Chemring
Innovating to protect

Smart Manufacturing Technology

2022 CAD/PAD Technical Exchange Workshop

Indian Head, MD

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Abstract

Automation continues to increase in presence as industrialization caters to high volume commodities. The needs to meet product demand often precede the quality and performance benefits achieved through automated process control. As the CAD/PAD industry is largely characterized as a High-Mix Low-Volume manufacturing environment, automating processes within the value stream is sometimes cost prohibitive. Over the last several years, Chemring Energetic Devices (CED) has invested in significant research, development, and successfully executed integration to automate key manufacturing areas such as hot-wire welding, energetic blending, and loading of electro-explosive devices. In addition to automating manual routines through robotics and PLCs, CED's innovation has specifically been able to capitalize on the benefits associated with smart manufacturing technology. Through the integration of multi-sensor metrology, loop feedback instrumentation, and SCADA, various processing attributes are able to be collected and trended in real time. The result has been an increased ability to mitigate and protect out-of-control processes at the point of manufacture, rather than traditional reliance on downstream product testing. In the presentation, CED will illustrate how it has adopted intelligent automation and the intrinsic benefits in overcoming common challenges associated with the manufacture of CAD/PAD commodities.

Background

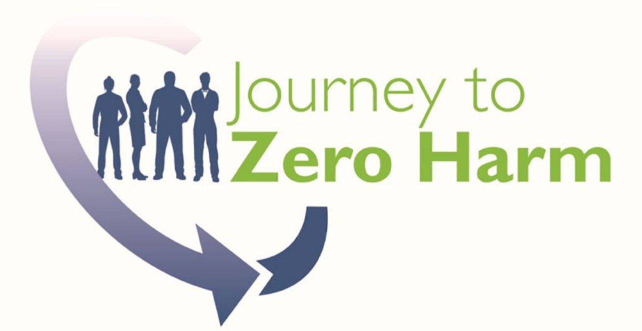
- What is Manufacturing Automation?

  The use of machinery and equipment to automate production process, reducing human intervention to a minimum.

- Benefits of Automation
  - Think O.E.E. – Availability, Performance, and Quality
  - Result - Reduced Cost and Improved Safety
- Typical Applications
  - High Volume
  - Design Maturity
  - Long Product Lifecycles
  - Hazardous Environments

Historically categorized as Hard or Fixed Automation – Specific Equipment for Repetitive Tasks

Automation at CED



- Primary justification at CED is and always will be **Safety** - removing Operators from the Hazards
  - Rigorous System Qualifications and Management of Change
  - All enclosures are Blast Shield tested to Max Credible Event (MCE)
- Focus on Quality rather than Cost
  - Improved Process Capability as a result of reduced human variation
  - Mitigate/protect against plant infrastructure anomalies (Power/Air)
  - Gain process insight to support future technical strategy
- Versatility
  - Systems are designed to process multiple commodity streams
  - Tooling follows Single-Minute-Exchange-of-Die (SMED) philosophy for rapid changeovers

