy Daxxx)	200°	4-6	43
Pet (Thermx Cg 907)	160°	4-6	41
Pet (Thermx Cg921)	160°	6	50
Peta (Thermx Ag 230)	330°	4	44
Polyarylate	250°	5-6	50
Polyetherimide	310°	4-5	52
Polyethylene (Black)	160°	3-4	34
PPO/Styrene (Noryl)	210°	2-3	49
Polyphenylene Sulfide	280°	2-3	50
Polysulfone	275°	3-4	50
Polyurethane	180°	2-3	48
SAN	180°	3-4	40
SMA (Dylark)	200°	2-3	38
TPE (Hytrel)	210°	2-3	48

sides and tow sides with perforated openings, which allow the passage of air. The desiccant is a porous material, which by nature is extremely hygroscopic. Since desiccants have a natural affinity for water, an air sample exposed to a desiccant will give up its moisture to the desiccant. At the same time, the desiccant is unchanged both in size and shape after taking the moisture out of the air.



Typical Operating Principle of a Dehumidifying Dryer

When the desiccant has completed its drying job, it is removed from the process air stream and separately regenerated with heat. The presence of heat will cause the desiccant to give up the moisture (through evaporation) that it had previously adsorbed. Once the accumulated moisture has driven from the desiccant, the bed is ready again for re-adsorption.

VARIABLES WHICH AFFECT DRYER DEWPOINT

Air Velocity Across the Beds

There is a basic relationship between air velocity across the desiccant bed and desiccant adsorption capacity. The greater the velocity the less capability the desiccant has to adsorb moisture. This is similar to cooling coils where the face area is sized to achieve the proper velocity across the coil. Accordingly, the proper designing of CFM to desiccant bed face area is critical and should be optimised to achieve proper balance between desiccant adsorption capability and size of the bed (i.e. size of the bed is limited by space requirements).

Depth of Desiccant Beds

There is an increasing rate of adsorption capability as the desiccant depth is increased up to a point, after which diminishing returns come into play. The desiccant bed depth should be deep enough to reach this critical point and also have some additional depth to provide a safety margin for desiccant contamination.

Again, relating this to cooling, up to a point each additional row of coils provide further cooling, after which, no work will be done.

Type of Desiccant Used

The adsorption capability of the desiccant bed is dependent upon the type and size of desiccant used. **The types of desiccant used for air-drying include silica gel, activated alumina and molecular sieve**. Molecular sieve is used for plastic dryer applications due to its superior adsorption capability at low dewpoints and high entering temperatures.

The sieve size of the molecular sieve is also important. Like plastic pellets, the larger the size the greater is the average diffusion path of heat and moisture. Thus the larger the desiccant size, the harder it is to reactivate the desiccant and drive out the moisture that has been adsorbed.

Accordingly, smaller desiccant sieve sizes allow for easier reactivation and greater adsorption.

There are however, two considerations that limit the degree to which sieve size can be reduced. The first is that the desiccant size must be larger enough to be able to be contained by the perforated bed screen; a smaller sieve size will induce a greater pressure drop (resistance) through the desiccant bed. Therefore, the size of the desiccant is limited by the static pressure capability of the system blower.

Direction of Process and Reactivation Air Flows

Counter-current airflow is such that the process and reactivation airflows are moving in opposite directions. Co-current airflow design occurs when both airflows are moving in the same direction.

We have found that counter-current airflow provides a significantly greater degree of reactivation and adsorption that does co-current. The reason for this lies in the fact that the desiccant on the process entering side of the bed adsorbs the greatest percentage of moisture.

When the bed is reactivated, instead of driving the bulk of the moisture through the entire length of the bed (as would be in the case of co-current air flow) it is much easier to drive the moisture out in the opposite direction (counter-current) from which it had come, since this path provides the shortest length.

Dehumidifying Dryer
(Incorporating unique four bed design)
and Hopper with Auto Loader

Reactivation Temperature

The reactivation temperature of molecular sieve is substantially higher than other types of desiccants. Molecular sieve should not be reactivated with lower than 300°F. Typically (assuming cooling of the bed after reactivation), the higher the reactivation temperature the greater is the amount of moisture that is released from the desiccant and the greater it its future adsorption capability.

Again, the optimisation must be reached in which an appropriate balance between bed depth, KW requirements and dew points is reached.

Cycle Time

Cycle time is the amount of time one bed is in process and another bed is in reactivation.

Cycle time is important because it is critical that the reactivation bed is substantially regenerated before going into process (breakthrough of moisture has occurred). It is also important for the process bed to adsorb an optimal amount of moisture under the existing conditions. Once the desiccant has adsorbed the optimal amount of moisture, additional time in process results in marginal diminishing returns. Accordingly, it the reactivation time is too long, energy (KW) is not put to efficient use.

Therefore, the time cycle must be of proper length to optimise both moisture adsorption in process, and moisture removal in reactivation for the particular bed depth involved. Typically, larger bed depths have longer cycle times (2-4 hours) than smaller bed depths (17 minutes to 1 hour).

Purge Cycle (Bed Cooling After Reactivation)

After reactivation the desiccant itself is rather hot (400-500°F). If the desiccant bed is placed into process directly after it has been reactivated, the desiccant will not begin adsorbing moisture immediately. Since the desiccant is still hot, it will be wanting to continue to release than adsorb moisture.

In order to avoid this problem, a cooling stage should be employed after the reactivation stage. But before the process stage. An efficient cooling stage should be designed to that the desiccant bed is cooled below the process entering air temperature (usually 100° - 180°F). Efficiency would also imply that the bed not be cooled with ambient or moisture laden air which would only serve to load the desiccant with moisture before it even goes into the process stage. A closed-loop cooling system is the most preferable.

Return Air Temperature From Hopper

There is an inverse relationship between the return air temperature and desiccant moisture removal capacity. The higher the return air temperature from the hopper the lower is the adsorption capability of the desiccant and the dewpoint output from the dryer. As was shown above, the presence of heat will induce the desiccant to give up moisture rather than take it on.

This is the reason why in many applications in which materials require drying at high temperature (i.e. PET) an after-cooler is used to reduce the return air temperature.

Closed Loop Process System

In order to obtain low dewpoint performance (i.e. -40°F dp) it is absolutely necessary for the drying system to be totally closed-looped. This requires no leakage in air hoses and drying hoppers. Further, it necessitates the use of two separate blowers for process and reactivation air streams. If only one main blower is used for both process and reactivation, ambient (moisture-laden) air must be introduced into the system in order to make up the deficiency resulting from the reactivation outlet air being exhausted. Ambient make up air then serves only to significantly increase the dewpoints of both the process entering (return) air and the process (supply) air.