PURDUE PROCESS SAFETY AND ASSURANCE CENTER (P2SAC): Overview, history, and mission *and* goals of P2SAC

Osman Basaran

Burton and Kathyrn Gedge Professor *and*
Academic and Founding Director of P2SAC
Davidson School of Chemical Engineering/Purdue University
https://engineering.purdue.edu/P2SAC

ROADMAP

- Primary goals of the presentation are to provide an overview of P2SAC for *industry colleagues who are new to the center* and *students*, and also to give an update to *current members*

- The entire presentation can be found online at the center website (see next slide)

CENTER MANAGEMENT

- **Osman Basaran**, Burton and Kathryn Gedge Professor of Chemical Engineering: Academic and Founding Director (AD) of P2SAC [obasaran@purdue.edu]

- **Ray Mentzer**, Visiting Professor of Chemical Engineering: Executive Director (ED) of P2SAC [rmentzer@purdue.edu]

- **Web site:** https://engineering.purdue.edu/P2SAC

OUTLINE OF PRESENTATION

- Executive overview of what the center is all about, current membership, P2SAC's unique approach, member company benefits, and ways in which PhD, Master's, and Undergraduate projects are determined and managed.
- Detailed historical perspective on the founding and growth of P2SAC.
- Why safety and assurance? Some examples.
- Center organization and other important details.

https://engineering.purdue.edu/P2SAC

WHAT IS P2SAC?

- P2SAC is an academic research center that is based in the Davidson School of Chemical Engineering at Purdue University.
- P2SAC was conceived in 2013 and launched in 2014 by Professor Osman Basaran who is the Academic and Founding Director of the center (henceforward the AD).
- P2SAC is focused on problems that fall in the large subject of safety and process and/or product assurance (hence the name the ***Purdue Process Safety and Assurance Center,* P2SAC**).
- The approach adopted at P2SAC, while **driven by problems in industry**, is **research-based**. P2SAC is not involved in critically important but more applied safety issues, e.g. the training of first responders.
- P2SAC is almost entirely funded by membership fees paid by its industrial member companies or sponsors.

CURRENT INDUSTRIAL MEMBERS/SPONSORS*

*The center's Advisory Board also includes **Air Products** and The National Institute for Occupational Safety & Health (**NIOSH**).

UNIQUE FEATURES AND APPROACHES

- Participation by **multiple faculty** (rather than a single individual) in management of center projects.
- Involvement of students from all levels:
  - PhD students (**2+ year projects mentored by faculty**)
  - PMP students (intense summer projects for Professional Master's students **mentored by member companies**)
  - Exceptional undergraduate (UG) students (**mostly mentored by Ray Mentzer**) in safety-related research
- Teaching a core (required) course on safety to all undergraduate and a select group of graduate students in the School of Chemical Engineering. (*According to informal polling of first year graduate students, **Purdue ChE is one of a handful of departments nationally and internationally** that requires all undergraduates to take a core course on safety in order to receive a BS degree.*)

MEMBER COMPANY BENEFITS

- Attendance at the annual program review and technical conferences (one in the spring and the other in the fall)
- **Helping to determine/identify PhD projects to be funded and research areas to be pursued *and* guiding projects** (voting every two years during/after the fall conference)
- **Direct involvement with PMP students, i.e. mentoring** (tantamount to 1,000 man-hours of “free” work!)
- Early access to and “royalty-free” use of research findings
- Increased access to uniquely trained graduate students (PhD and MS) and postdocs, in addition to undergraduate students, as ***permanent hires*** and/or ***interns***
- Teaching as well as participation in “tutorials” on process safety and assurance at P2SAC conferences

FUNDED PhD PROJECTS FOR 2019-2020

Carl Laird: Optimal placement of detectors and new directions driven by systems engineering approaches

Brett Savoie: High throughput quantum chemical calculation of Benson group values for reliable thermodynamic calculations

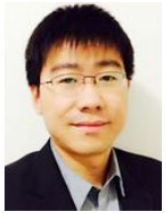
Kingsly Ambrose: Sensing dust concentrations by imaging

Zoltan Nagy: Modeling and uncertainty analysis of dust explosions

Raj Gounder: New directions in prevention by catalyst design (PTD)

Arvind Varma: Catalyst design and reactor runaway: selective oxidation of alcohols

Vilas Pol: Battery safety by materials design



Letian Dou: Safer materials and processing design for next-generation printed electronics

Osman Basaran: The role of chemical agents (surfactants) and electrostatics in coalescence

PROCESS FOR DETERMINING AND FUNDING PhD PROJECTS

(Program managed by Osman Basaran, AD)

- **There are two ways for coming up with new projects.** Either
  - Faculty or groups of faculty (within and outside ChE) come up with project ideas on their own or
  - Industrial members work with faculty to develop new projects
- **Timing for formulating projects:** *summer and early fall*
- **Timing and mechanism(s) for proposing projects:** either by
  - Making an oral presentation/pitch during the fall conference or
  - Submitting a 1.5-page written project proposal to Osman Basaran (AD) in early December [this year: December 7]
- **How are projects to be funded determined?** Member companies rank order the projects and send their rankings electronically to the AD with cc to ED by December 21
- **Final determination on funding:** AD selects projects to be supported based on input received and availability of funds (Dec 31)

PROCESS FOR DETERMINING PMP PROJECTS (Program managed by Ray Mentzer, ED)

- **October-November:** Engage with Ray Mentzer (Executive Director).
- **December 2:** Commitment from industrial partner in the form of mentor's (or mentors') name(s) and a working title for the proposed project(s) are made.
- **February 7:** Firm titles and working problem statements are provided to the Professional MS Program students.
- **February 10 – March 20:** Students and industrial sponsors interact in order to begin the matching process.
- **April 14:** All students and industrial projects are matched and the teams are formed.
- **April 15 – May 15:** Informal meetings between students and mentors begins as the Spring semester concludes.
- **May 18:** The summer semester begins and the projects start in an official capacity.
- **July 27:** Written reports are due.
- **July 29-31:** Oral reports are delivered on campus.

