

# **POLYMERIC FILMS**

**For Graphic and Industrial  
Applications**

Aug. 3, 2004

Polymer films 101

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# POLYMER FILMS 101

- **The following presentation is an introduction to Tekra's most important film products. It will help one understand how these films compare to one another and to other common films. It also demonstrates how an understanding of some basic properties can be used to help make recommendations for applications where a specific film has not been identified.**

# TYPICAL POLYMER FILMS

- **PET - Polyester**
- **PEN - Polyethylenenaphthalate**
- **PC - Polycarbonate**
- **Polycarbonate blends and composites**
- **PS/HIPS - Polystyrene**
- **RPVC - Rigid Vinyl**
- **Flexible Vinyl**
- **PETG/APET - Copolyester**
- **Polyolefins**
  - **PP - Polypropylene**
  - **PE - Polyethylene**
    - **Spun Bonded**
    - **Cross Laminated**

# PET Polyester

- **Biaxially oriented (stretched) film from extruded polyethyleneterephthalate resin.**
- **Characterized by high tensile strength and flexural modulus (stiffness), excellent chemical resistance, high heat capability.**
- **Drawbacks:**
  - **Clear only up to 10 mils**
  - **Needs print treatment for ink adhesion.**
  - **Difficult to die cut / emboss.**
  - **May need to be stabilized for thermal processing.**

# Applications for PET

- **Nameplates, tags and labels**
- **Membrane switch overlays, circuits and spacers**
- **Graphic Protection (overlaminating films)**
- **Electrical/Motor insulation**
- **Packaging**
- **Medical diagnostics**
- **Flexible circuits**
- **Cards: ID, smart phone, etc.**
- **Casting films for:**
  - **Filter media**
  - **Green film ceramics**
  - **Thermoset lay-up**

# PEN Polyethylenenaphthalate

- Biaxially oriented film from extruded polyethylenenaphthalate resin.
- Characterized by high tensile strength and flexural modulus, excellent chemical resistance, **very high heat capability**.
- Performance level between PET and polyimide
- Drawbacks:
  - Clear only to 10 mils or under
  - Needs print treatment for ink adhesion.
  - Difficult to die cut / emboss.
  - May need to be stabilized for thermal processing.
  - High priced.

# Applications for PEN

- Flexible circuits
- Membrane switch circuits
- High temperature nameplates, tags and labels
- Under-the-hood auto graphics
- Packaging
- Medical diagnostics
- Flat cables
- Electrical/Motor insulation
- Capacitors

# Polycarbonate (PC)

- A wide variety of films extruded from polycarbonate resin.
- Characterized by **excellent clarity in all gauges**, good impact and temperature resistance, **easy to process** and **thermoformable**.
- Drawbacks:
  - Soft – scratches easily
  - Relatively poor chemical resistance

# Applications for PC

- **Nameplates**
- **Membrane switch overlays (not formed)**
- **Durable POP displays**
- **Automotive instrument clusters**
- **Thermoformed signage**
- **Carrier for in-mold decoration**
- **Thermoformed bodies for RC cars and trucks**
- **Sterilizable, formed medical packaging**
- **Lenses for safety goggles**

# PC Blends and Composites

- **Alloys of PC and other materials to:**
  - Minimize PC's chemical resistance shortfall
  - Enhance flame resistance
  - Alter optical properties
- **Surface treatments to:**
  - Improve scratch/abrasion resistance
  - Improve chemical resistance
  - Forestall the effects of outdoor exposure

# Uses for PC Composite Films

- Embossed membrane switch overlays
- Overlays for use in chemically aggressive environments
- Outdoor graphics
- Light diffusers for back lit graphics
- UV protection for decorative panels
- Graphics requiring flame resistance

# COPOLYESTER FILMS

- Film extruded from PET polyester that has been modified to retard crystallization resulting in a clear film without the need for orientation (biaxial stretching).
- Available in gloss, velvet and lenticular
- Characterized by:
  - **Clarity** in all gauges
  - Higher temperature resistance than rigid vinyl
  - **Hardness – stiffer and more abrasion resistant than rigid vinyl**
  - **Thermoformable**
  - inexpensive
- Drawbacks:
  - Tendency to roll set in thicker gauges

# USES FOR COPOLYESTER FILM

- **Thermoformed packaging**
- **Point of purchase displays**
- **Sport helmet shells**
- **Signage**
- **Toys**
- **Eye protection**

# Polystyrene – PS, HIPS

- Extruded film from polystyrene resin mixed with additives to reduce brittleness.
- PS film processes easily, **thermoforms** and is **inexpensive**
- Drawbacks:
  - Not available clear (except when oriented – OPS)
  - Can be brittle
  - Tears easily
  - Poor heat and chemical resistance

# Uses for Polystyrene Film

- Point-of-Purchase displays
- Hang tags
- Thermoformed signage
- Menu strips
- Graphics for toys and games
- Thermoformed packaging

# RIGID VINYL - RPVC

- Calendered from polyvinyl chloride resin
- Available smooth, velvet, matte and polished. Clear and variety of colors
- **Inherently flame retarded**
- Easily die cut and thermoformed
- **Inexpensive**
- **Drawbacks:**
  - Shrinkage
  - May require treatment for ink adhesion
  - Corrosive combustion products

# USES FOR RPVC

- **Packaging:**
  - **Food**
  - **Thermoformed**
- **Point-of-Purchase displays**
- **Outdoor signage**
- **Tags and labels**
- **Nameplates, faceplates and overlays**
- **Electrical insulation**

# FLEXIBLE VINYL

- Extruded or cast from polyvinyl chloride resin that contains various levels of plasticizer to make it more pliable.
- **Weatherable**
- **Conformable**
- **Drawbacks**
  - Shrinkage
  - Low temperature resistance
  - Plasticizer migration

# USES FOR FLEXIBLE VINYL

- **Label stock**
- **Tape**
- **Fleet Marking**
- **Decals**
- **Static Cling point-of purchase displays**
- **Banners**
- **Packaging**
  - **Food wrap**
  - **Shrink wrap**

# POLYOLEFINS

- A family of **inexpensive** resins that include polyethylene (PE) and polypropylene (PP). A wide variety of films are made from these resins. They are typically **soft, flexible** and slippery. Heat resistance is moderate and **chemical resistance is excellent**. In nearly all cases the films surface must be treated for ink and coating adhesion. PE is usually made as a blown film and PP can be blown or extruded and is commonly oriented. Spun bonded, mineral filled and cross-laminated varieties add tear resistance and stiffness.

