

New method to measure the mechanical collection mechanisms of full-scale air filters

*Original*

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# Plenary & Keynote Lectures



Prof. Kuo-Lun Tung  
National Taiwan University  
Taiwan

Nature-inspired separation  
membranes: Geomimicry  
versus biomimicry

PL



Prof. Markus Lehner  
Montanuniversität Leoben  
Austria

Industrial gas cleaning processes –  
Trends and perspectives

K1



Prof. Dietmar Lerche  
L.U.M. GmbH  
Germany

Sedimentation and consolidation  
behavior of stable and flocculated  
suspensions. In situ visualization  
and analysis

K2



Prof. Urs Peuker  
TU Bergakademie Freiberg  
Germany

Separation and classification in the  
size range below 10  $\mu\text{m}$  – Challenges  
and new approaches

K3



Dr. Anthony Stickland  
The University of Melbourne  
Australia

Compressibility effects in solid-  
liquid separation

K4



Prof. Bhaskar Narayan Thorat  
Institute of Chemical Techno-  
logy – India

Solid-liquid separation –  
An Indian Perspective

K5



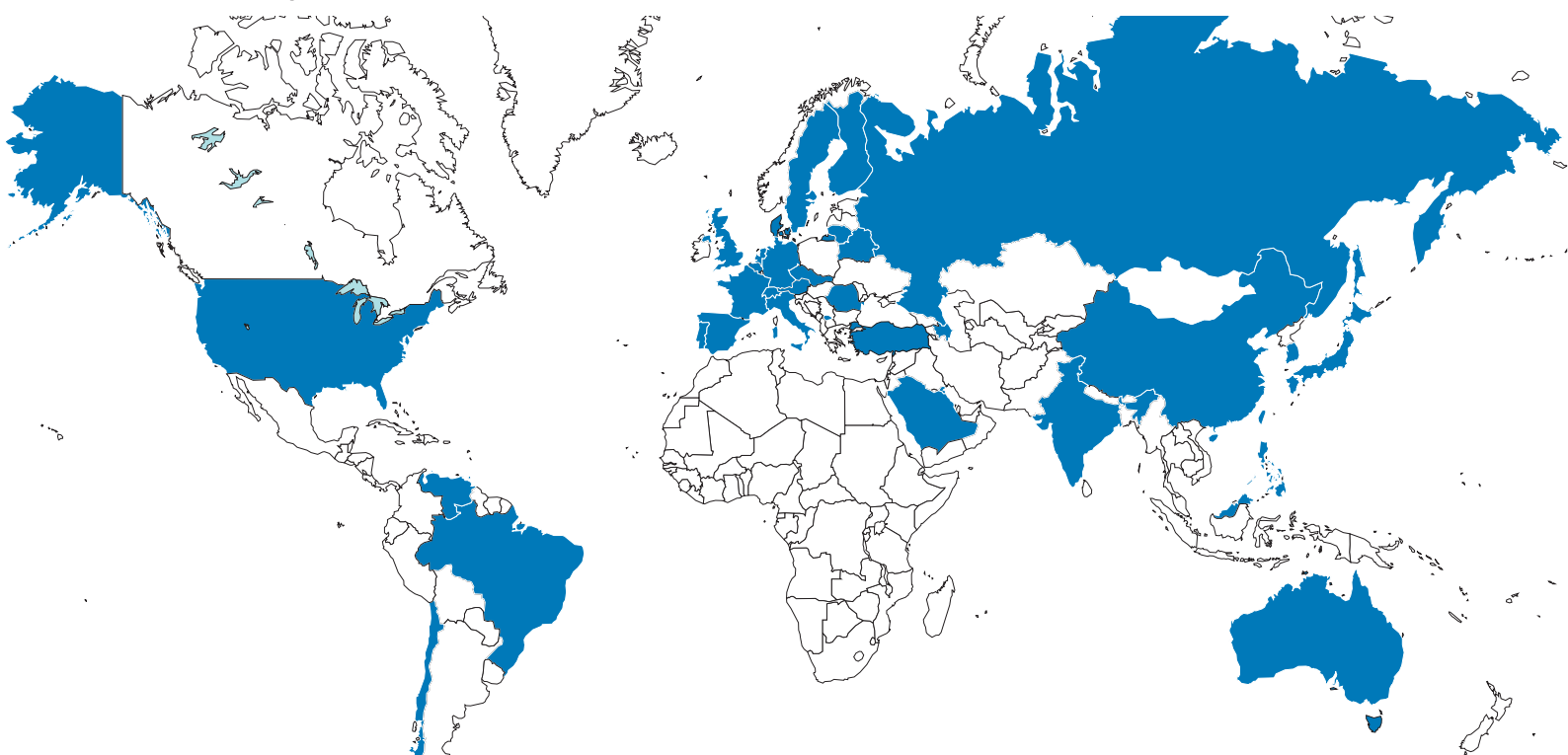
Prof. Mônica Lopes Aguiar  
Universidade Federal de São  
Carlos – Brazil

Separation of particles out of gases  
by fabric filtration

K6

## International Participation

Where FILTECH Speakers come from...



# Session Overview

## Tuesday, 22.10.2013

08:30 – 09:45	Registration				
09:45 – 11:30	<div>Opening Session</div> <div>PL Plenary Lecture – Prof. Kuo-Lun Tung Nature-inspired separation membranes: Geomimicry versus biomimicry</div>				
11:30 – 12:15	Walk Around – Fair				
12:15 – 13:15	Lunch – Fair				
13:15 – 14:30	<div>K1</div> <div>Keynote Lecture 1 Prof. Markus Lehner</div>	<div>L1</div> <div>Cake Filtration-Influences on Cake Properties I</div>	<div>L2</div> <div>Filtration of Metal Melts</div>	<div>L3</div> <div>Classification/Sorting</div>	<div>M1</div> <div>Ceramic Membranes</div>
14:30 – 15:00	Coffee Break – Fair				
15:00 – 16:15	<div>K2</div> <div>Keynote Lecture 2 Prof. Dietmar Lerche</div>	<div>L4</div> <div>Cake Filtration-Influences on Cake Properties II</div>	<div>G1</div> <div>Filter Test Systems I</div>	<div>G2</div> <div>Nano Particle Separation</div>	<div>M2</div> <div>Special Membranes</div>
16:15 – 16:45	Coffee Break – Fair				
16:45 – 18:00	<div>K3</div> <div>Keynote Lecture 3 Prof. Urs Peuker</div>	<div>L5</div> <div>Cake Filtration-Desaturation</div>	<div>G3</div> <div>Filter Test Systems II</div>	<div>G4</div> <div>Airborne Molecular Contaminations</div>	<div>M3</div> <div>Membrane Characterization</div>

## Wednesday, 23.10.2013

08:30 – 09:45	<b>L6</b> Electric / Thermal Separation Enhancement	<b>L7</b> Poster Session I	<b>G5</b> Poster Session I	<b>M4</b> Poster Session I
09:45 – 11:00	Poster Viewing		Poster Viewing	Poster Viewing
11:00 – 12:15	<b>L8</b> Hydrothermal / Enzymatic Separation Enhancement	<b>L9</b> Slurry Concentration / Thickening	<b>G6</b> Surface Filtration I	<b>M5</b> Layer Formation
12:15 – 13:15	Lunch – Fair			
13:15 – 14:30	<b>K4</b> Keynote Lecture 4 Dr. Anthony Stickland	<b>L10</b> Filter Media Cleaning	<b>G7</b> Surface Filtration II	<b>M6</b> Cross Flow Techniques
14:30 – 15:00	Coffee Break – Fair			
15:00 – 16:15	<b>K5</b> Keynote Lecture 5 Prof. Bhaskar Narayan Thorat	<b>L11</b> In-Situ Analysis of Slurry Separation Properties	<b>G8</b> Automotive Application I	<b>M7</b> Ultra Filtration
16:15 – 16:45	Coffee Break – Fair			
16:45 – 18:00	<b>K6</b> Keynote Lecture 6 Prof. Mônica Lopes Aguiar	<b>L12</b> Continuous Cake Filters	<b>G9</b> Automotive Application II	<b>M8</b> Membrane Bio Reactor

## Thursday, 24.10.2013

08:30 – 09:45	<b>L13</b> New Filter Testing Procedures and Apparatus	<b>L14</b> Poster Session II	<b>G10</b> Poster Session II	<b>G11</b> Monitoring and Control
09:45 – 11:00	Poster Viewing		Poster Viewing	
11:00 – 12:15	<b>L15</b> Components for improved Filter Performance	<b>L16</b> Functionalized Filter Media I	<b>G12</b> Particle Deposition	<b>G13</b> Industrial Gas Cleaning
12:15 – 13:15	Lunch – Fair			
13:15 – 14:30	<b>L17</b> Monitoring of Separation Processes	<b>L18</b> Functionalized Filter Media II	<b>G14</b> Numerical Filter Simulation I	<b>G15</b> Cabin Air Filters
14:30 – 15:00	Coffee Break – Fair			
15:00 – 16:15	<b>L19</b> Microscreens / Strainers	<b>L20</b> Depth Filtration in Granular Media	<b>G16</b> Numerical Filter Simulation II	<b>G17</b> Pleated Filter Media
16:15 – 16:45	Coffee Break – Fair			
16:45 – 18:00	<b>L21</b> Coalescer	<b>L22</b> Backwash Filters	<b>G18</b> Numerical Filter Simulation III	<b>G19</b> Special Filter Media

