PNC Playbook

2024 - 2025

Introduction

Background

PA Consulting has collaborated with PNC and the co-manufacturing network to develop a best-in-class (BiC) operations guide. This manual serves as a comprehensive guide to achieving operational excellence in manufacturing by establishing best practices and standardized approaches. It draws from industry insights, process improvements, and co-manufacturer site visits to create a framework that supports consistency, collaboration, and continuous improvement across all facets of manufacturing operations. The guide is intended to be a living document which is continuously updated as operations are further characterized and improved.

Purpose

The purpose of this manual is to provide manufacturing teams with actionable guidelines to build and sustain best-in-class operations. It focuses on key areas such as co-manufacturing strategy, operational standardization, technology adoption, workforce development, and relationship management. By applying the principles described in this document, PNC will be able to enhance performance, ensure quality, and execute strategies for long-term growth with confidence.

Scope & Objectives

This manual is organized into the following key chapters, each addressing critical aspects of manufacturing operations:

- **Driving Manufacturing Standardization and Excellence**: Focuses on establishing process standards, ensuring quality, and driving consistent performance with data-driven insights across specialized processes, from raw materials through final packaging.
- **Co-Man Strategic Network Planning**: Offers guidance on structuring co-manufacturing networks to align with business objectives, manage risks, and foster innovation through strategic partnerships.
- **Technology and Innovation**: Provides strategies for setting technology standards, promoting adoption across networks, and promoting continuous improvement.
- **Workforce Development**: Addresses the need for training programs to build a skilled and resilient workforce.
- **Co-Man Relationship Management**: Details best practices for managing co-manufacturer relationships, ensuring alignment on strategy, mitigating risks, and driving collaboration and innovation.
- **Co-Manufacturer Capabilities**: Highlights the importance of evaluating and enhancing co-manufacturer technology, equipment, and workforce capabilities to meet operational demands and drive success.

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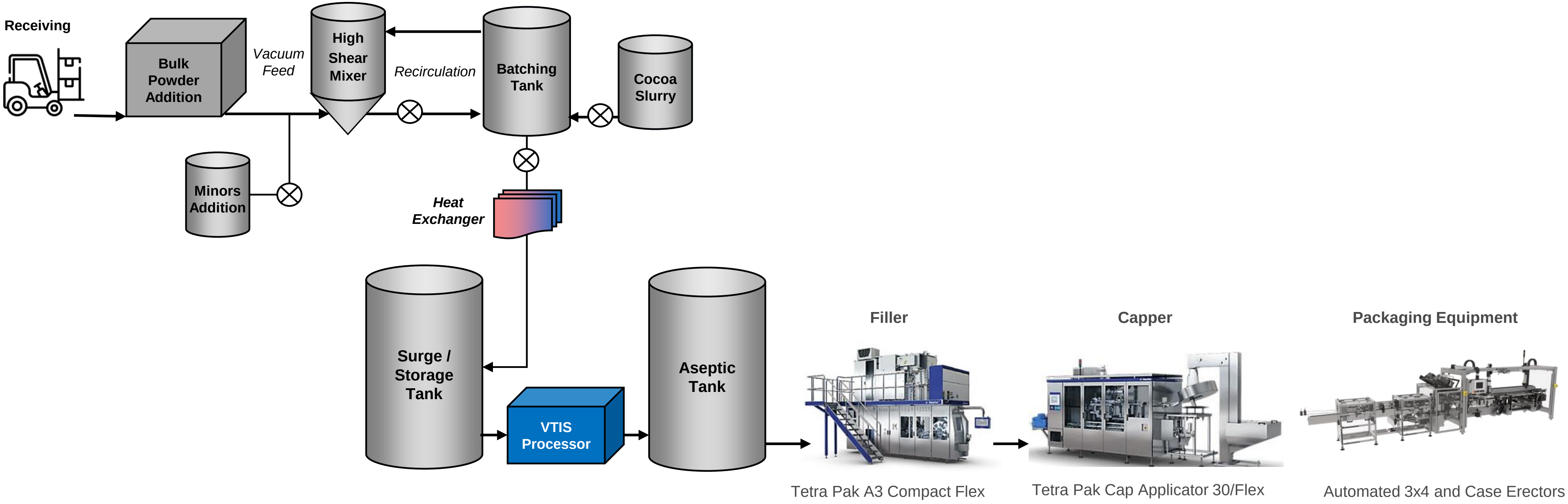
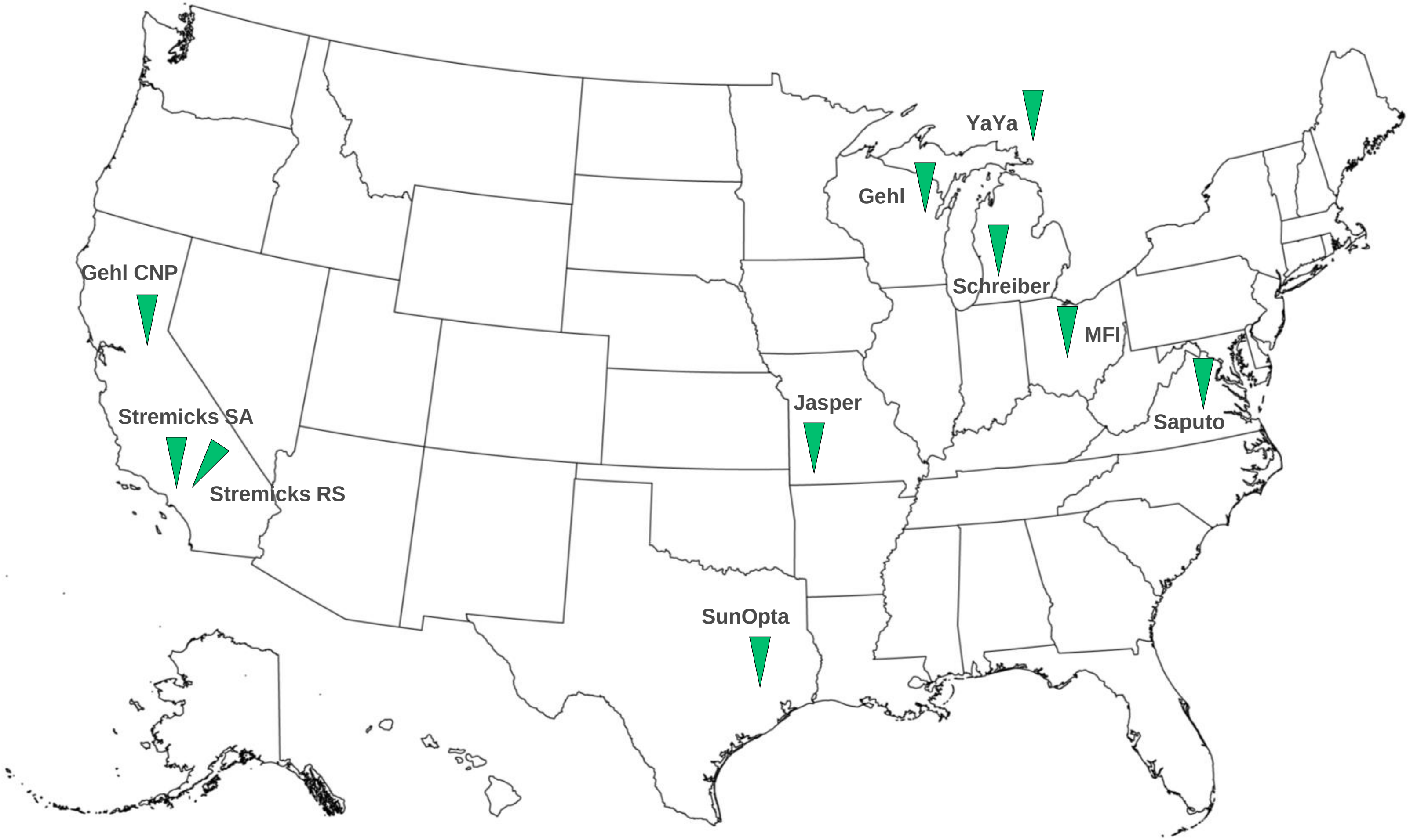
Update page numbers

Overview of aseptic manufacturing facility and terms referenced throughout the guide



Premier Protein co-man network for 325mL protein shake production



Site	Site Max Capacity (mo)	Average Production
Stremicks – SA	22,000,000	
Stremicks – RS	22,000,000	
SunOpta	22,000,000	
Jasper		
Schreiber	22,000,000	
Saputo	22,000,000	
Gehl – Germantown	22,000,000	
Gehl – CNP	22,000,000	
YaYa	22,000,000	
Total		

Site visits completed during the manufacturing excellence program include a report detailing findings and inform this guide

Site	Visit Date	Report Link	Covered Topics
SunOpta	August 20– 21, 2024	SunOpta Visit Report_WestRock 3x4 Equipment.docx	• 3x4 Overwrap Equipment
Stremicks – Santa Ana	August 22, 2024	Stremicks Visit Report.docx	• Batching • Filling • Tertiary packaging • Carton measurements
Stremicks – Riverside	August 23, 2024	Stremicks Visit Report.docx	• Batching • Filling • Secondary packaging (ADCO) • Carton measurements
Schreiber	August 28, 2024	Schreiber Visit Report.docx	• Packaging seal integrity • Capping equipment & leak failures • Open case flaps • Carton measurements
Gehl – Germantown	December 3 – 4, 2024	Gehl - Visit Report.docx	• Batching yield loss troubleshooting • Total plant waste troubleshooting • Batching time study • Plant performance metrics • SPC implementation • Carton measurements
Jasper	January 21, 2025	CapFix700 Production Trial.docx	• Glue trial for Tetra Pak carton cap • Operating parameters for capping equipment
Saputo	January 28 – 29, 2025	Saputo - Visit Report.docx	• Batching and standardization process • Incoming packaging materials • 3x4 WestRock equipment • Filler operations • Plant performance metrics • Carton measurements
MFI	March 18 – 20, 2025	MFI - Visit Report.docx	• Batching and standardization process • Waste analysis • Packaging materials • Plant performance metrics

Driving Manufacturing Standard, Excellence, and Execution

Chapter Overview

Protein shake manufacturing requires precise control across specialized processes, from raw materials through final packaging. This chapter provides tools for establishing standards in critical operations including material validation, batching, filling, and packaging. By implementing stringent controls and standardized processes, these practices ensure consistent protein stability, product safety, and operational efficiency across the co-manufacturing network.

Chapter Contents

- Maintenance & Protocol Adherence
- Incoming Packaging Material Standards
- Batching & Standardization
- Filler Operation & Carton Formation
- Capping Equipment
- Packaging Equipment: 3x4 Overwrap & Case Erector
- Performance Management
- Quality Control & Assurance

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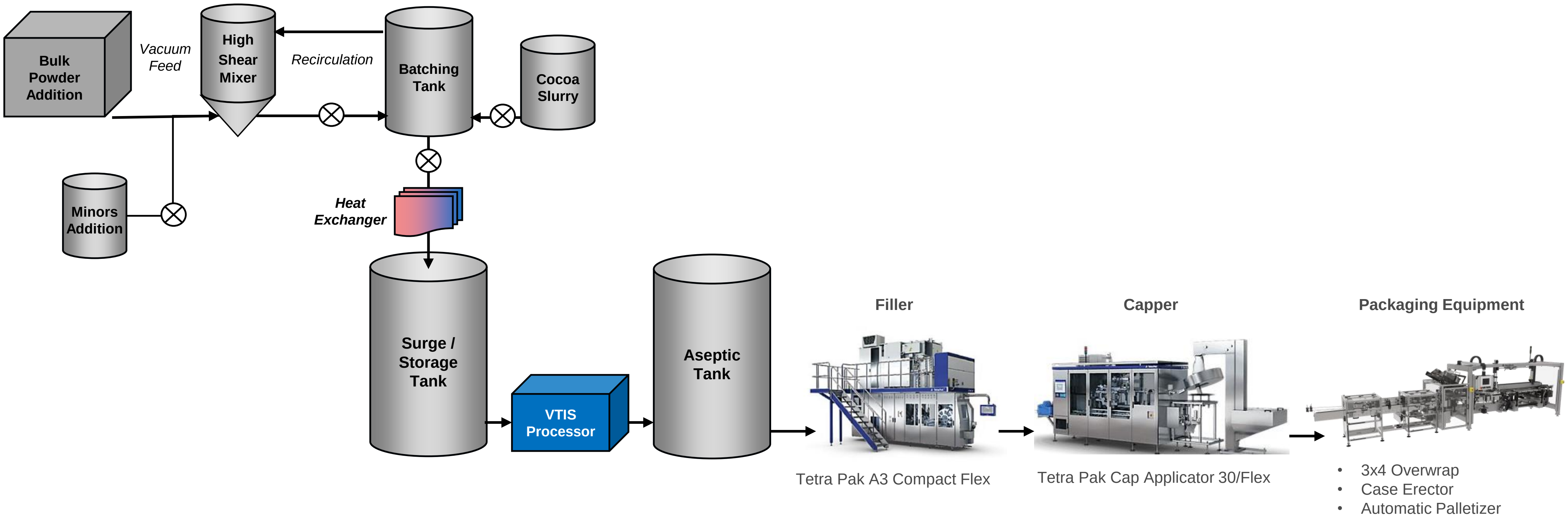
Manufacturing End-to-End Overview



Maintenance and Protocol Adherence

Overview

Best-in-class maintenance and protocol adherence are crucial for ensuring product integrity, operational efficiency, and regulatory compliance. By integrating modern methodologies and technologies, facilities can effectively manage their assets, minimize downtime, and maintain high-quality standards. A focus on proactive maintenance practices and strong relationships with Original Equipment Manufacturers (OEMs) can enhance performance, reduce operational risks, and improve efficiency.

Attributes of Best-In-Class

Asset Management System

- Contains detailed records of asset performance, history, and maintenance schedules.
- Enables facility managers to prioritize maintenance tasks, assess the lifecycle of equipment, and make informed decisions regarding upgrades or replacements.
- Backlog of maintenance is tracked with a target of zero days

Predictive Maintenance

- Gather and analyze real-time data from machinery and equipment to predict potential equipment failures before they occur.
- Maintenance protocols from OEMs are updated continuously for real factory conditions
- Required updates to maintenance service intervals are tracked and large deviations open investigation into root cause (CAPA)

Spare Parts Optimization

- A just-in-time strategy balances inventory levels to ensure essential spare parts are available when needed without overstocking.
- Tracking consumption trends and maintenance schedules allows for accurate predictions of future spare parts requirements.

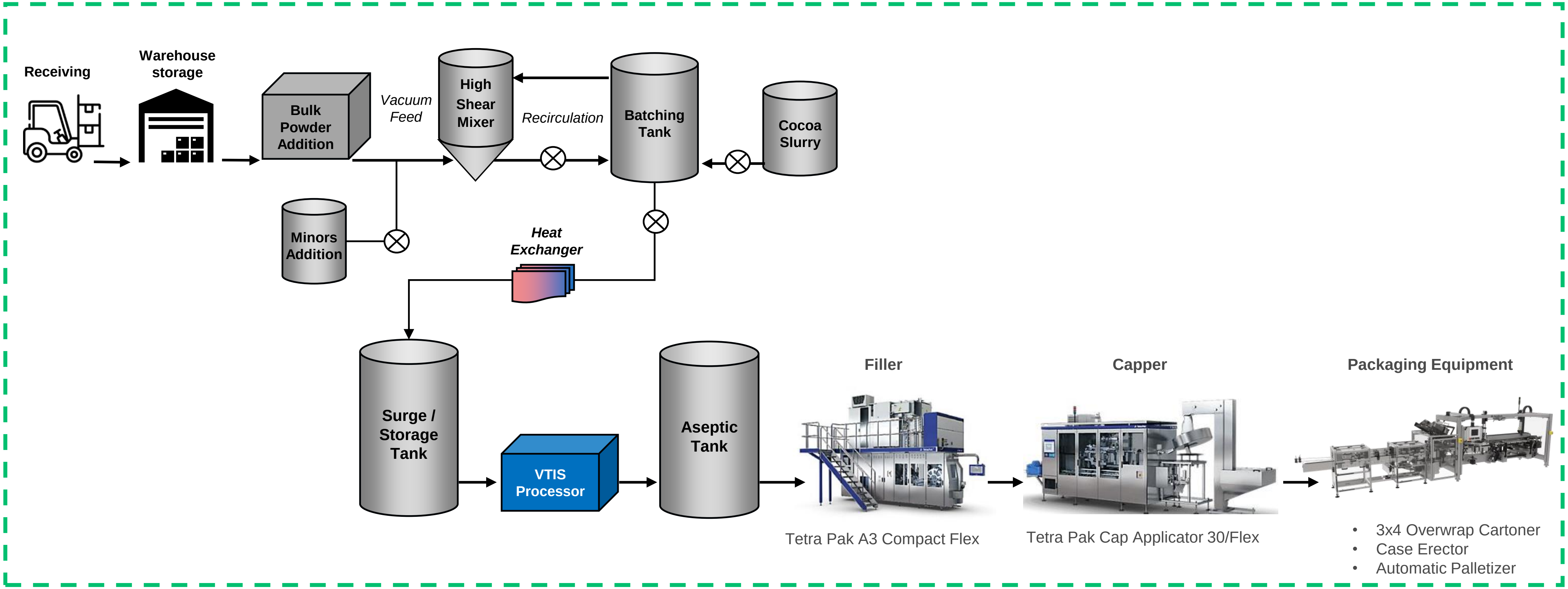
OEM Engagement

- Direct communication with OEMs provides timely technical support and troubleshooting assistance.
- Training sessions conducted by OEMs improve staff operation and maintenance practices.
- Collaboration with OEMs keeps the facility informed about innovations and upgrades to leverage the latest technologies.

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Maintenance and Protocol Adherence – Production Areas Targeted for Improvement



Incoming Packaging Material Standards

Overview

Ensuring high-quality incoming materials is critical to highly automated and high-volume aseptic beverage manufacturing, as raw material variability or defects can lead to production downtime. A best-in-class approach to incoming material standards includes well-defined quality criteria, robust supplier partnerships, and effective inspection and training protocols to ensure products received from suppliers are compliant to the defined specification.

Attributes of Best-In-Class

Comprehensive Material Specifications and Guidelines

- All raw materials (e.g. ingredients, packaging) have controlled and clearly documented specifications from suppliers
- Critical specifications can be verified by the receiving party (i.e. co-man)
- Documentation is revision-controlled, and design changes are tracked systematically

Packaging Receiving Process

- A streamlined, risk-based inspection protocol ensures materials are assessed quickly and accurately
- Material handlers are trained to inspect and quarantine material as required
- Inventory location and quantity is stored electronically and communicated to PNC via EDI transaction

Methodology for Issue Resolution

- Non-conformance management system allows for effective disposition and traceability to issues
- Root cause analysis tools are leveraged for issue resolution with corrective actions clearly documented (CAPA)
- Suppliers are notified of issues and reoccurring issues are prioritized

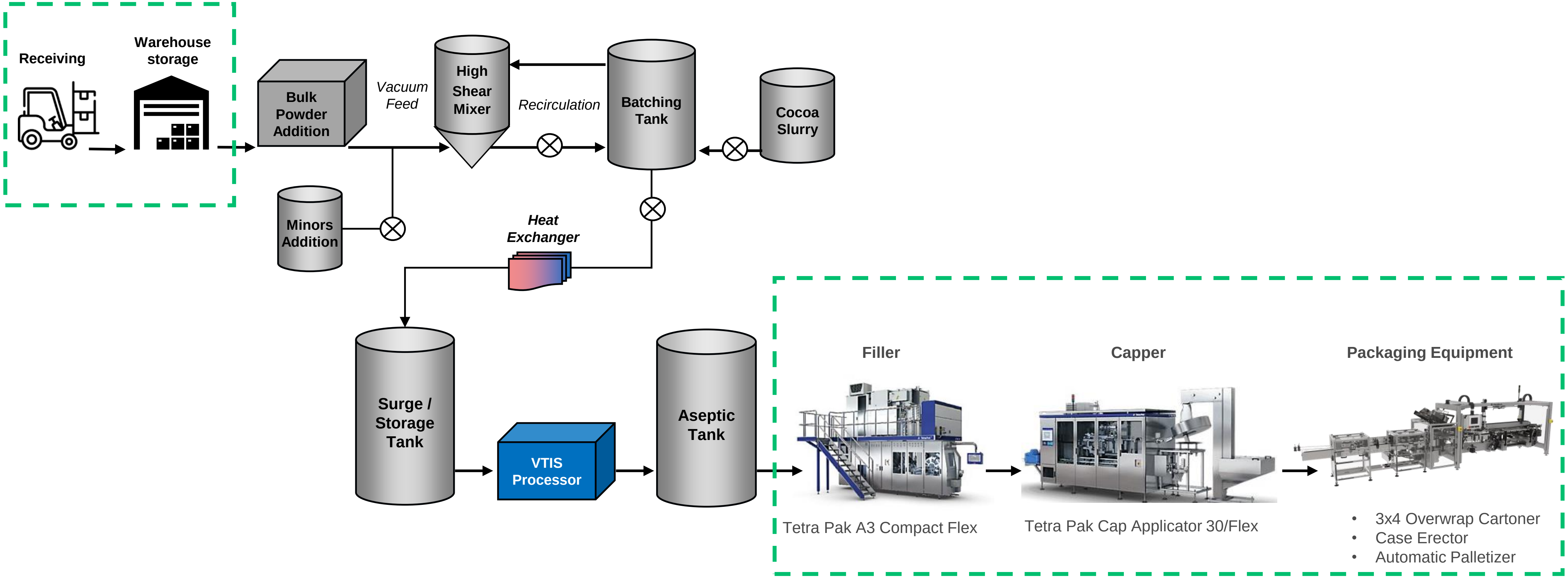
Supplier Performance Monitoring and Targets

- Supplier performance data is aggregated from the co-man network and tracked systematically
- Scorecards and regular business reviews drive accountability
- Partnerships are formed with suppliers to focus on innovation and process optimization

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)
Packaging Specification Templates	Templates for each packaging format		• Packaging Engineering • Raw Material Quality	
Completed Packaging Specifications	Approved specifications for each packaging format		• Packaging Engineering • Raw Material Quality	
Corrugate and Carton Defect Guide	Co-Man guide to typical packaging defects so they can identify and communicate the issue for investigation.		• Packaging Engineering • Co-man Quality	
Supplier Outbound Quality Release Guide	What pre-checks are required to ensure the components are not damaged in transit, are delivered in good condition and comply to incoming specification requirements.		• Packaging Engineering • Co-man Quality	

Incoming Packaging Material Standards – Production Areas Targeted for Improvement



Receiving Material Process Flow – Detailed Handling & Storage

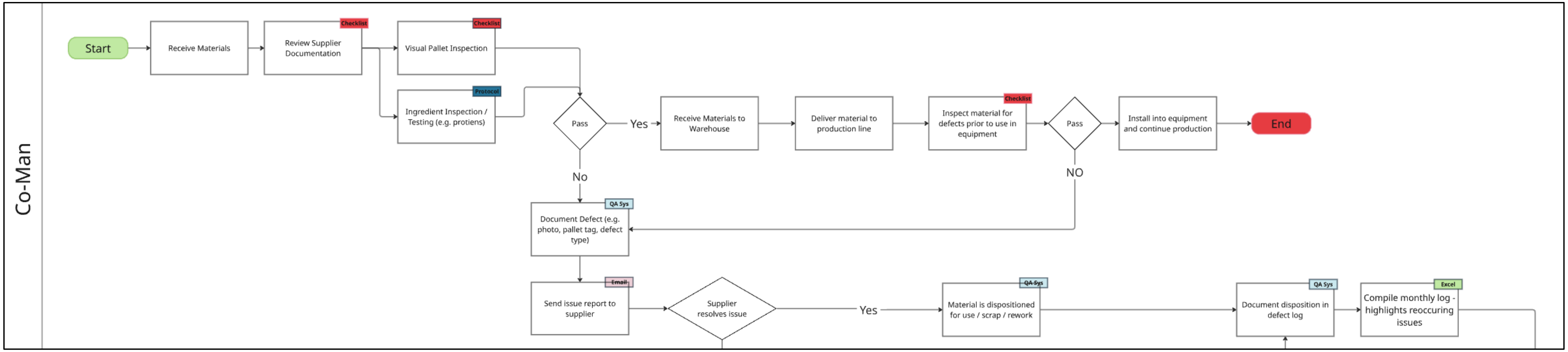
This process outlines the steps a typical Co-Man would follow from the receipt of materials to their final disposition in production or handling of defective items. This process represents best–practices which ensures non-conformances are tracked and only good materials enter production equipment.

1. Material Receipt and Initial Review

- The process begins with the receipt of materials at the facility.
- The Co-Man reviews documentation accompanying the materials to ensure compliance with requirements.
- A checklist is used to conduct a visual inspection of the pallet for any obvious damage or issues.
- Some ingredients (e.g., proteins) undergo more detailed testing per established protocols.

2. Passing Inspection Outcome

- They are received into the warehouse.
- Delivered to the production line.
- Before installation into equipment, another visual inspection is conducted using a checklist.
- If the material passes, it is installed into equipment and used in production, leading to the end of the process.



Material Specifications and Guidelines – Overview

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Detailed Overview

Specifications are required to establish a standard definition of packaging formats delivered from the supplier to contract manufacturing sites. The specification is the agreement and defines the required quality as committed by the supplier, and when materials are delivered damaged, it provides a basis for rejection and quality improvement exercises. Packaging specification were created for all primary and secondary Tetra Pak shake configurations and incorporated into the PNC Intelex database. An overview of the process followed:

Scope Packaging → **Develop Specification Templates** → **Create Specification with Supplier** ⟳ **Cross Functional PNC Review** → **Release Specification to Intelex**

Packaging Type	Approved Suppliers	Completed Formats
Corrugate Cases	Menasha, Georgia Pacific	3x4ct ,12, 15 and 18 count cases
3x4ct Overwrap Cartons	GPI, WestRock	3x4ct (both glued and locking tab versions)
Tetra Pak Prism container	Tetra Pak	Barrier Paper Laminate, Caps, Glue
Ingredients / Powders	Not Scoped – To be developed	Not Scoped – To be developed
Bottle and Bottle Cases	Not Scoped – To be developed	Not Scoped – To be developed

Developed Content

- **Packaging Material Specification Templates:** Templates generated for suppliers to populate with content relevant to the packaging material type.
- **Completed Packaging Material Specifications:** Approved documentation with detailed specifications including; Incoming pallet information and quality requirements, storage requirements, performance metrics, technical drawings, artwork die lines etc.
- **Released and Revision Controlled Specifications:** Specification released to document control system (Intelex)

Implementation Strategy

- Create specification templates for each packaging material type with input from all stakeholders within PNC
- Request specification data from suppliers for current delivered components
- Agree a management system for specifications to ensure all updates are document controlled and follow an approval process (e.g. Intelex)
- Release the specifications to the management system and collect approvals from all core stakeholders
- Manage supplier or internal revisions with the same process

Common Challenges

- Ensuring the specifications meet the requirements of all internal (e.g. procurement, quality, packaging engineering) and external stakeholders (e.g. co-mans, packaging suppliers)
- Ensure the specifications contain relevant and valid information which can be repeatably achieved and controlled by suppliers
- Setting up a system of review to ensure approvals are done in a timely manner
- Maintaining specifications as any changes need to be tracked and the document approved and up-versioned.

Material Specifications and Guidelines – Real World Example

Litho Lam Case Specification

Figure 1 shows key parameters from a Litho Lam case specification that defines critical requirements for the packaging material.

- The document is structured this way to provide comprehensive guidance from suppliers to co-mans and PNC, with each parameter directly impacting package quality, line performance, or product protection (Table 1).
- The specifications include both physical properties (e.g. ECT, BCT values) and functional requirements (e.g. varnish coefficients, strapping details) to ensure consistent performance throughout the supply chain.
- This specification is maintained in the PNC Intelex database and includes detailed technical requirements covering materials, performance, dimensions, and handling.

Table 1: Parameter Description and Impact on Performance Key

No	Description / Impact on Performance
1	Specification of coated paper that allows high quality Litho printing and lamination onto corrugate
2	Flute type creates strength, internal and external dimensional accuracy
3	ECT (Edge Compression Test) is the traditional way of specifying the strength of the board
4	BCT (Box Compression Test) is a value that tests the actual case under compression and allows calculations on the required case strength based on the pallet configuration.
5	COF (Coefficient of Friction) of the varnish describes how the case surface slips against another case which can cause issues with incoming and outgoing pallet stability.
6	Statement that covers the quality of inbound packaging to deliver the cases in good condition
7	Detail of required strapping and protection for the pallet contents

Status	IN REVIEW	
Materials	Litho Paper Type	10PT SBS
	Upper Facing paper (G/M^2+- xx%)	N/A
	Flute Paper (G/M^2+- xx%)	33M
	Inner Facing paper (G/M^2+- xx%)	42K
	Flute type	B
Performance	ECT (lbs/in)	40ECT (hits 44ECT just not 100% of time so must be called 40ECT by rule)
	BCT (lbs)	data from 8/1/2024 avg. BCT 384 with low of 357 (cartons tested from Madera plant)
Dimensions and weight	External case size (WxLxH)	155.57 x 127 x 357.187 mm (6.125 x 5 x14.0625 inch)
	Internal case size (WxLxH)	147.624 x 120.65 x 347.662 mm (5.812 x 4.75 x 13.6875 inch)
	Corrugate board total thickness	3.175 mm (.125 inch)
	Case weight	169 g

Functional Decoration

Decoration Method	Lithography (Litho) followed by lamination onto the corrugate
(See artwork specification for specific SKU artworks and printing details)	
Exterior Varnish	Currently Spot Gloss Aqueous (Testing is currently being done to change to Non-Skid UV)
Exterior Varnish Coverage +- 10%	90%
COF (Dynamic and static) +- 10%	Slide Angle = 14 -/+ 2

Inbound Packaging Requirments

Requirments statement concerning inbound packaging quality	The incoming packaging needs to be fit for purpose and protect the contents from any damage from inbound transit, appropriate storage and handling. There should be no pallet overhang and the packaging d secured well enough to prevent leaning and movement during transit and appropriate handling .
Pallet size (L x W x H)mm	1219.2 x 1016 x 127 mm (48 x 40 x 5 inch)
Pallet Material Type	Wooden
Number of cases on pallet	1,500
Pallet Weight	286.3 kg / 630 lbs
PP Sprapped with top corrugate sheet	2 tensioned straps on long and short side
Stretch Wraping	Y
Labelling	On one long and short side with supplier and pallet details suitable for tracability
Binding of cases	N
How many cases in each bind	N/A

Figure 1: PNC Litho Lam Case Specification

Material Specifications and Guidelines – Real World Example

Placement of Date Code in Unvarnished Coding Area

A warehouse inspection revealed the supplier shipped non-conforming 3x4 overwrap cartons. The date code unvarnished area on 3x4 overwrap cartons were not standardized, leading to some sites receiving a date coding area that was too small to contain the required information. This example demonstrates the consequences of uncontrolled specifications, which can **lead to potential quality issues and production downtime.**

On-site Inspection

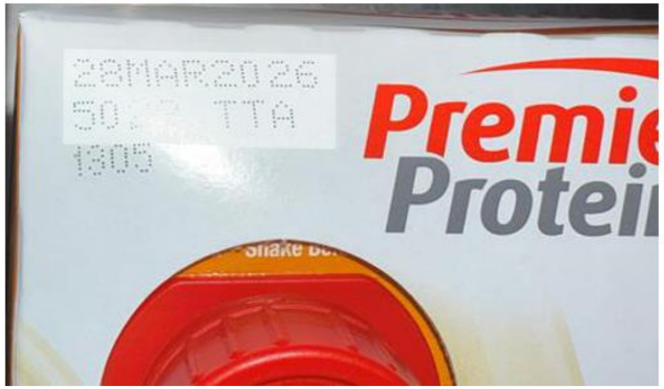

Figure 1: Date coding on varnished area of overwrap

Figure 2: Variation in unvarnished date coding area size on overwrap cartons from WestRock

Implications

Unvarnished coding area is too small (Fig 1)	Supplier ships out of specification product
Defect undetected in receiving inspection	**1st opportunity to prevent downtime:** An approved PNC sample should be used to check against the attached pallet sample for defect detection (see overwrap specification).
Cartons placed into production equipment	**2nd opportunity to prevent downtime:** Open a case of cartons to check against the approved PNC sample. If defect is detected, contact PNC for approval and next step.
Coding from ink jet printer can not fit in the unvarnished areas	The standard coding does not fit in the new unvarnished area
Ink on varnished area gets smudged	**3rd opportunity to prevent downtime:** Adjust printing head to the correct position and size for the unvarnished coding area.

Packaging Receiving Process – Overview

Detailed Overview

An efficient receiving process is critical as delays or errors in material acceptance can significantly impact production schedules and quality. A streamlined, risk-based approach to receiving goods ensures materials meet specifications while optimizing quality, throughput and maintaining compliance.

The process begins with material arrival verification, continues through systematic inspection and testing protocols, and concludes with proper material storage and documentation. Electronic systems support real-time inventory tracking and communication with PNC, enabling quick material availability for production while maintaining full traceability.

Material Arrival → **Document Check** → **Risk-Based Inspection** → **Material Release** → **Handling & Storage** → **EDI Transaction** → **Inventory Update**

Developed Content

- **Packaging Material Training Guides:** Templates generated for suppliers to populate with content relevant to the packaging material type.
- **Completed Packaging Specifications:** Approved documentation with detailed specifications including; pallet and case labels, technical drawings, artwork die lines and specification history
- **Critical to Quality Attributes Identified:** Attributes from specifications which are critical to quality are defined and highlighted in material training guidelines.

Implementation Strategy

- Validate requirements for incoming packaging specifications
- Ensure inspection checks are achievable in the warehouse environment (e.g., poor lighting, lack of space, time pressure to release goods, resources, etc.)
- Implement proper handling and storage protocols for different packaging materials
- Agree on standardized receiving processes with input from all stakeholders
- Create network-wide bulletins to share quality issues and improvement strategies

Common Challenges

- Ensuring the specifications meet the requirements of all internal and external stakeholders.
- Ensuring the specifications contain relevant and valid information which can be met and controlled by suppliers.
- Setting up a system of review updates to ensure new version approvals are done in a timely manner.
- Creating a network wide method of capturing issues and communicating them to PNC or directly with the supplier.

Defect Guide

Packaging Receiving Process – Detailed Handling & Storage

Description

- Incoming packaging materials require careful inspection upon receipt to ensure no damage has occurred in transit that would require rejection at the line.
- Proper storage and handling according to supplier recommendations ensures Critical to Quality attributes do not deteriorate over time through the material's lifecycle.