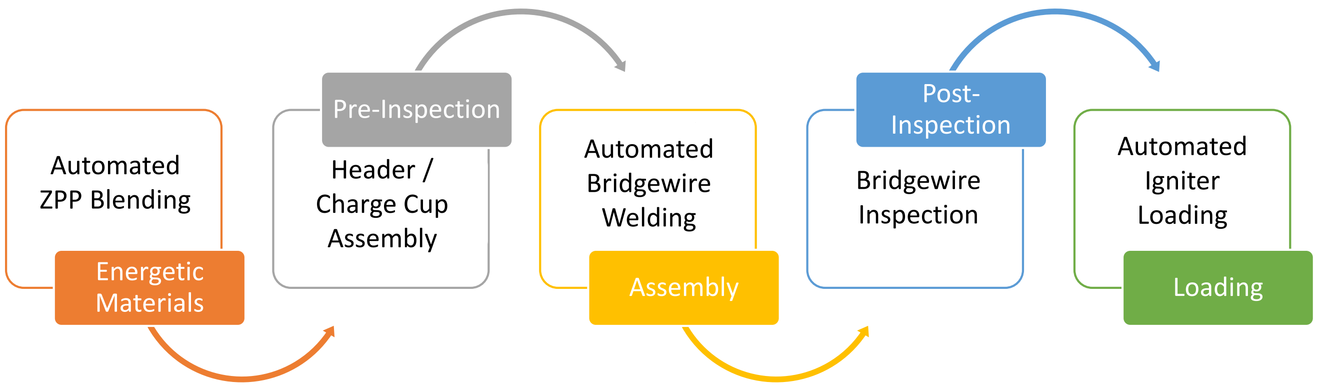
CED Implementation Methodology

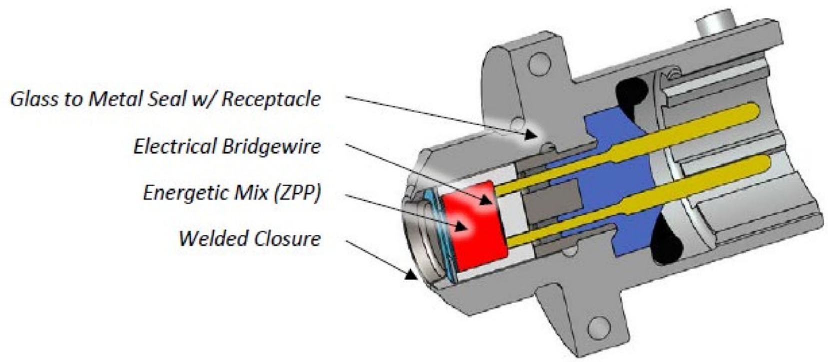
- In Energetics, errors in process automation can result in dangerous or catastrophic consequences.
- How does Chemring protect against these potential scenarios?
  - Adoption of FDA/Pharmaceutical Methodology
- Installation Qualification (IQ)
  - Design conformity
  - Safety Systems
  - Calibration, PM, and Spares
- Operational Qualification (OQ)
  - I/O Analysis
  - Failure Mode and Effect Analysis (FMEA)
  - Determine control limits – temp, servos, pressure, weight, etc.
- Performance Qualification (PQ)
  - Manufacturing run-at-rate
  - Product test data
  - SOP/Training

"Where the results of a process cannot be fully verified by subsequent inspection and test, the process shall be validated with a high degree of assurance and approved according to established procedures."
-21 CFR 820

IQ INSTALLATION QUALIFICATION	OQ OPERATIONAL QUALIFICATION	PQ PERFORMANCE QUALIFICATION
TESTS Verification of correct equipment installation	**TESTS** Verification of correct equipment operation	**TESTS** Verification of correct equipment performance
ENSURES Correct installation of system per specs	**ENSURES** Correct operation of system per specs	**ENSURES** Correct performance of system per specs
ESTABLISHES baseline for equipment	**VERIFIES** System meets claims from parameters	**VERIFIES** System meets customers intended purpose

The EED Automation Value Stream





Prior to Automated Blending

<u>Background</u>

The blending of Zirconium Potassium Perchlorate (ZPP) and Titanium Hydride Potassium Perchlorate (THPP) has historically been performed via a manual process at CED's Torrance facility. Throughout the manufacturing process, the Operator would handle energetics and their constituents, exposing them to the hazards of fire, explosion, injury and/or death.

During the transfer of product lines from CED's Torrance CA facility to Downers Grove IL, a goal was imposed to automate the process and subsequently remove the Operator from the hazards. A concept for the machine and associated building infrastructure was initiated in 2017, completed in 2019, and commissioned for live energetics operations in 2020.

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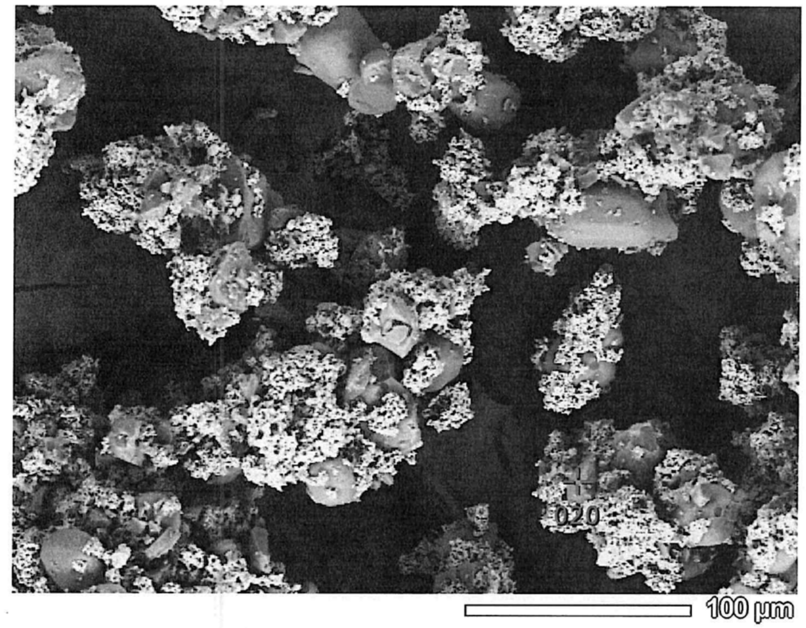
Automated Blending - System Overview

