THE PARTICLE TECHNOLOGY FORUM (PTF) NEWSLETTER

An American Institute of Chemical Engineers (AIChE) Forum

Message From The Chair...

Greetings and Celebration of 30 Years of PTF Community Achievements

X-ray & Radio Image of the Milky Way's Galactic Center
Credit: X-Ray: NASA/CXC/UMass/D. Wang et al.; Radio: SARAO/MeerKAT

The Fall is here, and so is the AIChE Annual Meeting in Orlando, FL!

We are having the PTF Awards Dinner on Wednesday evening at Rodizio Grill - Pointe Orlando, social interactions during our poster session and planning meetings, and invited talks by some of our awards winners. A hearty congratulations to all of our award winners! You can read about them in this issue and hear about their research at the conference in person. I will have much more to say about this year's winners at our PTF Awards Dinner. Let's celebrate the diversity and achievements!

As you all know, we initiated a special PTF Webinar series addressing some of the new emerging technology fields utilizing particle technology. First one was kicked off by Mr. Michael Molnar and was well attended. I am looking for an exciting speaker for the next webinar in the emerging technologies area. If you have recommendations, please reach out to me.

I would like to express my gratitude to the newsletter's editor, Dr. Shrikant Dhodapkar, for creating informative newsletter, Dr. Ben Freireich for planning all PTF sessions, and all members of the executive committee who keep programming and events running smoothly. We have two special sessions with invited speakers. Thanks to Prof. Maria Tomassone, Vice-Chair, who took care of PTF awards.

You are all invited to the PTF General Business meeting held on Monday, November 6, 2023 at 6:00 PM-7:00 PM (*Bayhill 19)*. In addition, all past PTF chairs and PTF EC members are also invited to attend the PTF Executive Committee (EC) meeting on Sunday, November 5, 2023, 5:30 PM-6:30 PM (*Bayhill 28)*. Please let me know if you plan to attend the EC meeting or if you have questions. Please

A Peek At The Contents

2023 AIChE ANNUAL MEETING
November 5 — November 10, 2023
Hyatt Regency Orlando
Orlando, FL

AIChE Annual Meeting

November 5 - 10, 2023

Orlando, Florida (USA)

Registration Is Now Open

Registration

Technical Program

Accommodations

also attend the PTF programming meetings for groups 3a=3e. The meetings will be held on Tuesday, 10:30 am – 11:50 am in *Bayhill 19-22 & 26*, *Hyatt Regency*. Please reach out to area chairs and co-chairs ahead of time if you want to volunteer for 2023 programming or attend these meetings.

Lastly, please join us for the PTF Awards session that will include three major award lectures. It is scheduled during 12:30 PM - 03:00 PM, Wednesday, November 08, 2023, *Bayhill 21*, *Hyatt Regency*. You can learn from outstanding people in our field and congratulate these winners.

Hope to see you in person at AIChE Annual Meeting - November 5-10, 2023, Hyatt Regency Orlando, Orlando, FL, USA. Remember to purchase PTF dinner tickets as part of the registration. Tickets are almost sold out.

Hope to see you in person at AIChE Annual Meeting - November 5-10, 2023, Hyatt Regency Orlando, Orlando, FL, USA.

S.B. Reddy Karri, PhD, President &. CEO, PSRI
Chair, The Particle Technology Forum of AIChE
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EDITORIAL

We meet in Orlando to share our scientific knowledge, celebrate the accomplishments of our peers and proudly reflect on the journey taken together since the founding of the Particle Technology Forum about 30 years ago. The strength of our community is not necessarily in the numbers, but in the "cohesiveness" of our purpose and the diversity of interests which we continue to broaden further.

Special thanks to my Editorial Advisory Group (EAG), Ray Cocco, Reza Mostofi-Ashtiani, George Klinzing, Mayank Kashyap, Mike Molinar, Reddy Karri and Maria Tomassone for their continued support and guidance.

Hope to see you all at the Annual Meeting in Orlando. Safe travels!

Shrikant Dhodapkar, PhD
Senior R&D Fellow, AIChE Fellow
The Dow Chemical Company
sdhodapkar@dow.com

A Legacy of Leadership In The Particle Technology Forum

Year	PTF Chair
1992 – 1994	L. S. Fan Ohio State University
1994 – 1996	Reg Davies DuPont Company
1996 – 1998	Mike Roco National Science Foundation
1998 – 2000	Karl Jacob The Dow Chemical Company
2000 – 2002	George Klinzing University of Pittsburgh
2002 – 2004	Ralph Nelson DuPont Company
2004 – 2006	Alan Weimer University of Colorado, Boulder
2006 – 2008	Shrikant Dhodapkar The Dow Chemical Company
2008 – 2010	Hugo Caram Lehigh University
2010 – 2012	Raymond Cocco PSRI
2012 – 2014	Jennifer Sinclair Curtis University of Florida
2014 – 2016	Reza Mostofi UOP
2016 – 2018	Raj Dave NJIT
2018 – 2020	Bruce Hook The Dow Chemical Company
2020 – 2022	Jim Gilchrist Lehigh University
2022 – 2024	Reddy Karri PSRI

PTF Award Winner 2023

Elsevier Life Time Achievement Award

Dr. Raymond Cocco

President

Particles in Motion, LLC

B.S. in Ch.E. at University of Florida in 1982

Ph.D. in Ch.E. at Auburn University in 1989

Citation: For his innovative technology development focusing on multiphase fluid dynamics and for his outstanding mentorship and service to Particle Technology Forum

Ray is president of Particles in Motion, LLC, a consulting company focusing on complex granular-fluid hydrodynamics in commercial applications. Before his current role, Ray Cocco was with PSRI for 16 years, where he was President and CEO. Before PSRI, Ray spent 17 years with The Dow Chemical Company, where he led research and development efforts in numerous particle technology platforms, including the production of WoodStalkTM (a particleboard made of straw) for Dow BioProducts, the production of vinyl chloride monomer, and RCl oxidation using fluidized beds, the production of hydrocarbon using circulating fluidized beds, the development of polyolefin catalyst for fluidized beds, and in the production of aluminum nitride and silicon carbide ceramic powders using moving bed reactors. Today, he is a member of the University of Florida Chemical Engineering Advisory Board, Auburn University Chemical Engineering Alumni Committee, and University College at London's CNIE. He is also on the editorial boards for Powder and Bulk Engineering, Powder Technology, and Frontiers in Chemical Engineering: Mixing and Particle Technology. Ray was the past chair of the AIChE Particle Technology Forum (Group 3), a past member of the AIChE Chemical Technology Operating Council (CTOC), and an AIChE Fellow. Ray was also the chairman of the World Congress in Particle Technology VIII in April 2018. He has over 80 publications, three book chapters, several patents, numerous invited presentations, and consults for industry, national labs, and universities regularly.

Award Lecture: Evolution and Prospects of Scale-Up Tools for Fluidized Bed Technology

Abstract

Fluidized bed technology has garnered significant attention across various industries due to its versatile nature, efficient heat transfer capabilities, and in-situ particle mobility. This paper delves into the history and future of scale-up tools for fluidized bed applications, presenting a comprehensive overview of the advancements and challenges encountered with this technology.

The historical perspective encompasses the early applications of fluidized beds, tracing their roots from the gasification industry to their widespread adoption in chemical production, energy production, pharmaceuticals, and materials engineering sectors. Notably, the evolution of scale-up methodologies from Edisonian exploration with empirical correlations to more sophisticated computational techniques to exploiting artificial intelligence is explored, shedding light on the pivotal role of interdisciplinary collaborations in driving innovation.

