

# MIXING XV

## 15TH BIENNIAL NORTH AMERICAN MIXING CONFERENCE

JUNE 18-23, 1995  
THE BANFF CENTRE FOR CONFERENCES  
BANFF, ALBERTA, CANADA

Sponsored by  
**NAMEF**

**North American Mixing Forum of the  
American Institute of Chemical Engineers**

Co-sponsor: Working Party on Mixing of the  
European Federation of Chemical Engineering

**Chair: Richard V. Calabrese, University of Maryland (USA)**

## *Program*

### *Sunday, June 18, 1995*

3:00 PM to 9:00 PM	REGISTRATION AND CHECK-IN
5:30 PM to 7:30 PM	DINNER
9:00 PM to 11:00 PM	RECEPTION

### *Monday, June 19, 1995*

7:00 AM to 8:30 AM	BREAKFAST
8:30 AM to 12 Noon	TECHNICAL SESSION

#### **1. Industrial Mixing Practices**

Chairs: I. Midey Chang-Mateu, Rohm and Haas Co. (USA)  
Ramesh R. Hemrajani, Exxon Research and Engineering Co. (USA)

- 1.1 **Art and Science of Mixing Applications in Refinery Operations**  
Ramesh R. Hemrajani, Exxon Research and Engineering Co. (USA)
- 1.2 **Increase in Three Phase Reactor Capacity by Improving Gas-Liquid Dispersion with Smith Turbine Impellers**  
Kulin D. Lodaya, Air Products and Chemicals, Inc. (USA)
- 1.3 **Mixing in Channels for the Water Industry - A Comparison of Model and Full Scale Installations**  
Roger King\*, Steven Hearn, BHR Group Ltd. (UK), Thomas Schofield, Severn Trent Water Plc (UK) and Julian B. Fasano, Chemineer, Inc. (USA)
- 1.4 **Circulation Versus Blend Time**  
James Y. Oldshue, Oldshue Technologies International, Inc. (USA)
- 1.5 **Blending of Miscible Liquids in the Turbulent and Transitional Regimes**  
Richard Grenville\*, Dupont Engineering (USA), Steve Ruszkowski, The Procter & Gamble Co. (USA) and Elisabeth Garred, BHR Group Ltd. (UK)

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- 1.6 **Power Reduction with High D/T Impellers for Fluid Mixing**  
John A. Von Essen, Philadelphia Mixers Corp. (USA)
- 1.7 **Characterization of the Axial Thrust of Agitation Impellers for Flow Controlled Processes**  
James W. Althouse, ProQuip, Inc. (USA)
- 1.8 **Critical Hydraulic Conditions for Complete Solids Suspension in a Mixing Tank**  
Hanna Gladki, ITT Flygt Corp. (USA)
- 1.9 **Measurement and Calculation of Heat Transfer Coefficient to Suspended Solids**  
Wojciech Wyczalkowski, Philadelphia Mixers Corp. (USA)

12:00 Noon to 1:30 PM                      LUNCH

5:00 PM to 6:00 PM                      SOCIAL HOUR

5:30 PM to 7:00 PM                      DINNER

7:00 PM to 10:00 PM                    TECHNICAL SESSION

## 2. **Viscous and non-Newtonian Systems**

Chairs: Philippe A. Tanguy, Ecole Polytechnique-Montreal (Canada)  
E. Bruce Nauman, Rensselaer Polytechnic Institute (USA)