- One foot thick concrete, steel reinforced Bay with blow-out ceiling panels
- PLC control for precision metering/blending of constituents and solvents
- High shear mix impeller for improved blend homogenization
- Blending capability of 400 gram batch sizes
- Material conveyor with puck pass through into magazine storage

CED Results of Automation

- Removal of Operator from Hazards
  - Operator(s) responsible for material prep/staging
  - 400g typical batch sizes; 50-100g considered lethal quantity
- Increased process capability through PLC control
  - Mix RPM and Duration
  - Vibratory Feed and Granulation
  - Addition of shocking agent
- Improved blend homogeneity
  - Consistent agglomerations of Zirconium particles
  - Uniform precipitation of Viton



Successful blending through qualification of (3) NASA Batch Acceptance Powder Lots

Component Inspection

Background

Before and after bridgewire welding, a visual inspection is performed against documented acceptance/rejection criteria. Historically this process has been performed manually, with an Operator utilizing a digital microscope. In scenarios where artifacts of record are required, the manual process presents challenges with data recording/archiving, as well as proves time consuming.

Advancements in multi-sensor and optical metrology have provided a useful business case for implementation. Data reporting, active measurement capability, and cycle time were all factors taken into account during vendor evaluation and down-select.

Prior Challenges and Limitations - Hi-Rox Digital Microscope

- Process reliant on Operator input and adjustment
  - Lighting
  - Focus
  - Magnification
- Depth of Field / Field of View
  - Requires glass changeovers for increased capability
- Manual data collection
  - Operator to record image, re-focus, record, etc.
- Measuring capability limitations
  - Certain systems incorporate measurement capability, however precision and accuracy suffer

Capabilities of 3D Multi-Sensor Metrology

- Integrated laser, optical, and tactile probing capabilities
  - Laser – Quick Feature/Surface Acquisition
  - Optical – Geometries and Profile Measurement
  - Tactile – Orthogonal/Undercut Features
- Auto generated inspection reports
- Machine network integration for live data recording
- Interchangeable fixture plates for rapid changeovers
- Dual use as Coordinate Measuring Machine (CMM)

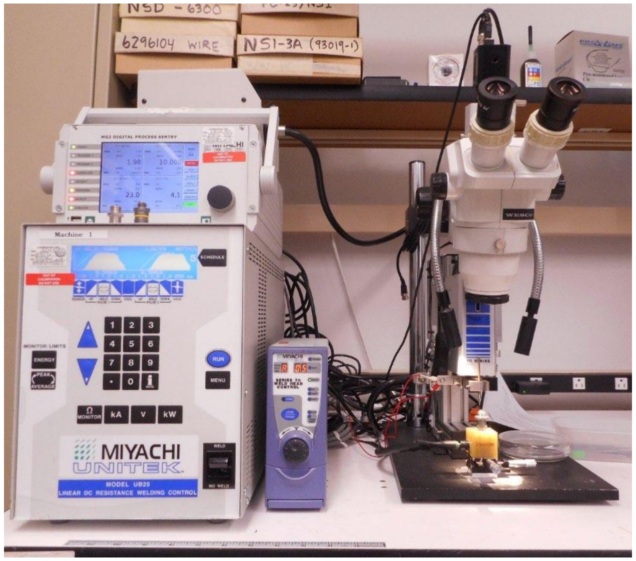
CED Results of Automation from 3D Multi-Sensor Metrology