Sponsor of the Lifetime Achievement Award

PTF Award Winner 2023

PSRI Fluidization and Fluid-Particle Systems Award

Dr. Bing Du

Principal Scientist, Process Reactor Development

ExxonMobil Technology and Engineering Company

1545 US Route 22, Annandale, NJ 08801

bing.du@exxonmobil.com

Citation: For contributions to fundamental understanding of choking phenomena and gas-solids mixing phenomena in turbulent fluidzation, and to fluidized bed reactor scale-up as a leader at ExxonMobil

Dr. Bing Du has been actively working in the area of fluidization and fluid-particle flow systems for more than 20 years and currently is the Principal Scientist for Process Reactor Development at ExxonMobil Technology and Engineering Company. He has actively participated in or led the development and scale-up of multiple processes related to fluidized bed reactors or fluid-solid systems. Applications cover Upstream, Downstream and Chemicals in the oil/gas industry, and include FCC/Fluid Coking™ process/hardware improvements, EMTAM™ (Fluid bed Toluene Alkylation with Methanol) process development, Fluid Bed MTG (Methanol to Gasoline) technology development, and new chemical processes and waste recycling technology. Recently the fluid bed MTG process has successfully demonstrated the production of eFuels from methanol synthesized from CO_2 and green hydrogen. Bing Du received his PhD in Chemical Engineering from the Ohio State University in 2005, MS and BS in Chemical Engineering from Tsinghua University. Before joining ExxonMobil, Bing worked at Dow Chemical for two years

PSRI Particulate Solid Research, Inc.

Sponsor of the Lectureship in Fluidization Award

PTF Award Winner 2023

Shell Thomas Baron Award In Fluid-Particle Systems

Dr. Mark Swihart

Distinguished Professor and Chair

Department of Chemical and Biological Engineering

University of Buffalo (SUNY)

swihart@buffalo.edu

Citation: For outstanding contributions and sustained innovation in the colloidal and aerosol synthesis of nanomaterials and their applications

Prof. Mark T. Swihart is SUNY Distinguished Professor and Chair of the Department of Chemical and Biological Engineering, and an Empire Innovation Professor in the RENEW Institute at The University at Buffalo (SUNY). His research interests and activities center on the synthesis and applications of inorganic nanomateri als, in fields ranging from sustainability to medicine. His research group develops and advances both gas-phase (aerosol) and solution-phase (colloidal) synthesis methods for producing novel nanomaterials and also conducts modeling and simulation work in support of material and process development. These materials have broad applications in bioimaging, catalysis, photo-catalysis, electrocatalysis, sensing, and photovoltaics. Swihart earned a B.S. in Chemical Engineering from Rice University in 1992, and a Ph.D. in Chemical Engineering in 1997 from the University of Minnesota under the advisement of Robert W. Carr, then spent one year as a postdoctoral researcher in the Particle Technology Laboratory in the Department of Mechanical Engineering at the University of Minnesota. He joined the Department of Chemical and Biological Engineering at the University at Buffalo (SUNY) in 1998, where he has remained for his entire faculty career. He was named department chair and Empire Innovation Professor in 2018 and SUNY Distinguished Professor in 2021. Swihart has co-authored the two most recent editions of Introduction to Chemical Engineering Thermodynamics (Smith, van Ness, Abbott, and Swihart), as well as over 300 peer-reviewed journal manuscripts. He has served as research advisor to more than 95 current and former graduate students and 110 undergraduate researchers at UB. He is a co-founder of NanoHydroChem, LLC and ProOsseus, LLC.

Shell Global Solutions
Sponsor of the
Thomas Baron Award

PTF Award Winner 2023

Dow Particle Processing Recognition Award

Dr. Jörg Theuerkauf

R&D Fellow

Engineering and Process Sciences, Core R&D

The Dow Chemical Company, Midland

JTheuerkauf@dow.com

Citation: For significant contributions on commercialization of multiple chemical products by utilizing particle technology fundamental knowledge and expertise

This award recognizes a Particle Technology Forum member who has made a significant contribution to the science and technology of particle processing in its commercialization, and who has shown leadership in the engineering community.

Dr. Jörg Theuerkauf is a Research and Development Fellow at Dow Chemical with over 23 years of industry experience in particle technology and fluid mechanics. Over his tenure at Dow, Jörg has been developing new products and processes, introduced new computational methods and experimental techniques, and worked on process troubleshooting for internal and external Dow customers, providing significant value. Jörg is known for his experience in Discrete Element Method (DEM) simulations where he pioneered the establishment of the simulation techniques as a tool in the industry thereby enabling realistic mapping of material properties. Jörg was an early adapter of the combination of DEM and computational fluid dynamics allowing to study reaction in packed beds and later fluidized beds. Besides the detailed studies of granular flow Jörg has always been interested in simulating entire processes and has championed solids flow sheeting effort allowing to optimize unit operations and entire manufacturing plants. While Jörg had an opportunity to work in the Pharma and Food solutions business at Dow he used the Particle Design Morphology platform to create excipients with superior flowability for more efficient manufacture of oral dosage forms (Methocel DC2 TM) which allowed a significant productivity increase using these products. The product developments or product modifications are all based on a deep understanding of particle technology. Many of these products have been patented.Several of these commercialized products have been awarded with multiple recognitions namely R&D 100 awards and an Edison Gold award. He is active in the European working party on mechanics of particulate solids supporting a renewed effort on wall friction measurements evaluation between many labs around the globe. He is an elected member of the German Fachausschuss for Solids handling and agglomeration. He has been teaching as an invited lecturer of particle technology at Delft in the Netherlands. Jörg has been mentoring many colleges in Dow and beyond in various aspects of solids handling and process technology helping our community to grow.

PTF Award Winner 2023

SABIC Young Professional Award

Dr. Kevin E. Buettner

Engineering Associate

Process Innovation and Scale-Up

ExxonMobil Technology and Engineering Company

kevin.buettner@outlook.com

Citation: For outstanding contributions in experimentation, CFD and DEM modeling, and industrial scale-up of fluid-particle processes.

Kevin E. Buettner is a lead pilot plant engineer within Process Innovation and Scale-Up at the ExxonMobil Technology and Engineering Company. He is a chemical engineering alumnus of the University of Oklahoma (2013) and the University of Florida (2018, Ph.D.) where he was a member of Professor Jennifer Sinclair Curtis' research group focused on model development for CFD simulations of granular flows. After joining ExxonMobil in 2018, he has made significant contributions in the process development and scale-up of "new-to-the-world" process technologies focused on complex fluidization systems. This has required the development and expansion of fluidization modeling capabilities to impact reactor design, and the operation of a new pilot plant to validate the reaction and hydrodynamic models required for novel process scale-up. Kevin currently serves as the Co-Chair for the Particle Technology Forum's (PTF) Area 3B, has over ten peer reviewed journal publications, and is an active referee for AIChE Journal, Chemical Engineering Science, and Powder Technology.

PTF Award Winner 2023

George Klinzing Best PhD Award

Dr. Sarah Hamilton

Department of Energy

Office of Fossil Energy and Carbon Management

sara.hamilton.triana@gmail.com

Citation: For her contributions to the advancement of new hybrid materials for electrochemical energy storage and reactive carbon capture integral to tackling the climate crisis.

Sara T. Hamilton received her M.Eng. in Chemical Engineering from Imperial College London in 2018 and her Ph.D. in Earth and Environmental Enginee ring from Columbia University in 2022 under the supervision of Ah-Hyung Alissa Park. During her Ph.D., she researched nanoscale hybrid electrolytes for electrochemical energy storage and combined CO_2 capture and conversion. She also received the SCGSR Fellowship from the Department of Energy's Office of Science, which supported her research at the National Renewable Energy Laboratory (NREL) on electrochemical interfaces in reactive carbon capture. Sara joined the Department of Energy's Office of Fossil Energy and Carbon Management in 2023 as an ORISE Science, Technology and Policy Fellow.

This award recognizes an outstanding original dissertation by an individual who has earned a doctoral degree. The dissertation can be in any discipline in the physical, biomedical or engineering sciences, with particle science and engineering as its focus. The nominee must have received a doctoral degree within the last three calendar years prior to the year the award is given, and it is based only on the contributions made during the course of the PhD.

PTF Award Winner 2023

ANSYS PTF Service Award

Dr. Bruce Hook

R&D Fellow, Dow Chemical (Retired)

bdhook1981@gmail.com

The ANSYS PTF Service Award recognizes a forum member's lifetime outstanding scientific/technical contributions to the field of particle technology, as well as leadership in promoting scholarship, research, development, service and/or education in this field.