- 2.1 **Turbulent Flow of non-Newtonian Liquids from a Rushton Turbine in a Stirred Vessel**  
B.C.H. Venneker\* and H.E.A. van den Akker, Delft University of Technology  
(The Netherlands)
- 2.2 **Cavern Development in Mixing a Yield Stress Fluid by Different Impeller Combinations**  
L. Serrano-Carreón, A. Martínez, D. Velasco, V. Albiter and E. Galindo\*, Universidad Nacional Autónoma de Mexico
- 2.3 **Mixing of Rheologically Evolving Fluids with a New Mixer-Disperser System**  
Francis Thibault, Philippe A. Tanguy\*, Ecole Polytechnique-Montreal (Canada) and Teodoro Espinosa Solares, Edmundo Brito De La Fuente, Universidad Nacional Autónoma de Mexico
- 2.4 **Using Time-Dependent Flows to Enhance Mixing in Stirred Tank Systems**  
F. J. Muzzio\* and D.J. Lamberto, Rutgers University (USA)
- 2.5 **Laminar Mixing of Incompatible Polymers in Extruders**  
E. Bruce Nauman\*, David Q. He and S. Kwak, Rensselaer Polytechnic Institute (USA)
- 2.6 **The CSTR Extruder**  
D. B. Todd\*, Y. M. Lu and J. A. Biesenberger, Stevens Institute of Technology (USA)
- 2.7 **Fluid Velocity Measurements in Laminar Flow Static Mixers**  
Shaffiq Jaffer and Philip Wood\*, McMaster University (Canada)
- 2.8 **Characterization of Radial Mixing and Residence Time Distribution in Motionless Mixers in Laminar Flow**  
Julian B. Fasano\*, Chemineer, Inc. (USA) and Deepak Doraiswamy, Arthur W. Etchells, Barry Rubin, E.I. du Pont de Nemours & Co., Inc. (USA)

10:00 PM to 11:00 PM                    SOCIAL HOUR

*Tuesday, June 20, 1995*

7:00 AM to 8:30 AM                      BREAKFAST

8:30 AM to 10:10 AM                    TECHNICAL SESSION

**3. Experimental Methods**

Chairs: Gary B. Tatterson, North Carolina A&T State University (USA)  
Douglas E. Leng, The Dow Chemical Company (USA)

**3.1 On Full Field Measurements in Complex Turbulent Mixing Flows**

Robert S. Brodkey, The Ohio State University (USA)

**3.2 Measurements of Fluid Velocities in a Stirred Vessel Using Particle Image Velocimetry**

I. C. Shepherd\* and R.F. La Fontaine, CSIRO Division of Building Construction and Engineering (Australia)

**3.3 A DPIV Investigation of Flow Pattern Instabilities of Axial Flow Impellers**

Kevin J. Myers\*, Richard W. Ward, University of Dayton (USA)  
and André Bakker, Julian B. Fasano, Chemineer, Inc. (USA)

**3.4 Comparison of Turbulence Energy Dissipation for Various Impellers Using Three Experimental Approaches**

Genwen Zhou, Bilyana Grcic and S.M. Kresta\*, University of Alberta (Canada)

**3.5 Analysis of Flow Macro-Instabilities in a Stirred System with Pitched Blade Impeller and Baffles**

Ivan Fort\*, O. Brůha and P. Smolka, Czech Technical University (Czech Republic)

10:10 AM to 10:40 AM                    COFFEE BREAK

10:40 AM to 12 Noon                    TECHNICAL SESSION

**4. High Shear (Stress) Mixers - An Introduction and Overview**

Chairs: Arthur W. Etchells, Du Pont Engineering (USA)  
Mark Meili, The Procter & Gamble Co. (USA)

**4.1 Use of High Shear Equipment in Industry**

Mark Meili, The Procter & Gamble Co. (USA)

**4.2 Drop Generation in a Rotor Stator Mixer**

Douglas Cohen\* and James Ross, Charles Ross & Son Co. (USA)

**4.3 Centrifugal Pumps as High Shear Mixers**

Steven Hearn, BHR Group Ltd. (UK)

**4.4 Preliminary Theories of High Shear Mixing**

Arthur W. Etchells, Du Pont Engineering (USA)

12:00 Noon to 1:30 PM                    LUNCH

5:00 PM to 6:00 PM                    SOCIAL HOUR

*Tuesday, June 20, 1995*

5:30 PM to 7:00 PM                      DINNER

7:00 PM to 10:00 PM                    TECHNICAL SESSION

**5. Liquid-Liquid Systems**

Chairs: G. Narsimhan, Purdue University (USA)  
Costas Tsouris, Oak Ridge National Laboratory (USA)