Theory

- Implementing proper controls during receiving and storage prevents subsequent downstream issues such as warping, deformation, and case erector jams that can halt production lines and increase waste.
- Paper-based components naturally absorb and releases environmental moisture, performing optimally when maintained at recommended temperature and humidity conditions (7-8% moisture at 23˚C and 50 RH).
- Components must be used within supplier-recommended timeframes when stored in required conditions.
- Systematic defect reporting to PNC enables supplier awareness and preventive action

Achieving Best-in-Class

- Manage seasonal temperature and humidity variations that affect paper-based components' moisture content, with special attention to storage and pre-conditioning requirements.
- Keep pallets wrapped/strapped until use, only unwrapping immediately before production to maintain controlled moisture content
- Implement standardized inspection and reporting protocols across all co-man sites.
- Practice effective stock rotation (FIFO) to ensure components are used within required timeframes.
- Utilize a standardized defect classification guide for consistent identification, terminology and reporting throughout the network.

Figure 1: Inadequate stretch wrap coverage at pallet base allows load movement during transport, creating instability and safety hazards.

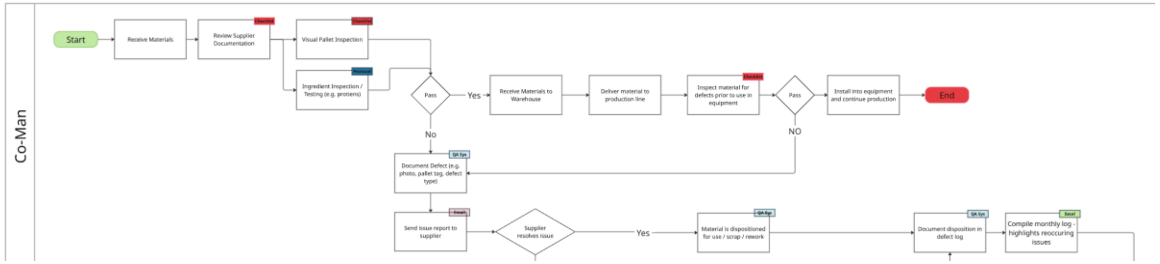

Figure 1: Handling & Storage process flow

Packaging Receiving Process – Critical to Quality (CtQ)

Description

- Critical to Quality (CtQ) attributes are key measurable characteristics of a product or process that directly impact quality, performance, and customer satisfaction.
- In the receiving process, CtQs ensure raw materials meet critical specifications that allow them to function correctly in the manufacturing process and deliver the intended end user experience.

Theory

- CTQ attributes emerge from three essential sources:
  - **Packaging material & artwork specifications:** physical and visual properties
  - **Finished product requirements:** shelf-life, seal integrity, and safety of the final product
  - **Equipment requirements:** machinability, coefficient of friction
- The CTQ framework integrates three specification types, which converge to create a subset of critical packaging specifications that must be verified during the receiving inspection (Figure 1)

Achieving Best-in-Class

- Implement a four-step CtQ documentation process that involves identifying and documenting CtQs, distributing to suppliers and maintaining version control (figure 2)
- Apply CtQ in practice through:
  - Train warehouse receivers on identifying critical attributes and inspection techniques
  - Establish guidelines as to what is Target, Acceptable, Marginal, and Unacceptable (TAMU)
  - Track CtQ performance metrics by supplier and material type
  - Define escalation protocols for CtQ defects / failures with appropriate containment actions
  - Ensure that the receiving CtQ process links to the finished product CtQ process

PNC Finished Product Specification
- PNC requirements for finished product
- Co-man designs a process to meet this specification

+

Packaging Material & Artwork Specification
- Establishes performance requirements
- Represents the supplier's production commitment

+

Equipment Requirements
- Attributes of materials which ensure compatibility with automated packaging equipment

→ **CtQ** A subset of critical packaging specifications

Figure 1: CtQ framework

1. Identify
- Identify critical attributes through product and line equipment requirements

2. Document
- Ensure that the attributes are captured in material specifications
- Capture CtQ attributes in a quality reference document

3. Distribute
- Share quality reference document with packaging suppliers as a release document
- Suppliers distribute to co-mans as a receiving document to ensure CtQ attributes are in control

4. Maintain
- Implement version control system to maintain updated critical attributes from co-man network learnings
- Provide accessible documentation to all stakeholders

Figure 2: CtQ documentation process

Packaging Receiving Process – CtQ Representative Example

Case Pallet CtQ Failure

A warehouse inspection revealed numerous failed Menasha "Litho Lam" case pallets damaged during transit (see figures 1 & 2), which would lead to case erector jams and line stoppages. This failure demonstrates how identifying critical quality attributes across packaging specifications, equipment requirements, and finished product standards enables effective problem-solving and prevents production downtime, ensuring continuous operations.

On-site Inspection

Figure 1: Due to excessive braking in transit, the whole bottom layer of cases has slid forward.

Figure 2: Incoming Pallet rejects due to movement in transit

CtQ Evaluation

PNC Finished Product Specification
- Damaged pallets risked compromising case integrity
- Case damage could potentially affect final product appearance and quality

+

Packaging Material & Artwork Specification
- Pallet wrap and strapping was inadequate for transit conditions
- Material performance requirement failed under real-world transport stress

+

Equipment Requirements
- Damaged cases cause jams in case erector leading to production downtime
- Equipment maintenance required to resolve jammed cases

CtQ attributes to prevent load shifting during transit:
- Stretch wrap extends and connects onto the pallet
- PP tensioned strapping wrap under pallet

Methodology for Issue Resolution – Packaging Defect Reporting Process

Description

- Effective issue resolution in manufacturing requires a structured approach to identify, assess, track, and mitigate defects.
- A systematic four-step methodology ensures consistent handling of defects across the co-man network and drives continuous improvement.

Theory

- Identifying root causes and implementing corrective actions is essential to prevent future occurrences.
- Ensuring suppliers have complete information (batch numbers, production date, quantity affected, circumstances) is critical to properly identify root causes and understand issue scale.
- Reporting even the smallest issues cultivates continuous improvement and ensures optimal component supply.

Achieving Best-in-Class

- **Defect Data Collection:**
  - Gather comprehensive defect data comparing packaging against specifications and approved sample
  - Use standardized reporting formats and digital tracking systems
  - Implement processes to record pallet/case label details for traceability once unwrapped
- **Defect Disposition:**
  - Determine appropriate actions for defective materials
  - Share required details with suppliers to identify root causes
  - Ensure suppliers maintain clear, visible pallet labels matching Packaging Material requirements
- **Monitoring & Reporting:**
  - Track defects on scorecards to monitor supplier performance
  - Establish clear expectations with suppliers regarding response times
  - Maintain communication channels between quality, production and suppliers
- **Corrective Action Management:**
  - Implement corrective and preventive actions (CAPA) based on data insights
  - Assign ownership, set deadlines, and track completion of improvement initiatives
  - Validate effectiveness through follow-up verification

1. Defect Data Collection

- Quantity Impacted
- Purchase Order
- Supplier

2. Defect Disposition

- EDI Data Flows
- Automated alerts for defective packaging

3. Monitoring & Reporting

- Tableau Dashboard
- Supplier Scorecard
- Benchmark Data

4. Corrective Action Management

- Supplier Management Process
- Corrective and Preventive Action (CAPA)

Methodology for Issue Resolution – Detailed Defect Reporting Process for Raw Materials

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1

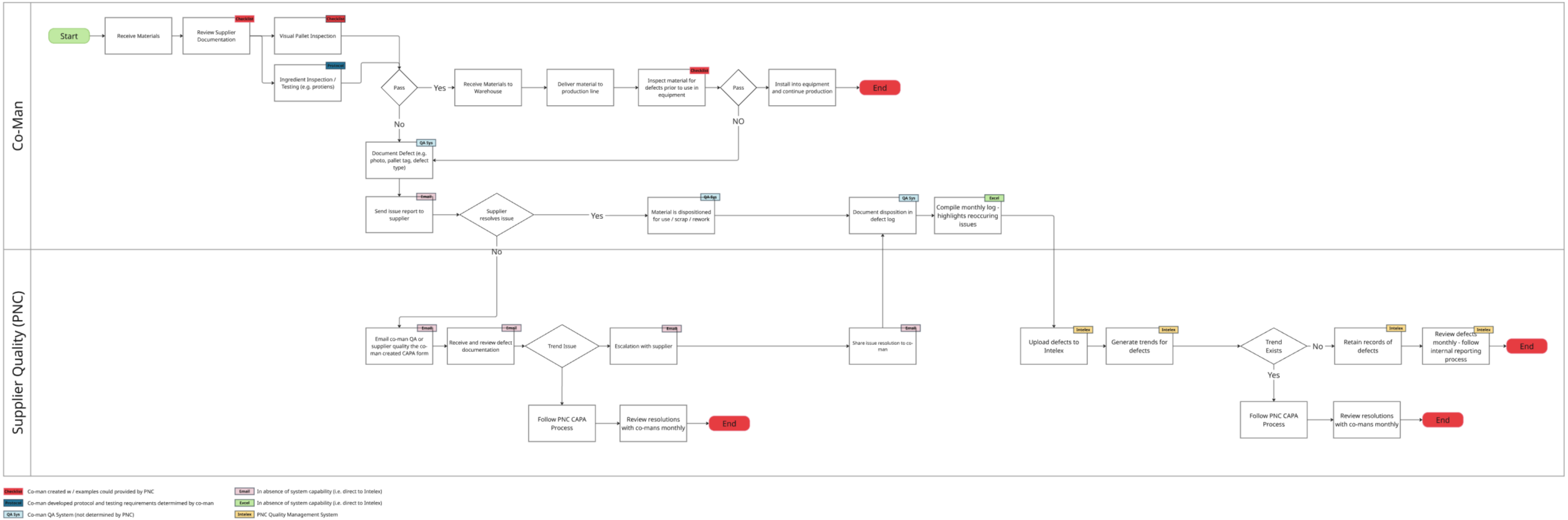
If Material Fails:
- Defect is documented and reported to the supplier.
- If resolved, the material is dispositioned and logged.
- Issues are compiled monthly to highlight recurring problems.

2

If Supplier Doesn't Resolve:
- PNC takes control of the supplier issue
- CAPA form initiated, issue trended and escalated
- Follow CAPA process and share resolutions with Co-Man.

3

Defect Trend Analysis:
- All issues uploaded to Intelex.
- Trends assessed; CAPA triggered if trends exist.
- Resolutions reviewed monthly with Co-Man or records retained.



Methodology for Issue Resolution – Representative Example

1. Data Collection

Defect: Unvarnished area too small to print date/batch code on packaging

- Detection method tools include:
  - Incoming inspection procedures
  - Approved reference sample supplied to co-mans
  - Packaging Specifications
  - Packaging Guidelines
  - Reporting defect tools
  - Reporting process established between PNC and co-man
  - Standardized forms

2. Defect Disposition

Disposition: Overwrap was scrapped with supplier replacement

- Immediate containment actions implemented, such as:
  - Conduct additional inspection at receiving site
  - Isolate affected stock both finished goods and defective cartons
  - Check further stock in the same batch for the defect
  - Send technical bulletin to co-man network of defect

3. Monitor & Reporting

Reporting: Supplier is operating below performance threshold

- Performance data is compiled into supplier dashboard
  - Supplier first time quality found to be below target (<95%)
  - Supplier quality team leverages dashboard to negotiate terms with supplier to improve performance
- Ongoing improvement efforts communicated with co-mans

4. Corrective Action

Corrective Action: Varnish free area on specification not clearly defined

- Root-cause analysis conducted by the supplier
- Long-term corrective action implemented:
  - Artwork Specification updated
  - Samples verified in compliance to varnish window sizing
  - Approved samples shared with the co-man network
  - Verify the resolution that prevents the issue from reoccurring

Figure 1: Defect identified in packaging; unvarnished area too small for batch code

Figure 2: A structured defect management process ensures rapid resolution

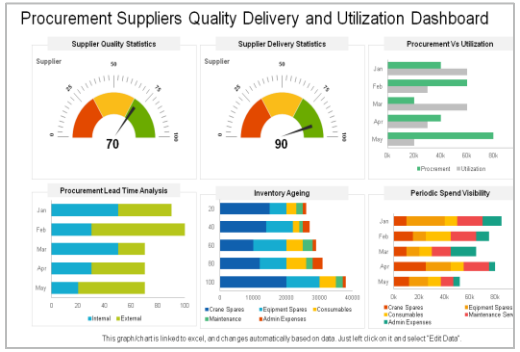


Figure 3: Dashboard tracks supplier performance and ability to hit contractual targets (example)

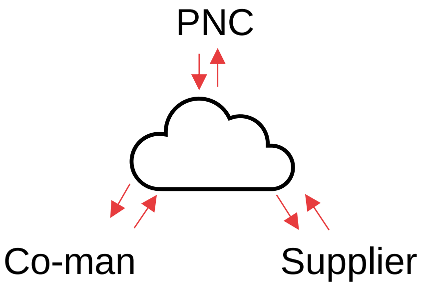


Figure 4: Communication channels between supplier, co-man and PNC are open

Packaging Supplier Performance Monitoring and Targets – Overview

Detailed Overview

Best-in-class supplier performance monitoring ensures raw materials consistently meet quality, cost, and delivery expectations. This process relies on clear Key Performance Indicators (KPIs), such as defect rates, on-time delivery, and specification compliance, tracked across all supplier relationships. Given that raw materials are purchased by PNC for the co-man network, a structured reporting system must be in place to ensure visibility and accountability. Regular business reviews, corrective action tracking, and continuous improvement initiatives drive long-term supplier reliability and alignment with production needs.

Review what metrics and

Material Receipt & Inspection → **Defect & Delivery Performance** → **Report to PNC** → **Supplier Review & CAPA** → **Notify Network of CA** → **Monitor Performance**

Content Development Plan

- **Supplier Performance Dashboard:** Under development…
- **Supplier KPIs:** Under development…
- **Data Strategy:** Under development…

Implementation Strategy

- **Define Performance Metrics & Requirements** – Establish key KPIs (quality, delivery, compliance) aligned with business needs.
- **Develop Data Collection & Reporting Framework** – Set up standardized processes for Co-Man to report supplier performance data to the OEM.
- **Implement Supplier Review & Accountability Process** – Conduct regular performance reviews, enforce corrective actions, and drive continuous improvement.
- **Leverage Technology & Automation** – Utilize digital tools for real-time tracking, analytics, and supplier scorecards.

Common Challenges

- **Data Inconsistencies & Visibility Gaps** – Co-Man and OEM may have misaligned reporting standards, leading to unreliable performance data.
- **Supplier Resistance to Change** – Suppliers may push back on new performance expectations or corrective action requirements.
- **Limited Resources for Oversight** – PNC may struggle to allocate dedicated personnel or tools to actively manage supplier performance.
- **Complex Multi-Tier Supply Chains** – Managing indirect material flows and multiple stakeholders complicates accountability and issue resolution.

Batching & Standardization

Overview

The batching process is the foundation of aseptic beverage manufacturing, ensuring accurate formulation, efficient mixing and seamless transfer to downstream processing. Best-in-class batching integrates standardization to verify batches meet PNC defined specification ranges for total solids (%) and pH before advancing to downstream processes. This integrated approach minimizes errors, enhances efficiency, reduces cycle times, and eliminates rework by ensuring each batch meets quality specifications on the first attempt.

Attributes of Best-In-Class

Precision Ingredient Dosing and Control

- Metering systems ensure accurate addition of raw materials, reducing human error.
- Inline flow meters, load cells, and loss-in-weight feeders verify ingredient quantities and agree upon reported volume.
- Pre-calibrated batch recipes ensure consistent composition across all production runs.

Optimized Mixing & Homogenization

- Mixing parameters are controlled to ensure uniform dispersion of ingredients.
- Controlled and documented sequencing of ingredient additions prevents common mixing issues.
- Real-time monitoring of batch parameters to ensure it meets specifications, with automated alerts triggered by deviations.
- Homogenization processes are validated and maintained to achieve target particle size and stability.

Batching System Designed for Process Throughput

- Configuration and sizing of batch tanks should be scaled for the line and optimized for production flow and CIP.
- Optimized water addition, heating, and recirculation rates to minimize batch cycle time while ensuring product quality.
- Design flexibility including recirculation loops and CIP systems that minimize changeover times and maximize equipment utilization.
- Process design verified through statistical time studies and sensitivity analysis to prevent bottlenecks in production.

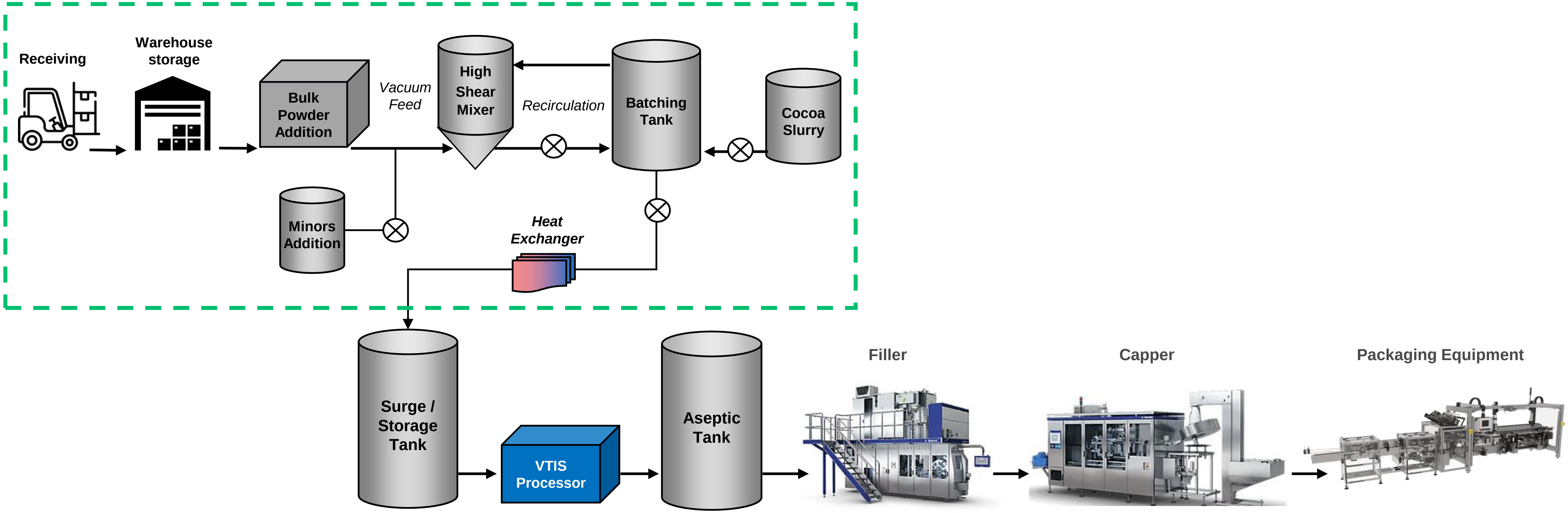
Minimized Variation

- Tight control of ingredient handling, mixing sequences, and processing conditions reduces batch-to-batch variability.
- Raw material adjustments based on statistical analysis of historical data to accommodate ingredient fluctuations.
- Standardized formulations with sensitivity limits for critical ingredient additions to optimize consistency.
- Continuous batch record monitoring to identify equipment failures or operator errors in real-time.

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)
Batching Time & Motion Datasheet	Time study sheet for capturing process	• Here	• R&I Team	• Batching Time Study Form
Batching Capacity Analysis Tool	Model to determine batching & plant capacity	• Here	• R&I Team	• Batching Capacity Tool (TBD)
Standardization Elimination Data Form	A data collection format for collecting and interpreting standardization results	• Here	• R&I Team	• Standardization Elimination Form.xlsx
Standardization Elimination Workbook	A model for determining if elimination of process steps are possible	• Here	• R&I Team	• Elimination of Standardization - Co-man Copy.docx
Gauge R&R Study	Method for measuring equipment capability	• Here	• R&I Team	• Gauge Repeatability and Reproducibility Study.docx

Batching & Standardization – Production Areas Targeted for Improvement



Tetra Pak A3 Compact Flex

Tetra Pak Cap Applicator 30/Flex

- 3x4 Overwrap Cartoner
- Case Erector
- Automatic Palletizer

Batching Process Flow – Real world example (MFI)

Standardization Process Flow – Real world example (MFI)

Precision Ingredient Dosing – Overview

Detailed Overview

The majority ingredients are dosed into a high shear mixer which is coupled with a separate batching tank via a shear pump to allow recirculation of the product between the tanks. For chocolate base recipes the cocoa is mixed in a separate high shear mixer and added directly to the batching tank following the gum hydration step.

The accurate addition of solids and liquids during batching is essential to:

- Ensure the product meets specification, with all ingredients being present within the specified concentration limits.
- Minimize or eliminate the requirements for pH and solids standardization with associated labor and time savings, resulting in greater batching capacity.
- Accurate batching records are essential to ensure traceability and confirm product conformance. A digital system using scanned ‘bar’ or ‘QR’ codes has the additional benefit of reducing the time required to transcribe batching information reducing batching time and increasing batching capacity.

Receive Ingredients → **Cocoa Hydration** → **Gum Hydration** → **Recirulation** → **Bulk Powder Addition** → **Minor Addition**

Developed Content

- **Solids / Liquids Accuracy Calculator:** A calculator to determine the allowable variability in the measurement of solids and liquid addition given real-world operating parameters to meet the production specification.
- **Waste Analysis:** Study to investigate any net gains or losses from ingredients, which includes cyclones, additional moisture, giveaways, etc.

Implementation Strategy

- Identify best-in-class metering performance for all liquids and solids.
- Confirm average mass and distribution for supplier weighed solids.
- Confirm moisture content for bulk powder additions.
- Establish losses from:
  - Batching
  - Powder remaining in bags
  - Fugitive powder on floor
  - Volume of liquid that enters the batching tanks after the valve has been actuated to close.
- Verify dosing performance meets specification through regular calibrations.
- Introduce digital batch records to reduce batching time and allow for ease of traceability.

Common Challenges

- Powders are almost always shipped from suppliers with moistures approaching the top of the specification range. The recipe needs to allow for the shipped moistures to not be a mid-specification value.
- Liquid dosing values must also include the volume of liquid that can still enter the tank once the valve is actuated to close.
- All liquid metering and measurement systems must be calibrated based on the measured liquid, accounting for the liquid density which will be dependent on temperature and ingredient composition.

Precision Ingredient Dosing – Controlling Liquid

Description

- Precise liquid measurement is fundamental to achieving consistent total solids content, as even minor water variations directly impact protein stability, texture, and shelf life of the final product.
- Effective liquid control ensures batch-to-batch consistency and meets quality specifications.

Theory

- Liquid-to-solids ratio directly determines final product solids percentage through a dilution relationship where any excess liquid proportionally reduces solids concentration.
- With solids dosing accuracy of 1% (verified by suppliers) and minor weighing (same precision), liquid additions must be accurate to ±1.0% for 99.7% (6σ) of batches to meet target range.
- Fluid dynamics in closed systems create two distinct sources of measurement error:
    - Momentum effects cause continued flow after valve actuation signals (water hammer).
    - Volume contained in transfer lines introduces systematic measurement offsets.

Achieving Best-in-Class

- Control bulk liquids via flow meters with ±0.2% accuracy (4 parts in 1,000). Calibrate flow meters per manufacturers instructions.
- Implement secondary verification steps to confirm liquid transfer volumes match expected amounts (e.g., tank level verification after transfer completion).
- Verify volumes in bulk liquid tanks using pressure sensors or load cells with regular calibration.
- Account for residual liquid flow entering tanks after valve closure:
    - Maintain appropriate closing speed to prevent water hammer/hydraulic shock.
    - Account for water volume between control valve and tank that drains after valve closure.
- Measure by mass (e.g., bin on pallet balance) to accurately determine water volume continuing to flow after valve closure signal.

Table 1: Impact of the accuracy of Liquids addition on the final batching solids assuming a fixed solids addition accuracy of ±0.5% =1% (equivalent to ±5g in a Kg)

Vanilla	Liquids Variability (99.7% confidence)				
	0%	± 0.25%	± 0.5%	± 0.75%	± 1.0%
Standard Deviation	0.023%	0.034%	0.041%	0.057%	0.069%
Max Solids 12.40% (highest solids, lowest volume of water)	12.27%	12.30%	12.34%	12.37%	12.41%
Min Solids 12.00% (Lowest solids, highest volume of water)	12.13%	12.10%	12.06%	12.03%	11.99%

Notes:

1. *This analysis assumes perfect accuracy in solids measurement. Any variation in solids measurement will increase the spread of values.*
2. *If solids metering is less accurate than ±0.5%, liquid additions will need tighter control than ±1.0% to maintain target specifications.*
3. *"Max Solids" (12.40%) represents the upper boundary condition with highest possible solids concentration and lowest possible water volume.*
4. *"Min Solids" (12.00%) represents the lower boundary condition with lowest possible solids concentration and highest possible water volume.*

Precision Ingredient Dosing – Controlling Solids

Description

- Precise solids metering and measurement ensures all PNC 30g protein product batches consistently meet specification ranges, delivering product quality and stability.
- Accurate solids addition directly impacts final product performance, mouthfeel, and nutritional content, including legally enforceable claims.

Theory

- Solids-to-liquid ratio determines final product concentration through a balanced formulation relationship.
- With water dosing accuracy of 0.4% from calibrated meters, solids additions must be accurate to 2.5% (±1.25%) to maintain 99.7% (6σ) of batches within target range.
- Precise solids control requires accurate batch records and QC verification to establish a reliable baseline with minimal variation.

Achieving Best-in-Class – Bulk Raw Material Addition

- Control bulk materials (milk protein concentrate and calcium caseinate) in two formats: super sacks or 20kg bags (some suppliers provide 25kg).
- Confirm the manufacturer accurately measures weights and it is assumed they will target the minimum mass in the specifications and reduce "giveaway“.
- Confirm powder loss during batching the assumption is that excess material will balance losses and total variation from target must not exceed 2.5% (Table 1).
- For recipe calculations, assume all powder raw materials are at or near top of specification range for moisture, as suppliers target maximum allowable water content to optimize production costs.

Achieving Best-in-Class – Minor Ingredients Addition

- Weigh minor ingredients individually with documented measurements.
- Measure to at least 3 significant figures with control within 2.5% (Table 1).

Table 1: Impact of the accuracy of solids addition on the final batching solids assuming a fixed water addition accuracy is ±0.2% (a real-world process control limit)

Vanilla	Solids Variability (99.7% confidence)				
	0%	± 0.25%	± 0.5%	± 1.00%	± 1.25%
Standard Deviation	0.009%	0.021%	0.032%	0.055%	0.067%
Max Solids 12.40% (Highest solids, lowest volume of water)	12.23%	12.26%	12.30%	12.37%	12.40%
Min Solids 12.00% (Lowest solids, highest volume of water)	12.17%	12.14%	12.10%	12.04%	12.00%

Notes:

1. *If water metering is less accurate than ±0.2%, solids additions require tighter control than ±2.5% to maintain target range.*
2. *Any variation in solids measurement increases the spread of measured values.*
3. *"Max Solids" (12.40%) represents upper boundary condition with highest solids concentration and lowest water volume.*
4. *"Min Solids" (12.00%) represents lower boundary condition with lowest solids concentration and highest water volume.*

Precision Ingredient Dosing – Controlling Solids Example

Placeholder – Collect Data at MFI for Waste Analysis

Sample #	Specified Weight (kg)	Measured Excess Weight (kg)	Calculated Loss Due to Cyclone (kg)	Losses from Manual Debagging (kg)
1	44.09	+0.036	-0.00	-0.018
2	44.09	+0.036	-0.00	-0.008
3	44.09	+0.096	-0.02	-0.028
4	44.09	+0.076	-0.01	-0.048
Average (All Samples)	44.09	+0.061	-0.0050	-0.026
			Calculated Loss	

Precision Ingredient Dosing – Characterizing

Description

- Determining process capability is essential for **ensuring that a manufacturing process consistently produces products between the upper and lower specification limits (USL & LSL)**, reducing defects and waste while improving efficiency.
- By using metrics like Cp and Cpk, manufacturers can assess whether a process is capable of meeting customer and regulatory requirements and identify areas for improvement.
- Understanding process capability also supports data-driven decision-making, enabling proactive process control and continuous improvement initiatives.

Theory

Cp - Potential Capability *

- Cp measures how well your process can fit within the specification limits **assuming it is centered**
- σ = standard deviation of the process
- Cp > 1.33 typically indicates a capable process, assuming it is centered.

$$cp = \frac{USL - LSL}{6\sigma}$$

Cpk - Actual Capability *

- Cpk accounts for whether the process is centered within the limits. It is calculated as:

$$cpk = min(\frac{USL - Mean}{3\sigma}, \frac{Mean - LSL}{3\sigma})$$

Achieving Best-in-Class

- **Cp = Cpk:** The process is centered.
- **Cpk < Cp:** The process is off-center, meaning it’s closer to one specification limit.
- **Cpk ≥ 1.33:** The process is highly capable, with 99.73% of output within specification limits.
- **Cpk < 1:** The process is not meeting specifications consistently.

1. Collect Process Data and Plot Histogram
2. Test Normality
3. Calculate Mean / Standard Deviation
4. Determine Process & Measurement Capability

** Assumes data follows a normal distribution*

Precision Ingredient Dosing – Characterizing Example

Initial Validation / Start Up Curve (first 6 months) – Is the process controlled prior to starting

A test case of a real-world example from a batching process in MFI:

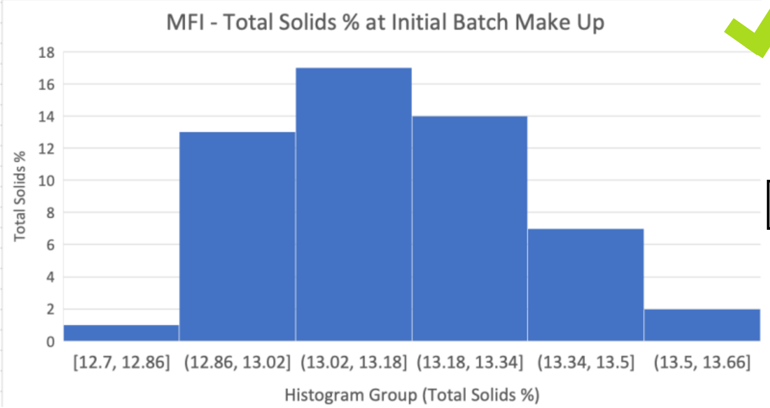
1. Data was collected for initial batch makeups where a consistent amount of water and raw ingredients were added to each chocolate batch. This was plotted to the histogram shown below.
2. The data was tested for normality using the Shapiro-Wilk test. The result is considered to follow a normal distribution if the p-value is greater than 0.05
3. The process capability was determined to be below the threshold of 1.33, indicating the process can not consistently meet the product specifications

Interpreting results: Any process with a Cpk < 1 is predicted to have some batches which do not meet specification. Targeted process improvement efforts are needed to increase the Cpk to ensure most batches are made correctly the first time. Sources of these issues could be process, measurement equipment, people / training, or raw ingredient variability.

Tools

- **Fishbone diagram**
- **Root cause analysis**

Collect Data & Plot Histogram — **Test Normality** — **Determine Process Capability**




```
import scipy.stats as stats

# Data set provided by the user
data = [
    12.7, 12.9, 12.92, 12.93, 12.93, 12.94, 12.97, 12.97, 12.97, 12.99,
    12.99, 12.99, 13.01, 13.02, 13.03, 13.06, 13.09, 13.09, 13.1, 13.1,
    13.11, 13.12, 13.13, 13.13, 13.14, 13.15, 13.15, 13.15, 13.15, 13.17,
    13.17, 13.19, 13.2, 13.21, 13.22, 13.23, 13.26, 13.26, 13.27, 13.27,
    13.28, 13.28, 13.29, 13.32, 13.32, 13.35, 13.35, 13.35, 13.35, 13.38,
    13.39, 13.44, 13.56, 13.57
]

# Perform Shapiro-Wilk test
shapiro_test = stats.shapiro(data)

# Extract test statistic and p-value
shapiro_test.statistic, shapiro_test.pvalue
```

Result

```
(0.9854572415351868, 0.7528645992279053)
```

USL = 12.85

LSL = 12.45

Mean = 13.16

Std Dev = 0.17

Cp = $\frac{12.85-12.45}{6*.17}$ = 0.39

Cpk = $min\left(\frac{12.85-13.16}{3*0.17}, \frac{13.16-12.45}{3*0.17}\right)$ = 0.60

Result: Cp, Cpk are less than target (1.33) indicating poor process control

Optimized Mixing & Homogenization – Overview

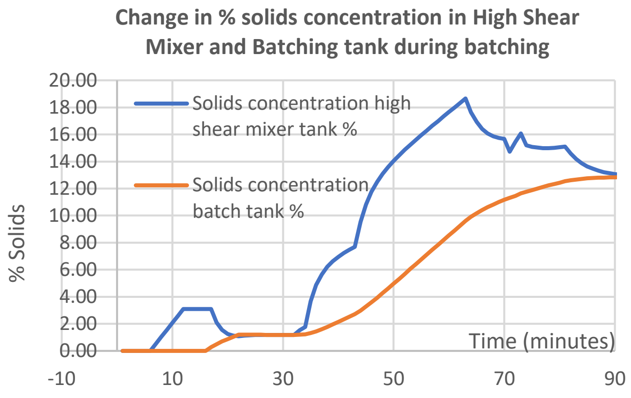
Louise – update

Detailed Overview

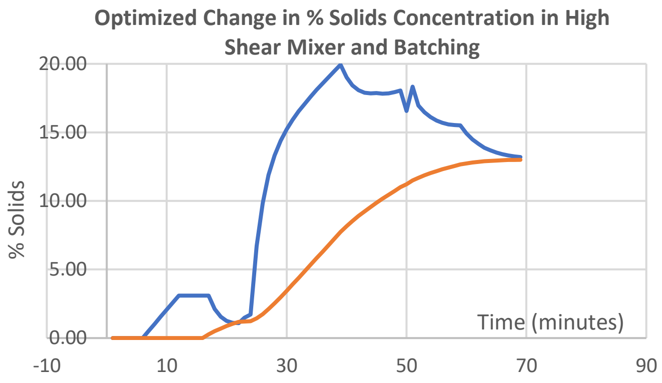
Mixing effectiveness for protein shakes is critical to ensure product quality and should be optimized to ensure it takes the minimum required time maximizing capacity. Proteins, carbohydrates and fats are mixed under high shear to prevent clumping, while stabilizers and emulsifiers are added to maintain suspension and texture.

The pH is adjusted to optimize protein stability and prevent precipitation. Ensuring that batching capacity matches or exceeds the downstream processing performance is critical to preventing bottlenecks and costly line shutdowns.