Tuesday, October 22, 2013

## Plenary Lecture

10:30-11:30 h

PL

### Nature-inspired separation membranes: Geomimicry versus biomimicry

Prof. Kuo-Lun Tung  
National Taiwan University, Taiwan

## Keynote Lecture 1

13:15-14:30 h

K1

### Industrial gas cleaning processes – Trends and perspectives

Prof. Markus Lehner, Montan University Leoben, Austria

## Cake Filtration-Influences on Cake Properties I

13:15-14:30 h

L1

Evaluation of filter cake properties in microfiltration of microbial suspensions, N. Katagiri\*, H. Kawahara, E. Iritani, Nagoya University, Japan

Influence of lysozyme crystal morphology on extent of crystal breakage during filter cake compression, B. Cornehl\*, A. Schwab, P. Büser, H. Nirschl, Karlsruhe Institute of Technology, Germany

Influence of ionic strength on the local filtration properties of  $\text{TiO}_2$ , T. Mattsson, J. Wetterling, J. Durruty\*, H. Theliander, Chalmers University of Technology, Sweden

## Filtration of Metal Melts

13:15-14:30 h

L2

Modeling and simulation of metal melt filtration process, E. Werzner\*, M.A.A. Mendes, S. Ray, D. Trimis, Technical University Bergakademie Freiberg, Germany

Development of a model system to investigate the filtration efficiency of ceramic foam filters used in metal melt filtration, F. Heuzeroth\*, U.A. Peuker, Technical University Bergakademie Freiberg, Germany

The influence of particle agglomeration on the filtration efficiency of ceramic foam filters, J. Fritzsche\*, U.A. Peuker, Technical University Bergakademie Freiberg, Germany

## Classification / Sorting

13:15-14:30 h

L3

Classification of zinc sulfide nanoparticles by using size selective precipitation method, Y. Mori\*, S. Komada, K. Tsuchiya, Doshisha University, Japan; D. Segets, W. Peukert, University Erlangen-Nuremberg, Germany

Advances in semi-continuous centrifugal processes for classification of colloidal particles, M. Konrath\*, H. Nirschl, Karlsruhe Institute of Technology, Germany

Magnetically enhanced centrifugation with a longitudinal permanent magnet, J. Lindner\*, K. Menzel, H. Nirschl, Karlsruhe Institute of Technology, Germany

## Ceramic Membranes

13:15-14:30 h

M1

Enhanced oil recovery monitoring for oilfield produced water treatment using rotating ceramic membranes, B. Schnabel\*, M. Ebrahimi, O. Schmitz\*, S. Kerker, J. Hild, P. Czermak, University of Applied Sciences Mittelhessen; C. Gutman, M. Aden, Faudi Aviation Sensor GmbH, F. Liebermann, Novoflow, Germany

Assessment of the process performance of produced water treatment with ceramic membranes through integration of online oil-monitoring, S.J. Kerker\*, M. Ebrahimi, J. Hild, P. Czermak, University of Applied Sciences Mittelhessen; A.A. Schmidt, DECKMA HAMBURG GmbH, Germany

Microfiltration of waxy maize starch hydrolysate to isolate starch nanocrystals, A. Romdhane\*, M. Aourousseau, A. Guillet, E. Mauret, Grenoble INP-Pagora; J. Yao, N. Hengl, S. Baup, F. Pignon, University Joseph Fourier Grenoble, France



## Keynote Lecture 2

15:00-16:15 h

K2

Sedimentation and consolidation behavior of stable and flocculated suspensions. Direct in situ visualization and analysis, Prof. Dietmar Lerche, L.U.M. GmbH, Germany

## Cake Filtration-Influences on Cake Properties II

15:00-16:15 h

L4

Cake formation and particle rejection in filtration of binary mixtures of particles with different sizes, E. Iritani\*, N. Katagiri, Y. Ishikawa, Nagoya University, Japan

A new filtration law for fiber suspensions based on the random rod packings, A.P. Philipse\*, Utrecht University, Netherlands

The Blaine index measurement and correlation to average specific cake resistance, M. Huhtanen\*, R. Salmimies, D. Safonov, A. Kraslawski, A. Häkkinen, Lappeenranta University of Technology; J. Palmer, B. Ekberg, Outotec Filters, Finland

## Filter Test Systems I

15:00-16:15 h

G1

Influence on the clean gas volume on the transient differential pressure during jet pulse cleaning in a filter media testing rig, O. Kurtz\*, G. Kasper, J. Meyer, Karlsruhe Institute of Technology, Germany

Semi-automated gas turbine inlet filter testing according ARAMCO standard or for performance optimization, D. Renschen\*, J. Schamberg, DMT GmbH & Co. KG; N. Guttentbrunner, N. Schneider, Bilfinger-Gerber GmbH, Germany

New method to measure the mechanical collection mechanisms of full-scale air filters, P. Tronville\*, Politecnico di Torino, Italy; R. Rivers, EQS Inc., USA

## Nano Particle Separation

15:00-16:15 h

G2

Evaluation of the behaviour and performance of a polypropylene filter in removing nanoparticles, P.M. Barros\*, M.L. Aguiar, Federal University of São Carlos, Brazil

Influences on the fractional separation efficiency determination of air filter media in the size range of 5 nm up to 1 µm, M. Schmidt\*, Palas® GmbH, Germany

Intensification of nanoparticles collection efficiency in a bubble column, M.-C. Cadavid-Rodriguez\*, D. Bémer, INRS - Institut National de Recherche et de Sécurité; A. Charvet, D. Thomas, LRGP - Laboratoire Réactions et Génie des Procédés, France

## Special Membranes

15:00-16:15 h

M2

Wet chemicals ultrapurification for the electronic industry by reverse osmosis membrane cascades, R. Abejón\*, A. Gareia, A. Irabien, University of Cantabria, Spain

Relationship between preparation conditions of nanofiber membrane and filtration performances of Particle Suspensions, Y. Mukai\*, K. Takiguchi, E. Amano, Nagoya University, Japan

Tubular membrane filtration for lime softening water treatment, D. Frick\*, POREX Filtration, USA

## Keynote Lecture 3

16:45-18:00 h

K3

Separation and classification in the size range below 10 µm – Challenges and new approaches, Prof. Urs Peuker, Technical University Bergakademie Freiberg, Germany

## Cake Filtration-Desaturation

16:45-18:00 h

L5

Desaturation and/or consolidation – Limits of mechanical dewatering of filter cakes, H. Anlauf\*, Karlsruhe Institute of Technology, Germany

Dryness limit: A useful parameter to assess sludge dewatering, P. Ginisty\*, F. Guei, IFTS International Filter Testing Services; J. Olivier, J. Vaxelaire, Université de Pau et des Pays de l'Adour; R. Girault, J. Tosoni, IRSTEA, France

Dewatering mechanisms of compressible filter cakes, S. Strubel\*, H. Anlauf, H. Nirschl, Karlsruhe Institute of Technology, Germany

## Filter Test Systems II

16:45-18:00 h

G3

Air filter testing under overpressure up to 10 bar and isobaric conditions in accordance with ISO 12500, S. Schütz\*, L. Mölter, Palas® GmbH, Germany

Not all air filters class F7 to EN 779:2012 are created equal, J. H. Wenzek\*, FT & C BV; L. Delfs, J. Verlaan, AFPRO Filters B.V., Netherlands





**Comparison of the particle penetration through personal protection filter media using three different test methods**, H.-G. Horn\*, TSI GmbH, Germany; T. Johnson, TSI Inc., USA

**Airborne Molecular Contaminations**  
16:45-18:00 h

**G4**

**Filtration for advanced AMC control for leading-edge microelectronics manufacturing**, C. Muller\*, R. van Dijke, A. Edeling, Purafil, Inc, USA

**Performance of adsorptive materials - Test line based on FT-IR as an analytical method**, M. Puutio\*, S.-L. Jäppinen, Defence Forces Technical Research Centre, Finland

**Assessment of gas cleaning systems for removing AMC and TIC / TIM**, H. Finger\*, U. Schneiderwind, W. Mölter-Siemens, S. Haep, D. Bathen, Institute for Energy and Environmental Technology (IUTA), Germany

**Membrane Characterization**  
16:45-18:00 h

**M3**

**Capillary flow porometry a tool for the characterisation of pore size distribution of through pores in filters and membranes**, C. Agarwal, A.K. Pandey, A. Goswami, Bhabha Atomic Research Centre, India; D. Pattyn\*, A. Cano-Odena, Porometer, N.V., Belgium

**Empirical evaluation of measurement uncertainty of vickers hardness of ceramic filter media**, M. Mannila\*, A. Häkkinen, Lappeenranta University of Technology, Finland

**Application of ceramic multi-channel flat membranes for filtration of digestate sewage**, H. Heymer, H.-J. Richter, O. Scheithauer\*, B. Fassauer, J. Adler, Fraunhofer-Institute for Ceramic Technologies and Systems, Germany

## Wednesday, October 23, 2013

**Electric / Thermal Separation Enhancement**  
08:30-09:45 h

**L6**

**Electrodewatering of wastewater sludge: Factors affecting kinetics and energy consumption**, J.-B. Conrardy\*, J. Olivier, J. Vaxelaire, Université de Pau et des Pays de l'Adour, France

