Resin Drying and Moisture Measurement

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Why Do We Dry?

Cosmetics

Property Retention

Reduced Levels of Equipment and Tool Corrosion

Improved Melt Uniformity

The Last Two Are Unintended Benefits

Some Facts About Water And Polymers

- Water Is A Polar Molecule (Like a Magnet)
- The Polar Bond In Water Molecules Is A Special Type of Bond Known As A Hydrogen Bond
- Non-Polar Polymers Do Not Absorb Water (Hydrophobic)
- Polar Polymers Will Absorb Water – Typical Equilibrium Levels Are 0.10-0.30%
- Hydrogen Bonded Polymers Will Absorb Much Greater Amounts of Moisture (1-2.5%)

Moisture In Plastics

Hydrophobic	Hydrophilic	Hydrolyzable
■ PE	PVC	PET Polyester
■ PP	ABS	Polycarbonate
■ PS	SAN	Polyurethane
■ BDS	PPO	Nylons
	Acrylic	PBT Polyester
	PPS	PEI
	Acetal	
	Sulfone Polymers	

What Is At Stake In Drying?

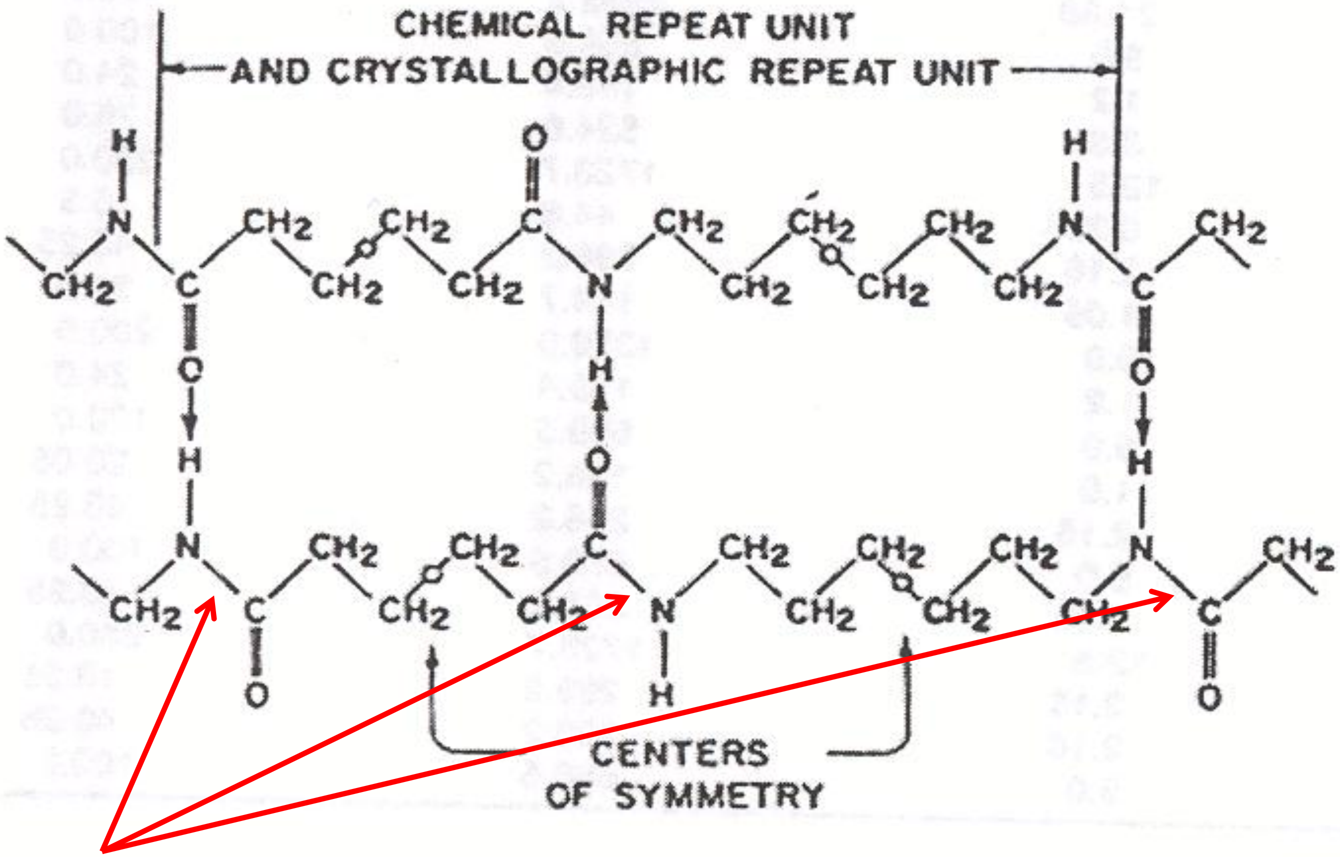
Polymers In the Hydrophilic Class Are Dried Primarily for Cosmetic Concerns

If These Materials Are Molded with Excessive Moisture Content the Material Is Not Damaged At A Molecular Level and Can Be Recycled

Polymers in the Hydrolyzable Class Degrade If Molded Wet

The Polymer In These Parts Has Reduced Molecular Weight and Will Exhibit Poor Mechanical Performance – Material Cannot Be Recycled

Nylon 6/6 Repeating Unit and Inter Chain Bonding



Vulnerable Points In the Nylon Polymer Chain

What About Blends?

PPO/Nylon

ABS/Nylon

ABS/PC

ABS/PBT

Acetal/Polyurethane

Acrylic/PC

All of These Blends Contain A Hydrolyzable Constituent

Approximate Maximum Moisture Contents for Hydrophilic Materials

Polymer	Maximum Moisture Content (%)
ABS, SAN	0.10
Acrylic	0.10
PPO	0.05
Acetal	0.06
PPS	0.05
PVC	0.08

Values May Vary with Part Geometry and Process Conditions – Requirements May Be More Stringent for Extrusion Than Injection Molding

Maximum Moisture Content Values for Hydrolyzable Polymers

Polymer	Maximum Moisture Content (%)
PET Polyester	0.02
Polycarbonate	0.02
Polyurethane	0.02-0.03
PBT Polyester	0.04
Polyetherimide	0.05
Nylon (Unfilled)	0.20
Nylon – 40% Glass	0.12

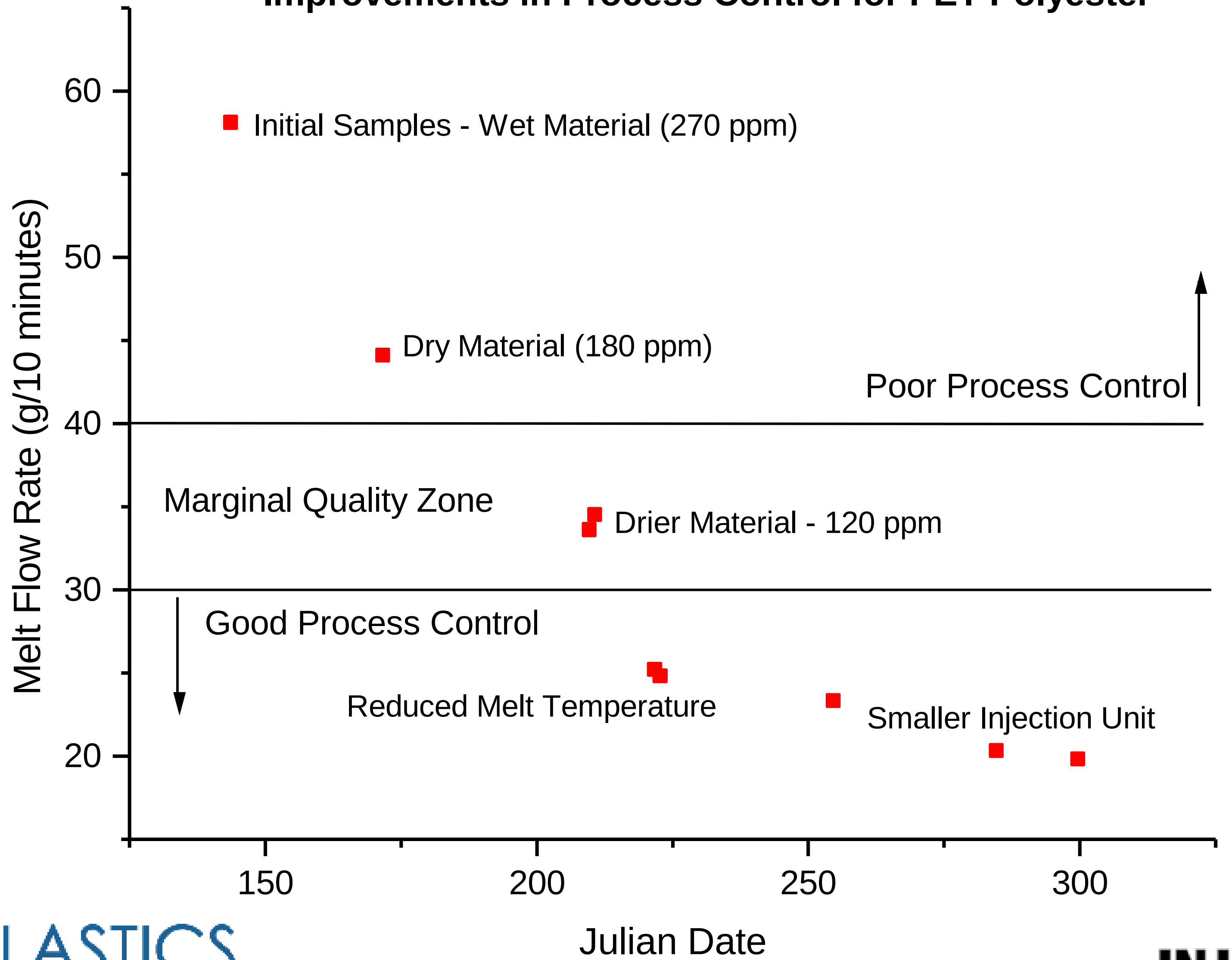
Some Considerations for Processing Hydrolyzable Polymers

