Operational Technology Cybersecurity in the Chemical Process Industries

Implications of Compromised Distributed Control Systems and Safety Instrumented Systems

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Outline

- Hazards associated with CPI
  - Industrial incident in my community
- Traditional risk mitigation
  - Distributed control systems and safety instrumented systems
- Increasing cybersecurity risk
- Cybersecurity risk mitigation
- Promoting awareness of cybersecurity

Hazards Associated with CPI

- Refining and petrochemicals
- Hydrocarbons and chemicals
- Explosion, fire, and toxic release

Highsmith, Carol M, photographer.
An oil refinery in Groves, Texas, near Port Arthur.
Texas Groves United States, 2014. -02-27.
Photograph. https://www.loc.gov/item/2014630814/.

Hazards associated with CPI

- TPC Group Port Neches, TX, facility Wednesday, November 27, 2019
- Fractionator Loss of containment.
- Bottom level 6,000 gallons (30,000 pounds) escaped in less than one minute
- Vapor cloud explosion and fire
- Doors blown in and windows shattered

Just Close A Valve…

Vachon, John, photographer. Borger, Texas. Worker on night tour operating valve in Phillips refinery. Hutchinson County Borger United States Texas, 1942. Nov. Photograph. https://www.loc.gov/item/2017840482/.

Hazards associated with CPI

- Piping heavily damaged and some could not be isolated
- Two additional explosions resulting in four additional towers falling
- Four-mile radius evacuation order until 10:00am November 29th
- Fires burned for over a month
- Air quality issues

Hazards associated with CPI

- Loss of containment from process equipment
  - Vapor cloud explosion
  - Fire
  - Toxic release
- Equipment damage
  - Vessels
  - Compressors
  - Furnaces
- Unscheduled shutdowns

Traditional Risk Mitigation

- Control rooms consolidated and moved outside boundary limits
- Non-essential personnel moved outside boundary limits
- Adjacent land purchased by operators
- Flares located outside boundary limits