Recently retired from the Dow Chemical Company, Bruce Hook is a distinguished chemical engineer with over 40 years of research and development and process design experience, including work in process optimization for new product development, process scale-up, particle engineering, particle coating fluidization, pneumatic conveying and solids handling, drying and storage, modeling gas-solid hydrodynamics, multiphase and heterogeneous reactor modeling and design, catalyst development, reaction kinetics for heterogeneous catalytic systems, non-catalytic gas-solid systems and liquid phase homogenous systems, high temperature solid state thermodynamics, and process separations. He has received 23 granted patents, several more still in process, has several peer-reviewed publications and over 20 presentations at conferences or invited talks. He has been active in AIChE programming for over 30 years, as chair/cochair at sessions for over 25 of the last 34 Annual Meetings. He was an early proponent of cross-sponsoring sessions between PTF and other groups to expand the influence of particle technology development. He chaired Group 3C before being elected as Industrial Liason to the PTF Executive Committee. He was elected co-Chair of the PTF in November 2016, and became PTF Chair in November 2018. During that time he helped bring forth for approval by EC, the PTF Diversity statement.

In other external responsibilities, he was active with PSRI for 17 years, including five years chairing their Technical Committee and seven years on the board of directors. He is currently on the Industrial Advisory Boards of two Chemical Engineering Departments: Rensselaer Polytechnic Institute (since 2011) and Texas A&M University (since 2023).

The Legacy and Impact of the Particle Technology Forum

Ray Cocco, Bob Pfeffer, Liang-Shih Fan, and Ah-Hyung Alissa Park

This coming AIChE Annual Meeting in Orlando, Florida, we get to celebrate the 30-year anniversary of the Particle Technology Forum or PTF. Particle technology is a multidisciplinary field focused on studying, manipulating, and applying particles and powders ranging in size from nanometers to millimeters. Many products we use today were particles, use particles, or are particles. In 1984, 62% of du Pont de Nemours & Co. 3000 products and 50% of Dow Chemical's products involved particles [1]. Indeed, the history of particle technology is closely tied to the development of various industries and scientific disciplines.

The foundation of today's PTF was laid at the very beginning of the formation of the PTF. The founders of the Particle Technology Forum (PTF) of the American Institute of Chemical Engineers (AIChE) realized this early in the 1990s. Before that, the AIChE was limited to fluidization and fluid-particle systems. It was a justified direction with the global focus on energy and fuels of the 1970s and 1980s, along with chemical productions with polyethylene, acrylonitrile, oxychlorination, and maleic anhydride [2].

However, it was realized that the AIChE's future investment in particle technology must be broader. Particle synthesis showed significant inroads in manufacturing advanced particle architecture In early 1990s, that particle technology in the AIChE's eyes must be broader in order to be valid with future demands. Those involved in particle technology saw this need. Under L.-S. Fan of Ohio State University with Wen-Chang Yang and Dale Keairns of Westinghouse, John C. Chen of Lehigh University, Fred Thomson and Reg Davis of E.I. du Pont de Nemours & Co., Chi Tien of Syracuse University Mike Roco of the NSF, Bob Pfeffer of City College of New York, Bryan Ennis of E&G Associates, and Ray Anthony of Texas A&M, a new directive was proposed and submitted to the AIChE as "Rationale and Proposed Plan for the Formation of the PTF" [13]. L.-S. Fan worked tirelessly with the AIChE executives and staff during the discussion and planning stage to convince the AIChE of the merits of approving the new forum. When the AIChE officially launched the Particle Technology Forum (PTF) on September 19, 1992. The team elected L.S. Fan as the PTF's or Group 3's first chair.

The need for a technology conduit in powder technology became more and more evident in the early 1990's. As noted above, the technology experienced a Renaissance with advanced techniques, tribology, agglomeration, comminution, mixing, slurry rheology, and reaction engineering. Before this time, particle technology was married to mixing as the Group 3 AIChE forum. It consisted of four subgroups:

Group 3a: Mixing,
Group 3b: Fluidization and Fluid-Particle Systems,
Group 3c: Solids Flow, Handling and Processing, and
Group 4d: Powder Technology.

It was effective but not well suited for the advancements to come in both fields. Group 3a, Mixing, overlapped with Group 2, the North American Mixing Forum. The PTF needed to be a technology conduit of information to all those involved in powder technology globally. The PTF needed to provide platforms for the dissemination and validation of new technologies. It needed to simulate both formal and casual discussions for the exchange of ideas. It also had to provide the seed to inspire new scientists to enter the field. Finally, the PTF needed to provide a mechanism for rewarding those who have made significant contributions in the field through advancing technology, scholarship, and/or stewardship.

In September 1993, it was proposed [3] that Group 3 be reorganized, with Group 3a being integrated into Group 2. New subgroups were proposed and consisting of

- Particle Formation,
- Size Enlargement and Agglomeration,
- Comminution and Attrition,
- Tribology, Friction, and Interparticle Forces,
- Particles Characterization,

- Fluidization and Multiphase Flow,
- Solids Flow, Handling, and Processing,
- Particle Mixing, Segregation, and Classification,
- Powder Mechanics and Slurry Rheology (Colloids and Interfaces), and
- Particle Reaction Engineering.

It certainly was an ambitious proposal under the direction of L.S. Fan, W.C. Yang, Dale Keairns, J.C. Chen, F. Thompson, Reg Davis, Chi Tien, Mike Roco, and Bob Pfeffer. Others were involved, too, but not formalized in this list. Brian Scarlett from Delft University of Technology certainly comes to mind.

On October 8, 1992, the Executive Committee provided the bylaws for the new PTF as Group 3 [4]. In it, the bylaws state that the PTF will give a stronger emphasis to

Cover a wide range of interdisciplinary topics in particle technology,
Serve as an international forum for particle technology, and
Foster and promote industrial and academic interactions.

The AIChE approved the formation of the new Group 3, or the PTF, at the AIChE Annual Meeting in November 1992. The AIChE received more than 100 responses showing a keen interest in becoming PTF members from both academia and industry professionals [15]. The new officers for the new PTF were

L.S. Fan with Ohio State University as Chair,
R. Davies with E.I. du Pont de Nemours & Co and Vice-Chair,
W.C. Yang with Westinghouse as Secretary, and
R. Pfeffer with New Jersey Institute of Technology as Treasurer.

The new PTF EC certainly maintained this drive. The proposed subgroups were reduced to nine focuses as

Particle formation,
Size enlargement and agglomeration,
Comminution and attrition,
Tribology, friction, and interparticle forces,
Particle characterization,
Fluidization and multiphase flow,
Solids flow, handling and processing,
Particle mixing, segregation and classification, and
Powder mechanics and slurry rheology

Powder Mechanics and Slurry Rheology and Particle Reaction Engineering were omitted due to overlap with other sub-groups or groups.

Three recognition awards were approved by the AIChE and consisted of

The Thomas Baron Award in Fluid-Particle Systems, sponsored by Shell Development Co.,
The Fluidization Processes Recognition Award sponsored by Dow Chemical with continued administration under Group 3b, and
The Particle Technology Forum Award sponsored by E.I. du Pont de Nemours & Co.

The first PTF Newsletter was published in Summer 1993 [5] and published several times a year thereafter. By Fall 1993, the PTF had grown to 335 members, of which a little over 40% were AIChE Members [19]. As shown in Figure 1, the PTF was indeed an international organization, with 30% of its members not from the United States. Society affiliations also grew to include the ACS, ASME, SPE, and CSChE.

In the next decades, the PTF focused more on emerging technologies than process research. Research on particle synthesis, nanoparticles, nano-composites, pharmaceutical powders, atomic layer deposition, particle characterization,

cellulose-based particles, fibrous particles, etc., was in demand. The PTF realized this direction early on and reorganized its subgroups to reflect that change. That change, which is still in use today, is as follows:

Group A: Particle Production and Characterization,
Group B: Fluidization and Fluid-Particle Systems,
Group C: Solids Flow, Handling, and Processing,
Group D: Nanoparticles, and
Group E: Energetics.

