Choosing the Best Polyurethane Cast Elastomer for Demanding Applications

Dr. R. Scott Archibald, Ph.D.

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Polyurethane Industry

- The 2016 market for polyurethanes is estimated to be over $55 Billion.
- The 2016 diisocyanate (limited to MDI and TDI) market is estimated at $22 Billion.
- The 2016 US polyurethane market is expected to reach over $19 Billion and employ over 200,000 jobs.

*2014 UTECH Conference Website

Overview

- Markets
- Applications
- Urethane Chemistry
- Reasons to use urethane elastomers
- Application types
- Urethane elastomer comparisons to metal, rubber, and plastic
- Urethane limitations
- Control of Urethane Properties
- Urethane general selection
- Selecting the best urethane for a new application
- Field Testing

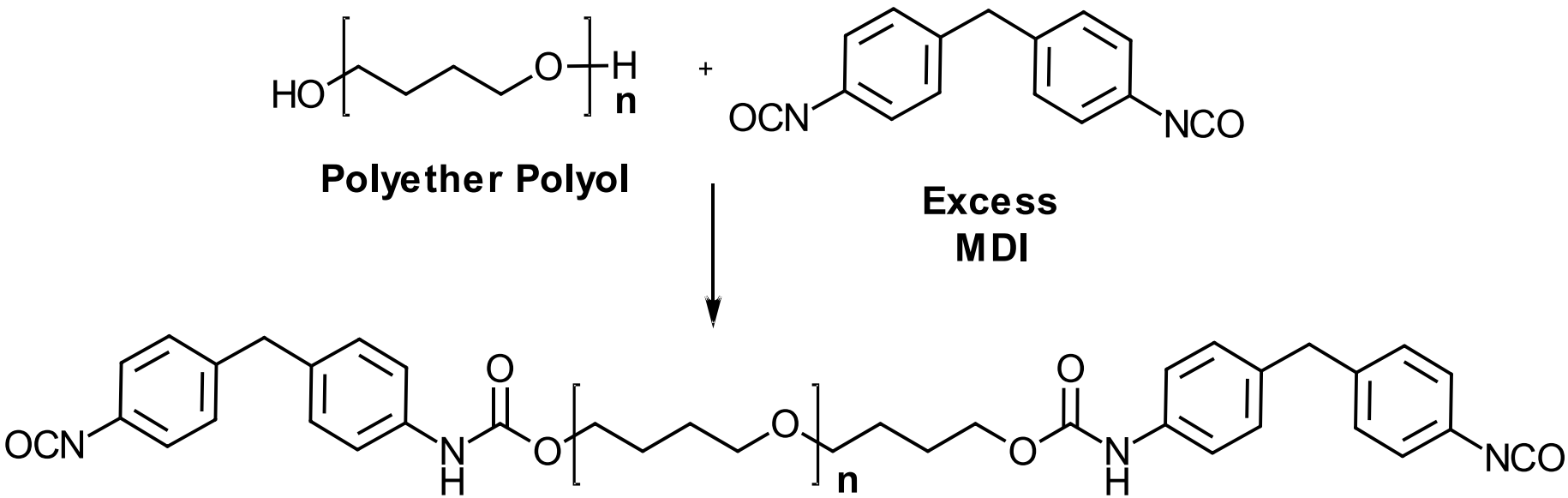
Major Polyurethane Markets

- Construction – rigid foam insulation
- Automotive – seating, vehicular interiors, facia
- Bedding and Furniture
- Footwear – shoe soles
- Textiles – Spandex,
- Adhesives and Sealants - flooring
- Electronics
- Machinery & Foundry
- Thermoplastic Urethanes (TPU)
- Coatings
- CAST ELASTOMERS – 2-3%