# USES FOR PE AND PP FILM

- **Bags and Packaging**
- **Vapor barrier**
- **Tags and Labels**
- **Banners**
- **Synthetic Paper**
- **Folders and Binders**
- **FR versions (PP) for E/E insulation**

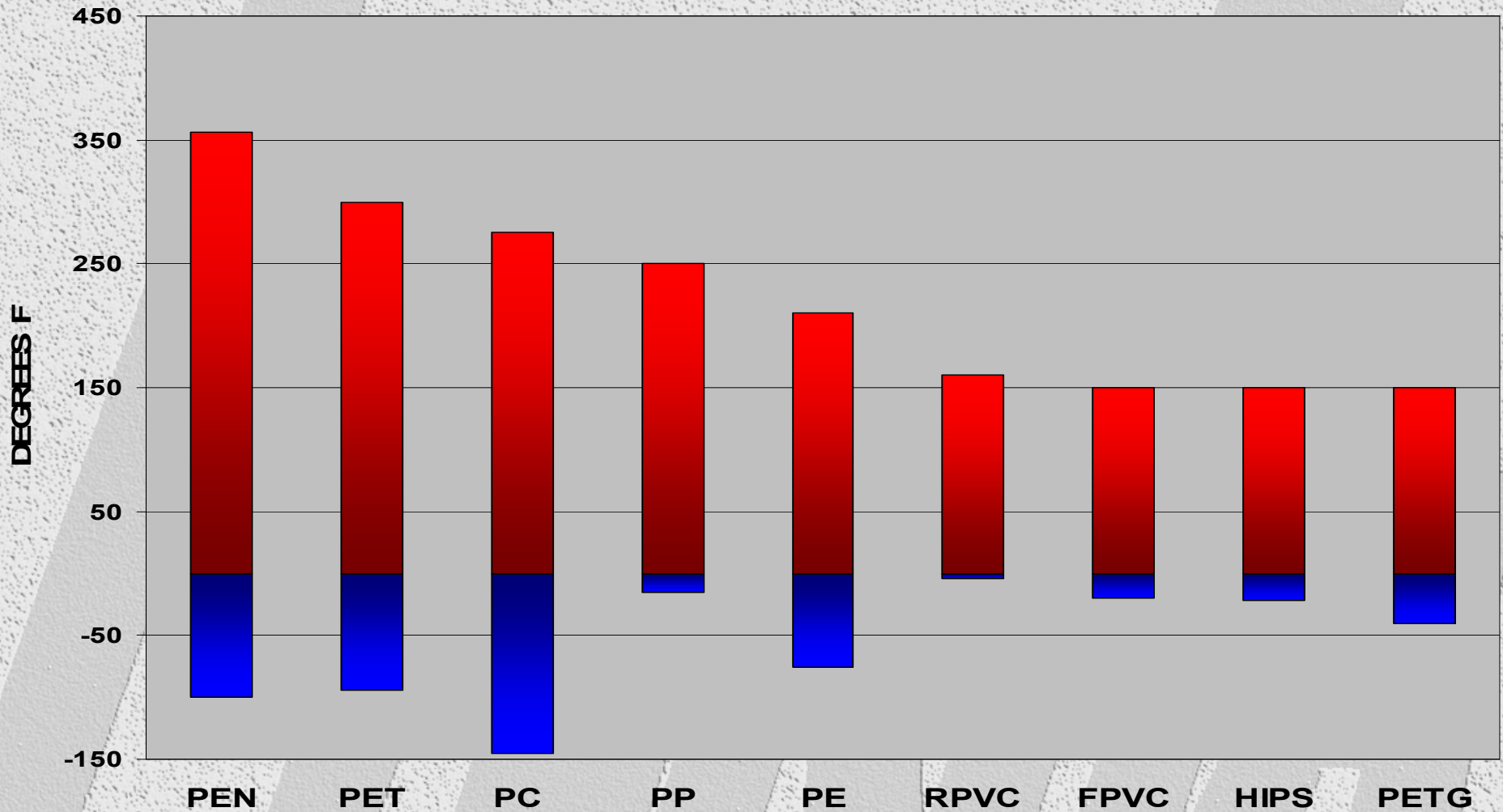
# FILM PROPERTIES

- The following charts can be used to compare typical properties of the previously mentioned films.
- These property values describe films that are made from resins that have not been specially modified. They do not include films that have been coated or treated in any way that would alter the base resin properties.

**BECAUSE OF THE WIDE VARIABILITY OF RESINS USED IN SOME FILMS, THE VALUES CITED HEREIN CAN VARY SIGNIFICANTLY. IMPORTANT PROPERTY REQUIREMENTS SHOULD BE DISCUSSED WITH THE FILM MANUFACTURER.**

# THERMAL PROPERTIES

## UTILIZATION TEMPERATURE



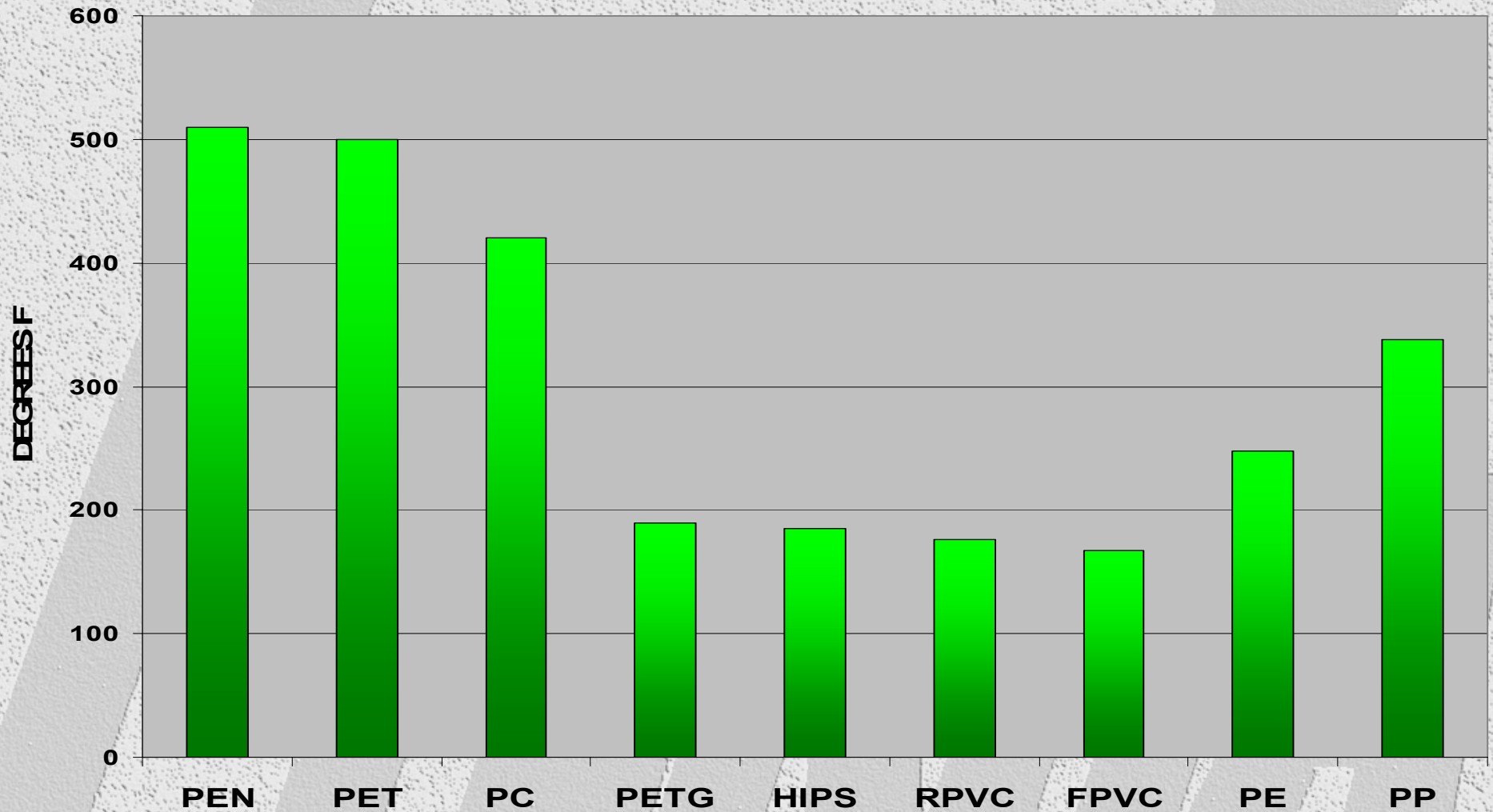
# UTILIZATION TEMPERATURE

- The temperature range within which the film can be typically processed and used without causing any serious problems.
- At the low end, this is the temperature at which the film becomes brittle enough to crack when bent or flexed.
- At the high end, this is the limit of the films resistance to deformation due to thermal processing and occasional elevated temperature excursions . **This is not the same as “Continuous Use Temperature”**