- EED Value Stream – 80% Utilization
  - Connector End (Broach) Dimensional Inspection
    - Cycle time reduction from 5 min (CMM) to 40 sec
  - Charge Cup Inspection
    - Cycle time reduction from 8 min (Manual) to 35 sec
  - Bridgewire Weld Image Recording
    - Cycle time reduction from 5 min (HiRox) to 45 sec
- Incoming Part Inspection
  - (3) Piece Parts evaluated for average 80% Cycle Time reduction

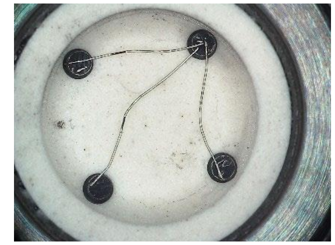
Bridgewire Welding

<u>Background</u>

Bridgewire welding consists of spot welding a thin, resistance wire to electrical contact pins to create a hot-wire circuit in a Electro-Explosive Device (EED). The process has traditionally been performed by Operators utilizing manual weld stations with magnification aid. The process is time-consuming and entirely dependent on Operator skill to ensure repeatability across all welds.

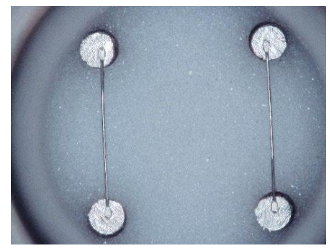


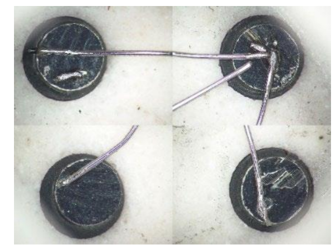
Manual Bridgewire Welding



<u>Process Challenges</u>

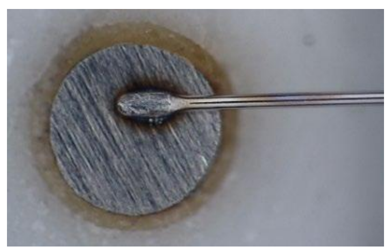
- Formation of bridgewire
- Placement and location of weld
- Pigtail removal post welding