Major Cast Elastomer Polyurethane Applications

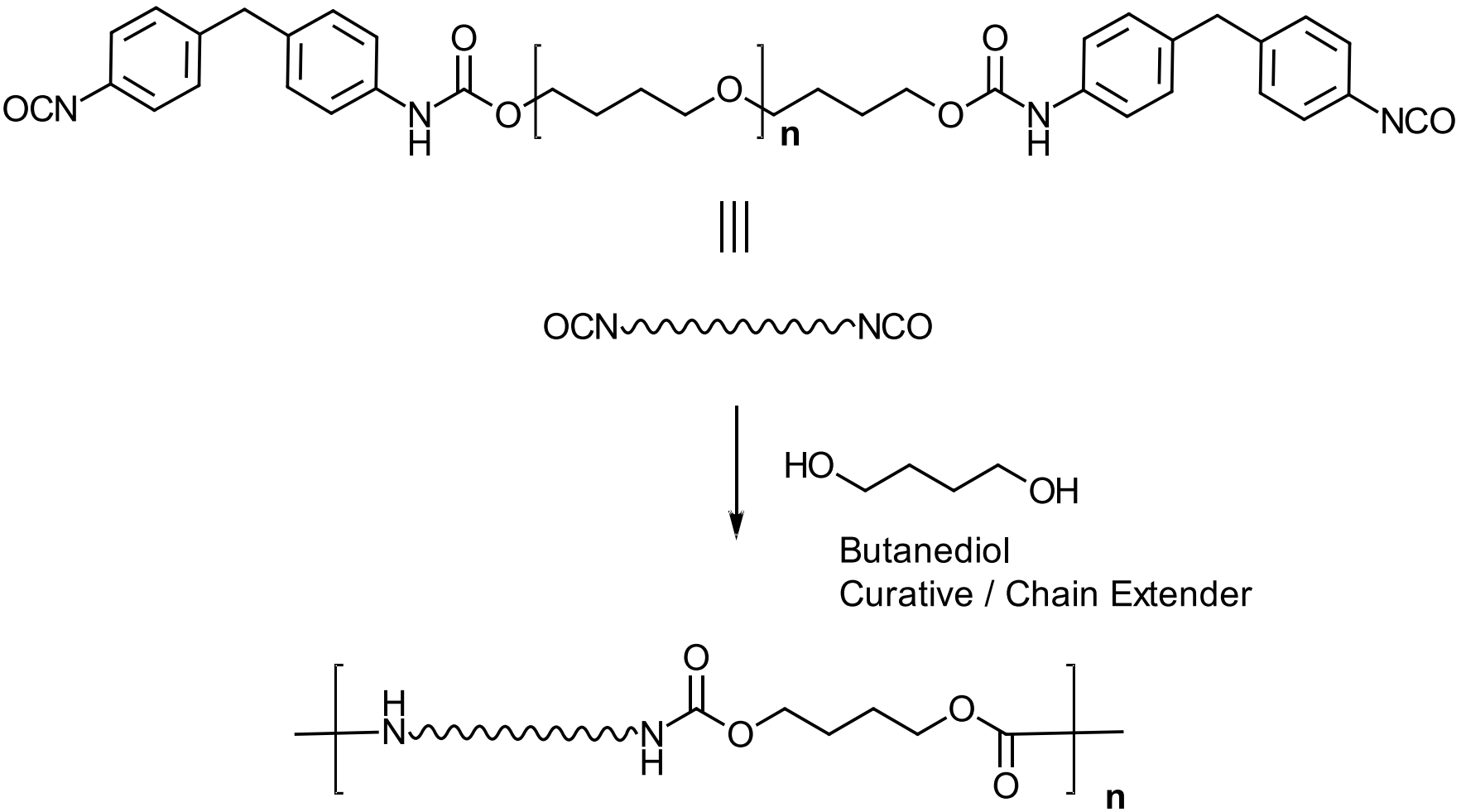
- Agriculture and Food Processing
- Office Machinery
- Oil and Gas Pipeline Parts
- Tire and Wheels
- Papermaking and Printer rolls
- Mining Parts
- Recreational – Golf Balls, Inline Skate wheels, Skateboard wheels, bowling balls

Urethane Prepolymer Synthesis



MDI Ether Prepolymer

Cast Elastomer Production



Production Supply Arrival

Prepolymer

Curative / Chain Extender

Prepolymer Preparation

Prepolymer

- Melting in Oven
- Transfer to Machine Tank or Dispense to Pail
- Degassing
- Maintain Production Temperature

Curative/Chain Extender Preparation

- Transfer to Machine Tank for Melting or Melt enough for single pour
- Maintain Liquid State
- Degassing
- Maintain Production Temperature