Return to [Utilization Temperature](#) graph

# THERMAL PROPERTIES

## MELT TEMPERATURE



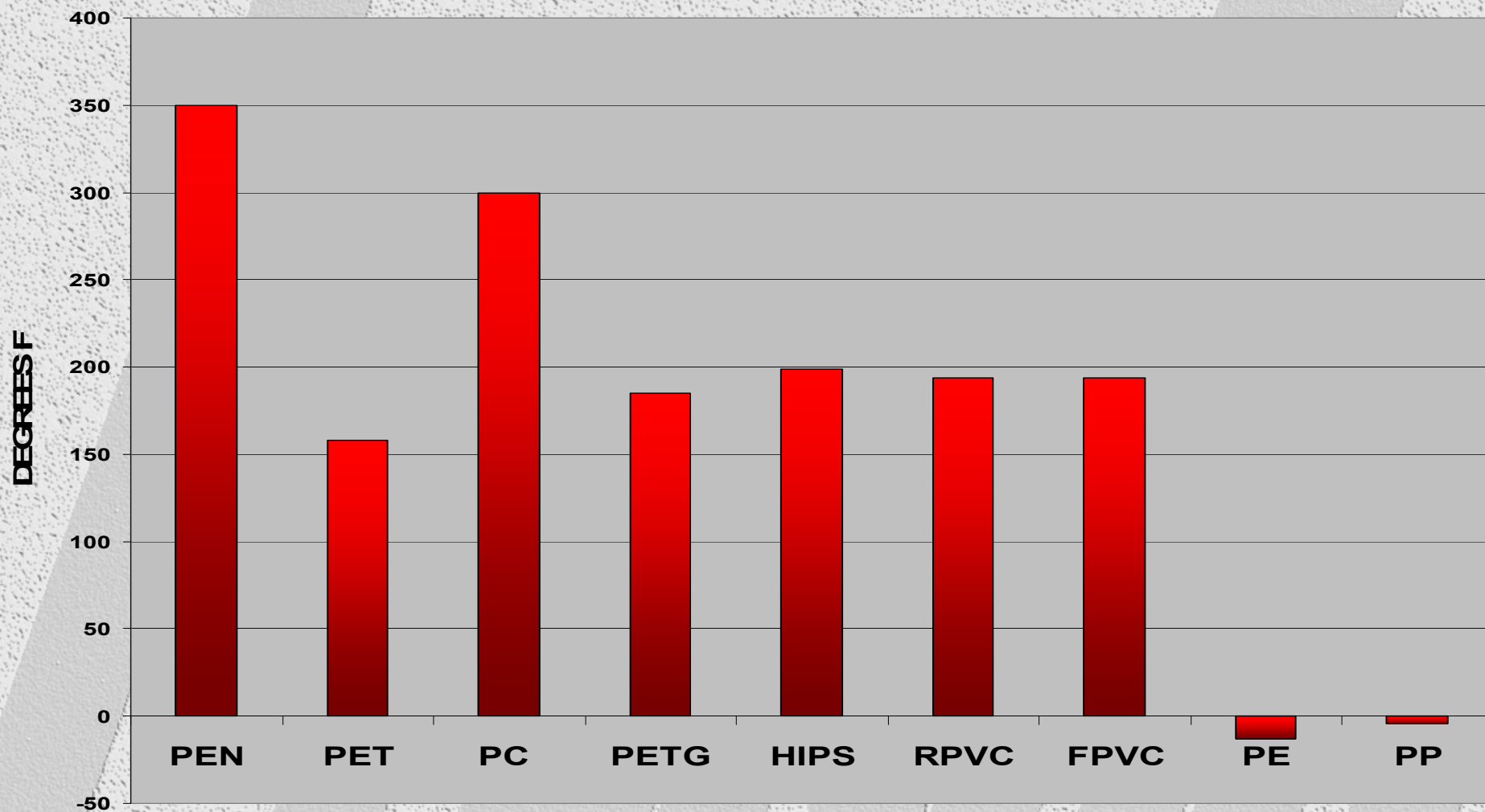
# MELT TEMPERATURE

- The temperature at which a plastic material begins to melt to a consistency resembling a viscous liquid.

Return to [Melt Temperature](#) graph

# THERMAL PROPERTIES

## GLASS TRANSITION TEMPERATURE



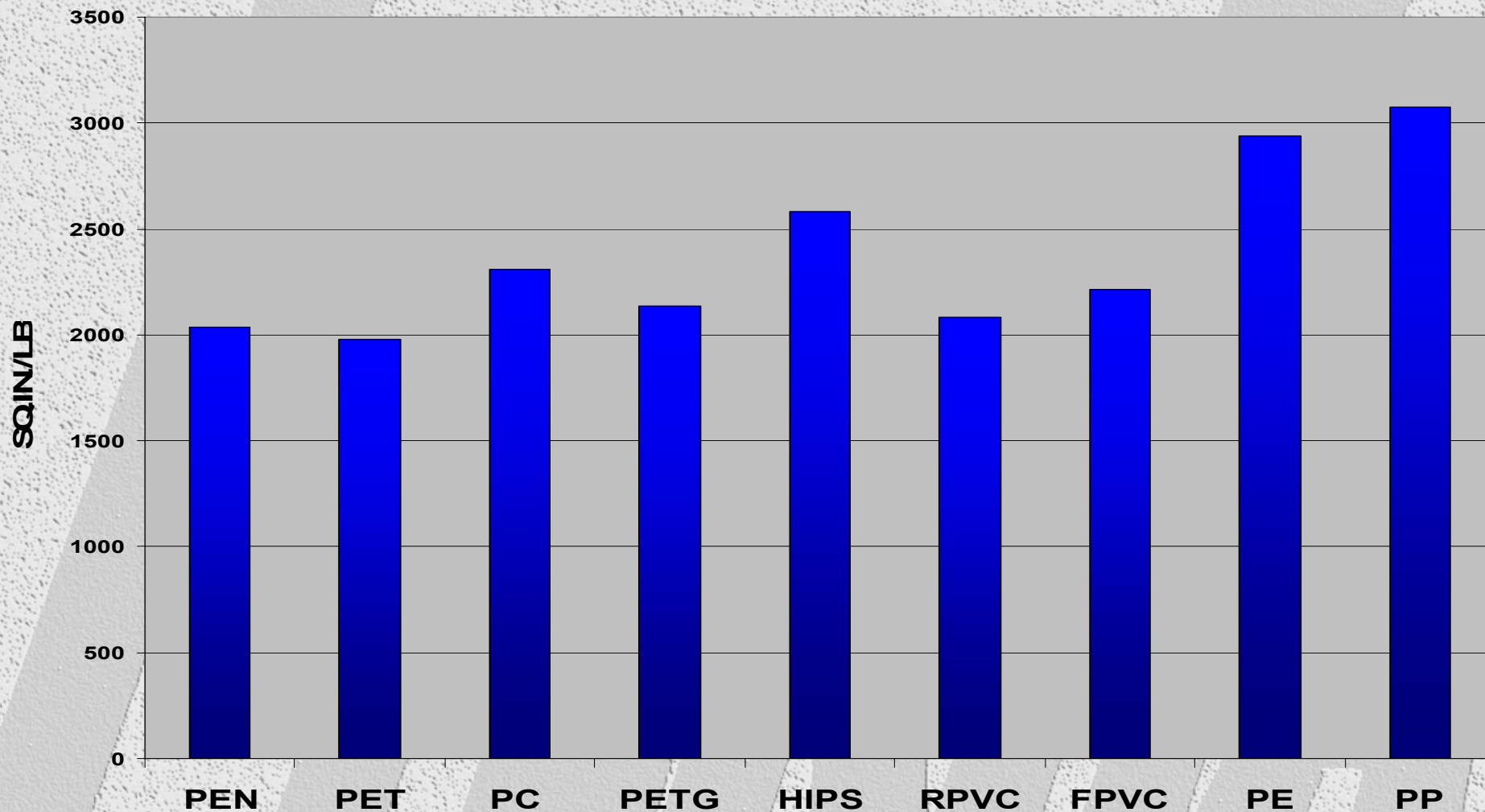
# GLASS TRANSITION TEMPERATURE

- The temperature at which a polymers molecular state alternates between a hard, glass like structure and one that is softer and rubbery