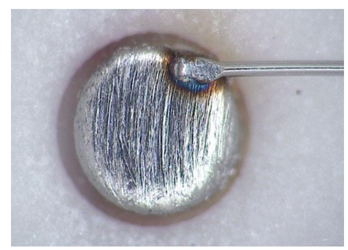


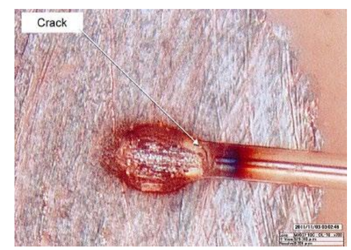


<u>Common Defects</u>

- Cracks/Voids
- Kinks
- Heat Discoloration
- Neckdown
- Poor Joint Adhesion

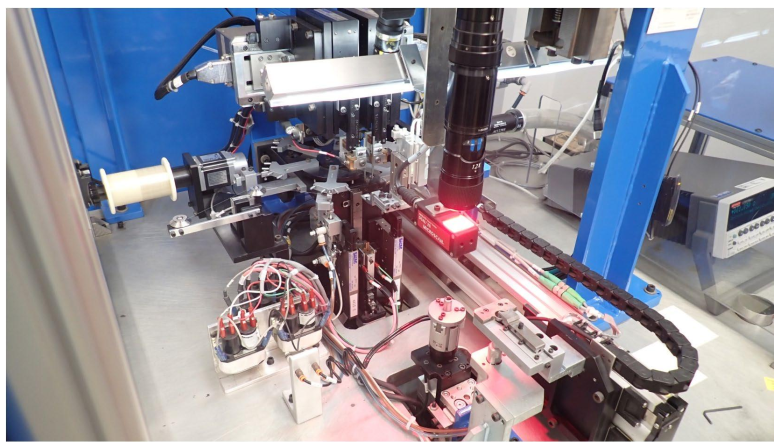






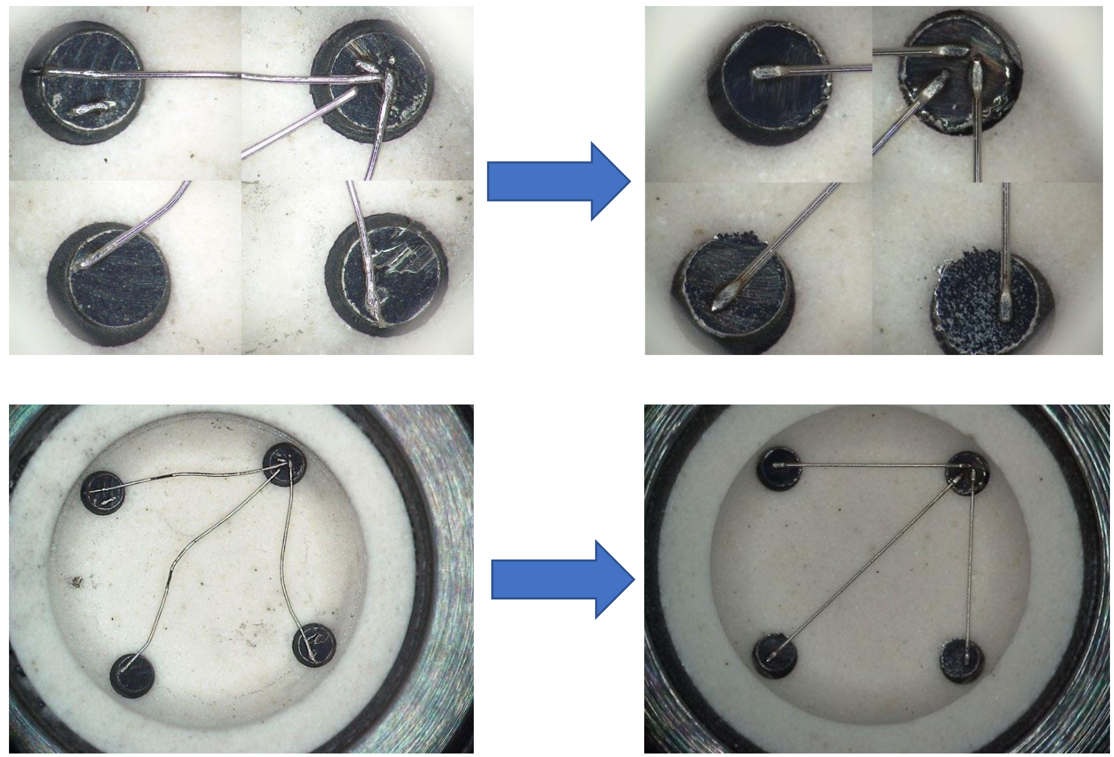
System Overview of Automated Bridgewire Welding

- PLC driven control system
- PC based HMI for Recipe Management
- Cognex Vision System for part orientation
- Automatic wire tensioning system
- Post-weld cut-off and scrap wire vacuum
- In-process resistance measurement



CED Results from Automated Bridgewire Welding

- Consistency and repeatability
- Resistance verification at point of manufacture
- Increased throughput and uptime
- Ease of commodity scalability
  - Program new parts through Recipe Dashboard
  - Vision system teach/learn
  - Tooling/electrode interchangeability



Manual Bridgewire Weld | Automated Bridgewire Weld

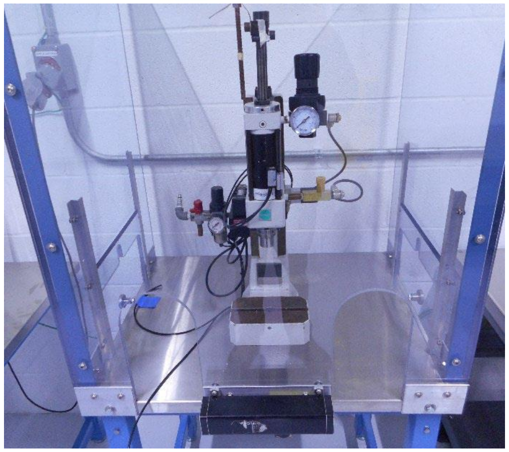
Charge Loading

Background

The loading of EEDs at CED is performed via gravimetric dosing in varied increments, followed by application of consolidation pressure to attain required pack densities. This process has historically been manual, utilizing a vibratory feeder to dispense the energetics, weighing on precision scales, and presenting to a pneumatic station for consolidation. Short production runs, varied geometries, and powder chemistry have traditionally counteracted the argument to process automation. CED has invested significant research and development to not only automate the process, but improve upon process capability resulting in peak EED performance.

