Purdue Process Safety & Assurance Center (P2SAC)

Overview

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Purdue University

December 7, 2020

PURDUE UNIVERSITY | Davidson School of Chemical Engineering

P2SAC Formed in 2014

- Process Safety a challenging quantitative / technical discipline; scope not widely recognized
- Conduct process safety related research focusing on fundamental science
- Teach rigorous process safety ChE core course *(172 UG and Grad students enrolled Fall '20)*
- Engage UG & Professional MS students in process safety research
- Source of expertise for industry and other stakeholders regarding process safety related standards & best practices
- Focus on oil & gas industry, chemicals, pharmaceuticals, agriculture, consumer products and manufacturing
- Research projects solicited from industry sponsors, as well as other stakeholders such as academia & government labs

Process Safety Conferences Held Each Semester

Attendees – December 7, 2020 Fall Conference

Sponsors

ACC – Am Chem Council
AcuTech
AMGEN
BP
Chevron
Corteva
CountryMark
Dow
Endress+Hauser
Fauske & Associates
GSK
Honeywell
Kenexis
Lilly
Marsh Risk
Phillips 66
Pfizer
SABIC
3M

Guests

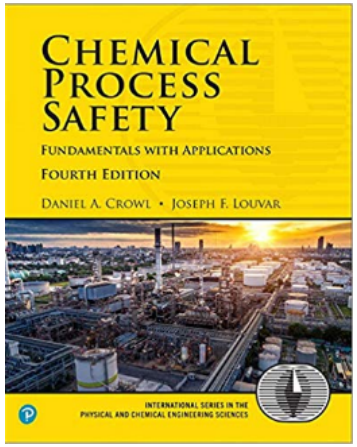
- AB InBev*
- ACM Facility Safety*
- Aerie Pharma*
- aeSolutions
- Air Products
- AstraZeneca*
- Atul Ltd*
- Biocon Ltd*
- BMS
- Cadila*
- CCPS
- CDC - NIOSH
- Celanese*
- Cummins
- DEKRA
- ExxonMobil
- George Booth, Inc*
- Gilead*
- Husky*
- IChemE*
- ioMosaic*
- Ingredion*
- Johnson Matthey
- LANGAN*
- Lima Refining*
- Merck
- Mettler Toledo*
- Organix Inc*
- Occidental
- PharmaTech*
- PI Industries*
- Smith Burgess*
- Tate & Lyle
- Umicore*
- Univ CO, Bolder*
- Vertex

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

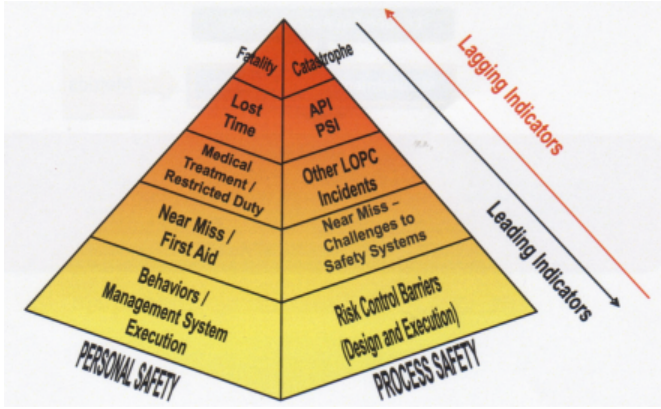
**denotes 1st meeting*

Chemical Process Safety - Core Class

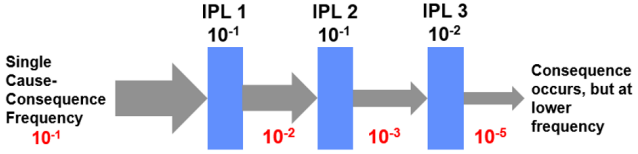
- Personnel vs. Process Safety & Metrics
- Applicable regulations: OSHA PSM, EPA RMP, etc
- Source Term Modeling
- Toxicants & Industrial Hygiene
- Toxic/Flammable Gas Release
- Dispersion Modeling
- Fire & Explosion Protection
- Chemical Reactivity
- Relief System Design
- Hazards Identification (HAZOP, ..)
- Risk Assessment (Matrix, QRA, ..)
- Accident Investigations



Process Safety Metrics



LOPA Frequencies



HAZOP

Node # _:
Design Intent:

