



GE Plastics

Sharing The Knowledge

Module 1

Families of Polymers



Module 1

Families of Polymers

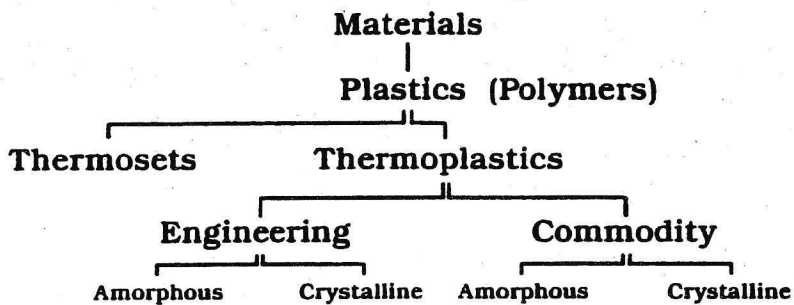
- Polymer Science
- Factors Which Effect Polymer Properties
- Polymer Families
- Material, Design, and Processing Relationships

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Participant's Notes: _____



Families of Polymers



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Participant's Notes: _____

Introduction

Families of Polymers

Module 1 of Sharing The Knowledge lays the foundation for future modules by defining the term polymer and by differentiating the various families of polymers that exist today. At the end of this module you should be able to identify the basic characteristics of polymers as well as describe the major differences between thermoplastics and thermosets, between engineering and commodity plastics, and between amorphous and crystalline resins. **STK 101**

Objectives:

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

- Identify the basic characteristics of polymers.
- Describe the major differences between the following polymer families: commodity vs. engineering and thermosets vs. thermoplastics.
- Describe the relationship between material, design, and processing in plastic part production.
- Classify the materials you are working with according to their polymer family.

Families of Polymers "Tree"

Plastics - or polymers - are manmade materials used to make an assortment of different things we use everyday. The tires on your car, your car dashboard, and the lid on your coffee cup are all made of plastic, and yet each material is very different. Each of these materials belongs to a different "family" of polymers.

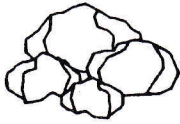
Categories or family tree of polymers.

In this module we'll learn how an automobile tire, which is a thermoset, differs from an automobile dashboard, which is a thermoplastic. And we'll see why the dash is considered an engineering thermoplastic while the coffee lid is considered a commodity thermoplastic. Finally, we'll learn that even within the engineering and commodity families, thermoplastics can either be amorphous or crystalline. By understanding these variations, you'll begin to appreciate the wonderful diversity and unique properties these polymer materials have to offer. **STK 102**

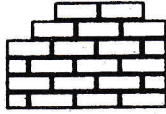


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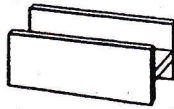
The Development of Materials



Stone



Brick



Metal



Plastics

All materials are made of molecules.

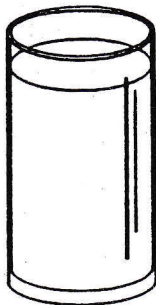
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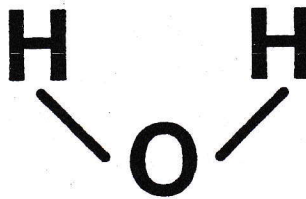


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All Molecules Are Made of Atoms



Many, many water
molecules



One water
molecule
(H₂O)

1

Participant's Notes: _____

Polymer Science

Plastics are the next step in the development of materials.

The Development of Materials

Through the years, man has used a variety of materials: from stone, to brick, to metal, and finally to plastics. All these materials are made of molecules. In fact, everything is made of molecules. And it is the molecular structure of each of these materials that makes it unique.

STK 103

Molecules are made of atoms.

Materials around us are made of many molecules.

All Molecules Are Made of Atoms

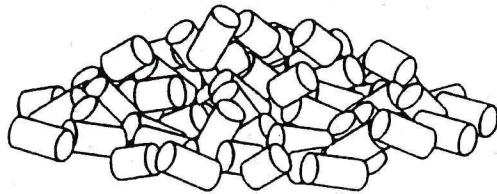
Every molecule is made up of atoms. You've probably heard water referred to as H_2O . That's because water is made up of many H_2O molecules. H_2O stands for the two Hydrogen atoms and one Oxygen atom bonded together to make up one H_2O molecule. This is an example of chemical notation that will be helpful to you as our discussion proceeds.

STK 104



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Plastics



There are many, many molecules in each plastic pellet.

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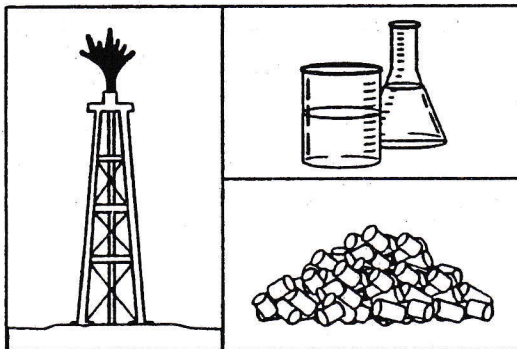
Participant's Notes: _____



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Making Plastics

Petroleum



Chemistry

Plastics

Natural

Manmade

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Participant's Notes: _____

There are many molecules in a typical pellet.

Plastics

Just as water is made up of many water molecules, a plastic is made up of many "plastic" molecules. To give you an idea of the size of a molecule, there are over a million molecules in a typical plastic pellet.

STK 105

Plastics are derived from sources such as oil and natural gas.

Making Plastics

While some materials exist naturally such as stone, wood, and petroleum oil, plastics are made by man. Man isolates the molecules found in such natural materials as crude oil and mixes them up or adds many together to form an entirely new molecule – a long, chain-like molecule – a polymer molecule.