Polyurethane Processing

(Melting),
Warming &
Degassing

Meter Streams

Mixing

Dispensing

Molding

Curing

Demold

Post-Curing

Finishing

(Melting),
Warming &
Degassing

Polyurethane Processing

Meter Streams

Mixing

Dispensing

Molding

Machine Mixing

Dispensing

Hand Batching

Polyurethane Processing

Molding

Curing

Demold

Curing Oven

Demolding

Polyurethane Processing

Demold

Post-Curing

Finishing

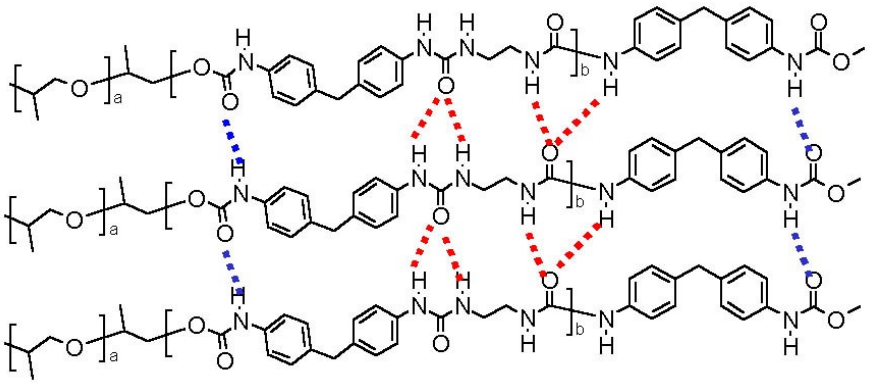
Post-Curing Oven

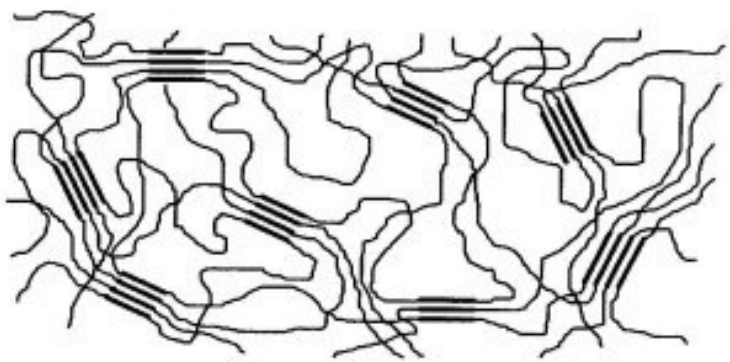
Tradename Printing

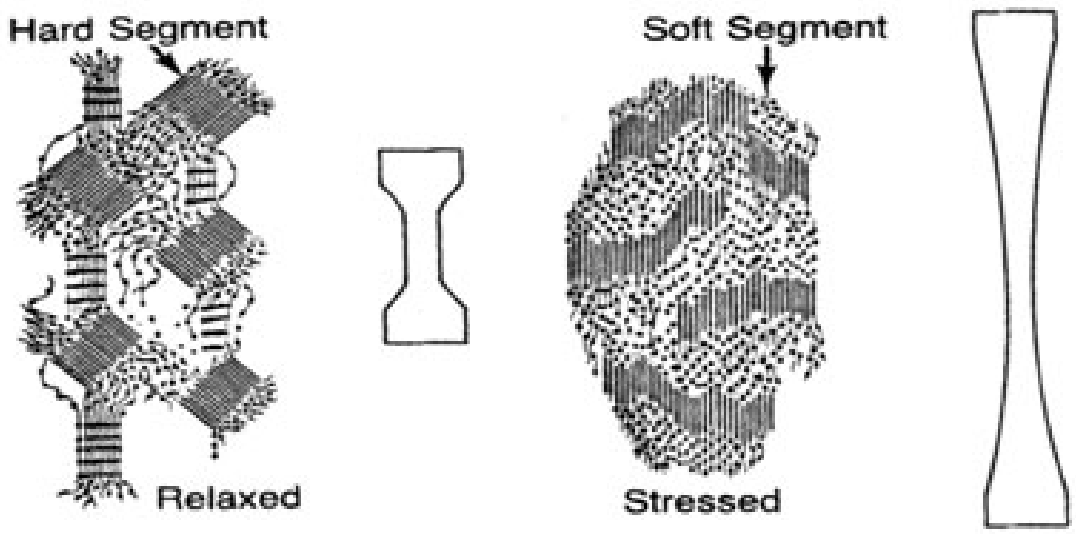
Finishing

Polyurethane Elastomer

Think Elastic







Urethane Elastomer Performance Advantages

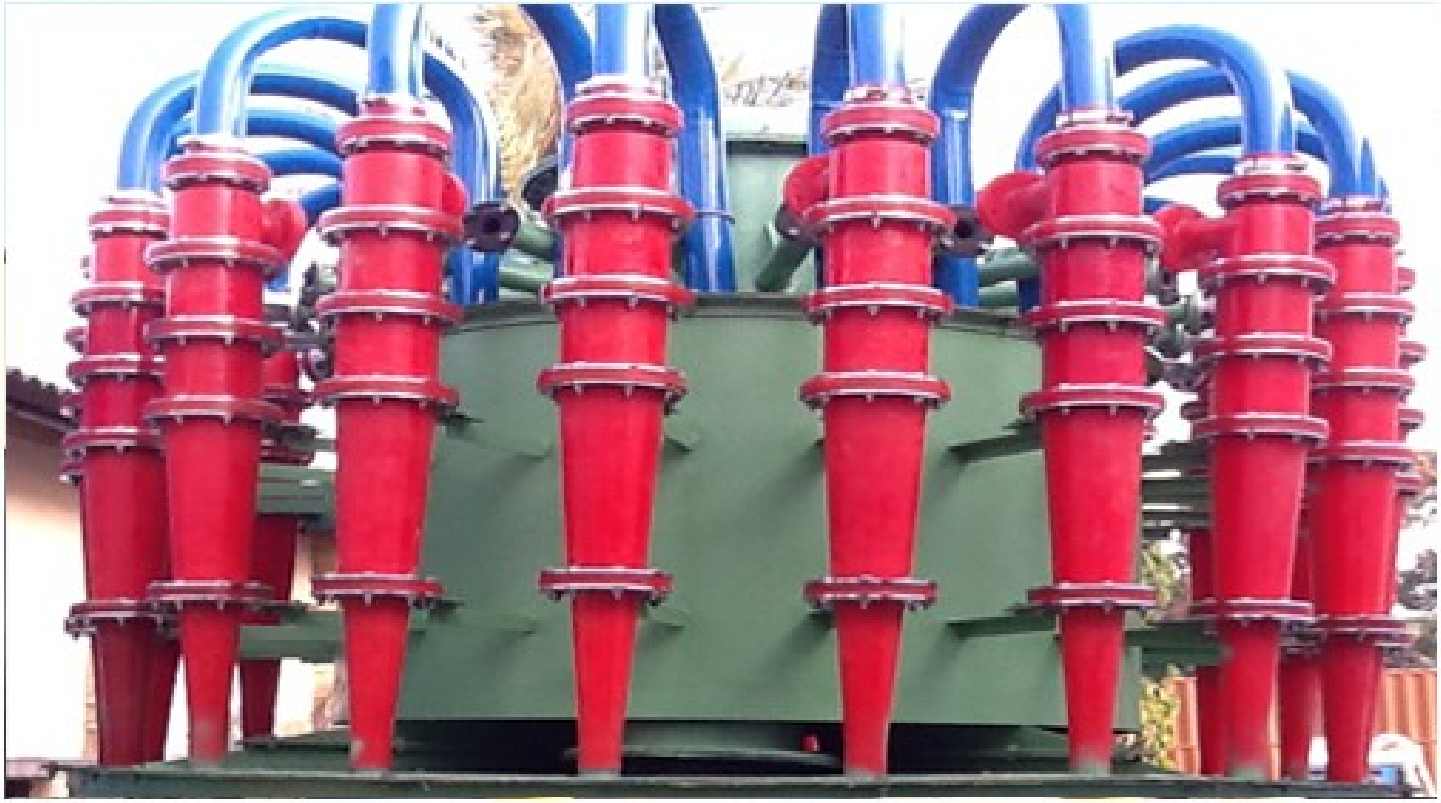
- Tear Resistance
- Abrasion Resistance
- Toughness
- Load-bearing Ability