Return to [Glass Transition Temperature](#) graph

# PHYSICAL PROPERTIES

## YIELD FOR 10 MIL FILM



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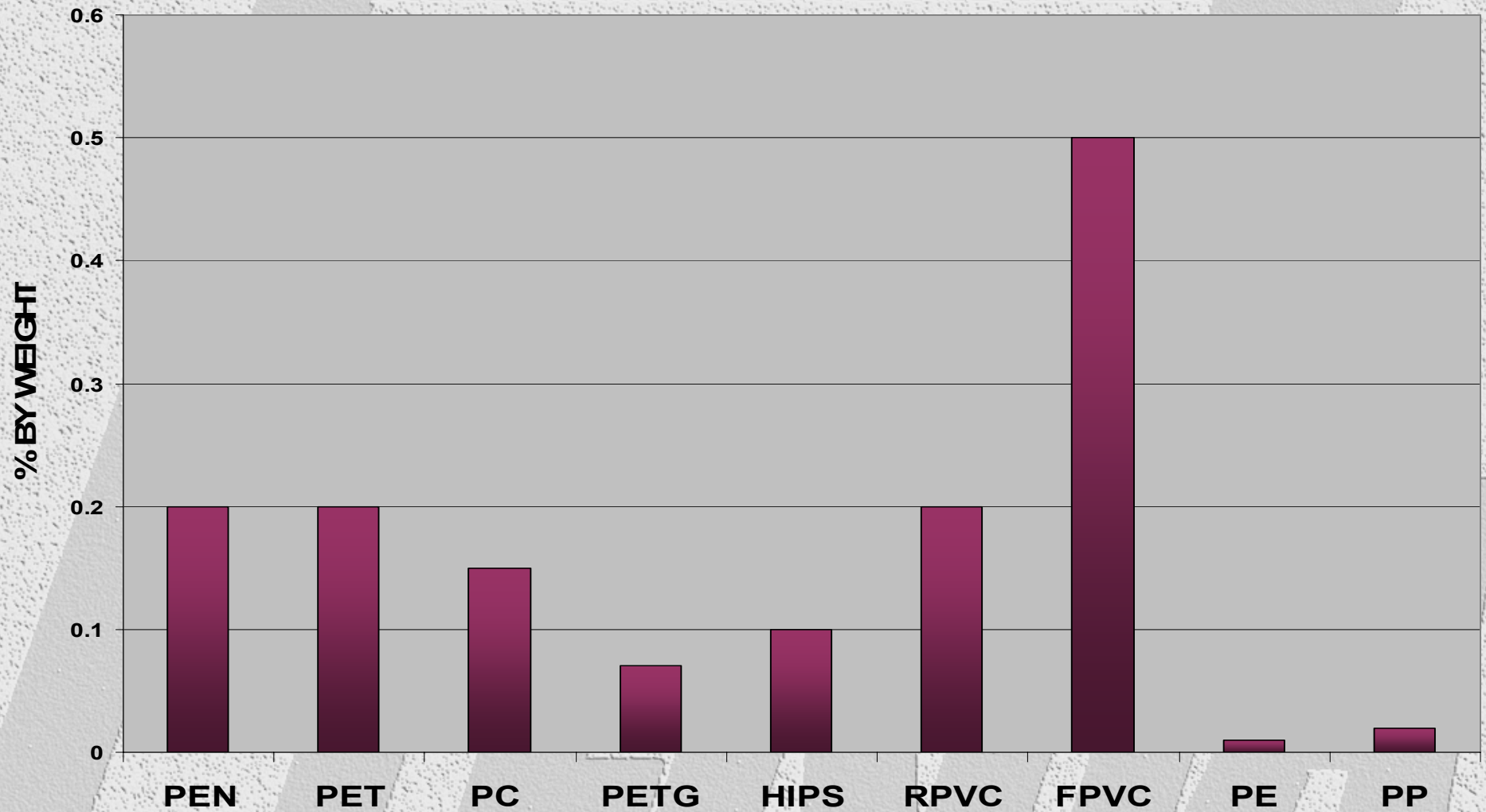
# YIELD / AREA FACTOR

- A method of determining the coverage for a certain quantity of film at a given thickness. Some typical units used are:
  - sq.in./lb or sq.ft./lb or sq.yd./lb
  - MSI/lb (MSI=1000 sq.in.)
  - sq.in./lb/mil
  - cm<sup>2</sup>/kg or m<sup>2</sup>/kg or cm<sup>2</sup>/kg/mm or m<sup>2</sup>/kg/mm