STK 106



GE Plastics

STK 107

States of Matter

Gas	Methane One Carbon	$\begin{array}{c} \text{H} \\ \\ \text{H} - \text{C} - \text{H} \\ \\ \text{H} \end{array}$
Liquid	Octane (Gasoline) Eight Carbons	$\begin{array}{cccccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & & & \\ \text{H} - & \text{C} - & \text{C} - & \text{C} - & \text{C} - & \text{C} - & \text{C} - & \text{H} \\ & & & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
Wax	Paraffin 50 Carbons	$\begin{array}{cccc} \text{H} & \text{H} & \text{H} & \text{H} \\ & & & \\ -\text{C} - & \text{C} - & \text{C} - & \text{C} - \dots \\ & & & \\ \text{H} & \text{H} & \text{H} & \text{H} \end{array}$
Plastic	Polyethylene 10,000 Carbons	$\begin{array}{cccc} \text{H} & \text{H} & \text{H} & \text{H} \\ & & & \\ -\text{C} - & \text{C} - & \text{C} - & \text{C} - \dots \\ & & & \\ \text{H} & \text{H} & \text{H} & \text{H} \end{array}$

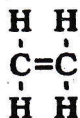
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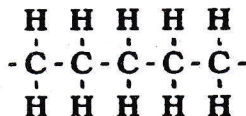


GE Plastics

STK 108



Ethylene Monomer



Polyethylene Molecule

Polyethylene is a polymer.
All plastics are polymers.

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Participant's Notes: _____

Increasing the length of a polymer molecule can change its properties.

The length of the polymer molecule (chain) determines its molecular weight.

Each polymer molecule comes from a unique monomer.

States of Matter

For example, we can take the molecules from a natural material such as oil and then rearrange them through a chemical process to create a new molecule, a polymer molecule. Though the resulting polymer molecule will contain the same base unit as the methane and the octane found in the oil, it will still be a very different material.

You see, there are three states of matter - gas, liquid, and solid and a material's state depends on the degree to which its molecules are packed together. Increasing the number of atoms in a molecule tends to increase the compactness of these molecules within a material.

Because methane is a very small molecule, containing only one Carbon atom surrounded by four Hydrogen atoms, its molecules are so loosely packed that they exist as a gas. Octane is a slightly bigger molecule than Methane, containing eight Carbon atoms surrounded by several Hydrogen atoms, so its molecules cling together more closely and therefore exist as a liquid.

Paraffin is an even bigger molecule, containing as many as 50 Carbons and at least 100 Hydrogen atoms. Paraffin molecules are so compact that they exist as a waxy solid. Methane, Octane, and Paraffin all exist naturally. Plastics, however, are manmade.

Man uses advanced chemistry to form very long molecules like this polyethylene molecule which contains thousands of Carbons and thousands of Hydrogen atoms. These molecules are very densely packed and exist as a plastic solid called a polymer. Polyethylene is a polymer. All plastics are polymers. STK 107

Monomer/Polymer

The base molecular unit that was isolated from the petroleum is called a monomer - mono meaning one, mer meaning unit. This is an example of an ethylene monomer. Thousands of these monomers linked together create a long chain-like molecule called a polymer - poly meaning many. This is an example of a polymer molecule - a polyethylene molecule. Many polyethylene molecules form the polymer material called polyethylene.

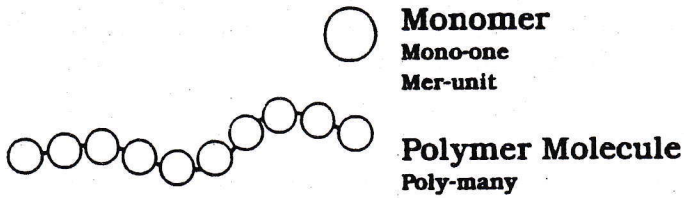
All plastics are polymers. STK 108



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Polymer

A chemical compound formed by many monomers linking to form larger molecules that contain repeating structural units.



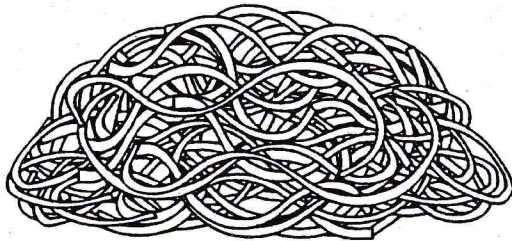
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Participant's Notes: _____



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Polymers Have a Spaghetti-like Structure



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Participant's Notes: _____

Polymers are made up of many single repeat units called monomers.

Polymer

A polymer is a chemical compound containing many repeating monomers linked together to form a very long chain-like molecule. Just imagine a string of beads where one single bead represents a monomer unit, and the entire strand represents the polymer molecule.

STK 109

Random alignment and entanglement of polymer chains.

Polymers Have Spaghetti-like Structure

This long molecular chain bends, twists, turns, tangles, and bends in on itself and its neighbors to form a structural mass that resembles cooked spaghetti. It is this intertwined structure that gives the polymer some of its unique characteristics.

STK 110



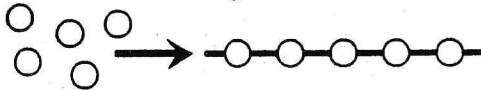
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Polymerization

The Process of Forming Polymers

Addition Polymerization

Combining or Adding Simple Repeat
Units to Form Long Chain-like Molecules



Condensation Polymerization

Combining Two or More Units with a Liberation
of By-products



1

Participant's Notes: _____



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Properties of Polymers Depend Upon:

- **Chemical Composition of the Monomers**
- **Shape and Length of the Polymer Chains**
- **Alignment of the Polymer Chains**

1

Participant's Notes: _____

Two methods of making polymers are addition polymerization and condensation polymerization.

Polymerization

The process of forming a polymer is called polymerization and two types are: addition and condensation. In addition polymerization, many of the same type of monomers are added together to form a very long chain of repeating monomer units. Condensation polymerization unites two or more different molecules to create a new monomer and a by-product. These monomers add together to form a long chain of repeating structural units with the liberation of by-products.

STK 111

Polymer Properties

Polymer properties depend on three primary factors.