Urethane Elastomer Cost Advantages

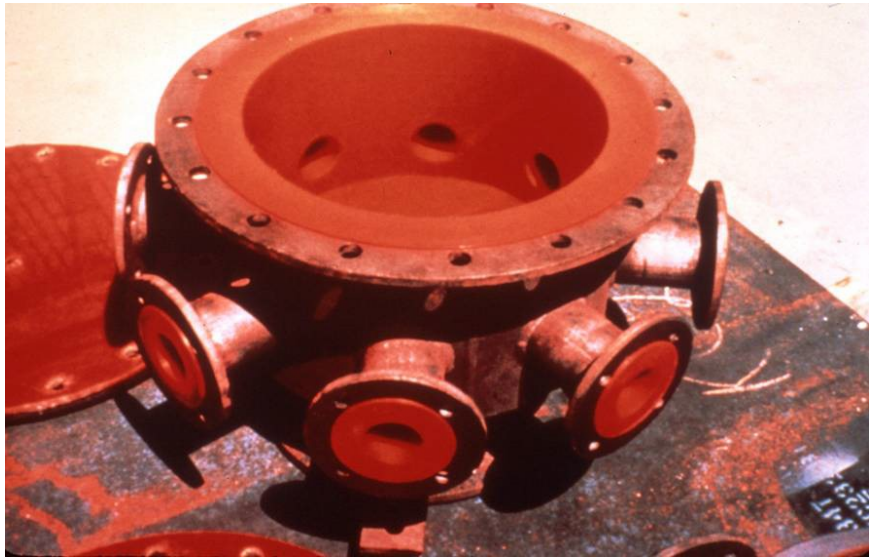
- Reduced Downtime in Manufacturing Processes
  - Mining
  - Paper Mills
  - Pipelines
  - Machine Parts
- Lower Tooling and Equipment Costs for Small Production Runs

Mining - Hydrocyclones

Mining - Hydrocyclones

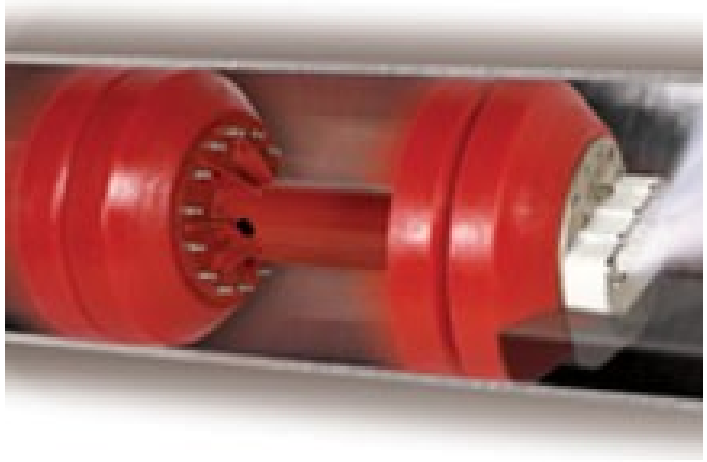


Urethane Lined Hydrocyclone Distributor



Paper Mill Rolls

Pipeline Pigs/Spheres



Pipeline Cleaning Pigs

Crossover Pads

Wheels for Forklifts and Lift Trucks

Processing Urethane Prepolymers

- **Open Casting** (Most Common, low cost)
- **Compression Molding** (for Precision Parts)
- **Centrifugal Molding** (Pipelining, multi-cavity, circular molds)
- **Liquid Injection Molding** (low pressure bottom fill)

Most Common

- **Ribbon Molding** (Rolls, to big to open cast)
- **Spraying** (High/Low pressure; No Solvent/Solvent)
- **Rotational Molding** (Hollow Items)
- **Vacuum Casting** (Wire or Fiber Inserts)
- **Transfer Molding** (Multiple Precison Parts)
- **RIM – Reaction Injection Molding** (High Pressure Impingement Mixing)
- **B – Staging** (When molds can't hold liquid)
- **Pressure Casting** (Pressure Chamber)
- **Solvent Casting** (Low Viscosity for Fabric Penetration)
- **Trowelling** (Repairs and Special Apps)
- **Dipping** (Long Pot life, Heat Activated)