**Optimisation of the mineral sludge pressure electro-dewatering: Combination of flocculation, electric treatment and cake heating**, M. Citeau, M. Loginov\*, N. Lebovka, O. Larue, E. Vorobiev, University of Compiègne, France

**Dehydration: Coupling centrifuge drainage with microwave drying operation**, X. Apaolaza, P. Ginisty\*, IFTS International Filter Testing Services; M. Valat, W. Jomaa, A. Sommier, Bordeaux et Arts et Métiers ParisTech, France

**Poster Session I**  
08:30-09:45 h

**L7**

**BASP Star Filter to replace cartridge filters - In continuous operating large chemical plants**, B. Patil\*, BASP Industries, India

**Filtration of emulsified polymer waste water**, B. Patil\*, V. Patil, BASP Industries, India

**Flocculation behaviour of colloidal suspension by use of inorganic and polymer flocculants in powder form**, H. Kadooka\*, Y. Kiso, T. Tanaka, M. Iwata, Osaka Prefecture University, Japan; M.S. Jami, Islamic University Malaysia, Malaysia

**Simplified flocculation model for inorganic and polymer flocculants**, H. Kadooka\*, T. Tanaka, M. Iwata, Osaka Prefecture University, Japan; M.S. Jami, Islamic University Malaysia, Malaysia

**Analysis of solid concentration distribution in batch sedimentation for viscous Newtonian and Non-Newtonian fluids**, B.A. Moreira, F.O. Arouca, J.J.R. Damasceno\*, Federal University of Uberlândia, Brazil

**Antisolvent crystallization and pressure filtration of salicylic acid: Influence of mixing conditions**, S. U. Deulgaonkar\*, B. N. Thorat, Institute of Chemical Technology (Formerly UDCT), India; A. Häkkinen, Lappeenranta University of Technology, Finland

**Determination of permeability characteristics of solid/liquid separation using simplex algorithm**, T. Tanaka\*, H. Kato, R. Fukuyama, N. Hayashi, M. Iwata, Osaka Prefecture University, Japan; M.S. Jami, Islamic University Malaysia, Malaysia

**Flushing - filter cake washing with miscible and immiscible fluids**, M. Wilkens, M. Burisch\*, U.A. Peuker, Technical University Bergakademie Freiberg, Germany

**Analysis of centrifugal dewatering: Consolidation behaviour with and without supernatant**, R. Fukuyama\*, T. Tanaka, M. Iwata, Osaka Prefecture University, Japan; M.S. Jami, Islamic University Malaysia, Malaysia

**Preparation of activated carbon electrodes for water purification**, N. Hoda\*, E. Bayram, B. Uysal, Akdeniz University, Turkey

**Electrosorption of aromatic organic compounds onto activated carbon electrodes for water purification**, B. Uysal, M. B. Adanali, F. Sakliyan, E. Bayram\*, Akdeniz University, Turkey

**Poster Session I**  
08:30-09:45 h

**G5**

**Analysis of the effect of the filtration velocity in hot gas filtration**, B. Alonso-Fariñas\*, M. Lupion, M. Rodriguez-Galan, V. J. Cortes, B. Navarrete, University of Seville, Spain

**Evaluation of cake porosity behaviour under high pressure conditions**, E.H. Tanabe\*, Federal University of Santa Maria; B.J.C. Castro, M.L. Aguiar, Federal University of São Carlos, Brazil

**Simulation of the dust cake build-up on surface filters**, S.M.S. Rocha, E.R. Nucci\*, Federal University of São João Del Rei; M.L. Aguiar, Federal University of São Carlos, Brazil

**Behaviour of the number of cycles of filtration and pulse-jet cleaning on polypropylene fabric filter**, S.S.R. Cirqueira, P.M. Barros\*, M.L. Aguiar, Federal University of São Carlos, Brazil

**A comparative assessment of existing gas-solid filtration systems and a novel pulse-less filter**, S.D. Sharma\*, K. McLennan, M. Dolan, A.Ilyushechkin, CSIRO Energy Technology, Australia

**New development in fabric filter design leading to lower CAPEX**, L. Gamborg\*, K. Skriver, C.-V. Rasmussen, K. Poulsen, FLSmidth A/S, Denmark

**Filtration of dust particulates using a granular bed filter**, Y.-S. Chen\*, Y.-P. Chyow, S.-C. Li, Atomic Energy Council; S.-S. Hsiao, National Central University, Taiwan

**Evaluation of the efficiency in the bioaerosols eradication of filters doped with silver nanoparticles**, P.F. Rosa, A. Bernardo, M.L. Aguiar\*, Federal University of São Carlos, Brazil

**Nanofibre structures in bacteria deactivation and removal from wastewater and polluted air**, D. Kimmer\*, I. Vincent, SPUR a.s., J. Lev, ASIO spol. s r.o.; L. Kalhotka, Mendel University of Brno; P. Mikula, Institute of Botany of the ASCR; R. Korinkova, COC s.r.o.; M. Zatloukal, Tomas Bata University in Zlin, Czech Republic

**Separation of particles out of air by individual flat movable collectors**, G. Reznik\*, E. Schmidt, University of Wuppertal, Germany



**Poster Session I**  
08:30-09:45 h

**M4**

**Simulation of FIB-SEM images for segmentation of porous microstructures**, T. Prill, K. Schladitz\*, Fraunhofer Institute for Industrial Mathematics ITWM, Germany

**Analysis and modelling of the microstructure of ceramic foams**, J. Kampf, C. Redenbach\*, University of Kaiserslautern, Germany

**A reliable method for approximating the PPI value of foams**, A. Moghiseh\*, J. Ohser, University of Applied Sciences Darmstadt; C. Redenbach, University of Kaiserslautern, Germany

**Ceramic nanofiltration membranes in chemical and pharmaceutical applications**, S. Düscher\*, Inopor GmbH, Germany

**Preparation and properties of thin film composite membranes by a spin coating method**, M. Karthik\*, A.K. Suresh, Indian Institute of Technology Bombay, India

**Treatment of textile effluents using membrane provided from FP7 collaborative project (BioNexGen)**, E.A. Abdel-Aal\*, Central Metallurgical Research and Development Institute, Egypt



**Removal of cesium from contaminated water using affinity membrane prepared by combining nanofiber with iron ferrocyanide**, A. Mizuno\*, Y. Mukai, Nagoya University, Japan

**New ways of mobile drinking water purification for disaster response and military**, M.K. Saygin, J. Raiser\*, R. Schönfeld, Blücher GmbH, INC Leipzig, Germany

**Compact module for simultaneous particle filtration and disinfection of aqueous media in chilling units**, B. Gemende\*, A. Gerbeth, R. Hahn, N. Pausch, S. Röhlig; University of Applied Sciences Zwickau; J. Bossert, Friedrich Schiller University Jena; W. Schellbach, A. Werner, OFS Online Fluid Sensoric GmbH, Germany

**Separation of gentamicin C<sub>1</sub> from biosynthetic gentamicins by facilitated pertraction for increasing antibiotic activity**, A.C. Blaga\*, D. Cascaval, L. Kloetzer, Technical University of Iasi; A.I. Galaction, University of Medicine and Pharmacy of Iasi, Romania

**Study on separation of folic acid by synergic reactive extraction**, L. Kloetzer\*, A.C. Blaga, D. Cascaval, Technical University of Iasi; A.I. Galaction, University of Medicine and Pharmacy of Iasi, Romania

**Operations of direct contact membrane distillation and vacuum membrane distillation on seawater desalination**, T.W. Cheng\*, K.-L. Yeh, Tamkang University, Taiwan

**Simulation and experimental studies of multi-effect air gap membrane distillation on saline water desalination**, C.-D. Ho\*, C.-H. Cheng, T.-J. Yang, Tamkang University, Taiwan



## Hydrothermal / Enzymatic Separation Enhancement

11:00-12:15 h

**L8**

**Effect of hydrothermal reaction conditions on filtration performance of sewage sludge**, N. Kobayashi\*, K. Nakayama, S. Tachibana, Y. Tanabe, Nagoya University; Y. Itaya, Gifu University, Japan

**Reduction of fiber size during enzymatic hydrolysis of biomass and determination of filtration properties of biomass suspensions**, T. Kinnarinen\*, A. Häkkinen, Lappeenranta University of Technology, Finland

**Use of filter aids for improving the filterability of biomass suspensions**, M. Golmaei\*, T. Kinnarinen, A. Häkkinen, Lappeenranta University of Technology, Finland

## Slurry Concentration / Thickening

11:00-12:15 h

**L9**

**Reducing energy footprint of a waste water treatment plant by increasing harvesting efficiency of solids during primary clarification**, A.R. Völkel\*, H.B. Hsieh, N. Chang, A. Kole, K. Melde, M. Stephenson, M. Sheridan, D. Johnson, Palo Alto Research Center, Inc., USA

**Optimisation of throughput of a dynamic cross flow filter by adding coarse particles to the retentate**, G. Grim\*, Andritz KMPT GmbH, Germany

**Properties of the lautering filter cake structure evaluated by x-ray microtomography**, M. Kuhn\*, K. Mathmann, J. Engstle, P. Först, H. Briesen, Technical University Munich, Germany

## Surface Filtration I

11:00-12:15 h

**G6**

**Filter performance under non-uniformly distributed cake**, M. Koch, G. Krammer\*, Graz University of Technology, Austria