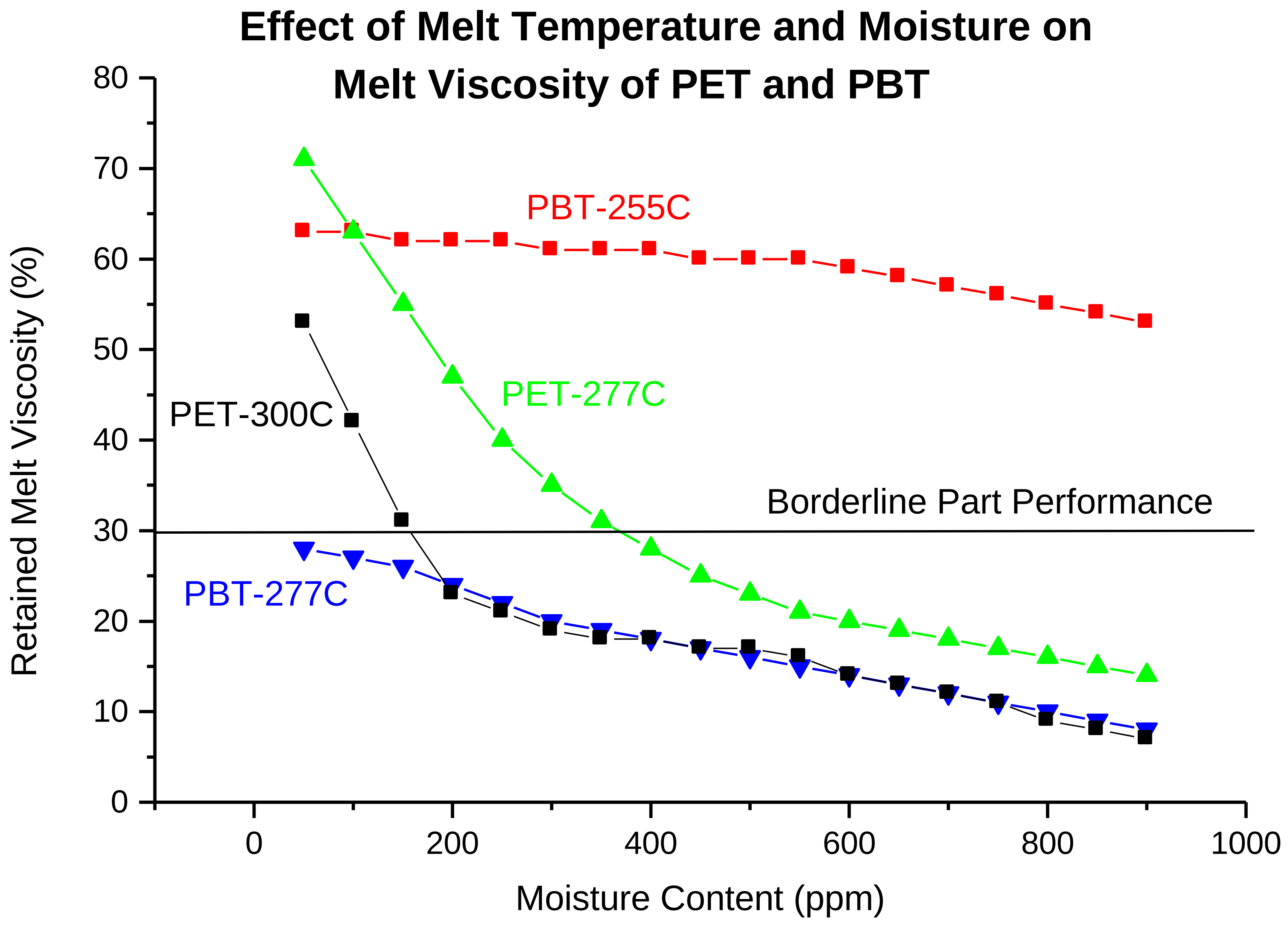
Polymer Degradation Is Influenced By Both Moisture Content and Thermal History (Melt Temperature and Residence Time)

Maximum Allowable Moisture Content May Be Exceeded for Processes Where Melt Temperatures Are Low and Residence Times Are Short

Even Permissible Moisture Contents May Be Too High If Melt Temperatures Are Elevated and Residence Times Are Extended