Least Common

Lined Steel Pipe – Centrifugal Cast

Gaskets/Seals – Compression Molding

Ride Wheels – Open Cast

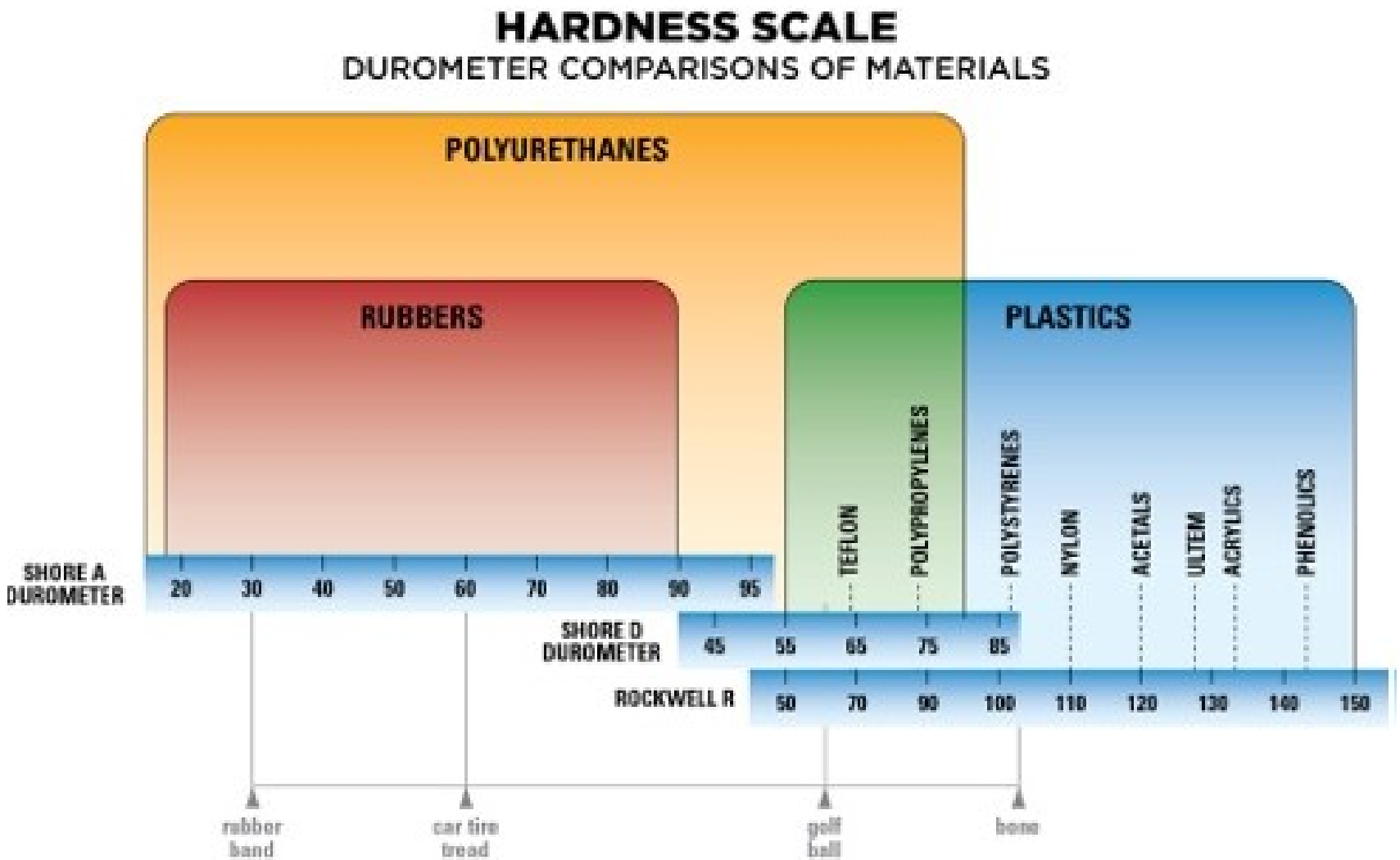
Big Rolls - Ribbon Molding

Polyurethane Advantages over Metal

- Impact Resistance
- Lighter Weight
- Less Noise
- Better Wear
- Corrosion Resistance
- Low Cost Manufacturing
- Non- Sparking
- Non-Conductive

Mining Screen Operation

Polyurethane Working Hardness Range



Polyurethane Advantages over Rubber

- **Abrasion Resistance**
- **Cut and Tear Resistance**
- **Oil Resistance**
- **Higher Load Bearing**
- **Harder Durometer Range**
- **Clarity; Translucence**
- **Non-Marking, non-Staining**
- **Pourable; Castable**
- **Ozone Resistance**
- **Microorganism Resistance ***
- **High or Low Hysteresis**
- **Versatility**

* Polyether only

General Comparison of Polyurethane Elastomers with Various Rubbers

General Comparison of Polyurethane Elastomers with Various Rubbers

Property	Polyurethane	Nitrile	Neoprene	Natural	SBR	Butyl
Tensile Strength (MPa)	20.7 to 65.5	13.8+/-	20.7+/-	20.7+/-	13.8+/-	13.8+/-
Durometer	5A to 85D	40 to 95A	40 to 95A	30 to 90A	40 to 90A	40 to 75A
Specific Gravity	1.10 to 1.24	1.0	1.23	0.93	0.94	0.92
Tear Resistance	Outstanding	Fair	Good	Good	Fair	Good
Abrasion Resistance	Outstanding	Good	Excellent	Excellent	Good-Excel.	Good
Compression Set	Good	Good	Fair-Good	Good	Good	Fair
Rebound	Very High to Very Low	Medium	High	Very High	Medium	Very Low
Gas Permeability	Fair-Good	Fair	Low	Fair	Fair	Very Low
Acid Resistance	Fair-Good	Good	Excellent	Fair-Good	Fair-Good	Excellent
Aliphatic Hydrocarbons	Excellent	Excellent	Good	Poor	Poor	Poor
Aromatic Hydrocarbons	Fair-Good	Good	Fair	Poor	Poor	Poor
Oil and Gas Resistance	Excellent	Excellent	Good	Poor	Poor	Poor
Oxidation Resistance	Outstanding	Good	Excellent	Good	Good	Excellent
Ozone Resistance	Outstanding	Fair	Excellent	Fair	Fair	Excellent
Low Temperature Resistance	Excellent	Good	Good	Excellent	Excellent	Good

Polyurethane Advantages over Plastic

- Non-Brittle
- Flex Resistance
- Abrasion Resistance
- Elastomeric Memory

Limitations of Polyurethane

- High Temperature Service
- Moist, Hot Environments
- Certain Chemical Environments
- Higher Cost versus other Polymers

Prepolymer Chemistry Controls Polyurethane Properties

- **Diisocyanate Type**

  TDI

  MDI

  Specialty (PPDI, Aliphatic, LF, etc.)