**Dust emission and operation performance of pulse cleaned needle felts in a pilot-size bag house filter for different operation parameters**, O. Kurtz\*, J. Meyer, G. Kasper, Karlsruhe Institute of Technology, Germany

**Characterization of industrial surface filter in pulse-jet filtration**, A.K. Choudhary, A. Mukhopadhyay\*, National Institute of Technology Jalandhar, India

## Layer Formation

11:00-12:15 h

**M5**

**Investigation of the filterability of beer using different layer formation in the static and dynamic membrane filtration**, M. Kupetz\*, M. Zarnkow, T. Becker, Technical University Munich, Germany

**Effects of membrane morphology on the performance of cross-flow microfiltration of protein/polysaccharide mixtures**, K.-J. Hwang\*, Y.-C. Chiang, Tamkang University, Taiwan

**Validation of a long channel membrane test cell (LCMTC) for investigation of fouling in RO systems**, W. Uhl\*, N. Siebrath, W. Ding, A. Lerch, E. Pietsch, Technische Universität Dresden, Germany; H. Vrouwenvelder, Delft University of Technology, Netherlands

## Keynote Lecture 4

13:15-14:30 h

**K4**

**Compressibility effects in solid-liquid separation**, Dr. Anthony Stickland, The University of Melbourne, Australia

## Filter Media Cleaning

13:15-14:30 h

**L10**

**Cleaning of filter media in solid liquid separation**, H. Nirschl\*, C. Weidemann, Karlsruhe Institute of Technology, Germany

**Chemical regeneration of a ceramic filter medium used in hematite dewatering**, R. Salmimies\*, M. Matveinen, A. Häkkinen, Lappeenranta University of Technology; B. Ekberg, Outotec (Filters) Oy, Finland

**Influence of magnetic fields on the adhesive behaviour of magnetizable particles – Simulation and verification**, J. Knoll\*, H. Nirschl, Karlsruhe Institute of Technology; A. Haarmann\*, E. Schmidt, University of Wuppertal, Germany

## Surface Filtration II

13:15-14:30 h

**G7**

**Modeling the pressure drop of cleanable dust filter media during aging in laboratory test rigs**, M. Stecher\*, G. Matuschitz, W. Höflinger, Vienna University of Technology, Austria

**Multiple-use of precoat materials for the fine dust filtration of a baghouse filter for wood-fired heaters**, S. Schiller\*, H.-J. Schmid, University of Paderborn, Germany

**Drum filter with cleanable filter media for the separation of fibrous dust including nano particles**, J. Wolflechner\*, T. Laming, W. Höflinger, Vienna University of Technology, Austria

## Cross Flow Techniques

13:15-14:30 h

**M6**

**The role of an electrical field for the fractionation of milk peptides**, A. Holder\*, J. Weik, J. Hinrichs, University of Hohenheim, Germany

**Dynamic polishing filter in metallurgical water treatment**, P. Rantala, V. Hakala\*, Sofi Filtration Ltd., Finland

**Application of Si<sub>3</sub>N<sub>4</sub>-microsieves in laboratory scale filtration for a rapid detection of microorganisms in beverage industries**, R. Novy\*, J. Tippmann, T. Becker, Technical University Munich, Germany

## Keynote Lecture 5

15:00-16:15 h

**K5**

**Solid-liquid separation – An Indian perspective**, Prof. Bhaskar Narayan Thorat, Institute of Chemical Technology Mumbai, India

## In-Situ Analysis of Slurry Separation Properties

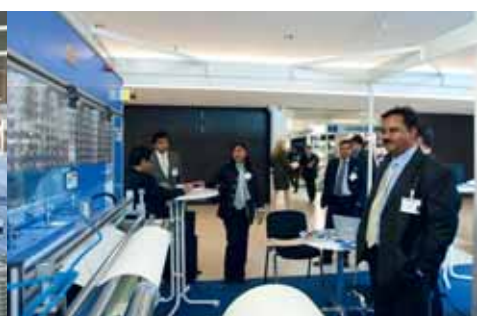
15:00-16:15 h

**L11**

**Multistage centrifugation (MC): A new method for quantitative evaluation of filterability using the analytical photocentrifuge**, M. Loginov\*, M. Citeau, N. Lebovka, E. Vorobiev, University of Compiègne, France

**Experimental determination of velocity distributions at gravity: In-situ measurement by STEP-Technology**, T. Sobisch, H. Woehlecke, D. Lerche\*, LUM GmbH, Germany

**In-situ characterization of separation behaviour of aqueous metal oxide dispersions as function of pH and electrolyte**, T. Sobisch, D. Lerche\*, LUM GmbH, Germany





#### Automotive Application I

15:00-16:15 h

G8

**Small cause – Large effect: Nanofiber technology for engine air filtration**, I. Poljak\*, A. Kilian, M. Heim, M. Lehmann, MANN + HUMMEL GmbH, Germany

**High performance air intake module for trucks: Combination of high efficient nanofiber filter medium and innovative filter element concept**, B. Renz\*, A. Enderich, C. Feuchter, M. Steppe, M. Traub, MAHLE Filtersystems GmbH, Germany

**Morphology of particle deposits on oil treated model filter fibers and the associated impact on efficiency evolution**, T.K. Müller\*, J. Meyer, G. Kasper, Karlsruhe Institute of Technology; E. Thébaud, MANN+HUMMEL GmbH, Germany

#### Ultra Filtration

15:00-16:15 h

M7

**Development of ultrafiltration processes for recovery of hemicelluloses from wood extracts**, M. Kallioinen\*, E. Koivula, T. Nevalainen, M. Al-Manasrah, T. Sainio, M. Mänttari, Lappeenranta University of Technology, Finland

**Selective separation of bio-compounds by biological membranes permeabilized by pulsed electric field: a new way for "green" purification technologies**, E. Vorobiev\*, Technical University of Compiègne, France

**Micellar enhanced ultrafiltration: More than water treatment**, M. Schwarze\*, L.A.T. Nguyen, M. Schmidt, M. Göttker, M. Kraume, R. Schomäcker, Berlin Technical University; A. Drews, HTW Berlin University of Applied Science, Germany

#### Keynote Lecture 6

16:45-18:00 h

K6

**Separation of particles out of gases by fabric filtration**, Prof. Mônica Lopes Aguiar, Federal University of São Carlos, Brazil

#### Continous Cake Filters

16:45-18:00 h

L12

**Separation and washing of fatty acids from acetone on a BHS belt filter in pressure tight design**, S. Ahlert\*, BHS-Sonthofen GmbH, Germany

**Hi-Bar filtration with large filters units**, R. Bott\*, T. Langeloh, BOKELA GmbH, Germany

**Applicability of filter cake steam conditioning in hyperbaric disk filters**, K. Hausharter, R. Raberger, G. Krammer\*, Andritz AG, Austria

#### Automotive Application II

16:45-18:00 h

G9

**A new type of compact aerosol centrifuge**, M. Junker\*, M. Piesche, University of Stuttgart, Germany

**Study and development of synthetic composite non-woven filter media using specialty fibres dedicated to dust filtration application**, W. Jabri\*, P. Vroman, A. Perwuelz, University Lille Nord de France, France

**Size and rate consideration of entrainment from oil-mist filters for different operating conditions**, S. Wurster\*, D. Kampa, J. Meyer, G. Kasper, Karlsruhe Institute of Technology, Germany; B. Mullins, Curtin University of Technology, Australia

#### Membrane Bio Reactor

16:45-18:00 h

M8

**Intensification of a fermentation process for producing lactic acid in a ceramic membrane combined bioreactor system**, R. Fan\*, M. Ebrahimi, P. Czermak, University of Applied Sciences Mittelhessen; M. Aden, Faudi Aviation Sensor GmbH, Germany

**Anaerobic membrane reactor (AMBER) for industrial wastewater treatment – Comparative operation of different membrane types**, U. Theilen\*, S. Herbert, University of Applied Sciences Mittelhessen; U. Witte, U. Austermann-Haun, J. F. Meier, University of Applied Sciences Ostwestfalen-Lippe, Germany

**Sustainable process water treatment with membrane bioreactors**, C. Hoffmann\*, A. Rach, Microdyn-Nadir GmbH, Germany

### Thursday, October 24, 2013

#### New Filter Testing Procedures and Apparatus

08:30-09:45 h

L13

**New international standard test methods of aerospace filters**, C. Peuchot\*, IFTS International Filter Testing Services, France

**How to compare performances of domestic pools and spas filters**, C. Peuchot\*, H. Saidani, IFTS International Filter Testing Services, France

**Hi pressure filterability and compressibility test cell**, J. P. Féraud\*, D. Bourcier\*, D. Ode, CEA Marcoule; F. Puel, Université de Lyon, France

#### Poster Session II

08:30-09:45 h

L14

**An experimental approach to get high performance in coal filtration with filter press**, E. Babin, D. Collini\*, A. Grosso, F.Kaswalder, L. Tozzola, Bilfinger Water Technologies srl, Italy

**Removal of emulsion droplets by immobilization in calcium alginate gel**, N. Hayashi\*, T. Tanaka, R. Yamada, M. Iwata, Osaka Prefecture University, Japan; M.S. Jami, Islamic University Malaysia, Malaysia

**Material and equipment for water purification from lead**, G.V. Medyak, V.I. Sokolova, A.A. Shunkevich, A.V. Bilydukevich\*, V.P. Sokol, A.P. Polikarpov, National Academy of Sciences of Belarus, Belarus