Properties of Polymers Depend Upon:

Remember, not all polymers are alike. Though they all share certain unique characteristics, the individual properties of each are dependent upon the chemical composition of the polymer, the shape of the polymer chains, and the alignment of these molecular chains. We'll discuss these differentiating characteristics in more depth as we continue.

STK 112

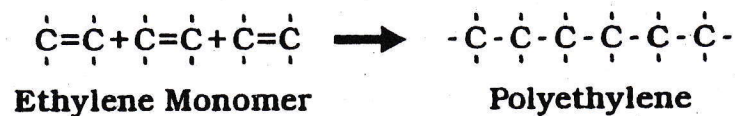


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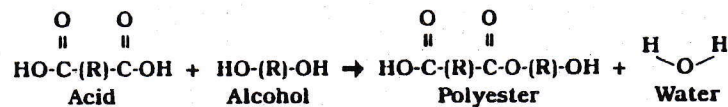
STK 113

Chemical Composition

Addition Reaction (Polymerization)



Condensation Reaction (Polymerization)



1

Participant's Notes: _____



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STK 114

Addition Polymerization

Manmade

Polyethylene

Polystyrene

Polyvinylchloride

Natural

Rubber

Cellulose

Sugar

1

Participant's Notes: _____

Polymer Properties

Chemical Composition

This is an example of addition polymerization and a condensation reaction.

Addition polymerization makes simple natural or manmade polymer molecules.

Chemical Composition

Here are examples of addition and condensation polymerization using scientific notation. In the first example, several ethylene monomers are added together to form the long chain molecule, polyethylene. We've simply "polied" our ethylenes. In the second example, we've united two different molecules, alcohol and acid, to form the polyester monomer, releasing a water molecule which is removed in the process. This new monomer then becomes the repeating structural unit that makes up the long chain molecule, polyester.

Polyethylene is the chemical name for the material used to make plastic sandwich bags and plastic containers for liquid laundry detergent. Polyester is a chemical name as well. Polyester is often used as synthetic fabric for clothing and a variety of other applications.

STK 113

Addition Polymerization

We actually reproduce processes that are found in nature when we create "manmade" materials. Addition polymerization is a rather simple process that occurs fairly often in nature and is responsible for producing materials such as rubber, cellulose, and sugar. It is also a fairly simple manmade process responsible for producing such manmade polymers as polyethylene, polystyrene, and polyvinylchloride (PVC).

STK 114



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Condensation Polymerization

Manmade

Nylon 6

Polycarbonate

Polyphenylene Oxide

Natural

DNA

Protein

Skin

1

Participant's Notes: _____



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Shape of Polymer Chains



Linear Polymers

Characterized by Linear Alignment
of Base Molecular Units

1

Participant's Notes: _____

Condensation polymerization makes more complex natural or manmade molecules.

Condensation Polymerization

Condensation polymerization is a more complex process. In nature, it is responsible for the creation of such complex materials as DNA, protein, and even living skin tissue. Likewise, it is a more complex laboratory process responsible for producing highly specialized materials such as Nylon 6, polycarbonate, and polyphenylene oxide (PPO). These complex materials are more difficult to create and are usually of greater value than those created by addition polymerization.

STK 115

Polymer Properties

Shape and Length

Monomer units of linear polymers are aligned like an open strand of pearls.

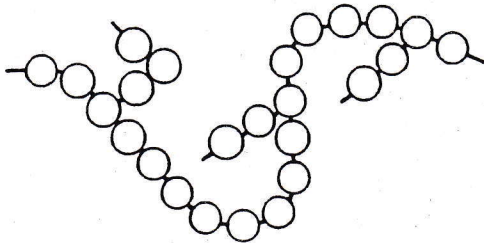
Shape of Polymer Chains: Linear Polymers

Both addition and condensation polymerization are chemical reactions that occur when initiated by a catalyst. Polymers can be either linear or branched depending on the catalyst used. When a molecule is said to be linear, it is not a long straight molecular chain, but a long, bending, flexible chain of monomers similar to a strand of pearls. High density polyethylene is an example of a linear polymer.

STK 116



Shape of Polymer Chains



Low Density
Polyethylene

Branched Polymer

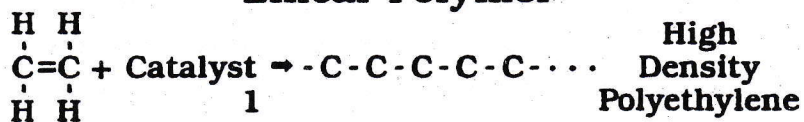
Characterized by Branched Formation
of Base Molecular Units

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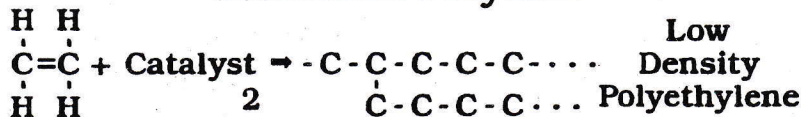
Participant's Notes: _____



Linear Polymer



Branched Polymer



Chemists can modify processing
characteristics through branching.

1

Participant's Notes: _____

Branched polymers have additional monomer chains growing off the primary chain.

Shape of Molecular Chains: Branched Polymers

Now imagine this same strand of pearls with several short strands branching from it. This long chain molecule with intermittent offshoots is referred to as a branched polymer. It is still long and chainlike but with branching occurring occasionally. Low density polyethylene is an example of a branched polymer. It is still polyethylene, but the shape of its molecular chains is different from high density polyethylene.

STK 117

The same monomer can produce either linear or branched molecules.

Linear and Branched Polymers

Both low density and high density polyethylene are the result of addition polymerization, but by altering the catalyst, the polymer will branch just enough to affect the flow capability of the material. The base monomer is the same in both, and therefore the material is essentially the same. But the chemist can change the way the material flows to make it more compatible with specific processing conditions.

