Professional Development Program

Course Outlines

PU 101 - POLYURETHANE CHEMISTRY

Instructor:

Brian Fogg completed 50 years of involvement in the polyurethane industry in 2013. His extensive technical and market experience was obtained working in several countries, with involvement in every aspect of the industry. He holds degrees in Chemistry, Chemical Engineering and Micro-molecular Science. Following a 40 years career in the global PU industry, he now works as an international polyurethane consultant.

The course is divided into two parts:

Morning session – The Chemistry of Polyurethanes

9:00 – 9:30

- Description of Polyurethane - a Brief History
- Short overview of PU market segments.
- Rigid Foam, Flexible Foam and C.A.S.E**.**

9:30 – 10:30

- Introduction to Polymer Chemistry focusing on Polyurethane
- Polymerization Reactions
- Reactant Functionality
- Cross-linking
- Polymer Properties
- Crystalline and Amorphous behavior of Polymers

Morning Break

10:45 – 12:15

- Isocyanates and Polyols Explained - Polyether – Polyester - Pre-polymers – Reactions of Isocyanates - Terminology – Urethane Calculations

Lunch Break

Afternoon session – Raw Materials and Formulating Techniques

1:00 – 1:30

- Manufacture of Isocyanates – MDI/TDI/Aliphatic

1:30 -2:00

- Manufacture of Polyols from Petroleum and Sustainable Resources

2:00 – 3:00

- Additives used in PU Formulating – Explanation of Foam Formation Catalysts – Surfactants – Chain Extenders – Cross-linkers

Afternoon Break

3:15 – 4:00

- Blowing Agents – Thermal conductivity – Flame Retardants
- Fillers and Reinforcement Agents
- Color – UV Stabilization – Anti-oxidants – Stabilizers – Anti-microbial agents – Mold Release

4:00 – 4:30

- Formulating Techniques for Rigid and Flexible Foams, C.A.S.E.

PU 102 – INTRODUCTION TO POLYURETHANE TECHNOLOGY & PRODUCTS

Instructor: Paul Farkas

Course Objective

Technology: *"The purposeful application of information in the design, production and utilization of goods and services and in the organization of human activities"* (**Source: Internet, Business Dictionary).**

Polyurethane Technology: An Integration of **Polymer Chemistry** knowledge with that of specific **Equipment** and manufacturing **Processes**.

The Objective of PDP-102, by way of representative examples, is to elucidate the corroboration and interdependence required of these three technology domains. The course covers PU Foams, the fundament for all later developments, extending into PU Composites, one of the most complex and valuable latest additions.

PDP PU102 is equally useful to attendees who are just beginning their foray in the field of polyurethanes as those interested in a deeper understanding of its potential.

The "World of Polyurethanes"

- Polyurethanes in a changing world market.
- The Complex Technology of the Polyurethanes: an Integration of Specialized Chemistry, Process and Equipment.

Flexible Polyurethane Foams

- Cellular Structure and Chemistry: open cell flexible foams
- Mechanism of flexible foam cell formation
- Types of flexible foams:
    - Conventional flexible foams,
    - High Resilience foams (HR)
    - Combustion Modified foams (CMHR)
    - High load Bearing foams
    - Soft/Supersoft foams
    - Viscoelastic foams
    - 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 required properties while managing costs
- Combustibility issues and flame retardants
- Blowing agents and related issues; CO2 blowing
- EH&S
- Understanding Flexible Foams: Interactive Exercises # 1; # 2

Rigid Polyurethane Foams

- Cellular Structure and Chemistry: Closed cell, Open cell
- Mechanism of Rigid foam formation
- Types of Isocyanate chemistry based rigid foams:
    - PU Foams
    - PIR Foams
    - Modified PIR foams
- Effect of Chemical Constituents:
    - Isocyanates, Surfactants, Catalysts
    - Blowing agents; thermal conductivity, gas diffusion issues
    - Polyester, Polyether, NOP polyols
- Combustibility and Flame Retardants
- Energy Saving through thermal insulation: the role of Rigid PU
- Diversity in Manufacturing Technologies:
    - Pour in Place: Refrigeration, Appliances, Pipe insulation technology, variants.
    - Injection technology: some typical applications
    - Analysis: Pour in place vs. Injection technology
    - Discontinuous lines: Bunstock-Block vs. finished parts molding
    - Continuous lines; Slabstock; Double Band lamination and sandwich panels manufacturing technology
    - Spray foam, building industry, pipe insulation; specifics of formulations and process control; equipment issues
    - Structural Building elements. Formulation variables
- Formulating for the Technologies and Equipment available
- Choosing proper starting raw materials for the required properties while managing costs. Recognizing specific foam quality issues; bio-polyols and polyols based on CO2.
- Understanding Rigid Foams: Interactive Exercises # 3; # 4