**Pigment separation by adsorption on coconut shell triturated**, D.B. Soto, M.P. Gomes, P.S.S. Porto, S. M.S. Rocha\*, Federal University of Espírito Santo, Brazil

**Using biosorbent filters for removal of copper from water**, S. M. Alfadul\*, Mohammad A. Khiyami, King Abdulaziz City for Technology, Saudi Arabia

**Disinfection of secondary effluents by using slow sand filtration combined with electric fields – Contribution for direct reuse of domestic wastewater**, D. Haaken, V. Schmalz, T. Dittmar\*, E. Worch, Technische Universität Dresden, Germany

**Feasibility of modeling by adsorption the low gradient magnetic separation of iron nanoparticles**, F. Lancellotti, H.K. Hansen\*, P. Núñez, F. Retamal, Technical University Federico Santa María, Chile

**Chemical measurements of boiler acid cleaning**, N.S. Al-Deffeeri\*, Ministry of Electricity & Water, Kuwait

**Nordson adhesive application technology - Save overall production cost and enhance sustainability by integrating future technology**, S. Müller\*, J. Klein, Nordson Deutschland GmbH, Germany



#### Poster Session II

08:30-09:45 h

G10

**Saving energy with lower-pressure-drop filtration media**, I. Parker\*, Ahlstrom, Filtration LLC, USA; S. Chavan, Ahlstrom Research Services, France; G. Costa, Ahlstrom Italy s.p.a., Italy

**Particle deposition within fiber filters using Open-FOAM**, N. Riefler\*, U. Fritsching, IWT Institute; M. Becker, U. Heck, DHCAE Tools GmbH, Germany

**A new approach in modeling the porous-fluid interface for CFD simulations of pleated filter elements**, A. Traut\*, Graduate School of Excellence in advanced Manufacturing Engineering Stuttgart; A. Beck, M. Lehmann, MANN+HUMMEL GMBH, Germany; M. Ali, Indian Institute of Technology Kanpur, India

**The applicability investigation on two models for porous airfilters**, Y. Sun, J.J. Lu, China North Vehicle Research Institute, China; L.-P. Cheng\*, Fraunhofer Institute for Industrial Mathematics ITWM, Germany

**A CFD preliminary study of filtration of gases at high pressures**, G.C. Lopes\*, M.L. Aguiar, Federal University of São Carlos, Brazil

**Computational fluid dynamics (CFD) study of air flow and deposition of particles in bifurcated ducts resembling human lungs**, L.L.X. Augusto, C.C.C. Silva, J.A.S. Gonçalves\*, Federal University of São Carlos, Brazil

**Numerically optimized cyclones for value-added product recovery**, J. Paiva, P. Araujo\*, Advanced Cyclone Systems, R. Salcedo, LEPAE, Portugal

**Evaluation of pendular liquid bridge formation in an environmental scanning electron microscope**, F. Schröter\*, E. Schmidt, University of Wuppertal, Germany



**The study of gas effluent inlet layout over the performance of an industrial fabric filter: A CFD approach**, K. Simon, F.B. Marques, F.A.R. Pereira, D.C. Ribeiro, S. M.S. Rocha\*, Federal University of Espirito Santo, Brazil

**Monitoring and Control**  
08:30-09:45 h

**G11**

**Setup and validation of a novel coded ring sensor to detect charged particles**, W. Moelter-Siemens\*, S. Opiolka, A. Bankodad, S. Haep, Institute for Energy and Environmental Technology (IUTA), Germany

**iPhone application for energy saving of filter replacement and maintenance routines**, P. Ödling\*, Dinair Group; L. Ekberg, CIT Energy Management AB; D. Broman, Sweden

**Instrumental and methodological complex for monitoring inhalation intake radioactive aerosols**, A. G. Tsovyanyan, E. A. Karev\*, Federal Medical-Biophysical Center - A.I. Burnazyan FMBA; E. A. Kramer-Ageev, National Research Nuclear University MEPhI, Russia

**Components for Improved Filter Performance**  
11:00-12:15 h

**L15**

**RBG - High-corrosion-resistant filtersystem made of glass alternative to coated housings**, B. Wenninger\*, H. Duderstadt, A. Lock, adfiltec GmbH, Germany

**Adhesives and sealants for filter manufacturing applications - Adhesion - Prospects**, F. Steegmanns\*, Stockmeier Urethanes, Germany; B. Blundell, Greenfield Polymers Ltd, UK

**Fast and safe filter cloth fixing on drum filters and pan filters with BOKELA FrameTrak**, R. Bott\*, T. Langeloh, BOKELA GmbH, Germany

**Functionalized Filter Media I**  
11:00-12:15 h

**L16**

**New material for water purification from natural organic matters**, G.V. Medyak, V.I. Sokolova, A.A. Shunkevich, A.V. Bilyukevich\*, National Academy of Sciences of Belarus, Belarus

**Innovative filtration textiles for the adsorption and recovery of dissolved metals**, T. Mayer-Gall\*, P. Schuchardt, K. Opwis, J.S. Gutmann, Deutsches Textilforschungszentrum Nord-West GmbH (DTNW), Germany

**Environmentally friendly low pressure plasma nanocoatings for filtration and separation**, E. Rogge\*, P. Legein, Europlasma B.V., Belgium

**Particle Deposition**  
11:00-12:15 h

**G12**

**Impaction of spherical particles on an array of parallel bare filter fibers: A CFD study of collision probabilities and velocities upon contact**, T.K. Müller\*, J. Meyer, G. Kasper, Karlsruhe Institute of Technology, Germany

**Characterization of open-pored foams with respect to aerosol deposition by means of measurement and simulation**, A. Hellmann\*, K. Schmidt, S. Ripperger, Kaiserslautern University of Technology, Germany

**Surface dust-loading of pleated filters: Comparison of simulation with experiment**, P. Hettkamp\*, J. Meyer, G. Kasper, Karlsruhe Institute of Technology, Germany

**Industrial Gas Cleaning**  
11:00-12:15 h

**G13**

**"Down Stream" bag house filter for industrial gas and air filtration**, K.R.K. Schumann\*, G.F.L. Schumann, Schumann Kompaktfilter, Germany

**Effect of inlet dust concentration and pulse cleaning pressure on pulse jet filtration performances**, A.K. Choudhary\*, A. Mukhopadhyay, National Institute of Technology Jalandhar, India

**High performing felts for industrial filtration**, D. De Angelis\*, E. Galletta, L. Cattaneo, M. Motta, Testori S.p.A., Italy

**Monitoring of Separation Processes**  
13:15-14:30 h

**L17**

**Online measurement of centrate solids content for centrifugation process monitoring and control**, M. Konrath\*, H. Nirschl, Karlsruhe Institute of Technology, Germany

**An electrical resistance tomography analysis on the behaviour of industrial filter press**, F. Kaswalder\*, L. Tozzola, D. Collini, Bilfinger Water Technologies srl; S. Ansaloni, A. Paglianti, G. Montante, F. Magelli, University of Bologna, Italy

**Wax precipitation assessment of gas condensate in Haradh gas plant**, B. Fadhel, N. Al-Qahtani, N.A. Alkhazam\*, Saudi Aramco, Saudi Arabia



**Functionalized Filter Media II**  
13:15-14:30 h

**L18**

**Viscose speciality fibres for filtration applications**, P. Wimmer\*, Kelheim Fibres GmbH, Germany

**Advanced cellulosic multilayer filter media to maximise fine particle filtration**, A. Slater\*, M. Gallo, Lenzing Fibers, Austria

**Ion exchange characteristics of functionalised filter sheets**, S. Lösch\*, U.A. Peuker, Technical University Bergakademie Freiberg, Germany

**Numerical Filter Simulation I**  
13:15-14:30 h

**G14**

**Modeling of NaCl aerosol deposition at electrically charged microfibers**, K. Schmidt\*, A. Hellmann, M. Pitz, S. Ripperger, Technical University Kaiserslautern, Germany

**Flow simulations of air filter media containing nanofibers**, C. Feuchter\*, A. Stief, Aalen University; R. Handel, G. Baelz, A. Enderich, B. Renz, Mahle Filtersysteme GmbH, Germany; K. Langfeld, University of Plymouth, UK

**Theoretical prediction of the filtration resistance across glass fiber filter media**, M. Tang\*, Y. Liang, J. Hu, Z. Yang, South China University of Technology, China

**Cabin Air Filters**  
13:15-14:30 h

**G15**

**Conclusions of a project how to interpret standardized lab tests versus olfactory tests for the characterization of the filter performance for the reduction of odors and gaseous substances**, S. Trnitschek\*, fiatec GmbH, Germany

**Improving the air permeability and peel strength of supported meltblown cabin air filter media**, S. Jarrett, M. Tipper\*, S.J. Russell, Nonwovens Innovation & Research Institute Ltd, UK; L. Van der Molen, Bonar, Netherlands

**Advantages of using nanofibers on downstream**, F. Lybrand\*, Emarco, Inc., USA; C. Tekmen, Elmarco s.r.o., Czech Republic

**Microscreens / Strainer**  
15:00-16:15 h

**L19**

**High capacity micro filter belts – A new concept and new opportunities**, C. Maurer\*, Sefar AG, Switzerland

**Importance of initial design of horizontal strainers - Liquid petroleum product pipeline - Project engineering**, B. Patil\*, V. Patil, BASP Industries, India