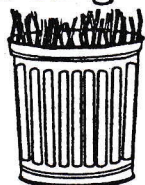
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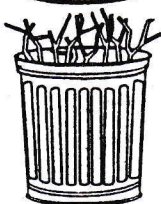
Shape of Polymer Chains Affects Alignment

High Density
Linear Polymer



Many "linear"
molecules fit in
a given volume.

Low Density
Branched Polymer



Fewer "branched"
molecules fit in
the same volume.

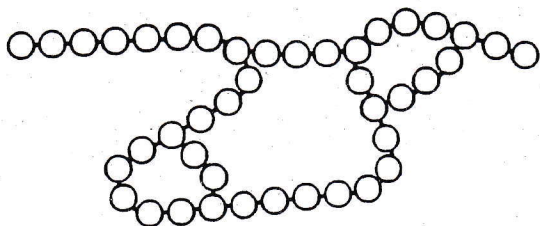
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Participant's Notes: _____



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Thermoset



The ultimate branched polymer becomes a
crosslinked network called a Thermoset.

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Participant's Notes: _____

Shape of Polymer Chains Affects Alignment

To better understand what we mean by density, try to imagine a trashcan of sticks. Just as more sticks fit in a trashcan if they are lined up and tightly packed, so will more polymer chains fit into a certain volume of material if they are tightly packed. Linear polymers are able to bend, fold, and collapse on themselves more easily than branched polymers and therefore produce a higher density material.

The density of a polymer can be a direct result of the amount of branching.

Branched polymers also tend to bend and fold tightly together, but are restricted by the offshoots that result from branching. So just as fewer sticks will fit in a trashcan if they are tossed in loosely, so will fewer polymers fit in a volume of material if they are branched. Branched polymers, therefore, produce a lower density material.

High density polyethylene, a resin built of a linear polymer, flows very easily and is suitable for most injection molding applications. Low density polyethylene is built of branched polymers and consequently flows more stiffly, making it more suitable for blow molding and extrusion.

STK 119

Thermoset

A thermoset is the result of a high degree of crosslinking.

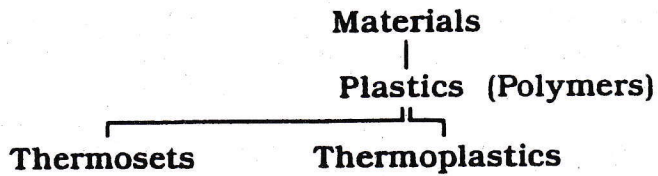
Up until now, all the polymers we've talked about have been thermoplastics. Remember when we discussed the shape of polymer chains, the ultimate branched polymer is a thermoset. A thermoset is so heavily branched that a complex network of irreversible crosslinks is created. Though thermoplastics and thermosets are both polymers, they are still fundamentally different.

STK 120



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Families of Polymers



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Participant's Notes: _____



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Thermoplastics

Plastics capable of softening and flowing when heated, hardening when cooled, and softening when reheated -

REVERSIBLE PROCESS

Thermosets

Plastics which become permanently rigid when heated and cooled -

NONREVERSIBLE PROCESS

1

Participant's Notes: _____

Thermoplastics and Thermosets

**Thermoplastics are
differentiated from
thermosets through
crosslinking.**

Families of Polymers "Tree"

Here is our first important differentiation. Thermoplastics and thermosets belong to two different polymer families. They differ structurally which renders them entirely different in terms of processing.

STK 121

**Thermoplastics can be
remelted and formed.**

Thermoplastics vs. Thermosets

When heated, thermoplastics are capable of softening, flowing and forming - hardening when cooled - and then softening, flowing, and forming again when reheated. Thermoplastic processing is a reversible process. Thermosets, on the other hand, become permanently set when heated and cooled. Thermoset processing is a nonreversible process.

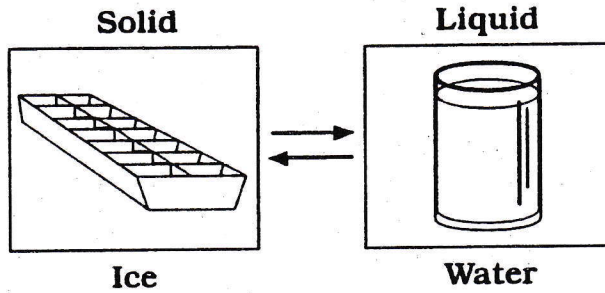
STK 122



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Thermoplastics

Change PHYSICAL state when processed similar to water:



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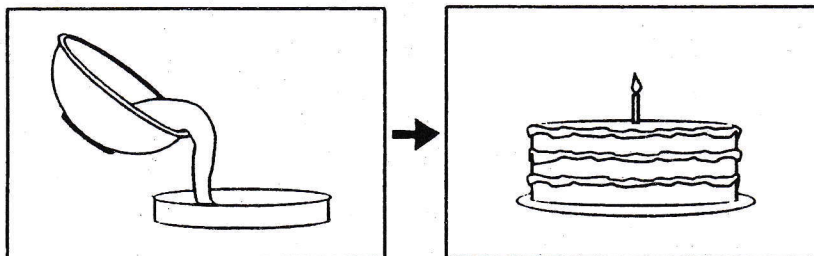
Participant's Notes: _____



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Thermosets

Change CHEMICAL state when processed similar to baking a cake:



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Participant's Notes: _____

Thermoplastics can change physical states when melted.

Thermoplastics: Physical Change

Thermoplastics go through a physical change when processed, the same way water goes through a physical change when cooled and heated. Water becomes solid upon cooling, liquid upon heating and solid upon cooling. The material has merely changed state and the process is continually reversible.

STK 123

Thermosets cannot remelt.