- **Polyol (Prepolymer Backbone) Type**

  PTMG (Premium) Polyether

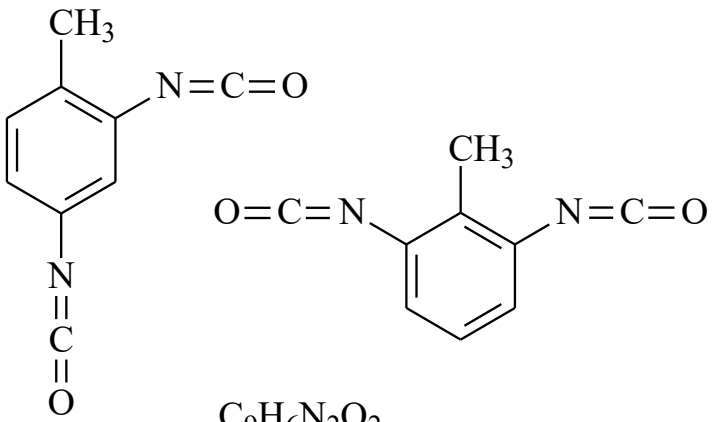
  PPG Polyether

  Polyesters (%Ethylene, %Butylene, Adipate, Succinate)

  Specialty (Polycaprolactones, Polycarbonates, etc.)

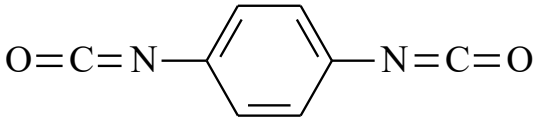
Diisocyanates

TDI



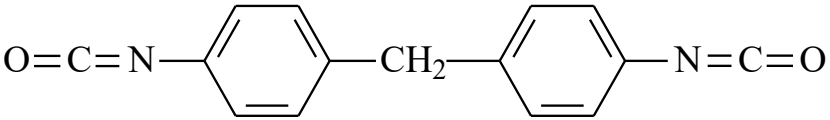
$C_9H_6N_2O_2$
174.16
Toluene Diisocyanate

PPDI



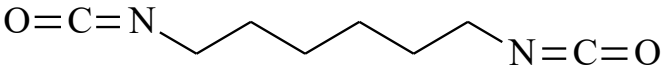
$C_8H_4N_2O_2$
160.13
Paraphenylene Diisocyanate

MDI



$C_{15}H_{10}N_2O_2$
250.26
Methylenediphenyl Diisocyanate

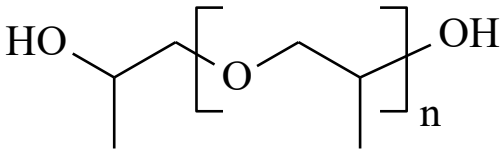
HDI



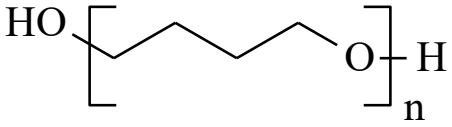
$C_8H_{12}N_2O_2$
168.20
Hexamethylene Diisocyanate

Prepolymer Backbones

Polyethers

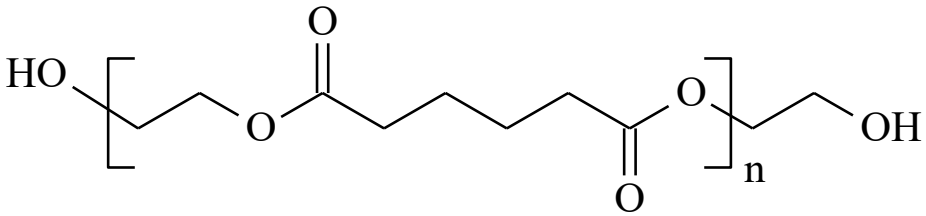


PPG
Polypropylene glycol



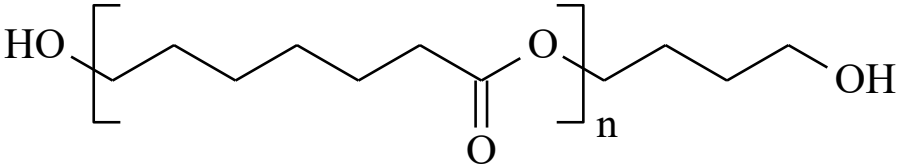
PTMEG
Polytetramethylene ether glycol

Polyesters



PEAG
Polyester

Polycaprolactone



PCl
Polycaprolactone

Physical Properties

Relative Performance for MDI Systems

(Performance: 1 = Best, 10 = Worst)

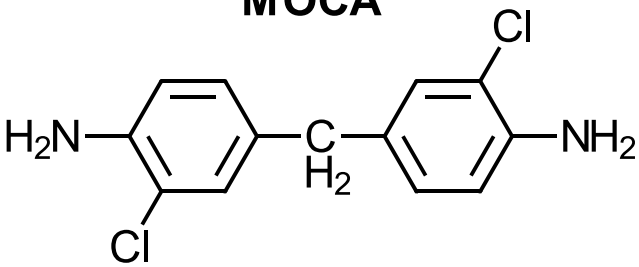
Material	Abrasion	Low Temp	Hydrolysis	Oxidation
Ester (standard)	3	8	6	1
Ester (high abr)	1	8	6	1
Polycaprolactone	4	4	4	1
PTMG Ether	6	1	1	4
PPG Ether	8	2	1	7