**Cloth characteristics: Air and liquid permeability and pore size distribution**, M. Shakhanova\*, R. Salmimies, A. Hakkinen, Lappeenranta University of Technology, Finland

**Depth Filtration in Granular Media**  
15:00-16:15 h

**L20**

**Removal of pharmaceutical residues in drinking water**, R. Schönfeld, J. Raiser\*, BLÜCHER GmbH, Germany

**Activated carbon honeycombs - Function, advantages, application**, M. Hartmann, O. Schmolinski\*, helsatech GmbH, Germany

**Assessment of filter backwash in deep bed filtration on basis of drinking water productivity**, I. Slavik\*, A. Jehmlich, W. Uhl, Technische Universität Dresden, Germany

**Numerical Filter Simulation II**  
15:00-16:15 h

**G16**

**Simulating the compression of filter materials**, M. Kabel\*, H. Andrá, Fraunhofer Institute for Industrial Mathematics ITWM, F. Hahn, M. Lehmann, MANN+HUMMEL GmbH, Germany

**New simulation tool embedded in the MAHLE filter media development process to generate new innovative media solutions in short time to market**, A. Enderich\*, B. Renz, C. Feuchter, M. Steppe, MAHLE Filtersysteme GmbH, Germany





**Modelling and simulation of fluid-porous structure interaction (FPSI) on the filter element scale**, D. Iliev, O. Iliev, R. Kirsch\*, Fraunhofer Institute for Industrial Mathematics ITWM; M. Dederich, IBS FILTRAN GmbH, Germany; A. Mikelic, Université Claude-Bernard Lyon, France

**Pleated Filter Media**

15:00-16:15 h

**G17**

**An experimental protocol to analyze the structure of nanoparticles deposit in pleats of industrial HEPA filters**, S. Bourrous\*, L. Bouilloux, Institut de Radioprotection et de Sécurité Nucléaire (IRSN); J.-C. Appert-Collin, D. Thomas, Université de Lorraine; D. Bemer, Institut National de Recherche et de Sécurité (INRS); L. Tampère, Camfil, et al., France

**Synthetic pleatable filter media – New nonwoven materials set standards**, U. Hornfeck, A. Burger\*, Sandler AG, Germany

**Combination of HVAC filter media development and pleating process design for optimum performance**, A. Seeberger\*, A. Jung, T. Ertl, IREMA-Filter GmbH, Germany

**Coalescer**

16:45-18:00 h

**L21**

**Numerical simulation of the electrostatic coalescence process for an ideal water-in-crude-oil emulsion using a numerical approach**, R. Olea-Pérez\*, H. Nirschl, Karlsruhe Institute of Technology, Germany

**Innovative coalescence media and water removal applications in fuels and oils**, R. Chen\*, Kaydon Filtration Corp; T. Ramsey, Purafil, Inc, USA

**Backwash Filters**

16:45-18:00 h

**L22**

**Removal of fine particles from karst spring water by means of an automatic backwash filter and micro filter mesh**, M. Hochedlinger\*, P. Stimpfl, E. Hawle Armaturenwerke GmbH; A. Kavazovic, R. Sulzbacher, G. Gruber, Graz University of Technology; S. Strasser, S. Schöpf, Lenzing Technik GmbH, Austria

**Automatic backwash filter improves performance in pharmaceutical process**, S. Schöpf\*, S. Strasser, Lenzing Technik GmbH, Austria

**Filtration of cleaning baths with automatic filtration system**, J. Wögerer\*, S. Strasser, A. Wimmer, Lenzing Technik GmbH, Austria



**Numerical Filter Simulation III**

16:45-18:00 h

**G18**

**Improved modeling of filter efficiency in life-time simulations on fibrous filter media**, J. Becker\*, A. Wiegmann, Math2Market GmbH; F. Hahn, M. Lehmann, Mann+Hummel GmbH, Germany

**Numerical simulation of non Darcy flow using filter element simulation toolbox (FiltEST)**, O. Iliev, R. Kirsch, Z. Lakdawala\*, Fraunhofer Institute for Industrial Mathematics ITWM, Germany; V. Starikovicius, Vilnius Geimnias University, Lithuania

**PleatLab: a pleat scale simulation environment for filtration simulation**, L. Cheng\*, A. Wiegmann, Math2Market GmbH; R. Kirsch, Fraunhofer Institute for Industrial Mathematics ITWM, Germany; D. Tomas, N. Bardin-Monnier, P.C. Gervais, CNRS LRGP, France

**Special Filter Media**

16:45-18:00 h

**G19**

**Technostat® Plus as a value adding proposition in respiratory equipment**, B. Keil\*, P. Lindblom, J. Mills, J. Manns, H&V, Germany

**GEA Delbag Firetex® - A new grade of fire-resistant synthetic filter media**, T. Stoffel\*, M. Sauer-Kunze, GEA Air Treatment GmbH, Germany

**Effect of nucleating agents on the performance of electret filters**, A. Kilic\*, Istanbul Technical University, Turkey; E. Shim, B. Pourdeyimi, B.-Y. Yeom, North Carolina State University, USA

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## **NEW METHOD TO MEASURE THE MECHANICAL COLLECTION MECHANISMS OF FULL-SCALE AIR FILTERS**

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### **ABSTRACT**

Air filters are chosen for the minimum particle-capture efficiency they can provide in a specific application. Some media can achieve high efficiencies at low resistance to air flow by adding electrostatic charges on fairly coarse fibers. However, prolonged filter exposure to fine particles reduces the electrostatic enhancement effect. The filter efficiency must then rely mainly on mechanical collection mechanisms, and can fall well below the initial value. It is useful to test filter media when the effect of electrostatic charges is eliminated.

To estimate the efficiency drop that may occur, air filter test standards include filter conditioning procedures to inhibit the effect of electrostatic charges. These treatments should leave only particle capture effects from mechanical collection mechanisms such as sieving, aerodynamics and diffusion, but not reduce or enhance these effects. EN779:2012 and ISO 21220:2009 describe such a conditioning treatment for filter media, and ASHRAE 52.2-2012 describes one for full-scale filters.

The ASHRAE 52.2-2012 optional treatment suggests that air filters be exposed to a potassium chloride aerosol having approximately 35 nm count mean diameter. Following the charge-elimination treatment, procedures measuring efficiency as a function particle size are performed. In ISO/TS 21220:2009 and EN779:2012 the discharging treatment is also mandatory, but is performed on samples of the media used to manufacture the filter. This treatment requires a 2 minute soak in essentially pure isopropyl alcohol (IPA), after which the media samples are dried for 24 hours before further tests. This method presents problems, namely, that soaking in a liquid may alter the mechanical efficiency of media, and that samples of media may not be representative of the media used in the full-scale filter.

A new approach, developed by T. Hayashi in Japan, eliminated electrostatic effects in electret-enhanced media sheets by exposure to IPA vapor for 16 hours or longer. This procedure was successfully duplicated by J. Cai in China, and at the Politecnico di Torino. ISO/TC142/WG9 in 2010 ran an inter-laboratory comparison to assess this procedure, and in 2011 organized another comparison which extended the method to full-scale filters. The full-scale tests have included three different types of air filters, comparing the results with the other approaches previously mentioned. These results will be useful for revising the current ISO 29461-1 test method and also for developing the new ISO 16890 series for general ventilation applications. Here we summarize the data obtained at the Politecnico di Torino, and describe the new test protocol that could be adopted by future international filter test standards.

### **KEYWORDS:**

Filter test, Filter Efficiency, Electrostatic Charges, Service life, ISO standards, EN 779:2012, ASHRAE

## 1. Introduction

Fibrous air filter media composed of polymer fibers carrying relatively permanent electrostatic charges (electrets) have widespread use in air filters because they provide substantially improved particle capture efficiency without increasing the pressure drop (resistance) of the fibrous media in such filters. Many studies present examples of particle capture improvement by electret-enhanced media. Indeed, studies of electret-media degradation from various exposures are testimonies to the efficiency improvement which is obtained by electret-enhancement.

Electrostatic forces may also enhance the efficiency of fibrous media which have not been intentionally charged, for both natural and test aerosols may carry randomly-distributed charges (Hoppel, 1990). These charges induce "image" charges in dielectrics, such as the glass and polymer fibers in filter media. The resultant electrostatic forces on charged aerosol particles are directed toward fibers, hence enhance particle capture. Image-force phenomena are described in Brown (1993, p 158-166). In addition, the adhesion of particles to fibers, which influences efficiency, depends in part on electrostatic effects (Zimon, 1969).

Many studies have shown, however, that electrostatic effects decline under various conditions met in actual filter service. Examples of efficiency degradation with exposure to ambient and workroom aerosols are described by Brown (1980, 1988), Chen (1993), Janssen (2003), Ji (2003), Raynor (2004), and Hanley (2005). Filter applications require knowledge of worst-case performance, rather than average or best-case performance. For this reason, experimenters and standards-writing committees have sought media treatments which eliminate electrostatic effects from filter media, while leaving the aerodynamic and diffusional effects unchanged. The choice of an agent to do this in a repeatable, reliable manner for all forms of electrified fibers is not simple. Such treatment could degrade some media and not others, and therefore should be applied to all media before performance tests. It should be applicable to full-scale filters as well as media samples without undue testing burdens.