Five recognition awards were added to better acknowledge outstanding contributions in the field. Three of those awards were directed towards young professionals. The Particle Technology Forum Award was replaced with the Particle Technology Forum Lifetime Achievement Award. Today, the PTF has the following awards:

- The Thomas Baron Award in Fluid-Particle Systems, sponsored by Shell Development Co.,
- Particle Technology Forum Lifetime Achievement Award sponsored by Elsevier,
- The Fluidization and Fluid Particle Systems Award sponsored by PSRI with continued administration under Group 3b,
- Particle Technology Forum Service Award sponsored by Ansys, Inc.,
- Particle Processing Recognition Award sponsored by Dow,
- George Klinzing Best Ph.D. Award sponsored by alums of the University of Pittsburgh,
- Particle Technology Young Professional Award sponsored by SABIC Technology Center, and
- Particle Technology Forum Student Poster Competition Award sponsored by CPFD.

New conference sponsorships have also been added to the PTF's portfolio including the World Congress on Particle Technology in 2006 and 2018, and the Frontiers in Particle Science and Technology Conferences (FPST) which started on 2016. The PTF started participating in the AIChE Student Workshop, which preludes the AIChE Annual Meeting. Each year, the PTF gives a presentation on Particle Technology with live demonstrations to educate undergraduates on particle technology and inspire those few looking for a rewarding career in research in particle technology. It has become one of the most attended presentations, with attendance usually exceeding 200 students.

Today, the PFT is over 1200 members strong and continues to provide a technology transfer conduit in particle technology. The PTF has made global in-roads in providing a conduit for advancing particle technology. Its meetings are attended by researchers worldwide with academic or industrial focus. However, its job is not done. Today's global challenges are in need of such conduits more than ever. Electrification, sustainability, circularity, pollution, greenhouse emissions, food and water security, and health have taken center stage in all forms of research, including particle technology. As before, the PTF will be there to make sure that a conduit of technology is broad and specific while supporting the all-important scientific method.

References

- J.L. Sinclair, A Survey Course in Particle Technology, Chemical Engineering Education, Fall 1999, 266-269.
- J. W. Chew,, W. C. Q. LaMarche and R. A. Cocco, 100 years of scaling up fluidized bed and circulating fluidized bed reactors, Powder Technology 409 (2022) 117813.
- L.S. Fan, Rationale and Proposed Plan for Formation of an AIChE Affiliate Organization Particle Technology Forum (PTF), September 9, 1992 (Draft) and October 2, 1992 (Final).
- L.S. Fan, Bylaws for the ParticleTechnologyForum of the American Institute of Chemical Engineers, October 8, 1992.
- PTF Newsletter, vol 1, no 1, Summer 1993.

Time Capsule: PTF BYLAWS - The Beginnings...

New page

10/8/92

BYLAWS
for the
Particle Technology Forum of the
American Institute of Chemical Engineers

Article I-Name and Purpose:

Section 1. The name of the organization shall be "Particle Technology Forum (PTF) of the American Institute of Chemical Engineers (AIChE)."

Section 2. The purpose of the PTF is to serve as an international forum and to promote information exchange, scholarship, research and education in the field of Particle Technology, covering science and engineering related to all particulate systems, wet or dry, reactive or non-reactive.

Section 3. The Forum will function similar to an AIChE Division but is organized to give stronger emphasis to the following objectives:

a. to cover a wide range of interdisciplinary topics in particle technology
b. to serve as an international forum for particle technology
c. to foster and promote industrial and academic interactions

Article II-Relationship to the Institute:

Section 1. The Forum is a part of AIChE and its activities are open to co-sponsoring not-for-profit societies; members are encouraged to become members of AIChE and co-sponsoring not-for-profit societies.

Section 2. The Forum is under the supervision and oversight of the Council of the Institute.

Section 3. All forum committees shall work in coordination with corresponding National committees. Forum programming activity shall be carried out in coordination with the National Program Committee of the Institute.

Section 4. The Forum shall not have authority to act for or in the name of the Institute except with the explicit prior authorization of Council of the Institute. The Forum does not have the authority to incur any financial obligation in the name of the Institute.

Article III-Membership:

Membership in PTF is by self-selection. Anyone who pays the PTF dues will be considered a member.

Article IV-Organization:

Time Capsule: PTF BYLAWS - The Beginnings...

Section 1. Governance

The PTF will be governed by an Executive Committee consisting of nine individuals elected by and from the general membership. Each Committee member shall be a member of the AIChE at the time of election. Participation of the international community will be encouraged.

Section 2. Election and Term of Office

The term of office will be four years with four or five of the Executive Committee members standing for office at each Biennial Meeting. There is no restriction on consecutive terms.

NOTE: Transition rules apply in 1993 and 1995. Four of the appointed members will resign or be selected by lot to stand for election in 1993. Another five will resign or be selected by lot to stand for election in 1995.

New Executive Committee members will be elected by a simple plurality of the general membership who are present and voting at the Biennial Meeting, or by mail voting. Each voting member may select candidates from a slate prepared by the Nominating Committee but open to nominations from the floor. The slate prepared by the Nominating Committee shall allow conformance to the requirements for membership in the Executive Committee. If the votes from the general membership would elect candidates who would violate these requirements, the non-conforming candidates receiving the lowest number of votes shall be replaced by conforming candidates having the highest number of votes among those not elected.

Should any Executive Committee memberships become vacant, temporary members can be appointed by the Executive Committee of the Forum. Elections for any unexpired terms will be held at the next Biennial Meeting.

Section 3. Meetings of the Executive Committee

The Executive Committee will hold at least one meeting per year to elect officers, appoint committee chairs, and conduct other business as appropriate.

Section 4. Officers

Officers of the Executive Committee consist of a Chair, Vice Chair, Secretary, and Treasurer. These are elected from among Executive Committee members for two year terms, with the Vice Chair automatically succeeding to the Chair. All elections and other votes of the Executive Committee require a majority of those present. A quorum is five members.

Section 5. Co-sponsoring not-for-profit societies

Other professional societies which promote Particle Technology may apply for co-sponsorship of a PTF activity. The application must be sent in writing to the Executive Committee, which will reply within six months. The co-sponsoring societies will be listed in all PTF publications.

Section 6. Standing Committees

Time Capsule: PTF BYLAWS - The Beginnings...

Each of the Standing Committees will have a liaison with the appropriate Institute Committee. The liaison will be appointed by the Chair of each Standing Committee.

The Standing Committees and their duties are:

Technical Advisory Committee (TAC) -To advise the Executive Committee in matters of technical direction to the Forum. The TAC will consist of a TAC Chair and a Chair and Vice Chair of each Subgroup Area. The Subgroups shall consist but not be limited to the following Areas:

- Particle Formation
- Size Enlargement and Agglomeration
- Comminution and Attrition
- Tribology, Friction and Interparticle Forces
- Particle Characterization
- Fluidization and Multiphase Flow
- Solids Flow, Handling and Processing
- Particle Mixing, Segregation and Classification
- Powder Mechanics and Slurry Rheology
- Particulate Reaction Engineering

Colloid + Interfacial

The term of office for the TAC Chair will be four years with no restriction on consecutive terms. The TAC Chair will be a voting member of the Executive Committee and Institute membership is required. The term of office for the Subgroup Chairs and Vice Chairs will be two years, with the Vice Chair automatically succeeding the Chair. Institute membership is encouraged but not required of the Subgroup Chairs and Vice Chairs. Nominations for the Chair of the TAC and the Subgroup Vice Chairs may come from the Executive Committee and from the general membership. The Subgroup Vice Chairs will be elected by a simple plurality of the general membership who are present and voting at the Biennial Meeting, or by mail voting. The Chair of the TAC will be elected by a majority vote of the TAC members. A quorum is twelve members. Recommendations for modifications to the current Subgroup Areas may be submitted to the TAC by the general membership. Such modifications require a majority vote of the TAC as well as the Executive Committee.

An interim ad-hoc TAC to be composed of Subgroup Chairs of the above Areas will be appointed by the Executive Committee, to stand down at the first Biennial Meeting at which time both Chairs and Vice Chairs will be elected.