Parameter	Guide Word	Deviation	Causes	Consequences	Recommendations

Typical 4x4 Risk Matrix

		Likelihood			
		Frequent	Possible	Rare	Remote
Severity	Major	Very High	Very High	High	Moderate
	Serious	Very High	High	Moderate	Low
	Minor	High	Moderate	Low	Low
	Incidental	Moderate	Low	Low	Low

Multiple Faculty Engaged in Process Safety Related Research – *2019/2020 Program*

PhD Research

Sensing dust concentrations by imaging

Safer materials and processing design for next-generation printed electronics

New directions in prevention by catalyst design

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

Modeling and uncertainty analysis of dust explosions

Battery safety by materials design

High throughput Predictions of Molecular Thermodynamics and Reactivity

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

PMP Capstone Process Safety Projects – 2019 / 20

Modeling Indoor Release of Hazardous Chemicals (3M)

Real World Application of Artificial Intelligence and Machine Learning in Process Safety (AcuTech)

The Role of Shift Handover in Achieving Positive Process Safety Outcomes (Marsh)

Safety Protection System Analysis / Common Cause Failures (BP)

Thermal Hazards in the Pharmaceutical Industry (AMGEN) – cont'd

Refine the Design of a Benchtop Prototype Device for Chemical Reactivity Screening (Fauske) – cont'd

Heat Transfer Model for Accelerating Rate Calorimeter (Dow) – cont'd

Leveraging Data Science for Oil & Gas Asset Integrity Mgmt (Chevron / DowAgro)

Dimensional analysis and similitude for multiphase flows in pipe reactors (Chevron / DowAgro)

Understanding Ignition Properties of Flammable Gas / Particulate Mixtures & Mitigation Through Inerting (3M)

Determination of Minimum Sufficient Dispersion Model Scenarios for Gas Detection Optimization (Kenexis)

Improving Understanding of Hazards of Process Plants through PHA Gamification (Kenexis)

Undergraduate P2SAC Research Projects – 2019 / 20

Organizational culture – what it consists of, how it's measured and keys to improvement – w / ACC & Marsh

Survey of heats of reaction for some common reaction types in pharma industry & comparison with predictions – w / Amgen, Corteva, GSK, JP, Lilly, Merck, Vertex

Self-ignition of solids, comparison of measurement techniques and determination of kinetic parameters – w / Corteva

Heat transfer modeling in Accelerating Rate Calorimeter – w / Dow

Condition-Based Monitoring Techniques for Valves, Pumps, and Storage Tanks – w/ BP

Identification of Gaps in Inherently Safer Design Analysis Methodologies and Possible Solutions – w / AcuTech

Contribution of human error in significant incidents & actions to resolve

Identification of specific deficiencies in PHAs that led to major incidents

Guidance for Prevention of Tank Overflows

Analysis of process safety incidents across 14 industries & comparison of root causes - *published*

Analysis of process safety incidents in the pharmaceutical industry - *published*

‘Other’ P2SAC Projects – 2019 / 20

Joint NSF Funded Projects with CISTAR – **2018 – 2020**

- *Safety in Academic & Industrial Laboratories* - *w / Corteva*
- *Inherently Safe & Secure Cyber Physical Systems* – *w / AcuTech*

Factors Contributing to US Chemical Plant Process Safety Incidents from 2010 – 2020 – w / Univ of Utah; ACC - sponsor

Safety Shower & Eyewash Systems – w / CountryMark, SABIC, 3M

Safe Disposal of Drilling Fluids From High Temperature & Pressure Wells - w / Chevron