Establish Performance Requirement → **Measure Performance** → **Identify Opportunities** ⟳ **Implement Actions** → **Monitor Process**



Compressed cycle 20min saving



Developed Content

- **Batch Time Study Template:** A template to record batching time as a basis for process improvement, breaking down batch time into critical process steps.
- **Solids / Liquids Accuracy Calculator:** A calculator to determine the allowable variability in the solids and liquid addition given real-world operating parameters to meet the production specification.
- **Recirculation Loop Solids Calculator:** Calculates the solids percentage in the recirculation loop between the batching tank and high shear mixer for a given flow rate. (Figures above)

Implementation Strategy

- Model the solids content throughout the batching process with the recirculation loop calculator to identify the optimal solids addition rate.
- Apply model to batching at the maximum rate/minimum time for the appropriate scale of process to applicable co-mans.
- For each step in the process, verify solids addition rate in the high shear mixer does not exceed the maximum of 20%.
- Perform validation testing of model through line trials.

Common Challenges

- Co-mans may be reluctant to share details of best-in-class batching process. This will require negotiation, building on trust.
- Identify differences between high shear mixers, pump types and powder addition methods that can impact the rate of mixing. This can be mitigated through trials.
- Limited time and resources to validate optimized mixing processes without interfering with product quality or interrupting production schedule.

How the modeling sheet works -

Precision Ingredient Dosing – Factory Equipment

John - update

Description

- x

Theory

- x

Achieving Best-in-Class

- x

Co-man site	Batch Size (gal)	Equipment	Known Batch Times
MFI	4,000	All mix (Tetra)	• Vanilla: 105 min (38 gal / min) • Chocolate: 125 min (32 gal / min)
SunOpta	4,000	All mix (Tetra)	• Vanilla: 180 min (22 gal / min) • Chocolate: TBC
Stremicks (SA)	2,750	Breddo Liquefier	• Vanilla Base: 40 min (68 gal / min) • Chocolate Base: 65 min (42 gal / min)
Stremicks (RS)	3,500	Breddo Liquefier	• Vanilla Base: 45 min (78 gal / min) • Chocolate Base: 65 min (54 gal / min)
Niagara	10,000	All mix (Tetra)	• No data
Gehl	14,400	Breddo Liquefier	• Vanilla Base: 242 min (60 gal / min)
Saputo	4,000	All mix (Tetra)	• Vanilla Base: 90 min (44 gal / min)

Bar Chart w Batching Speed (Vanilla / Chocolate) for each co-man make up? What would be the impact to other? how co-mans with an optimized process?

Optimized Mixing & Homogenization – Modeling

Description

- Mathematical modeling allows the batching process to be, adjusted and optimized prior to any confirmatory trials. This saves money in trials and allows trials to be directed within controlled parameters such as max % solids.

Theory

- Using tank volumes, the flow rates and solid addition rates can flow rates can be varied in silico.
- The impact on solids concentration within the high shear mixer (HSM) and batch tank can be assessed to ensure the solids never exceeds a specified maximum of 20%.
- The overall process time can be reduced within defined limits without the requirement to run consecutive trials, with incurred costs.
- Trials can then be performed using the modeled optimized parameters to confirm reduced timings and product quality.

Achieving Best-in-Class

- A reduction in the batching time (not including transfers) has been predicted of 22 minutes, a time saving of nearly 30%.
- Max solids within the high shear mixer remains below the target threshold of 20% for the duration of the batching process.
- Validation trials to confirm findings to be booked, following which implementation of the faster 55-minute batching time is anticipated.
- This modeling can be applied directly to any equivalent Tetra Pak batching process across the co-man network.
- With some minor modifications this could be applied to any batching system.
- Once batch time has been consistently reduced to 55 minutes, there is an opportunity to continue investigating further reductions in batching time.

Table 1: Comparison of original and modelled batching process

Ingredient	Original duration (Min)	Original addition rate (Kg/min)	Proposed duration (Min)	Proposed addition rate (Kg/min)
Water added to HSM	5	N/A	5	N/A
Gums	5	7.5	5	7.5
Gum hydration	5	N/A	5	N/A
Chocolate addition and mixing	16	N/A	6	N/A
Caseinate bags addition	9	31.8	6	47.6
Super sack protein addition	20	60	15	80
Protein bag addition	7	25.3	4	44.3
Oil addition	2	39.3	1	78.5
Sucralose addition	1	1.8	1	1.8
Minors addition	7	16.3	7	6.3
Total	**77**	**N/A**	**55**	**N/A**

Optimized Mixing & Homogenization – Homogenization Process

Description

- Homogenization is a critical process that removes under-hydrated powder lumps to ensure product safety and quality.
- Homogenizer performance is a CCP (Critical Control Point) because semi / non-hydrated powders have lower thermal conductivity than fully wetted powders and liquids, potentially preventing proper sterilization temperatures and risking contamination.
- Product attributes and the consumer experience can also be impacted by inadequate homogenization as solid particles (as small as 30-50µm) can be detectable in the mouth as a gritty texture.

Theory

- Tetra Pak homogenizers uses shear to break up aggregates by forcing liquid through a 50-100µm gap under high pressure.
- The liquid path contains multiple edges to maximize shear in a narrow annulus from the front (Figure 1).
- Gap dimensions directly impact shear forces and particle size reduction capability.
- Wear on homogenizer components increases gap width over time, reducing the shear effectiveness.
- Mixing parameters prior to homogenization (shear rate, residence time, temperature, pH) determine initial aggregate formation.

Achieving Best-in-Class

- Limit maximum particle size, <30-50µm for both sterilization effectiveness and mouth feel.
- Maintain high tolerances (≤±10µm) for critical dimensions (e.g., anulus gap width).
- Use wear-resistant materials (e.g., hardened metals) for high-wear components (e.g., annulus gap width)
- Implement regular and defined maintenance schedule to ensure homogenizer functions within specification.
- Control upstream factors to minimize aggregate formation:
    - Establish optimum pH before protein addition to prevent localized changes in protein morphology.
    - Control mixing parameters (shear rate, residence time, temperature) for uniform dispersion.
    - Avoid excessively rapid powder addition and insufficient residence time to prevent ‘fish eyes’.
- Validate target particle size achievement for each batch to confirm aseptic processing requirements.

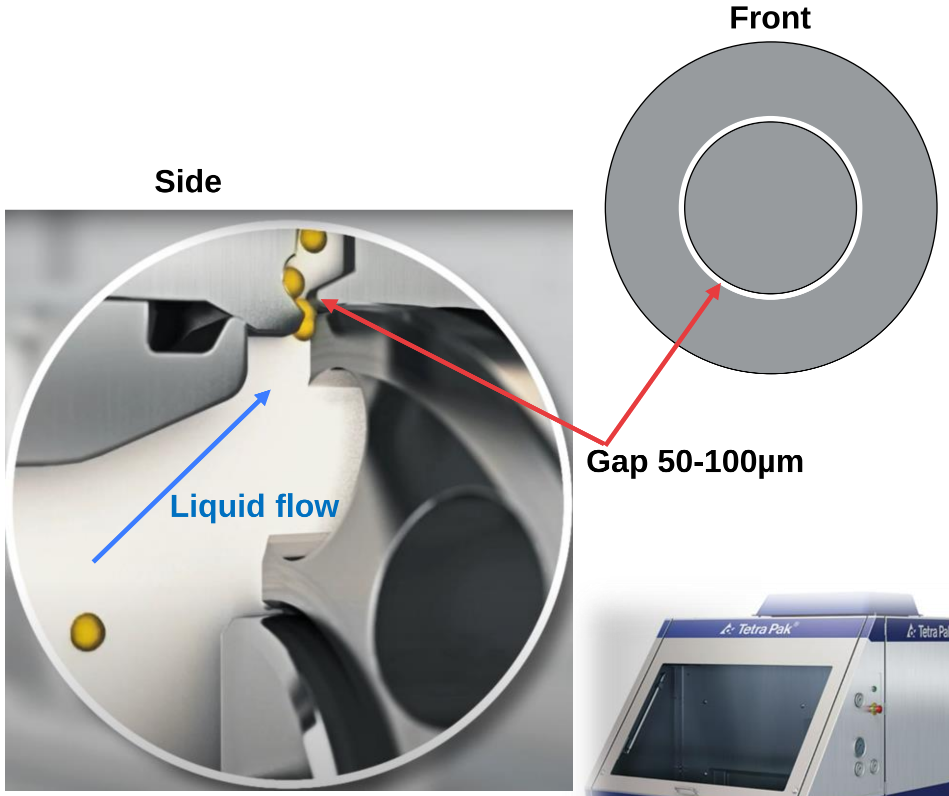


Figure 1: Theory of operation of internal homogenizer components

Figure 2: Tetra Pak Homogenizer

Optimized Mixing & Homogenization – Process Monitoring

Description

- Effective monitoring of critical process parameters ensures consistent product quality and enables early detection of process deviations before they impact final product attributes.
- Visual and automated monitoring systems provide operators with real-time feedback to maintain optimal mixing and homogenization conditions.

Theory

- Overall batch time directly impacts production capacity:
  - Critical steps like gum hydration require precise timing for proper functionality.
  - Manual addition rates must be regulated to maintain optimum mixing conditions.
- Liquid temperature relationships affect multiple quality attributes:
  - Higher temperatures increase solubility and hydration rates during batch preparation.
  - Reduced temperatures in surge tanks extend holding time before microbial issues arise.
- Mixing rate control determines final product uniformity:
  - Solids addition rate relative to residence time affects dispersion quality.
  - Real-time adjustment capability ensures optimum mixing for both solids content and average mixing time.

Achieving Best-in-Class

- Monitor overall batch time:
  - Use a visual timer system visible to operators during batch preparation (See Figure 1).
  - Track batch preparations against target times to ensure mixing meets capacity requirements.
  - Regulate manual addition rates (e.g., 4 bags per minute) to maintain optimum conditions.
- Control liquid temperatures prior to sterilization:
  - Monitor water additions and in-tank temperatures throughout batch preparation.
  - Establish temperature set-points with appropriate alarms for out-of-specification conditions.
  - Track temperature trends to identify equipment performance issues.
- Implement automated mixing rate control:
  - Synchronize HMI and PLC systems with regulated powder addition equipment (Figure 2)
  - Use vacuum conveyor or auger/LIW (loss in weight) systems for precision.
  - Capture batch-to-batch data for statistical process control and continuous improvement.

Figure 1: Visual timer

Figure 2: HMI as part of Digital monitoring / "Digital Twin"

Optimized Mixing & Homogenization – Process Monitoring Example (MFI)

Placeholder – Collect Data at MFI for Waste Analysis

John

Batching System Designed for Process Throughput – Overview

nutrition
THE GOOD ENERGY PEOPLE

Detailed Overview

An optimized batching system is the foundation of efficient production operations, directly impacting capacity, quality, and flexibility. Strategic engineering of tank configurations, water systems, and process controls enables consistent product delivery while maximizing equipment utilization and minimizing cycle times.

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Developed Content

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Implementation Strate

Update

- Scale batch tanks appropriately for production line requirements with optimized geometry for efficient mixing and CIP operations
- Design water addition and heating systems to achieve rapid temperature targets while maintaining precision control
- Implement variable-speed recirculation loops to balance residence time, prevent aggregation, and minimize equilibrium time
- Validate system performance through statistical time studies and sensitivity analysis to identify and eliminate potential bottlenecks

Common Challenges

- Temperature fluctuations affect water heating rates and powder hydration kinetics
- Different recipes/products require varying mixing parameters and residence times
- Systems optimized at pilot scale may encounter unforeseen challenges at production scale
- Balancing production time with adequate cleaning cycles without compromising either
- Implementing appropriate instrumentation to verify critical parameters in real-time for process monitoring

Batching System Designed for Process Throughput – Critical Factors

Description

- Strategic design of batching systems maximizes production efficiency through optimized tank configuration, water systems and process flexibility.
- Properly sized batch tanks, optimized water addition/heating/recirculation rates, efficient CIP systems, and validated process design collectively minimize cycle times, prevent production bottlenecks, and ensure consistent product quality.

Theory

- Four critical parameters determine overall batching efficiency and throughput capacity:
  - **Water addition rate:** Controlled by water source (volume) and pressure, pump rate, and transfer pipe dimensions to high shear mixer (HSM) and batching tank (BT).
  - **Water heating rate:** Determined by heat exchanger capacity (surface area, plate packs) and ΔT across the exchanger.
  - **Recirculation rate:** Governs residence time and solids content equilibrium between high shear mixer (HSM) and batching tank (BT).
  - **Solids addition rate:** Limited by vacuum transfer system capacity and proper hopper level management.

Achieving Best-in-Class

- Optimize solids addition rate through proper method selection:
  - Vacuum Transfer: Balance valve actuation timing and vacuum pressure with mixing capacity and recirculation rate.
  - Manual Addition: Use visual checks of liquid level, viscosity, and unwetted powder with standard addition rates (e.g., 4 bags per minute, equivalent to 80Kg/min).
- Monitor solids concentration changes during batching (Figure 1) to identify process improvement opportunities.
- Balance recirculation rates against equilibrium time requirements to achieve optimal throughput (Table 1).

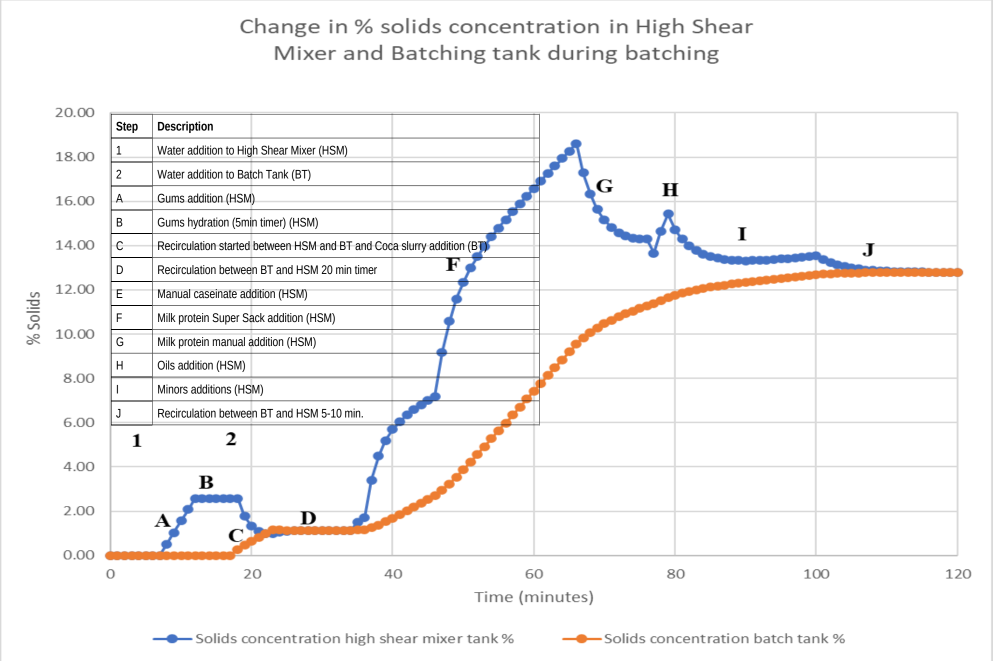

Figure 1: *Change in solids within High Shear Mixer and Batching tank during mixing at MFI*

Table 1: Impact of recirculation rate on equilibrium time between mixer and batching tank

Recirculation Rate (l/min)	Max Solids in high shear mixer (%)	Mean residence time in high shear mixer (min)	Time to equilibrate to within 5% solids from end of bulk powder addition (min)
200	39.8	6.6	37
300	31.2	4.4	22
400	26.2	3.3	15
600	21.1	2.2	9
800	18.6	1.65	6
1000	17.6	1.32	4

John

Batching System Designed for Process Throughput – Analysis

Simulation Model

- **Calculating Batch Time Requirements**
- **Factory Design Theory**

Description	Value	U
Downstream Equipment		
Filler Capacity	9,000.00	Carto
# Fillers	4	Each
OEE	39%	
Total Throughput	13,978.80	Cartons (hr)
Total Throughput	1,200.16	Gallons (hr)
Total Throughput	20.00	Gallons (min)
Batching Process		
Batching Time	200.0	min
Batch Tank Capacity	4000	gal
Batch Throughput	20	gal / min
Surplus / Shortage		
Batch Production	(0.00)	gal / min

Description	Value	Units
Downstream Equipment		
Filler Capacity	9,000.00	Cartons (hr)
# Fillers	4	Each
OEE	65%	
Total Throughput	23,392.80	Cartons (hr)
Total Throughput	2,008.41	Gallons (hr)
Total Throughput	33.47	Gallons (min)
Batching Process		
Batching Time	119.5	min
Batch Tank Capacity	4000	gal
Batch Throughput	33.4728033	gal / min
Surplus / Shortage		
Batch Production	(0.00)	gal / min

Batching System Designed for Process Throughput – Real World Example

Measure

- **Time Studies**
  - Conduct time studies to establish baseline performance.
  - Perform studies across **all shifts** to capture variability.
  - Determine the **optimal number of studies** needed for statistical significance (e.g. minimum of 5 studies per shift).
- **Key Metrics to Capture**
  - Cycle time per batch with the process broke down into sufficiently small sections **(see time study collection form)**
  - Downtime occurrences and causes
  - Variability in batch times across shifts

Analyze

- **Data Interpretation**
  - Compare actual cycle times against expected targets and evaluate using a sensitivity analysis comparing filler OEE to batch time to understand tipping points where constraints occur (see Figure 1) **(see sensitivity analysis calculator)**
  - Identify variations between shifts, operators, and equipment conditions.
  - The batching process **should not be a constraint that starves downstream equipment** – this analysis should be completed prior to deeming a batching process ready for long-term production
- **Waterfall Diagram for Process Improvement**
  - Use a waterfall diagram to visualize time allocation and process improvement opportunities (see Figure 2)
  - Identify improvement opportunities to reduce non-value-added time and align with targets (i.e. process time for a given filler OEE %)

Monitor

- Real-time monitoring of batch parameters to ensure it meets specifications.
- Deviations trigger automated alerts, allowing operators to take corrective action before quality is compromised.

		Batch Shortage / Surplus Capacity (gal / min)					
		Batch Time (Min)					
	(0.00)	100	120	140	160	180	200
Filler OEE	40%	19.4	12.7	8.0	4.4	1.6	-0.6
	45%	16.8	10.2	5.4	1.8	-1.0	-3.2
	50%	14.2	7.6	2.8	-0.8	-3.5	-5.8
	55%	11.7	5.0	0.2	-3.3	-6.1	-8.3
	60%	9.1	2.4	-2.3	-5.9	-8.7	-10.9
	65%	6.5	-0.2	-4.9	-8.5	-11.3	-13.5
	70%	3.9	-2.7	-7.5	-11.1	-13.8	-16.1
	75%	1.4	-5.3	-10.1	-13.6	-16.4	-18.6

Figure 1: Sensitivity analysis of batching speed (min) to filler OEE

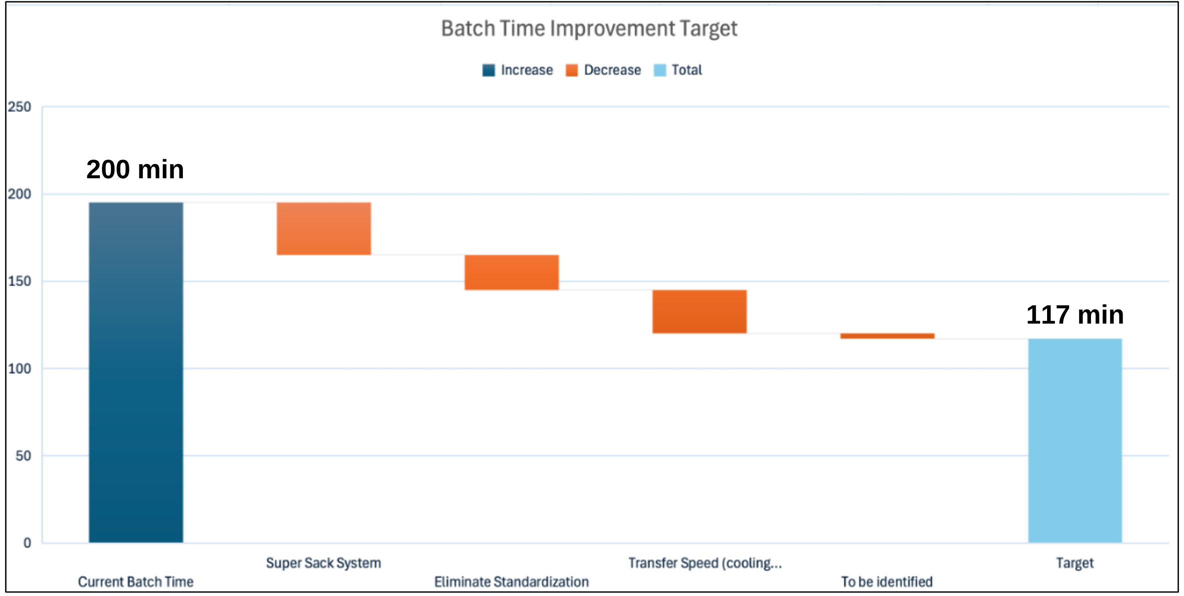

Figure 2: Waterfall diagram of batching process improvement opportunities

Minimize Variation – Overview

Detailed Overview

Standardizing a batch to control for **total solids** and **pH** is intended to ensure consistency in product quality. Once the batch is prepared, **lab testing** is conducted to measure total solids and pH, ensuring they fall within specified tolerances (Table 1). If deviations occur, **adjustments** are made by adding water (for solids), or KOH (for pH) to bring the batch within target specifications before release to production. In a **best-in-class scenario**, process improvements—such as tighter ingredient control, precise mixing and automation can reduce variability to the point where batch adjustments are no longer required, streamlining operations and increasing efficiency.

Batch Make Up → **Collect Batch Sample** → **Measure Total Solids and pH** ⟲ **Adjust Solids and pH** → **Release Batch to Downstream Processing**

Table 1: Example core flavors specifications controlled during the standardization process

Flavor	Total Solids *Post Standardization (%)	Total Solids Final Specification (%)	pH Specification
Caramel	12.22 – 12.62	12.12 – 12.52	6.80 – 7.00
Café Latte	12.43 – 12.83	12.33 – 12.73	6.80 – 7.00
Chocolate	12.55 – 12.95	12.45 – 12.85	6.80 – 7.00
Vanilla	12.10 – 12.50	12.00 – 12.40	6.80 – 7.00

*Note: *Solids post standardization will typically be made 0.1% higher than the final specification to allow for the dilution effect of the water that will be used to transfer the product to the surge tank, 'water push'.*

Developed Content

- **Standardization Calculator:** A calculator to identify the correct amount of water and KOH additions to construct a batch within the specification on the first attempt.
- **Gauge R&R Protocol:** An approach to evaluate measurement system capability. It includes selecting operators, parts, and repetitions, defining measurement criteria, and establishing acceptance thresholds.
- **Root Causes Analysis:**

Implementation Strategy

Data Collection

- Using the proformas' developed by PA, historic batch KOH and water additions have been provided by two participating Co-mans.

Data Analysis

- Statistically compare the data to identify KOH and water additions to ascertain:
  - Variation in initial batch values for solids and pH.
  - The impact of subsequent water addition on solids.
  - Establish the impact of the variation observed in solids& pH on a line run without a standardization step.

Root Cause Analysis

- Identify scale and sources of variation post batching.
- Identify variation in and rational for additions made as part of Standardization.
- Establish impact of the measurement technique on results.

Common Challenges

- It is important co-mans share as much standardization data as possible. The more data they share the better the statistical calculations will be.
- Validating the adjusted batching method through trials at each co-man will reduce any risk. A step-by-step approach could be taken where the solids and pH are assessed to see if they align with the calculated values.

John

Update

Minimize Variation – Empirical adjustment of Solids and pH

Description

- Precise, data-driven adjustment of solids and pH is essential for consistent product quality across different flavors and batch sizes.
- By applying statistical analysis to historical processing data, manufacturers can develop accurate prediction models to optimize standardization procedures.

Theory

- Standardization adjustments for solids and pH must be based on empirical data specific to the flavor and scale of the batching process
- Linear regression analysis of historical standardization data demonstrates predictable relationships between water/KOH addition and resulting solids/pH changes
- The regression line passes through the origin since adding zero water or KOH will have no impact on solids and pH respectively
- The equation for the best fit line can be expressed as:

$$\mathbf{y}_{\text{(change in solids)}} = \mathbf{m}_{\text{(gradient)}} + \mathbf{x}_{\text{(water addition)}}$$

  - This can be rearranged to calculate required water addition:

  Volume of water to be added = ((Target % Solids - %Solids after batching) / gradient) – volume of water push

- For pH adjustment where water push has no impact:

Volume of KOH to be added = (Target pH - pH after batching) / gradient)

Achieving Best-in-Class

- Develop flavor-specific standardization models (Table 1) with separate regressions for:
  - Solids adjustment (data points, gradient, fit of line)
  - pH adjustment (data points, gradient, fit of line)
- Ensure data accuracy by:
  - Excluding outlier data points (<500lbs and >2,000lbs batches)
  - Excluding standardizations where pH was used to adjust for

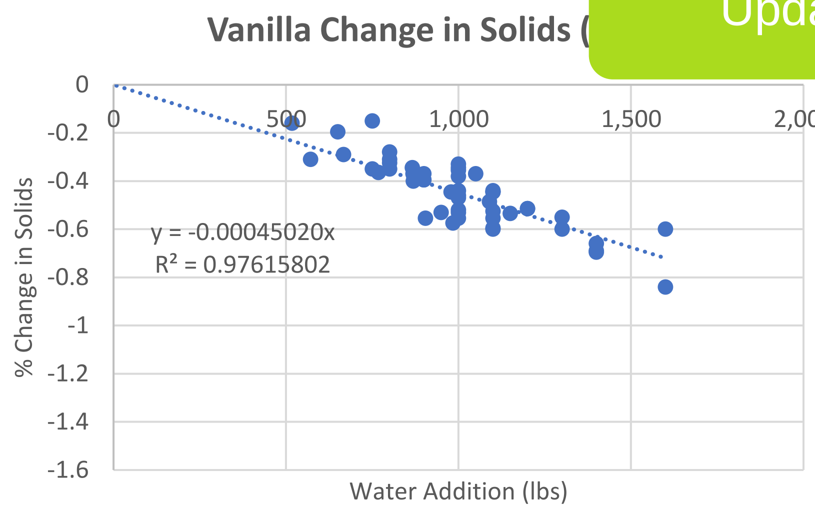

Figure 1: Batching data for Vanilla with best fit linear regression through the origin

Table 1: Comparison of solids & pH standardization best fit lines for four flavors from MFI

Flavour	Solids			pH		
	Data points	Gradient 'm'	Fit of line (R^2) (1.0 = perfect)	Data points	Gradient 'm'	Fit of line (R^2) (1.0 = perfect)
Caramel	62	-0.00044236	0.984	68	0.01075690	0.986
45	49	-0.00045020	0.976	84	0.01138701	0.984
Café Latte	32	-0.00046554	0.977	47	0.01028010	0.978
Chocolate	29	-0.00044080	0.961	52	0.01072679	0.983

Minimize Variation – pH Variability Example (MFI)

Observations

- We observe a very predictable change in pH depending upon the amount of KOH added (Figure 1)
    - ±3σ variation (99.7% of product) for Caramel is only 0.012 pH units (0.002 x 6) which is significantly smaller than the difference between the highest and lowest values for the specified pH range of 6.80-7.00 = 0.20 pH units.
- Sufficient variation exists in the initial pH measured post batching and prior to standardizing Caramel, Chocolate and Vanilla, that standardization elimination would not currently be possible without identifying what portion of the variability is due to measurement. (Table 1)
    - ±3σ variation (99.7% of product) for Vanilla is 0.38 pH units (0.062 x 6) which is greater than the difference between the highest and lowest values for the specified pH range of 6.80-7.00 = 0.20 pH units.
    - ±3σ variation for Café Latte is 0.012 pH units (0.02 x 6), which is sufficiently small to eliminate standardization for this flavor.

Challenges

- Understanding the cause of the initial variation in pH measured post batching and minimize this.
- A Gauge R&R study performed on pH measurement will allow us to identify the sources of variation in pH measurement.
- Once we have identified the proportion of the variation (for each site) that originates from pH measurement, it is possible that the process will be under sufficient control with respect to pH that we could eliminate pH standardization.

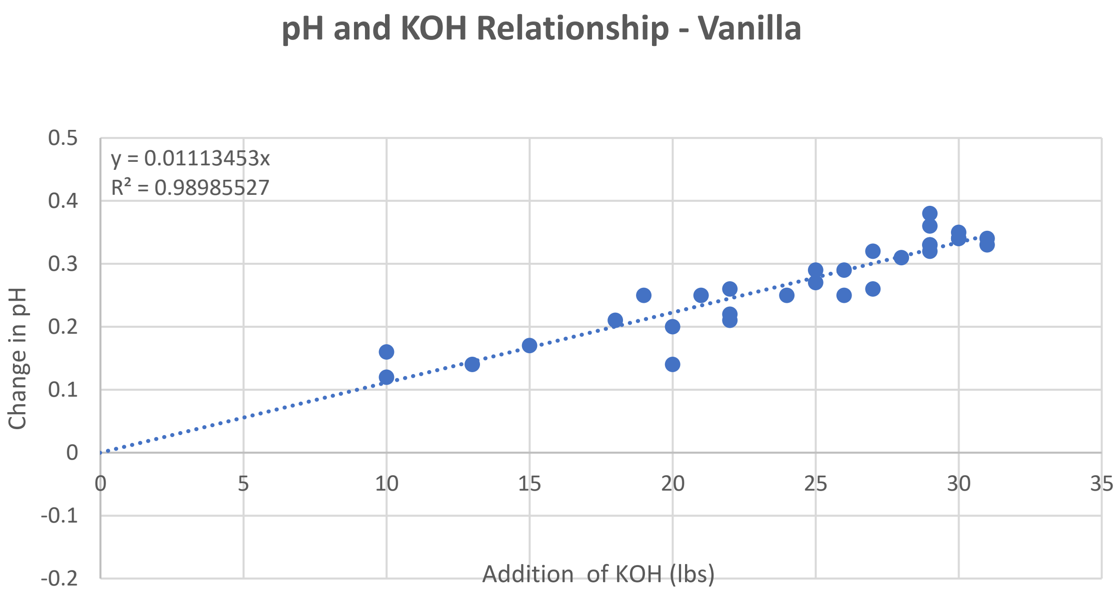

Figure 1: pH adjustment of Vanilla recipe using KOH

Table 1: Process variability in pH and accuracy of pH adjustment which equates to measurement accuracy.

Recipe	Average pH (pre adjustment)	St Dev (pH units after batching)	Average pH (post adjustment)	St Dev (pH units per lb KOH added)
Caramel	6.65	0.033	6.90	0.002
Vanilla	6.65	0.062	6.92	0.001
Café Latte	6.65	0.016	6.88	0.002
Chocolate	6.74	0.039	6.91	0.002

Minimize Variation – Solids Variability Example (MFI)

Problem Statement

- Significant variation exists in initial total solids measurement prior to standardizing a batch (Figure 1).
- The width of the distribution is wider than process upper and lower control limits

Findings from Study

- 3σ variation is 0.52% of total solids (Vanilla) which is greater than the range of the specification (0.4%).
- It is expected this initial range would be quite tight (given the same solids and liquids should be added every time).
- When attempting to standardize a batch it appears smaller water additions, 500lbs or less, **show a significantly higher variation of effect on total solids** (Figure 2). This could be attributed to:
    - Process controls when adding water.
    - Water flow equipment are not precise enough for the process requirements.

Problem Statement

- Process **variability exceeds the total allowable range for TS acceptance criteria** – this will need to be addressed to remove the standardization process with confidence.

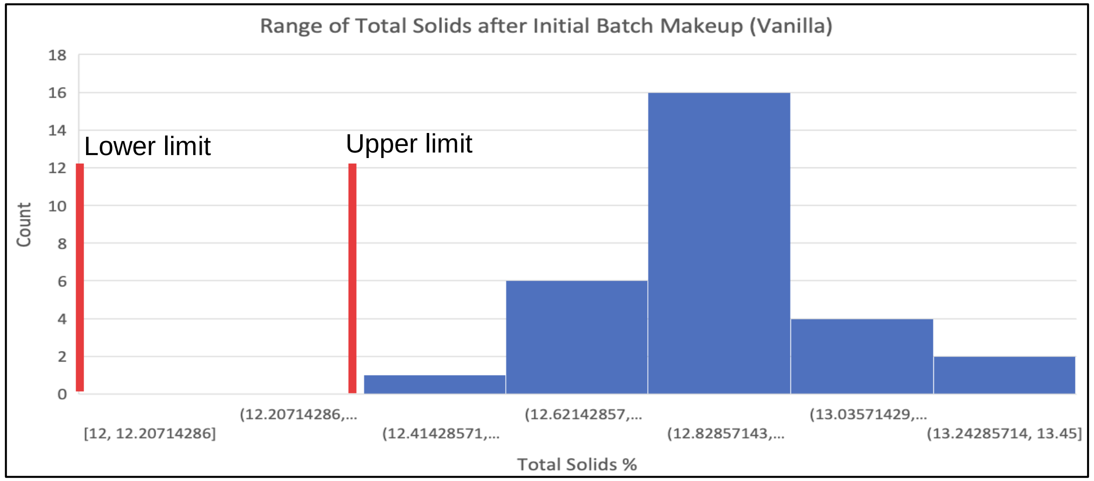

Figure 1: Total solids after initial batch makeup

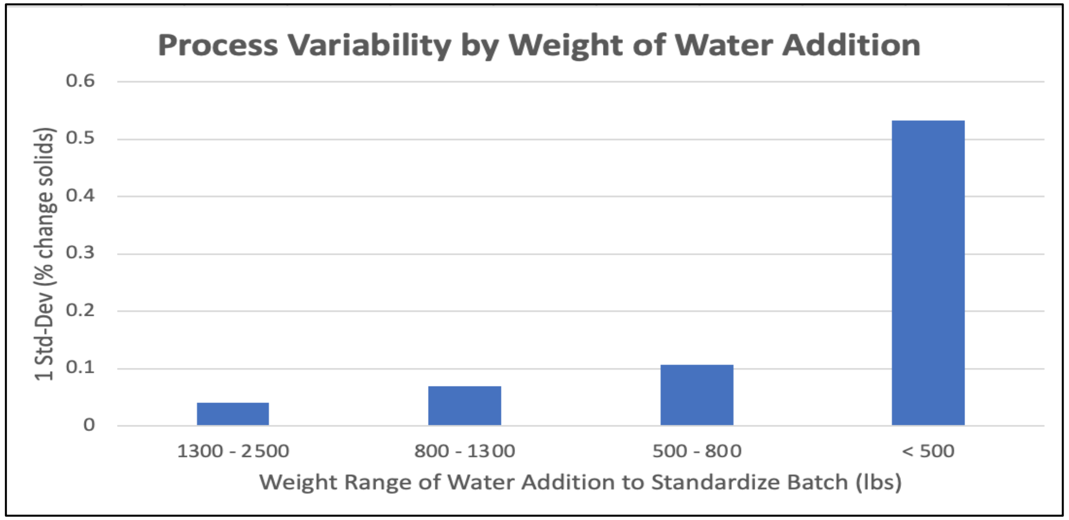

Figure 2: Process variability associated with total solids relative to the total water added during standardization

John Review

Minimized Variation - Gauge R&R (Repeatability & Reproducibility)

Description

- Gauge R&R (Repeatability and Reproducibility) studies quantify measurement system variability to determine if equipment can reliably detect true process variation.
- This analysis is critical when monitoring parameters like total solids percentage and pH levels that directly impact product quality, safety, and customer satisfaction.