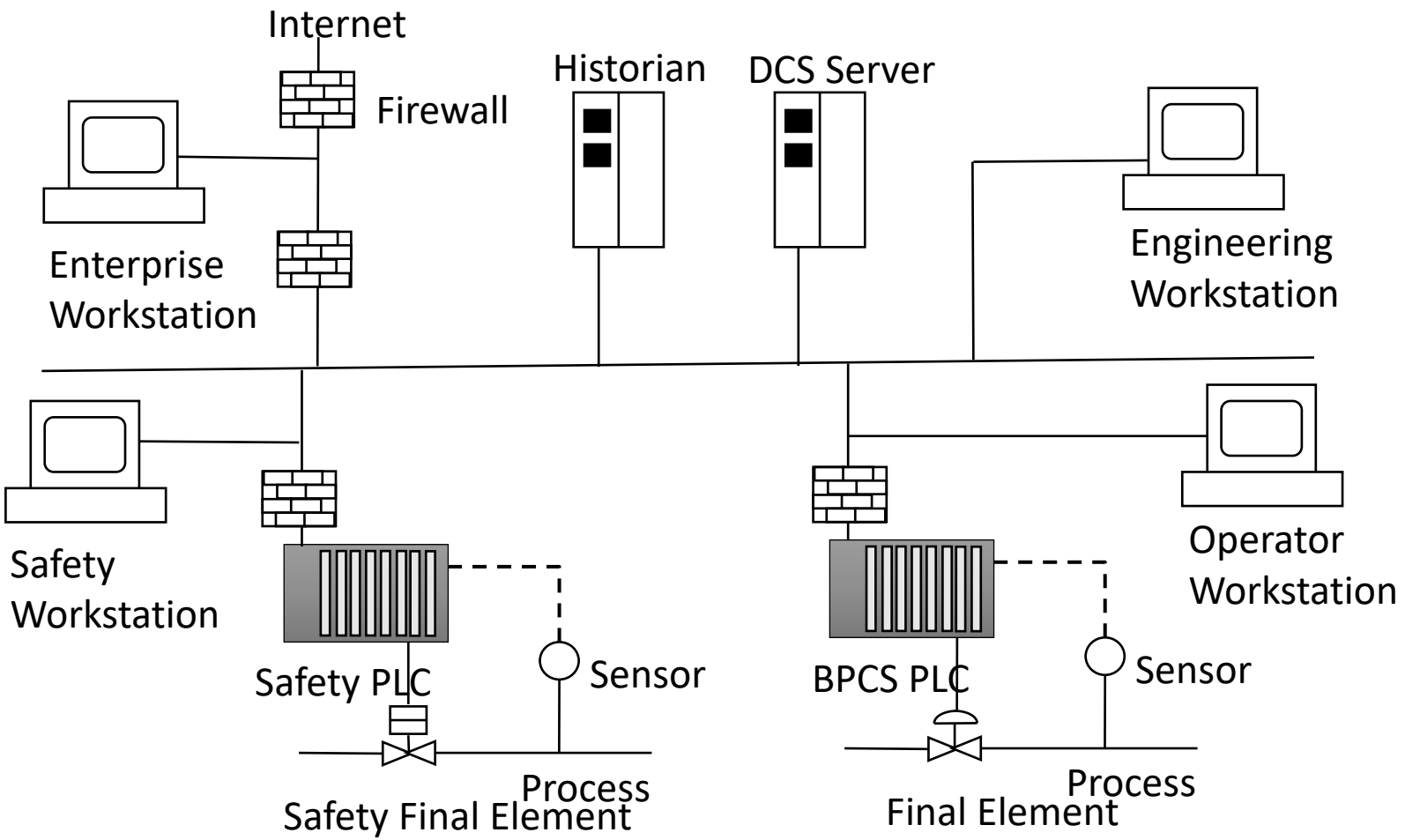
Traditional Risk Mitigation

- Process Safety Management
  - Regulations to manage highly hazardous chemicals
  - Process Hazard Analysis
- Hazard and Operability Study
  - Systematic method to identify and evaluate potential hazards and operability issues
- Layer of Protection Analysis
  - Technique to evaluate hazards and their mitigation

Traditional Risk Mitigation

- Basic Process Control System (BPCS)
  - Normal activity controlling process variables
  - Process alarms
- Safety Instrumented System
  - Safety shutdown systems
- Active protective systems
- Passive protective systems
- Disaster emergency response

Increasing Cybersecurity Risks



Increasing Cybersecurity Risks

- Modern operational technology uses Windows infrastructure
  - Corporate IT groups not suited for operational demands
  - Operators rely on control engineers for support
  - Control engineers with chemical engineering backgrounds
- Availability prioritized over security
  - DCS access required 24/7
  - SIS availability mandatory for safe operation