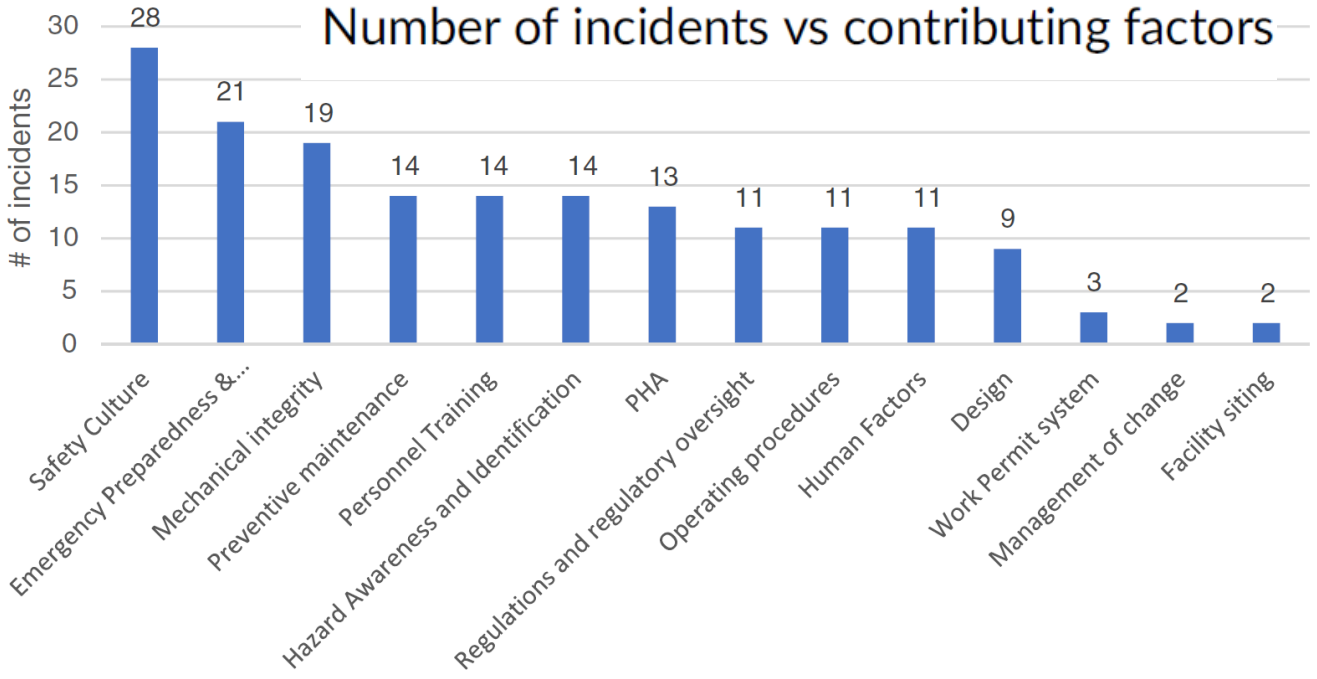
Use of ARSST Calorimeter to Study Reagents Common to the Pharmaceutical Industry

Temperature at Which Time to Maximum Rate is 24 Hours – w / Amgen

Investigating Correlations Between Minor & Major Incidents & Underlying Causes

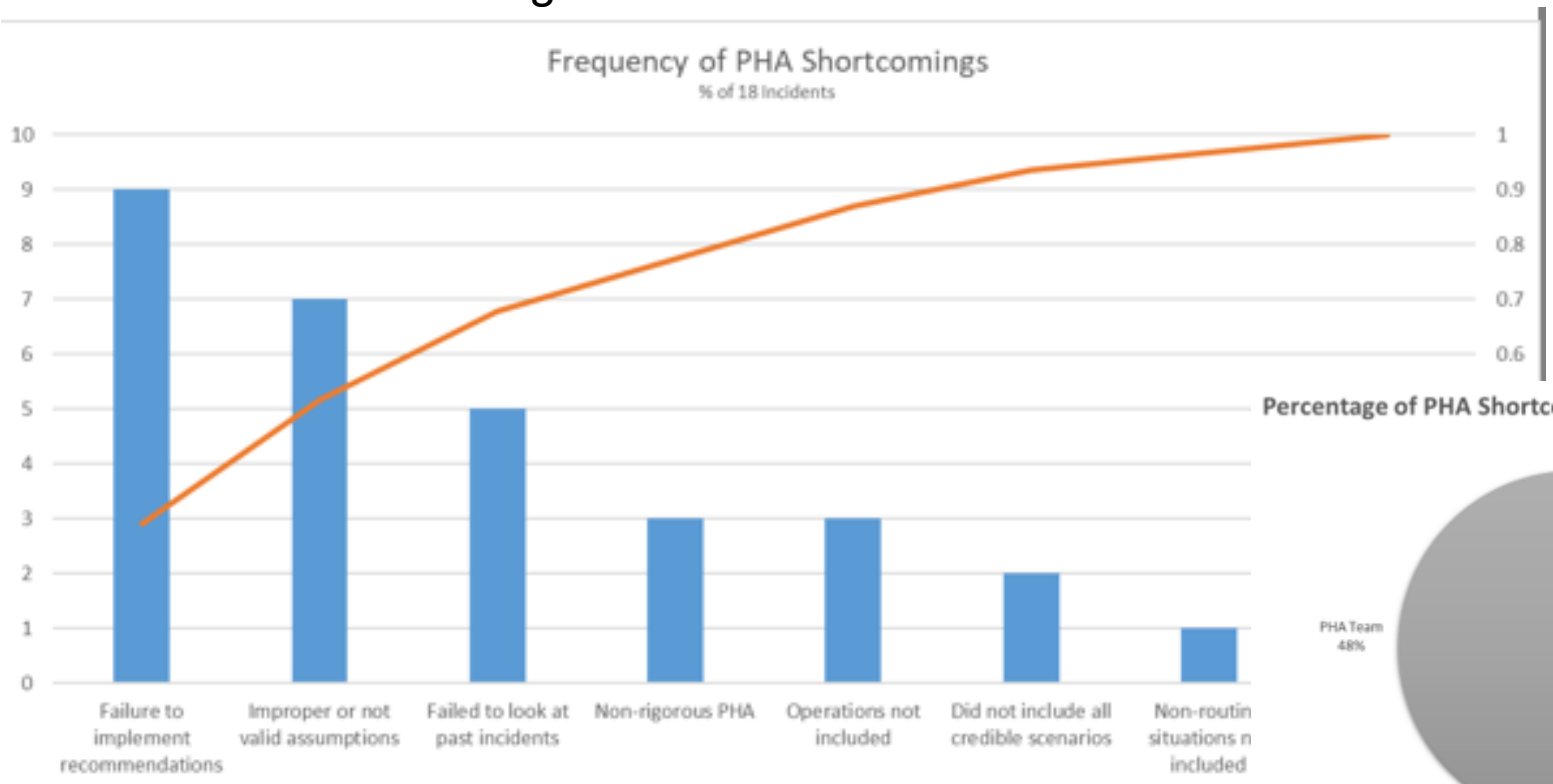
Analysis of Root Causes of Process Safety Incidents Across 14 Industries – PMP / UG