Improvements in Process Control for PET Polyester

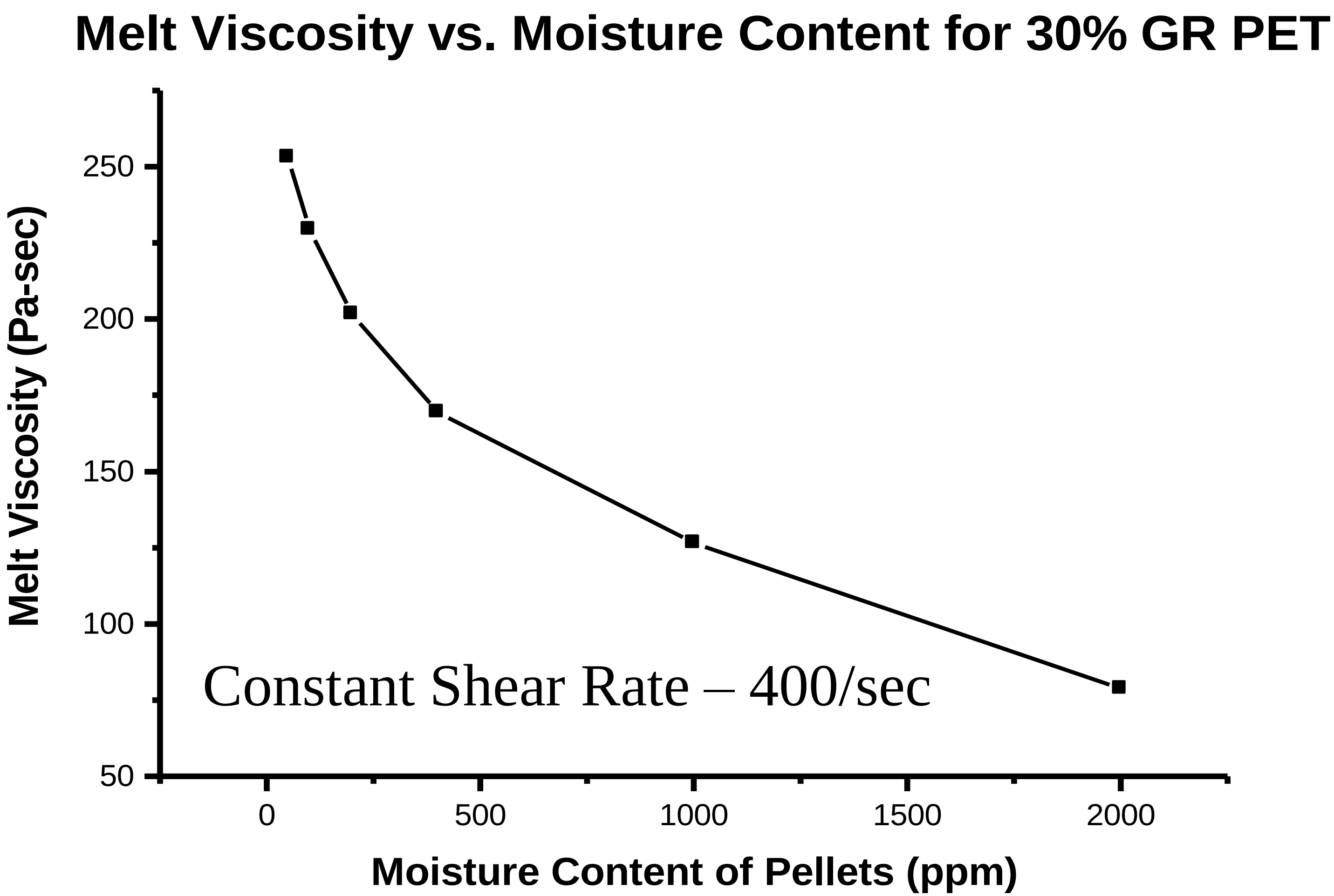


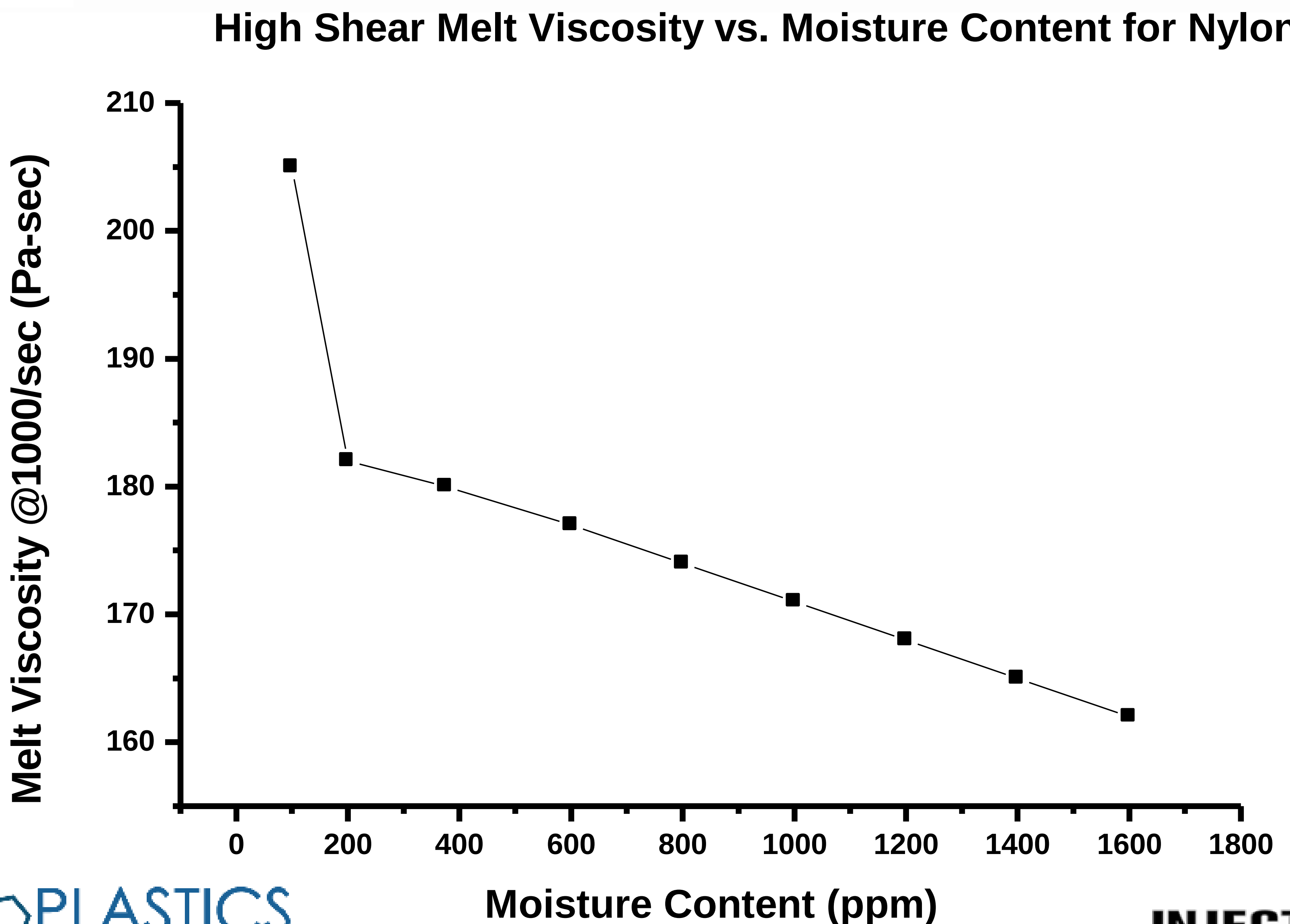


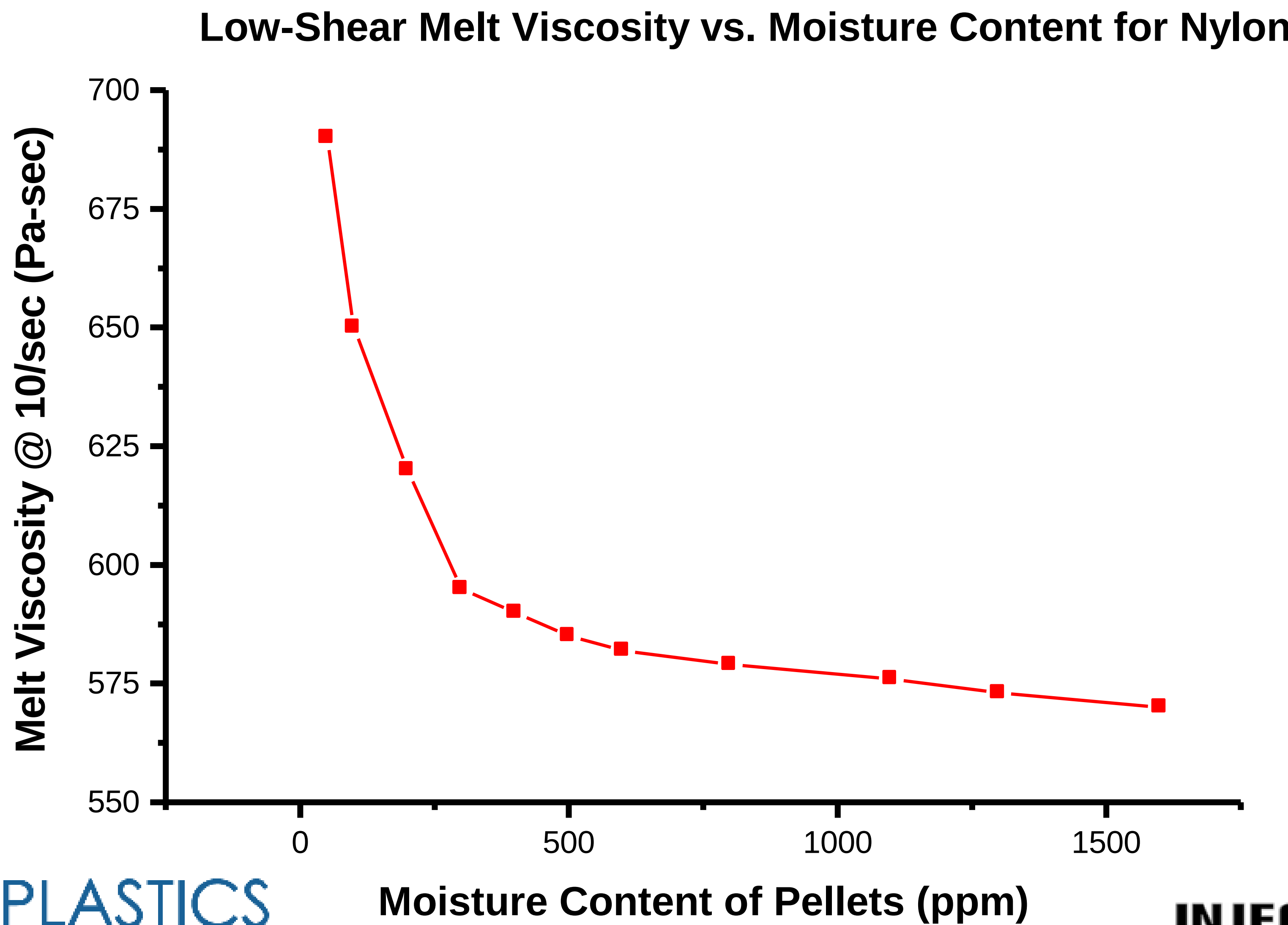
Effect of Melt Temperature and Moisture on
Melt Viscosity of PET and PBT
Retained Melt Viscosity (%)
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
Moisture Content (ppm)
PBT-255C
PET-277C
PET-300C
Borderline Part Performance
PBT-277C

Can You Remove Too Much Moisture During the Drying Process?