Theory

- An effective Gauge R&R program distinguishes between actual process variation and measurement system noise
- Measurement systems have two primary variation components:
  - **Repeatability:** Variation when same operator measures same part multiple times (Equipment Variation)
  - **Reproducibility:** Variation between different operators measuring same part (Operator Variation)
- Total measurement system variation should be small relative to process tolerance range
- Measurement reliability is essential for monitoring critical quality parameters

Achieving Best-in-Class

- Implement Gauge R&R studies for key measurement equipment:
  - CEM for Total Solids %
  - pH Probes
- Apply clear acceptance criteria:
  - Total GRR < 10% of tolerance range: Excellent measurement system
  - 10% < GRR < 30% of tolerance range: Acceptable for some applications
  - GRR > 30% of tolerance range: Measurement system requires modification
- Regularly validate measurement systems to ensure:
  - Low-performing systems (GRR > 30%, Figure 1) are identified and improved
  - High-performing systems (GRR < 30%, Figure 2) are maintained
  - Focus remains on addressing true process variability rather than measurement noise

Low Performing Example: Total Gauge R&R > 30%

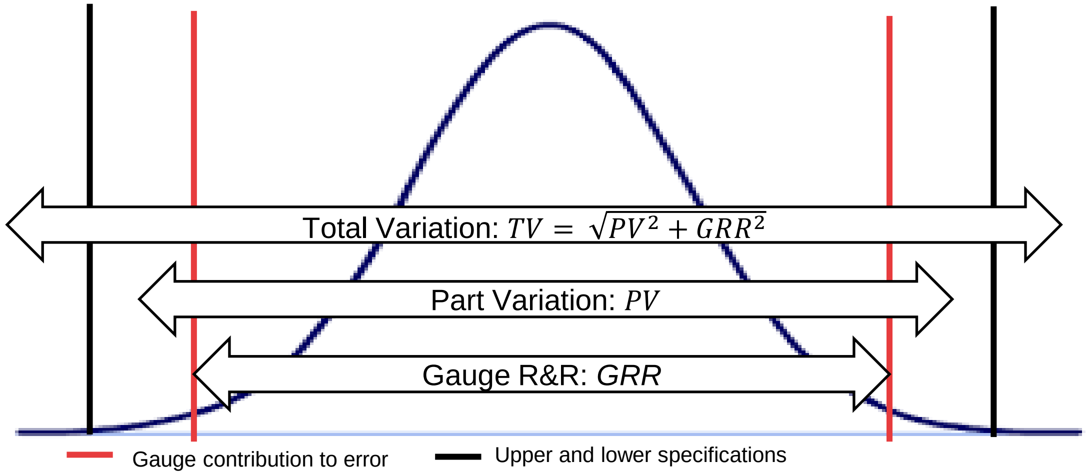

Figure 1: Measurement system analysis components. Note the Gauge R&R (measurement variation, should be a small component of total variation, and relatively small compared to the tolerance range

High Performing Example: Total Gauge R&R < 30%

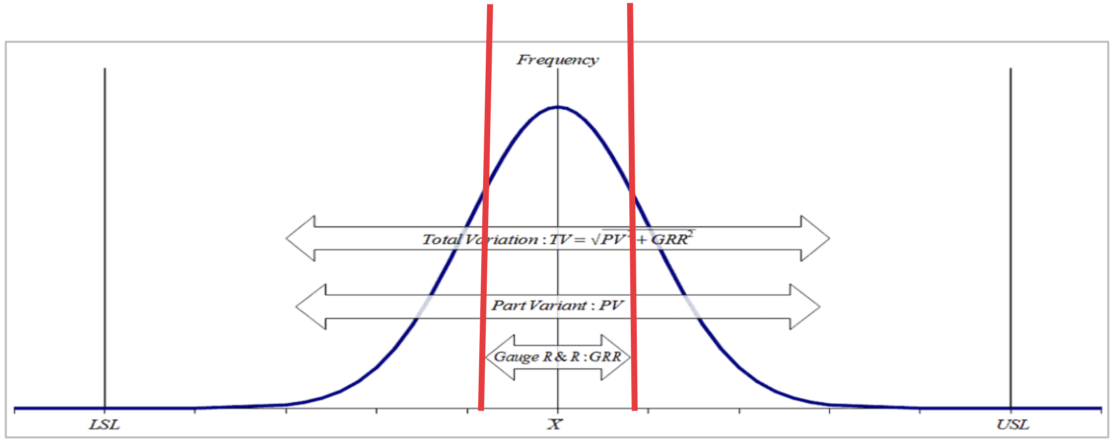

Figure 2: Measurement system analysis components. Note the Gauge R&R (measurement variation, should be a small component of total variation, and relatively small compared to the tolerance range

Minimize Variation – Real world Gauge R&R results of PNC collected total solids data from finished product using the CEM machine

Write Study Protocol

The study protocol (see Gauge R&R protocol) defines the approach to evaluating measurement system capability. It includes selecting operators, parts, and repetitions, defining measurement criteria, and establishing acceptance thresholds.

Collect Data

Data collection (see Gauge R&R Data Collection) follows the protocol, with multiple operators measuring the same set of parts with multiple repetitions. This step should be controlled to minimize external influences, ensuring that observed variation reflects the true performance of the measurement system.

Test Data for Normality

The data must be tested for normality (see Gauge R&R analysis code) using tools such as histograms, probability plots, or statistical tests (e.g., Shapiro-Wilk) (**Figure 1**). This ensures accurate variance decomposition and meaningful statistical conclusions.

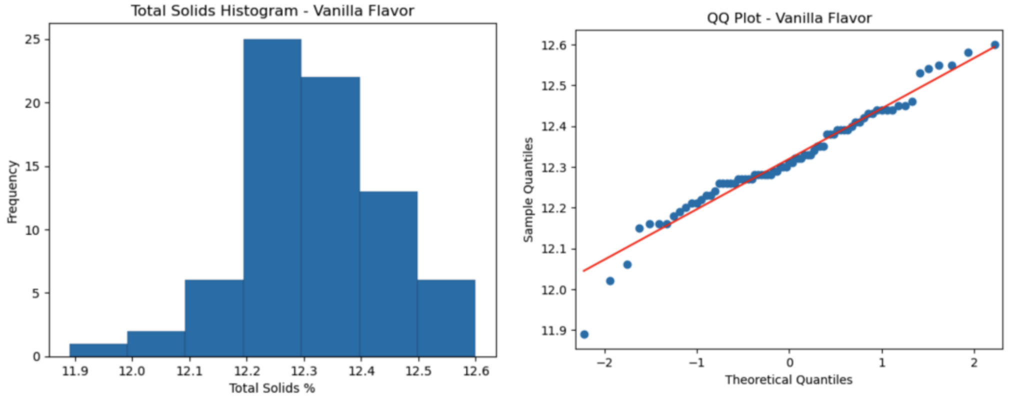

Figure 1: Histogram and QQ plot for total solids measurements – visual inspection gives indication a normal distribution is followed. Further analysis using Shapiro-Wilks method confirms the data follows a normal distribution (p value = .066)

Execute Gauge R&R Study

The analysis quantifies the sources of measurement variation, breaking it down into **repeatability** (equipment variation) and **reproducibility** (operator variation). Using ANOVA (see Gauge R&R analysis code), the study calculates how much of the total variation is attributable to measurement error versus actual part differences.

Sources of Variance	DF	SS	MS	Var	Std	F-value	P-value
Operator	2	0.073	0.037	0.001	0.032	3.230	0.094
Part	4	0.649	0.162	0.01	0.1	14.273	0.001
Operator by Part	8	0.091	0.011	0.001	0.034	2.055	0.055
$\boxed{\text{Measurement}}$	60	0.332	0.006	0.006	$\boxed{0.074}$		
Total	74	1.145	0.015	0.018	0.133		

Table 1: Standard deviation of operator, part, and measurement error. Note the operator variation is non-significant (p-value > 0.05) and it was not included as source of variation in the analysis.

Analyze Results

$$\textbf{Acceptable Result}: \frac{100 * (6 * \sigma_{measurement})}{USL - LSL} < 30\%$$

$$\textbf{Measured Result}: \frac{100 * (6 * 0.074)}{12.40 - 12.00} = 111\%$$

Interpretation: The **measurement error is excessive** (**Table 1**) and corrective actions such as equipment calibration, process improvements, or new measurement systems may be necessary. The study indicates the system can't reliably distinguish between part-to-part variation and improvements are required to reduce measurement uncertainty.

Minimize Variation – Comparison Solids Batching Data (MFI and Saputo)

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Initial Batch Make Up Data Collected from Co-mans

- The following data was collected from two co-mans. Solids post batching, the volume of water added during standardization and the subsequent solids measured post water addition.
- Data sets for Saputo were smaller than for MFI which likely explains the larger standard deviation observed for Vanilla flavor.
- All data has been cleaned to remove atypical batches such as ones used to adjust the solids in combination with a previous batch, or where subsequent water additions were 500lbs or less, or exceed 2,000lbs.
- As part of the analysis the Average Solids and variation (standard deviation, (StdDev)) were calculated.
- The total variation post batching both between flavors and between plants (where larger data sets were available) was remarkably consistent with a StdDev of 0.11% solids.
- **The total variation observed post Batching and prior to Standardization was 0.11%**

Table 1: Comparison between MFI and Saputo of Initial batching % solids before adjustment and the variability observed in those measurements.

Recipe	Number of samples		Average Solids		Solids StdDev	
	MFI	Saputo	MFI	Saputo	MFI	Saputo
Caramel	63	--	12.97	--	**0.11**	--
Vanilla	50	7	12.84	12.90	**0.11**	0.27
Café Late	36	14*	13.17	12.88*	**0.11**	0.10*
Chocolate	30	33	13.26	13.14	**0.11**	**0.11**

** Saputo Café Late data includes samples which has subsequent water additions below 500lbs, due to there being only 5 qualifying data points available.*

Minimize Variation – Impact of Gauge R&R study and batch data analysis

Detailed Overview

- The relative contribution from the process, method and operators to the variation observed from initial batch solids measurements can be identified using information from:
  - Gauge R&R study performed at PNC into the variation in Dry Weight analysis using loss in weight measurement.
  - Batching information provided for 233 separate batches consisting of 4 flavors from two separate Co-mans (MFI and Saputo).

Table 1: Size of variation observed from the Gauge R&R study

Source of Variation	Size of variation
A. The standard deviation observed in solids post batching	0.11%
B. The standard deviation from the loss in weight measurement	0.074%
C. The standard deviation from between operators	0.032%
D. Calculated process standard deviation $\sqrt{A^2 - (B^2 + C^2)}$	0.075%

- From this analysis, majority of the variation in the solids measurement originates from the solids measurement and inter-operator variability (see Figure 1)
- The mass of powder and mass of water combined to form the batches at both the co-mans who have provided data shows almost identical process variation 0.11% STD.
- The act of measuring solids with the intent of subsequently performing Standardization, introduces more variation than the batching process itself.

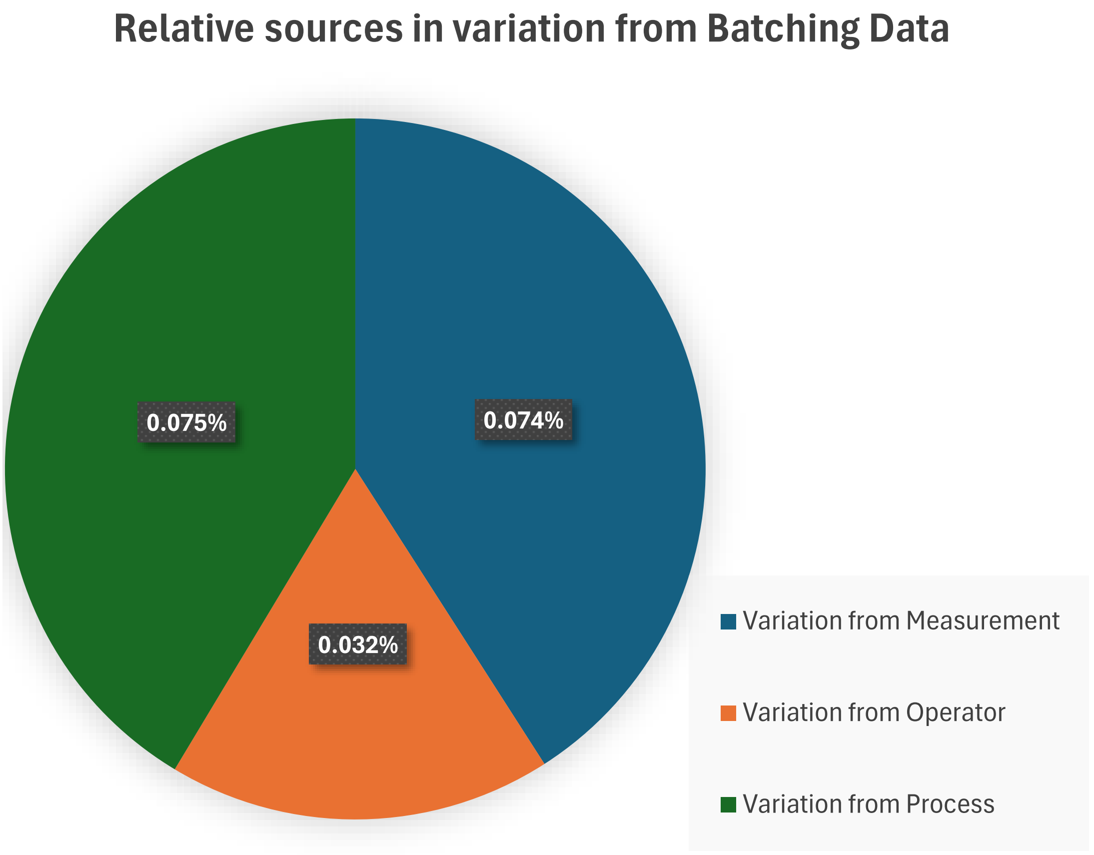


Figure 1: *Distribution of variation observed from the Gauge R&R study*

Minimize Variation – What does the process need to be to eliminate standardization

John - Review

- The standard deviation from the manufacturing process for solids has been calculated to be 0.075% for both MFI and Saputo.
- This data has been used to generates a table (below) showing the variability that would be observed for the 4 core flavours manufacturing without a standardization step with a 99.7% confidence.
- It is intended that some water is withheld (~225lbs) as we are initially targeting a solids content post batching that is 0.1% above target to accommodate the dilution effect of the subsequent water push to the surge tank.

Table 1: Calculation of the variability in solids for a process running without a solid's standardization step

Recipe	%Solids post batching ±3σ 99.7% confidence			Impact to % solids of 'water push' to surge tank. Around 220lbs for Tetra Pak line	%Solids in Surge Tank ±3σ 99.7% confidence		
	Min	Target	Max		Min	Target	Max
Caramel 12.12% - 12.52%	12.20	12.42	12.65	-0.1% to solids	12.10	12.32	12.55
Vanilla 12.00% - 12.40%	12.08	12.30	12.53	-0.1% to solids	11.98	12.20	12.43
Café Latte 12.33% - 12.73%	12.41	12.63	12.86	-0.1% to solids	12.31	12.53	12.76
Chocolate 12.45% - 12.85%	12.52	12.75	12.97	-0.1% to solids	12.42	12.65	12.87

Minimize Variation – Example of a process to eliminate standardization

Ensure all balances and flow meters are of sufficient accuracy and are in calibration

+

Relax solids specification by ±0.05%.

+

Ensure all batch data including masses and calibration (dates and results) are recorded.

+

Quantify and factor in any additional water added after the instruction has been sent to close the valve

+

Verify legal conformity & check for drifts in performance using protein assays at an agreed frequency

Batching Solids – Current Status

- The current level of process variation would result in a very small proportion of products being made outside of the target solids range. Using Vanilla as an example t99.7%, (997 batches in 1,000) would be within the range 11.98% to 12.43% which is slightly wider than the current target range of 12.00% to 12.40%.
- Reducing the variation in solids resulting from manufacturing is desirable, however this may be challenging given that we see two separate manufactures with different levels of experience, manufacturing to an almost identical degree of solids variation.

The following steps would provide the most pragmatic means with minimal capital expenditure to eliminate the need for standardization for solids.

1. Accurate 3 significant figure weighing using calibrated balances of minor solids components on site, with record keeping specific to each batch.
2. Water additions made using a calibrated flow meter accurate to ±0.2% or better.
3. The mass of water added once the water valve has been instructed to close needs to calculated and factored into all water additions.
4. There should be secondary verification of the mass of water added and the total batch weigh using calibrated pressure or load cells on the bulk liquid tanks. These would be expected to agree within the accuracy of these systems with the liquid flow meter reading and solids additions.
5. Increase in the solids range for all recipes by ±0.05%. For example, the solids specification for Vanilla would increase from 12.00% - 12.40% to 11.95% - 12.45%. There needs to be a sufficient difference between the lower end of the solids range and the legal minimum protein level to ensure compliance.
6. Legal and regulatory confirmation that the product is within specification should be provided through documentation of all additions and the calibration records for all balances and flow meters in the same way as pharmaceuticals and medical devices are regulated.
7. Verification of protein levels can be made by PNC at an agreed frequency, however the accuracy of the protein assay used must also be considered.

Filler Operation and Carton Formation

John

Overview

Filler operation and carton formation are some of the most critical and difficult components of the process to manage. The technicians and operators must ensure that product sterility, weight accuracy, and structural formation are maintained with minimized variation. The Tetra Pak A3 Compact Flex filler is a highly sophisticated system requiring precise control and rigorous maintenance to prevent downtime and ensure consistent performance. Tetra Pak Prism 330 cartons must be formed correctly to preserve the sterile barrier and maintain dimensional consistency for downstream processes to function at the highest level. The fillers control the flow of the factory and must be operated with the highest level of precision possible.

Attributes of Best-In-Class

Precision Filling & Weight Control

- High-accuracy filling ensures consistent product weight within tight tolerances to avoid underfills or overfills.
- Inline mass flow meters and load cells monitor fill weight in real time, automatically adjusting for variations.
- Foaming and bloating are controlled through optimized filling parameters and deaeration techniques.

Carton Integrity & Sterile Barrier Assurance

- Strict controls on carton forming, sealing, and cutting ensure the sterile barrier remains intact throughout the process.
- Mechanical checks verify proper sealing, avoiding microleaks that could compromise sterility.
- Dimensional accuracy is monitored, ensuring that cartons meet specifications for fit and function in secondary packaging.

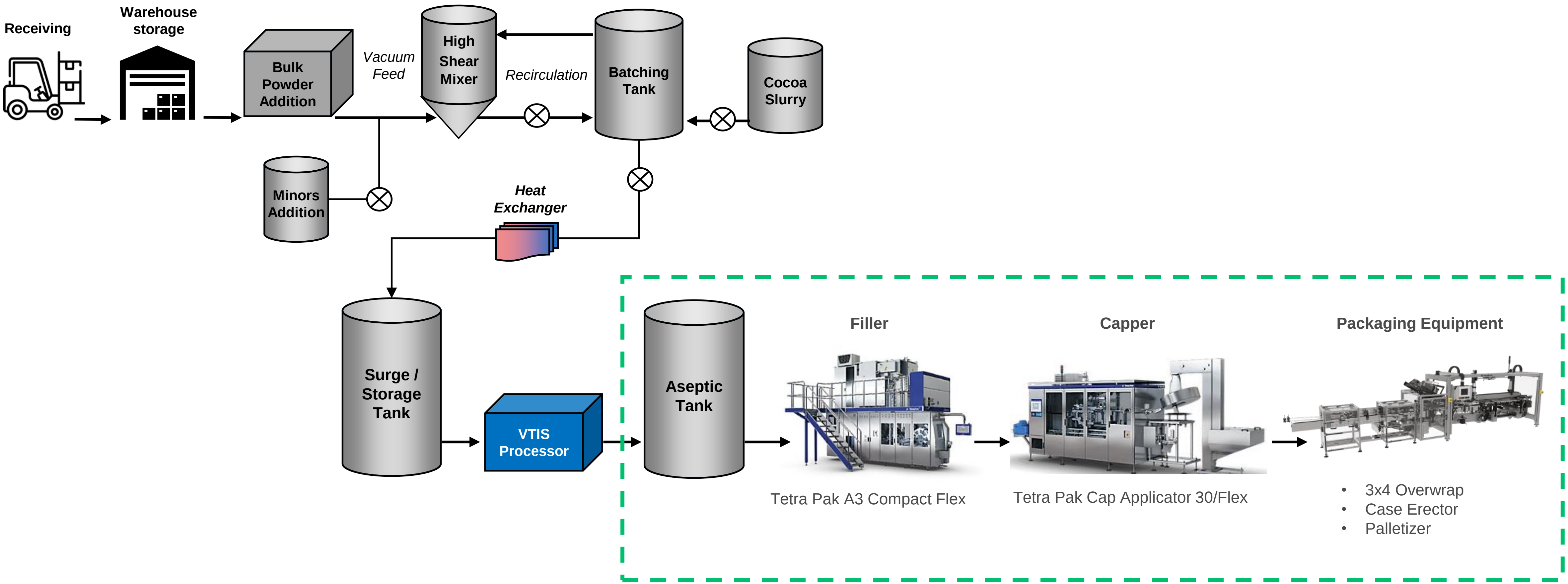
Automated Monitoring & Data-Driven Process Control

- Real-time data collection from the filler and packaging line enables immediate corrective action for process deviations.
- Statistical Process Control (SPC) techniques track weight trends, seal integrity, and carton defects to minimize waste.
- Integration with Manufacturing Execution Systems (MES) supports batch traceability and performance optimization.

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)
				• SPC Overview.pptx

Filler Operation and Carton Formation – Production Areas Targeted for Improvement



John

Precision Filling & Weight Control – Overview

Detailed Overview

x

Build out section after Tetra Pak engagement Mar 11

Implementation Strategy

- x

Common Challenges

- x

Developed Content

- **x**

Precision Filling and Weight Control – Controlling Carton Dimensions

John

Description

- x

Theory

- x

Achieving Best-in-Class

- x

Figure 1: Tetra Pak A3 Compact Flex automated aseptic filler – used to run 330 mL prisma cartons

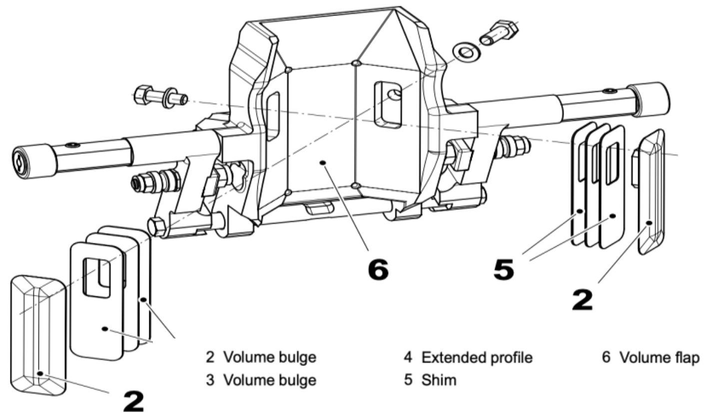


Figure 2: Carton forming jaw for Tetra Pak A3 Compact Flex – shims shown in the figure control the exterior dimensions of the carton and influence process parameters which control weight

Precision Filling and Weight Control – Real World Example

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Investigation Overview

- The two formation jaws within the A3 Compact Flex can produce variable product weights.
- It is critical to setup each formation jaw such that the variation between cartons is reduced as much as possible.
- Excess variation results in excess product giveaway.
- The purpose of this investigation was to understand variability between both jaws (left / right).

Sampling Plan

- 30 samples were selected sequentially from all the operating filler lines at the Saputo facility (**Figure 1**)
- Each sample had the weight recorded, as well as overall dimensions measured

Investigation Findings

- Saputo demonstrates superior jaw-to-jaw weight control versus Gehl
    - Saputo range: 0.2g (Line C) to 1.45g (Line D)
    - Gehl: 2.26g difference between jaws
    - 0.42% potential batch loss if only Line D was operating
    - Line C shows exceptional consistency (0.2g difference) and suggests potential best practices that could be shared across the network

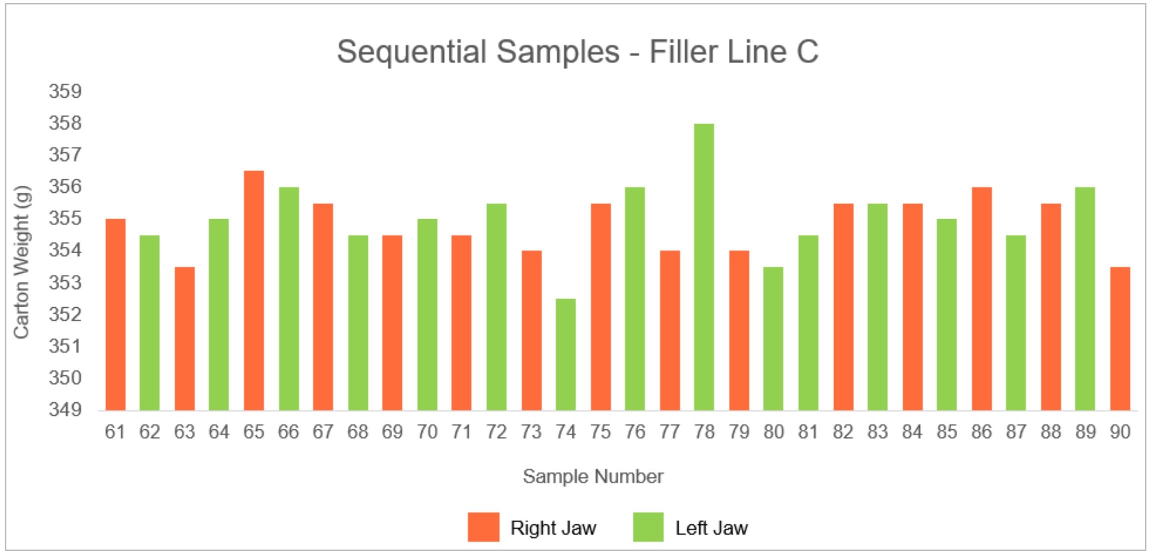


Figure 1: Saputo filler Line C collected weight - sequential groups of 30 cartons

Filler Line	Average Weight of R Jaw (g)	Average Weight of L Jaw (g)	Difference of Average Weights (g)
A	358.10	358.96	0.86
C	354.87	355.07	0.2
D	361.93	363.38	1.45
Gehl	351.21	353.46	2.26

Table 1: Right vs Left jaw fill weight comparison across Saputo filler lines and Gehl fillers

Tetra Pak Aseptic Production Equipment Operating Principals and Optimization

Initial Engagement

Filler Operation (2-3 days)
- Review preventative maintenance best practices
- Understand mechanical mechanisms which lead to pack formation variability
- Overview of sterilization and cleaning processes required to maintain a sterile barrier
- Managing filler shutdowns
- Comprehensive review of operating training requirements / ensuring competency

Capping Equipment (1-2 days)
- Review preventative maintenance best practices
- Troubleshooting leaking caps
- Optimal operating parameters

Simulation (1-2 days)
- Modeling plant layouts and optimizing equipment

Best-In-Class Site Visit

Filler Operation (2-3 days)
- Validate preventative maintenance practices implemented / up to date
- Measure carton formation before and after operating parameters are optimized
- Audit sterility practices by operators, technicians and environment
- Document and implement best filler shutdown principles
- Interview filler operators and test knowledge to best practice

Capping Equipment (1-2 days)
- Validate preventative maintenance practices implemented / up to date
- Measure glue deposition and optimize
- Identify root cause of leaking caps and implement fix

Simulation (1-2 days)
- Build model of site and validate model against actual performance

Monitor Response

Filler Operation (1 day)
- Record factory KPIs before and after site visit
- Brainstorm sources of improvement or stagnating performance

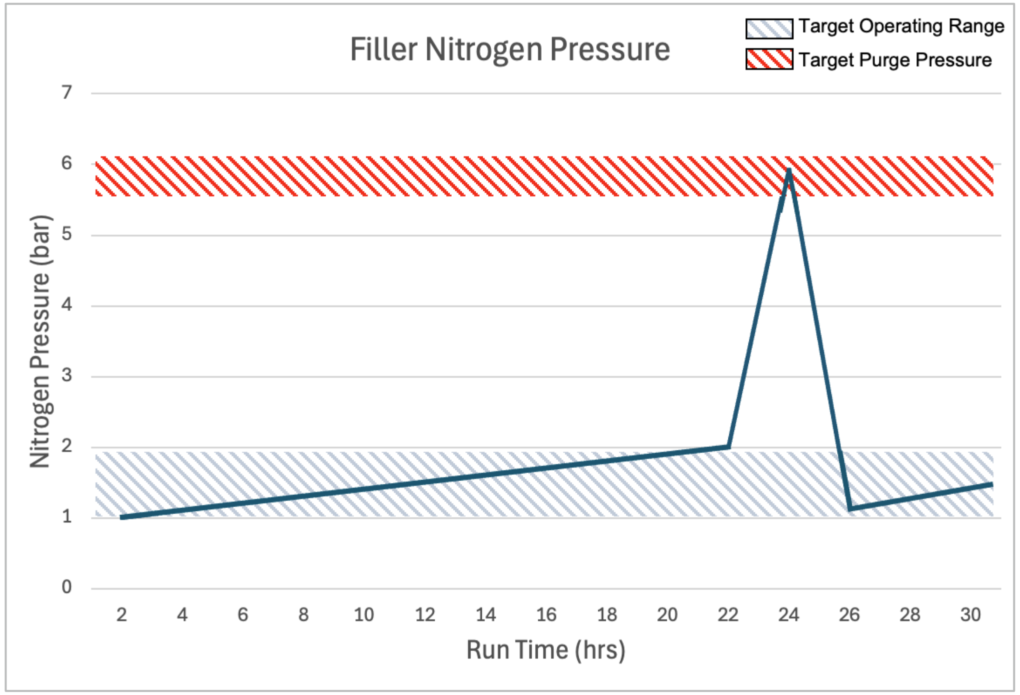
Capping Equipment (1 day)
- Record factory KPIs before and after site visit
- Brainstorm sources of improvement or stagnating performance

Simulation (1 day)
- Troubleshoot gaps from model to real world

Saputo and Jasper had similar operating principles for fillers which were more robust than other sites visited

Operating Parameters:

Filler Parameter	Ideal Range	Other Sites
Nitrogen Pressure	0.8 – 1.3 bar	Any range to hit spec’
Aseptic Tank Pressure	20 psi	10 – 24 psi
Aseptic Tank Temperature	66 – 72F	66 – 72F
Aseptic Tank Level	> 1,000 gal	No minimums
Weight Variation (jaws)	< 1.5g	> 4g



Maintaining Nitrogen Pressure:

- The pressure injection nozzle will increase as the nozzle becomes partial blocked.
- When the pressure reaches 2.0bar, it is recommended to pause production and temporarily increase the N_2 pressure to 6.0bar to purge the nozzle
- Other co-mans sites increase pressure to compensate (without the burst) leading to excess foaming and carton size variability

Carton Integrity & Sterile Barrier Assurance – Overview

John

Detailed Overview

x

Implementation Strategy

- x

Common Challenges

- x

Developed Content

- **x**

Automated Monitoring & Data-Driven Process Control – Overview

John

Detailed Overview

x

Implementation Strategy

- x

Common Challenges

- x

Developed Content

- **x**

Capping Equipment

John

Overview

The automated capping equipment (e.g. Cap Applicator 30 Flex) ensures precise application of caps using a glue-based sealing method, which is critical for product integrity and leak prevention. A best-in-class system maintains consistent glue volume, precise cap placement, and automated quality control to minimize defects and rework. Advanced monitoring, feedback loops, and proactive maintenance ensur

Attributes of Best-In-Class

Build out section after Tetra Pak engagement Mar 11

Precision Glue Application & Control

- Dual glue nozzles consistently dispense adhesive at the target volume to ensure secure cap attachment.
- Automated pressure adjustments based on real-time glu volume feedback maintain optimal glue weight
- Regular nozzle maintenance prevents clogging and ens even glue distribution across all caps.

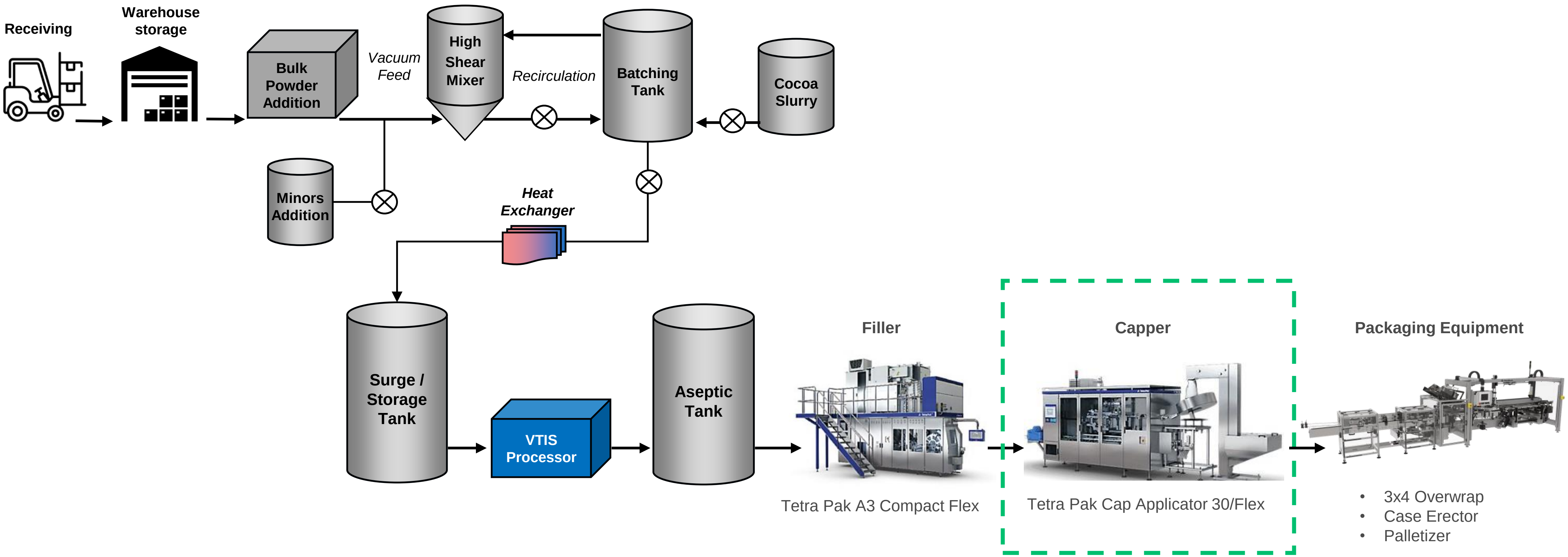
Proactive Maintenance & Reliability

- Predictive maintenance schedules include glue nozzle cleaning, dispenser calibration, and camera alignment verification.
- Sensor-driven diagnostics detect variations in glue pressure or nozzle performance before they impact production.
- Quick-change glue nozzles and dispensers minimize downtime and enable rapid adjustments during production.