Return to [Yield for 10 Mil Film](#) graph

# PHYSICAL PROPERTIES

## 24 HOUR WATER ABSORPTION



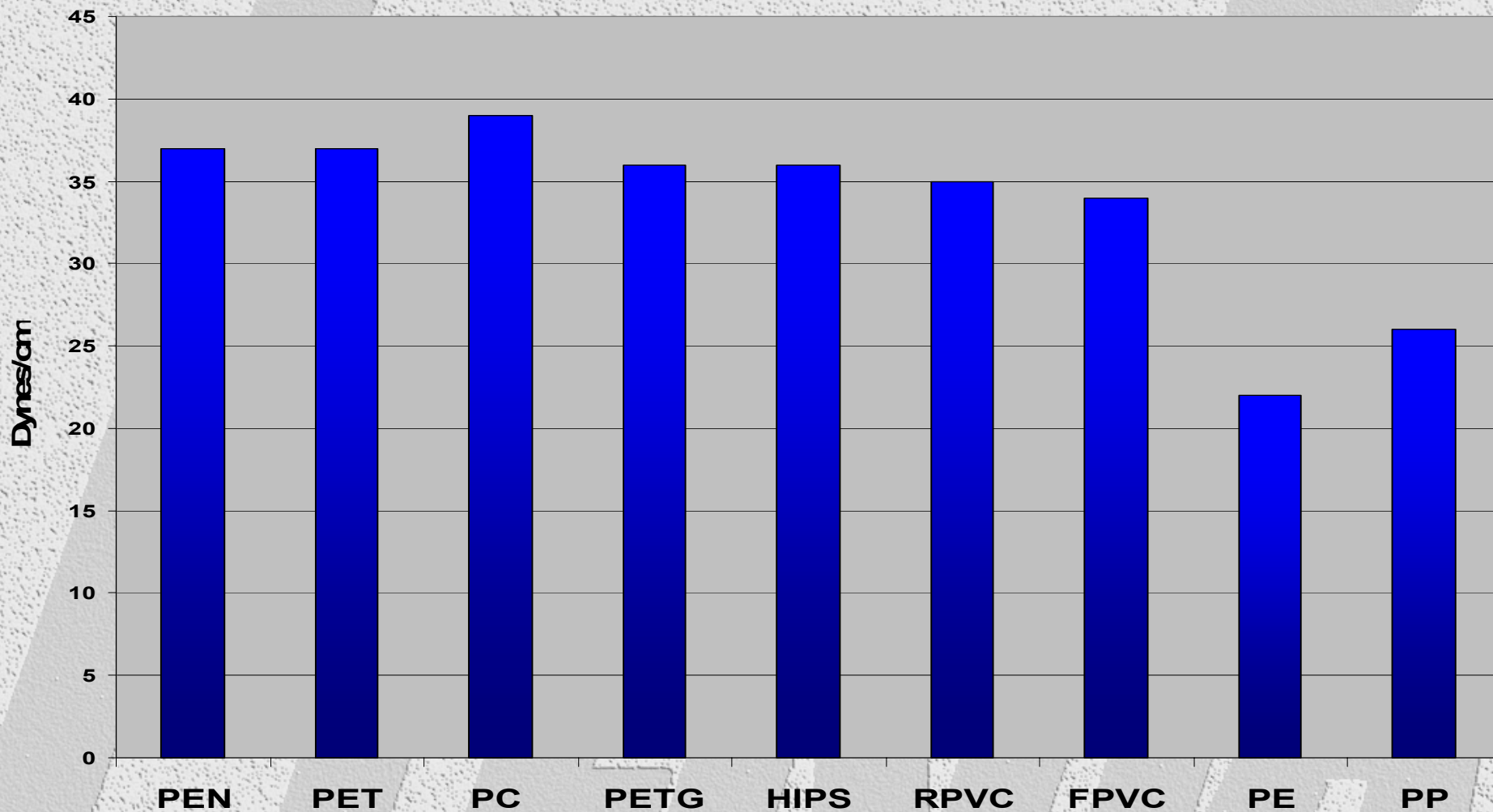
# WATER ABSORPTION

- This the amount of water - based on % weight gain – that a polymer will absorb when submerged for a given period of time usually at room temperature

Return to [24 Hour Water Absorption](#) graph

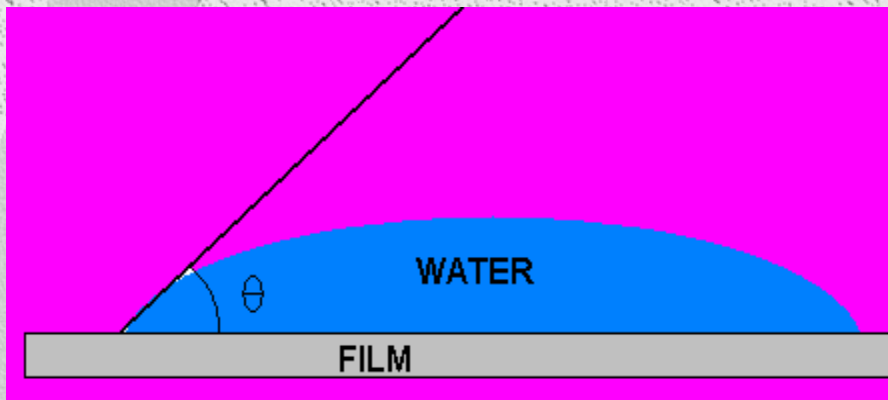
# PHYSICAL PROPERTIES

## SURFACE ENERGY

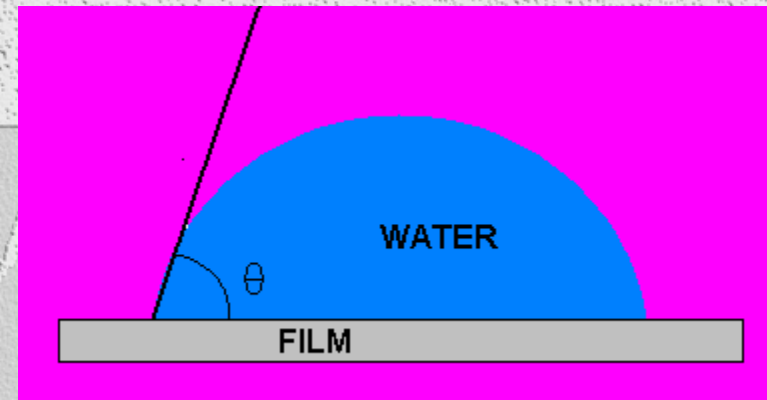


# SURFACE ENERGY

- A measurement of how readily a solid surface will attract a liquid. Higher surface energy equates to better wetting of inks and coatings.
- Based on the contact angle ( $\theta$ ) of a drop of liquid – typically water – on the surface.
- Lower contact angle=higher surface energy