Thermosets: Chemical Change

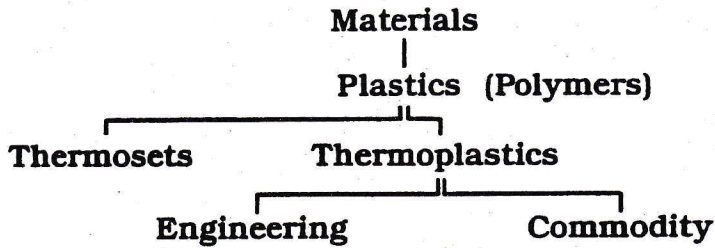
Thermosets go through a chemical change when processed, the same way cake batter goes through a chemical change upon baking. Once the batter is baked into a cake, it will never again be batter. If heated again, it will be burnt cake. If cooled, it will be frozen cake. The material has gone through a chemical change and the process is irreversible.

STK 124



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Families of Polymers



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Characteristics of Engineering Thermoplastics Engineering and Commodity

- Corrosion Resistance
- Thermal/Electrical Resistance
- Practical Toughness and Stiffness
- Light Weight

Engineering

- High Temperature Resistance
- Flame Resistance

1

Participant's Notes: _____

Commodity and engineering thermoplastics are generally differentiated based on a combination of their physical properties.

Families of Polymers "Tree"

Though engineering and commodity materials are both part of the thermoplastic family, their differences constitute further distinction. Engineering and commodity thermoplastics belong to two different polymer families. They are generally differentiated in accordance with their combination of physical properties.

STK 125

Engineering plastics are differentiated based on their performance characteristics.

Characteristics of Engineering Thermoplastics

Commodity and engineering thermoplastics share several characteristics: they are lightweight for use in automobiles; they provide practical toughness and stiffness for use in toys; they offer thermal and electrical insulation for use in wire coating; and they provide corrosion resistance for use in corrosive environments. But engineering thermoplastics tend to provide the kind of high temperature resistance necessary for use in motors, electronics, and demanding aircraft applications.

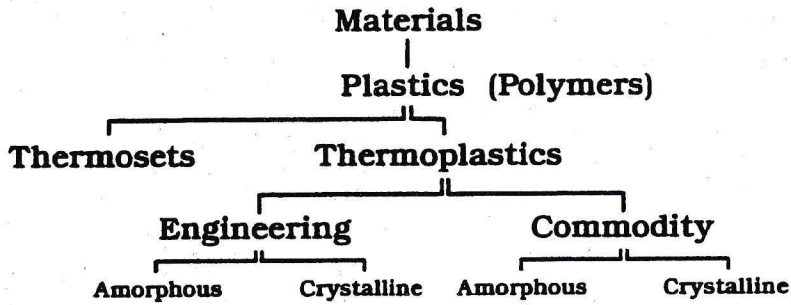
In addition to high heat resistance, engineering materials tend to offer higher performance in terms of flame resistance. In general, commodity thermoplastics are low performance materials, while engineering thermoplastics are considered high performance materials.

STK 126



GE Plastics

Families of Polymers



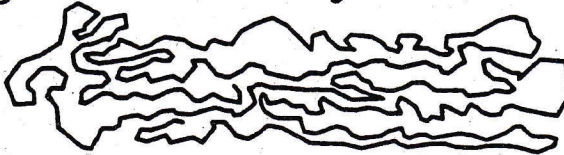
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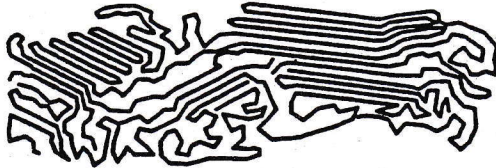


GE Plastics

Alignment of Polymer Chains



Amorphous Resins



Crystalline Resins

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Participant's Notes: _____

Amorphous vs. Crystalline

**Differentiate amorphous
from crystalline
polymers by the chain
alignment.**

Families of Polymers "Tree"

Amorphous and Crystalline resins are two more polymer families found in either the engineering or commodity thermoplastic families. Their structures are discussed in depth in Module 2.

STK 127

Polymer Properties Alignment

**Some polymers produce
areas of ordered
alignment called
crystalline structure.**

Alignment of Polymer Chains

Thermoplastics, whether engineering or commodity, can be either amorphous or crystalline in structure. The structure of the material is determined by the alignment of the polymer chains. "Morphology" means the study of "structure," hence "morphous" means "structural." So "amorphous" literally means "without structure." Amorphous polymers are comprised of random entanglements of polymer chains.

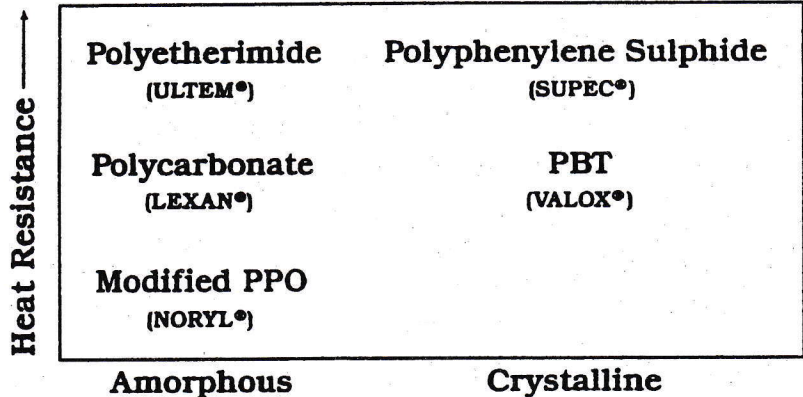
Crystalline resins contain areas of order in an otherwise amorphous mass. In these crystalline regions, the molecules bend and fold in an orderly fashion, lying together in relatively straight lines.