## 2. Media Discharging / Neutralization Methods

### 2.1 Discharging Mechanisms

The physical mechanisms that suppress the electrostatic charges on electret fibers are not agreed upon by those who have made these studies. These general mechanisms have been proposed:

- Neutralization by gaseous ions and charged particle contact;
- Shielding by a layer of conductive particles or conductive liquid film;
- Dissolution of fiber surface layer by a solvent;
- Chemical reactions with the fiber surface;
- Conduction between charged patches by ions of a liquid coating.

The understanding of electret suppression is further complicated by the fact that some treatments of some media have improved, rather than degraded, particle-capture efficiency. Particle-based treatments, for example, may improve mechanical capture mechanisms as they suppress electrostatic effects. Treatments can alter the structure of media, and hence its flow resistance. An example of this is possible clumping of fibers after media immersion in a liquid. An examination of past charge suppression studies is helpful in evaluating which method is likely to be effective in



charge suppression and yet minimally alter media mechanical particle capture mechanisms.

## 2.2 Discharge by Exposure to Ion Clouds and X-Rays

The obvious way to neutralize an electret would seem to be to add ions to the air passing through the medium. Ions of sign opposite to the charge on the medium could be added, to neutralize the charges on the fibers. Ions can be added by X-rays and corona-discharge generators. Studies of these procedures (Brown, 1980; Fjeld, 1988; Lee, 2004; Agranovski, 2006; Chazelet, 2011) have shown that they usually increase, rather than decrease, particle capture efficiency. This is apparently because ions attach themselves to the aerosol particles, and because the charge patches on the fibers are tightly bound. Charging particles brings coulombic electrostatic forces into action, which substantially improves particle capture for electret media. Improvement was observed for both ion-cloud polarities. Intentional charging of particles ahead of an electret filter may, however, lead to unexpected effects. If the particle capture capability of the dust-loaded electret media decreases (perhaps from high humidity), the charged particles will be captured on downstream surfaces, with clearly visible deposit patterns.

Exposing the media itself to X-rays, however, is another matter. Janssen (2003) found that even quite soft X-rays directed toward electret media overcame the energy barriers binding electret charges, and eliminate the electrostatic properties. The charge reduction was, however, less pronounced than that produced by dipping the media in IPA, and given the difficulties of X-ray media exposure, especially for full-scale filters, does not seem to be a suitable method.

## 2.3 Discharge by Exposure to Elevated Temperature and Prolonged Storage

Tsai (1999) describes the rapid efficiency decline resulting from increasing corona-enhanced electret media temperature above 120 °C for a few minutes. Huang (2001) studied thermal degradation of electret media experimentally, and provides a theoretical basis for it. Some studies showed only minor declines in efficiency from prolonged storage at ambient temperatures, even with relative humidity up to 100%, for example Viscusi (2009), while others (Tsai, 1999) showed substantial declines from 9 months storage. The methods used to form electrets in the media used in these tests may not have been alike.

## 2.4 Discharge by Particulate Loading

Several studies using aerosols to eliminate electrostatic effects have been undertaken. Aerosols used for this purpose have included: ambient natural aerosol; soot and other carbon forms; Diesel engine exhaust fumes; stearic acid, "oil", Di-octyl Sebacate (DOS), Di-Octyl Phthalate (DOP), and NaCl and KCl micro- and nano-particles. Of these, air filter preconditioning with KCl nano-particles has been included in ASHRAE 52.2 test standard. Exposure of full-scale filters is easily implemented with a small diesel engine and a test duct with outdoor discharge. The ASHRAE 52.2-2012 standard uses nanoparticles for charge suppression, but requires rather more additional test equipment (see section 3 below). In general, initial accumulations of nanoparticles reduce the efficiency of electret media, apparently by shielding the electrostatic fields of the electrets. As larger particles accumulate, mechanical filtration mechanisms grow stronger, and efficiency improves, especially for exposure to solid particles. Simultaneously, however, media

pressure drop rises. These effects are documented by Biermann (1982); Blackford (1986); Chen (1993); Walsh (1998); Barrett (1998); Hanley (2005); and Plebani (2012).

## 2.5 Discharge by Liquid Immersion

Studies of charge suppression by immersion of electret media in liquids, or “dipping”, have produced mixed results. Pure water is reported (Biermann, 1982) to have had minimal discharging ability, but water with ionic additives which fully wet the fibers, such as NaCl plus surfactants, did decrease efficiency markedly. Immersion in the organic solvents hexane, heptane, iso-octane, benzene, toluene, and a methylethyl ketone/acetone mixture have been tried, with varying levels of charge suppression (Biermann, 1982; Jasper, 2005, 2007; Kim 2007,2009). Immersion in liquid isopropyl alcohol (IPA) has been studied extensively, and adopted as a discharging method for the EN779 (CEN, 2012) filter test standard, and ISO/TS 21220 (ISO, 2009). The results of these tests indicate that to be effective, the liquid must wet the fibers, and be ionic. It is not clear to what extent fiber rearrangement – clumping – might explain some of the reduction in efficiency from immersion and drying of the media samples. Some studies have examined the fiber surfaces after discharge by immersion, using scanning electron microscope images, and found no evidence of surface changes.

## 2.6 Discharge by Surfactants

Surfactants can to some degree energize water to discharge electrets (Biermann, 1982). However, a surfactant can also be used to convert an uncharged polymer into an electret (Yang, 2004). The choice of a preconditioning agent must be made carefully to avoid unforeseen behavior.

## 2.7 Discharge by Exposure to Vapors

The effects of high relative humidity, with condensation of pure water vapor on electret fibers, appear to be limited (Moytl, 2006; Moyer, 1989). Vapors of organic liquids are altogether different. Studies of the effect of organic vapor exposure on electret filter media have been reported by investigators interested in the reliability of face masks employing such media. Jasper (2005, 2006) reported significant efficiency loss with exposure to toluene and xylene vapors. A combination of vapors of methylethyl ketone and acetone decreased electret media efficiency, but the effect of ethylbenzene vapors was minimal (Biermann, 1982). Isopropyl alcohol (IPA) vapor has been stated to eliminate charge even more effectively than liquid IPA, according to Hayashi and Cai (ISO 2010). Again, ionic properties of the condensed vapor and the length of exposure time seem to be essential for successful charge suppression.

# 3. Standardized Test Procedures to Obtain Discharged Filter Media and Filters

## 3.1 Filter media

EN 779:2012 and ISO/TS 21220:2009 required that filter media undergo a procedure intended to nullify electrostatic effects. This procedure began with measurement of initial efficiency followed by immersion of flat-sheet samples of media in liquid IPA. After immersion the samples are drained, allowed to dry for 24 hours, then tested for particle capture efficiency using the standard's diethyhexyl-sebacate (DEHS) aerosol.

### 3.2 Full-scale filters

While almost all tests of the immersion (“dipping”) procedure report significant efficiency decreases for electret-fiber media, and relatively small changes in efficiencies for non-electrified media, the standards merely assume that the mechanical filtration mechanisms for the media are not affected by immersion in IPA and drying. The immersion procedure has been applied to full-scale filters, but the large amount of liquid IPA needed is hazardous, and troublesome from the environmental impact of its disposal.

The ASHRAE 52.2 Air Filter Test Standard originally essentially ignored charge-suppression procedures, but in 2000-2004 a study was funded by ASHRAE to provide a standardized, normative procedure. In 2007 an addendum to the Standard (ASHRAE, 2008) incorporating the results of this study was approved. The procedure can be applied to full-scale pleated or extended-media filters, but its use is voluntary, not normative. The suppression agent is an aerosol of potassium chloride (KCl) particles with approximate count-mean diameter of 35 nm, considerably finer than the aerosol specified for testing the particle-size-efficiency of filters. This aerosol is produced in the needed quantity for full-scale filters by using a few Laskin-nozzle generators and a very diluted solution of KCl in water. A condensation nucleus counter (CNC) is required to demonstrate conformity of this charge-suppression aerosol with the specifications in the ASHRAE standard. Details of the procedure are given in Hanley (2005). The procedure described in ASHARE 52.2 may take a long time to be completed and the testing lab must proceed very carefully to avoid clogging the filter instead of neutralizing it. The consequence is that the cost of the test would be much higher than in the case of the IPA immersion. At the same time laboratories and filter manufacturers were reluctant to invest in the generators and CNC needed for the ASHARE 52.2 procedure, and other solutions were sought by ISO/TC142/WG9.

## 4. IPA Vapor Charge Suppression

A promising method for electret charge suppression for both full-scale filters and small media samples was proposed to ISO/TC142/WG9 early in 2010 by Toshiaki Hayashi of Toyobo Co. Ltd. in Japan. He had found that electret media charge could be fully suppressed by exposure to IPA vapor for a period of at least 24 hours. Some charge suppression by IPA vapor had been observed earlier, exposures were shorter. In July 2010, Jie Cai, of the Chinese Contamination Control Society informed WG9 that he and a group at the Dongguan Hengyong company had confirmed Hayashi’s results on two types of polypropylene electret media, one thin and pleatable, the other suitable for bag filters (ISO, 2010).

The procedure for media samples was the subject of a round-robin study in 2010 by eight laboratories from several different countries under the supervision of ISO Technical Committee 142, Working Group 9. The method was deemed reliable and reproducible, and is now included in ISO 29461-1:2013. The procedures and results of that inter-laboratory effort are described in Tronville (2011).

