Brief History
Orientation of World and NAFTA PU Market Statistics

- Types of Polyurethanes
  - Rigid foam
  - Flexible slabstock, visco-elastic and Molded Foams
  - Coatings, adhesives sealants, elastomers and binders
  - Integral skin foams and reaction injection molding

- Polymer Properties
  - Fundamentals
  - Polymerization reactions
  - Reactant functionality and the effect on cross-linking
  - Crystalline & amorphous polymers

- Urethane Chemistry
  - Fundamentals
  - Reactions of isocyanates
  - Urethane calculations

- Major Component Chemicals Manufacture
  - Polyols from petroleum and renewable resources
  - Isocyanates
  - Prepolymers

- Additives and how they function
  - Catalysts
  - Blowing agents
  - Chain extenders cross-linkers
  - Surfactants
  - Flame retardants
  - Filler & reinforcement agents
  - Color
  - Antimicrobial agents
  - Fragrance
  - Mold release

- Antioxidants & Stabilizers
- Formulating Techniques
- Market Area Examples
  - Flexible
  - Rigid
  - CASE
  - Polyurea

- Safety
- References
1. The “World of Polyurethanes”
   - Polyurethanes in a changing world market
   - The complex technology of polyurethanes: an integration of specialized chemistry, process and equipment.

2. Flexible Polyurethane Foams
   - Cellular structure and chemistry: open cell flexible foams
   - Mechanism of flexible foam formation
   - Types of flexible foams:
     o Conventional flexible foams,
     o High Resilience foams (HR)
     o Combustion Modified foams (CMHR)
     o High load bearing foams
     o Soft/Supersoft foams
     o Viscoelastic foams
     o Renewable polyol based foams
   - Formulation variables effect on foam properties; critical factors for making quality foams; recognizing specific foam quality issues.
   - Manufacturing technologies: slab, molded, spray; equipment specifics
   - Formulating for the diversity of technologies and equipment
   - Choosing proper starting raw materials for the desired properties
   - Combustibility and flame retardants
   - Blowing agents; CO₂ blowing
   - EH&S considerations

3. Rigid Polyurethane Foams
   - Cellular structure and chemistry: closed-cell, open-cell
   - Mechanism of rigid foam formation
   - Types of isocyanate chemistry based rigid foams:
     o PU Foams
     o PIR Foams
     o Modified PIR foams
   - Effect of chemical constituents:
     o Isocyanates, surfactants, catalysts
     o Blowing agents; thermal conductivity, gas diffusion
     o Polyester, polyether, NOP polyols
   - Combustibility and Flame Retardants
   - Diversity in manufacturing technologies:
     o Pour in Place; typical applications: refrigeration, appliances, etc.
Injection technology: some typical applications
- Analysis: pour in place vs. injection
- Discontinuous lines: bunstock-block vs. finished parts molding
- Continuous lines; slabstock; double band lamination and variants
- Spray foam; specifics of formulations and process control; equipment
- Structural building elements. formulation variables
- Formulating for the technologies and equipment available
- Choosing proper starting raw materials for the desired properties
- Recognizing specific foam quality issues

4. Introduction to Polyurethane Composites.
- What is a polyurethane composite?
- Why PU composites?
- Types of PU composites: filled, reinforced, multiple layered structures
- About: mineral fillers, synthetic and natural fibers, filaments, metallic fibers, reinforcements, facing materials
- Composites properties: mechanical, physical, chemical (CLTE, flexural and compression modulus, specific gravity)
- Wetting by a liquid with time-dependent degree of polymerization and viscosity:
  - Air entrapment issues
  - Humidity concerns and its avoidance
  - Other adverse contaminants
  - Release agents, internal mold release
  - Adhesion to facings, inter-laid materials
- Coupling Agents: titanates, silanes
- Composites Manufacturing Technologies:
  - PU Injection technologies: RRIM, SRIM
  - PU Pouring in closed, open molds
  - PU Spray and Froth, lamination on thermoplastics
  - Pultrusion: chemistry and system design, process control issues
  - Composite technologies are “alive”: new, emerging technologies
- Shaping PU composites: molds and dies
- Molds, dies: design issues for quality products
- Examples of commercial composites PU technologies
- Formulating for the technologies and equipment available
- Choosing proper starting raw materials for the desired properties
- Some typical part quality problems
- The potential of PU composites in today’s energy-conscious world.