HIGH SURFACE ENERGY

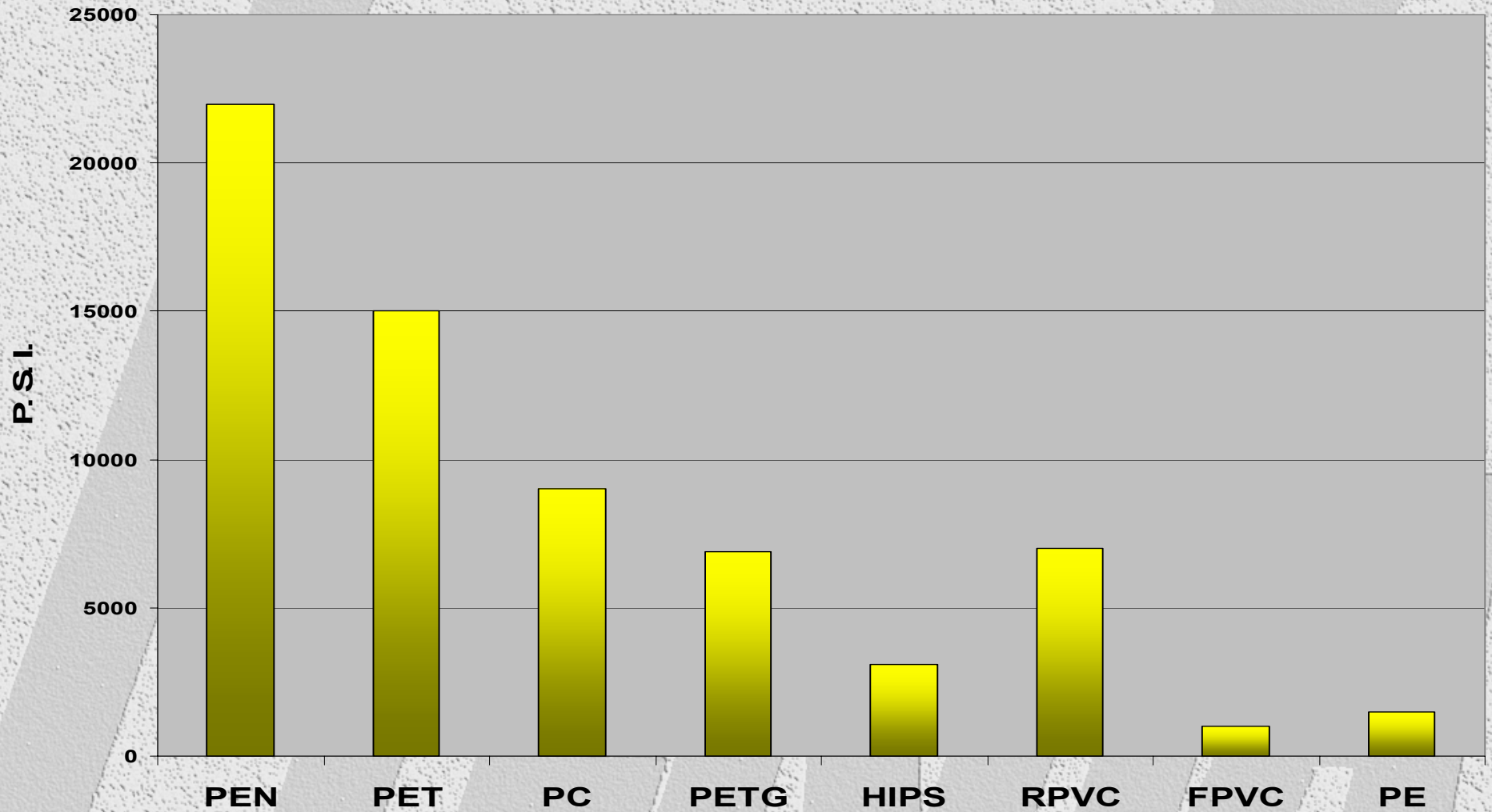


LOW SURFACE ENERGY

Return to [Surface Energy](#) graph

# MECHANICAL PROPERTIES

## TENSILE YIELD STRENGTH



# TENSILE STRENGTH

- **YIELD** – The amount of force it takes to stretch a section of film to permanent deformation.



Return to [Tensile Yield Strength](#) graph

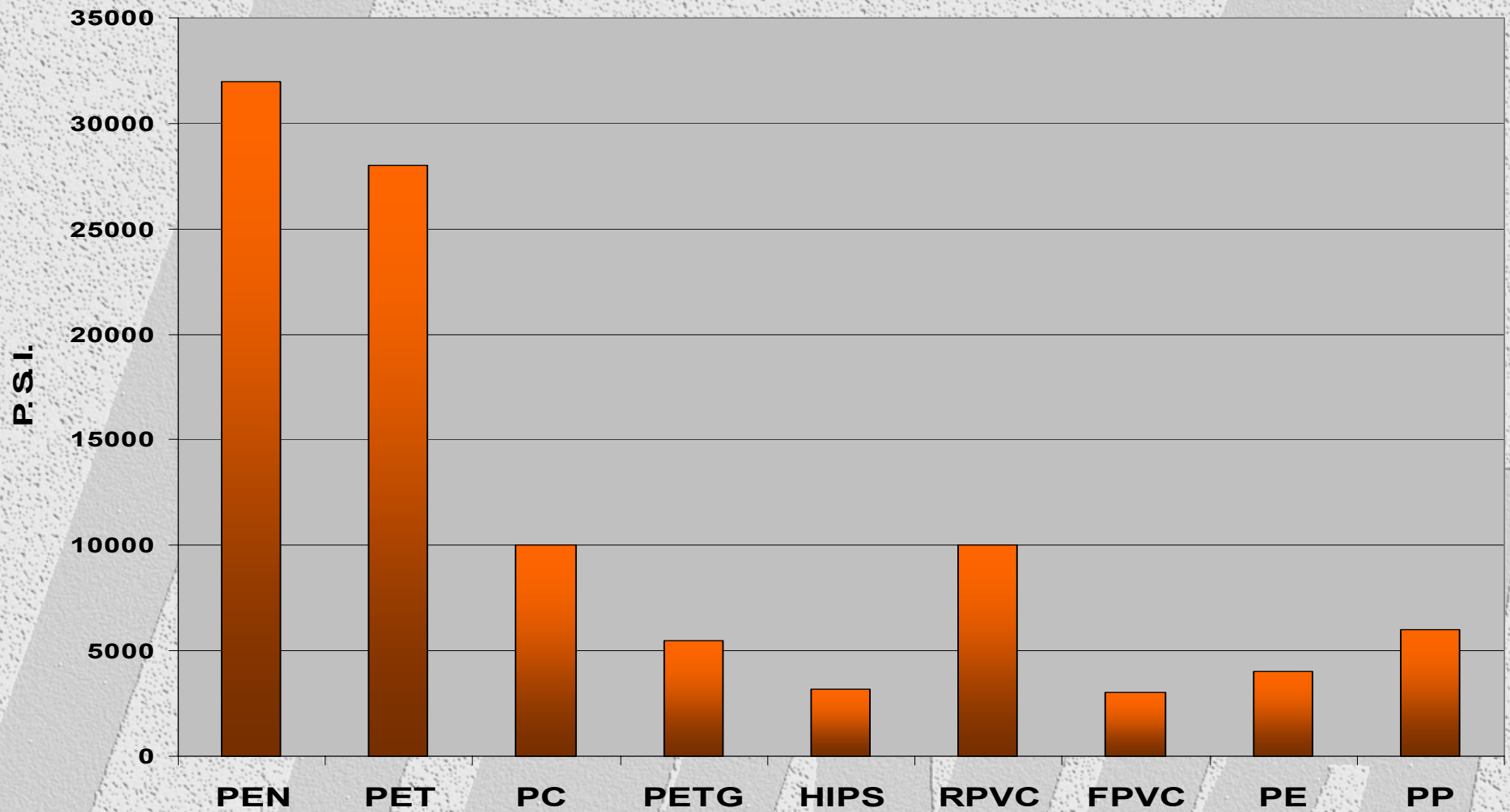
- **AT BREAK** – The amount of force it takes to stretch a section of film until it breaks.