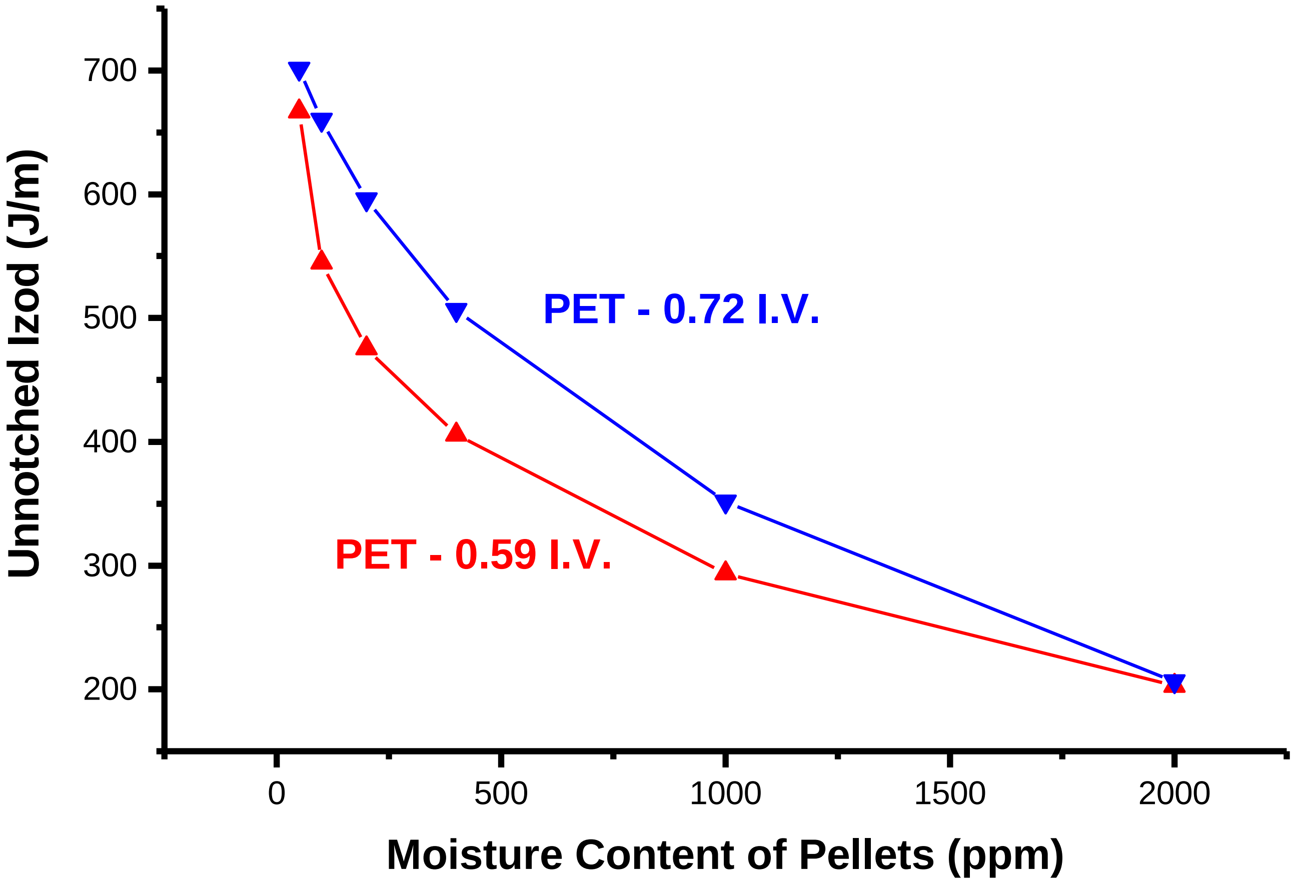
NO!

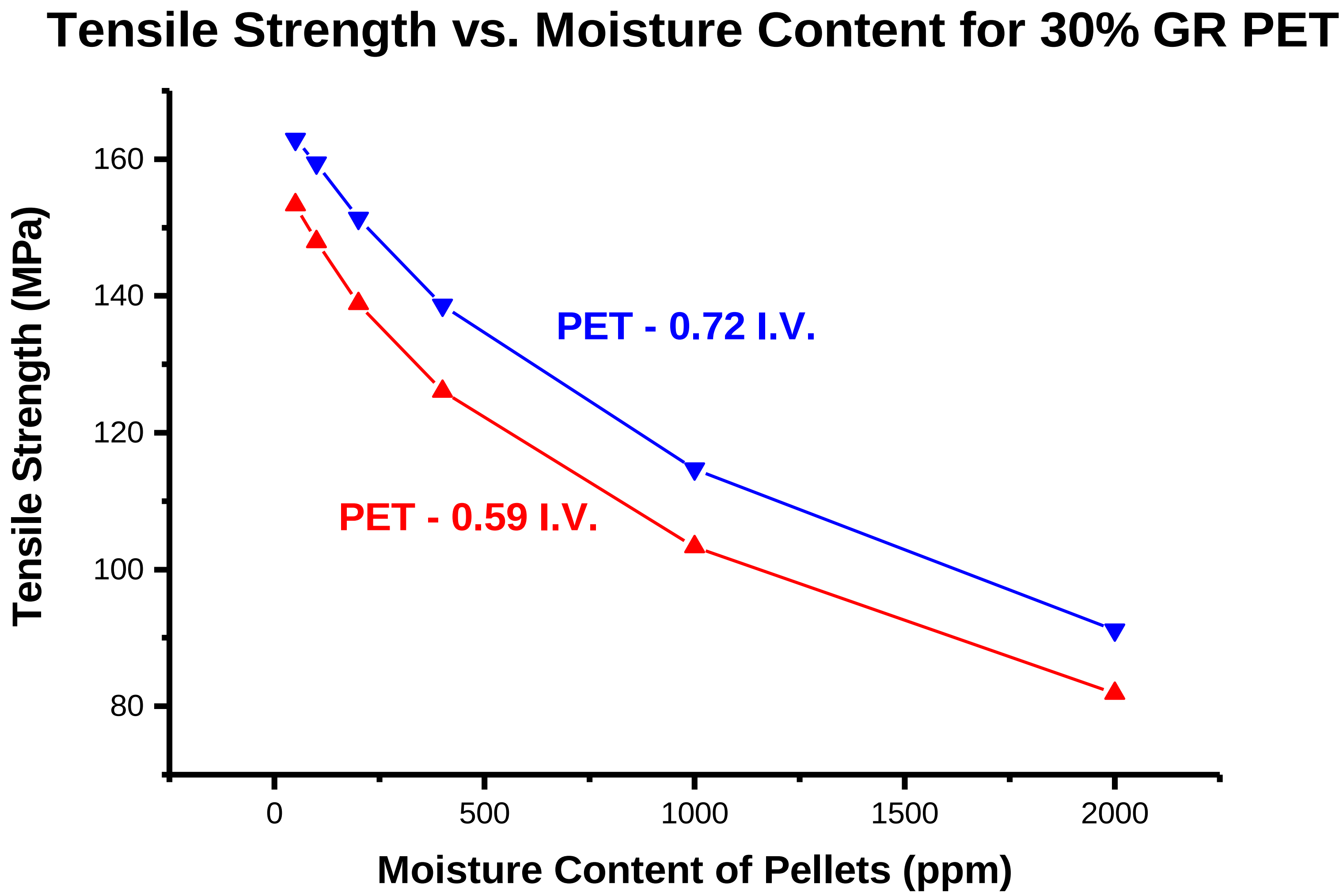

Melt Viscosity vs. Moisture Content for 30% GR PET
Melt Viscosity (Pa-sec)
250
200
150
100
50
0
500
1000
1500
2000
Moisture Content of Pellets (ppm)
Constant Shear Rate – 400/sec


High Shear Melt Viscosity vs. Moisture Content for Nylon
Melt Viscosity @1000/sec (Pa-sec)
210
200
190
180
170
160
0
200
400
600
800
1000
1200
1400
1600
1800
Moisture Content (ppm)


Low-Shear Melt Viscosity vs. Moisture Content for Nylon
Melt Viscosity @ 10/sec (Pa-sec)
700
675
650
625
600
575
550
0
500
1000
1500
Moisture Content of Pellets (ppm)

Unnotched Izod vs. Moisture Content for 30% GR PET




Tensile Strength vs. Moisture Content for 30% GR PET
Tensile Strength (MPa)
160
140
120
100
80
PET - 0.72 I.V.
PET - 0.59 I.V.
0
500
1000
1500
2000
Moisture Content of Pellets (ppm)

Can You Alter a Polymer In A Negative Way During the Drying Process?

Absolutely!