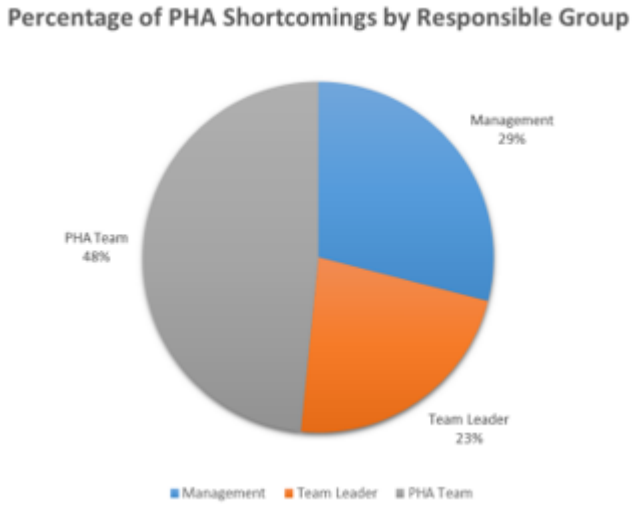
- Studied: Refining, Chemicals, Oil & Gas, Storage, Pipeline, Fertilizer, Pharmaceutical, Agriculture, Food, … *3 primary incidents per industry*
- Analyzed significant data set in terms of root causes, fatalities, monetary damage, impact beyond plant fence, state of operation, and developed / developing country
- 81 incidents analyzed; identified14 primary root causes; several per incident
- Published: *Process Safety Progress*: e12158 (2020)



PHA Shortcomings Leading to Incidents - UG

- 35 incidents investigated by CSB had PHA as a root cause, with half (17) 'no PHA'
- PHA shortcomings for remaining 18 incidents were grouped into 8 categories shown below: failure to implement recommendations, invalid assumptions, didn't consider past incidents, non-rigorous PHA, …
- Developed guidance to address shortcomings, including responsible parties shown on lower right





Condition-Based Monitoring Techniques for Valves, Pumps, and Storage Tanks – UG (w / BP)