Return to [Tensile Strength at Break](#) graph

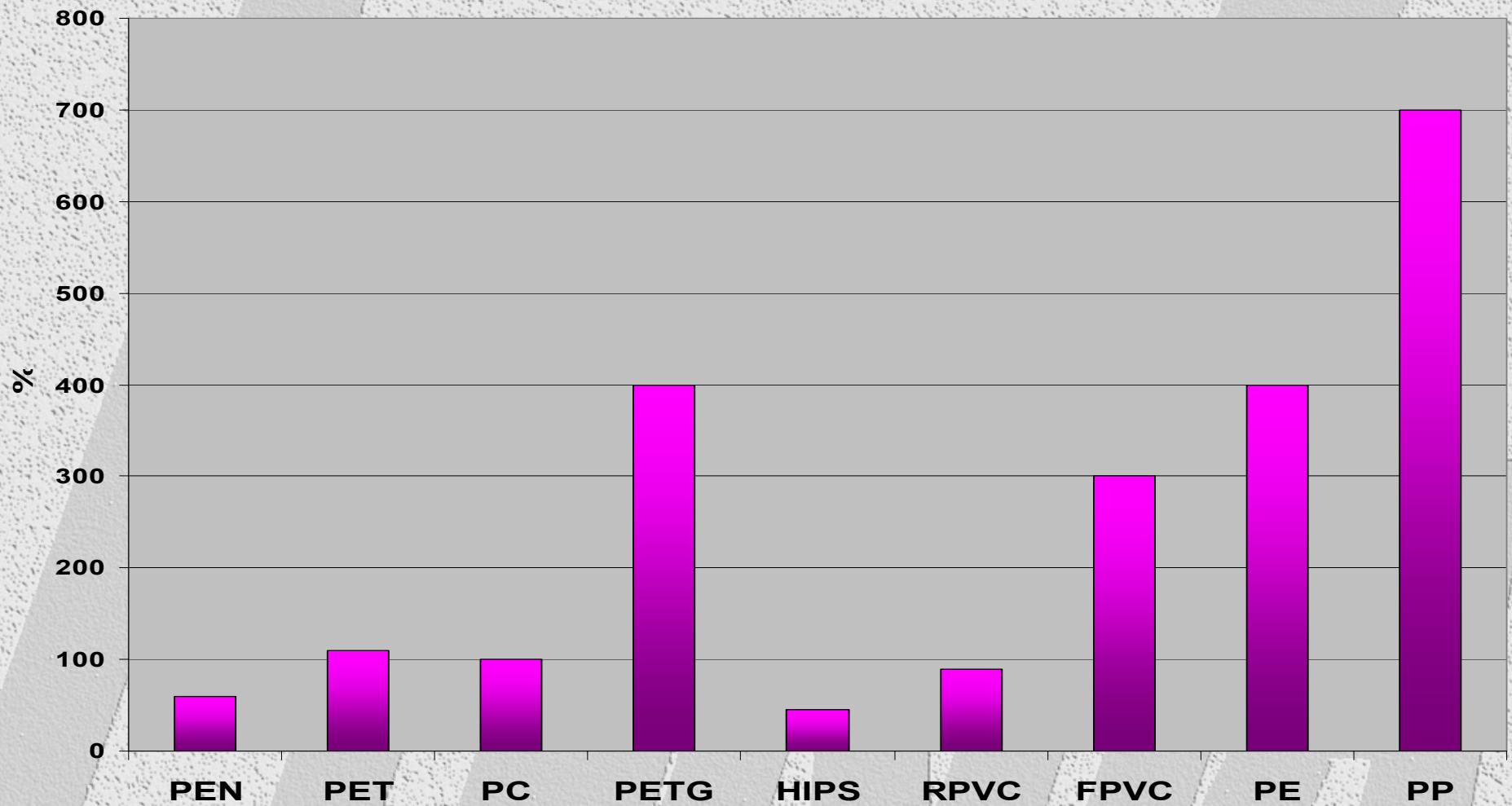
# MECHANICAL PROPERTIES

## TENSILE STRENGTH AT BREAK



# MECHANICAL PROPERTIES

## ELONGATION AT BREAK



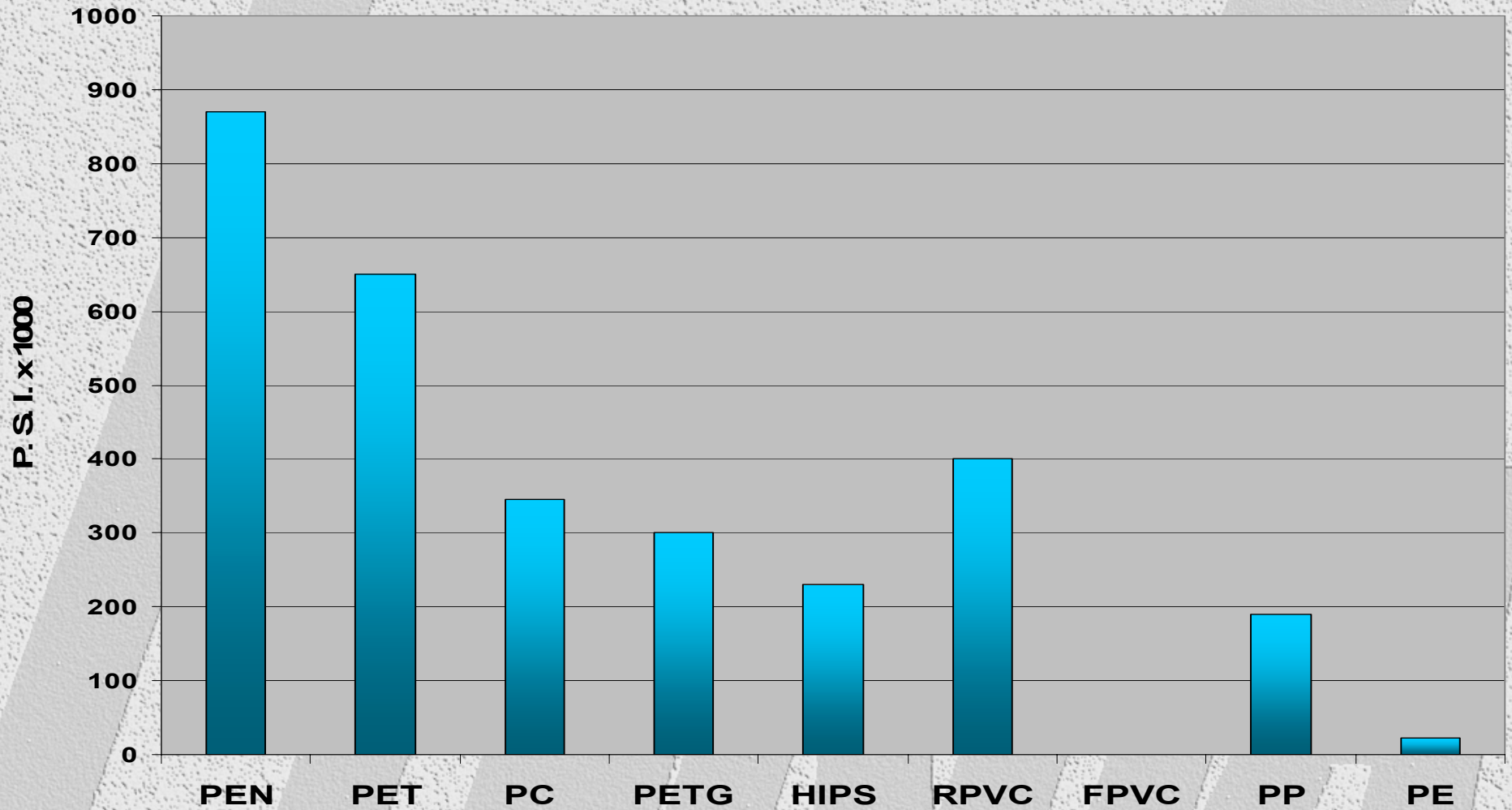
# ELONGATION

- The amount a plastic will stretch during tensile testing at break.
- Measured as a percent beyond the original length at the start of the test.
  - Length at start = 4"
  - Length at break = 7" (3" beyond start)
  - Elongation =  $\frac{3}{4} \times 100 = 75\%$