## 5. ISO Round-Robin IPA Vapor Conditioning Study: Full-Scale Filters

The members of ISO/TC142/WG9 recognized that the IPA vapor charge-suppression procedure could be extended to full-scale filters by use of a sealed exposure chamber large enough to accommodate such filters. A design for the chamber was



proposed, and a round-robin test program organized. The test program included four full-scale filter designs which were distributed to the participants along with samples of the media used in the full-scale filters. Test equipment and procedures and data-reporting requirements were stated in detail (ISO 2012a, b, c).

Efficiency measurements followed the existing ISO 29461-1 procedure, using a polydisperse aerosol of (DEHS). Optical aerosol spectrometer results for the complete aerosol size spectrum were included, with a requirement for a measurement in a reasonably narrow range centered at 0.4  $\mu\text{m}$  diameter. At least six efficiency runs at each test condition were required, and the uncertainty of each set required to be calculated. One important purpose of these tests was to determine, for each of the filter types, the duration of IPA vapor exposure required to reach a steady state minimum efficiency level, which should represent the efficiency due to mechanical filtration mechanisms alone. Hence data was required showing the decline in efficiency, if any, until essentially steady-state conditions were reached. Pressure drops for all efficiency measurement conditions were to be reported, along with air temperature and relative humidity.

The vapor exposure chamber has two compartments. The smaller contains a vertical rack to hold several plastic trays about 30 mm deep, into which liquid IPA is poured just prior to the start of a filter exposure. The larger compartment can hold either panel filters or bag filters with face areas up to 610 x 610 mm in their normal operating position. The cabinet has a gasket-sealed door. The entire chamber is designed to be operated inside a laboratory hood having an outdoor exhaust. The hood fan is operated whenever IPA is present, for fire safety and operator health.

In the ISO round-robin tests, the full-scale filters tested had face dimensions 595 x 595 mm, and were designated Types A, B, C and D. The descriptions of each are:

- Type A: Panel filter, with a relatively thin pleated media made of glass fibers (media area: 8.86 m<sup>2</sup>).
- Type B: Panel filter, with a relatively thin pleated media formed of fibers made from an organic polymer, often referred to as “synthetic media” (media area: 1.6 m<sup>2</sup>).
- Type C: Bag filter, with a thicker media than A or B. The media for this filter was formed from fibers of an organic polymer (media area: 7.5 m<sup>2</sup>).
- Type D: Bag filter, with a thicker media than A or B. The media for this filter was formed from glass fibers (media area: 7.5 m<sup>2</sup>).

## 6. Electret Charge-Suppression Studies at the Politecnico di Torino

Samples of the four filters and their media were supplied to the Politecnico in 2012, and the test protocol described in Section 5 followed in the DENERG laboratory. The tests showed, as had been the case for media samples exposed to IPA vapors, that exposure durations well in excess of eight hours are needed for a steady-state reduced efficiency to be reached. Figure 1 is a plot of the 0.4  $\mu\text{m}$  diameter DEHS particle efficiencies and pressure drops measured for the filters of Types A and C at different stages in the vapor-exposure cycle. These curves depict the performance at 5.3 cm/s media velocity on Type A and C filters. The efficiency values for the runs at 11 cm/s on the same filters were slightly lower (Fig. 2). For filter C – presumably an electret-fiber filter – the efficiency at 4 hours exposure was greater than the efficiency at 24 hours, confirming the need for a 24-hour exposure. Similar results were obtained for the other filters and their media samples.

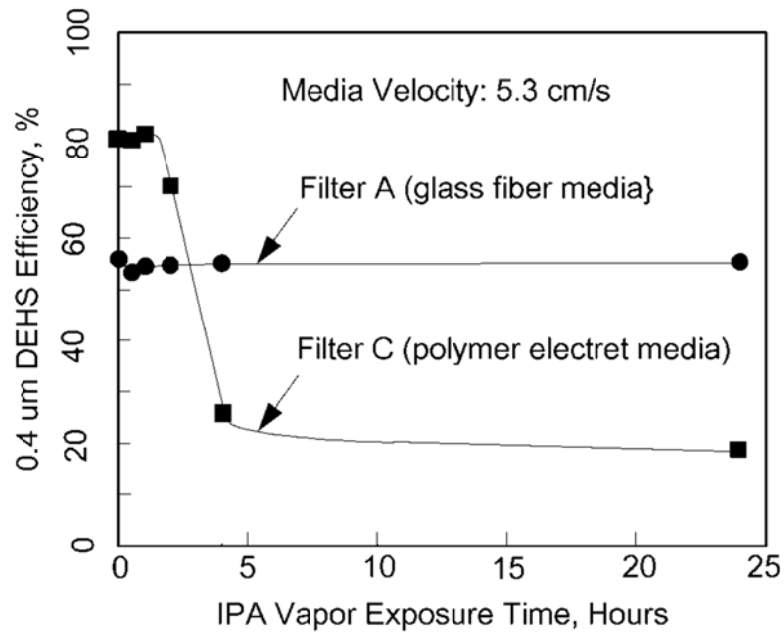


Fig. 1. Efficiency for 0.4  $\mu\text{m}$  DEHS Particles at 5.3 cm/s Media Velocity vs. IPA Vapor Exposure Time

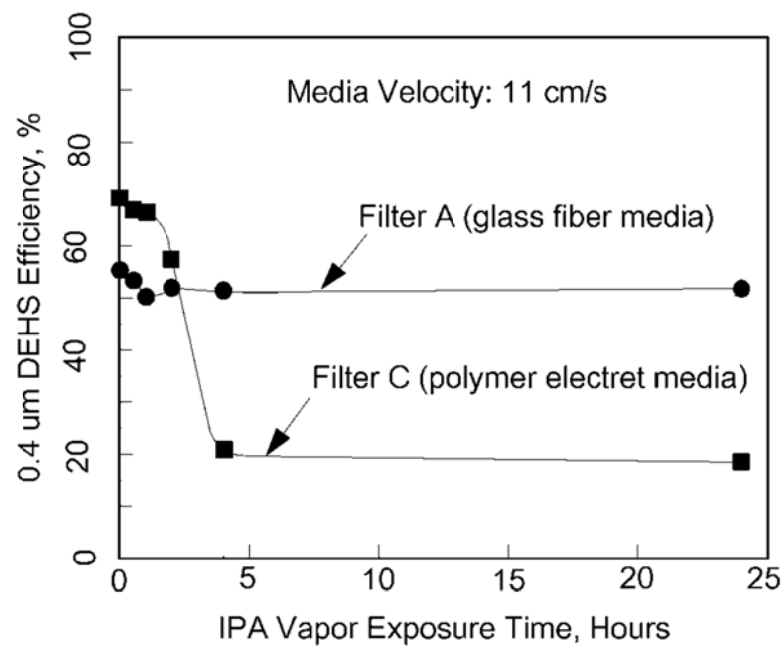


Fig. 2. Efficiency for 0.4  $\mu\text{m}$  DEHS Particles at 11 cm/s Media Velocity vs. IPA Vapor Exposure Time

Tables 1 and 2 compare the efficiencies of the media samples before and after treatment by IPA dipping and by IPA vapor exposure to the full-scale filter efficiencies before and after IPA vapor treatment.

Table 1. Politecnico Tests: 0.4 µm DEHS Particle Efficiencies at 5.3 cm/s (10.4 ft/min) Media Velocity

		Data for Media Sample Tests				Data for Full-Scale Filter Tests	
Media Code	Filter - Sample Description	IPA Liquid Treatment 2- Minute Dip & Dry		IPA Vapor Treatment 24-hour Exposure		IPA Vapor Treatment 24-hour Exposure	
		Efficiency Before Treatment, %	Efficiency After Treatment, %	Efficiency Before Treatment, %	Efficiency After Treatment, %	Efficiency Before Treatment, %	Efficiency After Treatment, %
A	Pleated - glass	53.8	52.8	56.2	55.4	55.4	55.5
B	Pleated – polymer	69.2	7.6	68.6	6.3	56.4	6.1
C	Bag Filter - polymer	82.4	25.0	82.5	18.7	78.8	18.4
D	Bag Filter - glass	63.7	61.8	64.1	60.8	70.6	65.6

Table 2. Politecnico Tests: 0.4 µm DEHS Particle Efficiencies at 11 cm/s (21.7 ft/min) Media Velocity

		Data for Media Sample Tests				Data for Full-Scale Filter Tests	
Media Code	Filter - Sample Description	IPA Liquid Treatment 2- Minute Dip & Dry		IPA Vapor Treatment 24-hour Exposure		IPA Vapor Treatment 24-hour Exposure	
		Efficiency Before Treatment, %	Efficiency After Treatment, %	Efficiency Before Treatment, %	Efficiency After Treatment, %	Efficiency Before Treatment, %	Efficiency After Treatment, %
A	Pleated - glass	52.1	51.7	52.4	51.7	52.6	51.3
B	Pleated - polymer	64.6	4.8	54.9	2.9	32.0	6.2
C	Bag Filter - polymer	74.3	18.7	73.8	18.2	69.2	18.6
D	Bag Filter - glass	61.0	60.9	60.1	60.7	70.4	64.5



## 7. Conclusions

At the laboratory of Politecnico di Torino the full-scale results of vapor treatment matched the sample results well, and the efficiency reduction by vapor treatment was similar to that obtained by liquid IPA treatment of the media samples.

It will be interesting to study the reproducibility of the data shown here with the data measured by the other laboratories participating in the round robin exercise.

It will be also important to define the requirements to be met by the discharging cabinet.

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