Biennial Meeting Committee-To organize the Biennial Meeting and to select the incoming Chair of the Meeting. This committee is chaired by the current Meeting Chair and shall include its past Chair, the TAC Chair, the TAC Subgroup Chairs (or a Vice Chair in the absence of a Subgroup Chair) and the Program Chairs of the Institute subgroup areas. (NOTE: this currently would consist of 3b-Fluidization & Fluid Particle Systems, 3c-Solids Flow, Handling & Processing, 3d-Powder Technology).

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The remaining Standing Committees are as follows:

Program Committee -To arrange technical sessions on particle technology at the Institute Meeting.

Awards Committee-To recognize members of the Forum who have made outstanding contributions to research and Scholarship, education or services in particle technology.

Education Committee-To promote education in particle technology at the university and postgraduate levels.

Research Committee-To promote research and opportunities for research funding in particle technology from funding agencies.

Communications Committee-To promote communications within the Forum and to liaise with external organizations.

Nominating Committee-To nominate a slate of candidates for election to the executive Committee. To nominate candidates to serve as Chairs of the various standing Committees, except for the TAC and the Biennial Meeting Committee which select their own Chairs.

Membership Committee-To maintain and promote membership drive.

Ad hoc committees may be formed by the Executive Committee as needed.

Except for the Chairs of the TAC and the Biennial Meeting Committee, each Committee Chair will be elected by the Executive Committee for a two year term. Committee Chairs may come from the Executive Committee of the Forum or from the general membership. If not a member of the Executive Committee, The Chair of a Standing Committee will become a non-voting, ex-officio member. Except for the TAC and the Biennial Meeting Committee, committee members are appointed by the Chairs of the various committees from members of the Forum.

Article V-The Biennial Meeting:

The Forum will hold a technical and business meeting at a North American site every two years. This meeting will generally be in the form of a Topical Meeting. The purpose of the business meeting is to elect members of the Executive Committee and to conduct other business as may be brought to the general membership by the Executive Committee.

Article VI-Dues:

Dues will be collected from members of the Forum. The amount of the assessment will be determined by the Executive Committee.

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Article VII-Budgets:

An annual budget for the PTF will be approved by the Executive Committee. Disbursement of funds and other fiscal matters will be the responsibility of the Treasurer. The Chair is also authorized to disburse funds.

Article VIII-Amendments

Section 1. All proposed amendments of these Bylaws shall be reduced to writing. Amendments shall be proposed to the membership by the Executive Committee or by a petition of ten percent (10%) of the members of the Forum to the Executive Committee. Such proposed amendments will be subject to a two-thirds majority vote by the general membership present and voting at the Business Meeting of the Biennial Meeting immediately subsequent to the petition. The amendment shall then be submitted to the Council of the Institute and shall become an effective part of the Bylaws upon its approval.

Section 2. The names of Sections of the Forum may be added or deleted in the list in Article IV, Section 5 by vote of the Executive Committee. Such action does not constitute an amendment to these Bylaws.

Section 3. The names of Organizations to which official liaison is maintained may be added or deleted in the list in Article IV, Section 5, by vote of the Executive Committee. Such action does not constitute an amendment to these Bylaws.

Article IX-General Provisions:

Section 1. The decision of the Executive Committee shall be final on any question concerning the interpretation of the Bylaws, subject to the jurisdiction of the Council of the Institute.

Section 2. In all respects not specifically covered by these Bylaws, the general rules of the Institute governing the conduct of Divisions shall apply with equal force as if included in these Bylaws.

Section 3. The Secretary of the Forum shall serve as Parliamentarian and shall rule on points of order and give information as requested by the presiding officer.

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10/2/92

Rationale and Proposed Plan for Formation of an AIChE Affiliate Organization
PARTICLE TECHNOLOGY FORUM (PTF)

Rationale

Particle technology is an important field in engineering research. It has been estimated that products in chemical process industries are disproportionately in granular form (e.g., 80% of the DuPont products) and these particulates undergo a variety of interactions with the fluid media. Besides its applications in traditional chemical, petrochemical, energy and mineral processing industries, this field has been prominent in emerging technologies such as material processing and biotechnology. It is estimated that over 10% of all published papers in chemical engineering deal with fluid particle technology, making it one of the most reported fields in chemical engineering research.

AIChE Group 3 "Contacting and Particulates, Operations and Processes" comprises of the following four subgroups:

Subgroup 3a - Mixing
Subgroup 3b - Fluidization and Fluid-Particle Systems
Subgroup 3c - Solids Flow, Handling and Processing
Subgroup 3d - Powder Technology

Subgroup 3a is a very active, demanding programming group. Its programming needs are now also served by another AIChE affiliate organization "North American Mixing Forum", which consists of large international constituents. The remaining groups, i.e., Subgroups 3b, 3c and 3d, are core groups of the Particle Technology in the AIChE, although there are other programming groups in AIChE also dealing with Fluid Particle Technology, e.g., Subgroup 2f (Fluid-Particle Separation) and Subgroup 7e (Multiphase Flow). Fluid-Particle programs led by Group 3 have been very active for over two decades and have been steadily growing in strength. The Fluid-Particle Symposia at the AIChE Annual Meeting has remained over these years as one of the major forums in the field where a large number of high quality papers are presented. The symposia have their plenary lecture series, as well as annual recognition dinners. Most importantly, they are attended routinely by prominent researchers internationally. Numerous conference proceedings are published from these symposia, and are well in demand (an average of over 1000 copies sold for any recent issue). Examples of some of these publications are:

(1) A. Weimer, Editor, "Fluidized Processes: Theory and Practice", AIChE Symposium Series, 1992 (in press).
(2) A. Weimer, Editor, "Advances in Fluidized Systems", AIChE Symposium Series, No. 281, Vol. 87, 1991.
(3) L.-S. Fan, Editor, "Advances in Fluidization Engineering", AIChE Symposium Series, No. 276, Vol. 86, 1990.
(4) L.-S. Fan, Editor, "Fluidization and Fluid Particle Systems - Fundamentals and Applications", AIChE Symposium Series, No. 270, Vol. 85, 1989.
(5) W.-C. Yang, Editor, "Fluidization Engineering - Fundamentals and

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Applications", AIChE Symposium Series, No. 262, Vol. 84, 1988.
(6) W.-C. Yang, Editor, "New Developments in Fluidization and Fluid Particle Systems", AIChE Symposium Series, No. 255, Vol. 83, 1987.
(7) G.E. Klinzing, Editor, "Fluidization and Fluid-Particle Systems: Recent Advances", AIChE Symposium Series, No. 241, Vol. 80, 1984.
(8) T.M. Knowlton, Editor, "Fluidization and Fluid-Particle Systems: Theories and Applications", AIChE Symposium Series, No. 234, Vol. 80, 1984.
(9) T.M. Knowlton, Editor, "Fluidization and Fluid-Particle Systems: Theories and Applications", AIChE Symposium Series, No. 222, Vol. 79, 1983.
(10) D.V. Punwani, Editor, "Recent Advances in Fluidization and Fluid-Particle Systems", AIChE Symposium Series, No. 205, Vol. 77, 1981.
(11) C.Y. Wen, Editor, "Fluidization - Application to Coal Conversion Processes", AIChE Symposium Series, No. 176, Vol. 74, 1978.
(12) J.S. Halow, Editor, "Fluidization: Theories and Applications", AIChE Symposium Series, No. 161, Vol. 73, 1977.
(13) H. Littman, R. Pfeffer, C.Y. Wen, O. Levenspiel and D.K. Keairns, Editors, "Fluidization: Fundamental Studies, Solid-Fluid Reactions and Applications", AIChE Symposium Series, No. 116, Vol. 67, 1971.
(14) M.A. Bergougnou, J.D. Gabor, B.L. Tarmx and N.J. Weinstein, Editors, "Fundamental Processes in Fluidized Beds", AIChE Symposium Series, No. 101, Vol. 66, 1970.
(15) H. Littman, R. Pfeffer, J. Feinman, B.S. Lee and N. Levitz, Editors, "Fluidization Fundamentals and Applications", AIChE Symposium Series, No. 105, Vol. 66, 1970.
(16) B.S. Lee, Editor, "Fluid Particle Technology", AIChE Symposium Series, No. 62, Vol. 62, 1966.