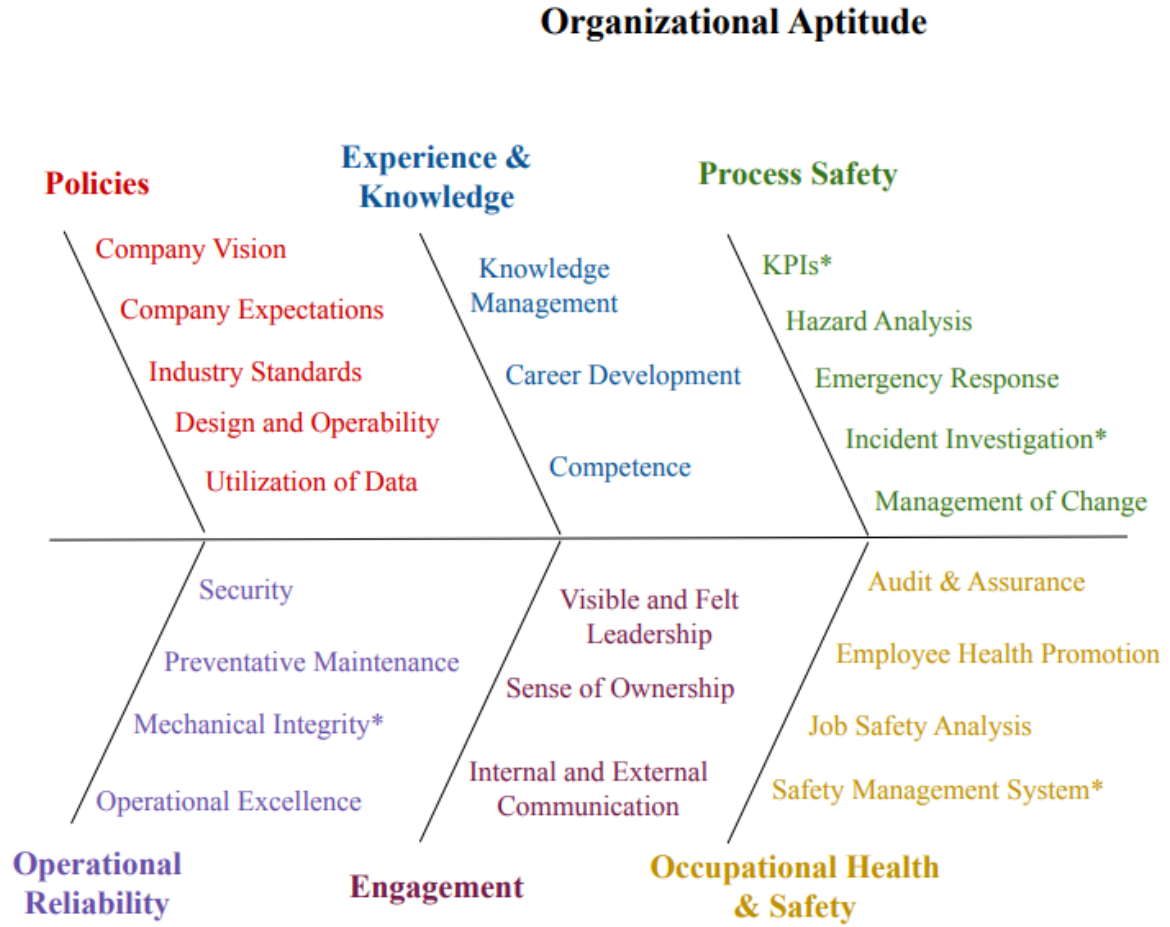
- Condition based monitoring (CBM) addresses some of the shortcomings of preventative maintenance programs
- CBM uses sensors and monitors to identify the current operating condition of equipment to identify if it is running as intended, if it is showing signs of wear and needs to be repaired, or is close to failure
- Tables were produced for three asset classes to show which failure modes each monitoring technique could identify

Application of Condition-Based Monitoring Techniques to Valve Failure Modes

	Inspection		**Condition Monitoring**			**Predictive**		
Valve Failure Mode	Pressure Testing	IR-Leak Detection	Valve Torque	Travel Time/ Hysteresis Curve	Position Monitoring	Acoustic Testing	Valve Flow Coefficients	Electricity Consumption
Seat Leakage	x					x		
Seat Damage			x	x	x		x	
Packing Leaks	x	x						
Flange Leaks	x	x						
Actuator Failure								x
Stem Failure			x	x				
Control Failure					x			

Organizational Health / Safety Culture – UG (w / ACC & Marsh)

'An organization's ability to align around a common vision, execute against that vision effectively, and renew itself through innovation and creative thinking.' McKinsey & Co



Operational Reliability
Operational Excellence, Mechanical Integrity, Preventative Maintenance, Security
Standard Compliance Score
% Root Cause Analysis completed
Strategic Organizantional Health Initiatives Completed
Tier 1 & 2's Reported: Includes First aid and adverse incidents
Tier 3 & 4's Reported: Includes Near Miss
Recordable Injury Illness Rate
Serious Incidents Reported
PM Completed (% On Time)
Work Permit Proccess with proper authorizations
Critical equipment identified & included in PM
Mechanical Integrity Progams (testing, inspection, & maintenance)
Long term shutdown of facilities planned
Quality-assurance processes
Safety Culture Initiative Scores (Safety programs differ per company)
Risk Target Score
Near Miss Incentive Reporting
Completed use of leading indicators (Near Miss reporting)