Increasing Cybersecurity Risks

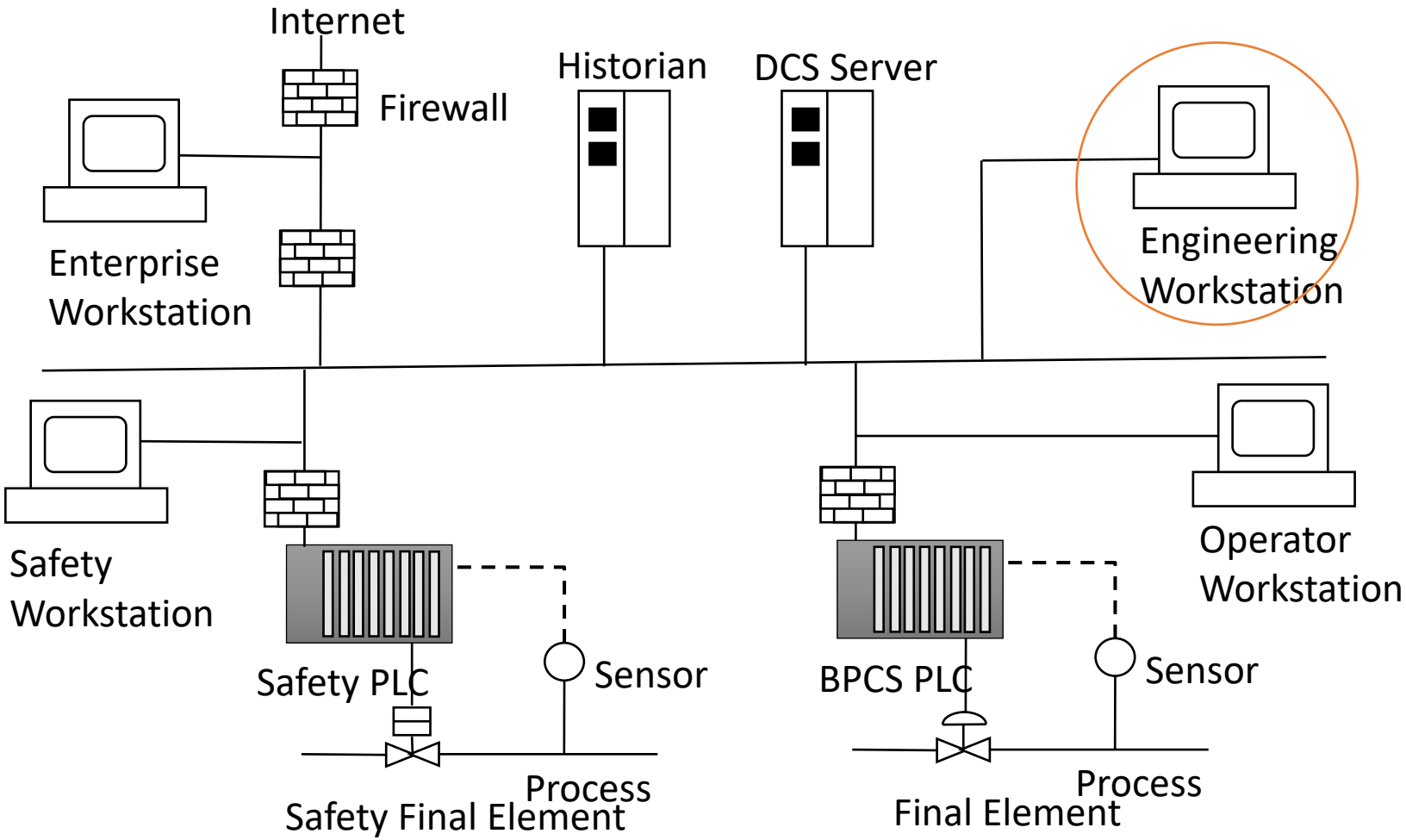
- Major cybersecurity incidents
  - Stuxnet, Triton, Colonial Pipeline Ransomware, Florida Water System
- Hacking tools for operational technology increasingly sophisticated
  - Windows zero-day vulnerability can be used to attack CPI OT systems.
  - Windows patches must be validated by DCS vendor

Cybersecurity Risk Mitigation

- Process Hazard Analysis (PHA)
- Process safety
  - Risk = Consequence x Frequency
- Cybersecurity
  - Risk = Consequence x Likelihood
  - Likelihood = Threat x Vulnerability x Value

Managing Cybersecurity in the Process Industries: A Risk-based Approach, CCPS (Center for Chemical Process Safety), April 2022