5. Course Ending Open Discussions:
- Questions and Answers
PU 103: Polyurethane Markets & Applications

Instructor: Brian Fogg
Tuesday, September 25, 2012, 9:00 AM – 4:30 PM
Historical Overview of the Polyurethanes Industry

Polymers and Polyurethanes World and NAFTA Market Statistics

What is Polyurethane and how is it made?

Raw Materials
- Isocyanates
- Polyols
- Additives
- Bio-renewable resources
- Formulating polyurethanes
- Foam formation
- Processing equipment

Rigid Foams
- Explanation of thermal insulation concepts
- Continuous and discontinuous panels
- Slabstock
- Sprayed foam
- One component foam
- Refrigerators and appliances
- In-situ foam
- Insulated pipe
- Molded foam

Flexible Foams
- Concepts of comfort, energy, and sound absorption explained
- Block - flexible polyurethane foam, polyether and polyester foams
- Molded foams for transport and furniture
- Visco-elastic foam
- Carpet backing
- Sound insulation
- Semi-rigid foam
- Integral skin foam

CASE
- Coatings – auto, architectural, roof/deck, wood, textile, leather
- Adhesives – automotive, packing, footwear
- Sealants - construction, automotive, glazing
- Elastomers – cast, TPU, fibers, footwear, synthetic leather.
- Binders – forest products rubber crumb, foundry core

Processing – Mixing Equipment, Molds and Production Lines
Industry Segments:
- Construction
- Automotive and transportation
- Furniture and bedding

Properties of Polyurethanes – Aging and Environmental Effects

Safe Handling

Flammability
PU104A: Polyurethane Sealants, Adhesives and Binders

Instructor: Jim Oconnor
Sunday, September 23, 2012, 9:00 AM – 4:30 PM

The CASE designation: Coatings, Adhesives, Sealants, Elastomers.
- The general differences among the CASE Polyurethanes
- What are the different types / forms of CASE?
- Different types and uses: solvent borne, water borne or 100% solids; one and two component; moisture cure; blocked isocyanates
- Structure property effects, the effect of various components on properties and polymer morphology
- Overview of CASE markets

World Adhesive and Sealant Market and Uses

Overlapping Classification between Sealants and Adhesives

Sealants
- Defining a sealant and the different types
- Advantages /disadvantages of polyurethane sealants
- Properties versus silicones
- Urethane sealant market and different market segments
- Raw materials
- Different sealant types, how to formulate a sealant, some of the unique chemistries utilized in producing a polyurethane sealant
  - One and two component
  - Moisture cure
  - Hybrid sealants
- Testing of Sealants

Adhesives
- Defining an adhesive and the different types
- Adhesive testing
- Advantages /disadvantages of polyurethane adhesives
- Urethane adhesive market and different market segments
- Raw materials
- Different adhesive types
  - Reactive and non-reactive
  - One or two component,
- How to formulate an adhesive
  - One and two component
  - Moisture cure
  - Thermal cure
  - Hybrid adhesives
  - Polyurethane dispersions

Urethane Binders
- Binder Market and Different Market Segments
- Metal casting (foundry)
- Carpet industry
- Construction
- Miscellaneous molded rubber products
The CASE designation: Coatings, Adhesives, Sealants, Elastomers

- The general differences among the CASE Polyurethanes
- What are the different types / forms of CASE?
- Different types and uses: solvent borne, water borne or 100% solids; one and two component; moisture cure; blocked isocyanates