PROCESS FOR DETERMINING UG PROJECTS (Program managed by Ray Mentzer, ED)

- Projects are solicited from companies and others throughout the year by Ray Mentzer (ED). [Companies are free to propose projects without solicitation.]
- Projects are advertised to undergraduate (UG) students prior to the start of each semester.
- Students are matched to projects by Ray Mentzer at the start of the semester.

With top-caliber undergraduate students, projects have resulted in serious scholarly research, publications in leading journals, and valuable technical reports.

MEMBERSHIP FEES

- Large company: $25K/year
- Medium-size company: $12.5/year
- Small-size and consulting firms: $5K/year
- Although membership fees are paid yearly, companies typically commit for a three-year membership

HISTORY OF P2SAC

HISTORY OF P2SAC

- **Concept of P2SAC: Proposed by Basaran to ChE faculty at school retreat on 5/2013**

- **Conception and birth of center: Following extensive interactions between Basaran and industry, and input provided by *some members of ChE IAC* (12/2013)**

- **Inaugural conference and official launch of P2SAC: Monday, October 13, 2014**

- **History of industry membership in P2SAC:**
  - **Spring 2014: Honeywell, BP, ExxonMobil (hereafter EM) (3 members) [First industry contact: Prasad Goteti of Honeywell, our tutorial speaker on Dec 1]**

HISTORY AND STATUS OF P2SAC

- **History of and current industry membership in P2SAC:**
  - **Spring 2014: Honeywell, BP, EM (3 members)**
  - **Summer/Fall 2014: Honeywell, BP, EM, and Eli Lilly (4 members)**
  - **Spring/Fall 2015: Honeywell, BP, EM, Eli Lilly, and Shell (5 members)**
  - **Fall 2016: Honeywell, BP, EM, Eli Lilly, Shell, and Chevron (6 members)** ***[Ray Mentzer joins P2SAC]***
  - **Spring 2017: Honeywell, BP, EM, Eli Lilly, Shell, Chevron, Dow, Phillips 66, and Kenexis (9 members)**
  - **Spring 2018: Honeywell, BP, EM, Eli Lilly, Shell, Chevron, Dow, P66, Kenexis, Fauske, and Amgen (11 members)**
  - **Fall 2018: Honeywell, BP, EM, Eli Lilly, Shell, Chevron, Dow, P66, Kenexis, Fauske, Amgen, 3M, and GSK (13 members)**
  - **Spring 2019: Honeywell, BP, Eli Lilly, Chevron, Dow, P66, Kenexis, Fauske, Amgen, 3M, GSK, and Pfizer (12 members)**

CURRENT INDUSTRIAL MEMBERS/SPONSORS*

*The center's Advisory Board also includes **Air Products** and The National Institute for Occupational Safety & Health (**NIOSH**).

REMEMBERING THE P2SAC INAUGURAL CONFERENCE

- **Date: Monday, October 13, 2014**
- **Location: FRNY Hall of ChE**
- **Who was there: Honeywell, BP, ExxonMobil, Eli Lilly, Air Products, and about ten Purdue ChE faculty plus a few graduate students (*fewer than 20 people*)**
- **What was the agenda? An order of magnitude more modest than what we had during 7-9 May 2019 and on 4-5 December 2019 (attended by about 130 people)**

WHY A PURDUE SAFETY CENTER AND WHAT ARE ITS UNIQUE FEATURES?

- There are very few such centers, e.g. Mary Kay O'Connor (MKO) Safety Center at TAMU (focus is mostly on petrochemical industry).
- Representatives of member companies on the School of Chemical Engineering's Industrial Advisory Committee (IAC) report that only a small fraction of the needs of industry in the safety arena is met by existing academic centers.
- It was and continues to be strongly recommended by members of the IAC and other colleagues from industry that the Purdue Center should also focus on **process and/or product assurance**---the reason the center was/is named the ***Purdue Process Safety and Assurance Center*** (**P2SAC**).
- The approach adopted at P2SAC, while **driven by problems in industry**, would be/is **research-based**. We leave more applied safety issues, e.g. the training of first responders, to others.

SAFETY AND ASSURANCE

Purdue Process Safety and Assurance Center (P2SAC)

We all understand the **safety** part!

(See next few slides.)

Plant Explosion Tears at the Heart of a Texas Town

By MANNY FERNANDEZ and JOHN SCHWARTZ
Published: April 18, 2013 (New York Times)

WEST, Tex. — The blast was so powerful that the United States Geological Survey registered it as a 2.1-magnitude earthquake. It reduced an apartment complex to a charred skeleton, leveled homes in a five-block radius and burned with such intensity that railroad tracks were fused. It killed up to 15 people and injured up to 180. Volunteer firefighters were missing. Residents of a nursing home were pulled from debris and rushed to hospitals.