In addition, several short courses in Particle Technology are offered under AIChE Continuing Education and are presented by prominent members in this field. Examples are:

1. "Fluid Bed Technology", by A.A. Avidan, D. King, T. Knowlton and M. Pell, offered thrice a year.
2. "Advanced Fluid Bed Design. Analogies Between Molecular and Particulate Behavior in Fluid Bed and Related Technologies", by F.A. Zenz, offered thrice a year.
3. "Particulate Solids Characterization and Agglomeration", by M.E. Fayed and Wolfgang Pietsch, offered twice a year.
4. "Conveying of Bulk Solids", by S.S. Grossel, M.E. Fayed and F.M. Thomson, offered twice a year.
5. "Flow of Solids in Bins, Hoppers and Feeders", by J.W. Carson and J. Marinelli, offered four times a year.
6. "Pneumatic Transport of Solids in Pipes", by G.E. Klinzing and P.E. Solt, offered thrice a year.
7. "Static Electricity in Powder and Bulk Solids Handling", by J.J. Piret, P. Poldras and T.H. Pratt, offered twice a year.

Several factors necessitate the formation of this AIChE affiliated organization "Particle Technology Forum". As the members of the Subgroups 3b, 3c and 3d strongly

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desire that the fluid-particle symposia be held at the annual meeting (instead of national meetings), the current AIChE session allocation does not meet the programming needs of this field which is ever expanding. Furthermore, there is tremendous interest in the AIChE fluid-particle program by the international community. A number of international people wishing to solely affiliate with the fluid-particle group at the AIChE and participate in the group activity wish to be able to pay only a nominal fee to become a member of the group without being burdened with a large regular AIChE membership fee. More importantly, however, there is an urgent need to establish an organization which can serve as an international forum for this rapidly expanding interdisciplinary field of Particle Technology, and to foster and promote industrial and academic interactions. Thus, it is an opportunity for AIChE to assume leadership in this area via the affiliate PTF.

The PTF will cover a wide range of interdisciplinary topics in particle technology, and will be initially structured around Subgroups 3b, 3c and 3d; in due course it can expand to cover other areas such as mineral, pharmaceutical and food processing, and include other disciplines besides chemical engineering. It is noted that the formation of PTF has been supported and endorsed by the Group 3 advisory committees, as well as many members in the subgroup committees. There are several very successful international conferences already in place such as Engineering Foundation Conference on Fluidization and World Congress in Particle Technology. Thus, the meetings of PTF are not intended to compete with them, but to supplement them. The PTF meeting will typically be arranged as a topical meeting in conjunction with the AIChE meetings. It will serve as an international forum to facilitate and expedite exchange of ideas and information.

Proposed Plan

We request that the AIChE Council approve the formation of this organization and the attached Bylaws at its Council meeting in Miami. During the initial phase of the Forum operation, the following will be appointed to serve in the Executive Committee:

L.-S. Fan (Chair, Group 3), Ohio State University
W.-C. Yang (Vice Chair, Group 3), Westinghouse
J.C. Chen (Chair, Group 3b), Lehigh University
F. Thomson (Chair, Group 3c), DuPont (retired)
C. Tien (Chair, Group 3d), Syracuse University
M. Roco, National Science Foundation
B. Pfeffer, City College of the City University of New York
R. Davies, DuPont
D. Keairns, Westinghouse

According to the transition rule in the draft of the Bylaws (Article IV, Section 2), four of these appointed members will resign or be selected by lot to stand for election in 1993; another five will resign or be selected by lot to stand for election in 1995. The initial Executive Committee members will meet at the 1992 Miami Meeting to elect the Chair, Vice Chair, Secretary and Treasurer of the organization, and to appoint the Standing Committee Chairs. Also at the Miami Meeting, a massive membership drive will take place. In addition, we will also map out the short term and long term organizational plans including biennial

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meeting activity and assisting in the 1994 World Congress in Particle Technology.

Therefore, important purposes of PTF are to accommodate participation of international members interested in particle technology, to bring increased awareness of this important area to both academic and industrial community, and to provide leadership of AIChE in this field. There is indeed an urgent need to found the PTF - an AIChE affiliate organization to better serve the community. I urge the expeditious approval of the formation of this organization.

Submitted by:

L.-S. Fan
Chairman, AIChE Group 3
Professor of Chemical Engineering
Ohio State University

PTF Membership

To continue receiving the PTF newsletters (3 issues per year) and stay current with particle technology events and news, please make sure to renew/ start your membership by either:

- Checking Particle Technology Forum when renewing your AIChE membership annually,
- Becoming a PTF lifetime member so that you don't have to renew membership every year

Become a PTF only member (Annually $15, Lifetime $150)

If you don't see the PT membership in your renewal screen, you can choose "Update Membership Options" and add PTF to your order.

You can also contact AIChE customer service at 800-242-4363 (US); 203-702-7660 (Outside the US); or email customerservice@aiche.org for membership questions and help.

PTF Membership Committee

Particle Playground: Understanding Density In Particle Technology

Ray Cocco, Particles In Motion

Shrikant Dhodapkar, The Dow Chemical Company

What is density? For gases, liquids, and pure solids, this is reasonably straightforward. It is the mass divided by the volume in which it is contained. In particle technology, density is much less implicit. The British Standards Institute has fourteen definitions for density, and the ASTM has over forty [1,2]. The reason is that particles are often a combination of solids, cracks, pores, and surface irregularities, making one definition of density a poor descriptor[3].

For example, if we use density in its typical definition of the mass of the material divided by the volume of the container holding the material, we get the density of the bulk material. It may not represent the density of the material and does not even represent the density of a particle. Now, if we know the diameter of a single, spherical particle, we should be able to get the density of a material, right. Most often, this is not correct either. This density does not account for those solids, cracks, pores, and surface irregularities common with most particles. As a result, many different types of densities are used in particle technology — each service is a descriptor for a particular particle morphology or environment. Thus, one needs to understand which density is appropriate for your application.

Which density should you be using?

Absolute Powder Density: This density is defined[1] as the mass of a particle divided by its volume, excluding all pores, both open and closed. Sometimes, the absolute powder density is called the true density. It is the density of the material and the material only. This is not to be confused with the density of an element or compound. Different lattice structures or lattice defects in a material will lead to a different absolute powder density despite the same element or compound being used. The absolute powder density is rarely used in particle technology because most particle technology problems have to deal with inter- and intra-particle voidages (solids, cracks, pores, surface irregularities, and interstitial spacings). In other words, the precise volume of only the material can be challenging to obtain.

Particle Density: The particle density or apparent particle density is the mass of a particle divided by its apparent particle volume, excluding closed pores and very small open pores[1]. This should not be confused with the less commonly used effective particle density, where the closed pore volumes are included and is more in line with the absolute particle density. Mercury pycnometers are often used to measure the particle density of a particle because mercury is too dense to penetrate the small open pores (nonwetting) or the closed pores. The true density of alumina is 3.69 g/cc, but the particle density of an alumina particle ranges from 1 to 2 g/cc.

The particle density is a common parameter used in particle technology. Many particle-based calculations, such as terminal velocity or acceleration (i.e., drag) are based on this particle density. Using the absolute powder density would not be appropriate because the closed pores make the particle lighter than the actual material, and the terminal velocity would be artificially higher than it should be. Many bulk correlations the particle density as well but with a voidage or loading multiplier. This reduces the particle density to be more in line with a bulk density value, which is discussed later.

Envelope Density: ASTM [4] defines the envelope density as the ratio of the mass of a particle to the sum of the volumes, including the solid in each piece and the voids within each piece. The BSI defines[1] envelope density as the ratio of mass of a particle to the envelope volume of the particle. That is, the volume is within close-fitting imaginary envelopes that completely surround each piece. For example, the envelope density could assume that the volume of a particle is spherical. Thus, if a 75-micron particle weighed 0.0001 g, then the envelope density would be 0.0001 g divided by the volume of a 75-micron diameter sphere. The BSI definition does not include interparticle voids where the ASTM method does. Envelope densities typically are not as precise as particle density. Fortunately, envelope density is not frequently used in particle technology.