Hard Segment Chemistry Controls Polyurethane Properties

- **Curative / Chain Extender Type**
  - Diamine (fast reactivity - used with slower TDI Prepolymers)
  - Diol, Triol (slower reactivity - used with faster MDI Prepolymers)
- **Polyol (Prepolymer Backbone) Type**
  - Curative Ratio
  - Temperatures (Prepolymer, Curing, Post-curing)
- **Additives**
  - Plasticizers
  - Fillers
  - Stabilizers

Common Curatives

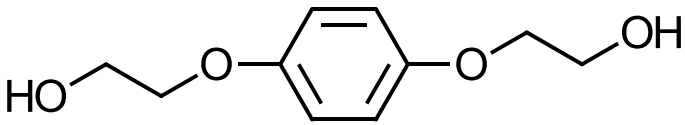
MOCA



Molecular Mass = 267.1537 u

Molecular Formula = $C_{13}H_{12}Cl_2N_2$

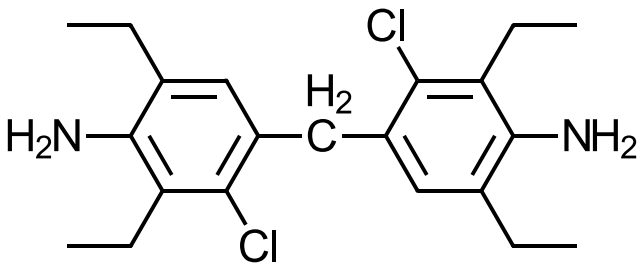
HQEE



Molecular Mass = 198.2157 u

Molecular Formula = $C_{10}H_{14}O_4$

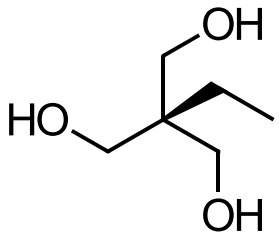
MCDEA



Molecular Mass = 379.3665 u

Molecular Formula = $C_{21}H_{28}Cl_2N_2$

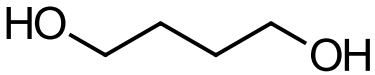
TMP



Molecular Mass = 134.1736 u

Molecular Formula = $C_6H_{14}O_3$

BDO



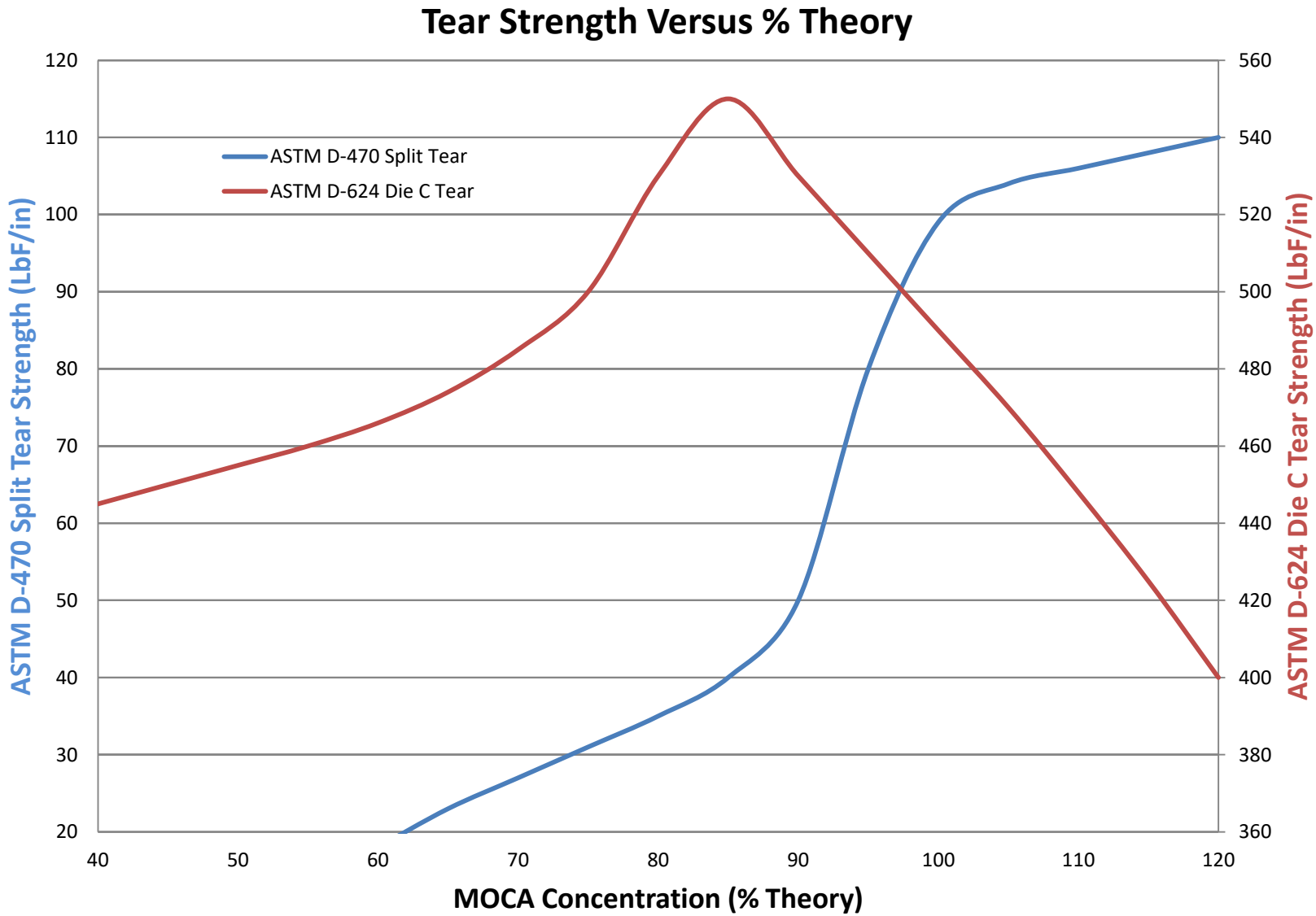
Molecular Mass = 90.1210 u

Molecular Formula = $C_4H_{10}O_2$

Equivalent Weight is ½ Molecular Mass for Di-functional Curatives

Equivalent Weight is 1/3 Molecular Mass for Tri-functional Curatives

Tear Strength Versus Stoichiometry



Selection of a Polyurethane Elastomer for a Specific Application

- Properties Needed for the Job
- Most Probable Failure Mechanism
- Processing Characteristics

  Pot Life

  Ratio Control

  Viscosity

  Demold Time

  Process Temperatures

Polyurethane Elastomer Selection Guidelines

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Property	Greatest	Least
Hardness	N/A	N/A
Tensile Strength	Ester	Ether
Elongation	N/A	N/A
Modulus	N/A	N/A
Tear Strength	Ester	PPG Ether
Compression Set	TDI	MDI
Rebound	MDI Ether	PPG Ether/ Ester
Low Temperature Usage	MDI Ether	TDI Ester
High Temperature Usage	TDI	MDI
Sliding Abrasion Resistance	Ester	PPG Ether
Impingement Abrasion Resistance	MDI Ether	PPG Ether
Heat Buildup	Ether	Ester
Hydrolysis Resistance	MDI Ether	TDI Ester
Oil Resistance	Ester	Ether
Heat Aging	Ester	PPG Ether
Low Cost	PPG Ether	Ether

Polyurethane Elastomer Other Selection Guidelines

Property	Greatest	Least
Low Durometer Formulations (<60A)	TDI Ester	Ether
Formulation Flexibility	MDI	TDI
FDA Dry Food	N/A	N/A
FDA Wet Food	MDI Ester	TDI
Low Cost	PPG Ether	MDI Ether

FDA Food Contact Systems

- Wet Food regulated by 21CFR 177.2600
- Dry Food regulated by 21CFR 177.1680
- Your prepolymer supplier can determine if their resins meet chemical standards
- Wet food approval requires water extraction of final part
- Dry food approval requires abrasion test of final part surface that contacts food
- Wet food formulations chemically qualify for dry food approval with positive abrasion test