Some Effects of Inappropriately Aggressive Drying Conditions

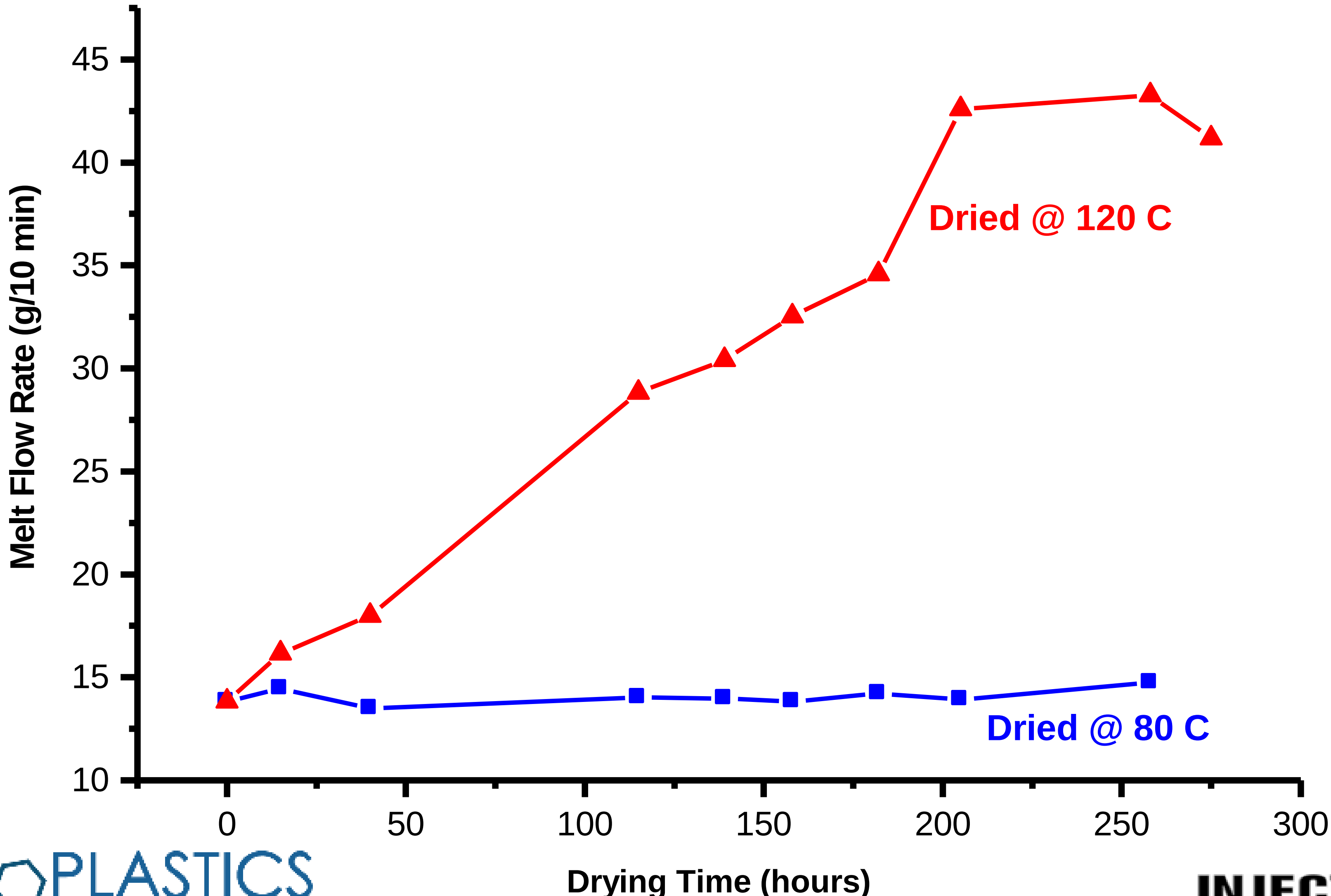
Color Changes

Oxidation (Leads to Polymer Degradation)

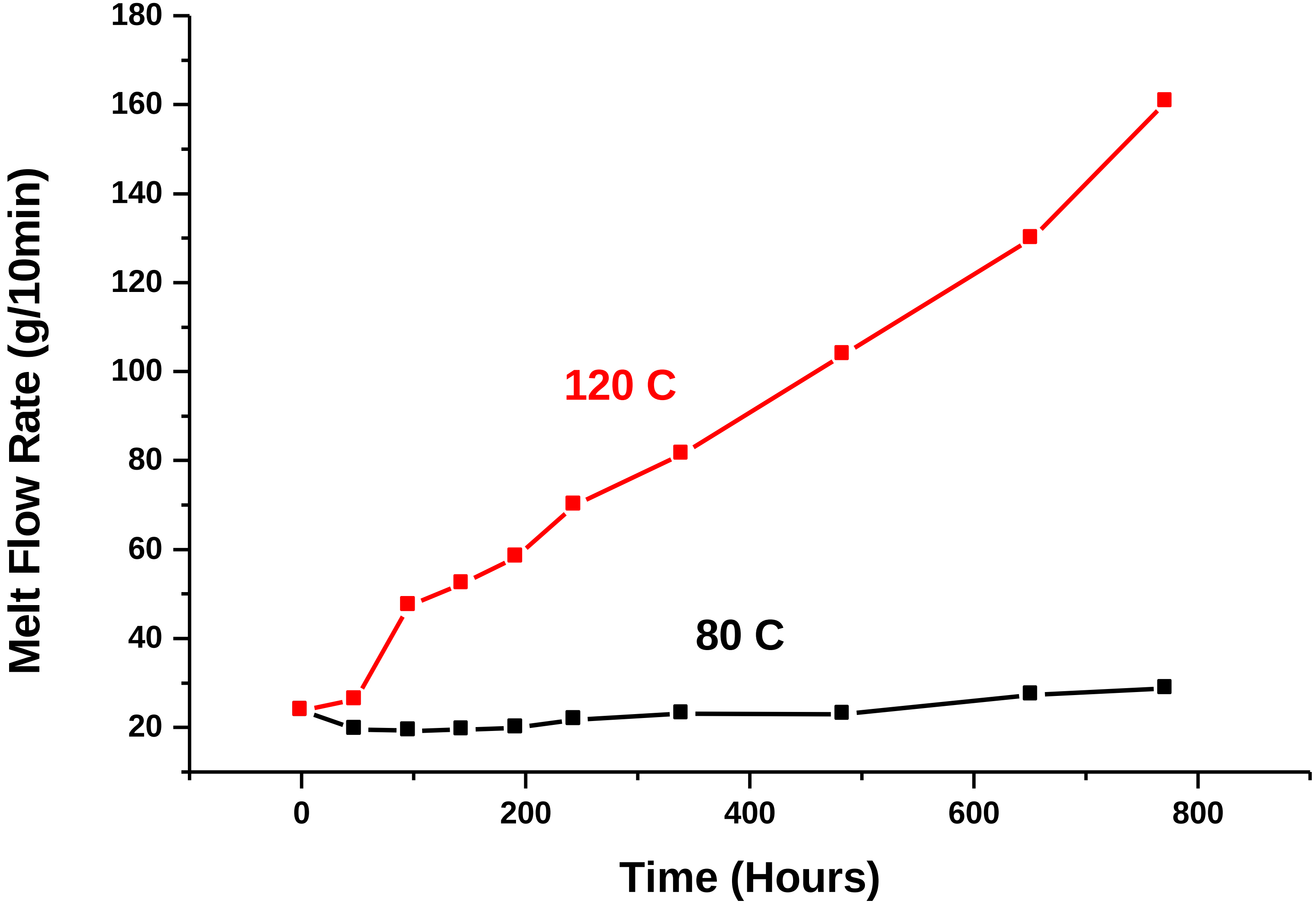
Loss of Lubricants, Plasticizers, and Other Additives

It Is Not A Question of How Much Moisture You Remove, It Is A Matter of the Manner In Which You Remove It

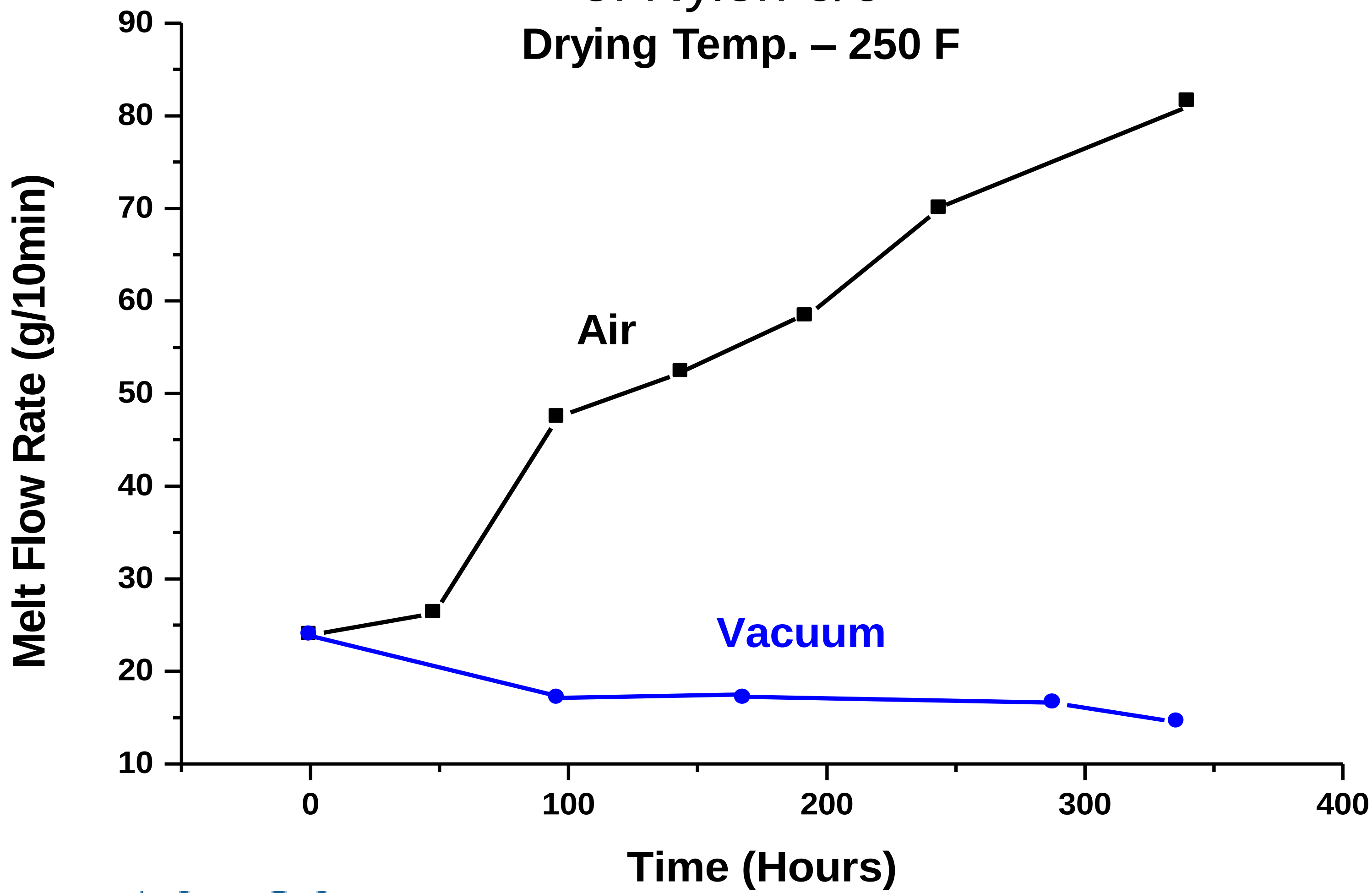
Effect of Drying Time and Temperature on MFR of Unfilled Nylon 6