Skeletal Density: The ASTM defines[2] the skeletal density as the ratio of the mass of discrete pieces of solid material to the sum of the volumes of the solid material in the pieces and open pores within the pieces. Open pores are not considered as part of the particle volume. Pycnometers using helium or nitrogen are commonly used to measure particle densities by employing the Archimedes' principle of fluid displacement and gas expansion. The gas penetrates only the open pores. Skeletal densities should be equal or greater than the envelope or particle densities, but these two densities seem to be lumped into "particle density."

Bulk Density: This is another common density used in solids processing and powder technology. The bulk density is the ratio of the mass of the particles to the volume of the filled container holding the particles. It is the mass of the particles divided by the volume of the particles, including open and closed pores plus the interstitial spaces between the particles. It is often determined by adding particles to a container of known volume, weighing the mass of the particles (less the tare of the container) and dividing the mass by the known volume. It is related to the particle density as

$$\rho_b = \lambda_{bed}\rho_p = (1 - \varepsilon_{bed})\rho_p$$

where ρ_b is the bulk density, ρ_p is the particle density, λ_{bed} is the particle loading, and ε_{bed} is the bed voidage. So, if the particle density of an alumina particle is 1.5 g/cc, and a packed bed voidage is 0.63, the bulk density of that material would be 0.95 g/cc.

There is more than one bulk density value as it is environmentally dependent. Powders settle or expand depending on whether the container was exposed to vibration, humidity, temperature, etc. The bulk density of a box of cereal is much lower when filled at the plant than when you open it for breakfast in the morning. Settling caused the particles, or in this case, the flakes, to rearrange themselves such that they take up less volume. Less volume for the same mass means a higher bulk density. This same analogy also applies to tank cars or any other contained used for shipping. Vibrations during transit can lead to an increase in the bulk density. Thus, bulk density limits are defined as either the loose or tapped or vibrated bulk density.

Loose Bulk Density: The loose bulk density is defined by the ASTM [6] as the density that results from pouring the powder into a heap or container in the absence of any applied compression. It is typically measured using a graduated cylinder and determined by the mass of the powder in the graduated cylinder divided by the volume of the powder in the cylinder, including the intra- and inter-particle voidage. For the cereal box, the loose bulk density is obtained just after the cereal box has been filled.

Tapped Bulk Density: The tap density, tapped density or vibrated bulk density is the bulk density, but after it has been under a state of tapping or vibration. The ASTM [5,7] definition for the tapped bulk density is the bulk density resulting from the application of compression, such as, impact or vibration. The tapped bulk density can be thought of as the maximum bulk density.

The tapping or vibrating causes the smaller particles to better fill the spaces between the larger particles. Under controlled conditions of tap rate, tap force, and container size, the condition of maximum packing efficiency is highly reproducible. Excessive tapping or vibrating can also result in particle size segregation.

The difference between the loose and tapped bulk densities can be significant depending on the material. Particles having a wide particle size distribution will have a greater difference between the tapped and bulk densities than monodispersed particles. Thus, it is important to understand which bulk density is being used and the environment it is being used in.

Compressibility: For fine granular materials and powders or coarse granular material with significant fraction of fines, the bulk density is a function of consolidation stress. A typical relationship between bulk density and consolidation stress is shown in Figure 1. As the consolidation stress increases, so does the bulk density. However, the rate of increase levels off at higher stress levels unless the particles begin to fracture. The dependence of bulk density on the

consolidation stress is termed compressibility. This relationship is expressed mathematically in various functional forms, some of which are listed below.

Jenike [8]:

$$\frac{\rho}{\rho_p} = [\frac{\sigma}{\sigma_o}]^b$$

Johanson & Cox [9]:

$$\frac{\rho}{\rho_p} = (1 + b_1\sigma)^{b_2}$$

Gu, Arnold & McLean [10]:

$$\rho = \rho_o + b_1\sigma^{b_2}$$

Schulze [11]:

$$\rho = \rho_o + a\,ln[\frac{\sigma}{\sigma_o}]$$

where ρ is the bulk density at major consolidation stress σ, ρ_0 is the bulk density at major consolidation stress σ_0, and σ_0 is an arbitrary reference value of stress. Constants *a*, b_1, and b_2 are regressed from experimental data.

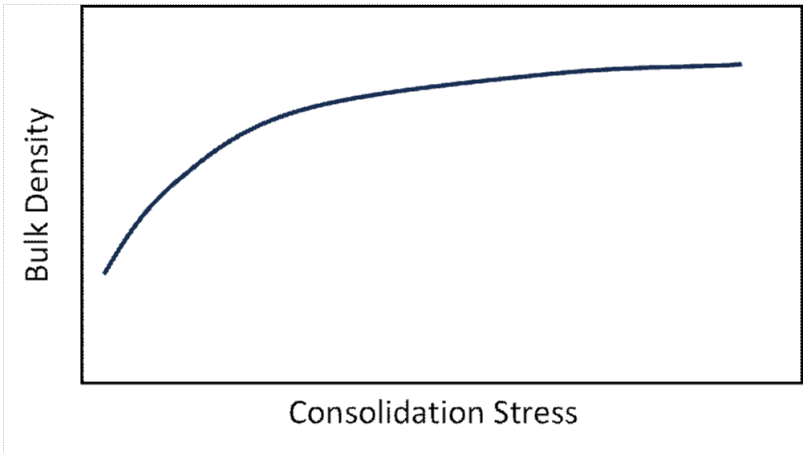


Figure 1: Bulk density characteristics of compressible bulk solids.

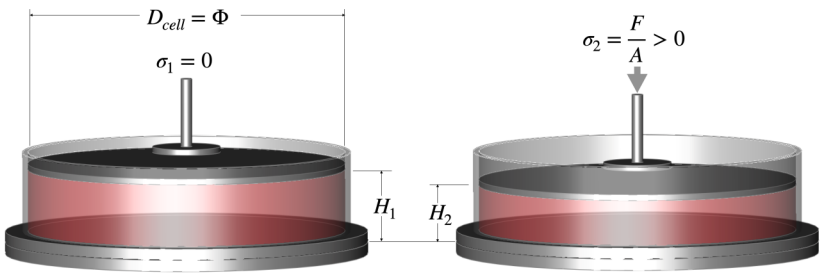


Figure 2: An example of a compressibility test.

Compressibility data can be obtained from a fairly simple device, as shown in Figure 2. The bulk solid of known mass is loaded into a cylindrical cell of diameter D and cross-section area A. The height of the bed is measured at increasing levels of consolidation stress by applying a vertical force on the top lid. The bulk density is calculated by dividing the mass of the sample by the sample volume. To minimize the wall effects, the walls can be lubricated, the H/D ratio of the sample is kept below 0.3, and the cell diameter is much larger than particle size. To compare the compressibility characteristics of two bulk materials (powders), the compressibility curves generated over a range of consolidation stress are more discriminatory than the ratio of tapped density to loose-poured bulk density. Estimating the bulk density at varying consolidation stresses is essential for designing and predicting flow out of bins/hoppers, estimating the capacity of volumetric feeding devices and in understanding tableting and roll compaction processes.

Emulsion Density: The emulsion density is more a state than a property. In fluidized beds and standpipes, this is often referred to as the bed density. It is the combined density of the material and fluid in a specific environment. This type of density is commonly used to describe the state of solids and gas in risers, standpipes, pneumatic conveying, fluidized beds, and circulating fluidized beds. The combination of the density of particles and gas in a fluidized bed is the emulsion density. In other words, the particles, bubbles, and voidage in the interstitial spacings are all considered. If the particle density of alumina particles in a packed bed is 1.5 g/cc, then the loose bulk density would be approximately 0.95 g/cc, as noted before. In a fluidized bed, the bubbles and voidage would make the bed or emulsion density on the order of 0.5 g/cc (i,e, $\rho_b = (1 - \varepsilon_{bed})\rho_p = (1 - 0.35)1.5 g/cc$).