By Thursday evening, one day after a fertilizer plant here caught fire and then exploded, no one among the hundreds of local, state and federal officials and first responders who converged on this town north of Waco was certain about the cause. They only knew its effect.

The Texas Fertilizer Plant Explosion

By Mike Elk, Published: April 23 (Washington Post)

Mike Elk is a labor reporter and staff writer for In These Times Magazine.

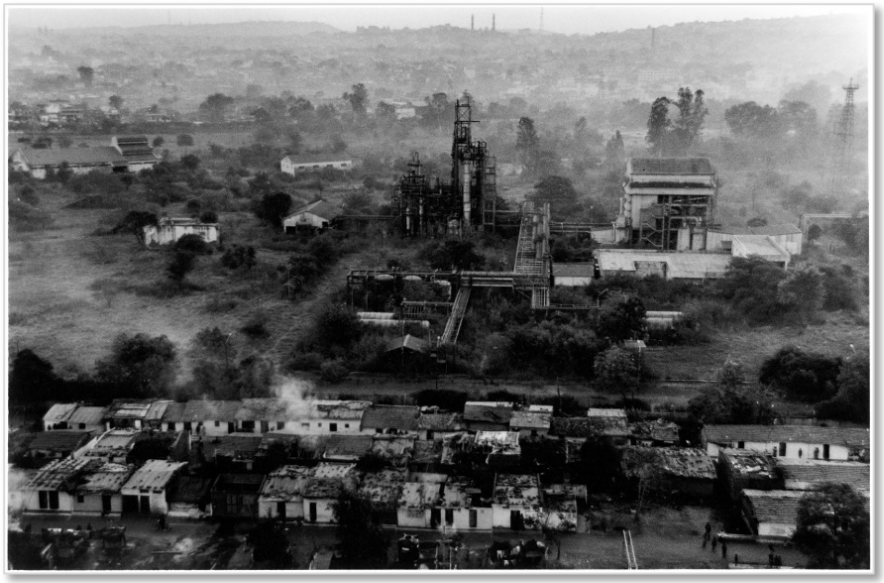
Erich Schlegel/Getty Images - WEST, TX - APRIL 18: The remains of an apartment complex next to the fertilizer plant that exploded on April 17, 2013 in West, Texas. Around 14 people, including 10 first responders, were killed and more than 150 people were injured. (Photo by Erich Schlegel/Getty Images)

From the New York Times (April 19, 2013)

Larry W. Smith/European Pressphoto Agency

The remains of the plant. The authorities say there is no indication of criminal activity in the explosion, which followed a fire.

Purdue Process Safety & Assurance Center (P2SAC)



Bhopal, India (1984): At least 3,787 and over 16,000 claimed fatalities

West Pharmaceuticals, NC (2003): 6 fatalities

BP Texas City (2005): 15 fatalities

Imperial Sugar, Georgia (2008): 14 fatalities

Refinery explosion: How Philly dodged a catastrophe

(June 21, 2019, Philadelphia Inquirer)

Philadelphia Oil Refinery Explosion Shakes City With Huge Fireball

(June 21, 2019, The New York Times)

Firefighters responded to a report of an explosion around 4 a.m. at Philadelphia Energy Solutions, a refining complex near the Schuylkill between the city's international airport and downtown. The complex includes two refineries, which together can process about 335,000 barrels of crude oil per day. It is the largest oil refining complex on the Eastern Seaboard, according to the company.

Thousands Evacuated in Texas After Explosion at Port Neches Chemical Plant

A second blast at the plant sent fire and a piece of a tower into the sky. Now residents are being evacuated the night before Thanksgiving.

By Margaret Toal, Nicholas Bogel-Burroughs and Manny Fernandez

•Nov. 27, 2019

https://www.nytimes.com/

Accidents and safety

- Accidents not only result in *the* ***tragic loss of human lives****, damage to property and infrastructure, and financial loss* but also reduce confidence in industry and manufacturing among the general population.

- They also add to the existing and unfortunately ***growing mistrust in technology, engineering, and science***.

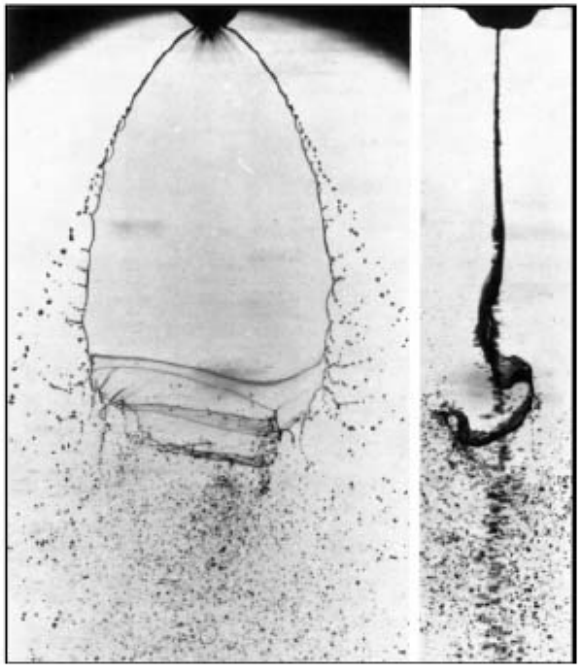
Purdue Process Safety and Assurance Center (P2SAC)

What is and why **assurance**?