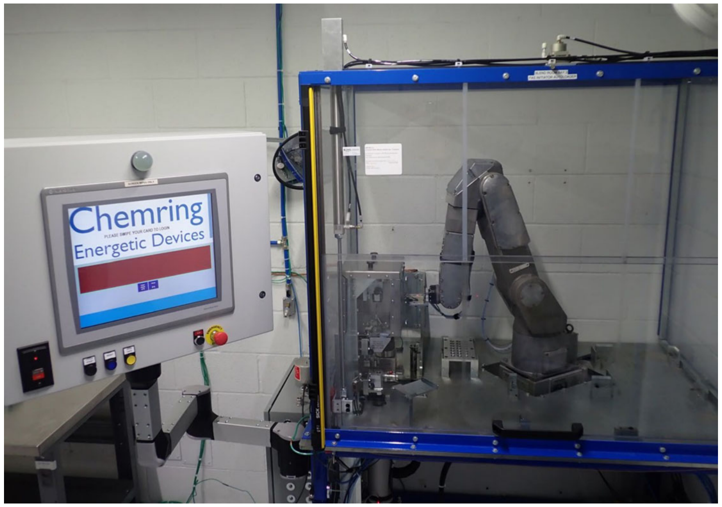
Challenges and Limitations with Manual Charge Loading

- Fluctuations in supply Air creates potential for out-of-control conditions
  - Typically mitigated with redundant compressors or in-line load cells
- Variations in energetic homogeneity contribute to inconsistent flow rates
  - Powder stratification and cohesive chemistry
- Lack of data recording provides zero process insight
  - Force/weight relationship over time
- Setup limitations do not allow parallel processing of multi-increment loads



CED Autoloading – System Capabilities

- Automated dispense, weigh, fill, and consolidation
  - Fanuc Paint Mate 6 Axis Robot
  - Allen Bradley PLC and HMI
  - Sartorius Explosion Rated Weigh Cell
  - Integrated Load, Proximity, and Laser Sensors
- Real-time in process data collection and trending
- PID energetic dispense functionality
- Recipe Management with interchangeable tooling nests for rapid changeover and product scalability



CED Results from Automation of Autoloading

- Closed-loop manufacturing (CLM) cell for the weigh, fill, and consolidation of energetics
  - Control and monitoring of force, weight, and time
  - Integrated alarms for out-of-control condition
- Data recording of all process attributes with auto-generated compliance reports
- Auto-learning dispense logic to accommodate differing flow characteristics of energetic constituents – ZPP, THPP, RDX, HNS, Lead Azide, etc.
- Capability to maintain repeatable dispense beyond 1mg weigh tolerance

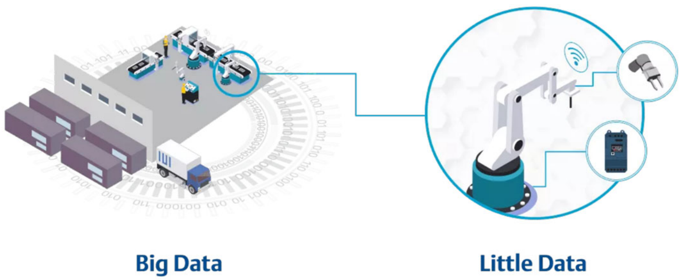
IT & OT Integration - SCADA

Background

As a result of increasing investment into automation capabilities towards vertical integration, an initiative was launched to onboard a control system architecture to remotely monitor and control integrated plant machinery and processes. In 2021 a project to implement Supervisory Control and Data Acquisition (SCADA) was commissioned. The project consisted of multiple phases: first the development of a local machine network which would handle secure data communications, and second the SCADA software installation and integration across various key assets.