Safety Shower & Eyewash System Best Practices – PMP (w / CountryMark, SABIC, 3M)

- Literature search of regulations & standards, and industry survey of issues with safety shower and eyewash units in refinery, chemical and manufacturing facilities
- 18 question survey completed by: Tate & Lyle, Celanese, Cummins, 3M, Marathon, CountryMark, Corteva, American Chemistry Council, SABIC, and QualEx
- Addresses: water source; corrosion; maintenance, training, and management systems; self-contained devices; general / other issues
- Best practices recommended for each category
- Summarized in 52-page report; looking for appropriate conference to share

Selecting pipe material for specific applications

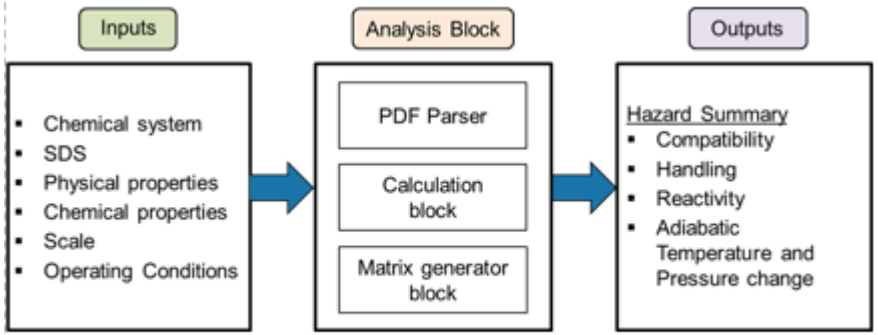
Property	Application and pipe material rating										
5=Highest 1=Lowest	Application Importance	Steel	Galvanized Steel	Stainless Steel	Copper	PVC	CPVC	PP	PVDF	PEX	FRP
Cost	5	4	3	2	3	5	5	4	2	5	3
Rigidity	2	5	5	5	4	2	2	2	2	1	3
Strength	2	5	5	5	4	2	2	2	2	1	3
Corrosion	3	1	2	4	3	5	4	5	5	4	4
Flammability	2	5	5	5	5	2	3	1	4	2	2
UV resistance	1	5	5	5	5	2	2	1	2	1	3
Purity	1	1	2	3	3	4	4	5	5*	3	3
Total	–	59	58	60	58	58	57	51	48	49	49

Joint P2SAC / CISTAR Projects Funded by NSF

Lab Safety – Academic & Industrial

Focused on:

- Surveys of academic & industrial labs; establishing / sharing best practices
- Development of software tool for hazard analysis, toxicity, flammability



Process Block Diagram for the Reactive Hazard Evaluation, Analysis and Compilation Tool (RHEACT)

RHEACT Features:

- PDF parser for chemical SDS
- generation of hazard matrix
- calculation of adiabatic T & P change
- compatibility matrix

Cybersecurity Best Practices

Address cybersecurity implications of proposed CISTAR facilities: remote sites, unmanned well-site facilities or regional/centralized processing facilities

300% increase in energy sector cyber-attacks since '12

Computer & Informational Technology,

MS student – 2018 / 19

- Survey of companies in three subject areas: demographics, cybersecurity & physical security
- **80%** of cos employ 4+ cyber professionals; **93%** of cos use a layered cyber defense
- **Best practices**: Password requirements; scheduled software patch cycles; antivirus software; two-factor authentication; cloud-based services

Assessment of cyber vulnerability of specific facilities and steps to mitigate

– w / AcuTech – 2020 / 21

- Identification of possible cyber vulnerabilities in shale gas extraction facilities
- Developing a guide for carrying out Process Hazard Analyses and Standard Operating Procedures for safe operation with a focus on cyber threats

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2020 P2SAC Closing

- Two new Sponsors
- Progressed 10 PhD / 9 PMP / 6 UG research projects
- Active engagement of multiple companies in student research via WebEx, teleconferences, etc
- COVID implications:
  - no face-to-face conferences
  - laboratory with ARSST calorimeter to reopen in spring
  - *nearly all research progressed as planned*
  - fewer international PMP students will reduce number of students with summer Capstone projects
- *ALWAYS interested in your process safety research ideas & projects*

P2SAC Sponsors