(See next few slides.)

Why Assurance? Spray drift example from crop spraying or crop protection

Liquid sheet from a fan spray nozzle (Crapper et al. JFM 1973; Villermaux ARFM 2007, Altieri and Cryer 2018)



Small drops are undesirable because they lead to drift (Basaran group research funded by Corteva).

Mystery: modern spray solutions do not disintegrate like pure fluids! Why?

Spray drift is the most common cause of off-target movement of chemicals (e.g. pesticides) in crop spraying. It can injure or damage plants, animals, the environment or property, and even affect human health. "Drift" is the airborne movement of agricultural chemicals as droplets, particles or vapor.

Nonstandard Inkjets

Annu. Rev. Fluid Mech. 2013. 45:85–113

Osman A. Basaran,[1] Haijing Gao,[1,2] and Pradeep P. Bhat[1,3]

[1]School of Chemical Engineering, Purdue University, West Lafayette, Indiana 47906; email: obasaran@purdue.edu

[2]Advanced Production Systems, Chevron Energy Technology Company, Houston, Texas 77002; email: Haijing.Gao@chevron.com

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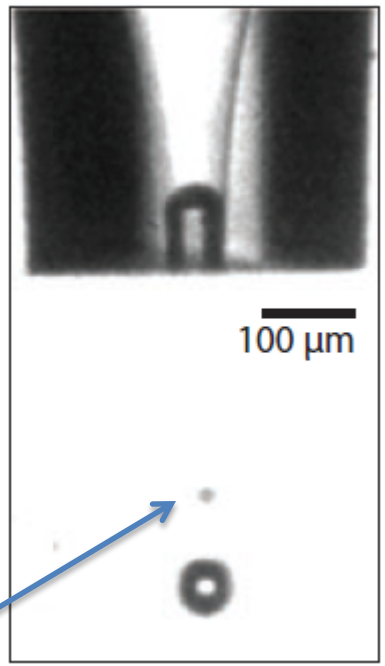
*Production of **monodisperse drops** and prevention of undesirable satellites are also key **flow assurance** issues in **ink jet printing** and **drop-wise (drop-based) manufacturing (e.g. personalized medicine)***

Pharma!

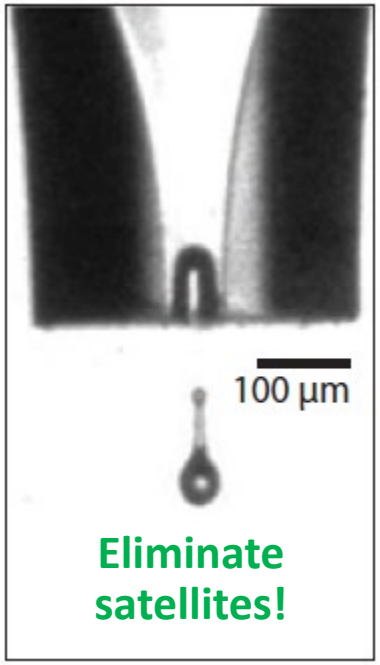
3D Printing!

Squeeze-mode piezo sleeve and 35 μm glass nozzle used in DNA microarraying and other cutting edge applications



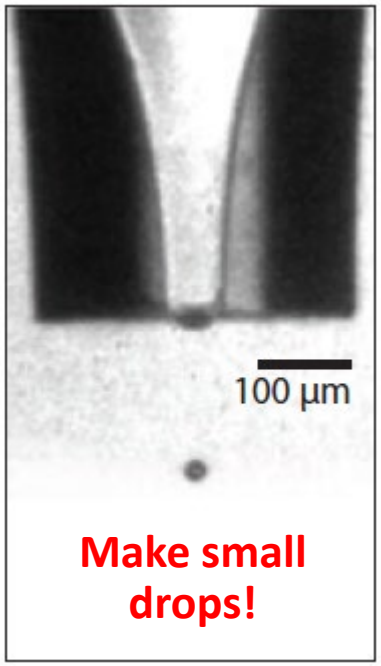
"Standard" waveform and "big" drops (plus *undesirable satellites*!)

"Standard"



Eliminate satellites!

"New and better"