The emulsion density is determined by measuring the weight of a material suspended by a gas or liquid in a container of known volume during operation or corrected for operating conditions. This is important because pressure, humidity, temperature, etc. can impact the emulsion density. For example, the emulsion density of small particles (i.e., 100 micron particle size) can be sensitive to pressure. High pressure tends to lower the emulsion density substantially. Not accounting for this pressure effect could result in under-predicting the bed height of a fluidized bed at operating conditions. There are cases where this has been an issue in commercial units.

In summary, there is a menagerie of density definitions. In solids processing and particle technology, particle density, and bulk density are the most commonly used descriptors, yet there are differences within these terms as well. Table 1 illustrates the relationship of all these densities and how they differ. Therefore, when we talk about the density of powders, we need to be specific. All too often, a particle density is confused with a bulk density, or a loose bulk density is confused with a tapped density. To avoid these pitfalls, the following questions should be considered whenever working with the density of powders or solids [12]:

⇒ What density is being used: absolute powder density, particle density, envelope density, skeletal density, loose bulk density, or tapped bulk density?
⇒ How was the density measured? What standard was used? How repeatable is the standard for the material in question?
⇒ Does the density measurement apply to the material in question? Is the particle size distribution the same? Is it moisture-sensitive, or does it exhibit some other type of environmental sensitivity?
⇒ Where has the sample been? Was it shipped? Should compaction or expansion of the material be expected? and,
⇒ Is the correct density being used for the calculation or correlation under consideration?

Remember, don't assume you know which density is being given to you. More often than not, it may not be what you think it is.

References:

1. British Standard BS 2955 Glossary of Terms Related to Particle Technology, BSI, London (1991).
2. Compilation of ASTM Standard Definitions, 8th Edition, ASTM, Philadelphia (1994).
3. Webb, P., Volume and Density Determinations for Particle Technologists, Micrometritics Instrument Corp, Feb 16, 2001.
4. ASTM Method D3766, "Standard Terminology Relating to Catalysts and Catalysis"

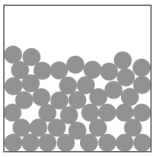
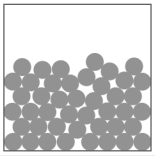
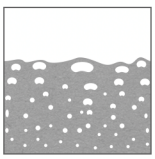
5. ASTM Method D5550, "Standard Test Method for Specific Gravity of Soil Solids by Gas Pycnometer"
6. ASTM D7481, "Standard Test Methods for Determining Loose and Tapped Bulk Densities of Powders using a Graduated Cylinder."
7. ASTM D6683, "Standard Test Method for Measuring Bulk Density Values of Powders and Other Bulk Solids as Function of Compressive Stress."

8. Jenike, A.W., Gravity Flow of Bulk Solids, Bulletin 108, Utah Engineering Experiment Station, Univ. of Utah, 1961

9. Johanson, J.R. and Cox, B.D., Practical Solutions To Fine Powder Handling, Powder Handling & Processing, 1[1] (1989) 61-65.
10. Gu, Z.H., Arnold, P.C. and McLean, A.G., Consolidation-related bulk density and permeability models for bulk solids, Powder Technology, 72 (1992) 39-44.

11. Schulze, D., " Behavior, Characterization, Storage and Flow, Powder and Bulk Solids, Springer (2008) p 99.
12. Cocco, R. (2010). "What is density in particle technology." Powder and Bulk Engineering: 1-3.

Table 1: Description of the more common densities used in particle technology

Scale	Density Type	Volume Included in Definition					Graphical Representation
		Material Volume	Close Pore Volume	Open Pore Volume	Inter-particle Voidage	System Voidage (i.e., Bubbles)	
Material	Absolute Powder Density or True Density	✔					
Particle	Particle Density or Apparent Particle Density	✔	✔				
	Envelope Density	✔	✔	?			
	Skeletal Density	✔	✔				
Bulk	Loose Bulk Density	✔	✔	✔	✓		
	Tapped Bulk Density	✔	✔	✔	✔		
Unit	Emulsion Density	✔	✔	✔	✔	✔	

2023 Annual Meeting - Programming Highlights

Date	Time	Event	Location
Monday November 6	12:30 PM - 3:00 PM	Session 112 - Invited: Celebrating 30 years of the PTF (The First 15 years)	Bayhill 21 (Lobby Level, Hyatt Regency Orlando)
Monday November 6	3:30 PM - 6:00 PM	Session 35 - Invited: Celebrating 30 years of the PTF (Last 15 years)	Bayhill 21 (Lobby Level, Hyatt Regency Orlando)
Tuesday November 7	3:30 PM - 6:00 PM	Session 290 - Honorary Session: Ray Cocco's Special Topics	Bayhill 21 (Lobby Level, Hyatt Regency Orlando)
Wednesday November 8	12:30 PM - 3:00 PM	Session 237 - Particle Technology Forum Award Presentations	Bayhill 21 (Lobby Level, Hyatt Regency Orlando)
Wednesday November 8	3:30 PM - 5:00 PM	Session 303 - Poster Session: Particle Technology Forum	Regency Ballroom R/S (Convention Level, Hyatt Regency Orlando)

Meeting	Date / Time	Location
PTF Executive Committee (EC) Meeting	November 5, 2023 (5:30 – 6:30 PM)	Bayhill 28
PTF General Business Meeting	November 6, 2023 (6 – 7 PM)	Bayhill 19
Group 3a – Programming Meeting	November 7, 2023 (10:30 – 11:50 PM)	Bayhill 19
Group 3b – Programming Meeting	November 7, 2023 (10:30 – 11:50 PM)	Bayhill 20
Group 3c – Programming Meeting	November 7, 2023 (10:30 – 11:50 PM)	Bayhill 21
Group 3d – Programming Meeting	November 7, 2023 (10:30 – 11:50 PM)	Bayhill 22
Group 3e – Programming Meeting	November 7, 2023 (10:30 – 11:50 PM)	Bayhill 26

Particle Technology Forum Awards Dinner 2023

Wednesday, November 8, 2023; 6:00-9:30 PM

Venue: Rodizio Grill Brazilian Steakhouse

Address: 9101 International Dr #1220, Orlando, FL 32819,
Phone: **1-**407-748-9606

PTF Contact: Dr. S.B. Reddy Karri, Phone: 1-630-291-5682

Program: Reception, dinner and PTF Award presentations

Enjoy and Chill in a professionally responsible manner

Tickets are getting sold out fast, please get your tickets

PTF Awards and Dinner Sponsors

Sponsor of the Lifetime Achievement Award

Shell Global Solutions
Sponsor of the
Thomas Baron Award

The Dow Chemical Co.
Sponsor of the
Particle Processing Award

Sponsor of the Lectureship in Fluidization Award

Sponsor of the Young Professional Award

University of Pittsburgh Alumni
Sponsor of the
George Klinzing Best PhD Award

Sponsor of
PTF Service Award

Sponsor of PTF Awards Dinner

Sponsor of Student Poster Competition Award

Particle Technology Forum Organization

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Statement on Diversity

The AIChE Particle Technology Forum is committed to maintaining a diverse and inclusive community of highly skilled chemical engineering professionals within the environment of the Institute and profession in which all members, regardless of characteristics such as gender identity and expression, race, religion, age, physical condition, disability, sexual orientation, educational level, socioeconomic class, nationality or ethnicity, are valued and respected."

As a global scientific and engineering society, we affirm the international principles that the responsible practice of science, free from discrimination in all of its forms, is fundamental to scientific advancement and human wellbeing, as outlined by the International Council for Science's (ICSU) Statute 51. We also affirm our commitment to an engineering and scientific environment that facilitates the planning, execution, review and communication of engineering and scientific work with integrity, fairness, and transparency at all organizational levels. This extends to our general scientific endeavors—including our professional interactions and engagement with other engineers, scientists, students, trainees, and the general public. We recognize that harm to our profession, our scientific credibility, individual wellbeing, and society at large is caused by not doing so.

To this end, the PTF will implement the principles of diversity, inclusivity, and equity within PTF leadership and membership to build a community across the chemical enterprise. We are committed to quantifying and monitoring our diversity at least annually at the Executive Committee and reported at the general business meeting.