Cybersecurity Risk Mitigation



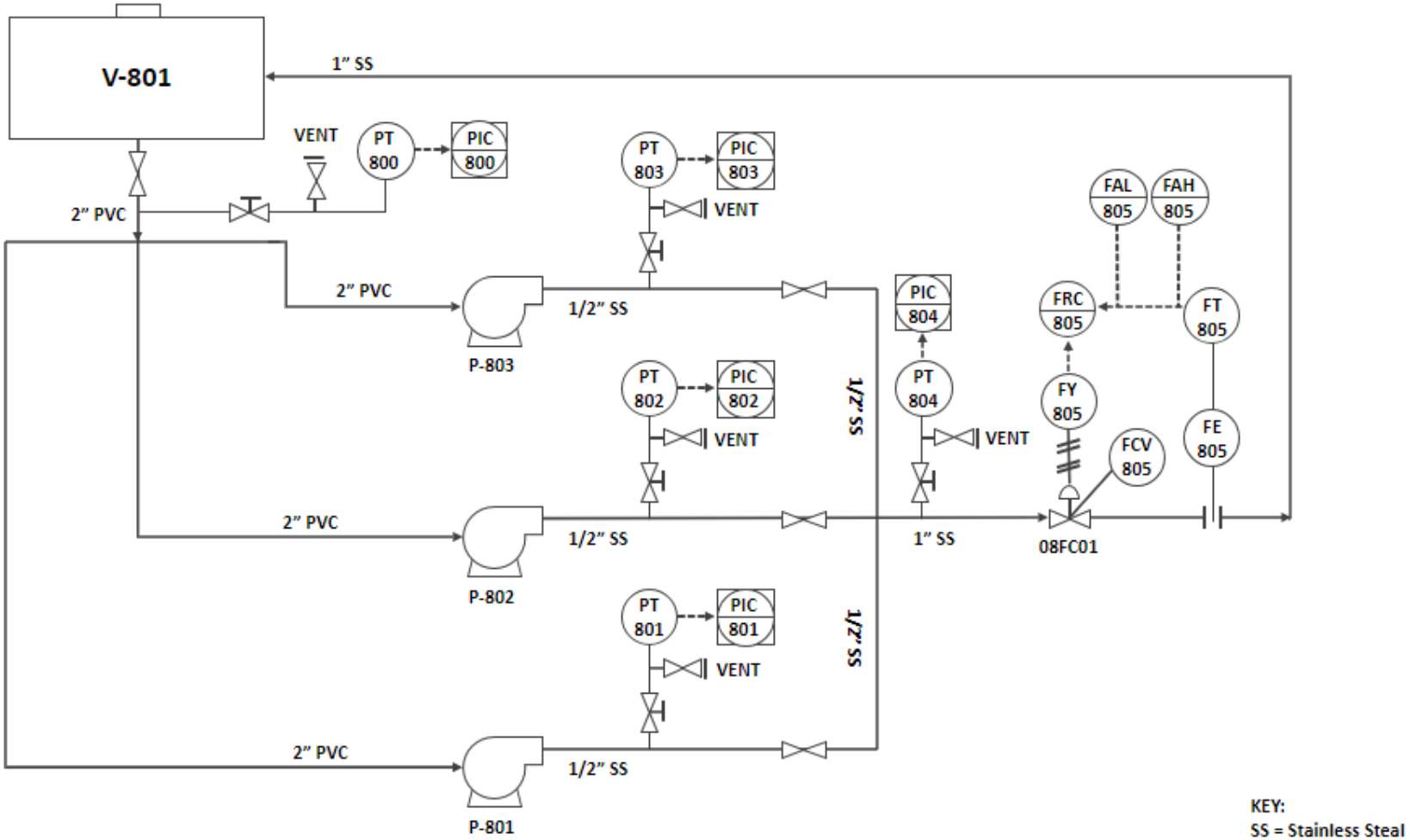
Cybersecurity Risk Mitigation

- Compromise engineering or safety workstation(s)
- Disrupt basic process control system (BPCS)
  - Cause operating deviations of critical control systems and/or interlocks
- Disable safety instrumented system (SIS)
  - Disable protective measures and cause initiating event
- Release, fire, explosion, or fatalities

Promoting Awareness

- Unit Operations Laboratory with Industrial DCS
- Operating groups perform normal process control lab activities (flow, level, temperature)
- Process Control group map control connections then simulate cyber attacks
- Demonstrates cybersecurity vulnerability in the context of chemical process operations

Pump Curve Experiment (Flow Control)