STK 128



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Engineering Thermoplastics

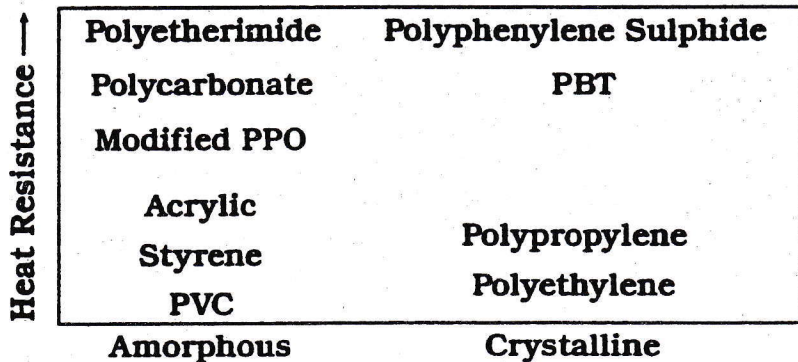


Participant's Notes: _____



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Engineering Thermoplastics Offer High Temperature Performance



Participant's Notes: _____

Crystalline and amorphous thermoplastics can be differentiated based on heat resistance.

Engineering Thermoplastics

Crystalline and amorphous thermoplastics can be differentiated based on heat resistance. For example ULTEM®, an amorphous resin, and SUPEC®, a crystalline resin, offer higher heat resistance than the amorphous resin, LEXAN® or the crystalline resin, VALOX®. Still, LEXAN, VALOX, and NORYL® offer higher heat resistance than the commodity plastics.

GE Plastics sells only engineering materials.

STK 129

Differentiate amorphous from crystalline polymers based on heat resistance.

Heat Resistance

Whether amorphous or crystalline, engineering thermoplastics withstand high heat. Amorphous engineering resins like polyetherimide, polycarbonate, and modified PPO, and crystalline engineering resins like polyphenylene sulfide and PBT all offer high heat resistance.

STK 130



Typical Engineering Thermoplastics

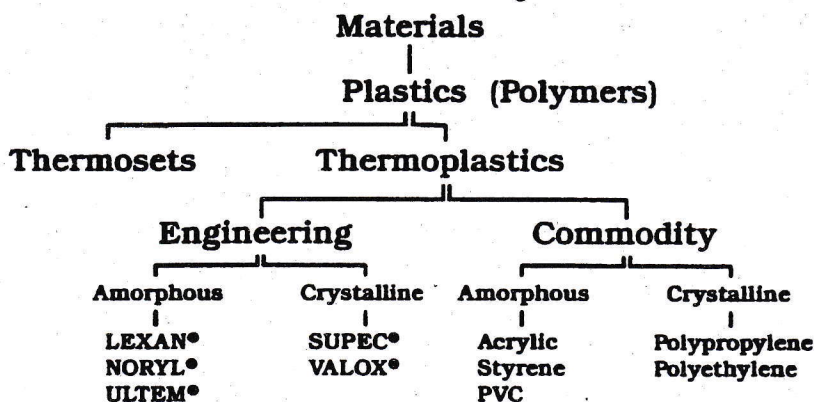
Polycarbonate (LEXAN®)
Modified PPO (NORYL®)
Polybutylene Terephthalate (VALOX®)
Polyethylene Terephthalate (VALOX®)
Polyphenylene Sulphide (SUPEC®)
Polyetherimide (ULTEM®)
ABS (CYCOLAC®)
Polyamide (NYLON®)
Acetal (DELTRIN®/CELCON®)
Polysulphone (UDEL®)
PES (VICTREX®)
PEEK (VICTREX®)

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Participant's Notes: _____



Families of Polymers



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Participant's Notes: _____

There are a variety of engineering thermoplastics.

Typical Engineering Thermoplastics

Here are some examples of engineering thermoplastics. Plastics can be referred to by either their generic or trade names. Polycarbonate is the generic or chemical name of a resin consisting primarily of the polycarbonate polymer. GE Plastics sells polycarbonate under the trade or brand name LEXAN®.

STK 131

Categories or family tree of thermoplastic brand names.

Families of Polymers

Within the various polymer families we've outlined, there are numerous individual polymers. And even these polymers can be broken down into grades. LEXAN®, for example, comes in over 300 grades. And there are several other manufacturers who sell their own brands of polycarbonate, each with its own particular grades.

As we've seen, there are many important differences between the many families of polymers. Still, the one thing that all plastics have in common is their ability to be molded.

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GE Plastics

"Plastikos" "Able to Be Molded"

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Participant's Notes: _____



GE Plastics

The Manufacturing Process

Oil Company - Isolates Molecular
Units from Petroleum

Plastic Company - Polymerizes the Unit
to Make Polymers

Converter - Processes the Polymer
into the Part

Manufacturer - Assembles Parts to
Make Product

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Participant's Notes: _____

Material, Design and Processing Relationships

**Plastic refers to anything
capable of being
molded.**

“Plastikos” – Able To Be Molded

In fact, the word “plastics” comes from the Greek work “plastikos” meaning “the ability to be molded.” Aside from all the chemical definitions and differentiations, a plastic resin is a material that is capable of being molded.

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The Manufacturing Process

The converter is an important part of the manufacturing process. An oil company such as Shell isolates molecular units from petroleum oil and sells them to a material supplier such as GE Plastics. The material supplier then polymerizes these units into a variety of polymers and sells them to the converter in the form of pellets.

**Everyone plays an
important role in making
a high quality plastic part.**

The converter is then responsible for turning these thermoplastic pellets into high performance parts. It is the responsibility of the material supplier to furnish the converter with high quality resin. But it is the responsibility of the converter to maintain the material's inherent properties throughout the molding process and supply the manufacturer with high quality, high performance parts that are ready for assembly.

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GE Plastics

STK 135

Processing

Thermosets

Melt
Flow
Solidify
(Heat & Cure)
Scrap

First Heat
↓
Apply Pressure
↓
In Mold
↓
Runners & Rework

Thermoplastics

Melt
Flow
Solidify
(Cool & Freeze)
Reuse

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Participant's Notes: _____



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Material Dictates Processing

Clay

Cold Molding
Cool Material
Poured in Cold
Mold
Heated in Oven



Thermosets

Compression Molding
Warm Material
Pressed in Hot
Mold Under Pressure
Cooled



Thermoplastics

Injection Molding
Heated Material
Injected in "Cold"
Mold
Cooled



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Participant's Notes: _____

Similar processes can produce thermoset or thermoplastic applications.