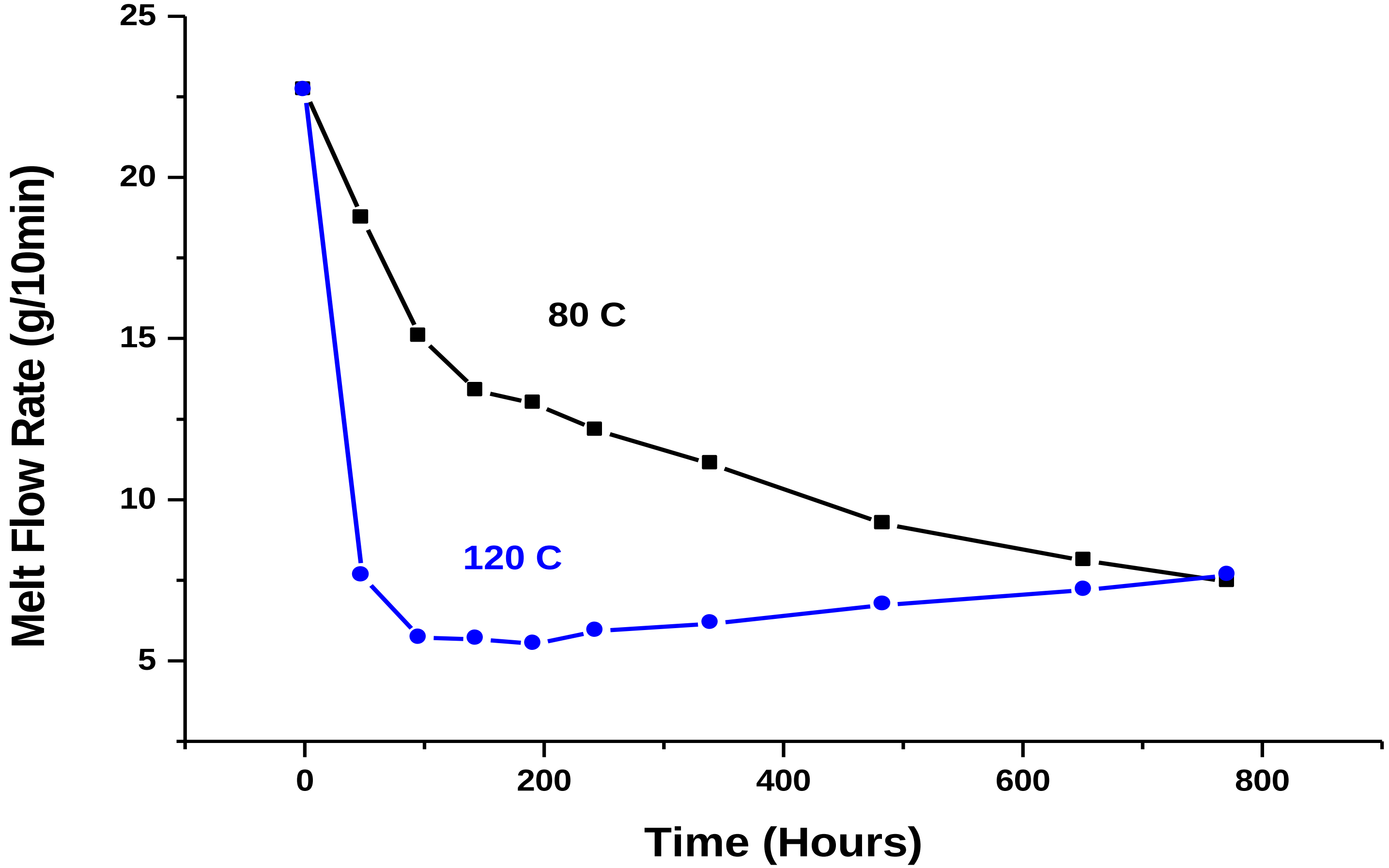
Effects of Drying Temperature on Melt Flow Rate of Nylon 6/6



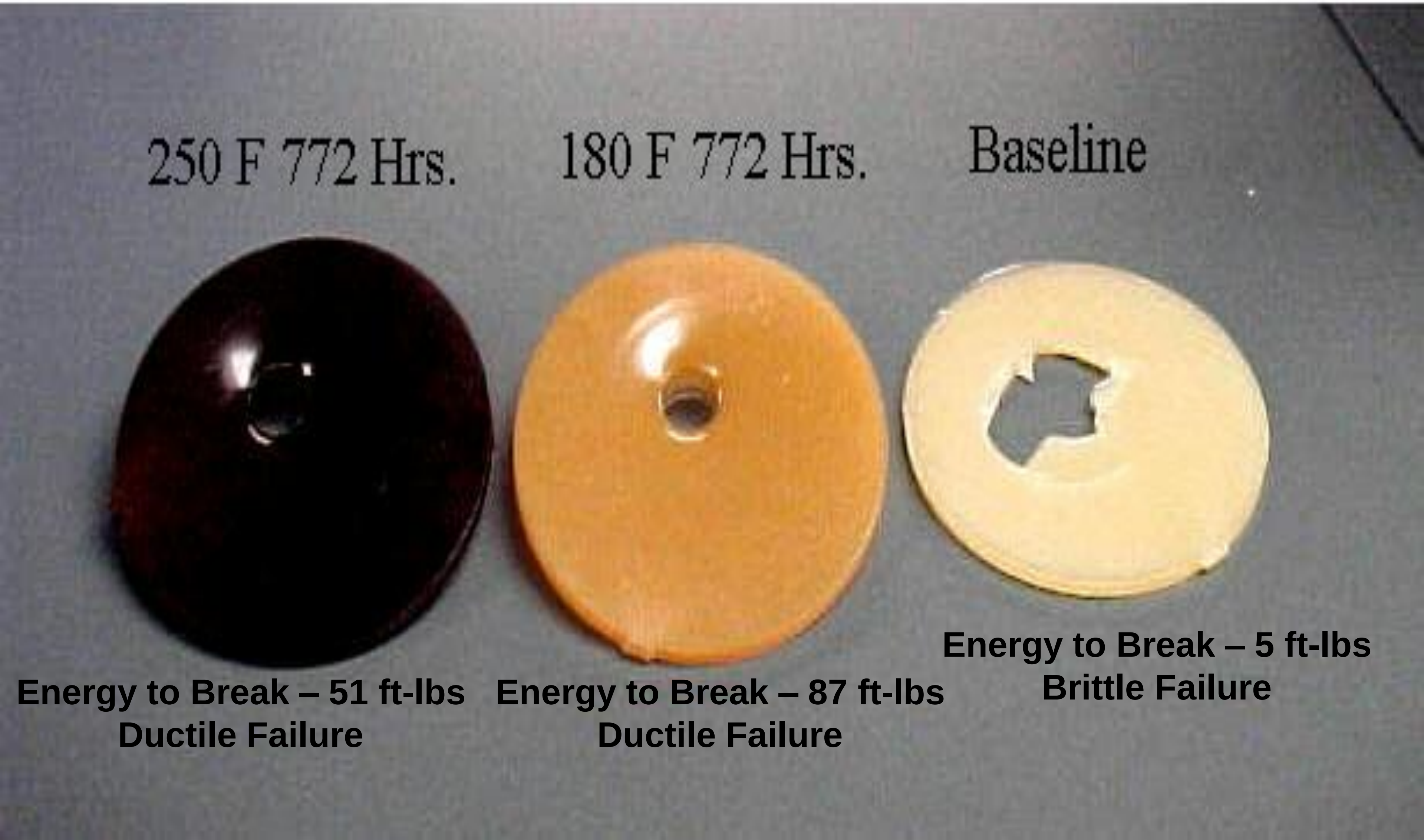
Effects of Drying Environment on Melt Flow Rate of Nylon 6/6