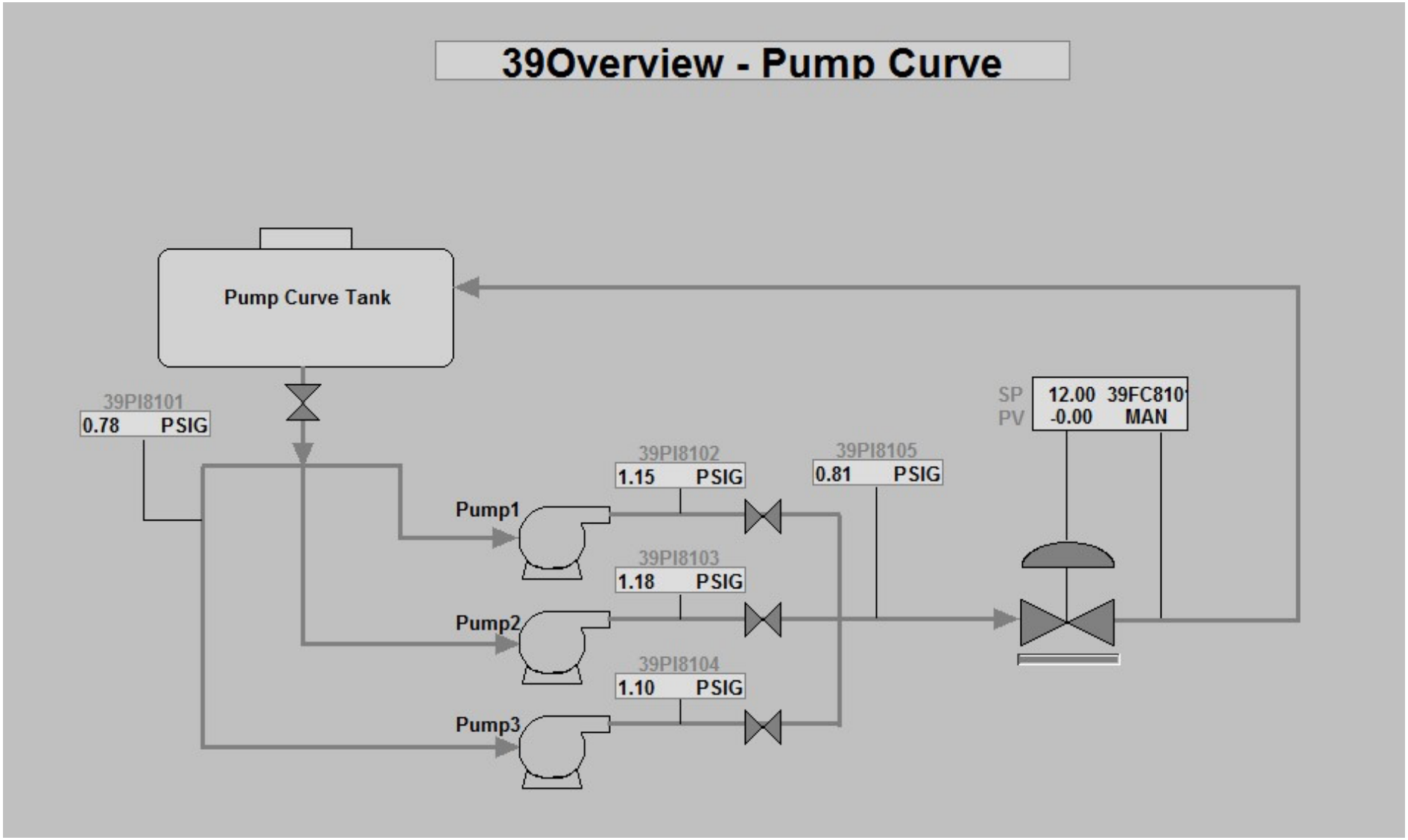


Pump Curve Experiment (Flow Control)

Pump Curve Experiment (Flow Control)

- Line-up and turn on appropriate pump
- Operate pumps with various impeller sizes and record flows and pressures
- Place PID loop in manual and manipulate valve while recording flows
- Place PID loop in automatic and tune flow control loop

Pump Curve Experiment (Flow Control)



Process Control Group Activities

- Identify tags associated with experiments
- Diagram controls from control module diagrams
- Review additional parameters and modes accessible to process control engineers
- Simulate attacks forcing the operating group to detect and respond before continuing their work