- 5.1 **Turbulent Hydrodynamic Analysis of a Two-Phase Tubular Reactor**  
S. L. Yarbrow\*, Los Alamos National Laboratory (USA) and  
Richard Long, New Mexico State University (USA)
- 5.2 **Mechanisms of Drop Breakage-Effect of Dispersed Phase Concentration**  
A.M Boye, M. Y.A. Lo and P. Ayazi Shamlou\*, University College London (UK)
- 5.3 **Droplet Breakage in Stirred Dispersions: Breakage Functions from Experimental Drop Size Distributions**  
A. N. Sathyagal, D. Ramkrishna and G. Narsimhan\*, Purdue University (USA)
- 5.4 **Coalescence Phenomena in Liquid-Liquid Dispersions**  
G. Sanchez\*, Intervep SA (Venezuela), G. McGrath, BHR Group Ltd. (UK) and  
A. W. Nienow, University of Birmingham (UK)
- 5.5 **Droplet Size Distributions of a Continuous System with Minimal Retention Time: Example Shown for Copper Solvent Extraction**  
M. Dilley, Davy Process Technology (UK) and C. Bahr, R. Howk, T. Post\*, Lightnin (USA)
- 5.6 **Factors Affecting Formation of Liquid-Liquid Dispersion in a Horizontal Pipe**  
E. Kocianova, IPT Moore\*, University of Birmingham (UK) and K. J. Carpenter, Zeneca FCMO, Ltd. (UK)
- 5.7 **Multivariable Extraction Column Control at Optimal Operating Conditions**  
W. Shen and L. L. Tavlarides\*, Syracuse University (USA)
- 5.8 **Mixing Quality Characterization in Separation Process Tanks: Stages of Dispersion and Scaleup Relationships**  
A.H.P. Skelland, Georgia Institute of Technology (USA) and N. M. Hassan\*,  
Westinghouse Savannah River Co. (USA)

10:00 PM to 11:00 PM                    SOCIAL HOUR

*Wednesday, June 21, 1995*

7:00 AM to 8:30 AM                      BREAKFAST

8:30 AM to 12:00 Noon                   TECHNICAL SESSION

**6. Gas-Liquid Systems**

Chairs: Gary K. Patterson, University of Missouri-Rolla (USA)  
Alvin W. Nienow, University of Birmingham (UK)

- 6.1 **Characterisation of the Flooding Transition of Pitched Blade Turbines**  
D. Birch and N. Ahmed\*, The University of Newcastle (Australia)

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- 6.2 **An Application of Local Void Fraction Measurements in Discharge Flow of Single and Dual Rushton Turbine Impellers**  
A. Bombac\* and I. Zun, University of Ljubljana (Slovenia)
- 6.3 **Gas Behavior in Sparged Reactors Stirred with Multiple Impellers**  
D. Pinelli, M. Nocentini and F. Magelli\*, University of Bologna (Italy)
- 6.4 **Sparged Boiling Reactors: Flow Fields and Agitated Power Draw**  
John M. Smith, University of Surrey (UK)
- 6.5 **A Comparative Study of Aerated Power and the Bulk Blending Characteristics of a Newly Designed Impeller**  
N. G. Ozcan-Taskin, F. Fabreguette, R. B. Badham, K. N. Dyster, Z. Jaworski, IPT Moore, A. W. Nienow\*, University of Birmingham (UK) and J. McKemmie, APV Baker Ltd. (UK)
- 6.6 **Gas-Liquid Hydrodynamics of Aerated Stirred Vessels**  
Harry E.A. van den Akker, Delft University of Technology (The Netherlands)
- 6.7 **Effect of Bubble Size and Size Dispersion on Bubble Column Behavior**  
Gary K. Patterson, University of Missouri-Rolla (USA)
- 6.8 **Gas-Liquid Mass Transfer in a Static Mixer**  
Pavel Dittl\* and Petr Votruba, Czech Technical University (Czech Republic)
- 6.9 **Electrostatic Dispersion of Gases into Liquids**  
C. Tsouris\*, D. W. DePaoli, J. Q. Feng and T. C. Scott, Oak Ridge National Laboratory (USA)

12:00 Noon to 1:30 PM LUNCH

2:00 PM to 6:00 PM POSTER SESSION (includes Social Hour)

## 7. Poster Session

Chairs: Michael Midler, Merck & Co. (USA)  
Roger King, BHR Group Ltd. (UK)