Processing

Thermoplastics and thermosets are processed in similar ways. Heat is applied to the material to make it soften and flow, pressure is applied to form it into a shape, then the material is allowed to cool so it hardens into a part. But thermosets cure when processed, while thermoplastics cool and freeze. Thermoset runners are not reusable, while thermoplastic runners are reusable.

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The process is selected based on the characteristics of the materials.

Material Dictates Processing

The material to be molded will dictate the processing. Clay, for example, is cold molded. It is mixed cold, poured into a cold mold, and then baked in an oven until it sets. Thermosets are generally compression molded. The raw material is first warmed, then pressed into a hot mold and subjected to heat and pressure until it forms and cures. Both the clay pot and the handle of the frying pan are considered thermosets.

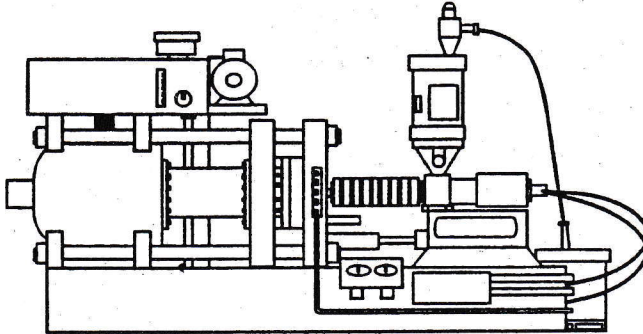
Thermoplastics are often injection molded. The material is heated so it flows, then injected into a "cold" mold until it cools and freezes. Referring to the mold as "cold" is a relative term, since the mold may be as hot as 250°F or more. But the plastic entering the mold may be as hot as 700°F or higher, making the mold cold by comparison. A general rule of thumb is to make sure the mold temperature is no higher than the material's drying temperature. A computer housing is an example of a thermoplastic part that may be injection molded.

STK 136



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A Typical Conversion Process



Understanding the characteristics of your material will ensure proper processing.

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Participant's Notes: _____



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Plastic Part Production

- Part Dictates Performance
- Performance Dictates Material
- Material Dictates Tooling
- Tooling and Materials Dictate Processing

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Participant's Notes: _____

Injection molding is a typical process.

A Typical Conversion Process

Injection molding is a typical conversion process, but each material has its own set of processing "rules." It is important to follow the suggested rules outlined on the processing data sheet for the specific material and resin grade you are processing. It's just like following a recipe. Only by following the recipe exactly can you be confident that the high performance properties in the resin pellet will be maintained throughout processing and be present in the finished part. Only by practicing proper processing can you consistently deliver high quality, high performance parts ready for assembly.

STK 137

The final part will determine the material and the process used.

Plastic Part Production

Proper processing rules are determined by these steps. The part dictates the performance required of the material. For example, a car bumper will have to have very good impact resistance. The performance dictates the material. A material is therefore selected that has good impact properties. Once the material is selected, it will dictate certain tooling requirements. Finally, the material and the tooling parameters will then dictate the rules for processing.

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STK 139

Material Dictates Processing

Engineering thermoplastics
provide high temperature
resistance and therefore,
require more heat to process.

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Participant's Notes: _____



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STK 140

Material Dictates Processing

Amorphous resins have a broad softening
range and may require heating well beyond
the softening temperature in order to flow
sufficiently. (wide processing range)

Crystalline resins have a sharp melting
point and flow readily above that
temperature. (narrow processing range)

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Participant's Notes: _____

High heat resistant materials require high heat processing.

Material Dictates Processing

The cycle is then completed by the converter. Once the material dictates the rules for processing, it is the converter who must follow these rules exactly to produce a high quality part. As a general rule, because engineering thermoplastics provide high temperature resistance, they also tend to have high processing temperatures.

STK 139

Material Dictates Processing Amorphous/Crystalline

More specifically, amorphous resins and crystalline resins have different processing requirements. An amorphous resin has a broad softening range while a crystalline resin has a sharp melting point. For example, an amorphous resin softens the way butter softens: gradually over a range of increasing temperature. While a crystalline resin melts the way ice melts: immediately upon reaching its melting temperature. Because amorphous resins have a broad softening range, they may require heating well beyond the softening temperature in order to flow sufficiently. And because crystalline resins have a sharp melting point, they tend to flow readily just above that temperature.

STK 140



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Material Dictates Processing

Each engineering resin family responds differently to processing and has a unique set of processing "rules."

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Participant's Notes: _____



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But Sometimes Processing Dictates Material

By branching a polymer we increase melt strength of the material making it able to support its own weight and therefore, suitable for processes such as Blow Molding and Extrusion.

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Participant's Notes: _____

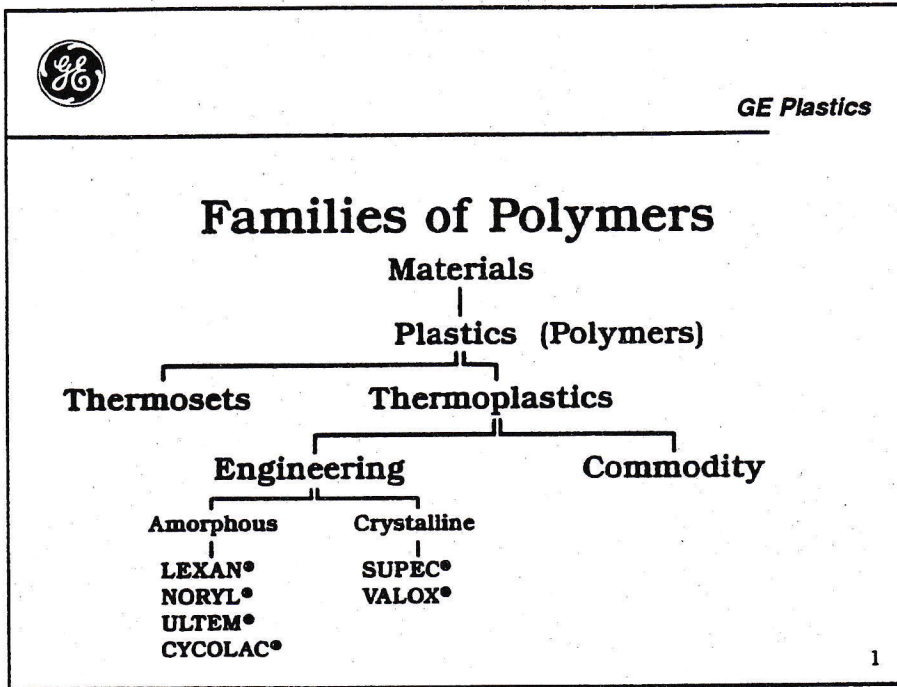
Understand the processing rules to properly process each plastic resin.