Process Control Group Activities

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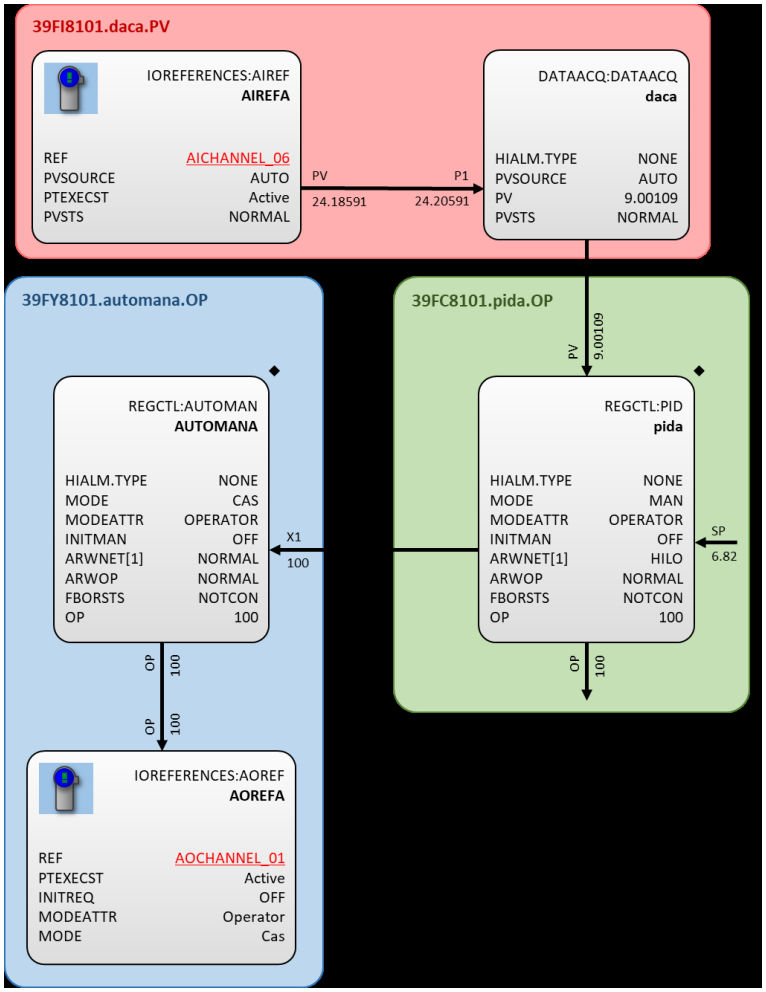

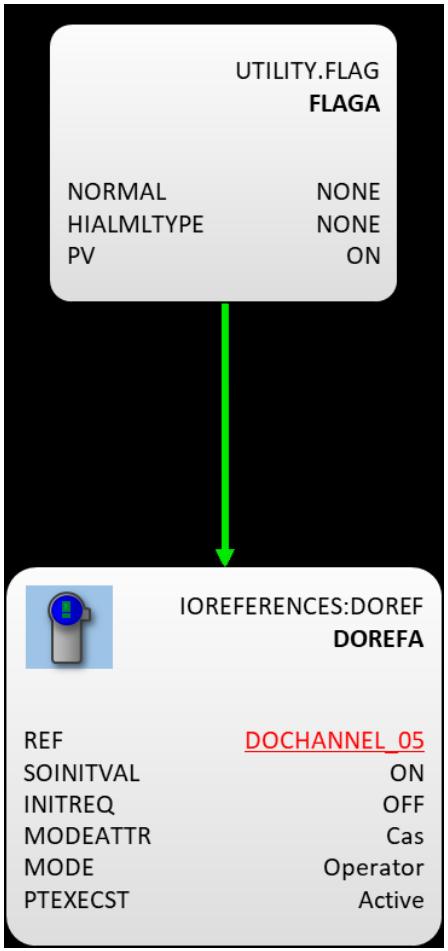

Attack Scenarios

- Inactivate tags
- Place components in manual
- Misconfigure PID controllers
  - Change output limits
  - Change action (direct/reverse)
  - Change alarm settings
- Disable digital outputs
- Spoof inputs

Process Control Group Activities

- Shutdown a pump and the targeted team recognized that the action was beyond their control within seconds
- Manipulated a temperature reading and the affected team took more time to recognize the discrepancy
- Took away access to a level controller and, since the team was seated immediately behind us, they understand that they were being targeted relatively quickly
- Changed the temperature PID from direct acting to reverse acting causing the value to open 100% and not correct itself and the group was not able to determine the cause of this unusual control activity

Process Control Group Activities

- Access a pump interlock to falsely indicate a low level and turn of the pump. The targeted group did not see the alarm and it took them several minutes to notice the pump was turned off.
- Changed a pressure indicator to read much higher than its actual value and the targeted group did not notice it before the 3-minute deadline
- Changed the high limit output to 60% for the level controller
- Changed the temperature controller to manual and back to automatic repeatedly and it took the group significant time to realize their system was in manual control

Conclusions

- Hazards associated with CPI discussed
  - Explosion, fire, toxic release risks
- Traditional risk mitigation
  - Distributed control systems and safety instrumented systems
- Chemical processing cybersecurity risks increasing
  - Windows based modern manufacturing environment
  - Operational technology hacking tools increasingly sophisticated
- Cybersecurity risk mitigation
  - Cybersecurity in the context of Process Hazards Analysis
- Promote awareness with undergraduate process control laboratory module
  - Increased student awareness of cyber security risks

Acknowledgment

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