- 7.1 **The FMP Impeller Model: Toward Confident CFD Predictions of Stirred Tank Flows**  
Y. Xu, G. McGrath and R. King\*, BHR Group Ltd. (UK)
- 7.2 **The Effect of Baffles and Rotation on the Shape of the Free Surface in a Stirred Tank**  
Ahmad H. Haidari\* and Boris Makarov, Fluent, Inc. (USA)
- 7.3 **Computation Fluid Dynamics Simulation of Impingement Mixing**  
Sameer Choudhary, C. Kurt Svihla and Thomas R. Hanley\*, University of Louisville (USA)
- 7.4 **Mixing Induced by Feed Pipes in Tubes and Open Channels**  
Joe Hannon, Performance Fluid Dynamics (Ireland)
- 7.5 **CFD Analysis of Cavitation Induced in High-Speed Rotor-Stator Mixers for the Purpose of Creating Sub-micron Dispersions and Performing Cell Lysis**  
Mark L. LeClair, KADY International (USA)
- 7.6 **Analysis of Networks of Zones Models for Steel Converter Pneumatic Mixing**  
M.E. García\* and M. Díaz, University of Oviedo (Spain)
- 7.7 **PDF Simulation of Polymerization in a Tubular Low-Density Polyethylene Reactor**  
Kuochen Tasi\* and Rodney O. Fox, Kansas University (USA)

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- 7.8 **Small Scales in the Turbulent Liquid Flow of Chemical Reactors**  
R.A. Bakker\* and H.E.A van den Akker, Delft University of Technology (The Netherlands)
- 7.9 **Velocity and Turbulence Measurements in a Stirred Tank Using LDV and Autocorrelation Techniques**  
K.P. Barton\*, S.P. Wood and P.A. Gillis, The Dow Chemical Company (USA)
- 7.10 **Effect of Reynolds No. on the Flow Generated by Pitched Blade and High Efficiency Turbines**  
Min-Hua Wang, Richard V. Calabrese\*, University of Maryland (USA), and André Bakker, Chemineer, Inc. (USA)
- 7.11 **Turbulent Flow of Liquid in a Mechanically Agitated Closed Vessel**  
Ivan Fort, Petr Votruba, Czech Technical University and Jaroslav Medek, Czech Academy of Sciences (Czech Republic)
- 7.12 **The Effect of Viscosity on the Mixing Performance of Multiple-Turbine Agitated Tanks**  
Jorge M.T. Vasconcelos, Jorge M. Barata and Sebastião S. Alves\*, Instituto Superior Técnico (Portugal)
- 7.13 **Reversing Impellers: Adaptable Performance with Minimal Complication**  
John M. Smith\*, University of Surrey (UK) and Julian B. Fasano, Chemineer, Inc. (USA)
- 7.14 **A Revisit to the Effect of Baffle Width on Power Drawn in Stirred Tanks**  
A. Martínez, E.J. Vázquez and E. Galindo\*, Universidad Nacional Autónoma de México
- 7.15 **Development of Impeller Prototypes by Selective Laser Sintering Technology**  
Sundeeep Dronawat\*, C. Kurt Svihla and Thomas R. Hanley, University of Louisville (USA)
- 7.16 **The Synthesis of Polymer Blends Via Reactive Extrusion**  
A.J. van der Goot and L.P. B.M. Janssen\*, University of Groningen (The Netherlands)
- 7.17 **The Effect of Shear on the Gelatinization of Starch**  
M.C. van der Burgt and L.B.P.M. Janssen\*, University of Gronigen (The Netherlands)
- 7.18 **Measurement of Turbulent Eddy Diffusivity in Bubble Columns Using Computer Automated Radioactive Particle Tracking (CARPT)**  
Sujatha Degaleesan\* and M.P. Dudukovic, Washington University in St. Louis (USA)
- 7.19 **Correlation of Mass Transfer Coefficient for Vortex Induction of Gas in a Fluid Mixer**  
John A. Von Essen, Philadelphia Mixers Corp. (USA)
- 7.20 **The Performance of Mixed High-Efficiency/Disc Impeller Systems in Gas Dispersion**  
Kevin J. Myers\*, Molly I. Russell, University of Dayton (USA), and Julian B. Fasano, André Bakker, Chemineer, Inc. (USA)
- 7.21 **Oxygen Transfer into non-Newton Liquids in Aerated Stirred Fermenters**  
Luigi Manna and Silvio Sicardi\*, Politecnico di Torino (Italy)
- 7.22 **Scale-up of Tower Bioreactors for Oxygen Limited Cultivation**  
S. Yonsel and W.D. Deckwer\*, GBF-Gesellschaft für Biotechnologische Forschung mbH (FRG)
- 7.23 **Liquid-Liquid Bioreactor Systems for Oil Desulfurization**  
C. Tsouris\*, H.M. Lizama, L.A. Wilkins and T.C. Scott, Oak Ridge National Laboratory (USA)
- 7.24 **Drop Size Distributions in Lean Dispersions: Long Time Results**  
Andrew Lam, A. Sathyagal, Sanjeer Kumar and D. Ramkrishna, Purdue University (USA)