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Capping Equipment – Production Areas Targeted for Improvement



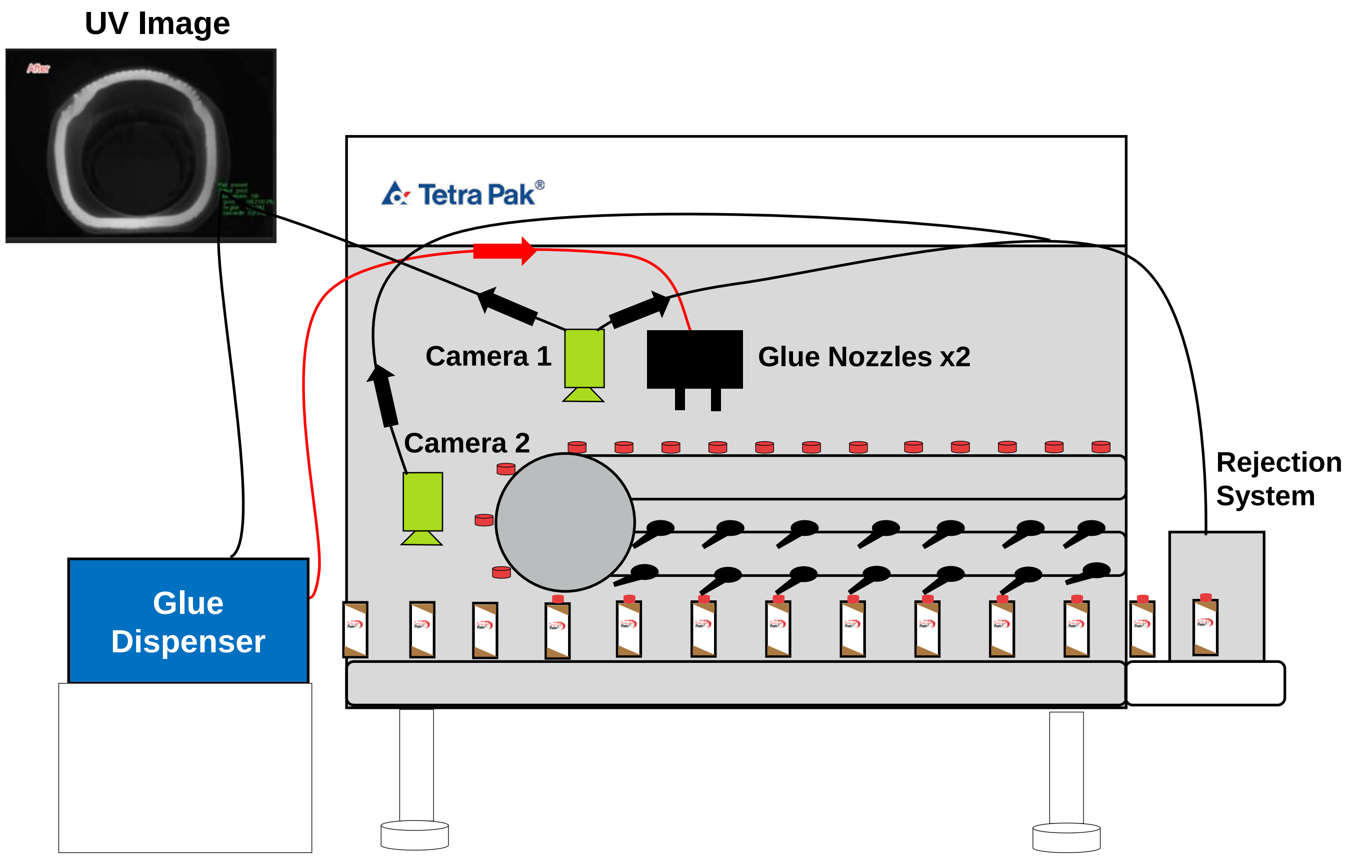
Capping Equipment Standards – Learnings from Jasper

John

- **Theory of operation**
  - **Glue Nozzles :** Two nozzles deposit glue to incoming caps
  - **Camera 1** : Captures an image and calculates the glue volume (length x width)
    - Out of specification glue volume (< 0.15g, > 0.23g) is kicked from the line
    - A signal is sent to the glue dispenser to adjust pressure up / down to meet target
  - **Camera 2** : Ensures the cap opening is aligned on the carton
  - **Rejection System :** Signals from Camera 1 or 2 will reject selected cartons from the line
- **Ideal Operating Parameters**

Parameter	Tetra Recommendation	Best Practice
Nozzle Diameter	0.34mm	0.36mm
Target Glue Weight	0.14g	0.16g
Packs for Leak Test	6	12 - 18

- **Maintenance Best Practices**
  - Rebuild carriages (x18) every 2500 hours to ensure consistent cap pressure
  - Replace nozzles after clog occurs – do not attempt to clean



Packaging Equipment – 3x4 and Case Erector

John

Overview

The 4-pack overwrapping machines, used to package "3x4" configurations, play a critical role in secondary packaging by ensuring accurate grouping and secure application of the carton. These machines require precise setup, regular maintenance, and thorough cleaning to function reliably. Centerlining procedures are essential to maintain consistency across production runs and minimize downtime due to misfeeds or jams. The case erector inserts the required number of Tetra Paks into the base of the case and then wraps the case around the contents. Hot melt glue is applied to the end and top glue flaps and the case is held in position until the glue cures. This is an enclosed automatic system, and the glue applied keeps the case assembled through to palletization.

Attributes of Best-In-Class

Clearly Defined Centerlining Process

- Standardized centerlining procedures ensure optimal machine settings for consistent overwrap application.
- Regular verification of settings (e.g., infeed spacing, glue application, fold integrity) reduces defects and rework.
- Equipment is not adjusted outside of the recommendations established in the centerlining procedure

Packaging Material Inspection

- Prechecks are done to the pre-staged cases to ensure compatibility with the equipment
- Critical to quality parameters are trained to and understood by operators
- Ability to troubleshoot equipment issues caused by packaging material

Automated Monitoring & Quality Assurance

- Vision systems and sensors detect missing cartons or glue pattern issues, triggering automatic corrective actions.
- Weight and dimension checks ensure each carton meets specification before downstream processing.
- Data-driven performance tracking identifies trends in mispacks and machine faults, supporting continuous improvement.

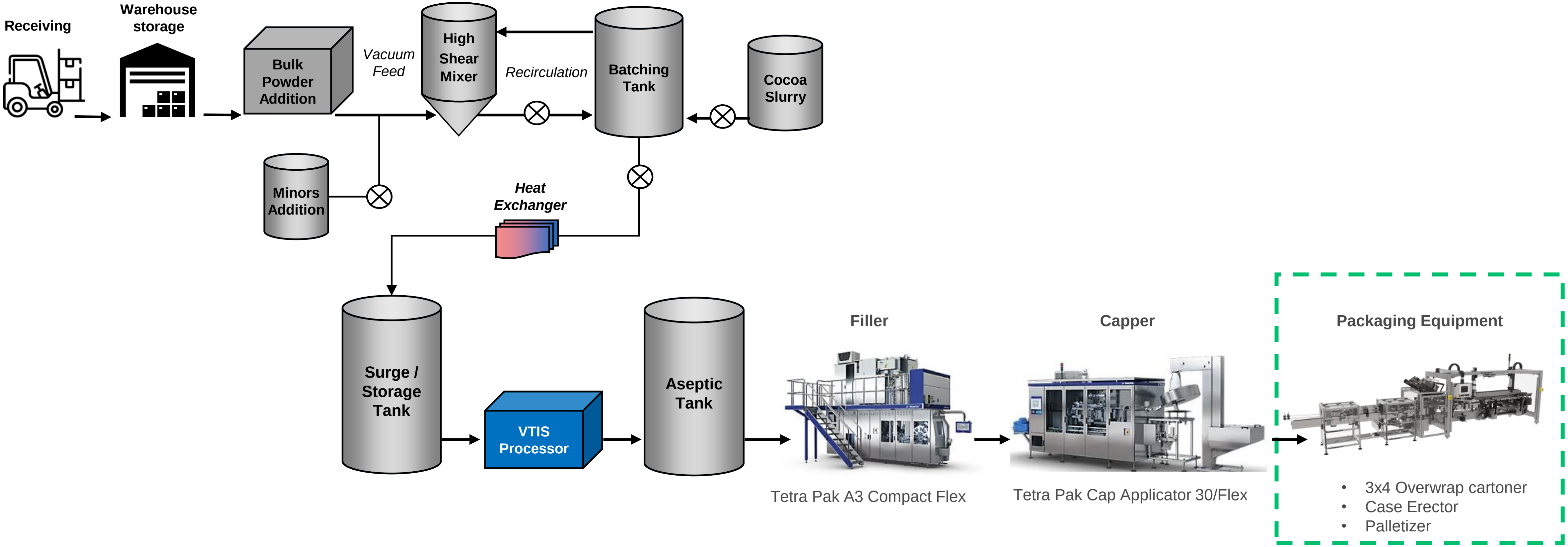
Comprehensive Maintenance & Cleaning Program

- Scheduled preventative maintenance ensures reliable operation and prevents unexpected failures.
- Critical components such as belts, guides, and glue systems are inspected and serviced regularly to prevent jams and misfeeds.
- Cleaning procedures ensure that product contact surfaces and mechanical components remain free of buildup.

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)
WestRock Manual	Centerlining process for equipment		• Packaging Engineering	
ADCO Manual	Centerlining process for equipment		• Packaging Engineering	

Packaging Equipment – Production Areas Targeted for Improvement



Clearly Defined Centerlining Process – Overview

John

Detailed Overview

Centerlining documents the optimal equipment settings and establishes the standard operating procedures for consistent finished product packaging output and quality. This standardized approach establishes verified optimal values for each critical parameter, defines acceptable operating ranges, and creates visual references directly on the equipment. Properly implemented centerlining reduces variation, simplifies setup, and provides a clear baseline for troubleshooting across all the packaging line variables.

The implementation flow includes:

- **Parameter Identification:** Document all critical settings that impact product quality
- **Golden Setting Determination:** Establish optimal values through testing and validation
- **Operating Range Definition:** Set acceptable tolerances around golden settings
- **Visual Marking:** Create clear indicators directly on equipment and adjustment gauges for easy reference
- **Documentation & Training:** Develop standard work procedures for all operators
- **Verification Protocol:** Implement routine checks to ensure settings remain within range

Parameter Identification → Ideal Settings Identified → Operating Range Definition → Visual Marking → Documentation & Training → Verification Protocol

Key Centerlining Parameters

Parameter	Golden Setting	Acceptable Range	Visual Indicator
Machine dimensions	Format-specific	±1mm	Marked guides
Timing parameters	Equipment-specific	±2%	Digital displays
Product positioning	Format-specific	±2mm	Position markers
Temperature settings	Process-specific	±3°C	Gauge markings
Pressure/tension	Equipment-specific	±5%	Pressure indicators

Implementation Strategy

- Document centerline settings for each piece of packaging equipment with clear visual references
- Establish regular verification schedules for critical parameters across all pieces of equipment.
- Train operators on proper adjustment procedures and the importance of staying within defined ranges
- Create clear protocols that prevent unauthorized adjustments outside recommended settings
- Implement audit system to ensure centerline compliance and proper documentation across all packaging equipment

Common Challenges

- Parameter drift over time requires regular verification and recalibration
- Knowledge gaps between shifts lead to inconsistent implementation
- Operator adjustments outside recommended ranges to address immediate issues
- Inadequate documentation and lack of visual indicators of optimal settings and acceptable ranges
- Resistance to standardization from experienced operators
- Variable product specifications requiring multiple centerline configurations

John

Update

Clearly Defined Centerlining Process – Real World Example

Description

- x

Theory

- x

Achieving Best-in-Class

- x

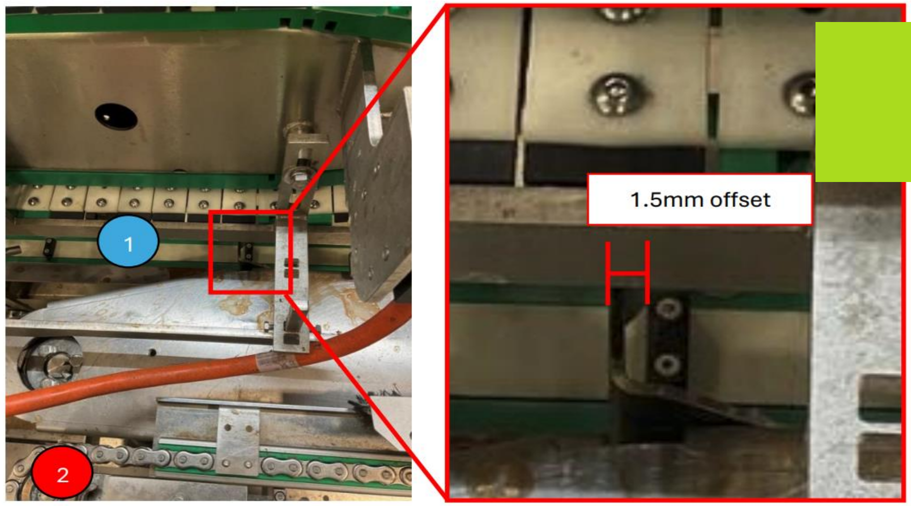


Figure 1: Objective measures for equipment offsets for critical control points

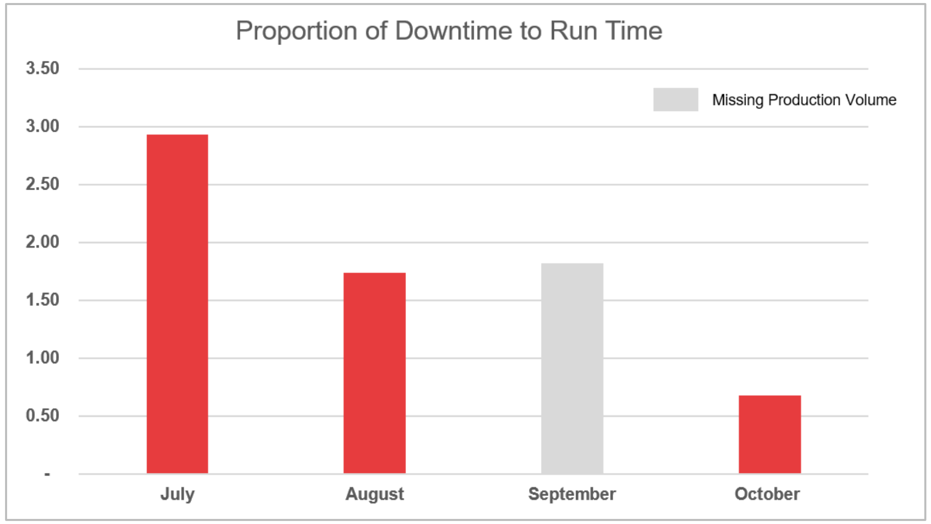


Figure 2: WestRock improvements at SunOpta leading to a 4.5x improvement in downtime

Manufacturer	Co-man Sites	Centerline Process
WestRock	SunOpta, Saputo, Schreiber, Jasper	Yes
ADCO	Stremicks RS, MFI	In-Progress
SMI	Gehl GT	TBD
Mariani	Gehl CNP	TBD

Packaging Material Inspection – Overview

Detailed Overview

Pre-checking that packaging materials are suitable for automatic packing equipment is essential to verify critical elements like dimensions, incoming damage, and surface treatments that affect machinery performance. Proper inspection is essential as it prevents costly downtime, ensures quality, maintains consistent appearance, and reduces waste from unsuitable materials.

The inspection process follows these key steps:

- **Precondition Cases/Cartons (>48hrs):** Ensure temperature and humidity conditioning to the production environment before use.
- **Unwrap/Unstrap Material:** Carefully remove packaging at the line while retaining pallet and case labels
- **Visual Inspection & Specific Checks:** Compared to the PNC approved sample, verify varnish free areas, artwork and dimensions etc.
- **Line Release Decision:** Accept or reject
- **Document Defects:** Record and report all defects for traceability, root, cause, fix and continual improvement.

Precondition Cases (48hrs) → **Unwrap / Unstrap Material** → **Visual Inspection & Specific Checks** → **Line Release Decision** → **Document Defects**

Developed Content

- x

Implementation Strategy

- Refer to the standardized inspection guides with visual references (**see corrugate and overwrap carton handbooks**)
- Train operators on critical-to-quality attributes for both case erector and 3x4 equipment (**see CtQ section**)
- Establish well-lit inspection stations with appropriate library of approved sample examples
- Implement regular update of library of approved samples
- Develop digital logging system for defect tracking and trend analysis

Common Challenges

- Inconsistent lighting conditions affecting visual inspection accuracy
- Time pressure to release materials leading to rushed inspections
- Variation in inspector experience, training levels and application of acceptance criteria
- Difficult-to-detect defects like varnish coverage issues
- Handling damage occurring after inspection
- Multiple material types requiring different inspection protocols

Packaging Material Inspection – Critical Inspection Points

Jim – to update
DONE 23/4

Description

- Following the visual acceptance of the incoming packaging, it is critical to carry out further in-depth checks to ensure that the packaging component quality is as required until the finished product is released.

Theory

- Throughout the life of the packaging component, it is essential that it continues to perform as required. It may be negatively affected by line transformations during assembly such as gluing/sealing and coding or even by the handling and palletization process.
- The impact of allowing poor quality packaging to be used by an automated process such as case erection will cause stops and downtime.
- Some of the key performance characteristics such as the strength of the case gluing are not visible and require a destructive inspection test to ensure the required gluing pattern ands adhesion is achieved.
- It is then also critical to inspect the final finished product quality as the next person to see it is the consumer.
- Other checks such as the legibility and smudge resistance of the date and batch coding are less destructive and can be easily carried out before the finished product is released.

Achieving Best-in-Class

- Incoming inspection procedure: visual check
- Pre line material check: visual and approved sample comparison check.
- Production set up and ongoing checks: case and Tetra Pak date/batch coding, case glue pattern, 3x4 glue pattern tetra seal and cap, Tetra Pak carton shape.
- End of line assembled packaging: visual and destructive check
- Final pallet release: visual check

Critical Inspection Points

Check Point	Check	Standard	
Incoming Release	Incoming damage to pallet	Match PNC sample	
	Incoming damage to contents of pallet identified once unwrapped	Match PNC sample	
Line Release	Artwork	Match PNC approve artwork code	
	Dimensions	Match PNC sample	
	External cut profile	Match PNC sample	
	Material warping/distortion	No warping visible	
	Surface treatments (e.g.: unvarnished areas)	Match PNC sample	
Assembly Defects	Glue Pattern	Match PNC finished product quality stand	
	Date coding		
Final Pallet Release	Pallet Plan	Match PNC finished product quality standard	Collapsed pallet
	Pallet Labeling		Pallet identification
	Pallet Wrapping		Pallet instability

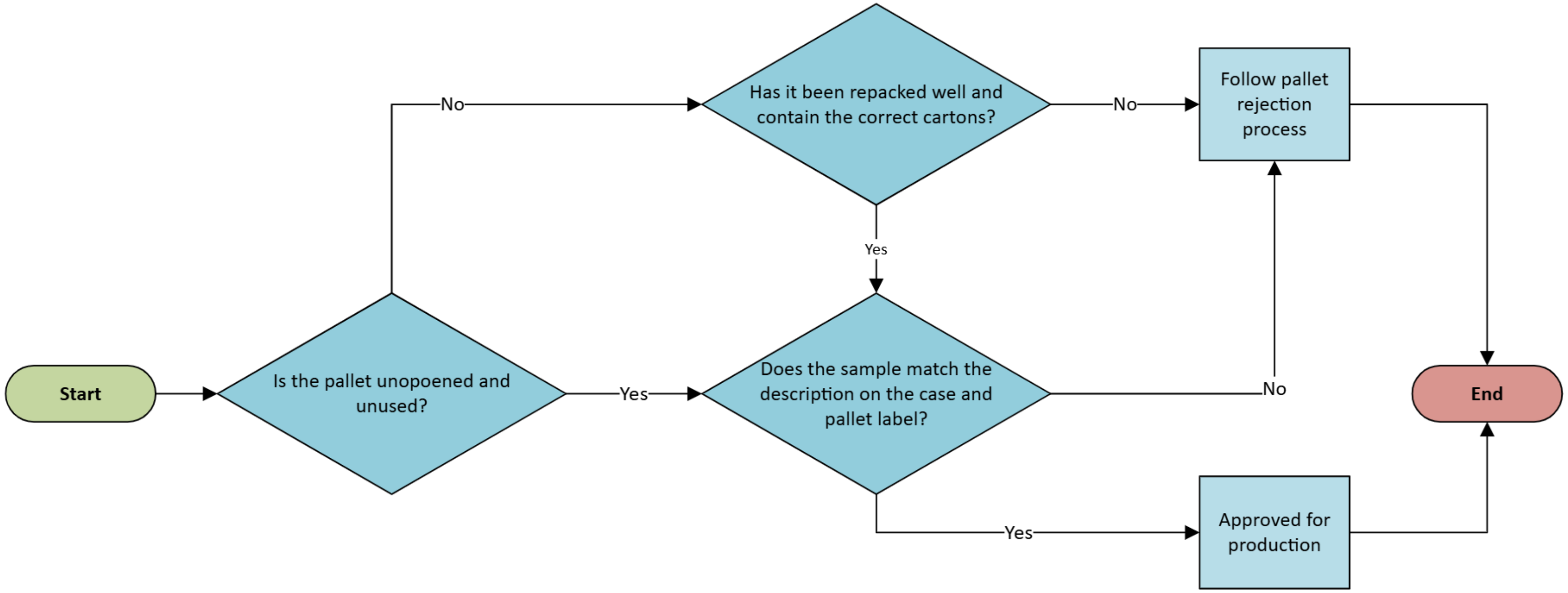
Based on initial pass of future-state defect reporting process flow: Remove language like "required", "use PNC's checklist", etc.

Next steps to investigate:
- Review each co-man's inspection checklist

Packaging Material Inspection – Decision Tree Example

Overview

When the pallets of components are delivered on site



Packaging Material Inspection – Examples of Common Defects

Common Defects Gallery

Below are some categorized examples of critical defects that should be rejected from the case erector and documented to be reported to the supplier/PNC (**see Methodology for Issue Resolution section**).

Case Construction

Figure 1: Inner paper liner delamination weakens corrugated case structural integrity, causing failure during case erection.

Figure 2: Pallet straps connected to the pallet leading to shifted / damaged cases.

Print & Varnish

Figure 3: Unvarnished date code areas vary in size, causing smudged ink when printed on varnished surfaces due to poor drying and bonding.

Figure 4: Inconsistent case tab glue application to varnished areas prevents proper bonding, compromising case strength and integrity.

Dimensional

Figure 5: Warped cases prevent flat stacking in magazine feeders, causing misalignment and jams in automatic case erectors.

Figure 6: Inadequate stretch wrap coverage at pallet base allows load movement during transport, creating instability and safety hazards.

Palletizing

Figure 7: Lack of protection on the pallet leads to damage from straps and contact with other pallets

Figure 8: Obscured pallet labels prevent proper identification, hindering receiving verification and compromising inventory traceability.

Packaging Material Inspection – Real World Example

Real-World Case: Variation in Case Glue Tabs Unvarnished Areas

A warehouse inspection identified inconsistent unvarnished areas on case tabs, which could cause glue adhesion failures during case erection. This example demonstrates how proper material inspection protocols at receiving can prevent downstream production issues and product failures. By implementing standardized inspection procedures for unvarnished areas, co-mans can identify defects before they impact production.

- Inconsistent unvarnished area on case tabs prevents proper glue bonding
- Defect creates weak cases that fail during handling, palletization, and transit
- Standardized inspection procedures could prevent production impacts

On-site Inspection

A. Varnished area
B. Matte unvarnished area

Figure 1: Variation in case tab glue unvarnished areas in same batch

Implications

Position of unvarnished area varies (Fig 1)	Supplier ships out of specification product
Defect undetected in receiving inspection	**1st opportunity to prevent downtime:** An approved PNC sample should be used to check against the attached pallet case sample for defect detection (see corrugate specification).
Cases fed into auto case erector	**2nd opportunity to prevent downtime:** Inspect several cases on the pallet to check against the approved PNC case sample. If defect is detected, contact PNC for approval and next step.
Glue application fails on varnished surface	Inadequate surface bonding from any glue landing on varnished areas
Cases collapse from open and weak case glue flaps	**3rd opportunity to prevent downtime:** If cases are identified as defective before transit from the co-man, repack stock and repalletize with new cases

Automated Monitoring & Quality Assurance – Overview

Jim

Detailed Overview

Automated monitoring systems use sensors, vision systems, and data collection to detect packaging defects in real-time before they impact downstream operations. These systems verify critical parameters including product positioning, seal integrity, code readability, and package completion throughout the production process. Proper implementation matters because it prevents production losses, eliminates manual inspection variability, provides data for continuous improvement, and protects brand reputation through consistent quality.

The automated monitoring process includes these key steps:

- **Equipment Setup Verification:** Confirm sensors, cameras, and monitoring systems are calibrated and positioned
- **In-line Monitoring:** Continuous monitoring of critical parameters (weight, position, seal integrity) during production
- **Automated Inspection:** Vision systems and sensors detect defects, misalignment, or other quality issues
- **Exception Handling:** Automatic rejection of non-conforming products or line stoppage for critical issues
- **Data Collection & Analysis:** Capture performance data to identify trends and improvement opportunities

Equipment Setup Verification → **In-Line Monitoring** → **Automated Inspection** → **Exception Handling** → **Data Collection & Analysis**

Developed Content

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Implementation Strategy

- Assess critical control points across packaging processes
- Select appropriate technology based on product requirements
- Establish clear standards and tolerances for automated systems
- Integrate data collection systems for performance tracking
- Develop escalation procedures for system alerts
- Train operators on system interaction and basic troubleshooting

Common Challenges and Solutions

Challenge	Solution
False rejects	Regular system calibration and threshold adjustment
Data overload	Focus on critical parameters with dashboard visualization
Integration with legacy equipment	Modular sensor additions with standalone controllers
Maintenance expertise	Training program and supplier support agreements
Balancing sensitivity vs. productivity	Staged implementation with performance validation

Automated Monitoring & Quality Assurance – Quality Contr

Jim – to update
IN PROGRESS

Description

Automated monitoring systems permits a number of critical quality checks to be carried out prior, during and at the end of production maintaining line speed, quality and reducing the number line stops. These systems can be used to automatically adjust processing parameters to ensure optimal efficiency.

Theory

- Automated monitoring captures real time data and can be used to track key parameters to ensure the processing and packing process remains in control and at runs at maximum efficiency.
- The data collected from weight verification can be used to demonstrate regulatory compliance regarding product weights and measures.
- The data collected forms the basis of continual improvement and best in class that can track the performance of the co-man network together with the packaging component and machinery suppliers.
- The improvement in quality drives waste reduction and therefore cost saving.
- Automated systems reduce monotonous tasks and remove human error allowing key staff to focus on other key requirements.

Achieving Best-in-Class

- This technology should be utilized throughout the supply chain and not just at the co-mans. Examples being - suppliers of decorated components should be utilizing vision systems to ensure registration of inks and varnishes and to ensure print quality.
- All co-mans should be use the latest UV monitoring cameras for their Tetra capper lines to ensure the bead of glue is consistent and leak proof when the cap is applied.
- Bar code scan check at Start up to ensure its readable for the retailor, the correct code number for the product.

Examples of Automated Quality Controls

Monitoring System	Function	Benefits
2D Vision systems	Detect missing components, misalignment, inconsistent glue bead causing leakage on Tetra Caps	Consistent inspection criteria, no inspector fatigue
3D Vision systems	To monitor dimensions of components	Ensured packs don't get oversized and have difficulty in fitting into Secondary and Tertiary packaging
Weight verification	Confirming fill weight, Confirming product count in Tertiary packaging	Accurate product count, regulatory compliance
Position sensors	Verify proper product orientation before processing	Prevents equipment jams and product damage
Barcode/QR scanners	Verify correct packaging components	Ensures readability and correct packaging and artwork versions for product
Temperature monitors	Ensures key processing temperatures are monitored and adjusted automatically.	E.g - Verify kill step temperature in shake processing and ensuring hot melt glue temperatures are optimal.

Quality Control of Gluing Application – Common Defect Exa

Real-World Case: Top Glue Flap

An online inspection revealed inconsistent gluing application onto the top glue flap. The top glue flap requires specific pattern placement and bonding to maintain case structure and strength throughout distribution and retail display. This example demonstrates proper glue pattern standards versus common defects that compromises case integrity throughout the supply chain.

Potential Quality Impact:

- Case opens during transit
- Cases collapse on the pallet, crushing and bursting the Tetra Paks
- Pallet partially collapses during transit or becomes unstable
- Retailer rejections
- Consumer complaints, brand equity effected

Key Inspection Points

Feature	Target Standard	Common Defect	Remedy
Number of glue spots	6 spots total	Missing spots	Unblock glue nozzle
Adhesion to board	Full fiber tear	Partial contact	Adjust pusher pressure
Glue spacing	Equal distribution	Clustered on one side	Reset nozzle positioning

Findings

Target Pattern (Figure 1)	Marginal (Figure 2)
6 evenly spaced spots	Uneven distribution of glue spots (defect 2)
Full fiber tear present	Lack of fiber tear (defect 1)
Complete compression	Poor adhesion (defect 1)

Figure 1: All Top Glue Flap glue spots show fiber tear and the other required bonding attributes

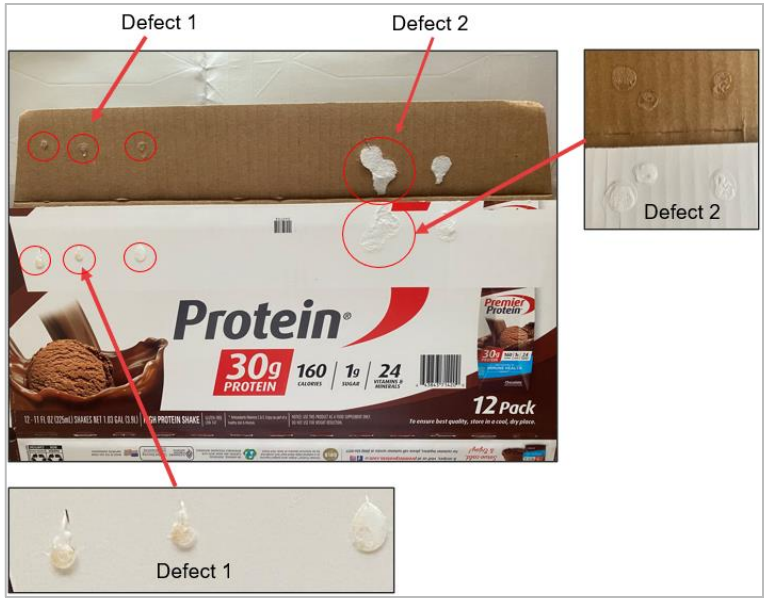

Figure 2: Defect examples showing (1) partial contact with insufficient pressure and (2) poor spot spacing on right side

Set up, Maintenance, & Cleaning Programs – Overvi

Option 1: time-based schedule approach

Detailed Overview

Equipment maintenance and cleaning programs establish specific schedules, responsibilities, and procedures for ensuring equipment function and preventing costly unplanned downtime. Regular care and effective programs prevent mechanical failures, reduces waste from malfunctioning systems, extend equipment life, and maintain consistent package formation and quality.

A systematic approach to equipment care follows a time-based schedule:

- **Cleaning as Required:** Address residue adhesive buildup, product residue, and contamination when detected
- **Daily Checks:** Inspect critical components, fluid levels, and basic operation parameters
- **Weekly Inspections:** Perform deeper checks of wear on parts, drive systems, and alignment
- **Monthly Maintenance:** Conduct scheduled component replacements and system calibrations
- **Quarterly Overhauls:** Complete thorough system reviews and major component replacements

Cleaning as Required → **Daily Checks** → **Weekly Inspection** → **Monthly Maintenance** → **Quarterly Overhaul**

Developed Content

- x

Implementation Strategy

- Develop equipment-specific maintenance schedules based on manufacturer recommendations
- Create detailed cleaning procedures with approved materials and methods
- Implement lockout/tagout protocols for maintenance safety
- Establish critical onsite spare parts inventory
- Develop skills matrix for maintenance personnel
- Schedule maintenance during planned downtime when possible

Common Challenges and Solutions

Challenge	Solution
Time constraints for maintenance	Develop pre-assembled maintenance packages for specific procedures
Inconsistent cleaning practices	Visual work instructions with clear standards
Maintenance skill gaps	Cross-training program with certification levels
Reactive vs. preventive culture	Data-driven approach showing downtime cost impacts
Undocumented modifications	Establish equipment change management process

Option 2: functional approach

Set up, Maintenance, & Cleaning Programs – Overvi

Detailed Overview

Equipment maintenance and cleaning programs establish specific schedules, responsibilities, and procedures for ensuring equipment function and preventing costly unplanned downtime. Regular care and effective programs prevent mechanical failures, reduces waste from malfunctioning systems, extend equipment life, and maintain consistent package formation and quality.

A systematic approach to equipment care includes these key functional areas:

- **Cleaning Activities:** Remove product residue, residue adhesive buildup, and debris that can affect performance
- **Preventive Maintenance:** Conduct scheduled checks and component replacements before failures occur
- **Performance Verification:** Test equipment function including glue application against established standards
- **Documentation:** Maintain records of all maintenance activities for compliance and trend analysis
- **Training:** Ensure operators understand basic maintenance and cleaning procedures

Cleaning Activities → **Preventative Maintenance** → **Performance Verification** → **Documentation** → **Operator Training**

Developed Content

- x

Implementation Strategy

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Undocumented modifications	Establish equipment change management process

Set up, Maintenance, & Cleaning Programs – Maintenance Points

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Description

To optimise performance and productivity a rigorous maintenance schedule, together with a thorough cleaning regimen and documented set up process using structured SOP's is essential.