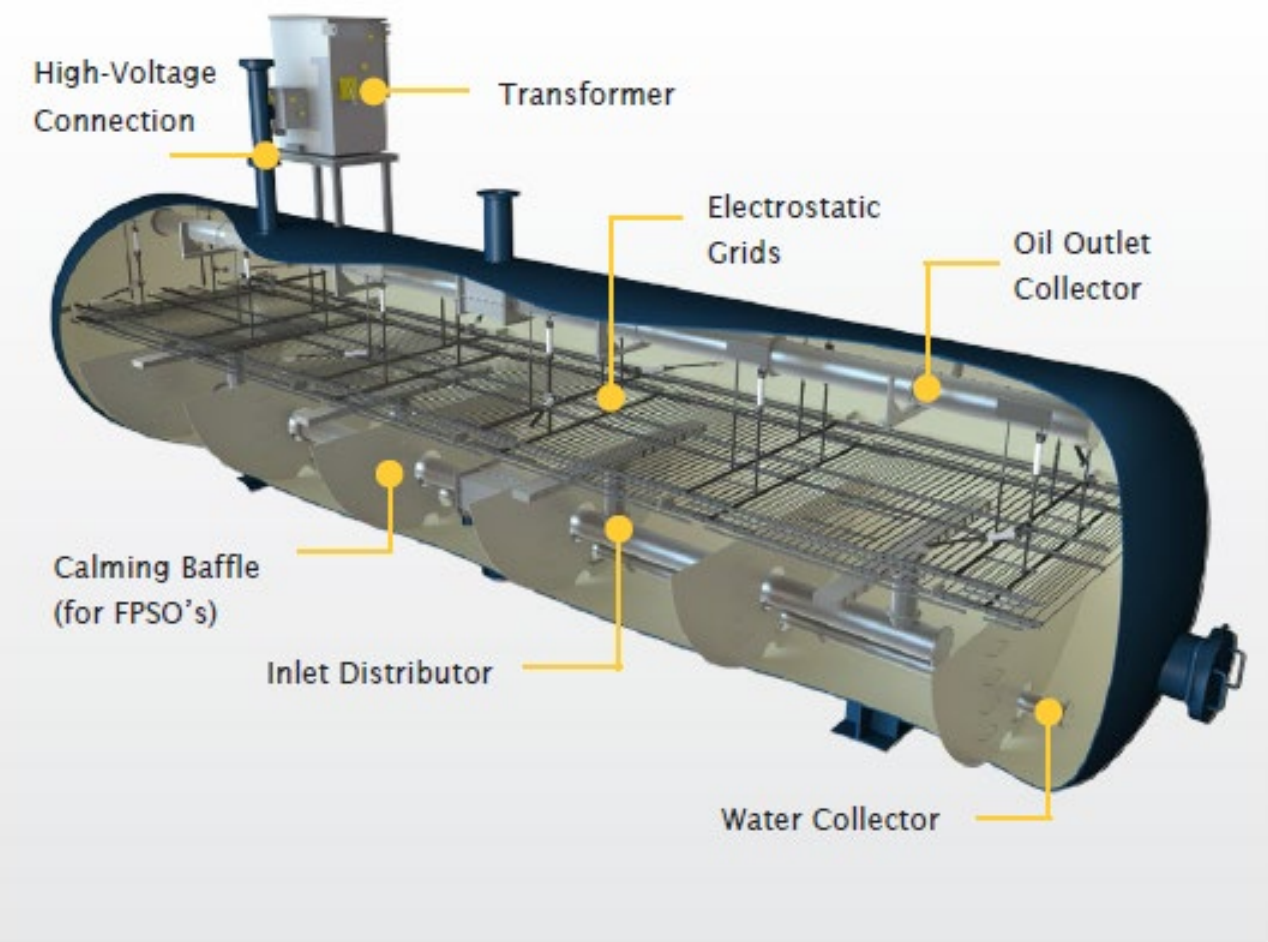


Make small drops!

"New and best"

"Novel" waveform(s) invented at Purdue make "small" drops (we can use nozzles from a 1984 HP Thinkjet to make drops as small as is possible with today's printers!)

Electrostatic coalescers (dehydrators/desalters)



3D model of Frames Electrostatic Coalescer

Frames
Separation Technologies
Glazenmakersweg 3
3449 JK Woerden
The Netherlands

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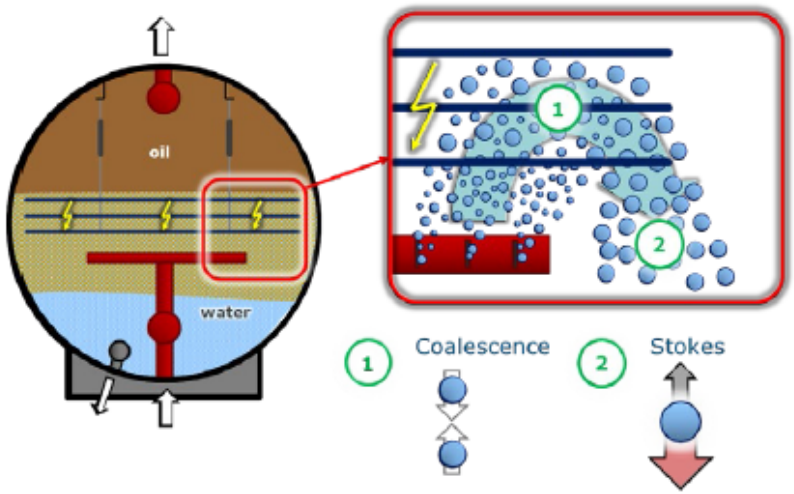
separation@frames-group.com
frames-group.com

FRAMES
a family of oil & gas solutions

Process Description

Frames builds on its vast experience in coalescer engineering, enabling us to give our clients a competitive advantage when it comes to cleaning crude oil. By efficiently and effectively removing undesirable water and salts, our clients are able to increase the quality of their crude oil, cut their transport costs and protect their downstream processes and equipment.

Removal of water and contaminants generally comprises two steps: dehydration and desalting. Frames coalescers are designed for both steps, and are applied in upstream as well as downstream applications. In oilfields, the emphasis is generally on a combination of dehydration and desalting, whereas in refineries the focus is primarily on desalting.