Material Dictates Processing Resin Families

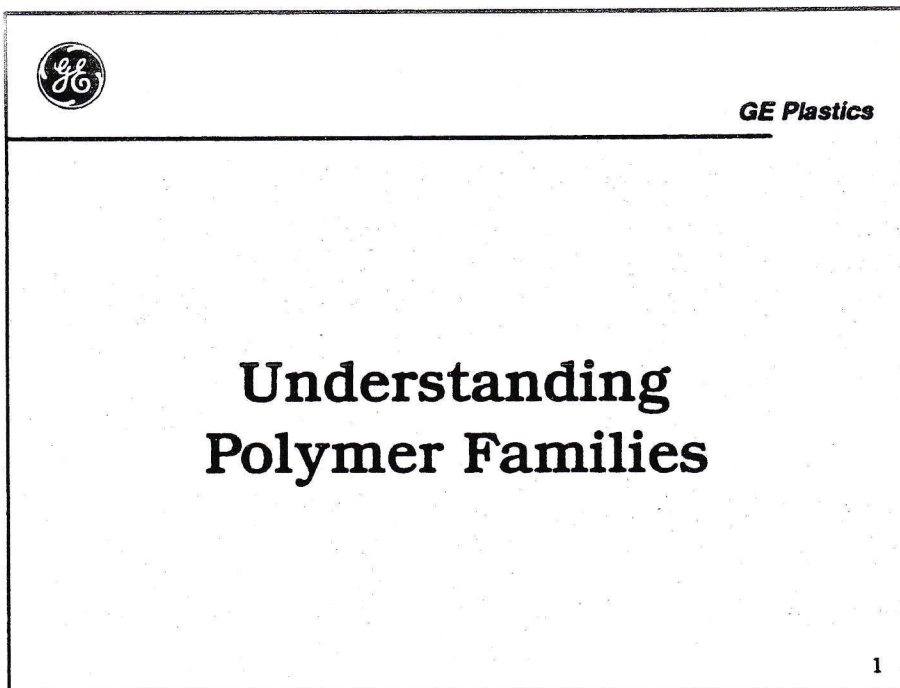
But most importantly, each engineering resin has its own set of processing "rules" that are outlined on its individual processing data sheet. These processing "rules" must be followed exactly to properly produce high quality, high performance parts. **STK 141**

Processing Dictates Material

Not only does the material dictate the processing, but the processing can sometimes dictate the material. For example, branching a polymer will increase its melt strength and make it able to support its own weight if suspended during processing. It is critical that a material have this kind of melt strength for use in either blow molding or extrusion. Therefore, branched polymers are more suitable in these processes. **STK 142**



Participant's Notes: _____



Participant's Notes: _____

Summary and Performance Feedback

Categories or family tree of polymers.

Families of Polymers

Now let's review the entire polymer "Family Tree." We started with the huge category of materials but were able to differentiate polymers from all other materials, thermoplastics from thermosets, engineering thermoplastics from commodity thermoplastics, and amorphous resins from crystalline resins. We also learned the importance of these material distinctions in terms of processing, and the importance of the processing data sheet for processing each individual resin grade.

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Low Density or High Density...

Which is the result of
Polymer Branching and why?

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Participant's Notes: _____



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Shape of Polymer Chains Affects Alignment

High Density
Linear Polymer



Many "linear"
molecules fit in
a given volume.

Low Density
Branched Polymer



Fewer "branched"
molecules fit in
the same volume.

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Participant's Notes: _____



GE Plastics

STK 147

Thermoplastics or Thermosets...

Which cannot be
reprocessed and why?

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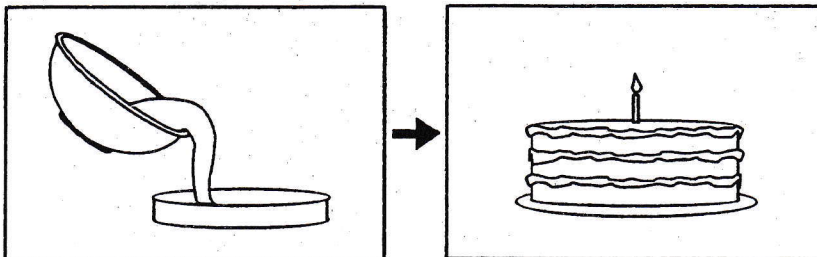
Participant's Notes: _____

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Thermosets Cannot Be Reprocessed



Thermosets go through a chemical state change
when heated and cooled - a nonreversible process.

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Participant's Notes: _____



Module 2

Polymer Structure

- Amorphous vs. Crystalline Resins
- Glass Transition Temperature
- Melting Temperature
- Crystallization Temperature
- Shrinkage

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Participant's Notes: _____



Module 1

Performance Feedback

1. Identify the basic characteristics of polymers.
2. Describe the major differences between commodity and engineering.
3. Describe the major differences between thermosets and thermoplastics.
4. Describe the major differences between amorphous and crystalline polymers.
5. Classify the materials you are working with according to their polymer family.
6. Describe the relationship between material, design and process in plastic part production.