Return to [Elongation at Break](#) graph

# MECHANICAL PROPERTIES

## TENSILE (YOUNG'S) MODULUS



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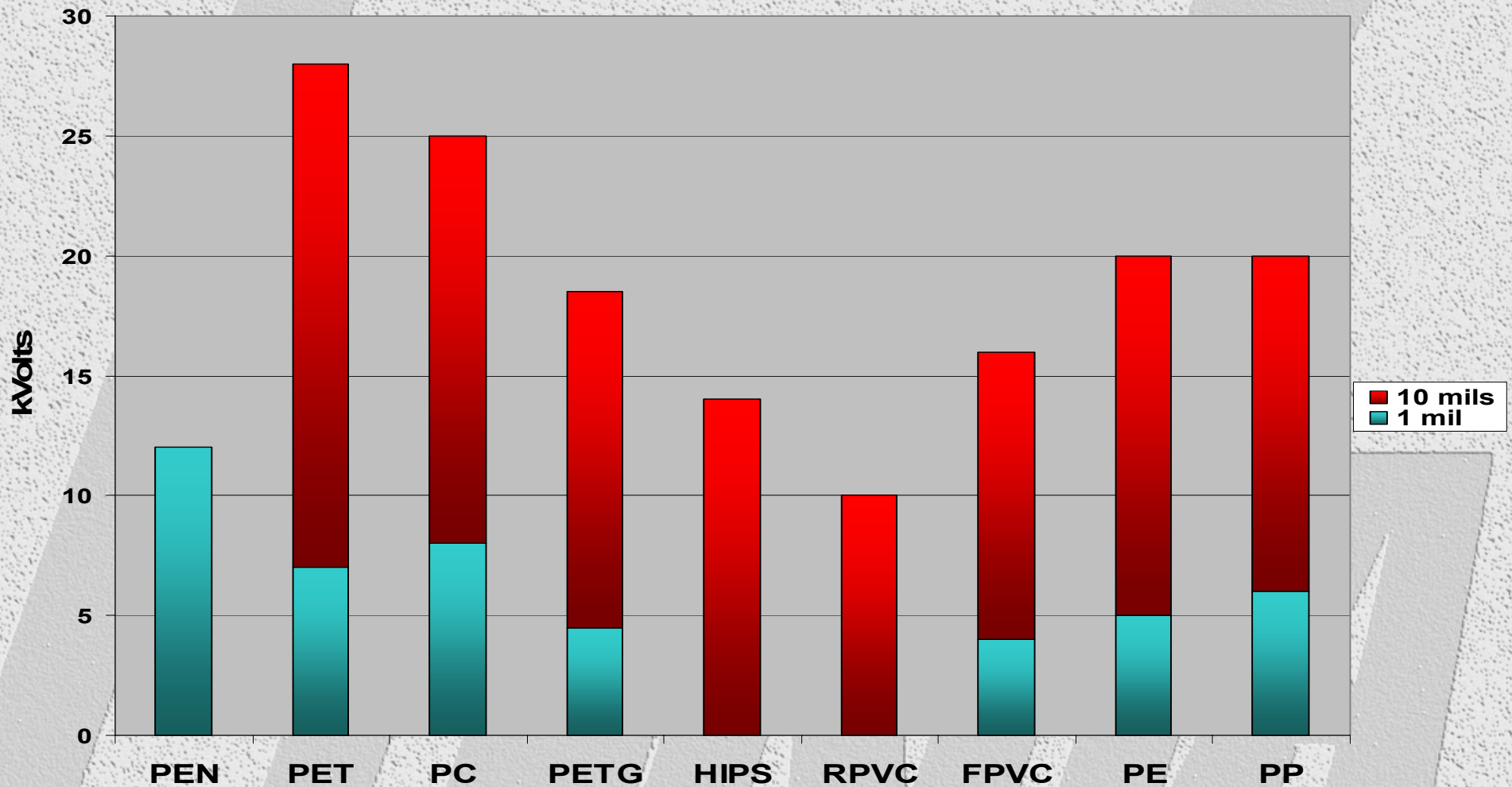
# TENSILE (YOUNG'S) MODULUS

- The ratio of stress (tensile strength) to strain (stretch) that occurs before the elastic limit or below tensile yield.
- For film it is usually a measure of rigidity or stiffness. A stiffer, less elastic material typically has a high modulus.

Return to [Tensile \(Young's\) Modulus](#) graph

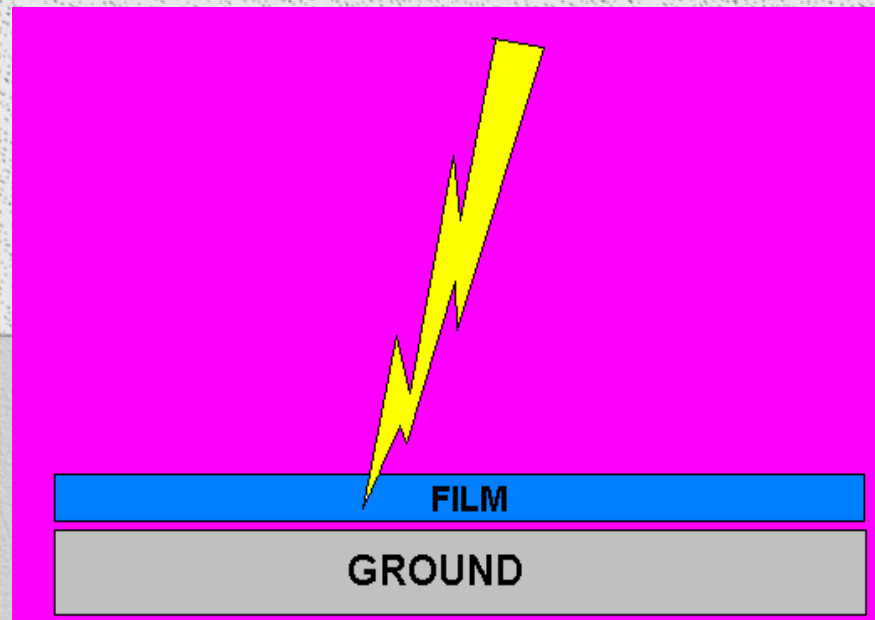
# ELECTRICAL PROPERTIES

## DIELECTRIC STRENGTH



# DIELECTRIC STRENGTH

- The polymers resistance to electrical penetration by a high voltage discharge.



Return to [Dielectric Strength](#) graph

# APPLICATION EXAMPLES

**The following pages are scenarios on how the previous, very basic information can be used to help make an informed decision on what film may be the best choice for a certain application.**

**These are actual cases where a successful product recommendation was made during a phone or e-mail conversation with a customer.**

# APPLICATION EXAMPLE #1

## MEDICAL PACKAGE

- A medical packaging manufacturer who currently uses only PET film called looking for a recommendation for a film that can be used to make a thermoformed package.
- In addition to thermoformability the film needs to be clear (like PET) and must withstand steam sterilization (several minutes at 250°F) without melting or deforming.

# APPLICATION EXAMPLE #1

## MEDICAL PACKAGE

- Based on the information in the text portion of this presentation there are several films that can be thermoformed – PC, Copolyester, PVC, HIPS.
- The only films in this presentation that are not clear are PS and HIPS.
- The “Utilization Temperature” chart shows that the films capable of withstanding the sterilization conditions are PET, PEN, PC ad PP.
- **THE FILM RECOMMENDED FOR THIS APPLICATION WAS CLEAR POLYCARBONATE.**

# APPLICATION EXAMPLE #2

## MILITARY APPLICATION

- A manufacturer of weaponry for military applications has a new application for a film that will act as a defroster on a 1" diameter lens for an IR (infrared) imaging device.
- He had tried PET and PC and found that the heat used to activate the adhesive used to mount the film would cause the film to distort.
- The maximum gauge that can be used is 2 mil (0.002" or approximately 50 $\mu$ ).
- The wavelength of the IR used was not available for security reasons.

# APPLICATION EXAMPLE #2

## MILITARY APPLICATION

- A film will distort when exposed to a temperature greater than its utilization temperature or when it is stressed while above its glass transition temperature.
- Only PEN has a “Utilization Temperature” greater than PET.
- All films listed in this presentation except PP and PE have a glass transition temperature greater than PET. But only one is greater than PC – PEN.
- **PEN WAS RECOMMENDED BECAUSE IT HAS A HIGHER UTILIZATION TEMPERATURE THAN PET AND A HIGHER GLASS TRANSITION THAN PC. (Customer will need to test for IR transmission)**

# APPLICATION EXAMPLE

## DISCLAIMER

- It is nearly impossible to get all the information about an application that could effect the choice of a film in one or two phone calls or e-mails.
- Tekra recommends that the customer:
  - **THOROUGHLY TESTS THE FILM FOR COMPATIBILITY WITH HIS PROCESS and**
  - **MAKES SURE THAT THE PROCESSED FILM MEETS ALL THE REQUIREMENTS OF THE APPLICATION and**
  - **TESTS FOR SUITABILTY IN THE END-USE ENVIRONMENT.**