Working principle of coalescence (1) and separation (2) inside Electrostatic Coalescer

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FRAMES
a family of oil & gas solutions

P2SAC-funded PhD project in Basaran group:
The role of chemical agents (**surfactants**) and **electrostatics** in coalescence

Examples of flow assurance

- Coalescers, dehydrators, desalters, and oil-water-gas separators (widely used in the O&G industry)
- Hydrate formation in oil and gas pipelines
- Spray drift in agriculture
- "Drop size-modulation" and "satellite droplet or misting prevention" in ink jet printing and other drop-wise, e.g. additive, manufacturing operations
- Bottle filling (e.g. detergent bottles and drug vials)
- Rupture/integrity of coated films on substrates
- Rupture of free thin films/sheets (important in atomization and polymer processing)

Other examples of flow and/or process assurance

- Avoiding polymorphs in the pharmaceutical industry (e.g. in the emerging area of personalized medicine)
- Control of particle (or capsule) size as well as shape in diverse industries
- Safety, reliability, and durability of biomedical (e.g. implants) and surgical devices (e.g. Basaran group's work on new microfluidics-based devices from B+L for eye surgery and vitreous removal)

Safety and quality often go hand in hand (I)

Airlines cancel thousands of flights as Boeing works to fix 737 Max software problems (Washington Post, July 9, 2019)

Safety and quality often go hand in hand (II)

Boeing Under Fire Over The Safety Of The 787 Dreamliner. Boeing is under fire for one more of its planes – the Boeing 787 Dreamliner. While the wounds are still fresh from the two Boeing 737 MAX crashes, journalists have dealt another blow to the company. (Apr 24, 2019)

Boeing's Dreamliner jet is now facing claims of manufacturing issues
Published Sat, Apr 20 2019 3:13 PM EDTUpdated Tue, Apr 23 2019 10:53 AM EDT.
https://www.cnbc.com/2019/04/20/boeings-dreamliner-jet-now-facing-claims-of-manufacturing-issues-nyt-report.html

1. The New York Times reported on Saturday that the newspaper's investigation of a Boeing plant "reveals **a culture that often valued production speed over quality**."
2. The Times said it reviewed "hundreds of pages of internal emails, corporate documents and federal records."
3. **Boeing workers have filed numerous safety complaints with the federal government over issues ranging from shoddy manufacturing practices to tools and debris being left on planes**, The New York Times reports.

MORE ON P2SAC

Center vision

- The goal of the Purdue Process Safety and Assurance Center (P2SAC) is to become the world-wide center-of-excellence in research, education, and service in safety as well as process and product assurance
- The aim of P2SAC is to carry out research to address and solve problems having applied as well as fundamental importance in the safe and reliable operation of industrial processes in diverse fields
- However, P2SAC does not deal in non-research-intensive activities such as the training of first responders
- Work in P2SAC is and will continue to be quite **broad** but be **focused** on the ***energy, chemical, petrochemical, and pharmaceutical industries*** (among others, **e.g. agriculture**)

Center activities and unique features

- Involve **multiple faculty** (rather than a single person), PhD students (**2+ year projects**), PMP students (intense summer projects **mentored by member companies**), and exceptional undergraduates (mostly mentored by Ray Mentzer) in safety-related research.
- Additionally, P2SAC aims in the long term to become a leader in certain aspects of safety education through development and teaching of primarily undergraduate and graduate courses. (*According to informal polling of first year graduate students in our program,* ***Purdue ChE is one of a handful of departments nationally and internationally*** *that requires all undergraduates to take a core course on safety in order to receive a BS degree*) *(The course is also offered to graduate students, which is even more unusual.)*

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List of funded PhD projects for 2019

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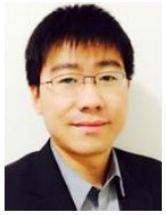


Letian Dou: Safer materials and processing design for next-generation printed electronics