Theory

- Routine Predictive and Preventative maintenance should be used to inspect and replace parts before failure.
- A effective maintenance management system enhances equipment longevity and reliability.
- Engineering related cleaning programmes extend the lifespan of machinery and equipment by preventing the buildup of residues and contaminants that can cause wear and tear.

Achieving Best-in-Class

- The parts required for recommended maintenance and part replacement need to available when required using an effective inventory management system.
- Only recommended cleaning agents should be used to avoid corrosion and removing the required lubrication.

Examples of Maintenance Points

Jim – to update

Component	Check Frequency	Maintenance Action	Warning Signs
Glue systems	Every shift	Check for glue blockages and impeded flow	Uneven application patterns, brown burnt discoloration of glue
Critical wear parts	Daily	Inspect and clean	Unusual noise or movement
Drive systems	Weekly	Lubricate and tension	Speed variations
Control systems	Monthly	Verify calibration	Performance drift
Structural elements	Quarterly	Check alignment	Product inconsistency

Leverage Tetra Pak's Spare parts inventory output (NYC engagement)

Set up, Maintenance, & Cleaning Programs – Real World Exa

John

Real World Case: WestRock 3x4 Equipment Cleaning

Background

- Issues SunOpta is having

Centerlining Process Development

- Overview of work with WestRock
- Equipment components clearly labeled
- Centerline Process (**Figure 1**)
- Do not adjust parameters

Realized Benefits from Centerline Process

- SunOpta results (e.g. 40% reduction in downtime) (**Figure 2**)

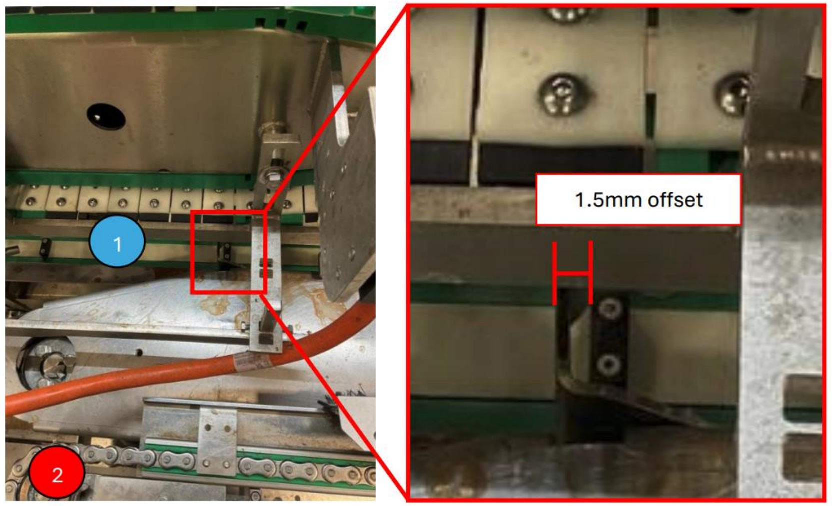


Figure 1: Objective measures for equipment offsets for critical control points

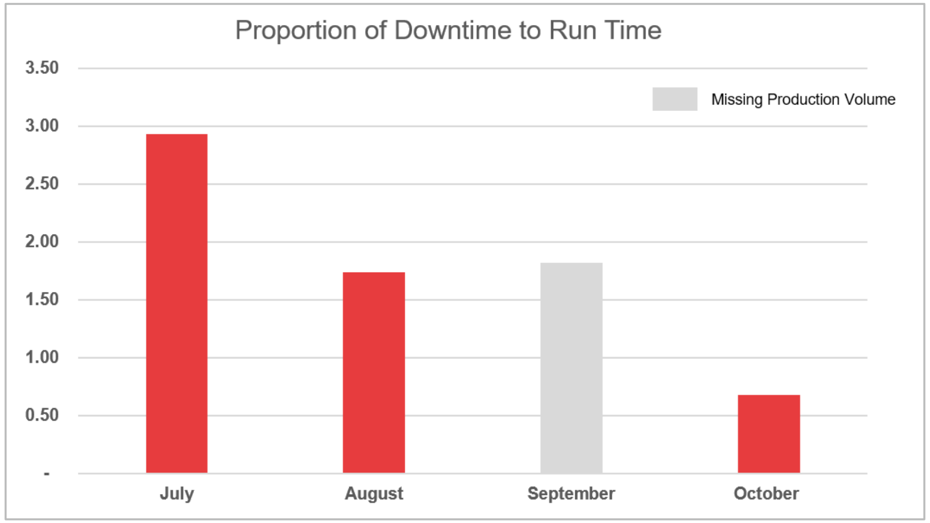


Figure 2: WestRock improvements at SunOpta leading to a 4.5x improvement in downtime

Performance Management

Overview

Performance management of a co-man network ensures alignment with strategic targets, maintains product quality, and optimizes operational efficiency. KPIs are critical as they provide measurable benchmarks to assess performance, identify areas for continuous improvement, and enforce accountability in contracts. This drives operational excellence, reduces costs, and strengthens collaborative partnerships.

Attributes of Best-In-Class

Standardized KPIs

- Balanced scorecard integrates operational, quality, delivery, and sustainability performance
- Standardized definitions and calculations ensure consistent performance evaluation
- Seamless, automated data collection and validation processes ensure data integrity

Performance Targets

- Targets are established leveraging OEM benchmarks and industry standards to set realistic and achievable goals
- Regular capability assessments inform target adjustments and drive improvement
- Product-specific requirements are incorporated into targets to account for complexity differences

Performance Monitoring

- Real-time dashboards supported by automated alert systems enable proactive issue identification and response
- Regular performance reviews drive accountability and improvement actions
- Service level agreement requirements are monitored automatically to ensure contractual compliance

Data-Driven Issue Resolution

- Root cause analysis protocols identify true performance drivers
- Trend analysis and predictive modeling enable performance optimization
- Historical performance data informs contract negotiations, investment decisions, and target setting
- Improvement initiatives tracked to ensure sustained performance gains

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)
KPI Distribution Pack	KPIs and frameworks for measuring co-man performance	• Here	• Co-man Management • Supplier Quality	• Co-man KPI Distribution Pack_final.pdf • Co-man KPI Distribution Pack_final.pptx
KPI Data Report Template	KPI data collection template			• KPI Data Report Template.xlsx

Standardized KPIs – Overview

Sara – to update

Detailed Overview

Below is a framework of 11 KPIs across 4 strategic categories, measuring performance, quality, delivery and sustainability throughout the co-man network.

The KPI framework aims to address inconsistencies from data & reporting collection and formats, which prevents PNC from effective performance baselining and site comparisons and measuring the effect of continuous improvement initiatives.

Developed Content

- x

Implementation Strategy

This was designed to be as least burdensome as possible, we did this with the following:

- KPIs can be calculated using data accessible to co-mans with existing tools / processes
- Outlined in black can be sourced from **Tetra Pak filler data** reports
- Outlined in purple is calculated using **data already shared to PNC**
- Outlined in blue is sourced from **annual sustainability reports**

Common Challenges

- KPIs are measured differently between co-mans – **a standardized calculation method is here**
- Complexity of gathering and reporting data on a re-occurring basis can create excess burden – See **implementation strategy** on how to mitigate

Standardized KPIs – KPI Framework

Sara – to update

Description

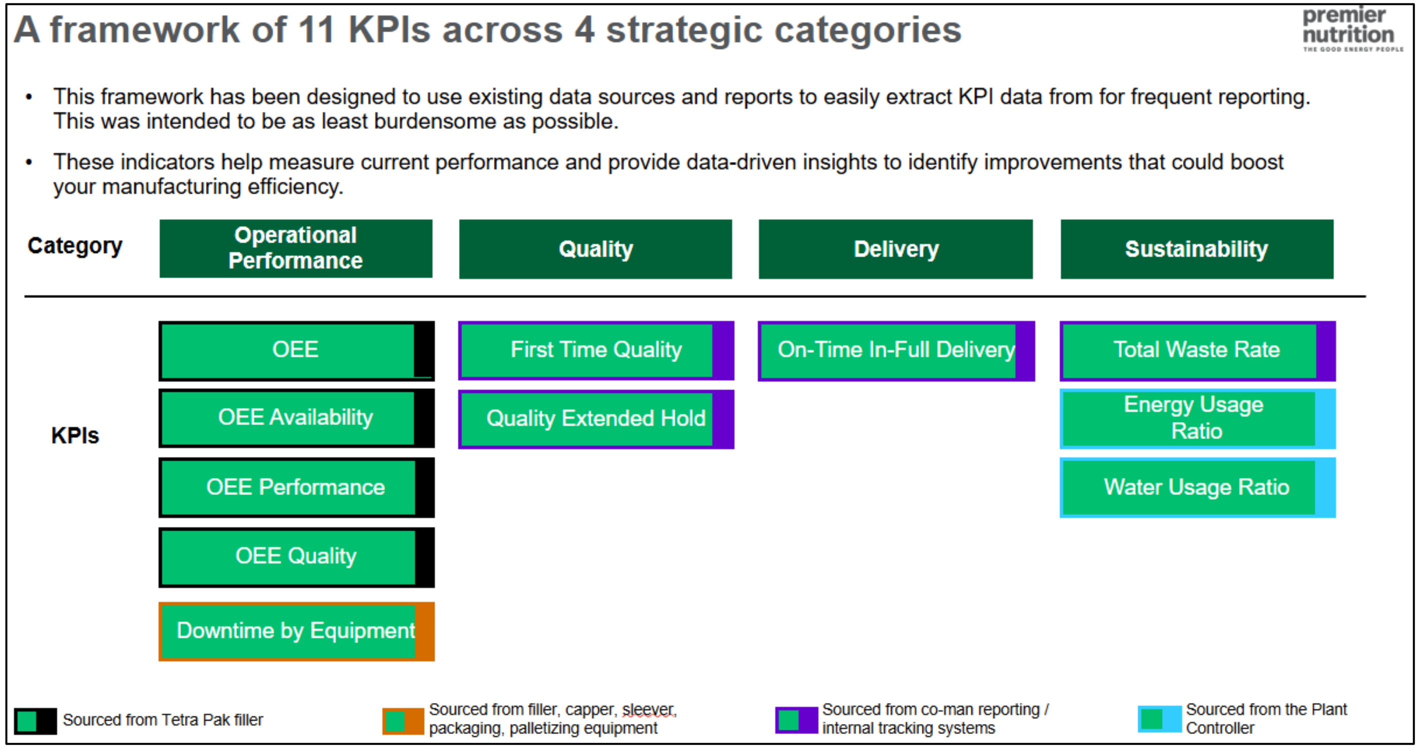
- x

Theory

- x

Achieving Best-in-Class

- **x**



Standardize KPIs – Detail of definitions, reporting cadence data sources

To be updated once further validated

Category	KPI	What it measures	Calculation	Cadence	Data Source
Operational Performance	OEE (%)	Overall equipment effectiveness combining availability, performance, and quality	Availability * Performance * Quality	Monthly	Tetra Pak filler
	OEE Availability (%) (Production Time UTE)	Percentage of production run time compared to available production time	Production Run Time / Planned Production Time	Monthly	Tetra Pak filler
	OEE Performance (%) (Line Efficiency)	How well the equipment is running compared to its designed speed	Actual Units Produced / Ideal Produced Units	Monthly	Tetra Pak filler
	OEE Quality (%) (First Pass Filler Quality)	Percentage of units that meet specifications at the filler without any defects/reprocessing, indicating initial production quality	Good Units at Filler / Actual Units at Filler	Monthly	Tetra Pak filler
	Downtime by Equipment (%)	Percentage contribution of each equipment's stop time to total downtime, showing impact of individual machines on overall line stoppages	Sum of Stop Times by Equipment / Total Downtime	As requested[1]	Filler, capper, sleever, packaging, palletizing equipment
Quality	First Time Quality (%)	Percentage of units that meet all specifications first time without any rework/reprocessing	Units Meeting All Specs First Time / Total Production Units	Monthly	Quality Team
	Quality Extended Hold (%)	Percentage of production placed on extended hold for longer than 15 days from production date	Products on Extended Hold / Total Production Units	Monthly	Quality Hold Report
Delivery	On-Time In-Full (OTIF) (%)	Orders delivered completely and on schedule to co-man warehouses (excluding 3PL logistics)	Total Orders Made On-Time & In-Full / Total Orders	Monthly	Internal system / manual tracking
Sustainability	Total Waste Rate (%)	Combined waste as % of production, which includes product and packaging wastes	Waste Generated / Total Production Units	Monthly	ERP system
	Water Usage Ratio (gal/gal)	Total water used per gallon produced, which includes process water, CIP/sanitation, cleaning, utilities	Total Water Used / Total Gallons Produced	Annual	Plant Controller
	Energy Usage Ratio (kWh/1000gal)	Total energy consumed per 1000 gallons, which includes processing, HVAC, refrigeration, compressed air, utilities	Total Energy Consumed in kWh / Total Production Volume in thousands of gallons	Annual	Plant Controller

1. Monthly data, last 12-month period to support initial baseline

Sara – to update

Performance Targets – Overview

Detailed Overview

x

Implementation Strategy

- x

Common Challenges

- x

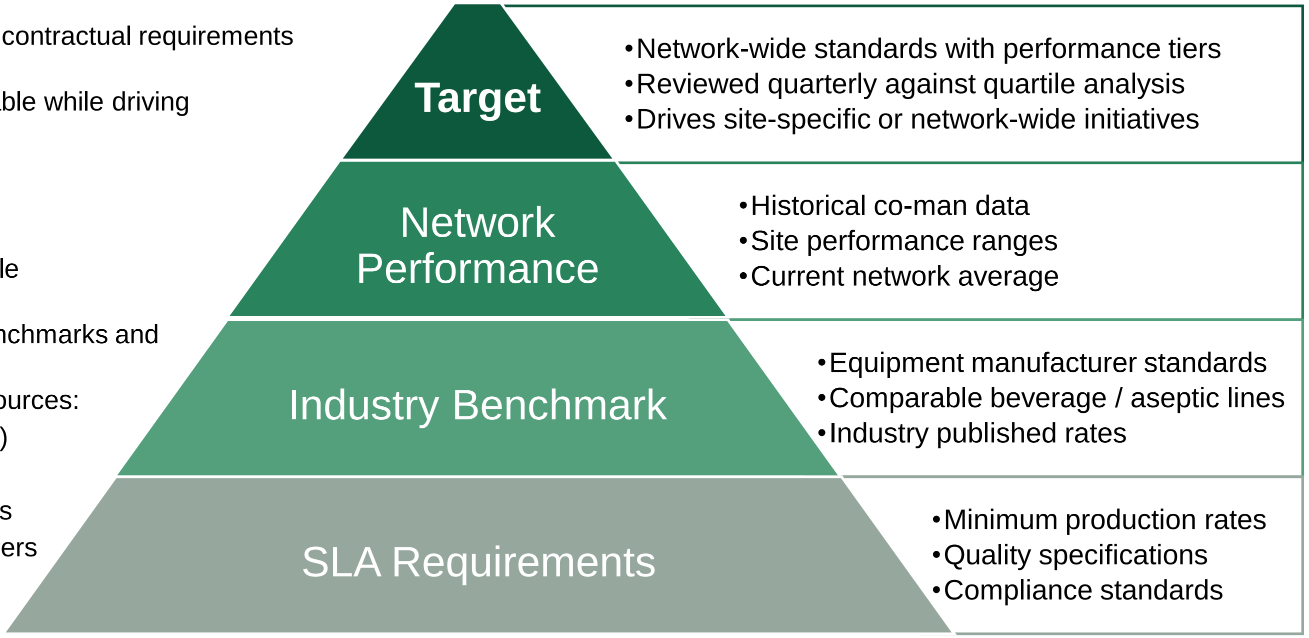
Developed Content

- **x**

Performance Targets – Target Setting

Description

- Setting appropriate performance targets requires balancing multiple data sources: contractual requirements (SLAs), industry benchmarks, and network performance data.
- This systematic approach ensures standards remain both challenging and achievable while driving continuous improvement across the co-manufacturing network.



Theory

- Performance targets must be built upon a foundation of minimum requirements while incorporating ambitious and achievable goals that drive improvement
- Starting with minimum SLA requirements, targets are elevated through industry benchmarks and validated against network capabilities
- The pyramid framework demonstrates the hierarchical relationship between data sources:
  - SLA Requirements form the foundation (minimum acceptable performance)
  - Industry Benchmarks provide external reference points and capabilities
  - Network Performance Data validates achievability within existing operations
  - Final Target balances all inputs and establishes appropriate performance tiers
- This structured methodology applies across operational, quality, delivery, and sustainability KPIs to ensure consistent target-setting throughout the network

Achieving Best-in-Class

- Follow a five-step target-setting process:
  1. Collect information from contractual SLAs, OEM benchmarks, and historical performance
  2. Process collected data to account for site variations and equipment capabilities
  3. Establish goals that balance ambition with achievability
  4. Review with stakeholders and refine based on feedback
  5. Deploy across the network with regular monitoring that feeds back into analysis
- Create tiered performance standards with defined network benchmarks, regular reviews, and targeted improvement initiatives
- Leverage diverse data sources including historical performance, equipment standards, industry benchmarks, and contractual requirements to establish realistic yet challenging targets.

Performance Targets – OEE Availability Example

Target Setting Application

Here is an example walk through how to apply our target-setting methodology to OEE Availability - a critical metric that measures equipment uptime against scheduled production time.

The target-setting process uses quartile analysis of network performance data to establish performance tiers, supplemented by industry benchmarks provided by Tetra Pak. With network OEE Availability ranging from 36-65%, the performance categories are:

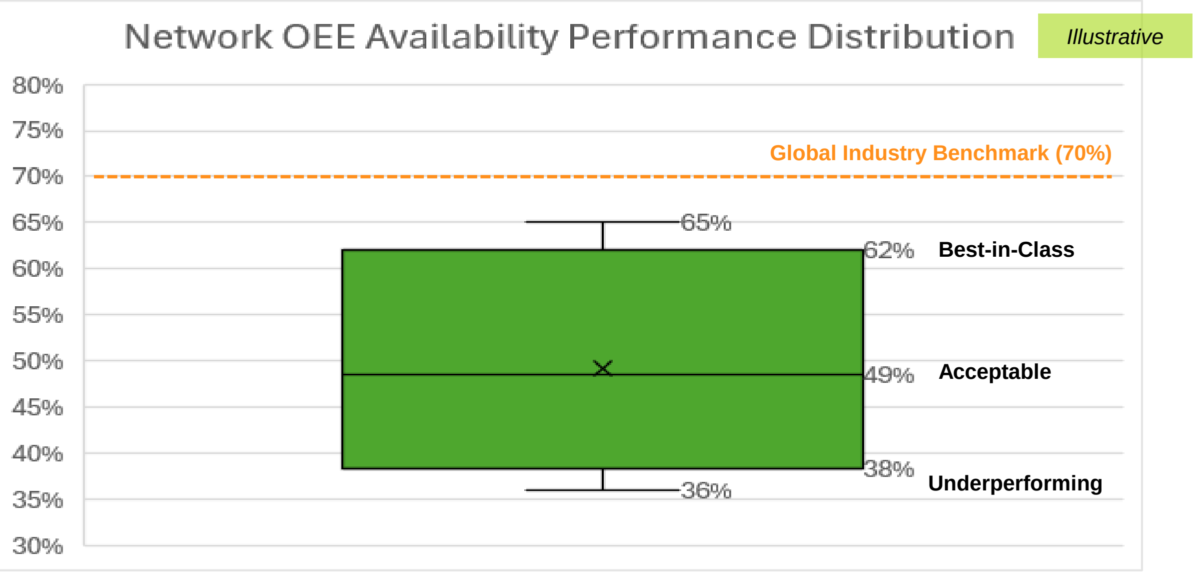
Updated Annually:

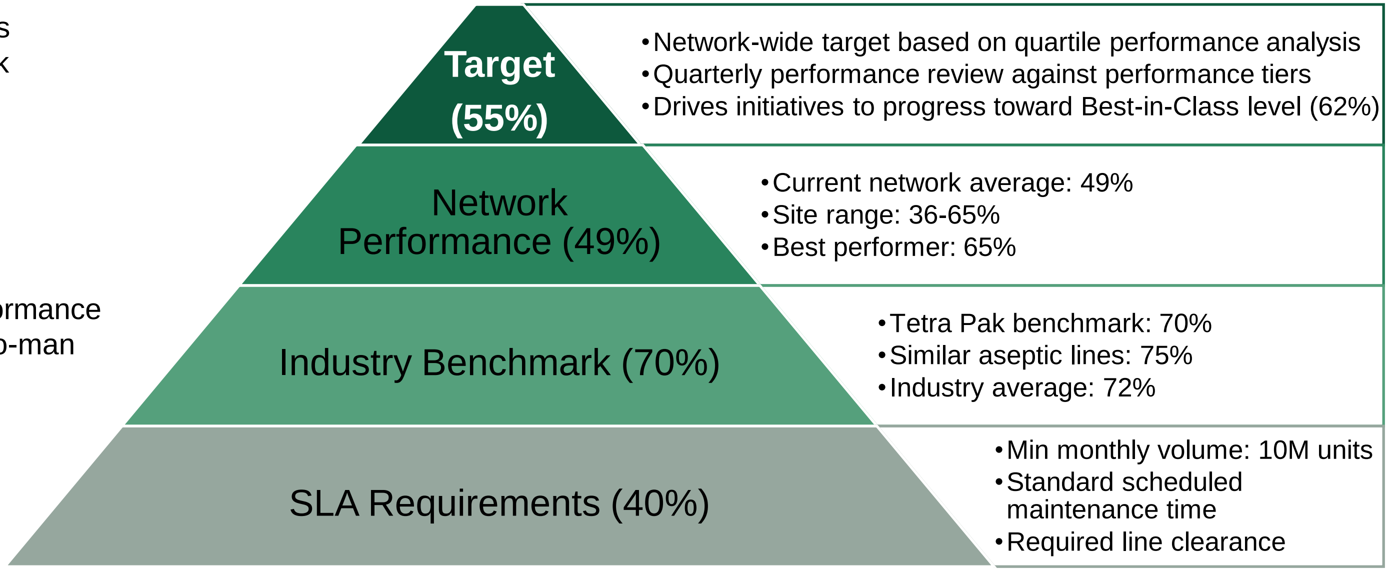
- **Best-in-Class (≥62%)**: Upper quartile performance sets benchmark
- **Acceptable (38-62%)**: Interquartile range defines expected performance
- **Underperforming (<38%)**: Lower quartile requiring intervention

The 55% target represents a meaningful step toward Best-in-Class performance while remaining achievable based on current network capabilities. Final targets are validated against:

- Volume commitments (e.g. 10M units monthly)
- Equipment capability (Tetra Pak benchmark: 70%)
- Demonstrated performance (two sites at 65%)

This quartile-based methodology provides statistically sound performance categorization while driving continuous improvement across the co-man network.





Performance Monitoring – Overview

Sara – to update

Detailed Overview

x

Implementation Strategy

- x

Common Challenges

- x

Developed Content

- **x**

Performance Monitoring – Monitoring & Reporting Approach

Description

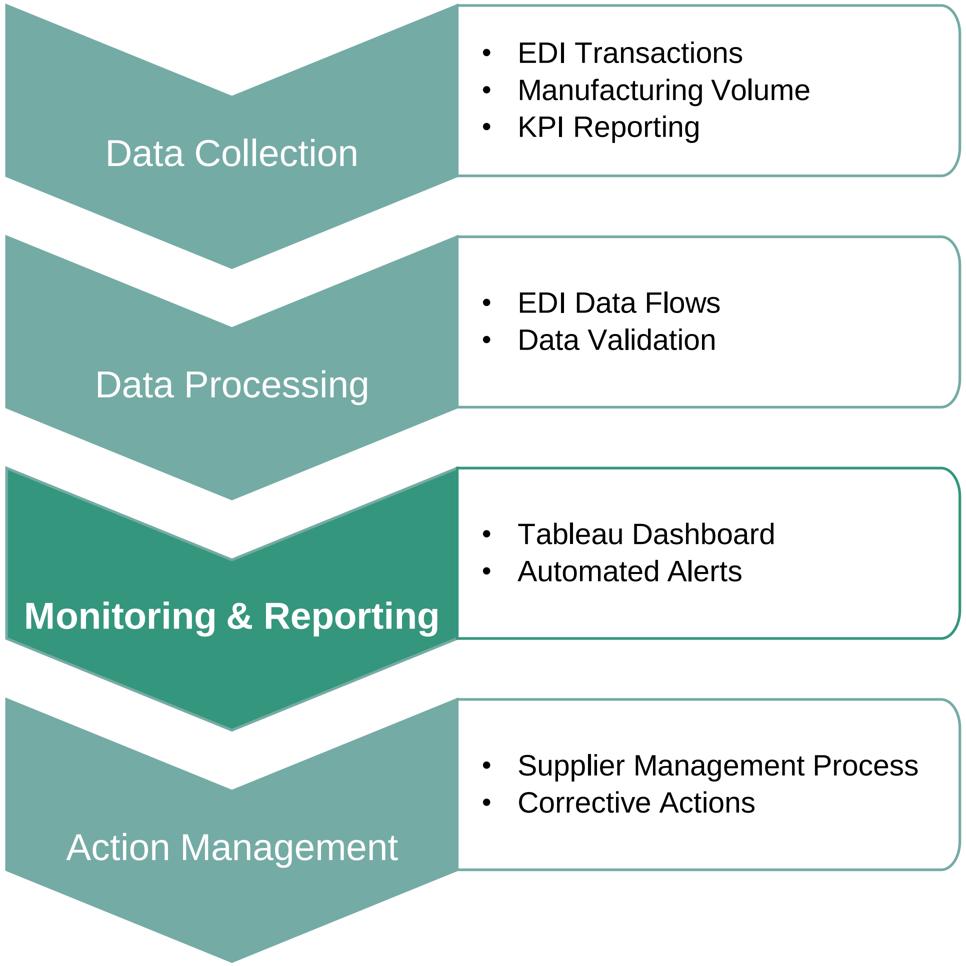
- A systematic approach for monitoring co-man performance against established thresholds through automated data collection, real-time monitoring, and structured response protocols.
- This process integrates EDI data flows, service level agreements, and quality specifications into unified dashboards and alert systems to ensure consistent product quality while enabling proactive issue identification.

Theory

- Standardized performance monitoring creates a data-driven basis for network evaluation and supplier management decision-making (e.g. effective contract negotiations and continuous improvement initiatives)
- Performance visibility across the co-man network enables consistent quality and delivery standards
- The integration of diverse data sources provides a comprehensive view of operational performance
- Proactive identification of issues prevents customer impact and supports continuous improvement

Achieving Best-in-Class

- Implement automated data collection systems:
  - EDI transactions for real-time operational visibility
  - Manufacturing volume tracking for capacity utilization
  - Standardized KPI reporting across the network
- Establish robust data processing protocols:
  - EDI data flow validation to ensure information accuracy
  - Consistent data validation standards across all sources
- Deploy comprehensive monitoring tools:
  - Tableau dashboards for visual performance tracking
  - Automated alert systems for threshold violations
- Create structured action management processes:
  - Defined supplier management protocols
  - Systematic corrective action implementation and tracking



Performance Monitoring – Dashboard Example

Monitoring & Reporting

The performance monitoring dashboard provides visibility to KPI performance across the co-man network. By combining **automated alerts, color-coded visualization, and drill-down capabilities**, the system enables proactive management of operational performance.

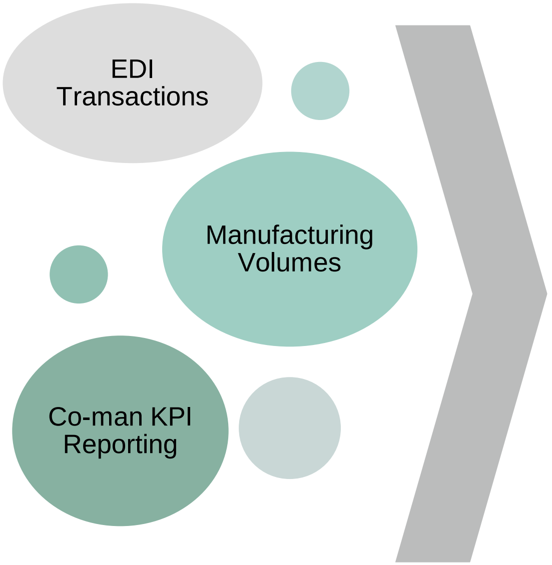
Application Example

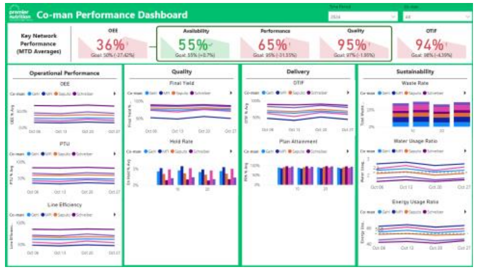
When data inputs are received and processed into the dashboard, the system will compare the data against determined thresholds. When pre-defined KPIs breach performance expectations, alerts can be set for specified users and the system will:

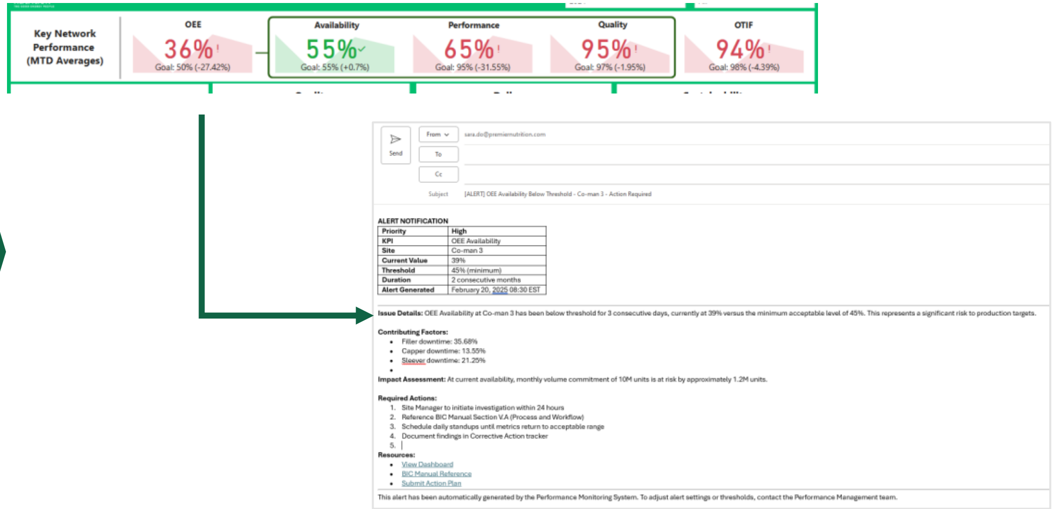
1. Creates notification with priority level
2. Provides context with contributing factors
3. Initiates standardized response protocol

Tableau Dashboard

Automated Alerts







Data Flows **Monitoring** **Reporting**

Sara – to update

Data Driven Issue Resolution – Overview

Detailed Overview

x

Implementation Strategy

- x

Common Challenges

- x

Developed Content

- **x**

Data Driven Issue Resolution – Resolution Approach

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Description

- The data-driven issue resolution process provides a structured approach to identifying, analyzing, and resolving manufacturing performance issues using real-time data and the BIC manual as a reference guide.
- This systematic three-tier methodology—Performance Data, Investigation, and Resolution—enables teams to efficiently diagnose problems and implement proven solutions from the BIC framework that address immediate performance gaps while creating a continuous improvement cycle.

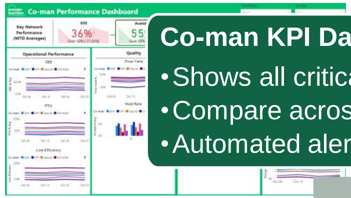
Theory

- Effective issue resolution integrates real-time monitoring with standardized analysis and response protocols
- The process creates a continuous improvement cycle where solutions are documented, shared network-wide, and refined over time
- Structured prioritization of issues maximizes resource efficiency and operational impact
- Success depends on balancing immediate fixes with systemic improvements

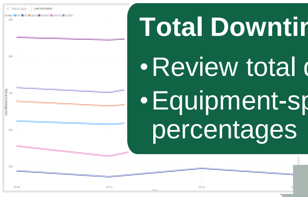
Achieving Best-in-Class

- **Performance Data:** Implement network-wide dashboards with automated data collection, comparative analysis capabilities, and configurable alerts to quickly identify deviations from expected performance.
- **Investigation:** Conduct detailed analysis of issues through monthly reviews and backlog assessment to determine underlying issues rather than symptoms.
- **Resolution:** Apply standardized solutions from the BIC manual, document effectiveness, and share successful interventions across the network to create a continuous improvement cycle.

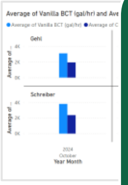
Performance Data



Co-man KPI Dashboard:
- Shows all critical KPIs
- Compare across co-mans
- Automated alerts set up



Total Downtime Visualization:
- Review total downtime hours
- Equipment-specific downtime percentages



Detailed Downtime Analysis:
- Drill-down to equipment-specific metrics
- Historical trending by equipment

Investigation

Monthly Performance Review:
- Detailed month-over-month analysis
- Equipment-specific trend identification
- Impact quantification (hours lost)

Backlog/Anomaly Investigation:
- Determine root causes
- Identify systemic issues and common failure modes
- Prioritize highest impact areas

Resolution

BIC Solution Implementation:
- Reference relevant standards
- Apply documented best practices and standardized maintenance procedures
- Track improvement effectiveness

Quality Control and Assurance

Overview

Xx ensures…

Attributes of Best-In-Class

Statistical Process Control (SPC)	x	x	x
• x	• x	• x	• x

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Statistical Process Control (SPC) – Overview

Louise

Detailed Overview

Statistical process control (SPC) is a tried and tested method of quality control that uses statistical techniques to monitor and control a manufacturing process, ensuring it operates efficiently and produces products that meet specifications.

By employing tools like control charts, SPC helps identify and reduce variability in the process, leading to higher quality and less waste.

Implementation Strategy

- Statistical process control (SPC) is a tried and tested method of quality control that uses statistical techniques to monitor and control a manufacturing process, ensuring it operates efficiently and produces products that meet specifications.
- By employing tools like control charts, SPC helps identify and reduce variability in the process, leading to higher quality and less waste.