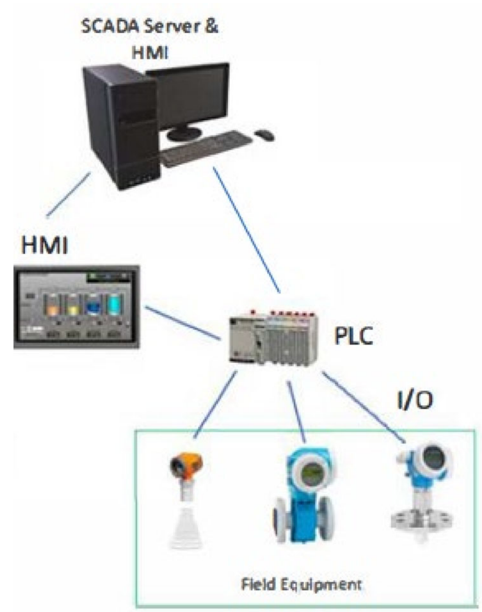
Digital Transformation of Automation Technology

- Advancements in computer vision, sensor integration, and data/process monitoring have created a departure from typical fixed automation, to adaptable systems.
- Manufacturing technology is changing as a result of IT/OT convergence.
  - IT (Information Technology) – Computers, Software, Networks – Big Data
  - OT (Operation Technology) – PLCs, Robots, Sensors – Little Data
- The Future is Adaptive and Flexible Automation
  - Scalability to process multiple commodities
  - Real-time process monitoring
  - Reactive decision making
- Benefits
  - Low Volume, High Variety
  - Greater Process Capability
  - Safety



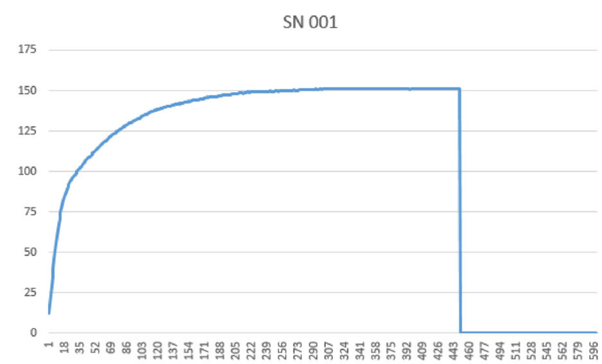
SCADA - System Capabilities

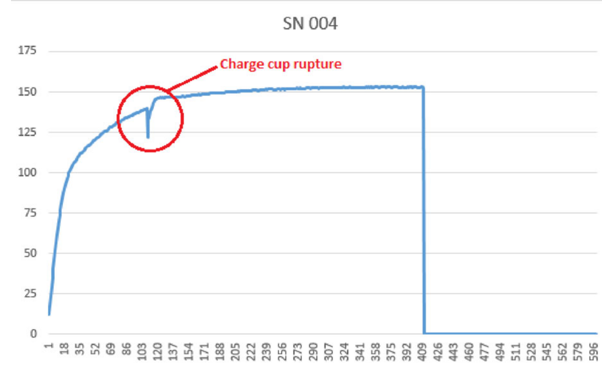
- System based on Rockwell Automation software suite:
  - FactoryTalk View SE - Development Software & Client Module
  - FactoryTalk Historian - Captures Operational Process Data
  - VantagePoint EMI - Real-time Reporting, Data Analytics, and Dashboards
- Compliant and capability-ready with industry requirements
  - Federal Information Processing Standards (FIPS) compliance for data encryption
  - Cybersecurity Maturity Model Certification (CMMC) capable
- Equipment PLCs and RTUs communicate with factory floor equipment and sensors to collect data for processes
- Data is presented to Operators through HMIs which in turn communicates with SCADA software
- SCADA software handles the processing, storage, and distribution of data



CED Results of from SCADA Implementation

- Control of processes and equipment, locally or remote
- Collect, monitor, and process data in real-time
  - Trends – Force, Weight, Pass/Fail
  - SPC – Process Capability, Process Performance
  - KPI – Overall Equipment Effectiveness, Utilization
- Capability for reactive failure monitoring
  - Monitor disruptions in force over time; quarantine/reject hardware at point in manufacture
- Fault notification to escalate equipment line-down scenarios
- Automated data Exhibit reports, eliminating transcription errors and reducing COPQ
- Track process change events for product traceability
  - Integration with Key Card terminals





CED gains numerous benefits from automating our energetics processes

- Worker **<u>safety</u>** will always be our primary justification for improvement to operations
- Automation improves quality and repeatability of manufacturing process
- Our automation systems are designed with versatility in mind, for quick changes to different product streams

Disclaimer