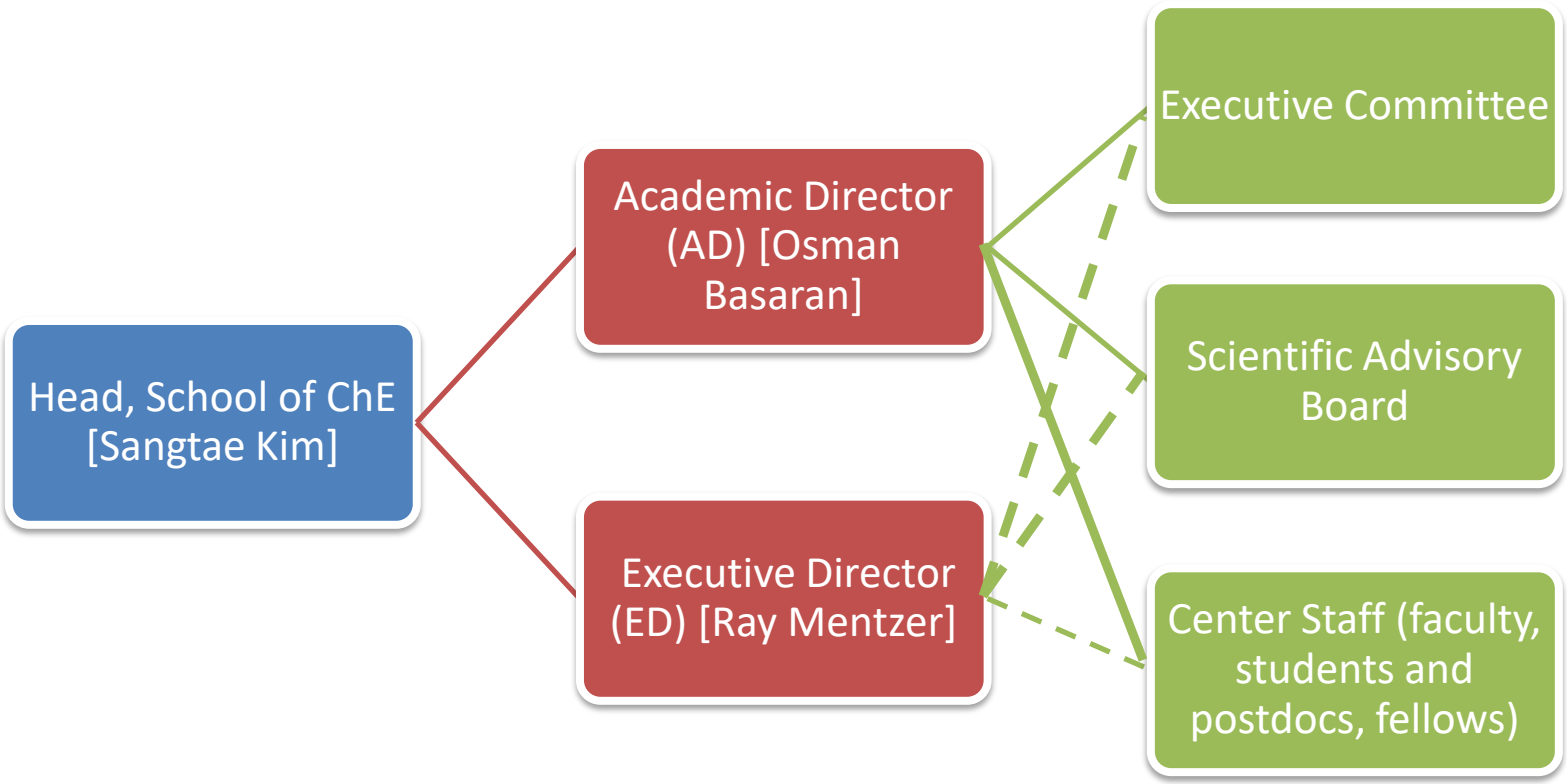
Osman Basaran: The role of chemical agents (surfactants) and electrostatics in coalescence

P2SAC Organization by Sectors

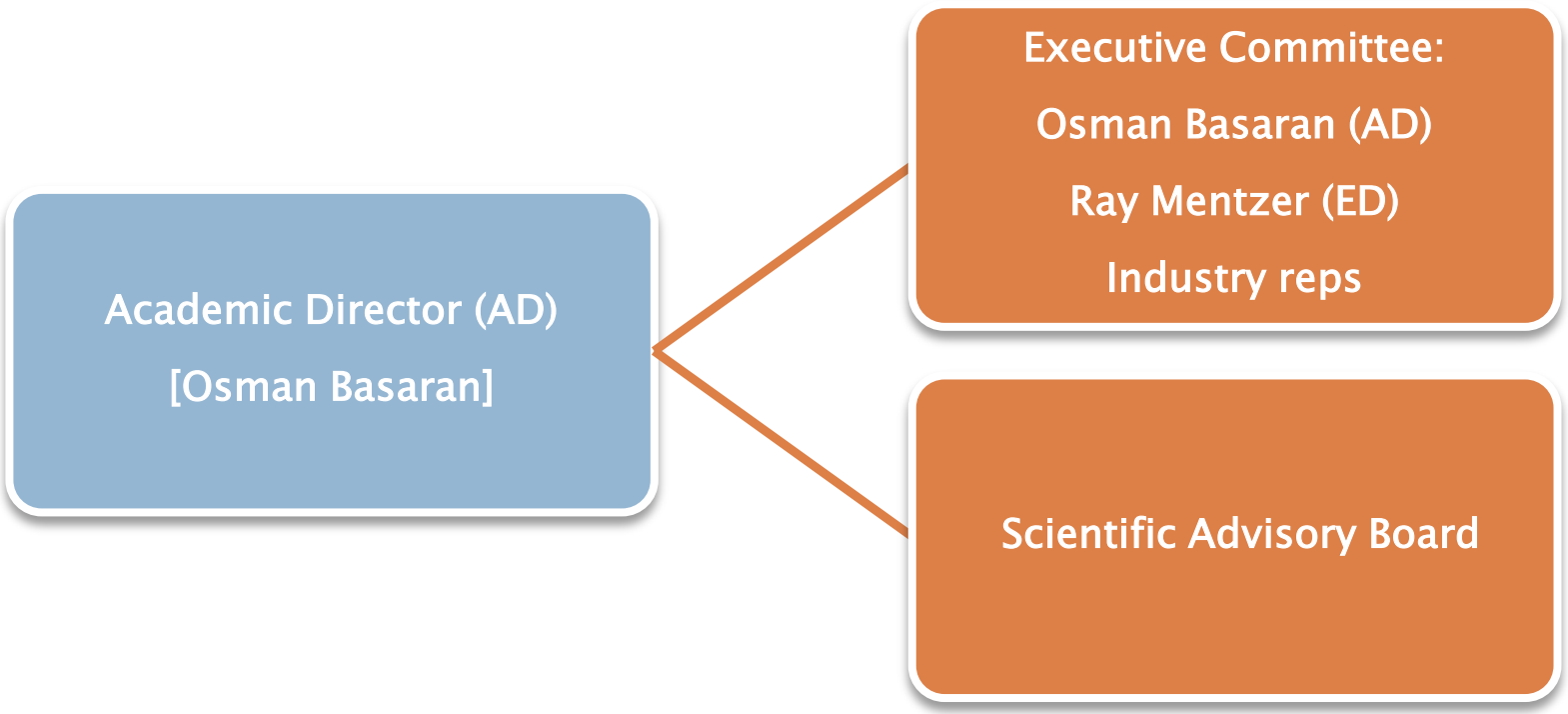
- Oil, gas, and petrochemicals
- Chemicals
- Technology, including consumer products and diversified manufacturing
- Pharmaceuticals (a growth area)
- Future: focus especially on developing “agriculture” while continuing to grow pharma and other areas