Common Challenges

- x

Developed Content

- **x**

Statistical Process Control (SPC) – Control Points & Implementation

Description

- x

Theory

- x

Achieving Best-in-Class

- x

Figure 1: Visual timer

Figure 2: HMI as part of Digital monitoring / "Digital Twin"

Benefits of SPC

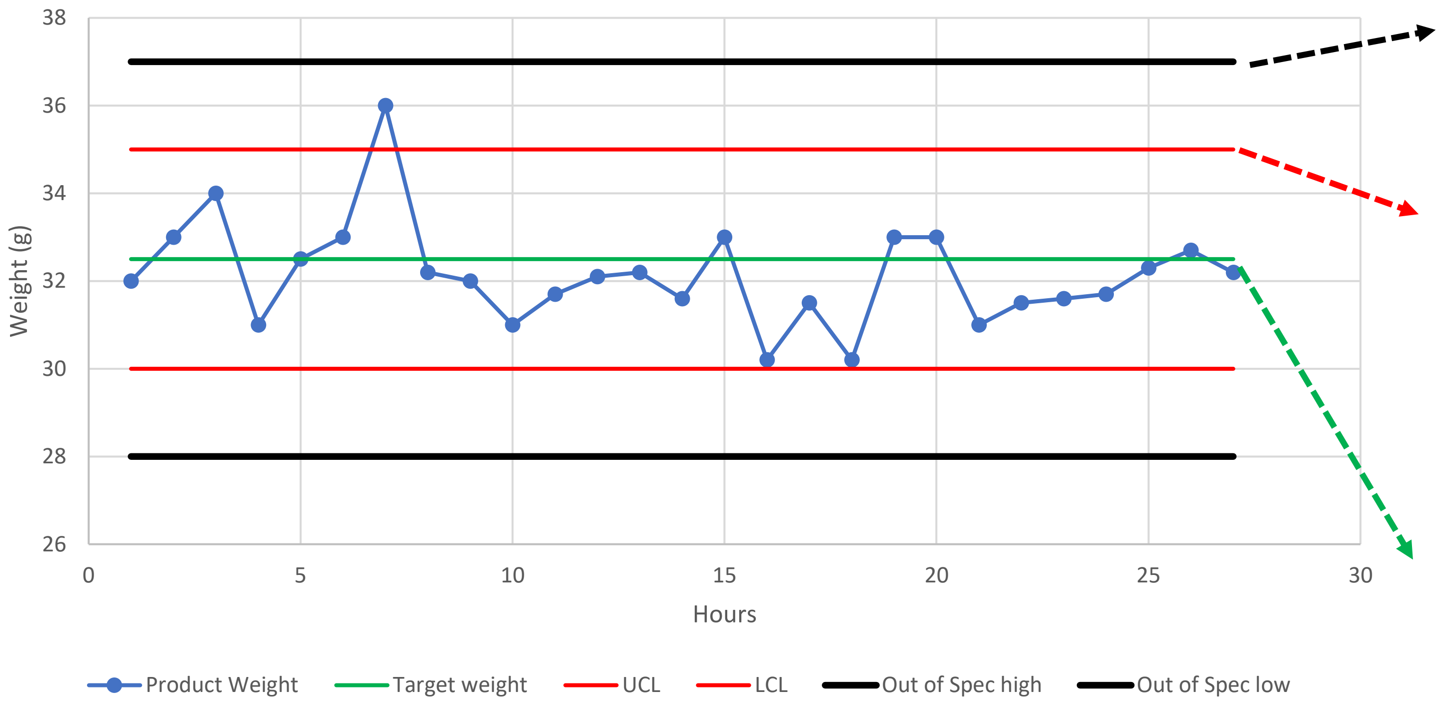
1. **Improved Quality:** By identifying and reducing variability in processes, SPC ensures that products consistently meet quality standards.

2. **Increased Efficiency:** Continuous monitoring helps detect issues early, reducing waste and rework.

3. **Data-Driven Decisions:** SPC provides real-time insights into process performance, enabling informed decision-making.

Statistical Process Control (SPC) – Tools & Techniques

Example Chart

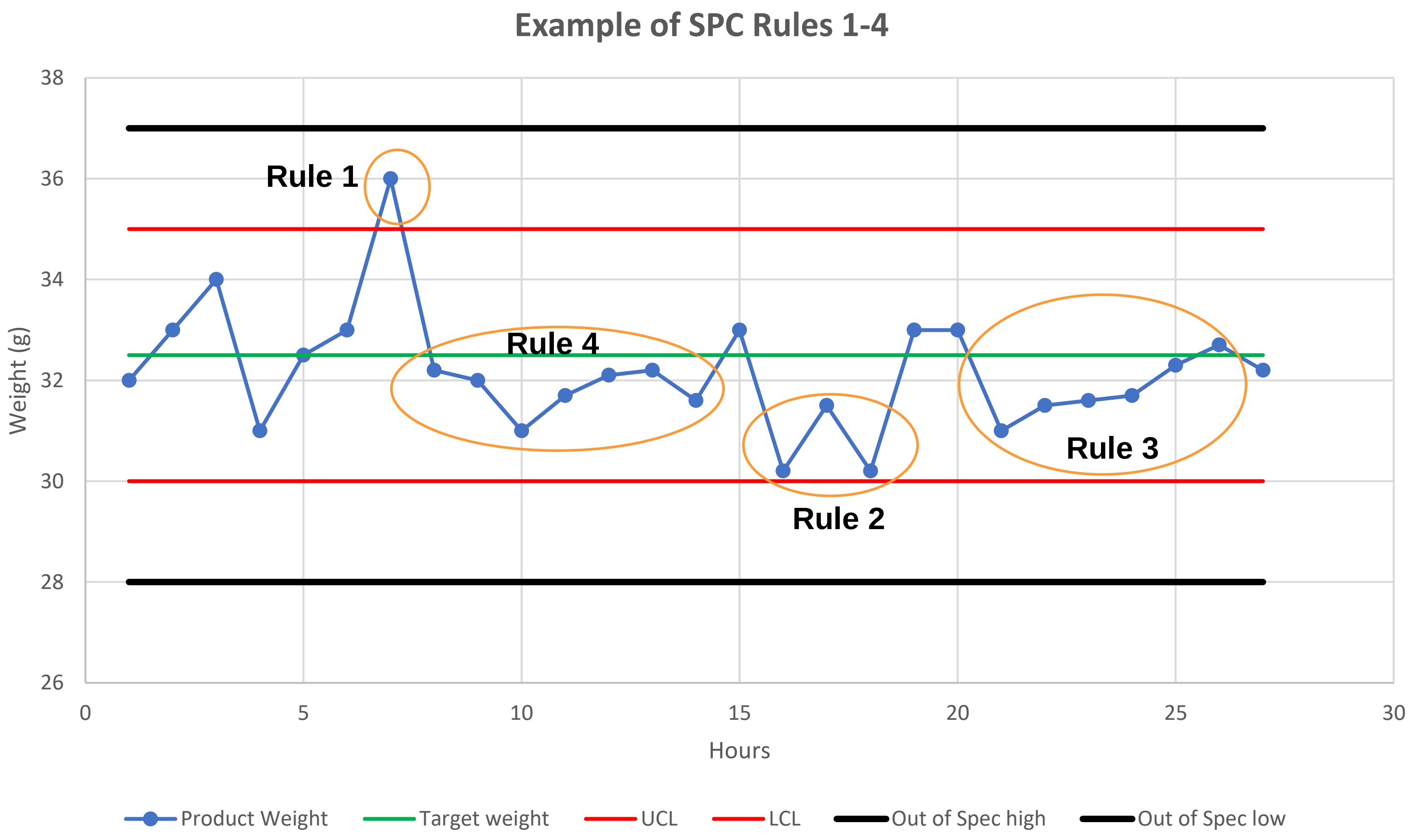


Definitions

- **Specification**: The range of values defined by the upper and lower values between which the product is suitable for sale.
- **Upper and Lower Control limits UCL and LCL:** The limits within specification at which an immediate action must be taken should they be exceeded, or risk product going out of specification. This may be statistically defined based on the specification limits, target value and historical statistical information for line performance.
- **Process Target:** The optimum specification for the product, typically but not always the middle point between the upper and lower limits for the specification.

Statistical Process Control (SPC) – Control Charts

SPC employs various statistical tools, which includes Control charts as the primary tool in SPC. They are used to monitor process variation over time and instigate rule-based actions.



In this example left to right:

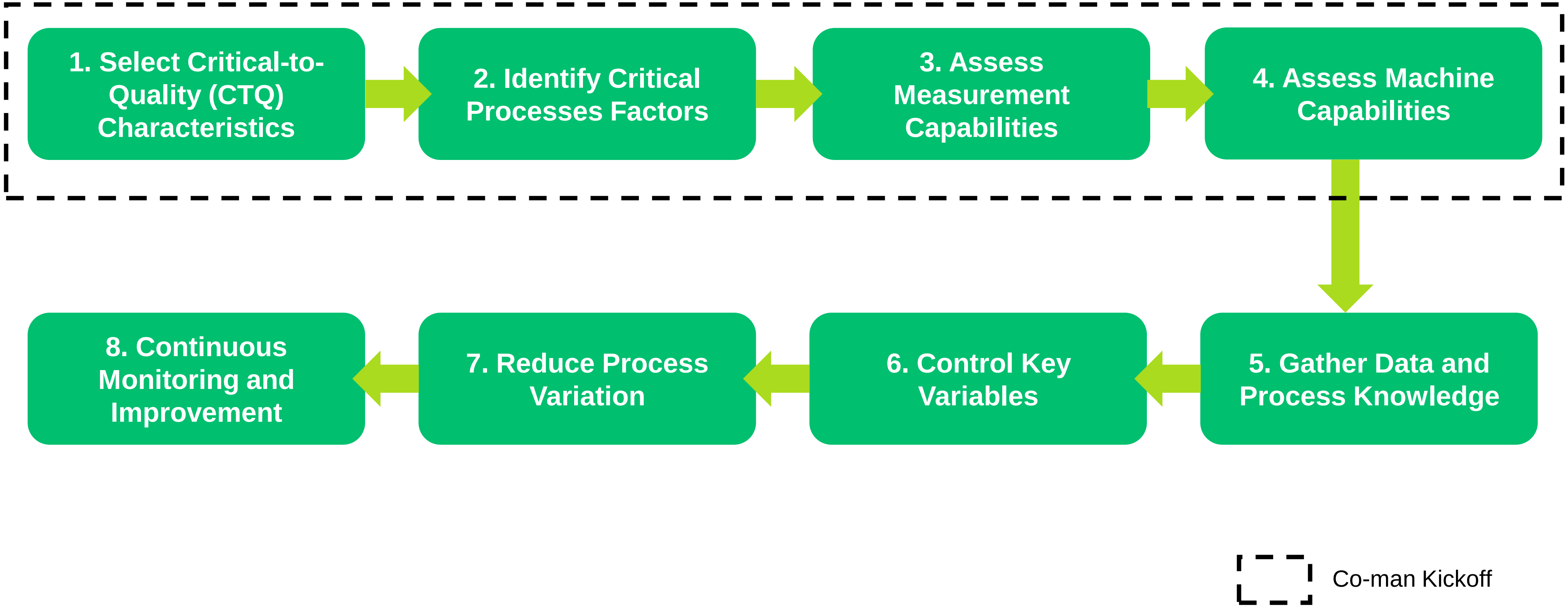
- Rule 1 action: take significant action to reduce weight to target.
- Rule 4 action: make small adjustment to increase weight to target.
- Rule 2 action: make small adjustment to increase weight to target.
- Rule 3 action: make small adjustment to decrease weight to target.

UCL = *upper control limit*

LCL = *lower control limit*

Statistical Process Control (SPC) – SPC Implementation Process

Implementation of SPC requires all operational and quality staff and managers to be familiar with the SPC rules. This includes understanding 1) the underlying reasons and implications of these rules as well as 2) the benefits on product quality, operator workload and reduced costs through their implementation.



Technology & Innovation

Chapter Overview

Leveraging technology effectively across manufacturing operations is critical for maintaining competitive advantage and operational efficiency at scale. This chapter establishes frameworks for evaluating technologies, standardizing equipment, accelerating adoption, and fostering improvement programs. These practices ensure technology investments deliver measurable value by enhancing manufacturing capabilities and efficiency, while promoting innovation throughout the network.

Chapter Contents

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Content Roadmap

Wave 1 & 2 Content	Wave 3 Content to be Developed	Long Term Strategic Content

Defining Technology and Equipment Standards

Overview

Xx ensures…

Attributes of Best-In-Class

x	x	x	x
• x	• x	• x	• x

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Defining Technology and Equipment Standards – pH Probe Equipment

Detailed Overview

- SPC rules have been i
- Co-mans to engage w

Louise/John

operating principals, accuracy, calibration, recommended equipment

reference from: 12/20 - Standardization Elimination MFI Data Review OneNote

Developed Conte

- Statistical process contr
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  product quality by applyi
- In order to use SPC it is
  line is first identified. Th
  period of time (typically a shift or 24hrs) without operator intervention and measuring the key quality attributes (KQAs) of the product during this period.
- It is important to understand which line variables impact which KQAs of the product.
- Charts either paper or electronic are used to track the KQAs.
- Typically 3-4 simple statistical rules are applied to the KQAs with the intention of limiting operator intervention to only that which is necessary.

mentation Strategy

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, down time, manufacturing

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Common Challenges and Solutions

- ‘Not invented here’, risk of resistance when SPC is introduced. The benefits for everyone needs to be shared prior to training to gain support.
- Training and charts need to be clear and SPC can be introduced initially to a few of the most important line elements.
- Continued support and follow up is required until SPC is embedded in the culture.

Defining Technology and Equipment Standards – Total Solid Measurement Equipment

Detailed Overview

- SPC rules have been identifi
- Co-mans to engage with ha

Louise/John

operating principals, accuracy, calibration, recommended equipment

reference from: 12/20 - Standardization Elimination MFI Data Review OneNote

Developed Content

- Statistical process control (SP
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- Continued support and follow up is required until SPC is embedded in the culture.

An initial feasibility study proved viability for non-contact measurements of cartons at production speeds

Testing Conditions

- Tested cartons on a conveyor which represented approximate production speed
- Cartons purchased from retail store
- Equipment: In-Line 3D Laser Profiler

Results

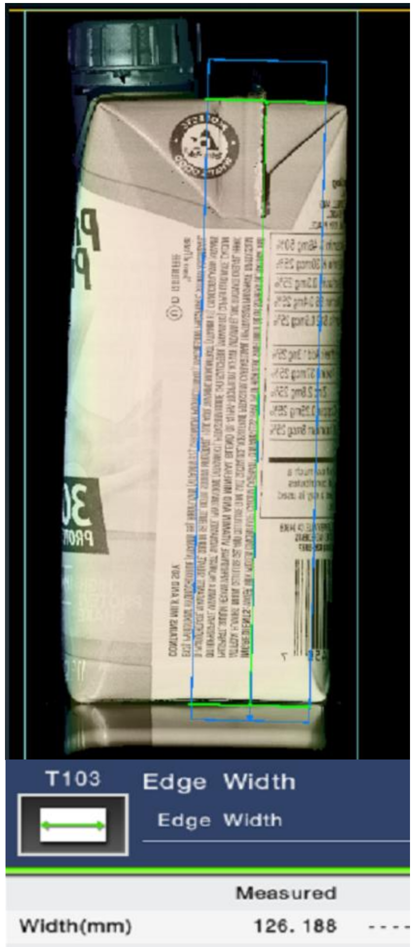
- Testing results prove the feasibility of the equipment - can measure accurately at production speed

Next Steps

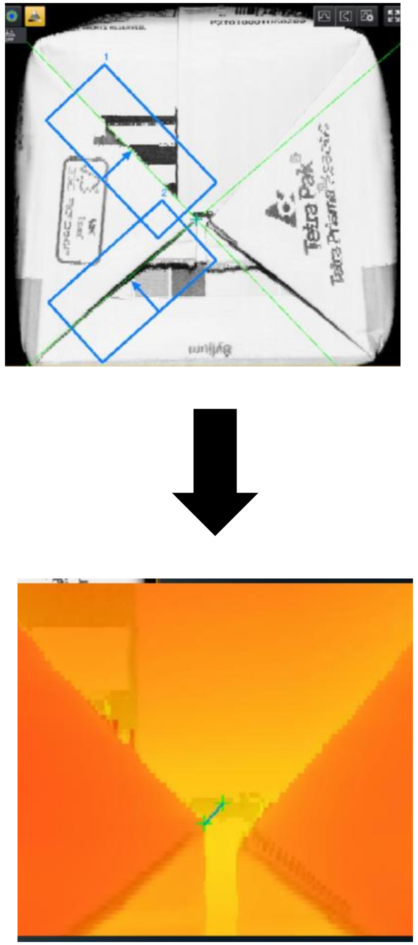
- Collect samples for 18 cartons
- Determine total footprint of equipment with images to share with co-mans
- Implement into SPC control loop

Width

Length



Fold Misalignment



Technology exists to detect foam in tanks using non-contact methods but validation would be required

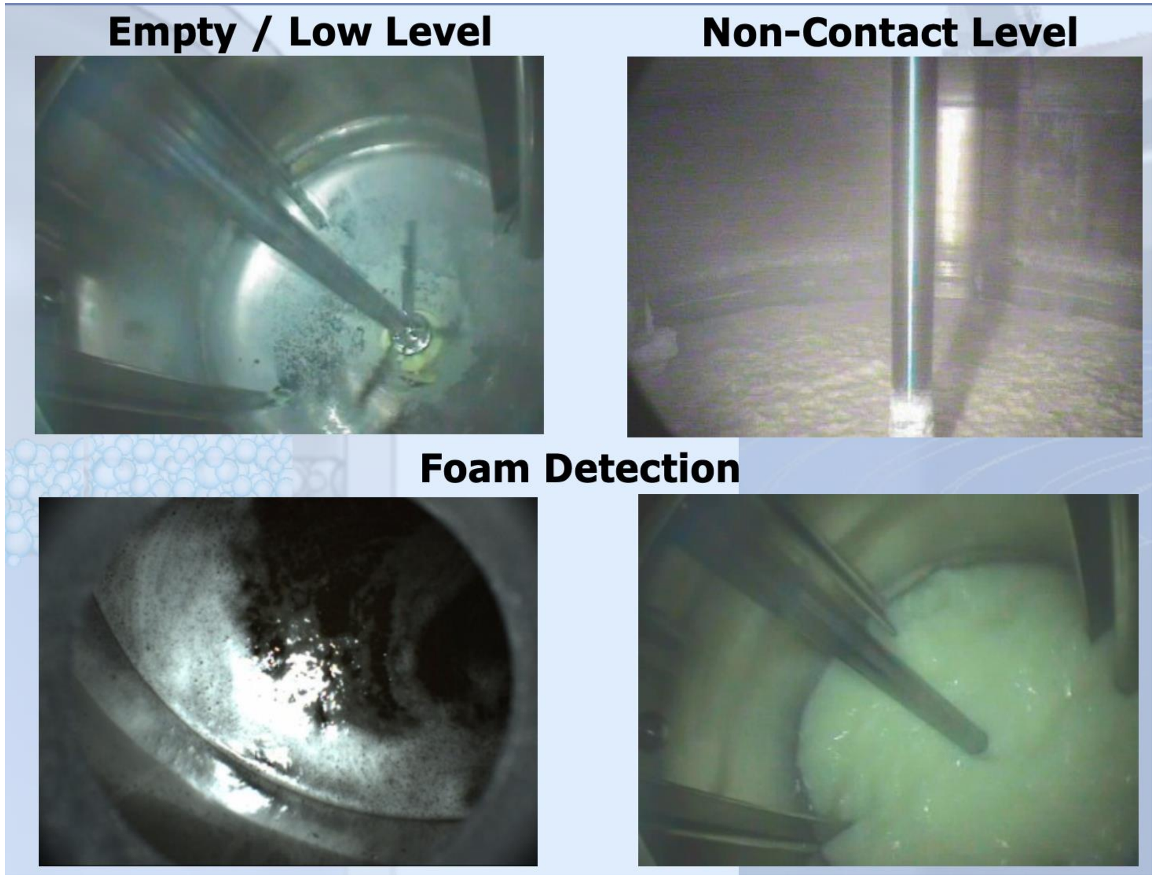
Foaming

Able have suggested that both non-contact camera systems or contact probes may be suitable for foam detection. The challenge is in exactly what type of foam it is (e.g. open foam like a milk shake or a dense foam like a cappuccino)

Liquid measurement for batching.

Able have confirmed that metering the liquid in is more accurate than measuring it in a tank. Their recommendation would be a Rheonlik Coriolis water meter which has an accuracy of 0.2% (2 parts in 1,000)

Non-contact foam detection system



Driving Adoption Across Network

Overview

Xx ensures…

Attributes of Best-In-Class

x	x	x	x
• x	• x	• x	• x

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Continuous Improvement

Overview

Xx ensures…

Attributes of Best-In-Class

x	x	x	x
• x	• x	• x	• x

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Workforce Development

Chapter Overview

Building and maintaining a skilled, adaptable workforce is fundamental to manufacturing excellence. This chapter establishes comprehensive guides and frameworks for training and skill development. These practices ensure teams are equipped with the necessary skills to operate effectively and adapt to evolving manufacturing requirements.

Chapter Contents

Content Roadmap

Wave 1 & 2 Content	Wave 3 Content to be Developed	Long Term Strategic Content

Training and Skill Development

Overview

Robust workforce development ensures…

Consolidated training attributes across all sections

Comprehensive Training

- Standard operating procedures (SOPs) guide operators through best practices for ingredient addition, mixing, and sampling.
- Training programs ensure operators understand the impact of process deviations on final product quality.
- Cross-training programs build expertise across the team, reducing dependency on a small number of experienced operators.

Clear Operating Procedures

- Well-documented Standard Operating Procedures (SOPs) ensure repeatability and compliance with quality standards.
- Operators receive hands-on training with clear escalation protocols for batch deviations.
- Cross-functional training ensures operators understand the impact of batching on downstream processes

Attributes of Best-In-Class

Case

Comprehensive Maintenance & Cleaning Program

- Glue nozzle checks to ensure they are not blocked
- The condition of the glue in the reservoir needs regular checks to ensure it not burnt or discolored.
- Temperature of the glue needs to be checked.
- Excess glue around the nozzles can build up and cause line stops.
- Check glue lines are not blocked.

3x4 Overwrap

Operator Training & Troubleshooting Protocols

- Well-defined SOPs guide operators in machine setup, troubleshooting, and minor adjustments to maintain production flow.
- Cross-training programs ensure operators understand both mechanical and quality aspects of overwrapping.
- Quick-reference troubleshooting guides and digital maintenance logs support rapid issue resolution.

Capping Equip

Operator Training & Process Optimization

- Operators receive hands-on training on glue weight adjustments, nozzle maintenance, and troubleshooting misaligned caps.
- Continuous improvement programs analyze rejection trends to optimize glue application parameters and reduce waste.
- Statistical Process Control (SPC) is used to track glue weight consistency and cap placement accuracy over time.

Filler Ops

Rigorous Maintenance & Operator Training

- A structured maintenance program prevents unplanned downtime and ensures long-term filler reliability.
- Operators and maintenance technicians undergo specialized training to quickly identify and resolve issues.
- Predictive maintenance technologies (e.g. vibration analysis) detect potential failures before they impact production.

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Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)
Packaging Material Training Handbook				
Filler Operation				
Capping Equipment				

Packaging Material Training Handbook

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Detailed Overview

- Each materials and the scope of content has been identified
- A template has been created and the content populated
- The information in the training will cover some of the contents of the material specification
- NDA's have been signed with packaging suppliers to allow information to be shared.

Packaging Material Type	Completed Formats	Links
Corrugate Cases	12, 15, 18 Count	
Overwrap Cartons	3x4 Count	

Developed Content

There currently are no dedicated Packaging Technologists on site at each co-man and therefore little support for the warehouse or operation staff regarding packaging issues. This document aims to fill that gap in knowledge and demonstrate the best practice for receiving materials, handling and storage, inspection before being brought to the line loading on the line and also identifying defects.

Implementation Strategy

- Obtain a benchmark of the level of understanding of the equipment and packaging materials used at co-mans.
- Create a document that explains best practice for each packaging material from their delivery on site, through to handling and to storage and then use on the line.
- Align technical content with packaging material suppliers.
- Create a document that can illustrate best practice and can be trained out and used as a point of reference within PNC and for co-mans.

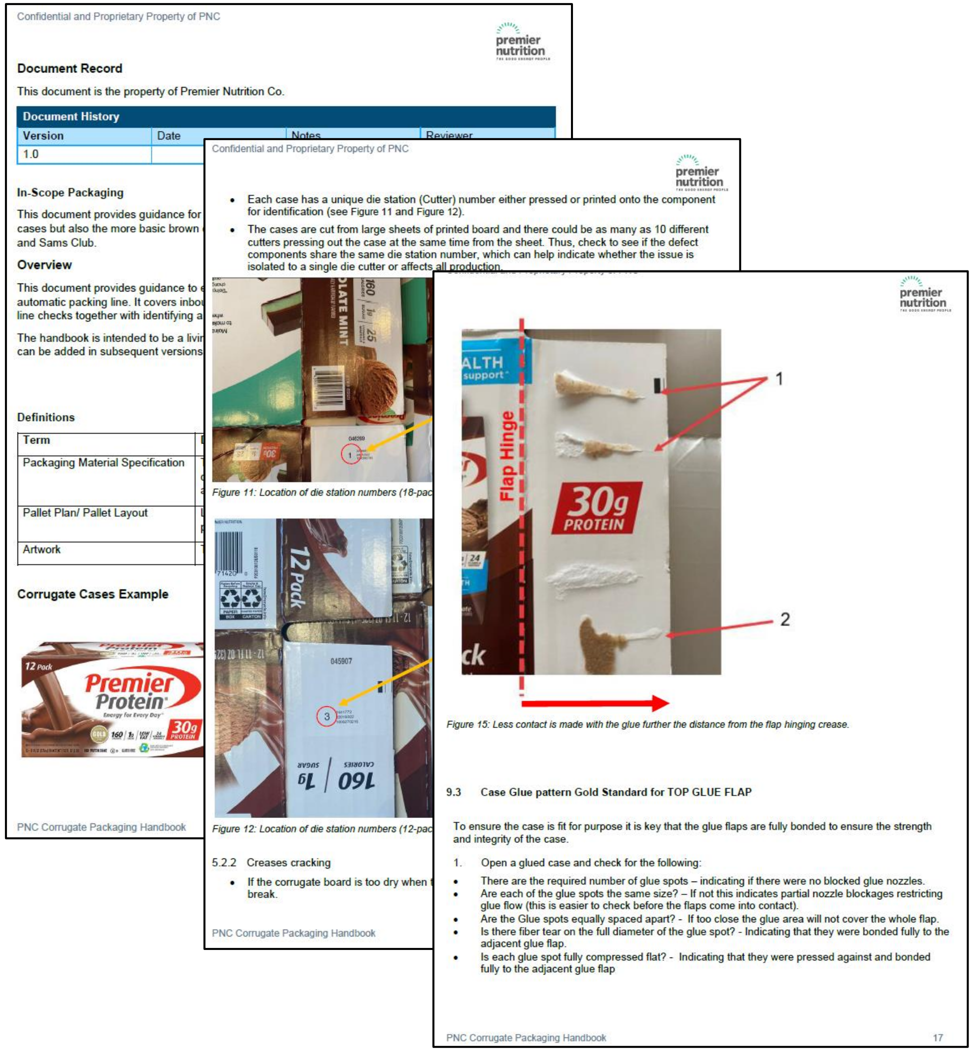
Common Challenges and Solutions

- Understanding the level of detail required to inform but not overload the audience with information.
- Creating content and a format that is memorable and valid for the level of interaction with the materials.
- Option to add content from further questions during the roll out of the information.
- Using the commonly used language and terminology for the materials

Packaging Materials Training Handbooks

Why training manuals?

- Tailor made PNC packaging information that can be easily understood and valid for their operation
- To ensure PNC packaging is stored and handled as recommended by supplier
- Key points to check before loading on to the line to maximize uptime



SPC

Louise

Detailed Overview

- SPC rules have been identified.
- Co-mans to engage with have been chosen.

Developed Content

- Statistical process control (SPC) is a method used to run manufacturing lines to minimise operator intervention, reduce process variation and improve product quality by applying a limited number of statistical rules.
- In order to use SPC it is important that the inherent variability/capability of the line is first identified. This is achieved by running the line for an extended period of time (typically a shift or 24hrs) without operator intervention and measuring the key quality attributes (KQAs) of the product during this period.
- It is important to understand which line variables impact which KQAs of the product.
- Charts either paper or electronic are used to track the KQAs.
- Typically 3-4 simple statistical rules are applied to the KQAs with the intention of limiting operator intervention to only that which is necessary.

Implementation Strategy

- Define SPC rules to apply.
- Identify KQAs
- Establish interactions between process inputs and KQAs
- Perform trials to understand inherent line variability.
- Engage manufacturing sites so everyone from operators to managers sees how this benefits them.
- Prepare charts
- Prepare and deliver training
- Review: quality, down time, manufacturing production etc.
- Follow up training with continued periodic support.

Common Challenges and Solutions

- ‘Not invented here’, risk of resistance when SPC is introduced. The benefits for everyone needs to be shared prior to training to gain support.
- Training and charts need to be clear and SPC can be introduced initially to a few of the most important line elements.
- Continued support and follow up is required until SPC is embedded in the culture.

Health and Safety Standards

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Overview

Robust workforce development ensures…

Attributes of Best-In-Class

x	x	x	x
• x	• x	• x	• x

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Co-Man Relationship Management

Chapter Overview

Effective co-manufacturing partnerships demand specialized relationship management approaches. This chapter outlines best practices for partner selection, risk management, collaboration, and innovation. By establishing clear requirements, managing risks, and fostering innovation, these practices build lasting partnerships that drive product quality, knowledge sharing, and business growth.