- Some catalysts, plasticizers are also allowed

Polyurethane Elastomer Application Selection

Application	Urethane Type	Basis of Choice
Squeegees	MDI Ester	Chemical Resistance
Paper Mill Rolls	TDI Ether	Hydrolysis Resistance, Hardness Stability, Dynamics
Laundry Equipment	MDI Ether	Hydrolysis Resistance
Sandblast Curtains	MDI Ether	High Resilience, Impingement Abrasion Resistance
Hammers	TDI Ester	Tear Resistance, Low Resilience,
Fork Lift Tires	TDI Ether (TDI Ester)	Low Heat Buildup
Grain Handling Equipment	MDI Ester	Abrasion Resistance
Oil Pipeline Pigs	TDI/MDI Ester	Oil and Abrasion Resistance
Roller Skate Wheels	MDI Ether	High Resilience
Printing & Coating Rolls	TDI Ester	Solvent Resistance, Good Physicals at Low Durometers

Low-Free Diisocyanate Prepolymers

(<0.1% Free Diisocyanate TDI, MDI, PPDI, HMDI, etc)

- Easier Processing
  - Lower Viscosity
  - Longer Pot Life
- Better Dynamics
  - Less Heat Buildup
- Health & Safety
  - Easier Plant Engineering Controls

Selecting a Polyurethane Elastomer for a New Application

- Decide What Properties are of Key Importance
  - Physical Requirements and Environmental Resistance
  - Consider most likely Mechanism of Failure
- Select Prepolymer / Curative Systems Which are Likely Candidates
- Consider the Engineering Design of the Part
- Consult Your Suppliers for Recommendations and Further Information
- Review Your Plant/ Processing Capabilities

Selecting a Polyurethane Elastomer for a New Application – Next Steps

- Run Whatever Preliminary Tests are Available
- Make Prototype Units of One or More Candidate Systems
- Field Test in Actual Service,
- Make Comparisons to Existing Materials
- Get Approval from Future Customers
- Gear up for Production

Field Testing – Scrapper Blades

- Is the Scrapper Blade used outside or is in contact with water?
- Is Abrasion the most likely failure mechanism?

Field Testing – Track Pads

- Track Pad is used outside.
- Is Impingement Abrasion Resistance or Sliding Abrasion Resistance most important?
- Is Cut and Tear resistance important?

Field Testing – Chock Blocks

- What materials will bear the load required to keep cargo in place?
- Will the new material be tough enough to resist wear and tear?

Review

- Applications
- Urethane Technology
- Overview
- Why use Urethane elastomers
- Types of Applications
- Comparisons to metal, rubber, and plastic
- Limitations of Urethane
- What Controls Urethane Properties
- Urethane Selection
- Selecting Urethane for a new application
- Field Testing

Thanks for your Attention!

Obrigada pela atenção!

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