Polyurethane Elastomers (Solid and Microcellular)

- Raw materials
- Structure/property relationships of polyurethane elastomers
  - Basic polymer morphology fundamentals (soft and hard segments)
  - T_g and T_m, how to measure and their importance on physical properties
  - The effect of the different components on properties
- Comparison of urethanes versus non-urethane elastomers
- Market and market segments
- The different types of urethane elastomers, how they are formulated, and the different applications
  - Cast elastomers
    - Prepolymers and quasi prepolymers
  - One shot and RIM
  - Spray elastomers
  - TPU
  - Microcellular elastomers
    - Different foaming techniques

Polyurethane Coatings

What is a coating and how is it applied?

- Raw Materials
- What are the different types of coatings and how are they used?
- What are the advantages and disadvantages of the different technologies?
- Some special chemistries for coatings
- Coatings raw materials
  - The effects of various components on properties
  - Effect of other constituents in the formulation
- Coatings market and different market segments and industry trends
- Urethane coatings versus other technologies
- How to formulate the different coatings types
  - Water borne
  - 100% solids
  - UV/E beam
  - One and two component
  - Moisture cure
  - Blocked isocyanates
- Different testing methods
PU 105: Polyurethane Processing Equipment

Instructors: Christian Decker, Lutz Heidrich, Richard Werner
Monday, September 24, 2012, 9:00 AM – 4:30 PM

Opening Remarks
• Legal notice, anti-trust, fire exits
• Presenter introductions
• Course outline

Metering Machines
• Overview of polyurethane processing machines
• Machine types and capability
• Basic operation via flow sheets (chemical and hydraulic)
• Basic components, parameters, and spare parts
• Types and function of metering pumps and cylinders
• Output rate adjustment
• Shaft sealing and magnetic couplings
• Low and high pressure comparisons

Mixing Head Technologies
• Introduction to the variety of mixing heads
• Design & function of low-pressure mixing heads
• Design & function of high-pressure impingement heads
• Specialty & spray foam mixing heads
• Changing of nozzles and adjusting the mixing pressure
• Nozzle selection, trouble shooting, and regular maintenance

Basic Electrical Control
• Basic metering controls
• Process information and operator interface
• Open and closed loop control
• Chronological sequence of a shot cycle

Plant Design & Special Applications
• Continuous and discontinuous production
• Injection, casting, & spray applications
• Single station applications
• Race track, caurosel, and conveyor systems
• Rotary table systems
• Continuous & slabstock plant design
• Pultrusion plant design

Closing
• Final questions & answers
• Feedback form

Instructors: Victoria Gray, David Mullen, Randy Myrab, Joe Otruba
Monday, September 24, 2012, 1:00 – 5:00 PM

Introduction
- Presenters
- The urethane chemical reaction

Isocyanates (-NCO)
- Isocyanate content as % NCO

Polyols
- Hydroxyl content (-OH)

Other Isocyanate Methods
- Acidity as %HCl
- Viscosity
- Monomer & isomers in polymeric MDI
- TDI isomers
- Color methods

Other Polyol Methods
- Acid number
- Basicity (alkalinity)
- Basicity as % nitrogen
- Water
- Blended and formulated polyol methods

Relationship between Testing and Specifications

Applications or Performance Testing

Conclusions and Open Discussion
PU 204: Physical Testing of Polyurethane Foams

Instructor: Roy Pask
Sunday, September 23, 2012, 1:00 – 5:00 PM

Introduction
- Terminology
- Sample conditioning
- Sample orientation (anisotropic effects)

Rigid foam methods
- Description and discussion

Flexible foam methods
- Description and discussion

Miscellaneous methods
- Description and discussion

Thermal analysis
- DMA, TGA, DSC

Data use and interpretation
- Planning experiments
- Critical properties
- Understanding method precision

Standards
- In-house standards
- Industry standards
- Regulatory standards
- National standards
- International standards