Chapter Contents

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Content Roadmap

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Wave 1 & 2 Content	Wave 3 Content to be Developed	Long Term Strategic Content

Defining Strategic Requirements

Consider changing name here and maturity model – duplicated

Overview

Robust workforce development ensures…

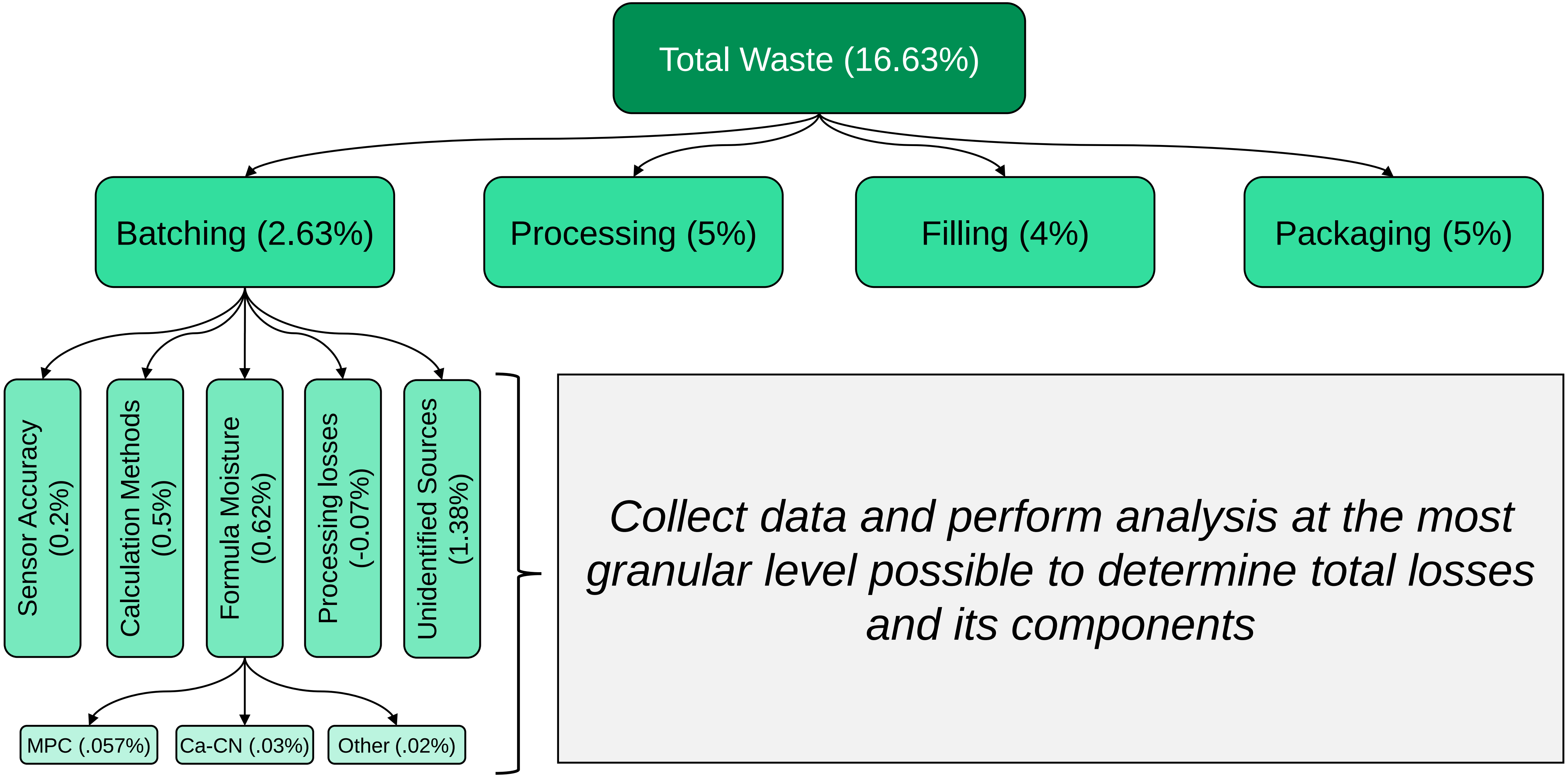
Attributes of Best-In-Class

x	x	x	x
• x	• x	• x	• x

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Loss Tree Analysis logic used at Gehl to determine waste sources can be leveraged for additional providers in the co-man network



Improving production waste to be better than contractual agreements is critical to reducing cost and improving working relationships

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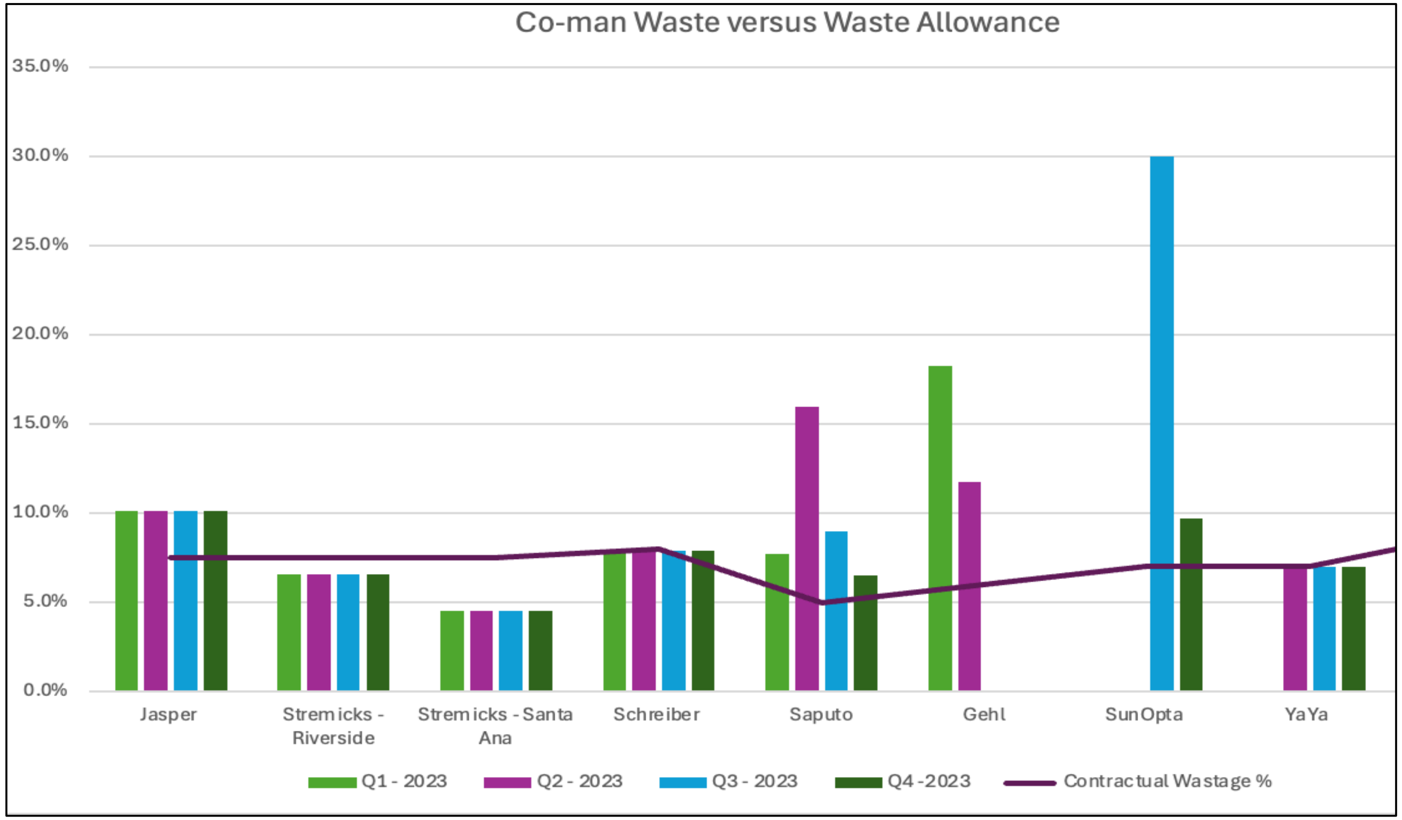
Raw materials are supplied to co-mans from PNC and excess waste is paid back to PNC

The formula can be seen as a significant source of waste

Calculating and identifying sources of actual production losses is difficult



Planning for Waste

When waste is higher than target

- Co-mans must issue payment for excess waste
- Pressure from co-mans to PNC to improve formula / reduce waste
- Contract negotiations to lower prices are challenged

Example of overall losses at Gehl – Level 1 of loss tree

Key takeaways:

- Overall factory production losses of ~17% broken into four main groups (figure 1):
  - Batching losses: 2.63%
  - Processes finished goods w/o package: 5%
  - Processing finished goods: 4%
  - Defect quality rejects: 5%
- if there is excess waste within the batching process it's easy to target the formula as a reason for losses

Recommendations:

- Targeted troubleshooting methods and data collection can help to fully characterize downstream losses (see slide 13)

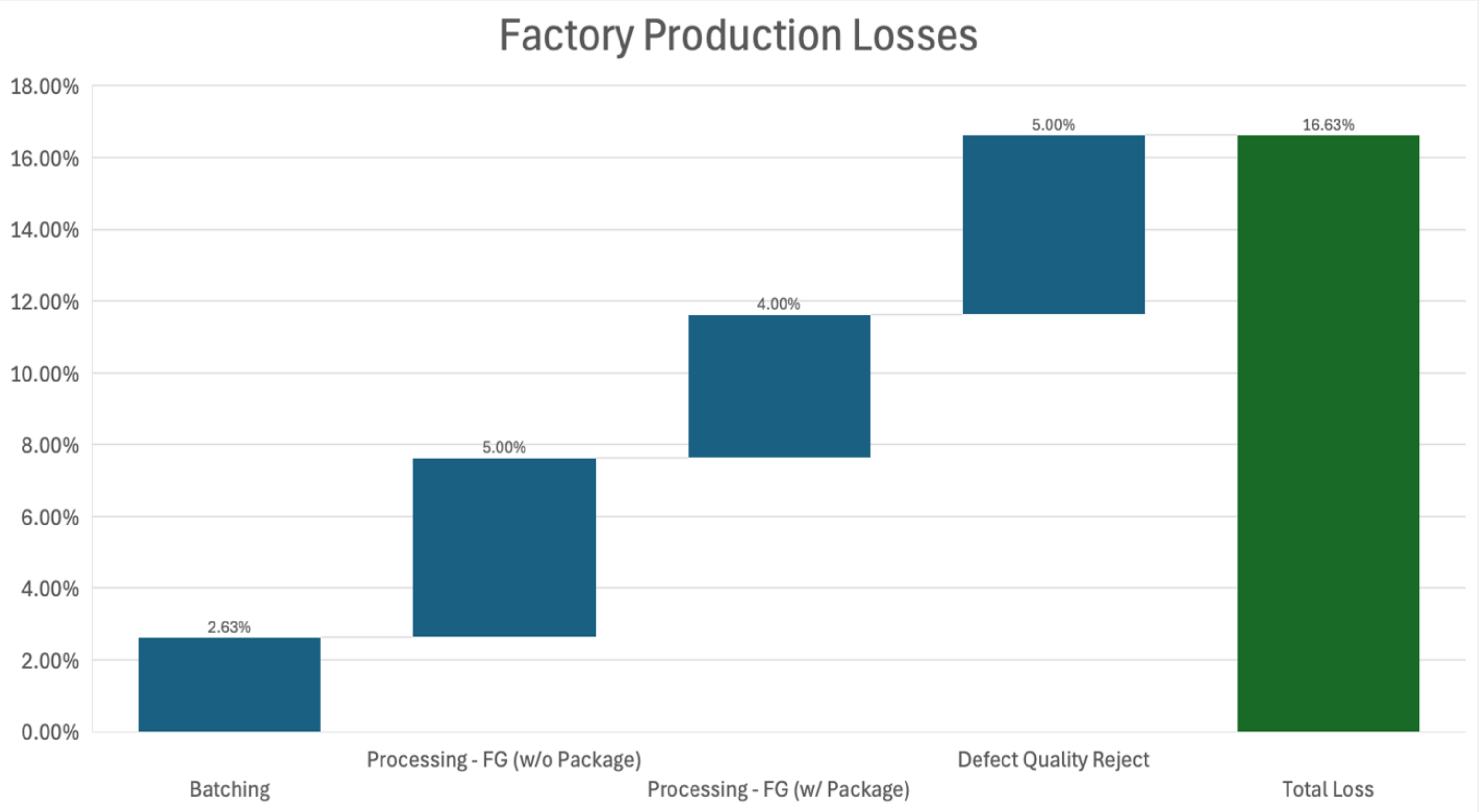


Figure 1: Factory production loss overview

Losses at batching for Gehl facility – Level 2 of loss tree

Key Takeaways:

- Gehl reports a weighted average MPC batching loss of 2.63% across all flavors and batches produced from Sept – Nov 2024
- **Identified Losses:**
  - Moisture losses in MPC (~0.6%)
  - Measurement inaccuracy in the tank weight measurement system (0.2%)
  - Density value used to calculate tank weight did not reflect actual (~0.5%)
  - A small amount of excess product is shipped with each MPC bag, this excess was negated with MPC losses during the batching process
  - Almost half of the losses (~1.38%) remain yet to be identified

Recommendations:

- Data collection with clear documentation can help validate assumptions about measurement discrepancies versus actual material losses
- Building deep understanding of process losses can enable better supplier conversations and build credibility when discussing improvement initiatives

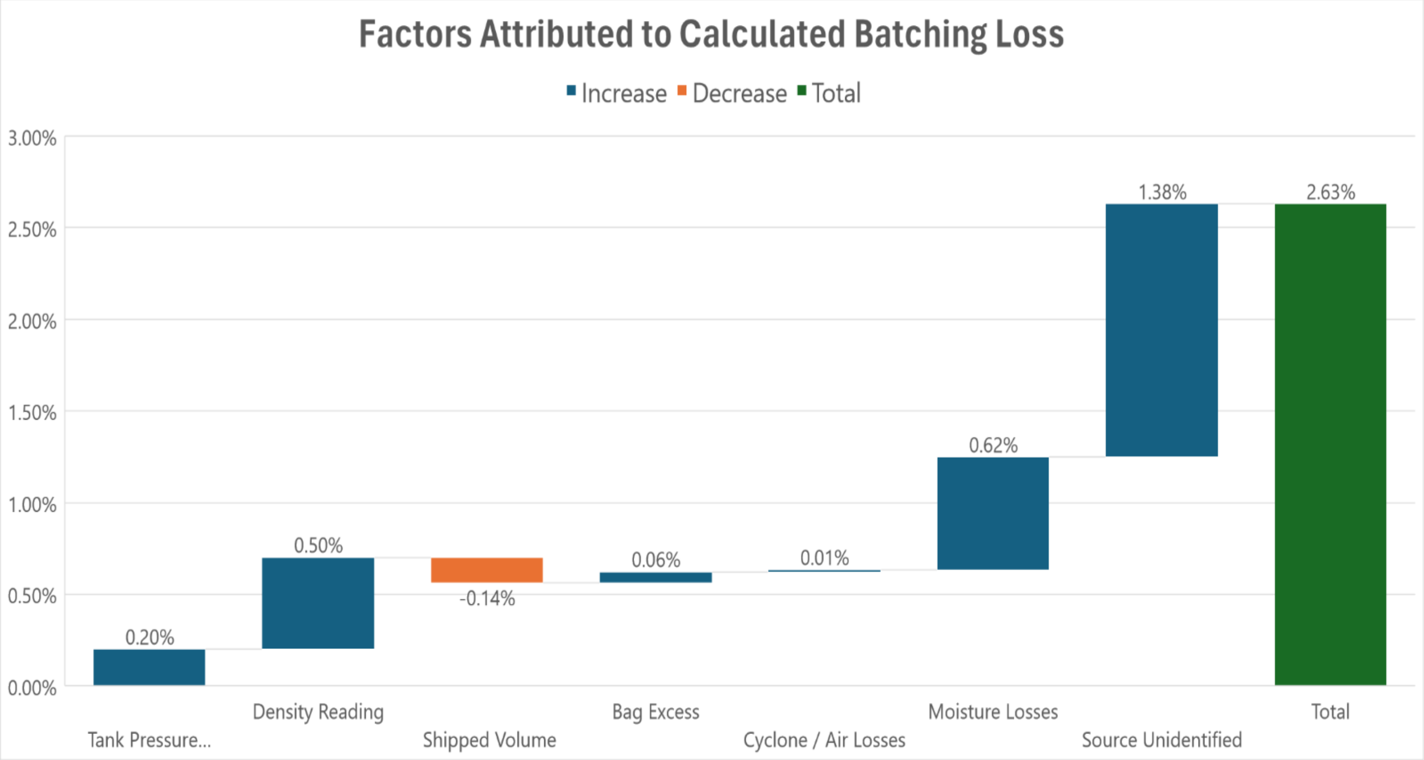
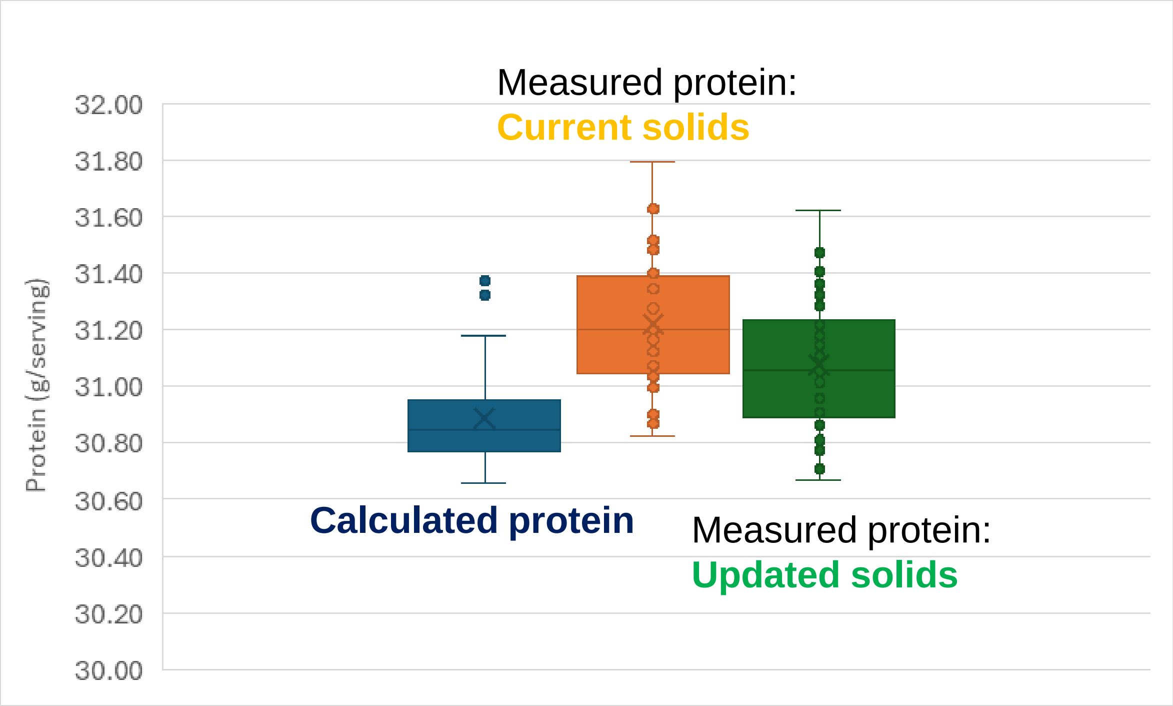


Figure 1: Batching yield losses and identified / measured sources

Decrease in Batch sheet T.S.: Impact on Protein Levels

- Production from FY24 at Denton measured for protein
  - Results consistent MPC moisture being underestimated
- Ingredient moisture is a very small part of overall yield loss (0.6%)
  - More impactful to focus on other areas of opportunity



n = 50 batches over 1yr at Denton

Recommendation: Do not update MPC solids on batch sheet
Will monitor solids on an on-going basis – any material changes can re-discuss

Collaborating with PA to finalize playbook for discussions, deep dive into data and assumption

How do we communicate about losses due to formulation?

Background

- Material waste can split into two categories: a) **manufacturing** process losses from production and b) **design**-inherent formula losses
- Some loss due to formula should be expected due to suppliers shipping on the allowable high side of the solids range – this variance is within design specification, not waste.

Key Considerations

Raw materials will be shipped on the low side of solids

Losses due to formula are waste when received outside of the target range

Manufacturing losses will typically be the largest sources of waste

How to support co-mans with excess losses?

- Develop data-driven approach to distinguish between actual production losses and formula-related waste
- Provide technical support for loss troubleshooting and root cause analysis
- Share clear documentation and best practices for waste calculation, material handling and process control

How to drive continuous improvement and partnership?

- Emphasize collaborative troubleshooting engagements rather than contractual penalties
- Develop and utilize standardized troubleshooting methods (e.g. fishbone, loss tree)
- Establish structured communication channels between R&I, manufacturing and procurement
- Share success stories and best practices across network

Risk Management and Mitigation

Overview

Robust workforce development ensures…

Attributes of Best-In-Class

x	x	x	x
• x	• x	• x	• x

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Collaboration

Overview

Robust workforce development ensures…

Attributes of Best-In-Class

x	x	x	x
• x	• x	• x	• x

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Innovation and Commercialization

Overview

Robust workforce development ensures…

Attributes of Best-In-Class

x	x	x	x
• x	• x	• x	• x

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Co-Manufacturer Capabilities

Chapter Overview

Chapter Contents

- Technology and Equipment
- Workforce Management and Training

Content Roadmap

Wave 1 & 2 Content	Wave 3 Content to be Developed	Long Term Strategic Content

Technology and Equipment

Overview

Robust workforce development ensures…

Attributes of Best-In-Class

x	x	x	x
• x	• x	• x	• x

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Workforce Management and Training

Overview

Robust workforce development ensures…

Attributes of Best-In-Class

x	x	x	x
• x	• x	• x	• x

Supporting Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

PA

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Thank you

Content Roadmap

Wave 1 & 2 Content	Wave 3 Content to be Developed	Long Term Strategic Content
KPI Framework	• Resolve data collection gaps identified in Wave 2 • Standardize current methods across all co-man sites KPI dashboard	• Standardized data collection and reporting handbook

Packaging Receiving Process – Training & Best Practice Guidelines

Purpose of Training Manuals

The training manuals (**see Corrugate Packaging and Overwrap Carton Packaging Training Handbooks**) are comprehensive guides created to standardize packaging processes across the co-man network and bring the following benefits:

- Provide standardized packaging information tailored for co-man operations to ensure consistent implementation across the network
- Ensure packaging materials are stored and handled according to manufacturer specifications to maintain optimal performance
- Establish critical quality check points prior to production to maximize uptime and prevent issues
- Create a network-wide approach for handling and documenting quality issues to drive supplier accountability
- Maintain all documentation in Intelex with part numbers and revision control to ensure access to current information

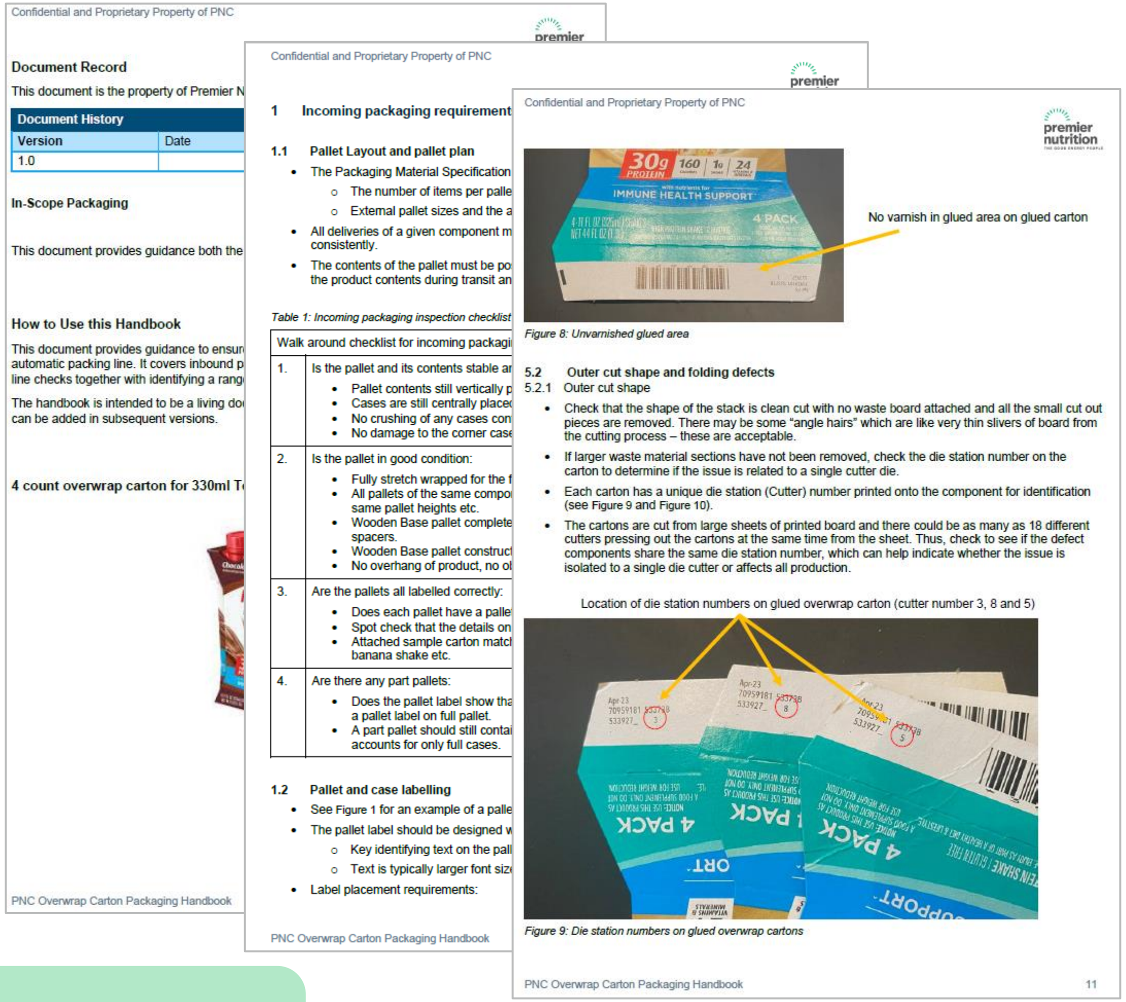

Confidential and Proprietary Property of PNC

Figure 8: Unvarnished glued area

5.2 Outer cut shape and folding defects

5.2.1 Outer cut shape

- Check that the shape of the stack is clean cut with no waste board attached and all the small cut out pieces are removed. There may be some "angle hairs" which are like very thin slivers of board from the cutting process – these are acceptable.
- If larger waste material sections have not been removed, check the die station number on the carton to determine if the issue is related to a single cutter die.
- Each carton has a unique die station (Cutter) number printed onto the component for identification (see Figure 9 and Figure 10).
- The cartons are cut from large sheets of printed board and there could be as many as 18 different cutters pressing out the cartons at the same time from the sheet. Thus, check to see if the defect components share the same die station number, which can help indicate whether the issue is isolated to a single die cutter or affects all production.

Location of die station numbers on glued overwrap carton (cutter number 3, 8 and 5)

Figure 9: Die station numbers on glued overwrap cartons

PNC Overwrap Carton Packaging Handbook 11

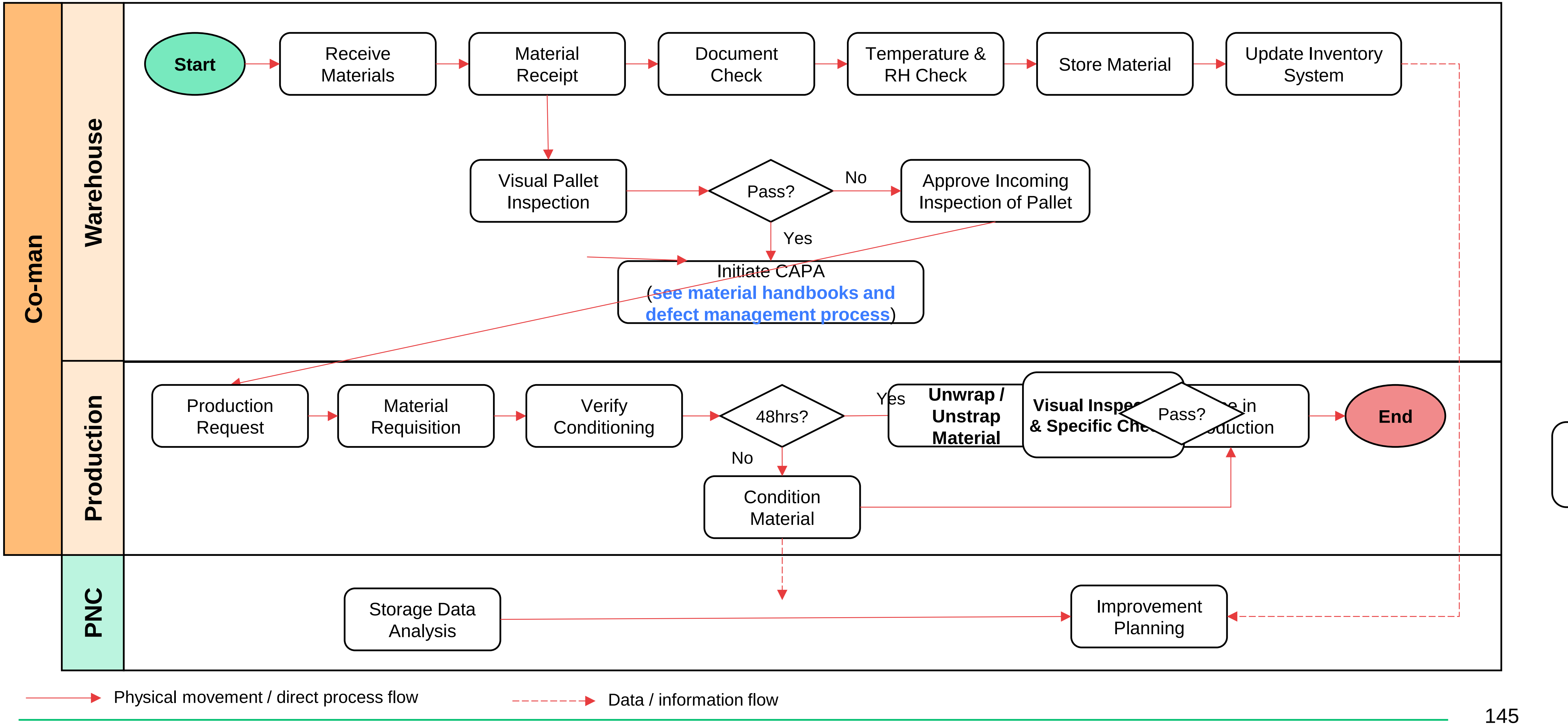
Train the Trainer Implementation

- Provide one-on-one training with lead operators, focusing on detailed understanding of protocols and addressing questions to build mastery and ownership
- Conduct hands-on practical sessions demonstrating direct application of manual guidelines during actual production conditions
- Develop co-man trainers through certification process to ensure self-sufficiency and ability to onboard new team members independently
- Establish regular knowledge-sharing sessions across the co-man network to exchange best practices and lessons learned

Document Control

- Stored in Intelex with unique document IDs
- Revision controlled with change history tracking
- Quarterly review cycle
- Co-man notification system for all updates and revisions

Packaging Receiving Process – Detailed Handling & Storage Process for Packaging Materials



JR – Review

Quality Control of Gluing Application – Common Defect Exa

Real-World Case: Top Glue Flap

A warehouse inspection revealed inconsistent gluing application onto the top glue flap. The top glue flap requires specific pattern placement and bonding to maintain case structure throughout distribution and retail display. This example demonstrates proper glue pattern standards versus common defects that compromise case integrity throughout the supply chain.

Key Inspection Points

Feature	Target Standard	Common Defect	Remedy
Number of spots	6 spots total	Missing spots	Reposition glue nozzle
Adhesion	Full fiber tear	Partial contact	Adjust pusher pressure
Spacing	Equal distribution	Clustered on one side	Reset nozzle positioning

Target Pattern (figure 1)

Findings:

- 6 evenly spaced spots
- Full fiber tear present
- Complete compression

Figure 1: All Top Glue Flap glue spots show fiber tear and the other required bonding attributes

Marginal (figure 2)

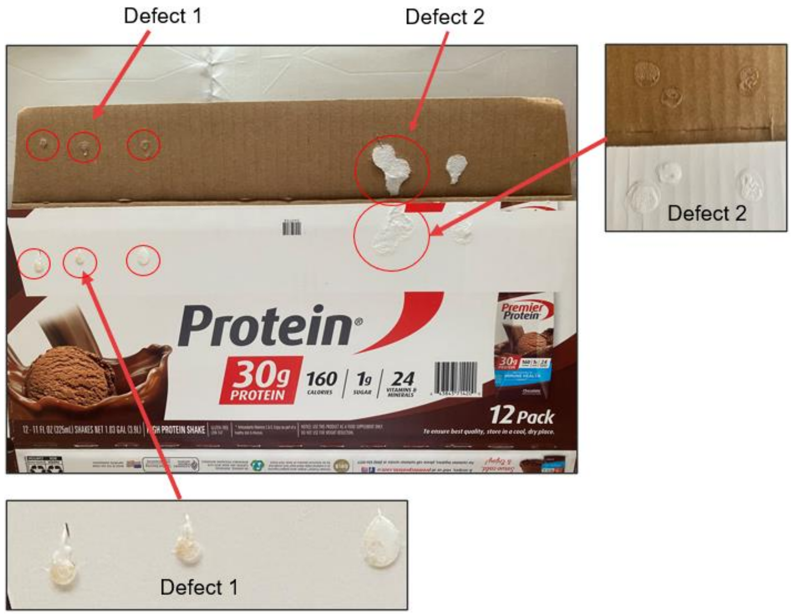


Figure 2: Defect examples showing (1) partial contact with insufficient pressure and (2) poor spot spacing on right side

Defect Findings:

- Uneven distribution (defect 2)
- Lack of fiber tear (defect 1)
- Poor adhesion (defect 1)

Potential Quality Impact:

- Case opens during transit
- Product damage
- Retailed rejections
- Consumer complains

Quality Control of Gluing Application – Overview

Jim

Detailed Overview

The corrugated case is only held together with the application of hot melt glue at the case erector. Proper glue coverage and placement is critical to case integrity throughout the entire product lifecycle.

Why this matters:

- Case strength directly impacts product protection during transport
- Insufficient glue can cause case failure during palletization or shipping
- Glue failures may result in product damage, retailer rejections, and consumer complaints
- Proper quality control prevents costly downstream issues and maintains brand reputation

To ensure consistent quality, the following systematic inspection process addresses each critical aspect of glue application:

Setup Check	**Glue Pattern Validation**	**Adhesion Check**	**Visual Inspection**	**Periodic check**	**Document Issues**
Align glue nozzles; position backstops	Coverage / position all 5 glue flaps (**see corrugate handbook**)	Break glued case apart and inspect glue pattern	No external /internal glue spillage	Random sampling regularly	Record findings

Examples of Critical Quality Standards

CtQ / Parameter	Specification	Inspection Method	Frequency
Glue coverage/position	Align in designated unvarnished areas	Visual check	Hourly
Adhesion bond strength	Fiber tear on attached surfaces	Pull check	Hourly
Over spill of glue	No glue on internal product / external case	Visual check	Hourly
Glue temperature	Check glue specification	Equipment check	Shift startup

Set up, Maintenance, & Cleaning Programs – Case Ere

JR – Review

Detailed Overview

The nature of liquid hot melt glue jet application and its rapid curing can lead to equipment issues that directly impact case quality. Blockages in glue nozzles and feed pipes can develop progressively or cause immediate failure, resulting in insufficient or completely absent glue application.

Proper equipment management is critical because:
- Precise nozzle targeting ensures glue reaches unvarnished areas only
- Even glue distribution across flaps is essential for uniform strength
- Back stop positioning affects critical curing time and bond formation
- Regular maintenance prevents costly downtime and quality issues

A systematic approach to equipment care ensures consistent case quality and production efficiency.

Cleaning as Required → Glue buildup

Daily Checks → Nozzle inspection and glue deposits

Monthly Inspection → Component replacement if needed

Quarterly → ?

Quality Verification Procedures

- Perform regular case break-down tests to verify fiber tear (bond strength)
- Inspect glue patterns on rejected cases to identify equipment issues
- Document temperature readings throughout shift
- Create visual standards showing proper vs. improper equipment setup

Examples of Maintenance Points

Component	Check Frequency	Maintenance Action	Warning Signs
Glue nozzle	As required	Clean/clear blockages	Uneven glue pattern
Glue reservoir	Every shift	Check for discoloration and overheating	Darkened glue color
Glue feed line	As required	Clean or replace glue line	Varying pressure leading to uneven glue pattern
Temperature control	Shift startup	Verify within range	Inconsistent flow of glue
Back stops	Daily	Check alignment	Poor case formation

Co-Man Strategic Network Planning

Chapter Overview

Designing a co-manufacturing network which meets strategic operational objectives and remains cost efficient is essential to remaining competitive in the market. This chapter establishes the best practices to guide network planning decisions, minimize risks, and build strong partnerships. By aligning strategy, improving collaboration, and driving innovation, these practices ensure the network operates efficiently and supports long-term growth.

Chapter Contents

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Content Roadmap

Wave 1 & 2 Content	Wave 3 Content to be Developed	Long Term Strategic Content

Defining Strategic Requirements

Overview

The process of establishing network requirements that balance cost, quality, and risk across co-man partners. This includes evaluation of manufacturing capabilities, formula handling, ingredient sourcing, and compliance with food safety standards.

Attributes of Best-In-Class

Strategic Planning

- Long-range network strategy aligned with product portfolio
- Balancing cost, quality, and flexibility in partner selection
- Frequent strategy reviews against market trends

Manufacturing Capability

- Standardized internal vs. external manufacturing capability assessment
- Verified FDA compliance

Cost Management

- Total cost modelling (ingredients, processing, logistics)
- Yield optimization & waste reduction
- Packaging efficiency
- Energy and cleaning cost monitoring

Risk Assessment

- Quality consistency tracking
- Reviewing capacity constraints during peak seasons
- Material supply chain monitoring

Reference Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)
Maturity Model	Manufacturing Maturity Model provides a holistic view into current manufacturing operations across the PNC Co-Man Network			• PNC - Mfg Excellence - Maturity Model.pptx

Risk Management & Mitigation

Overview

The process for identifying, assessing, and mitigating risks across the co-man network. This encompasses food safety, quality, supply chain, capacity, and regulatory compliance risks.

Attributes of Best-In-Class

Risk Identification

- Continuous monitoring system in place with early warning indicators
- Multi-level risk categorization
- Consistently capturing stakeholder inputs

Assessment Framework

- Risk scoring model quantifying potential impact
- Probability modeling of risk events
- Defined thresholds trigger escalation and mitigation actions
- Cross-functional evaluation

Mitigation Strategy

- Detailed contingency plans with required actions
- Clear ownership
- Response time targets scaled to risk severity
- Regular scenario testing to validate mitigation effectiveness

Monitoring System

- Performance metrics
- Reviewing capacity constraints during peak seasons
- Partner scorecards
- Standardized risk reviews with senior leadership on an agreed cadence

Reference Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Partner Selection and Onboarding

Overview

X

Attributes of Best-In-Class

X	X	X	X
• X	• X	• X	• X

Reference Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Partner Collaboration

Overview

x

Attributes of Best-In-Class

x	x	x	x
• test	• x	• x	• x

Reference Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)

Driving Innovation & Commercialization

Overview

x

Attributes of Best-In-Class

x	x	x	x
• x	• x	• x	• x

Reference Documents

BIC Document	Description	Reference Slide	PNC Team Ownership	PNC Sharepoint Link(s)