Polyurethane Composites

- What is a Polyurethane Composite? Why PU based 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: oils, etc.
    - 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:
    - CSM-Baypreg, Baypreg-NF/Nafpurtec
    - LFI
    - Interwet
    - CSM-Baydur/ Fipurtec, CSM-Multitec
    - Metal-PU-Metal Composites
    - PU Filament Winding
    - PU Vacuum Infusion
    - Agrifiber, Fulcrum
- Formulating for the Technologies and Equipment available
- Choosing proper starting raw materials for the required properties while managing costs
- Some typical part quality problems
- The potential of PU Composites in today's energy conscious world.
- Understanding Composites: Interactive Exercises # 5; # 6

Questions and Answers

PU 103 – POLYURETHANES MARKETS & APPLICATIONS

Instructor:

Brian Fogg completed 50 years of involvement in the polyurethane industry in 2013. His extensive technical and market experience was obtained working in several countries, with involvement in every aspect of the industry. He holds degrees in Chemistry, Chemical Engineering and Micro-molecular Science. Following a 40 years career in the global PU industry, he now works as an international polyurethane consultant.

The course is divided into two parts:

Morning Session – The Markets

9:00 – 10:00

- Historical Overview of the PU Industry – What is Polyurethane?
- Polymers and the Polyurethanes - World, NAFTA, Latin America Market Statistics. Emphasis on NAFTA
- Raw Materials Manufacture and Demand – Isocyanates, Polyols, Additives

10:00 – 10:30

- Rigid Foams, Flexible Foams and C.A.S.E. Markets – Consumption and Growth Trends

Morning Break

10:45 – 11:45

- Overview and Analysis of Market Segments
- Construction –Appliance – Decorative – Leisure
- Residential and Institutional Furniture and Bedding Transportation and Automotive – Seating and Acoustic Insulation
- Coatings – Adhesives –Sealants – Elastomers - (Integral Skin – Footwear –Synthetic Leather - Fibers - Binders)

11:45 – 12:15

- Recycling, By-product and renewable resource materials

Lunch Break

Afternoon session – Applications

1:00 – 1:30

- Equipment and Processing Techniques - Mixing PU – Metering Equipment

1:30 – 2:45

- Rigid Foams
- Explanation of Thermal Insulation Concept – Blowing Agents
- Continuous and discontinuous panels – Slab-stock
- Sprayed Foam - One Component Foam
- Refrigerator and Appliance - In-situ foam - Insulated Pipe -Molded Foam

Afternoon Break

3:00 – 3:45

- Flexible Foams
- Concepts of Comfort and Energy and Sound Absorption explained
- Slab Foam - Polyether – Polyester – Visco-elastic
- Molded Foam for Furniture – Automotive Transportation

3:45 – 4:30

- **C.A.S.E.**
  - **Coatings –** Auto, Architectural, Roof/Deck, Wood, Textile, Leather
  - **Adhesives –** Automotive, Packing, Footwear. Binders - Forest Products - Rubber Crumb, Foundry Core
  - **Sealants -** Construction, Automotive, Glazing
  - **Elastomers –** Cast, TPU, Fibers, Footwear, Synthetic Leather

PU 104A – POLYURETHANE SEALANTS, ADHESIVES & BINDERS

Instructor: **Jim O'Connor**

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 polymer properties and polymer morphology

World Adhesive and Sealant Market and Uses

Overlapping classification between Sealants and Adhesives.