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- 7.25 **Measurement of Rapid Coalescence Under Pure Shear and Highly Turbulent Flow Conditions Using Phase Doppler Anemometry**  
V.P. Mishra\*, S. Kresta and J.H. Masliyah, University of Alberta (Canada)
- 7.26 **Numerical Simulation of Particle Agglomeration**  
Richard V. Calabrese\*, James W. Gentry, S.H. Cheng and J.R. Lin, University of Maryland (USA)
- 7.27 **Solids Suspension in Three-Phase Stirred Vessels**  
R. Parthasarathy, A.R. Aziz, M.A. Hashim, University of Malaya (Malaysia) and N. Ahmed\*, University of Newcastle (Australia)
- 7.28 **The Study of Solids Suspension in Large Scale Stirred Tanks**  
Bee Yung, Andrew Mak and Steven Hearn\*, BHR Group, Ltd. (UK)
- 7.29 **The Effect of Mixing Impeller Geometry and Pumping Direction on Solids Suspension Homogeneity**  
Richard A. Howk, Jeffrey R. Kelly, and Paul M. Kubera\*, Lightnin (USA)
- 7.30 **Ball Formation in Stirred Mineral Fibre Slurries**  
Iain P.T. Moore, University of Birmingham (UK)

5:30 PM to 7:00 PM DINNER

7:00 PM to 10:00 PM TECHNICAL SESSION

## 8. **Mixing Applications in Biotechnology**

Chairs: Enrique Galindo, Universidad Nacional Autónoma de Mexico  
Edmundo Brito-de la Fuente - Universidad Nacional Autónoma de Mexico

- 8.1 **Effect of Mixing on Functionalization of Bacterial Polysaccharides and its Impact on Vaccine Immunogenicity**  
Elizabeth Fisher\*, Cindy Starbuck, Mauricio Futran, John Hennessey and Edward Paul, Merck & Co. (USA)
- 8.2 **Influence of Agitator Geometry on Fungal Morphology**  
Peter Jüsten, University of Birmingham (UK)
- 8.3 **Mixing and Liquid Circulation Times as Key Design and Operating Parameters of Tower Reactors for Oxygen Sensitive Bioprocesses.**  
A. P. Zeng and W. D. Deckwer\*, GBF-Gesellschaft für Biotechnologische Forschung mbH (FRG)
- 8.4 **Optimization and Control of Agitation and Aeration in Fermenters**  
Sebastião S. Alves\*, Irene P. Leitão, Jorge M. Vasconcelos, Instituto Superior Técnico (Portugal) and João M. Lemos, Instituto Nacional de Engenharia de Sistemas e Computadores (Portugal)
- 8.5 **Mixing Characteristics in Bioreactors with non-Newtonian Fermentation Media**  
Y. Kawase\*, M. Tsujimura and T. Shimodaira, Toyo University (Japan)
- 8.6 **Mixing Behavior of a Large Scale Stirred Reactor with Multiple Rushton Turbines**  
Y. Q. Cui\*, RGJM van der Lans and K. Ch.A.M. Luyben, Delft University of Technology (The Netherlands)
- 8.7 **Steady Shear Characteristics of Cellulose Fiber Suspensions and Filamentous Fermentation Broths**  
Sundeep Dronawat, Jennifer Donnelly, C. Kurt Svihla, and Thomas R. Hanley\*, University of Louisville (USA)

10:00 PM to 11:00 PM SOCIAL HOUR





Thursday, June 22, 1995

8:00 PM to 10:00 PM

TECHNICAL SESSION

**10. Computational Fluid Mixing Including Experimental Validation**

Chairs: André Bakker, Chemineer, Inc. (USA)