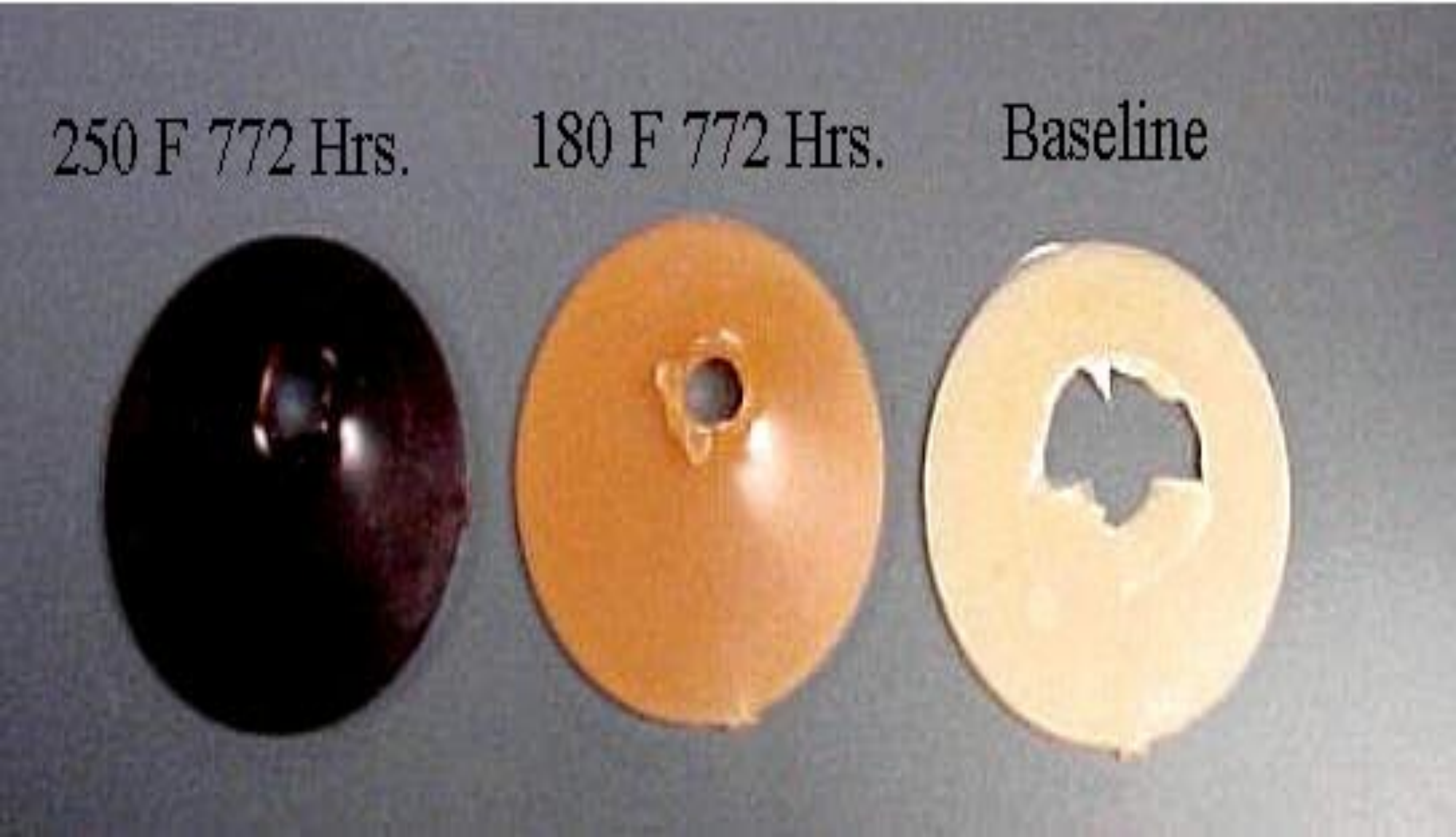
Effects of Drying Temperature on Melt Flow Rate of Heat Stablized Nylon 6/6



Front Side Impacts of Heat Stablized Nylon 6/6



Backside Impacts of Heat Stablized Nylon 6/6



Drying Methods

Hot Air Oven

Hot Air Dryer

Desiccant Dryer

Vacuum Dryer

RF or Infrared Dryer

Refrigeration Dryer

Important Drying Parameters

Inlet Air Temperature

Inlet Air Dew Point

Air Flow Rate (Filter Condition)

Inventory in Hopper (Funnel or Plug Flow?)

Return Air Temperature

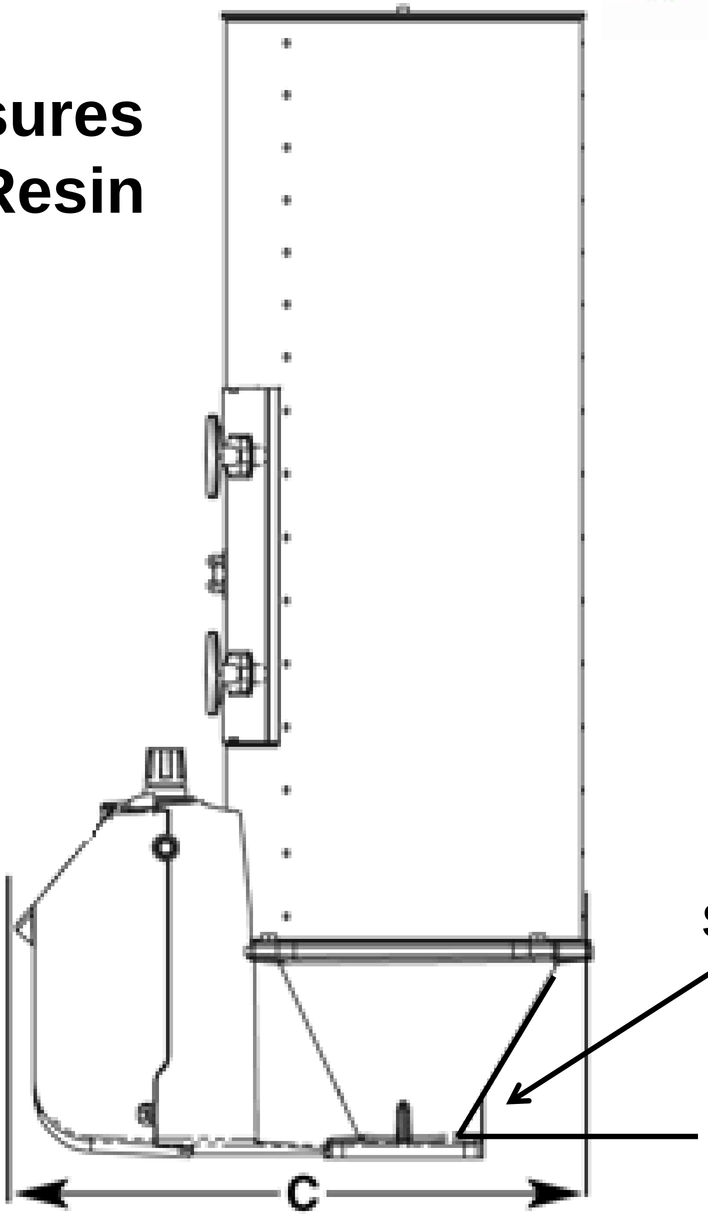
Desiccant Condition

Source of Regeneration Air

Air Regeneration Temperature

Is Your System Sealed?

Proper Cone Angle Ensures Mass or Plug Flow of Resin



How Do You Know If Your Material Is Dry?