Sealants

- Defining a sealant and the different types (Chemistries and Uses).
- Urethane Sealant market and different market segments
- Advantages /Disadvantages of Polyurethane Sealants
- Properties versus Silicones
- 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 and failure modes.
- Adhesive Testing
- World Adhesives market and different market segments
- Advantages /Disadvantages of Polyurethane Adhesives
- Different adhesive types and Chemistries
    - Urethane vs. Silicone vs. epoxy vs. etc.
    - Reactive and Non-reactive
    - One or two component,
- Raw materials
- How to formulate an adhesive
    - One and two component
    - Moisture cure
    - Thermal Cure
    - Reactive hot melts
    - Hybrid Adhesives
    - Polyurethane Dispersions
    - Latent Reactive

Urethane Binders

- Binder Market and Different Market Segments
    - Metal casting (foundry)
    - Carpet industry
    - Construction
    - Miscellaneous molded rubber products

PU 104B – POLYURETHANE ELASTOMERS & COATINGS

Instructor: Jim O'Connor

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 relationships of Polyurethane Elastomers
  - Basic polymer morphology fundamentals (soft and hard segments).
  - T_g and T_m, how to measure and the effect on physical properties
  - Dynamic Properties of Polyurethanes
  - The effect of the different formulation components on properties.

Polyurethane Elastomers (Solid and Microcellular)

- Comparison of urethanes versus non urethane elastomers
- Raw Materials
- Different Types of Polyurethane Elastomers and 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
  - Millable Polyurethane Elastomers
  - Microcellular elastomers
    - Different foaming techniques

Polyurethane Coatings

What is a coating and how is it applied?

- What is a Paint?
- Who are the top Coatings Companies in the World?
- Different Coatings Resins - Urethane coatings versus other technologies
- Coatings market and different market segments and Industry trends
- VOC Considerations
- Coatings raw materials
  - The effects of various components on properties.
  - Effect of other constituents in the formulation
- How to formulate the different coatings types
  - One and two component
  - 100% solids
  - Moisture cure
  - UV/E beam
  - Blocked isocyanates
  - Water borne

- Different testing methods

PU 105 – POLYURETHANE PROCESSING EQUIPMENT

Instructors: **Christian Decker, Lutz Heidrich, and Dick Werner**

Opening Remarks

- Required Topics: Legal Notice, Anti-Trust, and Fire Exits
- Presenter Introductions
- Course Outline

Metering Machines

- Overview of Polyurethane processing machines
- Basic low pressure machine type and capability
- Low Pressure and High Pressure machine comparisons
- Basic High Pressure machine type and capability
- Basic operation via flow sheets (Chemical & Hydraulic)
- Basic components, parameters, and spare parts

Morning Break

Metering Machines (continued)

- Types and function of metering pumps and cylinders
- Output rate adjustment
- Shaft Sealing and Magnetic Coupling
- Impacts of formulation changes

Lunch Break

Metering Machine Mixing Heads

- Introduction to the variety of mixing heads
- Design & Function of low-pressure mixing heads
- Design & Function of high-pressure impingement heads
- Specialty impingement mixing heads
- Nozzle flow rates and adjusting the mixing pressure
- Spray Foam mixing heads

Electrical Control

- Basic Metering Controls
- Process information and operator interface
- Open and closed loop control
- Chronological sequence of a shot cycle.

Afternoon Break

Plant Design

- Continuous and discontinuous production
- Injection, casting & spray applications
- Single & Multiple Station applications
- Rotary table systems
- Gasketing plant design
- Racetrack, carousel & conveyor systems
- Continuous & slabstock plant design
- Pultrusion plant design

Closing

- Final questions & answers
- Feedback form

PU 201: POLYURETHANE RAW MATERIAL TESTING, SPECIFICATIONS AND PERFORMANCE: "THE MYTH AND THE MAGIC"

Instructor: Nadata Green (Huntsman), Randy Myrabo (BASF), Dave Mullen (Rubicon) and Joe Otruba (Bayer)

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 FOAM

Instructor: **Roy Pask**

Course Objective: This course is designed to give attendees an overview of the many test measurements used to characterize polyurethane foams. It is not meant to make one a testing expert, but rather to create a better understanding of the unique properties of foam. The many types of foam that can be produced make it an extremely versatile product. This versatility, in itself, makes testing foam extremely challenging. The course begins by covering the following subject matter.

- Testing Jargon
- Temperature/Humidity Effects in Manufacturing & Testing
- Anisotropicity in Foam
- Modulus & Poisson's Ratio

It, then, goes through individual test methods.

- Rigid Foam Methods
- Flexible Foam Methods
- Miscellaneous Methods
- Sound/Vibration Methods
- Thermal Analysis Methods

The course concludes with the following subject matter.

- Use and Understanding the Data
- Test Result Variability
- Writing Specifications/Data Sheets
- Types of Standards

Attendees are encouraged to be interactive and ask many questions relevant to their individual job situations.