Bring people together from different industries, backgrounds, and interests who normally would not interact with one another with the goal of creating synergisms that may not arise under ordinary circumstances

P2SAC Organizational Chart



P2SAC organization for setting research and funding priorities



Scientific Advisory Board

- Osman Basaran - Professor, Purdue Chemical Engineering, Academic Director
- Ray Mentzer - Visiting Professor, Purdue Chemical Engineering, Executive Director
- George Harriott - Air Products (safety and consequence analysis/modeling)
- Hari Subramani - Chevron (flow assurance, oil and gas)
- Pritish Kamat - Dow (flow assurance, chemicals and manufacturing)
- Prasad Goteti - Honeywell (quantitative risk analysis)
- Stan Kolis - Lilly (pharmaceutical safety)
- Jonathan Bach - NIOSH/CDC (prevention through design, PTD)
- Edward Marszal - Kenexis (risk analysis for design of protective systems)
- Laurence Pearlman - Marsh Risk (risk consulting)
- Ashok Dastidar - Fauske and Associates (dust, liquid, and vapor explosions, electrostatic hazards, hazard analysis)
- Rob DiValerio - BP (oil and gas, upstream, and refining)
- Steven Horsch - Dow (reactive chemicals and fundamental problem solving)
- Bruce Vaughen - CCPS (risk reduction approaches and management)
- Jeffrey Sperry - Vertex (pharmaceutical safety)

Three-day P2SAC conference in May 2019

- May 7: ***Pharma*** (organized by Ray Mentzer)
- May 8: ***"Regular" P2SAC spring 2019 conference***
- May 9: ***Flow assurance*** (organized by Osman Basaran)
- Approximately 120 people from more than three dozen organizations attended the conference

Process Safety Conferences Held Each Semester
Attendees – May 8, 2019 Spring Conference

Sponsors

AMGEN
BP
Chevron
Dow
Fauske & Associates
GSK
Honeywell
Kenexis
Lilly
Phillips 66
Pfizer
Shell
3M

Guests

- ADM*
- aeSolutions
- Air Products
- Alkermes*
- American Chem Soc*
- Americas Styrenics*
- AMRI
- BakerRisk
- CCPS
- CDC - NIOSH
- Corteva AgroScience
- DEKRA*
- Eastman Chemical*
- Endress+Hauser
- Evonik
- FujiFilm Dimatix*
- Gexcon*
- Jensen Hughes
- Johnson Matthey*
- Marsh Risk Mgmt
- Merck*
- Occidental Oil & Gas
- Tate & Lyle*

**denotes 1st meeting*

Additional/frequent guests at some past meetings:
Bechtel, CF Industries, SABIC, **SOCMA** (trade organization involving hundred companies, e.g. Polysciences and BASF), Swift Fuels

Process Safety Conferences Held Each Semester

Attendees – December 12, 2018 Fall Conference

Sponsors

AMGEN
BP
Chevron
Dow
ExxonMobil
Fauske & Associates
GSK
Honeywell
Kenexis
Lilly
Phillips 66
Pfizer
Shell
3M

Guests

- aeSolutions*
- Air Products
- AMRI–Grafton*
- Baker Eng & Risk*
- CF Industries*
- CountryMark*
- Cummins
- CCPS
- Dow AgroSciences
- Endress+Hauser*
- Evonik
- ICASE*
- Jensen Hughes*
- Marsh Risk Mgmt*
- Occidental*
- SABIC*
- Swift Fuels*

** denotes 1st meeting*

On-going dialog with other Depts:
AAE, ABE, CHEM, IE, IPPH, ME & CV

P2SAC FALL 2019 CONFERENCE (December 4 and 5, 2019)

- December 4: four industry-led tutorials on process safety
- December 5: regular P2SAC Fall 2019 Conference
- https://engineering.purdue.edu/P2SAC/news/events/2019-p2sac-fall-conference-dec4-5

CONFERENCES IN 2020

- Spring 2020 conference was canceled on account of the Covid-19 pandemic

- Fall 2020 conference: virtual mini-conferences spread out over three days in December 2020 (outline to follow)