Followed the Material Supplier Recommendations for Drying Time, Temperature and Type of Equipment

The Parts Look OK

The Machine Response Indicates That the Viscosity of the Polymer Is In the Normal Range

Measured the Moisture Content of the Raw Material

Mass Based versus Sensor Based Moisture Measurement

Mass Based Techniques Do Not Distinguish between Water and Other Volatiles

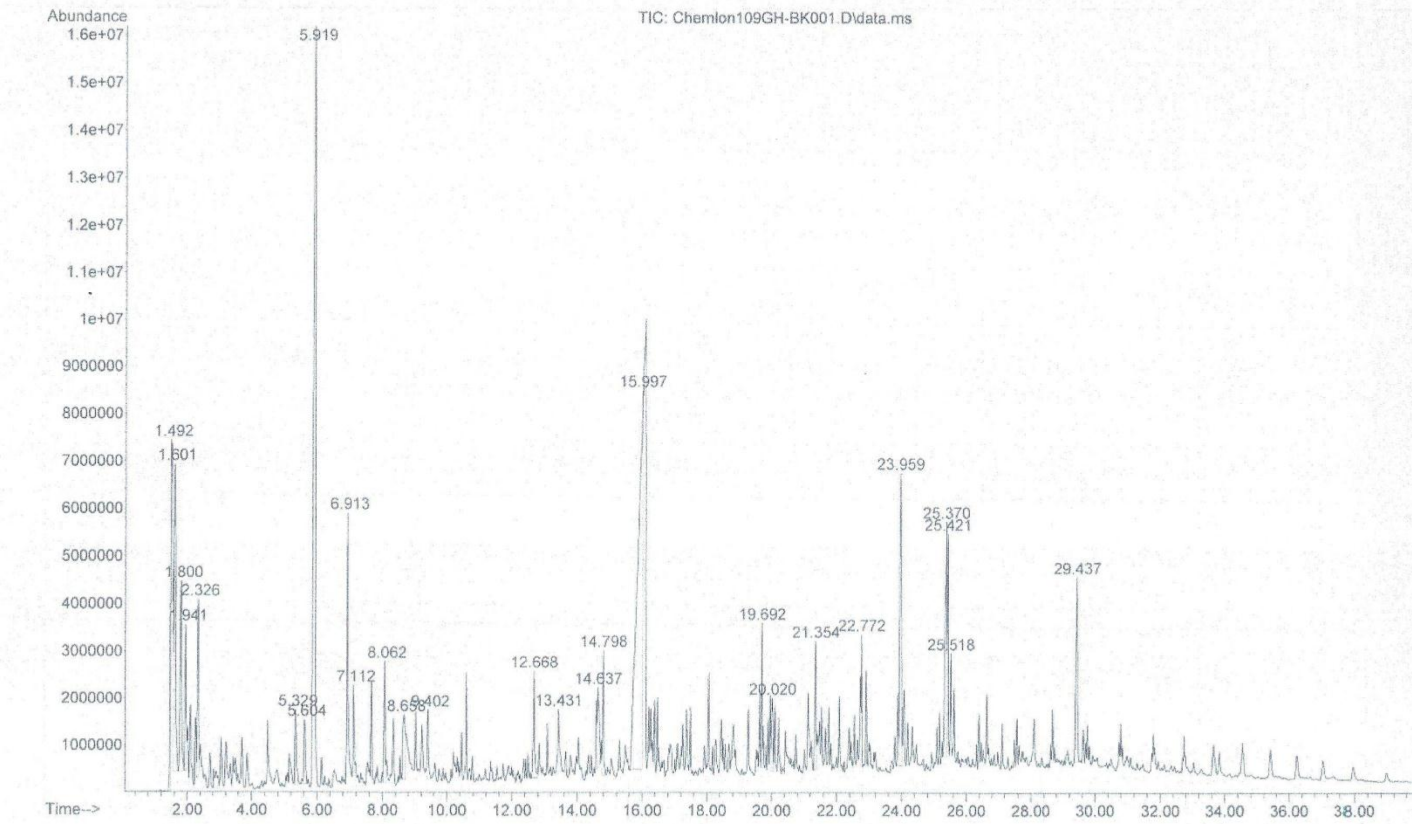
These Techniques Work Well for Products Where Typical Moisture Content Values Are Relatively High and the Levels of Other Volatile Materials Present Are Comparatively Low

Sensor Based Instruments Are Moisture Specific – They Drive Off Multiple Volatile Compounds But They Only Measure the Water

These Devices Are Required Where Moisture Content Is Relatively Low and the Level of Other Volatiles Is Relatively High

Polymers Fit Into the Latter Category

Gas Chromatography-Mass Spectroscopy of a Nylon Material



Every One of These Peaks Represents A Volatile Component
One of Them Is Water – All of Them Will Influence A Mass Loss System

The Appeal of Mass Loss Systems

Simple To Use

Lower Purchase Price

Use No Chemicals Or Other Consumables

Produce Results In A Relatively Short Time Frame

Users Are Told That the Units Are Calibrated

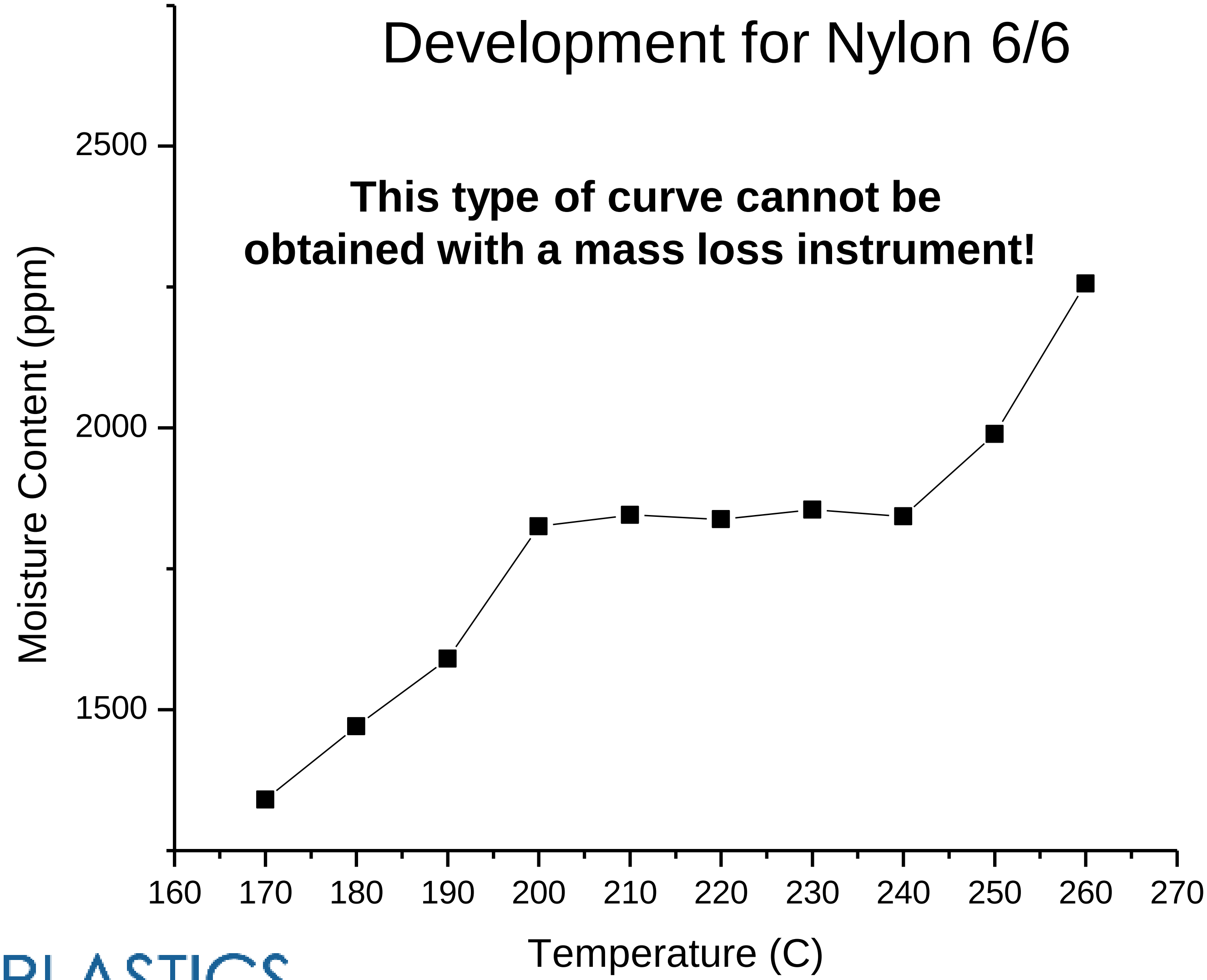
The Problem With Mass Loss Systems

Cannot Distinguish between Water and All Other Volatiles

The Appropriate Technique for Establishing the Correct Test Temperature Cannot Be Performed with Mass Loss Systems

Calibration Consists of Adjusting Test Conditions Until the Mass Loss Result Agrees with a Result Obtained Previously On A Sensor-Based Instrument (Usually Karl Fischer)

Results of Moisture Content Method Development for Nylon 6/6



Criteria For Moisture Measurement In Polymers In A Manufacturing Environment

Efficient – Results In 5-10 Minutes

Accurate – Must Remove All Moisture and Measure Only That Moisture – Nothing Else

Precise – Results That Are Repeatable

Can Be Calibrated Based On Known Principles of Chemistry and Physics

Can Be Used By Production Personnel

What Works?

Chemical Techniques

- Karl-Fischer Titration
- Brabender (Calcium Hydride Method)

Dielectric Measurements

- Calibration Curve Required
- Potential for On Line Measurements

Water Activity

- Currently Used In Food and Pharmaceuticals
- No Instruments Developed for Polymers Yet

"Things should be made as simple as possible, but not any simpler."

Albert Einstein

Questions ?

Time for Today’s Live Q&A

Thank you all for attending

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presented by

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