Harry E.A. van den Akker, Delft University of Technology (The Netherlands)

**10.1 Computational Fluid Mixing of Partial Segregation: Validation Using Visualization of Twin Color Tracers**

R. Mann\* and A. Togatorop, University of Manchester Institute of Science & Technology (UK)

**10.2 Mixing Impellers: Selection and Development Using CFD and LDV**

Ronald J. Weetman, Lightnin (USA)

**10.3 Sliding Mesh Simulation of the Flow Pattern of Axial Pumping Impellers at Low and Intermediate Reynolds Numbers**

André Bakker\*, Chemineer, Inc. (USA), Richard D. LaRoche, Cray Research, Inc. (USA) and Min-Hua Wang, Richard V. Calabrese, University of Maryland (USA)

**10.4 Sliding Mesh CFD Flow Simulations for Stirred Tanks**

Z. Jaworski\*, M.L. Wyszyski, Mechanical Engineering, University of Birmingham (UK), R.B. Badham, K.N. Dyster, I.P.T Moore, A.W. Nienow, N.G. Ozcan-Taskin, Chemical Engineering, University of Birmingham (UK), and J. McKemie, AVP Baker, Ltd. (UK)

**10.5 Modeling and Experimental Studies of the Dual 45° Pitched Blade Turbine System**

Cassian K. Lee\*, Gerrit Hommersom, Stewart P. Wood and Douglas E. Leng, The Dow Chemical Co. (USA)

**10.6 Velocity Profiles in a Baffled Vessel Provided with a Single or Double Pitched-Blade Turbine Agitation System: Comparison Between Experimental LDV Data and Numerical CFD Prediction**

Peiro M. Armenante\* and Chun-Chiao Chou, New Jersey Institute of Technology (USA)

10:00 PM to 11:00 PM

SOCIAL HOUR

Friday, June 23, 1995

7:00 AM to 8:30 AM

BREAKFAST

8:30 AM to 12 Noon

TECHNICAL SESSION

**11. Mass Transfer and Chemical Reaction**

Chairs: Steve Ruszkowski, The Procter & Gamble Co. (USA)

Thomas R. Hanley, University of Louisville (USA)

**11.1 Using Eddy Number Distribution in Isotropic Turbulence for Correlation of Mass Transfer Coefficients**

Zhibing Zhang\* and Colin R. Thomas, University of Birmingham (UK)

**11.2 Quantification of the Mixing Behavior and Homogeneity of Mass Transfer in Static Mixers/Spacers**

C.C. Zimmerer\*, E. Ehni and V. Kottke, University of Hohenheim (FRG)

**11.3 Gas-Liquid Mass Transfer in Pulp Suspension Mixing Operations**

G. Owusu and C.P.J. Bennington\*, The University of British Columbia (Canada)

*Friday, June 23, 1995*

- 11.4 **Mixing Efficiency Quantification by Laser Sheet Visualization**  
B. Marcant\*, E. Vallier and A. Bonnet, Rhone-Poulenc Recherches (France)
- 11.5 **Optical Tomography for Measurement of Concentration Distributions in a Stirred Tank**  
Jamal N. Al-Saeedi, Marianne O. Kirkpatrick and Ralph W. Pike\*, Louisiana State University (USA)
- 11.6 **Jet Reactor Scale-up for Mixing-Controlled Reactions**  
John R. Bourne, ETH Zurich (Switzerland)
- 11.7 **Optimum Jet Mixing for Fast Reactions**  
N. Nour-eddine, L.J. Forney, Georgia Institute of Technology (USA), and Hanh X. Vo\*,  
S.J. Gelderbloom, Dow Corning Corp (USA)
- 11.8 **Fast Competitive Reactions in Agitated Vessels: Status of Scaleup and Design Procedures Using In-Tank Agitators and Static Mixers in Recycle Loops**  
C.S. Knight, W. Roy Penney\*, University of Arkansas (USA), and J.B. Fasano, Chemineer, Inc. (USA)
- 11.9 **Influence of Turbulence Modification by Suspended Particles on Selectivity of Mixing Sensitive Reactions**  
Antonello A. Barresi, Marco Vanni and Giancarlo Baldi\*, Politecnico di Torino (Italy)

12:00 Noon

LUNCH/ADJOURNMENT